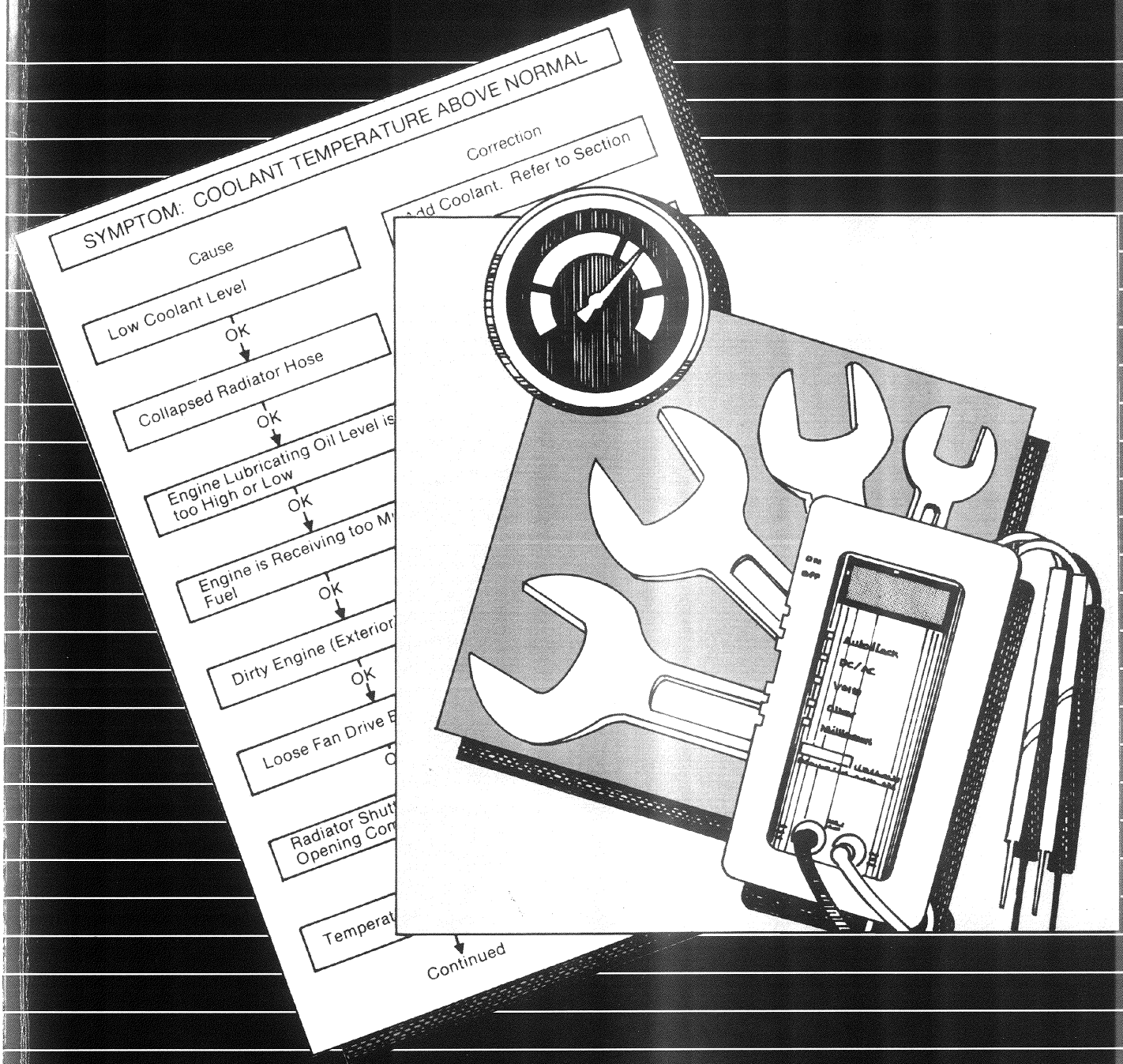
Service Manual
QSF3.8 CM2350 F107
Volume 1



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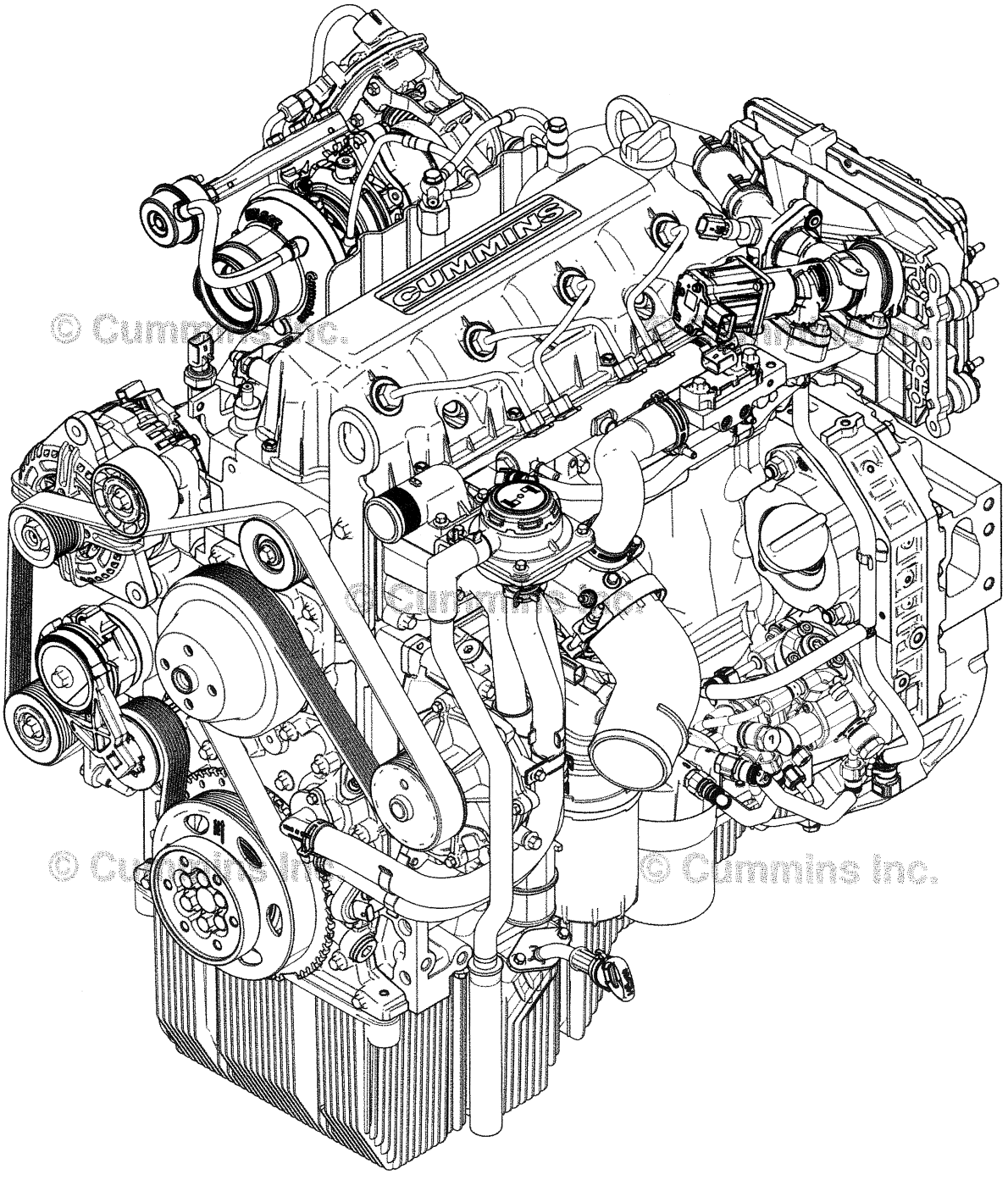

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Foreword

This manual contains instructions for troubleshooting and repairing this engine in the chassis, complete rebuild procedures and specifications. Disassembly, cleaning, inspection, and assembly instructions are included. A listing of accessory and component suppliers is located in Section M - Component Manufacturers. Suppliers can be contacted directly for any information not covered in 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.

The repair procedures in this manual are based on the engine or component removed from chassis. Some rebuild procedures require the use of special service tools. Make sure the correct tools are used as described in the procedures.

When a specific brand name, number, or special tool is referenced in this manual, an equivalent product can be used in place of the recommended item.

A series of specific service manuals (for example: Troubleshooting and Repair, 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).

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 is 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.

Table of Contents

Section i - Introduction

Section Contents

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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 enviromental governing agency.

Symbols

General Information

The 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.

NOTE: It is possible to have four symbols for each text and graphic combination.

⚠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, and assembly, or the engine can be damaged if the caution instructions are not followed.

Indicates a **REMOVAL** or **Dissassembly** 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**.

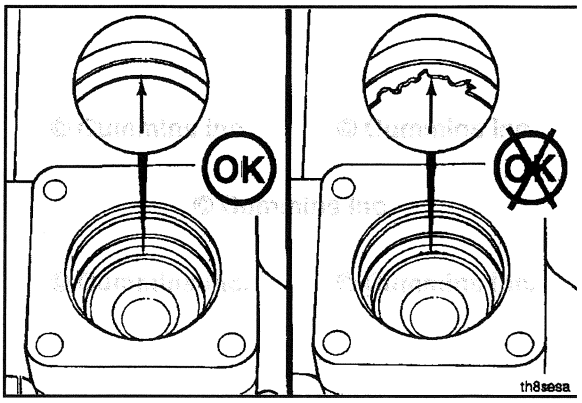
Refer to another location in this manual or another publication for additional information.

The component weighs 23kg [50 lbs] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift the component.

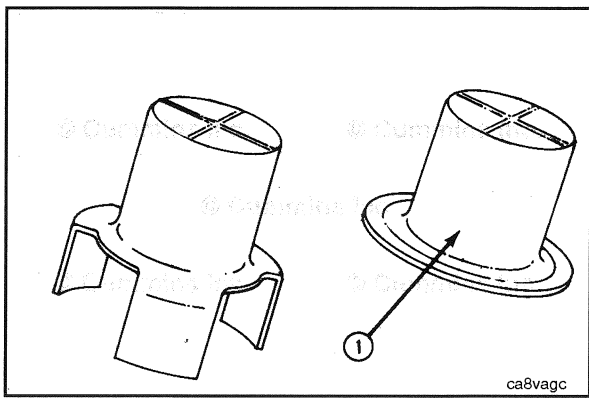
Illustrations

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

⚠WARNING⚠

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 be 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 o 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 connec 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.

⚠WARNING⚠

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

⚠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.

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.

△CAUTION△

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.

△CAUTION△

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** sure 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 Indentifier
GVW	Gross Vehicle Weight
Hg	Mercury
hp	Horsepower
H_2O	Water
inHg	Inches of Mercury
in H_20	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

Section Contents

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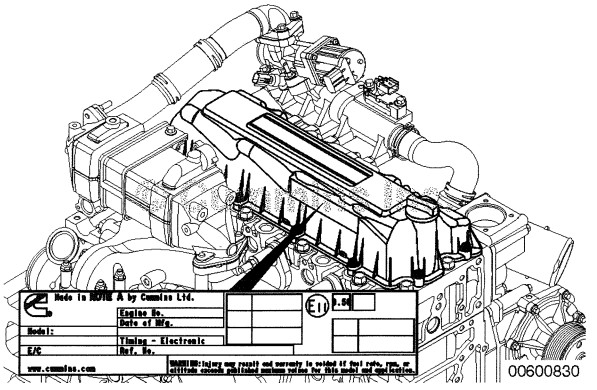
Engine Identification

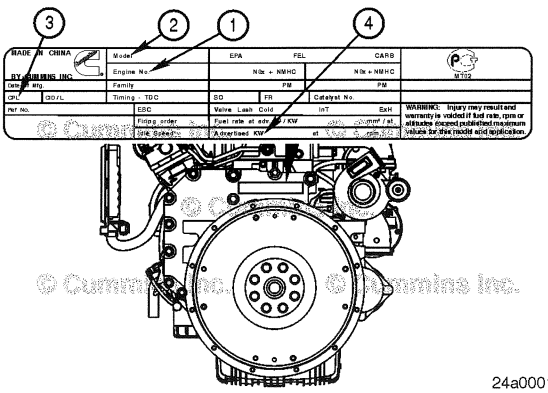
General Information



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.

NOTE: The dataplates used on engines can differ in appearance and location of information. The following illustrations show examples of common dataplates used and the information contained on these dataplates.

The engine dataplate shows specific facts about an engine. The dataplate is typically located on the engine rocker lever cover, but can also be located on the side of the gear housing. The engine serial number and control parts list (CPL) provide data for ordering parts and service. The engine dataplate **must not** be changed unless approved by Cummins Inc.



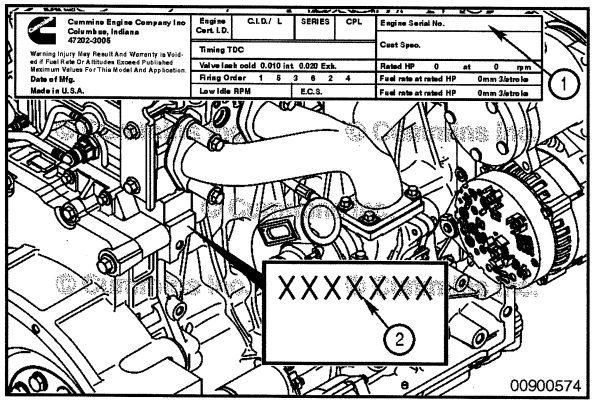
There are four possible dataplates that can be found on the engine rocker lever cover, but can also be located on the side of the gear housing. They contain the following information:

1 Engine serial number

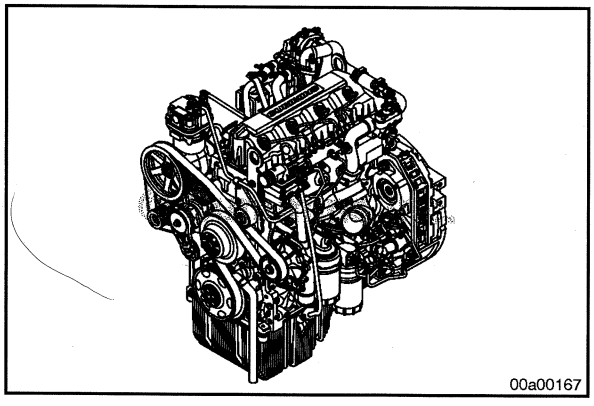
2 Engine model information

3 Control parts list

4 Horsepower and rpm rating.



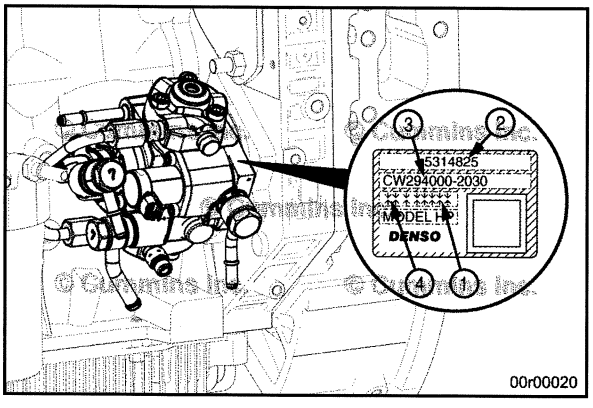
NOTE: If the engine dataplate (1) is **not** legible, the engine serial number (2) can be identified on the engine block. It is located on the exhaust side, next to the rear gear housing. Additional engine information is available by reading the engine control module (ECM) dataplate.



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.

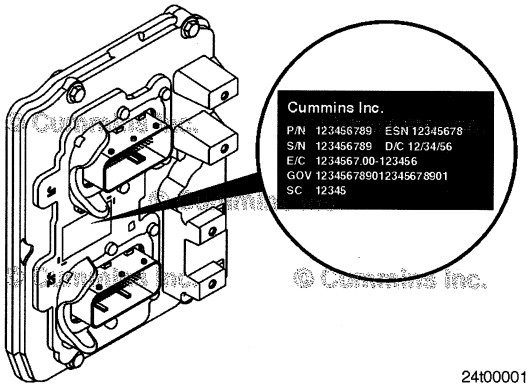


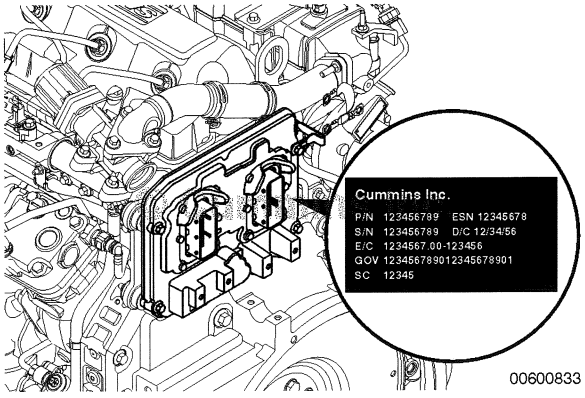
Fuel Pump Dataplate

The Denso™ fuel pump dataplate is located on the fuel pump. This dataplate contains the following information to assist in servicing or replacement:

1 Customer part number
2 Denso™ part number
3 Production month serial number
4 Customer's certification number
5 QR code.

Engine Control Module Dataplate



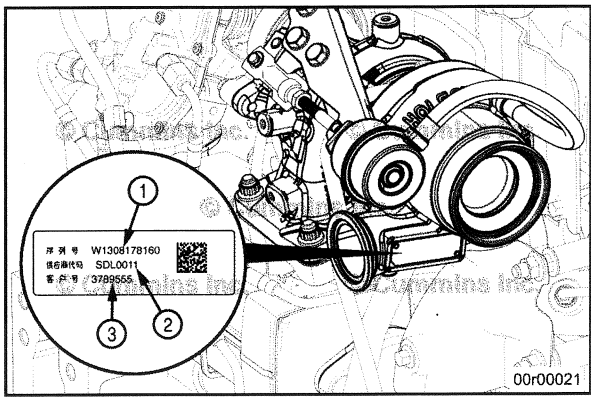


NOTE: Not all engines have ECM dataplates.

Engines covered by this manual are equipped with a CM2350 ECM. A CM2350 ECM has two 96-pin connectors. One of the 96-pin connectors is for engine inputs and outputs **only**. The second 96-pin connector and 14-pin connector are for aftertreatment and vehicle inputs and outputs

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.

Turbocharger Dataplate



The Holset® turbocharger dataplate is located on the turbocharger inlet compressor housing.

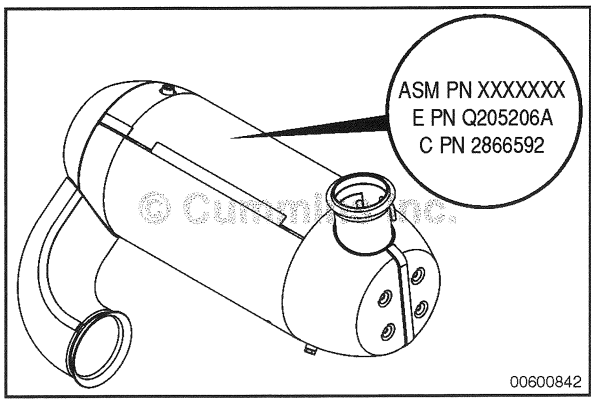
The dataplate contains the following information to assist in servicing or replacement.

1 Serial number

2 Supplier code

3 Customer number.

Exhaust System



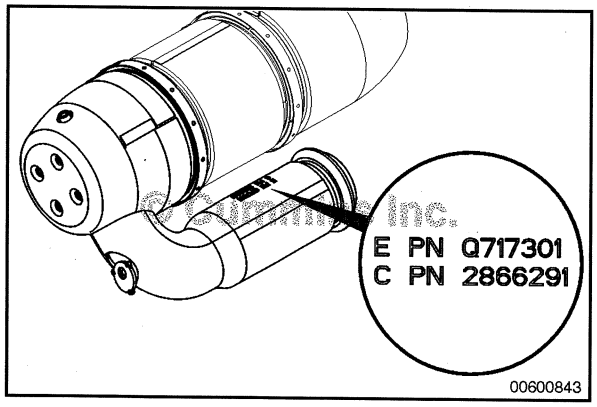
The aftertreatment selective catalytic reduction (SCR) catalyst identification is located on the side of the assembly and contains the following information to assist in servicing or replacement.

1 Assembly part number

2 Cummins Emission Solutions™ part number

3 Cummins® part number.

NOTE: Some aftertreatment components.may **only** have the Cummins Emission Solutions™ part number. For cross referencing and part number identification, reference QuickServe™ Online.

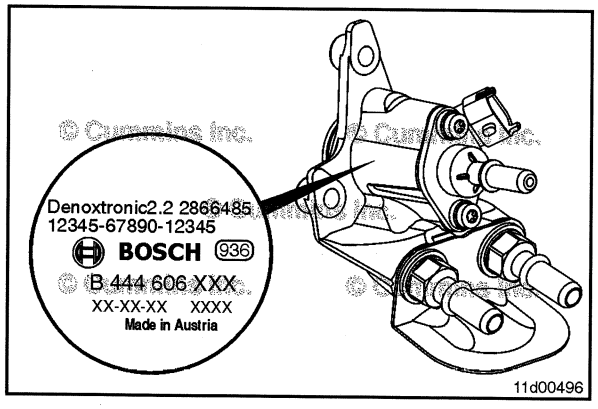


The aftertreatment decompostion tube identification is located on the side of the tube and contains the following information to assist in servicing or replacement.

1 Cummins Emission Solutions™ partnumber

2 Cummins® part number.

NOTE: Some aftertreatment components.may only have the Cummins Emission Solutions™ part number. For cross.referencing and part number identification, reference QuickServe™ Online.



The aftertreatment diesel exhaust fluid dosing (DEF) valve identification is located on the side of the valve and contains the following information to assist in servicing or replacement.

1 Cummins® part number

2 Cummins Emission Solutions™ partnumber

3 Bosch™ part number

4 Bosch™ production data (data code,serial number).

Example:

- 2866485 is the Cummins® part number
- 12345-67890-12345 is the location for 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 can have **only** the Cummins Emission Solutions™ part number. For cross referencing and part number identification, reference QuickServe™ Online.

The aftertreatment DEF dosing unit identification is located on the side of the unit and contains the following information to assist in servicing or replacement.

1 Cummins Emission Solutions™ partnumber

2 Cummins® part number

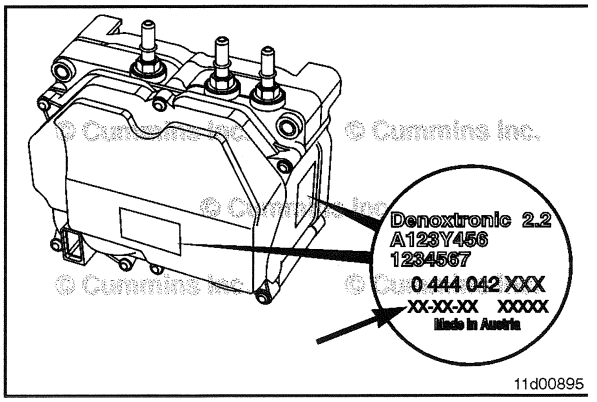
3 Bosch™ part number

4 Bosch™ production data (data code, serial number).

Example:

- A123Y456 is the Cummins EmissionSolutions™ part number
- 1234567 is the Cummins® part number
- 0 444 042 XXX is the Bosch™ partnumber
- XX-XX-XX is the date code
- XXXX is the serial number

NOTE: Some aftertreatment components.may have **only** the Cummins Emission Solutions™ part number. For cross referencing and part number identification, reference QuickServe™ Online.



Engine Diagrams

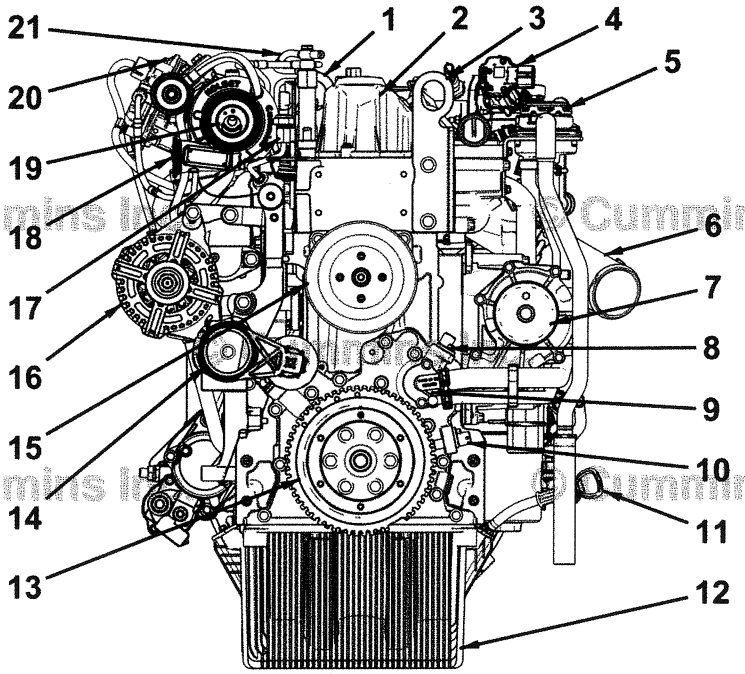
General Information

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

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

Engine Diagrams

General Information

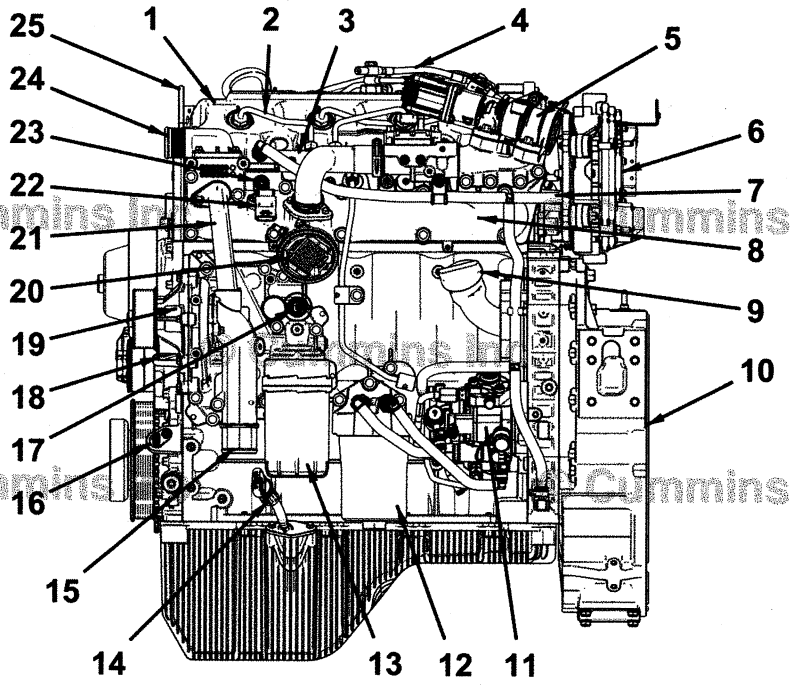


Front View

1 Rear engine lifting bracket
2 Rocker lever cover
3 Front engine lifting bracket
4 Exhaust gas recirculation (EGR) valve
5 Open crankcase ventilation valve
6 Air intake connection
7 Water pump pulley
8 Camshaft speed/position sensor
9 Crankcase breather adapter
10 Crankshaft speed/position sensor
11 Lubricating oil dipstick tube
12 Lubricating oil pan
13 Crankshaft pulley
14 Automatic belt tensioner
15 Fan drive pulley
16 Alternator
17 Exhaust pressure sensor
18 Wastegate turbocharger compressor outlet
19 Wastegate turbocharger compressor inlet
20 Exhaust pressure regulator
21 EGR coolant vent tube.

Engine Diagrams

General Information



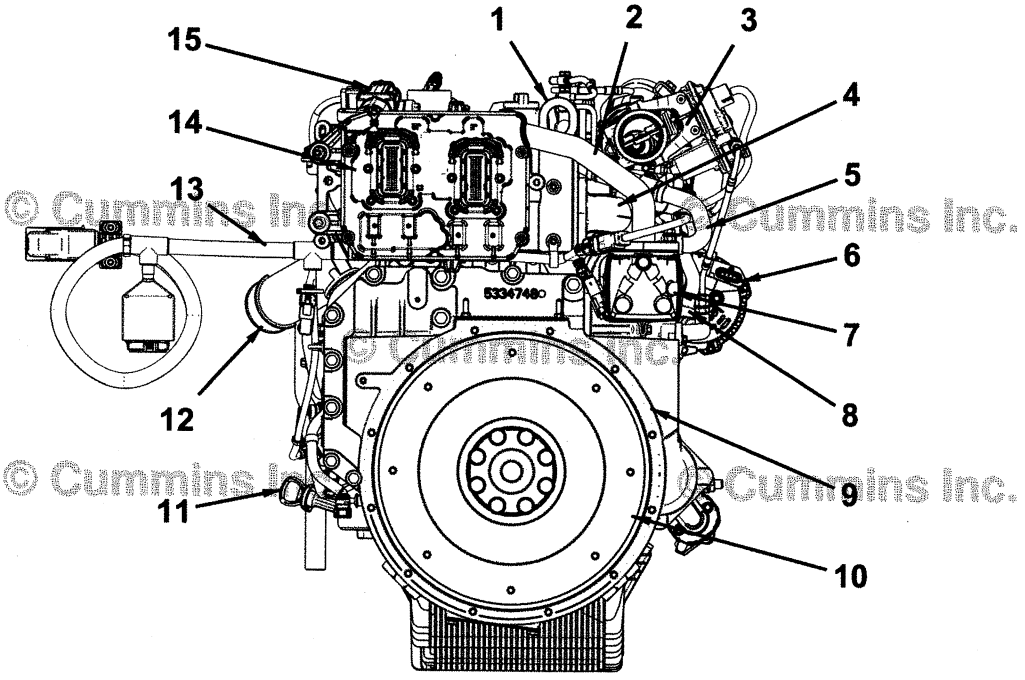
Left View

1 Rocker lever cover
2 Injector fuel supply line
3 Common rail fuel manifold
4 EGR coolant vent tube
5 EGR valve
6 Engine control module (ECM)
7 Fuel return line
8 Exhaust manifold
9 Lubricating oil fill cap
10 Flywheel housing
11 Fuel pump
12 Fuel filter
13 Lubricating oil filter
14 Lubricating oil dipstick
15 Water inlet connection
16 Crankshaft speed/position sensor
17 Oil pressure sensor
18 Camshaft speed/position sensor
19 Water pump
20 Intake air heater
21 Water bypass tube
22 Intake manifold pressure/temperature sensor
23 Engine coolant temperature sensor
24 Water outlet connection

25 Front engine lifting bracket.

Engine Diagrams

General Information

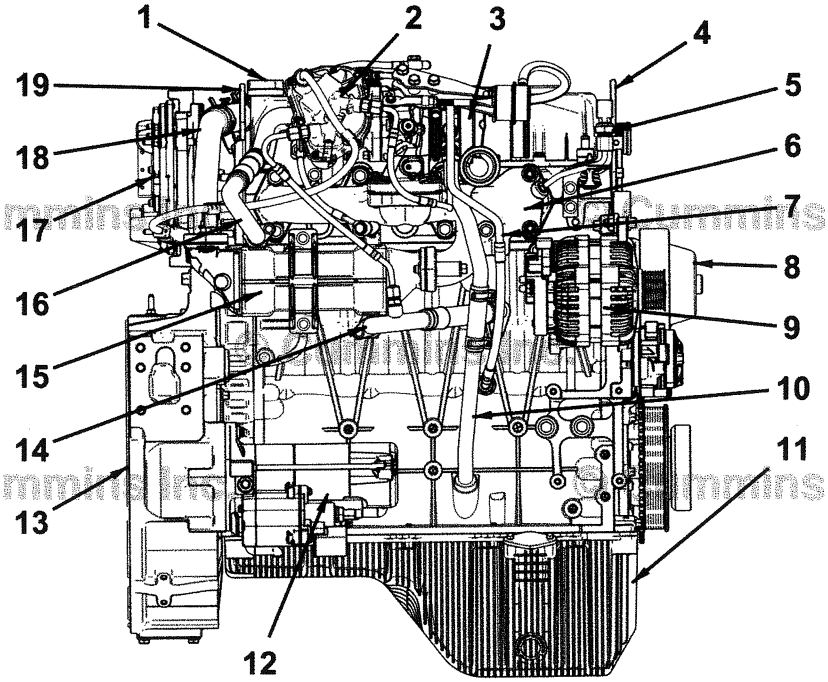


Rear View

1 Rear engine lifting bracket
2 EGR crossover tube
3 Exhaust pressure regulator
4 Exhaust manifold
5 EGR coolant outlet tube
6 Alternator
7 EGR cooler
8 EGR coolant inlet tube
9 Flywheel housing
10 Flywheel
11 Lubricating oil dipstick
12 Intake air connection
13 Wiring harness
14 ECM
15 EGR valve.

Engine Diagrams

General Information



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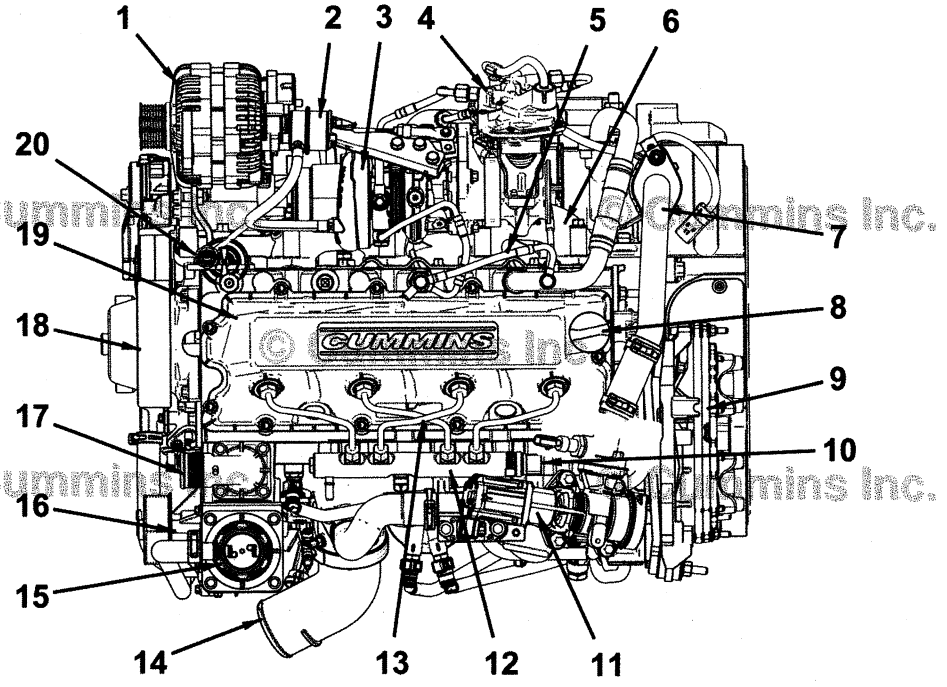
Right View

1 Lubricating oil fill cap
2 Exhaust pressure regulator
3 Wastegate turbocharger
4 Front engine lifting bracket
5 Exhaust pressure sensor
6 Exhaust manifold
7 Turbocharger lubricating oil supply tube
8 Fan hub
9 Alternator
10 Turbocharger lubricating oil drain tube
11 Lubricating oil pan
12 Starting motor
13 Flywheel housing
14 EGR cooler coolant inlet tube
15 EGR cooler
16 EGR cooler coolant outlet tube
17 ECM
18 EGR crossover tube
19 Rear engine lifting bracket.

Engine Diagrams

General Information



Top View

1 Alternator
2 Turbocharger wastegate actuator
3 Wastegate turbocharger
4 Exhaust pressure regulator
5 EGR coolant vent tube
6 Exhaust manifold
7 EGR crossover tube
8 Lubricating oil fill cap
9 ECM
10 Fuel rail pressure sensor
11 EGR valve
12 Common rail fuel manifold
13 Injector supply lines
14 Intake air connection
15 Open crankcase ventilation valve
16 Water pump
17 Water outlet connection (thermostat is underneath)
18 Fan hub
19 Rocker lever cover
20 Exhaust temperature sensor.

Cummins® Service Engine Model Identification

General Information

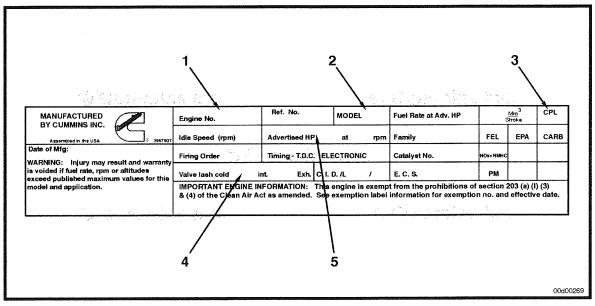
The Cummins® Service Engine Model Identification procedure describes:

- 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.

