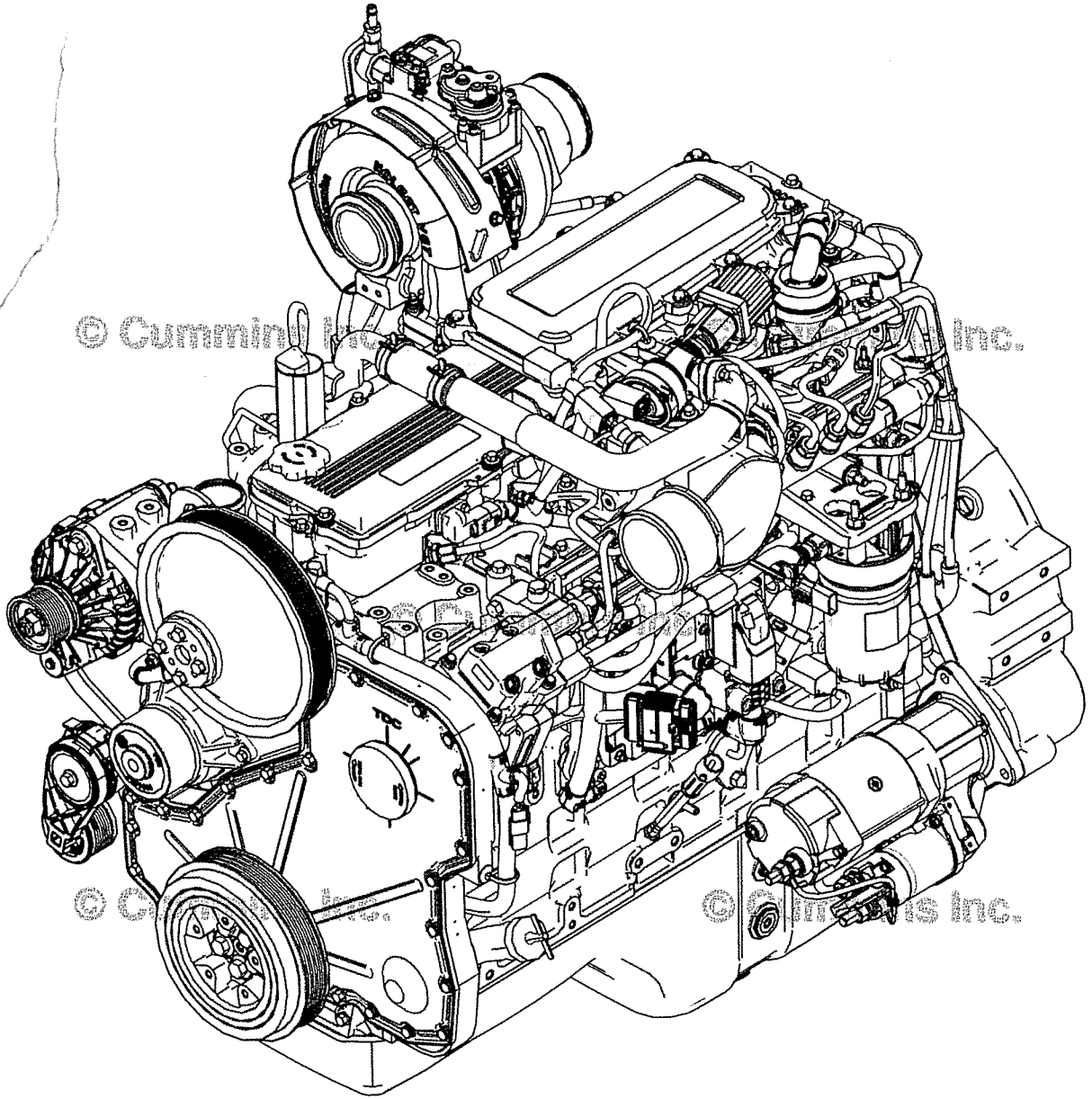




Service Manual QSL9 CM2350 L102 Volume 1



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Foreword

This manual provides instructions for troubleshooting and repairing this engine in the chassis. Component and assembly rebuild procedures are provided in the engine shop manual. Refer to Section i - Introduction for instructions on how to use this manual.

Read and follow all safety instructions. Refer to the WARNING in the General Safety Instructions in Section i - Introduction.

The manual is organized to guide a service technician through the logical steps of identifying and correcting problems related to the engine. This manual does not cover vehicle or equipment problems. Consult the vehicle or equipment manufacturer for repair procedures.

A series of specific service manuals (for example: Shop, Specifications, and Alternative Repair) are available and can be ordered by contacting your local area Cummins Regional office. A Cummins Regional office listing is located in Service Literature (Section L).

The repair procedures used in this manual are recommended by Cummins Inc. Some service procedures require the use of special service tools. Use the correct tools as described.

Cummins Inc. encourages the user of this manual to report errors, omissions, and recommendations for improvement. Please use the postage paid, pre-addressed Literature Survey Form in the back of this manual for communicating your comments.

The specifications and rebuild information in this manual are based on the information in effect at the time of printing. Cummins Inc. reserves the right to make any changes at any time without obligation. If differences are found between your engine and the information in this manual, contact a Cummins Authorized Repair Location or call 1-800-DIESELS (1-800-343-7357) toll free in the U.S. and Canada.

The latest technology and the highest quality components are used to manufacture Cummins engines. When replacement parts are needed, we recommend using only genuine Cummins or ReCon® exchange parts.

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About the Manual

General Information

This Service Manual is intended to aid in determining the cause of engine related problems and to provide recommended repair procedures. Additionally the manual is intended to aid mechanics in disassembly, inspecting parts for reuse, rebuilding and assembly of components.

The manual is divided into sections. Each section is equivalent to a group used in Cummins' filmcard system. Some sections contain **reference** numbers and **procedure** numbers. **Reference** numbers provide general information, specifications, diagrams, and service tools where applicable. **Procedure** numbers are used to identify and reference specific repair procedures for correcting the problem and describe specific rebuild procedures.

This manual **does not** contain fuel systems electronic troubleshooting. Use the troubleshooting trees in this manual, if there are no electronic fault codes.

This manual is designed so the troubleshooting trees are used to locate the cause of an engine problem. The troubleshooting trees then direct the user to the correct repair procedure. The repair procedures within a section are in numerical order. However, the repair steps within a given procedure are organized in the order the repair **must** be performed regardless of the numerical order of the steps. The user **must** use the contents pages or the index at the back of the manual to locate specific topics when **not** using the troubleshooting trees.

How to Use the Manual

General Information

This manual is divided into the same group system used for previous manuals and the Cummins' filmcard system. Section 00 is organized into a logical sequence of engine disassemble/assemble, all other sections are in numerical sequence. Refer to the Table of Contents at the front of the book to determine the section that details the desired information.

The disassemble/assemble sections of this manual is divided into the same group system used for previous manuals and the Cummins' filmcard system.

Section 00 is organized into a logical sequence of engine disassemble/assemble, all other sections are in numerical sequence. Refer to the Table of Contents at the front of the book to determine the section that details the desired information.

Each section contains the following in sequence:

- Table of Contents
- Required Service Tool Listings
- General Information containing the basic service, maintenance, design and revision information necessary to assist in the rebuild of an engine or a component
- Procedure instructions for the disassembly, inspection, maintenance, and assembly that can be required to rebuild an engine; additional procedures that are **not** necessary during **every** rebuild, but can be necessary, are included. These procedures depend on the length of time an engine has been in service and the conditions of the parts.

All the procedures are identified with a name and a number. Each digit in the procedure number has a specific meaning.

The first three digits of the number refer to the specific section that the procedure can be found within the manual. In this example, "001" represents Section 01 - Cylinder Block. This number will range from 000 to 022.

The second three digits of the number are unique and refer to a specific subject. In this example, "028" represents Cylinder Liner. This number will range from 001 to 999.

Refer to Section V for specifications recommended by Cummins Engine Company, Inc. for your engine. Specifications and torque values for each engine system are given in that section.

NOTE: Discharge of oil or oily water into or upon the water is a direct violation of today's laws. Violators are subject to a penalty of various monetary charges. Dispose of these substances in accordance with standards set by the local environmental governing agency.

Symbols

General Information

The following symbols have been used in this manual to help communicate the intent of the instructions. When one of the symbols appears, it conveys the meaning defined below:



WARNING - Serious personal injury or extensive property damage can result if the warning instructions are **not** followed.



CAUTION - Minor personal injury can result or a part, an assembly, or the engine can be damaged if the caution instructions are **not** followed.



Indicates a **REMOVAL** or **DISASSEMBLY** step.



Indicates an **INSTALLATION** or **ASSEMBLY** step.



INSPECTION is required.



CLEAN the part or assembly.



PERFORM a mechanical or time **MEASUREMENT**.



LUBRICATE the part or assembly.



Indicates that a **WRENCH** or **TOOL SIZE** will be given.



TIGHTEN to a specific torque.



PERFORM an electrical **MEASUREMENT**.

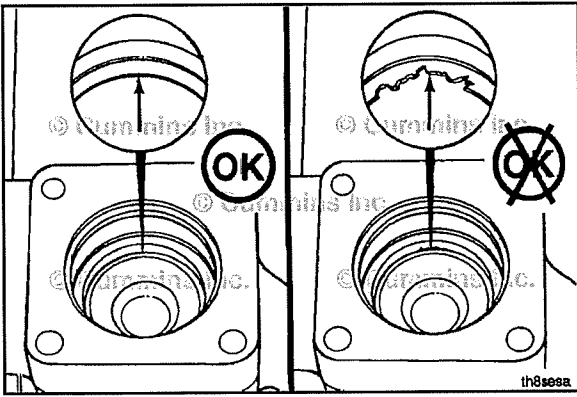


Refer to another location in this manual or another publication for additional information.



The component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

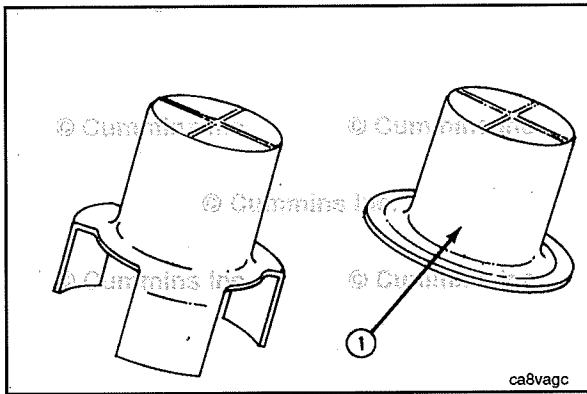
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Illustrations

General Information

Some of the illustrations throughout this manual are generic and will **not** look exactly like the engine or parts used in your application. The illustrations can contain symbols to indicate an action required and an acceptable or **not** acceptable condition.



The illustrations are intended to show repair or replacement procedures. The procedure will be the same for all applications, although the illustration can differ.

General Safety Instructions

Important Safety Notice



Improper practices, carelessness, or ignoring the warnings can cause burns, cuts, mutilation, asphyxiation or other personal injury or death.

Read and understand all of the safety precautions and warnings before performing any repair. This list contains the general safety precautions that **must** be followed to provide personal safety. Special safety precautions are included in the procedures when they apply.

- Work in an area surrounding the product that is dry, well lit, ventilated, free from clutter, loose tools, parts, ignition sources and hazardous substances. Be aware of hazardous conditions that can exist.
- **Always** wear protective glasses and protective shoes when working.
- Rotating parts can cause cuts, mutilation or strangulation.
- Do **not** wear loose-fitting or torn clothing. Remove all jewelry when working.
- Disconnect the battery (negative [-] cable first) and discharge any capacitors before beginning any repair work. Disconnect the air starting motor if equipped to prevent accidental engine starting. Put a "Do **Not** Operate" tag in the operator's compartment or on the controls.
- Use **ONLY** the proper engine barring techniques for manually rotating the engine. Do **not** attempt to rotate the crankshaft by pulling or prying on the fan. This practice can cause serious personal injury, property damage, or damage to the fan blade(s) causing premature fan failure.
- If an engine has been operating and the coolant is hot, allow the engine to cool before slowly loosening the filler cap to relieve the pressure from the cooling system.
- **Always** use blocks or proper stands to support the product before performing any service work. Do **not** work on anything that is supported **ONLY** by lifting jacks or a hoist.
- Relieve all pressure in the air, oil, fuel, and cooling systems before any lines, fittings, or related items are removed or disconnected. Be alert for possible pressure when disconnecting any device from a system that utilizes pressure. Do **not** check for pressure leaks with your hand. High pressure oil or fuel can cause personal injury.
- To reduce the possibility of suffocation and frostbite, wear protective clothing and **ONLY** disconnect liquid refrigerant (Freon) lines in a well ventilated area. To protect the environment, liquid refrigerant systems **must** be properly emptied and filled using equipment that prevents the release of refrigerant gas (fluorocarbons) into the atmosphere. Federal law requires capturing and recycling refrigerant.
- To reduce the possibility of personal injury, use a hoist or get assistance when lifting components that weigh 23 kg [50 lb] or more. Make sure all lifting devices such as chains, hooks, or slings are in good condition and are of the correct capacity. Make sure hooks are positioned correctly. **Always** use a spreader bar when necessary. The lifting hooks **must not** be side-loaded.
- Corrosion inhibitor, a component of SCA and lubricating oil, contains alkali. Do **not** get the substance in eyes. Avoid prolonged or repeated contact with skin. Do **not** swallow internally. In case of contact, immediately wash skin with soap and water. In case of contact, immediately flood eyes with large amounts of water for a minimum of 15 minutes. **IMMEDIATELY CALL A PHYSICIAN. KEEP OUT OF REACH OF CHILDREN.**
- Naptha and Methyl Ethyl Ketone (MEK) are flammable materials and **must** be used with caution. Follow the manufacturer's instructions to provide complete safety when using these materials. **KEEP OUT OF REACH OF CHILDREN.**
- To reduce the possibility of burns, be alert for hot parts on products that have just been turned off, exhaust gas flow, and hot fluids in lines, tubes, and compartments.
- **Always** use tools that are in good condition. Make sure you understand how to use the tools before performing any service work. Use **ONLY** genuine Cummins® or Cummins ReCon® replacement parts.
- **Always** use the same fastener part number (or equivalent) when replacing fasteners. Do **not** use a fastener of lesser quality if replacements are necessary.
- When necessary, the removal and replacement of any guards covering rotating components, drives, and/or belts should only be carried out by a trained technician. Before removing any guards the engine **must** be turned off and any starting mechanisms **must** be isolated. All fasteners **must** be replaced on re-fitting the guards.
- Do **not** perform any repair when fatigued or after consuming alcohol or drugs that can impair your functioning.

- Some state and federal agencies in the United States of America have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.
- Do **not** connect the jumper starting or battery charging cables to any ignition or governor control wiring. This can cause electrical damage to the ignition or governor.
- **Always** torque fasteners and fuel connections to the required specifications. Overtightening or undertightening can allow leakage. This is critical to the natural gas and liquefied petroleum gas fuel and air systems.
- **Always** test for fuel leaks as instructed, as odorant can fade.
- Close the manual fuel valves prior to performing maintenance and repairs, and when storing the vehicle inside.
- Coolant is toxic. If **not** reused, dispose of in accordance with local environmental regulations.
- The catalyst reagent contains urea. Do **not** get the substance in your eyes. In case of contact, immediately flood eyes with large amounts of water for a minimum of 15 minutes. Avoid prolonged contact with skin. In case of contact, immediately wash skin with soap and water. Do **not** swallow internally. In the event the catalyst reagent is ingested, contact a physician immediately.
- The catalyst substrate contains Vanadium Pentoxide. Vanadium Pentoxide has been determined by the State of California to cause cancer. Always wear protective gloves and eye protection when handling the catalyst assembly. Do not get the catalyst material in your eyes. In Case of contact, immediately flood eyes with large amounts of water for a minimum of 15 minutes. Avoid prolonged contact with skin. In case of contact, immediately wash skin with soap and water.
- The Catalyst substrate contains Vanadium Pentoxide. Vanadium Pentoxide has been determined by the State of California to cause cancer. In the event the catalyst is being replaced, dispose of in accordance with local regulations.
- 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.

General Repair Instructions

General Information

This system incorporates the latest technology at the time it was manufactured; yet, it is designed to be repaired using normal repair practices performed to quality standards.

WARNING

Cummins Inc. does not recommend or authorize any modifications or repairs to components except for those detailed in Cummins Service Information. In particular, unauthorized repair to safety-related components can cause personal injury or death. Below is a partial listing of components classified as safety-related:

- 1 Air Compressor
 - 2 Air Controls
 - 3 Air Shutoff Assemblies
 - 4 Balance Weights
 - 5 Cooling Fan
 - 6 Fan Hub Assembly
 - 7 Fan Mounting Bracket(s)
 - 8 Fan Mounting Capscrews
 - 9 Fan Hub Spindle
 - 10 Flywheel
 - 11 Flywheel Crankshaft Adapter
 - 12 Flywheel Mounting Capscrews
 - 13 Fuel Shutoff Assemblies
 - 14 Fuel Supply Tubes
 - 15 Lifting Brackets
 - 16 Throttle Controls
 - 17 Turbocharger Compressor Casing
 - 18 Turbocharger Oil Drain Line(s)
 - 19 Turbocharger Oil Supply Line(s)
 - 20 Turbocharger Turbine Casing
 - 21 Vibration Damper Mounting Capscrews
 - 22 Manual Service Disconnect
 - 23 High Voltage Interlock Loop
 - 24 High Voltage Connectors/Connections and Harnesses
 - 25 High Voltage Battery System
 - 26 Power Inverter
 - 27 Generator Motor
 - 28 Clutch Pressure Plate
- Follow all safety instructions noted in the procedures
 - Follow the manufacturer's recommendations for cleaning solvents and other substances used during repairs. Some solvents have been identified by government agencies as toxic or carcinogenic. Avoid excessive breathing, ingestion and contact with such substances. **Always** use good safety practices with tools and equipment
 - Provide a clean environment and follow the cleaning instructions specified in the procedures
 - All components **must** be kept clean during any repair. Contamination of the components will cause premature wear.
 - Perform the inspections specified in the procedures
 - Replace all components or assemblies which are damaged or worn beyond the specifications

- Use genuine Cummins new or ReCon® service parts and assemblies
- The assembly instructions have been written to use again as many components and assemblies as possible. When it is necessary to replace a component or assembly, the procedure is based on the use of new Cummins or Cummins ReCon® components. All of the repair services described in this manual are available from all Cummins Distributors and most Dealer locations.
- Follow the specified disassembly and assembly procedures to reduce the possibility of damage to the components

Welding on a Vehicle with an Electronic Controlled Fuel System

△CAUTION△

Disconnect both the positive (+) and negative (-) battery cables from the battery before welding on the vehicle. Attach the welder ground cable no more than 0.61 meters [2 feet] from the part being welded. Do not connect the ground clamp of the welder to any of the sensors, wiring harness, electronic control units or the components. Direct welding of any electronic components must not be attempted. Sensors, wiring harness, and electronic control unit should be removed if nearby welding will expose these components to temperatures beyond normal operation. Additionally, all electronic control unit connectors must be disconnected

General Cleaning Instructions

Definition of Clean

Parts **must** be free of debris that can contaminate any engine system. This does **not** necessarily mean they have to appear as new.

Sanding gasket surfaces until the factory machining marks are disturbed adds no value and is often harmful to forming a seal. It is important to maintain surface finish and flatness tolerances to form a quality sealing surface. Gaskets are designed to fill small voids in the specified surface finish.

Sanding gasket surfaces where edge-molded gaskets are used is most often unnecessary. Edge-molded gaskets are those metal carriers with sealing material bonded to the edges of the gasket to seal while the metal portion forms a metal to metal joint for stability. Any of the small amounts of sealing material that can stick to the parts are better removed with a blunt-edged scraper on the spots rather than spending time polishing the whole surface with an air sander or disc.

For those gaskets that do **not** have the edge molding, nearly all have a material that contains release agents to prevent sticking. Certainly this is **not** to say that some gaskets are **not** difficult to remove because the gasket has been in place a long time, has been overheated or the purpose of the release agent has been defeated by the application of some sealant. The object however is just to remove the gasket without damaging the surfaces of the mating parts without contaminating the engine (don't let the little bits fall where they can not be removed).

Bead blasting piston crowns until the dark stain is removed is unnecessary. All that is required is to remove the carbon build-up above the top ring and in the ring grooves. There is more information on bead blasting and piston cleaning later in this document.

Cummins Inc. does **not** recommend sanding or grinding the carbon ring at the top of cylinder liners until clean metal is visible. The liner will be ruined and any signs of a problem at the top ring reversal point (like a dust-out) will be destroyed. It is necessary to remove the carbon ring to provide for easier removal of the piston assembly. A medium bristle, high quality, steel wire wheel that is rated above the rpm of the power tool being used will be just as quick and there will be less damage. Yes, one **must** look carefully for broken wires after the piston is removed but the wires are more visible and can be attracted by a magnet.

Oil on parts that have been removed from the engine will attract dirt in the air. The dirt will adhere to the oil. If possible, leave the old oil on the part until it is ready to be cleaned, inspected and installed, and then clean it off along with any attracted dirt. If the part is cleaned then left exposed it can have to be cleaned again before installation. Make sure parts are lubricated with clean oil before installation. They do **not** need to be oiled all over but do need oil between moving parts (or a good lube system priming process conducted before cranking the engine).

Bead blasting parts to remove exterior paint is also usually unnecessary. The part will most likely be painted again so all that needs happen is remove any loose paint.

Abrasive Pads and Abrasive Paper

The keyword here is "abrasive". There is no part of an engine designed to withstand abrasion. That is they are all supposed to lock together or slide across each other. Abrasives and dirt particles will degrade both functions.



Abrasive material must be kept out of or removed from oil passages and parts wear points. Abrasive material in oil passages can cause bearing and bushing failures that can progress to major component damage beyond reuse. This is particularly true of main and rod bearings.

Cummins Inc. does **not** recommend the use of emery cloth or sand paper on any part of an **assembled** engine or component including but **not** limited to removing the carbon ridge from cylinder liners or to clean block decks or counterbores.

Great care **must** be taken when using abrasive products to clean engine parts, particularly on partially assembled engines. Abrasive cleaning products come in many forms and sizes. All of them contain aluminum oxide particles, silicon carbide, or sand or some other similar hard material. These particles are harder than most of the parts in the engine. Since they are harder, if they are pressed against softer material they will either damage the material or become embedded in it. These materials fall off the holding media as the product is used. If the products are used with power equipment the particles are thrown about the engine. If the particles fall between two moving parts, damage to the moving parts is likely.

If particles that are smaller than the clearance between the parts while they are at rest (engine stopped), but larger than the running clearance then damage will occur when the parts move relative to each other (engine started). While the engine is running and there is oil pressure, particles that are smaller than the bearing clearance are likely to pass between the parts without damage and be trapped in the oil filter. However, particles larger than the bearing clearance will remove material from one part and can become embedded in one of the parts. Once embedded in one part it will

abrade the other part until contact is no longer being made between the two parts. If the damage sufficiently degrades the oil film, the two parts will come into contact resulting in early wear-out or failure from lack of effective lubrication.

Abrasive particles can fly about during cleaning it is **very** important to block these particles from entering the engine as much as possible. This is particularly true of lubricating oil ports and oil drilling holes, especially those located downstream of the lubricating oil filters. Plug the holes instead of trying to blow the abrasive particles and debris with compressed air because the debris is often simply blown further into the oil drilling.

All old gasket material **must** be removed from the parts gasket surfaces. However, it is **not** necessary to clean and polish the gasket surface until the machining marks are erased. Excessive sanding or buffing can damage the gasket surface. Many newer gaskets are of the edge molded type (a steel carrier with a sealing member bonded to the steel). What little sealing material that can adhere is best removed with a blunt-edged scraper or putty knife. Cleaning gasket surfaces where an edge-molded gasket is used with abrasive pads or paper is usually a waste of time.

WARNING

Excessive sanding or grinding the carbon ring from the top of the cylinder liners can damage the liner beyond reuse. The surface finish will be damaged and abrasive particles can be forced into the liner material which can cause early cylinder wear-out or piston ring failures.

Tape off or plug all openings to any component interior before using abrasive pads or wire brushes. If really necessary because of time to use a power tool with abrasive pads, tape the oil drillings closed or use plug and clean as much of the surface as possible with the tool but clean around the oil hole/opening by hand so as to prevent contamination of the drilling. Then remove the tape or plug and clean the remaining area carefully and without the tool. **DO NOT** use compressed air to blow the debris out of oil drilling on an assembled engine! More likely than **not**, the debris can be blown further into the drilling. Using compressed air is fine if both ends of the drilling are open but that is rarely the case when dealing with an assembled engine.

Gasket Surfaces

The object of cleaning gasket surfaces is to remove any gasket material, not refinish the gasket surface of the part.

Cummins Inc. does **not** recommend any specific brand of liquid gasket remover. If a liquid gasket remover is used, check the directions to make sure the material being cleaned will **not** be harmed.

Air powered gasket scrapers can save time but care must be taken to **not** damage the surface. The angled part of the scraper must be against the gasket surface to prevent the blade from digging into the surface. Using air powered gasket scrapers on parts made of soft materials takes skill and care to prevent damage.

Do **not** scrape or brush across the gasket surface if at all possible.

Solvent and Acid Cleaning

Several solvent and acid-type cleaners can be used to clean the disassembled engine parts (other than pistons. See Below). Experience has shown that the best results can be obtained using a cleaner that can be heated to 90° to 95° Celsius (180° to 200° Fahrenheit). Kerosene emulsion based cleaners have different temperature specifications, see below. A cleaning tank that provides a constant mixing and filtering of the cleaning solution will give the best results. Cummins Inc. does not recommend any specific cleaners. Always follow the cleaner manufacturer's instructions. Remove all the gasket material, o-rings, and the deposits of sludge, carbon, etc., with a wire brush or scraper before putting the parts in a cleaning tank. Be careful not to damage any gasket surfaces. When possible, steam clean the parts before putting them in the cleaning tank.

WARNING

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturers recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

Experience has shown that kerosene emulsion based cleaners perform the best to clean pistons. These cleaners should **not** be heated to temperature in excess of 77°C (170°F). The solution begins to break down at temperatures in excess of 82°C (180°F) and will be less effective.

Do **not** use solutions composed mainly of chlorinated hydrocarbons with cresols, phenols and/or cresylic components. They often do **not** do a good job of removing deposits from the ring groove and are costly to dispose of properly.

Solutions with a pH above approximately 9.5 will cause aluminum to turn black; therefore do **not** use high alkaline solutions.

Chemicals with a pH above 7.0 are considered alkaline and those below 7.0 are acidic. As you move further away from the neutral 7.0, the chemicals become highly alkaline or highly acidic.

Remove all the gasket material, o-rings, and the deposits of sludge, carbon, etc., with a wire brush or scraper before putting the parts in a cleaning tank. Be careful to **not** damage any gasket surfaces. When possible use hot high

pressure water or steam clean the parts before putting them in the cleaning tank. Removing the heaviest dirt before placing in the tank will allow the cleaner to work more effectively and the cleaning agent will last longer.

Rinse all the parts in hot water after cleaning. Dry completely with compressed air. Blow the rinse water from all the capscrew holes and the oil drillings.

If the parts are **not** to be used immediately after cleaning, dip them in a suitable rust proofing compound. The rust proofing compound **must** be removed from the parts before assembly or installation on the engine.

Steam Cleaning

Steam cleaning can be used to remove all types of dirt that can contaminate the cleaning tank. It is a good method for cleaning the oil drillings and coolant passages



When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

Do **not** steam clean the following components:

- Electrical Components
- Wiring Harnesses
- Belts and Hoses
- Bearings (ball or taper roller)
- Electronic Control Module (ECM)
- ECM Connectors
- Capacitive Coil Driver Module (CCD)
- Ignition Coils and Leads
- NOx Sensor
- Fuel Control Valve
- Throttle Driver and Actuator.

Plastic Bead Cleaning

Cummins Inc. does **not** recommend the use of glass bead blast or walnut shell media on **any** engine part. Cummins Inc. recommends using **only** plastic bead media, Part Number 3822735 or equivalent on any engine part. **Never** use sand as a blast media to clean engine parts. Glass and walnut shell media when **not** used to the media manufacturer's recommendations can cause excess dust and can embed in engine parts that can result in premature failure of components through abrasive wear.

Plastic bead cleaning can be used on many engine components to remove carbon deposits. The cleaning process is controlled by the use of plastic beads, the operating pressure and cleaning time.



Do not use bead blasting cleaning methods on aluminum pistons skirts or the pin bores in any piston, piston skirt or piston crown. Small particles of the media will embed in the aluminum or other soft metal and result in premature wear of the cylinder liner, piston rings, pins and pin bores. Valves, turbocharger shafts, etc., can also be damaged. Follow the cleaning directions listed in the procedures.



Do not contaminate wash tanks and tank type solvent cleaners with the foreign material and plastic beads. Remove the foreign material and plastic beads with compressed air, hot high pressure water or steam before placing them in tanks or cleaners. The foreign material and plastic beads can contaminate the tank and any other engine parts cleaned in the tank. Contaminated parts may cause failures from abrasive wear.

Plastic bead blasting media, Part Number 3822735, can be used to clean all piston ring grooves. Do **not** use any bead blasting media on piston pin bores or aluminum skirts.

Follow the equipment manufacturer's cleaning instructions. Make sure to adjust the air pressure in the blasting machine to the bead manufacturer's recommendations. Turning up the pressure can move material on the part and cause the plastic bead media to wear out more quickly. The following guidelines can be used to adapt to manufacturer's instructions:

- 1 Bead size: U.S. size Number 16 — 20 for piston cleaning with plastic bead media, Part Number 3822735

- 2 Operating Pressure — 270 kPa (40 psi) for piston cleaning. Pressure should not cause beads to break.
- 3 Steam clean or wash the parts with solvent to remove all of the foreign material and plastic beads after cleaning. Rinse with hot water. Dry with compressed air.

▲CAUTION▲

The bead blasting operation must not disturb the metal surface. If the metal surface is disturbed the engine can be damaged due to increased parts clearance or inadequate surface finish on parts that move against other parts.

When cleaning pistons, it is **not** necessary to remove all the dark stain from the piston. All that is necessary is to remove the carbon on the rim and in the ring grooves. This is best done by directing the blast across the part as opposed to straight at the part. If the machining marks are disturbed by the blasting process, then the pressure is too high or the blast is being held on one spot too long. The blast operation **must not** disturb the metal surface.

Walnut shell bead blast material is sometimes used to clean ferrous metals (iron and steel). Walnut shell blasting produces a great amount of dust particularly when the pressure if the air pressure on the blasting machine is increased above media manufacturer's recommendation. Cummins Inc. recommends **not** using walnut shell media to clean engine parts due to the risk media embedment and subsequent contamination of the engine.

Cummins Inc. now recommends glass bead media **NOT** used to clean any engine parts. Glass media is too easily embedded into the material particularly in soft materials and when air pressures greater than media manufacturer's recommend are used. The glass is an abrasive so when it is in a moving part, that part is abrading all the parts in contact with it. When higher pressures are used the media is broken and forms a dust of a very small size that floats easily in the air. This dust is very hard to control in the shop, particularly if **only** compressed air (and not hot water) is used to blow the media after it is removed from the blasting cabinet (blowing the part off inside the cabinet may remove large accumulations but never removes all the media).

Bead blasting is best used on stubborn dirt/carbon build-up that has **not** been removed by first steam/higher pressure washing then washing in a heated wash tank. This is particularly true of pistons. Steam and soak the pistons first then use the plastic bead method to safely remove the carbon remaining in the grooves (instead of running the risk of damaging the surface finish of the groove with a wire wheel or end of a broken piston ring. Make sure the parts are dry and oil free before bead blasting to prevent clogging the return on the blasting machine.

Always direct the bead blaster nozzle "across" rather than directly at the part. This allows the bead to get under the unwanted material. Keep the nozzle moving rather than hold on one place. Keeping the nozzle directed at one-place too long causes the metal to heat up and be moved around. Remember that the spray is **not** just hitting the dirt or carbon. If the machining marks on the piston groove or rim have been disturbed then there has **not** been enough movement of the nozzle and/or the air pressure is too high.

Never bead blast valve stems. Tape or use a sleeve to protect the stems during bead blasting. Direct the nozzle across the seat surface and radius rather than straight at them. The object is to remove any carbon build up and continuing to blast to remove the stain is a waste of time.

Fuel System

When servicing any fuel system components, which can be exposed to potential contaminants, prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. If the surrounding areas are **not** cleaned, dirt or contaminants can be introduced into the fuel system.

The internal drillings of some injectors are extremely small and susceptible to plugging from contamination. Some fuel injection systems can operate at very high pressures. High pressure fuel can convert simple particles of dirt and rust into a highly abrasive contaminant that can damage the high pressure pumping components and fuel injectors.

Electrical contact cleaner can be used if steam cleaning tools are **not** available. Use electrical contact cleaner rather than compressed air, to wash dirt and debris away from fuel system fittings. Diesel fuel on exposed fuel system parts attracts airborne contaminants.

Choose lint free towels for fuel system work.

Cap and plug fuel lines, fittings, and ports whenever the fuel system is opened. Rust, dirt, and paint can enter the fuel system whenever a fuel line or other component is loosened or removed from the engine. In many instances, a good practice is to loosen a line or fitting to break the rust and paint loose, and then clean off the loosened material.

When removing fuel lines or fittings from a new or newly-painted engine, make sure to remove loose paint flakes/chips that can be created when a wrench contacts painted line nuts or fittings, or when quick disconnect fittings are removed.

Fuel filters are rated in microns. The word micron is the abbreviation for a micrometer, or one millionth of a meter. The micron rating is the size of the smallest particles that will be captured by the filter media. As a reference, a human hair

is 76 microns [0.003 in] in diameter. One micron measures 0.001 mm [0.00004 in.]. The contaminants being filtered out are smaller than can be seen with the human eye, a magnifying glass, or a low powered microscope.

The tools used for fuel system troubleshooting and repair are to be cleaned regularly to avoid contamination. Like fuel system parts, tools that are coated with oil or fuel attract airborne contaminants. Remember the following points regarding your fuel system tools:

- Fuel system tools are to be kept as clean as possible.
- Clean and dry the tools before returning them to the tool box.
- If possible, store fuel system tools in sealed containers.
- Make sure fuel system tools are clean before use.

Acronyms and Abbreviations

General Information

The following list contains some of the acronyms and abbreviations used in this manual.

ANSI	American National Standards Institute
API	American Petroleum Institute
ASTM	American Society of Testing and Materials
ATDC	After Top Dead Center
BTU	British Thermal Unit
BTDC	Before Top Dead Center
°C	Celsius
CAN	Controller Area Network
CO	Carbon Monoxide
CCA	Cold Cranking Amperes
CARB	California Air Resources Board
C.I.B.	Customer Interface Box
C.I.D.	Cubic Inch Displacement
CNG	Compressed Natural Gas
CPL	Control Parts List
cSt	Centistokes
DEF	Diesel Exhaust Fluid
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
ECM	Engine Control Module
EFC	Electronic Fuel Control
EGR	Exhaust Gas Recirculation
EPA	Environmental Protection Agency
°F	Fahrenheit
ft-lb	Foot-Pound Force
FMI	Failure Mode Identifier
GVW	Gross Vehicle Weight
Hg	Mercury
hp	Horsepower
H₂O	Water
inHg	Inches of Mercury
in H₂O	Inches of Water
ICM	Ignition Control Module
IEC	International Electrotechnical Commission
km/l	Kilometers per Liter
kPa	Kilopascal
LNG	Liquid Natural Gas
LPG	Liquified Petroleum Gas
LTA	Low Temperature Aftercooling
MCRS	Modular Common Rail System
MIL	Malfunction Indicator Lamp
MPa	Megapascal
mph	Miles Per Hour
mpq	Miles Per Quart
N•m	Newton-meter

NOx	Mono-Nitrogen Oxides
NG	Natural Gas
O2	Oxygen
OBD	On-Board Diagnostics
OEM	Original Equipment Manufacturer
OSHA	Occupational Safety and Health Administration
PID	Parameter Identification Descriptions
ppm	Parts Per Million
psi	Pounds Per Square Inch
PTO	Power Takeoff
REPTO	Rear Power Take Off
RGT	Rear Gear Train
rpm	Revolutions Per Minute
SAE	Society of Automotive Engineers
SCA	Supplemental Coolant Additive
SCR	Selective Catalytic Reduction
STC	Step Timing Control
SID	Subsystem Identification Descriptions
TDC	Top Dead Center
VDC	Volts of Direct Current
VGT	Variable Geometry Turbocharger
VS	Variable Speed
VSS	Vehicle Speed Sensor

Section E - Engine and System Identification

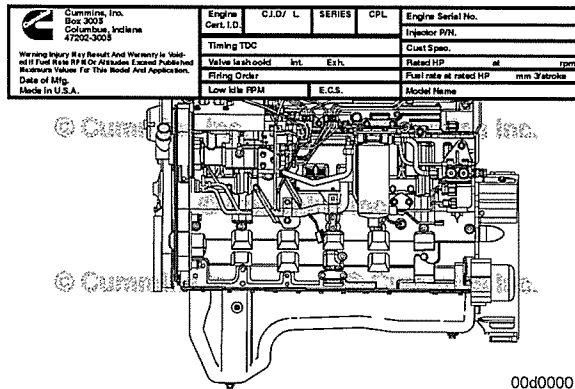
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Engine Identification


Engine Dataplate



00d00001

The engine dataplate provides important information about the engine. The engine serial number (ESN) and control part list (CPL) provide information for service and for ordering parts. The engine dataplate **must not** be changed unless approved by Cummins Inc.

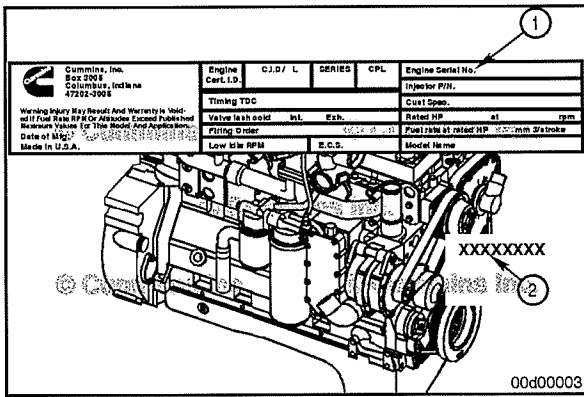
Have the following engine data available when communicating with a Cummins® Authorized Repair Location. The information on the dataplate is mandatory when sourcing service parts.

<p>MANUFACTURED BY CUMMINS INC.</p>  <p>Assembled in the USA © 3987607</p> <p>Date of Mfg:</p> <p>WARNING: Injury may result and warranty is voided if fuel rate, rpm or altitudes exceed published maximum values for this model and application.</p>	Engine No.	Ref. No.	MODEL	Fuel Rate at Adv. HP	Mm ³ Stroke		CPL
	Idle Speed (rpm)	Advertised HP	at rpm	Family	FEL	EPA	CARB
	Firing Order	Timing T.D.C.	ELECTRONIC	Catalyst No.	NOx+NMHC		
	Valve lash cold	int.	Exh.	C.I. D./L /	E. C. S.	PM	
	<p>IMPORTANT ENGINE INFORMATION: This engine is exempt from the prohibitions of section 203 (a) (1) (3) & (4) of the Clean Air Act as amended. See exemption label information for exemption no. and effective date.</p>						

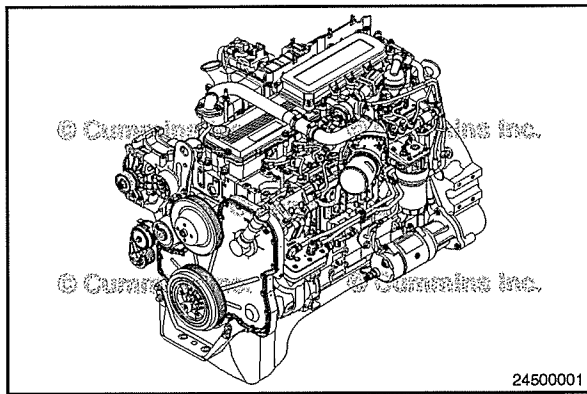
00d00269

- 1 Engine serial number (ESN)
- 2 Engine model information
- 3 Control parts list (CPL)
- 4 Valve lash (overhead) setting
- 5 Horsepower and rpm rating.

NOTE: Depending on the manufacturing plant, calibration data may also be found on the engine dataplate.



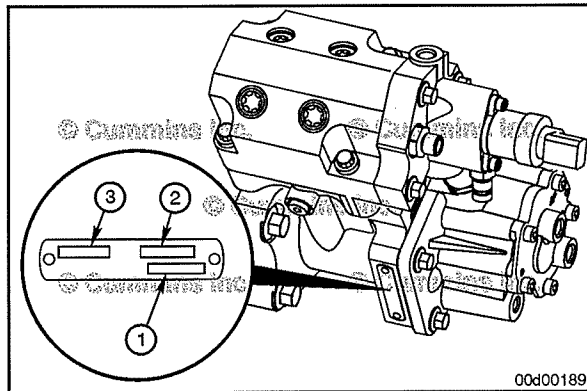
If the engine dataplate (1) is **not** legible, the engine serial number (ESN) (2) can be found on the engine block, on top of the lubricating oil cooler housing. Additional engine information is on the engine control module dataplate.



Cummins® Engine Nomenclature

The Cummins® Service Engine Model Identification procedure describes how to use the Cummins® Service Model Name to identify an engine. Refer to Procedure 100-005 in Section E.

The Cummins® Product Technology procedure provides the Cummins® Service Model Name and describes the unique technology used by the engine covered by this manual. Refer to Procedure 100-006 in section E



Fuel Pump Dataplate

The fuel pump dataplate is located on the side of the high-pressure pump. The dataplate contains the following information:

- 1 Cummins® part number
- 2 Pump serial number
- 3 Factory code.

Engine Control Module Dataplate

The engine control module (ECM) dataplate is located on the front of the ECM.

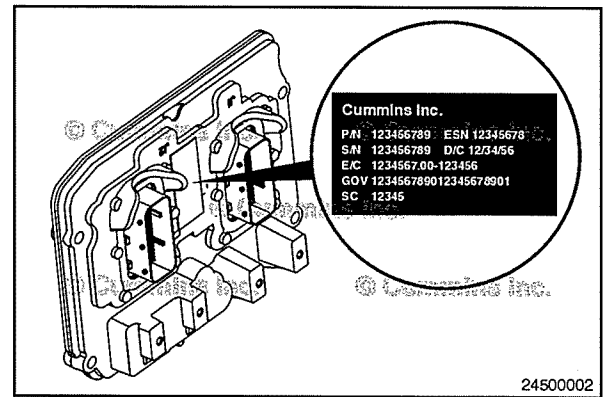
The following information is found on the engine control module dataplate:

- ECM part number (PN)
- ECM serial number (SN)
- ECM date code (DC)
- Engine serial number (ESN)
- ECM Code: identifies the software in the ECM).

NOTE: The presence of an ECM dataplate depends on the manufacturing plant and the date the engine was manufactured. If an ECM dataplate was **not** installed by the manufacturing plant, calibration data can be found on the engine dataplate.

NOTE: Not all engines will have ECM dataplates.

Engines covered by this manual are equipped with a CM2350 ECM. A CM2350 engine control module has two 96-pin connectors.

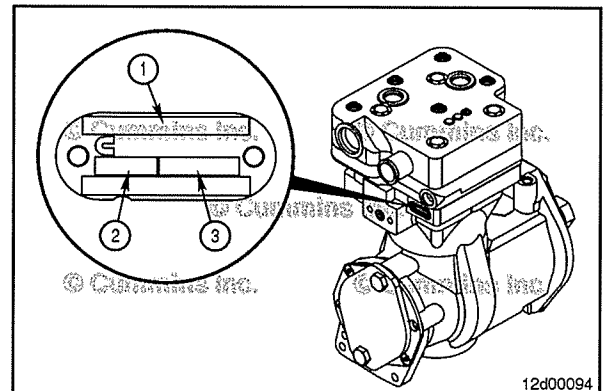


Air Compressor

NOTE: Not all engines are equipped with an air compressor.

The Cummins® branded air compressor dataplate, identified by the Cummins Inc. logo on the dataplate, is typically located on the rear side of the air compressor. The dataplate contains the following information that assists in service or replacement.

- 1 Cummins® part number
- 2 Date code
- 3 Serial number.

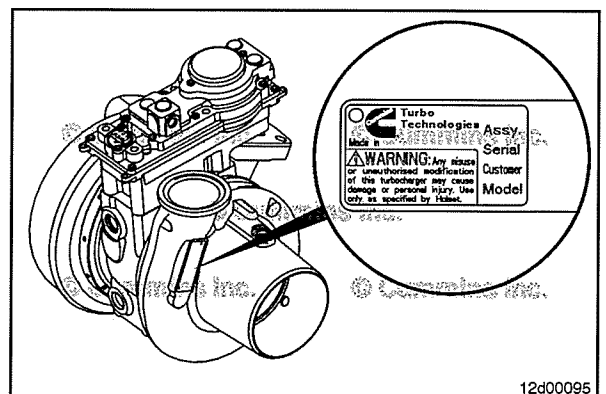


Variable Geometry Turbocharger

The variable geometry turbocharger dataplate is located on the turbocharger inlet compressor housing. The dataplate contains the following information which will assist in service or replacement.

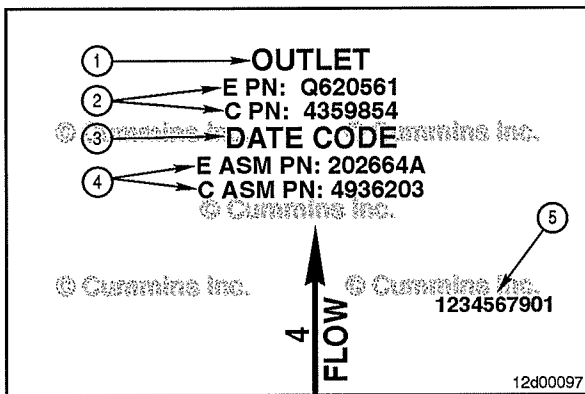
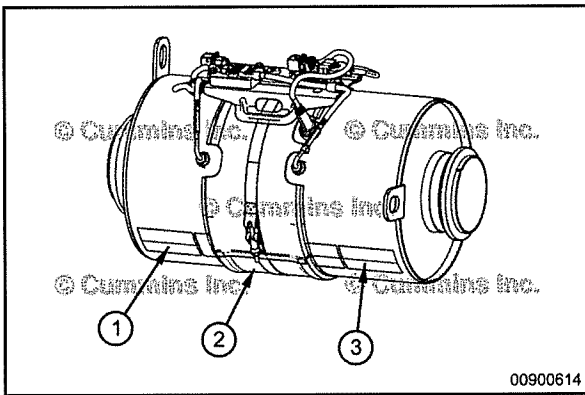
- Cummins® assembly part number
- Serial number
- Customer number
- Model number.

NOTE: The electronic actuator on the variable geometry turbocharger is a serviceable component and has a separate dataplate that assists in service or replacement.



Exhaust System

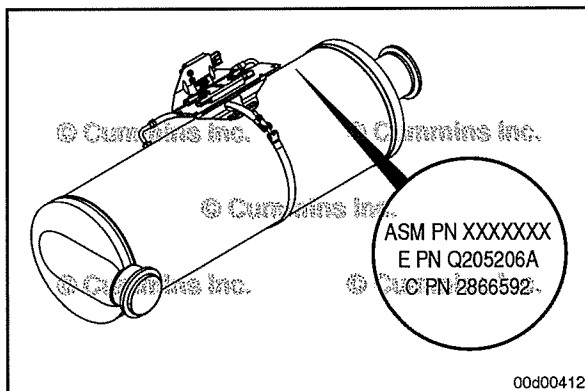
The diesel oxidation catalyst (DOC) aftertreatment assembly has important information for service and replacement stamped into the canister.



A typical aftertreatment information stamping can provide the following:

- 1 Section name
- 2 Part number
- 3 Date code
- 4 Assembly number (**only** located on the outlet section)
- 5 Serial number.

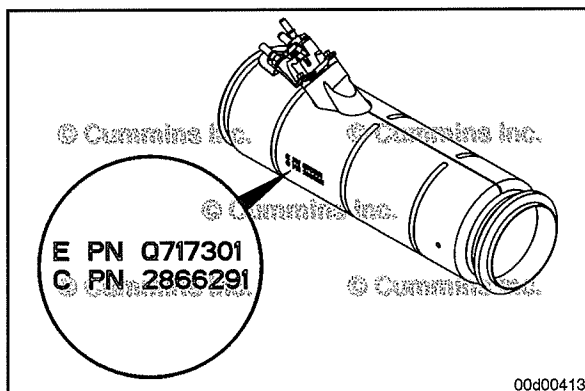
NOTE: Some aftertreatment components could possibly **only** have the Cummins Emission Solutions™ part number for cross referencing and part number identification. Reference to QuickServe® Online.



The aftertreatment selective catalytic reduction catalyst identification is located on the side of the part and contains the following information to assist in service or replacement:

- Assembly part number
- Cummins Emission Solutions™ part number
- Cummins® part number.

NOTE: Some aftertreatment components could possibly **only** have the Cummins Emission Solutions™ part number for cross referencing and part number identification. Reference to QuickServe® Online.



The aftertreatment decomposition tube identification is located on the side of the part and contains the following information to assist in service or replacement:

- Cummins Emission Solutions™ part number
- Cummins® part number.

NOTE: Some aftertreatment components may **only** have the Cummins Emission Solutions™ part number for cross referencing and part number identification. Reference to QuickServe® Online.

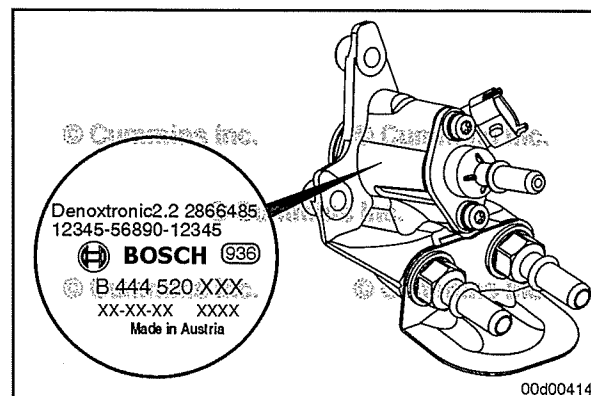
The aftertreatment diesel exhaust fluid dosing valve identification is located on the side of the valve and contains the following information to assist in service or replacement:

- Cummins® part number
- Cummins Emission Solutions™ part number
- Bosch™ part number
- Bosch™ production data (date code and serial number).

Example:

- 2866485 is the Cummins® part number
- 12345-67890-12345 is the Cummins Emission Solutions™ part number
- B 444 606 XXX is the Bosch™ part number
- XX-XX-XX is the date code
- XXXX is the serial number.

NOTE: Some aftertreatment components may **only** have the Cummins Emission Solutions™ part number for cross referencing and part number identification. Reference to QuickServe® Online.



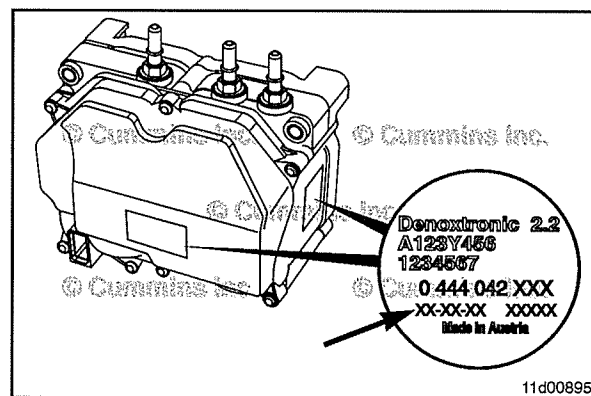
The aftertreatment diesel exhaust fluid dosing unit identification is located on the side of the part and contains the following information to assist in servicing or replacement:

- Cummins Emission Solutions™ part number
- Cummins® part number
- Bosch™ part number
- Bosch™ production data (date code and serial number).

Example:

- A123Y456 is the Cummins Emission Solutions™ part number
- 1234567 is the Cummins® part number
- 0 444 042 XXX is the Bosch™ part number
- XX-XX-XX is the date code
- XXXXX is the serial number.

NOTE: Some aftertreatment components may **only** have the Cummins Emission Solutions™ part number for cross referencing and part number identification. Reference to QuickServe® Online.



Engine Diagrams

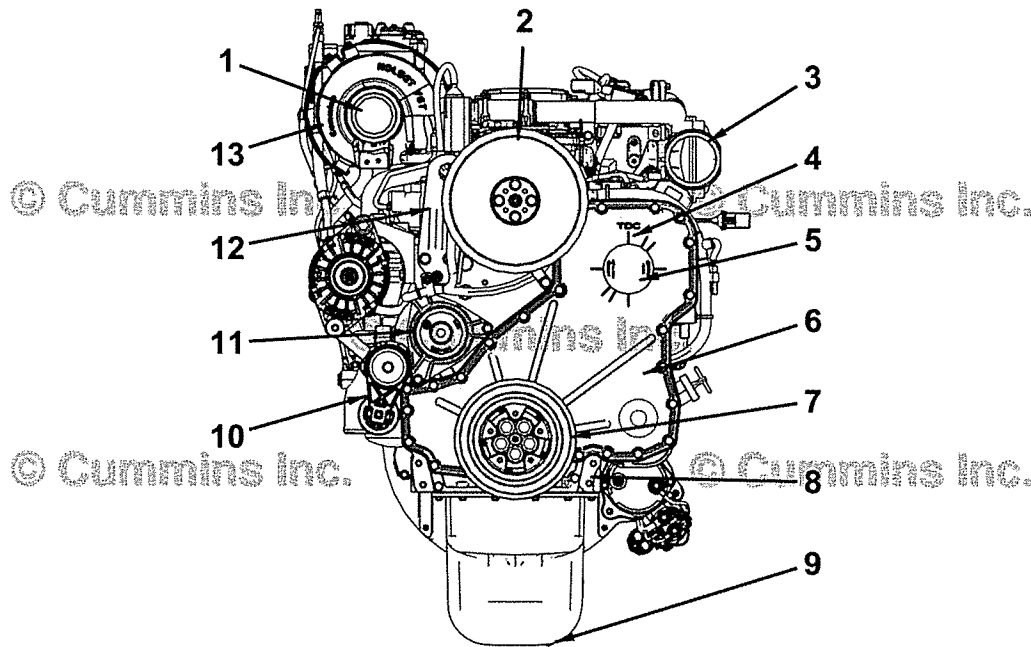
Engine Views

The following illustrations provide the locations of the major external engine components, filters, and other service and maintenance points. Some external components will be at different locations for different engine models.

The illustrations are **only** a reference to show a typical engine.

Engine Diagrams

Engine Views



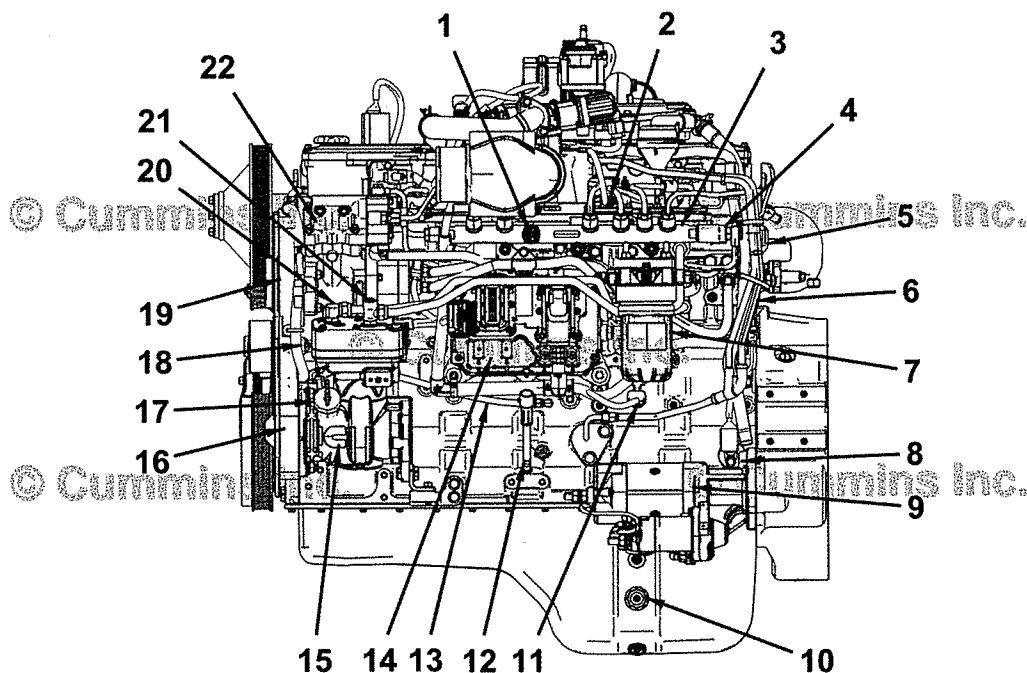
Front View - QSL9 CM2350

00900615

- 1 Turbocharger compressor air inlet
- 2 Fan pulley
- 3 Air intake connection
- 4 Top dead center indicator
- 5 Fuel pump drive gear access cover
- 6 Front gear cover
- 7 Vibration damper
- 8 Front engine mounting bracket
- 9 Engine lubricating oil pan drain plug
- 10 Belt tensioner
- 11 Water pump
- 12 Front engine lifting bracket
- 13 Turbocharger.

Engine Diagrams

Engine Views



Left View - QSL9 CM2350

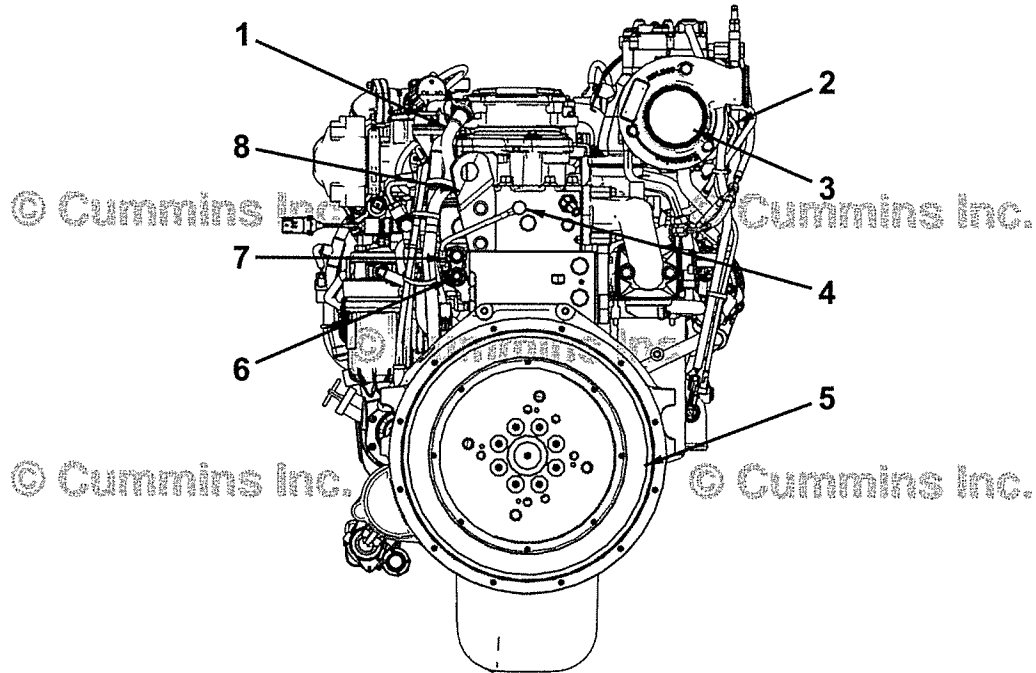
00900616

- 1 Fuel rail pressure sensor
- 2 Intake manifold temperature and pressure sensor
- 3 Fuel rail
- 4 Fuel rail high pressure relief valve
- 5 Fuel drain line
- 6 Crankcase breather oil drain tubes
- 7 Fuel filter
- 8 Crankshaft speed sensor
- 9 Starter
- 10 Engine oil heater mounting boss
- 11 Lubricating oil pressure sensor
- 12 Dipstick location
- 13 Air compressor oil supply line
- 14 Engine control module (ECM)
- 15 Air compressor
- 16 Gear housing
- 17 Engine lubricating oil fill location
- 18 Camshaft speed sensor
- 19 Engine dataplate
- 20 Air compressor coolant drain line
- 21 Air compressor coolant supply line
- 22 Fuel pump.

NOTE: The fuel lift pump is behind the ECM and is not shown in the illustration.

Engine Diagrams

Engine Views



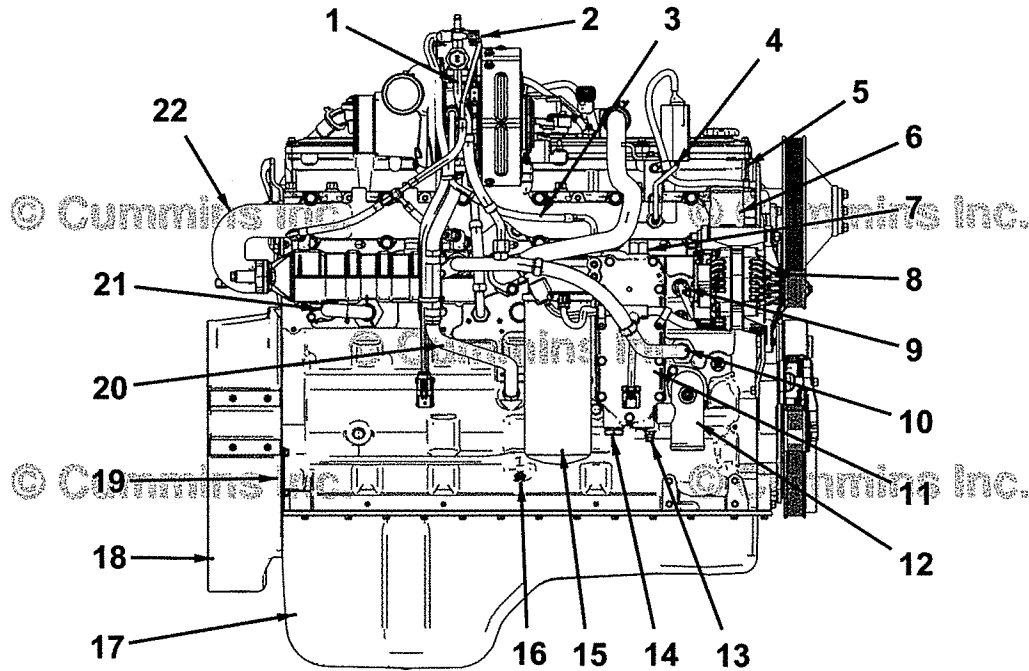
Rear View - QSL9 CM2350

00900617

- 1 Crankcase breather draft tube
- 2 Turbocharger speed sensor
- 3 Turbocharger exhaust outlet
- 4 Injector drain line connection
- 5 Flywheel
- 6 Original equipment manufacturer (OEM) fuel supply line connection
- 7 OEM fuel drain line connection
- 8 Rear engine lifting bracket.

Engine Diagrams

Engine Views



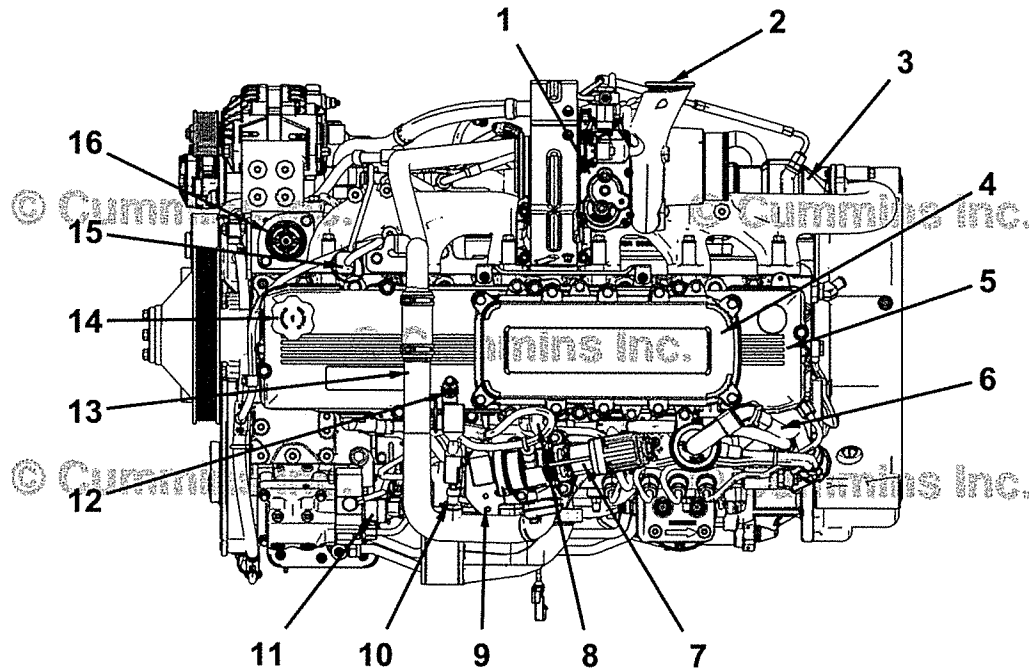
Right View - QSL9 CM2350

00900618

- 1 Turbocharger and actuator coolant supply
- 2 Turbocharger and actuator coolant drain
- 3 Turbocharger oil supply line
- 4 Exhaust gas pressure sensor tube
- 5 Rocker lever housing
- 6 Coolant outlet connection
- 7 Lubricating oil thermostat
- 8 Alternator
- 9 Coolant temperature sensor
- 10 Exhaust gas recirculation (EGR) cooler coolant return
- 11 Lubricating oil cooler
- 12 Coolant inlet connection
- 13 Coolant drain petcock
- 14 Lubricating oil pressure regulator
- 15 Lubricating oil filter
- 16 Dipstick location
- 17 Lubricating oil pan
- 18 Flywheel housing
- 19 Engine barring port
- 20 Turbocharger oil drain line
- 21 EGR cooler coolant supply
- 22 Exhaust manifold.

Engine Diagrams

Engine Views



Top View - QSL9 CM2350

- 1 Turbocharger actuator
- 2 Turbocharger compressor air outlet
- 3 EGR cooler
- 4 Crankcase breather
- 5 Rocker lever cover
- 6 Crankcase breather draft tube
- 7 EGR valve
- 8 Crankcase breather oil drain tubes
- 9 EGR differential pressure sensor
- 10 Exhaust gas temperature sensor
- 11 Fuel pump actuator
- 12 Crankcase pressure sensor
- 13 EGR crossover tube
- 14 Engine oil fill
- 15 Exhaust gas pressure sensor
- 16 Thermostat.

Cummins® Service Engine Model Identification

General Information

The Cummins® Service Engine Model Identification procedure describes:

- The purpose of the Cummins® Service Model Name.
- How to interpret a Cummins® Service Model Name to identify a Cummins® Engine.

This includes 2013 and later products.

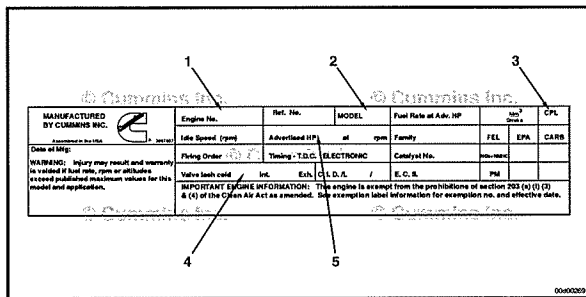
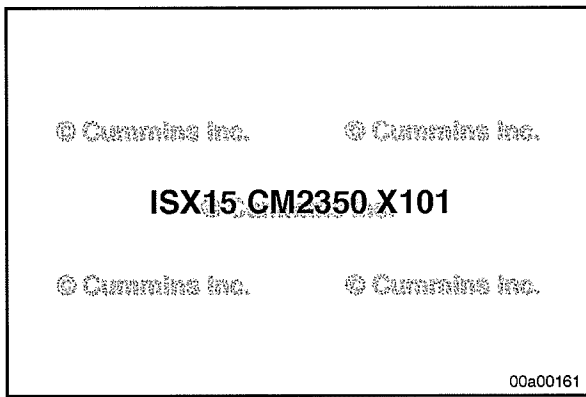
The Cummins® Service Model Name differs from the Cummins® marketing model name. Service model names are more specific and help to match the correct Cummins® service information to the correct engine. Marketing engine model names are more generic and can capture multiple engine variations in the same model name.

Marketing Engine Model Name	Service Model Name
ISX15	ISX15 CM2350 X101

Marketing engine model names (2) can be found on the engine dataplate, Cummins® brochures, and Cummins® promotional literature.

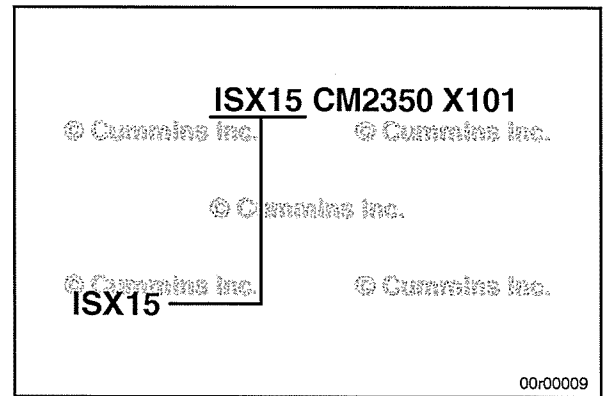
Examples of Cummins® service information and products that use service model names:

- QuickServe™ Online
- INSITE™ electronic service tool
- Owner's Manual
- Operation and Maintenance Manual
- Master Repair Manual
- Service Manual
- Wiring Diagram
- Fault Code Troubleshooting Manual
- Standard Repair Times
- Technical Service Bulletins
- Service Bulletins



The Cummins® Service Model Name begins with the marketing engine model name.

NOTE: For engines released specifically for the European market, marketing model names may include an “e” between the engine platform designation and the engine liter displacement. Service model names will not display this “e”.



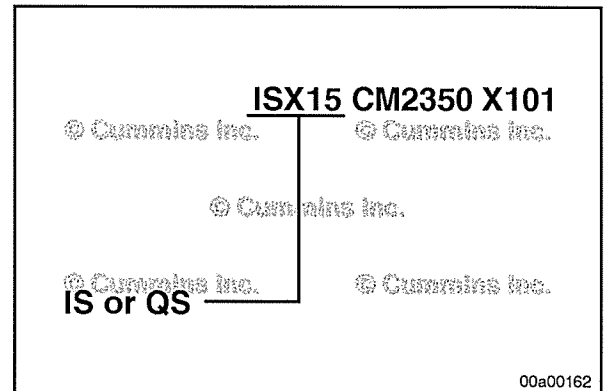
Typically, the first two letters of the marketing model name contain an “IS” or “QS” if the engine is an electronic engine.

“IS” prefix designates an On-Highway automotive engine.

“QS” prefix designates an Off-Highway industrial engine.

NOTE: Not all electronic engines use the “IS” or “QS” prefix. To verify if the engine is an electronic engine, check to see if an electronic control system is listed in the service model name. The control system that is identified as part of the service model name is referenced later in this procedure.

Non-electronic engines do not have an “IS” or “QS” prefix and do not have an electronic control system listed in the service model name.

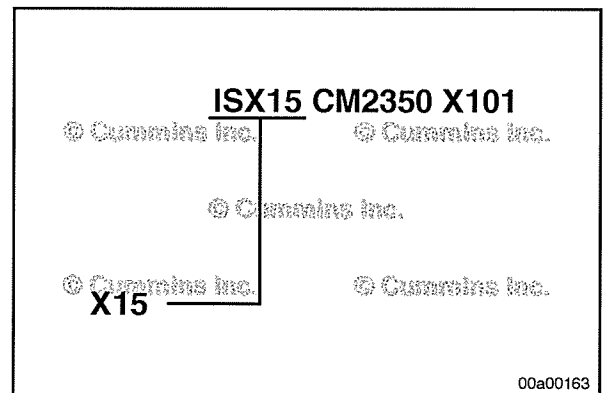


Typically, the third letter is the engine platform/series designation followed by the engine liter displacement. For the example shown in the graphic, the engine is a:

X Series engine

15 Liters in Displacement

NOTE: Some legacy engines will use the cubic inch rather than liter for engine displacement.

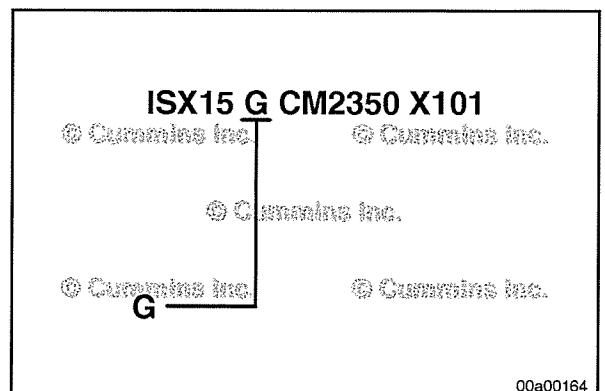


If a “G” indicator is located after the liter displacement, the engine is fueled by natural gas.

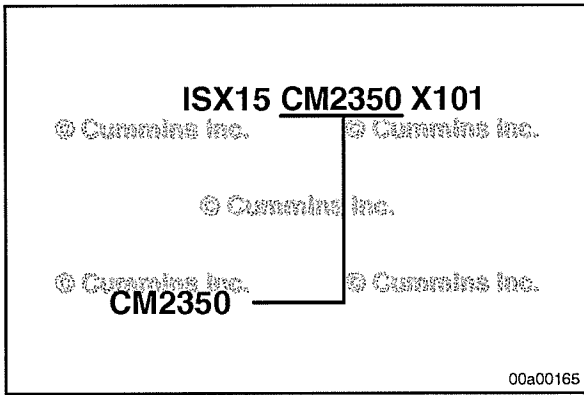
NOTE: Not all engines fueled by natural gas will have a “G” located after the displacement.

If a “M” is located after the liter displacement, the engine is in a marine application.

NOTE: Not all engines used in a marine application will have “M” located after the displacement.



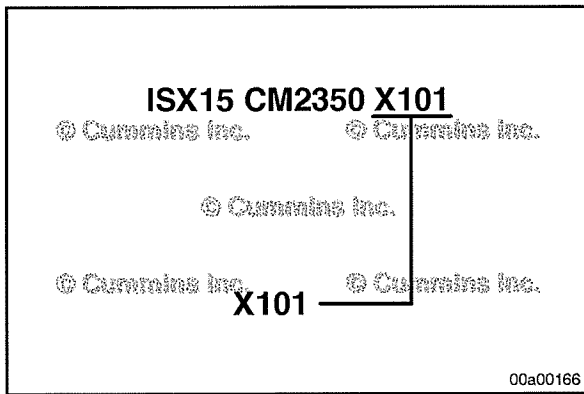
The engine control system is identified with the letters "CM" followed by the control system model number.



The identifier after the control system is a letter and number combination to identify variations between products.

The letter is the engine platform designation.

The number increments as new variations of the engine platform/series are released. The first number is 101.



Cummins® Product Technology

General Information

The service model name for this product is **QSL9 CM2350 L102**.

This engine is being released to meet the following emission regulations:

- United States and Canada
- Tier 4 (EPA Final)
- European Union
- Stage IV (Euro)
- Japan
- Korea (South).

This engine has the following Agency defined Emissions Control System (ECS) hardware, which can also be found on the engine dataplate. Use the following procedure for the location of the engine dataplate. Refer to Procedure 100-001 in Section E.

EPA Products

- Engine Control Module (ECM)
- Exhaust Gas Recirculation (EGR)
- Oxidation Catalyst (OC)
- Selective Catalytic Reduction - Urea (SCR-U)
- Turbocharger (TC).

This engine uses the following product technology:

Engine

- Number of Cylinders - 6
- Engine Configuration - Inline
- Cylinder Block Material - Cast Iron
- Cylinder Head Material - Cast Iron
- Camshaft Location - Cylinder Block.

Electronic Control System

- Control Module: CM2350
- Engine Coolant Level Sensor
- Engine Coolant Temperature Sensor
- Engine Oil Pressure Sensor
- Engine Oil Pressure Switch
- Engine Oil Level Sensor
- Fuel Rail Pressure Sensor
- Fuel Pump Actuator
- Water-in-Fuel Sensor
- Camshaft Position Sensor
- Crankshaft Position Sensor
- EGR Differential Pressure Sensor
- Exhaust Gas Pressure Sensor
- EGR Temperature Sensor
- Intake Manifold Pressure/Temperature Sensor
- Turbocharger Speed Sensor

- Turbocharger Compressor Intake Pressure/Temperature Sensor
- Ambient Air Temperature Sensor
- Crankcase Pressure Sensor
- Aftertreatment Exhaust Gas Temperature Sensor
- Diesel Exhaust Fluid Quality Sensor
- Aftertreatment Intake mono-nitrogen oxides (NOx) Sensor
- Aftertreatment Outlet NOx Sensor.

Air Handling

- Turbocharger (Single)
- Variable Geometry
- Intake Air Heater.

Fuel System

- Diesel
- Common Rail Fuel System
- Cummins XPI Common Rail Fuel System.

Exhaust System

- Exhaust Gas Recirculation (EGR)
- Aftertreatment Fuel Injection
- Internal
- Diesel Oxidation Catalyst (DOC)
- Selective Catalytic Reduction (SCR) Catalyst
- Aftertreatment Diesel Exhaust Fluid Dosing System
- Airless Diesel Exhaust Fluid Dosing Unit
- Integrated Diesel Exhaust Fluid Controller (controlled by the engine's ECM).

Market applications that will use this engine include, but are **not** limited to:

Industrial

- Agriculture
- Construction
- Fire Pump
- Locomotive
- Power Unit
- Rail Car
- Oil and Gas
- Welding
- Air Compressor
- Underground Mining
- Track Maintenance.

Section F - Familiarization

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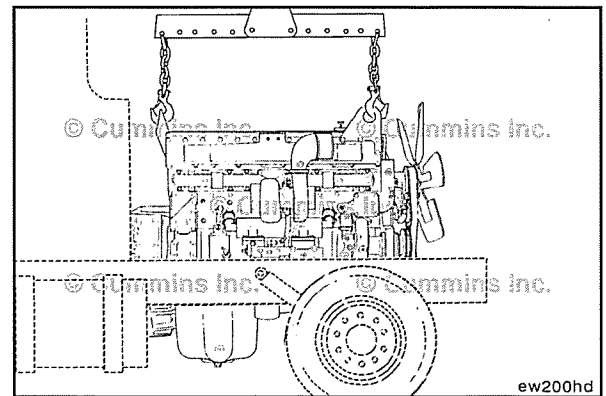
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Complete Engine - Overview (000-999)

General Information

The procedures required to replace an engine will vary with different engine models, the type of equipment, optional equipment, and the shop facilities. Use the following procedures as a guide.

All replacement steps will **not** apply to all types of equipment. Complete **only** the steps that apply to the equipment involved. Use the equipment manufacturer's recommendations and precautions for removal of chassis parts to gain access to the engine.



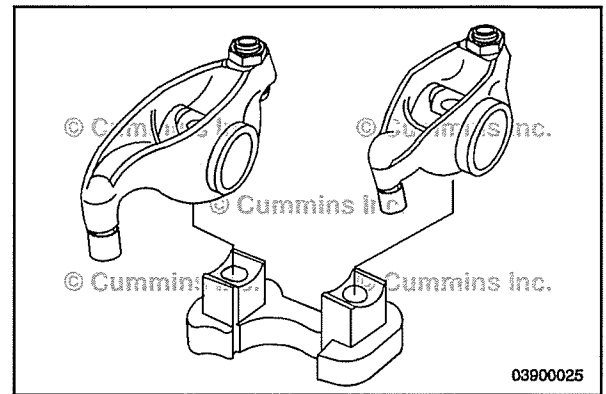
Rocker Levers - Overview (003-999)

General Information

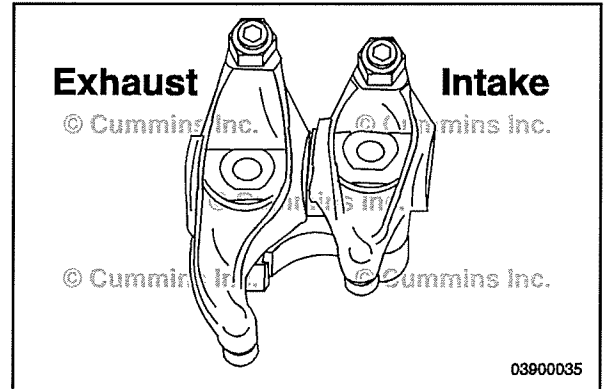
Rocker Levers

The exhaust and intake rocker levers are mounted on a common pedestal, but rotate on separate shafts.

Oil is supplied through a drilling in the cylinder head through the pedestals to supply oil to the rocker shafts, socket, and adjusting screw.



The exhaust and intake rocker levers are **not** interchangeable and **must** be located as shown.



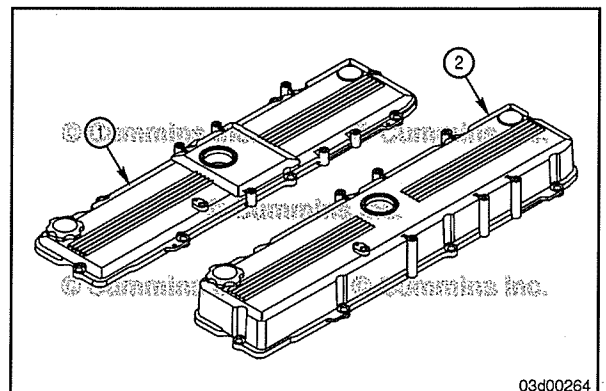
Rocker Lever Cover

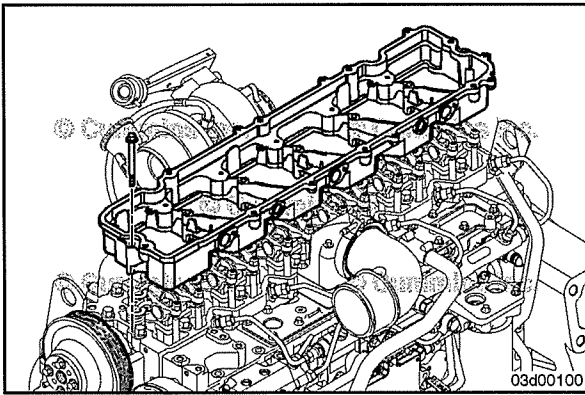
Several different kinds of rocker lever covers are available:

A tall rocker lever cover for engines with compression brakes (2).

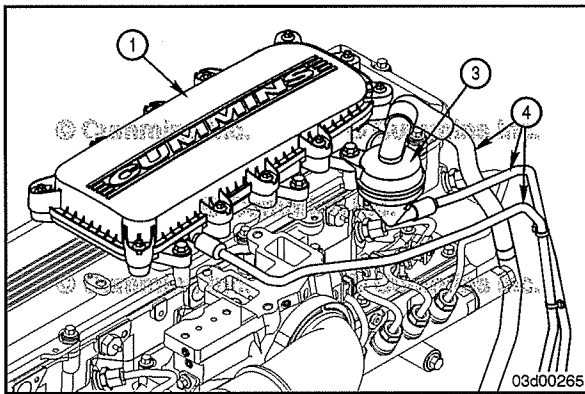
A short rocker lever cover for engines without compression brakes (1).

Additionally, various oil fill options are available (front oil fill, rear oil fill, or no oil fill).





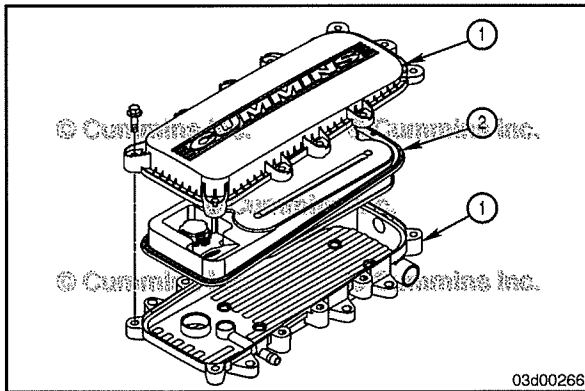
A rocker housing spacer is required on the engines covered by this manual to accommodate a pass-through location for the injector wiring harness. The rocker housing utilizes a press-in-place gasket to form a seal with the cylinder head. The valve cover is mounted to the rocker housing by capscrews, isolators, and a press-in-place gasket.



Crankcase Breather

The crankcase breather is located on top of the rocker lever cover towards the rear of the engine and consists of four main parts:

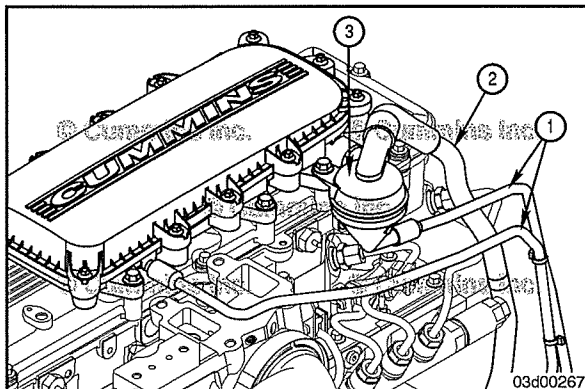
- 1 Crankcase breather housing
- 2 Crankcase breather element (**not shown**)
- 3 Oil separator
- 4 Oil drain and draft tubes.



The crankcase breather housing (1) is attached to the valve cover and contains the crankcase breather element.

The crankcase breather element (2) filters engine oil from the blowby gas and returns it to the crankcase via an oil drain tube.

The crankcase breather element requires periodic replacement. See the appropriate Operation and Maintenance and/or Owner's Manual for the correct maintenance specification.



The drain lines (1) return excess lubricating oil from the crankcase breather housing and oil separator to the lubricating oil pan.

The crankcase breather draft tube (2) attaches to the oil separator and vents the filtered blowby gas to the atmosphere.

The oil separator (3) is attached to the outlet of the crankcase breather housing and removes any remaining lubricating oil from the blowby gas before the blowby gas is vented to the atmosphere.

Fuel System - Overview (005-999)

General Information

Cummins® Common Rail Fuel System

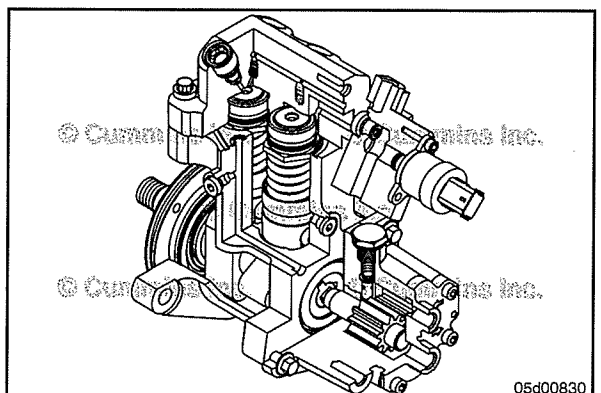
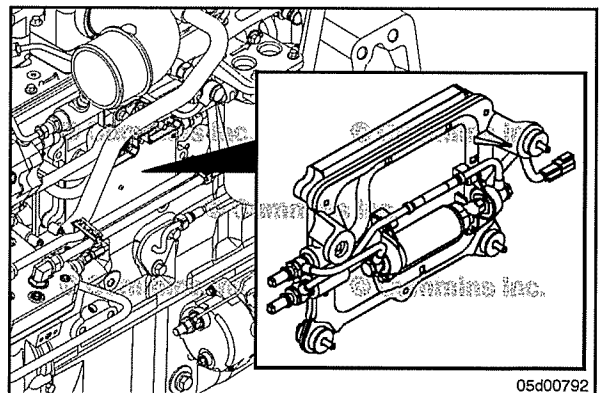
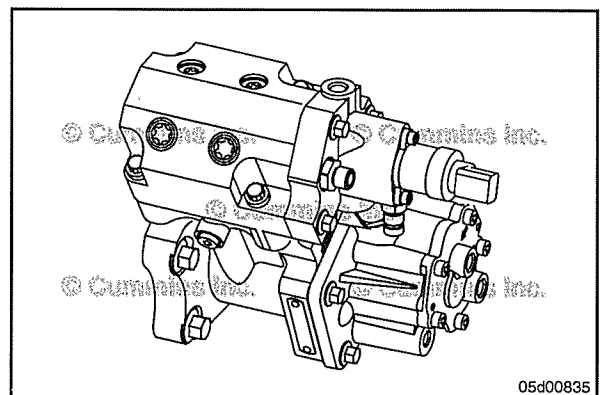
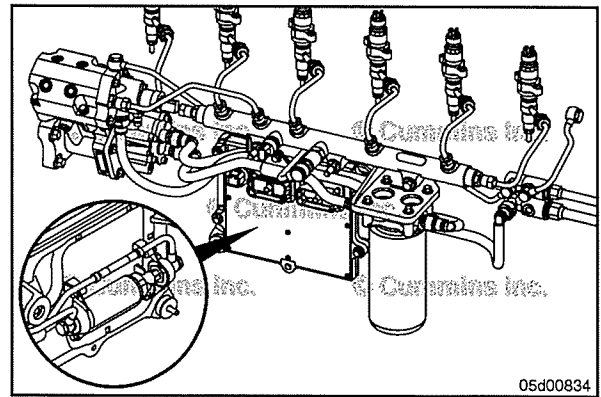
The fuel system is a high-pressure common rail injection system. A fuel rail is used to store pressurized fuel for fuel injection. There are four components that provide or receive input to the electronic control module (ECM). The ECM powers the electric fuel lift pump (located behind the ECM) for approximately 30 seconds at key-on to prime the fuel system. The normally open fuel pump actuator receives a pulse width modulated (PWM) signal from the ECM to open or close in response to the signal from the fuel rail pressure sensor. The injectors have individual solenoids. The ECM powers each injector individually to provide fueling to each cylinder.

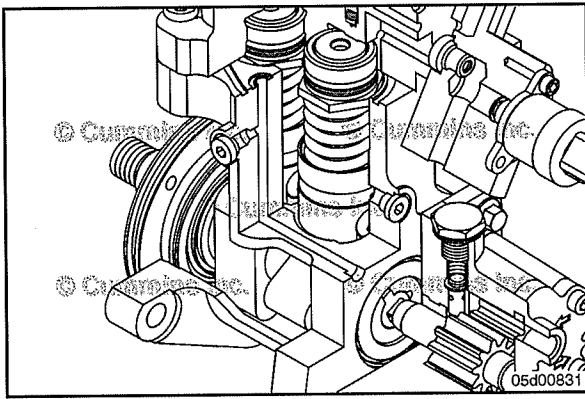
The high-pressure fuel pump can be divided into four distinct assemblies. They are the fuel gear pump, fuel pump actuator housing, cam housing, and high-pressure fuel pump head. Fuel flows through the gear pump to a 5-micron pressure-side filter. After the pressure-side filter, fuel enters the fuel pump actuator housing. The fuel pump actuator housing includes an air-bleed fitting and the fuel pump actuator. Some fuel continuously returns to drain through the air-bleed orifice fitting. Fuel that is metered through the fuel pump actuator enters the high-pressure fuel pump head where it is pumped to fuel rail pressure and exits at the high-pressure outlet fitting.

A lift pump is used for priming the gear pump at start-up. The lift pump runs for approximately 30 seconds after key-on. Once the engine is started, the gear pump is able to maintain prime without any assistance from the lift pump.

The ECM and ECM cooling plate **must** be removed to access the lift pump and lift pump fuel lines. This is accomplished by disconnecting the engine harnesses and the quick disconnect style fuel lines first. Removal of the ECM cooling plate capscrews allows the ECM, cooling plate, lift pump and lift pump plumbing to be removed as one assembly.

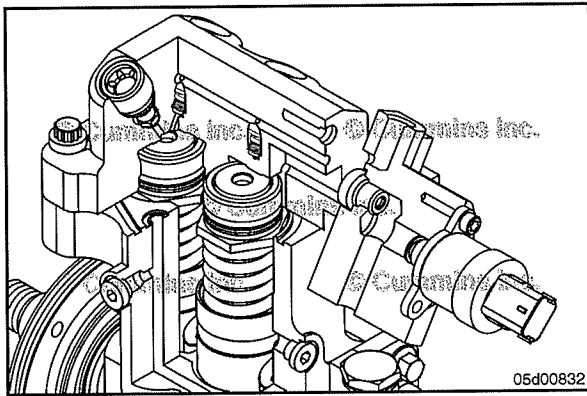
The high-pressure pump is driven by the engine camshaft. The gear pump is driven by the pump camshaft through an internal coupling.





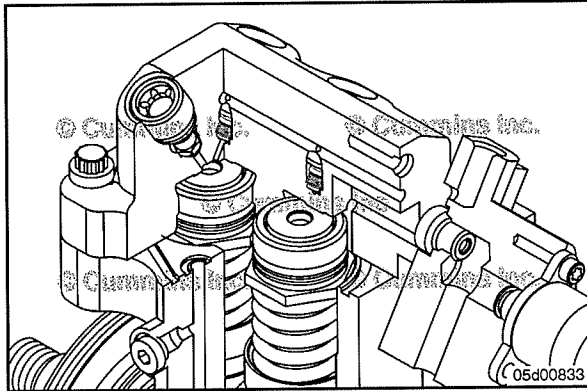
Each of the two pumping plungers is driven by a three lobed camshaft. The camshaft is located in the cam housing module by tapered roller bearings. The bearings that support the camshaft, as well as the tappets, rollers and camshaft itself are lubricated with engine oil. These are the only components in the pump lubricated with engine oil.

Engine oil to the high-pressure pump is supplied through a drilling in the engine gear housing. The oil passes from the engine gear housing to the high-pressure pump cam housing. A small o-ring in a recess on the back of the engine gear housing seals this passage.



Pressurized fuel from the gear pump is supplied to the fuel pump actuator. The fuel pump actuator is opened or closed by the ECM to maintain the appropriate fuel rail pressure.

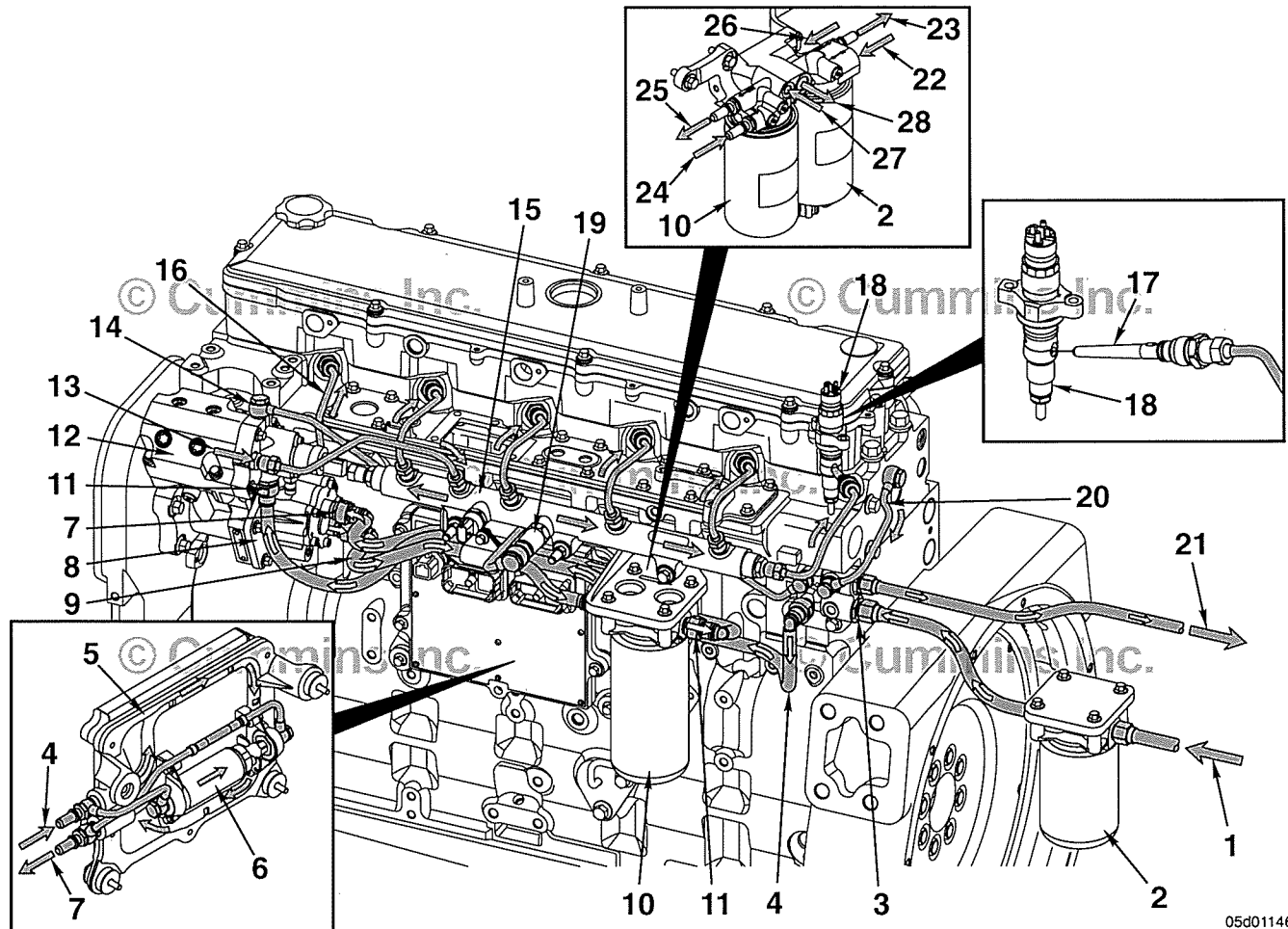
An air-bleed orifice fitting in the fuel pump actuator housing aids in purging air from the fuel supply. Because of the air-bleed orifice fitting, some fuel that is supplied by the gear pump will return to drain at all times.



Fuel that is metered past the fuel pump actuator enters the high-pressure fuel pump inlet drilling, past the inlet check valve, and fills the pumping chamber by pressing the pumping plunger downward. When the camshaft pushes the pumping plunger upward, fuel reaches rail pressure and causes the outlet check valve to lift. Fuel then enters the outlet drilling of the fuel pump and exits the high pressure fuel line to the fuel rail.

Flow Diagram, Fuel System (200-001)

General Information



05d01146

- 1 Fuel from supply tank
- 2 Fuel filter and water separator
- 3 Original equipment manufacturer (OEM) fuel supply connection
- 4 Fuel supply to engine control module (ECM) mounted fuel lift pump
- 5 ECM cooling plate
- 6 ECM mounted fuel lift pump
- 7 Fuel outlet from ECM mounted fuel lift pump/fuel to gear pump
- 8 Fuel gear pump
- 9 Fuel from gear pump to fuel filter
- 10 Pressure-side fuel filter
- 11 Fuel to fuel pump actuator
- 12 High-pressure fuel pump
- 13 Fuel outlet from high-pressure fuel pump
- 14 High-pressure pump drain flow connection
- 15 Fuel rail
- 16 High-pressure injector supply lines
- 17 High-pressure fuel connector
- 18 Fuel injector

- 19 Fuel pressure relief valve
- 20 Fuel injector drain flow line
- 21 Fuel return to supply tanks
- 22 Fuel supply to fuel filter and water separator*
- 23 Fuel supply to ECM mounted fuel lift pump*
- 24 Fuel supply to pressure-side fuel filter*
- 25 Fuel supply to high-pressure fuel pump*
- 26 Fuel drain from fuel rail and injector drains*
- 27 Fuel drain from high-pressure fuel pump*
- 28 Fuel return to supply tanks.*

* Some engines may have an optional dual fuel filter head which holds both the fuel filter and water separator (2) and the pressure-side fuel filter (10). The dual fuel filter head also contains a fuel drain manifold. See numbers 22 through 28 for fuel flow through the fuel filter head.

Injectors and Fuel Lines - Overview (006-999)

General Information

Cummins® Common Rail Fuel System

⚠ WARNING ⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

High-pressure common rail fuel systems use solenoid-actuated injectors. High-pressure fuel flows into the side of the injector. When the solenoid is activated, an internal needle lifts and fuel is injected. The clearances in the nozzle bore are extremely small and any dirt or contaminants can cause the injector to stick. This is why it is important to clean around all fuel connections before servicing the fuel system. Also, cap or cover any open fuel connections before a fuel system repair is performed.

⚠ CAUTION ⚠

To reduce the possibility of engine damage, always use the proper torque value and the proper torquing sequence on the high-pressure line nuts.

High-pressure fuel is supplied to the injector from the fuel rail by an injector supply line and a fuel connector. The fuel connector pushes against the injector body when the fuel connector nut is tightened. The injector supply line is then connected to the fuel connector.

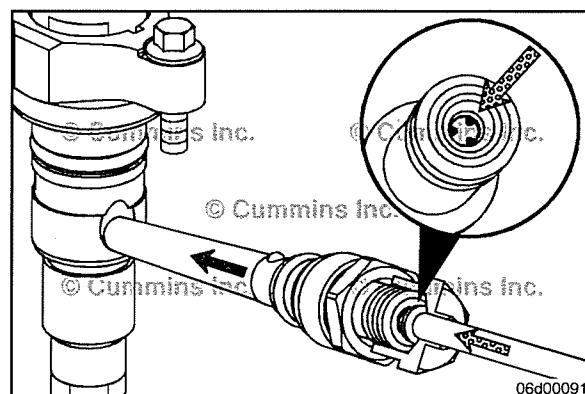
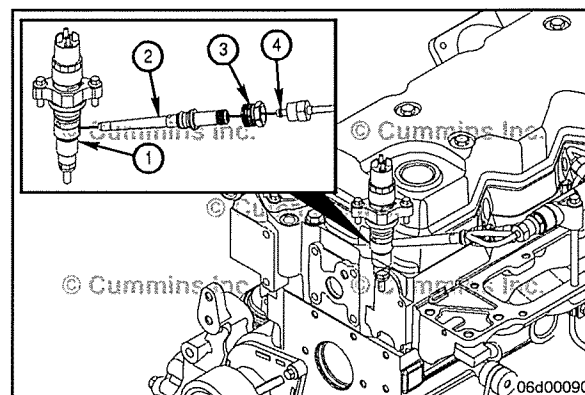
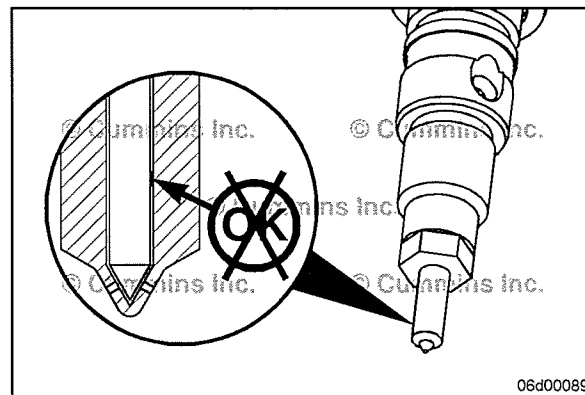
The torque and sequence for this joint is critical. If the nut or line is undertightened, the surfaces may **not** seal and a high-pressure fuel leak will result. If the nut is overtightened, the connector and injector will deform and can cause a high-pressure fuel leak. This leak will be inside the head and will **not** be visible. The result will be a fault code, low power, or no-start.

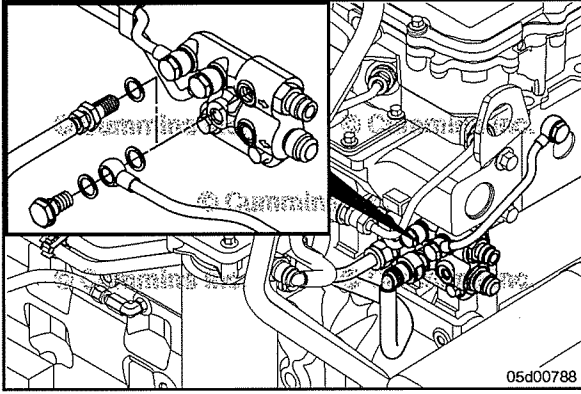
If the injector is **not** fully seated prior to the installation of the high-pressure connector, the joint will **not** seal.

The fuel connector contains an edge filter that breaks up small contaminants that enter the fuel system.

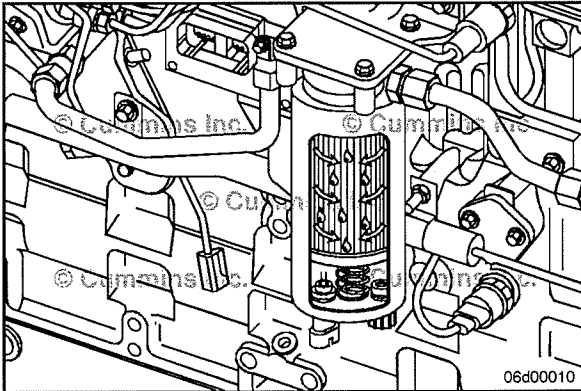
The edge filters are **not** a substitute for cleaning and covering all fuel system connections during repair.

Be sure to cap or cover all fuel fittings and ports.





All injectors feed into a common return drilling contained within the cylinder head. Any excess fuel is returned to the tank via this drilling and return line attached to the rear of the cylinder head. A back-pressure valve is located on the back of the cylinder head where the drain line attaches.



Fuel Filters

The engines covered in this manual require original equipment manufacturers (OEM's) to mount a 8-micron suction filter prior to the OEM fuel supply connection at the rear of the engine block. The 8-micron filter performs water stripping and includes a water-in-fuel sensor. The water-in-fuel sensor **must** be installed. If **not**, a fault code warning lamp will be active.

The engines covered in this manual also include a 5-micron pressure-side fuel filter. The pressure-side filter will be located downstream of the gear pump before the high-pressure fuel pump inlet. If a water-in-fuel fault is experienced, drain the water stripping filter and replace the pressure side fuel filter.



Lubricating Oil System - Overview (007-999)

General Information

Lubricating Oil

⚠ WARNING ⚠

Some state and federal agencies have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

⚠ WARNING ⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

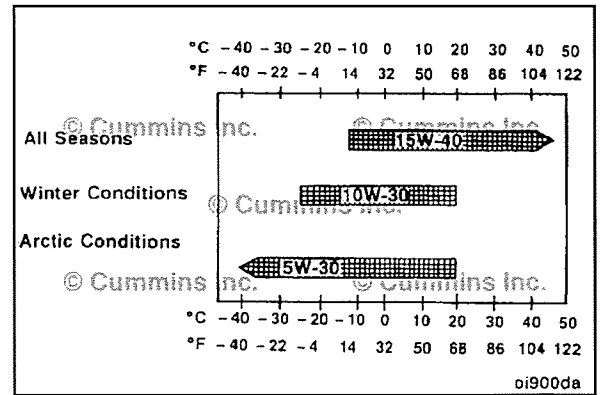
Cummins Inc. recommends the use of a high quality SAE 15W-40 heavy-duty engine oil, such as Premium Blue™, which meets the American Petroleum Institute (API) performance classification.

NOTE: For lubricating oil requirements and maintenance intervals, see the appropriate Operation and Maintenance and/or Owners manual for the engine being serviced.

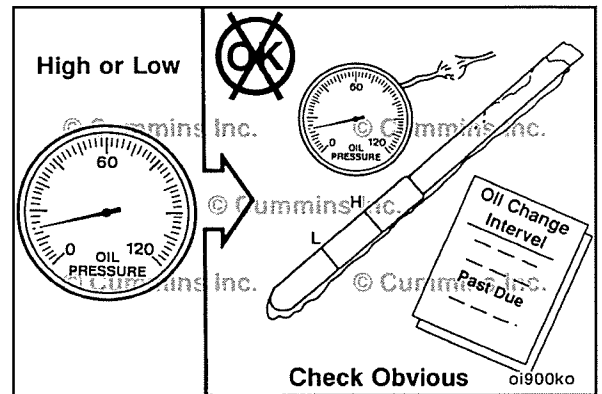
Arctic Operation Engine Oil

⚠CAUTION⚠

Limited use of low-viscosity lubricating oils, such as 10W-30, can aid in starting the engine and providing sufficient lubricating oil flow at ambient temperatures below -5°C [23°F] as shown in the illustration. However, the continuous use of low-viscosity lubricating oils can decrease engine life.

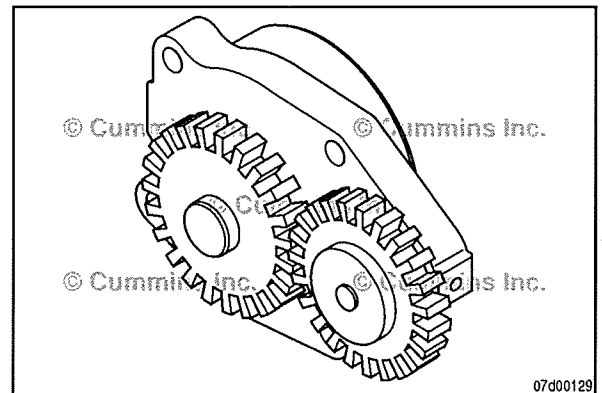


When diagnosing lubricating system malfunctions, check all obvious items related to oil pressure, such as gauges, high and low oil level, excessive oil contamination, and oil viscosity. Refer to Procedure 007-048 in Section 7.



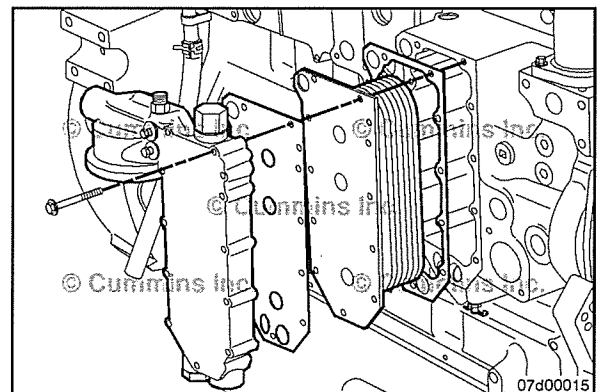
Lubricating Oil Pump

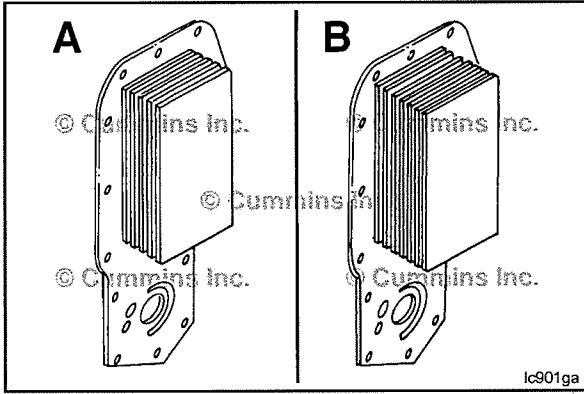
A gerotor type lubricating oil pump is used. It is similar in design to other same series engines. The lubricating oil pump is located at the front of the engine and is driven by the front crankshaft gear. Due to the lubricating oil pump similarity in design to other same series engine lubricating oil pumps, always verify the correct replacement lubricating pump is used before installing a new lubricating oil pump. Reference the appropriate part information resources when replacing the lubricating oil pump, to make sure the correct lubricating oil pump is installed.



Lubricating Oil Cooler

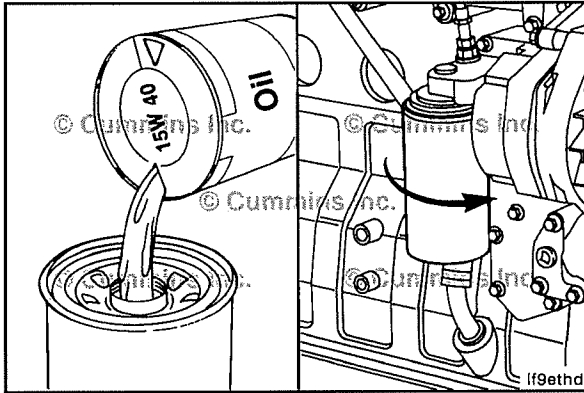
A full-flow, plate-type lubricating oil cooler is used. It is similar in design to other same series engines. The lubricating oil cooler is located in a cylinder block cavity on the exhaust side of the engine, mounted between the lubricating oil cooler cover and the cylinder block. Lubricating oil flows through the plates of the oil cooler where it is cooled by engine coolant flowing past the plates.





Due to the similarity in design to other same series engine lubricating oil coolers, always verify the correct replacement lubricating oil cooler is used before installing the new replacement. The main difference between the various lubricating oil coolers is the number of plates. Depending on engine configuration, the engine may require more (B) or less (A) plates to adequately cool the engine's lubricating oil.

The use of incorrect components can cause high or low oil temperature, varnish, and sludge buildup in the lubricating oil system.

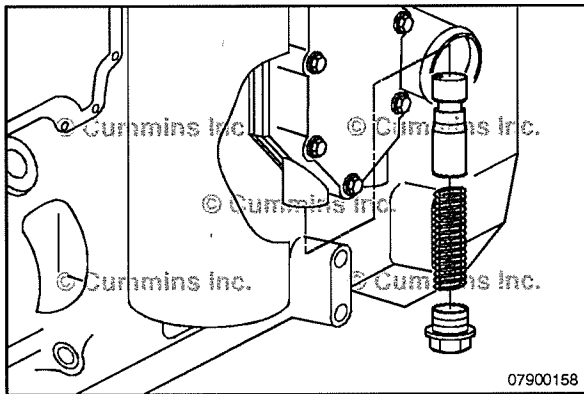


Lubricating Oil Filter

A full-flow oil filter is used for engine oil filtration. The oil filter is located on the exhaust side of the engine, toward the front. Some applications utilize a remote lubricating oil filter option, mounting the lubricating oil filter on the vehicle instead of the engine.

Cummins Inc. recommends that the oil filter be pre-filled when changed to prevent lubrication oil pressure delay at start-up.

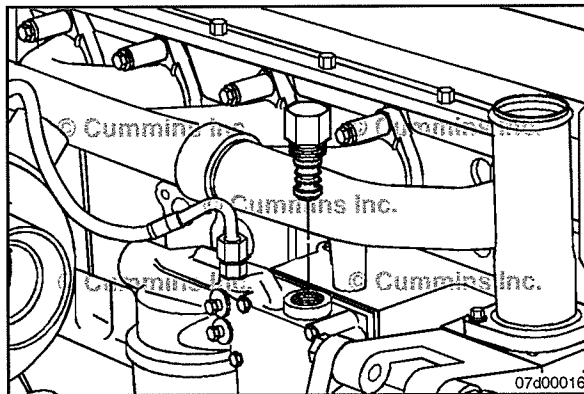
NOTE: Be careful that debris is **not** poured into the filter. If using an oil supply with a metallic or plastic seal under the cap, be careful to peel the seal back. Puncturing the seal with a knife or sharp object can put debris in the oil container.



Lubricating Oil Pressure Regulator

The lubricating oil pressure regulator is used to prevent high lubricating oil pressure. The oil pressure regulator is located in the lubricating oil cooler cover on the exhaust side of the engine. The lubricating oil pressure regulator consists of a cap, a spring, and a plunger.

The oil pressure regulator is similar in design to other same series engines. Always verify the correct replacement lubricating oil pressure regulator components are used before installation.

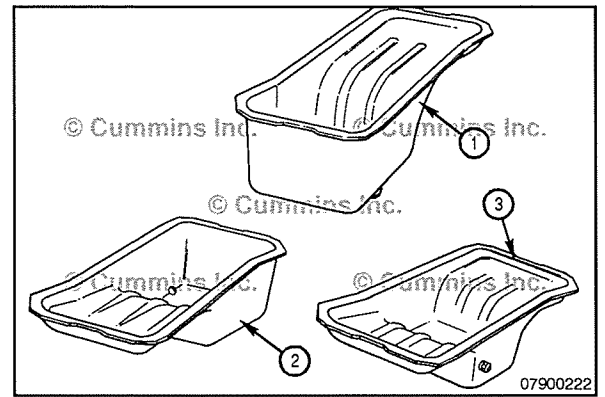


Lubricating Oil Thermostat

The lubricating oil thermostat mounted in the lubricating oil cooler regulates the temperature of the lubricating oil to 116°C [240°F] by bypassing the lubricating oil cooler at lower lubricating oil temperatures.

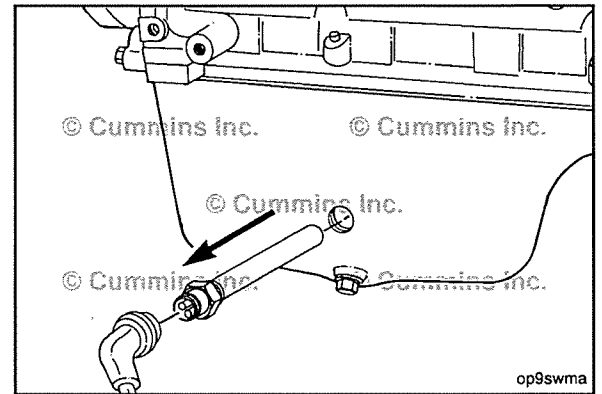
Lubricating Oil Pan

A front sump (1), rear sump (2), or center sump (3) lubricating oil pan option can be used, depending on the application. The mounting of the lubricating oil suction tube will vary with the type of lubricating oil pan used.



Engine Oil Heater

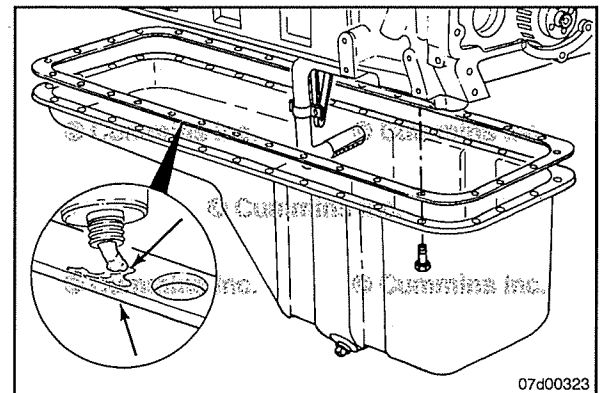
Some engine oil pans allow for an optional lubricating oil heater to be installed, to aid engines operating in cold climates.



Standard Oil Pan

A standard oil pan uses a non-reusable gasket between the lubricating oil pan and the cylinder block.

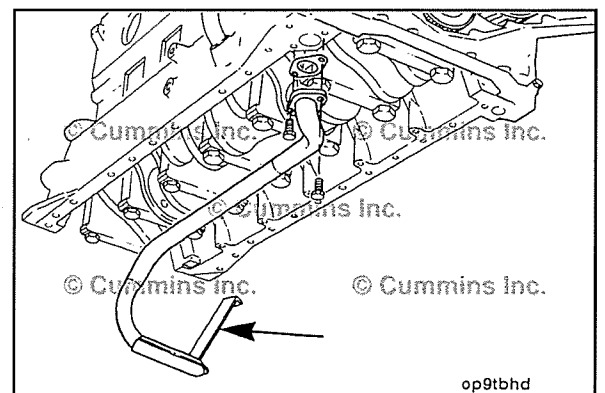
NOTE: Applying RTV sealant to the gasket will help to hold the gasket in place during assembly.

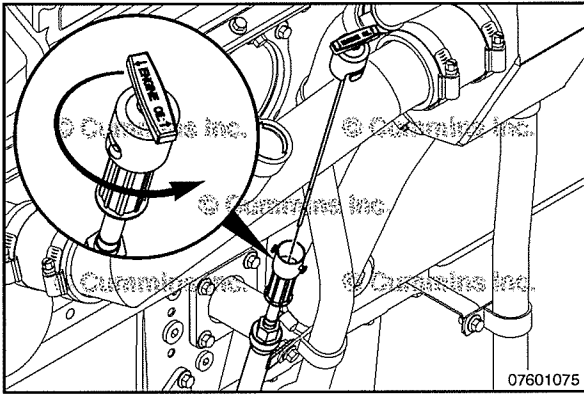


Lubricating Oil Suction Tube

The lubricating oil suction tube is a formed steel tube with a cast iron mount at the cylinder block. The submerged portion of the tube in lubricating oil is perforated to prevent any large debris particles from entering the lubricating oil system.

The mounting of the lubricating oil suction tube will vary with the type of lubricating oil pan used.



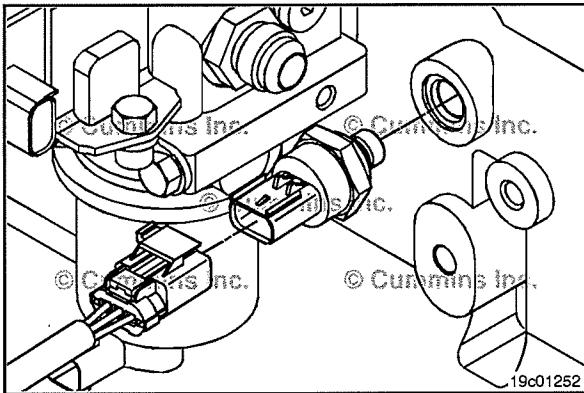


Lubricating Oil Dipstick

The lubricating oil dipstick location for checking engine oil level varies by engine application.

If the dipstick is a locking type, twist the handle **counterclockwise** to unlock and **clockwise** to lock.

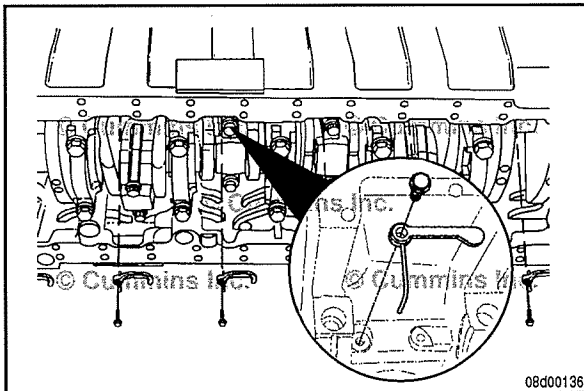
NOTE: Some engine/applications also have an optional oil level sensor to notify the operator when the lubricating oil level is low.



Lubricating Oil Pressure Sensor

To monitor oil pressure, an oil pressure sensor is used. If the oil pressure drops below a preset value, a fault will be recorded in the engine control module (ECM) and a dash light will illuminate to notify the driver that there is a problem with the engine.

The oil pressure sensor is located along the main oil rifle.



Piston Cooling Nozzles

The engines covered by this manual use J-jet piston coolant nozzles that are located in between the main bearing saddles on the exhaust side of the engine. Lubricating oil is supplied from an oil gallery in the cylinder block on the exhaust side of the engine.

Lubricating Oil Flow Description

Lubricating Oil Pump

The engine uses a gerotor-type lubricating oil pump (1). Lubricating oil flow through the engine enters the suction tube and travels into the gerotor-type lubrication pump. The oil is then pressurized and fed into the oil cooler cover to the pressure regulating valve.

Pressure Regulating Valve

The pressure regulating valve is designed to keep the lubricating oil pressure from exceeding 449 kPa [65 psi]. When the lubricating oil pressure from the pump is greater than 449 kPa [65 psi], the valve opens, uncovering the dump port so part of the lubricating oil is routed back to the oil pan. Because of manufacturing tolerances of the components and the oil passages, the lubricating oil pressure can differ as much as 69 kPa [10 psi] between engines.

Lubricating Oil Thermostat

The lubricating oil thermostat regulates the lubricating oil temperature at the oil filter inlet to 116°C [240°F] by allowing the oil to bypass the lubricating oil cooler as long as the lubricating oil temperature at the oil filter inlet is below 116°C [240°F].

Bypass Valve

Lubricating oil continues through the lubricating oil cooler to the lubricating oil bypass valve. The lubricating oil filter bypass valve will open if pressure across the lubricating oil filter exceeds 345 kPa [50 psi].

Oil Filter

Lubricating oil from the oil cooler flows through the full-flow lubricating oil filter. Oil exiting the full-flow oil filter is directed to the main oil gallery(s) of the cylinder block.

Lubrication for the Turbocharger

The turbocharger is the first component to receive filtered, cooled, and pressurized lubricating oil through a supply tube from the lubricating oil filter head. A drain tube connected to the bottom of the turbocharger housing returns the lubricating oil to the lubricating oil pan through a port in the cylinder block.

Lubrication for the Power Components

J-Jet Piston-Cooling Nozzle Oil Rifle

Lubricating oil leaving the full-flow oil filter supplies oil to the J-jet piston-cooling nozzle oil rifle, which supplies oil to the J-jet piston-cooling nozzles. Spray from the nozzles is directed at the underside of the pistons to an internal passage in the piston for cooling.

Main Oil Rifle

Lubricating oil from the oil filter also supplies oil to the main oil rifle through a drilling between cylinders 2 and 3. The main bearings, overhead components, and accessory drive are lubricated by pressurized oil directly from the main oil rifle. The other power components, connecting rods, pistons, and camshaft receive pressurized oil directly from the main oil rifle.

The drillings in the crankshaft supply oil to the connecting rod bearings. The oil is supplied to the camshaft journals through drillings in the main bearing saddle.

Lubrication for the overhead components is supplied through separate drillings in the block. The oil flows through the drillings and across the slot in the cylinder head gasket.

Lubrication for the Overhead Components

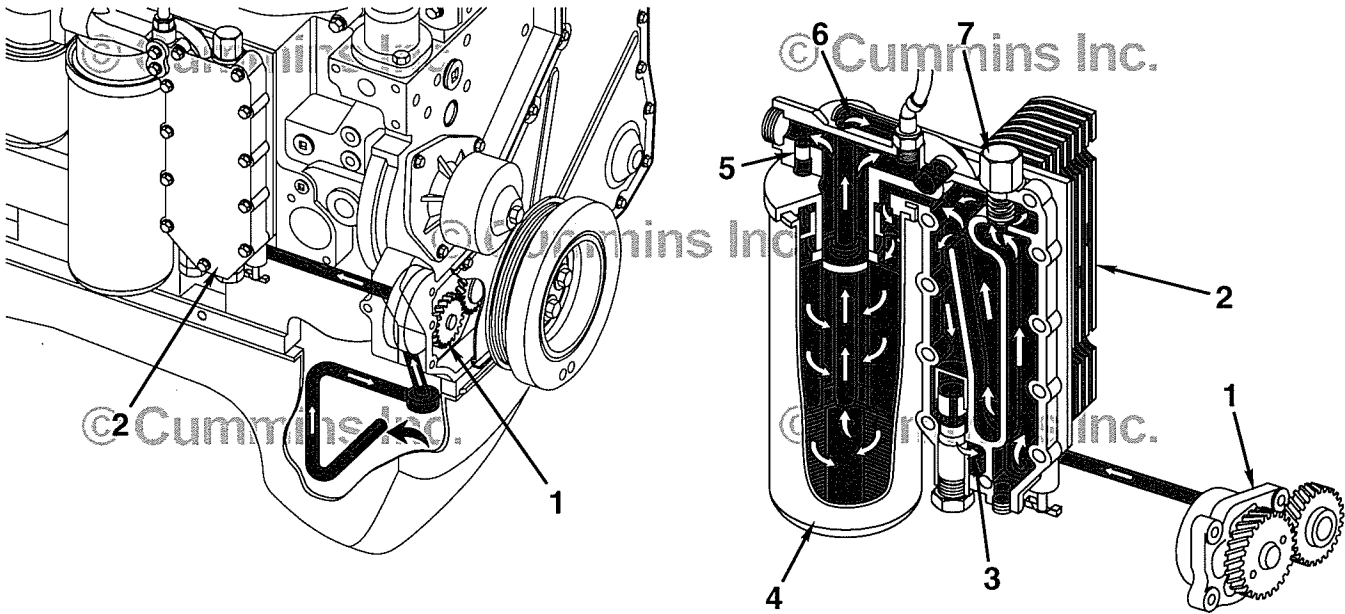
From the cylinder block, the drilling continues in the cylinder head to a drilling in the rocker lever pedestal. Internal drillings in the pedestal supply lubricating oil to the rocker shaft, push rod socket, and crosshead pad. Residual oil from the overhead lubricates the camshaft and tappets.

Lubrication for the Accessory Drive

From the main oil rifle, oil is supplied to a drilling in the rear gear housing that feeds the accessory drive. Return oil from the accessory drive is returned to the oil pan through the rear gear housing.

Flow Diagram, Lubricating Oil System (200-002)

General Information



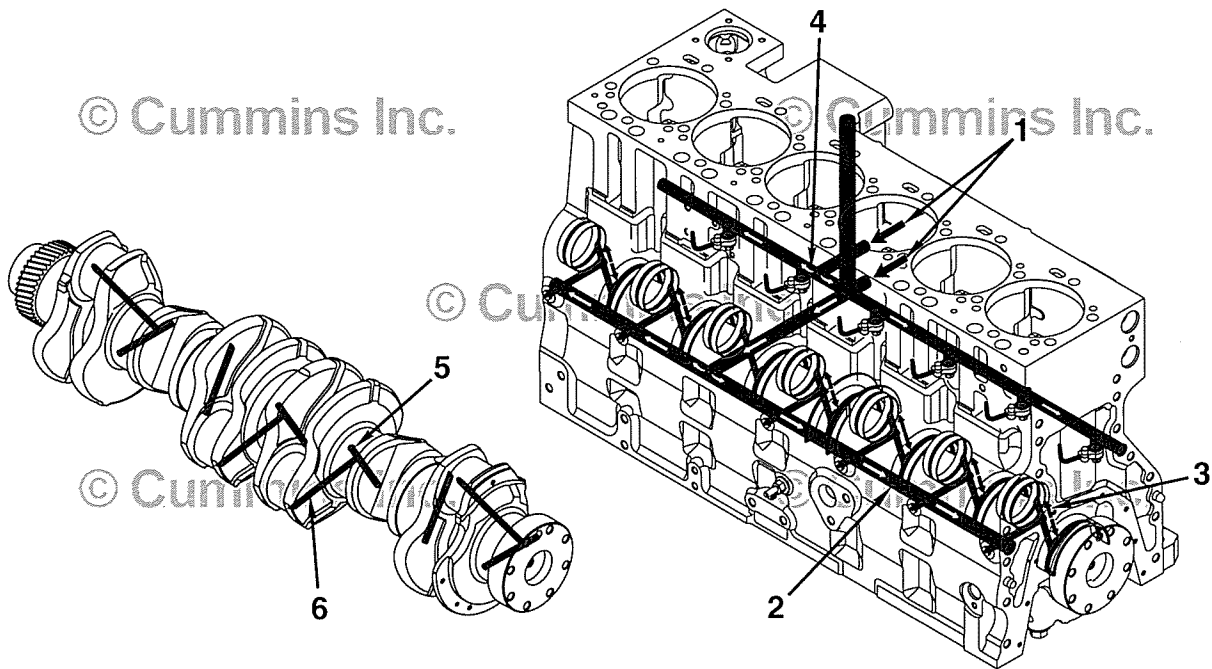
07d00183

Lubricating Oil Cooler Flow

- 1 Gerotor lubricating oil pump
- 2 Lubricating oil cooler
- 3 Bypass oil to lubricating oil pan
- 4 Full flow lubricating oil filter
- 5 Filter bypass valve
- 6 From lubricating oil filter to main oil rifle
- 7 Oil thermostat.

Flow Diagram, Lubricating Oil System (200-002)

General Information



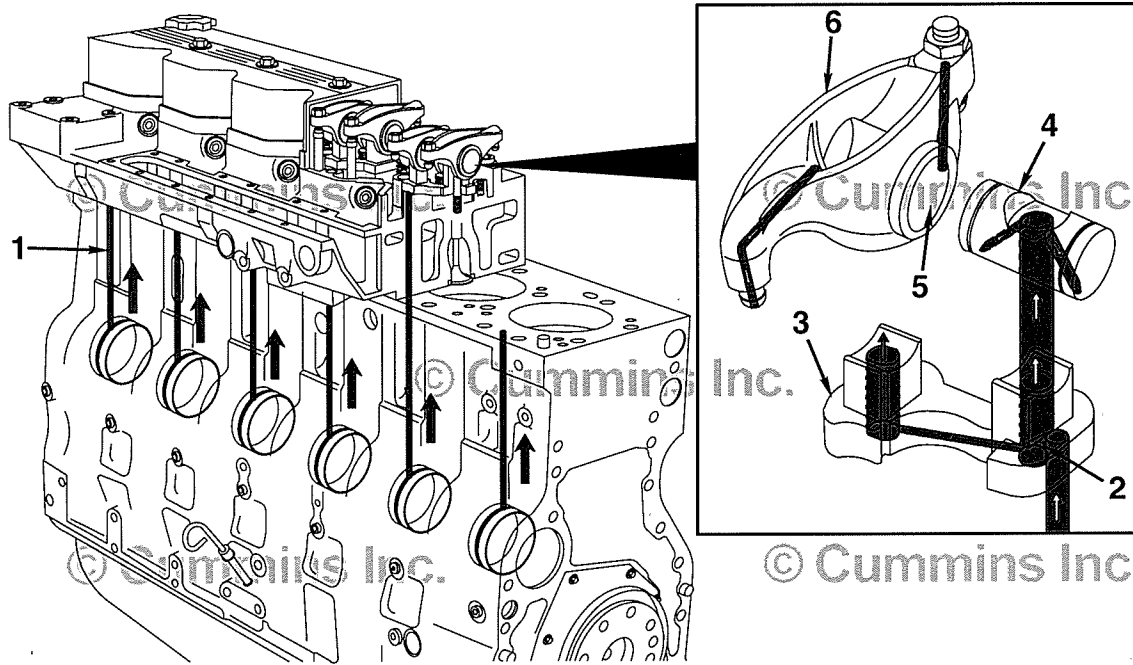
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Lubrication for Power Components

- 1 From lubricating oil filter
- 2 Main lubricating oil rifle
- 3 To camshaft
- 4 To piston cooling nozzle
- 5 From main lubricating oil rifle
- 6 To connecting rod bearing.

Flow Diagram, Lubricating Oil System (200-002)

General Information



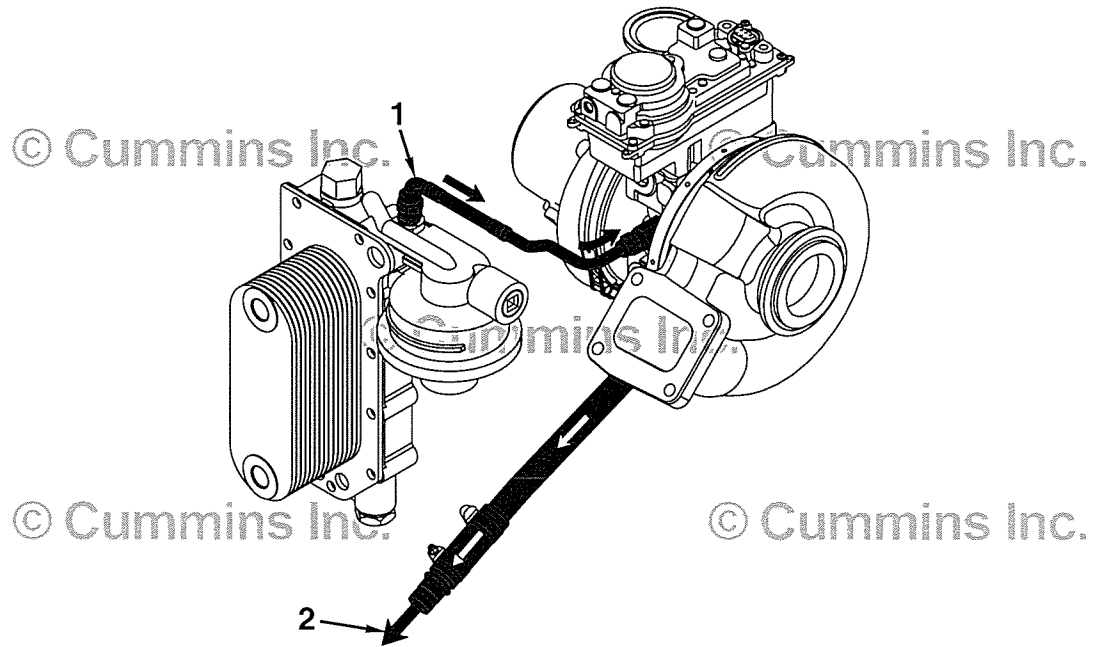
Lubrication for the Overhead

- 1 From cam bushings
- 2 Transfer slot
- 3 Rocker lever support
- 4 Rocker lever shaft
- 5 Rocker lever bore
- 6 Rocker lever.

07d00002

Flow Diagram, Lubricating Oil System (200-002)

General Information



Turbocharger Oil Flow

- 1 Turbocharger oil supply from oil filter head
- 2 Turbocharger oil drain to cylinder block.

Cooling System - Overview (008-999) General Information

The function of the cooling system is to maintain a specified operating temperature for the engine. Some of the heat generated by the engine is absorbed by the coolant flowing through the passages in the cylinder block and head. Then, heat is removed from the coolant as it flows through the radiator.

Conventionally cooled engines with automatic transmissions typically use oil-to-water transmission torque converter coolers plumbed between the radiator and the engine water pump.

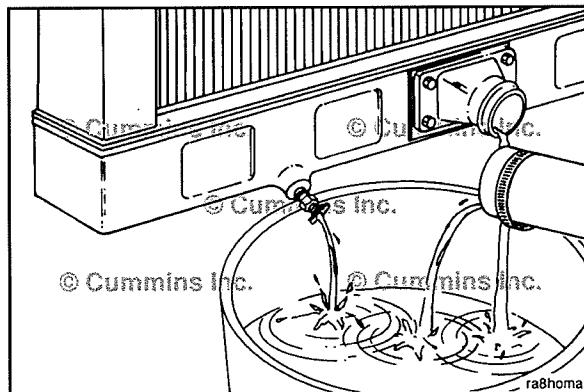
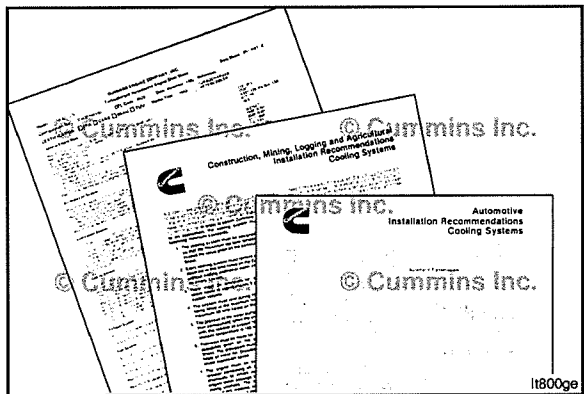
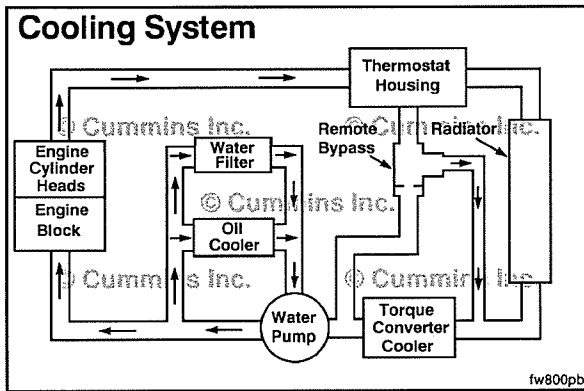
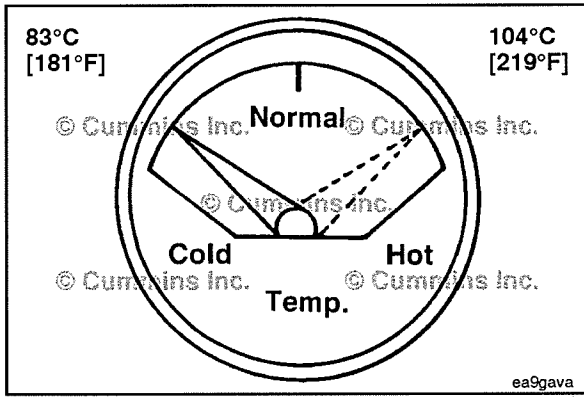
A torque converter cooling system with a remote bypass allows the torque converter to receive coolant flow when the thermostat is closed (engine cold).



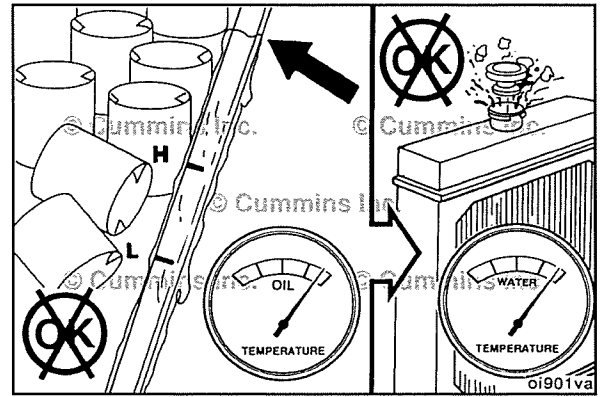
The following publications, available through Cummins Distributors or Cummins Dealers, provide cooling system installation recommendations and specifications approved by Cummins Inc.:

- Automotive Installation Recommendations (Cooling System), Bulletin 3382413
- Construction, Mining, Logging and Agriculture Installation Recommendations (Cooling System), Bulletin 3382171
- Data Sheets for specific engine models
- Operation of Diesel Engines in Cold Climates, Bulletin 3379009
- Heavy-Duty Coolant/SCA Maintenance Requirements, Bulletin 3387910.

Open the petcocks at the bottom of the radiator and at the bottom of the oil cooler housing. Remove the lower radiator hose. A 20 liter [4 gal] drain pan will contain the coolant in most applications.

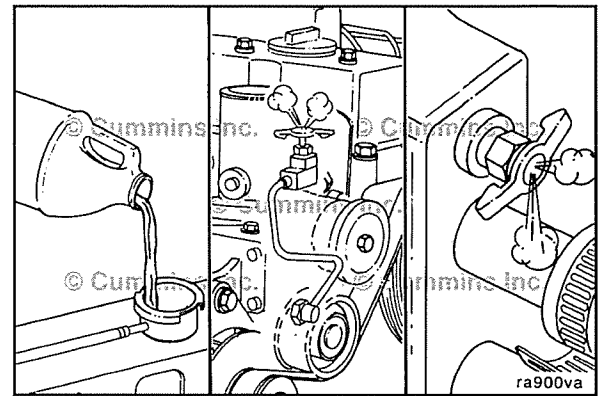


When troubleshooting overheating, remember that too much oil in the oil pan can cause additional heat from friction when the rod journals are submerged in oil. Overfilling with oil raises the oil temperature. This additional heat is transferred to the cooling system at the oil cooler.

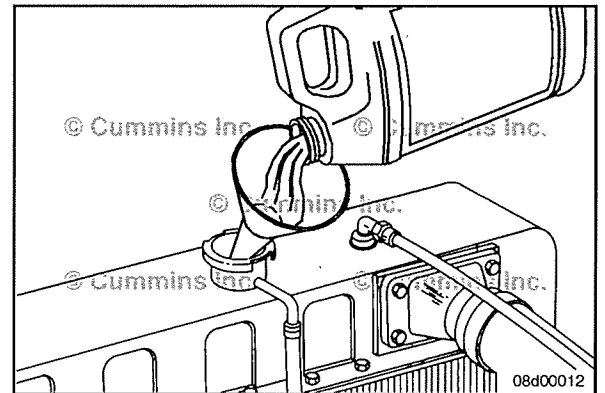


The system is designed to use a specific quantity of coolant. If the coolant level is low, the engine will run hot.

NOTE: If the engine or system has a leak and if frequent addition of coolant is necessary, find and repair the leak.

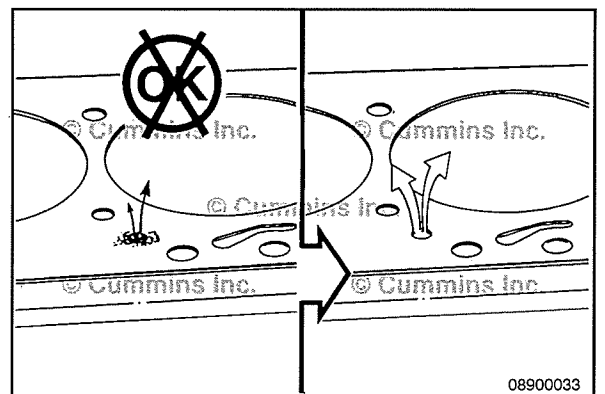


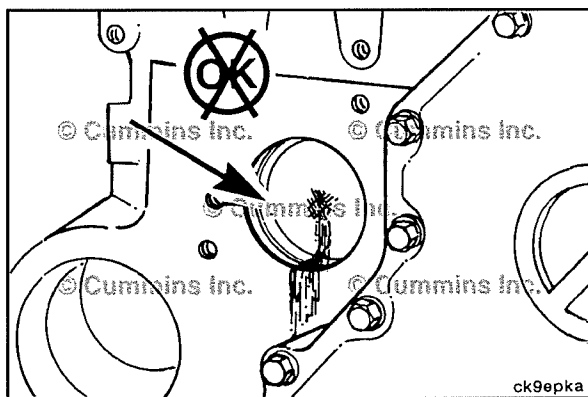
During operation, entrapped air mixes with the coolant, which results in cavitation corrosion and poor heat transfer. Highly aerated coolant can cause localized overheating of the cylinder head and block, which can result in a cracked head, scored cylinder liner, or blown head gasket.



Obstructions in the coolant passages will reduce coolant flow, which can lead to overheating.

NOTE: The small holes in the head gasket are especially susceptible to plugging. Their size is critical. Do **not** enlarge the size of the orifices. Doing so will disturb the coolant flow and will **not** solve an overheating problem.

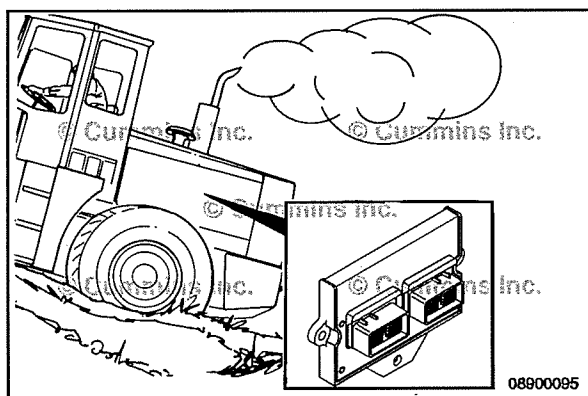




Water will cause rust formation, reducing the flow in the smaller coolant passages.

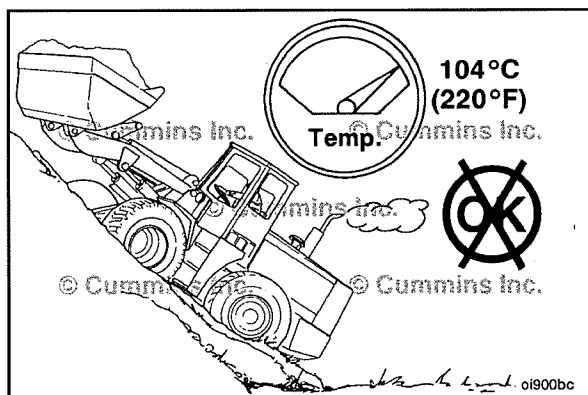
Also, water used as a coolant for even a relatively short period can result in the expansion plugs rusting through, which will allow the coolant to leak.

NOTE: A sudden loss of coolant from a heavily loaded engine can result in severe damage to the pistons and cylinder bores.



Overfueling and Loading

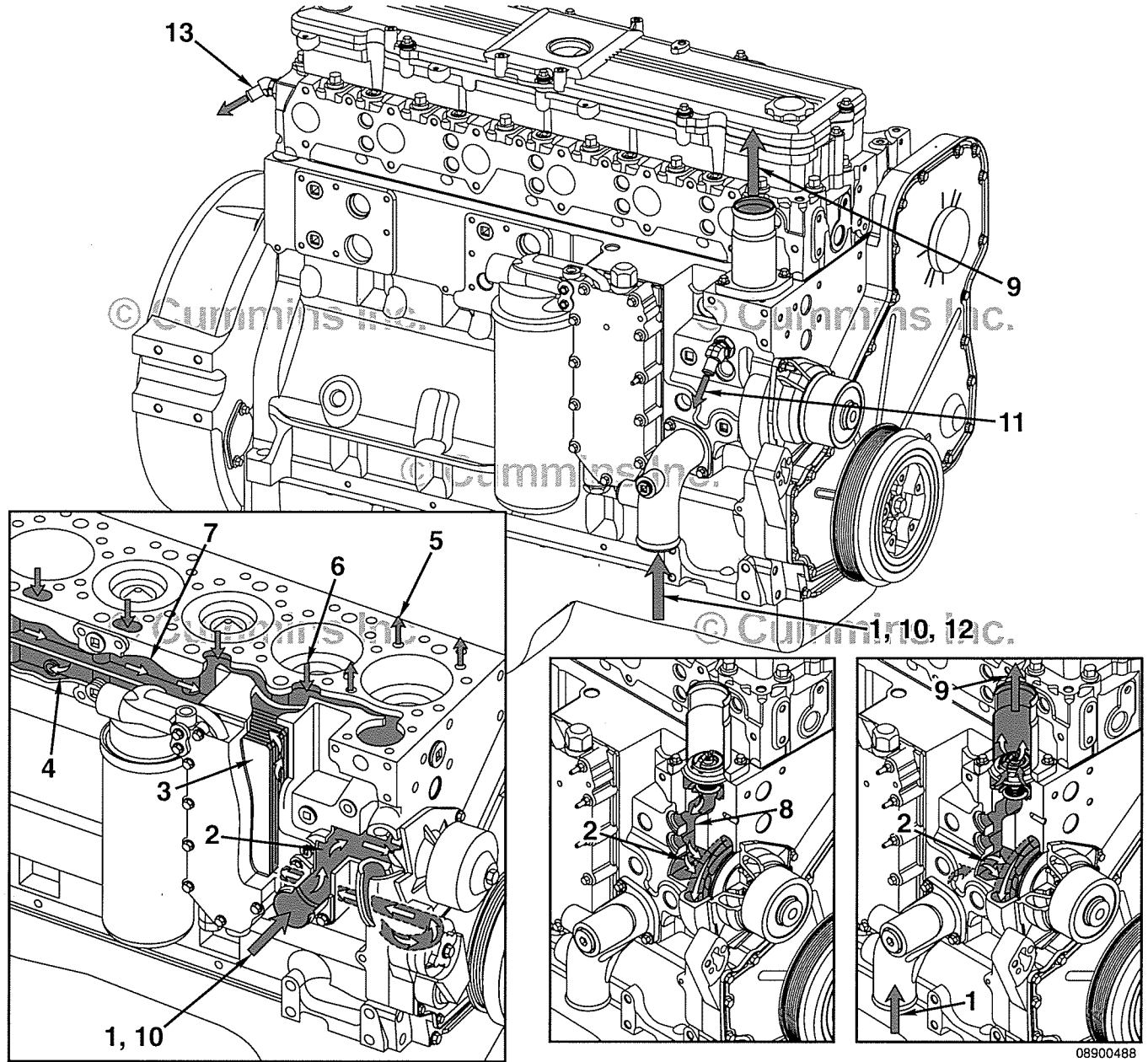
Overfueling can cause the engine to overheat. Make sure that the correct engine control module (ECM) calibration is being used.



Constant overloading (lugging) can cause the engine to run hot.

Flow Diagram, Cooling System (200-003)

Flow Diagram

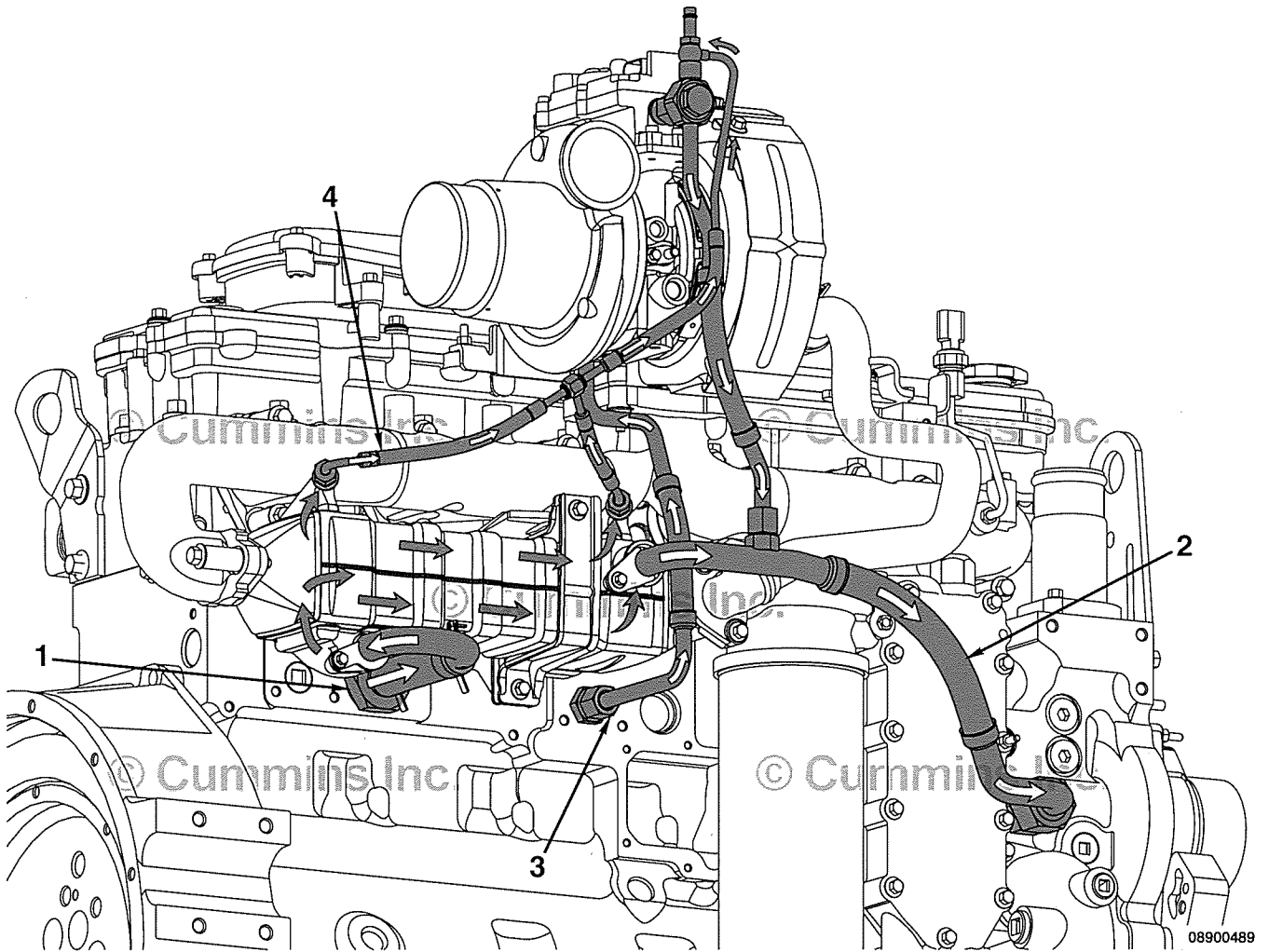


- 1 Water/coolant inlet from radiator
- 2 Water pump suction
- 3 Coolant flow through lubricating oil cooler
- 4 Block lower water manifold (to cylinders)
- 5 Coolant supply to cylinder head
- 6 Coolant return from cylinder head
- 7 Block upper water manifold
- 8 Thermostat bypass
- 9 Coolant return to radiator
- 10 Aftertreatment DEF valve and tank coolant return line to water/coolant inlet connection. Optional aftertreatment DEF dosing valve and tank coolant return is (1)
- 11 Optional torque converter coolant supply from cylinder block with thermostat closed

- 12 Optional torque converter coolant return to water/coolant inlet connection
- 13 Coolant supply to aftertreatment DEF fluid dosing valve and tank from cylinder head.

Flow Diagram, Cooling System (200-003)

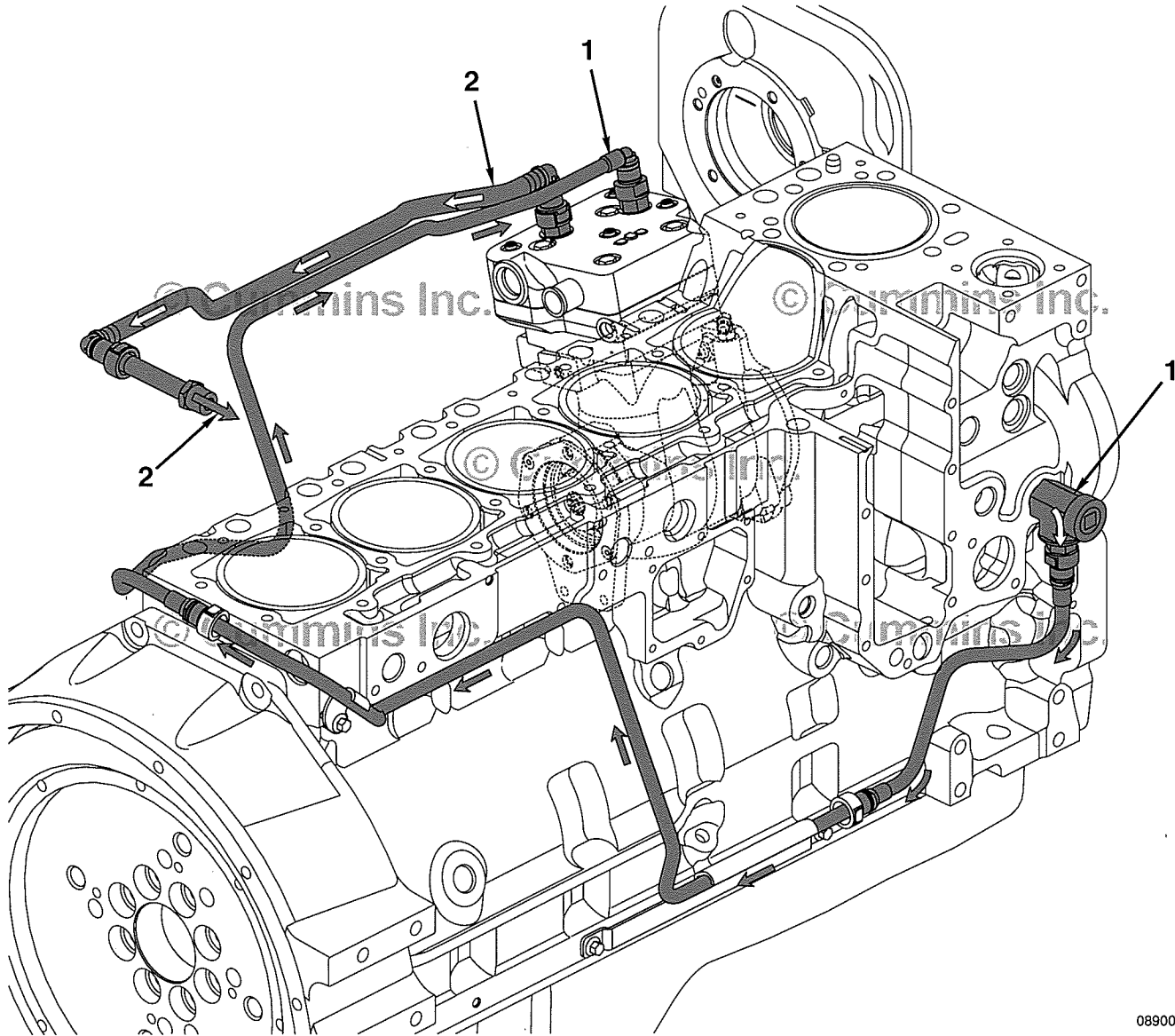
Flow Diagram



- 1 Coolant supply from the cylinder block to the exhaust gas recirculation (EGR) cooler
- 2 Coolant drain to the water pump inlet from the EGR cooler and the variable geometry turbocharger (VGT) actuator
- 3 Coolant supply to the VGT from the cylinder block
- 4 Coolant vent line to the VGT from the EGR cooler.

Flow Diagram, Cooling System (200-003)

Flow Diagram



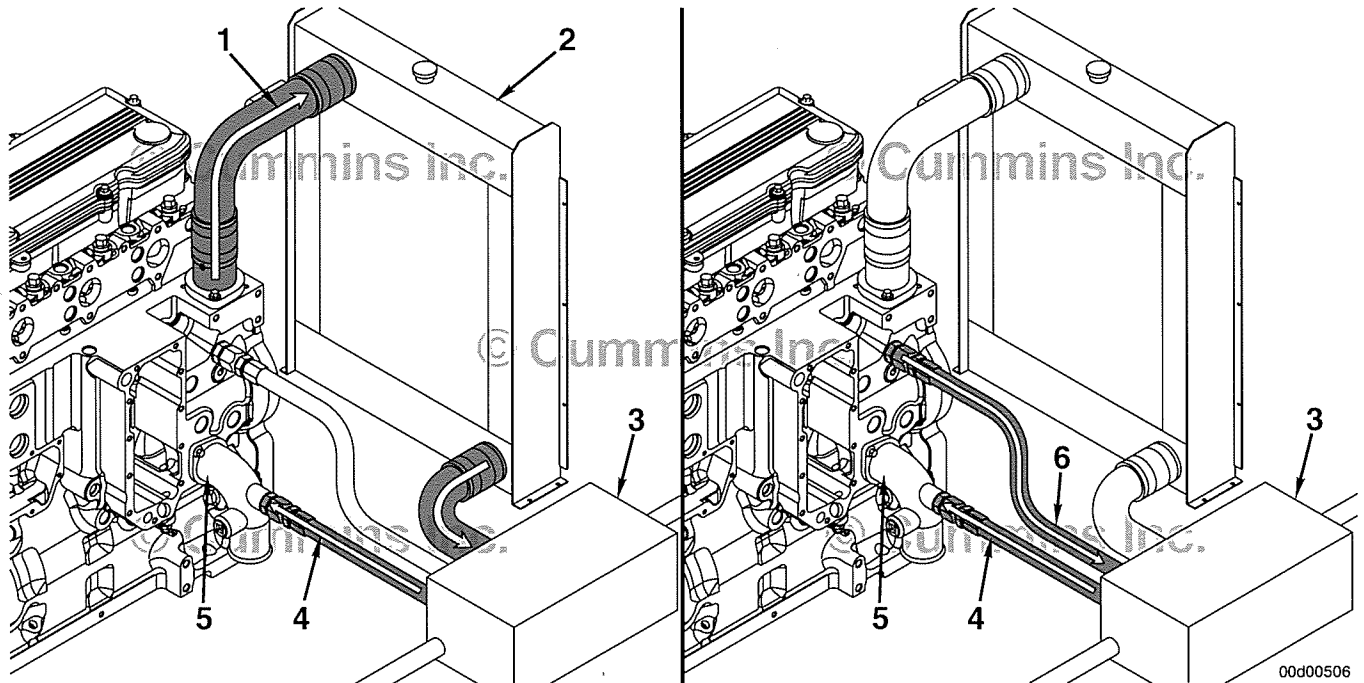
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Cold Side of Engine

- 1 Air compressor coolant supply from cylinder block
- 2 Air compressor coolant return to cylinder head.

Flow Diagram, Cooling System (200-003)

Flow Diagram



NOTE: For engines equipped with optional torque converter cooler option.

NOTE: Conventionally cooled engines with automatic transmissions typically use oil-to-water transmission torque converter coolers plumbed between the radiator and the engine water pump.

NOTE: A torque converter cooling system with a remote bypass allows the torque converter to receive coolant flow when the thermostat is closed (engine cold, no flow through radiator).

NOTE: For original equipment manufacturer (OEM) components, refer to the OEM service manual and literature.

- 1 Flow to radiator and torque converter when thermostat is open
- 2 Radiator
- 3 Torque converter cooler
- 4 Coolant return to engine inlet connection from torque converter cooler.
- 5 Engine inlet connection
- 6 Flow to torque converter **only** when the thermostat is closed.



Air Intake System - Overview (010-999) General Information

On an engine with exhaust gas recirculation (EGR), the air intake system and exhaust system components work together to provide the correct amount of intake charge flow into the engine. This overview will cover the major components of the intake system.

- 1 Turbocharger
- 2 Charge-air cooler (CAC)
- 3 Air intake connection
- 4 Air intake manifold/cold starting aid.

The exhaust system components are covered in Exhaust System - Overview. Refer to Procedure 011-999 in Section F.

Turbocharger

The turbocharger is a variable geometry turbocharger (VGT) with:

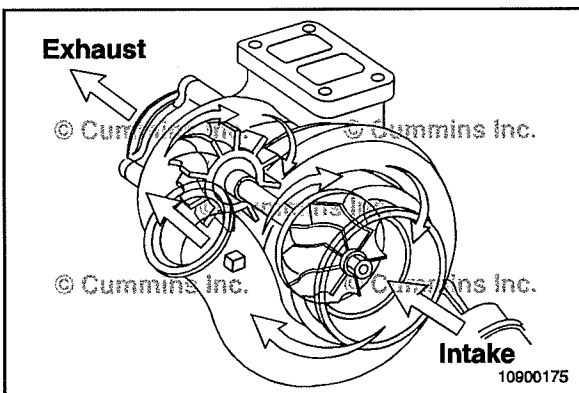
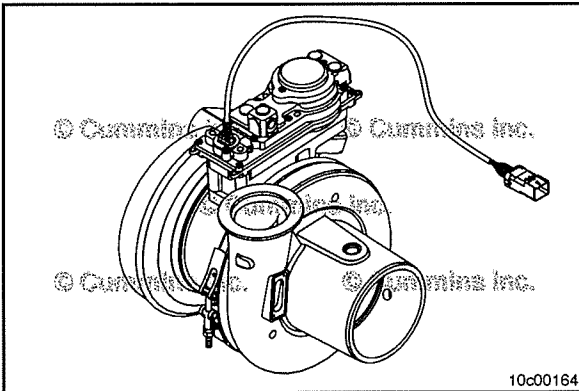
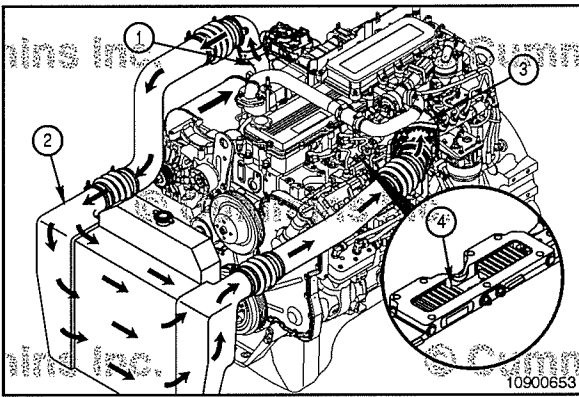
- Serviceable actuator mounted to the bearing housing of the turbocharger.
- Speed sensor in the bearing housing to monitor turbocharger operation.
- Water-cooled bearing housings (in addition to oil lubrication).

The turbocharger uses exhaust gas energy from the engine to turn the turbine wheel.

The turbine wheel drives the compressor wheel through a common shaft.

The impellers on the compressor wheel draw intake air through the original equipment manufacturer (OEM) air filter and inlet plumbing into the compressor housing of the turbocharger.

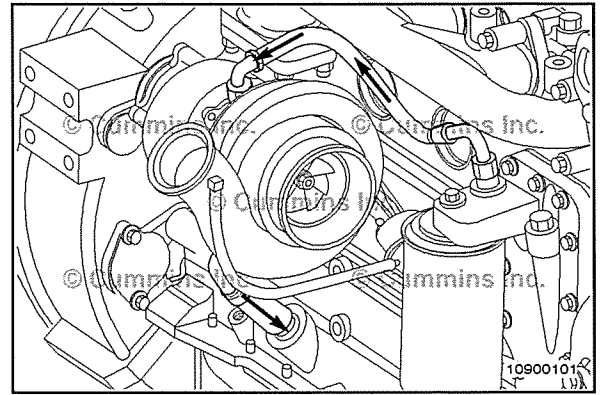
The air is then pressurized by the compressor wheel before being delivered to the charge-air cooler.



Engine lubricating oil is used to lubricate the bearings and provide some cooling for the turbocharger.

The lubricating oil supplied to the turbocharger through the supply line is at the engine oil operating pressure.

A return line connected to the bottom of the turbocharger routes the lubricating oil back to the engine lubricating oil pan.



The turbine, compressor wheel, and shaft are supported by two rotating bearings in the bearing housing.

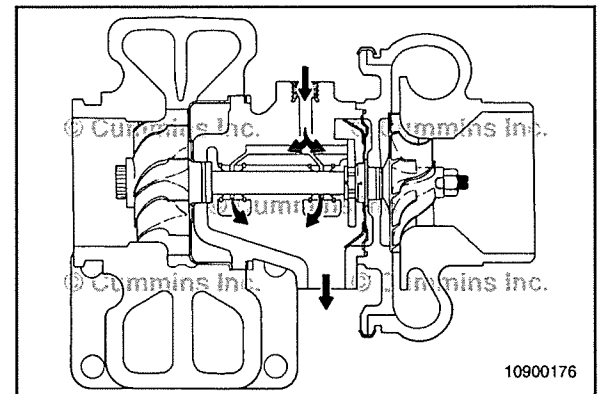
Passages in the bearing housing direct filtered, pressurized engine oil to the shaft bearings and thrust bearings.

The oil is used to lubricate and cool the rotating components.

Oil then drains from the bearing housing to the engine sump, through the oil drain line.

An adequate supply of good, filtered oil is very important to the life of the turbocharger.

Make sure a high quality oil is used and the oil and the oil filter are changed according to maintenance recommendations.



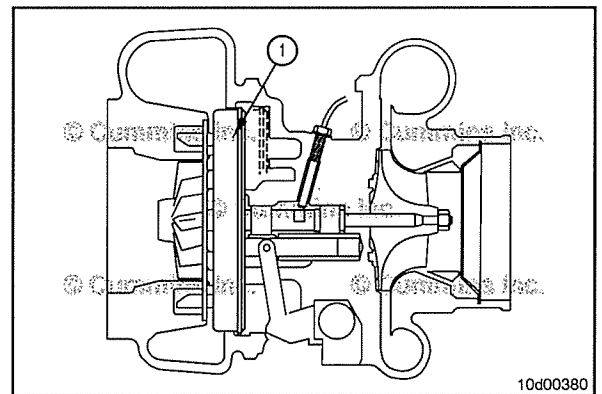
The actuator mounted on the turbocharger is used to control a sliding nozzle ring (1) internal to the turbine housing of the turbocharger.

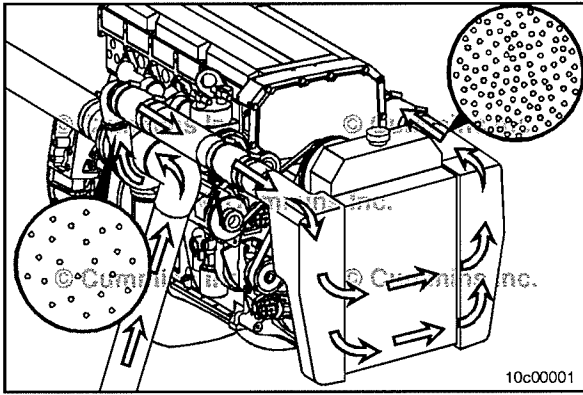
The position of the sliding nozzle ring is controlled by the engine control module (ECM) through a data link connection.

The position of the sliding nozzle ring, internal to the variable geometry turbocharger, allows for control of turbine wheel speed and exhaust flow through the turbocharger.

This allows for control of:

- Exhaust pressure
- Turbocharger compressor wheel speed
- Exhaust outlet temperatures.





Charge-Air Cooler (CAC)

Industrial engines use a chassis-mounted charge-air cooler to improve engine performance.

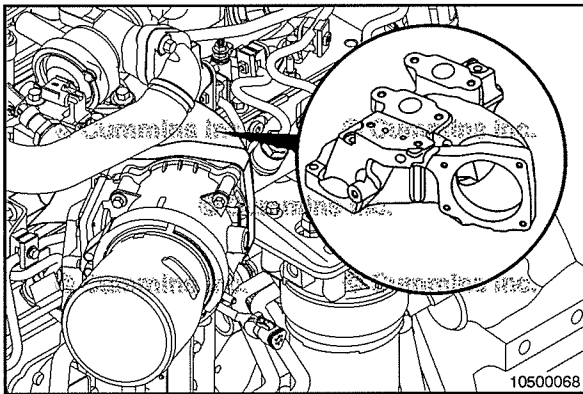
This system also uses large diameter piping to transfer the air from the engine turbocharger to the charge-air cooler, then returns the air from the charge-air cooler to the engine intake manifold.

As the intake air is compressed by the turbocharger, the air temperature increases.

This heated air is then passed through the charge-air cooler, which cools the air.

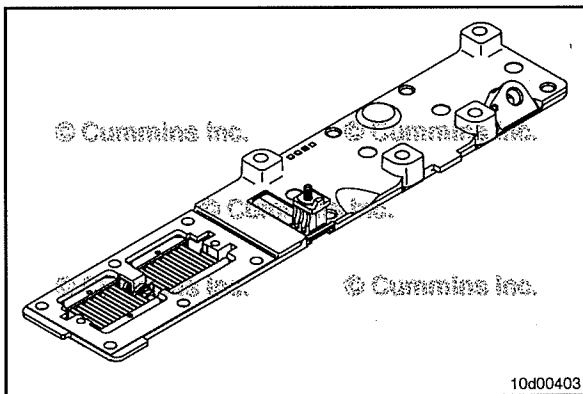
Cool air is more dense, which allows more air to be compressed into the cylinder, yielding higher combustion efficiency.

NOTE: The long-term integrity of the charge-air cooling system is the responsibility of the vehicle and component manufacturers.



Air Intake Connection

The air intake connection attaches to the top of the air intake manifold. It mixes compressed and cooled air from the charge-air plumbing with the cooled exhaust gases from the EGR cooler, then directs the mixture into the air intake manifold.



Air Intake Manifold/Cold Starting Aid

An air intake manifold with an integral cold starting aid is used to cover the intake portion of the cylinder head.

The integral cold starting aid is a single element intake air heater used to pre-heat the intake air under cold ambient conditions.

The ON/OFF operation of the intake air heater is controlled by the engine ECM.

The ECM controls a single OEM supplied relay which provides power for the intake air heater when commanded.

NOTE: The cold starting aid is **not** a serviceable part. If the cold starting aid has cracked, broken, or melted elements, the engine air intake manifold **must** be replaced. Refer to Procedure 010-023 in Section 10.

Intake Air Flow Description

Air Cleaner

Air first flows through the OEM supplied air cleaner, where foreign material and debris are removed from the air.

Air flows first through the Cummins Inc. supplied air cleaner element (direct flow) where foreign material and debris are removed from the air. Refer to Procedure 010-014 in Section 10.

Air Inlet Piping and Turbocharger

Air then flows through the OEM supplied air inlet piping to the turbocharger compressor inlet. Once air reaches the compressor wheel, it is compressed to a level determined by the ECM. The ECM regulates the level of pressure (boost) by using the electronically controlled variable geometry turbocharger. The electronic controls on the turbocharger adjust the compressor wheel speed, and thus boost, to meet the commands of the ECM.

Charge-Air Cooler

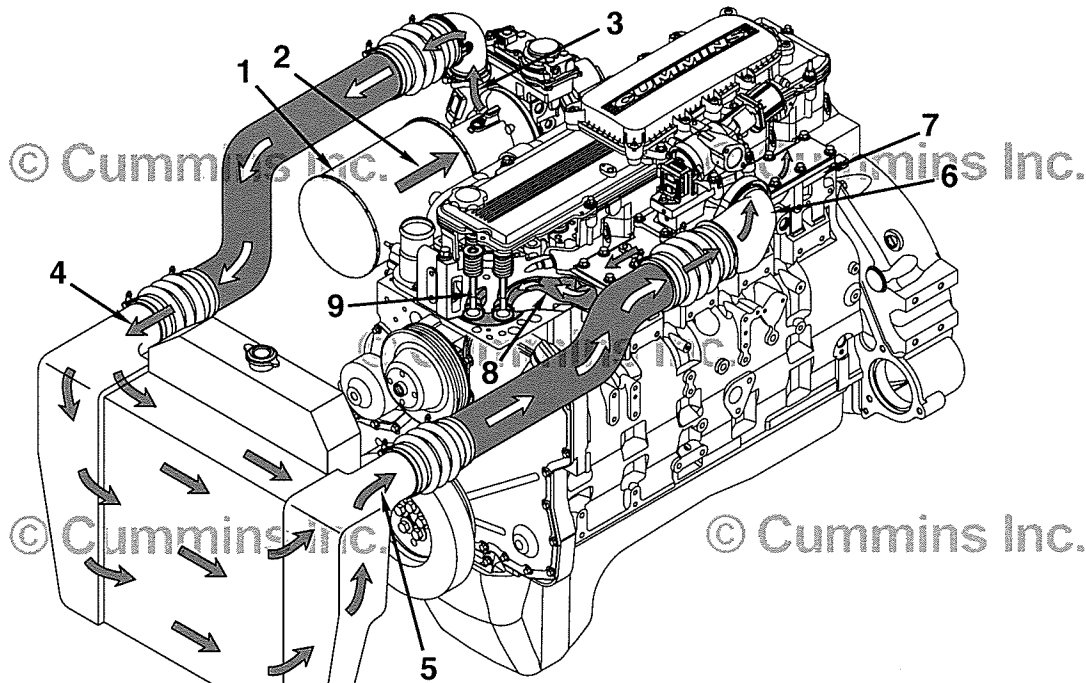
After the air flows through the turbocharger compressor outlet, it gets passed through an OEM supplied charge-air cooler to remove some of the heat generated by compressing the air. By lowering the temperature of the air, its density is increased. The increased density of the air allows the engine to maintain a higher level of performance.

Air Intake Connection Adapter, Air Intake Connection, and Air Intake Manifold

From the outlet of the charge air cooler compressed and cooled air flows into the air intake connection adapter. The air intake connection adapter allows different OEM arrangements to plumb to the engine. Compressed and cooled air then flows through the air intake connection. The air intake connection mixes the compressed and cooled air with the cooled exhaust gases then directs the mixture into the air intake manifold where the air is distributed to the cylinders for combustion.

Flow Diagram, Air Intake System (200-004)

General Information



Air Intake Flow

10d00375

- 1 Air cleaner
- 2 Turbocharger compressor inlet
- 3 Turbocharger compressor outlet
- 4 Charge air cooler inlet
- 5 Charge air cooler outlet
- 6 Air intake connection
- 7 Intake manifold (integral part of the cylinder head)
- 8 Intake port
- 9 Intake valve.

Exhaust System - Overview (011-999)

General Information

On an engine with exhaust gas recirculation (EGR), the air intake system and exhaust system components work together to provide the correct amount of intake charge flow into the engine. This overview covers the major components of the exhaust system.

- 1 Exhaust manifold
- 2 EGR cooler
- 3 EGR valve
- 4 Exhaust pressure sensor and mounting.

NOTE: The intake air system components are covered in Section 10 - Intake Air System - Overview.

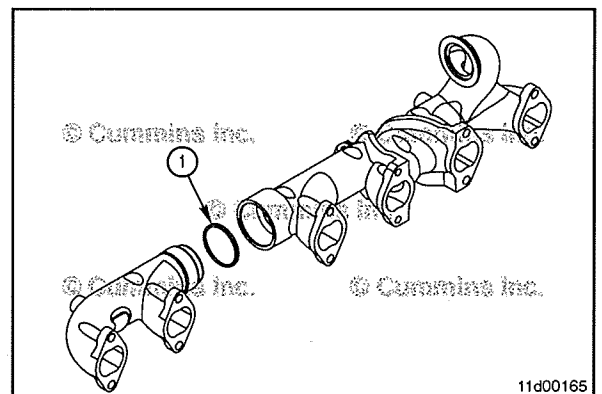
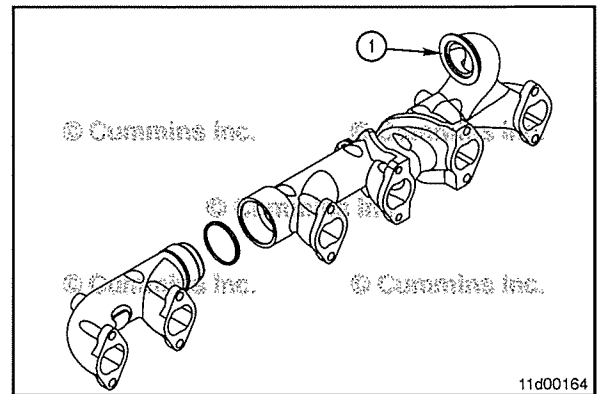
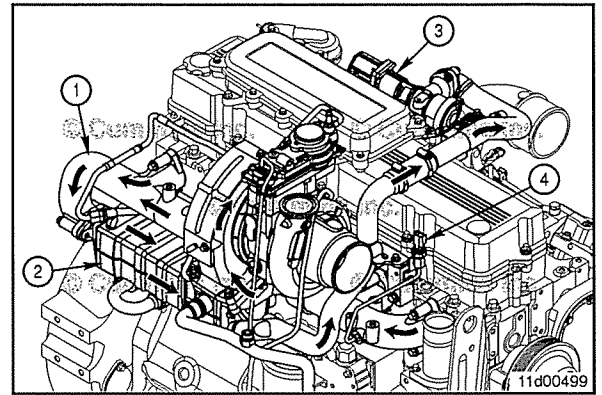
This overview also covers the aftertreatment system components located off the engine in the exhaust system.

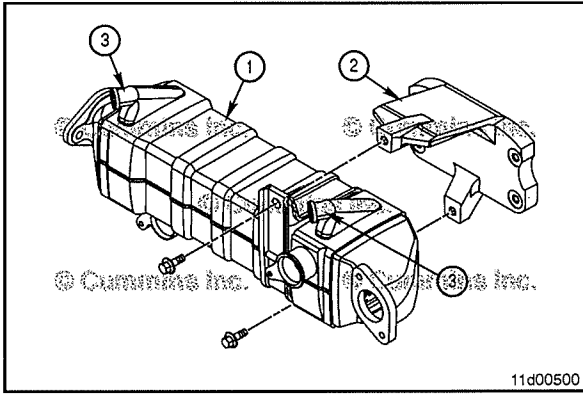
The exhaust manifold is a two-piece design with a sealed slip-joint to allow for thermal expansion.

The exhaust manifold has an additional port that connects to the EGR cooler inlet (1).

The exhaust manifold sections are sealed by a metallic exhaust seal (1), which is replaceable in the event the seal malfunctions and leaks exhaust gas.

The seal requires a special installation tool to be properly installed to the exhaust manifold.

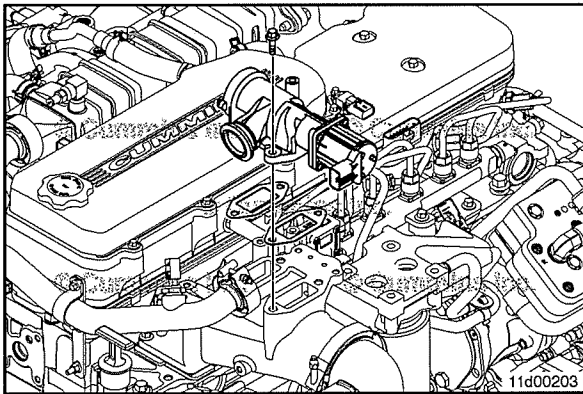




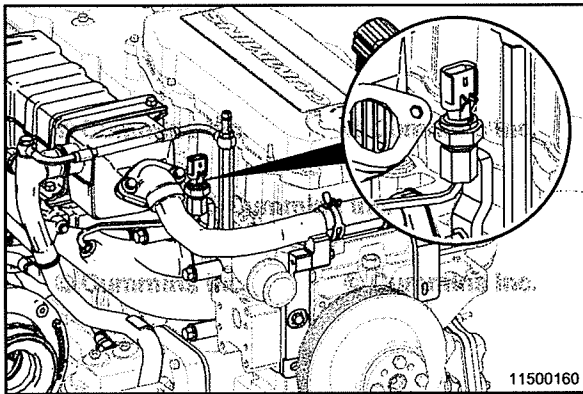
The EGR cooler (1) cools the exhaust gases flowing to the EGR valve. The EGR cooler is mounted below the exhaust manifold and is supported by the EGR cooler mounting bracket (2), attached to the cylinder block.

Because the EGR valve is mounted after the EGR cooler, the EGR cooler is at the same exhaust temperatures and pressures as the exhaust manifold.

The EGR cooler has two coolant vents (3), one near the exhaust inlet and one near the exhaust outlet of the EGR cooler. These vents prevent air from being trapped in the cooler during coolant filling and engine operation by continuously flowing coolant to the top tank of the vehicle cooling system.

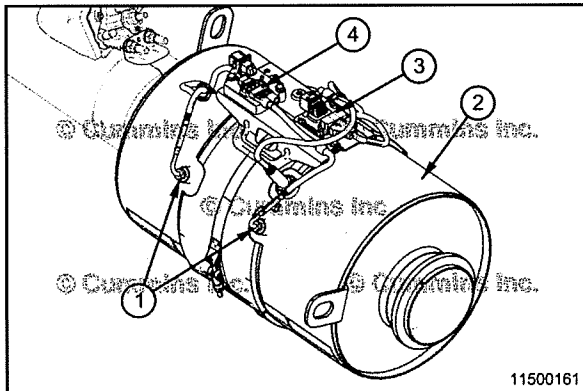


The EGR valve is mounted on top of the air intake connection. The EGR valve is an electric motor-driven valve that is controlled by the engine control module (ECM). The EGR valve uses a dual poppet valve to control the EGR flow into the air intake connection.



Exhaust pressure in the exhaust manifold (which determines the position of the variable geometry turbocharger and the EGR valve) is measured by an exhaust pressure sensor. To maximize the longevity of the exhaust pressure sensor, the sensor does **not** mount directly in the exhaust manifold. The exhaust pressure sensor is connected by a tube to another mounting location on the engine.

The exhaust pressure sensor is located on a mounting bracket attached to the rocker housing cover.



The aftertreatment diesel oxidation catalyst (DOC) system is used to reduce particulate emissions and is composed of four main components.

- 1 Aftertreatment exhaust gas temperature sensor probes
- 2 Aftertreatment DOC
- 3 Aftertreatment inlet mono-nitrogen oxides (NO_x) sensor
- 4 Aftertreatment exhaust gas temperature sensor module.

The aftertreatment selective catalyst reduction (SCR) system is designed to reduce the nitrogen oxide emissions from the engine exhaust into nitrogen and water. This is accomplished by two main entities: the aftertreatment SCR dosing system and the aftertreatment SCR exhaust system.

The aftertreatment SCR exhaust system mixes and converts the diesel exhaust fluid (DEF) to eliminate unwanted gases from being released in the atmosphere. This system includes the aftertreatment SCR catalyst, the aftertreatment decomposition tube, and any ancillary tubing (elbows, etc) involved.

The aftertreatment SCR dosing system monitors and injects DEF into the exhaust stream. The SCR dosing system is comprised of the aftertreatment DEF dosing valve, aftertreatment DEF dosing unit, aftertreatment DEF tank, and aftertreatment DEF lines.

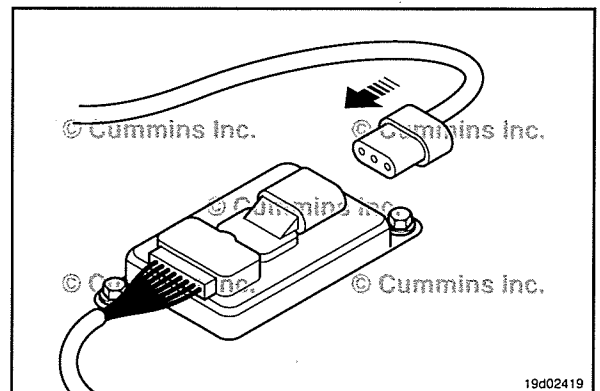
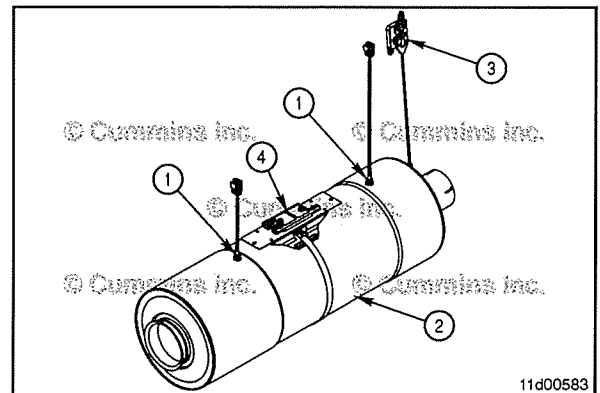
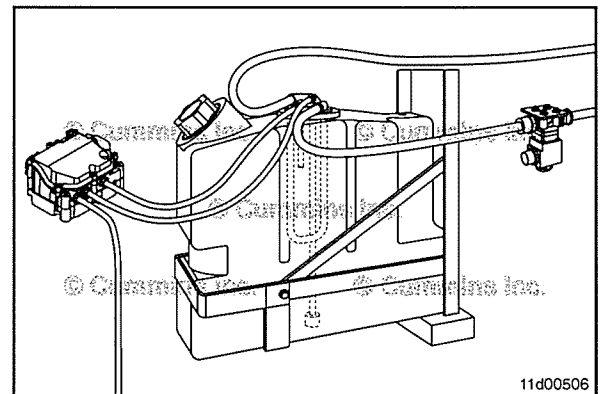
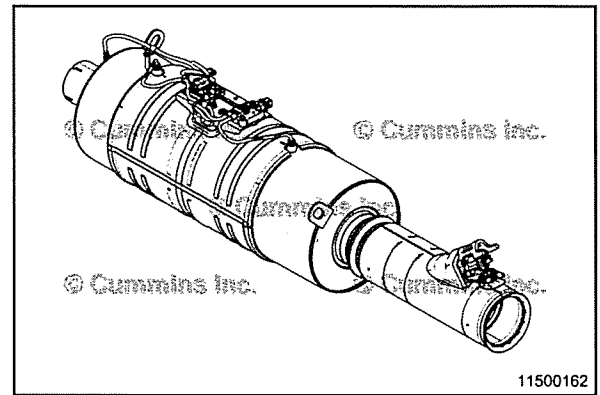
The aftertreatment SCR is designed to reduce nitrogen oxide emissions from the engine using these main components:

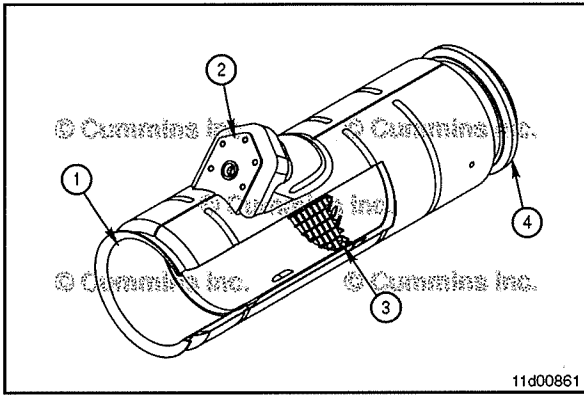
- 1 Aftertreatment SCR inlet/outlet temperature sensor probes
- 2 Aftertreatment SCR catalyst
- 3 Aftertreatment outlet NOx sensor
- 4 Aftertreatment exhaust gas temperature sensor interface module and sensors.

NOTE: The temperature sensor module and temperature sensor probes are not serviceable separately and **must** be replaced as an assembly.

During initial cold start up the engine will go into SCR warm up condition. This condition will sound and act similar to active SCR/exhaust system cleaning. The SCR catalyst will need to have a temperature of over 160°C [320°F] degrees in order to properly convert NOx in the exhaust stream.

The NOx sensors at the DOC and SCR catalyst will monitor the NOx output of the exhaust system and relay the information back to the ECM.

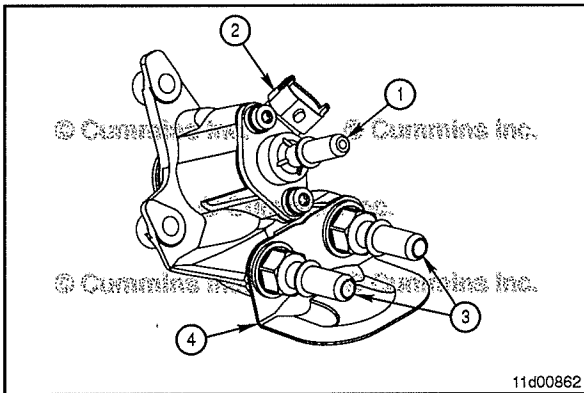




Aftertreatment Decomposition Tube:

The DEF dosing valve is mounted to the decomposition tube. The decomposition tube contains a mixer to help DEF mists distribute evenly in the exhaust stream to convert DEF into ammonia.

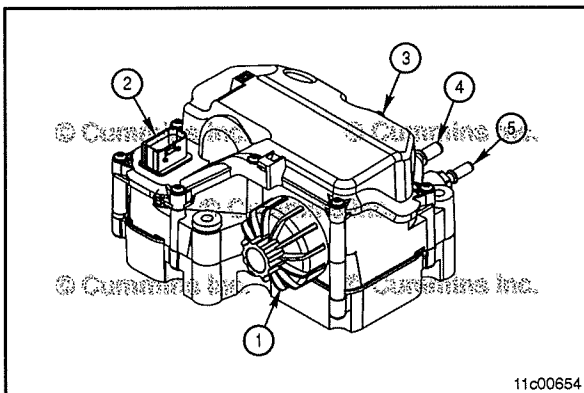
- 1 Aftertreatment decomposition tube inlet
- 2 Aftertreatment DEF dosing valve mounting
- 3 Aftertreatment decomposition tube mixer
- 4 Aftertreatment decomposition tube outlet.



Aftertreatment DEF Dosing Valve:

The aftertreatment DEF dosing valve is controlled by the ECM and sprays the correct amount of DEF into the exhaust stream. Engine coolant is supplied to the DEF dosing valve to keep the valve cool and operable.

- 1 DEF intake port
- 2 Electrical connection to original equipment manufacturer (OEM) harness
- 3 Coolant ports
- 4 Heat shield.



Aftertreatment DEF Dosing Unit:

The aftertreatment DEF dosing unit is the pumping mechanism of the dosing system. The aftertreatment DEF dosing unit draws DEF through its suction port and pressurizes it. The aftertreatment DEF dosing unit then filters the DEF which is eventually sprayed into the exhaust stream via the pressure port. Any unused DEF is returned to the DEF tank through the return port.

The main components of the aftertreatment DEF dosing unit:

- 1 Aftertreatment DEF dosing unit filter (internal) and cap
- 2 Electrical connector
- 3 Inlet port
- 4 Backflow port
- 5 Outlet port.

Aftertreatment DEF Tank:

The DEF tank is designed to store DEF and report DEF tank level, tank temperature, and DEF quality to the ECM.

If the tank level becomes too low, it will set fault codes followed by a power derate. For further details on the tank level sensor, refer to the OEM service manual.

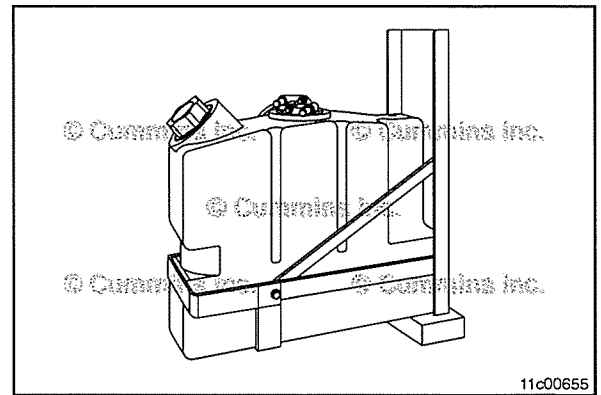
If the tank temperature becomes too high, it will set fault codes followed by a power derate. For further details on the tank temperature sensor, refer to the OEM service manual.

If the tank is filled with the incorrect fluid, (anything other than DEF), the aftertreatment system will fail to operate correctly. A fault will become active and a power derate will follow. For further details on the urea quality sensor, see the following procedure. Refer to Procedure 019-475 in Section 19.

See the following procedure in the QSB6.7 CM2350 B105 Operation and Maintenance Manual, Bulletin 4332778, for DEF specifications. Refer to Procedure 018-026 in Section V.

Refer to service bulletin, Diesel Exhaust Fluid (DEF) Specifications for Cummins® Selective Catalytic Reduction (SCR) Systems, Bulletin 4021566.

DEF tanks will vary in size and shape. For further details, refer to the OEM service manual.

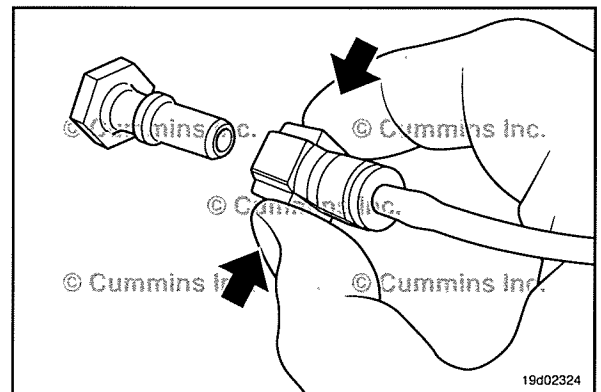


Aftertreatment DEF Lines:

The aftertreatment DEF lines carry the DEF to and from the DEF tank, aftertreatment DEF dosing unit, and aftertreatment DEF dosing valve.

DEF will fill the lines during a prime or operating state and then be removed in a purge state to prevent freezing of the lines.

DEF line connectors, length, and design will vary by vehicle manufacturer. The DEF lines incorporate electrically heated elements. For further details, refer to the OEM service manual.



The SCR system is comprised of many components, but requires a minimal amount of servicing or driver intervention. The SCR system is comprised of four main states: priming, dosing, purging, and heating.

Priming State

- Once the SCR reaches a temperature of 190°C [375°F] the ECM will command the aftertreatment DEF dosing unit to start its priming process. The aftertreatment DEF dosing unit will draw DEF from the DEF tank, pressurize the DEF, and then filter the DEF to the aftertreatment DEF dosing valve. The aftertreatment DEF dosing valve will open and close to rid any air from the system. Once the system is able to build up pressure and has removed most of the air bubbles from the DEF lines, the aftertreatment DEF dosing system is capable of dosing.

Dosing State

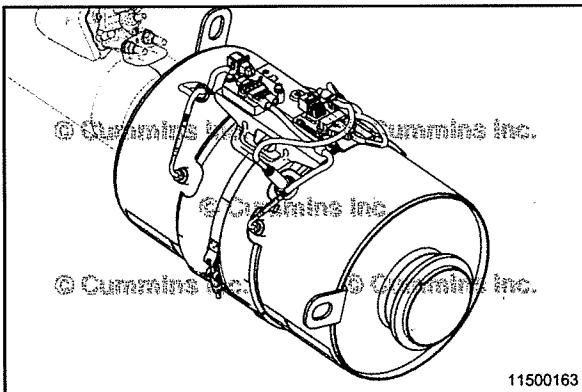
- The aftertreatment DEF dosing valve will open and spray DEF in the exhaust stream when the ECM aftertreatment calibration limits are met. The DEF will then be chemically altered by the aftertreatment SCR catalyst to clean the exhaust gases. As long as the dosing system is in the dosing state, the aftertreatment DEF dosing unit will continue to run regardless if the aftertreatment DEF dosing valve is or is not spraying DEF. DEF dosing rates are dependent on vehicle duty cycle. The dosing rates are not necessarily constant under most duty cycles. The aftertreatment DEF dosing valve will pulse the demanded amount of DEF into the exhaust stream. Any DEF that is not used by the aftertreatment DEF dosing valve is returned to the DEF tank.

Purging State

- When a driver keys OFF, the dosing system will shut itself down with a purge cycle to prevent DEF from being left in the system, and in cold climates, potentially freezing. An audible click and pumping sound will be heard from the DEF dosing unit when it is in a purge cycle. The DEF dosing unit will slide its internal reverting valve and cause a change in the flow direction of the DEF. The DEF dosing unit will pull all of the DEF out of the aftertreatment DEF dosing valve and pressure line, and then return the unused DEF to the DEF tank. In this process the aftertreatment DEF dosing valve will open, eliminating the vacuum created in the lines for a more complete purge process. After a complete purge the majority of the system will be free of any remaining DEF. If the main power to the ECM is removed, via battery cut off or other means before the purging state is completed, an internal fault will be logged in the ECM. The incomplete purge counter can be viewed in INSITE™ electronic service tool.

Heating State

- DEF freezes at -11°C [12°F]. If a driver starts the engine in a cold climate the dosing heating state will be activated. If the ambient air temperature sensor reads ambient conditions are below -4°C [25°F] the ECM will command the dosing system to go into the defrost state. The aftertreatment dosing unit will turn on its internal heater to defrost any remaining DEF that still may be inside it. The heated DEF lines will also be commanded on. If the DEF tank temperature drops below -5°C [23°F], the DEF tank coolant valve will be commanded open by the ECM. Engine coolant will flow through the tank to defrost the frozen DEF. The DEF dosing system will **not** prime until every component is completely defrosted. If ambient conditions continue to be cold after the system has primed, the ECM will command a maintenance heating feature to prevent the DEF dosing system from refreezing. This feature will cycle the heating on and off to the DEF lines, DEF tank, and aftertreatment DEF dosing unit.



SCR/exhaust system cleaning occurs to diminish DEF deposits and condition the aftertreatment system.

Passive SCR/exhaust system cleaning occurs when the exhaust temperatures are naturally high enough to meet regeneration requirements.

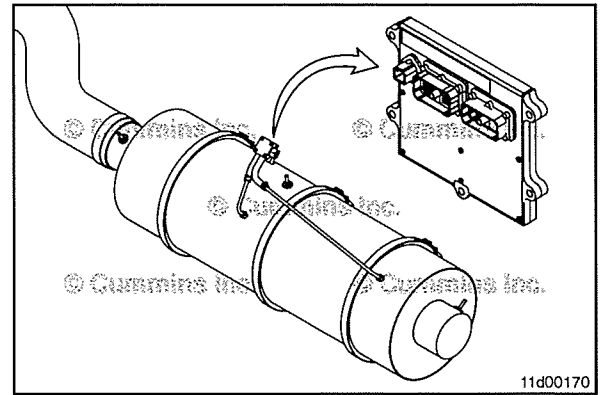
Passive SCR/exhaust system cleaning typically occurs when the temperature of the aftertreatment DOC is above 350°C [662°F]. This occurs during high engine duty cycles.

Since passive SCR/exhaust system cleaning occurs naturally, it is considered to be normal engine operation. No fuel is added to the exhaust stream during passive SCR/exhaust system cleaning.

Active SCR/exhaust system cleaning occurs when the exhaust temperatures are **not** naturally high enough to meet cleaning requirements.

Active SCR/exhaust system cleaning requires assistance from the engine in order to increase the exhaust temperature. This is typically done by injecting a small amount of diesel fuel into the exhaust stream (called aftertreatment injection) which is then oxidized by the aftertreatment DOC. The oxidation of this additional fuel creates the heat needed to clean the aftertreatment system.

For active SCR/exhaust system cleaning to occur, the ECM **must** detect that the aftertreatment time or duty cycle-based algorithms have reached a specified limit. Once this limit is reached, the engine will alter its operation in order to create exhaust temperatures high enough to actively clean the aftertreatment system.



Aftertreatment injection requires that temperatures in the aftertreatment system reach approximately 250°C [482°F]. At this temperature and above, the small quantities of fuel injected into the exhaust will properly oxidize across the aftertreatment DOC, creating the additional heat required to actively clean the aftertreatment system.

During active SCR/exhaust system cleaning, the ECM monitors the exhaust temperatures before and after the aftertreatment DOC and maintains the temperatures in a range of approximately 260 to 650°C [500 to 1202°F]. The quantity of fuel used for aftertreatment injection will vary as the temperature is controlled within these limits.

The temperatures achieved during active SCR/exhaust system cleaning are typically higher than those achieved during passive SCR/exhaust system cleaning. The conversion of soot to carbon dioxide occurs much faster as temperatures increase.

A typical active SCR/exhaust system cleaning event will take approximately 20 to 60 minutes to complete while the equipment is operating. The equipment operator may notice additional turbocharger noise during this time, along with an illuminated high exhaust temperature lamp or blinking SCR system cleaning lamp.

The frequency at which an engine will require an active SCR/exhaust system cleaning varies greatly from application to application. In general, equipment with a low load duty cycle will require more active SCR/exhaust system cleanings than equipment that is heavily loaded.

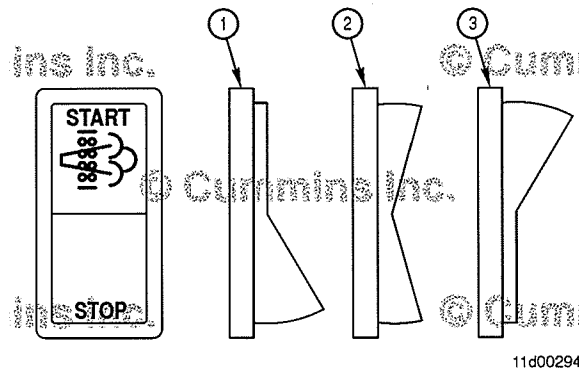
The ECM also contains a time-based feature for active SCR/exhaust system cleanings which is used to verify correct aftertreatment operation when the equipment duty cycle is typically high enough that active SCR/exhaust system cleanings are **not** necessary.

If the engine has **not** completed an active SCR/exhaust system cleaning within the last 60 hours of operation, the ECM will call for a time-based active SCR/exhaust system cleaning event.

The 60-hour timer resets each time the ECM detects that an active SCR/exhaust system cleaning event has been completed.

Under some operating conditions, such as low speed, low load, or stop-and-go duty cycles, the engine may **not** have enough opportunity to clean the aftertreatment system during normal equipment operation. When this occurs, the engine illuminates the SCR system cleaning lamp to inform the equipment operator that assistance is required, typically in the form of a manual (non-mission) SCR/exhaust system cleaning.

Manual (non-mission) SCR/exhaust system cleaning is a form of active cleaning that is initiated by the equipment operator when the equipment is **not** in operation. Refer to Procedure 014-015 in Section 14.



The equipment manufacturer has the option to install two switches that control aftertreatment functions; the start switch and the permit switch.

The start switch (known as the SCR system cleaning start switch in INSITE™ electronic service tool) is used to start a manual (non-mission) SCR/exhaust system cleaning when the SCR system cleaning lamp is illuminated. The equipment manufacturer can also reference this switch as a manual regeneration switch, start switch, or parked regeneration switch.

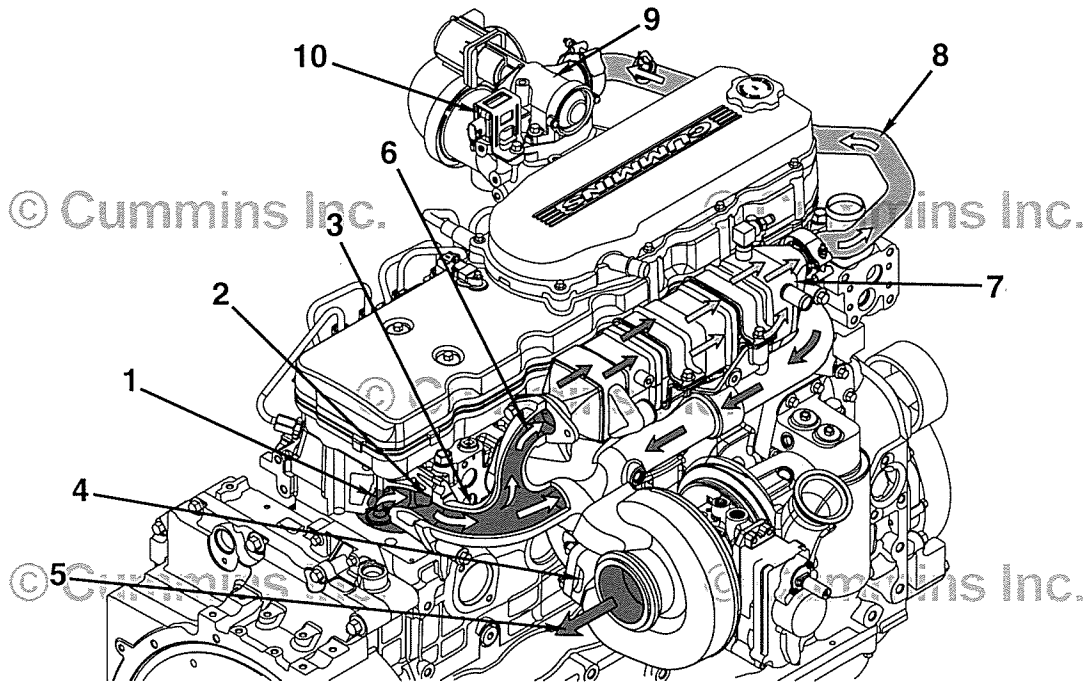
The permit switch (known as the SCR system cleaning permit switch in INSITE™ electronic service tool) is used to allow the equipment operator to disable active SCR/exhaust system cleaning, if necessary. The equipment manufacturer can also reference this switch as an inhibit switch, stop switch, or disable switch.

Refer to Procedure 011-056 in Section 11.

NOTE: The start and permit switches, as well as the SCR/exhaust system cleaning lamp, are common with other Cummins systems utilizing a diesel particulate filter (DPF). Some OEMs, documentation, and tools may reference these as Aftertreatment DPF Regeneration or Aftertreatment Regeneration parameters.

Flow Diagram, Exhaust System (200-005)

General Information

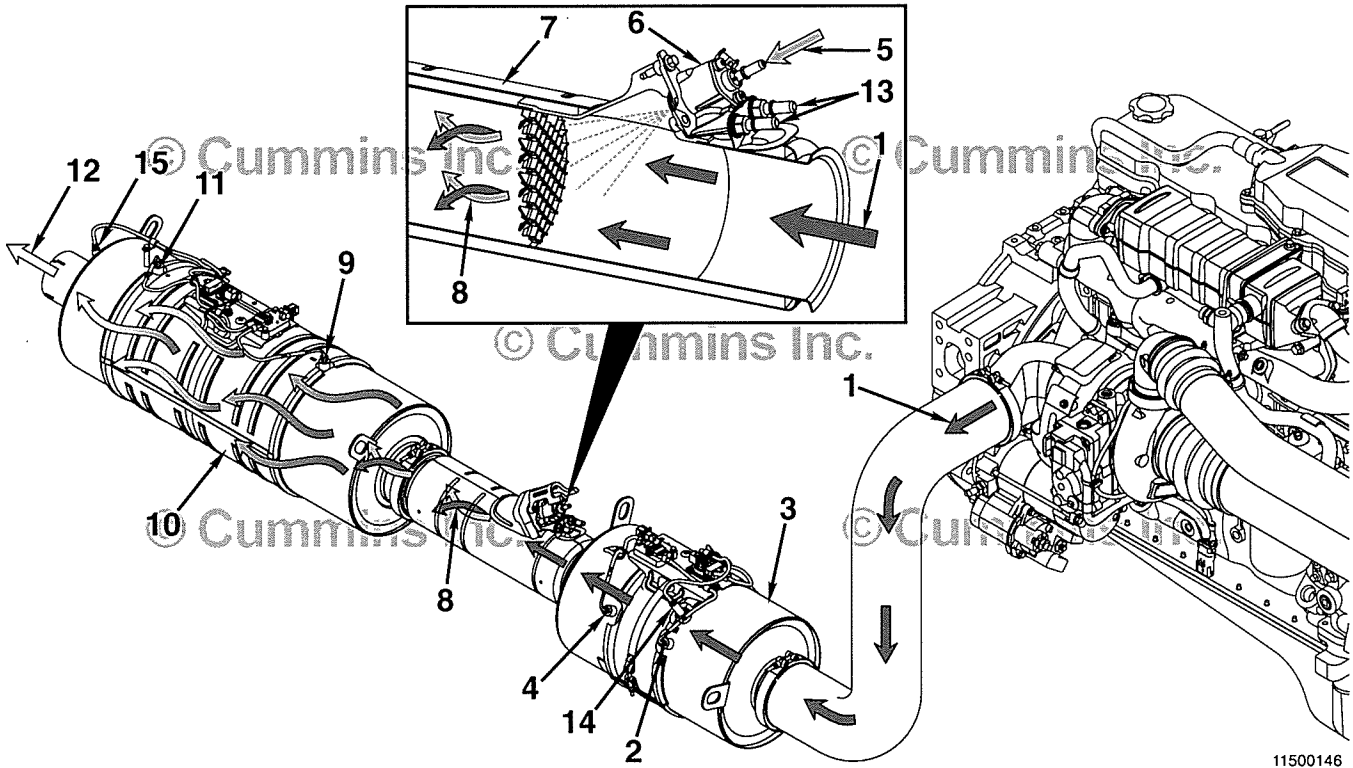


Exhaust Flow

- 1 Exhaust valves
- 2 Exhaust port
- 3 Exhaust manifold
- 4 Turbocharger
- 5 Turbocharger exhaust outlet
- 6 Exhaust inlet to exhaust gas recirculation (EGR) cooler
- 7 EGR cooler
- 8 Cooled exhaust outlet to EGR valve
- 9 EGR valve
- 10 EGR valve differential pressure sensor.

Flow Diagram, Exhaust System (200-005)

General Information

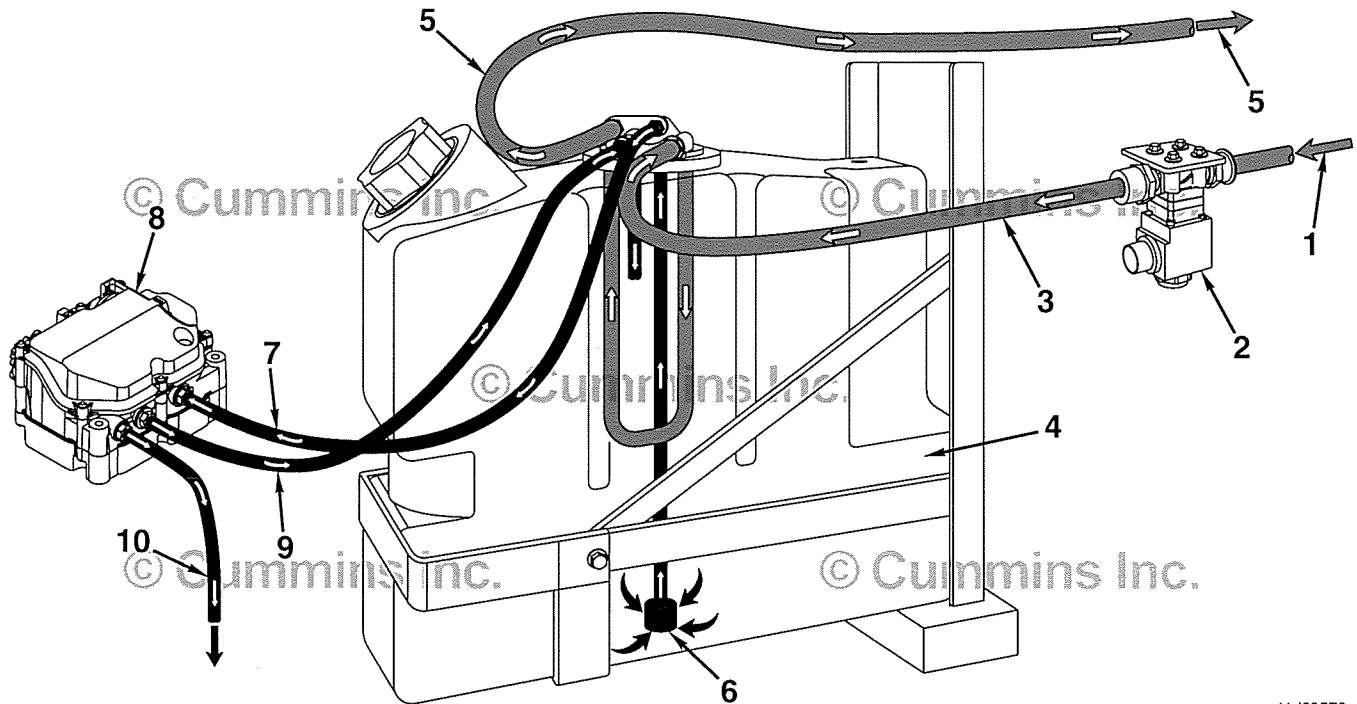


11500146

- 1 Exhaust from turbocharger
- 2 Aftertreatment diesel oxidation catalyst (DOC) intake temperature sensor probe
- 3 Aftertreatment DOC
- 4 Aftertreatment DOC outlet temperature sensor probe
- 5 Diesel exhaust fluid (DEF) supply to aftertreatment DEF dosing valve
- 6 Aftertreatment DEF dosing valve
- 7 Decomposition reactor
- 8 Exhaust and DEF mixture
- 9 Aftertreatment selective catalyst reduction (SCR) intake temperature sensor probe
- 10 Aftertreatment SCR catalyst
- 11 Aftertreatment SCR outlet temperature sensor probe
- 12 Exhaust flow exiting aftertreatment system
- 13 Aftertreatment DEF dosing valve coolant fittings
- 14 Aftertreatment inlet mono-nitrogen oxides (NOx) sensor probe
- 15 Aftertreatment outlet NOx sensor probe.

Flow Diagram, Exhaust System (200-005)

General Information



- 1 Coolant flow from engine to aftertreatment DEF
- 2 Aftertreatment DEF tank coolant valve
- 3 Coolant flow to aftertreatment DEF tank (**Only** when aftertreatment DEF tank coolant valve is open)
- 4 Aftertreatment DEF tank
- 5 Coolant return to engine
- 6 Aftertreatment DEF supply from aftertreatment DEF tank
- 7 Aftertreatment DEF flow to aftertreatment DEF dosing unit
- 8 Aftertreatment DEF dosing unit
- 9 Aftertreatment DEF return to aftertreatment DEF tank
- 10 Aftertreatment DEF flow to aftertreatment DEF dosing valve.

NOTE: For additional information regarding the diesel exhaust fluid tank or coolant valve, refer to the original equipment manufacturer (OEM) service manual.

Compressed Air System - Overview (012-999)

General Information

The compressed air system normally consists of an on-engine/gear-driven air compressor, air governor, air tanks, and all necessary plumbing.

The components listed below are commonly used in a compressed air system:

- 1 Air governor
- 2 Discharge line
- 3 Air dryer
- 4 Supply tank
- 5 Check valve
- 6 Primary tank
- 7 Secondary tank
- 8 Check valve
- 9 Air compressor.

The engine is supplied with the air compressor and related intake air and coolant plumbing **only**. The remainder of the compressed air system is the responsibility of the vehicle manufacturer.

Air Compressor

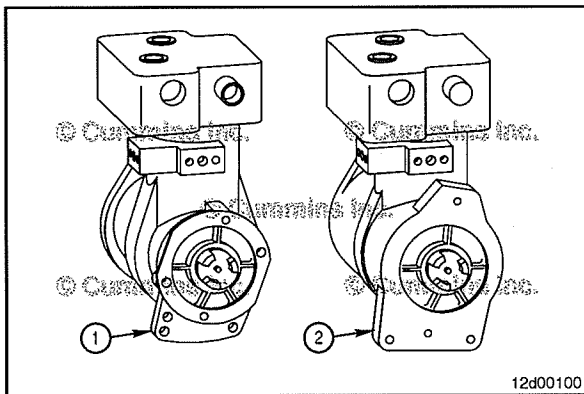
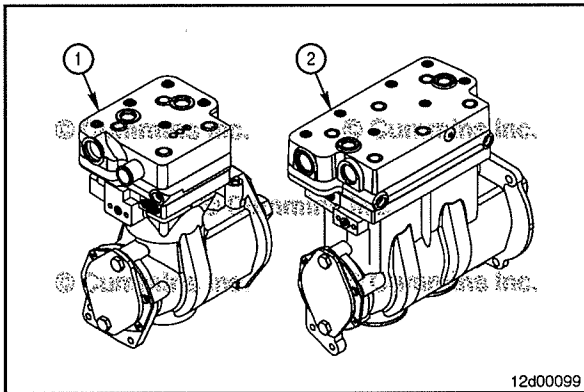
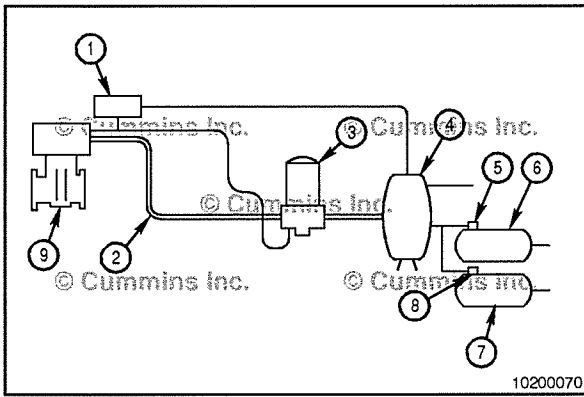
Several different air compressors are available for the engines covered in this manual. Both single cylinder (1) and two cylinder (2) modules are available.

The air compressors can either be turbocharged or naturally aspirated, depending on the configuration.

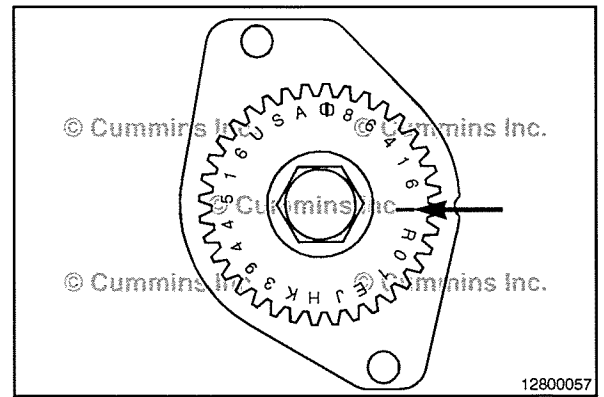
The air compressor can also be a low throughput torque or high throughput torque model, depending on the application.

Low throughput torque models have an SAE A rear flange (1).

High throughput torque models have an SAE B rear flange (2).

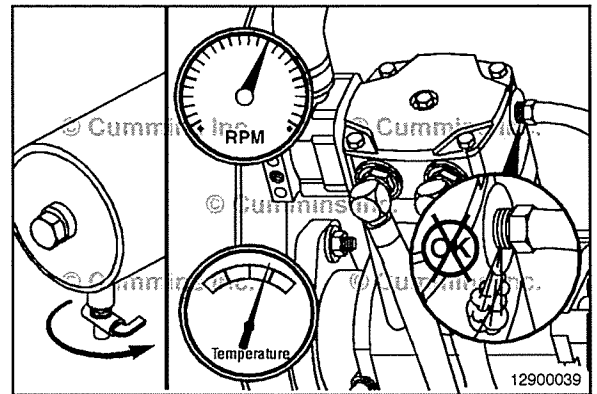


To make sure the air compressor does **not** contribute to engine vibrations, when installed, the air compressor **must** be properly timed on the engine.



The key factor which determines the reliability and durability of an air compressor in an application is the amount of time the air compressor is supplying air during the vehicle/machine operation, known as the duty cycle of the air compressor.

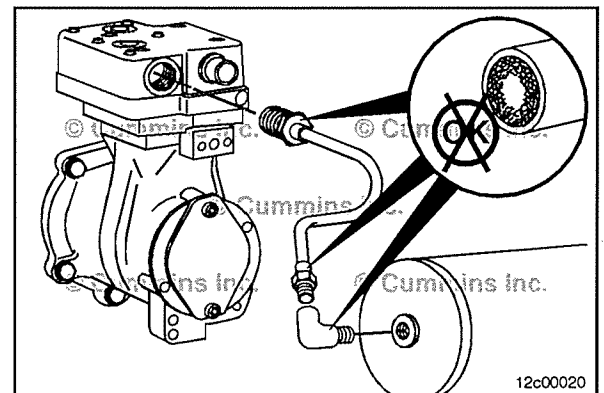
Air compressors are **not** designed to pump continuously and will generate a lot of heat when pumping, which is dissipated during the time the compressor is **not** pumping (called the unloaded operation).

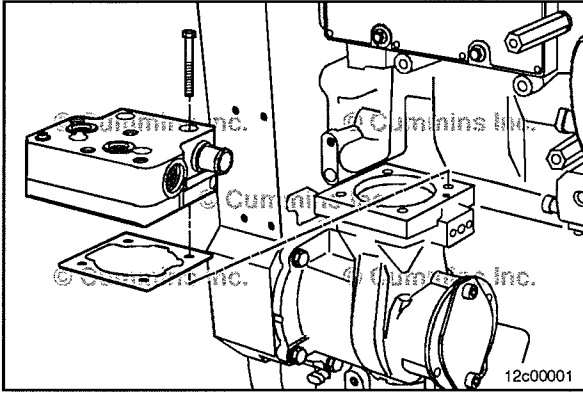


Compressed air system maintenance/servicing can help minimize air compressor duty cycle and ensure reliability and durability of the air compressor. These items include but are **not** limited to:

- 1 Find and stop all leaks in the system. Air leaks can double or triple operating duty cycles. Close attention to correcting air system leaks is critical.
- 2 Checking the air compressor exhaust port, discharge line, and fittings for carbon build up. If the carbon buildup is greater than 1.6 mm [0.06 in], clean or replace as necessary.
- 3 Check the air lines and fittings between the outlet port of the air dryer and the first tank after the air dryer for any water or oil. The tank should be dry. If oil is present, replace the dryer desiccant and clean the downstream system and components as required.

Refer to the original equipment manufacturer (OEM) manual for the vehicle for maintenance and service information for the compressed air system. For air compressor specific maintenance, see the Operation and Maintenance and/or Owner's manual for the engine being serviced.



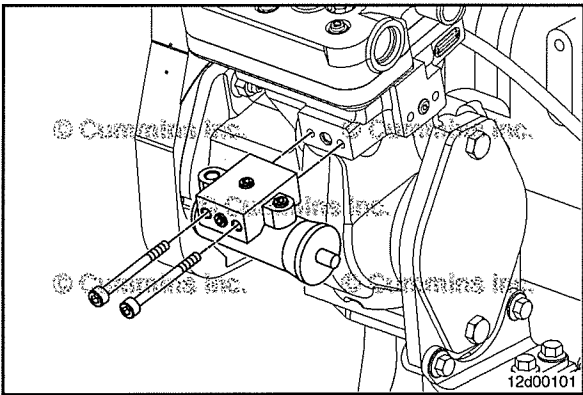


Air Compressor Cylinder Head

The air compressor cylinder head is cooled by engine coolant. The cylinder contains intake and exhaust valves to regulate air flow into and out of the cylinder head.

Most air compressor cylinder heads can be serviced without removing the compressor from the engine. This manual covers servicing of the cylinder head with the compressor installed on the engine. If there is internal damage to the air compressor, the air compressor **must** be replaced.

Prior to removing the air compressor cylinder, make sure to check if replacement parts are available. Some air compressor cylinder heads may **not** be able to be serviced separately from the air compressor.



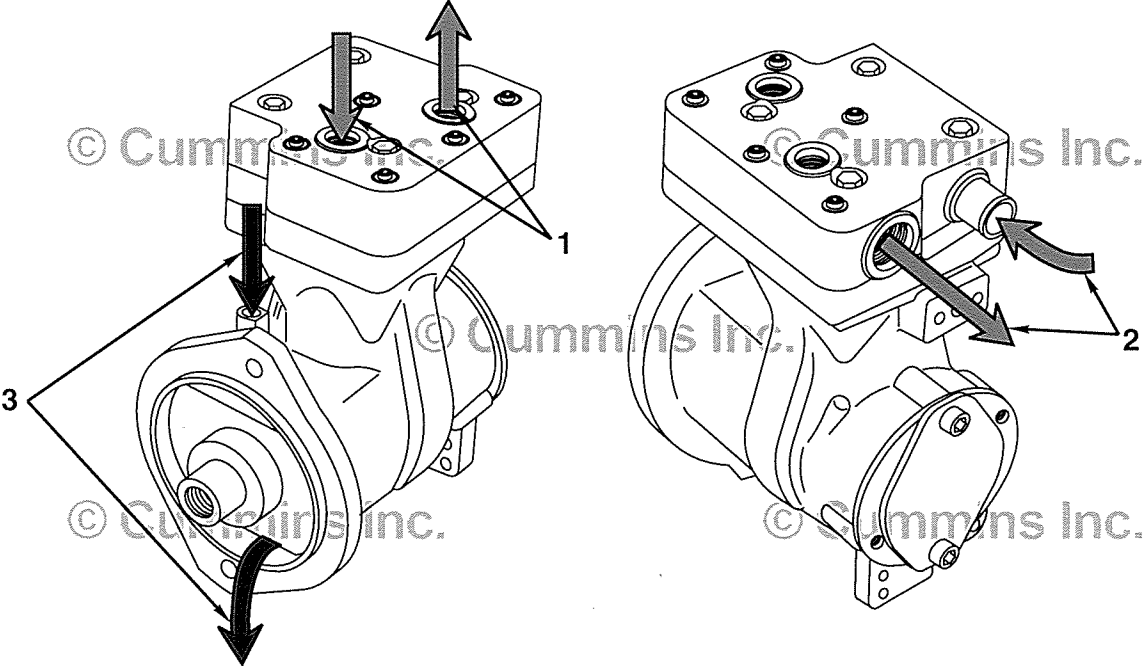
The compressor operates continuously, but has a "loaded" and "unloaded" operating mode. The operating mode is controlled by a pressure activated air governor and the air compressor unloader assembly. The air governor can be located on the air compressor or remotely on the vehicle.

When the air system reaches a predetermined pressure, the governor applies an air signal to the unloader assembly, causing the unloader to either hold open or shutoff the compressor's intake valve. This causes compressed air to stop flowing into the compressed air system.

As the system is used, the pressure drops. At a predetermined pressure, the governor directs an air signal to the compressor unloader assembly, allowing the compressor to again pump compressed air into the system.

Flow Diagram, Compressed Air System (200-006)

General Information



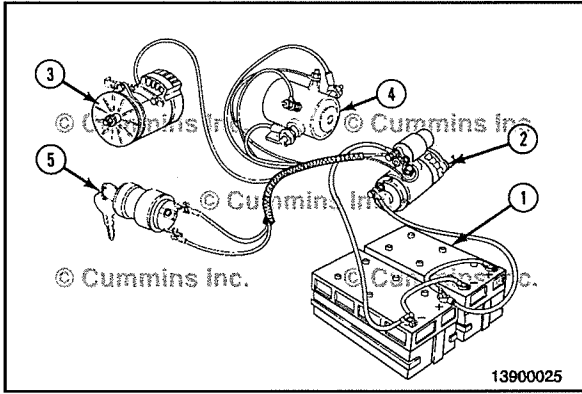
- 1 Coolant
- 2 Air
- 3 Lubricant.

Electrical Equipment - Overview (013-999)

General Information

The basic heavy-duty electrical system consists of:

- Batteries (1)
- Starting motor (2)
- Alternator (generator) (3)
- Magnetic switch (4)
- Push-button switch or keyswitch (5)
- Control (or relay) circuit wiring
- Battery cables or cranking circuit.



Engine Testing - Overview (014-999)

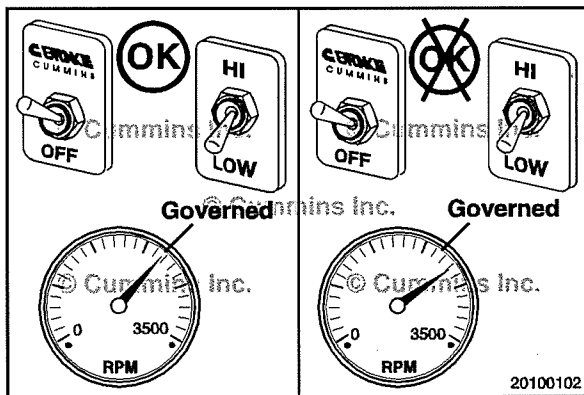
General Information

The engine test is a combination of an engine run-in and a performance check. The engine run-in procedure provides an operating period that allows the engine parts to achieve a final finish and fit. The performance check provides an opportunity to perform final adjustments needed to optimize the engine's performance.

An engine test can be performed using **either** an engine dynamometer **or** a chassis dynamometer. If a dynamometer is **not** available, an engine test **must** be performed in a manner that simulates a dynamometer test.

Check the dynamometer before beginning the test. The dynamometer **must** have the capability to test the performance of the engine when the engine is operating at the maximum rpm and horsepower range (full power).

The engine crankcase pressure, often referred to as engine blowby, is an important factor that indicates when the piston rings have achieved the correct finish and fit. Rapid changes of blowby or values that exceed specification by more than 50 percent indicate that something is wrong. The engine test **must** be discontinued until the cause has been determined and corrected.



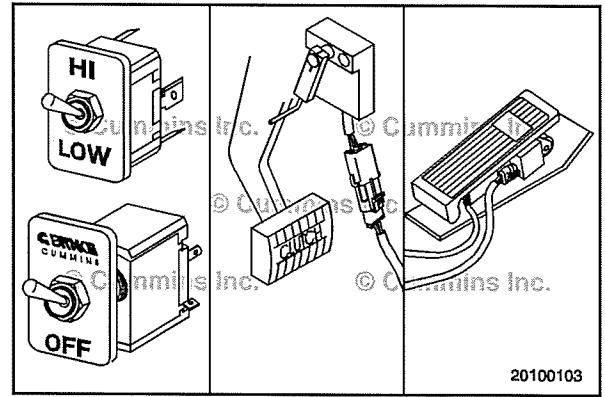
Vehicle Braking - Overview (020-999)

General Information

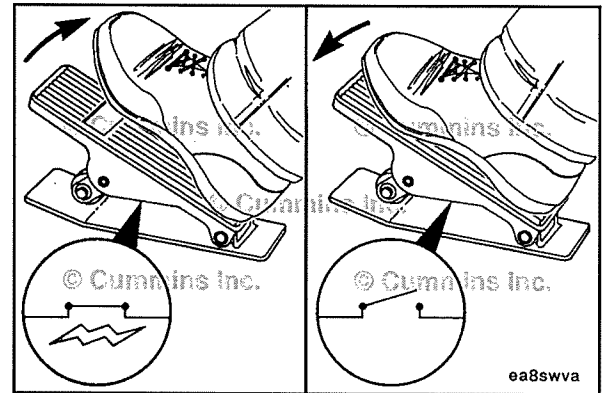
NOTE: The engine brake is comprised of two assemblies. The following instructions apply to both of the engine brake assemblies.

Engine brake controls consist of the following:

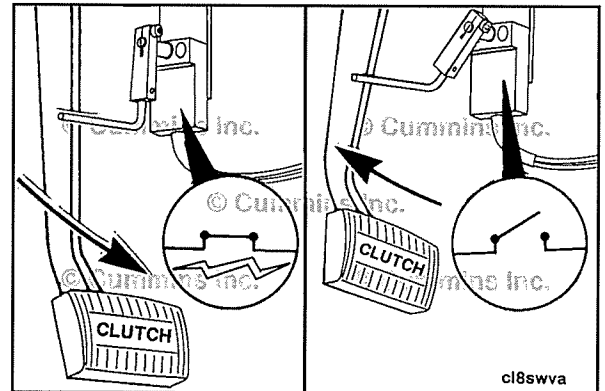
- An ON/OFF switch
- Clutch switch
- Throttle sensor
- Two-position selector switch (optional).



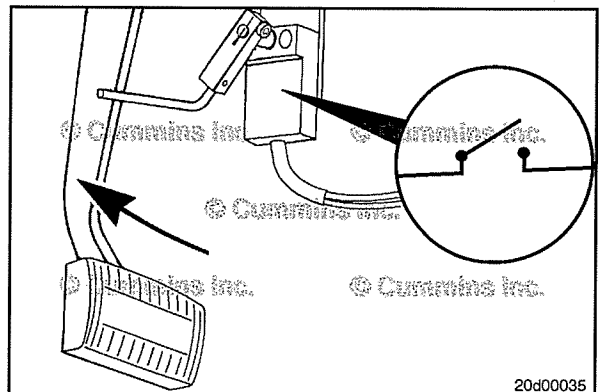
The throttle sensor is part of the accelerator pedal assembly located in the cab, and will deactivate the engine brakes when depressed.

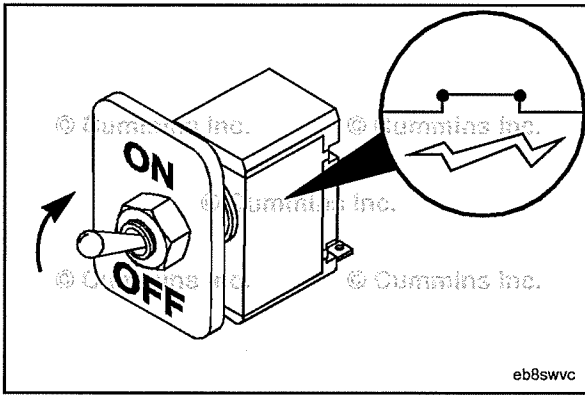


The clutch switch uses the motion of the clutch linkage to deactivate the engine brakes when the clutch pedal is depressed. Depressing the clutch while in cruise control will disengage the cruise control.



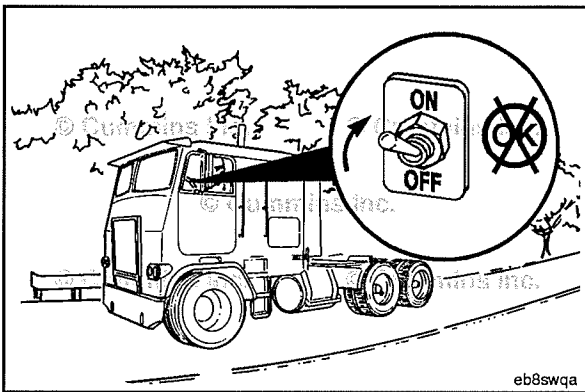
The service brake switch is attached to the service brake. Applying the service brakes while in cruise control will disengage the cruise control and enable the engine brakes.





NOTE: See the appropriate pages in this section for specific information about engine brake operation under certain road conditions.

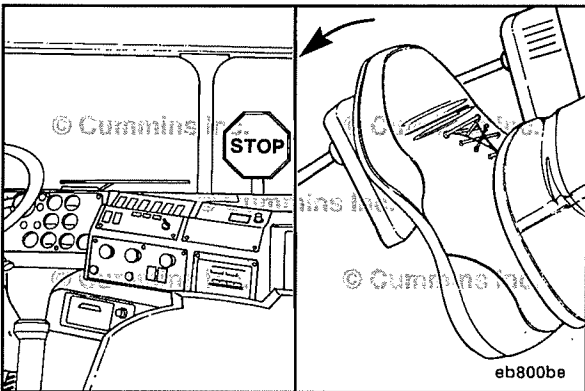
To activate the engine brakes, switch the ON/OFF switch to the ON position. Once activated, the operation of the engine brakes is fully automatic.



⚠ WARNING ⚠

Do not use the engine brakes while bobtailing or pulling an empty trailer. With the engine brakes in operation, wheel lockup can occur more quickly when the service brakes are applied, especially on vehicles with single-drive axles.

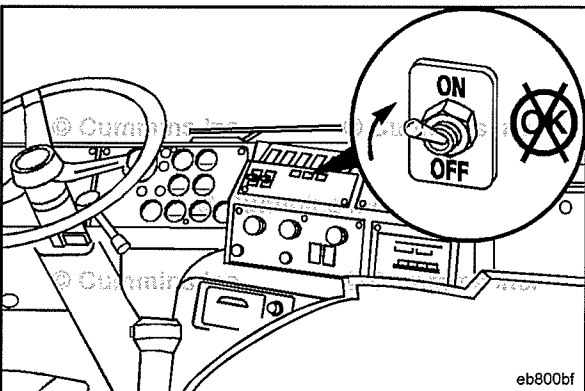
Make sure the engine brakes are switched to the OFF position when bobtailing or pulling an empty trailer.



⚠ CAUTION ⚠

The engine harness are designed to assist the vehicle's service brakes in slowing the vehicle to a stop.

Remember, service brakes will be required to bring the vehicle to a stop.



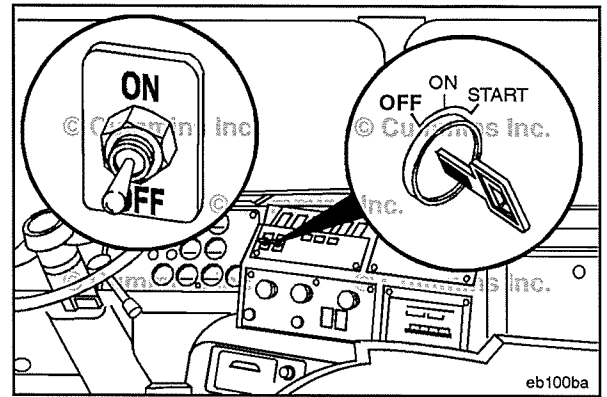
⚠ CAUTION ⚠

Do not use the engine brakes to aid clutchless gearshifting. This can cause the engine to stall or lead to engine damage.

⚠ CAUTION ⚠

Do not operate the engine if the engine brakes will not deactivate.

If the engine brakes will **not** shut off, shut off the engine immediately.



Service Tools and Hardware - Overview

General Information

Cummins Inc. produces many engines that are electronically controlled. These engines have special diagnostic requirements for the engine control module (ECM) in the system. To interface with the ECMs, electronic service tools, such as INSITE™ electronic service tool, have been developed.

INSITE™ electronic service tool interfaces with the electronic engines via a data link. A data link provides a means of transmitting and sorting electric signals, and consists of special electronic circuitry and electrical harnesses. Connection points from electronic service tools are also part of the data link. An OEM data link, if available, is provided by the OEM and consists of circuitry located in the OEM harness. An engine data link consists of circuitry located in the engine harness. Both engine and OEM data links alike are defined by standards written by the Society of Automotive Engineers (SAE). Cummins Inc. uses two such standards for electronic service tools. One is a combination of SAE J1587 and SAE J1708 and the other is SAE J1939. The J1939 data link is described in more detail in Procedure 019-165 in the appropriate engine service manual. The J1587/J1708 data link is described in more detail in Procedure 019-166 in the appropriate service manual, and is hereafter referred to as J1708 in this document. Engine data links (both J1939 and J1708) are discussed in more detail in Procedure 019-428 in the appropriate engine service manual.

INSITE™ Electronic Service Tool Description

General Information

INSITE™ electronic service tool is a Windows® based software application that works with Cummins® ECMs to diagnose and troubleshoot engine problems, store and analyze historical information about an engine, and to modify an engine's operating values. INSITE™ electronic service tool Professional also enables you to transfer calibrations to an ECM.

INSITE™ electronic service tool is used on an IBM® compatible personal computer (PC) that is attached to an ECM through an INLINE™, INLINE™ I, INLINE™ II₁, INLINE™ 4, INLINE™ 5, or INLINE™ 6 data link adapter kit.

NOTE: 1. The INLINE™ II adapter has become obsolete. It can be used with INSITE™, but technical support for this adapter is **not** available.

After registering a copy of INSITE™ electronic service tool and connecting to an ECM data source, INSITE™ electronic service tool enables you to retrieve present or recorded data about an engine, alter ECM settings, store data for viewing at a later time, analyze data to monitor and assess the operation of an engine, and view active or inactive engine fault codes.

INSITE™ electronic service tool is installed in the INTELECT™ folder on the hard drive of a personal computer. INSITE™ User's Manuals are available in the INTELECT™ and Manuals folder for specific Cummins® electronic engines. Additional information for service and support from a Cummins® distributor for INSITE™ electronic service tool questions is included in the front of the User's Manuals.

Different versions of INSITE™ electronic service tool may be available for use at one time, although some INSITE™ electronic service tool versions may **not** be compatible with some ECMs. ECM and INSITE™ electronic service tool compatibility information is available at the INSITE™ Product website. INSITE™ electronic service tool improvements are sometimes released as Feature Packs. The latest Feature Pack information for specific INSITE™ electronic service tool versions is also available at the INSITE™ Electronic Service Tool product website. It is important to maintain the INSITE™ electronic service tool with the latest versions and Feature Packs that become available.

INSITE™ electronic service tool can utilize either a communication port (COM port) or a Universal Serial Bus (USB) on the PC when communicating with an ECM. A COM port **must** be configured properly for INSITE™ electronic service tool to function correctly. It is possible for other software programs on the PC to take control of a COM port and prevent INSITE™ electronic service tool from accessing the COM port. Troubleshooting information for INSITE™ electronic service tool communication issues is available in the Base INSITE™ USER's Manual and also in the ECM No Communication Troubleshooting Tree on QuickServe™ Online or Intercept.

Initial Check

INSITE™

- In the main INSITE™ electronic service tool window, verify that the data link selected in the ECM Data Source Connection drop-down matches the data link hardware being used
- Verify that the correct INSITE™ version is installed. The INSITE™ version can be determined from the main INSITE™ electronic service tool window by selecting Help, About INSITE
- Verify that the infrared port is disabled so the serial port is **only** being used for ECM communications

- If you have the Palm Pilot Hot Sync Manager on a PC that **only** has one serial port, you **must** disable the Hot Sync Manager before connecting to an ECM.

Datalink Adapters

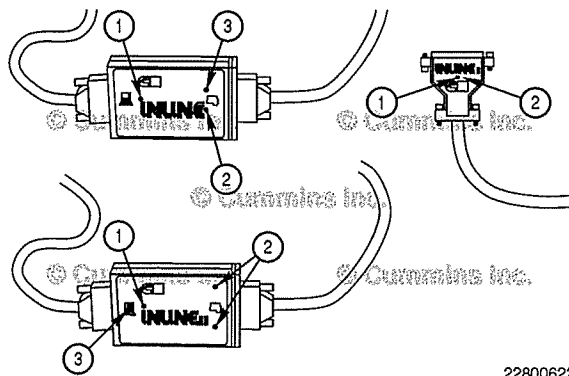
- Check the firmware version of the INLINE™ II₁, INLINE™ 4, INLINE™ 5, or INLINE™ 6 data link adapter to make sure it is the latest firmware version available
- Verify that the data link adapter being used is compatible with the data link wiring available on the engine or vehicle.

General Information

A data link adapter is a device that converts the J1708, or J1939 data link messages from the ECM into a message that a PC can process. Because INSITE™ electronic service tool is a PC based tool, a data link adapter is required to troubleshoot engines.

Cummins® Service Products offer the following data link adapter kits:

- INLINE™ adapter kit, Part Number 3163099
- INLINE™ I adapter kit, Part Number 3163583
- INLINE™ 6 adapter kit, Part Number 2892092.



Data Link Adapter Identification Diagram - INLINE™, INLINE™ I, AND INLINE™ II (see note 1).

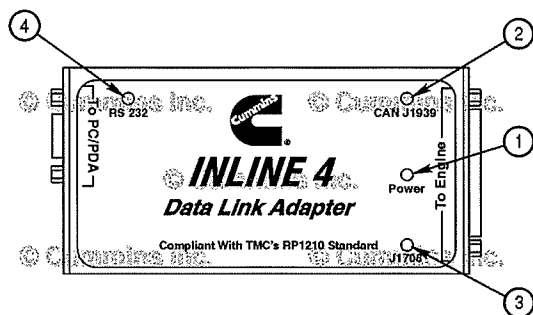
- 1 Power light
- 2 Communication light
- 3 To PC light.

Power for the INLINE™ I data link adapter is provided by the personal computer via the serial cable being used in the communication setup. In Windows XP™, Windows Vista™, and Windows™ 7, the power light will **only** be illuminated while INSITE™ electronic service tool has the COM port initialized and will **not** remain illuminated after exiting INSITE™ electronic service tool.

Power for the INLINE™, INLINE™ II₁, INLINE™ 4, INLINE™ 5, and INLINE™ 6 data link adapters depends upon the communication setup in use. The 12 VDC power is supplied by the vehicle power system for the vehicle and engine communication setups. The 12 VDC power is supplied by an auxiliary power supply for the bench communication setup.

The INLINE™ and INLINE™ I data link adapters will **only** support J1708 data link protocols. The INLINE™ II₁, INLINE™ 4, INLINE™ 5, or INLINE™ 6 data link adapter will support either J1708 or J1939 protocol. When connecting with INSITE™ electronic service tool using an INLINE™ II₁, INLINE™ 4, INLINE™ 5, and INLINE™ 6, INSITE™ electronic service tool will attempt to establish communication with an ECM on J1939 first. If no communication is established on J1939, INSITE™ electronic service tool will then attempt to establish communication on J1708.

NOTE: 1. The INLINE™ II adapter has become obsolete. It can be used with INSITE™, but technical support for this adapter is **not** available.

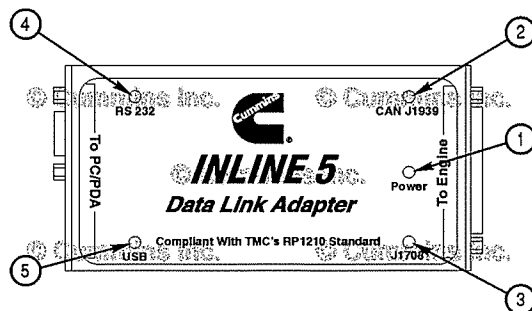


22800616

Data link Adapter Identification Diagram - INLINE™ 4.

- 1 Power light
- 2 J1939 communication light
- 3 J1708 communication light
- 4 RS-232 to PC light.

The INLINE™ 4 is an RP1210A compliant data link adapter that will support both J1708, and J1939 protocol. RP1210A is an industry wide standard that defines data link message format for service tools. The INLINE™ 4 **must** be configured correctly within INSITE™ electronic service tool to define the COM port being used on the PC and the type of data link protocol that is available, J1708, J1939, or autodetect.



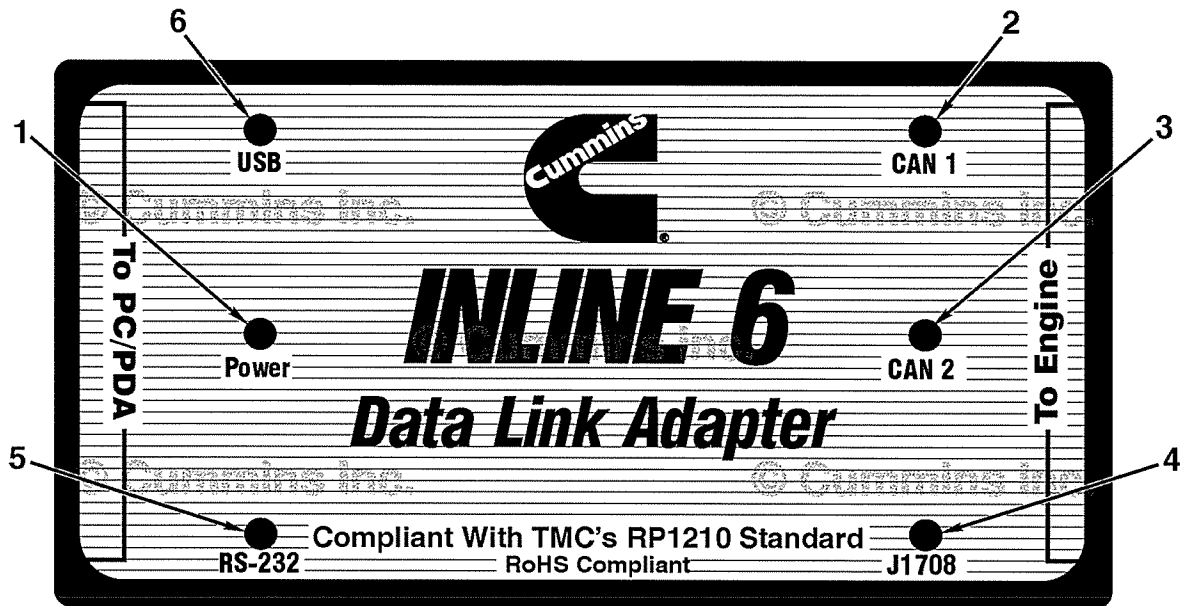
22800617

Datalink Adapter Identification Diagram - INLINE™ 5.

- 1 Power light
- 2 J1939 communication light
- 3 J1708 communication light
- 4 RS-232 to PC light
- 5 USB to PC light.

The INLINE™ 5 is an RP1210A compliant data link adapter that will support both J1708, and J1939 protocol. It can be used with either a COM port or USB port. The INLINE™ 5 **must** be configured correctly within INSITE™ electronic service tool to define the COM or USB port being used on the PC and the type of data link protocol that is available, J1708, or J193, or autodetect.

NOTE: 1. The INLINE™ II adapter has become obsolete. It can be used with INSITE™ electronic service tool, but technical support for this adapter is **not** available.



22r00008

Data Link Adapter Identification Diagram - INLINE™ 6

- 1 Power light
- 2 CAN 1 communication light (J1939)
- 3 CAN 2 communication light (J1939)
- 4 J1708 communication
- 5 RS-232 to PC light
- 6 USB to PC light.

The INLINE™ 6 is an RP1210A compliant data link adapter that will support both J1708 and J1939 protocols. It can be used with either a COM port or USB port. The INLINE™ 6 **must** be configured correctly within INSITE™ electronic service tool to define the COM or USB port being used on the PC and the type of data link protocol that is available, J1708, J1939, or autodetect.

The INLINE™ II₁, INLINE™ 4, INLINE™ 5, and INLINE™ 6 data link adapters require firmware software in order to operate correctly. Firmware versions are updated periodically and **must** be uploaded into data link adapters when updates are released. The latest firmware version is always available on the most recent INCAL™ DVD-ROM as well as from the website <http://inline.cummins.com>. The firmware version for a data link adapter is displayed at the lower right corner on the main INSITE™ electronic service tool window when connected to an ECM. INSITE™ electronic service tool **must** be connected to an ECM in order for the firmware version to be displayed.

Setup

General Information

Communication with the ECM can be established at three basic locations:

- Bench communication setup
- Vehicle communication setup
- Engine communication setup.

The communication setups are described in more detail in the remainder of this procedure. Each location utilizes different data link adapter cables. All three locations require either a serial cable or USB cable (INLINE™ 5 **only**) to interface from the data link adapter to the PC.

The ECM on newer engines can support data link communication on the OEM data link through the OEM connector at the ECM. It can also support data link communication on the engine data link through the engine connector at the ECM. The wiring diagram for a specific engine and ECM **must** be consulted to determine if an ECM supports both OEM data link and engine data link communication.

For Midrange and Heavy Duty engines, the recommended communication setup, if available, is the Cummins Inc. bench communication setup which establishes communication directly to the ECM. The bench communication setup can support both J1708 and J1939 data link protocols, when used with ECMs that support both protocols.

For High Horsepower engines with multiple ECMs, the recommended communication setup is the engine communication setup through the 9-pin connector provided in the engine harness.

J1939 data link communication, if available, is preferred for transferring calibrations because of less interference from other data link devices such as traction control systems and electronic dashes. J1708 communication can require extra time to disable the OEM ECMs that are also communicating on the J1708 data link in order to avoid interference from those devices. Also, the J1939 information transfer rate is faster than J1708 and a calibration download will take less time to complete using J1939 communication compared to J1708 communication.

The functionality of a communication setup can be verified by testing the communication setup on a second ECM or vehicle, if available, or by completing the resistance checks defined for each setup type.

The following table summarizes the ECM communication setups.

Communication Setup	Data link Connection Location	Engine ECM Data link Source	Data link Protocols Supported
Bench	ECM connector	OEM	J1708, J1939
Vehicle 6 pin	Dash 6 pin connector	OEM	J1708
Vehicle 9 pin	Dash 9 pin connector	OEM	J1708, J1939 ¹
Engine	Engine harness 3 pin connector	Engine	J1939
Engine	Engine harness 6 pin connector	Engine	J1708 ²
Engine	Engine harness 9 pin connector	Engine	J1939 ³

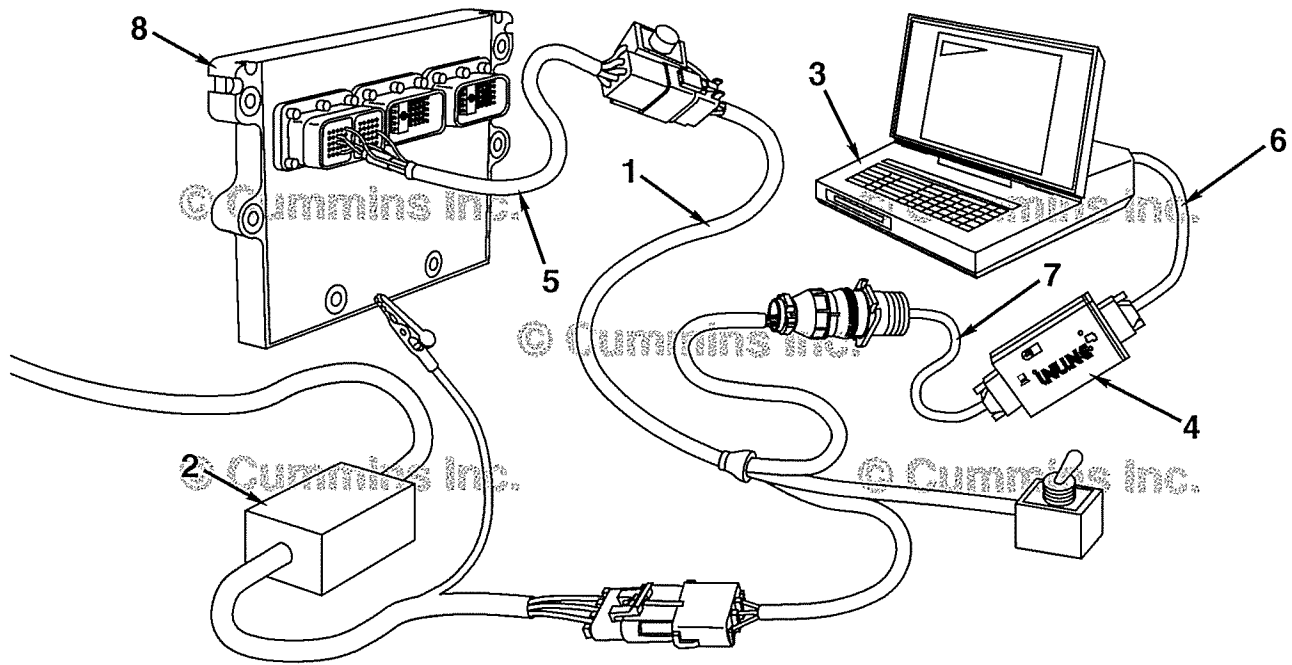
Notes:

- 1 The 9 pin connector **must** be fully wired to support J1939 protocol.
- 2 Available **only** on selected older engines.
- 3 Available **only** on selected High Horsepower engines.

Bench Communication Setup

The bench communication setup establishes communication directly with the ECM through the connector port on the ECM. An example of a bench communication setup is shown below.

The bench calibration harness (1) is common for most bench setups and can be used with the appropriate bench calibration cable (5) to communicate with various ECM's. A list of available bench calibration cables (5) for various ECM's is included in Bulletin 3377791, which is accessible on QuickServe™ Online. Proper function of the bench calibration harness (1) and bench calibration cable (5) can be verified by using the wiring diagrams provided to complete resistance checks.



22800563

Bench Communication Setup

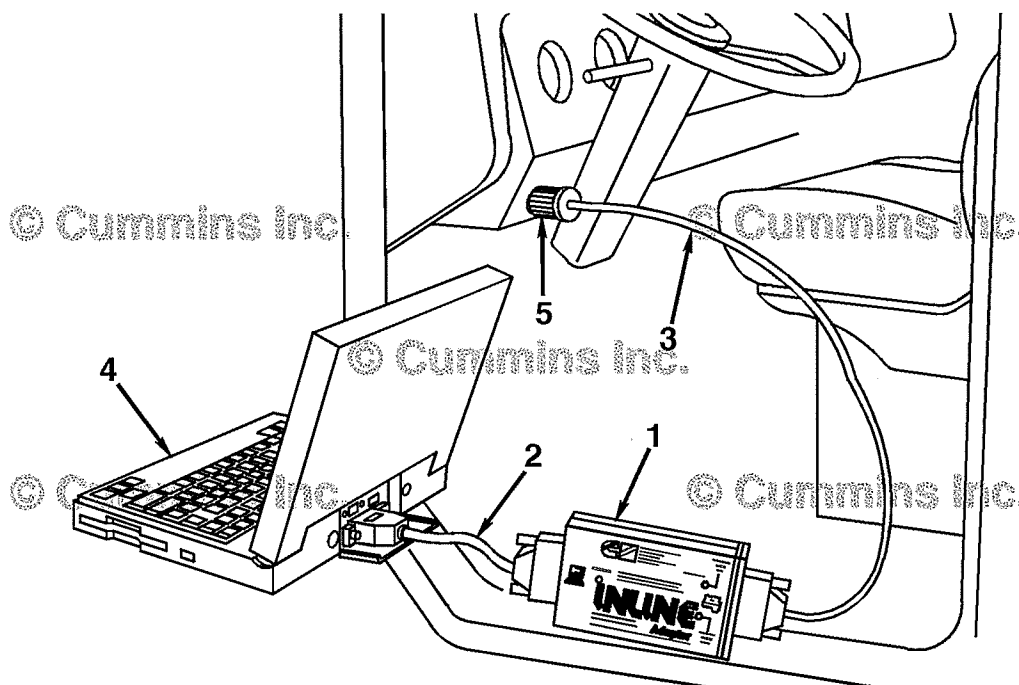
- 1 Bench calibration harness, Part Number 3163151
- 2 Power supply₁
- 3 PC with INSITE™ electronic service tool
- 4 Data link adapter
- 5 CM570 bench calibration cable, Part Number 3164789
- 6 PC Serial cable₂, Part Number 4918418.
- 7 Data link adapter cable, Part Number 3165159
- 8 CM570 ECM (example).

NOTE: 1. See Bulletin 3377791 for part number.

NOTE: 2. USB cable, Part Number 4918591, can be used with the INLINE™ 4, INLINE™ 5, and INLINE™ 6.

Vehicle Communication Setup

An additional communication setup is a 9 pin or 6 pin Deutsch™ connection that is commonly located in the cab of a vehicle. The vehicle communication setup utilizes the OEM harness and connects to the ECM at the OEM connector port. A 9 pin connector in the cab, if fully wired, is capable of supporting both J1939, and J1708 protocol. Some OEMs place a 9 pin connector in the cab but do **not** provide wiring to support J1939 protocol. A 6 pin connector will **only** support J1708 protocol.



On Vehicle Communication Setup

22800562

- 1 Data link adapter
- 2 PC serial cable₂, Part Number 4918418.
- 3 Data link adapter cable₁
- 4 PC with INSITE™ electronic service tool
- 5 Vehicle data link adapter connector₁.

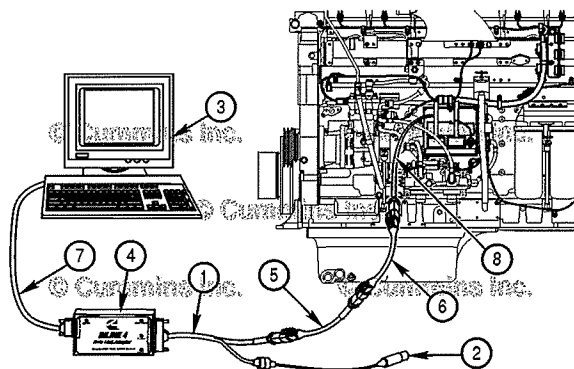
NOTE: 1. See Bulletin 3377791 for part number.

NOTE: 2. USB cable, Part Number 4918591, can be used with the INLINE™ 4, INLINE™ 5, and INLINE™ 6.

Engine Communication Setup

The engine communication setup utilizes the engine data link provided on the engine wiring harness. Depending upon the engine, the engine communication setup available on the engine harness can be a 3-pin Deutsch™ connector, a 6-pin Deutsch™ connector, or a 9-pin Deutsch™ connector.

A 3-pin Deutsch™ connector on the engine harness is available on newer engines and provides a connection point to the J1939 data link. A mini-backbone cable, which includes a 60 ohm resistor and a gender changer cable, may be required in order to connect to the ECM on the J1939 protocol. An auxiliary power supply is required for the data link adapter.



22800620

3-Pin Deutsch™ Connector

- 1 Data link cable₁
- 2 Power supply cable₁

- 3 PC with INSITE™ electronic service tool
- 4 Data link adapter
- 5 Gender changer cable, Part Number 3163597
- 6 Mini-backbone cable, Part Number 3163096
- 7 PC Serial cable₂, Part Number 4918418
- 8 Engine harness 3-pin connector, Part Number 3165141.

NOTE: 1. See Bulletin 3377791 for part number.

NOTE: 2. USB cable, Part Number 4918591, can be used with the INLINE™ 4, INLINE™ 5, and INLINE™ 6.

A 6-pin Deutsch™ connector is available on the engine harness for some older engines and provides a connection point to the engine J1939 data link. The 6-pin connector includes a power supply for the data link adapter.

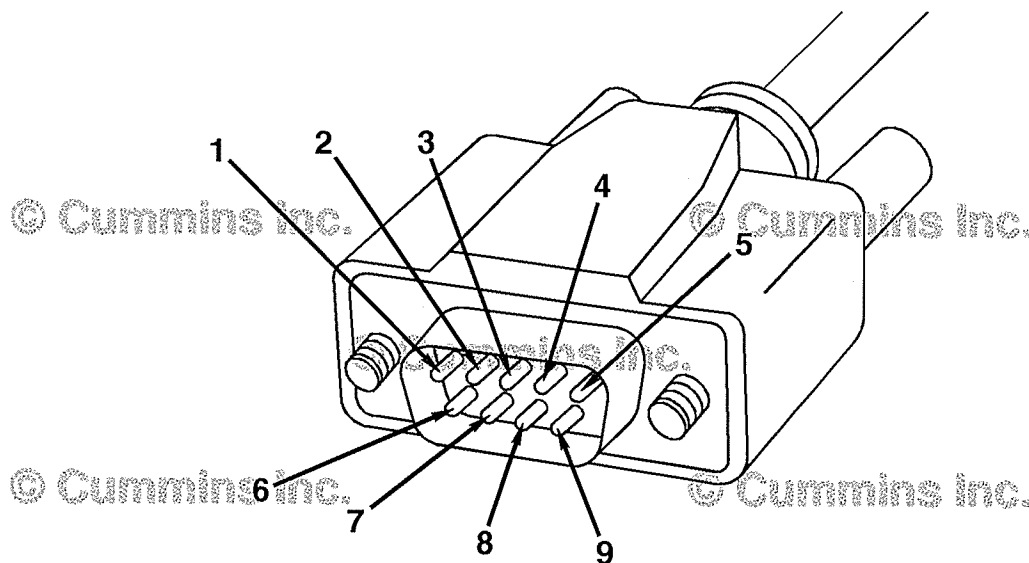
Resistance Check

General Information

A serial cable is required to interface from the data link adapter to the PC, or a USB cable can be used with an INLINE™ 5/6 data link adapter.

⚠ CAUTION ⚠

Use test lead, Part Number 3822758, and test lead, Part Number 3822917, to avoid the possibility of damage to the serial cable pins.



Serial Cable, Part Number 4918418

22800565

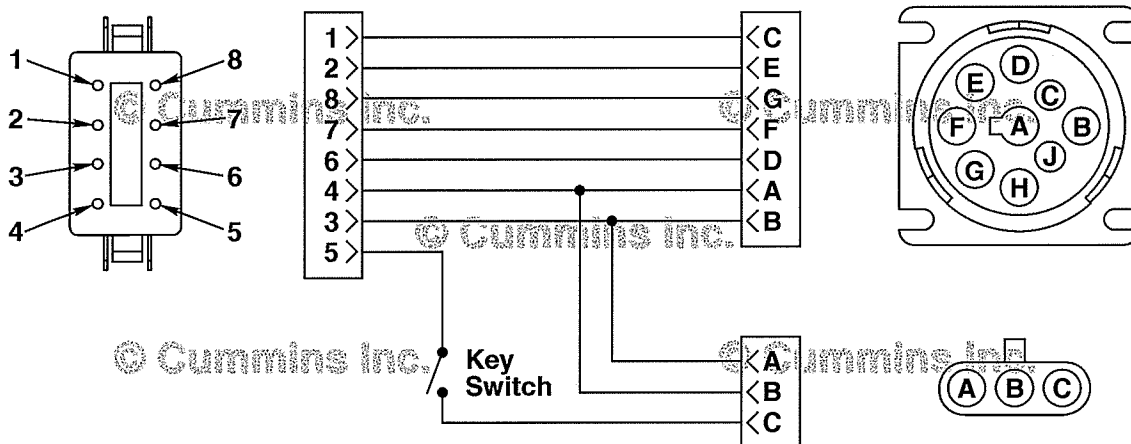
- 1 Open
- 2 Transmit data
- 3 Receive data
- 4 Data terminal ready (+5 VDC)
- 5 Signal ground
- 6 Open
- 7 Request to send (+5 VDC)
- 8 Clear to send
- 9 Open.

Insert a test lead into pin 1 of the female end of the serial cable, and connect it to the multimeter probe. Attach the other test lead to pin 1 of the male end of the serial cable, and connect it to the multimeter probe.

Measure the resistance. The multimeter **must** show a closed circuit (10 ohms or less). Repeat the resistance measurement for pins 2 through 9. The multimeter **must** show a closed circuit (10 ohms or less) for each pin. If the circuit is **not** closed, replace the serial cable.

⚠ CAUTION ⚠

To avoid the possibility of damage to connector pins, use test lead, Part Number 3823993, on the 8-pin connector. Use test lead, Part Number 3823994, on the round 9-pin connector. Use test lead, Part Number 3824812, on the 3-pin connector.



22800618

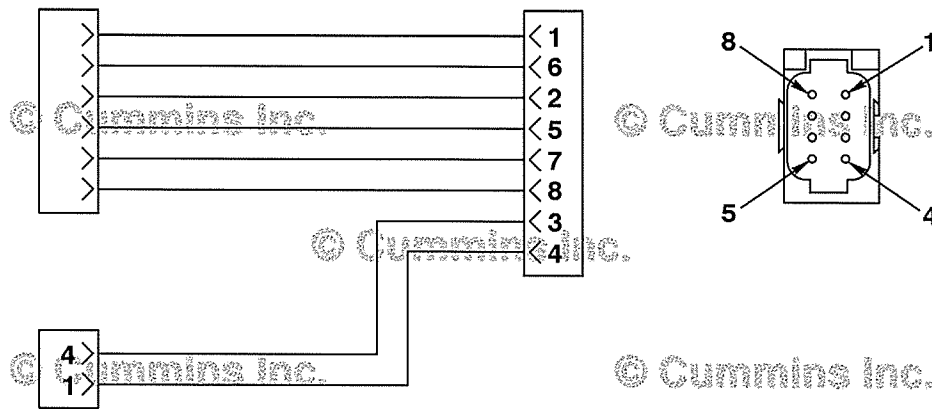
Bench Calibration Harness, Part Number 3163151

- 1 J1939 data link (+)
- 2 J1939 data link shield
- 3 Battery (+)
- 4 Battery (-)
- 5 Keyswitch
- 6 J1939 data link (-)
- 7 J1708 data link (+)
- 8 J1708 data link (-)

Measure the resistance from each pin in the 8-pin connector to be corresponding location in the 9-pin and/or 3 pin connector. The multimeter **must** show a closed circuit (10 ohms or less). If a circuit is **not** closed, replace the bench calibration harness.

⚠ CAUTION ⚠

To avoid the possibility of damage to connector pins, use test lead, Part Number 382994, on the 8 pin connector. Determine the appropriate test lead needed for the ECM connector on the bench calibration cable.



22800619

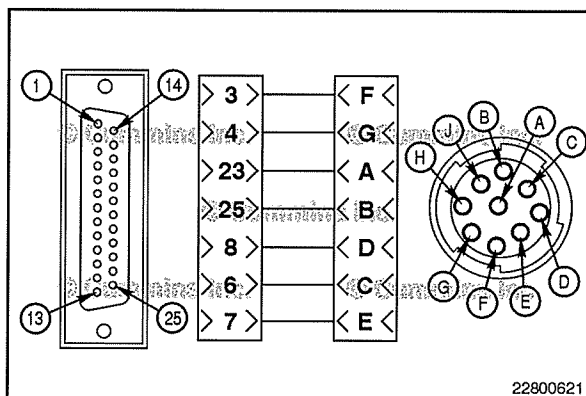
Bench Calibration Cable

- 1 J1939 data link (+)
- 2 J1939 data link shield
- 3 Battery (+)
- 4 Battery (-)
- 5 Keyswitch
- 6 J1939 data link (-)
- 7 J1708 data link (+)
- 8 J1708 data link (-).
- 9 ECM Connector (See wiring diagram for ECM connector pin identification).

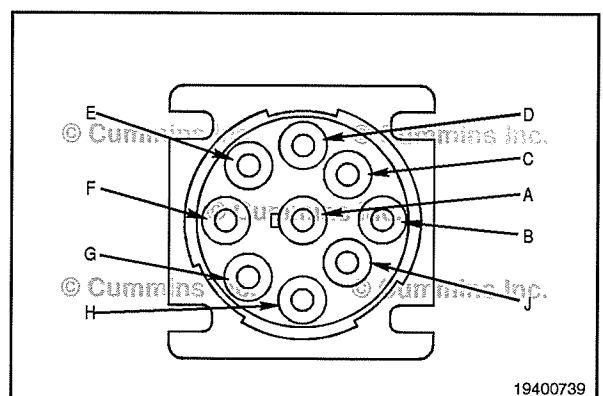
Measure the resistance from each pin in the 8 pin connector to the corresponding location in the ECM connector. See wiring diagram for the ECM for connector pin identification. The multimeter **must** show a closed circuit (10 ohms or less). If a circuit is **not** closed, replace the bench calibration cable.

⚠ CAUTION ⚠

To avoid the possibility of damage to connector pins, use male test lead, Part Number 3823993, on the 9-pin Deutsch™ connector. Use male test lead, Part Number 3822758, on the 25-pin connector.



9-Pin Data link Cable, Part Number 3165159



9-Pin In-Cab Data link Connector

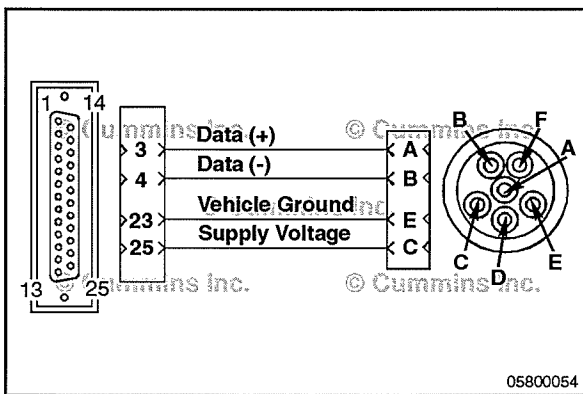
- A. Ground

- B. Battery (+)
- C. J1939 data link (+)
- D. J1939 data link (-)
- E. J1939 data link shield
- F. J1708 data link (+)
- G. J1708 data link (-)
- H. Open
- J. Open

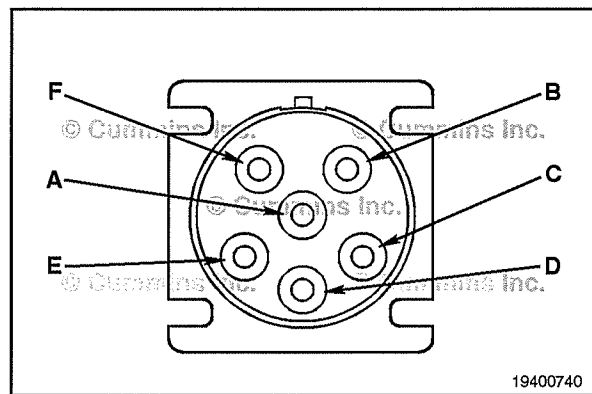
Measure the resistance from pins A, B, C, D, E, F, and G in the 9-pin connector to the corresponding location in the 25-pin connector as shown. The multimeter **must** show a closed circuit (10 ohms or less). If a circuit is **not** closed, replace the data link cable.

⚠ CAUTION ⚠

To avoid the possibility of damage to connector pins, use male test lead, Part Number 3824811, on the 6-pin Deutsch™ connector. Use male test lead, Part Number 3822758, on the 25-pin connector.



6-Pin Data link Cable, Part Number 3165160



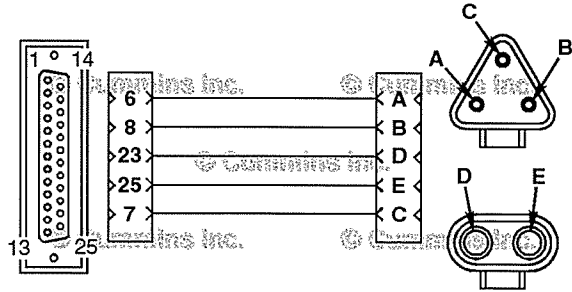
6-Pin In-Cab Data link Connector

- A J1708 data link (+)
- B J1708 data link (-)
- C Battery (+)
- D Open
- E Ground
- F Open.

Measure the resistance from pins A, B, C, and E in the 6-pin connector to the corresponding location in the 25-pin connector as shown. The multimeter **must** show a closed circuit (10 ohms or less). If a circuit is **not** closed, replace the data link cable.

⚠ CAUTION ⚠

To avoid the possibility of damage to the connector pins, use male test lead, Part Number 3822758, on the 25-pin connector. Use female test lead, Part Number 3823994, on the 3-pin connector. Use male test lead, Part Number 3822995, on the 2-pin power connector.



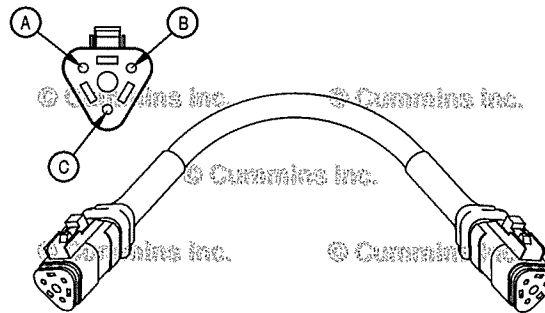
22800568

3-Pin Data link Cable, Part Number 3165141

Measure the resistance from pins A, B, and C in the 3-pin connector to the corresponding location in the 25-pin connector as shown. Measure the resistance from pins D and E in the 2-pin power supply connector to the corresponding location in the 5-pin connector as shown. The multimeter **must** show a closed circuit (10 ohms or less). If a circuit is **not** closed, replace the data link cable.

⚠CAUTION⚠

To avoid the possibility of damage to connector pins, use two male test leads, Part Number 3823993, on each 3-pin connector.



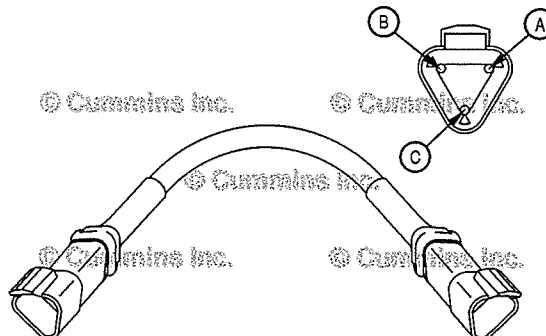
19803849

Mini Backbone Cable, Part Number 3163096

Measure the resistance from pin A in one end of the backbone cable to pin A in the opposite end of the backbone cable. Repeat for pins B and C. The multimeter **must** show a closed circuit (10 ohms or less). If a circuit is **not** closed, replace the backbone cable. Measure the resistance across pins A and B at either end of the cable to measure the terminating resistance. The terminating resistance value **must** measure between 50-70 ohms.

⚠CAUTION⚠

To avoid the possibility of damage to connector pins, use two female test leads, Part Number 3823994, on each 3-pin connector.



19901672

Gender Changer Cable, Part Number 3163597

Measure the resistance from pin A in one end of the gender changer cable to pin A in the opposite end of the gender changer cable. Repeat for pins B and C. The multimeter **must** show a closed circuit (10 ohms or less). If a circuit is **not** closed, replace the gender changer cable.

Section TS - Troubleshooting Symptoms

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Troubleshooting Procedures and Techniques

General Information

A thorough analysis of the customer's complaint is the key to successful troubleshooting. The more information known about a complaint, the faster and easier the problem can be solved.

The Troubleshooting Symptom Charts are organized so that a problem can be located and corrected by doing the easiest and most logical things first. Complete all steps in the sequence shown from top to bottom.

It is **not** possible to include all the solutions to problems that can occur; however, these charts are designed to stimulate a thought process that will lead to the cause and correction of the problem.

Follow these basic troubleshooting steps:

- Get all the facts concerning the complaint
- Analyze the problem thoroughly
- Relate the symptoms to the basic engine systems and components
- Consider any recent maintenance or repair action that can relate to the complaint
- Double-check before beginning any disassembly
- Solve the problem by using the symptom charts and doing the easiest things first
- Determine the cause of the problem and make a thorough repair
- After repairs have been made, operate the engine to make sure the cause of the complaint has been corrected

Troubleshooting Symptoms Charts

General Information

Use the charts on the following pages of this section to aid in diagnosing specific symptoms. Read each row of blocks from top to bottom. Follow through the chart to identify the corrective action.



Troubleshooting presents the risk of equipment damage, personal injury or death. Troubleshooting must be performed by trained, experienced technicians.

Troubleshooting Overview

Engine Noise Diagnostic Procedures - General Information

NOTE: When diagnosing engine noise problems, make sure that noises caused by accessories, such as the air compressor and power take-off, are **not** mistaken for engine noises. Remove the accessory drive belts to eliminate noise caused by these units. Noise will also travel to other metal parts **not** related to the problem. The use of a stethoscope can help locate an engine noise.

Engine noises heard at the crankshaft speed, engine rpm, are noises related to the crankshaft, rods, pistons, and piston pins. Noises heard at the camshaft speed, one-half of the engine rpm, are related to the valve train. A handheld digital tachometer can help determine if the noise is related to components operating at the crankshaft or camshaft speed.

Engine noise can sometimes be isolated by performing a cylinder cutout test. Refer to Procedure 014-008 in Section 14. If the volume of the noise decreases or the noise disappears, it is related to that particular engine cylinder.

There is **not** a definite rule or test that will positively determine the source of a noise complaint.

Engine-driven components and accessories, such as gear-driven fan clutches, hydraulic pumps, belt-driven alternators, air-conditioning compressors, and turbochargers, can contribute to engine noise. Use the following information as a guide to diagnosing engine noise.

Main Bearing Noise

(See Engine Noise Excessive - Main Bearing symptom tree)

The noise caused by a loose main bearing is a loud, dull knock heard when the engine is pulling a load. If all main bearings are loose, a loud clatter will be heard. The knock is heard regularly every other revolution. The noise is the loudest when the engine is lugging or under heavy load. The knock is duller than a connecting rod noise. Low oil pressure can also accompany this condition.

If the bearing is **not** loose enough to produce a knock by itself, the bearing can knock if the oil is too thin or if there is no oil on the bearing.

An irregular noise can indicate worn crankshaft thrust bearings.

An intermittent, sharp knock indicates excessive crankshaft end clearance. Repeated clutch disengagements can cause a change in the noise.

Connecting Rod Bearing Noise

(See Engine Noise Excessive - Connecting Rod symptom tree)

Connecting rods with excessive clearance will knock at all engine speeds under both idle and load conditions. When the bearings begin to become loose, the noise can be confused with piston slap or loose piston pins. The noise increases in volume with engine speed. Low oil pressure can also accompany this condition.