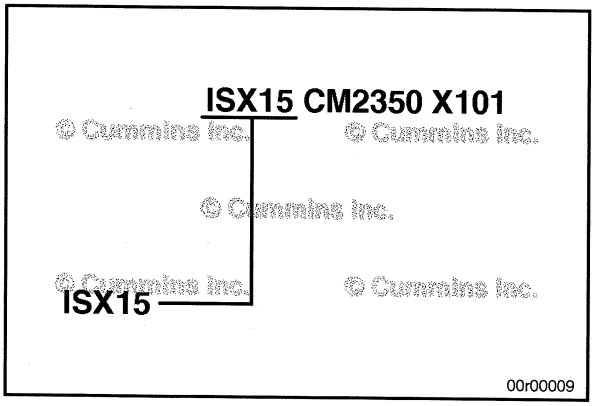
Marketing Engine Model Name	Service Model Name
ISX15	ISX15 CM2350 X101



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

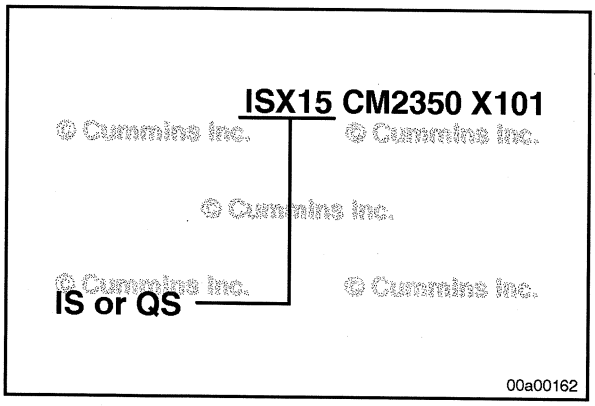
Examples of Cummins® service information and products that use service model names:

- 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".



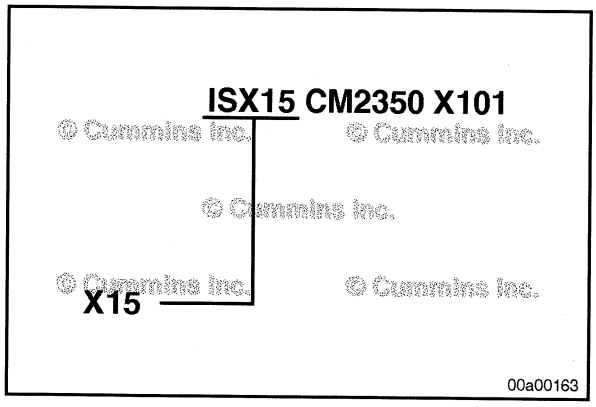
Typically, the first two letters of the marketing model name contain an "IS" or "QS" if the engine is an electronic engine.

"IS" prefix designates and 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.

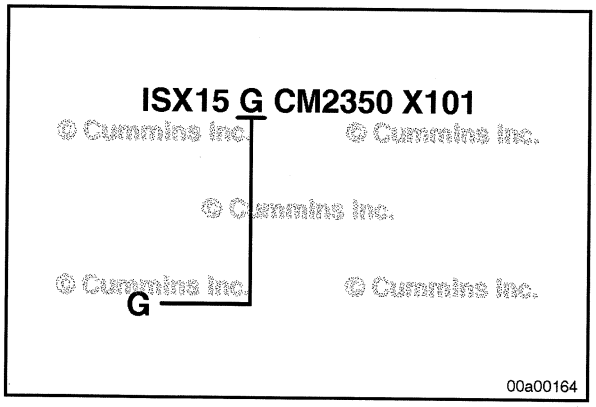


Typically, the third letter is the engine platform/series designation followed by the engine liter displacement. For the example shown in the graphic, the engine is a:

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.

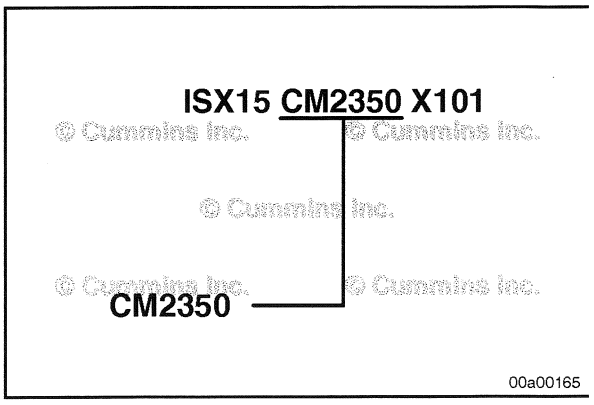
NOTE: Not all engines fueled by natural gas will have a "G" located after the displacement.

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.

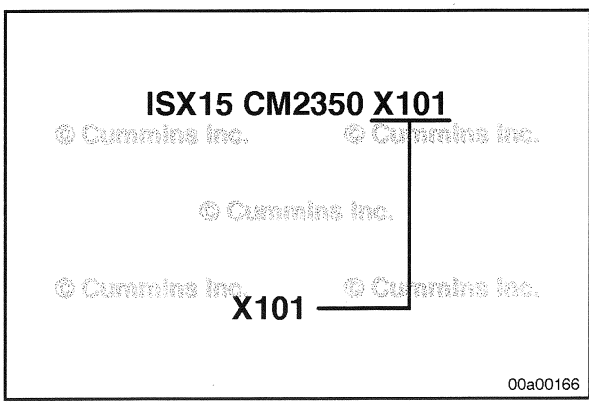
NOTE: Use of a parenthesis ( ) indicates that either engine control module (ECM) has been used on the product. Use of a slash "/" indicates that the product has multiple ECMs.



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 **QSF3.8 CM2350 F107**.

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

United States and Canada

- Tier 4 (EPA Final).

European Union

- Stage IV (Euro).

This engine uses the following product agency defined emissions control system 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 Product

- Charge-Air Cooler (CAC).
- Direct Diesel Injection (DDI).
- Engine Control Module (ECM).
- Exhaust Gas Recirculation (EGR).
- Selective Catalytic Reduction - Urea (SCR-U).
- Turbocharger (TC).

This engine uses the following product technology:

Engine

- Number of Cylinders - 4.
- Engine Configuration - Inline.
- Cylinder Block Material - Cast Iron.
- Cylinder Head Material - Cast Iron.
- Camshaft Location - Cylinder Block.
- Accessory Drive Option.
- Crankcase Ventilation System - Open.

Air Handling

- Turbocharger (Single) - Wastegate.
- Charge-Air Cooler.
- Intake Air Heater.

Electronic Control System

- Engine Control Module (Single): CM2350.
- Electrical System Voltage.
- 12-VDC.
- 24-VDC.
- Engine Coolant Level Sensor.
- Engine Coolant Temperature Sensor.
- Engine Oil Pressure Switch.
- 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.
- Exhaust Temperature Sensor.
- EGR Temperature Sensor.
- Intake Manifold Pressure/Temperature Sensor.
- Aftertreatment Exhaust Gas Temperature Sensor.
- Diesel Exhaust Fluid Quality Sensor.
- Aftertreatment Intake NOx Sensor.
- Aftertreatment Outlet NOx Sensor.

Exhaust System

- Turbocharger Wastegate Assembly.
- Exhaust Pressure Regulator.
- Exhaust Gas Recirculation (EGR).
- Selective Catalytic Reduction (SCR) Catalyst.
- Aftertreatment Diesel Exhaust Fluid Dosing System.
- Integrated Diesel Exhaust Fluid Controller (controlled by the engine's ECM).

Fuel System

- Diesel.
- Common Rail Fuel System.
- Denso™ Common Rail Fuel System.

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

Industrial

- Construction.

Notes

Section F - Familiarization

Section Contents

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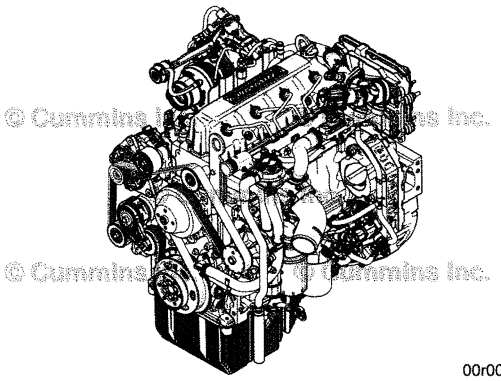
Complete Engine - Overview (000-999)

General Information



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

NOTE: 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.

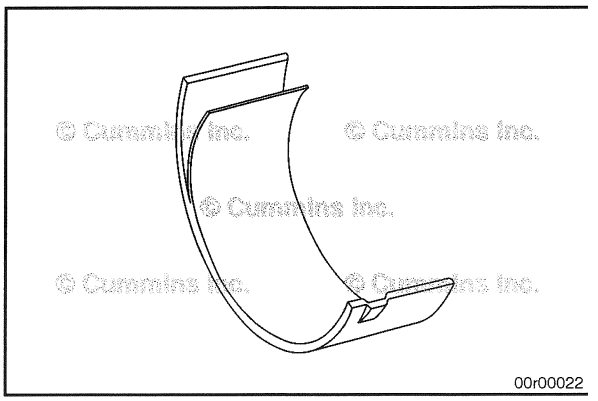
Cylinder Block - Overview (001-999)

General Information

Bearing, Connecting Rod

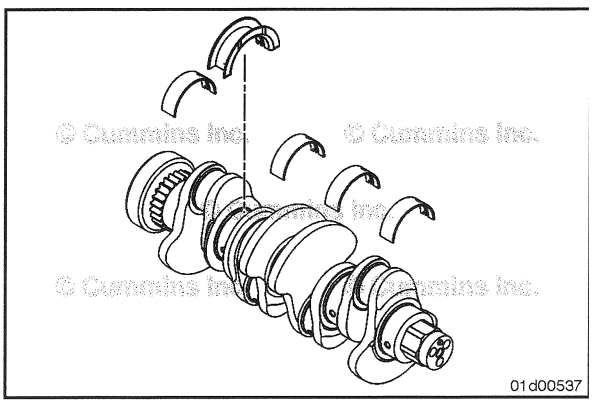
Bi-metal overlays are used in both the upper and lower connecting rod bearings.

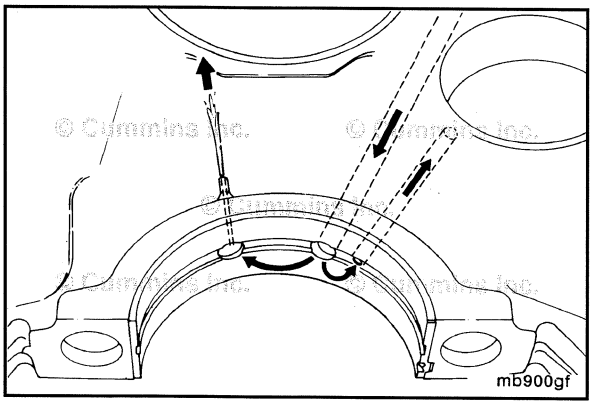
See the appropriate part information resources when replacing the connecting rod bearings, so the correct connecting rod bearings are installed.



Bearing, Main

The crankshaft and cylinder block utilize main bearing journals. The upper main bearings for each journal are the same, except for the number four main bearing journal, counted from the front of the engine. The number four main bearing journal is fitted with a flanged upper main bearing, referred to as a thrust bearing. The flanges on the main bearing control the end thrust of the crankshaft when axial loads are applied to the end of the crankshaft.

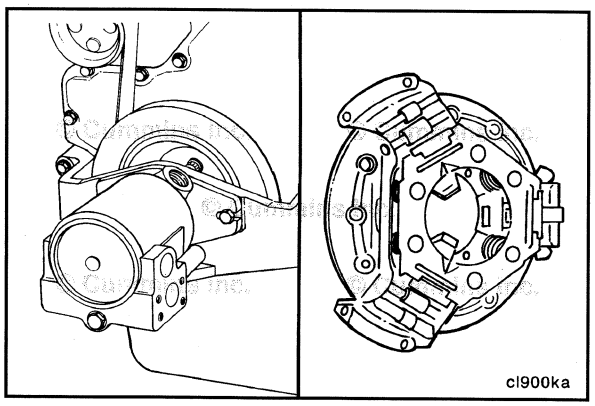




The upper bearings have three holes in them. The middle hole receives lubricating oil from the main bearing that receives lubricating oil from the main oil rifle. One of the adjacent holes is aligned with a drilling in the camshaft journal and serves as an orifice for lubricating flow to the camshaft journal. The third hole is used to supply lubricating oil for piston cooling nozzles.

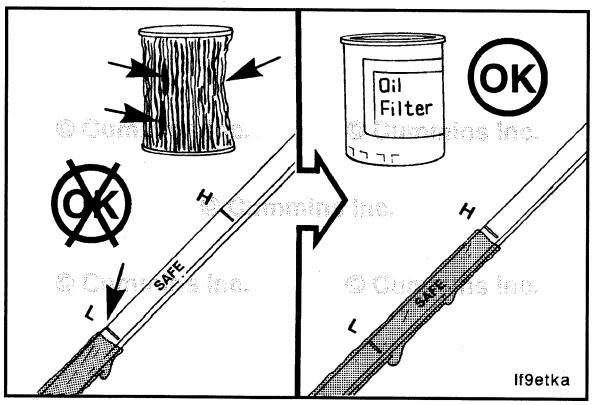
The upper bearings are identified by the mark "UPR" stamped on the back of the bearing. The lower bearings are identified by the mark "LWR" stamped on the back of the bearing.

Undersize main bearings are **not** available for the crankshaft.

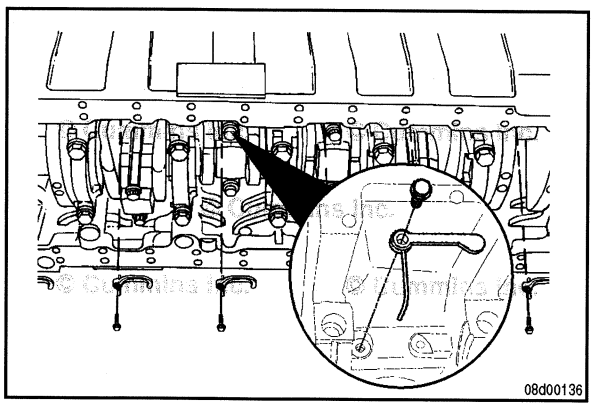


A common cause for increased crankshaft end play and thrust bearing damage is increased end-loading of the engine. The increased end-loading can be the result of driven units at the front or rear of the engine being:

- Incorrectly installed
- Incorrectly adjusted
- Incorrectly matched to the engine and exceeding the thrust load limits.



Improper maintenance of the lubricating system is the primary cause of reduced bearing life. Refer to Procedure 007-083 in Section 7.

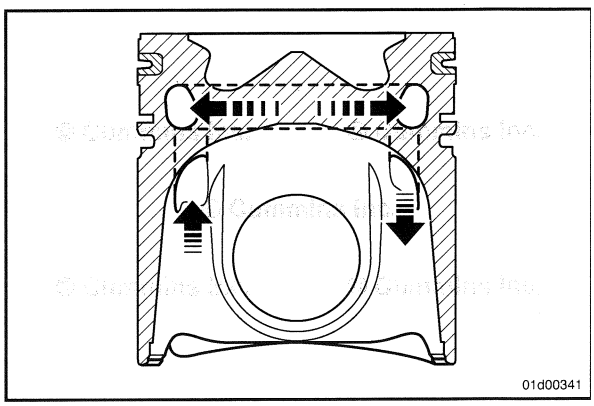


Piston Cooling Nozzles

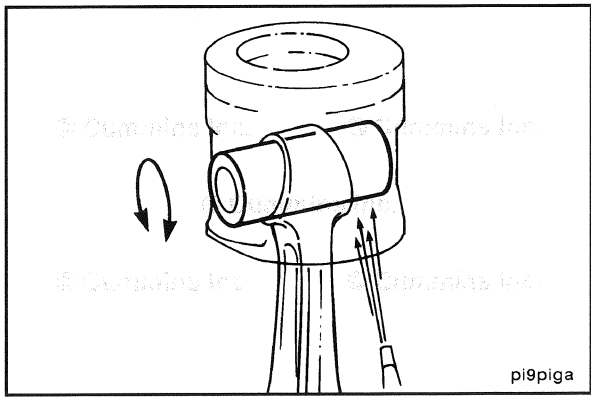
The engine uses J-jet piston cooling nozzles that are located in between the main bearing saddles on the intake side of the engine. Lubricating oil is supplied from an oil gallery in the cylinder block on the exhaust side of the engine.

Piston and Connecting Rod Assembly

The piston cooling nozzles supply lubricating oil to the underside of the pistons. The pistons have an oil passage cast into the top of the piston for cooling purposes.

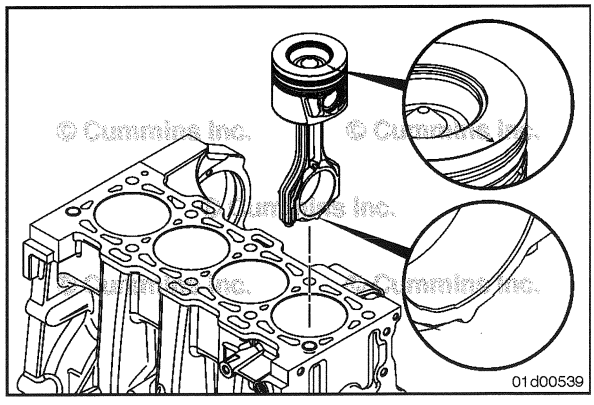


A free-floating, hollow piston pin is used to attach the piston to the connecting rod. Lubrication for the piston pin and journal is supplied by residual spray from the piston cooling nozzles.



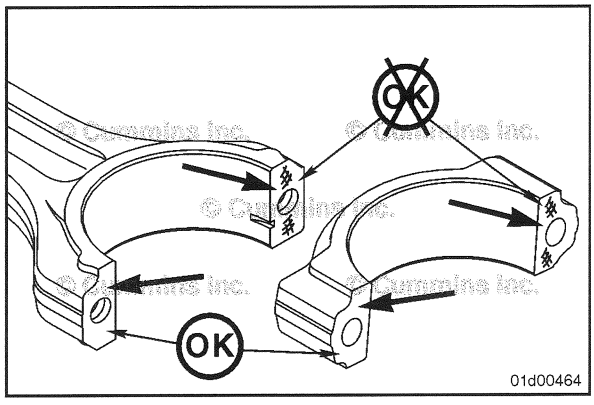
When assembling and installing the piston and connecting rod assembly, it is critical that the orientation of the components is correct.

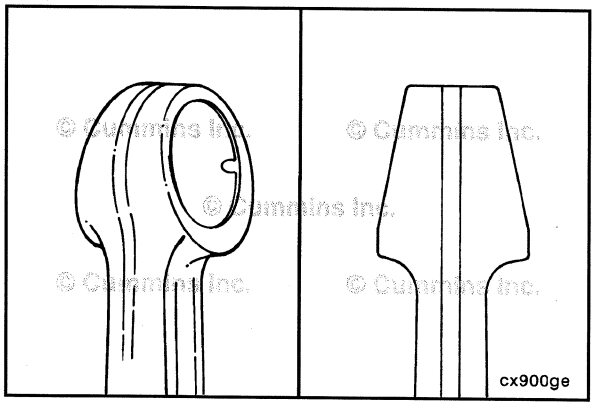
Piston grading is **not** required.



The contact surface between the connecting rod and the connecting rod cap is **not** a machined surface. The surface is the result of the connecting rod being fractured during the manufacturing process to separate the connecting rod cap from the connecting rod.

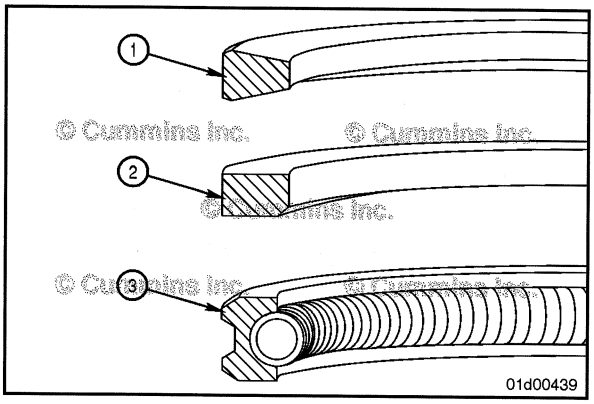
This surface can **not** be considered damaged unless there are deep nicks or cracks across the surface.





The piston pin end of the connecting rod is angle-cut to provide additional bearing surface and is fitted with a bushing.

The connecting rod small end bore does **not** have an oil drilling.



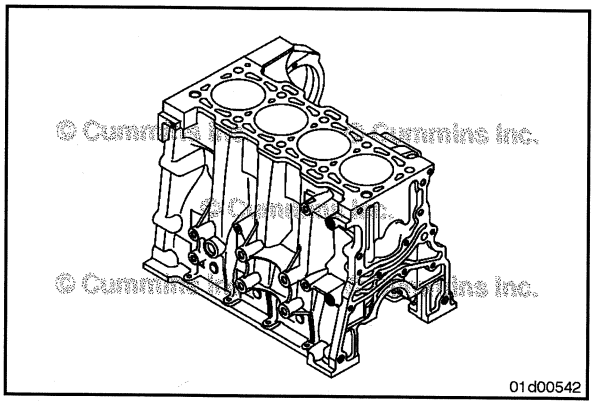
Piston Rings

The piston ring type and location can be identified by the piston ring profile.

1 Top piston ring

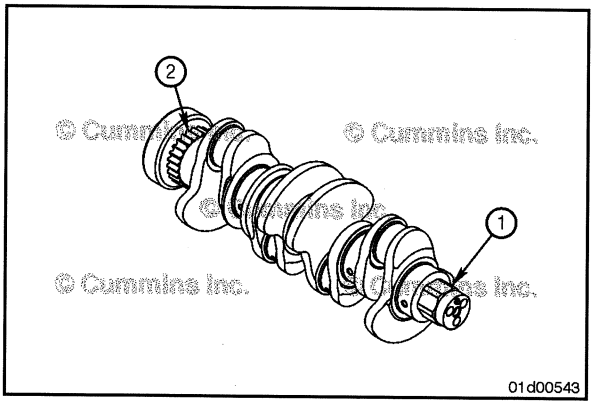
2 Intermediate piston ring

3 Oil control ring.



Cylinder Block

The cylinder block is a single piece, gray iron casting featuring a sculpted design that has less weight, but greater strength than traditional block designs. In the event of damage or wear of the cylinder bore surface, the cylinder block can be machined 0.5 mm [0.02 in] or 1.0 mm [0.040 in] to accept an oversize piston assembly.



Crankshaft and Gear

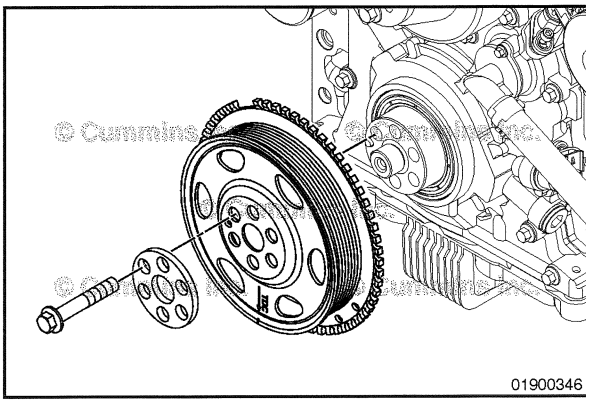
The crankshaft is a balanced, cast steel component.

The front nose of the crankshaft has an incorporated gear (1) that drives the lubricating oil pump, which is an integral part of the front gear cover.

A second crankshaft gear (2) is assembled to the crankshaft at the rear. This crankshaft gear drives the idler gear, which in turn drives the fuel pump. If damaged, the entire crankshaft assembly **must** be replaced.

Crank Pulley

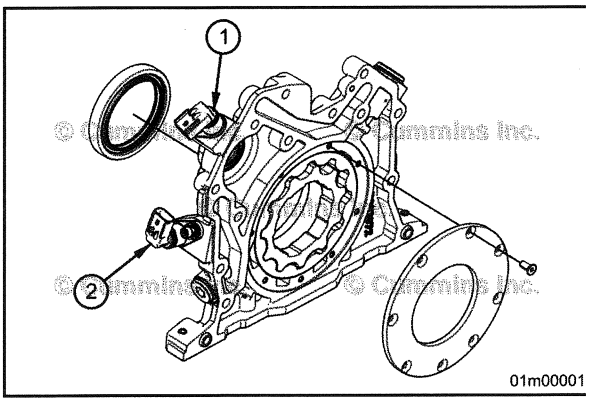
The crank pulley, vibration damper, and the crankshaft speed indicator ring are a permanent assembly. If **any** of these components are damaged, the entire assembly **must** be replaced.



Gear Cover, Front

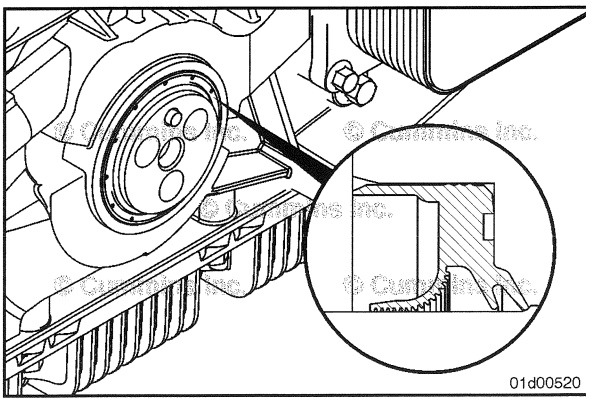
The front gear cover houses the lubricating oil pump, front crankshaft seal, and camshaft speed indicator ring.

The front gear covers also contains the oil pressure switch (1) and crankshaft speed and position sensor (2).



Crankshaft Seal, Front

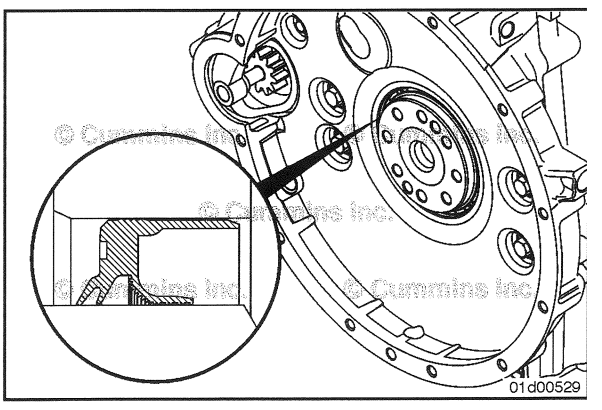
The engine uses a lip style front crankshaft seal in which the rotating portion of the sealing occurs at the contact surface between the lip of the seal and the crankshaft. **Always** replace the front crankshaft seal with the same style seal that was previously installed.

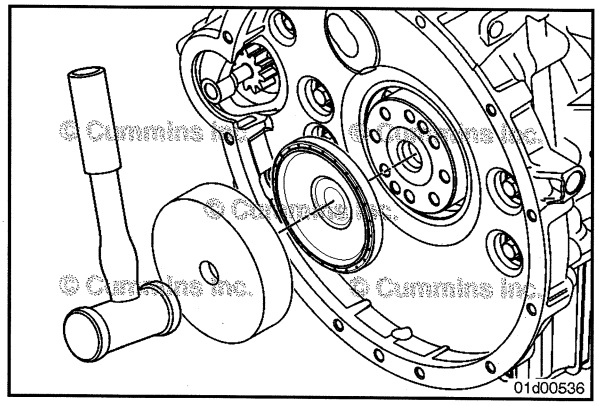


Crankshaft Seal, Rear

The engine uses a lip style rear crankshaft seal in which the rotating portion of sealing occurs at the contact surface between the lip of the seal and crankshaft.

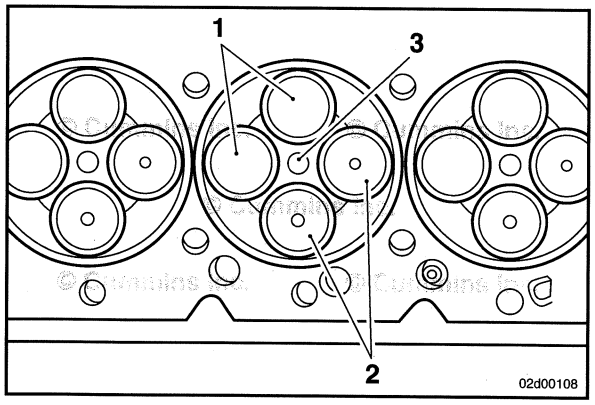
The rear crankshaft seal is installed in the flywheel housing bore.





Each new lip style rear crankshaft seal comes with a disposable seal driver.

The disposable seal driver should be used with the seal installation tool to drive the seal to the correct depth on the flywheel housing.



Cylinder Head - Overview (002-999)

General Information

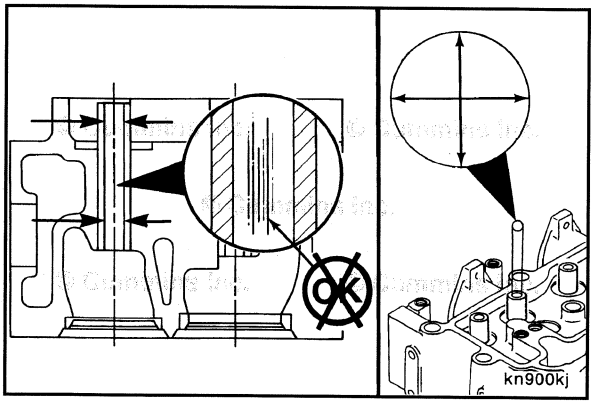
Cylinder Head Assembly

The cylinder head is a one-piece, cross flow design with four valves per cylinder. The four valve per cylinder design allows for a centered injector (3) in the cylinder head.

The intake manifold is a separate component, which is sealed with the cylinder head surfaces by a gasket. The thermostat is mounted in the thermostat housing portion of the intake manifold. The thermostat is sealed by compression of an edge mounted seal when the water outlet is installed.

The intake and exhaust valves (1 and 2) are made of heat resistant steel, and have chrome plated stems to prevent scuffing. The intake and exhaust valves are both similar in head diameter and overall length, but have unique face angles, which makes them non-interchangeable. The exhaust valves are distinguished by unique dimples on the valve head (2).

The exhaust valve springs are made from high strength, chrome silicon steel. The exhaust valve spring ratings allow for an exhaust back pressure device for enhanced engine braking.

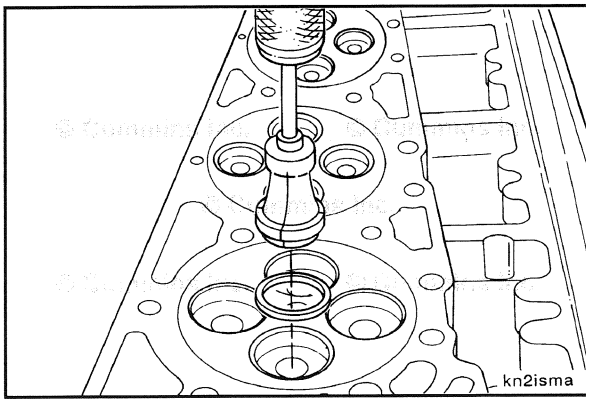


Valve Guides

The cylinder head has integrally cast valve guides that are **not** serviceable. If the valve guides are damaged, the cylinder head **must** be replaced.

Valve Seat Inserts

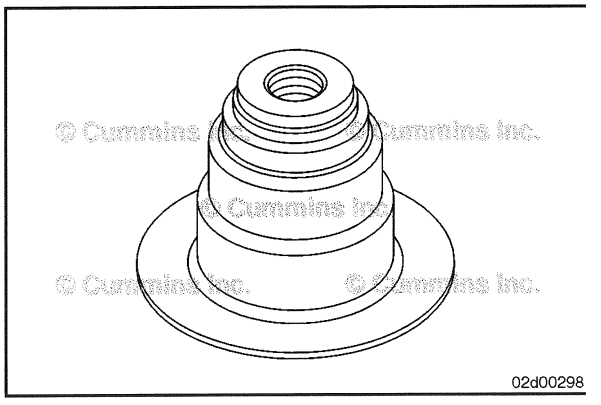
The valve seats are inserts that can be replaced if damaged. Oversize inserts are also available if the valve seat bore is out of specification.



Valve Stem Seals

The valve stem seals are of a "top hat" design, which utilizes the valve spring to secure the valve stem seal in place.

The stem seals prevent lubricating oil from entering the combustion chamber through the valve guides and prevent intake or exhaust gases from entering the crankcase through the valve guides.

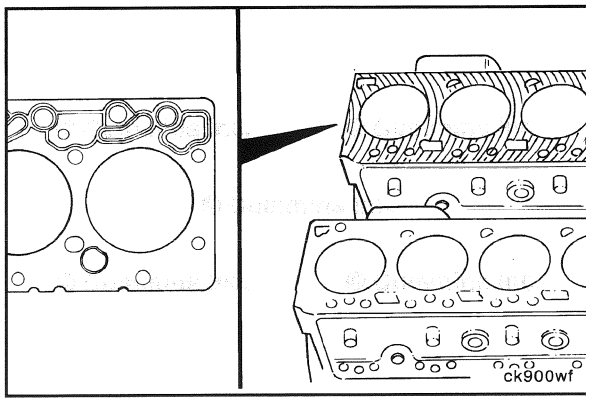


Cylinder Head Gasket

The cylinder head gasket is a specialized metal design with a printed o-seal on both sides, around the water holes. An embossment in the gasket seals the cylinder bores. The gasket also provides orifices to control coolant flow from the cylinder block to the cylinder head.

Cylinder head gasket grading is **not** required for the engines covered by this manual.

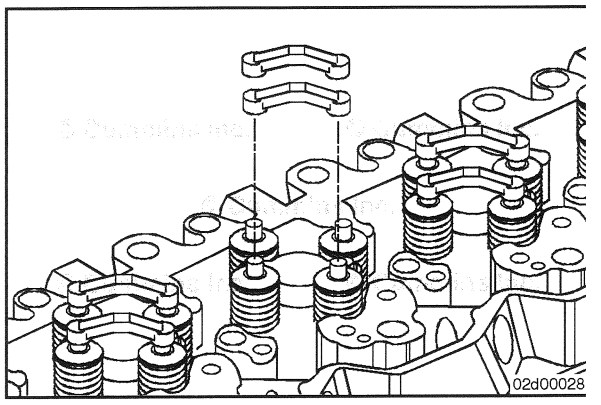
A cylinder head gasket with an increased thickness is **not** available for cylinder head or cylinder block combustion deck resurfacing.

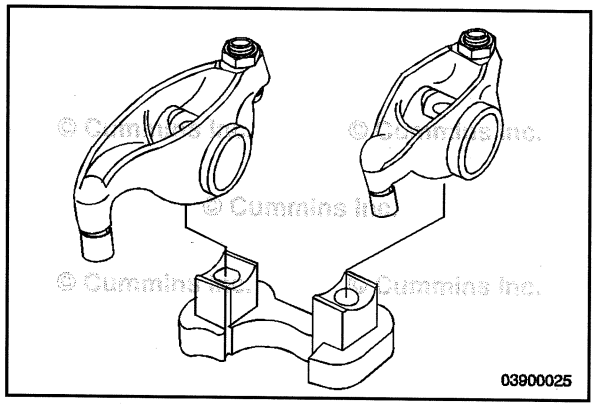


Crossheads

With the four valve per cylinder design, the rocker lever sockets do **not** directly contact the valve stem. With one rocker lever being required to operate two valves, a bridge, or crosshead, is needed to connect both intake and exhaust valves.

The socket on the rocker lever contacts the crosshead, which in turn contacts both corresponding valve stems.



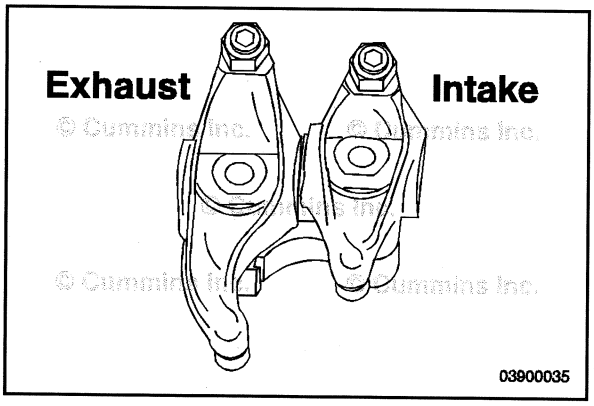


Rocker Levers - Overview (003-999)

General Information

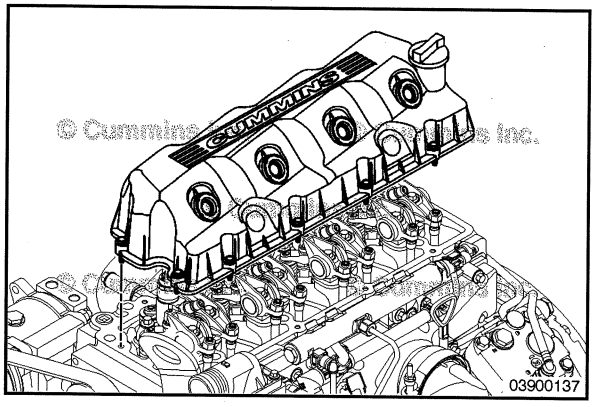
Rocker Levers

- The rocker levers transmit motion from the push rod to a crosshead, allowing two valves to be compressed by a single rocker lever.
- 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 lever shafts, sockets, and an adjusting screw.