Piston Noise

(See Engine Noise Excessive - Piston symptom tree)

It is difficult to tell the difference between piston pin, connecting rod, and piston noise. A loose piston pin causes a loud double knock that is usually heard when the engine is idling. When the injector to this cylinder is cut out, a noticeable change will be heard in the sound of the knocking noise. However, on some engines the knock becomes more noticeable when the vehicle is operated on the road at a steady speed.

Driveability - General Information

Driveability is a term that in general describes vehicle performance on the road. Driveability problems for an engine can be caused by several different factors. Some of the factors are engine-related and some are **not**.

Before troubleshooting, it is important to determine the exact complaint and whether the engine has a real driveability issue or if it simply does **not** meet driver expectations. The Driveability/Low-Power Customer Complaint Form is a valuable list of questions that **must** be used to assist the service technician in determining what type of driveability issue the vehicle is experiencing. Complete the checklist before troubleshooting the issue. The form can be found at the end of this section. If an engine is performing to factory specifications but does **not** meet the customer's expectations, explain to the customer that nothing is wrong with the vehicle and why.

The troubleshooting symptom charts have been set up to divide driveability problems into two different symptoms: Engine Power Output Low and Engine Acceleration or Response Poor.

Low power is a term that is used in the field to describe many different performance issues. However, in this manual low power is defined as the inability of the engine to produce the power necessary to move the vehicle at a speed that can be reasonably expected under the given conditions of load, grade, wind, and so on. Low power is usually caused by the lack of fuel flow that can be caused by any of the following factors:

- Lack of full travel of the accelerator pedal
- Failed boost sensor
- Excessive fuel inlet, intake, exhaust, or drainline restriction
- Loose fuel pump suction lines.

Low power is the inability of the vehicle to accelerate satisfactorily from a stop or the bottom of a grade. See the symptom tree Engine Power Output Low for the proper procedures to locate and correct a low-power issue. The chart starts off with basic items that can cause lower power.

Poor acceleration or response is described in this manual as the inability of the vehicle to accelerate satisfactorily from a stop or from the bottom of a grade. It can also be the lag in acceleration during an attempt to pass or overtake another vehicle at conditions less than rated speed and load. Poor acceleration or response is difficult to troubleshoot since it can be caused by factors such as:

- Engine or pump related factors
- Driver technique
- Improper gear shifting
- Improper engine application
- Worn clutch or clutch linkage.

Engine related poor acceleration or response can be caused by several different factors such as:

- Failed boost sensor
- Excessive drainline restriction
- Accelerator deadband.

See the symptom tree Engine Acceleration or Response Poor for the proper procedures to locate and correct a poor acceleration or response complaint. For additional information, see Troubleshooting Driveability Complaints, Bulletin 3387245.

Driveability/Low Power - Customer Complaint Form

Customer Name/Company/Driver _____ Date _____

- Describe Problem/Complaint _____
- Symptoms of the Problem/Complaint
- When cranking:
 - ___ Cranks too slowly
 - ___ Cranks OK but does **not** start easily
 - ___ Cranks OK but does **not** start
 - ___ Slow start; _____ seconds
 - ___ Starts then dies
 - ___ Idle RPM is rough when engine is cold
 - ___ Idle RPM is rough when engine is hot
- When driving
 - ___ Misses or hesitates during acceleration
 - ___ Misses or hesitates during deceleration
 - ___ Stalls (dies) during acceleration
 - ___ Stalls (dies) during deceleration
 - ___ Smokes: ___ black ___ white
 - ___ Low power

- Unusual _____ engine

- When do you notice the Problem/Complaint occurring?
- Engine conditions:
- When the coolant temperature for the engine is:
- cold normal hot all temperatures
- When the engine is RPM on the tachometer
- Weather conditions:
- cold (below 10°C [50°F]) hot (above 27°C [80°F]) humid or rainy other _____
- When driving:
- Accelerating
- Decelerating
- Climbing a grade / hill
- Down hill
- Braking
- Unloaded
- Loaded
- How did the problem occur? Suddenly _____ Gradually _____
- At what hour/mileage did the problem begin? Hours _____ Miles _____ Since New _____
- After engine repair? Yes _____ No _____
- After equipment repair? Yes _____ No _____
- After change in equipment use? Yes _____ No _____
- After change in selected programmable parameters? Yes _____ No _____
- If so, what was repaired and when? _____
- Does the vehicle also experience poor fuel economy? Yes _____ No _____

Answer questions 7 through 10 using selections (A through F) listed below. Circle the letter or letters that best describe the complaint.

A - Compared to fleet, B - compared to competition, C - compared to previous engine

D - Personal expectation, E - will **not** pull on hill, F - will **not** pull on flat terrain

- A B C D E F
- Can the vehicle obtain the expected road speed? Yes _____ No _____
- What is desired speed? rpm/mpg _____
- What is achieved speed? rpm/mpg _____
- Gross vehicle weight _____
- A B C D E F
- Has the vehicle's load changed? Yes _____ No _____
- Is the vehicle able to pull the load? Yes _____ No _____

When?

- On hilly terrain
- With a loaded trailer
- On flat terrain
- _____ Other

If no was the answer to the previous questions, fill out the Driveability/Low Power/Excessive Fuel Consumption Checklist and go to the Low Power performance tree.

A B C D E F

• Is the vehicle slow to accelerate or respond? Yes _____ No _____

When?

- From a stop? Yes _____ No _____
- After a shift? Yes _____ No _____ rpm _____
- Before a shift? Yes _____ No _____ rpm _____
- No shift? Yes _____ No _____ rpm _____
- A B C D E F
- Does the vehicle hesitate after periods of long deceleration or coasting? Yes _____ No _____ rpm _____

If yes was the answer to the previous two questions, fill out the Driveability/Low Power/ Excessive Fuel Consumption Checklist and go to the Poor Acceleration/Response performance tree.

Additional Comments:

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Driveability/Low Power/Excessive Fuel Consumption - Checklist

Vehicle/Equipment Specifications

Year, _____ Type, _____ and _____ Model: _____

Transmission (RT 14609, and so forth): _____,
 Duty Cycle: _____,
 Rear Axle Ratio, Number of Axles: _____, Application: Industrial _____, Marine _____, Genset _____, Automotive _____
 Typical Gross Vehicle Weight: _____, Engine Rating: _____
 Trailer Type and Size: _____, Height: _____, Weight: _____
 Tire Size (11R x 24.5, low profile, and so forth) _____
 Tire Type: Radial _____, Standard Tread _____, Extra Tread _____
 Fan Type: Direct Drive _____, Viscous _____, Clutch _____
 Power Steering: Yes _____ No _____ Air Conditioner: Yes _____ No _____ Air Shield: Yes _____
 No _____ Freon Compressor: Yes _____ No _____

General Information					
DO Number:		SC Number:			
Fuel Pump Code:		Fuel Pump Serial Number:			
Mileage:		Engine Serial Number:			
Date in Service:		Engine Model and Rating:			
Cruise Speed and rpm:		Rated Speed and rpm:			
Road Speed Governor:	Yes	No	Type:		
Engine Brake:	Yes	No	Type/Brand:		
Chassis and Other Related Items					
Tank Vents:	OK	Not OK	Obvious Fuel Leaks:	Yes	No
Brake Drag:	OK	Not OK	Axle Alignment:	OK	Not OK
Altitude:	Ambient Temperature:				

General Information					
Fuel Heater:	Conditions (Wind, Rain, Snow):				
Fuel Type:	Number 1D	Number 2D	Other		
Typical Terrain:	Flat	Hilly	Percent of Asphalt	Percent of Concrete	
Additional Comments:					
Use this information for VE/VMS® run.					
This Page Can Be Copied for Convenience					

Fuel Consumption - General Information

The cause of excessive fuel consumption is hard to diagnose and correct because of the potential number of factors involved. Actual fuel consumption problems can be caused by any of the following factors:

- Engine factors
- Vehicle factors and specifications
- Environmental factors
- Driver technique and operating practices
- Fuel system factors
- Low-power/driveability problems.

Before troubleshooting, it is important to determine the exact complaint. Is the complaint based on whether the problem is real or perceived, or does **not** meet driver expectations? The Fuel Consumption - Customer Complaint Form (on the next page) is a valuable list of questions that can be used to assist the service technician in determining the cause of the problem. Complete the form before troubleshooting the complaint. The following are some of the factors that **must** be considered when troubleshooting fuel consumption complaints.

- 1 **Result of a Low-Power/Driveability Problem:** An operator will change driving style to compensate for a low power/driveability problem. Some things the driver is likely to do are (a) shift to a higher engine rpm or (b) run on the droop curve in a lower gear instead of upshifting to drive at partial-throttle conditions. These changes in driving style will increase the amount of fuel used.
- 2 **Driver Technique and Operating Practices:** As a general rule, a 1-mph increase in road speed equals a 0.1 mpg increase in fuel consumption. For example, increasing road speed from 50 to 60 mph will result in a loss of fuel mileage of 1 mpg.
- 3 **Environmental and Seasonal Weather Changes:** As a general rule, there can be as much as a 1 to 1.5 mpg difference in fuel consumption depending on the season and the weather conditions.
- 4 **Excessive Idling Time:** Idling the engine can use from 0.5 to 1.5 gallons per hour depending on the engine idle speed.
- 5 **Truck Route and Terrain:** East/west routes experience almost continuous crosswinds and head winds. Less fuel can be used on north/south routes where parts of the trip are **not only** warmer, but also have less wind resistance.
- 6 **Vehicle Aerodynamics:** The largest single power requirement for a truck is the power needed to overcome air resistance. As a general rule, each 10-percent reduction in air resistance results in a 5 percent increase in mpg.
- 7 **Rolling Resistance:** Rolling resistance is the second largest consumer of power on a truck. The type of tire and tread design has a sizable effect on fuel economy and performance. Changing from a bias ply to low-profile radial tire can reduce rolling resistance by about 36 percent.
- 8 **Additional Devices Using the Same Fuel Source:** Additional devices may use the same fuel tank as the vehicle. For example, excessive use of generators or reefers can falsely indicate high fuel consumption.

Additional vehicle factors, vehicle specifications, and axle alignment can also affect fuel consumption. For additional information on troubleshooting fuel consumption complaints, see Troubleshooting Excessive Fuel Consumption, Bulletin 3387245.

A	10.0	10.6	12.0	400	425	475	650	675	775
4B	10.0	10.6	12.0	400	425	475	650	675	775
6B	10.0	10.6	12.0	400	425	475	650	675	775
6C	10.0	10.6	12.0	400	425	475	650	675	775
VVT-378	4.0	4.3	5.0	-	-	-	-	-	-
VVT-504	4.0	4.3	5.0	250	265	310	400	425	485
VVT-555	4.0	4.3	5.0	250	265	310	400	425	485
L Series	4.0	4.3	5.0	250	265	310	400	425	485
M Series	4.0	4.3	5.0	250	265	310	400	425	485
N Series	4.0	4.3	5.0	250	265	310	400	425	485
VVT/ VTA-903	4.0	4.3	5.0	250	265	310	400	425	485
KT/ KTA-19	3.0	3.2	3.75	200	210	250	320	340	390
VVT/ VTA28	2.0	2.1	2.5	-	-	-	-	-	-
KT/ KTA38	1.5	1.6	1.8	-	-	-	-	-	-
KTA50	1.1	1.2	1.3	-	-	-	-	-	-

Acceptable Oil Usage

(Transit Bus, Shuttle Bus, and School Bus)

Any Time During Coverage Period

ENGINE FAMILY	HRS PER QT	HRS PER LITER	HOURS PER IMPERIAL QUART	MILES PER QUART	MILES PER LITER	MILES PER IMPERIAL QUART	KM PER QUART	KM PER LITER	KM PER IMPERIAL QUART
B	10.0	10.6	12.0	200	210	240	320	340	385
C	8.0	8.5	10.0	150	160	180	240	255	290
L, M, N	4.0	4.3	5.0	100	105	120	160	170	195

Cummins Inc. defines "acceptable oil usage" as outlined in the following table.

Acceptable Oil Usage

Any Time During Coverage Period

ENGINE FAMILY	HRS PER QT	HRS PER LITER	HOURS PER IMPERIAL QUART	MILES PER QUART	MILES PER LITER	MILES PER IMPERIAL QUART	KM PER QUART	KM PER LITER	KM PER IMPERIAL QUART
A	10.0	10.6	12.0	400	425	475	650	675	775
4B	10.0	10.6	12.0	400	425	475	650	675	775
6B	10.0	10.6	12.0	400	425	475	650	675	775
6C	10.0	10.6	12.0	400	425	475	650	675	775
VVT-378	4.0	4.3	5.0	-	-	-	-	-	-
VVT-504	4.0	4.3	5.0	250	265	310	400	425	485
VVT-555	4.0	4.3	5.0	250	265	310	400	425	485
L Series	4.0	4.3	5.0	250	265	310	400	425	485
M Series	4.0	4.3	5.0	250	265	310	400	425	485
N Series	4.0	4.3	5.0	250	265	310	400	425	485
VVT/ VTA-903	4.0	4.3	5.0	250	265	310	400	425	485
KT/ KTA-19	3.0	3.2	3.75	200	210	250	320	340	390

V/VT/ VTA28	2.0	2.1	2.5	-	-	-	-	-	-
KT/ KTA38	1.5	1.6	1.8	-	-	-	-	-	-
KTA50	1.1	1.2	1.3	-	-	-	-	-	-

Acceptable Oil Usage

(Transit Bus, Shuttle Bus, and School Bus)

Any Time During Coverage Period

ENGINE FAMILY	HRS PER QT	HRS PER LITER	HOURS PER IMPERIAL QUART	MILES PER QUART	MILES PER LITER	MILES PER IMPERIAL QUART	KM PER QUART	KM PER LITER	KM PER IMPERIAL QUART
B	10.0	10.6	12.0	200	210	240	320	340	385
C	8.0	8.5	10.0	150	160	180	240	255	290
L, M, N	4.0	4.3	5.0	100	105	120	160	170	195



Cummins
Engine Company, Inc.
Box 3005
Columbus, IN, U.S.A.
47202-3005
15200020

Engine Lubricating Oil Consumption Report

Owner's Name	Date of Delivery	Engine Serial Number	
Month	Day	Year	
Address	Equipment Manufacturer	Engine Model and hp	
City	State/Province	Equipment Serial Number	Fuel Pump Serial Number
Engine Application (describe)	Oil and Filter Change Interval	Complaint Originally Registered	
Oil	Filters	Date	Mile/Hours/Kilometers
Lubricating Oil Added			
Date Added Oil	Engine Operation Miles/Hours/Kilometers	Quarts - Liters Oil Added	Brand and Viscosity of Oil Used
Start Test			
Last Mileage/Hours/Kilometers _____ Minus Start Mileage/Hours/Kilometers _____			
Equals Test Mileage/Hours/Kilometers _____ Divided by Oil Added _____			
Equals _____ Usage _____ Rate _____			
Customer Signature	Cummins Dealer	Cummins Distributor	
Cummins Inc. Form 4755			

Coolant Loss Pre-Troubleshooting Guide

Before troubleshooting, it is critical to know where the coolant is being lost. It is **not always** obvious where the missing coolant has gone.

Before troubleshooting, it is important to determine the exact complaint by interviewing the driver, looking at the service history and looking at the engine control module (ECM) information.

Driver Interview Questions

Drivers Name:

Engine Serial Number (ESN):

What is your complaint?

How is this engine used?

What sort of load factors?

Where is the vehicle driven?

- 1 How often do you add coolant?
- 2 How do you fill the radiator?
- 3 Do you fill to the High or Low mark when the engine is cold (less than 60°C [140°F])?
- 4 What type of coolant is added?
- 5 Any coolant on the ground under the truck?
- 6 Any green or white streaks on the engine or near the coolant overflow hose?
- 7 Is there any specific condition when indications of coolant loss (weather, altitude, or load)?
- 8 Does the engine ever overheat?
- 9 Does the warning light flash?
- 10 Under what condition?
- 11 What temperature does the coolant run at normally?
- 12 Does the cooling fan operate correctly?
- 13 Seen any white smoke at operating temperature, or has anyone told you that white smoke is coming out of the exhaust?
- 14 Has any oil analysis been performed as part of the maintenance?
- 15 Are there elevated levels of sodium or potassium?
- 16 Noticed any increase in moisture condensation on the dipstick or oil fill cap, or moisture in the blowby?
- 17 Noticed a milky appearance in the lube that might indicate coolant is present?
- 18 What other comments exists that might help Cummins® make the right repair?

Service History Review

Repeat cylinder head or cylinder gasket repairs can indicate the problem is likely **not** the cylinder head or cylinder head gasket. Repeat problems can indicate a deeper problem in the engine. Keep this information in mind while going through the troubleshooting procedure.

Look at the engine's warranty claims history:

- Who worked on the engine last and what did technician do?
- How many kilometers [miles] are on the engine?
- Has a cylinder head or cylinder head gasket been replaced before?
- At how many miles were the repairs made?

At this point, where is the coolant is going?

If **not** and the coolant loss is **not** severe, suggest mounting a catch bottle on the radiator overflow tube to catch any overflow that can possibly be blowing out and becoming lost while at speed. Send the vehicle out to collect more data about where the coolant is **not** going. If the catch bottle has some coolant in it, refer back to the Coolant Loss External (out the overflow) interview questions.

Air Compressor Air Pressure Rises Slowly

This is symptom tree t004

Cause

Correction

STEP 1

Air intake system restriction to air compressor is excessive

NOTE: Perform this check **only** if the air compressor is naturally aspirated. Replace the air compressor air cleaner, if installed. Check the air intake piping. Check the engine air intake restriction if the air compressor air inlet is plumbed to the vehicle or equipment intake system. Refer to Procedure 010-031 in Section 10.

OK

Go To Next Step

STEP 2

Air compressor assembly has malfunctioned

Check the air compressor assembly for proper operation. Perform the Air Compressor Diagnostic Test. Refer to Procedure 012-014 in Section 12.

OK

Go To Next Step

STEP 3

Air compressor cylinder head is cracked or porous, or has a leaking gasket

Inspect the air compressor air inlet and outlet tubes for signs of coolant. Refer to Procedure 012-003 in Section 12. If signs of coolant are present, inspect air compressor cylinder head. Refer to Procedure 012-007 in Section 12.

OK

Go To Next Step

STEP 4

Carbon buildup is excessive in the air discharge line or downstream air valves

NOTE: Perform this check **only** if the air compressor is naturally aspirated. Check for carbon buildup. Replace the air compressor discharge line and clean the air compressor cylinder head as necessary. Refer to Procedure 012-003 in Section 12.

OK

Go To Next Step

STEP 5

Air governor is malfunctioning or not set correctly

Check the air governor for correct operation. Refer to Procedure 012-016 in Section 12 and the original equipment manufacturer (OEM) service manual.

OK

Go To Next Step

STEP 6

Air system component is malfunctioning

Check the operation of the air system valves, air dryers, and other OEM-installed air system components. Refer to the OEM service manual.

OK

Go To Next Step

STEP 7

Air system leaks

Check for leaks from the air compressor gaskets, air system hoses, fittings, tanks, and valves. Refer to Procedure 012-019 in Section 12 and the OEM service manual. For vehicles equipped with air assisted aftertreatment components, check for leaks in the air supply lines.

Air Compressor Cycles Frequently

This is symptom tree t005

Cause

Correction

STEP 1
Air system leaks

Block the vehicle wheels and check the air system for leaks with the spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, tanks, and valves. Refer to Procedure 012-019 in Section 12 and the OEM service manual.

OK
Go To Next Step

STEP 2
Air governor is malfunctioning or **not** set correctly

Check the air governor for correct operation. Make sure the air governor is located less than 0.6 m [2 ft] from the air compressor. Refer to Procedure 012-016 in Section 12 and the OEM service manual.

OK
Go To Next Step

STEP 3
Air system component is malfunctioning

Check the operation of check valves, alcohol evaporators, air dryers, and other OEM-installed air system components. Refer to the manufacturer's instructions.

OK
Go To Next Step

STEP 4
E-type system is **not** plumbed correctly

Install an Econ valve, a check valve, and system hoses. Refer to the OEM service manual.

OK
Go To Next Step

STEP 5
Air compressor intake or exhaust valve system leaks air

Leak test the air compressor head assembly intake and exhaust valve. Refer to Procedure 012-014 in Section 12. The intake and exhaust valve on the air compressor head are **not** serviceable. Replace the air compressor cylinder head. Refer to Procedure 012-007 in Section 12.

OK
Go To Next Step

STEP 6
Air compressor pumping time is excessive

Replace the desiccant cartridge on the air dryer (if equipped). Refer to the OEM service manual. Check the air compressor duty cycle. Install a larger air compressor, if necessary. Refer to the OEM service manual.

OK
Go To Next Step

STEP 7
Air dryer outlet check valve is sticking

Lubricate or replace the air dryer outlet check valve assembly. Refer to the manufacturer's instructions.

Air Compressor Noise is Excessive

This is symptom tree t006

Cause

STEP 1

Ice buildup in the air system components

OK

Go To Next Step

STEP 2

Carbon buildup is excessive in the air discharge line or downstream air valves

OK

Go To Next Step

STEP 3

Air compressor is sending air pulses into the air tanks

OK

Go To Next Step

STEP 4

Air compressor mounting hardware is loose, worn, or broken

OK

Go To Next Step

STEP 5

Air compressor drive gear is adjusted incorrectly

OK

Go To Next Step

STEP 6

Air compressor drive gear or engine gear train is worn, damaged, or adjusted incorrectly

OK

Go To Next Step

STEP 7

Air compressor is excessively worn or internally damaged

Correction

Check for ice in low sections of the air discharge line.

Perform this check **only** if the air compressor is naturally aspirated. Check for carbon buildup. Clean or replace the air compressor discharge line, if necessary. Check the turbocharger for oil leaks. Check the air compressor intake tube for oil. Refer to Procedure 012-003 in Section 12.

Install a ping tank between the air dryer and the wet tank. Refer to the original service manufacturer (OEM) service manual.

Inspect all mounting hardware and brackets for being loose, worn, or broken. Refer to Procedure 012-014 in Section 12.

Load the air compressor and apply pressure to the hydraulic power steering pump by turning the wheel. If the noise goes away, the engine gear train is not adjusted correctly and needs to be adjusted. Refer to Procedure 001-012 in Section 1.

Inspect the air compressor drive gear and engine gear train, and repair or adjust as necessary. Refer to Procedure 012-014 in Section 12 and Procedure 001-012 in Section 1.

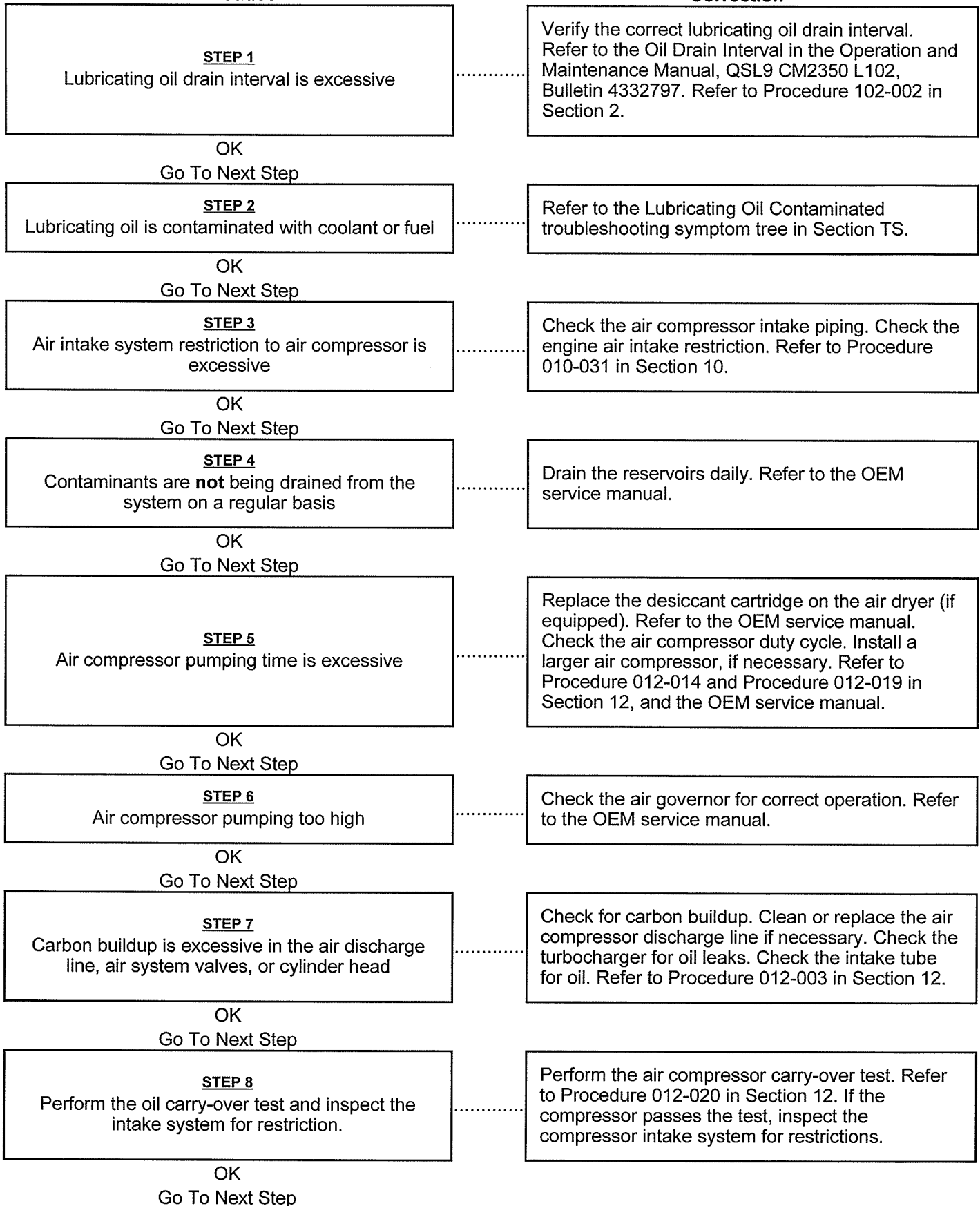
Replace the air compressor. Replace the desiccant element on the air dryer, if equipped. Refer to Procedure 012-014 in Section 12.

Air Compressor Pumping Excess Lubricating Oil into the Air System

This is symptom tree t007

Cause

Correction



Air Compressor Pumping Excess Lubricating Oil into the Air System

This is symptom tree t007

Cause

Correction

STEP 9

Engine angularity during operation exceeds specification

Refer to the Engine Specification data sheet.

OK

Go To Next Step

STEP 10

Crankcase pressure is excessive

Check for excessive blowby. Refer to the Crankcase Gases (blowby) Excessive troubleshooting symptom tree in Section TS.

OK

Go To Next Step

STEP 11

Lubricating oil pressure is above specification

Check the oil pressure. Refer to the Lubricating Oil Pressure High troubleshooting symptom tree in Section TS.

OK

Go To Next Step

STEP 12

Air compressor runs hot

If the coolant temperature is above normal, refer to the Coolant Temperature Above Normal - Gradual Overheat troubleshooting symptom tree in Section TS.

OK

Go To Next Step

STEP 13

Lubricating oil drain line is restricted

Remove the air compressor and check the oil drain holes in the air compressor and the accessory drive. Refer to Procedure 012-014 in Section 12.

OK

Go To Next Step

STEP 14

Air compressor drive gear or engine gear train is worn or damaged

Inspect the drive gears and gear train. Repair as necessary. Refer to Procedure 012-014 in Section 12.

OK

Go To Next Step

STEP 15

Air compressor is excessively worn or internally damaged

Inspect the air compressor. Refer to Procedure 012-014 in Section 12.

Air Compressor Will Not Maintain Adequate Air Pressure (Not Pumping Continuously)

This is symptom tree t008

Cause	Correction
<p>STEP 1 Air system leaks</p>	<p>Block the vehicle wheels and check the air system for leaks with the service brakes applied and released. Check for leaks from the air compressor gaskets and the air system lines, fittings, tanks, and valves. Refer to Procedure 012-019 in Section 12 and the original equipment manufacturer (OEM) service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Air governor is malfunctioning or not set correctly</p>	<p>Check the air governor for correct operation. Refer to Procedure 012-016 in Section 12 or the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Air compressor unloader and valve assembly is malfunctioning</p>	<p>Check the unloader valve operation and unloader body seal. Refer to Procedure 012-013 in Section 12. If required, clean the air compressor cylinder head. Refer to Procedure 012-003 in Section 12.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Air compressor intake or exhaust valve system leaks air</p>	<p>Leak test the air compressor head assembly intake and exhaust valve. Refer to Procedure 012-014 in Section 12. The intake and exhaust valve on the air compressor head are not serviceable, replace the air compressor cylinder head. Refer to Procedure 012-007 in Section 12.</p>

Air Compressor Will Not Pump Air

This is symptom tree t009

Cause

Correction

STEP 1

Air intake system restriction to air compressor is excessive

NOTE: Perform this check **only** if the air compressor is naturally aspirated. Replace the air compressor air cleaner, if installed. Check the air intake piping. Check the engine air intake restriction if the air compressor air inlet is plumbed to the vehicle or equipment intake system. Refer to Procedure 010-031 in Section 10.

OK

Go To Next Step

STEP 2

Air compressor assembly has malfunctioned

Inspect the air compressor air inlet and outlet tubes for signs of coolant. Refer to Procedure 012-003 in Section 12. If signs of coolant are present, inspect the air compressor cylinder. Refer to Procedure 012-007 in Section 12. Check the air compressor assembly for proper operation. Perform the Air Compressor Diagnostic Test. Refer to Procedure 012-014 in Section 12.

OK

Go To Next Step

STEP 3

Carbon buildup is excessive in the air discharge line or downstream air valves

Perform this check **only** if the air compressor is naturally aspirated. Check for carbon buildup. Clean or replace the air compressor discharge line, if necessary. Check the turbocharger for oil leaks. Check the air compressor intake tube for oil. Refer to Procedure 012-003 in Section 12.

OK

Go To Next Step

STEP 4

Air governor is malfunctioning or not set correctly

Check the air governor for correct operation. Refer to Procedure 012-016 in Section 12 and in the original equipment manufacturer (OEM) service manual.

OK

Go To Next Step

STEP 5

Air system component is malfunctioning

Check the operation of the air system valves, air dryers, and other OEM-installed air system components. Refer to the OEM service manual.

OK

Go To Next Step

STEP 6

Air system leaks

Check for leaks from the air compressor gaskets, air system hoses, fittings, tanks, and valves. Refer to Procedure 012-019 in Section 12 and the OEM service manual. For vehicles equipped with air assisted aftertreatment components, check for leaks in the air supply lines.

OK

Go To Next Step

Air Compressor Will Not Pump Air

This is symptom tree t009

Cause

Correction

STEP 7

Air compressor is excessively worn or internally damaged

Inspect the air compressor. Refer to Procedure 012-014 in Section 12.

Air Compressor Will Not Stop Pumping

This is symptom tree t010

Cause

Correction

STEP 1

Air compressor assembly has malfunctioned

Check the air compressor assembly for proper operation. Perform the Air Compressor Diagnostic Test. Refer to Procedure 012-014 in Section 12.

OK

Go To Next Step

STEP 2

Air governor is malfunctioning or not set correctly

Check the air governor for correct operation. Refer to Procedure 012-016 in Section 12 and the original equipment manufacturer (OEM) service manual.

OK

Go To Next Step

STEP 3

Air system component is malfunctioning

Check the operation of the air system valves, air dryers, and other OEM-installed air system components. Refer to the OEM service manual. Check the operation of the air shutoff valve, if applicable.

OK

Go To Next Step

STEP 4

Air system leaks

Check for leaks from the air compressor gaskets, air system hoses, fittings, tanks, and valves. Refer to Procedure 012-019 in Section 12 and the OEM service manual. For vehicles equipped with air assisted aftertreatment components, check for leaks in the air supply lines.

Alternator Not Charging or Insufficient Charging

This is symptom tree t013

Cause

Correction

STEP 1

Vehicle gauge is malfunctioning

Check the vehicle gauge. Refer to the original equipment manufacturer (OEM) service manual.

OK

Go To Next Step

STEP 2

Engine speed too low for charging

Move the throttle to raise the engine speed to 1200 rpm to excite the alternator. Refer to Procedure 101-015 in Section 1 of the Operation and Maintenance Manual, QSL9 CM2350 L102, Bulletin 4332797.

OK

Go To Next Step

STEP 3

Alternator belt is loose

Check the alternator belt tension. Refer to Procedure 013-001 in Section 13.

OK

Go To Next Step

STEP 4

Electrical system is "open" (blown fuses, broken wires, or loose connections)

Check the fuses, wires, and connections. Refer to the OEM service manual and the manufacturer's wiring diagrams.

OK

Go To Next Step

STEP 5

Battery cables or connections are loose, broken, or corroded (excessive resistance)

Check the battery cables and connections. Refer to the OEM service manual.

OK

Go To Next Step

STEP 6

Batteries have malfunctioned

Check the condition of the batteries. Replace the batteries, if necessary. Refer to the OEM service manual.

OK

Go To Next Step

STEP 7

Alternator pulley is loose on the shaft

Tighten the pulley. Refer to the OEM service manual.

OK

Go To Next Step

STEP 8

Battery temperature is above specification

Position the batteries away from heat sources. Refer to the OEM service manual.

OK

Go To Next Step

STEP 9

Alternator or voltage regulator is malfunctioning

Test the alternator output. Replace the alternator or voltage regulator, if necessary. Refer to Procedure 013-001 in Section 13 and the OEM service manual.

OK

Go To Next Step

Alternator Not Charging or Insufficient Charging

This is symptom tree t013

Cause

STEP 10

Alternator is overloaded, or alternator capacity is below specification

OK

Go To Next Step

STEP 11

Electronic fault codes active or high counts of inactive fault codes

Correction

Install an alternator with a higher capacity. Refer to Procedure 013-001 in Section 13 and the OEM service manual.

Read the fault codes with an electronic service tool. Refer to the Fault Code Troubleshooting Manual, QSL9 CM2350 L102, Bulletin 4332795, for fault code troubleshooting.

Alternator Overcharging

This is symptom tree t014

Cause

STEP 1

Battery cables or connections are loose, broken, or corroded (excessive resistance)

OK

Go To Next Step

STEP 2

Battery cell is damaged (open circuit)

OK

Go To Next Step

STEP 3

Voltage regulator is malfunctioning

OK

Go To Next Step

STEP 4

Alternator is malfunctioning

OK

Go To Next Step

STEP 5

Electronic fault codes active or high counts of inactive fault codes

Correction

Check the battery cables and connections. Refer to the original equipment manufacturer (OEM) service manual.

Check the condition of the batteries. Replace the batteries, if necessary. Refer to the OEM service manual.

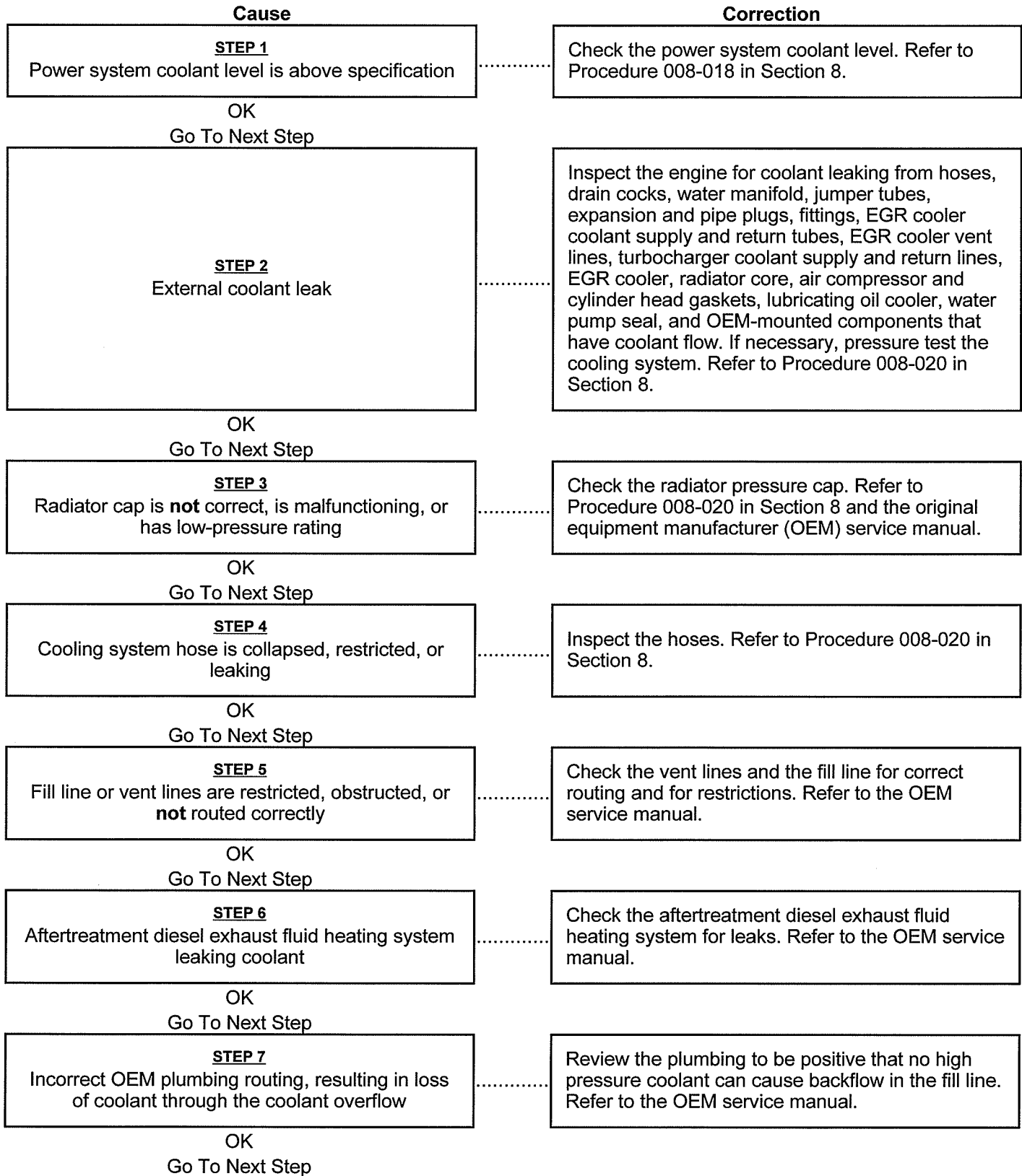
Check the voltage regulator. Replace the voltage regulator, if necessary. Refer to the OEM service manual.

Test the alternator output. Refer to Procedure 013-001 or the OEM service manual if a non-Cummins® alternator.

Read the fault codes with an electronic service tool. Refer to Section TF in the Fault Code Troubleshooting Manual, QSL9 CM2350 L102, Bulletin 4332795, for fault code troubleshooting.

Coolant Loss - External

This is symptom tree t020



Coolant Loss - External

This is symptom tree t020

Cause

STEP 8
Engine is overheating

OK
Go To Next Step

STEP 9
Air or combustion gases are entering the cooling system

Correction

Refer to the Coolant Temperature Above Normal - Gradual Overheat troubleshooting symptom tree or the Coolant Temperature is Above Normal - Sudden Overheat troubleshooting symptom tree in Section TS.

Check for air or combustion gases in the cooling system. Refer to Procedure 008-020 in Section 8.

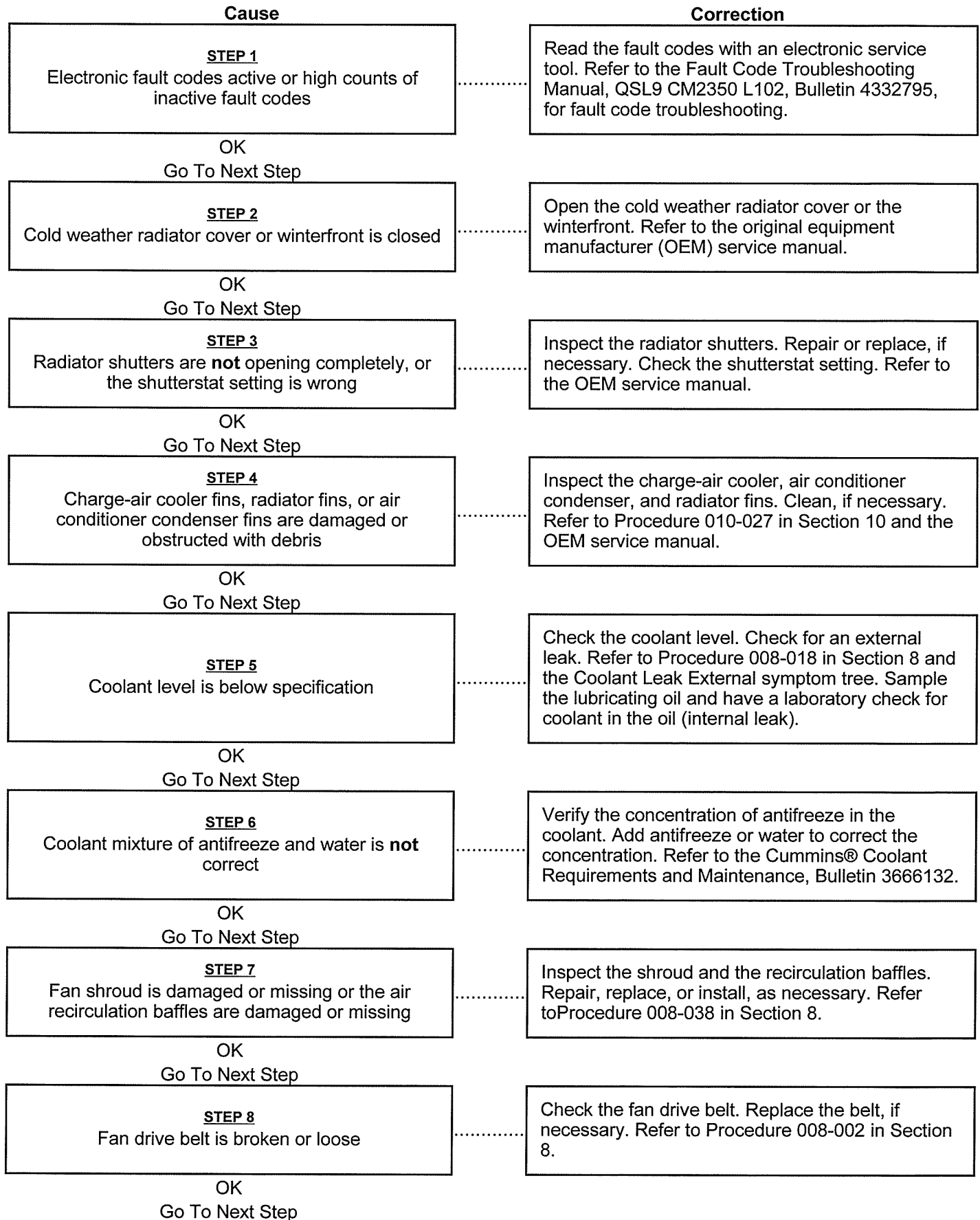
Coolant Loss - Internal

This is symptom tree t021

Cause	Correction
<p>STEP 1 Radiator cap is not correct, is malfunctioning, or has low-pressure rating</p>	<p>Check the radiator pressure cap. Refer to Procedure 008-020 in Section 8.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 EGR cooler leaking coolant</p>	<p>Check the EGR cooler for leaks. Refer to Procedure 011-019 in Section 11.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Air compressor cylinder head is cracked or porous, or has a leaking gasket</p>	<p>Inspect the air compressor air inlet and outlet tubes for signs of coolant. Refer to Procedure 012-007 in Section 12.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Lubricating oil is contaminated with coolant</p>	<p>Check the lubricating oil for coolant. Refer to the Coolant in the Lubricating Oil troubleshooting symptom tree in Section TS, if the lubricating oil is contaminated with coolant.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Internal coolant leaks</p>	<p>Pressure test the cooling system and look for internal coolant leaks. Refer to Procedure 008-020 in Section 8.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Variable Geometry Turbocharger leaking coolant</p>	<p>Perform the Crack Detection Test to determine if a cracked or porous turbocharger bearing housing exists. Refer to Procedure 010-033 in Section 10.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Cylinder head gasket is leaking</p>	<p>Check the cylinder head gasket. Remove the cylinder head gasket and inspect. Refer to Procedure 002-004 in Section 2.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Cylinder head is cracked or porous</p>	<p>Pressure test the cylinder head. Refer to Procedure 002-004 in Section 2.</p>
<p>OK Go To Next Step</p>	
<p>STEP 9 Cylinder block is cracked or porous</p>	<p>Inspect the cylinder block. Refer to Procedure 001-026 in Section 1.</p>

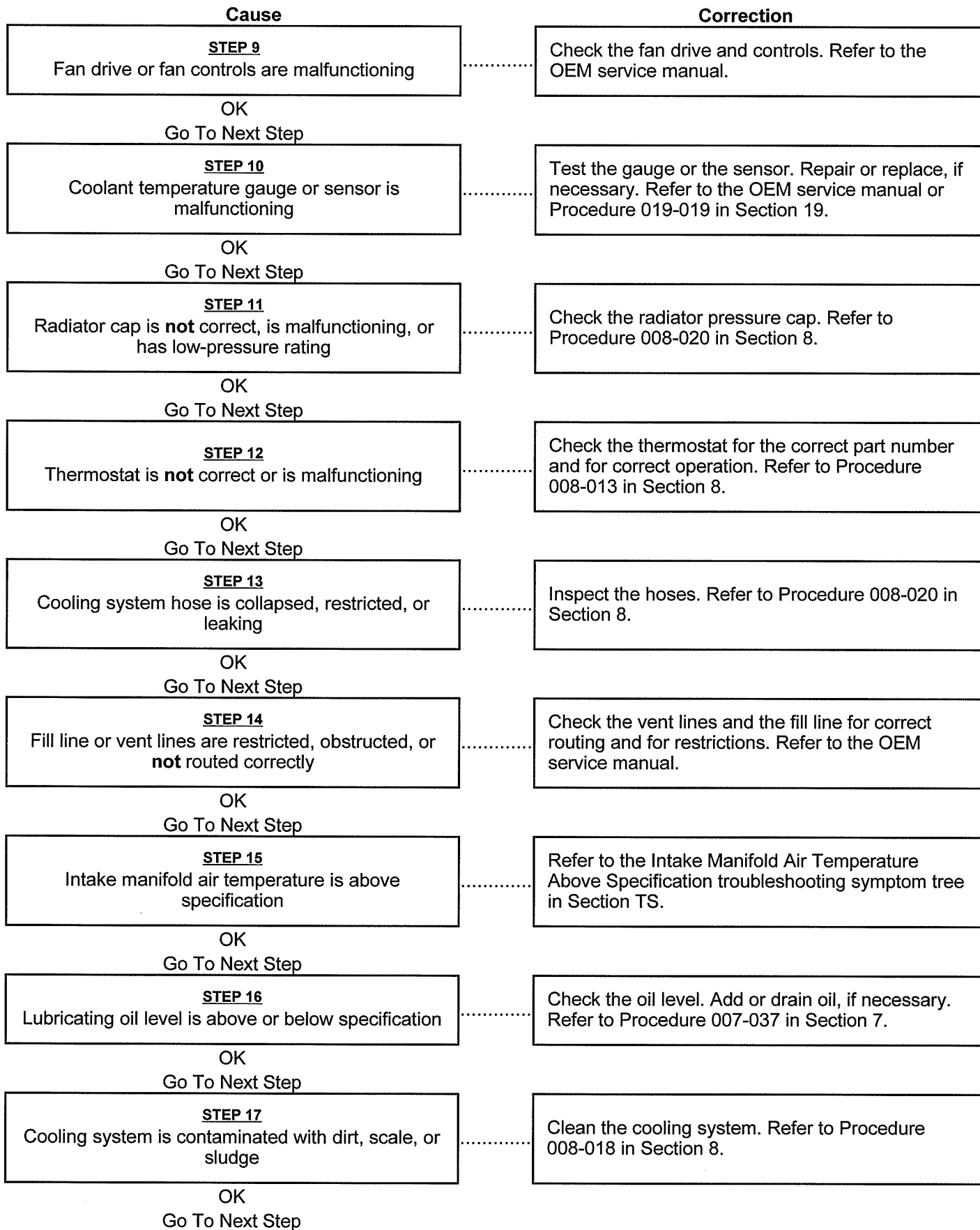
Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022



Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

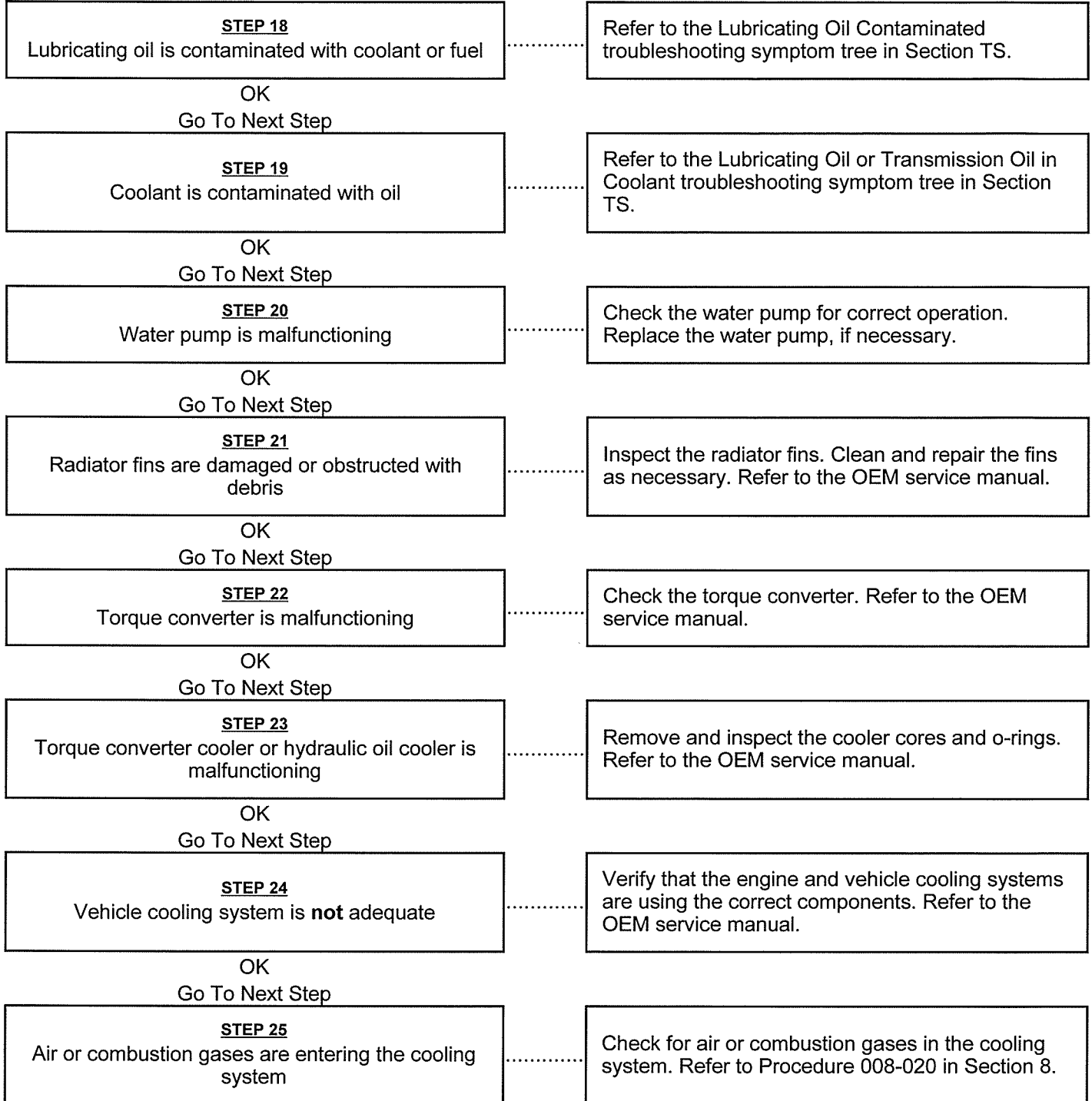


Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

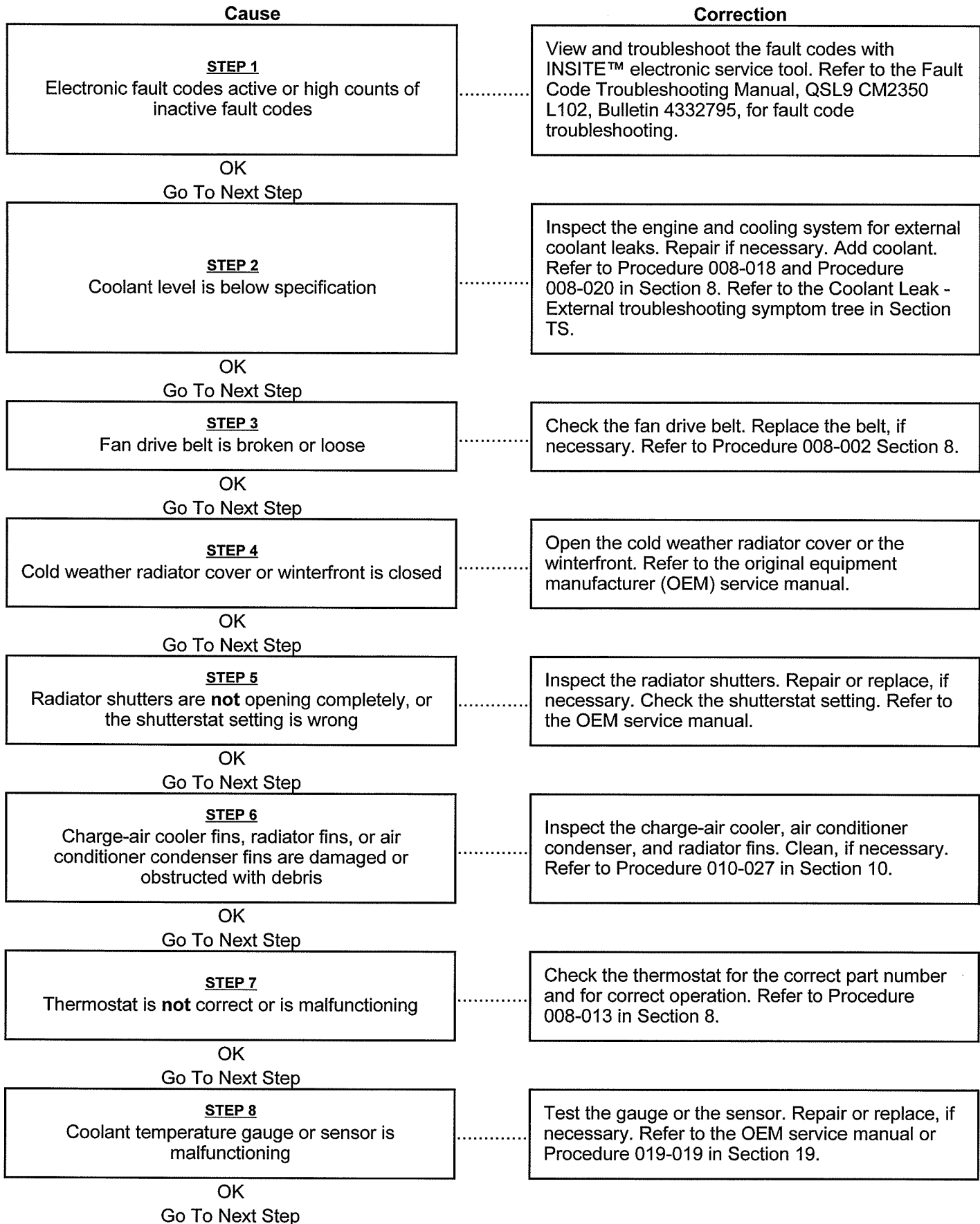
Cause

Correction



Coolant Temperature Above Normal - Sudden Overheat

This is symptom tree t023



Coolant Temperature Above Normal - Sudden Overheat

This is symptom tree t023

Cause	Correction
<p>STEP 9 Cooling system hose is collapsed, restricted, or leaking</p>	<p>Inspect the hoses. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 10 Fill line or vent lines are restricted, obstructed, or not routed correctly</p>	<p>Check the vent lines and the fill line for correct routing and for restrictions. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 11 Water pump is malfunctioning</p>	<p>Check the water pump for correct operation. Replace the water pump, if necessary.</p>
<p>OK Go To Next Step</p>	
<p>STEP 12 Radiator cap is not correct, is malfunctioning, or has low-pressure rating</p>	<p>Check the radiator pressure cap. Refer to Procedure 008-047 in Section 8.</p>
<p>OK Go To Next Step</p>	
<p>STEP 13 Fan drive or fan controls are malfunctioning</p>	<p>Check the fan drive and controls. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 14 Cooling system component is malfunctioning</p>	<p>Perform the Cooling System Diagnostics Test. Refer to Procedure 008-020 in Section 8.</p>
<p>OK Go To Next Step</p>	
<p>STEP 15 Torque converter cooler or hydraulic oil cooler is malfunctioning</p>	<p>Remove and inspect the cooler cores and o-rings. Refer to the OEM service manual.</p>

Coolant Temperature Below Normal

This is symptom tree t024

Cause

Correction

STEP 1

Engine is operating at low ambient temperature

Check the winterfront, shutters, and under-the-hood air. Use under-the-hood intake air in cold weather. Refer to the original equipment manufacturer (OEM) service manual.

OK

Go To Next Step

STEP 2

Electronic fault codes active or high counts of inactive fault codes

View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to the Fault Code Troubleshooting Manual, QSL9 CM2350 L102, Bulletin 4332795, for fault code troubleshooting.

OK

Go To Next Step

STEP 3

Coolant temperature gauge or sensor is malfunctioning

Test the gauge or the sensor. Repair or replace, if necessary. Refer to the OEM service manual or Procedure 019-019 in Section 19.

OK

Go To Next Step

STEP 4

Excessive coolant flow through OEM plumbing and heater cores

Close the valves to the heater cores. Run engine. If engine operates at normal temperature, refer to the OEM service manual.

OK

Go To Next Step

STEP 5

Thermostat is **not** correct or is malfunctioning

Check the thermostat for the correct part number and for correct operation. Refer to Procedure 008-013 in Section 8.

OK

Go To Next Step

STEP 6

Fan drive or fan controls are malfunctioning

Check the fan drive and controls. Refer to the OEM service manual.

OK

Go To Next Step

STEP 7

Engine idle time is excessive

Low oil and coolant temperatures can be caused by long idle times (greater than 10 minutes). Shut the engine OFF rather than idle for long periods. If idle time is necessary, raise the idle speed. Refer to Procedure 101-015 in Section 1 of the Operation and Maintenance Manual, QSL9 CM2350 L102, Bulletin 4332797.

OK

Go To Next Step

STEP 8

Cooling system component is malfunctioning

Perform the Cooling System Diagnostics Test. Refer to Procedure 008-020 in Section 8.

Coolant in the Lubricating Oil

This is symptom tree t025

Cause

Correction

<p>STEP 1 EGR cooler core is leaking</p>	<p>Check the EGR cooler core for leaks. Refer to Procedure 011-019 in Section 11.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Lubricating oil cooler is malfunctioning</p>	<p>Check the oil cooler. Refer to Procedure 007-003 in Section 7.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Air compressor cylinder head is cracked or porous, or has a leaking gasket</p>	<p>Inspect the air compressor cylinder head and gasket. Refer to Procedure 012-007 in Section 12. If the air compressor head is not serviceable, replace the air compressor. Refer to Procedure 012-014 in Section 12.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Internal coolant leaks</p>	<p>Refer to Procedure 008-020 in Section 8. Pressure test the cooling system and look for internal coolant leaks.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Variable geometry turbocharger leaking coolant</p>	<p>Refer to Procedure 010-033 in Section 10. Perform the "Crack Detection Test" to determine if a cracked or porous turbocharger bearing housing exists.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Cylinder head gasket is leaking</p>	<p>Check the cylinder head gasket. Refer to Procedure 002-004 in Section 2. Remove the cylinder head and inspect.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Cylinder head is cracked or porous</p>	<p>Pressure test the cylinder head. Refer to Procedure 002-004 in Section 2.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Cylinder block is cracked or porous</p>	<p>Inspect the cylinder block. Refer to Procedure 001-026 in Section 1.</p>

Crankcase Gases (Blowby) Excessive

This is symptom tree t027

Cause

Correction

STEP 1

Crankcase ventilation system is plugged

Check and clean the crankcase breather and vent tube. Refer to Procedure 003-001 and Procedure 003-018 in Section 3.

OK

Go To Next Step

STEP 2

Air compressor is malfunctioning

Check the air compressor engine blow-by contribution. Refer to Procedure 014-010 in Section 14. If the blowby contribution is out of specification, rebuild or replace the air compressor. Refer to Procedure 012-014 in Section 12.

OK

Go To Next Step

STEP 3

Turbocharger oil seal is leaking

Check the turbocharger compressor and turbine seals. Refer to Procedure 010-033 in Section 10. Check the turbocharger blowby contribution. Refer to Procedure 014-010 in Section 14. If the blowby contribution is out of specification, replace the turbocharger. Refer to Procedure 010-033 in Section 10.

OK

Go To Next Step

STEP 4

Valve stem clearance is excessive or the valve stem seals are damaged

Check the valve stems and seals. Refer to Procedure 002-004 in Section 2.

OK

Go To Next Step

STEP 5

Cylinder head valve guides are excessively worn

Check the valve guides for wear. Replace the cylinder head, if necessary. Refer to Procedure 002-004 in Section 2.

OK

Go To Next Step

STEP 6

Piston or piston rings are worn or damaged

Check for air intake system leaks. Refer to Procedure 010-024 in Section 10. Check the pistons and piston rings for wear or damage. For piston cleaning and reuse; Refer to Procedure 001-043 in Section 1. For cylinder liner inspection and reuse; Refer to Procedure 001-028 in Section 1. For piston ring inspection; Refer to Procedure 001-047 in Section 1.

Engine Brake Does Not Operate

This is symptom tree t036

Cause	Correction
<p>STEP 1 Engine brake on/off switch is OFF</p>	<p>Turn the switch ON.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Programmable parameters or selected features are not correct</p>	<p>Check the programmable parameters and the selected features with an electronic service tool. Set the parameters and features again, if necessary. Refer to Procedure 019-078 in Section 19.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Electronic fault codes active or high counts of inactive fault codes</p>	<p>Refer to the Fault Code Troubleshooting Manual, QSL9 CM2350 L102, Bulletin 4332795, for fault code troubleshooting.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Engine brake on/off switch or circuit is malfunctioning</p>	<p>Check the engine brake on/off switch and circuit. Refer to Procedure 019-034 and Procedure 019-035 in Section 19.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Clutch switch or circuit is malfunctioning</p>	<p>Check the clutch switch adjustment, switch, and circuit. Refer to Procedure 019-009 and Procedure 019-010 in Section 19.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Accelerator pedal or lever position sensor or circuit is malfunctioning</p>	<p>Check for foot pedal restriction. Check the accelerator pedal or lever position sensor and circuit. Refer to Procedure 019-085 in Section 19.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Service brake pressure switch or circuit is malfunctioning</p>	<p>Check the service brake pressure switch and circuit. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Engine electrical ground is malfunctioning</p>	<p>Check engine ground to chassis and chassis ground to battery negative (-) post. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	

Engine Brake Does Not Operate

This is symptom tree t036

Cause

Correction

STEP 9

Lubricating oil leak (internal)

Check the engine brake control valve and the engine brake piston. Refer to Procedure 020-012 in Section 20.

OK

Go To Next Step

STEP 10

Engine brake lubricating oil passage is restricted

Check the engine brake assembly for restriction. Refer to Procedure 020-004 in Section 20.

OK

Go To Next Step

STEP 11

Engine brake adjustment is **not** correct

Adjust the engine brakes. Refer to Procedure 020-004 in Section 20.

Engine Brake - Low Retarding Power or Slow to Activate

This is symptom tree t037

Cause

STEP 1

Interview the operator to verify the complaint

OK

Go To Next Step

STEP 2

Electronic fault codes active or high counts of inactive fault codes

OK

Go To Next Step

STEP 3

Programmable parameters or selected features are **not** correct

OK

Go To Next Step

STEP 4

Engine is cold

OK

Go To Next Step

STEP 5

Engine brake adjustment is **not** correct

OK

Go To Next Step

STEP 6

Air in the lubricating oil system

OK

Go To Next Step

STEP 7

Lubricating oil leak (internal)

OK

Go To Next Step

STEP 8

Engine brake solenoid(s) is malfunctioning

OK

Go To Next Step

Correction

Refer to the Troubleshooting Overview in Section TS. Follow the instructions on the forms before continuing with this tree.

Refer to the Fault Code Troubleshooting Manual, QSL9 CM2350 L102, Bulletin 4332795, for fault code troubleshooting.

Check the programmable parameters and the selected features with an electronic service tool. Set the parameters and features again, if necessary. Refer to a Cummins® Authorized Repair Location.

Allow the engine to warm to operating temperature. If the engine will **not** reach operating temperature, refer to the Coolant Temperature Below Normal troubleshooting symptom tree in Section TS.

Adjust the engine brakes. Refer to Procedure 020-004 in Section 20.

Check the oil level. If the level is high, check for a cracked oil suction tube. Refer to Procedure 007-035 in Section 7.

Check the engine brake control valve and the engine brake piston. Refer to Procedure 020-004.

Refer to Procedure 020-012 in Section 20.

Engine Brake - Low Retarding Power or Slow to Activate

This is symptom tree t037

Cause

Correction

STEP 9

Engine brake control valve(s) is malfunctioning

Check the engine brake control valve(s). Replace the engine brake control valve(s) if necessary. Refer to Procedure 020-004 in Section 20.

OK

Go To Next Step

STEP 10

Engine brake lubricating oil passage is restricted

Check the engine brake assembly for restriction. Refer to Procedure 020-004 in Section 20.

OK

Go To Next Step

STEP 11

Turbocharger is malfunctioning

Monitor the turbocharger boost pressure with an electronic service tool. Refer to the Engine Performance Troubleshooting Tree in Section TT.

Engine Difficult to Start or Will Not Start (No Exhaust Smoke)

This is symptom tree t044

Cause	Correction
<p>STEP 1 Low fuel level in the fuel tank</p>	<p>Check the fuel level in the fuel tanks. Verify the fuel gauge is working properly.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Engine indicator lamps illuminated</p>	<p>Refer to Section TF in the Fault Code Troubleshooting Manual, QSL9 CM2350 L102, Bulletin 4332795, to troubleshoot system fault codes and indicator lamps.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Poor fuel quality or fuel additives</p>	<p>Operate the engine with a known high quality fuel supply and determine if the performance symptoms are eliminated. Verify if the customer is using any fuel additives that could cause white smoke complaints.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Low fuel rail pressure</p>	<p>Attempt to start the engine by engaging the engine starting motor for at least 30 continuous seconds. Use INSITE™ electronic service tool to monitor Fuel Rail Pressure (Measured) and Fuel Rail Pressure (Commanded). Use INSITE™ electronic service tool to read the fault codes. Attempting to start the engine for 30 continuous seconds allows the fault code logic time to run. If Fault Code 559 becomes active, fuel rail pressure is not being developed.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Malfunctioning ECM power or ground circuit</p>	<p>Check the battery voltage of the ECM power supply and ground circuit. Refer to the corresponding wiring diagram for the engine being serviced for connector pin identification.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Malfunctioning keyswitch circuit</p>	<p>Check the vehicle keyswitch circuit for intermittent connections. Refer to Procedure 019-064 in Section 19. .</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Low battery voltage</p>	<p>Check the battery voltage. Measure the voltage from the positive (+) terminal to the negative (-) battery terminal while trying to start the engine.</p>
<p>OK Go To Next Step</p>	

Engine Difficult to Start or Will Not Start (No Exhaust Smoke)

This is symptom tree t044

Cause	Correction
<p>STEP 8 Slow cranking speed</p>	<p>The minimum cranking speed must be greater than 150 rpm.</p>
<p>OK Go To Next Step</p>	
<p>STEP 9 ROM-booted ECM</p>	<p>Connect INSITE™ electronic service tool. If the ECM is ROM-booted, either the ECM will not communicate or INSITE™ electronic service tool will indicate the ECM is ROM-booted and must be calibrated.</p>
<p>OK Go To Next Step</p>	
<p>STEP 10 Fuel drain-back to the fuel tanks</p>	<p>Verify all suction side fuel line connections are tight and air is not allowed to enter the fuel system. Verify the suction side fuel filter is tight. Refer to Procedure 006-024 and Procedure 006-015 in Section 6.</p>
<p>OK Go To Next Step</p>	
<p>STEP 11 Air in the fuel</p>	<p>Check for air in the fuel system. Refer to Procedure 006-003 in Section 6.</p>
<p>OK Go To Next Step</p>	
<p>STEP 12 OEM fuel drain line not routed to the bottom of the fuel supply tank</p>	<p>Verify the OEM fuel drain line is routed correctly to the bottom of the fuel tank. If the drain line is not routed to the bottom of the tank, air is allowed to enter the fuel system and the fuel will drain back to the tank on the suction side of the pump. This will cause a hard start condition after the engine is turned OFF for an extended period of time.</p>
<p>OK Go To Next Step</p>	
<p>STEP 13 Malfunctioning intake air heater</p>	<p>Connect INSITE™ electronic service tool. From the list of "ECM Diagnostic Tests", select "Grid Heater Override". Follow the instructions on the screen to determine if the cold starting aid is working properly. If the intake air heater is not functioning properly, troubleshoot the intake air heater wiring and relay circuits. Refer to Procedure 010-029 in Section 10.</p>
<p>OK Go To Next Step</p>	
<p>STEP 14 High exhaust restriction</p>	<p>Measure the exhaust restriction. Refer to Procedure 011-009 in Section 11.</p>
<p>OK Go To Next Step</p>	

Engine Difficult to Start or Will Not Start (No Exhaust Smoke)

This is symptom tree t044

Cause

Correction

STEP 15
Stuck in-range or drifting fuel rail pressure sensor

Relieve the fuel pressure from the high-pressure fuel rail by loosening the pump-to-rail line at the rail. Use INSITE™ electronic service tool to measure fuel rail pressure. The fuel rail pressure should read 0 ± 43 bar [0 ± 624 psi]. Refer to Procedure 006-061 in Section 6.

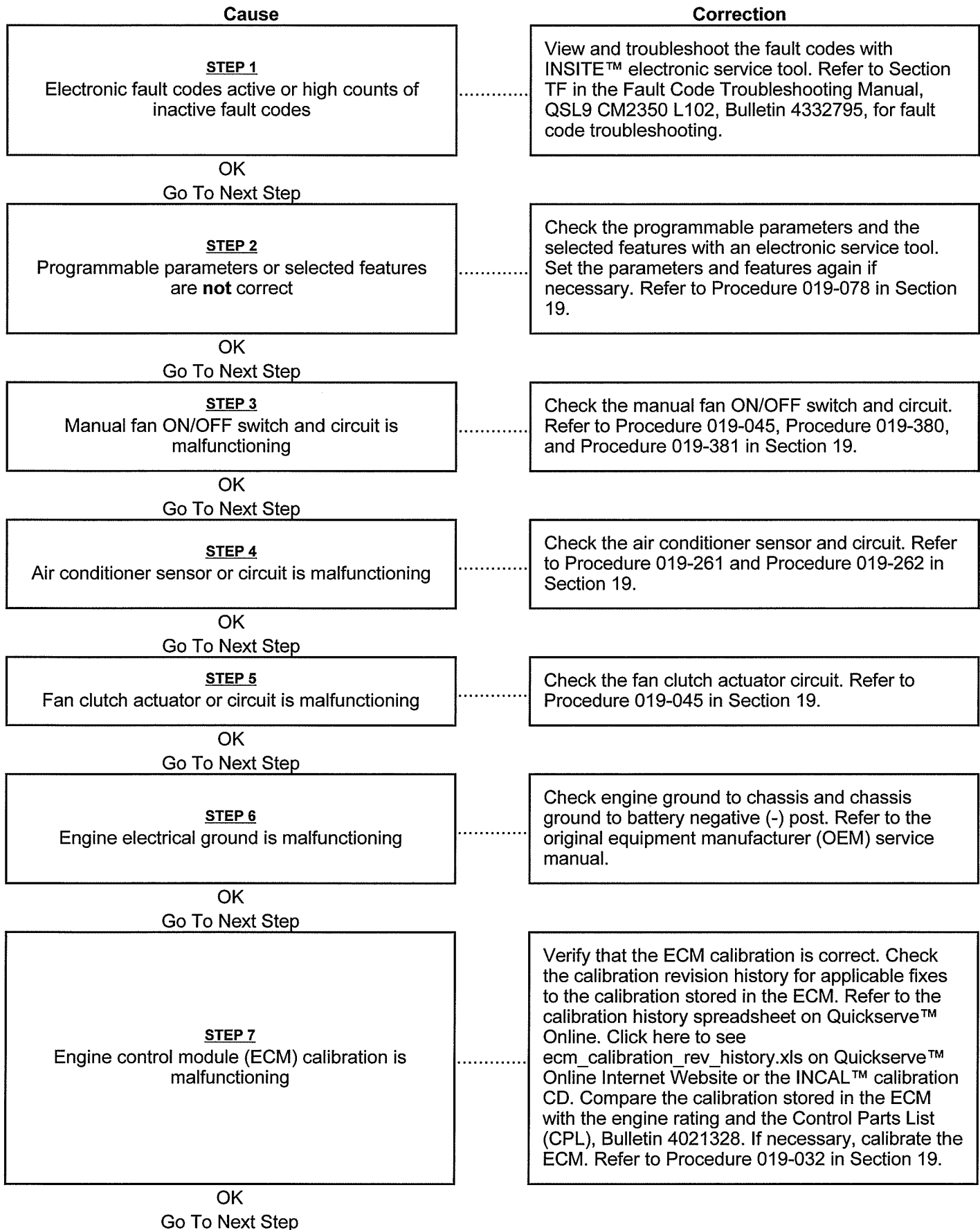
OK
Go To Next Step

STEP 16
Plugged OEM fuel tank vent

Remove the fuel tank cap. If the engine starts properly with the fuel cap removed, inspect the fuel tank vent for plugging or restriction.

Engine Fan Does Not Operate, Operates Erratically, or Operates Continuously

This is symptom tree t046



Engine Fan Does Not Operate, Operates Erratically, or Operates Continuously

This is symptom tree t046

Cause

STEP 8
Intake manifold temperature or coolant temperature is above the threshold to activate the cooling fan.

Correction

Refer to the Intake Manifold Air Temperature Above Specification and/or Coolant Temperature Above Normal - Gradual Overheat troubleshooting symptom trees in Section TS.

Engine Noise Excessive

This is symptom tree t047

When troubleshooting engine noise complaints, make sure the engine accessories (air compressor, fan clutch, refrigerant compressor, or hydraulic pump) are not the cause of the noise. Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.

Cause

Correction

STEP 1

Fan drive belt is loose

Check the belt tension and tighten, if necessary. Refer to Procedure 008-002 in Section 8.

OK

Go To Next Step

STEP 2

Fan is loose, damaged, or **not** balanced

Check the fan. Refer to the original equipment manufacturer (OEM) service manual.

OK

Go To Next Step

STEP 3

Fan clutch, hydraulic pump, or refrigerant compressor noise is excessive

Isolate each component and check for noise. Refer to Procedure 008-026 in Section 8 or Procedure 009-016 in Section 9 or the OEM service manual.

OK

Go To Next Step

STEP 4

Air intake or exhaust leaks

Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024 in Section 10.

OK

Go To Next Step

STEP 5

Air intake or exhaust piping is contacting the chassis or cab

Inspect the air piping, chassis, and cab for contact points. Refer to the OEM service manual.

OK

Go To Next Step

STEP 6

Lubricating oil level is above or below specification

Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-037 in Section 7.

OK

Go To Next Step

STEP 7

Lubricating oil is thin or diluted

Refer to Procedure 007-083 in Section 7. If the oil pressure is low, refer to the Lubricating Oil Pressure Low troubleshooting symptom tree in Section TS.

OK

Go To Next Step

STEP 8

Lubricating oil pressure is below specification

Check the oil pressure. Refer to Procedure 018-017 in Section V. If the pressure is low, refer to the Lubricating Oil Pressure Low troubleshooting symptom tree in Section TS.

OK

Go To Next Step

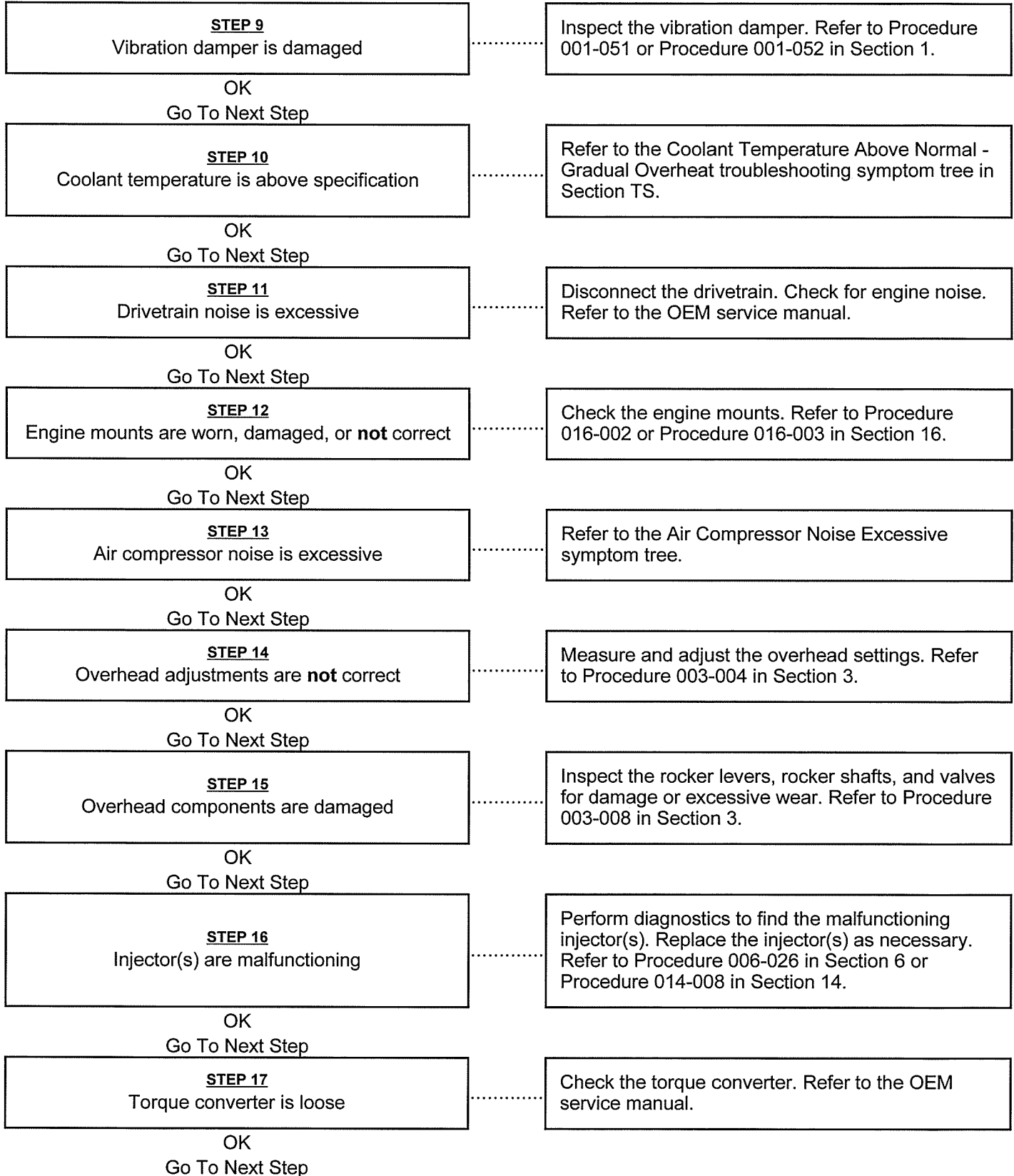
Engine Noise Excessive

This is symptom tree t047

When troubleshooting engine noise complaints, make sure the engine accessories (air compressor, fan clutch, refrigerant compressor, or hydraulic pump) are not the cause of the noise. Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.

Cause

Correction



Engine Noise Excessive

This is symptom tree t047

When troubleshooting engine noise complaints, make sure the engine accessories (air compressor, fan clutch, refrigerant compressor, or hydraulic pump) are not the cause of the noise. Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.

Cause	Correction
<p>STEP 18 Flywheel or flexplate capscrews are loose or broken</p>	<p>Check the flywheel or flexplate and the mounting capscrews. Refer to Procedure 016-005 and Procedure 016-004 in Section 16.</p>
<p>OK Go To Next Step</p>	
<p>STEP 19 Gear train backlash is excessive or the gear teeth are damaged</p>	<p>Check the gear backlash and the gear teeth. Refer to Procedure 001-008 in Section 1.</p>
<p>OK Go To Next Step</p>	
<p>STEP 20 Main bearing or connecting rod bearing noise</p>	<p>Refer to the Engine Noise Excessive - Connecting Rod troubleshooting symptom tree or the Engine Noise Excessive - Main Bearing troubleshooting symptom tree in Section TS.</p>
<p>OK Go To Next Step</p>	
<p>STEP 21 Turbocharger noise</p>	<p>Refer to the Engine Noise Excessive - Turbocharger troubleshooting symptom tree in Section TS.</p>
<p>OK Go To Next Step</p>	
<p>STEP 22 Combustion noise excessive</p>	<p>Refer to the Engine Noise Excessive - Combustion Knocks troubleshooting symptom tree in Section TS.</p>
<p>OK Go To Next Step</p>	
<p>STEP 23 Piston or piston rings are worn or damaged</p>	<p>Check for air intake system leaks. Check the pistons and piston rings for wear or damage. Refer to Procedure 010-024 in Section 10 or Procedure 001-047 in Section 1. Analyze the lubricating oil and oil filters to locate an area of probable damage and cause. Procedure 007-083 in Section 7.</p>

Engine Noise Excessive - Combustion Knocks

This is symptom tree t048

Refer to Engine Noise Diagnostic Procedures - General Information, in the troubleshooting overview procedure at the beginning of Section TS, before using this symptom tree.

Cause

Correction

<p>STEP 1 Electronic fault codes active or high counts of inactive fault codes</p>	<p>View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to Section TF in the Fault Code Troubleshooting Manual, QSL9 CM2350 L102, Bulletin 4332795.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Fuel grade is not correct for the application or the fuel quality is poor</p>	<p>Operate the engine from a tank of known high quality fuel. Refer to Procedure 018-016 in Section V.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Air in the fuel system</p>	<p>Check for air in the fuel system. Refer to Procedure 006-003 in Section 6.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Coolant temperature is above specification</p>	<p>Refer to the Coolant Temperature Above Normal - Gradual Overheat troubleshooting symptom tree in Section TS.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Overhead adjustments are not correct</p>	<p>Measure and adjust the overhead settings. Refer to Procedure 003-004 ins Section 3.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Injector(s) are malfunctioning</p>	<p>Perform diagnostics to find the malfunctioning injector(s). Replace the injector(s) as necessary. Refer to Procedure 006-026 in Section 6 and Procedure 014-008 in Section 14.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Camshaft timing is not correct (after engine rebuild or repair)</p>	<p>Check the gear train timing alignment. Refer to Procedure 001-008 in Section 1.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Piston is misassembled</p>	<p>Remove and inspect the pistons. Refer to Procedure 002-004 in Section 2 or Procedure 001-054 in Section 1.</p>

Engine Noise Excessive - Connecting Rod

This is symptom tree t049

Refer to Engine Noise Diagnostic Procedures - General Information, in the troubleshooting overview procedure at the beginning of Section TS, before using this symptom tree.

Cause

Correction

STEP 1
Lubricating oil level is below specification

Check the oil level. Verify the dipstick calibration and the oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-037 and Procedure 007-009 in Section 7.

OK
Go To Next Step

STEP 2
Lubricating oil pressure is below specification

Check the oil pressure. If the pressure is low, Use the following procedure for oil pressure specifications. Procedure 018-017 in Section V. If the oil pressure is out of specification, reference the Lubricating Oil Pressure Low troubleshooting symptom tree in Section TS.

OK
Go To Next Step

STEP 3
Lubricating oil is thin or diluted

Refer to Procedure 007-083 in Section 7. If the oil pressure is low, refer to the Lubricating Oil Pressure Low troubleshooting symptom tree in Section TS.

OK
Go To Next Step

STEP 4
Block stiffener plate is misassembled

Remove and inspect the block stiffener plate. Refer to Procedure 001-089 in Section 1.

OK
Go To Next Step

STEP 5
Lubricating oil suction or transfer tube misassembled

Remove and inspect the lubricating oil suction or transfer tube. Refer to Procedure 007-035 in Section 7.

OK
Go To Next Step

STEP 6
Crankshaft journals are damaged or out of round

Inspect the crankshaft journals. Refer to Procedure 001-016 in Section 1.

OK
Go To Next Step

STEP 7
Connecting rod capscrews are loose or **not** tightened correctly

Check the torque on the connecting rod capscrews. Refer to Procedure 001-014 in Section 1.

OK
Go To Next Step

STEP 8
Connecting rod is bent or out of alignment

Remove and inspect the connecting rods. Refer to Procedure 001-014 in Section 1.

OK
Go To Next Step

Engine Noise Excessive - Connecting Rod

This is symptom tree t049

Refer to Engine Noise Diagnostic Procedures - General Information, in the troubleshooting overview procedure at the beginning of Section TS, before using this symptom tree.

Cause

Correction

STEP 9

Connecting rod and bearings are damaged or worn, are **not** assembled correctly, or are the wrong bearings

Inspect the connecting rods and bearings. Refer to Procedure 001-014 in Section 1.

Engine Noise Excessive - Main Bearing

This is symptom tree t050

Refer to Engine Noise Diagnostic Procedures - General Information, in the troubleshooting overview procedure at the beginning of Section TS, before using this symptom tree.

Cause	Correction
<p>STEP 1 Lubricating oil pressure is below specification</p> <p>OK Go To Next Step</p>	<p>Check the oil pressure. If the pressure is low, refer to Procedure 018-017 in Section V. If the oil pressure is out of specification, reference the Lubricating Oil Pressure Low troubleshooting symptom tree in Section TS.</p>
<p>STEP 2 Lubricating oil level is below specification</p> <p>OK Go To Next Step</p>	<p>Check the oil level. Verify the dipstick calibration and the oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-037 and Procedure 007-009 in Section 7.</p>
<p>STEP 3 Lubricating oil is thin or diluted</p> <p>OK Go To Next Step</p>	<p>Refer to Procedure 007-083 in Section 7. If the oil pressure is low, refer to the Lubricating Oil Pressure Low troubleshooting symptom tree in Section TS.</p>
<p>STEP 4 Main bearing capscrews are loose, worn, or not tightened correctly</p> <p>OK Go To Next Step</p>	<p>Check the torque on the main bearing capscrews. Inspect the capscrews for wear. Refer to Procedure 001-006 in Section 1.</p>
<p>STEP 5 Main bearings are damaged or worn, or the wrong bearings are installed</p> <p>OK Go To Next Step</p>	<p>Inspect the main bearings for damage, excessive wear, and the correct part number. Refer to Procedure 001-006 in Section 1.</p>
<p>STEP 6 Crankshaft journals are damaged or out of round</p> <p>OK Go To Next Step</p>	<p>Inspect the crankshaft journals. Refer to Procedure 001-016 in Section 1.</p>
<p>STEP 7 Flywheel or flexplate capscrews are loose or broken</p>	<p>Check the flywheel or flexplate and the mounting capscrews. Refer to Procedure 016-005 in Section 16.</p>

Engine Noise Excessive - Piston

This is symptom tree t051

Refer to Engine Noise Diagnostic Procedures - General Information, in the troubleshooting overview procedure at the beginning of Section TS, before using this symptom tree.

Cause	Correction
<p>STEP 1 Electronic fault codes active or high counts of inactive fault codes</p>	<p>View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to Section TF in the Fault Code Troubleshooting Manual, QSL9 CM2350 L102, Bulletin 4332795, for fault code troubleshooting.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Fuel grade is not correct for the application or the fuel quality is poor</p>	<p>Operate the engine from a tank of known high quality fuel. Refer to Procedure 018-016 in Section V.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Overhead adjustments are not correct</p>	<p>Measure and adjust the overhead settings. Refer to Procedure 003-004 in Section 3.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Injector(s) are malfunctioning</p>	<p>Perform diagnostics to find the malfunctioning injector(s). Replace the injector(s) as necessary. Refer to Procedure 006-026 in Section 6 and Procedure 014-008 in Section 14.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Piston is misassembled</p>	<p>Remove and inspect the pistons. Refer to Procedure 001-054 in Section 1.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Connecting rod is bent or out of alignment</p>	<p>Remove and inspect the connecting rods. Refer to Procedure 001-014 in Section 1.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Connecting rod is misassembled</p>	<p>Remove and inspect the connecting rods. Refer to Procedure 001-014 in Section 1.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Piston pin or bushing is loose, worn, or not installed correctly</p>	<p>Remove the pistons and inspect the piston pins and bushings for damage, wear, and correct installation. Refer to Procedure 001-043 or Procedure 001-054 in Section 1.</p>

Engine Noise Excessive - Turbocharger

This is symptom tree t052

Refer to Engine Noise Diagnostic Procedures - General Information, in the troubleshooting overview procedure at the beginning of Section TS, before using this symptom tree.

Cause	Correction
<p>STEP 1 Turbocharger is not correct</p>	<p>Check the turbocharger part number and compare it to the Control Parts List (CPL), Bulletin 4021328. Replace the turbocharger, if necessary. Refer to Procedure 010-033 in Section 10.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Air intake system restriction is above specification</p>	<p>Check the air intake system for restrictions. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031 in Section 10.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Air intake or exhaust leaks</p>	<p>Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024 in Section 10. On engines equipped with exhaust gas recirculation (EGR), make certain to inspect the EGR tube connections for leaks. Refer to Procedure 011-025 in Section 11.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Air intake or exhaust piping is contacting the chassis or cab</p>	<p>Inspect the air piping, chassis, and cab for contact points. Refer to the original equipment manufacturer (OEM) service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Exhaust system restriction is not within specification</p>	<p>Check the exhaust system for restrictions. Refer to Procedure 011-009 in Section 11.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Air intake manifold heater starting aid is restricted or plugged</p>	<p>Inspect the air intake manifold heater for plugging or soot buildup. Refer to Procedure 010-023 in Section 10.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Turbocharger is worn or damaged</p>	<p>Check the turbocharger for damage. Measure the turbine and compressor wheel clearances. Refer to Procedure 010-033 in Section 10.</p>

Engine Power Output Low

This is symptom tree t057

Cause

Correction

STEP 1

Original equipment manufacturer (OEM) machine constrained operation

OEM machine constrained operation through an OEM controller. Verify that the OEM system is configured to deliver correct power output. Refer to the OEM service manual.

OK

Go To Next Step

STEP 2

Poor fuel quality or fuel additives

Operate the engine with a known high quality fuel supply and determine if the performance symptoms are eliminated. Verify if the customer is using any fuel additives that could cause white smoke complaints.

OK

Go To Next Step

STEP 3

Engine control module (ECM) calibration update available

Verify the ECM calibration is correct. Check the calibration revision history found on QuickServe™ Online for applicable corrections to the calibration stored in the ECM. If necessary, calibrate the ECM. Refer to Procedure 019-032 in Section 19.

OK

Go To Next Step

STEP 4

Low power basic poor performance checks

The following items should be verified before continuing the low power troubleshooting procedure. Verify the ECM calibration is correct for the engine application. Verify the electronic adjustable parameters are set correctly for the application. Verify the engine fan is **not** locked ON, causing excessive engine parasitic load. Verify engine parasitics have **not** changed. Verify the fuel grade is correct for the application.

OK

Go To Next Step

STEP 5

Leaking air intake system or charge-air cooler

Inspect the air intake and exhaust systems for air leaks. Check all air compressor plumbing, EGR plumbing, intake plumbing, charge-air cooler hoses, and exhaust plumbing for possible air leaks. Refer to Procedure 010-024 in Section 10.

OK

Go To Next Step

STEP 6

Leaks in the EGR plumbing or exhaust system

Check for leaks in the EGR and exhaust system. Specifically look for leaks at connection tubing, V-Band connections, EGR differential pressure sensor mounting surfaces, turbocharger mounting gaskets, and EGR cooler plumbing connections.

OK

Go To Next Step

Engine Power Output Low

This is symptom tree t057

Cause

Correction

STEP 7
Malfunctioning fuel injector

Perform INSITE™ electronic service tool Cylinder Cutout Test to determine if the misfire can be isolated to a single injector. Refer to Procedure 006-026 in Section 6.

OK
Go To Next Step

STEP 8
Incorrect engine operating state

Use INSITE™ electronic service tool to monitor the parameter "User Fueling State" or "Engine Operating State". The "Engine State Monitor" test found in the ECM Diagnostic Tests menu can also be used to monitor the Engine Operating State.

OK
Go To Next Step

STEP 9
Plugged pressure side fuel filter

Check for a plugged or restricted pressure side fuel filter. Refer to Procedure 006-015 in Section 6.

OK
Go To Next Step

STEP 10
High fuel inlet restriction

Perform the Fuel Inlet Restriction Test. Refer to Procedure 006-020 in Section 6.

OK
Go To Next Step

STEP 11
High air intake restriction

Check the air filter to make sure it is **not** plugged. Check the air intake system for restriction. Refer to Procedure 010-031 in Section 10.

OK
Go To Next Step

STEP 12
Seized variable geometry turbocharger (VGT)

Verify the turbocharger sector gear moves smoothly through the operating range. Refer to Procedure 008-018 in Section 8, Procedure 010-033 and Procedure 010-134 in Section 10.

OK
Go To Next Step

Engine Power Output Low

This is symptom tree t057

Cause

Correction

STEP 13
Stuck open EGR valve

If the engine idle speed is 1050 rpm or below, run the engine at idle and use INSITE™ electronic service tool to monitor the EGR differential pressure value. EGR differential pressure **must** read less than 3.4 kpa [1.0 in Hg]. If the EGR differential pressure is above this specification, a stuck open EGR valve has been detected. If the engine idle speed is above 1050 rpm, use INSITE™ electronic service tool to reduce the engine idle speed to below 1050 rpm. Refer to the OEM service manual to verify that no OEM components can be damaged due to the reduced idle speed.

OK
Go To Next Step

STEP 14
Air in the fuel

Check for air in the fuel system. Refer to Procedure 006-003 in Section 6.

OK
Go To Next Step

STEP 15
Plugged EGR differential pressure sensor supply ports

Check the EGR differential pressure sensor flow ports. Inspect the EGR differential pressure sensor flow port cross-drillings for soot blockage. Inspect the exhaust gas entrance ports for soot blockage. Refer to Procedure 010-080 in Section 10.

OK
Go To Next Step

STEP 16
High exhaust restriction

Measure the exhaust restriction. Refer to Procedure 011-009 in Section 11.

OK
Go To Next Step

STEP 17
Worn or damaged turbocharger blades

Inspect the turbocharger compressor and turbine blades for damage or wear. Measure the turbocharger wheel axial and radial clearance specifications. Refer to Procedure 010-033 in Section 10.

OK
Go To Next Step

STEP 18
Stuck in-range or drifting fuel rail pressure sensor

Relieve the fuel pressure from the high-pressure fuel rail by loosening the pump-to-rail line at the rail. Use INSITE™ electronic service tool to measure fuel rail pressure. The fuel rail pressure should read 0 ± 43 bar [0 ± 624 psi]. Refer to Procedure 006-061 in Section 6.

OK
Go To Next Step

Engine Power Output Low

This is symptom tree t057

Cause

Correction

STEP 19

High turbocharger compressor intake temperatures

The compressor intake temperature should be within a few degrees of ambient outside temperature. If a temperature increase is detected between the air cleaner (ambient outside temperature) and the compressor intake temperature, investigate the cause of the temperature increase.

OK

Go To Next Step

STEP 20

Incorrect overhead adjustments

Measure the overhead valve lash settings. Verify the lash measurement is within specification. Refer to Procedure 003-004 in Section 3.

OK

Go To Next Step

STEP 21

Malfunctioning accelerator pedal

Use INSITE™ electronic service tool to monitor the Percent Accelerator Pedal or Lever while fully depressing and releasing the accelerator pedal. Verify the accelerator pedal reads 0 percent when the accelerator is released and 100 percent when the accelerator is fully depressed.

OK

Go To Next Step

STEP 22

Excessive vehicle parasitics

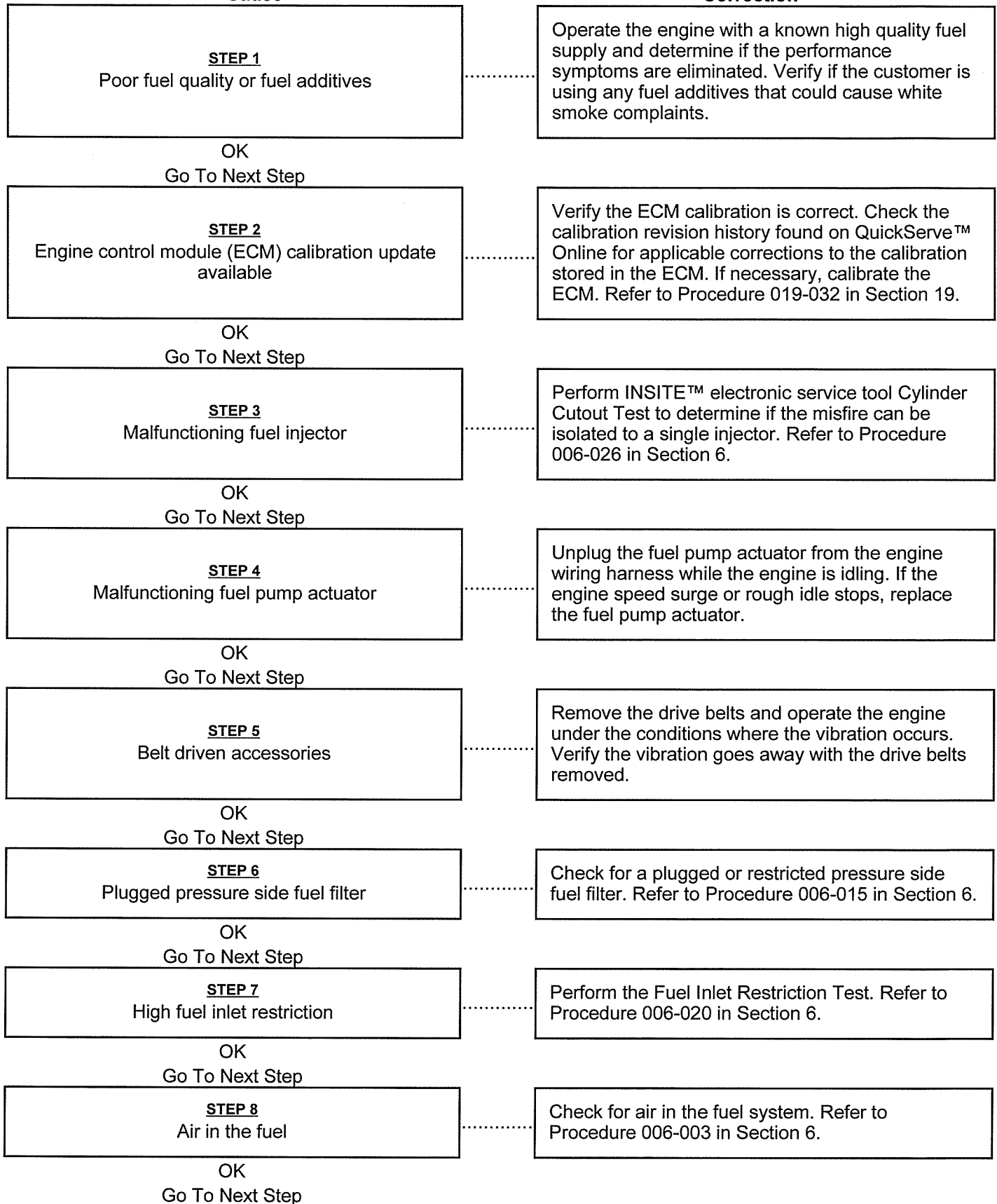
Check for any engine-driven units, such as air compressors or any PTO driven devices that could apply enough parasitic load to prevent the engine from obtaining the minimum cranking speed.

Engine Runs Rough or Misfires

This is symptom tree t062

Cause

Correction



Engine Runs Rough or Misfires

This is symptom tree t062

Cause

Correction

STEP 9
Incorrect overhead adjustments

Check the valve lash adjustment. If the valve seat insert is missing on a specific cylinder, the adjusting screw will be much higher than all other cylinders. Refer to Procedure 003-004 in Section 3.

OK
Go To Next Step

STEP 10
High fuel drain line restriction

Check for a blocked or restricted fuel drain line. Refer to Procedure 006-012 in Section 6.

OK
Go To Next Step

STEP 11
Damaged camshaft and/or tappets

Inspect the valve lobes and bearing journals for cracking, pitting, and scoring. Refer to Procedure 001-008 in Section 1.

Engine Speed Surges Under Load or in Operating Range

This is symptom tree t067

Cause

Correction

STEP 1

Engine control module (ECM) calibration update available

Verify the ECM calibration is correct. Check the calibration revision history found on QuickServe™ Online for applicable corrections to the calibration stored in the ECM. If necessary, calibrate the ECM. Refer to Procedure 019-032 in Section 19.

OK

Go To Next Step

STEP 2

Air in the fuel

Check for air in the fuel system. Refer to Procedure 006-003 in Section 6.

OK

Go To Next Step

STEP 3

Malfunctioning fuel pump actuator

Unplug the fuel pump actuator from the engine wiring harness while the engine is idling. If the engine speed surge or rough idle stops, replace the fuel pump actuator.

OK

Go To Next Step

STEP 4

EGR differential pressure sensor

The EGR differential pressure sensor should read 0 ± 1 kPa [0 ± 0.30 in-Hg] with the key ON and the engine OFF.

OK

Go To Next Step

STEP 5

Plugged pressure side fuel filter

Check for a plugged or restricted pressure side fuel filter. Refer to Procedure 006-015 in Section 6.

OK

Go To Next Step

STEP 6

High fuel inlet restriction

Perform the Fuel Inlet Restriction Test. Refer to Procedure 006-020 in Section 6.

OK

Go To Next Step

STEP 7

Malfunctioning fuel injector

Perform INSITE™ electronic service tool Cylinder Cutout Test to determine if the misfire can be isolated to a single injector.

OK

Go To Next Step

Engine Speed Surges Under Load or in Operating Range

This is symptom tree t067

Cause	Correction
<p>STEP 8 Stuck open EGR valve</p>	<p>If the engine idle speed is 1050 rpm or below, run the engine at idle and use INSITE™ electronic service tool to monitor the EGR differential pressure value. EGR differential pressure must read less than 3.4 kpa [1.0 in Hg]. If the EGR differential pressure is above this specification, a stuck open EGR valve has been detected. If the engine idle speed is above 1050 rpm, use INSITE™ electronic service tool to reduce the engine idle speed to below 1050 rpm. Refer to the OEM service manual to verify that no OEM components can be damaged due to the reduced idle speed.</p>
<p>OK Go To Next Step</p>	
<p>STEP 9 Plugged EGR differential pressure sensor supply ports</p>	<p>Check the EGR differential pressure sensor flow ports. Inspect the EGR differential pressure sensor flow port cross-drillings for soot blockage. Inspect the exhaust gas entrance ports for soot blockage. Refer to Procedure 010-080 in Section 10.</p>
<p>OK Go To Next Step</p>	
<p>STEP 10 High fuel drain line restriction</p>	<p>Check for a blocked or restricted fuel drain line. Refer to Procedure 006-012 in Section 6.</p>
<p>OK Go To Next Step</p>	
<p>STEP 11 Stuck in-range or drifting fuel rail pressure sensor</p>	<p>Relieve the fuel pressure from the high-pressure fuel rail by loosening the pump-to-rail line at the rail. Use INSITE™ electronic service tool to measure fuel rail pressure. The fuel rail pressure should read 0 ± 43 bar [0 ± 624 psi]. Refer to Procedure 006-061 in Section 6.</p>
<p>OK Go To Next Step</p>	
<p>STEP 12 Seized variable geometry turbocharger (VGT)</p>	<p>Verify the turbocharger sector gear moves smoothly through the operating range. Refer to Procedure 010-033 and Procedure 010-134 in Section 10. Refer to Procedure 008-018 in Section 8.</p>
<p>OK Go To Next Step</p>	
<p>STEP 13 High turbocharger compressor intake temperatures</p>	<p>The compressor intake temperature should be within a few degrees of ambient outside temperature. If a temperature increase is detected between the air cleaner (ambient outside temperature) and the compressor intake temperature, investigate the cause of the temperature increase.</p>

Engine Speed Surges in PTO or Cruise Control

This is symptom tree t068

Cause

Correction

STEP 1

Fuel level is low in the tank

Fill the supply tank. Refer to the original equipment manufacturer (OEM) service manual.

OK

Go To Next Step

STEP 2

Electronic fault codes active or high counts of inactive fault codes

Refer to Section TF of the Fault Code Troubleshooting Manual, QSL9 CM2350 L102, Bulletin 4332795.

OK

Go To Next Step

STEP 3

Fast Idle Warm Up feature is activating

If enabled, monitor Fast Idle Warm Up Status with INSITE™ electronic service tool while the vehicle is operating in PTO mode. Refer to Section TF of the Fault Code Troubleshooting Manual, QSL9 CM2350 L102, Bulletin 4332795.

OK

Go To Next Step

STEP 4

Fuel leak

Check the fuel lines, fuel connections, and fuel filters for leaks. Check the fuel lines to the supply tanks. Refer to the OEM service manual.

OK

Go To Next Step

STEP 5

Fuel inlet restriction

Check for fuel inlet restriction. Refer to Procedure 006-020 in Section 6.

OK

Go To Next Step

STEP 6

Fuel filter or fuel suction inlet restriction

Check the flow through the fuel filter. Replace the fuel filter, if necessary. Refer to Procedure 006-015 in Section 6.

OK

Go To Next Step

STEP 7

Air in the fuel system

Check for air in the fuel system. Refer to Procedure 006-003 in Section 6.

OK

Go To Next Step

Engine Speed Surges in PTO or Cruise Control

This is symptom tree t068

Cause

Correction

STEP 8

Engine control module (ECM) calibration is malfunctioning

Verify that the ECM calibration is correct. Check the calibration revision history for applicable fixes to the calibration stored in the ECM. Refer to the calibration history spreadsheet on Quickserve™ Online. Click here to see [ecm_calibration_rev_history.xls](#) on Quickserve™ Online Internet Website or the INCAL™ calibration CD. Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin 4021328. If necessary, calibrate the ECM. Refer to Procedure 019-032 in Section 19.

OK

Go To Next Step

STEP 9

Programmable parameters or selected features are **not** correct

Check the programmable parameters and the selected features with an electronic service tool. Set the parameters and features again, if necessary. Refer to Procedure 019-078 in Section 19.

OK

Go To Next Step

STEP 10

J1939 control devices are interfering with the engine controls

Alternately disconnect all other J1939 control devices from the data link circuit until communication or functionality is restored. Refer to the OEM service manual.

OK

Go To Next Step

STEP 11

Accelerator pedal or lever is restricted or malfunctioning

Check the percent accelerator pedal or lever reading on an electronic service tool. Verify that it reads 100 percent with the accelerator pedal depressed and 0 percent when released. Calibrate the accelerator, if possible. Replace the accelerator pedal, if necessary. Refer to Procedure 019-085 in Section 19 and/or the OEM service manual.

OK

Go To Next Step

STEP 12

Moisture in the wiring harness connectors

Dry the connectors with electrical contact cleaner, Part Number 3824510.

OK

Go To Next Step

STEP 13

Vehicle parasitics are excessive

Check the vehicle for brakes dragging, transmission malfunction, cooling fan operation cycle time, and engine-driven units. Refer to the OEM service manual.

OK

Go To Next Step

Engine Speed Surges in PTO or Cruise Control

This is symptom tree t068

Cause

Correction

STEP 14

Engine speed sensor or circuit is malfunctioning

Check the engine speed sensor for correct adjustment and for debris on the sensor. Check the engine speed sensor circuit. Refer to Procedure 019-363 in Section 19.

OK

Go To Next Step

STEP 15

Engine position sensor (EPS) or circuit is malfunctioning

Check the engine position sensor and circuit. Refer to Procedure 019-365 in Section 19.

OK

Go To Next Step

STEP 16

Vehicle speed sensor (VSS) or circuit is malfunctioning

Refer to the appropriate electronic service tool manual. If the monitor shows speed, check the sensor and circuit. Refer to Procedure 019-090 in Section 19 and Procedure 019-091 in Section 19.

OK

Go To Next Step

STEP 17

Fuel heater is malfunctioning (if equipped)

Check the fuel heater and replace if necessary. Refer to Procedure 005-008 in Section 5.

OK

Go To Next Step

STEP 18

Fuel connector is leaking fuel

Measure the drain line fuel quantity. Inspect the fuel connector and injector for nicks or damage that can cause fuel leaks. Refer to Procedure 006-026 in Section 6 and Procedure 006-052 in Section 6.

OK

Go To Next Step

STEP 19

Injector sealing washer is **not** correct

Remove the injectors and verify the injector sealing washer thickness. Refer to Procedure 006-026 in Section 6.

OK

Go To Next Step

STEP 20

Injector(s) are malfunctioning

Perform diagnostics to find the malfunctioning injector(s). Replace the injector(s) as necessary. Refer to Procedure 014-008 in Section 14 and Procedure 006-026 in Section 6.

OK

Go To Next Step

STEP 21

Injectors are **not** correct

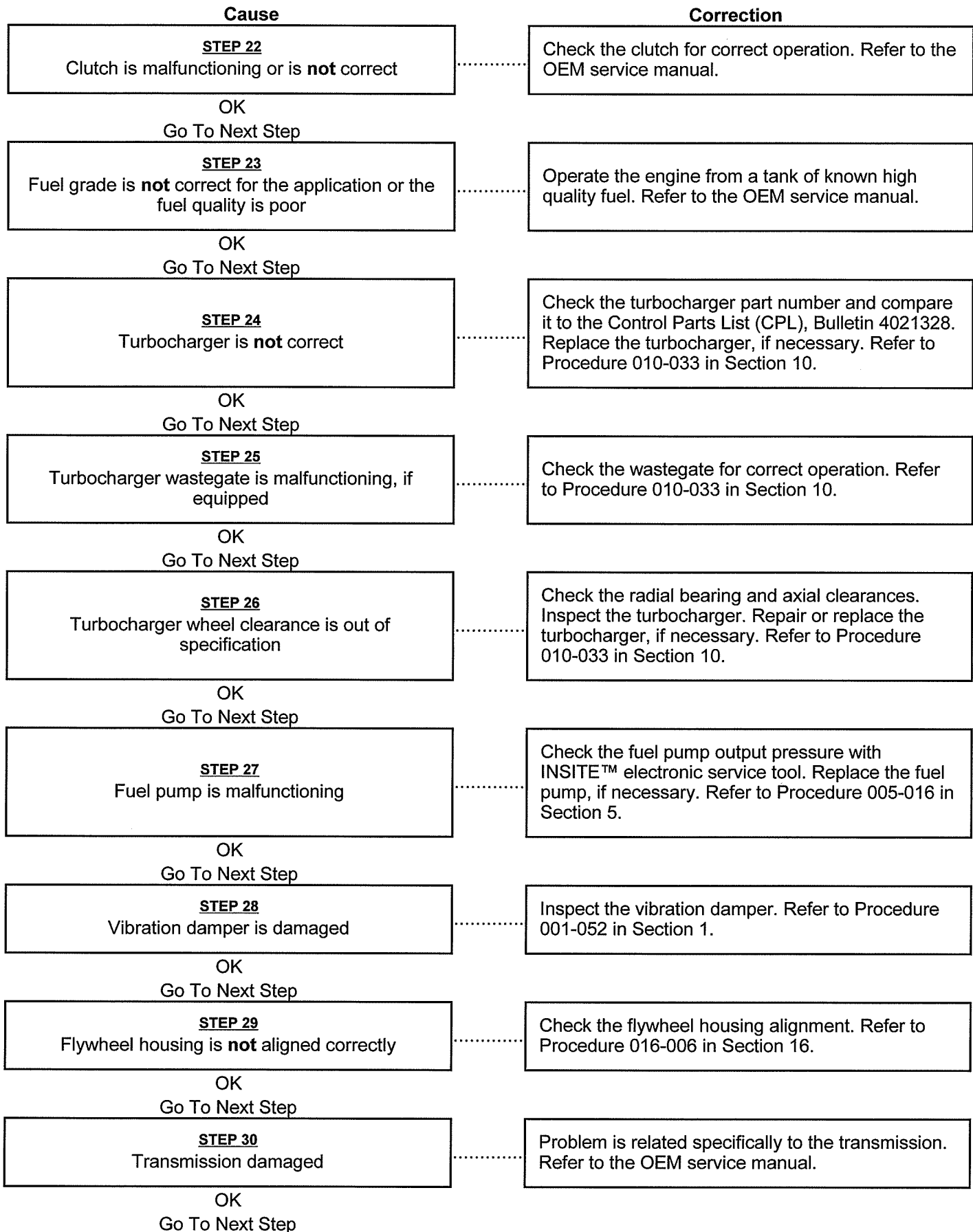
Reference QuickServe™ Online to verify the injector part numbers. Replace the injector(s), if necessary. Refer to Procedure 006-026 in Section 6.

OK

Go To Next Step

Engine Speed Surges in PTO or Cruise Control

This is symptom tree t068



Engine Speed Surges in PTO or Cruise Control

This is symptom tree t068

Cause

Correction

STEP 31
Internal engine damage

Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-083 in Section 7.

Engine Starts But Will Not Keep Running

This is symptom tree t072

Cause	Correction
<p>STEP 1 Electronic fault codes active or high counts of inactive fault codes</p>	<p>Refer to Section TF in the Fault Code Troubleshooting Manual, QLS9 CM2350 L102, Bulletin 4332795, for fault code troubleshooting .</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Idle Shutdown or PTO Shutdown features are activated.</p>	<p>Turn the keyswitch OFF for 5 seconds. Turn the keyswitch ON and check fault lamp operation. Use INSITE™ electronic service tool to check Idle Shutdown and PTO parameters..</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Fuel level is low in the tank</p>	<p>Fill the supply tank. Refer to the original equipment manufacturer (OEM) service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Battery voltage is low</p>	<p>Check the batteries and the unswitched battery supply circuit. Refer to Procedure 019-087 in Section 19.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Fuel inlet restriction</p>	<p>Check for fuel inlet restriction. Refer to Procedure 006-020 in Section 6.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Air in fuel system</p>	<p>Bleed the fuel system and correct the source of the leak. Refer to Procedure 006-003 in Section 6.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Keyswitch circuit is malfunctioning</p>	<p>Check the vehicle keyswitch circuit. Refer to Procedure 019-064 in Section 19.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Fuel shutoff valve(s) closed (electronically controlled injection)</p>	<p>Check the fuel shutoff valve and circuit. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 9 Fuel grade is not correct for the application or the fuel quality is poor</p>	<p>Operate the engine from a tank of known high quality fuel. Refer to Procedure 018-002 in Section V of the Operation and Maintenance Manual, QLS9 CM2350 L102, Bulletin 4332797. Refer to Fuels for Cummins® Engines, Bulletin 3379001.</p>
<p>OK Go To Next Step</p>	

Engine Starts But Will Not Keep Running

This is symptom tree t072

Cause

Correction

STEP 10
Vehicle parasitics are excessive

Check for transmission malfunctioning, cooling fan operation cycle time, and engine-driven units. Refer to the OEM service manual.

Engine Will Not Crank - (Electric Starter)

This is symptom tree t074-005

Cause	Correction
<p>STEP 1 Electronic fault codes active or high counts of inactive fault codes</p>	<p>Read the fault codes with an electronic service tool. Refer to Section TF of the Fault Code Troubleshooting Manual, QSL9 CM2350 L102, Bulletin 4332795, for fault code troubleshooting.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Battery voltage is low</p>	<p>Check the battery connections. Refer to the original equipment manufacturer (OEM) service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Broken, loose, or corroded starting circuit connections</p>	<p>Inspect, clean, and tighten both the positive and negative connections between the starting motor and battery, including the magnetic switch. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Battery capacity is below specification</p>	<p>Replace the batteries, if necessary. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 OEM starter interlock devices engaged</p>	<p>Check the starter interlock devices. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Starting circuit component is malfunctioning</p>	<p>Check the starting circuit components. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Starter solenoid does not make an audible sound</p>	<p>Check the magnetic switch and starter solenoid. Refer to Procedure 013-017 and Procedure 013-019 in Section 13.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Battery cables are not the correct gauge or length</p>	<p>Replace the battery cables with larger gauge or shorter length cables. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 9 Engine-driven units are engaged</p>	<p>Disengage any engine-driven units.</p>
<p>OK Go To Next Step</p>	

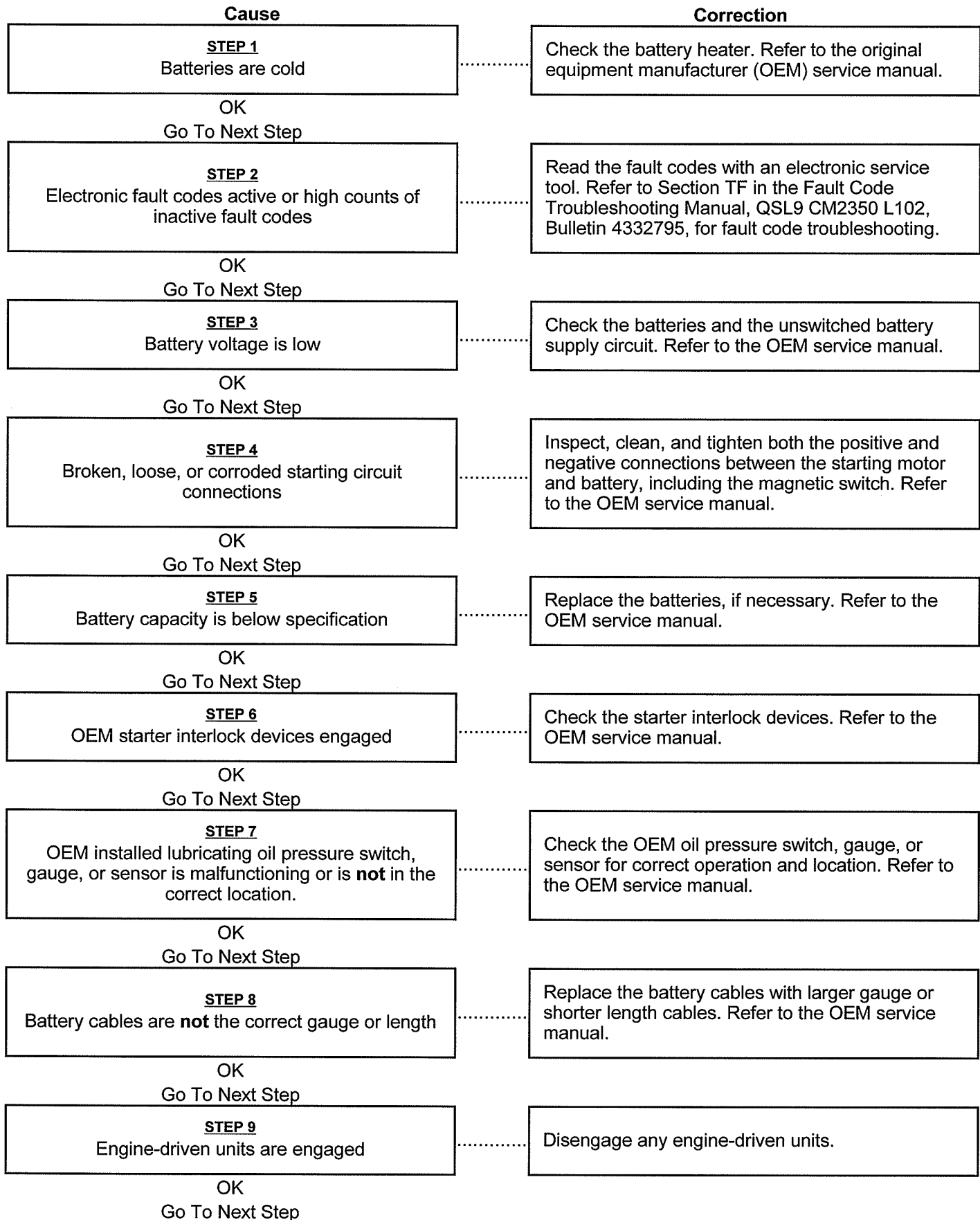
Engine Will Not Crank - (Electric Starter)

This is symptom tree t074-005

Cause	Correction
<p>STEP 10 Starter motor malfunction</p>	<p>Check the voltage drop at the starting motor. Refer to Procedure 013-020 in Section 13.</p>
<p>OK Go To Next Step</p>	
<p>STEP 11 Starting motor pinion or ring gear is damaged</p>	<p>Remove the starting motor and inspect the gear. Refer to Procedure 013-020 in Section 13.</p>
<p>OK Go To Next Step</p>	
<p>STEP 12 Crankshaft rotation is impaired</p>	<p>Check the crankshaft for ease of rotation. Refer to Procedure 001-016 in Section 1.</p>
<p>OK Go To Next Step</p>	
<p>STEP 13 Hydraulic lock in a cylinder</p>	<p>Remove the injectors and rotate the crankshaft. Look for the source of fluid in the cylinder. Refer to Procedure 006-026 in Section 6.</p>
<p>OK Go To Next Step</p>	
<p>STEP 14 Internal engine damage</p>	<p>Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-083 in Section 7.</p>

Engine Cranks Slowly - (Electric Starter)

This is symptom tree t074-010



Engine Cranks Slowly - (Electric Starter)

This is symptom tree t074-010

Cause

Correction

STEP 10

Starting circuit component is malfunctioning

Check the starting circuit components. Refer to the OEM service manual.

OK

Go To Next Step

STEP 11

Starter motor malfunction

Check the voltage drop at the starting motor. Refer to Procedure 013-020 in Section 13.

OK

Go To Next Step

STEP 12

Starting motor pinion or ring gear is damaged

Remove the starting motor and inspect the gear. Refer to Procedure 013-020 in Section 13.

OK

Go To Next Step

STEP 13

Lubricating oil level is above specification

Check the oil level. Verify the dipstick calibration and oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-009 in Section 7.

OK

Go To Next Step

STEP 14

Lubricating oil does **not** meet specifications for operating conditions

Change the oil and filters. Refer to Procedure 018-017 in Section V.

OK

Go To Next Step

STEP 15

Crankshaft rotation is impaired

Check the crankshaft for ease of rotation. Refer to Procedure 001-016 in Section 1.

OK

Go To Next Step

STEP 16

Internal engine damage

Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-083 in Section 7.

Engine Will Not Shut Off

This is symptom tree t081

Cause

STEP 1

Keyswitch circuit is malfunctioning

OK

Go To Next Step

STEP 2

Turbocharger oil seal is leaking

OK

Go To Next Step

STEP 3

Engine is running on fumes drawn into the air intake

OK

Go To Next Step

STEP 4

Equipment controller is trying to turn off the engine with a datalink message that is **not** supported by the engine

OK

Go To Next Step

STEP 5

Engine control module (ECM) is malfunctioning

Correction

Check the vehicle, equipment, or vessel keyswitch circuit. Refer to Procedure 019-064 in Section 19.

Check the turbocharger compressor and turbine seals. Refer to Procedure 010-033 in Section 10.

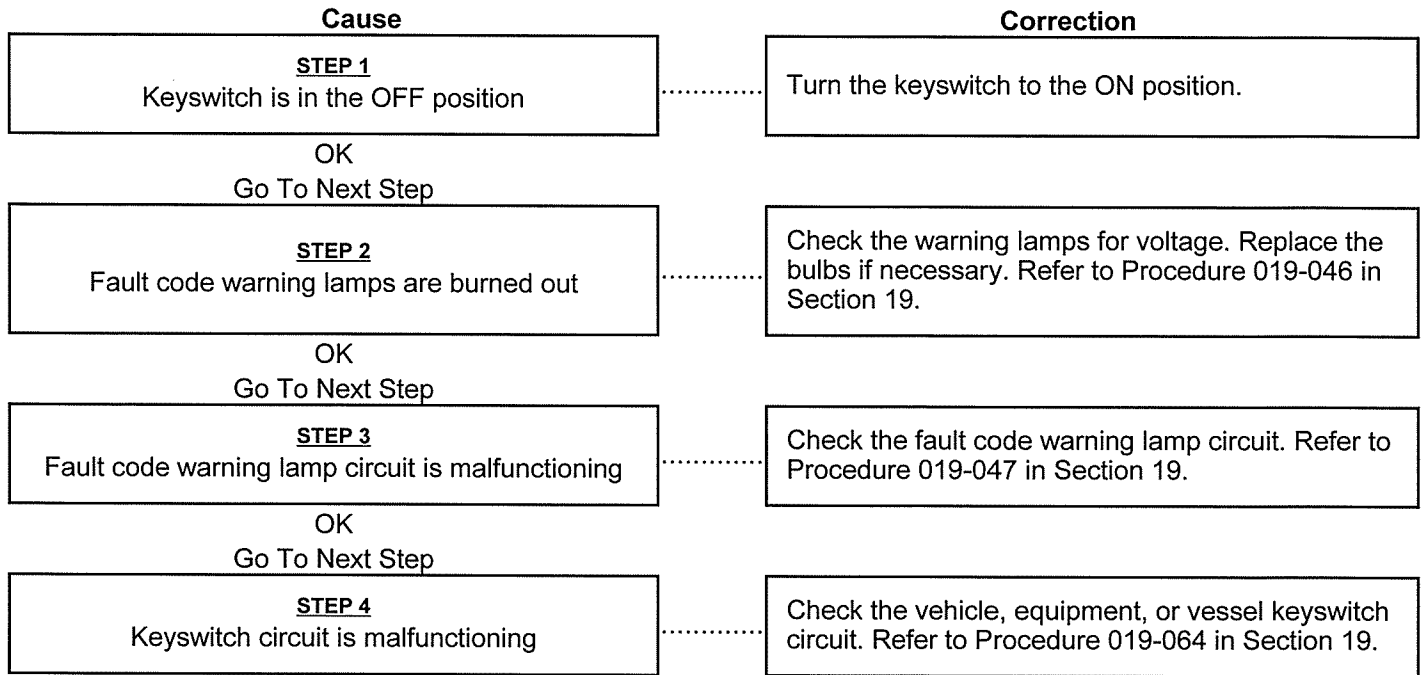
Check the air intake ducts. Locate and isolate the source of the fumes. Repair as necessary. Refer to the original equipment manufacturer (OEM) service manual.

The hardwired keyswitch signal is the **only** appropriate signal for shutting the engine OFF.

Replace the ECM. Refer to Procedure 019-031 in Section 19.

Fault Code Warning Lamps Do Not Illuminate

This is symptom tree t084



Fuel Consumption Excessive

This is symptom tree t087

Cause

Correction

STEP 1

Interview the operator to verify the complaint

Refer to the Driveability/Low Power - Customer Complaint Form at the beginning of the TS section. Follow the instructions on the form before continuing with this troubleshooting symptom tree.

OK

Go To Next Step

STEP 2

Operator technique is **not** correct

Explain correct engine operation to the operator. Refer to Procedure 101-015 in Section 1 of the Operation and Maintenance Manual, QSL9 CM2350 L102, Bulletin 4332797.

OK

Go To Next Step

STEP 3

Lubricating oil level is above specification

Check the oil level. Verify the dipstick calibration and oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-009 in Section 7 and Procedure 007-037 in Section 7.

OK

Go To Next Step

STEP 4

Lubricating oil does **not** meet specifications for operating conditions

Change the oil and filters. Refer to Procedure 007-037 or Procedure 007-013 in Section 7.

OK

Go To Next Step

STEP 5

Hubometer or odometer is miscalibrated

Check the hubometer and odometer calibrations. Calibrate or replace the hubometer or odometer, if necessary. Calculate fuel consumption with new mileage figures.

OK

Go To Next Step

STEP 6

Electronic fault codes active or high counts of inactive fault codes

View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to Section TF of the Fault Code Troubleshooting Manual, QSL9 CM2350 L102, Bulletin 4332795, for fault code troubleshooting.

OK

Go To Next Step

STEP 7

Programmable parameters or selected features are **not** correct

Check the programmable parameters and the selected features with an electronic service tool. Set the parameters and features again, if necessary. Refer to Procedure 019-078 in Section 19.

OK

Go To Next Step

Fuel Consumption Excessive

This is symptom tree t087

Cause

Correction

<p>STEP 8 Engine control module (ECM) calibration is malfunctioning</p>	<p>Verify the ECM calibration is correct. Check the calibration revision history for applicable fixes to the calibration stored in the ECM. Refer to the calibration history spreadsheet on QuickServe™ Online or the INCAL™ CD-ROM. Compare the calibration stored in the ECM with the engine rating and Control Parts List (CPL), Bulletin 4021328. If necessary, calibrate the ECM. Refer to Procedure 019-032 in Section 19.</p>
<p>OK Go To Next Step</p>	
<p>STEP 9 Engine idle or PTO time is excessive</p>	<p>Check the idle or PTO time with INSITE™ electronic service tool. Low oil and coolant temperatures can be caused by excessive idle time (greater than 10 minutes).</p>
<p>OK Go To Next Step</p>	
<p>STEP 10 Aftertreatment system active regeneration time is excessive</p>	<p>Check the aftertreatment system trip information with INSITE™ electronic service tool. Low duty cycle applications can possibly require more active regeneration time to keep the aftertreatment system functioning correctly. Change the vehicle route and/or duty cycle to increase the load on the engine, in order to decrease the amount of active regeneration time.</p>
<p>OK Go To Next Step</p>	
<p>STEP 11 Auxiliary devices using fuel from vehicle's fuel supply tank(s)</p>	<p>Check the fuel consumption of the auxiliary devices. Refer to the original equipment manufacturer (OEM) service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 12 Equipment and environmental factors are affecting fuel consumption</p>	<p>Consider ambient temperatures, wind, tire size, axle alignment, routes, and use of aerodynamic aids when evaluating fuel consumption.</p>
<p>OK Go To Next Step</p>	
<p>STEP 13 Vehicle parasitics are excessive</p>	<p>Check the vehicle for brakes dragging, transmission malfunction, cooling fan operation cycle time, and engine-driven units. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 14 Drivetrain is not correctly matched to the engine</p>	<p>Check for correct gearing and drivetrain components. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	

Fuel Consumption Excessive

This is symptom tree t087

Cause

Correction

STEP 15

Intake manifold pressure (boost) sensor or circuit is malfunctioning

Check the boost sensor and circuit. Compare the intake manifold pressure sensor reading in the monitor mode. Use INSITE™ electronic service tool to compare to a manual pressure gauge. Refer to Procedure 019-159 in Section 19.

OK

Go To Next Step

STEP 16

Vehicle speed sensor (VSS) or circuit is malfunctioning

Refer to the appropriate electronic service tool manual. If the monitor shows speed, check the sensor and circuit. Refer to Procedure 019-090 in Section 19 and Procedure 019-091 in Section 19.

OK

Go To Next Step

STEP 17

Vehicle speed sensor (VSS) tampering has occurred

Check the vehicle speed sensor and circuit for tampering. Check for Fault Code 242. Repair the circuit as necessary. Refer to Procedure 019-090 in Section 19 and Procedure 019-091 in Section 19.

OK

Go To Next Step

STEP 18

Fuel leak

Check the fuel lines, fuel connections, and fuel filters for leaks. Check the fuel lines to the supply tanks. Refer to the OEM service manual.

OK

Go To Next Step

STEP 19

Air intake or exhaust leaks

Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024 in Section 10.

OK

Go To Next Step

STEP 20

Charge-air cooler is restricted or leaking

Inspect the charge-air cooler for air restrictions or leaks. Refer to Procedure 010-027 in Section 10.

OK

Go To Next Step

STEP 21

Air intake system restriction is above specification

Check the air intake system for restrictions. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031 in Section 10.

OK

Go To Next Step

STEP 22

Exhaust system restriction is **not** within specification

Check the exhaust system for restrictions. Refer to Procedure 011-009 in Section 11.

OK

Go To Next Step

Fuel Consumption Excessive

This is symptom tree t087

Cause

STEP 23

Fuel grade is **not** correct for the application or the fuel quality is poor

OK

Go To Next Step

STEP 24

Overhead adjustments are **not** correct

OK

Go To Next Step

STEP 25

Injector(s) are malfunctioning

OK

Go To Next Step

STEP 26

Internal engine damage

Correction

Operate the engine from a tank of known high quality fuel. Refer to Procedure 018-003 in Section V of the Operation and Maintenance Manual, QSL9 CM2350 L102, Bulletin 4332797.

Measure and adjust the overhead settings. Refer to Procedure 003-004 in Section 3.

Perform diagnostics to find the malfunctioning injector(s). Replace the injector(s) as necessary. Refer to Procedure 014-008 in Section 14 and Procedure 006-026 in Section 6.

Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-048 in Section 7 and Procedure 007-083 in Section 7.

Fuel in Coolant

This is symptom tree t091

Cause

Correction

STEP 1

Bulk coolant supply is contaminated

Check the bulk coolant supply. Drain the coolant and replace with non-contaminated coolant. Replace the coolant filters. Refer to Procedure 008-018 in Section 8.

OK

Go To Next Step

STEP 2

Cylinder head is cracked or porous

Pressure test the cylinder head. Refer to Procedure 006-013 in Section 6 to disconnect the fuel drain connection at the rear of the cylinder head. Pressure test the cooling system and look for coolant leaks. Refer to Procedure 008-020 in Section 8.

Fuel in the Lubricating Oil

This is symptom tree t092

Cause

Correction

STEP 1

Electronic fault codes active or high counts of inactive fault codes

View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to Section TF in the Fault Code Troubleshooting Manual, QSL9 CM2350 L102, Bulletin 4332795, for fault code troubleshooting.

OK

Go To Next Step

STEP 2

Engine idle time is excessive

Low oil and coolant temperatures can be caused by long idle times (greater than 10 minutes). Shut the engine OFF rather than idle for long periods. If idle time is necessary, raise the idle speed. Refer to Procedure 101-015 in Section 1 in the Operation and Maintenance Manual, QSL9 CM2350 L102, Bulletin 4332797.

OK

Go To Next Step

STEP 3

Aftertreatment system active regeneration time is excessive.

Check the aftertreatment system trip information with INSITE™ electronic service tool, under Advanced ECM Data, Aftertreatment History. If the average time between regenerations is less than 3 hours, troubleshoot the root cause of excessive regeneration.. Refer to the Selective Catalytic Reduction (SCR) Conditioning - Excessive Automatic and/or Manual (Non-Mission) Conditioning troubleshooting symptom tree in Section TS.

OK

Go To Next Step

STEP 4

Fuel drain line restriction

Check the fuel drain lines for restriction. Clear or replace the fuel lines, check valves, or tank vents as necessary. Refer to Procedure 006-012 in Section 6.

OK

Go To Next Step

STEP 5

Injector is malfunctioning

Perform a high pressure injector return flow test. Replace the injector as necessary. Refer to Procedure 005-236 in Section 5.

OK

Go To Next Step

STEP 6

Internal fuel leaks

Inspect for fuel leaks. Add fluorescent tracer dye to the fuel system. Refer to Procedure 007-044 in Section 7.

OK

Go To Next Step

STEP 7

Troubleshooting tree has been exhausted

Refer to a Cummins® Authorized Repair Location for technical support.

Intake Manifold Air Temperature Above Specification

This is symptom tree t096

Cause

Correction

STEP 1

Fan drive belt is broken

Check the fan drive belt. Replace the belt, if necessary. Refer to Procedure 008-002 in Section 8.

OK

Go To Next Step

STEP 2

Fan drive belt is loose

Check the belt tension and tighten, if necessary. Refer to Procedure 008-002 in Section 8.

OK

Go To Next Step

STEP 3

Cold weather radiator cover or winterfront is closed

Open the cold weather radiator cover or the winterfront. Refer to the original equipment manufacturer (OEM) service manual.

OK

Go To Next Step

STEP 4

Radiator shutters are **not** opening completely or the shutterstat setting is wrong

Inspect the radiator shutters. Repair or replace if necessary. Refer to the OEM service manual. Check the shutterstat setting.

OK

Go To Next Step

STEP 5

Charge-air cooler fins, radiator fins, or air conditioner condenser fins are damaged or obstructed with debris

Inspect the charge-air cooler, air conditioner condenser, and radiator fins. Clean, if necessary. Refer to Procedure 010-027 in Section 10.

OK

Go To Next Step

STEP 6

Electronic fault codes active or high counts of inactive fault codes

View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to the Fault Code Troubleshooting Manual, QLS9 CM2350 L102, Bulletin 4332795.

OK

Go To Next Step

STEP 7

Intake manifold air temperature sensor has an in-range malfunction

Check the intake manifold air temperature sensors that correspond to the fault code. Replace the sensor, if necessary. Refer to the Fault Code Troubleshooting Manual, QLS9 CM2350 L102, Bulletin 4332795.

OK

Go To Next Step

STEP 8

Programmable parameters or selected features are **not** correct

Check the programmable parameters and the selected features with an electronic service tool. Set the parameters and features again, if necessary. Refer to Procedure 019-078 in Section 19.

OK

Go To Next Step

Intake Manifold Air Temperature Above Specification

This is symptom tree t096

Cause

Correction

STEP 9

Fan drive or fan controls are malfunctioning

Check the fan drive and controls. Refer to Procedure 008-026 in Section 8 if electronically controlled by the engine's engine control module (ECM). If OEM-controlled, see the OEM service manual.

OK

Go To Next Step

STEP 10

Fan is **not** correct

Check the fan part number and compare it to the OEM-specified part number. Replace the fan, if necessary. Refer to the OEM service manual.

OK

Go To Next Step

STEP 11

Fan shroud is damaged or missing or the air recirculation baffles are damaged or missing

Inspect the shroud and the recirculation baffles. Repair, replace, or install, as necessary. Refer to the OEM service manual.

OK

Go To Next Step

STEP 12

Exhaust system leaking hot air into engine compartment

Check the exhaust plumbing for leaks or broken components. Refer to Procedure 010-024 in Section 10.

OK

Go To Next Step

STEP 13

Malfunctioning intake air heater

Connect INSITE™ electronic service tool. From the list of "ECM Diagnostic Tests", select "Grid Heater Override". Follow the instructions on the screen to determine if the cold starting aid is working properly. If the intake air heater is **not** functioning properly, troubleshoot the intake air heater wiring and relay circuits. Refer to Procedure 019-408 in Section 19.

OK

Go To Next Step

STEP 14

Intake manifold pressure (boost) sensor or circuit is malfunctioning

Check the boost sensor and circuit. Compare the intake manifold pressure sensor reading in the monitor mode. Use INSITE™ electronic service tool to compare to a manual pressure gauge. Refer to Procedure 019-159 in Section 19.

OK

Go To Next Step

STEP 15

Exhaust gas recirculation (EGR) valve is leaking

Check the EGR valve for leaks. Refer to Procedure 011-022 in Section 11.

OK

Go To Next Step

Intake Manifold Air Temperature Above Specification

This is symptom tree t096

Cause

Correction

STEP 16
EGR cooler malfunctioning

Check the EGR cooler. Refer to Procedure 011-019 in Section 11.

OK
Go To Next Step

STEP 17
Vehicle cooling system is **not** adequate

Verify that the engine and vehicle cooling systems are using the correct components. Refer to the OEM service manual.

OK
Go To Next Step

STEP 18
Fan is **not** an adequate size for the application

Verify that the fan is the correct size. Refer to the OEM service manual.

Low Idle Adjust Switch Does Not Work

This is symptom tree t099

Cause

STEP 1

Engine idle speed is set at either the minimum or the maximum allowable value

OK

Go To Next Step

STEP 2

Low-idle adjust switch feature is **not** enabled

OK

Go To Next Step

STEP 3

Low-idle adjust switch and circuit is malfunctioning

Correction

The idle adjust switch will **not** adjust the idle speed outside the allowable range. Refer to Procedure 019-052 in Section 19.

Check the low-idle adjust switch feature with an electronic service tool. Refer to Procedure 019-078 in Section 19.

Check the idle adjust switch and circuit. Refer to Procedure 019-052 and Procedure 019-053 in Section 19.

Lubricating Oil Consumption Excessive

This is symptom tree t102

Cause

Correction

STEP 1

Verify the oil consumption rate

Check the amount of oil added versus the mileage. Refer to the Oil Consumption Report form in the Troubleshooting Overview in Section TS.

OK

Go To Next Step

STEP 2

Lubricating oil leak (external)

Inspect the engine for external oil leaks. Tighten the capscrews, pipe plugs, and fittings. Replace gaskets, if necessary. Refer to Procedure 007-048 in Section 7.

OK

Go To Next Step

STEP 3

Crankcase ventilation system is plugged

Check and clean the crankcase breather and vent tube. Refer to Procedure 003-001 and Procedure 003-018 in Section 3.

OK

Go To Next Step

STEP 4

Lubricating oil does **not** meet specifications for operating conditions

Change the oil and filters. Refer to Procedure 007-037 in Section 7. Also, refer to Procedure 018-003 in Section V of the Operation and Maintenance Manual, QSL9 CM2350 L102, Bulletin 4332797, for lubricating oil recommendations and specifications.

OK

Go To Next Step

STEP 5

Lubricating oil drain interval is excessive

Verify the correct lubricating oil drain interval. Refer to Procedure 102-002 in Section 2 of the Operation and Maintenance Manual, QSL9 CM2350 L102, Bulletin 4332797.

OK

Go To Next Step

STEP 6

Air compressor is pumping lubricating oil into the air system

Check the air lines for carbon buildup and lubricating oil. Refer to Procedure 012-003 in Section 12. If oil is found, refer to the Air Compressor Pumping Excess Lubricating Oil into the Air System troubleshooting symptom tree in Section TS.

OK

Go To Next Step

STEP 7

Lubricating oil cooler is leaking oil

Check the lubricating oil cooler for oil leaks. Refer to the Coolant Loss - Internal troubleshooting symptom tree in Section TS, if oil is found.

OK

Go To Next Step

Lubricating Oil Consumption Excessive

This is symptom tree t102

Cause

Correction

STEP 8

Lubricating oil level is above specification

Check the oil level. Verify the dipstick calibration and oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-009 in Section 7.

OK

Go To Next Step

STEP 9

Engine angularity during operation exceeds specification

Refer to the Engine Specification Data Sheet for angularity specifications for the engine being serviced.

OK

Go To Next Step

STEP 10

Turbocharger oil seal is leaking

Check the turbocharger compressor and turbine seals for signs of an oil leak. Refer to Procedure 010-033 in Section 10 in the Initial Check section. Refer to the Turbocharger - Compressor Seal Oil Leak troubleshooting symptom tree in Section TS, if a compressor seal oil leak is found. Refer to the Turbocharger - Turbine Seal Oil Leak troubleshooting symptom tree in Section TS, if a turbine side oil leak is found.

OK

Go To Next Step

STEP 11

Piston rings are not seated correctly (after an engine rebuild or piston installation)

Check blowby. Refer to Procedure 014-010 in Section 14. If the blowby is excessive, check the piston rings for correct seating. Refer to Procedure 001-043 and Procedure 001-047 in Section 1.

OK

Go To Next Step

STEP 12

Lubricating oil is contaminated with coolant or fuel

Refer to the Lubricating Oil Contaminated troubleshooting symptom tree in Section TS.

OK

Go To Next Step

STEP 13

Valve stem clearance is excessive or the valve stem seals are damaged

Check the valve stems and seals. Refer to Procedure 002-004 in Section 2.

OK

Go To Next Step

STEP 14

Cylinder head valve guides are excessively worn

Check the valve guides for wear. Replace the cylinder head, if necessary. Refer to Procedure 002-004 in Section 2.

OK

Go To Next Step

Lubricating Oil Consumption Excessive

This is symptom tree t102

Cause

Correction

STEP 15

Piston or piston rings are worn or damaged

Check for air intake system leaks. Check the pistons and piston rings for wear or damage. Refer to Procedure 010-024 in Section 10. Analyze the lubricating oil and oil filters to locate an area of probable damage and cause. Refer to Procedure 007-083 in Section 7.

OK

Go To Next Step

STEP 16

Internal engine damage

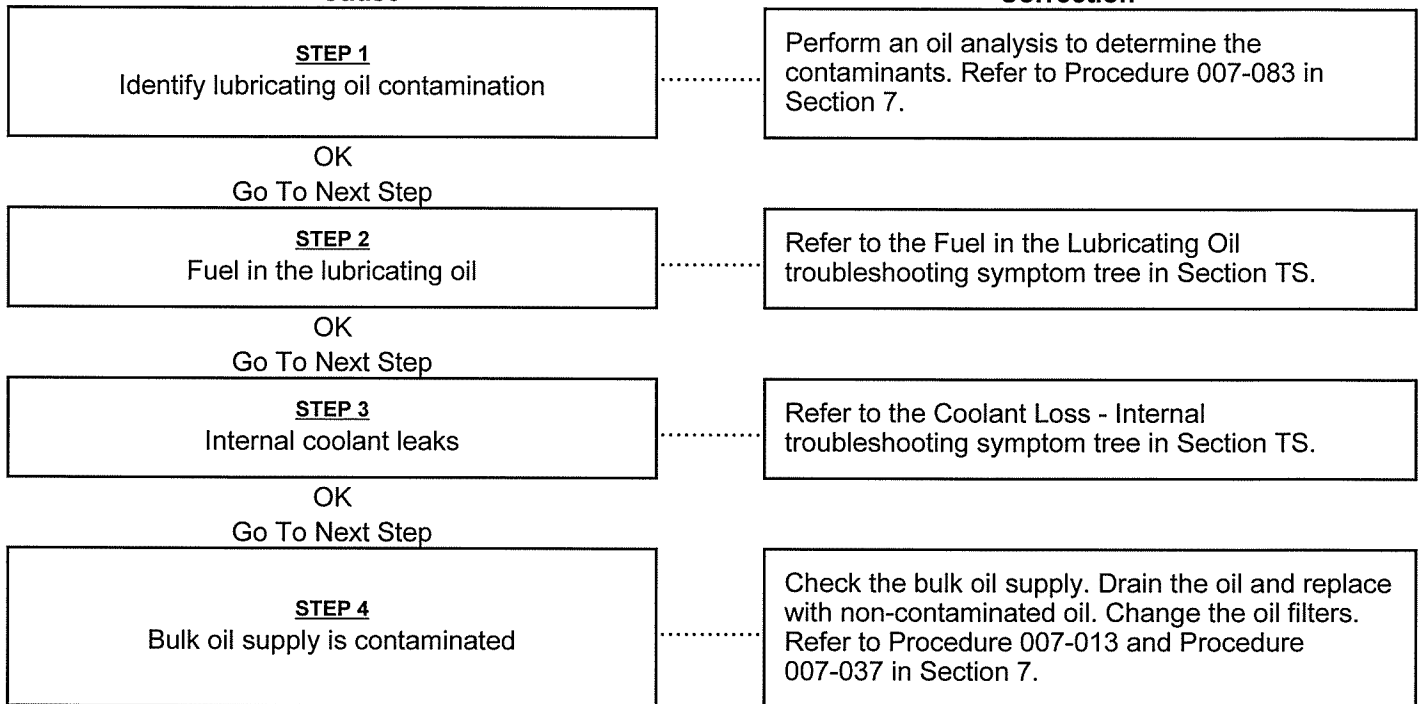
Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-083 in Section 7.

Lubricating Oil Contaminated

This is symptom tree t103

Cause

Correction



Lubricating Oil Pressure High

This is symptom tree t104

Cause

STEP 1

Coolant temperature is below specification

OK

Go To Next Step

STEP 2

Lubricating oil drain interval is excessive

OK

Go To Next Step

STEP 3

Lubricating oil pressure switch, gauge, or sensor is malfunctioning or is **not** in the correct location.

OK

Go To Next Step

STEP 4

Lubricating oil pressure sensor or circuit is malfunctioning (electronic controlled fuel system)

OK

Go To Next Step

STEP 5

Main oil pressure regulator is malfunctioning

Correction

Refer to the Coolant Temperature is Below Normal troubleshooting symptom tree in Section TS.

Verify the correct lubricating oil drain interval. Refer to the maintenance schedule in Procedure 102-002 in Section 2 in the Operation and Maintenance Manual, QSL9 CM2350 L102, Bulletin 4332797.

Check the oil pressure switch, gauge, or sensor for correct operation and location. Refer to the original equipment manufacturer (OEM) service manual.

Check the lubricating oil pressure sensor and circuit. Refer to Procedure 019-066 in Section 19.

Replace the main oil pressure regulator assembly. Refer to Procedure 007-029 in Section 7.

Lubricating Oil Pressure Low

This is symptom tree t105

Cause

Correction

STEP 1

Electronic fault codes active or high counts of inactive fault codes

Read the fault codes with an electronic service tool. Refer to Section TF in the Fault Code Troubleshooting Manual, QSL9 CM2350 L102, Bulletin 4332795, for fault code troubleshooting.

OK

Go To Next Step

STEP 2

Lubricating oil pressure switch, gauge, or sensor is malfunctioning or is **not** in the correct location.

Check the oil pressure switch, gauge, or sensor for correct operation and location. Refer to the original equipment manufacturer (OEM) service manual.

OK

Go To Next Step

STEP 3

Lubricating oil level is above or below specification

Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-037 and Procedure 007-009 in Section 7.

OK

Go To Next Step

STEP 4

Lubricating oil leak (external)

Inspect the engine for external oil leaks. Tighten the capscrews, pipe plugs, and fittings. Replace gaskets, if necessary. Refer to Procedure 007-001, Procedure 007-003, Procedure 007-013, Procedure 007-025, and Procedure 007-037 in Section 7.

OK

Go To Next Step

STEP 5

Lubricating oil does **not** meet specifications for operating conditions

Change the oil and filters. Refer to Procedure 018-017 in Section V.

OK

Go To Next Step

STEP 6

Lubricating oil filter is **not** correct

Make sure the correct oil filter is being used. Refer to Procedure 018-024 in Section V of the Operation and Maintenance Manual, QSL9 CM2350 L102, Bulletin 4332797.

OK

Go To Next Step

STEP 7

Lubricating oil is contaminated with coolant or fuel

Refer to the Lubricating Oil Contaminated troubleshooting symptom tree in Section TS.

OK

Go To Next Step

STEP 8

Engine angularity during operation exceeds specification

Refer to to the engine performance data sheet.

OK

Go To Next Step

Lubricating Oil Pressure Low

This is symptom tree t105

Cause

STEP 9

Lubricating oil pressure sensor or circuit is malfunctioning (electronic controlled fuel system)

OK

Go To Next Step

STEP 10

Main oil pressure regulator is malfunctioning

OK

Go To Next Step

STEP 11

Lubricating oil suction or transfer tube is loose or broken, or the gasket or o-rings are leaking

OK

Go To Next Step

STEP 12

Lubricating oil pump is malfunctioning

OK

Go To Next Step

STEP 13

Lubricating oil cooler is plugged

OK

Go To Next Step

STEP 14

Piston cooling nozzles are damaged or are **not** installed correctly

OK

Go To Next Step

STEP 15

Internal engine damage or internal lubricating oil leak

OK

Go To Next Step

STEP 16

Instant loss of lubricating engine oil

OK

Go To Next Step

Correction

Check the lubricating oil pressure sensor and circuit. Refer to Procedure 019-066 in Section 19.

Check the main oil pressure regulator assembly. Refer to Procedure 007-029 in Section 7.

Remove and inspect the oil pan or suction tube. Refer to Procedure 007-025 in Section 7.

Inspect the lubricating oil pump. Refer to Procedure 007-031 in Section 7.

Check the oil cooler. Refer to Procedure 007-003 in Section 7.

Check the piston cooling nozzles for damage and correct installation. Refer to Procedure 001-046 in Section 1.

Analyze the lubricating oil. Inspect the oil filter. Check the main bearings, rod bearings, camshaft bushings, and rocker lever bushings for excessive wear. Refer to Procedure 001-005, Procedure 001-006, Procedure 001-010 in Section 1, Procedure 007-083 in Section 7, and Procedure 003-008 in Section 3.

Inspect the connecting rod bearings, main bearings, turbocharger, lubricating oil pump, and lubricating oil cooler. Refer to Procedure 001-005, Procedure 001-006 in Section 1, Procedure 007-003, Procedure 007-031 in Section 7, and Procedure 010-033 in Section 10.

Lubricating Oil Pressure Low

This is symptom tree t105

Cause

STEP 17

Significant connecting rod and main bearing damage as a result of instant loss of lubricating engine oil

Correction

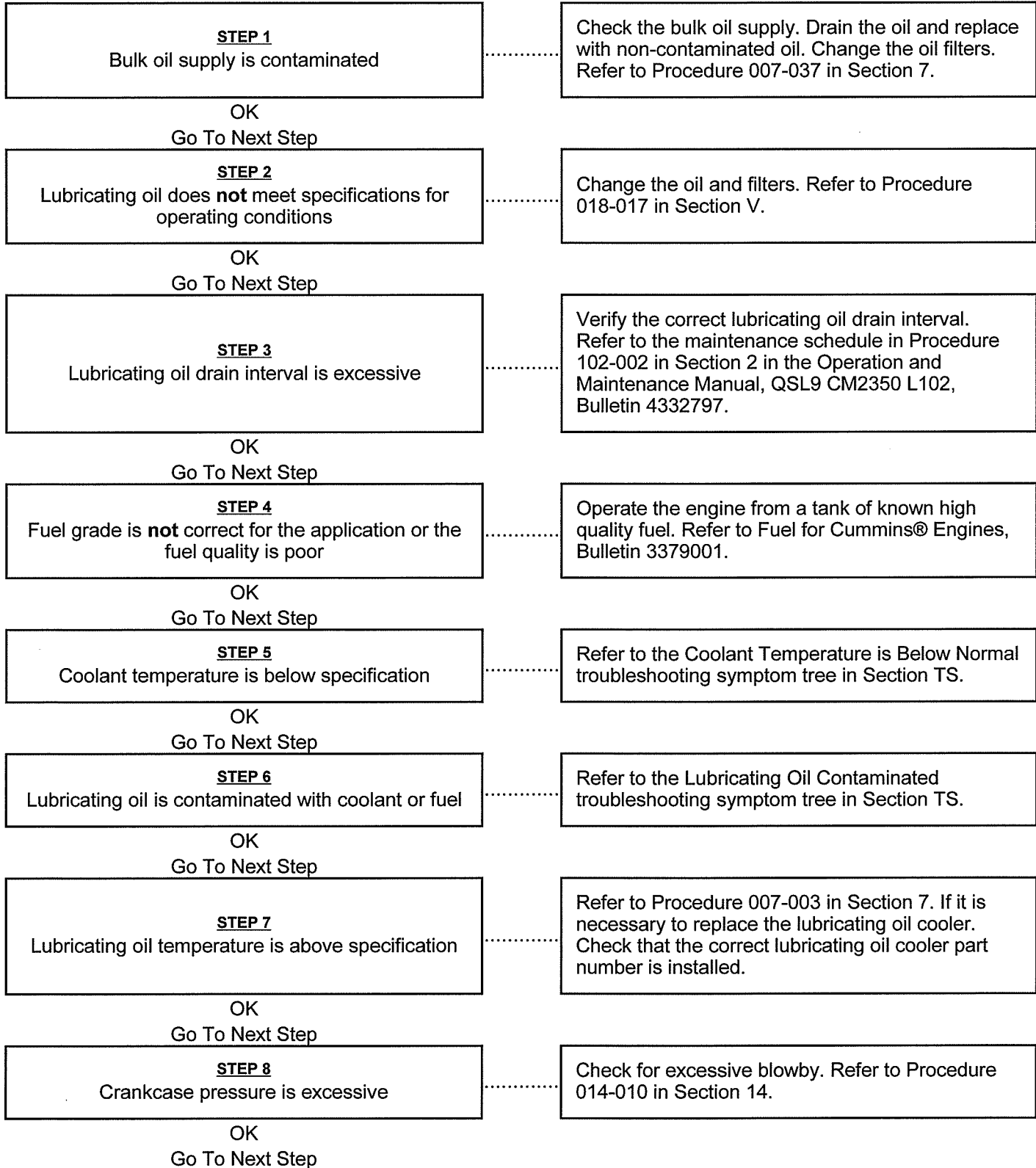
Inspect the air compressor bushings, camshaft bushings, connecting rods, crankshaft, pistons and cylinder liners. Refer to Procedure 001-010, Procedure 001-014, Procedure 001-016, Procedure 001-028, Procedure 001-043 in Section 1, and Procedure 012-014 in Section 12.

Lubricating Oil Sludge in the Crankcase Excessive

This is symptom tree t106

Cause

Correction



Lubricating Oil Sludge in the Crankcase Excessive

This is symptom tree t106

Cause

STEP 9

Exhaust system restriction is **not** within specification

Correction

Check the exhaust system for restrictions. Refer to Procedure 011-009 in Section 11.

Lubricating Oil Temperature Above Specification

This is symptom tree t107

Cause

STEP 1

Electronic fault codes active or high counts of inactive fault codes

OK

Go To Next Step

STEP 2

Coolant temperature is above specification

OK

Go To Next Step

STEP 3

Lubricating oil level is above or below specification

OK

Go To Next Step

STEP 4

OEM lubricating oil temperature switch, gauge, or sensor malfunctioning or **not** in the correct location.

OK

Go To Next Step

STEP 5

Lubricating oil thermostat is malfunctioning

OK

Go To Next Step

STEP 6

OEM components cooled with engine lubricating oil are malfunctioning

OK

Go To Next Step

STEP 7

Lubricating oil cooler is plugged

OK

Go To Next Step

STEP 8

Incorrect lubricating oil cooler installed

OK

Go To Next Step

Correction

View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to Section TF in the Fault Code Troubleshooting Manual, CM2350 L102, Bulletin 4332795, for fault code troubleshooting.

Refer to the Coolant Temperature Above Normal - Gradual Overheat troubleshooting symptom tree in Section TS.

Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-037 and Procedure 007-009 in Section 7.

Check the OEM oil temperature switch, gauge, or sensor for correct operation and location. Refer to the original equipment manufacturer (OEM) service manual.

Check the oil thermostat. Refer to Procedure 007-039 in Section 7.

Check OEM components. Refer to the OEM service manual.

Check the oil cooler. Refer to Procedure 007-003 in Section 7.

Check if the correct lubricating oil cooler part number is installed. Refer to Procedure 007-003 in Section 7.

Lubricating Oil Temperature Above Specification

This is symptom tree t107

Cause

STEP 9
Internal engine damage

Correction

Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-083 and Procedure 007-048 in Section 7.

Lubricating or Transmission Oil in the Coolant

This is symptom tree t108

Cause	Correction
<p>STEP 1 Bulk coolant supply is contaminated</p>	<p>Check the bulk coolant supply. Drain the coolant and replace with non-contaminated coolant. Replace the coolant filters. Refer to Procedure 008-018 and Procedure 008-006 in Section 8.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Lubricating oil cooler is malfunctioning</p>	<p>Check the oil cooler. Refer to Procedure 007-003 in Section 7.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Torque converter cooler or hydraulic oil cooler is malfunctioning</p>	<p>Remove and inspect the cooler cores and o-rings. Refer to the original equipment manufacturer (OEM) service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Turbocharger bearing housing is cracked or porous</p>	<p>Check the turbocharger bearing housing. Refer to Procedure 010-033 in Section 10.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Cylinder head gasket is leaking</p>	<p>Check the cylinder head gasket. Refer to Procedure 002-004 in Section 2.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Cylinder head is cracked or porous</p>	<p>Remove the intake and the exhaust manifolds. Check for evidence of coolant leaks. If necessary, operate the engine at low idle. Pressure test the cylinder head. Refer to Procedure 002-004 in Section 2.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Air compressor cylinder head is cracked or porous, or has a leaking gasket</p>	<p>Inspect the air compressor cylinder head and gasket. Refer to Procedure 012-014 in Section 12.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Cylinder block is cracked or porous</p>	<p>Inspect the cylinder block. Refer to Procedure 001-026 in Section 1.</p>

PTO or Cruise Control Does Not Operate

This is symptom tree t112

Cause

Correction

STEP 1

Programmable parameters or selected features are **not** correct

Check the programmable parameters and the selected features with an electronic service tool. Set the parameters and features again, if necessary. Refer to Procedure 019-078 in Section 19.

OK

Go To Next Step

STEP 2

Engine control module (ECM) calibration is malfunctioning

Verify that the ECM calibration is correct. Check the calibration revision history for applicable fixes to the calibration stored in the ECM. Refer to the calibration history spreadsheet on Quickserve™ Online. Click here to see [ecm_calibration_rev_history.xls](#) on Quickserve™ Online Internet Website or the INCAL™ calibration CD. Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin 4021328. If necessary, calibrate the ECM. Refer to Procedure 019-032 in Section 19.

OK

Go To Next Step

STEP 3

Vehicle speed sensor (VSS) or circuit is malfunctioning

Refer to the appropriate electronic service tool manual. If the monitor shows speed, check the sensor and circuit. Refer to Procedure 019-090, Procedure 019-091, and Procedure 019-093 in Section 19.

OK

Go To Next Step

STEP 4

Clutch switch or circuit is malfunctioning

Check the clutch switch adjustment, switch, and circuit. Refer to Procedure 019-009 or Procedure 019-010 in Section 19.

OK

Go To Next Step

STEP 5

Engine brake on/off switch or circuit is malfunctioning

Check the engine brake on/off switch and circuit. Refer to Procedure 019-034 and Procedure 019-035 in Section 19.

OK

Go To Next Step

STEP 6

Vehicle brake switch or circuit is malfunctioning

Check the vehicle brake switch and the circuit. Refer to Procedure 019-088 in Section 19.

OK

Go To Next Step

STEP 7

Cruise Control/PTO ON/OFF switch or circuit is malfunctioning

Check the Cruise Control/PTO ON/OFF switch and the circuit. Refer to Procedure 019-021 and Procedure 019-022 in Section 19.

OK

Go To Next Step

PTO or Cruise Control Does Not Operate

This is symptom tree t112

Cause

STEP 8

Cruise Control/PTO selector switch or circuit is malfunctioning

Correction

Check the Cruise Control/PTO selector switch and circuit. Refer to Procedure 019-023 and Procedure 019-024 in Section 19.

Smoke, Black - Excessive

This is symptom tree t116

Cause

Correction

STEP 1

Engine control module (ECM) calibration update available

Verify the ECM calibration is correct. Check the calibration revision history found on QuickServe™ Online for applicable corrections to the calibration stored in the ECM. If necessary, calibrate the ECM. Refer to Procedure 019-032 in Section 19.

OK

Go To Next Step

STEP 2

Leaking air intake system or charge-air cooler

Inspect the air intake and exhaust systems for air leaks. Check all air compressor plumbing, EGR plumbing, intake plumbing, charge-air cooler hoses, and exhaust plumbing for possible air leaks. Refer to Procedure 010-024 in Section 10.

OK

Go To Next Step

STEP 3

Malfunctioning fuel injector

Perform INSITE™ electronic service tool Cylinder Cutout Test to determine if the misfire can be isolated to a single injector. Refer to Procedure 014-008 in Section 14.

OK

Go To Next Step

STEP 4

High fuel inlet restriction

Perform the Fuel Inlet Restriction Test. Refer to Procedure 006-020 in Section 6.

OK

Go To Next Step

STEP 5

High air intake restriction

Check the air filter to make sure it is **not** plugged. Check the air intake system for restriction. Refer to Procedure 010-031 in Section 10.

OK

Go To Next Step

STEP 6

Air intake manifold heater starting aid is restricted or plugged, if equipped

Inspect the air intake manifold heater starting aid for plugging or soot buildup on the heating elements. Refer to Procedure 010-023 in Section 10.

OK

Go To Next Step

Smoke, Black - Excessive

This is symptom tree t116

Cause

Correction

STEP 7
Stuck open EGR valve

If the engine idle speed is 1050 rpm or below, run the engine at idle and use INSITE™ electronic service tool to monitor the EGR differential pressure value. EGR differential pressure **must** read less than 3.4 kpa [1.0 in Hg]. If the EGR differential pressure is above this specification, a stuck open EGR valve has been detected. If the engine idle speed is above 1050 rpm, use INSITE™ electronic service tool to reduce the engine idle speed to below 1050 rpm. Refer to the OEM service manual to verify that no OEM components can be damaged due to the reduced idle speed.

OK
Go To Next Step

STEP 8
Plugged EGR differential pressure sensor supply ports

Check the EGR differential pressure sensor flow ports. Inspect the EGR differential pressure sensor flow port cross-drillings for soot blockage. Inspect the exhaust gas entrance ports for soot blockage. Refer to Procedure 010-080 in Section 10.

OK
Go To Next Step

STEP 9
Worn or damaged turbocharger blades

Inspect the turbocharger compressor and turbine blades for damage or wear. Measure the turbocharger wheel axial and radial clearances against the specifications. Refer to Procedure 010-033 in Section 10. Check the EGR valve assembly for external and internal leaks. Check the EGR cooler for external leaks and inspect the cooler matrix for blockage.

OK
Go To Next Step

STEP 10
Broken valve seat insert

Check the valve lash adjustment. If the valve seat insert is missing on a specific cylinder, the adjusting screw will be much higher than all other cylinders. Refer to Procedure 003-004 in Section 3.

OK
Go To Next Step

STEP 11
Fuel injector is malfunctioning

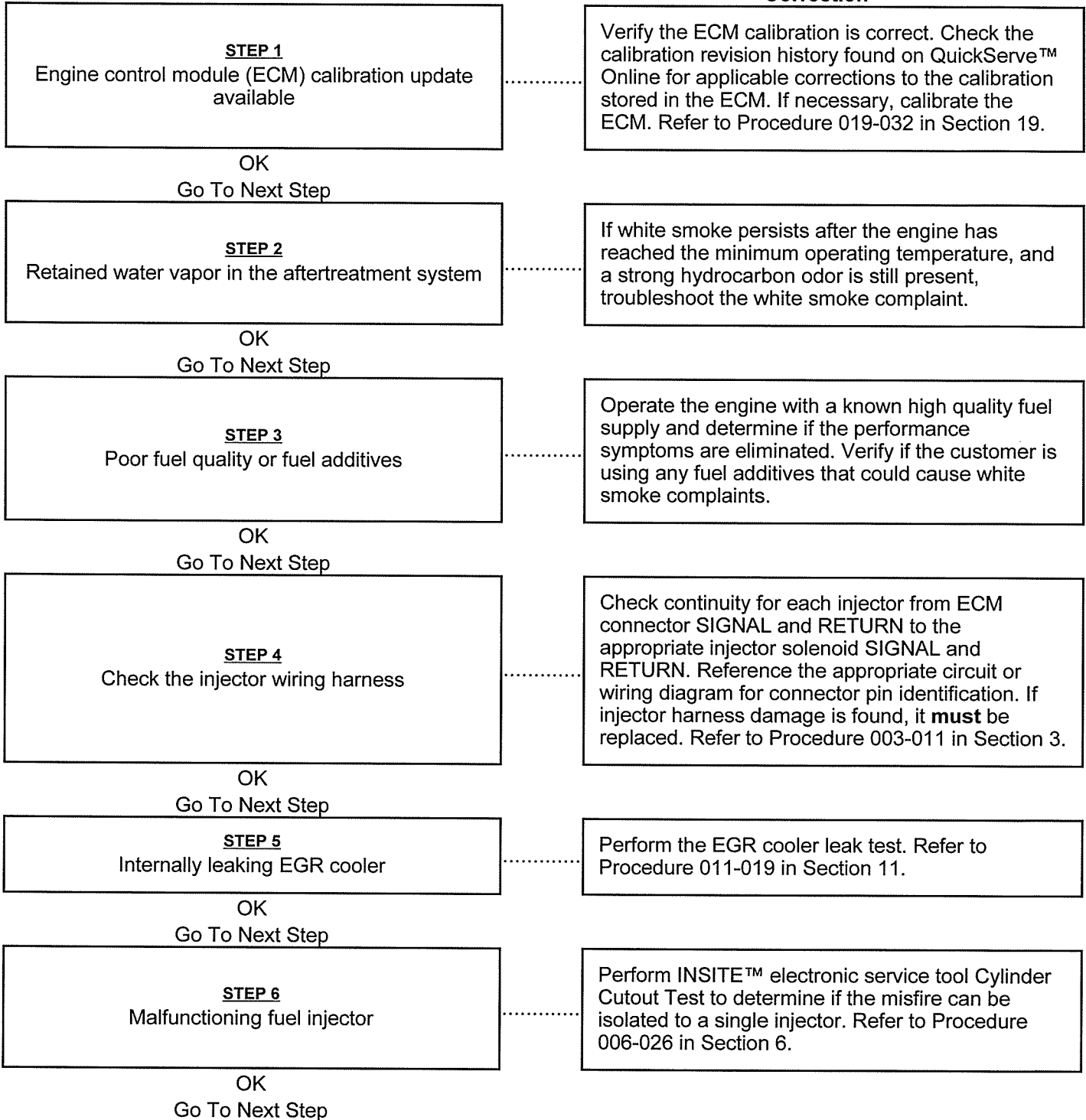
If the problem injector can **not** be found, replace all six injectors. Refer to Procedure 006-026 in Section 6.

Smoke, White - Excessive

This is symptom tree t118

Cause

Correction



Smoke, White - Excessive

This is symptom tree t118

Cause

Correction

STEP 7
Contaminated aftertreatment system

Inspect the aftertreatment diesel oxidation catalyst for signs of fuel, coolant, or lubricating oil contamination. Check the engine repair history to determine if a previous malfunction may have contaminated the aftertreatment diesel oxidation catalyst with coolant. Refer to Procedure 011-049 in Section 11.

OK
Go To Next Step

STEP 8
Stuck open exhaust gas recirculation (EGR) valve

Use INSITE™ electronic service tool to perform the Aftertreatment Regeneration Test. Allow the stationary regeneration procedure to run a minimum of 5 minutes. Use INSITE™ electronic service tool to monitor the EGR differential pressure value. EGR differential pressure **must** read less than 3.4 kPa [1.0 in-Hg] during the aftertreatment stationary regeneration procedure. If the EGR differential pressure is reading above this specification, a stuck open EGR valve has been detected.

OK
Go To Next Step

STEP 9
Cracked cylinder head

Pressurize the internal fuel drain line in the cylinder head and check for leaks. Refer to Procedure 002-004 in Section 2.

OK
Go To Next Step

STEP 10
Leaking cylinder head gasket

Check for a damaged cylinder head gasket. Refer to Procedure 002-004 in Section 2.

Turbocharger Leaks Engine Oil or Fuel

This is symptom tree t122

Cause	Correction
<p>STEP 1 Electronic fault codes active or high counts of inactive fault codes</p>	<p>View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to Section TF in the Fault Code Troubleshooting Manual, QSL9 CM2350 L102, Bulletin 4332795, for fault code troubleshooting.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Engine is operating for extended periods under light- or no-load conditions (slobbering)</p>	<p>Review the engine operating instructions. Refer to Procedure 101-999 in Section 1 of the Operation and Maintenance Manual, QSL9 CM2350 L102, Bulletin 4332797.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 White smoke is present</p>	<p>Refer to the Smoke, White - Excessive troubleshooting symptom tree in Section TS.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Lubricating oil lines leak oil</p>	<p>Check all oil lines and fittings for leaks. Tighten any loose fittings and replace leaking oil lines, if necessary.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Turbocharger oil drain line is restricted</p>	<p>Remove the turbocharger oil drain line and check for restriction. Clean or replace the oil drain line. Refer to Procedure 010-045 in Section 10.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Crankcase ventilation system is malfunctioning</p>	<p>Verify crankcase vent system operation. Refer to Procedure 003-001 and Procedure 003-019 in Section 3.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Crankcase pressure is excessive</p>	<p>Check for excessive blowby. Refer to Procedure 014-010 in Section 14. If blowby is above specifications, refer to Crankcase Gases (Blowby) Excessive troubleshooting symptom tree in Section TS.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Lubricating oil or fuel is entering the turbocharger</p>	<p>Remove the intake and exhaust piping, and check for oil or fuel.</p>
<p>OK Go To Next Step</p>	

Turbocharger Leaks Engine Oil or Fuel

This is symptom tree t122

Cause

Correction

STEP 9

Air intake system restriction is above specification

Check the air intake system for restrictions. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031 in Section 10.

OK

Go To Next Step

STEP 10

Exhaust system restriction is **not** within specification

Check the exhaust system for restrictions. Refer to Procedure 011-009 in Section 11.

OK

Go To Next Step

STEP 11

Turbocharger oil seal is leaking

Check the turbocharger compressor and turbine seals. Refer to Procedure 010-033 in Section 10.

OK

Go To Next Step

STEP 12

Turbocharger wheel clearance is out of specification

Check the radial bearing and axial clearances. Inspect the turbocharger. Repair or replace the turbocharger, if necessary. Refer to Procedure 010-033 in Section 10.

OK

Go To Next Step

STEP 13

Valve stem clearance is excessive or the valve stem seals are damaged

Check the valve stems and seals. Refer to Procedure 002-004 in Section 2.

Diesel Exhaust Fluid Usage - Abnormal

This is symptom tree t128

Use this TS tree to troubleshoot complaints of low or high diesel exhaust fluid usage.

Cause

Correction

STEP 1

Electronic fault codes active or high counts of inactive fault codes

View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to Section TF in the Fault Code Troubleshooting Manual, QSL9 CM2350 L102, Bulletin 4332795, for fault code troubleshooting.

OK

Go To Next Step

STEP 2

Aftertreatment diesel exhaust fluid leak (external)

Inspect for external aftertreatment diesel exhaust fluids leaks near the aftertreatment diesel exhaust fluid tank, aftertreatment diesel exhaust fluid lines, and associated connections. Repair or replace parts as necessary.

OK

Go To Next Step

STEP 3

Aftertreatment diesel exhaust fluid low level or warning level **not** set correctly

The vehicle manufacturer has the ability to change the settings for low warning activations, causing the low diesel exhaust fluid level warnings to activate earlier than expected. Verify the settings are correctly set. Refer to the original equipment manufacturer (OEM) service manual.

OK

Go To Next Step

STEP 4

Engine control module (ECM) calibration is malfunctioning

Verify that the ECM calibration is correct. Check the calibration revision history for applicable fixes to the calibration stored in the ECM. Refer to the calibration history spreadsheet on Quickserve™ Online. Click here to see [ecm_calibration_rev_history.xls](#) on Quickserve™ Online Internet Website or the INCAL™ calibration CD. Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin 4021328. If necessary, calibrate the ECM. Refer to Procedure 019-032 in Section 19.

OK

Go To Next Step

STEP 5

Aftertreatment diesel exhaust fluid level gauge is inaccurate

Verify that the aftertreatment diesel exhaust fluid level gauge is correctly calibrated and matched to the diesel exhaust fluid tank. Refer to the OEM service manual.

OK

Go To Next Step

STEP 6

Engine out NOx emissions above normal

Refer to the Engine Performance Tree in Section TT.

Diesel Exhaust Fluid Contaminated

This is symptom tree t163

Cause

STEP 1

Diesel exhaust fluid tank has been filled or partially filled with fluid other than diesel exhaust fluid.

OK

Go To Next Step

STEP 2

Diesel exhaust fluid tank is cracked or diesel exhaust fluid tank cap is leaking.

OK

Go To Next Step

STEP 3

Bulk diesel exhaust fluid supply is contaminated.

OK

Go To Next Step

STEP 4

Diesel exhaust fluid tank heater coolant lines leaking coolant.

Correction

Drain the diesel exhaust fluid tank and replace with non-contaminated diesel exhaust fluid. Refer to Procedure 011-056 in Section 11.

Repair or replace the diesel exhaust fluid tank or diesel exhaust fluid tank cap. Refer to the original equipment manufacturer (OEM) service manual.

Check the bulk diesel exhaust fluid supply. Drain the diesel exhaust fluid tank and replace with non-contaminated diesel exhaust fluid. Refer to Procedure 011-056 in Section 11.

Repair or replace the diesel exhaust fluid tank heater coolant lines. Refer to the OEM service manual.

Manual (Non-Mission) Regeneration - Will Not Activate

This is symptom tree t168

Cause

STEP 1
Manual (non-mission) regeneration will not activate

Correction

Refer to the Manual (Non-Mission) Selective Catalytic Reduction (SCR)/Exhaust System Cleaning - Will Not Activate (T205) troubleshooting symptom tree in Section TS.

Manual (Non-Mission) Regeneration - Will Not Complete

This is symptom tree t169

Cause

STEP 1

Manual (non-mission) regeneration will not complete

Correction

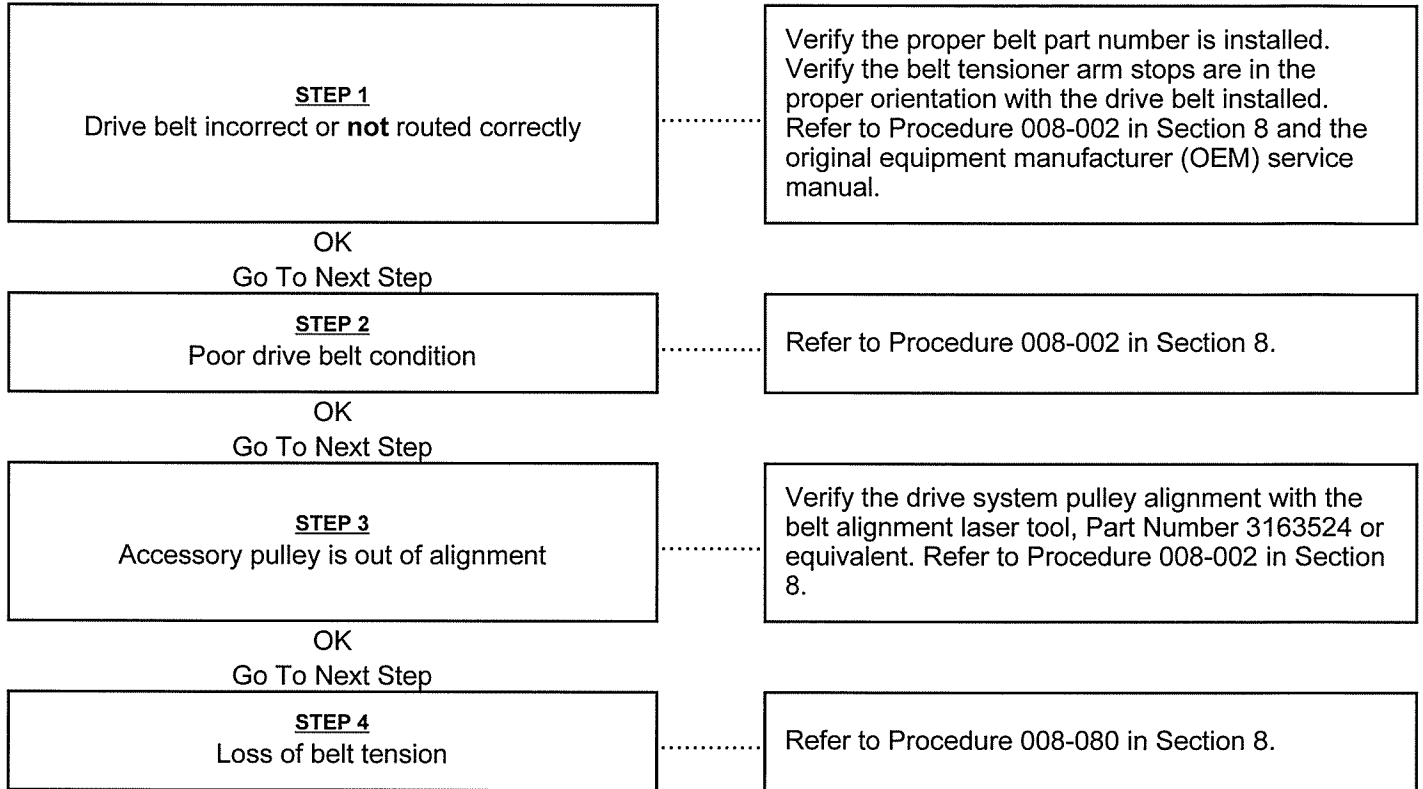
Refer to the Manual (Non-Mission) Selective Catalytic Reduction (SCR)/Exhaust System Cleaning - Will Not Complete (T206) troubleshooting symptom tree in Section TS.

Engine Noise Excessive - Drive Belt

This is symptom tree t170

Cause

Correction



Air Filter Plugging Frequent

This is symptom tree t172

Cause

Correction

STEP 1

Dust ejector valve maintenance schedule not followed.

Determine if the inspection and maintenance schedules for the dust ejection valve are being followed. Refer to Procedure 102-002 in Section 2 of the Operation and Maintenance Manual, QSL9 CM2350 L102, Bulletin 4332797.

OK

Go To Next Step

STEP 2

Dust ejector valve plugged.

Inspect the dust ejection valve for plugging. Clean and inspect the valve for reuse. Refer to Procedure 010-146 in Section 10.

OK

Go To Next Step

STEP 3

Dust ejector valve damaged or not installed correctly.

Inspect the dust ejection valve for damage and proper installation. Clean and inspect the valve for reuse. Refer to Procedure 010-146 in Section 10.

OK

Go To Next Step

STEP 4

Aspirator damaged or not operating correctly.

If equipped, inspect the aspirator for leaks or other damage. Refer to Aspirator Not Functioning troubleshooting symptom tree in Section TS.

OK

Go To Next Step

STEP 5

Air filter restriction indicator damaged or not operating properly.

Check the air filter restriction indicator for proper operation and damage. Refer to Procedure 010-031 in Section 10.

OK

Go To Next Step

STEP 6

Large debris blocking precleaner.

Inspect the precleaner for large debris that can disrupt the air flow.

OK

Go To Next Step

STEP 7

Precleaner damaged or **not** installed correctly.

Inspect the precleaner for damage and proper installation. Refer to Procedure 010-015 in Section 10.

OK

Go To Next Step

STEP 8

Precleaner or dust ejection valve **not** oriented correctly

Inspect the precleaner for proper orientation. Refer to Procedure 010-015 in Section 10.

OK

Go To Next Step

Air Filter Plugging Frequent

This is symptom tree t172

Cause	Correction
<p>STEP 9 Air filter media is excessively wet.</p>	<p>Inspect the air filter housing for cracks or other damage that would allow water into the housing. If equipped, inspect the rain cap and inlet piping for proper installation and damage. Refer to Procedure 010-014 in Section 10.</p>
<p>OK Go To Next Step</p>	
<p>STEP 10 Incorrect air filter elements installed.</p>	<p>Inspect the air filter elements for correct specifications. Refer to Procedure 010-014 in Section 10.</p>
<p>OK Go To Next Step</p>	
<p>STEP 11 Maintenance schedule for secondary air filter element was not followed.</p>	<p>Determine if the inspection and maintenance guidelines for secondary air filter elements are being followed. Refer to Procedure 010-014 in Section 10.</p>
<p>OK Go To Next Step</p>	
<p>STEP 12 Air filter housing damaged.</p>	<p>Inspect the air filter housing for damage. Inspect the air filter housing cover for proper installation. Refer to Procedure 010-014 in Section 10.</p>
<p>OK Go To Next Step</p>	
<p>STEP 13 Air filter inlet housing is located near the debris/ dust output of the vehicle or machine.</p>	<p>If the air filter air intake is ingesting contaminated air, filter replacement frequency will increase. Refer to the OEM service manual.</p>

Aspirator Not Functioning

This is symptom tree t173

Cause

Correction

STEP 1

Aspirator hose, venturi, or check valve is plugged

Inspect the aspirator hose, venturi, and check valve for blockage. Refer to Procedure 010-015 in Section 10.

OK

Go To Next Step

STEP 2

Aspirator hose is damaged or leaking

Inspect the aspirator hose for cracks, other damage, and loose connections. Refer to Procedure 010-015 in Section 10.

OK

Go To Next Step

STEP 3

Precleaner is damaged or obstructed

Inspect the air filter housing precleaner for damage and proper orientation. Be sure the precleaner is **not** obstructed. Refer to Procedure 010-015 in Section 10.

OK

Go To Next Step

STEP 4

Aspirator check valve is **not** functioning properly

Check the aspirator check valve for damage and proper operation. Refer to Procedure 010-015 in Section 10.

OK

Go To Next Step

STEP 5

Aspirator venturi is **not** functioning properly

Check the aspirator venturi for damage and proper operation. Refer to Procedure 010-015 in Section 10.

OK

Go To Next Step

STEP 6

Exhaust pipe is obstructed or back pressure is excessive

Check the exhaust pipe for obstructions and correct back pressure. Refer to the OEM service manual.

OK

Go To Next Step

STEP 7

Light engine load causing reduced aspirator efficiency

Determine the average load of the engine. Excessive idle or light duty operation can reduce the efficiency of the aspirator.

Excessive Automatic and/or Manual (Non-Mission) Regeneration

This is symptom tree t202

Cause

STEP 1
Automatic or manual (non-mission) regeneration is excessive

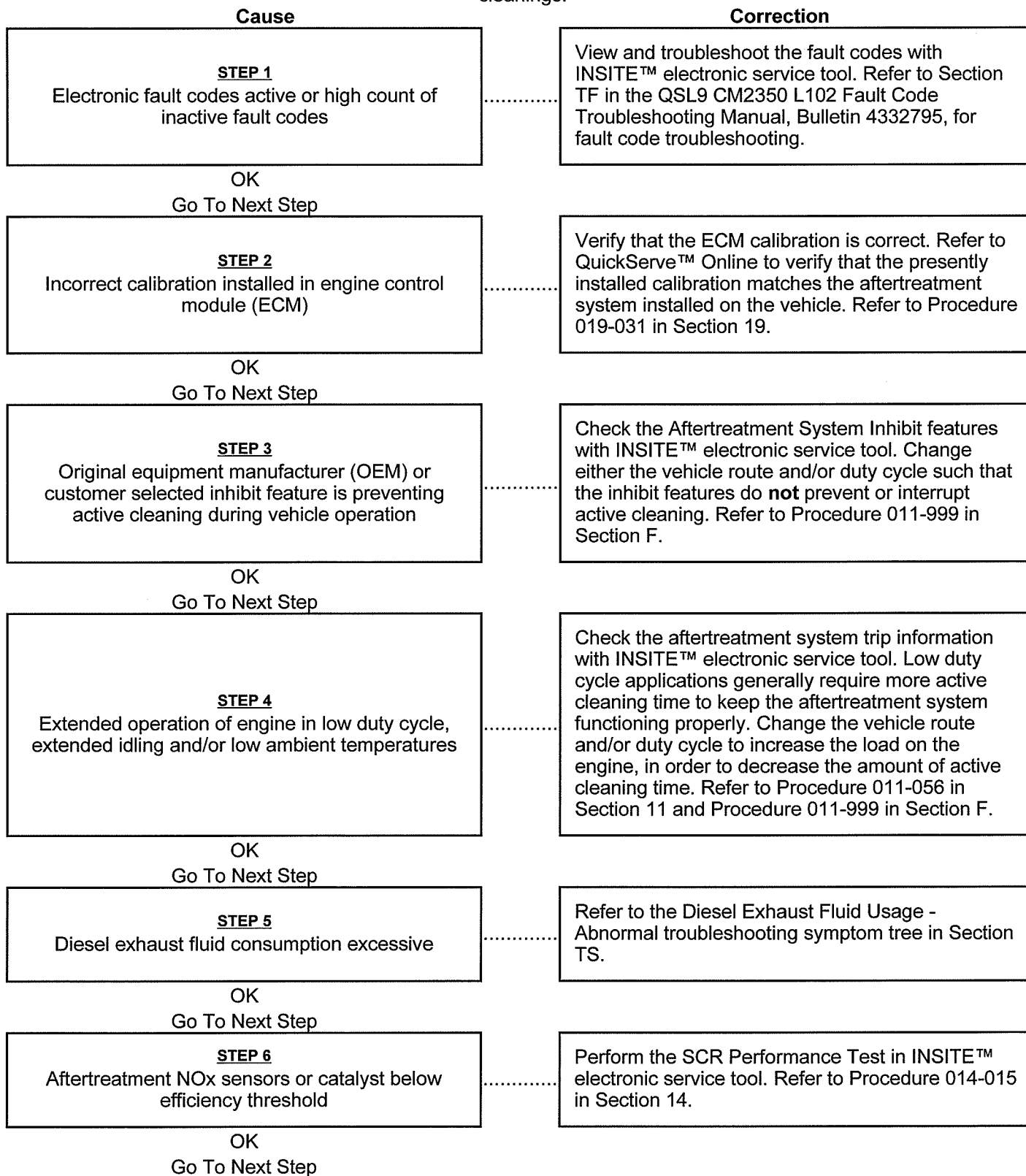
Correction

Refer to the Excessive Automatic and/or Manual (Non-Mission) Selective Catalytic Reduction (SCR)/Exhaust System Cleaning (T204) troubleshooting symptom tree in Section TS.

Excessive Automatic and/or Manual (Non-Mission) Selective Catalytic Reduction (SCR)/ Exhaust System Cleaning

This is symptom tree t204.

The steps in this tree are for equipment that has the aftertreatment lamp or optional high exhaust temperature lamp illuminating frequently, and/or requires frequent manual (non-mission) selective catalytic reduction (SCR) system cleanings.



Excessive Automatic and/or Manual (Non-Mission) Selective Catalytic Reduction (SCR)/ Exhaust System Cleaning

This is symptom tree t204

The steps in this tree are for equipment that has the aftertreatment lamp or optional high exhaust temperature lamp illuminating frequently, and/or requires frequent manual (non-mission) selective catalytic reduction (SCR) system cleanings.

Cause

STEP 7

Engine produces excessive black smoke

Correction

Refer to the Engine Performance Troubleshooting Tree in Section TT.

Manual (Non-Mission) Selective Catalytic Reduction (SCR)/Exhaust System Cleaning - Will Not Activate

This is symptom tree t205

The steps in this tree cover equipment equipped with an original equipment manufacturer (OEM) method of activating a manual (non-mission) SCR cleaning. This symptom tree can also be used if INSITE™ electronic service tool SCR Performance Test will not operate.

Cause

STEP 1

Electronic fault codes active or high count of inactive fault codes

OK

Go To Next Step

STEP 2

The correct cleaning procedure is **not** being followed

OK

Go To Next Step

STEP 3

Clutch pedal is depressed

OK

Go To Next Step

STEP 4

Brake pedal is depressed

OK

Go To Next Step

STEP 5

Power take off (PTO) or Remote PTO is engaged

OK

Go To Next Step

Correction

View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to Section TF in the QSL9 CM2350 L102 Fault Code Troubleshooting Manual, Bulletin 4332795, for fault code troubleshooting.

Refer to the OEM instructions on how to perform a manual (non-mission) SCR cleaning. Refer to Procedure 014-015 in Section 14.

The clutch pedal **must** be released for manual (non-mission) SCR cleaning to activate. Monitor the clutch pedal position switch with INSITE™ electronic service tool and verify it is released. If the vehicle does **not** have a clutch pedal, verify the clutch pedal position switch is **not** installed in Features and Parameters. If necessary, check the clutch switch adjustment, switch, and circuit. Refer to Procedure 019-009 in Section 19. Refer to Procedure 019-010 in Section 19.

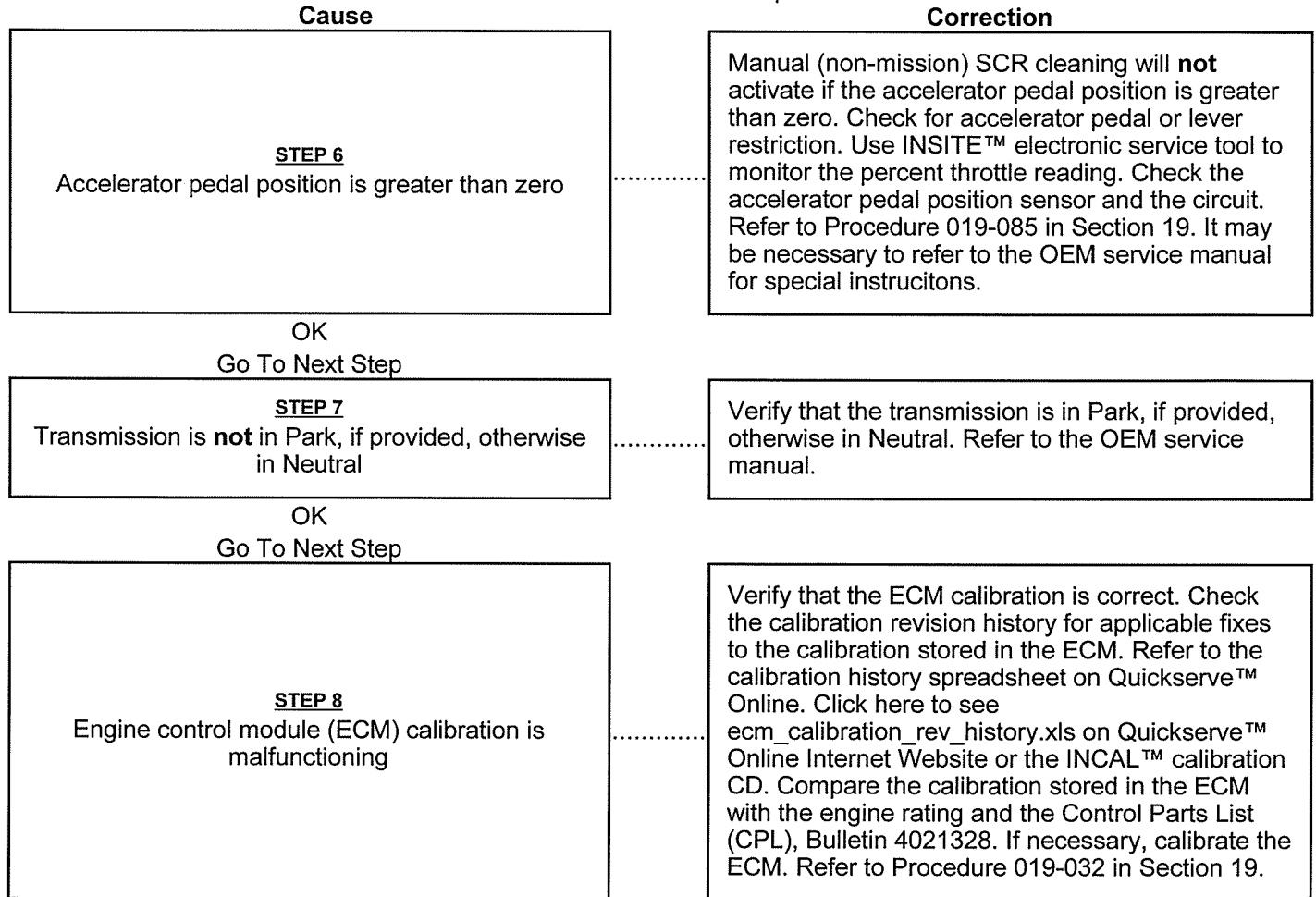
The brake pedal **must** be released for manual (non-mission) SCR cleaning to activate. Monitor the brake pedal position switch with INSITE™ electronic service tool and verify it is released. If necessary, check the vehicle brake switch and circuit. Refer to Procedure 019-088 in Section 19. Refer to Procedure 019-089 in Section 19.

Manual (non-mission) SCR cleaning will **not** activate if the engine is operating in PTO mode or Remote PTO mode. Verify the PTO or remote PTO switch is in the OFF position. If necessary, check the cruise control/PTO selector switch and circuit. Refer to Procedure 019-021 in Section 19. Refer to Procedure 019-022 in Section 19.

Manual (Non-Mission) Selective Catalytic Reduction (SCR)/Exhaust System Cleaning - Will Not Activate

This is symptom tree t205

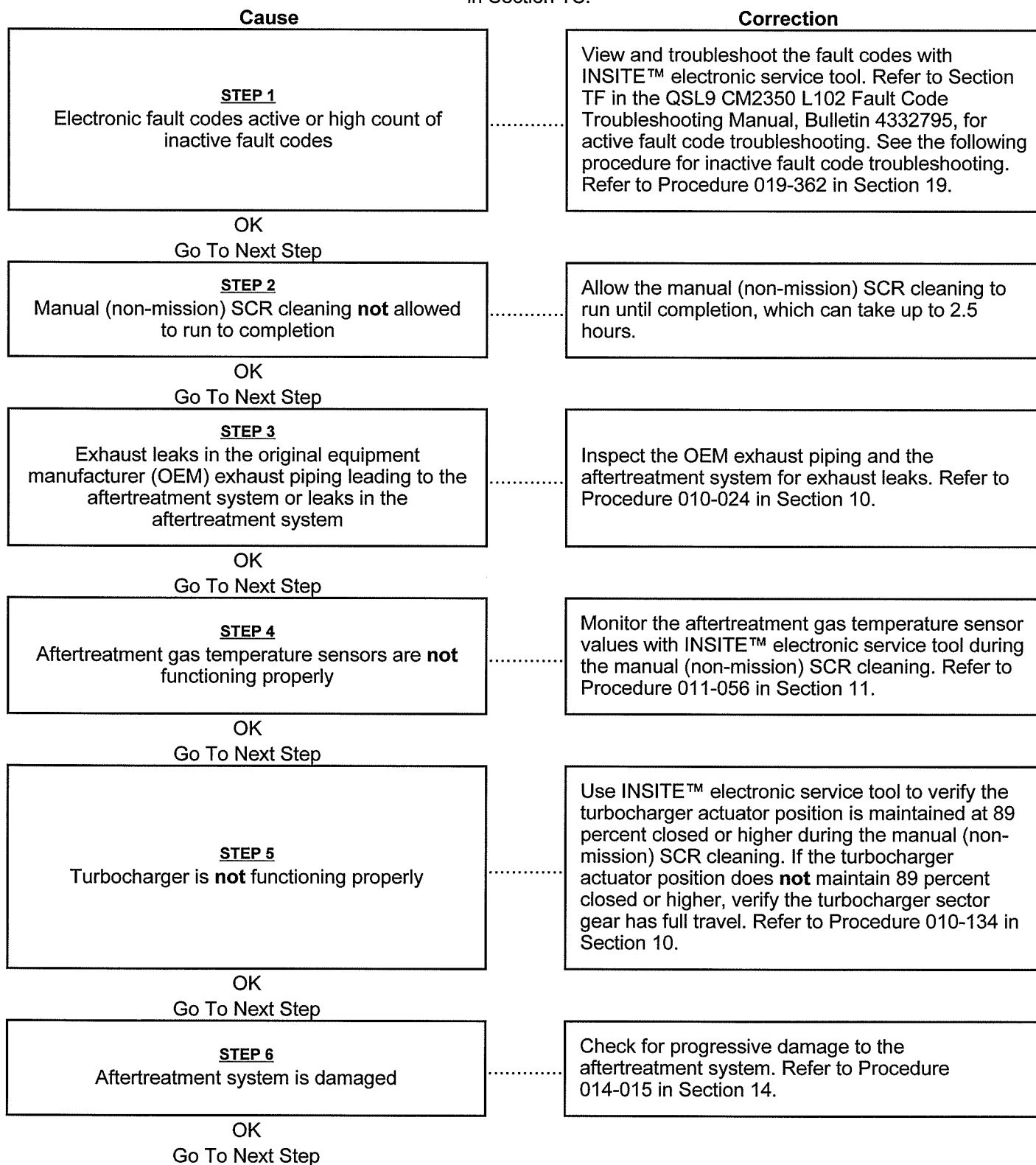
The steps in this tree cover equipment equipped with an original equipment manufacturer (OEM) method of activating a manual (non-mission) SCR cleaning. This symptom tree can also be used if INSITE™ electronic service tool SCR Performance Test will not operate.



Manual (Non-Mission) Selective Catalytic Reduction (SCR)/Exhaust System Cleaning - Will Not Complete

This is symptom tree t206

This tree is to be used when the manual (non-mission) cleaning is started and continues for an excessive period of time. If the aftertreatment cleaning lamp does not blink when the manual cleaning switch is toggled, refer to the Manual (Non-Mission) Selective Catalytic Regeneration (SCR) Cleaning - Will Not Activate troubleshooting symptom in Section TS.



Manual (Non-Mission) Selective Catalytic Reduction (SCR)/Exhaust System Cleaning - Will Not Complete

This is symptom tree t206

This tree is to be used when the manual (non-mission) cleaning is started and continues for an excessive period of time. If the aftertreatment cleaning lamp does not blink when the manual cleaning switch is toggled, refer to the Manual (Non-Mission) Selective Catalytic Regeneration (SCR) Cleaning - Will Not Activate troubleshooting symptom in Section TS.

Cause

Correction

STEP 7

Engine control module (ECM) calibration is malfunctioning

Verify that the ECM calibration is correct. Check the calibration revision history for applicable fixes to the calibration stored in the ECM. Refer to the calibration history spreadsheet on Quickserve™ Online. Click here to see [ecm_calibration_rev_history.xls](#) on Quickserve™ Online Internet Website or the INCAL™ calibration CD. Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL), Bulletin 4021328. If necessary, calibrate the ECM. Refer to Procedure 019-032 in Section 19.

Section TT - Troubleshooting Symptoms (New Format)

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Vibration Excessive

This troubleshooting procedure should be followed for the following symptoms:

- Vibration excessive
- Cab noise due to vibration

How to Use This Troubleshooting Procedure:

This symptom tree can be used to troubleshoot all vibration-based symptoms listed above. Start by performing Step 1 troubleshooting. Step 2 will ask a series of questions and will provide a list of troubleshooting steps to perform, depending on the symptoms. Perform the list of troubleshooting steps in the sequence shown in the Specifications/Repair section of the tree.

Shop Talk:

Vibration Troubleshooting Documentation Information Questions

- 1) What is the original equipment manufacturer (OEM) make/model?
- 2) What are the mileage/hours?
- 3) Has there been any recent repair and/or maintenance history?
 - Any engine/clutch/transmission rebuild, removal, and installation?
 - History of repeatedly broken brackets and/or capscrews (alternator, fan, exhaust, etc.)?
 - Structural modifications to the vehicle from OEM built?
- 4) Description of vibration?
 - What is shaking (mirror, seat, steering wheel, cab/dash, etc.)?
 - Is there excessive noise in the cab during the vibration?
- 5) What are the conditions when the complaint occurs?
 - Power take-off (PTO)?
 - Power output (hard pull, during lug down, etc.)?
 - During acceleration and/or deceleration?
 - At idle?
 - With or without a trailer?
 - Does vibration increase with engine speed?
 - Does vibration increase with road speed?
 - Is the vibration at certain engine revolutions per minute (rpm)?
- 6) Has the vibration been present since new? (From new, recent repair, modification to equipment)
- 7) Can the vibration be easily duplicated?
- 8) Do you have another piece of equipment with the same specification which exhibits the same complaint? (If yes, get the engine serial number (ESN) and possibly test the vehicle)
- 9) Are you the **only** operator of the equipment? (If no, are the symptoms noticed by other operators?)

General Information

Vibration complaints can be very difficult to troubleshoot and understand the root cause. This troubleshooting document was designed to help guide you through the logical steps of identifying the source. Vibration acceptance is very subjective; what is objectionable to one person can possibly be acceptable to another.

Vibration complaints can be caused by many parts in the system (system includes the engine, driven component, mounts, and equipment). The cause can be transmitted or generated from a remote point that is **not** readily apparent.

Cummins Inc. experience has shown that the engine is rarely the cause of an operator complaint. The majority of the time, it is the engine mounts or design of the various components on the equipment. The engine is **only** at fault if there is a misfire or an engine component that is out of balance.

Vibration complaints that occur **only** at idle speed are most likely caused by the engine mounts. If the engine mount natural frequency is close to the engine firing frequency, the engine will cause the mounts to amplify the normal vibration on an engine idling and cause the adjacent components to vibrate excessively.

Natural Frequency

- Natural frequency, as the name implies, is the frequency at which an object wants to naturally vibrate. The frequency is primarily dependent on mass and elasticity.

Types of Vibration

- 1) Linear
 - a) Rotating components
 - b) Torque reaction
 - Caused by unbalanced rotating components and cylinder firing impulses.
 - Can be felt and observed visibly.
 - When excessive, can cause operator discomfort and destruction of components.
- 2) Torsional - twisting stresses
 - Cyclic speeding and slowing of rotating components.
 - Controlled by flywheel mass and vibration damper.
 - Can **not** be felt by the operator.
 - Can damage gears and splines.
- 3) Resonant - component excited at natural frequency
 - Is actually linear vibration.
 - Resonant vibration occurs when a system or component is excited by linear vibration at its natural frequency.
 - Vibration will increase in amplitude as the system's natural frequency is approached. Amplitude will decrease as the exciting forces (engine firing frequency) increase in frequency beyond the system's natural frequency.
 - Resonant vibration can be many times larger in amplitude than the exciting force.
 - Vibration **must** be controlled by design of mounts (engine and cab) and components.

Engine and Cab Mounts

- The mounts **must** be designed to isolate or reduce the transmission of engine and equipment component vibrations.
- For maximum isolation, it is desired that the natural frequency of the mount be as low as possible.
- Good engine mounts will reduce the amount of engine vibration transmitted to the chassis frame by at least 50 percent at idle.
- Hard engine mounts will give little or no isolation, and can actually magnify the vibration transmitted to the chassis.
- Stiffness (durometer) and size of the isolator, along with the weight of the engine or component applied, are the determining factors when designing a mounting system. An isolator that is correct for one engine, can possibly **not** be right for another. Likewise, because of weight differential, a particular isolator designed for the rear of an engine, probably will **not** be ideal for the front.

TROUBLESHOOTING SUMMARY

STEPS	SPECIFICATIONS	SRT CODE
STEP 1: Perform the basic troubleshooting procedures.		
STEP 1A: Document the information questions in the Shop Talk section of this tree.	Documentation completed?	
STEP 1B: Duplicate the complaint based on the customer description.	Customer's complaint duplicated?	
STEP 1C: Check for active fault codes or high counts of inactive fault codes.	Active fault codes or high counts of inactive fault codes?	
STEP 1D: Perform the basic troubleshooting checks.	All steps verified to be correct?	
STEP 1E: Determine if the engine is running rough.	Engine running rough?	
STEP 1F: Perform a visual inspection of the engine mounts (without removal).	Visible engine mount damage?	
STEP 1G: Check for an engine mounted component contacting the frame or body.	Engine mounted components touching the frame or body?	
STEP 1H: Do an engine rpm sweep.	Vibration present stationary below 1050 rpm?	
STEP 1I: Do an engine rpm sweep.	Vibration present stationary above 1050 rpm?	
STEP 1J: Check the vibration engine speed range.	Vibration speed range greater than 300 to 400 rpm?	
STEP 2: Perform low rpm checks.		
STEP 2A: Check that the accessory load is not excessive for the idle speed setting.	All steps verified to be correct?	
STEP 2B: Check that the Fast Idle Warm-Up feature is activating (if applicable).	Fast Idle Warm-Up feature inactive?	
STEP 2C: Check that the Alternator Failure Warning feature is activating (if applicable).	Alternator Failure Warning feature inactive?	
STEP 2D: Check for malfunctioning belt driven accessories.	Vibration go away with the drive belts removed?	
STEP 2E: Check for equipment structural modifications.	Any structural modifications to the equipment present?	
STEP 2F: Check the engine mount transmissibility for the rear mount.	Vibration go away during the test condition?	
STEP 2F-1: Check the engine mount transmissibility for all mounts.	Vibration go away during the test condition?	
STEP 2G: Inspect the engine mounts.	All steps verified to be correct?	

STEP 2H:	Complaint since new.	Problem occurring since the equipment was new?
STEP 3:	Perform higher rpm checks.	
STEP 3A:	Inspect the engine mounts.	All steps verified to be correct?
STEP 3B:	Check for malfunctioning belt driven accessories.	Vibration go away with the drive belts removed?
STEP 3C:	Check for a damaged vibration damper.	Vibration damper damaged or out of specification?
STEP 3D:	Check the air compressor timing.	Air compressor timing correct?
STEP 3E:	Check the overhead adjustments.	Overhead adjustments correct?
STEP 3F:	Check for malfunctioning gear driven components.	Vibration go away?
STEP 3G:	Check for a damaged PTO.	Vibration go away?
STEP 3H:	Check the fuel pump timing.	Fuel pump timing correct?
STEP 3I:	Check the clutch or torque converter for vibration.	Engaging and disengaging the clutch affect the vibration?
STEP 3J:	Check for a loose or damaged flywheel or flex plate.	Flywheel meet specifications?
STEP 3K:	Check the flywheel housing for correct alignment.	Flywheel housing meet specifications?
STEP 3L:	Check to see if the crankshaft has been balanced.	Crankshaft balanced?
STEP 3M:	Check for internal engine damage.	Internal engine damage?
STEP 4:	Operate the mobile equipment.	
STEP 4A:	Perform a diagnostic road test.	Vibration present during a diagnostic road test?
STEP 4A-1:	Perform a diagnostic road test.	Vibration present with the transmission in neutral, under the road speed conditions, where the vibration was duplicated driving?
STEP 4B:	Inspect the engine mounts.	All steps verified to be correct?
STEP 4C:	Check for drive train components that are worn, unbalanced, malfunctioning, or are not correct.	All steps verified to be correct?

TROUBLESHOOTING STEP

STEP 1: Perform the basic troubleshooting procedures.

STEP 1A: Document the information questions in the Shop Talk section of this tree.

Condition: • None		
Action	Specification/Repair	Next Step
Perform the basic troubleshooting questionnaire. Complete the vibration troubleshooting documentation information questions contained in the Shop Talk section of this procedure.	Documentation completed? YES	1B
	Documentation completed? NO Repair: Complete the documentation.	1A

STEP 1B: Duplicate the complaint based on the customer description.

Condition: • None.		
Action	Specification/Repair	Next Step
Operate the equipment based on the description from the customer to duplicate the complaint. N/A	Customer's complaint duplicated? YES	1C
	Customer's complaint duplicated? NO	Repair complete

STEP 1C: Check for active fault codes or high counts of inactive fault codes.

Condition: • Turn keyswitch ON. • Connect INSITE™ electronic service tool.		
Action	Specification/Repair	Next Step
Check the fault codes. • Use INSITE™ electronic service tool to read the fault codes.	Active fault codes or high counts of inactive fault codes? YES Repair: See the corresponding Electronic Control System Troubleshooting and Repair manual for the engine being serviced.	Repair complete
	Active fault codes or high counts of inactive fault codes? NO	1D

STEP 1D: Perform the basic troubleshooting checks.

Condition: <ul style="list-style-type: none"> As required. 		
Action	Specification/Repair	Next Step
Check or verify the following items before continuing. <ul style="list-style-type: none"> Battery voltage is low (engine running) Lubricating oil level is above specification External fuel leak Engine idle speed is set too low Engine idle speed is set too high Throttle lever or pedal, return spring, or air throttle damaged or improperly adjusted (use INSITE™ electronic service tool for electronic engines) Air in the fuel Fuel pressure Inlet restriction. 	All steps verified to be correct? YES	1E
	All steps verified to be correct? NO	Repair complete

STEP 1E: Determine if the engine is running rough.

Condition: <ul style="list-style-type: none"> Operate engine at idle speed (less than 900 rpm). Turn accessories OFF (air conditioning, fan, PTO). Operate engine at operating temperature (greater than 170°C [338°F]). 		
Action	Specification/Repair	Next Step
Determine if the engine is running rough at engine idle. Refer to the Engine Runs Rough troubleshooting symptom tree in Section TS or the Engine Performance Troubleshooting Tree in Section TT.	Engine running rough? YES Repair: Refer to the Engine Runs Rough troubleshooting symptom tree in Section TS or the Engine Performance Troubleshooting Tree in Section TT.	Complete Engine Runs Rough troubleshooting tree
	Engine running rough? NO	1F

STEP 1F: Perform a visual inspection of the engine mounts (without removal).

Condition: <ul style="list-style-type: none"> Do not operate engine. Install engine mounts. 		
Action	Specification/Repair	Next Step
Perform a visual inspection of the engine mounts. Look for obvious damage or something shorting against the mounts, preventing isolation. A more detail inspection will be carried out later in the procedure.	Visible engine mount damage? YES Repair: Repair or replace the engine mounts. Refer to Procedure 016-010 in Section 16.	Repair complete
	Visible engine mount damage? NO	1G

STEP 1G: Check for an engine mounted component contacting the frame or body.

Condition: <ul style="list-style-type: none"> Do not operate engine. Install engine mounts. 		
Action	Specification/Repair	Next Step
Check for an engine mounted component touching the frame or body. Inspect the engine and engine mounted components to make sure none of them are touching the frame and/or body. Including but not limited to the following: <ul style="list-style-type: none"> Clamps Mounting hardware Exhaust system Air intake piping Cooling package support Etc. 	Engine mounted components touching the frame or body? YES Repair: Correct the mounting of the engine mounted component.	Repair complete
	Engine mounted components touching the frame or body? NO	1H

STEP 1H: Do an engine rpm sweep.

<p>Condition:</p> <ul style="list-style-type: none"> • Operate engine • Connect INSITE™ electronic service tool. • Make sure of 0 vehicle speed. 		
Action	Specification/Repair	Next Step
<p>Perform a slow (at 100 rpm per second) rpm sweep and observe where the vibration occurs.</p> <p>Record the engine speed at which any usual vibration or vibration related noise occurs (mirrors, panels, doors, seat, etc.). Record any speed points or ranges with excessive vibration.</p> <p>If a resonance is passed through quickly in getting up to the operating speed range and doesn't exist in the idle speed or peak operating range, it represents no major problem.</p>	<p>Vibration present stationary below 1050 rpm?</p> <p>YES</p>	2A
	<p>Vibration present stationary below 1050 rpm?</p> <p>NO</p>	1I

STEP 1I: Do an engine rpm sweep.

<p>Condition:</p> <ul style="list-style-type: none"> • Operate engine. • Connect INSITE™ electronic service tool. • Make sure of 0 vehicle speed. 		
Action	Specification/Repair	Next Step
<p>Perform a slow (at 100 rpm per second) rpm sweep and observe where the vibration occurs.</p> <p>Does the vibration increase progressively from idle to maximum speed? If so, rotating or reciprocating unbalance is the source. This can be caused by any rotating components or engine mount isolation.</p>	<p>Vibration present stationary above 1050 rpm?</p> <p>YES</p>	1J
	<p>Vibration present stationary above 1050 rpm?</p> <p>NO</p>	4A

STEP 1J: Check the vibration engine speed range.

<p>Condition:</p> <ul style="list-style-type: none"> Operate engine Connect INSITE™ electronic service tool. Make sure of 0 vehicle speed. 		
Action	Specification/Repair	Next Step
<p>Perform a slow (at 100 rpm per second) rpm sweep and observe where the vibration occurs.</p> <p>This step is to identify if the vibration progressively increases with engine speed or if it starts and stops within a slow engine rpm band. If the vibration progressively increases with engine speed and has a peak band greater than 300 rpm, this can indicate a rotating component that is out of balance.</p> <p>If the vibration peak is in a tight band of approximately 300 to 400 rpm or less, this indicates that a structural component of the engine or equipment is going into resonance because its natural frequency is close to or the same as the engine firing frequency.</p>	<p>Vibration speed range greater than 300 to 400 rpm? YES</p>	3A
	<p>Vibration speed range greater than 300 to 400 rpm? NO</p>	2A

STEP 2: Perform low rpm checks.

STEP 2A: Check that the accessory load is not excessive for the idle speed setting.

<p>Condition:</p> <ul style="list-style-type: none"> Operate engine at idle speed (less than 900 rpm). Turn accessories off (air conditioning, fan, and PTO). Operate engine at temperature (greater than 77°C [170°F]). 		
Action	Specification/Repair	Next Step
<p>Disable all engine driven accessories and PTOs to make sure they are not applying excessive load to the engine.</p> <p>N/A</p>	<p>All steps verified to be correct? YES</p>	2B
	<p>All steps verified to be correct? NO Repair: Repair as required.</p>	Repair complete

STEP 2B: Check that the Fast Idle Warm-Up feature is activating, if applicable.

Condition: <ul style="list-style-type: none"> • Turn keyswitch ON. • Connect INSITE™ electronic service tool. 		
Action	Specification/Repair	Next Step
Check the Fast Idle Warm-Up status. Use INSITE™ electronic service tool Data Monitor/Logger to check the status of the Fast Idle Warm-Up feature.	Fast Idle Warm-Up feature inactive? YES	2C
	Fast Idle Warm-Up feature inactive? NO Repair: Disable the Fast Idle Warm-Up feature and retest for the customer's complaint.	Repair complete

STEP 2C: Check that the Alternator Failure Warning feature is activating, if applicable.

Condition: <ul style="list-style-type: none"> • Turn keyswitch ON. • Connect INSITE™ electronic service tool. 		
Action	Specification/Repair	Next Step
Check to see if the Alternator Failure Warning feature is active. Use INSITE™ electronic service tool Data Monitor/Logger to check that the Alternator Failure Warning feature is active.	Alternator Failure Warning feature inactive? YES	2D
	Alternator Failure Warning feature inactive? NO Repair: Disable the Alternator Failure Warning feature and retest for the customer's complaint.	Repair complete

STEP 2D: Check for malfunctioning belt driven accessories.

Condition: <ul style="list-style-type: none"> • Remove drive belt(s). 		
Action	Specification/Repair	Next Step
Remove the drive belt(s) and operate the engine under the conditions where the vibration occurs. Caution: For engines with a belt driven water pump, do not allow the engine to overheat during the test. Engine damage will occur.	Vibration go away with the drive belts removed? YES Repair: Repair or replace the malfunctioning belt driven component.	Repair complete
	Vibration go away with the drive belts removed? NO	2E

STEP 2E: Check for equipment structural modifications.

Condition: • Inspect.		
Action	Specification/Repair	Next Step
Check for any structural modifications to the equipment. Check for any structural modifications to the equipment in the engine area that were completed by the OEM after equipment manufacture. • Snow plows, frame rail extensions, front bumpers, etc. Structural modifications can change the natural frequency of the frame and engine mounting system, which can result in a vibration complaint.	Any structural modifications to the equipment present? YES Repair: Contact the equipment manufacturer. If possible, remove or isolate the structural modification.	Repair complete
	Any structural modifications to the equipment present? NO	2F

STEP 2F: Check the engine mount transmissibility of the rear mount.

Condition: • Loosen the front engine mount capscrews. • Operate engine at the documented rpm where the complaint occurs.		
Action	Specification/Repair	Next Step
Check the engine mounts. This step is checking to see if the engine mounts are amplifying the firing frequency of the engine, since the vibration only occurs in a low engine rpm range. • Loosen only the isolator capscrews for the front engine mount(s) and run the engine at idle.	Vibration go away during the test condition? YES	2G
	Vibration go away during the test condition? NO	2F-1

STEP 2F-1: Check the engine mount transmissibility for all mounts.

Condition: • Loosen all engine mount capscrews. • Operate engine at the documented rpm where the complaint occurs.		
Action	Specification/Repair	Next Step
Check the engine mounts. This step is checking to see if the engine mounts are amplifying the firing frequency of the engine, since the vibration only occurs in a low engine rpm range. • Loosen the isolator capscrews for all of the engine mounts and run the engine at idle.	Vibration go away during the test condition? YES	2G
	Vibration go away during the test condition? NO	2G

STEP 2G: Inspect the engine mounts.

<p>Condition:</p> <ul style="list-style-type: none"> • Do not operate engine. • Remove engine mount isolators. 		
Action	Specification/Repair	Next Step
<p>This step is a detailed inspection of the engine mount brackets, isolators, and mounting hardware.</p> <ul style="list-style-type: none"> • Check the engine mount isolators for installation damage. • Check the alignment of the engine mount brackets. • Check for premature wear on the engine mount isolators and mounting hardware. 	<p>All steps verified to be correct? YES</p>	2H
	<p>All steps verified to be correct? NO Repair: Repair or replace the damaged components.</p>	Repair complete

STEP 2H: Complaint since new.

<p>Condition:</p> <ul style="list-style-type: none"> • Record the odometer/hour meter. • Review the troubleshooting documentation information questions. 		
Action	Specification/Repair	Next Step
<p>Check the equipment. Check the equipment mileage/hours and compare to the vibration customer interview form completed in Step 1A.</p> <ul style="list-style-type: none"> • Low mileage is an indication that the complaint has been present since the equipment was new. • Complaints on new equipment are typically due to a manufacturing defect in the system or an inadequate engine mounting design. 	<p>Problem occurring since the equipment was new? YES Repair: The engine mounts are not the right specification for the application, or a structural resonance exists.</p>	Contact a Cummins® Technical Support Specialist or the OEM
	<p>Problem occurring since the equipment was new? NO Repair: Recheck for shorts, a rough running engine, or malfunctioning engine mounts.</p>	Contact a Cummins® Technical Support Specialist or the OEM

STEP 3: Perform higher rpm checks.

STEP 3A: Inspect the engine mounts.

Condition: <ul style="list-style-type: none"> Do not operate engine. Remove the engine mount isolators. 		
Action	Specification/Repair	Next Step
Inspect the engine mount brackets, isolators, and mounting hardware. <ul style="list-style-type: none"> Check the engine mount isolators for installation damage. Check the alignment of the engine mount brackets. Check for premature wear on the engine mount isolators and mounting hardware. 	All steps verified to be correct? YES	3B
	All steps verified to be correct? NO Repair: Repair or replace the malfunctioning components. Refer to Procedure 016-010 in Section 16.	Repair complete

STEP 3B: Check for malfunctioning belt driven accessories.

Condition: <ul style="list-style-type: none"> Remove the drive belts. 		
Action	Specification/Repair	Next Step
Check the belt driven accessories. Remove the drive belts and operate the engine under the conditions where the vibration occurs. Caution: For engines with a belt driven water pump, do not allow the engine to overheat during the test. Engine damage will occur.	Vibration go away with the drive belts removed? YES Repair: Repair or replace the malfunctioning belt driven accessory.	Repair complete
	Vibration go away with the drive belts removed? NO	3C

STEP 3C: Check for a damaged vibration damper.

Condition: <ul style="list-style-type: none"> Do not operate engine. 		
Action	Specification/Repair	Next Step
Remove and visually inspect the vibration damper. Use the following procedure for vibration damper inspection specifications. Refer to Procedure 001-052 in Section 1.	Vibration damper damaged or out of specification? YES Repair: Replace the vibration damper. Refer to Procedure 001-051 in Section 1. Refer to Procedure 001-052 in Section 1.	Repair complete
	Vibration damper damaged or out of specification? NO	3D

STEP 3D: Check the air compressor timing.

Condition: <ul style="list-style-type: none"> Do not operate engine. Remove air compressor. 		
Action	Specification/Repair	Next Step
Check the air compressor timing. Refer to Procedure 012-014 in Section 12.	Air compressor timing correct? YES	3E
	Air compressor timing correct? NO Repair: Correct the air compressor timing and retest for the vibration complaint. Refer to Procedure 012-014 in Section 12.	Repair complete

STEP 3E: Check the overhead adjustments.

Condition: <ul style="list-style-type: none"> Do not operate engine. Remove rocker lever cover. 		
Action	Specification/Repair	Next Step
Measure and adjust the overhead settings. <ul style="list-style-type: none"> Check the overhead components for damage. Refer to Procedure 003-004 in Section 3.	Overhead adjustments correct? YES	3F
	Overhead adjustments correct? NO Repair: Repair or adjust the overhead. Refer to Procedure 003-004 in Section 3.	Repair complete

STEP 3F: Check for malfunctioning gear driven components.

Condition: None.		
Action	Specification/Repair	Next Step
Check the hydraulic pump and air compressor. If possible, isolate any gear-driven accessories and check for vibration.	Vibration go away? YES Repair: Repair or replace the gear driven components.	Repair complete
	Vibration go away? NO	3G

STEP 3G: Check for a damaged PTO.

Condition: • Disconnect the PTO.		
Action	Specification/Repair	Next Step
Check the PTO for damage and correct installation. Refer to the OEM service manual.	Vibration go away? YES Repair: Repair the PTO. Refer to the OEM service manual.	Repair complete
	Vibration go away? NO	3H

STEP 3H: Check the fuel pump timing.

Condition: Do not operate engine. Remove fuel pump.		
Action	Specification/Repair	Next Step
Check the fuel pump timing Refer to Procedure 005-037 in Section 5.	Fuel pump timing correct? YES	3I
	Fuel pump timing correct? NO Repair: Correct the fuel pump timing and test for the vibration complaint. Refer to Procedure 005-037 in Section 5.	Repair complete

STEP 3I: Check the clutch or torque converter for vibration.

Condition: <ul style="list-style-type: none"> Operate engine. 		
Action	Specification/Repair	Next Step
With engine running in the operating condition of the vibration, disengage and engage the clutch several times. If there is a significant vibration reduction, clutch plate(s) balance is the source.	Engaging and disengaging the clutch affect the vibration? YES Repair: Repair or replace the clutch. Refer to the OEM service manual.	Repair complete
	Engaging and disengaging the clutch affect the vibration? NO	3J

STEP 3J: Check for a loose or damaged flywheel or flex plate.

Condition: <ul style="list-style-type: none"> Remove transmission. 		
Action	Specification/Repair	Next Step
Check the flywheel. <ul style="list-style-type: none"> Check the flywheel bore and face run out. Check the flywheel for damage. Refer to Procedure 016-005 in Section 16.	Flywheel meet specifications? YES	3K
	Flywheel meet specifications? NO Repair: Repair or replace the flywheel or flexplate. Refer to Procedure 016-005 in Section 16.	Repair complete

STEP 3K: Check the flywheel housing for correct alignment.

Condition: <ul style="list-style-type: none"> Remove transmission. Remove flywheel/flexplate. 		
Action	Specification/Repair	Next Step
Check the flywheel housing bore and face alignment. Refer to Procedure 016-006 in Section 16.	Flywheel housing meet specifications? YES	3L
	Flywheel housing meet specifications? NO Repair: Repair or replace the flywheel housing. Refer to Procedure 016-006 in Section 16.	Repair complete

STEP 3L: Check to see if the crankshaft has been balanced.

Condition: <ul style="list-style-type: none"> Do not operate engine. Remove lubricating oil pan. 		
Action	Specification/Repair	Next Step
Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7. Check the crankshaft to see if it has been balanced. Refer to Procedure 001-016 in Section 16. This step only applies if the complaint has been present since the engine was new or after a crankshaft replacement.	Crankshaft balanced? YES	3M
	Crankshaft balanced? NO Repair: Replace the crankshaft. Contact a Cummins® Technical Support/Warranty specialist before proceeding with the repair.	Repair complete

STEP 3M: Check for internal engine damage.

Condition: <ul style="list-style-type: none"> None. 		
Action	Specification/Repair	Next Step
Contact a support specialist. At this point, a significant amount of labor has been invested in the repair. Before disassembling the engine, seek troubleshooting assistance. Contact the appropriate Technical Support Channel for your facility. They will provide the necessary guidance and schedule on-site support, if deemed necessary. <ul style="list-style-type: none"> Camshaft journals and number 1 camshaft bushing are severely damaged Gear train backlash is excessive or the gear teeth are damaged Idler gear bushing damaged or worn Main or connecting rod bearing damage Gears out of balance or gear bushing damage Connecting rod damage. 	Internal engine damage? YES	Contact Technical Support
	Internal engine damage? NO	Contact Technical Support

STEP 4: Operate the mobile equipment.

STEP 4A: Perform a diagnostic road test.

Condition: <ul style="list-style-type: none"> • Perform a diagnostic road test. 		
Action	Specification/Repair	Next Step
Perform a diagnostic road test, observing where the vibration occurs. If the vibration can be duplicated on the road, place the transmission in neutral and allow the engine speed to drop to idle under the road speed conditions of the vibration.	Vibration present during a diagnostic road test? YES	4A-1
	Vibration present during a diagnostic road test? NO	No repair

STEP 4A-1: Perform a diagnostic road test.

Condition: <ul style="list-style-type: none"> • Perform a diagnostic road test. 		
Action	Specification/Repair	Next Step
Perform a diagnostic road test, observing where the vibration occurs. If the vibration can be duplicated on the road, place the transmission in neutral and allow the engine speed to drop to idle under the conditions of the vibration.	Vibration present with the transmission in neutral, under the road speed conditions, where the vibration was duplicated driving? YES	4C
	Vibration present with the transmission in neutral, under the road speed conditions, where the vibration was duplicated driving? NO	4B

STEP 4B: Inspect the engine mounts.

Condition: <ul style="list-style-type: none"> • Do not operate engine. • Remove the engine mount isolators. 		
Action	Specification/Repair	Next Step
This step is a detailed inspection of the engine mount brackets, isolators, and mounting hardware. <ul style="list-style-type: none"> • Check the engine mount isolators for installation damage. • Check the alignment of the engine mount brackets. • Check for premature wear on the engine mount isolators and mounting hardware. • If the equipment is new, check for the proper mount specification. Refer to Procedure 016-010 in Section 16.	All steps verified to be correct? YES	4C
	All steps verified to be correct? NO Repair: Repair or replace damaged components.	Repair complete

STEP 4C: Check for drive train components that are worn, unbalanced, malfunctioning, or are not correct.

Condition: • None.		
Action	Specification/Repair	Next Step
Compare the drive train components to the engine and equipment specifications. Isolate the drive train components and check for vibrations. Refer to the OEM service manual.	All steps verified to be correct? YES	Contact Cummins® Technical Support and the OEM.
	All steps verified to be correct? NO	Contact Cummins® Technical Support and the OEM.

ECM - No Communication Troubleshooting Tree

This troubleshooting procedure should be followed for the following symptoms:

- No communication and engine will **not** start
- No communication and engine will start
- No communication related INSITE™ electronic service tool errors
- Communication with some ECMs but **not** all ECMs on a multi-module engine.

How to Use This Troubleshooting Procedure:

This troubleshooting procedure can be used to troubleshoot J1939 and J1587 data link communication issues between the electronic service tool and the ECM. There are four procedures that can be used to support this troubleshooting tree:

- Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, in the appropriate electronic control system troubleshooting and repair manual.
- Procedure 019-165 (Data Link Circuit, SAE J1939) in Section 19 in the appropriate electronic control system troubleshooting and repair manual.
- Procedure 019-166 (Data Link Circuit, SAE J1587) in Section 19 in the appropriate electronic control system troubleshooting and repair manual.

The troubleshooting steps in this procedure build upon information obtained in previous steps. The troubleshooting steps **must** be performed in the sequence specified in the troubleshooting procedure.

This troubleshooting procedure supports several engine families, therefore some instructions are stated in a general manner. Apply the requested procedures and actions to the specific engine family with the support of engine specific documentation that can be found in the Troubleshooting and Repair manuals for the specific engine family.

Shop Talk:

Three basic principles were used to define and sequence the troubleshooting steps that are listed in this tree.

- Verify high level system operation prior to troubleshooting individual components of the system. The purpose for this is to learn from the behavior of the system in order to direct the next steps for troubleshooting.
- Use the Bench Top Harness to separate the ECM from the vehicle so the ECM can be isolated from vehicle issues that could be causing no communication.
- Use a second vehicle or a second ECM to isolate high level system issues before troubleshooting individual components of the system.

TROUBLESHOOTING SUMMARY

STEPS		SRT CODE
STEP 1: INSITE™ electronic service tool error code check		
STEP 1A:	Check for INSITE™ electronic service tool error code 5023.	Is INSITE™ electronic service tool error code 5023 present?
STEP 1B:	INSITE™ electronic service tool error code 5080 or 5081 check.	Is INSITE™ electronic service tool error code 5080 or 5081 present?
STEP 1C:	INSITE™ electronic service tool other error code checks.	Are any INSITE™ electronic service tool error codes present other than 5023, 5080, or 5081?
STEP 1D:	ECM password check	Does INSITE™ electronic service tool indicate the ECM is password protected?
STEP 2: Initial data link adapter and INSITE™ electronic service tool check		
STEP 2A:	Initial data link adapter check	Are the communication lights on the data link adapter flashing?
STEP 2B:	data link adapter reset check	Does the ECM communicate?
STEP 2C:	Initial INSITE™ electronic service tool check	Does the ECM communicate?
STEP 2D:	data link adapter verification check	Is an Inline or Inline I being use to communicate with the ECM?
STEP 2E:	data link adapter firmware check	Is firmware version compatible with ECM?
STEP 3: Bench communication setup checks		
STEP 3A:	Bench setup availability check	Is a bench setup available?
STEP 3A-1:	Engine start check	Will engine start?
STEP 3B:	Initial bench setup communication check	Does the ECM communicated using bench setup?
STEP 3B-1:	Engine start check	Will engine start?
STEP 3C:	Second vehicle or second ECM availability check for bench setup	Is second vehicle or second ECM available to connect to the bench setup?
STEP 3D:	Initial bench setup functionality check	Does the second ECM communicate using bench setup?
STEP 3E:	Troubleshoot bench setup	Does bench setup check OK?
STEP 3F:	data link adapter replacement check	Does bench setup communicate with the second ECM using a replacement data link adapter?
STEP 4: ECM power up circuit check		
STEP 4A:	Engine configuration check	Is the engine equipped with a fuel shutoff valve?
STEP 4A-1:	Check fuel shutoff valve voltage	Is the fuel shutoff valve voltage within 1-VDC of vehicle system voltage?

STEP 4A-2:	Coolant temperature sensor signal voltage check	Is the coolant temperature signal voltage greater than 4.5-VDC?
STEP 4B:	ECM keyswitch voltage check	Is the keyswitch voltage within 1-VDC or vehicle system voltage?
STEP 4C:	Check the ECM power and ground	Is the ECM battery supply voltage equal to the battery voltage?
STEP 5:	Initial electronic tool check	
STEP 5A:	Bench setup previously used for troubleshooting check	In Step 3 checks, was bench setup used to successfully communicate with the ECM?
STEP 5B:	Second vehicle availability check for electronic tool	Is a second vehicle available to connect to the electronic tool?
STEP 5C:	Initial electronic tool functionality check	Does the second ECM communicate using electronic tool?
STEP 6:	data link adapter power check	
STEP 6A:	data link adapter determination check	Is an Inline I data link adapter being used to communicate with INSITE™ electronic service tool?
STEP 6B:	Check data link adapter power	Is the data link adapter power light on?
STEP 6C:	Determination if communication is being attempted at OEM dash connector	Is the communication being attempted at the OEM data link dash connector?
STEP 6D:	OEM data link dash connector voltage check	Is the voltage equal to or greater than 9-VDC?
STEP 6E:	Check voltage at data link adapter auxiliary power supply	Is the voltage equal to or greater than 9-VDC?
STEP 6F:	Check voltage at vehicle battery	Is the voltage equal or greater than 11-VDC?
STEP 6G:	Computer serial port voltage check	Is a minimum of 5 VDC available?
STEP 7:	data link circuit check	
STEP 7A:	Check J1939 or J1587 circuits	Does the circuit check OK?
STEP 8:	Initial electronic tool check	
STEP 8A:	Second vehicle availability check for electronic tool	Is a second vehicle available to connect to the electronic tool?
STEP 8B:	Initial electronic tool functionality check	Does the second ECM communicate using the electronic tool?
STEP 9:	Detailed electronic tool check	
STEP 9A:	Troubleshoot electronic tool hardware	Does the electronic tool hardware check OK?
STEP 10:	Serial cable and computer check	
STEP 10A:	Troubleshoot serial cable and computer	Do the serial cable and computer check OK?

STEP 11: ROM boot ECM

- STEP 11A:** ROM boot tool availability check Is the ROM boot tool available?
STEP 11B: ROM boot ECM Does the ECM communicate?

TROUBLESHOOTING STEP

STEP 1: INSITE™ electronic service tool error code check

STEP 1A: INSITE™ electronic service tool error code 5023 check

Condition: <ul style="list-style-type: none"> • Connect INSITE™ electronic service tool. • Turn keyswitch ON. 		
Action	Specification/Repair	Next Step
Check for INSITE™ electronic service tool error code 5023. <ul style="list-style-type: none"> • Use INSITE™ electronic service tool to read the error codes. 	Is INSITE™ electronic service tool error code 5023 present? YES	2A
	Is INSITE™ electronic service tool error code 5023 present? NO	1B

STEP 1B: INSITE™ electronic service tool error code 5080 or 5081 check

Condition: <ul style="list-style-type: none"> • Connect INSITE™ electronic service tool. • Turn keyswitch ON. 		
Action	Specification/Repair	Next Step
Check for INSITE™ error code 5080 or 5081. <ul style="list-style-type: none"> • Use INSITE™ electronic service tool to read the error codes. 	Is INSITE™ electronic service tool error code 5080 or 5081 present? YES Repair: Perform the ECM calibration download	Repair complete
	Is INSITE™ electronic service tool error code 5080 or 5081 present? NO	1C

STEP 1C: INSITE™ electronic service tool other error code checks.

<p>Condition:</p> <ul style="list-style-type: none"> • Connect Is INSITE™ electronic service tool. • Turn keyswitch ON. 		
Action	Specification/Repair	Next Step
<p>Are any INSITE™ electronic service tool error codes present other than 5023, 5080, or 5081?</p> <ul style="list-style-type: none"> • Use INSITE™ electronic service tool to read the error codes. 	<p>Are any INSITE™ electronic service tool error codes present other than 5023, 5080, or 5081?</p> <p>YES</p> <p>Repair:</p> <p>See the INSITE™ Electronic Service Tool manual for troubleshooting guidelines.</p>	<p>Repair Complete</p>
	<p>Are any INSITE™ electronic service tool error codes present other than 5023, 5080, or 5081?</p> <p>NO</p>	<p>1D</p>

STEP 1D: ECM password check

<p>Condition:</p> <ul style="list-style-type: none"> • Connect INSITE™ electronic service tool. • Turn keyswitch ON. 		
Action	Specification/Repair	Next Step
<p>Does INSITE™ electronic service tool indicate the ECM is password protected?</p> <ul style="list-style-type: none"> • Use INSITE™ electronic service tool. 	<p>Does INSITE™ electronic service tool indicate the ECM is password protected?</p> <p>YES</p> <p>Repair:</p> <p>Enter correct password</p> <p>If password is unavailable, contact customer to request password information. If customer can not supply password information, see the INSITE™ electronic service tool manual for password removal information. Normal warranty guidelines will apply if ECM password removal is required.</p>	<p>Repair complete</p>
	<p>Does INSITE™ electronic service tool indicate the ECM is password protected?</p> <p>NO</p>	<p>2A</p>

STEP 2: Initial data link adapter and INSITE™ electronic service tool check

STEP 2A: Initial data link adapter check

<p>Condition:</p> <ul style="list-style-type: none"> • data link adapter connected to OEM data link connector in vehicle. • INSITE™ electronic service tool computer must not be connected. • Note: If connected to the 3 pin engine data link connector the communication lights will not blink, continue to Step 2B. 		
Action	Specification/Repair	Next Step
Turn keyswitch on.	Are the communication lights on the data link adapter flashing? • J1708 light for Inline • J1708 or J1939 for Inline II, Inline 4, and Inline 5. YES Repair: No Repair	2C
	Are the communication lights on the data link adapter flashing? • J1708 light for Inline • J1708 or J1939 for Inline II, Inline 4, and Inline 5. NO	2B

STEP 2B: data link adapter reset check

<p>Condition: INSITE™ electronic service tool connected to vehicle.</p>		
Action	Specification/Repair	Next Step
Data link adapter reset check • Disconnect power from the data link adapter. • Leave disconnected for 30 seconds • Connect power again to the Inline adapter • Turn keyswitch ON.	Does the ECM communicate? YES	Repair complete
	Does the ECM communicate? NO	3A

STEP 2C: Initial INSITE™ electronic service tool check

<p>Condition:</p> <ul style="list-style-type: none"> • INSITE™ electronic service tool connected to vehicle • Turn keyswitch ON. 		
Action	Specification/Repair	Next Step
Reboot INSITE™ electronic service tool PC. • Launch INSITE™ electronic service tool • Check for communication.	Does the ECM communicate? YES	Repair complete
	Does the ECM communicate? NO	2D

STEP 2D: data link adapter verification check

Condition: None		
Action	Specification/Repair	Next Step
Verify if an Inline or Inline I data link adapter is being used to communicate with ECM. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, for General Information - data link Adapters, in the appropriate electronic control system troubleshooting and repair manual for data link adapter identification information.	Is an Inline or Inline I being used to communicate with the ECM? YES	8A
	Is an Inline or Inline I being used to communicate with the ECM? NO	2E

STEP 2E: data link adapter firmware check

Condition: None		
Action	Specification/Repair	Next Step
Verify data link adapter firmware version is compatible with ECM. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, for General Information - data link Adapters, in the appropriate Electronic Control System Troubleshooting and Repair manual for data link adapter identification information.	Is firmware version compatible with the ECM? YES	8A
	Is firmware version compatible with the ECM? NO Repair: Load correct firmware version	2C

STEP 3: Bench communication setup checks

STEP 3A: Bench setup availability check

Condition: • Bench setup available.		
Action	Specification/Repair	Next Step
Verify bench setup is available.	Is a bench setup available? YES	3B
	Is a bench setup available? NO	3A-1

STEP 3A-1: Engine start check

Condition: • None		
Action	Specification/Repair	Next Step
Verify if engine will start.	Will engine start? YES	5A
	Will engine start? NO	4A

STEP 3B: Initial bench setup communication check.

Condition: • Use the same INSITE™ electronic service tool PC as was used for the previous checks • Bench setup connected to ECM • Bench top calibration harness keyswitch ON.		
Action	Specification/Repair	Next Step
Attempt to communicate with the ECM using bench setup.	Does the ECM communicate with bench setup? YES	3B-1
	Does the ECM communicate with bench setup? NO	3C

STEP 3B-1: Engine start check

Condition: • None		
Action	Specification/Repair	Next Step
Disconnect the bench top calibration cable from the ECM. Reconnect the ECM to the original engine or OEM wiring harness connector. Verify if the engine will start.	Will the engine start? YES	5A
	Will the engine start? NO	4A

STEP 3C: Second vehicle or second ECM availability check for bench setup

Condition: <ul style="list-style-type: none"> Second vehicle or second ECM available for testing. 		
Action	Specification/Repair	Next Step
Verify if a second vehicle or second ECM is available to connect to the bench setup.	Is a second vehicle or second ECM available to connect to the bench setup? YES	3D
	Is a second vehicle or second ECM available to connect to the bench setup? NO	3E

STEP 3D: Initial bench setup functionality check

Condition: <ul style="list-style-type: none"> Use the same INSITE™ electronic service tool PC and bench setup tools that were originally used on the problem vehicle. Bench setup connected to second vehicle or second ECM Bench top calibration harness keyswitch ON. 		
Action	Specification/Repair	Next Step
Attempt to communicate with the ECM on the second vehicle or a spare ECM using bench setup.	Does the second ECM communicate using bench setup? YES	11A
	Does the second ECM communicate using bench setup? NO	3E

STEP 3E: Troubleshoot bench setup hardware

Condition: <ul style="list-style-type: none"> None 		
Action	Specification/Repair	Next Step
Troubleshoot bench calibration cable, bench calibration harness, and serial cable. <ul style="list-style-type: none"> Perform troubleshooting procedures for evaluating the bench calibration cable, bench calibration harness, and serial cable. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, for Resistance Check - Serial Cable, Benchtop Calibration Harness, Benchtop Calibration Cable, in the appropriate Electronic Control System Troubleshooting and Repair manual. 	Does bench setup check OK? YES	3F
	Does bench setup check OK? NO Repair: Repair or replace bench calibration cable, bench calibration harness, or serial cable.	3B

STEP 3F: data link adapter replacement check

Condition: • None		
Action	Specification/Repair	Next Step
Try to communicate with the bench setup using a replacement datalink.	Does bench setup communicate with the second ECM using a replacement data link adapter? YES Repair: Use replacement data link adapter.	3B
	Does bench setup communicate with the second ECM using a replacement data link adapter? NO Repair: Issue with bench setup should have been found. Troubleshoot the bench setup again.	3E

STEP 4: ECM power up circuit check

STEP 4A: Engine configuration check

Condition: • None		
Action	Specification/Repair	Next Step
Determine if the engine is equipped with a fuel shutoff valve	Is the engine equipped with a fuel shutoff valve? YES	4A-1
	Is the engine equipped with a fuel shutoff valve? NO	4A-2

STEP 4A-1: Check fuel shutoff valve voltage

Condition: • Turn keyswitch ON.		
Action	Specification/Repair	Next Step
Measure the voltage from the fuel shutoff valve post to engine block ground. There are 12 and 24 volt systems, the fuel shutoff valve voltage needs to be within 1-VDC of the vehicle system voltage.	Is the fuel shutoff valve voltage within 1-VDC of vehicle system voltage? YES	5A
	Is the fuel shutoff valve voltage within 1 VDC of vehicle system voltage? NO	4B

STEP 4A-2: Coolant temperature sensor signal voltage check

<p>Condition:</p> <ul style="list-style-type: none"> • Turn keyswitch ON. • Disconnect the coolant temperature sensor connector. 		
Action	Specification/Repair	Next Step
<p>Measure the voltage across the two pins of the coolant temperature sensor on the wiring harness connector.</p> <p>Reference the wiring diagram or circuit diagram for connector pin identification.</p>	<p>Is the coolant temperature signal voltage greater than 4.5-VDC?</p> <p>YES</p>	5A
	<p>Is the coolant temperature signal voltage greater than 4.5-VDC?</p> <p>NO</p>	4B

STEP 4B: ECM keyswitch voltage check

<p>Condition:</p> <ul style="list-style-type: none"> • Turn keyswitch OFF. • Disconnect the wiring harness connector that contains the keyswitch signal from the ECM. • Turn the keyswitch ON. 		
Action	Specification/Repair	Next Step
<p>Measure the voltage from the keyswitch input SIGNAL wire of the wiring harness to engine block ground.</p> <p>Reference the wiring diagram or circuit diagram for connector pin identification.</p>	<p>Is the keyswitch voltage within 1-VDC of vehicle system voltage?</p> <p>YES</p>	4C
	<p>Is the keyswitch voltage within 1-VDC of vehicle system voltage?</p> <p>NO</p> <p>Repair:</p> <p>Repair or replace the wiring harness that contains the keyswitch signal, or repair or replace the keyswitch, or check the battery connection. Reference Procedure 019-064 (Key Switch Battery Supply Circuit) in Section 19 in the appropriate troubleshooting and repair manual.</p> <p>See the Engine Performance Troubleshooting Tree in the appropriate troubleshooting and repair manual, if the no start condition is still present.</p>	Repair complete

STEP 4C: Check the ECM power and ground

<p>Condition:</p> <ul style="list-style-type: none"> • Turn keyswitch OFF • Disconnect from the ECM the wiring harness connector that contains the ECM battery SUPPLY (-) and SUPPLY (+) wiring. 		
Action	Specification/Repair	Next Step
<p>Measure the voltage from each ECM battery SUPPLY (+) pin to all battery SUPPLY (-) pins in the wiring harness connector.</p> <p>Reference the wiring diagram or circuit diagram for connector pin identification.</p>	<p>Is the ECM battery supply voltage equal to the battery voltage?</p> <p>YES</p> <p>Repair:</p> <p>Call for authorization.</p> <p>Replace the ECM. Reference Procedure 019-031 (Electronic Control Module (ECM)) in Section 19 in the appropriate troubleshooting and repair manual.</p>	<p>Repair complete</p>
	<p>Is the ECM battery supply voltage equal to the battery voltage?</p> <p>NO</p> <p>Repair:</p> <p>Repair or replace the wiring harness that contains the ECM battery SUPPLY (+) and battery SUPPLY (-) wiring.</p> <p>See the Engine Performance Troubleshooting Tree if no start condition is still present.</p>	<p>Repair complete</p>

STEP 5: Initial electronic tool check

STEP 5A: Bench setup previously used for troubleshooting check

<p>Condition:</p> <ul style="list-style-type: none"> • None 		
Action	Specification/Repair	Next Step
<p>In Step 3 checks, was bench setup used to successfully communicate with the ECM?</p>	<p>In Step 3 checks, was bench setup used to successfully communicate with the ECM?</p> <p>YES</p> <p>Repair:</p> <p>ECM is OK, repair complete if communication is not required through OEM data link connector or harness.</p> <p>If communication is required through the OEM data link connector or harness continue to Step 6A.</p>	<p>6A</p>
	<p>In Step 3 checks, was bench setup used to successfully communicate with the ECM?</p> <p>NO</p>	<p>5B</p>

STEP 5B: Second vehicle availability check for electronic tool

Condition: <ul style="list-style-type: none"> Second vehicle available for testing 		
Action	Specification/Repair	Next Step
Verify a second vehicle is available to connect to the electronic tool.	Is a second vehicle available to connect to the electronic tool? YES	5C
	Is a second vehicle available to connect to the electronic tool? NO	6A

STEP 5C: Initial electronic tool functionality check

Condition: <ul style="list-style-type: none"> Electronic tool connected to a second vehicle. Keyswitch ON. 		
Action	Specification/Repair	Next Step
Attempt to communicate with the ECM on the second vehicle using the same electronic tool hardware used on the problem vehicle.	Does the second ECM communicate using electronic tool? YES	6A
	Does the second ECM communicate using electronic tool? NO	9A

STEP 6: data link adapter power check

STEP 6A: data link adapter determination check

Condition: <ul style="list-style-type: none"> None 		
Action	Specification/Repair	Next Step
Determine if an Inline I datalink adapter is being used to communicate with INSITE™ electronic service tool. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, for General Information - data link adapter, in the appropriate electronic control system troubleshooting and repair manual.	Is an Inline I data link adapter being used to communicate with INSITE™ electronic service tool? YES	6G
	Is an Inline I data link adapter being used to communicate with INSITE™ electronic service tool? NO	6B

STEP 6B: Check data link adapter power

Condition: <ul style="list-style-type: none"> Do not use an Inline I Electronic tool hardware connected to the vehicle. INSITE™ electronic service tool launched Keyswitch ON. 		
Action	Specification/Repair	Next Step
Note: For all datalink adapters except Inline I. Attempt to communicate with INSITE™ electronic service tool and check to see if the data link adapter power light is on. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, for General Information - data link Adapter, in the appropriate electronic control system troubleshooting and repair manual.	Is the data link adapter power light on? YES	7A
	Is the data link adapter power light on? NO	6C

STEP 6C: Determination if communication is being attempted at the OEM data link dash connector

Condition: <ul style="list-style-type: none"> None 		
Action	Specification/Repair	Next Step
Check to see if communication is being attempted at the OEM datalink dash connector.	Is communication being attempted at the OEM data link dash connector? YES	6D
	Is communication being attempted at the OEM data link dash connector? NO	6E

STEP 6D: OEM data link dash connector voltage check

Condition: <ul style="list-style-type: none"> Turn keyswitch ON. 		
Action	Specification/Repair	Next Step
Measure voltage across the SUPPLY and ground pins of the OEM datalink connector. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, for In Cab data link Connector or 6-pin In Cab data link connector, in the appropriate Electronic Control System Troubleshooting and Repair manual for pin locations.	Is the voltage equal to or greater than 9 VDC? YES Repair: Replace data link adapter	Repair complete
	Is the voltage equal to or greater than 9 VDC? NO	6F

STEP 6E: Check voltage at data link adapter auxiliary power supply

Condition: • Turn keyswitch ON.		
Action	Specification/Repair	Next Step
Measure the data link adapter supply voltage at the datalink adapter harness connector. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, for 3-pin data link Cable, in the appropriate Electronic Control System Troubleshooting and Repair manual for pin locations.	Is the voltage equal to or greater than 9-VDC? YES Repair: Replace data link adapter.	Repair complete
	Is the voltage equal to or greater than 9-VDC? NO	6F

STEP 6F: Check voltage at vehicle battery

Condition: • None		
Action	Specification/Repair	Next Step
Measure vehicle battery voltage in all cases except if using an Inline I. If using an Inline I measure data link adapter voltage supply from computer.	Is the voltage equal to or greater than 11-VDC? YES Repair: Repair or replace damaged wiring.	Repair complete
	Is the voltage equal to or greater than 11-VDC? NO Repair: Clean the battery connections or replace the batteries.	Repair complete

STEP 6G: Computer serial port voltage check

Condition: • None		
Action	Specification/Repair	Next Step
Note: For Inline I only. Measure voltage across the SIGNAL ground pin and the data terminal ready pin and the SIGNAL ground pin and the request to send pin on the computer serial port. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, for Serial Cable, in the appropriate Electronic and Control System Troubleshooting and Repair manual for pin locations.	Is a minimum of 5 VDC available? YES Repair: Replace data link adapter	Repair complete
	Is a minimum of 5 VDC available? NO Repair: Contact PC administration support.	Repair complete

STEP 7: data link circuit check

STEP 7A: Check J1939 or J1587 circuits

Condition: • None		
Action	Specification/Repair	Next Step
Use the following procedures to perform J1939 or J1587 circuit checks depending on the datalink circuit being used. Reference Procedure 019-165 (Data Link Circuit, SAE J1939) in Section 19 in the appropriate troubleshooting and repair manual. This procedure gives information for a complete resistance check, check for short circuit to ground, and check for short circuit from pin-to-pin. Reference Procedure 019-166 (Data Link Circuit, SAE J1587) in Section 19 in the appropriate troubleshooting and repair manual. This procedure gives information for a complete resistance check, check for short circuit to ground, check for short circuit from pin-to-pin, and voltage check. Reference Procedure 019-428 (Engine data links) in Section 19 in the appropriate troubleshooting and repair manual. Complete resistance check, check for short circuit to ground, and check for short circuit from pin-to-pin.	Does the circuit check OK? YES	11A
	Does the circuit check OK? NO Repair: Repair or replace the harness with the data link problem, either the engine or OEM harness.	Repair complete

STEP 8: Initial electronic tool check

STEP 8A: Second vehicle availability check for electronic tool

Condition: <ul style="list-style-type: none"> Second vehicle available for testing 		
Action	Specification/Repair	Next Step
Verify if a second vehicle is available to connect to electronic tool?	Is a second vehicle available to connect to the electronic tool? YES	8B
	Is a second vehicle available to connect to the electronic tool? NO	10A

STEP 8B: Initial electronic tool functionality check

Condition: <ul style="list-style-type: none"> Electronic tool connected to second vehicle 		
Action	Specification/Repair	Next Step
Attempt to communicate with the ECM on the second vehicle using the electronic tool.	Does the second ECM communicate using the electronic tool? YES	11A
	Does the second ECM communicate using the electronic tool? NO	10A

STEP 9: Detailed electronic tool check

STEP 9A: Troubleshoot electronic tool hardware

Condition: <ul style="list-style-type: none"> None 		
Action	Specification/Repair	Next Step
Perform troubleshooting procedures for evaluating electronic tool hardware: <ul style="list-style-type: none"> data link adapter cable data link adapter power supply cable data link adapter Serial cable Computer. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, in the appropriate troubleshooting and repair manual. Complete the following checks: <ul style="list-style-type: none"> Initial Check - INSITE™ electronic service tool Initial Check - data link Adapters Resistance Check - Serial Cable Resistance Check for data link adapter cable and data link adapter power supply cable. 	Does the electronic tool hardware check OK? YES Repair: Communication issue found.	11A
		Does the electronic tool hardware check OK? NO Repair: Repair or replace damaged hardware.

STEP 10: Serial cable and computer check

STEP 10A: Troubleshoot serial cable and computer

Condition: • None		
Action	Specification/Repair	Next Step
Perform troubleshooting procedures for evaluating the serial cable and computer. Reference Procedure 022-999 (Service Tools and Hardware - Overview) in Section F, in the appropriate troubleshooting and repair manual. Complete the following checks: • Initial Check - INSITE™ electronic service tool • Resistance Check - Serial Cable.	Do the serial cable and computer check OK? YES Repair: Communication issue found	11A
	Do the serial cable and computer check OK? NO Repair: Repair or replace damaged hardware.	Repair complete

STEP 11: ROM boot ECM

STEP 11A: ROM boot tool availability check

Condition: • None		
Action	Specification/Repair	Next Step
Verify if ROM boot tool is available for specific ECM.	Is the ROM boot tool available? YES	11B
	Is the ROM boot tool available? NO Repair: Call for pre-authorization Replace the ECM. Reference Procedure 019-031 (Electronic Control Module (ECM)) in Section 19 in the appropriate troubleshooting and repair manual.	Repair complete

STEP 11B: ROM boot the ECM

Condition:		
<ul style="list-style-type: none"> • None 		
Action	Specification/Repair	Next Step
ROM boot the ECM. Reference Procedure 019-427 (ECM ROM Boot) in Section 19 in the appropriate troubleshooting and repair manual.	Does the ECM communicate? YES Repair: Calibrate the ECM again.	Repair complete
	Does the ECM communicate? NO Repair: Call for pre-authorization Replace the ECM. Reference Procedure 019-031 (Electronic Control Module (ECM)) in Section 19 in the appropriate troubleshooting and repair manual.	Repair complete

Section DS - Engine Disassembly - Group 00

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Remove.....	DS-8
Crosshead	DS-26
Remove.....	DS-26
Cylinder Head	DS-27
Remove.....	DS-27
Cylinder Liner	DS-35
Remove.....	DS-35
Drive Belt, Cooling Fan	DS-2
Remove.....	DS-2
Drive Belt, Refrigerant Compressor	DS-4
Remove.....	DS-4
EGR Connection Tubes	DS-13

Remove.....	DS-13
EGR Cooler	DS-15
Remove.....	DS-15
EGR Cooler Coolant Lines	DS-14
Remove.....	DS-14
EGR Cooler Mounting Bracket	DS-16
Remove.....	DS-16
EGR Valve	DS-17
Remove.....	DS-17
Engine Brake Assembly	DS-25
Remove.....	DS-25
Engine Control Module Cooling Plate, Fuel Cooled	DS-23
Remove.....	DS-23
Engine Oil Heater	DS-29
Remove.....	DS-29
Engine Support Bracket, Front	DS-2
Remove.....	DS-2
Engine Support Bracket, Rear	DS-6
Remove.....	DS-6
Exhaust Gas Pressure Sensor Tube	DS-13
Remove.....	DS-13
Exhaust Manifold, Dry	DS-16
Remove.....	DS-16
Fan Hub, Belt Driven	DS-3
Remove.....	DS-3
Fan Spacer and Pulley	DS-3
Remove.....	DS-3
Flexplate	DS-7
Remove.....	DS-7
Flywheel	DS-7
Remove.....	DS-7
Flywheel Housing	DS-8
Remove.....	DS-8
Fuel Connector (Head Mounted)	DS-21
Remove.....	DS-21
Fuel Drain Lines	DS-19
Remove.....	DS-19
Fuel Filter (Spin-On Type)	DS-1
Remove.....	DS-1
Fuel Filter Head Bracket	DS-20
Remove.....	DS-20
Fuel Pump	DS-21
Remove.....	DS-21
Fuel Rail	DS-21
Remove.....	DS-21
Fuel Supply Lines	DS-18
Remove.....	DS-18
Gear Cover, Front	DS-28
Remove.....	DS-28
Gear Housing, Front	DS-32
Remove.....	DS-32
Injector	DS-26
Remove.....	DS-26
Injector Supply Lines (High Pressure)	DS-20
Remove.....	DS-20
Lubricating Oil Cooler	DS-16
Remove.....	DS-16
Lubricating Oil Dipstick Tube	DS-10
Remove.....	DS-10
Lubricating Oil Filter (Spin-On)	DS-1
Remove.....	DS-1
Lubricating Oil Pan	DS-29
Remove.....	DS-29
Lubricating Oil Pump	DS-28

Remove.....	DS-28
Lubricating Oil Suction Tube (Block-Mounted)	DS-29
Remove.....	DS-29
Piston and Connecting Rod Assembly	DS-33
Remove.....	DS-33
Piston Cooling Nozzle	DS-32
Remove.....	DS-32
Push Rods or Tubes	DS-26
Remove.....	DS-26
Refrigerant Compressor Mounting Bracket	DS-5
Remove.....	DS-5
Rocker Lever	DS-26
Remove.....	DS-26
Rocker Lever Cover	DS-24
Remove.....	DS-24
Rocker Lever Housing	DS-27
Remove.....	DS-27
Starting Motor	DS-7
Remove.....	DS-7
Tappet	DS-30
Remove.....	DS-30
Turbocharger	DS-12
Remove.....	DS-12
Turbocharger Compressor Outlet Connection	DS-10
Remove.....	DS-10
Turbocharger Coolant Hoses	DS-10
Remove.....	DS-10
Turbocharger Heat Shield	DS-13
Remove.....	DS-13
Turbocharger Oil Drain Line	DS-11
Remove.....	DS-11
Turbocharger Oil Supply Line	DS-12
Remove.....	DS-12
Vibration Damper, Rubber	DS-27
Remove.....	DS-27
Vibration Damper, Viscous	DS-27
Remove.....	DS-27
Water Inlet Connection	DS-6
Remove.....	DS-6
Water Pump	DS-6
Remove.....	DS-6

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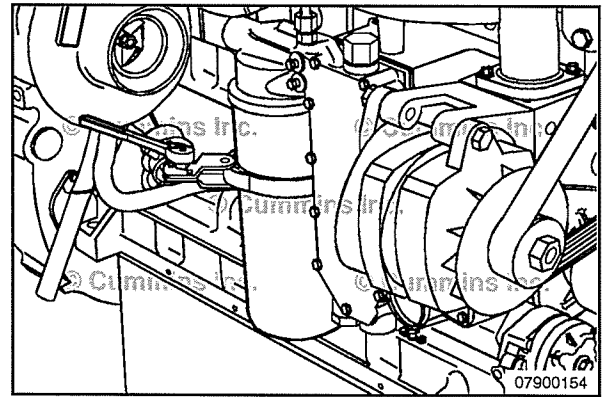
Lubricating Oil Filter (Spin-On) (007-013)

Remove

Clean the area around the lubricating oil filter head.

Use oil filter wrench, Part Number 3375049, to remove the lubricating oil filter.

Clean the gasket surface of the filter head with a clean lint-free cloth.



Coolant Filter (008-006)

Remove

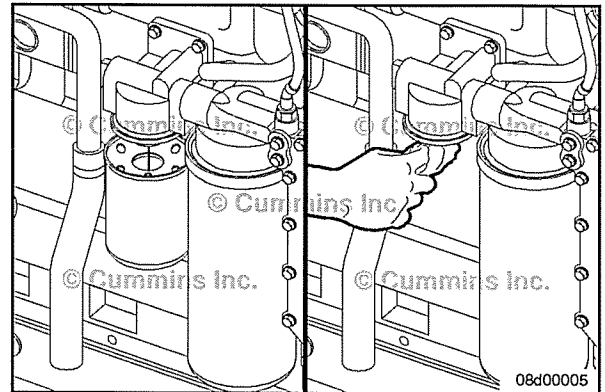
⚠ WARNING ⚠

A small amount of coolant can leak when servicing the coolant filter with the shutoff valve in the OFF position. To reduce the possibility of personal injury, avoid contact with hot coolant.

⚠ WARNING ⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Remove and discard the coolant filter.



Fuel Filter (Spin-On Type) (006-015)

Remove

⚠ WARNING ⚠

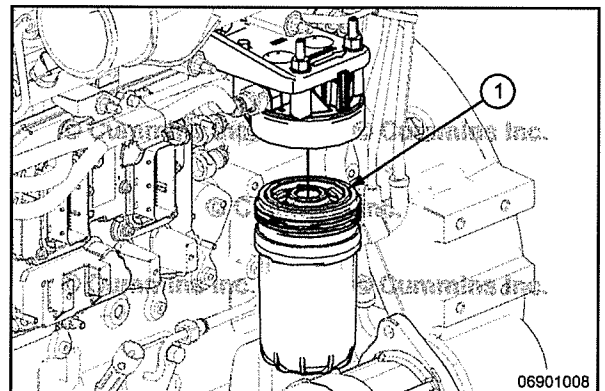
Depending on the circumstance, diesel fuel is flammable. When inspecting or performing service or repairs on the fuel system, to reduce the possibility of fire and resulting severe personal injury, death, or property damage, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area.

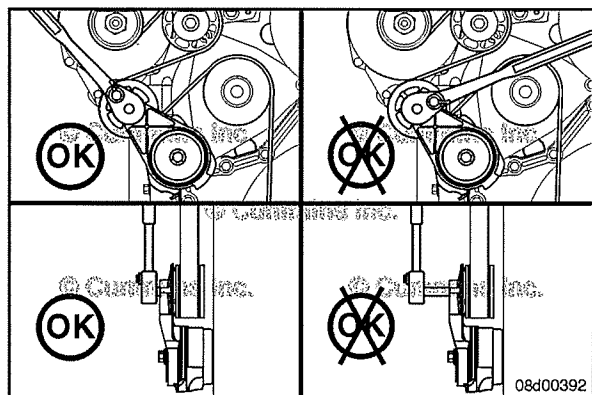
Disconnect the wiring harness from the water-in-fuel sensor, if equipped.

Loosen and remove the fuel filter.

Make sure the seal ring (1) does **not** stick to the filter head.

Remove the ring with an o-ring pick, if necessary.





Drive Belt, Cooling Fan (008-002)

Remove

⚠CAUTION⚠

The belt tensioner is spring-loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

⚠CAUTION⚠

Applying excessive force in the opposite direction of windup or after the tensioner has been wound up to the positive stop can cause the tensioner arm to break.

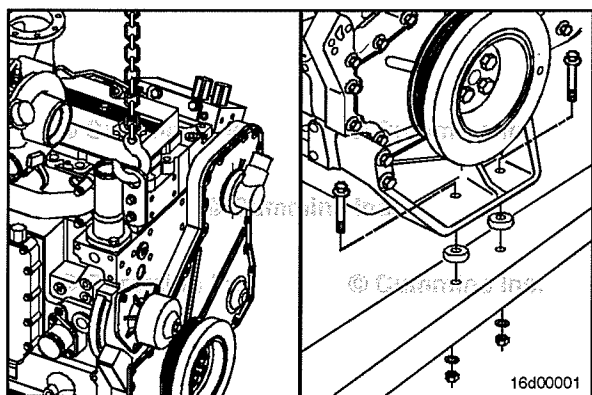
⚠CAUTION⚠

Using a socket extension is not recommended because it can cause axial twisting damage to the belt tensioner.

NOTE: Make a diagram of the belt arrangement prior to removing the drive belt. This aids in installation and proper routing of the cooling fan drive belt.

Lift the tensioner to remove the drive belt.

NOTE: If a socket extension is necessary, support the head of the ratchet with one hand to prevent the belt tensioner arm from unintended loading.



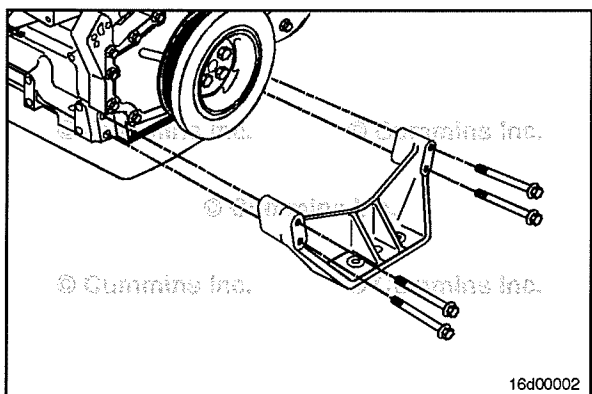
Engine Support Bracket, Front (016-002)

Remove

Use a hoist or lifting fixture to support the front of the engine.

Remove the capscrews from the front engine mount.

NOTE: Make sure to save any shims or spacers removed and record their location.



Remove the four mounting capscrews and the front engine support.

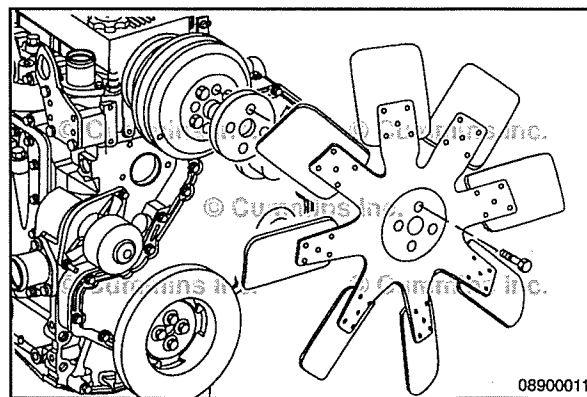
Fan Spacer and Pulley (008-039)

Remove

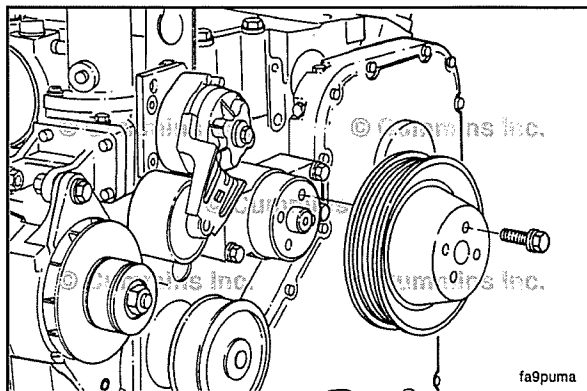
NOTE: Some applications do **not** have a cooling fan or the cooling fan is located elsewhere on the application.

If equipped, remove the cooling fan. Refer to the OEM service manual for instructions.

For engines equipped with an engine driven cooling fan, the fan holds the fan pulley and spacer in place. Remove the fan pulley and spacer.



If the engine is **not** equipped with an engine driven cooling fan, remove the fan pulley mounting capscrews and fan pulley.

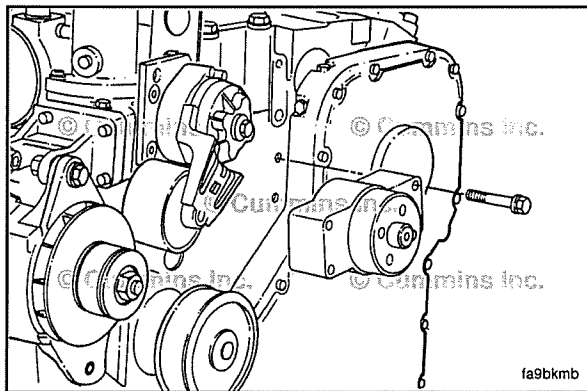


Fan Hub, Belt Driven (008-036)

Remove

Remove the fan hub mounting capscrews.

Remove the fan hub.

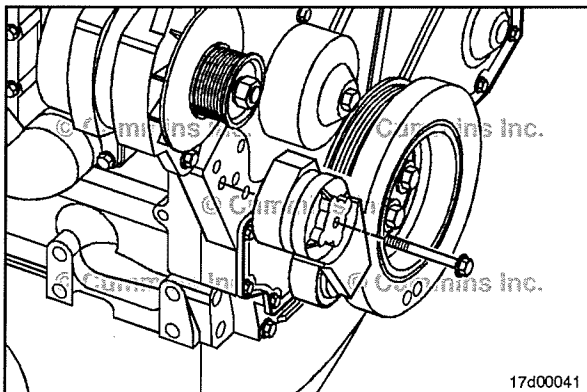


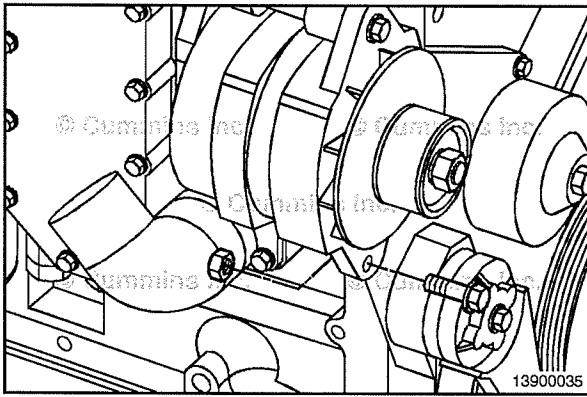
Belt Tensioner, Automatic (Water Pump) (008-080)

Remove

Remove the capscrew and belt tensioner from the bracket.

NOTE: Most belt tensioners are mounted to the water inlet connection. Some belt tensioners are mounted to a separate mounting bracket and use internal fasteners for clearance.

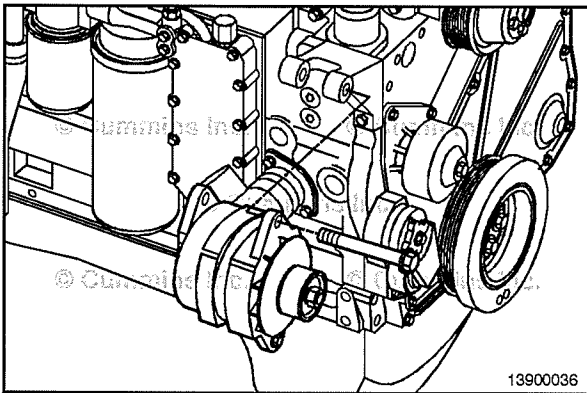




Alternator (013-001)

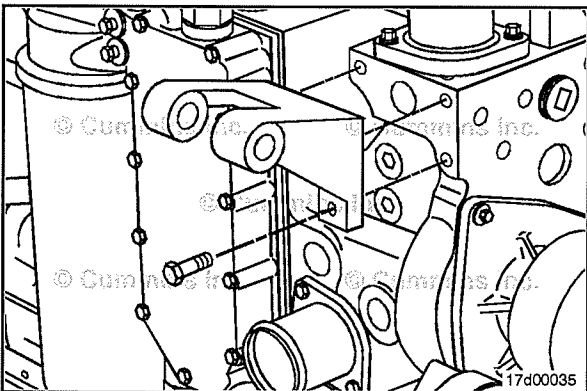
Remove

Remove the alternator link cap screw.



Remove the alternator mounting cap screw.

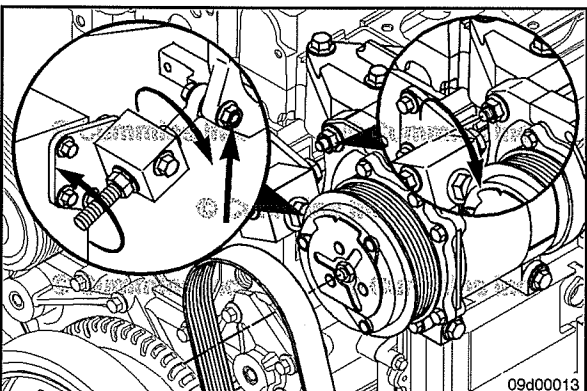
Remove the alternator.



Alternator Bracket (013-003)

Remove

Remove the bracket mounting cap screws and the side mounted bracket.



Drive Belt, Refrigerant Compressor (009-052)

Remove

Loosen the pivot bolt.

Loosen the bolt that attaches the adjusting link to the compressor bracket.

Loosen the adjusting nuts on the adjusting link to remove tension from the belt.

Remove the refrigerant compressor drive belt.

Refrigerant Compressor Mounting Bracket (009-055)



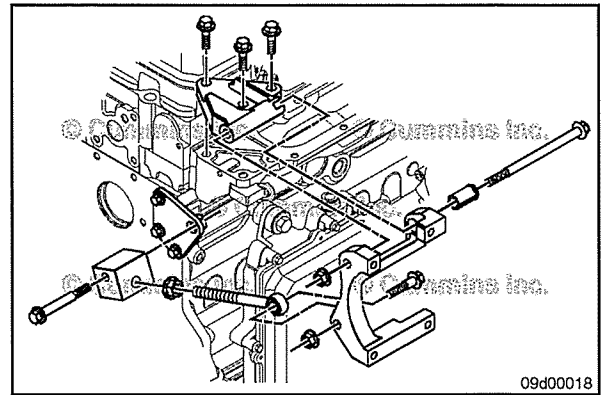
Remove

Remove the adjusting link capscrews.

Remove the adjusting link.

Remove the pivot capscrew and the refrigerant compressor support.

Remove the remaining capscrews and brackets.

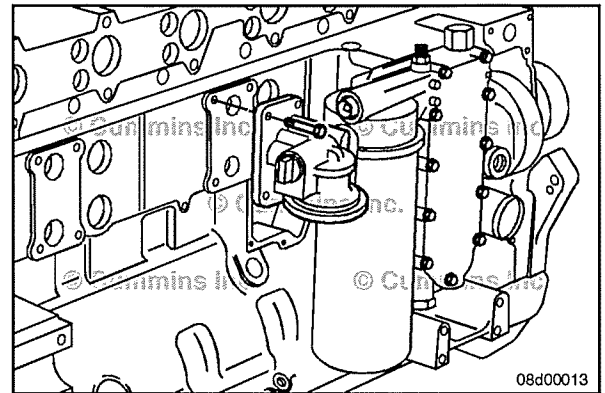


Coolant Filter Head (008-007)

Remove

Loosen the four filter head capscrews.

Remove the filter head and gasket.

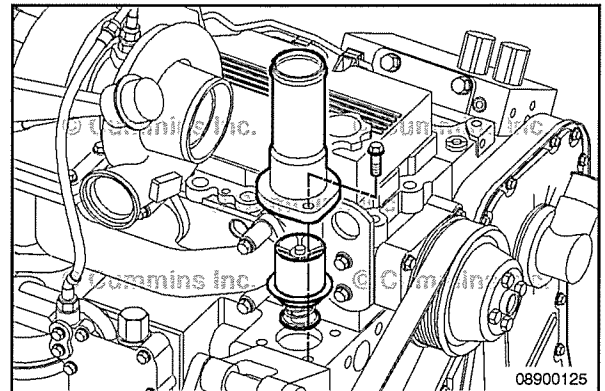


Coolant Thermostat (008-013)

Remove

Remove the water outlet connection capscrews and water outlet connection.

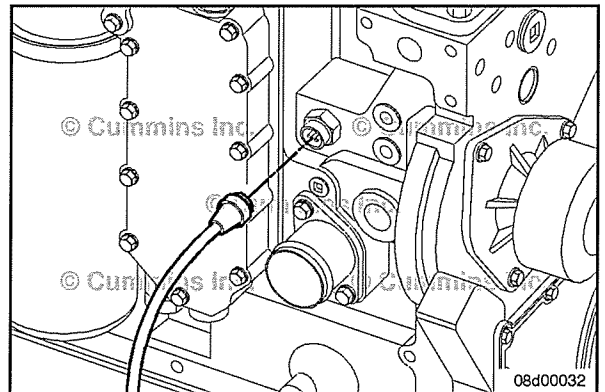
Remove the thermostat.

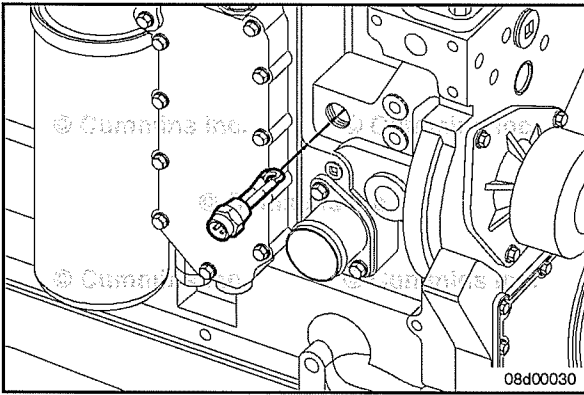


Coolant Heater (008-011)

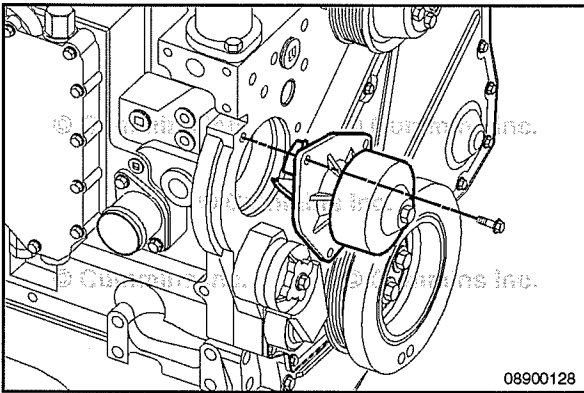
Remove

Disconnect the coolant heater electrical cord.





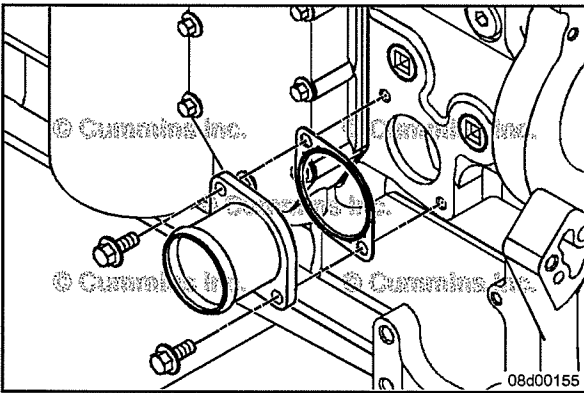
Loosen the coolant heater and remove it from the cylinder block.



Water Pump (008-062)

Remove

Remove the water pump capscrews and the water pump.

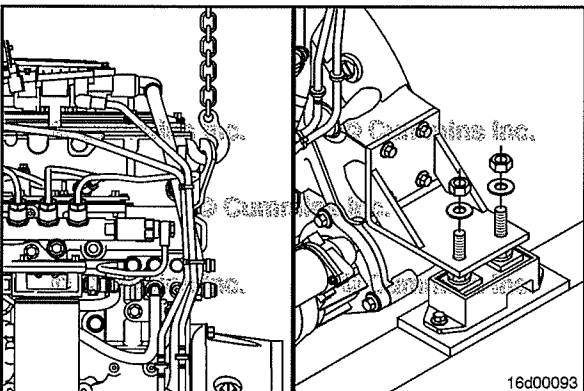


Water Inlet Connection (008-082)

Remove



Remove the water inlet connection capscrews.



Engine Support Bracket, Rear (016-003)

Remove

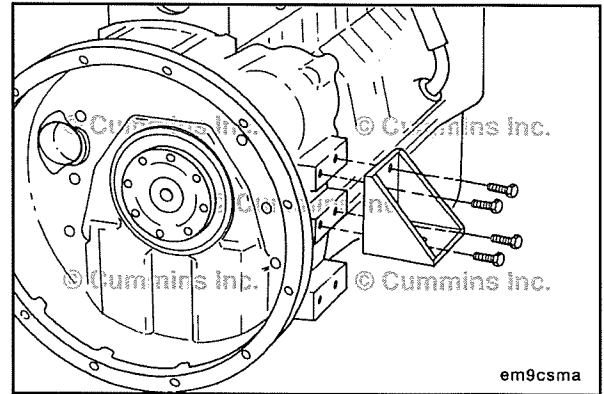
⚠ WARNING ⚠

The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

Use a hoist or lifting fixture to support the rear of the engine.

Remove the capscrew from the rear engine mount.

Remove the four capscrews and rear support bracket.

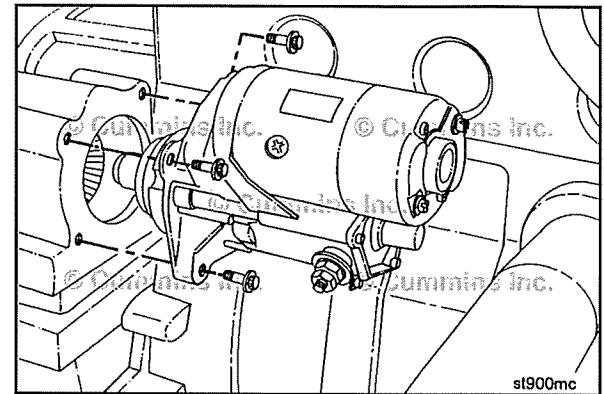


Starting Motor (013-020)

Remove

Remove the three capscrews and the starting motor.

If equipped with a starting motor spacer, remove the spacer and clean all surfaces between the starting motor, starting motor spacer, and flywheel housing with a wire brush.

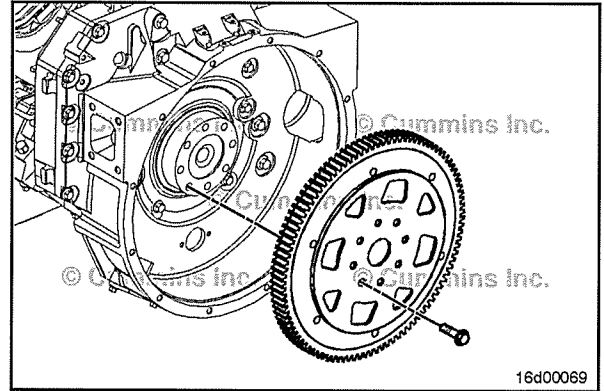


Flexplate (016-004)

Remove

Remove the flexplate capscrews and flexplate.

NOTE: Some flexplates require mounting plates and/or adapters. It may be necessary to remove any mounting plates and/or adapters prior to or with the flexplate. Make sure to note the location of any mounting plates and/or adapters for later installation.



Flywheel (016-005)

Remove

NOTE: Use the barring tool, Part Number 3824591, to hold the flywheel to prevent rotation.

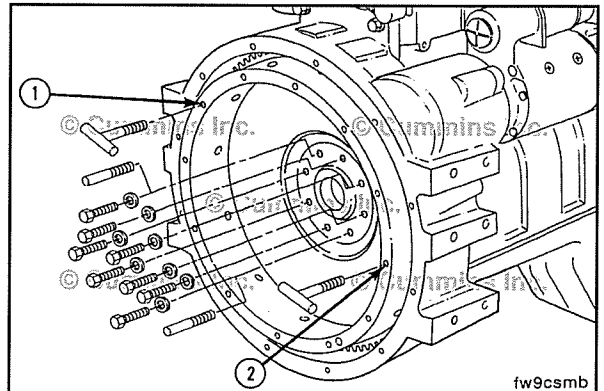
Remove two capscrews 180 degrees apart.

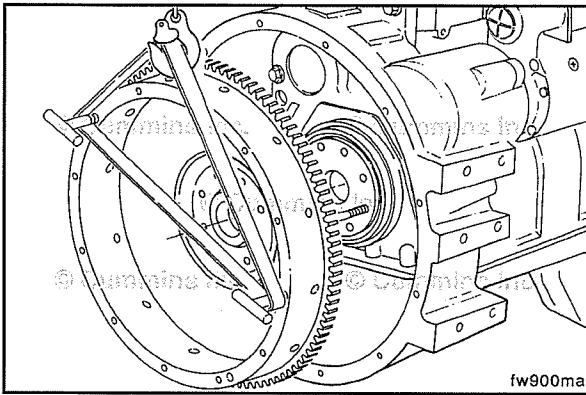
Install two M12 x 1.25 x 90-mm guide pins.

NOTE: If a clutch is used in the equipment, the threads in the clutch pressure plate mounting capscrew holes can be metric or standard. Be sure to use the correct capscrews.

Determine the capscrew thread design and size, and install two T-handles in the flywheel at points (1) and (2).

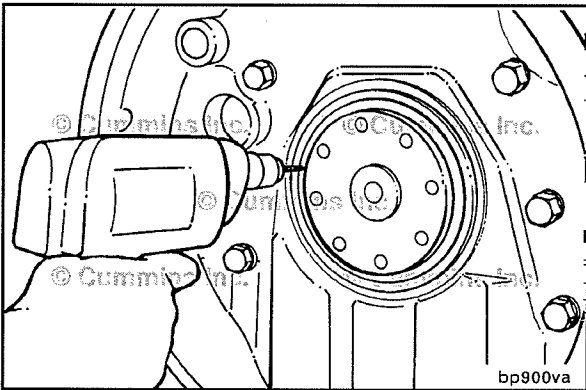
Remove the remaining six flywheel mounting capscrews.





▲ WARNING ▲
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

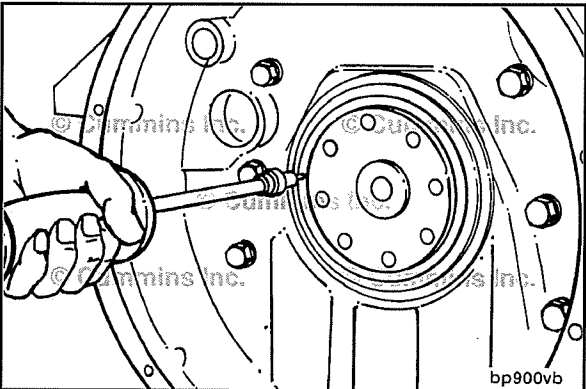
Remove the flywheel from the guide pins.



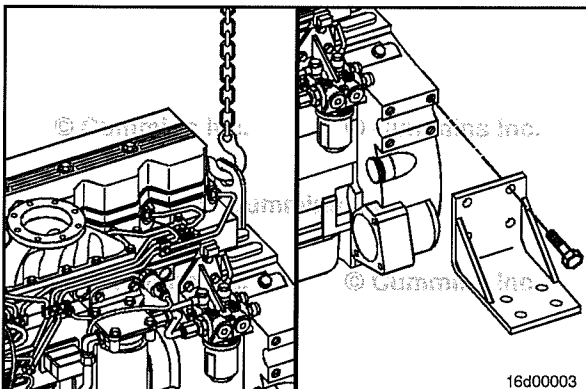
Crankshaft Seal, Rear (001-024)

Remove

Drill two holes 180 degrees apart into the seal.



Use a screwdriver and a slide hammer to remove the rear seal.



Flywheel Housing (016-006)

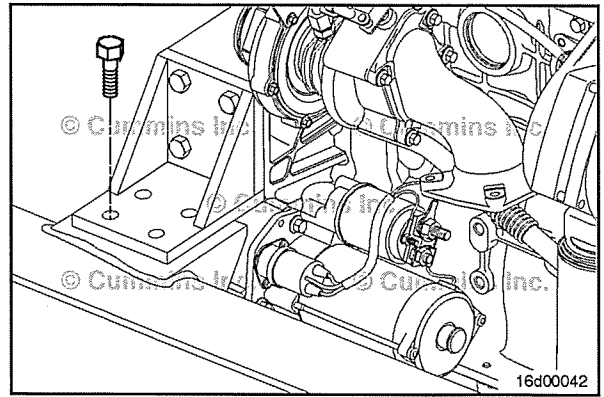
Remove

▲ WARNING ▲
The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

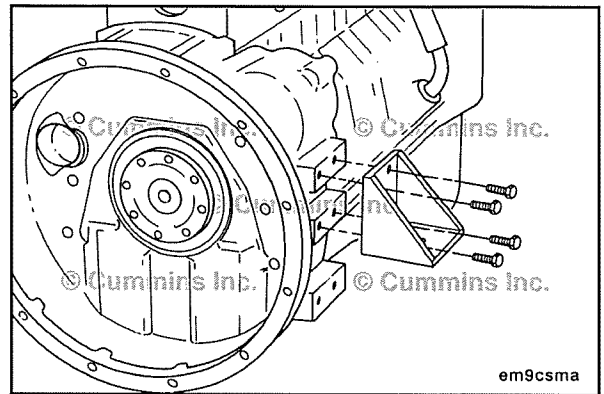
Use a hoist or lifting fixture to support the rear of the engine.

NOTE: When removing the rear engine mount fasteners, keep track of the location of any shims or spacers used.

Remove the engine mount fasteners.

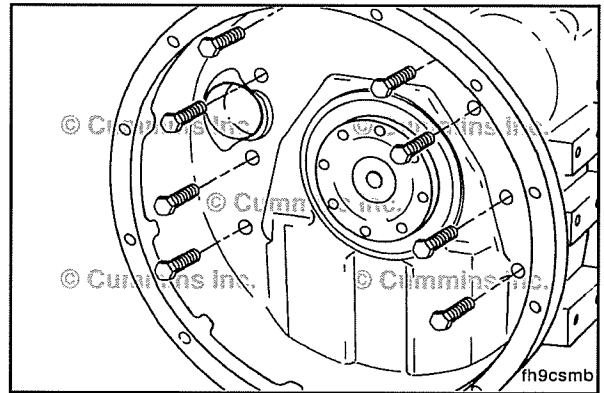


Remove the rear support capscrews and bracket.



⚠ WARNING ⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

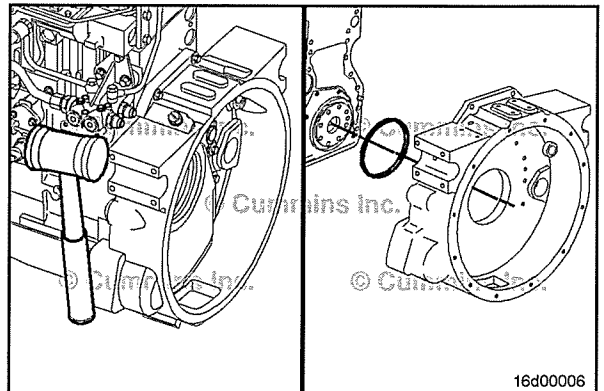
Remove the mounting capscrews while supporting the flywheel housing.

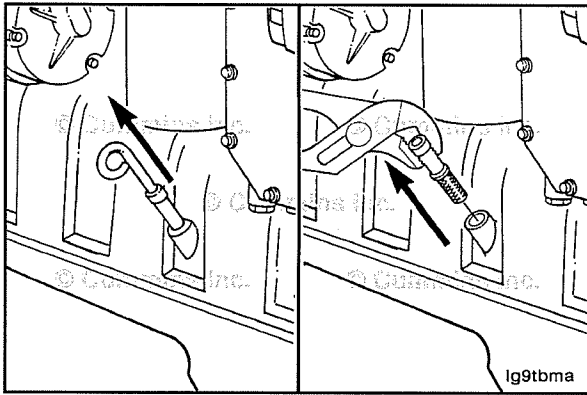


While supporting the flywheel housing, use a rubber hammer to loosen the flywheel housing.

Remove the flywheel housing.

NOTE: When removing the flywheel housing, note the location of any locating dowel rings.





Lubricating Oil Dipstick Tube (007-011)

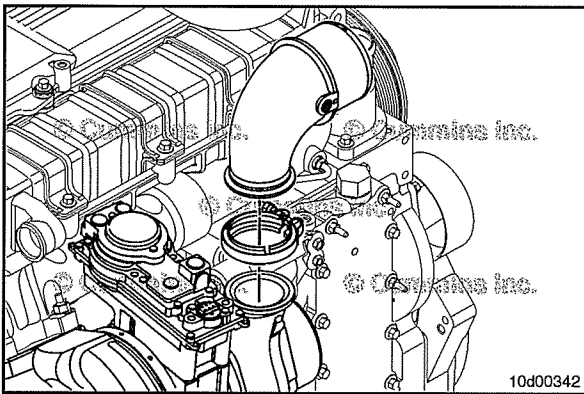


Remove

Remove the dipstick from the dipstick tube.

Remove the dipstick tube from the cylinder block.

Service Tip: Use a dent puller and a M8 x 1.25 x 21-mm self-tapping capscrew. Thread the capscrew into the dipstick tube and remove the tube.



Turbocharger Compressor Outlet Connection (010-132)

Remove

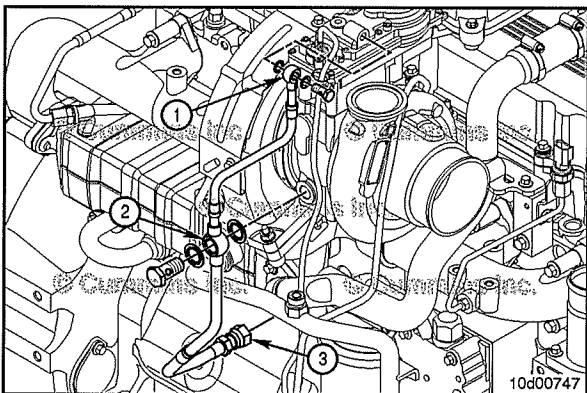
Remove the turbocharger outlet elbow, V-band clamp, and o-ring from the turbocharger compressor outlet.

Use protective caps from the Air Handling Clean Care Kit, Part Number 5298776, to cover both of the connection points.

Turbocharger Coolant Hoses (010-041)

Remove

There are two different turbochargers used on the engine, depending on the engine rating. Each turbocharger has different plumbing. This procedure has been written to be common. **Not all** illustrations within this procedure represent the application that is being serviced.

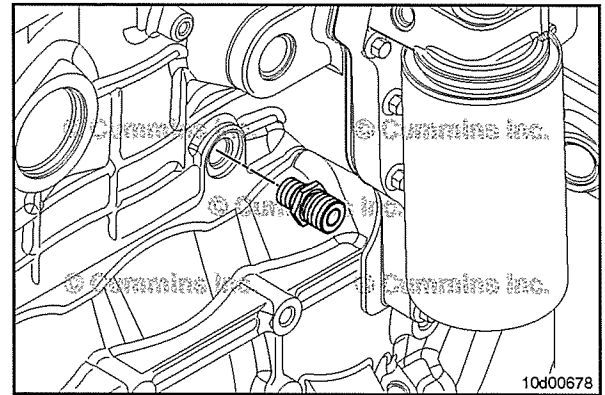


Remove the turbocharger coolant supply hose by first removing the banjo screw attached to the variable geometry turbocharger (VGT) actuator (1) and/or remove the banjo screw attached to the turbocharger bearing housing (2).

Remove the coolant connection from the cylinder block fitting (3).

NOTE: Use a second wrench to hold the coolant connection fittings at the cylinder block and turbocharger bearing housing to prevent accidental loosening of the fittings. Hold the turbocharger coolant supply line while loosening to prevent kinking the line.

Remove the turbocharger coolant supply hose fitting from the cylinder block.

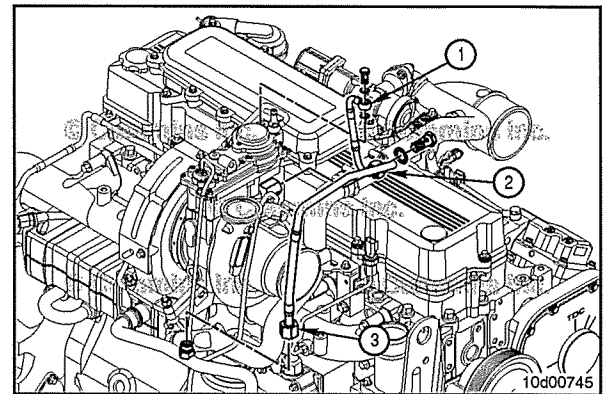


Remove the turbocharger coolant return hose by first removing the banjo screw attached to the VGT actuator (1) and/or remove the banjo screw attached to the turbocharger bearing housing (2).

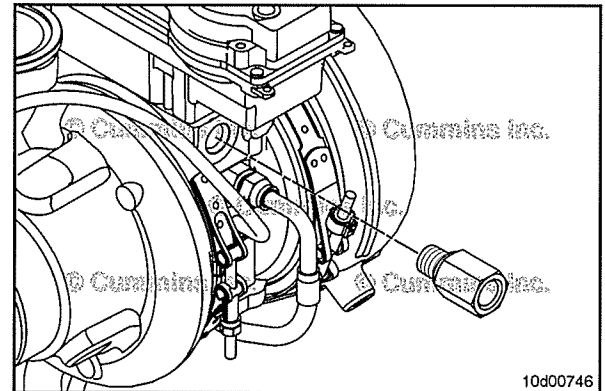


Remove the coolant connection from the cylinder block fitting (3).

NOTE: Use a second wrench to hold the coolant connection fittings at the cylinder block and turbocharger bearing housing to prevent accidental loosening of the fittings. Hold the turbocharger coolant supply line while loosening to prevent kinking the line.



Remove the turbocharger coolant supply hose fitting and the turbocharger coolant return hose fitting from the turbocharger bearing housing or VGT actuator.



Turbocharger Oil Drain Line (010-045)

Remove

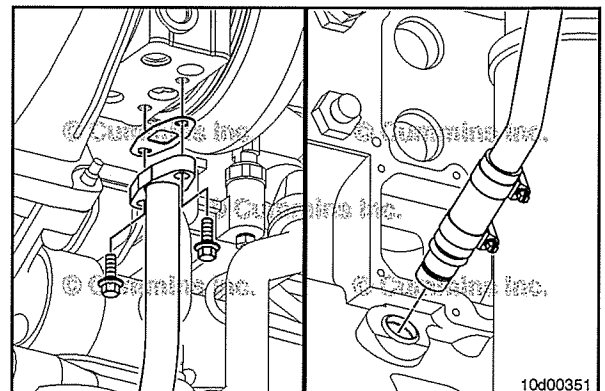
Clean around the area where the oil drain line inserts into the cylinder block with a clean cloth.

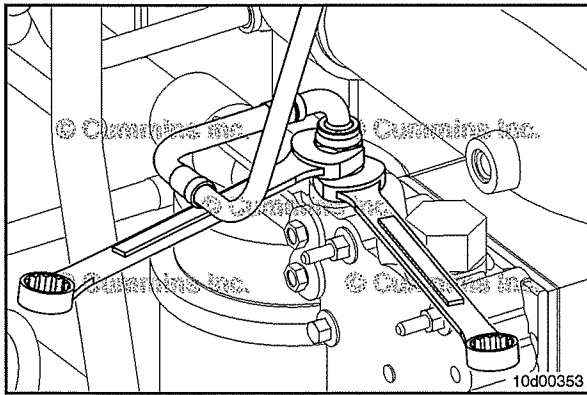
Loosen the hose clamps that hold the upper oil drain tube to the oil drain hose.

Remove the two capscrews that hold the upper oil drain tube to the turbocharger. Discard the gasket.

Remove the upper oil drain tube from the turbocharger and oil drain hose.

Pull the oil drain hose and lower drain tube out of the cylinder block.





Turbocharger Oil Supply Line (010-046)

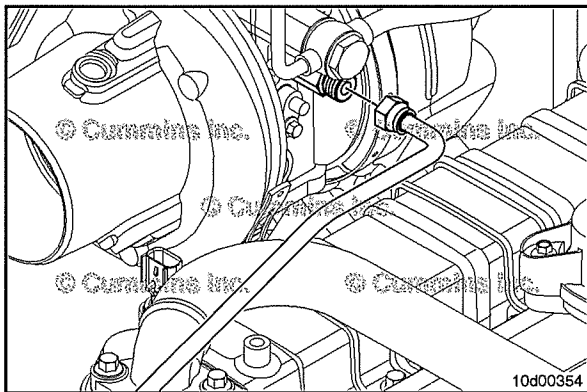
Remove

⚠ CAUTION ⚠

When handling the oil supply line, avoid bending the flexible portion into a tight bend, as this will cause damage to the flexible material. It is advisable to remove the line from the engine, when servicing the engine, to avoid accidentally overbending the flexible material.

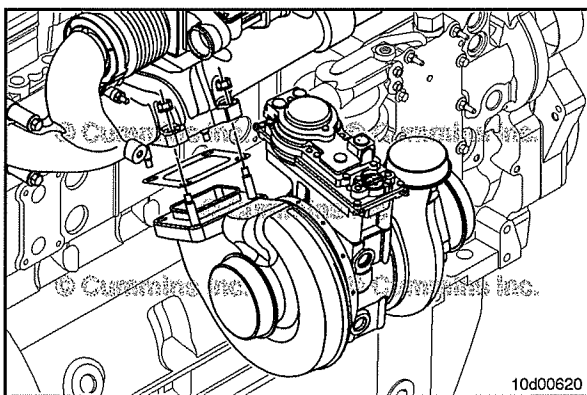
Remove the oil supply line from the fitting in the oil filter head.

NOTE: Use a wrench to hold the fittings below the oil supply line on both the turbocharger bearing housing and the oil filter head. This will prevent the fittings from loosening.



Remove the oil supply line from the turbocharger bearing housing fitting.

Discard the old o-ring seals.



Turbocharger (010-033)

Remove

⚠ WARNING ⚠

This component or assembly weights greater than 25 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift the component or assembly.

Remove the four turbocharger mounting nuts.

Remove the turbocharger and discard the gaskets.

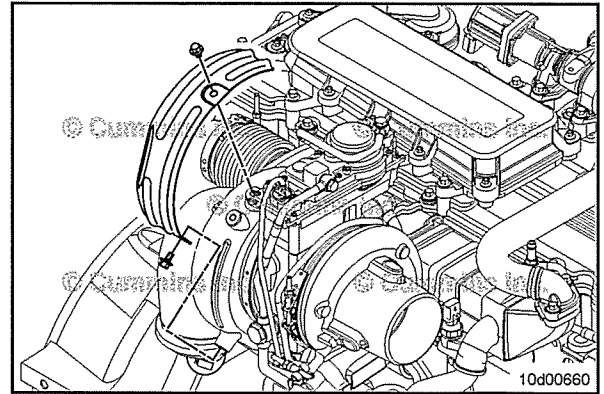
Cover the turbocharger exhaust inlet port with a cap from the Air Handling Clean Care Kit, Part Number 5298776. Cover the openings on the exhaust manifold with heavy tape.

If required, remove the turbocharger actuator. Refer to Procedure 010-134 in Section 10.

Turbocharger Heat Shield (010-076)

Remove

Remove the capscrews securing the turbocharger heat shield to the turbocharger turbine housing.



EGR Connection Tubes (011-025)

Remove

⚠ CAUTION ⚠

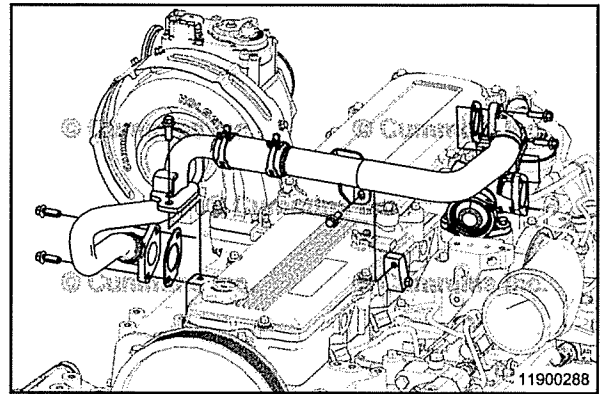
Do not twist or bend the EGR connection tube during removal or installation, or damage to the hose can result.

Remove the two capscrews from each support flange of the EGR connection tubes.

Remove the EGR connection tube by loosening the bolted flanges from both sides of the EGR connection tube.

Use caution to keep debris from falling into the EGR cooler and the EGR valve when removing the EGR connection tube.

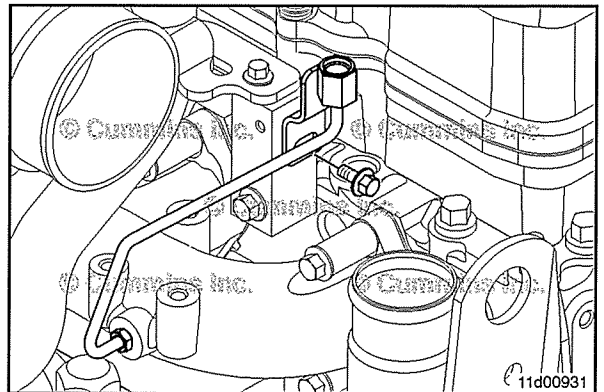
Cover all open connections with protective caps from the Air Handling Clean Care Kit, Part Number 4919508.

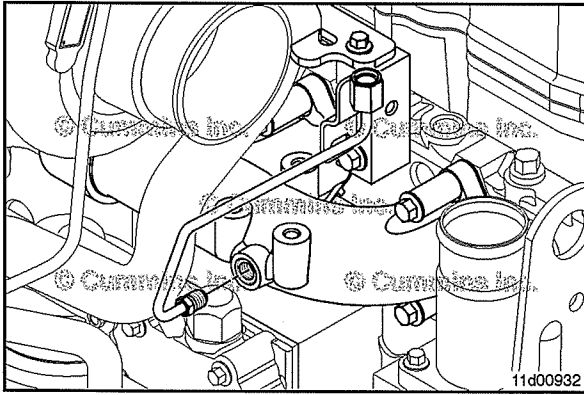


Exhaust Gas Pressure Sensor Tube (011-027)

Remove

Remove the mounting fastener securing the exhaust gas pressure sensor tube to the cylinder head.





▲ WARNING ▲

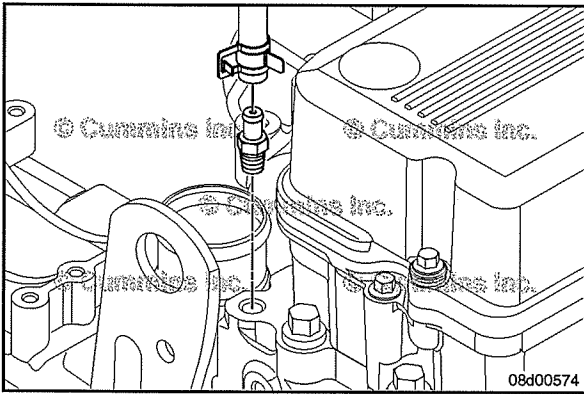
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.



Use compressed air to clean around the fitting where the exhaust gas pressure sensor tube connects to the exhaust manifold.

Disconnect the exhaust gas pressure sensor tube from the exhaust manifold.

Remove the exhaust gas pressure sensor tube.

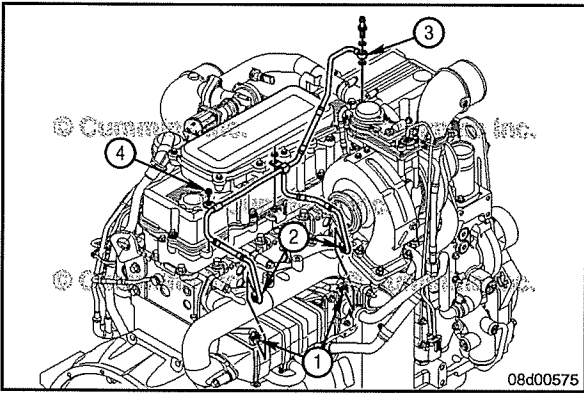


Coolant Vent Lines (008-017)

Remove

Remove the coolant vent line.

Remove the coolant vent line fitting from the cylinder head.

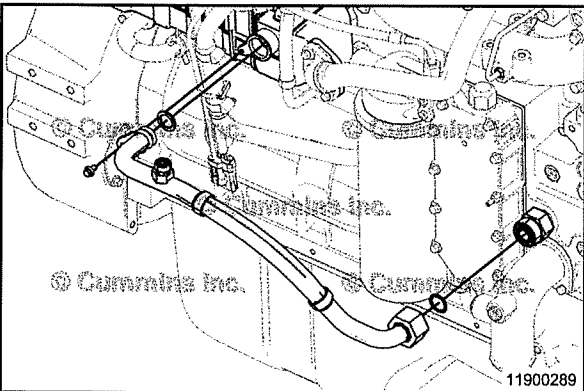


Remove the vent line mounting screws (4).

Remove the banjo bolt from the turbocharger (3).

Remove the vent line mounting nuts from the EGR cooler (2).

Remove the fittings from the EGR cooler (1).



EGR Cooler Coolant Lines (011-031)

Remove

NOTE: Discard and replace all o-ring seals.

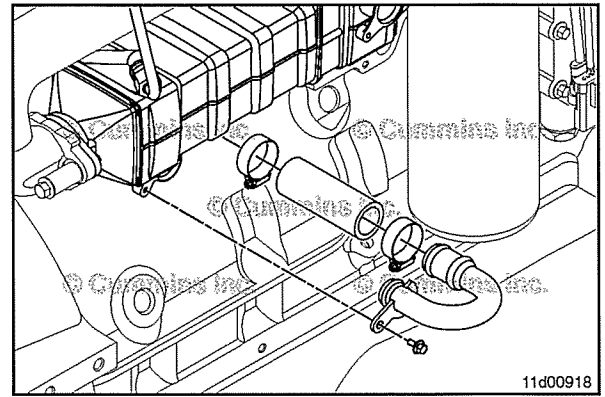
EGR Cooler Coolant Return Line

- Remove the capscrew attaching the EGR cooler coolant return line to the EGR cooler
- Remove the EGR cooler coolant return line.
- Unscrew the nut for the block side return line.
- Do **not** attempt to remove the crimped flex section.

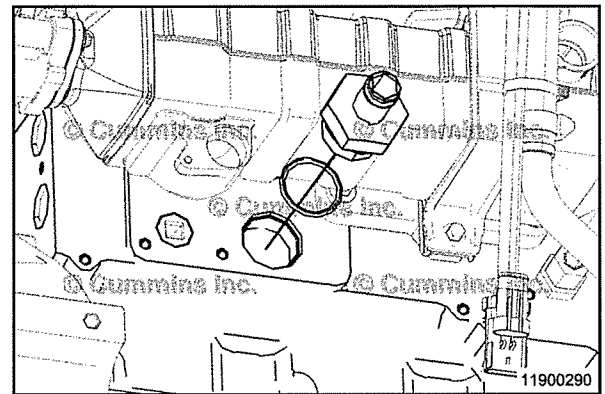
NOTE: Discard and replace all o-ring seals.

EGR Cooler Coolant Supply Line

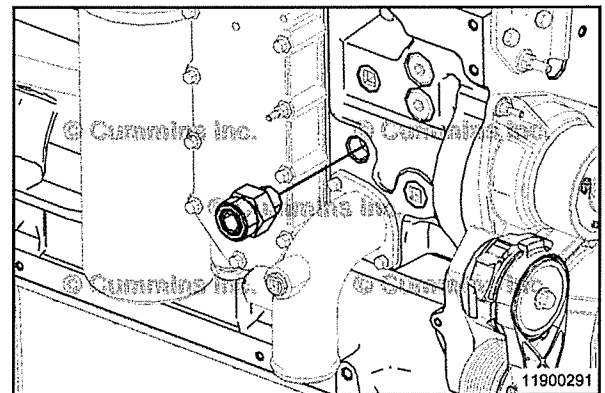
- Remove the capscrew attaching the EGR cooler coolant supply line to the EGR cooler
- Remove the two hose clamps from the EGR cooler coolant supply line hose
- Remove the EGR cooler coolant supply line
- Remove the EGR coolant coolant supply line hose.



Remove the EGR cooler coolant supply line fitting from the cylinder block (rear of engine).



Remove the EGR cooler coolant return line fitting from the cylinder block (front of engine).



EGR Cooler (011-019)

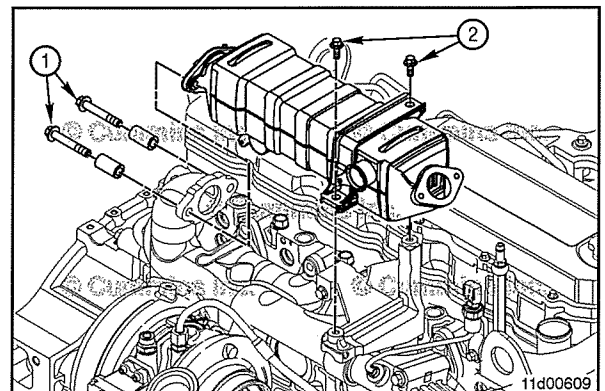
Remove

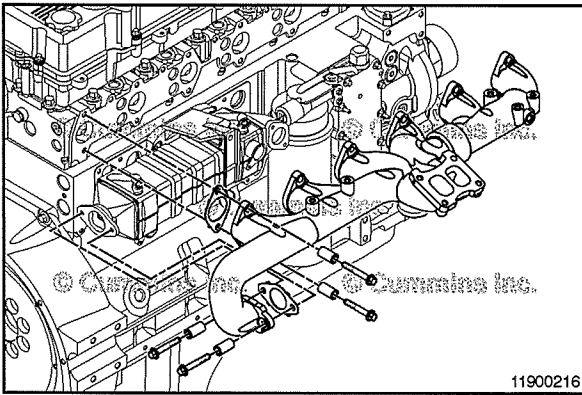
Remove the EGR cooler exhaust manifold capscrews and spacers (1) and the EGR cooler mounting capscrews (2).

Remove the EGR cooler assembly.

Remove and discard gaskets.

Cover open connections with protective caps from the Cummins® Air Handling Clean Care Kit, Part Number 4919498.





Exhaust Manifold, Dry (011-007)

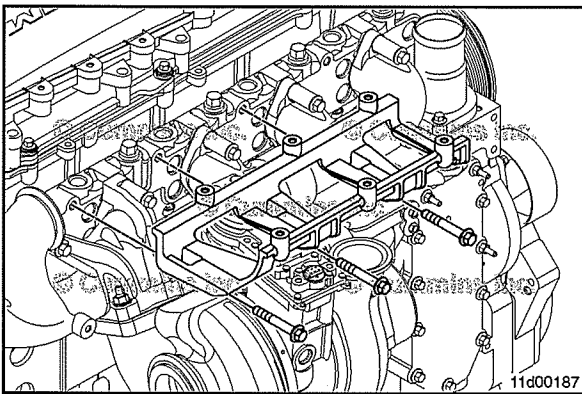
Remove

NOTE: The two sections of the exhaust manifold are sealed by an exhaust manifold seal. If preliminary inspection shows that the seal is **not** leaking, it is **not** necessary to separate the two parts of the exhaust manifold.

Remove the 12 capscrews from the exhaust manifold and remove the exhaust manifold.

Remove the gasket from the exhaust manifold to the EGR cooler inlet connection.

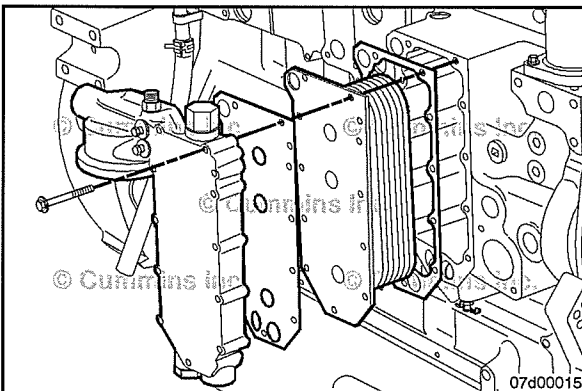
Use heavy tape to cover open points in the exhaust manifold and cylinder head.



EGR Cooler Mounting Bracket (011-029)

Remove

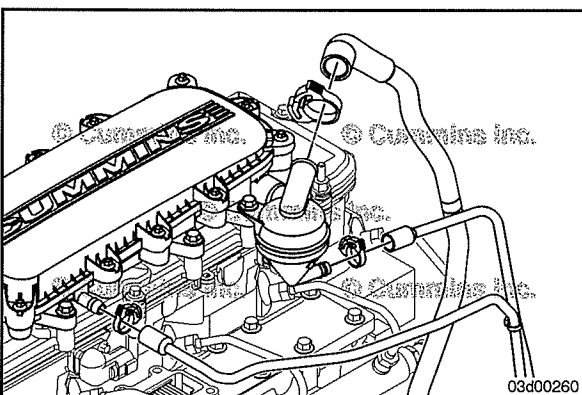
Remove the three capscrews that attach the EGR cooler bracket to the cylinder head and remove the EGR cooler bracket.



Lubricating Oil Cooler (007-003)

Remove

Remove the lubricating oil cooler cover, gaskets, and oil cooler element.



Crankcase Breather Tube (003-018)

Remove

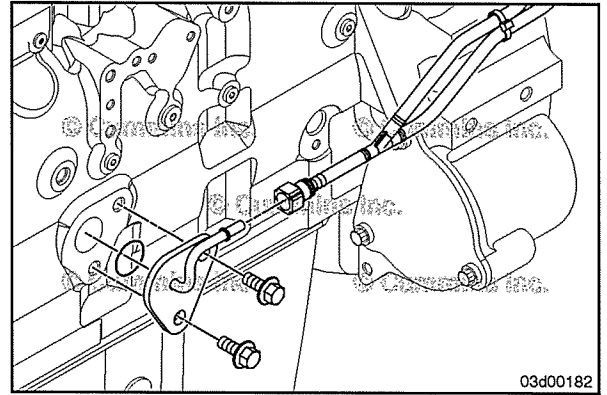
Rocker Lever Cover Mounted Crankcase Breather

Remove the crankcase breather tube from the crankcase breather assembly.

Remove the crankcase drain lines from the crankcase breather assembly.

Remove the snapper hose clamps from the drain tube and lines.

Remove the breather drain lines, breather drain line cover, and gasket from the cylinder block.



03d00182

EGR Valve (011-022)

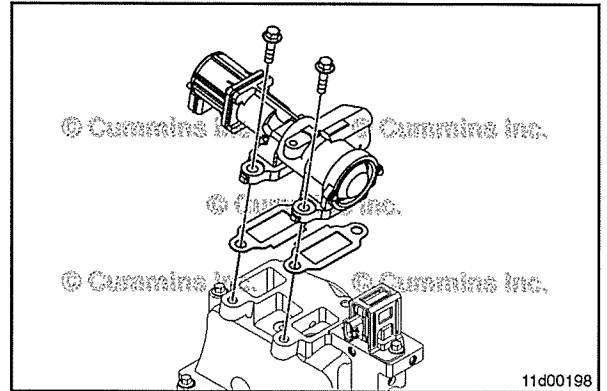
Remove

Clean the area around the EGR valve with a clean cloth to help prevent debris from entering the air intake system when the EGR valve is removed.



Remove the four capscrews holding the EGR valve to the air intake connection and remove the EGR valve.

Use protective caps from the Air Handling Clean Care Kit, Part Number 4919498, or equivalent, or heavy tape to cover any open connections to prevent debris from entering the system.



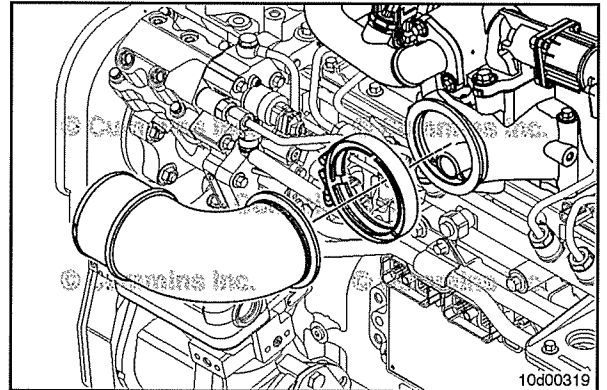
11d00198

Air Intake Connection Adapter (010-131)

Remove

Remove the V-band clamp holding the air intake connection adapter to the air intake connection.

Remove the air intake connection adapter.



10d00319

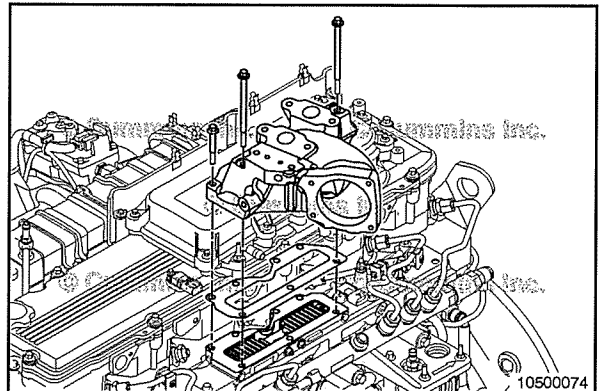
Air Intake Connection (010-080)

Remove

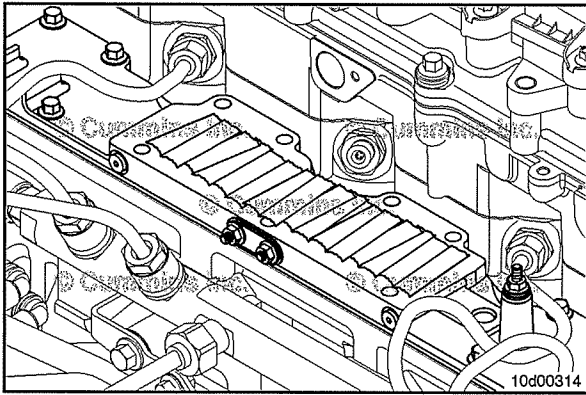
Remove the capscrews that hold the air intake connection to the air intake manifold and remove the air intake connection.

Use protective caps from the Air Handling Clean Care Kit, Part Number 5298776, to cover all open connections.

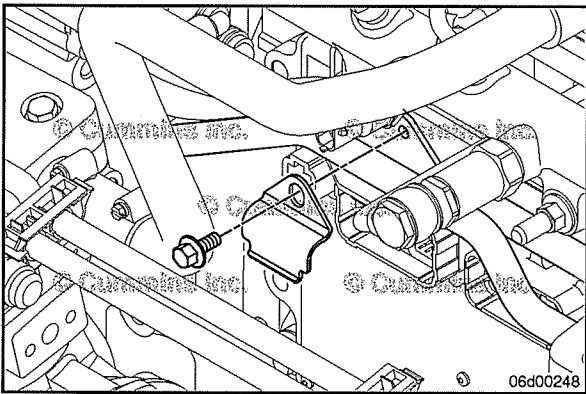
NOTE: If the engine experiences a turbocharger malfunction or any other occasion in which oil, debris, or coolant is put into the charge-air system, the EGR differential pressure sensor flow ports **must** be cleaned.



10500074

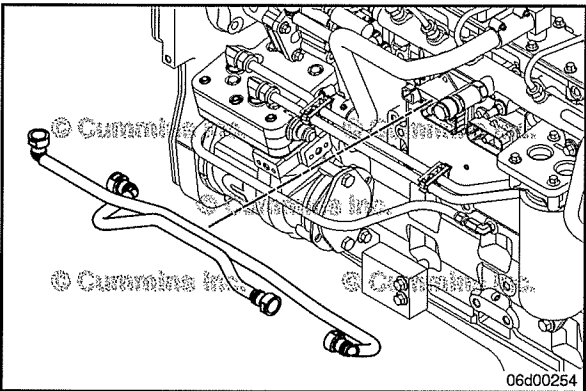


Use heavy tape to cover the intake manifold opening to prevent debris from entering the engine.



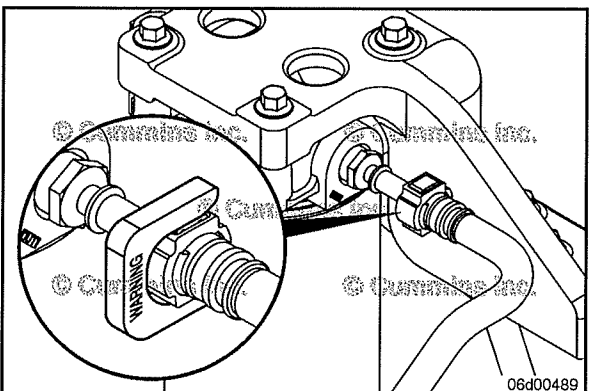
Fuel Supply Lines (006-024) Remove

For quick disconnect style fuel lines, remove the clasp from the fuel line brace. This will allow the lines to move so they can be disconnected.



Loosen all quick disconnect lines from the brace.

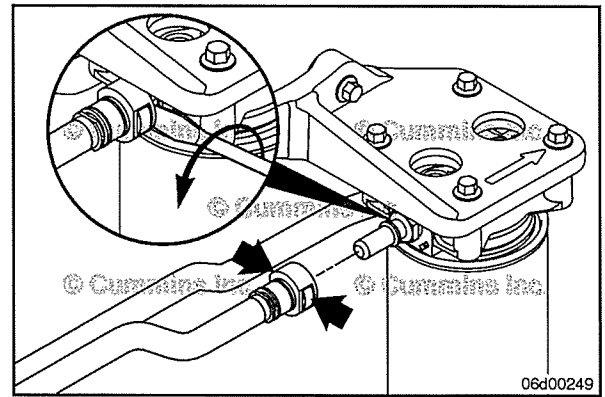
To remove the gear pump outlet line, the gear pump inlet line **must** be removed first.



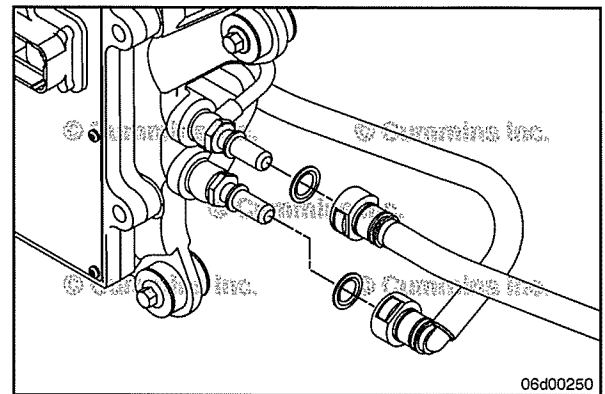
Remove the quick disconnect style fuel lines by pressing in the locking tangs on both sides of the quick disconnect fitting.

To aid in the removal of quick disconnect style fuel lines, slide removal tool, Part Number 4918878, over the locking tangs. Make sure the tool is removed from the fuel line as soon as possible after line has been disconnected. Inadvertently leaving the tool in place can result in fuel leaks.

To aid removal, a screwdriver may be inserted between the fuel line end and quick disconnect male union. After pressing the opposing locking tangs, twisting the flat blade of the screwdriver helps to remove the fuel line.



If fuel leaks or suction side air entry is suspected, remove the fuel hoses or quick disconnect fittings.



Fuel Drain Lines (006-013)

Remove

⚠ WARNING ⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

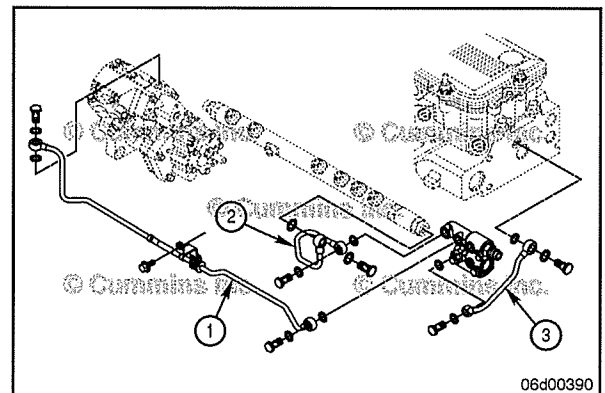
⚠ WARNING ⚠

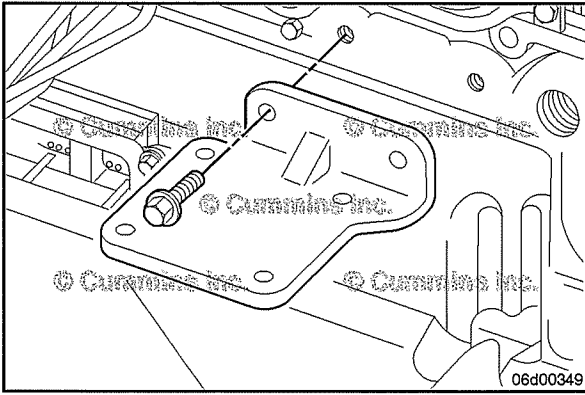
Do not vent the fuel system on a hot engine; this can cause fuel to spill onto a hot exhaust manifold, which can cause a fire.

There are three drain lines on the engine:

- 1 The fuel pump drain line connects the fuel pump to the fuel drain manifold.
- 2 The fuel rail pressure relief valve drain line connects the fuel rail pressure relief valve to the fuel drain manifold.
- 3 The injector drain line connects the back of the cylinder head to the fuel drain manifold.

These lines are removed by removing the banjo bolts and sealing washers.

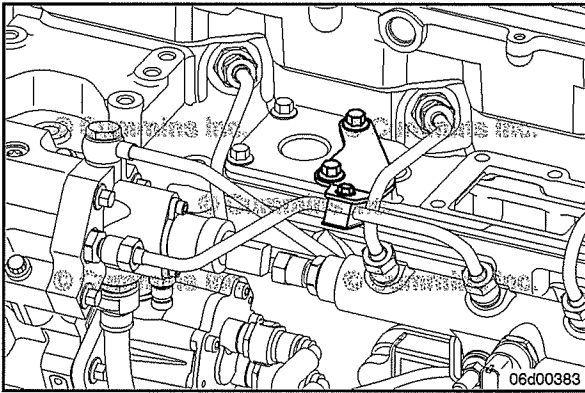




Fuel Filter Head Bracket (006-018)

Remove

For engines equipped with a single fuel filter head.
Remove the filter head bracket from the engine.



Injector Supply Lines (High Pressure) (006-051)

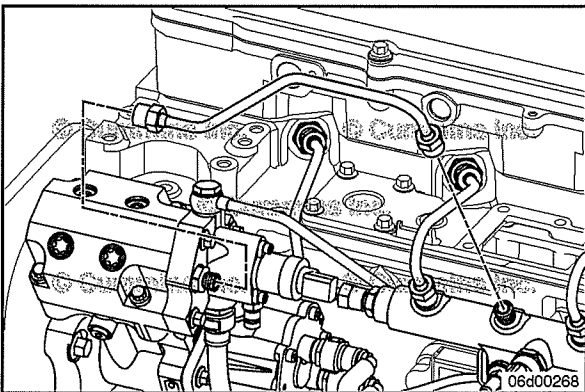
Remove

⚠ WARNING ⚠
Depending on the circumstance, diesel fuel is flammable. When inspecting or performing service or repairs on the fuel system, to reduce the possibility of fire and resulting severe personal injury, death or property damage, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area.

Loosen the fuel lines at the fuel rail, the fuel connector, and the high-pressure fuel pump outlet fitting.

Loosen the capscrews on the fuel line support bracket and isolator.

Remove the high-pressure fuel lines.



⚠ WARNING ⚠
Depending on the circumstance, diesel fuel is flammable. When inspecting or performing service or repairs on the fuel system, to reduce the possibility of fire and resulting severe personal injury, death or property damage, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area.

Loosen the fuel lines at the fuel rail, the fuel connector, and the high-pressure fuel pump outlet fitting.

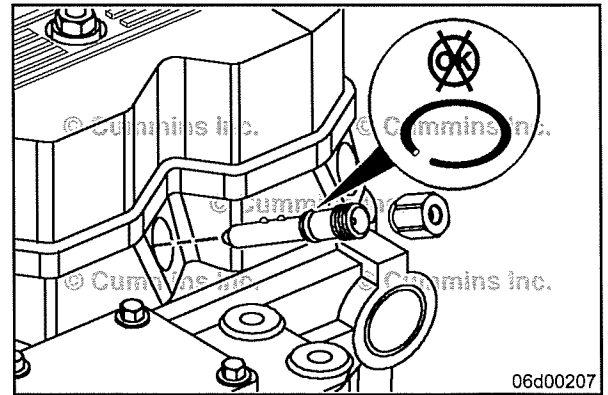
Remove the high-pressure fuel lines.

Fuel Connector (Head Mounted) (006-052)

Remove

Remove the fuel connector retaining nut.

Use fuel connector puller, Part Number 3164025, to remove the fuel connector from the cylinder head.

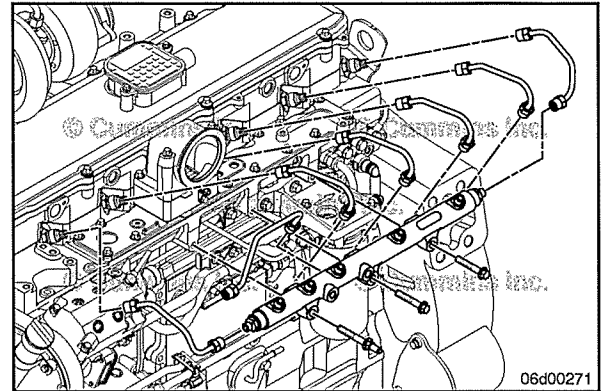


Fuel Rail (006-060)

Remove

Remove the capscrews that secure the fuel rail to the cylinder head.

Remove the fuel rail assembly.

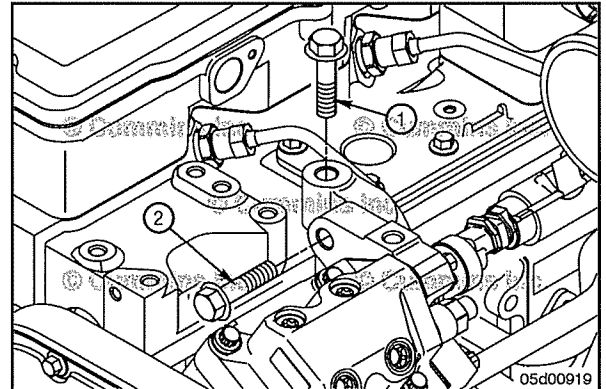


Fuel Pump (005-016)

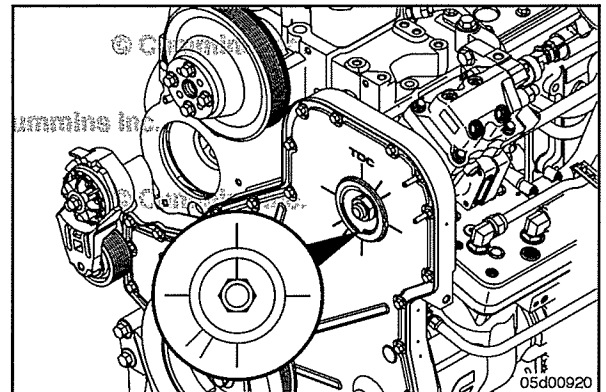
Remove

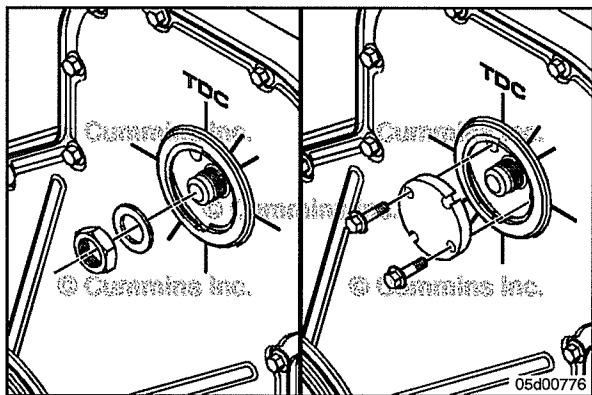
Remove the fuel pump upper support bracket by removing the two bolts (1) and (2).

The upper support bracket is located on the fuel pump actuator housing. Refer to Procedure 005-228 in Section 5.



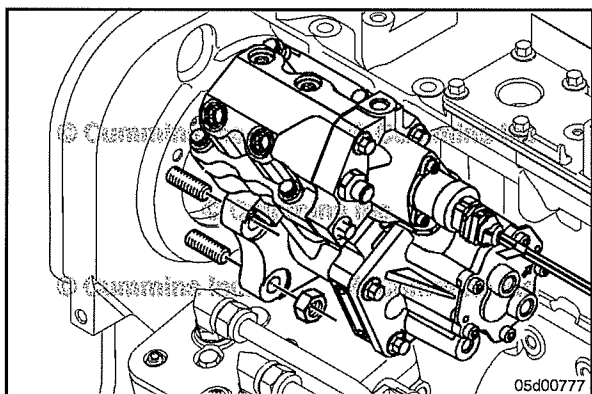
Locate top dead center for cylinder Number 1 by barring the engine until the line on the fuel pump gear aligns with the front cover mark for top dead center.





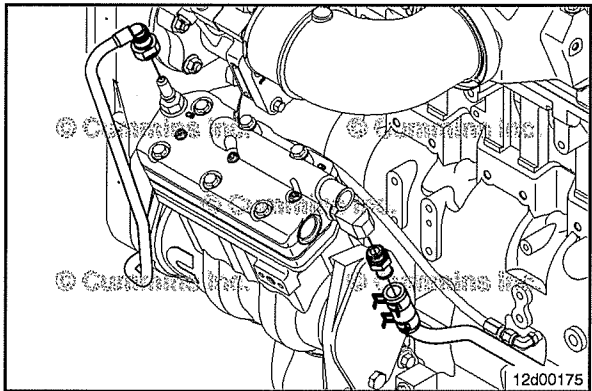
Remove the fuel pump gear nut and washer.

Use fuel pump gear puller, Part Number 3824469, to pull the fuel injection pump drive gear loose from the fuel pump drive shaft.



Remove the four mounting nuts that hold the fuel pump to the gear housing.

Remove the fuel pump.



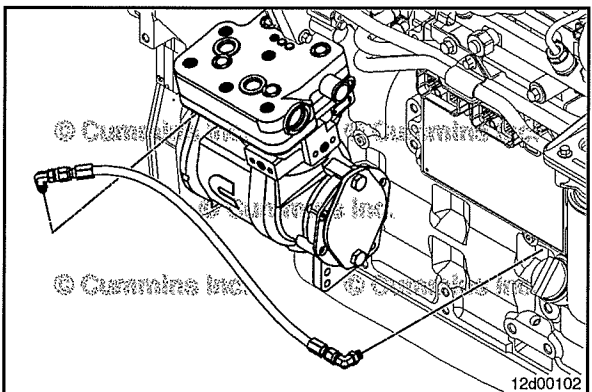
Air Compressor Coolant Lines (012-004)

Remove

NOTE: The air compressor cooling lines illustrated can differ depending on compressor installed. Although different, the procedure remains the same.

Remove the coolant supply and return lines from the air compressor cylinder head.

Remove the coolant supply line from the engine cylinder head and coolant return line from the water inlet connection.



Air Compressor Oil Supply Line (012-110)

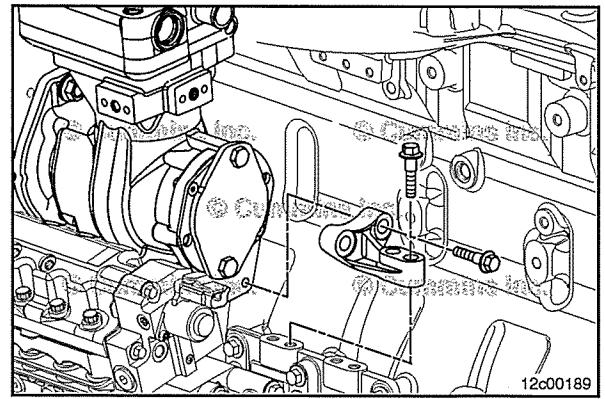
Remove

Remove the air compressor oil supply line from the air compressor and cylinder block.

Air Compressor (012-014)

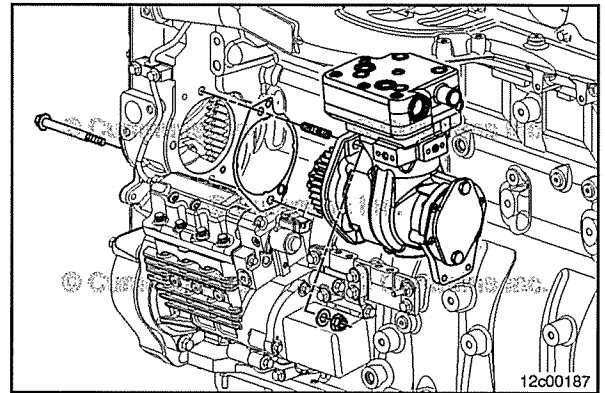
Remove

Remove the air compressor support brackets and cap screws.



Remove the mounting nut and cap screw and the air compressor.

Discard the gasket.

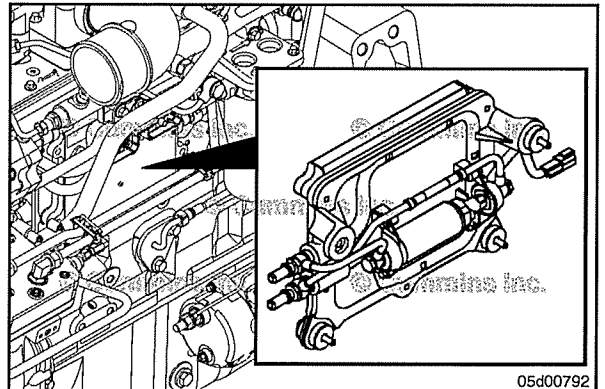


Engine Control Module Cooling Plate, Fuel Cooled (006-006)

Remove

NOTE: The electric fuel priming pump and priming pump fuel lines will be attached to the ECM cooling plate while the cooling plate is being removed.

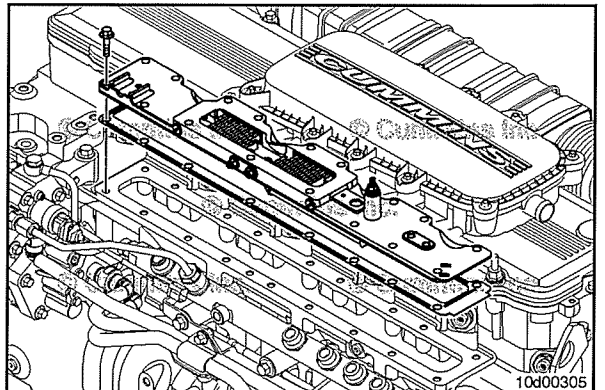
Remove the ECM cooling plate cap screws and the ECM cooling plate from the engine block.

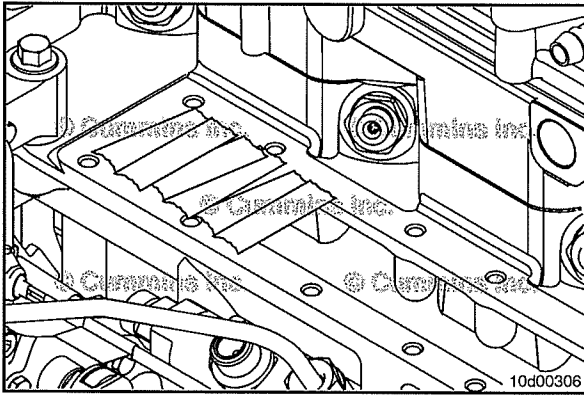


Air Intake Manifold (010-023)

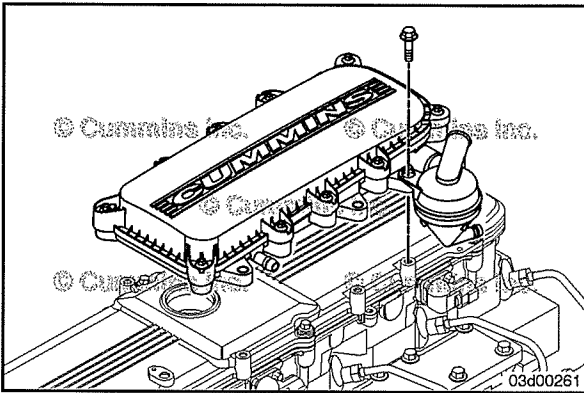
Remove

Remove the remaining cap screws holding the air intake manifold to the cylinder head.





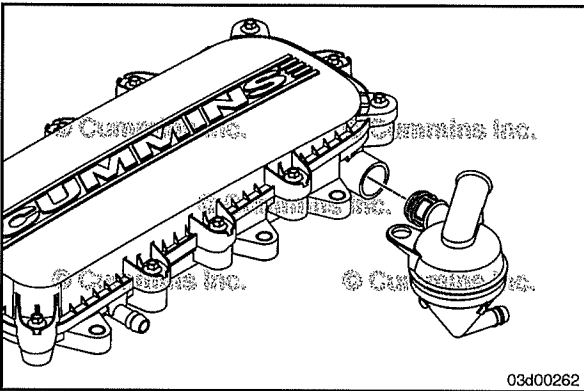
Use heavy tape to cover the intake manifold opening in the cylinder head to prevent debris from entering the engine.



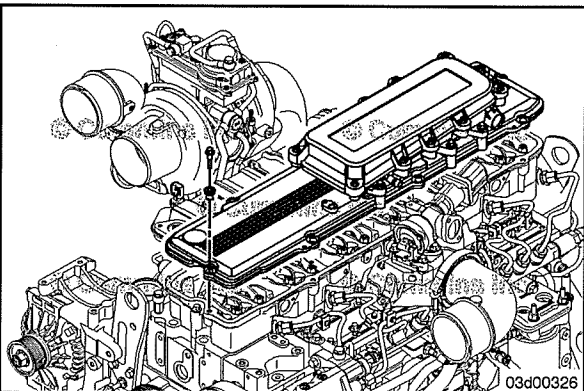
Crankcase Breather (External) (003-001) Remove

Remove the six mounting capscrews.

Remove the breather from the rocker lever cover by pulling straight up on the breather assembly.



Remove the oil separator from the breather housing.



Rocker Lever Cover (003-011) Remove

Remove the capscrews.

Remove the rocker lever cover and gasket.

NOTE: The rocker lever cover can be taller if the engine is equipped with engine brakes.

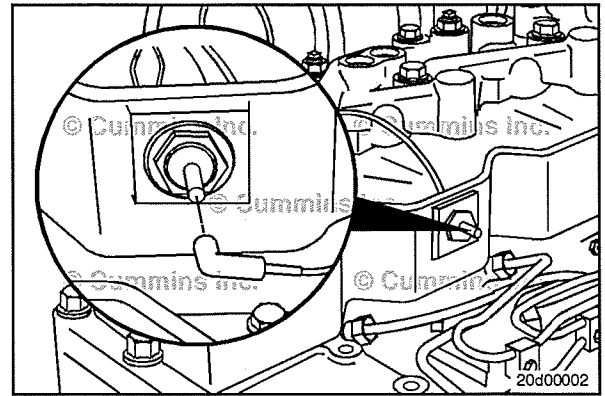
NOTE: It is **not** necessary to remove the crankcase breather in order to remove the rocker lever cover.

NOTE: It is **not** necessary to remove the heat shield in order to remove the rocker lever cover.

Engine Brake Assembly (020-004)

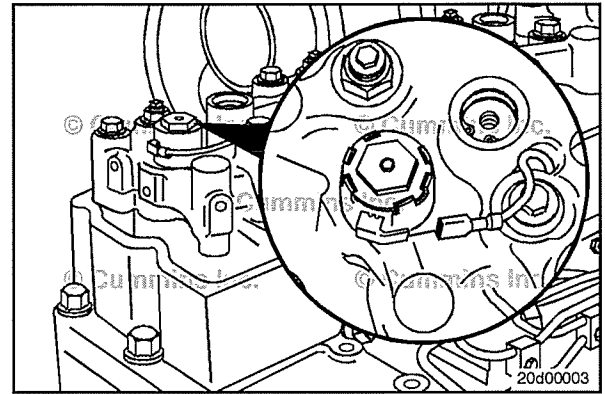
Remove

Disconnect the wiring harness from the electrical connectors in the rocker lever housing.



NOTE: It is easier to remove the wire from the rocker lever housing after the brake is removed.

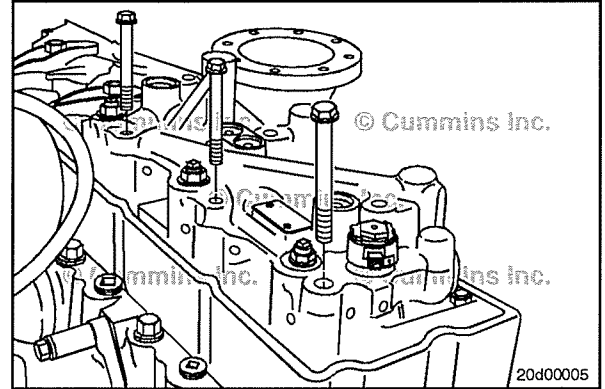
Unplug the wires from the brake solenoid.



NOTE: Use **only** grade 12.9 mounting capscrews for engine brake assemblies. Verify all mounting capscrews are grade 12.9. If any capscrews are found that are **not** grade 12.9, replace the capscrews.

Remove the six mounting capscrews and flat washers from one or both of the engine brake assemblies, as required.

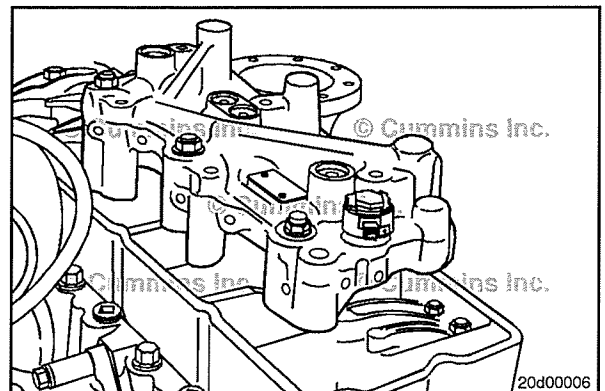
NOTE: Engines with an engine serial number (ESN) of 73001424 and higher use a bracket underneath the mounting capscrews above cylinders 1 and 4, in place of a hardened washer. This bracket is used to route the solenoid wire away from moving parts and prevent wire chafing.

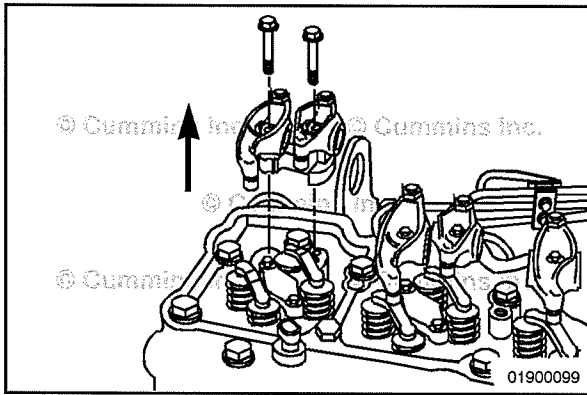


Remove the brake assembly or assemblies, as required.

Remove the adjusting cap from the exhaust rocker arms.

Remove the rocker lever housing, if necessary. Refer to Procedure 003-013 in Section 3.





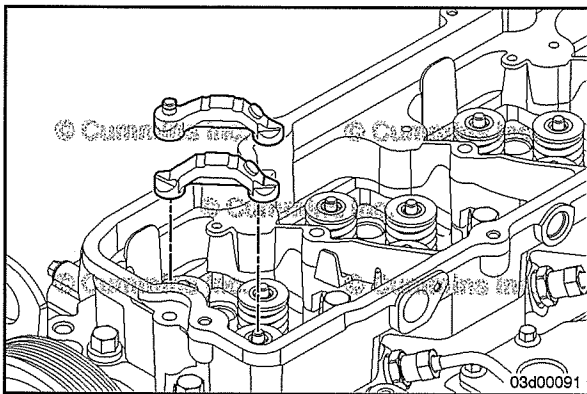
Rocker Lever (003-008)

Remove

Remove the capscrews from the rocker lever pedestals.

Remove and mark the pedestals and rocker lever assemblies one at a time as to their location and position.

The rocker assemblies **must** be installed in their original location and position.

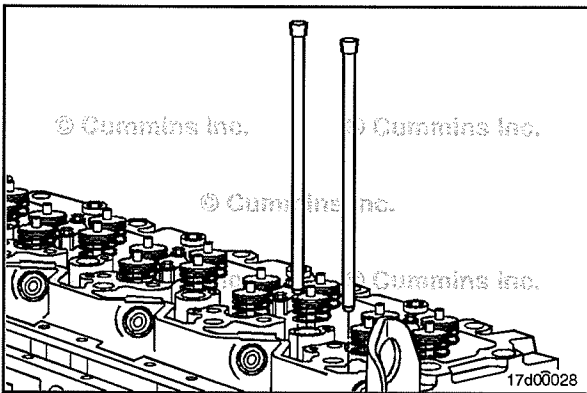


Crosshead (002-001)

Remove

NOTE: Make note of the crosshead location and orientation. If the crossheads are reused, they **must** be installed in their original location and orientation.

Remove the crossheads.

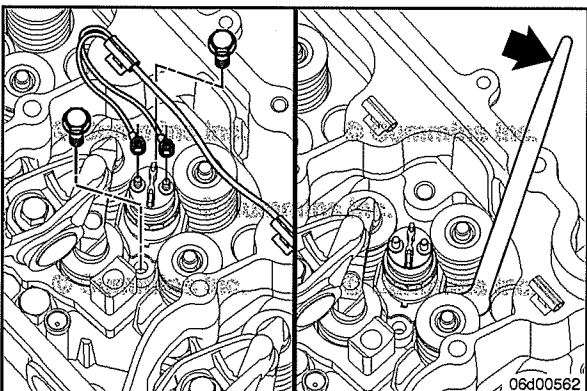


Push Rods or Tubes (004-014)

Remove

Mark the push tubes to identify their location.

Remove the push tubes.



Injector (006-026)

Remove

Disconnect the injector wire harness from the injector.

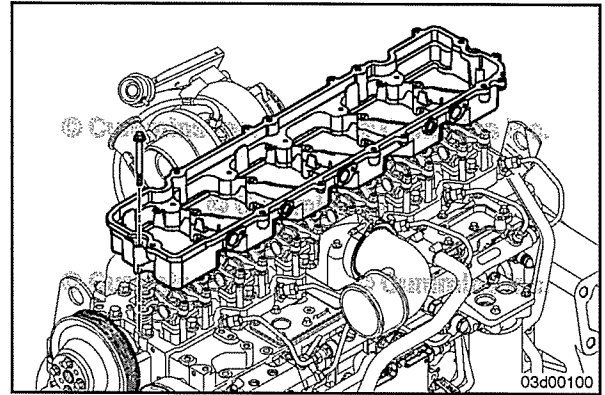
Remove the two injector hold-down clamp capscrews.

Use a small heel-bar to pry up on the injector hold-down clamp.

Rocker Lever Housing (003-013)

Remove

Remove the rocker lever housing mounting capscrews.
Remove the rocker lever housing and gasket from the cylinder head.



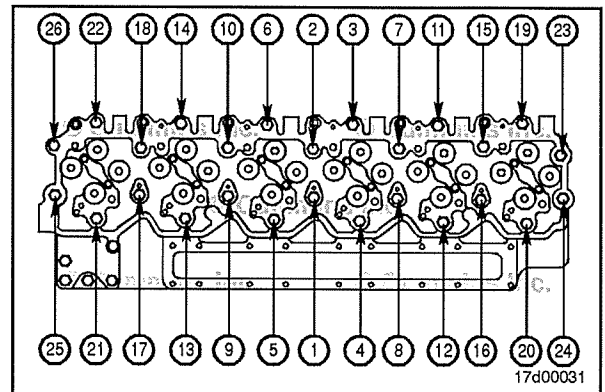
Cylinder Head (002-004)

Remove

⚠ WARNING ⚠

This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Remove the cylinder head capscrews.

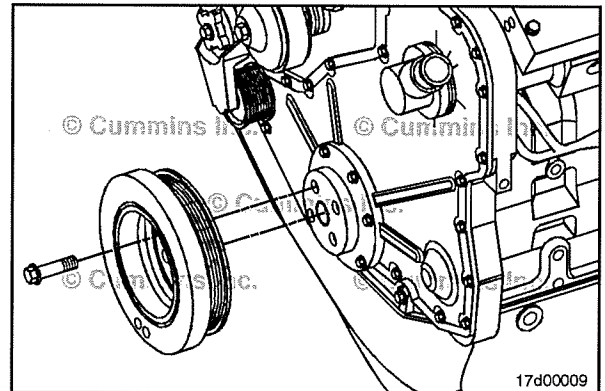


Vibration Damper, Rubber (001-051)

Remove

NOTE: Some engines use four damper capscrews while others use five damper capscrews.

Remove the vibration damper.

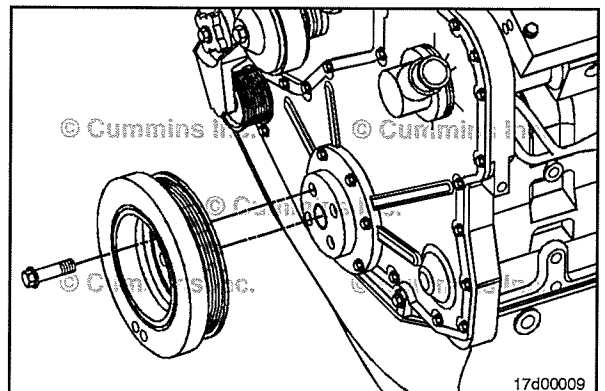


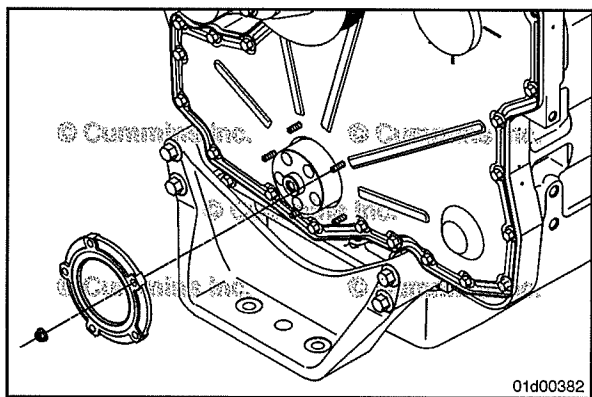
Vibration Damper, Viscous (001-052)

Remove

NOTE: Some engines use four damper capscrews while others use five damper capscrews.

Remove vibration damper.

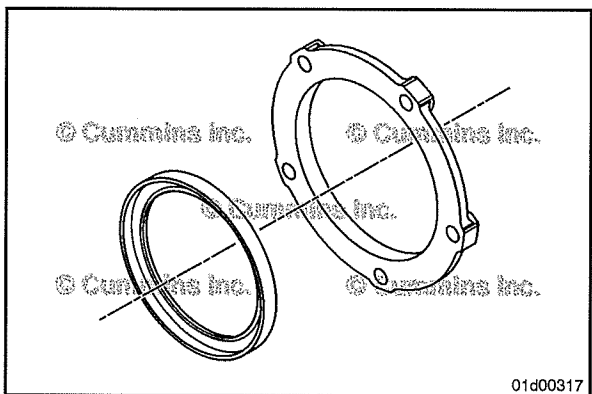




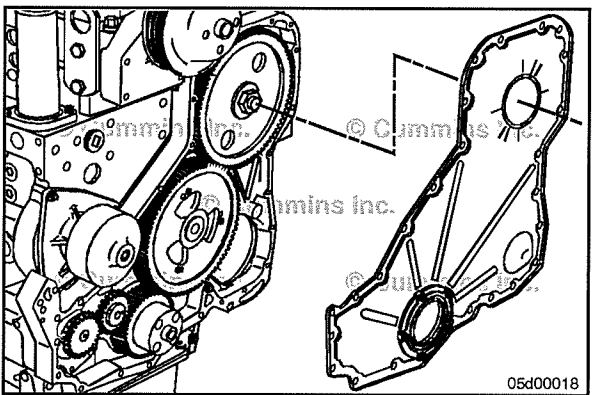
Crankshaft Seal, Front (001-023)

Remove

Remove the front crankshaft seal carrier.



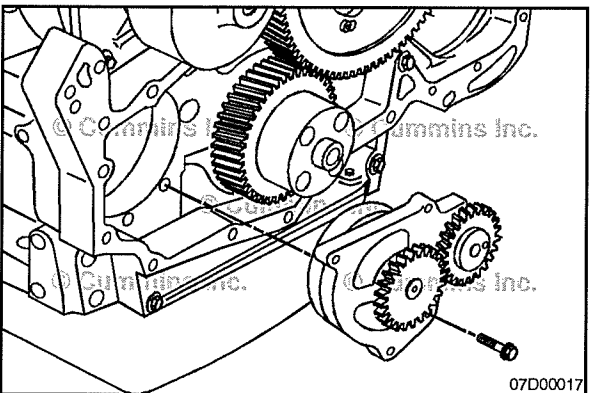
Remove the oil seal from the carrier. Drive the oil seal from the back side of the carrier toward the front side of the carrier, while supporting the carrier.



Gear Cover, Front (001-031)

Remove

Remove the front gear cover.



Lubricating Oil Pump (007-031)

Remove

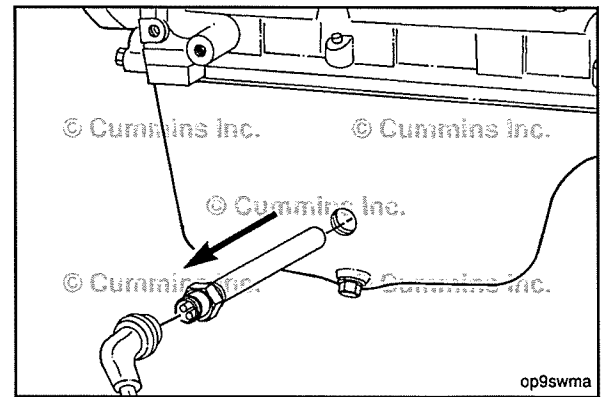
Remove the four mounting capscrews.

Remove the lubricating oil pump from the bore in the cylinder block.

Engine Oil Heater (007-001)

Remove

Disconnect the oil heater electrical cord.
Remove the heater element.



Lubricating Oil Pan (007-025)

Remove

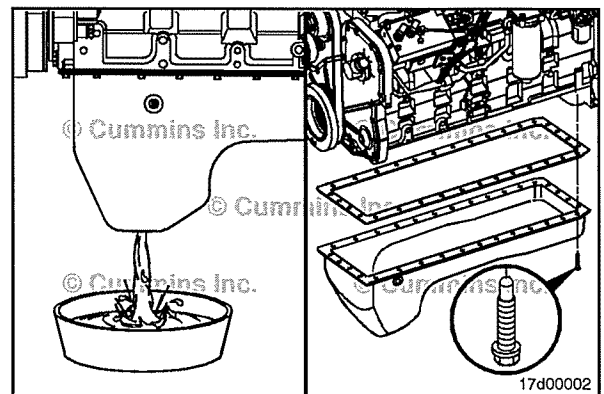
⚠ CAUTION ⚠

Do not use a pry bar or screwdriver to remove the oil pan. The lubricating oil pan flange can be damaged if a pry bar or screwdriver is used to break the sealant at the corners of the oil pan. Use a utility knife or the edge of a putty knife to cut the seal and loosen the pan.

Remove the lubricating oil pan and gasket.

Remove the suction tube if necessary. Refer to Procedure 007-035 in Section 7.

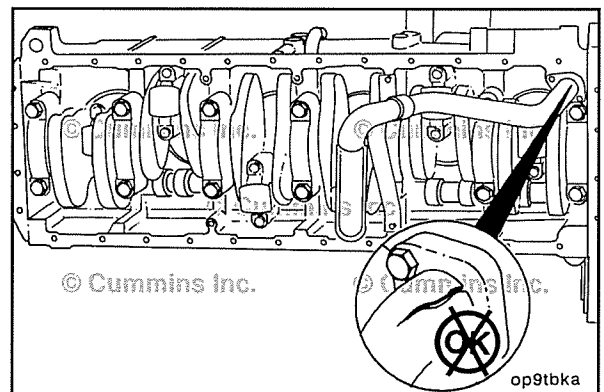
Remove the block stiffener plate, if equipped. Refer to Procedure 001-089 in Section 1.

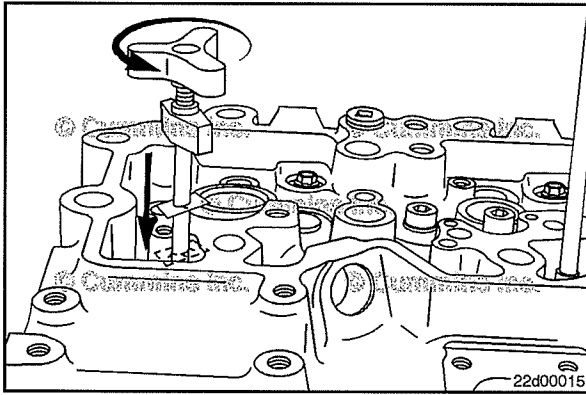


Lubricating Oil Suction Tube (Block-Mounted) (007-035)

Remove

Remove the lubricating oil suction tube.





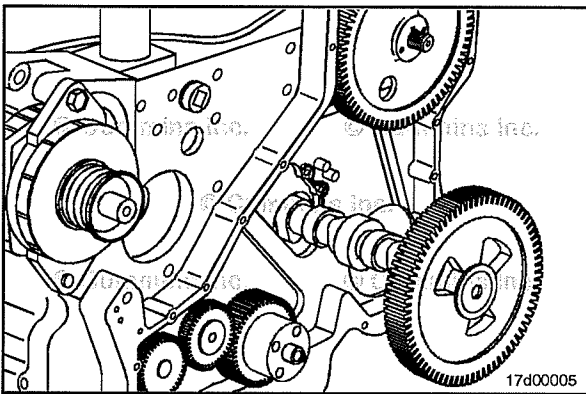
Tappet (004-015) Remove

Use tappet removal tool kit, Part Number 3165088, to remove the tappets.

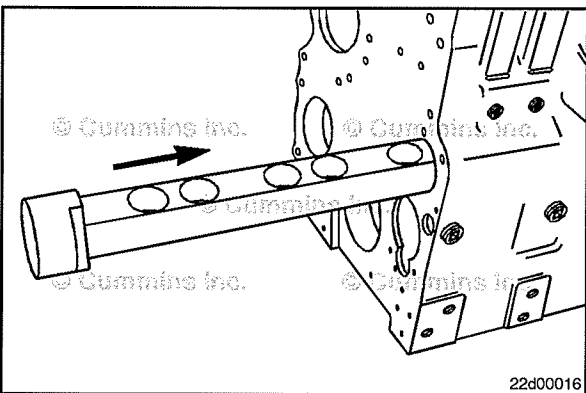
Insert the tappet extractor tool (2) into the tappet bore. Turn the top knob **counterclockwise** while holding the bottom knob to expand and secure the tool into the tappet.

Raise the tappet extractor (2) until it stops, and push the metal tab down against the head surface to secure the tool and captured tappet in the up position.

Repeat for the remaining tappets.

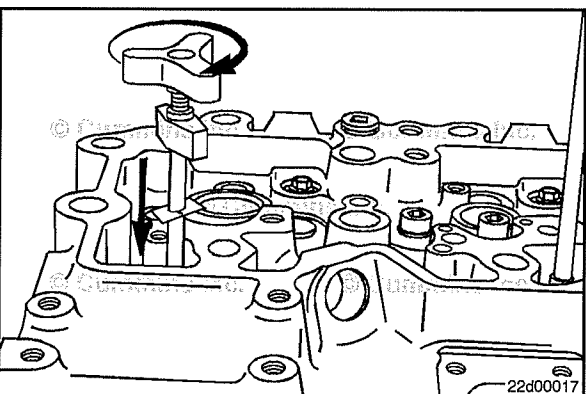


Remove the camshaft. Refer to Procedure 001-008 in Section 1.



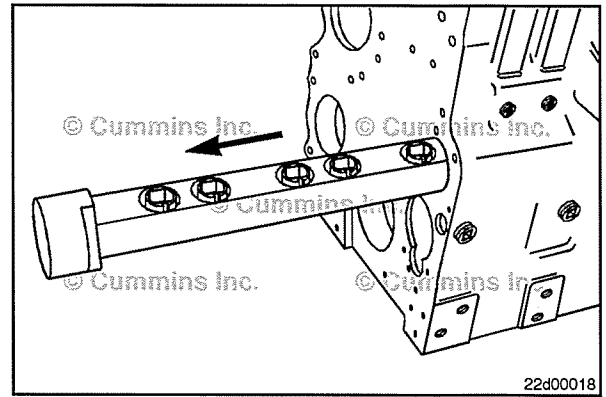
Make sure the holes are in the up position.

Insert the tappet holder to the full length of the camshaft bore.



Lower the tappet extractor, and seat the tappet into the tappet holder. Turn the top knob **clockwise** while holding the bottom knob to disengage the extractor from the tappet. Repeat the step for the remaining tappets.

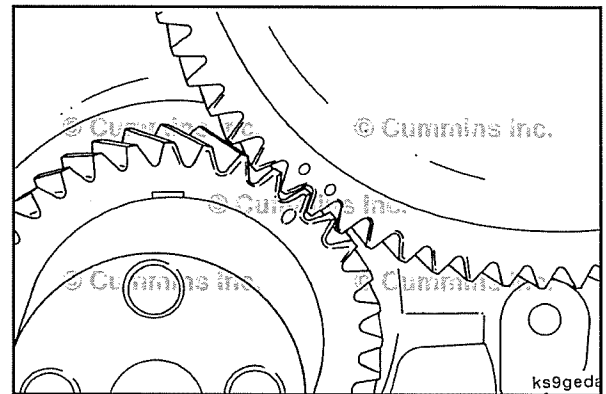
Carefully pull the tappet holder and tappets from the camshaft bore. If the tappets will be reused, be sure to note their position. Do **not** install a tappet in a different position.



Camshaft (001-008)

Remove

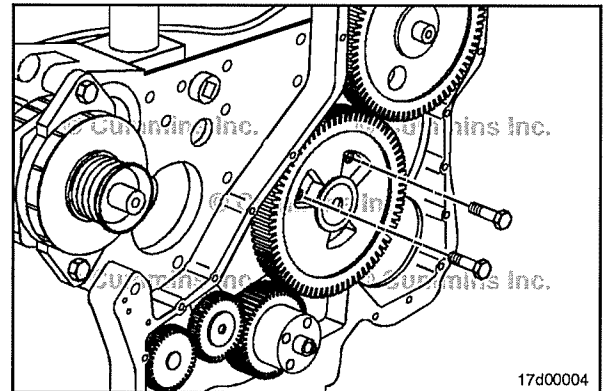
Rotate the crankshaft to align the crankshaft to camshaft timing marks.



NOTE: Because the thrust plate extends more than 180 degrees around the camshaft, the thrust plate can **only** be removed from the camshaft after removing the cam gear from the camshaft.

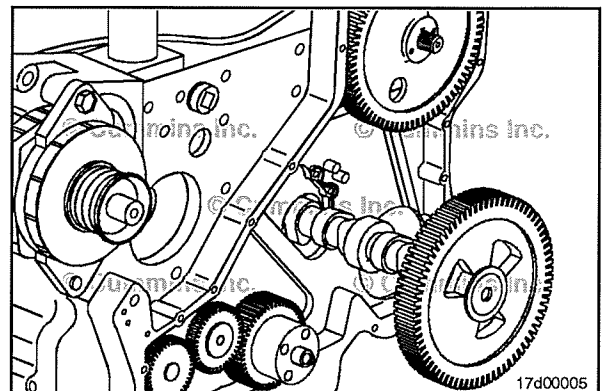


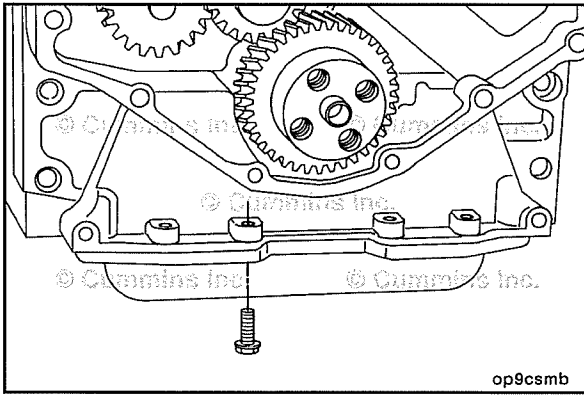
Remove the capscrews from the thrust plate.



Remove the camshaft and thrust plate together.

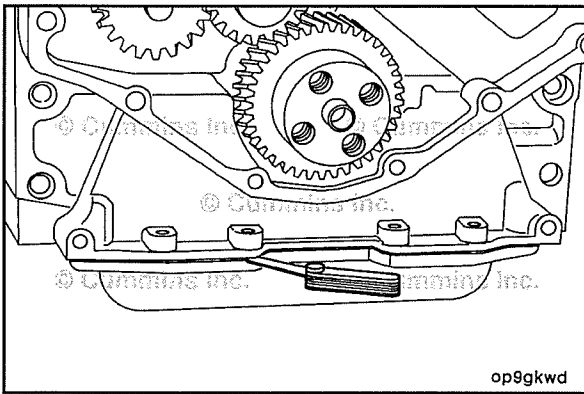
NOTE: Rotate the camshaft as it is being removed. Use extreme care to make sure the camshaft bushings are not damaged during the camshaft removal process.



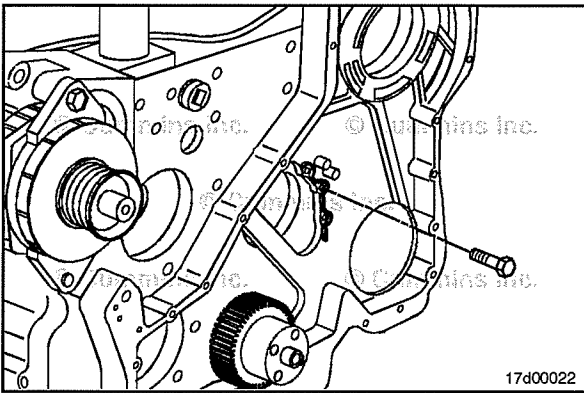


Gear Housing, Front (001-033) Remove

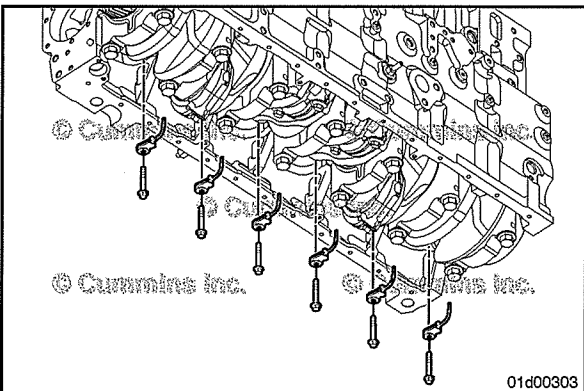
Remove the four front oil pan capscrews.



Use a feeler gauge to separate the lubricating oil pan gasket from the gear housing.



Remove the gear housing capscrews and remove the gear housing.



Piston Cooling Nozzle (001-046) Remove

Remove the piston cooling nozzle capscrews and nozzles.

NOTE: The crankshaft **must** be rotated to allow access to remove the nozzles.

NOTE: The number six (6) piston cooling nozzle can **not** be removed without first disconnecting the connecting rod from the crankshaft and moving the piston out of the way. Also, a crows foot socket will be required to access the capscrew.

Piston and Connecting Rod Assembly (001-054)

Remove

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

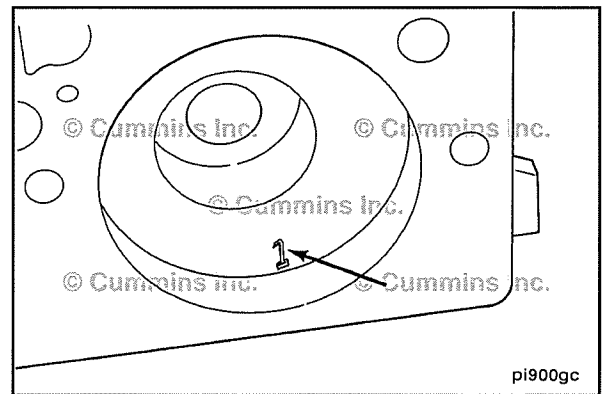
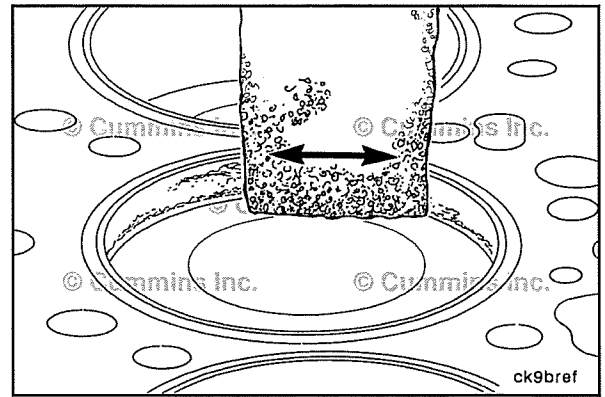
⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Rotate the crankshaft until the pistons are just below the carbon deposits that are found above the ring travel area.

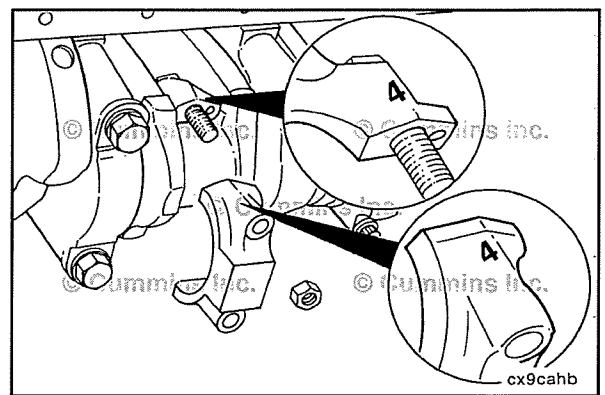
Use an abrasive pad, Part Number 3823258 or equivalent, and solvent to remove the carbon deposits.

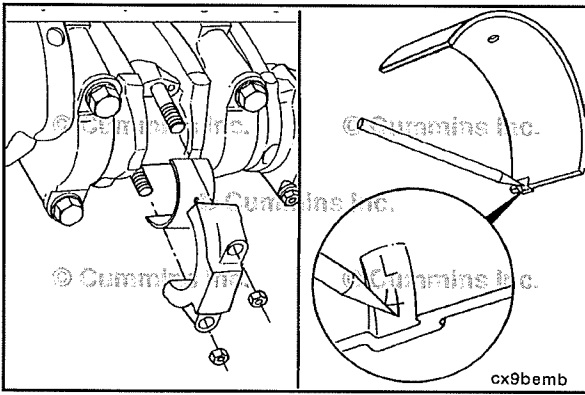
Mark each piston according to the cylinder location.



Rotate the crankshaft to position the rod cap at Bottom Dead Center (BDC) for removal.

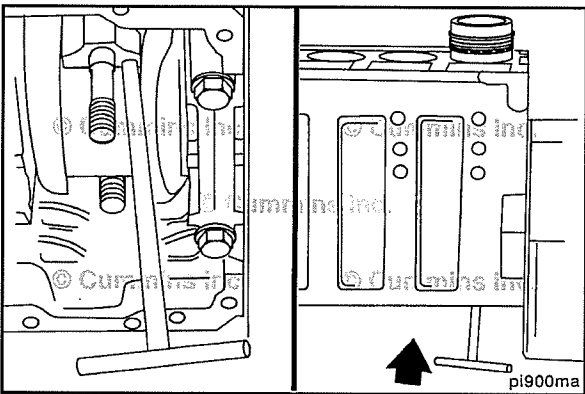
Mark each connecting rod and rod cap according to the cylinder number location.



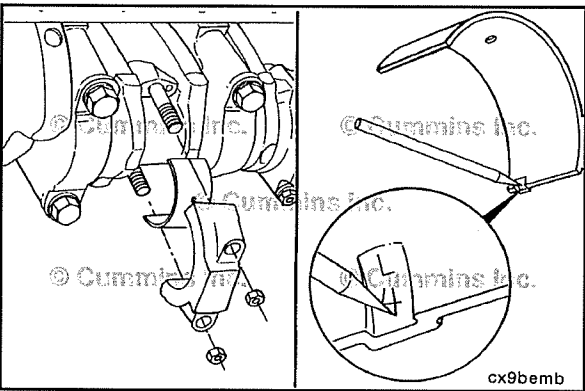


Engines with Horizontal Split Connecting Rods

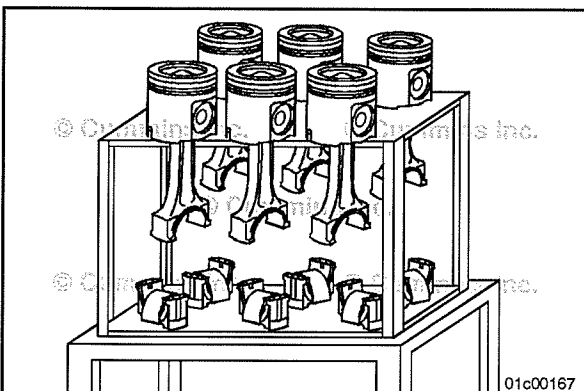
- Remove the nuts, connecting rod cap, and lower connecting rod bearing.
- Mark the cylinder number and the letter "L" (lower) on the flat surface of the bearing tang.



Push the connecting rod and piston assembly out of the cylinder bore. Care **must** be taken to **not** damage the connecting rod or bearing.



Remove the upper rod bearing.
Mark the cylinder number and the letter "U" (upper) on the flat surface of the bearing tang.



Use both hands to remove the piston and connecting rod assembly.

If parts are reused, the piston and connecting rod assemblies **must** be installed in the same cylinder locations from which they were removed to provide the proper fit of worn mating surfaces.

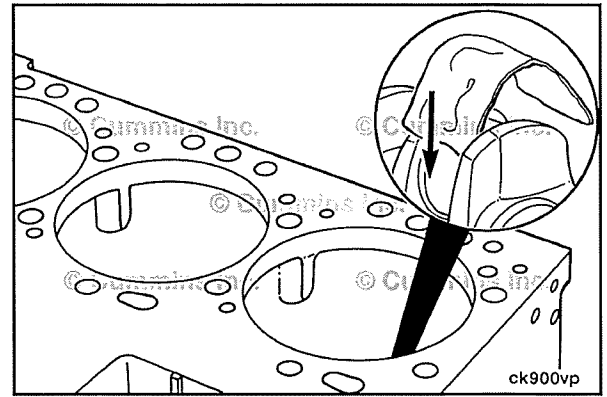
Use tags to mark the piston and connecting rod assembly locations as they are removed.

Place the rod and piston assemblies in a container to protect them from damage.

Cylinder Liner (001-028)

Remove

Use clean shop rags to cover the crankshaft to prevent debris from falling into the main journal area or into the connecting rod journal oil drilling.



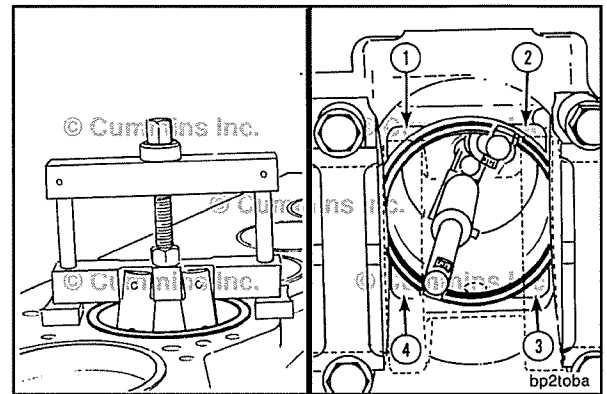
⚠CAUTION⚠

The liner puller must be installed and used as described to avoid damage to the cylinder block. The puller must not contact the block casting at points (1), (2), (3), and (4).

Universal Cylinder Liner Puller Method

Cylinder Liner Puller, Part Number 3376015

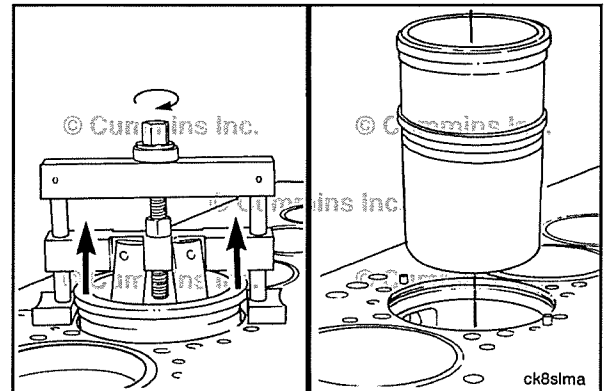
Insert the liner puller into the top of the cylinder block.



NOTE: The liner puller **must** be centered on the top of the cylinder block.

Turn the puller jackscrew **clockwise** to loosen the liner from the cylinder block.

Use both hands to remove the liner.



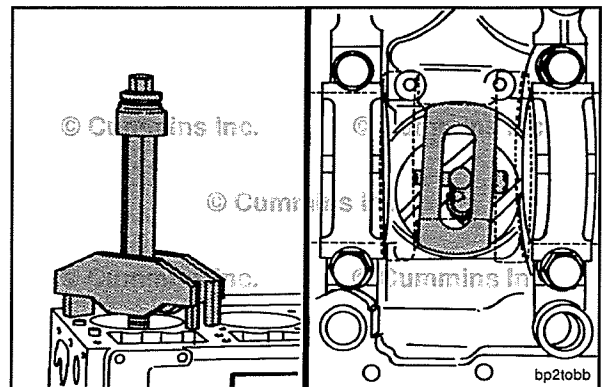
⚠CAUTION⚠

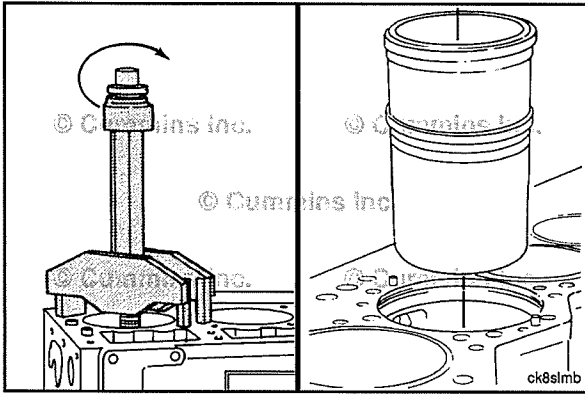
The liner puller must be installed and used as described to reduce the possibility of damage to the cylinder block. The puller plate must be parallel to the main bearing saddles and must not overlap the liner outside diameter.

Standard Liner Puller Method

Liner Puller, Part Number 3163745, may be used as an alternative to the standard puller. The universal puller **must** be used with remover plate, Part Number 3822786.

Insert the liner puller into the top of the cylinder block.

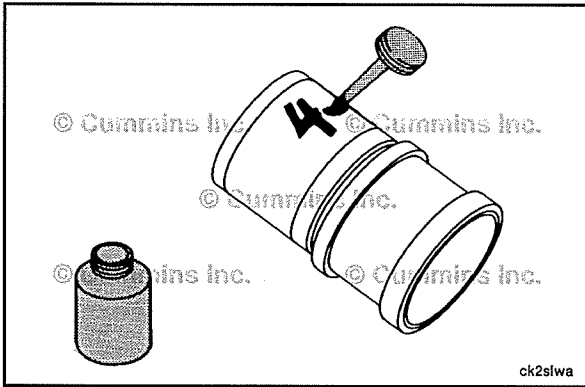




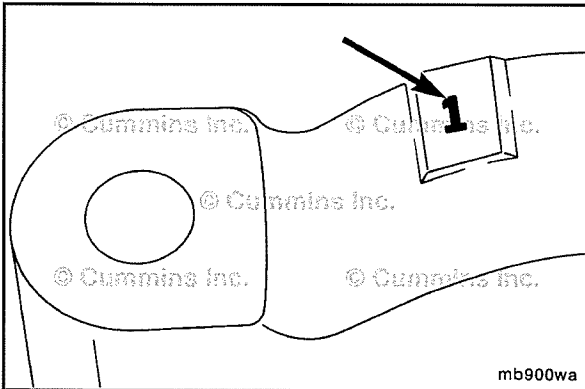
NOTE: The liner puller **must** be centered on the top of the cylinder block.

Turn the puller jackscrew **clockwise** to loosen the liner from the cylinder block.

Use both hands to remove the liner.



Mark the cylinder number on each liner.

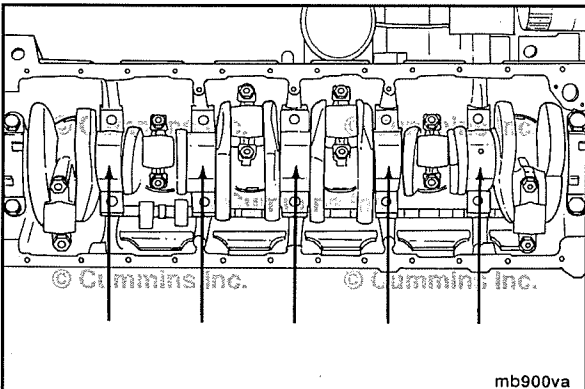


Bearings, Main (001-006)

Remove

Before removing the main bearing caps, make certain that the caps are clearly marked for their location on the lubricating oil cooler side of the main bearing cap.

The number one cap is at the front of the engine.



When replacing bearings in chassis, replace number 2 through number 6 while the number 1 and number 7 caps support the crankshaft. After replacing number 2 through number 6, replace number 1 and number 7.

Remove all main bearing caps except the number 1 and number 7 main bearing caps.

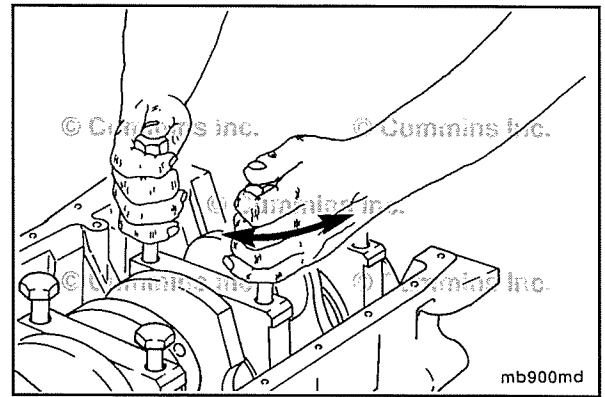
⚠CAUTION⚠

Do not pry on the main bearing caps to free them from the cylinder block. Damage to the main bearing caps and cylinder block can result.

Loosen the main bearing capscrews completely, but do **not** remove.

Use two of the main bearing cap bolts to wiggle the main bearing cap loose, being careful **not** to damage the bolt threads.

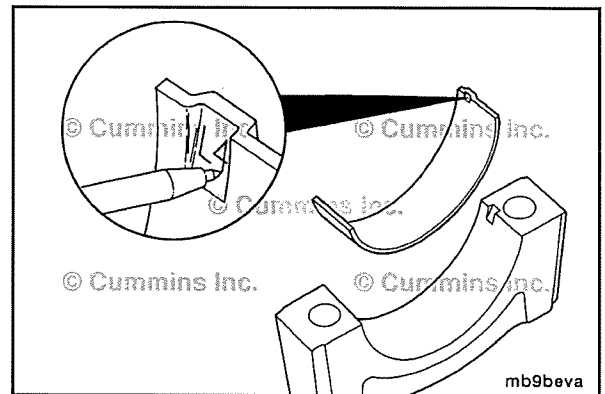
Remove the main bearing cap.



Mark the main bearings for position and number as they are removed.

Use an awl to mark the bearing position in the tang area.

NOTE: Marking the bearing position is for future identification or possible future analysis.



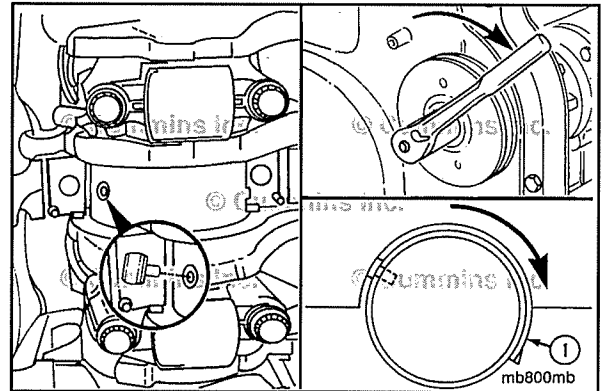
To remove the upper main bearings, install the main bearing replacer, Part Number 3823818, in the oil hole of the crankshaft main bearing journal.

Rotate the crankshaft so that the replacer contacts the upper main bearing on the side opposite the tang.

Continue to rotate the crankshaft in the direction that will remove the tang side (1) of the upper main bearing first.

Remove the bearing.

Follow this procedure to remove the other main bearings except for number 1 front main bearing.

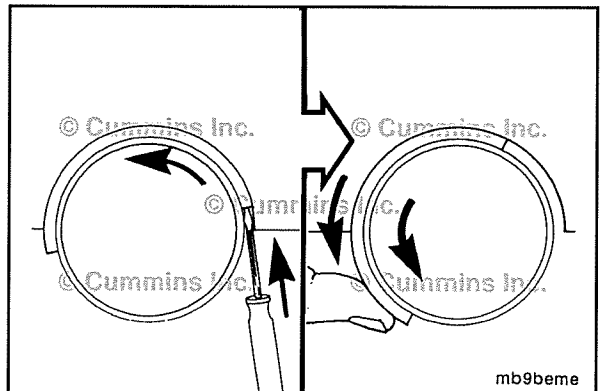


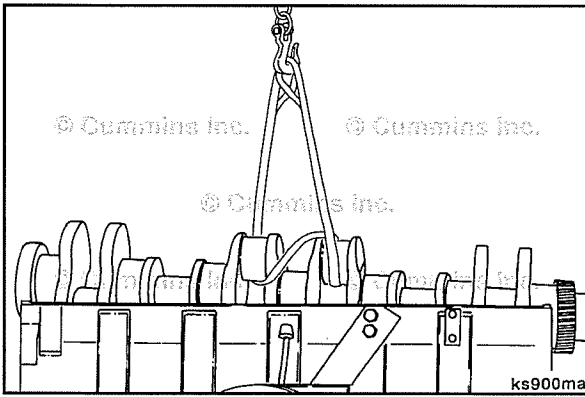
⚠CAUTION⚠

Use care so the screwdriver does not damage the crankshaft or cylinder block.

NOTE: The front main bearing, number 1, does **not** have a hole in the journal, so the tool can **not** be used to replace the bearing.

Use a flat blade screwdriver to gently bump the end of the bearing to loosen it from the cylinder block. Then, use finger pressure against the main bearing shell and rotate the crankshaft to roll the main bearing out.





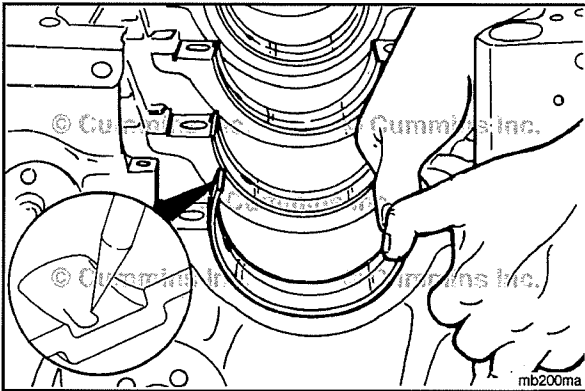
Crankshaft (001-016)

Remove

NOTE: Lift the crankshaft straight up to avoid damage to the crankshaft and cylinder block.

Install nylon lift sling, Part Number 3375957, around the number 3 and number 4 rod bearing journals.

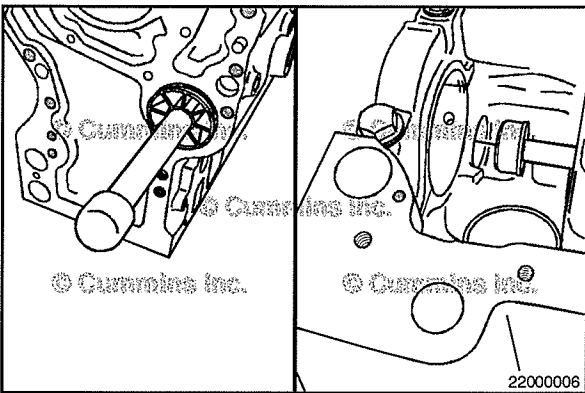
Attach the sling to a hoist and remove the crankshaft.



Remove the upper main bearings.

Use an awl to mark the bearing position in the tang area.

NOTE: Mark the bearing position for future identification or possible failure analysis.



Camshaft Bushings (001-010)

Remove

Remove the camshaft bushings. Use the camshaft bushing replacer kit, Part Number 3165045.

The following kits are also available for camshaft bushing installation and removal:

- Hydraulic Actuator Kit, Part Number 3823621
- Camshaft Bushing Kit, Part Number 3162253

Slide the drive bar through the centering guide and insert the drive bar from the rear of the cylinder block through the camshaft bores.

Insert the camshaft bushing replacer and drive the front camshaft bushing from the cylinder block.

Remove the replacer and drive bar from the cylinder block.

Insert the drive bar, camshaft bushing replacer, and centering guide from the front of the cylinder block.

Drive the remaining camshaft bushings from the cylinder block in succession, starting with the number two camshaft bushing.

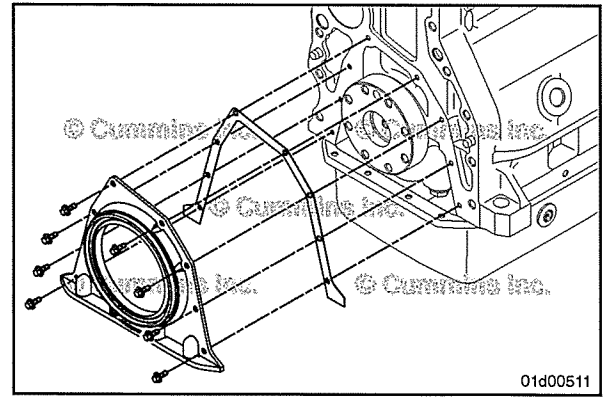
Remove the drive bar, replacer, and guide from the front of the cylinder block.

Crankshaft Seal Carrier, Rear

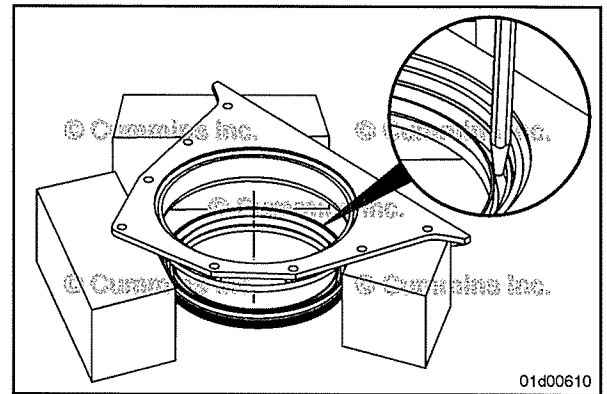


Remove

Remove the capscrews from the rear cover.
Remove the cover from the crankshaft flange.



Support the rear seal carrier on a flat work surface with wooden blocks. Use a suitable punch and hammer to drive the old seal out of the rear seal carrier.



Section AS - Engine Assembly - Group 00

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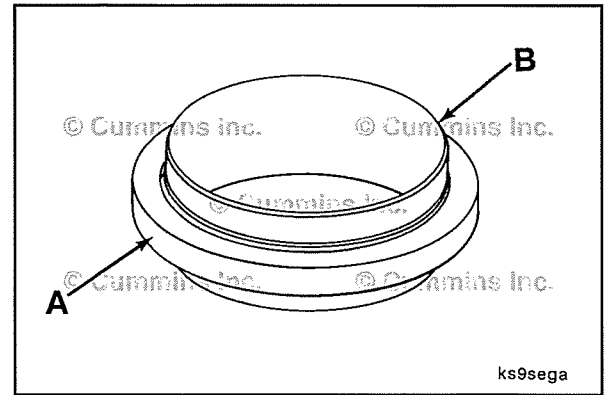
Crankshaft Seal Carrier, Rear (001-104)



Install

NOTE: For engines equipped with a wet flywheel housing, make sure to replace the rear crankshaft seal with the correct rear seal. Rear crankshaft seals for wet and dry flywheel housings may **not** be the same.

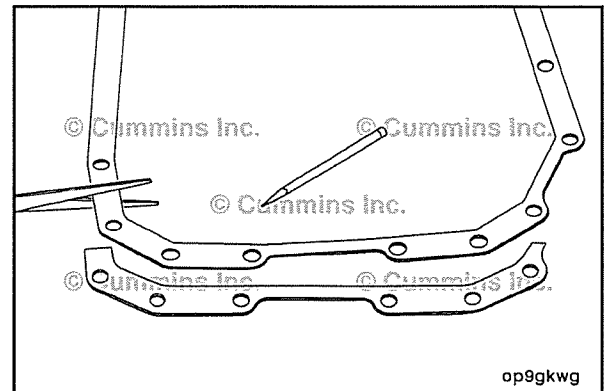
The new rear crankshaft seal (A) will come installed on a seal pilot (B). The seal **must** be left on the seal pilot while installing the seal onto the nose of the crankshaft. This will keep the lips of the seal from being damaged during installation.



Service Tip:

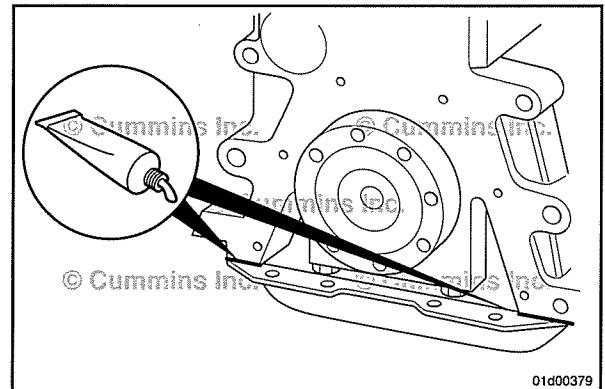
If the oil pan gasket was damaged during removal of the rear seal carrier, remove the damaged gasket and:

- If previously equipped with a paper oil pan gasket, use the old gasket as a pattern and cut a section of new gasket to the same size. Use a light coat of sealant, Part Number 3164067 or equivalent, to hold the gasket in place
- If previously equipped with a sealant only oil pan gasket, apply a bead of sealant, Part Number 3164070 or equivalent, to the oil pan flange
- If previously equipped with a suspended oil pan, the oil pan **must** be removed and a new gasket installed. Refer to Procedure 007-025 in Section 7.

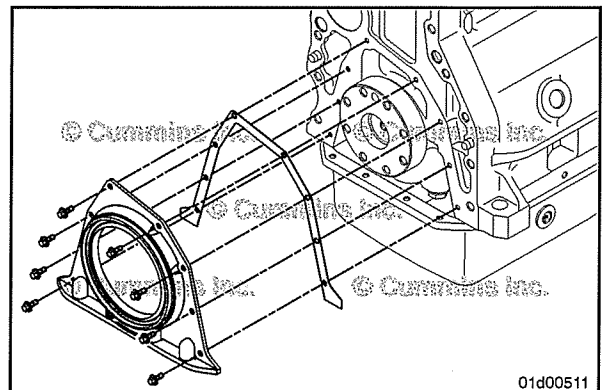


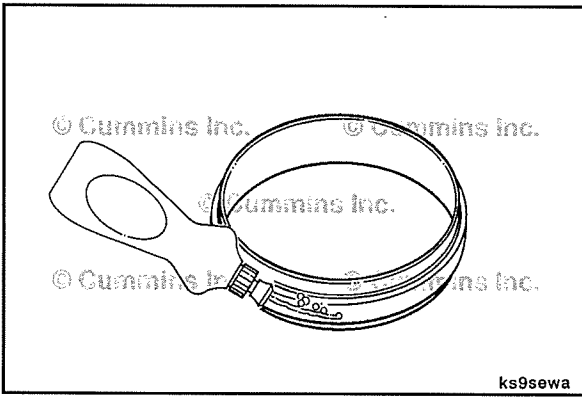
NOTE: It could be necessary to trim the rear seal carrier gasket so that it is even with the oil pan mounting surface. Test fit the gasket prior to installing.

Apply a thin bead of sealant, Part Number 3164067, at the intersecting joint of the oil pan and cylinder block prior to installing the rear crankshaft seal carrier. The rear crankshaft seal carrier **must** be installed within 10 minutes of applying the sealant.

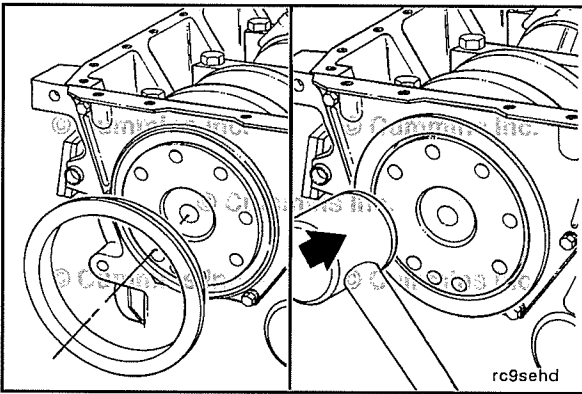


Install the rear crankshaft seal carrier and gasket. Apply Loctite® 262 or 271 to the mounting capscrews and loosely tighten the rear seal carrier to the block.





To aid in installation, the lubricating oil seal requires the application of a mild soap on the outside diameter of the seal case.



Place the new rear crankshaft seal, with the seal pilot, over the crankshaft nose and slide it by hand toward the flywheel housing.

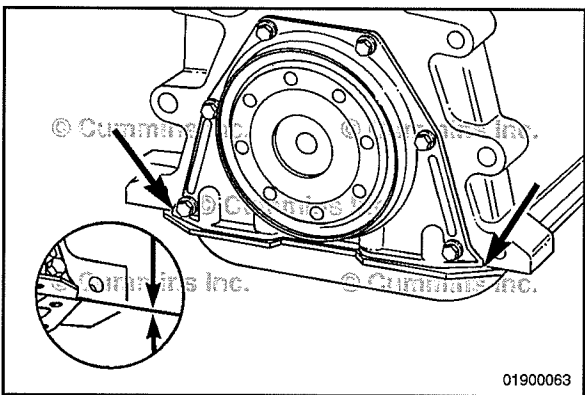
Remove the seal pilot.

Use the disposable seal driver for Front Gear Train engines to drive the rear crankshaft seal into the rear crankshaft seal carrier.

NOTE: Service tool, Part Number 3824078 or equivalent, used to install the rear crankshaft seal/wear sleeve assembly, can also be used to install the rear crankshaft seal.

Use a plastic hammer to drive the seal into the housing until the alignment tool stops against the housing.

Hit the tool at the 12, 3, 6 and 9 o'clock positions to drive the seal evenly and to prevent bending the seal carrier. Hit the seal driver until contact is made with the rear crankshaft seal carrier.



⚠ CAUTION ⚠

Do not push or force the cover in any direction. This may cause an irregular seal lip position after seal installation. An engine oil leak will result.

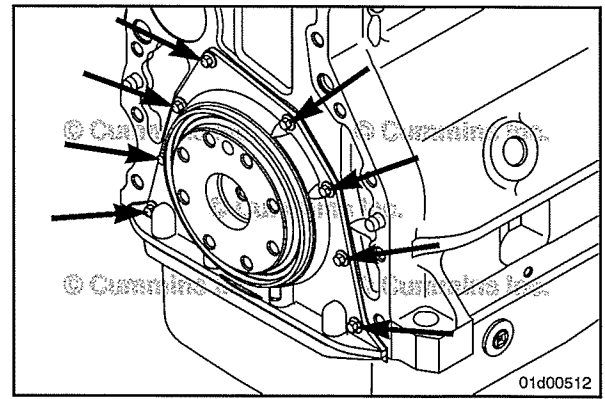
Align the rear cover even with both sides of the oil pan rail on the cylinder block.

Tighten the rear cover capscrews.

The chart below shows the proper torque value when using a 9.8 or a 10.9 grade bolt. The grade is embossed on the top of each bolt.

Apply Loctite® 262 or 271 to both part numbers below during installation.

Rear Seal Carrier				
Bolt Number	Bolt Size	Bolt Class	Torque	Loctite®
3913638	M-6	9.8	10 N•m [89 in-lb]	Yes
3991306	M-6	10.9	13 N•m [115 in-lb]	Yes

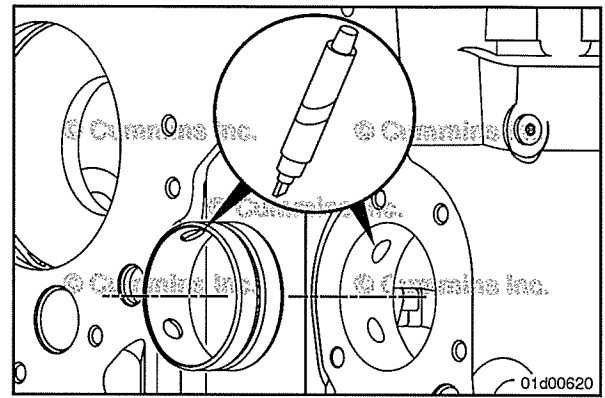


Camshaft Bushings (001-010)

Install

Mark the oil holes on the camshaft bushing and cylinder block with a felt tip pen. This aids proper alignment of the bushing and bore during installation.

NOTE: The top hole on the front and rear camshaft bushings will **not** line up with the top hole of the cylinder block bores. **Only** the bottom hole will line up for the front and rear camshaft bushings.



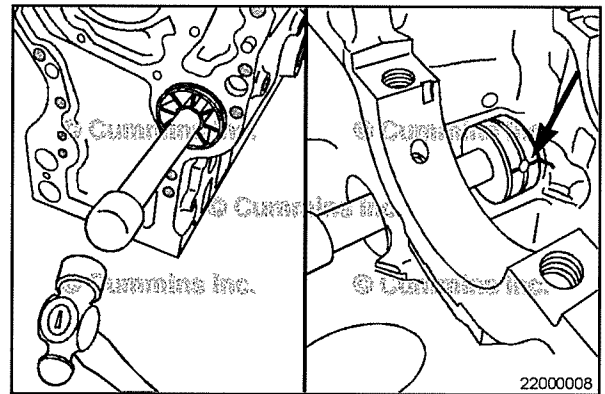
Slide the camshaft bushing on the replacer. Position the notch on the edge of the bushing to the top rear of the block and align the marks on the camshaft bushing and the cylinder block.



Drive the front camshaft bushing to the correct installed depth. The correct installed depth is when the camshaft bushing oil hole aligns with the cylinder block oil hole.



Install the remaining camshaft bushings in succession, starting at the rear of the cylinder block and working toward the front. Remove the drive bar, replacer, and guide from the cylinder block.

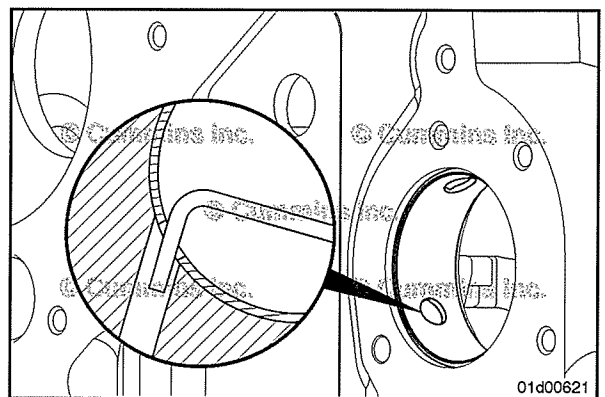


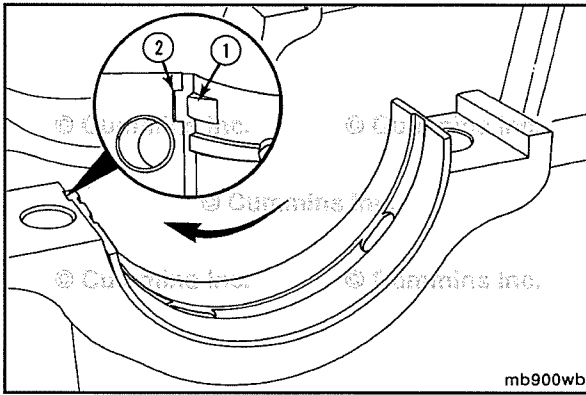
Remove the drive bar, replacer, and guide from the cylinder block.

Make sure the lubricating oil holes in the camshaft bushing are aligned with the oil holes in the camshaft bore. For the front and rear camshaft bushings **only** the bottom hole will line up with the hole in the cylinder block.



A 3.2 mm [0.128 in] diameter rod **must** be able to pass through the lubricating oil holes.





Crankshaft (001-016)

Install

⚠CAUTION⚠

The tang (1) on the bearing shell must be in the slot (2) of the bearing saddle to correctly position the bearing and prevent engine damage.

Upper Main Bearings

Do **not** lubricate the side of the main bearing that is against the cylinder block.

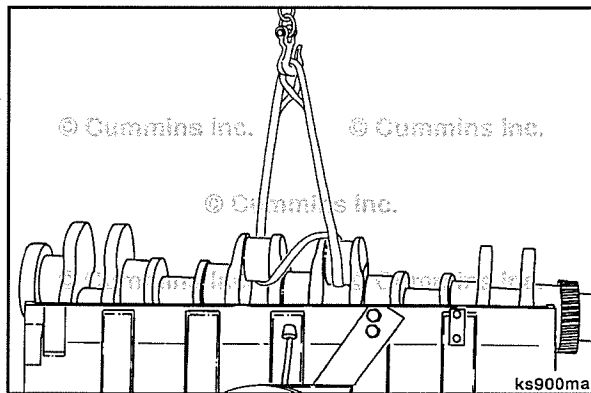
Apply a coat of assembly lubricant, Part Number 3163087 or equivalent, to the crankshaft side of the upper main bearings.

NOTE: Make sure the main bearing being installed is the same size as the main bearing that was removed. The size is engraved on the back of the main bearing.

NOTE: The crankshaft thrust bearing **must** be installed in the number four position.

NOTE: The upper and lower main bearing shells of some engines are **not** interchangeable. The backs of the main bearings are marked with the proper orientation, if required.

NOTE: If used bearing shells are to be installed, they **must** be installed in their original locations, as marked during disassembly.



Use a hoist and nylon list sling, Part Number 3375957.

Install the sling around the number 3 and number 4 connecting rod bearing journals.

Install the crankshaft.

Bearings, Main (001-006)

Install

Upper Main Bearings

Do **not** lubricate the side that is against the cylinder block.

NOTE: Make sure the main bearing being installed is same size as the main bearing removed. The size is engraved on the back of the main bearing.

Apply a coat of assembly lubricant, Part Number 3163086, or equivalent, to the crankshaft side of the main bearings.

NOTE: The crankshaft thrust bearing **must** be installed in the number four position.

NOTE: The upper and lower main bearing shells of some engines are **not** interchangeable. The backs of the main bearings are marked with the proper orientation, if required.

Insert the side of the main bearing opposite the tang first. Install as far as possible by hand.

When installing the thrust bearing in the number four journal, it could be necessary to push the crankshaft to the front or rear of the cylinder block.

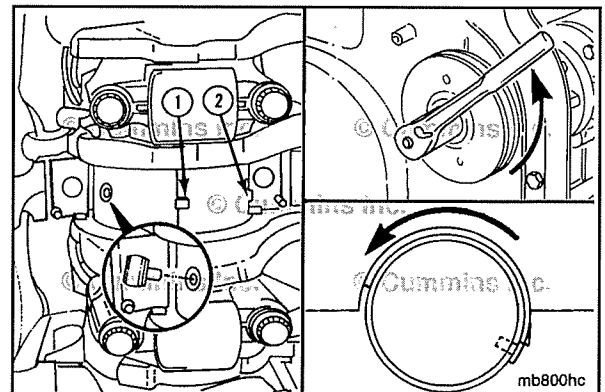
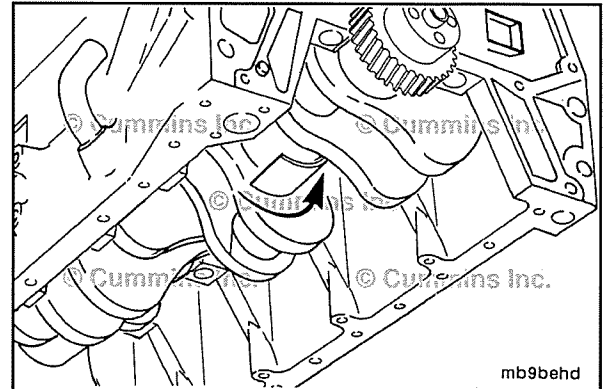
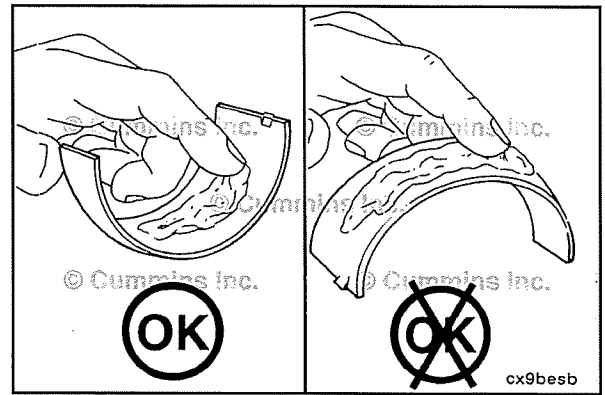
Follow this step to finish installing the upper main bearings, except for number 1 front main bearing.

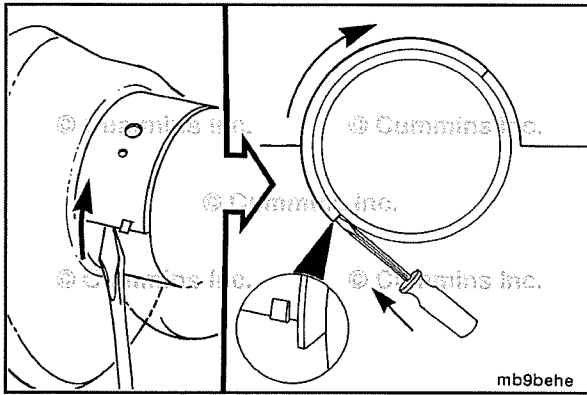
Make sure the pin does not slide under the bearing.

Use the main bearing replacer, Part Number 3823818, to finish installing the main bearing by rotating the crankshaft. Rotate the crankshaft using the barring tool, Part Number 3824591.

Make sure the tang (1) on the main bearing is located in the notch (2) of the cylinder block.

Finish pushing the main bearing into position.





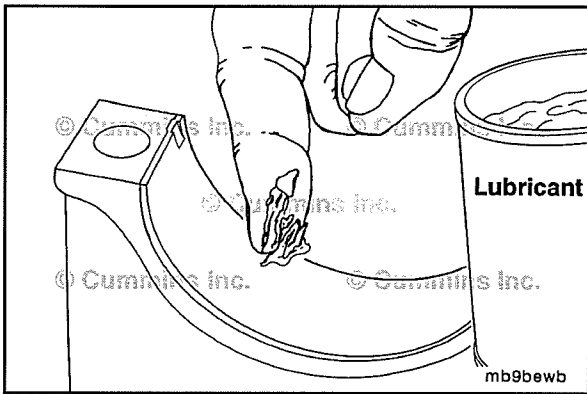
NOTE: The front main bearing, number 1, does **not** have a hole in the journal so the pin can **not** be used to replace the bearing.



Lubricate and install the number 1 main bearing.

Insert the side of the main bearing opposite the tang first. Install as far as possible by hand.

Use a screwdriver to push the main bearings into position as the crankshaft is rotated.



Lower Main Bearings

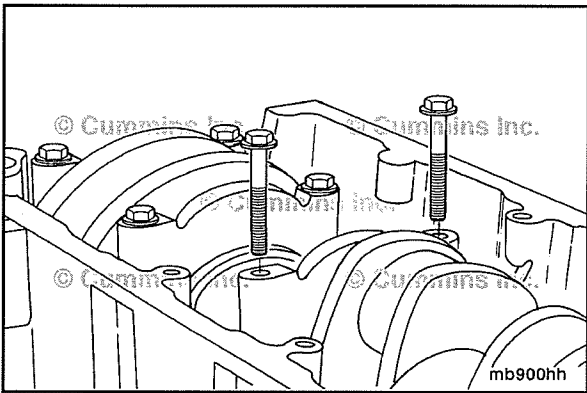
The backside of the bearings **must** be clean and free of debris.



Install the lower main bearings into the main bearing caps.

Align the tangs of the bearings with the tangs on the main bearing caps.

Apply a coat of assembly lubricant, Part Number 3163086, or equivalent, to the crankshaft side of the main bearings.



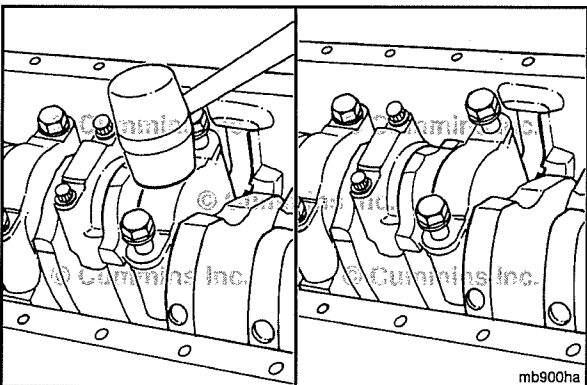
NOTE: The main bearing caps are numbered for location. Number 1 starts with the front of the block. Install the cap so that numbers face the intake side of the engine.



The main bearing cap surfaces between the main bearing cap and the block **must** be clean and free of debris.

Install a main bearing cap after each upper main bearing is installed to keep the main bearing in place while the other uppers are installed.

Lubricate the main bearing capscrew under the cap and lubricate the main bearing capscrew threads using clean 15W-40 engine oil.



Gently tap the main bearing cap into position with a plastic or rubber mallet.

When seated, install the main bearing capscrews and tighten.



Torque Value: 50 N•m [37 ft-lb]

Do **not** tighten to the final torque value at this time. The final torque **must** be applied after all main bearing caps are installed.

Use the barring tool, Part Number 3824591, to make sure the crankshaft rotates freely after installing the main bearing caps.

While applying final torque to the main bearing capscrews, frequently check that the crankshaft rotates freely.

If the crankshaft does **not** rotate freely:

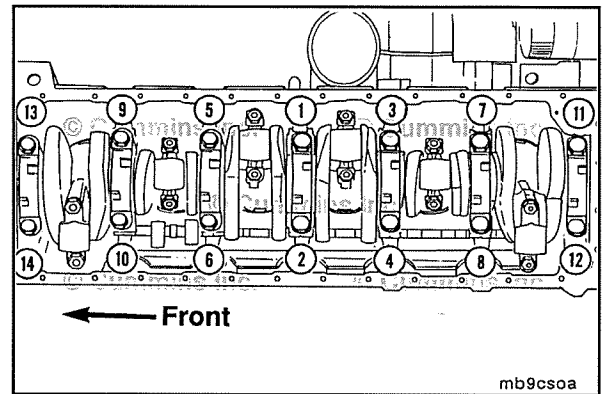
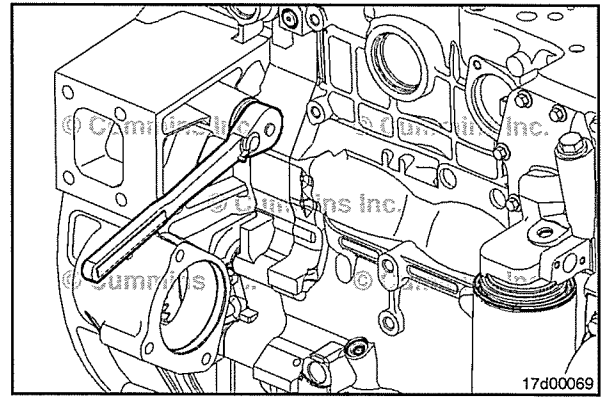
- 1 Confirm the crankshaft is **not** contacting one of the connecting rods.
- 2 Confirm the correct main bearing caps were installed correctly.
- 3 Confirm the main bearing cap ring dowels or mounting surfaces were **not** damaged during installation.
- 4 Confirm the correct main bearings were installed.

Tighten the main bearing capscrews evenly and in sequence.

Torque Value:

- | | | |
|--------|--------------------|--------------|
| Step 1 | 50 N•m | [37 ft-lb] |
| Step 2 | 95 N•m | [70 ft-lb] |
| Step 3 | Rotate 60 degrees. | |

Check the main bearing installation and the size of the main bearings if the crankshaft does **not** rotate freely.



The dimensions of the thrust bearing and crankshaft journal determine end clearance.

Measure the crankshaft end clearance using dial indicator, Part Number 3824564, and magnetic base, Part Number 3377399.

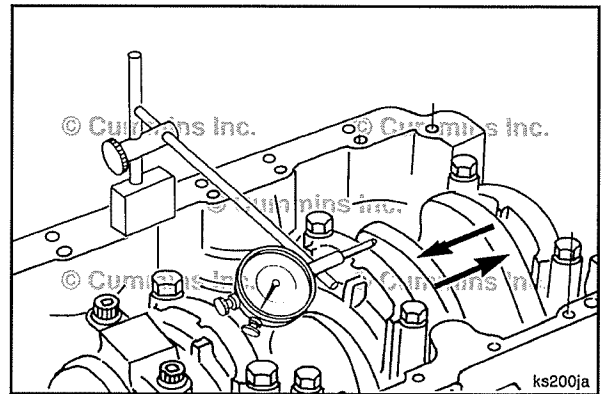
Crankshaft End Clearance Limits

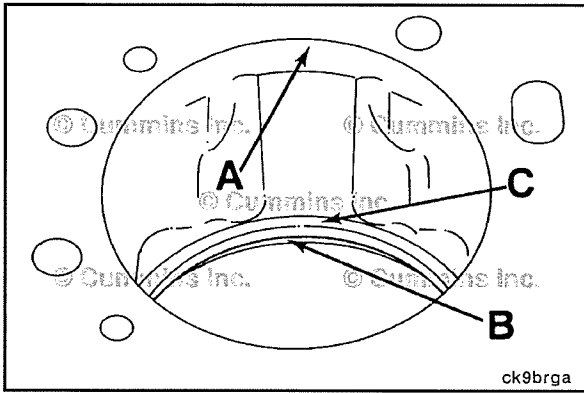
mm		in
0.085	MIN	0.003
0.385	MAX	0.015

If the crankshaft end clearance is **not** within specification:

- 1 If the crankshaft end clearance is below specification, check if there are any obstructions limiting the crankshaft's travel (lubricating oil pump, connecting rod, etc.)
- 2 If the crankshaft end clearance is above specification, inspect the crankshaft thrust bearing surface. Also check if the correct thrust bearing(s) were installed.

NOTE: Oversize thrust bearings are available if the end clearance is **not** within specifications. See the appropriate parts catalog.





Cylinder Liner (001-028)

Install

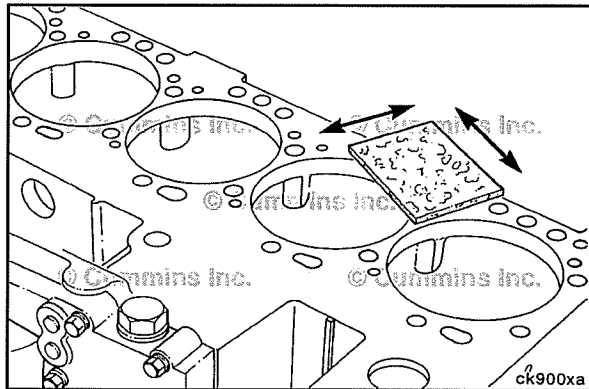
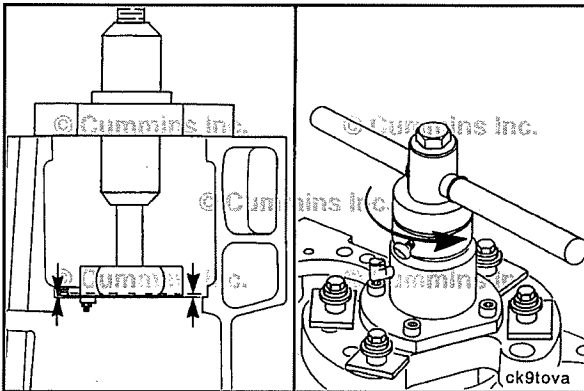
⚠ CAUTION ⚠

Clean all deposits and debris from sealing surfaces A, B, and C. Use abrasive pad, Part Number 3823258 or equivalent, and cleaning solvent to polish the surfaces. Due to the critical machined tolerances, care should be taken not to remove any additional material.

If surface C has cracks or signs of extreme wear, the counterbore will require machining and the installation of shims for the correct liner protrusion.

Using the Counterbore Cutter, Part Number 3163785, machine the counterbore to the proper depth.

NOTE: Part Number 3823567, cutter plate, and Part Number 3823570, cutter bit, **must** be used with the counterbore machining tool.



⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.



⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Clean the combustion deck with a gasket scraper or abrasive pad, Part Number 3823258 or equivalent, and diesel fuel or solvent.

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠ WARNING ⚠

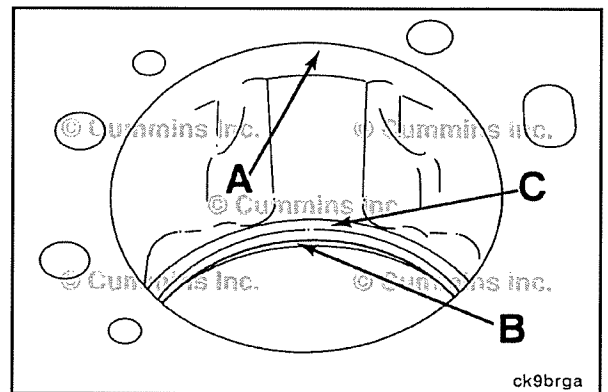
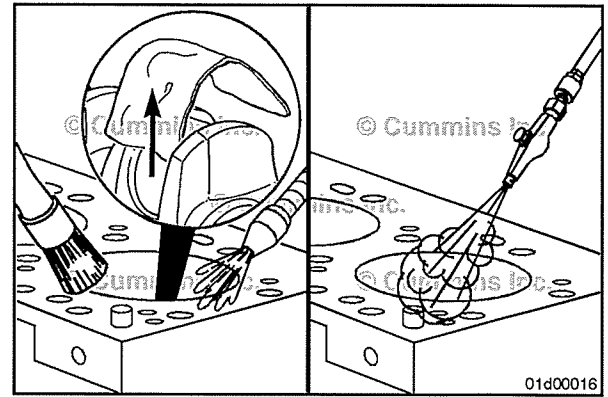
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Thoroughly flush the block with mineral spirits or cleaning solvent.

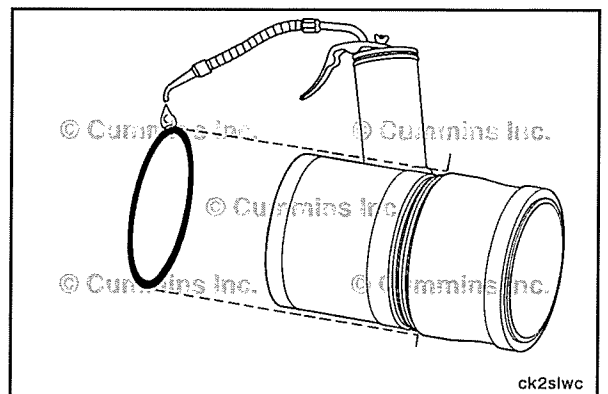
Remove the shop rags and clean the crankshaft with a cleaning solvent.

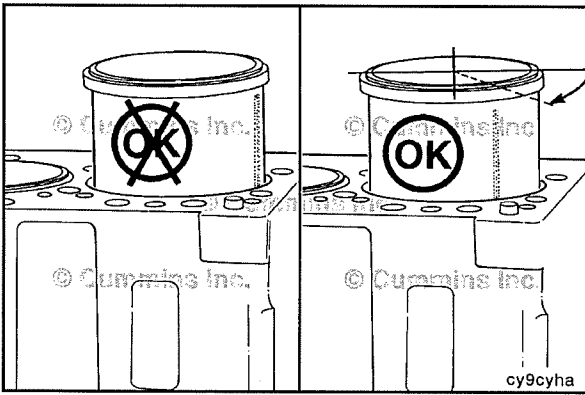
Blow the cylinder bores and crankshaft dry and wipe them clean with a lint-free cloth.

Lubricate surfaces A and B with clean 15W-40 engine oil.

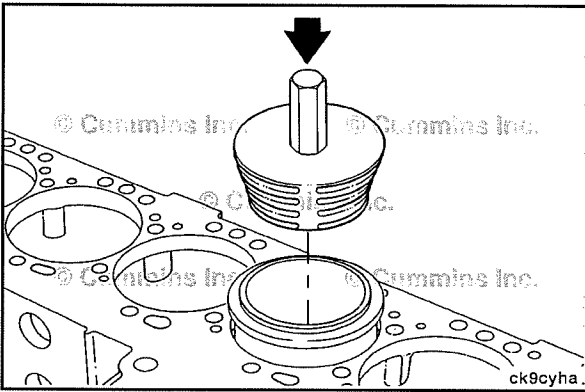


Use clean 15W-40 oil to coat the liner o-ring seals.
Install new o-ring seals on the liners.

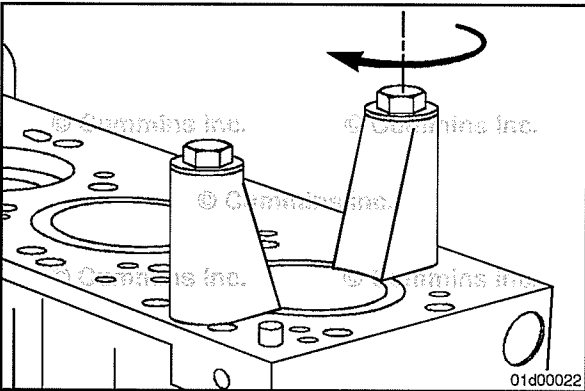




When reusing liners, install them in the same cylinder from where they were removed and rotate them 45 degrees (1/8 turn) from their original position. When correctly installed, any liner pitting **must** be positioned as illustrated so the pitted surface is rotated away from the location where pitting occurs.



Install the liner into the bore of the cylinder block, use liner driver, Part Number ST-1229.



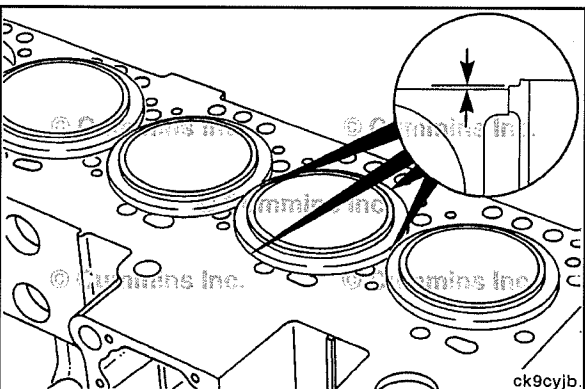
Use two (2) cylinder head capscrews and position the two (2) liner clamps, Part Number 3822503, as illustrated.

Tighten the capscrews.



Torque Value: 68 N•m [50 ft-lb]

Remove the clamps and repeat this procedure until all liners have been clamped and released.



Liner protrusion is the distance the liner protrudes above the block face.

Measure the liner protrusion at four points 90 degrees apart using gauge, Part Number 3164438.

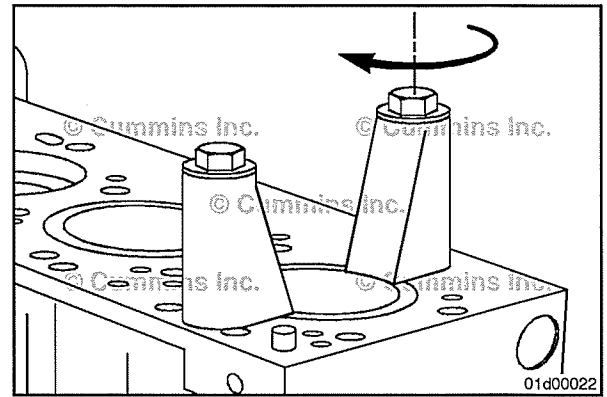
Cylinder Liner Protrusion

mm		in
0.026	MIN	0.0010
0.122	MAX	0.0048

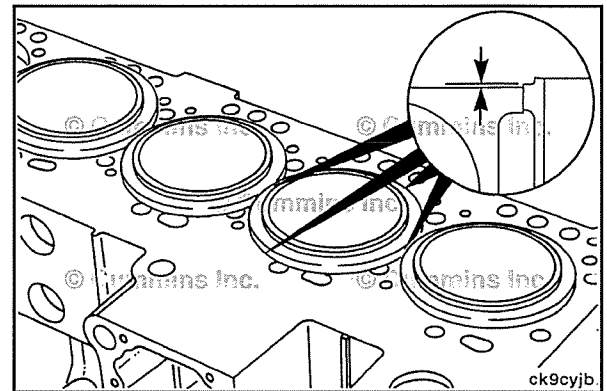
NOTE: If the liner protrusion varies more than 0.025 mm [0.0010 in] for 180 degrees:

- Install and tighten the liner clamps again.

Torque Value: 68 N•m [50 ft-lb]

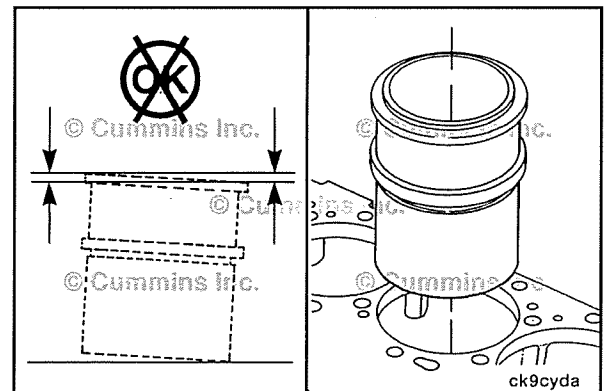


- Measure the liner protrusion again.

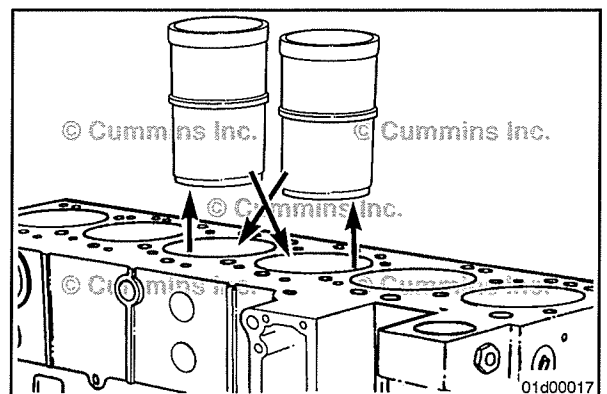


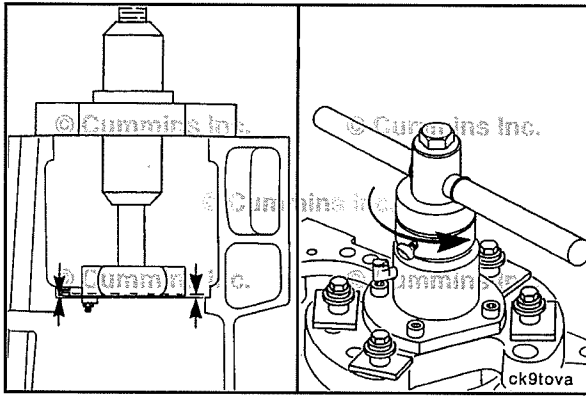
NOTE: If the protrusion still varies more than 0.025 mm [0.0010 in]:

- Remove the liner
- Inspect the liner sealing edge for burrs, dirt, or damage
- Replace the liner if it is damaged
- Install the liner again
- Measure the liner protrusion.



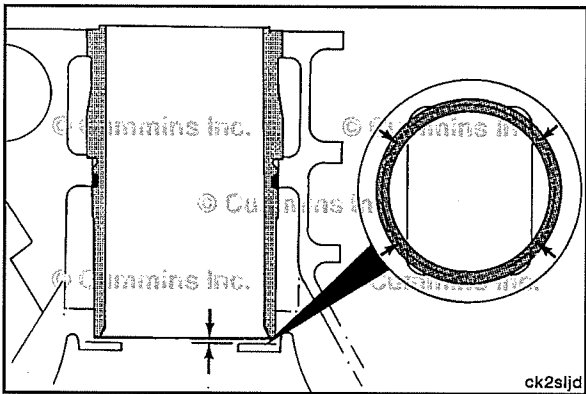
Service Tip: If the out-of-limit condition is minimal, tolerance stack-up may allow the protrusion limits to be obtained by installing other new liners in the out-of-limit bore.





NOTE: If the liner protrusion still does **not** meet the specifications, machine the cylinder block liner bore for shims using the following tools:

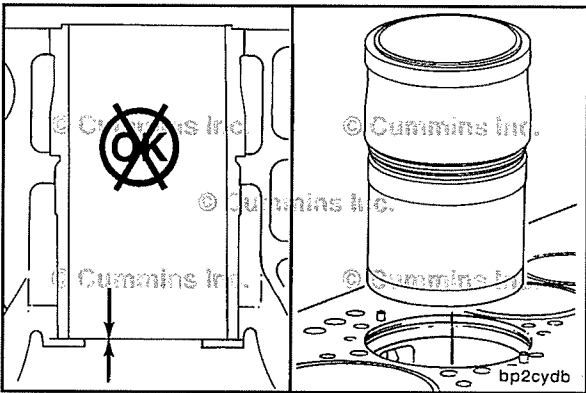
- Drive unit, Part Number 3163785
- Cutter plate, Part Number 3823567
- Cutter bit, Part Number 3823570.



Use a feeler gauge to inspect the liner to block clearance at the four block casting points.

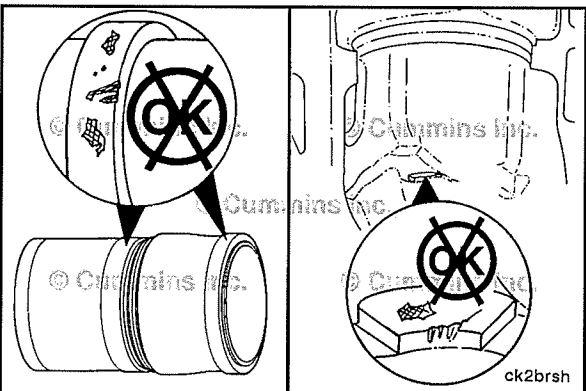
Cylinder Liner to Block Clearance

mm		in
0.229	MIN	0.009



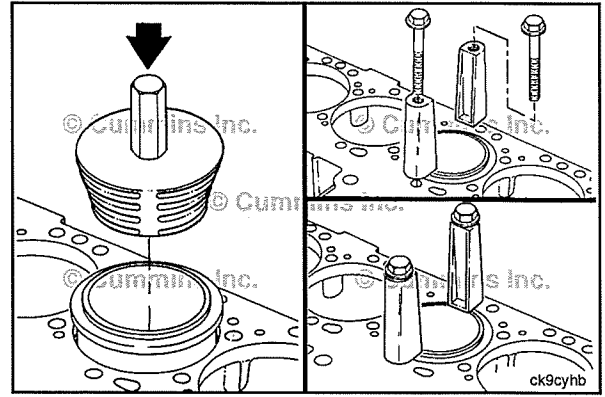
NOTE: If the clearance is **less** than 0.229 mm [0.009 in]:

- Remove the liner.

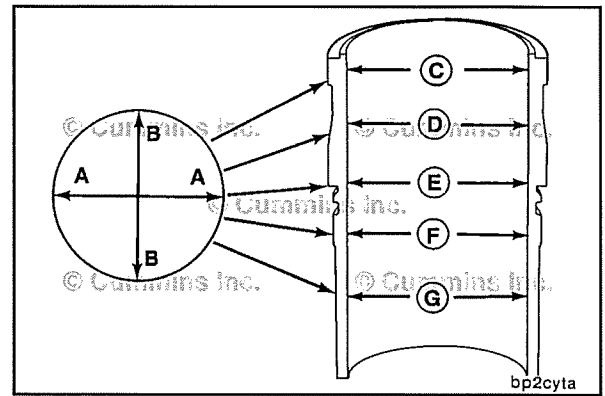


- Inspect the liner and cylinder block for dirt or damage.

- Replace the liner if it is damaged.
- Install the liner again.

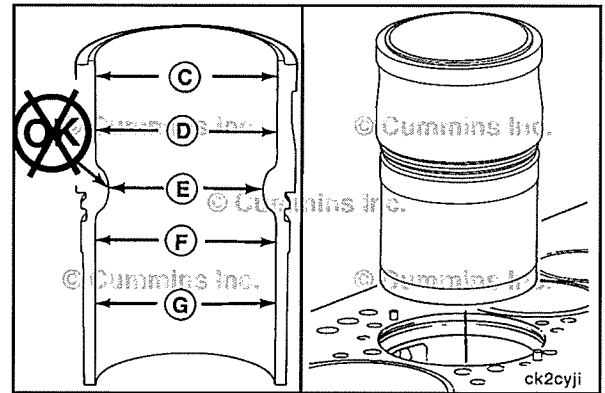


Measure the liner bore for out-of-roundness at points "C", "D", "E", "F", and "G". Measure each point in the direction "AA" and "BB". The bore **must not** be more than 0.04 mm [0.002 in] out-of-round.



NOTE: If the liner bore is more than 0.04 mm [0.002 in] out-of-round:

- Remove the liner so the cylinder block liner bore can be measured.



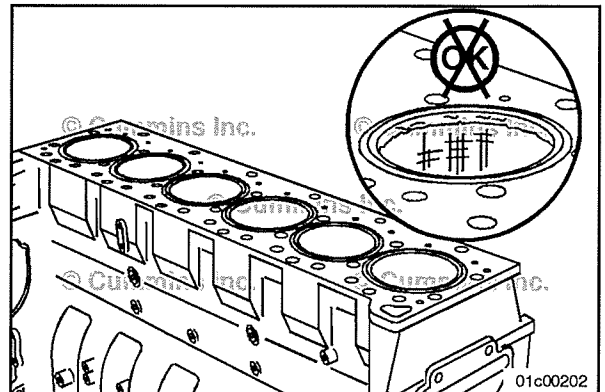
Piston and Connecting Rod Assembly (001-054)

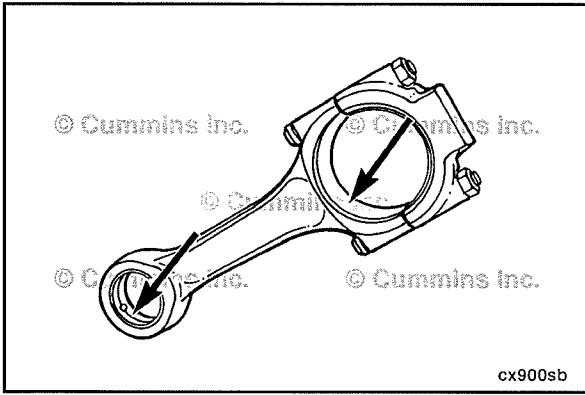
Install

The cylinder block and all parts **must** be clean before assembly. Inspect the cylinder liners for reuse.

Refer to Procedure 001-028 in Section 1.

Use a clean, lint-free cloth to clean the connecting rods and bearing shells.



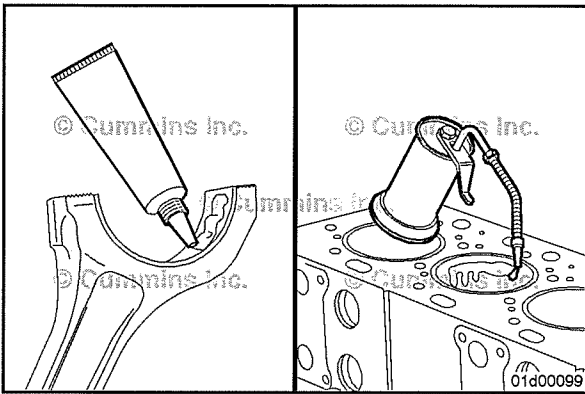


If new bearings are **not** used, the used bearings **must** be installed on the same connecting rod and location from where they were removed.



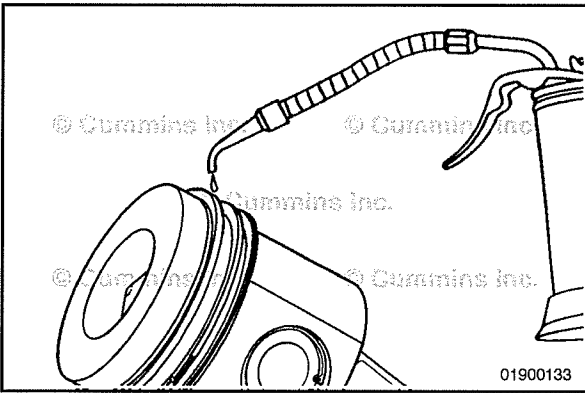
Install the upper bearing shell into the connecting rod.

The tang of the bearing shell **must** be in the slot of the rod. The end of the bearing shell **must** be even with the cap mounting surface.

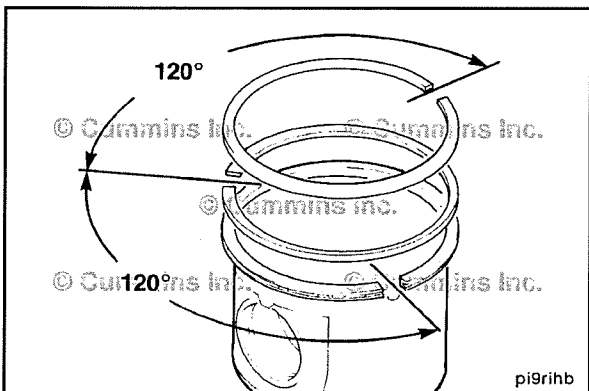


Use assembly lubricant, Part Number 3163087 or equivalent, to coat the inside circumference of the bearing shell.

Apply a film of clean 15W-40 engine oil to the cylinder liner.



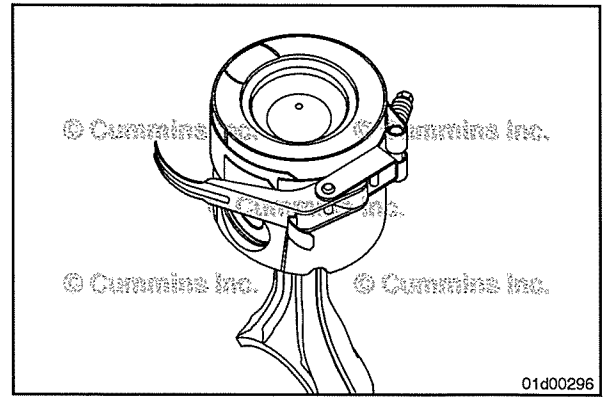
Lubricate the rings and piston skirts with clean engine lubricating oil.



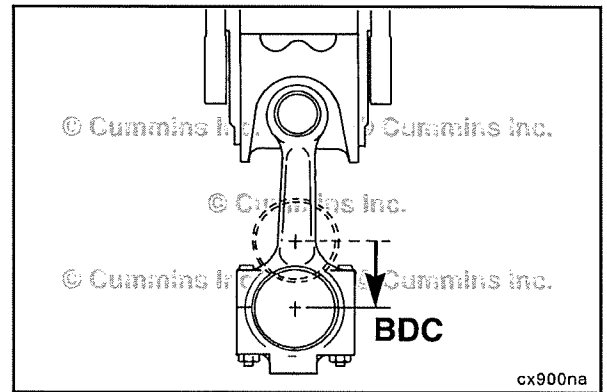
Rotate the rings to position the ring gaps as shown.

NOTE: The ring gap of each ring **must not** be aligned with the piston pin, or with any other ring. If the ring gaps are **not** aligned correctly, the rings will **not** seal properly.

Use piston ring compressor, Part Number 3823290, to compress the rings.



Rotate the crankshaft so the connecting rod journal of the connecting rod being installed is at BDC.

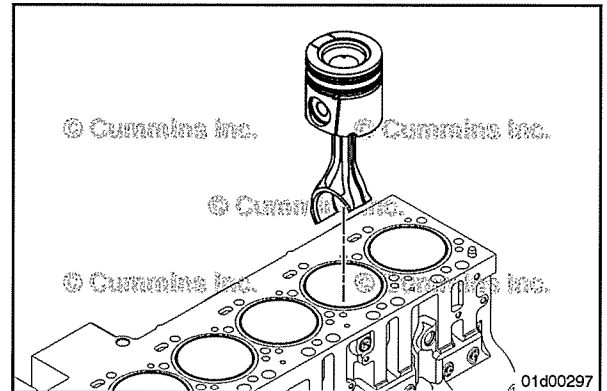


⚠ CAUTION ⚠
Omission of this step will result in extensive engine damage.

NOTE: For all piston types make sure that the "FRONT" marking on the piston crown is pointed toward the front of the engine block.

Align the piston crown deep valve pocket on the exhaust side of the engine.

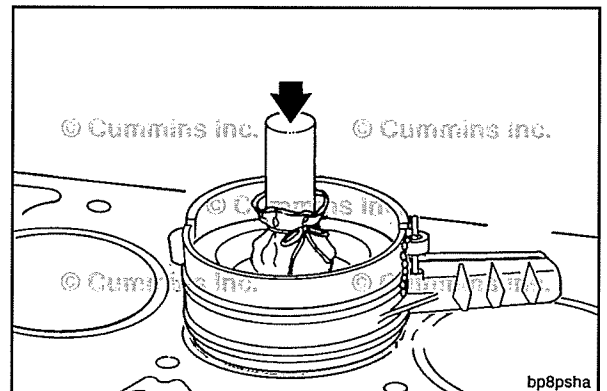
Insert the connecting rod through the cylinder liner until the ring compressor contacts the top of the liner.

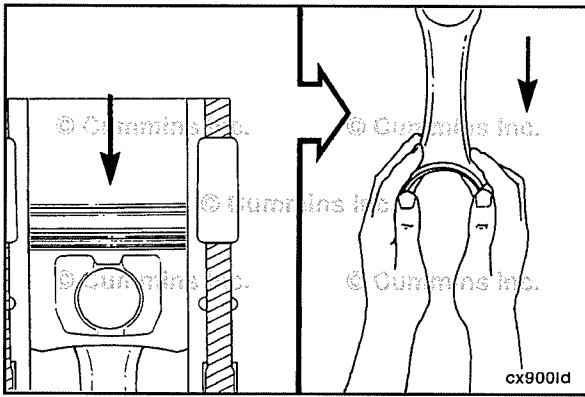


Hold the ring compressor against the cylinder liner.
Push the piston through the ring compressor and into the cylinder liner.

Push the piston until the top ring is completely in the cylinder liner.

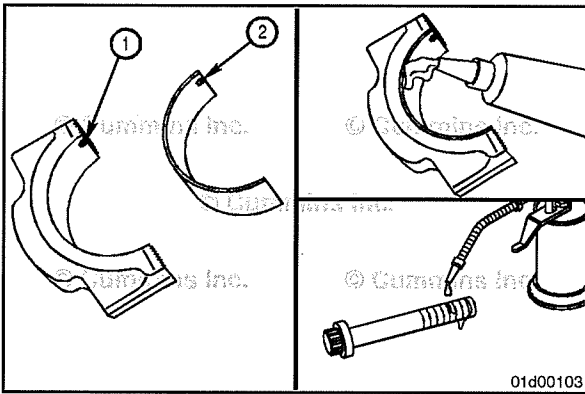
NOTE: If the piston does **not** move freely, remove the piston and inspect for broken or damaged rings.





Carefully push the piston into the bore while guiding the connecting rod to the crankshaft journal.

NOTE: Connecting rod guide, Part Number 3824476, can be used to aid installation on engines with connecting rod studs.



NOTE: If new bearings are **not** used, the used bearings **must** be installed on the same connecting rod cap from which they were removed.

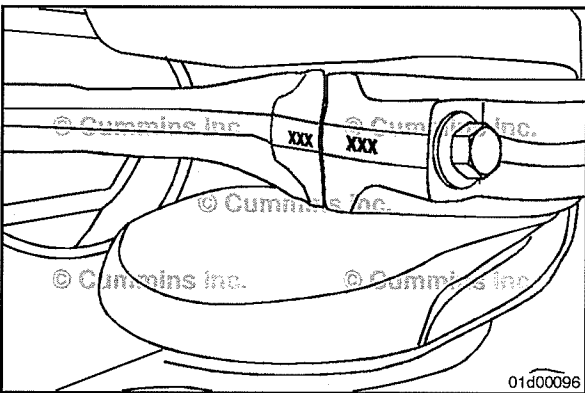


Install the bearing in the connecting rod cap.

The tang of the bearing (2) **must** be in the slot of the cap (1).

Use assembly lubricant, Part Number 3163087 or equivalent, to coat the inside diameter of the bearing shell.

Use clean 15W-40 engine oil to lubricate the connecting rod capscrew threads.



The connecting rod and cap **must** have the same number and **must** be installed in the proper cylinder. The connecting rod cap number and rod number **must** be on the same side of the connecting rod to prevent engine damage during engine operation.



Engines With Connecting Rod Studs and Nuts



- Install the connecting rod cap and nuts.
- Use a marked socket and torque wrench to tighten the connecting rod nuts.
- Use the torque plus angle method to tighten the connecting rod nuts in alternating sequence.

Torque Value:

Connecting Rod Nuts

Step 1	60 N•m	[44 ft-lb]
Step 2	Loosen capscrews	
Step 3	30 N•m	[22 ft-lb]
Step 4	50 N•m	[37 ft-lb]
Step 5	Advance 60 degrees.	

Engines With Connecting Rod Capscrews

- Install the connecting rod cap and capscrews.
- Use a marked socket and torque wrench to tighten the connecting rod capscrews.
- Use the torque plus angle method to tighten the connecting rod capscrews in alternating sequence.

Torque Value:

Connecting Rod Capscrews

Step 1	60 N•m	[44 ft-lb]
Step 2	Loosen capscrews	
Step 3	30 N•m	[22 ft-lb]
Step 4	50 N•m	[37 ft-lb]
Step 5	Advance 60 degrees	

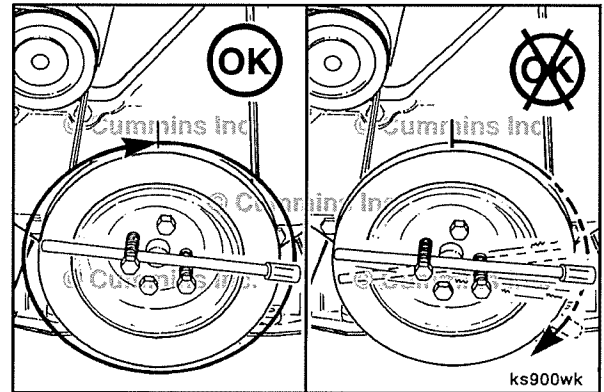
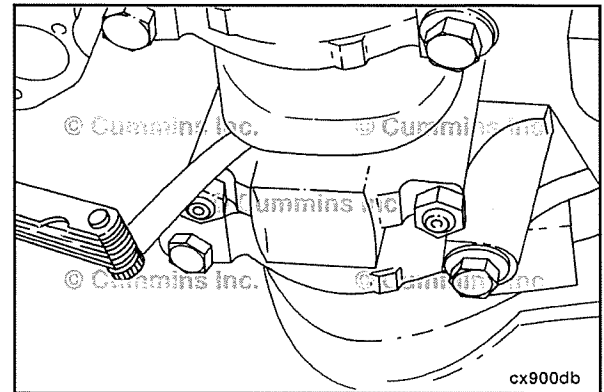
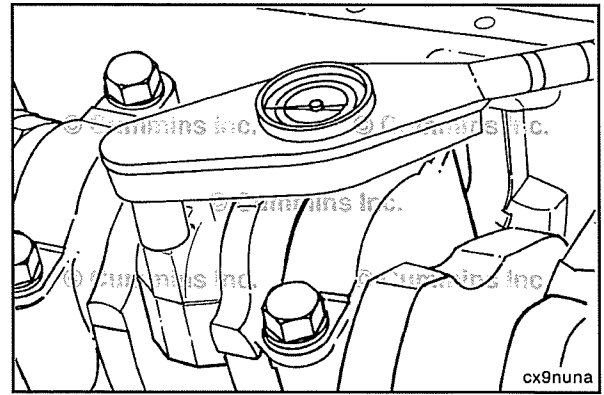
NOTE: Do **not** measure the clearance between the rod cap and crankshaft.

Measure the side clearance between the connecting rod and crankshaft.

Connecting Rod and Crankshaft Side Clearance

mm		in
0.10	MIN	0.004
0.30	MAX	0.012

Check for freedom of rotation as the connecting rod caps are installed. If the crankshaft does **not** rotate freely, check the installation of the connecting rod bearings and the bearing size.



Piston Cooling Nozzle (001-046)

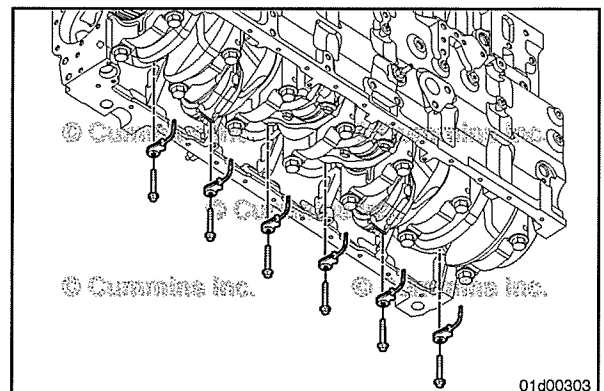
Install

NOTE: The crankshaft **must** be rotated to allow access to install the nozzles.

Install the piston cooling nozzles and capscrews.

Tighten the capscrews.

Torque Value: 33 N•m [24 ft-lb]

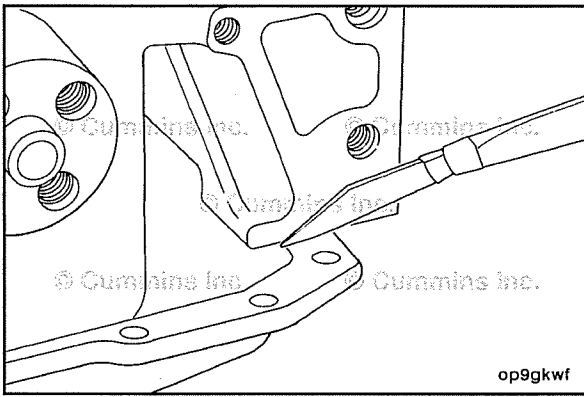


Gear Housing, Front (001-033)

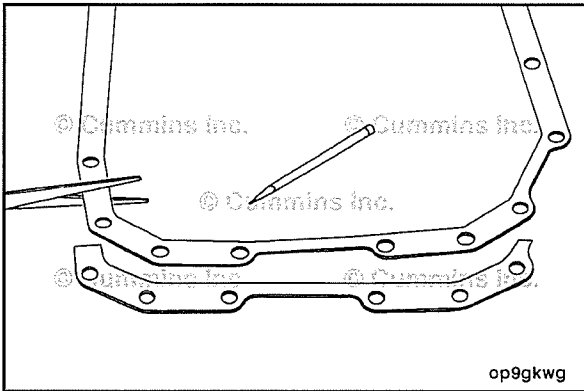
Install

If the lubricating oil pan gasket is damaged, it can be repaired.

Cut the damaged gasket off even with the front of the cylinder block.



Use the old gasket as a template to cut the front section of a new gasket to the same size.

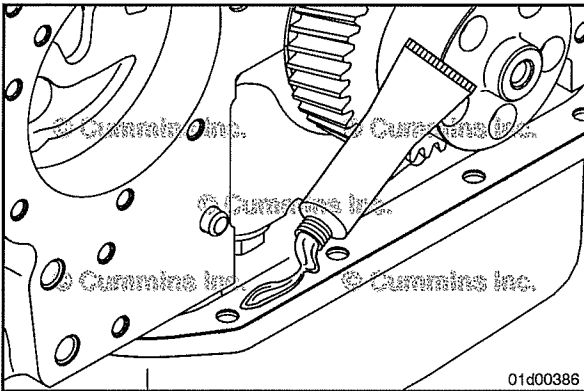


NOTE: The gear housing **must** be installed within 10 minutes of applying the sealant.

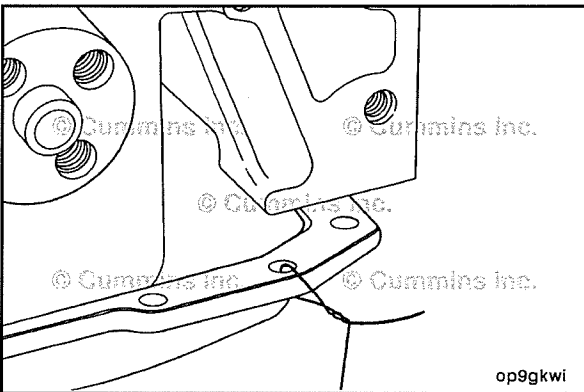
Clean the sealing surfaces.

Coat the new gasket on both sides with RTV sealant, Part Number 3823494 or equivalent.

Be sure there is a bead of sealant at the intersecting joint of the cylinder block, oil pan, and gear housing.

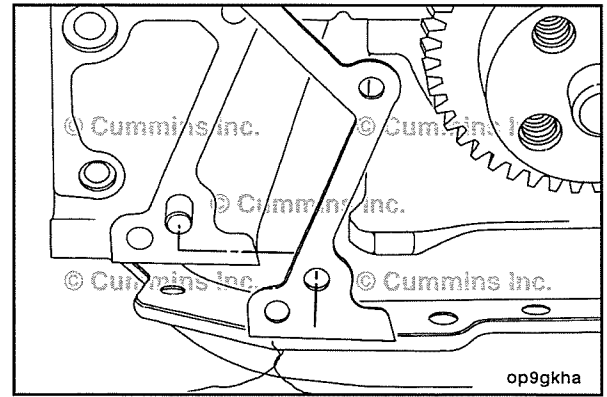


Use common thread or a very fine wire to hold the new gasket splice in position as illustrated.



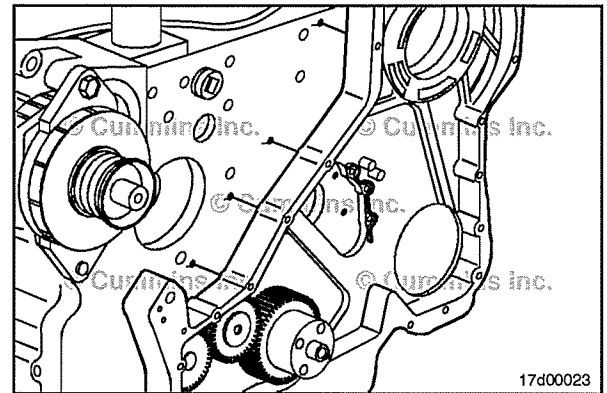
Position the gear housing gasket on the alignment dowels.

Use guide pins (M8 x 1.25 x 50) to assist in aligning the gasket and gear housing. Be sure to remove the guide pins after alignment.

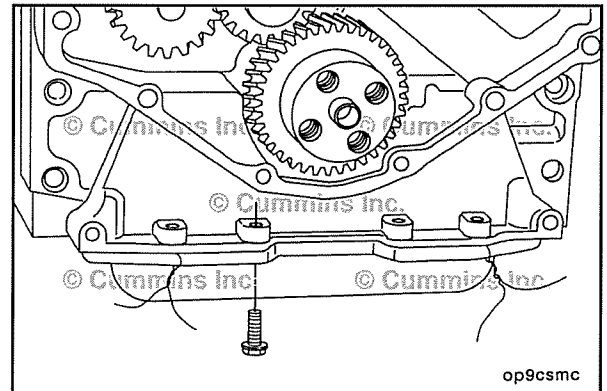


Install the gear housing.

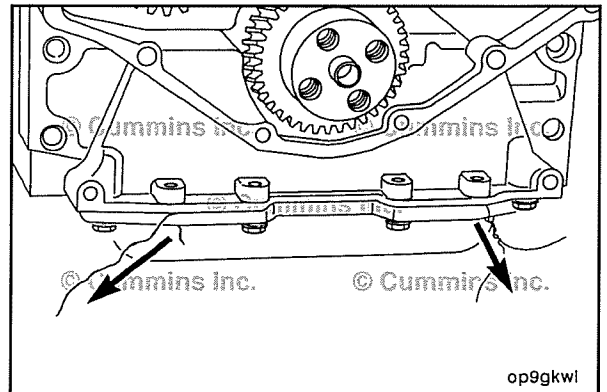
Torque Value: 40 N•m [30 ft-lb]

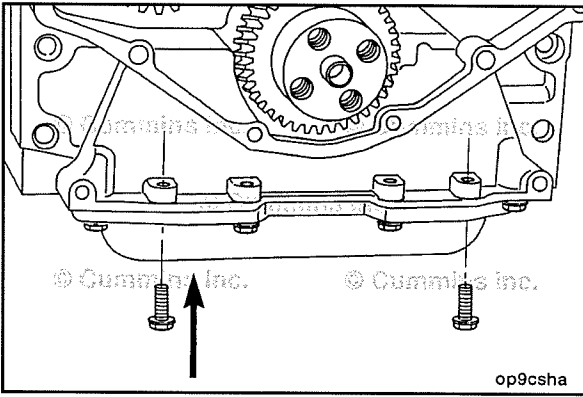


Start the oil pan capscrews in the holes **not** being used to tie the gasket in place.

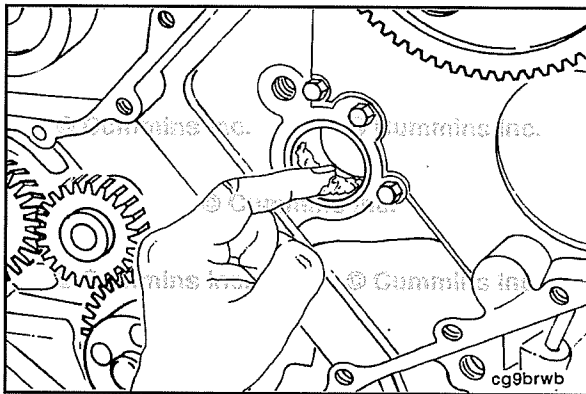


Remove the thread or wire holding the gasket in place.





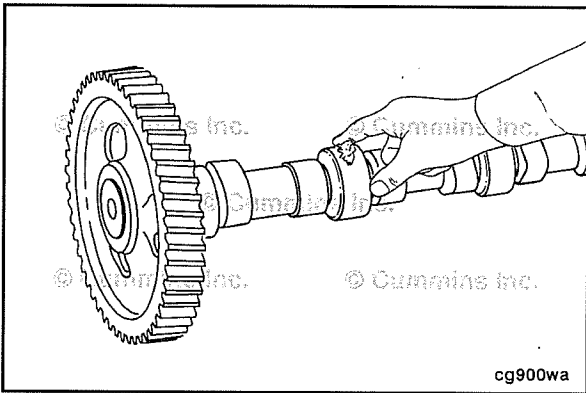
Install the remaining two oil pan capscrews and tighten. Refer to Procedure 007-025 in Section 7.



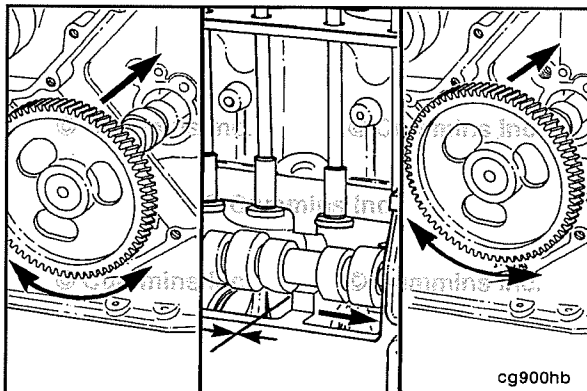
Camshaft (001-008)

Install

Apply a coat of assembly lubricant, Part Number 3163087 or equivalent, to the front camshaft bore.



Lubricate the camshaft lobes, journals and thrust plate with assembly lubricant, Part Number 3163087 or equivalent.

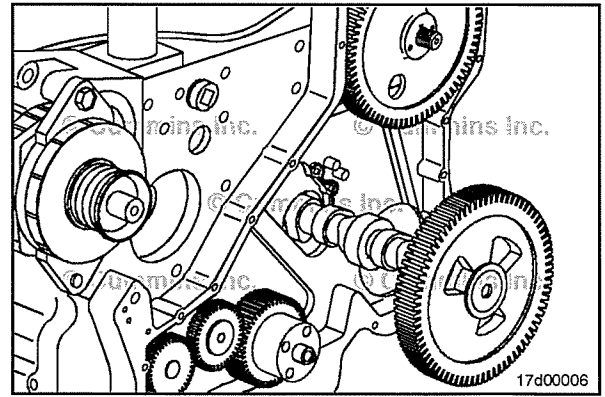


⚠ CAUTION ⚠

Do not try to force the camshaft into the camshaft bore as damage to the camshaft bushing can result.

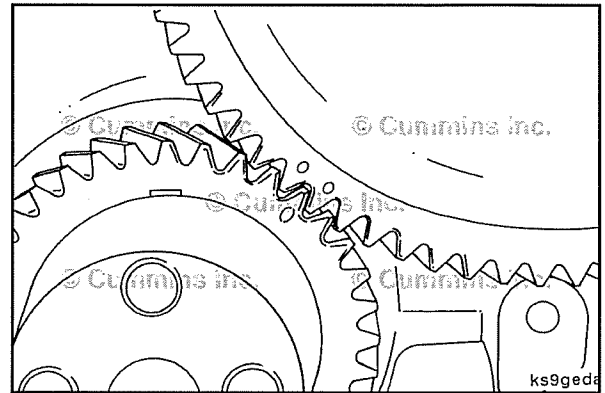
Install the camshaft. While pushing in slightly, rotate the camshaft and carefully work the camshaft through the camshaft bushings. As each camshaft journal passes through a bushing, the camshaft will drop slightly and the camshaft lobes will catch on the bushings. Rotating the camshaft will free the lobe from the bushing and allow the camshaft to be installed.

Before the camshaft gear engages the crankshaft gear, check the camshaft for ease of rotation. When installed properly, the camshaft **must** rotate freely.



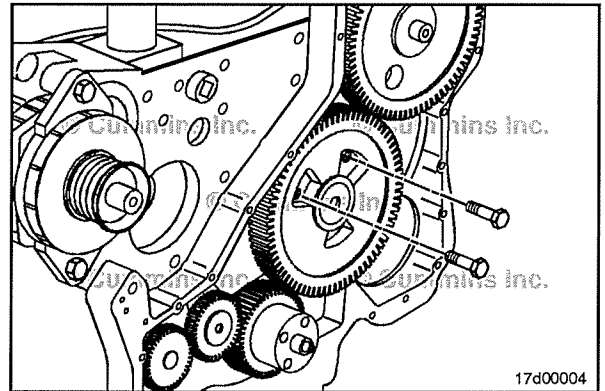
17d0006

Align the timing marks as illustrated and finish installing the camshaft.



ks9geda

Install the thrust plate cap screws.
Torque Value: 24 N•m [212 in-lb]



17d00004

Use gauge, Part Number 3824564, and magnetic base, Part Number 3377399, to verify that the camshaft has proper end clearance and backlash.

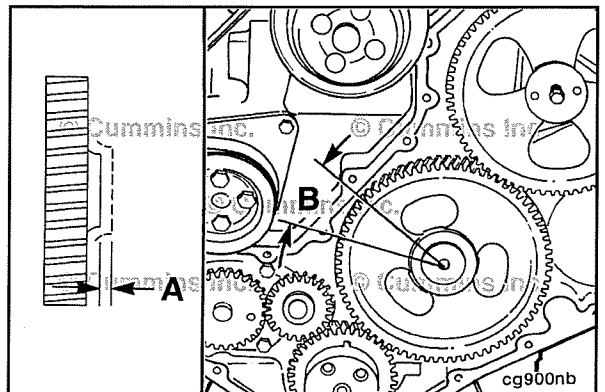


Camshaft End Clearance (A)

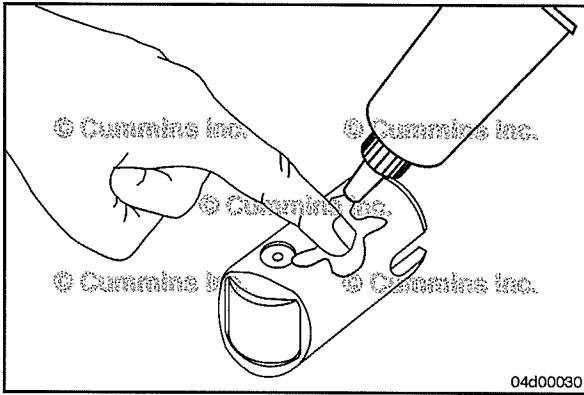
mm		in
0.12	MIN	0.005
0.50	MAX	0.020

Camshaft Gear Backlash Limits (B)

mm		in
0.08	MIN	0.003
0.33	MAX	0.013

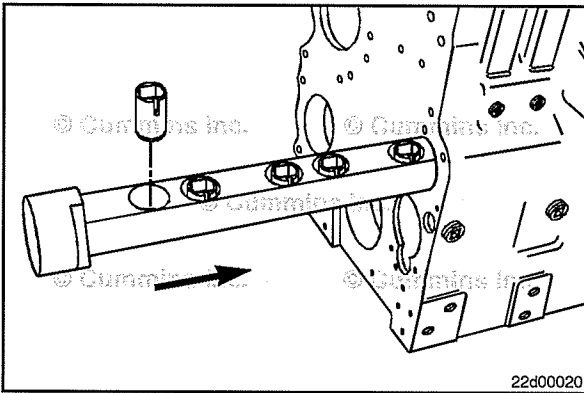


cg900nb



Tappet (004-015) Install

Lubricate the tappets with assembly lubricant, Part Number 3163087 or equivalent.



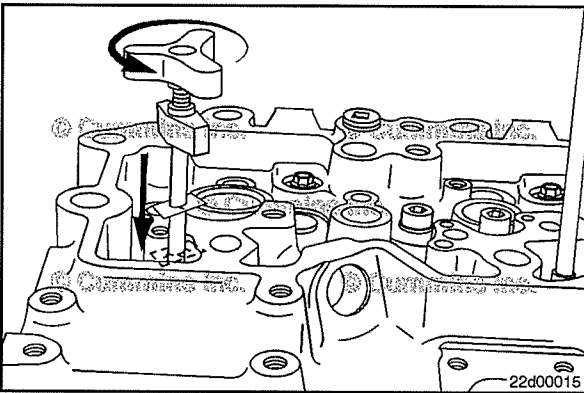
Make sure the tappets are installed with the pin slots toward the outside of the block.

Insert the tappets into the tappet holder.



NOTE: If the tappets are being reused, be sure to install them in their original position.

Insert the tappet holder the full length of the camshaft bore.

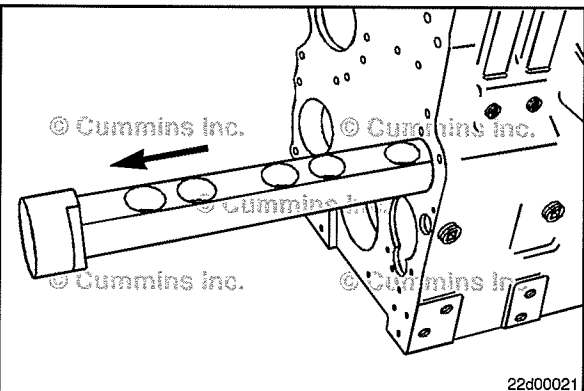


Insert the tappet extractor tool into the tappet bore. Turn the top **counterclockwise** to expand and secure the tool into the tappet.

Raise the tappet extractor until it stops, and push the metal tab down against the head surface to secure the tool in the up position.

NOTE: Some manipulation may be necessary to get the tappet to enter the bore. When the tappet enters the bore, attempt to rotate the extractor while applying light upward pressure. If the tool will **not** rotate, the tappet has engaged the guide pin. If the tool does rotate, continue until the tappet engages the guide pin.

Repeat for the remaining tappets.

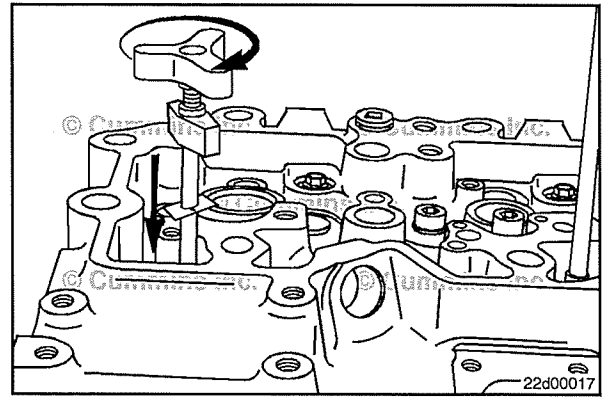


Remove the tappet holder.

Install the camshaft. Refer to Procedure 001-008 in Section 1.



Lower the tappet extractor, and seat the tappet into the camshaft. Turn the top knob **clockwise** while holding the bottom knob to disengage the extractor from the tappet. Repeat the step for the remaining tappets.



Lubricating Oil Suction Tube (Block-Mounted) (007-035)

Install

Install the lubricating oil suction tube and new gasket.

- Install all capscrews finger tight and check for correct alignment.
- Torque the lubricating oil suction tube to the block.

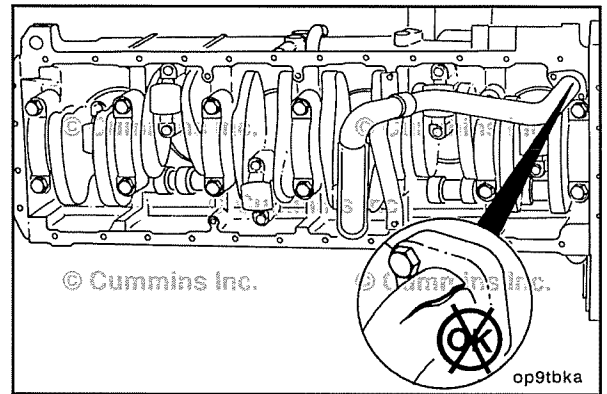
Torque Value: 10 N•m [89 in-lb]

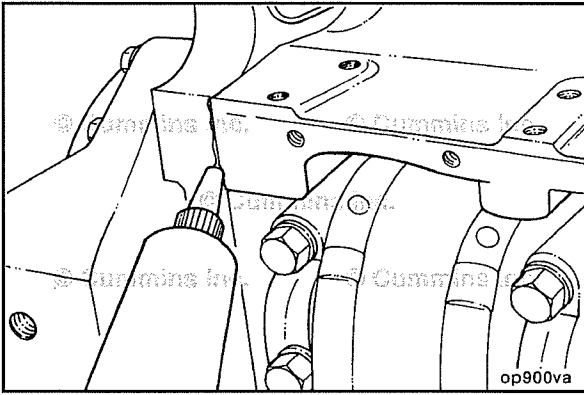
- Torque the lubricating oil suction tube brace to the engine block.

Torque Value: 10 N•m [89 in-lb]

- Torque the lubricating oil suction tube to the brace.

Torque Value: 10 N•m [89 in-lb]





Lubricating Oil Pan (007-025)

Install

NOTE: The engines use a variety of combinations of gaskets and/or RTV for sealing. When installing the oil pan, use the same combinations of gasket and/or RTV that were on the pan.

NOTE: To achieve a proper seal, **always** use a new gasket.

NOTE: If the engine is equipped with a block stiffener plate, it is recommended that paper gaskets **not** be used for sealing.

Apply a 4 mm [1/8 in] bead of sealant, Part Number 3164067 or equivalent, to the oil pan mounting surfaces at the cylinder block to front gear cover joints, and the cylinder block to rear gear housing joints.

NOTE: Install the oil pan within 10 minutes of applying the sealant, or it will **not** seal correctly. Once installed, allow the sealant to dry for a minimum of 30 minutes before running the engine.

Install the suction tube, if applicable. Refer to Procedure 007-035 in Section 7.

NOTE: Install three guide pins, Part Number 3164977, to improve the alignment of the oil pan sealing components to the cylinder block. It is recommended to install two of the guide pins at opposite corners and one in the middle.

Install the block stiffener, if applicable. Refer to Procedure 001-089 in Section 1.

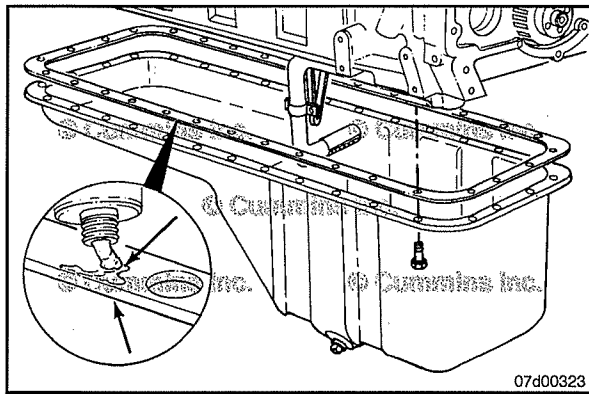
Install the gasket and lubricating oil pan.

Service Tip: To aid in installation of the gasket, apply a small amount of sealant, Part Number 3164067, or high tack spray adhesive to the gasket and oil pan flange. This will help to hold the gasket in place during assembly.

If RTV sealant is used to seal the oil pan, apply a 4 mm [1/8 in] bead of sealant, Part Number 3164067 or equivalent, to the oil pan flange and around the bolt holes.

Install the oil pan corner braces, if equipped.

NOTE: Install the oil pan within 10 minutes of applying the sealant, or it will **not** seal correctly. Once installed, allow the sealant to dry for a minimum of 30 minutes before running the engine.

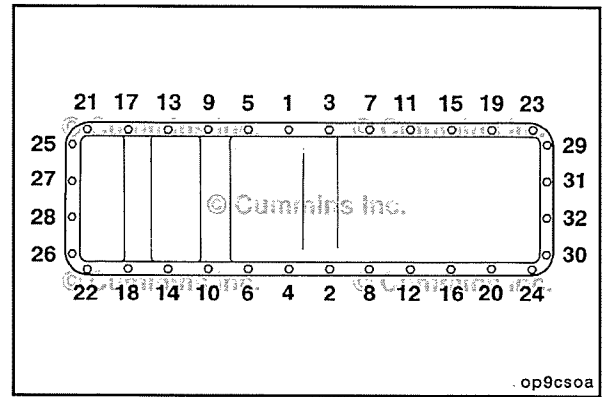


Assemble the washers and capscrews to secure the lubricating oil pan as illustrated.

Tighten all capscrews in the sequence shown in the illustration.

Torque Value: 28 N•m [248 in-lb]

NOTE: Make sure to follow the torque sequence shown. This allows for minimal assembly strains and evenly distributes pressure along the oil pan flange. Failure to follow the torque sequence can possibly lead to a cracked pan or joint leaks.



Clean and check the lubricating oil drain plug threads and sealing surface.

Install a new sealing washer if the lubricating oil pan plug was leaking, or if the sealing washer is damaged.

Install and tighten the lubricating oil pan drain plug.

Torque Value:

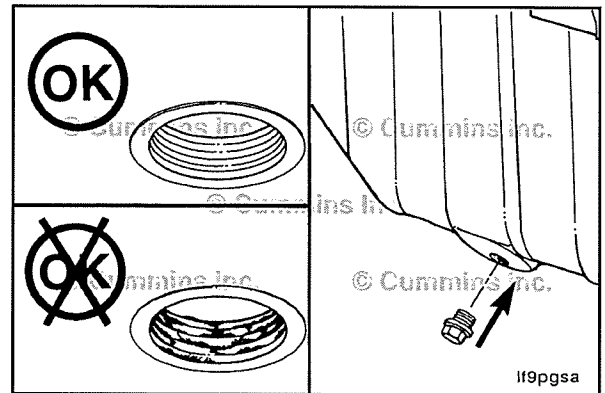
Steel Pan, M18 Plug 60 N•m [44 ft-lb]

Torque Value:

Steel Pan, M22 Plug 80 N•m [59 ft-lb]

Torque Value:

Cast Aluminum Pan, M22 Plug 60 N•m [44 ft-lb]

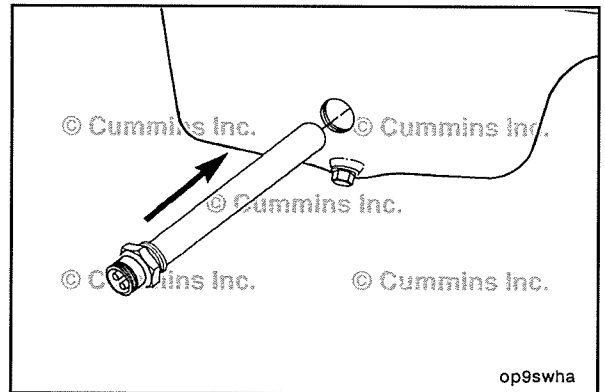


Engine Oil Heater (007-001)

Install

Install the heater element.

Torque Value: 80 N•m [59 ft-lb]



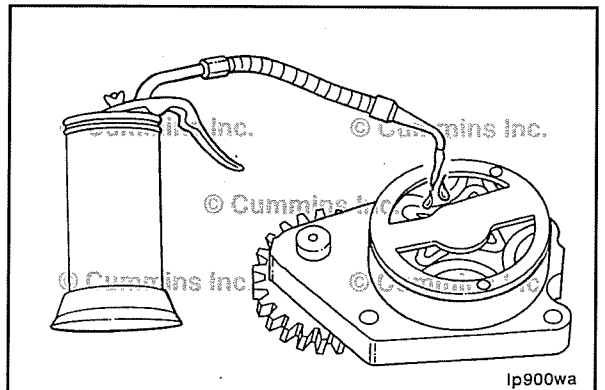
Lubricating Oil Pump (007-031)

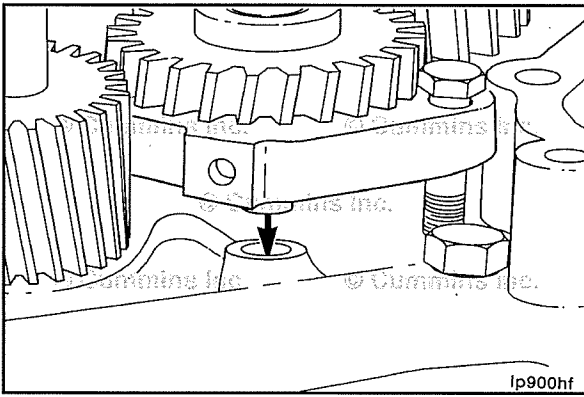
Install

⚠ CAUTION ⚠

Failure to fill the pump with oil at installation can result in the lubricating oil pump not priming at initial engine start-up, resulting in severe engine damage.

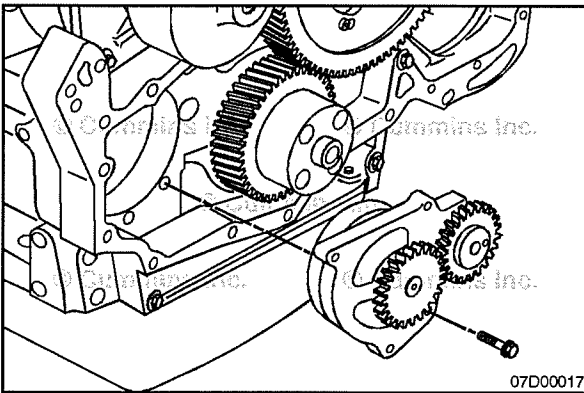
Lubricate the lubricating oil pump with clean 15W-40 engine oil.





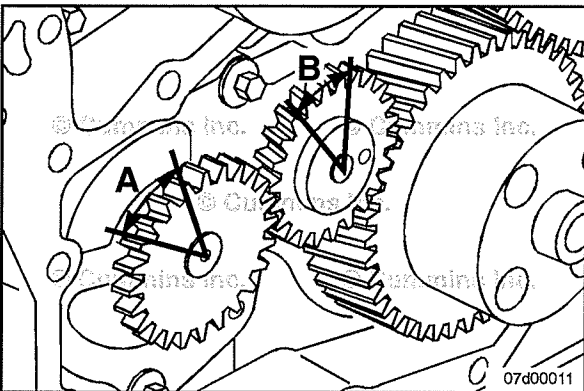
CAUTION
Make sure the idler gear pin is installed in the locating bore in the cylinder block.

Install the lubricating oil pump.



Tighten the capscrews in a crisscross pattern, starting with the upper right capscrew.

Torque Value: 24 N•m [212 in-lb]



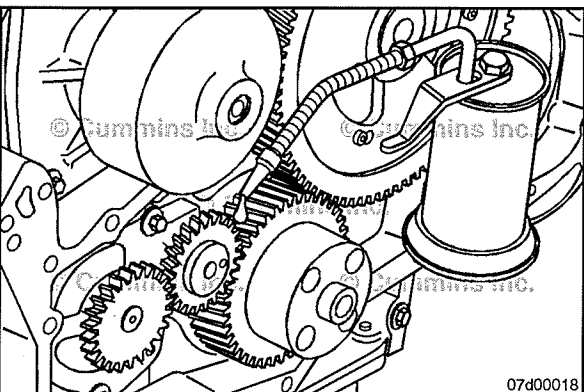
NOTE: Be sure the gear backlash is correct if installing a new lubricating oil pump.

Measure the gear backlash.

Lubricating Oil Pump Gears Backlash Limits (Installed)

	mm		in	
A	0.0762	MIN	0.003	
	0.3302	MAX	0.013	
B	0.0762	MIN	0.003	
	0.3302	MAX	0.013	

NOTE: If the adjoining gear moves when you measure the backlash, the reading will be incorrect.



Lubricate the front gear train with clean 15W-40 engine oil.

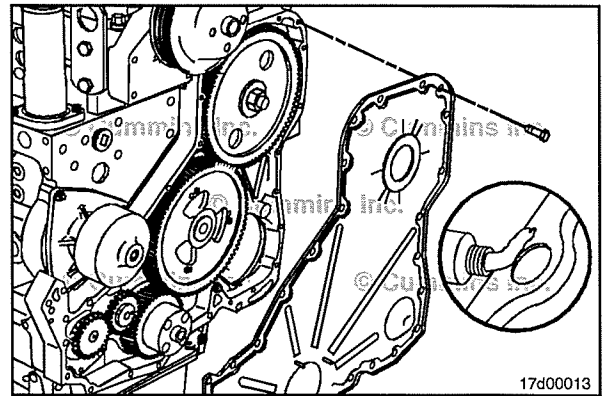
Gear Cover, Front (001-031)

Install

NOTE: Apply sealant to the inside of the bolt holes.

Apply a thin bead of RTV sealant 3 to 4 mm [0.12 to 0.16 in] wide, Part Number 3164067 or equivalent, to the engine side of the front cover **only**.

Install the front cover on the engine within 10 minutes.



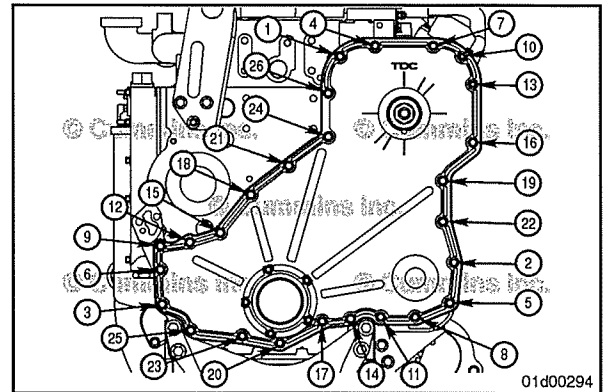
Tighten the front cover capscrews in the sequence shown.

Torque Value:

10 mm Front Cover Mounting Capscrews
Step 1 30 N•m [22 ft-lb]

Torque Value:

11 mm Front Cover Mounting Capscrews 40 N•m [30 ft-lb]

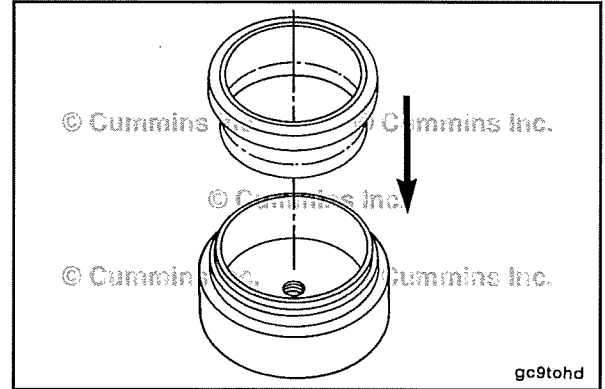


Crankshaft Seal, Front (001-023)

Install

Leave the plastic pilot installation tool in the lubricating oil seal.

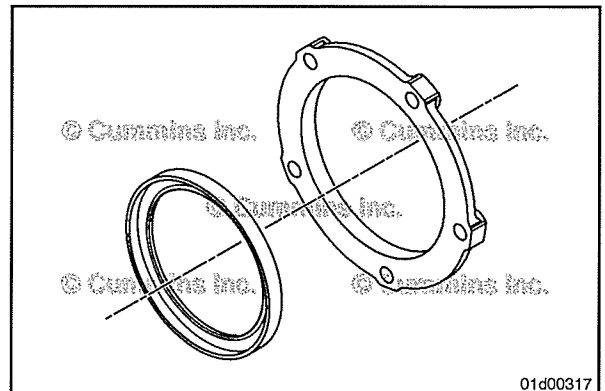
Position the seal on the service tool, Part Number 3824499, with the lubricating oil seal dust lip facing outward.

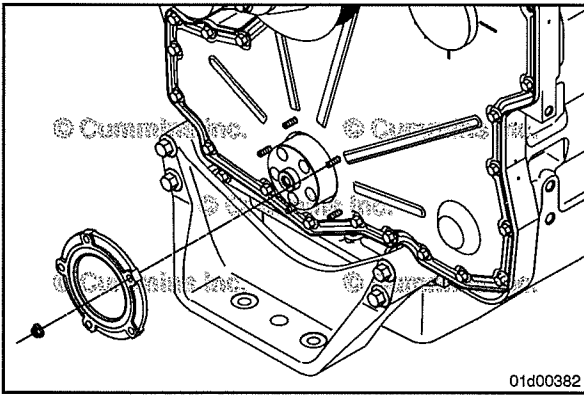


NOTE: Properly support the carrier lubricating oil seal flange to prevent damage to the lubricating oil seal and carrier.

Press the lubricating oil seal into the carrier from the back side of the carrier toward the front side of the carrier.

Press the lubricating oil seal until the seal is flush on front of the carrier.





Apply a bead of sealant, approximately 4 mm [0.16 in] thick and 4 mm [0.16 in] wide, around the inside of the seal carrier, between the mounting holes and the seal.



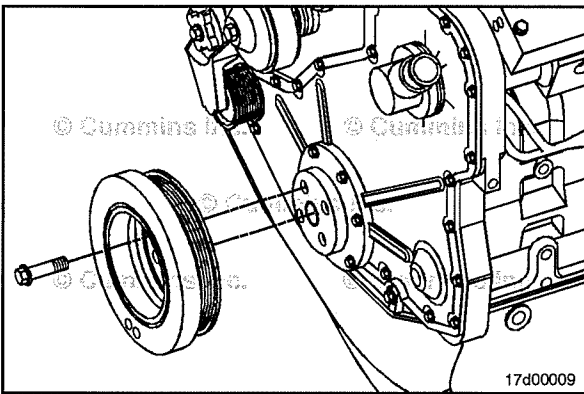
Apply a bead of sealant, approximately 4 mm [0.16 in] thick and 4 mm [0.16 in] wide, around all stud seams on the front cover.

Install the seal carrier on the front gear cover.

Remove the plastic installation tool.

Starting with the upper left stud (as shown in the graphic), tighten the carrier mounting nuts in a star pattern.

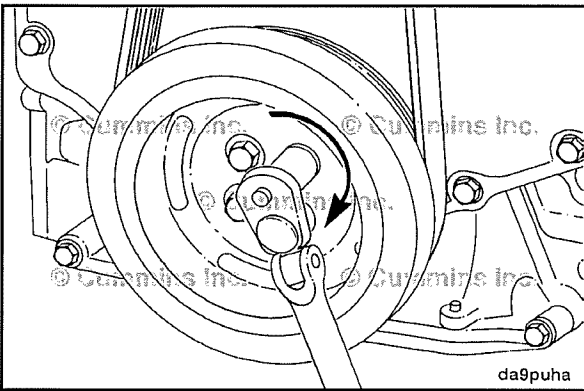
Torque Value: 12 N•m [106 in-lb]



Vibration Damper, Viscous (001-052) Install

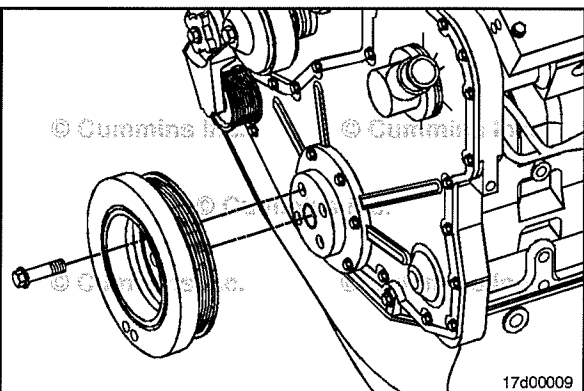
NOTE: Some engines use four damper capscrews while others use five damper capscrews.

Install the vibration damper.



Tighten the capscrews in a star pattern.

Torque Value: 200 N•m [148 ft-lb]



Vibration Damper, Rubber (001-051) Install



NOTE: Some engines use four damper capscrews while others use five damper capscrews.

Install the vibration damper.

Tighten the capscrews in a star pattern.

Torque Value: 200 N•m [148 ft-lb]

Cylinder Head (002-004)

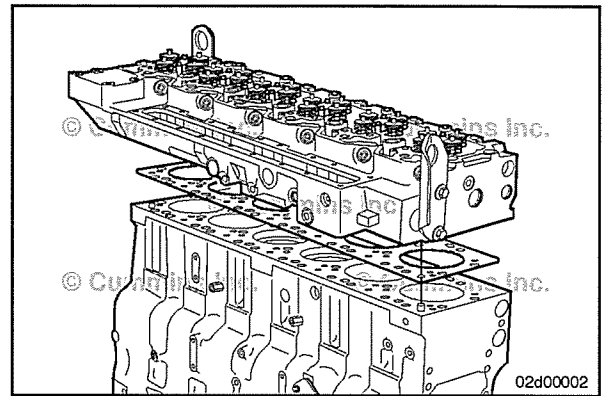
Install

⚠ CAUTION ⚠

Make sure the cylinder head gasket is correctly aligned with holes in the cylinder block. If not aligned properly, it can cause engine damage.

Do **not** attempt to reuse the cylinder head gasket.

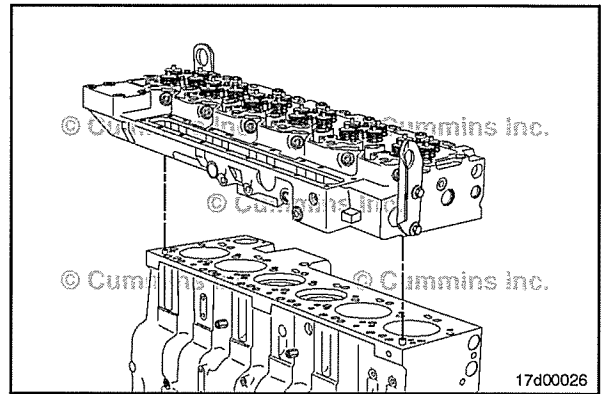
Position the new cylinder head gasket over the dowels.



⚠ WARNING ⚠

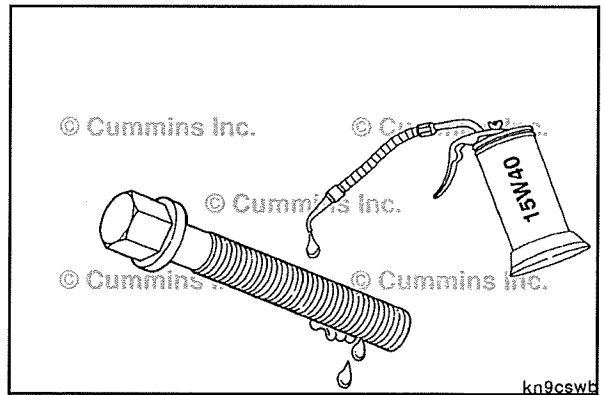
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Carefully put the cylinder head straight down onto the cylinder block, and seat it onto the dowels.



If new capscrews are used, capscrew threads are to be burnished. To burnish new capscrews, tighten the capscrews as described below. Loosen the capscrews and repeat the tightening sequence.

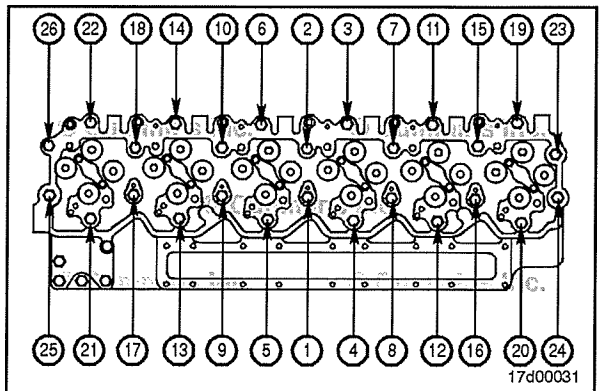
Lubricate the threads and under the heads on the cylinder head capscrews with clean 15W-40 engine lubricating oil.

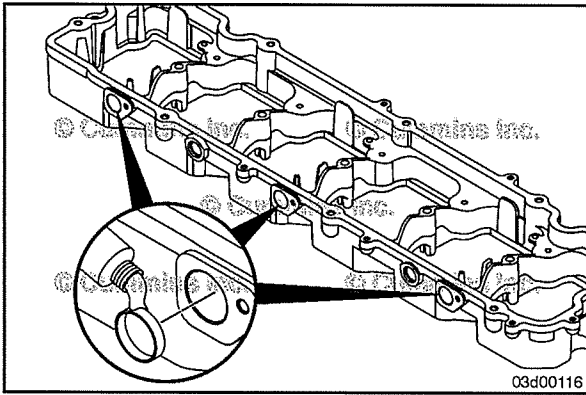


Tighten the cylinder head capscrews in the sequence shown in the illustration.

Torque Value:

Step 1	50 N•m	[37 ft-lb]
Step 2	150 N•m	[111 ft-lb]
Step 3	Loosen all capscrews	
Step 4	115 N•m	[85 ft-lb]
Step 5	115 N•m	[85 ft-lb]
Step 6	Advance 120 degrees.	





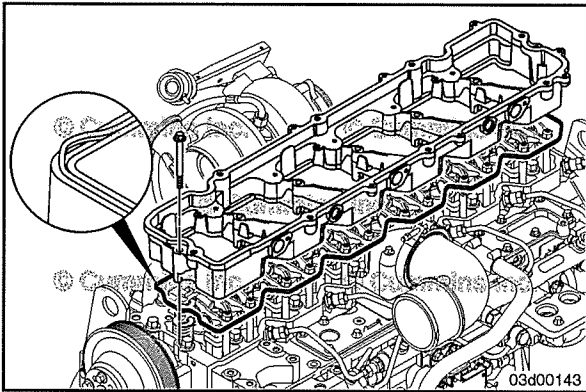
Rocker Lever Housing (003-013)

Install

Install the 22 mm cup plugs into the rocker lever housing.

Coat the contact surface of cup plug with Permatex® sealant, or equivalent.

Install the cup plugs flush with the outer surface of the rocker lever housing.



NOTE: A new rocker lever housing gasket **must** be used when the rocker lever housing is removed. Do **not** reuse the old gasket.



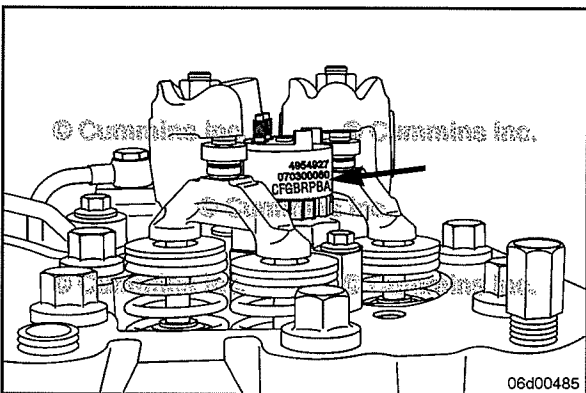
Install the new rocker lever housing gasket. Start by pressing the molded gasket into the corners of the rocker lever housing then press the remaining gasket into the housing.

Install the rocker lever housing on the cylinder head.

Install the capscrews and tighten. Start with the center capscrew and work outward, in a spiral pattern.

Torque Value: 24 N•m [212 in-lb]

NOTE: No capscrew goes in the outer end holes of the rocker lever housing.



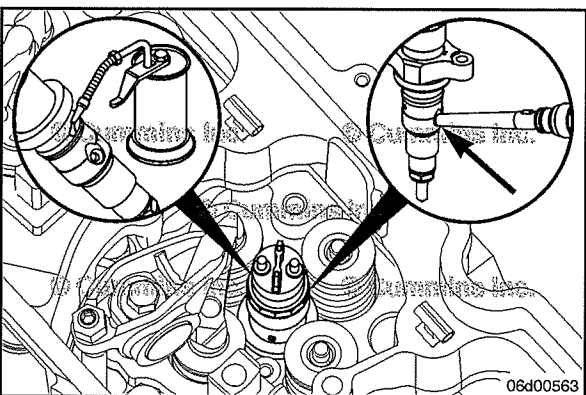
Injector (006-026)

Install

Record the injector trim codes that are listed on each injector.

Record the cylinder location where each injector will be installed.

NOTE: The injector trim codes are nine character alphanumeric codes located on the solenoid at the top of the injector.



NOTE: If a new injector is being installed, a new fuel connector must be used.



Make sure the injector bore is clean and that **only** one (1) sealing washer is installed on the injector nozzle.



Lubricate the injector o-ring with clean engine oil.

Place the injector in the cylinder head in the proper orientation (fuel inlet toward the high-pressure fuel connector).

Press down firmly on the injector to make sure it is seated in the injector bore.

NOTE: Start the injector hold-down clamp capscrews, but do **not** tighten.

Start the injector hold-down clamp capscrews, and tighten hand-tight.

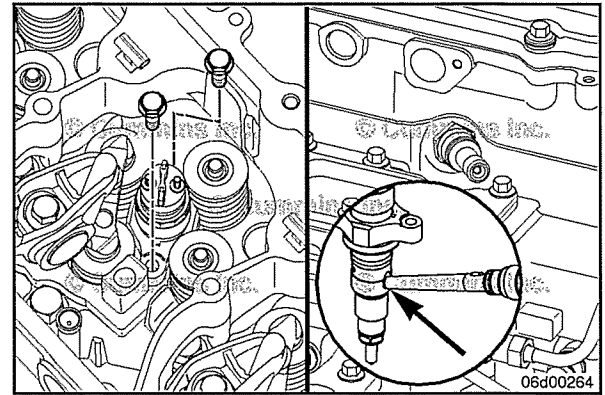
Install the high-pressure fuel connector, making sure the end of the high-pressure fuel connector is in the injector inlet port.

NOTE: The high-pressure fuel connector should click into place if it is seated in the injector inlet port correctly.

Start the high-pressure fuel connector retaining nut and tighten partially.

Torque Value: 15 N•m [133 in-lb]

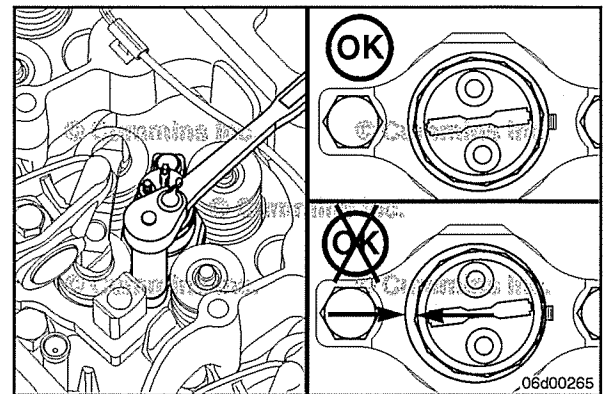
NOTE: This is **not** the final torque for the high-pressure fuel connector retaining nut.



Tighten the injector hold-down clamp capscrews.

NOTE: Make sure to tighten the hold-down clamp capscrews evenly. Check to make sure the gap between the hold-down clamp and the injector is equally spaced around the injector body.

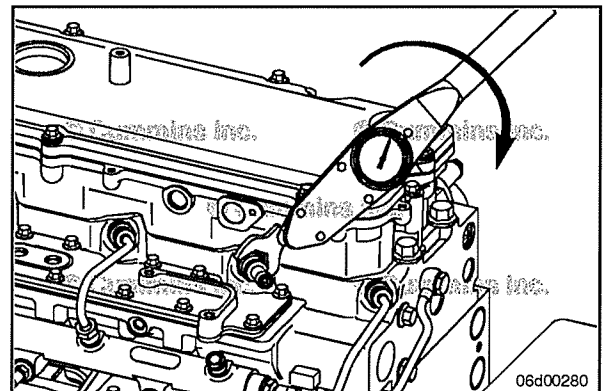
Torque Value: 10 N•m [89 in-lb]



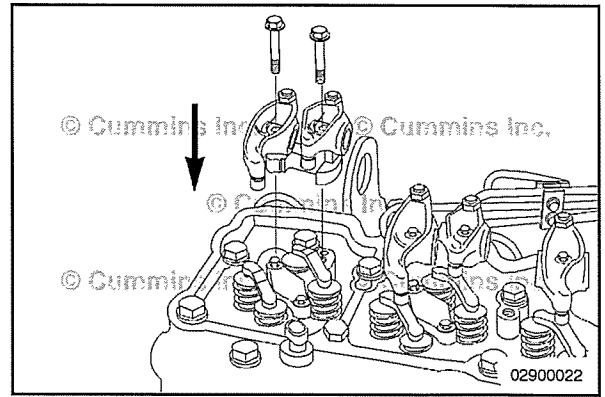
Tighten the high pressure fuel connector retaining nut.

Use the following procedure for the final torque value. Refer to Procedure 006-052 in Section 6.

NOTE: The high-pressure fuel connector **must** be properly tightened or an internal fuel leak can result, causing poor engine performance. A torque wrench **must** be used.

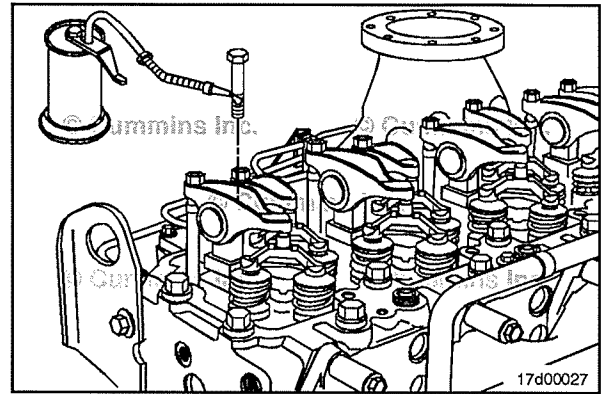


Install the rocker lever assemblies and pedestals in their original locations.



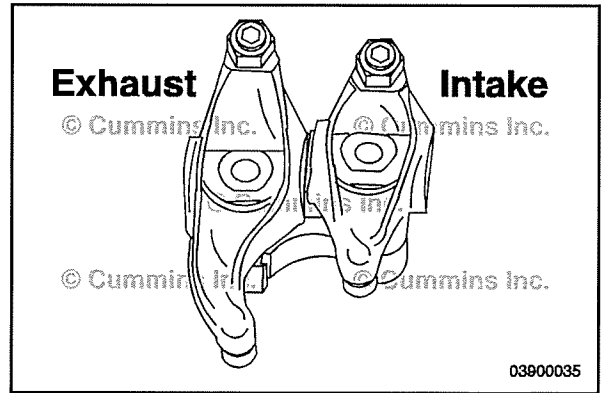
Lubricate the capscrew threads with clean engine oil.
Install and tighten the pedestal capscrews.

Torque Value: 65 N•m [48 ft-lb]



With Engine Brakes

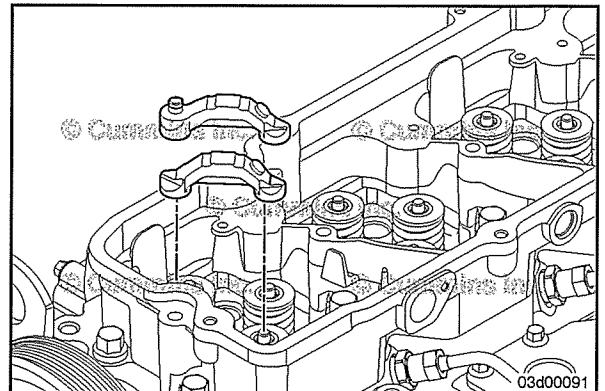
Position the rocker levers on the rocker pedestal.

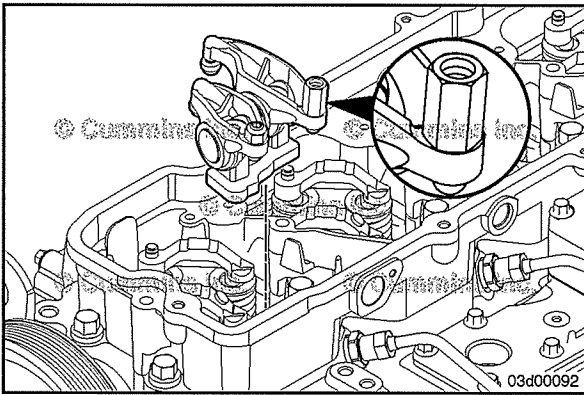


Install the crossheads in their original location and position.



Install the engine brake compatible exhaust crossheads with the pin facing the exhaust manifold.

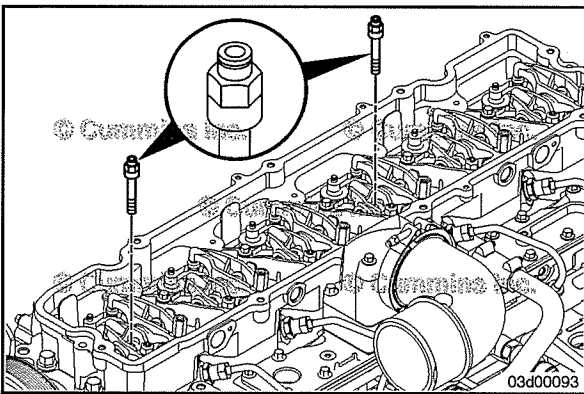




Install the rocker lever assemblies and pedestals in their original location.



Make sure the exhaust rocker levers have the longer adjusting screw locknut installed.

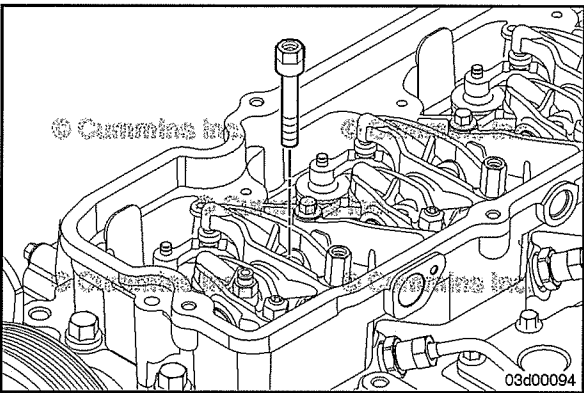


Lubricate the capscrew threads with clean engine oil.

Install the engine brake oil supply capscrews on intake rocker levers 1 and 4.



Torque Value: 65 N•m [48 ft-lb]

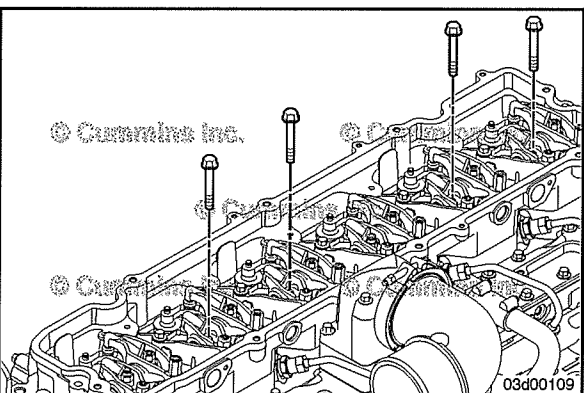


Lubricate the capscrew threads with clean engine oil.

Install the exhaust rocker lever capscrews into all exhaust levers.



Torque Value: 65 N•m [48 ft-lb]



Lubricate the capscrew threads with clean engine oil.

Install the pedestal capscrews in cylinders 2, 3, 5, and 6 intake rocker pedestals.

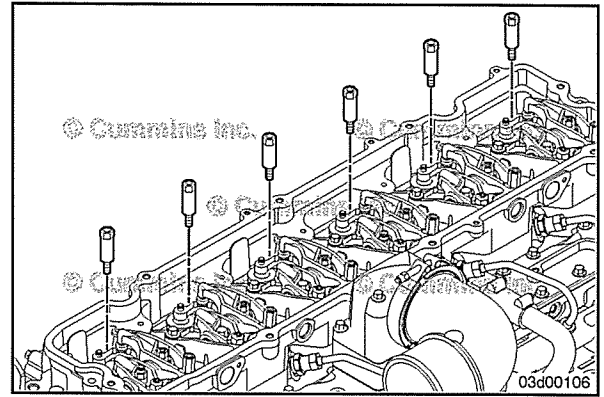


Torque Value: 65 N•m [48 ft-lb]



Lubricate the capscrew threads with clean engine oil.
Install the six threaded spacers into the cylinder head.

Torque Value: 24 N•m [212 in-lb]

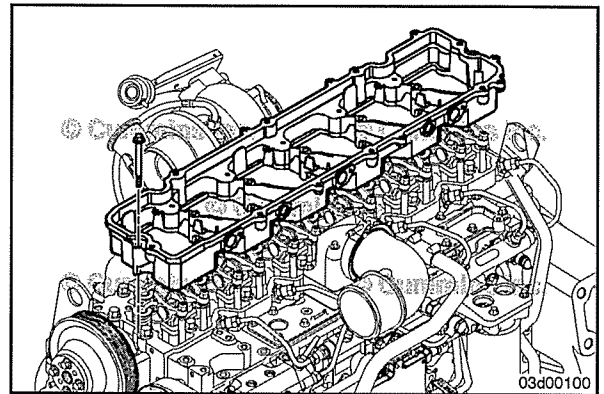


Engine Brake Assembly (020-004)

Install

If necessary, check and set the valve lash prior to installing the engine brake. Refer to Procedure 003-004 in Section 3.

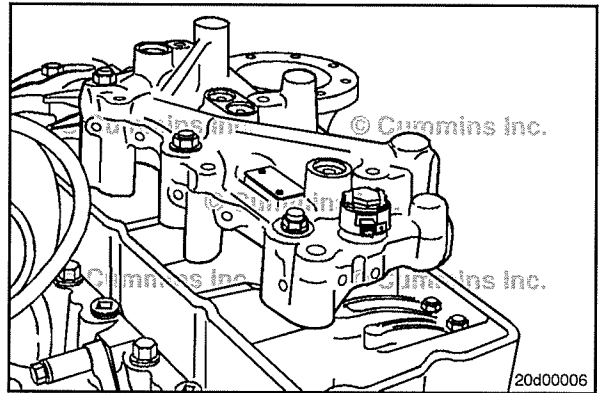
To install the engine brake specific crossheads and rocker lever hold-downs, see the following procedure. Refer to Procedure 003-008 in Section 3.

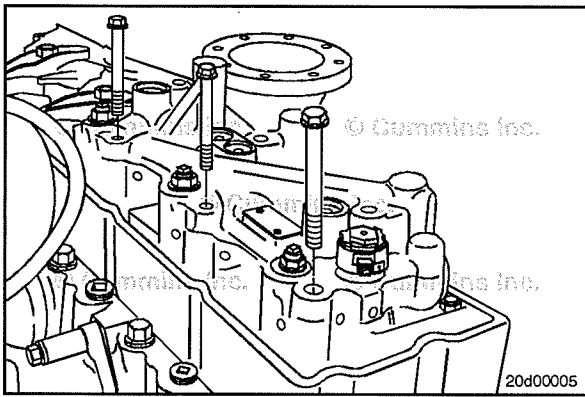


At the intake mounting stud (cylinder 1 and/or cylinder 4) lubricate the oil adapter and o-ring with lubricating oil.

Install the engine brake overhead assembly.

NOTE: Make sure the oil supply adapter at the intake manifold stud is fitted into the oil supply hole in the brake assembly.





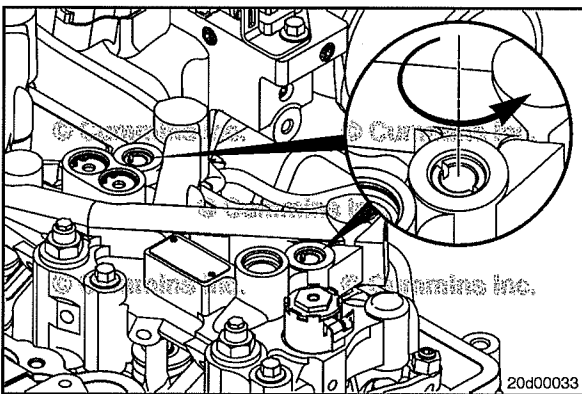
⚠ CAUTION ⚠

Use only grade 12.9 mounting capscrews for engine brake assemblies. Verify all mounting capscrews are grade 12.9. If any capscrews are found that are not grade 12.9, replace the capscrews.

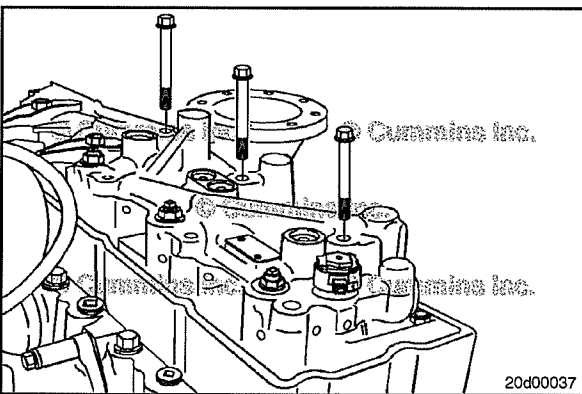
Install the six 10-mm mounting capscrews (three for the front brake assembly, three for the rear brake assembly) with flat washers at the brake mounting spacers (exhaust side of engine) and hand-tighten.

NOTE: Engines with an engine serial number (ESN) of 73001424 and higher use a bracket underneath the mounting capscrews above cylinders numbers 1 and 4, in place of a hardened washer. This bracket is used to route the solenoid wire away from moving parts and prevent wire chafing.

NOTE: Do **not** tighten the capscrews to their final torque specification at this time.



Turn the adjusting sleeves in the engine brake housing until they make contact with the rocker arm pedestals. No preload **must** be imparted on the housing.



Install the six 10-mm mounting capscrews (three for the front brake assembly, three for the rear brake assembly) with flat washers (intake side of the engine).



NOTE: Engines with an engine serial number (ESN) of 73001424 and higher use a bracket underneath the mounting capscrews above cylinders 1 and 4, in place of a hardened washer. This bracket is used to route the solenoid wire away from moving parts and prevent wire chafing.

Tighten the six 10-mm mounting capscrews for the front brake assembly and the six 10-mm mounting capscrews for the rear brake assembly.

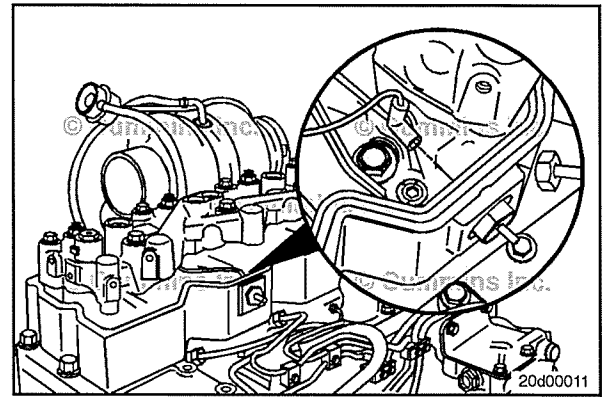
NOTE: No tightening sequence is required, but the capscrews can be tightened in a crossing sequence.

Torque Value: 32 N•m [24 ft-lb]

Install the wires to the terminals on the inside of the spacer.



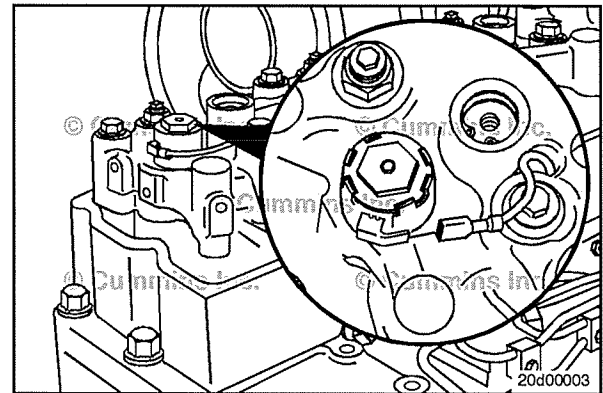
NOTE: The longer wire **must** be connected to the front engine brake solenoid. It is possible to install the wires in the incorrect orientation, which will result in an interference with the rocker levers.



NOTE: On engines equipped with a bracket to prevent the wire from chafing, secure the wire to the bracket, Part Number 4890404.

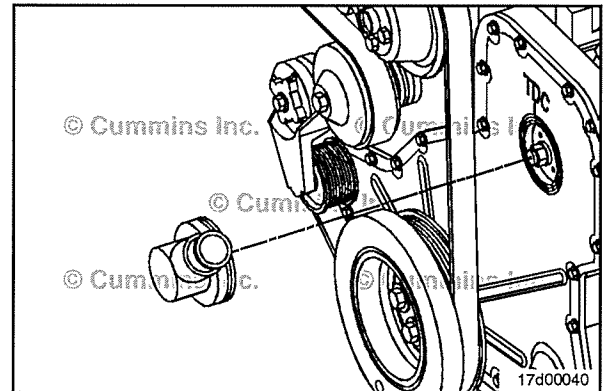


Connect the wires from the terminals on the inside of the spacer to the solenoid.

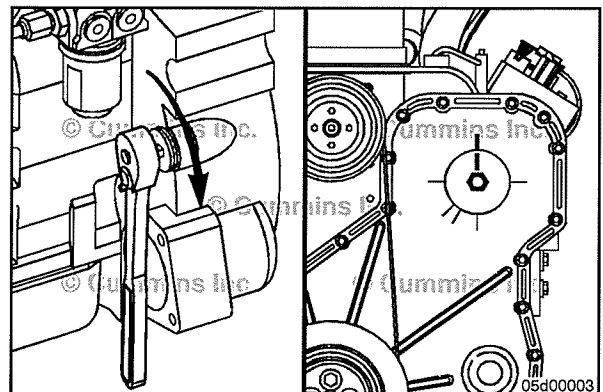


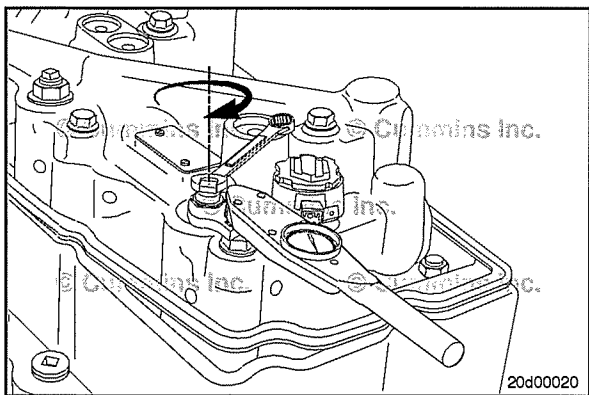
Adjust

Remove the plastic fuel pump drive cover located on the front of the engine.



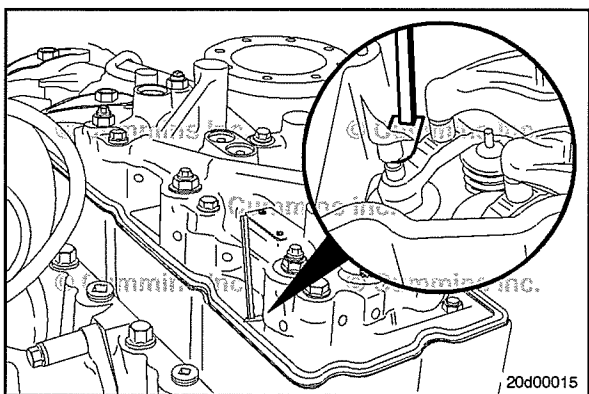
Use barring tool, Part Number 3824591, to rotate the crankshaft to align the mark on the fuel pump gear with the top dead center (TDC) mark on the gear cover.





When the engine is in the TDC position, brake lash can be set on cylinders 1, 3, and 5.

Use two wrenches to hold the adjusting nut and loosen the lock nuts on the brake at cylinders 1, 3, and 5.

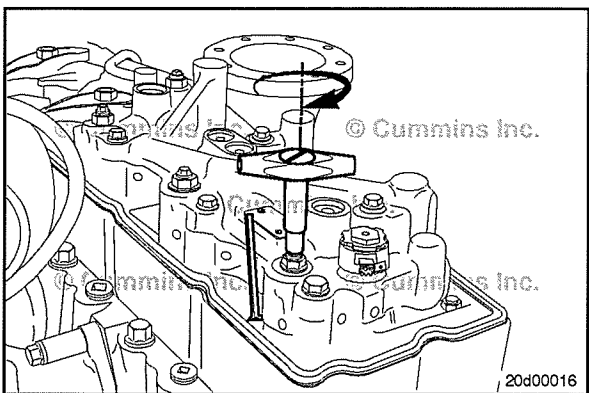


Brake Lash - Feeler Gauge Method

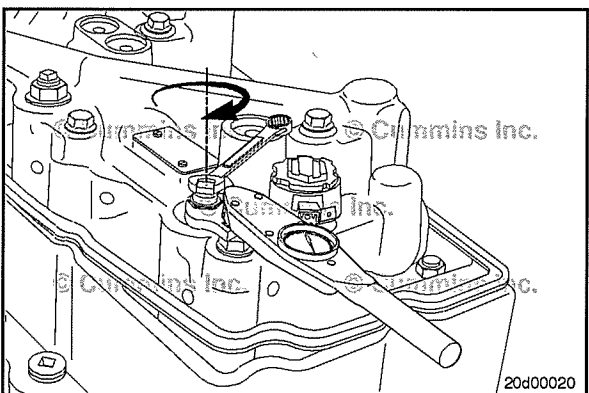
Insert the appropriate brake lash feeler gauge between the brake slave piston and exhaust crosshead pin on cylinder 1.

Brake Lash - Feeler Gauge	
Tool Part Number	Lash Specification
3163681	2.286 mm [0.090 in]

NOTE: If the correct size feeler gauge is **not** available, there is an alternate dial indicator method for setting the brake lash. This information is found later in this procedure.



Use the 0.68 N•m [6 in-lb] torque wrench, Part Number 3376592, to tighten the adjusting nut until the torque wrench clicks, or until drag is felt on the feeler gauge.



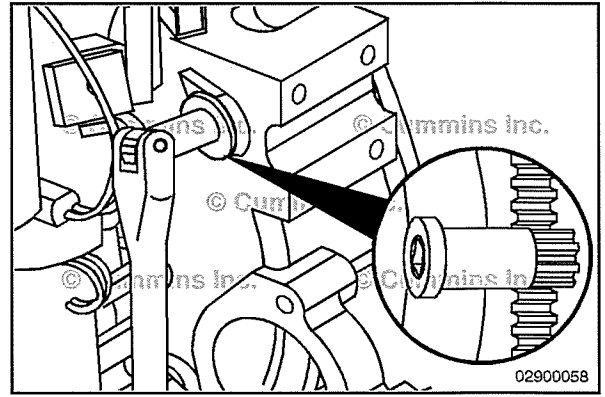
Remove the feeler gauge. Use two wrenches to hold the adjusting nut and tighten the locknut.

Torque Value: 35 N•m [26 ft-lb]

Repeat for cylinders 3 and 5.

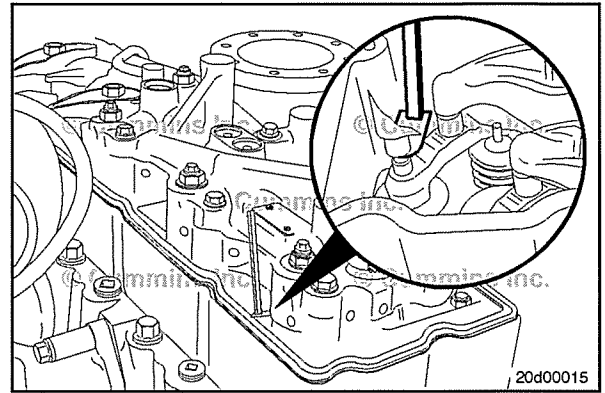
Use the engine barring tool, Part Number 3824591, to rotate the crankshaft 360 degrees to align the mark on the fuel pump gear with the mark on the gear cover that is 180 degrees away from TDC.

When the engine is in position, brake lash can be set on cylinders 2, 4, and 6.

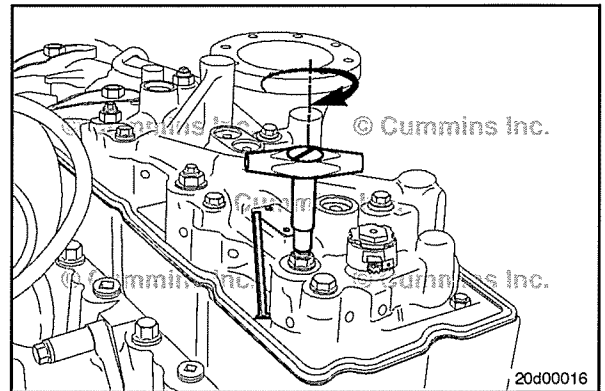


Insert the appropriate brake lash feeler gauge between the brake sleeve piston and the exhaust crosshead pin on cylinder 2.

Brake Lash - Feeler Gauge	
Tool Part Number	Lash Specification
3163681	2.286 mm [0.090 in]



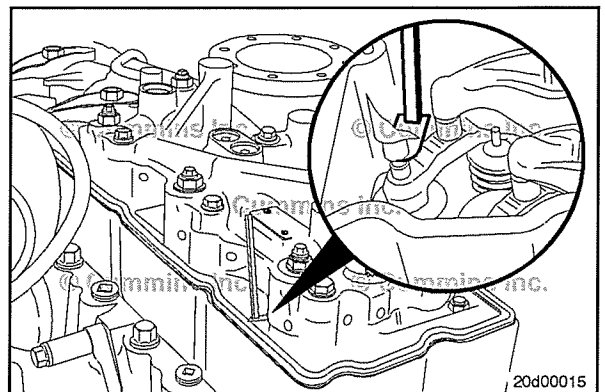
Use the 0.68 N•m [6 in-lb] torque wrench, Part Number 3376592, to tighten the adjusting nut until the torque wrench clicks or until drag is felt on the feeler gauge.

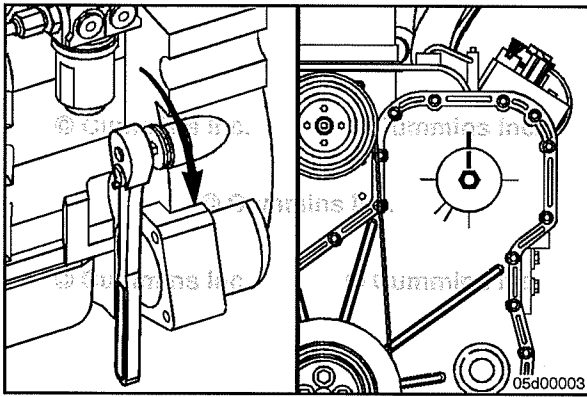


Remove the feeler gauge. Use two wrenches to hold the adjusting nut and tighten the locknut.

Torque Value: 35 N•m [26 ft-lb]

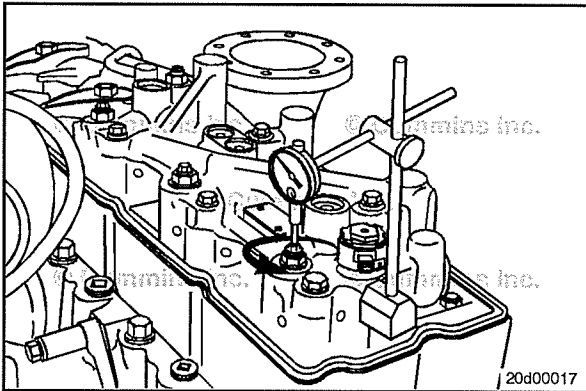
Repeat for cylinders 4 and 6.





The following method can be used instead of the feeler gauge method, if a feeler gauge of the proper size is **not** available.

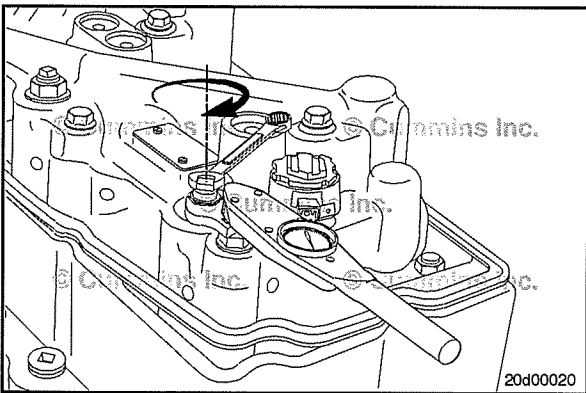
Use barring tool, Part Number 3824591, to rotate the crankshaft to align the mark on the fuel pump gear with the TDC mark on the gear cover.



Brake Lash - Dial Indicator

Tighten the backlash adjusting nut on cylinder 1 until resistance is felt. Place the dial indicator tip on the adjusting nut and zero the dial indicator. Turn the lash adjusting nut in a **counterclockwise** direction until the appropriate lash is reached.

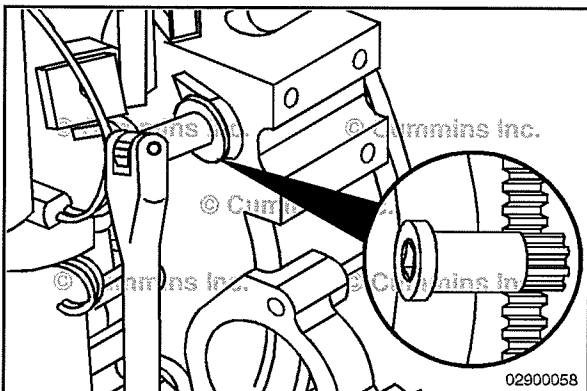
Brake Lash Specification 2.286 mm [0.090 in]



Use two wrenches to hold the adjusting nut and tighten the locknut.

Torque Value: 35 N•m [26 ft-lb]

Repeat for cylinders 3 and 5.



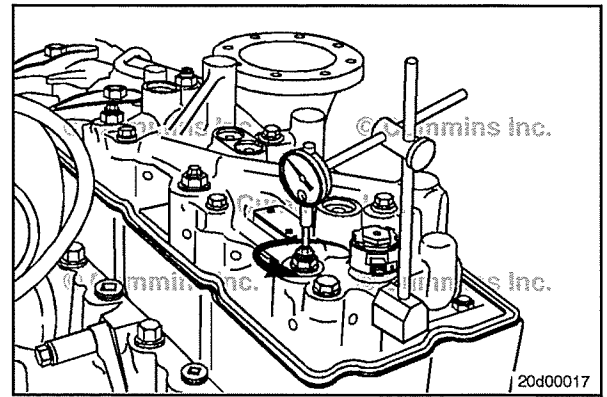
Use engine barring tool, Part Number 3824591, to rotate the crankshaft 360 degrees to align the mark on the fuel pump gear with the mark on the gear cover that is 180 degrees away from TDC.

When the engine is in position, brake lash can be set on cylinders 2, 4, and 6.

Tighten the backlash adjusting nut on cylinder number 2 until resistance is felt. Place the dial indicator tip on the adjusting nut and zero the dial indicator. Turn the lash adjusting nut in a **counterclockwise** direction until the appropriate lash is reached.



Brake Lash Specification 2.286 mm [0.090 in]

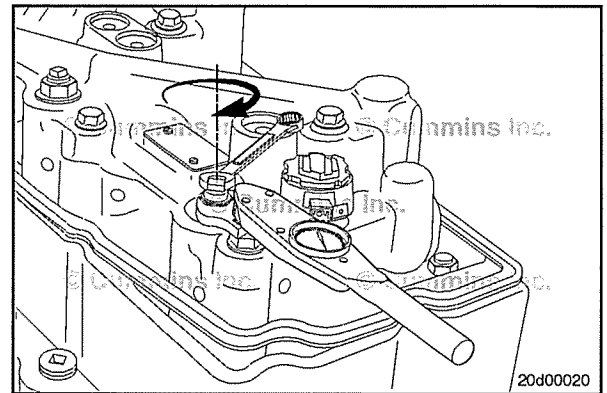


Use two wrenches, hold the adjusting nut and tighten the locknut.

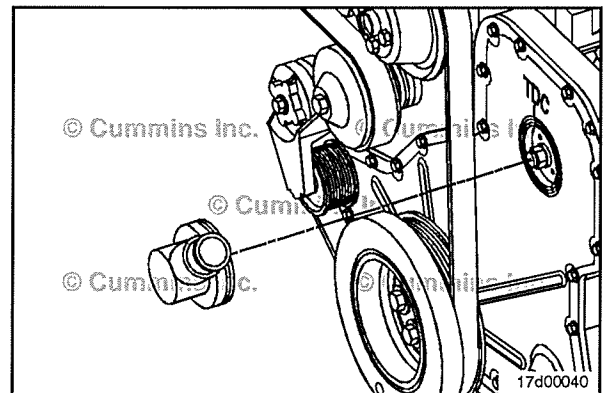


Torque Value: 35 N•m [26 ft-lb]

Repeat for cylinders 4 and 6.



Install the plastic fuel pump drive cover located on the front of the engine.



Rocker Lever Cover (003-011)

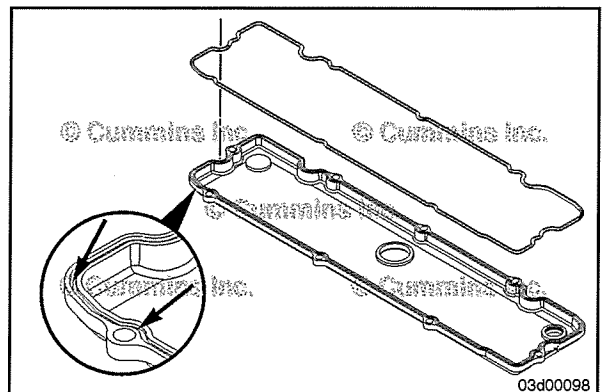
Install

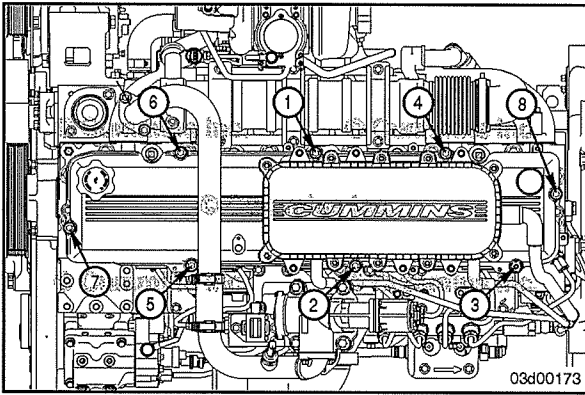


NOTE: If the gasket has been removed from the rocker lever cover, a new gasket **must** be installed.

The following installation procedure **must** be used when installing the press in gasket.

- 1 Press the molded gasket into the corners of the rocker lever cover.
- 2 Press the gasket around the capscrew mounting holes.
- 3 Press the remaining gasket into the rocker lever cover.

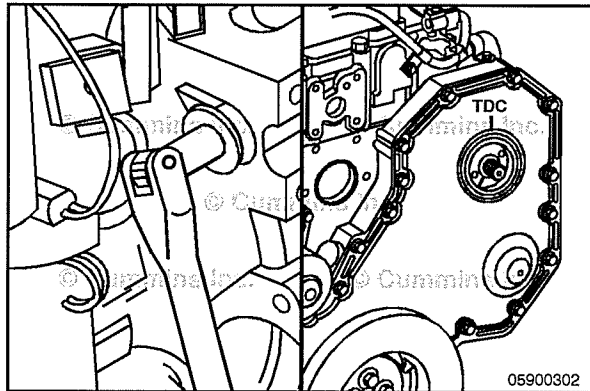




Install the rocker lever cover and capscrews.

Torque Value: 12 N•m [106 in-lb]

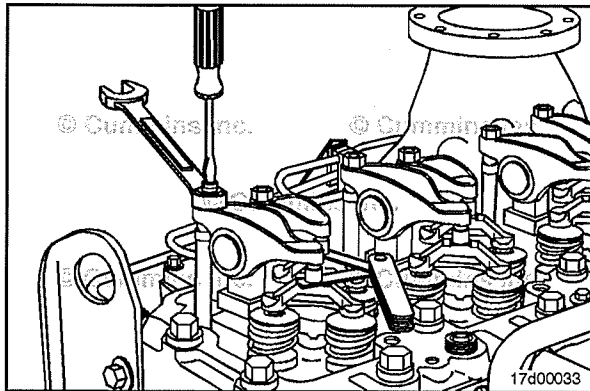
Tighten the capscrews in the sequence illustrated.



Overhead Set (003-004)

Adjust

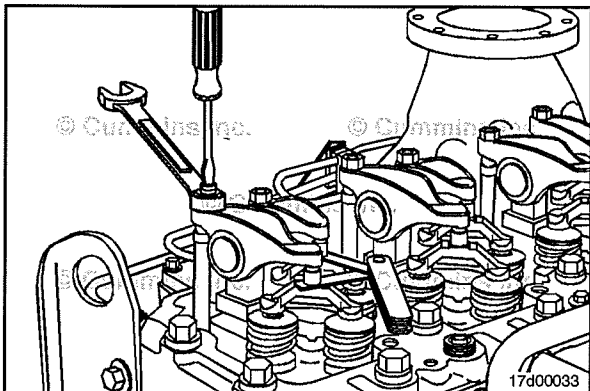
Use barring tool, Part Number 3824591 or equivalent. Rotate the crankshaft to align the top dead center marks on the gear cover and the fuel pump gear.



With the engine in this position, lash can be checked on the following rocker arms: 1I, 1E, 2I, 3E, 4I, and 5E.

Lash Check Limits

	mm		in	
Intake	0.152	MIN	0.006	
	0.559	MAX	0.022	
Exhaust	0.381	MIN	0.015	
	0.813	MAX	0.032	



Measure lash by inserting a feeler gauge between the crosshead and the rocker lever ball insert and socket while lifting up on the end of the rocker arm. If the lash measurement is out of specification, loosen the locknut and adjust the lash to the nominal specification.



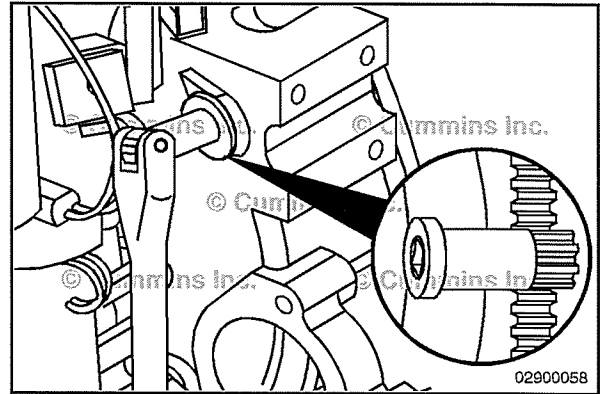
Lash Reset Specifications

	mm		in	
Intake	0.305	NOM	0.012	
Exhaust	0.559	NOM	0.022	

Tighten the locknut and measure again.

Torque Value: 24 N•m [212 in-lb]

Use the barring tool, Part Number 3824591 or equivalent, and rotate the crankshaft 360 degrees and measure lash for rocker arms 2E, 3I, 4E, 5I, 6I, and 6E. Reset the lash, if out of specification.



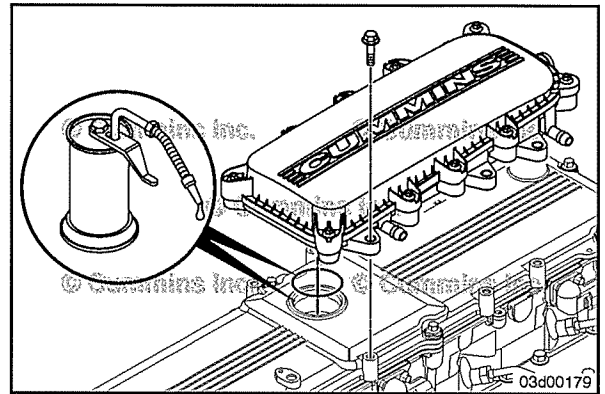
Crankcase Breather (External) (003-001)

Install

Install a new o-ring on the breather.

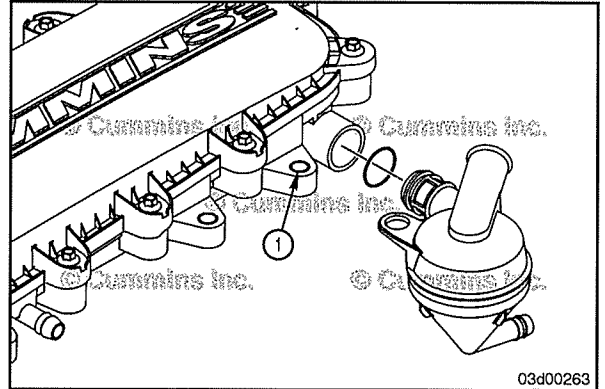
Lubricate the o-ring and the valve cover o-ring seat with clean lubricating oil.

Install the breather into the rocker lever cover.



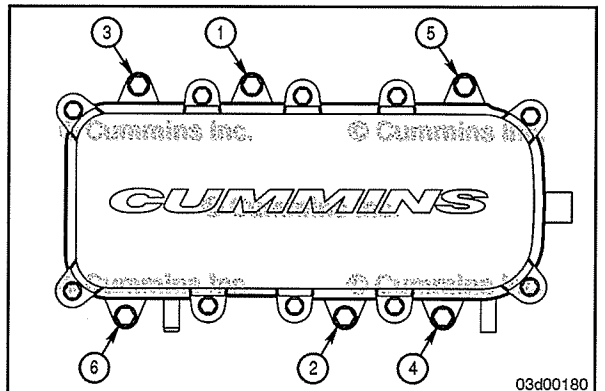
Install a new o-ring on the oil separator and attach it to the breather housing.

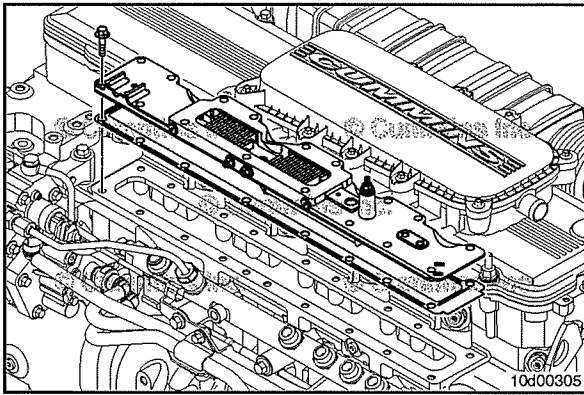
Make sure the mounting location for the oil separator is aligned with a rear breather housing mounting location (1).



Tighten the capscrews in the sequence shown.

Torque Value: 24 N•m [212 in-lb]





Air Intake Manifold (010-023)

Install



If previously taped off, remove the tape from the cylinder head prior to installing the intake manifold.

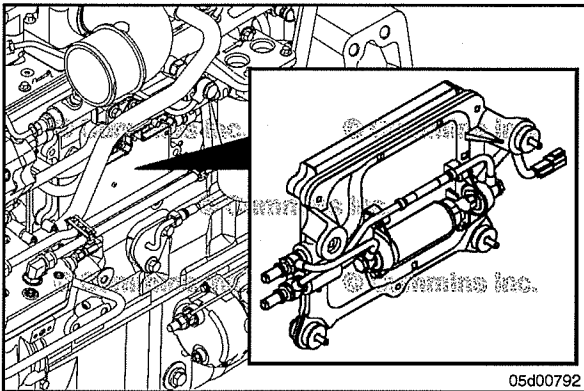
If a new air intake manifold is being installed, verify that the correct voltage manifold is being installed, since both 12-VDC and 24-VDC versions exist.

Install the air intake manifold to the cylinder head with a new gasket.

If the capscrews are being reused, lightly coat the threads with thread sealant, Part Number 3824041, to prevent boost leaks.

Tighten the capscrews in a crisscross pattern, starting from the middle of the manifold.

Torque Value: 24 N•m [212 in-lb]



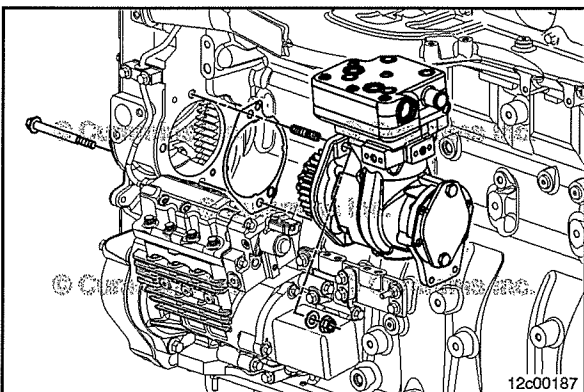
Engine Control Module Cooling Plate, Fuel Cooled (006-006)

Install



Install the ECM cooling plate assembly on the engine block. Tighten the capscrews.

Torque Value: 24 N•m [212 in-lb]



Air Compressor (012-014)

Install



Install the air compressor, gasket, mounting nut, and capscrew onto the front gear housing.

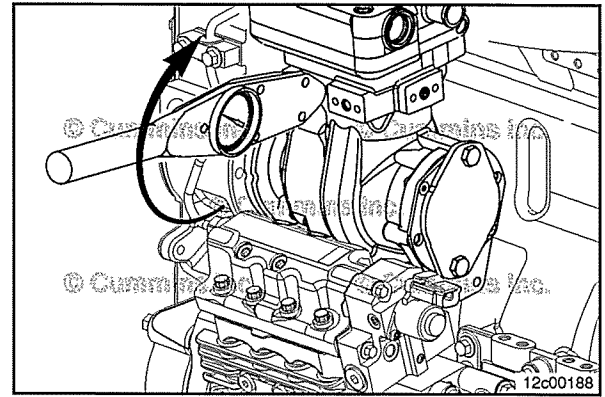
NOTE: If the stud is removed, use Loctite® 3822040 or equivalent, and install the stud.

Tighten the capscrews.

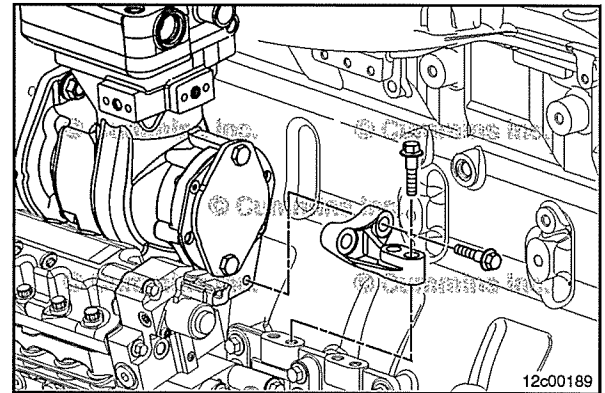
Torque Value: 81 N•m [60 ft-lb]

Tighten the capscrews again.

Torque Value: 81 N•m [60 ft-lb]

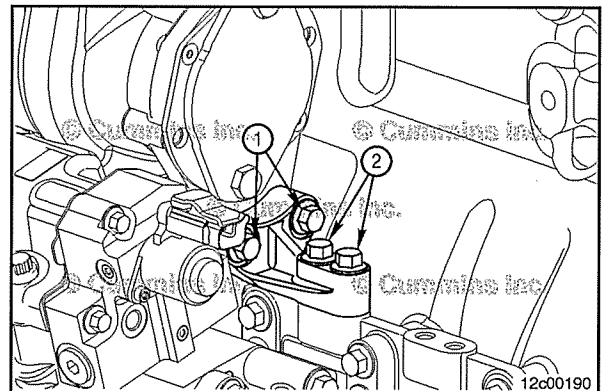


Install the air compressor mounting brace and four capscrews on the block beneath the air compressor. Start threading all four capscrews.



Tighten the capscrews in the sequence shown on the fuel pump support bracket and air compressor.

Torque Value: 61 N•m [45 ft-lb]

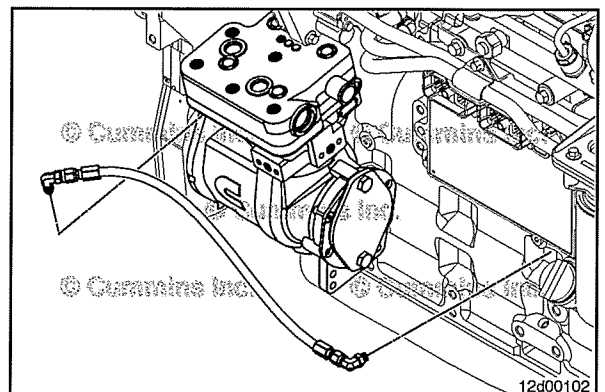


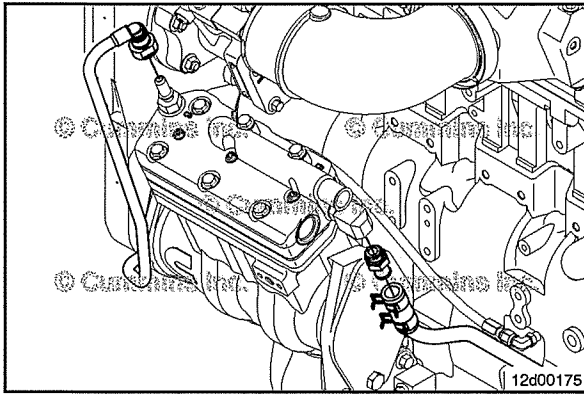
Air Compressor Oil Supply Line (012-110)

Install

Install the air compressor oil supply line to the air compressor and cylinder block.

Torque Value: 12 N•m [106 in-lb]





Air Compressor Coolant Lines (012-004)



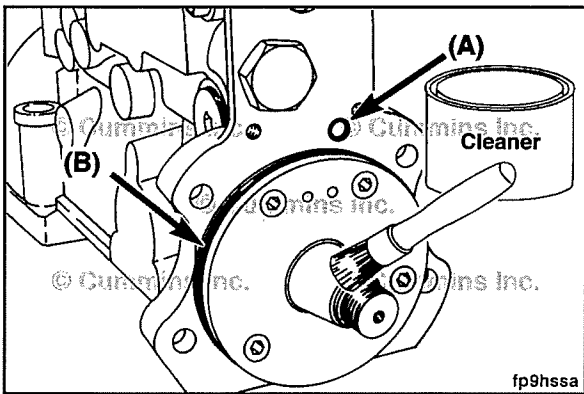
Install

NOTE: The air compressor cooling lines illustrated can differ depending on the compressor installed. Although different, the procedure remains the same.

Install the coolant supply and return lines onto the air compressor cylinder head.

Install the coolant supply line onto the engine cylinder head and coolant return line onto the water inlet connection.

Torque Value: 24 N•m [212 in-lb]



Fuel Pump (005-016)

Install



Make sure the engine is at Number 1 cylinder, top dead center. The fuel pump gear timing mark **must** align with the top dead center mark on the front cover.

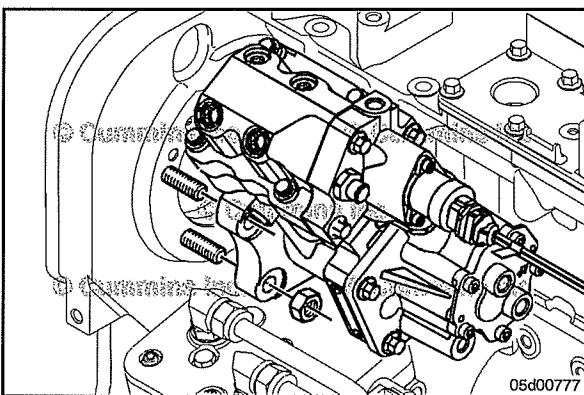


Make sure the o-ring seals for the oil feed orifice (A) and pilot (B) are installed correctly.

Lubricate the pilot o-ring (B) with clean engine oil.

Clean the nose of the drive shaft and the fuel pump gear inside diameter with electrical contact cleaner, Part Number 3824510, or equivalent.

The fuel pump drive gear inside diameter and the drive shaft outside diameter **must** be clean and dry before installing the gear.



Slide the fuel injection pump shaft through the drive gear and position the fuel injection pump flange onto the mounting studs.



Make sure the dowel pin in the drive shaft lines up with the keyway in the fuel injection pump gear.

Installation sequence for fuel pump actuator housing mounted support bracket:

- 1 Install the pump mounting nuts (leave loose).
- 2 Install the bolt to the cylinder head (1) and the bolt through the pump flange (2) into the support bracket (leave loose).
- 3 Tighten the pump mounting nuts.

Torque Value: 44 N•m [32 ft-lb]

- 1 Tighten the bolt into the cylinder head (1).