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

All elongated holes are to the exhaust side during engine assembly.



⚠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⚠
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.

Rocker Lever Cover

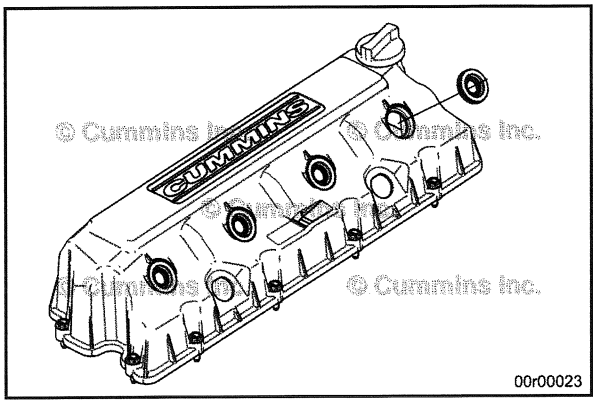
- In order to remove a rocker lever cover, all high-pressure fuel lines need to be removed.

Rocker Lever Cover Gasket

- The rocker lever cover uses a molded rubber gasket.
- The molded gasket is inserted into a groove along the perimeter of the rocker lever cover.

Rocker Lever Cover Gasket

- The injector fuel supply tubes pass through the rocker lever cover. Rubber grommets are used to seal around the fuel tubes.

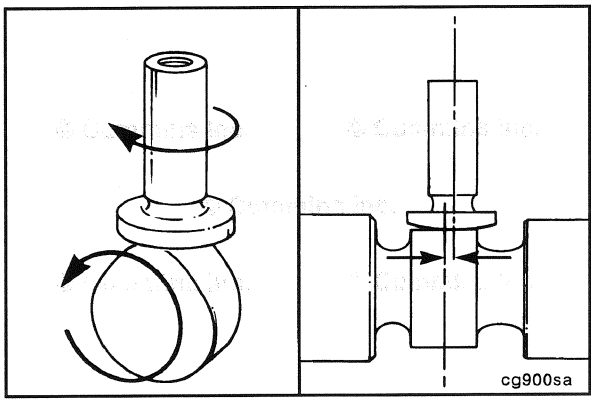


Cam Followers/Tappets - Overview (004-999)

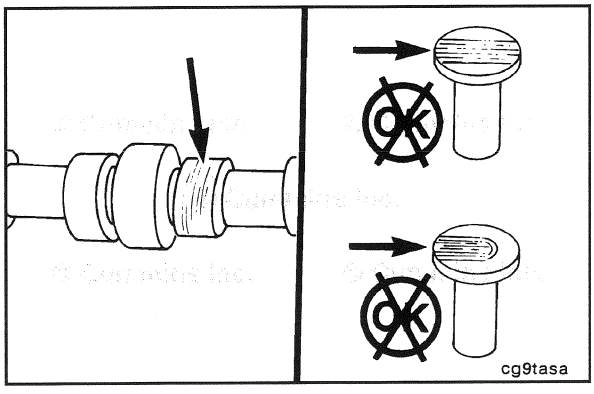
General Information

The tappets have a mushroom shape that stays in constant contact with the camshaft valve lobe and is commonly referred to as a sliding tappet. The convex shape of the tappet surface that contacts the camshaft valve lobe and the offset from the center line of the camshaft valve lobe causes the tappets to rotate as the tappet is lifted.

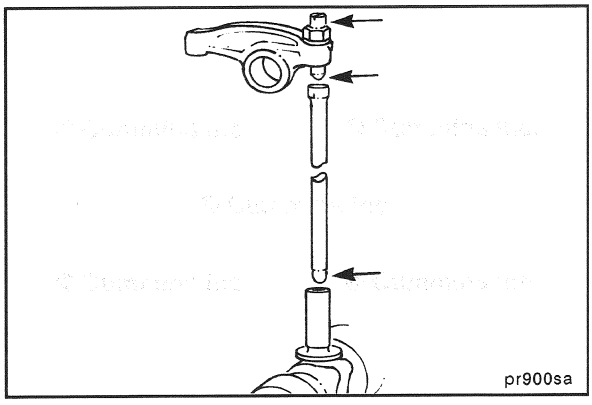
Due to the mushroom shape of the tappet, the tappets can **only** be removed once the camshaft is removed. The tappets can then either be accessed by removing the oil pan or using the appropriate service tool.



Loose rocker lever lash and the need to reset the valve clearance frequently can indicate camshaft valve lobe or tappet wear. If an inspection of the rocker levers, valve stems, crossheads, and push rods does **not** show wear, tappet and/or camshaft valve lobe wear **must** then be checked.

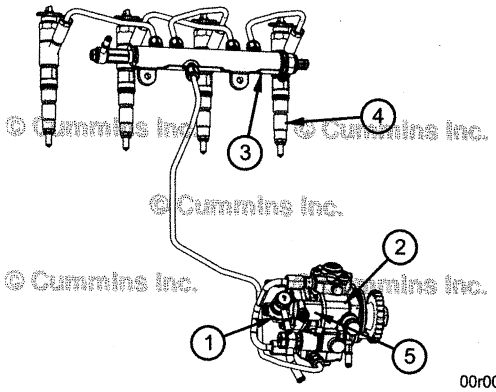


The push rod is a solid link between the tappet and the rocker lever. At the bottom, the ball end of the push rod fits into a ball socket in the tappet. At the top, the push rod is fitted with a socket into which the ball end of the rocker lever adjusting screw is seated.



Fuel System - Overview (005-999)

General Information

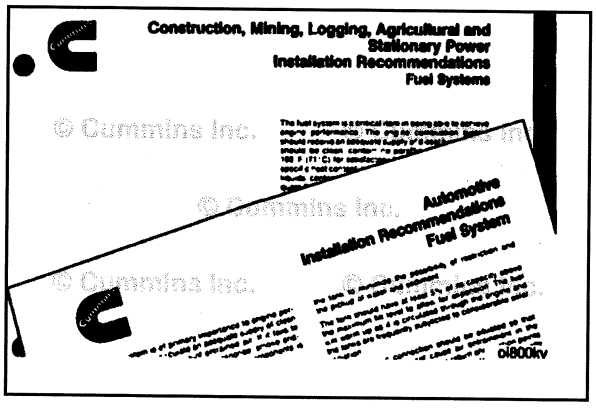


The fuel system is a high-pressure common rail electronically controlled fuel system The high-pressure common rail system consists of four main components: fuel pump gear pump (1), high-pressure pump (2), fuel rail (3), and injectors (4). The high-pressure pump supplies high-pressure fuel to the fuel rail independent of engine speed. The high-pressure fuel is then accumulated in the fuel rail. High-pressure fuel is constantly supplied to the injectors by the fuel rail. The engine control module (ECM) controls the fueling and timing of the engine by actuating the injectors.

The fuel that enters the high-pressure fuel pump is pressurized between 250 and 2000 bar [3626 to 29008 psi] by two horizontal pumping chambers.

A fuel pump actuator valve (5) (fuel metering device), at the fuel inlet of the pumping chambers, regulates the volume of fuel that is allowed to enter the pumping chambers. By regulating the volume of fuel that is pressurized, the fuel pump actuator valve uses signals from the ECM to maintain the pressure in the fuel rail at a desired level. Fuel that is not allowed to enter the pumping chambers is directed through the overflow valve. The overflow valve directs a certain amount of fuel to the lubrication channels of the high-pressure pump and then returns the fuel to the fuel tank.

The fuel rail acts as a fuel manifold accumulating and distributing fuel to each of the injector supply lines. Within the fuel rail, there is a fuel rail pressure sensor that monitors the pressure provided to the fuel rail from the high-pressure fuel pump. Pressure measured by the fuel rail pressure sensor is used by the engine control module (ECM) to adjust the fuel output of the high-pressure pump. The fuel rail also contains a fuel rail pressure relief valve. The fuel rail pressure relief valve is a safety valve used to bleed off excess pressure if the rail pressure exceeds a preset threshold. Fuel bled off by the fuel rail pressure relief valve is returned to the fuel tank through a fuel drain line connected to the fuel rail.

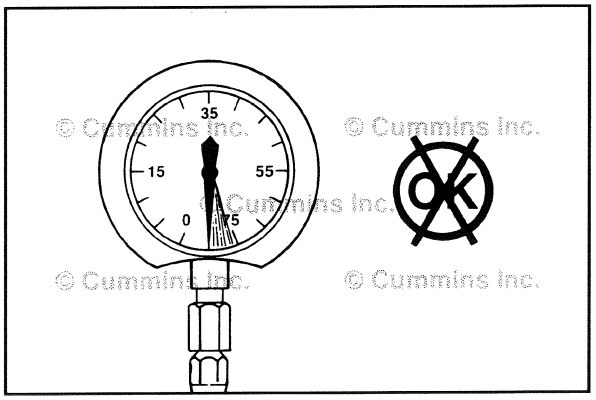


Installation Publications

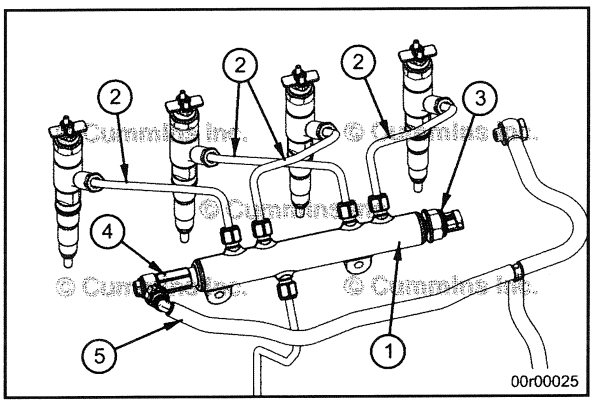
Contact a Cummins® Authorized Repair Location for engine fuel system specifications and requirements provided on the Engine Data Sheet for the specific engine and application.

⚠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. Personal injury and property damage can result. 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.

△CAUTION△
Never exceed the maximum capacity of the gauge or flowmeter. Exceeding the maximum capacity will cause the gauge to read incorrectly. If the maximum is exceeded, check the gauge against a reference gauge.

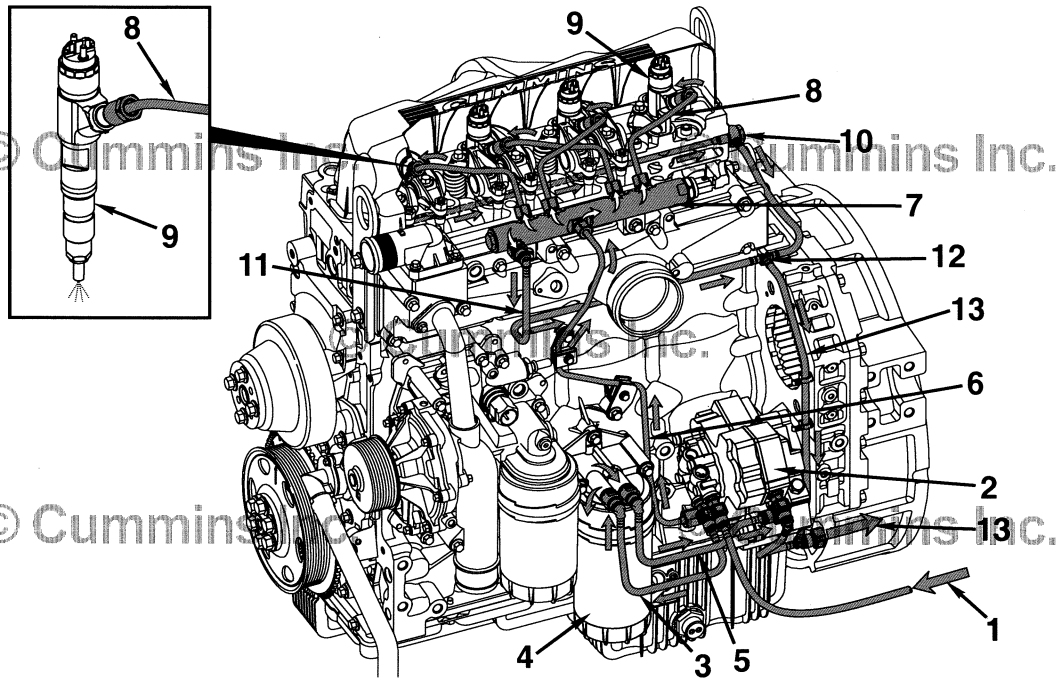


The fuel rail (1) acts as a fuel manifold accumulating and distributing fuel to each of the injector supply lines (2). Within the fuel rail, there is a fuel rail pressure sensor (3) that monitors the pressure provided to the fuel rail from the high-pressure fuel pump. Pressure measured by the fuel rail pressure sensor is used by the ECM to adjust the fuel output of the high-pressure pump. The fuel rail also contains a fuel rail pressure relief valve (4). The fuel pressure relief valve is a safety valve used to bleed off excess pressure if the rail pressure exceeds a preset threshold. Fuel bled off by the fuel rail pressure relief valve is returned to the fuel tank through a fuel drain line (5) connected to the fuel rail.



Flow Diagram, Fuel System (200-001)

Flow Diagram

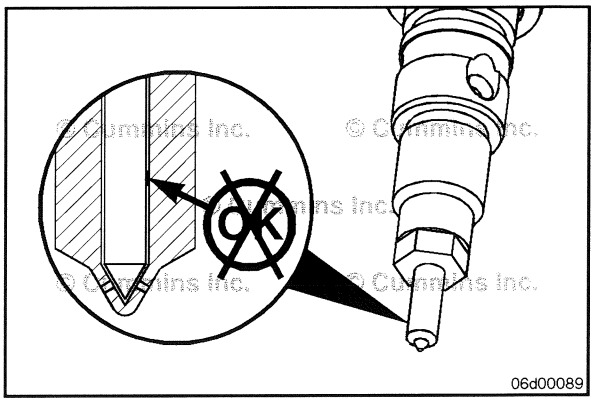


05900952

1 Fuel supply from tank
2 Fuel pump
3 Fuel supply to filter
4 Fuel filter (spin-on)
5 Fuel flow out of fuel pump
6 Fuel supply to common fuel rail
7 Common fuel rail
8 High pressure fuel to injector
9 Injector
10 Fuel return from cylinder head
11 Fuel return from common rail
12 Fuel return junction
13 Fuel return to tank.

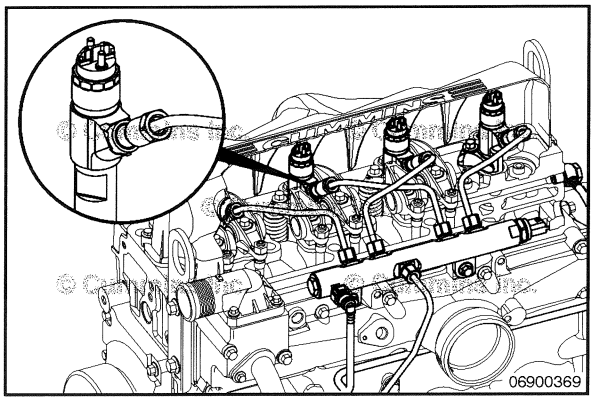
Injectors and Fuel Lines - Overview (006-999)

General Information



⚠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.

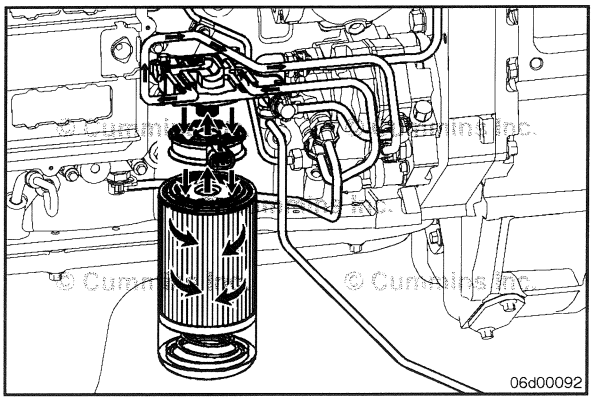
High-pressure common rail fuel systems use solenoid-actuated injectors. High-pressure fuel flows into the side of the injector. When the solenoid is activated, an internal needle lifts and fuel is injected. The clearances in the nozzle bore are extremely small and any dirt or contaminants will cause 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 on the high-pressure line nuts.

High-pressure fuel is supplied to the injector from the fuel rail by an injector supply line.

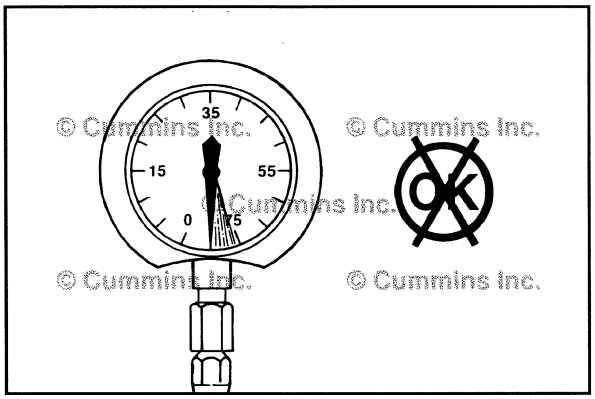
The torque on the injector supply lines is critical. If the nut or line is under tightened, the surfaces will **not** seal and a high-pressure fuel leak will result. If the nut is overtightened, the injector will deform and cause a high-pressure fuel leak. This leak will be inside the rocker cover and will **not** be visible. The result may be a fault code, low power, or no-start.



All injectors feed into a common return circuit contained within the cylinder head. Any excess fuel is returned to the tank via this drilling in the cylinder head 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. The fuel drain lines may have either a quick-disconnect fitting or a banjo fitting at ends of the fuel drain lines.

Each of the fuel drain lines combine together at the fuel return manifold.

The engine control module (ECM) controls the fueling and timing of the engine by actuating the solenoids on the injector. An electronic pulse is sent to the solenoids to lift the needle and start the injection event. By electronically controlling the injectors, there is a more precise and accurate control of fueling quantity and timing. Also, multiple injection events can be achieved by electronically controlling the injectors.



⚠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. Personal injury and property damage can result. 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.

△CAUTION△
Never exceed the maximum capacity of the gauge or flowmeter. Exceeding the maximum capacity will cause the gauge to read incorrectly. If the maximum is exceeded, check the gauge against a reference gauge.

Lubricating Oil System - Overview (007-999)

General Information

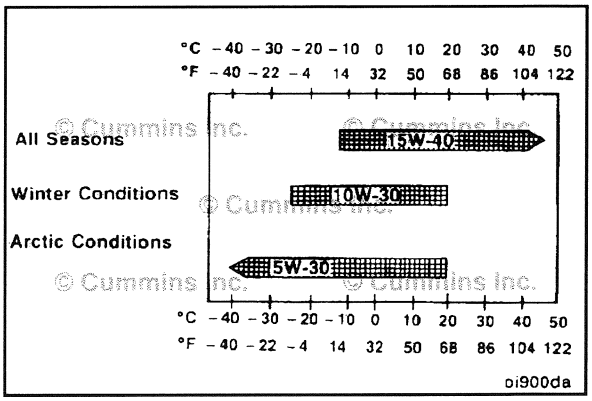
⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

⚠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 Valvoline Premium Blue™ (USA) or Valvoline Premium Blue™ Extra (International).

NOTE: For lubricating oil requirements and maintenance intervals, see the QSF3.8 CM2350 F107 Operation and Maintenance Manual, Bulletin 4367317, and/or the QSF3.8 CM2350 F107 Owners Manual, Bulletin 4367318, for the engine being serviced.

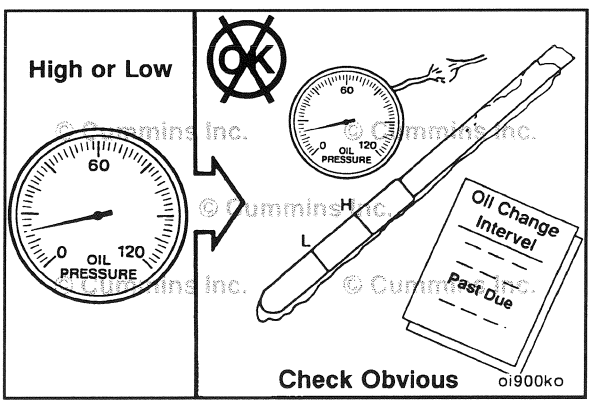
⚠CAUTION⚠
Limited use of low-viscosity lubricating oils, such as 10W-30, can aid in starting the engine and providing sufficient lubricating oil flow at ambient temperatures below -5°C [23°F] as shown in the illustration. However, the continuous use of low-viscosity lubricating oils can decrease engine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

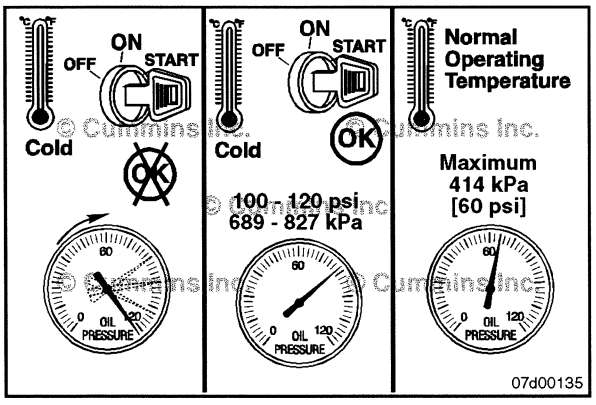


Oil flow through the engine enters the lubrication pump. The oil is pressurized and fed into the oil cooler. Within the cover, a pressure-regulating valve regulates the oil to 372 kPa [54 psi]. Excess oil is returned to the suction side of the lubricating oil pump. Oil continues through the lubricating oil cooler to the lubricating oil filter bypass valve. The lubricating oil filter bypass valve will open if the pressure across the filter exceeds 345 kPa [50 psi]. Oil leaves the filter and supplies a line to the turbocharger(s), directed cooling nozzle rifle, and main oil rifle, through a drilling between cylinders 1 and 2.

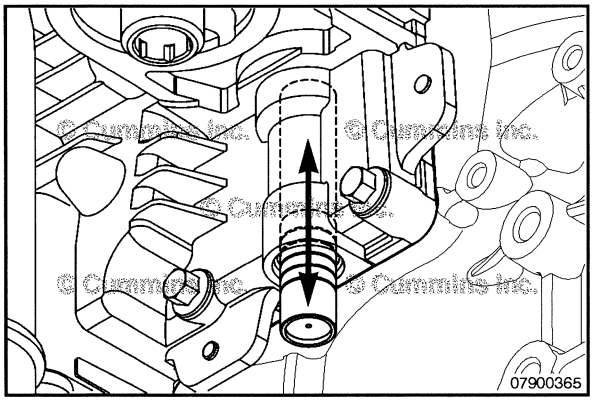
A main rifle runs the length of the cylinder block on the fuel pump side of the engine. The rifle supplies lubricating oil to the main bearings and crankshaft. Lubricating oil flows from the main bearings to the cam journals/bushings and piston-cooling nozzles. The drilling in the crankshaft supplies lubricating oil to the rod bearings. Vertical drillings from the cylinder head deck to the main oil rifle supply oil to the cylinder head. Oil passes through the cylinder head gasket and enters the cylinder head. 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 tube socket, and crosshead pad. A second main lubricating oil rifle runs the length of the cylinder block on the oil cooler side. This rifle supplies lubricating oil to the directed piston-cooling nozzles.

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.



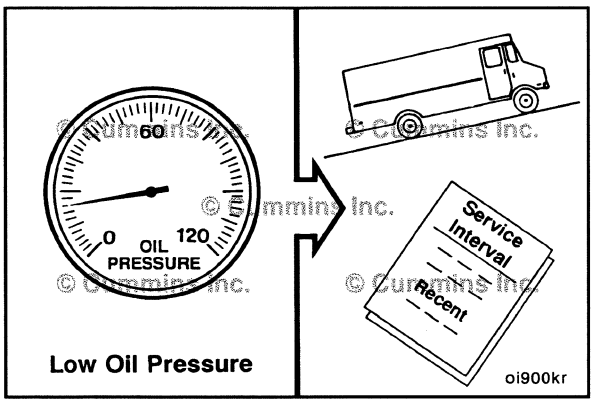


High lubricating oil pressure occurs after the engine is first started in cold weather. Cold-start oil pressure typically will be approximately 689 to 827 kPa [100 to 120 psi]. If the pressure regulator plunger is operating properly, the oil pressure should drop back to approximately 414 kPa [60 psi] when normal operating temperature is reached.



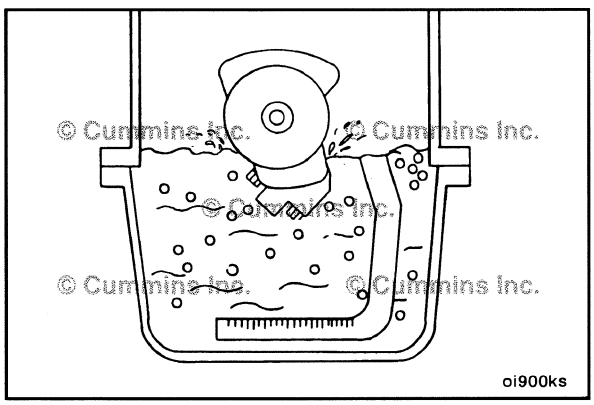
The engine will have high oil pressure at normal operating temperature if the lubricating oil pressure regulator valve sticks in the closed position.

Check the regulator for freedom of movement. Refer to Procedure 007-029 in Section 7.



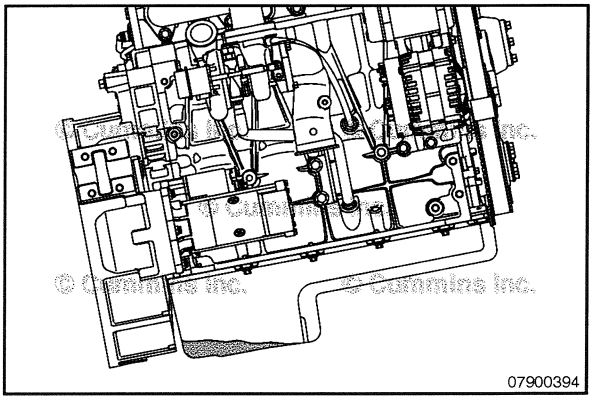
Low lubricating oil pressure (or no oil pressure) can be caused by several lubricating system-related malfunctions. To begin the investigation, determine the engine operating conditions when the low pressure was first observed. The following are conditions of low lubricating oil pressure:

- Following a service interval
- At idle **only**
- Operating on a steep grade.

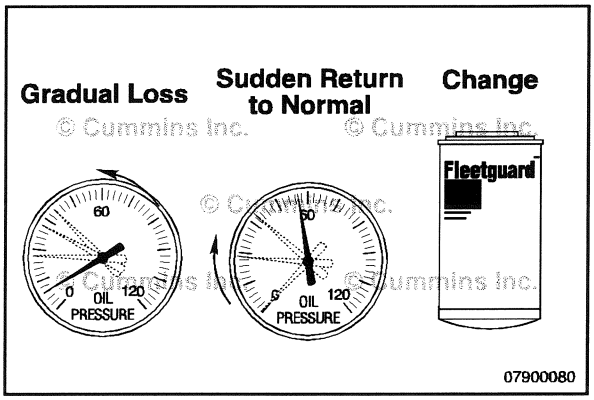


High lubricating oil level can cause low oil pressure. If the oil level is high enough for the connecting rods to dip into the oil while operating, the oil can become aerated, resulting in low oil pressure.

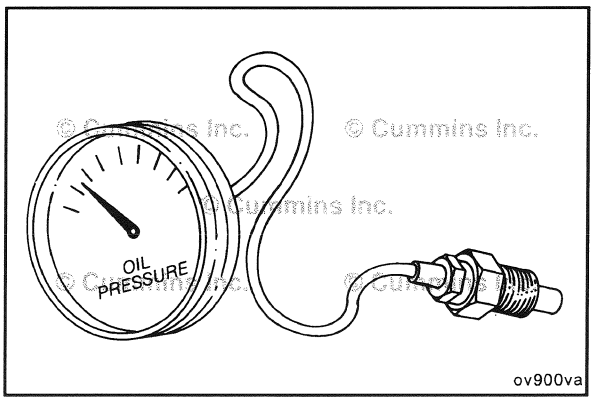
Low oil level will **not** normally appear as low oil pressure. Typically, it will appear as an intermittent loss of oil pressure when rounding a corner or operating on a steep grade. This condition exists when the oil level is extremely low and the suction tube can **not** pick up oil during all modes of operation.



A plugged lubricating oil filter will cause a gradual loss of 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.

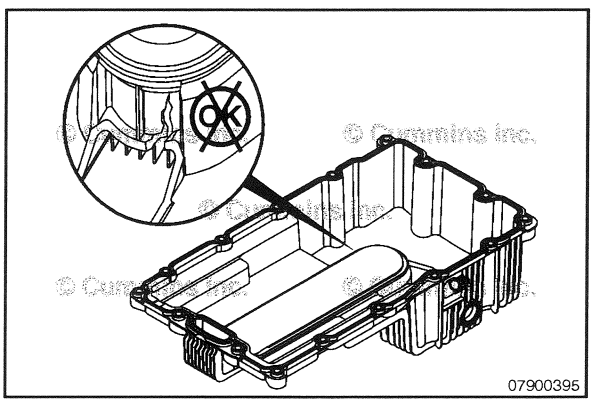


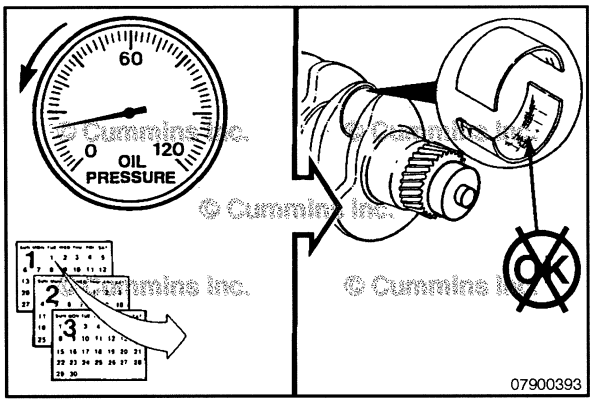
Check the lubricating oil gauge and sending unit to make sure they are operating correctly by verifying the pressure with a manual gauge.



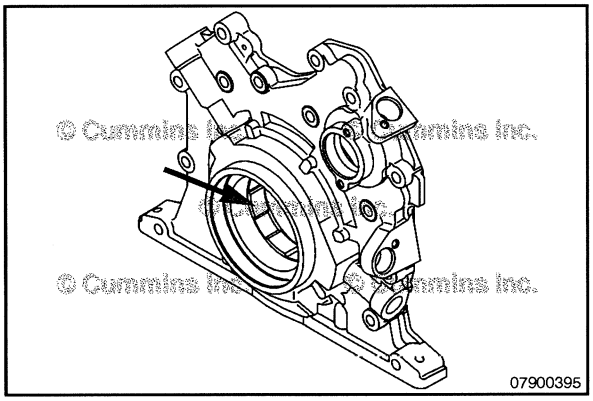
A damaged oil pan gasket or crack in the internal suction tube can cause a loss of prime for the oil pump. The engine may have low pressure or no oil pressure during starting, possibly followed by normal oil pressure.

NOTE: A front and rear sump lubricating oil pan option is available, depending on the application. Due to the lubricating oil suction tube being integrated into the lubricating oil pan, different lubricating oil pan part numbers are used, depending on the configuration.



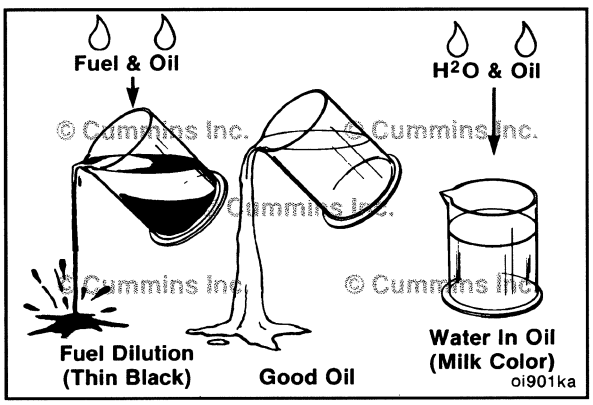


A steady decrease in oil pressure over a long period can be an indication of worn bearings or excessive lubricating oil pump wear.



The lubricating oil pump is an integral part of the front cover. If a new pump is required upon inspection, the front cover should be replaced.

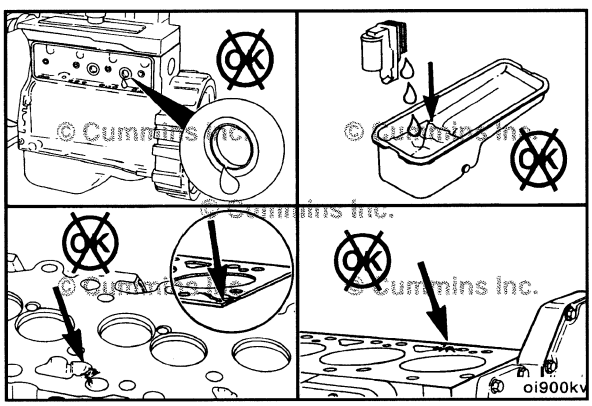
Use the following procedure for removal and installation and inspection. Refer to Procedure 007-031 in Section 7. Refer to Procedure 001-031 in Section 1. See QuickServe™ Online to determine the correct front cover part number.



⚠CAUTION⚠
Using diluted oil can cause severe engine damage.

Check the condition of the lubricating oil:

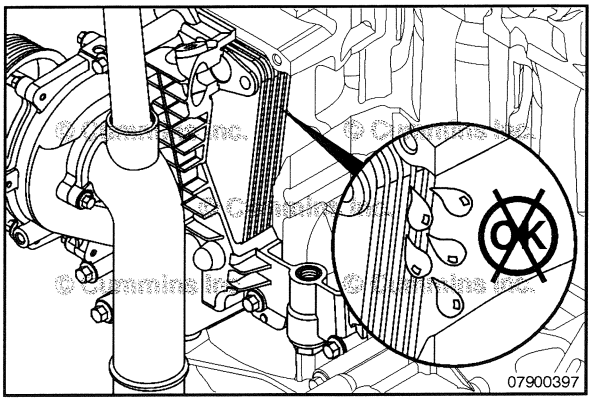
- Thin, black oil is an indication of fuel in the oil
- Milky discoloration is an indication of coolant in the oil.



Coolant in the oil can be caused by:

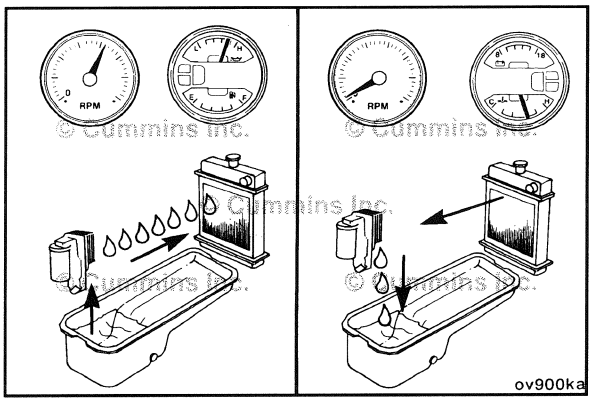
- Expansion plugs leaking
- Oil cooler element leaking
- Damaged cylinder head or gasket
- Cracked engine block
- Casting porosity.

The lubricating oil cooler design requires gaskets to maintain the separation of oil and coolant. If the element leaks, it will allow mixing of the fluids. Refer to Procedure 007-003 in Section 7.



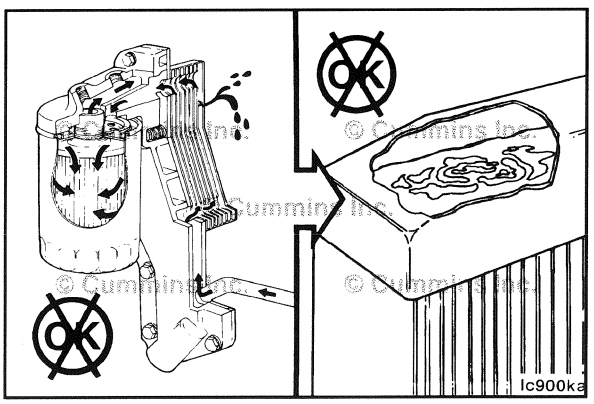
While operating, the oil pressure will be higher than coolant pressure. A leak in the oil cooler will show as oil in the coolant.

However, following an engine shutdown, the residual pressure in the coolant system can cause coolant to seep through the leak path into the oil.