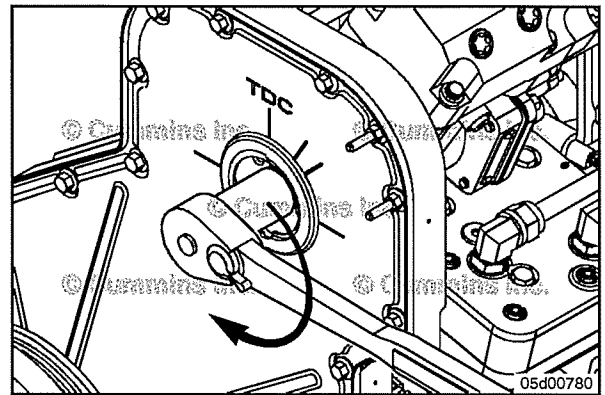
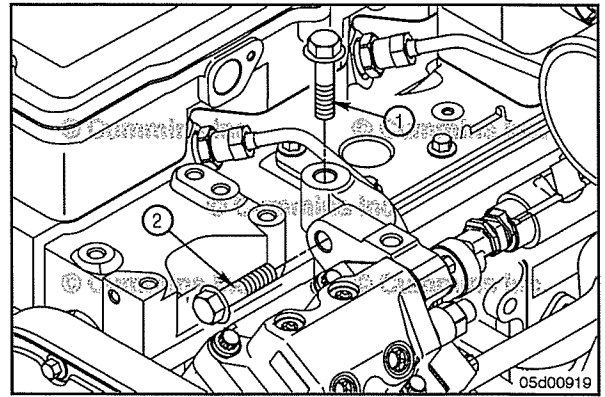
Torque Value: 65 N•m [48 ft-lb]

- 1 Tighten the bolt into the pump flange (2).

Torque Value: 80 N•m [59 ft-lb]

Tighten the fuel injection pump drive gear nut.

Torque Value: 180 N•m [133 ft-lb]



Fuel Rail (006-060)

Install

Install the fuel rail assembly. Follow the proper sequence to make sure that high-pressure fuel lines are properly aligned.

- Install the fuel rail assembly capscrews hand-tight.
- Install the fuel line from the high-pressure pump to the fuel rail.
- Tighten the rail connection.

Torque Value: 65 N•m [48 ft-lb]

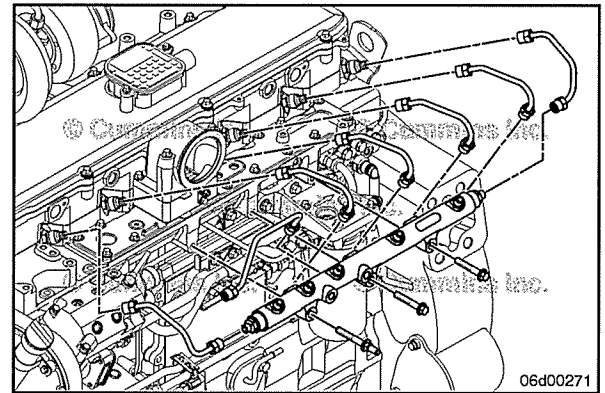
- Tighten the pump connection.

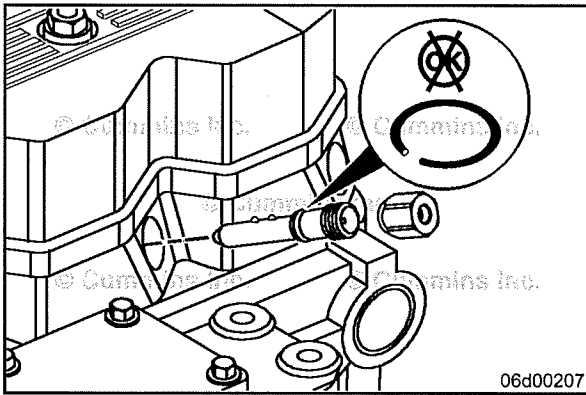
Torque Value: 50 N•m [37 ft-lb]

- Install the high-pressure fuel lines hand-tight.

Tighten the fuel rail assembly capscrews.

Torque Value: 43 N•m [32 ft-lb]





Fuel Connector (Head Mounted) (006-052)

Install



NOTE: If a new injector has been installed, a new fuel connector **must** be used.



Lubricate the fuel connector o-ring and the threads on the fuel connector retaining nut.



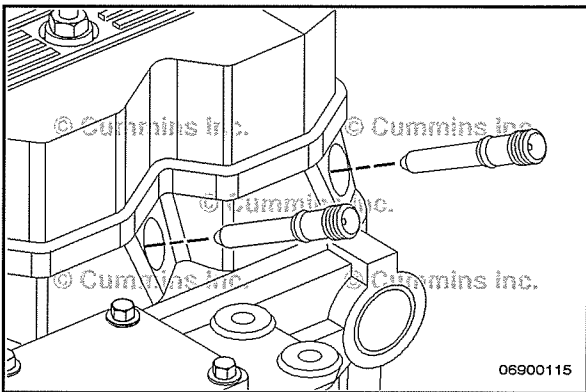
Carefully insert the fuel connector, aligning the guide pin with the slot in the cylinder head at the 12-o'clock position.

NOTE: If the injector was removed along with the high-pressure fuel connector, the installation steps **must** be followed. Refer to Procedure 006-026 in Section 6.

Tighten the fuel connector retaining nut.

Torque Value: 50 N•m [37 ft-lb]

The high-pressure fuel connector **must** be properly tightened or an internal fuel leak can result, causing poor engine performance. A torque wrench **must** be used.



Injector Supply Lines (High Pressure) (006-051)

Install



Before installing the injector supply lines, make sure the fuel connector is fully and properly seated against the injector. Make sure the high-pressure connector retaining nut is tightened. Refer to Procedure 006-052 in Section 6.

⚠ WARNING ⚠

Depending on the circumstance, diesel fuel is flammable. When inspecting or performing service or repairs on the fuel system, to reduce the possibility of fire and resulting severe personal injury, death or property damage, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area.

Follow the proper sequence to make sure the high-pressure fuel lines are properly aligned.

- 1 Loosen the fuel rail capscrews so that they are **only** finger tight.
- 2 Install the fuel line from the high-pressure pump to the fuel rail.
- 3 Tighten the rail connection.

Torque Value: 65 N•m [48 ft-lb]

Tighten the pump connection.

Torque Value: 50 N•m [37 ft-lb]

Tighten the fuel line support bracket capscrew.

Torque Value: 24 N•m [212 in-lb]

Install the fuel lines from the fuel rail to the fuel connectors and hand-tighten.

Tighten the high-pressure fuel line at the rail.

Torque Value: 65 N•m [48 ft-lb]

Tighten the high-pressure fuel line at the high-pressure fuel connector.

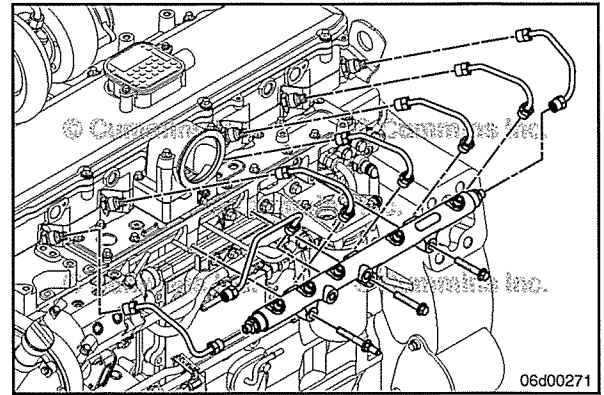
Torque Value: 50 N•m [37 ft-lb]

Tighten the fuel line support bracket capscrew.

Torque Value: 24 N•m [212 in-lb]

Tighten the fuel rail assembly capscrews.

Torque Value: 43 N•m [32 ft-lb]



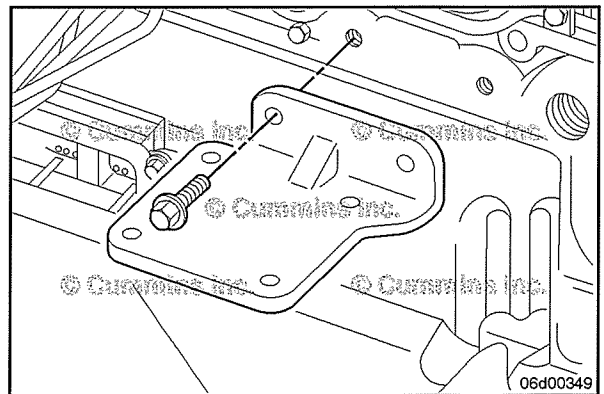
Fuel Filter Head Bracket (006-018)

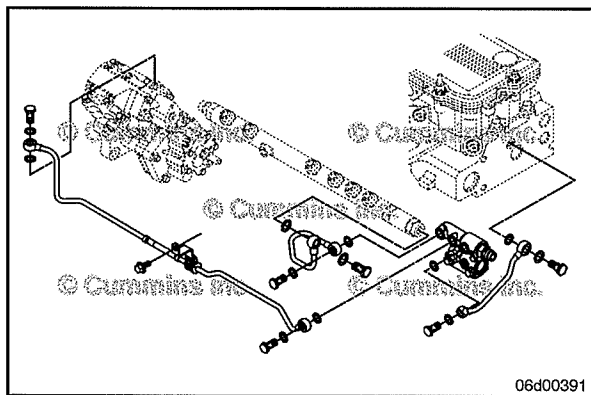
Install

For engines equipped with a single fuel filter head, install the fuel filter mounting bracket.

Tighten the retaining capscrews.

Torque Value: 43 N•m [32 ft-lb]





Fuel Drain Lines (006-013)

Install



Install the three drain lines on the engine.

High pressure fuel pump drain:

- Install the p-clip bracket
- Install the banjo bolt at the fuel drain manifold
- Install the banjo bolt at the fuel pump.

Pressure relief valve drain line:

- Install the banjo bolt at the fuel drain manifold
- Install the banjo bolt at the pressure relief valve. Hold the line so that it will **not** twist and wear against the bottom of the cylinder head.

Injector drain line.

Torque Value:

M12 banjo bolts 24 N•m [212 in-lb]

Torque Value:

M16 banjo bolts 43 N•m [32 in-lb]

Torque Value:

P-clip capscrew 24 N•m [212 in-lb]

Fuel Supply Lines (006-024)

Install

Install the quick disconnect fuel lines.

Install the quick disconnect fittings.

Torque Value: 24 N•m [212 in-lb]

Make sure the quick disconnect style fuel lines clasp onto the quick disconnect fittings.

Make sure the lines are routed and connected correctly. If the lines are connected incorrectly, the engine will **not** operate.

- 1 OEM connection to the upper fitting at the engine control module (ECM) cooling plate.
- 2 Lower ECM cooling plate fitting to the upper gear pump fitting.
- 3 Lower gear pump fitting to the pressure side fuel filter inlet.
- 4 Pressure side fuel filter outlet to the fuel pump fuel control actuator housing.

Fuel lines are routed in the following order:

- 1 OEM connection to the upper fitting at the ECM cooling plate
- 2 Lower ECM cooling plate fitting to the upper gear pump fitting
- 3 Lower gear pump fitting to the pressure side fuel filter inlet
- 4 Pressure side fuel filter outlet to the fuel pump fuel control actuator housing.

The fuel supply line brace holds the fuel lines in the following order:

- 1 The inside line connects the upper gear pump fitting to the lower ECM cooling plate fitting
- 2 The middle line connects the pressure side fuel filter outlet to the fuel pump fuel control actuator housing
- 3 The outside line connects the lower gear pump fitting to the pressure side fuel filter inlet.

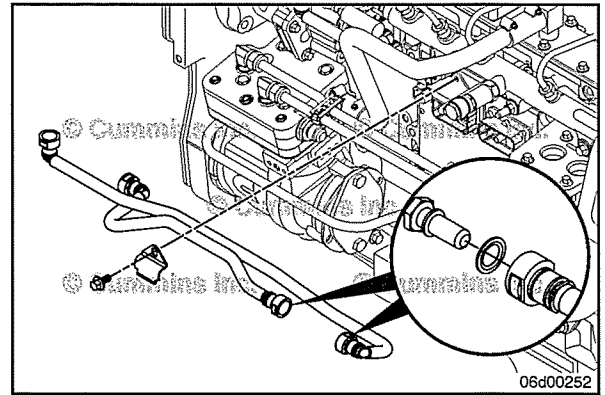
Install the fuel line brace clasp (quick disconnect style fuel lines **only**) and the brace, if necessary.

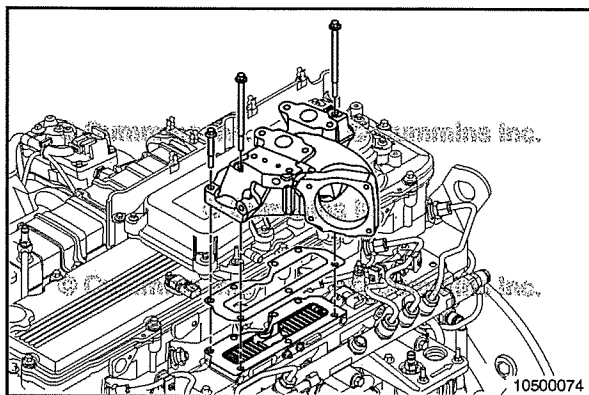
Torque Value:

Fuel Line Brace 24 N•m [212 in-lb]

Torque Value:

Fuel Line Brace Clasp 24 N•m [212 in-lb]





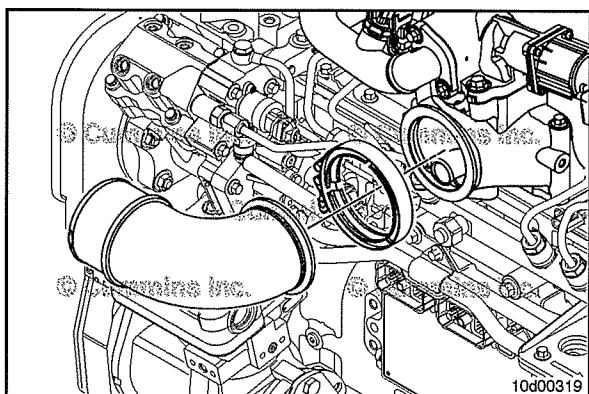
Air Intake Connection (010-080)

Install



Install the air intake connection. Use a new gasket.

Torque Value: 24 N•m [212 in-lb]



Air Intake Connection Adapter (010-131)

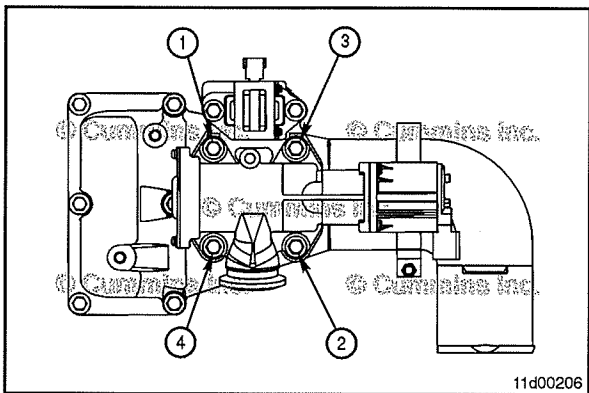
Install



Install the air intake connection adapter, sealing o-ring, and V-band clamp to the air intake connection.

Tighten the clamp.

Torque Value: 8 N•m [71 in-lb]



EGR Valve (011-022)

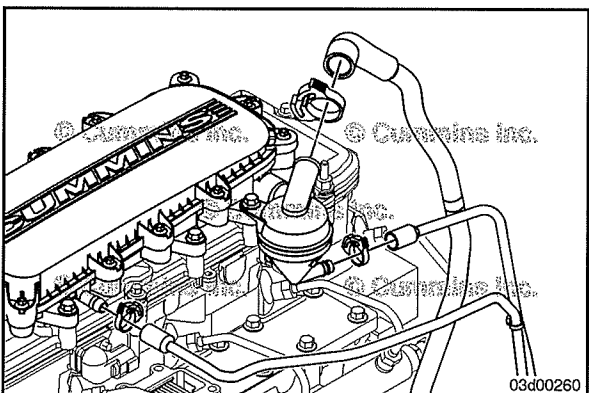
Install



Install the EGR valve, with new mounting gaskets, onto the air intake connection.

Install the four capscrews holding the EGR valve to the air intake connection hand tight to minimize assembly stresses on the EGR connection tube. Tighten in a criss-cross pattern.

Torque Value: 24 N•m [212 in-lb]



Crankcase Breather Tube (003-018)

Install

Rocker Lever Cover Mounted Crankcase Breather

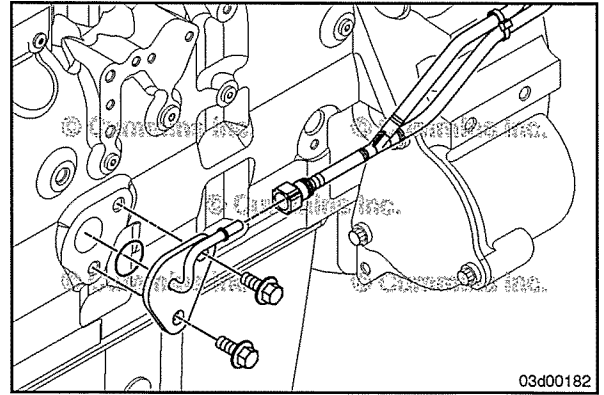
NOTE: Make sure the crankcase breather tube or drain lines do **not** contact any high-pressure fuel lines.

Install the crankcase breather tube to the crankcase breather assembly.

Install the crankcase drain lines to the crankcase breather assembly.

Install the breather drain line cover, gasket, and tube to the cylinder block.

Torque Value: 24 N•m [212 in-lb]



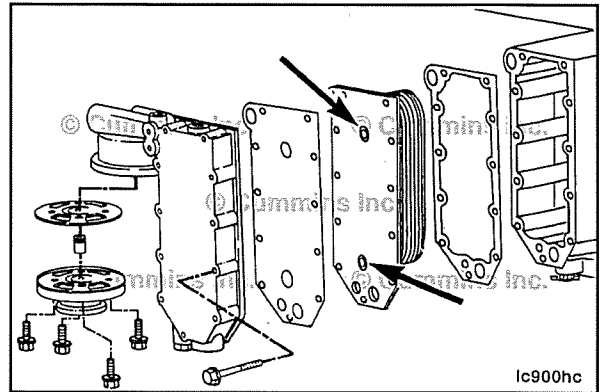
03d00182

Lubricating Oil Cooler (007-003) Install

NOTE: Be sure to remove the shipping plugs from a new oil cooler element.

Discard used gaskets and install new gaskets.

Assemble the lubricating oil cooler gaskets, element, and cover.

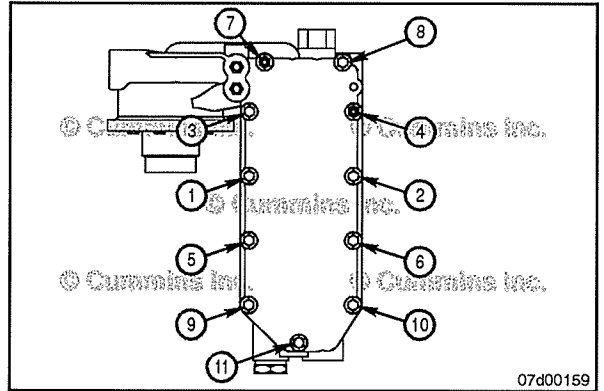


lc900hc

If the oil cooler cover does **not** have a dimple, tighten the capscrews in the sequence shown.

Torque Value:

Step 1	15 N•m	[133 in-lb]
Step 2	32 N•m	[24 ft-lb]

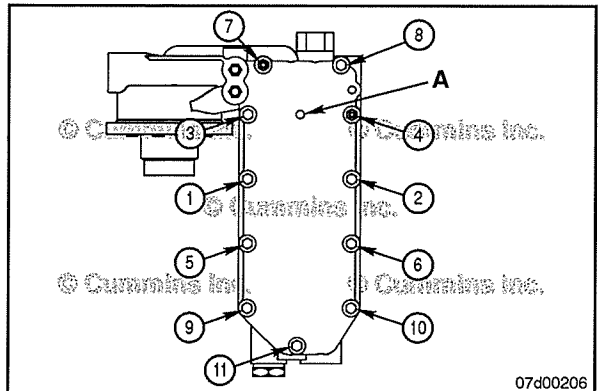


07d00159

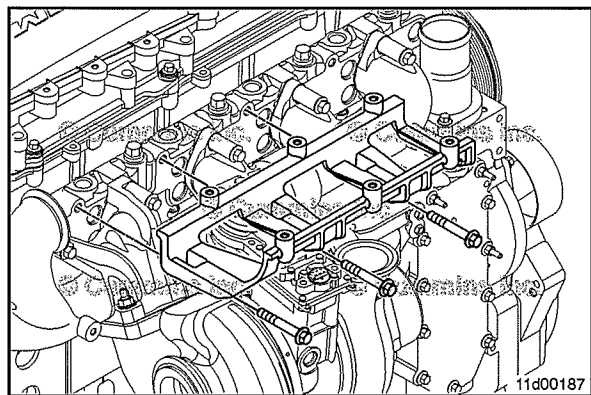
If the oil cooler cover has a dimple, tighten the capscrews in the sequence shown. The arrow (A) points to the location of the dimple.

Torque Value:

Step 1	15 N•m	[133 in-lb]
Step 2	27 N•m	[239 in-lb]



07d00206



EGR Cooler Mounting Bracket (011-029)

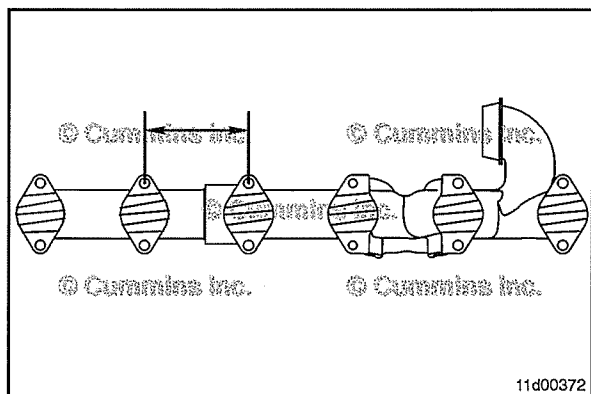


Install

Install the EGR cooler bracket to the cylinder head, leaving capscrews finger tight.

Tighten the capscrews.

Torque Value: 43 N•m [32 ft-lb]



Exhaust Manifold, Dry (011-007)

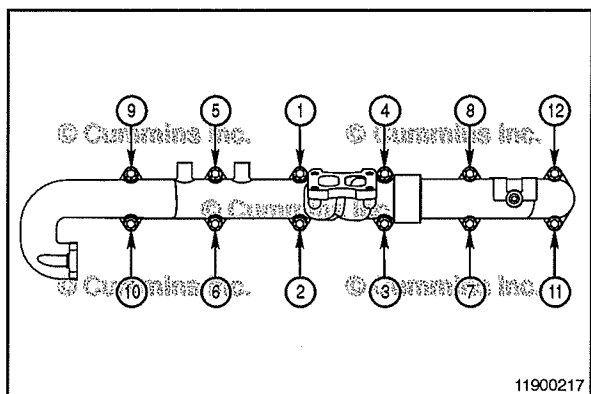
Install

Measure the distance between the center of the mounting holes on ports 4 and 5 of the manifold.

If the distance is **not** within specification, put the manifold on a flat surface with the ports face down and lightly tap the manifold with a soft-faced mallet until the measurements are within specification.

Manifold Section Distance

mm		in
136	MIN	5.35
138	MAX	5.43



Install the exhaust manifold to the cylinder head and EGR cooler inlet. Use new gaskets.

Lubricate the capscrews prior to installation.



Torque Value: 53 N•m [39 ft-lb]

Follow the tightening sequence shown in the illustration.



EGR Cooler (011-019)

Install

NOTE: Following these installation instructions in order is very important.

Install the EGR cooler to the EGR cooler bracket.

Install the EGR cooler with a new gasket between the EGR cooler and the exhaust manifold.

Install the capscrews and spacers, hand-tight **only**, that connect the EGR cooler to the exhaust manifold.

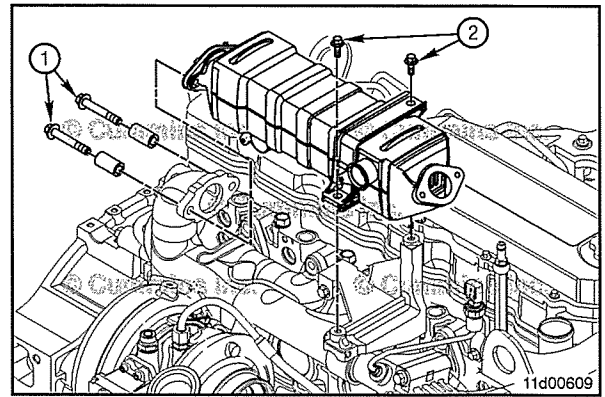
Install the EGR cooler to mounting bracket capscrews, hand-tight **only**.

Tighten the exhaust manifold capscrews (1) first.

Torque Value: 43 N•m [32 ft-lb]

Tighten the EGR cooler to mounting bracket capscrews (2).

Torque Value: 24 N•m [212 in-lb]

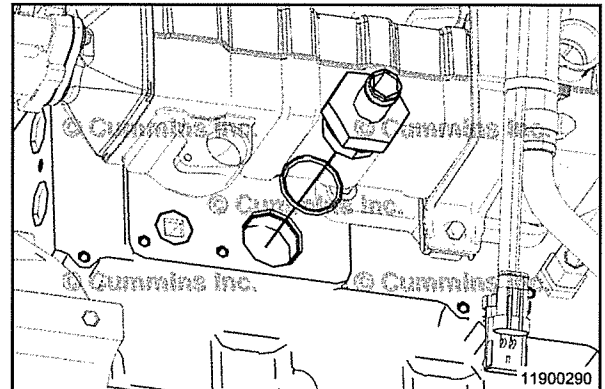


EGR Cooler Coolant Lines (011-031)

Install

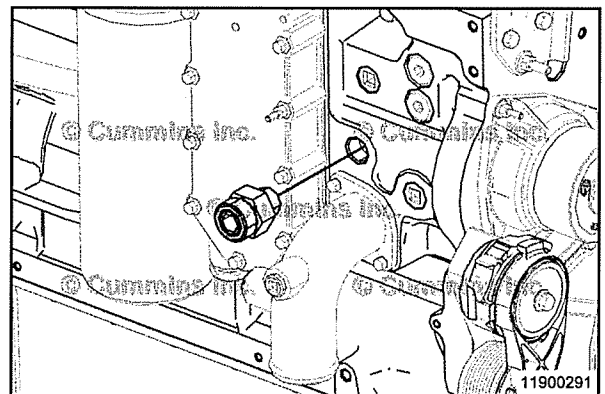
Install the EGR cooler coolant supply line fitting into the cylinder block (rear of engine).

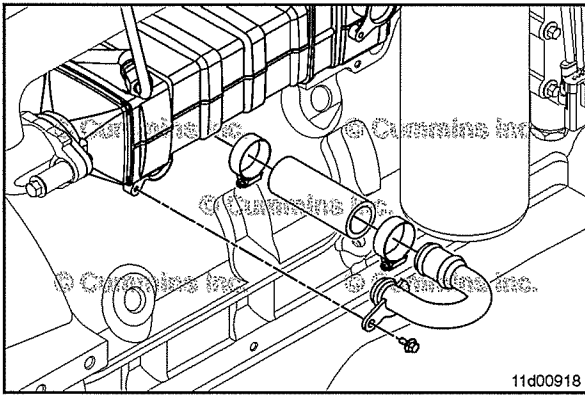
Torque Value: 115 N•m [85 ft-lb]



Install the EGR cooler coolant return line fitting into the cylinder block (front of engine).

Torque Value: 85 N•m [63 ft-lb]





Discard and replace all o-ring seals.

EGR Cooler Coolant Supply Line

- Install the EGR cooler coolant supply line hose to the engine block fitting. Use assembly lubricant, Part Number 3824878, to aid in installation of the hose.
- Install the EGR cooler coolant supply line to the coolant supply line hose and the EGR cooler inlet.

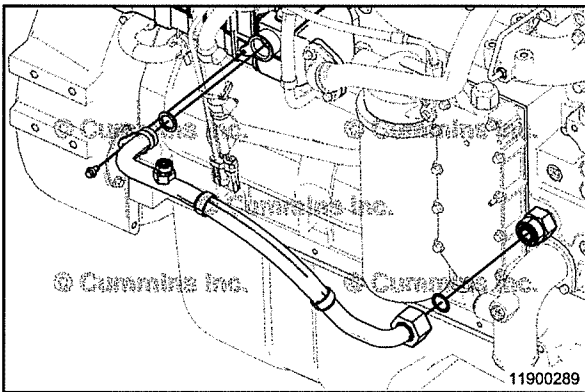


NOTE: Allow the tube brace to sit flush on the EGR cooler inlet bore.

Install the capscrew attaching the EGR cooler coolant supply line to the EGR cooler. Tighten the capscrew.

Torque Value: 10 N•m [89 in-lb]

Install the two hose clamps from the EGR cooler coolant supply line hose.



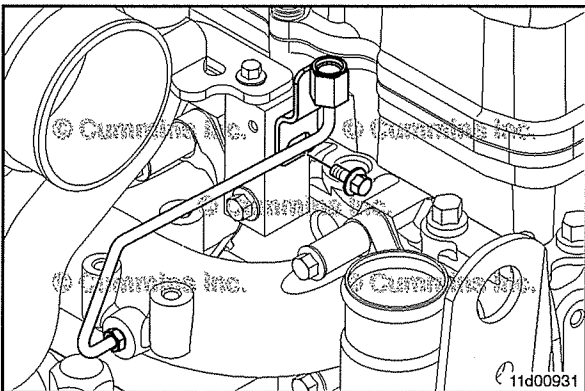
Discard and replace all o-ring seals.

Hand tighten the EGR cooler side, then the block side. Tighten the 10 mm EGR cooler side capscrew, then the nut on the block-side.

Torque Value: 85 N•m [63 ft-lb]

Install the capscrew attaching the EGR cooler coolant return line to the EGR cooler. Tighten the capscrew.

Torque Value: 10 N•m [89 in-lb]



Exhaust Gas Pressure Sensor Tube (011-027)

Install

NOTE: Install a light coating of high-temperature anti-seize compound to the threads of the exhaust pressure sensor tube prior to installation.

Install the exhaust gas pressure sensor tube to the port on the exhaust manifold.

Install the mounting fastener securing the exhaust pressure sensor tube to the cylinder head and tighten.

Tighten the capscrew:

Torque Value: 24 N•m [212 in-lb]

Tighten the exhaust gas pressure sensor tube fitting.

Torque Value: 18 N•m [159 in-lb]

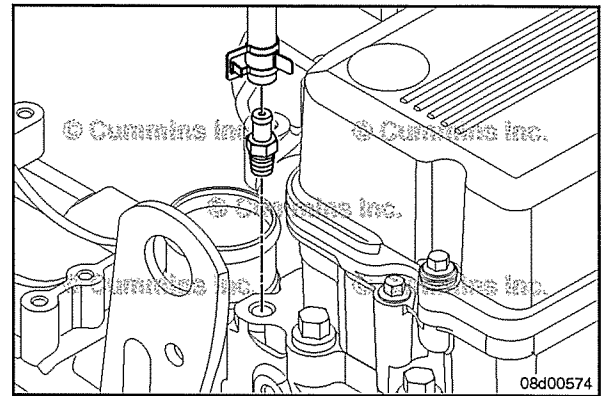


Coolant Vent Lines (008-017)

Install

Install the coolant vent line cylinder head fitting.

Torque Value: 25 N•m [221 in-lb]



Install using new sealing washers on all connections.

Install the fittings to the EGR cooler vent ports (1).

Torque Value: 24 N•m [212 in-lb]

Install the vent line mounting nuts to the EGR cooler (2).

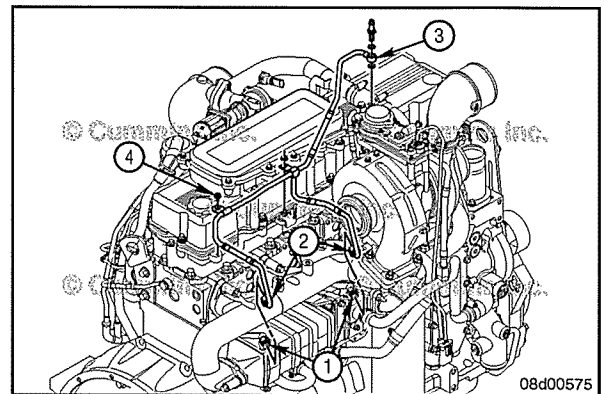
Torque Value: 15 N•m [133 in-lb]

Install the banjo bolt onto the turbocharger (3).

Torque Value: 15 N•m [133 in-lb]

Install the vent line mounting screws (4).

Torque Value: 12 N•m [106 in-lb]



EGR Connection Tubes (011-025)

Install

⚠ CAUTION ⚠

Do not twist or bend the EGR connection tube during removal or installation or damage to the hose can result.

Install the EGR connection tube using new gaskets.

Install the capscrew and mounting capscrews at the EGR cooler outlet, EGR valve inlet, and tube braces hand tight, and check for correct alignment at all locations. Make sure the EGR crossover tube does **not** contact the rocker lever cover.

Tighten the capscrews and mounting capscrews in the following sequence:

Tighten the capscrews at the EGR cooler outlet.

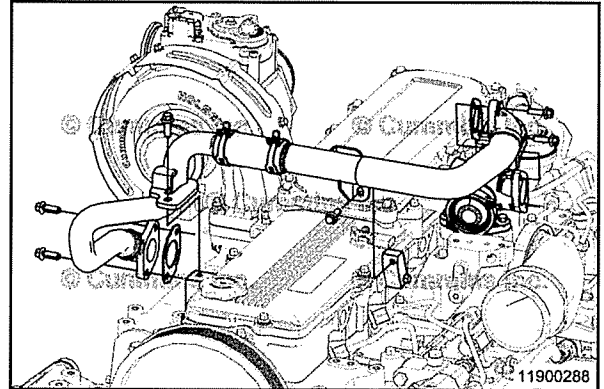
Torque Value: 24 N•m [212 in-lb]

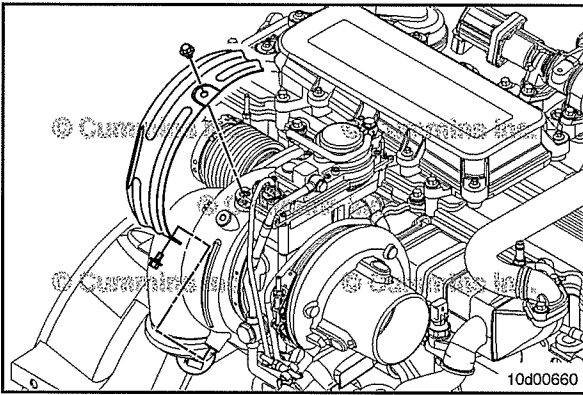
Tighten the capscrews at the EGR valve inlet.

Torque Value: 24 N•m [212 in-lb]

Tighten the brace mounting capscrew.

Torque Value: 24 N•m [212 in-lb]





Turbocharger Heat Shield (010-076)

Install



Place a light coating of high-temperature anti-seize compound, Part Number 3824732 or equivalent, on the retaining capscrews prior to installation.

Install the turbocharger heat shield.

Tighten the capscrews.

Torque Value: 25 N•m [221 in-lb]

Turbocharger (010-033)

Install

▲ WARNING ▲

This component or assembly weights greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift the component or assembly.

▲ CAUTION ▲

Do not use a metal hammer.

▲ CAUTION ▲

Do not pinch the turbocharger speed sensor with the V-band or compressor cover.

▲ CAUTION ▲

Do not remove the compressor cover to reduce the possibility of compressor wheel damage.

NOTE: Make sure to install the lines in the proper orientation.

NOTE: If installing a new turbocharger, orient the compressor housing to the same position as the turbocharger that was removed. Begin by taking note of the current turbocharger speed sensor and actuator jumper harness routing. Move the turbocharger speed sensor away from the bearing housing to compressor housing joint. Orient the compressor housing by loosening the V-band clamp. Do **not** remove the V-band clamp or uninstall the compressor cover from the bearing housing. Reorient the compressor housing by softly tapping the housing (**not** compressor outlet flange) with a soft hammer. Tighten the V-band to 8.5 N•m [75 in-lb]. Route the turbocharger speed sensor and actuator jumper harness to the original routing path. When finished, check to make sure the compressor wheel is freely rotating and no clearance/rubbing issues are seen. If the compressor wheel is rubbing on the compressor housing, replace the turbocharger.

Torque Value: 8.5 N•m [75 in-lb]

Only remove clean care caps as the connections are being made.

Apply a film of high-temperature anti-seize compound to the turbocharger mounting studs.

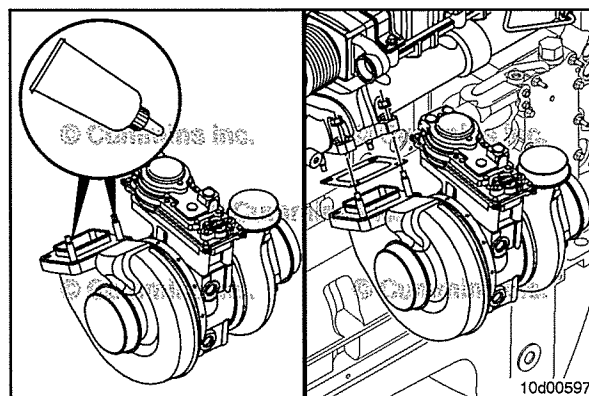
Install a new gasket and install the turbocharger.

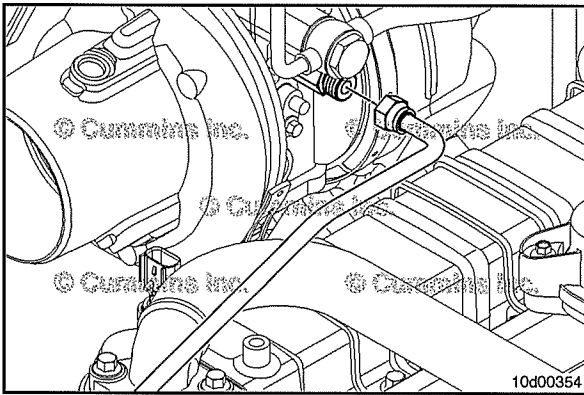
Install and tighten the four mounting nuts.

NOTE: The torque values have been established with anti-seize compound as a lubricant.

Torque Value: 55 N•m [41 ft-lb]

If required, install the turbocharger actuator. Refer to Procedure 010-134 in Section 10.





Turbocharger Oil Supply Line (010-046)

Install



⚠CAUTION⚠

When handling the oil supply line, avoid bending the flexible portion into a tight bend, as this will cause damage to the flexible material. It is advisable to remove the line from the engine, when servicing the engine, to avoid accidentally overbending the flexible material.



Apply a thin film of clean engine oil to the oil supply line o-ring seals.

Install the oil supply line to the turbocharger and to the oil filter head. Use new o-ring seals and hand-tighten.

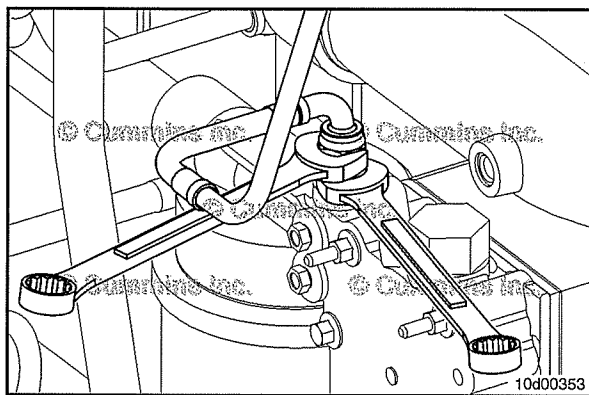
Tighten the oil supply line at the turbocharger bearing housing.

Torque Value: 35 N•m [26 ft-lb]

If the fitting at the turbocharger bearing housing was removed, tighten the fitting.

Torque Value: 36 N•m [27 ft-lb]

NOTE: Use a wrench to hold the fitting below the oil supply line on the turbocharger bearing housing. This will prevent the fitting from being overtightened.



⚠CAUTION⚠

Maintain at least 10 mm [0.40 in] clearance between the turbocharger oil supply line and the turbocharger turbine housing and exhaust manifold.

Tighten the oil supply line at the oil filter head fitting.

NOTE: Use a wrench to hold the fitting below the oil supply line on the oil filter head. This will prevent the fitting from being overtightened.

Torque Value: 35 N•m [26 ft-lb]

If the fitting at the oil filter head was removed, tighten the fitting.

Torque Value: 24 N•m [212 in-lb]

NOTE: Make sure all turbocharger plumbing lines are not in contact with other lines or components.

Turbocharger Oil Drain Line (010-045)

Install

Apply a thin film of clean engine oil to the drain line o-rings.

Push the assembled oil drain hose and lower oil drain tube into the cylinder block. Make sure both o-rings are completely seated in the bore.

Install a new gasket to the upper oil drain tube.

Insert the upper oil drain tube into the oil drain hose and align to the turbocharger oil drain.

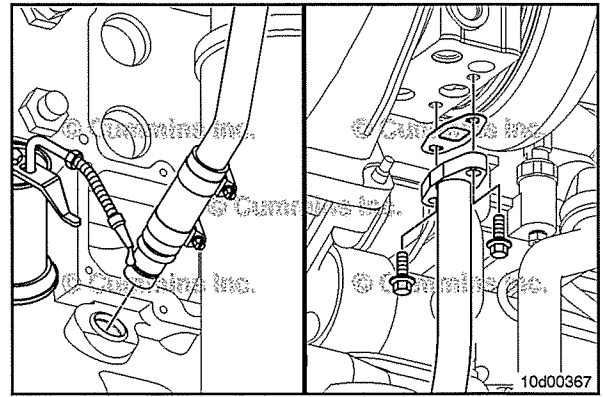
Install and tighten the upper drain tube capscrews.

Torque Value: 24 N•m [212 in-lb]

Tighten the hose clamps.

Torque Value: 5 N•m [44 in-lb]

NOTE: Be sure that the turbocharger plumbing lines are **not** in contact with other lines or components.

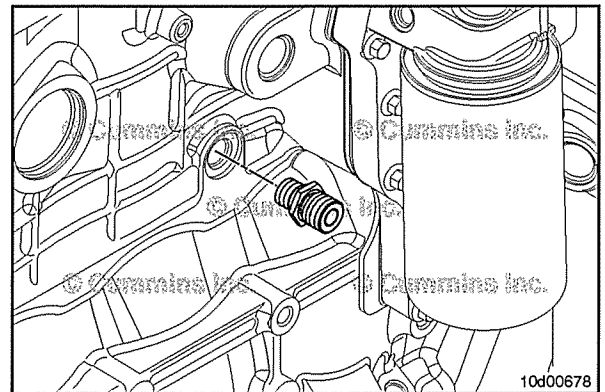


Turbocharger Coolant Hoses (010-041)

Install

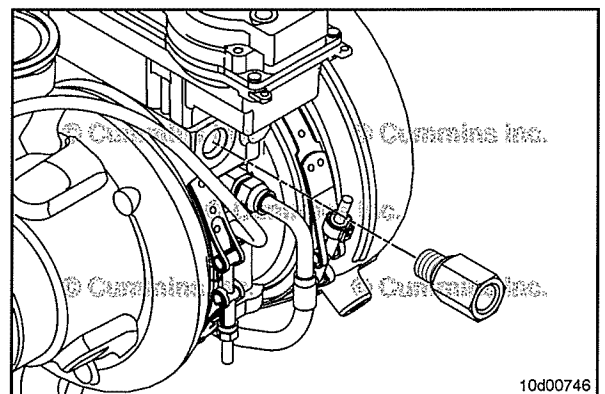
Install the turbocharger coolant supply hose fitting into the cylinder block.

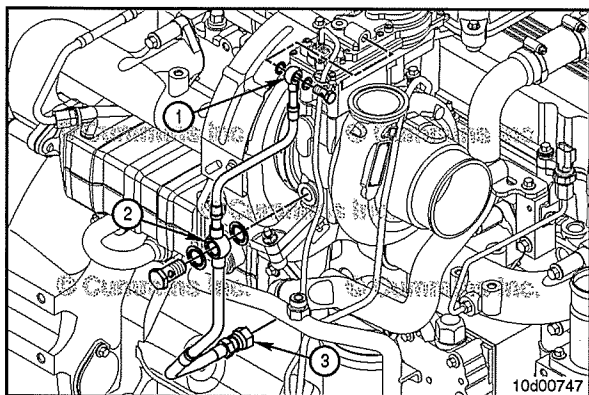
Torque Value: 75 N•m [55 ft-lb]



Install the turbocharger coolant supply hose fitting and the turbocharger coolant return hose fitting into the turbocharger bearing housing or VGT actuator.

Torque Value: 35 N•m [26 ft-lb]





Install the turbocharger coolant supply hose by first installing the banjo screw attached to the VGT actuator (1) and hand-tighten and/or install the banjo screw attached to the turbocharger bearing housing (2) and hand-tighten.



Install the coolant connection to the cylinder block fitting (3) and hand-tighten.

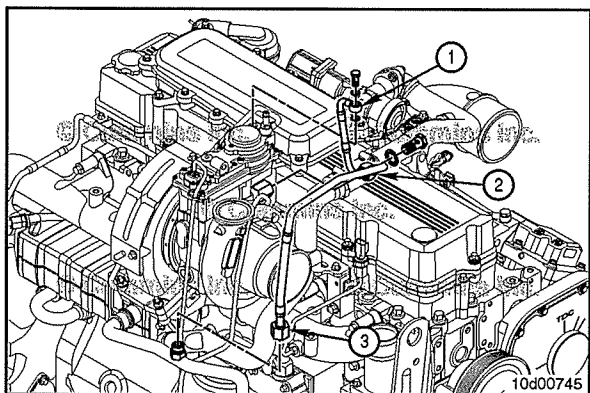
NOTE: Use a second wrench to hold the coolant connection fittings at the cylinder block and turbocharger bearing housing to prevent accidental overtightening of the fitting.

Tighten the fittings in the following sequence:

Torque Value:
Fitting 1 25 N•m [225 in-lb]

Torque Value:
Fitting 2 35 N•m [26 ft-lb]

Torque Value:
Fitting 3 37 N•m [27 ft-lb]



Install the turbocharger coolant return hose by first installing the banjo screw attached to the VGT actuator (1).



Install the banjo screw attached to the turbocharger bearing housing (2).

Install the coolant connection to the exhaust gas recirculation (EGR) coolant return hose.

NOTE: Use a second wrench to hold the coolant connection fittings at the cylinder block and turbocharger bearing housing to prevent accidental overtightening of the fittings.

Tighten the fittings in the following sequence:

Torque Value:
Fitting 1
Step 1 25 N•m [221 in-lb]

Torque Value:
Fitting 2
Step 1 35 N•m [26 ft-lb]

Torque Value:
Fitting 3
Step 1 37 N•m [27 ft-lb]

NOTE: Be sure **all** turbocharger plumbing lines are **not** in contact with other lines or components.

Turbocharger Compressor Outlet Connection (010-132)

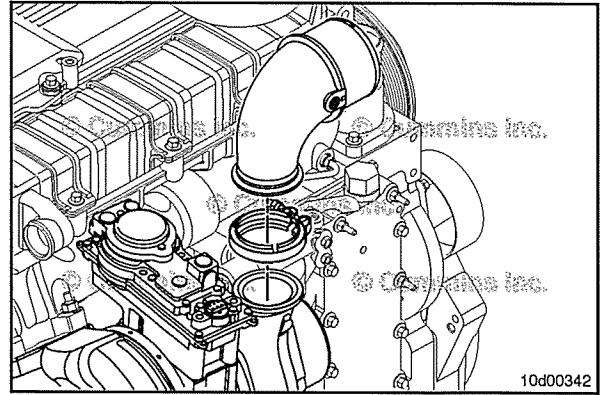
Install

Install the turbocharger compressor outlet elbow, V-band clamp, and new o-ring seal on the turbocharger compressor discharge outlet.

Make sure to remove the protective caps.

Tighten the clamp.

Torque Value: 8 N•m [71 in-lb]



Lubricating Oil Dipstick Tube (007-011)

Install

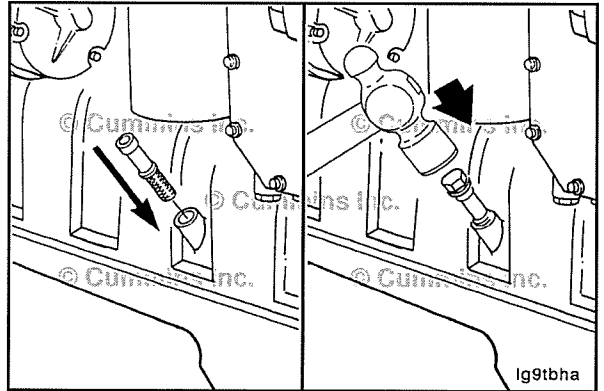
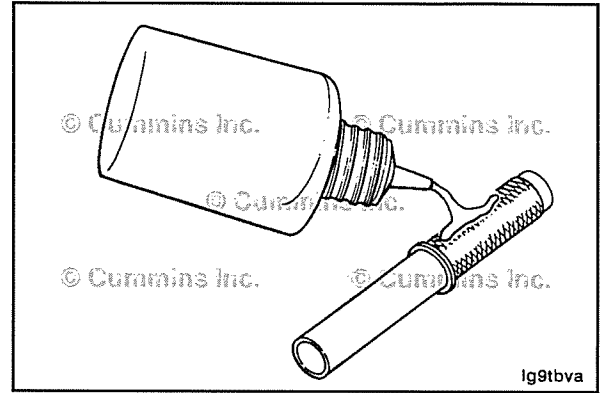
Apply a thin bead of sleeve retaining compound, Part Number 3823718 or equivalent, around the bottom of the knurled end of the tube.

Place the knurled end of the tube into the dipstick tube bore in the cylinder block.

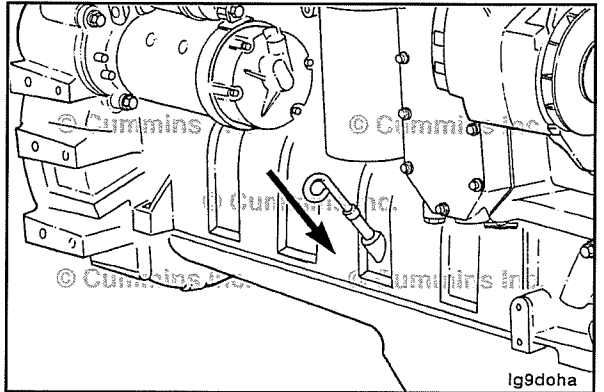
Use a flat washer and hex head capscrew to drive the tube into the cylinder block.

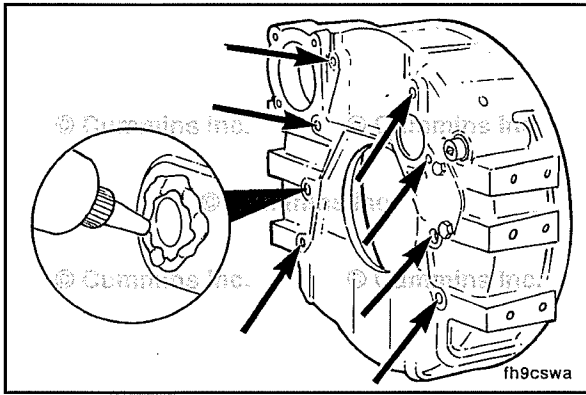
Lightly drive the dipstick tube until it seats against the block casting.

Remove the flat washer and hex head capscrew.



Install the dipstick into the dipstick tube.



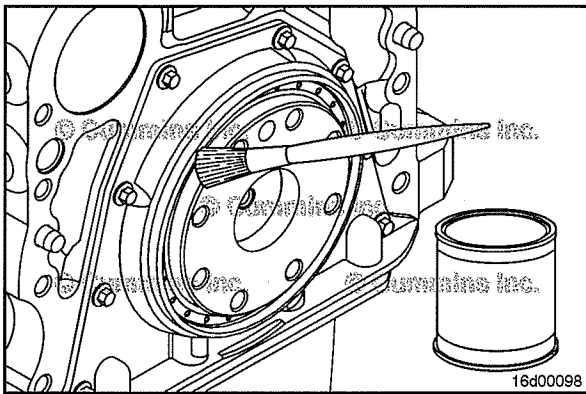


Flywheel Housing (016-006)

Install

Wet Flywheel Applications

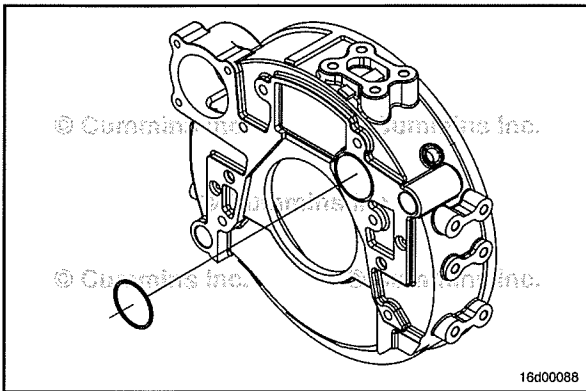
Apply a continuous bead of sealant, Part Number 3164067 or equivalent, around all capscrew holes on the mounting surface of the flywheel housing.



NOTE: Before installing the flywheel housing, make sure any locating dowel rings are in the same position as when the flywheel housing was removed.

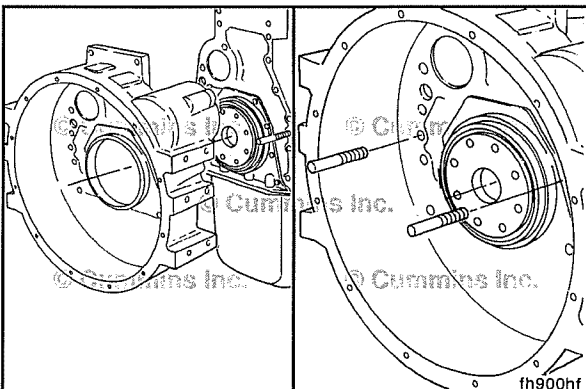


Install a new rectangular seal on the rear seal carrier and apply assembly lubricant, Part Number 3163087.



If previously equipped, install a new rectangular seal for the camshaft journal bore to the back side of the flywheel housing.

Apply a small amount of sealant, Part Number 3164067, to hold the seal in place until the flywheel housing is installed.



Inspect the rear face of the cylinder block and flywheel housing mounting surface for cleanliness and raised nicks or burrs.

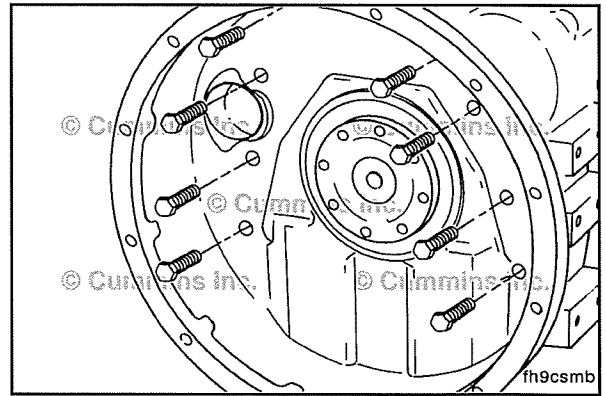


Install two guide pins, Part Number 3163934.

Install the flywheel housing over the guide pins, making sure the flywheel housing is located on the dowel rings.

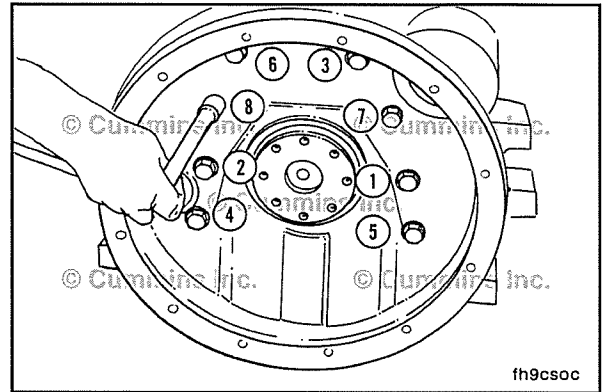
NOTE: Be sure the sealing ring is **not** damaged during installation.

Remove the guide pins.
Install the mounting capscrews.

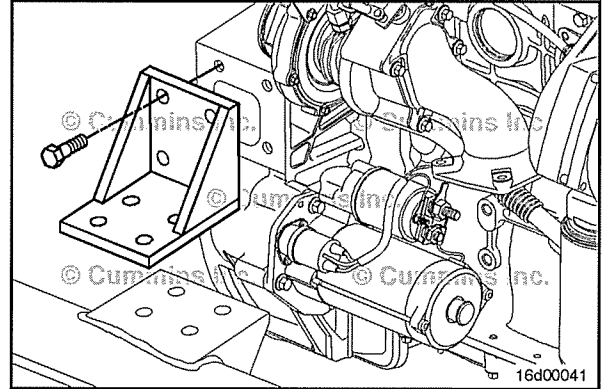


Tighten the flywheel housing capscrews in the sequence shown.

Torque Value: 77 N•m [57 ft-lb]



Install the rear engine support bracket and mounting capscrews. Refer to Procedure 016-003 in Section 16.



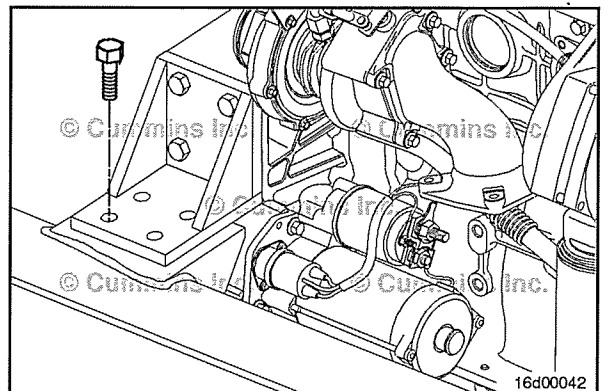
NOTE: Make sure to install any shims or spacers in the same location as removed.

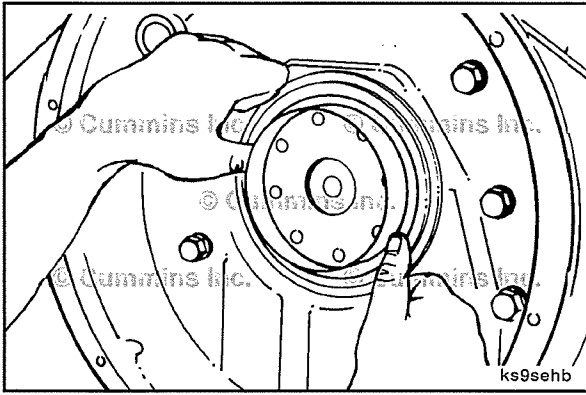
Lower the rear of the engine.

Install the rear engine mount fasteners.

Tighten to the OEM specification.

Remove the lifting fixture or hoist from the rear of the engine.





Crankshaft Seal, Rear (001-024)

Install



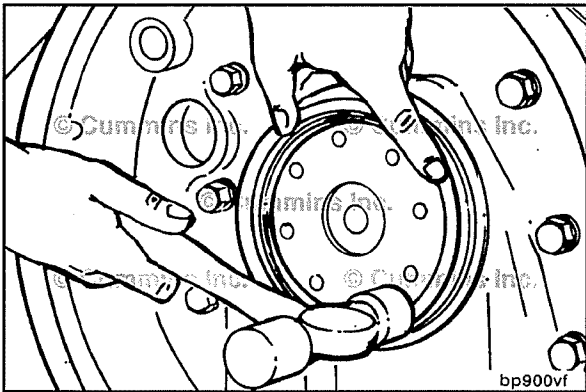
NOTE: For installation, the oil seal requires the application of a mild soap solution on the outside diameter of the seal carrier.



Install the seal pilot, provided in the replacement kit, onto the crankshaft. Push the seal onto the pilot and crankshaft.

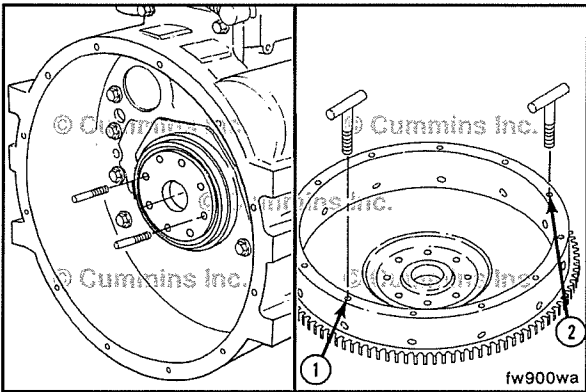
Remove the seal pilot.

NOTE: Use the following procedure for installation with the rear seal carrier already removed. Refer to Procedure 001-067 in Section 1.



Use the alignment tool to install the seal to the correct depth in the housing. Use a hammer to drive the seal into the housing until the alignment tool stops against the housing.

Hit the tool at the 12, 3, 6 and 9-o'clock positions to drive the seal evenly and to prevent bending the seal carrier.



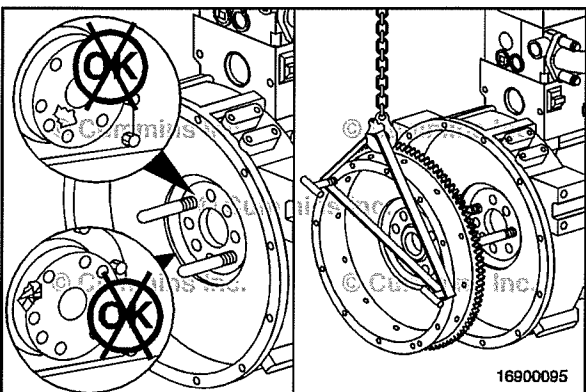
Flywheel (016-005)

Install

Install two M12 x 1.25 x 90-mm guide pins into the crankshaft flange 180 degrees apart.

NOTE: If a clutch is used in the equipment, the threads in the clutch pressure plate mounting capscrew holes can be metric or standard. Be sure to use the correct capscrews.

Determine the capscrew thread design and size, and install two T-handles into the flywheel at points (1) and (2).



▲ WARNING ▲

This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.



Inspect the rear face of crankshaft and flywheel mounting flange for cleanliness and nicks or burrs.

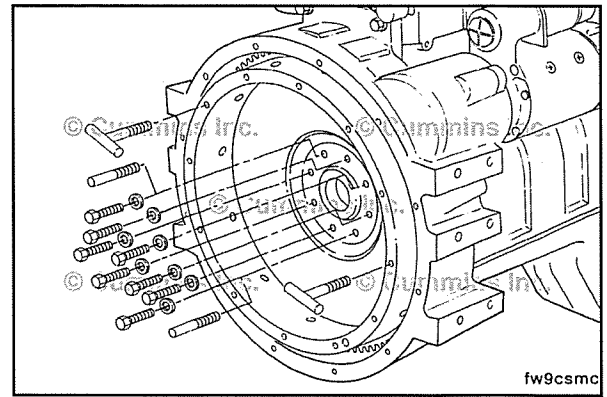
Install the flywheel on the guide pins.

Lubricate the threads of the capscrews and the surface of the washers with clean lubricating engine oil.

Install the six capscrews.

Remove the T-handle and guide pins.

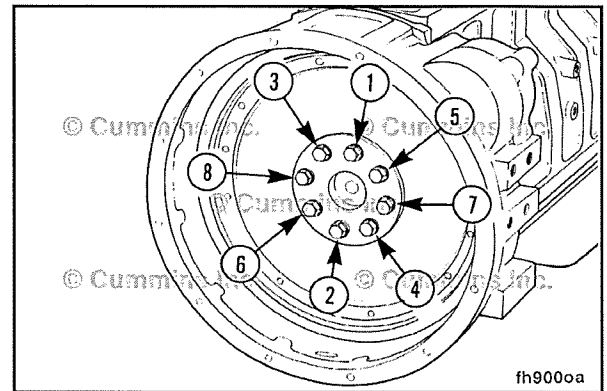
Install the remaining capscrews into the holes from where the guide pins were removed.



Hold the crankshaft when tightening the flywheel capscrews, use the barring tool, Part Number 3824591.

Tighten the capscrews in a star pattern.

Torque Value: 137 N•m [101 ft-lb]



Measure

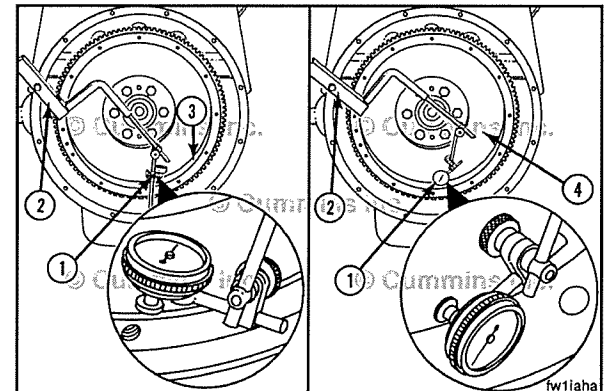
Bore Runout

Use the dial indicator gauge (1), Part Number 3376050 or equivalent, and dial gauge attachment (2), Part Number ST-1325, to inspect the flywheel bore (3) and the surface (4) runout.

Install the attachment to the flywheel housing.

Install the gauge on the attachment.

Install the contact tip of the indicator against the inside diameter of the flywheel bore, and set the dial indicator at zero.

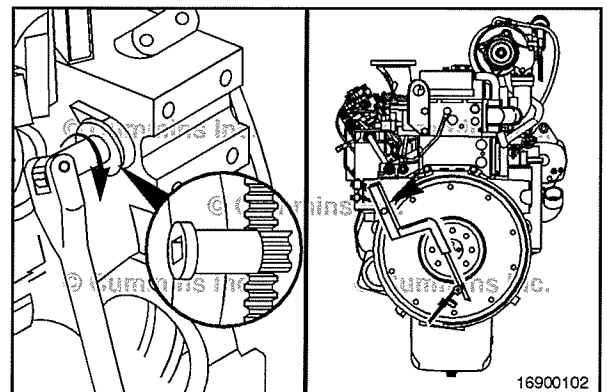


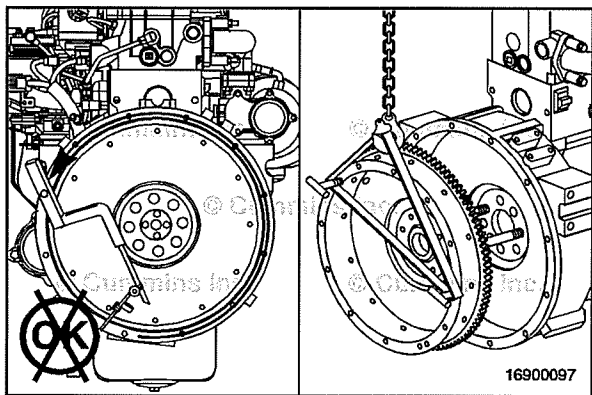
Use the barring tool, Part Number 3374591, to rotate the crankshaft one complete revolution.



Flywheel Total Indicator Reading

mm		in
0.127	MAX	0.0050



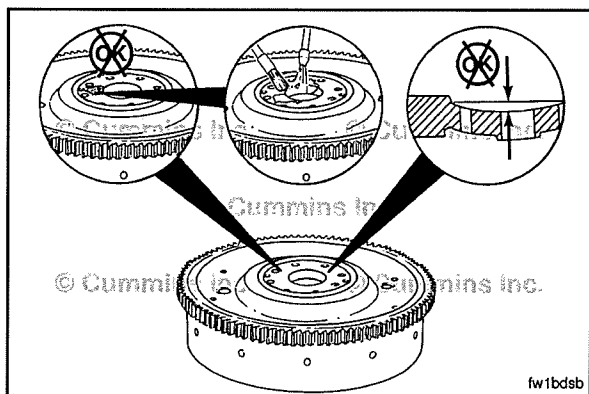


▲ WARNING ▲

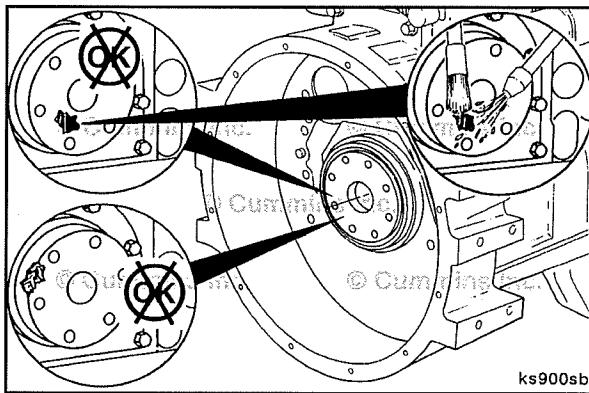
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

NOTE: If the total indicator reading (TIR) is greater than the specification, do the following:

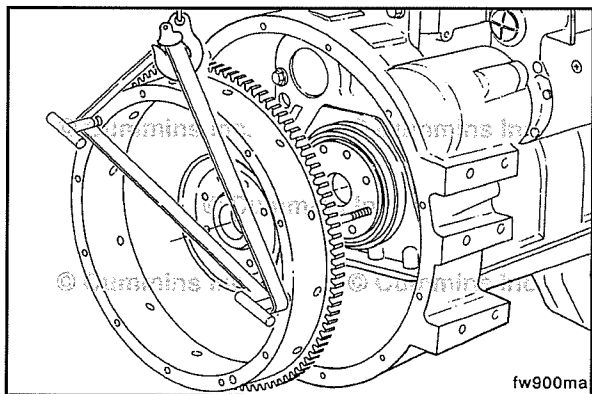
Remove the flywheel.



Inspect the flywheel mounting surface for dirt or damage.



Inspect the crankshaft for dirt or damage.



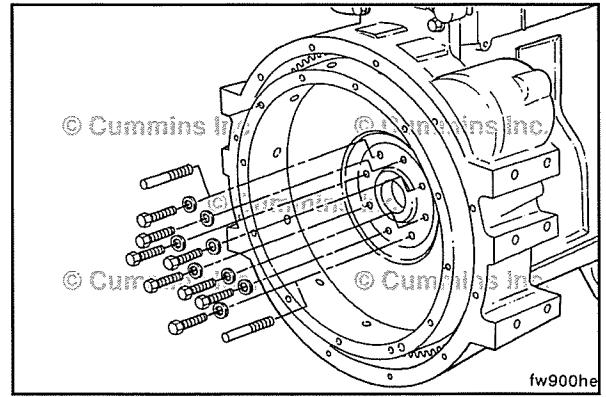
▲ WARNING ▲

This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Install the flywheel.

Inspect the bore runout.

Replace the flywheel if the runout does **not** meet specifications.

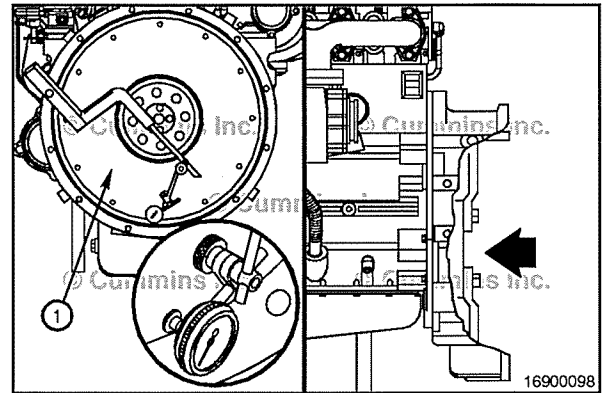


Face Runout

Install the contact tip of the indicator against the flywheel face.

When locating the contact tip, see the Flywheel Face Runout Total Indicator Reading Table later in this procedure. Locate the contact tip so that it corresponds with a radius listed in the table, but is still as close to the outside diameter of the flywheel as possible, to inspect the flywheel face (1) runout.

Push the flywheel forward to remove the crankshaft end clearance. Adjust the dial on the indicator until the needle points to zero.

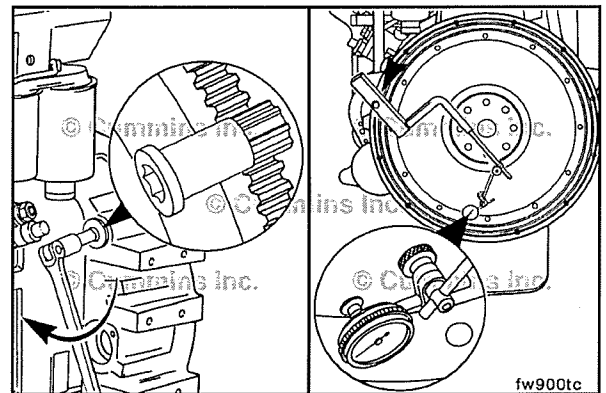


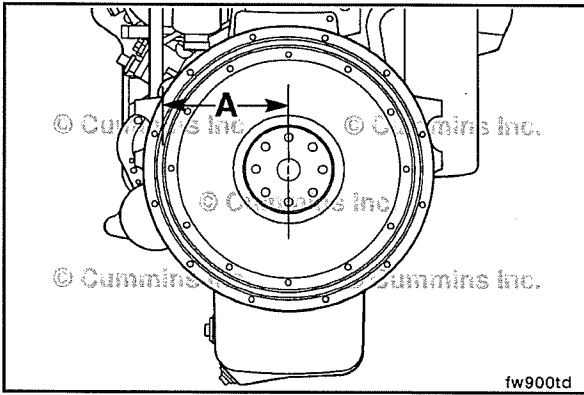
Use the barring tool, Part Number 3824591, to rotate the crankshaft one complete revolution. Measure and record the flywheel runout at four equal points on the flywheel.

The flywheel **must** be pushed toward the front of the engine to remove the crankshaft end clearance each time a point is measured.

Determine the total indicator reading (TIR).

TIR is determined by calculating the difference between the highest and lowest measurement from the four locations measured.

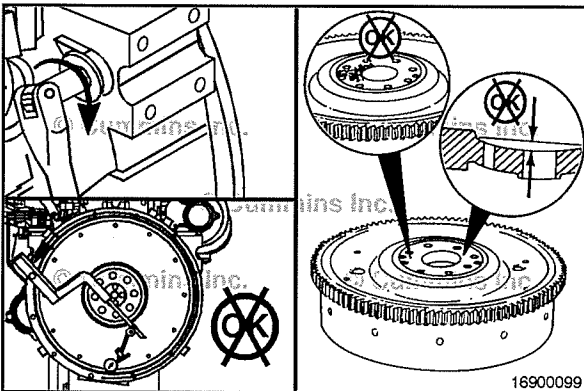




Measure the distance from the center of the flywheel to the contact tip of the indicator (A). Use this measurement to determine which specification to use from the table below.

The total indicator reading **must not** exceed the following specifications:

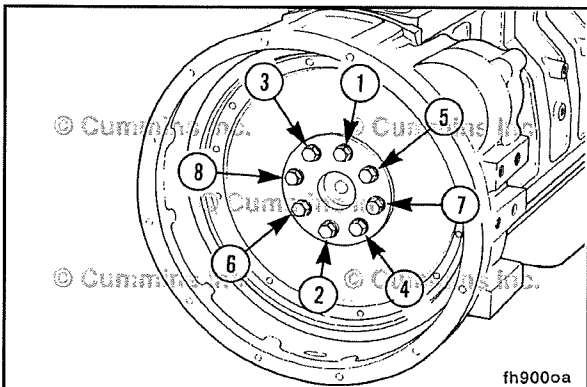
Flywheel Radius (A)		Maximum Total Indicator Reading of Flywheel Face	
mm	in	mm	in
203	8	0.203	0.008
254	10	0.254	0.010
305	12	0.305	0.012
356	14	0.356	0.014
406	16	0.406	0.016



If the flywheel face runout is **not** within specifications, remove the flywheel. Check for nicks, burrs, or foreign material between the flywheel mounting surface and the crankshaft flange.



Replace the flywheel if the runout is **not** within specification.



Flexplate (016-004)

Install



NOTE: Some flexplates require mounting plates and/or clamp rings. It may be necessary to install any mounting plates and/or clamp rings prior to or with the flexplate as noted during removal.

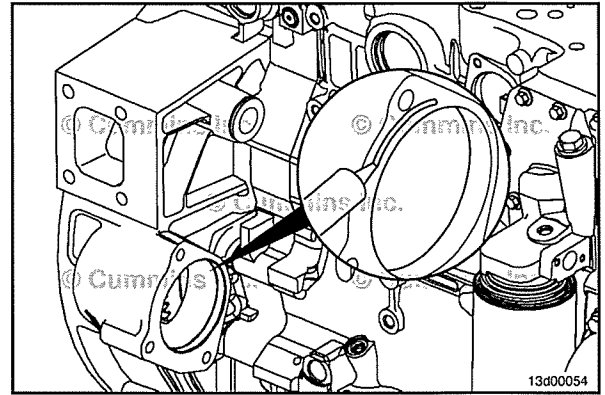
Install the flexplate, the flexplate cap screws, and tighten.

Torque Value: 137 N·m [101 ft-lb]

Starting Motor (013-020)

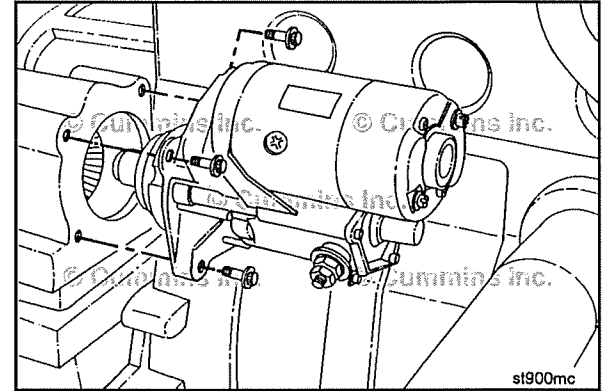
Install

NOTE: If a starting motor spacer is required, make sure to apply sealant to the side of the spacer that contacts the starting motor.



Install the three capscrews, the starting motor, and starting motor spacer, if required.

Torque Value: 43 N•m [32 ft-lb]



Cummins® Branded Starters

⚠ CAUTION ⚠

Do not overtighten the electrical connections. Starting motor damage can result.

NOTE: Use the location tags to help identify where each wire connection goes.

Connect the electrical connections to the starting motor.

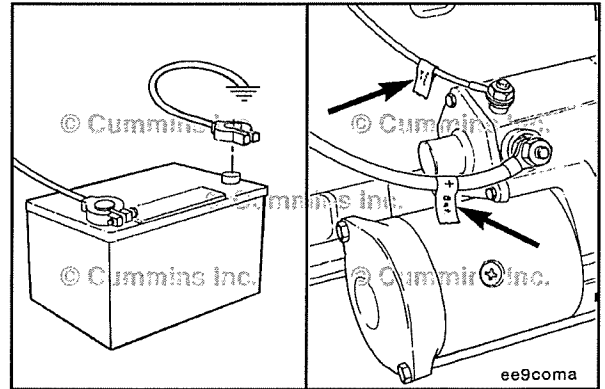
Torque Value:
M5 4 N•m [35 in-lb]

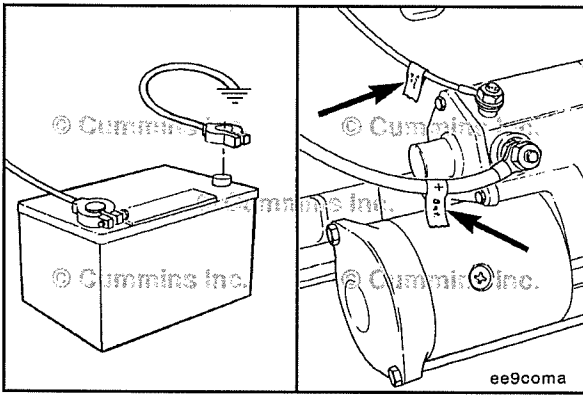
Torque Value:
M10 21 N•m [186 in-lb]

If starter came installed with the the JSP cover, install the JSP and JSP cover nut on the M terminal post.

Torque Value:
M5 4 N•m [35 in-lb]

NOTE: The JSP cover nut is the third nut on the M terminal, M5 terminal size. Failure to observe the proper torque specification can result in loss of conductivity to the M lead and result in a no crank condition for the starter and engine.





Non-Cummins® Branded Starters

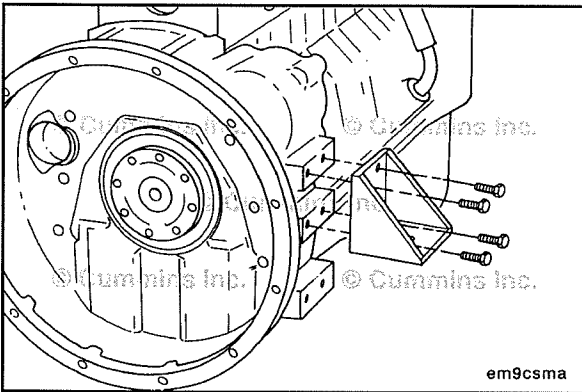
⚠ CAUTION ⚠

Do not overtighten the electrical connections. Starting motor damage can result.

NOTE: Use the location tags to help identify where each wire connection goes.

Connect the electrical connections to the starting motor.

For Non-Cummins® branded starters, refer to the OEM service manual for torque specifications.

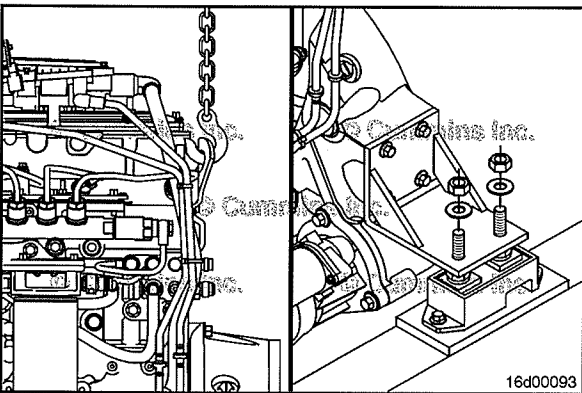


Engine Support Bracket, Rear (016-003)

Install

Install the support bracket and mounting capscrews.

Torque Value: 71 N•m [52 ft-lb]



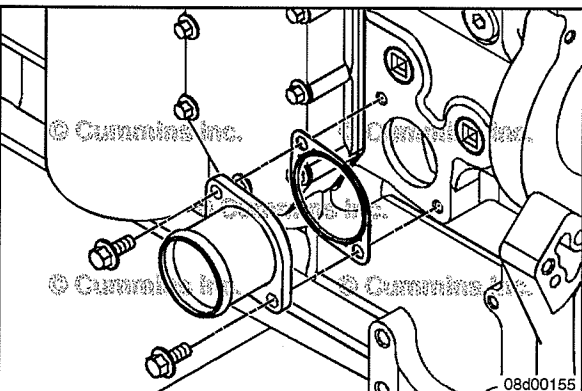
Lower the rear of the engine.

Install the rear engine mount capscrews.

Tighten to the manufacturer's specifications.

Remove the lifting fixture or hoist from the rear of the engine.

NOTE: Make sure to install any shims or spacers in the same location as removed.



Water Inlet Connection (008-082)

Install

Install a new water inlet connection gasket.

Install the water inlet connection and mounting capscrews.

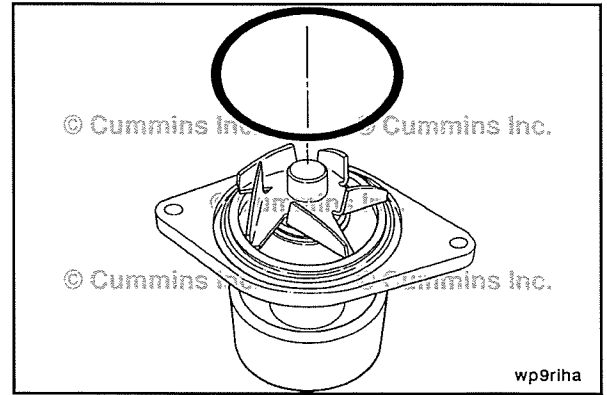
NOTE: Use pipe plug sealant, Part Number 3375066, or equivalent, to install any OEM coolant fittings removed from the water inlet connection.

Torque Value: 24 N•m [212 in-lb]

Water Pump (008-062)

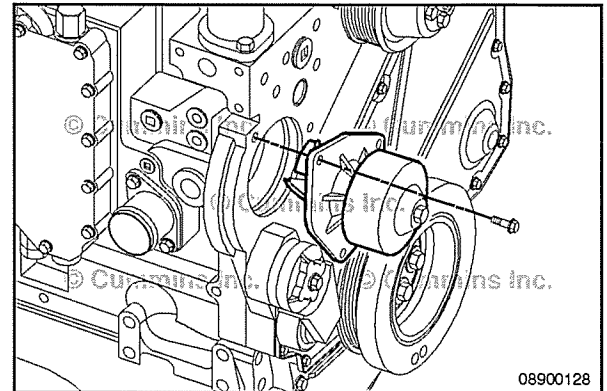
Install

Install a new sealing ring into the groove in the water pump housing.



Install the water pump.

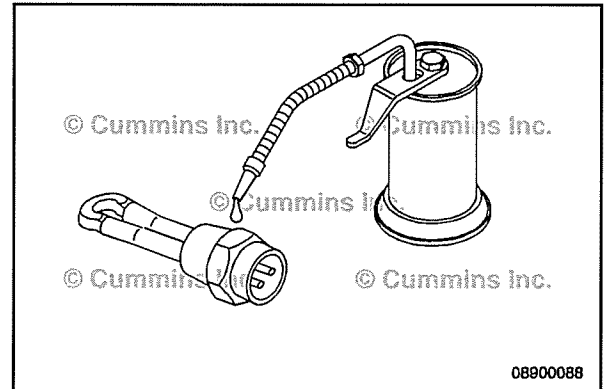
Torque Value: 30 N•m [22 ft-lb]



Coolant Heater (008-011)

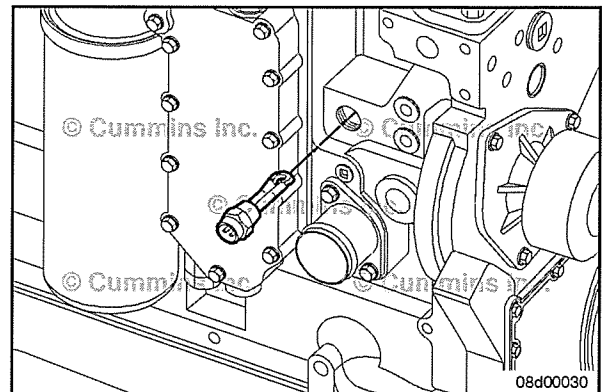
Install

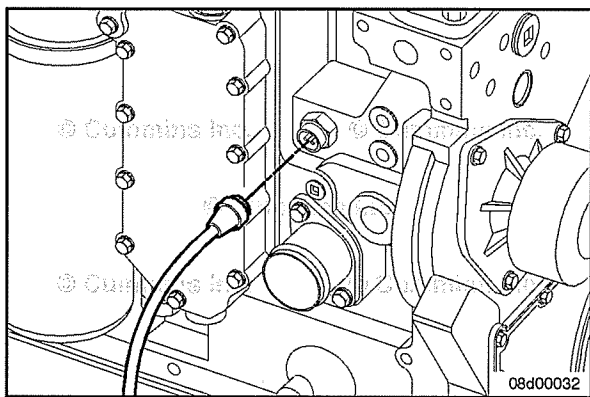
Lubricate the new coolant heater threads with clean engine oil.



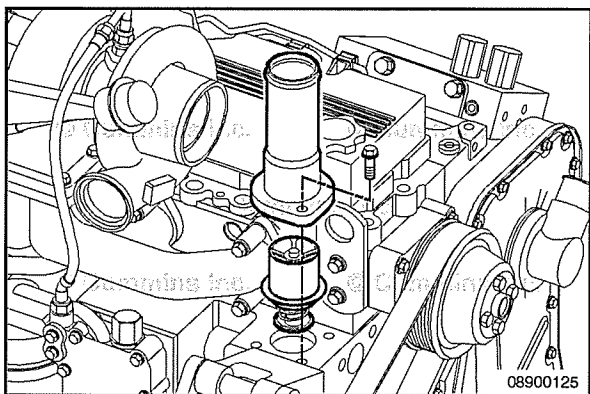
Install the coolant heater.

Torque Value: 75 N•m [55 ft-lb]





Attach the coolant heater electrical cord.



Coolant Thermostat (008-013)

Install



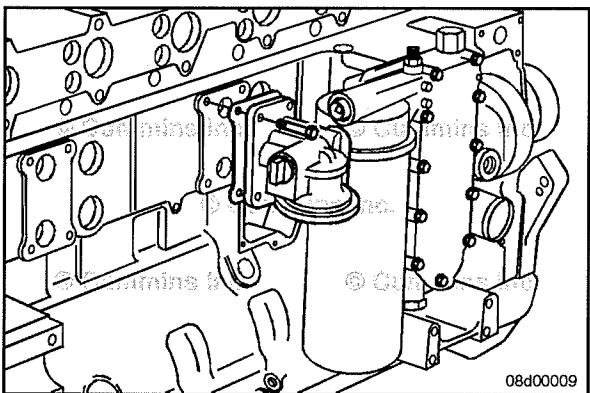
Install the new thermostat into the cylinder block.

Install a new gasket over the thermostat and onto the block.

NOTE: A new gasket **must** be installed each time the thermostat or water outlet connection is removed.

Install the water outlet connection and mounting capscrews.

Torque Value: 24 N•m [212 in-lb]



Coolant Filter Head (008-007)

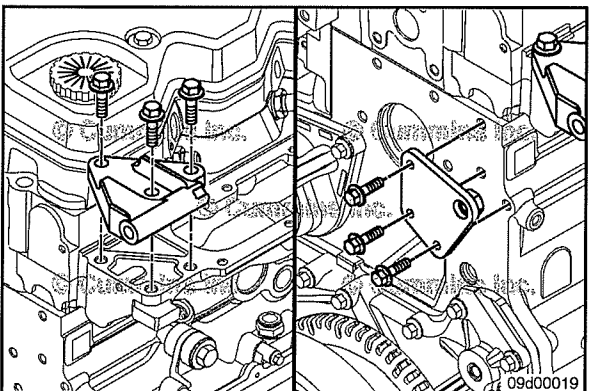
Install



Install a new gasket and the filter head.

Tighten the four capscrews.

Torque Value: 24 N•m [212 in-lb]



Refrigerant Compressor Mounting Bracket (009-055)

Install



Install the two mounting brackets and capscrews.

Tighten the capscrews.

Torque Value:
M8 23 N•m [204 ft-lb]

Torque Value:
M10 43 N•m [32 ft-lb]

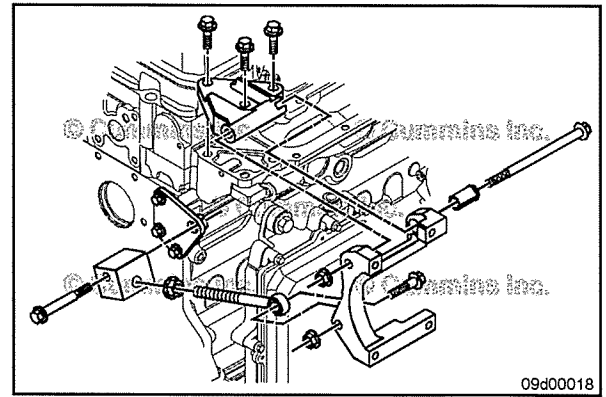
Install the refrigerant compressor support.

Install the pivot capscrew hand-tight.

Install the adjusting link.

Install the adjusting link capscrew hand-tight.

Tighten the adjusting link capscrews and the pivot capscrew after the refrigerant compressor is installed and the drive belt has been tensioned. Refer to Procedure 009-052 in Section 9.



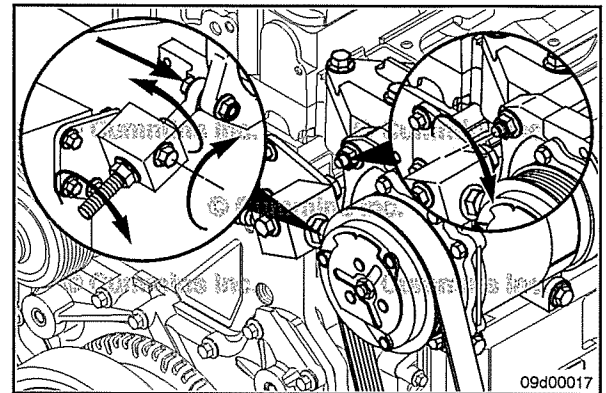
Drive Belt, Refrigerant Compressor (009-052)

Install

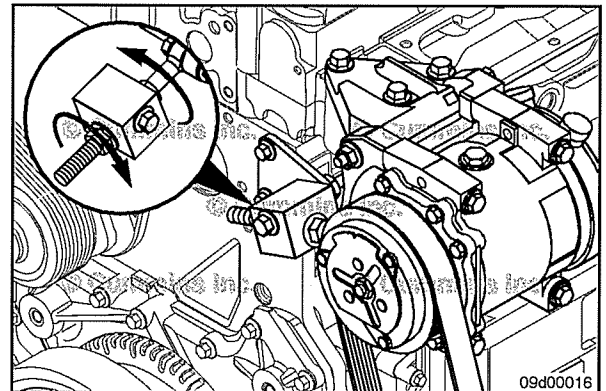
Tighten the pivot bolts and the adjusting link bolts finger tight.

Tighten the bolt that attaches the adjusting link to the compressor bracket finger tight.

Install the refrigerant compressor drive belt.



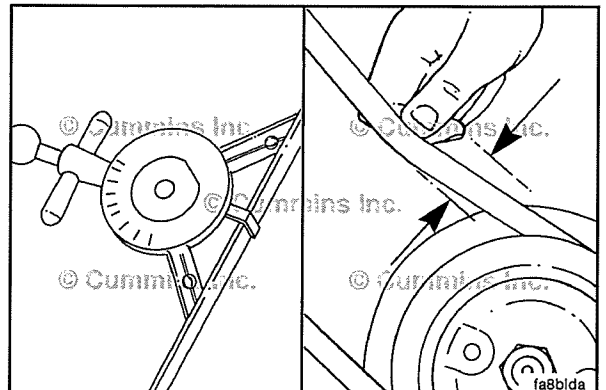
Use the adjusting nuts on the adjusting link to tighten the refrigerant compressor drive belt.

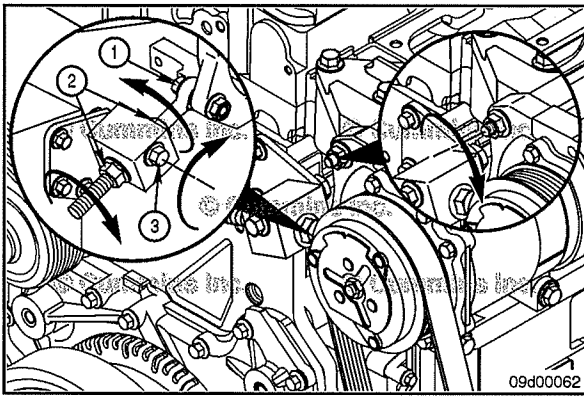


Use a belt gauge to measure the belt tension. Use the following procedure for the correct gauge and tension value for the belt width used. Refer to Procedure 018-005 in Section V.



Belt Tension 534 N [120 lbf]



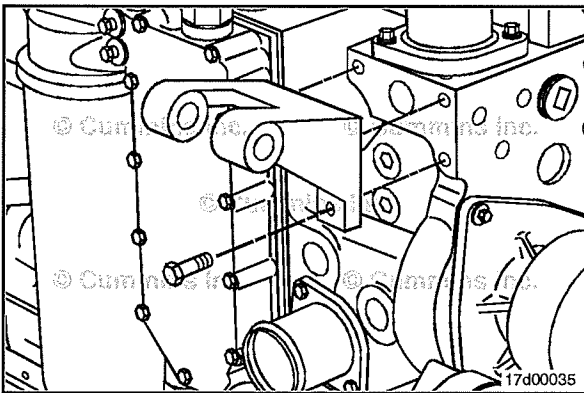


Tighten the pivot bolt, the adjusting link bolts, and the adjusting link to bracket mounting bolt.

Torque Value:
Pivot Bolt (1) 43 N•m [32 ft-lb]

Torque Value:
Adjusting Link Bolts (2) 77 N•m [57 ft-lb]

Torque Value:
Adjusting Link to Bracket Mounting Bolt (3) 43 N•m [32 ft-lb]



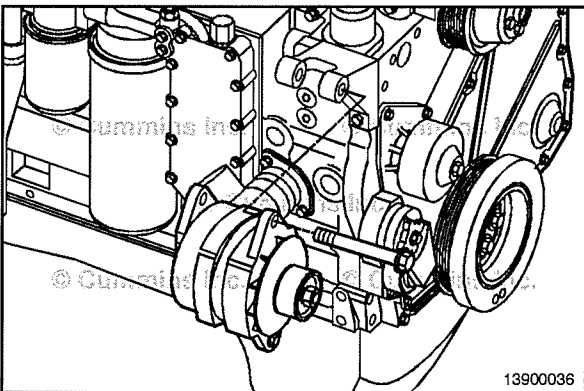
Alternator Bracket (013-003)

Install



Install the side mounted bracket and bracket mounting capscrews.

Torque Value: 24 N•m [212 in-lb]



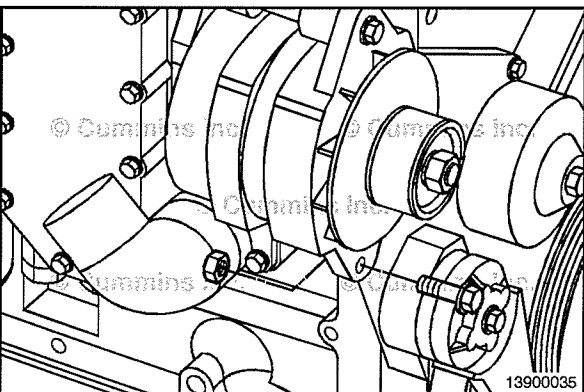
Alternator (013-001)

Install



Install the alternator and alternator capscrews in the reverse order of removal.

Torque Value: 43 N•m [32 ft-lb]



Install the alternator link capscrew.

Torque Value: 24 N•m [212 in-lb]



Belt Tensioner, Automatic (Water Pump) (008-080)

Install

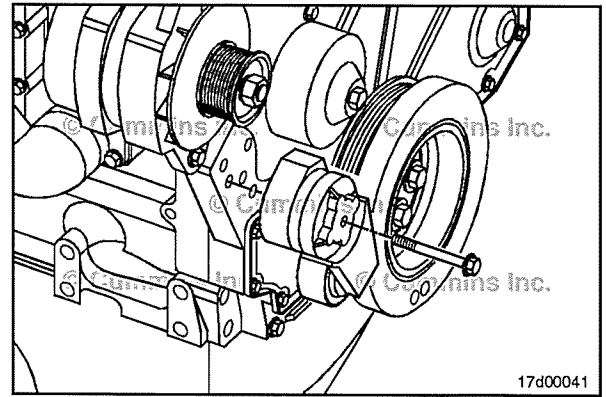
If removed, install the belt tensioner mounting bracket and mounting bracket capscrews.

NOTE: Some belt tensioner mounting brackets use internal fasteners for clearance.

Torque Value: 24 N•m [212 in-lb]

Install the belt tensioner and capscrew.

Torque Value: 43 N•m [32 ft-lb]



Fan Hub, Belt Driven (008-036)

Install

Install the fan hub and capscrews.

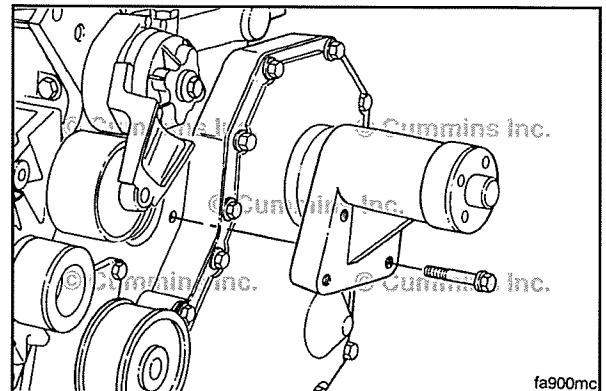
Tighten the capscrews.

Torque Value:

M10 Grade 8.8 43 N•m [32 ft-lb]

Torque Value:

M10 Grade 10.9 54 N•m [40 ft-lb]



Fan Spacer and Pulley (008-039)

Install

If the engine is **not** equipped with an engine driven cooling fan, install the fan pulley mounting capscrews and fan pulley.

Tighten the mounting capscrews finger-tight.

Tighten the mounting capscrews to the final torque value after the drive belt is installed, using the tension of the drive belt to keep the fan pulley from rotating.

Torque Value:

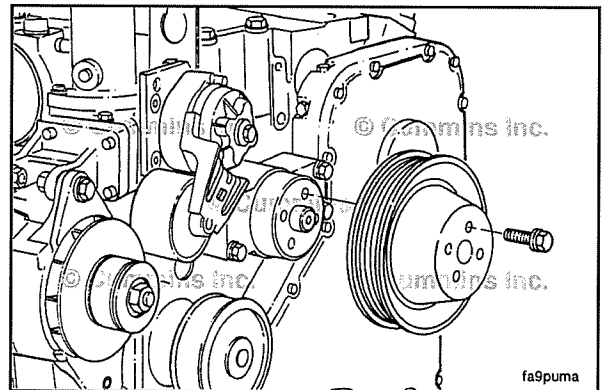
M6 10 N•m [89 in-lb]

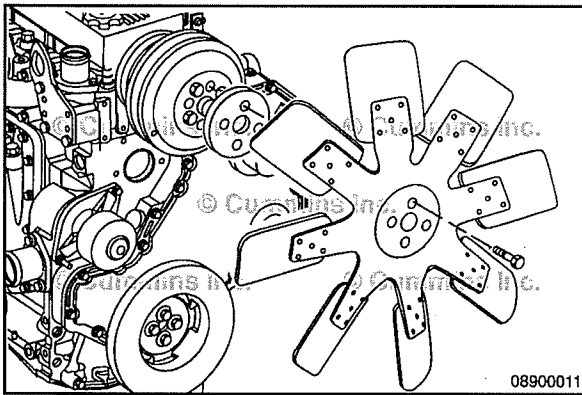
Torque Value:

M10 43 N•m [32 ft-lb]

Torque Value:

M12 77 N•m [57 ft-lb]





For engines equipped with an engine driven cooling fan, the fan holds the fan pulley and spacer in place. Install the fan pulley and spacer.



If removed, install the cooling fan. Refer to the OEM service manual for instructions.

Tighten the mounting capscrews finger tight.

Tighten the mounting capscrews to the final torque value after the drive belt is installed, using the tension of the drive belt to keep the fan pulley from rotating.

Do **not** hold the fan blades to keep the fan pulley or cooling fan from rotating.

Torque Value:

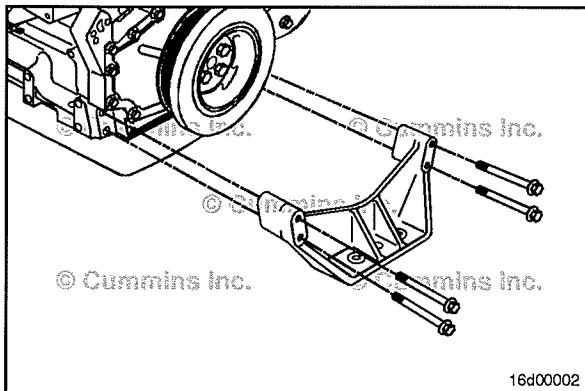
M6 10 N•m [89 in-lb]

Torque Value:

M10 43 N•m [32 ft-lb]

Torque Value:

M12 77 N•m [57 ft-lb]



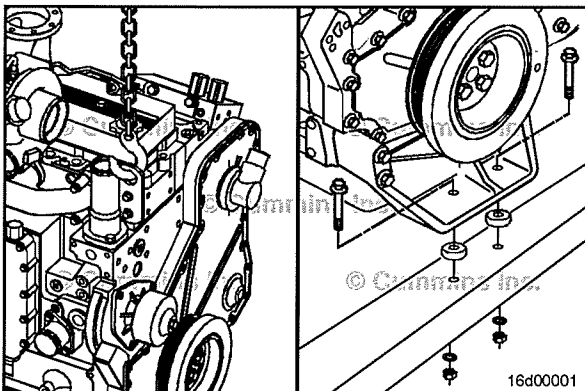
Engine Support Bracket, Front (016-002)

Install



Install the front support and mounting capscrews.

Torque Value: 112 N•m [83 ft-lb]



Lower the front of the engine.

NOTE: Make sure to install any shims or spacers in the same location as removed.



Install the front engine mount capscrews.

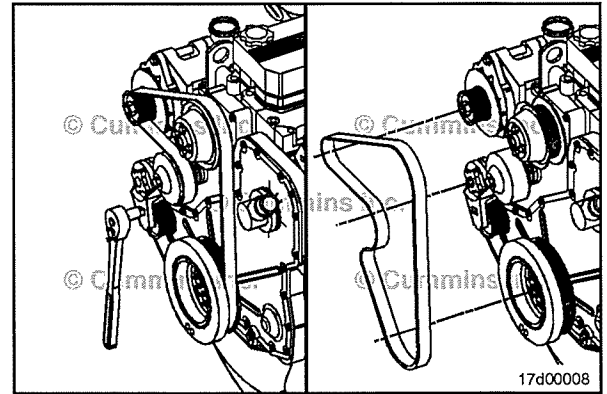
Tighten the capscrews to the manufacturer's specifications.

Remove the lifting fixture or hoist from the front of the engine.

Drive Belt, Cooling Fan (008-002)

Install

Route the drive belt on the engine. Use the belt diagram created in the Remove section. Do **not** install the belt over the water pump pulley at this time.



⚠CAUTION⚠

The belt tensioner is spring-loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

⚠CAUTION⚠

Applying excessive force in the opposite direction of windup or after the tensioner has been wound up to the positive stop can cause the tensioner arm to crack or break.

⚠CAUTION⚠

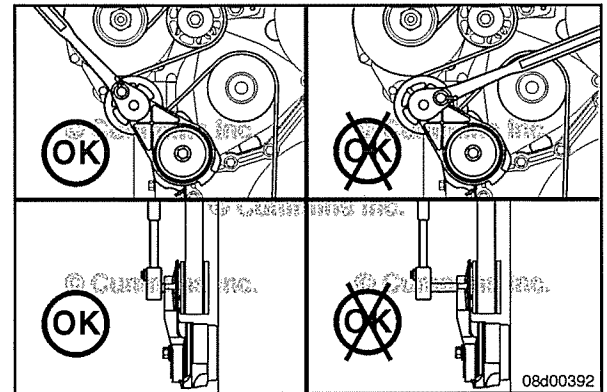
Using a socket extension is not recommended because it can cause axial twisting damage to the belt tensioner.

Pivot the tensioner in the direction of the spring tang and install the drive belt, slipping the belt over the water pump pulley last.

Slowly release the belt tensioner to apply tension to the drive belt.

NOTE: If a socket extension is necessary, support the head of the ratchet with one hand to prevent the belt tensioner arm from unintended loading.

Check the alignment of the belt with the tensioner and the rest of the front-end accessory drive.



Fuel Filter (Spin-On Type) (006-015)

Install

⚠CAUTION⚠

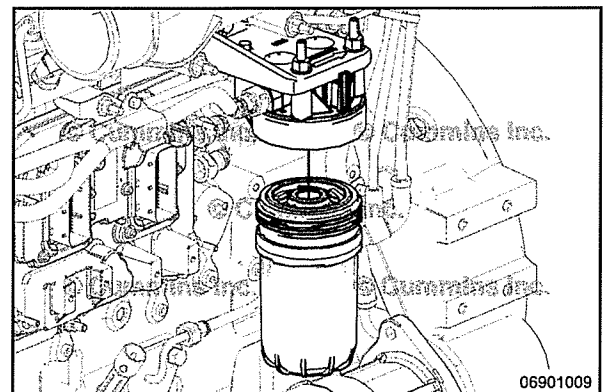
Mechanical overtightening can distort the threads as well as damage the filter element seal or filter canister.

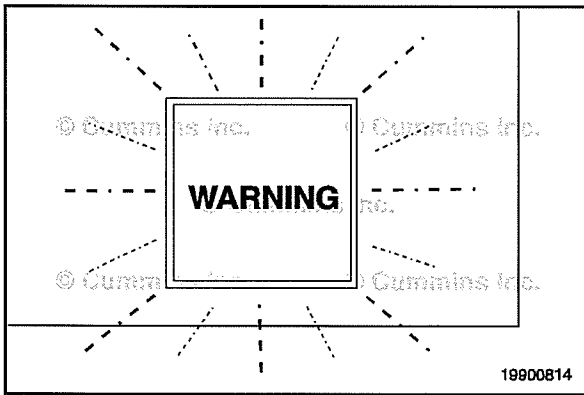
It will be necessary to fill the 8-micron water stripping (suction-side) fuel filter with fuel.

Do **not** fill the 5-micron (pressure-side) fuel filter with fuel before installation; instead, prime the fuel system using the fuel lift pump.

Install the filter as specified by the filter manufacturer.

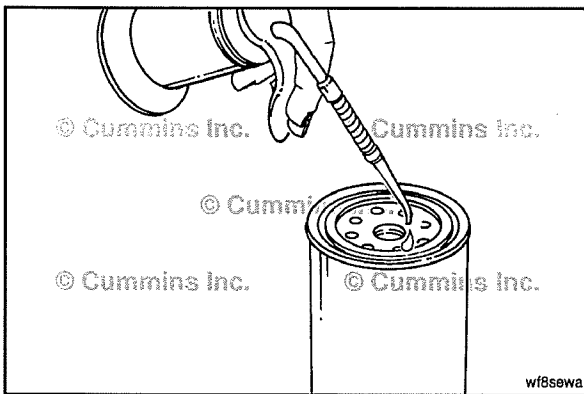
Connect the water-in-fuel sensor, if equipped.





The fuel system is capable of detecting the presence of the correct water-in-fuel sensor.

If the water-in-fuel sensor is incompatible or disconnected, the engine WARNING lamp will illuminate.



Coolant Filter (008-006)

Install



⚠ CAUTION ⚠

Do not allow oil to get into the filter. Oil will damage the DCA.



⚠ CAUTION ⚠

Mechanical over tightening can distort the threads or damage the filter head.



Apply a thin film of clean lubricating oil to the gasket sealing surface before installing the new coolant filter.

Install the coolant filter on the filter head. Tighten the filter until the gasket contacts the filter head surface.

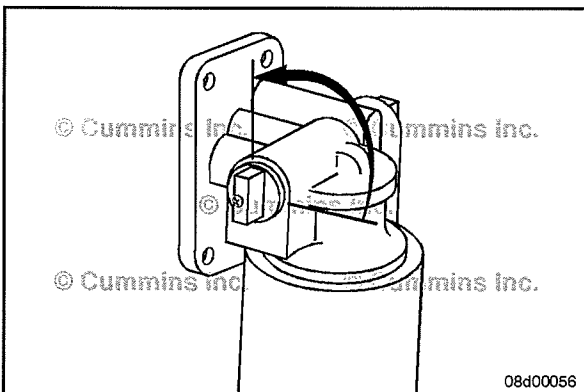
Tighten the coolant filter an additional $\frac{1}{2}$ to $\frac{3}{4}$ of a turn, or as specified by the filter manufacturer.

See Section V for coolant filter recommendations.

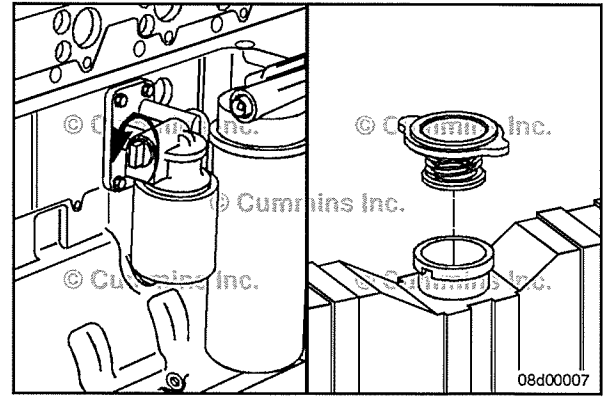
⚠ CAUTION ⚠

The valve must be in the ON position to prevent engine damage.

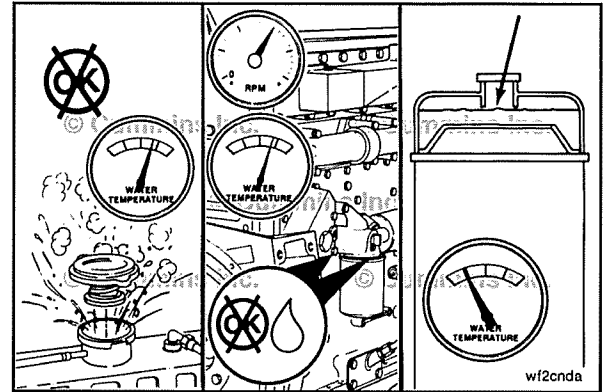
Turn the shutoff to the ON position by rotating the knob from the horizontal to the vertical position, as shown.



Install the coolant system pressure cap.



Operate the engine and check for coolant leaks.
Check the coolant level again after the air has been purged from the system.



Lubricating Oil Filter (Spin-On) (007-013)

Install

⚠ CAUTION ⚠

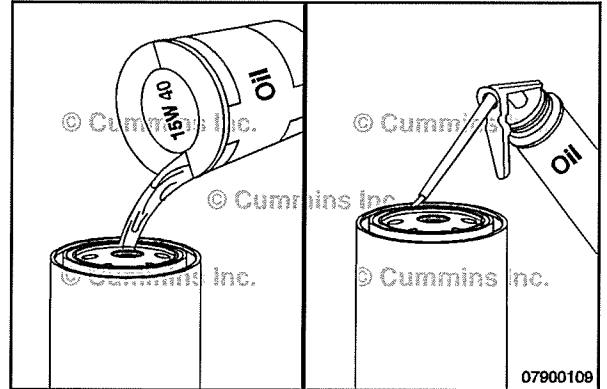
The lubricating oil filter should be full of oil at start-up to prevent engine damage.

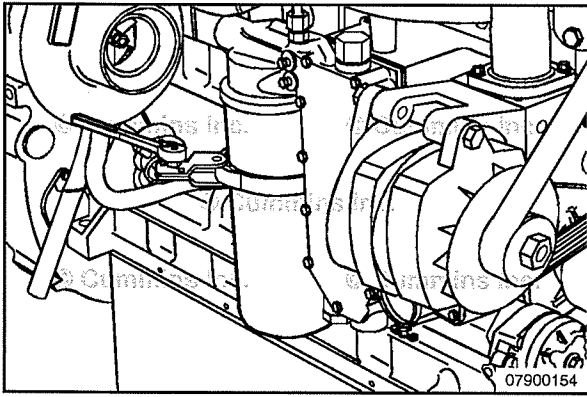
Use clean 15W-40 oil to coat the gasket surface of the filter.

Fill the filter with clean 15W-40 oil.

NOTE: Lubricating oil filters **must** have a filter bypass valve. Using a lubricating oil filter without a filter bypass valve will result in low engine oil pressure if the filter becomes plugged.

See Section V for lubricating oil filter recommendations.





⚠ CAUTION ⚠

Mechanical overtightening of the filter can distort the threads or damage the filter element seal.



Install the filter on the oil filter head. Tighten the filter until the gasket contacts the filter head surface.

Use an oil filter wrench to tighten the filter. See the filter manufacturer's instructions supplied with the filter.

Section 0 - Product - Group 00

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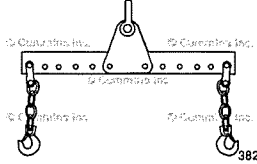
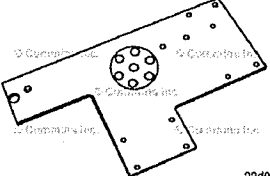
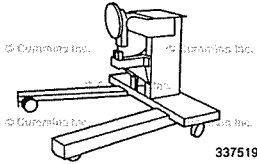
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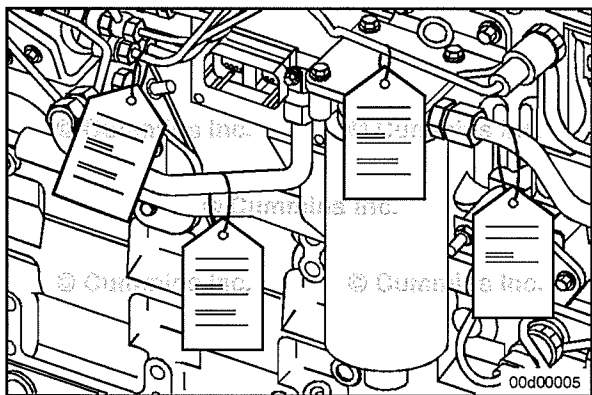
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Service Tools

Engine Disassembly/Assembly

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3162871	<p align="center">Engine Lifting Fixture</p> <p>Used to lift the engine during removal and installation.</p>	 <p align="right">3822512</p>
3822607	<p align="center">Engine Stand Adapter Plate</p> <p>Used to mount the engine to the rebuild stand.</p>	 <p align="right">22d00144</p>
3375194 or 3375193	<p align="center">Engine Rebuild Stand</p> <p>Portable tilt type engine rebuild stand.</p>	 <p align="right">3375194</p>



Engine Removal (000-001)

Remove

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ WARNING ⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠ WARNING ⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠ WARNING ⚠

Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

- Place a tag on all hoses, lines, linkages, and electrical connections as they are removed to identify their locations.
- Close the gas supply valve.
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Disconnect the starter cable, engine ground straps, cab or chassis to engine hoses, tubing, electrical wires, wire harnesses and hydraulic lines.
- Disconnect the drive units from the flywheel. Refer to the OEM service manual.
- Remove all chassis components necessary to remove the engine from the equipment.
- Cover all engine openings to prevent dirt and debris from entering the engine.

NOTE: On applications where the rear engine mounts are attached to the transmission, it will often be necessary to remove the engine and transmission as an assembly. Refer to the OEM service manual for instructions.

⚠ WARNING ⚠

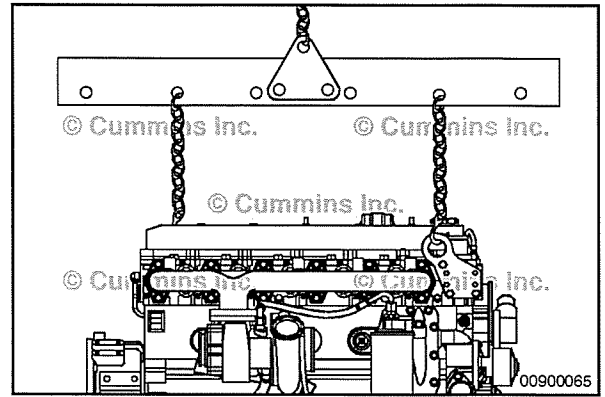
The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

Use a properly rated hoist and engine lifting fixture, attached to the engine-mounted lifting brackets, to remove the engine. Refer to Procedure 018-015 in Section V.

NOTE: If the transmission is **not** removed with the engine, place a support under the transmission to prevent it from falling before removing the engine.

Place the engine on suitable engine support stands.

Remove all remaining accessories and brackets to use with the replacement engine.



Engine Installation (000-002)

Install

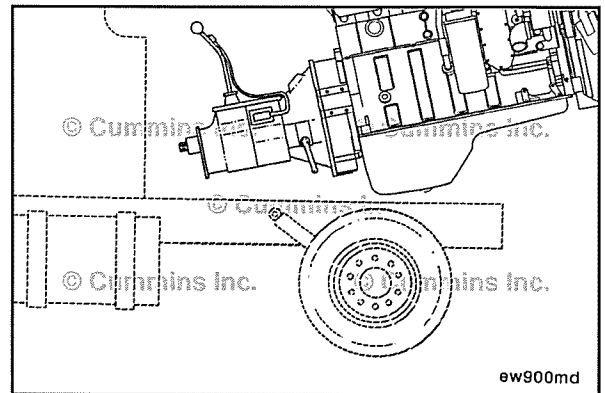
⚠ WARNING ⚠

The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

Install all accessories and brackets that were removed from the previous engine.

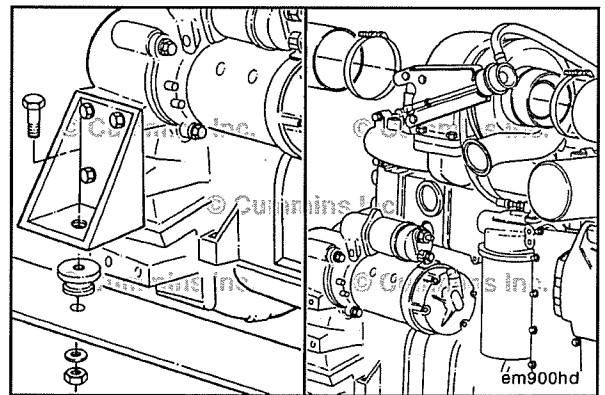
NOTE: On applications where the rear engine mounts are attached to the transmission, it will often be necessary to install the engine and transmission as an assembly.

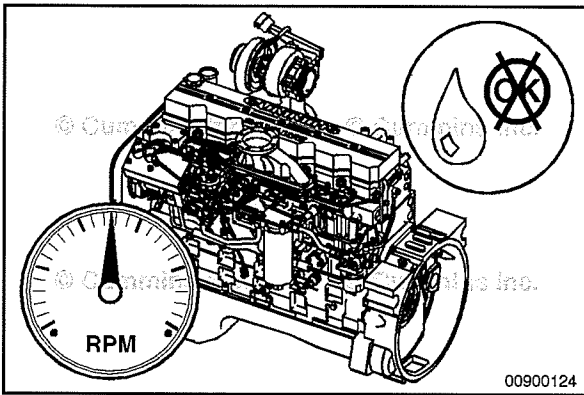
Use a properly rated hoist and engine lifting fixture, attached to the engine-mounted lifting brackets, to install the engine.



Align the engine in the chassis and tighten the engine-mounting capscrews. Refer to the OEM service manual for torque specifications.

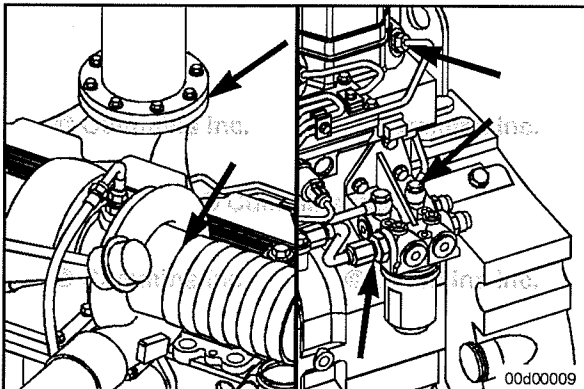
Connect all engine- and chassis-mounted accessories that were removed.



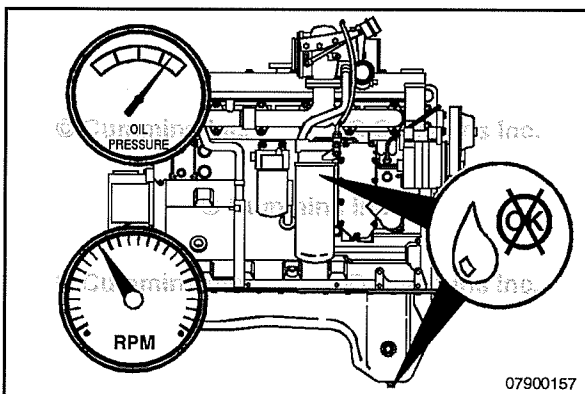


- Uncover all engine openings.
- Connect the drive units to the flywheel. Refer to the OEM service manual.
- Connect the starter cable, engine ground straps, cab or chassis to engine hoses, tubing, electrical wires, wire harnesses and hydraulic lines.
- Fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Fill the engine cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Remove all tags on all hoses, lines, linkages and electrical connections.

NOTE: Make sure all lines, hoses and tubes are properly routed and fastened to prevent damage. Make sure the air intake and exhaust pipe connections are tight and free of leaks.



Perform a final inspection to make sure that all hoses, wires, linkages, and components have been properly installed and tightened.



Crank the engine until the oil pressure gauge indicates a positive pressure.

Operate the engine at low idle for two to three minutes.

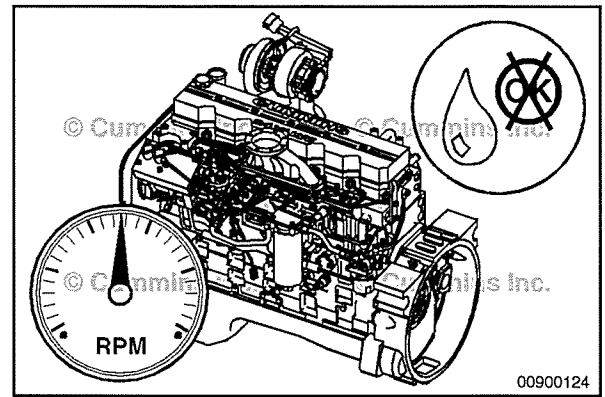
Shut off the engine and wait five to seven minutes for the oil to drain to the oil pan, and check the oil and coolant levels again.

Fill the engine to the correct oil and coolant levels, if necessary.

Operate the engine at 1000 to 1200 rpm for eight to 10 minutes. Check for proper operation, unusual noises, and coolant or oil leaks.



Repair all leaks and component problems. Refer to Procedure 014-008 in Section 14.



Engine Storage - Long Term (000-005)

General Information

⚠ CAUTION ⚠

After 24 months in storage, the engine cooling system must be drained and flushed with a suitable solvent or a hot, lightweight mineral oil. Repeat flushing procedure a second time before being put back into service.

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ WARNING ⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

This procedure describes the proper method for the long-term (more than 6 months) storage of an engine that is currently in running condition. This procedure applies to this engine either remaining in chassis - or being removed out of chassis upon completion of the steps below.

⚠ CAUTION ⚠

DO NO use fuel system preservative oil on Natural Gas or Propane Engines.

- Operate the engine at high idle until the coolant temperature is 70°C [160°F].
- Turn the engine off.
- Drain the oil.
- Install the drain plugs.
- Fill the engine to the high mark using Tectyl™ 910 or equivalent engine preservative oil. This will provide long term engine rust protection. The oil **must** meet military specification MIL-PRF-21260, Type P-10, Grade 2, SAE 30.
- Let the engine run for approximately 25 minutes at low idle in order to ensure that the engine preservative oil (Tectyl 910 E or equivalent) is distributed around the engine and its internal components.
- Turn the engine "OFF"
- Drain all the preservative oil from the engine oil pan sump, the air compressor (if applicable), and all the fuel filters and oil filters.
- Install the drain plugs.
- If the engine is being stored as a loose engine, drain the engine coolant and cover all cooling system openings with plastic and tape.
- If the engine is not being removed from chassis and the engine has an extended life coolant with rust inhibitor, then coolant does NOT need to be drained.
- If the engine will remain in storage for over 24 months, the engine cooling system must be drained and flushed with a suitable solvent or a hot, lightweight mineral oil. Repeat after each 24 month period.
- Remove the intake and exhaust manifolds.

- Spray preservative oil into the intake and exhaust ports in the cylinder heads and in the exhaust manifolds only. Do NOT use preservative oil on the intake manifold or any fuel system components as this may permanently damage sensors or valves.
- Spray preservative oil in the inlet port on the air compressor (if applicable)
- Remove the rocker lever covers.
- Spray the rocker levers, the valve stems, the springs, the valve guides, the crossheads, and the push rods with preservative oil.
- Install the rocker lever covers, intake and exhaust manifolds.
- Brush or spray the preservative oil on all the exposed metal surfaces that are **not** painted. Preservative oil should NOT be applied to any plastic, rubber, or similar surfaces. Make sure to coat the flywheel, flywheel housing and all other unpainted machined surfaces with this preservative oil. Use a rust preservative oil compound that meets military specification MIL-C-16173C, type P-2, Grade 1 or 2.
- For components containing exposed bearings that are not easily accessible e.g. Fan Hubs, remove the component to aid access. Brush or spray preservative oil on all surfaces that are not painted and refit the component. Use a rust preservative oil compound that meets military specification, MIL-C-16173C, type P-2, Grade 1 or 2
- Cover all the openings (engine and components) with heavy paper and tape to prevent dirt and moisture from entering the engine. Cover the entire engine with plastic.
- Put a warning tag on the engine. The tag **must** indicate:
 - Do **not** operate the engine.
 - Do **not** bar the crankshaft.
 - The engine has been treated with preservatives.
 - The coolant has been removed.
 - The date of treatment.
 - The date of the 6 week inspection if required.

△CAUTION△

The engine must be stored in an area that is dry and has uniform temperature.

- Remove any accessory drive belts to prevent localized stretching and deformation.
- If the engine can be stored inside a designated storage facility isolated from the external environment , ignore the following step.
- Excluding the crankshaft, ensure that all external dynamic engine components are rotated every 6 weeks. Ensure parts are free from corrosion, debris and water ingress. Record and date this on the engine tag created.

NOTE:

To remove the engine from long term storage, follow the following steps:

△CAUTION△

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

- Flush the engine preservative oil out of the engine by removing the plug from the main engine oil rifle and pumping a hot, lightweight mineral oil through it. Make sure that the engine crankshaft is barred at least three to four revolutions during this flushing procedure.
- Drain all the mineral oil that was used to flush the engine clean of the engine preservative oil.
- Install the drain plugs.
- Install new oil, fuel and coolant filters.
- Fill the engine to the high mark with engine oil.
 - If the engine has been in storage for less than 24 months and if the cooling system was drained, fill the cooling system with coolant. Refer to Procedure 018-004(Coolant Recommendations/Specifications) in Section V for antifreeze, water, and SCA specifications.
 - If the engine has been in storage for 24 months, every 24 months the engine cooling system must be drained and flushed with a suitable solvent or a hot, lightweight mineral oil. Fill the cooling system with coolant. Refer to Procedure 018-004(Coolant Recommendations/Specifications) in Section V for antifreeze, water, and SCA specifications.

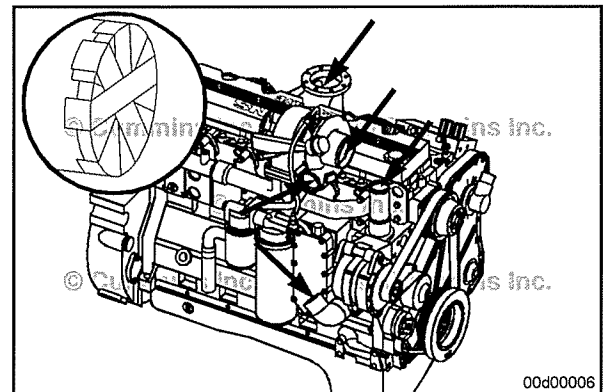
- If the engine has been in storage for less than 24 months and the engine has an extended life coolant with a rust inhibitor, drain the cooling system. Fill the cooling system with coolant. Refer to Procedure 018-004(Coolant Recommendations/Specifications) in Section V for antifreeze, water, and SCA specifications.
- Adjust the engine brake (if applicable) and valve clearances. Refer to the Overhead Set procedure in the corresponding Base Troubleshooting and Repair Manual or Service Manual for the engine being serviced.
- Tighten the intake and exhaust manifold mounting capscrews.
- Prime the lubricating system.
- Reinstall any accessory drive belts that were removed.
- Replace all spark plugs. Refer to the Spark Plugs procedure in the corresponding Base Troubleshooting and Repair Manual or Service Manual for engine being serviced.
 - Make sure all fuel lines are securely tightened and all fuel shutoff valves are open prior to attempting to start the engine.
- Start the engine.
 - Note that it might take multiple cranking attempts to start the engine. Do not crank the engine more than 30 seconds at a time as this might cause the starter to overheat and fail.
 - Note that the engine might run rough until the fuel system is completely primed or until all residual fuel system preservative oil is completely flushed out of the fuel system (if the fuel has been treated with fuel system preservative oil).
- Install the exhaust aftertreatment components (if applicable).
- Force an active regeneration (if applicable).

Engine Painting (000-007) Preparatory Steps

Remove all belts from the engine.

Cover the following parts of the engine:

- Exhaust and intake openings
- Electrical components
- Fuel inlet and drain connections.



⚠ WARNING ⚠

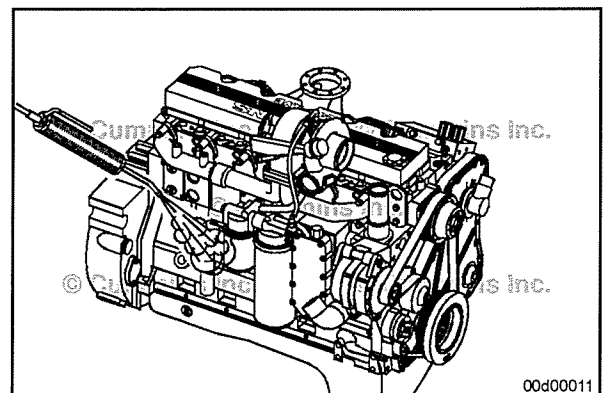
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

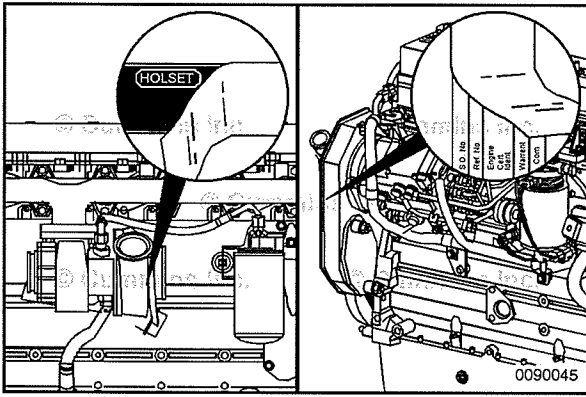
⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use steam to clean the engine, and dry with compressed air. Avoid prolonged, direct steam or water spray on electrical components.

NOTE: Make sure all engine surfaces are clean and dry before painting the engine.

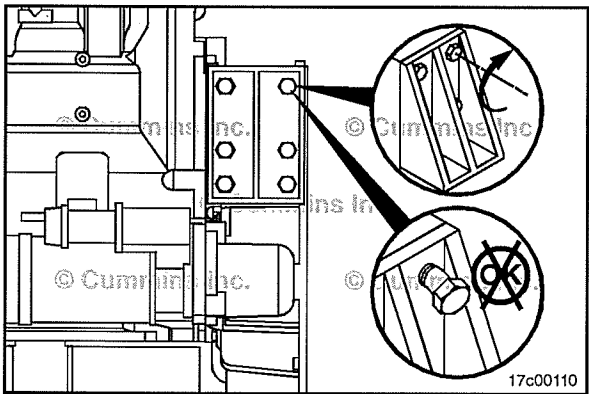
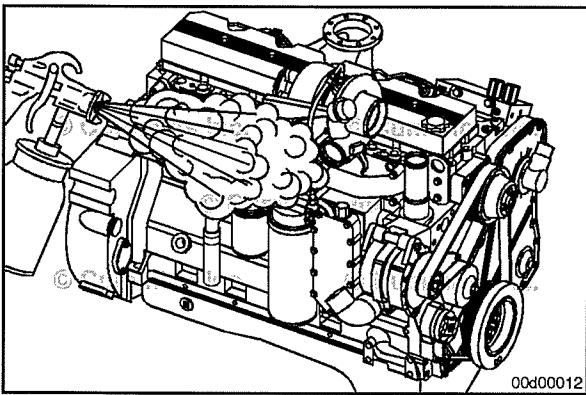




Protect the following components from the paint:

- All dataplates (engine, engine control module (ECM), fuel pump, turbocharger, air compressor, etc.)
- Exhaust manifold
- Turbocharger turbine housing
- Flywheel
- Flywheel housing transmission mounting surface
- Electrical connections
- All decals
- All pulley belt surfaces
- Any exposed fittings, threads, and electrical wire terminals.

Paint the engine.



Engine Mounting Bolts (000-008) Maintenance Check



⚠CAUTION⚠

Damaged engine mounts and brackets can cause engine misalignment. Driveline component damage can result in vibration complaints.



Inspect all rubber-cushioned mounts for cracks or damage.

Inspect all mounting brackets for cracks or damaged bolt holes.

Check the torque on the engine-mounting nuts and bolts. Tighten any that are loose. Refer to the original equipment manufacturer (OEM) service manual for torque specifications.

Engine Steam Cleaning (000-009) Clean

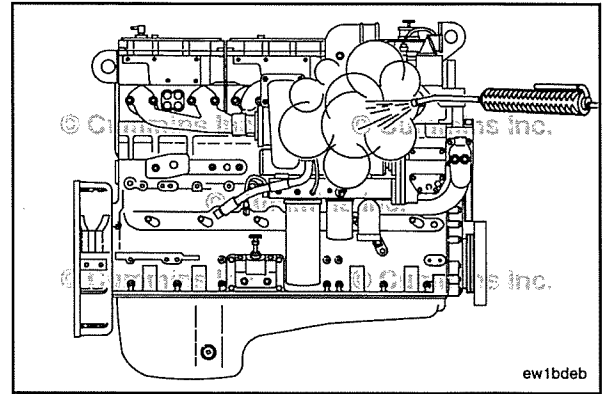


⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

Steam is the best method of cleaning a dirty engine or a piece of equipment. If steam is **not** available, use a solvent to wash the engine.

Protect all electrical components, openings, and wiring from the full force of the cleaner spray nozzle.



Section 1 - Cylinder Block - Group 01

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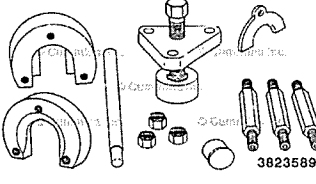
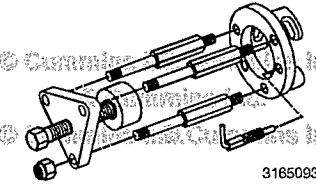
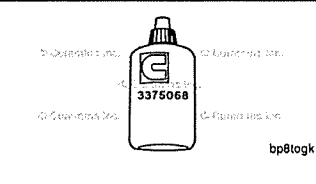
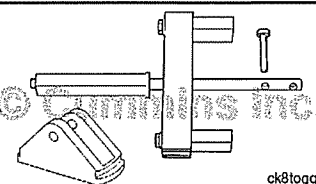
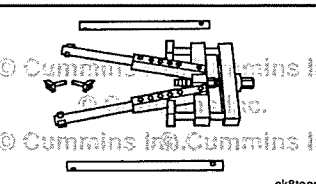
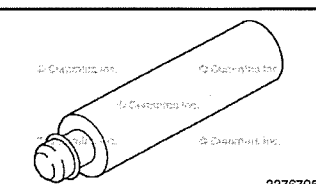
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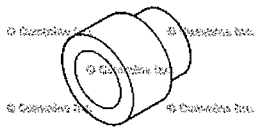
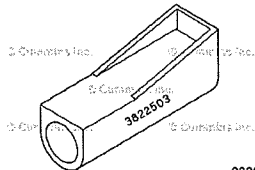
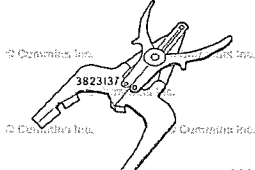
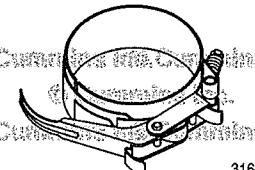
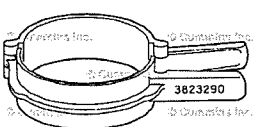
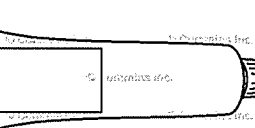
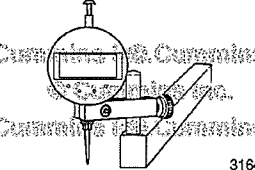
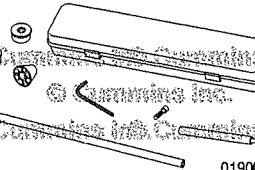
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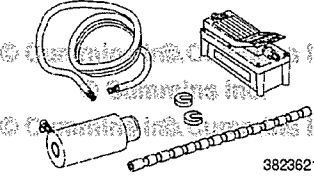
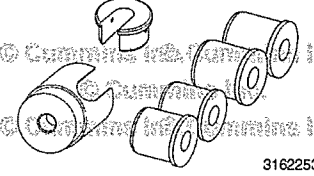
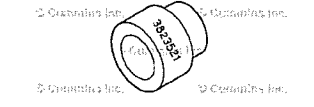
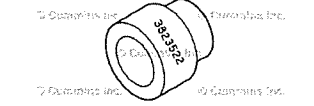

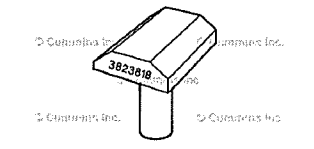
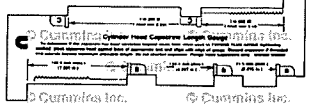
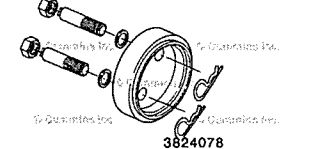
Service Tools

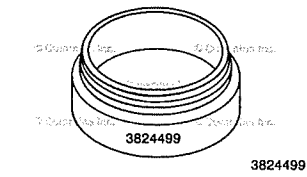
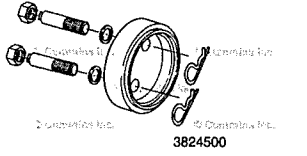
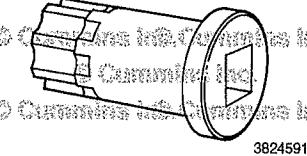
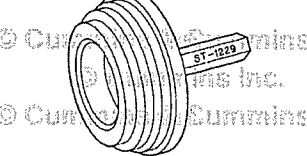
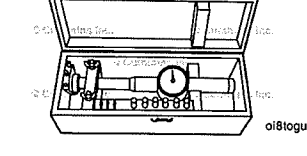
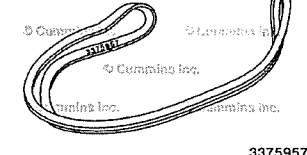
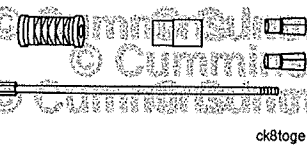

Cylinder Block

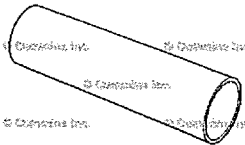
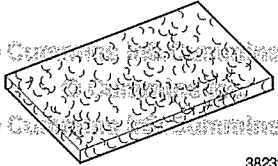
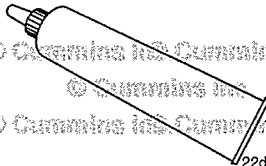
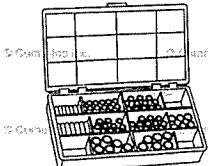
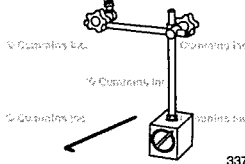
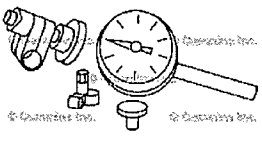
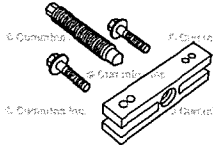
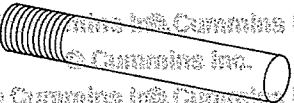
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

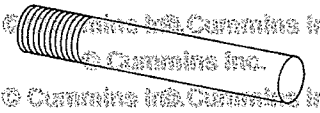
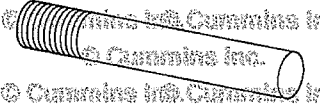
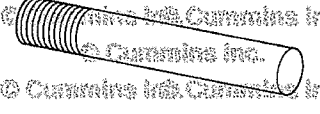
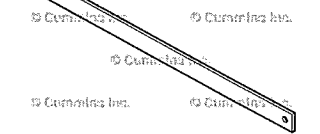
Tool No.	Tool Description	Tool Illustration
3163054	<p align="center">Camshaft Gear Installation and Removal Tool</p> <p>Used to remove and install the camshaft gear. Engines without a tapped hole in the camshaft will require partial camshaft removal in order to remove the camshaft gear.</p>	 <p align="right">3823589</p>
3165093	<p align="center">Camshaft Gear Installation and Removal Tool</p> <p>Used to remove and install the camshaft gear without removing the camshaft. Can only be used on engines with a tapped hole in the camshaft. Use with camshaft gear installation and removal tool, Part Number 3163054.</p>	 <p align="right">3165093</p>
3375068	<p align="center">Cup Plug Sealant</p> <p>Used when installing pipe plugs and cup plugs, to prevent leaks.</p>	 <p align="right">bp8togk</p>
3163745	<p align="center">Cylinder Liner Puller</p> <p>Used to remove cylinder liners from the cylinder block. Requires the cylinder liner puller plate, Part Number 3822786.</p>	 <p align="right">ck8togq</p>
3376015	<p align="center">Cylinder Liner Puller (Universal)</p> <p>Used to remove cylinder liners from the cylinder block. Requires two puller arm extension feet, Part Number 3376649.</p>	 <p align="right">ck8togr</p>
3164085	<p align="center">Expansion Plug Driver Handle</p> <p>Used with all expansion plug drivers larger than 9.525 mm [0.375 in] diameter.</p>	 <p align="right">3376795</p>

Tool No.	Tool Description	Tool Illustration
3376816	<p align="center">Expansion Plug Driver</p> <p>Used to install 25.4 mm [1.00 in] expansion plug to specified depth. Used with expansion plug driver handle, Part Number 3164085.</p>	 <p align="right">3376816</p>
3822503	<p align="center">Cylinder Liner Clamp Set</p> <p>Used to clamp the liner into the bore of the cylinder block. Requires two cylinder head capscrews not included in clamp set.</p>	 <p align="right">3822503</p>
3823137	<p align="center">Piston Ring Expander</p> <p>Used to install piston rings onto pistons without damaging or distorting the rings.</p>	 <p align="right">3823137</p>
3164604	<p align="center">Piston Ring Compressor</p> <p>Used to compress the piston rings while installing the pistons into the cylinder bores.</p>	 <p align="right">3164604</p>
3823290	<p align="center">Piston Ring Compressor</p> <p>Used to compress the piston rings while installing the pistons into the cylinder bores.</p>	 <p align="right">3823290</p>
3164067	<p align="center">RTV Sealant</p> <p>Used to seal the front gear cover and other joints.</p>	 <p align="right">22d00152</p>
3164438	<p align="center">Depth Gauge Assembly</p> <p>Used to measure cylinder liner protrusion, cylinder block counterbore depths, and valve intrusion and or protrusion. Equipped with an electronic digital indicator.</p>	 <p align="right">3164438</p>
3165045	<p align="center">Camshaft Bushing Tool</p> <p>Used to remove and install camshaft bushings. NOTE: The following 2 kits are also available for this purpose.</p>	 <p align="right">01900239</p>

Tool No.	Tool Description	Tool Illustration
3823621	<p align="center">Hydraulic Actuator Kit</p> <p>Used to remove and install camshaft bushings.</p>	 <p align="right">3823621</p>
3162253	<p align="center">Camshaft Bushing Installation/Removal Kit</p> <p>Used to remove and install camshaft bushings.</p>	 <p align="right">3162253</p>
3823521	<p align="center">Expansion Plug Driver</p> <p>Used to install 20.638 mm [0.8125 in] expansion plug to specified depth. Used with expansion plug driver handle, Part Number 3164085.</p>	 <p align="right">3823521</p>
3823522	<p align="center">Expansion Plug Driver</p> <p>Used to install 30.16 mm [1.1875 in] expansion plug to specified depth. Used with expansion plug driver handle, Part Number 3376795.</p>	 <p align="right">3823522</p>
3823523	<p align="center">Expansion Plug Driver</p> <p>Used to install 34.925 mm [1.375 in] expansion plug to specified depth. Used with expansion plug driver handle, Part Number 3376795.</p>	 <p align="right">3823523</p>
3823818	<p align="center">Main Bearing Rollout Tool</p> <p>Used to remove and install main bearings with the crankshaft installed.</p>	 <p align="right">3823818</p>
3823921	<p align="center">Capscrew Length Gauge</p> <p>Used to measure capscrew free length.</p>	 <p align="right">3823921</p>
3824078	<p align="center">Rear Wear Sleeve Installation Tool</p> <p>Used to install the rear crankshaft lubricating oil seal wear sleeve.</p>	 <p align="right">3824078</p>

Tool No.	Tool Description	Tool Illustration
3824499	<p align="center">Lubricating Oil Seal Installation Tool</p> <p>Used to install the front crankshaft lubricating oil seal in the front cover seal carrier.</p>	 <p align="right">3824499</p>
3165112	<p align="center">Wear Sleeve Installation Tool</p> <p>Used to install the crankshaft front oil wear sleeves.</p>	 <p align="right">3824500</p>
3824591	<p align="center">Engine Barring Gear</p> <p>Used to engage the flywheel ring gear to rotate the crankshaft.</p>	 <p align="right">3824591</p>
ST-1229	<p align="center">Cylinder Liner Driver</p> <p>Used to install cylinder liners into the cylinder block.</p>	 <p align="right">ST-1229</p>
3376619	<p align="center">Dial Bore Gauge Kit</p> <p>Used to measure internal diameter bores from 78.5 mm [3.09 in] to 203.2 mm [8.00 in].</p>	 <p align="right">3376619</p>
3375957	<p align="center">Nylon Lifting Sling</p> <p>Aid in removal and installation of the crankshaft, flywheel, and other heavy components up to 907 kg [2000 lb].</p>	 <p align="right">3375957</p>
3163720	<p align="center">Dowel Pin Extractor Kit</p> <p>Used to remove solid locating pins from the cylinder block. Kit includes SAE and metric sizes.</p>	 <p align="right">3163720</p>
3375432	<p align="center">Crack Detection Kit</p> <p>Used to locate cracks in cylinder blocks, cylinder heads; as well as in other engine components.</p>	 <p align="right">3375432</p>

Tool No.	Tool Description	Tool Illustration
3824496	<p align="center">Connecting Rod Guide Pins</p> <p>Used to prevent damage to the crankshaft during piston installation on engines built with connecting rod studs.</p>	 <p align="right">3824496</p>
3823258	<p align="center">Abrasive Hand Pad</p> <p>Used to remove corrosion or carbon buildup.</p>	 <p align="right">3823258</p>
3163087	<p align="center">Assembly Lubricant</p> <p>A 10-ounce tube of multi-purpose lubricant.</p>	 <p align="right">22d00293</p>
3822709	<p align="center">Thread Insert Kit</p> <p>Used to repair several sizes of cylinder block threads.</p>	 <p align="right">3822709</p>
3377399	<p align="center">Dial Indicator Magnetic Base</p> <p>Used in conjunction with dial indicator, Part Number 3824564 (metric), or Part Number 4918289 (SAE).</p>	 <p align="right">3377399</p>
3824564	<p align="center">Dial Indicator, Metric</p> <p>Used with indicator base, Part Number 3377399.</p>	 <p align="right">3824564</p>
ST-647	<p align="center">Standard Puller</p> <p>Used to remove drive pulleys, impellers, and air compressor counterweights.</p>	 <p align="right">ad8toga</p>
3163934	<p align="center">Assembly Guide Pin</p> <p>M12 x 1.75</p>	 <p align="right">3822784</p>

Tool No.	Tool Description	Tool Illustration
3163935	<p style="text-align: center;">Assembly Guide Pin</p> <p>M10 x 1.25</p>	 <p style="text-align: right;">3822784</p>
3163936	<p style="text-align: center;">Assembly Guide Pin</p> <p>M8 x 1.0</p>	 <p style="text-align: right;">3822784</p>
3376488	<p style="text-align: center;">Assembly Guide Pin</p> <p>M10 x 1.5</p>	 <p style="text-align: right;">3822784</p>
3164977	<p style="text-align: center;">Assembly Guide Pin</p> <p>M8 x 1.25</p>	 <p style="text-align: right;">3822784</p>
4918219	<p style="text-align: center;">Precision Straightedge</p> <p>Used to check cylinder blocks for flatness.</p>	 <p style="text-align: right;">22d00222</p>

Bearings, Connecting Rod (001-005)

Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠ WARNING ⚠

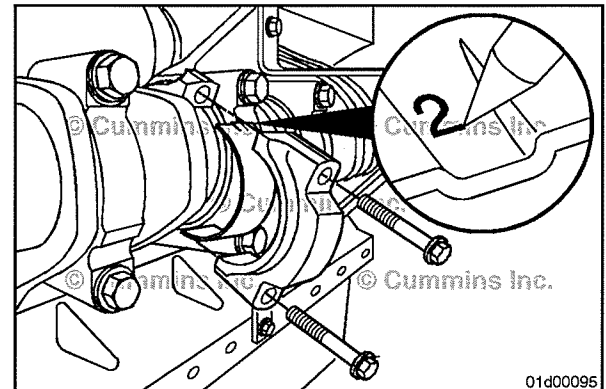
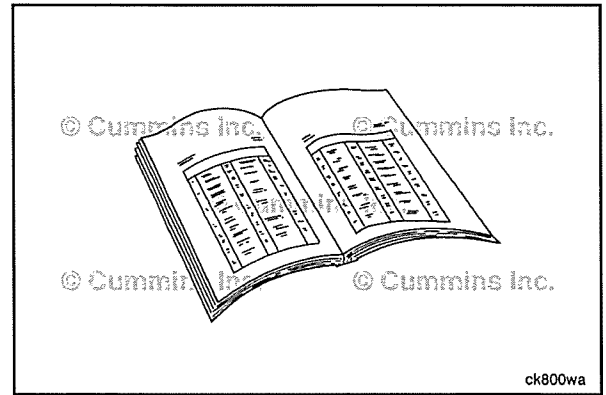
Some state and federal agencies have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

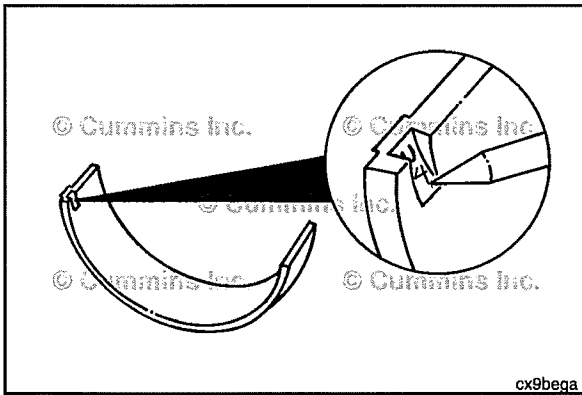
- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7.
- Remove the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.

Remove

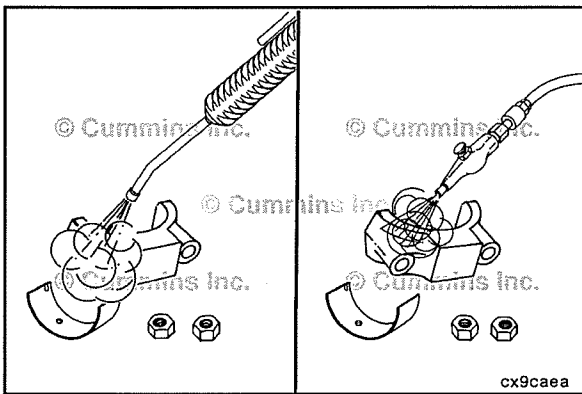
NOTE: The cylinder head does **not** need to be removed if the connecting rod bearings are being inspected or replaced.

Remove the connecting rod caps. Refer to Procedure 001-054 in Section 1.





Remove the upper bearing shell and mark it with the letter "U" (upper) and the cylinder number from where it was removed. The upper bearings also have a red color coating.



Clean and Inspect for Reuse

⚠️ WARNING ⚠️

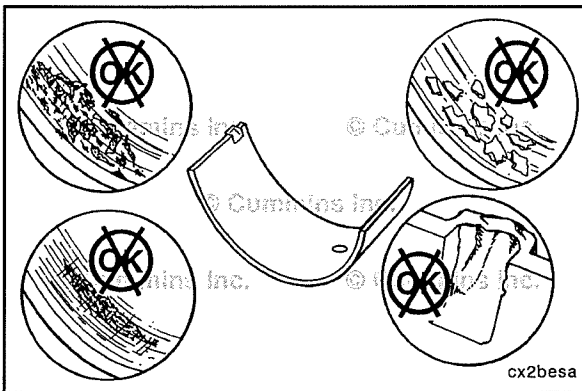


Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Wash the bearing and connecting rod caps.

Dry with compressed air.

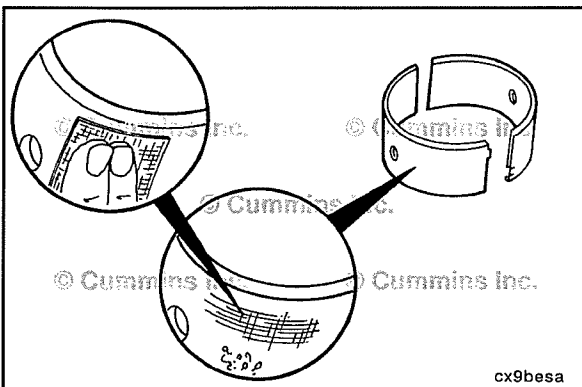
Inspect the connecting rod caps, connecting rod bearing saddles, and capscrews for nicks, cracks, burrs, scratches, or fretting.



Inspect the bearings for damage.

Replace any bearings with the following damage:

- Pitting
- Flaking
- Corrosion
- Lock tang damage
- Scratches.



Inspect the bearing shell seating surface for nicks or burrs.



If nicks or burrs can **not** be removed with abrasive pad, Part Number 3823258, or equivalent, the bearings **must** be replaced.

NOTE: If bearings are damaged they **must** be replaced as a set.

NOTE: For more detailed information of bearing damage, see to Analysis and Prevention of Bearing Failures, Bulletin 3810387.

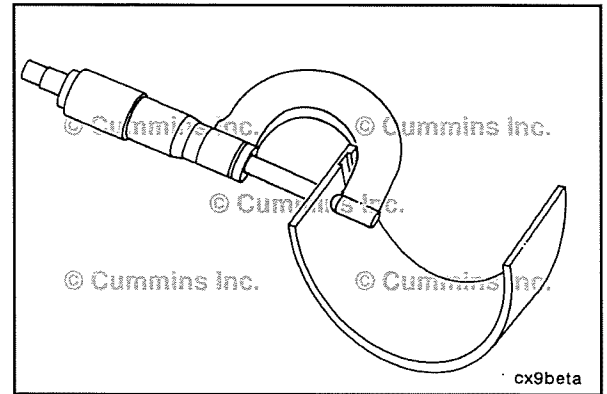
Measure the rod bearing shell thickness with an outside micrometer that has a ball tip.



Connecting Rod Bearing Dimensions

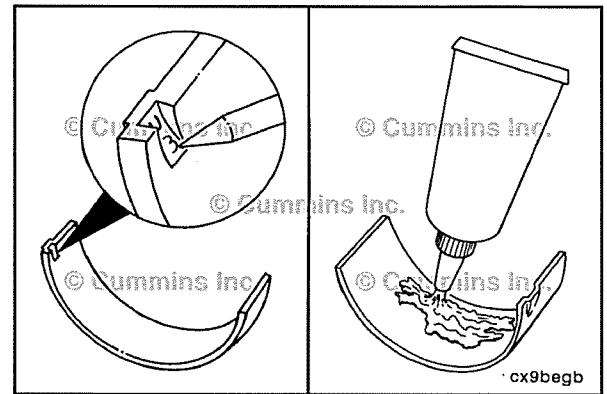
	mm		in
Standard	2.457	MIN	0.0968
	2.469	MAX	0.0972

Discard a bearing shell if its thickness is below the minimum specification.



Install

For connecting rod bearing installation instructions use the following. Refer to Procedure 001-054 in Section 1.

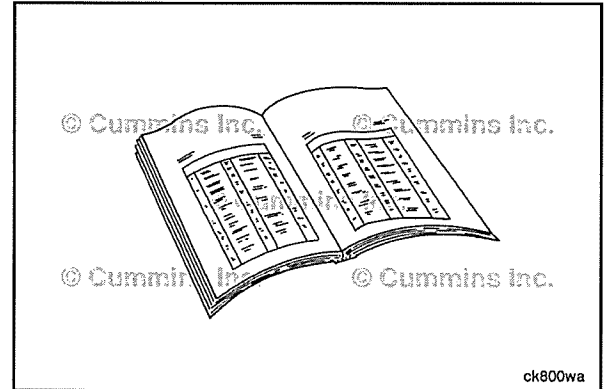


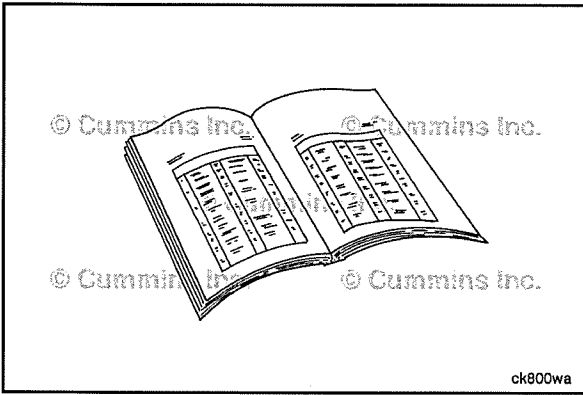
Finishing Steps

⚠ WARNING ⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7.
- Fill the lubricating oil pan. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.





Bearings, Main (001-006)

Preparatory Steps



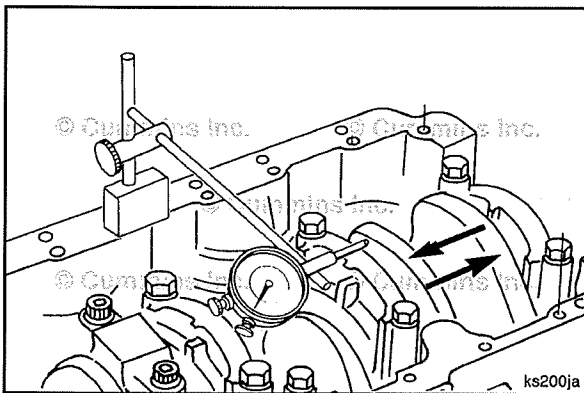
⚠ WARNING ⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠ WARNING ⚠

Some state and local agencies have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7.
- Remove the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.



Initial Check

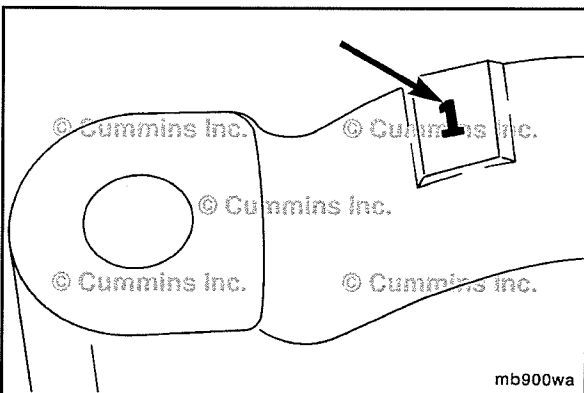
The dimensions of the thrust bearing and crankshaft journal determine end clearance.

Measure the crankshaft end clearance using dial indicator, Part Number 3824564, and magnetic base, Part Number 3377399.

Crankshaft End Clearance Limits

mm		in
0.085	MIN	0.003
0.385	MAX	0.015

If the crankshaft end clearance is **not** within specification, make sure to inspect the crankshaft and thrust bearing surfaces for damage.



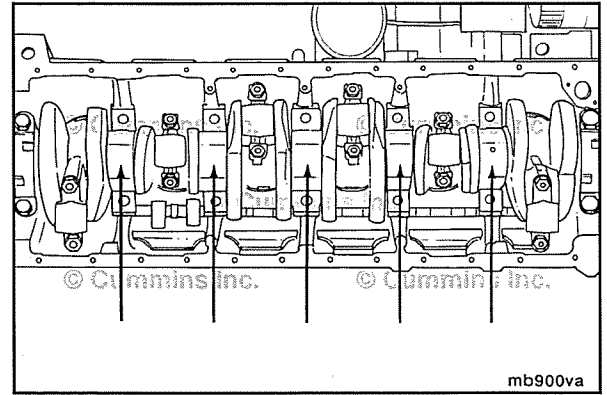
Remove

Before removing the main bearing caps, make certain that the caps are clearly marked for their location on the lubricating oil cooler side of the main bearing cap.

The number one cap is at the front of the engine.

When replacing bearings in chassis, replace number 2 through number 6 while the number 1 and number 7 caps support the crankshaft. After replacing number 2 through number 6, replace number 1 and number 7.

Remove all main bearing caps except the number 1 and number 7 main bearing caps.



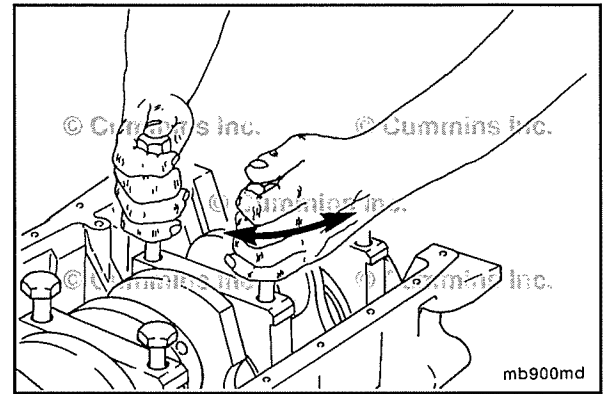
⚠ CAUTION ⚠

Do not pry on the main bearing caps to free them from the cylinder block. Damage to the main bearing caps and cylinder block can result.

Loosen the main bearing capscrews completely, but do not remove.

Use two of the main bearing cap bolts to wiggle the main bearing cap loose, being careful not to damage the bolt threads.

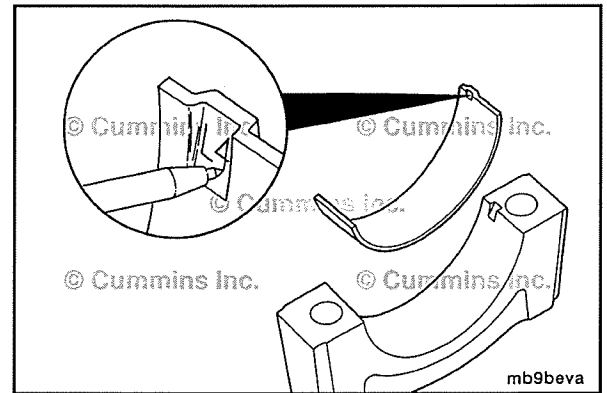
Remove the main bearing cap.



Mark the main bearings for position and number as they are removed.

Use an awl to mark the bearing position in the tang area.

NOTE: Marking the bearing position is for future identification or possible future analysis.



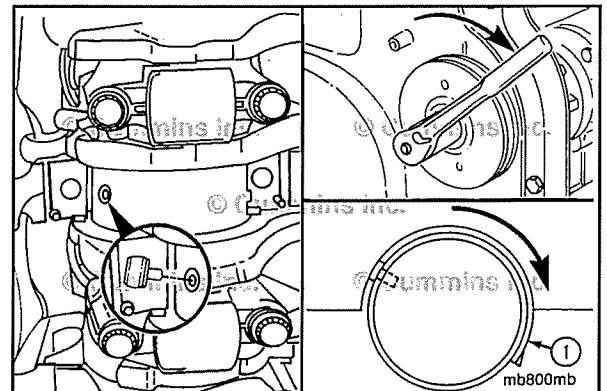
To remove the upper main bearings, install the main bearing replacer, Part Number 3823818, in the oil hole of the crankshaft main bearing journal.

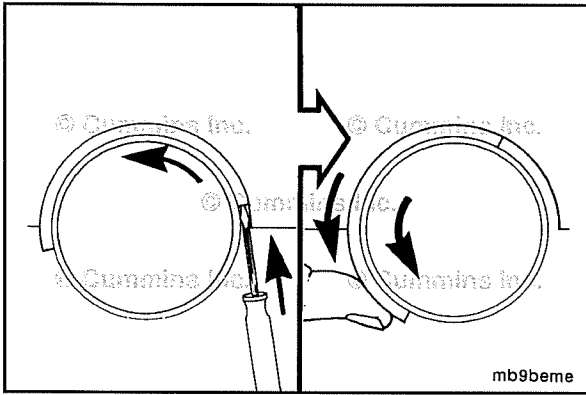
Rotate the crankshaft so that the replacer contacts the upper main bearing on the side opposite the tang.

Continue to rotate the crankshaft in the direction that will remove the tang side (1) of the upper main bearing first.

Remove the bearing.

Follow this procedure to remove the other main bearings except for number 1 front main bearing.



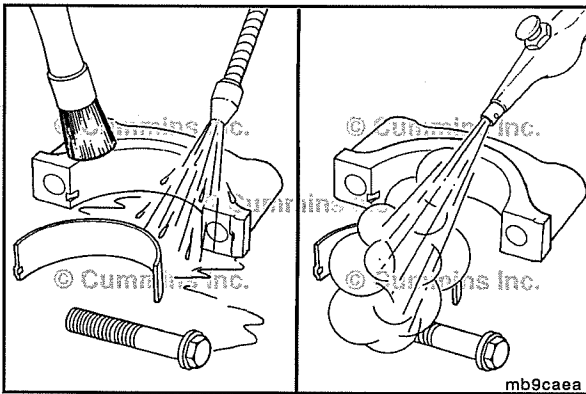


⚠ CAUTION ⚠

Use care so the screwdriver does not damage the crankshaft or cylinder block.

NOTE: The front main bearing, number 1, does **not** have a hole in the journal, so the tool can **not** be used to replace the bearing.

Use a flat blade screwdriver to gently bump the end of the bearing to loosen it from the cylinder block. Then, use finger pressure against the main bearing shell and rotate the crankshaft to roll the main bearing out.



Clean and Inspect for Reuse

⚠ WARNING ⚠

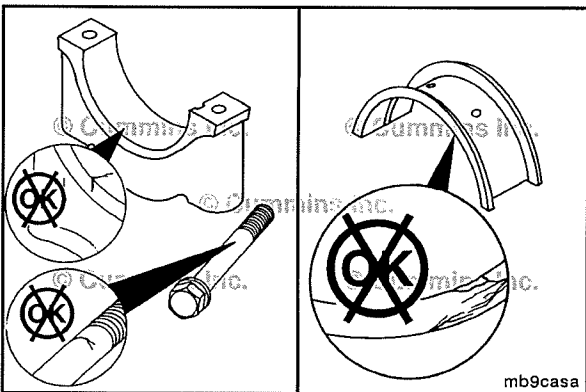
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

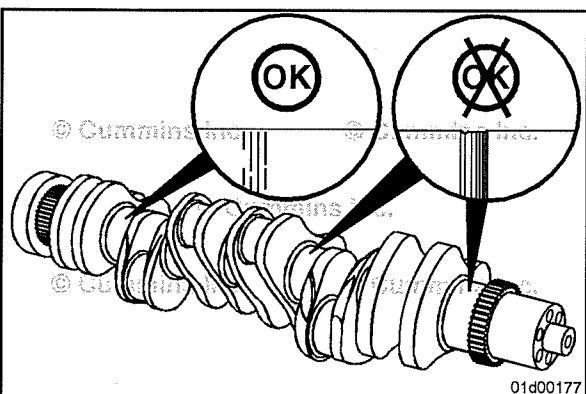
Steam clean the main bearing caps.

Dry with compressed air.



Inspect all main bearing caps and main bearing crankshaft journals for deep scoring, overheating, etc.

Replace any damaged components. If the main bearing cap is damaged, the block **must** be replaced.



Check the crankshaft main bearing journals for damage or excessive wear. Minor scratches are acceptable.

If crankshaft end clearance measured during the initial check was found to be out of specification, make sure to inspect the crankshaft thrust surface for excessive wear or damage. Minor scratches are acceptable.

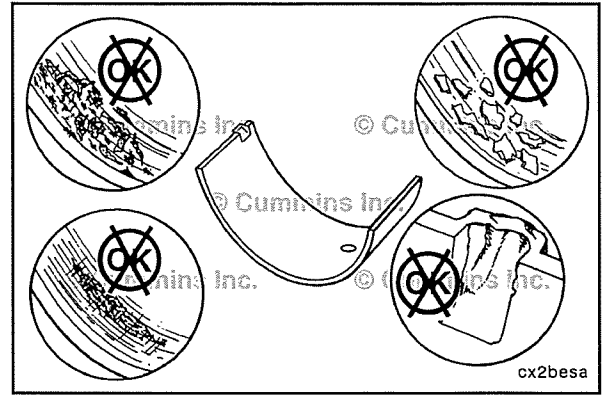
If damage is found, the crankshaft **must** be removed. Refer to Procedure 001-016 in Section 1.

Also inspect the thrust bearing surfaces for excessive wear. Replace the thrust bearing(s) if excessive wear is found.

Inspect the bearings for damage.

Replace any bearings with the following damage:

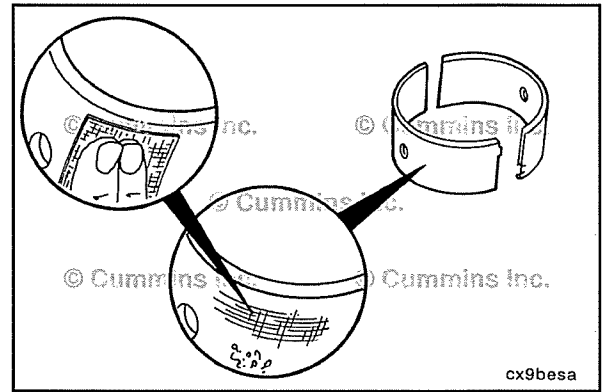
- Pitting
- Flaking
- Corrosion
- Lock tang damage
- Scratches.



Inspect the bearing shell seating surfaces for nicks or burrs. If nicks or burrs can **not** be removed with an abrasive pad, Part Number 3823258, or equivalent, the bearings **must** be replaced.

NOTE: If bearings are damaged, they **must** be replaced as a set.

NOTE: For more detailed information on bearing damage, see Analysis and Prevention of Bearing Failures, Bulletin 3810387.

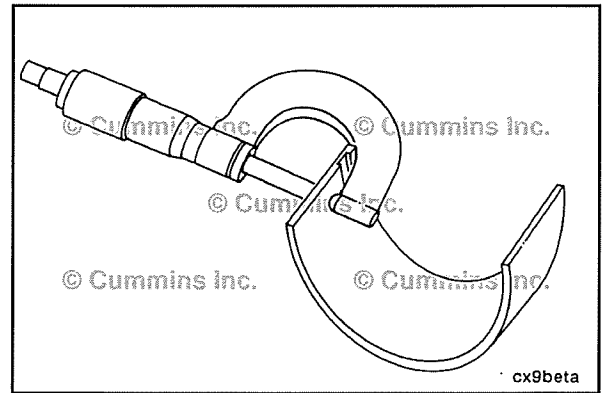


Measure the main bearing shell thickness with an outside micrometer that has a ball tip.

Main Bearing Dimensions

	mm		in
Standard	3.446	MIN	0.1357
	3.454	MAX	0.1360

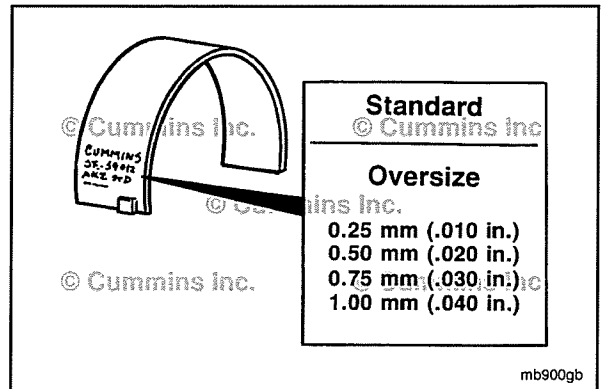
Discard a bearing shell if its thickness is below the minimum specification.

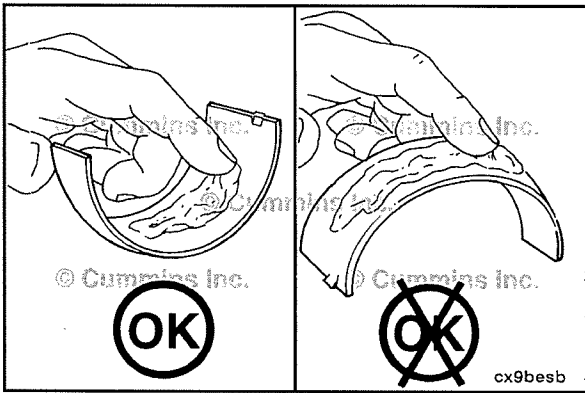


NOTE: Main bearings are identified with a part number and size stamped on the back side.

If replacing the bearings, determine the size of the removed main bearings and obtain a set of the same size.

Oversize service main bearings are available for use with crankshafts that have been machined undersize. See the appropriate parts catalog.





Install

Upper Main Bearings

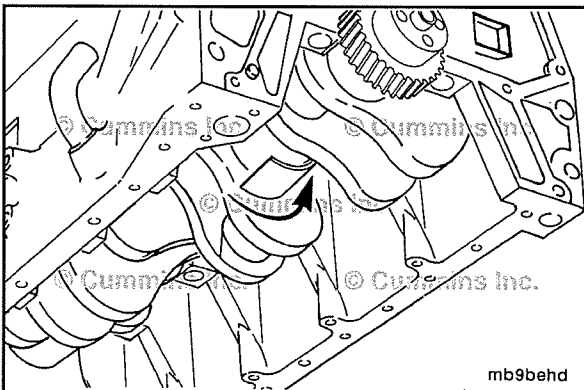
Do **not** lubricate the side that is against the cylinder block.

NOTE: Make sure the main bearing being installed is same size as the main bearing removed. The size is engraved on the back of the main bearing.

Apply a coat of assembly lubricant, Part Number 3163086, or equivalent, to the crankshaft side of the main bearings.

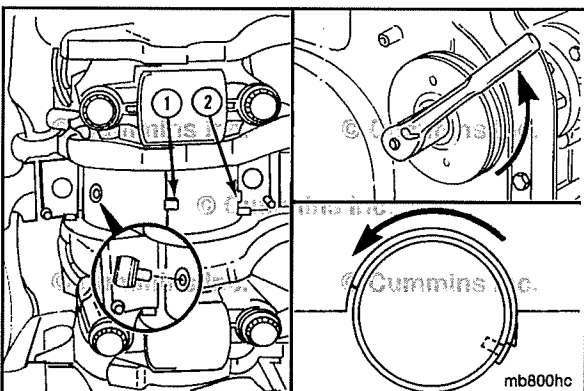
NOTE: The crankshaft thrust bearing **must** be installed in the number four position.

NOTE: The upper and lower main bearing shells of some engines are **not** interchangeable. The backs of the main bearings are marked with the proper orientation, if required.



Insert the side of the main bearing opposite the tang first. Install as far as possible by hand.

When installing the thrust bearing in the number four journal, it could be necessary to push the crankshaft to the front or rear of the cylinder block.



Follow this step to finish installing the upper main bearings, except for number 1 front main bearing.

Make sure the pin does not slide under the bearing.

Use the main bearing replacer, Part Number 3823818, to finish installing the main bearing by rotating the crankshaft. Rotate the crankshaft using the barring tool, Part Number 3824591.

Make sure the tang (1) on the main bearing is located in the notch (2) of the cylinder block.

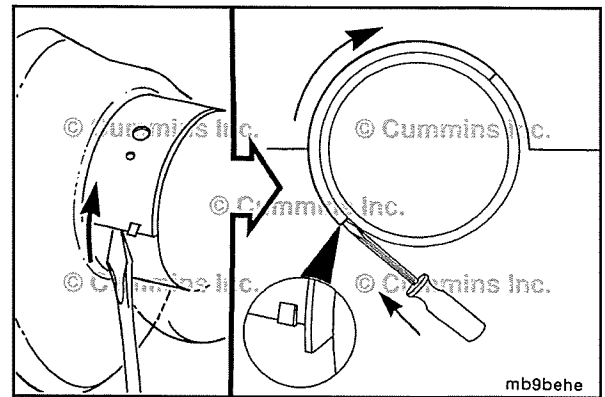
Finish pushing the main bearing into position.

NOTE: The front main bearing, number 1, does **not** have a hole in the journal so the pin can **not** be used to replace the bearing.

Lubricate and install the number 1 main bearing.

Insert the side of the main bearing opposite the tang first. Install as far as possible by hand.

Use a screwdriver to push the main bearings into position as the crankshaft is rotated.



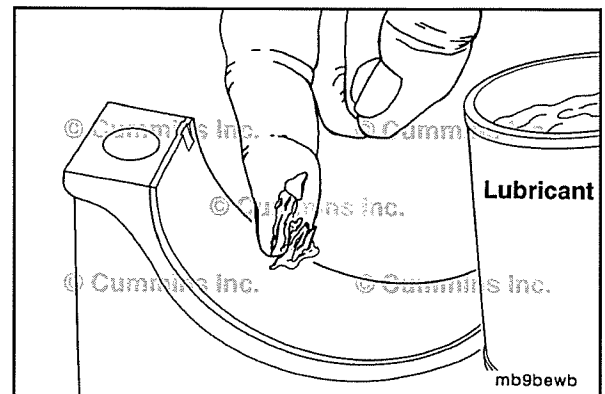
Lower Main Bearings

The backside of the bearings **must** be clean and free of debris.

Install the lower main bearings into the main bearing caps.

Align the tangs of the bearings with the tangs on the main bearing caps.

Apply a coat of assembly lubricant, Part Number 3163086, or equivalent, to the crankshaft side of the main bearings.

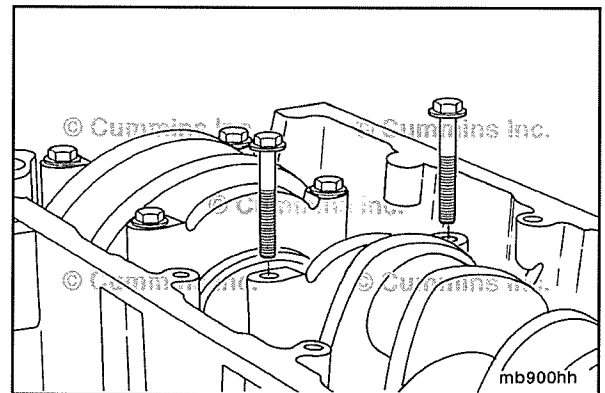


NOTE: The main bearing caps are numbered for location. Number 1 starts with the front of the block. Install the cap so that numbers face the intake side of the engine.

The main bearing cap surfaces between the main bearing cap and the block **must** be clean and free of debris.

Install a main bearing cap after each upper main bearing is installed to keep the main bearing in place while the other uppers are installed.

Lubricate the main bearing capscrew under the cap and lubricate the main bearing capscrew threads using clean 15W-40 engine oil.

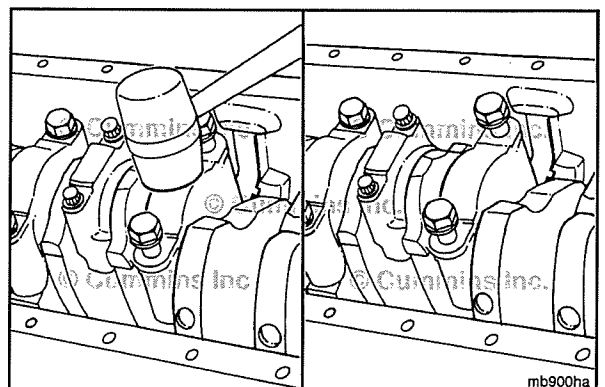


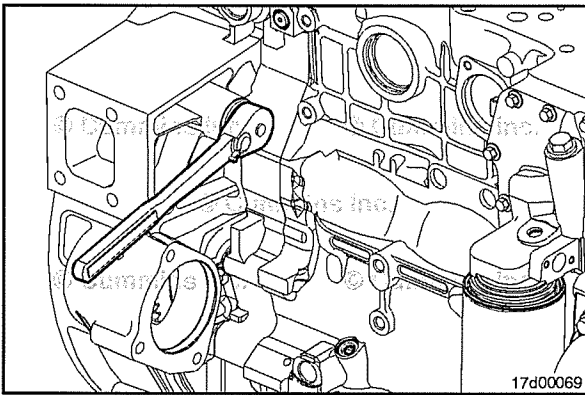
Gently tap the main bearing cap into position with a plastic or rubber mallet.

When seated, install the main bearing capscrews and tighten.

Torque Value: 50 N•m [37 ft-lb]

Do **not** tighten to the final torque value at this time. The final torque **must** be applied after all main bearing caps are installed.



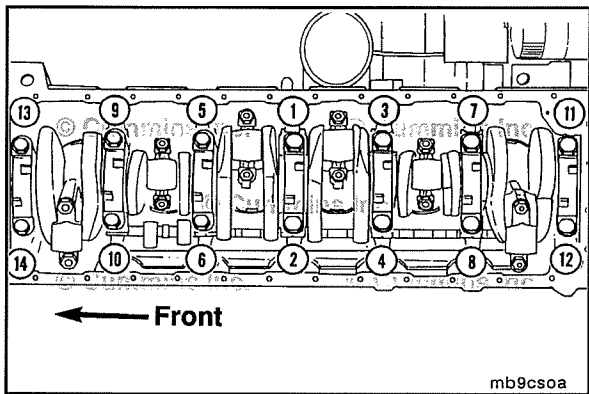


Use the barring tool, Part Number 3824591, to make sure the crankshaft rotates freely after installing the main bearing caps.

While applying final torque to the main bearing capscrews, frequently check that the crankshaft rotates freely.

If the crankshaft does **not** rotate freely:

- 1 Confirm the crankshaft is **not** contacting one of the connecting rods.
- 2 Confirm the correct main bearing caps were installed correctly.
- 3 Confirm the main bearing cap ring dowels or mounting surfaces were **not** damaged during installation.
- 4 Confirm the correct main bearings were installed.



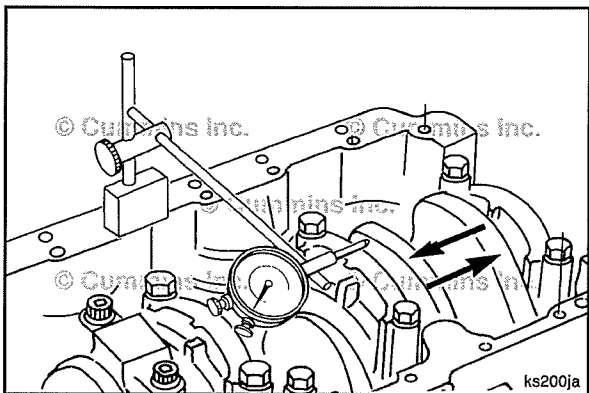
Tighten the main bearing capscrews evenly and in sequence.

Torque Value:

- | | | |
|--------|--------------------|--------------|
| Step 1 | 50 N•m | [37 ft-lb] |
| Step 2 | 95 N•m | [70 ft-lb] |
| Step 3 | Rotate 60 degrees. | |



Check the main bearing installation and the size of the main bearings if the crankshaft does **not** rotate freely.



The dimensions of the thrust bearing and crankshaft journal determine end clearance.

Measure the crankshaft end clearance using dial indicator, Part Number 3824564, and magnetic base, Part Number 3377399.

Crankshaft End Clearance Limits

mm		in
0.085	MIN	0.003
0.385	MAX	0.015

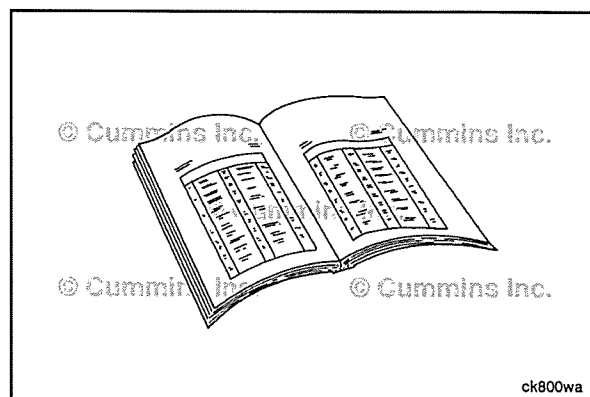
If the crankshaft end clearance is **not** within specification:

- 1 If the crankshaft end clearance is below specification, check if there are any obstructions limiting the crankshaft's travel (lubricating oil pump, connecting rod, etc.)
- 2 If the crankshaft end clearance is above specification, inspect the crankshaft thrust bearing surface. Also check if the correct thrust bearing(s) were installed.

NOTE: Oversize thrust bearings are available if the end clearance is **not** within specifications. See the appropriate parts catalog.

Finishing Steps

- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7..
- Fill the lubricating oil pan. Refer to Procedure 007-037 in Section 7.
- Operate the engine and check for leaks.



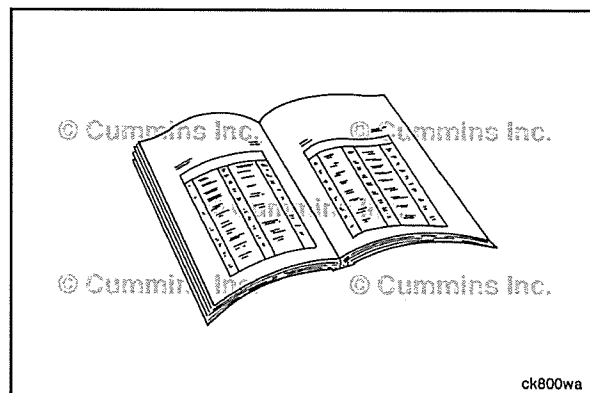
Camshaft (001-008)

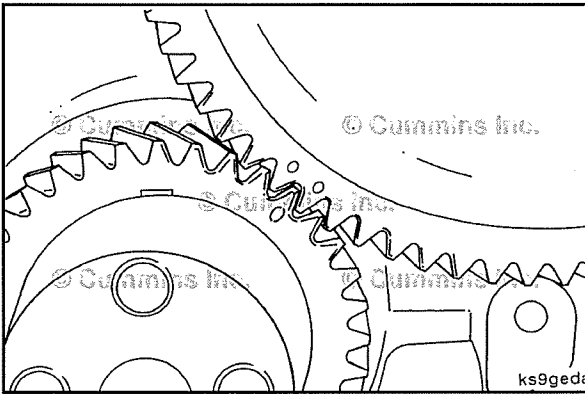
Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

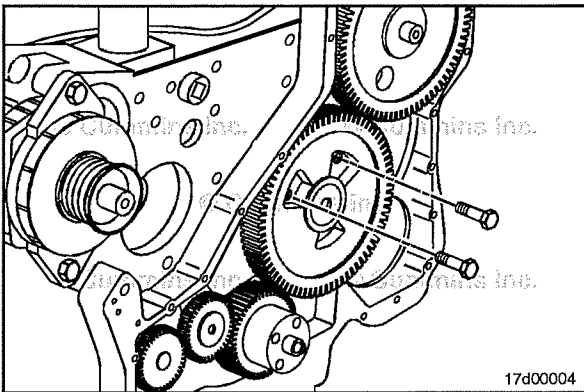
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the engine brakes, if equipped. Refer to Procedure 020-004 in Section 20.
- Remove the rocker lever housing. Refer to Procedure 003-013 in Section 3.
- Remove the rocker levers. Refer to Procedure 003-008 in Section 3.
- Remove the push rods. Refer to Procedure 004-014 in Section 4.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the rubber vibration damper, if installed. Refer to Procedure 001-051 in Section 1.
- Remove the viscous vibration damper, if installed. Refer to Procedure 001-052 in Section 1.
- Remove the gear cover. Refer to Procedure 001-031 in Section 1.
- Raise the tappets. Refer to Procedure 004-015 in Section 4.





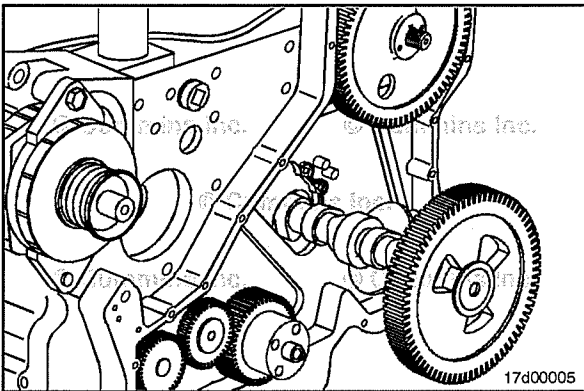
Remove

Rotate the crankshaft to align the crankshaft to camshaft timing marks.



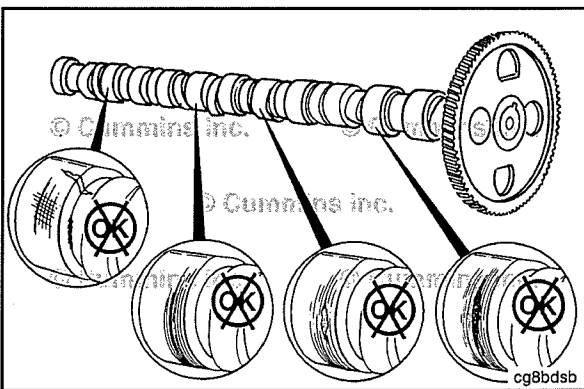
NOTE: Because the thrust plate extends more than 180 degrees around the camshaft, the thrust plate can **only** be removed from the camshaft after removing the cam gear from the camshaft.

Remove the capscrews from the thrust plate.



Remove the camshaft and thrust plate together.

NOTE: Rotate the camshaft as it is being removed. Use extreme care to make sure the camshaft bushings are not damaged during the camshaft removal process.



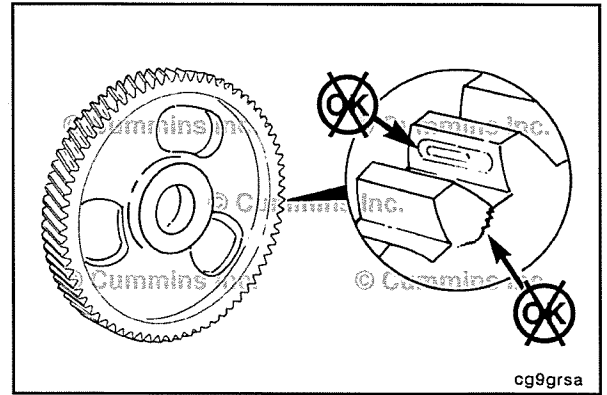
Clean and Inspect for Reuse

Inspect the valve lobes and bearing journals for cracking, pitting, and scoring.



Refer to Camshaft Reuse Guidelines for Cummins® Engines with Roller Followers or Roller Tappets, Bulletin 3666052.

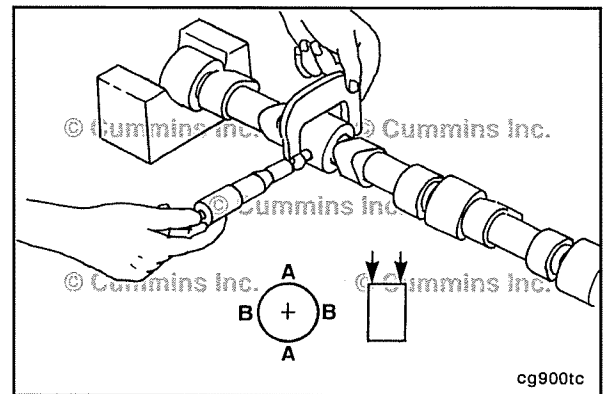
Inspect the camshaft gear and replace if necessary. Refer to Procedure 001-013 in Section 1.



NOTE: Replace the camshaft if the outside diameter of any bearing surface is less than 59.962 mm [2.3607 in].

Camshaft Bearing Journal Diameter

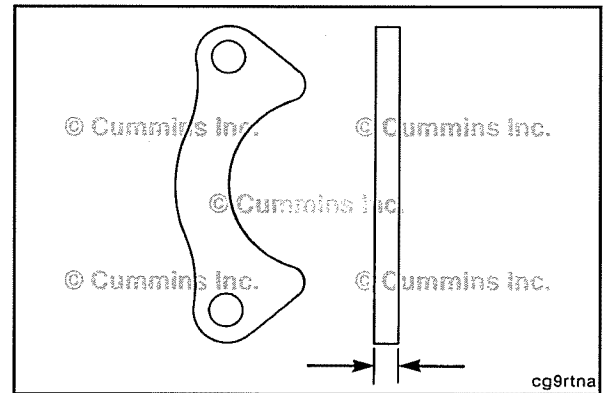
mm		in
59.962	MIN	2.3607
60.013	MAX	2.3627



Measure camshaft thrust plate thickness.

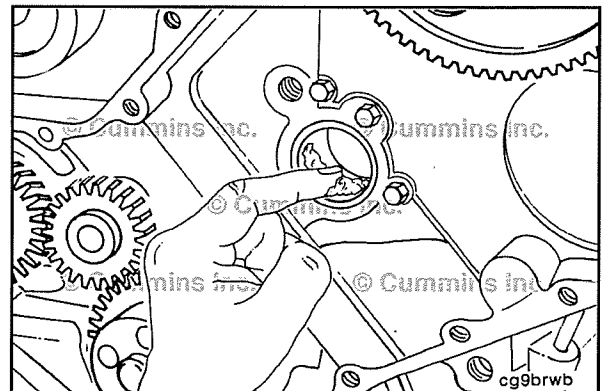
Camshaft Thrust Plate

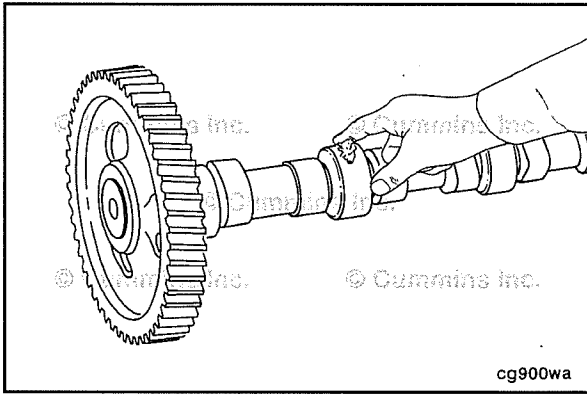
mm		in
9.40	MIN	0.370
9.60	MAX	0.378



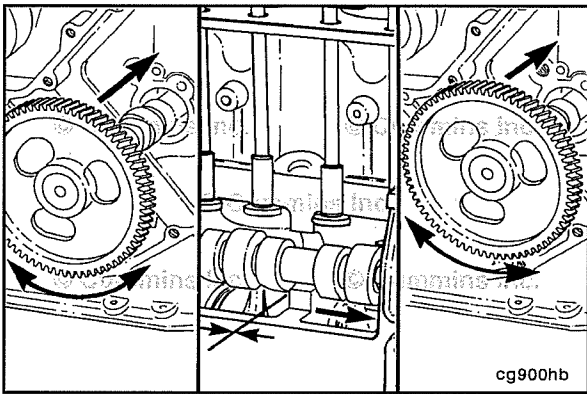
Install

Apply a coat of assembly lubricant, Part Number 3163087 or equivalent, to the front camshaft bore.



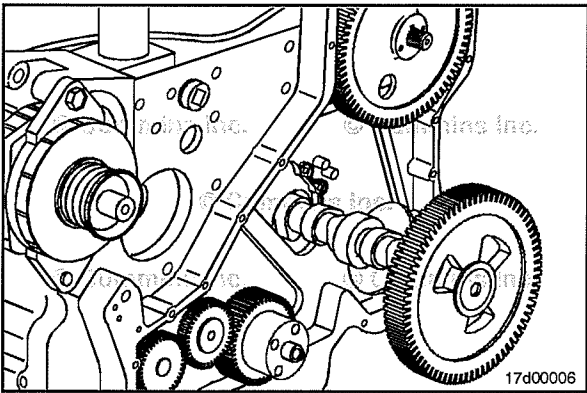


Lubricate the camshaft lobes, journals and thrust plate with assembly lubricant, Part Number 3163087 or equivalent.

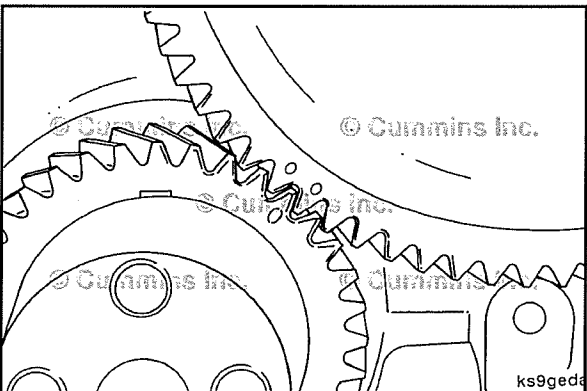


CAUTION
Do not try to force the camshaft into the camshaft bore as damage to the camshaft bushing can result.

Install the camshaft. While pushing in slightly, rotate the camshaft and carefully work the camshaft through the camshaft bushings. As each camshaft journal passes through a bushing, the camshaft will drop slightly and the camshaft lobes will catch on the bushings. Rotating the camshaft will free the lobe from the bushing and allow the camshaft to be installed.



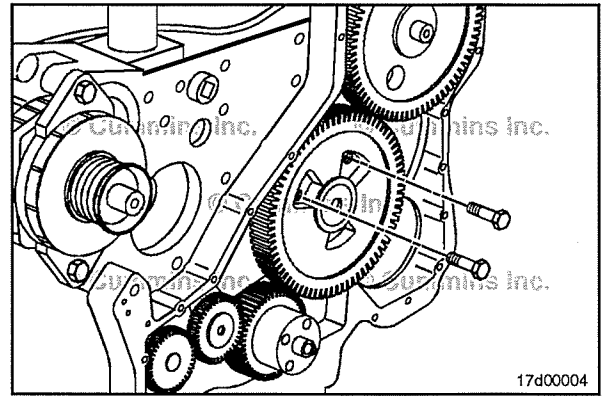
Before the camshaft gear engages the crankshaft gear, check the camshaft for ease of rotation. When installed properly, the camshaft **must** rotate freely.



Align the timing marks as illustrated and finish installing the camshaft.

Install the thrust plate capscrews.

Torque Value: 24 N•m [212 in-lb]



Use gauge, Part Number 3824564, and magnetic base, Part Number 3377399, to verify that the camshaft has proper end clearance and backlash.

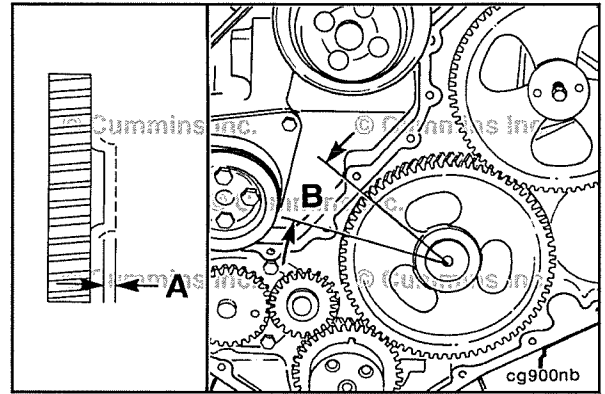


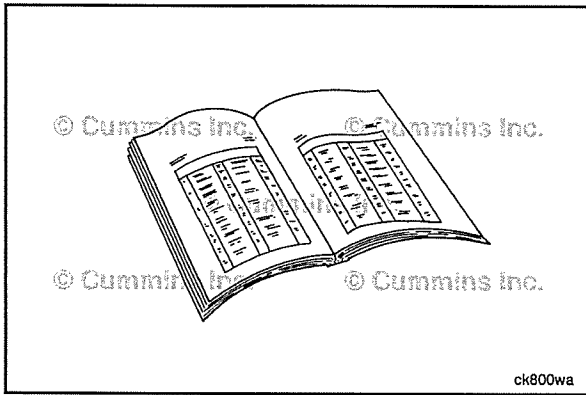
Camshaft End Clearance (A)

mm		in
0.12	MIN	0.005
0.50	MAX	0.020

Camshaft Gear Backlash Limits (B)

mm		in
0.08	MIN	0.003
0.33	MAX	0.013





Finishing Steps



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the gear cover. Refer to Procedure 001-031 in Section 1.
- Install the rubber vibration damper. Refer to Procedure 001-051 in Section 1.
- Install the viscous vibration damper. Refer to Procedure 001-052 in Section 1.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Release the tappets. Refer to Procedure 004-015 in Section 4.
- Install the push rods. Refer to Procedure 004-014 in Section 4.
- Install the rocker levers. Refer to Procedure 003-008 in Section 3.
- Adjust the valve lash. Refer to Procedure 003-004 in Section 3.
- Install the engine brakes, if equipped. Refer to Procedure 020-004 in Section 20.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Camshaft Bushings (001-010)

General Information

The engines covered by this manual have seven camshaft bushings, starting with camshaft bushing 1 at the front of the engine.

Camshaft bushings 1 through 6 can be replaced through the front of the engine by driving them towards the rear of the engine.

Replacing camshaft bushing 7 requires the flywheel housing and the cup plug at the rear of the camshaft be removed to drive camshaft bushing 7 forward for replacement.

Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the starting motor. Refer to Procedure 013-020 in Section 13.
- Remove the flexplate, if installed. Refer to Procedure 016-004 in Section 16.
- Remove the flywheel, if installed. Refer to Procedure 016-005 in Section 16.
- Remove the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Remove the camshaft. Refer to Procedure 001-008 in Section 1.
- Remove the rear camshaft cup plug. Refer to Procedure 017-002 in Section 17.

Remove

Remove the camshaft bushings. Use the camshaft bushing replacer kit, Part Number 3165045.

The following kits are also available for camshaft bushing installation and removal:

- Hydraulic Actuator Kit, Part Number 3823621
- Camshaft Bushing Kit, Part Number 3162253

Slide the drive bar through the centering guide and insert the drive bar from the rear of the cylinder block through the camshaft bores.

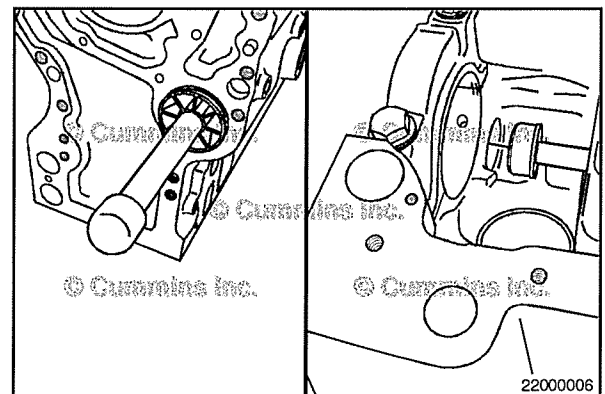
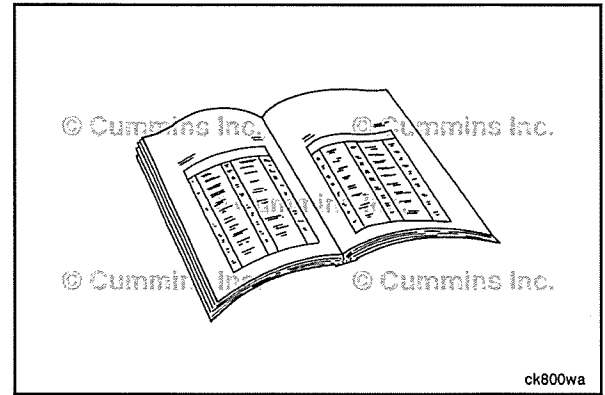
Insert the camshaft bushing replacer and drive the front camshaft bushing from the cylinder block.

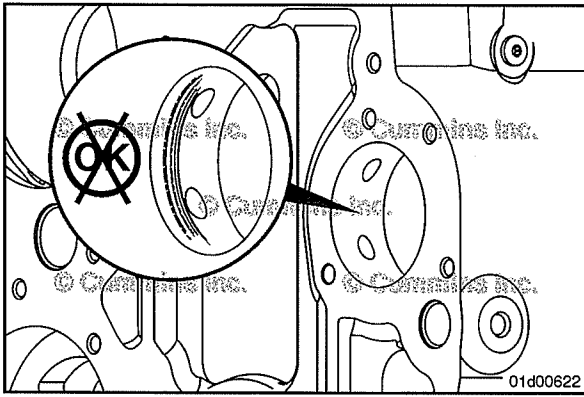
Remove the replacer and drive bar from the cylinder block.

Insert the drive bar, camshaft bushing replacer, and centering guide from the front of the cylinder block.

Drive the remaining camshaft bushings from the cylinder block in succession, starting with the number two camshaft bushing.

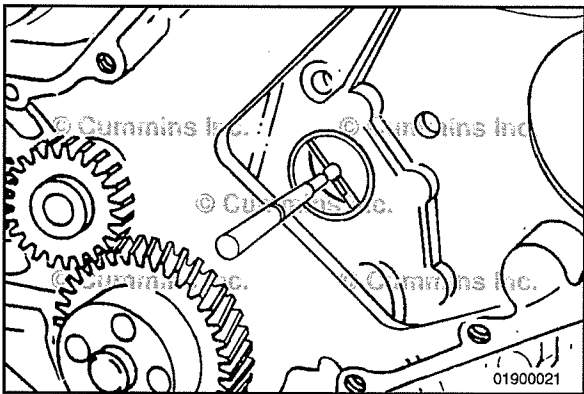
Remove the drive bar, replacer, and guide from the front of the cylinder block.





Clean and Inspect for Reuse

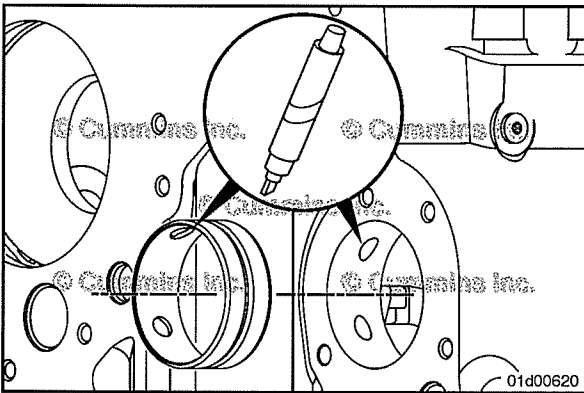
Inspect the camshaft bore for damage and excessive wear. Refer to Procedure 001-026 in Section 1.



Measure the camshaft bore.

Camshaft Bore Diameter (Maximum)

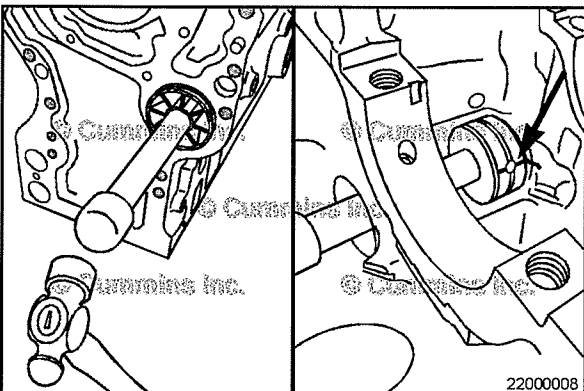
	mm		in
Without bushing	64.013	MAX	2.5202
With bushing	60.120	MAX	2.3669



Install

Mark the oil holes on the camshaft bushing and cylinder block with a felt tip pen. This aids proper alignment of the bushing and bore during installation.

NOTE: The top hole on the front and rear camshaft bushings will **not** line up with the top hole of the cylinder block bores. **Only** the bottom hole will line up for the front and rear camshaft bushings.



Slide the camshaft bushing on the replacer. Position the notch on the edge of the bushing to the top rear of the block and align the marks on the camshaft bushing and the cylinder block.

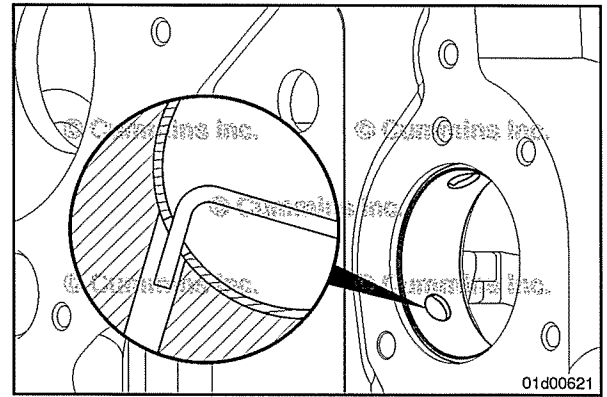
Drive the front camshaft bushing to the correct installed depth. The correct installed depth is when the camshaft bushing oil hole aligns with the cylinder block oil hole.

Install the remaining camshaft bushings in succession, starting at the rear of the cylinder block and working toward the front. Remove the drive bar, replacer, and guide from the cylinder block.

Remove the drive bar, replacer, and guide from the cylinder block.

Make sure the lubricating oil holes in the camshaft bushing are aligned with the oil holes in the camshaft bore. For the front and rear camshaft bushings **only** the bottom hole will line up with the hole in the cylinder block.

A 3.2 mm [0.128 in] diameter rod **must** be able to pass through the lubricating oil holes.

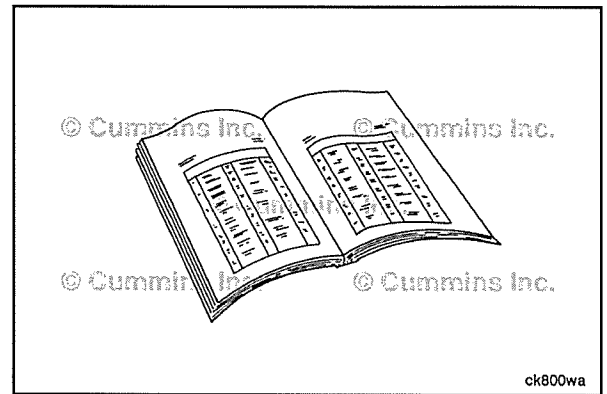


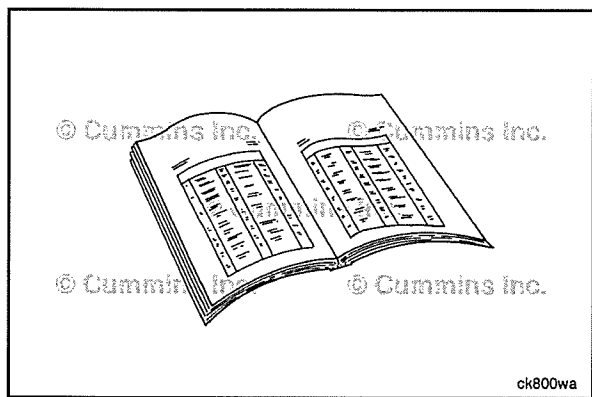
Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the rear camshaft cup plug. Refer to Procedure 017-002 in Section 17.
- Install the camshaft. Refer to Procedure 001-008 in Section 1.
- Install the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Install the flexplate, if installed. Refer to Procedure 016-004 in Section 16, if installed.
- Install the flywheel, if installed. Refer to Procedure 016-005 in Section 16.
- Install the starting motor. Refer to Procedure 013-020 in Section 13.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.





Camshaft Gear (Camshaft Installed) (001-012)

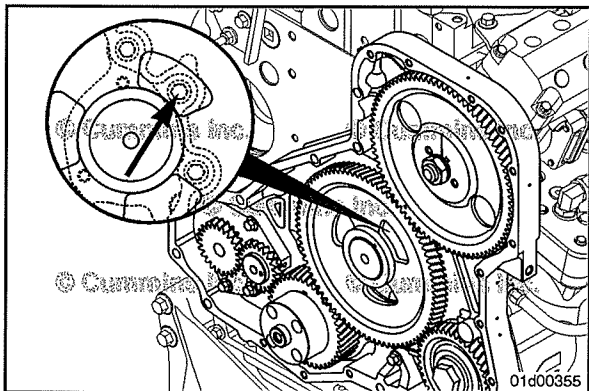


Preparatory Steps

⚠ WARNING ⚠

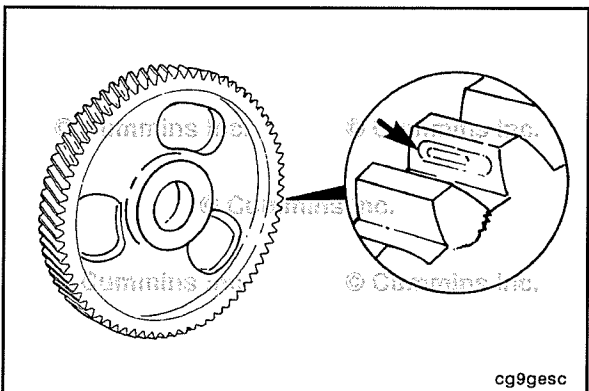
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the rubber vibration damper, if installed. Refer to Procedure 001-051 in Section 1.
- Remove the viscous vibration damper, if installed. Refer to Procedure 001-052 in Section 1.
- Remove the gear cover. Refer to Procedure 001-031 in Section 1.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Loosen the rocker lever assemblies. Refer to Procedure 003-008 in Section 3.



Remove

Use cam gear removal and installation tool, Part Number 3163054, and puller assembly, Part Number 3165093, to remove the camshaft gear from the camshaft.



Clean and Inspect for Reuse

Inspect the camshaft gear for cracked, chipped, or broken teeth.

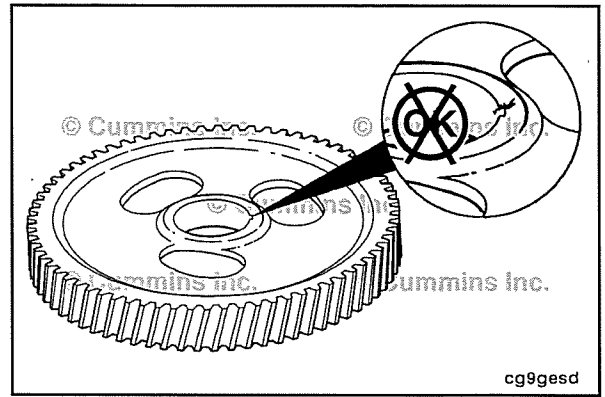
Inspect the camshaft bore for fretting or burrs.

NOTE: If the fretting, burrs, or raised material can **not** be removed with abrasive pad, Part Number 3823258 or equivalent, replace the camshaft gear.

Inspect the camshaft gear keyway for burrs.

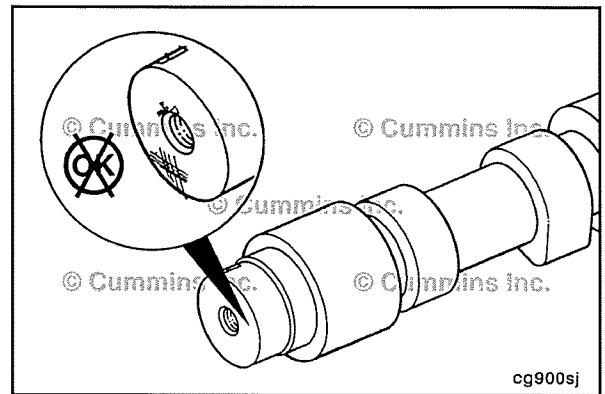
Remove burrs with abrasive pad, Part Number 3823258 or equivalent.

NOTE: If the keyway is damaged or the burrs can **not** be removed, the camshaft gear **must** be replaced.



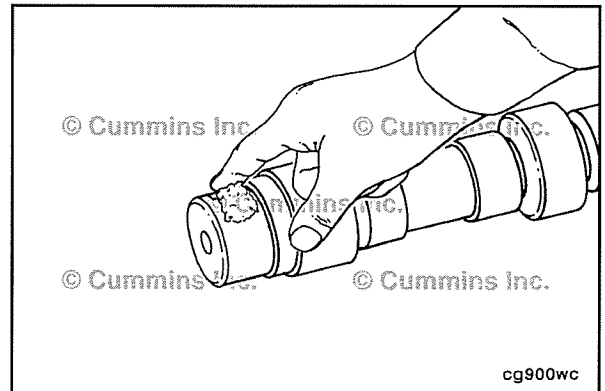
Inspect the camshaft nose for fretting or burrs.

NOTE: If fretting or burrs can **not** be removed with abrasive pad, Part Number 3823258 or equivalent, replace the camshaft. Refer to Procedure 001-008 in Section 1.



Install

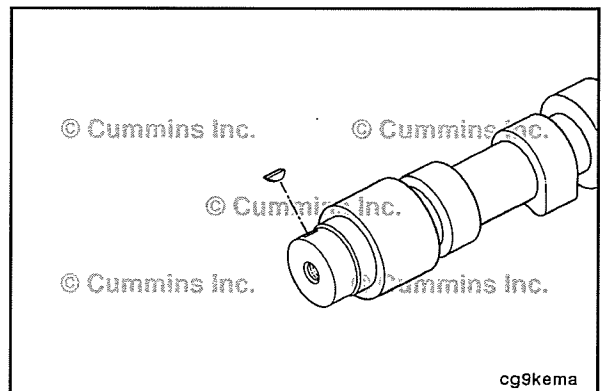
Lubricate the camshaft surface with assembly lubricant, Part Number 3163087 or equivalent.

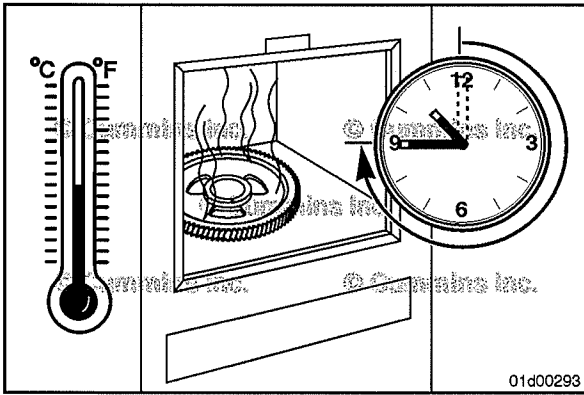


Install the key into the camshaft nose.

Tighten the thrust plate capscrews.

Torque Value: 24 N•m [212 in-lb]





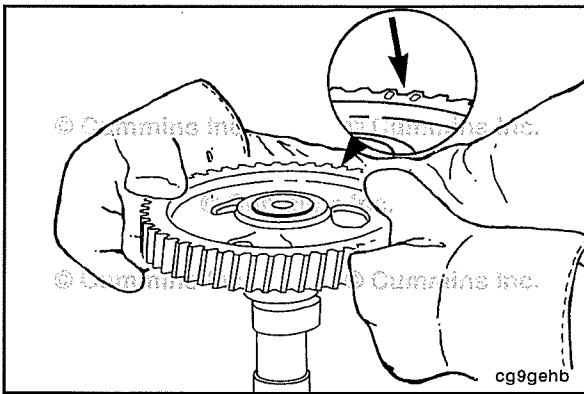
CAUTION

The camshaft gear will be permanently distorted if overheated. The oven temperature should never exceed 204°C [400°F].

Heat the camshaft gear for 45 minutes.

Oven Temperature 204 °C [400 °F]

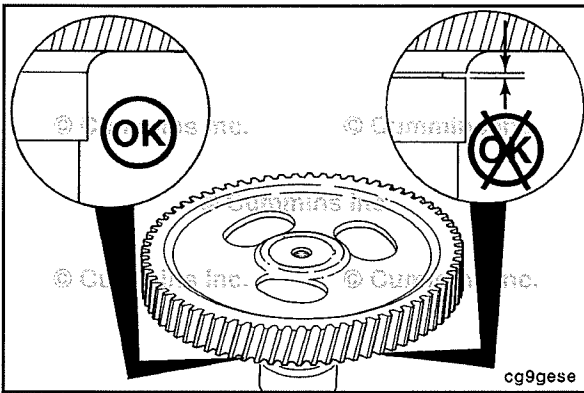
Use camshaft gear removal and installation tool, Part Number 3163054, and puller assembly, Part Number 3165093, to install the camshaft gear onto the camshaft.



WARNING

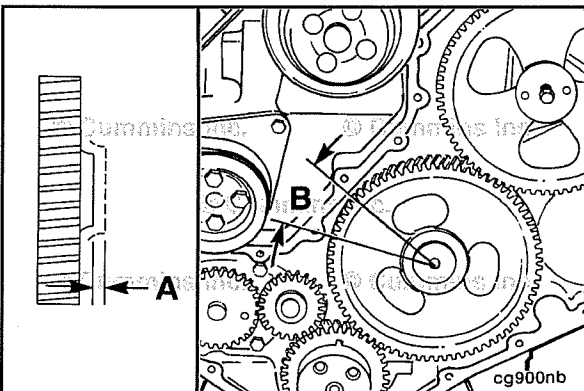
To reduce the possibility of personal injury, wear protective gloves when handling parts that have been heated.

Install the camshaft gear with the timing marks away from the camshaft.



NOTE: Be sure the gear is seated against camshaft shoulder.

Use a 0.02 mm [0.001] feeler gauge. If the feeler gauge can be inserted between the camshaft gear and the shoulder on the camshaft. Insert the feeler gauge in multiple locations. If the feeler gauge can be inserted, the camshaft gear is **not** properly seated.



Use gauge, Part Number 3824564, and magnetic base, Part Number 3377399, to verify the camshaft has proper backlash and end clearance.



Camshaft End Clearance (A)

mm		in
0.12	MIN	0.005
0.50	MAX	0.020

Camshaft Gear Backlash Limits (B)

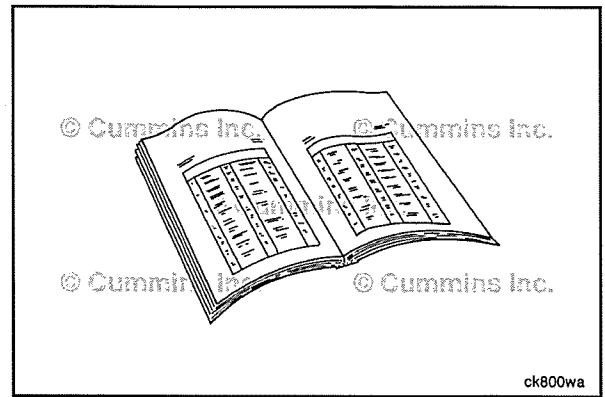
mm		in
0.08	MIN	0.003
0.33	MAX	0.013

Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

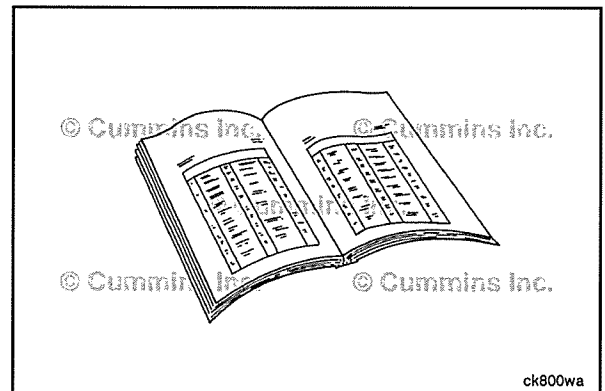
- Install the gear cover. Refer to Procedure 001-031 in Section 1.
- Install the rubber vibration damper, if installed. Refer to Procedure 001-051 in Section 1.
- Install the viscous vibration damper, if installed. Refer to Procedure 001-052 in Section 1.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Tighten the rocker lever assemblies. Refer to Procedure 003-008 in Section 3.
- Adjust the valve lash. Refer to Procedure 003-004 in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Connect the battery cables. Refer to the OEM service manual.



Camshaft Gear (Camshaft Removed) (001-013)

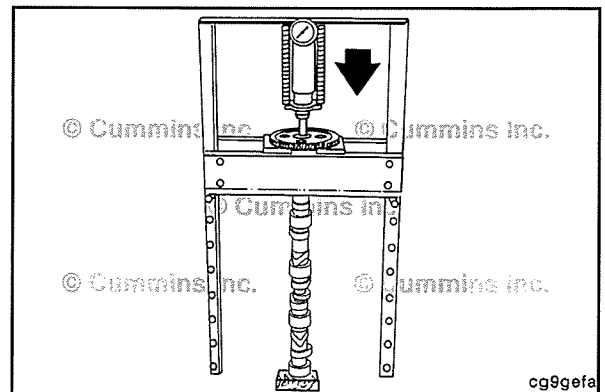
Preparatory Steps

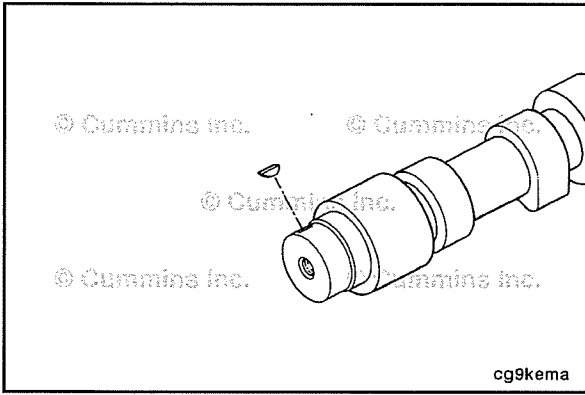
- Remove the camshaft. Refer to Procedure 001-008 in Section 1.



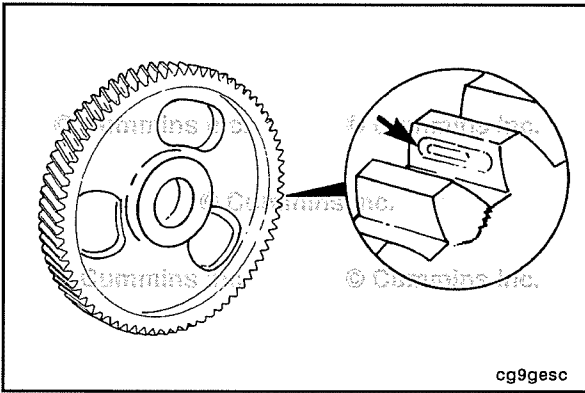
Remove

Remove the gear by using a press.
Remove the thrust plate.





Remove the camshaft key.

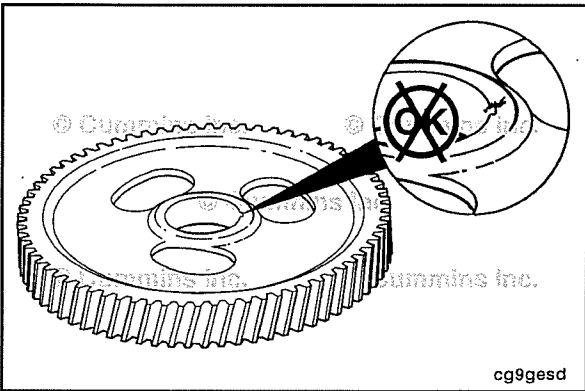


Clean and Inspect for Reuse

Inspect the camshaft gear for cracked, chipped, or broken teeth.

Inspect the camshaft bore for fretting or burrs.

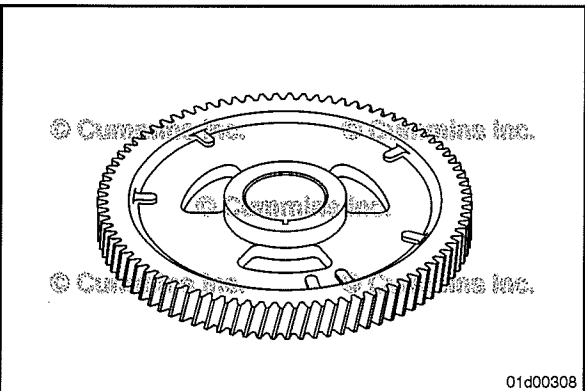
NOTE: If the fretting, burrs, or raised material can **not** be removed with abrasive pad, Part Number 3823258 or equivalent, replace the camshaft gear.



Inspect the camshaft gear keyway for burrs.

Remove burrs with abrasive pad, Part Number 3823258 or equivalent.

NOTE: If the keyway is damaged or the burrs can **not** be removed, the camshaft gear **must** be replaced.

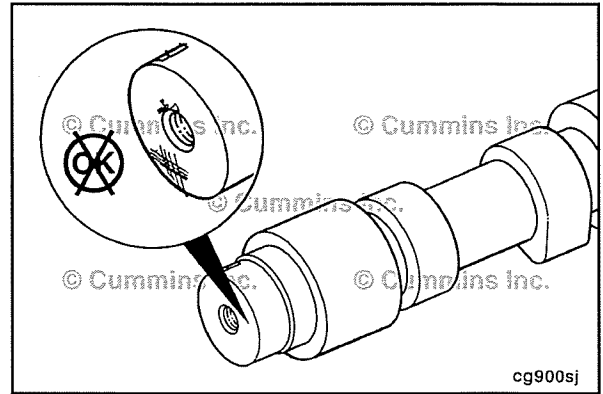


Inspect the camshaft gear and speed sensor targets.

Replace the camshaft gear if any damage is found.

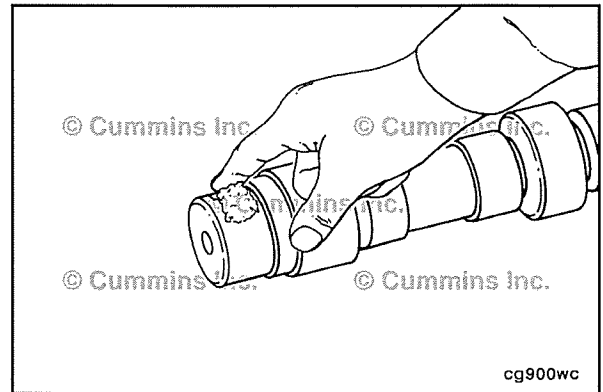
Inspect the camshaft nose for fretting or burrs.

NOTE: If fretting or burrs can **not** be removed with abrasive pad, Part Number 3823258 or equivalent, replace the camshaft.



Install

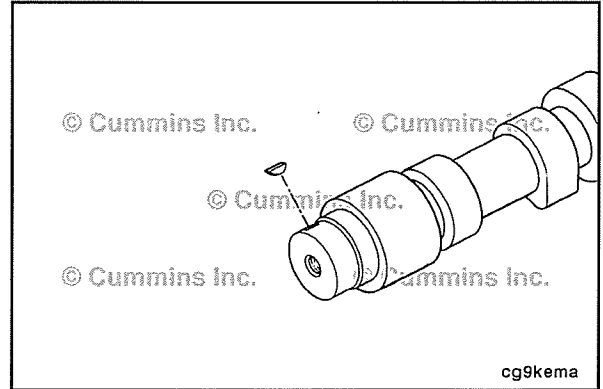
Lubricate the camshaft surface with assembly lubricant, Part Number 3163087 or equivalent.



Install the key.

Install the thrust plate.

NOTE: Because the thrust plate extends more than 180 degrees around the camshaft, the thrust plate **must** be installed before installing the cam gear on the camshaft.

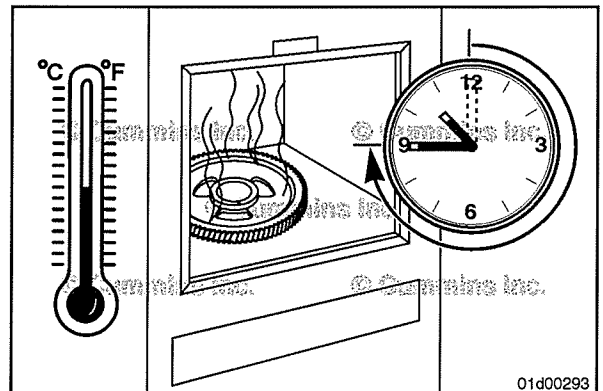


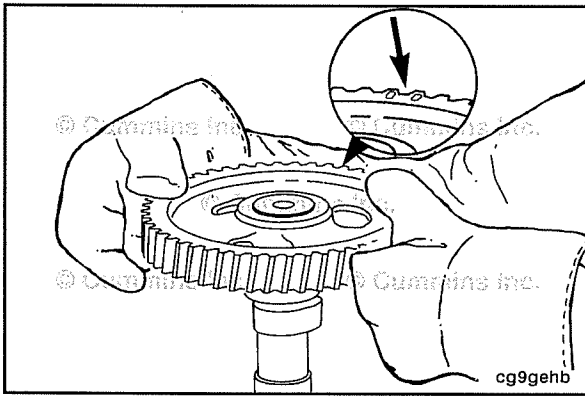
⚠CAUTION⚠

The camshaft gear will be permanently distorted if overheated. The oven temperature should never exceed 204°C [400°F].

Heat the camshaft gear for 45 minutes.

Oven Temperature 204 °C [400 °F]



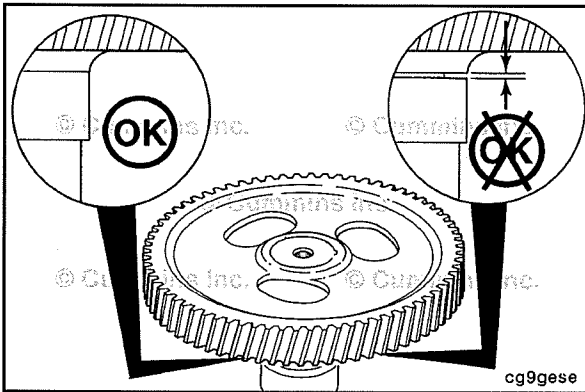


WARNING

Wear protective gloves to reduce the possibility of personal injury when handling parts that have been heated.

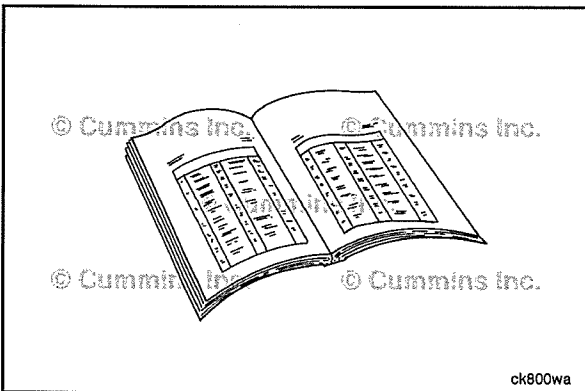
NOTE: When clamping the camshaft to install the gear, do **not** place clamps directly on the camshaft lobes or journals, which could damage the surfaces. Clamp **only** the cast surfaces between the lobes, or place padding between the clamps and the camshaft surfaces.

Install the camshaft gear with the timing marks away from the camshaft.



NOTE: Be sure the gear is seated against camshaft shoulder.

Use a 0.02 mm [0.001 in] feeler gauge, to see if the feeler gauge can be inserted between the camshaft gear and the shoulder on the camshaft. If the feeler gauge can be inserted, the camshaft gear is **not** properly seated.



Finishing Steps

- Install the camshaft. Refer to Procedure 001-008 in Section 1.
- Operate the engine and check for leaks.



Connecting Rod (001-014)

Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ WARNING ⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

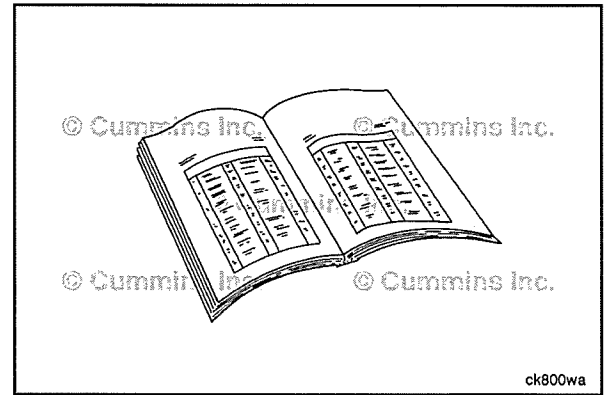
⚠ WARNING ⚠

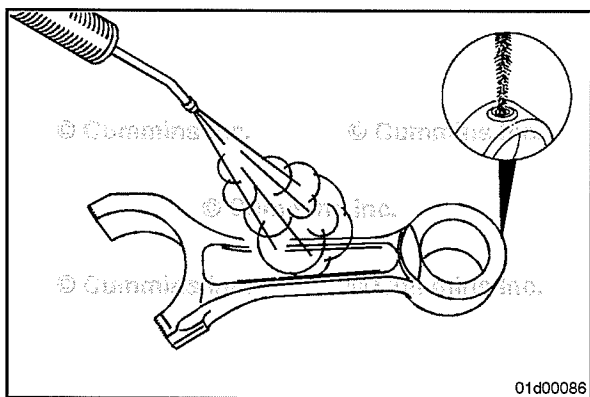
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠ WARNING ⚠

Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the cooling system. Refer to Procedure 008-018 in Section 8.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the cylinder head. Refer to Procedure 002-004 in Section 2.
- Remove the lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7.
- Remove the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Remove the piston cooling nozzles. Refer to Procedure 001-046 in Section 1.
- Remove the piston and connecting rod, and disassemble. Refer to Procedure 001-054 in Section 1.





Clean and Inspect for Reuse

⚠ WARNING ⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ WARNING ⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

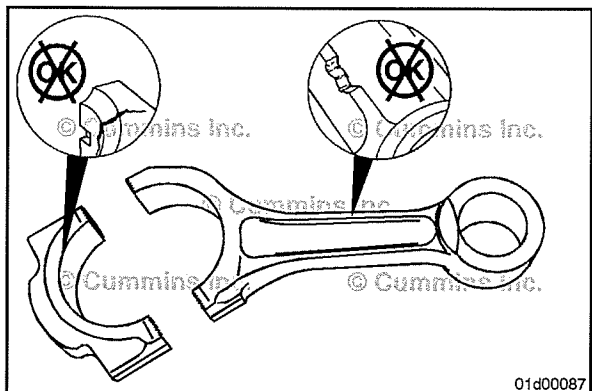
⚠ WARNING ⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠ WARNING ⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use a nylon bristle brush to clean the oil drillings.

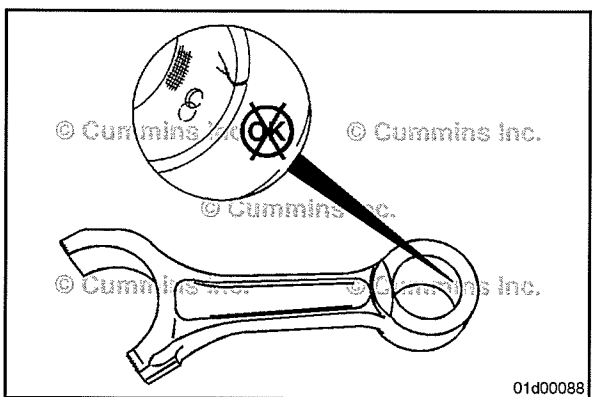
Use steam or solvent to clean the connecting rods.

Dry with compressed air.



Inspect the connecting rods and connecting rod caps for damage.

Replace the connecting rod if the "I-beam" is nicked or otherwise damaged.



Inspect the piston pin bore for damage or misalignment of the oil passage and bushing.

Replace the connecting rod if any damage is found.

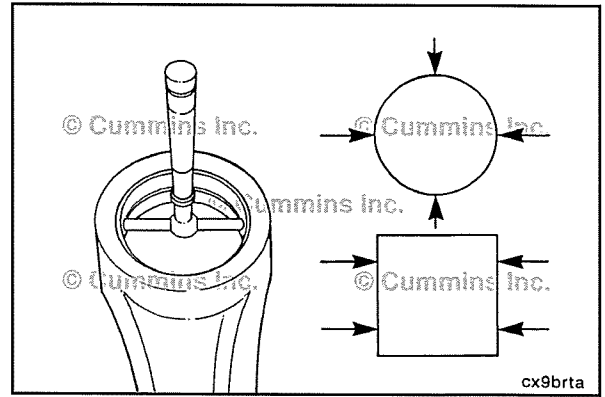
Measure the connecting rod piston pin bushing inside diameter.



Connecting Rod Piston Pin Bushing Diameter

mm		in
45.023	MIN	1.7726
45.035	MAX	1.7730

If the connecting rod piston pin bushing inside diameter is out of specification, replace the connecting rod.



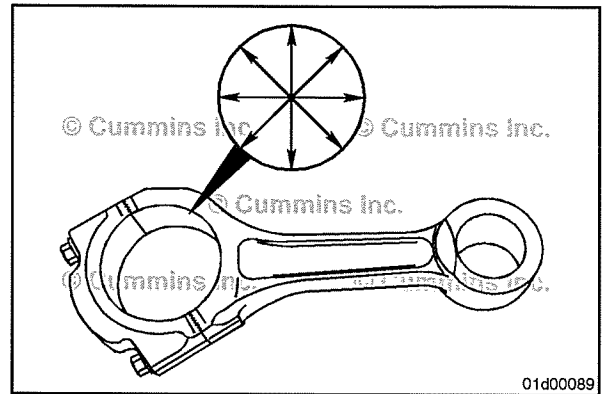
Measure the connecting rod crankshaft bore with the bearing shells removed and the caps tightened to the proper torque value. Refer to Procedure 001-054 in Section 1.



Connecting Rod Crank Bore Diameter (Bearings Removed)

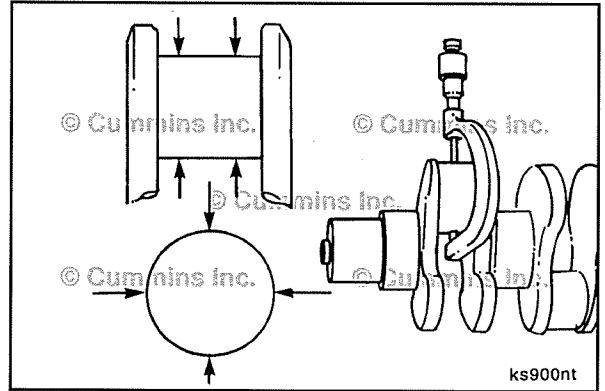
mm		in
80.987	MIN	3.1885
81.013	MAX	3.1895

If the connecting rod crank bore diameter is out of specification, replace the connecting rod.



Measure the diameter of the rod journal on the crankshaft.

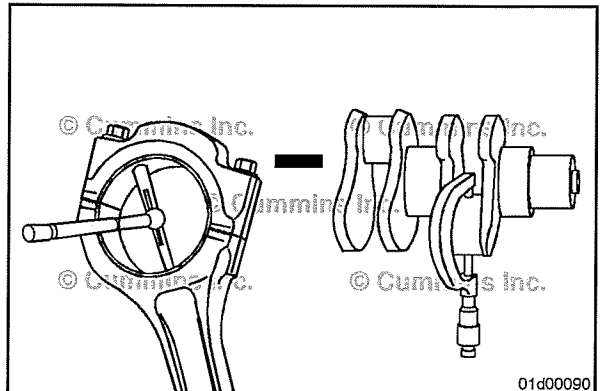
Refer to Procedure 001-016 in Section 1.

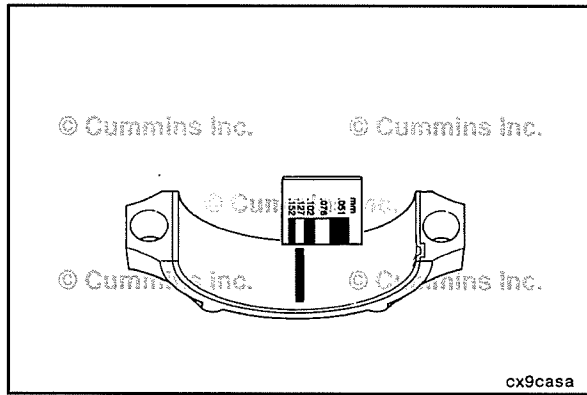


Bearing Clearance

mm		in
0.038	MIN	0.0015
0.116	MAX	0.0045

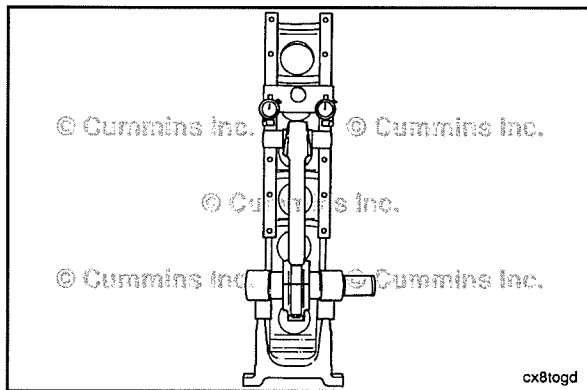
Bearing clearance: rod inside diameter (with bearing) minus crankshaft journal diameter.





Bearing clearance can also be determined with a plastigauge during engine assembly.

NOTE: If the clearance is found to be out of specification, replace or try another set of connecting rod bearings.



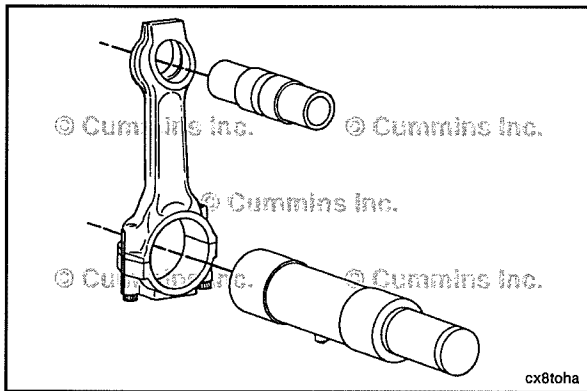
Bend and Twist Inspect

Calibration Procedure

Use a connecting rod checking fixture, Part Number ST-561, and a connecting rod mandrel set, Part Number 3823286, to inspect the bend and twist of the rods.

Calibrate the checking fixture with a new rod that has been measured for correct center-to-center length, 215.975 to 216.025 mm [8.5029 to 8.5040 in].

Assemble the connecting rod cap to the rod, as described previously in this procedure.

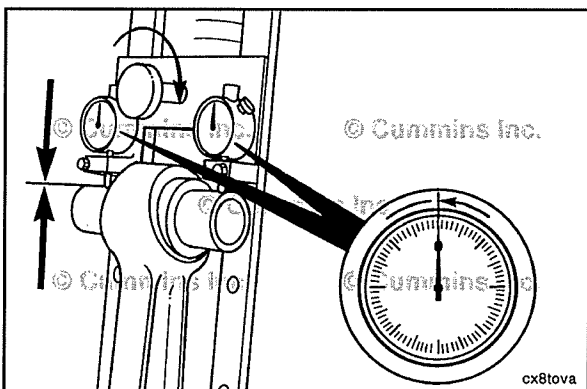


Install the piston pin mandrel from the mandrel set, Part Number 3823286, into the piston pin bore.

NOTE: Use a mandrel, Part Number 3823283, if a piston bushing has been removed, or mandrel, Part Number 3823284, if the bushing is still in place.

Install the mandrel, Part Number 3823303, into the crankshaft bore and expand the mandrel.

NOTE: Make sure the pin on the mandrel is down and locked in position in the center of the connecting rod.



Install the connecting rod into the fixture.

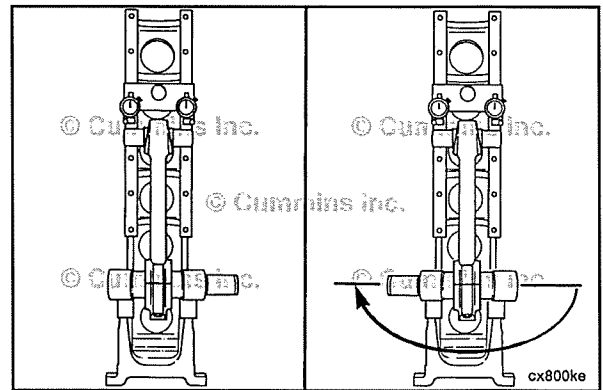
Move the dial holder to position the contact points of the indicators on the mandrel in the piston pin bore.



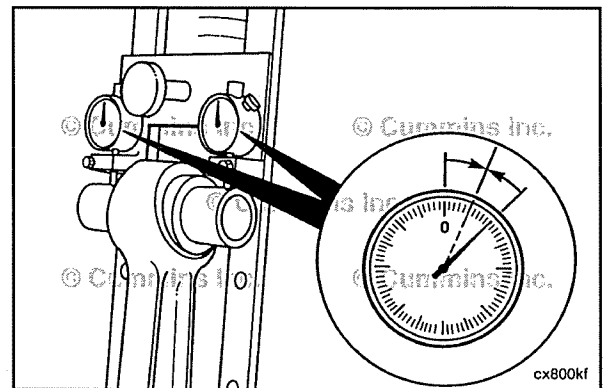
Tighten the bracket to hold the indicators in position.

Set the dial indicators to zero.

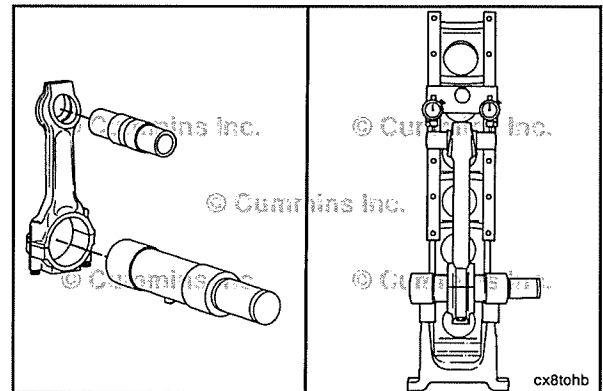
Remove the connecting rod from the fixture.
Turn the rod 180 degrees horizontally and install the rod into the fixture again.



Check the dial indicators for zero position again.
If the dial indicators show any change from zero, adjust the dials to half the indicated reading.
The fixture is now calibrated to allow the connecting rod to be installed into the fixture in either direction and the dials will indicate an equal deflection on either side or zero.



Test
Install the mandrel and arbor into the connecting rod to be inspected.
Install the connecting rod into the fixture.



Measure the connecting rod length and bend (alignment).

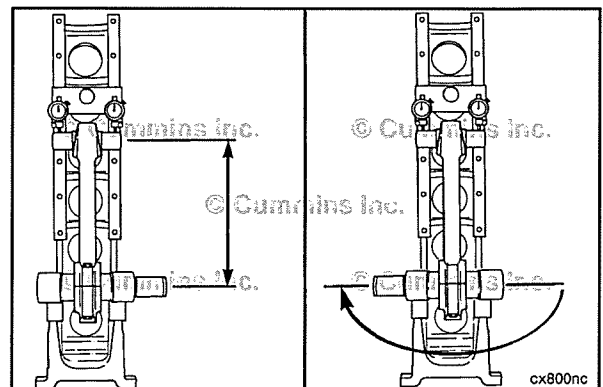


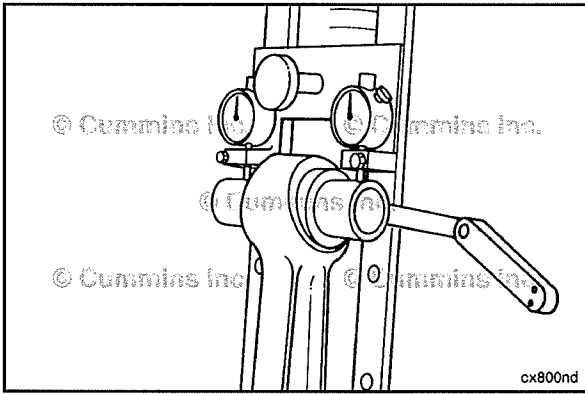
Straight Split Connecting Rod Length

mm		in
215.975	MIN	8.5029
216.025	MAX	8.5049

Connecting Rod Bend (Alignment)

	mm		in
Bushing removed	0.20	MAX	0.008
Bushing installed	0.15	MAX	0.006



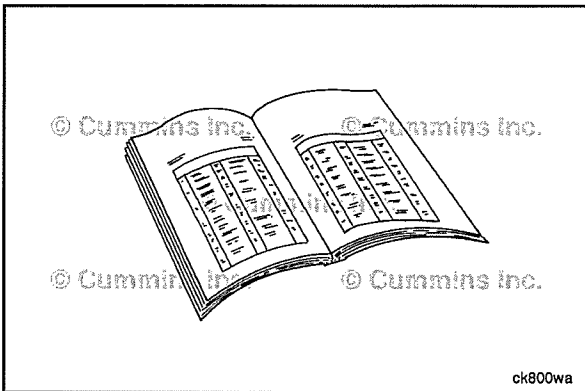


Install a feeler gauge between the mandrel and the dial indicator holding plate, as shown in illustration.



Connecting Rod Twist

	mm		in
Bushing removed	0.20	MAX	0.008
Bushing installed	0.30	MAX	0.012



Finishing Steps

⚠ WARNING ⚠



Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



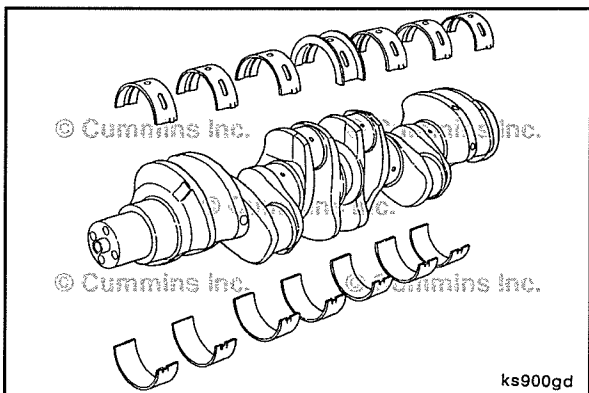
- Assemble and install the pistons and connecting rod assemblies. Refer to Procedure 001-054 in Section 1.
- Install the piston cooling nozzles. Refer to Procedure 001-046 in Section 1.
- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7.
- Install the cylinder head. Refer to Procedure 002-004 in Section 2.
- Fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Crankshaft (001-016)

General Information

The crankshaft uses forged counterweights.

Oversize main bearings, thrust bearings, and connecting rod bearings are available for service. Cummins Inc. recommends regrinding all of the main or the connecting rod journals when one requires regrinding. See the appropriate parts catalog.

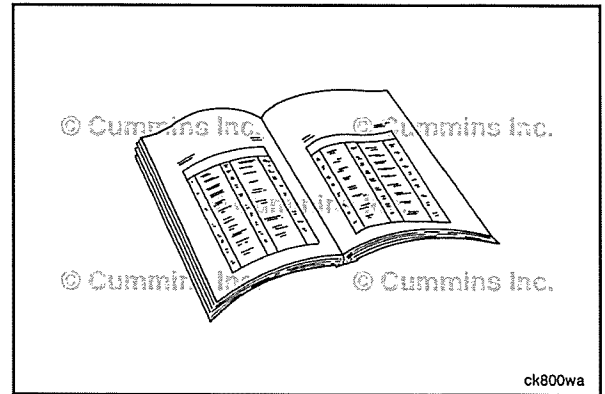


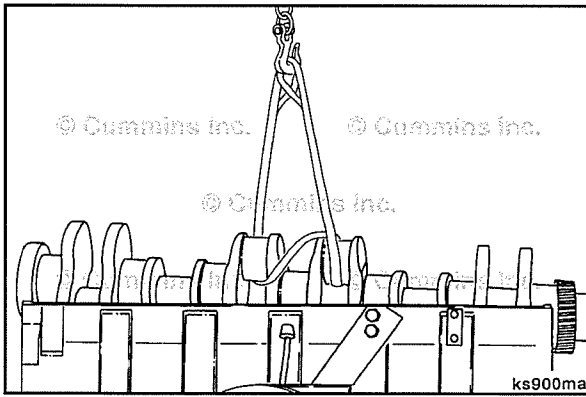
Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the engine and place it on an engine stand. Refer to Procedure 000-001 in Section 0.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the rubber vibration damper, if installed. Refer to Procedure 001-051 in Section 1.
- Remove the viscous vibration damper, if installed. Refer to Procedure 001-052 in Section 1.
- Remove the front cover. Refer to Procedure 001-031 in Section 1.
- Remove the starter. Refer to Procedure 013-020 in Section 13.
- Remove the flexplate, if installed. Refer to Procedure 016-004 in Section 16.
- Remove the flywheel, if installed. Refer to Procedure 016-005 in Section 16.
- Remove the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Remove the rear crankshaft seal carrier. Refer to Procedure 001-067 in Section 1.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Remove the fuel pump. Refer to Procedure 005-016 in Section 5.
- Remove the air compressor, if required. Refer to Procedure 012-014 in Section 12.
- Remove the camshaft gear. Refer to Procedure 001-012 in Section 1.
- Remove the front gear housing. Refer to Procedure 001-033 in Section 1.
- Remove the connecting rod caps. Refer to Procedure 001-005 in Section 1.
- Remove the main bearing caps. Refer to Procedure 001-006 in Section 1.



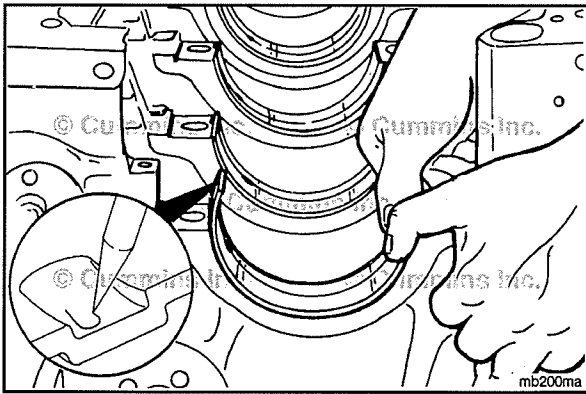


Remove

NOTE: Lift the crankshaft straight up to avoid damage to the crankshaft and cylinder block.

Install nylon lift sling, Part Number 3375957, around the number 3 and number 4 rod bearing journals.

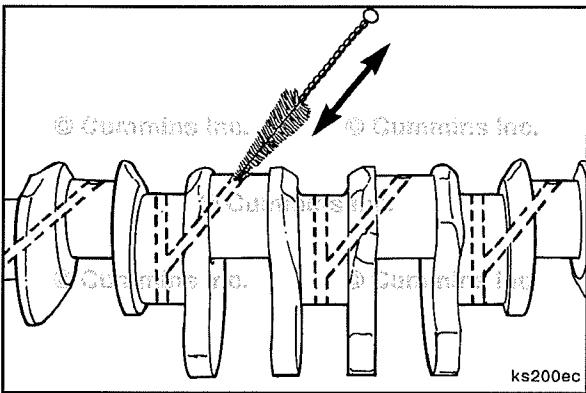
Attach the sling to a hoist and remove the crankshaft.



Remove the upper main bearings.

Use an awl to mark the bearing position in the tang area.

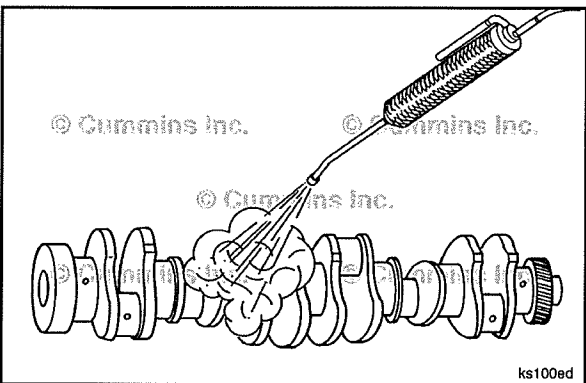
NOTE: Mark the bearing position for future identification or possible failure analysis.



Clean and Inspect for Reuse

Use fine crocus cloth to polish the machined surfaces.

Use a bristle brush to clean the oil drillings.



⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Steam clean the crankshaft and dry with compressed air.

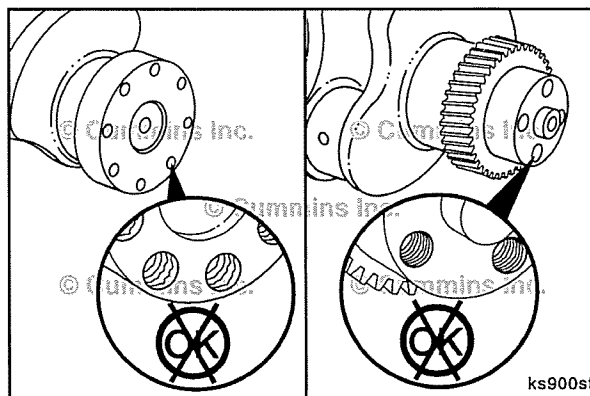
Make sure to blow out the threaded holes on each end of the crankshaft and oil drillings.

Inspect the threaded capscrew holes for damage.

Use one of the following methods to repair any damaged threaded holes:

- Chase the threads.
- Use the threaded insert kit, Part Number 3822709.

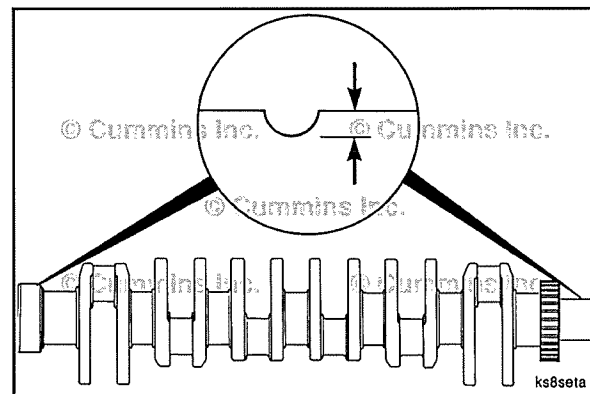
NOTE: A maximum of one front crankshaft threaded hole and three rear crankshaft holes can be repaired. If more than one threaded hole in the front of the crankshaft or three threaded holes in the rear of the crankshaft requires repair, the crankshaft can **not** be salvaged.



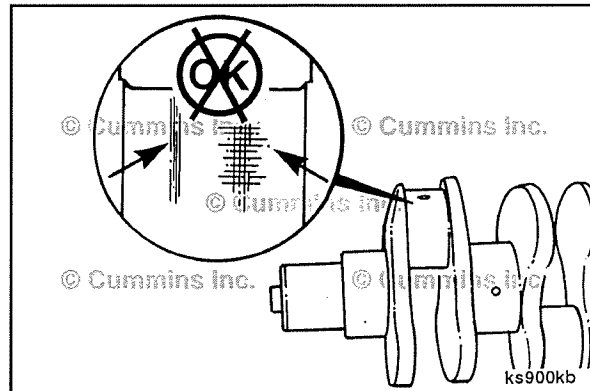
Measure the front and rear oil seal contact areas for a wear groove.

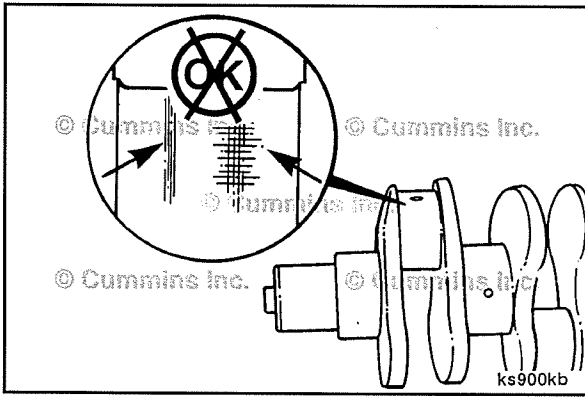
Crankshaft Front and Rear Oil Seal Wear Groove

mm		in
0.25	MAX	0.010



Inspect the crankshaft connecting rod and main journals for deep scoring, overheating, etc. Minor scratches are acceptable.





Use a micrometer to measure the connecting rod journals.

Crankshaft Connecting Rod Journal Diameter

mm		in
76.000	MIN	2.9921
76.026	MAX	2.9931

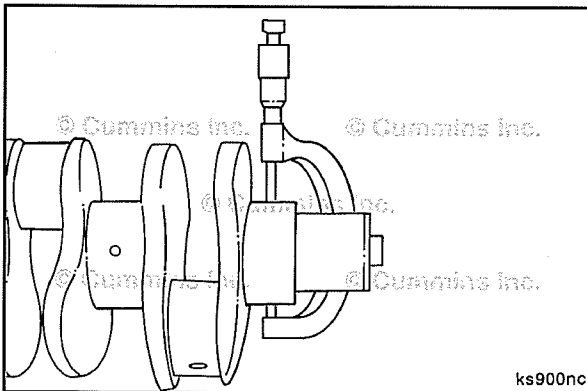
Crankshaft Connecting Rod Out of Roundness

mm		in
0.050	MAX	0.002

Crankshaft Connecting Rod Journal Taper

mm		in
0.013	MAX	0.0005

NOTE: If the crankshaft connecting rod journals are **not** within the given specifications, the crankshaft **must** be reground. Always grind all of the journals when one is **not** within specifications. Oversize connecting rod bearings are available; see the appropriate parts catalog.



Use a micrometer to measure the crankshaft main bearing journals.

Crankshaft Main Bearing Journal Diameter

mm		in
98.006	MIN	3.8585
98.032	MAX	3.8595

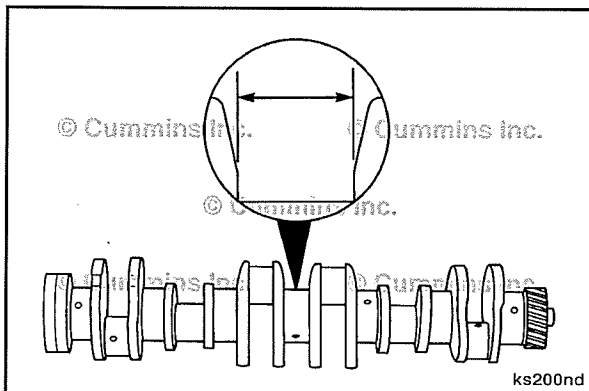
Crankshaft Main Bearing Journal Out of Roundness

mm		in
0.050	MAX	0.002

Crankshaft Main Bearing Journal Taper

mm		in
0.013	MAX	0.0005

NOTE: If the crankshaft main bearing journals are **not** within the given specifications, the crankshaft **must** be reground. Always grind all of the journals when one is **not** within specifications. Oversize connecting rod bearings are available; see the appropriate parts catalog.



Measure the thrust face width. Minor scratches are acceptable. Use a fine crocus cloth to polish the machined surfaces.

Crankshaft Thrust Face Width (Standard)

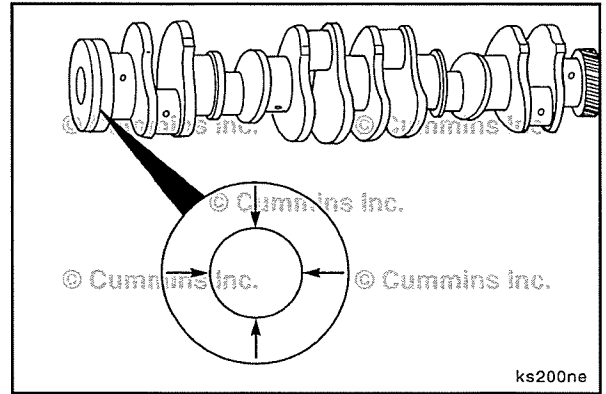
mm		in
42.98	MIN	1.692
43.08	MAX	1.696

NOTE: Oversize thrust bearings are available if the thrust distance is **not** within specifications. See the appropriate parts catalog.

Measure the rear oil seal flange outside diameter.

Crankshaft Rear Oil Seal Flange Outside Diameter

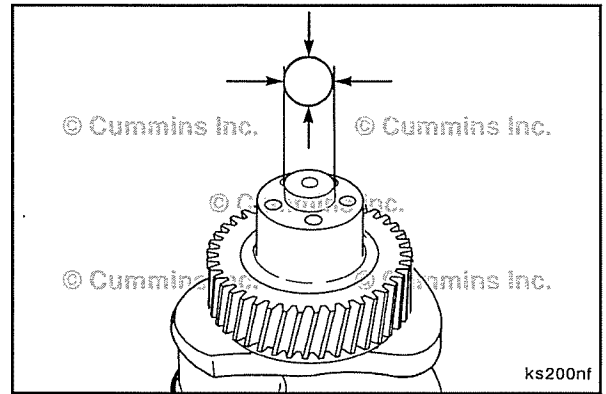
mm		in
129.98	MIN	5.117
130.03	MAX	5.119



Measure the damper pilot outside diameter.

Crankshaft Damper Pilot Outside Diameter

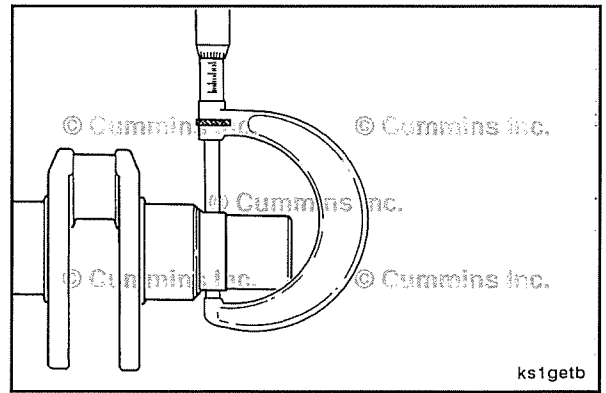
mm		in
23.92	MIN	0.942
24.00	MAX	0.945



Measure the crankshaft gear journal outside diameter.

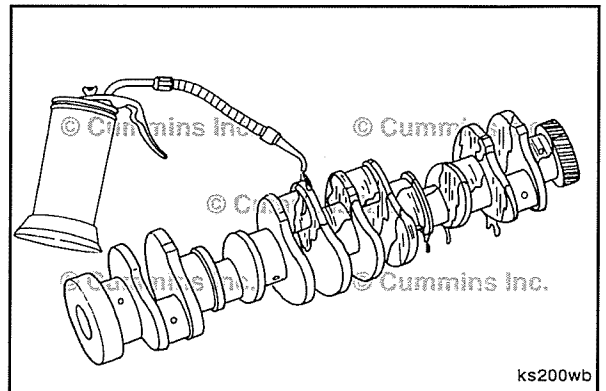
Crankshaft Gear Journal Outside Diameter

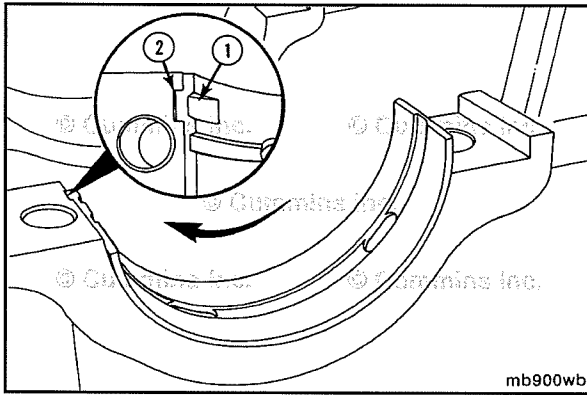
mm		in
75.987	MIN	2.9916
76.006	MAX	2.9924



Use a light preservative oil to lubricate the crankshaft to prevent rust.

NOTE: If the crankshaft is **not** going to be used immediately, protect the part with a plastic cover to prevent dirt from sticking to the oil.





Install

⚠CAUTION⚠

The tang (1) on the bearing shell must be in the slot (2) of the bearing saddle to correctly position the bearing and prevent engine damage.

Upper Main Bearings

Do **not** lubricate the side of the main bearing that is against the cylinder block.

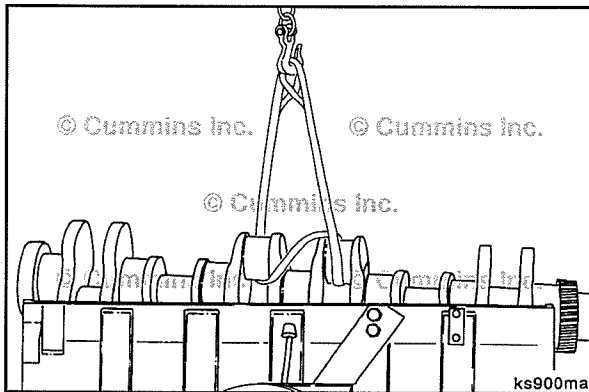
Apply a coat of assembly lubricant, Part Number 3163087 or equivalent, to the crankshaft side of the upper main bearings.

NOTE: Make sure the main bearing being installed is the same size as the main bearing that was removed. The size is engraved on the back of the main bearing.

NOTE: The crankshaft thrust bearing **must** be installed in the number four position.

NOTE: The upper and lower main bearing shells of some engines are **not** interchangeable. The backs of the main bearings are marked with the proper orientation, if required.

NOTE: If used bearing shells are to be installed, they **must** be installed in their original locations, as marked during disassembly.



Use a hoist and nylon list sling, Part Number 3375957.

Install the sling around the number 3 and number 4 connecting rod bearing journals.

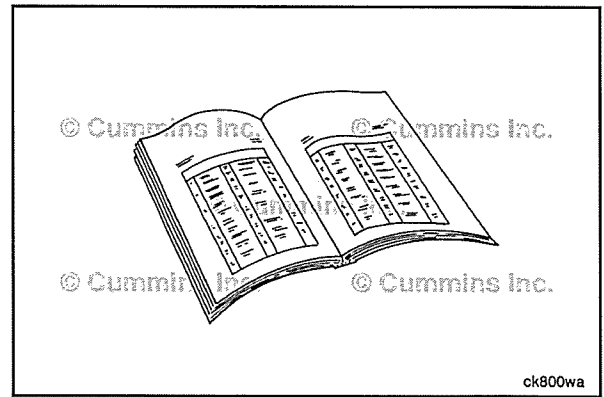
Install the crankshaft.

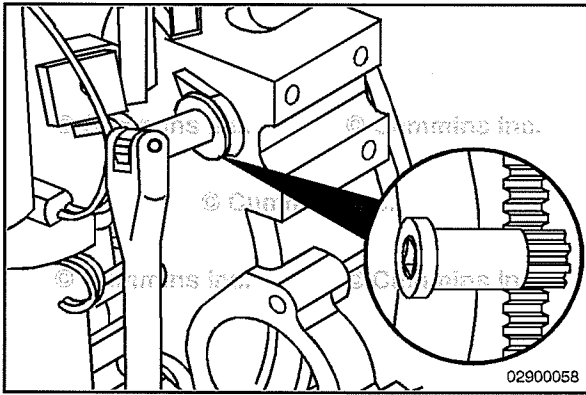
Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the main bearing caps. Refer to Procedure 001-006 in Section 1.
- Install the connecting rod caps. Refer to Procedure 001-005 in Section 1.
- Install the rear crankshaft seal carrier. Refer to Procedure 001-067 in Section 1.
- Install the front gear housing. Refer to Procedure 001-033 in Section 1.
- Install the camshaft gear. Refer to Procedure 001-012 in Section 1.
- Install the fuel pump. Refer to Procedure 005-016 in Section 5.
- Install the air compressor, if required. Refer to Procedure 012-014 in Section 12.
- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Install the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Install the flexplate, if removed. Refer to Procedure 016-004 in Section 16.
- Install the flywheel, if removed. Refer to Procedure 016-005 in Section 16.
- Install the front cover. Refer to Procedure 001-031 in Section 1.
- Install the rubber vibration damper, if removed. Refer to Procedure 001-051 in Section 1.
- Install the viscous vibration damper, if removed. Refer to Procedure 001-052 in Section 1.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Check the engine rotation. See the Rotation Check section of this procedure.
- Install the engine. Refer to Procedure 000-002 in Section 0.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



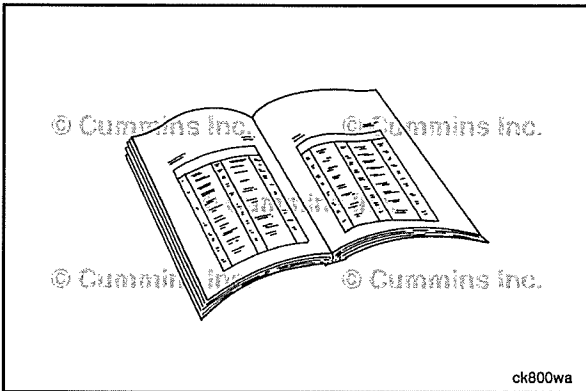


Rotation Check

With the engine fully assembled, check to be sure the engine rotates freely. Use barring tool, Part Number 3824591.

Insert the barring tool into the flywheel housing and engage the flywheel/flexplate ring gear. The crankshaft can then be rotated by hand, using a ½-inch ratchet or breaker bar.

If the engine does **not** rotate freely, check for any external obstructions (flywheel/flexplate, engine-driven accessories, etc.). If no obstructions are found, remove the oil pan and look for internal damage.

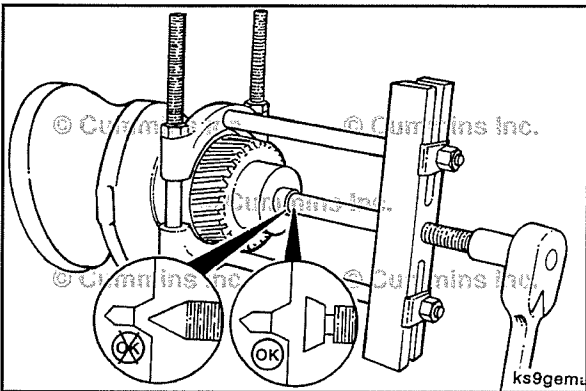


Crankshaft Gear, Front (Crankshaft Removed) (001-019)



Preparatory Steps

- Remove the crankshaft. Refer to Procedure 001-016 in Section 1.



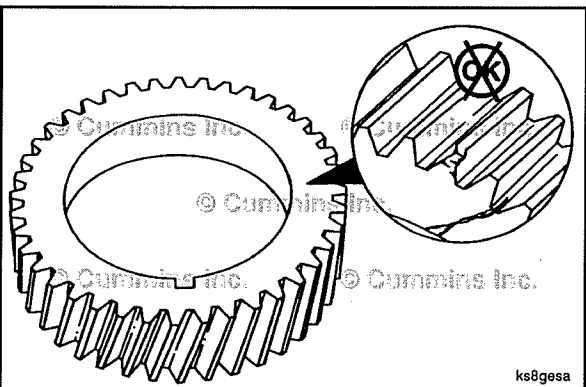
Remove

⚠CAUTION⚠

Do not try to split the front crankshaft gear to remove. The gear is made out of steel and will not split. Damage to the tool and the crankshaft can result.

NOTE: If a front crankshaft seal wear sleeve has been installed during a previous repair, it **must** be removed before the crankshaft gear is removed. Refer to Procedure 001-025 in Section 1.

Use a heavy-duty bearing separator, Part Number 316427, or gear puller, as illustrated, to remove the crankshaft gear.

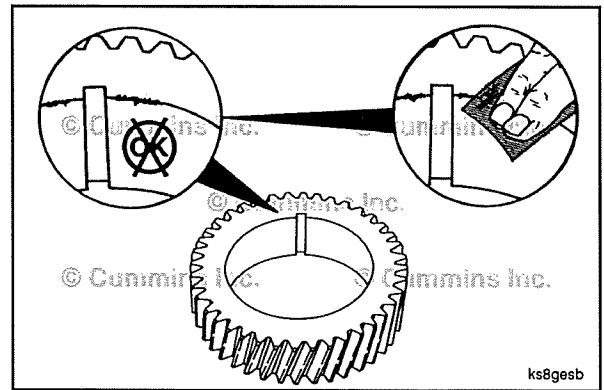


Clean and Inspect for Reuse

Inspect for cracks, broken, or chipped teeth.

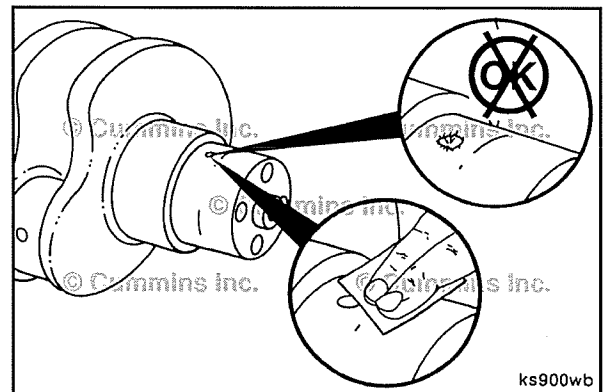
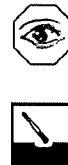
The gear **must** be replaced if it is damaged.