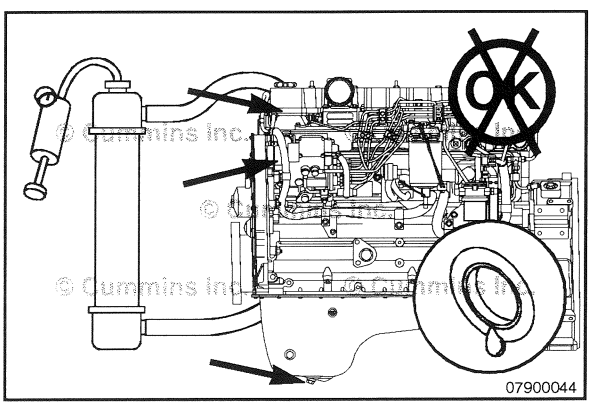
If the oil cooler element ruptures, the oil pressure will force oil into the cooling system.

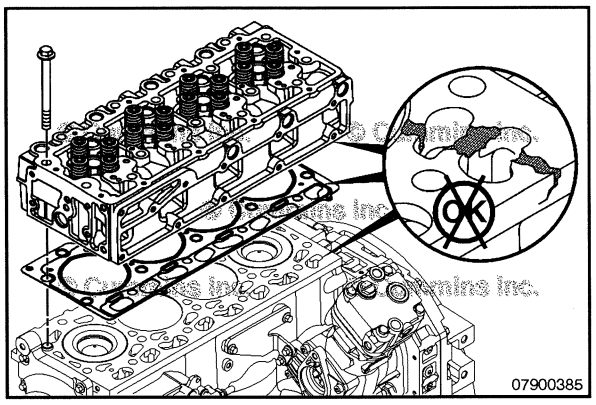
Oil in the coolant should be visible when the radiator cap is removed. Refer to Procedure 007-003 in Section 7.



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 defective oil cooler, cylinder head gasket, or cracked cylinder head or block.

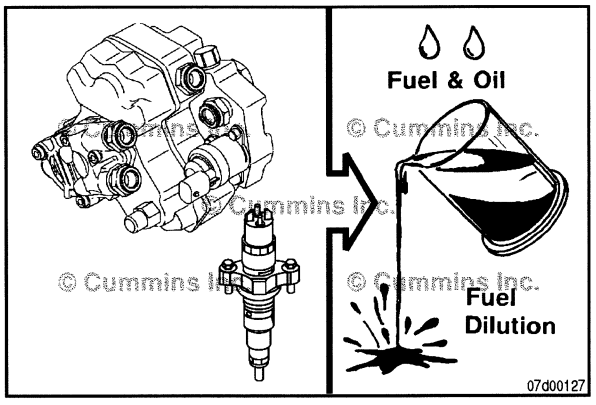




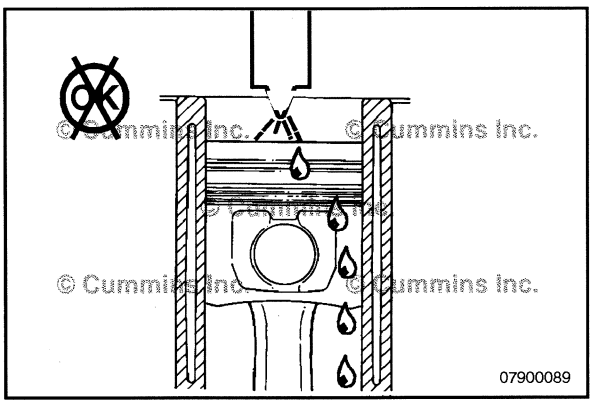
Coolant in the lubricating oil can be caused by a damaged cylinder head gasket or cracked cylinder head or block.

Remove the cylinder head and gasket. Refer to Procedure 002-004 in Section 2.

Inspect for cracks or any other damage.

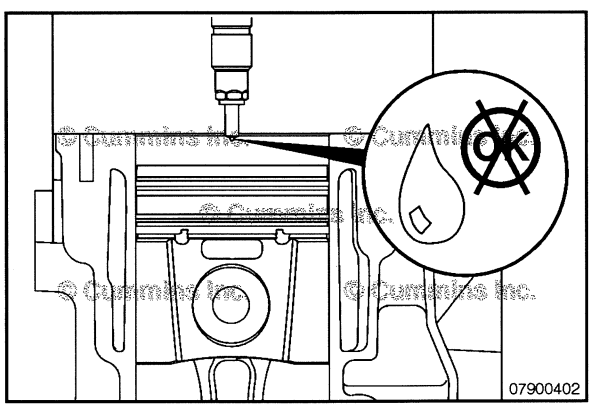


Fuel dilution of the lubricating system is generally due to the injector but may also be due to internal damage to the high-pressure pump.



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.



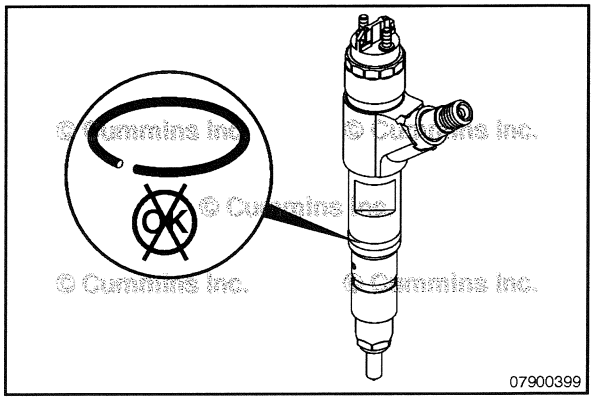
An increase in white exhaust smoke during the first start of the day is a symptom that an injector is leaking.

An injector leak will also cause the engine to run rough and have low power.

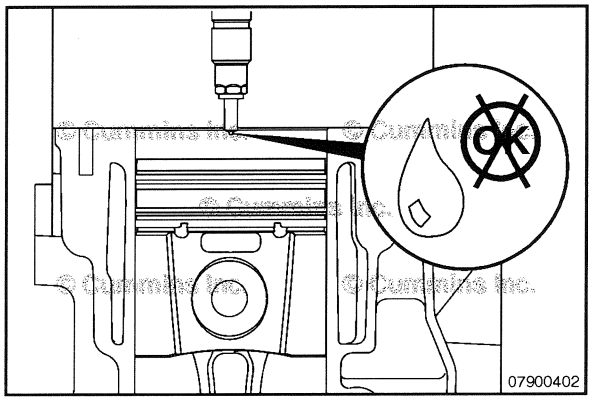
Remove and repair, or replace leaking injectors. Refer to Procedure 006-026 in Section 6.

The o-rings in the injectors can be inspected for cracks or wear. A missing or damaged o-ring in an injector can result in improper distribution of fuel into the cylinder.

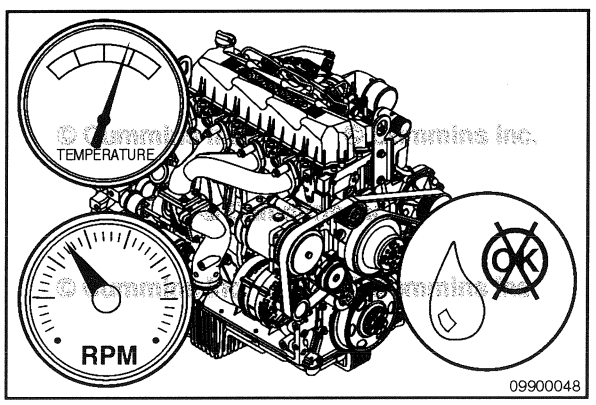
Also, a poor seal between the injector and the high-pressure transfer tube can also cause the injector o-rings to fail or leak into the top of the cylinder head.



Inspect the injector o-ring. Refer to Procedure 006-026 in Section 6.



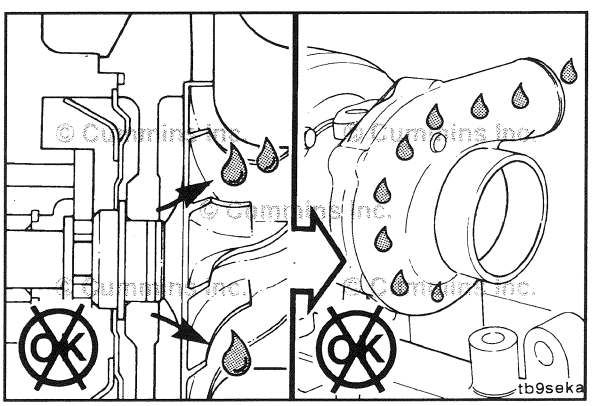
Various gaskets, seals, and plugs are used to contain the lubricating oil. Most leaks can be identified during routine inspections of the engine and vehicle.

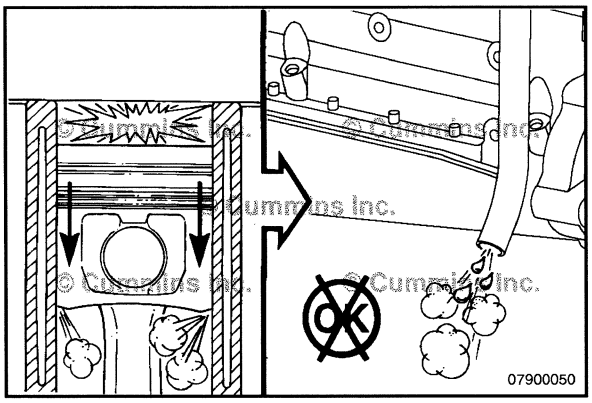


Worn or damaged seals in the turbocharger can also allow oil to leak into the charge-air cooler system and be burned in the engine.

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 failure or any other occasion where oil or debris is put into the charge-air cooler, the charge-air cooler **must** be cleaned.

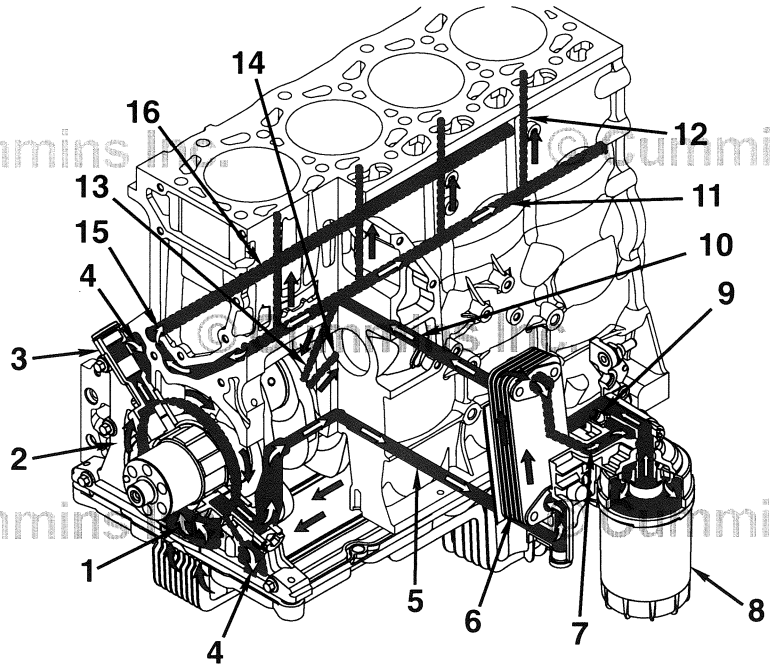




Inadequate sealing of the piston rings will result in oil being blown out the breather tube and/or consumed by the engine. Refer to Procedure 014-010 in Section 14.

Flow Diagram, Lubricating Oil System (200-002)

Flow Diagram



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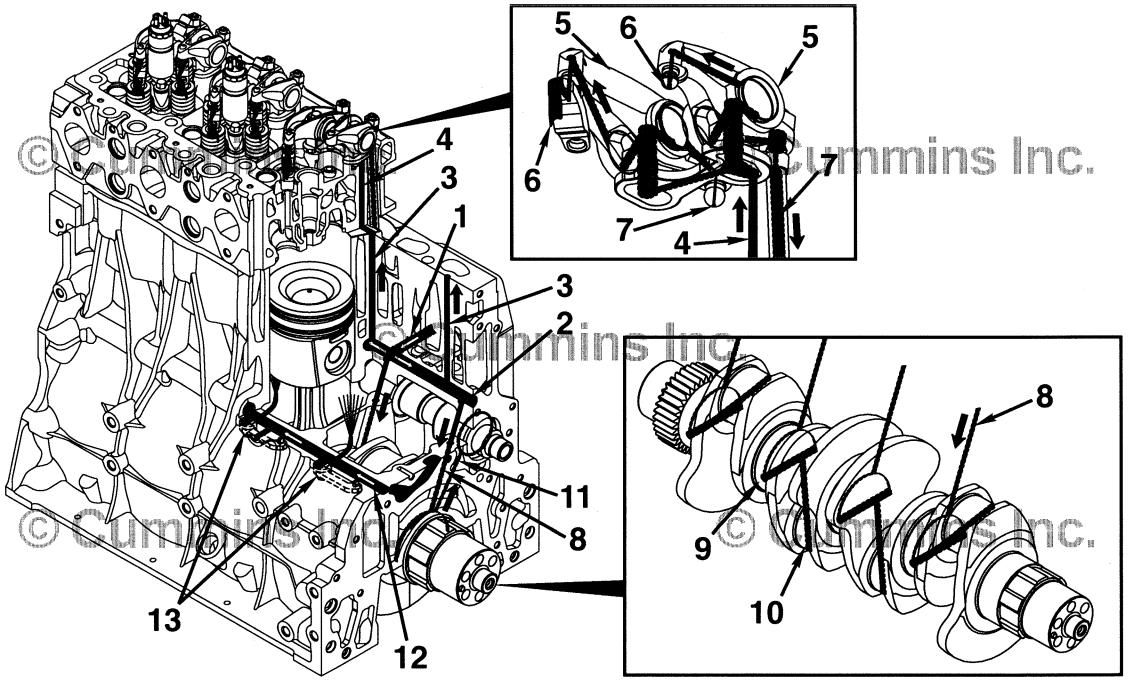
1 Lubricating oil pump inlet from oil pan
2 Lubricating oil pump
3 Lubricating oil pressure regulator
4 Lubricating oil return to oil pan
5 Lubricating oil flow to oil filter
6 Lubricating oil cooler
7 Lubricating oil flow from cooler to filter
8 Lubricating oil filter
9 Lubricating oil filter bypass valve
10 Flow to main oil rifle
11 Main oil rifle
12 Lubricating oil flow to overhead
13 Lubricating oil supply to main bearing feed
14 Lubricating oil supply to camshaft
15 Lubricating oil flow to piston cooling rifle
16 Piston cooling rifle.

Flow Diagram, Lubricating Oil System (200-002)

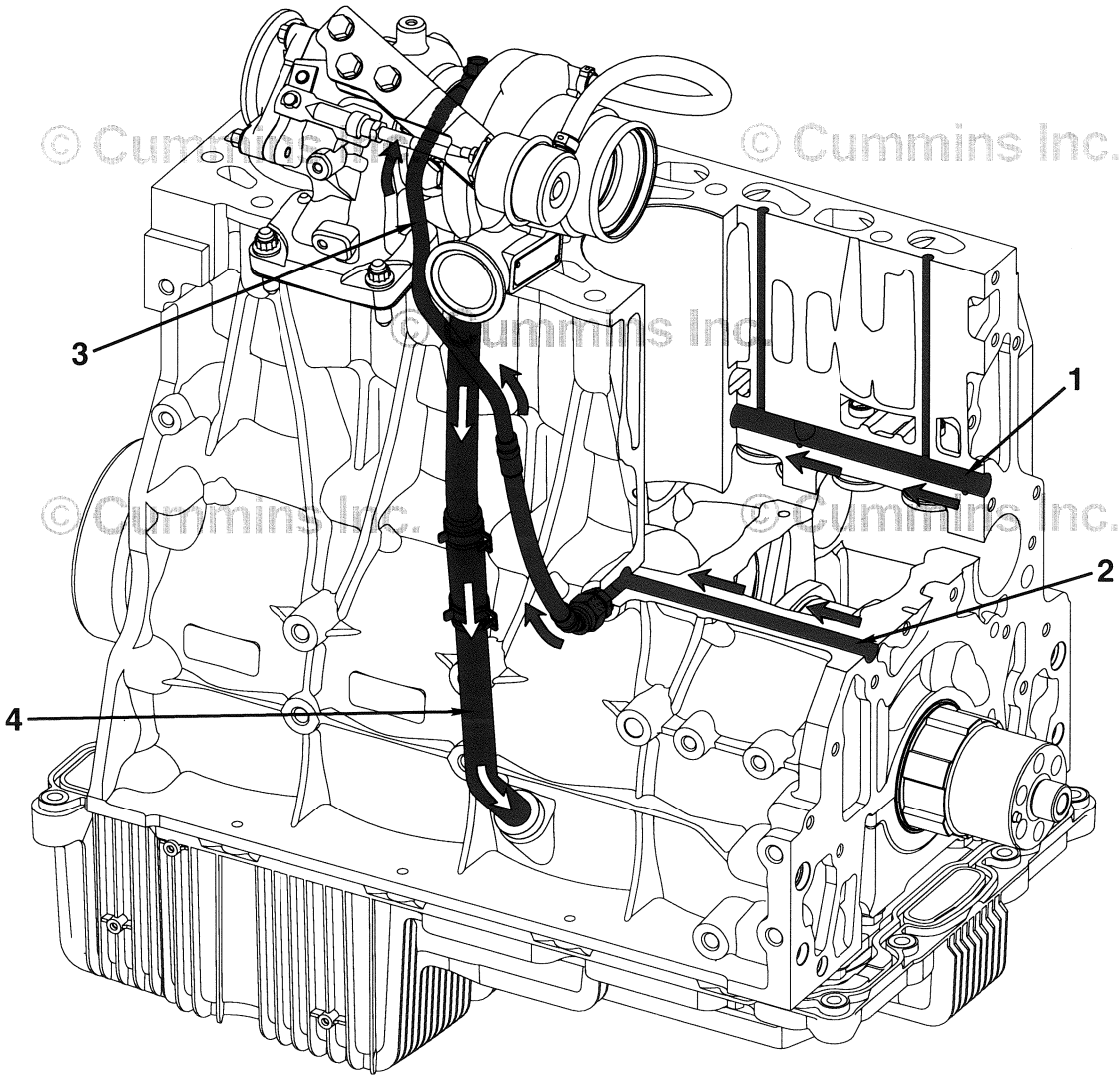
Flow Diagram



1 Lubricating oil flow from oil cooler
2 Main oil rifle
3 Lubricating oil flow to overhead
4 Lubricating oil flow to rocker levers
5 Rocker lever
6 Lubricating oil return to oil pan
7 Lubricating oil flow through push tube
8 Lubricating oil flow to crankshaft main journal
9 Crankshaft main journal
10 Crankshaft connecting rod journal
11 Lubricating oil flow to camshaft
12 Piston cooling rifle
13 Piston cooling nozzle.

Flow Diagram, Lubricating Oil System (200-002)

Flow Diagram



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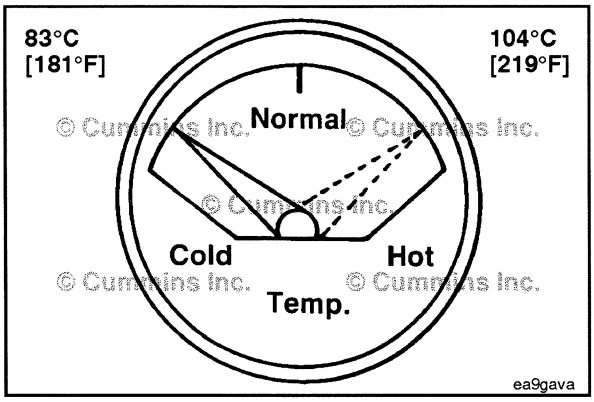
Turbocharger Oil Lubrication

1 Main oil rifle
2 Piston cooling rifle
3 Turbocharger oil supply
4 Turbocharger oil drain.



Cooling System - Overview (008-999)

General Information

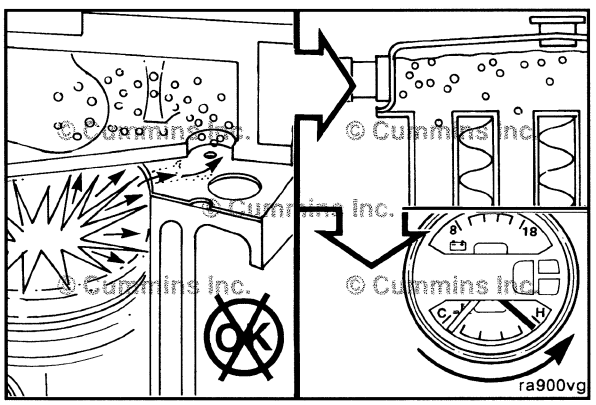
All coolants **must** meet the standards listed in the cooling system specifications. Refer to Procedure 018-004 in Section V of the QSF3.8 CM2350 F107 Operation and Maintenance Manual, Bulletin 4367218. The engine cooling system is compatible with long life coolants.

The cooling system is fully deaerating and has a low coolant level sensor connected to the engine control module (ECM) that will illuminate an instrument lamp and impose a power derate if the coolant reaches and unacceptable level.

An original equipment manufacturer (OEM) coolant supply port is available in the cylinder head.

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 engine coolant flowing through the passages in the cylinder block and cylinder head. Heat is then removed from the engine coolant as it flows through the radiator. Refer to Procedure 200-003 in Section F.

Engine coolant is drawn into a water pump and is pressurized. Engine coolant first flows around the oil cooler plates and enters a cavity around the cylinders. The engine coolant also flows from an internal passage in the cylinder block to the exhaust gas recirculation (EGR) cooler, exhaust pressure regulator, turbocharger actuator, and selective catalyst reduction (SCR). Engine coolant flow continues through holes in the top deck through orifices in the cylinder head gasket. These drillings are around and between each cylinder. Engine coolant flows into the cylinder head and around the valve bridge and injector areas. Engine coolant continues to the exhaust side of the cylinder head past the OEM port locations and to the integral thermostat housing. Before the engine reaches thermostat opening temperature, a bypass port is open to allow engine coolant to enter the suction side of the water pump. Once the engine reaches the thermostat opening temperature, the thermostat opens, allowing the engine coolant to enter the radiator. This action also closes the bypass passage to the water pump.

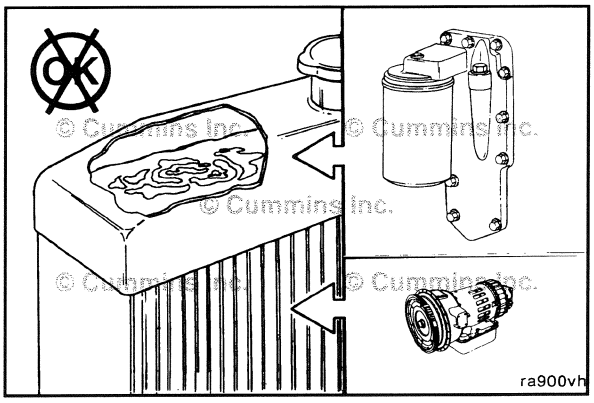


Air in the coolant can result in loss of coolant from the overflow when the aerated coolant is hot. The heated air expands, increasing the pressure in the system, causing the cap to open.

Similarly, coolant can be displaced through the overflow if the cylinder head gasket leaks compression gas into the coolant system.

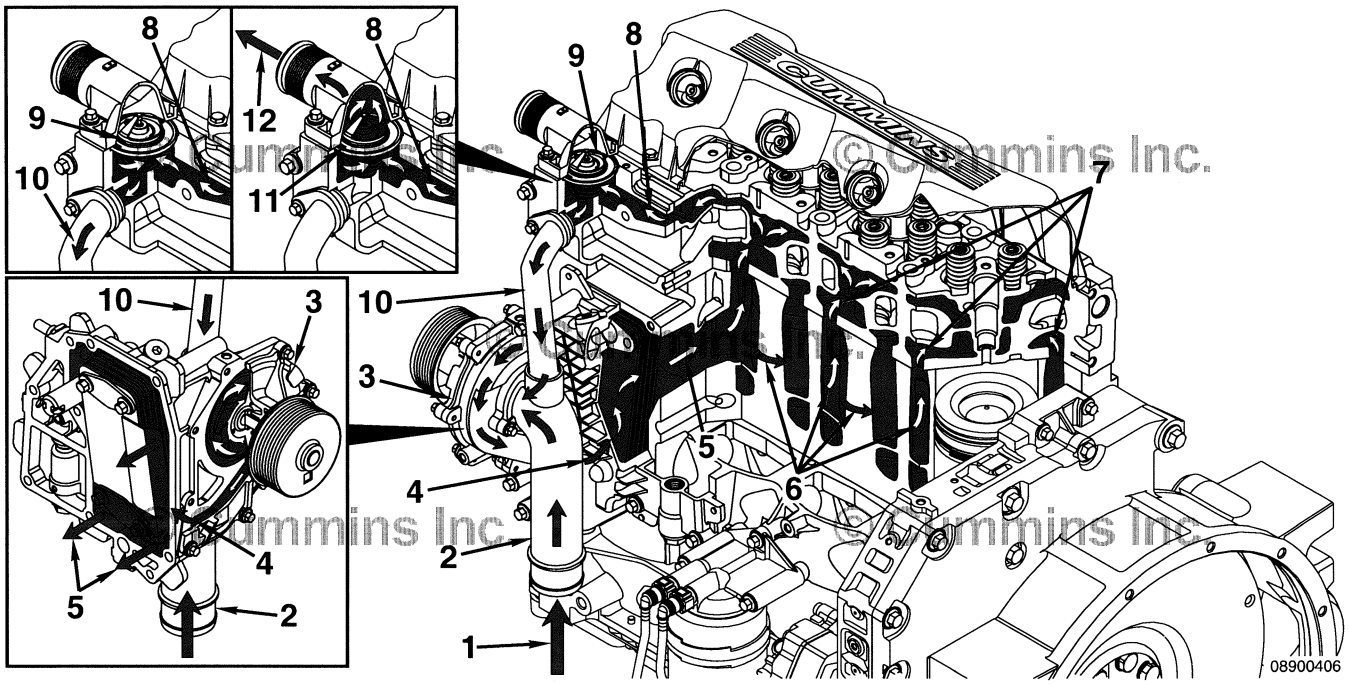
The operating pressure of the coolant system and the lubricating system can result in the mixing of the fluids if there is a leak between the systems, such as the cylinder head gasket or oil cooler. Refer to Procedure 007-999 in Section F.

NOTE: Transmission fluid can also leak into the coolant through radiator bottom tank transmission oil coolers.

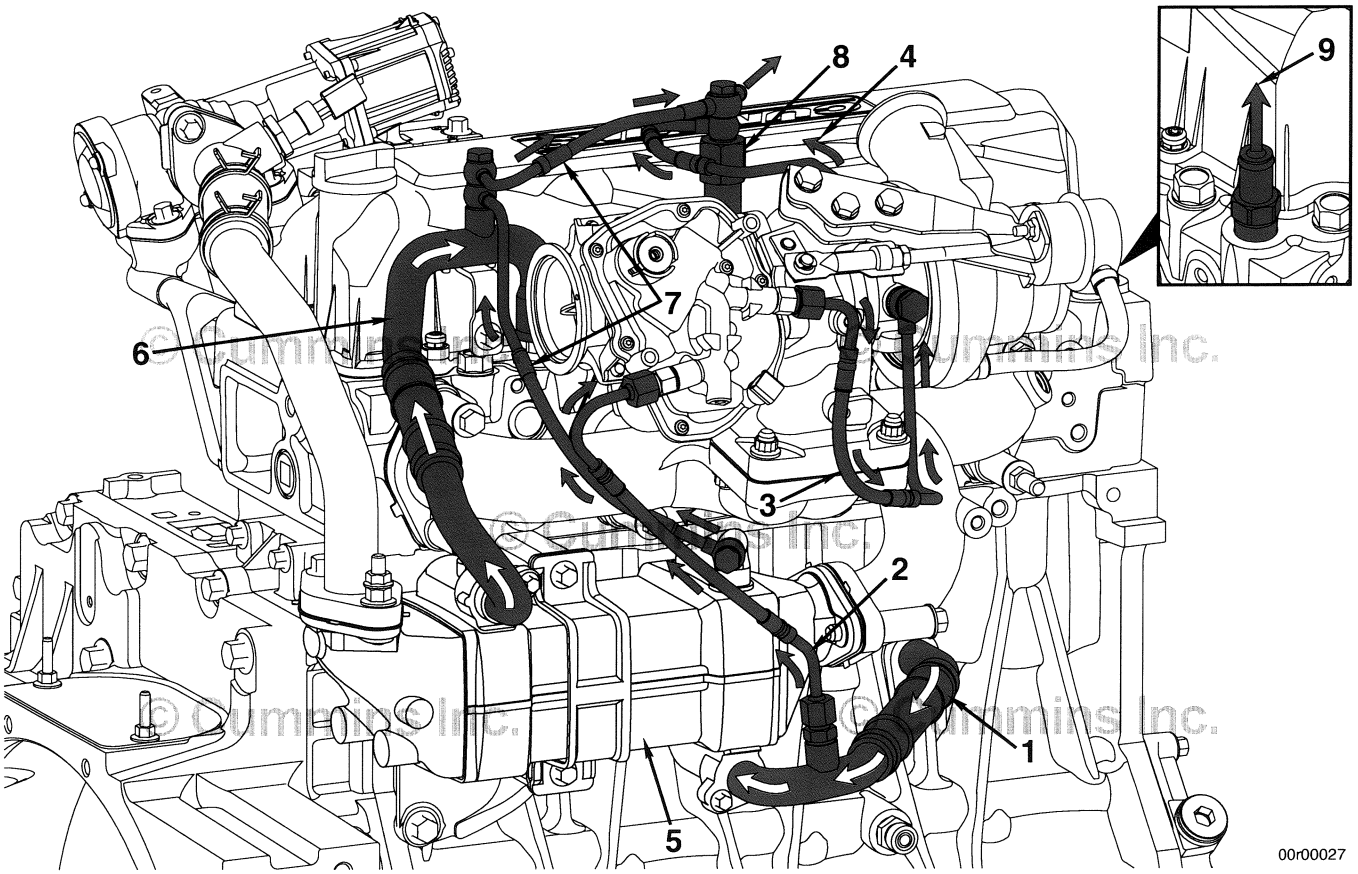


Flow Diagram, Cooling System (200-003)

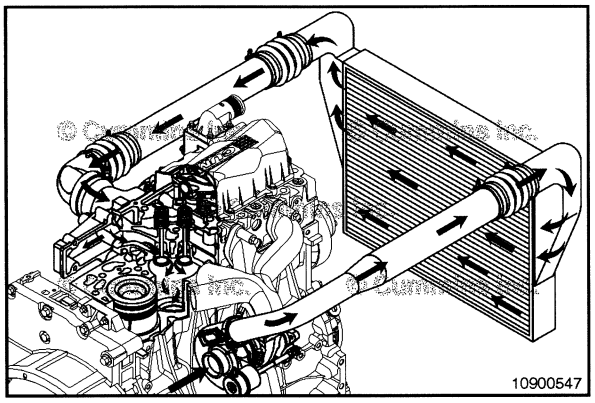
Flow Diagram



1 Coolant flow from radiator
2 Water pump inlet
3 Water pump
4 Coolant flow from water pump to lubricating oil cooler
5 Coolant flow from lubricating oil cooler to cylinder block
6 Coolant flow around cylinders
7 Coolant flow from cylinder block to cylinder head
8 Coolant flow from cylinder head to thermostat housing
9 Thermostat closed
10 Coolant bypass to water pump
11 Thermostat open
12 Coolant return to radiator.



1 EGR cooler coolant inlet
2 Exhaust pressure regulator coolant inlet
3 Exhaust pressure regulator coolant out and turbocharger coolant inlet
4 Turbocharger coolant outlet
5 EGR cooler
6 EGR coolant cooler outlet
7 EGR cooler vent line
8 Coolant vent to OEM expansion tank
9 Cylinder head coolant vent

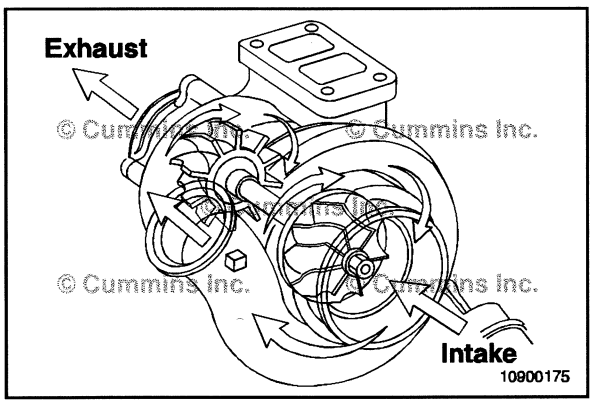


Air Intake System - Overview (010-999)

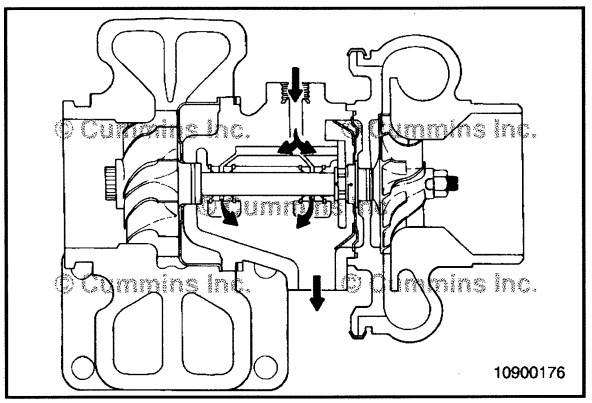
General Information

The combustion air system consists of the following:

- Air cleaner
- Intake air piping
- Turbocharger
- Charge-air piping
- Charge-air cooler
- Intake connection
- Intake air heater
- Exhaust gas recirculation (EGR) piping.



The turbocharger uses exhaust gas energy to turn the turbine wheel. The turbine wheel drives the compressor wheel through a common shaft. The vanes on the compressor wheel then draw intake air through the original equipment manufacturer (OEM) air filter and inlet plumbing into the compressor housing of turbocharger. The air is then pressurized by the compressor wheel before being delivered to the charge-air cooler.



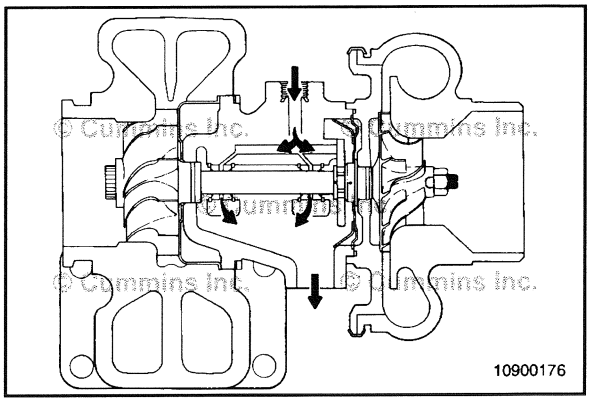
△CAUTION△

A restricted oil drain line can cause the turbocharger bearing housing to be pressurized, causing oil to leak past the seal rings.

NOTE: An adequate supply of good filtered oil is very important to the life of the turbocharger. Make sure that a high-quality oil is used and that it and the oil filter are changed according to maintenance recommendations. See the corresponding Operation and Maintenance, or Owner's Manual for the engine being serviced.

⚠CAUTION⚠

The turbocharger is a performance part and must not be tampered with. The wastegate bracket is an integral part of the turbocharger. Tampering with the wastegate components can reduce durability by increasing cylinder pressure and thermal loading due to incorrect inlet and exhaust manifold pressure. Poor fuel economy can result. Increasing the turbocharger boost will not increase engine power.



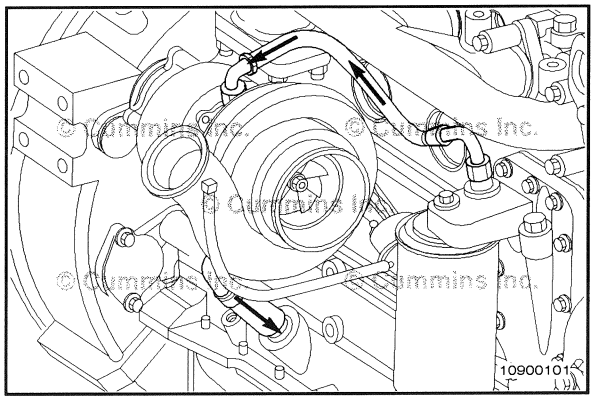
Wastegate turbochargers are used to optimize performance.

NOTE: The wastegate design allows maximum boost to be developed quickly while making sure that the turbocharger does **not** overspeed at higher engine rpm.

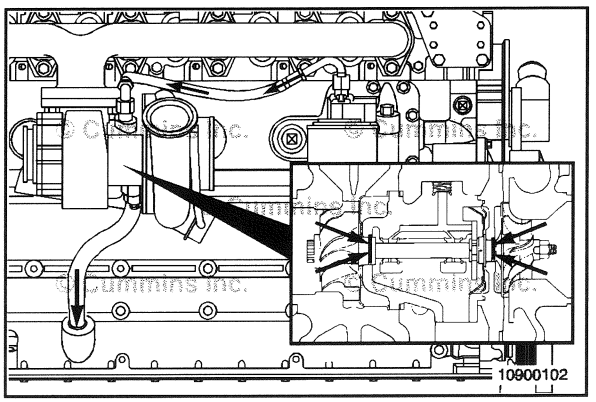
Wastegate operation is controlled by an actuator that senses compressor pressure and balances it against a preset spring-load. The wastegate valve is located in the turbine inlet passage. When open, it diverts a portion of the exhaust gas away from the turbine wheel, thereby controlling the shaft speed and boost.

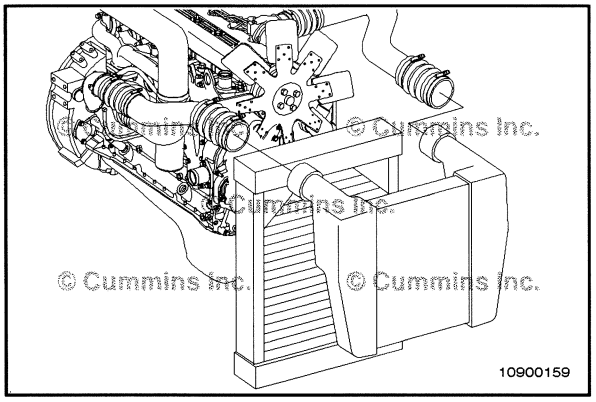
Lubricating Oil Consumption and Leaks

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



Seal rings are used on each end of the rotor assembly. The primary function of the seals is to prevent exhaust gases and compressed air from entering the turbocharger housing. Lubricating oil leakage from the seals is rare, but can occur.

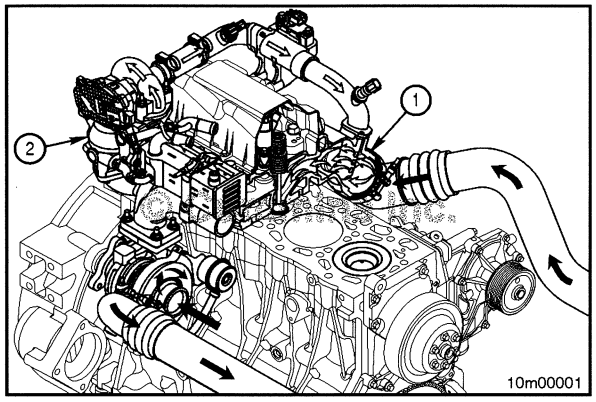




Charge-Air Cooled Engines

- Most engines utilize a chassis-mounted charge-air cooler to improve engine performance and reduce emissions. This system also uses large diameter piping to transfer the air from the engine turbocharger to the charge-air cooler, and then returns the air from the charge-air cooler to the engine intake manifold.

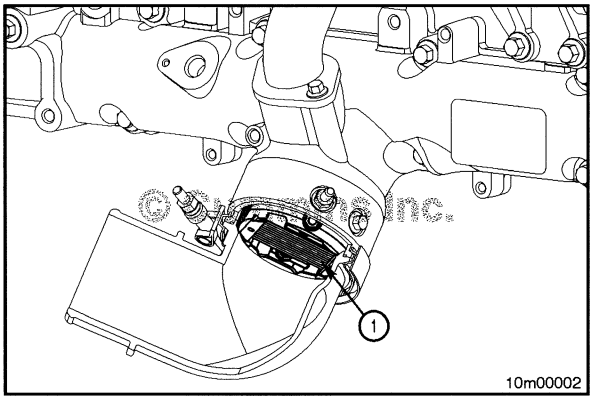
NOTE: The long-term integrity of the charge-air cooling system is the responsibility of the vehicle and component manufacturers.



NOTE: The style of the air intake connection can vary, depending on the application. Although the air intake connection can appear different, the function is still the same.

Air Intake System

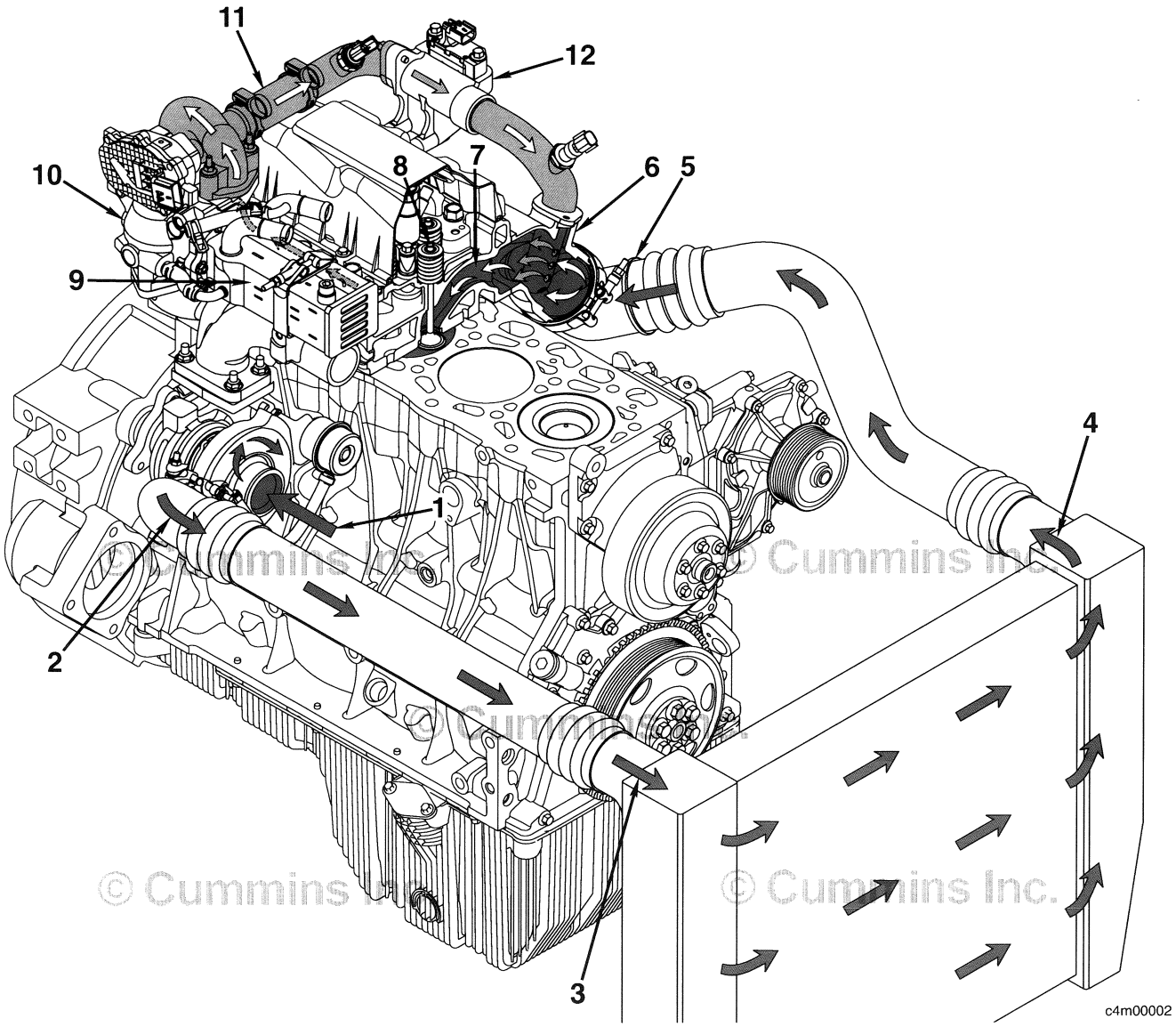
- The air intake connection (1) is a critical piece in combining the EGR flow and the fresh intake air of the engine. The EGR valve (2) is mounted on the exhaust side of the engine and controls the amount of exhaust gases that are recirculated through the EGR cooler and into the intake of the engine.



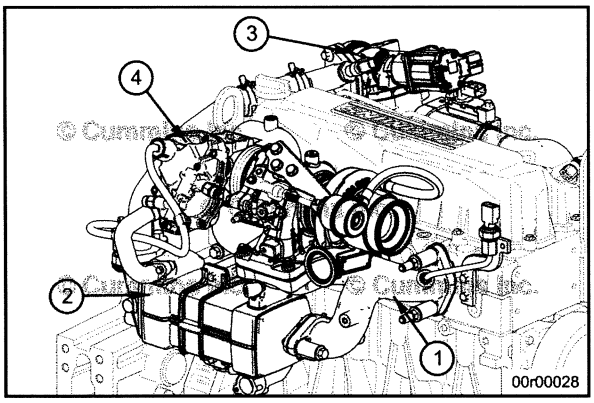
The integral cold starting aid (1) is a single-element intake air heater used to preheat intake air under cold ambient conditions. The ON/OFF operation of the intake air heater is controlled by the engine control module (ECM). The engine ECM controls a single OEM-supplied solenoid which provides power for the intake air heater when commanded.

Flow Diagram, Air Intake System (200-004)

Flow Diagram



1 Filtered air supply to turbocharger compressor inlet
2 Turbocharger compressor outlet
3 Charge-air cooler inlet
4 Charge-air cooler outlet
5 Air intake connection
6 Air intake manifold
7 Intake port
8 Intake valve
9 Exhaust gas recirculation (EGR) cooler
10 EGR valve
11 EGR crossover tube
12 EGR mass measurement flow assembly.



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 in to the engine.

The major components of the exhaust system:

1 Exhaust manifold

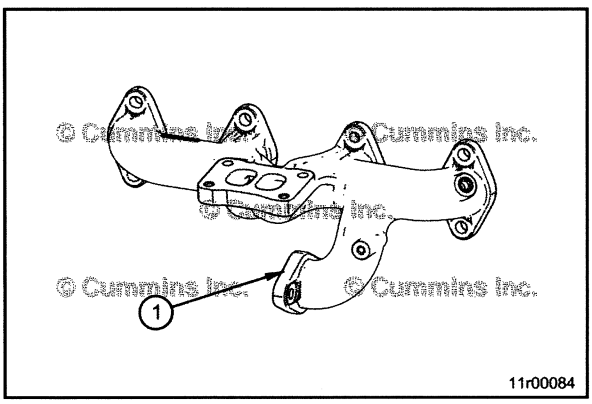
2 EGR cooler

3 EGR valve

4 Exhaust pressure regulator.

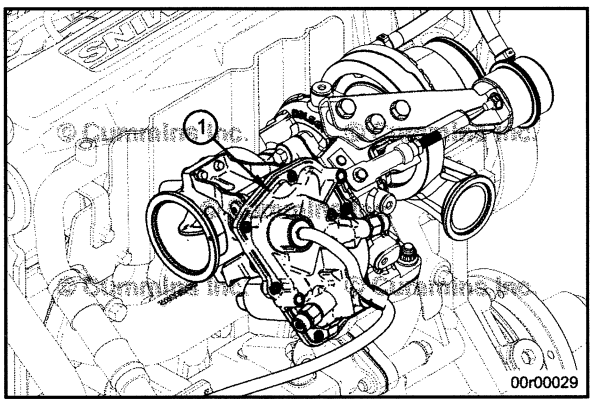
NOTE: The following procedure contains an overview of air intake system components. Refer to Procedure 010-999 in Section F.

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



Exhaust Manifold

- The exhaust manifold is a single piece design
- The exhaust manifold has a port (1) for the EGR cooler.



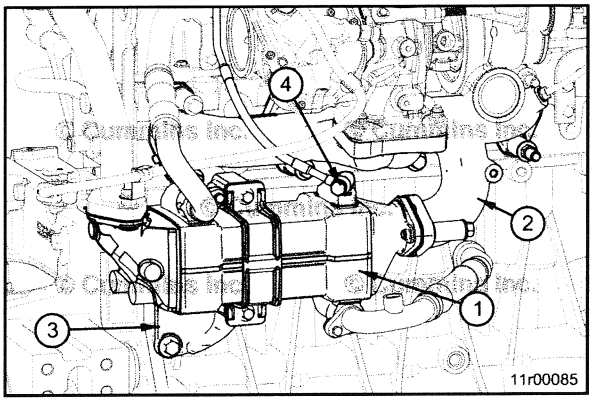
Exhaust Pressure Regulator

- The engine control module (ECM) uses the exhaust pressure regulator (1) to regulate air flow at the turbine exhaust outlet to aid in the thermal control of the wastegate turbocharger and EGR valve.

EGR Cooler

- The EGR cooler (1) cools the exhaust gases flowing from the exhaust manifold.
- The EGR cooler is mounted below the exhaust manifold (2), and is supported by an EGR cooler mounting bracket (3) attached to the cylinder block.

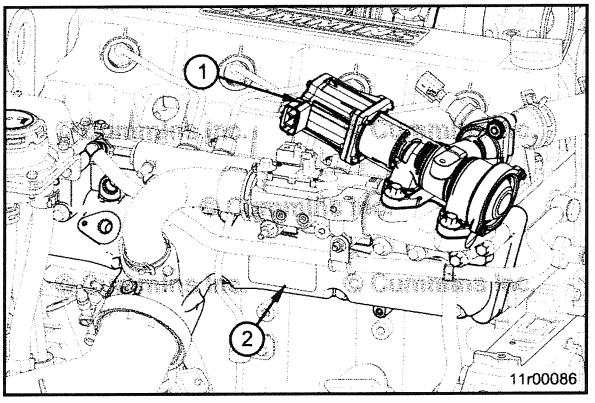
The EGR cooler has a coolant vent (4) on the top. This vent prevents air from being trapped in the cooler during filling of the coolant.



EGR Valve

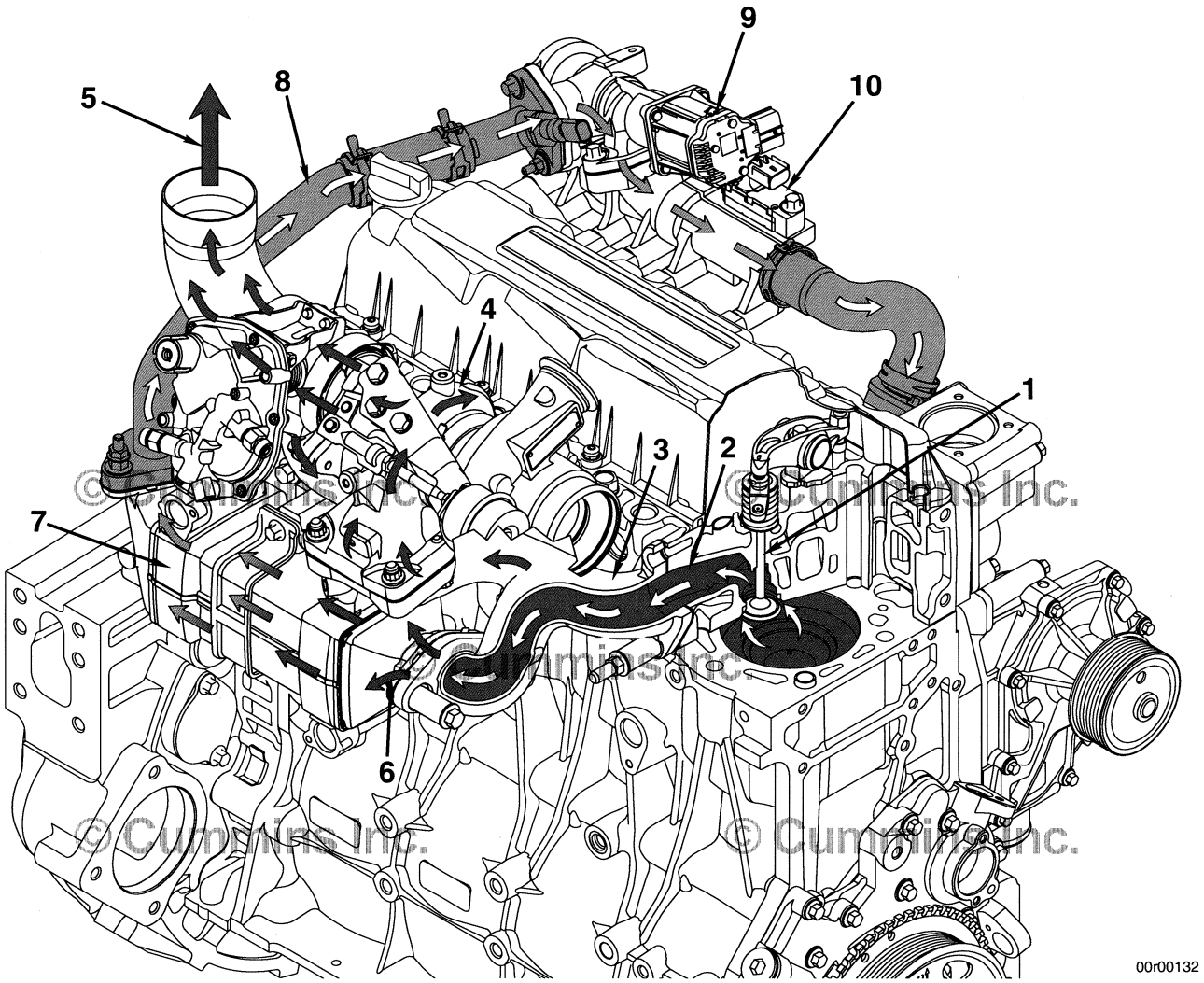
- The EGR valve (1) is mounted on top of the intake manifold (2). The EGR valve is an electric motor-driven valve that is controlled by the ECM. The EGR valve uses a poppet valve to control the EGR flow into the intake manifold.

NOTE: The EGR valve motor is **not** a serviceable part. If damaged, the entire EGR valve assembly **must** be replaced.



Flow Diagram, Exhaust System (200-005)

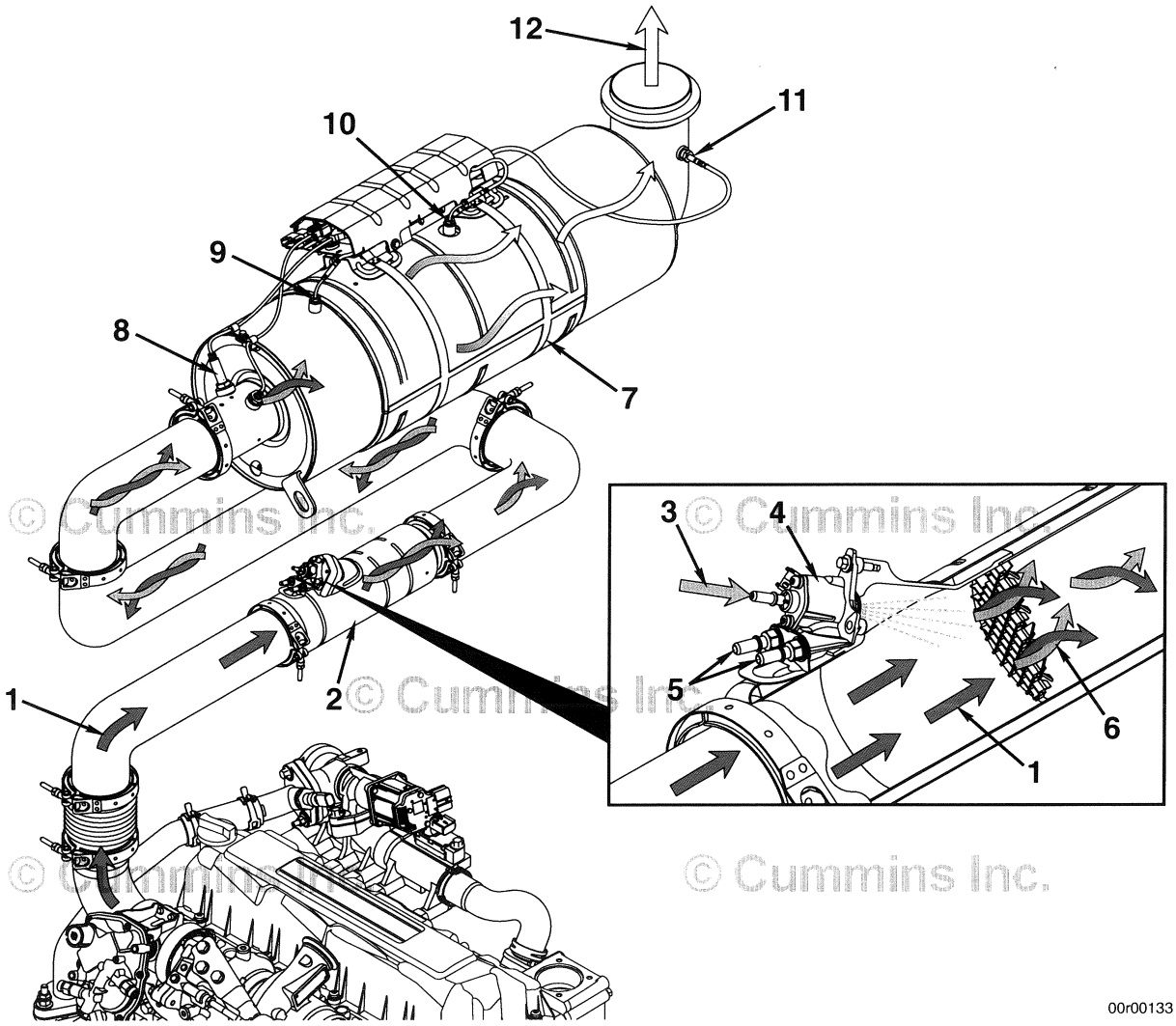
Flow Diagram



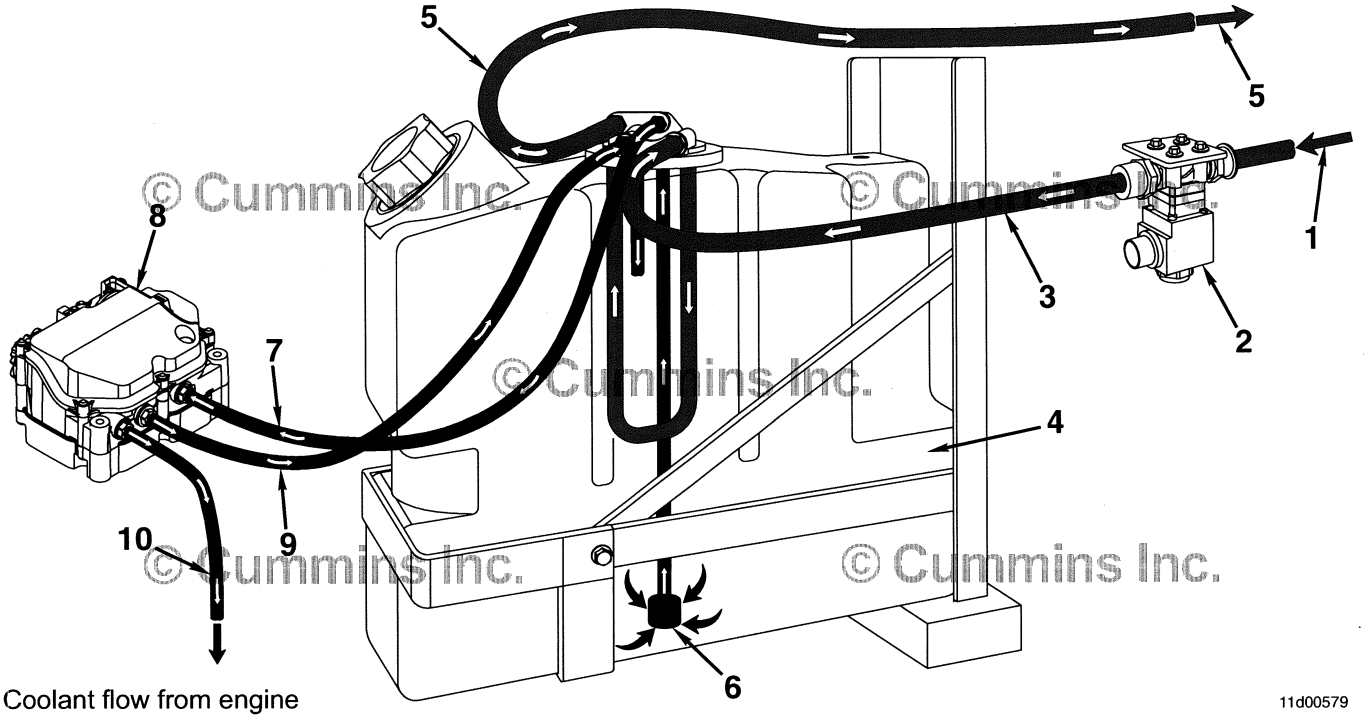
1 Exhaust valve
2 Exhaust port
3 Exhaust manifold
4 Turbocharger
5 Turbocharger exhaust outlet to aftertreatment
6 Exhaust inlet to EGR cooler
7 EGR cooler
8 Cooled exhaust outlet to EGR valve
9 EGR valve
10 Exhaust valve differential pressure sensor.

Flow Diagram, Exhaust System (200-005)

Flow Diagram



1 Exhaust from turbocharger
2 Decomposition reactor
3 DEF supply to aftertreatment DEF dosing valve
4 Aftertreatment DEF dosing valve
5 Aftertreatment DEF dosing valve coolant fittings
6 Exhaust and DEF mixture
7 Aftertreatment SCR catalyst
8 Aftertreatment SCR outlet NOx sensor
9 Aftertreatment SCR intake temperature sensor
10 Aftertreatment SCR outlet temperature sensor
11 Aftertreatment SCR outlet NOx sensor
12 Exhaust flow exiting aftertreatment system.



1 Coolant flow from engine
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 flow to engine
6 Aftertreatment DEF supply from aftertreatment DEF tank
7 Aftertreatment DEF flow to aftertreatment DEF dosing control valve
8 Aftertreatment DEF control valve
9 Aftertreatment DEF flow to aftertreatment DEF tank
10 Aftertreatment DEF flow to aftertreatment DEF dosing valve.

Electrical Equipment - Overview (013-999)

General Information

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of severe personal injury, always ventilate the compartment before beginning work. Always detach the negative (-) battery cable first, and attach the negative (-) battery cable last.

⚠WARNING⚠
To reduce the possibility of personal injury, keep hands, long hair, jewelry, and loose-fitting or torn clothing away from fans and other moving parts.

The basic electrical system consists of:

1 Batteries

2 A starter motor

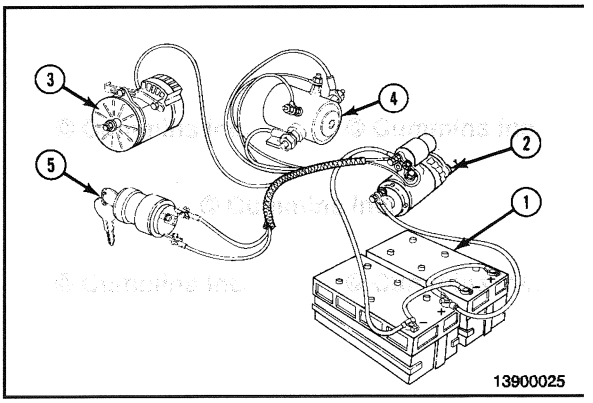
3 An alternator

4 A magnetic switch

5 A keyswitch.

The basic electrical system also consists of all necessary wiring.

All components **must** be carefully matched.



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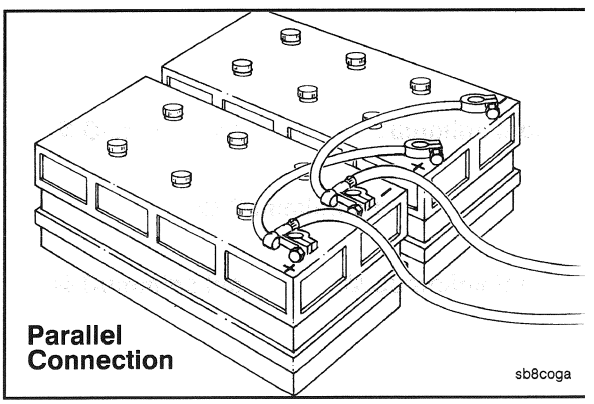
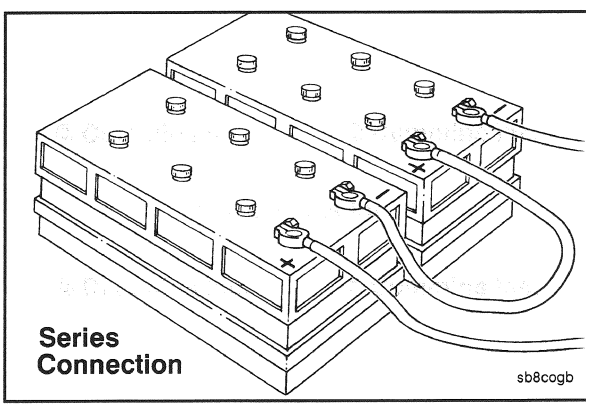
The accompanying illustrations show typical parallel and series battery connections:

- Parallel connection



sb8coga

- Series connection.



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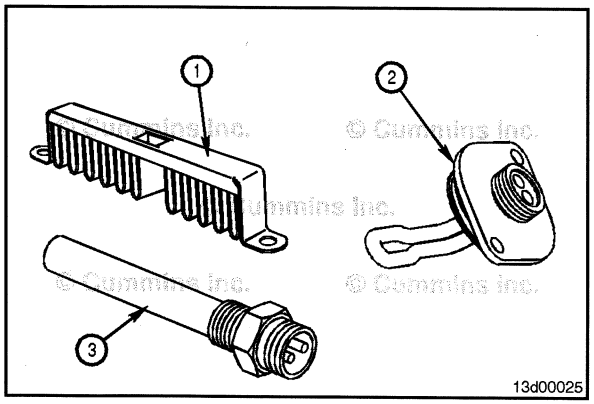

Other electrical accessories available are:

1 Intake heater

2 Engine coolant heater

3 Oil pan heater.

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 specifications more than 50 percent indicate that something is wrong. The engine test **must** be discontinued until the cause has been determined and corrected.

Section TS - Troubleshooting Symptoms

Section Contents

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.

⚠WARNING⚠

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. See Procedure 014-008 in the corresponding Troubleshooting and Repair Manual or Service manual for the engine being worked on. 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

(Refer to 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 at 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

(Refer to Engine Noise Excessive - Connecting Rod symptom tree)

Connecting rods with excessive clearance knock at all engine speeds, and 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

(Refer to 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 which 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 steady speed condition.

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.

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, if equipped
- 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. Refer to 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, if equipped
- Excessive drainline restriction
- Accelerator deadband.

Driveability/Low Power - Customer Complaint Form

Customer Name/Company _____ 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 behavior
- When do you notice the Problem/Complaint occuring?
- 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 _____

Driveability/Low Power - Customer Complaint Form

Answer the following questions 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/mph _____
- What is achieved speed? rpm/mph _____
- 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 THE ANSWER WAS NO TO ONE OF THE PREVIOUS QUESTIONS, FILL OUT THE DRIVEABILITY/LOW-POWER/EXCESSIVE FUEL CONSUMPTION CHECKLIST AND GO TO THE LOW-POWER SYMPTOM 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 THE ANSWER WAS YES TO ONE OF THE PREVIOUS QUESTIONS, FILL OUT THE DRIVEABILITY/LOW-POWER/EXCESSIVE FUEL CONSUMPTION CHECKLIST, AND GO TO THE POOR ACCELERATION/RESPONSE SYMPTOM 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, No. 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:		
Fuel Heater:			Conditions (Wind, Rain, Snow):		
Fuel Type:			Number 1D	Number 2D	Other
Typical Terrain:		Flat	Hilly	Percent Asphalt	Percent Concrete

Additional Comments:

_____

_____

_____

NOTE: Use this information for VE/VMS® run.

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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.

Fuel Consumption - Customer Complaint Form

Customer Name/Company _____ Date _____

Answer the following questions. Some questions require making an X next to the appropriate answer.

1 What fuel mileage is expected? _____ Expected mpg

2 What are the expectations based on? Original mileage _____, Other units in fleet _____, Competitive engines _____Previous engine owned_____, Expectations **only** _____, VE/VMS® report _____

3 When did the problem occur? Since New _____, Suddenly _____, Gradually _____

4 Did the problem start after a repair? Yes _____ No _____If so, what was repaired and when? _____

5 Is the vehicle also experiencing a driveability issue (low power or poor acceleration/response)? Yes _____ No _____

IF ANSWERED YES, FILL OUT THE DRIVEABILITY/LOW-POWER/EXCESSIVE FUEL CONSUMPTION CHECKLIST, AND GO TO THE ENGINE POWER OUTPUT LOW TROUBLESHOOTING SYMPTOM CHART.

1 Is the problem seasonal? Yes _____ No _____

2 Weather conditions during fuel consumption check? Rain _____, Snow_____, Wind _____, Hot temperatures _____, Cold temperatures _____

3 How is the fuel mileage measured? Tank _____, Trip _____, Month_____, Year _____Hubometer _____, Odometer _____

4 Are accurate records kept of fuel added on the road? Yes _____No _____

5 Do routes vary between compared vehicles? Yes _____ No _____

6 Have routes changed for the engine being checked? Yes _____ No_____

7 What are the loads hauled, compared to comparison unit? Gross Vehicle Weight _____Heavier _____, Lighter _____

8 What is the altitude during operation? Below 10,000 feet _____, Above 10,000 feet _____

9 How much of the time is the truck spent idling? Hours/day _____

10 Is the driver technique or operating practices affecting fuel economy?

- High road speed: mph _____
- Operate at rated speed or above: rpm _____
- Incorrect shift rpm: Shift rpm _____, Torque peak _____
- Operate at a cruise speed: rpm _____
- Compensating for low power: Yes _____ No _____

IF, AFTER FILLING OUT THIS FORM, IT APPEARS THAT THE ISSUE IS NOT CAUSED BY VEHICLE FACTORS, ENVIRONMENTAL FACTORS, OR DRIVER TECHNIQUE, FILL OUT THE DRIVEABILITY/LOW-POWER/ EXCESSIVE FUEL CONSUMPTION CHECKLIST, AND GO TO THE FUEL CONSUMPTION EXCESSIVE TROUBLESHOOTING SYMPTOM TREE.

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Oil Consumption

In addition to the information that follows, a service publication is available titled Technical Overview of Oi Consumption, Bulletin 3379214.

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

ACCEPTABLE OIL USAGE									
ANY TIME DURING COVERAGE PERIOD									
ENGINE FAMILY	MILES PER QUART	MILES PER LITER	MILES PER IMPERIAL QUART	KM PER QUART	KM PER LITER	KM PER IMPERIAL QUART	HRS PER QT	HRS PER LITER	HOURS PER IMPERIAL QUART
A - Series	-	-	-	-	-	-	10.0	10.6	12.0
B3.3/4B	400	425	475	650	675	775	10.0	10.6	12.0
ISF	400	425	475	650	675	775	10.0	10.6	12.0
6B/ISB/ QSB	400	425	475	650	675	775	10.0	10.6	12.0
6C/ISC/ QSC/ISL	400	425	475	650	675	775	10.0	10.6	12.0
V/VT-378	-	-	-	-	-	-	4.0	4.3	5.0
V/VT-504	250	265	310	400	425	485	4.0	4.3	4.8
V/VT-555	250	265	310	400	425	485	4.0	4.3	4.8
L10	500	530	620	800	850	970	7.0	7.4	8.4
M11/ISM	500	530	620	800	850	970	7.0	7.4	8.4
N14/NT	500	530	620	800	850	970	7.0	7.4	8.4
ISX/QSX/ Signature™	500	530	620	800	850	970	7.0	7.4	8.4
V/VT/ VTA-903	250	265	310	400	425	485	4.0	4.3	4.8
KT/KTA19	200	210	250	320	340	390	3.0	3.2	3.6
V/VT/ VTA28	-	-	-	-	-	-	2.0	2.1	1.1
KT/KTA38	-	-	-	-	-	-	1.5	1.6	1.8
KTA50	-	-	-	-	-	-	1.1	1.2	1.3
QSK19	-	-	-	-	-	-	3.0	3.2	3.6
QST30	-	-	-	-	-	-	1.7	1.8	2.0
QSK23	-	-	-	-	-	-	1.7	1.8	2.0
QSK38	-	-	-	-	-	-	1.3	1.4	1.5
QSK45	-	-	-	-	-	-	1.25	1.3	1.5
QSK50	-	-	-	-	-	-	1.0	1.1	1.2
QSK60	-	-	-	-	-	-	0.9	0.95	1.1
QSK78	-	-	-	-	-	-	0.6	0.65	0.72

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

Oil Consumption

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

15200020

Engine Lubricating Oil Consumption Report				
Owner's Name	Engine Serial Number		Engine Model and Horsepower	
	Date of Delivery			
	Month		Day	Year
Address	Equipment Manufacturer			
City	State/ Province	Equipment Serial Number		Fuel Pump Serial Number
Engine Application (describe)	Oil and Filter Change Interval		Complaint Originally Registered	
	Oil	Filters	Date	Miles/Hours/ Kilometers

Lubricating Oil Added			
Date Added Oil	Engine Operation Miles/Hours/ Kilometers	Oil Added Liters/Quarts	Oil Used Brand/ Viscosity
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

Oil Consumption

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

15200020

OIL CONSUMPTION REPORT	
Customer Name:	D/r:
Engine Model:	Mi/Km/Hr:
Engine Serial Number:	CPL Number:
Vehicle Make/Model:	Date:
Signed: _____	

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 equipment manufacturer service information.
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 the QSF3.8 CM2350 F107 Owners Manual. Bulletin 4367318 or the QSF3.8 CM2350 F107 Operation and Maintenance Manual, Bulletin 4367317 for the engine being serviced to verify correct engine idle speed and operation.
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 equipment manufacturer service information 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 Procedure 013-009 in Section 13.
OK Go To Next Step	
STEP 6 Batteries have malfunctioned	Check the condition of the batteries. Replace the batteries, if necessary. Refer to Procedure 013-007 in Section 13.
OK Go To Next Step	
STEP 7 Alternator pulley is loose on the shaft	Tighten the pulley. Refer to the alternator manufacturers' and/or equipment manufacturer service information.
OK Go To Next Step	
STEP 8 Battery temperature is above specification	Position the batteries away from heat sources. Refer to equipment manufacturer service information.
OK Go To Next Step	

Alternator Not Charging or Insufficient Charging

This is symptom tree t013

Cause	Correction
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 or equipment manufacturer service information.