Inspect the gear and keyway for nicks or burrs.
 Use fine crocus cloth to remove nicks and burrs.



ks8gesb

Inspect the crankshaft gear journal and the gear alignment dowel pin hole for burrs or damage.
 Use fine crocus cloth to remove burrs.

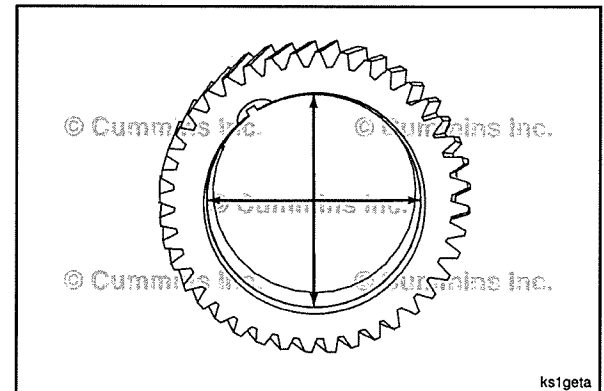


ks900wb

Measure the crankshaft gear bore inside diameter.

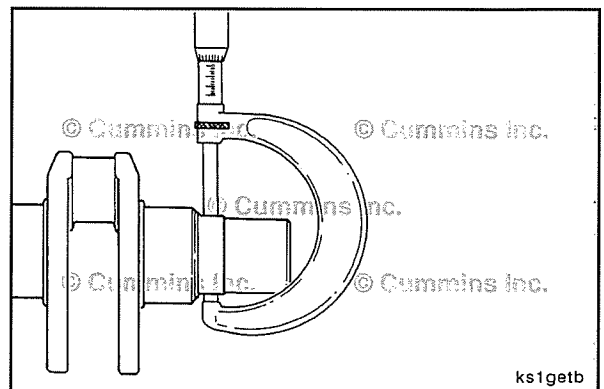
Crankshaft Gear Bore Inside Diameter

mm		in
75.898	MIN	2.9881
75.923	MAX	2.9891



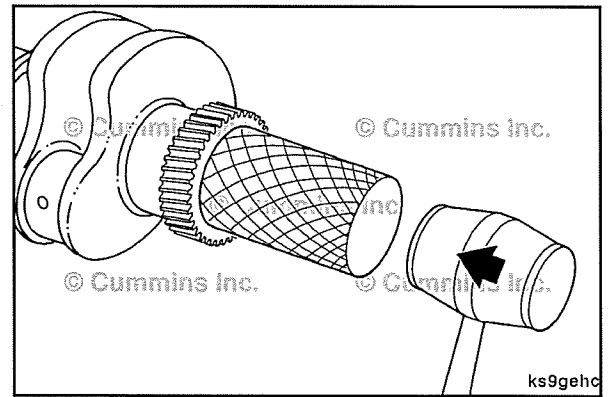
ks1geta

Measure the crankshaft gear journal outside diameter.
 Refer to Procedure 001-016 in Section 1.



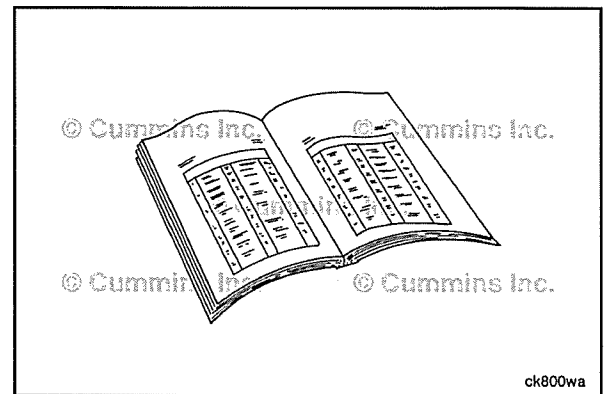
ks1getb

If the gear cools and stops on the crankshaft before it is fully installed, use a driver to complete the installation.



Finishing Steps

- Install the crankshaft. Refer to Procedure 001-016 in Section 1.
- Operate the engine and check for leaks.

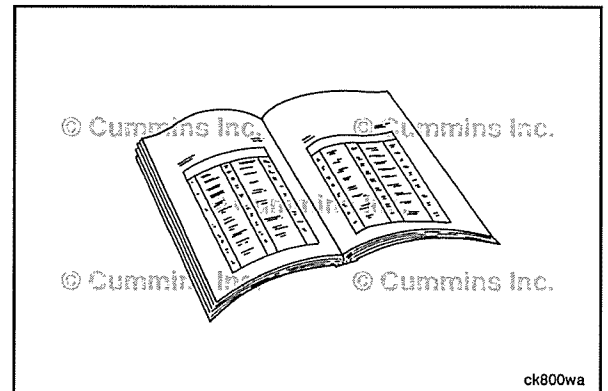


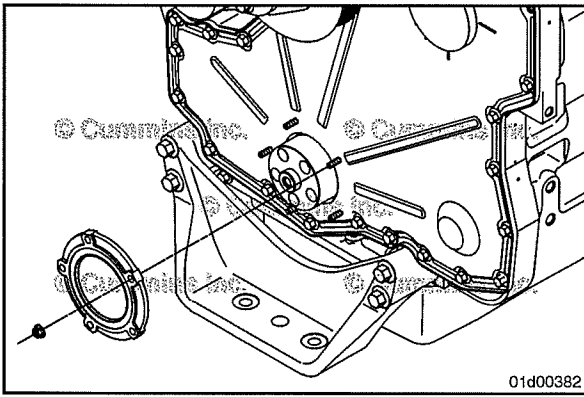
Crankshaft Seal, Front (001-023) Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

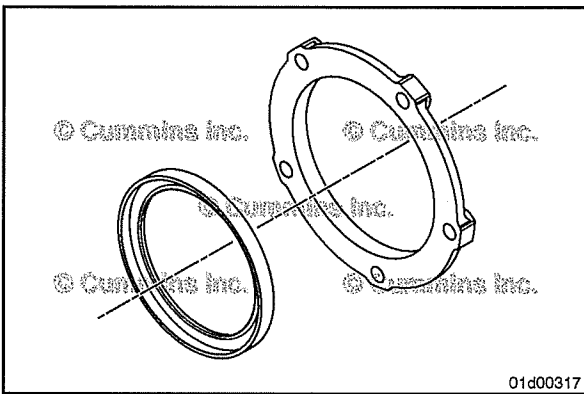
- Disconnect the battery. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the rubber vibration damper, if installed. Refer to Procedure 001-051 in Section 1.
- Remove the viscous vibration damper, if installed. Refer to Procedure 001-052 in Section 1.



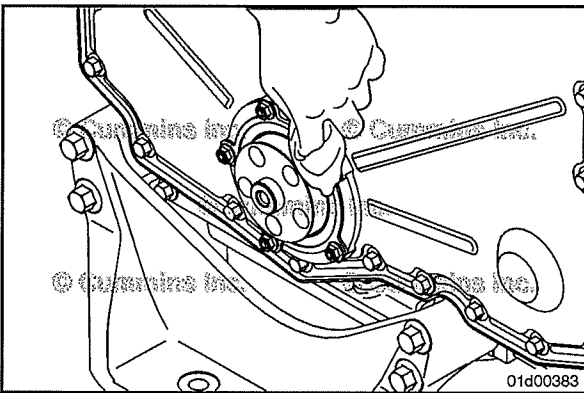


Remove

Remove the front crankshaft seal carrier.

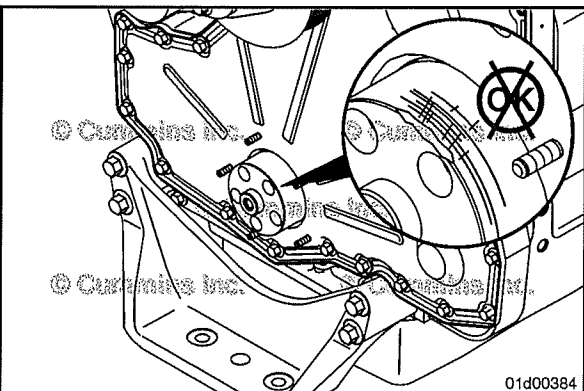


Remove the oil seal from the carrier. Drive the oil seal from the back side of the carrier toward the front side of the carrier, while supporting the carrier.



Clean and Inspect for Reuse

Clean the gear cover seal bore and the crankshaft surface of all oil and seal residue.



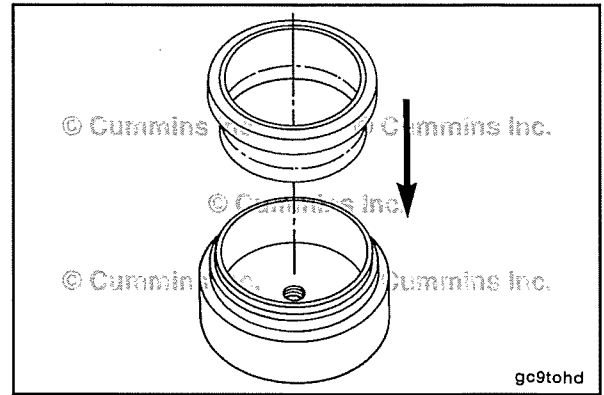
Inspect the crankshaft for excessive wear.

NOTE: If the crankshaft has excessive wear, a service wear sleeve is available. Refer to Procedure 001-025 in Section 1.

Install

Leave the plastic pilot installation tool in the lubricating oil seal.

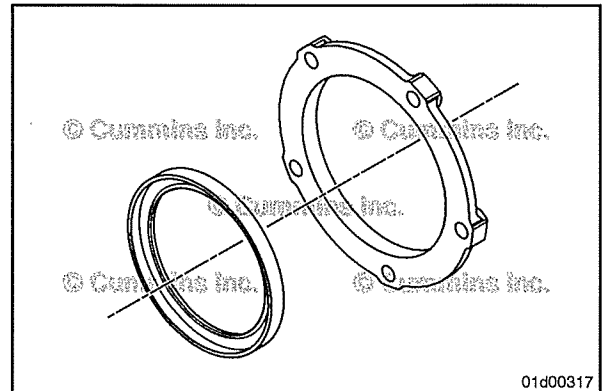
Position the seal on the service tool, Part Number 3824499, with the lubricating oil seal dust lip facing outward.



NOTE: Properly support the carrier lubricating oil seal flange to prevent damage to the lubricating oil seal and carrier.

Press the lubricating oil seal into the carrier from the back side of the carrier toward the front side of the carrier.

Press the lubricating oil seal until the seal is flush on front of the carrier.



Apply a bead of sealant, approximately 4 mm [0.16 in] thick and 4 mm [0.16 in] wide, around the inside of the seal carrier, between the mounting holes and the seal.

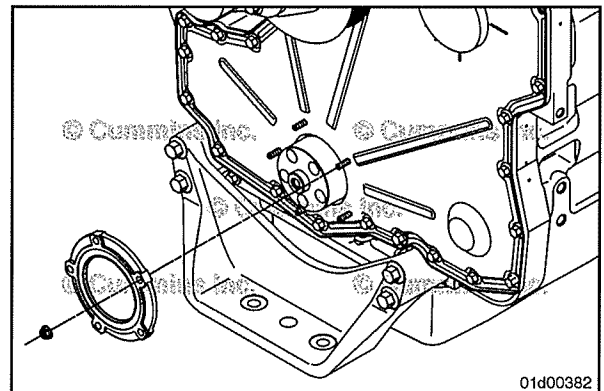
Apply a bead of sealant, approximately 4 mm [0.16 in] thick and 4 mm [0.16 in] wide, around all stud seams on the front cover.

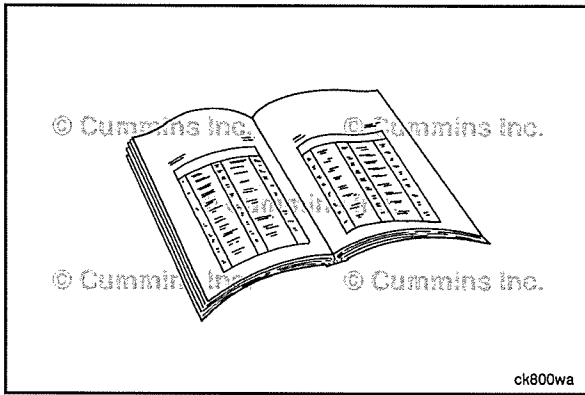
Install the seal carrier on the front gear cover.

Remove the plastic installation tool.

Starting with the upper left stud (as shown in the graphic), tighten the carrier mounting nuts in a star pattern.

Torque Value: 12 N•m [106 in-lb]





Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



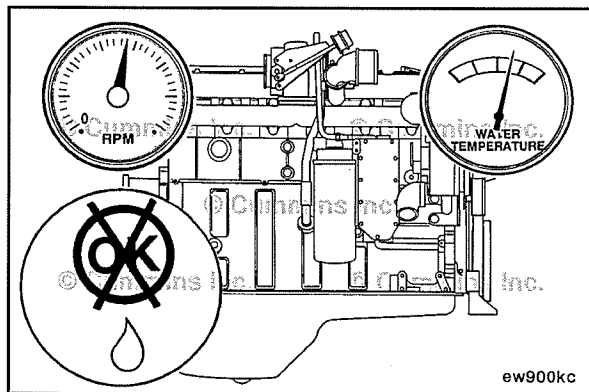
- Install the rubber vibration damper, if installed. Refer to Procedure 001-051 in Section 1.
- Install the viscous vibration damper, if installed. Refer to Procedure 001-052 in Section 1.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the battery. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Crankshaft Seal, Rear (001-024)

Initial Check



Verify that the rear crankshaft seal is the source of the oil leak by using fluorescent tracer, Part Number 3376891 or equivalent. Refer to Procedure 007-024 in Section 7.



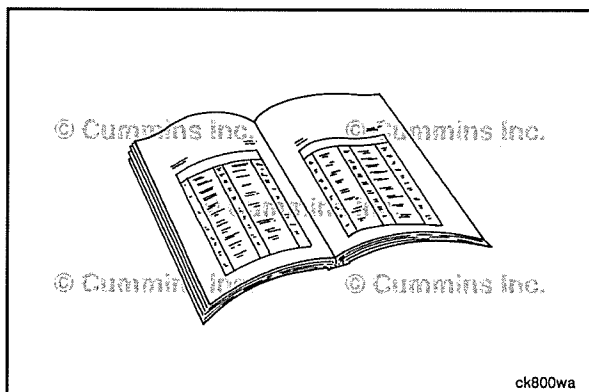
Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

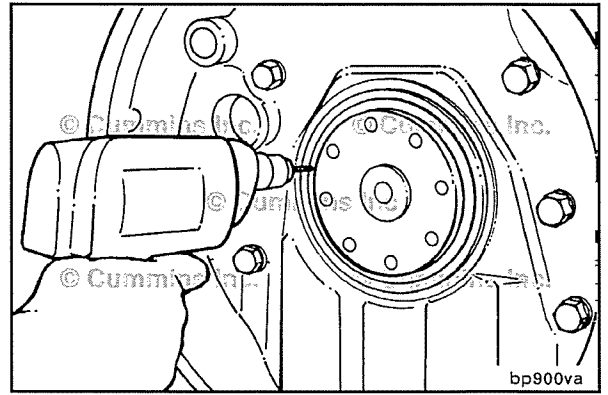


- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the clutch and transmission. Refer to the OEM service manual.
- Remove the starting motor. Refer to Procedure 013-020 in Section 13.
- Remove the flexplate, if installed. Refer to Procedure 016-004 in Section 16.
- Remove the flywheel, if installed. Refer to Procedure 016-005 in Section 16.

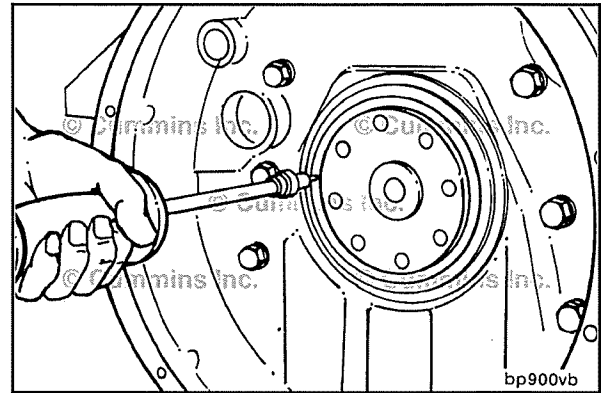


Remove

Drill two holes 180 degrees apart into the seal.



Use a screwdriver and a slide hammer to remove the rear seal.

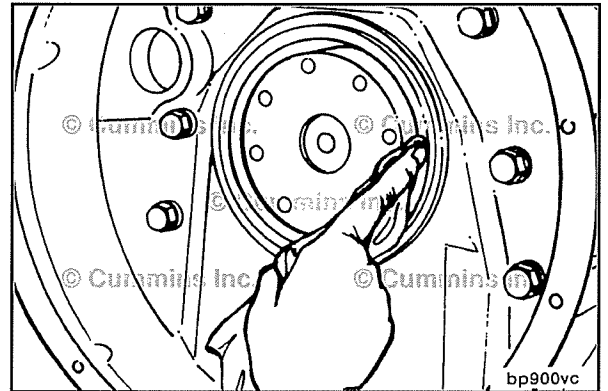


Clean and Inspect for Reuse

⚠ CAUTION ⚠

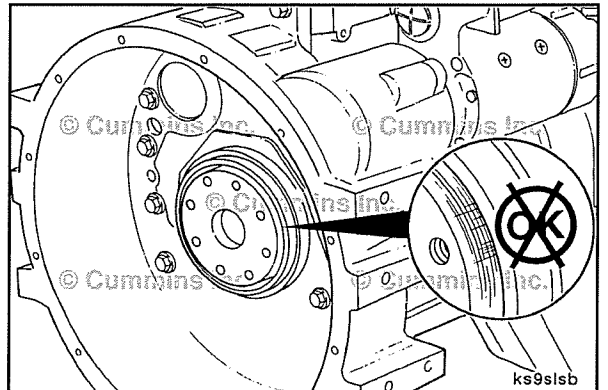
The seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

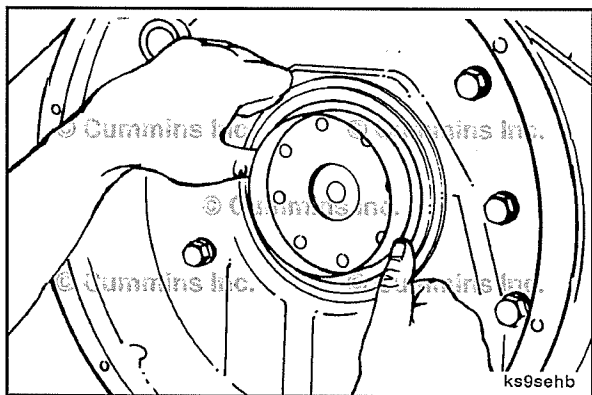
Clean and dry the rear crankshaft sealing surface.



Inspect the crankshaft for excessive wear.

NOTE: If the crankshaft has excessive wear, a service wear sleeve is available. Refer to Procedure 001-067 in Section 1.





Install

NOTE: For installation, the oil seal requires the application of a mild soap solution on the outside diameter of the seal carrier.

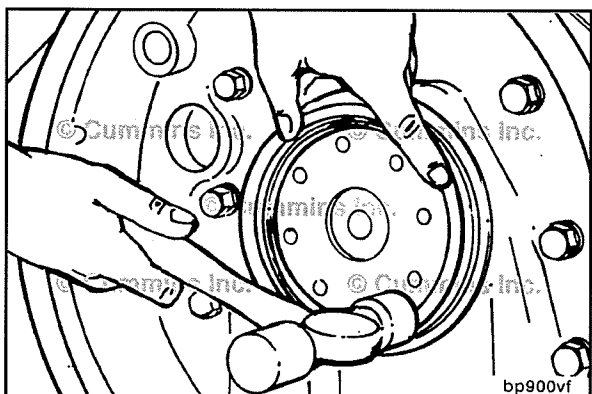


Install the seal pilot, provided in the replacement kit, onto the crankshaft. Push the seal onto the pilot and crankshaft.



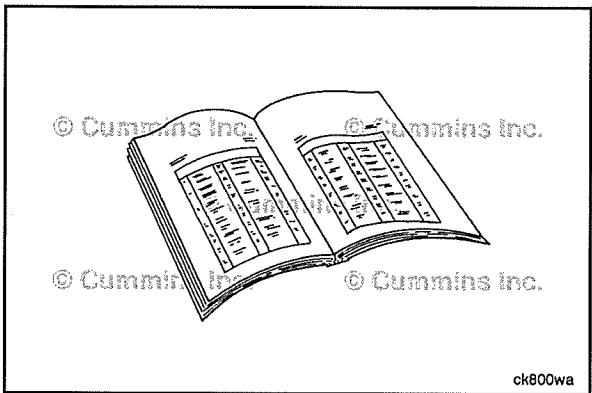
Remove the seal pilot.

NOTE: Use the following procedure for installation with the rear seal carrier already removed. Refer to Procedure 001-067 in Section 1.



Use the alignment tool to install the seal to the correct depth in the housing. Use a hammer to drive the seal into the housing until the alignment tool stops against the housing.

Hit the tool at the 12, 3, 6 and 9-o'clock positions to drive the seal evenly and to prevent bending the seal carrier.



Finishing Steps



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the flywheel, if installed. Refer to Procedure 016-005 in Section 16.
- Install the flexplate, if installed. Refer to Procedure 016-004 in Section 16.
- Install the starting motor. Refer to Procedure 013-020 in Section 13.
- Install the clutch and transmission. Refer to the OEM service manual.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Crankshaft Wear Sleeve, Front (001-025)



Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) cable first and attach the negative (-) cable last.

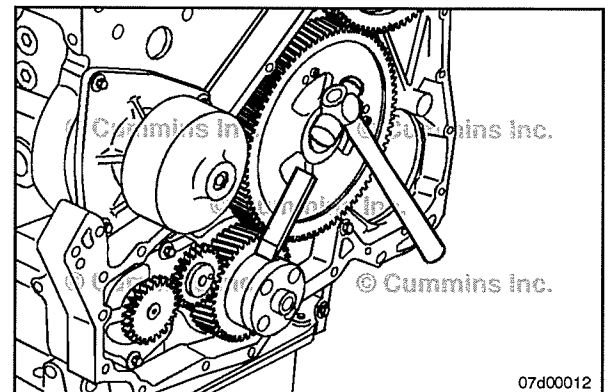
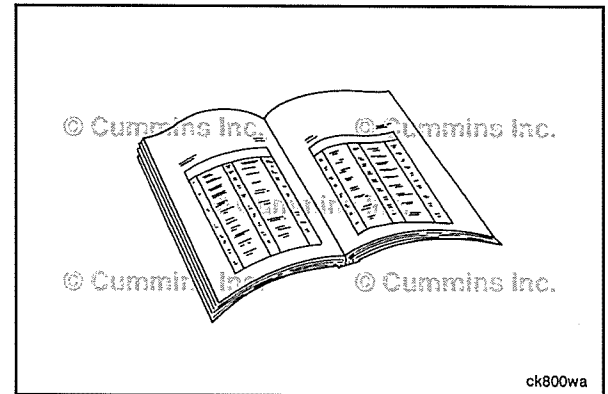
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the rubber vibration damper, if installed. Refer to Procedure 001-051 in Section 1.
- Remove the viscous vibration damper, if installed. Refer to Procedure 001-052 in Section 1.
- Remove the front cover. Refer to Procedure 001-031 in Section 1.

Remove

⚠ CAUTION ⚠

Do not nick or gouge the crankshaft with the chisel. If the crankshaft is severely damaged, it must be replaced.

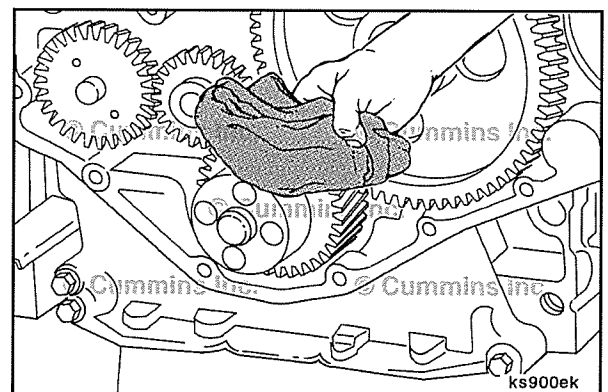
Use a hammer and a chisel that is **only** as wide as the wear sleeve. Make one or two chisel marks across the wear sleeve. This will expand the wear sleeve allowing the sleeve to be removed.

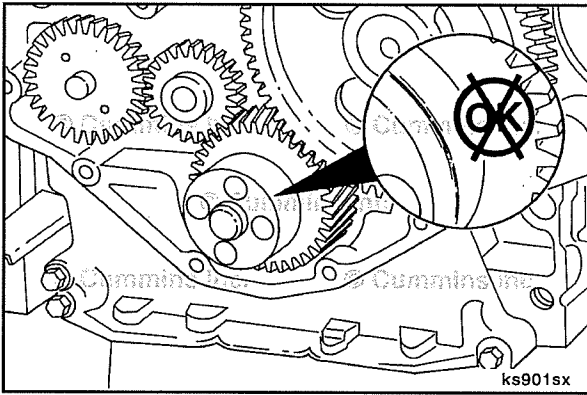


Clean and Inspect for Reuse

Use a crocus cloth to remove any rust or other deposits from the crankshaft flange.

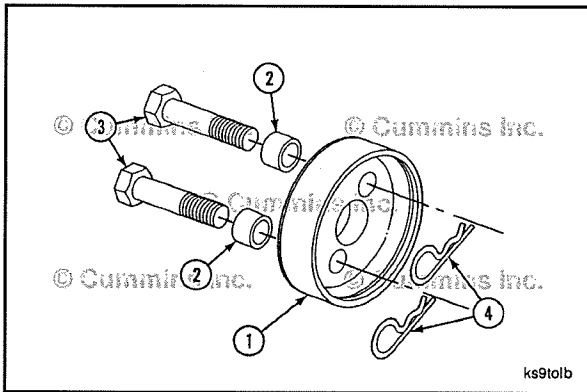
Use a clean cloth to clean the crankshaft flange.





Inspect the seal contact area of the crankshaft for a wear groove. If the seal has worn a groove deep enough to be felt with a sharp object or fingernail, it will be necessary to install a wear sleeve to prevent an oil leak.

The oil seal used with the wear sleeve has a larger inside diameter than the standard seal. The two seals are **not** interchangeable. See the appropriate parts catalog for the correct part number.

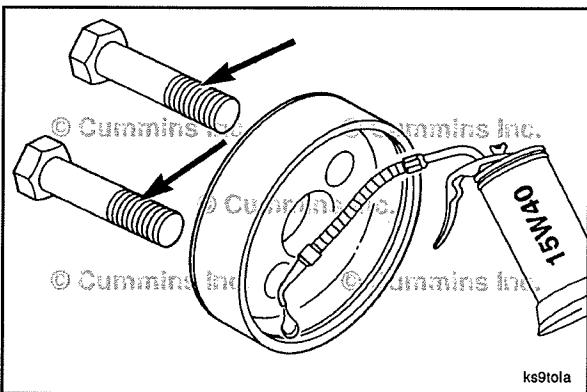


Install

NOTE: Engines with four capscrew holes on the front of the crankshaft use two capscrews with the sleeve installation kit, engines with five capscrew holes on the front of the crankshaft use three capscrews with the sleeve installation kit.

Use the wear sleeve installation kit, Part Number 3165112, to install the wear sleeve to the correct position on the crankshaft. The kit consists of the following:

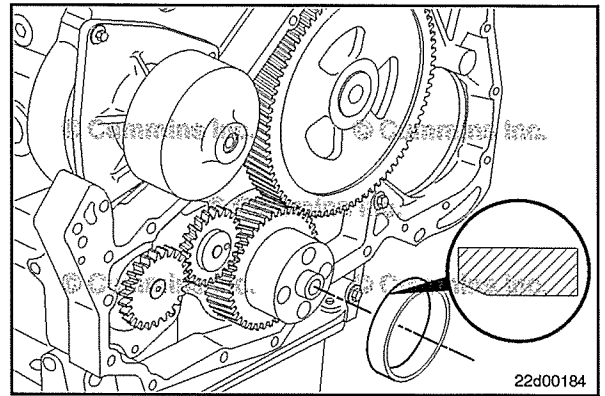
Reference Number	Description	Quantity
1	Driver	1
2	Spacer	3
3	Capscrew M14x1.5x60 mm	3



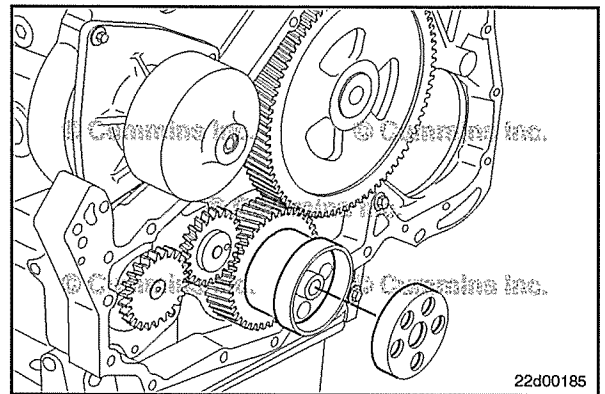
Apply a thin coat of clean 15W-40 lubricating oil to the inside diameter of the driver and to the capscrew threads.

Apply a thin coat of clean 15W-40 lubricating oil to the crankshaft flange.

Position the chamfered end of the wear sleeve onto the end of the crankshaft.



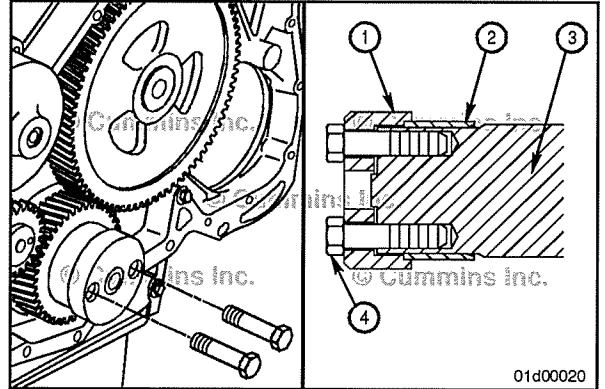
Position the counterbore end of the driver onto the wear sleeve.



Install the capscrews (without spacers) through the driver and into the crankshaft capscrew holes. Align the wear sleeve and driver perpendicular with the crankshaft. Tighten the capscrews "finger tight".



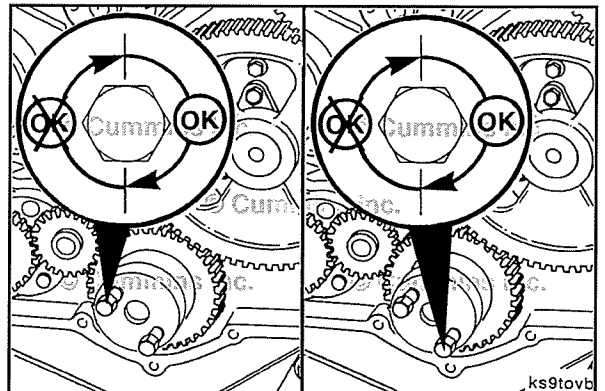
- 1 Driver
- 2 Wear Sleeve
- 3 Crankshaft
- 4 Capscrew.

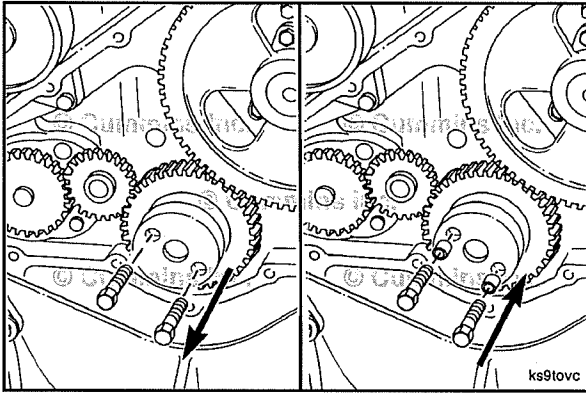


NOTE: To prevent damage to the wear sleeve, do not exceed 1/2 revolution of each capscrew.

Alternately tighten the capscrews until the sleeve is installed to a depth of approximately 16 mm [0.625 in].

Torque Value: 20 N•m [177 in-lb]

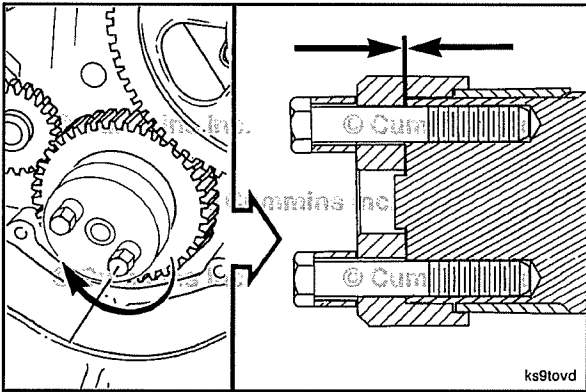




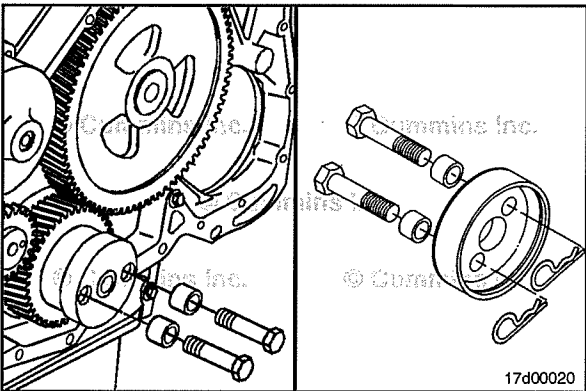
Remove the capscrews and install the spacer on each capscrew.



Install the capscrews again.



Continue to alternately tighten the capscrews until the bottom of the driver contacts the end of the crankshaft.



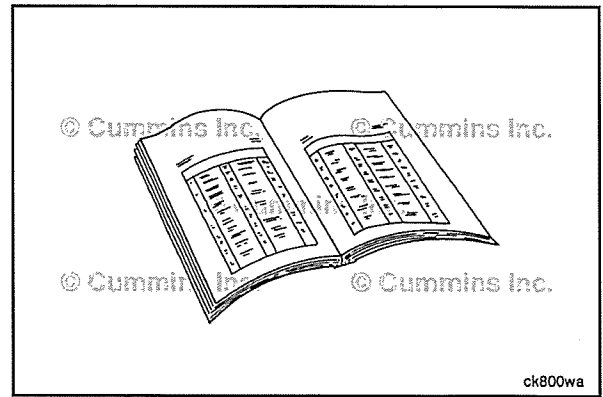
Remove the driver.

Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) cable first and attach the negative (-) cable last.

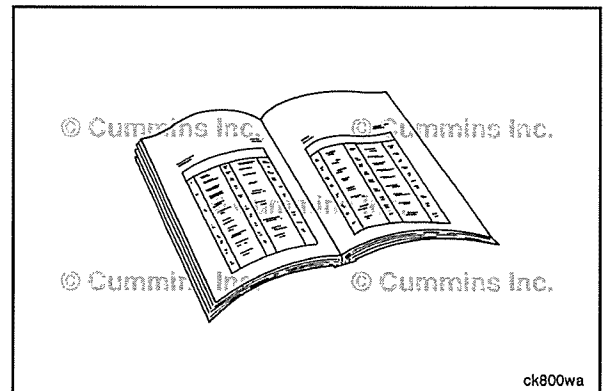
- Install the gear cover. Refer to Procedure 001-031 in Section 1.
- Install the front crankshaft seal. Refer to Procedure 001-023 in Section 1.
- Install the rubber vibration damper, if installed. Refer to Procedure 001-051 in Section 1.
- Install the viscous vibration damper, if installed. Refer to Procedure 001-052 in Section 1.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Cylinder Block (001-026)

Preparatory Steps

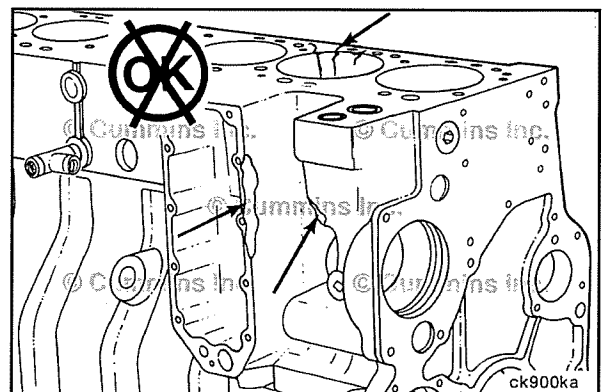
- Remove the engine and place it on an engine stand. Refer to Procedure 000-001 in Section 0.
- Disassemble the engine. See Section DS - Engine Disassembly.

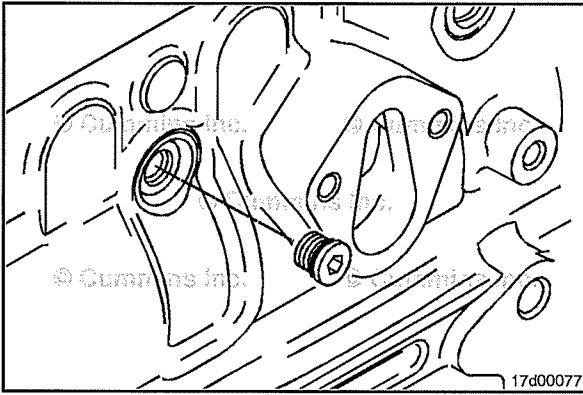


Initial Check

Before cleaning or further disassembly of the block, perform an inspection to see if there is any damage (cracks, fretting, etc.) that would prohibit reuse. Give special attention to areas of the block that include:

- Main bearing caps and bores
- Camshaft bores
- Cylinder bores
- Tappet bores
- Cylinder block combustion deck
- Oil pan mounting surface
- Lubricating oil pump mounting area
- Water pump mounting area
- Front and rear of block sealing surfaces
- Lubricating oil cooler cavity.





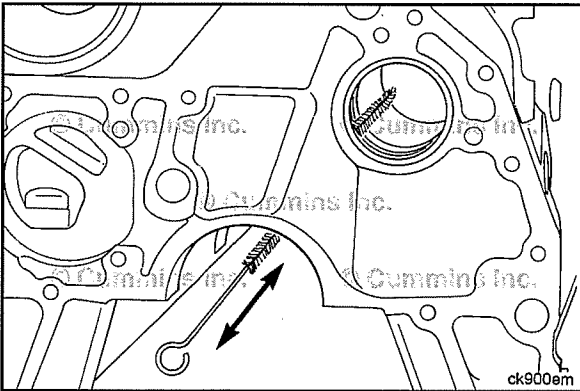
Clean and Inspect for Reuse

Inspect all pipe plugs, expansion plugs, and straight thread plugs for signs damage or leaks.

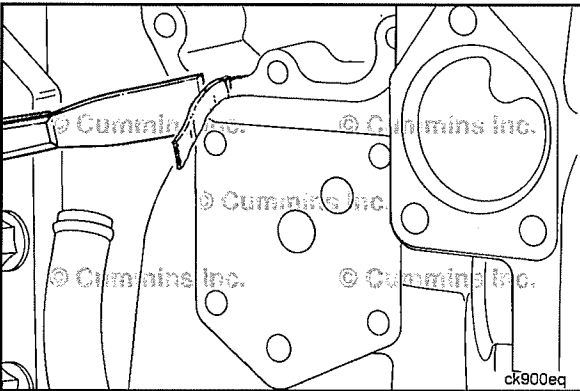


If it is necessary to thoroughly clean the cylinder block for reuse, remove all pipe plugs, expansion plugs, and straight thread plugs, as necessary. This will make sure all oil and coolant passages can be cleaned out.

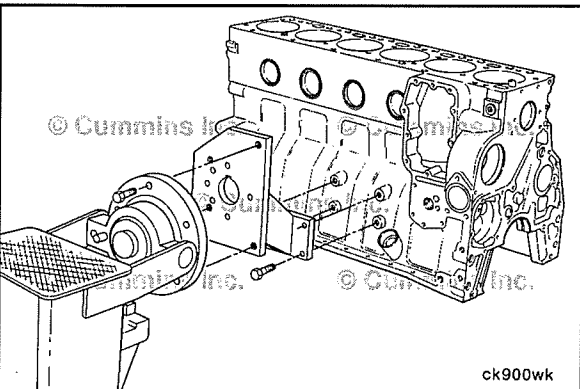
See Section 17 of this manual for removal and installation procedures.



Use clean solvent and a non-metallic brush to clean the block oil drillings.



Thoroughly clean all gasket sealing surfaces of any remaining gasket residue.



WARNING

This component or assembly weighs greater than 23 kg [50 lb]. To prevent personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Remove the block from the engine stand.

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ CAUTION ⚠

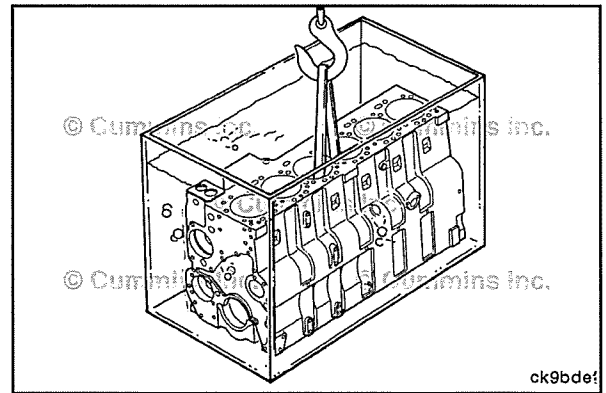
If the camshaft bushings have not been removed, make sure to use a cleaning solution that will not damage the camshaft bushing(s).

Follow the manufacturer's operating instructions for the cleaning tank.

Follow the solvent manufacturer's instructions for using the solvent.

NOTE: Cummins Inc. does **not** recommend any specific cleaning solution. Experience has shown the best results are obtained by the use of a cleaning solution that can be heated from 80 to 95°C [176 to 203°F] and a cleaning tank that will mix and filter the cleaning solution.

Clean the cylinder block in the cleaning tank.



⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

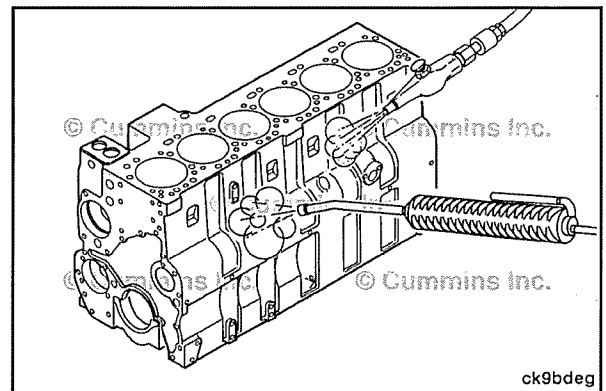
⚠ CAUTION ⚠

To reduce the possibility of engine damage, make sure all debris is removed from the capscrew holes and oil passages.

Remove the block from the cleaning tank.

Use steam to clean the block thoroughly.

Use compressed air to dry the block.

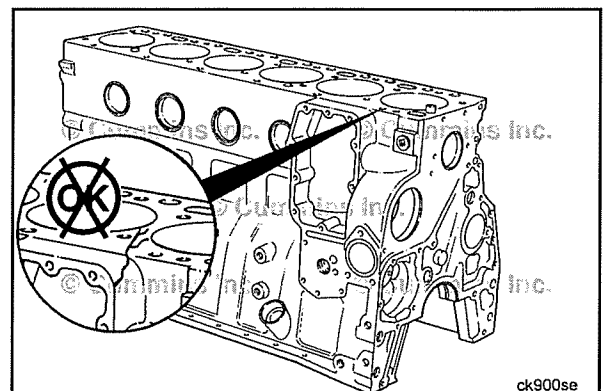


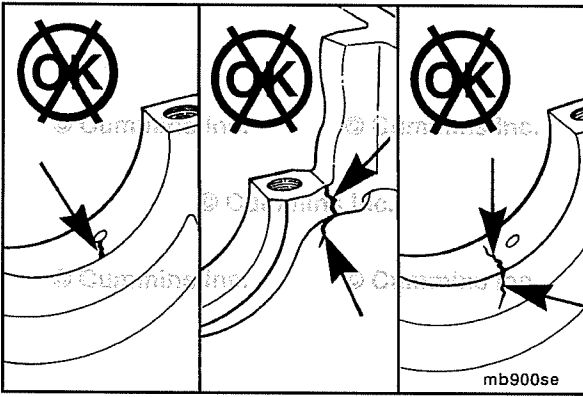
With the cylinder block cleaned, inspect the cylinder block for signs of cracks, fretting, and discoloration that would prohibit reuse.

To help identify cracks in the cylinder block, use the crack detection kit, Part Number 3375432.

Give special attention to areas of the block that include:

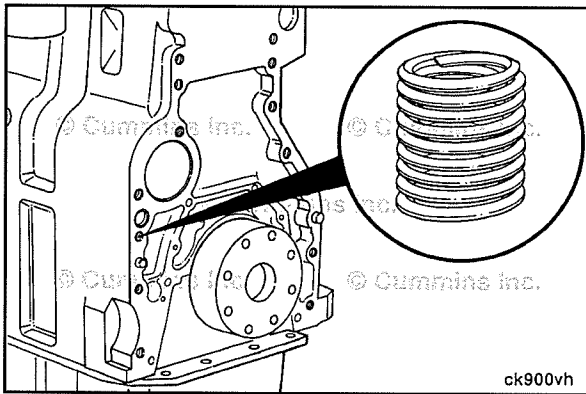
- Main bearing caps and bores
- Camshaft bores
- Cylinder bores
- Tappet bores
- Cylinder block combustion deck
- Oil pan mounting surface
- Lubricating oil pump mounting area
- Water pump mounting area
- Front and rear of block sealing surfaces
- Lubricating oil cooler cavity.





Make sure to inspect the main bearing caps and main bearing saddle areas for cracks, fretting and signs of discoloration.

If any cracks are found, the block **must** be replaced.

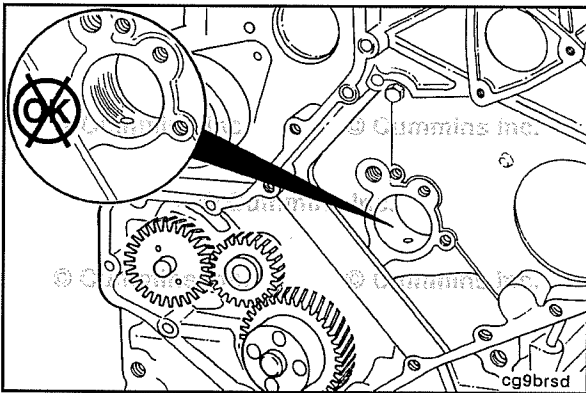


Inspect all threaded capscrew holes for damaged threads. Coiled thread inserts may be used to repair any damaged threads.

Service tool thread repair kits are available:

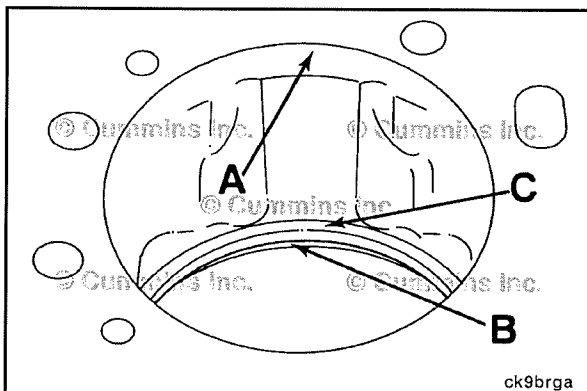
- 1 Part Number 3377905 for standard threads.
- 2 Part Number 3377903 for metric threads.

NOTE: Coiled thread inserts should **not** be used to repair main bearing saddle threaded capscrew holes. If damaged, the block **must** be replaced.



Inspect the camshaft bores for scoring, scuffing, or excessive wear.

If the camshaft bore is damaged, the cylinder block **must** be replaced. Oversize cam bushings are **not** available.



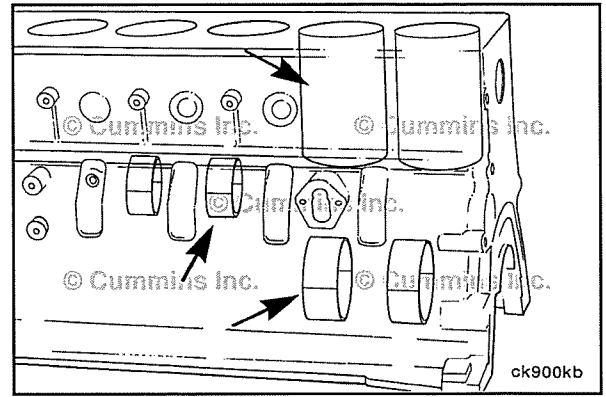
Inspect the counterbore for extreme wear or cracks.

If surface C has signs of extreme wear, the counterbore will require machining and the installation of shims for the correct liner protrusion. See the Repair section of this procedure.

Measure

All measurements of the cylinder block **must** be made when the cylinder block is positioned on a flat surface with the main bearing caps installed.

If the cylinder block is mounted on the engine stand and/or the main bearing caps are **not** installed, the measurements can be incorrect because of distortion to the cylinder bores, main bearing bores, camshaft bores, etc.

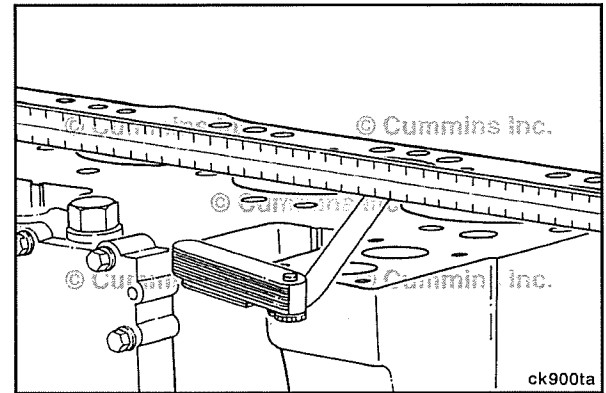


Inspect the cylinder block head deck for damage.

Check the cylinder block head deck for flatness between each cylinder.

Cylinder Block Flatness Specification		
mm		in
0.075	End-to-end	0.003
0.075	Side-to-side	0.003

Inspect for any localized dips or imperfections. If any damage is detected, or the flatness is out of specification, the cylinder block **must** be replaced.

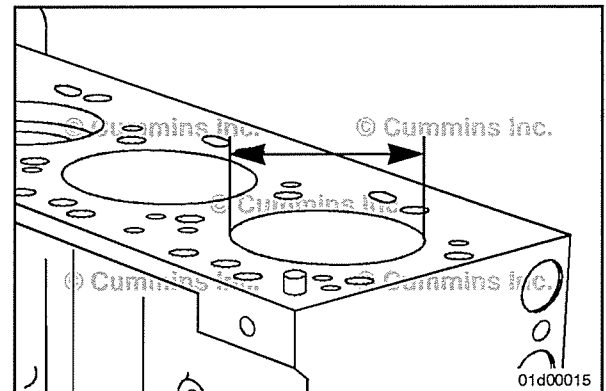


Measure the cylinder liner bore in the block.

Cylinder Liner Bore in Block (Press Fit Bore)

mm		in
130.900	MIN	5.1535
130.950	MAX	5.1555

NOTE: If any of the cylinder liner bores are out of specification, the cylinder block **must** be replaced.

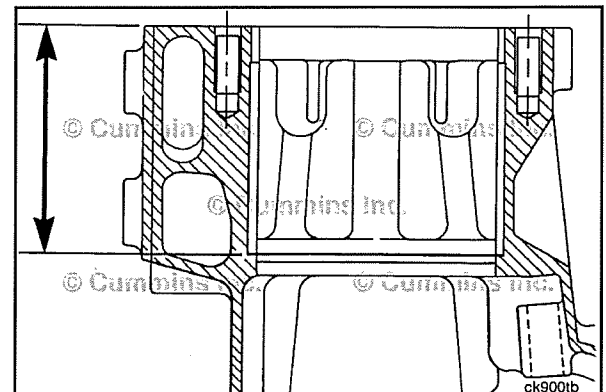


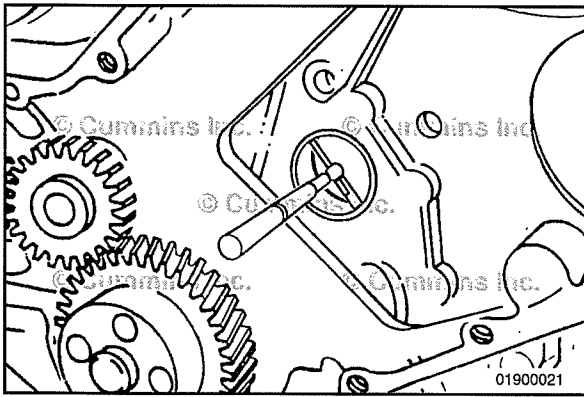
Measure the liner counterbore depth.

Cylinder Block Counterbore Depth from Cylinder Block Head Deck

mm		in
122.930	MIN	4.8397
123.000	MAX	4.8425

NOTE: If any of the liner counterbore depths are out of specification, the counterbore can be machined and shims installed. See the Repair section of this procedure.



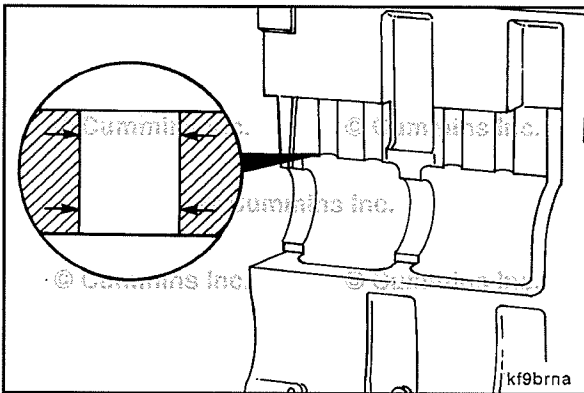


Measure the camshaft bores without the camshaft bushing installed.

Camshaft Bore Diameter (Without Bushing)

mm		in
64.01	MAX	2.520

NOTE: If any of the camshaft bore diameters are out of specification, the cylinder block **must** be replaced.



Inspect the tappet bores for scoring or excessive wear.

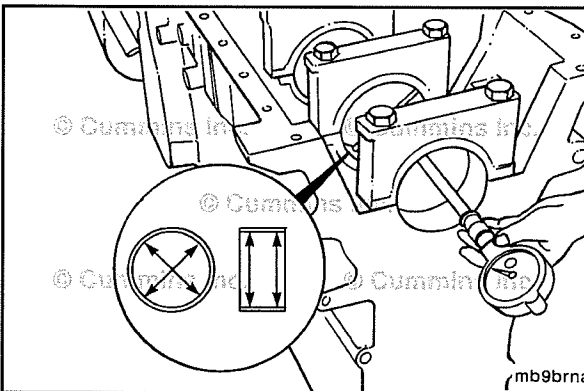
Measure the tappet bores.



Tappet Bore Diameter

mm		in
31.295	MIN	1.2321
31.325	MAX	1.2333

NOTE: If any of the tappet bores are out of specification, the cylinder block **must** be replaced.



Install the main bearing caps without the main bearings.

Tighten the main bearing cap capscrews.

Torque Value: 176 N•m [130 ft-lb]



Measure the main bearing bore with the bearings removed.



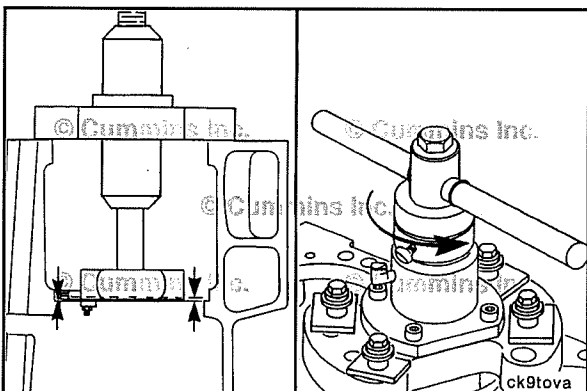
Main Bearing Bore Diameter

mm		in
104.982	MIN	4.1331
105.018	MAX	4.1346

NOTE: The maximum bore misalignment is 0.0127 mm [0.005 in].

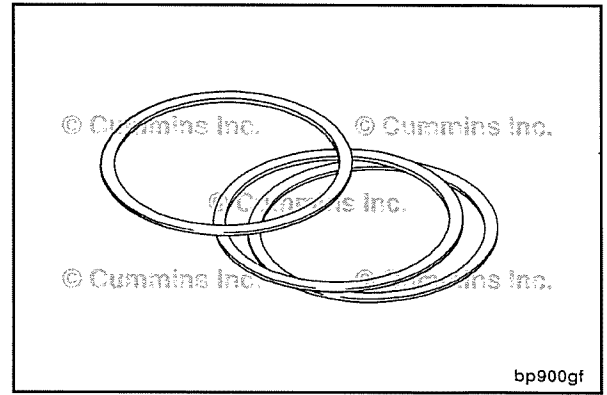
Repair

If the counterbores require machining, use counterbore cutter, Part Number 3163785, to machine the counterbore to the proper depth.



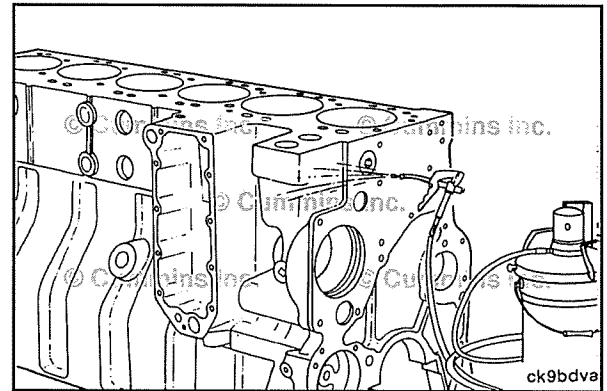
Cylinder liner shims are available in the following thicknesses.

Cylinder Liner Shim Thickness	
mm	in
0.25	0.010
0.38	0.015
0.51	0.020
0.76	0.030
1.00	0.040



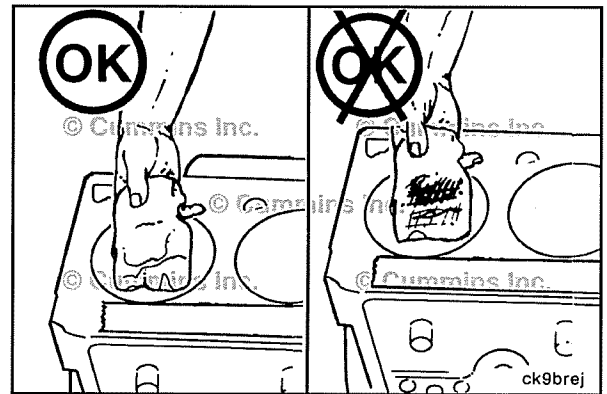
If the cylinder block is **not** to be used right away, coat all machined surfaces with a rust preventative solvent.

Make sure to cover the cylinder block to prevent dust and debris from collecting on and in the cylinder block.



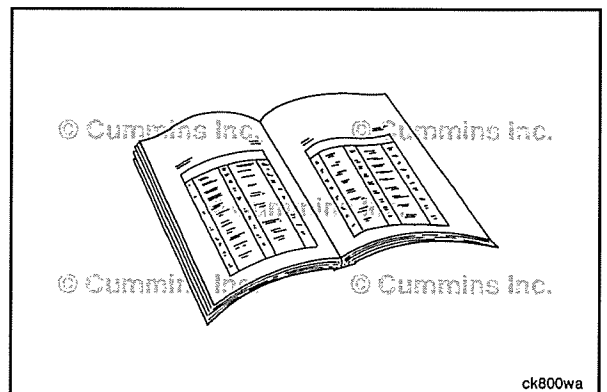
New Cylinder Block

If replacing the cylinder block or using a previously stored cylinder block, make sure to clean any oil/rust preventative solvent from the cylinder bores, gasket sealing areas, and main bearing bores prior to use.



Finishing Steps

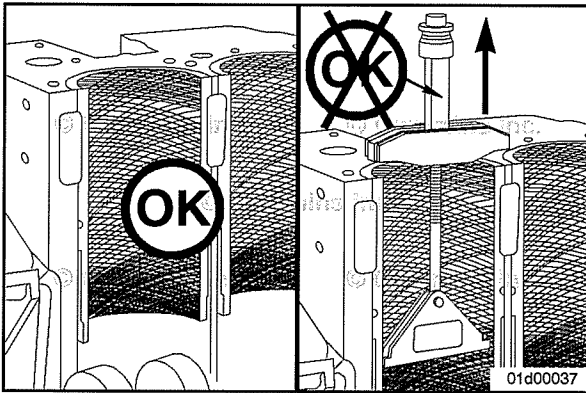
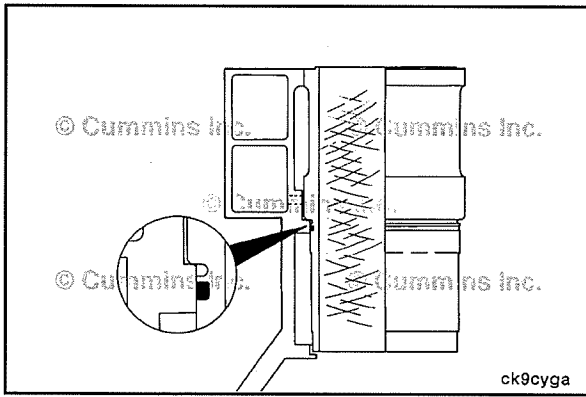
- Assemble the engine. See Section AS - Engine Assembly.
- Remove the engine from the engine stand and install the engine. Refer to Procedure 000-002 in Section 0.
- Operate the engine and check for leaks.



Cylinder Liner (001-028)

General Information

The cylinder block has a replaceable cylinder liner. A mid-stop design is used to locate the liner in the block. A press fit between the liner and the block provides coolant sealing at the top of the liner. A rectangular ring seal (liner seal) is used for sealing at the mid-stop portion of the liner.



NOTE: Cummins Inc. does **not** recommend removing the cylinder liners to repair an oil consumption problem if the inside diameters of the liners are within the inspection limits included in this procedure. Careful analysis of the condition of the liner bores, piston rings, and pistons can result in the restoration of cylinder sealing with a minimum replacement of parts.

Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ WARNING ⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

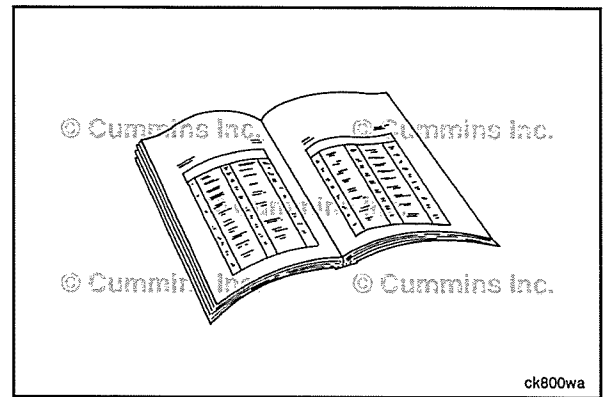
⚠ WARNING ⚠

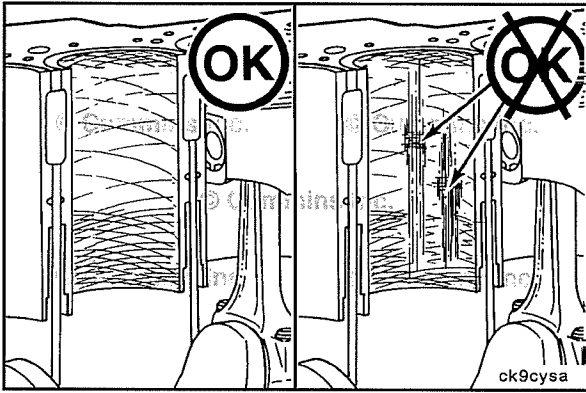
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠ WARNING ⚠

Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the cooling system. Refer to Procedure 008-018 in Section 8.
- Remove rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the cylinder head. Refer to Procedure 002-004 in Section 2.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Remove the piston and connecting rod assemblies. Refer to Procedure 001-054 in Section 1.





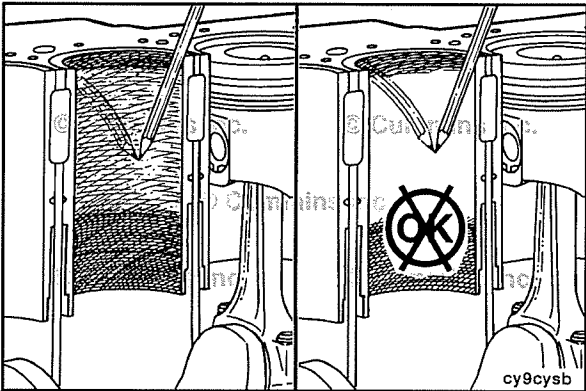
Initial Check

NOTE: Before removing the cylinder liners, inspect the condition to determine reuse.

Inspect the inside diameters of the liners for cracks, scuffing, and scoring.

Inspect the inside diameters for vertical scratches deep enough to be felt with a fingernail.

NOTE: If a fingernail catches in the scratch, the liner **must** be replaced.

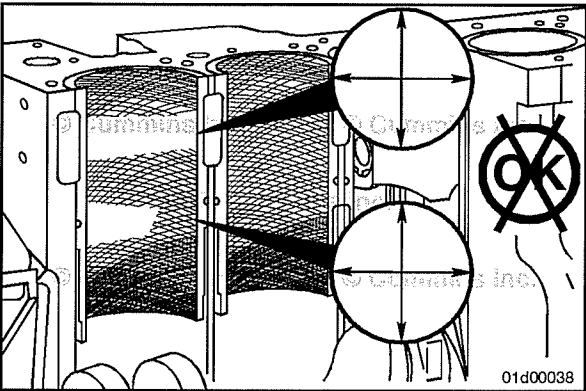


Inspect the inside diameter for liner bore polishing.

A moderate polish produces a bright mirror finish in the worn area with traces of the original hone marks or an indication of an etch pattern.

A heavy polish produces a bright mirror finish in the worn area with no traces of hone marks or an etch pattern.

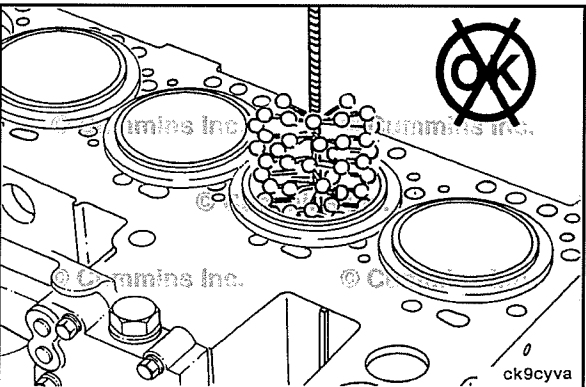
Do **not** reuse liners exhibiting heavy polish or any indications of particle embedment from a failure. Severely worn liners will have a ridge near the top of the liner bore.



If the wear pattern indicates the liner bore is **not** straight or **not** round, use a dial bore gauge to measure the liner inside diameter in four places 90 degrees apart at the top and bottom of the piston travel area.

Cylinder Liner Dimensions

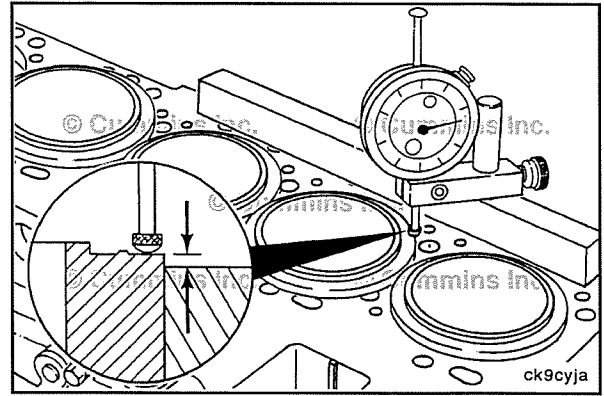
	mm		in
Taper	0.04	MAX	0.0016
Out Of Round	0.04	MAX	0.0016
Bore Diameter	114.04	MAX	4.4898



NOTE: If a liner bore is **not** acceptable for reuse, it **must** be replaced. Damaged liners can **not** be honed or deglazed. This would destroy the cross-hatch pattern needed for oil control.

NOTE: Do **not** remove or disturb the liner seals for liners which pass the inspection criteria.

Liner protrusion is the distance the liner protrudes above the block face. Before removing the liners, check the protrusion in the "unclamped" stage. Use liner protrusion gauge, Part Number 3164438, to measure the liner protrusion.



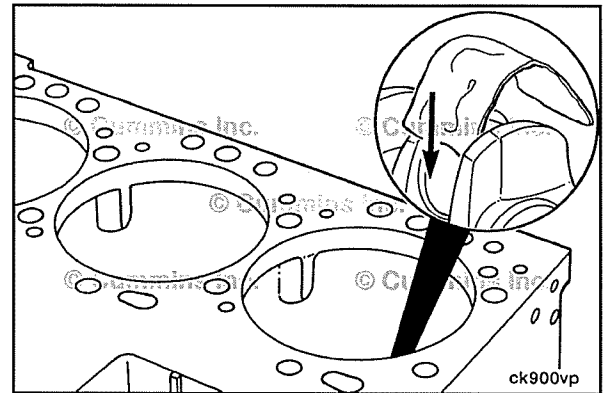
Cylinder Liner Protrusion

mm		in
0.026	MIN	0.0010
0.122	MAX	0.0048

If the liner was installed correctly and the liner protrusion is out of limits, it will be necessary to machine the counterbore and add shims to restore to the original specifications.

Remove

Use clean shop rags to cover the crankshaft to prevent debris from falling into the main journal area or into the connecting rod journal oil drilling.



CAUTION

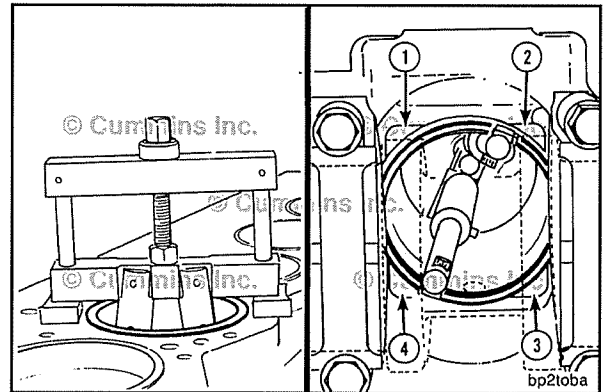
The liner puller must be installed and used as described to avoid damage to the cylinder block. The puller must not contact the block casting at points (1), (2), (3), and (4).



Universal Cylinder Liner Puller Method

Cylinder Liner Puller, Part Number 3376015

Insert the liner puller into the top of the cylinder block.

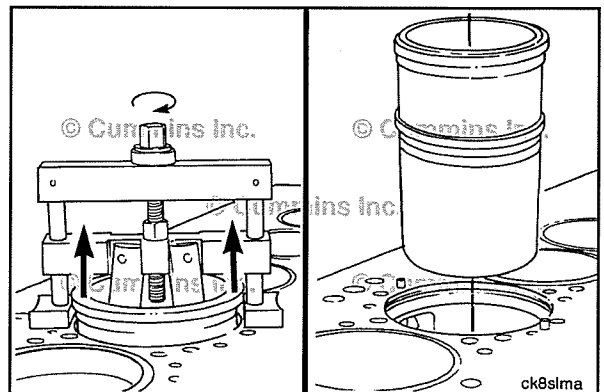


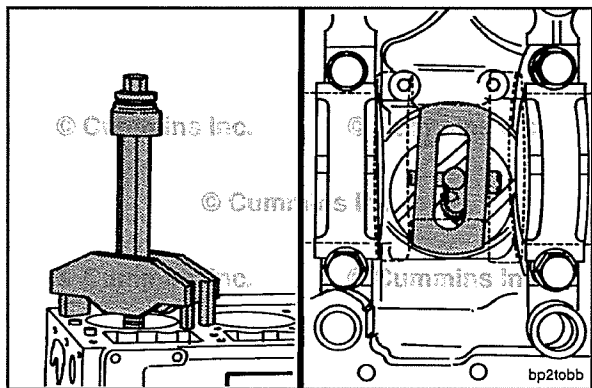
NOTE: The liner puller **must** be centered on the top of the cylinder block.



Turn the puller jackscrew **clockwise** to loosen the liner from the cylinder block.

Use both hands to remove the liner.





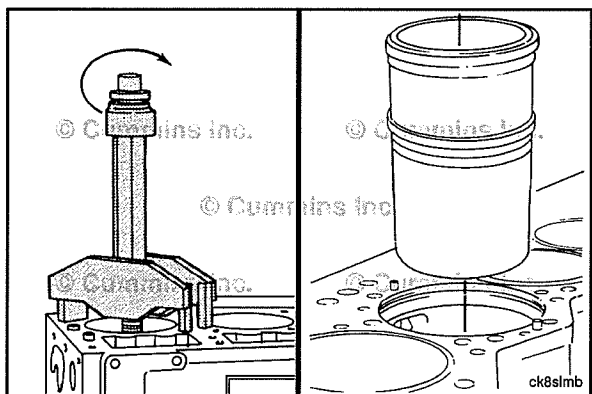
CAUTION

The liner puller must be installed and used as described to reduce the possibility of damage to the cylinder block. The puller plate must be parallel to the main bearing saddles and must not overlap the liner outside diameter.

Standard Liner Puller Method

Liner Puller, Part Number 3163745, may be used as an alternative to the standard puller. The universal puller **must** be used with remover plate, Part Number 3822786.

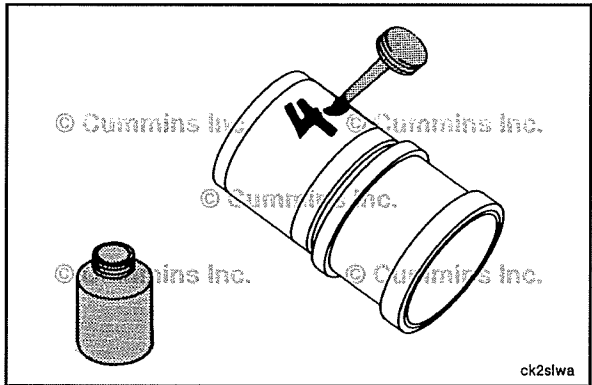
Insert the liner puller into the top of the cylinder block.



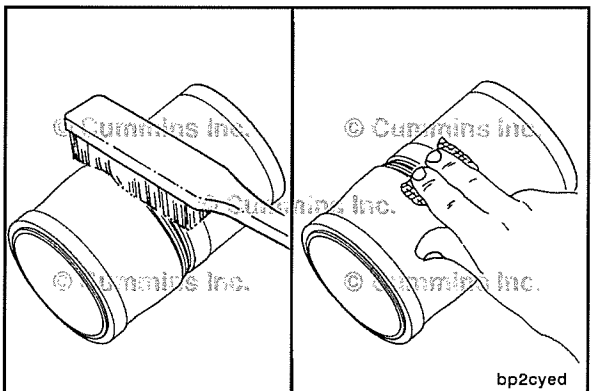
NOTE: The liner puller **must** be centered on the top of the cylinder block.

Turn the puller jackscrew **clockwise** to loosen the liner from the cylinder block.

Use both hands to remove the liner.



Mark the cylinder number on each liner.



Clean and Inspect for Reuse

CAUTION

Do not use any abrasives in the ring travel area of the liner. The liner can be damaged.

Use a soft wire brush or a fine fibrous abrasive pad such as abrasive pad, Part Number 3823258 or equivalent, to clean the flange seating area.

⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use solvent or steam clean the liners and dry with compressed air.

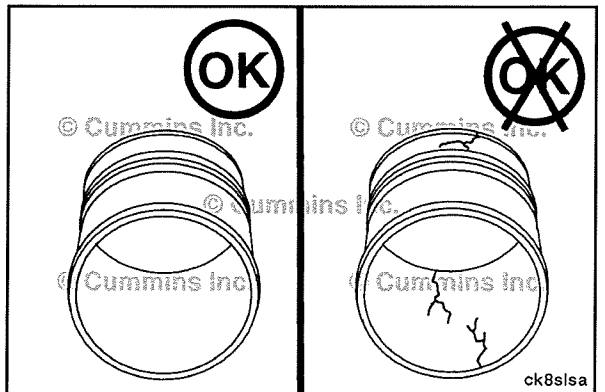
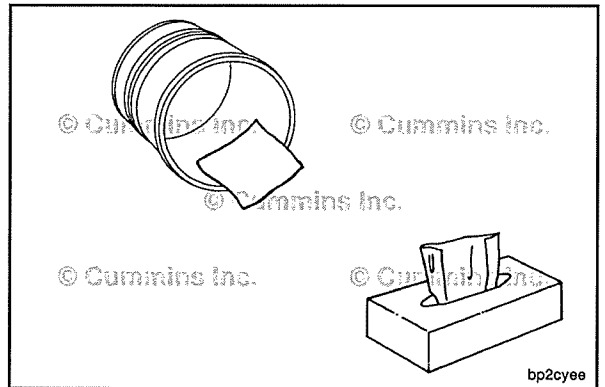
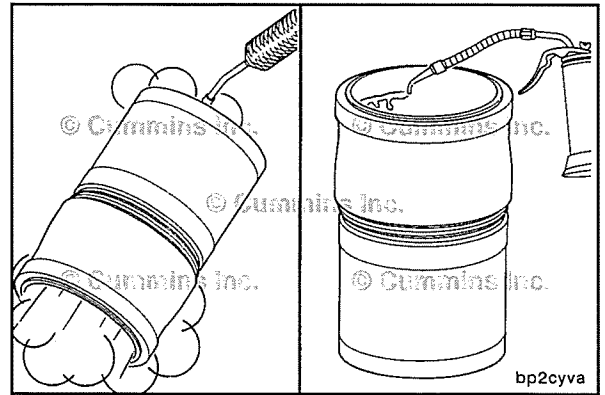
Use clean 15W-40 oil to lubricate the inside diameter of the liners.

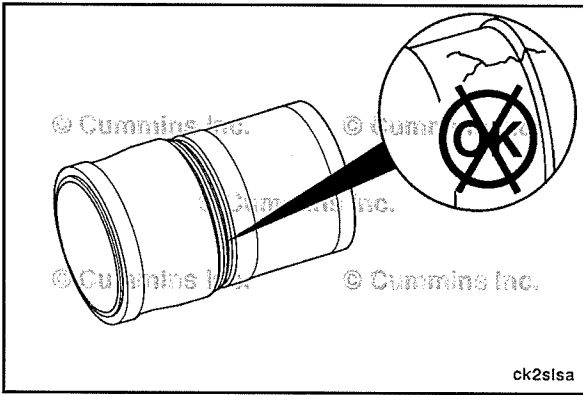
Allow the oil to soak in the liner for 5 to 10 minutes.

NOTE: Use "lint-free" paper towels to wipe the oil from the inside of the liners.

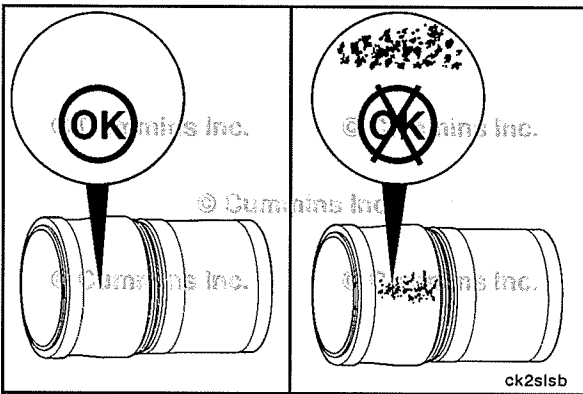
Continue to lubricate the inside of the liners and wipe clean until the paper towel does **not** show gray or black residue.

Inspect the liners for cracks on the inside and outside diameters.





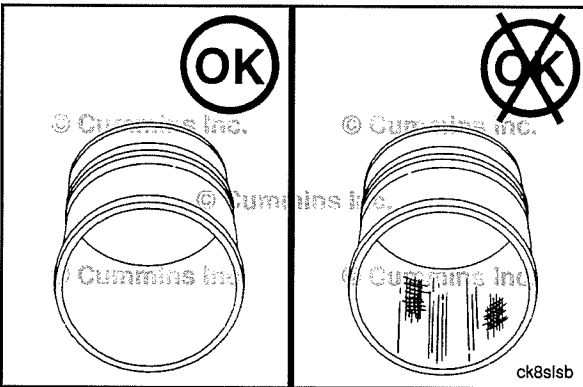
Inspect for cracks under the flange.



Inspect the outside diameter and seat area for excessive corrosion or pitting.

NOTE: Pits **must not** be more than 1.6 mm [0.06 in] deep.

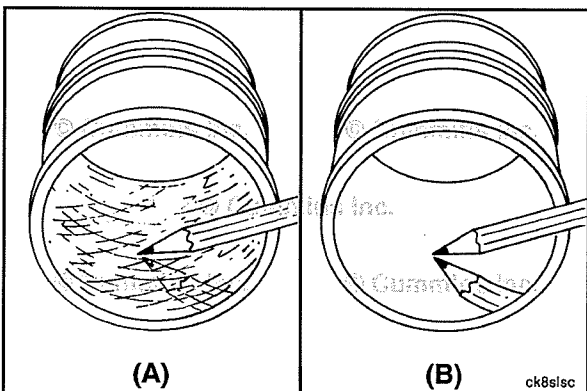
Replace the liner if the pits are too deep or if the corrosion can **not** be removed with fine emery cloth.



Inspect the inside diameters for vertical scratches deep enough to be felt with a fingernail.

NOTE: If a fingernail catches in the scratch, the liner **must** be replaced.

Inspect the inside diameter for scuffing or scoring.



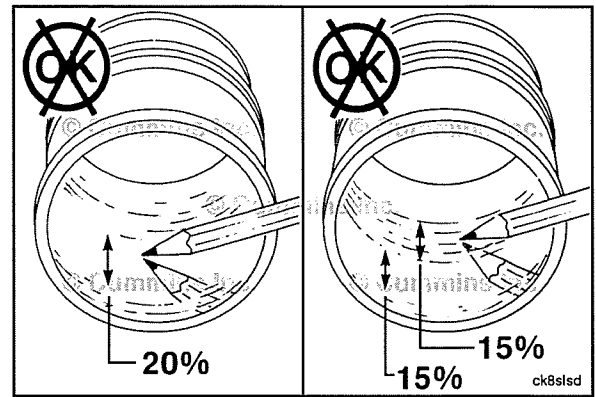
Inspect the inside diameter for liner bore polishing.

A moderate polish produces a bright mirror finish in the worn area with traces of the original hone marks or an indication of an etch pattern.

A heavy polish produces a bright mirror finish in the worn area with no traces of hone marks or an etch pattern.

Replace the liner if:

- A heavy polish is present over 20 percent of the piston ring travel area.
- Both moderate and heavy polish over 30 percent of the piston ring travel area and one half (15 percent) is heavy polish.



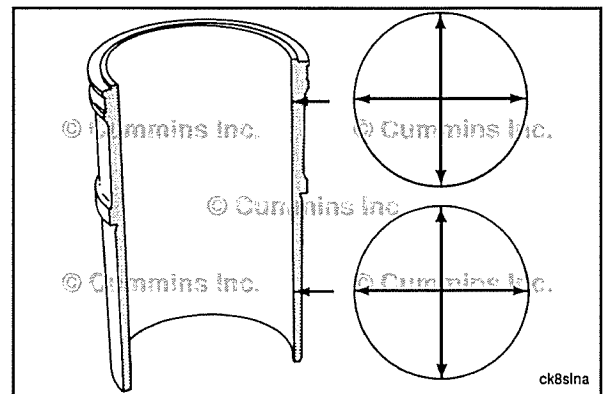
Dial Bore Gauge, Part Number 3376619

Measure the liner inside diameter in four places 90 degrees apart at the top and bottom of the piston travel area.



Cylinder Liner Inside Diameter

mm		in
114.000	MIN	4.4882
114.040	MAX	4.4898

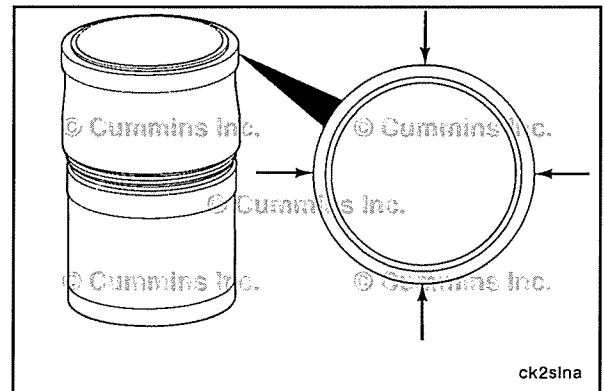


Measure the outside diameter of the liner top press fit area.

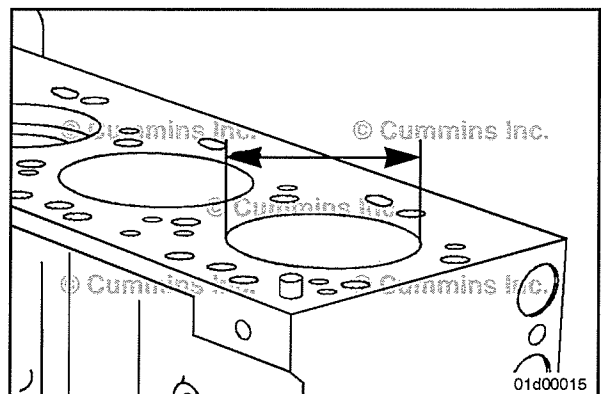


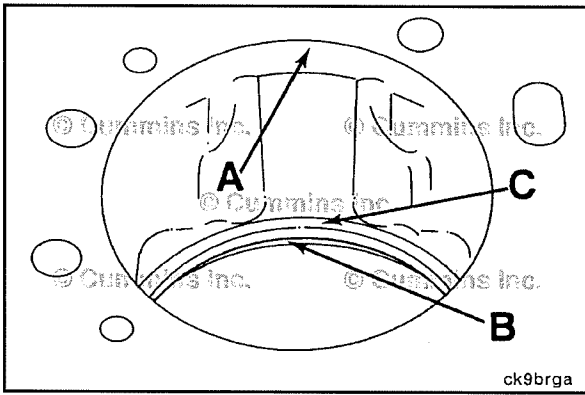
Cylinder Liner Out Diameter (Top Press Fit)

mm		in
130.938	MIN	5.1550
130.958	MAX	5.1558



Measure the cylinder liner bore in the block. Refer to Procedure 001-026 in Section 1.



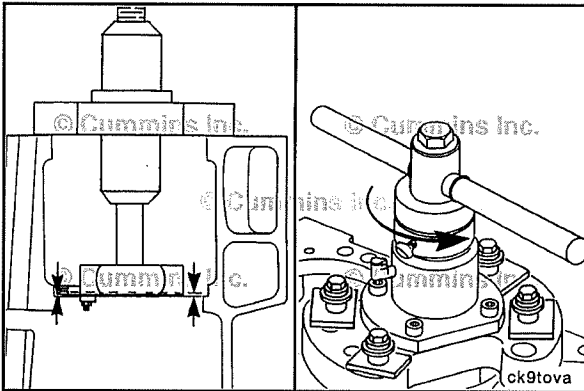


Install

⚠ CAUTION ⚠

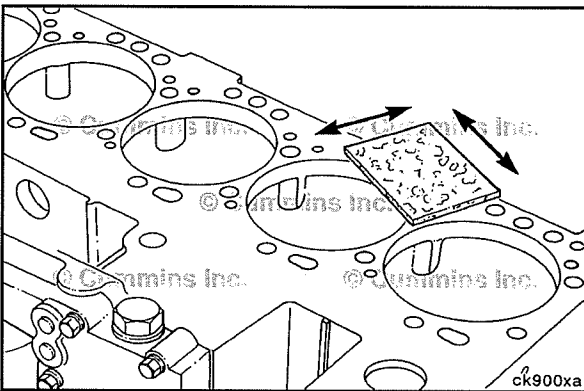
Clean all deposits and debris from sealing surfaces A, B, and C. Use abrasive pad, Part Number 3823258 or equivalent, and cleaning solvent to polish the surfaces. Due to the critical machined tolerances, care should be taken not to remove any additional material.

If surface C has cracks or signs of extreme wear, the counterbore will require machining and the installation of shims for the correct liner protrusion.



Using the Counterbore Cutter, Part Number 3163785, machine the counterbore to the proper depth.

NOTE: Part Number 3823567, cutter plate, and Part Number 3823570, cutter bit, **must** be used with the counterbore machining tool.



⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.



⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Clean the combustion deck with a gasket scraper or abrasive pad, Part Number 3823258 or equivalent, and diesel fuel or solvent.

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠ WARNING ⚠

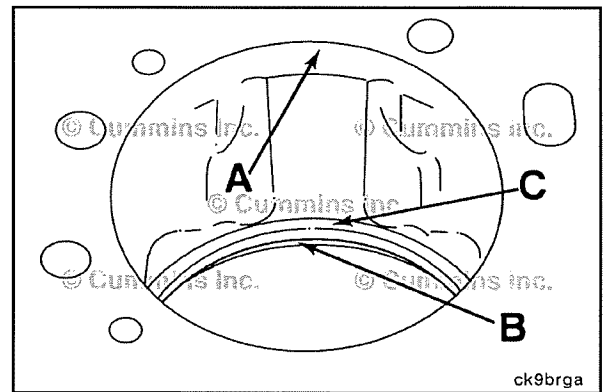
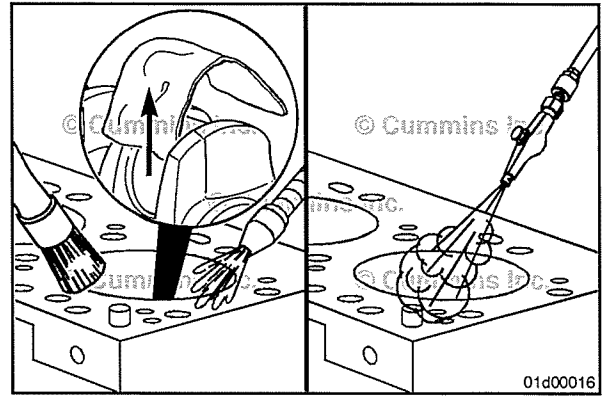
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Thoroughly flush the block with mineral spirits or cleaning solvent.

Remove the shop rags and clean the crankshaft with a cleaning solvent.

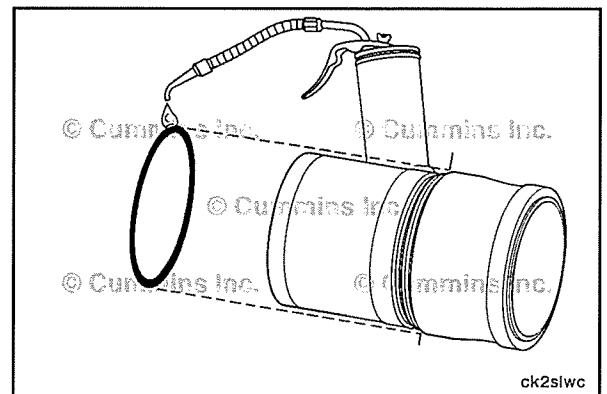
Blow the cylinder bores and crankshaft dry and wipe them clean with a lint-free cloth.

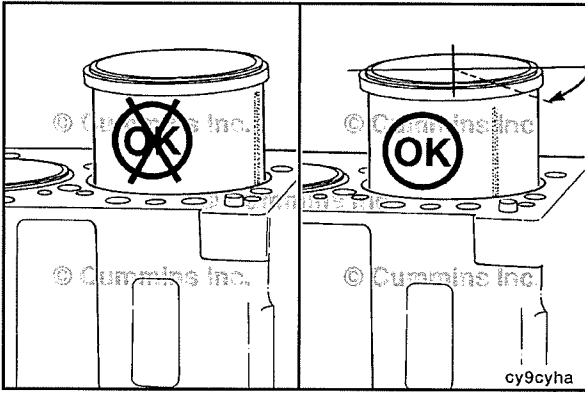
Lubricate surfaces A and B with clean 15W-40 engine oil.



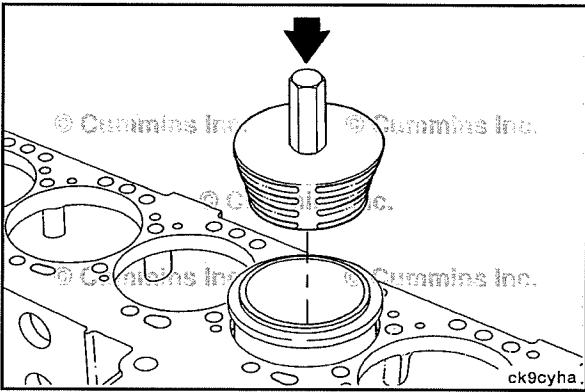
Use clean 15W-40 oil to coat the liner o-ring seals.

Install new o-ring seals on the liners.

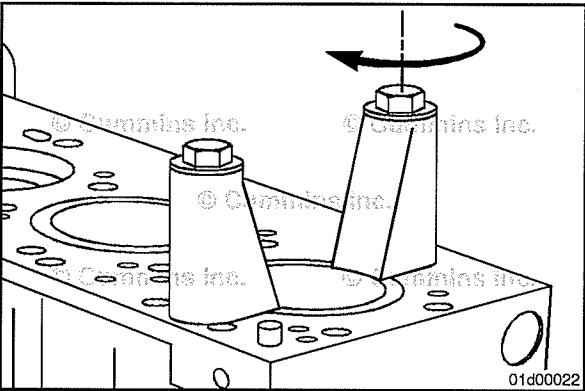




When reusing liners, install them in the same cylinder from where they were removed and rotate them 45 degrees (1/8 turn) from their original position. When correctly installed, any liner pitting **must** be positioned as illustrated so the pitted surface is rotated away from the location where pitting occurs.



Install the liner into the bore of the cylinder block, use liner driver, Part Number ST-1229.



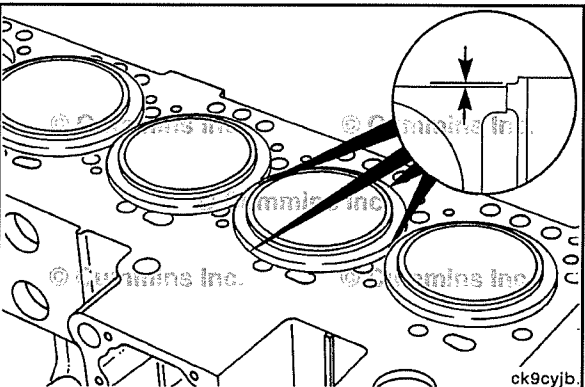
Use two (2) cylinder head capscrews and position the two (2) liner clamps, Part Number 3822503, as illustrated.

Tighten the capscrews.



Torque Value: 68 N•m [50 ft-lb]

Remove the clamps and repeat this procedure until all liners have been clamped and released.



Liner protrusion is the distance the liner protrudes above the block face.

Measure the liner protrusion at four points 90 degrees apart using gauge, Part Number 3164438.

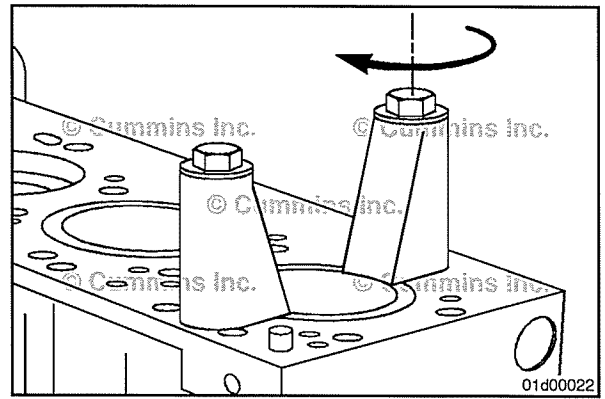
Cylinder Liner Protrusion

mm		in
0.026	MIN	0.0010
0.122	MAX	0.0048

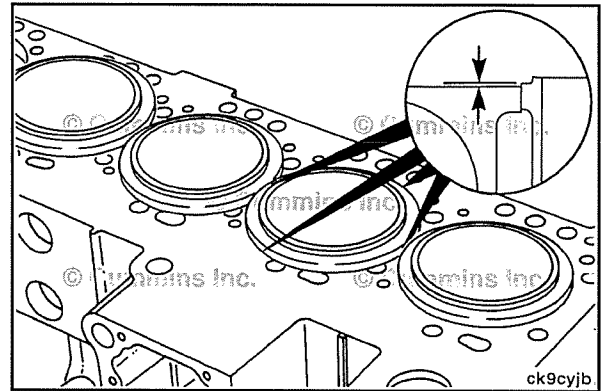
NOTE: If the liner protrusion varies more than 0.025 mm [0.0010 in] for 180 degrees:

- Install and tighten the liner clamps again.

Torque Value: 68 N•m [50 ft-lb]

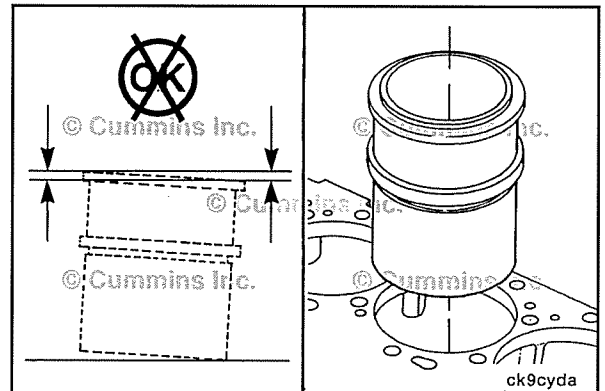


- Measure the liner protrusion again.

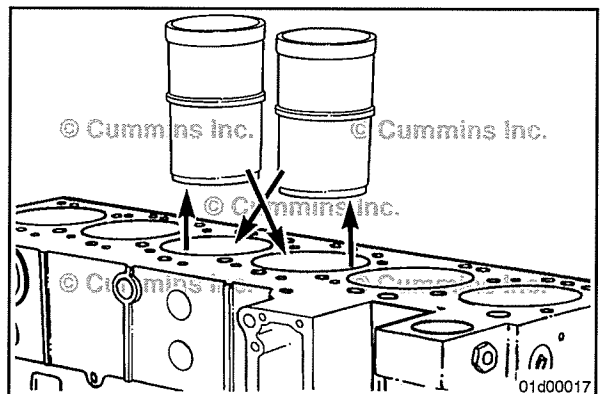


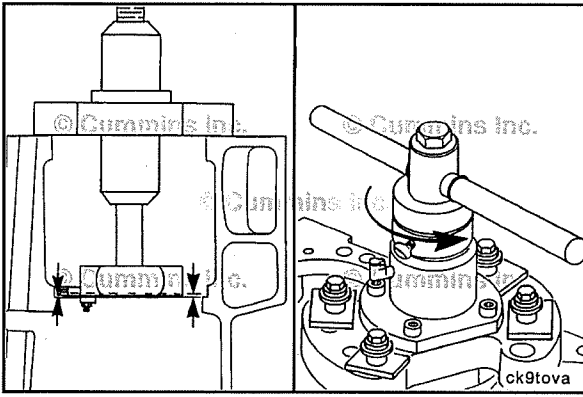
NOTE: If the protrusion still varies more than 0.025 mm [0.0010 in]:

- Remove the liner
- Inspect the liner sealing edge for burrs, dirt, or damage
- Replace the liner if it is damaged
- Install the liner again
- Measure the liner protrusion.



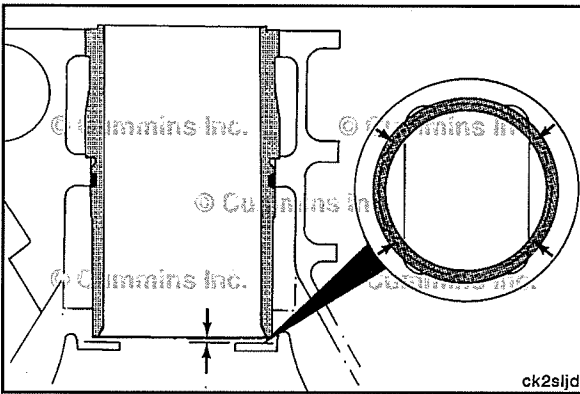
Service Tip: If the out-of-limit condition is minimal, tolerance stack-up may allow the protrusion limits to be obtained by installing other new liners in the out-of-limit bore.





NOTE: If the liner protrusion still does **not** meet the specifications, machine the cylinder block liner bore for shims using the following tools:

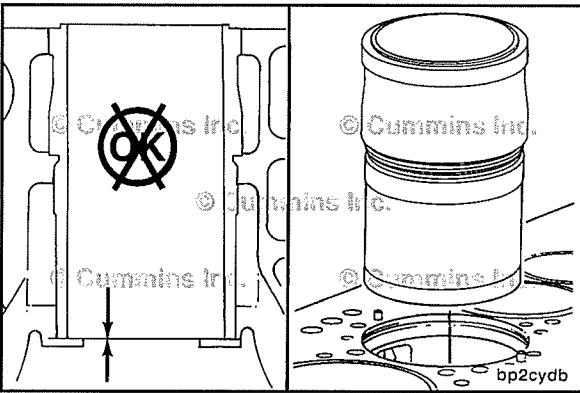
- Drive unit, Part Number 3163785
- Cutter plate, Part Number 3823567
- Cutter bit, Part Number 3823570.



Use a feeler gauge to inspect the liner to block clearance at the four block casting points.

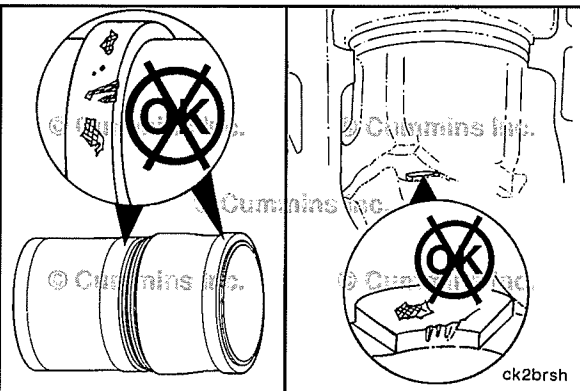
Cylinder Liner to Block Clearance

mm		in
0.229	MIN	0.009



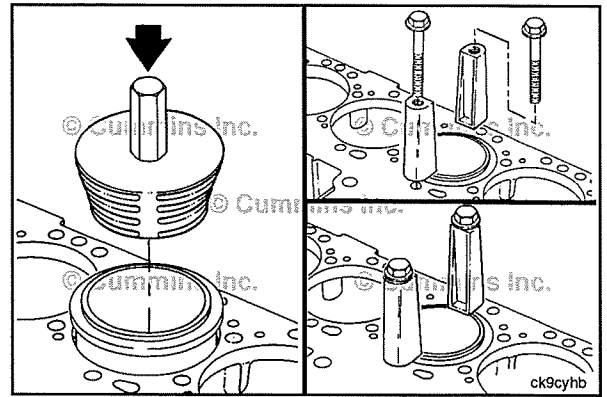
NOTE: If the clearance is **less** than 0.229 mm [0.009 in]:

- Remove the liner.

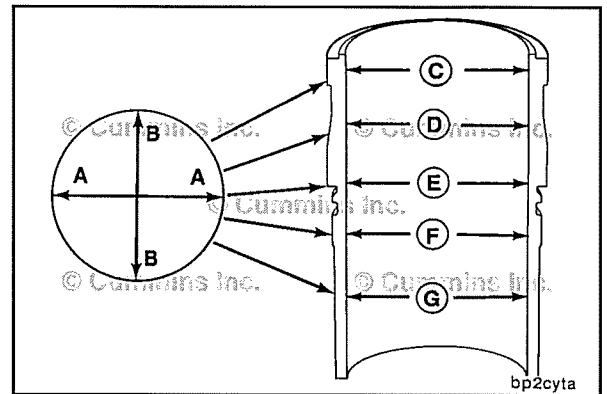


- Inspect the liner and cylinder block for dirt or damage.

- Replace the liner if it is damaged.
- Install the liner again.

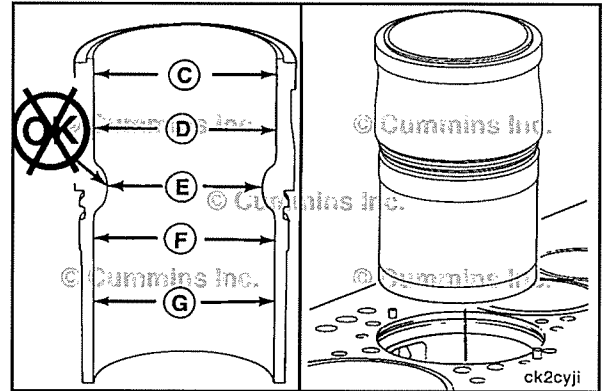


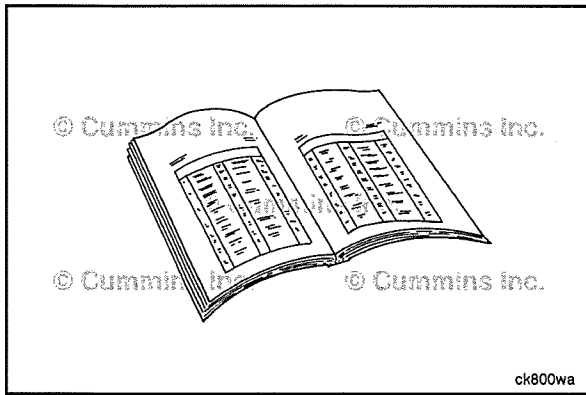
Measure the liner bore for out-of-roundness at points "C", "D", "E", "F", and "G". Measure each point in the direction "AA" and "BB". The bore **must not** be more than 0.04 mm [0.002 in] out-of-round.



NOTE: If the liner bore is more than 0.04 mm [0.002 in] out-of-round:

- Remove the liner so the cylinder block liner bore can be measured.





Finishing Steps

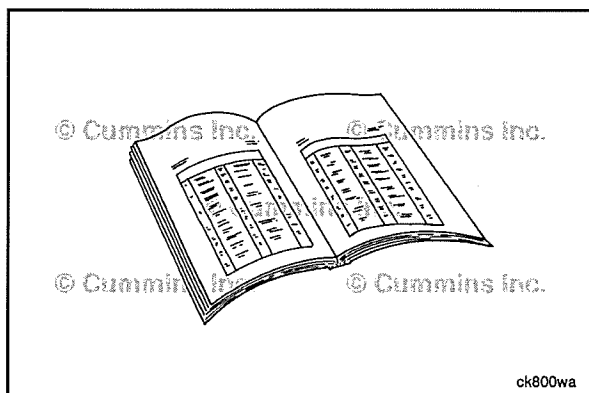


⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the pistons and connecting rods. Refer to Procedure 001-054 in Section 1.
- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Install the cylinder head. Refer to Procedure 002-004 in Section 2.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Fill lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Gear Cover, Front (001-031)

Preparatory Steps



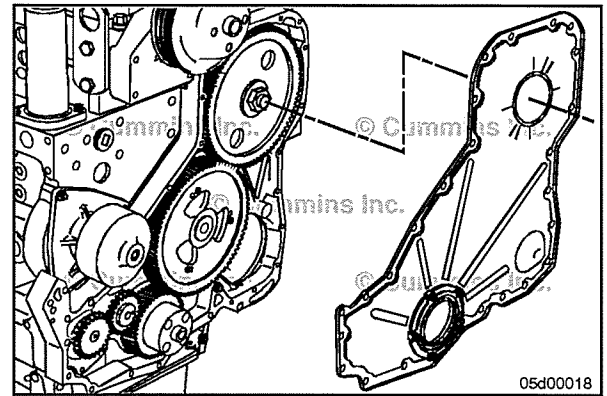
⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the rubber vibration damper, if installed. Refer to Procedure 001-051 in Section 1.
- Remove the viscous vibration damper, if installed. Refer to Procedure 001-052 in Section 1.
- Remove the front seal. Refer to Procedure 001-023 in Section 1.

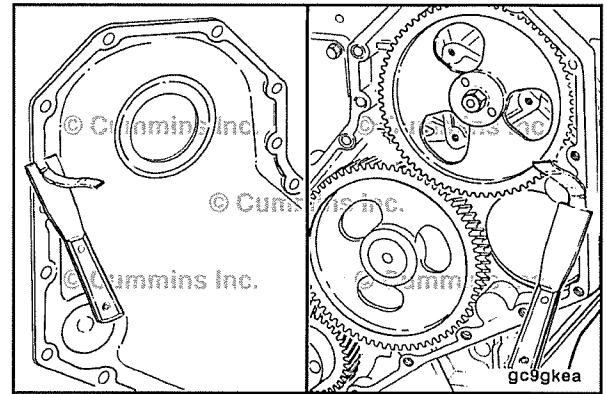
Remove

Remove the front gear cover.

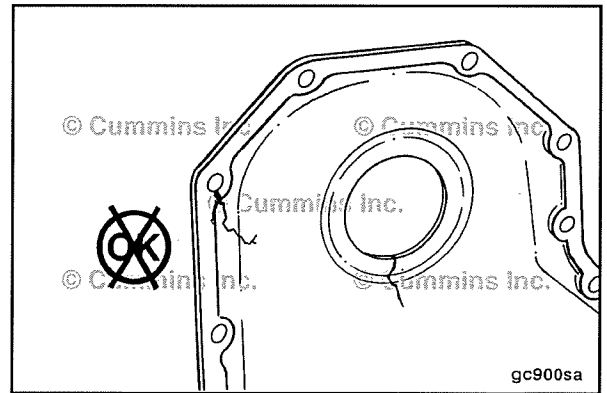


Clean and Inspect for Reuse

Clean the residual sealant from the gear cover and gear housing gasket surface.



Inspect the gear cover for cracks or other damage.

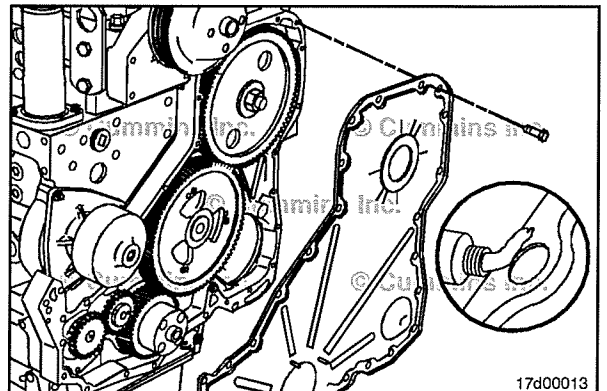


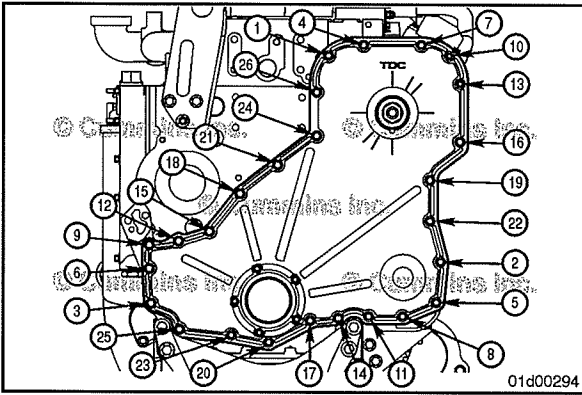
Install

NOTE: Apply sealant to the inside of the bolt holes.

Apply a thin bead of RTV sealant 3 to 4 mm [0.12 to 0.16 in] wide, Part Number 3164067 or equivalent, to the engine side of the front cover **only**.

Install the front cover on the engine within 10 minutes.





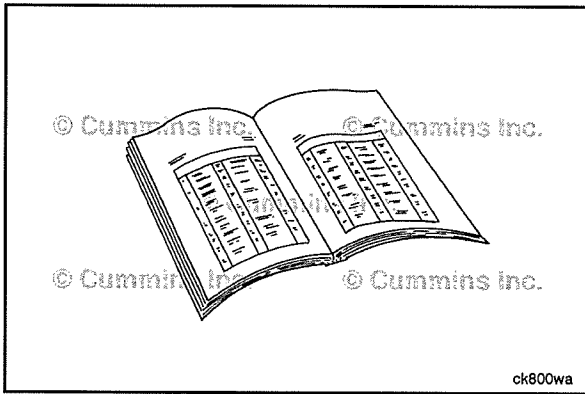
Tighten the front cover capscrews in the sequence shown.

Torque Value:

10 mm Front Cover Mounting Capscrews
Step 1 30 N•m [22 ft-lb]

Torque Value:

11 mm Front Cover Mounting Capscrews 40 N•m [30 ft-lb]



Finishing Steps



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the seal carrier on the front cover. Refer to Procedure 001-023 in Section 1.
- Install the rubber vibration damper, if installed. Refer to Procedure 001-051 in Section 1.
- Install the viscous vibration damper, if installed. Refer to Procedure 001-052 in Section 1.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Gear Housing, Front (001-033)

Preparatory Steps

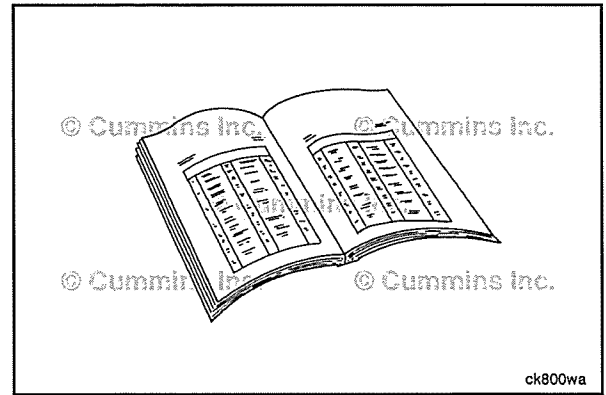
⚠ WARNING ⚠

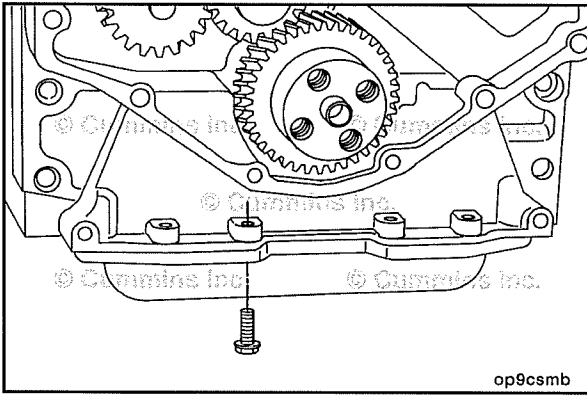
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

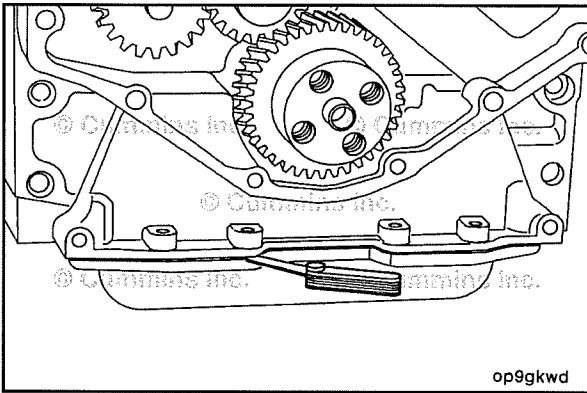
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Shut off the fuel supply. Refer to the OEM service manual.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the rubber vibration damper, if installed. Refer to Procedure 001-051 in Section 1.
- Remove the viscous vibration damper, if installed. Refer to Procedure 001-052 in Section 1.
- Remove the gear cover. Refer to Procedure 001-031 in Section 1.
- Remove the air compressor, if equipped. Refer to Procedure 012-014 in Section 12.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the rocker levers. Refer to Procedure 003-008 in Section 3.
- Remove the push rods. Refer to Procedure 004-014 in Section 4.
- Remove the fuel pump. Refer to Procedure 005-016 in Section 5.
- Remove the camshaft gear. Refer to Procedure 001-012 in Section 1.
- Remove or disconnect gear driven accessories, such as air compressor and hydraulic pump.



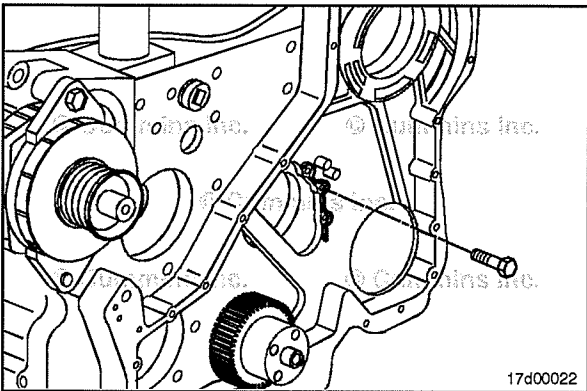


Remove

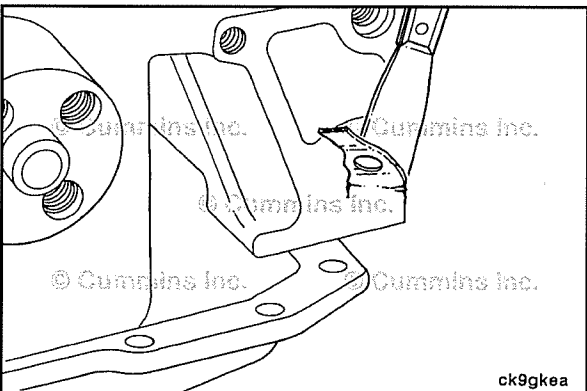
Remove the four front oil pan cap screws.



Use a feeler gauge to separate the lubricating oil pan gasket from the gear housing.



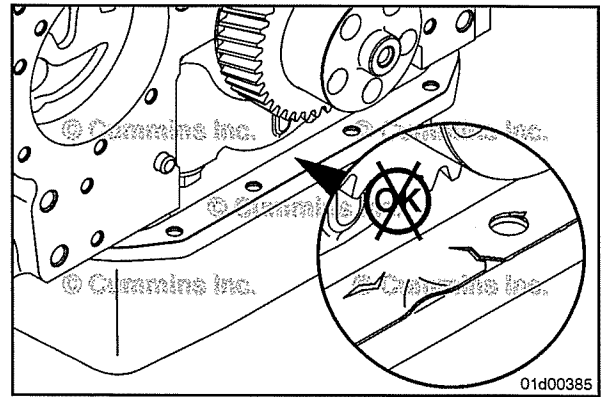
Remove the gear housing cap screws and remove the gear housing.



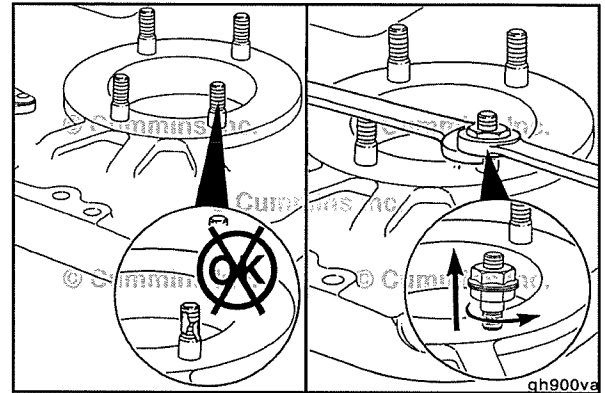
Clean and Inspect for Reuse

Clean the gasket material from the cylinder block.

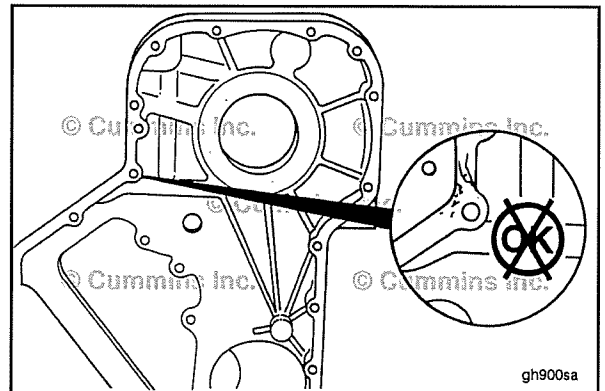
Inspect the lubricating oil pan gasket for tears or other damage. See the Install section of this procedure if the gasket is damaged.



Inspect fuel pump mounting studs for damage.
To install or remove the fuel pump studs, use two nuts locked together on the stud.



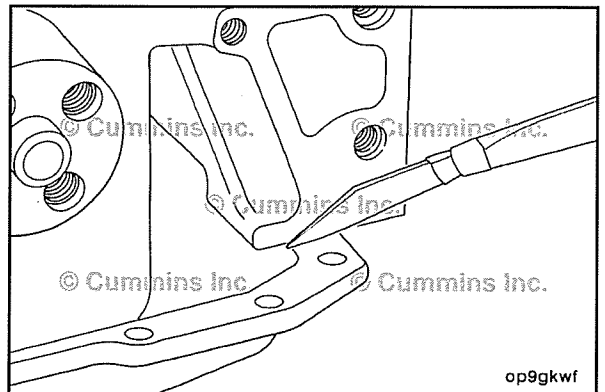
Inspect the gear housing sealing surfaces for cracks or other damage. Replace the gear housing if any damage is found.

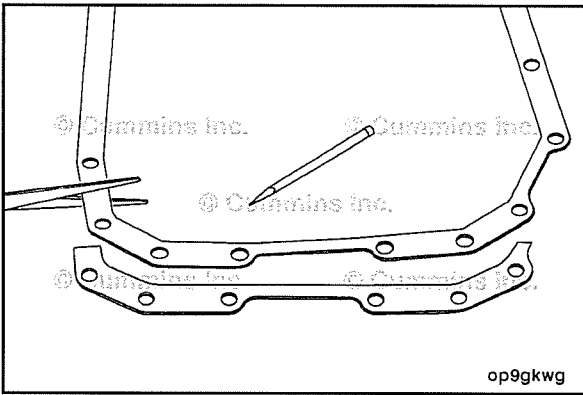


Install

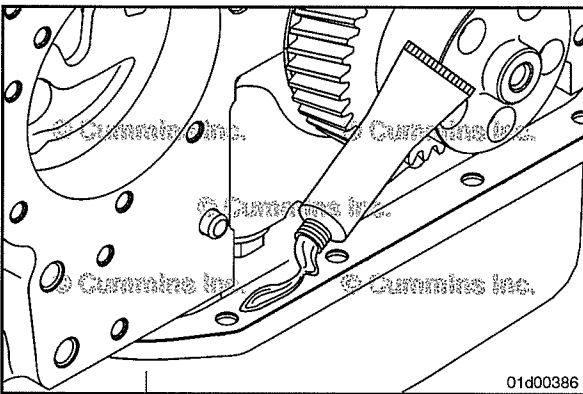
If the lubricating oil pan gasket is damaged, it can be repaired.

Cut the damaged gasket off even with the front of the cylinder block.





Use the old gasket as a template to cut the front section of a new gasket to the same size.



NOTE: The gear housing **must** be installed within 10 minutes of applying the sealant.

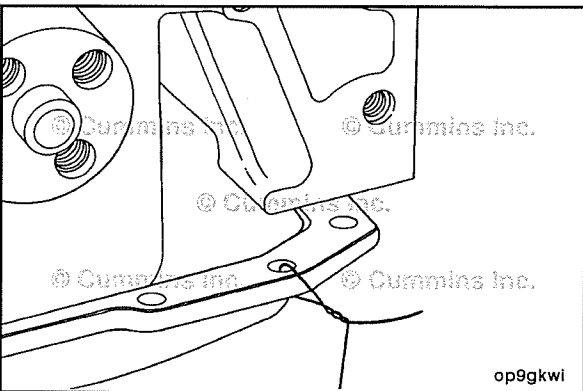
Clean the sealing surfaces.



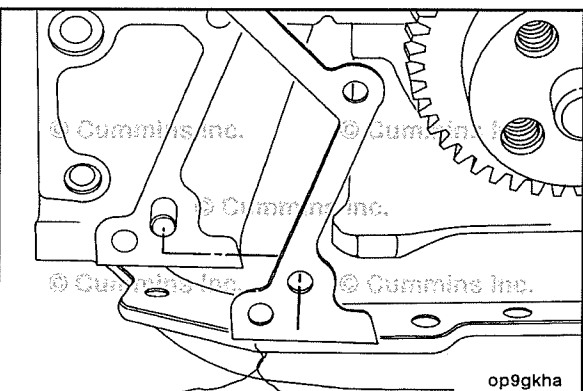
Coat the new gasket on both sides with RTV sealant, Part Number 3823494 or equivalent.



Be sure there is a bead of sealant at the intersecting joint of the cylinder block, oil pan, and gear housing.



Use common thread or a very fine wire to hold the new gasket splice in position as illustrated.

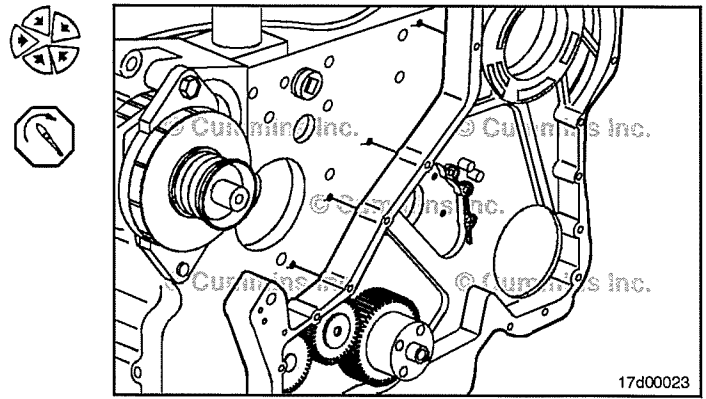


Position the gear housing gasket on the alignment dowels.

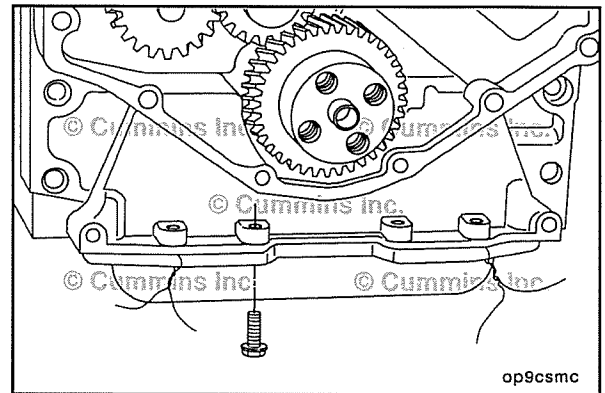
Use guide pins (M8 x 1.25 x 50) to assist in aligning the gasket and gear housing. Be sure to remove the guide pins after alignment.

Install the gear housing.

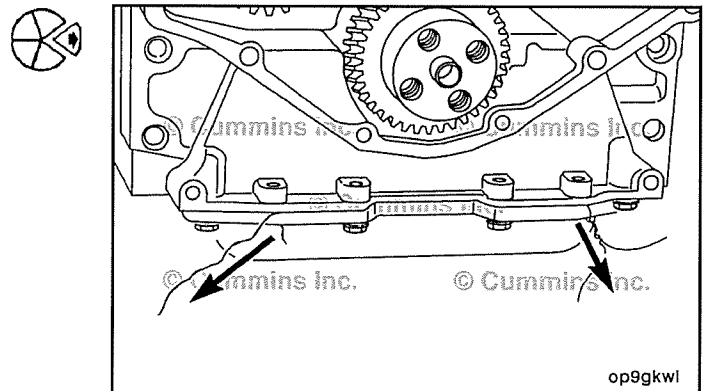
Torque Value: 40 N•m [30 ft-lb]



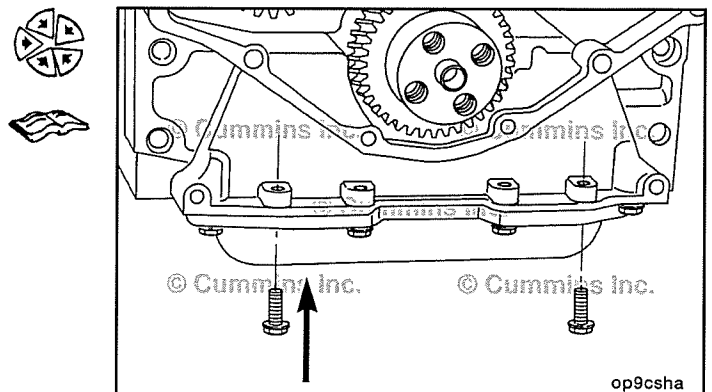
Start the oil pan capscrews in the holes **not** being used to tie the gasket in place.

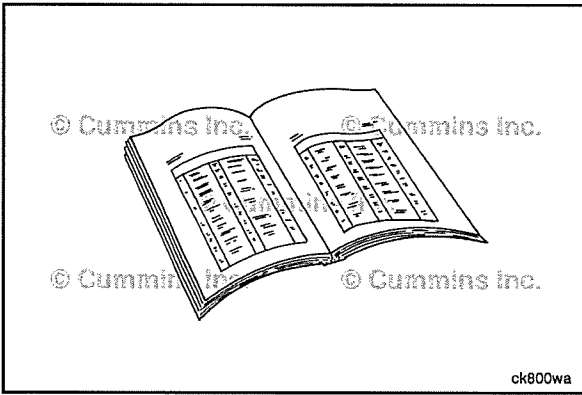


Remove the thread or wire holding the gasket in place.



Install the remaining two oil pan capscrews and tighten.
Refer to Procedure 007-025 in Section 7.





Finishing Steps

⚠️ WARNING ⚠️

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠️ WARNING ⚠️

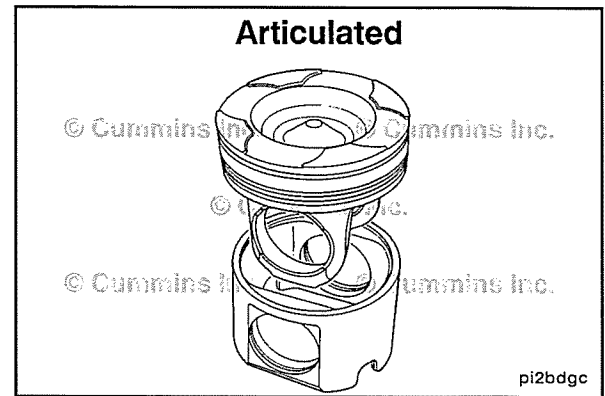
Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

- Install the camshaft gear. Refer to Procedure 001-012 in Section 1.
- Install the push rods. Refer to Procedure 004-014 in Section 4.
- Install the rocker levers. Refer to Procedure 003-008 in Section 3.
- Adjust the overhead. Refer to Procedure 003-004 in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the accessory drive or air compressor, if equipped. Refer to Procedure 012-014 in Section 12. Refer to the OEM service manual.
- Install the gear cover. Refer to Procedure 001-031 in Section 1.
- Install the front crankshaft seal. Refer to Procedure 001-023 in Section 1.
- Install the rubber vibration damper, if installed. Refer to Procedure 001-051 in Section 1.
- Install the viscous vibration damper, if installed. Refer to Procedure 001-052 in Section 1.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Install the fuel pump. Refer to Procedure 005-016 in Section 5.
- Install or connect gear driven or accessories. Refer to the OEM service manual.
- Open the fuel valve. Refer to the OEM service manual.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Piston (001-043)

General Information

Some engines are equipped with articulated pistons. The articulated piston is a two (2) piece piston consisting of a forged steel crown and an aluminum skirt. An open chamber oil gallery is located on the underside of the crown of the piston to provide more oil contact with the piston and give better piston cooling.



Clean and Inspect for Reuse

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ CAUTION ⚠

Do not use the bead blast method to clean the piston. The piston will be damaged by blast material embedded in the aluminum.

⚠ CAUTION ⚠

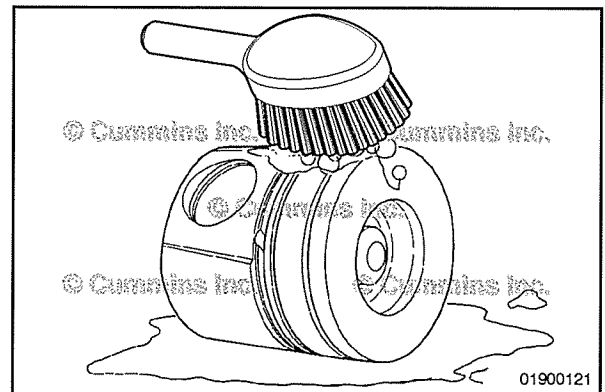
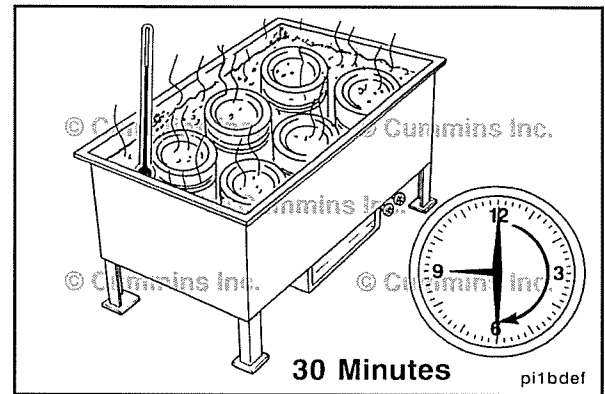
Do not clean the pistons and connecting rods in an acid tank.

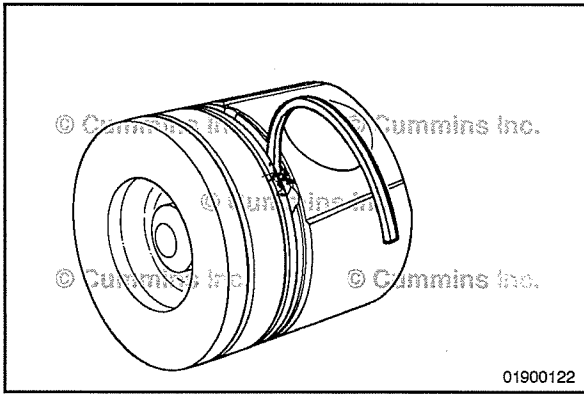
Allow the piston to soak for a minimum of 30 minutes in a tank containing a cleaning solvent suitable for steel and aluminum.

⚠ CAUTION ⚠

Do not use a metal brush. A metal brush will damage the piston ring grooves.

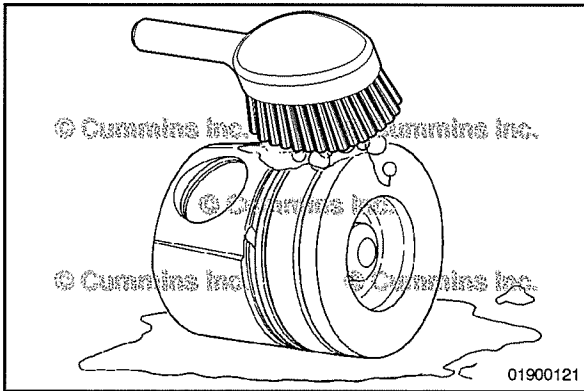
Wash the pistons and connecting rods in a strong solution of laundry detergent in hot water. Use a non-metallic brush to remove carbon deposits.





⚠ CAUTION ⚠
Do not use a ring groove cleaner to clean the ring grooves. Do not to scratch the ring sealing surface in the piston groove.

Clean the remaining deposits from the ring grooves with the square end of a broken piston ring.



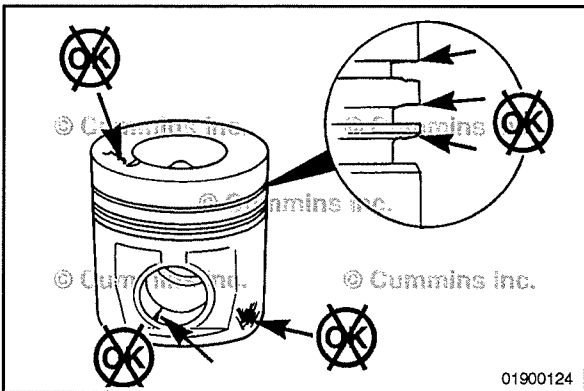
⚠ WARNING ⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING ⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠ WARNING ⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Wash the pistons again in a detergent solution or solvent.

After rinsing, use compressed air to dry.



Failure Analysis Inspection

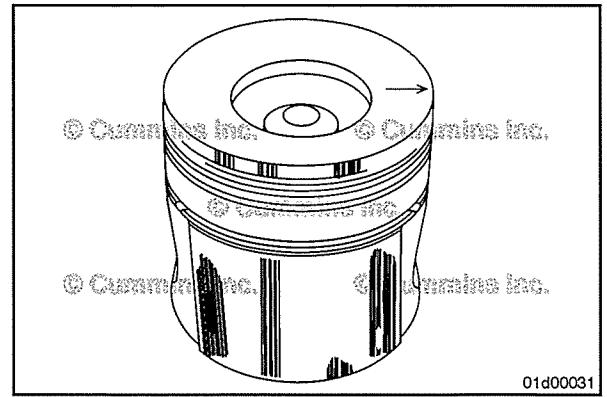
Inspect the piston for damage and excessive wear. Check the top, ring grooves, skirt, and pin bore for cracks or other damage.

NOTE: If severe piston damage has occurred, check the turbocharger and other exhaust components for damage from debris.

Abrasive and/or Debris Wear

Scratching on the piston skirt with material embedded in the piston can be caused by:

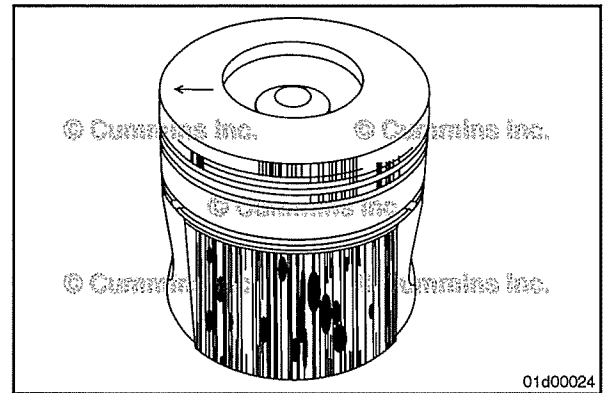
- 1 Ingested abrasive material
- 2 Inadequate cleaning during a previous repair
- 3 Particles embedded in the cylinder bore
- 4 Improper maintenance of the lubrication system
- 5 Debris in the lubrication oil system from another failure
- 6 Scuffing and scoring.



Scuffing and scoring can be caused by:

- 1 Engine overheating
- 2 Oil dilution
- 3 Improper maintenance of the lubrication system
- 4 Piston cooling nozzle malfunction
- 5 Oil ring plugged by deposits
- 6 Injector overfueling/engine running on an alternative fuel source, i.e. oil in the intake system.

NOTE: Scuffing and scoring on the piston rings indicates a breakdown of the oil film on the cylinder bore wall, causing transfer of material from the piston ring face to the cylinder bore wall.



Other Types of Piston Failures

Hydraulic Lock

Hydraulic locks (oil, fuel, or water) can cause the piston to split in half, or the lands can break and the connecting rods can be bent.

Dustouts

Particular attention to the wear pattern of the intermediate (second) ring is required for diagnosis of a dustout piston scuff.

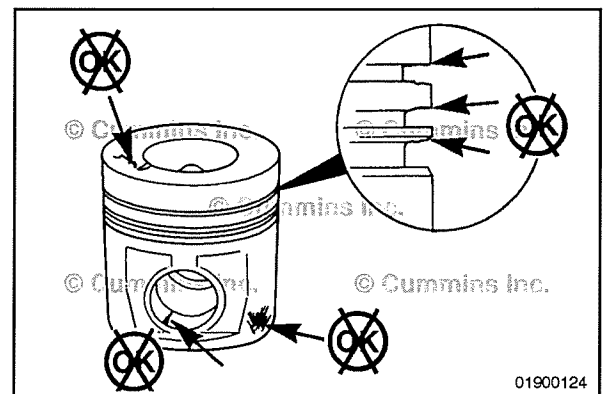
The ring will have a polished appearance on the full-face ear of the intermediate ring, where the blackened areas of the ring become more polished.

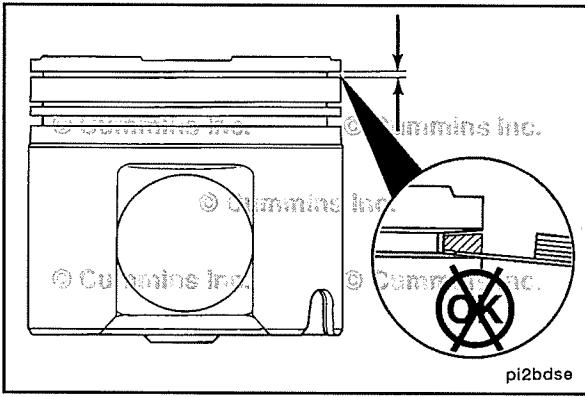
The polished area starts at the bottom of the ring and continues upward on the tapered ring.

Occasionally, the edges of the rings are razor sharp, and the block cylinder bore has indications of ridges approximately 1-1/2 inches below the top deck.

Top of Piston Meltdown

The top of the piston appears to be melted down, and the failure resembles an overfueling situation such as a stuck injector. A plugged piston cooling nozzle can resemble this failure as well.





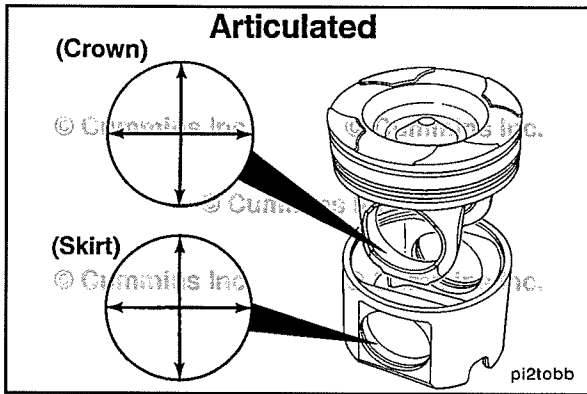
Measure

The ring groove can be inspected with a new ring and a feeler gauge.

Hold a new ring in the groove even with the outside diameter of the piston.

Install a 0.15 mm [0.006 in] feeler gauge.

If the feeler gauge enters the groove without resistance, there is too much wear. Replace the piston.

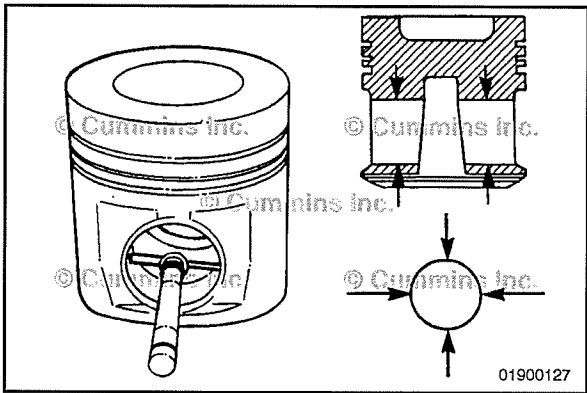


Articulated Pistons

Measure the piston pin bore inside diameter on both the crown and skirt.

Articulated Piston Pin Bore Inside Diameter

	mm		in
Crown	45.016	MIN	1.7723
	45.036	MAX	1.7731
Skirt	45.012	MIN	1.7721
	45.026	MAX	1.7727



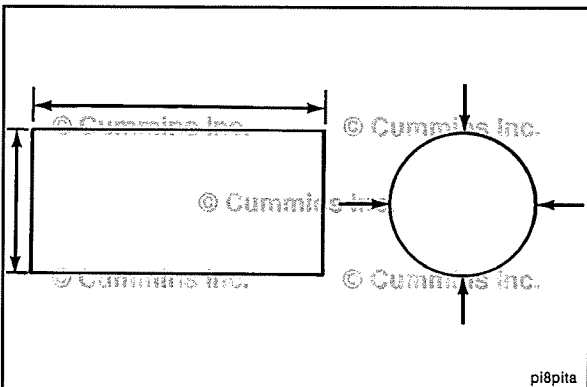
Single Piece Pistons

Measure the pin bore when the piston temperature is at 20°C [68°F].

Piston Pin Bore Diameter

mm		in
45.010	MIN	1.7720
45.016	MAX	1.7723

NOTE: Add 0.013 mm [0.0005 in] to the bore diameter per 5°C [10°F] temperature rise up to 32°C [90°F].



Inspect the piston pin for nicks, gouges, and excessive wear.

Measure the piston pin outside diameter.



Piston Pin Diameter

mm		in
44.997	MIN	1.7715
45.003	MAX	1.7718

Replace the piston pin if it is more than 0.003 mm [0.0001 in] out of round.

Piston Cooling Nozzle (001-046)

Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠ WARNING ⚠

Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

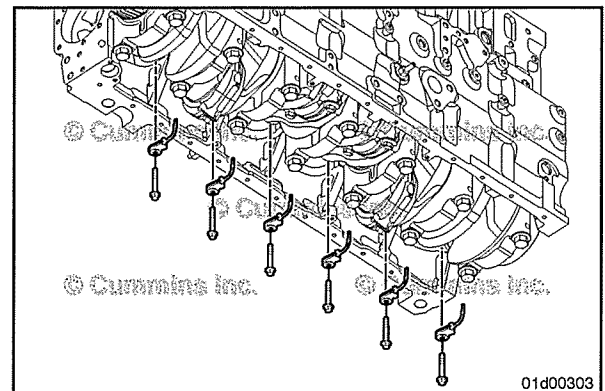
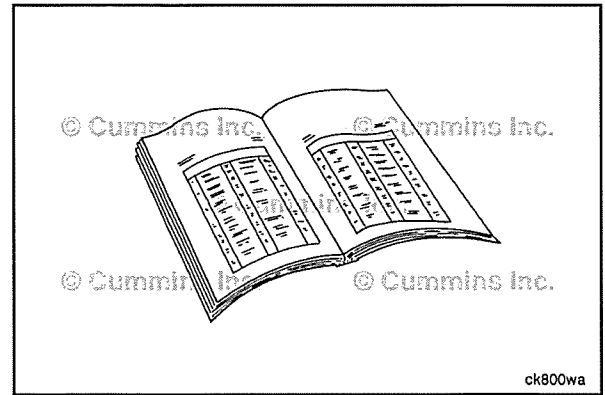
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.

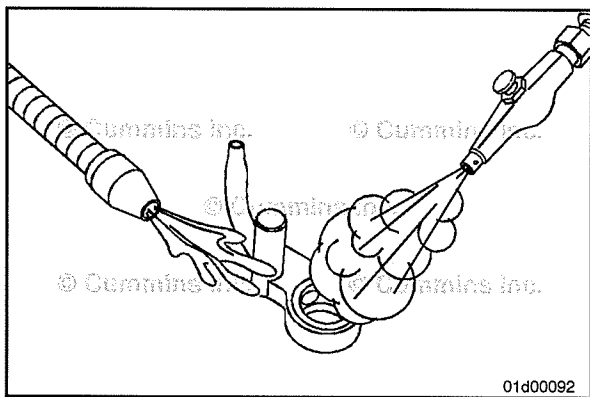
Remove

Remove the piston cooling nozzle capscrews and nozzles.

NOTE: The crankshaft **must** be rotated to allow access to remove the nozzles.

NOTE: The number six (6) piston cooling nozzle can **not** be removed without first disconnecting the connecting rod from the crankshaft and moving the piston out of the way. Also, a crows foot socket will be required to access the capscrew.





Clean and Inspect for Reuse

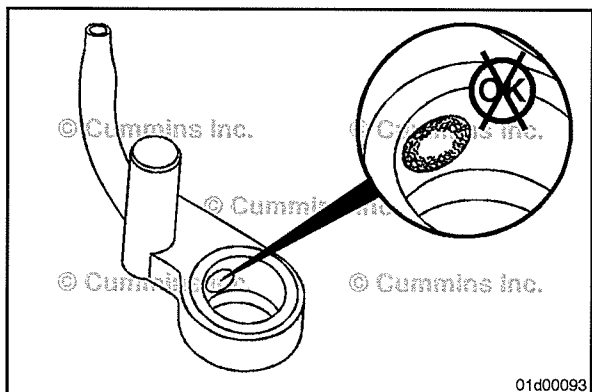
⚠ WARNING ⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING ⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠ WARNING ⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

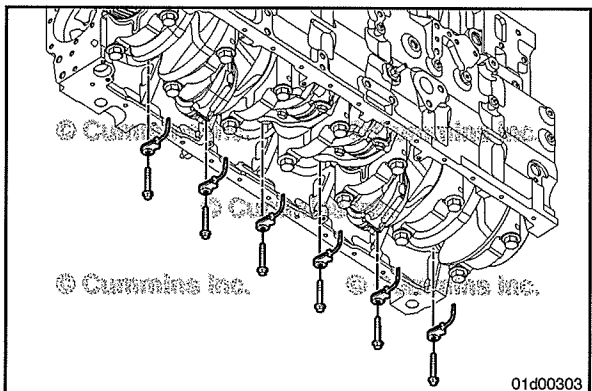
Clean the piston cooling nozzles and capscrew with solvent.

Dry with compressed air.



Inspect the piston cooling nozzles for flow restriction or any other damage. Replace if necessary.

NOTE: Do not reuse the saddle jet piston cooling nozzles or plugs once removed.



Install

NOTE: The crankshaft **must** be rotated to allow access to install the nozzles.

Install the piston cooling nozzles and capscrews.

Tighten the capscrews.

Torque Value: 33 N•m [24 ft-lb]

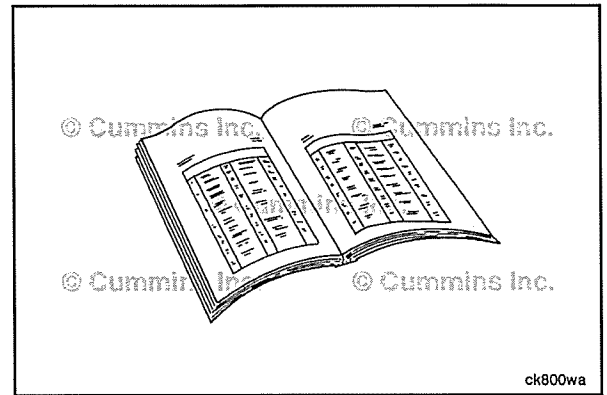


Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Fill the engine with lubricating oil. Refer to Procedure 007-037 in Section 7.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for oil leaks.



Piston Rings (001-047)

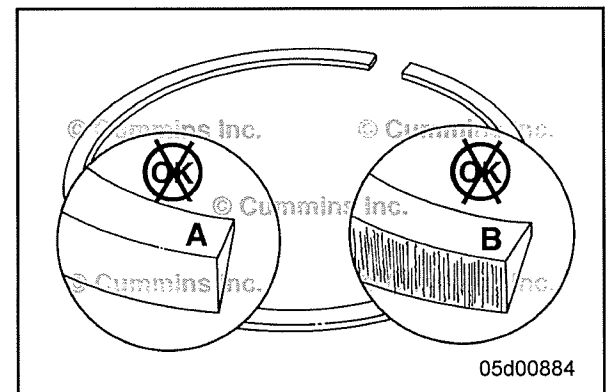
Failure Analysis Inspection

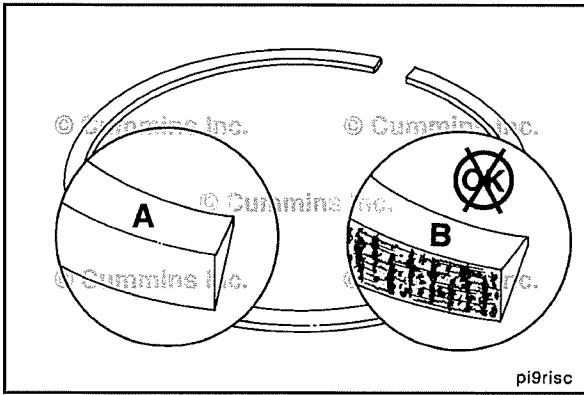
Inspect the piston rings for abrasive wear.

NOTE: Abrasive wear of the intermediate ring can be indicated by a rapid reduction of the dark finish coating on the front face of the ring, in some cases to the point where the dark finish coating is no longer visible (A). This is commonly referred to as full face ring wear. This rapid reduction will typically leave a sharp edge on the bottom of the intermediate ring. Abrasive wear can also be indicated by concentrated vertical scratches on the top ring (B).

Abrasive wear can be caused by:

- 1 Ingested abrasive material
- 2 Inadequate cleaning during a previous repair
- 3 Particles embedded in the bore
- 4 High soot content in the lubricating oil from extended oil drain intervals
- 5 Scuffing and scoring.



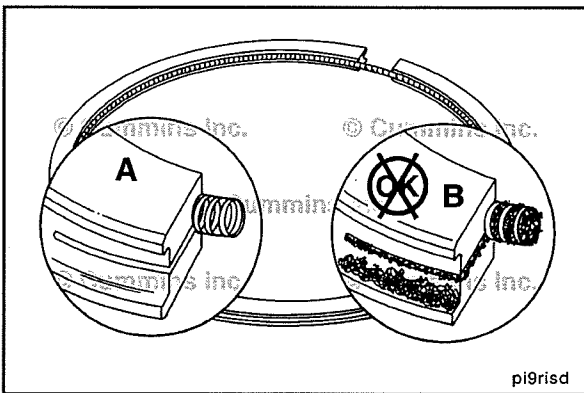


NOTE: Scuffing and scoring is indicated by heavy scratches, metal discoloration, and voids (B).

Scuffing and scoring can be caused by:

- 1 Engine overheating
- 2 Oil dilution
- 3 Improper maintenance of the lubrication system
- 4 Piston cooling nozzle malfunction
- 5 Oil ring plugged by deposits.

NOTE: Scuffing and scoring on the piston rings indicates a breakdown of the oil film on the cylinder bore wall, causing transfer of material from the piston ring face to the cylinder bore.

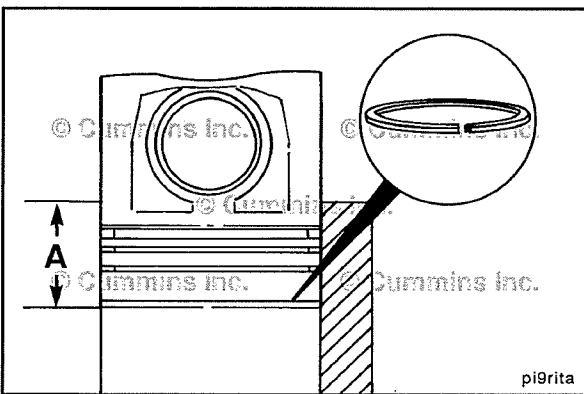


NOTE: Oil ring plugging is indicated by deposits on the oil ring grooves (B).

Oil ring plugging can be caused by:

- 1 Low engine operating temperatures - long periods of idling or a cooling system malfunction
- 2 Extended oil change intervals
- 3 Use of the wrong grade of engine oil
- 4 Use of a poor quality engine oil.

NOTE: Plugging of the oil ring drains restricts oil drain-back, which floods the piston ring belt area, resulting in a loss of oil control.



NOTE: The following measurements are intended for inspecting new piston rings.



NOTE: Before completing this inspection, make sure the cylinder liner is within specification. Refer to Procedure 001-028 in Section 1.

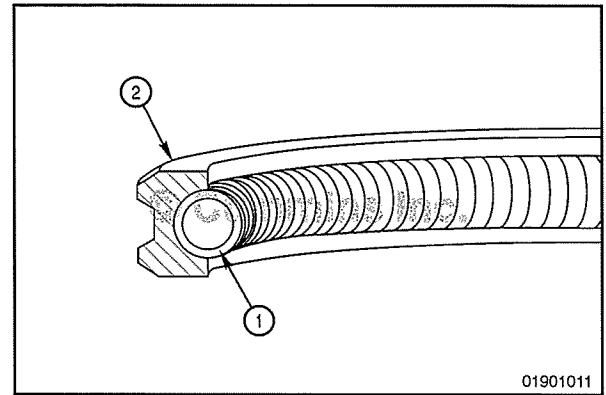
Measure the piston ring gap by installing the piston rings into the cylinder bore in which they will be used. Position the rings below the ring reversal area by positioning each ring in the cylinder 89 mm [3.5 in] below the top deck (A). Use a piston to square the rings with the bore.

The installation location for the compression rings can be determined by the finish.

- The top ring has a chrome finish.
- The intermediate ring has a phosphate (black) finish.

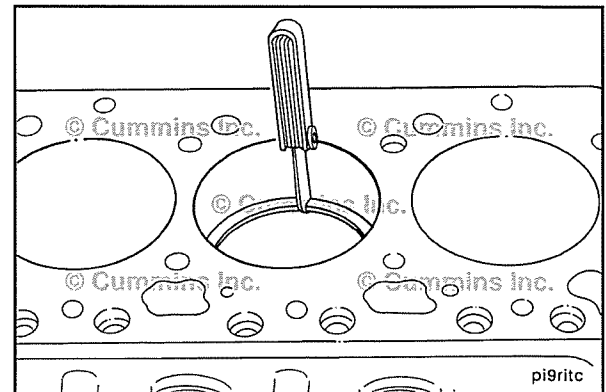
The oil control ring is a two-piece ring made of an expander (1) and scraper (2).

The expander is installed on the inside of the profiled scraper ring.



Use a feeler gauge to measure the gap.

Ring Gap	mm		in
Top Ring	0.30	MIN	0.012
	0.525	MAX	0.021
Intermediate Ring for Steel Articulated Piston	0.4	MIN	0.015
	0.825	MAX	0.032
Intermediate Ring for Aluminum Piston	0.85	MIN	0.033
	1.275	MAX	0.050
Oil Control Ring	0.3	MIN	0.012
	0.725	MAX	0.029



If the piston ring gap is **not** within specification:

- 1 Verify the correct type and part number piston ring is being used.
- 2 Verify the cylinder liner is within specification. Refer to Procedure 001-028 in Section 1.
- 3 Verify the piston ring gap measurement is being taken 89 mm [3.5 in] below the cylinder block deck
- 4 Try another set of piston rings.

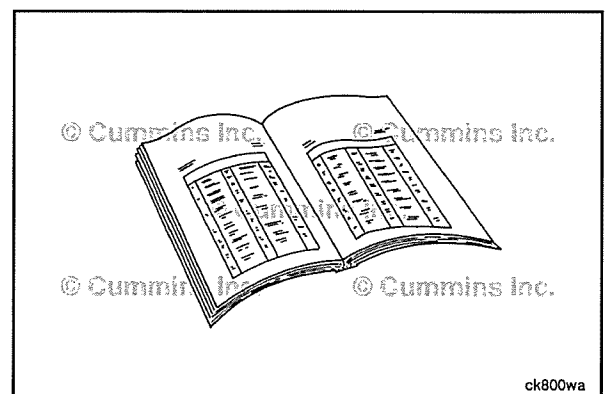
Vibration Damper, Rubber (001-051)

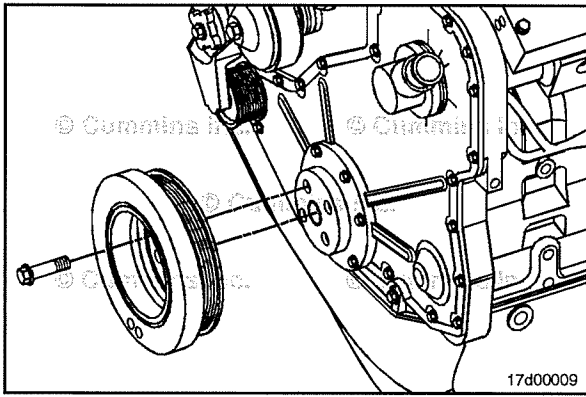
Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the fan and fan shroud, if necessary.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.

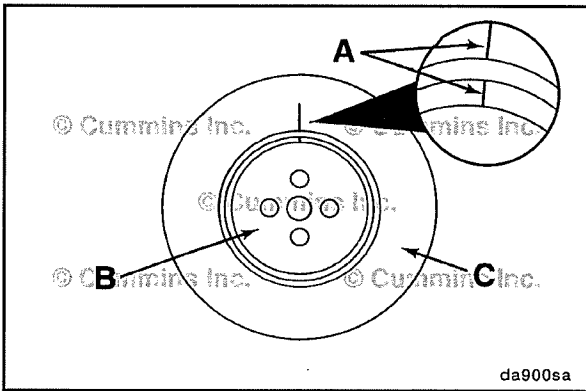




Remove

NOTE: Some engines use four damper capscrews while others use five damper capscrews.

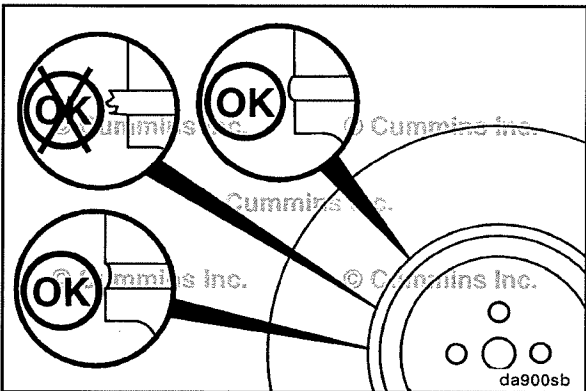
Remove the vibration damper.



Inspect for Reuse

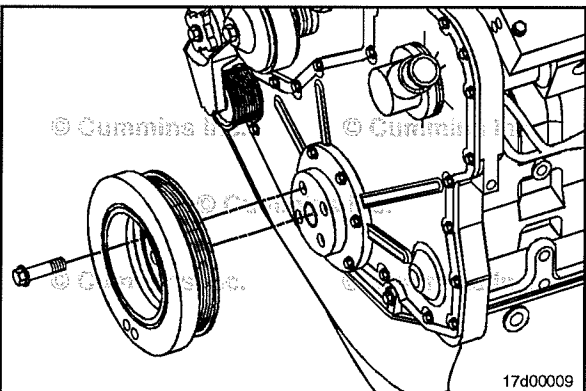
Check the index lines (A) on the damper hub (B) and the inertia member (C). If the lines are more than 1.59 mm [1/16 in] out of alignment, replace the damper.

Inspect the vibration damper hub (B) for cracks. Replace the damper if the hub is cracked.



Inspect the rubber member for deterioration. If pieces of rubber are missing or if the elastic member is more than 3.18 mm [1/8 in] below the metal surface, replace the damper.

NOTE: Also look for forward movement of the damper ring on the hub. Replace the damper if any movement is detected.



Install

NOTE: Some engines use four damper capscrews while others use five damper capscrews.

Install the vibration damper.

Tighten the capscrews in a star pattern.

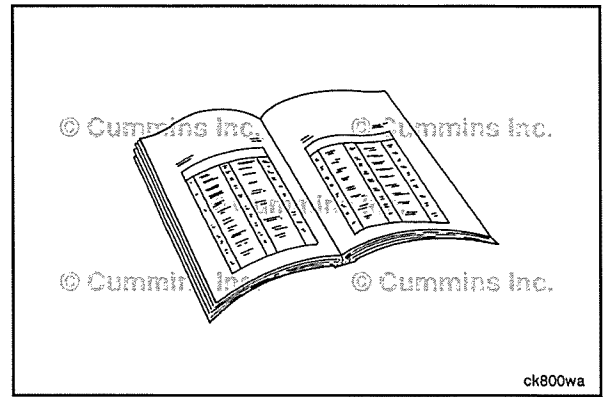
Torque Value: 200 N•m [148 ft-lb]

Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Install the fan and fan shroud, if removed.
- Connect the battery cables. Refer to the OEM service manual.
- Start the engine and check for proper operation.



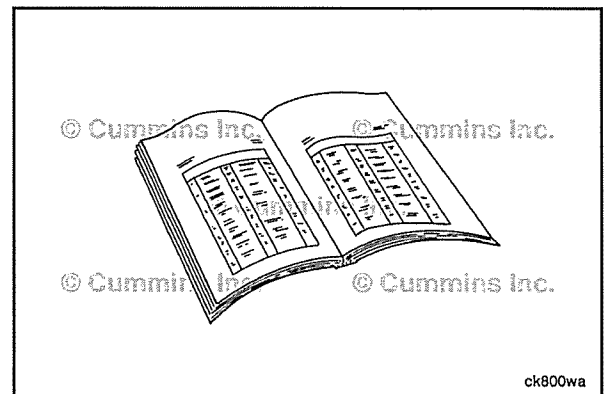
Vibration Damper, Viscous (001-052)

Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

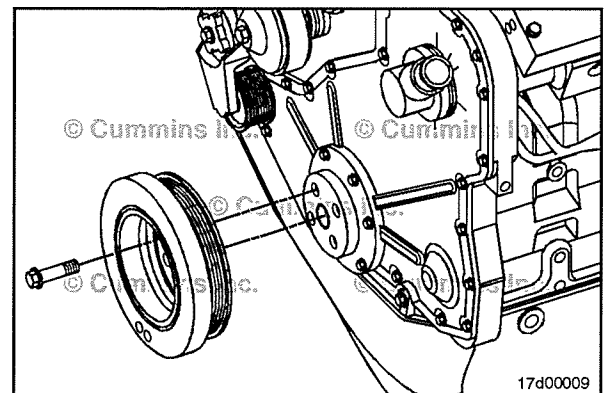
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the fan and fan shroud, if necessary.

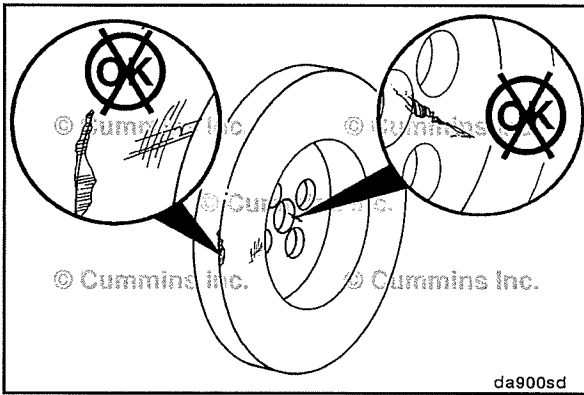


Remove

NOTE: Some engines use four damper capscrews while others use five damper capscrews.

Remove vibration damper.



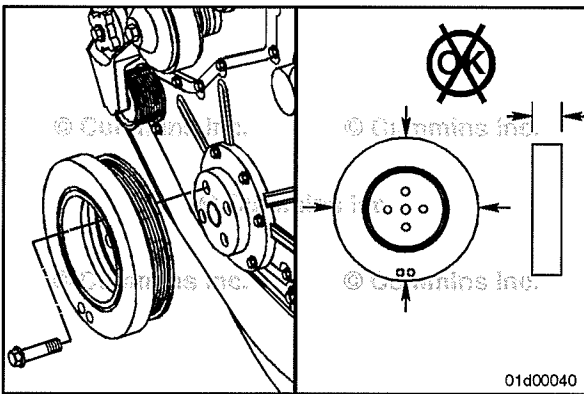


Clean and Inspect for Reuse

Check the mounting web for cracks.

Check the housing for dents or raised surfaces.

Replace the damper if any of these defects are identified.



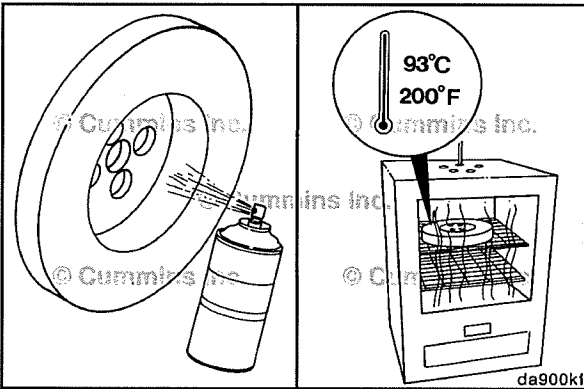
The viscous damper is filled with a silicone fluid. After many hours of use, the silicone fluid may become thicker and expand.



To determine if the damper thickness is correct, remove the paint from the damper in four locations on either side of the damper. Measure and record the thickness of the damper in four places.

Measure the thickness 3.175 mm [0.125 in] from the outside of the damper.

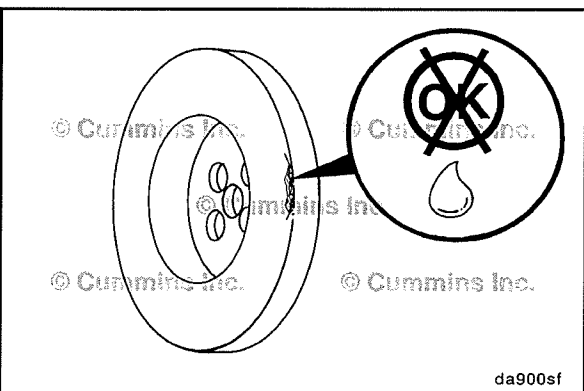
Replace the damper if its thickness varies by more than 0.25 mm [0.010 in].



Spray the damper with spot check developer, type SKD-NF or equivalent.

Heat the damper in an oven (rolled lip side down) for two (2) hours.

Temperature 93 °C [200 °F]



WARNING

Wear protective gloves to reduce the possibility of personal injury when handling parts that have been heated.



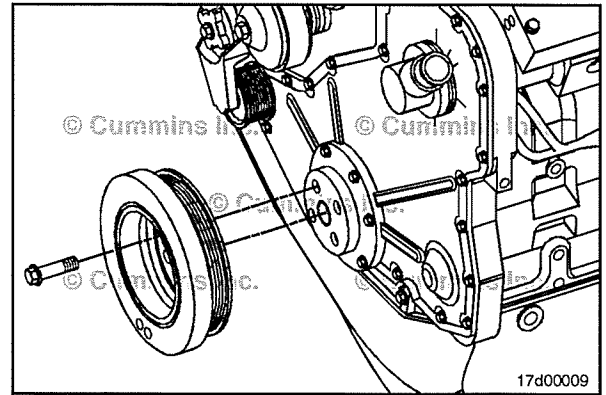
Remove the damper from the oven and check for fluid leakage.

If there is leakage, replace the damper.

Install

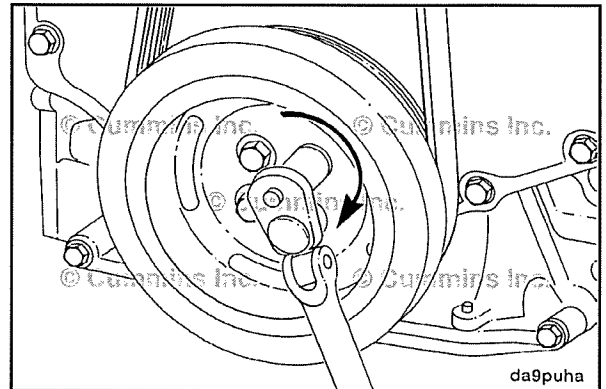
NOTE: Some engines use four damper capscrews while others use five damper capscrews.

Install the vibration damper.



Tighten the capscrews in a star pattern.

Torque Value: 200 N•m [148 ft-lb]



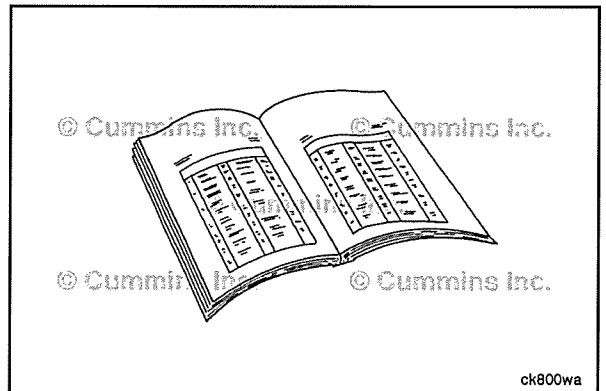
Finishing Steps

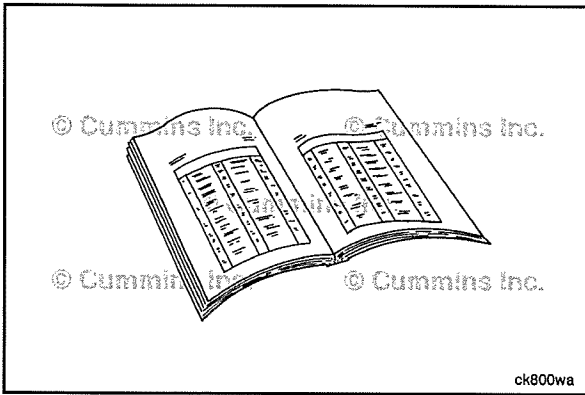
⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Install the fan and fan shroud, if removed.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for loose parts.





Piston and Connecting Rod Assembly (001-054)

Preparatory Steps

⚠️ WARNING ⚠️

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠️ WARNING ⚠️

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠️ WARNING ⚠️

Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

⚠️ WARNING ⚠️

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠️ WARNING ⚠️

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Remove the piston cooling nozzles, if required. Refer to Procedure 001-046 in Section 1.
- Remove the cylinder head. Refer to Procedure 002-004 in Section 2.

Remove

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Rotate the crankshaft until the pistons are just below the carbon deposits that are found above the ring travel area.

Use an abrasive pad, Part Number 3823258 or equivalent, and solvent to remove the carbon deposits.

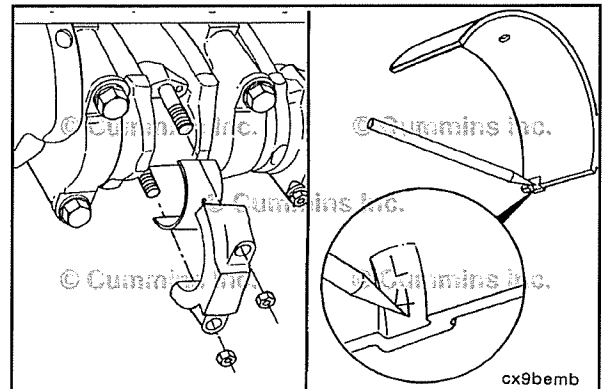
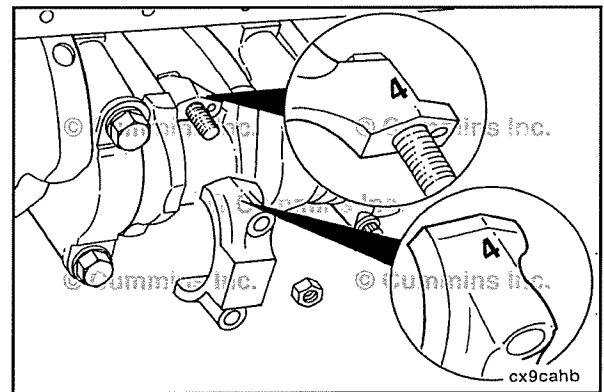
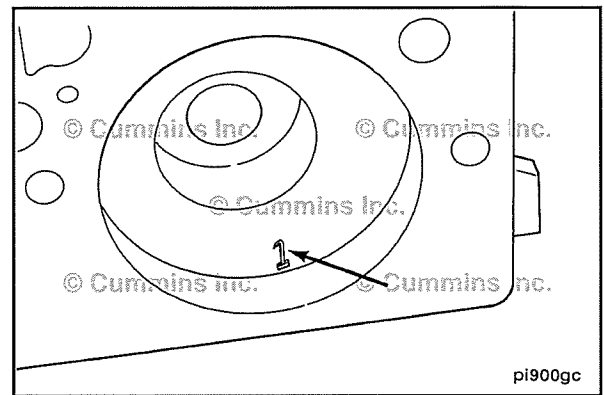
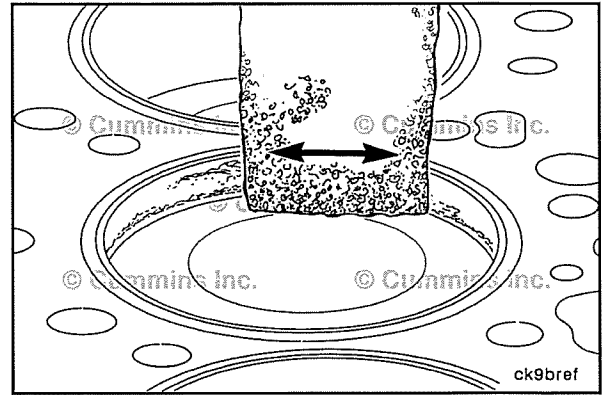
Mark each piston according to the cylinder location.

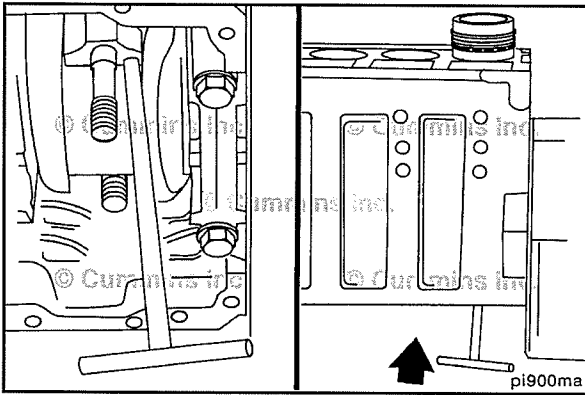
Rotate the crankshaft to position the rod cap at Bottom Dead Center (BDC) for removal.

Mark each connecting rod and rod cap according to the cylinder number location.

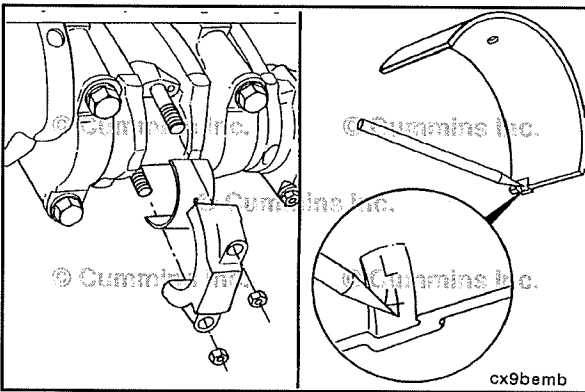
Engines with Horizontal Split Connecting Rods

- Remove the nuts, connecting rod cap, and lower connecting rod bearing.
- Mark the cylinder number and the letter "L" (lower) on the flat surface of the bearing tang.

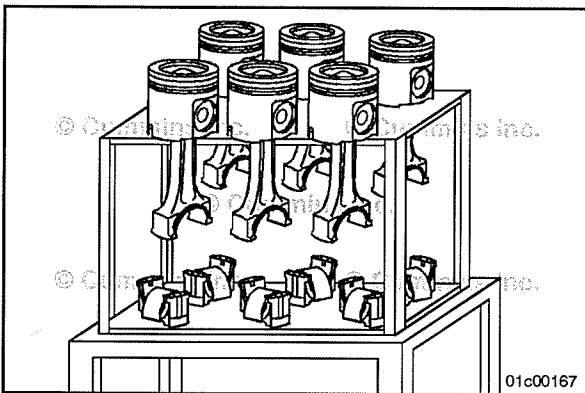




Push the connecting rod and piston assembly out of the cylinder bore. Care **must** be taken to **not** damage the connecting rod or bearing.



Remove the upper rod bearing.
Mark the cylinder number and the letter "U" (upper) on the flat surface of the bearing tang.

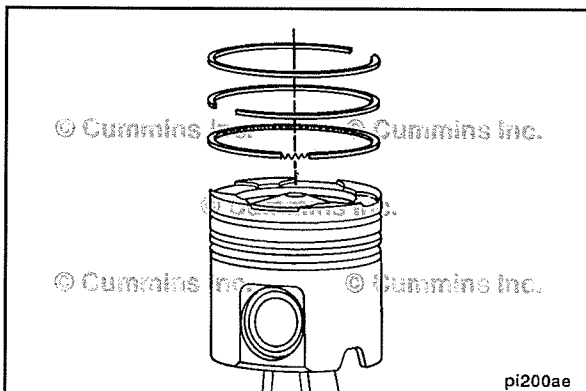


Use both hands to remove the piston and connecting rod assembly.

If parts are reused, the piston and connecting rod assemblies **must** be installed in the same cylinder locations from which they were removed to provide the proper fit of worn mating surfaces.

Use tags to mark the piston and connecting rod assembly locations as they are removed.

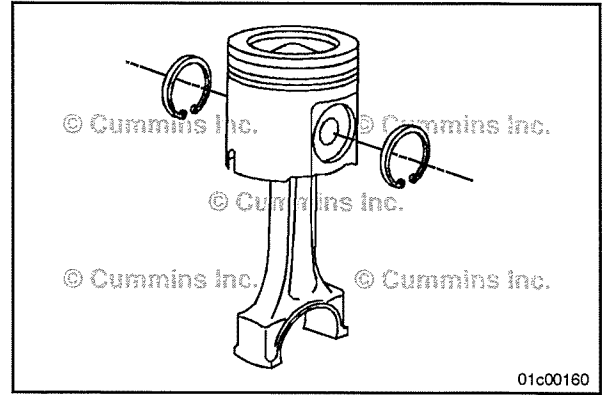
Place the rod and piston assemblies in a container to protect them from damage.



Disassemble

Use piston ring expander, Part Number 3823137, to remove the piston rings.

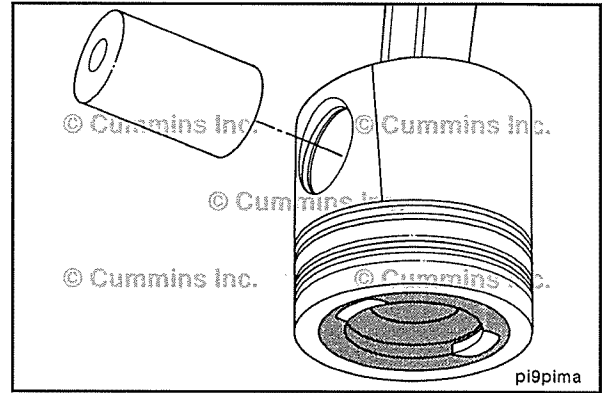
Use internal snap ring pliers to remove the snap rings from both sides of the piston.



Remove the piston pin.

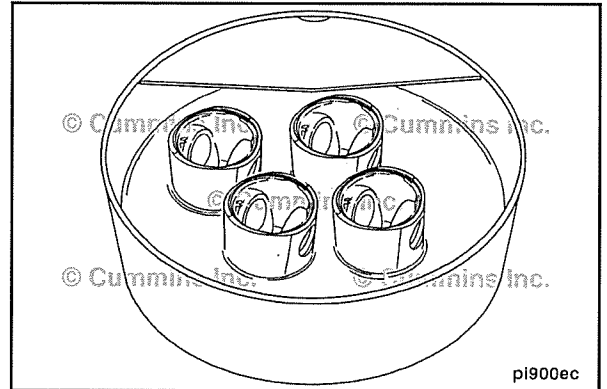
NOTE: Heating the piston is **not** required.

If the parts are to be reused, mark each component (piston, pin, and rings) with the cylinder number from which they were removed. Create an alignment mark on one side of each piston pin, piston, and connecting rod to make sure of the correct orientation during assembly.

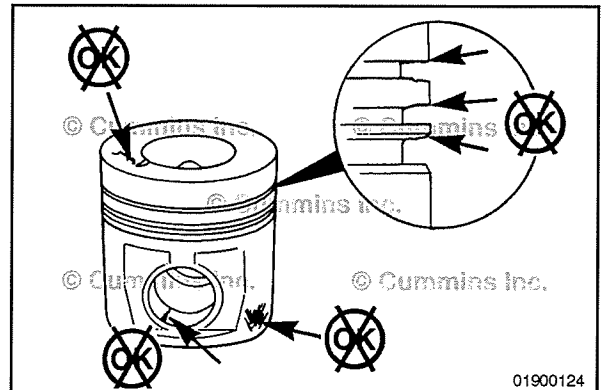


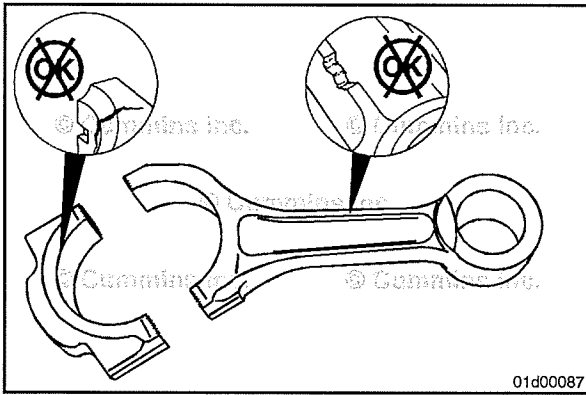
Clean and Inspect for Reuse

Clean the pistons. Refer to Procedure 001-043 in Section 1.

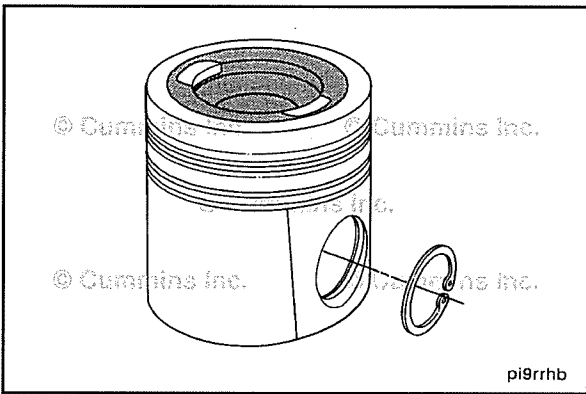


Inspect the pistons. Refer to Procedure 001-043 in Section 1.



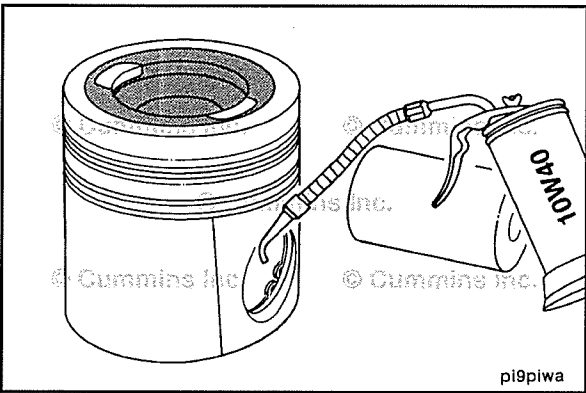


Inspect the connecting rods. Refer to Procedure 001-014 in Section 1.

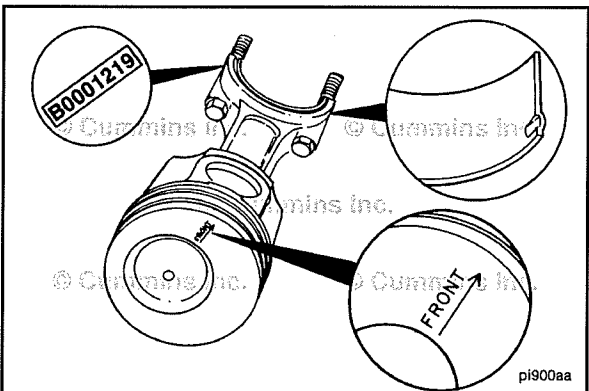


Assemble Single-Piece Piston

Install the retaining ring in the pin groove on one side of the piston.



Lubricate the pin and pin bores with clean engine lubricating oil.



CAUTION

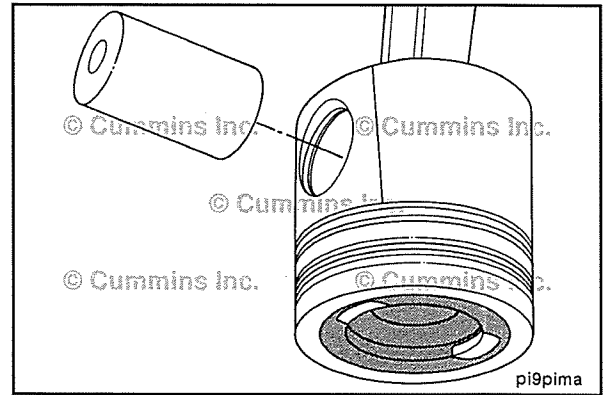
Make sure "front" marking on the piston and the numbers on the rod and cap are oriented as illustrated.

Align the pin bore of the rod with the pin bore of the piston skirt, and install the piston pin.

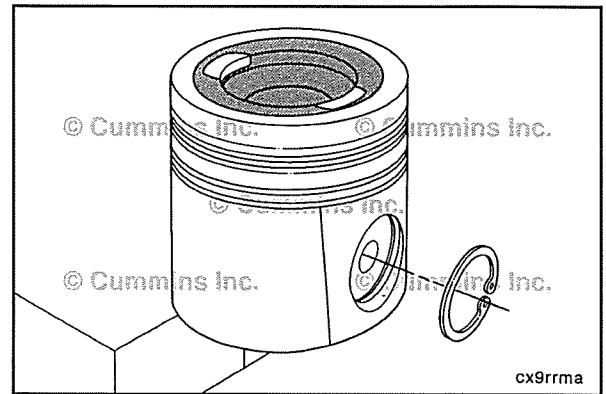
Engines with Horizontal Split Connecting Rods

- Install the pin through the piston and connecting rod.

NOTE: Pistons do **not** require heating to install the pin. However, the pistons do need to be at room temperature or above.



Install the second retaining ring.

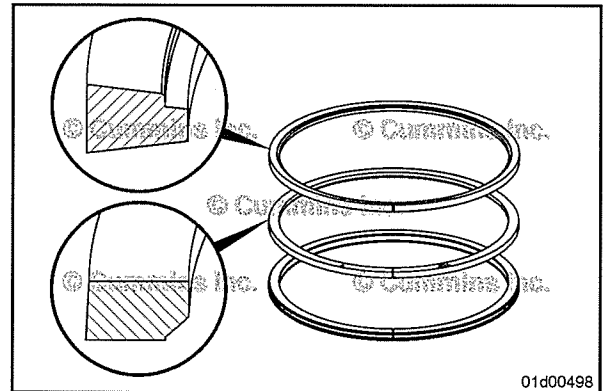


⚠CAUTION⚠

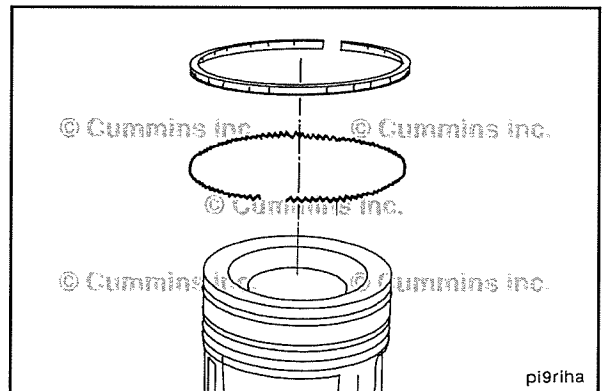
Most piston rings look similar but have significant difference. Make sure the correct part number is being used for the engine.

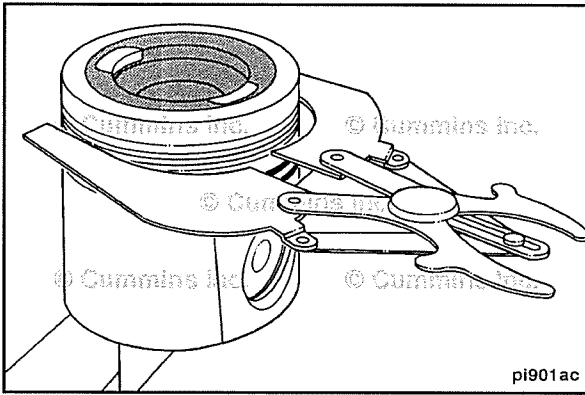
The top surface of the upper and intermediate rings are identified either with the word "TOP" or a supplier identification mark, such as a dot. Assemble with the word "TOP" or the supplier mark facing upward.

The bottom, or oil control ring, can be installed with either side up.

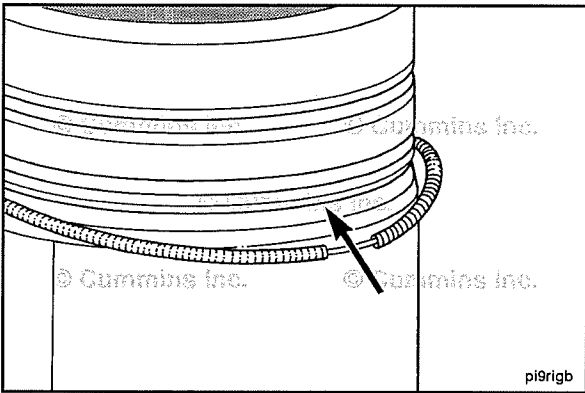


NOTE: The two-piece oil control ring **must** be installed with the expander ring gap 180 degrees from the gap of the oil ring.

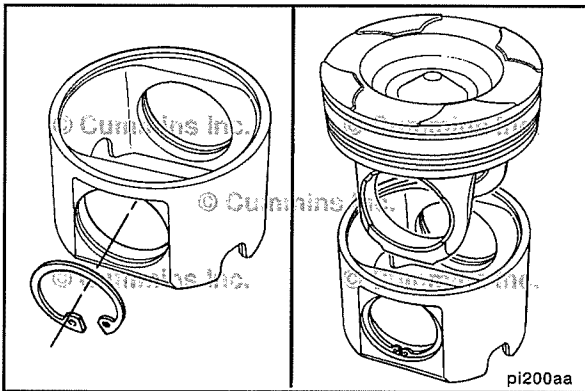




Use piston ring expander, Part Number 3823137, to install the rings on the piston.



Position the oil ring expander in the oil control ring groove.



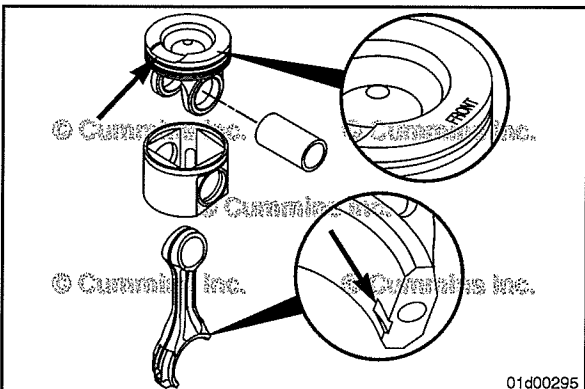
Articulated Piston

NOTE: If the pistons are being reused, the crown, skirt, and pin **must** be matched as they were when they were removed.

Position the skirt over the piston crown.

NOTE: It is **not** necessary to heat the articulated pistons before assembly. The piston pin is a slip fit.

Install the retaining ring in the pin groove on one side of the piston.



CAUTION

Do not use a hammer to install the piston pin. The piston can distort, causing it to seize in the liner.



CAUTION

The lock tang on the connecting rod must be on the side opposite the deep valve pocket of the piston crown.

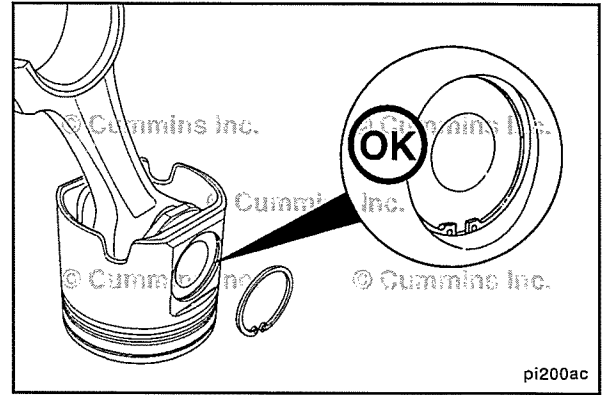
Lubricate the pin and pin bores with clean engine lubricating oil.

Align the pin bore of the rod with the pin bore of the piston skirt and crown, and install the piston pin.

⚠CAUTION⚠

The snap ring must be seated completely in the piston groove to prevent engine damage during engine operation.

Install the second retaining ring.



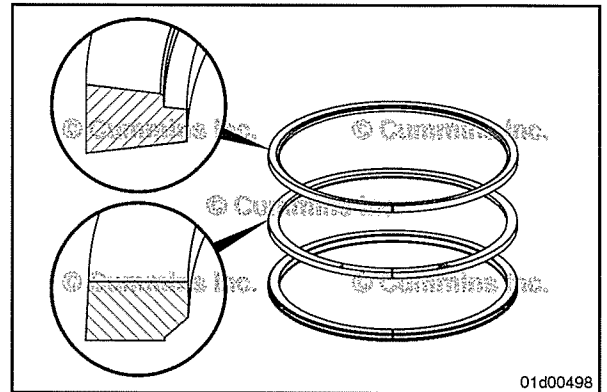
pi200ac

⚠CAUTION⚠

Most piston rings look similar but have significant difference. Make sure the correct part number is being used for the engine.

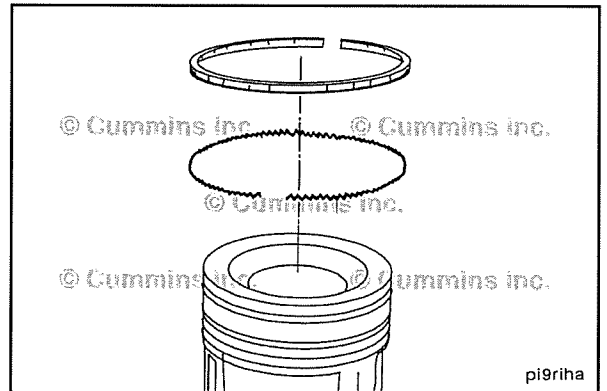
The top surface of the upper and intermediate rings are identified either with the word "TOP" or a supplier identification mark, such as a dot. Assemble with the word "TOP" or the supplier mark facing upward.

The bottom, or oil control ring, can be installed with either side up.



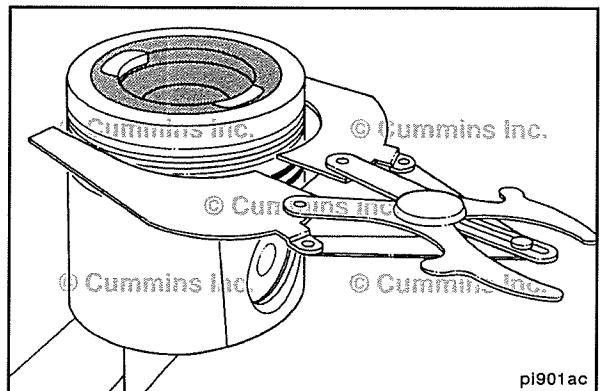
01d00498

NOTE: The two-piece oil control ring **must** be installed with the expander ring gap 180 degrees from the gap of the oil ring.

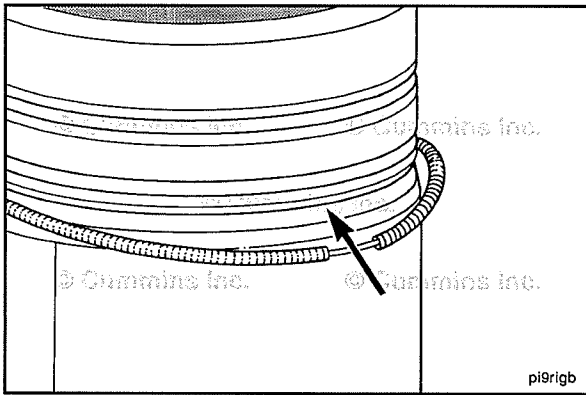


pi9riha

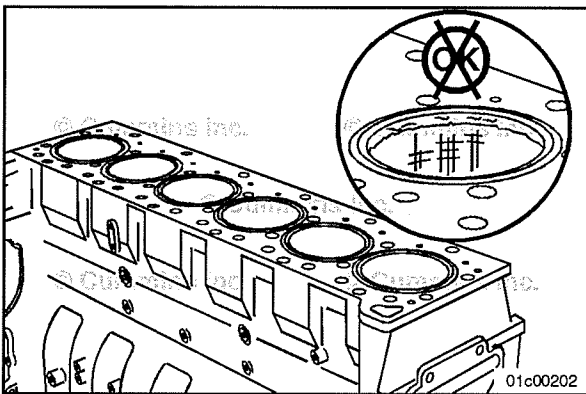
Use piston ring expander, Part Number 3823137, to install the rings on the piston.



pi901ac



Position the oil ring expander in the oil control ring groove.

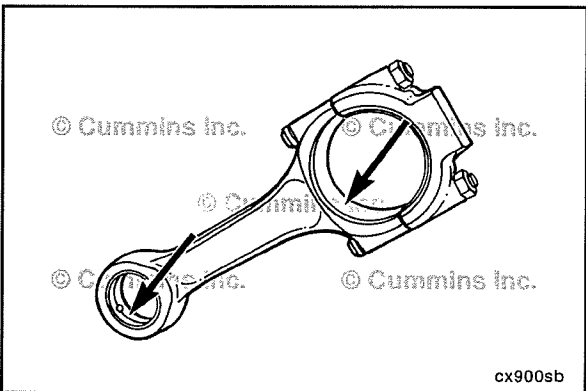


Install

The cylinder block and all parts **must** be clean before assembly. Inspect the cylinder liners for reuse.

Refer to Procedure 001-028 in Section 1.

Use a clean, lint-free cloth to clean the connecting rods and bearing shells.

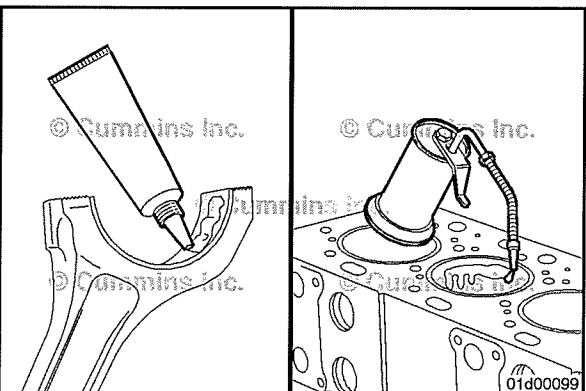


If new bearings are **not** used, the used bearings **must** be installed on the same connecting rod and location from where they were removed.



Install the upper bearing shell into the connecting rod.

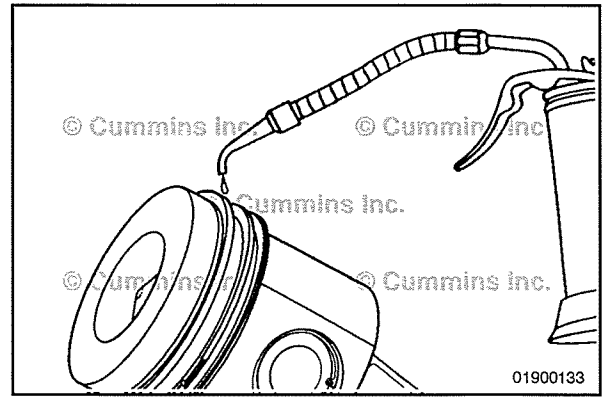
The tang of the bearing shell **must** be in the slot of the rod. The end of the bearing shell **must** be even with the cap mounting surface.



Use assembly lubricant, Part Number 3163087 or equivalent, to coat the inside circumference of the bearing shell.

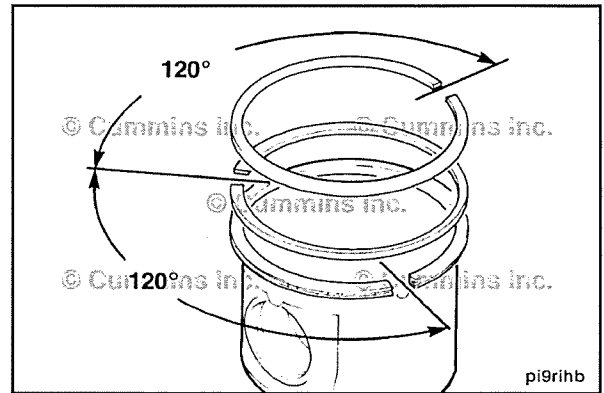
Apply a film of clean 15W-40 engine oil to the cylinder liner.

Lubricate the rings and piston skirts with clean engine lubricating oil.

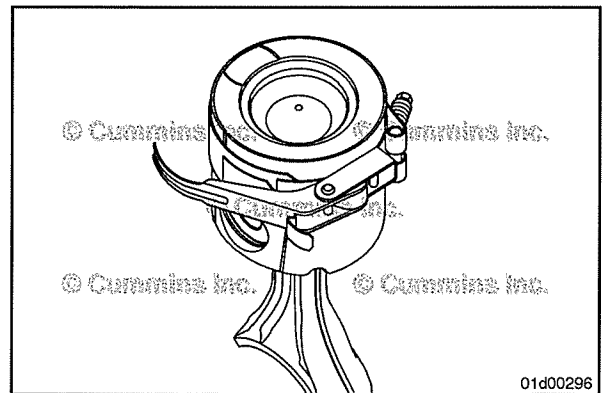


Rotate the rings to position the ring gaps as shown.

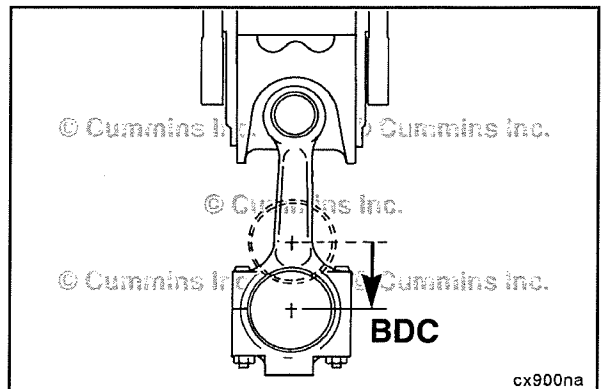
NOTE: The ring gap of each ring **must not** be aligned with the piston pin, or with any other ring. If the ring gaps are **not** aligned correctly, the rings will **not** seal properly.

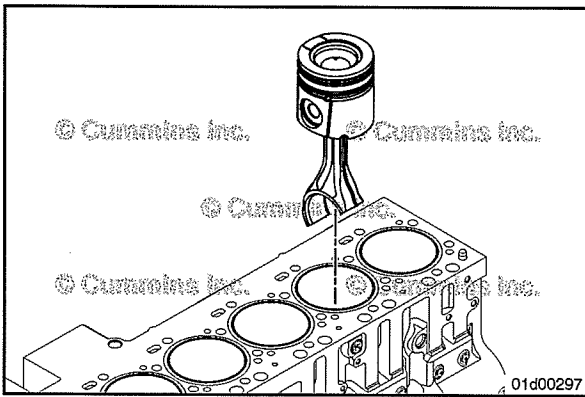


Use piston ring compressor, Part Number 3823290, to compress the rings.



Rotate the crankshaft so the connecting rod journal of the connecting rod being installed is at BDC.





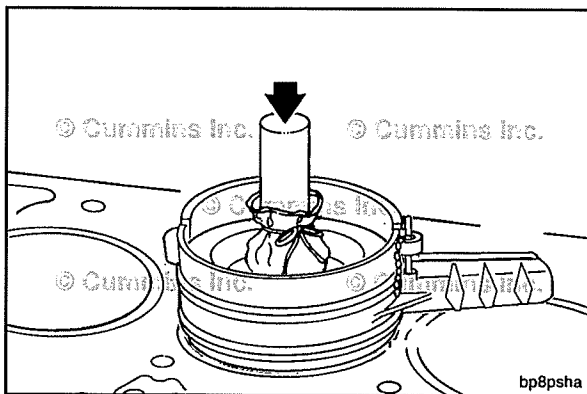
⚠ CAUTION ⚠

Omission of this step will result in extensive engine damage.

NOTE: For all piston types make sure that the "FRONT" marking on the piston crown is pointed toward the front of the engine block.

Align the piston crown deep valve pocket on the exhaust side of the engine.

Insert the connecting rod through the cylinder liner until the ring compressor contacts the top of the liner.

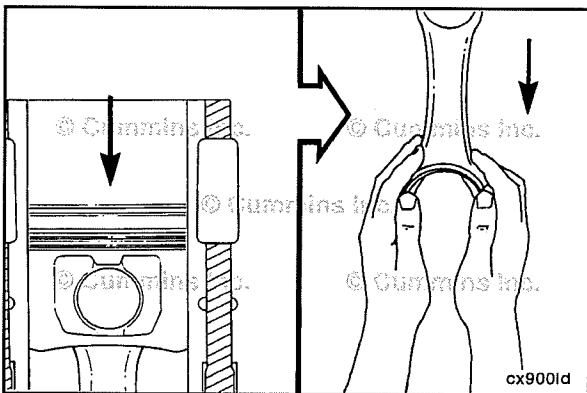


Hold the ring compressor against the cylinder liner.

Push the piston through the ring compressor and into the cylinder liner.

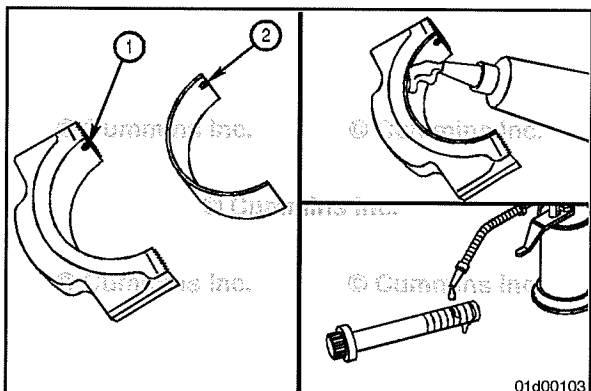
Push the piston until the top ring is completely in the cylinder liner.

NOTE: If the piston does **not** move freely, remove the piston and inspect for broken or damaged rings.



Carefully push the piston into the bore while guiding the connecting rod to the crankshaft journal.

NOTE: Connecting rod guide, Part Number 3824476, can be used to aid installation on engines with connecting rod studs.



NOTE: If new bearings are **not** used, the used bearings **must** be installed on the same connecting rod cap from which they were removed.



Install the bearing in the connecting rod cap.

The tang of the bearing (2) **must** be in the slot of the cap (1).

Use assembly lubricant, Part Number 3163087 or equivalent, to coat the inside diameter of the bearing shell.

Use clean 15W-40 engine oil to lubricate the connecting rod capscrew threads.

The connecting rod and cap **must** have the same number and **must** be installed in the proper cylinder. The connecting rod cap number and rod number **must** be on the same side of the connecting rod to prevent engine damage during engine operation.

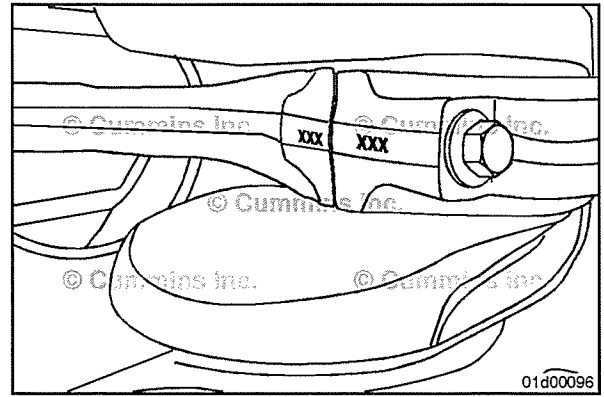
Engines With Connecting Rod Studs and Nuts

- Install the connecting rod cap and nuts.
- Use a marked socket and torque wrench to tighten the connecting rod nuts.
- Use the torque plus angle method to tighten the connecting rod nuts in alternating sequence.

Torque Value:

Connecting Rod Nuts

Step 1	60 N•m	[44 ft-lb]
Step 2	Loosen capscrews	
Step 3	30 N•m	[22 ft-lb]
Step 4	50 N•m	[37 ft-lb]
Step 5	Advance 60 degrees.	



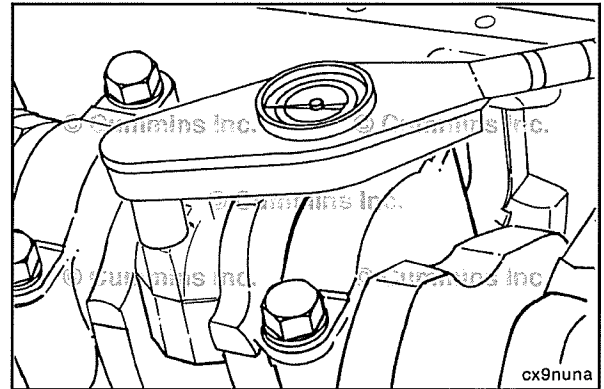
Engines With Connecting Rod Capscrews

- Install the connecting rod cap and capscrews.
- Use a marked socket and torque wrench to tighten the connecting rod capscrews.
- Use the torque plus angle method to tighten the connecting rod capscrews in alternating sequence.

Torque Value:

Connecting Rod Capscrews

Step 1	60 N•m	[44 ft-lb]
Step 2	Loosen capscrews	
Step 3	30 N•m	[22 ft-lb]
Step 4	50 N•m	[37 ft-lb]
Step 5	Advance 60 degrees	

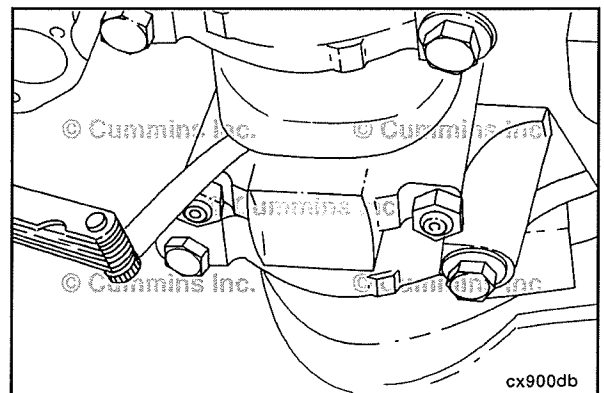


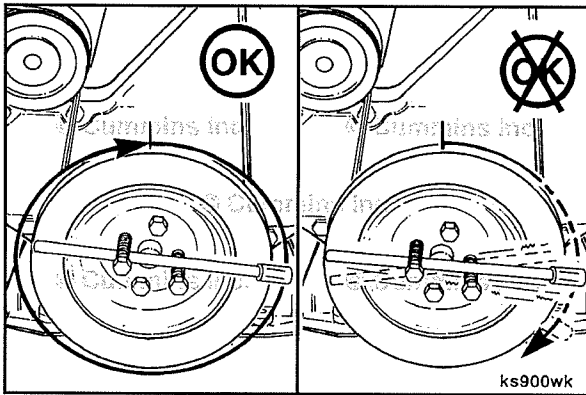
NOTE: Do **not** measure the clearance between the rod cap and crankshaft.

Measure the side clearance between the connecting rod and crankshaft.

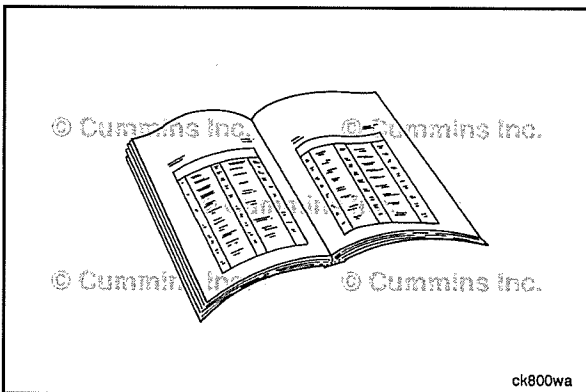
Connecting Rod and Crankshaft Side Clearance

mm		in
0.10	MIN	0.004
0.30	MAX	0.012





Check for freedom of rotation as the connecting rod caps are installed. If the crankshaft does **not** rotate freely, check the installation of the connecting rod bearings and the bearing size.



Finishing Steps

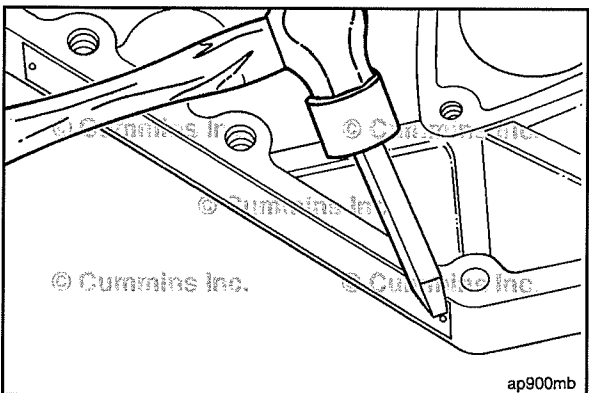
⚠ WARNING ⚠



Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the piston cooling nozzles, if required. Refer to Procedure 001-046 in Section 1.
- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Install the cylinder head. Refer to Procedure 002-004 in Section 2.
- Fill the engine with lubricating oil. Refer to Procedure 007-037 in Section 7.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to OEM service manual.
- Operate the engine and check for leaks.



Engine Dataplate (001-057)

Remove

Remove the rivets securing the engine dataplate.

NOTE: If the dataplate is to be reused, care **must** be taken **not** to damage the data on the plate.

Pry out the rivet by using a hammer to drive a flat chisel under the head of the rivet.

Install

⚠CAUTION⚠

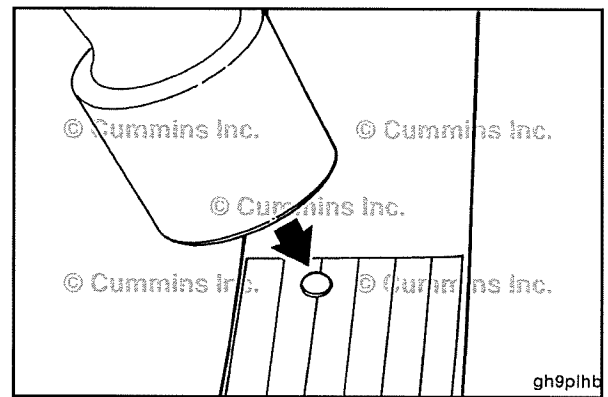
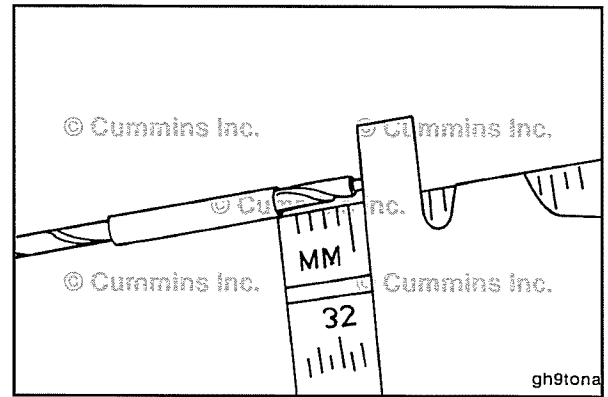
When drilling holes for the dataplate location, do not completely drill through the mounting location. Drill only deep enough to install the new blind rivets. Drilling through will result in an oil leak.

If attaching the dataplate to a new component or if the old rivet locations are damaged, drill new 2 mm [0.066 in] diameter holes and attach with new blind rivets.

NOTE: The dataplate should be located in the same area as it was previously installed.

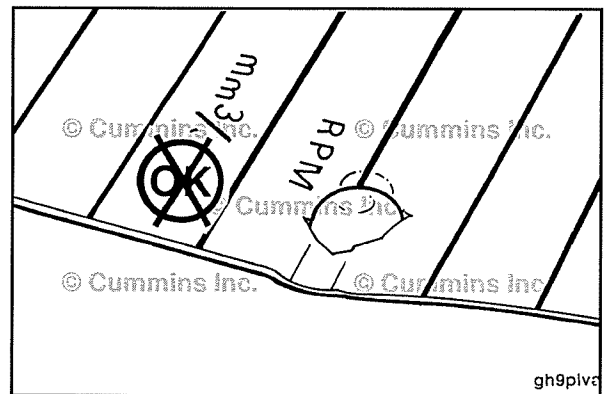
NOTE: Mark the drill bit at 6.0 mm [0.236 in] to reduce the possibility of drilling too deep in the gear housing.

Drive the rivets in until they contact the dataplate.



⚠CAUTION⚠

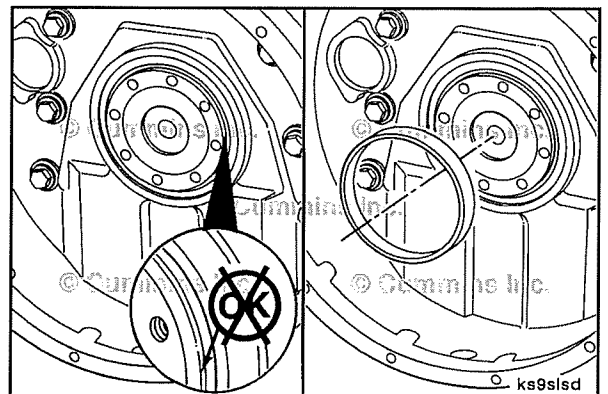
If the rivets are driven in too far, they will cut through the dataplate.

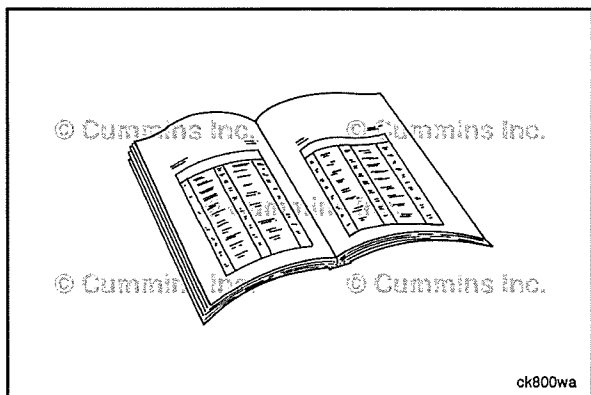


Crankshaft Wear Sleeve, Rear (001-067)

Initial Check

If the crankshaft seal has worn a groove in the crankshaft flange, a wear sleeve **must** be installed to reduce the possibility of oil leakage.





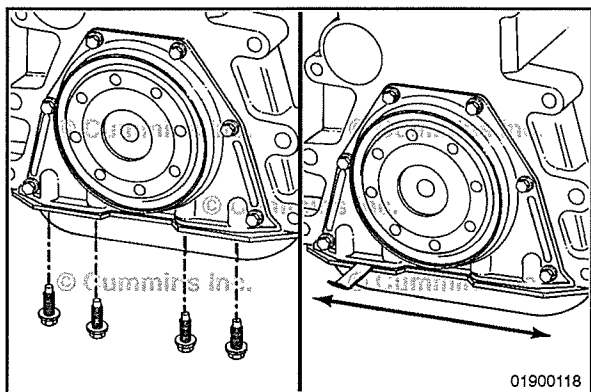
Preparatory Steps



⚠️ WARNING ⚠️

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Disconnect the driveline and remove the transmission, if equipped. Refer to the OEM service manual.
- Remove the flexplate, if installed. Refer to Procedure 016-004 in Section 16.
- Remove the flywheel, if installed. Refer to Procedure 016-005 in Section 16.
- Remove the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Loosen the lubricating oil pan mounting capscrews four revolutions.



Remove

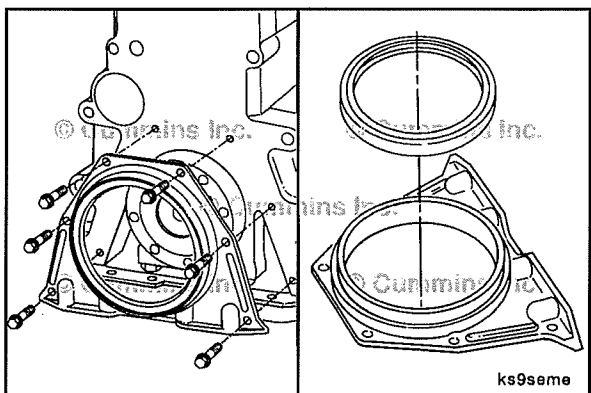


⚠️ CAUTION ⚠️

Use extreme care when releasing the oil pan gasket from the rear cover to prevent damage to the gasket. If the gasket is damaged, the oil pan must be removed and the gasket replaced. Refer to Procedure 007-025 in Section 7.

Remove the four lubricating oil pan mounting capscrews which secure the oil pan to the rear cover.

Insert a feeler gauge or shim stock between the rear cover and the oil pan gasket. Move the feeler gauge or the shim stock back and forth to release the gasket from the rear cover.



Remove the capscrews from the rear cover, and remove the cover from the crankshaft flange.

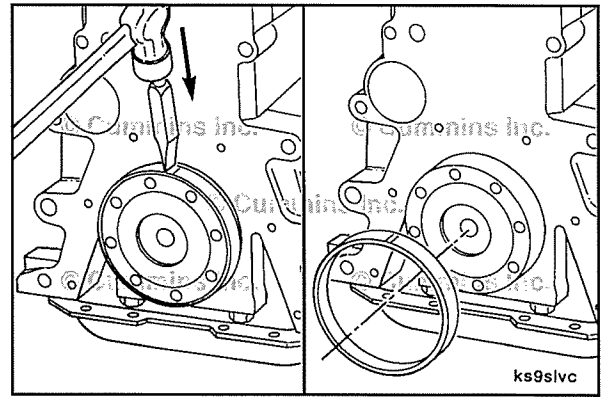
Remove the seal from the rear cover.

⚠ CAUTION ⚠

Do not nick or gouge the crankshaft with the chisel. If the crankshaft is damaged, it must be replaced.

Use a dull chisel that is **only** as wide as the wear sleeve.

Make one or two soft blows with a hammer to make chisel marks across the wear sleeve. This will expand the wear sleeve allowing the sleeve to be removed.

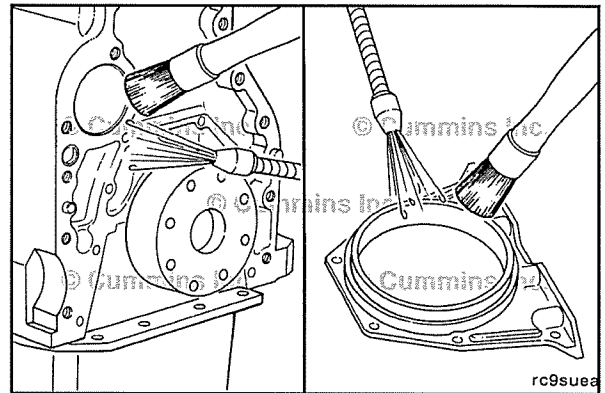


Clean and Inspect for Reuse

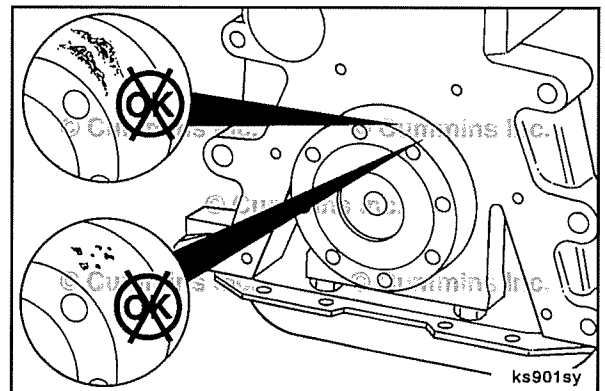
Clean the gasket surface of the cylinder block and rear cover.

Use a crocus cloth to remove any rust or other deposits from the crankshaft flange.

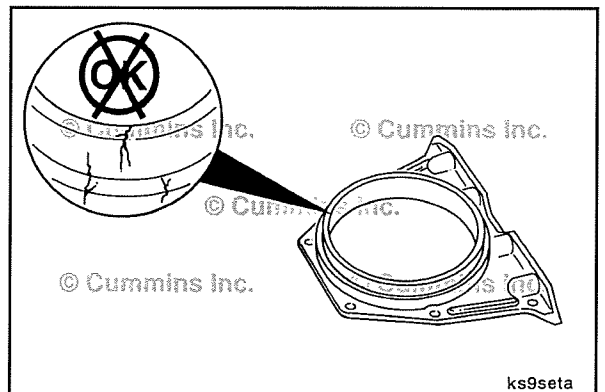
Use a clean cloth to clean the crankshaft flange.

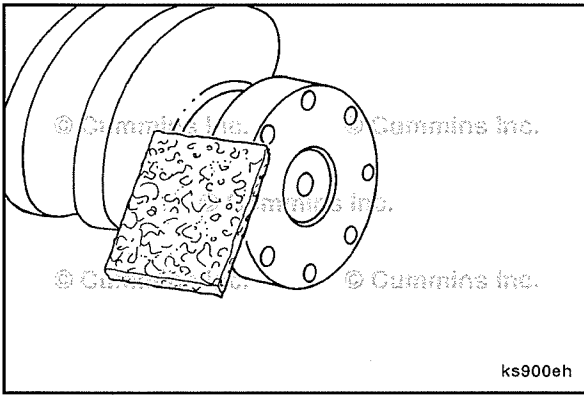


Inspect the crankshaft flange for dirt or nicks.



Inspect the rear cover for cracks or other damage.

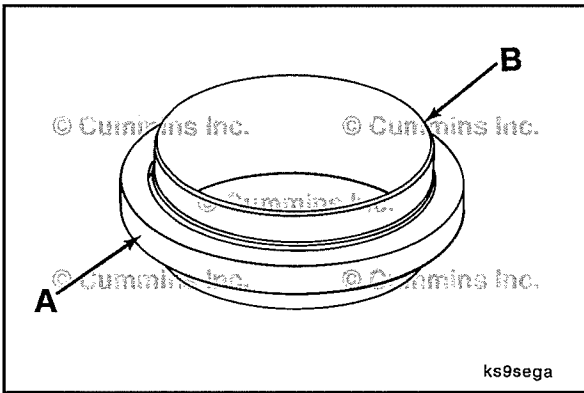




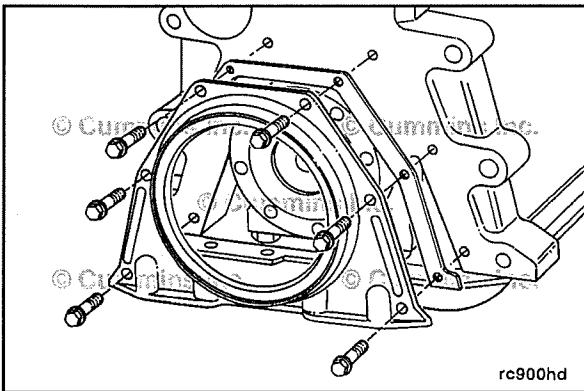
Install

NOTE: Do **not** use any kind of lubricant to install the seal. The oil seal **must** be installed with the lip of the oil seal and the crankshaft clean and dry to make sure of proper oil sealing.

Clean any lubricant from the lip of the oil seal.



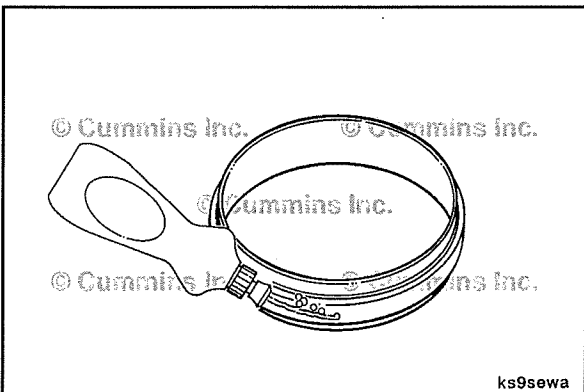
The combination crankshaft oil seal (A) wear sleeve (B) replacement kit for service usage is installed on the crankshaft as an assembly. The crankshaft rear oil seal should **not** be removed from the crankshaft rear seal wear sleeve.



NOTE: If the oil pan is installed, loosen the oil pan capscrews to allow clearance for rear cover and gasket clearance.

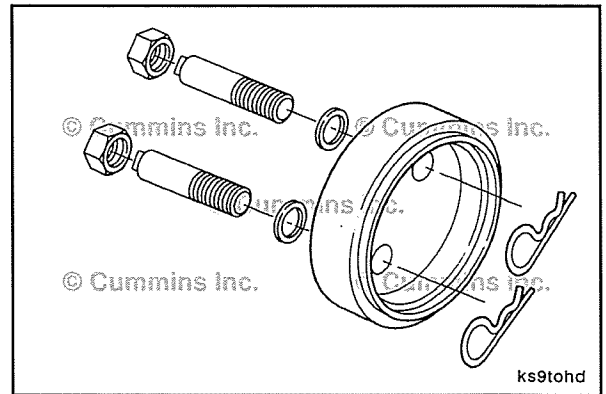
Install the rear cover and gasket.

The seal installation is being used to properly align the rear cover. Do **not** push or force the cover in any direction to prevent irregular seal lip position after seal installation.



The oil seal for a wet flywheel housing requires soap on the outside diameter of the seal case. Nothing is required on the outside diameter of the seal case for dry housings.

Use a Rear Seal/Sleeve Installer, Part Number 3824078, to install oil seal/wear sleeve assembly. Install two (2) threaded studs into the crankshaft capscrew holes.

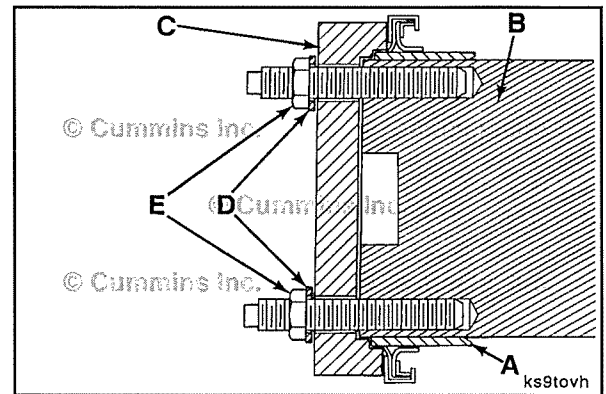


Apply a small amount of clean 15W-40 engine oil to the crankshaft, threaded studs, and inside diameter of the crankshaft rear seal/wear sleeve installation tool.

Position the chamfered end of the wear sleeve (A) onto the end of the crankshaft (B).

Position the counterbore end of installation tool (C) over threaded studs and align with wear sleeve, perpendicular to the end of the crankshaft.

Install the washers (D) and nuts (E) onto the threaded studs.

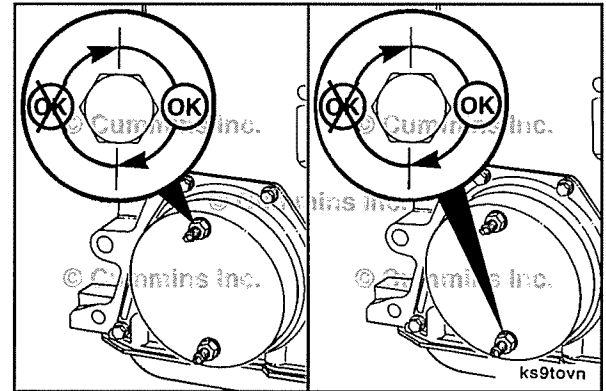


Alternately tighten the nuts until the installation tool contacts the end of the crankshaft.

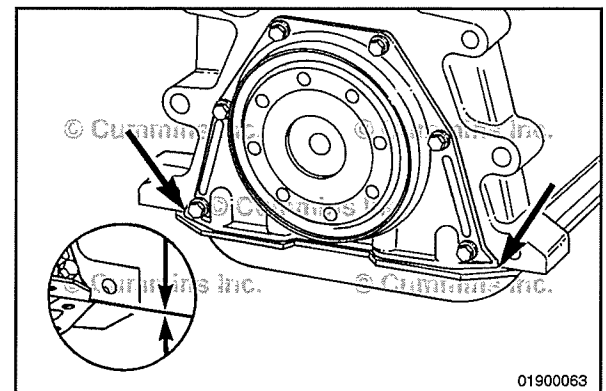
Do **not** exceed 1/2 revolution on each nut to prevent wear sleeve binding and irregular stretch.

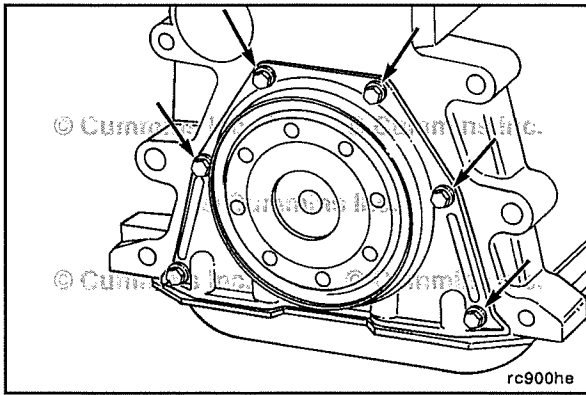
Torque Value: 20 N•m [180 in-lb]

Remove the installation tool and threaded studs.



Align the rear cover even with both sides of the oil pan rail on the cylinder block.



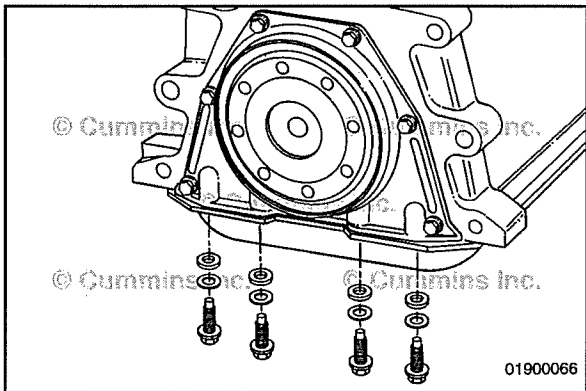


Tighten the rear cover capscrews.

The chart below shows the proper torque value when using either a 9.8 or a 10.9 grade bolt. The grade is embossed on the top of each bolt.

Apply Dri-Loc™ to both part numbers below during installation. Dri-Loc™ 205 is recommended. Use Dri-Loc™ 204 or 211, when 205 is **not** available.

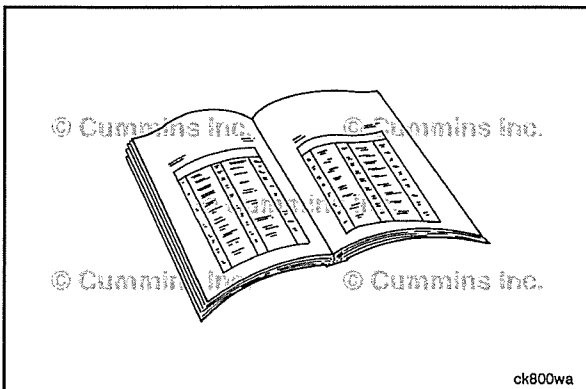
Rear Seal Carrier				
Bolt Number	Bolt Size	Bolt Class	Torque	Dri-Loc™
3913638	M-6	9.8	10 N•m [88.5 in-lb]	No
3991306	M-6	10.9	13 N•m [115 in-lb]	Yes



Install the four (4) rear oil pan mounting capscrews to the pan.



Tighten the oil pan capscrews. Refer to Procedure 007-025 in Section 7.



Finishing Steps



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Install the flexplate, if installed. Refer to Procedure 016-004 in Section 16.
- Install the flywheel, if installed. Refer to Procedure 016-005 in Section 16.
- Install the transmission and connect the driveline, if equipped. Refer to the OEM service manual.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

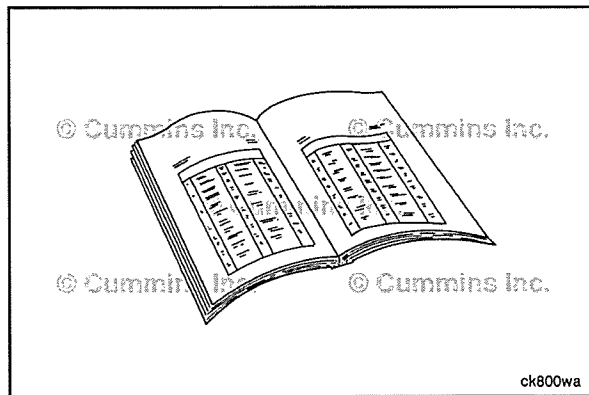
Crankshaft Speed Indicator Ring (001-071)



Preparatory Steps



- Remove the crankshaft. Refer to Procedure 001-016 in Section 1.

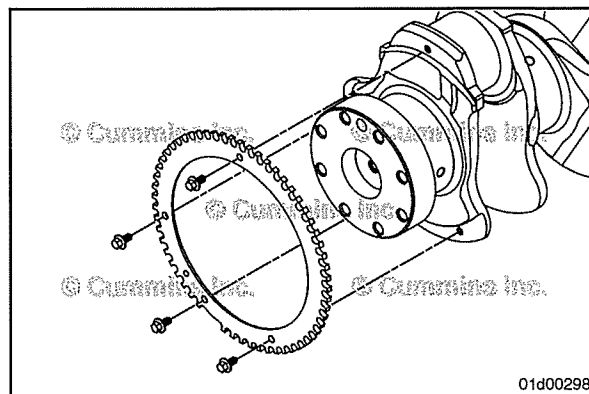


Remove

Remove and discard the four crankshaft speed indicator ring mounting capscrews.



NOTE: The capscrews are one-time use **only**. They can **not** be reused.



Clean and Inspect for Reuse

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

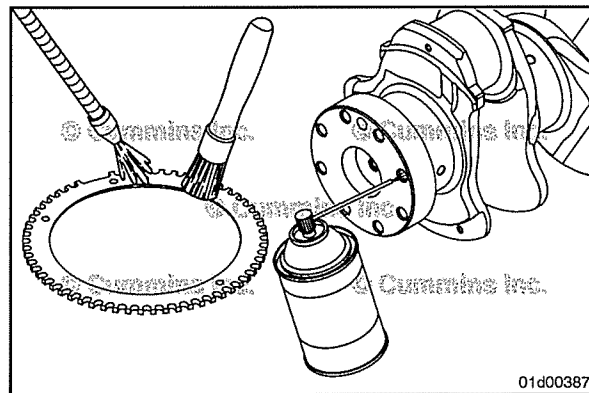


⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Clean any oil from the speed indicator ring.

Clean the capscrew holes in the crankshaft. Use degreaser solvent such as electrical contact cleaner, Part Number 3824510.

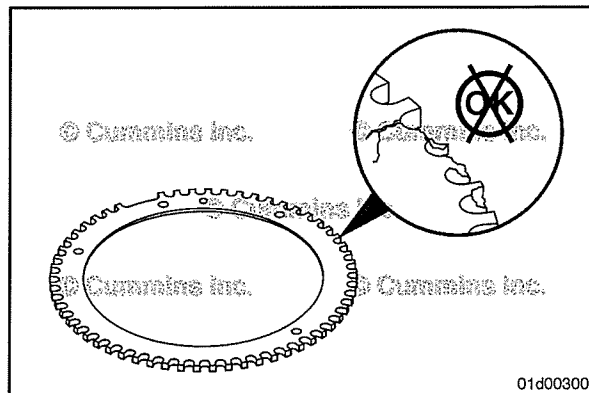


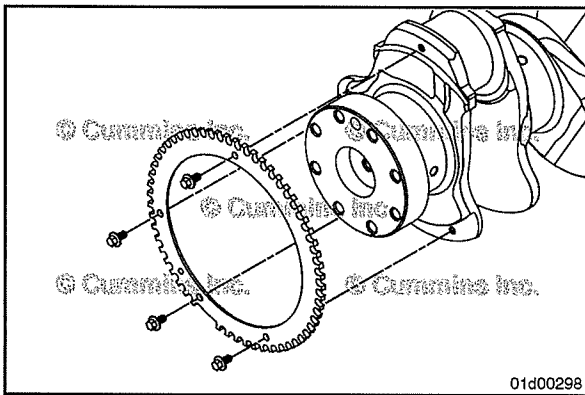
Inspect the speed indicator ring for missing, bent, or damaged teeth.



Inspect for cracks or damaged surfaces.

If any visual damage is found, the speed indicator ring **must** be replaced.





Install

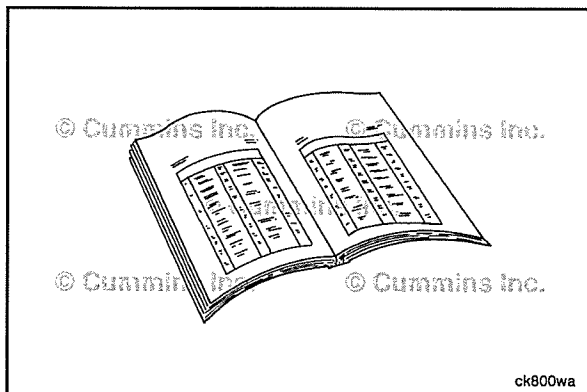
Install the speed indicator ring.



Install new capscrews.

Tighten the capscrews in an alternating pattern.

Torque Value: 10 N•m [89 in-lb]



Finishing Steps

• Install the crankshaft. Refer to Procedure 001-016 in Section 1.



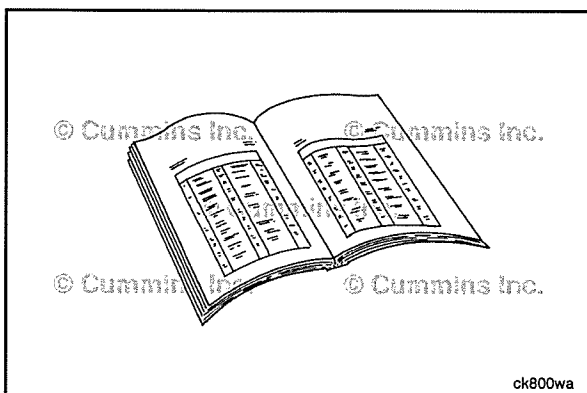
• Operate the engine and check for leaks and proper operation.



Block Stiffener Plate (001-089)

General Information

The block stiffener plate will **only** be found on some engines.



Preparatory Steps

⚠ WARNING ⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.



⚠ WARNING ⚠

Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

• Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.

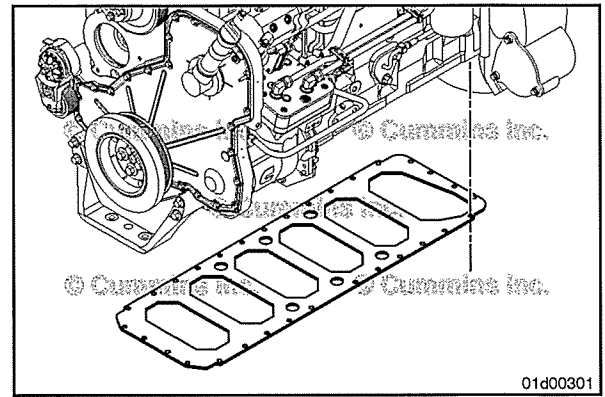
• Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.

• Remove the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.

Remove

Remove the block stiffener plate.

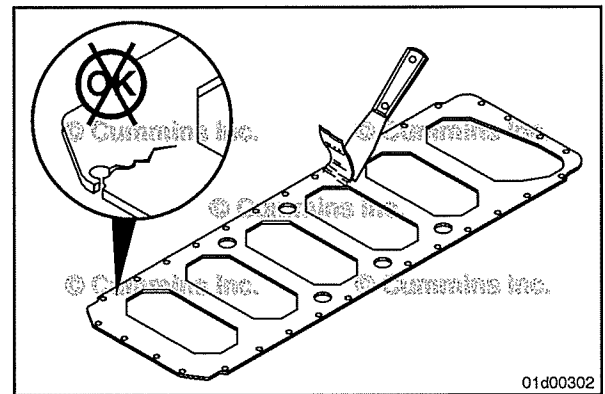
NOTE: The plate will be loose after the oil pan capscrews are removed.



Clean and Inspect for Reuse

Remove all gasket material from both gasket surfaces.

Inspect the block stiffener plate for cracks or other damage.

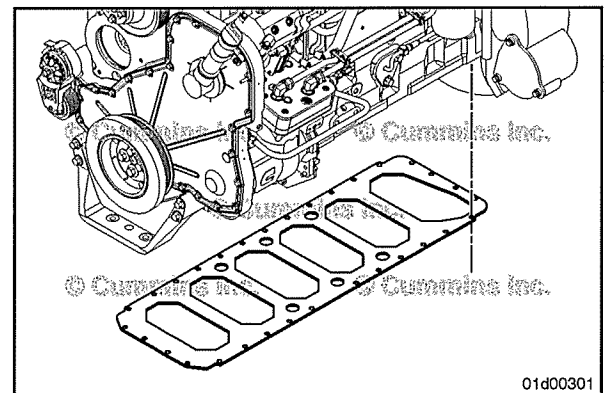


Install

Install the block stiffener plate. Use a new gasket and/or RTV sealant.

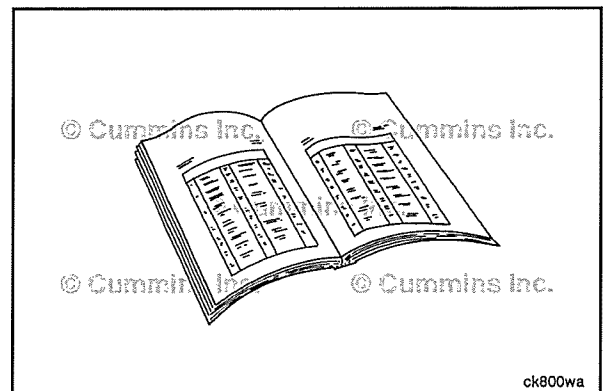
NOTE: The engines use a variety of combinations of gaskets and/or RTV sealant. When installing the oil pan and block stiffener plate, use the same combination of gaskets and/or RTV sealant.

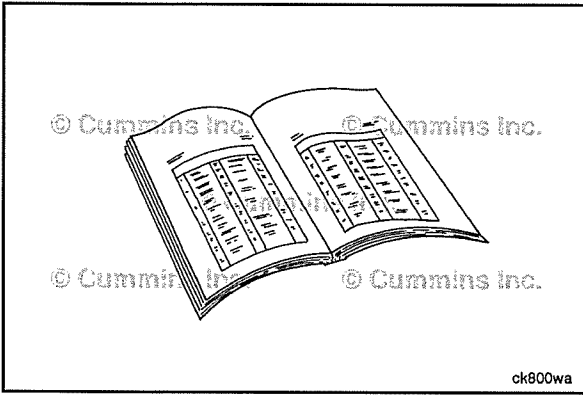
NOTE: The block stiffener **must** be held in place while the lubricating oil suction tube is installed. Use a few lubricating oil pan capscrews or wire ties to accomplish this.



Finishing Steps

- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Fill the engine with lubricating oil. Refer to Procedure 007-037 in Section 7.
- Operate the engine and check for leaks.





Crankshaft Seal Carrier, Rear (001-104)

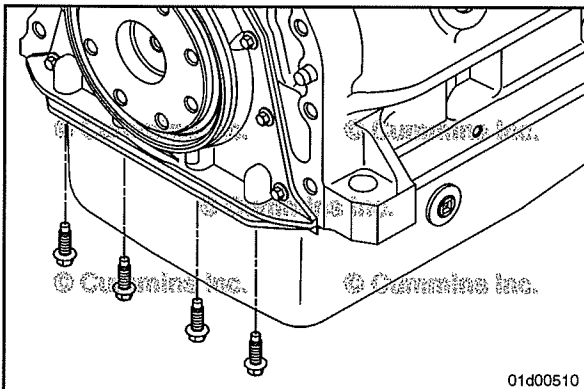


Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- If equipped with a wet flywheel housing, drain the oil from the flywheel housing by removing the plug in the bottom of the flywheel housing.
- Remove the starting motor. Refer to Procedure 013-020 in Section 13.
- Remove the transmission and all related components, if equipped. Refer to the OEM service manual.
- Remove the flywheel/flexplate assembly. Refer to Procedure 016-005 in Section 16. Refer to Procedure 016-004 in Section 16.
- Remove any components attached by the OEM to the flywheel housing (e.g., mufflers, shift mechanisms, air filters, and so forth). Refer to the OEM service manual.
- Remove the flywheel housing. Refer to Procedure 016-006 in Section 16.



Remove

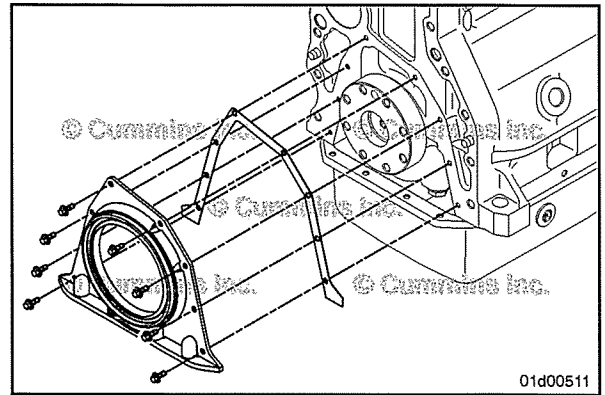
⚠ CAUTION ⚠

Use extreme care when releasing the lubricating oil pan gasket from the rear cover to prevent damage to the gasket.

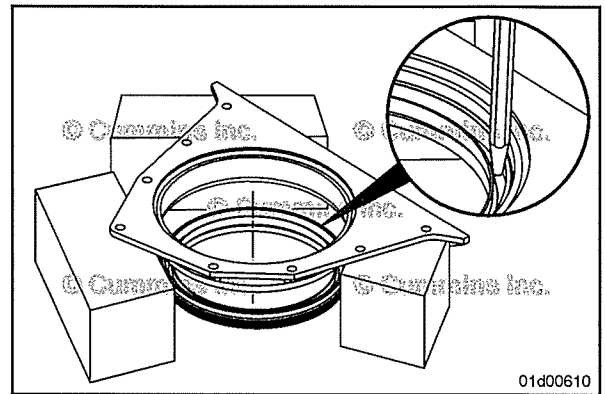
Remove the four lubricating oil pan mounting capscrews that secure the oil pan to the rear cover.

Insert the feeler gauge or shim stock between the rear cover and the oil pan gasket. Move the feeler gauge back and forth to release the gasket from the rear cover.

Remove the capscrews from the rear cover.
Remove the cover from the crankshaft flange.



Support the rear seal carrier on a flat work surface with wooden blocks. Use a suitable punch and hammer to drive the old seal out of the rear seal carrier.



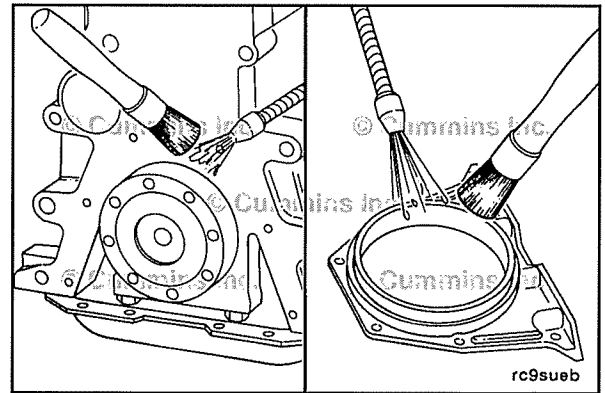
Clean and Inspect for Reuse

⚠ WARNING ⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

⚠ WARNING ⚠
Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

Clean the gasket surface of the cylinder block and rear seal carrier.

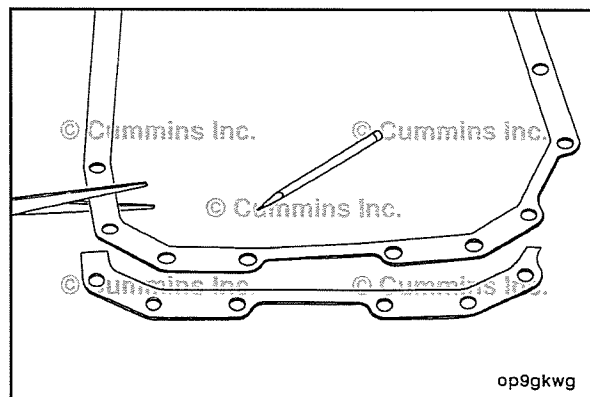
Dry these areas with compressed air.



Service Tip:

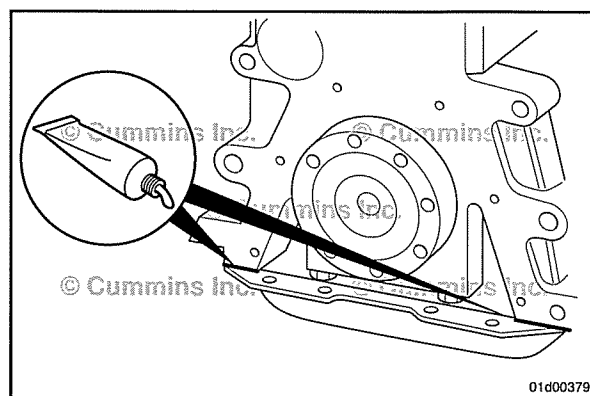
If the oil pan gasket was damaged during removal of the rear seal carrier, remove the damaged gasket and:

- If previously equipped with a paper oil pan gasket, use the old gasket as a pattern and cut a section of new gasket to the same size. Use a light coat of sealant, Part Number 3164067 or equivalent, to hold the gasket in place
- If previously equipped with a sealant only oil pan gasket, apply a bead of sealant, Part Number 3164070 or equivalent, to the oil pan flange
- If previously equipped with a suspended oil pan, the oil pan **must** be removed and a new gasket installed. Refer to Procedure 007-025 in Section 7.

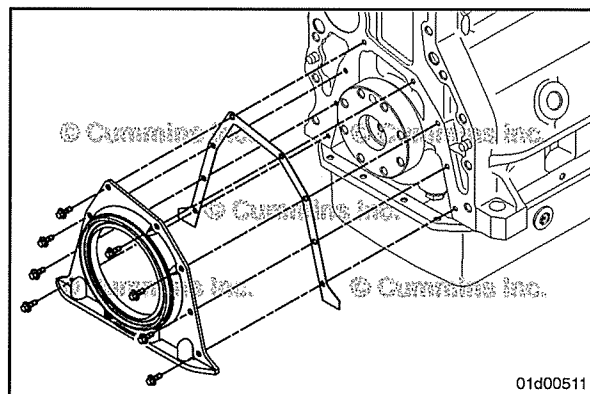


NOTE: It could be necessary to trim the rear seal carrier gasket so that it is even with the oil pan mounting surface. Test fit the gasket prior to installing.

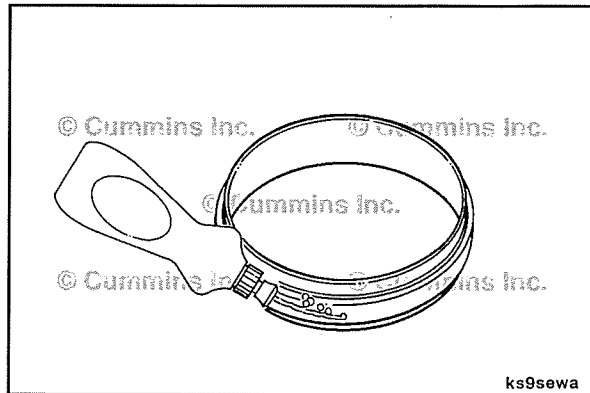
Apply a thin bead of sealant, Part Number 3164067, at the intersecting joint of the oil pan and cylinder block prior to installing the rear crankshaft seal carrier. The rear crankshaft seal carrier **must** be installed within 10 minutes of applying the sealant.

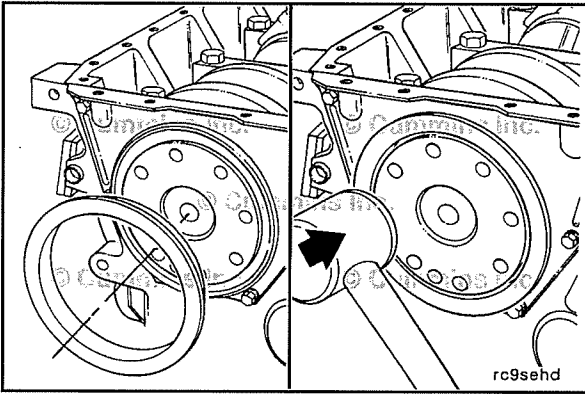


Install the rear crankshaft seal carrier and gasket. Apply Loctite® 262 or 271 to the mounting capscrews and loosely tighten the rear seal carrier to the block.



To aid in installation, the lubricating oil seal requires the application of a mild soap on the outside diameter of the seal case.





Place the new rear crankshaft seal, with the seal pilot, over the crankshaft nose and slide it by hand toward the flywheel housing.

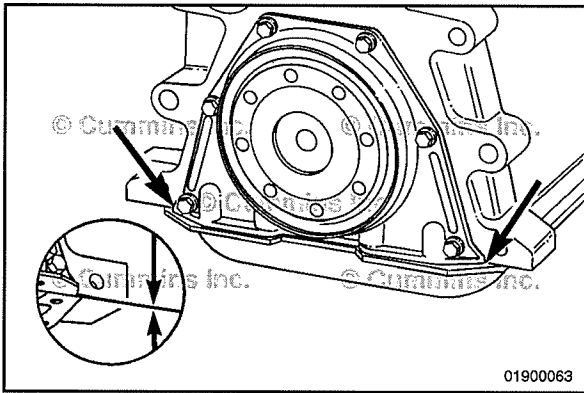
Remove the seal pilot.

Use the disposable seal driver for Front Gear Train engines to drive the rear crankshaft seal into the rear crankshaft seal carrier.

NOTE: Service tool, Part Number 3824078 or equivalent, used to install the rear crankshaft seal/wear sleeve assembly, can also be used to install the rear crankshaft seal.

Use a plastic hammer to drive the seal into the housing until the alignment tool stops against the housing.

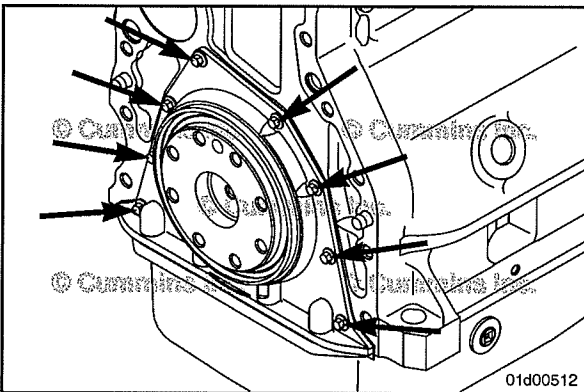
Hit the tool at the 12, 3, 6 and 9 o'clock positions to drive the seal evenly and to prevent bending the seal carrier. Hit the seal driver until contact is made with the rear crankshaft seal carrier.



⚠CAUTION⚠

Do not push or force the cover in any direction. This may cause an irregular seal lip position after seal installation. An engine oil leak will result.

Align the rear cover even with both sides of the oil pan rail on the cylinder block.



Tighten the rear cover capscrews.

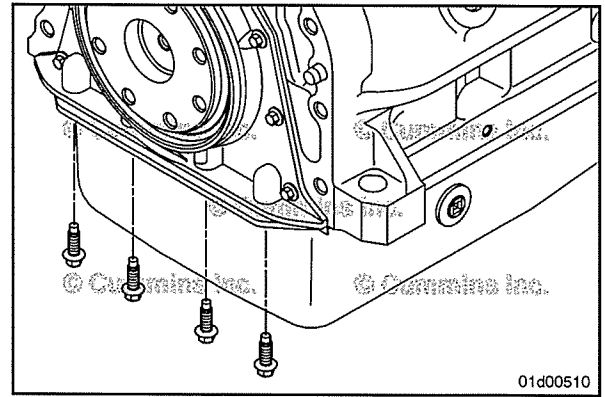
The chart below shows the proper torque value when using a 9.8 or a 10.9 grade bolt. The grade is embossed on the top of each bolt.

Apply Loctite® 262 or 271 to both part numbers below during installation.

Rear Seal Carrier				
Bolt Number	Bolt Size	Bolt Class	Torque	Loctite®
3913638	M-6	9.8	10 N•m [89 in-lb]	Yes
3991306	M-6	10.9	13 N•m [115 in-lb]	Yes

Install the four rear lubricating oil pan mounting capscrews into the rear cover.

Torque Value: 28 N•m [248 in-lb]

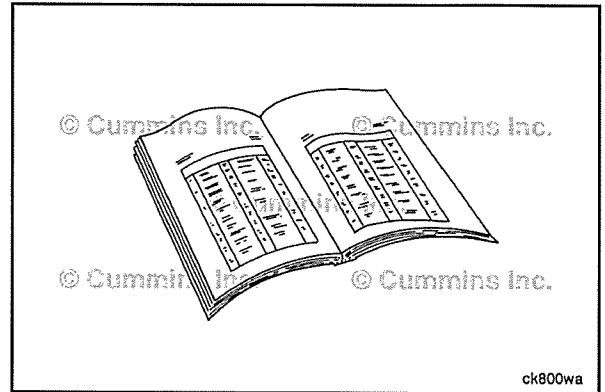


Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the flywheel/flexplate assembly. Refer to Procedure 016-005 in Section 16. Refer to Procedure 016-004 in Section 16.
- Install the starting motor. Refer to Procedure 013-020 in Section 13.
- Install the transmission and all related components, if equipped. Refer to the OEM service manual
- If equipped with a wet flywheel housing, fill the flywheel housing with oil. Refer to the OEM service manual
- If previously removed install any components attached by the OEM to the flywheel housing (e.g., mufflers, shift mechanisms, air filters, and so forth.) to the flywheel housing. Refer to the OEM service manual.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Section 2 - Cylinder Head - Group 02

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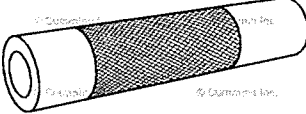
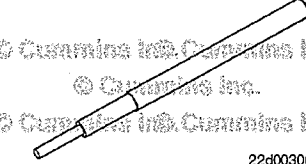
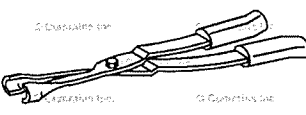

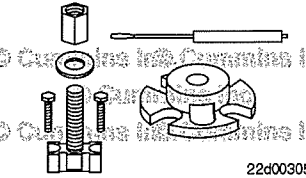
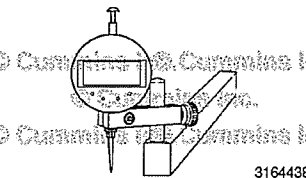
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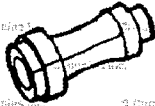

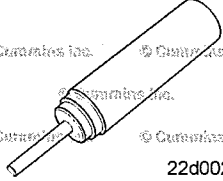
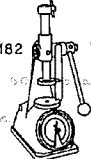
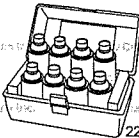
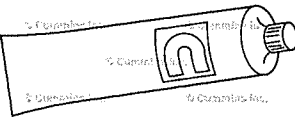
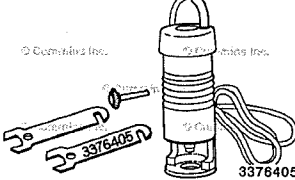
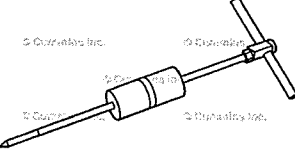
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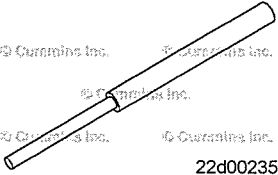
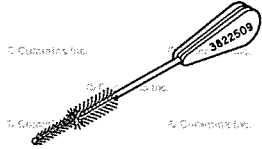
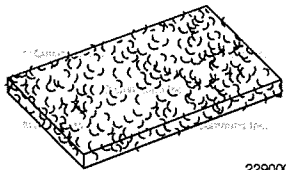
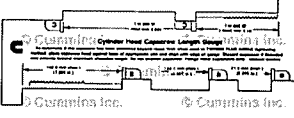
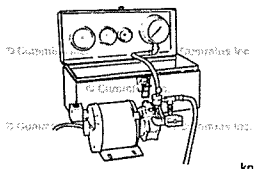
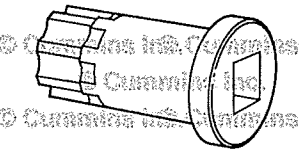
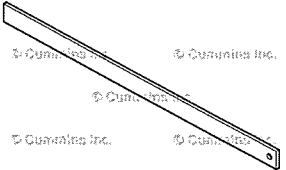
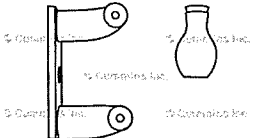
Service Tools

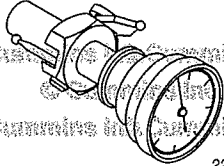
Cylinder Head

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3163100	<p align="center">Valve Guide Installer</p> <p>Used to install valve guides.</p>	 <p align="right">3163293</p>
3163101	<p align="center">Valve Guide Remover</p> <p>Used to remove valve guides.</p>	 <p align="right">22d00306</p>
3163293	<p align="center">Boot Pliers</p> <p>Used to remove valve stem seals. The twist and pull action frees the boot and the serrated jaws provide a secure grip.</p>	 <p align="right">3163294</p>
3163720	<p align="center">Dowel Pin Extractor</p> <p>This puller contains various sized collets to remove crosshead guides or dowels throughout the engine.</p>	 <p align="right">ck8toge</p>
3164329	<p align="center">Valve Spring Compressor</p> <p>Used to remove and install valve collets.</p>	 <p align="right">22d00305</p>
3164438	<p align="center">Depth Gauge Assembly</p> <p>Used to measure injector protrusion and valve intrusion and/or protrusion. Equipped with electronic digital indicator.</p>	 <p align="right">3164438</p>

Tool No.	Tool Description	Tool Illustration
3165113	<p align="center">Intake Valve Seat Extractor Collet</p> <p>Used with slide hammer, Part Number 3376517. The slide hammer is sold separately.</p>	 <p align="right">3376146</p>
3165114	<p align="center">Exhaust Valve Seat Extractor Collet</p> <p>Used with slide hammer, Part Number 3376517. The slide hammer is sold separately.</p>	 <p align="right">3376146</p>
3165115	<p align="center">Valve Seat Installer</p> <p>Used for installing intake and exhaust valve seats.</p>	 <p align="right">22d00234</p>
3375182	<p align="center">Valve Spring Tester</p> <p>Used to check spring tension.</p>	 <p align="right">3375182</p>
3375432	<p align="center">Crack Detection Kit (Dye Type)</p> <p>Used to clean and inspect components for cracks.</p>	 <p align="right">22d00239</p>
3375805	<p align="center">Valve Lapping Compound</p> <p>An abrasive compound used to lap the valves.</p>	 <p align="right">3377182</p>
3376405	<p align="center">Valve Seat Grooving Tool</p> <p>Used to cut a groove in the valve seat. This is often required prior to use of the valve seat extractor. It requires cutter bit, Part Number 3376407. The cutter bit is sold separately.</p>	 <p align="right">3376405</p>
3376617	<p align="center">Slide Hammer Assembly</p> <p>Used with the valve seat extractor to remove the valve seat inserts from the cylinder head.</p>	 <p align="right">bp8logd</p>

Tool No.	Tool Description	Tool Illustration
3823186	<p align="center">Valve guide Arbor</p> <p>Used for positioning to valve guide inside diameter, to cut valve seats, and to cut valve seat pockets for oversize seats. It can also be used with gauge, Part Number ST-685-4, to check valve seat concentricity.</p>	 <p align="right">22d00235</p>
3822509	<p align="center">Injector Bore Brush</p> <p>Used to clean carbon from injector bores.</p>	 <p align="right">3822509</p>
3823258	<p align="center">Abrasive Pad</p> <p>Used to clean carbon from the upper liner bores, remove rust and corrosion, and scuff surfaces.</p>	 <p align="right">22900039</p>
3823921	<p align="center">Capscrew Length Gauge</p> <p>Used to measure capscrew free length.</p>	 <p align="right">3823921</p>
3824277	<p align="center">Valve Vacuum Tester</p> <p>Used with vacuum cup, Part Number ST-1257-6, to vacuum test the cylinder head, to determine if the valves are properly seated.</p>	 <p align="right">kn8togr</p>
3824591	<p align="center">Engine Barring Gear</p> <p>Used to engage the flywheel ring gear to rotate the crankshaft.</p>	 <p align="right">3824591</p>
4918219	<p align="center">Precision Straightedge</p> <p>Used to check cylinder head combustion decks for flatness.</p>	 <p align="right">22d00222</p>
ST-1166	<p align="center">Magnetic Crack Detector</p> <p>Used to inspect the cylinder head combustion face for cracks in the injector bore and valve seat areas. The kit includes powder spray bulb, Part Number ST-1166-7, used for spraying the metal powder, Part Number ST-1166-8.</p>	 <p align="right">kn8togo</p>

Tool No.	Tool Description	Tool Illustration
ST-685-4	Eccentrimeter Gauge Used to measure the valve seat to valve guide runout.	 <p>© Cummins Inc. 22d00308</p>

Crosshead (002-001)

Preparatory Steps

⚠ WARNING ⚠

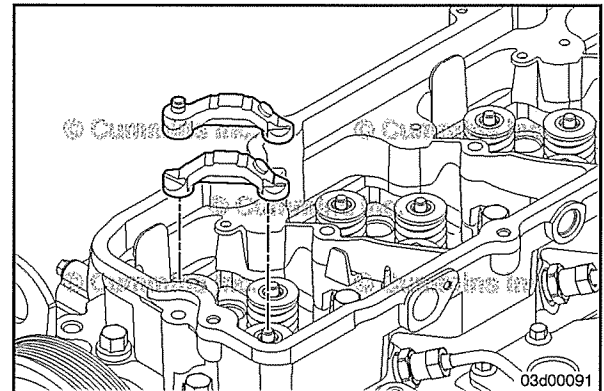
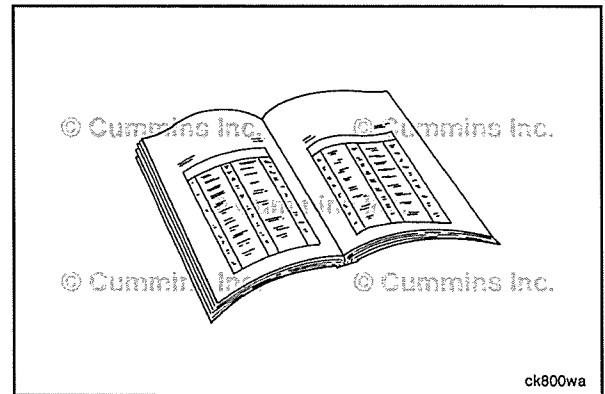
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

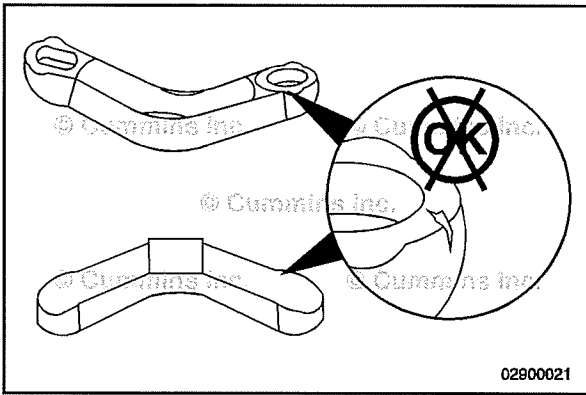
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the crankcase breather tube and drain tube. Refer to Procedure 003-018 in Section 3.
- Remove the exhaust gas recirculation (EGR) connection tube. Refer to Procedure 011-025 in Section 11.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Remove the rocker lever assembly. Refer to Procedure 003-008 in Section 3.

Remove

NOTE: Make note of the crosshead location and orientation. If the crossheads are reused, they **must** be installed in their original location and orientation.

Remove the crossheads.





Clean and Inspect for Reuse



⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠ WARNING ⚠

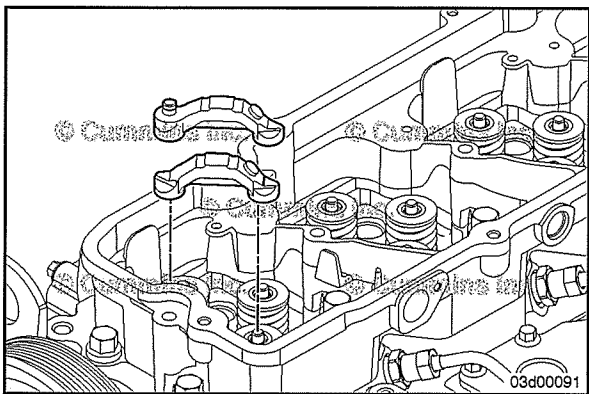
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the crossheads with solvent.

Dry with compressed air.

Inspect the crossheads for cracks and/or excessive wear on the rocker lever and valve tip mating surfaces.

Inspect the contact pads for cracks and other damage.



Install

NOTE: The crosshead has a round hole and an oval hole. If installing new crossheads, it is **not** required to place the holes in a particular position.

NOTE: When reusing the crossheads, make sure to install them in their original location and orientation.

Install the crossheads on the valve stems.

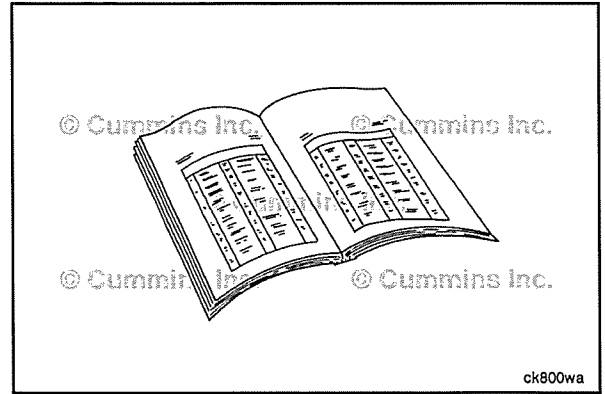
When installing the crossheads on engines equipped with engine brakes, the pin on the crosshead **must** be facing the exhaust manifold.

Finishing Steps

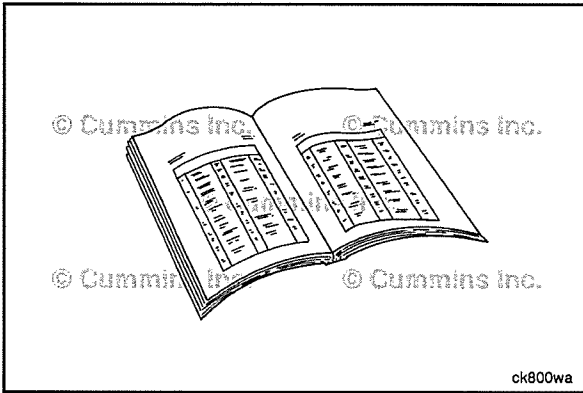
⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the rocker lever assembly. Refer to Procedure 003-008 in Section 3.
- Adjust the overhead. Refer to Procedure 003-004
- Install the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the crankcase breather tube and drain tube. Refer to Procedure 003-018 in Section 3.
- Install the EGR connection tube. Refer to Procedure 011-025.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



ck800wa



Cylinder Head (002-004)

Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ WARNING ⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠ CAUTION ⚠

If removing the cylinder head with the injectors installed, be careful not to damage the tips of the injector. Do not set the cylinder head down on the combustion face with the injectors installed. Damage to the injector tips will result.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the air crossover tube. Refer to Procedure 010-019 in Section 10.
- Remove the air intake connection adapter. Refer to Procedure 010-131 in Section 10.
- Remove the air intake connection. Refer to Procedure 010-080 in Section 10.
- Remove the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Remove the air intake manifold. Refer to Procedure 010-023 in Section 10.
- Remove the fuel rail. Refer to Procedure 006-060 in Section 6.
- Remove the fuel connection tubes. Refer to Procedure 006-052 in Section 6.
- Remove the crankcase breather tube and drain tube. Refer to Procedure 003-018 in Section 3.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the rocker lever housing. Refer to Procedure 003-013 in Section 3.
- Remove the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Remove the rocker lever. Refer to Procedure 003-008 in Section 3.
- Remove the crossheads. Refer to Procedure 002-001 in Section 2.
- Remove the push rods or tubes. Refer to Procedure 004-014 in Section 4.
- Remove the fuel drain lines. Refer to Procedure 006-013 in Section 6.
- Remove the turbocharger. Refer to Procedure 010-033 in Section 10.
- Remove the exhaust manifold. Refer to Procedure 011-007 in Section 11.

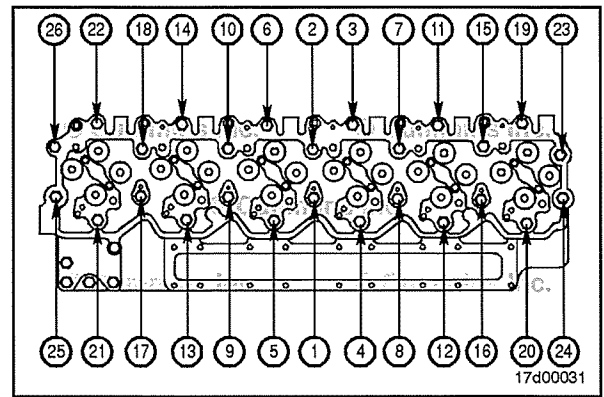
NOTE: Do not remove the injectors at this time. Remove the cylinder head with the injectors installed so the injector protrusion can be checked.

Remove

⚠ WARNING ⚠

This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Remove the cylinder head capscrews.



Vacuum Test

NOTE: If a leaking valve is suspected, use valve vacuum tester, Part Number 3824277, and cup, Part Number ST-1247-6, to vacuum test the valves and valve seats. The vacuum **must not** drop more than 254 mm Hg [10 in Hg] in 10 seconds.

Valve to Valve Seat Vacuum		
457 mm Hg	Used	18 in Hg
635 mm Hg	New	25 in Hg

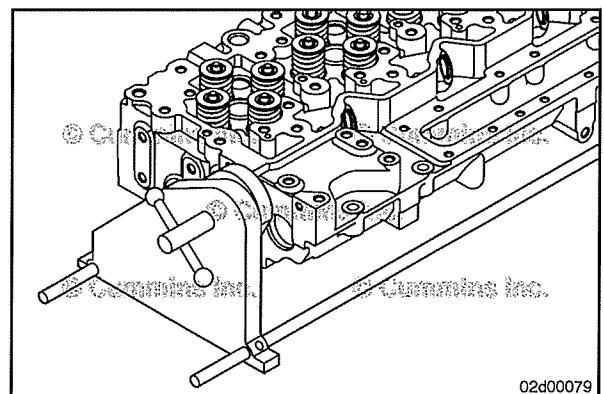
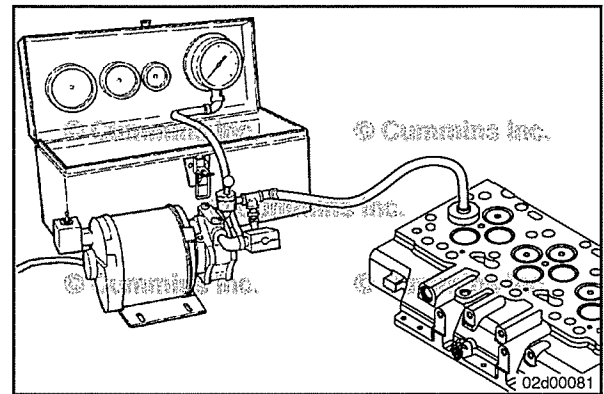
NOTE: If a vacuum tester is **not** available, use a lead pencil or Dykem™ marking pen with the valve removed to mark across the valve face. Install the valve in the valve guide. Hold the valve against the valve seat and rotate the valve backward and forward three or four times. Correct contact against the valve seat will break the marks on the valve face.

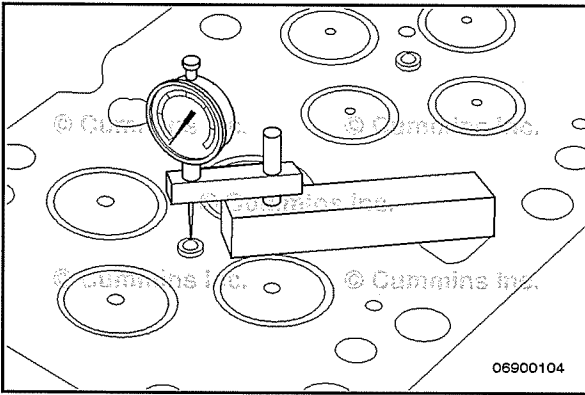
If out of specification, disassemble the cylinder head and inspect for damaged valves and/or valve seat inserts. Repair as necessary:

- 1 Clean the valve, valve seat inserts, and lap the valves.
- 2 Replace the damaged valve/valve seat inserts, if available.
- 3 Replace the cylinder head.