OK
Go To Next Step

STEP 10 Alternator is overloaded, or alternator capacity is below specification	Install an alternator with a higher capacity. Refer to Procedure 013-001 in Section 13 and equipment manufacturer service information.

OK
Go To Next Step

STEP 11 Electronic fault codes active or high counts of inactive fault codes	Read the fault codes with an electronic service tool. Refer to the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319 for the engine being serviced.

Alternator Overcharging

This is symptom tree t014

Cause	Correction
STEP 1 Battery cables or connections are loose, broken, or corroded (excessive resistance)	Check the battery cables and connections. Refer to Procedure 013-009 in Section 13.
OK Go To Next Step	
STEP 2 Battery cell is damaged (open circuit)	Check the condition of the batteries. Replace the batteries, if necessary. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 3 Voltage regulator is malfunctioning	Check the voltage regulator. Replace the voltage regulator, if necessary. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 4 Electronic fault codes active or high counts of inactive fault codes	Read the fault codes with an electronic service tool. Refer to the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.

Coolant Loss - External

This is symptom tree t020

Cause	Correction
STEP 1 Power system coolant level is above specification	Check the power system coolant level. Refer to Procedure 008-018 in Section 8.
OK Go To Next Step	
STEP 2 External coolant leak	Inspect the engine for coolant leaking from hoses, drain cocks, water manifold, jumper tubes, expansion and pipe plugs, fittings, EGR cooler coolant supply and return tubes, EGR cooler vent lines, exhaust pressure regulator coolant lines, turbocharger coolant supply and return lines, EGR cooler, radiator core, cylinder head gaskets, lubricating oil cooler, water pump seal, and OEM-mounted components that have coolant flow. If necessary, pressure test the cooling system. Refer to Procedure 008-020 in Section 8.
OK Go To Next Step	
STEP 3 Radiator cap is **not** correct, is malfunctioning, or has low-pressure rating	Check the radiator pressure cap. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 4 Cooling system hose is collapsed, restricted, or leaking	Inspect the hoses. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 5 Fill line or vent lines are restricted, obstructed, or **not** routed correctly	Check the vent lines and the fill line for correct routing and for restrictions. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 6 Incorrect OEM plumbing routing, resulting in loss of coolant through the coolant overflow	Review the plumbing to be positive that no high pressure coolant can cause backflow in the fill line. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 7 Engine is overheating	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.
OK Go To Next Step	

Coolant Loss - External

This is symptom tree t020

Cause	Correction
STEP 8 Air or combustion gases are entering the cooling system	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
STEP 1 Radiator cap is **not** correct, is malfunctioning, or has low-pressure rating	Check the radiator pressure cap. Refer to Procedure 008-020 in Section 8.
OK Go To Next Step	
STEP 2 EGR cooler leaking coolant	Check the EGR cooler for leaks. Refer to Procedure 011-019 in Section 11.
OK Go To Next Step	
STEP 3 Lubricating oil is contaminated with coolant	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.
OK Go To Next Step	
STEP 4 Internal coolant leaks	Refer to Procedure 008-020 in Section 8 to pressure test the cooling system and look for internal coolant leaks.
OK Go To Next Step	
STEP 5 Turbocharger leaking coolant	Refer to Procedure 008-020 in Section 8 to pressure test the cooling system and look for internal coolant leaks.
OK Go To Next Step	
STEP 6 Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to Procedure 002-004 in Section 2 to remove the cylinder head gasket and inspect.
OK Go To Next Step	
STEP 7 Cylinder head is cracked or porous	Pressure test the cylinder head. Refer to Procedure 002-004 in Section 2.
OK Go To Next Step	
STEP 8 Cylinder block is cracked or porous	Inspect the cylinder block. Refer to Procedure 001-026 in Section 1.

Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

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 the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.
OK Go To Next Step	
STEP 2 Cold weather radiator cover or winterfront is closed	Open the cold weather radiator cover or the winterfront. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 3 Radiator shutters are **not** opening completely or the shutterstat setting is wrong	Inspect the radiator shutters. Repair or replace, if necessary. Check the shutterstat setting. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 4 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 and equipment manufacturer service information.
OK Go To Next Step	
STEP 5 Coolant level is below specification	Check the coolant level. Check for an external leak. Refer to Procedure 008-018 in Section 8 and the Coolant Leak External troubleshooting symptom tree in Section TS. Sample the lubricating oil and have a laboratory check for coolant in the oil (internal leak).
OK Go To Next Step	
STEP 6 Coolant mixture of antifreeze and water is **not** correct	Verify the concentration of antifreeze in the coolant. Add antifreeze or water to correct the concentration. Refer to the Cummins® Coolant Requirements and Maintenance, Bulletin 3666132.
OK Go To Next Step	
STEP 7 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 equipment manufacturer service information.
OK Go To Next Step	

Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

Cause	Correction
STEP 8 Fan drive belt is broken or loose	Check the fan drive belt. Replace the belt, if necessary. Refer to Procedure 008-002 in Section 8.
OK Go To Next Step	
STEP 9 Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure 008-027 in Section 8 if electronically controlled by the engine control module (ECM). If OEM controlled, see equipment manufacturer service information.
OK Go To Next Step	
STEP 10 Coolant temperature gauge or sensor is malfunctioning	Test the gauge or the sensor. Repair or replace, if necessary. Refer to equipment manufacturer service information on troubleshooting the gauge. Reference the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319, to monitor and check the coolant temperature sensor.
OK Go To Next Step	
STEP 11 Radiator cap is **not** correct, is malfunctioning, or has low-pressure rating	Check the radiator pressure cap. Refer to Procedure 008-047 in Section 8.
OK Go To Next Step	
STEP 12 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 13 Cooling system hose is collapsed, restricted, or leaking	Inspect the hoses. Refer to Procedure 008-020 in Section 8.
OK Go To Next Step	
STEP 14 Fill line or vent lines are restricted, obstructed, or **not** routed correctly	Check the vent lines and the fill line for correct routing and for restrictions. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 15 Intake manifold air temperature is above specification	Refer to the Intake Manifold Air Temperature Above Specification troubleshooting symptom tree in Section TS.
OK Go To Next Step	

Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

Cause	Correction
STEP 16 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 17 Cooling system is contaminated with dirt, scale, or sludge	Clean the cooling system. Refer to Procedure 008-018 in Section 8.
OK Go To Next Step	
STEP 18 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 19 Coolant is contaminated with oil	Refer to the Lubricating or Transmission Oil in Coolant troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 20 Water pump is malfunctioning	Check the cylinder block water pressure. Replace the water pump, if necessary. Refer to Procedure 008-020 or Procedure 008-062 in Section 8.
OK Go To Next Step	
STEP 21 Radiator fins are damaged or obstructed with debris	Inspect the radiator fins. Clean and repair the fins as necessary. Refer to Procedure 008-042 in Section 8.
OK Go To Next Step	
STEP 22 Torque converter is malfunctioning	Check the torque converter. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 23 Torque converter cooler or hydraulic oil cooler is malfunctioning	Remove and inspect the cooler cores and o-rings. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 24 Vehicle cooling system is **not** adequate	Verify that the engine and vehicle cooling systems are using the correct components. Refer to equipment manufacturer service information.
OK Go To Next Step	

Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

Cause	Correction
STEP 25 Air or combustion gases are entering the cooling system	Check for air or combustion gases in the cooling system. Refer to Procedure 008-020 in Section 8.

Coolant Temperature Above Normal - Sudden Overheat

This is symptom tree t023

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 the Coolant Temperature Above Normal - Sudden Overheat troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 2 Coolant level is below specification	Check the coolant level. Check for an external leak. Refer to Procedure 008-018 and Procedure 008-020 in Section 8 and the Coolant Leak External troubleshooting symptom tree in Section TS. Sample the lubricating oil and have a laboratory check for coolant in the oil (internal leak).
OK Go To Next Step	
STEP 3 Fan drive belt is broken or loose	Check the fan drive belt. Replace the belt, if necessary. Refer to Procedure 008-002 in Section 8.
OK Go To Next Step	
STEP 4 Cold weather radiator cover or winterfront is closed	Open the cold weather radiator cover or the winterfront. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 5 Radiator shutters are **not** opening completely or the shutterstat setting is wrong	Inspect the radiator shutters. Repair or replace, if necessary. Check the shutterstat setting. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 6 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 19.
OK Go To Next Step	
STEP 7 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	

Coolant Temperature Above Normal - Sudden Overheat

This is symptom tree t023

Cause	Correction
STEP 8 Coolant temperature gauge is malfunctioning	Test the temperature gauge. Repair or replace the gauge, if necessary. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 9 Coolant temperature gauge or sensor is malfunctioning	Test the gauge or the sensor. Repair or replace, if necessary. Refer to equipment manufacturer service information on troubleshooting the gauge. Reference the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319, to monitor and check the coolant temperature sensor.
OK Go To Next Step	
STEP 10 Cooling system hose is collapsed, restricted, or leaking	Inspect the hoses. Refer to Procedure 008-020 in Section 8.
OK Go To Next Step	
STEP 11 Fill line or vent lines are restricted, obstructed, or **not** routed correctly	Check the vent lines and the fill line for correct routing and for restrictions. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 12 Water pump is malfunctioning	Check the water pump for correct operation. Replace the water pump, if necessary.
OK Go To Next Step	
STEP 13 Radiator cap is **not** correct, is malfunctioning, or has low-pressure rating	Check the radiator pressure cap. Refer to Procedure 008-047 in Section 8.
OK Go To Next Step	
STEP 14 Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure 008-027 in Section 8 if electronically controlled by the engine control module (ECM). If OEM controlled, see equipment manufacturer service information.
OK Go To Next Step	
STEP 15 Cooling system component is malfunctioning	Perform the Cooling System Diagnostics Test. Refer to Procedure 008-020 in Section 8.
OK Go To Next Step	

Coolant Temperature Above Normal - Sudden Overheat

This is symptom tree t023

Cause		Correction
STEP 16 Torque converter cooler or hydraulic oil cooler is malfunctioning	.....	Remove and inspect the cooler cores and o-rings. Refer to equipment manufacturer service information.

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 equipment manufacturer service information.
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 QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.
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 equipment manufacturer service information.
OK Go To Next Step	
STEP 4 Coolant temperature gauge or sensor is malfunctioning	Test the gauge or the sensor. Repair or replace, if necessary. Refer to equipment manufacturer service information on troubleshooting the gauge. See the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319, to monitor and check the coolant temperature sensor.
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 Procedure 008-027 in Section 8, if electronically controlled by the engine control module (ECM). If OEM controlled, see equipment manufacturer service information.
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 008-027 in Section 8, if electronically controlled by the engine control module (ECM). If OEM controlled, see equipment manufacturer service information.
OK Go To Next Step	

Coolant Temperature Below Normal

This is symptom tree t024

Cause	Correction
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
STEP 1 Lubricating oil cooler is malfunctioning	Check the oil cooler. Refer to Procedure 007-003 in Section 7.
OK Go To Next Step	
STEP 2 Internal coolant leaks	Refer to Procedure 008-020 in Section 8 to pressure test the cooling system and look for internal coolant leaks.
OK Go To Next Step	
STEP 3 Turbocharger leaking coolant	Refer to Procedure 008-020 in Section 8 to pressure test the cooling system and look for internal coolant leaks.
OK Go To Next Step	
STEP 4 Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to Procedure 002-004 in Section 2 to remove the cylinder head and inspect.
OK Go To Next Step	
STEP 5 Cylinder head is cracked or porous	Pressure test the cylinder head. Refer to Procedure 002-004 in Section 2.
OK Go To Next Step	
STEP 6 Cylinder block is cracked or porous	Inspect the cylinder block. Refer to Procedure 001-026 n Section 1.

Crankcase Gases (Blowby) Excessive

This is symptom tree t027

The symptom of excessive crankcase gases (blowby) can also be referred to as excessive crankcase pressure. This symptom tree covers both symptoms.

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 the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.
OK Go To Next Step	
STEP 2 Crankcase ventilation system is malfunctioning	Verify crankcase vent system operation. Refer to Procedure 003-002 in Section 3.
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.
OK Go To Next Step	
STEP 4 Engine angularity during operation exceeds specification	Refer to the Engine Specification Data Sheet for angularity specifications..
OK Go To Next Step	
STEP 5 Crankcase pressure is excessive	Check for excessive blowby. Refer to Procedure 014-010 in Section 14.
OK Go To Next Step	
STEP 6 Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedure 014-010 in Section 14 to check the turbocharger blow-by contribution. Replace the turbocharger if necessary. Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	
STEP 7 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 8 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	

Crankcase Gases (Blowby) Excessive

This is symptom tree t027

The symptom of excessive crankcase gases (blowby) can also be referred to as excessive crankcase pressure. This symptom tree covers both symptoms.

Cause	Correction
STEP 9 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 001-047 in Section 1 and 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.

Cranking Fuel Pressure is Low

This is symptom tree t029

Cause	Correction
STEP 1 Fuel level is low in the tank	Fill the supply tank. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 2 Fuel filter is plugged	Measure the fuel pressure before and after the fuel filter. Refer to Procedure 005-010 in Section 5.
OK Go To Next Step	
STEP 3 Fuel leak	Check the fuel lines, fuel connections, and fuel filters for leaks. Check the fuel lines to the supply tanks. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 4 Fuel inlet restriction	Check for fuel inlet restriction. Refer to Procedure 006-020 in Section 6.
OK Go To Next Step	
STEP 5 Air in the fuel system	Check for air in the fuel system. Completely vent any air from the fuel system. Refer to Procedure 006-003 in Section 6.
OK Go To Next Step	
STEP 6 Fuel suction standpipe in the fuel tank is broken	Check and repair the standpipe, if necessary. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 7 Gear pump is malfunctioning	Check the gear pump output pressure. Replace the gear pump, if necessary. Refer to Procedure 005-236 in Section 5.
OK Go To Next Step	
STEP 8 Fuel pump is malfunctioning	Check the fuel pump output pressure with INSITE™ electronic service tool. Replace the fuel pump, if necessary. Refer to Procedure 005-016 in Section 5.

Engine Decelerates Slowly

This is symptom tree t041

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Refer to the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319 for fault code troubleshooting.
OK Go To Next Step	
STEP 2 Engine control module system is **not** calibrated or has incorrect calibration	Compare the calibration in the engine control system with the engine rating and the Control Parts List, Bulletin 4021328. If necessary, calibrate the system. Refer to Procedure 019-032 in Section 19.
OK Go To Next Step	
STEP 3 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. Check the remote accelerator pedal. Calibrate the accelerator pedal if possible. Refer to Procedure 019-085 in Section 19.
OK Go To Next Step	
STEP 4 Injector(s) are malfunctioning	Perform diagnostics to find the malfunctioning injector(s). Replace the injector(s) as necessary. Refer to Procedure 006-026 in Section 6 or Procedure 014-008 in Section 14.
OK Go To Next Step	
STEP 5 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 Procedure 019-428 in Section 19.
OK Go To Next Step	
STEP 6 Clutch is malfunctioning or is **not** correct	Compare the drivetrain specifications to Cummins Inc. recommendations. Check the clutch for correct operation. Refer to equipment manufacturer service information.

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

This is symptom tree t044

Cause	Correction
STEP 1 Low fuel level in the fuel tank	Check the fuel level in the fuel tanks. Verify the fuel gauge is working properly.
OK Go To Next Step	
STEP 2 Electronic fault codes active or high count of inactive fault codes	View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4337319.
OK Go To Next Step	
STEP 3 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.
OK Go To Next Step	
STEP 4 Low fuel rail pressure	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 or 2372 becomes active, fuel rail pressure is **not** being developed.
OK Go To Next Step	
STEP 5 Malfunctioning engine control module (ECM) power or ground circuit	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.
OK Go To Next Step	
STEP 6 Malfunctioning keyswitch circuit	Check the vessel keyswitch circuit for intermittent connections. Refer to Procedure 019-064 in Section 19.
OK Go To Next Step	
STEP 7 Low battery voltage	Check the battery voltage. Measure the voltage from the positive (+) terminal to the negative (−) battery terminal while trying to start the engine.
OK Go To Next Step	

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

This is symptom tree t044

Cause	Correction
STEP 8 Slow cranking speed	The minimum cranking speed **must** be greater than 120 rpm.

OK
Go To Next Step

STEP 9 ROM-booted ECM	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.

OK
Go To Next Step

STEP 10 Fuel drain-back to the fuel tanks	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 006-013 in Section 6.

OK
Go To Next Step

STEP 11 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 12 Original equipment manufacturer (OEM) fuel drain line not routed to the bottom of the fuel supply tank	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.

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 010-029 in Section 10.

OK
Go To Next Step

STEP 14 Air intake system restriction is above specification	Inspect the air intake system for restriction. Change the air filter. Refer to Procedure 010-031 in Section 10.

OK
Go To Next Step

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

This is symptom tree t044

Cause	Correction
STEP 15 High exhaust restriction	Measure the exhaust restriction. Refer to Procedure 011-009 in Section 11.
OK Go To Next Step	
STEP 16 Exhaust pressure regulator malfunctioning	Remove the exhaust pipe connection. Turn the keyswitch ON and OFF. The regulator valve should travel freely in between the fully open and fully closed position. Refer to Procedure 011-105 in Section 11.
OK Go To Next Step	
STEP 17 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 18 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.
OK Go To Next Step	
STEP 19 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.

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

This is symptom tree t046

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 QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4337319.
OK Go To Next Step	
STEP 2 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 3 Manual fan ON/OFF switch and circuit is malfunctioning	Check the manual fan ON/OFF switch and circuit. Refer to Procedure 019-045, Procedure 019-380, and Procedure 019-381 in Section 19 for the Manual Fan ON/OFF Switch, Resistance Check, and Short Circuit to Ground Check.
OK Go To Next Step	
STEP 4 Air conditioner sensor or circuit is malfunctioning	Check the air conditioner sensor and circuit. Refer to Procedure 019-261 and Procedure 019-262 in Section 19.
OK Go To Next Step	
STEP 5 Fan clutch actuator or circuit is malfunctioning	Check the fan clutch actuator circuit. Refer to Procedure 019-045 in Section 19.
OK Go To Next Step	
STEP 6 Engine electrical ground is malfunctioning	Check engine ground to chassis and chassis ground to battery negative (-) post. Refer to equipment manufacturer service information and Procedure 013-009 in Section 13.
OK Go To Next Step	
STEP 7 Engine control module (ECM) calibration is malfunctioning	Verify that the engine control module (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. 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	

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

This is symptom tree t046

Cause	Correction
STEP 8 Intake manifold temperature or coolant temperature is above the threshold to activate the cooling fan.	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 (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 troubleshooting 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 equipment manufacturer service information.
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 009-016 in Section 9 or see equipment manufacturer service information.
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 equipment manufacturer service information.
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	Check the viscosity of the oil sample. Refer to Procedure 007-044 in Section 7.
OK Go To Next Step	
STEP 8 Lubricating oil pressure is below specification	Check the oil pressure. If the pressure is low, reference the following procedure. Refer to Procedure 007-029 in Section 7.
OK Go To Next Step	
STEP 9 Coolant temperature is above specification	Refer to the Coolant Temperature Above Normal - Gradual Overheat 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 (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 troubleshooting symptom tree.

Cause	Correction
STEP 10 Drivetrain noise is excessive	Disconnect the drivetrain. Check for engine noise. Refer to equipment manufacturer service information.

OK
Go To Next Step

STEP 11 Engine mounts are worn, damaged, or **not** correct	Check the engine mounts. Refer to Procedure 016-002 or Procedure 016-003 in Section 16.

OK
Go To Next Step

STEP 12 Valve lash adjustments are **not** correct	Measure and adjust the valve lash setting. Refer to Procedure 003-004 in Section 3.

OK
Go To Next Step

STEP 13 Overhead components are damaged	Inspect the rocker levers, rocker shafts, and valves for damage or excessive wear. Refer to Procedure 003-008 in Section 3.

OK
Go To Next Step

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

OK
Go To Next Step

STEP 15 Torque converter is loose	Check the torque converter. Refer to equipment manufacturer service information.

OK
Go To Next Step

STEP 16 Flywheel or flexplate capscrews are loose or broken	Check the flywheel or flexplate and the mounting capscrews. Refer to Procedure 016-005 and Procedure 016-004 in Section 16.

OK
Go To Next Step

STEP 17 Gear train backlash is excessive or the gear teeth are damaged	Check the gear backlash and the gear teeth. Refer to Procedure 001-008 in Section 1.

OK
Go To Next Step

Engine Noise Excessive

This is symptom tree t047

When troubleshooting engine noise complaints, make sure the engine accessories (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 troubleshooting symptom tree.

Cause	Correction
STEP 18 Main bearing or connecting rod bearing noise	Refer to the Engine Noise Excessive - Connecting Rod or the Engine Noise Excessive - Main Bearing troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 19 Turbocharger noise	Refer to the Engine Noise Excessive - Turbocharger troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 20 Combustion noise excessive	Refer to the Engine Noise Excessive - Combustion Knocks troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 21 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 or Procedure 001-047 in Section 1. Analyze the lubricating oil and oil filters to locate an area of probable damage and cause. Refer to Procedure 007-044 and Procedure 007-083 in Section 7.

Engine Noise Excessive - Combustion Knocks

This is symptom tree t048

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 the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.
OK Go To Next Step	
STEP 2 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of known high quality fuel. Refer to the following procedure in the QSF3.8 CM2350 F107 Operation and Maintenance Manual, Bulletin 4367317. Refer to Procedure 018-002 in Section V.
OK Go To Next Step	
STEP 3 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	
STEP 4 Coolant temperature is above specification	Refer to Coolant Temperature Above Normal - Gradual Overheat troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 5 Valve lash adjustments are **not** correct	Measure and adjust the valve lash setting. Refer to Procedure 003-004 in Section 3.
OK Go To Next Step	
STEP 6 Injector(s) are malfunctioning	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.
OK Go To Next Step	
STEP 7 Camshaft timing is **not** correct (after engine rebuild or repair)	Check the gear train timing alignment. Refer to Procedure 001-008 in Section 1.
OK Go To Next Step	
STEP 8 Piston is misassembled	Remove and inspect the pistons. Refer to Procedure 002-004 in Section 2 and inspect the orientation and tops of the pistons for debris. Refer to Procedure 001-054 in Section I for piston orientation and if necessary, piston removal.

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 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 QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319, for the engine being serviced.
OK Go To Next Step	
STEP 2 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 007-009 in Section 7.
OK Go To Next Step	
STEP 3 Lubricating oil is thin or diluted	Check the viscosity of the oil sample. Refer to Procedure 007-044 in Section 7 to check if the oil is contaminated. If the lubricating oil is contaminated, see the Lubricating Oil Contaminated troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 4 Lubricating oil pressure is below specification	Check the oil pressure. If the pressure is low, refer to Procedure 007-029 in Section 7. Refer to Procedure 018-017 in Section V.
OK Go To Next Step	
STEP 5 Cylinder 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 6 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 7 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.
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 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

STEP 9 Crankshaft journals are damaged or out of round	Inspect the crankshaft journals. Refer to Procedure 001-016 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
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 the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.
OK Go To Next Step	
STEP 2 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 007-009 in Section 7.
OK Go To Next Step	
STEP 3 Lubricating oil is thin or diluted	Check the viscosity of the oil sample. Refer to Procedure 007-044 in Section 7 to check for contaminated lubricating oil. If the lubricating oil is contaminated, see the Lubricating Oil Contaminated troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 4 Lubricating oil pressure is below specification	Check the oil pressure. If the pressure is low, reference the following procedure. Refer to Procedure 007-029 in Section 7. If the oil pressure is low, see the Lubricating Oil Pressure Low troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 5 Main bearing capscrews are loose, worn, or **not** tightened correctly	Check the torque on the main bearing capscrews. Inspect the capscrews for wear. Refer to Procedure 001-006 in Section 1.
OK Go To Next Step	
STEP 6 Main bearings are damaged or worn, or the wrong bearings are installed	Inspect the main bearings for damage, excessive wear, and the correct part number. Refer to Procedure 001-006 in Section 1.
OK Go To Next Step	
STEP 7 Crankshaft journals are damaged or out of round	Inspect the crankshaft journals. Refer to Procedure 001-006 in Section 1.
OK Go To Next Step	

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
STEP 8 Flywheel or flexplate capscrews are loose or broken	Check the flywheel or flexplate and the mounting capscrews. Refer to Procedure 016-004 or Procedure 016-005 in Section 16.

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
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 the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319..
OK Go To Next Step	
STEP 2 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of known high quality fuel. Refer to the following procedure in the QSF3.8 CM2350 F107 Operation and Maintenance manual, Bulletin 4367217. Refer to Procedure 018-002 in Section V.
OK Go To Next Step	
STEP 3 Valve lash adjustments are **not** correct	Measure and adjust the valve lash setting. Refer to Procedure 003-004 in Section 3.
OK Go To Next Step	
STEP 4 Injector(s) are malfunctioning	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.
OK Go To Next Step	
STEP 5 Piston is misassembled	Remove and inspect the pistons. Refer to Procedure 002-004 in Section 2 and inspect the orientation and tops of the pistons for debris. Refer to Procedure 001-054 in Section 1 for piston orientation and if necessary, piston removal.
OK Go To Next Step	
STEP 6 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	
STEP 7 Connecting rod is misassembled	Remove and inspect the connecting rods. Refer to Procedure 001-014 in Section 1.
OK Go To Next Step	
STEP 8 Piston pin or bushing is loose, worn, or **not** installed correctly	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.

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
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 the QSF3.8 CM2320 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.
OK Go To Next Step	
STEP 2 Turbocharger is **not** correct	Reference QuickServe Online™ to verify the turbocharger part number. Replace the turbocharger, if necessary. Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	
STEP 3 Air intake system restriction is above specification	Check the air intake system for restriction. Replace the air filter and inlet piping as necessary. Refer to Procedure 010-031 in Section 10.
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. Make sure to inspect the exhaust gas recirculation (EGR) tube connections for leaks. Refer to Procedure 011-070 in Section 11.
OK Go To Next Step	
STEP 5 Debris in the system or rotor touching housing	Replace the turbocharger if necessary. Refer to Procedure 010-139 and Procedure 010-033 in Section 10.
OK Go To Next Step	
STEP 6 Air intake or exhaust piping is contacting the chassis or cab	Inspect the air piping, chassis, and cab for contact points. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 7 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	

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
STEP 8 Exhaust pressure regulator malfunctioning	.....	Remove the exhaust pipe connection. Turn the keyswitch ON and OFF. The regulator valve should travel freely in between the fully open and fully closed position. Refer to Procedure 011-105 in Section 11.

OK
Go To Next Step

STEP 9 Air intake manifold heater starting aid is restricted or plugged	.....	Inspect the air intake manifold heater for plugging or soot buildup. Refer to Procedure 010-029 in Section 10.

OK
Go To Next Step

STEP 10 Turbocharger is worn or damaged	.....	Check the turbocharger for damage. Measure the turbine and compressor wheel clearances. Refer to Procedure 010-033 in Section 10.

Engine Power Output Low

This is symptom tree t057

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 the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367219.
OK Go To Next Step	
STEP 2 Engine control module (ECM) calibration is malfunctioning	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 internet website or the INCAL™ calibration CD-ROM. Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL) using the INCAL™ CD-ROM or QuickServe™ Online. If necessary, calibrate the ECM. Refer to Procedure 019-032 in Section 19.
OK Go To Next Step	
STEP 3 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 4 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 5 Leaking air intake system or charge-air cooler	Inspect the air intake system for air leaks. Check the intake plumbing and charge-air cooler hoses for possible air leaks. Refer to Procedure 010-024 in Section 10.
OK Go To Next Step	
STEP 6 Leaks in the exhaust gas recirculation (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 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 8 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filter(s). Refer to Procedure 018-017 in Section V.
OK Go To Next Step	
STEP 9 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 10 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 11 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 12 High fuel inlet restriction	Perform the Fuel Inlet Restriction Test. Refer to Procedure 006-020 in Section 6.
OK Go To Next Step	
STEP 13 Stuck open exhaust gas recirculation (EGR) valve	Use INSITE™ electronic service tool to perform the Aftertreatment Diesel Particulate Filter 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	

Engine Power Output Low

This is symptom tree t057

Cause	Correction
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 Exhaust pressure regulator malfunctioning	Remove the exhaust pipe connection. Turn the keyswitch ON and OFF. The regulator valve should travel freely in between the fully open and fully closed position. Refer to Procedure 011-105 in Section 11.

OK
Go To Next Step

STEP 18 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 19 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. Refer to Procedure 006-060 in Section 6.

OK
Go To Next Step

STEP 20 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

Engine Power Output Low

This is symptom tree t057

Cause	Correction
STEP 21 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 22 Malfunctioning accelerator pedal	Use INSITE™ electronic service tool to monitor Accelerator Pedal Position, 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.

Engine Runs Rough or Misfires

This is symptom tree t062

Cause	Correction
STEP 1 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 2 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 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 006-026 in Section 6.
OK Go To Next Step	
STEP 4 Malfunctioning fuel pump actuator	Unplug the fuel pump actuator from the engine wiring harness while the engine is idling. Refer to Procedure 006-026 in Section 6. If the engine speed surge or rough idle stops, replace the fuel pump actuator.
OK Go To Next Step	
STEP 5 Belt driven accessories	Remove the drive belts and operate the engine under the conditions where the vibration occurs. Verify the vibration goes away with the drive belts removed.
OK Go To Next Step	
STEP 6 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 7 High fuel inlet restriction	Perform the Fuel Inlet Restriction Test. Refer to Procedure 006-020 in Section 6.
OK Go To Next Step	
STEP 8 Air in the fuel	Check for air in the fuel system. Refer to Procedure 006-003 in Section 6.
OK Go To Next Step	

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 Electronic fault codes active or high counts of inactive fault codes	Read the fault codes with an electronic service tool. Refer to the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.
OK Go To Next Step	
STEP 2 Engine control module (ECM) calibration is malfunctioning	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 internet website or the INCAL™ calibration CD-ROM. Compare the calibration stored in the ECM with the engine rating and the Control Parts List (CPL) using the INCAL™ CD-ROM or QuickServe™ Online. If necessary, calibrate the ECM. Refer to Procedure 019-032 in Section 19.
OK Go To Next Step	
STEP 3 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 4 Malfunctioning fuel pump actuator	Unplug the fuel pump actuator from the engine wiring harness while the engine is idling. Refer to Procedure 006-003 in Section 6. If the engine speed surge or rough idle stops, replace the fuel pump actuator.
OK Go To Next Step	
STEP 5 Exhaust gas recirculation (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 6 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 7 High fuel inlet restriction	Perform the Fuel Inlet Restriction Test. Refer to Procedure 006-020 in Section 6.
OK Go To Next Step	

Engine Speed Surges Under Load or in Operating Range

This is symptom tree t067

Cause	Correction
STEP 8 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	
STEP 9 Stuck open exhaust gas recirculation (EGR) valve	Use INSITE™ electronic service tool to monitor the EGR differential pressure value. If the EGR differential pressure is reading above this specification, a stuck open EGR valve has been detected.
OK Go To Next Step	
STEP 10 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 11 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 12 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. Refer to Procedure 006-061 in Section 6.
OK Go To Next Step	
STEP 13 Exhaust pressure regulator malfunctioning	Remove the exhaust pipe connection. Turn the keyswitch ON and OFF. The regulator valve should travel freely in between the fully open and fully closed position. Refer to Procedure 011-105 in Section 11.
OK Go To Next Step	
STEP 14 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.

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 equipment manufacturer service information.
OK Go To Next Step	
STEP 2 Electronic fault codes active or high counts of inactive fault codes	Refer to the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.
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 Power Take-Off (PTO) mode. Refer to the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.
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 equipment manufacturer service information.
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 to determine if the fuel filter is restricted.
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 engine control module (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. 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 equipment manufacturer service information to locate and repair J1939 control devices.

OK
Go To Next Step

STEP 11 Accelerator pedal or lever is restricted or malfunctioning	Check the percent accelerator pedal or lever reading with 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 equipment manufacturer service information and/ or Procedure 019-085 in Section 19.

OK
Go To Next Step

STEP 12 Moisture in the wiring harness connectors	Dry the connector with Cummins® electrical contact cleaner, Part Number 3824510. Refer to equipment manufacturer service information and/ or Procedure 019-085 in Section 19.

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 equipment manufacturer service information.

OK
Go To Next Step

Engine Speed Surges in PTO or Cruise Control

This is symptom tree t068

Cause	Correction
STEP 14 Crankshaft position sensor or circuit is malfunctioning	Check the crankshaft position sensor for correct adjustment and for debris on the sensor. Check the engine speed sensor circuit. Refer to Procedure 019-365 in Section 19.
OK Go To Next Step	
STEP 15 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 16 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 17 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.
OK Go To Next Step	
STEP 18 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 19 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 20 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	
STEP 21 Clutch is malfunctioning or is **not** correct	Check the clutch for correct operation. Refer to equipment manufacturer service information.
OK Go To Next Step	

Engine Speed Surges in PTO or Cruise Control

This is symptom tree t068

Cause	Correction
STEP 22 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of known high quality fuel. Refer to equipment manufacturer service information for fuel specifications.
OK Go To Next Step	
STEP 23 Turbocharger is **not** correct	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.
OK Go To Next Step	
STEP 24 Turbocharger wastegate is malfunctioning, if equipped	Check the wastegate for correct operation. Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	
STEP 25 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 26 Fuel pump is malfunctioning	Check the fuel pump output pressure with INSITE™ electronic service tool. Replace the fuel pump, if necessary. Refer to Procedure 005-016 in Section 5. Monitor fuel rail pressure commanded against that measured while the vehicle is operating in PTO mode. Reference the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367316.
OK Go To Next Step	
STEP 27 Flywheel housing is **not** aligned correctly	Check the flywheel housing alignment. Refer to Procedure 016-006 in Section 16.
OK Go To Next Step	
STEP 28 Transmission damaged	Problem is related specifically to the transmission. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 29 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 Crank - (Electric Starter)

This is symptom tree t074-005

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 the QSF CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.
OK Go To Next Step	
STEP 2 Battery voltage is low	Check the battery connections. Refer to Procedure 013-007 in Section 13.
OK Go To Next Step	
STEP 3 Broken, loose, or corroded starting circuit connections	Inspect, clean, and tighten both the positive and negative connections between the starting motor and battery, including the magnetic switch. Refer to Procedure 013-009 in Section 13.
OK Go To Next Step	
STEP 4 Battery capacity is below specification	Replace the batteries, if necessary. Refer to Procedure 013-007 in Section 13.
OK Go To Next Step	
STEP 5 Original equipment manufacturer (OEM) starter interlock devices engaged	Check the starter interlock devices. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 6 Starting circuit component is malfunctioning	Check the starting circuit components. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 7 Starter solenoid does **not** make an audible sound	Check the magnetic switch and starter solenoid. Refer to Procedure 013-017 and Procedure 013-019 in Section 13.
OK Go To Next Step	
STEP 8 Battery cables are **not** the correct gauge or length	Replace the battery cables with larger gauge or shorter length cables. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 9 Engine-driven units are engaged	Disengage any engine-driven units.
OK Go To Next Step	

Engine Will Not Crank - (Electric Starter)

This is symptom tree t074-005

Cause	Correction
STEP 10 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 11 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 12 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 13 Hydraulic lock in a cylinder	Remove the injectors and rotate the crankshaft. Look for the source of fluid in the cylinder. Refer to Procedure 006-026 in Section 6.