Disassemble

Install the cylinder head in the cylinder head holding fixture, Part Number ST-583.

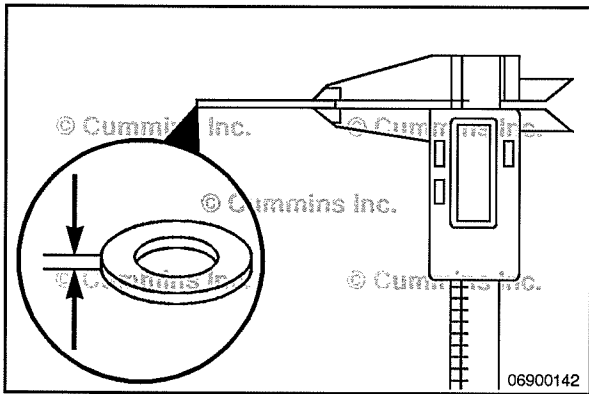




Before removing the injectors, use gauge block, Part Number 3164438, to measure the injector protrusion.

Place the injector protrusion tool on the flat surface of the head. Measure the injector protrusion to the highest point on the injector. The protrusion **must** be within the following specifications:

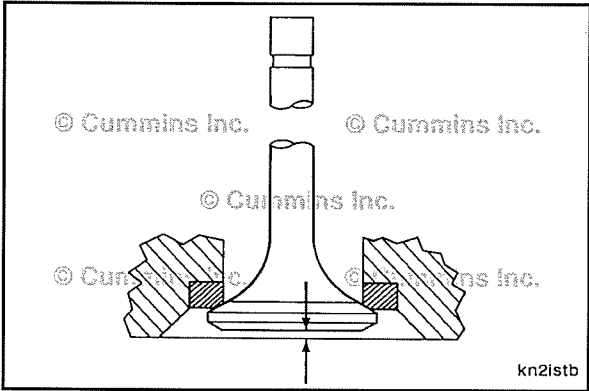
Injector Protrusion		
mm		in
2.25	MIN	0.088
2.80	MAX	0.110



Remove the injector. Refer to Procedure 006-026 in Section 6.

If the injector protrusion is out of specification, check the thickness of the injector sealing washer. Refer to Procedure 006-026 in Section 6.

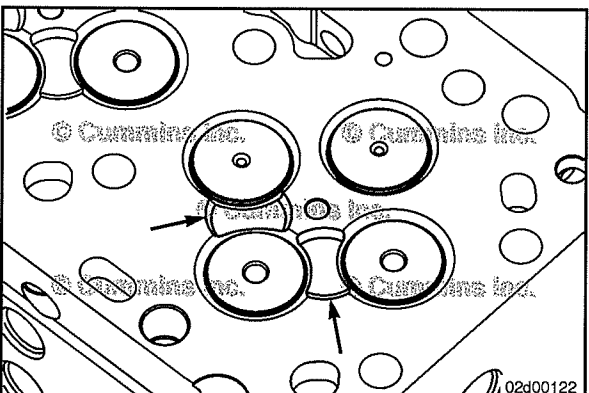
If the sealing washer is the correct thickness, check to make sure the injector bore is clean and free of debris. Also make sure that sealing washers are **not** "stacked" in the injector bore.



Standard Cylinder Head
Measure the valve recess.

Standard Head Valve Recess in Cylinder Head		
mm		in
0.84	MIN	0.033
1.32	MAX	0.052

If the valve recess is outside the specifications, replace the valve. If the valve recess is still outside the specifications, the valve seat insert or cylinder head **must** be replaced.



Scalloped Cylinder Head
Measure the valve recess.

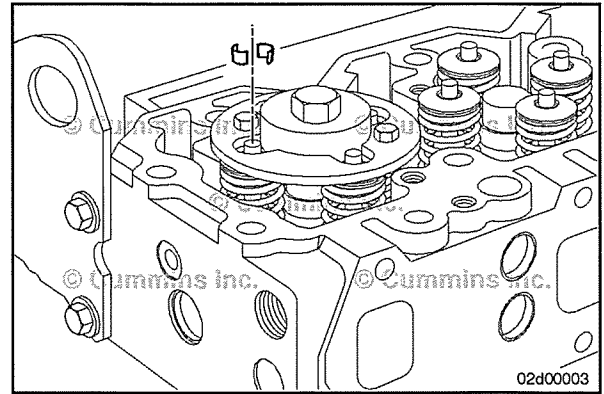
Scalloped Head Valve Recess in Cylinder Head		
mm		in
0.69	MIN	0.027
1.17	MAX	0.046

If the valve recess is outside of the specifications, replace the valve. If the valve recess is still outside the specifications, the valve seat insert or cylinder head **must** be replaced.

Compress the valve springs and remove the valve stem collets. Use valve spring compressor, Part Number 3164329.



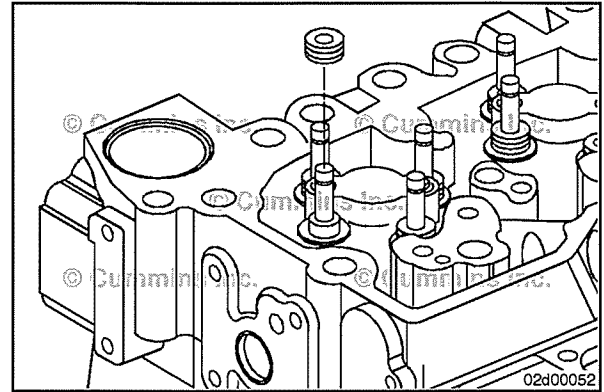
Release the valve springs and remove the spring retainers and springs.



Use the boot pliers, Part Number 3163293, to remove the valve stem seal.



Remove and discard the valve stem seals.

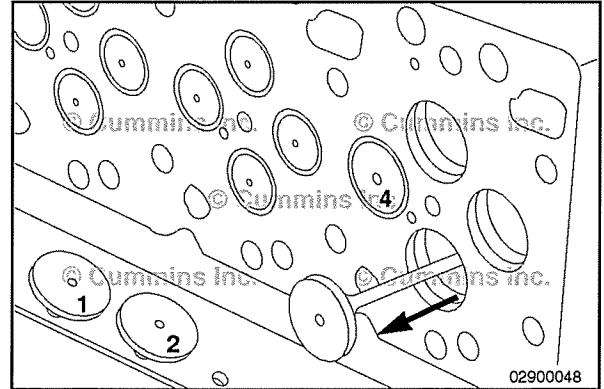


Keep the valves in a labeled rack for a correct match with companion seats while making measurements.



Mark the valves to identify their location. Any numbering system can be used as long as the valves are put back in their original location if they are to be reused.

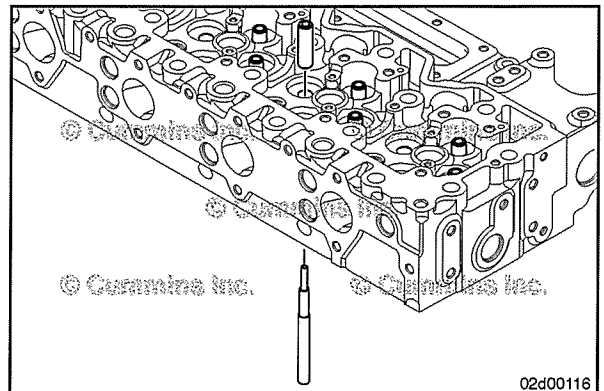
Remove the valves.

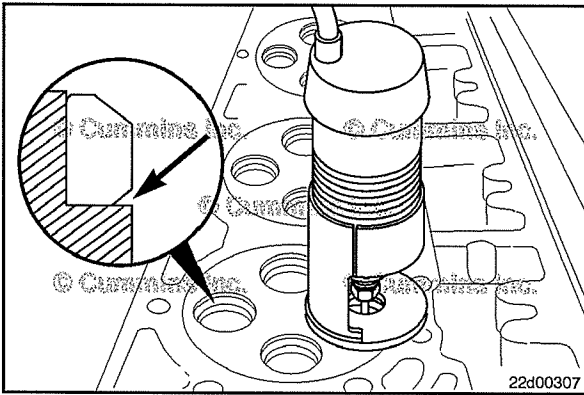


NOTE: Prior to removing the valve guide, reference the Inspect for Reuse section in this procedure. The condition of the valve guide will help to determine if it needs to be replaced.



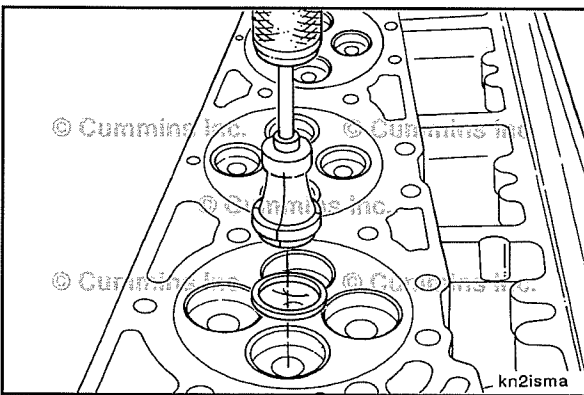
Use valve guide driver, Part Number 3163101, to remove the old valve guides.





NOTE: Prior to the removal of the valve seat inserts, reference the Clean and Inspect for Reuse section in this procedure. The condition of the valve, the amount of recess, and the sealing of the valve on the seat insert all help to determine if a valve seat insert needs to be replaced.

- 1 If required, remove the valve seat inserts.
- 2 Inspect the valve-insert-to-cylinder-head contact area. A sufficient groove for the remover **must** exist.
- 3 If there is sufficient valve seat insert groove area, proceed to the next step.
- 4 If the valve seat insert groove area is **not** sufficient, use the valve seat insert cutting kit, Part Number 3376405, to create a sufficient groove.

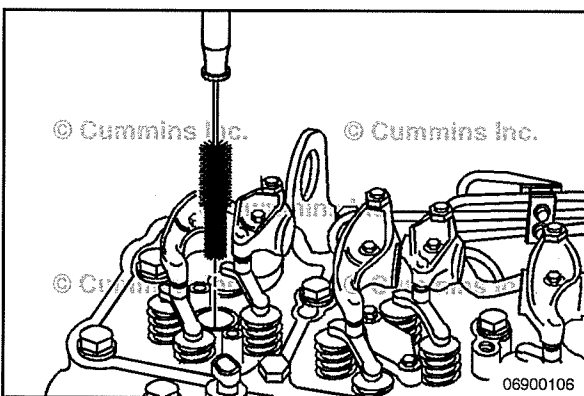


Use the slide hammer remover, Part Number 3376617, with intake valve seat insert extractor, Part Number 3165113, and exhaust valve seat insert extractor, Part Number 3165114, to remove the valve seat inserts.

NOTE: Make certain the valve seat insert remover assembly is perpendicular to the cylinder head when installed. Place the valve seat insert remover assembly into the valve seat insert and rotate the t-handle **clockwise** until the remover loosely grips the valve seat insert.

Position the valve seat insert remover assembly into the valve seat insert groove area. Tighten the t-handle firmly, allowing the remover to expand under the valve seat insert or into the cut groove.

Strike the slide hammer remover against the top nut until the valve seat insert is removed. Turn the t-handle **counterclockwise** to release the valve seat insert from the remover.



Clean and Inspect for Reuse

Use injector bore brush, Part Number 3822509, to clean the carbon from the injector nozzle seat.

Scrape the gasket material from all gasket surfaces on the block and head.

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠ WARNING ⚠

To reduce the possibility of personal injury, wear goggles and protective clothing.

Clean the buildup of deposits from the coolant passages. Excessive deposits can be cleaned in an acid tank, but the expansion plugs **must** first be removed.

Clean the cylinder head combustion deck with an abrasive pad, Part Number 3823258, or equivalent, and diesel fuel or solvent. The surface finish (RA - roughness average) maximum is 3.2 μm [0.0001 in].

Inspect the area within 1/8-inch of the firing ring diameter. Any wear that can be felt with a fingernail within the 1/8-inch area is unacceptable, making the cylinder head **not** reusable.

Wear beyond this 1/8-inch area will have no effect on future combustion sealing and the usability of the cylinder head.

Clean carbon deposits from the valve pockets with a high quality steel wire wheel installed in a drill or a die grinder.

NOTE: An inferior quality wire wheel will lose steel bristles during operation, causing additional contamination.

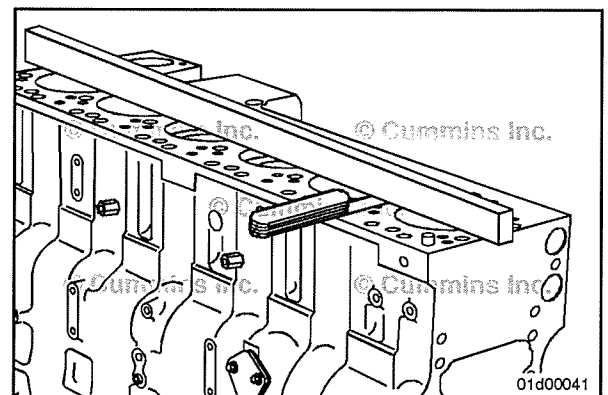
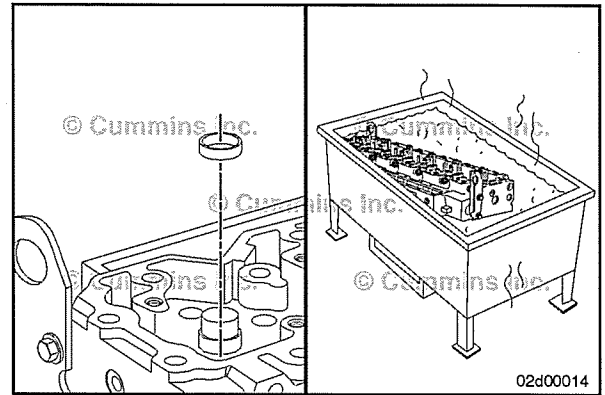
Wash the cylinder head in a hot, soapy water solution.

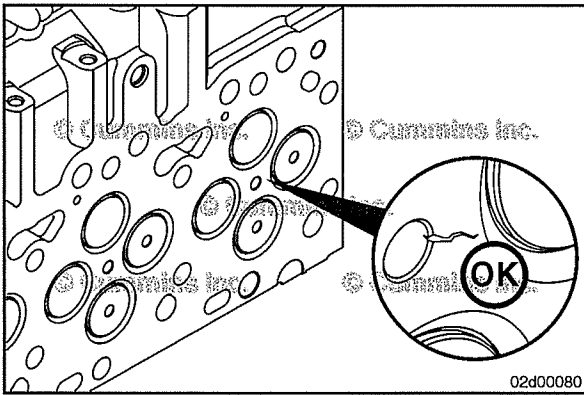
Dry with compressed air.

Use a straight edge, Part Number 4918219, and a feeler gauge to measure the overall flatness of the cylinder block.

The overall flatness, end to end and side to side, **must not** exceed 0.075 mm [0.003 in].

Use a 2-foot straight edge and a 0.0254 mm [0.001 in] feeler gauge to measure local cylinder block combustion surfaces flatness. Check between the cylinder bores and also between the coolant passages. If the 0.0254 mm [0.001 in] feeler gauge fits under the 2-foot straight edge, or if the cylinder block is pitted, has grooves or other damage, the cylinder block **must** be replaced.

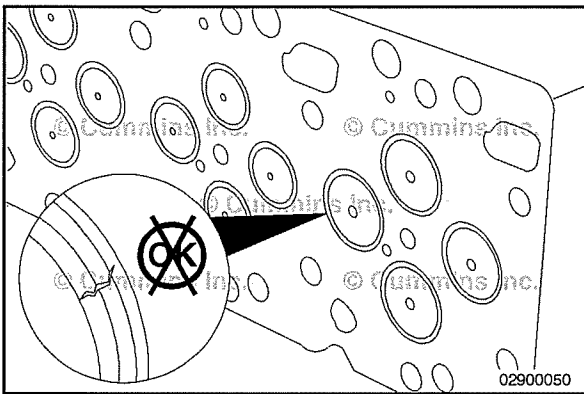




Cylinder Head Cracks - Reuse Guidelines

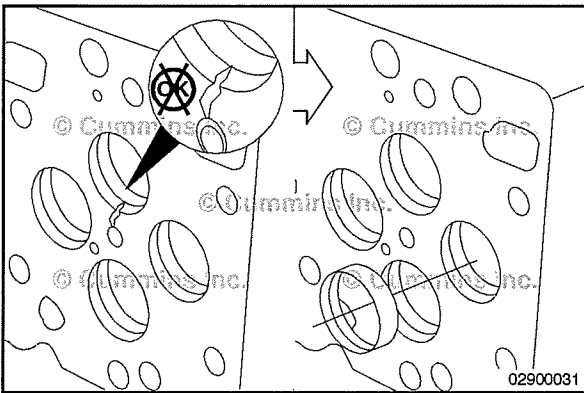
The reuse guidelines for a cylinder head with a crack extending from the injector bore to the intake valve seat are as follows:

- If a crack does **not** extend into the valve seat, the cylinder head is reusable.



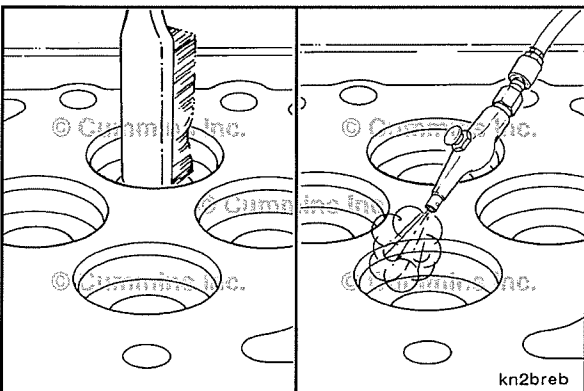
Inspect the valve seats for cracks or burn spots.

- If the valve seats are cracked or burned, the valve seat **must** be replaced.
- If the valve seat has dropped out and caused damage to the cylinder head combustion face, the cylinder head **must** be replaced.



If a crack extends into or through the valve seat bore, the cylinder head **must** be replaced.

Use crack detection kit, Part Number 3375432, to help identify cylinder head cracks.



⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

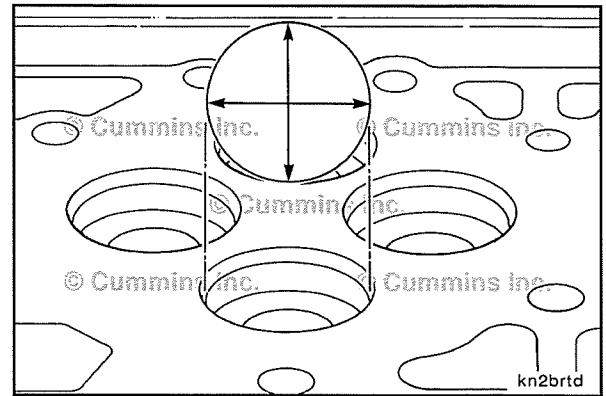
⚠ WARNING ⚠

To reduce the possibility of personal injury, wear goggles and protective clothing.

Use a wire brush and solvent to clean the deposits from the valve seat insert bores, if it was necessary to remove the valve seat inserts.

Dry with compressed air.

If the valve seat insert was removed in the Disassemble section, measure the inside diameter of the valve seat insert bore in the cylinder head.



Cylinder Head Insert Bore Inside Diameter (ID)

mm		in
39.371	MIN	1.550
39.401	MAX	1.551

NOTE: Before cutting the cylinder head, verify the valve seat inserts are available for the engine being serviced. If none are available, the cylinder head **must** be replaced.

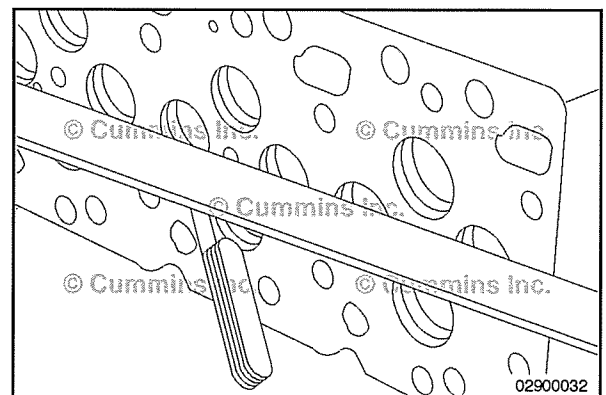
If out of specification, the valve seat insert bore can be oversized 0.254 mm [0.010 in].

Cylinder Head Insert Bore Inside Diameter (ID) for Oversized Seats

mm		in
39.625	MIN	1.560
39.655	MAX	1.561

NOTE: It is very important to take precise measurements of the valve seat pocket diameter. A 4-point contact gauge is recommended for this measurement process. Failure to take proper diameter measurements will lead to a poor press fit of the valve seat, which may lead to a dropped valve seat and damage to the cylinder head combustion face.

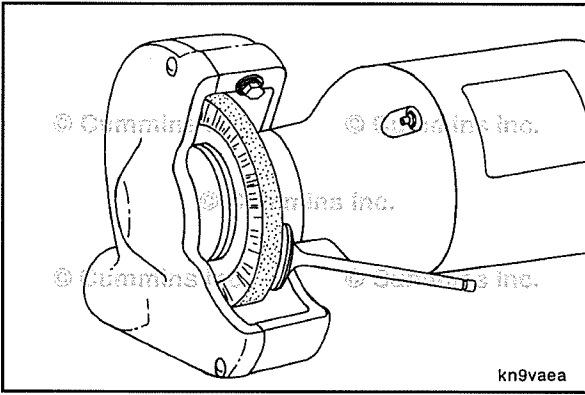
Use a straight edge, Part Number 4918219, and a feeler gauge to inspect the cylinder head combustion surface for flatness.



Cylinder Head Flatness

	mm		in
End to End	0.203	MAX	0.008
Side to Side	0.075	MAX	0.003

Use a 2-foot straight edge and a 0.0254 mm [0.001 in] feeler gauge to measure local cylinder head combustion surface flatness. Check between the cylinder bores and also between the coolant passages. If the 0.0254 mm [0.001 in] feeler gauge fits under the 2-foot straight edge or if the cylinder head is pitted, has grooves or other damage, the cylinder head **must** be replaced.



⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

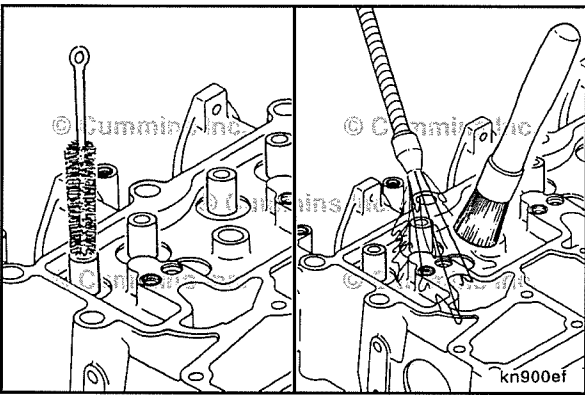
⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Clean the valve heads with a soft wire wheel.

NOTE: Keep the valves in a labeled rack to prevent mixing prior to making measurements.

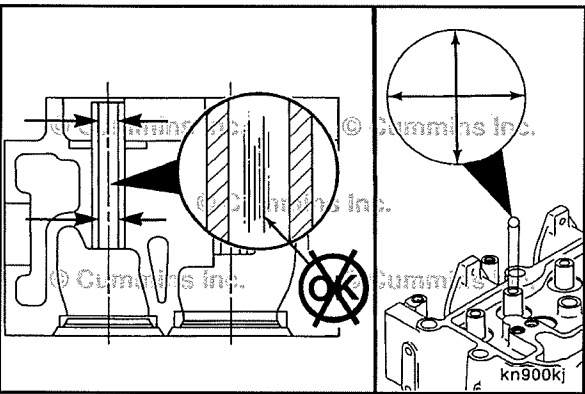
Polish the valve stems with an abrasive pad, Part Number 3823258 or equivalent, and diesel fuel or solvent.



⚠ WARNING ⚠

To reduce the possibility of personal injury, wear goggles and protective clothing.

Use a bristle brush to clean the inside diameter of the valve guide bore and blow out with compressed air.



Inspect the valve guides for scuffing, scoring, chips, or cracks.

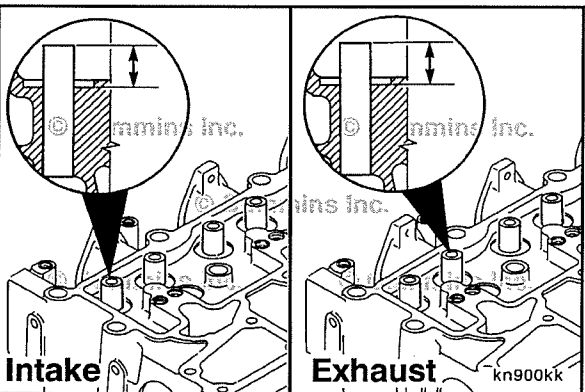
Measure the valve guide inside diameter.



Valve Guide Inside Diameter

mm		in
8.019	MIN	0.3157
8.071	MAX	0.3178

If the valve guide inside diameter is worn larger than the maximum specified, the cylinder head **must** be replaced.



Use a depth micrometer to measure the valve guide installed height. Measure from the top of the valve guide to the bottom of the recessed area.

Valve Guide Height (Installed)

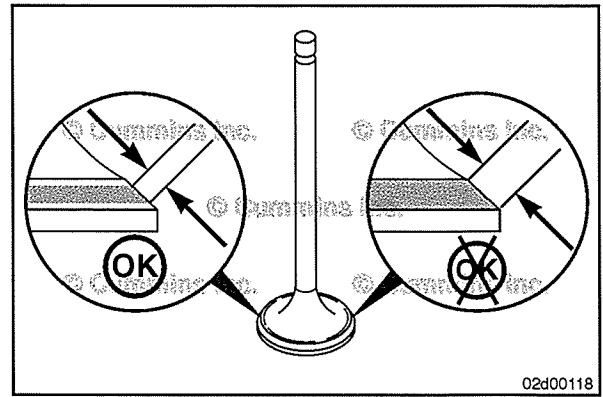
mm		in
13.15	MIN	0.518
13.65	MAX	0.537

If the valve guide height is outside the specification, the cylinder head **must** be replaced.

Verify the valve sealing area is in the center of the valve. If the sealing area extends to the top or bottom of the valve, the valve **must** be replaced.

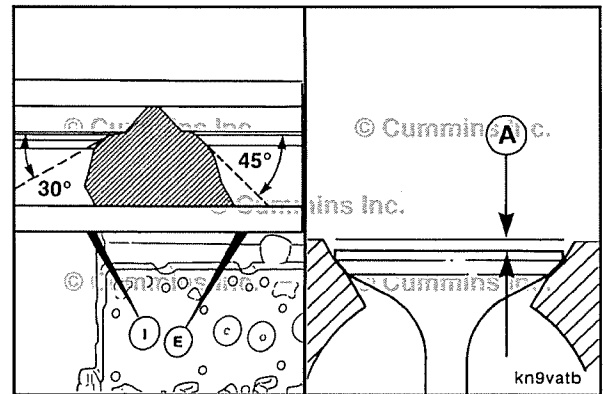
After replacing the valve, recheck the valve sealing area. If the sealing area still extends to the top or bottom of the valve, the valve seat **must** be replaced.

Use a lead pencil or Dykem™ marking pen to mark across the valve face. Install the valve in the valve guide. Hold the valve against the valve seat and rotate the valve backward and forward three or four times. Correct contact against the valve seat will break the marks on the valve face.



Valve seat angle:

- Intake is 30 degrees
- Exhaust is 45 degrees.



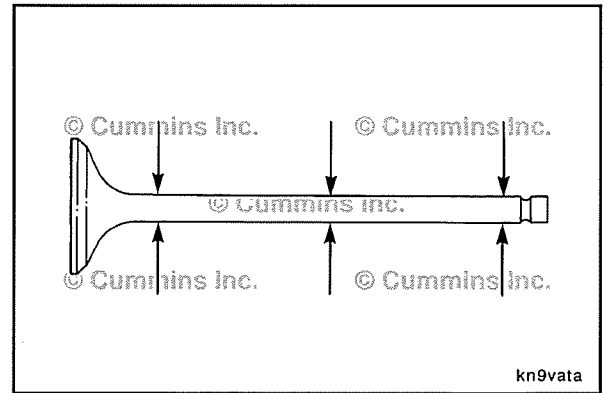
Inspect for abnormal wear or scuffing on the heads and stems.

Measure the valve stem diameter.

Valve Stem Diameter

mm		in
7.96	MIN	0.313
7.98	MAX	0.314

Replace any valve found outside these dimensions.



Check the valve stem tip for flatness.

Inspect for bent valves.

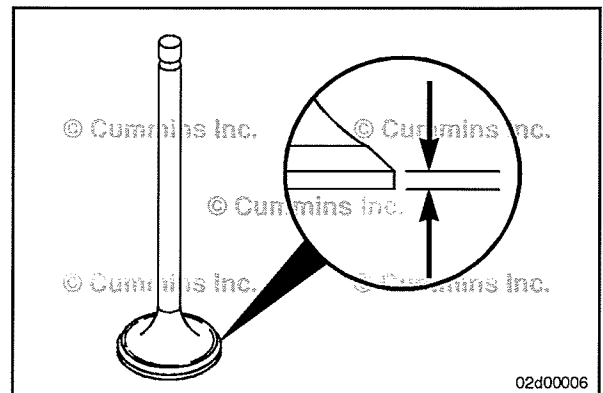
Measure the rim thickness.

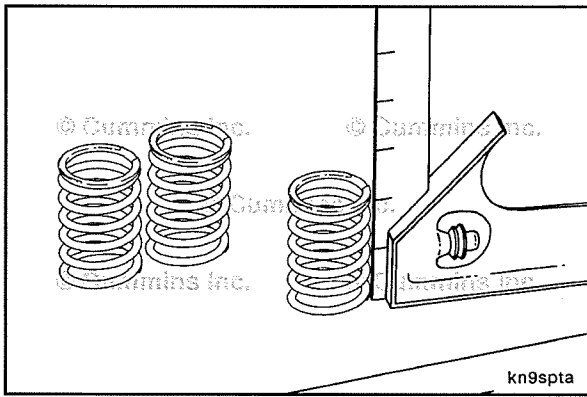
NOTE: Measure 90 degrees apart to verify uniformity of lap.

If the valve thickness is **not** within the limits, a new valve **must** be used.

Valve Rim Thickness

	mm		in
Exhaust	1.83	MIN	0.072
Intake	2.20	MIN	0.087



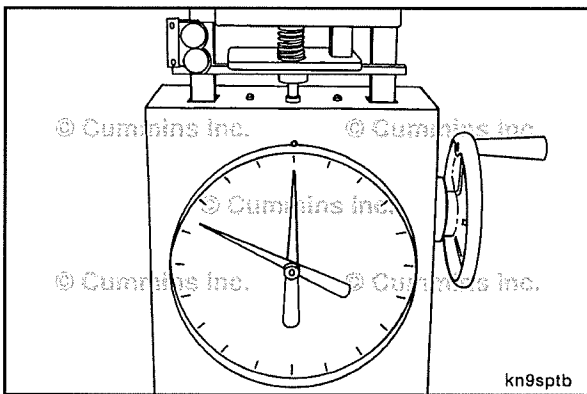


Inspect the valve springs.

Measure the valve spring.



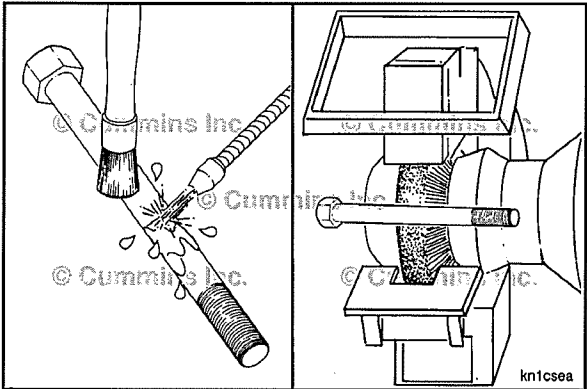
Approximate Free Length 59.18 mm [2.330 in]



A load of 906 to 1007 N [204 to 226 lbf] is required to compress the spring to a height of 30.6 mm [1.20 in]. Use spring compressor tool, Part Number 3375182, to measure spring force.



Replace the valve spring if the load required to compress the spring is outside the specification.



⚠ WARNING ⚠

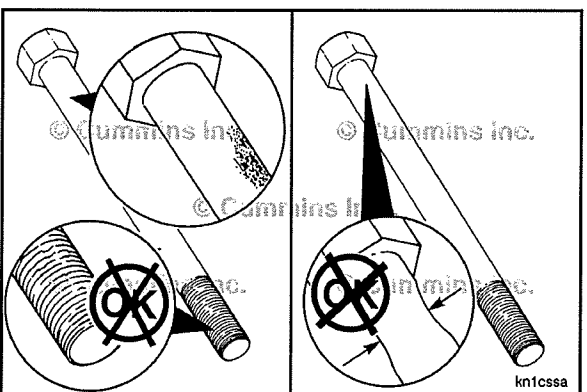
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Use a petroleum-based solvent to clean the capscrews.

Clean the capscrews thoroughly with a wire brush or a soft wire wheel. A non-abrasive bead blaster can be used to remove deposits from the shank and the threads.

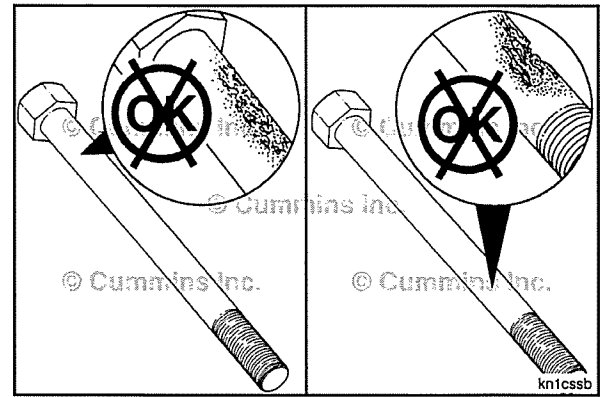


Inspect the cylinder head capscrews for damaged threads, corroded surfaces, or a reduced diameter (due to cap screw stretching).

Do **not** reuse cylinder head capscrews under the following conditions:

Visible corrosion or pitting exceeds 1 sq cm [0.155 sq in] in area. Example:

- Acceptable is 9.525 x 9.525 mm [3/8 x 3/8 in].
- Unacceptable is 12.700 x 12.700 mm [1/2 x 1/2 in].
- Visible corrosion or pitting exceeds 0.12 mm [0.005 in] in depth.
- Visible corrosion or pitting is located within 3.2 mm [1/8 in] of the fillet or threads
- Stretched beyond "free length" maximum. Reference the measurement procedure below.

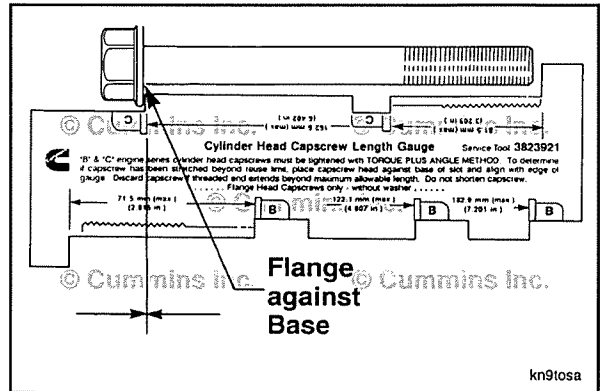


Capscrew Length Gauge, Part Number 3823921

Free Length Measurement

NOTE: If the capscrews are **not** damaged, they can be reused throughout the life of the engine, unless the specified "free length" is exceeded.

To check the capscrew free length, place the head of the capscrew in the appropriate slot with the flange against the base of the slot.

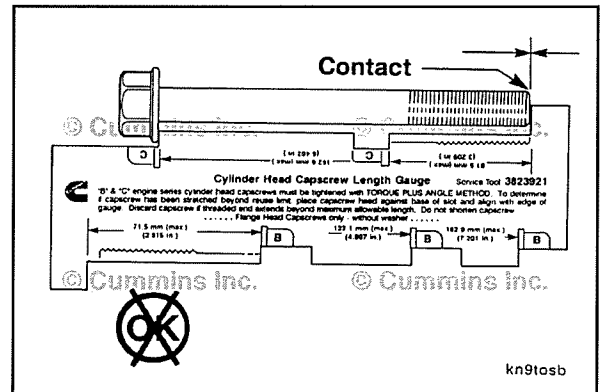


If the end of the capscrew touches the foot of the gauge, the capscrew is too long and **must** be discarded. The maximum capscrew free length is 162.6 mm [6.4 in].



Cylinder Head Capscrew Free Length

mm		in
162.6	MAX	6.4

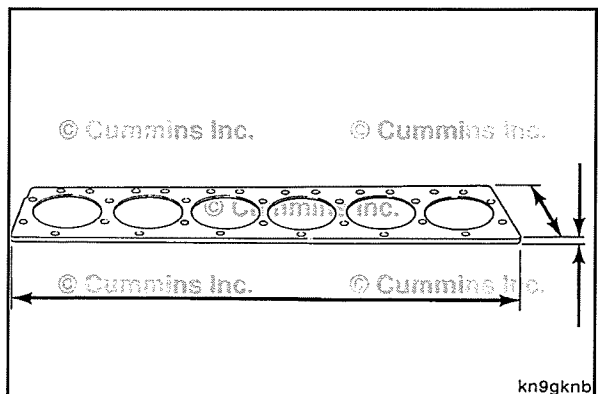


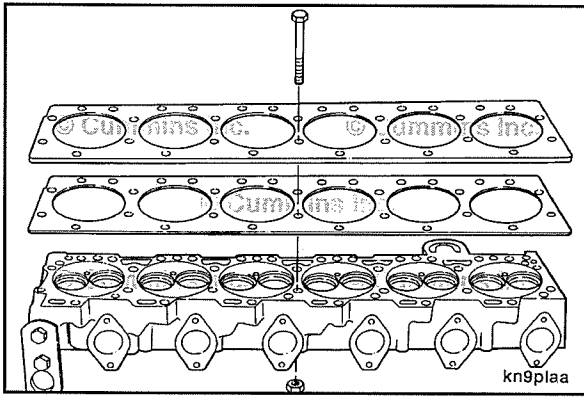
Pressure Test

A cylinder head test fixture can be fabricated from a flat piece of steel or aluminum. Reference the following table for test fixture dimensions.

Test Fixture Dimensions		
16 mm	Thickness	0.630 in
749 mm	Length	29.5 in
193 mm	Width	7.6 in

Use a cylinder head gasket as a pattern for drilling the capscrew holes.





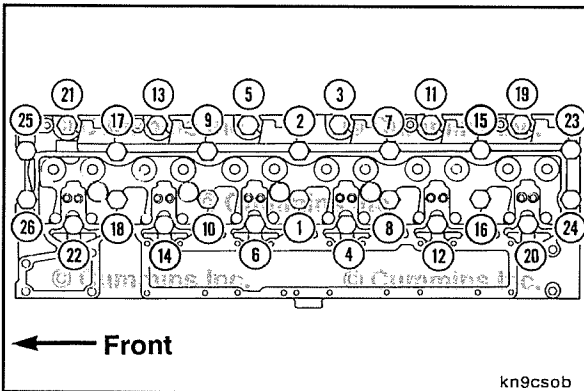
Install the cylinder head water test fixture.

- Install a new head gasket.
- Install the test plate.

Install the following:

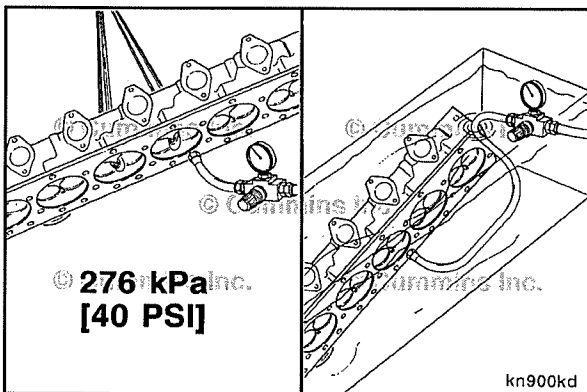
- 26 - 180 mm long head capscrews, Part Number 3920781
- 26 - M12 x 1.75 hexagon flange nuts
- 52 - 12 mm washers, Part Number 3900269.

Place a washer between each capscrew and the head, and between each nut and test plate. This will prevent mutilation on the surface of the cylinder head.



Follow the illustrated torque sequence; tighten all capscrews.

Torque Value: 80 N•m [59 ft-lb]



⚠ WARNING ⚠

This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Connect a regulated air supply hose to the test fixture plate.

Apply air pressure.

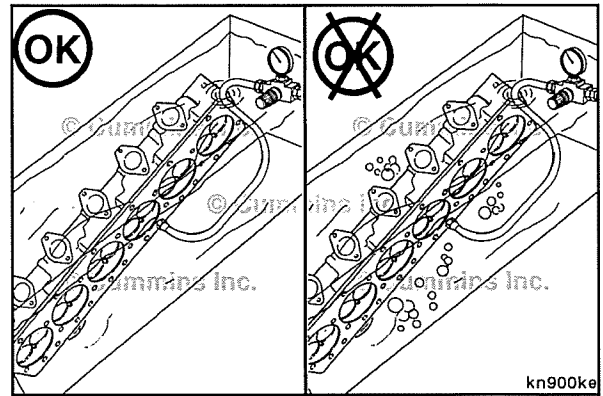
Air Pressure 276 kPa [40 psi]

Use a nylon lifting strap and hoist to place the cylinder head in a tank of heated water.

Water Temperature 60 °C [140 °F]

The cylinder head **must** be completely submerged in the water.

Inspect the cylinder head. Bubbles indicate an air leak.
If the cylinder head leaks, it **must** be replaced.

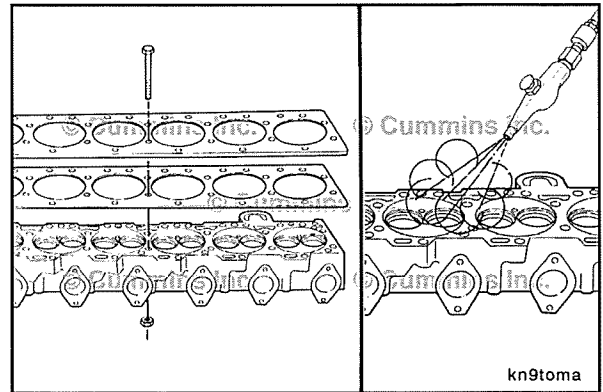


⚠ WARNING ⚠

To reduce the possibility of personal injury, wear goggles and protective clothing.

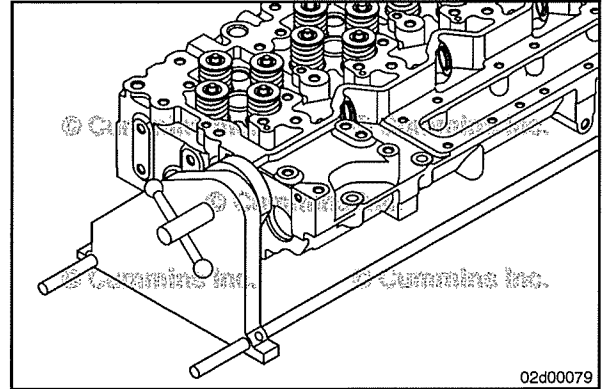
Remove the test fixture.

Use compressed air to dry the cylinder head.



Assemble

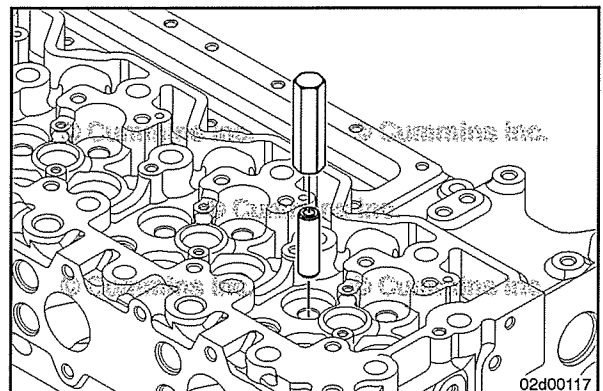
Install the cylinder head in the cylinder head holding fixture, Part Number ST-583.

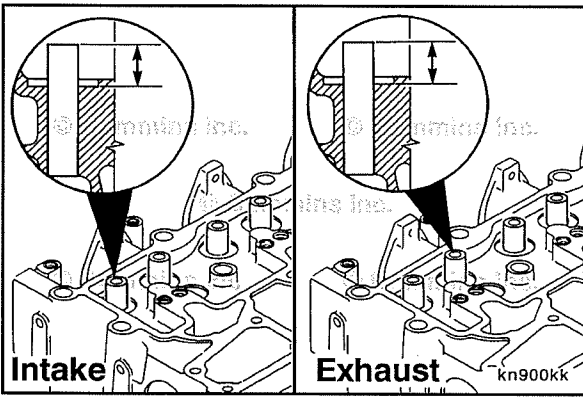


Use valve guide driver, Part Number 3163100, to install the new valve guides.

Verify the valve slides freely in the valve guide. If **not**, it may be necessary to ream the guide bore.

See the Clean and Inspect for Reuse step for valve guide inside diameter specifications.



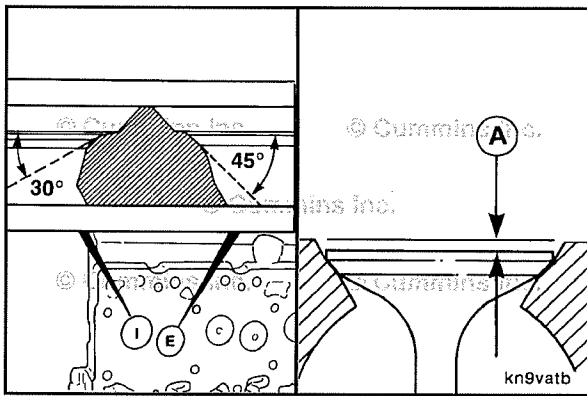


Use a depth micrometer to measure the valve guide installed height. Measure from the top of the valve guide to the bottom of the recessed area.

Valve Guide Height (Installed)

mm		in
13.15	MIN	0.518
13.65	MAX	0.537

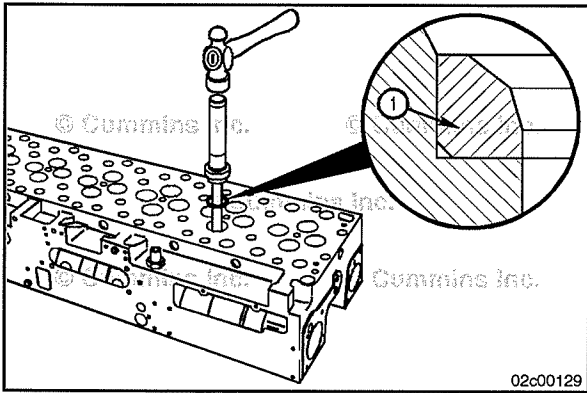
If the valve guide height is **not** within specifications, seat the guide with the installation tool.



When installing the valve seat inserts, the exhaust and intake valve seat inserts are **not** the same.

Valve seat angle:

- Intake is 30 degrees
- Exhaust is 45 degrees.



If the valve seat inserts were removed in the Disassemble section, new inserts **must** be installed.

NOTE: The valve guide **must** be installed prior to installing the valve seats.

Make sure the valve seat pocket and valve seat is clean before installing.

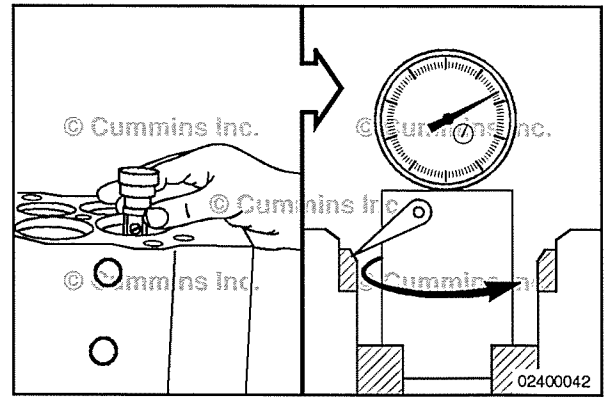
The insert chamfer (1) **must** be installed toward the bottom of the counterbore.

Use valve seat installer, Part Number 3165115, to drive the intake and exhaust valve seat inserts into the counterbore.

Use a dead blow hammer with the seat drivers to install the new valve seat inserts.

The seats **must** be fully seated into the valve seat pocket. There should **not** be a gap between the seat and the bottom of the pocket.

Measure the valve-seat-to-valve-guide runout. Use arbor set, Part Number 3823186, and eccentricmeter, Part Number ST-685-4, or equivalent.



Valve-Seat-to-Valve-Guide Runout

mm		in
0.2	MAX	0.008

If the valve-seat-to-valve-guide runout is **not** within specifications, one of the following actions can be taken:

- Apply Dykem™ marking pen to the valve seat and valve seating surfaces and allow to dry. Install the valve in the valve guide. Hold the valve against the valve seat, and rotate the valve backward and forward three to four times. Verify the contact against the valve seat forms a uniform band on the valve sealing surface. If a uniform band is formed, the assembly is within specifications.
- Clean the valve/valve seat and lap the valves.
- Remove the valve seat and make sure no debris is causing an issue under the seat. Reinstall the valve seat if debris is found.
- Remove the valve seat and machine the valve seat pocket oversize so that an oversize valve seat can be installed. Reference the Clean and Inspect for Reuse section above for valve seat pocket diameter specifications. Use the valve guide ID during machining to help position the valve seat pocket to valve guide ID, to make sure of a proper runout measurement after the oversize valve seat is installed.
- Replace the cylinder head.

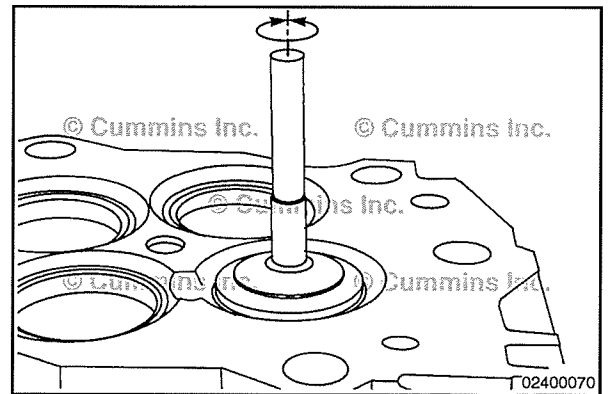
If new valve seat inserts were installed and/or the valve leakage was above specification, the valve seat/valve can be lapped.

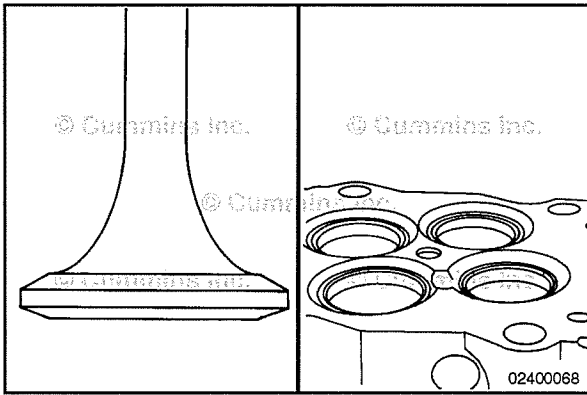
Lubricate the stems with SAE 15W-40 engine oil before installing the valves.

Use a fine lapping compound, Part Number 3375805, or equivalent. Apply a thin and even coating on the valve.

Use a power or a hand suction lapping tool to provide pressure in the center of the valve.

Turn the valve backward and forward. Continue lapping until the compound shows a continuous contact pattern on both the valve seat insert and the valve.





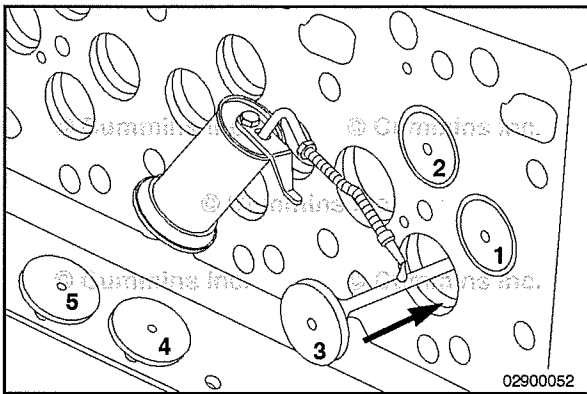
CAUTION

Lapping compound is an abrasive material. Damage will result if the cylinder head, valves, and valve seats are not cleaned thoroughly.



Clean the lapping compound from the parts.

Measure the valve rim thickness. Reference the Clean and Inspect for Reuse section.

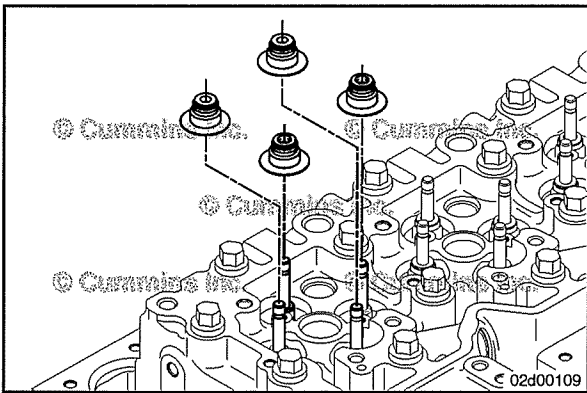


Valves that are being reused **must** be installed in the same location from which they were removed.

Lubricate the stems with SAE 90W or 15W-40 engine oil before installing the valves.

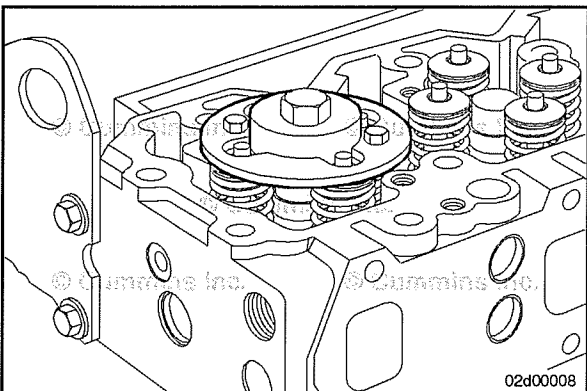


Install the valves.



Install the valve seals over the exhaust valve guides.

Install the valve seals over the intake valve guides.

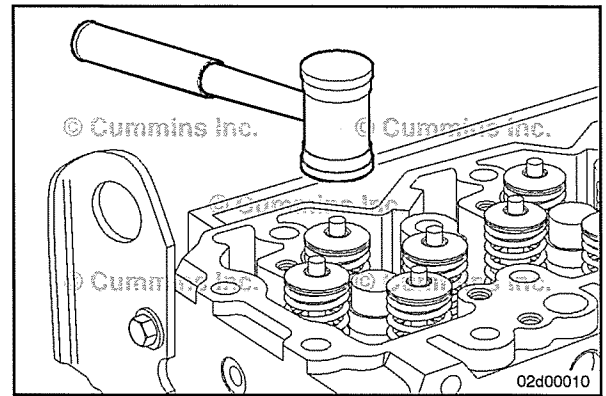


Install the valve spring retainers and valve springs.

Use valve spring compressor, Part Number 3164329, to compress the valve springs.

Install the valve collets and release the spring tension.

After assembly, hit the valve stems with a plastic hammer to make sure the collets are seated.

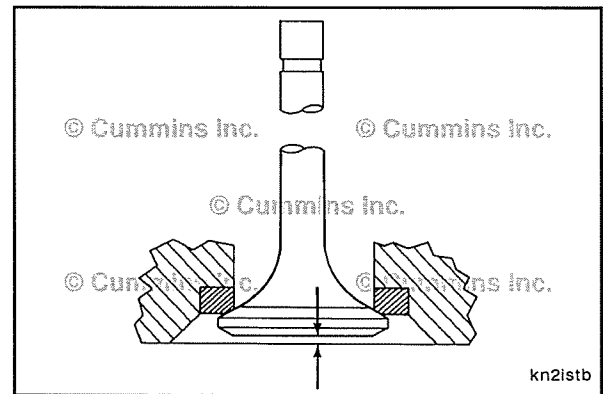


Standard Cylinder Head
Measure the valve recess.

Standard Head Valve Recess in Cylinder Head

mm		in
0.84	MIN	0.033
1.32	MAX	0.052

If the valve recess is outside the specifications, replace the valve. If the valve recess is still outside the specifications, the valve seat insert or cylinder head **must** be replaced.

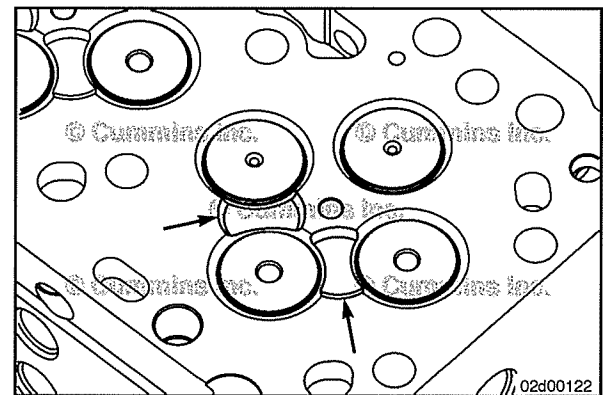


Scallop Cylinder Head
Measure the valve recess.

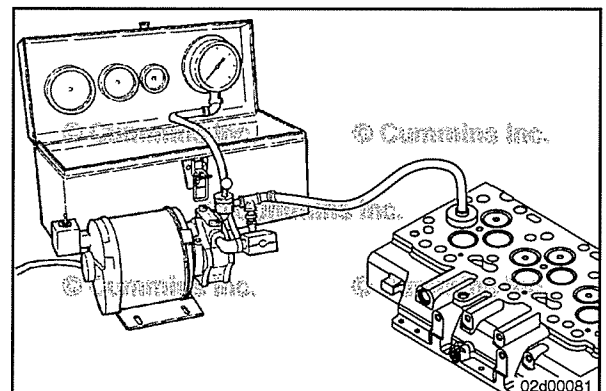
Scallop Head Valve Recess in Cylinder Head

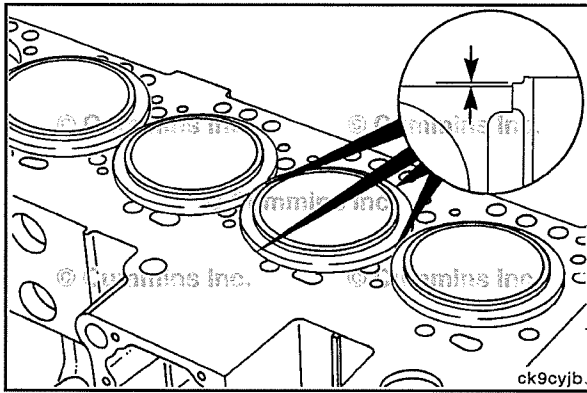
mm		in
0.69	MIN	0.027
1.17	MAX	0.046

If the valve recess is outside of the specifications, replace the valve. If the valve recess is still outside the specifications, the valve seat insert or cylinder head **must** be replaced.

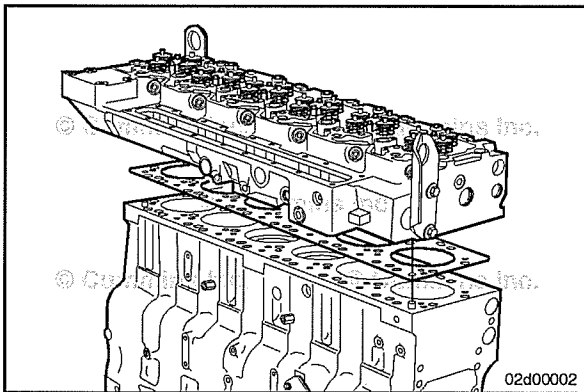


Before installing the cylinder head, vacuum test the cylinder head again. Reference the information above in the Vacuum Test section of this procedure.





Before installing the cylinder head, check the cylinder liner protrusion. Refer to Procedure 001-028 in Section 1.



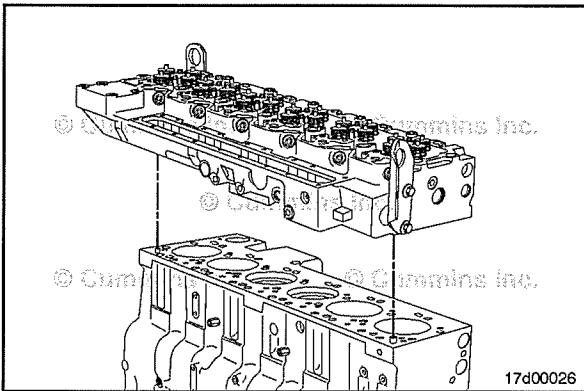
Install

⚠ CAUTION ⚠

Make sure the cylinder head gasket is correctly aligned with holes in the cylinder block. If not aligned properly, it can cause engine damage.

Do not attempt to reuse the cylinder head gasket.

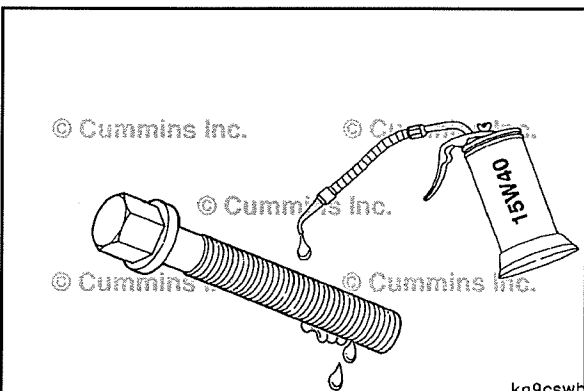
Position the new cylinder head gasket over the dowels.



⚠ WARNING ⚠

This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Carefully put the cylinder head straight down onto the cylinder block, and seat it onto the dowels.



If new capscrews are used, cap screw threads are to be burnished. To burnish new capscrews, tighten the capscrews as described below. Loosen the capscrews and repeat the tightening sequence.

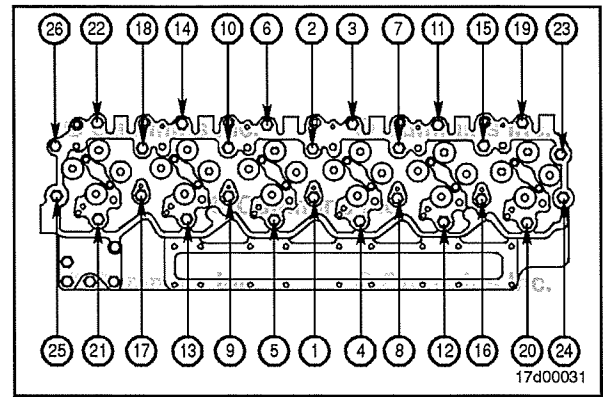
Lubricate the threads and under the heads on the cylinder head capscrews with clean 15W-40 engine lubricating oil.

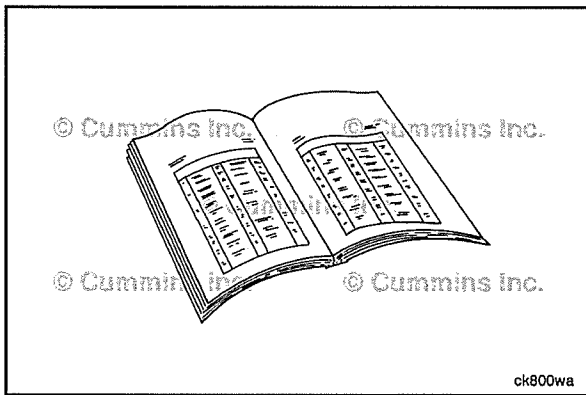
Tighten the cylinder head capscrews in the sequence shown in the illustration.



Torque Value:

- | | | |
|--------|----------------------|---------------|
| Step 1 | 50 N•m | [37 ft-lb] |
| Step 2 | 150 N•m | [111 ft-lb] |
| Step 3 | Loosen all capscrews | |
| Step 4 | 115 N•m | [85 ft-lb] |
| Step 5 | 115 N•m | [85 ft-lb] |
| Step 6 | Advance 120 degrees. | |





Finishing Steps



⚠ WARNING ⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.



⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

NOTE: If the cylinder head is being replaced due to damaged exhaust valves, intake valves, pistons, or other debris-generating malfunctions, see the following service bulletin. Refer to Prevention of Turbocharger Damage After Engine Mechanical Issue, Bulletin 4326040.

- Install the exhaust manifold. Refer to Procedure 011-007 in Section 11.
- Install the turbocharger. Refer to Procedure 010-033 in Section 10.
- Install the fuel drain lines. Refer to Procedure 006-013 in Section 6.
- Install the push rods or tubes. Refer to Procedure 004-014 in Section 4.
- Install the crossheads. Refer to Procedure 002-001 in Section 2.
- Install the rocker lever. Refer to Procedure 003-008 in Section 3.
- Install the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Adjust the overhead. Refer to Procedure 003-004 in Section 3.
- Install the rocker lever housing. Refer to Procedure 003-013 in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.

NOTE: If the cylinder head or the cylinder head gasket is being replaced due to a malfunction that caused an internal coolant leak, the crankcase breather element **must** be replaced.

- Install the crankcase breather tube and drain tube. Refer to Procedure 003-018 in Section 3.
- Install the fuel connection tubes. Refer to Procedure 006-052 in Section 6.
- Install the fuel rail. Refer to Procedure 006-060 in Section 6.
- Install the air intake manifold. Refer to Procedure 010-023 in Section 10.
- Install the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Install the air crossover tube. Refer to Procedure 010-019 in Section 10.
- Install the air intake connection. Refer to Procedure 010-080 in Section 10.
- Fill the coolant. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Valve Guide Seal, Cylinder Head (002-016)

General Information

The following procedure is for removing the valve stem seals with the cylinder head installed.

For removing the valve stem seals with the cylinder head removed, Refer to Procedure 002-004 in Section 2.

NOTE: This procedure can also be used for removing the valve springs, valve spring retainers, and valve collets with the cylinder head installed.

Preparatory Steps

⚠ WARNING ⚠

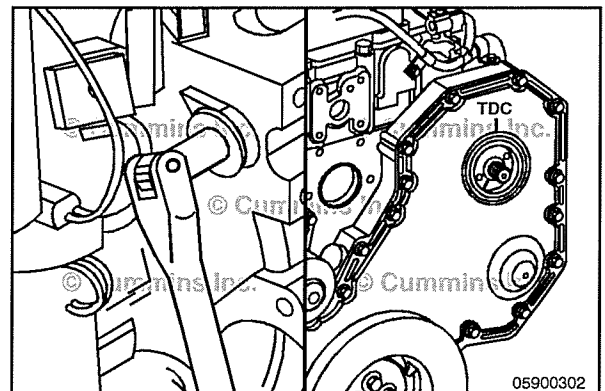
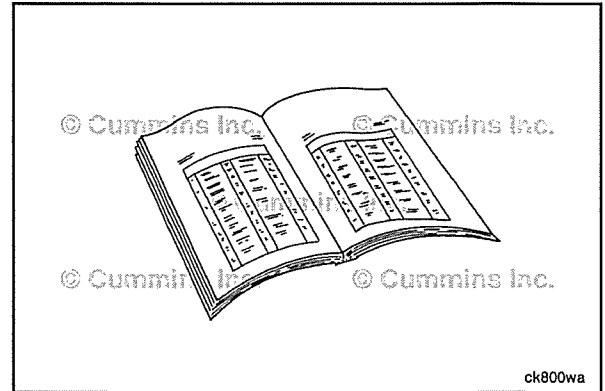
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

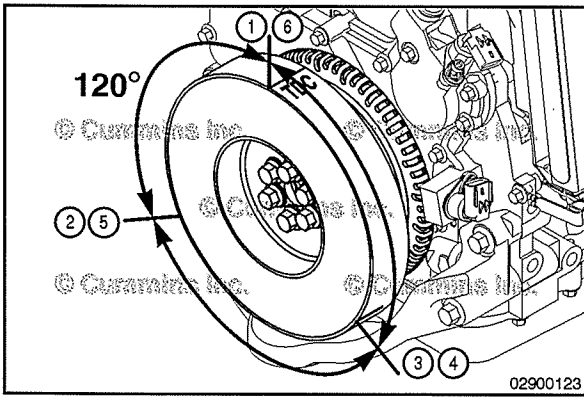
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- If necessary, remove the engine brake assemblies. Refer to Procedure 020-004 in Section 2.
- Remove the rocker lever assemblies. Refer to Procedure 003-008 in Section 3.
- Remove the crossheads. Refer to Procedure 002-001 in Section 2.
- Remove all injectors. Refer to Procedure 006-026 in Section 6.

Remove

NOTE: In order to remove the valve springs with the cylinder head installed, the piston of the cylinder being worked on **must** be brought to top dead center (TDC) to support the valves.

Use a barring tool, Part Number 3824591, to rotate the crankshaft to align the (TDC) marks on the gear cover and fuel pump gear.



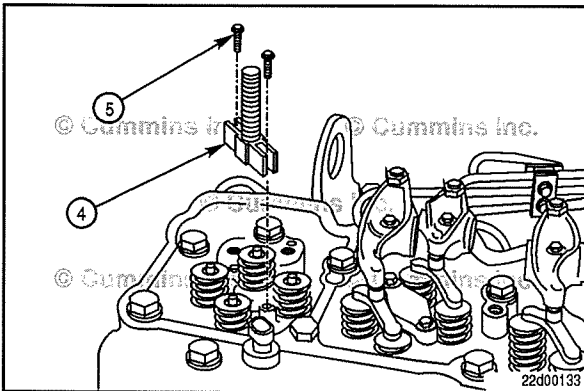


With the (TDC) marks for the number 1 cylinder aligned, mark the vibration damper for the location of (TDC) for the other cylinders.

- Mark the vibration damper every 120 degrees with a marker directly on the damper or to a piece of masking tape applied to the outside diameter of the damper.

Service Tip: A protractor, camshaft degree wheel or angle/level indicator, Part Number 3375855, can be used to locate 120 degree increments around the vibration damper.

- Mark the damper with the TDC indicator for each cylinder as shown. Two cylinders correspond to each 120 degree line.



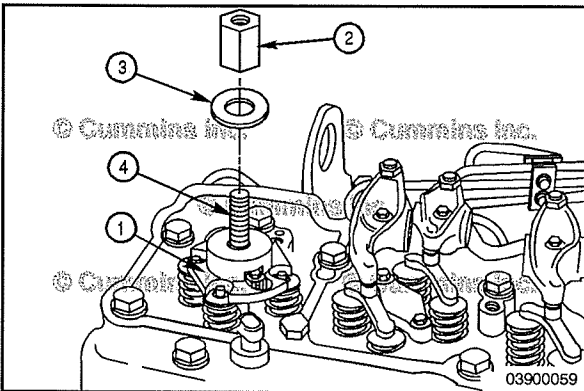
Compress the valve springs using the valve spring compressor service tool, Part Number 3164329.



Position the replacer screw (4) above the injector bore and install the two cap screws (5) in the cylinder head where the hold-down clamp cap screws were removed.

Tighten the cap screws.

Torque Value: 5 N•m [44 in-lb]



NOTE: The valves are **not** evenly spaced from the injector bore. It is important to align the slots in the valve spring compressor plate with the valve springs.



Apply anti-seize compound to the replacer screw (4) threads. **Always** read and follow label precautions.

Position the valve spring compressor plate (1) on the replacer screw (4) and align the slots in the valve spring compressor plate with the valve springs.

Install the washer (3) and nut (2) on the replacer screw (4).

⚠ WARNING ⚠

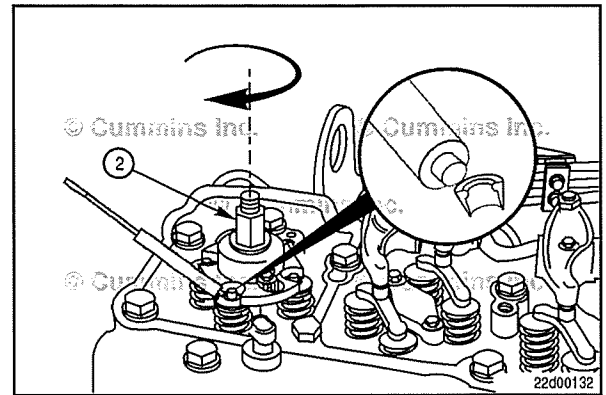
Valve springs are under compression and can act as projectiles if released. To reduce the possibility of eye injury, wear safety glasses with side shields.

Turn the nut (2) **clockwise** to compress the valve springs.

Continue turning the nut (2) **clockwise** until the valve collets can be removed using a magnetic tool, such as the end of a magnetic screwdriver.

NOTE: Because there is a gap between the top of the piston and the valve face, it may be necessary to use a second magnet to hold the valve stem up to remove the valve collets.

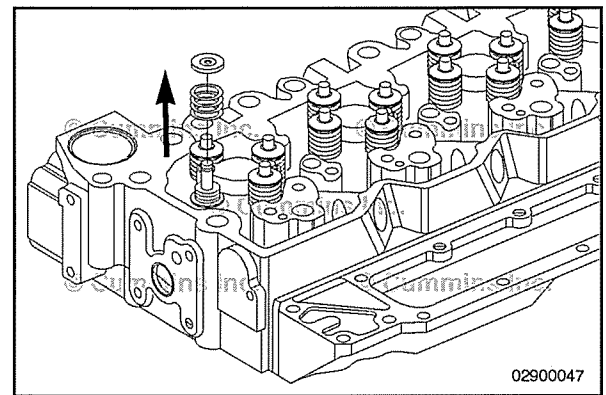
Remove the valve collets and the valve spring compressor service tool.



⚠ CAUTION ⚠

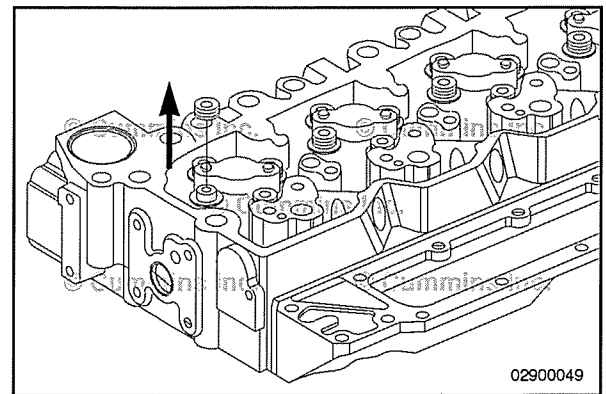
With the valve collets, valve springs, and valve spring retainers removed, do not rotate the engine. Rotating the engine will allow the valves to drop into the cylinder requiring the cylinder head to be removed or possible engine damage.

Remove the four valve spring retainers and the valve springs.



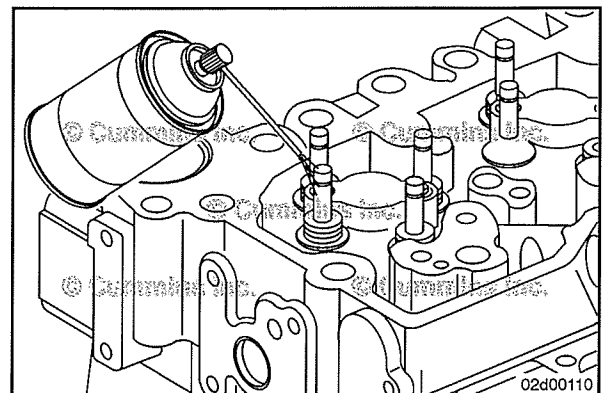
Use boot pliers, Part Number 3163293, to remove the valve stem seals.

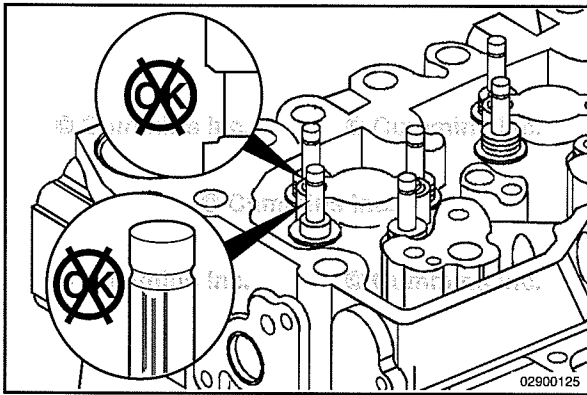
Note the color and location of the seal, and then discard the old seal.



Clean and Inspect for Reuse

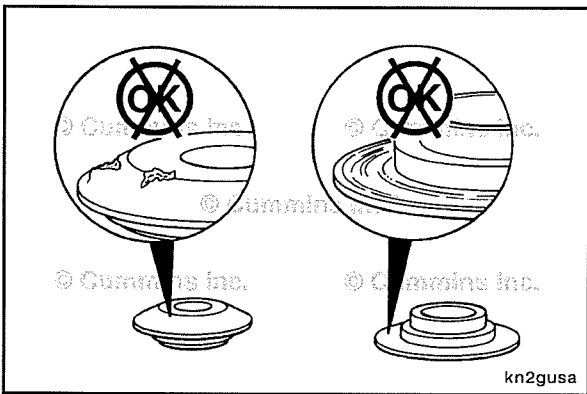
Clean the seal tower and valve stem with contact cleaner, Part Number 3824510.





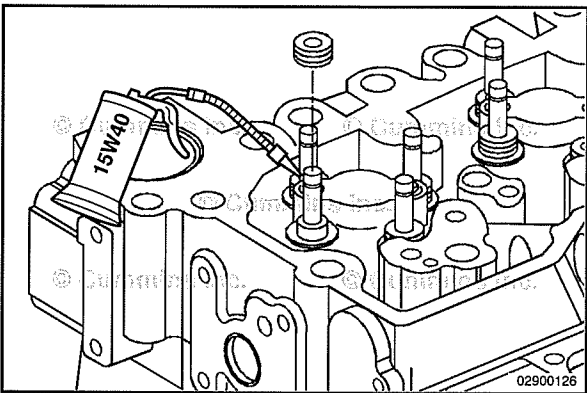
Inspect the exposed valve stem for scoring or heavy polishing. Inspect the valve collet grooves for wear.

If the valve stem is damaged, the cylinder head **must** be removed and the valve replaced. Refer to Procedure 002-004 in Section 2.



Inspect the valve spring retainers and valve collets for damage or worn areas.

Discard and replace damaged and worn parts.



Install

⚠CAUTION⚠

The same color valve stem seal must be installed in the same location as removed. Incorrect valve stem seals will result in excessive oil consumption and internal engine damage.

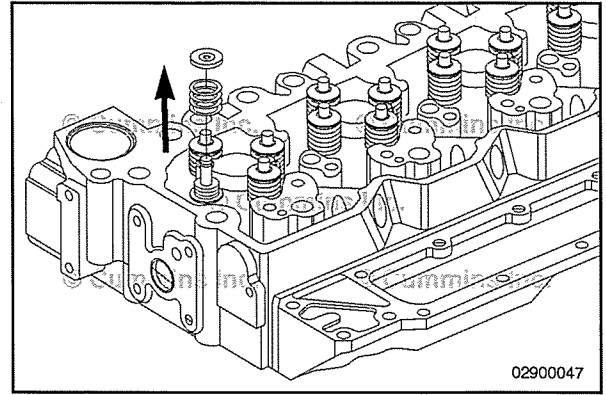
⚠CAUTION⚠

Lubricate all the valve guide bores and valve stems with SAE 15W-40 engine oil. Failure to lubricate the valve guides and valve stems can result in premature valve guide wear.

Install new valve stem seals of the same color as removed and in the same location. The black valve guide seals are for the exhaust valves; the blue valve guide seals are for the intake valves.

Lubricate the stems with SAE 15W-40 engine oil before installing the valve stem seals.

Install the valve spring retainer and the valve springs.

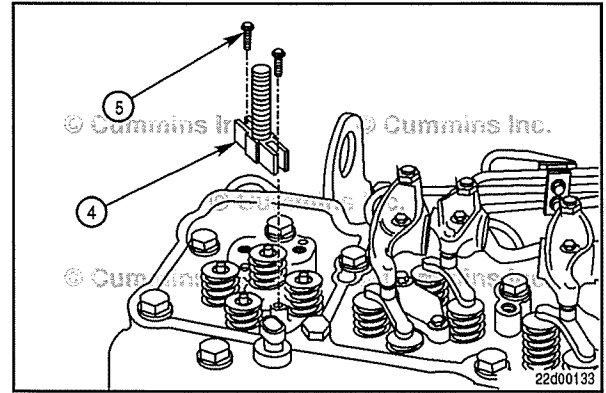


Compress the valve springs using the valve spring compressor service tool, Part Number 3164329.

Position the replacer screw (4) above the injector bore and install the two capscrews (5) in the cylinder head where the hold-down clamp screws were removed.

Tighten the capscrews.

Torque Value: 5 N•m [44 in-lb]

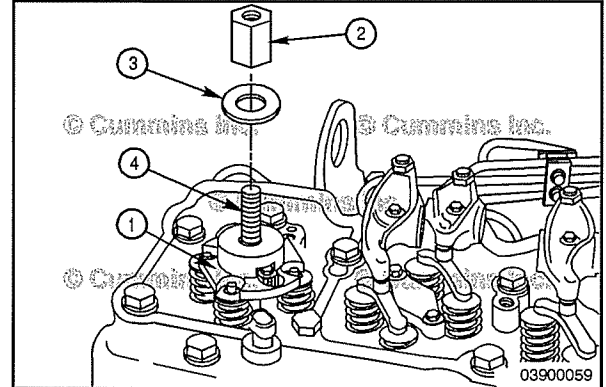


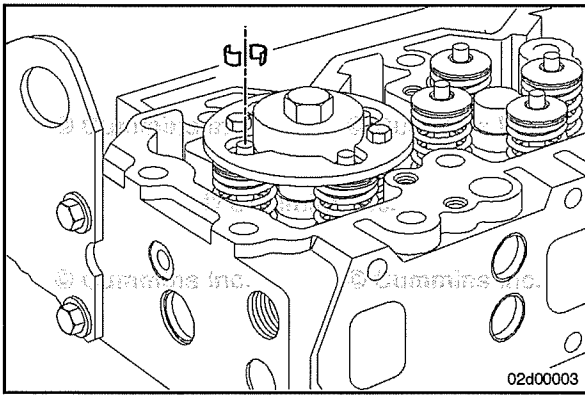
NOTE: The valves are **not** evenly spaced from the injector bore. It is important to align the slots in the valve spring compressor plate with the valve springs.

Apply anti-seize compound to the replacer screw (4) threads. **Always** read and follow label precautions.

Position the valve spring compressor plate (1) on the replacer screw (4) and align the slots in the valve spring compressor plate with the valve springs.

Install the washer (3) and nut (2) on the replacer screw (4).





▲ WARNING ▲
Valve springs are under compression and can act as projectiles if released. To reduce the possibility of eye injury, wear safety glasses with side shields.



NOTE: Because there is a gap between the top of the piston and the valve face, it may be necessary to use a second magnet to pull the valve stem up to remove the valve collets.

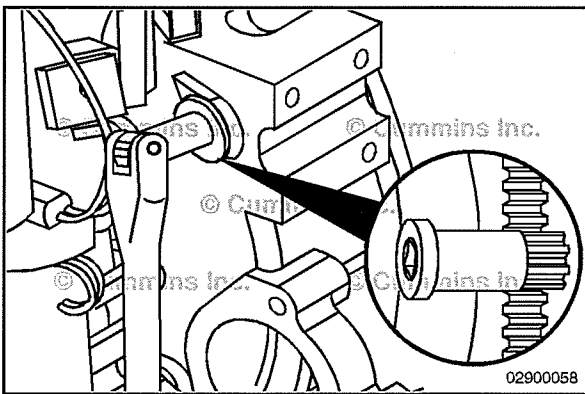
Compress the valve springs until the valve collets can be installed.

Install the valve collets.

Service Tip: Use assembly lubricant, Part Number 3163087 or equivalent, on the valve collets to help hold them in place until the valve spring compressor is released.

Remove the valve spring compressor service tool.

Using the marks made previously on the vibration damper, rotate the engine to the next mark to replace the valve guide seals on the next pair of cylinders.

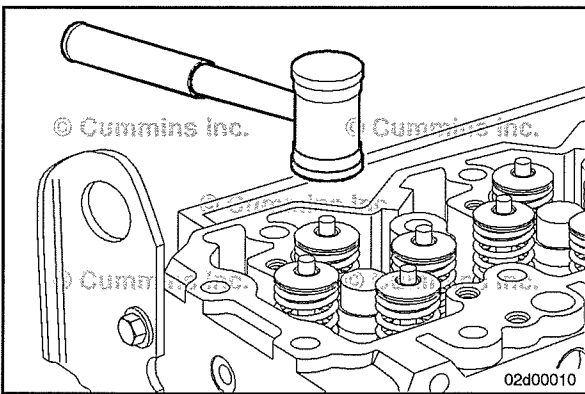


▲ WARNING ▲
To reduce the possibility of personal injury, wear eye protection. If the collets are not correctly installed, they can fly out when the stems are hit with a hammer.

▲ CAUTION ▲
Rotate the engine to the next cylinder in the firing order before hitting the valve stem of the cylinder previously worked on. This will ensure the valve does not contact the piston, resulting in a bent valve and internal engine damage.

After rotating the engine to the next cylinder in the firing order, hit the valve stems of the cylinder previously worked on with a plastic hammer to make sure the collets are seated.

Repeat the previous steps until all of the valve stem seals have been replaced.

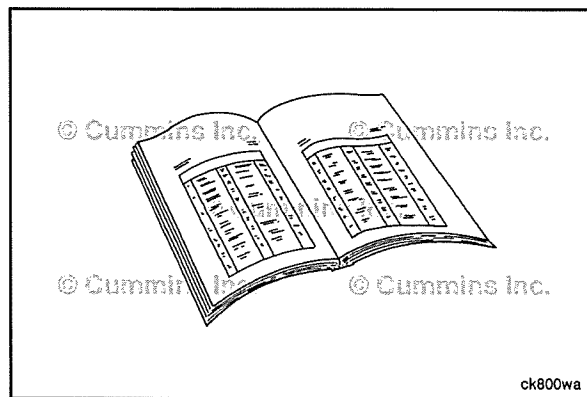


Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the injectors. Refer to Procedure 006-026 in Section 6.
- Install the crossheads. Refer to Procedure 002-001 in Section 2.
- Install the rocker lever assemblies. Refer to Procedure 003-008 in Section 3.
- Adjust the overhead. Refer to Procedure 003-004 in Section 3.
- Install the engine brake assemblies, if removed. Refer to Procedure 020-004 in Section 20.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Section 3 - Rocker Levers - Group 03

Section Contents

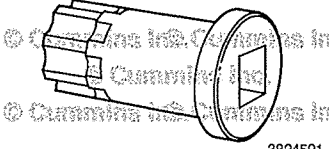
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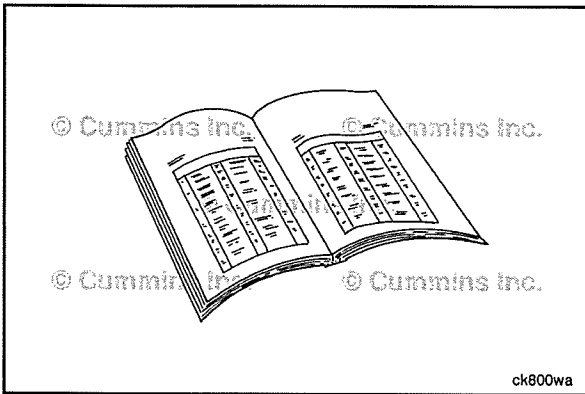
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Service Tools

Rocker Levers

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3824591	Engine Barring Gear Used to engage the flywheel ring gear to rotate the crankshaft.	 3824591



Crankcase Breather (External) (003-001)

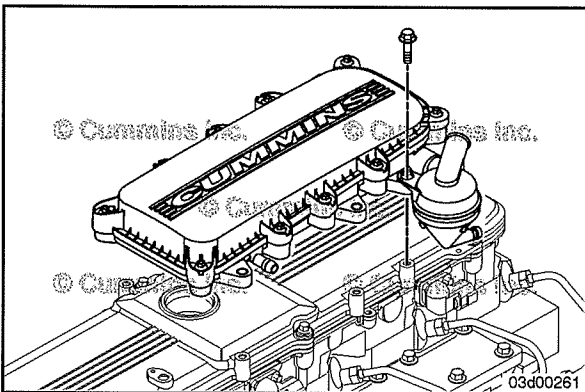


Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

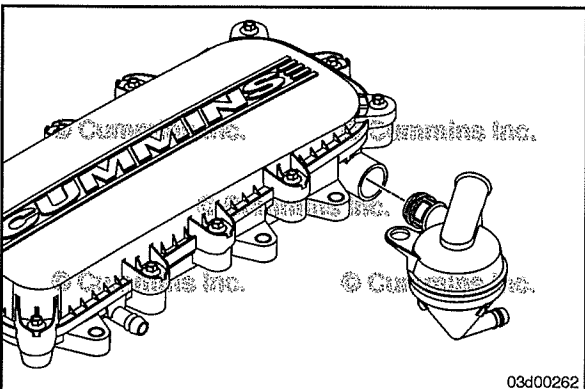
- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the crankcase breather tube and drain tubes. Refer to Procedure 003-018 in Section 3.



Remove

Remove the six mounting capscrews.

Remove the breather from the rocker lever cover by pulling straight up on the breather assembly.



Remove the oil separator from the breather housing.

Clean and Inspect for Reuse

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Cover the oil inlet, oil drain, and draft line connections to prevent debris from entering the crankcase breather element, and use hot soapy water and a soft brush to clean the crankcase breather and separator.

Dry with compressed air.

NOTE: If necessary, disassemble the crankcase breather and remove the crankcase breather element in order to clean the housing. Refer to Procedure 003-019 in Section 3.

Inspect the crankcase breather and separator for cracks or other damage.

Replace damaged parts as necessary.

Install

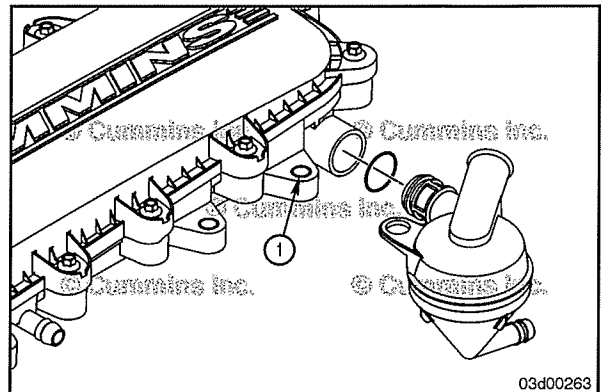
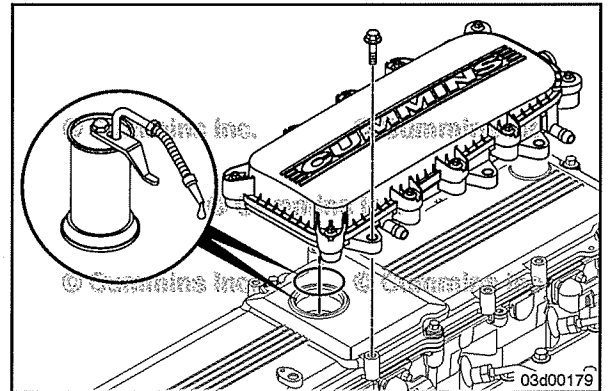
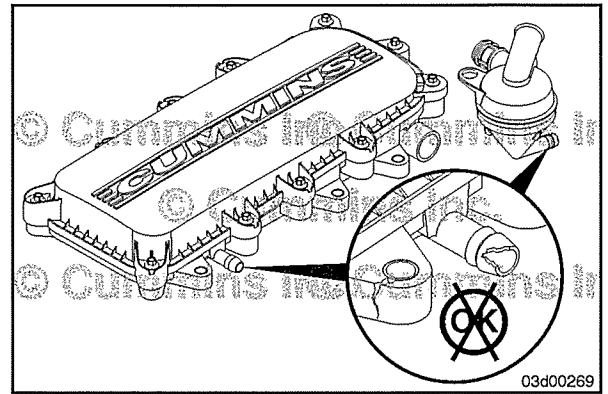
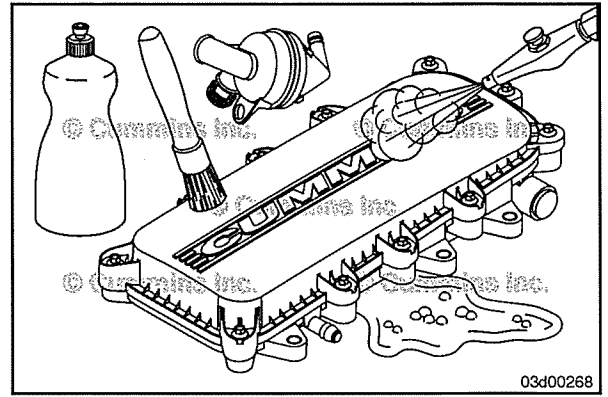
Install a new o-ring on the breather.

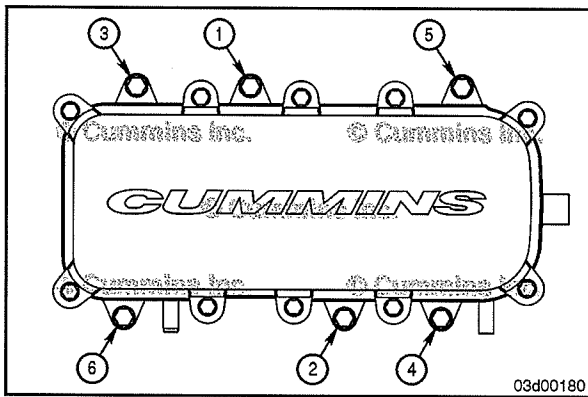
Lubricate the o-ring and the valve cover o-ring seat with clean lubricating oil.

Install the breather into the rocker lever cover.

Install a new o-ring on the oil separator and attach it to the breather housing.

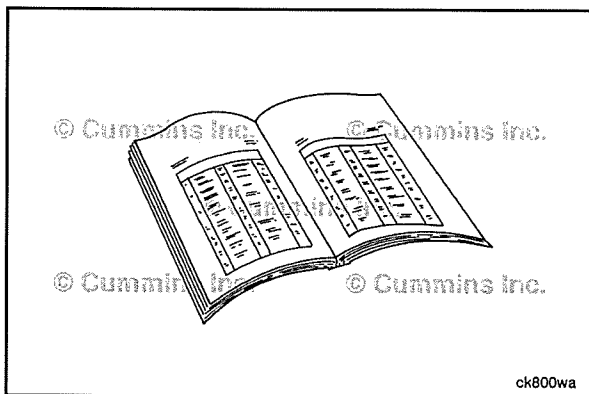
Make sure the mounting location for the oil separator is aligned with a rear breather housing mounting location (1).





Tighten the capscrews in the sequence shown.

Torque Value: 24 N•m [212 in-lb]



Finishing Steps

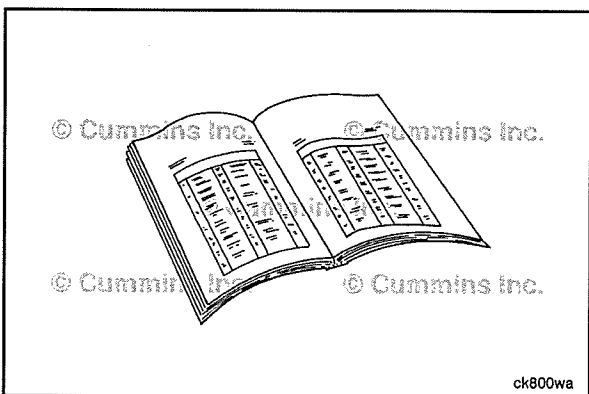
⚠ WARNING ⚠



Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the crankcase breather tube and drain tube. Refer to Procedure 003-018 in Section 3.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Overhead Set (003-004)

Preparatory Steps



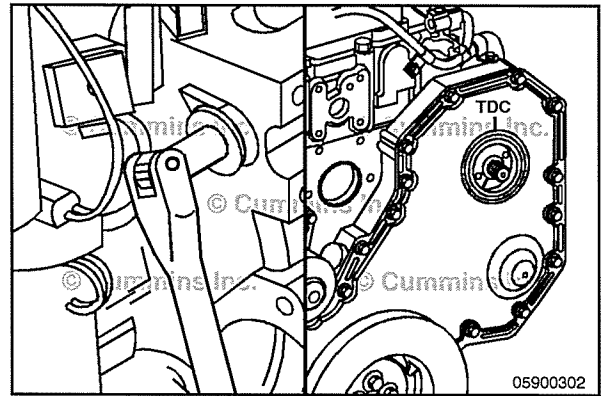
⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the EGR connection tube. Refer to Procedure 011-025 in Section 11.
- Remove the crankcase breather tube and drain tube. Refer to Procedure 003-018 in Section 3.
- Remove the plastic fuel pump drive cover located on the front of the engine.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.

Adjust

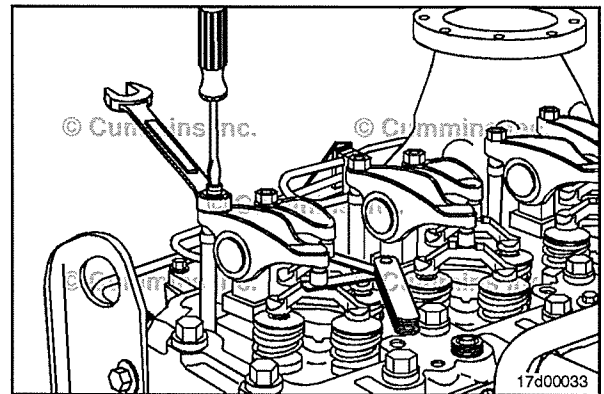
Use barring tool, Part Number 3824591 or equivalent. Rotate the crankshaft to align the top dead center marks on the gear cover and the fuel pump gear.



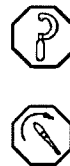
With the engine in this position, lash can be checked on the following rocker arms: 1I, 1E, 2I, 3E, 4I, and 5E.

Lash Check Limits

	mm		in
Intake	0.152	MIN	0.006
	0.559	MAX	0.022
Exhaust	0.381	MIN	0.015
	0.813	MAX	0.032



Measure lash by inserting a feeler gauge between the crosshead and the rocker lever ball insert and socket while lifting up on the end of the rocker arm. If the lash measurement is out of specification, loosen the locknut and adjust the lash to the nominal specification.

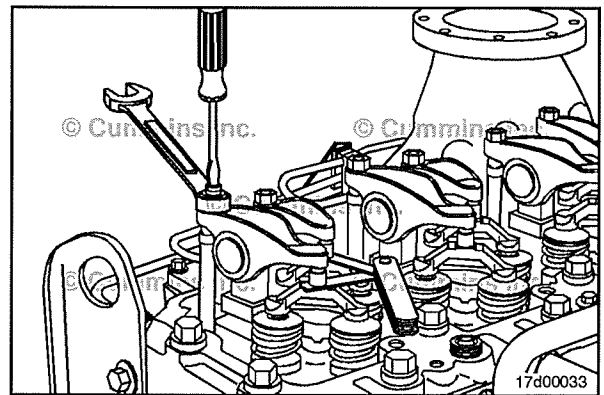


Lash Reset Specifications

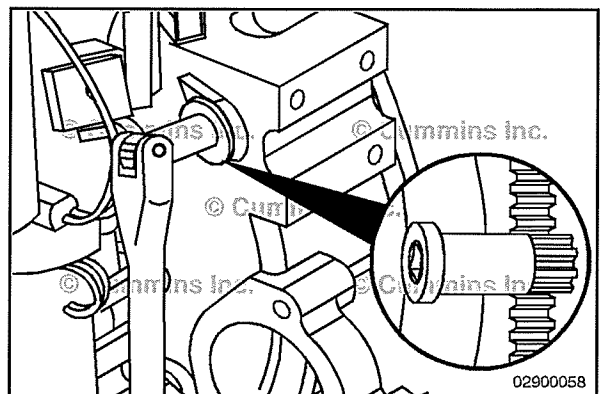
	mm		in
Intake	0.305	NOM	0.012
Exhaust	0.559	NOM	0.022

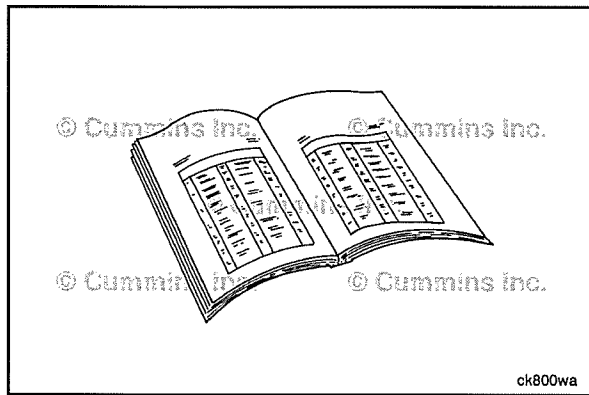
Tighten the locknut and measure again.

Torque Value: 24 N•m [212 in-lb]



Use the barring tool, Part Number 3824591 or equivalent, and rotate the crankshaft 360 degrees and measure lash for rocker arms 2E, 3I, 4E, 5I, 6I, and 6E. Reset the lash, if out of specification.





Finishing Steps

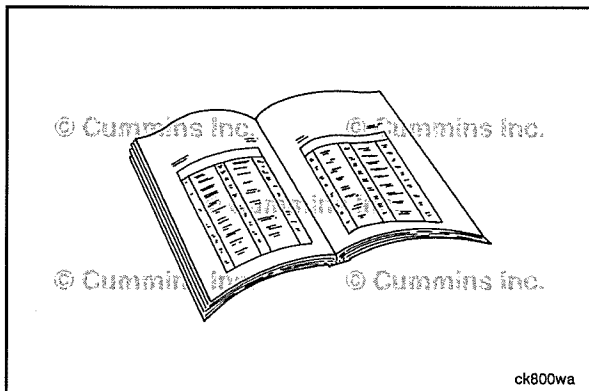
▲ WARNING ▲



Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the crankcase breather tube and drain tube. Refer to Procedure 003-018 in Section 3.
- Install the EGR connection tube. Refer to Procedure 011-025 in Section 11.
- Install the plastic fuel pump drive cover located on the front of the engine.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Rocker Lever (003-008)

Preparatory Steps



▲ WARNING ▲

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

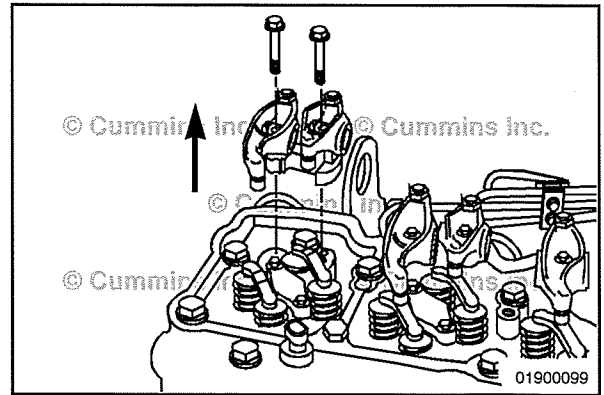
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the crankcase breather tube. Refer to Procedure 003-018 in Section 3.
- Remove the exhaust gas recirculation (EGR) connection tube. Refer to Procedure 011-025 in Section 11.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.

Remove

Remove the capscrews from the rocker lever pedestals.

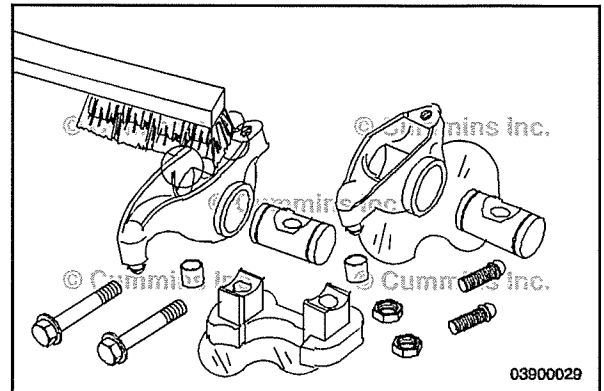
Remove and mark the pedestals and rocker lever assemblies one at a time as to their location and position.

The rocker assemblies **must** be installed in their original location and position.



Clean and Inspect for Reuse

Clean all parts in a strong solution of laundry detergent in hot water.



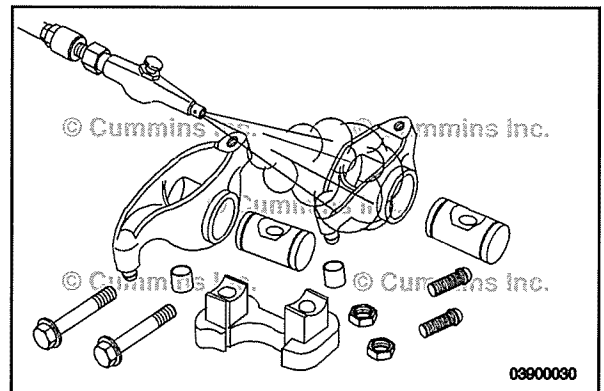
⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use compressed air to dry the parts after rinsing in clean hot water.

The pedestals are made from powdered metal and will continue to show wetness after they have been cleaned and dried.

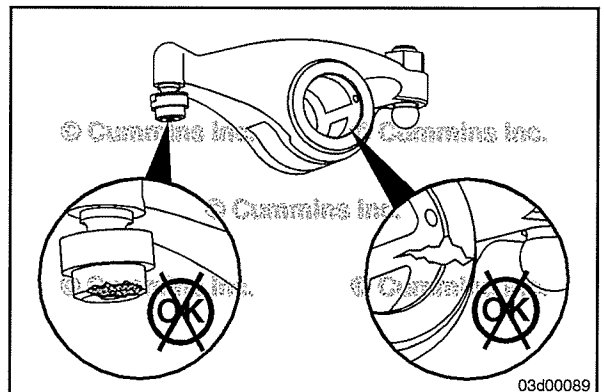
Be sure oil drillings in the rocker arms and shafts are unobstructed.

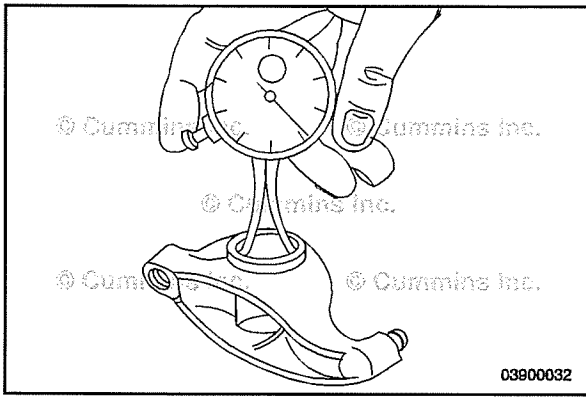


Inspect for cracks and excessive wear in the bore.

The socket should move freely on the rocker lever and the plastic socket retainer should be in place and **not** cracked.

Inspect for wear on the nose of the socket.

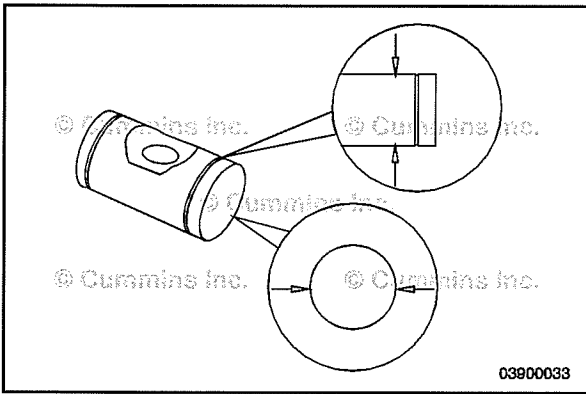




Measure the rocker lever bore.

Rocker Lever Bore

mm		in
24.987	MIN	0.984
25.013	MAX	0.985



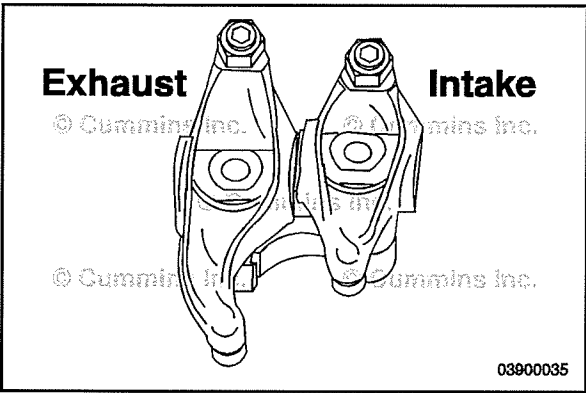
Inspect the rocker lever pedestal and rocker lever shaft for cracks.

Measure the rocker lever shaft diameter.



Rocker Lever Shaft

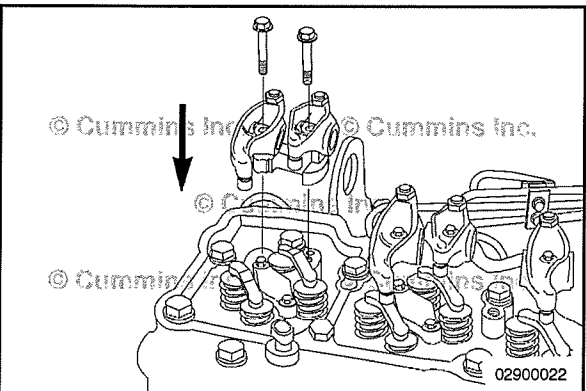
mm		in
24.950	MIN	0.982
24.962	MAX	0.983



Install

Without Engine Brakes

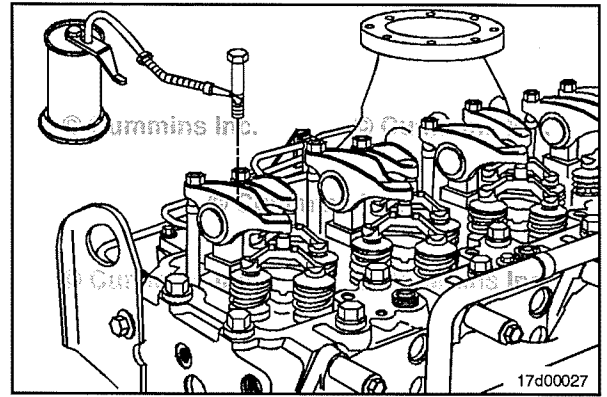
Position the rocker levers on the rocker pedestal.



Install the rocker lever assemblies and pedestals in their original locations.

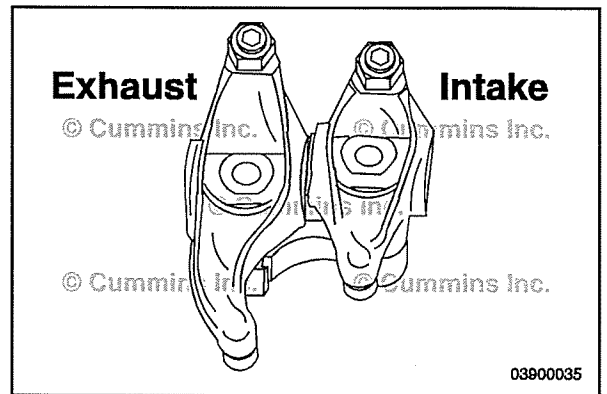
Lubricate the capscrew threads with clean engine oil.
Install and tighten the pedestal capscrews.

Torque Value: 65 N•m [48 ft-lb]



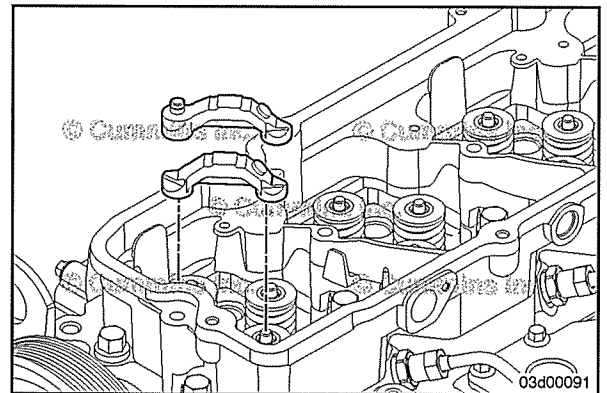
With Engine Brakes

Position the rocker levers on the rocker pedestal.



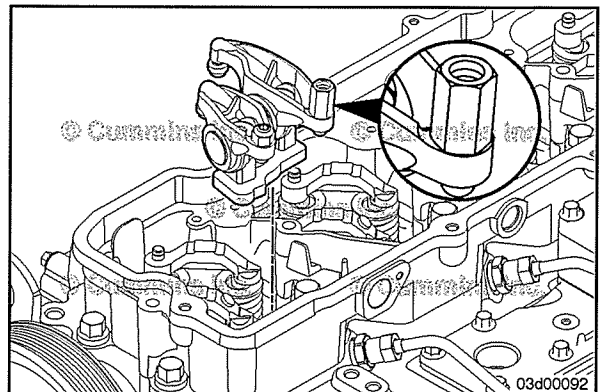
Install the crossheads in their original location and position.

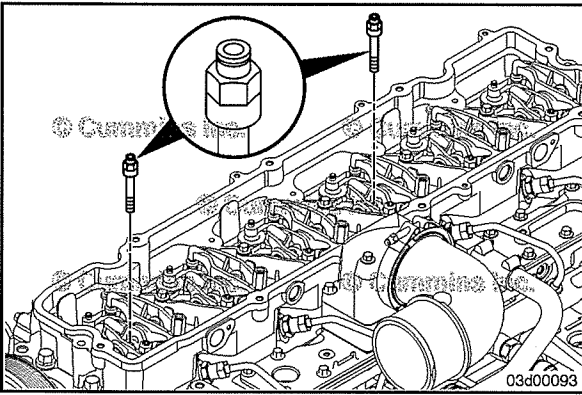
Install the engine brake compatible exhaust crossheads with the pin facing the exhaust manifold.



Install the rocker lever assemblies and pedestals in their original location.

Make sure the exhaust rocker levers have the longer adjusting screw locknut installed.

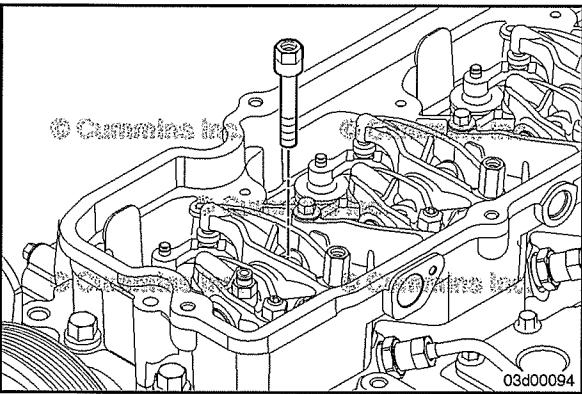




Lubricate the capscrew threads with clean engine oil.
Install the engine brake oil supply capscrews on intake
rocker levers 1 and 4.



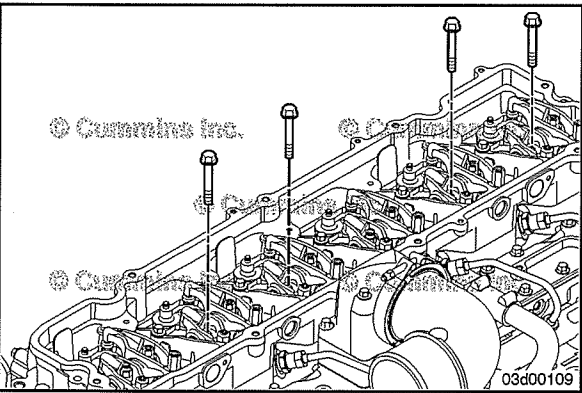
Torque Value: 65 N•m [48 ft-lb]



Lubricate the capscrew threads with clean engine oil.
Install the exhaust rocker lever capscrews into all exhaust
levers.



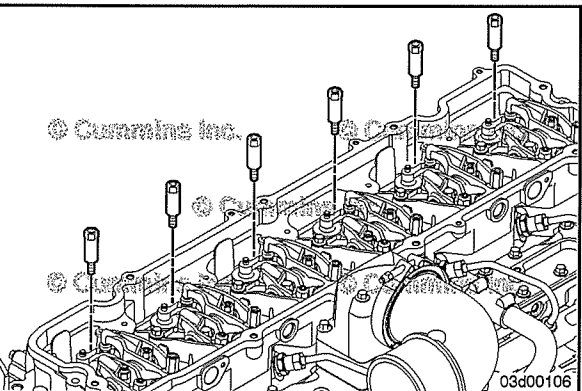
Torque Value: 65 N•m [48 ft-lb]



Lubricate the capscrew threads with clean engine oil.
Install the pedestal capscrews in cylinders 2, 3, 5, and 6
intake rocker pedestals.



Torque Value: 65 N•m [48 ft-lb]



Lubricate the capscrew threads with clean engine oil.
Install the six threaded spacers into the cylinder head.



Torque Value: 24 N•m [212 in-lb]

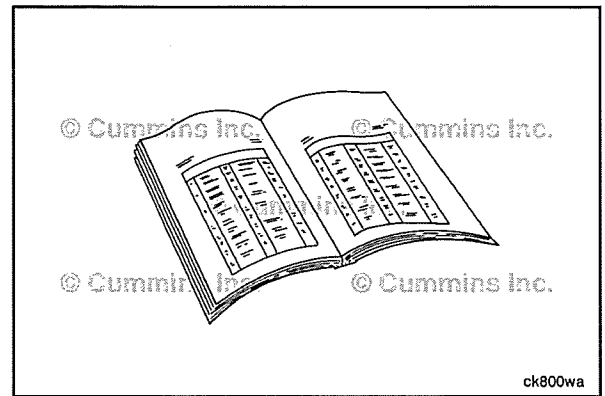


Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Adjust the overhead. Refer to Procedure 003-004 in Section 3.
- Install the engine brake assemblies, if equipped. Refer to Procedure 020-004 in Section 20.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the crankcase breather tube. Refer to Procedure 003-018 in Section 3.
- Install the EGR connection tube. Refer to Procedure 011-025 in Section 11.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



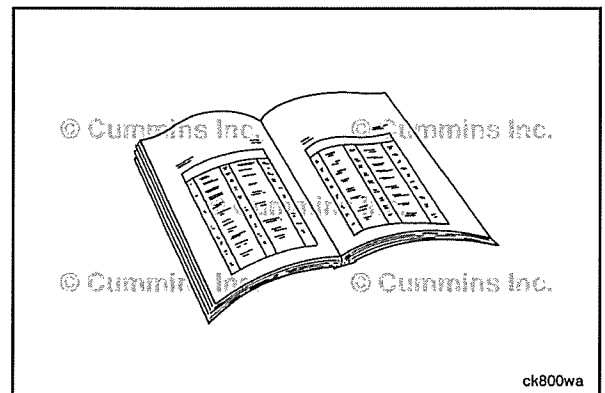
Rocker Lever Cover (003-011)

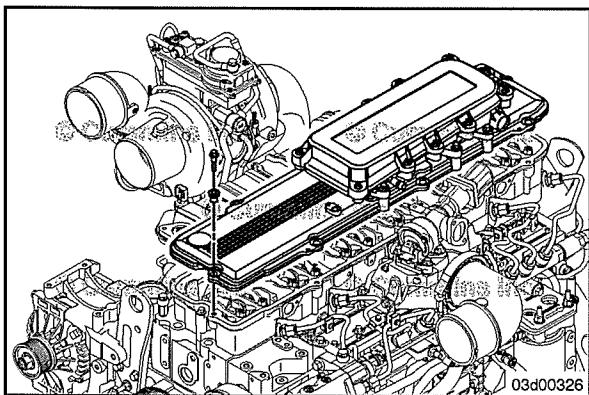
Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the exhaust gas recirculation (EGR) connection tube. Refer to Procedure 011-025 in Section 11.
- Disconnect the crankcase pressure sensor. Refer to Procedure 019-445 in Section 19.
- Remove the crankcase breather tube and drain tube. Refer to Procedure 003-018 in Section 3.





Remove

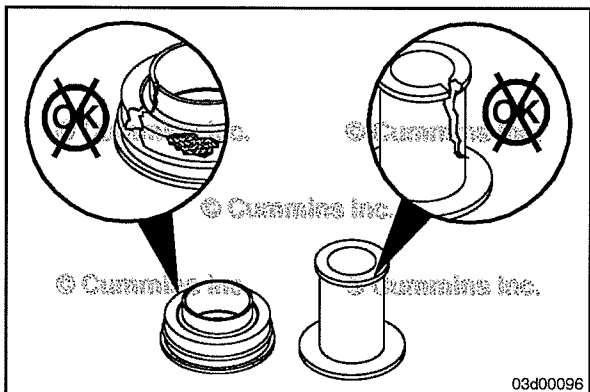
Remove the capscrews.

Remove the rocker lever cover and gasket.

NOTE: The rocker lever cover can be taller if the engine is equipped with engine brakes.

NOTE: It is **not** necessary to remove the crankcase breather in order to remove the rocker lever cover.

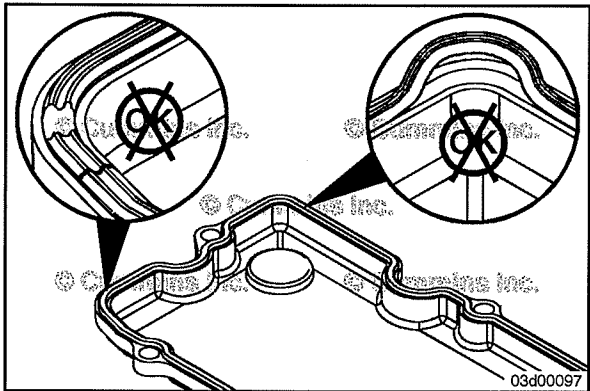
NOTE: It is **not** necessary to remove the heat shield in order to remove the rocker lever cover.



Clean and Inspect for Reuse

Check the isolators for cracks, tears, or brittleness.

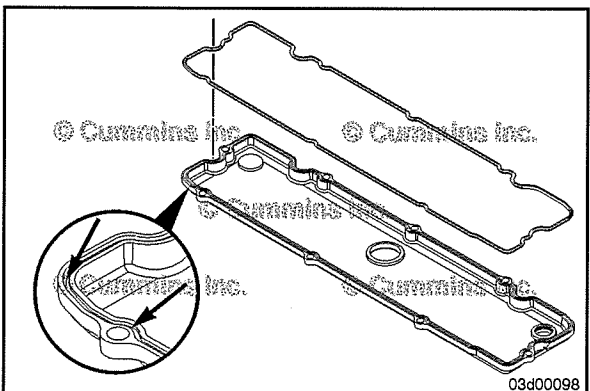
Replace the isolators if any damage is found.



Check the gasket for cracks on the sealing surface.

Replace the gasket if damage is present.

Replace the gasket if it is removed from the groove in the rocker lever cover.



Install

NOTE: If the gasket has been removed from the rocker lever cover, a new gasket **must** be installed.

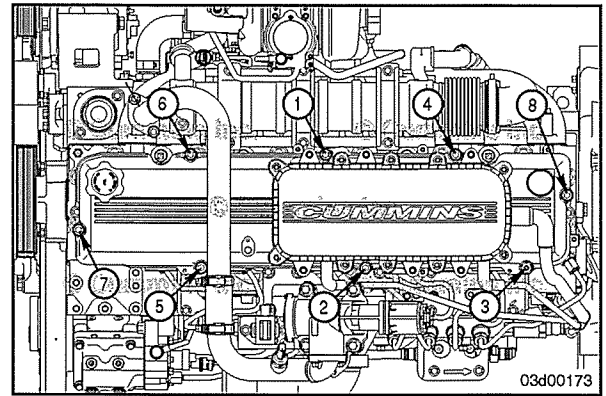
The following installation procedure **must** be used when installing the press in gasket.

- 1 Press the molded gasket into the corners of the rocker lever cover.
- 2 Press the gasket around the capscrew mounting holes.
- 3 Press the remaining gasket into the rocker lever cover.

Install the rocker lever cover and capscrews.

Torque Value: 12 N•m [106 in-lb]

Tighten the capscrews in the sequence illustrated.

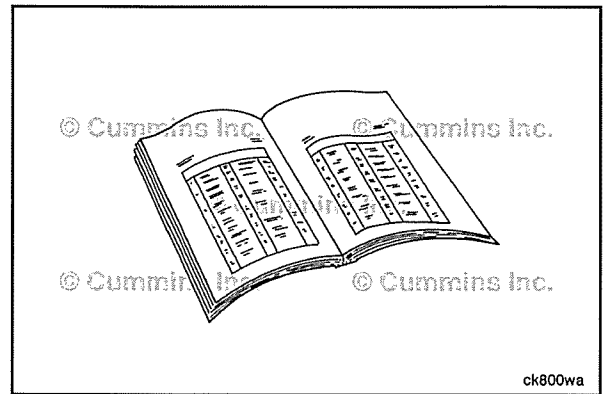


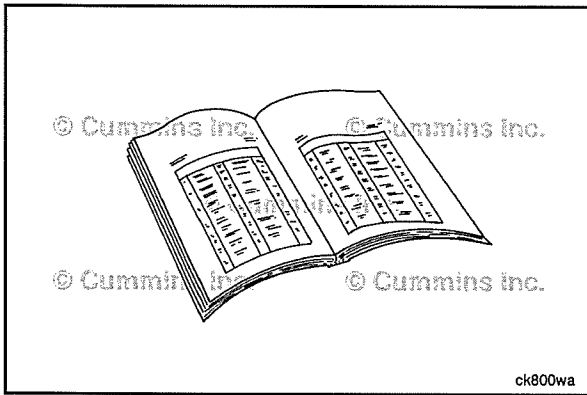
Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the crankcase breather tube and drain tube. Refer to Procedure 003-018 in Section 3.
- Connect the crankcase pressure sensor. Refer to Procedure 019-445 in Section 19.
- Install the EGR connection tube. Refer to Procedure 011-025 in Section 11.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.





Rocker Lever Housing (003-013)

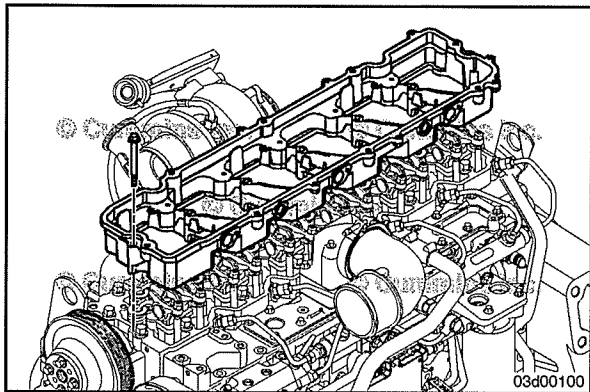
Preparatory Steps



▲ WARNING ▲

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the exhaust gas recirculation (EGR) connection tube. Refer to Procedure 011-025 in Section 11.
- Remove the crankcase breather tube and drain tube. Refer to Procedure 003-018 in Section 3.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Disconnect the injector harness pass-through connectors.
- Remove the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Disconnect the injector wiring harness from the injector. Refer to Procedure 006-026 in Section 6.



Remove

Remove the rocker lever housing mounting capscrews.
Remove the rocker lever housing and gasket from the cylinder head.

Clean and Inspect for Reuse

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

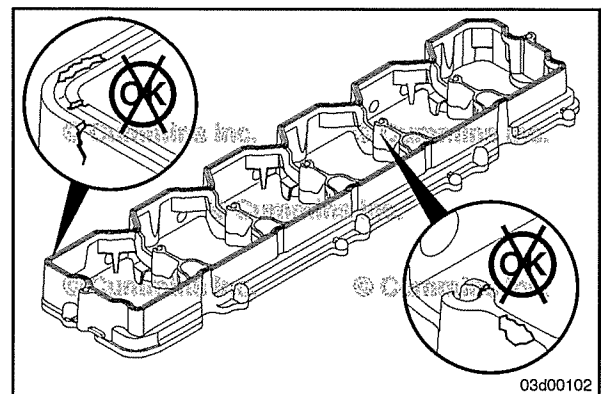
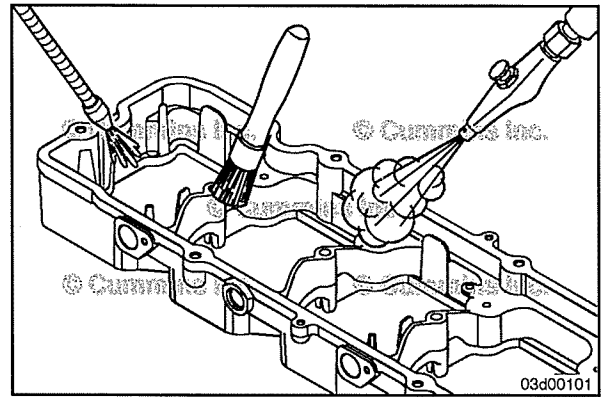
Remove the rocker lever housing gasket.

Make sure the work surface is clean and free from any oil, dirt, or debris.

Dry with compressed air.

Inspect the rocker lever housing for cracks or any other damage, especially on the cylinder head mounting surface.

Inspect the bridge area in the center of the rocker lever housing for cracks.

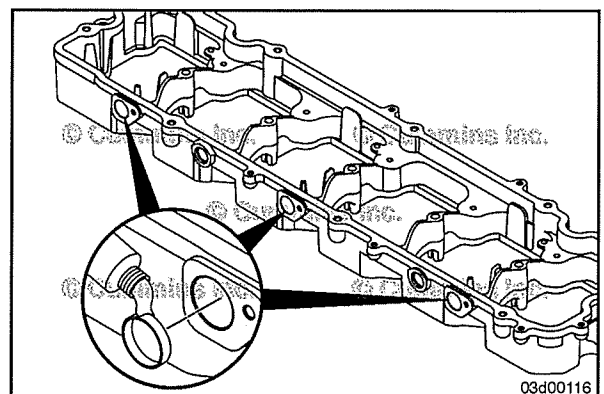


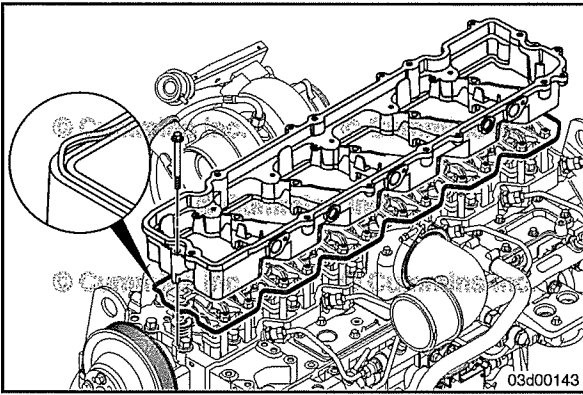
Install

Install the 22 mm cup plugs into the rocker lever housing.

Coat the contact surface of cup plug with Permatex® sealant, or equivalent.

Install the cup plugs flush with the outer surface of the rocker lever housing.





NOTE: A new rocker lever housing gasket **must** be used when the rocker lever housing is removed. Do **not** reuse the old gasket.



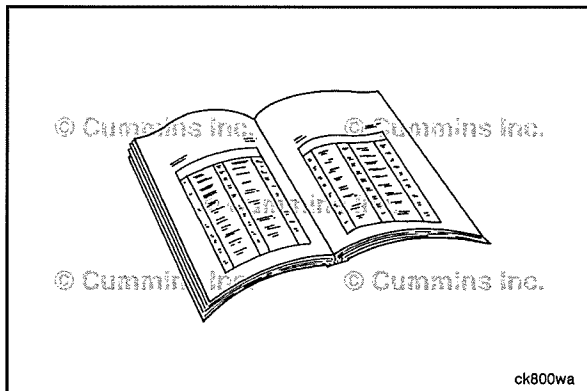
Install the new rocker lever housing gasket. Start by pressing the molded gasket into the corners of the rocker lever housing then press the remaining gasket into the housing.

Install the rocker lever housing on the cylinder head.

Install the capscrews and tighten. Start with the center capscrew and work outward, in a spiral pattern.

Torque Value: 24 N•m [212 in-lb]

NOTE: No capscrew goes in the outer end holes of the rocker lever housing.



Finishing Steps

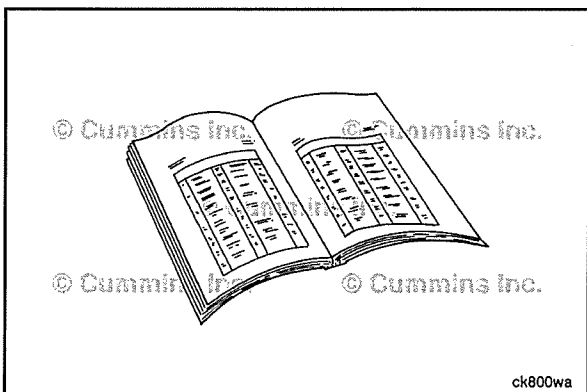


⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Connect the injector wiring harness to the injectors. Refer to Procedure 006-026 in Section 6.
- Connect the injector harness pass through connectors.
- Install the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the crankcase breather tube and drain tube. Refer to Procedure 003-018 in Section 3.
- Install the EGR connection tube. Refer to Procedure 011-025 in Section 11.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Crankcase Breather Tube (003-018)

Preparatory Steps



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.

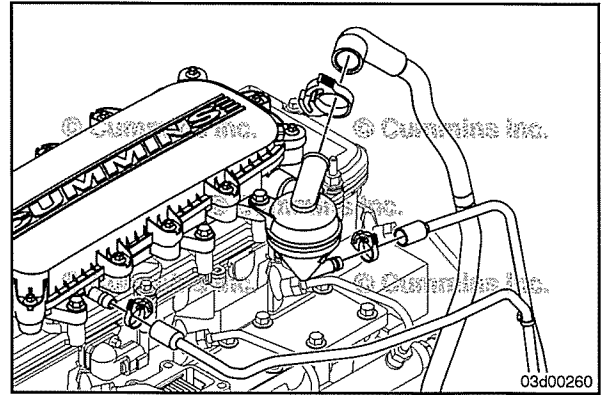
Remove

Rocker Lever Cover Mounted Crankcase Breather

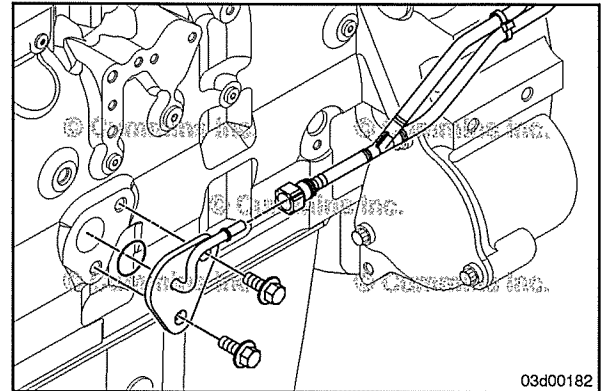
Remove the crankcase breather tube from the crankcase breather assembly.

Remove the crankcase drain lines from the crankcase breather assembly.

Remove the snapper hose clamps from the drain tube and lines.



Remove the breather drain lines, breather drain line cover, and gasket from the cylinder block.



Clean and Inspect for Reuse

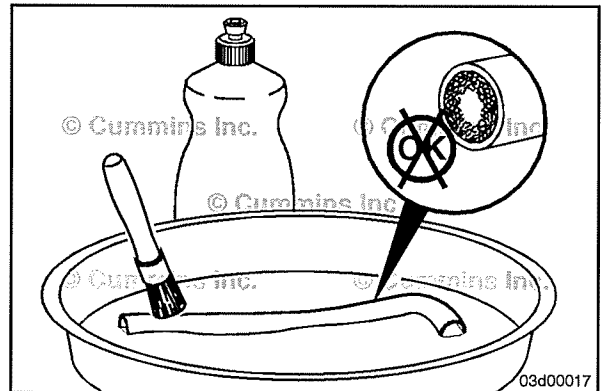
⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Check the tube and lines internally for obstructions or sludge buildup.

Clean the tube and lines with hot, soapy water and a soft brush.

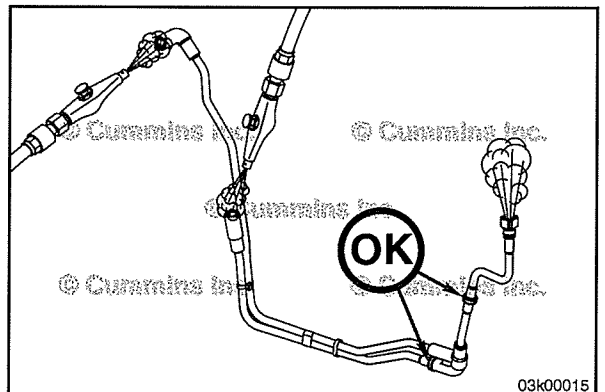
Use compressed air to dry the tube and lines after rinsing in clean water.

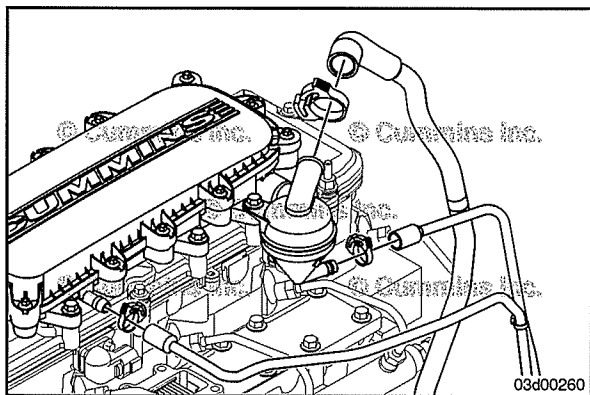


Inspect the breather drain line check valve for correct operation. A small amount of air can be blown through the line (less than 34 kPa [5 psi]) to check the check valve operation.

NOTE: To properly test each check valve, the inlet of the breather drain line **not** being tested **must** be covered to force air down the correct path.

NOTE: An obstructed drain tube or line will lead to excessive crankcase pressure.





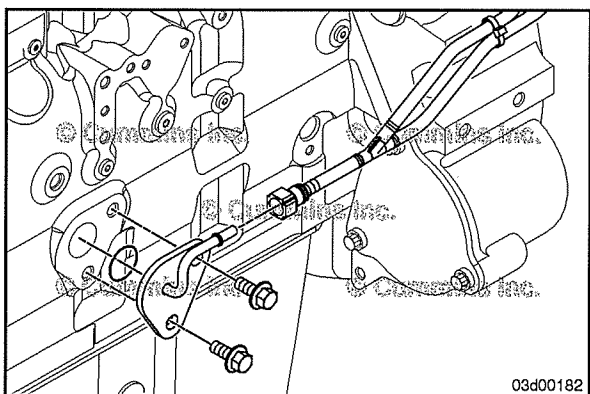
Install

Rocker Lever Cover Mounted Crankcase Breather

NOTE: Make sure the crankcase breather tube or drain lines do **not** contact any high-pressure fuel lines.

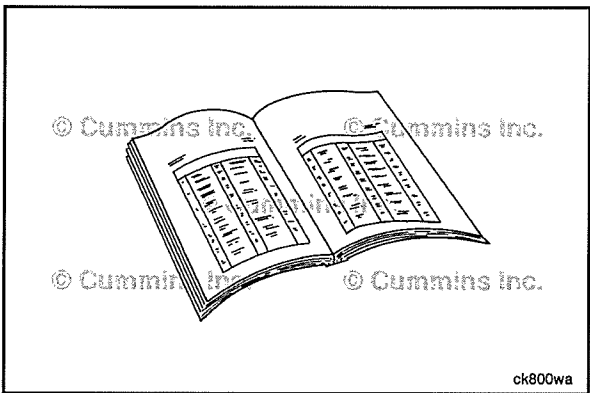
Install the crankcase breather tube to the crankcase breather assembly.

Install the crankcase drain lines to the crankcase breather assembly.



Install the breather drain line cover, gasket, and tube to the cylinder block.

Torque Value: 24 N•m [212 in-lb]



Finishing Steps

▲WARNING▲

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Crankcase Breather Element (003-019)

Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Steam clean the crankcase breather cover area.
- Dry with compressed air.

Remove

Remove the 11 crankcase breather cover capscrews.

NOTE: The six capscrews attaching the crankcase breather base to the valve cover do **not** need to be removed.

Remove the crankcase breather cover.

Remove the crankcase breather element.

Clean and Inspect for Reuse

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

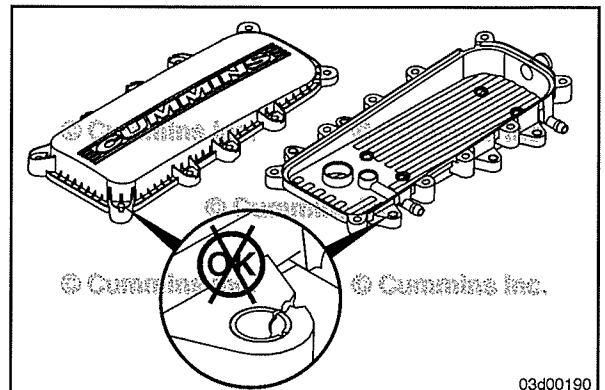
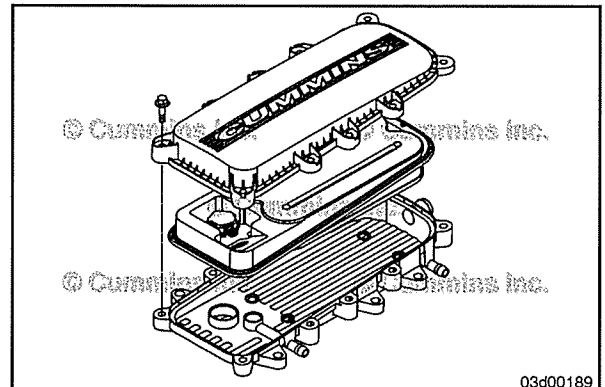
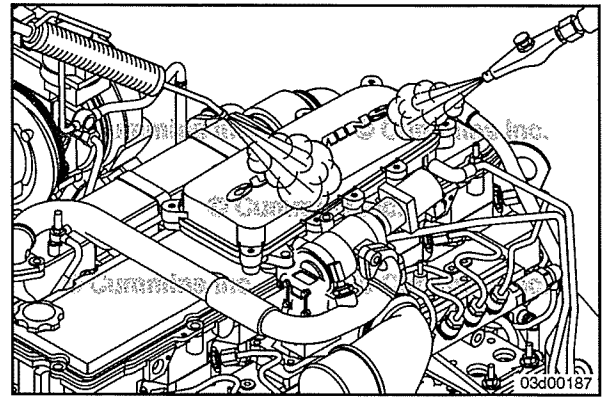
Inspect the breather cover and base for cracks or other damage.

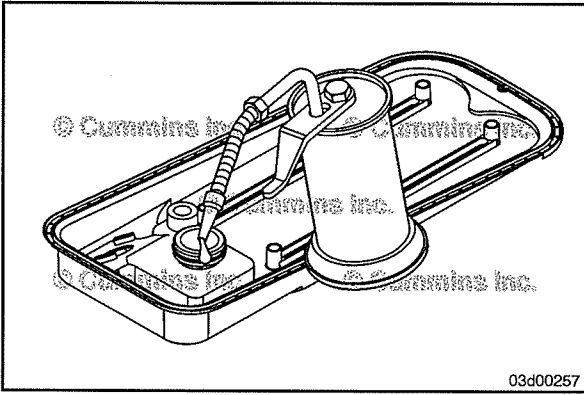
Check for internal obstructions or sludge buildup.

Clean the crankcase breather cover with hot, soapy water and a soft brush.

Rinse the cover with clean water and dry with compressed air.

NOTE: Do **not** use soapy water to clean or rinse the breather base. Clean the base with a wet rag to prevent water from entering the crankcase.



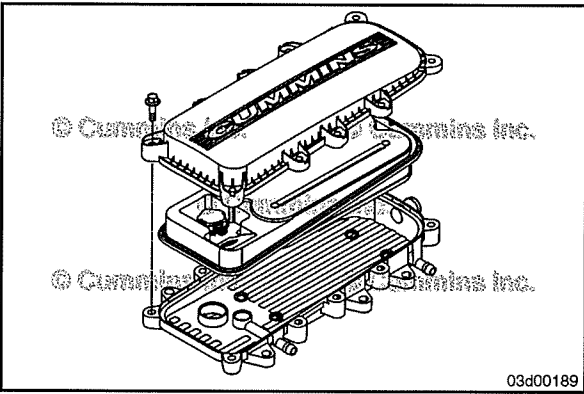


Install

Lubricate the breather element o-ring seal with clean lubricating oil.



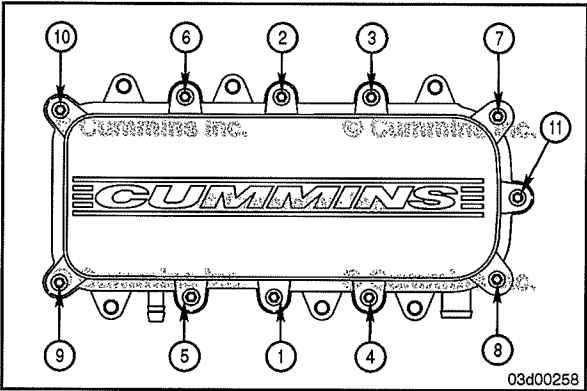
Use the following procedure for breather element recommendations. Refer to Procedure 018-024 in Section V.



Install the new breather element onto the breather base.

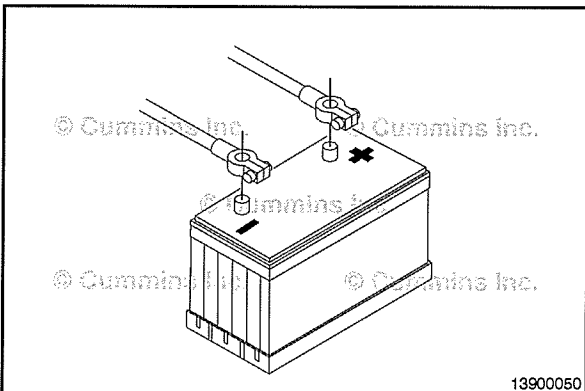
Install the crankcase breather cover.

Install the eleven crankcase breather cover capscrews.



Tighten the capscrews in the sequence shown.

Torque Value: 10 N•m [89 in-lb]



Finishing Steps



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Section 4 - Cam Followers/Tappets - Group 04

Section Contents

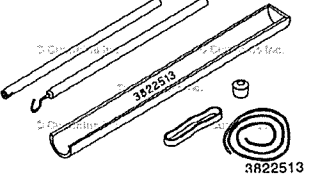
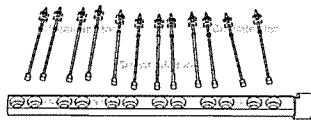

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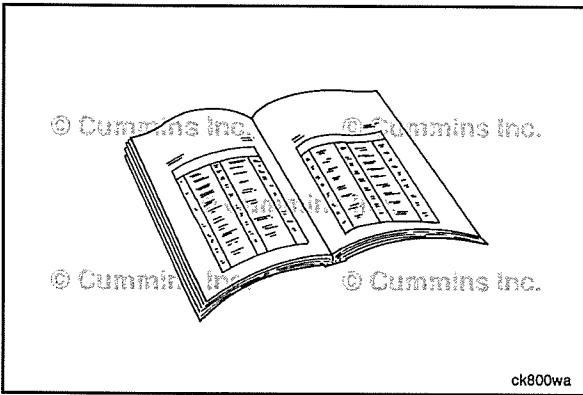
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Service Tools

Cam Followers/Tappets

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3822513	<p align="center">Tappet Removal Tool Kit</p> <p>Used to remove and install sliding valve tappets.</p>	 <p align="right">3822513</p>
3165088	<p align="center">Tappet Removal Tool Kit</p> <p>Used to remove and install roller tappets.</p>	 <p align="right">22d00022</p>
3165086	<p align="center">Tappet Removal Tool</p> <p>Tappet trough for engines using the larger bore tappets. Used to update Tappet Removal Tool Kit, Part Number 3163468.</p>	 <p align="right">22d00181</p>



Push Rods or Tubes (004-014)

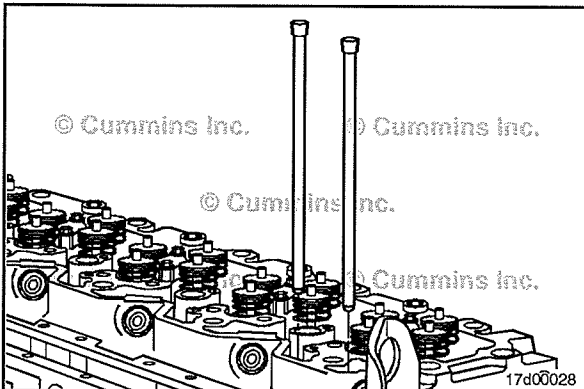
Preparatory Steps



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

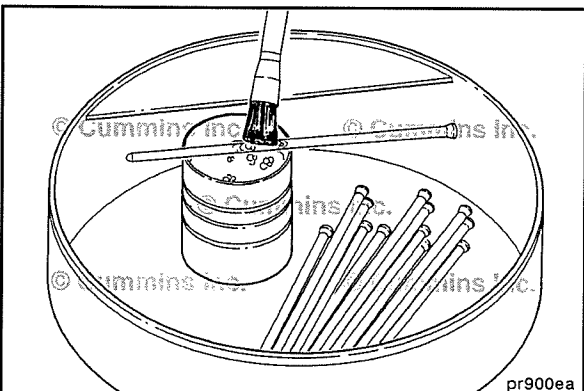
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the exhaust gas recirculation (EGR) connection tube. Refer to Procedure 011-025 in Section 11.
- Remove the crankcase breather tube. Refer to Procedure 003-018 in Section 3.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Remove the rocker levers. Refer to Procedure 003-008 in Section 3.



Remove

Mark the push tubes to identify their location.

Remove the push tubes.



Clean and Inspect for Reuse

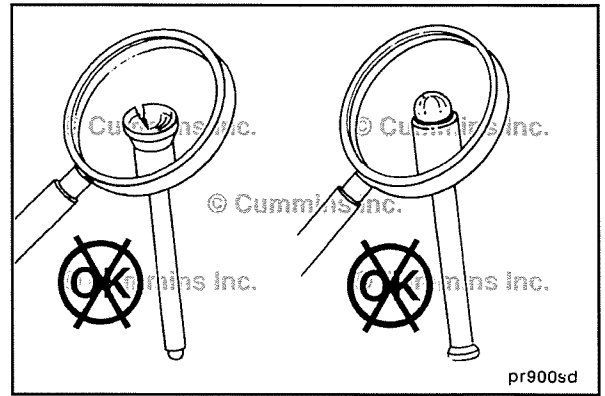
⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

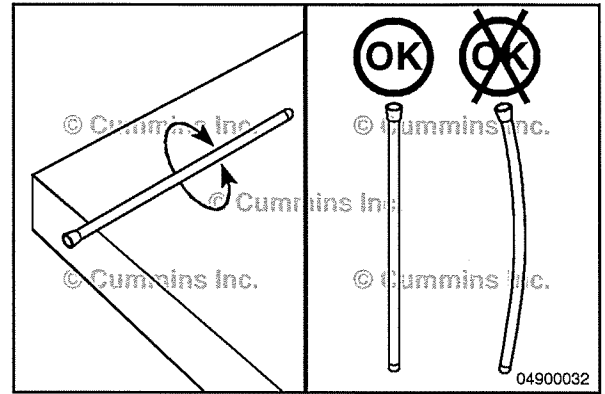
Clean the push tubes in hot soapy water.

Dry with compressed air.

Inspect the push tube ball and socket for signs of scoring. Check for cracks where the ball and the socket are welded into the tube.

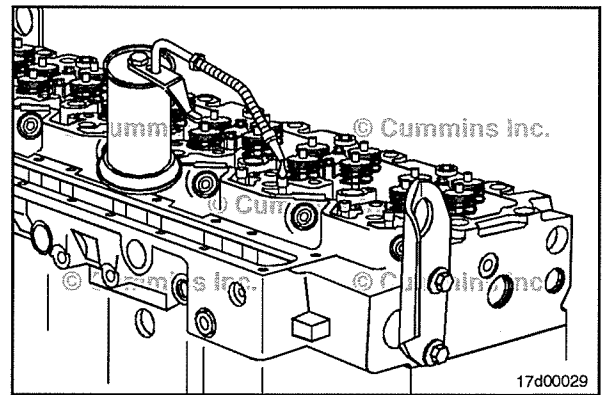


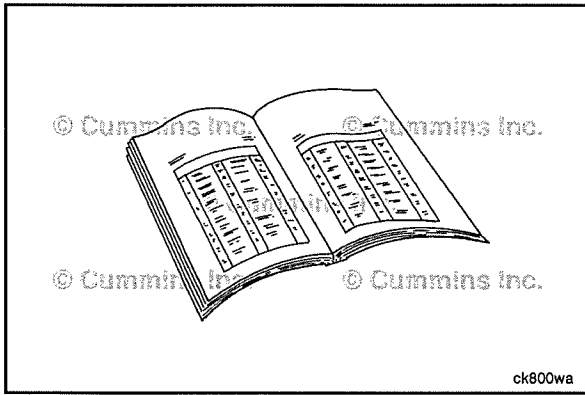
Check the push tubes for straightness.



Install

Install the push tubes in their original location.
Install the push tubes into the sockets of the valve tappets.
Lubricate the push tube sockets with clean 15W-40 engine oil.





Finishing Steps

▲ WARNING ▲

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the rocker levers. Refer to Procedure 003-008 in Section 3.
- Adjust the valve lash. Refer to Procedure 003-004 in Section 3.
- Install the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the crankcase breather tube. Refer to Procedure 003-018 in Section 3.
- Install the EGR connection tube. Refer to Procedure 011-025 in Section 11.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Tappet (004-015)

Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the exhaust gas recirculation (EGR) connection tube. Refer to Procedure 011-025 in Section 11.
- Remove the crankcase breather tube and drain tube. Refer to Procedure 003-018 in Section 3.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Remove the rocker levers. Refer to Procedure 003-008 in Section 3.
- Remove the push rods or tubes. Refer to Procedure 004-014 in Section 4.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the rubber vibration damper, if installed. Refer to Procedure 001-051 in Section 1.
- Remove the viscous vibration damper, if installed. Refer to Procedure 001-052 in Section 1.
- Remove the gear cover. Refer to Procedure 001-031 in Section 1.

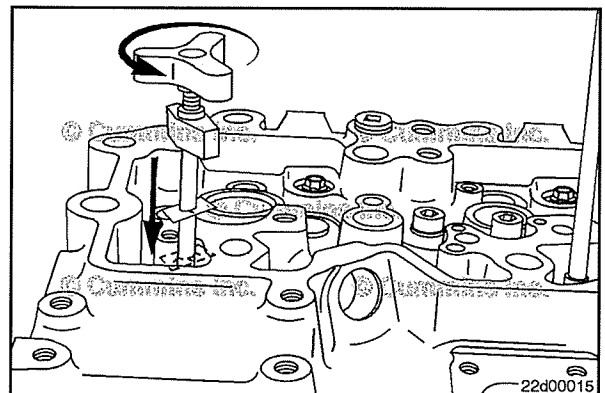
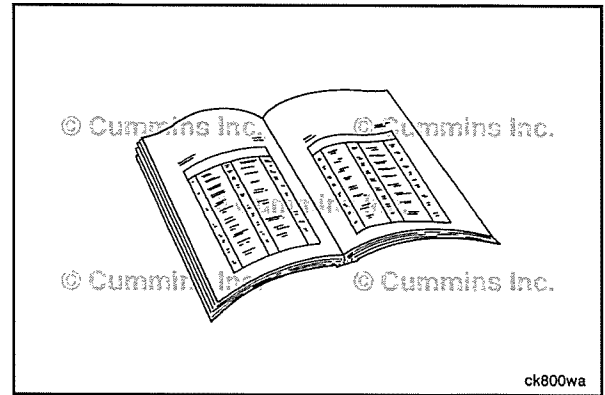
Remove

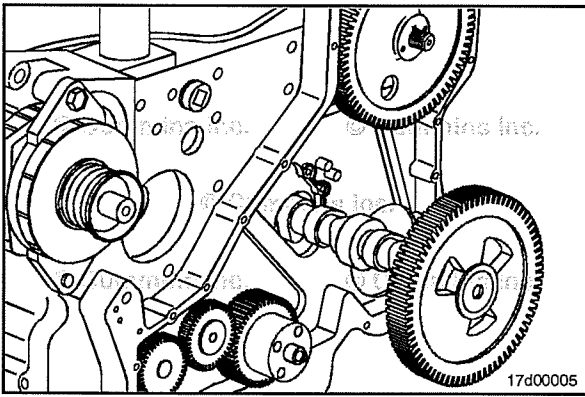
Use tappet removal tool kit, Part Number 3165088, to remove the tappets.

Insert the tappet extractor tool (2) into the tappet bore. Turn the top knob **counterclockwise** while holding the bottom knob to expand and secure the tool into the tappet.

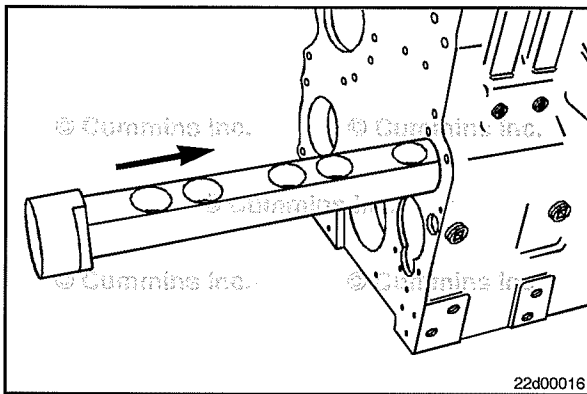
Raise the tappet extractor (2) until it stops, and push the metal tab down against the head surface to secure the tool and captured tappet in the up position.

Repeat for the remaining tappets.

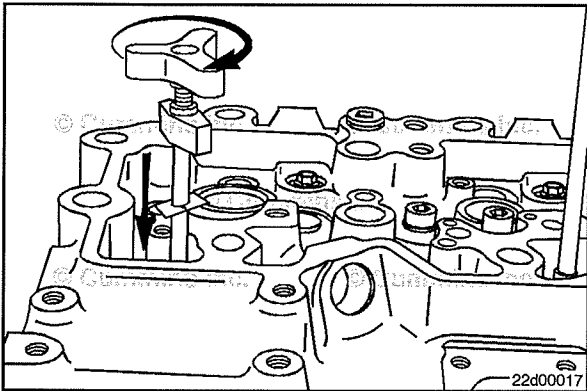




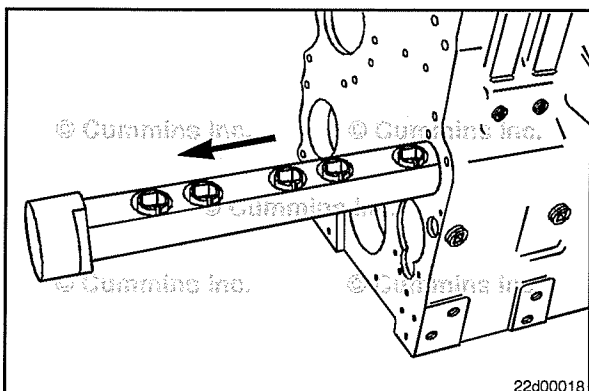
Remove the camshaft. Refer to Procedure 001-008 in Section 1.



Make sure the holes are in the up position. Insert the tappet holder to the full length of the camshaft bore.



Lower the tappet extractor, and seat the tappet into the tappet holder. Turn the top knob **clockwise** while holding the bottom knob to disengage the extractor from the tappet. Repeat the step for the remaining tappets.



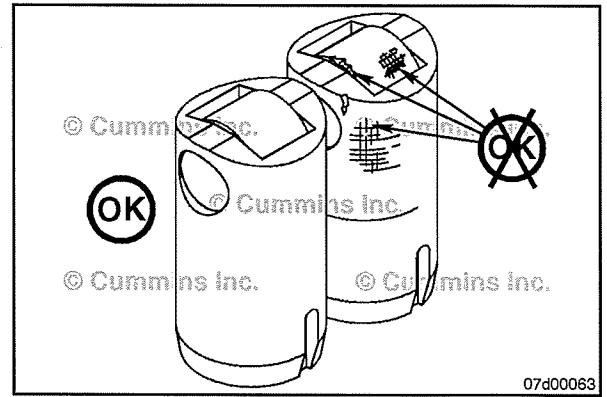
Carefully pull the tappet holder and tappets from the camshaft bore. If the tappets will be reused, be sure to note their position. Do **not** install a tappet in a different position.

Clean and Inspect for Reuse

Inspect the tappet body for cracks or other damage.

Inspect the roller for flat spots or pitting. Refer to Camshaft Reuse Guidelines for Cummins® Engines with Roller Followers or Roller Tappets, Bulletin 3666052. If excessive wear is found, replace the tappet, and inspect the camshaft.

The roller **must** rotate freely. If it does **not**, replace the tappet.



Inspect the tappet body guide screw groove for damage.

If damage to the groove is found, remove the guide screw from the cylinder block.

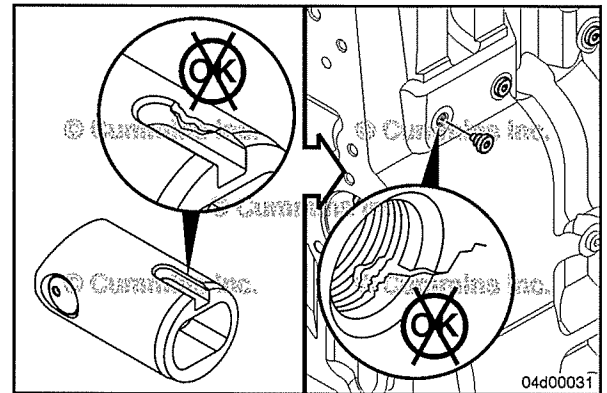
Inspect the guide screw and guide screw hole for thread condition and cracks.

NOTE: Damage to the tappet body guide screw is **not** common.

Apply thread locker, Part Number 324038 or equivalent to the tappet guide screw if it is **not** precoated.

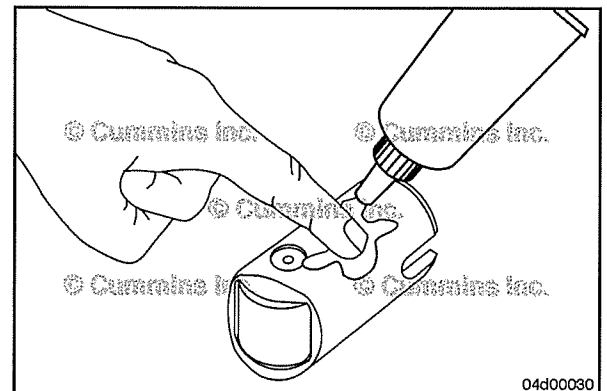
Install the tappet guide screw and tighten.

Torque Value: 10 N•m [89 in-lb]



Install

Lubricate the tappets with assembly lubricant, Part Number 3163087 or equivalent.

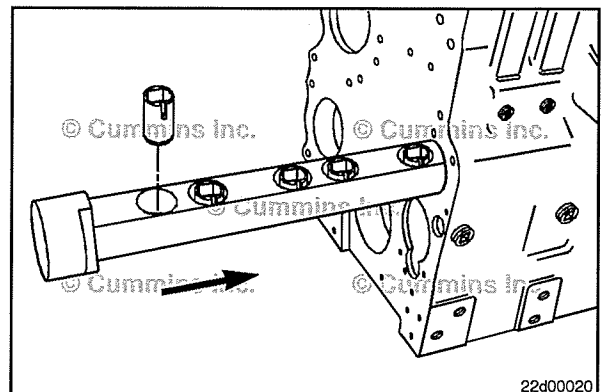


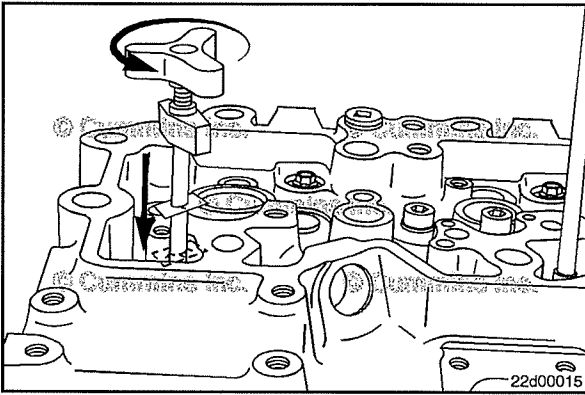
Make sure the tappets are installed with the pin slots toward the outside of the block.

Insert the tappets into the tappet holder.

NOTE: If the tappets are being reused, be sure to install them in their original position.

Insert the tappet holder the full length of the camshaft bore.



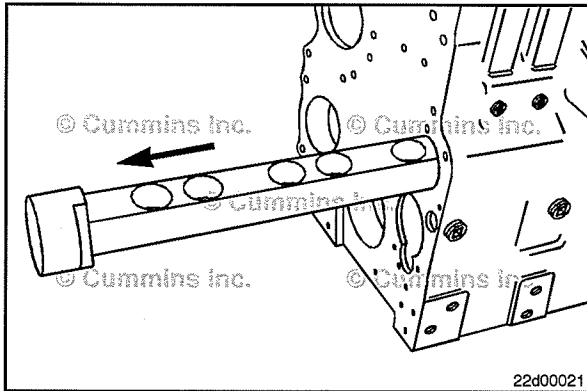


Insert the tappet extractor tool into the tappet bore. Turn the top **counterclockwise** to expand and secure the tool into the tappet.

Raise the tappet extractor until it stops, and push the metal tab down against the head surface to secure the tool in the up position.

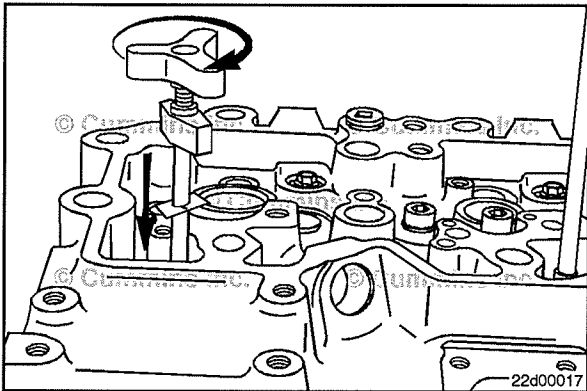
NOTE: Some manipulation may be necessary to get the tappet to enter the bore. When the tappet enters the bore, attempt to rotate the extractor while applying light upward pressure. If the tool will **not** rotate, the tappet has engaged the guide pin. If the tool does rotate, continue until the tappet engages the guide pin.

Repeat for the remaining tappets.



Remove the tappet holder.

Install the camshaft. Refer to Procedure 001-008 in Section 1.



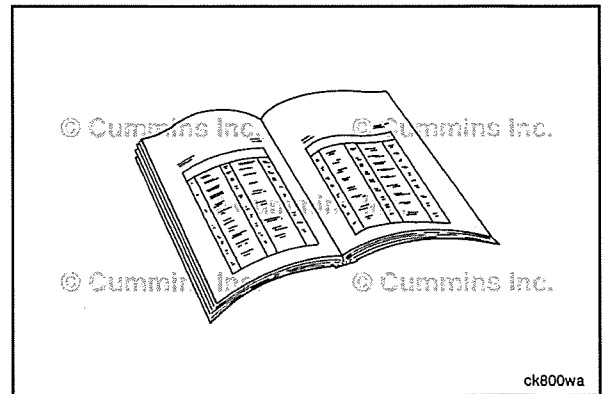
Lower the tappet extractor, and seat the tappet into the camshaft. Turn the top knob **clockwise** while holding the bottom knob to disengage the extractor from the tappet. Repeat the step for the remaining tappets.

Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the gear cover. Refer to Procedure 001-031 in Section 1.
- Install the rubber vibration damper, if required. Refer to Procedure 001-051 in Section 1.
- Install the viscous vibration damper, if required. Refer to Procedure 001-052 in Section 1.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Install the push rods or tubes. Refer to Procedure 004-014 in Section 4.
- Install the rocker levers. Refer to Procedure 003-008 in Section 3.
- Adjust the valves. Refer to Procedure 003-004 in Section 3.
- Install the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the crankcase breather tube and drain tube. Refer to Procedure 003-018 in Section 3.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Section 5 - Fuel System - Group 05

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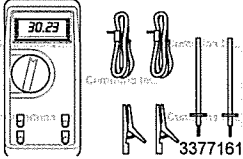
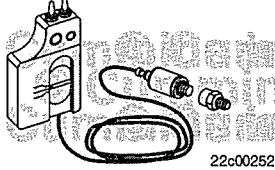
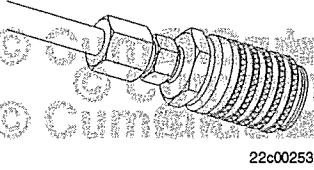
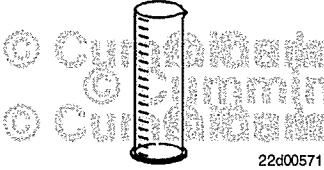
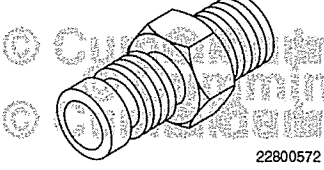
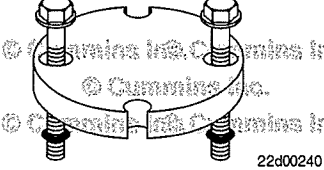
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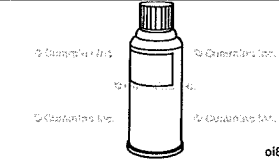
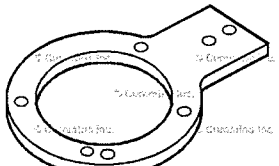
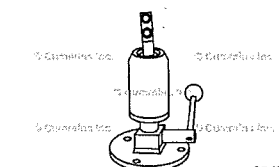
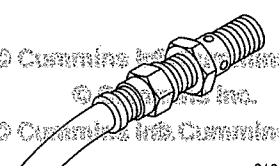
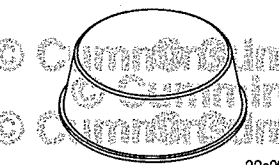
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Service Tools

Fuel System

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3164488	<p align="center">Multimeter</p> <p>Used to measure voltage, resistance, and current in electrical circuits.</p>	
3164499	<p align="center">Pressure and Vacuum Module</p> <p>Used with multimeter, Part Number 3164488, to measure pressures and restriction in the fuel system.</p>	
3164621	<p align="center">0.043-Inch Diagnostic Fuel Line</p> <p>Used to create rated fuel flows through the low-pressure fuel system without loading the engine.</p>	
Not Applicable	<p align="center">1000 cc Graduated Cylinder</p> <p>Used to measure high-pressure pump drain flow (leakage).</p>	
3824842	<p align="center">M10 Compucheck® Fitting</p> <p>Used to measure fuel system pressure at the fuel filter head.</p>	
3163381	<p align="center">Fuel Pump Gear Puller</p> <p>Used to pull the fuel pump gear. Includes Part Number 3900633, capscrews.</p>	

Tool No.	Tool Description	Tool Illustration
3824510	<p align="center">Electrical Contact Cleaner</p> <p>Non-petroleum cleaner used to clean electrical connections and fuel pump internal parts.</p>	 <p align="right">01810g1</p>
3162897	<p align="center">Fuel Pump Mounting Plate</p> <p>Used to hold the fuel pump in the ball joint vise during service.</p>	 <p align="right">05d00150</p>
ST 302	<p align="center">Ball Joint Vise</p> <p>Used with the fuel pump mounting plate for holding the fuel pump during service.</p>	 <p align="right">05d00145</p>
3164618	<p align="center">12 mm Banjo Adapter Fitting (Leakage Flow Adapter)</p> <p>Used to isolate drain flow from the fuel drain lines where they connect to the fuel drain manifold. Allows fuel leakage measurement from the fuel pump, injector, or fuel rail pressure relief valve drain lines.</p>	 <p align="right">3164614</p>
5298776	<p align="center">Fuel System Clean Care Kit</p> <p>Used to maintain cleanliness during fuel system service.</p>	 <p align="right">22c00356</p>

Engine Fuel Heater, Electric (005-008)

General Information

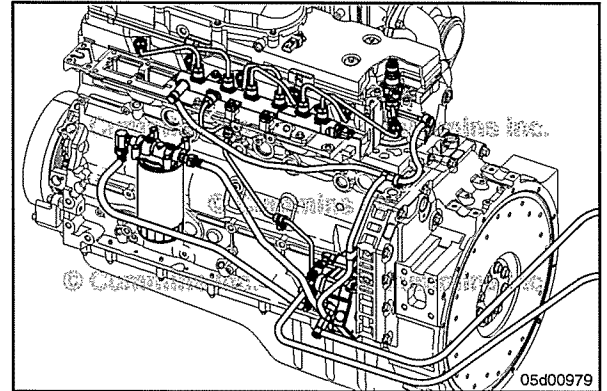
This procedure applies to all engines equipped with Cummins®/Fleetguard® fuel heaters.

NOTE: The fuel heater is **not** controlled by the engine control module (ECM). A bimetallic strip acts as a thermostat.

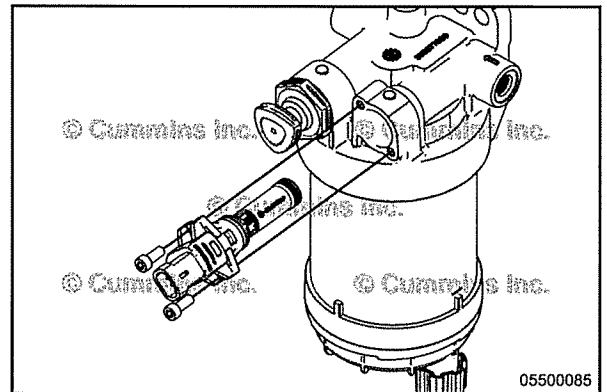
Fuel heater versions include 12 VDC and 24 VDC.

12 VDC fuel heaters will turn on below approximately 2°C [35.6°F] and turn off above approximately 24°C [75°F].

24 VDC fuel heaters will turn on below approximately 2°C [35.6°F] and turn off above approximately 18°C [64°F].

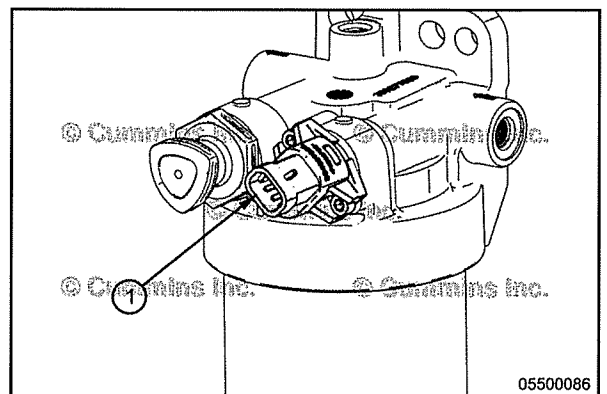


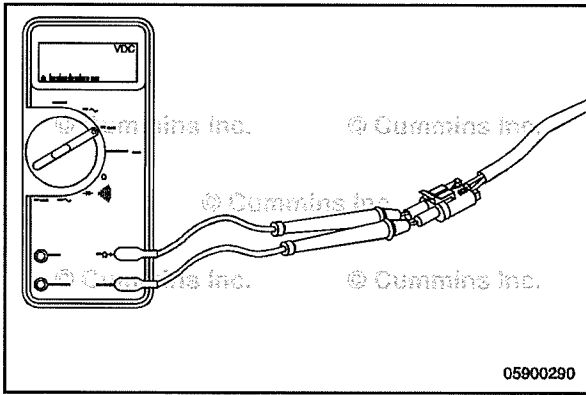
The fuel heater (stick type) is integrated into the remote mounted priming pump and is installed in the fuel filter head. The location of the priming pump/fuel filter will be determined by the original equipment manufacturer (OEM).



Test

Remove the connector from the fuel heater (1).





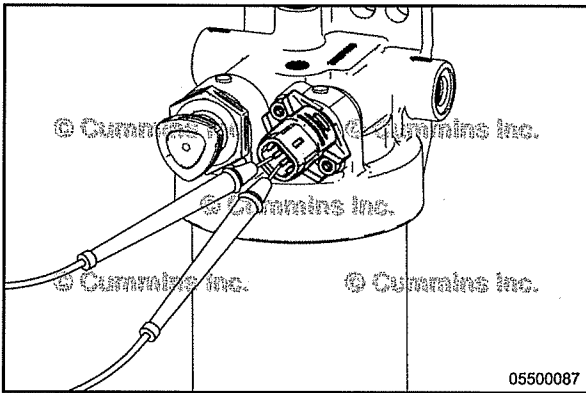
Check for proper voltage to the fuel heater at the OEM connector.

Fuel heater voltage:

12 volt system: 12-VDC

24 volt system: 24-VDC

If the voltage is **not** within specifications, refer to the OEM service manual.



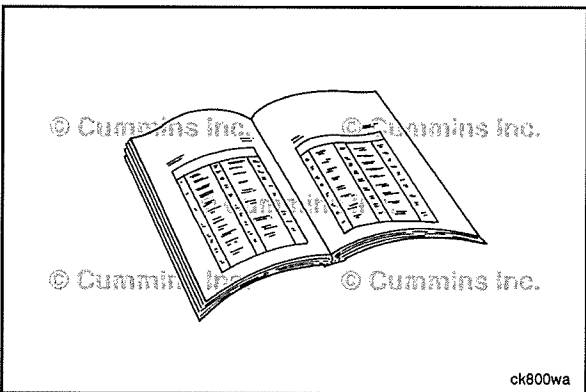
Measure the resistance across the two connector pins on the fuel heater connector.

NOTE: Resistance at the connector pins will be zero if the temperature is above the range needed to turn on the thermostat. It will be necessary to place ice around the fuel heater to bring the temperature down to the activation point of the thermostat.

For 12-VDC fuel heaters, the operating range is 0.43 to 0.53 ohms.

For 24-VDC fuel heaters, the operating range is 2.02 to 2.46 ohms.

If resistance is out of range, replace the fuel heater assembly.



Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



⚠ WARNING ⚠

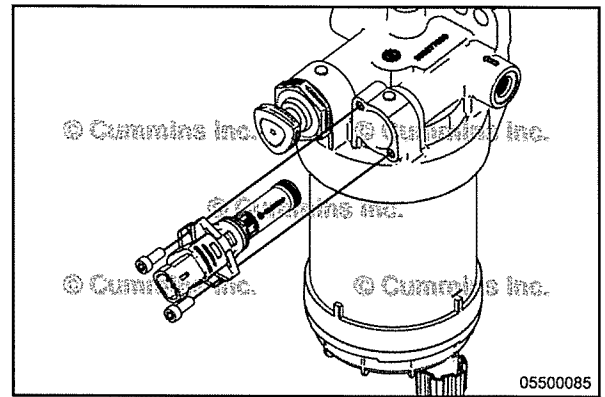
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

- Steam clean the fuel heater and area around the fuel heater. Dry with compressed air.
- Disconnect the battery cables. Refer to the OEM service manual.
- Disconnect all electrical connections.

Remove

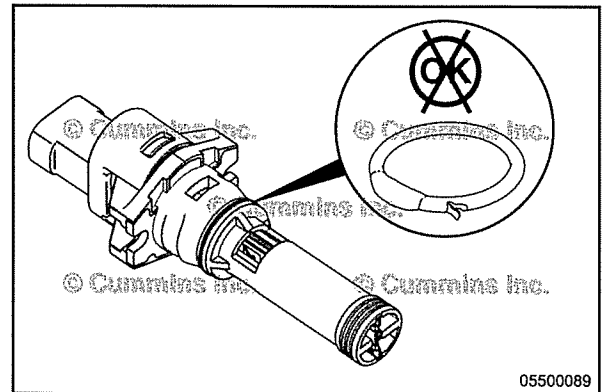
Remove the two bolts holding the fuel heater into the filter head.

Remove the fuel heater by pulling it out of the filter head.

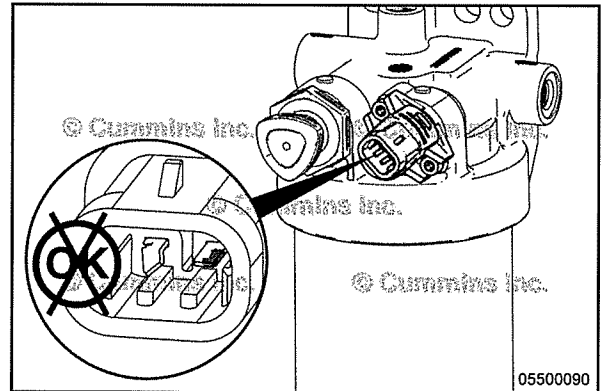


Clean and Inspect for Reuse

Inspect the o-rings (1) for damage. Replace any damaged o-rings.



Inspect the fuel heater for broken terminals (1) or other damage. Replace the fuel heater if any damage is found.



Install

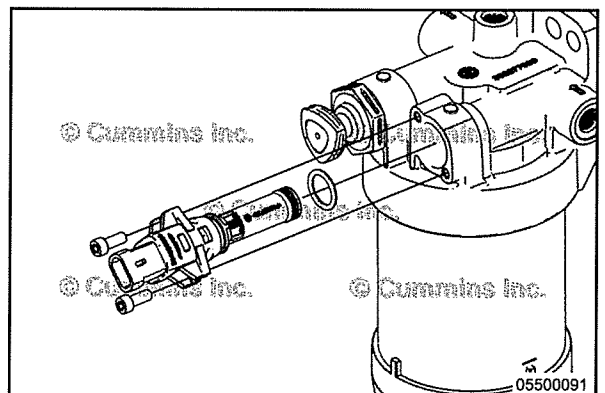
⚠ CAUTION ⚠

Make sure that no dirt or debris enters the fuel heater to prevent the passing of contaminants to the high-pressure fuel pump and injectors. Small amounts of dirt and debris can cause a malfunction of these components.

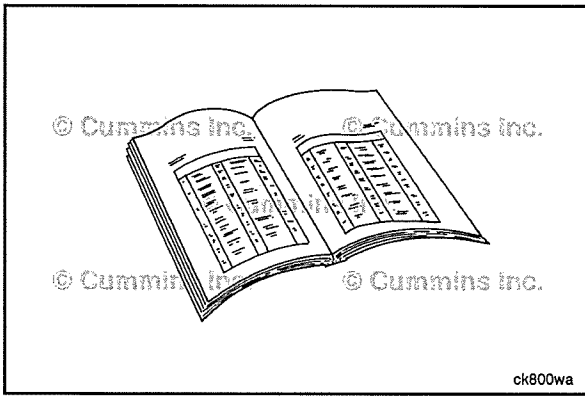
Install a new o-ring onto the fuel heater.

Insert the fuel heater into the filter head assembly.

Tighten the two bolts holding the fuel heater onto the filter head.



Torque Value: 9 N•m [80 in-lb]



Finishing Steps

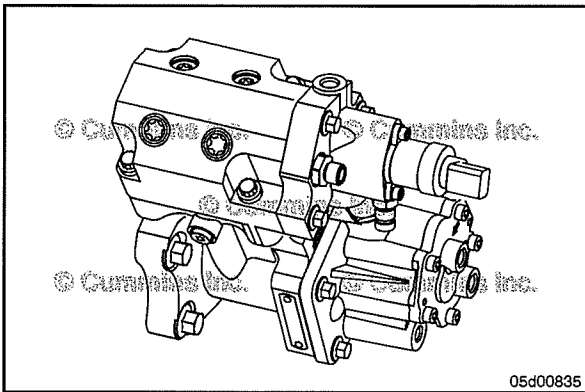


⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Connect all electrical connections.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Fuel Pump (005-016)

General Information

This procedure refers to the Cummins® Common Rail fuel system.

Preparatory Steps

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

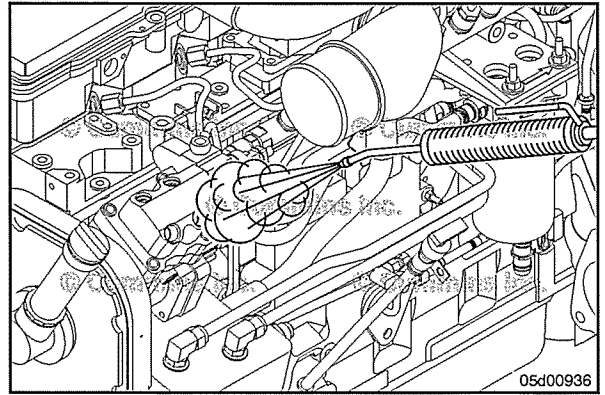
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

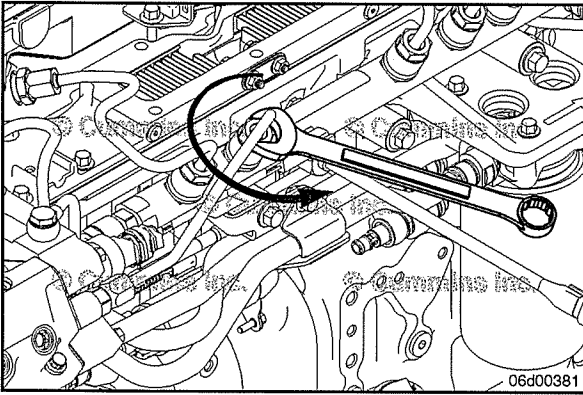
⚠ CAUTION ⚠

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine.

- Clean the fuel pump and surrounding area. Refer to Procedure 000-009 in Section 0.
- Use electrical contact cleaner, Part Number 3824510 or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, or cleaning solution does **not** get inside the fuel system.





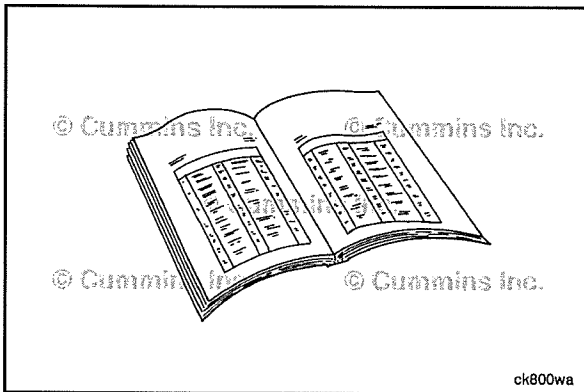
▲ WARNING ▲

Normal engine operation creates highly pressurized fuel in the fuel line which will remain in the fuel line after engine shutdown. Never open the fuel system when the engine is operating. Before servicing the fuel system, always loosen the pump-to-rail fuel line at the rail to vent the pressure. Keep hands clear of the line when loosening. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

Before servicing the fuel system, loosen the pump-to-rail line at the rail to vent the pressure.

Keep hands clear of the line when loosening.

NOTE: A machined slot in this fitting directs the fuel spray towards the engine block.

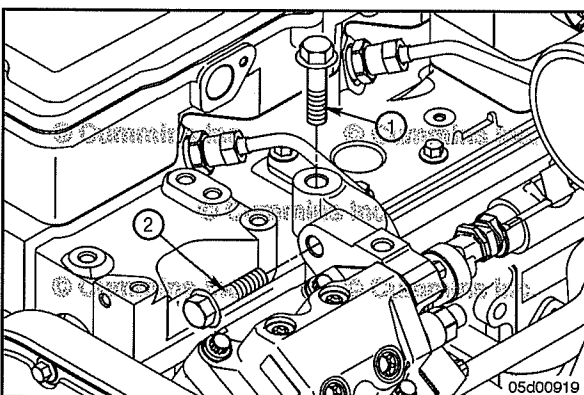


▲ WARNING ▲

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the fuel supply lines from the fuel pump. Refer to Procedure 006-024 in Section 6.
- Remove the fuel drain line from the fuel pump. Refer to Procedure 006-013 in Section 6.
- Remove the pump to rail high pressure line. Refer to Procedure 006-051 in Section 6.
- Disconnect the engine harness from the fuel pump actuator. Refer to Procedure 019-117 in Section 19.
- Remove the fuel pump gear access cover.



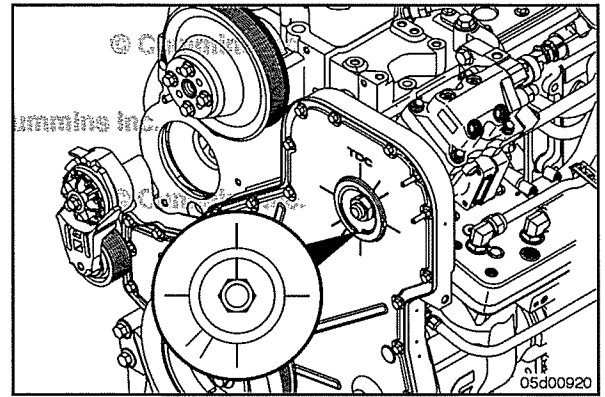
Remove

Remove the fuel pump upper support bracket by removing the two bolts (1) and (2).



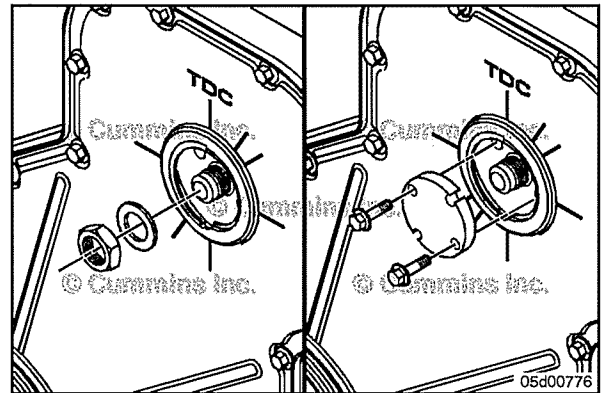
The upper support bracket is located on the fuel pump actuator housing. Refer to Procedure 005-228 in Section 5.

Locate top dead center for cylinder Number 1 by barring the engine until the line on the fuel pump gear aligns with the front cover mark for top dead center.



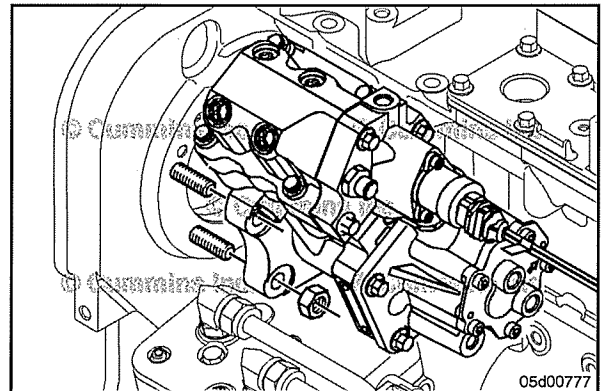
Remove the fuel pump gear nut and washer.

Use fuel pump gear puller, Part Number 3824469, to pull the fuel injection pump drive gear loose from the fuel pump drive shaft.



Remove the four mounting nuts that hold the fuel pump to the gear housing.

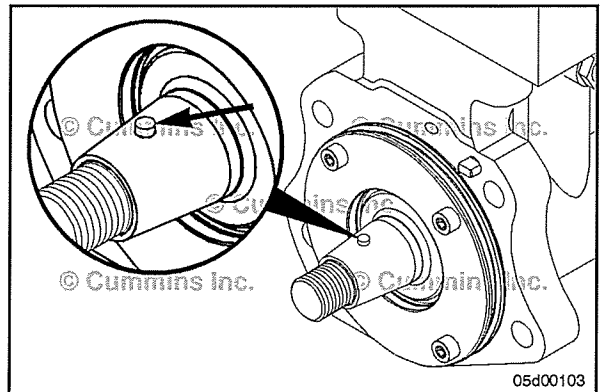
Remove the fuel pump.

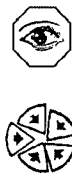
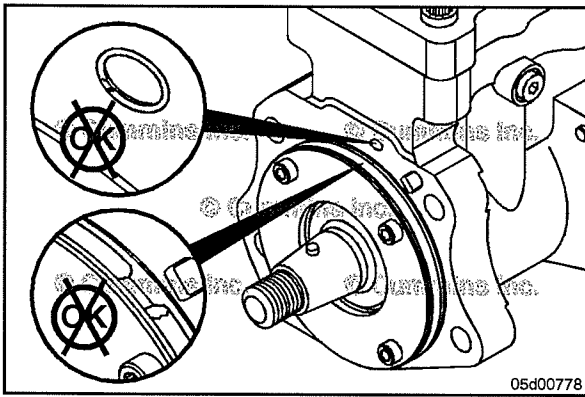


Inspect for Reuse

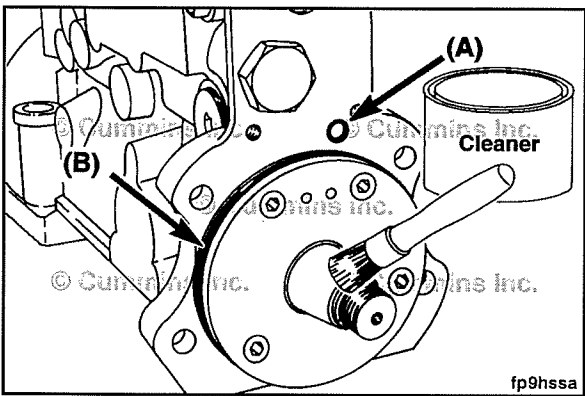
The dowel pin in the fuel pump drive shaft **must not** be sheared.

If the dowel is sheared, the camshaft housing or fuel pump **must** be replaced, and the drive gear **must** be replaced.





Be sure the pilot o-ring is **not** cut or otherwise damaged.
The pump oil supply o-ring **must** be replaced. Make sure it is **not** damaged.



Install

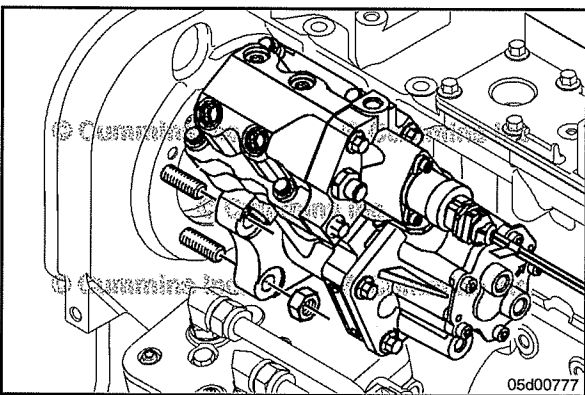
Make sure the engine is at Number 1 cylinder, top dead center. The fuel pump gear timing mark **must** align with the top dead center mark on the front cover.

Make sure the o-ring seals for the oil feed orifice (A) and pilot (B) are installed correctly.

Lubricate the pilot o-ring (B) with clean engine oil.

Clean the nose of the drive shaft and the fuel pump gear inside diameter with electrical contact cleaner, Part Number 3824510, or equivalent.

The fuel pump drive gear inside diameter and the drive shaft outside diameter **must** be clean and dry before installing the gear.



Slide the fuel injection pump shaft through the drive gear and position the fuel injection pump flange onto the mounting studs.

Make sure the dowel pin in the drive shaft lines up with the keyway in the fuel injection pump gear.

Installation sequence for fuel pump actuator housing mounted support bracket:

- 1 Install the pump mounting nuts (leave loose).
- 2 Install the bolt to the cylinder head (1) and the bolt through the pump flange (2) into the support bracket (leave loose).
- 3 Tighten the pump mounting nuts.

Torque Value: 44 N•m [32 ft-lb]

- 1 Tighten the bolt into the cylinder head (1).

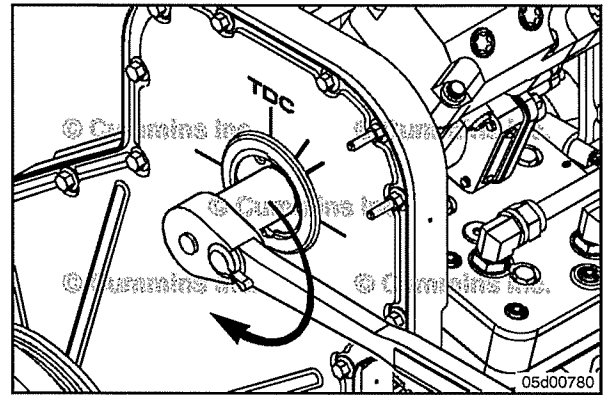
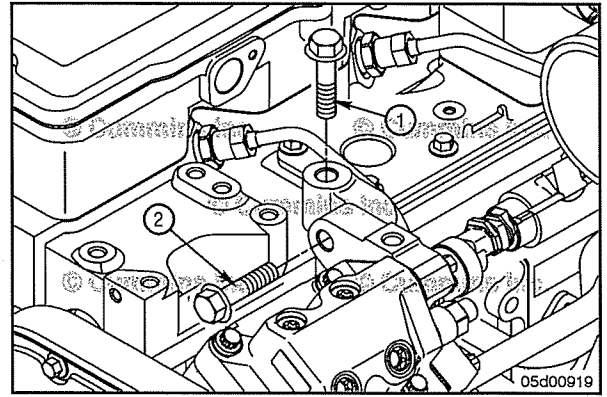
Torque Value: 65 N•m [48 ft-lb]

- 1 Tighten the bolt into the pump flange (2).

Torque Value: 80 N•m [59 ft-lb]

Tighten the fuel injection pump drive gear nut.

Torque Value: 180 N•m [133 ft-lb]

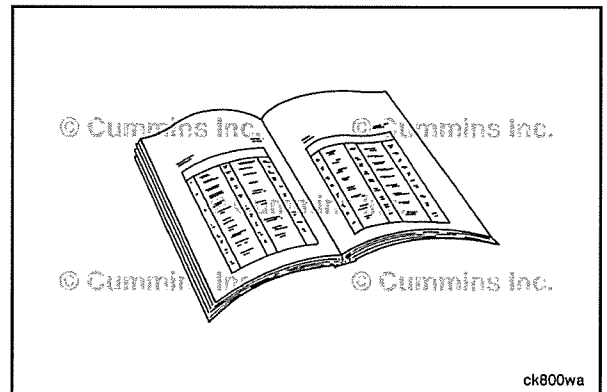


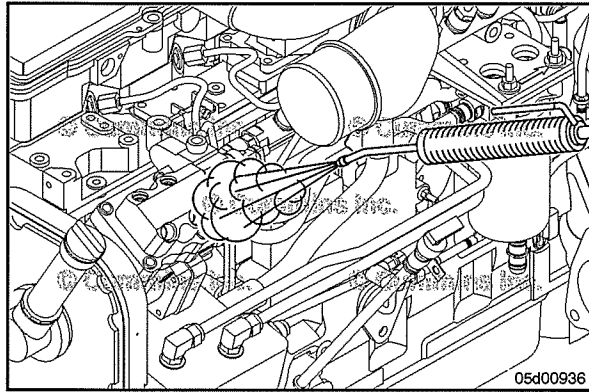
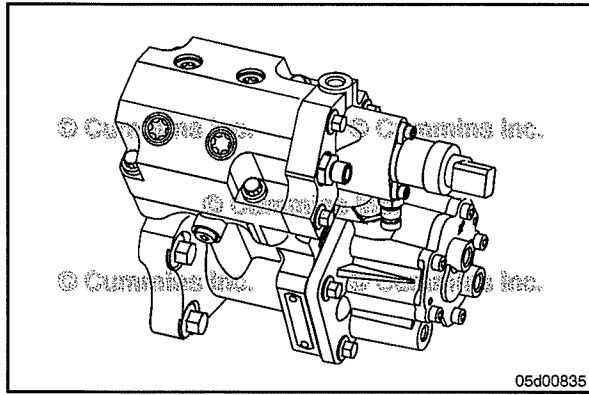
Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the access cover in the front cover.
- Install the fuel supply lines to the fuel pump. Refer to Procedure 006-024 in Section 6.
- Install the pump to rail high pressure line. Refer to Procedure 006-051 in Section 6.
- Install the fuel drain line to the fuel pump. Refer to Procedure 006-013 in Section 6.
- Connect the wire harness to the fuel pump actuator. Refer to Procedure 019-117 in Section 19.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.





Fuel Pump Gear Pump (005-025)

General Information

This procedure refers to the Cummins® Common Rail fuel system.

Preparatory Steps



⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ CAUTION ⚠

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

NOTE: All fuel system diagnostics procedures and component specifications have been moved to Procedure 005-236 (Fuel System Diagnostics).

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine.

- Clean the engine. Refer to Procedure 000-009 in Section 0.
- Use electrical contact cleaner, Part Number 3824510 or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, and cleaning solution does **not** get inside the fuel system.

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



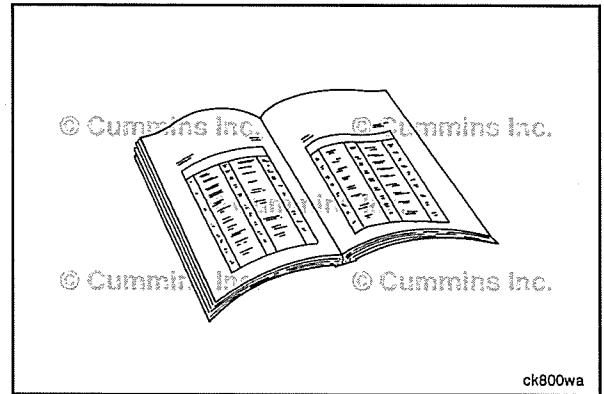
⚠ WARNING ⚠

Depending on the circumstance, diesel fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

⚠ WARNING ⚠

Do not vent the fuel system on a hot engine; this can cause fuel to spill onto a hot exhaust manifold, which can cause a fire.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Clean any fuel, oil, and debris from the gear pump.
- Remove the fuel supply lines from the gear pump. Refer to Procedure 006-024 in Section 6.



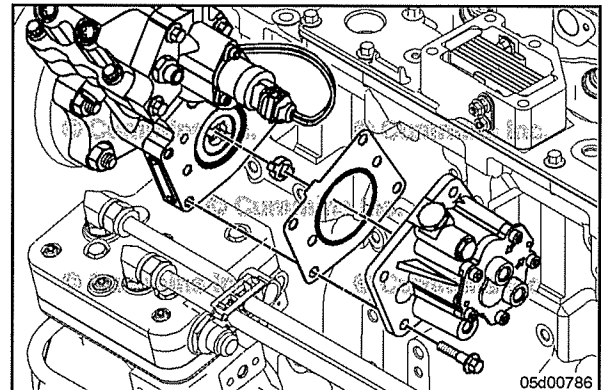
ck800wa

Remove

Remove the four bolts that hold the gear pump to the fuel pump.

Remove the drive coupling if it remains attached to the rear of the fuel pump camshaft.

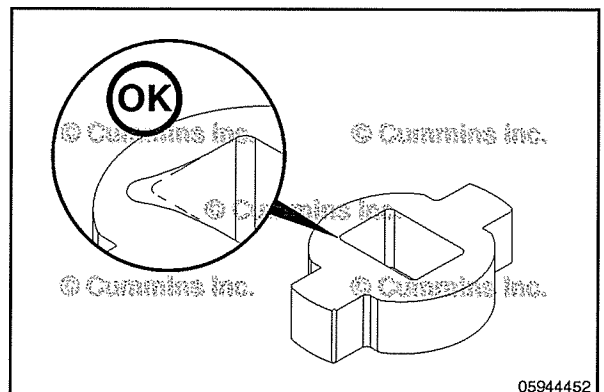
Remove the gear pump gasket.

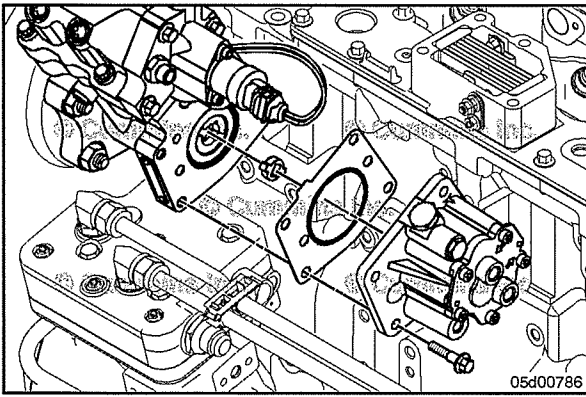


Clean and Inspect for Reuse

Inspect the gear pump for damage.

NOTE: Gear pump coupling wear is normal. The gear pump should **not** be replaced due to coupling or shaft wear.





Install

Install the drive coupling into the back of the high-pressure pump camshaft.



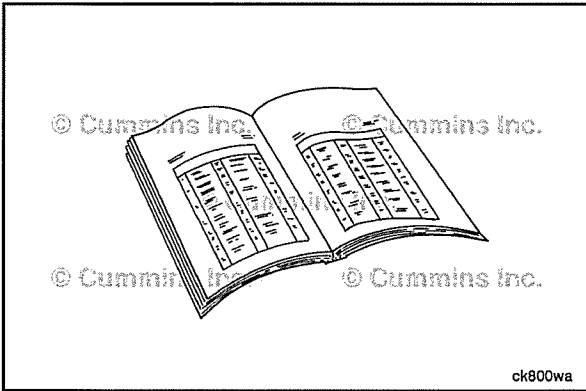
Insert the mounting bolts through the gear pump flange.

Install a new gasket onto the bolts.

Index the gear pump input shaft to engage the drive coupling and install the gear pump.

Install the four gear pump bolts and tighten.

Torque Value: 34 N•m [25 ft-lb]



Finishing Steps

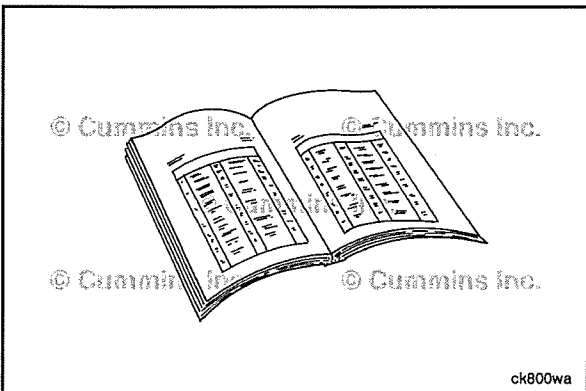
⚠ WARNING ⚠



Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Fuel Pump Timing (005-037)

Preparatory Steps



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the gear cover. Refer to Procedure 001-031 in Section 1.
- Remove the fuel pump camshaft nut. Refer to Procedure 005-016 in Section 5.

Clean and Inspect for Reuse

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ CAUTION ⚠

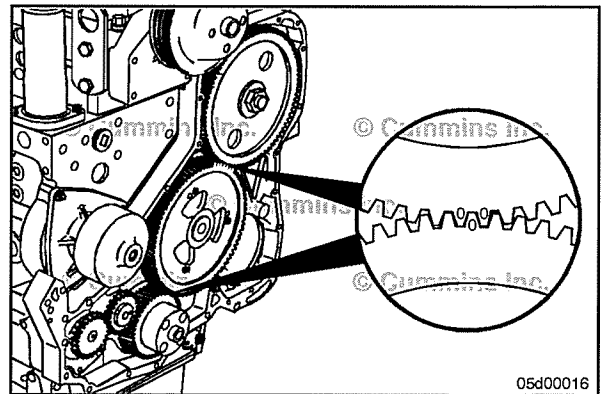
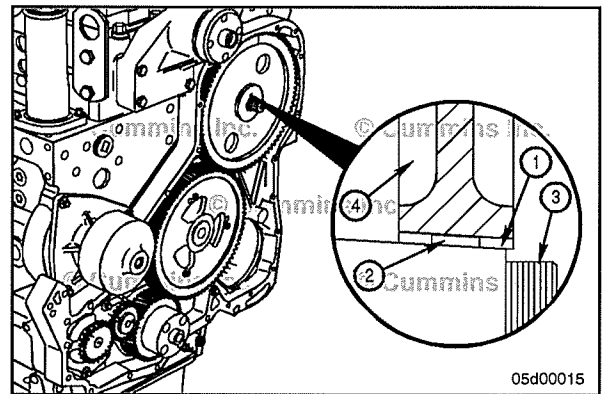
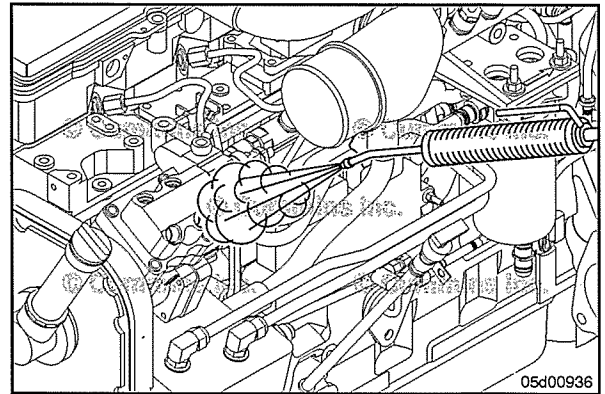
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

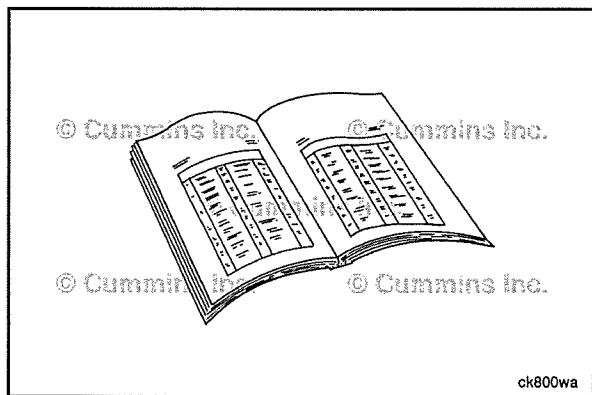
Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine. Refer to Procedure 000-009 in Section 0.

Check that the fuel pump camshaft alignment dowel is present in the fuel pump drive gear keyway. If the alignment dowel is **not** visible, remove the injection pump, determine the cause of misalignment, and repair or replace any damaged components.

- 1 Fuel pump gear keyway
- 2 Fuel pump timing dowel pin
- 3 Fuel pump camshaft
- 4 Fuel pump gear.

If this inspection is being performed due to a performance complaint, and the problem first occurred after gear train removal and replacement, then check the timing of the camshaft gear to the crankshaft gear and the camshaft gear to the fuel pump drive gear. Refer to Procedure 001-012 in Section 1.





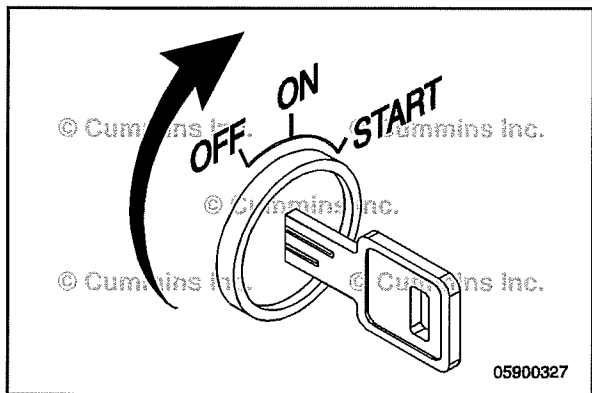
Finishing Steps



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Install and tighten the injection pump camshaft nut. Refer to Procedure 005-016 in Section 5.
- Install the front gear cover. Refer to Procedure 001-031 in Section 1.
- Operate the engine and check for leaks.

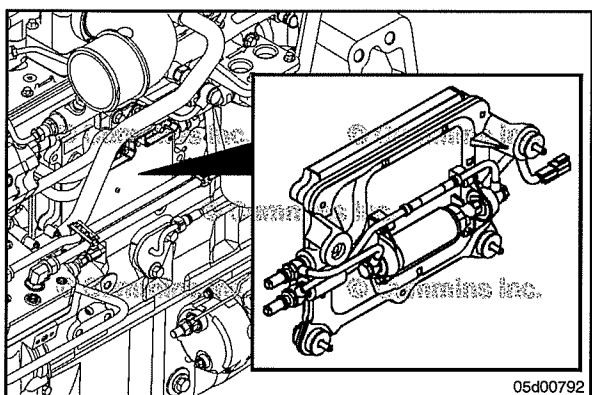


Fuel Lift Pump (005-045)

Initial Check

A malfunctioning electric fuel lift pump can cause slow engine starts or can result in an engine failing to start. The fuel lift pump can be cleaned and repaired to a limited extent.

The lift pump will operate for 30 to 60 seconds when the key is switched ON. The lift pump will also operate while the engine is cranking.



Engine Control Module Cooling Plate Mounted Lift Pump

A lift pump is mounted to the back of the engine control module (ECM) cooling plate.

A bypass check valve in the ECM cooling plate makes sure the system is primed by the lift pump. This check valve opens under vacuum created by the gear pump, once the engine is started. High vacuum measured between the electric lift pump and the gear pump can indicate this check valve has become plugged.

The ECM cooling plate check valve is integral with the lower (outlet) fitting of the ECM cooling plate.

Preparatory Steps

▲ WARNING ▲

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

▲ WARNING ▲

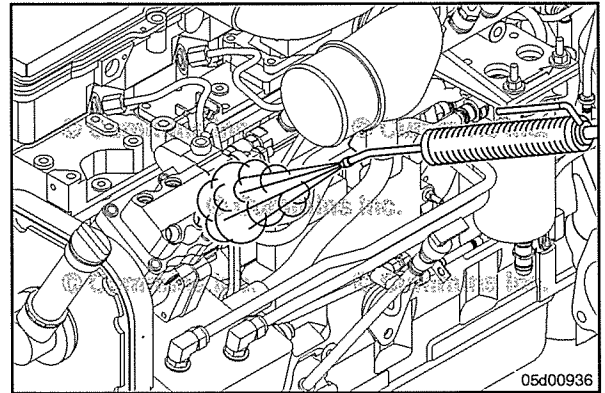
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

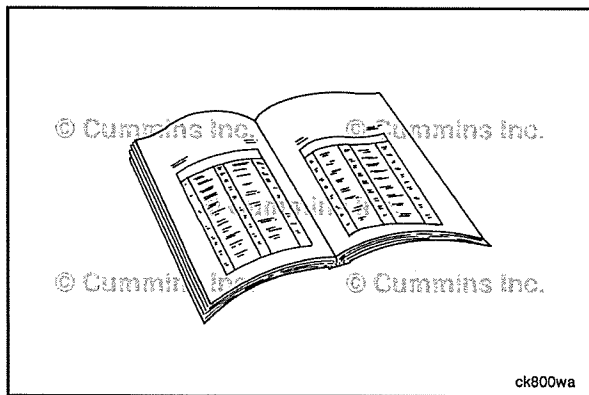
▲ CAUTION ▲

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which can expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine.

- Clean the engine. Refer to Procedure 000-009 in Section 0.
- Use contact cleaner, Part Number 3824510 or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, or cleaning solution does **not** get inside the fuel system.





▲ WARNING ▲

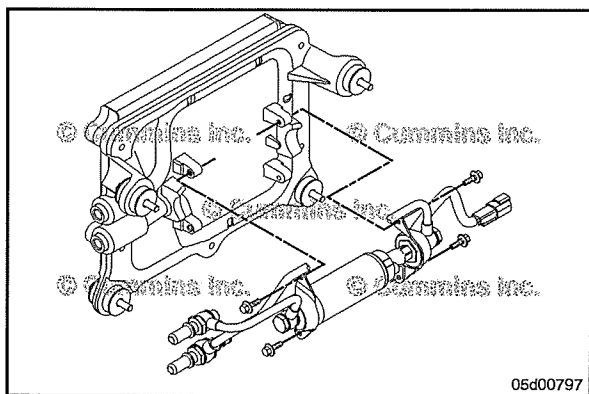
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



▲ WARNING ▲

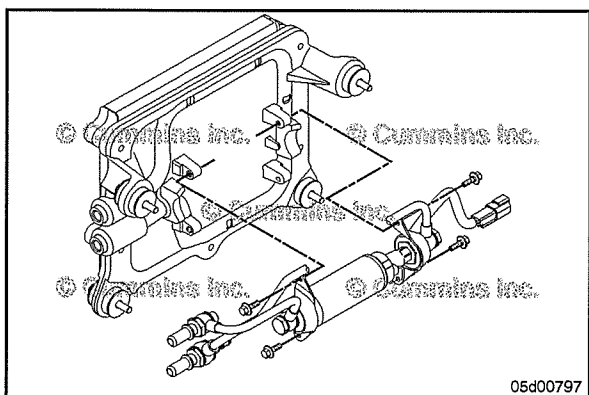
The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.

- Disconnect the battery cables. Refer to the OEM service manual.
- Disconnect the electric fuel priming pump from the engine wiring harness.
- Remove the fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Remove the ECM cooling plate. Refer to Procedure 006-006 in Section 6.



Remove

Remove the electric lift pump from the ECM cooling plate.



Install

Install the electric lift pump to the ECM cooling plate.



Tighten the mounting capscrews.

Torque Value: 10 N•m [89 in-lb]

NOTE: The ECM cooling plate check valve **must** be free of debris and installed into the lower ECM cooling plate port (outlet port).

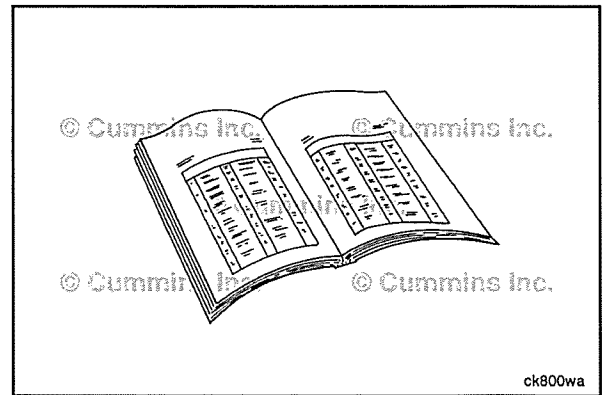
NOTE: Hold the fuel lines, as illustrated, so they can **not** come into contact with each other or the engine block.

Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

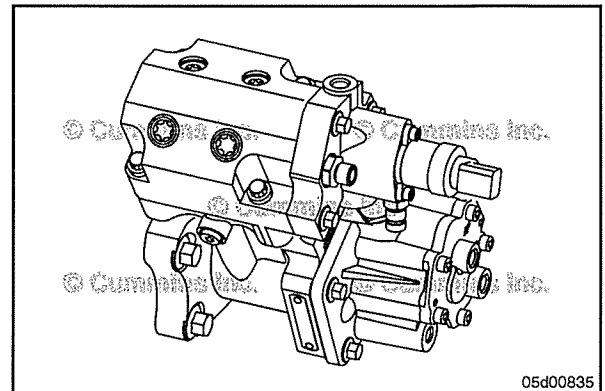
- Install the ECM cooling plate to the engine block. Refer to Procedure 006-006 in Section 6.
- Install all fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

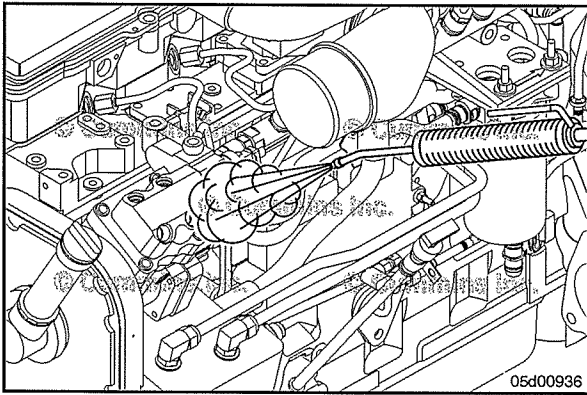


Fuel Pump Head Outlet Fitting (005-226)

General Information

This procedure refers to the Cummins® Common Rail fuel system.





Preparatory Steps

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ CAUTION ⚠

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine.

- Clean the engine. Refer to Procedure 000-009 in Section 0.
- Use electrical contact cleaner, Part Number 3824510 or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, or cleaning solution does **not** get inside the fuel system.

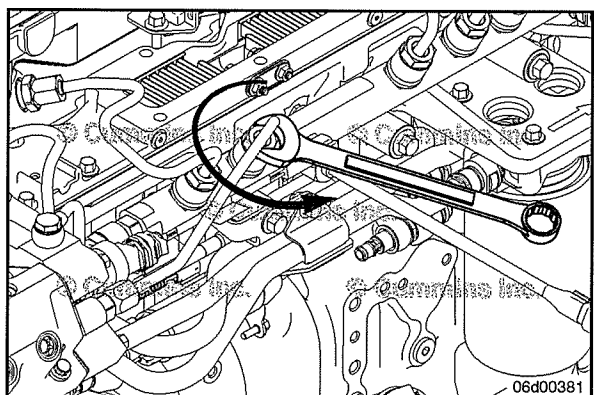
⚠ WARNING ⚠

Normal engine operation creates highly pressurized fuel in the fuel line which will remain in the fuel line after engine shutdown. Never open the fuel system when the engine is operating. Before servicing the fuel system, always loosen the pump to rail fuel line at the rail to vent the pressure. Keep hands clear of the line when loosening. High pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

NOTE: A machined slot in this fitting directs the fuel spray towards the engine block.

Before servicing the fuel system, loosen the pump-to-rail line at the rail to vent the pressure.

Keep hands clear of the line when loosening.



⚠ WARNING ⚠

The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris or dirt can cause personal injury.

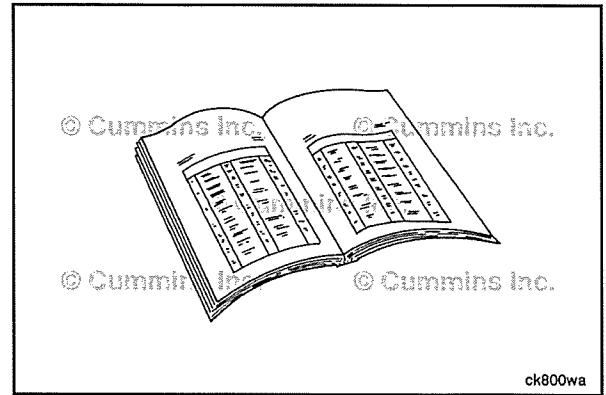
⚠ WARNING ⚠

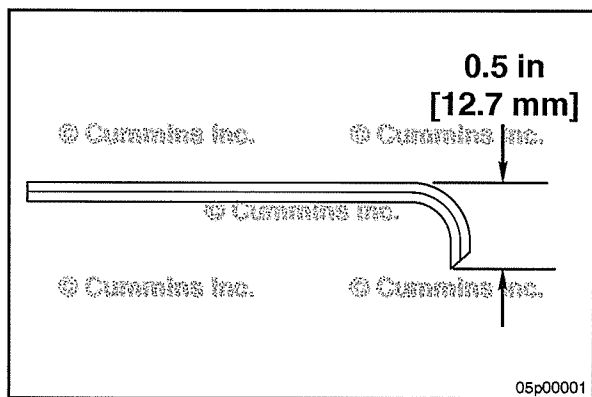
Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

⚠ WARNING ⚠

Do not vent the fuel system on a hot engine; this can cause fuel to spill onto a hot exhaust manifold, which can cause a fire.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Thoroughly clean the entire fuel pump. Dry the fuel pump with compressed air.
- Close the fuel supply valve. Refer to the OEM service manual.
- Remove the high-pressure fuel line from the fuel pump actuator housing. Refer to Procedure 006-051 in Section 6.
- Remove the fuel drain line from the actuator housing. Refer to Procedure 006-013 in Section 6.
- Remove the fuel supply line from the fuel pump actuator housing. Refer to Procedure 006-024 in Section 6.
- Remove the fuel pump actuator housing from the high-pressure fuel pump. Refer to Procedure 005-228 in Section 5.





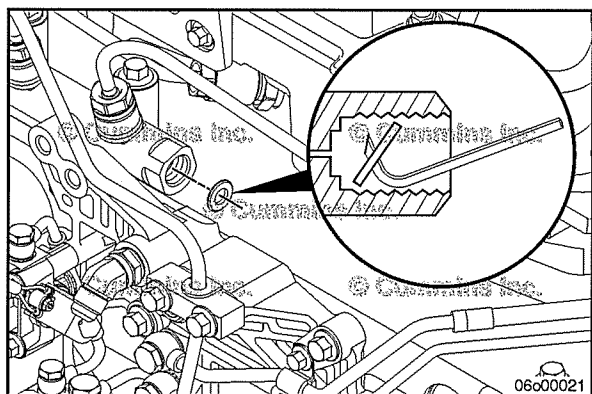
Remove

Removal of a “flat washer”

The flat sealing washer is swaged into the inlet fitting bore during installation.

A special tool can be created to aid in its removal by grinding a 45 degree angle on the short leg of a 1/8-inch or 3/16-inch Allen wrench, so that the wrench is no longer than 13-mm [1/2-in] long (measured from the outside of the long leg).

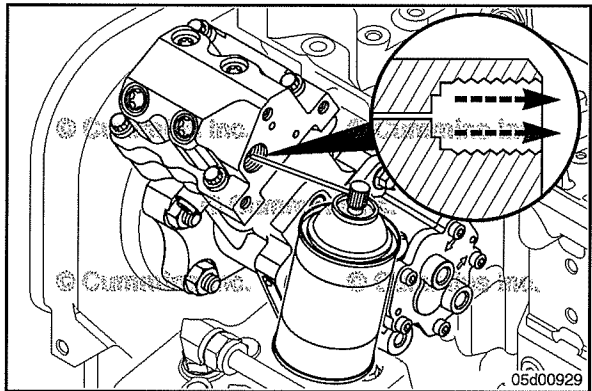
This tool acts as a mini heel bar to pry out the sealing washer without damaging the back of the hole.



Remove the fuel pump head outlet fitting.

Pry out the old sealing washer from the threaded hole in the back of the high-pressure pump head using the modified Allen wrench.

NOTE: Considerable force is required to remove the sealing washer.



Clean and Inspect for Reuse

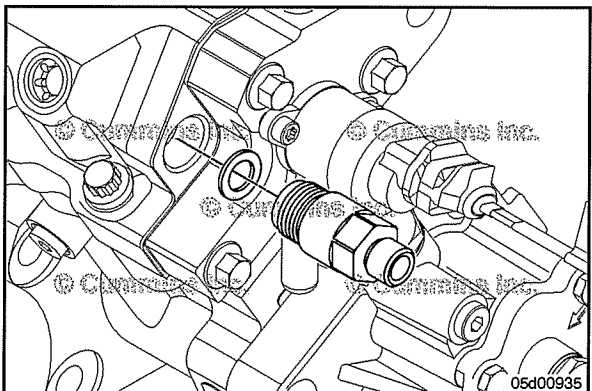
Clean the threaded hole in the high-pressure pump head with electrical contact cleaner, Part Number 3824510 or equivalent.



Inspect the threads and cavity in the high-pressure pump head for burrs or debris.

Inspect the seal washer end of the outlet fitting. There should be a polished crown that is free of nicks or inclusions. If the crown is damaged or severely flattened, the male union **must** be replaced.

Clean any burrs with a wire brush, then flush the bore clean.



Install

NOTE: This joint is designed to seal in excess of 179,264 kPa [26,000 psi]. Seal washers **must not** be reused.



Install a new seal washer onto the outlet fitting. The seal washer should pilot into the outlet fitting. A small amount of clean grease, such as assembly lubricant, will help in keeping the seal attached to the outlet fitting during installation.

Torque Value:

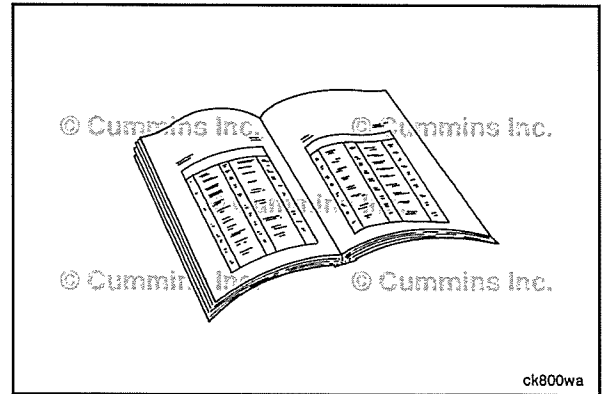
Step 1	13.6 N•m	[120 in-lb]
Step 2	Rotate 90 degrees	

Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

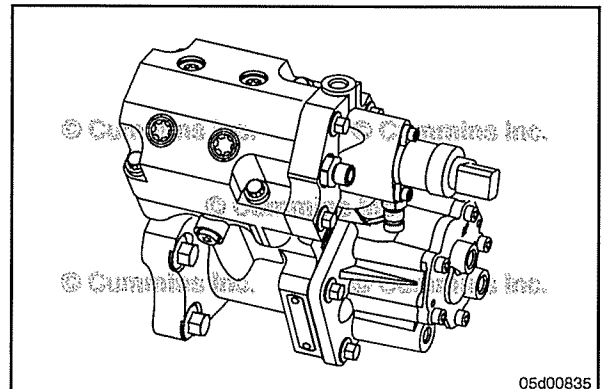
- Install the fuel pump actuator housing to the high-pressure fuel pump. Refer to Procedure 005-228 in Section 5.
- Install the high-pressure fuel line to the fuel pump actuator housing. Refer to Procedure 006-051 in Section 6.
- Install the fuel drain line to the actuator housing. Refer to Procedure 006-013 in Section 6.
- Install the fuel supply line to the fuel pump actuator housing. Refer to Procedure 006-024 in Section 6.
- Open the fuel supply valve. Refer to the OEM service manual.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.
- Perform several throttle snaps so that increased fuel rail pressure will be developed.

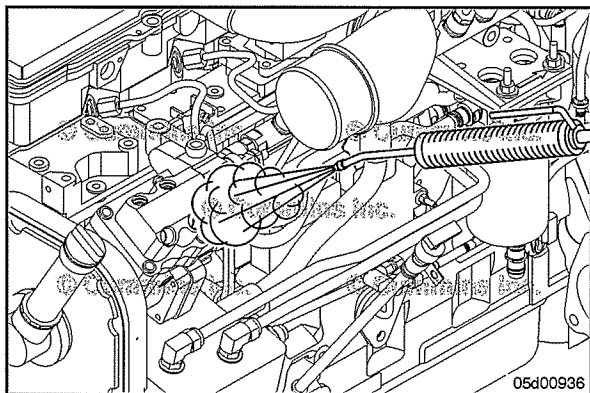


Fuel Pump Head (005-227)

General Information

This procedure refers to the Cummins® Common Rail fuel system.





Preparatory Steps

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠ WARNING ⚠

Depending on the circumstances, diesel fuel is flammable. When inspecting or performing service or repairs on the fuel system, to reduce the possibility of fire and resulting severe personal injury, death or property damage, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area.

⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ CAUTION ⚠

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

NOTE: See the following procedure for fuel system diagnostic procedures and component specifications. Refer to Procedure 005-236 in Section 5.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine.

Use the following two procedures to clean the engine.

- Refer to Procedure 000-009 in Section 0.
- Refer to Procedure 204-008 in Section i.

Use contact cleaner, Part Number 3824510 or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.

- Make sure that debris, water, steam, or cleaning solution does **not** get inside the fuel system.

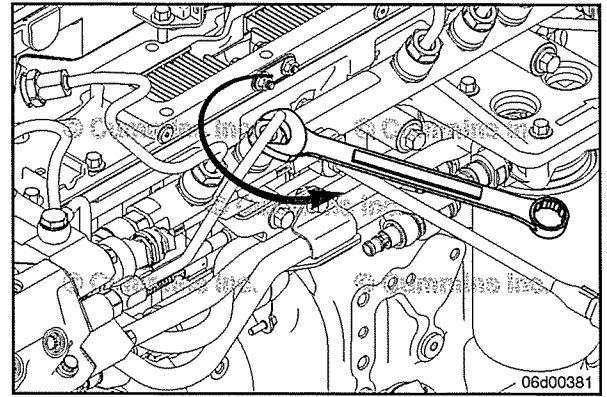
⚠ WARNING ⚠

Normal engine operation creates highly pressurized fuel in the fuel line which will remain in the fuel line after engine shutdown. Never open the fuel system when the engine is operating. Before servicing the fuel system, always loosen the pump to rail fuel line at the rail to vent the pressure. Keep hands clear of the line when loosening. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

NOTE: A machined slot in this fitting directs the fuel spray toward the engine block.

Before servicing the fuel system, loosen the pump-to-rail line at the rail to vent the pressure.

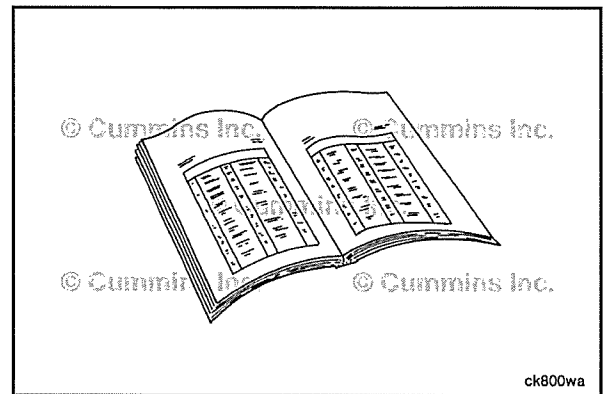
Keep hands clear of the line when loosening.



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

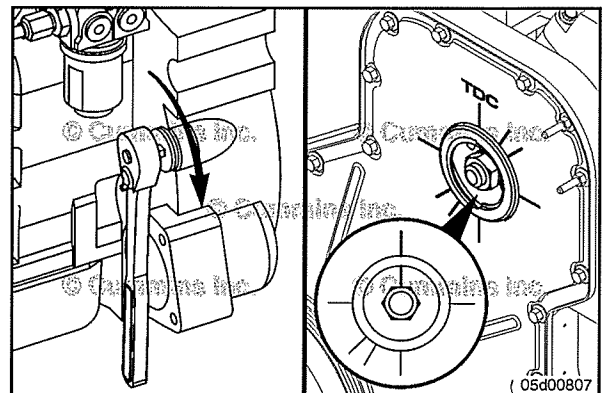
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the high-pressure fuel line from the high-pressure pump. Refer to Procedure 006-051 in Section 6.
- Remove the fuel drain line from the fuel pump actuator housing. Refer to Procedure 006-013 in Section 6.
- Remove the fuel supply line from the fuel pump actuator housing. Refer to Procedure 006-024 in Section 6.
- Disconnect the wiring harness from the fuel pump actuator.
- Remove the fuel pump actuator housing. Refer to Procedure 005-228 in Section 5.

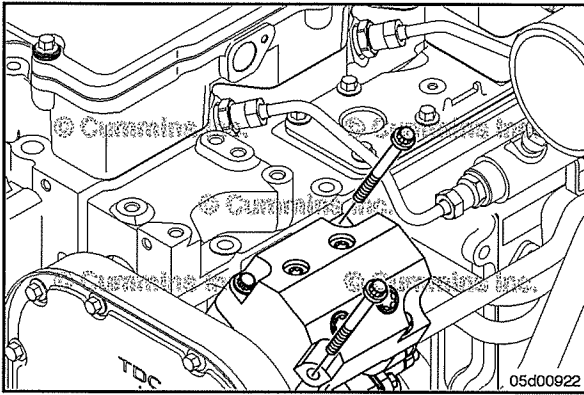


Remove

Remove the fuel pump drive gear cover.

Locate top dead center for cylinder number 1 by barring the engine slowly until the line on the pump gear lines up with the line on the gear cover.

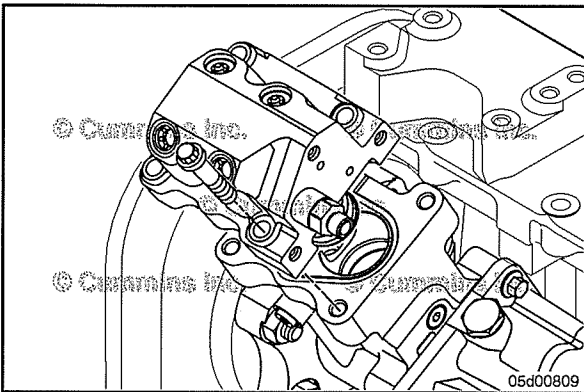




⚠ CAUTION ⚠

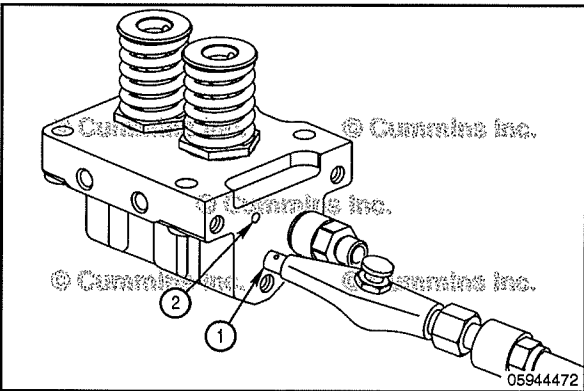
Do not use air tools. The use of air tools will possibly damage the fuel pump.

Remove two of the four capscrews that are located diagonally from one another.



Remove the last two capscrews. Alternately loosen the capscrews to avoid binding. Loosen each capscrew about one turn at a time.

Carefully lift the fuel pump head from the camshaft housing, being careful to keep the tappet springs attached to the pump head. Place the head on a clean surface.



Clean and Inspect for Reuse

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Special care **must** be taken to be sure these parts are kept extremely clean if removed. Cover the camshaft housing with a clean shop towel while the head is removed.

Do **not** use cleaning agents, other than contact cleaner, on pump components.

NOTE: Do **not** perform the following test without the springs and spring retainers installed.

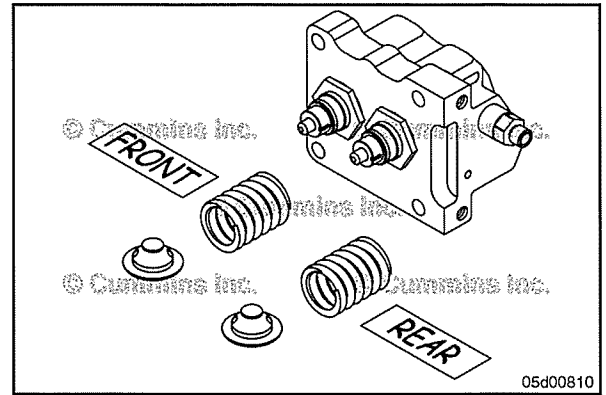
- 1 Drain
- 2 Inlet.

With the springs and spring retainers installed, blow compressed air (at least 276 kPa [40 psi]) into the inlet (2).

The plungers should extend to the tappet spring retainers. If the pumping plungers are stuck and do **not** extend to the tappet spring retainers, replace the fuel pump head.

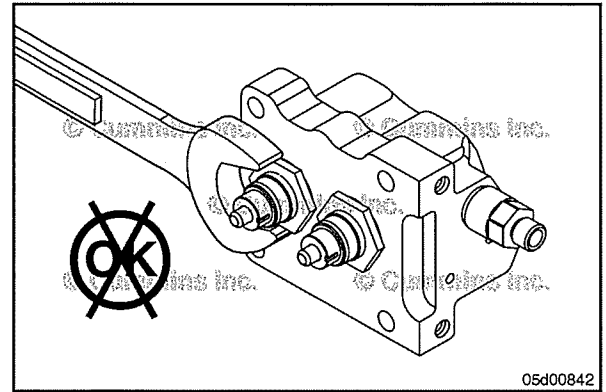
Remove the springs and spring retainers from the barrel retainers.

Make certain to keep track of which spring came from the front and rear. It is recommended that these parts be installed in the same location, even if a new high-pressure pump head is installed.



⚠CAUTION⚠

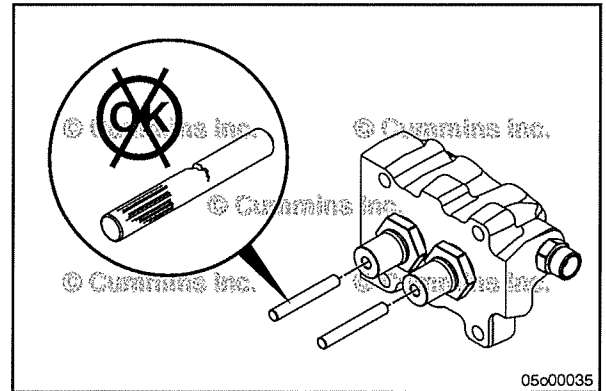
Do not remove the barrel retainers. Damage to the pump head and barrel retainers will result.



⚠CAUTION⚠

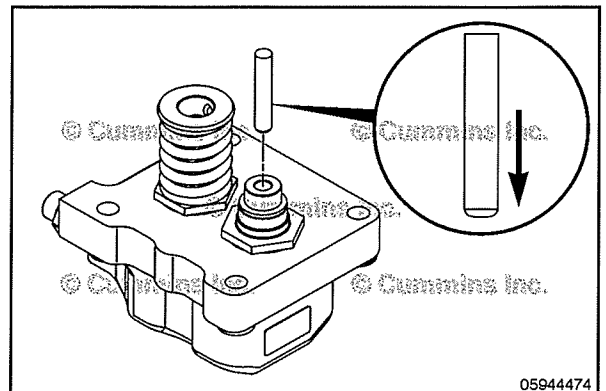
Each plunger must be installed in the same orientation and in the same barrel, or engine damage can result. Marking the bottoms of the plungers with a felt tip marker will help to make sure that correct orientation is maintained.

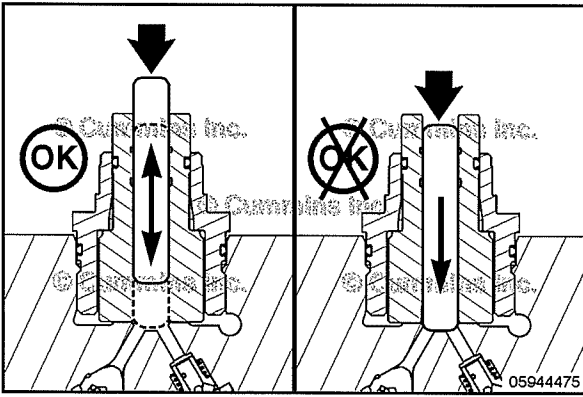
Remove and inspect the plungers. Slight discoloration can be evident. Deep scoring **must not** be present. If scoring or scratches exist that can be felt, the fuel pump head **must** be replaced.



Install the plungers into the barrel retainers.

NOTE: Some fuel pump heads are built with non-symmetric pumping plungers. The crowned end of the pumping plunger must be installed into the barrel. If the plunger is installed in the wrong orientation, fuel pump head damage will result.

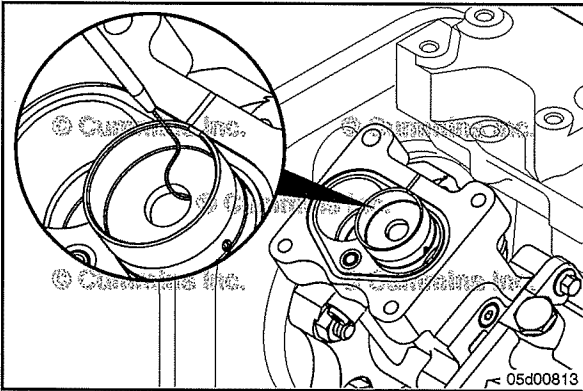




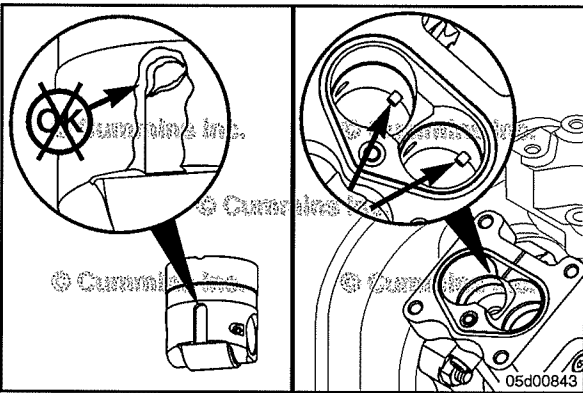
Use a finger to test the plunger action.

- Press the plunger halfway into the barrel quickly, with a pumping motion.
- Release it quickly.

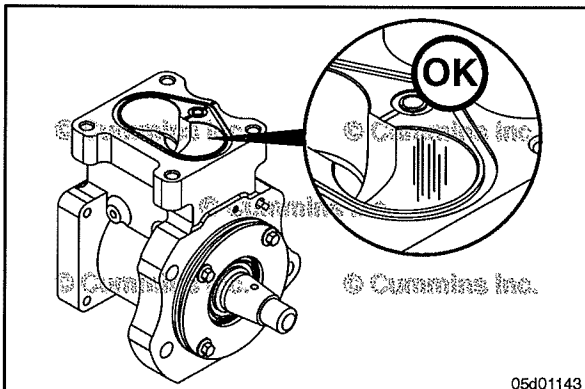
If the check valves in the fuel pump head are good, the trapped air will cause the plunger to bounce or rebound. If the plunger falls to the bottom, one of the check valves in the fuel pump head may be damaged.



While the fuel pump head is removed, inspect the camshaft housing. The tappets can be removed. Use an o-ring pick as the removal tool.



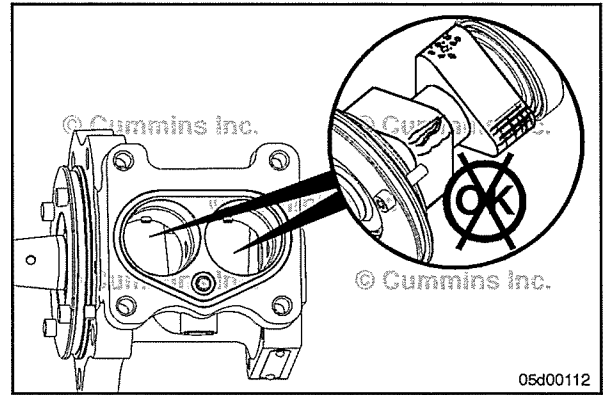
Inspect the tappet guide pins and tappet guide pin grooves for excessive wear. If more than 25-percent guide pin or groove wear is observed, the fuel pump **must** be replaced.



Normal operation creates vertical grooves in the cylinder bores of the fuel pump camshaft housing. These grooves are **not** an indication of a malfunction.

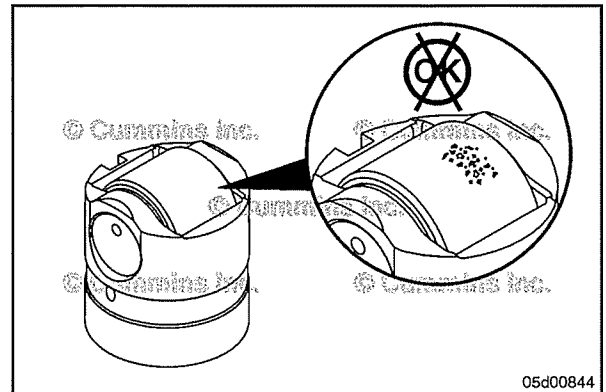
Camshaft housings with grooves are acceptable for reuse.

With the camshaft housing tappets removed, inspect the camshaft for wear.

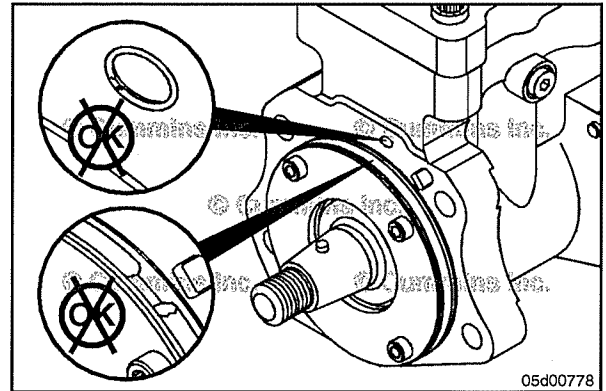


Inspect the tappet rollers for wear.

Normal operation creates bands around the circumference of the tappet roller. These bands are **not** an indicator of a malfunction. Tappet rollers with bands are acceptable for reuse.



If damage to the camshaft, tappets, or camshaft housing is observed, it is possible the fuel pump is **not** receiving adequate lubricating oil. When replacing the fuel pump, inspect the gear housing to make sure no blockages exist in the oil supply to the fuel pump.

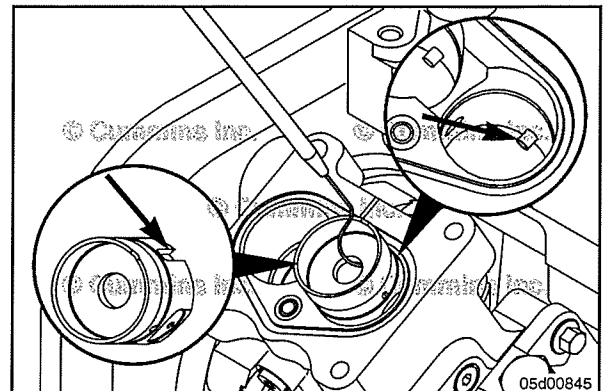


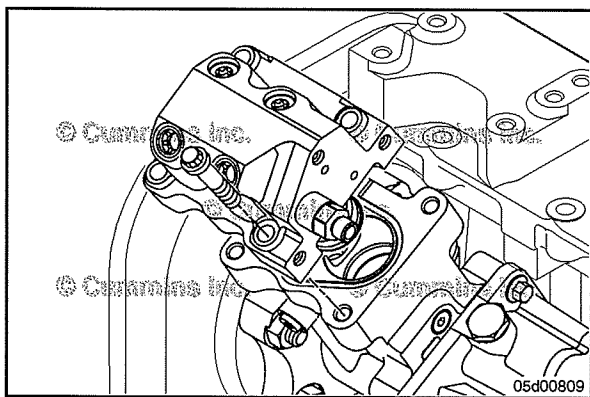
Install

Install the tappets in the original tappet bores.

Be certain the tappets are installed in the original locations.

Be certain that the tappet guide pins engage the guide pin grooves.





Install new fuel pump head o-rings onto the camshaft housing.



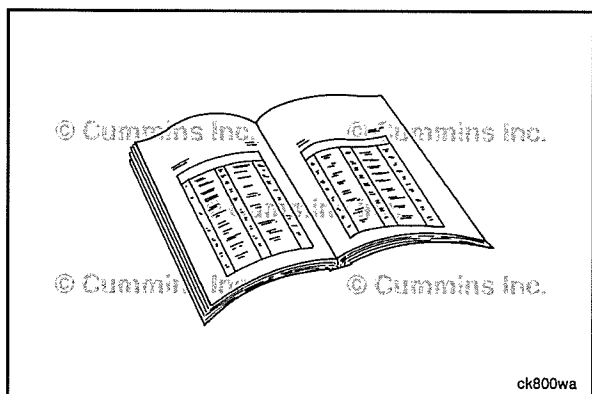
If installing a new or rebuilt pump head, install the new tappet springs and retainers provided with the pump head.

Place the high-pressure pump head onto the high-pressure pump camshaft housing.

Draw the high-pressure pump head down by alternately tightening the four high-pressure pump head capscrews until the head just contacts the camshaft housing.

Tighten the four high-pressure pump head capscrews to the final torque.

Torque Value: 68 N•m [50 ft-lb]



Finishing Steps

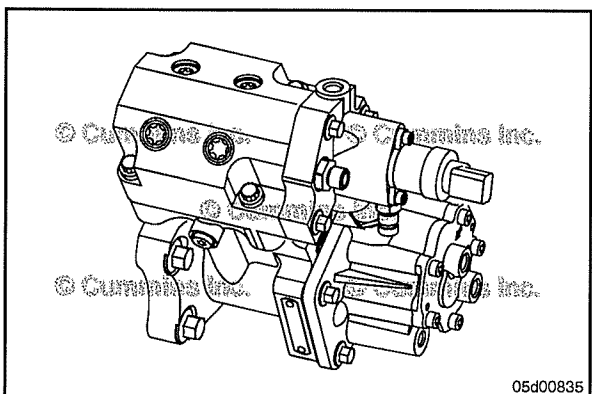


⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the fuel pump actuator housing. Refer to Procedure 005-228 in Section 5.
- Connect the high-pressure fuel supply line. Refer to Procedure 006-051 in Section 6.
- Connect the fuel drain line to the fuel pump actuator housing. Refer to Procedure 006-013 in Section 6.
- Connect the fuel supply line to the fuel pump actuator housing. Refer to Procedure 006-024 in Section 6.
- Connect the engine harness to the fuel pump actuator.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Fuel Pump Actuator Housing (005-228)

General Information

This procedure refers to the Cummins® Common Rail fuel system.

Preparatory Steps

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ CAUTION ⚠

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine.

Refer to Procedure 000-009 in Section 0.

- Clean the engine. Refer to Procedure 000-009 in Section 0.
- Use electrical contact cleaner, Part Number 3824510 or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, or cleaning solution does **not** get inside the fuel system.

⚠ WARNING ⚠

Normal engine operation creates highly pressurized fuel in the fuel line which will remain in the fuel line after engine shutdown. **Never** open the fuel system when the engine is operating. Before servicing the fuel system, always loosen the pump to rail fuel line at the rail to vent the pressure. Keep hands clear of the line when loosening. High pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

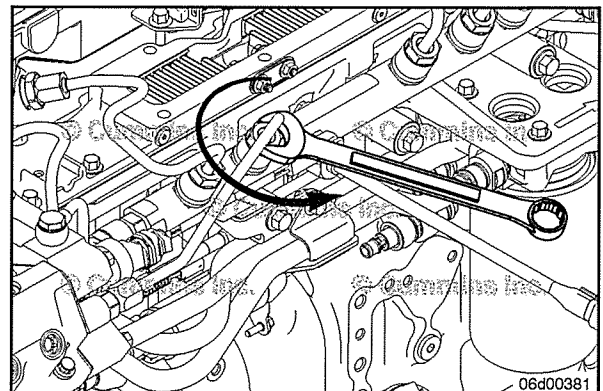
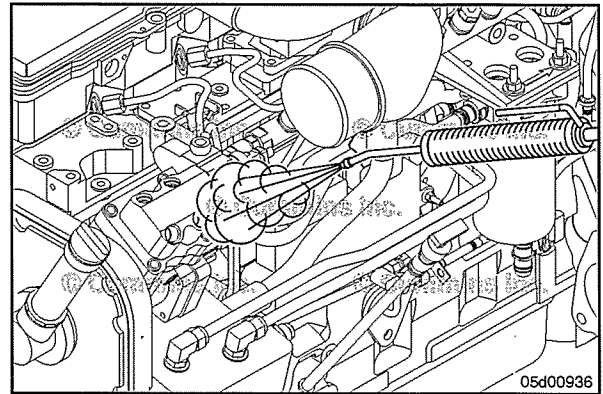
NOTE: A machined slot in this fitting directs the fuel spray towards the engine block.

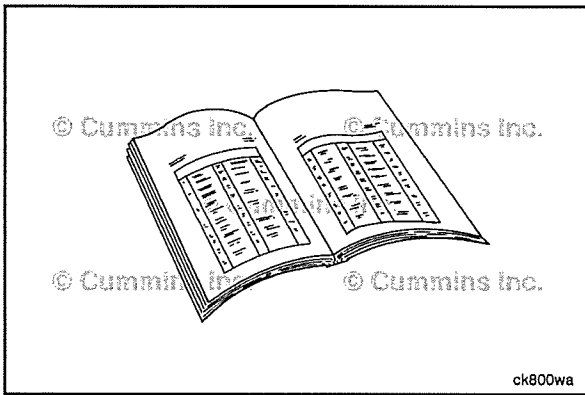
Before servicing the fuel system, loosen the pump-to-rail line at the rail to vent the pressure.

Keep hands clear of the line when loosening.

Tighten the fuel rail nut.

Torque Value: 65 N•m [48 ft-lb]





⚠ WARNING ⚠

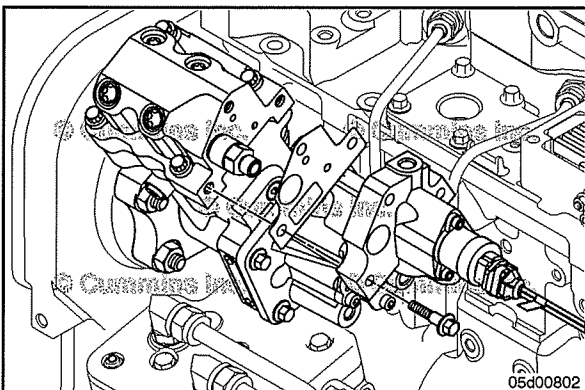
The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Disconnect the wire harness from the fuel pump actuator.
- Disconnect the fuel supply line from the fuel pump actuator housing. Refer to Procedure 006-024 in Section 6.
- Disconnect the high-pressure fuel line from the fuel pump actuator housing. Refer to Procedure 006-051 in Section 6.
- Disconnect the fuel drain from the fuel pump actuator housing. Refer to Procedure 006-013 in Section 6.
- Remove the upper support bracket from the fuel pump actuator bracket. Refer to Procedure 005-016 in Section 5.



Remove

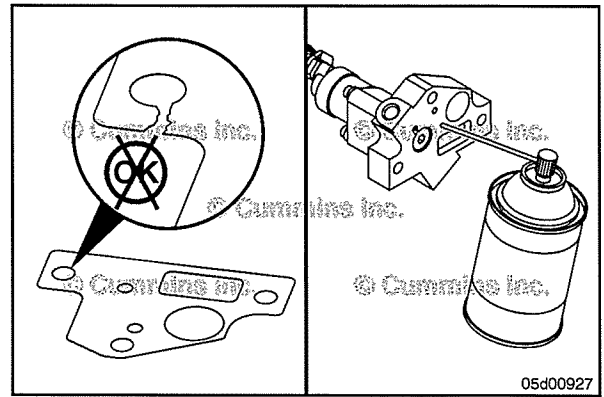
Remove the three bolts that hold the fuel pump actuator housing to the high-pressure fuel pump head.

Remove the fuel pump actuator housing and the gasket.

Clean and Inspect for Reuse

Inspect the fuel pump actuator housing gasket. Do **not** reuse the gasket if the material is cracked, torn, or otherwise damaged.

Be sure that the mounting surfaces of the high-pressure pump head and the fuel control valve adapter block are clean. Use contact cleaner to clean these surfaces.



Install

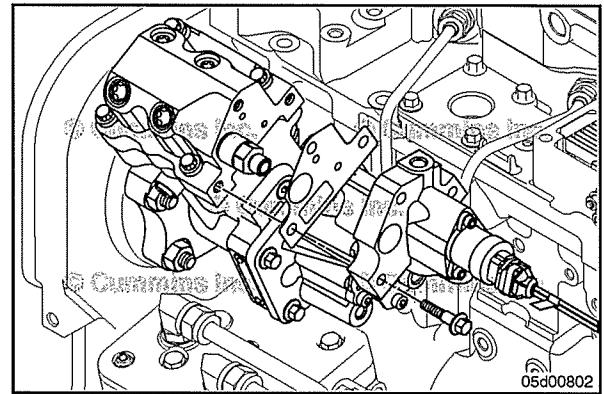
Insert the three mounting bolts through the fuel pump actuator housing.

Install the gasket over the bolts. The gasket **must** be installed dry.

Install the actuator housing.

Tighten the mounting bolts.

Torque Value: 34 N•m [25 ft-lb]

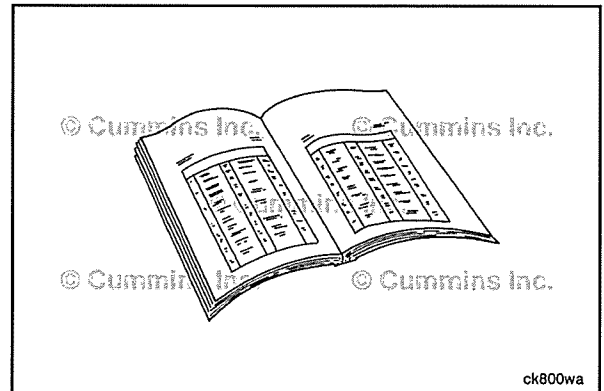


Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

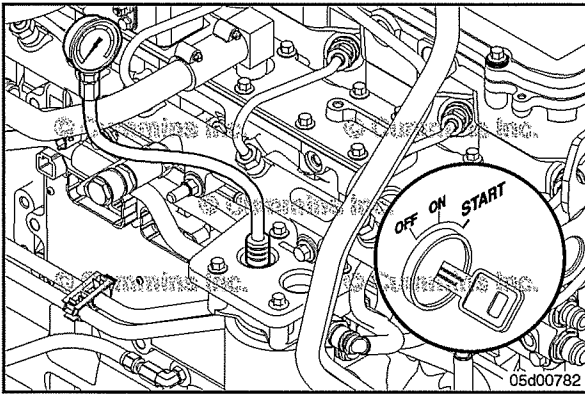
- Install the upper support bracket. Refer to Procedure 005-016 in Section 5.
- Connect the high-pressure fuel line to the fuel pump. Refer to Procedure 006-051 in Section 6.
- Connect the fuel supply line to the fuel pump. Refer to Procedure 006-024 in Section 6.
- Connect the fuel drain line to the fuel pump. Refer to Procedure 006-013 in Section 6.
- Connect the wire harness to the fuel pump actuator.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Fuel System Priming (005-234)

General Information

If the engine has been allowed to run out of fuel or the fuel system has been serviced or repaired, it will be necessary to prime the fuel system.



Prime

⚠ WARNING ⚠

When servicing the engine do not rotate the crankshaft with a high-pressure fuel system joint open. Rotating the crankshaft can create highly pressurized fuel in the fuel system. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.



Install an M10 male Compuchek™ fitting, Part Number 3824842, on the engine fuel filter head inlet port.

To assist in fuel system priming and removing air from the fuel system, an orificed diagnostic fuel line, Part Number 3164621, can be used to bleed air from the low-pressure fuel system.

Install the orificed diagnostic fuel line to the Compuchek™ fitting at the inlet to the pressure side fuel filter.

NOTE: If there is **not** enough clearance to install the 1.0922 mm [0.043 in] orificed diagnostic fuel line, Part Number 3164621, an adapter fitting, Part Number 3932302, and an 1/8-NPT male Compuchek™ fitting, Part Number 3377244, may be used to aid accessibility

Turn the key to the ON position. **do not** start the engine. Allow the priming pump to run and observe the orificed diagnostic fuel line. When a solid stream of fuel exits the line, the initial priming process is complete. It may be necessary to repeat this process two or three times.

Remove the diagnostic fuel line.

⚠ WARNING ⚠

When servicing the engine do not rotate the crankshaft with a high-pressure fuel system joint open. Rotating the crankshaft can create highly pressurized fuel in the fuel system. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

NOTE: The engine can possibly run rough for several minutes until the air is out of the system.

NOTE: If the air is **not** properly purged from the fuel system, the engine will be difficult to start, but will run smoothly once it starts. If the engine is shut OFF, it will be difficult to restart.

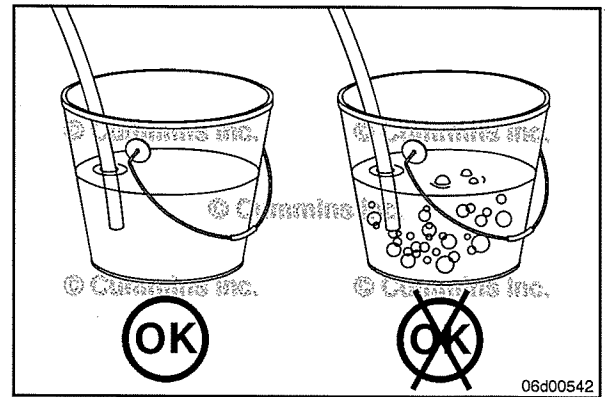
Start the engine and allow it to stabilize.

Attach the diagnostic fuel line, Part Number 3164621, to the Compuchek™ fitting at the inlet to the pressure side fuel filter.

Shut the engine OFF and observe the orificed diagnostic fuel line. Allow the entrapped air to expand and exit through the diagnostic fuel line. Repeat this process up to four times, or until air no longer exits the diagnostic fuel line.

NOTE: Remove the orificed diagnostic fuel line prior to starting the engine. The engine will be difficult to start if the orificed diagnostic fuel line is installed during starting.

If air continues to exit the diagnostic fuel line after four or more repetitions, check the suction side of the fuel system for leaks. Refer to Procedure 006-003 in Section 6.



⚠ WARNING ⚠

When servicing the engine do not rotate the crankshaft with a high-pressure fuel system joint open. Rotating the crankshaft can create highly pressurized fuel in the fuel system. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

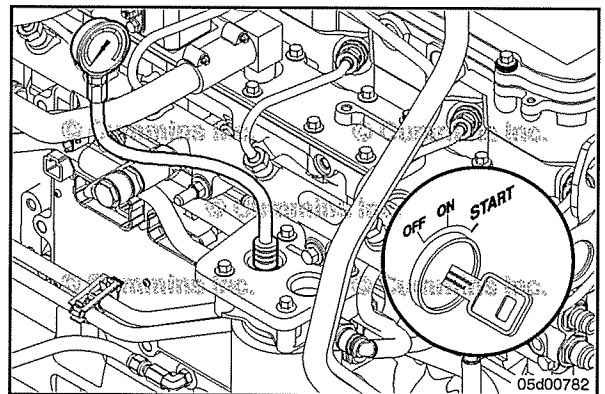
NOTE: If the air is **not** properly purged from the fuel system, the engine will be difficult to start, but will run smoothly once it starts. If the engine is shut OFF, it will be difficult to restart.

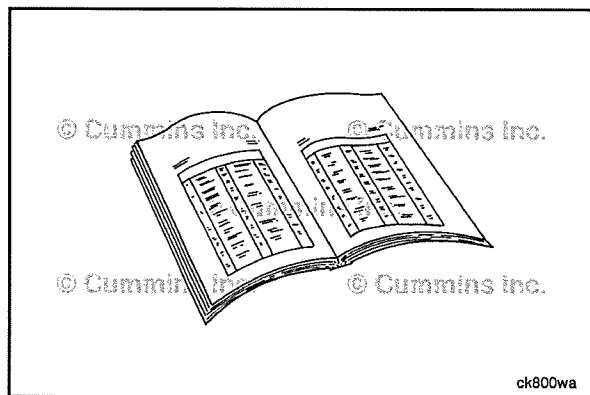
If the engine will **not** start, attach the diagnostic fuel line, Part Number 3164621, to the pressure side fuel filter and crank the engine for 15 seconds.

NOTE: Crank the engine in 15 second intervals with a 15 second break between cranking. This reduces the possibility of overheating the starter motor.

Stop cranking the engine and observe the orificed diagnostic fuel line. Allow the entrapped air to expand and exit through the diagnostic fuel line. Repeat this process up to four times or until the engine starts.

If air continues to exit the diagnostic fuel line after four or more repetitions, check the suction side of the fuel system for leaks. Refer to Procedure 006-003 in Section 6.





Fuel System Diagnostics (005-236)

General Information

⚠ WARNING ⚠

Normal engine operation creates highly pressurized fuel in the fuel line which will remain in the fuel line after engine shutdown. Never open the fuel system when the engine is operating. Before servicing the fuel system, always loosen the pump-to-rail fuel line at the rail to vent the pressure. Keep hands clear of the line when loosening. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

⚠ CAUTION ⚠

Do not engage the starter motor for more than 30 seconds at a time. Allow 2 minutes between cranking intervals.

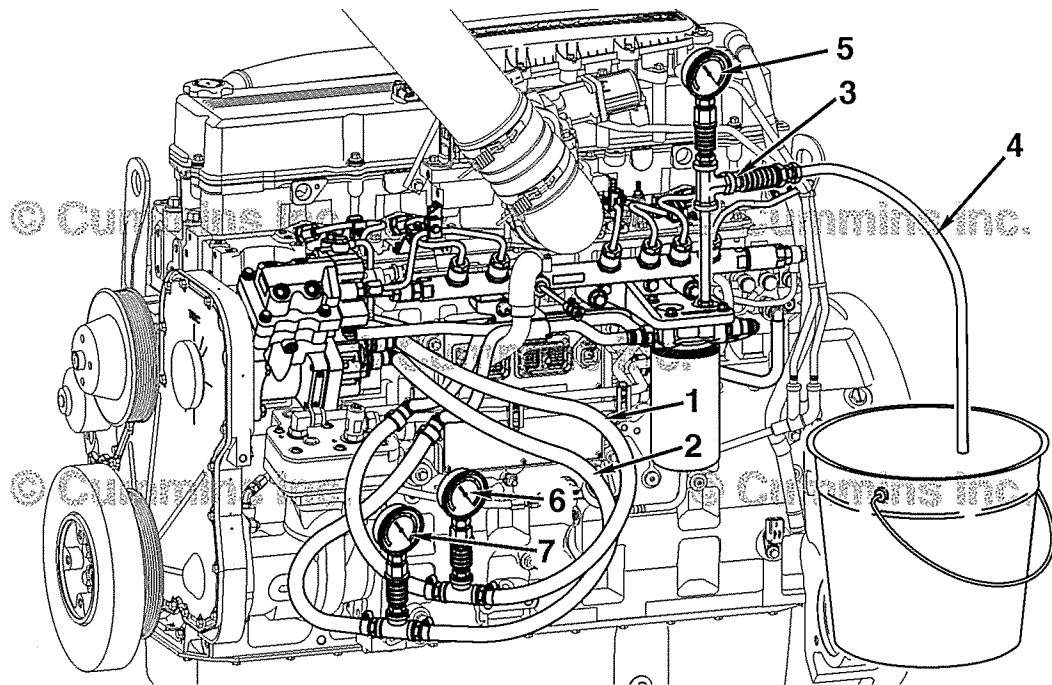
⚠ CAUTION ⚠

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

The following procedure contains measurement steps and specifications for the engine fuel system components.

NOTE: This procedure is **not** intended to take the place of the troubleshooting tree repair directions. Use the appropriate troubleshooting tree for repair directions.

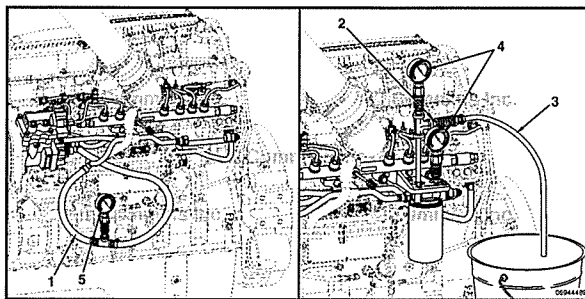
The diagrams below are intended to supplement the setup instructions in this procedure. Please refer to the appropriate setup section for step by step instructions.



05944488

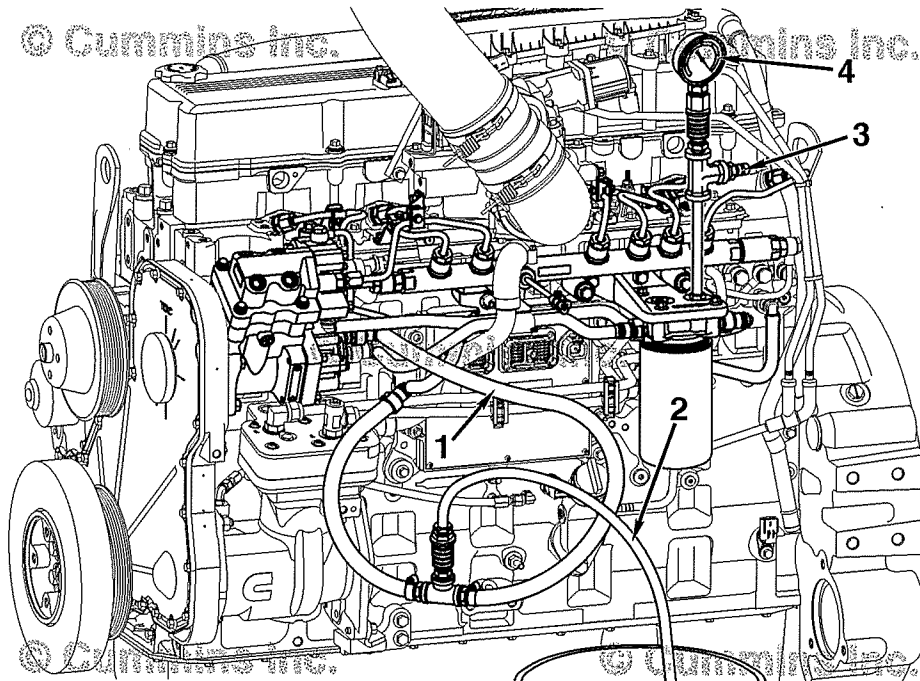
Engine Will Start - Engine Mounted Filter

- 1 Diagnostic Fuel Line, Part Number 4918895
- 2 Diagnostic Fuel Line, Part Number 4918895
- 3 "T" Adapter Fitting
- 4 Diagnostic Fuel Line 0.043-inch orificed, Part Number 3164621
- 5 Pressure Gauge 0 to 1034 kPa [0 to 150 psi]
- 6 Vacuum Gauge 0 to 762 mm-Hg [0 to 30 in-Hg]
- 7 Pressure Gauge 0 to 1034 kPa [0 to 150 psi].



Engine Will Start - Remote Mounted Filter/On Engine
Filter

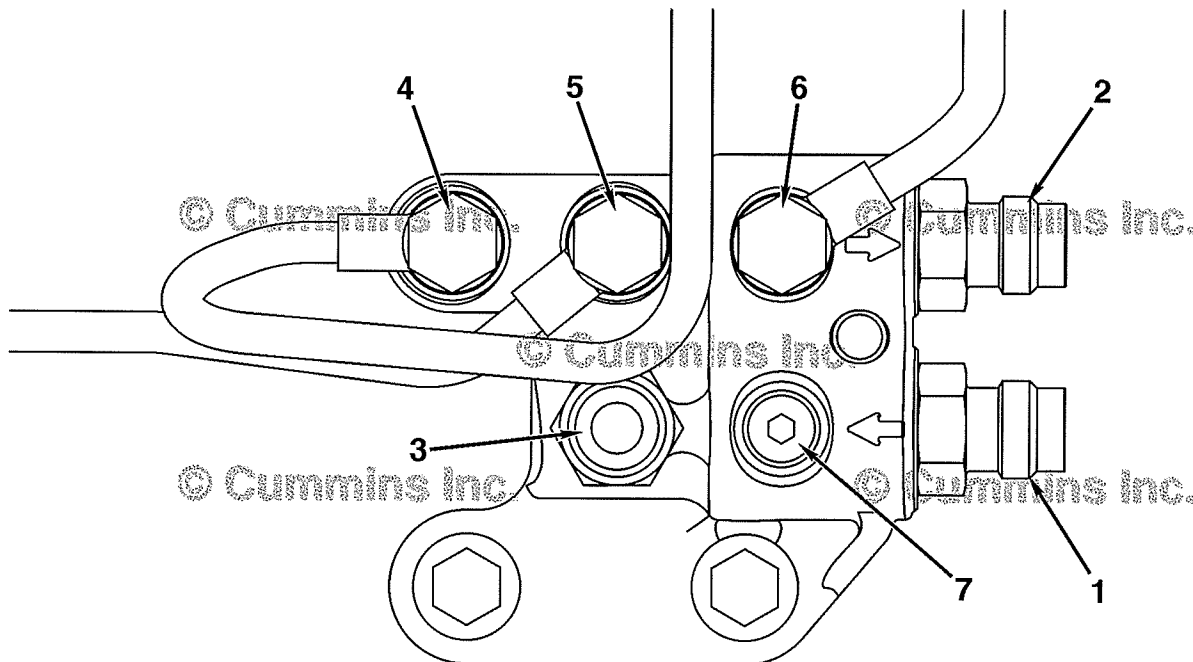
- 1 Diagnostic Fuel Line, Part Number 4918895
- 2 "T" Adapter Fitting
- 3 Diagnostic Fuel Line 0.043-inch orificed, Part Number 3164621
- 4 Pressure Gauge 0 to 1034 kPa [0 to 150 psi]
- 5 Vacuum Gauge 0 to 762 mm-Hg [0 to 30 in-Hg].



Engine Will Not Start - Remote Mounted

05944485

- 1 Diagnostic Fuel Line, Part Number 4918895
- 2 Diagnostic Fuel Line 0.043-inch orificed, Part Number 3164621
- 3 Compuchek™ fitting or "T" Adapter Fitting
- 4 Pressure Gauge 0 to 1034 kPa [0 to 150 psi].



Fuel Return Manifold

05944487

- 1 Original Equipment Manufacturer (OEM) Inlet
- 2 OEM Return
- 3 To Transfer Pump
- 4 Pressure Relief Valve Return Flow
- 5 Pump Head Return Flow

- 6 Injector Return Flow (can also check drain line restriction here)
- 7 Unused Port (can also check OEM inlet restriction here).

Preparatory Steps

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ WARNING ⚠

Depending on the circumstance, diesel fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

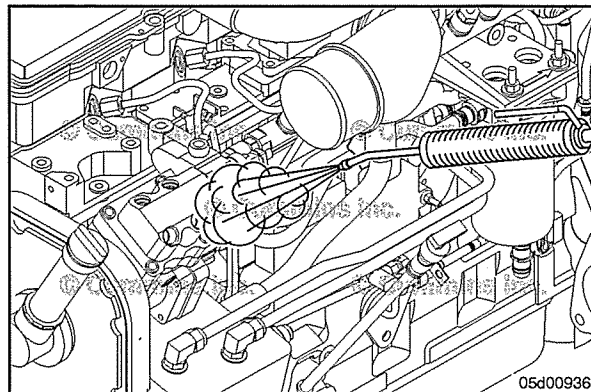
⚠ WARNING ⚠

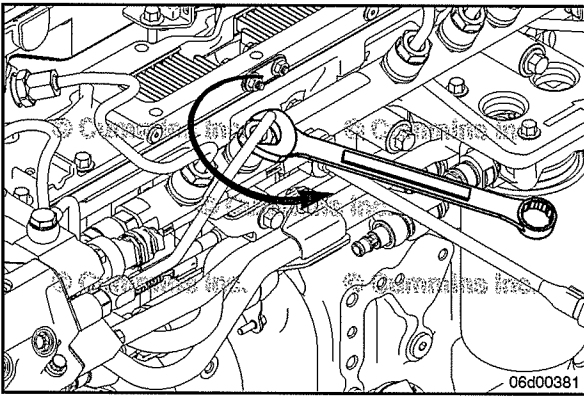
Do not vent the fuel system on a hot engine. This can cause fuel to spill onto a hot exhaust manifold, which can cause a fire.

⚠ CAUTION ⚠

Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel system connections clean during removal and installation. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are not cleaned, resulting in damage to the fuel system and engine.

- Clean the engine. Refer to Procedure 000-009 in Section 0.
- Use contact cleaner, Part Number 3824510, or equivalent, to thoroughly clean all fuel lines before removal from the engine. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, or cleaning solution does **not** enter the fuel system.





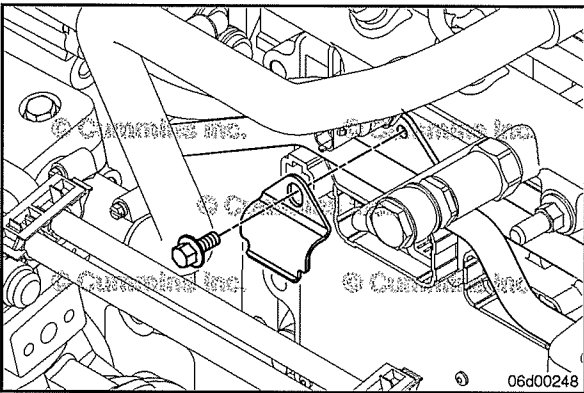
▲ WARNING ▲

Normal engine operation creates highly pressurized fuel in the fuel line which will remain in the fuel line after engine shutdown. Never open the fuel system when the engine is in operation. Before servicing the fuel system, always loosen the pump-to-rail fuel line at the rail to vent the pressure. Keep hand clear of the line when loosening. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

- Before servicing the fuel system, loosen the pump-to-rail line at the rail to vent the pressure. Keep hands clear of the line when loosening. Tighten the fuel rail nut, once pressure has been released.

Torque Value: 65 N•m [48 ft-lb]

NOTE: A machined slot in this fitting directs the fuel spray toward the engine block.

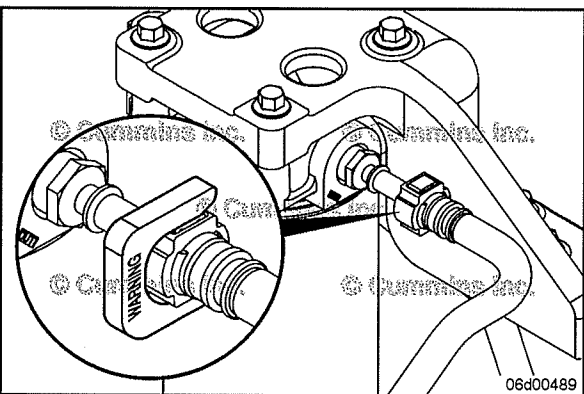


Low-Pressure System Check

Initial Setup

The low-pressure system check is designed to help troubleshoot the low-pressure side fuel system using one setup to take multiple fuel system checks. This procedure is optimized for engines with engine-mounted pressure-side filter. See supplementary diagrams in the general section of this procedure to view setup differences.

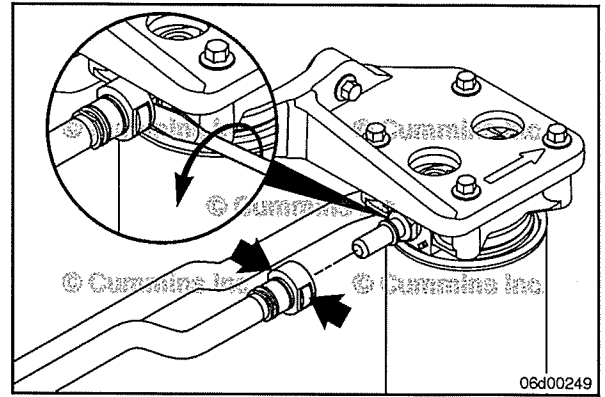
- Remove the clasp from the fuel line brace. This will allow the fuel lines to move so that test equipment can be installed properly.



- Disconnect the quick disconnect style fuel lines from the gear pump inlet and outlet by pressing in the locking tangs on both sides of the quick disconnect fitting OR slide the removal tool, Part Number 4918878, over the locking tangs.

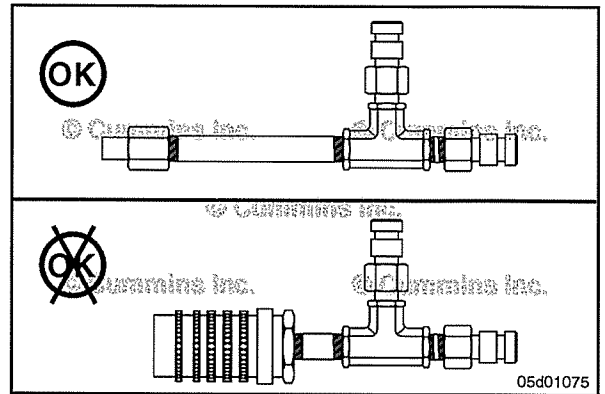
NOTE: Make sure the tool is removed from the fuel line as soon as possible after the line has been disconnected. Inadvertently leaving the tool in place can result in fuel leaks.

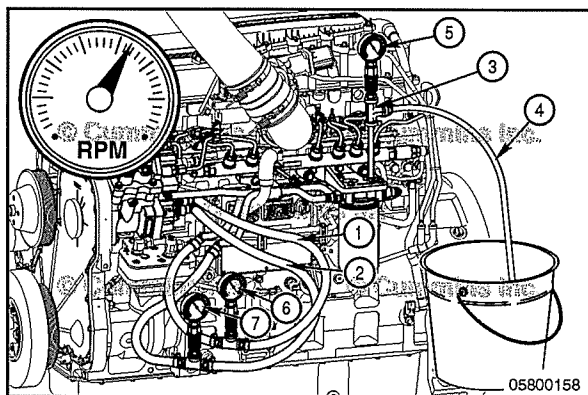
- To aid in removal, a screwdriver can be inserted between the fuel line end and the quick disconnect male union. After pressing the opposing locking tangs, twisting the flat blade of the screwdriver helps to remove the fuel line.



- Construct a "T" adapter fitting using one adapter fitting, Part Number 3932302, a 1/8 inch NTP pipe (of appropriate length for application), a 1/8 inch NPT "T" fitting, and two 1/8-inch NPT Compuchek™ fittings, Part Number 3042618

NOTE: Do **not** use female Compuchek™ fitting, Part Number 3376859, when constructing the "T" adapter. If female Compuchek™ fitting, Part Number 3376859, is used, pressure readings will be inaccurate.





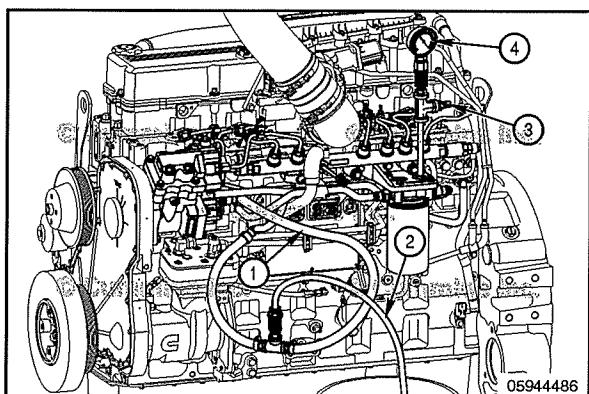
For Engine Will Start

- 1 Install one diagnostic fuel line (1), Part Number 4918895, between the gear pump fuel supply line and the gear pump inlet (upper fuel line fitting).
- 2 Install the second diagnostic fuel line (2), Part Number 4918895, between the gear pump outlet and the pressure-side fuel filter fuel supply line (lower fuel line fitting).
- 3 Install the "T" adapter fitting (3) at the outlet port of the pressure-side fuel filter.
- 4 Install a 0.043-inch orificed diagnostic fuel line (4), Part Number 3164621. Insert the fuel hose into the fuel tank or into a fuel collection device. This diagnostic line is used to simulate operating the engine at rated fuel system flow rate.
- 5 Install a 0 to 1034 kPa [0 to 150 psi] pressure gauge (5) at the "T" adapter fitting at the outlet of the fuel filter head.
- 6 Attach a 0 to 762 mm-Hg [0 to 30 in-Hg] vacuum gauge (6) on the diagnostic fuel line, Part Number 4918895, connected at the gear pump inlet.
- 7 Install a 0 to 1034 kPa [0 to 150 psi] pressure gauge (7) at the Compuchek™ fitting on the diagnostic fuel line, Part Number 4918895, connected at the gear pump outlet.

Start the engine and allow it to operate at high idle for 3 minutes, or until the air is purged from the newly installed diagnostic fuel lines.

NOTE: If the engine is difficult to start after installing the diagnostic fuel lines, it may be necessary to cycle the lift pump three or four times in order to purge the air out of the fuel system prior to starting. Refer to Procedure 005-234 in Section 5.

NOTE: If the engine is **not** equipped with an engine-mounted pressure-side fuel filter, diagnostic fuel line, Part Number 4918895, can **not** be installed at the gear pump outlet. To measure the pressure drop across a remote-mounted pressure-side fuel filter, install a second pressure gauge at the inlet port of the fuel filter head instead. See supplementary diagrams in the general section of this procedure to view setup differences.



For Engine Will Not Start

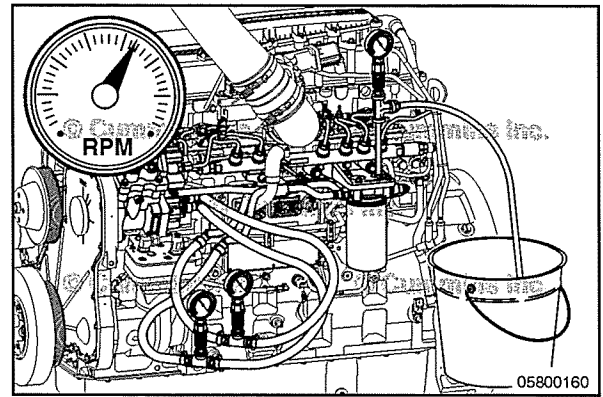
- 1 Install one diagnostic fuel line, Part Number 4918895, between the gear pump fuel supply line and the gear pump inlet (upper fuel line fitting).
- 2 Install a 0.043-inch orificed diagnostic fuel line, Part Number 3164621 on the diagnostic fuel line, Part Number 4918895, connected at the gear pump inlet.
- 3 Install a Compuchek™ fitting (to the outlet port of the filter head. The "T" adapter fitting can also be used).
- 4 Install a 0 to 1034 kPa [0 to 150 psi] pressure gauge at the outlet of the fuel filter head.

Measurement - Engine Will Start
Air-in-Fuel

- Refer to Procedure 006-003 in Section 6.

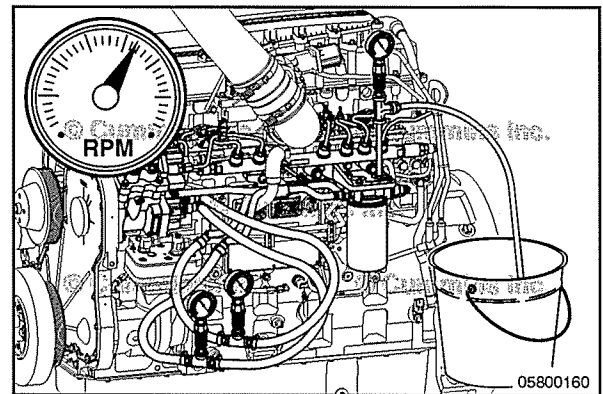
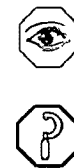
Inlet Restriction

- Refer to Procedure 006-020 in Section 6.



Fuel Gear Pump Pressure and Fuel Filter Restriction

- Operate the engine until it is at operating temperature.
- Operate the engine at high idle for 5 minutes.
- Record the fuel pressure at the inlet and outlet of the fuel filter.
- Subtract the outlet reading from the inlet reading to determine the restriction.
- Observe the gear pump pressure at the filter outlet.



Maximum Fuel Filter Restriction

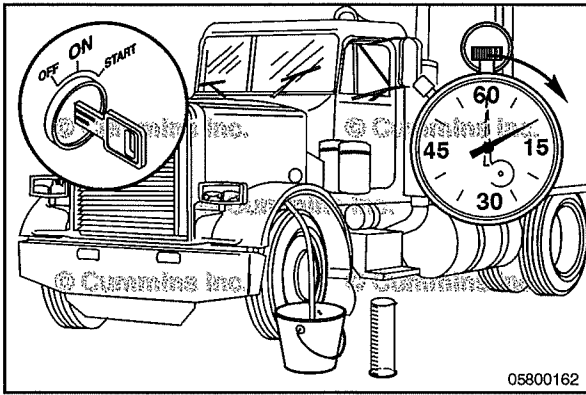
kPa		psi
80	MAX	11.7

Minimum Fuel Pump Gear Pump Pressure (Engine Operating)

kPa		psi
483	MIN	70

Measurement - Engine Will Not Start
Air-in-Fuel

- Refer to Procedure 006-003 in Section 6.

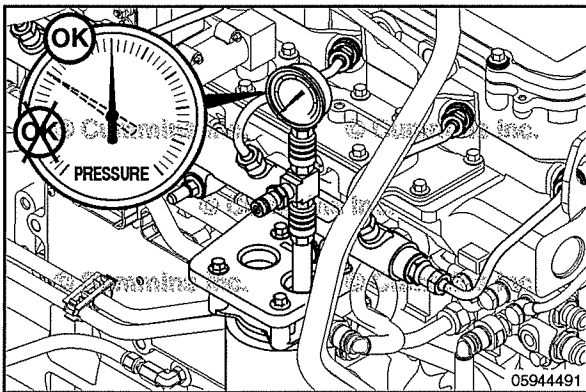


Lift Pump Flow

- Turn the keyswitch to the ON position and allow fuel to flow into a collection device for 10 seconds, or until the fuel stream is continuous.
- Once the fuel flow is continuous, transfer the orifice diagnostic fuel line to a clear graduated cylinder and allow fuel to flow into the graduated cylinder for 10 seconds.
- Remove the orifice diagnostic fuel line from the graduated cylinder after 10 seconds and turn the keyswitch to the OFF position.
- Record the volume of fuel collected over 10 seconds.
- Repeat this test three times and take an average of the flow rates.

Volume of Fuel During 10 Second Test	
ml	cc
100	100

NOTE: It may take longer than 10 seconds for the fuel stream to flow continuously during the first key ON cycle, due to air in the diagnostic fuel lines.



Fuel Gear Pump Pressure

- Remove the 0.043-inch orificed diagnostic fuel line, Part Number 3164621.
- Crank engine. Make sure engine cranking speed is at least 150 rpm.
- Monitor the gear pump pressure at the outlet port of the filter head, while the engine is cranking.

Gear Pump Pressure at Cranking

kPa		psi
105	MIN	15

NOTE: Crank the engine in 15 second intervals with a 15 second break between intervals. This reduces the possibility of overheating the starter motor.

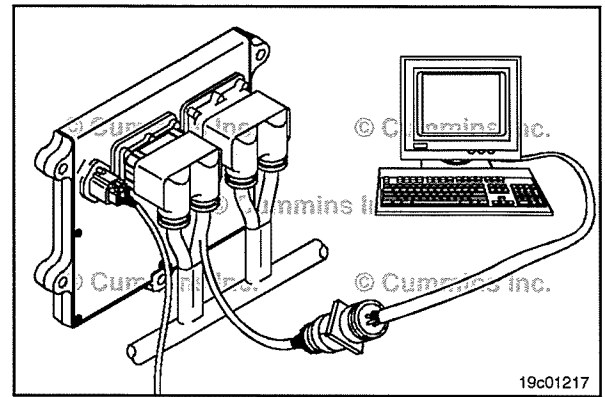
NOTE: Some vehicles are equipped with an Engine Starting Motor Protection feature. If the starting motor is engaged for 30 or more seconds, without the engine starting, the starting motor will be locked out from operating, allowing for proper cooling of the starting motor. During this time the Wait to Start lamp, if equipped, will flash for 2 minutes. Once the lamp discontinues flashing, the starting motor will be allowed to function again.

High-Pressure System Leak Down Test

The high-pressure system check is designed to troubleshoot the high-pressure side of the fuel system by determining if there is a leak in the system.

NOTE: This test can **not** be performed if the engine will **not** start.

- Operate the engine to operating temperature.
- Begin INSITE™ Fuel System Leakage Test
- Allow pressure to stabilize
- Select "Data Monitor/Logger" > "All Parameters" > "Fuel Rail Pressure Measured" and monitor the fuel rail pressure.
- Turn the keyswitch to the OFF position. Wait for the engine to stop, and turn the keyswitch ON quickly, without starting the engine.
- Monitor the fuel rail pressure decay rate for 1 minute.
- A change in fuel pressure greater than 300 bar [4351 psi] in 1 minute is an indication of a high-pressure fuel system leak.

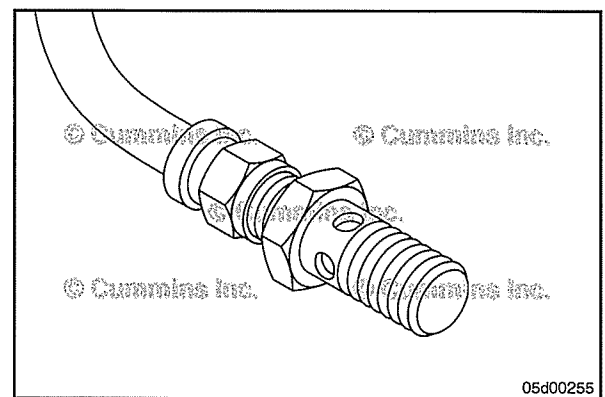


High-Pressure Fuel Rail Return Flow Test Initial Setup

⚠ CAUTION ⚠

Installation of the banjo flow adapter at any place other than the fuel drain manifold can cause damage to high-pressure fuel system components.

Return fuel is routed from the injectors, the fuel rail pressure relief valve, and the fuel pump head through three different drain lines. The measurement of fuel pressure relief valve leakage requires use of a fuel return flow hose, Part Number 3164618. This tool is used to isolate the leakage from just the fuel pressure relief valve, so the leakage can be measured in a graduated cylinder.



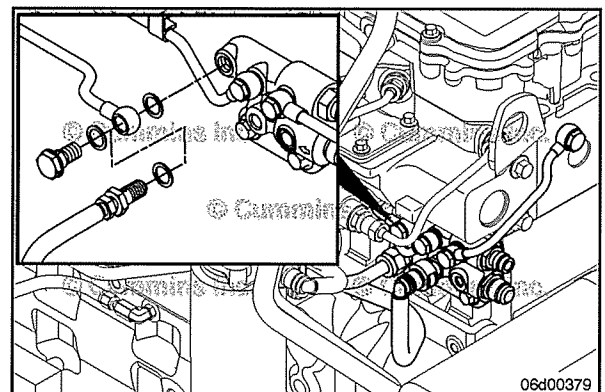
⚠ WARNING ⚠

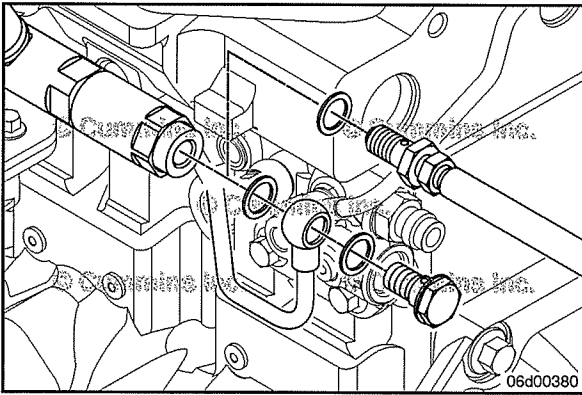
The pressure within the fuel rail is extremely high. High-pressure fuel can penetrate the skin. Stand clear of the engine while it is operating.

⚠ WARNING ⚠

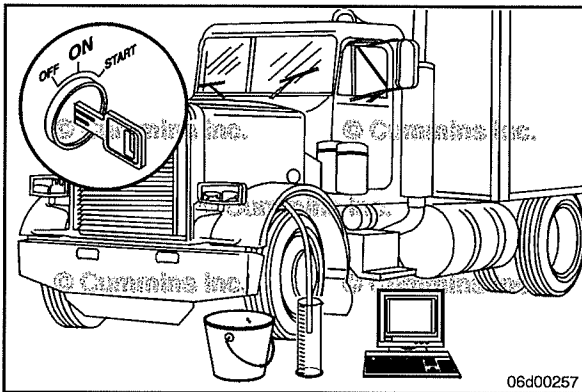
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. To reduce the possibility of personal injury, never loosen any fittings while the engine is operating.

- Remove the M12 banjo bolt that connects the fuel pressure relief valve drain line to the fuel drain manifold.
- Install a fuel return flow hose, Part Number 3164618, at the fuel drain manifold.
- Insert the fuel return flow hose into a collection device.





- Alternatively, fuel return flow hose (fuel pressure relief valve), Part Number 3164617, can be installed at the fuel pressure relief valve.



Measurement - Engine Will Start

⚠CAUTION⚠

Fuel is at high pressure during this test. After connecting the test fitting, close the engine cover and stand clear of high-pressure fuel lines.

- Operate the engine until it is at operating temperature.
- Begin INSITE™ Fuel System Leakage Test.
- Count the number of drops from the fuel return hose within 60 seconds.

**Maximum High-Pressure Fuel Rail Return Flow
(Engine Operating)**

Drops	Seconds
30	60

Measurement - Engine Will Not Start

⚠ CAUTION ⚠

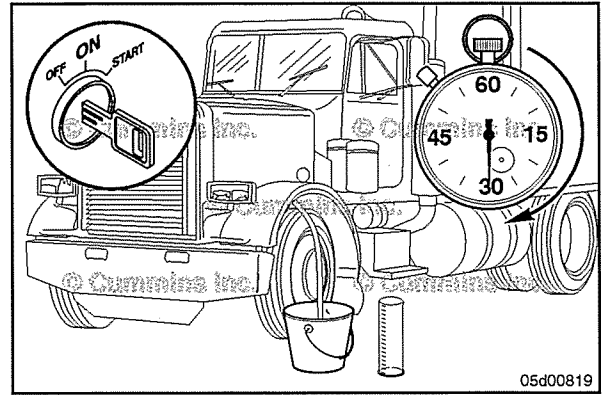
Fuel is at high pressure during this test. After connecting the test fitting, close the engine cover and stand clear of high-pressure fuel lines.

- Crank the engine for 30 seconds.
- Count the number of drops from the fuel return hose within 30 seconds.

Maximum High-Pressure Fuel Pump Return Flow (Engine Cranking)	
Drops	Seconds
5	30

NOTE: Do **not** crank the engine for 30 seconds continuously. Crank the engine in 15 second intervals with a 15 second break between cranking. This reduces the possibility of overheating the starter motor.

NOTE: Some vehicles are equipped with an Engine Starting Motor Protection feature. If the starting motor is engaged for 30 or more seconds, without the engine starting, the starting motor will be locked out from operating, allowing for proper cooling of the starting motor. During this time the Wait to Start lamp, if equipped, will flash for 2 minutes. Once the lamp discontinues flashing, the starting motor will be allowed to function again.



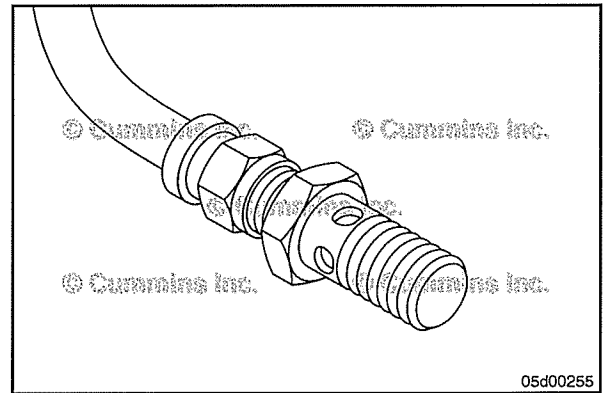
High-Pressure Injector Return Flow Test

Initial Setup

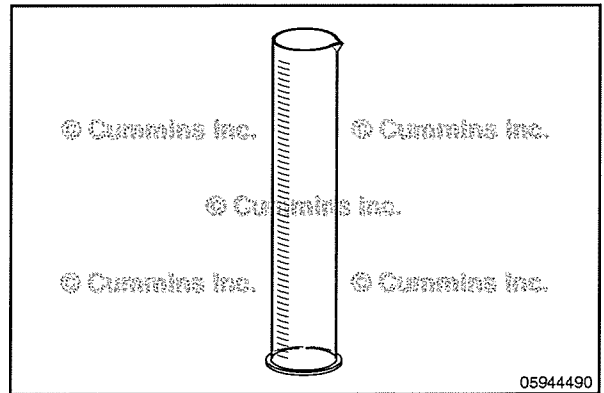
⚠ CAUTION ⚠

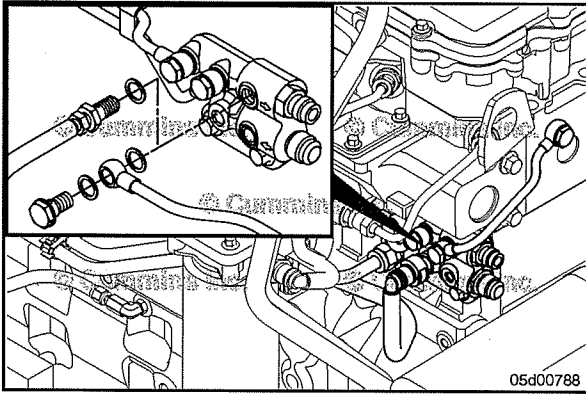
Installation of the banjo flow adapter at any place other than the fuel drain manifold can cause damage to high-pressure fuel system components.

Return fuel is routed from the injectors, the fuel rail pressure relief valve, and the fuel pump head through three different drain lines. The measurement of fuel injector leakage requires use of a fuel return flow hose, Part Number 3164618. This tool is used to isolate the leakage from the injectors, so the leakage can be measured in a graduated beaker.



Obtain a graduated beaker that is marked in cubic centimeters or milliliters, Part Number 4919139, or equivalent.





▲ WARNING ▲

Depending on the circumstance, diesel fuel is flammable. When inspecting or performing service or repairs on the fuel system, to reduce the possibility of fire and resulting severe personal injury, death or property damage, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area.



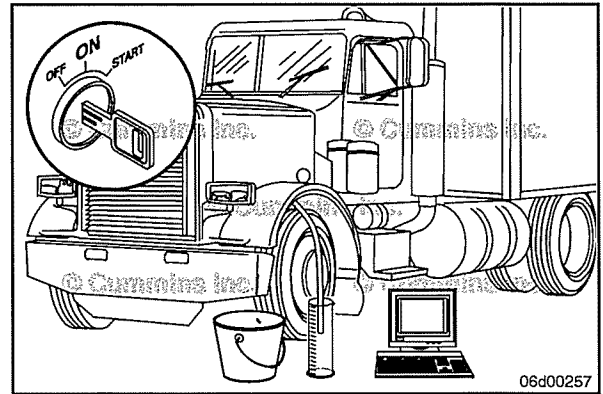
- Remove the M12 banjo bolt that connects the fuel injector drain line to the fuel drain manifold.
- Install the M12 fuel return hose, Part Number 3164618, at the fuel drain manifold.
- Route the fuel return hose into a collection device.

Measurement - Engine Will Start

⚠ CAUTION ⚠

Fuel is at high pressure during this test. After connecting the test fitting, close the engine cover and stand clear of high-pressure fuel lines.

- Connect INSITE™ electronic service tool.
- Operate the engine until it is at operating temperature.
- Allow the engine to idle with fuel flowing into a collection container.
- Begin the INSITE™ Fuel System Leakage Test and allow the engine to operate at high pressure for AT LEAST 1 minute.
- Use a graduated cylinder to collect fuel flow from the injector drain for EXACTLY 1 minute.
- IMMEDIATELY return the injector drain hose into collection container.
- After recording the fuel leakage quantity, stop INSITE™ High-Pressure Leakage Test and turn the keyswitch to OFF.

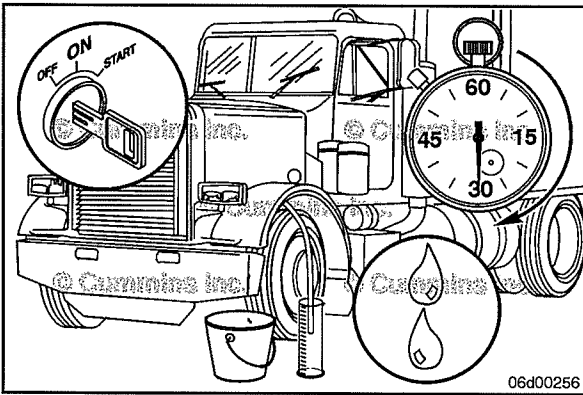


High-Pressure Fuel Injector Return Flow Specification (Engine Operating. Low Speed Idle of 1000 rpm, and Below.)	
Maximum leakage in 1 minute	70 ml/cc

High-Pressure Fuel Injector Return Flow Specification (Engine Operating. Low Speed Idle Above 1000 rpm.)	
Maximum leakage in 1 minute	125 ml/cc

NOTE: Fuel temperature and fuel type will influence this measurement. For example; as the engine is warmed up and the injectors become hot, the leakage rate will increase. Also, low viscosity fuels, such as kerosene, will cause the leakage rate to increase. The above specification is correct for on-highway diesel fuels where fuel inlet temperature is less than 49°C [120°F].

NOTE: Make sure a steady flow of fuel is present at the drain line before beginning the measurement. Air in the line and movement of the hose during measurement can result in inaccurate measurements.

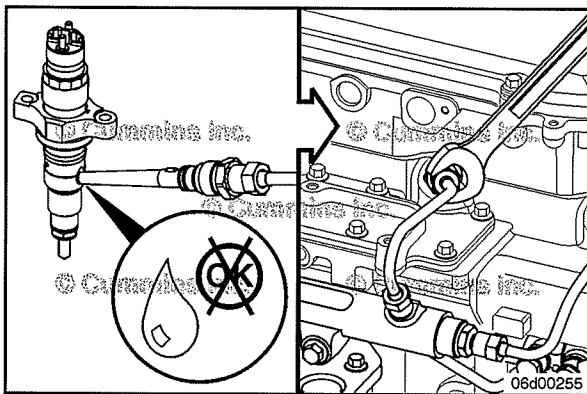


Measurement - Engine Will Not Start

- If the engine will **not** start, the injector return flow **must** be measured while engaging the starter for 30 seconds at a time.
- The leakage should **only** be a few drops. If leakage is greater than a few drops, an injector or a high-pressure connector is leaking.

NOTE: Do **not** crank the engine for 30 seconds continuously. Crank the engine in 15 second intervals with a 15 second break between cranking. This reduces the possibility of overheating the starter motor.

NOTE: Some vehicles are equipped with an Engine Starting Motor Protection feature. If the starting motor is engaged for 30 or more seconds, without the engine starting, the starting motor will be locked out from operating, allowing for proper cooling of the starting motor. During this time the Wait to Start lamp, if equipped, will flash for 2 minutes. Once the lamp discontinues flashing, the starting motor will be allowed to function again.



Initial Setup - Injector Isolation

▲ WARNING ▲

Normal engine operation creates highly pressurized fuel in the fuel line which will remain in the fuel line after engine shutdown. Never open the fuel system when the engine is operating. Before servicing the fuel system, always loosen the pump-to-rail fuel line at the rail to vent the pressure. Keep hands clear of the line when loosening. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

If injector drain flow is excessive, it will be necessary to isolate the injector(s) or fuel connector(s) that are damaged or worn. A loose fuel connector retaining nut results in a poor seal at the interface between the fuel connector and the injector. This loose condition will result in a leak of high-pressure fuel to the injector drain.

- Verify first that the fuel connectors are properly tightened. Refer to Procedure 006-052 in Section 6.
- If loose retaining nut(s) are found, test for leakage after tightening the retaining nut(s).

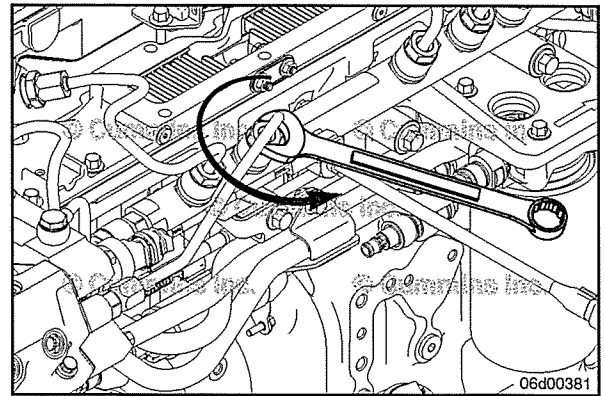
⚠ WARNING ⚠

Normal engine operation creates highly pressurized fuel in the fuel line which will remain in the fuel line after engine shutdown. Never open the fuel system when the engine is in operation. Before servicing the fuel system, always loosen the pump-to-rail fuel line at the rail to vent the pressure. Keep hand clear of the line when loosening. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

- Before servicing the fuel system, loosen the pump-to-rail line at the rail to vent the pressure. Keep hands clear of the line when loosening. Tighten the fuel rail nut, once pressure has been released.

Torque Value: 65 N•m [48 ft-lb]

NOTE: A machined slot in this fitting directs the fuel spray toward the engine block.



⚠ CAUTION ⚠

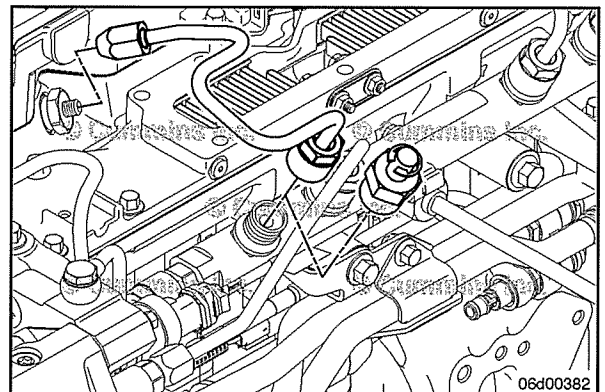
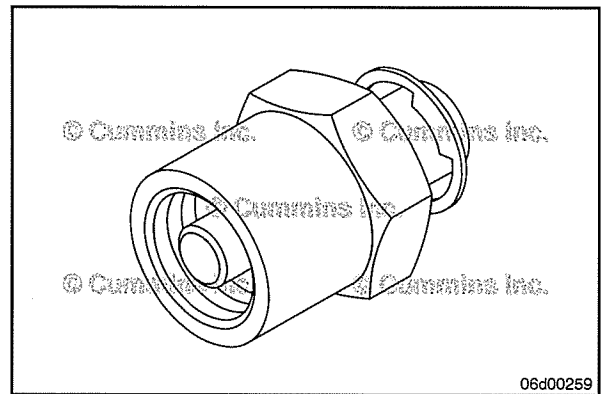
Do not install the isolation tool at the high-pressure pump outlet fitting. Severe engine damage will result. This tool must only be installed at the fuel rail for the purpose of isolating the high-pressure fuel supply from individual injectors.

⚠ CAUTION ⚠

Make certain the keyswitch is in the OFF position (Engine will Not Start) when loosening or tightening high-pressure fuel lines.

- Use leak test isolation tool, Part Number 4918563, to isolate excessive fuel drain from injectors or fuel connectors.
- Isolate the injector and fuel connector for each cylinder by installing the isolation tool at the fuel rail in place of the high-pressure fuel line that supplies the fuel connector.
- Tighten the isolation tool.

Torque Value: 65 N•m [48 ft-lb]



Cylinder	Quantity
1	
2	
3	
4	
5	
6	

06d00483

Measurement - Injector Isolation

- Record the amount of fuel flow from the injector drain line in 1 minute while the engine is operating. Use INSITE™ electronic service tool High-Pressure Leakage Test. If the engine will **not** start, drain flow **must** be measured while engaging the starter for 30 seconds.
- Do this up to six times, once while each line is isolated.
- If isolating a single injector and the high-pressure fuel connector causes the leakage to decrease significantly compared to the rest of the set, that injector and fuel connector **must** be inspected.

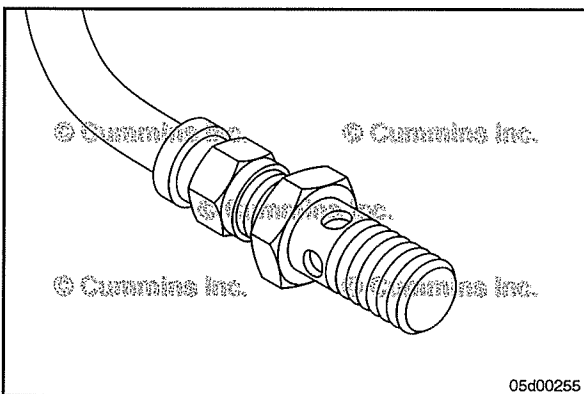
Injector Inspection: Refer to Procedure 006-026 in Section 6.

Fuel Connector Inspection: Refer to Procedure 006-052 in Section 6.

NOTE: Do **not** crank the engine for 30 seconds continuously. Crank the engine in 15 second intervals with a 15 second break between cranking. This reduces the possibility of overheating the starter motor.

NOTE: Some vehicles are equipped with an Engine Starting Motor Protection feature. If the starting motor is engaged for 30 or more seconds, without the engine starting, the starting motor will be locked out from operating, allowing for proper cooling of the starting motor. During this time the Wait to Start lamp, if equipped, will flash for 2 minutes. Once the lamp discontinues flashing, the starting motor will be allowed to function again.

NOTE: Make sure a steady flow of fuel is present at the drain line before beginning the measurement. Air in the line and movement of the hose during measurement can result in inaccurate measurements.

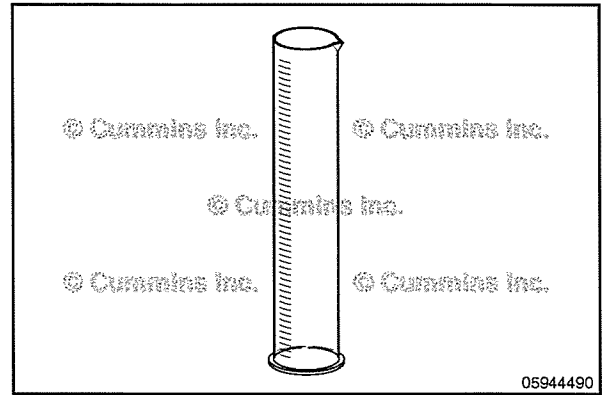


High-Pressure Fuel Pump Return Flow Test Initial Setup

⚠ WARNING ⚠
Depending on the circumstances, diesel fuel is flammable. When inspecting or performing service or repairs on the fuel system, to reduce the possibility of fire and resulting severe personal injury, death, or property damage, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area.

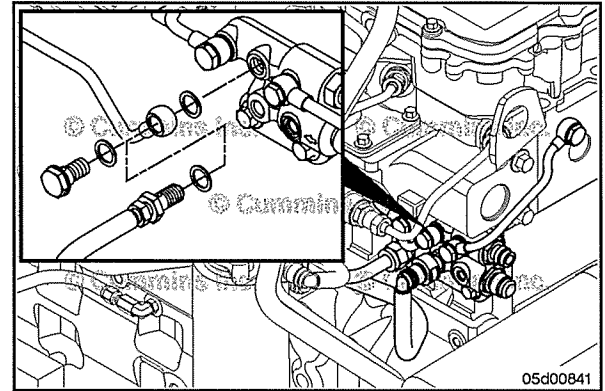
This fuel pump head leakage test uses a flow adapter fitting. The purpose of the flow adapter fitting is to route the drain flow of the fuel pump **only** into a collection device so that leakage may be measured.

Obtain a graduated cylinder that is marked in cubic centimeters or milliliters, graduated beaker Part Number 4919139, or equivalent.



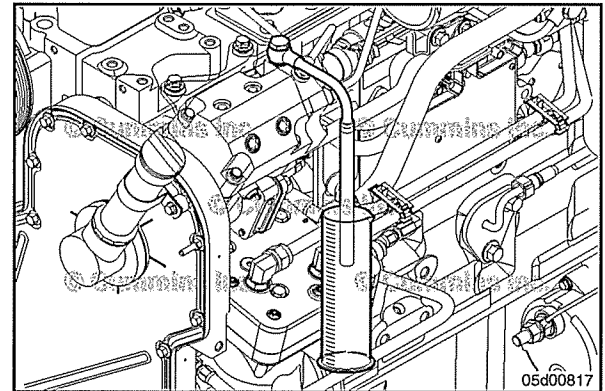
- Remove the banjo bolt from the fuel pump drain line at the fuel drain manifold.
- Install a banjo flow adapter, Part Number 3164618, at the fuel drain manifold and insert the hose into a bucket or the vehicle's fuel tanks.

NOTE: The pump drain line connects at the center connection point on the fuel drain manifold.



Alternate Test Setup

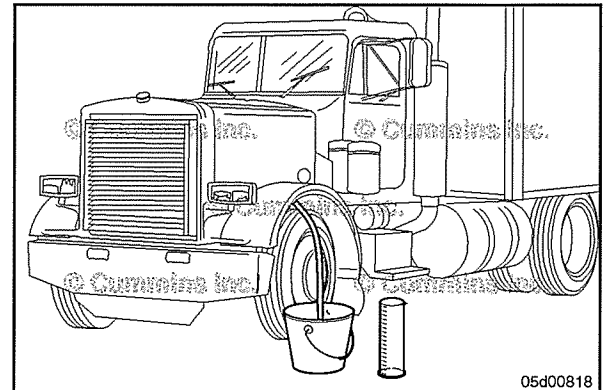
- If the drain manifold is **not** easily accessed, a M14 banjo may be attached at the pump head drain port with a fuel hose that is routed to the collection container.
- In this setup, a 12 x 1.5 banjo screw and cap, Part Number 4918295, is required to prevent fuel from flowing backward and leaking from the unused drain line. This kit also includes fuel hose to be routed into collection container.

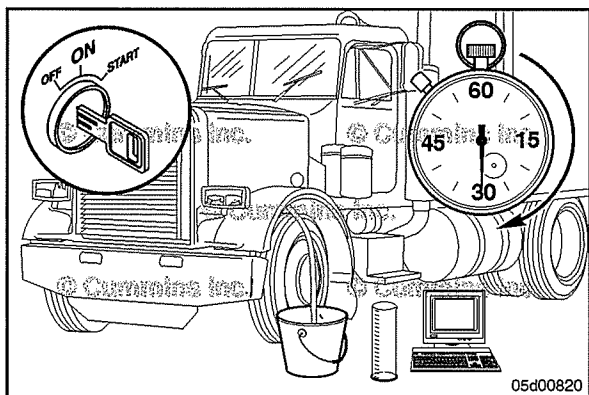


⚠CAUTION⚠

The High-Pressure Leakage Test in INSITE™ electronic service tool will cause the engine to operate at elevated pressures while the engine idles. The engine noise will change when this test is being performed due to the higher fuel injection pressures. Safety glasses should be worn while working near the operating engine. Fuel lines should not be adjusted while performing this test.

Close the engine cover(s) while performing these tests.



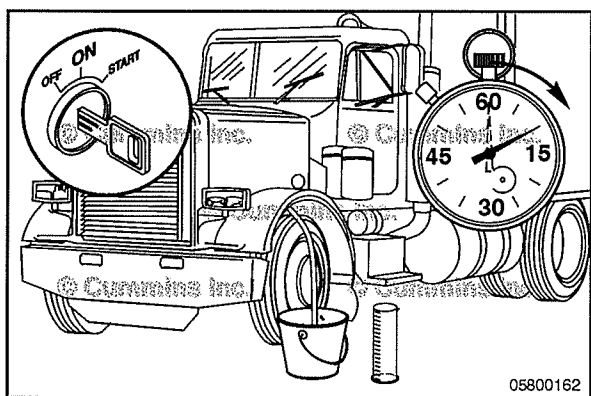


Measurement - Engine Will Start

- Connect INSITE™ electronic service tool.
- Operate the engine until operating temperature is reached.
- Allow the engine to idle with fuel flowing into a collection container.
- Begin the INSITE™ Fuel System Leakage Test and allow the engine to operate at high pressure for AT LEAST 1 minute.
- Use a graduated cylinder to collect the fuel pump return flow for EXACTLY 30 seconds.
- IMMEDIATELY return the injector drain hose into collection container.
- After recording the fuel leakage quantity, stop INSITE™ High-Pressure Leakage Test and turn the keyswitch to OFF.

Maximum High-Pressure Fuel Pump Return Flow (Engine Operating)	
ml/cc	Seconds
400	30

NOTE: This specification is valid for engines operating on diesel fuels. Low fuel viscosity will increase the leakage rate; for example, kerosene or aviation fuels will result in excessive leakage. Verify the fuel type before replacing a fuel pump head for excessive leakage.



Measurement - Engine Will Not Start

- Turn the keyswitch ON and allow the lift pump to complete the cycle. After the cycle is completed, begin cranking the engine until fuel exits the drain line.
- When fuel begins to exit the drain line, route the drain flow to a graduated cylinder and continue cranking for 30 seconds.

Maximum High-Pressure Fuel Pump Return Flow (Engine Cranking)	
ml/cc	Seconds
320	30

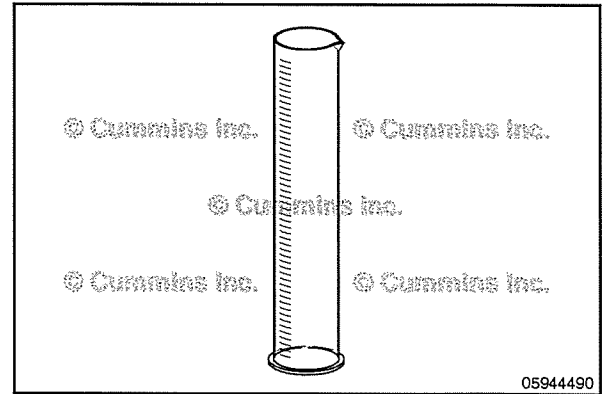
NOTE: Do **not** crank the engine for 30 seconds continuously. Crank the engine in 15 second intervals with a 15 second break between cranking. This reduces the possibility of overheating the starter motor.

NOTE: Some vehicles are equipped with an Engine Starting Motor Protection feature. If the starting motor is engaged for 30 or more seconds, without the engine starting, the starting motor will be locked out from operating, allowing for proper cooling of the starting motor. During this time the Wait to Start lamp, if equipped, will flash for 2 minutes. Once the lamp discontinues flashing, the starting motor will be allowed to function again.

High-Pressure Fuel Pump Supply Flow Test

Initial Setup

Obtain a graduated cylinder that is marked in cubic centimeters or milliliters, graduated beaker Part Number 4919139, or equivalent.



⚠ WARNING ⚠

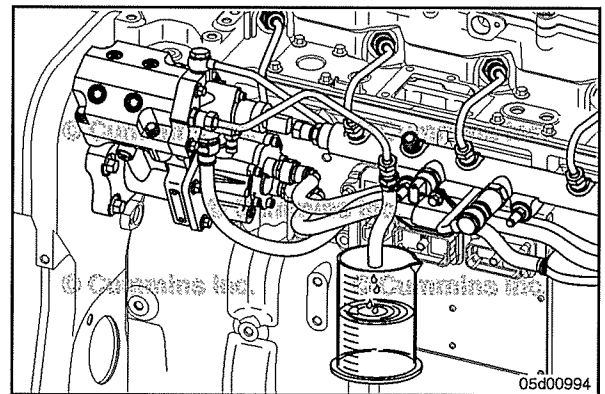
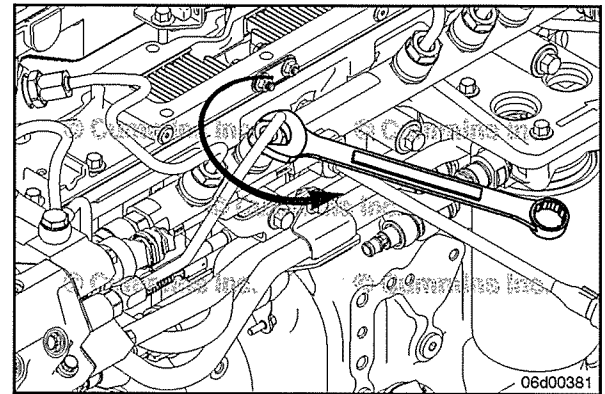
Normal engine operation creates highly pressurized fuel in the fuel line which will remain in the fuel line after engine shutdown. Never open the fuel system when the engine is in operation. Before servicing the fuel system, always loosen the pump-to-rail fuel line at the rail to vent the pressure. Keep hand clear of the line when loosening. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

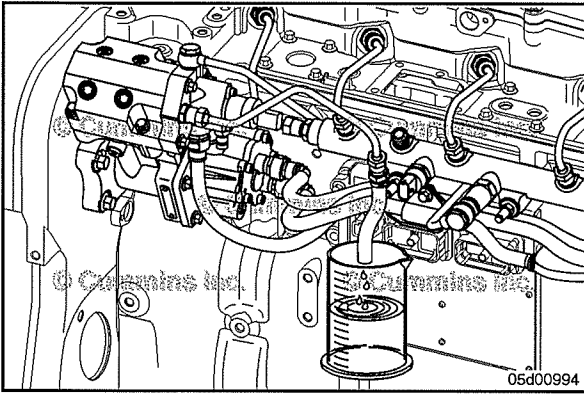
- Before servicing the fuel system, loosen the pump-to-rail line at the rail to vent the pressure. Keep hands clear of the line when loosening. Tighten the fuel rail nut, once pressure has been released.

Torque Value: 65 N•m [48 ft-lb]

NOTE: A machined slot in this fitting directs the fuel spray toward the engine block.

- Disconnect the high-pressure fuel line from the rail.
- Clamp a hose to the end of the fuel line.
- Route a hose from the test fitting into a clean graduated cylinder.





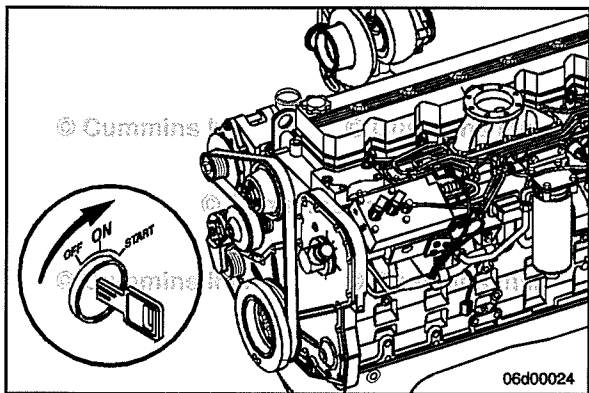
Measurement

Crank the engine for 30 seconds. Make sure engine cranking speed is at least 150 rpm.

Minimum High-Pressure Fuel Pump Supply Flow	
ml/cc	Seconds
75	30

NOTE: Do **not** crank the engine for 30 seconds continuously. Crank the engine in 15 second intervals with a 15 second break between cranking. This reduces the possibility of overheating the starter motor.

NOTE: Some vehicles are equipped with an Engine Starting Motor Protection feature. If the starting motor is engaged for 30 or more seconds, without the engine starting, the starting motor will be locked out from operating, allowing for proper cooling of the starting motor. During this time the Wait to Start lamp, if equipped, will flash for 2 minutes. Once the lamp discontinues flashing, the starting motor will be allowed to function again.



Finishing Steps

- Start the engine and check for proper operation.

Section 6 - Injectors and Fuel Lines - Group 06

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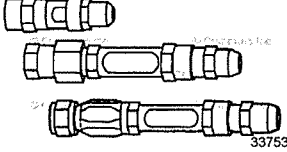
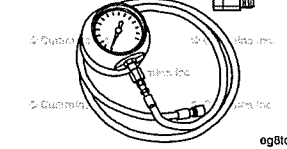
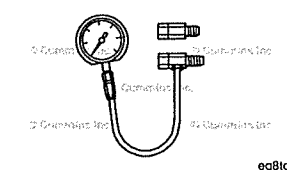
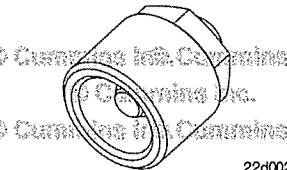
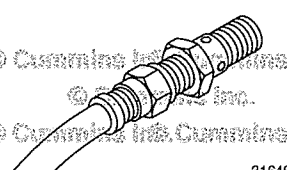
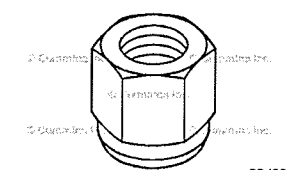
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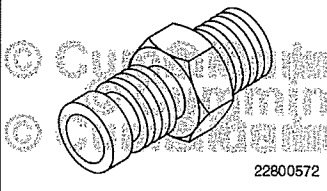
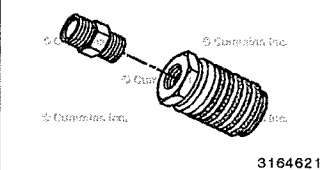
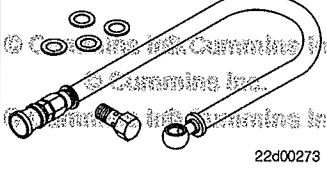
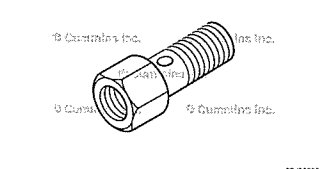
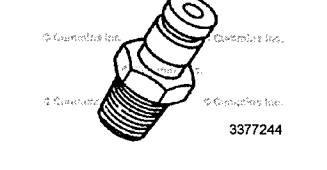
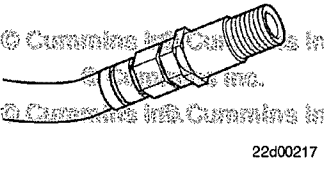
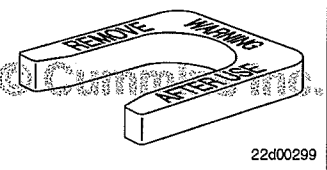
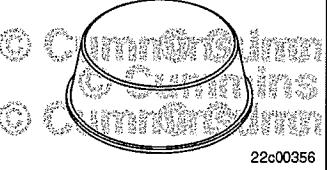
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Service Tools

Injectors and Fuel Lines

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3164383	<p>Fuel Sight Glass Assembly, Number 10 Society of Automotive Engineers (SAE)</p> <p>Used to observe fuel flow to detect air in fuel.</p>	
ST-1273	<p>Pressure Gauge (0 to 1905 mm Hg [0 to 75 in Hg])</p> <p>Used to measure engine intake manifold pressure, exhaust restriction, lift pump output pressure, and pressure drop across fuel filters.</p>	
ST-434	<p>Vacuum Gauge (0 to 762 mm Hg [0 to 30 in Hg])</p> <p>Used to measure lift pump inlet restriction. Hose adaptor, Part Number ST-434-2 and vacuum gauge, Part Number ST-434-12 are used to perform the test.</p>	
4918563	<p>Fuel System Leak Tester</p> <p>Used to block a single injector and high-pressure fuel connector from pressurized fuel. This tool helps identify a malfunctioning injector when injector return flow is excessive.</p>	
3164618	<p>Fuel Return Flow Hose</p> <p>This tool uses a special fitting to connect to the fuel return circuits to measure return flow from the injectors and the fuel pump.</p>	
3164025	<p>Fuel Connector Remover</p> <p>Used to pull the fuel connector.</p>	

Tool No.	Tool Description	Tool Illustration
3824842	<p align="center">M10 STORM Compuchek™ Diagnostic Fitting</p> <p>Used to measure fuel pressure or vacuum wherever STORM M10 diagnostic ports exist.</p>	 <p align="right">22800572</p>
3164621	<p align="center">Fuel line with 1.09 mm [0.043 in] orifice.</p> <p>Used in procedures to create rated flow through the low pressure fuel system, without the need to operate the engine under load.</p>	 <p align="right">3164621</p>
4918324	<p align="center">Fuel Pressure Test Kit</p> <p>Used with a vacuum gauge, Part Number ST-434 or equivalent, along with quick-disconnect fitting, Part Number 3972088, to check the fuel inlet restriction.</p>	 <p align="right">22d00273</p>
4918413	<p align="center">Banjo Fitting</p> <p>A banjo-style pressure gauge adapter may be used to measure pressure or vacuum at any point in the low-pressure fuel system where a banjo bolt exists at a fuel line.</p>	 <p align="right">22800230</p>
3377244	<p align="center">Fitting, Quick-Disconnect Male</p> <p>Used to perform a pressure side air-in-fuel test.</p>	 <p align="right">3377244</p>
3164617	<p align="center">Fuel Return Flow Hose (fuel pressure relief valve)</p> <p>The tool uses a special banjo fitting to connect to the fuel return circuit to measure the return flow from the fuel pressure relief valve.</p>	 <p align="right">22d00217</p>
4918878	<p align="center">Fuel Line Quick Disconnect Tool</p> <p>Used to remove 3/8 quick disconnect fittings female connectors.</p>	 <p align="right">22d00299</p>
5298776	<p align="center">Fuel System Clean Care Kit</p> <p>Used to maintain cleanliness during fuel system service.</p>	 <p align="right">22c00356</p>

Air in Fuel (006-003)

General Information

Perform the steps in the Priming Procedure before beginning this procedure to make sure all entrapped air is removed from the system. Refer to Procedure 005-236 in Section 5.

Setup

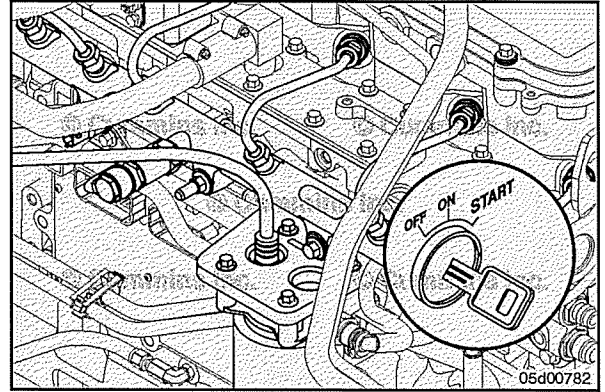
Initial Setup (Engine will Start)

NOTE: A symptom of air in fuel for the engines equipped with a common rail fuel system is an audible surge associated with fuel system pressure fluctuations, due to air in the fuel supply.

The following test method will simulate rated fuel flow through the system, so that air-in-fuel problems may be diagnosed.

Install a Compuchek™ fitting, Part Number 3824842, at the inlet to the 5 micron fuel filter and attach the 1.09 mm [0.043 in] diagnostic fuel line.

NOTE: If there is **not** enough clearance to install the female Compuchek™ fitting, Part Number 3824842, an adapter fitting, Part Number 3932302, and an 1/8-NPT male Compuchek™ fitting, Part Number 3377244, can be used to aid accessibility.

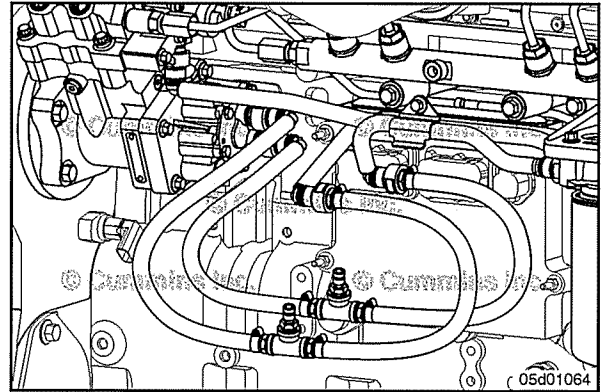


Obtain two diagnostic fuel lines, Part Number 4918895.

Install one diagnostic fuel line between the gear pump fuel supply line and the gear pump inlet (upper fuel line fitting).

Install the second diagnostic fuel line between the gear pump outlet and the pressure side fuel filter fuel supply line (lower fuel line fitting).

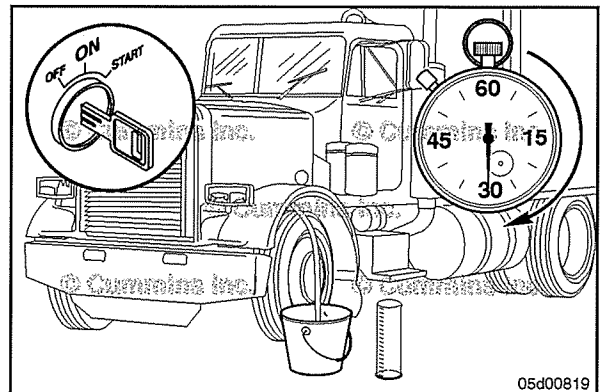
NOTE: If the engine is **not** equipped with an engine mounted pressure side fuel filter, diagnostic fuel line, Part Number 4918895, can **not** be installed at the gear pump outlet.

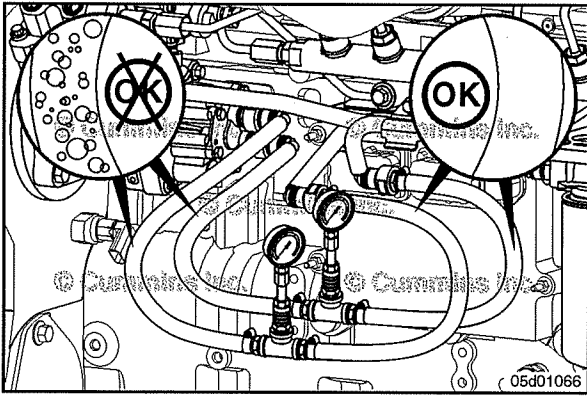


Measure

Route the outlet of the 1.09 mm [0.043 in] diagnostic fuel line into a collection device of suitable size (a 19 liter [5 gal] bucket is recommended).

Start the engine and operate the engine speed from idle to high idle several times to purge the air introduced while installing the diagnostic fuel line.





Observe the clarity of the fuel in the clear diagnostic fuel lines installed at the gear pump inlet and outlet. Air should **not** be present in the fuel.

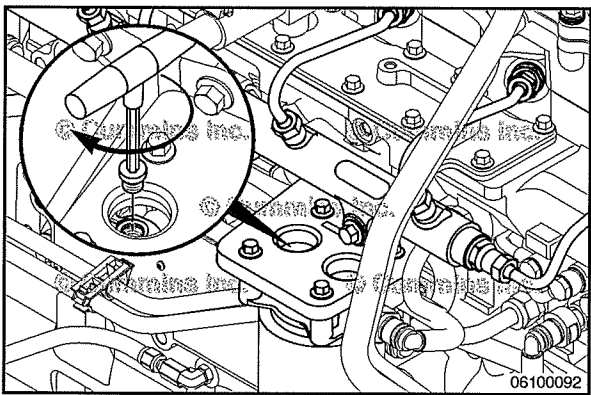
NOTE: Be sure a 0.043-inch orificed diagnostic fuel line, Part Number 3164621, is installed at the inlet of the fuel filter head. Make certain the test lines are **not** kinked or leaking after installation.

Bubbles at the inlet to the gear pump are an indication of a leak that allows air to enter, a severe inlet restriction that causes cavitation, or a system that is **not** yet primed. Refer to Procedure 006-020 Section 6.

- Suction fuel lines
- Engine control module (ECM) cooling plate assembly
- Original equipment manufacturer (OEM) fuel lines
- Suction-side fuel filter assemblies
- Stand-pipe(s) in the fuel tank(s).

NOTE: Inspect clear diagnostic fuel lines to make sure air is **not** entering the diagnostic fuel line at the Compuchek™ fitting.

Clear fuel at the inlet of the gear pump and bubbles at the outlet of the gear pump are an indication that the fuel pump gear pump is allowing air to enter the fuel system and the gear pump **must** be replaced. Refer to Procedure 005-025 in Section 5.



Test

▲ WARNING ▲

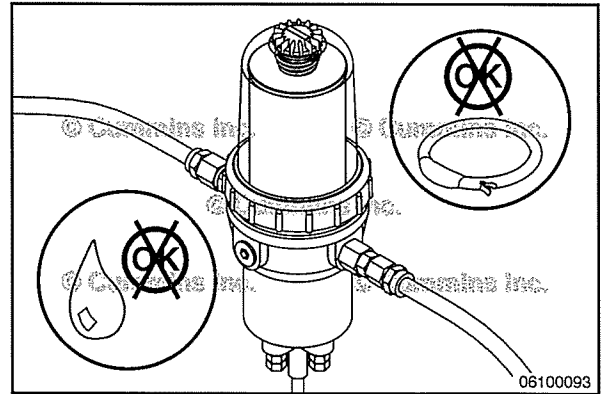
To reduce the possibility of fire and resulting severe personal injury, death or property damage, care must be taken when installing diagnostic equipment on the fuel system. Always allow a short period of time after shutting down the engine before loosening any fittings in the fuel system to allow residual fuel pressure to decrease.

If the engine is hard to start or will **not** start, perform the following test to check for trapped air.

Check For Trapped Air

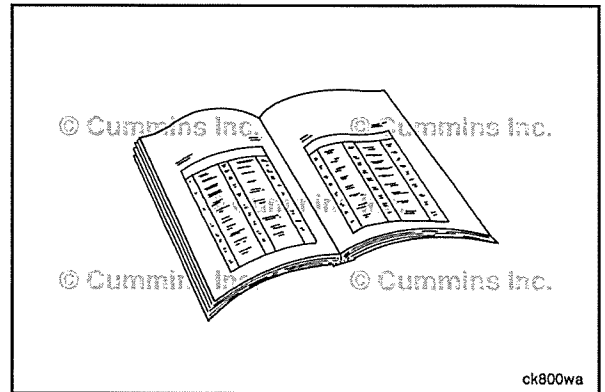
- Crank the engine for 5 seconds.
- Turn the keyswitch OFF.
- Loosen the diagnostic port plug at the top of the fuel filter head while shielding the area with a shop towel.
- Trapped air will retain pressure in the system causing a spray of air/fuel mixture from the diagnostic port fitting.

If air is found to be trapped in the system, inspect the OEM supplied suction side fuel filter for leaks, loose fittings, damaged o-rings, etc.



Finishing Steps

- Remove all test fuel lines. Refer to Procedure 006-024 in Section 6.
- Operate the engine and check for leaks.



Engine Control Module Cooling Plate, Fuel Cooled (006-006)

Initial Check

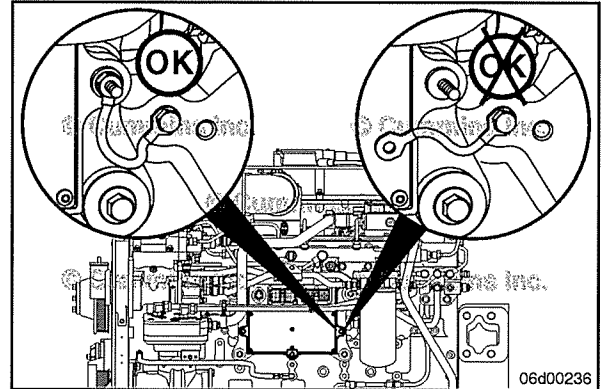
The engine control module (ECM) cooling plate assembly provides a vibration isolated mounting location for the ECM. The cooling plate also provides ECM cooling and incorporates the fuel lift pump. A check valve at the outlet port in the ECM cooling plate makes sure that the fuel system is primed while the fuel lift pump is running.

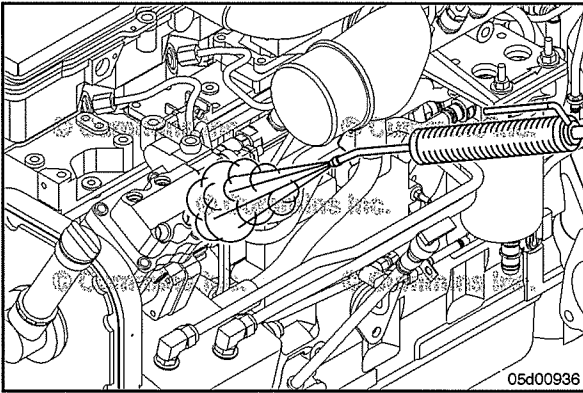
Check the ECM cooling plate for damaged vibration isolators, loose capscrews, or fuel leaks.

Make sure that the ground strap is properly installed. A missing or poorly connected ground strap may cause intermittent engine performance problems.

The ground strap **must** be connected between the head of the ECM mounting bolt and the ECM.

The ground strap **must** be connected to an unpainted block surface that is free of corrosion.





Preparatory Steps



⚠ WARNING ⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.



⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ CAUTION ⚠

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine.

- Clean the engine. Refer to Procedure 000-009 in Section 0. Refer to Procedure 204-008 in Section i.
- Use contact cleaner, Part Number 3824510 or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, or cleaning solution does **not** get inside the fuel system.

⚠ WARNING ⚠

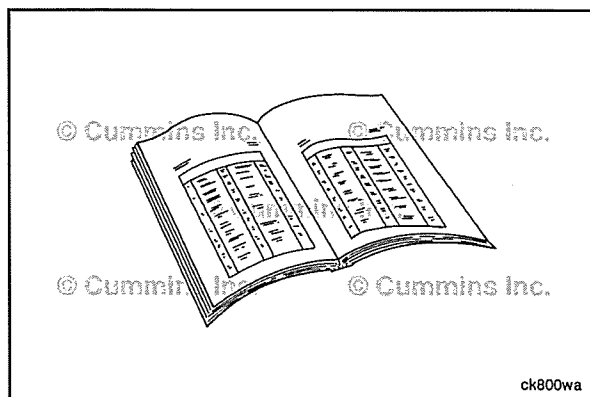
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



⚠ WARNING ⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

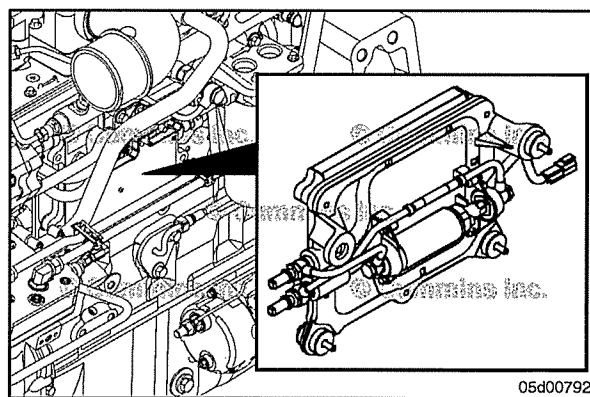
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Shut off the fuel supply and drain valves. Refer to the OEM service manual.
- Disconnect the rail fuel pressure sensor from the engine wiring harness. Refer to Procedure 019-115 in Section 19.
- Remove the high-pressure fuel lines from the fuel rail. Refer to Procedure 006-051 in Section 6.
- Remove the fuel drain line from the fuel pressure relief valve. Refer to Procedure 006-013 in Section 6.



Remove

NOTE: The electric fuel priming pump and priming pump fuel lines will be attached to the ECM cooling plate while the cooling plate is being removed.

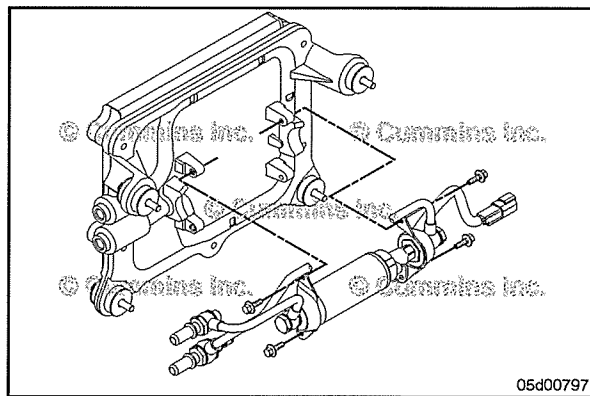
Remove the ECM cooling plate capscrews and the ECM cooling plate from the engine block.

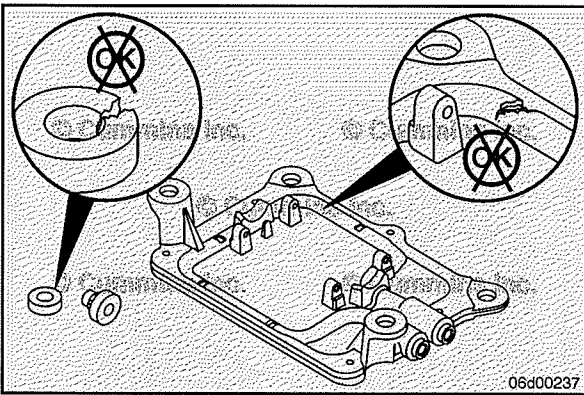


Disassemble

Remove the following components from the ECM cooling plate:

- Male banjo quick disconnect fitting
- Male banjo check valve fitting
- Fuel lift pump supply lines
- Fuel lift pump brackets
- Fuel lift pump.





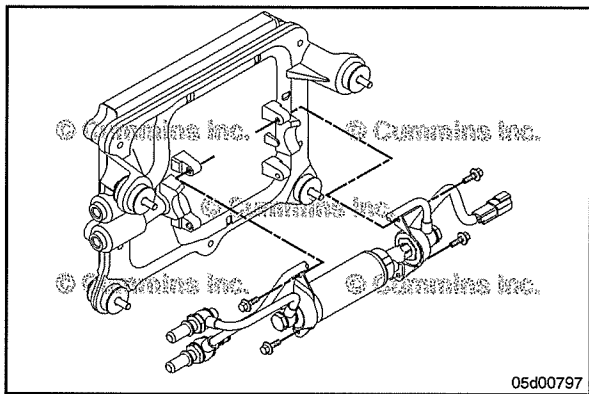
Inspect for Reuse

Inspect the ECM cooling plate for leaks (note that the fuel passages are contained in a tube that is cast into the cooling plate).

Replace any damaged vibration isolators.

Inspect for leaks in the electric fuel supply pump priming circuit. Look for cracked fuel tubes, damaged o-rings, or damaged seal washers.

Inspect the check valve for debris or damage.



Assemble

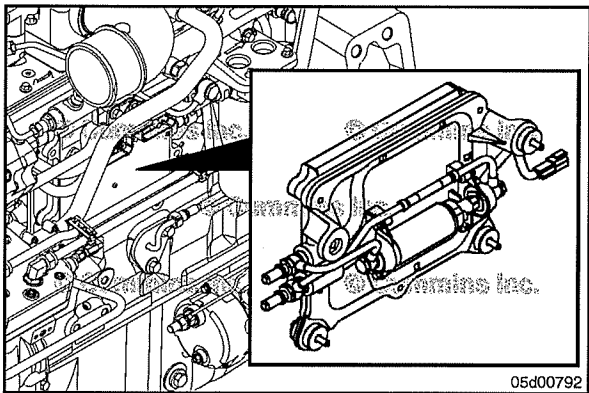
Install the electric fuel priming pump and the priming circuit fuel lines. Refer to Procedure 005-045 in Section 5.



Be sure the lines are supported while tightening the banjo screws. The lines **must not** be permitted to bind.



Be sure the ECM check valve is installed into the bottom (outlet) fitting of the ECM cooling plate.



Install

Install the ECM cooling plate assembly on the engine block. Tighten the capscrews.



Torque Value: 24 N•m [212 in-lb]

Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ CAUTION ⚠

Failure to properly install the ECM ground strap may cause intermittent engine symptoms including intermittent engine stalls. One end of the ground strap must be installed between the ECM housing and the head of the bottom most ECM mounting capscrew. The other end of the ground strap must be tightly bolted to an unpainted block surface that is free from corrosion.

NOTE: Be sure the vibrations isolators are installed correctly. The isolators fit in a single direction into the chamfered locators.

- Install the ECM on the ECM cooling plate. Refer to Procedure 019-031 in Section 19.
- Install the suction fuel lines, if removed.
- Connect the fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Connect the engine harness to the electric fuel priming pump.
- Connect the ECM ground strap.
- Connect the harness connections to the ECM.
- Connect the battery cables. Refer to the OEM service manual.
- Open the fuel supply valves, if equipped.
- Cycle the keyswitch and allow the lift pump to operate for 30 seconds. Afterwards, turn the keyswitch OFF and back ON again allowing the lift pump to operate again.
- Allow the lift pump to operate for three or four 30-second cycles before attempting to start the engine.
- Operate the engine and check for leaks.

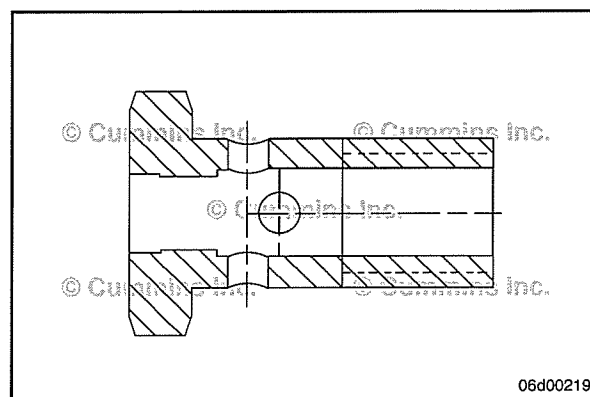
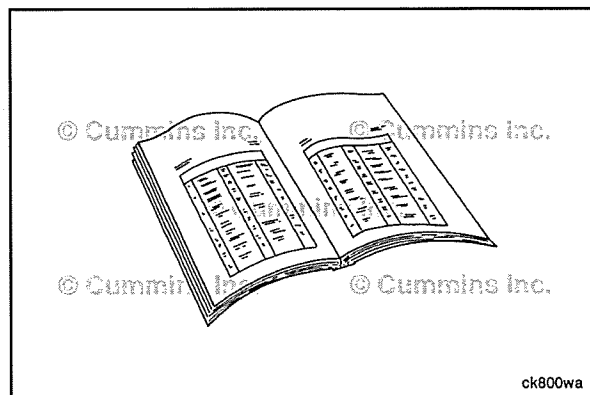
Fuel Drain Line Restriction (006-012)

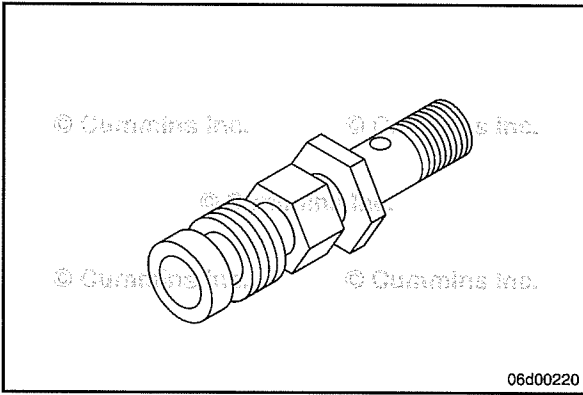
Preparatory Steps

Obtain a M12 banjo pressure gauge tool, Part Number 4918413.

A banjo-style pressure gauge adapter may be used to measure pressure or vacuum at any point in the low-pressure fuel system where a banjo bolt exists at a fuel line.

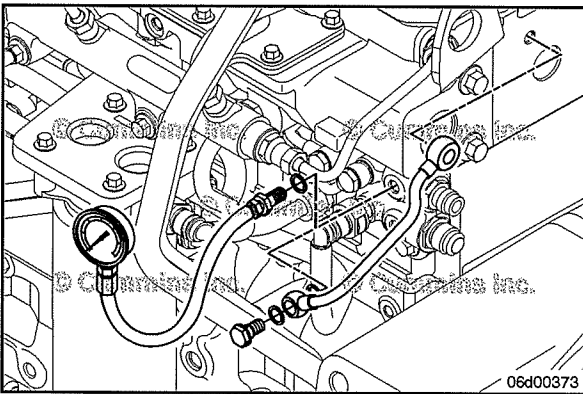
The engines use M12 x 1.5 banjo bolt connections. Part Number 4918413 may be used for measurement of drain line restriction (pressure) at the fuel drain manifold.



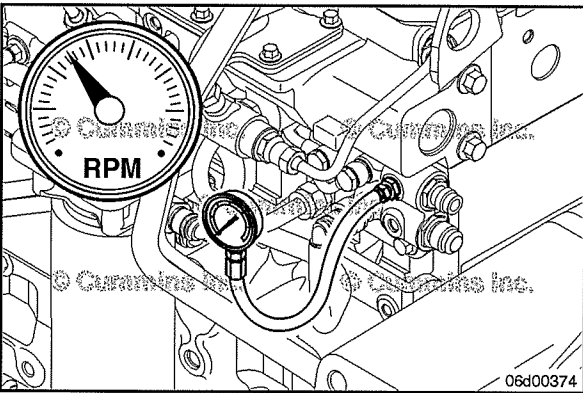


Assemble the banjo pressure gauge adapter.

- 1 Install the Compuchek™ fitting, Part Number 3377244, or other type fitting in the hex face of the banjo bolt.
- 2 Attach a hose or pressure gauge to the banjo pressure adapter.



Install the M12 banjo pressure gauge adapter in place of the injector drain line banjo at the fuel drain manifold.
Install a 0 to 762 mm Hg [0 to 30 in Hg] pressure gauge at the M12 banjo pressure gauge adapter.



Measure

Operate the engine at rated speed and no load.

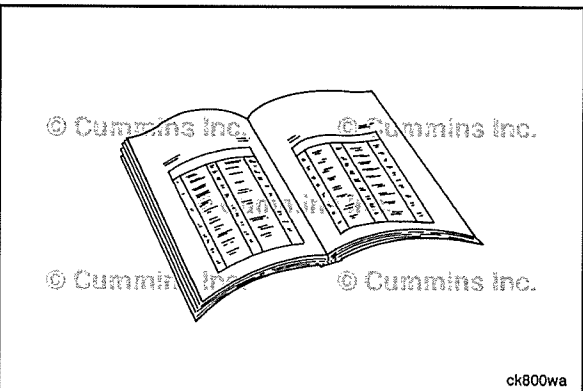


Observe the reading on the gauge.

Fuel Drain Line Pressure

mm Hg		in Hg
254.0	MAX	10.0

If the drain line pressure is out of specification, check for bends or kinks in the drain lines. Look for places where the OEM fuel lines may be pinched by wire ties or p-clips. Check for blocked fuel tank vents.



Finishing Steps

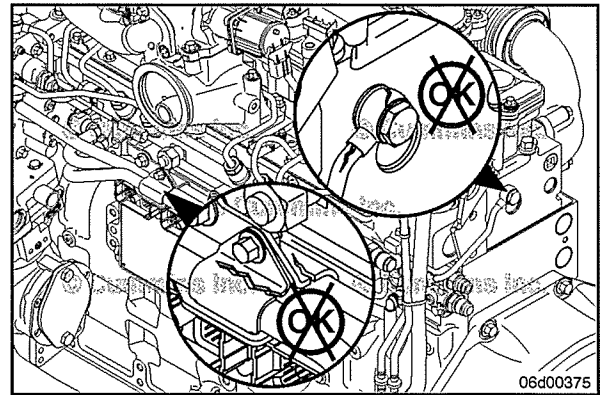
- Remove all test fittings and install the drain lines. Refer to Procedure 006-013 in Section 6.



Fuel Drain Lines (006-013)

Initial Check

Inspect the drain lines for any signs of leaks, cracks, chafing, or loose or broken brackets.



Preparatory Steps

⚠ WARNING ⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠ WARNING ⚠

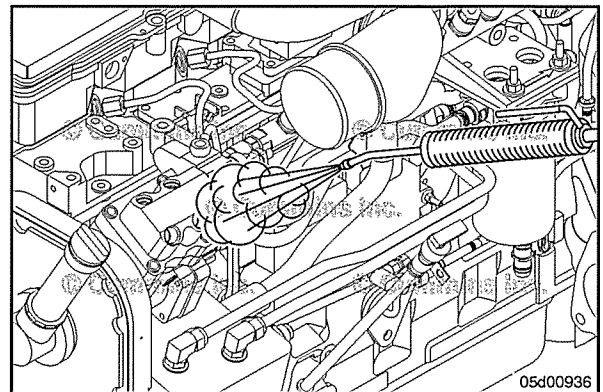
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

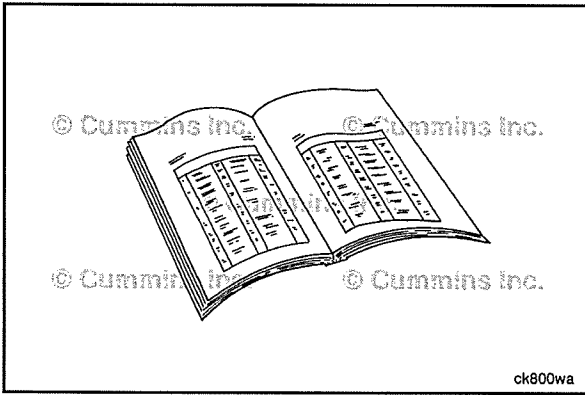
⚠ CAUTION ⚠

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine.

- Clean the engine. Refer to Procedure 000-009 in Section 0. Refer to Procedure 204-008 in Section i.
- Use contact cleaner, Part Number 3824510 or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, or cleaning solution does **not** get inside the fuel system.



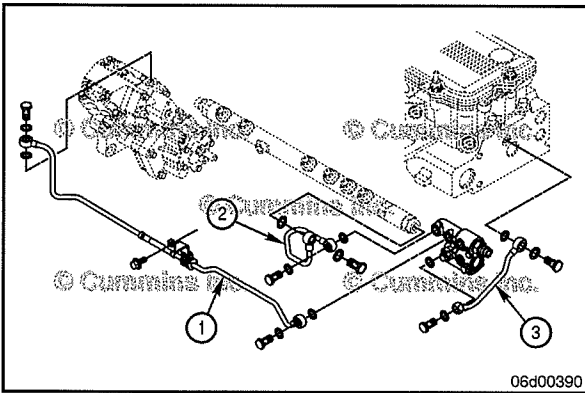


⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.



Remove

⚠ WARNING ⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

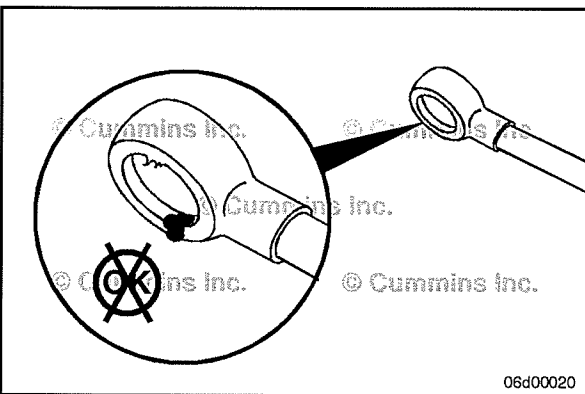
⚠ WARNING ⚠

Do not vent the fuel system on a hot engine; this can cause fuel to spill onto a hot exhaust manifold, which can cause a fire.

There are three drain lines on the engine:

- 1 The fuel pump drain line connects the fuel pump to the fuel drain manifold.
- 2 The fuel rail pressure relief valve drain line connects the fuel rail pressure relief valve to the fuel drain manifold.
- 3 The injector drain line connects the back of the cylinder head to the fuel drain manifold.

These lines are removed by removing the banjo bolts and sealing washers.



Inspect for Reuse

Inspect the lines for damage.

Inspect the banjo seal washers for damage.

Install

Install the three drain lines on the engine.

High pressure fuel pump drain:

- Install the p-clip bracket
- Install the banjo bolt at the fuel drain manifold
- Install the banjo bolt at the fuel pump.

Pressure relief valve drain line:

- Install the banjo bolt at the fuel drain manifold
- Install the banjo bolt at the pressure relief valve. Hold the line so that it will **not** twist and wear against the bottom of the cylinder head.

Injector drain line.

Torque Value:

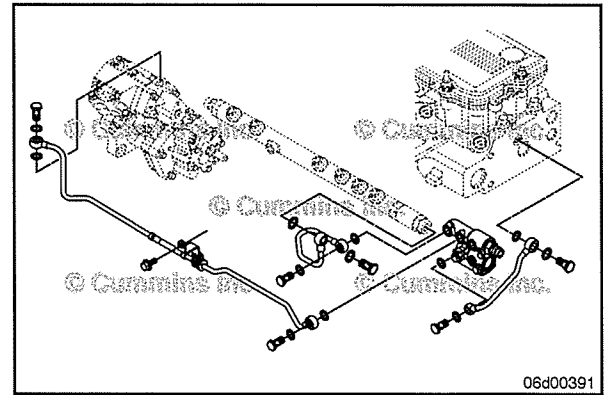
M12 banjo bolts 24 N•m [212 in-lb]

Torque Value:

M16 banjo bolts 43 N•m [32 in-lb]

Torque Value:

P-clip capscrew 24 N•m [212 in-lb]

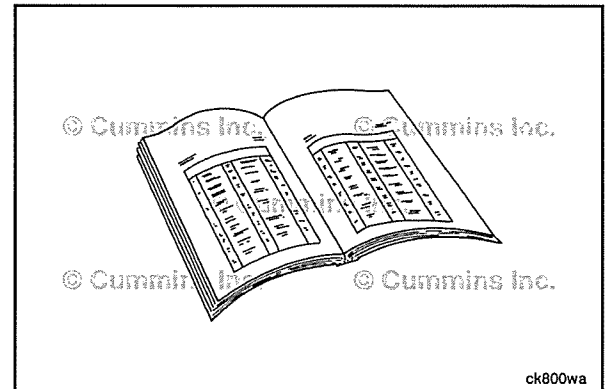


Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Fuel Filter (Spin-On Type) (006-015)

General Information

The fuel system requires the use of two fuel filters. The suction-side filter **must** have the following characteristics:

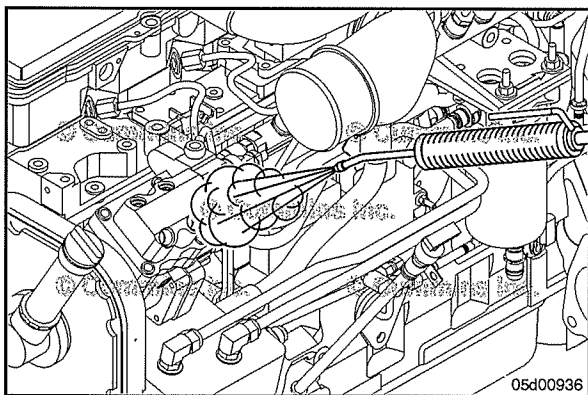
- Water-separating
- 8-micron rating
- Water-in-fuel sensor with shunt resistor
- Water-drain valve
- Engine mounted or chassis mounted.

The pressure-side filter **must** have the following characteristics:

- 5-micron rating
- Engine mounted or chassis mounted.

Use the following procedure in the QSL9 CM2350 L102 Operation and Maintenance Manual, Bulletin 4332797, for fuel filter recommendations. Refer to Procedure 018-024 in Section V.

If the engine has been allowed to run out of fuel or the fuel system has been serviced or repaired, it will be necessary to prime the fuel system.



Preparatory Steps



⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.



⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ CAUTION ⚠

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

NOTE: All fuel system diagnostics procedures and component specifications have been moved. Refer to Procedure 005-236 in Section 5.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine.

- Clean the engine. Refer to Procedure 000-009 in Section 0. Refer to Procedure 204-008 in Section i.
- Use electrical contact cleaner, Part Number 3824510 or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, or cleaning solution does **not** get inside the fuel system.



⚠ WARNING ⚠

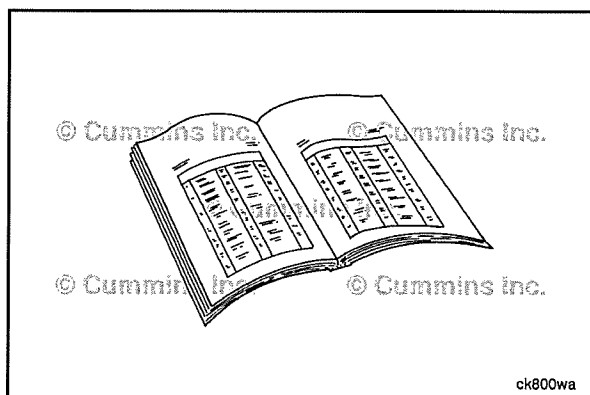
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



⚠ WARNING ⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.



Remove

⚠ WARNING ⚠

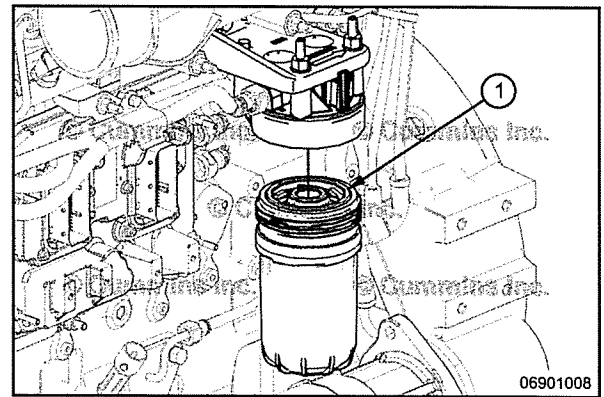
Depending on the circumstance, diesel fuel is flammable. When inspecting or performing service or repairs on the fuel system, to reduce the possibility of fire and resulting severe personal injury, death, or property damage, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area.

Disconnect the wiring harness from the water-in-fuel sensor, if equipped.

Loosen and remove the fuel filter.

Make sure the seal ring (1) does **not** stick to the filter head.

Remove the ring with an o-ring pick, if necessary.



Install

⚠ CAUTION ⚠

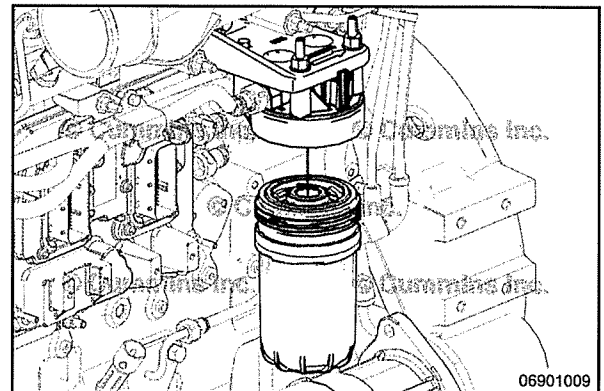
Mechanical overtightening can distort the threads as well as damage the filter element seal or filter canister.

It will be necessary to fill the 8-micron water stripping (suction-side) fuel filter with fuel.

Do **not** fill the 5-micron (pressure-side) fuel filter with fuel before installation; instead, prime the fuel system using the fuel lift pump.

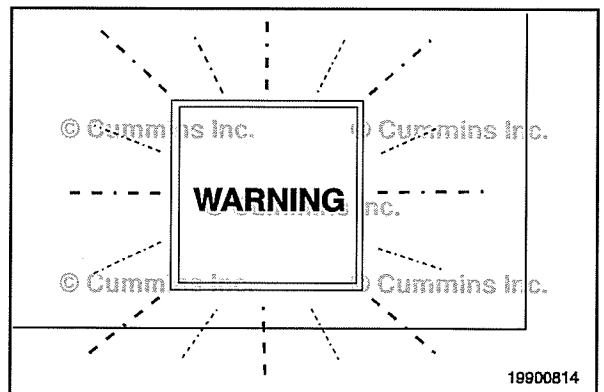
Install the filter as specified by the filter manufacturer.

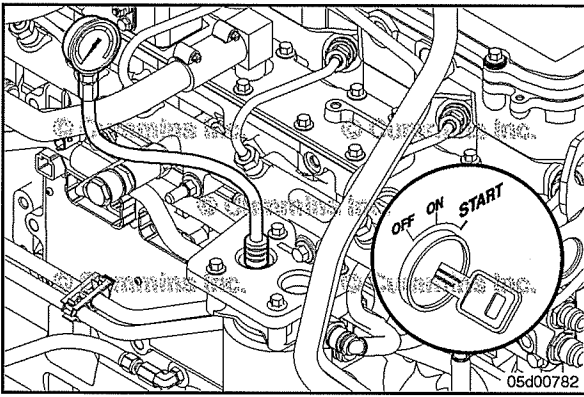
Connect the water-in-fuel sensor, if equipped.



The fuel system is capable of detecting the presence of the correct water-in-fuel sensor.

If the water-in-fuel sensor is incompatible or disconnected, the engine WARNING lamp will illuminate.





Prime

⚠ WARNING ⚠

When servicing the engine do not rotate engine with a high pressure fuel system joint open. Rotating the engine can create highly pressurized fuel in the fuel system. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

Install an M10 male Compuchek™ fitting, Part Number 3824842, at the on-engine fuel filter head inlet port.

To assist in fuel system priming and removing air from the fuel system, an orificed diagnostic fuel line, Part Number 3164621, can be used to bleed air from the low-pressure fuel system.

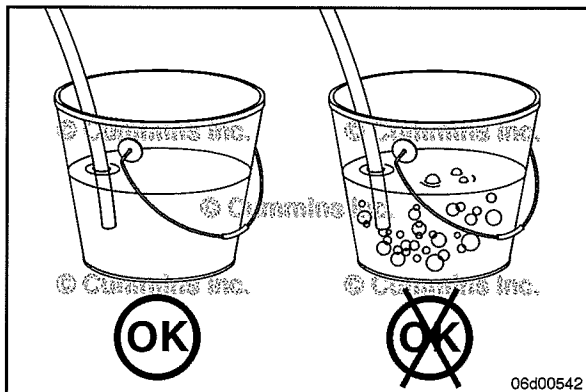
Install the orificed diagnostic fuel line to the M10 male Compuchek™ fitting at the inlet to the pressure-side fuel filter.

NOTE: If there is **not** enough clearance to install the 0.043-inch orificed diagnostic fuel line, Part Number 3164621, an adapter fitting, Part Number 3932302, and an 1/8-NPT male Compuchek™ fitting, Part Number 3377244, can be used to aid accessibility.

Turn the key to the ON position. Do **not** start the engine.

Allow the priming pump to operate and observe the orificed diagnostic fuel line. When a solid stream of fuel exits the line, the initial priming process is complete. It can be necessary to repeat this process two or three times.

Remove the diagnostic fuel line.



⚠ WARNING ⚠

When servicing the engine do not rotate engine with a high pressure fuel system joint open. Rotating the engine can create highly pressurized fuel in the fuel system. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

NOTE: The engine can possibly run rough for several minutes until the air is out of the system.

Start the engine and allow it to stabilize.

Attach the orificed diagnostic fuel line to the Compuchek™ fitting at the inlet to the pressure-side fuel filter. Allow engine to operate with the orificed diagnostic fuel line installed for 10 seconds.

Shut the engine OFF and observe the fuel/air exiting the orificed diagnostic fuel line.

Remove the orificed diagnostic fuel line from the engine.

Repeat this process up to four times, or until air no longer exits the diagnostic fuel line after shutdown.

NOTE: Remove the orificed diagnostic fuel line before starting the engine. The engine will be difficult to start if the orificed diagnostic fuel line is installed during starting.

If air continues to exit the diagnostic fuel line after four or more repetitions, check the suction side of the fuel system for leaks. Refer to Procedure 006-003 in Section 6.



⚠ WARNING ⚠

When servicing the engine do not rotate engine with a high pressure fuel system joint open. Rotating the engine can create highly pressurized fuel in the fuel system. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

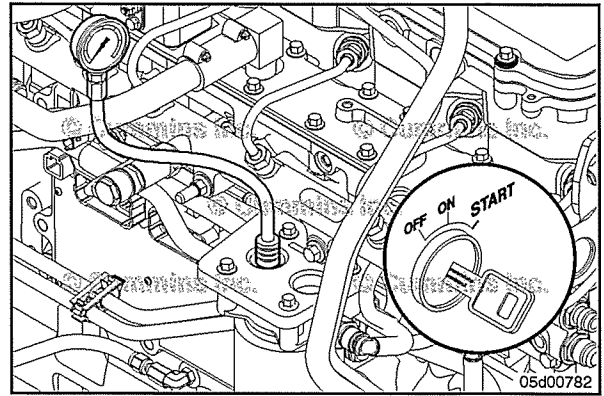
NOTE: The engine can possibly run rough for several minutes until the air is out of the system.

If the engine will **not** start, attach the diagnostic fuel line to the Compuchek™ fitting at the inlet to the pressure-side fuel filter and crank the engine for 15 seconds.

NOTE: Crank the engine in 15 second intervals with a 15 second break between cranking. This reduces the possibility of overheating the starter motor.

Stop cranking the engine and observe the orificed diagnostic fuel line. Allow the entrapped air to expand and exit through the diagnostic fuel line. Repeat this process up to four times, or until the engine starts.

If air continues to exit the diagnostic fuel line after four or more repetitions, check the suction side of the fuel system for leaks. Refer to Procedure 006-003 in Section 6.

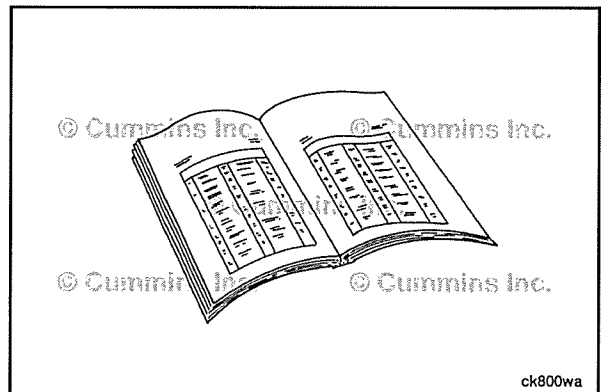
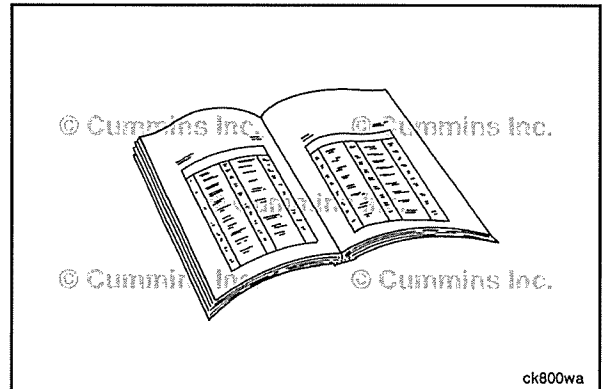


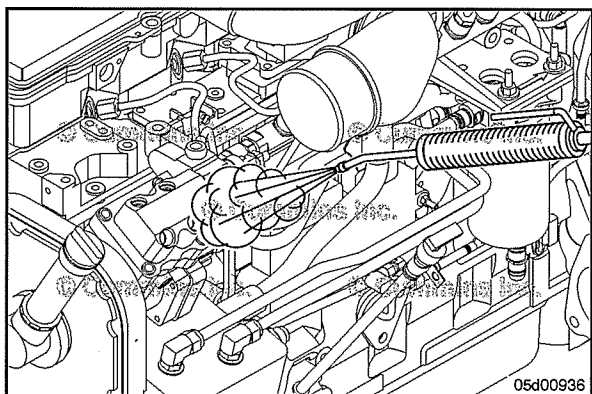
Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the battery cables. Refer to the OEM service manual.
- Operate the fuel lift pump to help prime the fuel system. Turn the keyswitch to RUN, but do **not** attempt to start the engine. This will cause the engine control module (ECM) to operate the fuel lift pump through a priming cycle which lasts at least 30 seconds. Cycle the lift pump several times by keying OFF, waiting 10 seconds, and keying ON again.
- Once the engine is started, slowly increase the engine speed while air is purged from the fuel plumbing.





Fuel Filter Head (006-017)

Preparatory Steps



⚠ WARNING ⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.



⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ CAUTION ⚠

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine.

- Clean the engine. Refer to Procedure 000-009 in Section 0. Refer to Procedure 204-008 in Section i.
- Use contact cleaner, Part Number 3824510 or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, or cleaning solution does **not** get inside the fuel system.

⚠ WARNING ⚠

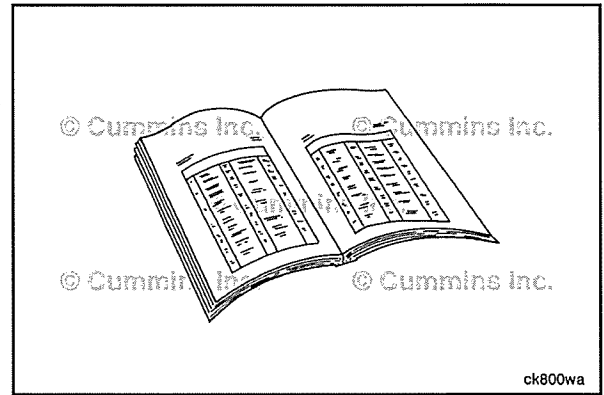
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



⚠ WARNING ⚠

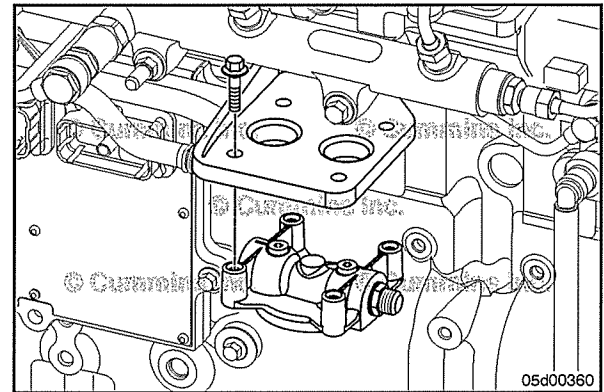
Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Shut off the fuel supply, if equipped. Refer to the OEM service manual.
- Remove the fuel filter. Refer to Procedure 006-015 in Section 6.
- Disconnect the fuel line supply and return line connections. Refer to Procedure 006-024 in Section 6.

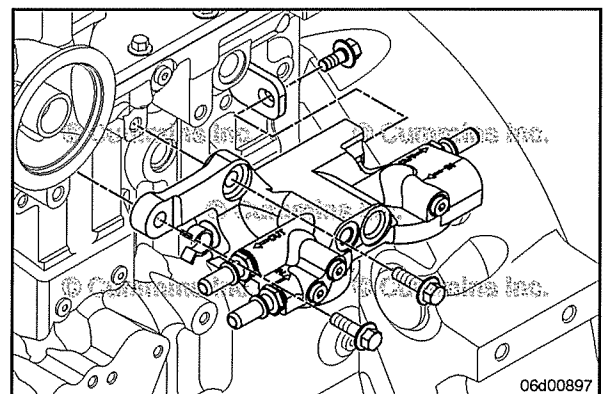


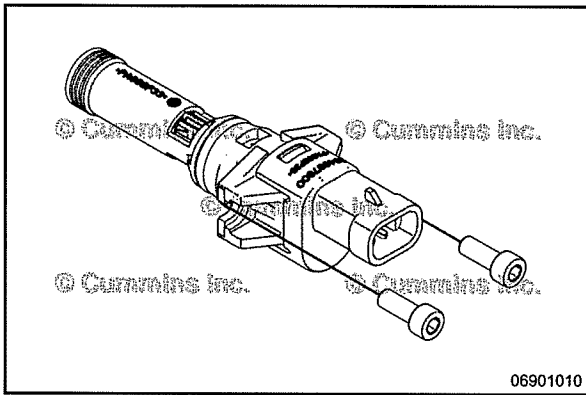
Remove

Remove the fuel filter head mounting capscrews.



For engines equipped with a dual fuel filter head, remove the fuel filter head mounting capscrews and filter head.

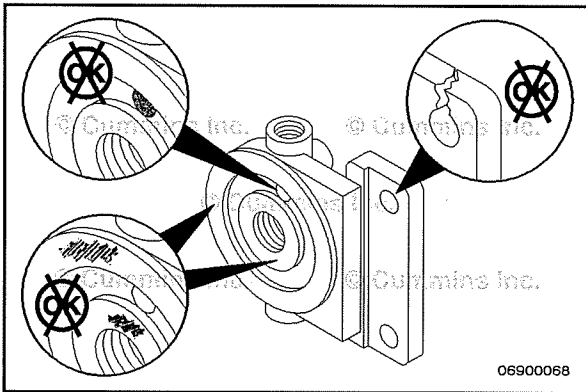




Disassemble
All Applications Except Marine

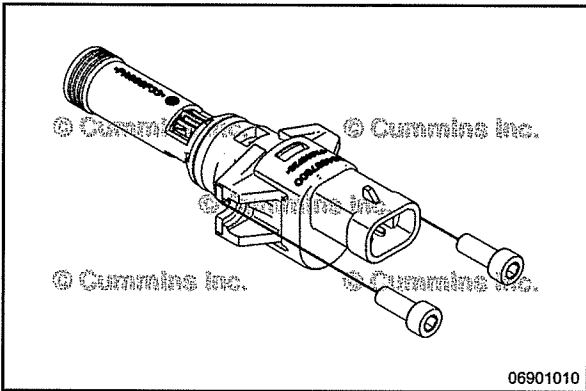


Remove the fuel heater, if equipped. Refer to Procedure 005-008 in Section 5.



Inspect for Reuse

Inspect the fuel filter head for cracks, passage blockage, and material or debris on the sealing surfaces.



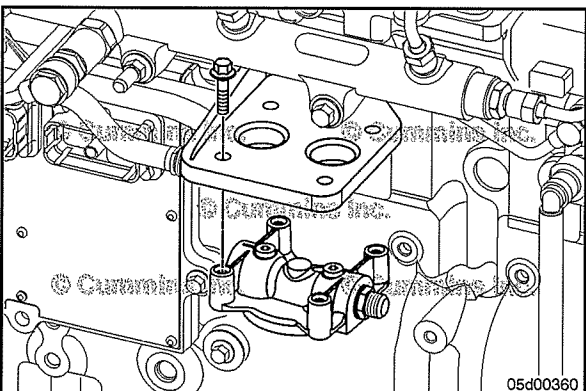
Assemble



Install the fuel heater, if equipped. Refer to Procedure 005-008 in Section 5.

Torque Value: 9 N•m [80 in-lb]

NOTE: Make sure there is an o-ring between the fuel filter head and the heater.



Install

Install the fuel filter head.

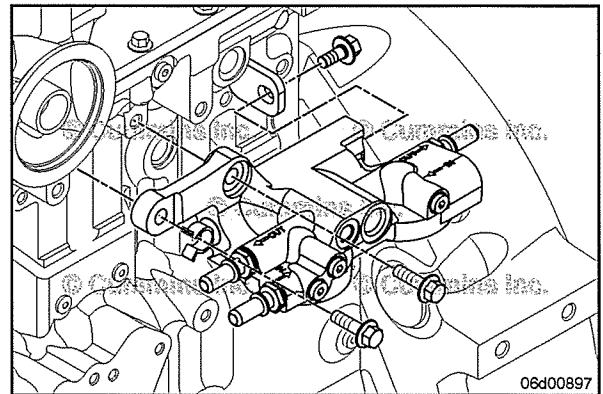
Tighten the retaining capscrews.

Torque Value: 24 N•m [212 in-lb]



For engines equipped with a dual fuel filter head, install the filter head and tighten the retaining capscrews.

Torque Value: 43 N•m [32 ft-lb]

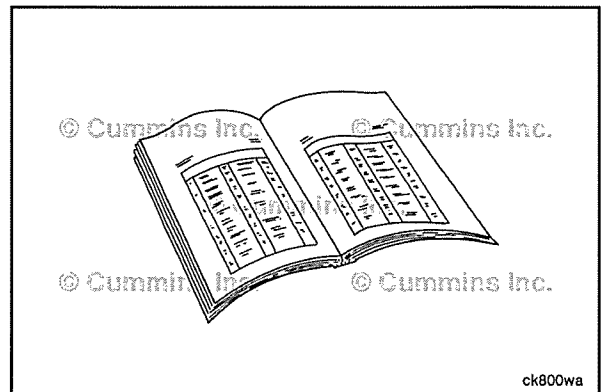


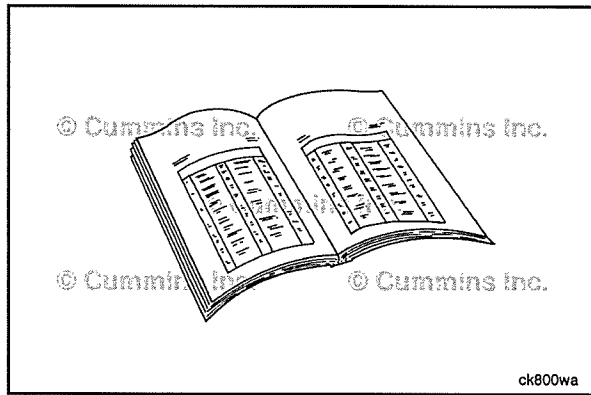
Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the fuel return and supply lines. Refer to Procedure 006-024 in Section 6.
- Install the fuel filter. Refer to Procedure 006-015 in Section 6.
- Open the fuel supply valve, if equipped. Refer to the OEM service manual.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.





Fuel Filter Head Bracket (006-018)

Preparatory Steps



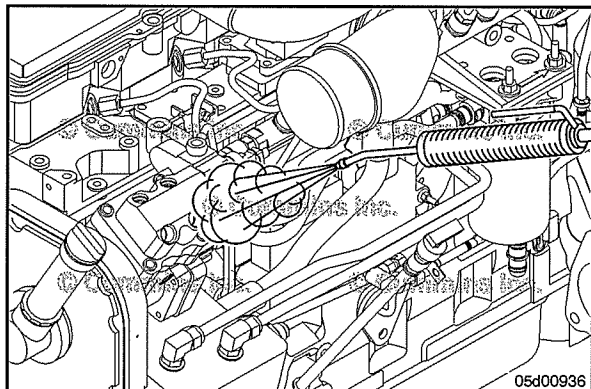
⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.
- For engines equipped with a single fuel filter head, remove the fuel filter. Refer to Procedure 006-015 in Section 6.
- Remove the fuel supply lines from the filter head. Refer to Procedure 006-024 in Section 6.
- For engines equipped with a single fuel filter head, remove the fuel filter head. Refer to Procedure 006-017 in Section 6.



⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.



⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

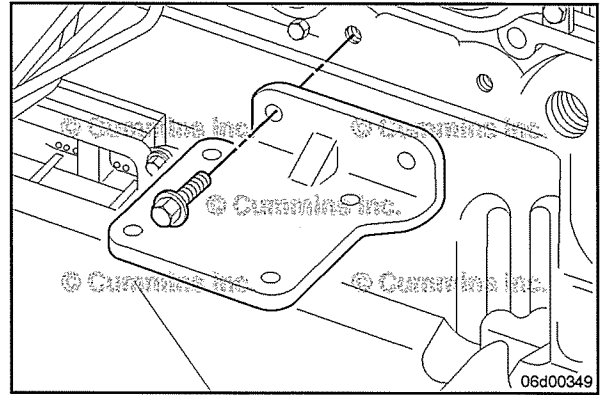
⚠ CAUTION ⚠

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which can expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine. Refer to Procedure 000-009 in Section 0.

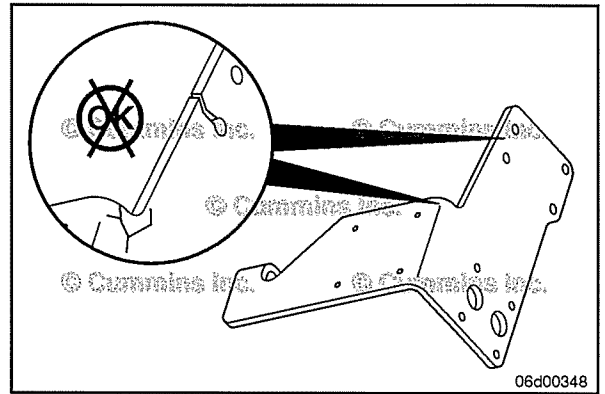
Remove

For engines equipped with a single fuel filter head.
Remove the filter head bracket from the engine.



Inspect for Reuse

Inspect the filter head for bracket mounting for cracks and signs of fretting on the mounting holes.
Replace the bracket if it is cracked or has signs of fretting.

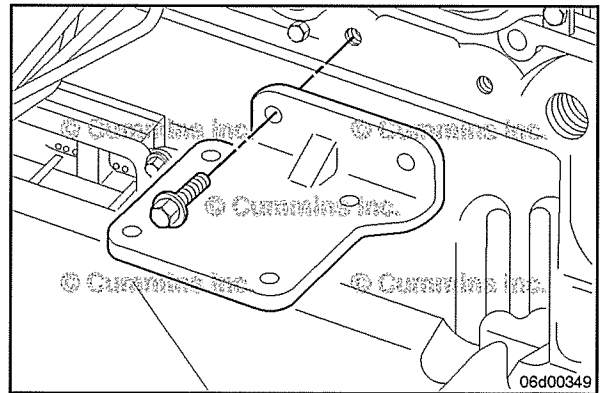


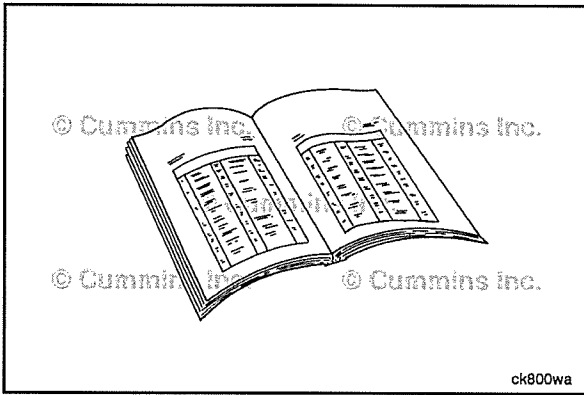
Install

For engines equipped with a single fuel filter head, install the fuel filter mounting bracket.

Tighten the retaining capscrews.

Torque Value: 43 N•m [32 ft-lb]





Finishing Steps



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- For engines equipped with a single fuel filter head, install the fuel filter head. Refer to Procedure 006-017 in Section 6.
- For engines equipped with a single fuel filter head, install the fuel filter. Refer to Procedure 006-015 in Section 6.
- Install the fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Fuel Inlet Restriction (006-020)

Preparatory Steps

Obtain a 1.09-mm [0.043-in] orificed diagnostic fuel line, Part Number 3164621.

Obtain a container suitable for collection of fuel that exits the diagnostic fuel line. A 19-liter [5-gal] bucket is recommended.

Install a pressure gauge adapter, Part Number 4918324. Use fuel line connector fitting, Part Number 3972088, at the inlet to the gear pump.

NOTE: The quick-disconnect fitting threaded into the inlet of the fuel pump **must** be substituted for a fuel line connector fitting, Part Number 3972088, in order to use a pressure gauge adapter, Part Number 4918324.

Install an M10 Compuchek™ fitting, Part Number 3824842, at the fuel filter head.

NOTE: If there is **not** enough clearance to install the female Compuchek™ fitting, Part Number 3824842, an adapter fitting, Part Number 3932302, and an 1/8-NPT male Compuchek™ fitting, Part Number 3377244, may be used to aid accessibility.

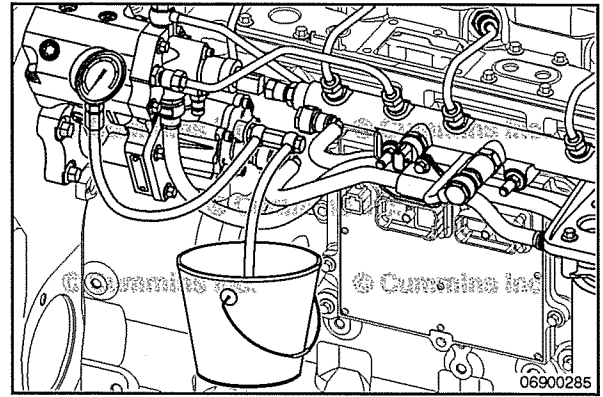
Attach the 1.09-mm [0.043-in] orificed diagnostic fuel line at the fuel filter head Compuchek™ fitting. Route this hose into a collection container or into the vehicle fuel tank.

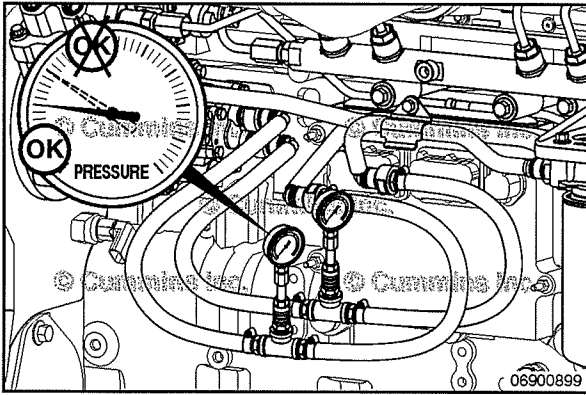
NOTE: It is necessary to attach the 1.09-mm [0.043-in] orificed diagnostic fuel line so that the fuel pump can reach rated flow. Failure to reach rated flow may result in an incorrect test result.

Attach a 0 to 762 mm-Hg [0 to 30 in-Hg] vacuum gauge to a pressure gauge adapter, Part Number 4918324, at the gear pump inlet.

Install an M10 Compuchek™ fitting, Part Number 3824842, at the OEM fuel inlet connection.

Attach a 0 to 762 mm-Hg [0 to 30 in-Hg] vacuum gauge at the OEM fuel inlet connection.





CAUTION

Make sure the slide removal tool is removed from the fuel line as soon as possible after the line has been disconnected. Inadvertently leaving the tool in place can result in fuel leaks.

Alternative Set-up

Install diagnostic fuel line, Part Number 4918895, between the gear pump fuel supply line and the gear pump inlet (upper fuel line fitting).

To aid in the removal of quick disconnect style fuel lines, slide removal tool, Part Number 4918878, over the locking tangs.

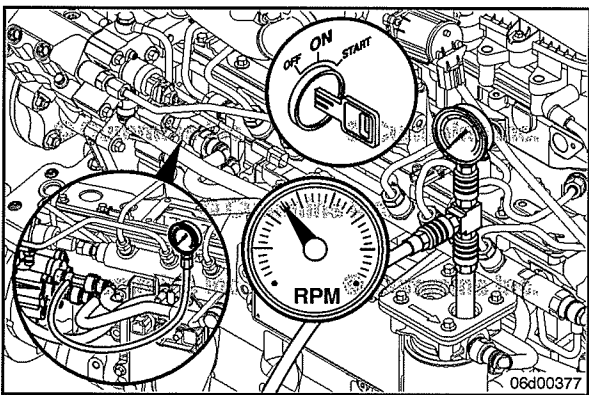
Attach a 0 to 762 mm-Hg [0 to 30 in-Hg] vacuum gauge to a pressure gauge adapter, Part Number 4918895, connected at the gear pump inlet.

Install an M10 Compuchek™ fitting, Part Number 3824842, at the fuel filter head.

NOTE: If there is **not** enough clearance to install the female Compuchek™ fitting, Part Number 3824842, an adapter fitting, Part Number 3932302, and an 1/8-NPT male Compuchek™ fitting, Part Number 3377244, may be used to aid accessibility.

Attach the 1.09-mm [0.043-in] orificed diagnostic fuel line at the fuel filter head Compuchek™ fitting. Route this hose into a collection container or into the vehicle fuel tank.

NOTE: It is necessary to attach the 1.09-mm [0.043-in] orificed diagnostic fuel line so that the fuel pump can reach rated flow. Failure to reach rated flow may result in an incorrect test result.



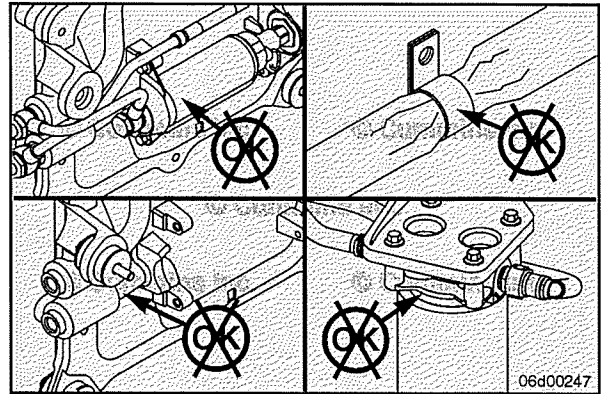
Measure

Operate the engine at high idle and measure the inlet vacuum.

Maximum Fuel Inlet Restriction		
	mm-Hg	in-Hg
At OEM connection (dirty filter) loaded condition	203.2	8.0
At inlet to fuel gear pump (dirty filter) loaded condition	304.8	10.0

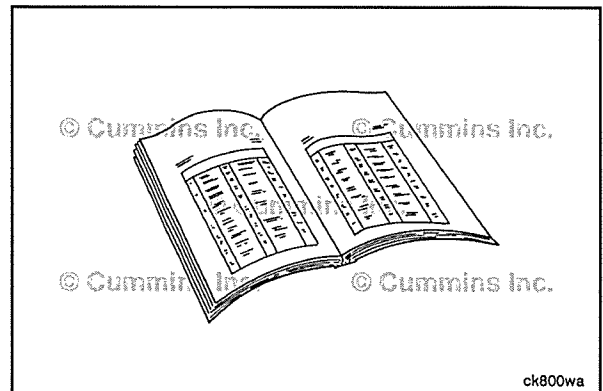
If the inlet restriction is excessive, look for the root cause:

- Suction side fuel filters plugged
- Fuel heater valves restricted
- ECM cooling plate plugged
- ECM cooling plate check valve restricted
- OEM fuel lines pinched or restricted
- Fuel tank stand pipes restricted.



Finishing Steps

- Disconnect all diagnostic test fittings and install all components removed during testing.

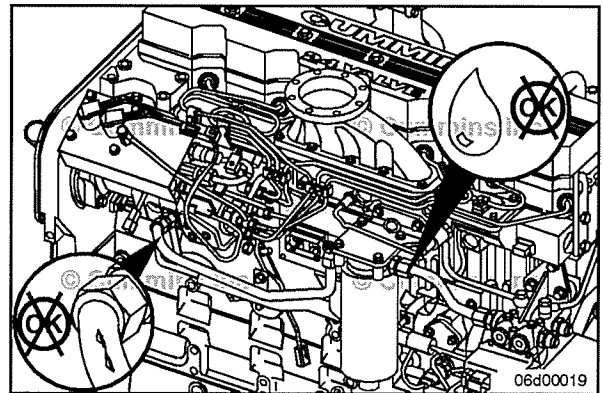


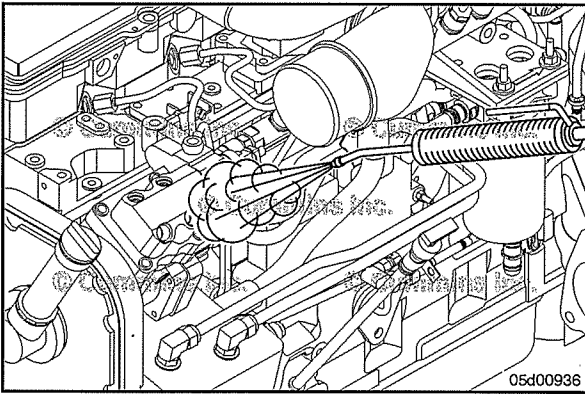
Fuel Supply Lines (006-024)

Initial Check

Inspect all fuel supply lines and fittings. Look for cracks in the lines or leaking fittings.

Inspect the quick-disconnect style fittings for damaged o-ring connections or broken locking tangs.





Preparatory Steps



⚠ WARNING ⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.



⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ CAUTION ⚠

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine.

- Clean the engine. Refer to Procedure 000-009 in Section 0. Refer to Procedure 204-008 in Section i.
- Use electrical contact cleaner, Part Number 3824510 or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, or cleaning solution does **not** get inside the fuel system.

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



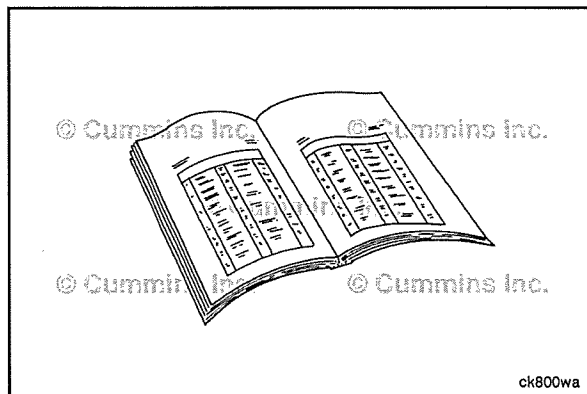
⚠ WARNING ⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

⚠ CAUTION ⚠

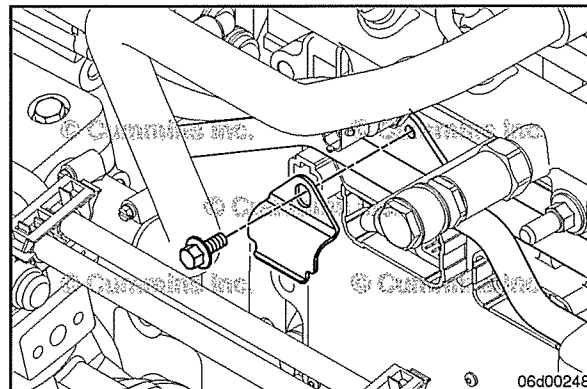
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Close the fuel supply and return valves. Refer to the OEM service manual.



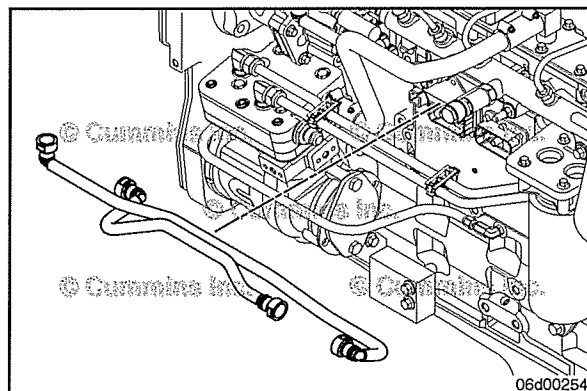
Remove

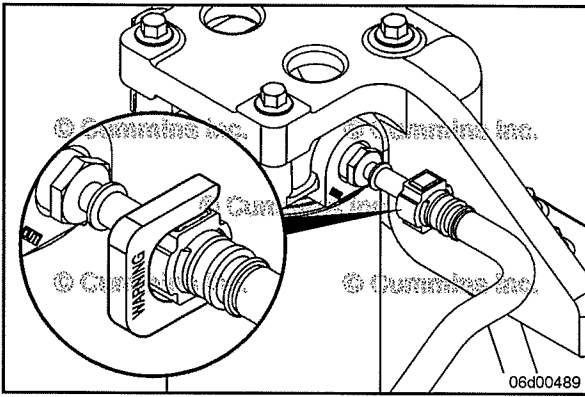
For quick disconnect style fuel lines, remove the clasp from the fuel line brace. This will allow the lines to move so they can be disconnected.



Loosen all quick disconnect lines from the brace.

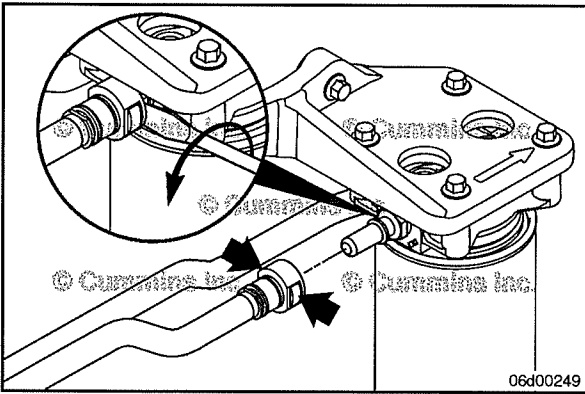
To remove the gear pump outlet line, the gear pump inlet line **must** be removed first.



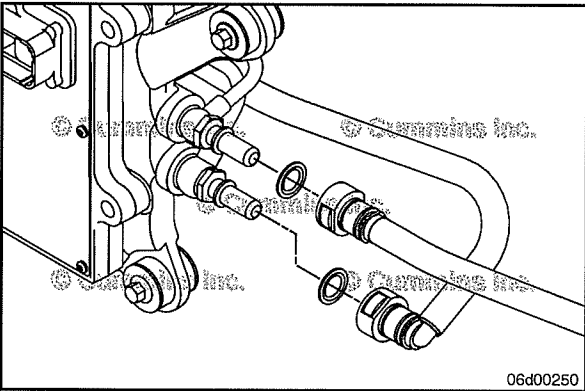


Remove the quick disconnect style fuel lines by pressing in the locking tangs on both sides of the quick disconnect fitting.

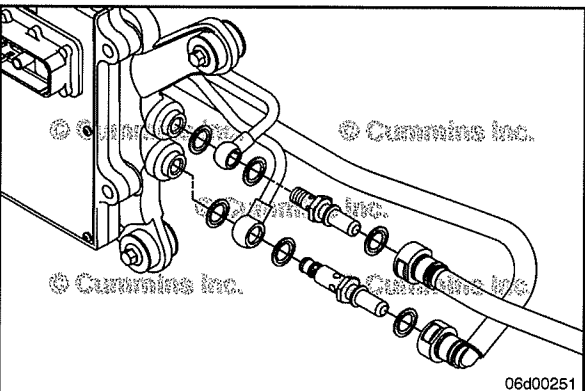
To aid in the removal of quick disconnect style fuel lines, slide removal tool, Part Number 4918878, over the locking tangs. Make sure the tool is removed from the fuel line as soon as possible after line has been disconnected. Inadvertently leaving the tool in place can result in fuel leaks.



To aid removal, a screwdriver may be inserted between the fuel line end and quick disconnect male union. After pressing the opposing locking tangs, twisting the flat blade of the screwdriver helps to remove the fuel line.



If fuel leaks or suction side air entry is suspected, remove the fuel hoses or quick disconnect fittings.



Inspect for Reuse

Inspect for burrs or debris on metal connectors that may cause leaks.

On straight thread o-ring metric connectors, be certain the o-rings are **not** frayed or cut.

On quick disconnect style fittings, be certain the o-rings are **not** frayed or cut, and the lock tangs are **not** damaged.

Install

Install the quick disconnect fuel lines.

Install the quick disconnect fittings.

Torque Value: 24 N•m [212 in-lb]

Make sure the quick disconnect style fuel lines clasp onto the quick disconnect fittings.

Make sure the lines are routed and connected correctly. If the lines are connected incorrectly, the engine will **not** operate.

- 1 OEM connection to the upper fitting at the engine control module (ECM) cooling plate.
- 2 Lower ECM cooling plate fitting to the upper gear pump fitting.
- 3 Lower gear pump fitting to the pressure side fuel filter inlet.
- 4 Pressure side fuel filter outlet to the fuel pump fuel control actuator housing.

Fuel lines are routed in the following order:

- 1 OEM connection to the upper fitting at the ECM cooling plate
- 2 Lower ECM cooling plate fitting to the upper gear pump fitting
- 3 Lower gear pump fitting to the pressure side fuel filter inlet
- 4 Pressure side fuel filter outlet to the fuel pump fuel control actuator housing.

The fuel supply line brace holds the fuel lines in the following order:

- 1 The inside line connects the upper gear pump fitting to the lower ECM cooling plate fitting
- 2 The middle line connects the pressure side fuel filter outlet to the fuel pump fuel control actuator housing
- 3 The outside line connects the lower gear pump fitting to the pressure side fuel filter inlet.

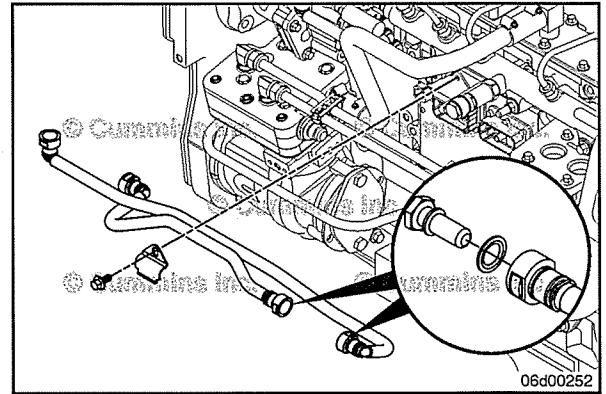
Install the fuel line brace clasp (quick disconnect style fuel lines **only**) and the brace, if necessary.

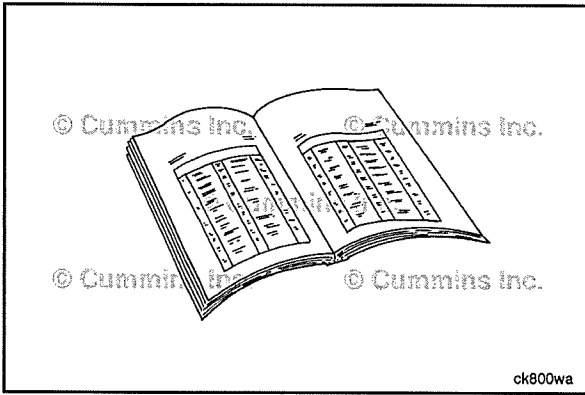
Torque Value:

Fuel Line Brace 24 N•m [212 in-lb]

Torque Value:

Fuel Line Brace Clasp 24 N•m [212 in-lb]





Finishing Steps

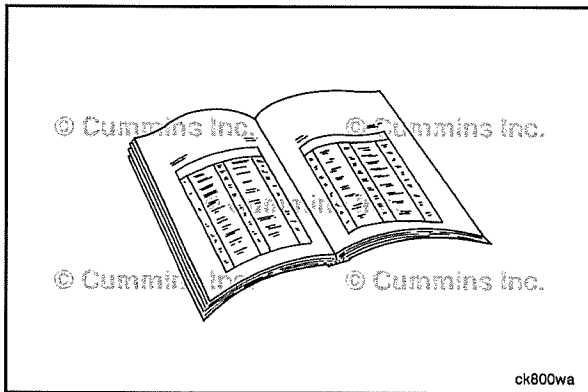


⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Open the fuel supply and return valves, if equipped.
- Connect the battery cables. Refer to the OEM service manual.
- Prime the fuel system. Refer to Procedure 006-015 in Section 6.
- Operate the engine and check for leaks.



Injector (006-026)

Preparatory Steps



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ CAUTION ⚠

Attempting to remove the injector without first removing the fuel connector will cause damage to the injector body and/or fuel connector.

NOTE: All fuel system diagnostics procedures and component specifications have been moved. Refer to Procedure 005-236 in Section 5.

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ CAUTION ⚠

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine.

- Clean the engine. Refer to Procedure 000-009 in Section 0. Refer to Procedure 204-008 in Section i.
- Use electrical contact cleaner, Part Number 3824510, or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, or cleaning solution does **not** get inside the fuel system.

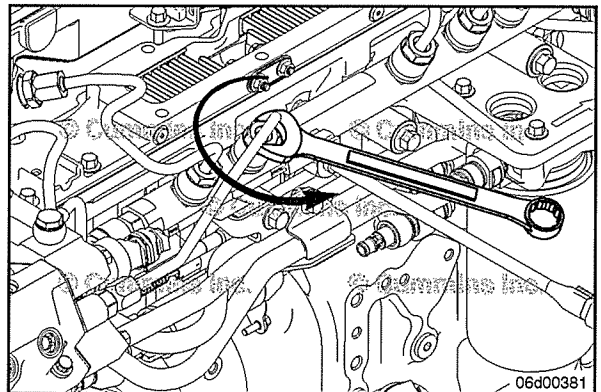
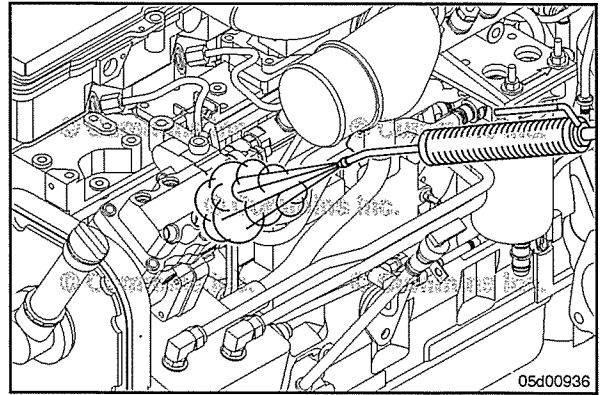
⚠ WARNING ⚠

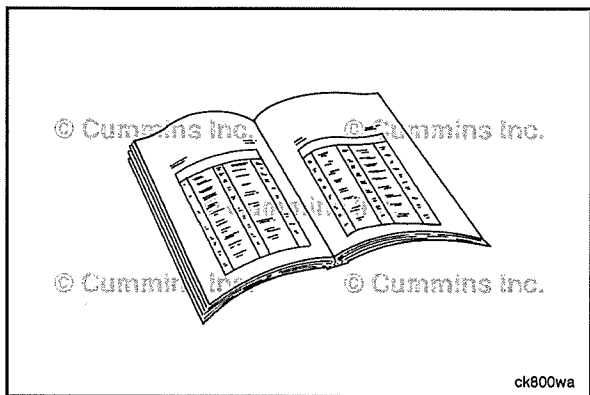
Normal engine operation creates highly pressurized fuel in the fuel line which will remain in the fuel line after engine shutdown. **Never open the fuel system when the engine is operating. Before servicing the fuel system, always loosen the pump-to-rail fuel line at the rail to vent the pressure. Keep hands clear of the line when loosening. High pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.**

- Before servicing the fuel system, loosen the pump-to-rail line at the rail to vent the pressure.
- Keep hands clear of the line when loosening.
- Tighten the pump-to-rail line nut.

Torque Value: 65 N·m [48 ft-lb]

NOTE: A machined slot in this fitting directs the fuel spray toward the cylinder block.





⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



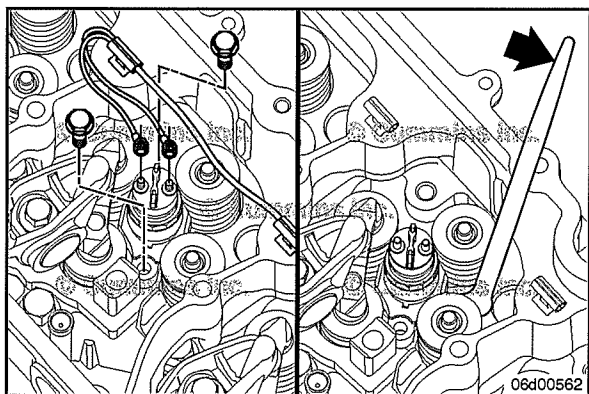
⚠ WARNING ⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

⚠ CAUTION ⚠

Attempting to remove the injector without first removing the fuel connector will cause damage to the injector body and/or fuel connector.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Close the fuel supply and drain valves. Refer to the OEM service manual.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the high-pressure fuel lines from the fuel rail. Refer to Procedure 006-051 in Section 6.
- Remove the engine brake, if equipped. Refer to Procedure 020-004 in Section 20.
- Remove the fuel connector. Refer to Procedure 006-052 in Section 6.
- Remove the exhaust rocker lever assembly. Refer to Procedure 003-008 in Section 3.



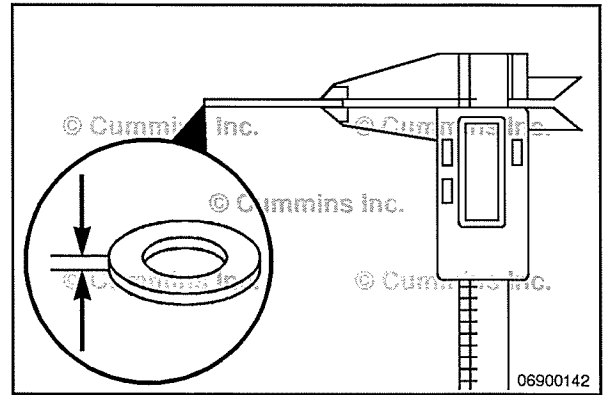
Remove

Disconnect the injector wire harness from the injector.
Remove the two injector hold-down clamp capscrews.
Use a small heel-bar to pry up on the injector hold-down clamp.

Clean and Inspect for Reuse

Install a new combustion sealing washer on the injector.

Verify the new injector sealing washer is the correct thickness. An incorrect sealing washer can cause high pressure fuel leaks and/or performance problems, due to incorrect injector protrusion.



⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

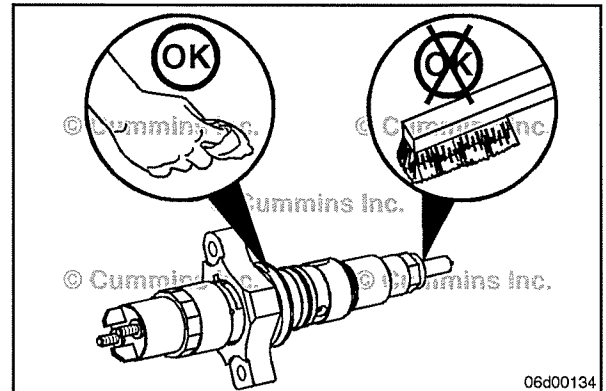
⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠ CAUTION ⚠

Do not use any abrasives (such as glass beading, sand paper, emery cloth, Scotch-Brite™ pads, etc) or metallic items (including wire brushes made of any metallic material) to clean the injectors. The use of any cleaning method other than safety solvent and a soft, clean, lint-free cloth will damage the nozzle holes and cause performance issues.

Clean the injector tip and body with safety solvent and a soft, clean cloth.



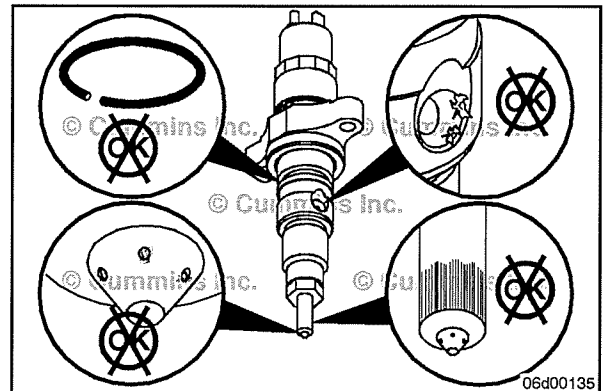
Inspect the injector and high-pressure connector o-rings for damage. Replace, if necessary. Refer to Procedure 006-052 in Section 6.

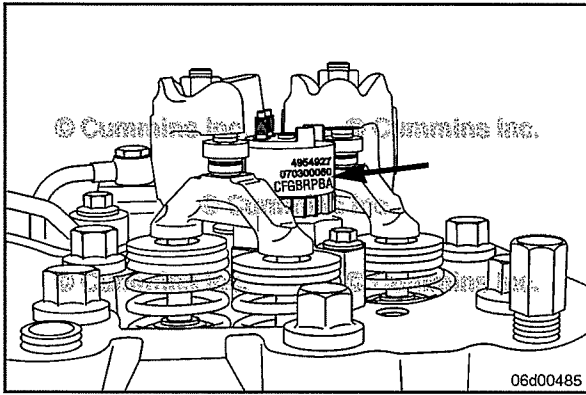
Inspect the injector inlet, high-pressure connector tip, and high-pressure connector inlet for damage.

Check the nozzle holes for any signs of damage, such as hole erosion or hole plugging.

Spray safety solvent on the injector body and inspect the fuel inlet passage for small cracks that can allow high pressure fuel to leak to the injector drain passage.

Inspect the solenoid terminals for damage.



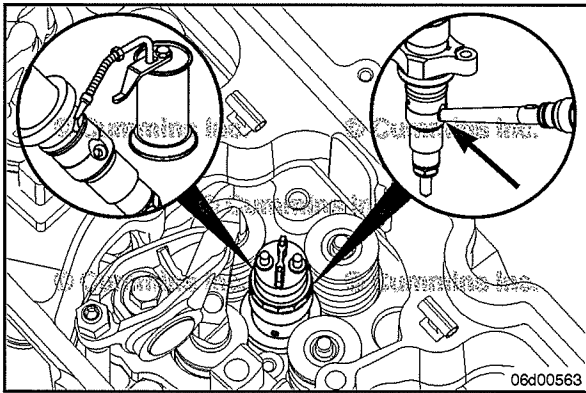


Install

Record the injector trim codes that are listed on each injector.

Record the cylinder location where each injector will be installed.

NOTE: The injector trim codes are nine character alphanumeric codes located on the solenoid at the top of the injector.



NOTE: If a new injector is being installed, a new fuel connector must be used.



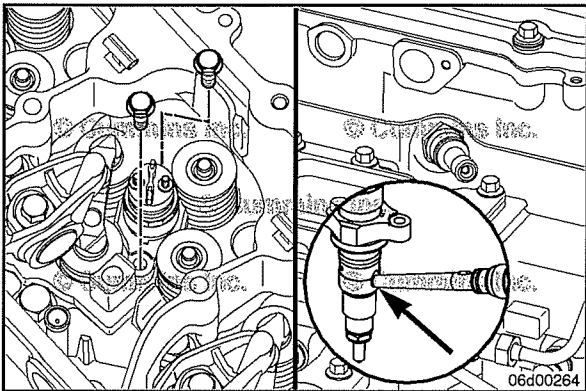
Make sure the injector bore is clean and that **only** one (1) sealing washer is installed on the injector nozzle.



Lubricate the injector o-ring with clean engine oil.

Place the injector in the cylinder head in the proper orientation (fuel inlet toward the high-pressure fuel connector).

Press down firmly on the injector to make sure it is seated in the injector bore.



NOTE: Start the injector hold-down clamp capscrews, but do **not** tighten.



Start the injector hold-down clamp capscrews, and tighten hand-tight.

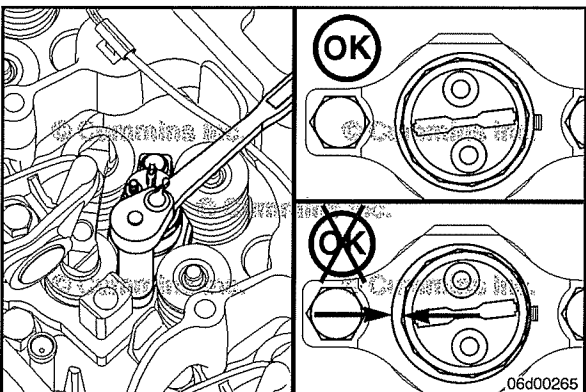
Install the high-pressure fuel connector, making sure the end of the high-pressure fuel connector is in the injector inlet port.

NOTE: The high-pressure fuel connector should click into place if it is seated in the injector inlet port correctly.

Start the high-pressure fuel connector retaining nut and tighten partially.

Torque Value: 15 N•m [133 in-lb]

NOTE: This is **not** the final torque for the high-pressure fuel connector retaining nut.



Tighten the injector hold-down clamp capscrews.

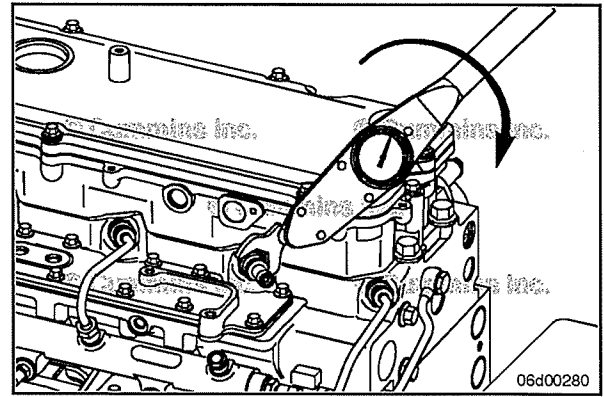
NOTE: Make sure to tighten the hold-down clamp capscrews evenly. Check to make sure the gap between the hold-down clamp and the injector is equally spaced around the injector body.

Torque Value: 10 N•m [89 in-lb]

Tighten the high pressure fuel connector retaining nut.

Use the following procedure for the final torque value. Refer to Procedure 006-052 in Section 6.

NOTE: The high-pressure fuel connector **must** be properly tightened or an internal fuel leak can result, causing poor engine performance. A torque wrench **must** be used.



⚠CAUTION⚠

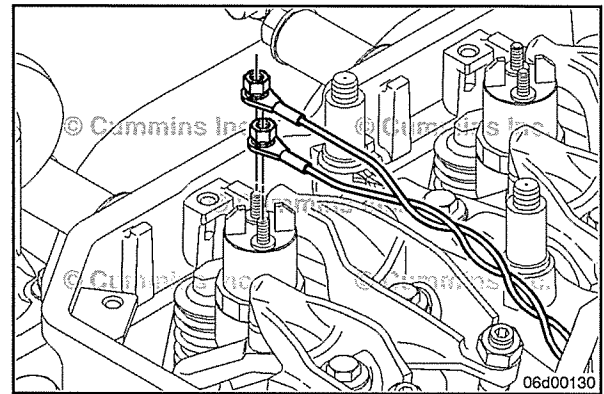
Do not over-tighten the injector harness. The injector terminals will be damaged if excessively over-tightened.

Install the injector wiring harness to the injector.

Torque Value: 2 N•m [18 in-lb]

NOTE: Polarity of the wiring is **not** significant. The SIGNAL and RETURN wires can be connected to either injector terminal.

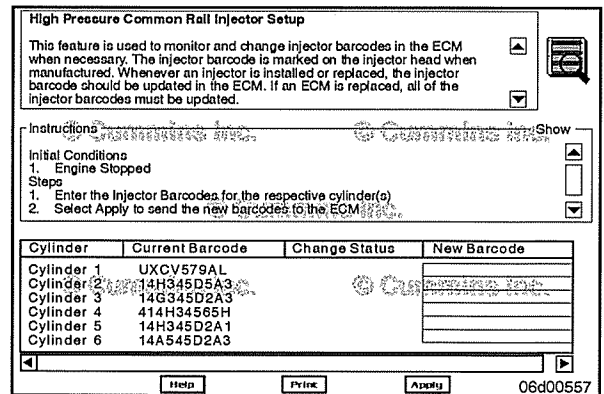
NOTE: Orient the injector wires so they will **not** interfere with a rocker lever or engine brake housing. If the rocker lever is able to come into contact with the injector harness, it will rub through the wire insulation and cause injector circuit fault codes.



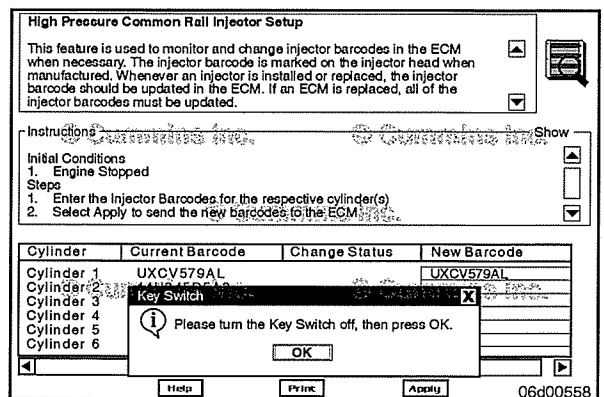
Finishing Steps

Trim Code Installation Instructions: INSITE™ 7.3 Feature Pack 1 and Newer

- 1 Connect INSITE™ electronic service tool to the engine control module (ECM).
- 2 Select "Advanced ECM Data".
- 3 Select "High Pressure Common Rail Injector Setup"
- 4 Read the information listed under the "High Pressure Common Rail Injector Setup" and "Instructions" headings.



- 1 Click on the "New Bar Code" section for the respective cylinder and enter the new bar code.
- 2 After all the injector trim information is entered, select "Apply". Turn the keyswitch OFF, then press the "OK" button to send the new barcode(s) to the ECM.



High Pressure Common Rail Injector Setup

This feature is used to monitor and change injector barcodes in the ECM when necessary. The injector barcode is marked on the injector head when manufactured. Whenever an injector is installed or replaced, the injector barcode should be updated in the ECM. If an ECM is replaced, all of the injector barcodes must be updated.

Instructions

Initial Conditions
1. Engine Stopped

Steps
1. Enter the Injector Barcodes for the respective cylinder(s)
2. Select Apply to send the new barcodes to the ECM.

Cylinder	Current Barcode	Change Status	New Barcode
Cylinder 1	UXCV579AL	SUCCESS	
Cylinder 2	14H345D5A3		
Cylinder 3	14G345D2A3		
Cylinder 4	414H34565H		
Cylinder 5	14H345D2A1		
Cylinder 6	14A545D2A3		

Buttons: Help, Print, Apply

06d00559

1 After INSITE™ electronic service tool reconnects with the ECM, verify that the "Change Status" = "Success".

NOTE: If "Change Status" = "Error Occurred", "Invalid Barcode", "Invalid Cylinder Number", or "Duplicate Barcode", check for the following:

- Verify the correct injector trim code was recorded from the injector.
 - Re-enter the trim codes.
2. Clear all inactive faults.

<input type="checkbox"/> Engine Warmup Protection	Enable
<input type="checkbox"/> Fan Control	Enable
<input type="checkbox"/> Fast Idle Warmup	Enable
<input type="checkbox"/> Gear-Down Protection	Enable
<input type="checkbox"/> Governor Type	
<input type="checkbox"/> High Pressure Common Rail Injector Setup	Enable
<input type="checkbox"/> Cylinder 1	
Barcode State	Set
Change Status	Success
Injector Barcode	14H845D...

06d00486



Trim Code Installation Instructions: Pre-INSITE™ 7.3 Feature Pack 1

- 1 Connect INSITE™ electronic service tool to the ECM.
- 2 Select "Features and Parameters".
- 3 Select "High Pressure Common Rail Injector Setup"
- 4 Expand each cylinder (Cylinder 1, Cylinder 2, etc.).

Enable	Find...	
Set	Send To	ECM Printer
Success	Expand	
4H345D2AS	Collapse	
	Restore Original Value	
	Restore All Original Values	
	Refresh	
	Units	

06d00487

Double click on the ECM value next to "Injector Barcode". Enter the injector trim information for the cylinder in which the injector will be installed.

NOTE: The alpha characters of the injector trim code **must** be entered in capital letters.

After all of the injector trim information is entered, right click on the screen and select "Send To", then "ECM". Follow the in-screen instructions.

Enable	
Set	
Success	
14H345D...	

06d00488

After INSITE™ electronic service tool reconnects with the ECM, verify that the "Barcode State" = "Set" and "Change Status" = "Success".

If "Barcode State" = "Not Set" and/or "Change Status" = "Unsuccessful", check the following:

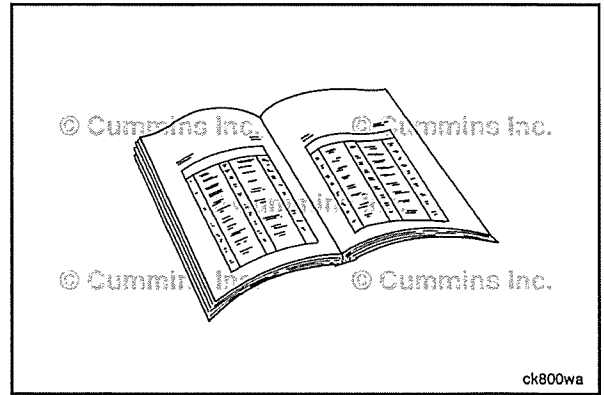
- 1 Verify the correct injector trim code was recorded from the injector.
- 2 Re-enter the trim codes.
- 3 Re-enter the trim codes with the alpha characters in all capital letters.

Clear all inactive faults.

▲ WARNING ▲

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Orient the injector wires so they will **not** interfere with a rocker lever or engine brake housing. If the rocker lever is able to come into contact with the injector harness, it will rub through the wire insulation and cause injector circuit fault codes.
- Install the exhaust rocker lever assembly. Refer to Procedure 003-008 in Section 3.
- Install the engine brake, if equipped. Refer to Procedure 020-004 in Section 20.
- Install the high pressure fuel lines. Refer to Procedure 006-051 in Section 6.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Open the fuel supply and return valves. Refer to the OEM service manual.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Injector Supply Lines (High Pressure) (006-051)

Initial Check

Check the fuel pump connection.

Torque Value: 50 N•m [37 ft-lb]

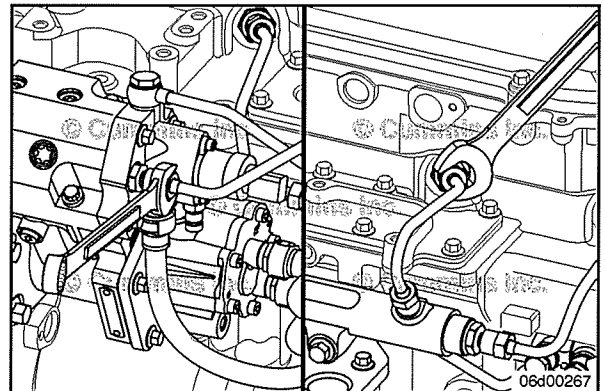
Check the cylinder head connections.

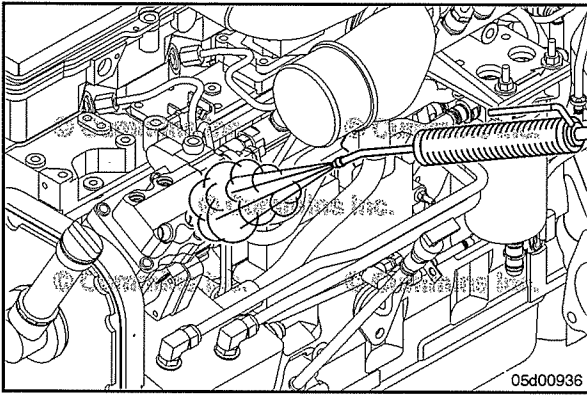
Torque Value: 50 N•m [37 ft-lb]

Check the fuel rail connections.

Torque Value: 65 N•m [48 ft-lb]

NOTE: The nuts **must** be properly tightened or an external fuel leak can result in poor engine performance. A torque wrench **must** be used.





Preparatory Steps



⚠ WARNING ⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.



⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ CAUTION ⚠

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine.

- Clean the engine. Refer to Procedure 000-009 in Section 0. Refer to Procedure 204-008 in Section i.
- Use electrical contact cleaner, Part Number 3824510 or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, or cleaning solution does **not** get inside the fuel system.

⚠ WARNING ⚠

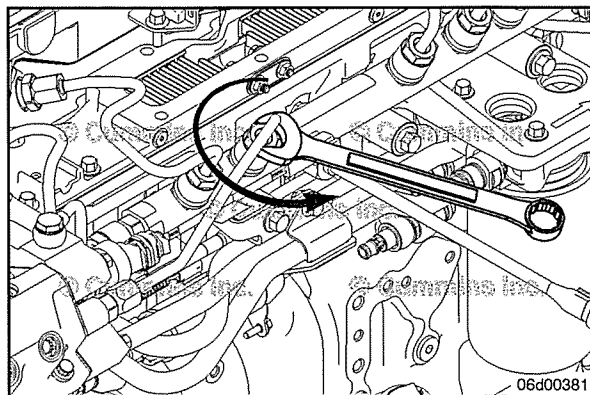
Normal engine operation creates highly pressurized fuel in the fuel line which will remain in the fuel line after engine shutdown. Never open the fuel system when the engine is operating. Before servicing the fuel system, always loosen the pump-to-rail fuel line at the rail to vent the pressure. Keep hands clear of the line when loosening. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

Before servicing the fuel system, loosen the pump-to-rail line at the rail to vent the pressure.

Keep hands clear of the line when loosening.

Tighten the fuel rail nut.

NOTE: A machined slot in this fitting directs the fuel spray toward the engine block.



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

⚠ CAUTION ⚠

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.

Remove

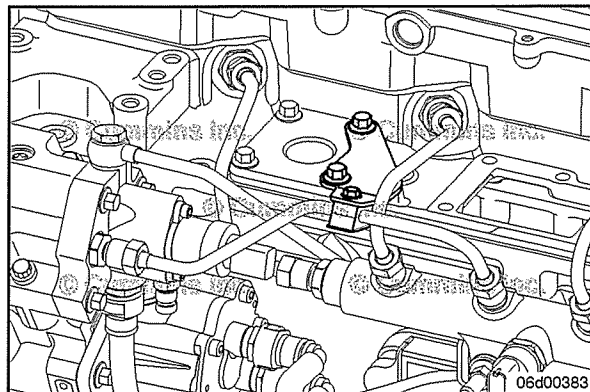
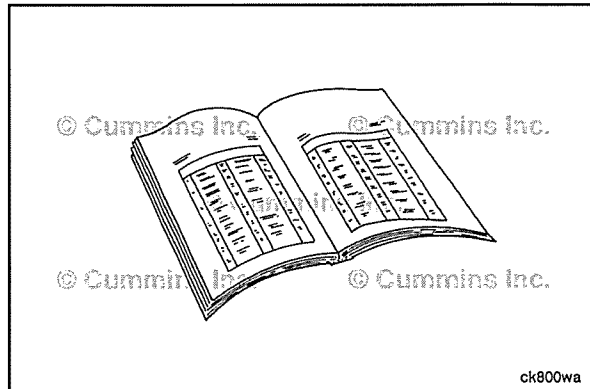
⚠ WARNING ⚠

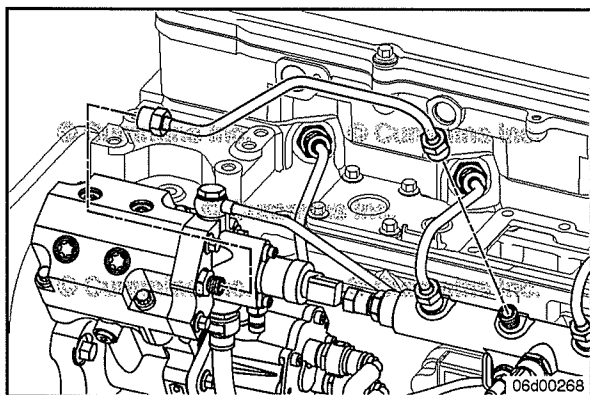
Depending on the circumstance, diesel fuel is flammable. When inspecting or performing service or repairs on the fuel system, to reduce the possibility of fire and resulting severe personal injury, death or property damage, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area.

Loosen the fuel lines at the fuel rail, the fuel connector, and the high-pressure fuel pump outlet fitting.

Loosen the capscrews on the fuel line support bracket and isolator.

Remove the high-pressure fuel lines.



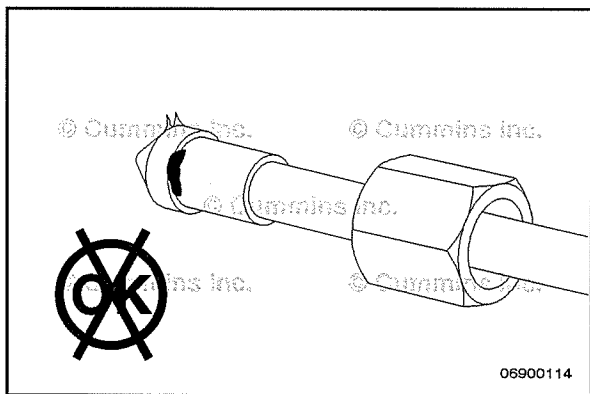


⚠ WARNING ⚠

Depending on the circumstance, diesel fuel is flammable. When inspecting or performing service or repairs on the fuel system, to reduce the possibility of fire and resulting severe personal injury, death or property damage, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area.

Loosen the fuel lines at the fuel rail, the fuel connector, and the high-pressure fuel pump outlet fitting.

Remove the high-pressure fuel lines.



Inspect for Reuse

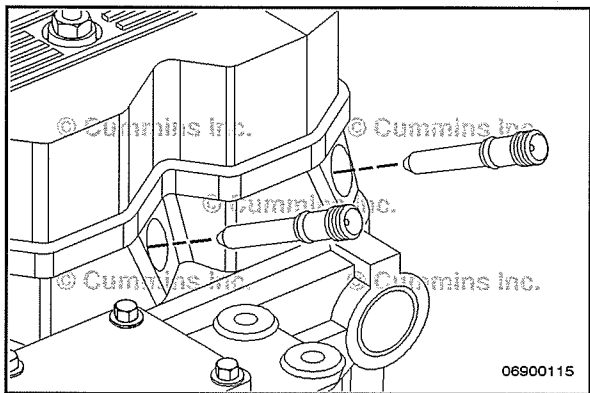
Inspect the high-pressure fuel supply line ferrules for signs of burrs, foreign material, rounding, or cracking.

Inspect the ends of the high-pressure lines for damaged sealing surfaces and signs of rust corrosion.

Check the high-pressure supply line body and ferrules for cracks, wear, or pinched areas.

Inspect the high-pressure lines for binding between the line ferrules and the mounting nuts.

If the high-pressure fuel line(s) do **not** meet the criteria listed above, the damaged fuel line(s) **must** be replaced.



Install



Before installing the injector supply lines, make sure the fuel connector is fully and properly seated against the injector. Make sure the high-pressure connector retaining nut is tightened. Refer to Procedure 006-052 in Section 6.

⚠ WARNING ⚠

Depending on the circumstance, diesel fuel is flammable. When inspecting or performing service or repairs on the fuel system, to reduce the possibility of fire and resulting severe personal injury, death or property damage, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area.

Follow the proper sequence to make sure the high-pressure fuel lines are properly aligned.

- 1 Loosen the fuel rail capscrews so that they are **only** finger tight.
- 2 Install the fuel line from the high-pressure pump to the fuel rail.
- 3 Tighten the rail connection.

Torque Value: 65 N•m [48 ft-lb]

Tighten the pump connection.

Torque Value: 50 N•m [37 ft-lb]

Tighten the fuel line support bracket capscrew.

Torque Value: 24 N•m [212 in-lb]

Install the fuel lines from the fuel rail to the fuel connectors and hand-tighten.

Tighten the high-pressure fuel line at the rail.

Torque Value: 65 N•m [48 ft-lb]

Tighten the high-pressure fuel line at the high-pressure fuel connector.

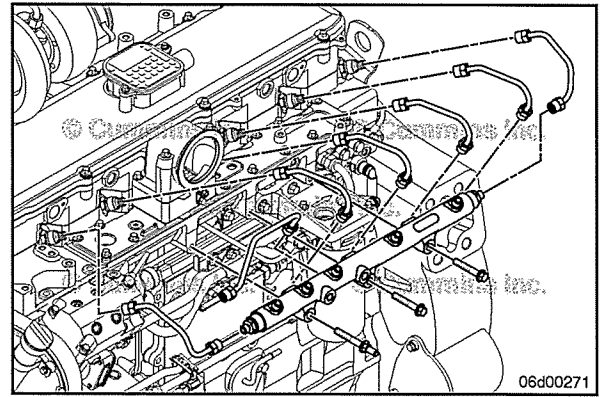
Torque Value: 50 N•m [37 ft-lb]

Tighten the fuel line support bracket capscrew.

Torque Value: 24 N•m [212 in-lb]

Tighten the fuel rail assembly capscrews.

Torque Value: 43 N•m [32 ft-lb]

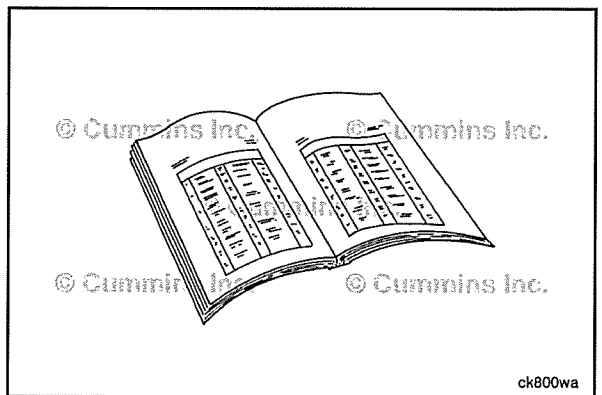


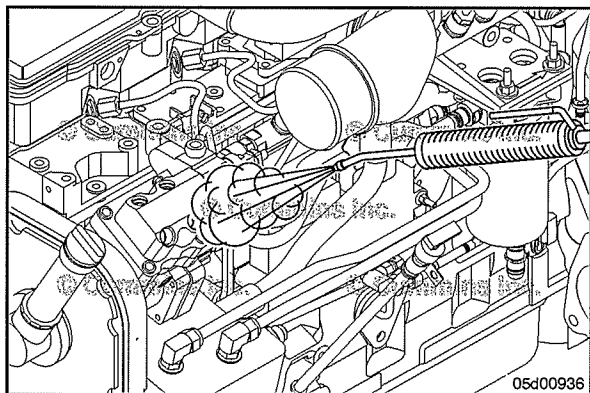
Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- If removed, install the air intake connection. Refer to Procedure 010-080 in Section 10.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.





Fuel Connector (Head Mounted) (006-052)



Preparatory Steps



▲WARNING▲

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

▲WARNING▲

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

▲WARNING▲

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

▲CAUTION▲

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine.

- Clean the engine. Refer to Procedure 000-009 in Section 0. Refer to Procedure 204-008 in Section i.
- Use contact cleaner, Part Number 3824510 or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, or cleaning solution does **not** get inside the fuel system.

⚠ WARNING ⚠

Normal engine operation creates highly pressurized fuel in the fuel line which will remain in the fuel line after engine shutdown. Never open the fuel system when the engine is operating. Before servicing the fuel system, always loosen the pump-to-rail fuel line at the rail to vent the pressure. Keep hands clear of the line when loosening. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

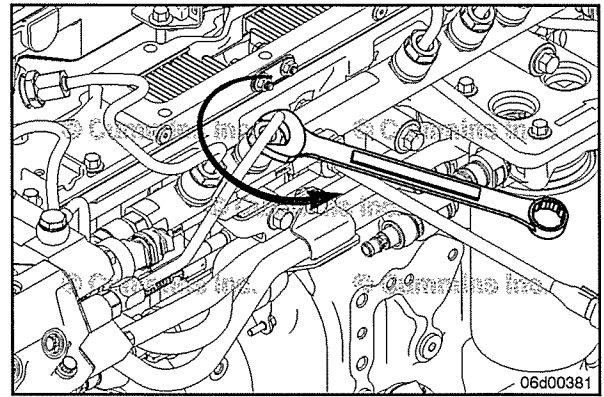
Before servicing the fuel system, loosen the pump-to-rail line at the rail to vent the pressure.

Keep hands clear of the line when loosening.

Tighten the fuel rail nut.

Torque Value: 65 N•m [48 ft-lb]

NOTE: A machined slot in this fitting directs the fuel spray toward the engine block.



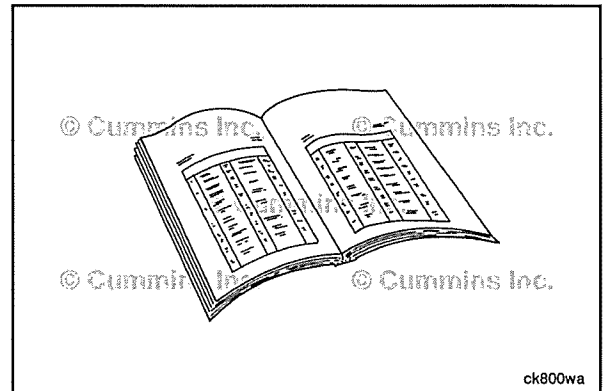
⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

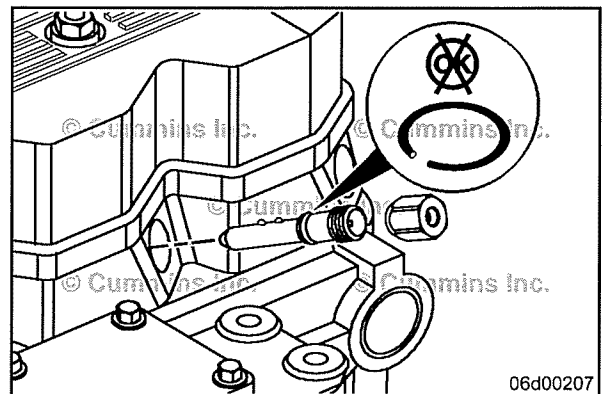
- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the high-pressure fuel supply lines. Refer to Procedure 006-051 in Section 6.

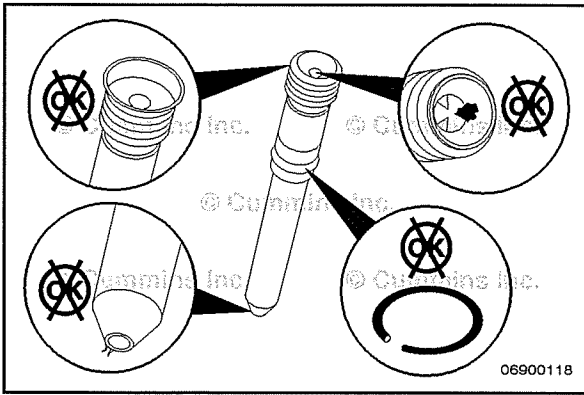


Remove

Remove the fuel connector retaining nut.

Use fuel connector puller, Part Number 3164025, to remove the fuel connector from the cylinder head.





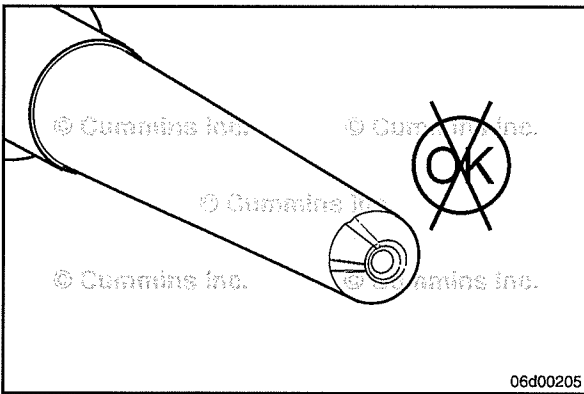
Inspect for Reuse

A new high-pressure connector **must** be installed if a new injector is being installed.

Inspect the fuel connector. Look for burrs or deformation around the inlet and outlet sides of the connector.

Check the edge filter for signs of plugging or material contamination. Do **not** reuse a high-pressure fuel connector if debris is present.

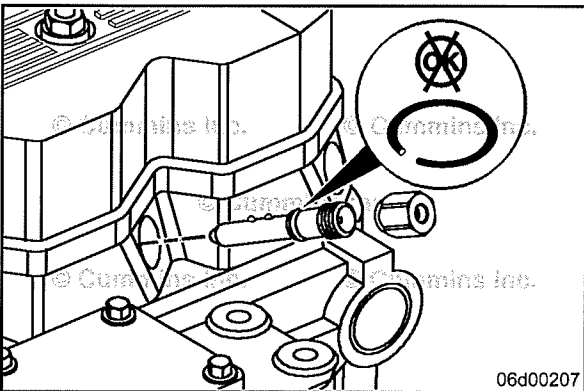
Check the o-ring for tearing or deterioration.



Inspect the outlet sealing surface of the high-pressure connector for wear, an uneven seating surface, or signs of leakage.

When a high-pressure fuel leak is present, small lines or cuts in the connector will be eroded into the seating surface.

The high-pressure connector and injector **must** be replaced when this condition is observed.



Install

NOTE: If a new injector has been installed, a new fuel connector **must** be used.



Lubricate the fuel connector o-ring and the threads on the fuel connector retaining nut.



Carefully insert the fuel connector, aligning the guide pin with the slot in the cylinder head at the 12-o'clock position.



NOTE: If the injector was removed along with the high-pressure fuel connector, the installation steps **must** be followed. Refer to Procedure 006-026 in Section 6.

Tighten the fuel connector retaining nut.

Torque Value: 50 N•m [37 ft-lb]

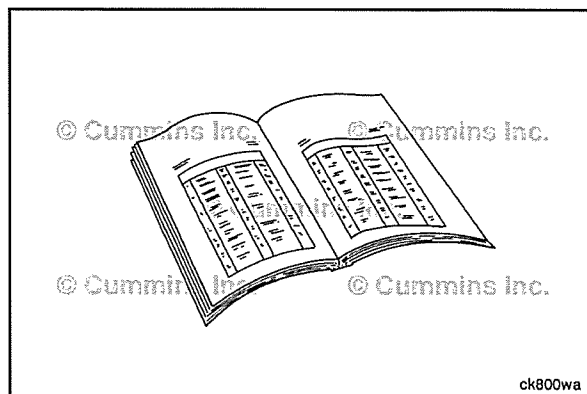
The high-pressure fuel connector **must** be properly tightened or an internal fuel leak can result, causing poor engine performance. A torque wrench **must** be used.

Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the high-pressure fuel supply lines. Refer to Procedure 006-051 in Section 6.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Fuel Rail (006-060)

Initial Check

⚠ WARNING ⚠

The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.

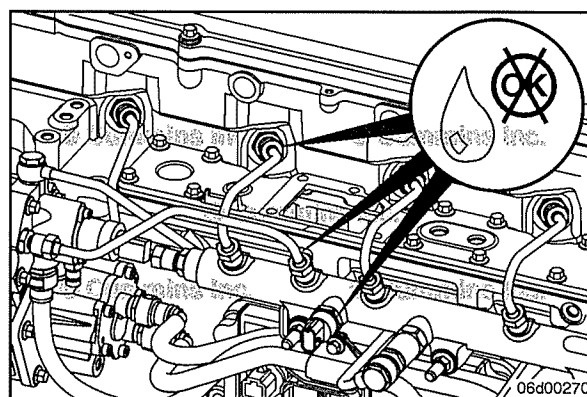
⚠ WARNING ⚠

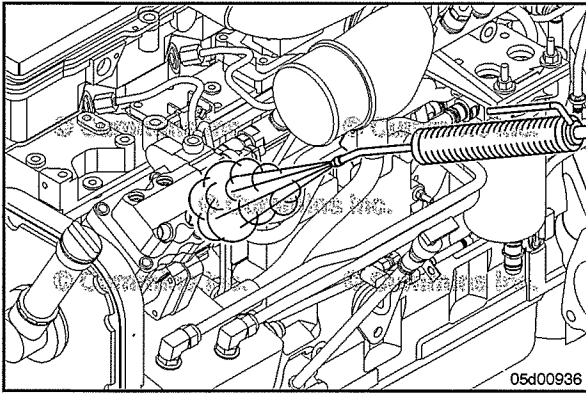
The pressure within the fuel rail is extremely high. High pressure can penetrate the skin. Stand clear of the engine while it is running.

⚠ WARNING ⚠

The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. To reduce the possibility of personal injury and property damage, never loosen any fittings while the engine is running.

Inspect the fuel pressure sensor, high-pressure fuel line connections, and male unions for leaks.





Preparatory Steps

▲WARNING▲

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.



▲WARNING▲

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

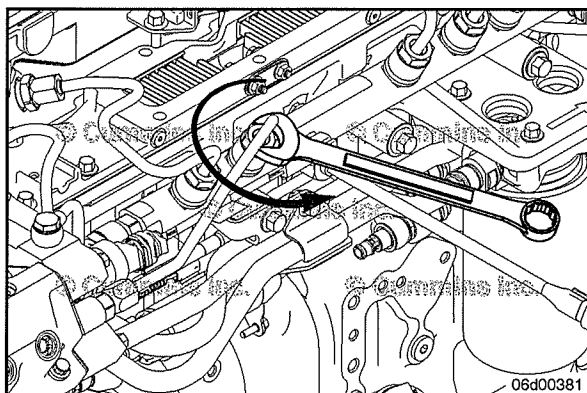


▲CAUTION▲

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine.

- Clean the engine. Refer to Procedure 000-009 in Section 0. Refer to Procedure 204-008 in Section i.
- Use contact cleaner, Part Number 3824510 or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, or cleaning solution does **not** get inside the fuel system.



▲WARNING▲

Normal engine operation creates highly pressurized fuel in the fuel line which will remain in the fuel line after engine shutdown. Never open the fuel system when the engine is operating. Before servicing the fuel system, always loosen the pump to rail fuel line at the rail to vent the pressure. Keep hands clear of the line when loosening. High pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

- Before servicing the fuel system, loosen the pump-to-rail line at the rail to vent the pressure.
- Keep hands clear of the line when loosening.

NOTE: A machined slot in this fitting directs the fuel spray toward the cylinder block.

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

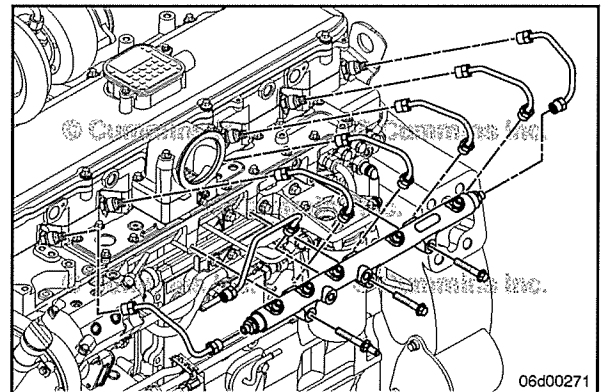
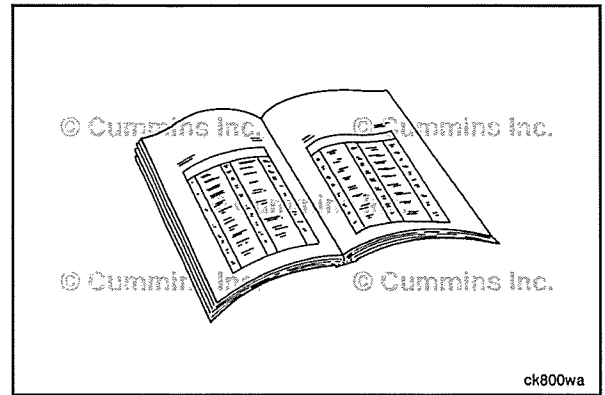
Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

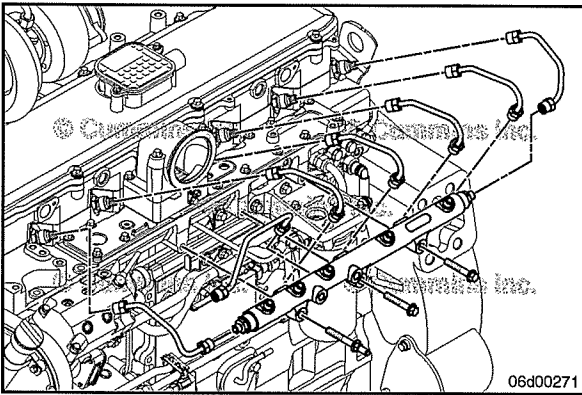
- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.
- Shut off the fuel supply and drain valves. Refer to the OEM service manual.
- Disconnect the rail fuel pressure sensor from the engine wiring harness. Refer to Procedure 019-115 in Section 19.
- Remove the high-pressure fuel lines from the fuel rail. Refer to Procedure 006-051 in Section 6.
- Remove the fuel drain line from the fuel pressure relief valve. Refer to Procedure 006-013 in Section 6.

Remove

Remove the capscrews that secure the fuel rail to the cylinder head.

Remove the fuel rail assembly.





Install

Install the fuel rail assembly. Follow the proper sequence to make sure that high-pressure fuel lines are properly aligned.



- Install the fuel rail assembly capscrews hand-tight.
- Install the fuel line from the high-pressure pump to the fuel rail.
- Tighten the rail connection.



Torque Value: 65 N•m [48 ft-lb]

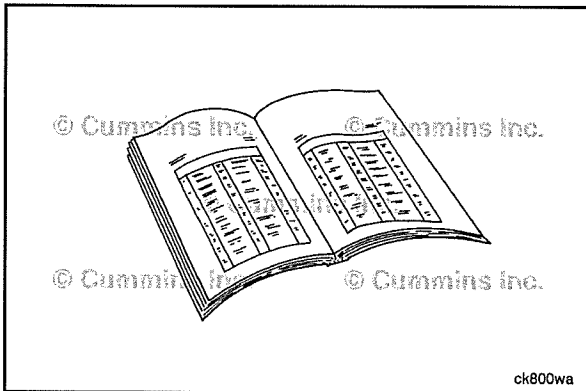
- Tighten the pump connection.

Torque Value: 50 N•m [37 ft-lb]

- Install the high-pressure fuel lines hand-tight.

Tighten the fuel rail assembly capscrews.

Torque Value: 43 N•m [32 ft-lb]



Finishing Steps



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the fuel drain line to the fuel pressure relief valve. Refer to Procedure 006-013 in Section 6.
- Install the rail fuel pressure sensor to the engine wiring harness. Refer to Procedure 019-115 in Section 19.
- Open the fuel supply and drain valves. Refer to the OEM service manual.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Fuel Pressure Relief Valve (006-061)

Initial Check

⚠ WARNING ⚠

The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.

⚠ WARNING ⚠

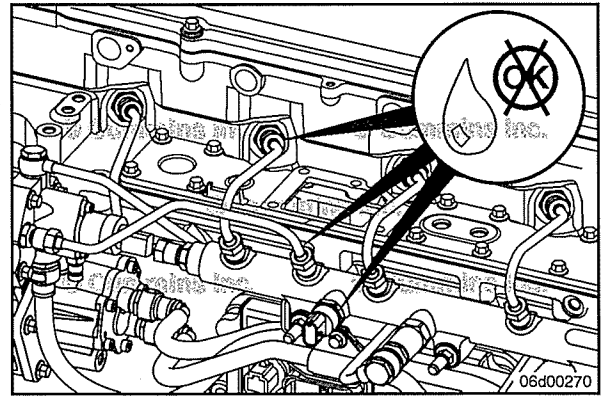
The pressure within the fuel rail is extremely high. High-pressure can penetrate the skin. Stand clear of the engine while it is running.

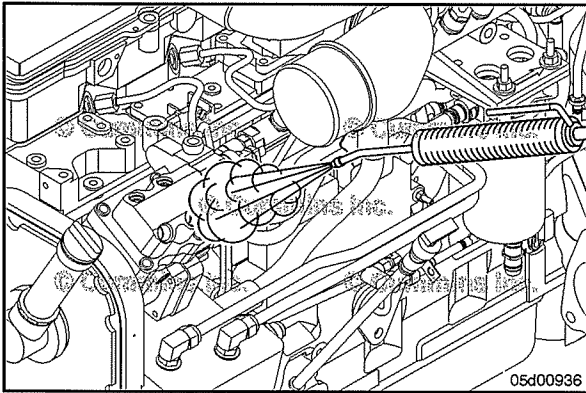
⚠ WARNING ⚠

The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. To reduce the possibility of personal injury, never loosen any fittings while the engine is running.

Operate the engine and check for external fuel leaks.

NOTE: All fuel system diagnostics procedures and component specifications have been moved. Refer to Procedure 005-236 in Section 5.





Preparatory Steps

▲WARNING▲

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.



▲WARNING▲

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

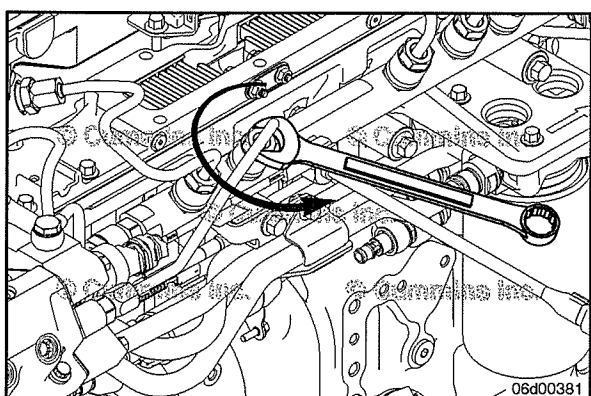


▲CAUTION▲

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine.

- Clean the engine. Refer to Procedure 000-009 in Section 0.
- Use contact cleaner, Part Number 3824510 or equivalent, to thoroughly clean all fuel lines before removal from the engine. Clean the connector fittings to remove as much debris as possible. It is very important that extra care is taken to keep the fuel connections clean during removal and installation. Refer to Procedure 204-008 in Section i.
- Make sure that debris, water, steam, or cleaning solution does **not** get inside the fuel system.



▲WARNING▲

Normal engine operation creates highly pressurized fuel in the fuel line which will remain in the fuel line after engine shutdown. Never open the fuel system when the engine is operating. Before servicing the fuel system, always loosen the pump to rail fuel line at the rail to vent the pressure. Keep hands clear of the line when loosening. High pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

- Before servicing the fuel system, loosen the pump-to-rail line at the rail to vent the pressure.
- Keep hands clear of the line when loosening.
- Tighten the pump to rail line nut.

Torque Value: 65 N•m [48 ft-lb]

NOTE: A machined slot in this fitting directs the fuel spray toward the cylinder block.

⚠ WARNING ⚠

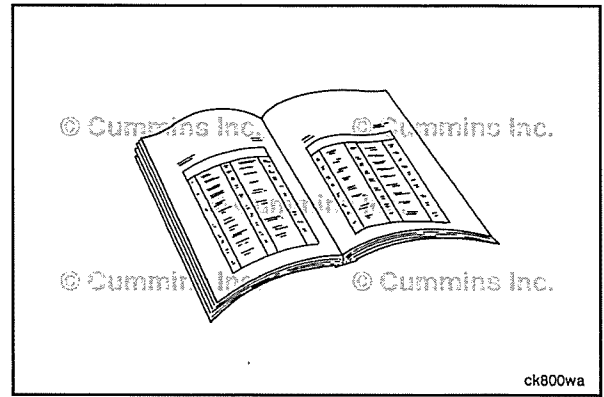
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



⚠ WARNING ⚠

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the fuel drain line from the fuel rail pressure relief valve. Refer to Procedure 006-013 in Section 6.
- Remove the fuel pressure relief valve reducer, if required.



Remove

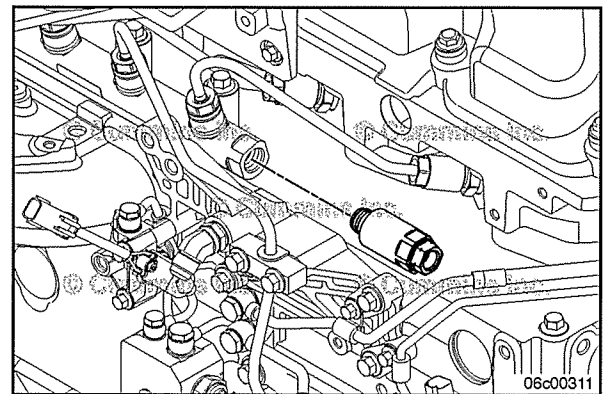
Remove the fuel pressure relief valve.

Remove and discard the sealing washer.

A flat sealing washer is swaged into the inlet fitting bore during installation.

A special tool can be created to aid in its removal by grinding a 45 degree angle on the short leg of a 1/8-inch or 3/16-inch Allen wrench, so that the wrench is no longer than 13-mm [1/2-in] long (measured from the outside of the long leg.)

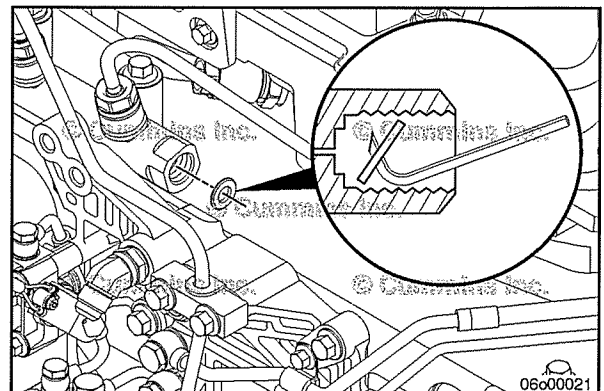
This tool acts as a mini heel bar to pry out the sealing washer without damaging the back of the hole.

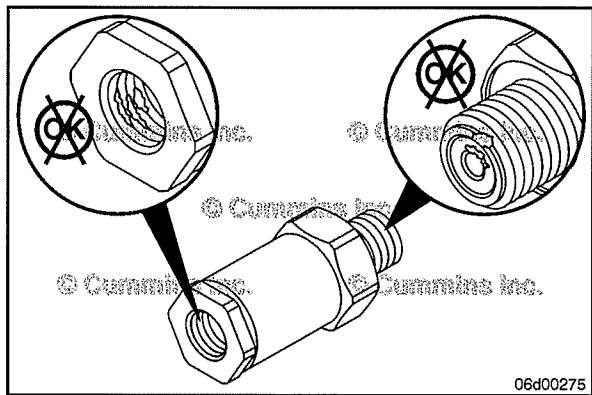


The high-pressure relief valve sealing washer **must** be replaced if the high-pressure relief valve is removed.

Use the modified Allen wrench to pry out the old sealing washer from the threaded hole in the fuel rail.

NOTE: Considerable force is required to remove the sealing washer.

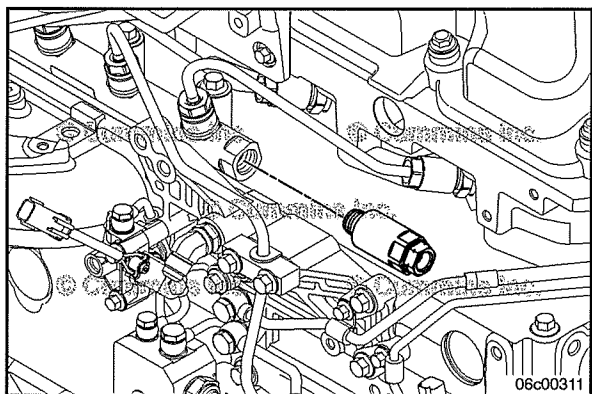




Inspect for Reuse

If the fuel pressure relief valve exhibits excessive leakage to drain, it **must not** be reused.

Inspect the high-pressure seal surface on the fuel pressure relief valve and in the fuel rail for damage. Do **not** reuse components if the high-pressure seal joint is damaged.



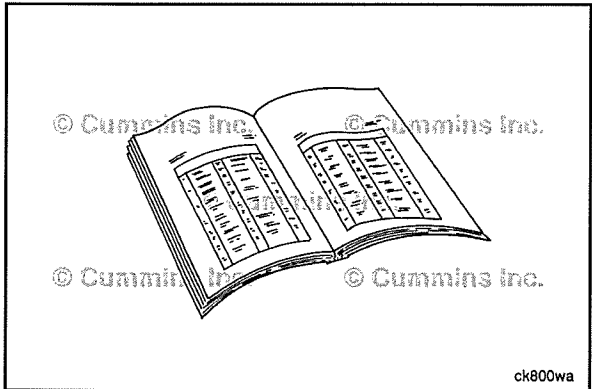
Install

Install the fuel pressure relief valve and a new sealing washer. Use assembly lubricant, Part Number 3163087 or equivalent, on the threads. Tighten the pressure relief valve with the torque plus angle method.



Torque Value:

Step 1	27 N•m	[239 in-lb]
Step 2	Rotate 90 degrees.	



Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the fuel drain line to the fuel pressure relief valve. Refer to Procedure 006-013 in Section 6.
- Open the fuel supply and drain valves. Refer to the OEM service manual.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Section 7 - Lubricating Oil System - Group 07

Section Contents

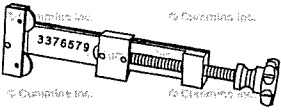
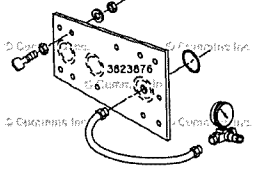
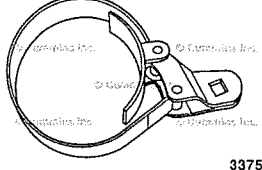
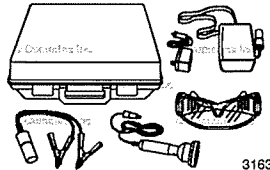
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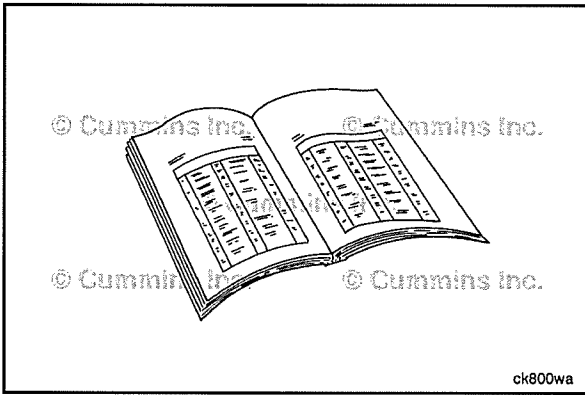
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Service Tools

Lubricating Oil System

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3376579	<p align="center">Tube (Filter) Cutter</p> <p>Used to cut open the filter to permit inspection of the filter element.</p>	 <p align="right">3376579</p>
3823876	<p align="center">Lubricating Oil Cooler Pressure Test Kit</p> <p>Used to seal and pressurize the lube oil cooler to test for leaks. Requires regulated pressure supply, Part Number 3164231 or equivalent (purchased separately).</p>	 <p align="right">3823876</p>
3375049	<p align="center">Oil Filter Wrench</p> <p>Used to remove the oil filter.</p>	 <p align="right">3375049</p>
3163338	<p align="center">Black Light Lamp (12 VDC)</p> <p>Black light with rechargeable battery and charger used with fluorescent tracer, Part Number 3376891, to locate oil leaks.</p>	 <p align="right">3163338</p>



Engine Oil Heater (007-001)

Preparatory Steps



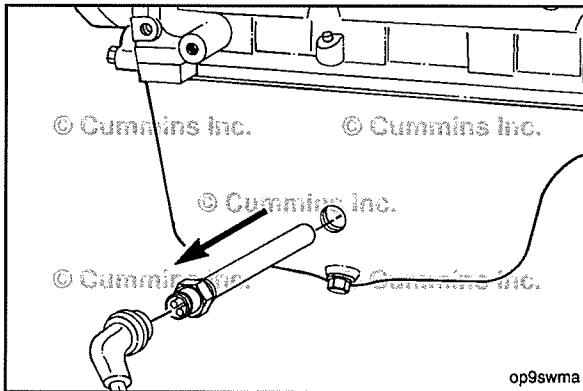
⚠ WARNING ⚠

Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

⚠ WARNING ⚠

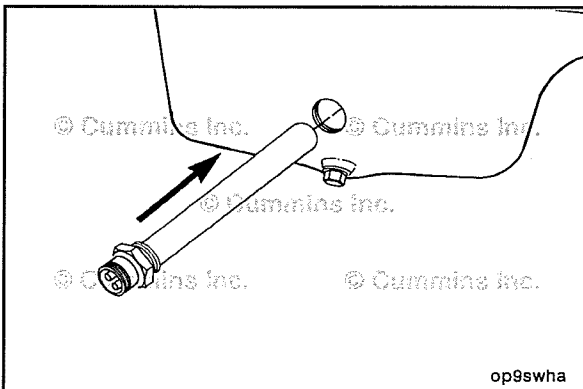
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.



Remove

Disconnect the oil heater electrical cord.
Remove the heater element.



Install

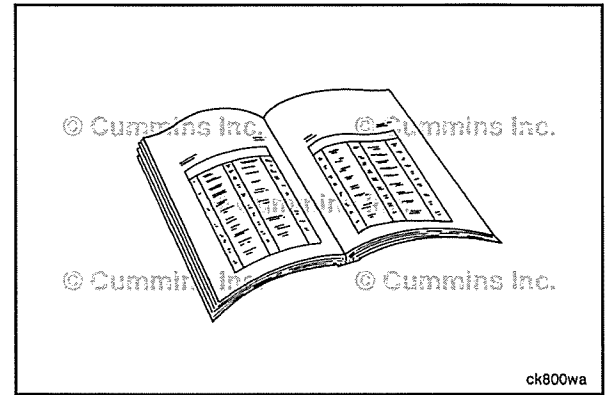
Install the heater element.

Torque Value: 80 N•m [59 ft-lb]



Finishing Steps

- Connect the oil heater electrical cord.
- Fill the engine with lubricating oil. Refer to Procedure 007-037 in Section 7.
- Operate the engine and check for leaks.

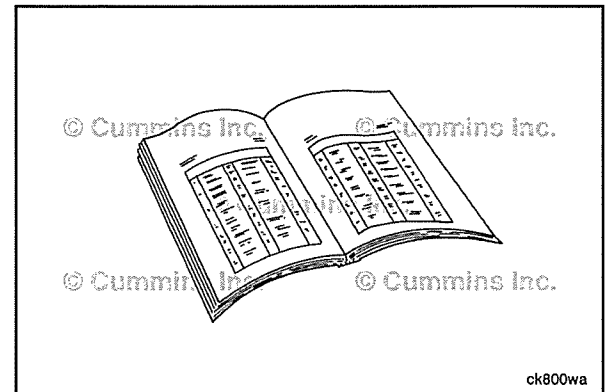


Lubricating Oil Cooler (007-003) Preparatory Steps

⚠ WARNING ⚠

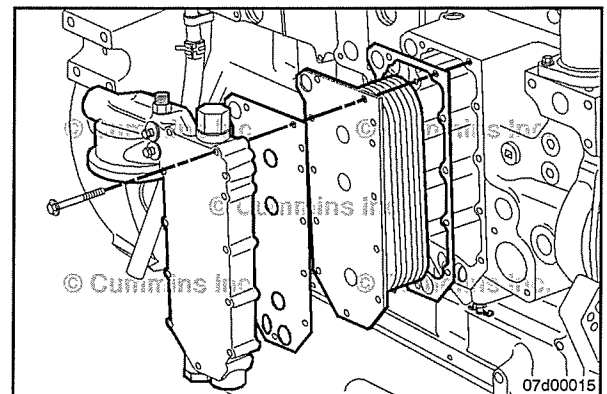
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

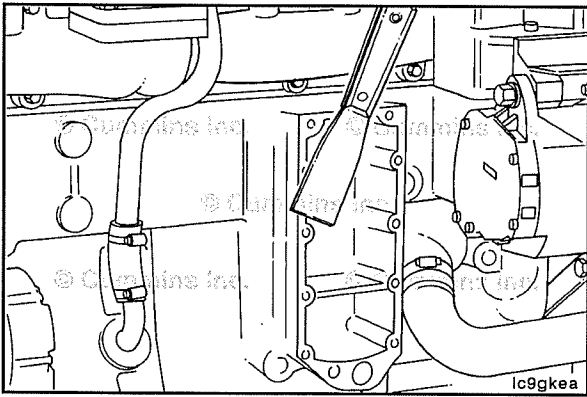
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Clean the area around the lubricating oil cooler cover.
- Remove the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Remove the turbocharger oil supply line. Refer to Procedure 010-046 in Section 10.
- Remove the exhaust gas recirculation (EGR) cooler coolant line. Refer to Procedure 011-031 in Section 11.
- Remove the EGR cooler mounting bracket. Refer to Procedure 011-029 in Section 11.



Remove

Remove the lubricating oil cooler cover, gaskets, and oil cooler element.





Clean and Inspect for Reuse

⚠ WARNING ⚠

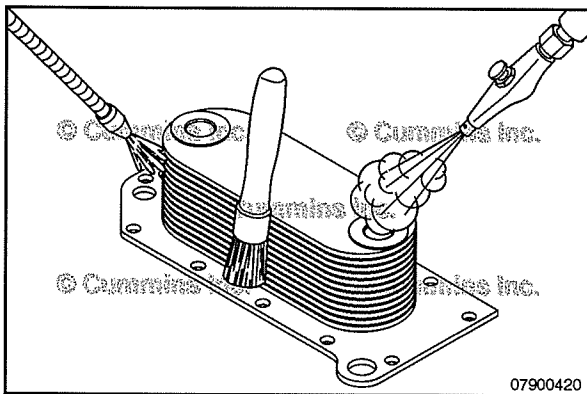
When using solvent, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ CAUTION ⚠

Use a solvent that will not harm copper to clean the oil cooler elements.

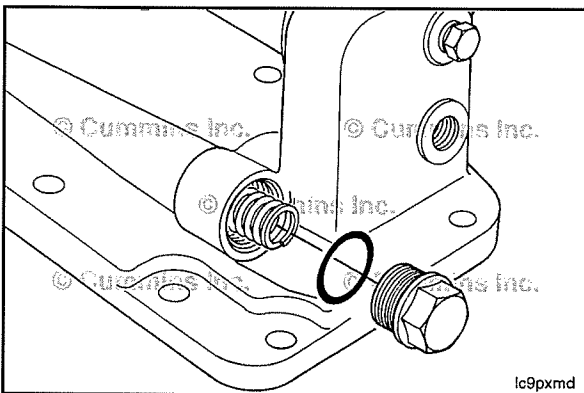
Clean the sealing surfaces of the cylinder block and the oil cooler cover.

NOTE: Replace the lubricating oil cooler if any debris is found, or if the engine has had a debris-generating failure.

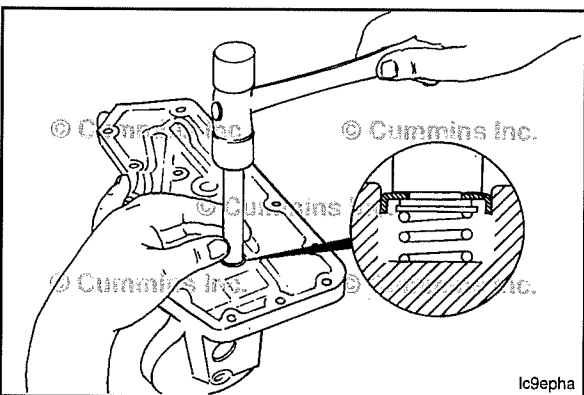


⚠ CAUTION ⚠

Do not reuse an oil cooler core after a debris related engine malfunction since there is no practical method for cleaning the cooler core. Metal particles which can circulate through the lubricating oil system can remain in the cooler core and cause engine damage.



If any debris is suspected to have gone through the engine, or if troubleshooting a lubricating oil pressure issue, remove and inspect the lubricating oil pressure regulator located in the lubricating oil cooler cover. Replace if necessary. Refer to Procedure 007-029 in Section 7.



If any debris is suspected to have gone through the engine, inspect the oil filter bypass valve located in the lubricating cooler cover. Make sure the valve is fully seated and opens and closes freely. Replace if necessary.

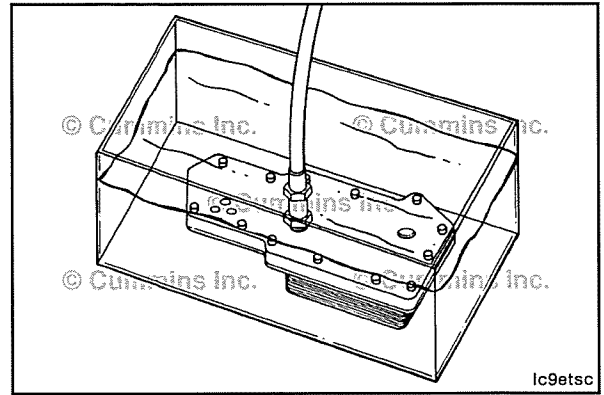
The bypass valve requires a 345 kPa [50 psi] pressure differential to open.

Leak Test

Pressure test the element to check for leaks. If leaks are detected, replace the element.

Air Pressure Test

kPa		psi
449	MIN	65
518	MAX	75

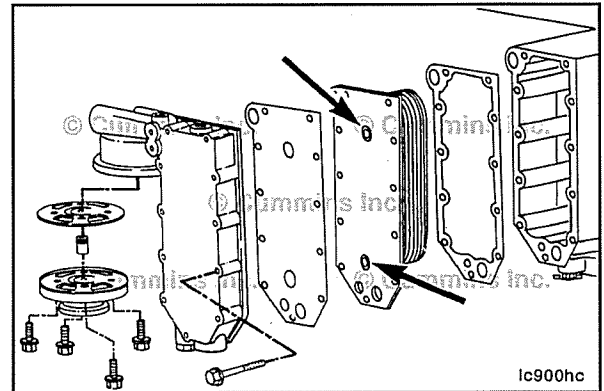


Install

NOTE: Be sure to remove the shipping plugs from a new oil cooler element.

Discard used gaskets and install new gaskets.

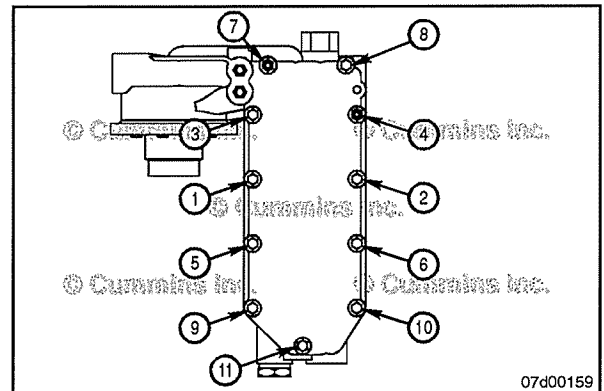
Assemble the lubricating oil cooler gaskets, element, and cover.



If the oil cooler cover does **not** have a dimple, tighten the capscrews in the sequence shown.

Torque Value:

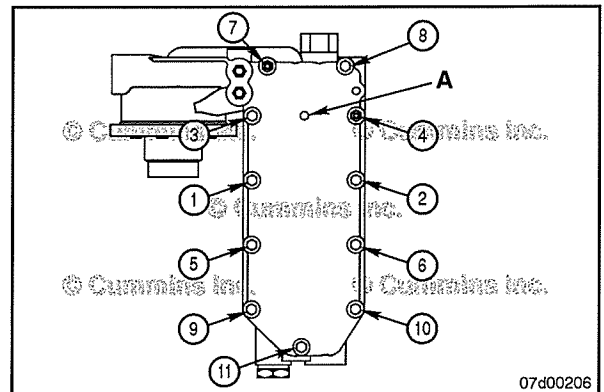
Step 1	15 N•m	[133 in-lb]
Step 2	32 N•m	[24 ft-lb]

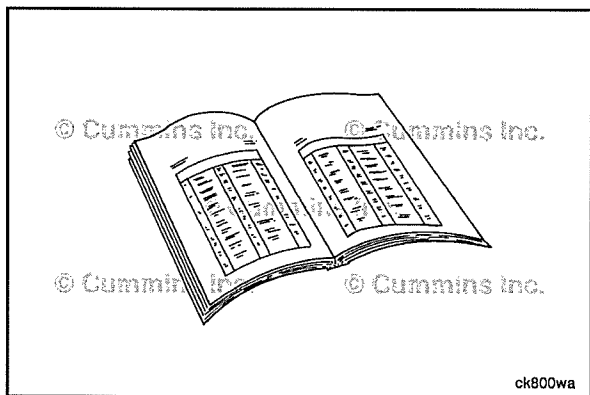


If the oil cooler cover has a dimple, tighten the capscrews in the sequence shown. The arrow (A) points to the location of the dimple.

Torque Value:

Step 1	15 N•m	[133 in-lb]
Step 2	27 N•m	[239 in-lb]





Finishing Steps



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the EGR cooler mounting bracket. Refer to Procedure 011-029 in Section 11.
- Install the EGR cooler coolant line. Refer to Procedure 011-031 in Section 11.
- Install the turbocharger oil supply line. Refer to Procedure 010-046 in Section 10.
- Install the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Lubricating Oil Dipstick (007-009)

Calibrate



⚠ WARNING ⚠

Some state and federal agencies have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

⚠ WARNING ⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.

Install the dipstick in the dipstick tube housing.

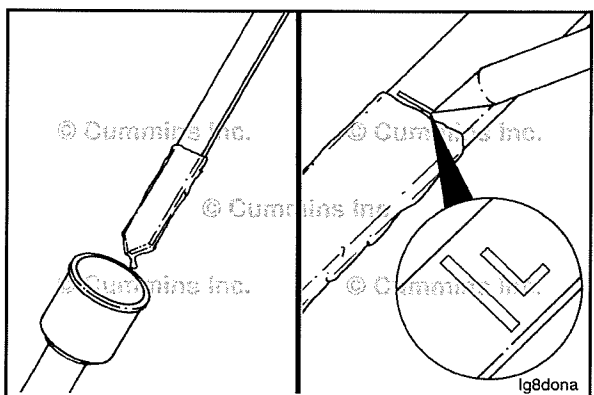
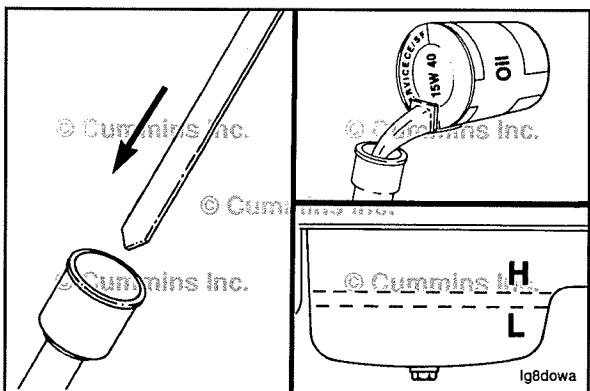
⚠ CAUTION ⚠

Use care when marking the dipstick. The dipstick will break if the scribe mark is too deep.

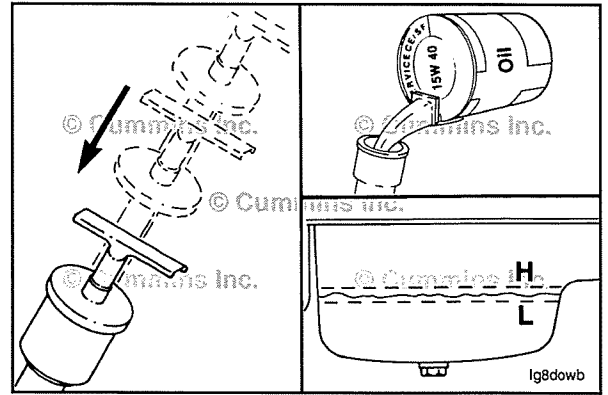


Remove the dipstick and scribe a mark across the stick at the oil level. Label the mark with an L to indicate the "LOW" oil level.

NOTE: If a new blank dipstick is being used, cut the dipstick off approximately 38 mm [1.5 in] below the LOW oil level mark.



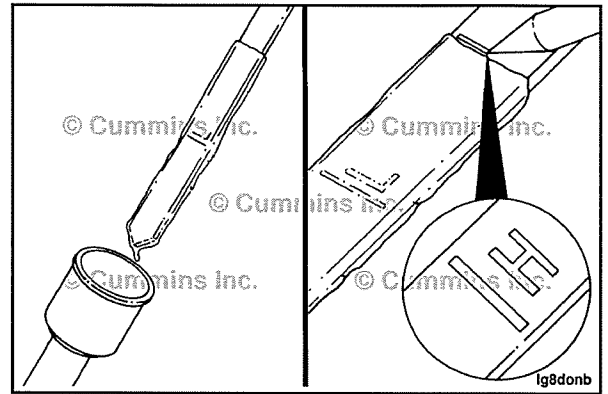
Wipe off the dipstick and install it in the dipstick tube housing.



CAUTION

Use care when marking the dipstick. The dipstick will break if the scribe mark is too deep.

Remove the dipstick and scribe a mark across the stick at the oil level. Label the mark with an H to indicate the HIGH oil level.



Lubricating Oil Dipstick Tube (007-011)



Preparatory Steps

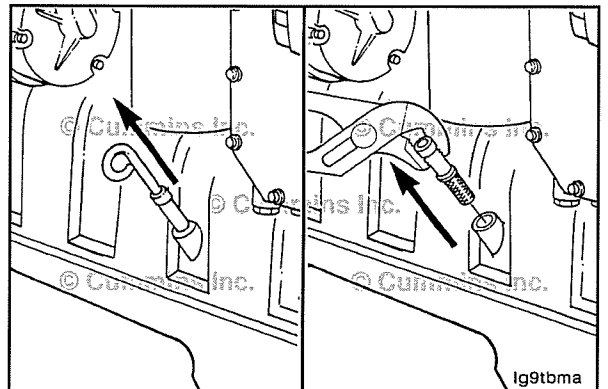
- Clean the area around the dipstick tube before removal to reduce the possibility of debris entering the oil system.

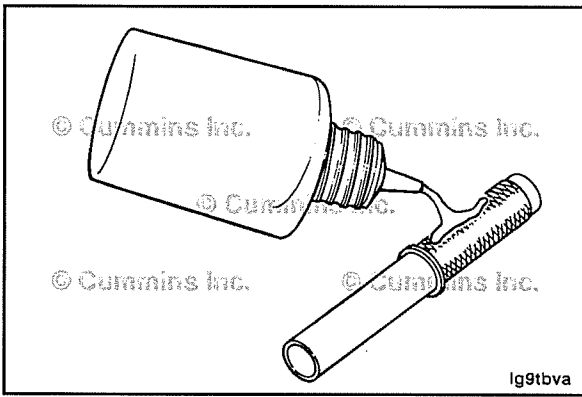
Remove

Remove the dipstick from the dipstick tube.

Remove the dipstick tube from the cylinder block.

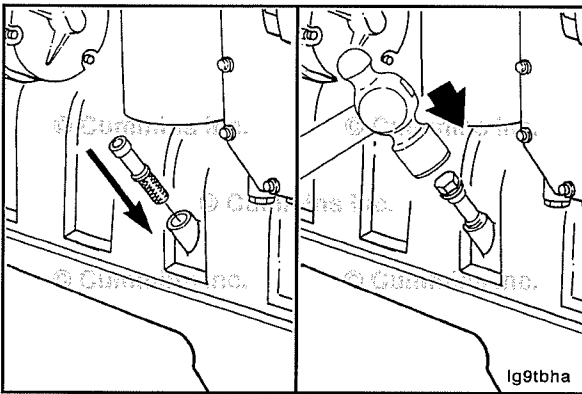
Service Tip: Use a dent puller and a M8 x 1.25 x 21-mm self-tapping capscrew. Thread the capscrew into the dipstick tube and remove the tube.





Install

Apply a thin bead of sleeve retaining compound, Part Number 3823718 or equivalent, around the bottom of the knurled end of the tube.

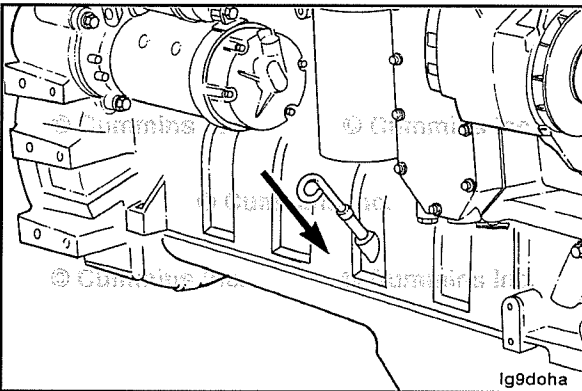


Place the knurled end of the tube into the dipstick tube bore in the cylinder block.

Use a flat washer and hex head capscrew to drive the tube into the cylinder block.

Lightly drive the dipstick tube until it seats against the block casting.

Remove the flat washer and hex head capscrew.



Install the dipstick into the dipstick tube.



Finishing Steps

- Operate the engine and check for leaks.

Lubricating Oil Filter (Spin-On) (007-013)

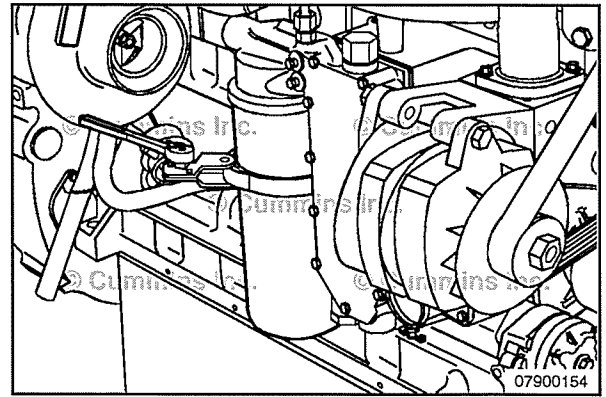
Measure

Remove the oil plugs from the lubricating oil cooler housing at the filter inlet and outlet pressure ports and install manual gauges.

The following parts, or equivalent, are available for use:

Part Number	Description
3377244	Compuchek™ fitting (1/8 inch 27 NPT)
3376920	Compuchek™ coupling (1/4 inch pipe thread)
3164491	Electronic pressure adapter for multimeter (1/4-NPT pipe)
3164488 or 3164489	Electronic digital multimeter

Engine Information	
Oil Filter Type	
Miles on Filter	
Oil Type	



Operate the engine at each rpm indicated and record the corresponding pressure values:

	Engine RPM	Oil Pressure Filter Inlet	Oil Filter Pressure Outlet	Inlet - Outlet = Differential Pressure	INSITE™ electronic service tool
Low Idle					
High Idle					

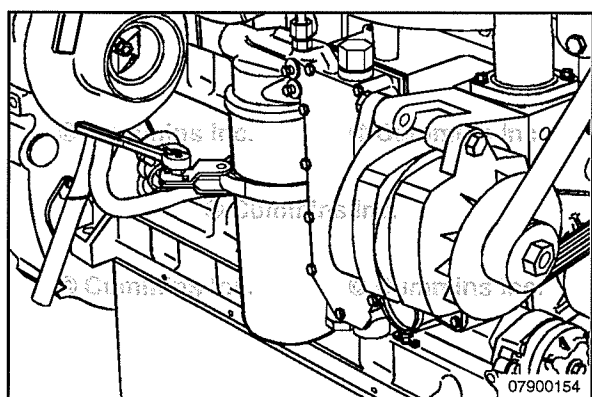
A pressure drop greater than 172 kPa [25 psi], at operating temperature using 15W-40 oil, indicates the filter is plugged.

Identify the causes of a plugged filter. Verify the Cummins Inc. maintenance guidelines are being met.

Use the following procedure to check for possible fluid contamination. Refer to Procedure 007-083 in Section 7

Change both the lubricating oil and the lubricating oil filter, if the filter is plugged.

See the following bulletin for additional information about lubricating oil filter plugging. Refer to Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340.



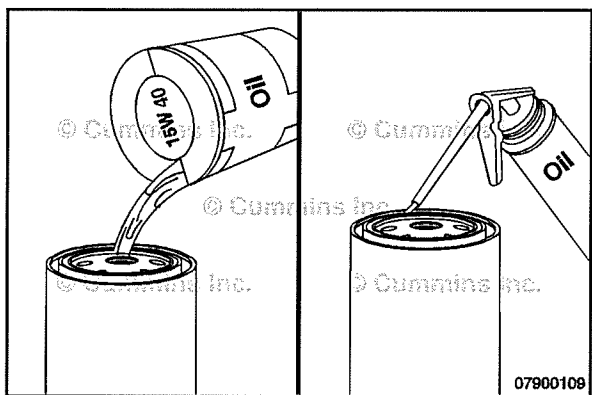
Remove

Clean the area around the lubricating oil filter head.



Use oil filter wrench, Part Number 3375049, to remove the lubricating oil filter.

Clean the gasket surface of the filter head with a clean lint-free cloth.



Install

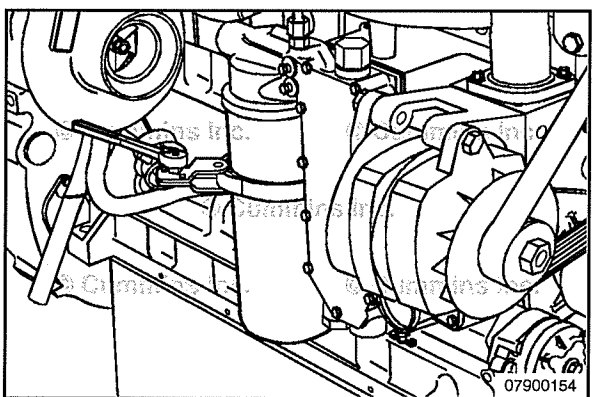
⚠CAUTION⚠

The lubricating oil filter should be full of oil at start-up to prevent engine damage.

Use clean 15W-40 oil to coat the gasket surface of the filter.

Fill the filter with clean 15W-40 oil.

NOTE: Lubricating oil filters **must** have a filter bypass valve. Using a lubricating oil filter without a filter bypass valve will result in low engine oil pressure if the filter becomes plugged.



⚠CAUTION⚠

Mechanical overtightening of the filter can distort the threads or damage the filter element seal.

Install the filter on the oil filter head. Tighten the filter until the gasket contacts the filter head surface.

Use an oil filter wrench to tighten the filter. See the filter manufacturer's instructions supplied with the filter.

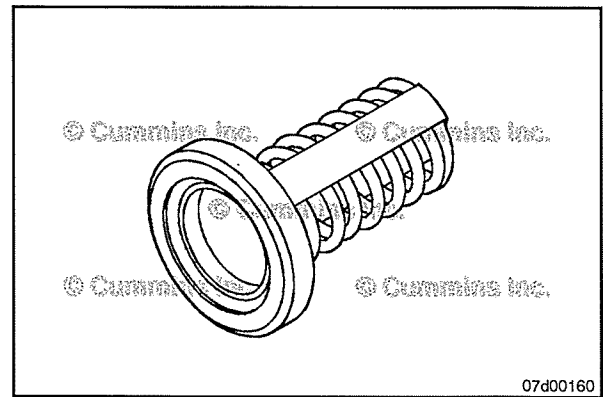
Lubricating Oil Filter Bypass Valve (007-014)

General Information

If the pressure drop across the lubricating oil filter exceeds a predetermined set point, the oil filter bypass valve opens and allows lubricating oil to bypass the lubricating oil filter.

This condition can occur during cold ambient (cold lubricating oil) engine start-ups.

The purpose of the bypass valve is to maintain lubricating oil flow to the engine and to prevent an oil filter collapse.



Preparatory Steps

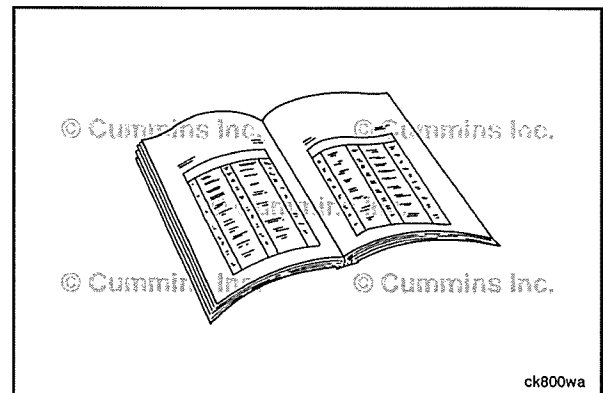
⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

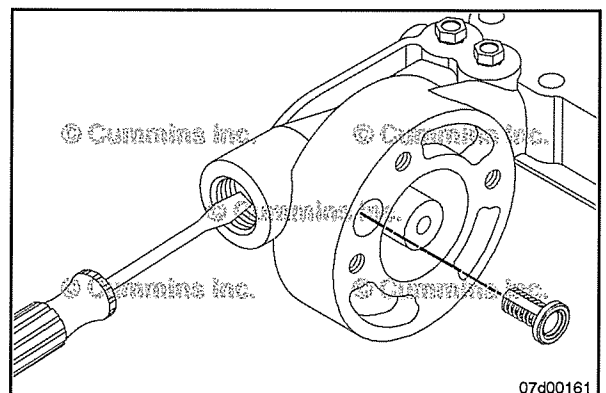
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Remove the lubricating oil filter head. Refer to Procedure 007-015 in Section 7.
- Remove the 3/4-inch pipe plug from the end of the oil filter head.

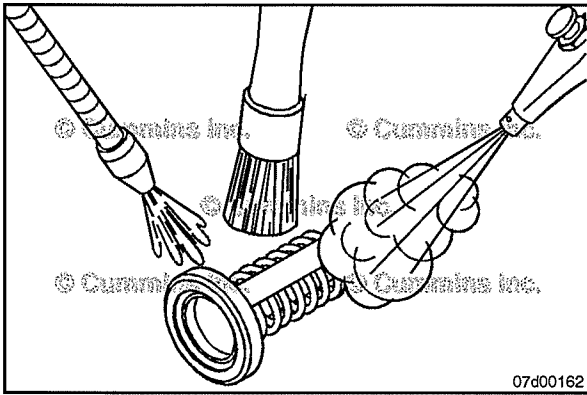


Remove

Remove the 3/4-inch pipe plug from the end of the oil filter head.

Use a screwdriver to gently push down on the top of the bypass valve to remove it from the bore.





Clean and Inspect for Reuse

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING ⚠

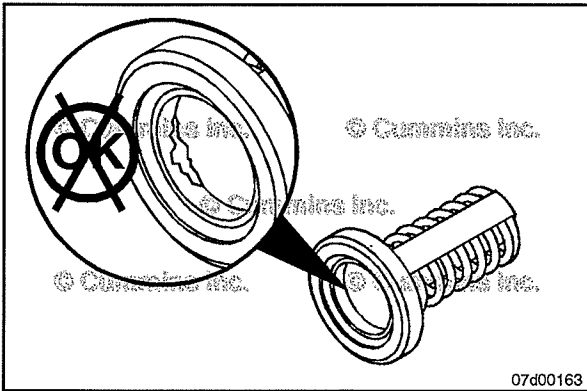
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠ WARNING ⚠

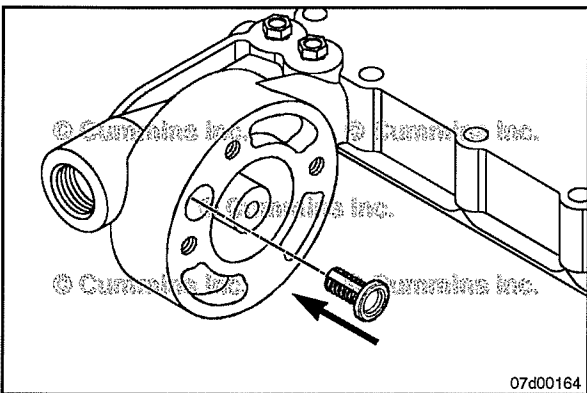
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the bypass valve with solvent.

Dry with compressed air.



Inspect the bypass valve seat for damage. Make sure the valve fully closes.



Install

Insert the bypass valve into the bore. The spring should be pointing upward into the bore.



Gently push the bypass valve into the bore until it seats.

Install the 3/4-inch pipe plug into the end of the oil filter head.

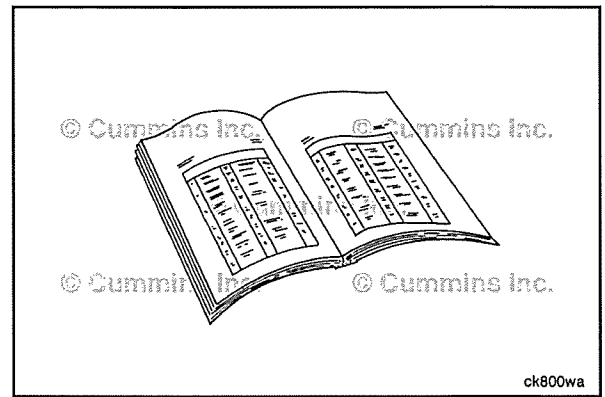
Torque Value: 45 N•m [33 ft-lb]

Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the lubricating oil filter head. Refer to Procedure 007-015 in Section 7.
- Install the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Lubricating Oil Filter Head (007-015)

Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

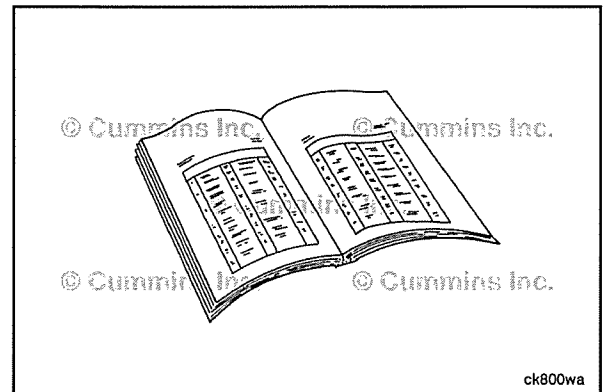
⚠ WARNING ⚠

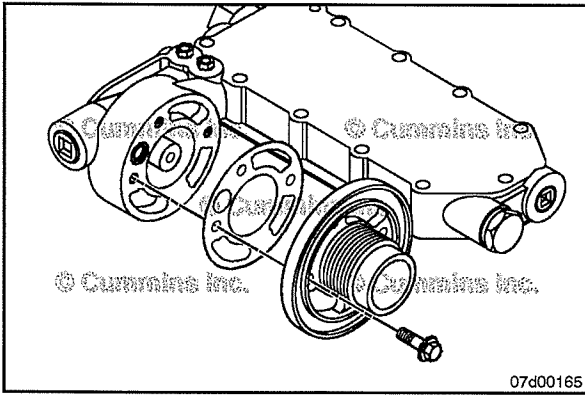
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠ WARNING ⚠

Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

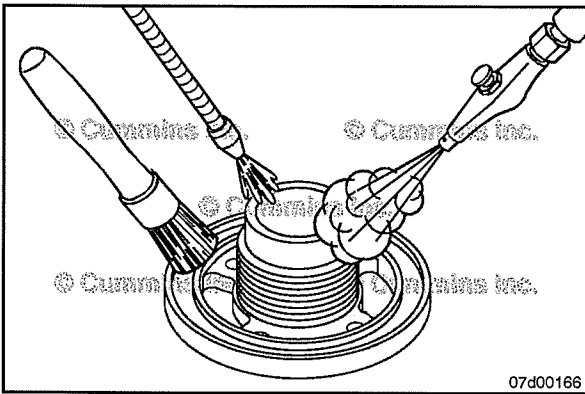
- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Remove the lubricating oil cooler. Refer to Procedure 007-003 in Section 7.





Remove

Remove the lubricating oil filter head adapter capscrews, filter head adapter, and gasket.



Clean and Inspect for Reuse

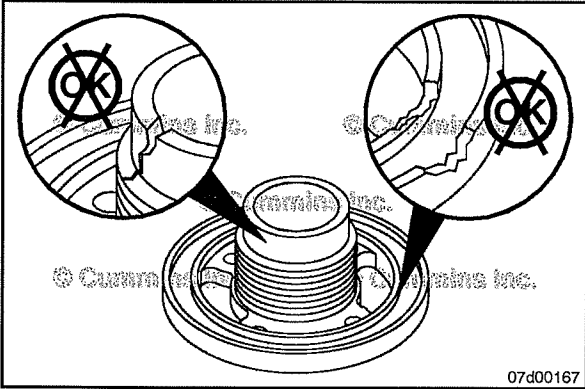
⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

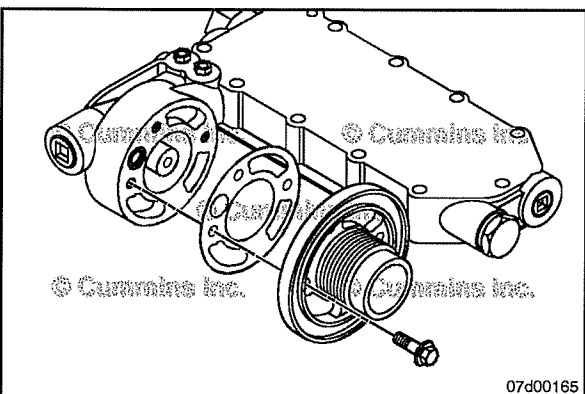
⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Use solvent to clean the filter head adapter.



Inspect the filter head adapter for cracks and other damage.



Install

Install a new gasket, the lubricating oil filter head adapter, and capscrews.



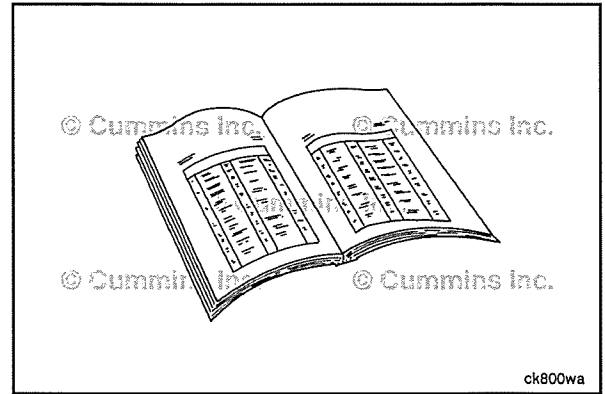
Torque Value: 27 N•m [239 in-lb]

Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the lubricating oil cooler. Refer to Procedure 007-003 in Section 7.
- Install the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.



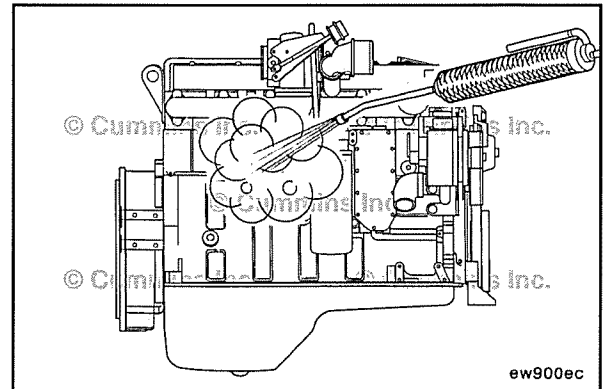
Lubricating Oil Leaks (007-024)

Initial Check

⚠ WARNING ⚠

Wear safety glasses or a face shield, as well as protective clothing, to prevent personal injury when using a steam cleaner or high-pressure water.

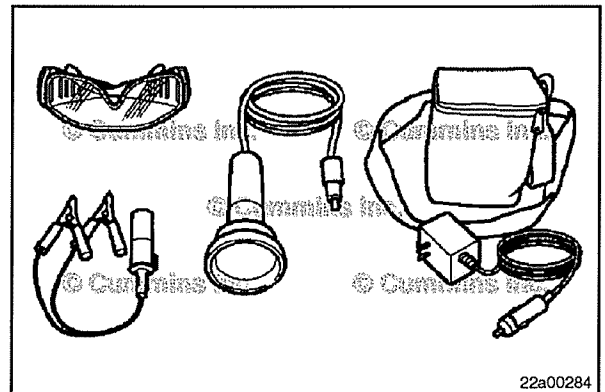
Use a steam cleaner or high-pressure washer to clean the engine.

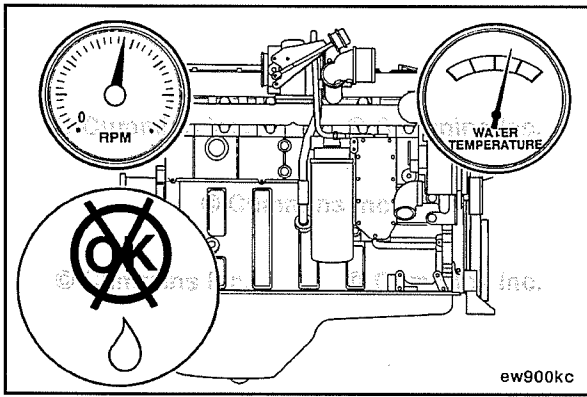


Add fluorescent tracer, Part Number 3376891, before running the engine.

Use black light kit, Part Number 3163338, to help identify the source of an oil leak.

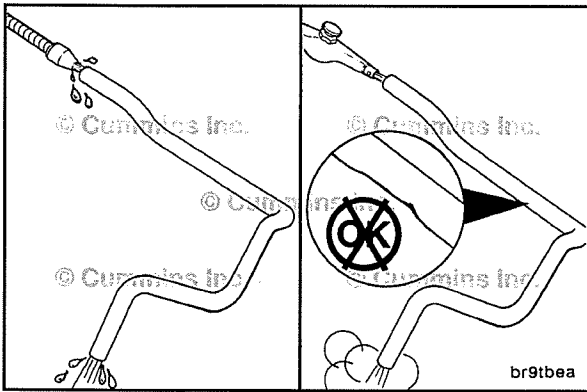
The tracer will be highlighted by the black light to help identify the source of the oil leak.



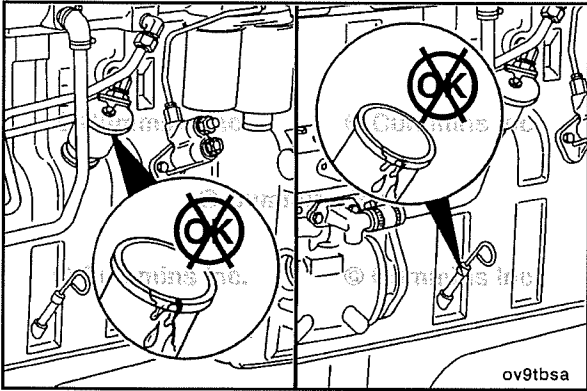


Operate the engine until the coolant temperature reaches 82°C [180°F]. If necessary, run the engine under load to create the conditions of the oil leak. Perform stall tests or a road test. Inspect the exterior of the engine for leaking gaskets, seals, o-rings, pipe plugs, or fittings.

NOTE: Before replacing any gaskets, check the capscrews to make sure they are tightened to the correct torque values.



Inspect the engine crankcase breather tube and hose for restriction or leaks. Refer to Procedure 003-018 in Section 3.



Check for a loose or missing oil dipstick tube, dipstick, or oil fill cap.

Lubricating Oil Pan (007-025)

Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠ WARNING ⚠

Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

NOTE: The engines use a variety of combinations of gaskets and/or RTV for sealing. When installing the oil pan, use the same combinations of gaskets and/or RTV that were on the pan.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Inspect the area around the lubricating oil pan plug. If there are signs of leakage, the lubricating oil pan plug sealing washer needs to be replaced.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.

Remove

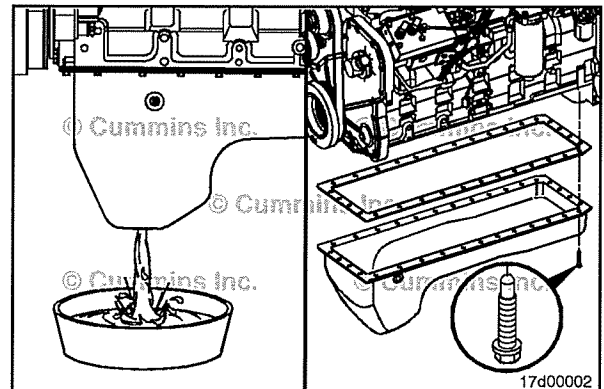
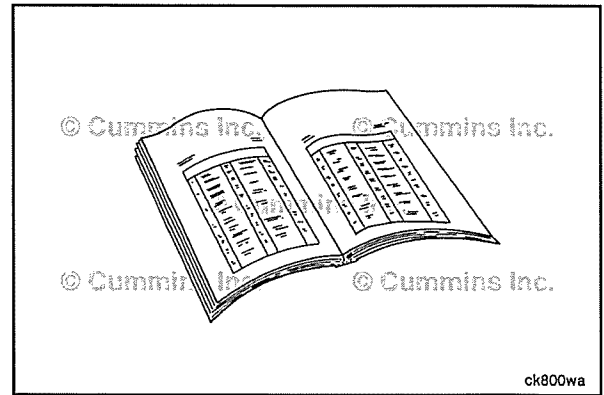
⚠ CAUTION ⚠

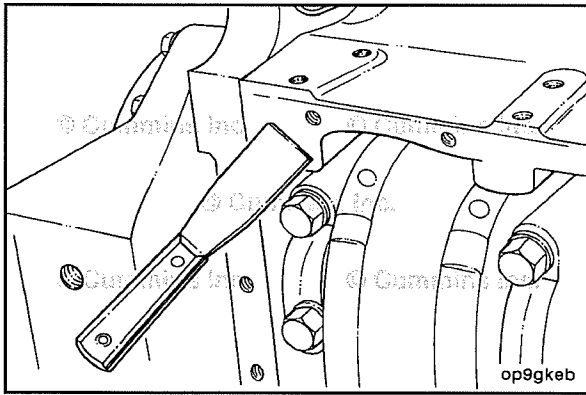
Do not use a pry bar or screwdriver to remove the oil pan. The lubricating oil pan flange can be damaged if a pry bar or screwdriver is used to break the sealant at the corners of the oil pan. Use a utility knife or the edge of a putty knife to cut the seal and loosen the pan.

Remove the lubricating oil pan and gasket.

Remove the suction tube if necessary. Refer to Procedure 007-035 in Section 7.

Remove the block stiffener plate, if equipped. Refer to Procedure 001-089 in Section 1.





Clean and Inspect for Reuse

⚠ WARNING ⚠

When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.



⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

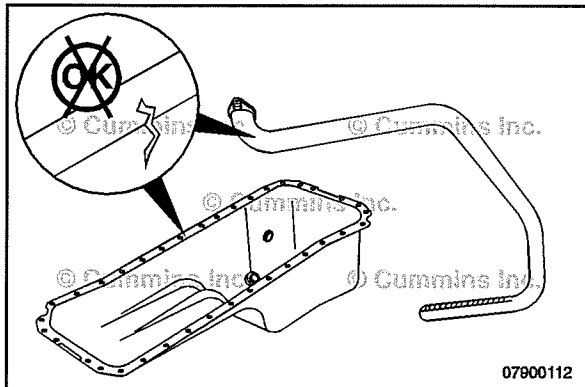
⚠ CAUTION ⚠

Do not use air or power tools, such as a high speed sander with an abrasive pad, to clean the gasket material from the oil pan. Air or power tools can overheat the oil pan and cause damage to the sealing flange.

Remove all gasket material from the cylinder block and lubricating oil pan surfaces.

Steam clean the lubricating oil pan.

Dry with compressed air.



Inspect the oil pan, suction tube, and tube braces for cracks or other damage.



NOTE: If cracks or other damage is found, replace the damaged part. Do **not** attempt to repair the oil pan by welding.

Use the following procedure if the suction tube **must** be replaced. Refer to Procedure 007-035 in Section 7.

Install

NOTE: The engines use a variety of combinations of gaskets and/or RTV for sealing. When installing the oil pan, use the same combinations of gasket and/or RTV that were on the pan.

NOTE: To achieve a proper seal, **always** use a new gasket.

NOTE: If the engine is equipped with a block stiffener plate, it is recommended that paper gaskets **not** be used for sealing.

Apply a 4 mm [1/8 in] bead of sealant, Part Number 3164067 or equivalent, to the oil pan mounting surfaces at the cylinder block to front gear cover joints, and the cylinder block to rear gear housing joints.

NOTE: Install the oil pan within 10 minutes of applying the sealant, or it will **not** seal correctly. Once installed, allow the sealant to dry for a minimum of 30 minutes before running the engine.

Install the suction tube, if applicable. Refer to Procedure 007-035 in Section 7.

NOTE: Install three guide pins, Part Number 3164977, to improve the alignment of the oil pan sealing components to the cylinder block. It is recommended to install two of the guide pins at opposite corners and one in the middle.

Install the block stiffener, if applicable. Refer to Procedure 001-089 in Section 1.

Install the gasket and lubricating oil pan.

Service Tip: To aid in installation of the gasket, apply a small amount of sealant, Part Number 3164067, or high tack spray adhesive to the gasket and oil pan flange. This will help to hold the gasket in place during assembly.

If RTV sealant is used to seal the oil pan, apply a 4 mm [1/8 in] bead of sealant, Part Number 3164067 or equivalent, to the oil pan flange and around the bolt holes.

Install the oil pan corner braces, if equipped.

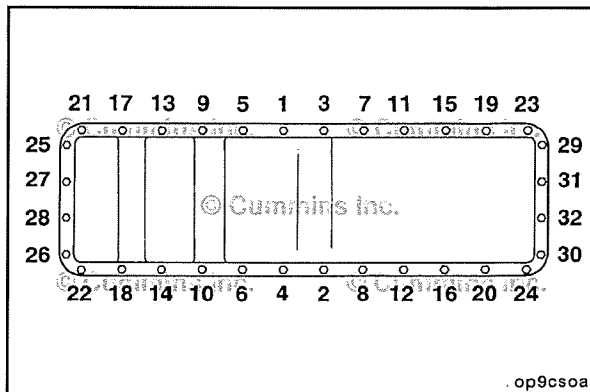
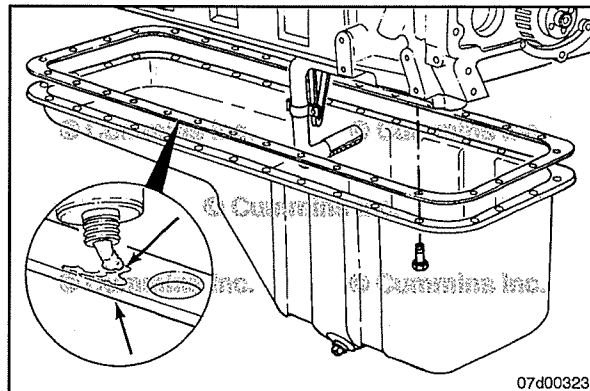
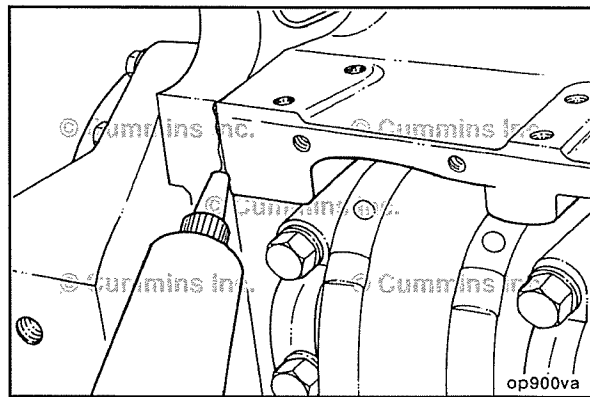
NOTE: Install the oil pan within 10 minutes of applying the sealant, or it will **not** seal correctly. Once installed, allow the sealant to dry for a minimum of 30 minutes before running the engine.

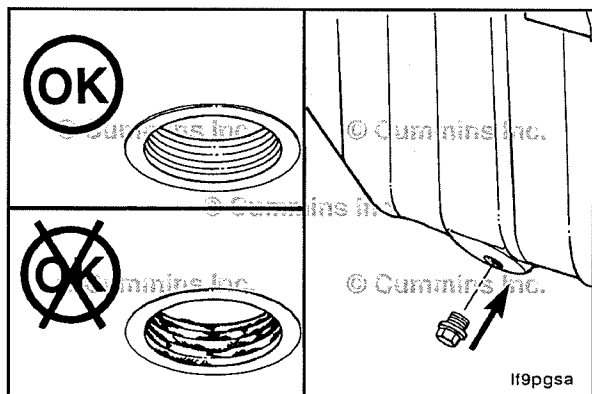
Assemble the washers and capscrews to secure the lubricating oil pan as illustrated.

Tighten all capscrews in the sequence shown in the illustration.

Torque Value: 28 N•m [248 in-lb]

NOTE: Make sure to follow the torque sequence shown. This allows for minimal assembly strains and evenly distributes pressure along the oil pan flange. Failure to follow the torque sequence can possibly lead to a cracked pan or joint leaks.





Clean and check the lubricating oil drain plug threads and sealing surface.



Install a new sealing washer if the lubricating oil pan plug was leaking, or if the sealing washer is damaged.

Install and tighten the lubricating oil pan drain plug.

Torque Value:

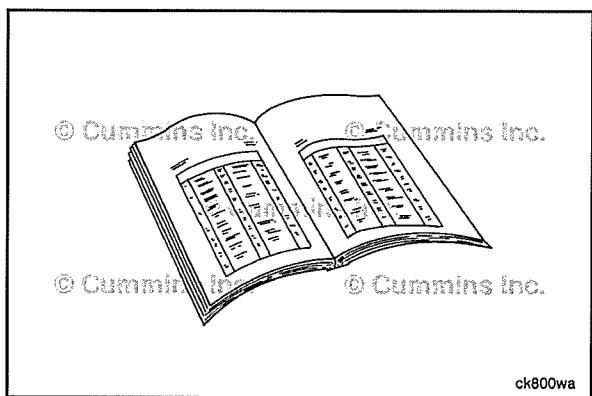
Steel Pan, M18 Plug 60 N•m [44 ft-lb]

Torque Value:

Steel Pan, M22 Plug 80 N•m [59 ft-lb]

Torque Value:

Cast Aluminum Pan, M22 Plug 60 N•m [44 ft-lb]



Finishing Steps

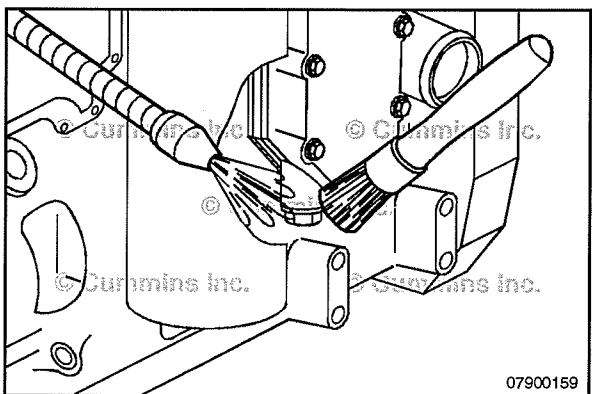


⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Lubricating Oil Pressure Regulator (Main Rifle) (007-029)

Remove

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

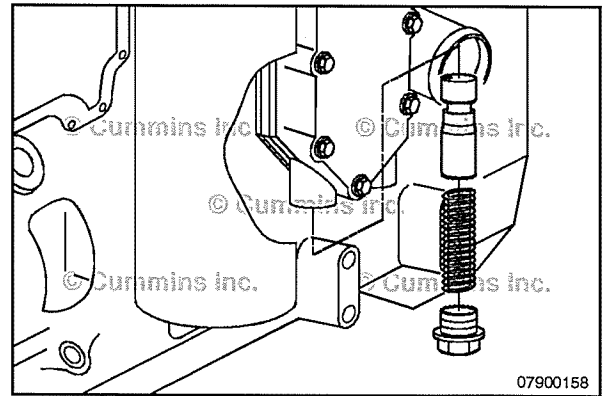
⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Thoroughly clean the area around the pressure regulator plug with clean solvent to prevent debris from falling into the plunger bore when the plug is removed.

Remove the threaded plug, spring, and plunger.

Service Tip: The plunger normally can be removed by inserting one finger into the plunger bore until snug and pulling down. If the plunger can **not** be removed in this manner, the plunger is probably stuck and will require removal of the housing for cleaning the plunger.



Clean and Inspect for Reuse

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠ WARNING ⚠

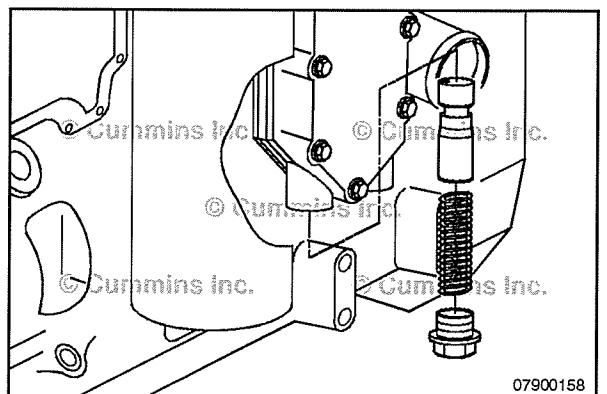
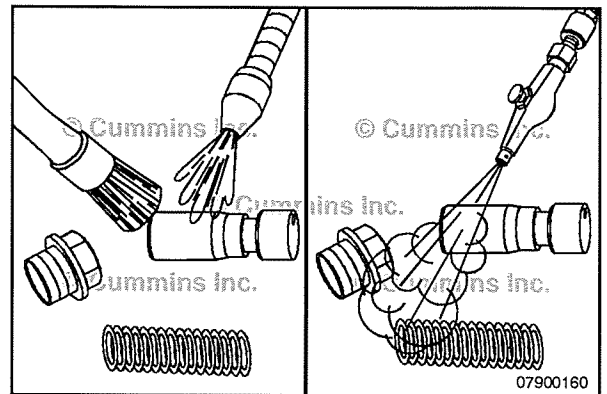
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

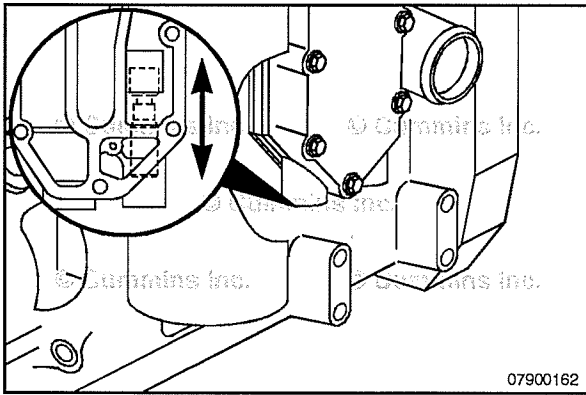
NOTE: If the plunger bore requires cleaning, remove the housing to avoid flushing debris into the engine.

Thoroughly clean all components with clean solvent.

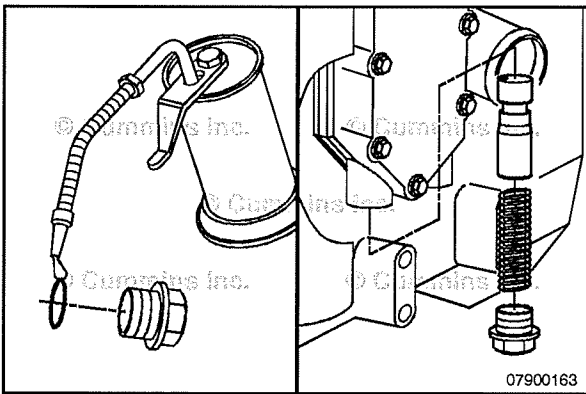
Dry with compressed air.

Inspect the plunger and plunger bore. Polished areas on the plunger and bore are acceptable.





Verify that the plunger moves freely in the bore.



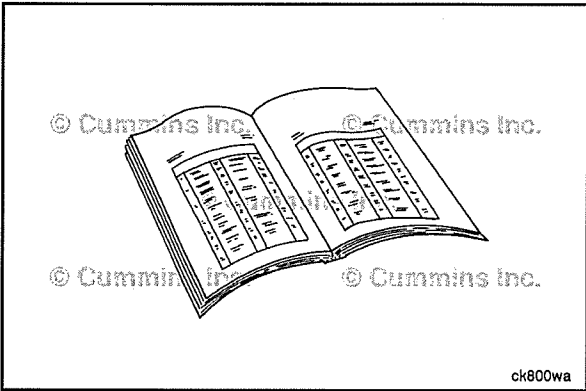
Install

Install a new sealing o-ring on the threaded plug and lubricate with clean engine oil.



Install the pressure regulator assembly.

Torque Value: 80 N•m [59 ft-lb]



Lubricating Oil Pump (007-031)

Preparatory Steps



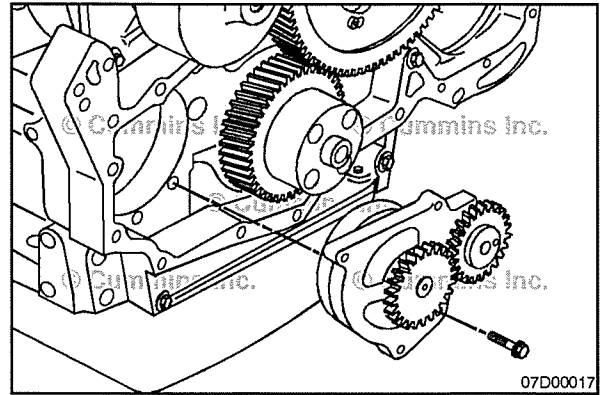
▲WARNING▲

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the operation and maintenance manual (OEM) service manual.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the rubber vibration damper, if installed. Refer to Procedure 001-051 if installed, in Section 1.
- Remove the viscous vibration damper, if installed. Refer to Procedure 001-052 if installed, in Section 1.
- Remove the front cover. Refer to Procedure 001-031 in Section 1.

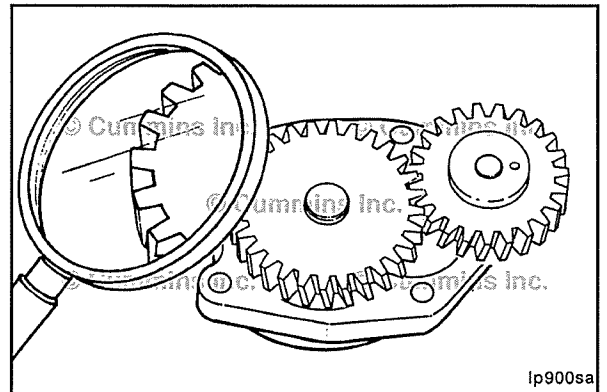
Remove

Remove the four mounting capscrews.
Remove the lubricating oil pump from the bore in the cylinder block.

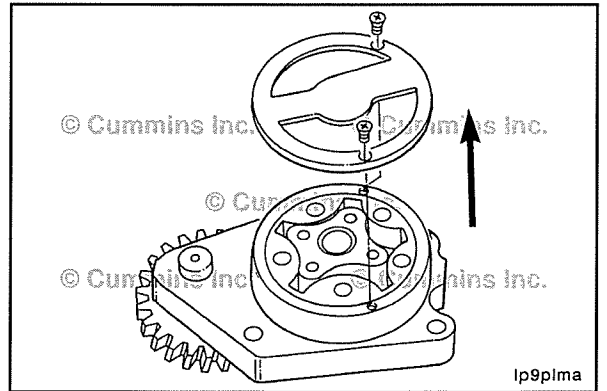


Disassemble

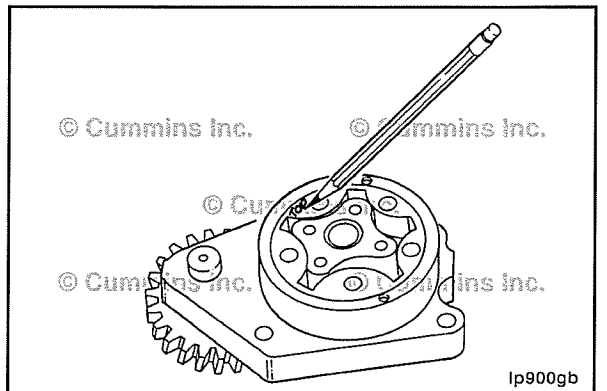
If the lubricating oil pump is to be inspected for reuse, follow these steps.
Inspect the lubricating oil pump gears for chips, cracks, or excessive wear.



Remove the back plate.



Mark TOP on the gerotor planetary.

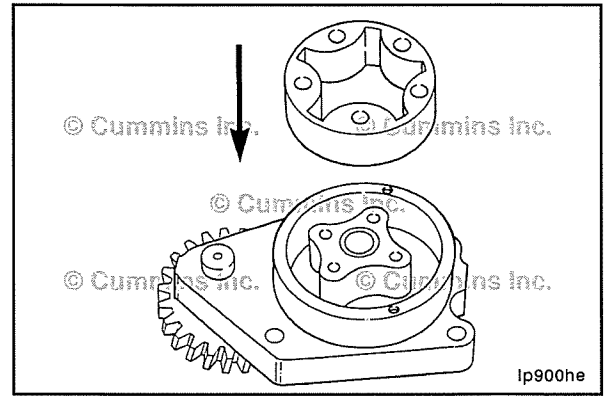


Measure

⚠ CAUTION ⚠

Make sure that the gerotor planetary is installed in the original position.

Install the gerotor planetary.

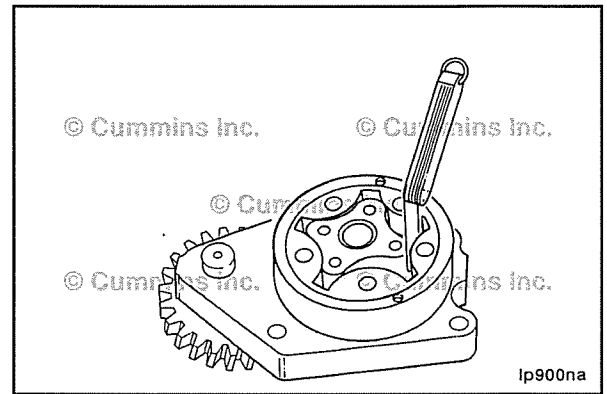


Measure the tip clearance.

Tip Clearance

mm		in
0.0254	MIN	0.001
0.1778	MAX	0.007

Replace the lubricating oil pump if the tip clearance is out of specification.

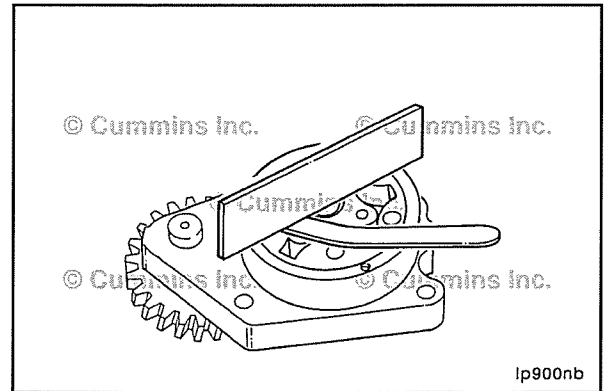


Measure the clearance of the gerotor drive/gerotor planetary to port plate.

Gerotor Drive/Gerotor Planetary to Port Plate

Clearance		
mm		in
0.0254	MIN	0.001
0.1270	MAX	0.005

Replace the lubricating oil pump if the gerotor drive/gerotor planetary to port plate clearance is out of specification.

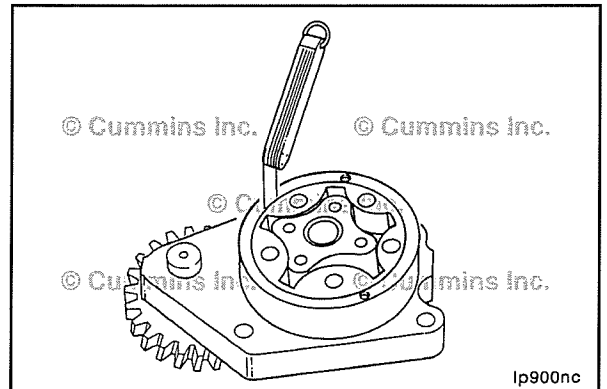


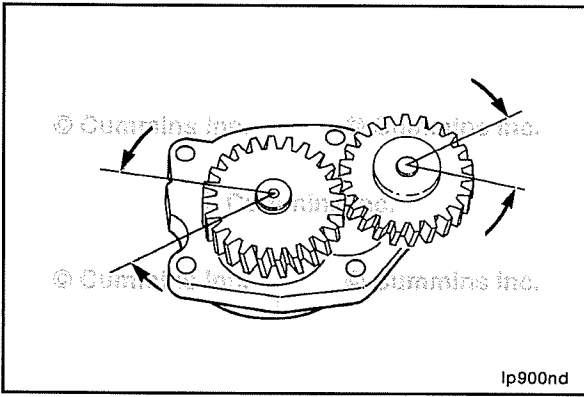
Measure the clearance of the gerotor planetary to the body bore.

Gerotor Planetary to Body Bore Clearance

mm		in
0.1778	MIN	0.007
0.3810	MAX	0.015

Replace the lubricating oil pump if the gerotor planetary to body bore clearance is out of specification.





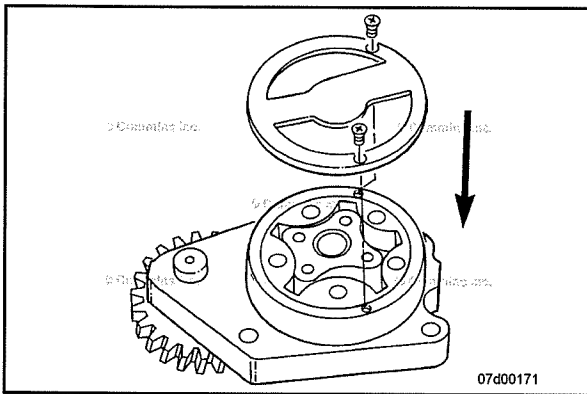
Measure the backlash.

Lubricating Oil Pump Gears Backlash Limits (Used Pump)

mm		in
0.0762	MIN	0.003
0.3302	MAX	0.013

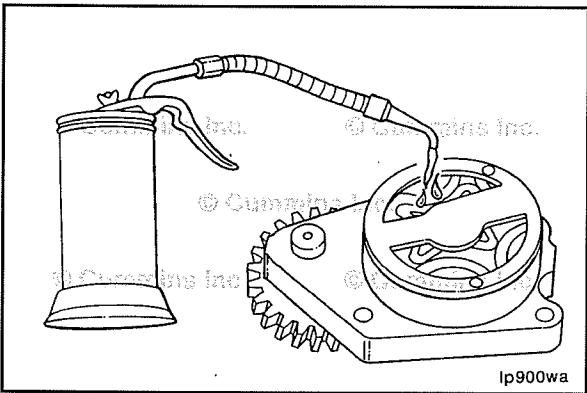
NOTE: Hold the adjoining gears to keep them from moving when checking backlash or else the reading will be the total of both gears.

Replace the lubricating oil pump if the gear backlash is out of specification.



Assemble

Install the back plate.

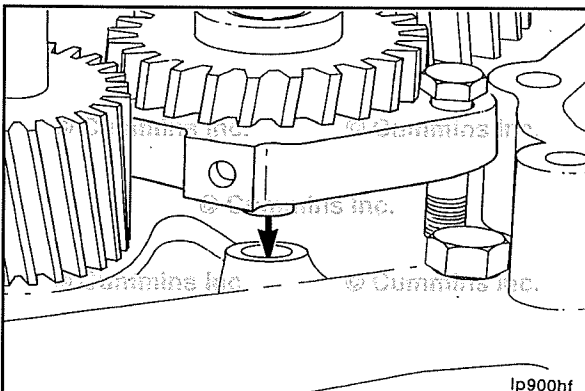


Install

⚠CAUTION⚠

Failure to fill the pump with oil at installation can result in the lubricating oil pump not priming at initial engine start-up, resulting in severe engine damage.

Lubricate the lubricating oil pump with clean 15W-40 engine oil.



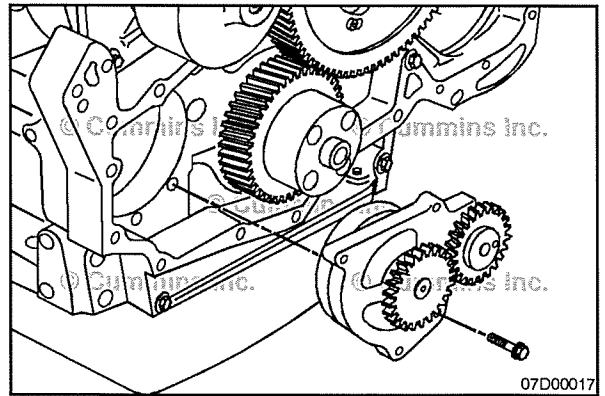
⚠CAUTION⚠

Make sure the idler gear pin is installed in the locating bore in the cylinder block.

Install the lubricating oil pump.

Tighten the capscrews in a crisscross pattern, starting with the upper right capscrew.

Torque Value: 24 N•m [212 in-lb]



07D00017

NOTE: Be sure the gear backlash is correct if installing a new lubricating oil pump.

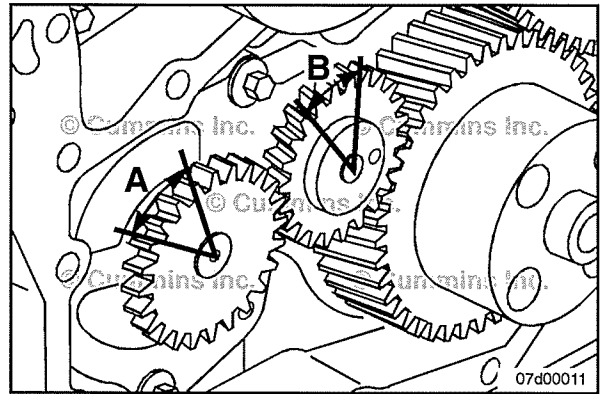
Measure the gear backlash.



Lubricating Oil Pump Gears Backlash Limits (Installed)

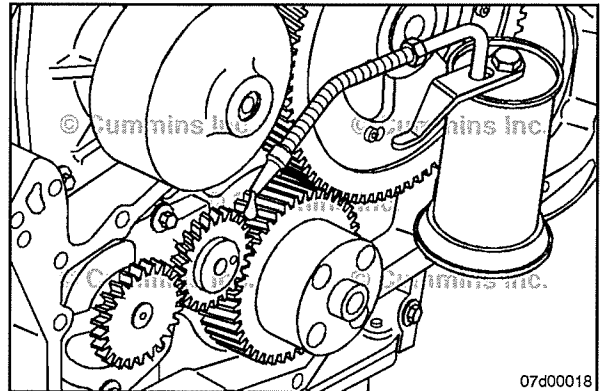
	mm		in	
A	0.0762	MIN	0.003	
	0.3302	MAX	0.013	
B	0.0762	MIN	0.003	
	0.3302	MAX	0.013	

NOTE: If the adjoining gear moves when you measure the backlash, the reading will be incorrect.

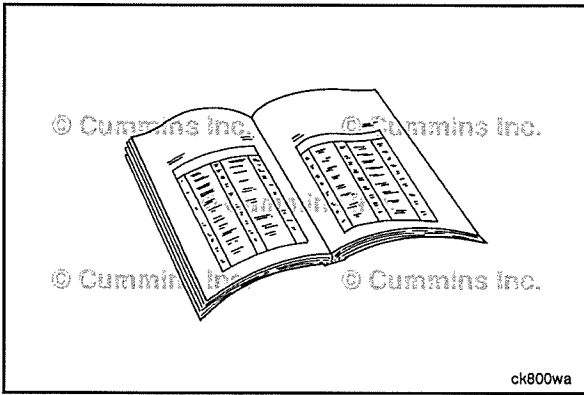


07d00011

Lubricate the front gear train with clean 15W-40 engine oil.



07d00018



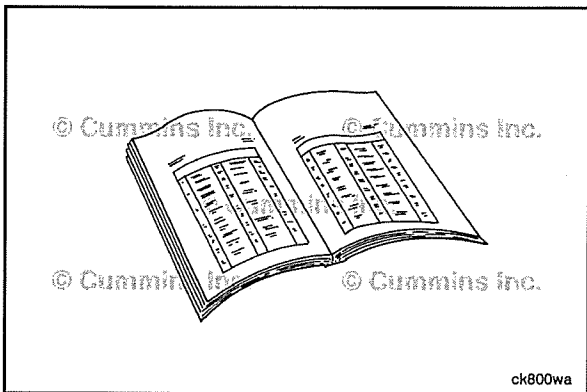
Finishing Steps

▲ WARNING ▲

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the front cover. Refer to Procedure 001-031 in Section 1.
- Install the rubber vibration damper, if removed. Refer to Procedure 001-051 if installed, in Section 1.
- Install the viscous vibration damper, if removed. Refer to Procedure 001-052 if installed, in Section 1.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Lubricating Oil Suction Tube (Block-Mounted) (007-035)

Preparatory Steps

▲ WARNING ▲

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



▲ WARNING ▲

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

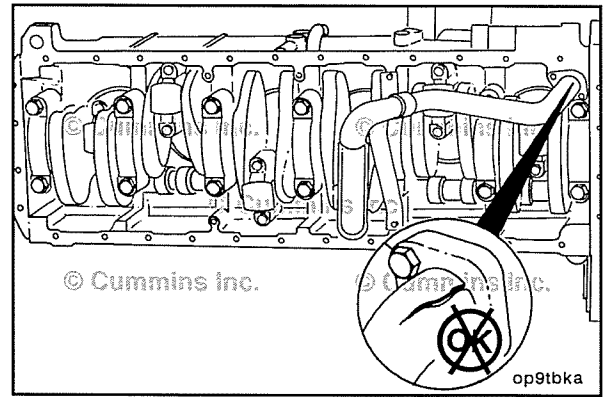
▲ WARNING ▲

Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7.

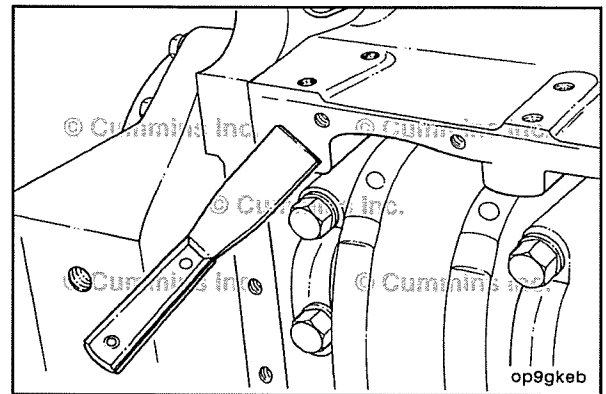
Remove

Remove the lubricating oil suction tube.

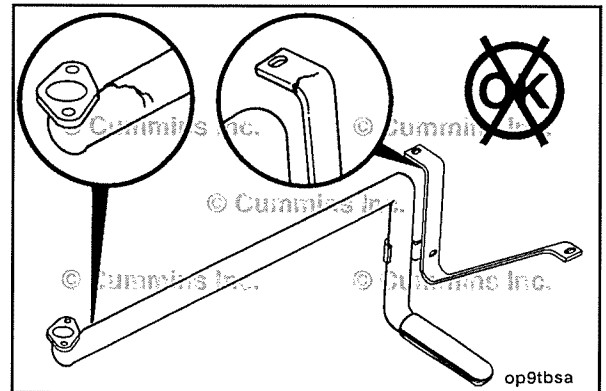


Clean and Inspect for Reuse

Clean the gasket surfaces.



Inspect the suction tube for cracks.



Install

Install the lubricating oil suction tube and new gasket.

- Install all capscrews finger tight and check for correct alignment.
- Torque the lubricating oil suction tube to the block.

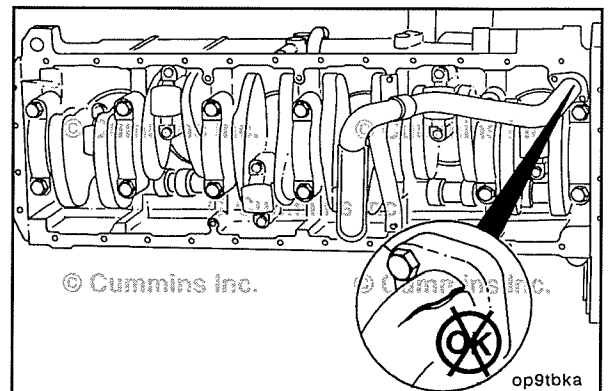
Torque Value: 10 N•m [89 in-lb]

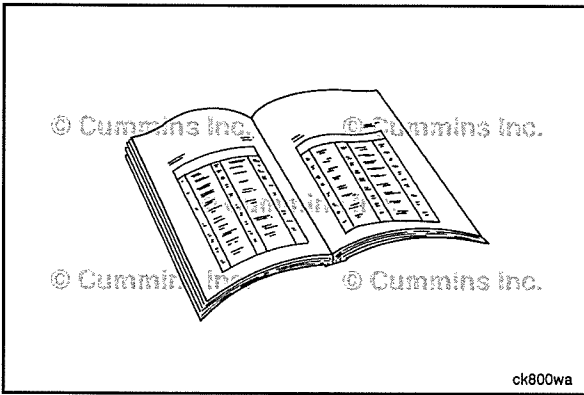
- Torque the lubricating oil suction tube brace to the engine block.

Torque Value: 10 N•m [89 in-lb]

- Torque the lubricating oil suction tube to the brace.

Torque Value: 10 N•m [89 in-lb]





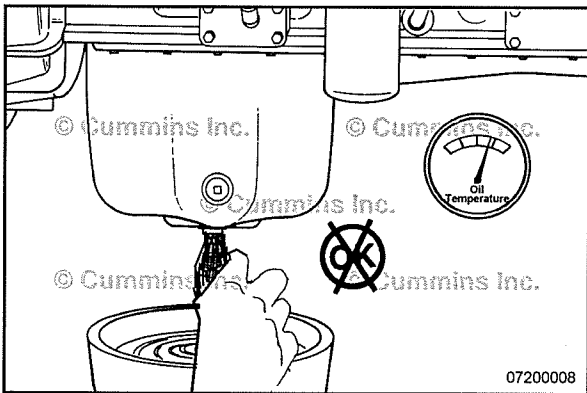
Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7.
- Fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Lubricating Oil System (007-037)

Drain



⚠ WARNING ⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠ WARNING ⚠

Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

NOTE: Use a container that can hold at least 28.4 liters [30 qt] of lubricating oil.

- Operate the engine until the coolant temperature reaches 60°C [140°F]. Shut the engine OFF.
NOTE: Be sure to remove the front and rear oil drain plugs, if equipped. Failure to do so will result in incomplete draining of oil from the lubricating oil pan.
- Remove the oil drain plug.
- Drain the oil immediately to make sure all the oil and suspended contaminants are removed from the engine.
- If performing an oil drain as part of a service maintenance interval, remove and replace the oil filter. Refer to Procedure 007-013 in Section 7.

Fill

Clean and check the lubricating oil drain plug threads and sealing surface.

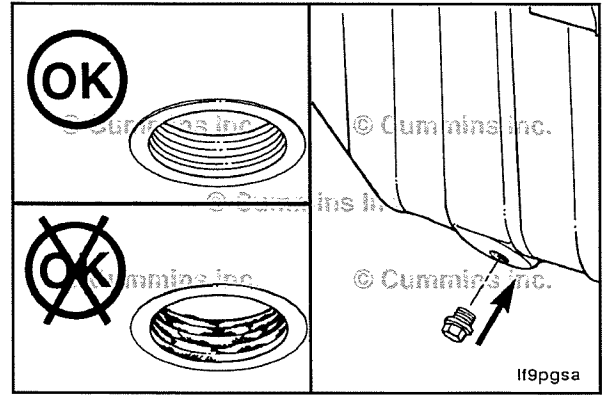
Install the lubricating oil pan drain plug.

Torque Value:

Steel Oil Pan 80 N•m [59 ft-lb]

Torque Value:

Cast Aluminum Oil Pan 60 N•m [44 ft-lb]



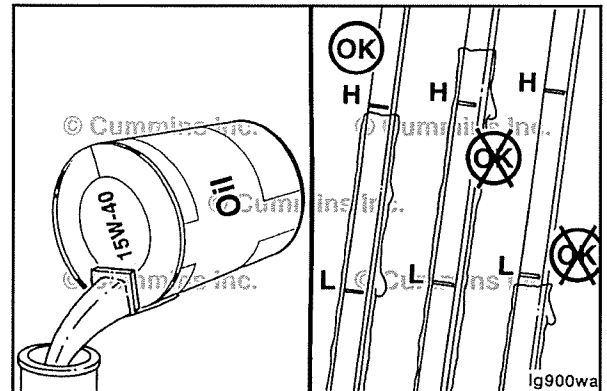
NOTE: Use a high quality 15W-40 multi-viscosity oil, such as Cummins® Premium Blue™, or equivalent, in Cummins® engines. Choose the correct oil for your operating climate as outlined in Section V.



Fill the engine with clean lubricating oil to the proper level.

NOTE: When filling the oil pan, use the fill tube on the side of the engine rather than on top of the rocker lever cover.

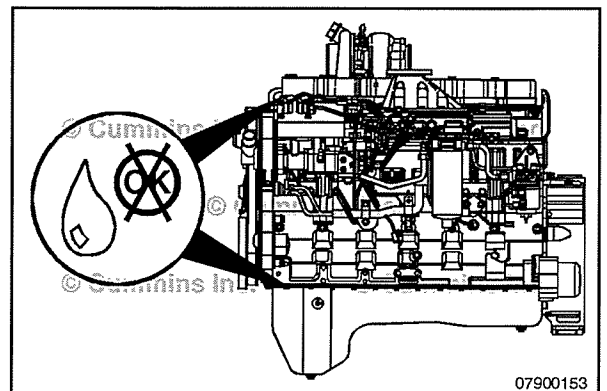
Verify the lubricating oil pan capacity. Refer to Procedure 018-017 in Section V.

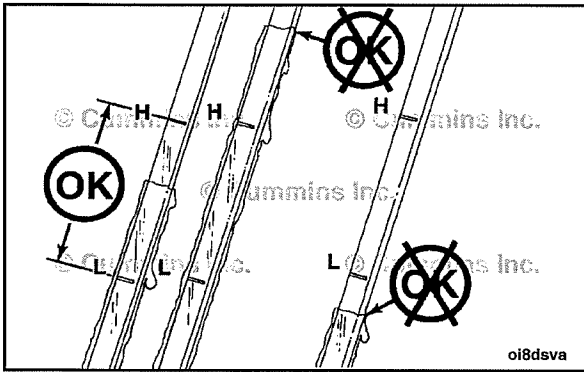


⚠ CAUTION ⚠

If no oil pressure is noted within 15 seconds after the engine is started, shut down the engine to reduce the possibility of internal engine damage.

Idle the engine to inspect for leaks at the drain plug.

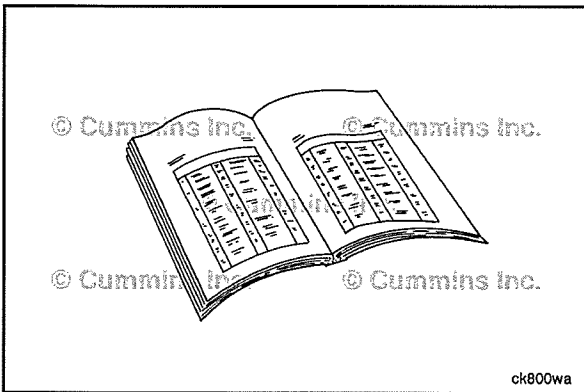




Shut the engine OFF. Wait approximately 10 minutes to let the oil drain from the upper parts of the engine. Check the level again.



Add oil as necessary to bring the oil level to the "H" (high) mark on the dipstick.



Lubricating Oil Thermostat (007-039) Preparatory Steps

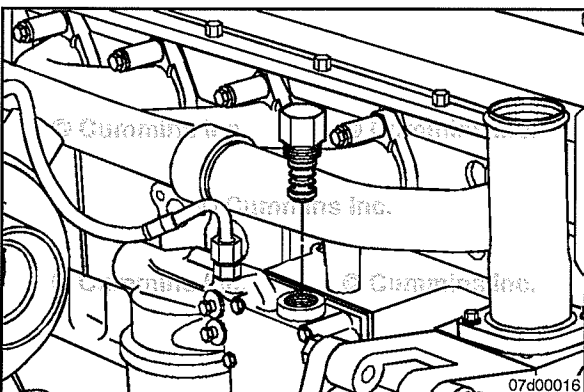


⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the exhaust gas recirculation (EGR) cooler mounting bracket. Refer to Procedure 011-029 in Section 11.
- Some applications may require removal of the EGR coolant return line to the water inlet connection. Refer to Procedure 011-031 in Section 11.
- Clean the area around the lubricating oil thermostat to prevent debris from entering the system.