OK
Go To Next Step

STEP 14 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 Cranks Slowly - (Electric Starter)

This is symptom tree t074-010

Cause	Correction
STEP 1 Batteries are cold	Check the battery heater. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 2 Electronic fault codes active or high counts of inactive fault codes	Read the fault codes with an electronic service tool. Refer to the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367219.
OK Go To Next Step	
STEP 3 Battery voltage is low	Check the batteries and the unswitched battery supply circuit. Refer to Procedure 013-007 in Section 13.
OK Go To Next Step	
STEP 4 Broken, loose, or corroded starting circuit connections	Inspect, clean, and tighten both the positive and negative connections between the starting motor and battery, including the magnetic switch. Refer to Procedure 013-009 in Section 13.
OK Go To Next Step	
STEP 5 Battery capacity is below specification	Replace the batteries, if necessary. Refer to Procedure 013-007 in Section 13.
OK Go To Next Step	
STEP 6 Original equipment manufacturer (OEM) starter interlock devices engaged	Check the starter interlock devices. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 7 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 equipment manufacturer service information.
OK Go To Next Step	
STEP 8 Battery cables are **not** the correct gauge or length	Replace the battery cables with larger gauge or shorter length cables. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 9 Engine-driven units are engaged	Disengage any engine-driven units.
OK Go To Next Step	

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 equipment manufacturer service information.
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 filter(s). Refer to Procedure 018-003 in Section V of the QSF3.8 CM2350 F107 Operation and Maintenance Manual, Bulletin 4367317.
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	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 the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.
OK Go To Next Step	
STEP 2 Keyswitch circuit is malfunctioning	Check the vehicle keyswitch circuit. Refer to Procedure 019-064 in Section 19.
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.
OK Go To Next Step	
STEP 4 Engine is running on fumes drawn into the air intake	Check the air intake ducts. Locate and isolate the source of the fumes. Repair as necessary. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 5 Engine control module (ECM) is malfunctioning	Replace the ECM. Refer to Procedure 019-031 in Section 19.

Fault Code Warning Lamps Do Not Illuminate

This is symptom tree t084

Cause	Correction
STEP 1 Keyswitch is in the OFF position	Turn the keyswitch to the ON position.
OK Go To Next Step	
STEP 2 Fault code warning lamps are burned out	Check the warning lamps for voltage. Replace the bulbs, if necessary. Refer to Procedure 019-046 in Section 19.
OK Go To Next Step	
STEP 3 Fault code warning lamp circuit is malfunctioning	Check the fault code warning lamp circuit. Refer to Procedure 019-047 in Section 19.
OK Go To Next Step	
STEP 4 Keyswitch circuit is malfunctioning	Check the equipment keyswitch circuit. Refer to Procedure 019-064 in Section 19.

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 Section TS. 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 QSF3.8 CM2350 F107 Operation and Maintenance Manual, Bulletin 4367317.
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 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 in Section 7. Refer to Procedure 018-003 in Section V of the QSF3.8 CM2350 F107 Operation and Maintenance Manual, Bulletin 4367317, for oil specifications.
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 in the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.
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
STEP 8 Engine control module (ECM) calibration is malfunctioning	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.
OK Go To Next Step	
STEP 9 Engine idle or power take-off (PTO) time is excessive	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).
OK Go To Next Step	
STEP 10 Auxiliary devices using fuel from vehicle's fuel supply tank(s)	Check the fuel consumption of the auxiliary devices. Refer to the original equipment manufacturer (OEM) service manual.
OK Go To Next Step	
STEP 11 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	
STEP 12 Drivetrain is **not** correctly matched to the engine	Check for correct gearing and drivetrain components. Refer to the OEM service manual.
OK Go To Next Step	
STEP 13 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 14 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 and Procedure 019-091 in Section 19.
OK Go To Next Step	

Fuel Consumption Excessive

This is symptom tree t087

Cause	Correction
STEP 15 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 and Procedure 019-091 in Section 19.
OK Go To Next Step	
STEP 16 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 17 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 18 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 19 Air intake system restriction is above specification	Check the air intake system for restrictions. Replace the air filter and inlet piping as necessary. Refer to Procedure 010-031 in Section 10.
OK Go To Next Step	
STEP 20 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 21 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of known high quality fuel. Refer to Procedure 018-002 in Section Vof the QSF3.8 CM2350 F107 Operation and Maintenance Manual, Bulletin 4367317, for fuel specifications.
OK Go To Next Step	
STEP 22 Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004 in Section 3.
OK Go To Next Step	

Fuel Consumption Excessive

This is symptom tree t087

Cause	Correction
STEP 23 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 24 Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-044 in Section 7.

Fuel in Coolant

This is symptom tree t091

Cause	Correction
STEP 1 Bulk coolant supply is contaminated	Check the coolant supply. Drain the coolant and replace with non-contaminated coolant. 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 002-004 in Section 2. 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 Bulk oil supply is contaminated	Check the bulk oil supply. Drain the oil and replace with non-contaminated oil. Change the oil filters. Refer to Procedure 007-037 in Section 7.
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 QSB3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.
OK Go To Next Step	
STEP 3 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 the QSB3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.
OK Go To Next Step	
STEP 4 Fuel line leaking at injector connection	Check the high pressure fuel supply lines at the injector connections for proper torque value or other damage. Refer to Procedure 006-051 in Section 6.
OK Go To Next Step	
STEP 5 Fuel drain line restriction	Check the fuel drain lines for restriction. Refer to Procedure 006-012 in Section 6.
OK Go To Next Step	
STEP 6 Injector hold-down clamp capscrews are loose	Tighten capscrews to specification. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 7 Injector o-rings are damaged or missing	Remove and check the injectors. Replace the injector o-rings. Refer to Procedure 006-026 in Section 6.
OK Go To Next Step	
STEP 8 Injector(s) are malfunctioning	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.
OK Go To Next Step	

Fuel in the Lubricating Oil

This is symptom tree t092

Cause	Correction
STEP 9 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 10 Cylinder head is cracked or porous	Pressure test the fuel drain drilling in the cylinder head. Refer to Procedure 002-004 in Section 2.
OK Go To Next Step	
STEP 11 Gear pump is malfunctioning	Check the gear pump output pressure. Replace the gear pump, if necessary. Refer to Procedure 005-016 in Section 5.
OK Go To Next Step	
STEP 12 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.

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 Cooling fan belt tensioner malfunctioning	.....	Check the cooling fan belt tensioner. Replace, if necessary. Refer to Procedure 008-087 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. Check the shutterstat setting. Refer to the OEM service manual.

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 Section TF in the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.

OK
Go To Next Step

STEP 7 Intake manifold air temperature sensor has an in-range malfunction	.....	Check the intake manifold air temperature sensor that corresponds to the fault code. Replace the sensor if necessary. Refer to Procedure 019-159 in Section 19 to monitor and check the manifold temperature sensor.

OK
Go To Next Step

Intake Manifold Air Temperature Above Specification

This is symptom tree t096

Cause	Correction
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

STEP 9 Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure 008-027 in Section 8, or Procedure 019-045 in Section 19, if electronically controlled by the engine control module (ECM). If OEM controlled, refer to 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 Vehicle speed is too low for adequate cooling with high engine load	Reduce the engine load. Increase the engine (fan) rpm by downshifting.

OK
Go To Next Step

STEP 13 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 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.

Intake Manifold Pressure (Boost) is Below Normal

This is symptom tree t097

Cause	Correction
STEP 1 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 2 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 3 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 4 Electronic fault codes active or high counts of inactive fault codes	Refer to the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.
OK Go To Next Step	
STEP 5 Intake manifold pressure sensor is malfunctioning	Check the intake manifold pressure sensor. Refer to Procedure 019-159 in Section 19.
OK Go To Next Step	
STEP 6 Debris in the system or rotor touching housing	Replace the turbocharger if necessary. Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	
STEP 7 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 8 Exhaust pressure regulator malfunctioning	Remove the exhaust pipe connection. Turn the keyswitch ON and OFF. The regulator valve should travel freely in between the fully open and fully closed position. Refer to Procedure 011-105 in Section 11.
OK Go To Next Step	
STEP 9 Wastegate turbocharger actuator is damaged or stuck open	Check the actuator functionality. Refer to Procedure 010-050 in Section 10.
OK Go To Next Step	

Intake Manifold Pressure (Boost) is Below Normal

This is symptom tree t097

Cause	Correction
STEP 10 Turbocharger is worn or damaged	Check the turbocharger for damage. Measure the turbine and compressor wheel clearances. Refer to Procedure 010-033 in Section 10.

OK
Go To Next Step

STEP 11 Engine power output is low	Refer to the Engine Power Output Low troubleshooting symptom tree in Section TS.

Low Idle Adjust Switch Does Not Work

This is symptom tree t099

Cause	Correction
STEP 1 Engine idle speed is set at either the minimum or the maximum allowable value	The idle adjust switch will **not** adjust the idle speed outside the allowable range. Refer to Procedure 019-052 in Section 19.
OK Go To Next Step	
STEP 2 Low-idle adjust switch feature is **not** enabled	Check the low-idle adjust switch feature with an electronic service tool. Refer to Procedure 019-078 in Section 19.
OK Go To Next Step	
STEP 3 Low-idle adjust switch and circuit is malfunctioning	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.
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 vent tube. Refer to Procedure 003-025 and Procedure 003-026 in Section 3.
OK Go To Next Step	
STEP 4 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filter(s). Refer to Procedure 007-037 in Section 7. Use the folowing procedure in the QSF3.8 CM2320 F107 Operation and Maintenance Manual, Bulletin 4367317. Refer to Procedure 018-003 in Section V.
OK Go To Next Step	
STEP 5 Lubricating oil drain interval is excessive	Verify the correct lubricating oil drain interval. Refer to the folowing procedure in the QSF3.8 CM2320 F107 Operation and Maintenance Manual, Bulletin 4337317. Refer to Procedure 102-002 in Section 2.
OK Go To Next Step	
STEP 6 Lubricating oil cooler is leaking	Check the lubricating oil cooler for coolant leaks. Refer to the Coolant Loss Internal troubleshooting symptom tree in Section TS, if oil is found.
OK Go To Next Step	
STEP 7 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 8 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	

Lubricating Oil Consumption Excessive

This is symptom tree t102

Cause	Correction
STEP 9 Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedure 010-033 in Section 10, in the Initial Check section. Reference the Turbocharger - Compressor Seal Oil Leak troubleshooting symptom tree in Section TS if a compressor seal oil leak is found. Reference 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 10 Piston rings are **not** seated correctly (after an engine rebuild or piston installation)	Check the crankcase pressure (blowby). Refer to Procedure 014-010 in Section 14. If 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 11 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 12 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 13 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 14 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 and Procedure 001-047 in Section 1. Analyze the lubricating oil and oil filters to locate an area of probable damage and cause. Refer to Procedure 007-048 and Procedure 007-083 in Section 7.

OK
Go To Next Step

STEP 15 Internal engine damage	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-048 and Procedure 007-083 in Section 7.

Lubricating Oil Contaminated

This is symptom tree t103

Cause	Correction
STEP 1 Identify lubricating oil contamination	Perform an oil analysis to determine the contaminants. Refer to Procedure 007-083 in Section 7.
OK Go To Next Step	
STEP 2 Fuel in the lubricating oil	Refer to the Fuel in the Lubricating Oil troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 3 Internal coolant leaks	Refer to the Coolant Loss - Internal troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 4 Lubricating oil sludge is excessive	Change the oil and filters. Refer to Procedure 007-037 in Section 7 and the Lubricating Oil Sludge in the Crankcase Excessive troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 5 Bulk oil supply is contaminated	Check the bulk oil supply. Drain the oil and replace with non-contaminated oil. Change the oil filters. Refer to Procedure 007-013 and Procedure 007-037 in Section 7.

Lubricating Oil Pressure High

This is symptom tree t104

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 the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.
OK Go To Next Step	
STEP 2 Coolant temperature is below specification	Refer to the Coolant Temperature is Below Normal troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 3 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filter(s). Refer to Procedure 007-037 in Section 7. See the QSF3.8 CM2350 F107 Operation and Maintenance Manual, Bulletin 4367317, and/or the QSF3.8 CM2350 F107 Owners Manual, Bulletin 4367318, for oil specifications.
OK Go To Next Step	
STEP 4 OEM installed lubricating oil pressure switch, gauge, or sensor is malfunctioning or is not in correct location	Measure the lubricating oil pressure. Refer to Procedure 007-037 in Section 7. Operate the engine and compare readings to the vehicle's OEM gauge or oil pressure sensor/switch. See equipment manufacturer service information.
OK Go To Next Step	
STEP 5 Engine installed lubricating oil pressure sensor/ switch or circuit is malfunctioning (electronic controlled fuel system)	Measure the lubricating oil pressure. Refer to Procedure 007-037 in Section 7. If equipped with an oil pressure sensor, monitor the oil pressure with INSITE™ electronic service tool. Operate the engine and compare readings. If necessary, replace the oil pressure sensor /switch. Refer to Procedure 019-066 in Section 19.
OK Go To Next Step	
STEP 6 Lubricating oil filter plumbing **not** routed correctly	Verify the routing of the lubricating filter plumbing is correct. Refer to Procedure 007-092 in Section 7.
OK Go To Next Step	
STEP 7 Main oil pressure regulator is malfunctioning	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	View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to the corresponding QSF3.8 CM2350 F107 Fault Code Troubleshooting and Repair Manual, Bulletin 4367319.
OK Go To Next Step	
STEP 2 Original equipment manufacturer (OEM) installed lubricating oil pressure switch, gauge, or sensor is malfunctioning or is not in correct location	Measure the lubricating oil pressure. Refer to Procedure 007-037 in Section 7. Operate the engine and compare readings to the vehicle OEM installed gauge. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Engine installed lubricating oil pressure sensor/ switch or circuit is malfunctioning (electronic controlled fuel system)	Measure the lubricating oil pressure. Refer to Procedure 007-037 in Section 7. If equipped with an oil pressure sensor, monitor the oil pressure with INSITE™ electronic service tool. Operate the engine and compare the readings.
OK Go To Next Step	
STEP 4 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 5 Lubricating oil leak (external)	Inspect the engine for external oil leaks. Tighten the capscrews, pipe plugs, and fittings. Replace gaskets, if necessary. Refer to the Black Light Kit, Part Number 2892320, and fluorescent tracer, Part Number 3376891, to help identify the source of the leak. Follow the corresponding instructions. Repair as necessary.
OK Go To Next Step	
STEP 6 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filter(s). Refer to Procedure 007-037 in Section 7. Use the following procedure in the QSF3.8 CM2320 F107 Operation and Maintenance Manual, Bulletin 4367317, for the oil specifications. Referr to Procedure 018-003 in Section V.
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	

Lubricating Oil Pressure Low

This is symptom tree t105

Cause	Correction
STEP 8 Engine angularity during operation exceeds specification	Refer to to the engine specification data sheets for angularity specifications for the engine being serviced.
OK Go To Next Step	
STEP 9 Coolant temperature is above specification	Refer to the Coolant Temperature Above Normal - Gradual Overheat troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 10 Main oil pressure regulator is malfunctioning	Check the main oil pressure regulator assembly. Refer to Procedure 007-029 in Section 7.
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	Remove and inspect the oil pan or suction tube. Refer to Procedure 007-025 in Section 7.
OK Go To Next Step	
STEP 12 Engine installed lubricating oil pressure sensor/ switch or circuit is blocked	Check if sealant is blocking the oil pressure sensor/switch port by removing the front gear cover. Refer to Procedure 007-031 in Section 7. Check if the gear cover has been removed or installed recently on an engine equipped with the oil pressure switch/sensor in the front gear cover.
OK Go To Next Step	
STEP 13 Lubricating oil pump is malfunctioning	Inspect the lubricating oil pump. Refer to Procedure 007-031 in Section 7.
OK Go To Next Step	
STEP 14 Lubricating oil cooler is plugged	Check the oil cooler. Refer to Procedure 007-003 in Section 7.
OK Go To Next Step	
STEP 15 Lubricating oil temperature is above specification	Refer to the Lubricating Oil Temperature Above Specification troubleshooting symptom tree in Section TS.
OK Go To Next Step	

Lubricating Oil Pressure Low

This is symptom tree t105

Cause		Correction
STEP 16 Piston cooling nozzles are damaged or are **not** installed correctly	.....	Check the piston cooling nozzles for damage and correct installation. Refer to Procedure 001-046 in Section 1.

OK
Go To Next Step

STEP 17 Internal engine damage or internal lubricating oil leak	.....	Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-048 and Procedure 007-083 in Section 7. Places for probable damage include internal cup plugs, main bearings, rod bearings, cam bushings and rocker levers.

Lubricating Oil Sludge in the Crankcase Excessive

This is symptom tree t106

Cause	Correction
STEP 1 Bulk oil supply is contaminated	Check the bulk oil supply. Drain the oil and replace with non-contaminated oil. Change the oil filters. Refer to Procedure 007-037 in Section 7.
OK Go To Next Step	
STEP 2 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Procedure 007-037 in Section 7. See the QSF3.8 CM2350 F107 Owners Manual, Bulletin 4367318 or the QSF3.8 CM2350 F107 Operation and Maintenance Manual, Bulletin 4367317, for oil specifications.
OK Go To Next Step	
STEP 3 Lubricating oil drain interval is excessive	Verify the correct lubricating oil drain interval. Refer to the QSF3.8 CM2350 F107 Owners Manual, Bulletin 4367318 or the QSF3.8 CM2350 F107 Operation and Maintenance Manual, Bulletin 4367317.
OK Go To Next Step	
STEP 4 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of known high quality fuel. Refer to the QSF3.8 CM2350 F107 Owners Manual, Bulletin 4367318 or the QSF3.8 CM2350 F107 Operation and Maintenance Manual, Bulletin 4367317, for fuel specifications.
OK Go To Next Step	
STEP 5 Coolant temperature is below specification	Refer to the Coolant Temperature is Below Normal troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 6 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 7 Lubricating oil temperature is above specification	Refer to Procedure 007-003 in Section 7 if it is necessary to replace the lubricating oil cooler. Check if the correct lubricating oil cooler part number is installed. See the appropriate parts manual and/or Quickserve™ Online.
OK Go To Next Step	

Lubricating Oil Sludge in the Crankcase Excessive

This is symptom tree t106

Cause	Correction
STEP 8 Crankcase pressure is excessive	Check for excessive blowby. Refer to Procedure 014-010 in Section 14.
OK Go To Next Step	
STEP 9 Exhaust system restriction is above or below specification	Check the exhaust system for restriction. Refer to Procedure 011-009 in Section 11.

Lubricating Oil Temperature Above Specification

This is symptom tree t107

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 the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.
OK Go To Next Step	
STEP 2 Coolant temperature is above specification	Refer to the Coolant Temperature Above Normal - Gradual Overheat troubleshooting symptom tree in Section TS.
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 OEM lubricating oil temperature switch, gauge, or sensor malfunctioning or **not** in the correct location.	Check the OEM oil temperature switch, gauge, or sensor for correct operation and location. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 5 OEM components cooled with engine lubricating oil are malfunctioning	Check OEM components. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 6 Lubricating oil cooler is plugged	Check the oil cooler. Refer to Procedure 007-003 in Section 7.
OK Go To Next Step	
STEP 7 Internal engine damage	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
STEP 1 Bulk coolant supply is contaminated	Check the coolant supply. Drain the coolant and replace with non-contaminated coolant. Refer to Procedure 008-018 in Section 8.
OK Go To Next Step	
STEP 2 Lubricating oil cooler is malfunctioning	Check the oil cooler. Refer to Procedure 007-003 in Section 7.
OK Go To Next Step	
STEP 3 Torque converter cooler or hydraulic oil cooler is malfunctioning	Remove and inspect the cooler cores and o-rings. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 4 Turbocharger bearing housing is cracked or porous, if equipped with liquid-cooled turbocharger bearing housing	Check the turbocharger bearing housing. Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	
STEP 5 Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to Procedure 002-021 in Section 2.
OK Go To Next Step	
STEP 6 Cylinder head is cracked or porous	Pressure test the cylinder head. Refer to Procedure 002-004 in Section 2. Pressure test the cooling system and look for internal coolant leaks. Procedure 008-020 in Section 8.
OK Go To Next Step	
STEP 7 Cylinder block is cracked or porous	Inspect the cylinder block. Refer to Procedure 001-026 in Section 1.

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 engine control module (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. 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 Vehicle brake switch or circuit is malfunctioning	Check the vehicle brake switch and the circuit. Refer to Procedure 019-088 and Procedure 019-089 in Section 19.
OK Go To Next Step	
STEP 6 Cruise Control/power takeoff (PTO) ON/OFF switch or circuit is malfunctioning	Check the Cruise Control/PTO ON/OFF switch and circuit. Refer to Procedure 019-021 and Procedure 019-022 in Section 19.
OK Go To Next Step	
STEP 7 Cruise Control/PTO selector switch or circuit is malfunctioning	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 Electronic fault codes active or high counts of inactive fault codes for the exhaust gas recirculation (EGR) valve, exhaust pressure regulator, or turbocharger	View fault codes with INSITE™ electronic service tool and troubleshoot as necessary. Refer to the appropriate fault code tree in the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319.
OK Go To Next Step	
STEP 2 Original equipment manufacturer (OEM) or customer selected inhibit feature is preventing active regeneration during vehicle operation	Check the aftertreatment system inhibit features with INSITE™ electronic service tool. Change either the vehicle route and/or duty cycle such that the inhibit features do **not** prevent or interrupt active regeneration. Refer to Procedure 011-999 in Section F. Continue troubleshooting the cause of excessive black smoke.
OK Go To Next Step	
STEP 3 Applicable calibration updates available	Verify that the engine control module calibration is correct. Refer to QuickServe™ Online to verify that the presently installed calibration matches the selective catalyst reduction installed on the vehicle. Refer to Procedure 019-031 in Section 19. Continue troubleshooting the cause of excessive black smoke.
OK Go To Next Step	
STEP 4 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 5 Leaking air intake system or charge-air cooler	Inspect the air intake and charge-air systems for air leaks. Check all exhaust gas recirculation plumbing, intake plumbing, and charge air-cooler hoses for possible air leaks. Refer to Procedure 010-024 in Section 10.
OK Go To Next Step	
STEP 6 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. If the Cylinder Cutout Test can **not** isolate a problematic injector(s), continue troubleshooting the root cause of excessive black smoke.
OK Go To Next Step	

Smoke, Black - Excessive

This is symptom tree t116

Cause	Correction
STEP 7 High fuel inlet restriction	Perform the Fuel Inlet Restriction Test. Refer to Procedure 006-020 in Section 6.
OK Go To Next Step	
STEP 8 Intake manifold pressure/temperature sensor is malfunctioning	Verify the correct sensor is installed by reviewing the parts list on QSOL. Inspect the intake manifold pressure/temperature sensor (boost sensor) for carbon buildup and heavy fouling. Refer to Procedure 019-159 in Section 19. Clean the sensor as necessary.
OK Go To Next Step	
STEP 9 Exhaust gas recirculation (EGR) valve malfunctioning	Use INSITE™ electronic service tool to perform the SCR Performance Test. Allow the stationary regeneration procedure to run a minimum of 15 minutes. Use INSITE™ electronic service tool to monitor the EGR differential pressure value. EGR differential pressure **must** read less than 1.7 kPA [0.5 in-Hg] during the aftertreatment stationary regeneration procedure. If the EGR differential pressure is reading above this specification, inspect the EGR differential pressure sensing ports for restriction. If no restriction is found, replace the EGR valve. Record values for the troubleshooting steps in the next step as well, while performing this INSITE™ electronic service tool-based stationary regeneration.
OK Go To Next Step	
STEP 10 Turbocharger malfunctioning	Use INSITE™ electronic service tool to perform the SCR Performance Test. Allow the stationary regeneration procedure to run a minimum of 15 minutes. Use INSITE™ electronic service tool to monitor the Turbocharger Actuator Position Measured (Percent Closed), and Enhanced Exhaust Gas Pressure. Turbocharger actuator position during a stationary regeneration **must** read greater than 90 percent, and exhaust gas pressure **must** read greater than or equal to 405 kPa [120 in-Hg] during the aftertreatment stationary regeneration procedure. If the turbocharger actuator position or exhaust gas pressure is reading below specification, a malfunctioning turbocharger or actuator has been detected. Refer to Procedure 010-050 in Section 10. If the actuator is installed properly, replace the turbocharger. Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	

Smoke, Black - Excessive

This is symptom tree t116

Cause	Correction
STEP 11 Wastegate turbocharger actuator is damaged or stuck open	Check the actuator functionality. Refer to Procedure 010-050 in Section 10.
OK Go To Next Step	
STEP 12 Engine crankcase gases (blowby) excessive	Measure the crankcase pressure. Refer to Procedure 014-010 in Section 14. If the crankcase blowby is above specification, reference the following. Refer to the Crankcase Gases (Blowby) Excessive troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 13 Malfunctioning fuel injector(s)	If a problematic fuel injector can **not** be isolated with the Fuel Injector Cutout Test and all above troubleshooting steps have been completed without identifying the root cause of excessive black smoke, replace all four fuel injectors. Refer to Procedure 014-008 in Section 14.

Smoke, White - Excessive

This is symptom tree t118

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 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 Internally leaking EGR cooler	Perform the EGR cooler leak test. Refer to Procedure 011-019 in Section 11.
OK Go To Next Step	
STEP 4 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 5 Retained water vapor in the aftertreatment system	If white smoke persists after the engine has reached the minimum operating temperature, and a strong hydrocarbon odor is still present, troubleshoot the white smoke complaint.
OK Go To Next Step	
STEP 6 Contaminated aftertreatment system	Inspect the aftertreatment selective catalytic reduction (SCR) for signs of coolant or lubricating oil contamination. Check for engine repair history to determine if a previous malfunction may have contaminated the aftertreatment SCR with coolant. Refer to Procedure 011-036 in Section 11.
OK Go To Next Step	

Smoke, White - Excessive

This is symptom tree t118

Cause	Correction
STEP 7 Stuck open exhaust gas recirculation (EGR) valve	Use INSITE™ electronic service tool to perform the Aftertreatment Selective Catalytic Reduction 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 8 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 9 Leaking cylinder head gasket	Check for a damaged cylinder head gasket. Refer to Procedure 002-021 in Section 2.
OK Go To Next Step	
STEP 10 Check the injector wiring harness	Check continuity for each injector from ECM connector SIGNAL and RETURN to the appropriate injector solenoid SIGNAL and RETURN. Reference the appropriate circuit or wiring diagram for connector pin identification. If injector harness damage is found, it **must** be replaced. Refer to Procedure 003-011 in Section 19.

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. Extended operation of the engine in low duty cycle, extended idling, and/or low ambient temperatures can result in reduced aftertreatment diesel exhaust fluid usage. Conversely, extended operation of the engine in high duty cycle and/or high ambient temperatures can result in increased aftertreatment 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 the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4337319.

OK
Go To Next Step

STEP 2 Aftertreatment diesel exhaust fluid leak (external)	Inspect for external aftertreatment diesel exhaust fluid leaks near the aftertreatment diesel exhaust fluid tank, aftertreatment diesel exhaust lines, and associated connections. Repair or replace parts as necessary.

OK
Go To Next Step

STEP 3 Engine control module (ECM) calibration is malfunctioning	Verify that the engine control module (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. 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 4 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. See equipment manufacturer service information.

OK
Go To Next Step

STEP 5 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. See equipment manufacturer service information.

Diesel Exhaust Fluid Contaminated

This is symptom tree t163

Cause	Correction
STEP 1 Diesel exhaust fluid tank has been filled or partially filled with fluid other than diesel exhaust fluid.	Drain the diesel exhaust fluid tank and replace with non-contaminated diesel exhaust fluid. Refer to Procedure 011-056 in Section 11.
OK Go To Next Step	
STEP 2 Debris in the diesel exhaust fluid or tank	Clean and flush the diesel exhaust fluid tank, lines, and pump. Refer to Procedure 011-056 in Section 11.
OK Go To Next Step	
STEP 3 Diesel exhaust fluid tank is cracked or diesel exhaust fluid tank cap is leaking.	Repair or replace the diesel exhaust fluid tank or diesel exhaust fluid tank cap. Refer to equipment manufacturer service information.
OK Go To Next Step	
STEP 4 Bulk diesel exhaust fluid supply is contaminated.	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.
OK Go To Next Step	
STEP 5 Diesel exhaust fluid tank heater coolant lines leaking coolant.	Repair or replace the diesel exhaust fluid tank heater coolant lines. Refer to equipment manufacturer service information.

Engine Noise Excessive - Drive Belt

This is symptom tree t170

Cause	Correction
STEP 1 Drive belt incorrect or **not** routed correctly	Verify the proper belt part number is installed. Verify the belt tensioner arm stops are in the proper orientation with the drive belt installed. Refer to Procedure 008-002 in Section 8.
OK Go To Next Step	
STEP 2 Poor drive belt condition	Refer to Procedure 008-002 in Section 8.
OK Go To Next Step	
STEP 3 Accessory pulley is out of alignment	Verify the drive system pulley alignment with the belt alignment laser tool, Part Number 3163524 or equivalent. Refer to Procedure 008-002 in Section 8.
OK Go To Next Step	
STEP 4 Loss of belt tension	Refer to Procedure 008-087 in Section 8.

Turbocharger - Compressor Seal Oil Leak

This is symptom tree t185

Cause	Correction
STEP 1 Engine is operating for extended periods under light- or no-load conditions (slobbering)	Review the engine operating instructions. Refer to Procedure 101-015 in Section 1 in the QSF3.8 CM2350 F107 Operation and Maintenance Manual, Bulletin 4367317.
OK Go To Next Step	
STEP 2 Boost leak or past boost leaks including hose "blow-offs".	Check for boost leaks. Refer to Procedure 010-024 in Section 10 and the original equipment manufacturer (OEM) service manual. Interview the operator regarding past boost leaks. If past boost leaks have occurred, make sure the boost piping is installed properly.
OK Go To Next Step	
STEP 3 Air filter is plugged or incorrect	Refer to the equipment manufacturer service information for the correct air filter part number. Refer to Procedure 010-031 in Section 10 to check for an air intake restriction.
OK Go To Next Step	
STEP 4 Collapsed or restricted air intake piping between the air filter and turbocharger inlet	Repair or replace the intake piping. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Obstructed or crushed turbocharger oil drain line	Check the turbocharger oil drain line for restrictions. Refer to Procedure 010-045 in Section 10.
OK Go To Next Step	
STEP 6 Excessive axial or radial clearance	Check the turbocharger shaft radial and axial end clearance. Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	
STEP 7 Restricted exhaust system	Check for crushed, collapsed, or restricted exhaust piping, muffler, etc. Refer to Procedure 011-009 in Section 11 and the OEM service manual.
OK Go To Next Step	

Turbocharger - Compressor Seal Oil Leak

This is symptom tree t185

Cause	Correction
STEP 8 Exhaust pressure regulator malfunctioning	Remove the exhaust pipe connection. Turn the keyswitch ON and OFF. The regulator valve should travel freely in between the fully open and fully closed position. Refer to Procedure 011-105 in Section 11.
OK Go To Next Step	
STEP 9 Engine oil viscosity incorrect	Check the engine oil. Compare to Cummins® Service Bulletin 3810340 (Cummins® Engine Oil and Oil Analysis Recommendations). Refer to Procedure 018-017 in Section V.

Turbocharger - Turbine Seal Oil Leak

This is symptom tree t186

Cause	Correction
STEP 1 Engine is operating for extended periods under light- or no-load conditions (slobbering)	Review the engine operating instructions. Refer to Procedure 101-015 in Section 1 in the QSF3.8 CM2350 F107 Operation and Maintenance Manual, Bulletin 4367317.
OK Go To Next Step	
STEP 2 Obstructed or crushed turbocharger drain line	Check the turbocharger oil drain line for restrictions. Refer to Procedure 010-045 in Section 10.
OK Go To Next Step	
STEP 3 Crankcase pressure is excessive	Check for excessive blowby. Refer to Crankcase Gases (Blowby) Excessive troubleshooting symptom tree in Section TS.
OK Go To Next Step	
STEP 4 Restricted exhaust system	Check for crushed, collapsed, or restricted exhaust piping, muffler, etc. Refer to Procedure 011-009 in Section 11 and see equipment manufacturer service information.
OK Go To Next Step	
STEP 5 Exhaust pressure regulator malfunctioning	Remove the exhaust pipe connection. Turn the keyswitch ON and OFF. The regulator valve should travel freely in between the fully open and fully closed position. Refer to Procedure 011-105 in Section 11.
OK Go To Next Step	
STEP 6 Excessive axial or radial clearance	Check the turbocharger shaft radial and axial end clearance. Refer to Procedure 010-033 in Section 10..
OK Go To Next Step	
STEP 7 Engine oil viscosity incorrect	Check the engine oil. Compare to Cummins® Service Bulletin 3810340 (Cummins® Engine Oil and Oil Analysis Recommendations). Refer to Procedure 018-017 in Section V.
OK Go To Next Step	

Turbocharger - Turbine Seal Oil Leak

This is symptom tree t186

Cause	Correction
STEP 8 Oil coming into the turbocharger from the engine	Refer to Procedure 010-033 in Section 10 to remove the turbocharger from the engine and to determine if the exhaust manifold outlet and turbine housing inlet is wet with oil. If oil is present, reference the Lubricating Oil Consumption Excessive troubleshooting symptom tree in Section TS to identify the source.

Smoke, White - Excessive

This is symptom tree t118

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 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 Internally leaking EGR cooler	Perform the EGR cooler leak test. Refer to Procedure 011-019 in Section 11.
OK Go To Next Step	
STEP 4 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 5 Retained water vapor in the aftertreatment system	If white smoke persists after the engine has reached the minimum operating temperature, and a strong hydrocarbon odor is still present, troubleshoot the white smoke complaint.
OK Go To Next Step	
STEP 6 Contaminated aftertreatment system	Inspect the aftertreatment selective catalytic reduction (SCR) for signs of coolant or lubricating oil contamination. Check for engine repair history to determine if a previous malfunction may have contaminated the aftertreatment SCR with coolant. Refer to Procedure 011-036 in Section 11.
OK Go To Next Step	

Smoke, White - Excessive

This is symptom tree t118

Cause	Correction
STEP 7 Stuck open exhaust gas recirculation (EGR) valve	Use INSITE™ electronic service tool to perform the Aftertreatment Selective Catalytic Reduction 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 8 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 9 Leaking cylinder head gasket	Check for a damaged cylinder head gasket. Refer to Procedure 002-021 in Section 2.
OK Go To Next Step	
STEP 10 Check the injector wiring harness	Check continuity for each injector from ECM connector SIGNAL and RETURN to the appropriate injector solenoid SIGNAL and RETURN. Reference the appropriate circuit or wiring diagram for connector pin identification. If injector harness damage is found, it **must** be replaced. Refer to Procedure 003-011 in Section 19.

Excessive Automatic and/or Manual (Non-Mission) Regeneration

This is symptom tree t202

Cause	Correction
STEP 1 Automatic or manual (non-mission) regeneration is excessive	Refer to the Excessive Automatic and/or Manual (Non-Mission) Selective Catalytic Reduction (SCR)/Exhaust System Cleaning 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.

Cause	Correction
STEP 1 Electronic fault codes active or high count of inactive fault codes	View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319, for fault code troubleshooting.

OK
Go To Next Step

STEP 2 Incorrect calibration installed in engine control module (ECM)	Verify that the ECM calibration is correct. Refer to QuickServe™ Online to verify that the presently installed calibration matches the aftertreatment system installed on the vehicle. Refer to Procedure 019-031 in Section 19.

OK
Go To Next Step

STEP 3 Original equipment manufacturer (OEM) or customer selected inhibit feature is preventing active cleaning during vehicle operation	Check the Aftertreatment System Inhibit features with INSITE™ electronic service tool. Change either the vehicle route and/or duty cycle such that the inhibit features do **not** prevent or interrupt active cleaning. Refer to Procedure 011-999 in Section F.

OK
Go To Next Step

STEP 4 Extended operation of engine in low duty cycle, extended idling, and/or low ambient temperatures	Check the aftertreatment system trip information with INSITE™ electronic service tool. Low duty cycle applications generally require more active cleaning time to keep the aftertreatment system functioning properly. Change the vehicle route and/or duty cycle to increase the load on the engine, in order to decrease the amount of active cleaning time. Refer to Procedure 011-056 in Section 11 and Procedure 011-999 in Section F.

OK
Go To Next Step

STEP 5 Diesel exhaust fluid consumption excessive	Refer to the Diesel Exhaust Fluid Usage - Abnormal troubleshooting symptom tree in Section TS.

OK
Go To Next Step

STEP 6 Aftertreatment mono-nitrogen oxide NOx sensors or catalyst below efficiency threshold	Perform the SCR Performance Test in INSITE™ electronic service tool. Refer to Procedure 014-015 in Section 14.

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	Correction
STEP 1 Electronic fault codes active or high count of inactive fault codes	View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319, for fault code troubleshooting.

OK
Go To Next Step

STEP 2 The correct cleaning procedure is **not** being followed	Refer to equipment manufacturer service information on how to perform a manual (non-mission) SCR cleaning. Refer to Procedure 014-015 in Section 14.

OK
Go To Next Step

STEP 3 Clutch pedal is depressed	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.

OK
Go To Next Step

STEP 4 Brake pedal is depressed	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.

OK
Go To Next Step

STEP 5 Power take off (PTO) or Remote PTO is engaged	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.

OK
Go To Next Step

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	Correction
STEP 6 Accelerator pedal position is greater than zero	Manual (non-mission) SCR cleaning will **not** activate if the accelerator pedal position is greater than zero. Check for accelerator pedal or lever restriction. Use INSITE™ electronic service tool to monitor the percent throttle reading. Check the accelerator pedal position sensor and the circuit. Refer to Procedure 019-085 in Section 19. It may be necessary to see equipment manufacturer service information for special instrucitons.

OK
Go To Next Step

STEP 7 Transmission is **not** in Park, if provided, otherwise in Neutral	Verify that the transmission is in Park, if provided, otherwise in Neutral. Refer to equipment manufacturer service information.