Remove

⚠ WARNING ⚠

To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠ WARNING ⚠

Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

Remove the lubricating oil thermostat.

Clean and Inspect for Reuse

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠ WARNING ⚠

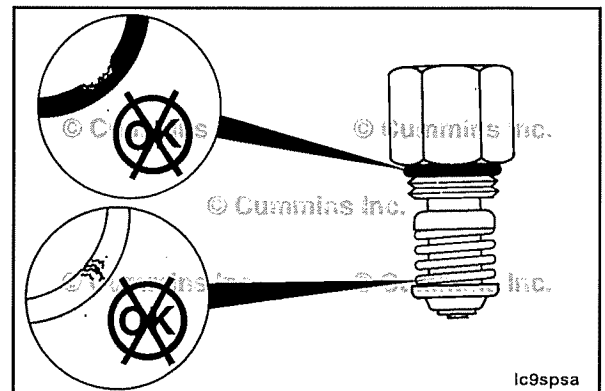
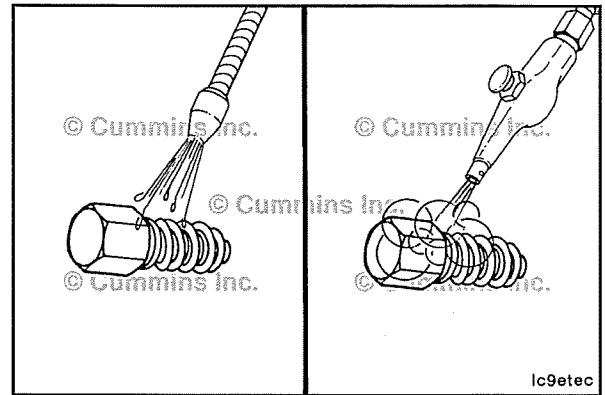
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the thermostat with solvent.

Dry with compressed air.

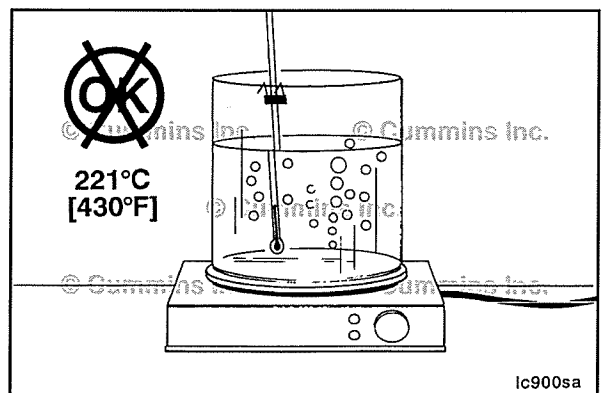
Inspect for a damaged o-ring, broken spring, or other damage.

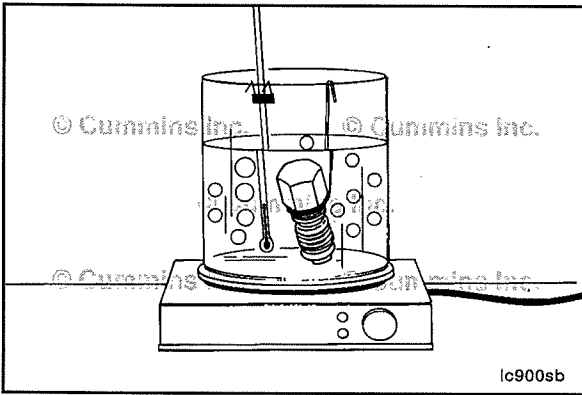
If any damage is found, the component must be replaced.



⚠ WARNING ⚠

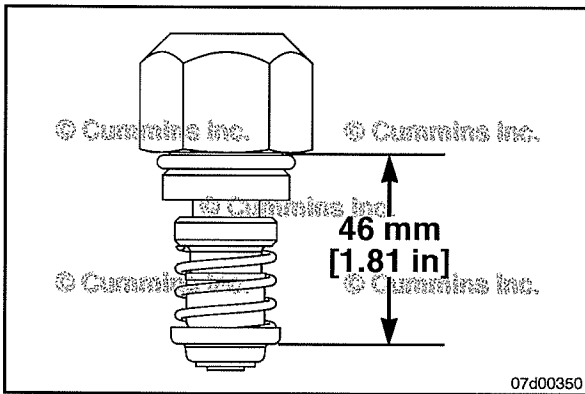
The flash point of new lubricating oil is approximately 221°C [430°F]. Do not allow oil temperature in the container to exceed 150°C [300°F]. Do not allow water droplets to enter the container of hot oil. Water droplets will cause a violent reaction, that can cause personal injury.





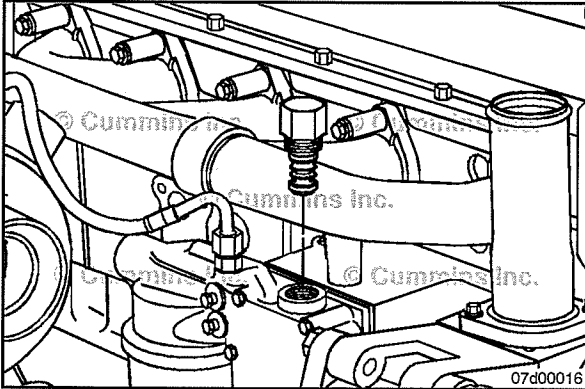
Suspend the thermostat and a 116°C [240°F] thermometer in a container of new lubricating oil. Do **not** allow the thermostat or the thermometer to touch the sides of the container.

Heat the lubricating oil.



NOTE: Write down the temperature when the thermostat is fully extended. The thermostat **must** be fully extended at least 46 mm [1.81 in] when the temperature reaches 116°C [240°F].

Replace the thermostat if it does **not** operate as described.



Install

Install the lubricating oil thermostat.



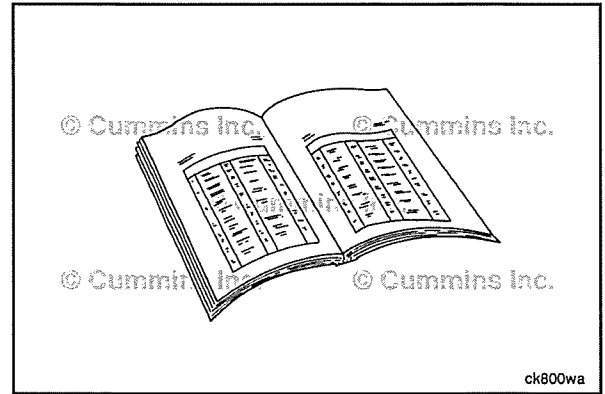
Torque Value: 50 N·m [37 ft-lb]

Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the EGR coolant return line. Refer to Procedure 011-031 in Section 11.
- Install the EGR cooler mounting bracket. Refer to Procedure 011-029 in Section 11.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

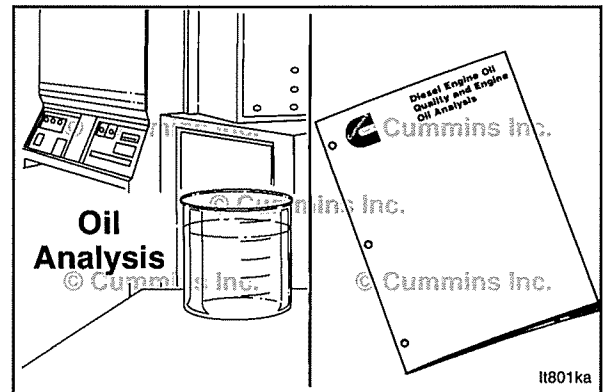


Lubricating Oil Contamination (007-044)

General Information

A used oil analysis can help diagnose internal damage and determine if it was caused by one of the following:

- Oil diluted with coolant
- Oil diluted with fuel.



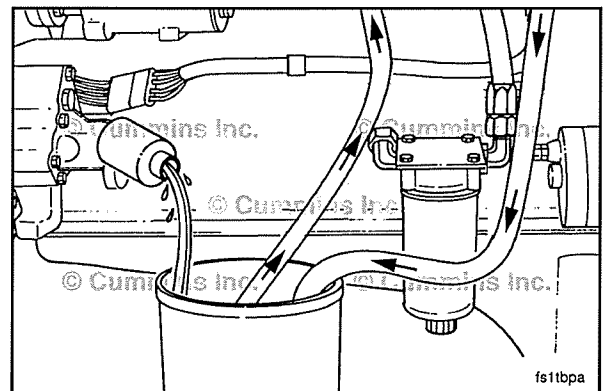
Fluorescent Dye Tracer

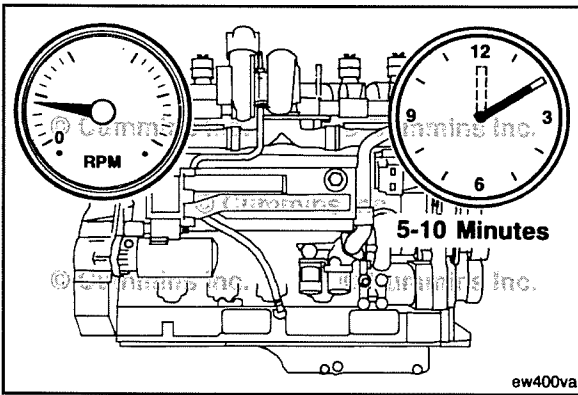
Lubricating Oil Dilution

NOTE: This test is **not** effective on a cold engine, less than 21°C [70°F] coolant temperature, or with a loose overhead setting.

Install an isolated fuel supply tank at the fuel inlet supply line and at the fuel drain line.

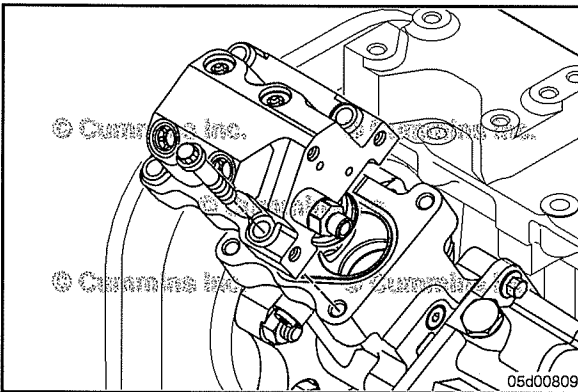
Add fluorescent tracer, Part Number 3376891, to the isolated fuel supply tank. Reference the instructions on the fluorescent tracer bottle for the proper tracer-to-fuel ratio.





- Connect INSITE™ electronic service tool.
- Start the engine.
- Operate the engine at idle for 3 minutes.
- After 3 minutes, use INSITE™ electronic service tool High-Pressure Leakage Test to create high fuel rail pressure.
- Operate the engine at high fuel pressure for 3 minutes.
- Shut the engine down.

NOTE: Do **not** allow the engine to operate from a remote fuel source for more than 10 minutes.



▲ WARNING ▲

Normal engine operation creates highly pressurized fuel in the fuel line which will remain in the fuel line after engine shutdown. Never open the fuel system when the engine is operating. Before servicing the fuel system, always loosen the pump to rail fuel line at the rail to vent the pressure. Keep hands clear of the line when loosening. High pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.



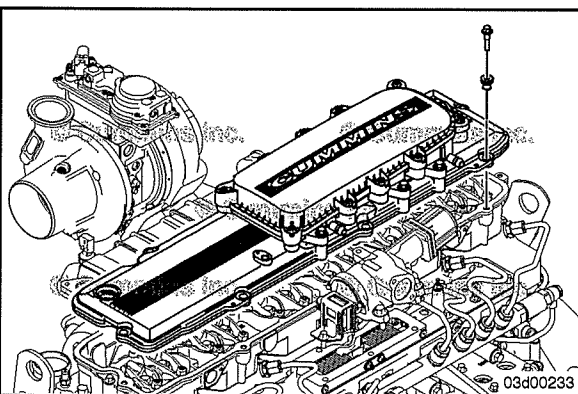
Remove the fuel pump head. Refer to Procedure 005-227 in Section 5.

Use a black light, Part Number 3163337, to inspect the camshaft housing for signs of fuel. Fuel will appear to be yellow if present.

NOTE: Do **not** remove the springs. A small amount of fuel on the pumping plungers is normal.

If there are signs of a significant amount of fuel in the camshaft housing or on the tappet springs, replace the fuel pump head.

Install the fuel pump head. Refer to Procedure 005-227 in Section 5.

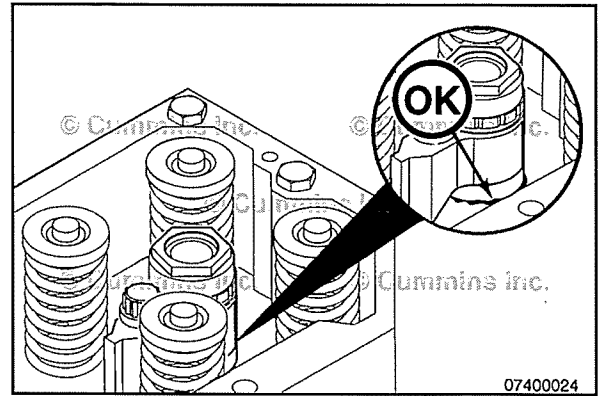


Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.



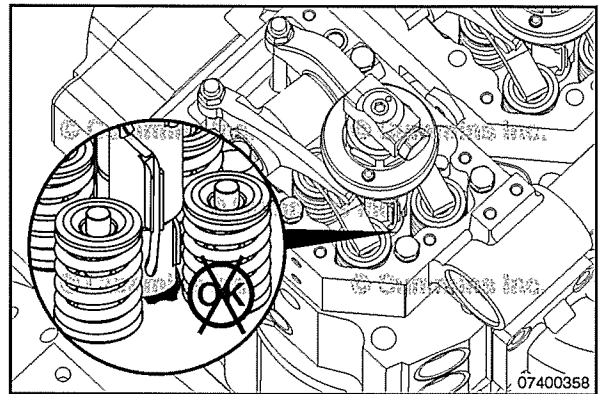
Use a black light to find fuel leaks from inside or around the injectors.

Fuel will appear to be yellow.



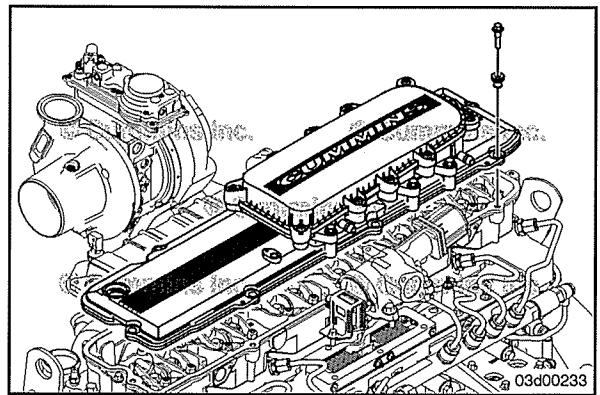
If there is excess leakage around the outside of the injector,

- Check the injector hold-down clamp capscrew torque.
- Remove the injectors and inspect the injector o-rings and injector body for damage.
- Replace the injector o-rings and the injector sealing washers if the injector is installed.
- Replace the injector if injector body damage is present.



Refer to Procedure 006-026 in Section 6.

Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.

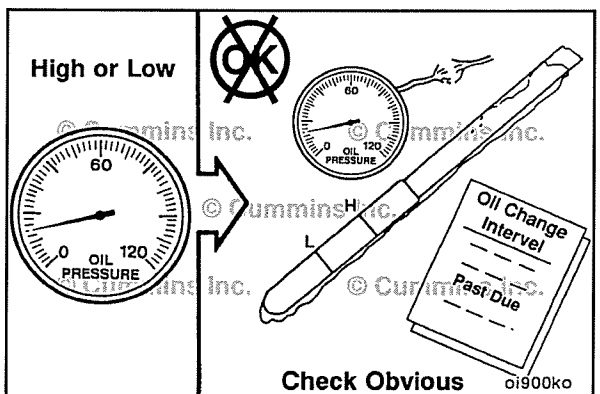


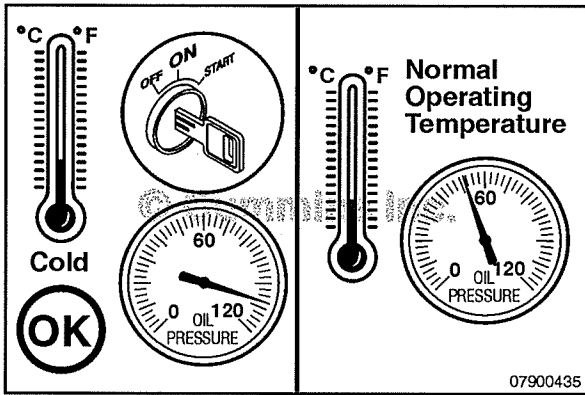
Lubricating Oil System Diagnostics (007-048)

General Information

Lubricating Oil Pressure

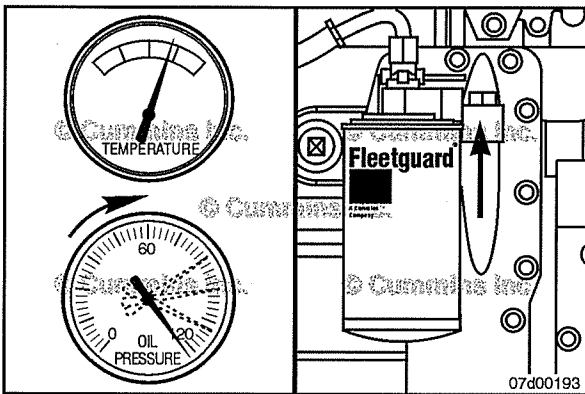
When the lubricating system malfunctions, check all obvious items related to oil pressure, such as gauges, high and low oil level, excessive oil contamination, and oil viscosity.





High lubricating oil pressure occurs after the engine is first started in cold weather. Cold-start oil pressure typically will be approximately 689 to 827 kPa [100 to 120 psi].

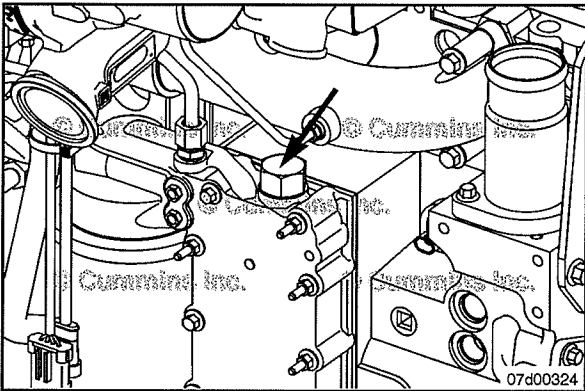
If the pressure regulator plunger is operating properly, the oil pressure is approximately 379 kPa [55 psi] when normal operating temperature is reached.



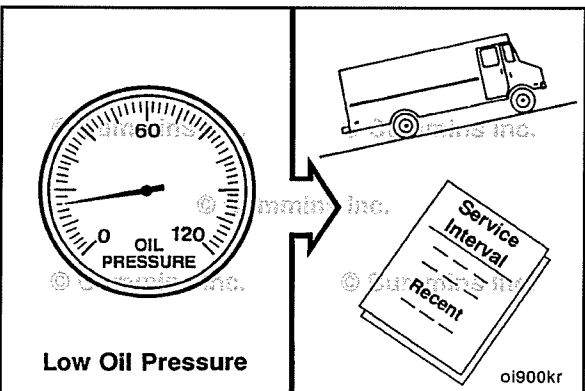
The engine will have high oil pressure at normal operating temperature if the lubricating oil pressure regulator valve sticks in the closed position.



Check the regulator for freedom of movement. Refer to Procedure 007-029 in Section 7.



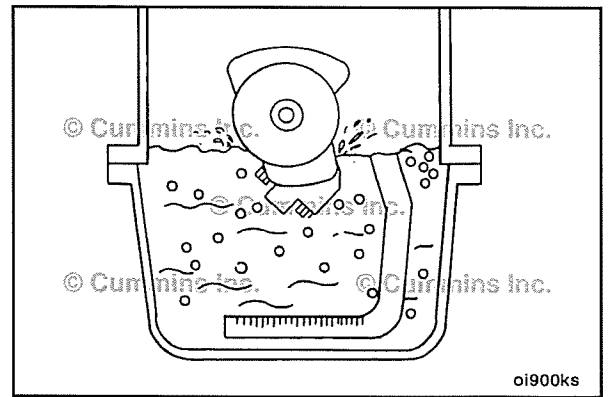
The lubricating oil cooler contains a lubricating oil thermostat which allows the lubricating oil to bypass the oil cooler to regulate the lubricating oil temperature to 116°C [240°F]. Verify the oil thermostat's operation. Refer to Procedure 007-039 in Section 7.



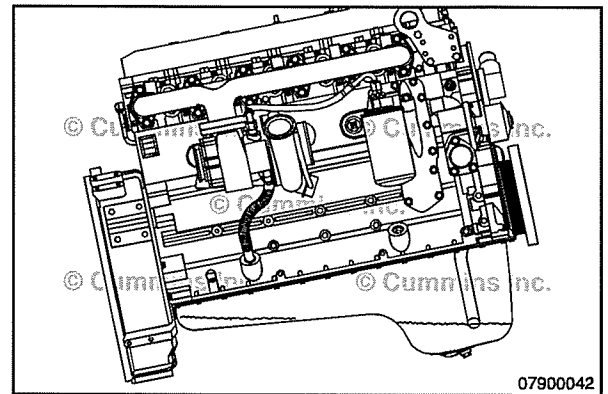
Low lubricating oil pressure (or no oil pressure) can be caused by several lubricating system-related malfunctions. To begin the investigation, determine the engine operating conditions when the low pressure was first observed. The following are possible conditions for low lubricating oil pressure:

- Following a service interval
- At idle **only**
- Operating on a steep grade
- Operating in rough seas.

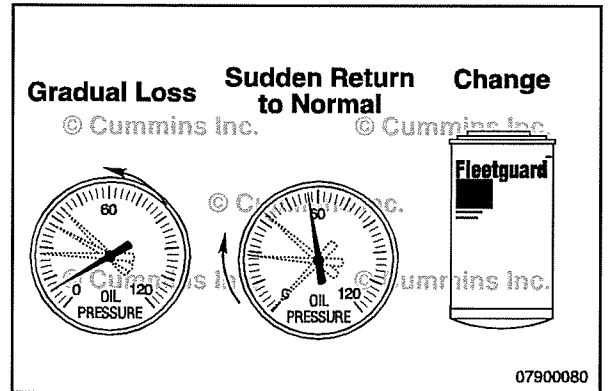
High lubricating oil level can cause low oil pressure. If the oil level is high enough for the connecting rods to dip into the oil while operating, the oil can become aerated, resulting in low oil pressure.



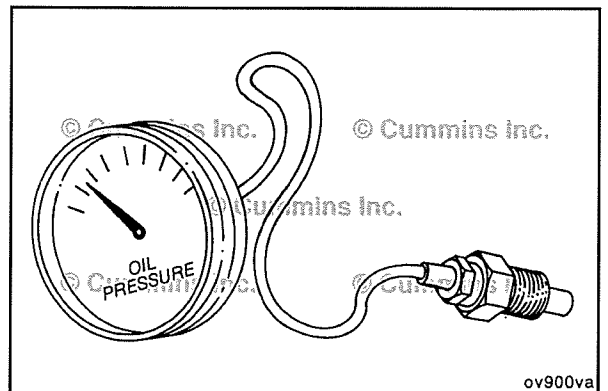
Low oil level will **not** normally appear as low oil pressure. Typically, it will appear as an intermittent loss of oil pressure when rounding a corner or operating on a steep grade. This condition exists when the oil level is extremely low and the suction tube can **not** pick up oil during all modes of operation.

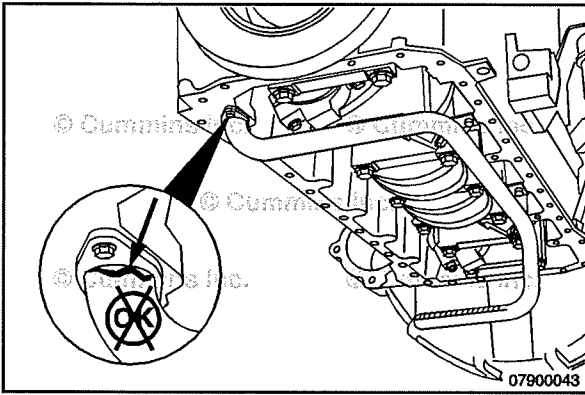


A plugged lubricating oil filter will cause a gradual reduction in oil pressure by approximately 69 kPa [10 psi]. The pressure will return to normal when the filter bypass valve opens. If **not** corrected, this will result in severe engine wear, as the engine is running on unfiltered oil when the bypass valve is open.

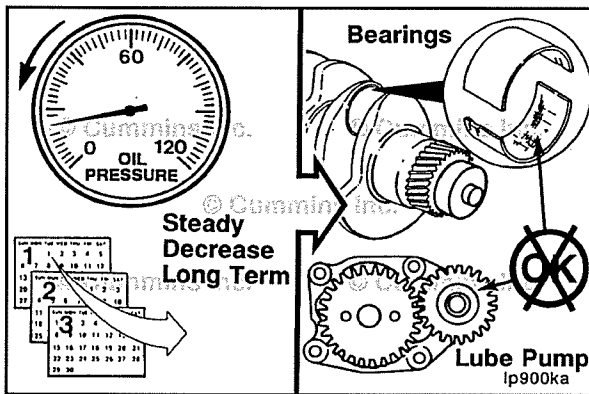


Verify the pressure with a manual gauge to make sure the lubricating oil gauge and the sending unit are operating correctly.

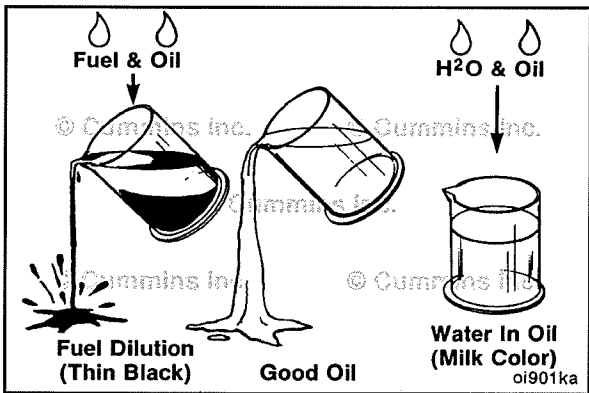




A loose lubricating oil suction tube, damaged gasket, or crack in the suction tube can cause a loss of prime for the oil pump. The engine will have low pressure or no oil pressure during starting, followed by normal oil pressure.



A steady decrease in oil pressure over a long period can be an indication of worn bearings or excessive lubricating oil pump wear.

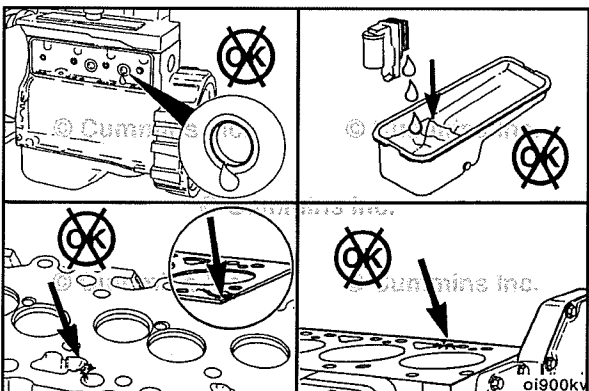


Lubricating Oil Dilution

CAUTION
Using diluted oil can cause severe engine damage.

Check the condition of the lubricating oil:

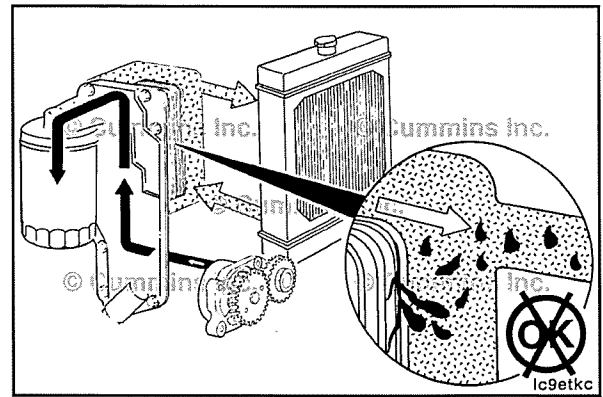
- Thin, black oil is an indication of fuel in the oil
- Milky discoloration is an indication of coolant in the oil.



Coolant in the oil can be caused by:

- Expansion plugs leaking
- Oil cooler element leaking
- Damaged cylinder head or gasket
- Cracked engine block
- Casting porosity
- Damaged turbocharger
- Damaged exhaust gas recirculation (EGR) cooler
- Damaged air compressor.

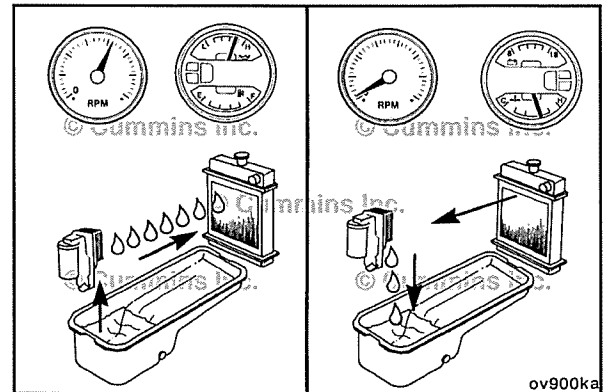
There are two places within the oil cooler assembly where oil and coolant could mix, the oil cooler gasket or lubricating oil cooler element. Refer to Procedure 007-003 in Section 7



While operating, the oil pressure will be higher than coolant pressure. A leak in the oil cooler will show as oil in the coolant.



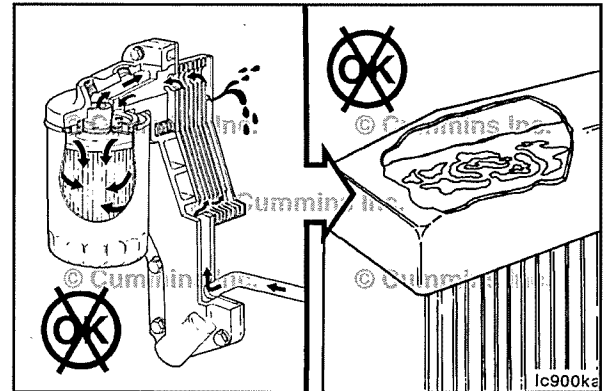
However, following an engine shutdown, the residual pressure in the coolant system can cause coolant to seep through the leak path into the oil.



If the oil cooler element ruptures, the oil pressure will force oil into the coolant system.



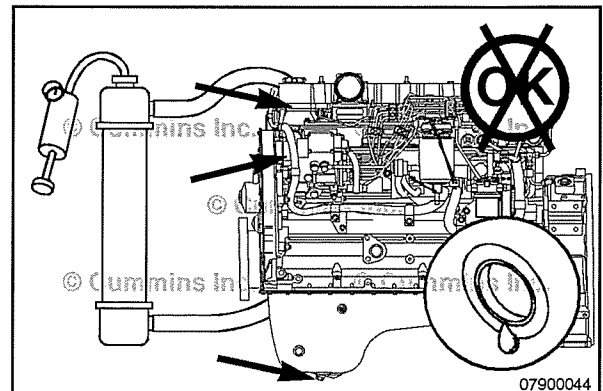
Oil in the coolant will be visible when the radiator cap is removed. Refer to Procedure 007-003 in Section 7.

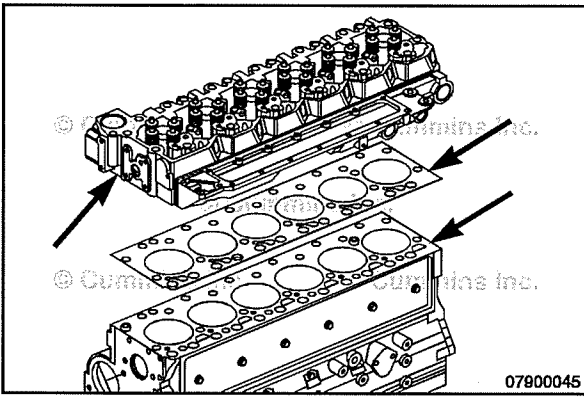


To check for leaks, pressurize the cooling system to 140 kPa [20 psi]. With the system pressurized, remove the following components and inspect for leaks:



- Rocker lever cover. Refer to Procedure 003-011 in Section 3. Leaks indicate a cracked cylinder head.
- Lubricating oil drain plug. Refer to Procedure 007-037 in Section 7. Leaks indicate a malfunctioning oil cooler or cylinder head gasket, or a cracked cylinder head or block.



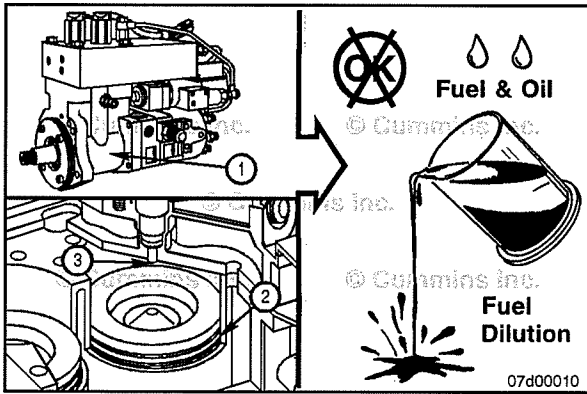


Coolant in the lubricating oil can be caused by a damaged cylinder head gasket or a cracked cylinder head or block.



Remove the cylinder head and gasket. Refer to Procedure 002-004 in Section 2.

Inspect for cracks or any other damage.



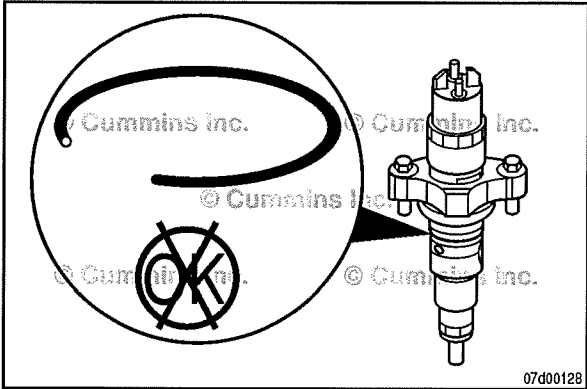
Fuel-Diluted Lubricating Oil:

Use the following logic to determine the source of the oil dilution with fuel.

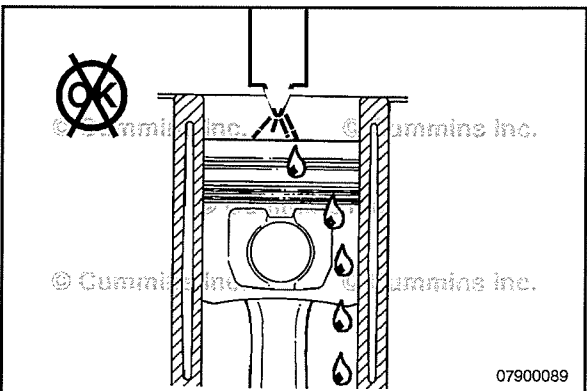
Fuel dilution is limited to three sources:

- Injection pump head
- Fuel leaking past the rings
- Injector leakage.

A cracked or damaged fuel pump head can cause fuel to leak in to the cam housing and then in to the lubricating oil pan.



A damaged or missing o-ring seal on the injector(s) can cause fuel dilution of the lubricating oil system. The o-ring seal on the injector seals the injector return fuel in the internal cylinder head drilling.

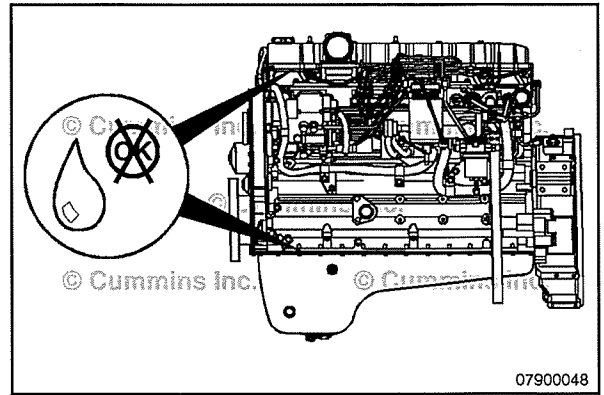


Incomplete combustion in the cylinders can result in unburned fuel draining into the oil pan.

This condition can be caused by a leaking injector or reduced compression caused by inadequate piston ring sealing.

Lubricating Oil Consumption and Leaks

Various gaskets, seals, and plugs are used to contain the lubricating oil. Most leaks can be identified during routine inspections of the engine and vehicle.

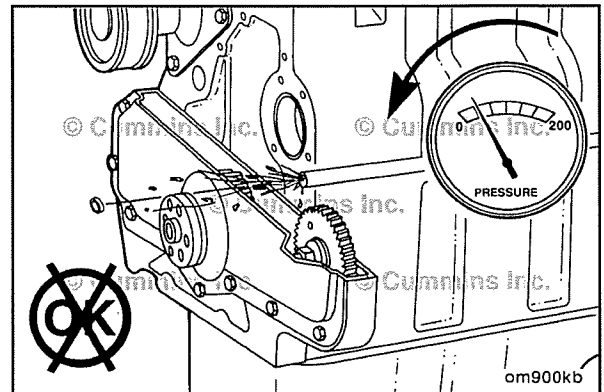


A blown expansion plug can allow a relatively large quantity of lubricating oil to escape, resulting in a sudden drop in the lubricating oil pressure.

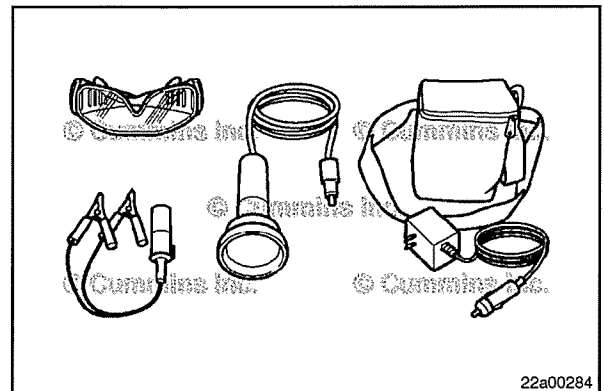


When checking for such a leak, make sure to check all expansion plugs that can be visually obscured by chassis parts.

Lubricating oil blowing out of the breather is an indicator of a blown expansion plug.



A black light kit, Part Number 3163338, or equivalent, and a fluorescent tracer, Part Number 3376891, or equivalent, **must** be used to verify the source of the oil leak.

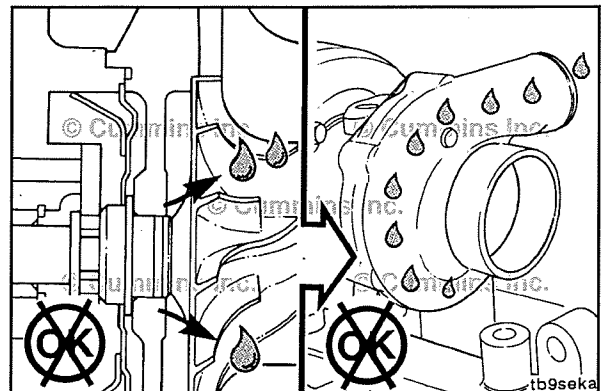


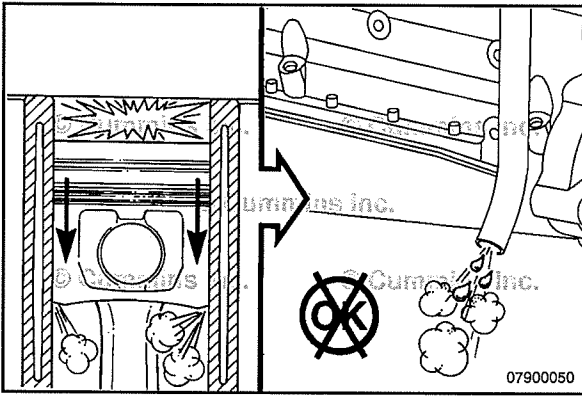
Worn or damaged seals in the turbocharger can also allow oil to leak into the charge-air cooler system and be burned in the engine.



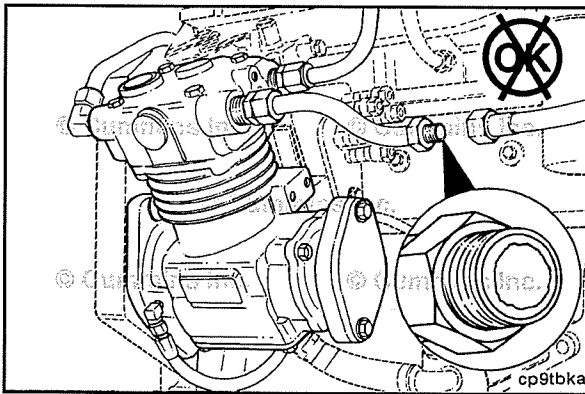
The condition can be verified by removing the air crossover tube or charge-air cooler tubing and looking for oil. Refer to Procedure 010-019 in Section 10. Refer to Procedure 010-027 in Section 10.

NOTE: If the engine experiences a turbocharger malfunction or any other occasion where oil or debris is put into the charge-air cooler, the charge-air cooler must be cleaned and the EGR differential pressure sensor ports must be cleaned. Refer to Procedure 010-027 in Section 10. Refer to Procedure 010-080 in Section 10.



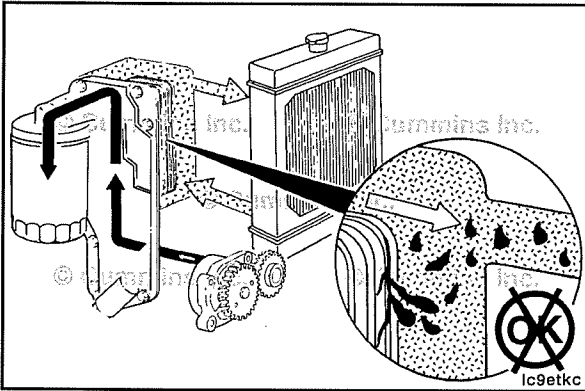


Inadequate sealing of the piston rings will result in excessive oil out of the crankcase breather system and/or oil being consumed by the engine.

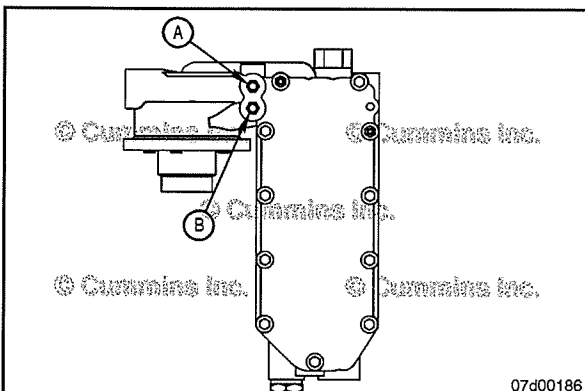


Lubricating oil can also be lost through a worn or malfunctioning air compressor. Look for carbon buildup in the air line from the compressor to the air tank.

Also, a malfunctioning air compressor head gasket or cylinder head gasket can allow oil to leak into the coolant or coolant to leak into the oil during a hot shutdown.



If the lubricating oil cooler element ruptures, the lubricating oil pressure can force lubricating oil into the cooling system. Lubricating oil in the coolant should be visible when the radiator cap is removed. Refer to Procedure 007-003 in Section 7.

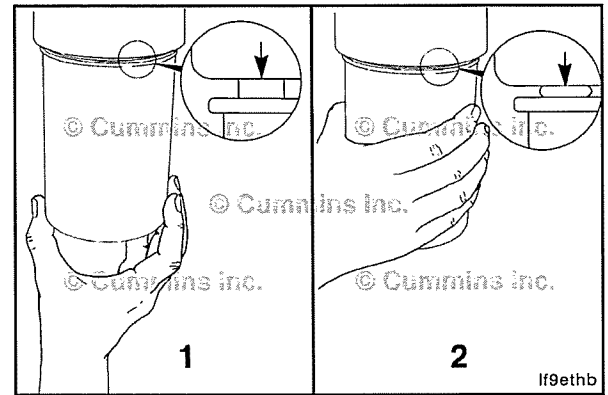


The lubricating oil cooler contains two ports for measuring oil pressure or recording oil pressure drop across the lubricating oil filter. The top port is after the lubricating oil filter, filtered oil pressure port (A). The bottom port is before the lubricating oil filter, unfiltered oil pressure port (B).

Lubricating Oil Filters

The filter is a spin-on element and contains an internal venturi that provides filter bypass oil flow through a stacked disk section of the filter. Lubricating oil filters **must** be of the venturi style. The use of a lubricating oil filter without a venturi will result in premature engine wear.

The LF9009 oil filter is used on all QSL9 CM2250 engines. This filter is a spin-on element and contains an internal venturi that provides filter bypass oil flow through a stacked disk section of the filter. Lubricating oil filters **must** be of the venturi style. The use of a lubricating oil filter without a venturi will result in premature engine wear.

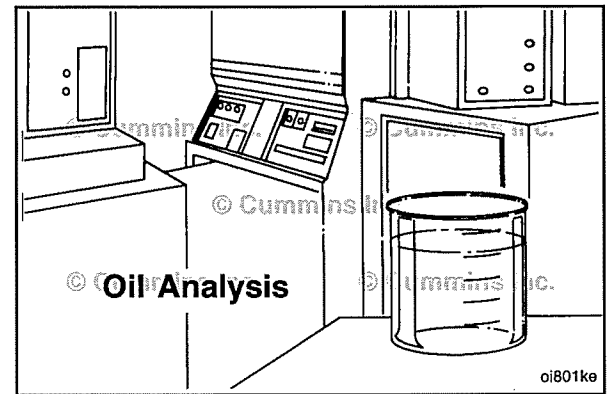


Lubricating Oil and Filter Analysis (007-083)

Inspect

An analysis of used oil can help diagnose internal engine damage and determine if it was caused by one of the following:

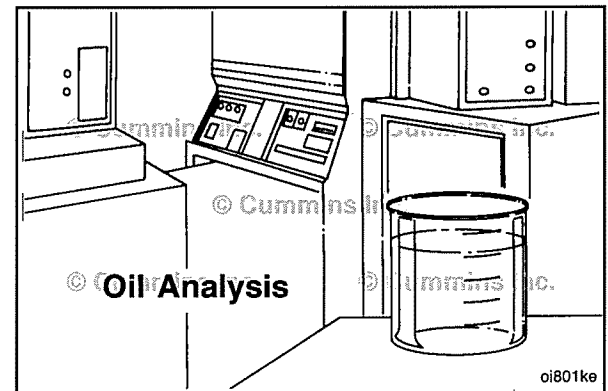
- Intake air filter malfunction
- Coolant leaks
- Oil diluted with fuel
- Metal particles causing wear.



For additional oil analysis information, refer to Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340.

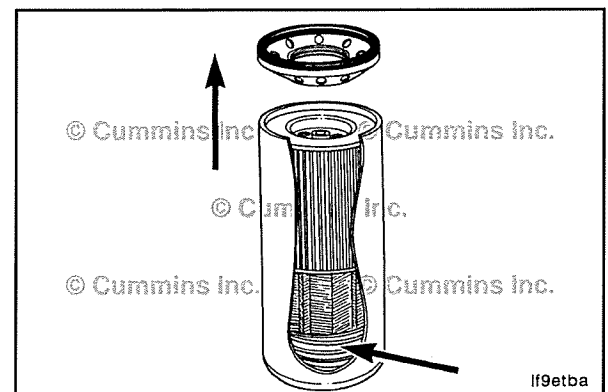


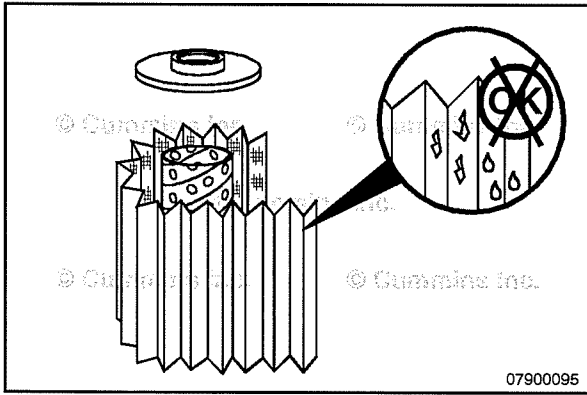
NOTE: Do **not** disassemble an engine for repair based solely on the results of an oil analysis. Inspect the oil filters. If an oil filter shows evidence of internal engine damage, find the source of the problem and repair the damage. Reference the appropriate procedure(s) based on the following oil filter inspection.



⚠ WARNING ⚠

Restrain the full flow lubricating oil filter and use care when cutting open the upper section of the combination filter. The filter element spring is under compression and can cause personal injury.





Use tube cutter, Part Number 3376579, to open the upper section of the bypass full-flow oil filter.



Inspect the filter element and oil for evidence of moisture or metal particles.

Metal	Possible Source
Copper	Bearings and bushings, or oil cooler*
Chromium	Piston rings
Iron	Cylinder liners
Lead	Bearing overlay material
Aluminum	Piston wear or scuffing

* Copper emitted from the lubricating oil cooler element diminishes significantly after the first oil change maintenance interval.

Section 8 - Cooling System - Group 08

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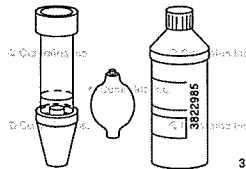
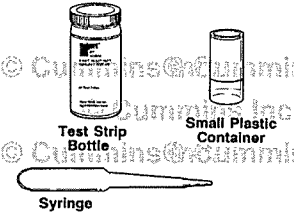
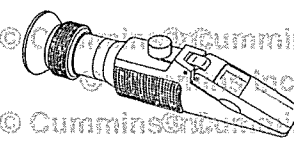
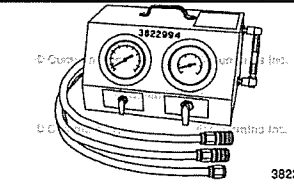
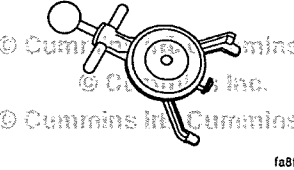

Preparatory Steps.....8-64
Remove.....8-65

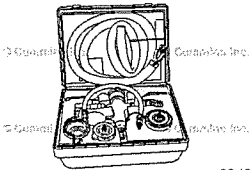
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Service Tools

Cooling System

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3822985	<p align="center">Combustion Gas Leak Test Kit</p> <p>Used to detect leaks. Includes Part Number 3822986, test fluid, Part Number 3822987, adapter, and Part Number 3877612, instructions.</p>	 <p align="right">3822985</p>
CC-2626	<p align="center">Cooling System Test Kit</p> <p>The Fleetguard® coolant test kit is used to check the concentration of coolant additives in the cooling system.</p>	 <p align="right">3822985</p>
CC-2800	<p align="center">Refractometer</p> <p>The Fleetguard® refractometer is used to measure the freezing point protection and antifreeze concentration.</p>	 <p align="right">r28004</p>
3822994	<p align="center">Engine Coolant Analyzer</p> <p>The Engine Coolant Analyzer is used to troubleshoot pressure loss, restriction, and improper temperature control.</p>	 <p align="right">3822994</p>
ST 1293	<p align="center">Belt Tension Gauge</p> <p>Used to measure the tension in the drive belt.</p>	 <p align="right">fa8t0gc</p>
3375411	<p align="center">Thermostat Seal Mandrel</p> <p>Used to install new thermostat seals on QSL9 marine keel cooled engines.</p>	 <p align="right">3375411</p>

Tool No.	Tool Description	Tool Illustration
3824319	<p align="center">Coolant Dam/Pressure Tester</p> <p>Using shop air pressure, the coolant dam creates a vacuum, holding the coolant in with little or no coolant loss.</p>	 <p>22d00167</p>

Drive Belt, Cooling Fan (008-002)

General Information

Due to the number of drive belt arrangements, this procedure does **not** cover all available cooling fan drive belt routing.

To make sure the cooling fan drive belt is routed correctly upon installation, make a diagram of the cooling fan belt routing prior to removing the belt as shown in the illustration.

The cooling fan belt routing typically consists of the following components, but may **not** include all of them:

- 1 Crankshaft pulley/vibration damper
- 2 Fan pulley
- 3 Water pump pulley
- 4 Refrigerant compressor pulley
- 5 Alternator pulley
- 6 Tensioner idler pulley.

NOTE: Some engine driven belts are installed/supplied by the vehicle's original equipment manufacturer (OEM). See the OEM service manual for removal and installation instructions.

Troubleshooting

NOTE: This content in this section is generic and may **not** apply to all available cooling fan drive belt systems.

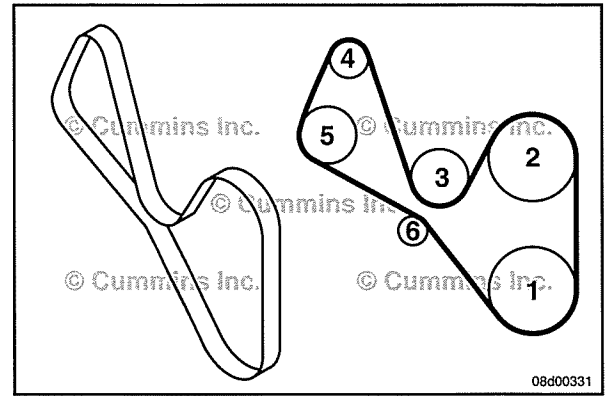
The following section contains diagnostic information and procedures to aid in identifying drive belt and accessory drive issues. These issues may include:

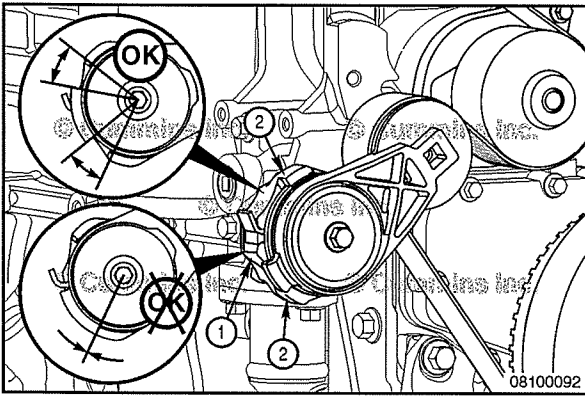
- Belt noise (squeal and chirp)
- Belt tracking (jumping)
- Belt fraying
- Snub breaks and punctures.

Common causes of drive belt noise, fraying and breaks are:

- Drive pulley misalignment
- Embedded debris in drive pulley grooves
- Incorrect belt material and/or belt length
- Damaged or incorrect automatic belt tensioner
- Improper drive belt routing
- Improper fan size and/or fan clutch.

The original drive belt and tensioner should be used if possible while troubleshooting drive belt issues. Replacement of a belt and/or tensioner prior to troubleshooting may mask the root cause of the issue due to the break-in time required for a belt and tensioner.



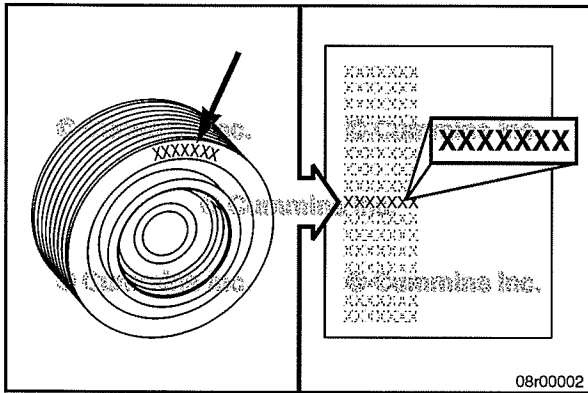


NOTE: A newly installed belt and/or tensioner will **not** come to rest properly until the engine is operated. Always operate the engine for a brief period of time prior to verifying the tensioner resting location.

Inspect the automatic belt tensioner. Refer to Procedure 008-080 in Section 8. If the belt tensioner does **not** meet the reuse criteria, the belt tensioner **must** be replaced.

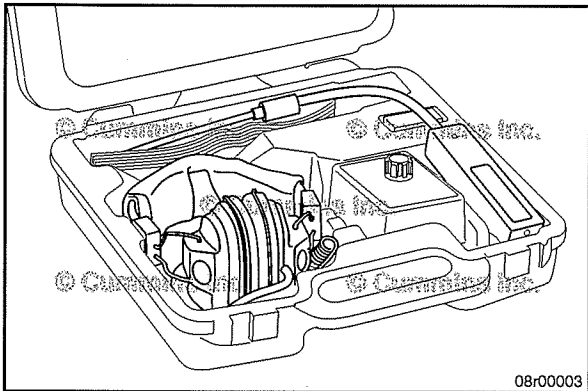
With the belt installed, check the automatic belt tensioner resting position. If the belt tensioner arm stop is contacting either of the spring case stops:

- Verify the correct belt part number is installed
- If the correct belt is installed, replace the belt.

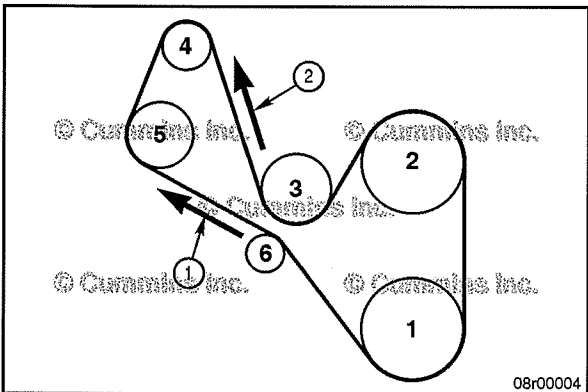


Verify all accessory drive components and pulleys are correct. Components yielding incorrect part numbers, or installed without the appropriate spacers and/or brackets may contribute to gross drive belt misalignment.

Verify proper drive belt routing, if available. Refer to the OEM service manual.



Isolating the source of drive belt noise may be done by use of an electronic stethoscope, or an equivalent device designed to block audible noise other than that desired by use of a microphone.



Drive belt noise may be difficult to isolate and troubleshoot. The origin of drive belt noise may **not** be located at the pulley out of alignment, rather 'upstream' from the noise origin.

Troubleshooting should always be completed in a direction opposite belt travel (i.e. counter clockwise) beginning at the pulley where the noise originates.

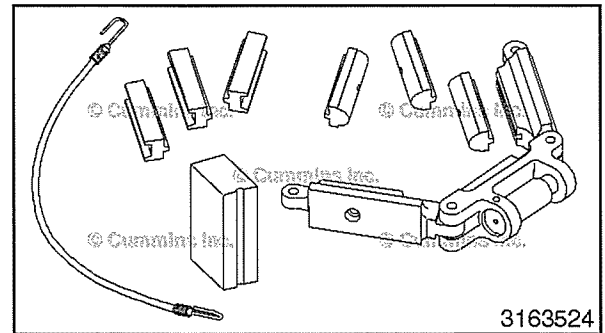
Arrow number (1) indicates belt travel direction, whereas arrow number (2) represents the direction in which troubleshooting should be conducted.

- Flat pulleys should be inspected for uneven wear patterns
- Grooved pulleys should be inspected for embedded debris, belt dust buildup, and pulley alignment.

NOTE: The belt alignment laser tool can identify misalignment of pulleys down to ½ of a belt rib. The capability of the alignment fixture is contingent upon proper calibration. Make sure all set-up and calibration procedures are followed before verifying pulley alignment.

Use a Belt Alignment Laser Tool, Part Number 3163524 or equivalent, to verify all pulleys are aligned correctly.

Pulley alignment should always be checked from the fan pulley and crankshaft pulley to other front end mounted grooved pulleys. Contact a Cummins® Authorized Repair Location for drive belt alignment.

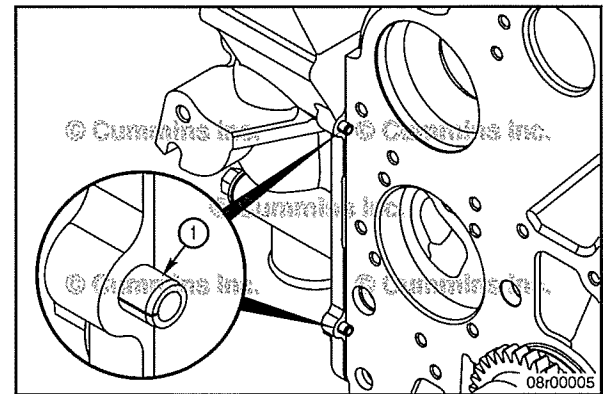


If a pulley is identified as out of alignment, verify the component mounting bracket installation.

Certain engines feature an automatic belt tensioner mounted to the water inlet connection. Verify the locating roll pins (1) are:

- Installed into the connection
- In contact with the cylinder block
- Do **not** appear to be bent or out of place.

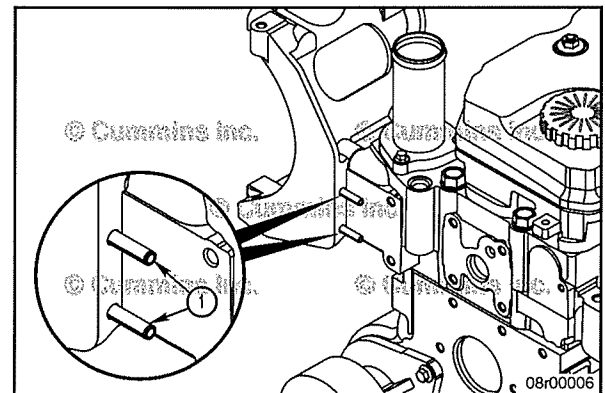
If the water inlet connection and/or roll pins are **not** installed correctly, remount the water inlet connection. Refer to Procedure 008-082 in Section 8.



Certain alternator mounting brackets are aligned to the cylinder head by roll pins. Verify the locating roll pins (1) are:

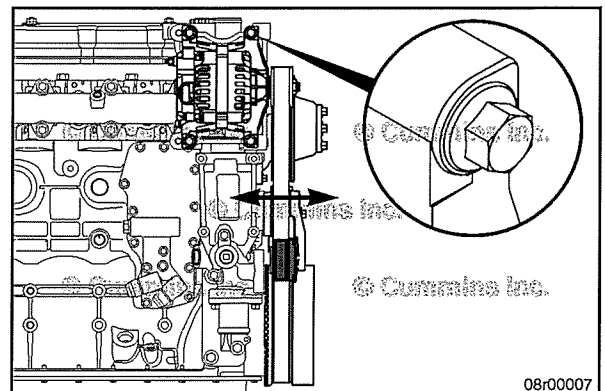
- Installed into the alternator bracket
- In contact with the cylinder head
- Do **not** appear to be bent or out of place.

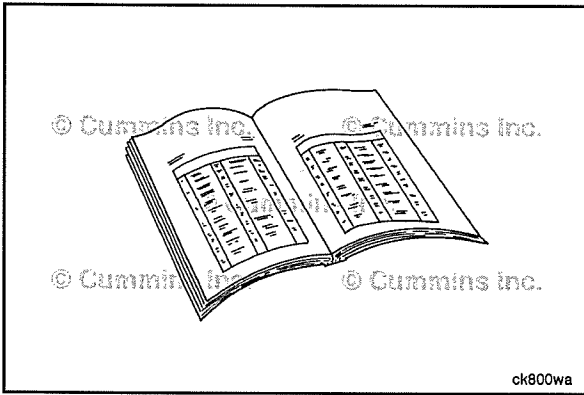
If the alternator bracket and/or roll pins are not installed correctly, remount the alternator bracket. Refer to Procedure 013-003 in Section 13.



Check drive pulley alignment with the belt alignment laser tool, Part Number 3163524 or equivalent, after any bracket adjustments are made.

Certain "pad mounted" components which do **not** contain locating features can be positioned on the mounting brackets for fine adjustments.



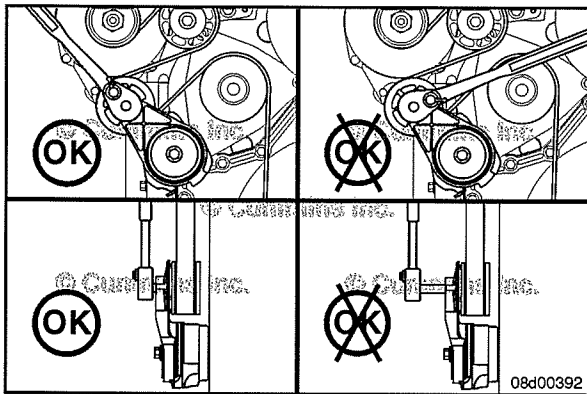


Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.



Remove

⚠ CAUTION ⚠

The belt tensioner is spring-loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

⚠ CAUTION ⚠

Applying excessive force in the opposite direction of windup or after the tensioner has been wound up to the positive stop can cause the tensioner arm to break.

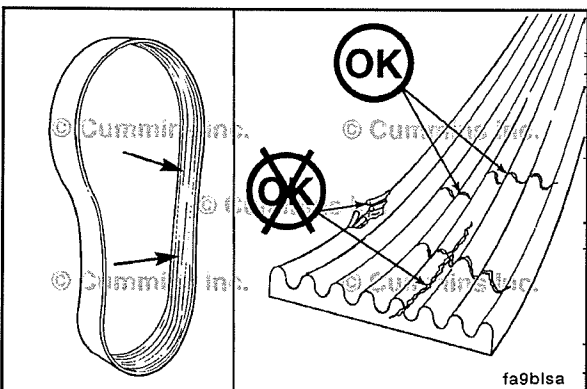
⚠ CAUTION ⚠

Using a socket extension is not recommended because it can cause axial twisting damage to the belt tensioner.

NOTE: Make a diagram of the belt arrangement prior to removing the drive belt. This aids in installation and proper routing of the cooling fan drive belt.

Lift the tensioner to remove the drive belt.

NOTE: If a socket extension is necessary, support the head of the ratchet with one hand to prevent the belt tensioner arm from unintended loading.



Clean and Inspect for Reuse

Inspect the drive belt for damage.

Transverse (across the belt) cracks are acceptable.

Longitudinal (direction of belt ribs) cracks that intersect with transverse cracks are **not** acceptable.

If the belt is frayed, punctured, or material is missing, the belt is unacceptable for reuse and **must** be replaced.

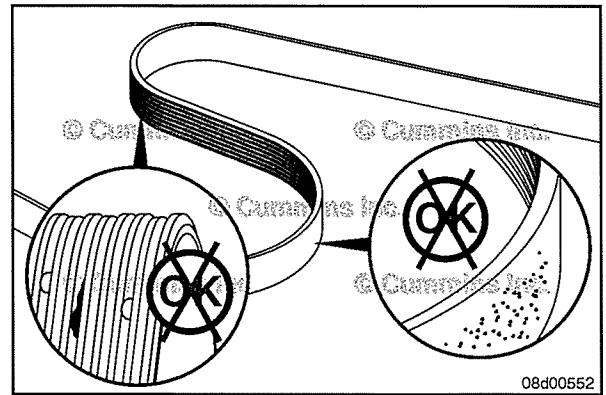
Inspect the belt grooves for:

- Embedded debris
- Uneven/excessive rib wear
- Exposed belt cords.

Inspect the backside of the belt for:

- Glazing (high heat)
- Embedded debris
- Exposed belt cords.

If any of the above conditions are present, the belt is unacceptable for reuse and **must** be replaced.



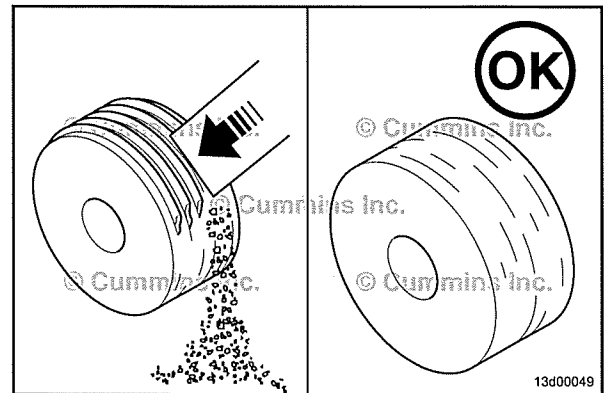
Inspect the idler and drive pulleys for wear or cracks.

Plastic pulleys often have a build-up of road dirt and belt material that is **not** to be confused with wear.

The dirt can be removed with a suitable tool to check for wear.

Clean, check, and reuse all pulleys in the front end accessory drive if **not** damaged, rather than replacing. Pulleys damaged from embedded debris **must** be replaced.

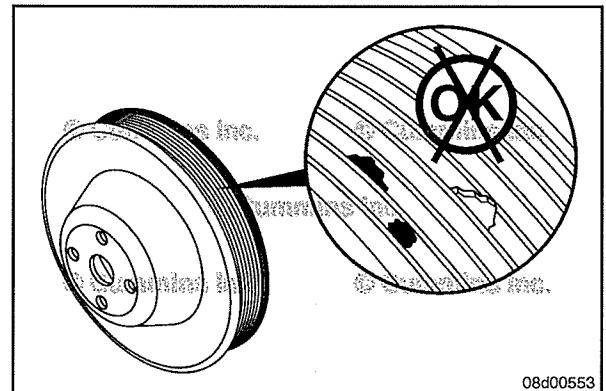
Inspect the tensioner. Refer to Procedure 008-080 in Section A.



Inspect all system pulleys for embedded debris:

- Rocks, stones
- Metal
- Belt material.

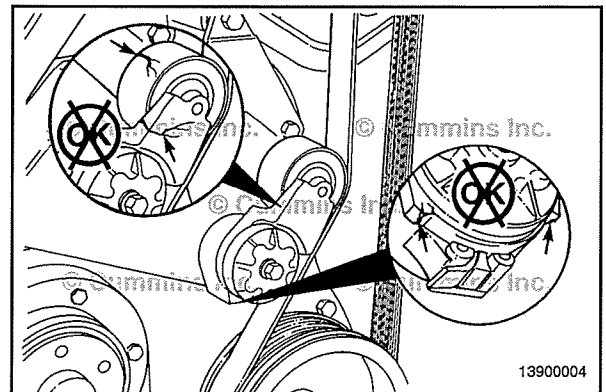
Remove the debris from the grooves of the pulley. If the pulley has been deformed as a result of foreign material embedment, the pulley **must** be replaced.

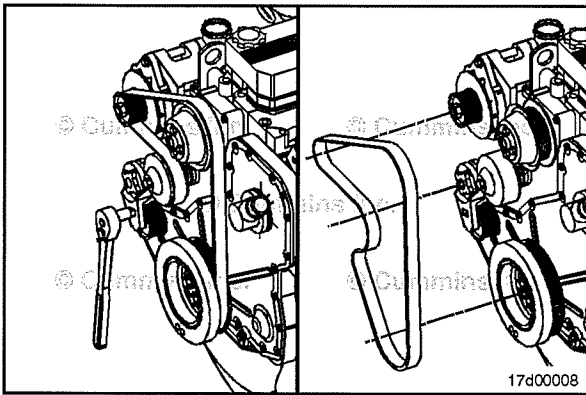


Inspect the drive belt pulleys and idlers for cracked or broken grooves.

Reference the following procedures if a pulley or idler is damaged:

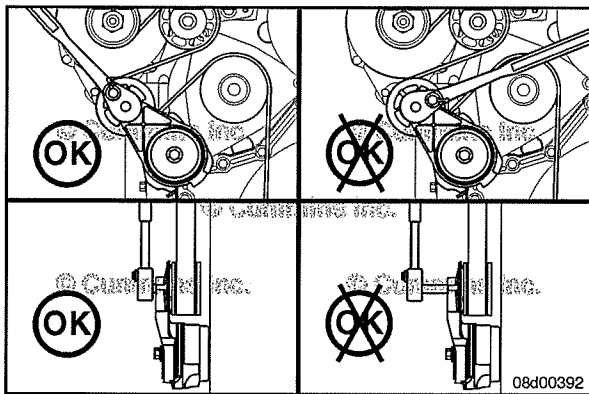
- Inspect the fan pulley. Refer to Procedure 008-039 in Section 8.
- Inspect the crankshaft pulley. Refer to Procedure 001-052 in Section 1.
- Inspect the belt tensioner pulley. Refer to Procedure 008-080 in Section A.





Install

Route the drive belt on the engine. Use the belt diagram created in the Remove section. Do **not** install the belt over the water pump pulley at this time.



⚠ CAUTION ⚠

The belt tensioner is spring-loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

⚠ CAUTION ⚠

Applying excessive force in the opposite direction of windup or after the tensioner has been wound up to the positive stop can cause the tensioner arm to crack or break.

⚠ CAUTION ⚠

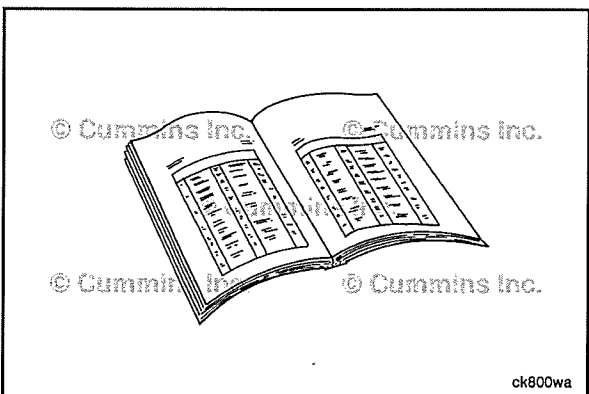
Using a socket extension is not recommended because it can cause axial twisting damage to the belt tensioner.

Pivot the tensioner in the direction of the spring tang and install the drive belt, slipping the belt over the water pump pulley last.

Slowly release the belt tensioner to apply tension to the drive belt.

NOTE: If a socket extension is necessary, support the head of the ratchet with one hand to prevent the belt tensioner arm from unintended loading.

Check the alignment of the belt with the tensioner and the rest of the front-end accessory drive.



Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for belt squeal. Excessive belt squeal indicates belt slippage.
- If belt squeal is present, check the routing of the belt to make sure that the belt is installed correctly on each pulley.

Coolant Filter (008-006)

Remove

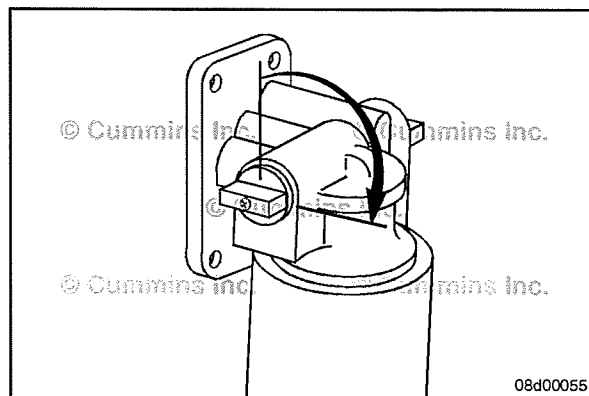
⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

NOTE: Some engine models do **not** require coolant filters.

Remove the coolant system pressure cap.

Turn the shutoff valve to the OFF position by rotating the knob from the vertical to the horizontal position, as shown.



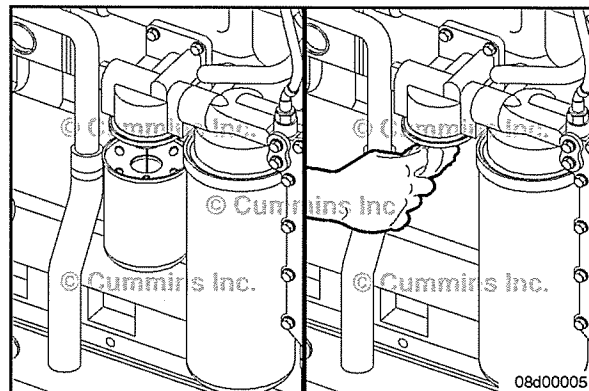
⚠ WARNING ⚠

A small amount of coolant can leak when servicing the coolant filter with the shutoff valve in the OFF position. To reduce the possibility of personal injury, avoid contact with hot coolant.

⚠ WARNING ⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Remove and discard the coolant filter.



Install

⚠ CAUTION ⚠

Do not allow oil to get into the filter. Oil will damage the DCA.

⚠ CAUTION ⚠

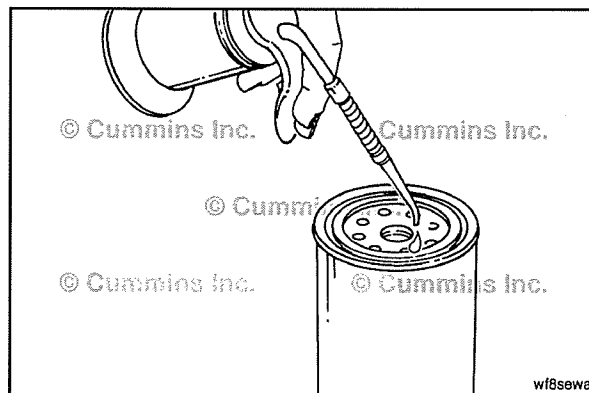
Mechanical over tightening can distort the threads or damage the filter head.

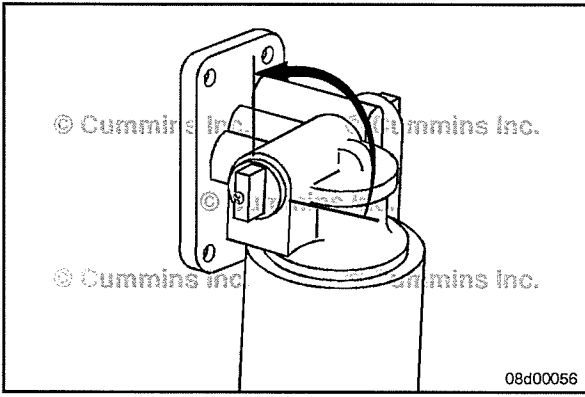
Apply a thin film of clean lubricating oil to the gasket sealing surface before installing the new coolant filter.

Install the coolant filter on the filter head. Tighten the filter until the gasket contacts the filter head surface.

Tighten the coolant filter an additional 1/2 to 3/4 of a turn, or as specified by the filter manufacturer.

See Section V for coolant filter recommendations.

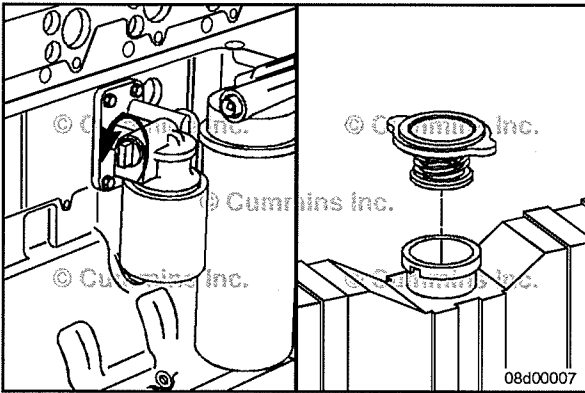




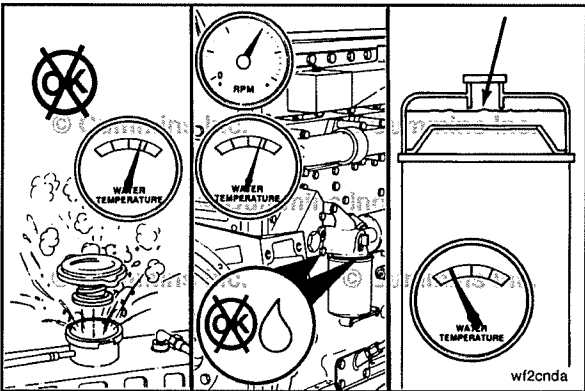
⚠CAUTION⚠

The valve must be in the ON position to prevent engine damage.

Turn the shutoff to the ON position by rotating the knob from the horizontal to the vertical position, as shown.



Install the coolant system pressure cap.



Operate the engine and check for coolant leaks.

Check the coolant level again after the air has been purged from the system.

Coolant Filter Head (008-007)

Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ WARNING ⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

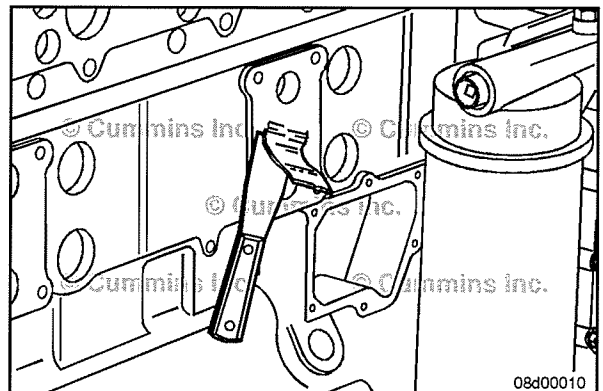
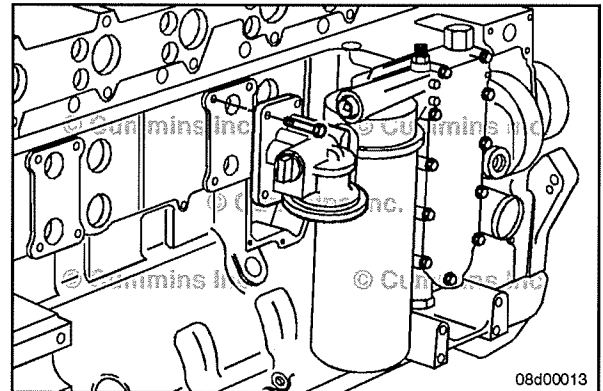
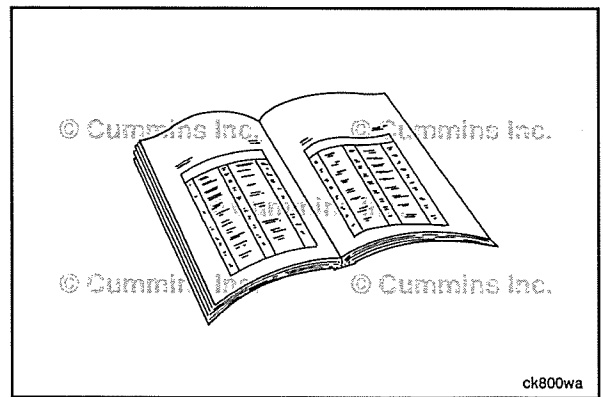
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.
- Remove the coolant filter. Refer to Procedure 008-006 in Section 8.

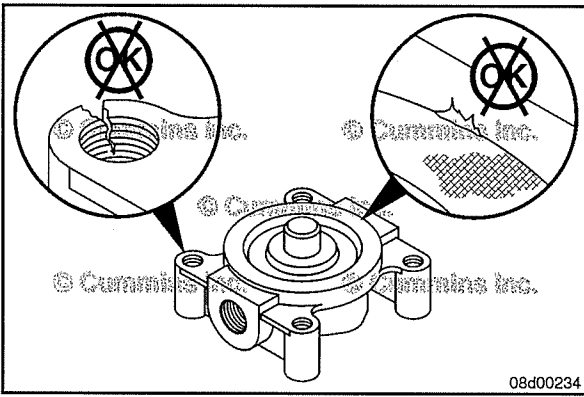
Remove

Loosen the four filter head capscrews.
Remove the filter head and gasket.

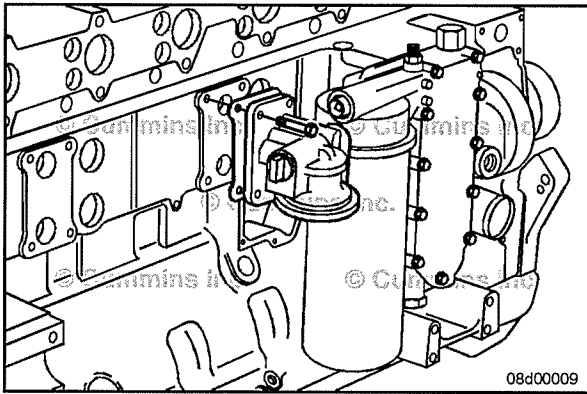
Clean and Inspect for Reuse

Clean the mating surfaces.





Inspect the filter head for cracks, burrs or other damage.
Replace the filter head if it is damaged.



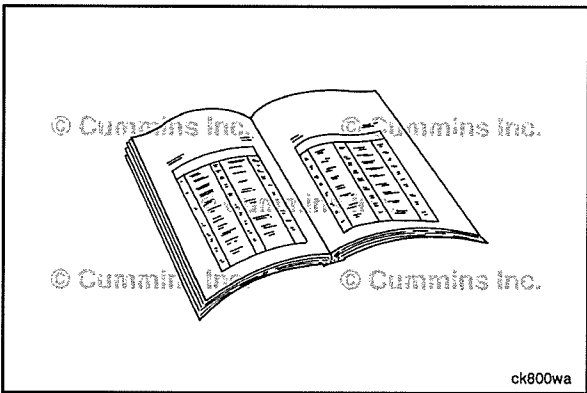
Install

Install a new gasket and the filter head.



Tighten the four capscrews.

Torque Value: 24 N•m [212 in-lb]



Finishing Steps



WARNING



Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the coolant filter. Refer to Procedure 008-006 in Section 8.
- Fill the cooling system with either a 50/50 mixture of good-quality water and fully formulated antifreeze or fully formulated coolant. The fully formulated antifreeze or coolant **must** meet ASTM D6210 (EG) and ASTM D6211 (PG) specifications. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Coolant Filter Valve (008-009)

Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ WARNING ⚠

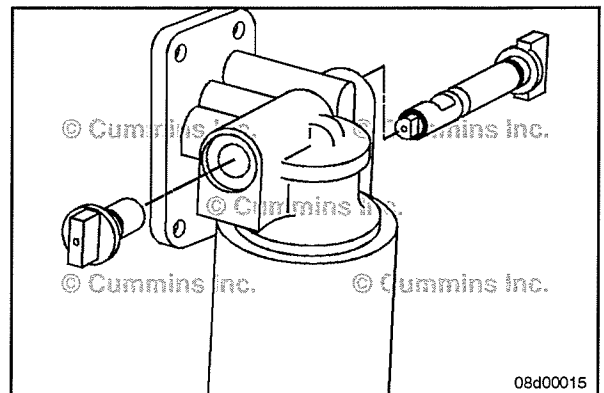
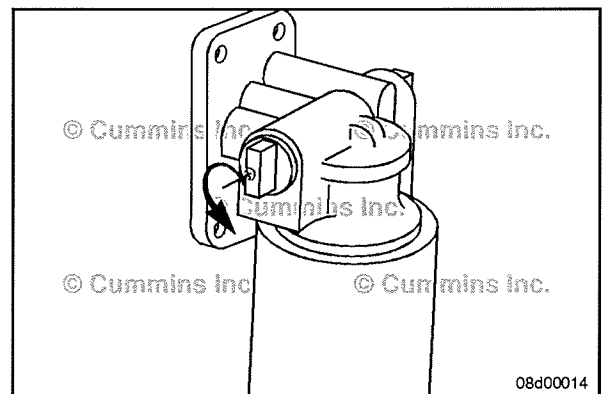
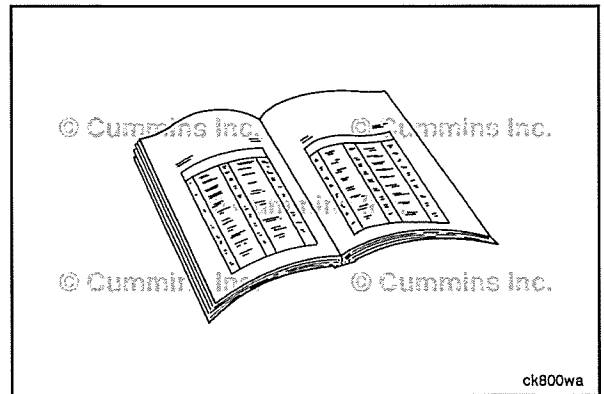
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

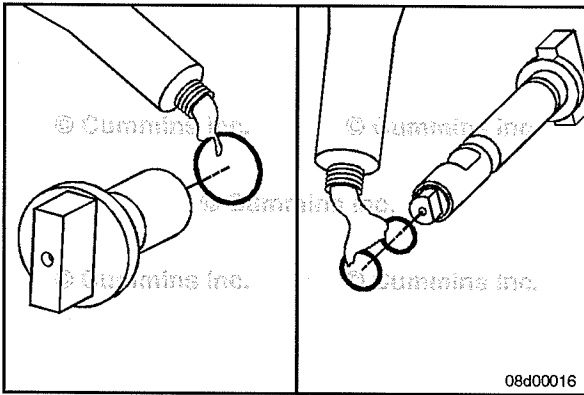
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.
- Remove the coolant filter. Refer to Procedure 008-006 in Section 8.
- Remove the coolant filter head. Refer to Procedure 008-007 in Section 8.

Remove

Loosen the shutoff valve screw from the end of the valve.

Remove the two pieces of the shutoff valve from both sides of the valve bore.

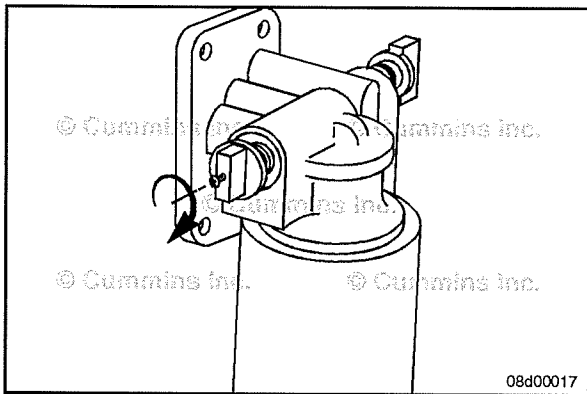




Install

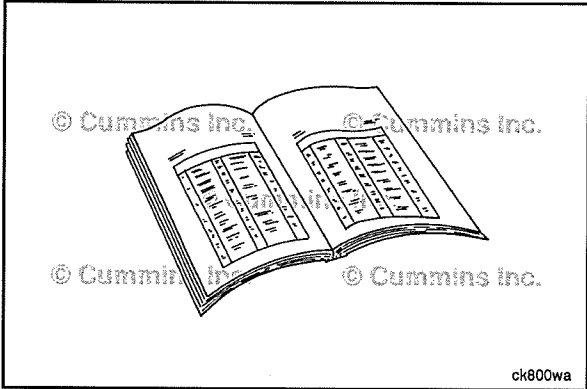
Replace the shutoff valve o-rings.

Lubricate the o-rings before installing the valve pieces back into the bore.



Tighten the shutoff valve screw to tighten the two pieces of the valve together.

Torque Value: 1.5 N•m [12 in-lb]



Finishing Steps

▲ WARNING ▲

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the coolant filter head on the engine. Refer to Procedure 008-007 in Section 8.
- Install the coolant filter. Refer to Procedure 008-006 in Section 8.
- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Coolant Heater (008-011)

Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ WARNING ⚠

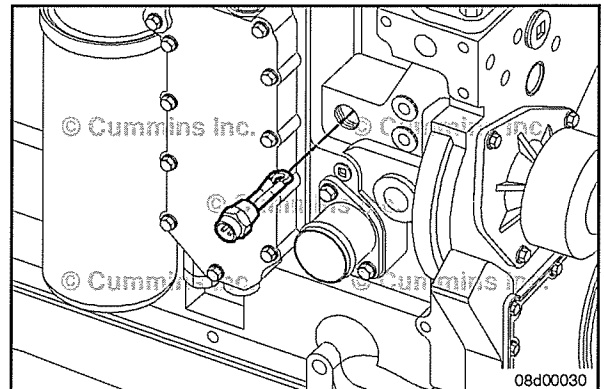
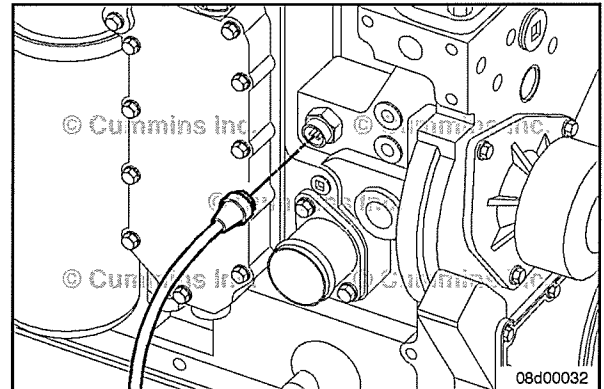
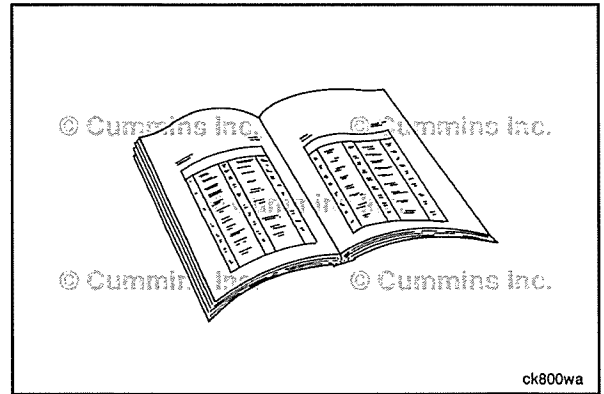
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

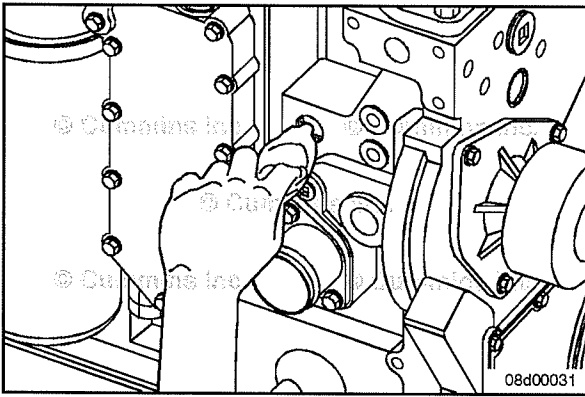
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.

Remove

Disconnect the coolant heater electrical cord.

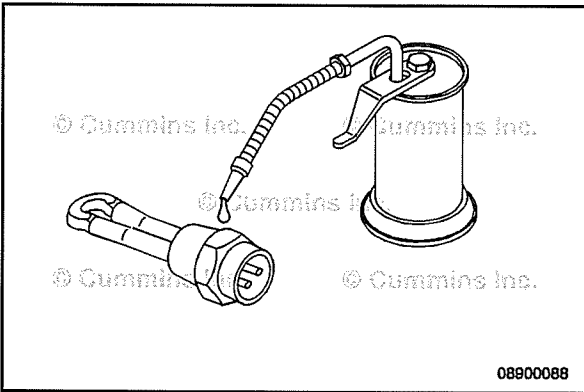
Loosen the coolant heater and remove it from the cylinder block.





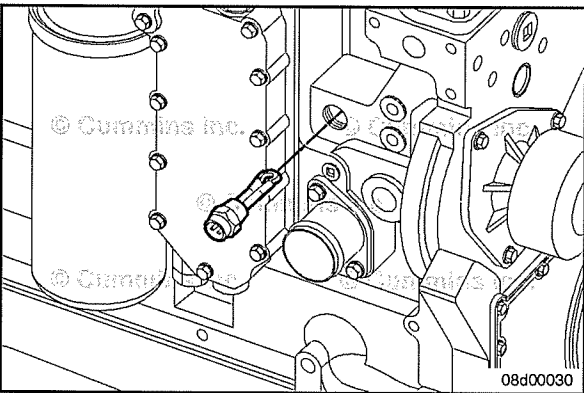
Clean

Clean the coolant heater and block threads thoroughly.



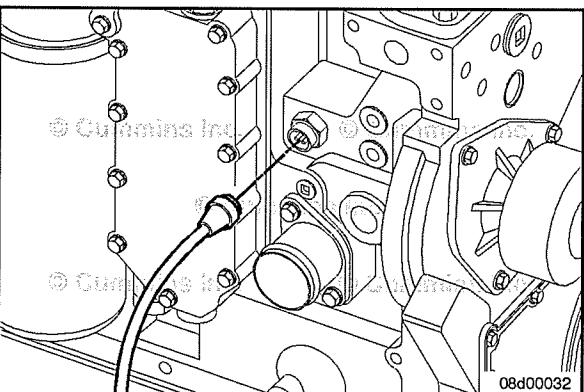
Install

Lubricate the new coolant heater threads with clean engine oil.



Install the coolant heater.

Torque Value: 75 N•m [55 ft-lb]



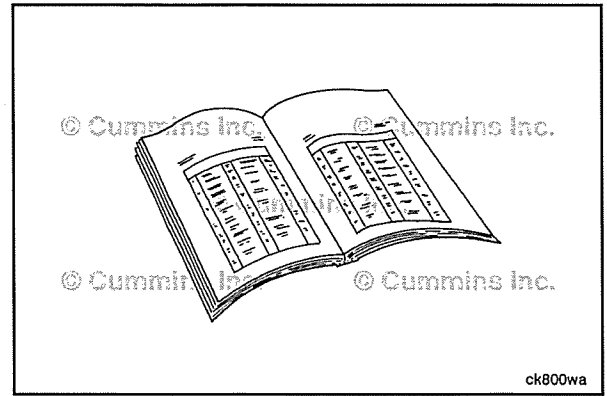
Attach the coolant heater electrical cord.

Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

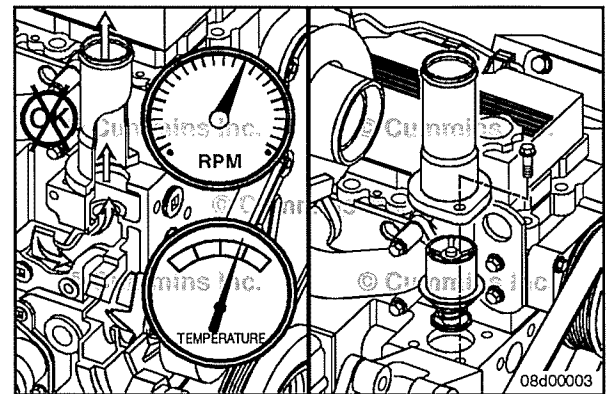
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Coolant Thermostat (008-013)

General Information

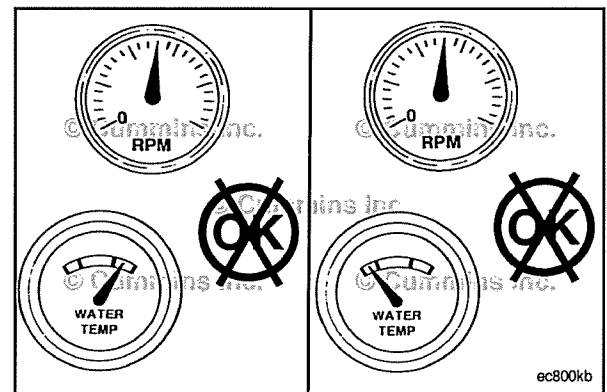
The thermostat controls the coolant temperature. When the coolant temperature is below operating temperature, coolant is bypassed to the inlet of the water pump. When the coolant temperature reaches the operating range, the thermostat opens, seals off the bypass, and forces coolant to flow to the radiator or the keel cooler on QSL9 marine engines. The thermostat begins opening at 82°C [180°F].



⚠ CAUTION ⚠

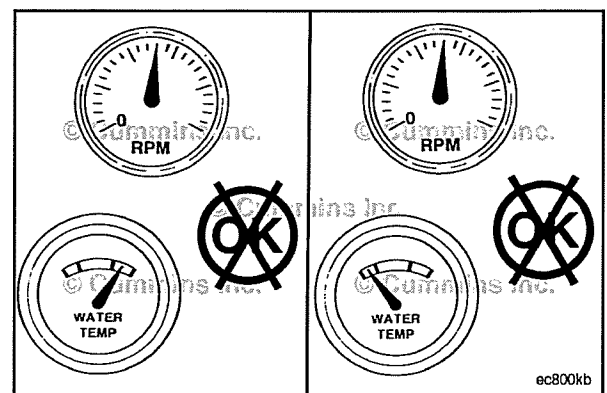
Never operate the engine without a thermostat. Without a thermostat, the path of least resistance for the coolant is through the bypass to the pump inlet. This will cause the engine to overheat.

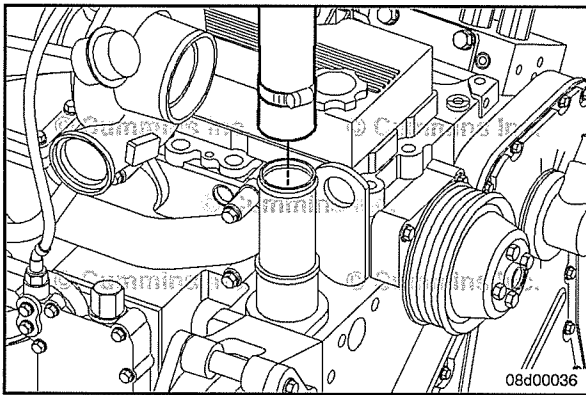
An incorrect or malfunctioning thermostat can cause the engine to run too hot or too cold.



Leak Test

The engine thermostat and thermostat seal **must** operate properly in order for the engine to operate in the most efficient heat range. Overheating or overcooling will shorten engine life.



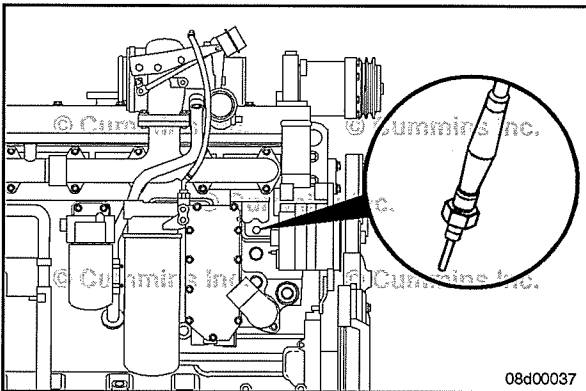


⚠ WARNING ⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

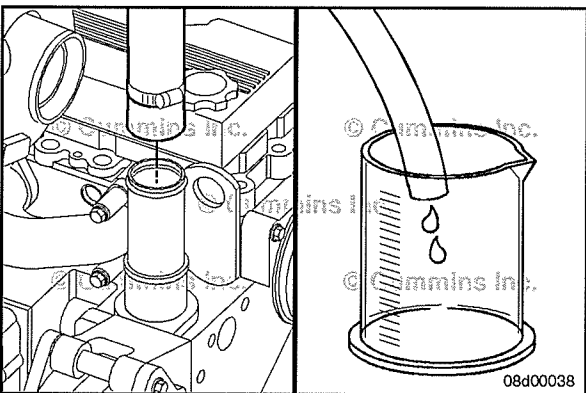
⚠ WARNING ⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Drain the coolant. Refer to Procedure 008-018 in Section 8.

Remove the radiator hose from the water outlet connection.



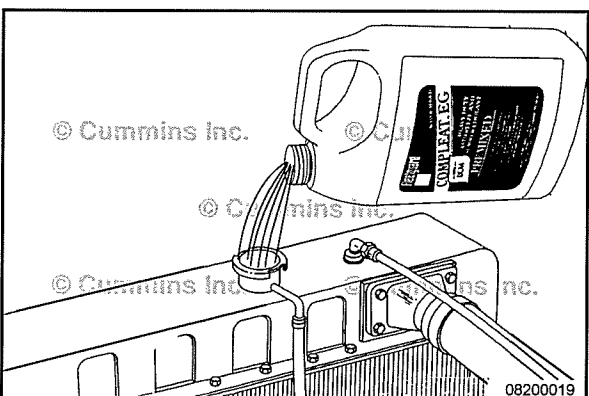
Use an electronic service tool to monitor the coolant temperature, or install a thermocouple or temperature gauge, which is known to be accurate, in the cylinder block on the engine side of the thermostat.



Install a hose of the same size on the water outlet connection. It must be long enough to reach a remote, dry container used to collect coolant.

Install and tighten a hose clamp on the housing outlet.

Place the other end of the hose in a dry container.



Fill the cooling system. Refer to Procedure 008-018 in Section 8.

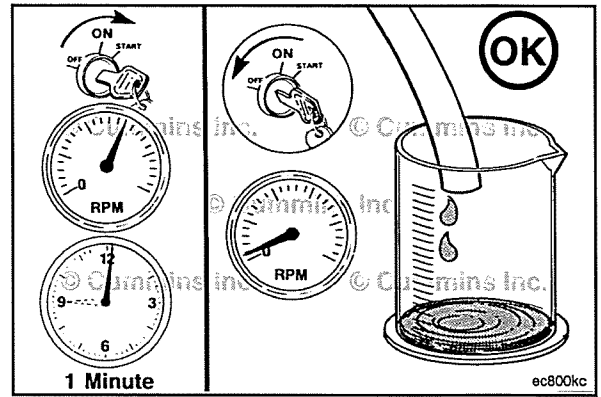


NOTE: The engine coolant temperature **must** be below the thermostat opening temperature to perform this test.

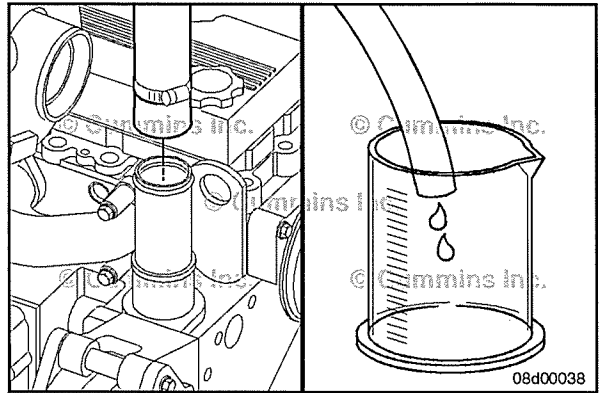
Operate the engine at rated speed for 1 minute.

Shut the engine OFF and measure the amount of coolant collected in the container.

The amount of coolant collected **must not** be more than 100 cc [3.3 fl oz].



If more than 100 cc [3.3 fl oz] of coolant is collected, the thermostat is leaking and **must** be replaced.

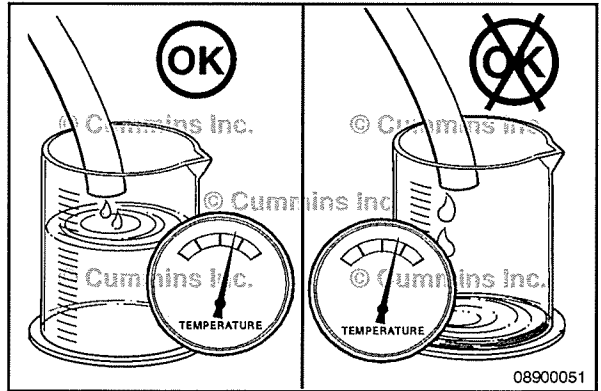


Complete the following test in-chassis to determine the thermostat opening temperature.

Start the engine and monitor the coolant temperature with INSITE™ electronic service tool or a gauge. Keep the engine speed below 1500 rpm during the test.

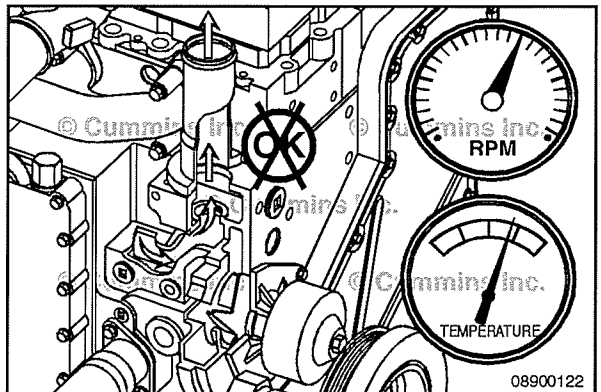
Thermostat Initial Opening Temperature

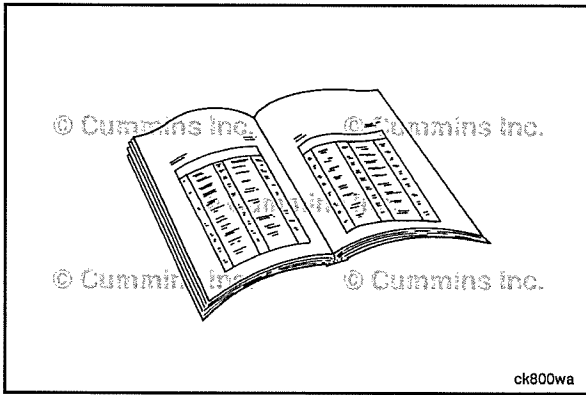
°C		°F
79	MIN	175
83	MAX	182



Shut the engine OFF when the coolant starts to flow.

If coolant does **not** start flowing into the container during the initial opening temperature range, the thermostat **must** be replaced.





Preparatory Steps



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ WARNING ⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

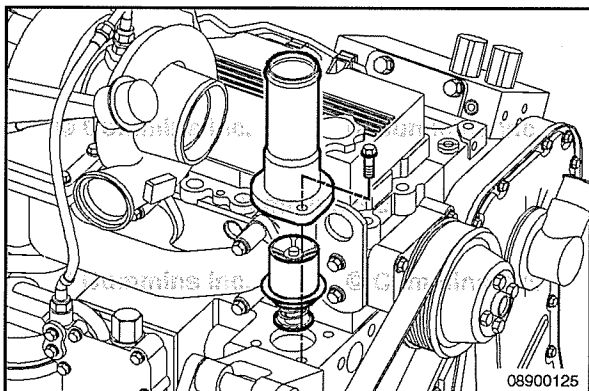
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the radiator hose from the water outlet connection.



Remove

Remove the water outlet connection capscrews and water outlet connection.

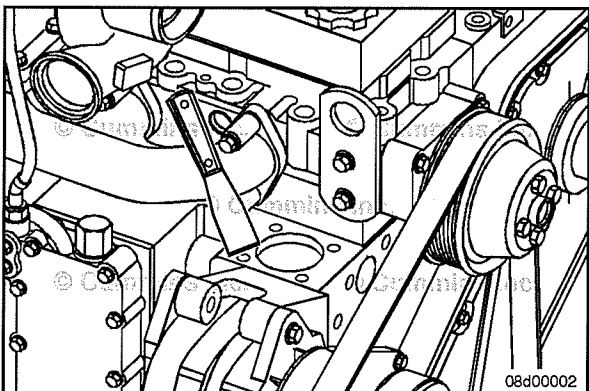
Remove the thermostat.



Clean and Inspect for Reuse

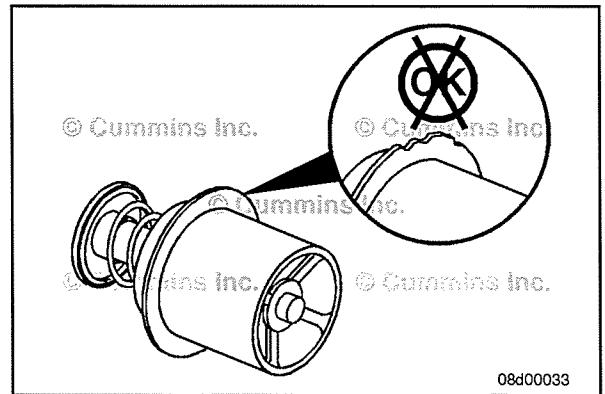
Clean all of the mating surfaces.

NOTE: Do **not** let any debris fall into the thermostat cavity when cleaning the surfaces.



Inspect the thermostat for damage.

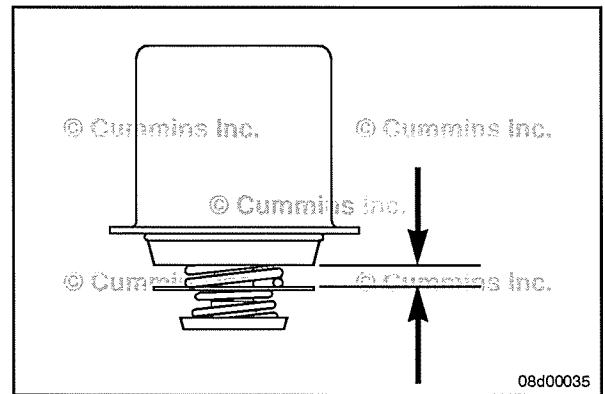
Inspect the thermostat gasket for damage. If the gasket is damaged, it **must** be replaced.



The nominal operating temperature is stamped on the thermostat. The thermostat **must** meet the following criteria:

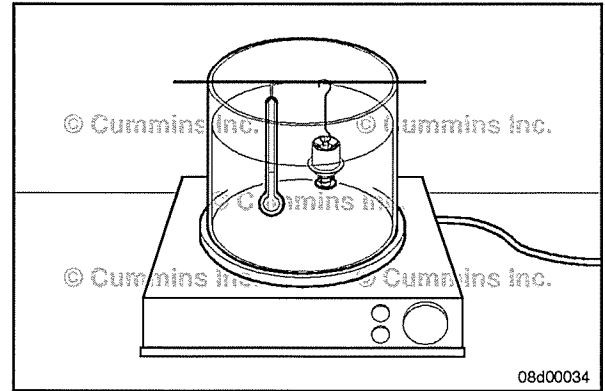
- The thermostat **must** begin to open within 1°C or 2°F of this nominal temperature.
- The thermostat **must** be fully open within 12°C or 22°F of this nominal temperature.

The fully open distance between the thermostat flange and housing is 10.16 mm [0.400 in].



Heat the water and check the thermostat as follows:

- Suspend the thermostat and a 100°C [212°F] thermometer in a container of water.
- Do **not** allow the thermostat or the thermometer to touch the sides of the container.



Install

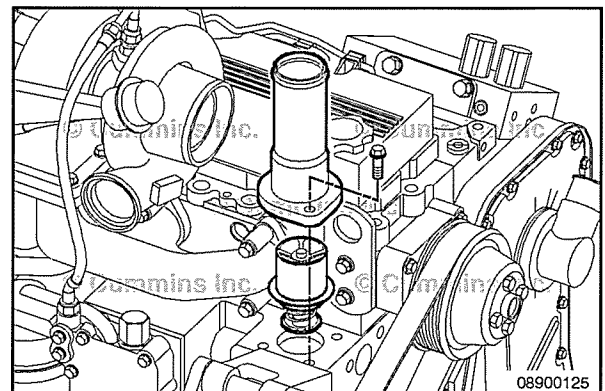
Install the new thermostat into the cylinder block.

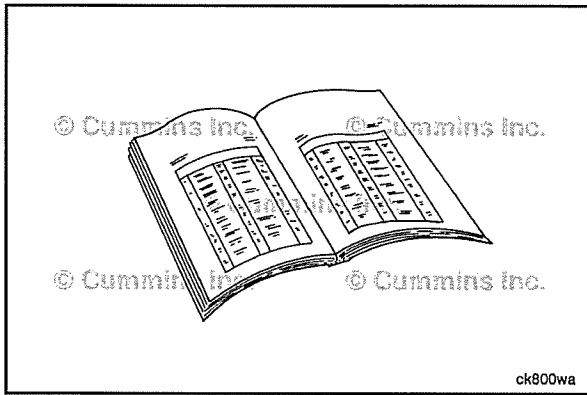
Install a new gasket over the thermostat and onto the block.

NOTE: A new gasket **must** be installed each time the thermostat or water outlet connection is removed.

Install the water outlet connection and mounting capscrews.

Torque Value: 24 N•m [212 in-lb]





Finishing Steps



⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Coolant Vent Lines (008-017)

General Information

The engines covered in this manual have two coolant vent line connections.

The first coolant vent line connection is on the cylinder head and vents the cylinder head.

The second coolant vent line connection is on top of the turbocharger and vents both the turbocharger and the exhaust gas recirculation (EGR) cooler.

Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

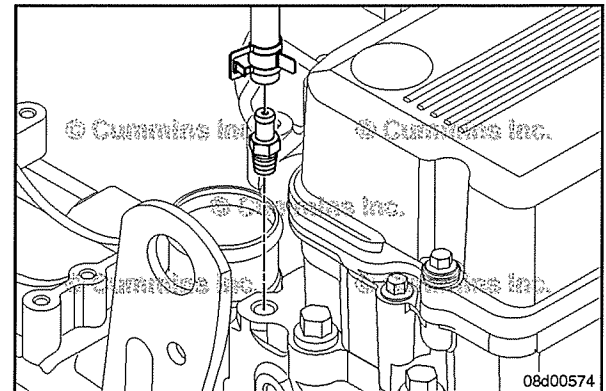
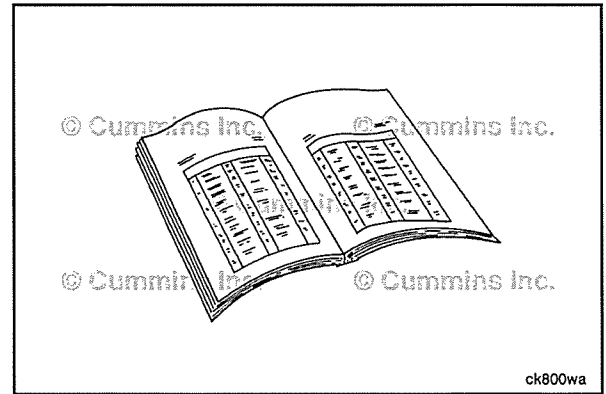
NOTE: Prior to removal, note the routing of the original equipment manufacturer (OEM) coolant vent line. The vent line **must** be routed "uphill" so that coolant is vented properly from the engine.

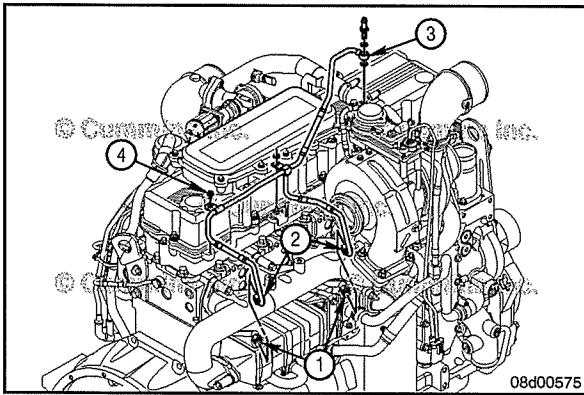
- Disconnect the battery cables. Refer to the OEM service manual.
- Drain the engine coolant. Refer to Procedure 008-018 in Section 7.
- Disconnect the coolant vent connection from the cylinder head.
- Disconnect the vehicle coolant vent lines from the coolant vent line connections on the EGR cooler and the turbocharger actuator. Refer to the OEM service manual.

Remove

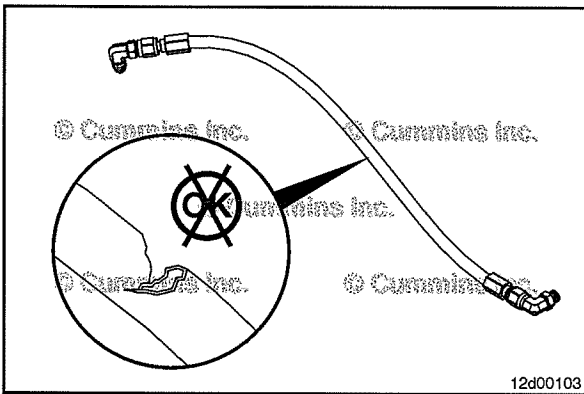
Remove the coolant vent line.

Remove the coolant vent line fitting from the cylinder head.



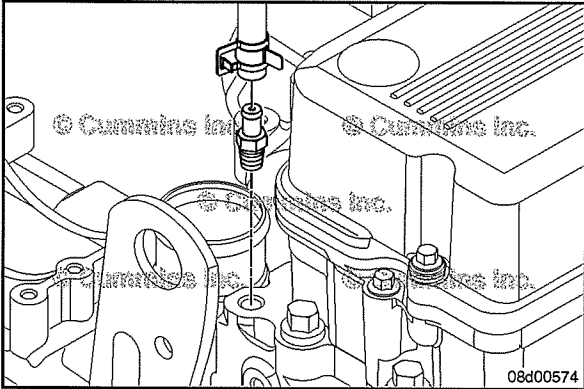


- Remove the vent line mounting screws (4).
- Remove the banjo bolt from the turbocharger (3).
- Remove the vent line mounting nuts from the EGR cooler (2).
- Remove the fittings from the EGR cooler (1).



Clean and Inspect for Reuse

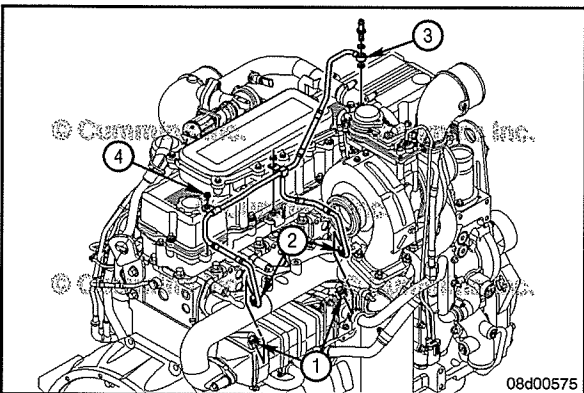
- Inspect the coolant vent line and fittings for cracks and other damage.
- Replace if any damage is found.



Install

- Install the coolant vent line cylinder head fitting.

Torque Value: 25 N•m [221 in-lb]



- Install using new sealing washers on all connections.
- Install the fittings to the EGR cooler vent ports (1).

Torque Value: 24 N•m [212 in-lb]



- Install the vent line mounting nuts to the EGR cooler (2).

Torque Value: 15 N•m [133 in-lb]

- Install the banjo bolt onto the turbocharger (3).

Torque Value: 15 N•m [133 in-lb]

- Install the vent line mounting screws (4).

Torque Value: 12 N•m [106 in-lb]

Finishing Steps

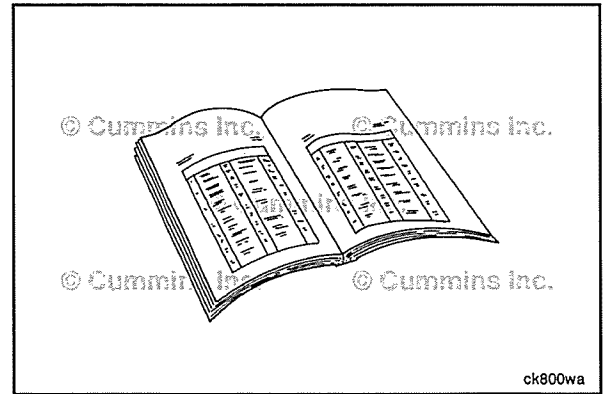
⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ CAUTION ⚠

During all coolant fill procedures, all coolant flow valves to equipment heating system must be opened in order to purge air from those system as well as from the base engine cooling system. These valve must remain open during the engine cooling system de-aeration process. Make sure adequate coolant levels are maintained in the coolant reservoir during the entire fill procedure. Special care must be take when filling EGR cooler equipped engines to make sure all air is purged from the cooling system.

- Connect the vehicle coolant vent line to the coolant vent line connections on the EGR cooler and the turbocharger actuator. Refer to the OEM service manual.
- Connect the coolant vent connection onto the cylinder head.
NOTE: The vent line **must** be routed "uphill" so that coolant is vented properly from the engine.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Cooling System (008-018)

General Information

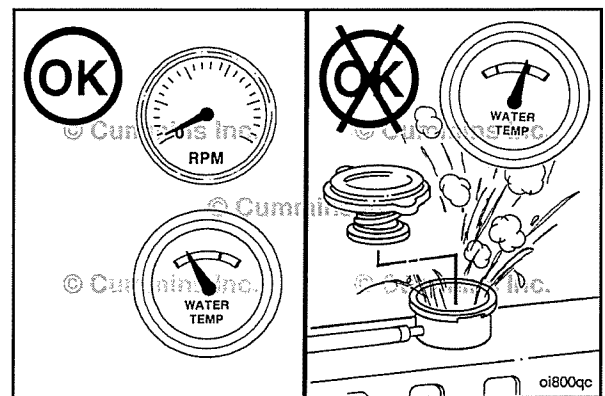
⚠ WARNING ⚠

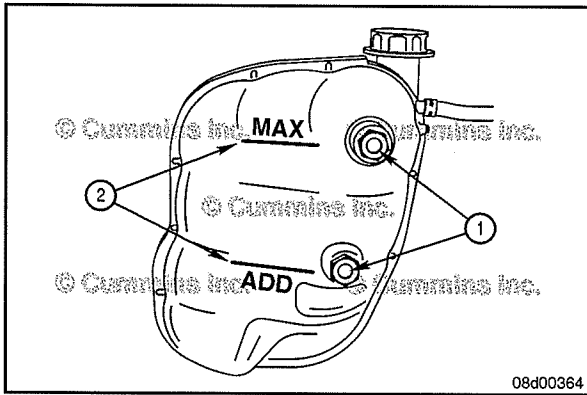
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

NOTE: Never use a sealing additive to stop leaks in the coolant system. This can result in coolant system plugging and inadequate coolant flow, causing the engine to overheat.

The engine coolant level **must** be checked daily.

NOTE: In order for proper engine operation coolant system pressure to be reached, the pressure cap **must** be installed prior to starting and warming up the engine. If the pressure cap is installed or removed while the engine is hot, the cooling system will **not** reach or maintain the proper operating pressure.





⚠CAUTION⚠

Do not add cold coolant to a hot engine. Engine castings can be damaged. Allow the engine to cool below 50°C [120°F] before adding coolant.

NOTE: Use the following procedure to inspect the engine coolant level sensor. Refer to Procedure 019-017 in Section 19.

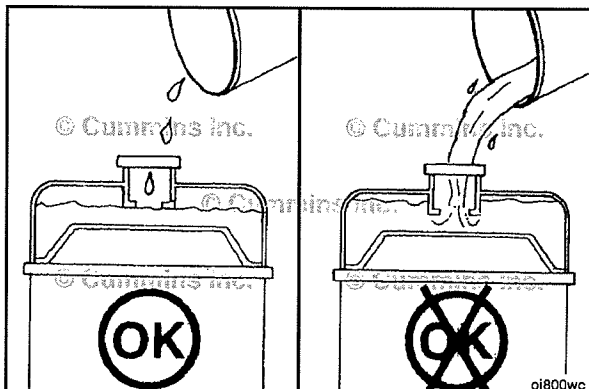
On applications that use a coolant recovery system, check to make sure the coolant is at the appropriate level on the coolant recovery tank for the engine temperature.

Many coolant recovery/expansion tanks, also called "auxiliary tanks", are made of a clear material (**not** shown) to aid in checking the coolant level (2) without removing the radiator cap.

It is important to understand the impact of temperature on the expansion of the coolant. Most "top tanks" do **not** have a provision for a "FULL HOT" coolant level. Filling the "top tank" while hot will result in a low operating level once the system has cooled.

Fill the cooling system with coolant to the bottom of the fill neck in the radiator fill or recovery/expansion tank.

NOTE: Some radiators have two fill necks, both of which **must** be filled when the cooling system is drained.



Drain

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [122°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

Position the vehicle or equipment on a level surface.

Isolate the engine from the vehicle cooling system by closing coolant flow valves to the equipment heating systems before initiating repair. This will prevent the heater circuit from draining, minimizing the chance for air pockets to be present during the fill process. Refer to the original equipment manufacturer (OEM) service manual for system isolation valve locations.

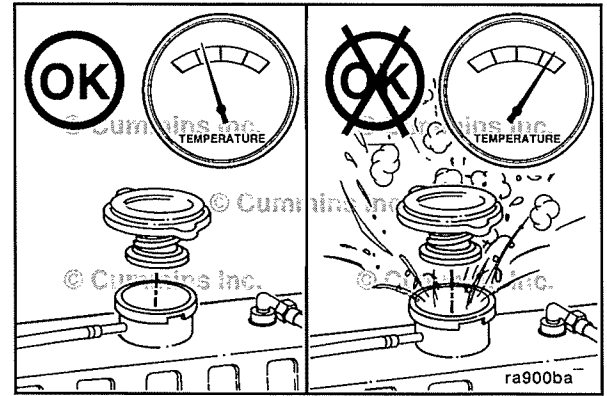
This air can be very difficult to purge in some applications that have several feet of plumbing and multiple heater cores.

NOTE: If the coolant is being changed, or if the cooling system is being flushed, it is desirable to leave the coolant flow valves to the equipment heating systems open, in order to completely drain the system.

Refer to the OEM service manual for any special coolant drain and fill requirements.

These special instructions can also be located near the cooling system access or fill door on the vehicle.

Remove all cooling system fill caps to allow the coolant to drain completely.



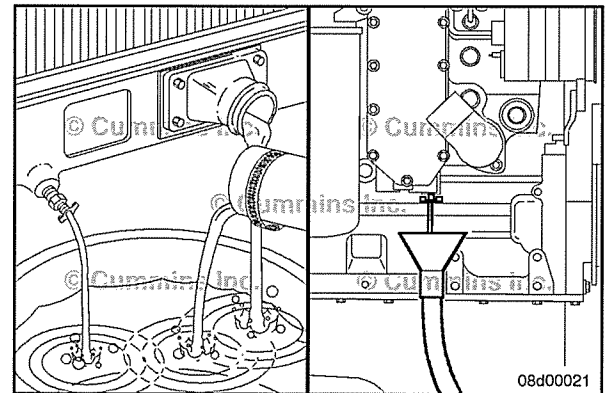
⚠ WARNING ⚠

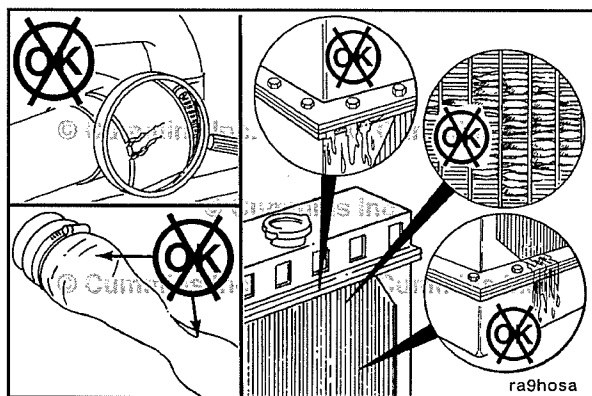
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

NOTE: If the coolant will be reused, drain the coolant into a clean container. Cover the container to reduce the possibility of coolant contamination after draining.

Drain the cooling system by opening the drain valve on the radiator and by opening the drain valve on the bottom of the engine oil cooler housing. A drain pan with a capacity of 57 liters [15 gal] is adequate for most applications.

After the cooling system is completely drained, close the drain valves. Refer to the OEM service manual for complete cooling system drain information.



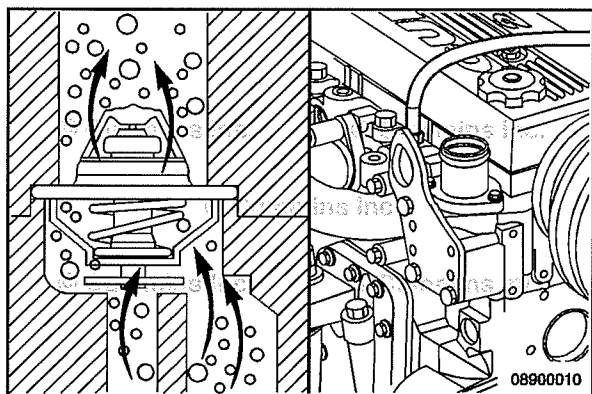


Check for damaged hoses and loose or damaged hose clamps. Replace as required.

Check the radiator for leaks, damage, and buildup of dirt.



Clean and replace as required.



Flush

⚠CAUTION⚠

The system must be filled properly to prevent air locks or serious engine damage can result. During filling, air must be vented from the engine coolant passages. Wait 2 to 3 minutes to allow air to be vented; then add mixture to bring the level to the top.

To be sure air is vented during the fill process:

- Some thermostats have check balls that allow air to vent through the thermostat when the thermostat is closed.
- An air vent port connection, which connects to the top tank/coolant recovery tank of the cooling system, is located next to the water outlet.

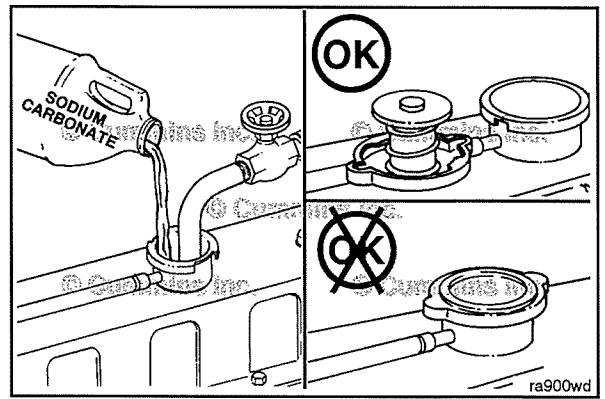
This provides adequate venting for a maximum fill rate of 19 liters [5 gal] per minute.

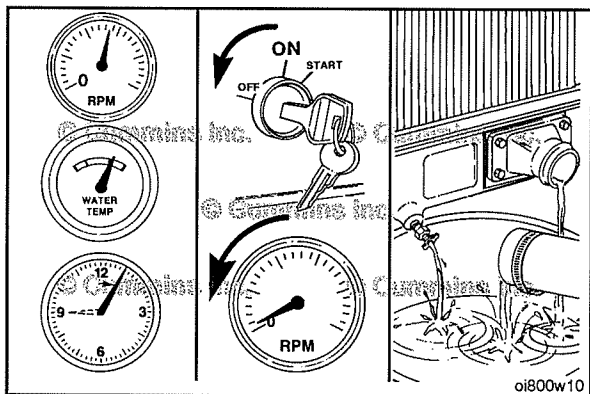
NOTE: An alternate to using sodium carbonate, as outlined in this procedure, is to use Restore™.

Restore™ is a heavy-duty cooling system cleaner that removes corrosion products, silica gel, and other deposits. The performance of Restore™ is dependent on time, temperature, and concentration levels. An extremely scaled or flow-restricted system, for example, can require higher concentrations of cleaners, higher temperatures, longer cleaning time, or the use of Restore Plus™. Up to twice the recommended concentration levels of Restore™ can be used safely. Restore Plus™ **must** be used **only** at its recommended concentration level. Extremely scaled or fouled systems can require more than one cleaning.



NOTE: Do **not** install the radiator cap. The engine is to be operated without the cap for this process.





⚠ WARNING ⚠
Coolant is toxic. Keep away from children and pets. Dispose of in accordance with local environmental regulations.

⚠ WARNING ⚠
Do not stand near the surge tank or radiator while operating the engine with the pressure cap OFF. If the vehicle is equipped with fill door on the side of the surge tank, keep it closed due to coolant expansion.

⚠ CAUTION ⚠
Do not operate the engine with the pressure cap off at temperatures above 93°C [200°F]. This can result in potential engine damage by cavitation of the water pump and localized boiling.

⚠ CAUTION ⚠
Before topping off coolant, allow the system temperature to cool to ambient. This will ensure that an adequate amount of coolant is available to the water pump during all periods of operation.

⚠ CAUTION ⚠
Do not relieve the system pressure while hot in order to “top off” immediately before returning the vehicle to service. The system will not be able to generate the pressure through the expansion of the coolant necessary for operation. This can result in potential engine damage by cavitation of the water pump and localized boiling.

Fill the cooling system with a mixture of sodium carbonate and water (or a commercially available equivalent) to the capacity or level stated in the OEM service manual.

NOTE: Adequate venting is provided for a maximum fill rate of 19 liters [5 gal] per minute.

Unless indicated otherwise by the OEM instructions, it is critical that all shutoff valves be returned to their open positions once the system has been refilled and the deaeration process is about to begin. This will help to make sure as much air as possible will be purged from the cooling system. Refer to the OEM service manual for valve locations.

Wait 2 to 3 minutes without starting the engine to allow the system to naturally purge entrained air and the coolant level to stabilize.

Add plain water to bring the level back to FULL.

Turn all cab heater switches to HIGH in order to allow maximum coolant flow through the heater core(s). The blower **must** be turned ON.

With the cooling system fill cap removed:

- Operate the engine at LOW idle for 2 minutes.
- Shut the engine OFF and add plain water to bring the level back to FULL.

With the cooling system fill cap removed:

- Start the engine.

NOTE: After starting a cold engine, increase the engine speed (rpm) slowly to provide adequate lubrication to the bearings and to allow the oil pressure to stabilize.

Operate the engine at HIGH idle until the thermostat opens.

Allow the engine to return to LOW idle 2 minutes before shutting it down. This allows adequate cool down of pistons, cylinders, bearings, and turbocharger components.

Shut the engine OFF and check the coolant level according to the OEM service manual recommendations and add coolant, if necessary, to bring it back to the FULL level.

Install the cooling system fill cap.

Operate the engine for 1 to 1½ hours with the coolant temperature above 80°C [176°F].

Shut the engine OFF. Allow the coolant temperature to drop to 50°C [122°F] before draining the cooling system.

Drain the cooling system.

⚠ WARNING ⚠

Do not stand near the surge tank or radiator while operating engine with pressure cap off. If the vehicle is equipped with a fill door on the side of the surge tank, keep it closed due to coolant expansion.

⚠ CAUTION ⚠

Do not operate the engine with the pressure cap off at temperatures above 93°C [200°F]. This can result in potential engine damage by cavitation of the water pump and localized boiling.

NOTE: Do not install the radiator cap.

Fill the cooling system with good quality water to the capacity or level stated in the OEM service manual.

Unless indicated otherwise by OEM instructions, it is critical that all shutoff valves be returned to their open positions once the system has been refilled and the deaeration process is about to begin. This will help to make sure as much air as possible will be purged from the cooling system. See the OEM service manual for valve locations.

Wait 2 to 3 minutes, without starting the engine, to allow the system to naturally purge entrained air and the coolant level to stabilize.

Add plain water to bring the level back to FULL.

Turn all cab heater switches to HIGH in order to allow maximum coolant flow through heater core(s). The blower **must** be turned ON.

With the cooling system fill cap removed:

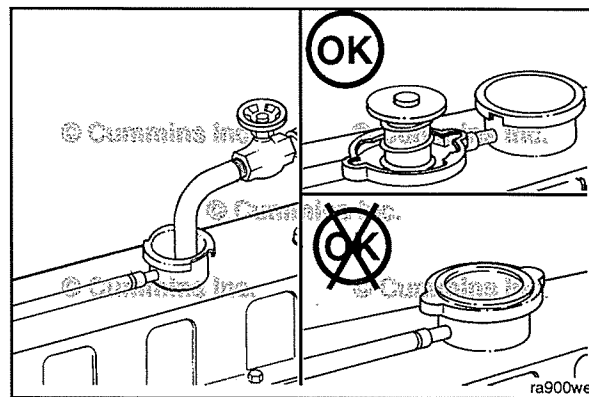
- Operate the engine at LOW idle for 2 minutes
- Shut the engine OFF and add plain water to bring the level back to FULL.

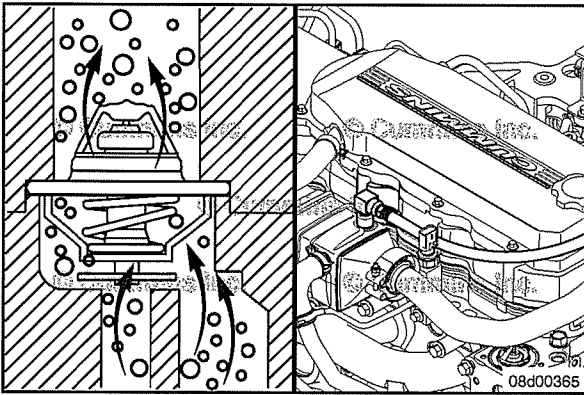
With the cooling system fill cap removed:

- Start the engine
- Operate the engine at HIGH idle until the thermostat opens.

NOTE: After starting a cold engine, increase the engine speed (rpm) slowly to provide adequate lubrication to the bearings and to allow the oil pressure to stabilize.

Allow the engine to return to LOW idle 2 minutes before shutting it down. This allows adequate cooldown of pistons, cylinders, bearings, and turbocharger components.





Fill

⚠CAUTION⚠

The system must be filled properly to prevent air locks or serious engine damage can result. During filling, air must be vented from the engine coolant passages. Wait 2 to 3 minutes to allow air to be vented; then add mixture to bring the level to the top.

Make sure air is vented during the fill process:

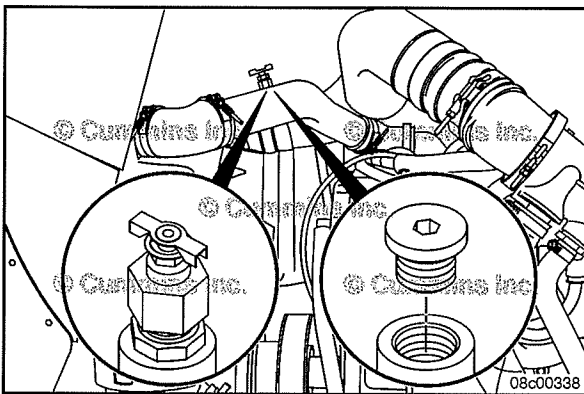
- Some thermostats have check balls that allow air to vent through the thermostat when the thermostat is closed.
- An air vent port connection, which connects to the top tank/coolant recovery tank of the cooling system, is located next to the water outlet.

The system has a design maximum fill rate of up to 19 liters [5 gal] per minute.

NOTE: Some applications may be equipped with a manual bleed valve which is to be opened to make sure of a proper fill. The upper radiator pipe is a common location for bleed valves. The illustration is for reference **only**.

If applicable, open the manual bleed valve before filling the cooling system.

Once properly filled, make sure to close the manual bleed valve.

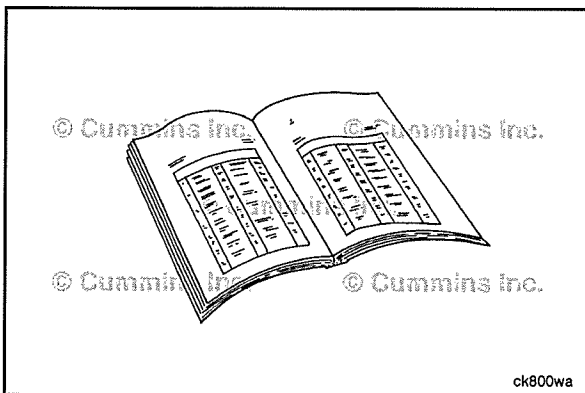


⚠CAUTION⚠

Never use water alone for coolant. Damage from corrosion can be the result of using water alone for coolant.

For engine coolant specifications. Refer to Cummins® Coolant Requirements and Maintenance, Bulletin 3666132.

NOTE: If the coolant is reused, it should be inspected for signs of contamination.



⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [122°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ WARNING ⚠

Do not stand near the surge tank or radiator while operating the engine with the pressure cap off. If the vehicle is equipped with a fill door on the side of the surge tank, keep it closed due to coolant expansion.

⚠ CAUTION ⚠

Do not operate the engine with the pressure cap off at temperatures above 93°C [200°F]. This can result in potential engine damage by cavitation of the water pump and localized boiling.

⚠ CAUTION ⚠

Topping off the system while hot is not recommended when using the fill door on transit bus applications equipped with surge tanks. Bringing the level to the bottom of the door while the system is hot will not provide adequate volume of coolant for lower operating temperatures. This can result in cavitation of the water pump and greatly increase the potential for engine damage.

⚠ CAUTION ⚠

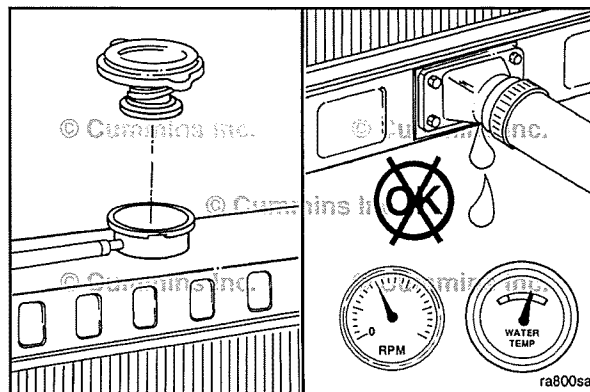
Before topping off coolant, allow the system temperature to cool to ambient. This will ensure that an adequate amount of coolant is available to the water pump during all periods of operation.

⚠ CAUTION ⚠

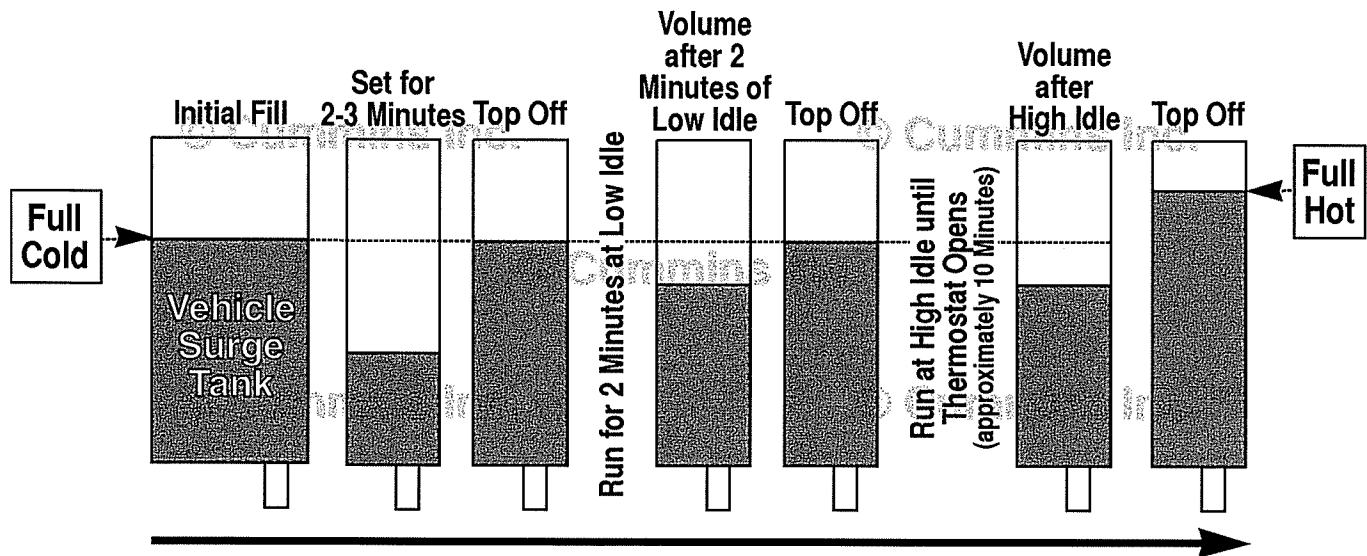
Engine and component damage may result if adequate cool down time is not given after the cooling system pressure has been relieved in order to "top off". System pressure is **ONLY** generated with temperature rise of coolant. Closing the cooling system while hot will not allow pressure to build.

Remove the cooling system fill cap.

Fill the cooling system to the capacity or level stated in the OEM service manual, using a mixture of 50 percent water and 50 percent ethylene glycol or propylene glycol antifreeze.



Sequence of Events for Coolant Fill and Deaeration



08100096

Figure 1: Sequence of Events for Coolant Fill and Deaeration.

NOTE: If all coolant drained from the system was collected, the same volume or more **must** go back into the system. If any drained coolant remains after filling, this is an indication of an air pocket which **must** be purged before returning the vehicle to service.

Unless indicated otherwise by OEM instructions, it is critical that all shutoff valves be returned to their open positions once the system has been refilled and the deaeration process is about to begin. This will help to make sure as much air as possible will be purged from the heating circuit. See the OEM service manual for valve locations.

Wait 2 to 3 minutes, without starting the engine, to allow the system to naturally purge entrained air and coolant level to stabilize.

Add a 50/50 mixture to bring the coolant level back to the FULL cold level.

Turn all cab heater switches to HIGH in order to allow maximum coolant flow through heater core(s). The blower **must** be turned ON.

With the cooling system fill cap removed:

- Operate the engine at LOW idle for 2 minutes.
- Shut the engine OFF and add coolant to bring the level back to the FULL cold level, using a 50/50 mixture.

With the radiator pressure cap off:

NOTE: After starting a cold engine, increase the engine speed (rpm) slowly to provide adequate lubrication to the bearings and to allow the oil pressure to stabilize.

- Start the engine.
- Operate the engine at HIGH idle until the thermostats open.

Allow the engine to idle 2 minutes before shutting it down. This allows adequate cool down of pistons, cylinders, bearings, and turbocharger components.

- Shut the engine OFF.
- Top off the coolant to the FULL hot level.
- It is the responsibility of the customer to check the cold coolant level and top off if necessary.

NOTE: Certain applications may require an additional 10 minutes of operation time at HIGH idle for complete deaeration. For best results, reference the OEM coolant fill procedure for specific instructions.

Allow the engine to cool to 50°C [122°F], then install the pressure cap. Operate the engine until it reaches a temperature of 80°C [176°F] and check for coolant leaks.

Reference Figure 1 for a graphic explanation of the fill process.

Cooling System Diagnostics (008-020)



General Information

The following procedure covers common troubleshooting steps to help identify:

- Engine overheating causes. See the Initial Check section of this procedure.

NOTE: At the end of this procedure, a worksheet is provided to record any measured values taken during troubleshooting. The worksheet will help in gathering and analyzing the data.

- External and internal coolant leaks/loss. See the Pressure Test section of this procedure.
- Combustion gas leaks into the cooling system. See the Test section of this procedure.

If the coolant reaches an unacceptable level in the recovery/expansion tank, a fault code should become active that will illuminate an instrument lamp and impose a power derate. This low level is detected by a coolant level switch mounted in the coolant surge/recovery tank.

In the event of a cooling system-related malfunction, it is recommended that the coolant level switches be checked for proper operation. Refer to the original equipment manufacturer (OEM) service manual for operational checks and repairs.

Removal and installation of the coolant level switch for diagnostics is **not** recommended. This poses a high likelihood of damage, due to the plastic construction of the switch. The coolant level switch **must only** be removed from the surge/recovery tank when replacing it with a new switch. Be certain **not** to overtighten the switch when installing. Most switches have a very low torque value, which can be found in the OEM service manual.

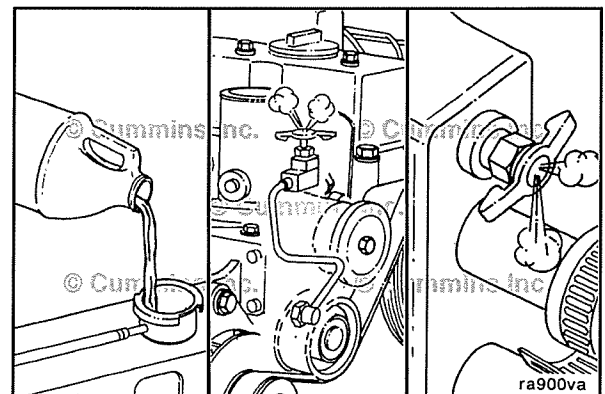
Coolant level switches are very susceptible to improper pH levels. For this reason, it is imperative that coolant be maintained in accordance with the following service bulletin. Cummins® Coolant Requirements and Maintenance, Bulletin 3666132.

NOTE: The engine or system has a leak if frequent addition of coolant is necessary. Locate and repair the leak.

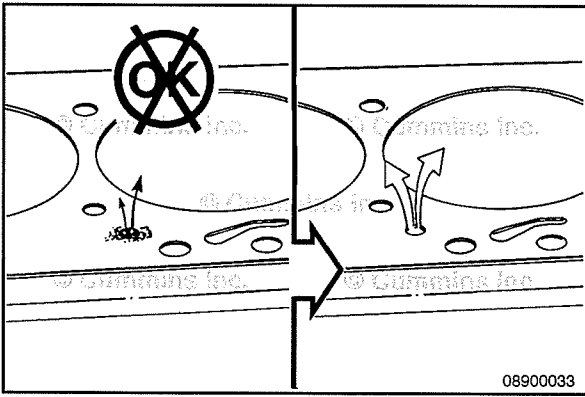
The system is designed to use a specific quantity of coolant. If the coolant level is low, the engine will run hot.

TEMPERATURE				PRESSURE			RADIATOR "IN LINE" STARTS GETTING HOT	FAN KICKS ON	SHUTTERS OPEN
THERMOSTAT HOUSING	BLOCK	CAB GAUGE	BLOCK	THERMOSTAT HOUSING					
		140							
		145							
		150							
		155							
		160							
		165							
		170							
		175							
		180							
		185							
		190							
		MONITOR							
		FAN							
		OPERATION							
		See * Below							
		195							

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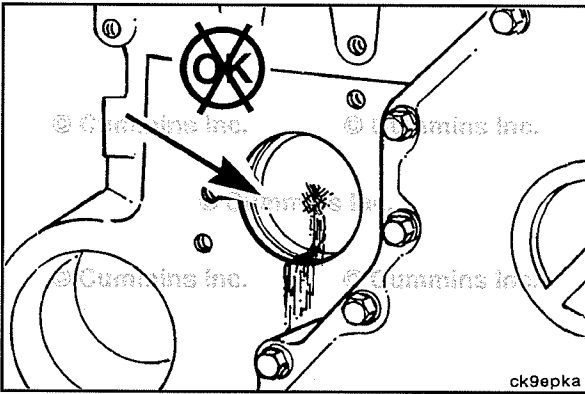


ra900va



NOTE: The small holes in the head gasket are especially susceptible to plugging. Their size is critical. Do **not** enlarge the size of the orifices. Doing so will disturb the coolant flow and will **not** solve an overheating problem.

Obstructions in the coolant passages will reduce coolant flow, which can lead to overheating.



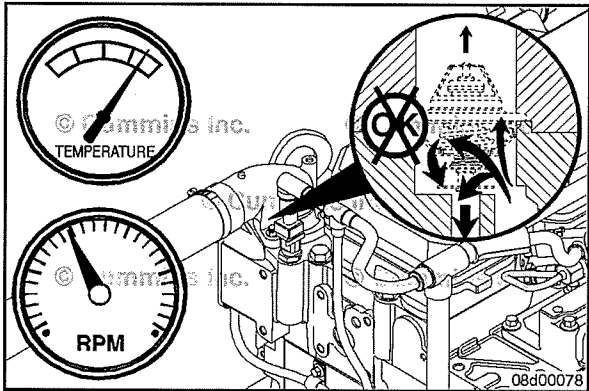
⚠CAUTION⚠

A sudden loss of coolant from a heavily loaded engine can result in severe damage of the pistons and cylinder bore.

Water will cause rust formation, reducing the flow in the smaller coolant passages.

Also, water used as a coolant for even a relatively short period can result in the expansion plugs rusting through, which will allow the coolant to leak.

Use a 50/50 mixture to fill the coolant system.

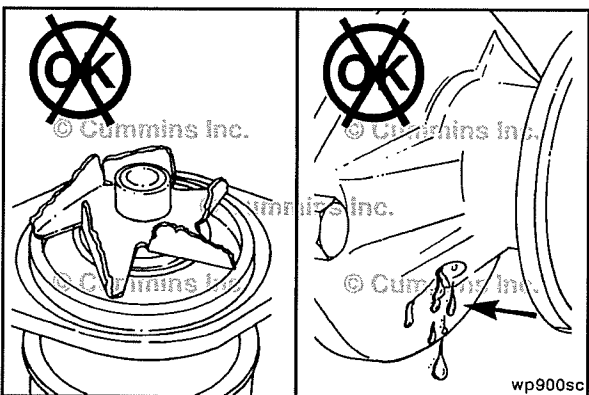


⚠CAUTION⚠

Never operate the engine without a thermostat. Without a thermostat, the path of least resistance for the coolant is through the bypass to the water pump inlet. This can cause the engine to overheat.

Thermostat

There are different temperature range thermostats available, depending on the engine type and application. The part number and nominal operating temperature are stamped on the thermostat. To verify that the correct temperature range and part number thermostat is installed, make sure to reference the appropriate part information resources. Refer to Procedure 008-013 in Section 8.



Water Pump

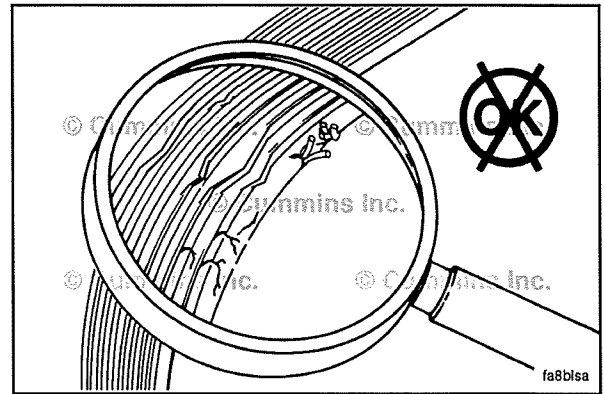
A damaged or an incorrect water pump can lead to an engine overheating condition. To verify that the correct water pump is installed, make sure to reference the appropriate parts information resources. Refer to Procedure 008-062 in Section 8.

Belt and Belt Tensioner

A worn/incorrect belt, belt tensioner, or misaligned pulley can cause:

- Belt slip
- Belt jump or "walk off"
- Noise
- Belt breaks and shredding
- Component bearing seizure.

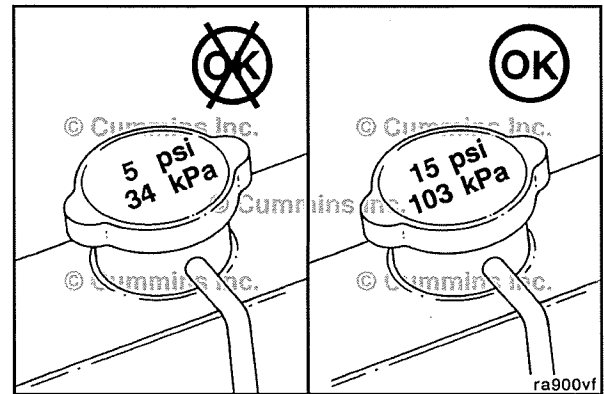
Refer to Procedure 008-002 or Refer to Procedure 008-080 in Section 8.



Pressure Cap

A commonly overlooked item when troubleshooting the cooling system is the radiator pressure/expansion tank cap. The cooling system is designed to use a pressure cap to prevent boiling of the coolant. An incorrect, damaged, or malfunctioning cap can result in the loss of coolant and in an engine overheating condition.

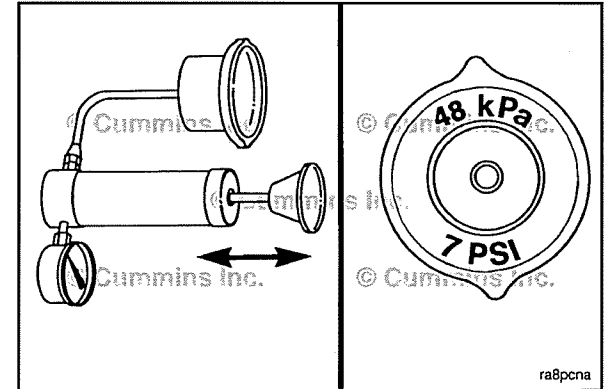
Refer to the OEM service manual for the recommended pressure cap rating. Refer to Procedure 018-018 in Section V.



An incorrect or malfunctioning cap can also result in the loss of coolant and in an engine overheat condition.

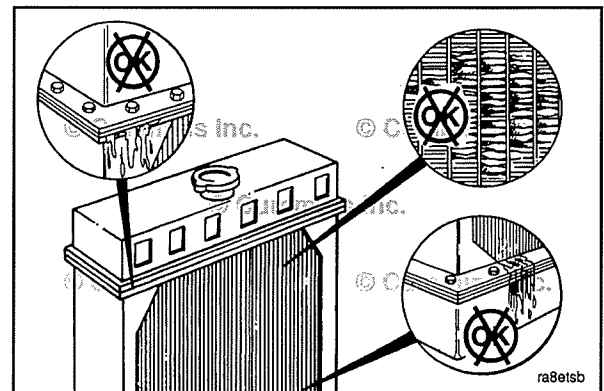
Pressure test the radiator cap. Refer to the OEM service manual.

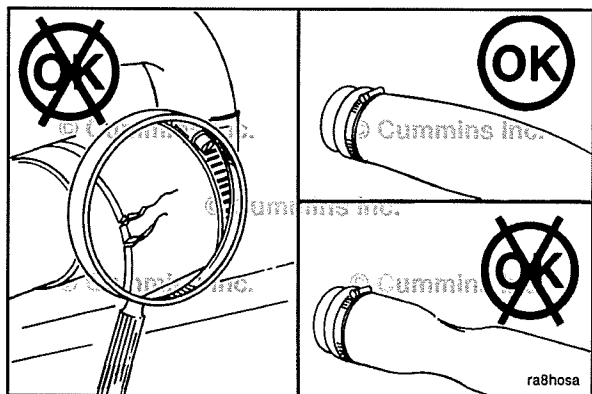
The pressure cap **must** seal within 14 kPa [2 psi] of the value stated on the cap, or it **must** be replaced.



The radiator **must** be inspected for bent/broken fins and coolant leaks periodically.

For maintenance, removal, or installation of the radiator, refer to the OEM service manual.

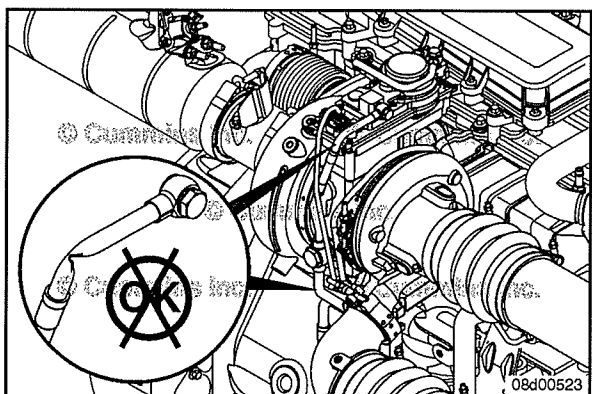




NOTE: The silicone engine coolant hose will exhibit swelling due to the elasticity of the hose.

Coolant Hoses

Collapsed or damaged coolant hoses can result in engine heating problems. Make sure to inspect all hoses for cracks, cuts, or collapsing. Replace any damaged hoses.



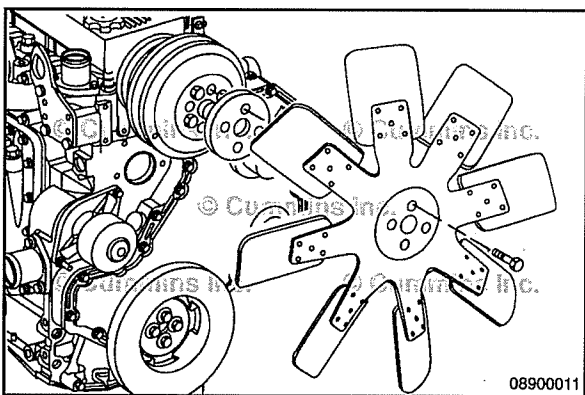
▲ WARNING ▲

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.



Inspect the coolant vent lines from the exhaust gas recirculation (EGR) cooler, cylinder head and variable geometry actuator (VGT). Make sure the lines are **not** pinched and that there are no sharp turns or dips in the vent lines from the engine connection point to the surge tank.

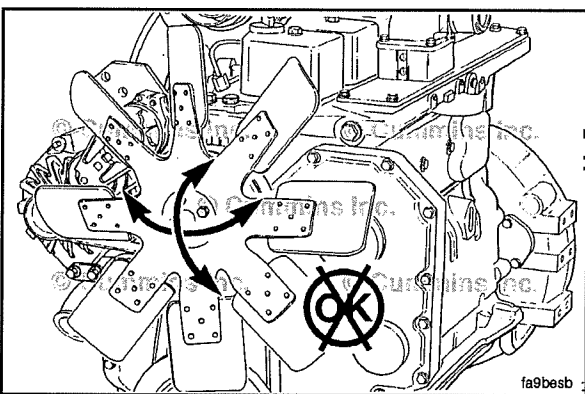
Blow compressed air through the suspected lines to make sure there is no excessive restriction inside the lines.



Cooling Fan

The engine cooling fan is typically driven by a crankshaft driven belt. In some applications, the fan is located off the engine for a remote mounted cooling system.

The cooling fan is supplied by the OEM. The OEM **must** be contacted for any service-related information. This procedure **only** highlights some of the items related to cooling fans.



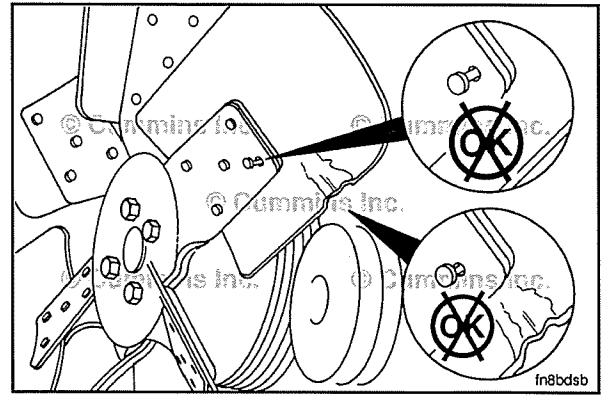
If the fan is belt-driven, a slipping belt will result in a slower fan speed and reduced cooling. A malfunctioning automatic belt tensioner can be the problem. Refer to Procedure 008-080 in Section 8.



Check the bearings in the fan hub and other pulleys to make sure they are **not** causing excessive belt vibration and slippage. Refer to Procedure 008-036 in Section 8.

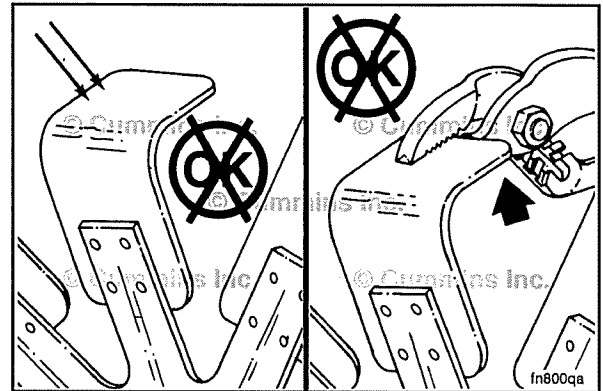
The cooling fan **must** be inspected periodically. Check for cracks, loose rivets, and bent or loose blades.

Check the fan to make sure it is securely mounted. Tighten the capscrews, if necessary.



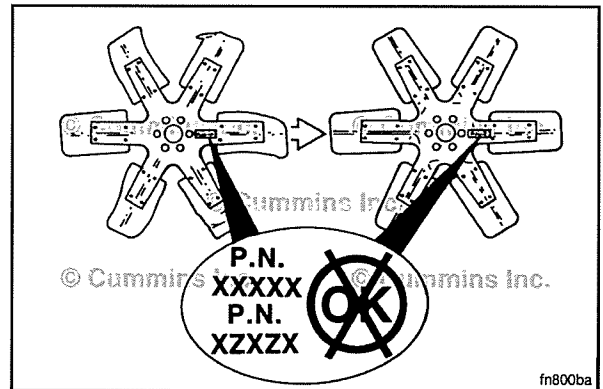
⚠ WARNING ⚠

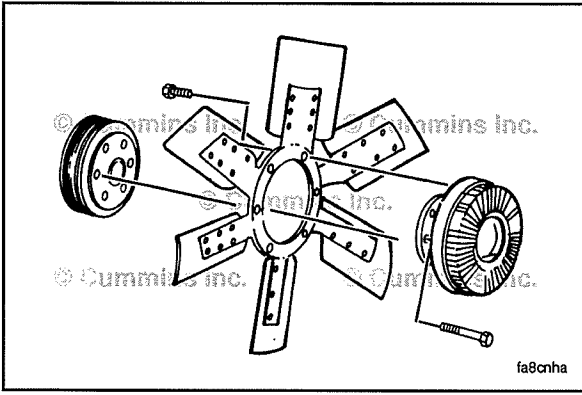
Do not straighten a bent fan blade or continue to use a damaged fan. A bent or damaged fan blade can fail during operation and cause personal injury or property damage.



Only replace a damaged cooling fan with an exact equivalent cooling fan. Although same size cooling fans can appear similar, there can be differences in the blade pitch and profile.

Some cooling fans can be installed backward. Check to make sure the fan is pushing or pulling air in the proper direction.





Fan Drive

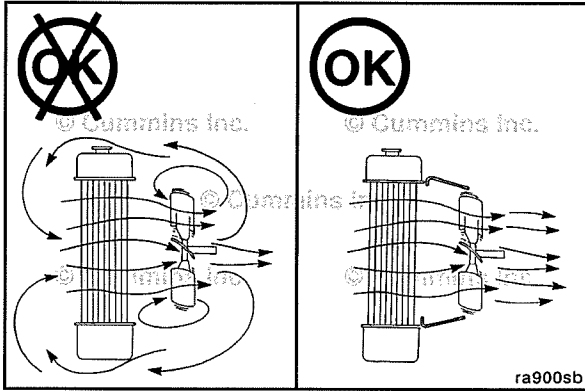
A malfunctioning fan drive can cause engine cooling problems.

Various fan drive configurations are used to determine when the fan is driven, which include:

- Direct drive - the fan is engaged all of the time
- Air engaged/disengaged clutch
- Electric/electromagnetic clutch
- Viscous clutch
- Hydraulic drive
- Crankshaft/power takeoff (PTO) driven.

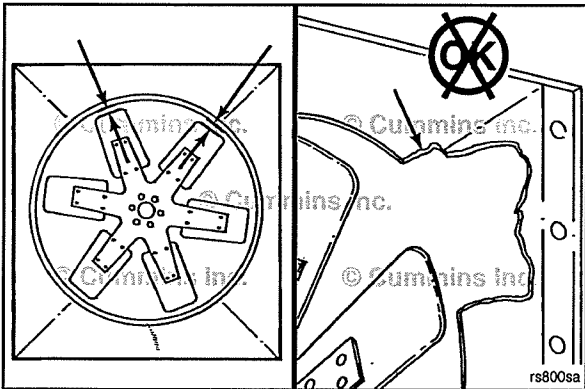
Use the following procedure for additional information on electromagnetic fan clutches supplied by Cummins Inc. Refer to Procedure 008-026 in Section 8.

Refer to the OEM service manual for other fan clutches.



Fan Shroud Assembly

A fan shroud assembly is used to direct air flow provided by the cooling fan. A missing or damaged fan shroud will reduce the amount of air flow provided by the cooling fan and can cause an engine coolant overheating condition.



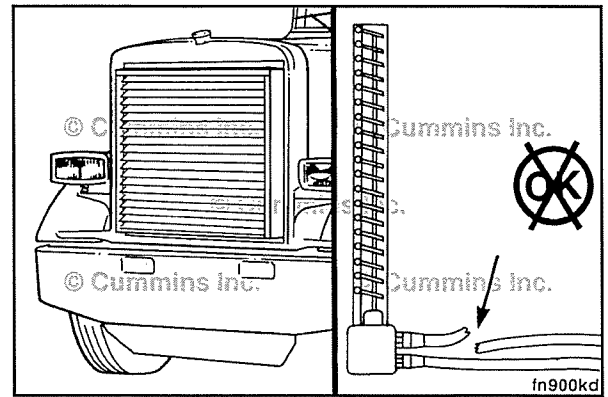
Check the fan shroud for damage and/or contact with the cooling fan. Replace any damaged components. Refer to Procedure 008-038 in Section 8.



Radiator Shutters

NOTE: Make sure the air temperature sensor is functioning correctly. Check the air-operated shutter controls. Check for air leaks. Refer to the OEM service manual.

Radiator shutters are designed to control airflow across the radiator. If the shutters fail to open when needed, the engine can run hot. Inability of the shutters to close can result in too much airflow and the engine running cold.

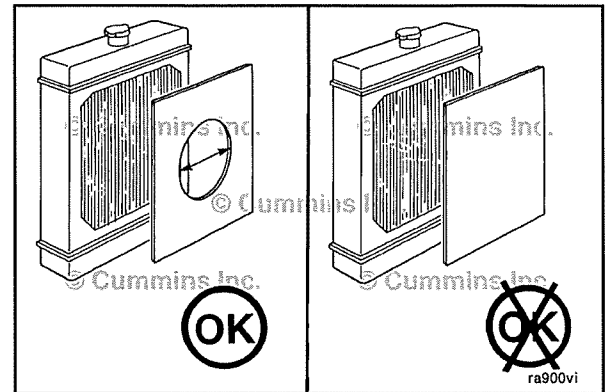


Winter Fronts

Winter fronts can be used to reduce the engine warm up time and help maintain engine heat in cold climate locations.

The winter fronts should **only** cover part of the frontal area of the cooling system, leaving part of the frontal area open to air flow. Use the following procedure for the minimum required air passage. Refer to Procedure 018-018 in Section V.

Failure to leave part of the front area open to air flow or leaving the winter fronts installed when ambient temperatures increase can lead to an engine overheating condition.

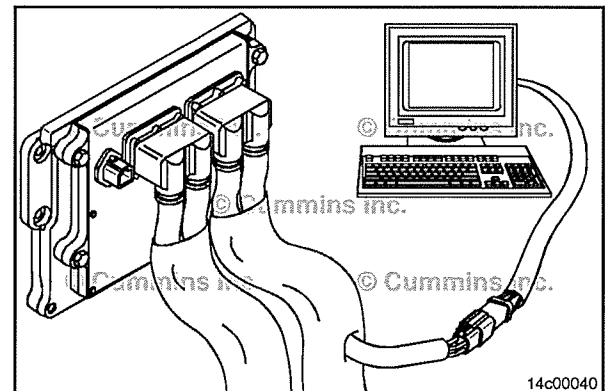


Initial Check

Connect an electronic service tool to the vehicle's data link.

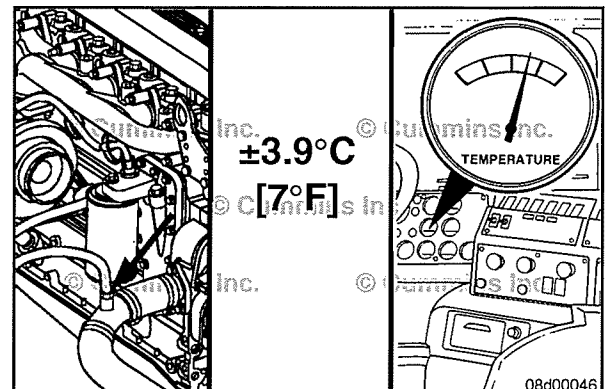
Turn the keyswitch to the ON position.

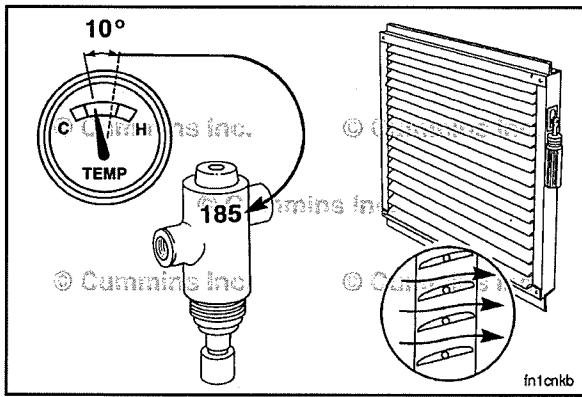
Monitor the coolant temperature with the electronic service tool.



If equipped with an in dash coolant temperature gauge, monitor coolant temperature with an electronic service tool and compare the cab temperature gauge reading. Replace the cab temperature gauge if it is **not** within the manufacturer's specifications of the correct reading.

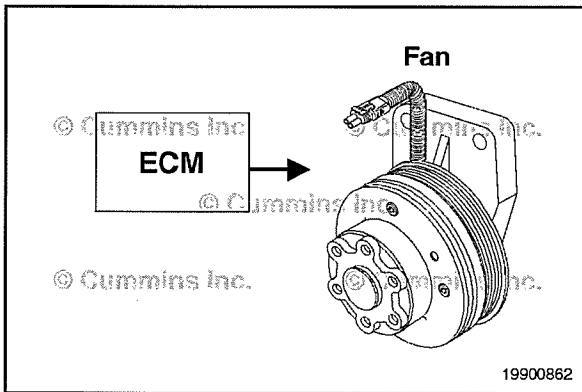
If the manufacturer's specifications are **not** available, replace the gauge if it is **not** within $\pm 3.9^{\circ}\text{C}$ or $\pm 7^{\circ}\text{F}$ of the correct reading.





For vehicles equipped with temperature controlled shutters, check the coolant temperature at which the shutters open and close. Compare this value to what is stamped on the shutter control.

Cummins Inc. recommends that the shutters open at 85°C [185°F] engine coolant temperature.



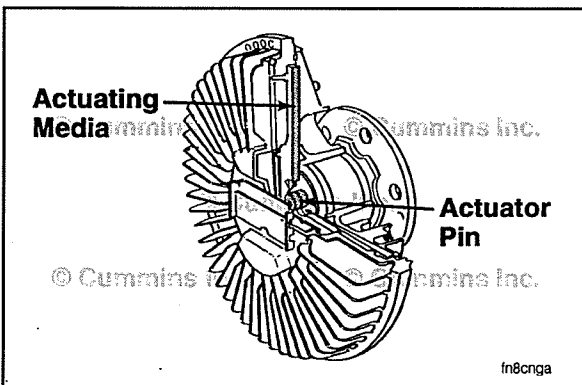
If equipped with a temperature controlled cooling fan clutch, check the coolant temperature at which the fan clutch engages.

If the fan clutch engagement is controlled by a fan control on the vehicle, compare the recorded value to what is stamped on the fan control and/or reference the OEM service manual.

If the fan clutch engagement is controlled by the engine's electronic control module (ECM), the engagement coolant temperature is a set value that can **not** be changed. If the fan clutch does **not** engage, check to make sure the fan control logic parameter is set correctly.

The ECM is capable of using either a zero ("0") VDC or system voltage signal to engage the fan clutch. The exact enable logic can be selected in the Features and Parameters section of INSITE™ electronic service tool.

Cummins Inc. recommends that the fan engage at 96°C [205°F] engine coolant temperature.



If equipped with a viscous fan drive, check the coolant temperature at which the fan engages. Viscous fan clutches are typically activated by a built-in sensor behind the radiator that monitors air temperature.

NOTE: Some viscous fan drives could possibly be electronically controlled.

When the air temperature reaches a specific level, depending on the temperature setting of the sensor used, the temperature-sensing control moves an actuator that allows viscous fluid to engage the fan drive and increase the fan speed. For more information, refer to the OEM service manual.

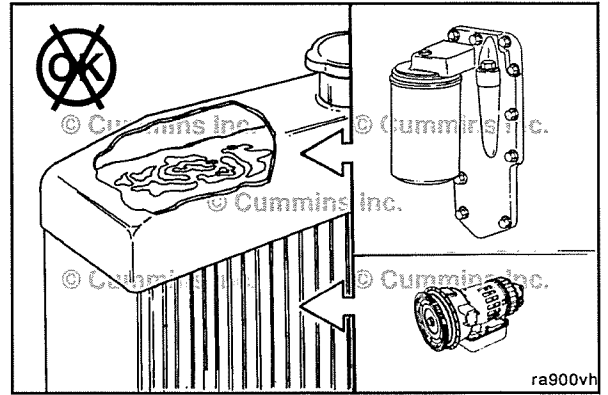
Cummins Inc. recommends that the fan engage at 96°C [205°F] engine coolant temperature.

Pressure Test

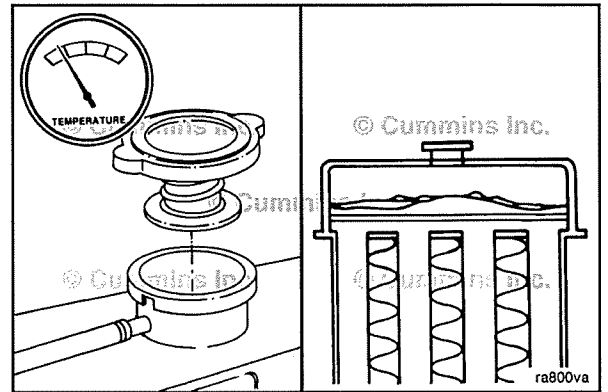
The operating pressure of the coolant system and the lubricating system can result in the mixing of the fluids if there is a leak between the systems:

- Cylinder head gasket
- Lubricating oil cooler, etc.

Transmission/power steering/hydraulic fluid can also leak into the coolant through radiator fluid coolers, if equipped. Refer to the OEM service manual.



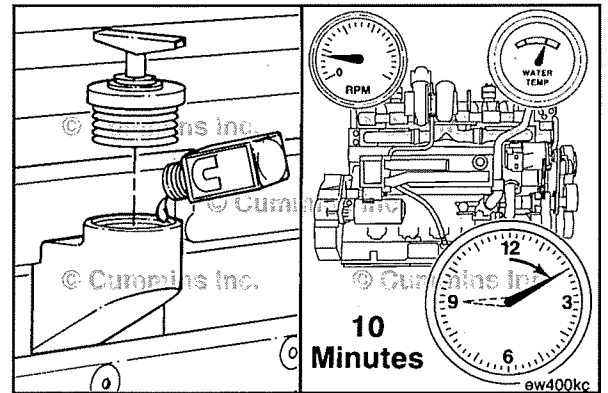
Check the coolant level and fill if necessary. Refer to Procedure 008-018 in Section 8.



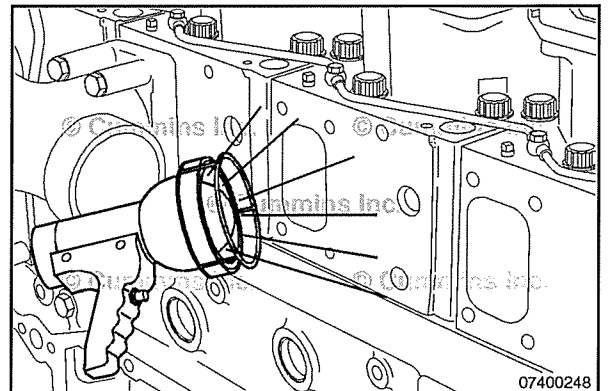
To aid in determining the location of the coolant leak, it may be necessary to add fluorescent tracer, Part Number 3377438, to the coolant.

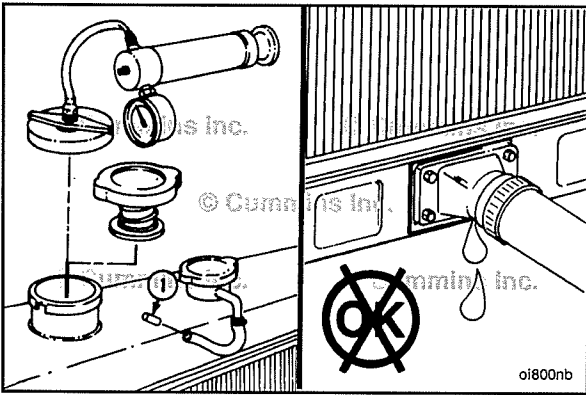
Add one unit of fluorescent tracer to each 38 liters [10 gal] of coolant.

Idle the engine for 5 to 10 minutes or until normal operating temperature is reached, to allow the dye to circulate through the cooling system.



Use a high intensity black light, Part Number 3163337 or equivalent, to illuminate the dye.





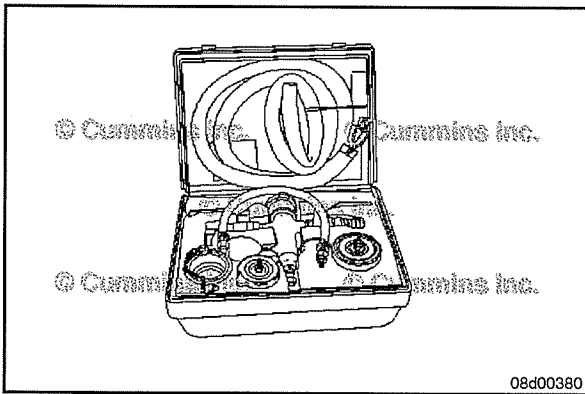
⚠CAUTION⚠

Do not apply more than 138 kPa [20 psi] air pressure to the cooling system or damage to the water pump seal can result.

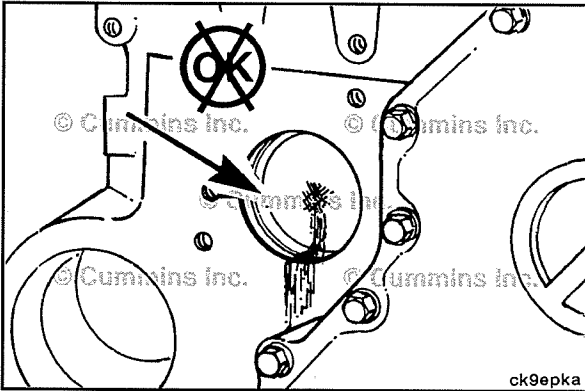
If the radiator is equipped with a pressure relief valve, plug the overflow line (1).

Install the pressure tester to the radiator fill neck or surge tank, if equipped, and apply air pressure.

Air Pressure 138 kPa [20 psi]



The Coolant Dam®/Pressure Tester service tool, Part Number 3824319, can also be used to pressurize the cooling system. The Coolant Dam®/Pressure Tester uses shop air rather than a hand air pump.



For external coolant leaks, inspect the exterior of the engine and repair if necessary.

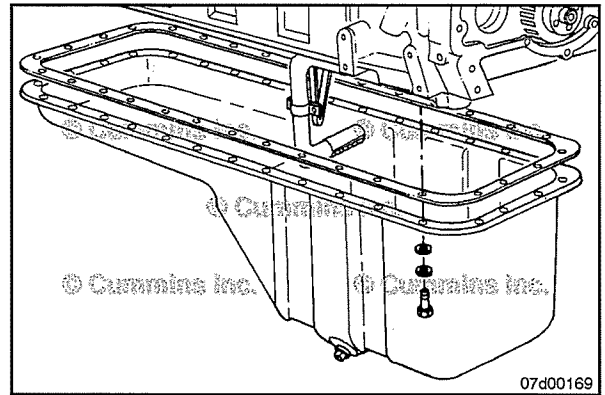
Pay close attention to areas around the:



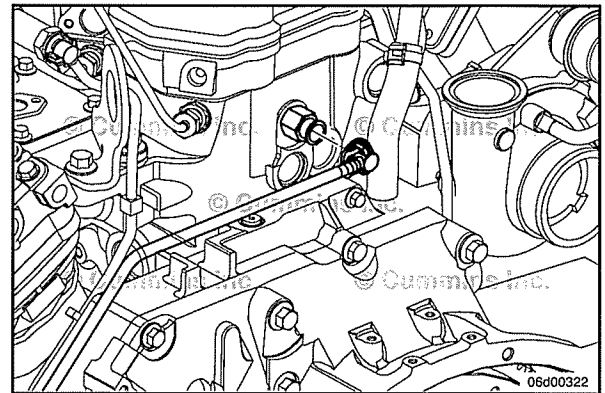
- Lubricating oil cooler. Refer to Procedure 007-003 in Section 7.
- Water pump. Refer to Procedure 008-062 in Section 8.
- Air compressor head gasket. Refer to Procedure 012-014 in Section 12.
- Cup plugs. Refer to Procedure 017-002 in Section 17.
- Pipe plugs. Refer to Procedure 017-007 in Section 17.
- EGR cooler. Refer to Procedure 011-019 in Section 11.
- EGR cooler coolant line. Refer to Procedure 011-031 in Section 11.
- Variable geometry turbocharger. Refer to Procedure 010-033 in Section 10.
- Turbocharger coolant lines. Refer to Procedure 010-041 in Section 10.

For internal coolant leaks, inspect the interior of the engine. It may be necessary to remove the following components to look for signs of a coolant leak:

- Rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Turbocharger oil drain line. Refer to Procedure 010-045 in Section 10.



For suspected fuel in the coolant or coolant in the fuel, disconnect the fuel drain connection at the rear of the cylinder head. Refer to Procedure 006-013 in Section 6.

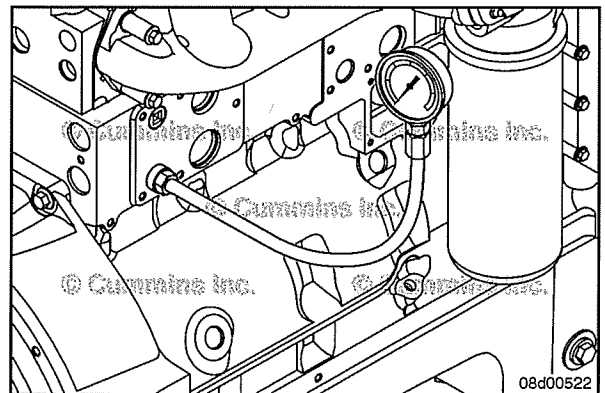


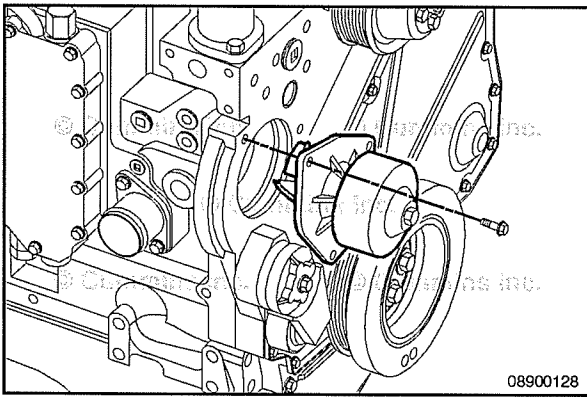
Coolant Pressure Check

Measure the coolant pressure at the coolant tap located on the exhaust side of the cylinder block, as shown in the illustration.

Coolant pressure can be affected by the following:

- Radiator pressure cap
- Debris in the cooling system
- OEM cooling options such as in-cab heaters and torque converter cooling
- Air in the cooling system
- Incorrect initial cooling system fill
- Less than 50/50 antifreeze mixture
- Engine operation at high altitude.

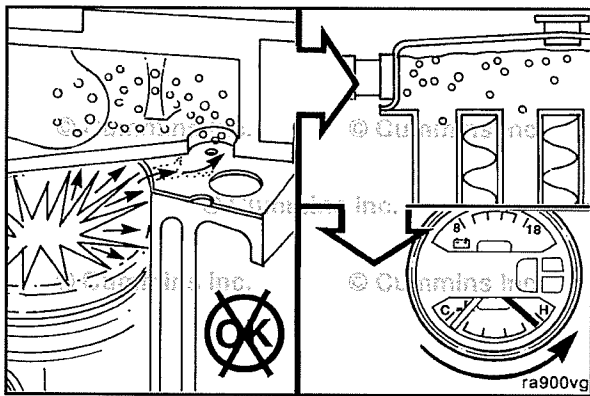




Record the block pressure at 60°C [140°F], closed thermostat, at high idle.

If the block coolant pressure is less than 138 kPa [20 psi] at high idle and without a pressure cap, do the following:

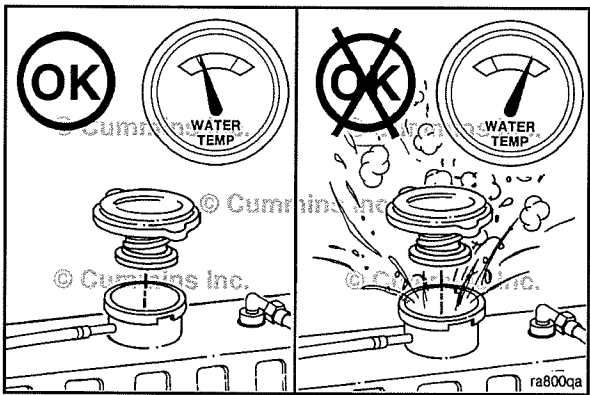
- Check the belt tension and condition.
- Remove the water pump, inspect the impeller integrity, and check for slippage on the shaft. Refer to Procedure 008-062 in Section 8.



Test

Air in the coolant can result in loss of coolant from the overflow when the aerated coolant is hot. The heated air expands, increasing the pressure in the system, causing the cap to open.

Similarly, coolant can be displaced through the overflow if the head gasket or a crack in the cylinder head leaks compression gases into the cooling system.

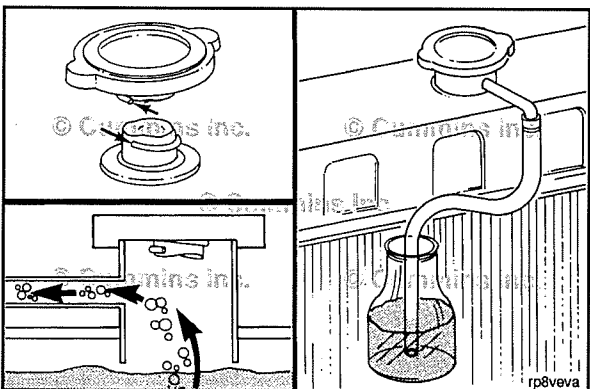


Overflow Method

▲ WARNING ▲

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

Allow the engine to cool and remove the radiator cap.



NOTE: The pressure cap **must** be tightly sealed in the top of the radiator fill neck.

Install a radiator pressure cap that has had the spring and the pressure relief valve removed to allow free flow from the overflow tube.

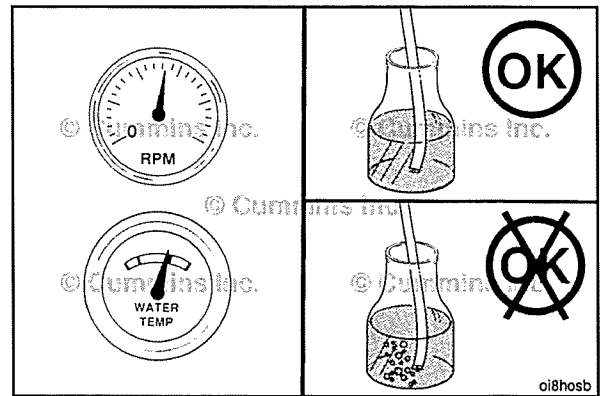
Attach a rubber hose to the radiator overflow connection.

Put the free end of the hose below the water level in a container of water.

NOTE: The engine coolant temperature **must** be stable to perform this test. An increasing coolant temperature will give a false indication of air due to expansion of the coolant in the system.

Operate the engine at rated rpm until it reaches a temperature of 82°C [180°F].

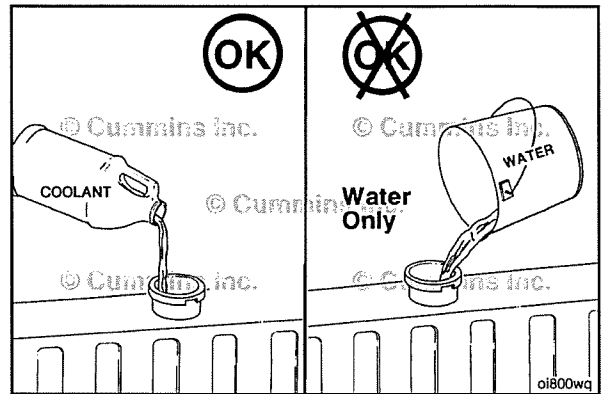
Check for a continuous flow of air bubbles from the hose in the water container.



Combustion Gas Leak

Use a combustion gas tester, Part Number 3822985 or equivalent, to test for combustion gases in the cooling system.

It is recommended that the cooling system contain a mixture of 50 percent antifreeze and 50 percent water during the combustion gas leak test. The use of water **only** can result in a color change in the test fluid from blue to turquoise or light green during the test. This is **not** an indication of a combustion gas leak.

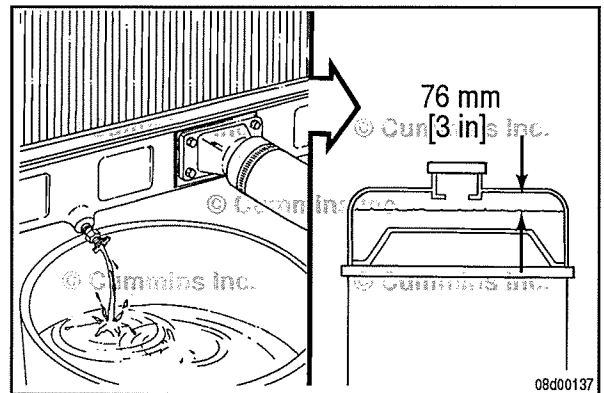


⚠ WARNING ⚠

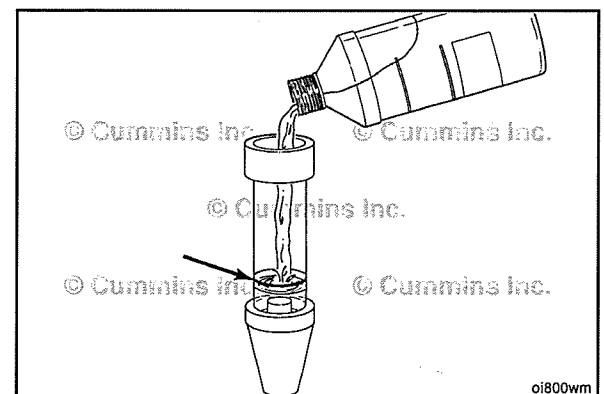
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

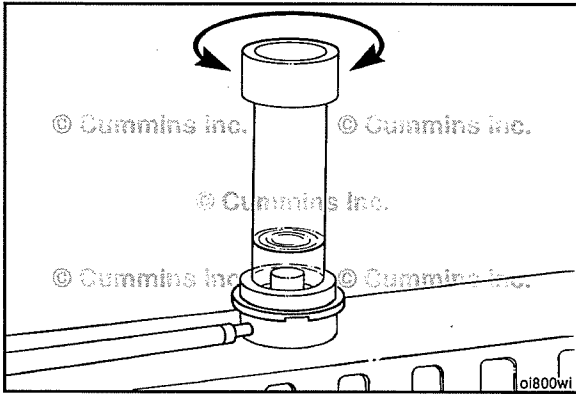
Drain the coolant level down approximately 76 mm [3 in] below the radiator cap seal ledge in the radiator fill neck.

If the coolant is above this point, the coolant can contaminate the test fluid, causing the test to be ineffective.

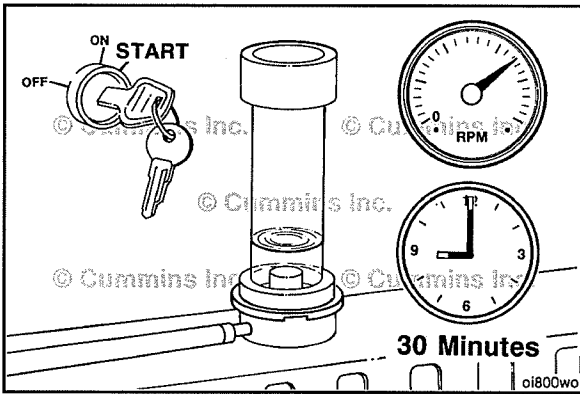


Pour the test fluid into the combustion gas leak test instrument until it is level with the yellow fill line on the instrument.

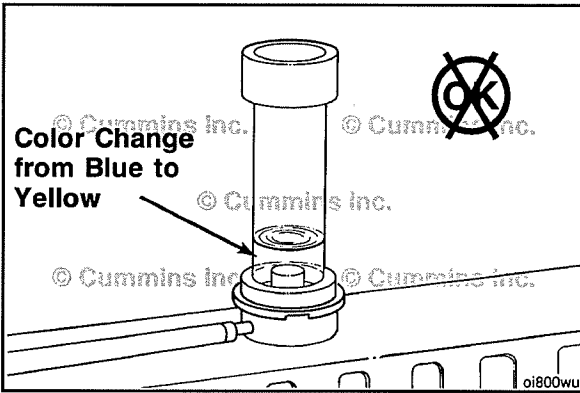




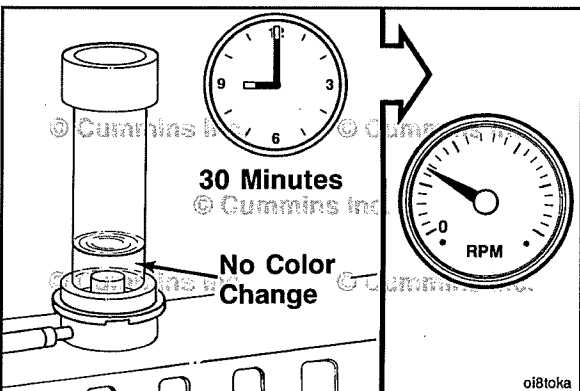
Insert the rubber tip of the combustion gas leak test instrument into the radiator fill neck. Hold the instrument down firmly and turn back and forth to make certain that an airtight seal is formed between the tester and the radiator fill neck.



Start the engine and run at idle for approximately 30 minutes. Monitor the engine temperature and color of the test fluid during engine operation. Do **not** allow the engine temperature to exceed 100°C [212°F] during the test.

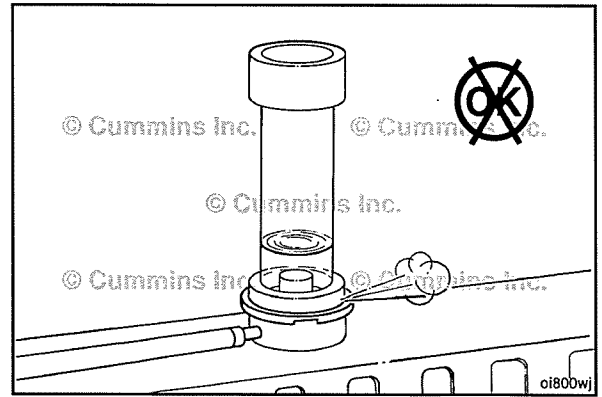


If the color of the test fluid changes from blue to yellow or green anytime during the test, combustion gases are leaking into the cooling system. Discontinue the test if the color of the test fluid changes from blue to yellow or green.



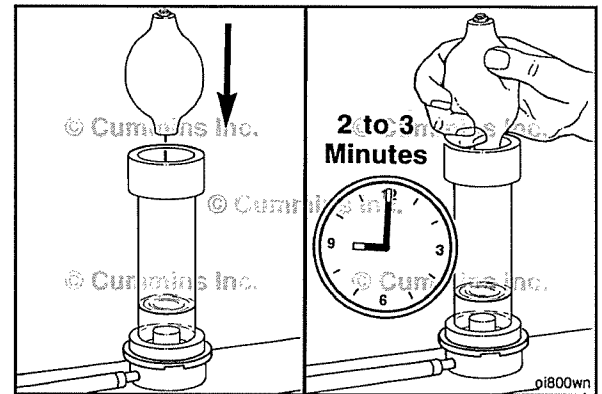
If the color of the test fluid does **not** change from blue to yellow or green during the 30 minute test period, return the engine to low idle.

Check the test instrument to make sure it is firmly sealed in the radiator fill neck.

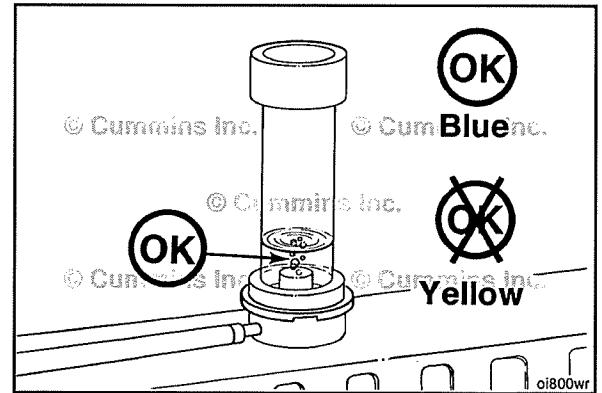


Insert the tip of the rubber ball into the hole in the top of the test instrument. Squeeze the rubber ball 2 to 3 minutes to draw air from the radiator through the test fluid.

If the color of the test fluid remains blue, combustion gases are **not** entering the cooling system. If the color of the test fluid changes from blue to yellow or green, combustion gases are entering the cooling system and further investigation is required to determine the source of the combustion leak.



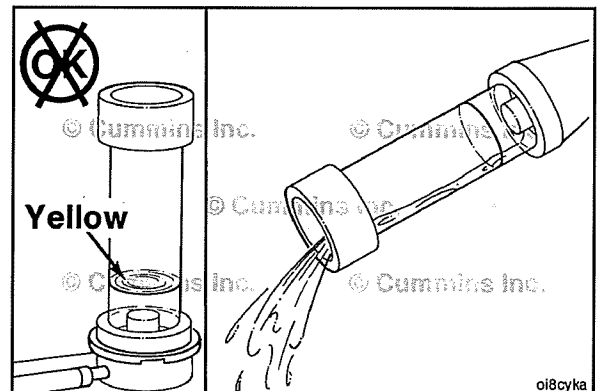
As the cooling system warms up to operating temperature, air will be expelled through the combustion gas tester in the form of bubbles in the test fluid. This is due to normal expansion of the coolant. Do **not** mistake the presence of air bubbles in the tester as combustion gases or air leaks into the cooling system. A change in the color of the test fluid from blue to yellow or green is the **only** indication of combustion gas in the cooling system.

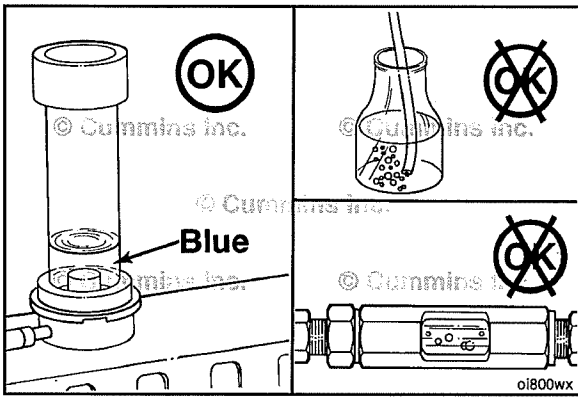


NOTE: Discard the tester fluid if it has indicated positive.



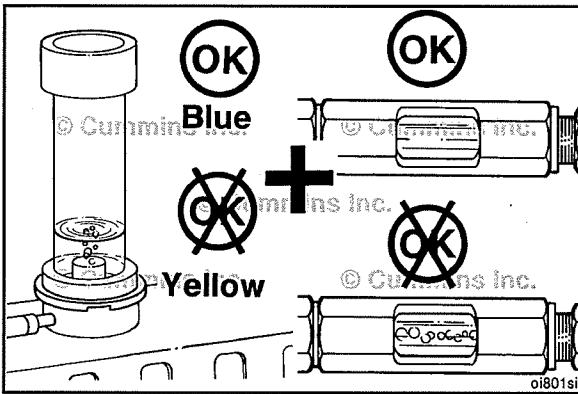
A positive result from the combustion gas leak tester indicates cylinder head gasket or cylinder head casting leakage. Refer to Procedure 002-004 in Section 2.





A negative result from the combustion gas leak tester, coupled with a continuous flow of air bubbles from the previous test, indicates the following:

- Damaged fan, shutter, or heater air control valve
- Air compressor head or head gasket leakage
- Air entrained due to a damaged radiator check valve or incorrect fill.
- Air entrained due to a damaged radiator check valve, incorrect fill, or restricted vent lines.



Analyzing the Data

Check the color of fluid in the combustion gas leak tester. A yellow or green (not shown in the illustration) color will indicate a combustion leak. A blue color will indicate there is no leak. This information will help isolate the source of air in the cooling system, if any.

NOTE: The test kit is **not** sensitive enough to detect very small combustion gas leaks.

Do **not** rule out combustion gas leaks if the combustion gas leak test does **not** indicate a combustion gas leak.

Worksheet

Fill in the blanks with the test data as the test is being run. Mark when the radiator line gets hot, when the fan starts operating, and when the shutters open.

Coolant Temperature (°F)	Pressure						
	Thermostat Housing	Cab Gauge	Cylinder Head	Radiator "In Line" Starts Getting Hot	Fan Starts Operating	Shutters Open	Notes
140							Engine at high idle throughout test
145							Monitor for air throughout test
150							Start monitoring radiator "in" line
155							
160							
165							Check water filter
170							
175							
180							
185							
190							

195						
200						
205						Cool engine down

Fan Clutch, Electric (008-026)

General Information

⚠ WARNING ⚠

The cooling fan will engage when the engine is started. To reduce the possibility of serious personal injury, keep your hands clear of the fan's path when starting the engine and during engine operation.

The Cummins Inc. developed electromagnetic fan clutch product is an integrated package with the clutch, bracket, shaft, bearings, pulley, and fan spacer designed as a unit. When cooling is needed, an electromagnet engages the fan. The fan is either fully engaged or fully disengaged. The electromagnetic fan clutch is driven by a poly-vee drive belt and is available with an accessory drive for vee-drive belts.

All fan clutches can be controlled by the engine engine control module (ECM). The ECM monitors coolant temperature and intake manifold temperature to determine when to engage the cooling fan. Some applications have additional sensors monitored by the ECM for fan control (for example, air conditioner pressure and transmission temperature). The original equipment manufacturer (OEM) can also install a manual override switch to engage the clutch manually at the operator's command.

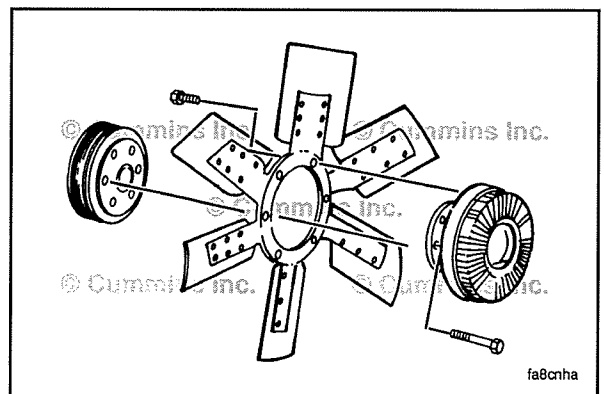
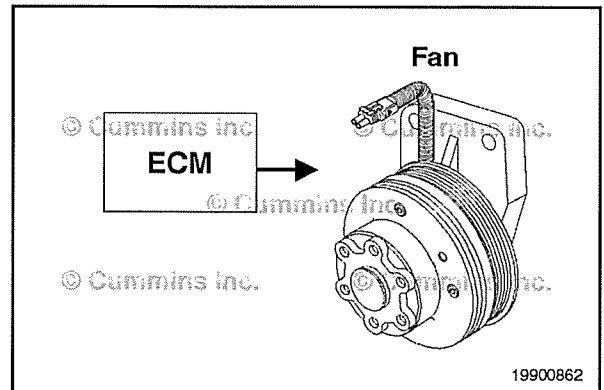
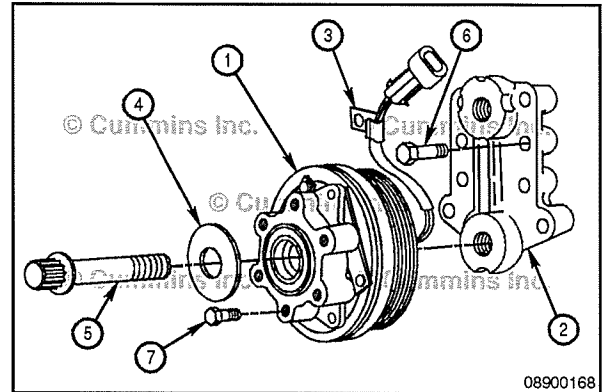
The ECM is capable of using a 0-VDC, 12-VDC, or 24-VDC signal to engage the fan clutch. The exact enable logic can be selected in the Features and Parameters section of INSITE™ electronic service tool.

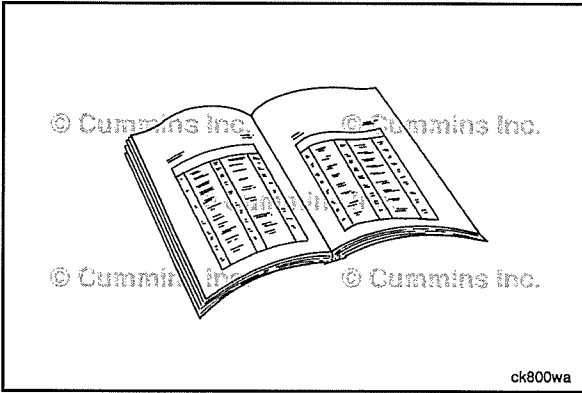
Reference the equipment manufacturer's service manual for fan clutch troubleshooting and repair information.

These are various fan clutch types such as:

- Air engaged
- Air disengaged
- Electric
- Viscous
- ON-OFF.

This procedure **only** applies to Cummins Inc. supplied electromagnetic fan clutches. For other fan clutches, reference the OEM service manual for all service related information.



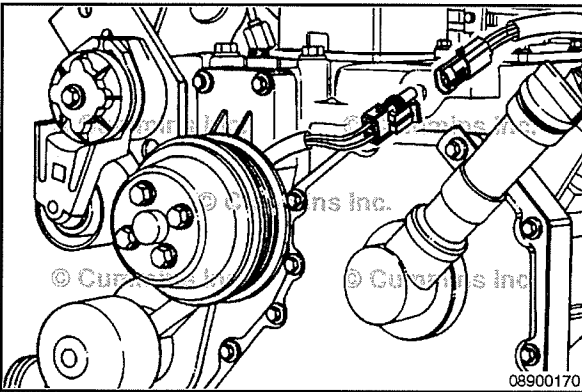


Preparatory Steps

⚠ WARNING ⚠

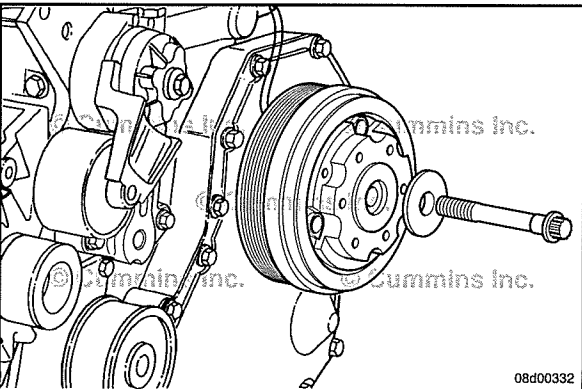
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the OEM service manual.
- Remove the cooling fan and spacers. Refer to the OEM service manual.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.



Remove

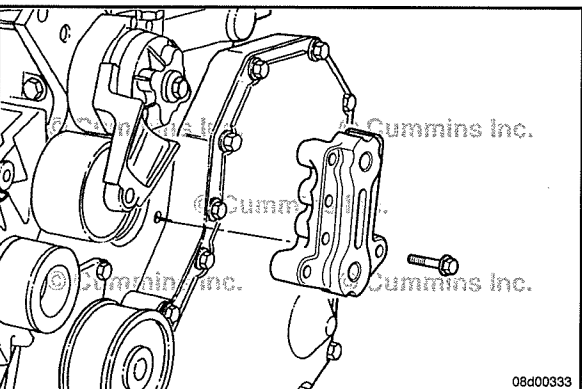
Disconnect the fan clutch connector on the base harness from the fan clutch.



NOTE: As the electric fan clutch mounting fastener is loosened, make sure to support the clutch.

NOTE: The electric fan clutch mounting capscrew has an external Torx™ head.

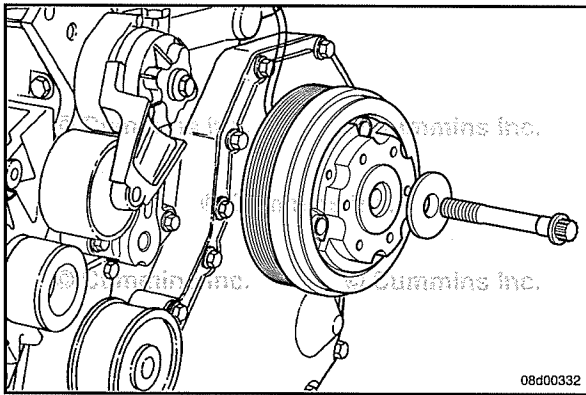
Remove the electric fan clutch mounting capscrew, washer, and electric fan clutch.



NOTE: Prior to removing the electric fan clutch support bracket, note the mounting location and orientation of the bracket. The mounting bracket can be installed in different orientations for different fan drive arrangements.

NOTE: Note the location of the P-clip for the electric fan clutch wiring harness pigtail.

Remove the electric fan clutch support bracket and mounting capscrews.



⚠ CAUTION ⚠

Correct loading of the fan clutch joint is necessary for proper cooling system operation. An over-torqued or under-torqued cap screw, caused by the use of air powered tools, an out-of-calibration wrench, or other methods could lead to significant damage to the front end accessory drive.

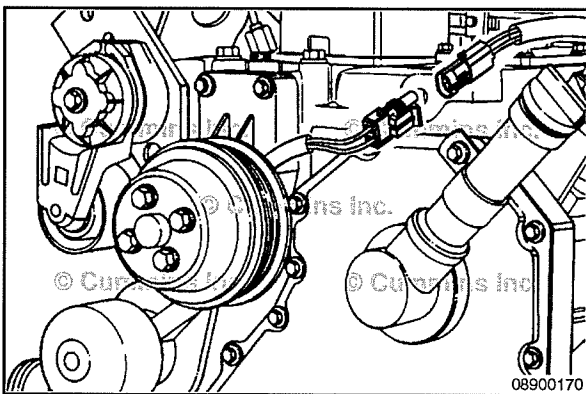
NOTE: The electric fan clutch mounting cap screw has an external Torx™ head.

Install the electric fan clutch, washer and mounting cap screw.

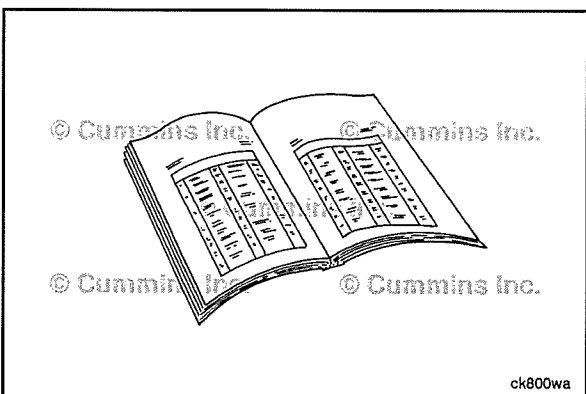
Prior to tightening the cap screw, rotate the fan clutch so that the wires coming out of the back of the fan clutch are captured by the P-clip. Bend the P-clip over by hand to secure the wires.

NOTE: Make sure that wires are **not** being pulled at the fan clutch.

Tighten the fan clutch mounting cap screw. Refer to the OEM service manual.



Connect the fan clutch connector on the base harness to the fan clutch.



Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Install the cooling fan and spacers. Refer to the OEM service manual.
- Connect the battery cables. Refer to the OEM service manual.

Fan Hub, Belt Driven (008-036)

General Information

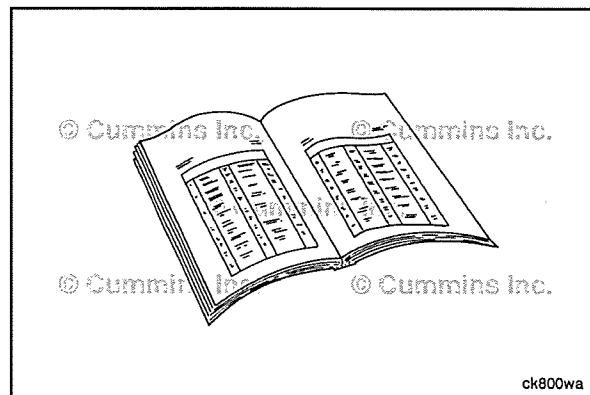
Several different fan hub mounting locations and fan hub options are available. The illustrations in this procedure are generic and may **not** represent the hardware on all engines.

Preparatory Steps

⚠ WARNING ⚠

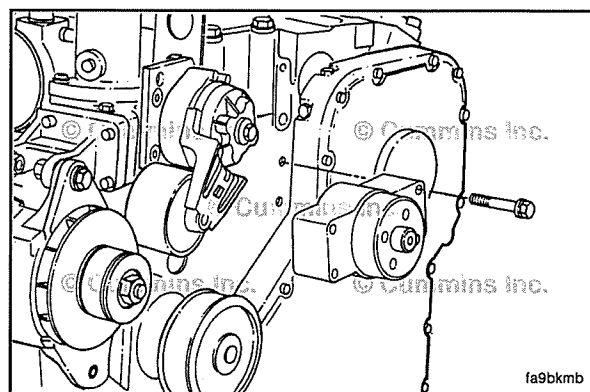
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- If necessary, remove the cooling fan. Refer to the OEM service manual.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the fan pulley and spacer. Refer to Procedure 008-039 in Section 8.



Remove

Remove the fan hub mounting capscrews.
Remove the fan hub.



Clean and Inspect for Reuse

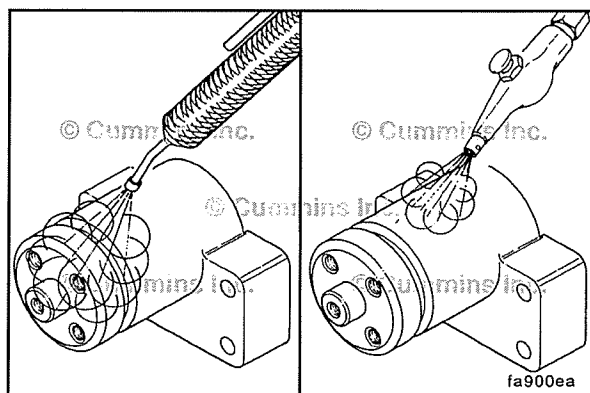
⚠ WARNING ⚠

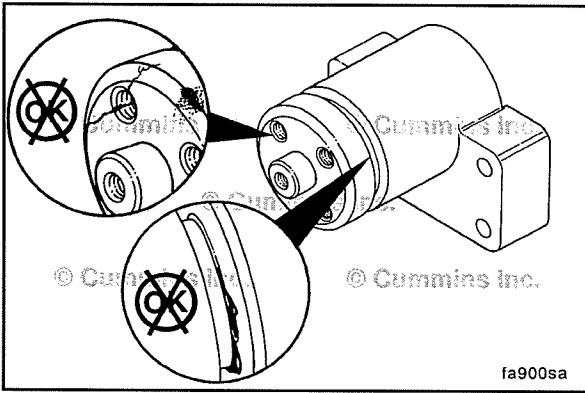
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ WARNING ⚠

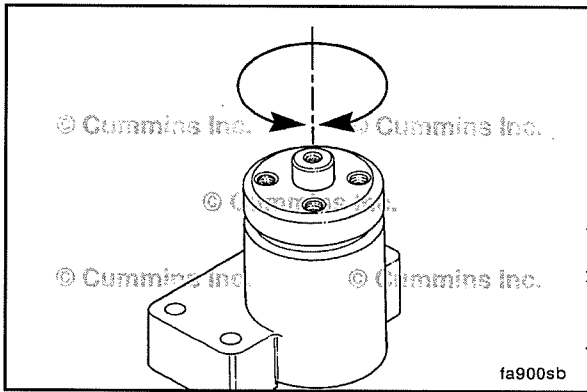
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Steam clean the exterior of the fan hub.
Dry with compressed air.

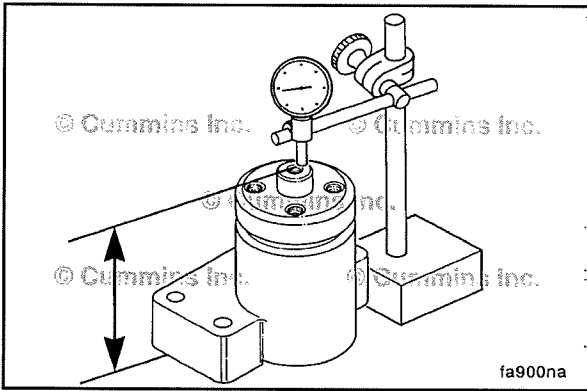




Inspect the fan hub for an indication of oil seal leakage.
Inspect the fan hub for cracks or damage.
Inspect the fan hub chamfer and pulley mating surface for damage.
Replace the fan hub if damage is found.



Turn the fan hub by hand to check for freedom of rotation.
The fan hub **must** spin freely without any wobble or excessive end clearance.

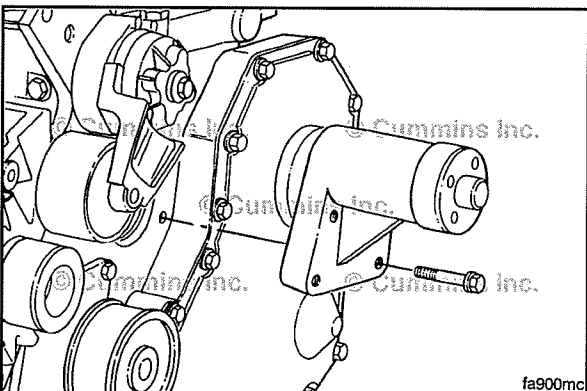


Inspect the fan hub bearing for wear.
The bearing **must** have a minimal amount of side-to-side or end clearance movement.
Replace the fan hub if there is more than 0.15 mm [0.006 in] of end clearance in the fan hub.

Fan Hub End Clearance

mm		in
0.15	MAX	0.006

NOTE: Some fan hub assemblies can be rebuilt with new bearings and related components. Check for part availability before disassembling the fan hub.



Install

Install the fan hub and capscrews.



Tighten the capscrews.

Torque Value:
M10 Grade 8.8 43 N•m [32 ft-lb]

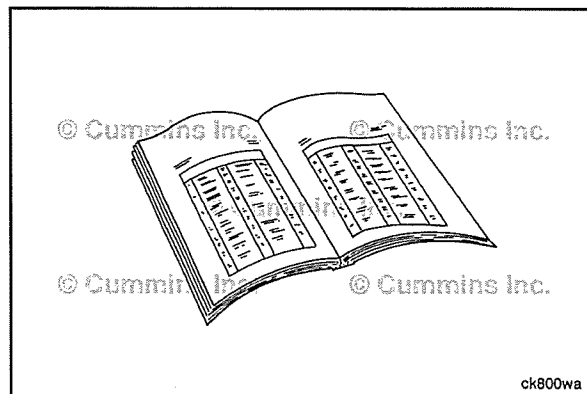
Torque Value:
M10 Grade 10.9 54 N•m [40 ft-lb]

Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the fan pulley and spacer. Refer to Procedure 008-039 in Section 8.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- If removed, install the cooling fan. Refer to the OEM service manual.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



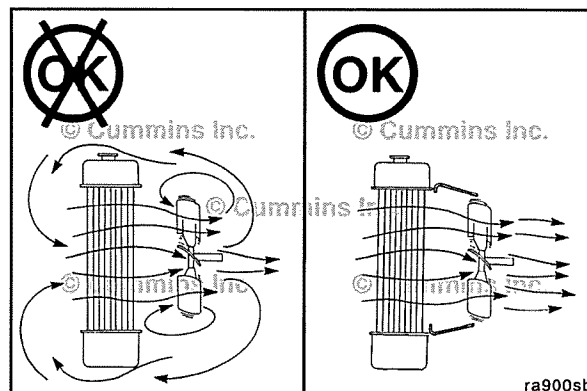
Fan Shroud Assembly (008-038)

General Information

The radiator or fan shroud is used to direct all air-flow across the radiator fins rather than around the edges of the radiator.

An incorrect fan shroud or obstructions can reduce air-flow and cause the engine to run hot.

NOTE: Check to be sure air is **not** recirculating. Check for missing baffles.

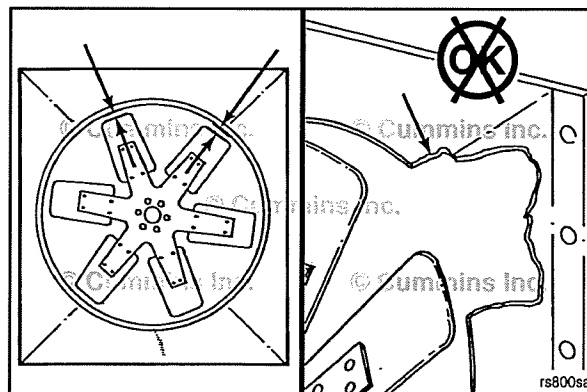


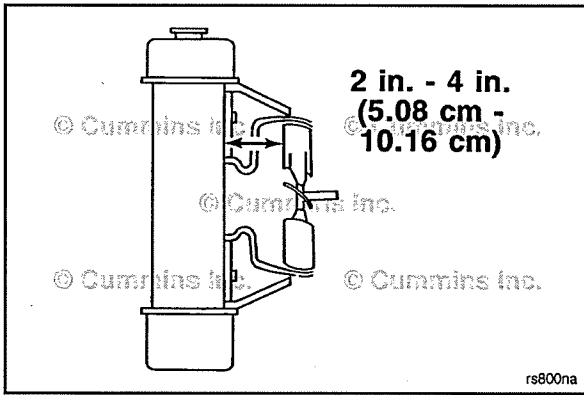
Initial Check

⚠ CAUTION ⚠

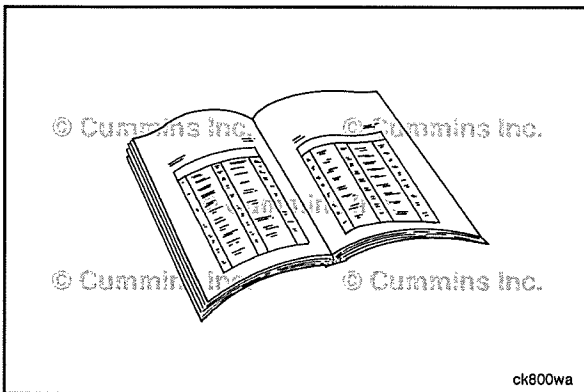
The fan shroud must be installed correctly, be in good condition, and the shroud-to-fan clearance must be within the manufacturer's specifications to allow proper airflow through the radiator to provide adequate engine cooling.

Inspect the fan shroud for proper fan clearance, cracks, air leaks, and damage. Replace if necessary. Refer to the original equipment manufacturer (OEM) service manual.





Cummins Inc. recommends that fan clearance be between 5.08 to 10.16 cm [2 to 4 in] from the radiator core. Refer to the OEM service manual for alternative positions.



Fan Spacer and Pulley (008-039) Preparatory Steps



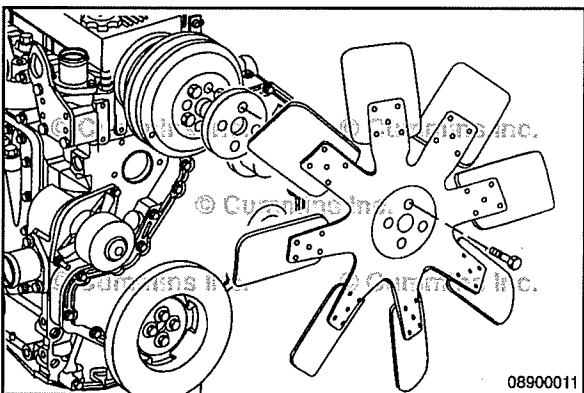
⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.

NOTE: Prior to removing the drive belt, loosen the fan pulley and cooling fan mounting capscrews, if equipped.

- Remove the fan drive belt. Refer to Procedure 008-002 in Section 8.



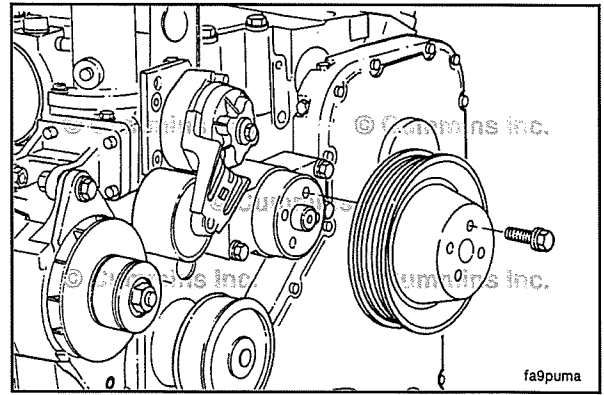
Remove

NOTE: Some applications do **not** have a cooling fan or the cooling fan is located elsewhere on the application.

If equipped, remove the cooling fan. Refer to the OEM service manual for instructions.

For engines equipped with an engine driven cooling fan, the fan holds the fan pulley and spacer in place. Remove the fan pulley and spacer.

If the engine is **not** equipped with an engine driven cooling fan, remove the fan pulley mounting capscrews and fan pulley.



Clean and Inspect for Reuse

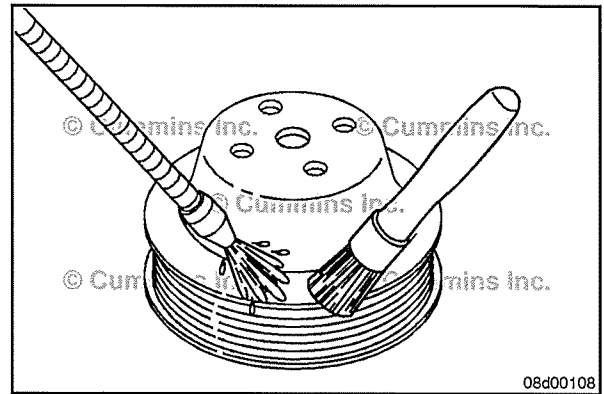
⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

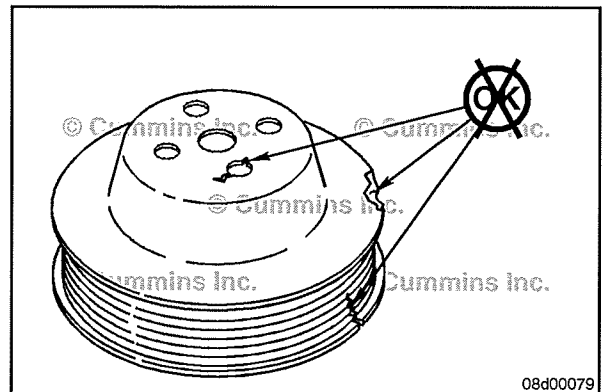
Clean the fan pulley and spacer with solvent and dry with compressed air.

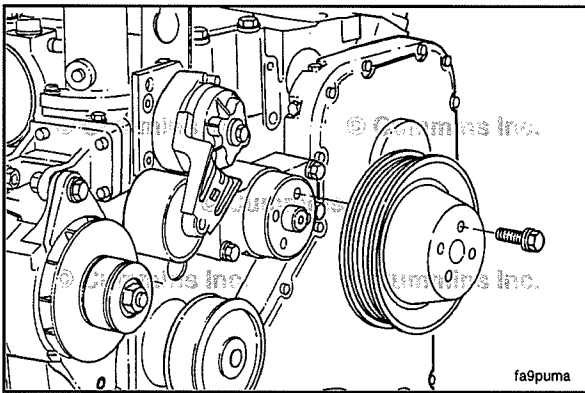


Inspect the fan pulley for cracks near the bolt holes and for damage at the drive belt contact surface.

If damage is found on the fan pulley, the fan hub **must** also be inspected. Refer to Procedure 008-036 in Section 8.

Replace the pulley if any damage is found.





Install

If the engine is **not** equipped with an engine driven cooling fan, install the fan pulley mounting capscrews and fan pulley.



Tighten the mounting capscrews finger-tight.

Tighten the mounting capscrews to the final torque value after the drive belt is installed, using the tension of the drive belt to keep the fan pulley from rotating.

Torque Value:

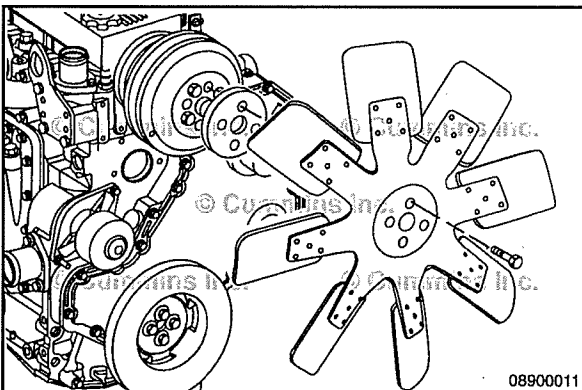
M6 10 N•m [89 in-lb]

Torque Value:

M10 43 N•m [32 ft-lb]

Torque Value:

M12 77 N•m [57 ft-lb]



For engines equipped with an engine driven cooling fan, the fan holds the fan pulley and spacer in place. Install the fan pulley and spacer.



If removed, install the cooling fan. Refer to the OEM service manual for instructions.

Tighten the mounting capscrews finger tight.

Tighten the mounting capscrews to the final torque value after the drive belt is installed, using the tension of the drive belt to keep the fan pulley from rotating.

Do **not** hold the fan blades to keep the fan pulley or cooling fan from rotating.

Torque Value:

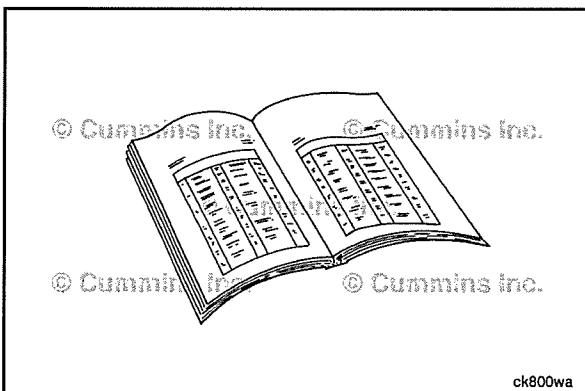
M6 10 N•m [89 in-lb]

Torque Value:

M10 43 N•m [32 ft-lb]

Torque Value:

M12 77 N•m [57 ft-lb]



Finishing Steps

⚠ WARNING ⚠



Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



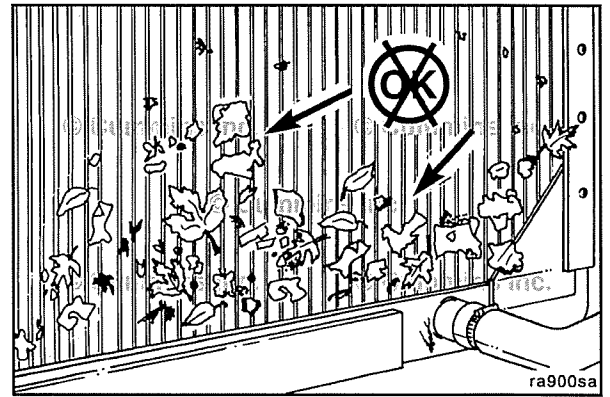
NOTE: Tighten the fan pulley and cooling fan mounting capscrews, if equipped.

- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for proper operation.

Radiator (008-042)

General Information

Air forced through the fins of the radiator by a fan cools the coolant pumped through the radiator. Environmental debris (such as paper, straw, lint, and dust) can obstruct the fins and stop the flow of air, which will reduce the cooling effect of the radiator.



Initial Check

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

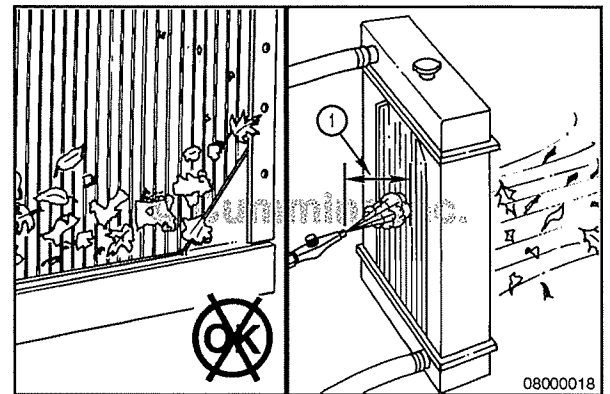
⚠ CAUTION ⚠

Keep the compressed air nozzle a minimum of 15cm [6 in] from the radiator core to avoid damaging the fins. See call out 1 in the illustration

Inspect for plugged radiator fins.

Use compressed air to blow out the dirt and debris.

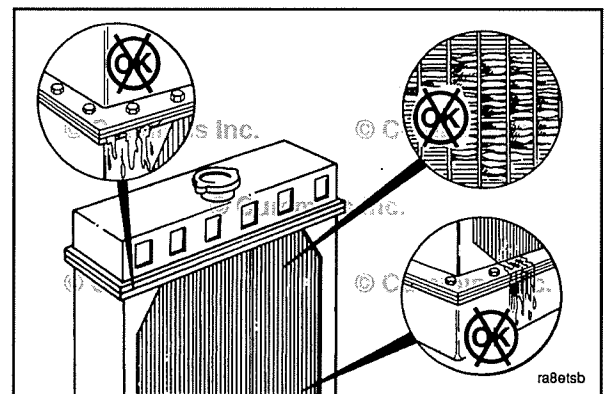
Air Pressure: 552 kPa [80 psi]

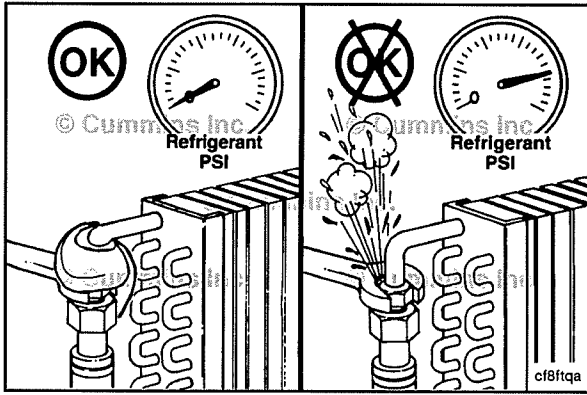


Inspect the radiator for bent or broken fins.

Inspect the radiator core and gasket for leaks.

If the radiator **must** be replaced, refer to the OEM service manual replacement procedures.





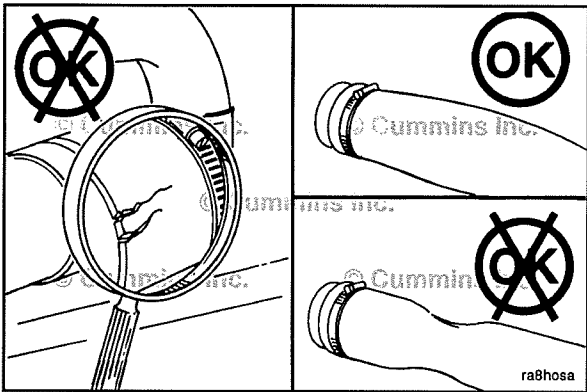
⚠ WARNING ⚠

If a liquid refrigerant system (air conditioning) is used, wear eye and face protection, and wrap a cloth around the fittings before removing. Liquid refrigerant can cause serious eye and skin injuries.

⚠ WARNING ⚠

To protect the environment, liquid refrigerant systems must be properly emptied and filled using equipment that prevents the release of refrigerant gas into the atmosphere. Federal law requires capturing and recycling the refrigerant.

Use care in removing the refrigerant system, if equipped, before removing the radiator.

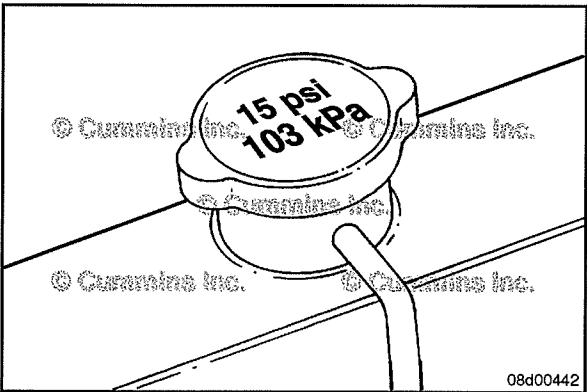


Radiator Hoses (008-045)

Inspect for Reuse

Inspect all hoses for cracks, cuts, or collapsing.

NOTE: The silicone engine coolant hose will exhibit swelling due to the elasticity of the hose.

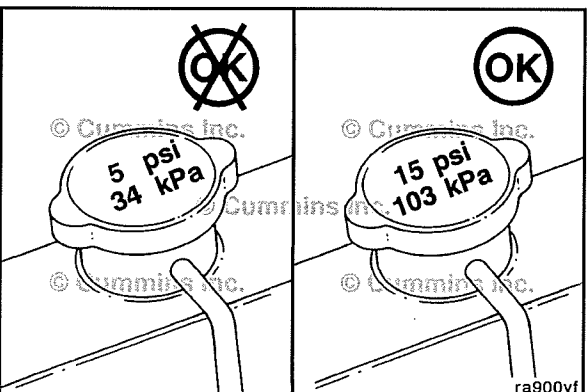


Radiator Pressure Cap (008-047)

General Information

The system is designed to use a pressure cap to prevent boiling of the coolant.

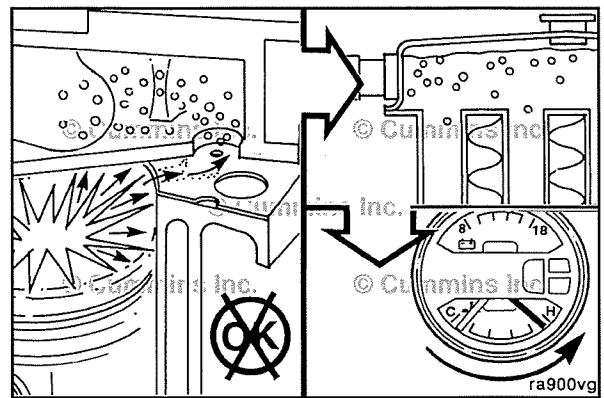
Radiator Cap Pressure Test	
System Temperature	Cap (Pressure Rating)
104°C [220°F]	103 kPa [15 psi]



An incorrect or malfunctioning cap can result in the loss of coolant and the engine running hot.

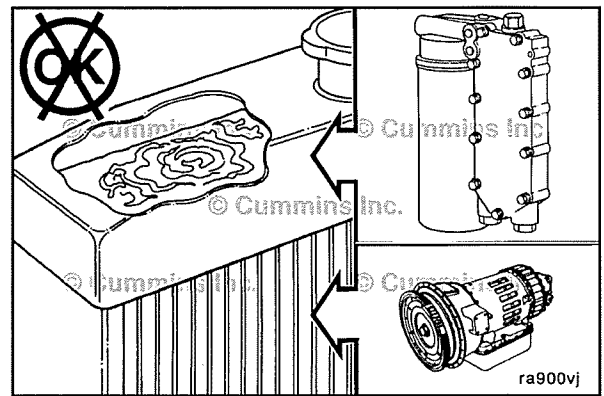
Air in the coolant can result in loss of coolant from the overflow when the aerated coolant is hot. The heated air expands, increasing the pressure in the system, causing the cap to open.

Similarly, coolant can be displaced through the overflow if the head gasket leaks compression gases into the cooling system.



The operating pressure of the cooling system and the lubricating system can result in the mixing of the fluids if there is a leak between the systems, such as the head gasket or oil cooler. Refer to Procedure 007-037 in Section 7.

NOTE: Transmission fluid can also leak into the coolant through radiator bottom tank transmission oil coolers.

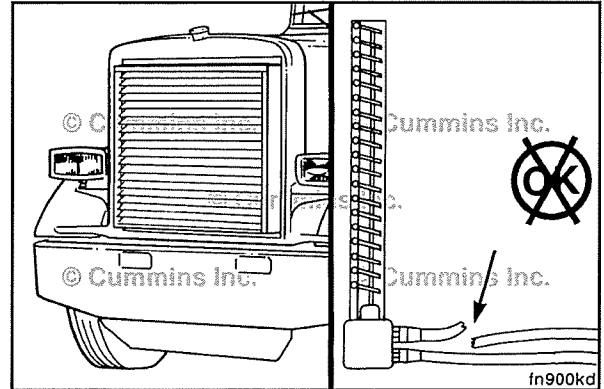


Radiator Shutter Assembly (008-049)

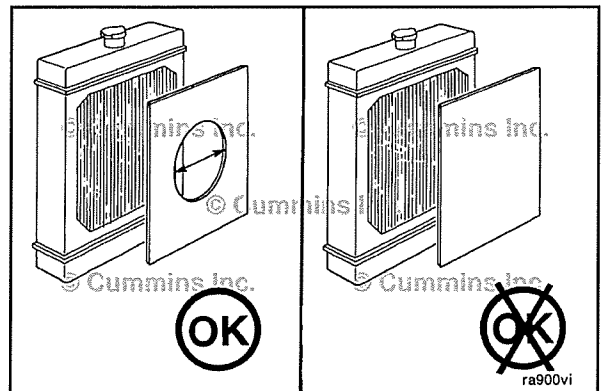
General Information

Shutters are designed to control air-flow across the radiator. If the shutters fail to open when needed, the engine can run hot. Failure of the shutters to close can result in too much air-flow and the engine running cold.

NOTE: Make sure that the air temperature sensor is functioning correctly. Check the air-operated shutter controls. Check for air leaks. Refer to the original equipment manufacturer (OEM) service manual.

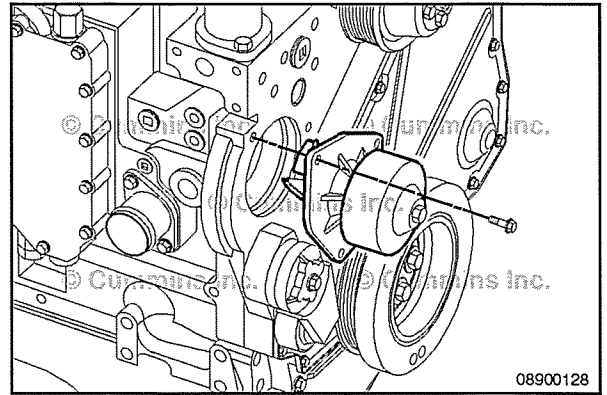


Winterfronts can be used on a charge air cooled engine, but **must** be designed to cover part of the frontal area of the cooling system. A minimum of 77419 sq mm [120 sq in] of charge air cooled frontal area **must** be left open to air-flow.



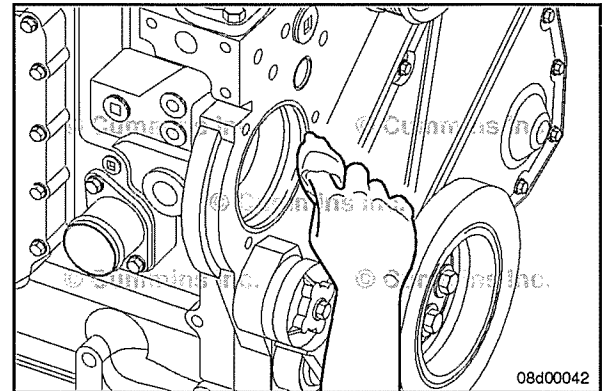
Remove

Remove the water pump capscrews and the water pump.



Clean and Inspect for Reuse

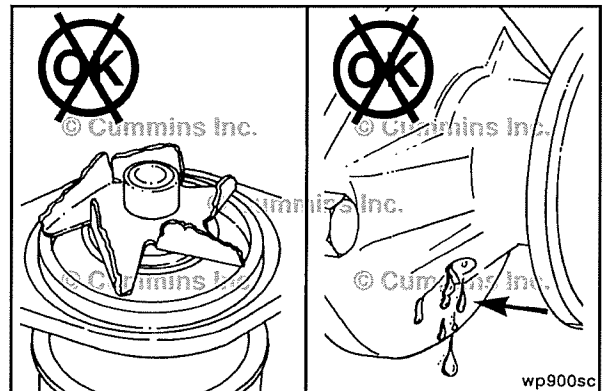
Clean the o-ring sealing surface on the water pump housing and the cylinder block.



Inspect the impeller for cracks, missing blades, slippage on the shaft, and other types of damage.

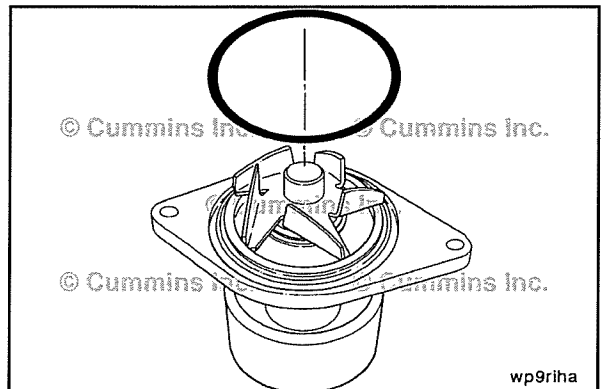
Inspect the water pump housing for cracks or other damage.

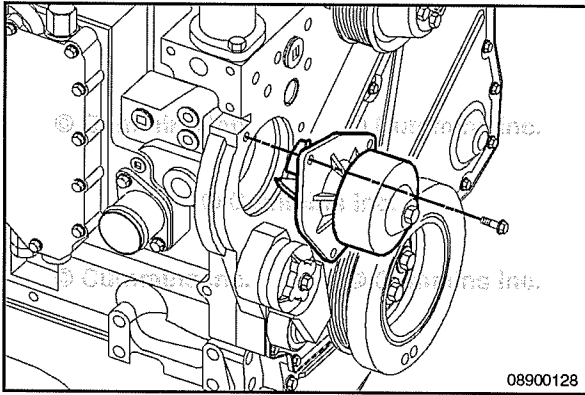
Replace the water pump if any damage is found.



Install

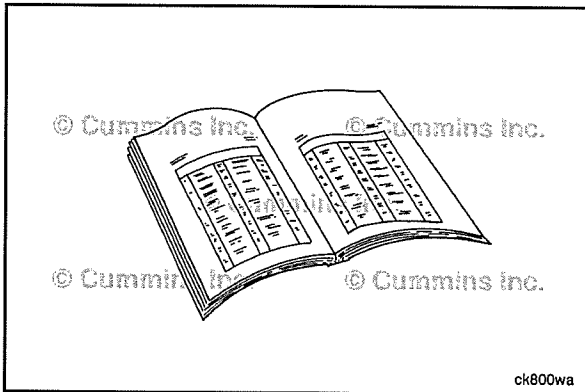
Install a new sealing ring into the groove in the water pump housing.





Install the water pump.

Torque Value: 30 N•m [22 ft-lb]



Finishing Steps

- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Torque Converter Cooler (008-065)

General Information

NOTE: For engines equipped with optional torque converter cooler.

Conventionally cooled engines with automatic transmissions typically use oil-to-water transmission torque converter coolers plumbed between the radiator and the engine water pump.

A torque converter cooling system with a remote bypass allows the torque converter to receive coolant flow when the thermostat is closed (engine cold, no flow through the radiator).

Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ WARNING ⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Disconnect the OEM torque converter plumbing as required. Refer to the OEM service manual.

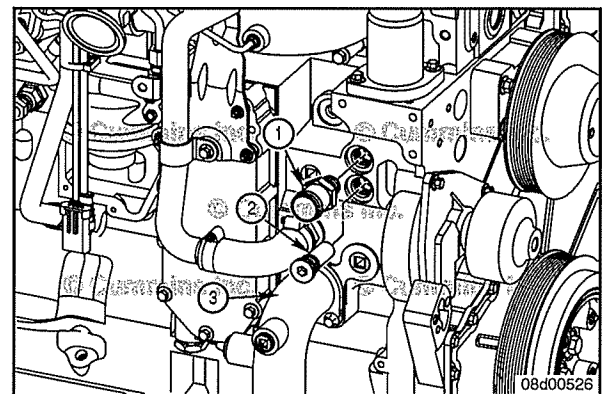
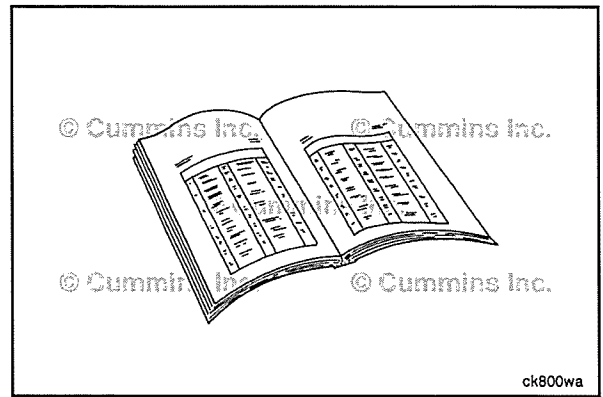
Remove

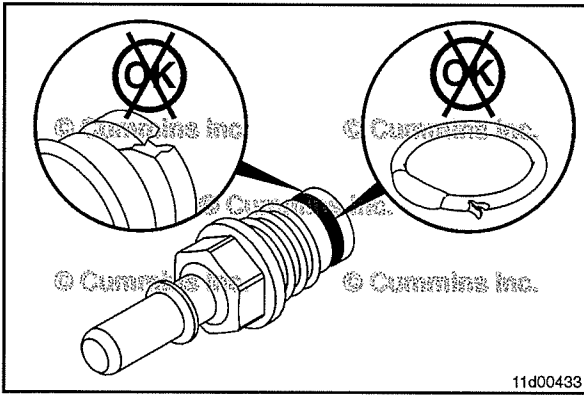
Remove the M22 x 1.5 fitting and plug the engine block coolant supply port.

Remove the torque converter coolant return fitting from the water inlet connection or radiator return. Location and size depends on the OEM. Refer to the OEM service manual.

NOTE: Make sure to note the orientation and location when removing any 90 or 45 degree coolant line fittings.

- 1 M22 x 1.5 fitting (supply port)
- 2 M22 plug
- 3 Water inlet connection.





Clean and Inspect for Reuse



⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠ WARNING ⚠

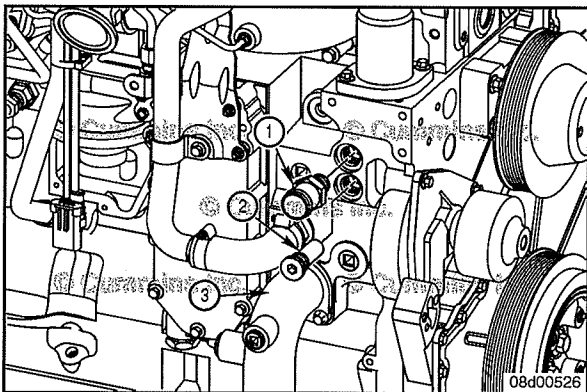
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the fittings with a cleaning solvent.

Dry with compressed air.

Inspect the fittings for cracks, corrosion, and other damage.

If a part is damaged it **must** be replaced.



Install

⚠ CAUTION ⚠

The fitting and plug must be installed in the proper locations. The plug blocks off the thermostat bypass. Do not install the plug upstream of the torque converter cooler supply fitting. Doing so blocks off coolant flow to both the thermostat bypass and the torque converter cooler, severe engine damage can occur.

Apply a film of pipe sealant, Part Number 3375066 or equivalent, to the threads of the M22 fitting and plug.

Install the M22 x 1.5 fitting and plug into the engine block coolant supply port

Torque Value: 60 N•m [44 ft-lb]

Apply a film of pipe sealant, Part Number 3375066 or equivalent, to the threads of the torque converter coolant return fitting.

Install the torque converter coolant return fitting into the water inlet connection or radiator return. Location and size depends on the OEM. Refer to the OEM service manual.

Use the following procedure for torque values on various fittings sizes. Refer to Procedure 017-011 in Section 17.

NOTE: When installing any 90 or 45 degree coolant line fittings, make sure to maintain proper orientation while tightening.

- 1 M22 x 1.5 fitting (supply port)
- 2 M22 plug
- 3 Water inlet connection.

Finishing Steps

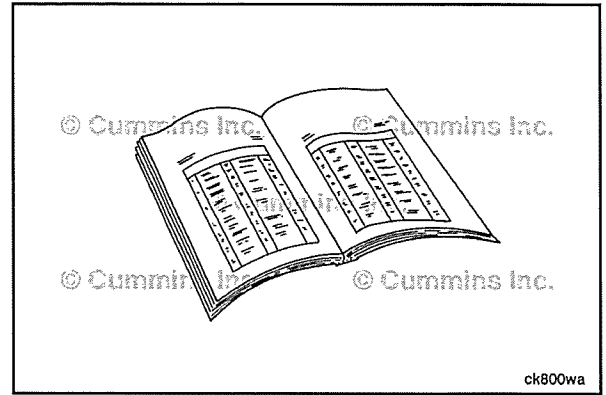
⚠️ WARNING ⚠️

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠️ CAUTION ⚠️

Always vent the engine during filling to remove air from the coolant system, or overheating can result.

- Connect the OEM torque converter plumbing as required. Refer to the OEM service manual.
- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Belt Tensioner, Automatic (Water Pump) (008-080)

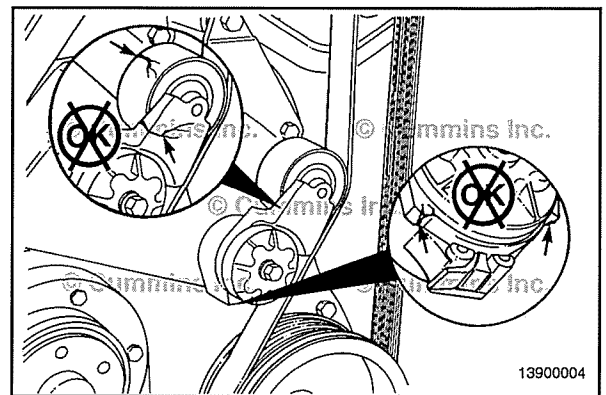
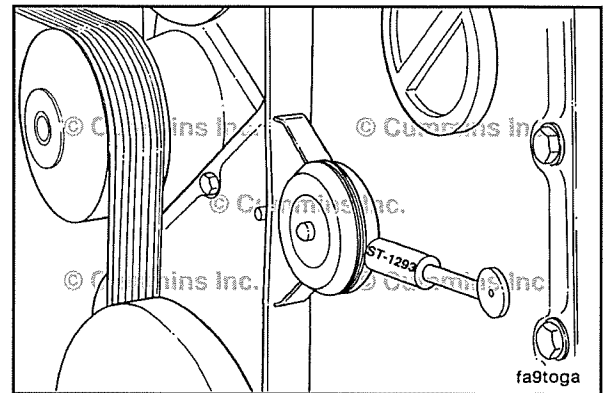
Initial Check

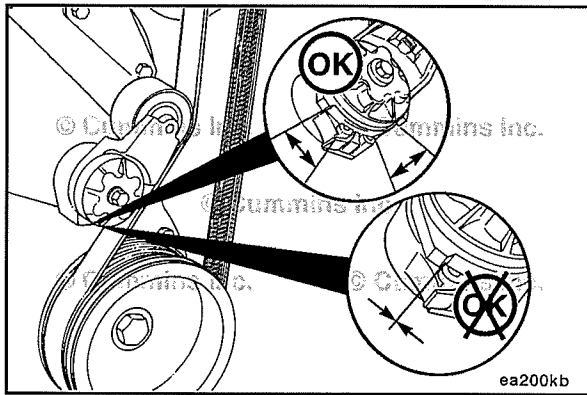
Use belt tensioner gauge, Part Number ST-1293, to measure the tension in the drive belt.

Belt Tension		
N		lbf
356	MIN	80
534	MAX	120

If the measurement is out of the specified range, replace **only** the belt and perform the tension test again. If the measurement is still outside of the specified rang after the new belt has been installed, replace the belt tensioner.

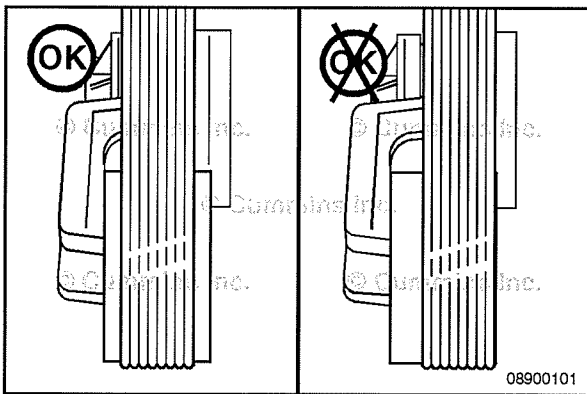
Check the tensioner arm, pulley, and stops for cracks. If any cracks are observed, the tensioner **must** be replaced.





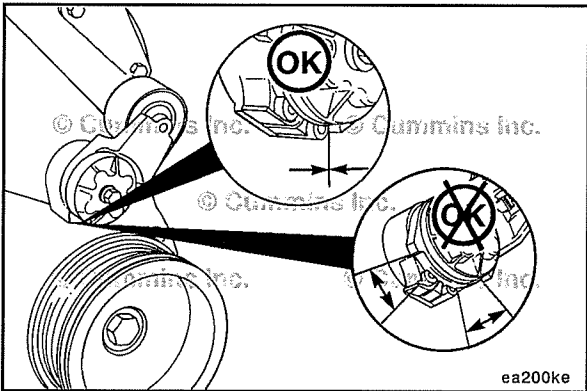
With the belt installed, verify that neither tensioner arm stop is in contact with the spring casing stop. If either stop is touching, replace the drive belt. Refer to Procedure 008-002 in Section 8.

After replacing the belt, if the tensioner arm stops are still in contact with the spring case stop, replace the tensioner.



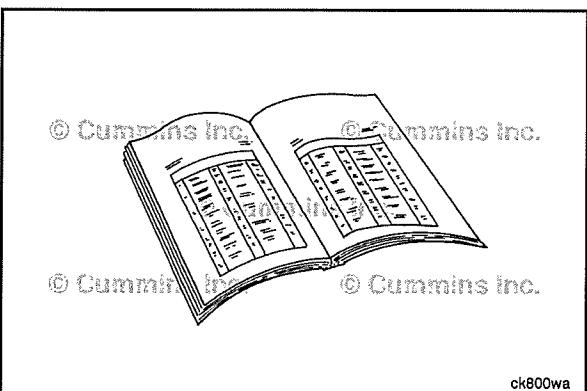
Check the location of the drive belt on the belt tensioner pulley. The belt **must** be centered on, or close to the middle of, the pulley. Misaligned belts, either too far forward or backward, can cause belt wear, belt roll-off failures, or increase uneven tensioner bushing wear.

Belt mis-alignment is **not always** a result of a malfunctioning or faulty belt tensioner. Make sure the adjacent pulleys and mounting brackets are aligned and mounted correctly. Refer to Procedure 008-002 in Section 8.



Remove the drive belt. Refer to Procedure 008-002 in Section 8.

With the belt removed, verify that the tensioner arm stop is in contact with the spring case stop. If they are **not** touching, the tensioner **must** be replaced.



Preparatory Steps

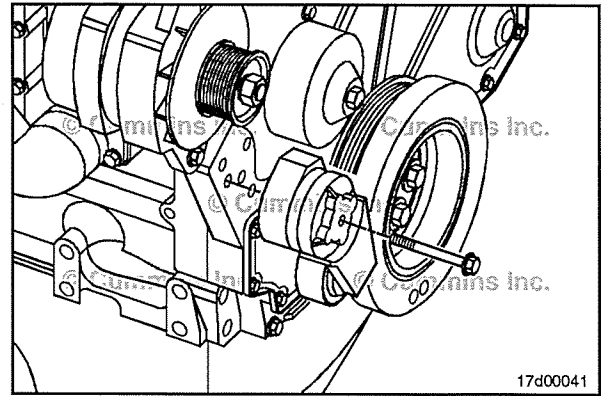
⚠ WARNING ⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.

Remove

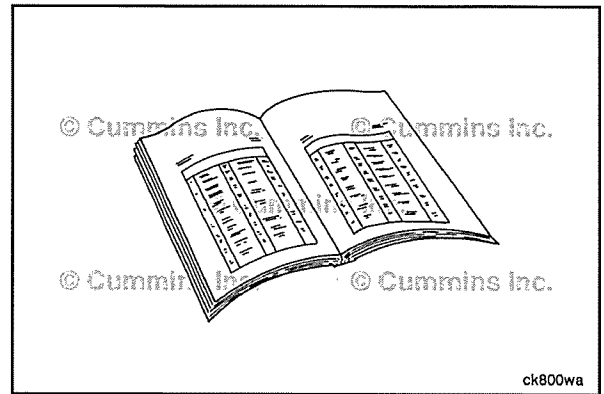
Remove the capscrew and belt tensioner from the bracket.

NOTE: Most belt tensioners are mounted to the water inlet connection. Some belt tensioners are mounted to a separate mounting bracket and use internal fasteners for clearance.



Inspect for Reuse

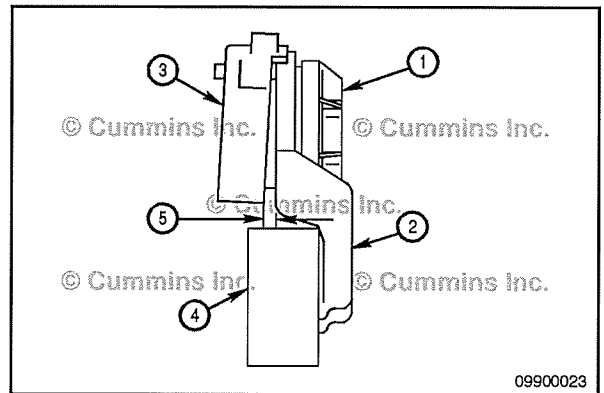
Inspect the cooling fan drive belt for reuse. Refer to Procedure 008-002 in Section 8.



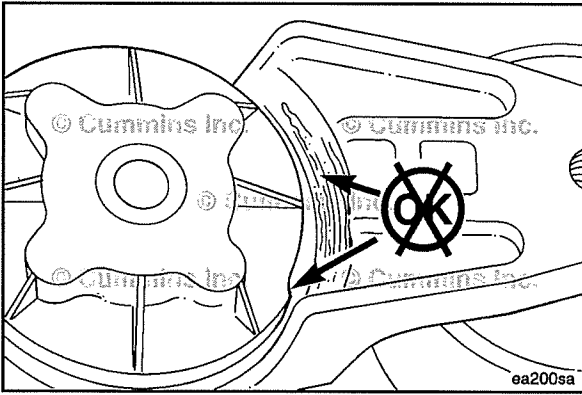
Measure the clearance between the tensioner spring case and the tensioner arm to verify tensioner wear-out and uneven bearing wear. If the clearance at the measurement point 5 exceeds 3 mm [0.12 in], the tensioner is damaged and **must** be replaced as a complete assembly.

Tensioners generally will show a larger clearance gap near the lower portion of the spring case, resulting in the upper portion rubbing against the tensioner arm.

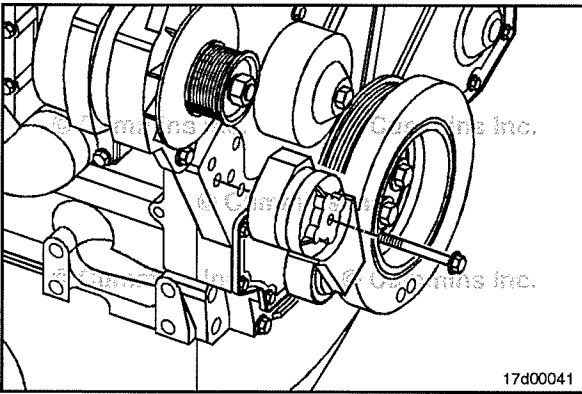
- 1 Tensioner cap
- 2 Tensioner arm
- 3 Spring case
- 4 Tensioner pulley
- 5 Clearance gap.



NOTE: Always replace the belt when a tensioner is replaced. However, it is **not always** necessary to replace a tensioner when a belt is replaced.



Inspect the tensioner for evidence of the tensioner arm contacting the tensioner cap. If there is evidence of the two areas making contact, the pivot tube bushing has failed and the tensioner **must** be replaced.



Install

If removed, install the belt tensioner mounting bracket and mounting bracket capscrews.

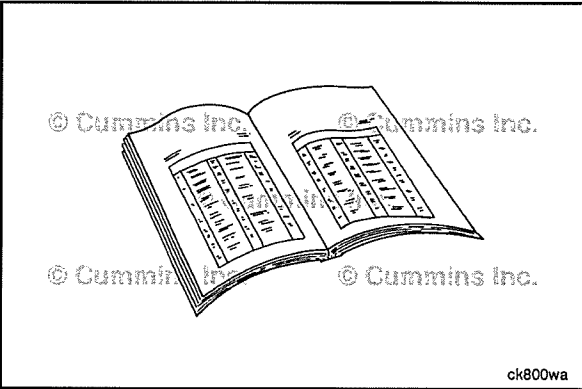


NOTE: Some belt tensioner mounting brackets use internal fasteners for clearance.

Torque Value: 24 N•m [212 in-lb]

Install the belt tensioner and capscrew.

Torque Value: 43 N•m [32 ft-lb]



Finishing Steps

▲ WARNING ▲



Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for proper operation.

Water Inlet Connection (008-082)

Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ WARNING ⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

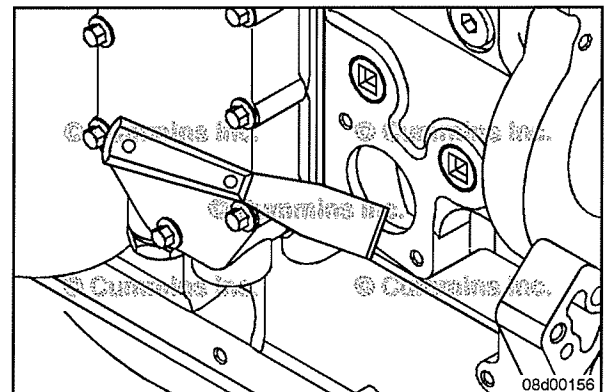
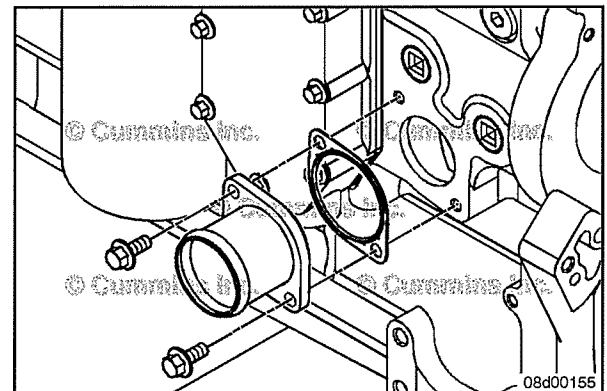
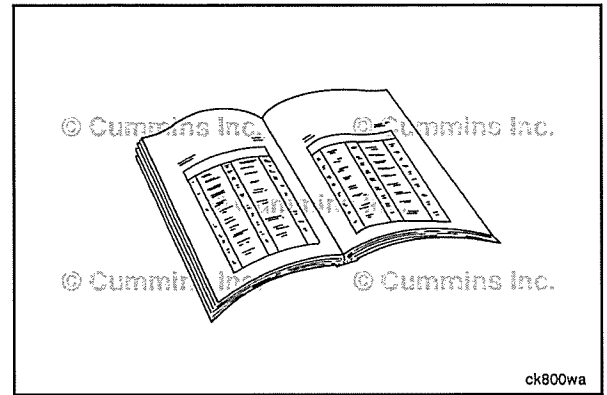
- Disconnect the battery cables. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Disconnect the water inlet connection. Refer to Procedure 008-082 in Section 8.

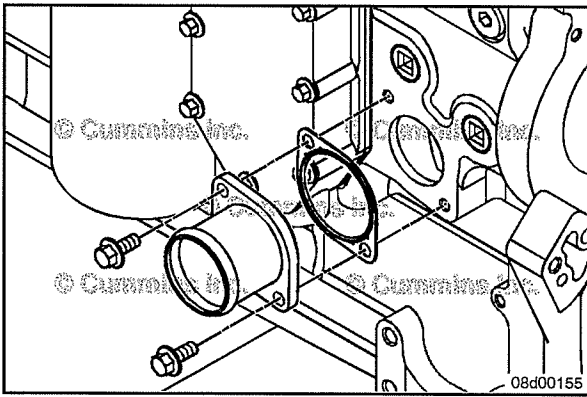
Remove

Remove the water inlet connection capscrews.

Clean and Inspect for Reuse

Clean all of the mating surfaces.





Install

Install a new water inlet connection gasket.

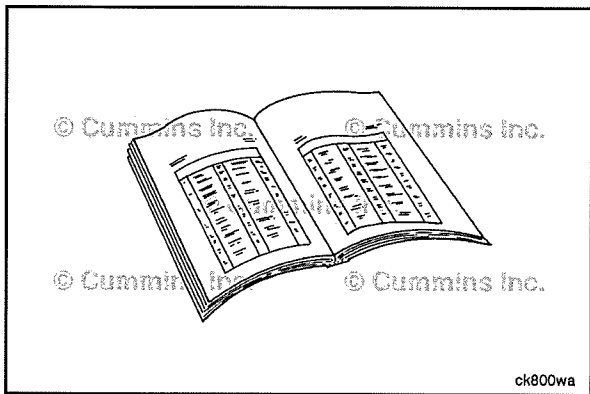


Install the water inlet connection and mounting capscrews.



NOTE: Use pipe plug sealant, Part Number 3375066, or equivalent, to install any OEM coolant fittings removed from the water inlet connection.

Torque Value: 24 N•m [212 in-lb]



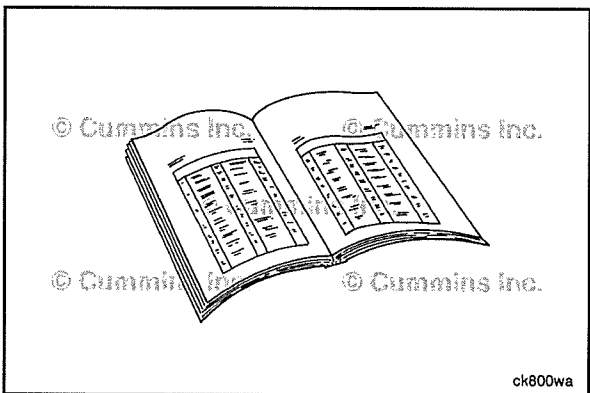
Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Connect the water inlet connection. Refer to Procedure 008-082 in Section 8.
- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Coolant Plumbing (008-124)

General Information



General Information

The purpose of this procedure is to explain how to install and remove the selective catalytic recirculation (SCR) coolant fittings that connect to the engine block.

The location and size of these fittings could possibly vary from original equipment manufacturer (OEM) to OEM. Refer to OEM service manual for detailed information.

Generally, the SCR coolant supply port is located at the rear of the engine block at the top side, and the SCR coolant return port is located at the water inlet connection.

Preparatory Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ WARNING ⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the batteries. Refer to the OEM service manual.
- Drain the cooling system. Refer to Procedure 008-018 in Section 8.
- Disconnect the OEM SCR coolant plumbing as required. Refer to the OEM service manual.

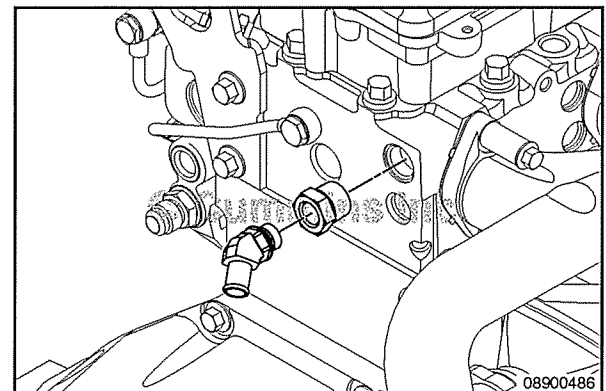
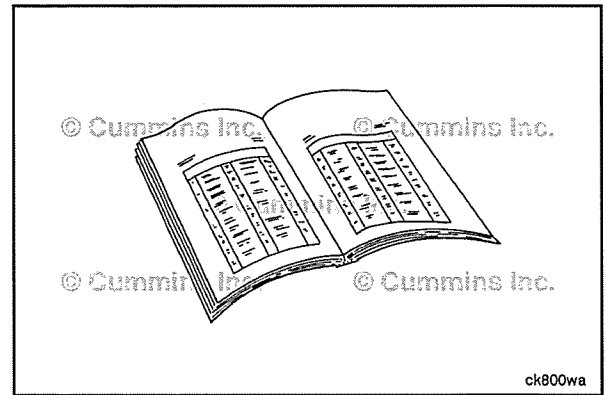
Remove

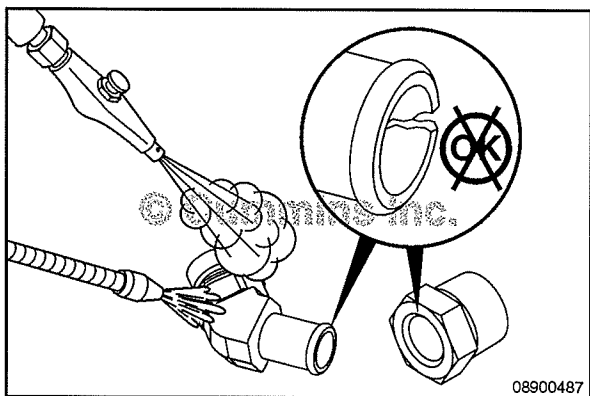
NOTE: This step applies to the removal of SCR coolant plumbing fittings.

NOTE: Make sure to check proper orientation and location when removing any 90 or 45 degree coolant line fittings.

Remove the 3/4 - 14 National Pipe Thread Fitting (NPTF) fitting from the engine block SCR coolant supply port.

Remove the SCR coolant return fitting. The location and size depends on the OEM. Refer to the OEM service manual.





Clean and Inspect for Reuse

⚠ WARNING ⚠

When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ WARNING ⚠

Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠ WARNING ⚠

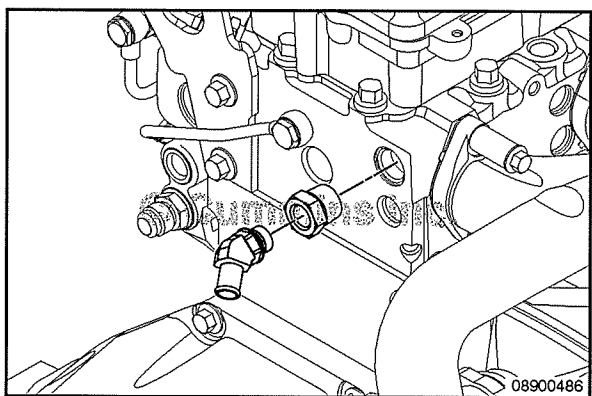
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the fittings with a cleaning solvent.

Dry with compressed air.

Inspect the fittings for cracks, corrosion, or other damage.

If the part is damaged, the part **must** be replaced.



Install

NOTE: This step applies to the installation of the SCR coolant plumbing fitting.



NOTE: When installing any 90 or 45 degree coolant line fittings, make sure proper orientation is maintained while tightening.



Apply a film of pipe sealant, Part Number 3375066, or equivalent, to threads of the 3/4 - 14 NPTF fitting.

Install the 3/4 - 14 NPTF fitting into the engine block SCR coolant supply port.

Torque Value: 75 N•m [55 ft-lb]

Apply a film of pipe sealant, Part Number 3375066, or equivalent, to the threads of the SCR coolant return fitting.

Install the SCR coolant return fitting. Location and size depends on the OEM. Refer to the OEM service manual for detailed information.

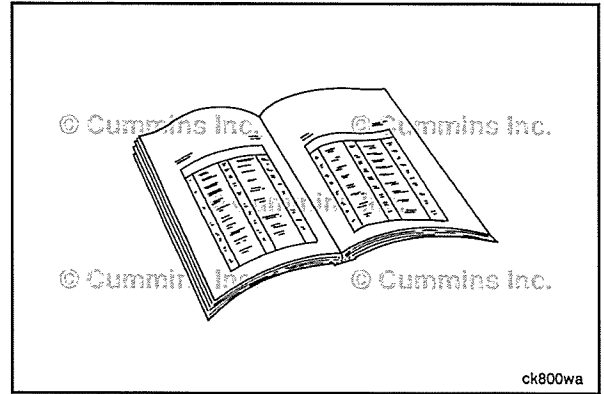
Use the following procedure for proper torque values on various fitting sizes. Refer to Procedure 017-007 in Section 17.

Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the OEM SCR coolant plumbing as required. Refer to the OEM service manual.
- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.



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