OK
Go To Next Step

STEP 8 Engine control module (ECM) calibration is malfunctioning	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 the Control Parts List (CPL), found on the engine dataplate. If necessary, calibrate the ECM. Refer to Procedure 019-032 in Section 19.

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 1 Electronic fault codes active or high count of inactive fault codes	View and troubleshoot the fault codes with INSITE™ electronic service tool. Refer to the QSF3.8 CM2350 F107 Fault Code Troubleshooting Manual, Bulletin 4367319, for active fault code troubleshooting. See the following procedure for inactive fault code troubleshooting. Refer to Procedure 019-362 in Section 19.

OK
Go To Next Step

STEP 2 Manual (non-mission) SCR cleaning **not** allowed to run to completion	Allow the manual (non-mission) SCR cleaning to run until completion, which can take up to 2.5 hours.

OK
Go To Next Step

STEP 3 Exhaust leaks in the original equipment manufacturer (OEM) exhaust piping leading to the aftertreatment system or leaks in the aftertreatment system	Inspect the OEM exhaust piping and the aftertreatment system for exhaust leaks. Refer to Procedure 010-024 in Section 10.

OK
Go To Next Step

STEP 4 Aftertreatment gas temperature sensors are **not** functioning properly	Monitor the aftertreatment gas temperature sensor values with INSITE™ electronic service tool during the manual (non-mission) SCR cleaning. Refer to Procedure 011-056 in Section 11.

OK
Go To Next Step

STEP 5 Turbocharger is **not** functioning properly	Use INSITE™ electronic service tool to verify the turbocharger actuator position is maintained at 89 percent closed or higher during the manual (non-mission) SCR cleaning. If the turbocharger actuator position does **not** maintain 89 percent closed or higher, verify the turbocharger wastegate actuator has full travel. Refer to Procedure 010-050 in Section 10.

OK
Go To Next Step

STEP 6 Aftertreatment system is damaged	Check for progressive damage to the aftertreatment system. Refer to Procedure 014-015 in Section 14.

OK
Go To Next Step

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 engine control module (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. 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)

Section Contents

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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		SPECIFICATIONS	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:
- Connect INSITE™ electronic service tool.
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
Check for INSITE™ electronic service tool error code 5023. • 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:
- Connect INSITE™ electronic service tool.
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
Check for INSITE™ error code 5080 or 5081. • 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.

Condition:
- Connect Is INSITE™ electronic service tool.
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
Are any INSITE™ electronic service tool error codes present other than 5023, 5080, or 5081? • Use INSITE™ electronic service tool to read the error codes.	Are any INSITE™ electronic service tool error codes present other than 5023, 5080, or 5081? **YES** **Repair:** See the INSITE™ Electronic Service Tool manual for troubleshooting guidelines.	Repair Complete
	Are any INSITE™ electronic service tool error codes present other than 5023, 5080, or 5081? **NO**	1D

STEP 1D: ECM password check

Condition:
- Connect INSITE™ electronic service tool.
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
Does INSITE™ electronic service tool indicate the ECM is password protected? • Use INSITE™ electronic service tool.	Does INSITE™ electronic service tool indicate the ECM is password protected? **YES** **Repair:** Enter correct password 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.	Repair complete
	Does INSITE™ electronic service tool indicate the ECM is password protected? **NO**	2A

STEP 2: Initial data link adapter and INSITE™ electronic service tool check

STEP 2A: Initial data link adapter check

Condition:
- 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

Condition:
INSITE™ electronic service tool connected to vehicle.

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

Condition:
- 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 comunicate 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:
- 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:
- 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:
- None

Action	Specification/Repair	Next Step
Troubleshoot bench calibration cable, bench calibration harness, and serial cable. • 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

Condition:
- Turn keyswitch ON.
- Disconnect the coolant temperature sensor connector.

Action	Specification/Repair	Next Step
Measure the voltage across the two pins of the coolant temperature sensor on the wiring harness connector. Reference the wiring diagram or circuit diagram for connector pin identification.	Is the coolant temperature signal voltage greater than 4.5-VDC? **YES**	5A
	Is the coolant temperature signal voltage greater than 4.5-VDC? **NO**	4B

STEP 4B: ECM keyswitch voltage check

Condition:
- 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
Measure the voltage from the keyswitch input SIGNAL wire of the wiring harness to engine block ground. Reference the wiring diagram or circuit diagram for connector pin identification.	Is the keyswitch voltage within 1-VDC of vehicle system voltage? **YES**	4C
	Is the keyswitch voltage within 1-VDC of vehicle system voltage? **NO** **Repair:** 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. See the Engine Performance Troubleshooting Tree in the appropriate troubleshooting and repair manual, if the no start condition is still present.	Repair complete

STEP 4C: Check the ECM power and ground

Condition:
- 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
Measure the voltage from each ECM battery SUPPLY (+) pin to all battery SUPPLY (-) pins in the wiring harness connector. Reference the wiring diagram or circuit diagram for connector pin identification.	Is the ECM battery supply voltage equal to the battery voltage? **YES** **Repair:** Call for authorization. Replace the ECM. Reference Procedure 019-031 (Electronic Control Module (ECM)) in Section 19 in the appropriate troubleshooting and repair manual.	Repair complete
	Is the ECM battery supply voltage equal to the battery voltage? **NO** **Repair:** Repair or replace the wiring harness that contains the ECM battery SUPPLY (+) and battery SUPPLY (-) wiring. See the Engine Performance Troubleshooting Tree if no start condition is still present.	Repair complete

STEP 5: Initial electronic tool check

STEP 5A: Bench setup previously used for troubleshooting check

Condition:
- None

Action	Specification/Repair	Next Step
In Step 3 checks, was bench setup used to successfully communicate with the ECM?	In Step 3 checks, was bench setup used to successfully communicate with the ECM? **YES** **Repair:** ECM is OK, repair complete if communication is **not** required through OEM data link connector or harness. If communication is required through the OEM data link connector or harness continue to Step 6A.	6A
	In Step 3 checks, was bench setup used to successfully communicate with the ECM? **NO**	5B

STEP 5B: Second vehicle availability check for electronic tool

Condition:
- 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:
- 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:
- 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:
- 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:
- 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:
- 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:
- 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:
- 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:
- None

Action	Specification/Repair	Next Step
Perform troubleshooting procedures for evaluating electronic tool hardware: • 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: • 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.	Repair complete

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:
- 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

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 a 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 be 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:	Marine application.	Engine installed in a marine application?	
STEP 1I:	Do an engine rpm sweep.	Vibration present stationary below 1050 rpm?	
STEP 1J:	Do an engine rpm sweep.	Vibration present stationary above 1050 rpm?	
STEP 1K:	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 been 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 for a malfunctioning engine internal balancer assembly (4 cylinder B-Series only).	Internal balancer meet specification?
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?

STEP 5: Marine applications.

STEP 5A:	Check the gear ratio and propeller configuration.	Gear ratio and the propeller incorrectly matched to the engine power?
STEP 5B:	Check for the correct engine mounting isolators and for	Engine mount isolators correct and installed correctly?

	proper installation requirements.	
STEP 5C:	Check for damaged engine mounts and isolators.	Engine mounts and isolators in good condition?
STEP 5D:	Check the exhaust system.	Exhaust system deficient?
STEP 5E:	Check the engine driven accessories.	Engine driven accessory malfunctioning?
STEP 5F:	Check the shaft coupling to gear coupling alignment.	Shaft coupling to gear coupling misaligned?
STEP 5G:	Check the propeller shaft for proper installation.	Propeller shaft installed correctly?
STEP 5H:	Check the propeller shaft for straightness.	Propeller shaft straightness within the OEM specification?
STEP 5I:	Isolate the engine.	Engine vibration persist?
STEP 5J:	Check for strut/cutlass bearing misalignment.	Strut/cutlass bearing misaligned or strut mounting not secure?
STEP 5K:	Check the propeller.	Propeller out of balance or not fitted properly to the shaft?
STEP 5L:	Check the V-angle on the V-strut.	V-angle on the V-strut match the angle of the blade on the prop?
STEP 5M:	Check the propeller tunnels.	Entry and exit of the propeller tunnel match with the propeller blades?
STEP 5N:	Check the engine to transmission torsional coupling.	Torsional coupling incorrect or worn?
STEP 5O:	Check the rudder.	Rudder have excessive play in the rudder post?
STEP 5P:	Check the engine flywheel housing to cylinder block alignment.	Flywheel housing alignment incorrect?

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 be duplicated? **YES**	1C
	Customer's complaint be 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:
- As required.

Action	Specification/Repair	Next Step
Check or verify the following items before continuing. • 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:
- 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 [70°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:
- 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:
- Do **not** operate engine.
- Install engine moun.

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: • 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: Marine application.

Condition:
None

Action	Specification/Repair	Next Step
Engine in a marine application? N/A	Engine installed in a marine application? **YES**	5A
	Engine installed in a marine application? **NO**	1I

STEP 1I: Do an engine rpm sweep.

Condition:
- Operate engine
- Connect INSITE™ electronic service tool.
- Make sure of 0 vehicle speed.

Action	Specification/Repair	Next Step
Perform a slow (at 100 rpm per second) rpm sweep and observe where the vibration occurs. 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. 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.	Vibration present stationary below 1050 rpm? **YES**	2A
	Vibration present stationary below 1050 rpm? **NO**	1J

STEP 1J: Do an engine rpm sweep.

Condition:
- Operate engine.
- Connect INSITE™ electronic service tool.
- 0 vehicle speed.

Action	Specification/Repair	Next Step
Perform a slow (at 100 rpm per second) rpm sweep and observe where the vibration occurs. 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.	Vibration present stationary above 1050 rpm? **YES**	1K
	Vibration present stationary above 1050 rpm? **NO**	4A

STEP 1K: Check the vibration engine speed range.

Condition:
- Operate engine
- Connect INSITE™ electronic service tool.
- Make sure of 0 vehicle speed.

Action	Specification/Repair	Next Step
Perform a slow (at 100 rpm per second) rpm sweep and observe where the vibration occurs. 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. 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.	Vibration speed range greater than 300 to 400 rpm? **YES**	3A
	Vibration speed range greater than 300 to 400 rpm? **NO**	2A

STEP 2: Perform low rpm checks.

STEP 2A: Check that the accessory load is not excessive for the idle speed setting.

Condition:
- Operate engine at idle speed (less than 900 rpm).
- Turn accessories off (air conditioning, fan, and PTO).
- Engine at operating temperature (greater than 77°C [170°F]).

Action	Specification/Repair	Next Step
Disable all engine driven accessories and PTOs to make sure they are **not** applying excessive load to the engine. N/A	All steps verified to be correct? **YES**	2B
	All steps verified to be correct? **NO** **Repair:** Repair as required.	Repair complete

STEP 2B: Check that the Fast Idle Warm-Up feature is activating, if applicable.

Condition:
- 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:
- 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:
- 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.

Condition:
- Do **not** operate engine.
- Remove engine mount isolators.

Action	Specification/Repair	Next Step
This step is a detailed inspection of the engine mount brackets, isolators, and mounting hardware. • 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**	2H
	All steps verified to be correct? **NO** **Repair:** Repair or replace the damaged components.	Repair complete

STEP 2H: Complaint since new.

Condition:
- Record the odometer/hour meter.
- Review the troubleshooting documentation information questions.

Action	Specification/Repair	Next Step
Check the equipment. Check the equipment mileage/hours and compare to the vibration customer interview form completed in Step 1A. • 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.	Problem been occurring since the equipment was new? **YES** **Repair:** The engine mounts are **not** the right specification for the application, or a structural resonance exists.	Contact a Cummins® Technical Support Specialist or the OEM
	Problem been occurring since the equipment was new? **NO** **Repair:** Recheck for shorts, a rough running engine, or malfunctioning engine mounts.	Contact a Cummins® Technical Support Specialist or the OEM

STEP 3: Perform higher rpm checks.

STEP 3A: Inspect the engine mounts.

Condition:
- Do **not** operate engine.
- Remove the engine mount isolators.

Action	Specification/Repair	Next Step
Inspect the engine mount brackets, isolators, and mounting hardware. • 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:
- 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:
- Do **not** operate engine.

Action	Specification/Repair	Next Step
Remove and visually inspect the vibration damper. Use Procedure 001-052 in Section 1 in the appropriate service manual for vibration damper inspection specifications.	Vibration damper damaged or out of specification? **YES** **Repair:** Replace the vibration damper. Reference the appropriate service manual.	Repair complete
	Vibration damper damaged or out of specification? **NO**	3D

STEP 3D: Check the air compressor timing.

Condition:
- Do **not** operate engine.
- Remove air compressor.

Action	Specification/Repair	Next Step
Check the air compressor timing. Reference Procedure 012-014 in Section 12 of the appropriate service manual.	Air compressor timing correct? **YES**	3E
	Air compressor timing correct? **NO** **Repair:** Correct the air compressor timing and retest for the vibration complaint. Reference Procedure 012-014 in Section 12 of the appropriate service manual.	Repair complete

STEP 3E: Check the overhead adjustments.

Condition:
- Do **not** operate engine.
- Remove rocker lever cover.

Action	Specification/Repair	Next Step
Measure and adjust the overhead settings. • Check the overhead components for damage. Reference Procedure 003-004 in Section 3 of the appropriate service manual.	Overhead adjustments correct? **YES**	3F
	Overhead adjustments correct? **NO** **Repair:** Repair or adjust the overhead. Reference Procedure 003-004 in Section 3 of the appropriate service manual.	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 for a malfunctioning engine internal balancer assembly (4 cylinder B-Series only).

Condition:
- None.

Action	Specification/Repair	Next Step
Inspect the engine internal balancer assembly. Reference Procedure 001-004 in Section 1 of the appropriate service manual. This applies to 4 cylinder B-Series engines **only**.	Internal balancer meet specification? **YES**	3I
	Internal balancer meet specification? **NO** **Repair:** Repair the internal balancer. Reference Procedure 001-004 in Section 1 of the appropriate service manual.	Repair complete

STEP 3I: Check the clutch or torque converter for vibration.

Condition:
- Operate engine.

Action	Specification/Repair	Next Step
With engine running in the operating condition of the vibration, disengage and engage the clutch serval 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:
- Remove transmission.

Action	Specification/Repair	Next Step
Check the flywheel. • Check the flywheel bore and face run out. • Check the flywheel for damage. Reference Procedure 016-005 in Section 16 of the appropriate service manual.	Flywheel meet specifications? **YES**	3K
	Flywheel meet specifications? **NO** **Repair:** Repair or replace the flywheel or flexplate. Reference Procedure 016-005 in Section 16 of the appropriate service manual.	Repair complete

STEP 3K: Check the flywheel housing for correct alignment.

Condition:
- Remove transmission.
- Remove flywheel/flexplate.

Action	Specification/Repair	Next Step
Check the flywheel housing bore and face alignment. Reference Procedure 016-006 in Section 16 of the appropriate service manual.	Flywheel housing meet specifications? **YES**	3L
	Flywheel housing meet specifications? **NO** **Repair:** Repair or replace the flywheel housing. Reference Procedure 016-006 in Section 16 of the appropriate service manual.	Repair complete

STEP 3L: Check to see if the crankshaft has been balanced.

Condition:
- Do **not** operate engine.
- Remove lubricating oil pan.

Action	Specification/Repair	Next Step
Remove the lubricating oil pan. Reference Procedure 007-025 in Section 7 of the appropriate service manual. Check the crankshaft to see if it has been balanced. Reference Procedure 001-016 in Section 16 of the appropriate service manual. This step **only** applies if the complaint has been present since the engine was new or after a crankshaft replacement. ISX engines built after 01-November-2008 have a marking on the crankshaft to indicate if it passed the balancing step in the manufacturing process. Reference Procedure 001-016 in Section 1 of the appropiate service manual.	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:
- 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. • 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:
- Preform 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:
- Perform 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:
- 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. • 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. Reference Procedure 016-010 in Section 16 of the appropriate service manual.	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

STEP 5: Marine applications.

STEP 5A: Check the gear ratio and propeller configuration.

Condition:
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
Check for an incorrect matching of the gear ratio and propeller to the engine power. N/A	Gear ratio and the propeller incorrectly matched to the engine power? **YES** **Repair:** Contact a Cummins® Distributor or a Marine District Field Service Manager.	Repair complete
	Gear ratio and the propeller incorrectly matched to the engine power? **NO**	5B

STEP 5B: Check for the correct engine mounting isolators and for proper installation requirements.

Condition:
- None.

Action	Specification/Repair	Next Step
Check for the correct engine mount isolators and for propeller installation requirements. N/A	Engine mount isolators correct and installed correctly? **YES**	5C
	Engine mount isolators correct and installed correctly? **NO** **Repair:** Check for proper isolator installation requirements. Replace and repair vibration isolators as needed. Reference Procedure 016-026 in Section 16 of the appropriate service manual and the Engine Mounting/ Drive Systems section in the Marine Recreational Installation Directions, Bulletin 3884649. If the isolators are **not** manufactured by Cummins Inc.; see the OEM service manual.	Repair complete

STEP 5C: Check for damaged engine mounts and isolators.

Condition:
- None.

Action	Specification/Repair	Next Step
Inspect the engine mount and isolators for damage. N/A	Engine mounts and isolators in good condition? **YES**	5D
	Engine mounts and isolators in good condition? **NO** **Repair:** Remove and replace the engine mount isolators. Reference Procedure 016-026 in Section 16 of the appropriate service manual and the Engine Mounting/Drive Systems section in the Marine Recreational Installation Directions, Bulletin 3884649. If the isolators are **not** manufactured by Cummins Inc.; see the OEM service manual.	Repair complete

STEP 5D: Check the exhaust system.

Condition:
- None.

Action	Specification/Repair	Next Step
Check for exhaust system deficiencies. N/A	Exhaust system deficient? **YES** **Repair:** Repair or replace as needed. See the Exhaust System section in the Marine Recreational Installation Directions, Bulletin 3884649, and the OEM service manual.	Repair complete
	Exhaust system deficient? **NO**	5E

STEP 5E: Check the engine driven accessories.

Condition:
- Turn keyswitch ON.
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
Check for engine driven accessory malfunctions. • Isolate or disconnect the accessories and check for vibration. • Do **not** operate the engine if the sea water pump is disconnected.	Engine driven accessory malfunctioning? **YES** **Repair:** Determine the cause of the malfunctioning accessories and correct the problem. See the Exhaust System section in the Marine Recreational Installation Directions, Bulletin 3884649, and the OEM service manual.	Repair complete
	Engine driven accessory malfunctioning? **NO**	5F

STEP 5F: Check the shaft coupling to gear coupling alignment.

Condition:
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
Check the shaft coupling to gear coupling alignment. N/A	Shaft coupling to gear coupling misaligned? **YES** **Repair:** Repair or replace as needed. Reference Procedure 016-025 in Section 16 of the appropriate service manual and the Engine Mounting/Drive Systems section in the Marine Recreational Installation Directions, Bulletin 3884649, and the gear manufacturer's recommendations.	Repair complete
	Shaft coupling to gear coupling misaligned? **NO**	5G

STEP 5G: Check the propeller shaft for proper installation.

Condition:
- None.

Action	Specification/Repair	Next Step
Check the propeller shaft for proper installation. N/A	Propeller shaft installed correctly? **YES**	5H
	Propeller shaft installed correctly? **NO** **Repair:** Repair or replace as needed. Reference Procedure 016-025 in Section 16 of the appropriate service manual and the Engine Mounting/Drive Systems section in the Marine Recreational Installation Directions, Bulletin 3884649, and the gear manufacturer's recommendations.	Repair complete

STEP 5H: Check the propeller shaft for straightness.

Condition:
- None.

Action	Specification/Repair	Next Step
Check the propeller shaft for straightness. N/A	Propeller shaft straightness within the OEM specification? **YES**	5I
	Propeller shaft straightness within the OEM specification? **NO** **Repair:** Repair or replace the propeller shaft as needed. Contact an authorized OEM service location.	Repair complete

STEP 5I: Isolate the engine.

Condition:
- Disconnect the drive shaft.

Action	Specification/Repair	Next Step
Run the engine without the drive shaft attached at the coupler. N/A	Engine vibration persist? **YES** **Repair:** Check the engine vibration damper for damage. Repair or replace as needed. Reference Procedure 001-052 in Section 1 of the appropriate service manual.	Repair complete
	Engine vibration persist? **NO**	5J

STEP 5J: Check for strut/cutlass bearing misalignment.

Condition:
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
Check for strut/cutlass bearing misalignment or strut mounting **not** secure. N/A	Strut/cutlass bearing misaligned or strut mounting not secure? **YES** **Repair:** Check the strut for mounting stiffness. Repair or replace as necessary. Contact an authorized OEM service location.	Repair complete
	Strut/cutlass bearing misaligned or strut mounting not secure? **NO**	5K

STEP 5K: Is the propeller out of balance or not fitted properly to the shaft?

Condition:
- None.

Action	Specification/Repair	Next Step
Check for propeller out-of-balance or propeller not fitted properly to shaft. N/A	Propeller out of balance or not fitted properly to the shaft? **YES** **Repair:** Check the propeller for accuracy. Repair or replace as needed. Contact an authorized OEM service location.	Repair complete
	Propeller out of balance or not fitted properly to the shaft? **NO**	5L

STEP 5L: Check the V-angle on the V-strut.

Condition:
- None.

Action	Specification/Repair	Next Step
Check to see if the V-angle on the V-strut does not match the angle of the blade on the propeller. N/A	V-angle on the V-strut match the angle of the blade on the prop? **YES**	5M
	V-angle on the V-strut match the angle of the blade on the prop? **NO** **Repair:** Repair or replace as needed. Refer to an Authorized OEM Service Location.	Repair complete

STEP 5M: Check the propeller tunnels.

Condition:
- None.

Action	Specification/Repair	Next Step
Check if the propeller tunnels are properly matched with the propellers. N/A	Entry and exit of the propeller tunnel match with the propeller blades? **YES**	5N
	Entry and exit of the propeller tunnel match with the propeller blades? **NO** **Repair:** Repair or replace as needed. Contact an authorized OEM service location.	Repair complete

STEP 5N: Check the engine-to-transmission torsional coupling.

Condition:
- None.

Action	Specification/Repair	Next Step
Check the engine-to-transmission torsional coupling. N/A	Torsional coupling incorrect or worn? **YES** **Repair:** Replace the coupling. Contact an authorized OEM service location.	Repair complete
	Torsional coupling incorrect or worn? **NO**	5O

STEP 5O: Check the rudder.

Condition:
None.

Action	Specification/Repair	Next Step
Check the rudder for excessive play in the rudder post. N/A	Rudder have excessive play in the rudder post? **YES** **Repair:** Repair or replace as needed. Contact an authorized OEM service location.	Repair complete
	Rudder have excessive play in the rudder post? **NO**	5P

STEP 5P: Check the engine flywheel housing-to-cylinder block alignment.

Condition:
- None.

Action	Specification/Repair	Next Step
Check the engine flywheel housing-to-cylinder block alignment. N/A	Flywheel housing alignment incorrect? **YES** **Repair:** Align the flywheel housing to cylinder block. Reference Procedure 016-006 in Section 16 of the appropriate service manual.	Repair complete
	Flywheel housing alignment incorrect? **NO** **Repair:** The engine can possibly have internal damage that has **not** been detected. Analyze the oil and inspect the filters to locate an area of probable damage. Reference Procedure 007-083 in Section 7 of the appropriate service manual. The engine can possibly need to be rebuilt. Reference Procedure 000-001 in Section 0 of the appropriate service manual and the engine rebuild specifications in the appropriate service manual. If the engine is **not** damaged, the problem can possibly be the vessel design. Contact an authorized OEM service location.	Repair complete

Notes

Section DS - Engine Disassembly - Group 00

Section Contents

Engine Support Bracket, Front (016-002)

Remove

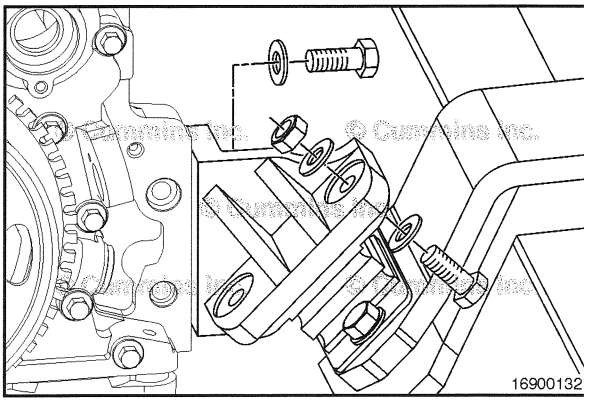
⚠WARNING⚠
The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

⚠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.

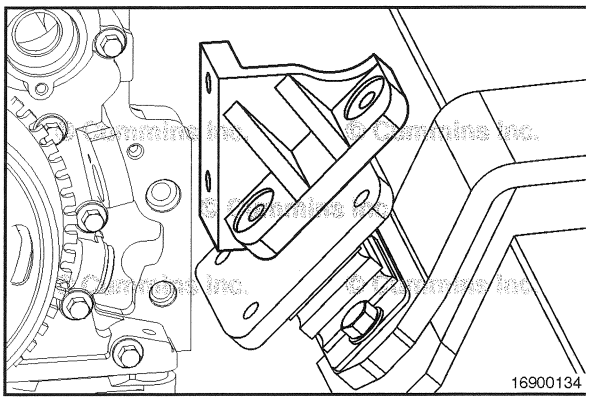
Use a hoist or lifting fixture to support the front of the engine.

NOTE: When removing the front engine mount fasteners, keep track of the location of any shims or spacers used.

Remove the capscrews from the front engine mount.



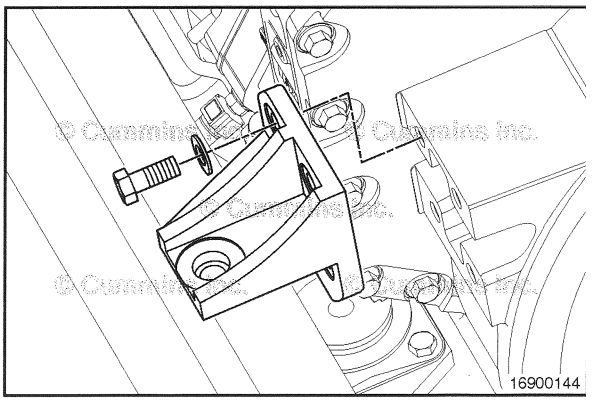
For side mount, remove the side engine mount capscrews and the brackets.

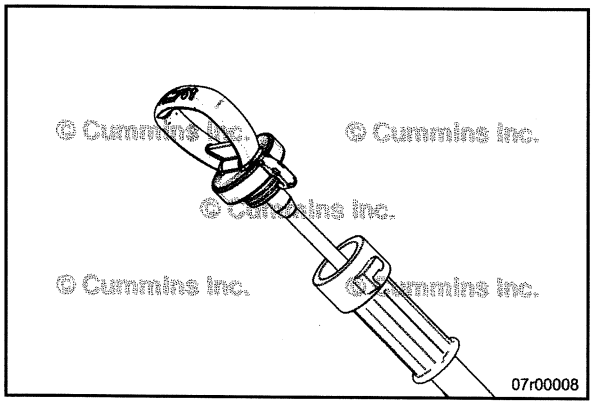


Engine Support Bracket, Rear (016-003)

Remove

Remove the rear support capscrews and bracket.

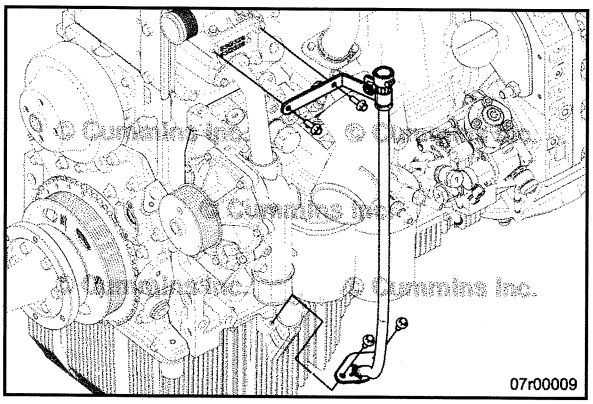




Lubricating Oil Dipstick Tube (007-011)

Remove

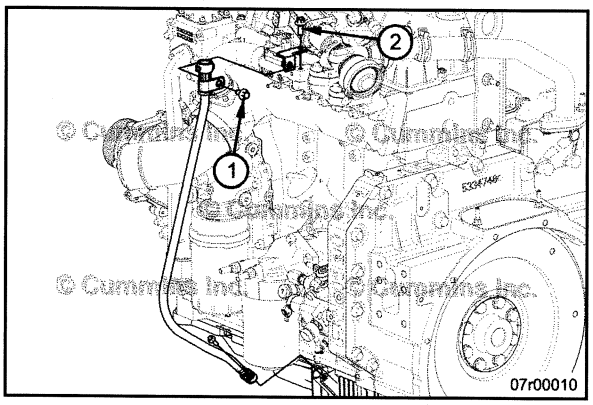
Remove the dipstick from the dipstick tube.



Long dipstick with front oil pan sump:

Remove dipstick tube brace capscrew from dipstick tube support.

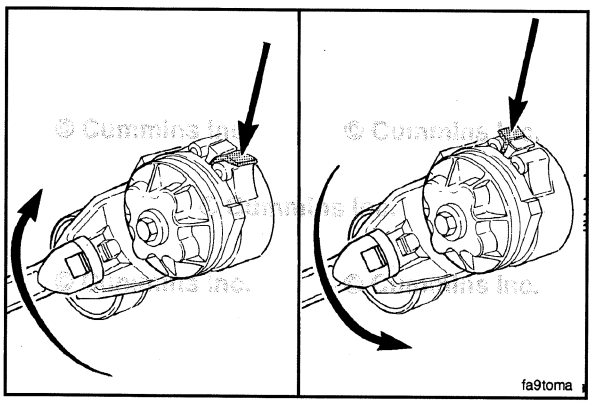
Remove the dipstick tube from the lubricating oil pan.



Long dipstick with rear oil pan sump:

Remove dipstick tube brace capscrew from dipstick tube support (1).

Remove dipstick tube support bracket capscrew from the air transfer tube (2).



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.

The belt tensioner winds in the direction that the spring tang is bent over the tensioner body. To loosen the tension on the belt, rotate the tensioner to wind the spring tighter.

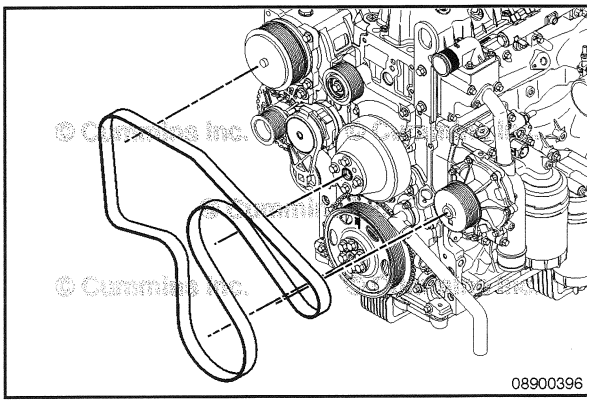
⚠CAUTION⚠
Applying excessive force in the opposite direction of windup or after the tensioner has been wound up to the positive stop can cause the tensioner arm to break.

NOTE: Make a diagram of the belt arrangement prior to removing the drive belt. This aids in installation for proper routing of the cooling fan drive belt.

NOTE: The location of the belt tensioner can vary, depending on the front engine accessory arrangement.

Pivot the tensioner in the direction of the spring tang to remove the belt.

Remove the belt.

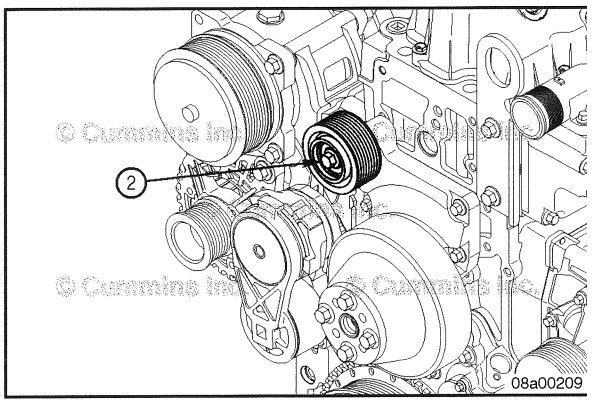


Pulley, Fan Idler (008-111)

Remove

Remove the idler pulley mounting capscrew (2).

Remove the idler pulley.

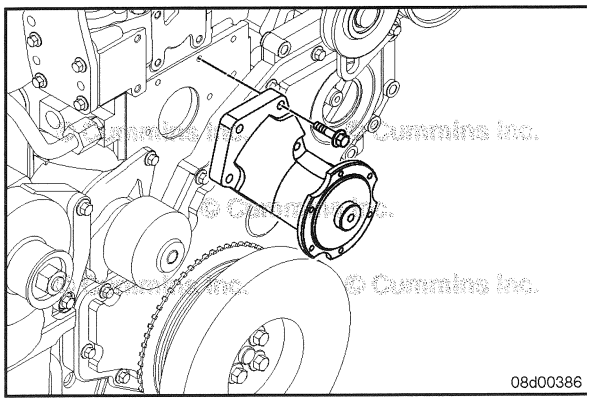


Fan Hub, Belt Driven (008-036)

Remove

NOTE: There are many available fan hub configurations. Be sure to note the location, orientation, and mounting pattern of the hub prior to removal from the engine.

Remove the four capscrews and the fan hub.

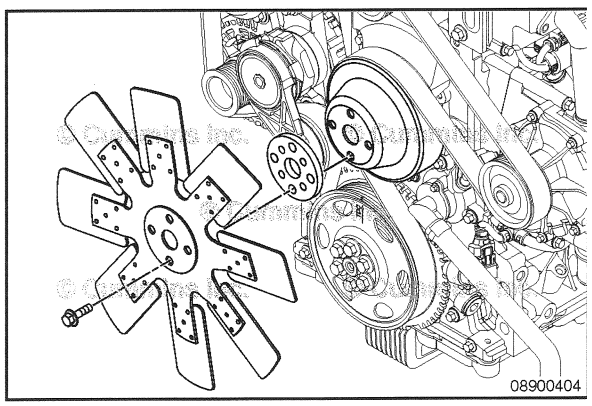


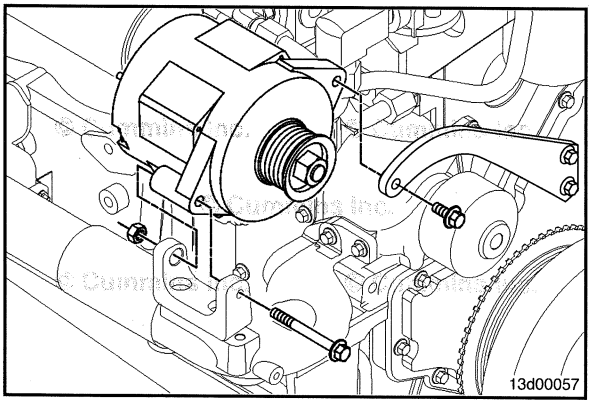
Fan Spacer and Pulley (008-039)

Remove

Remove the four fan capscrews, fan, and spacer.

Remove the fan pulley.



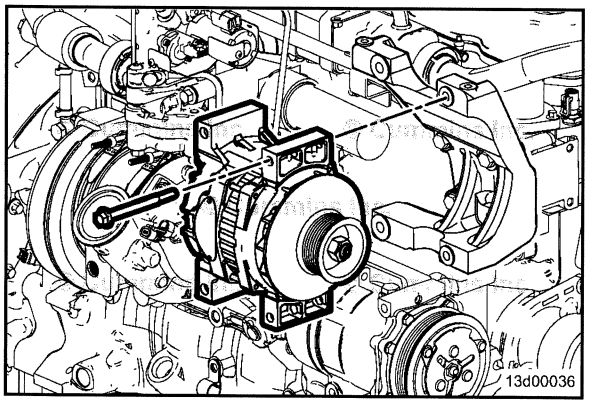


Charging System Alternator (013-001)

Remove

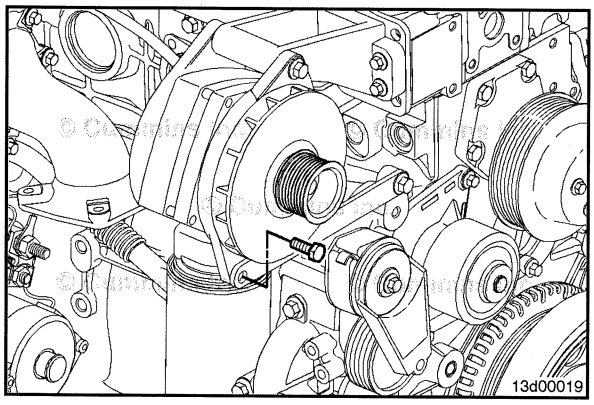
Spool Mount

- Remove the upper alternator link capscrew.
- Remove the mounting capscrew and nut at the bottom of the alternator and alternator mounting bracket.
- Remove the alternator.



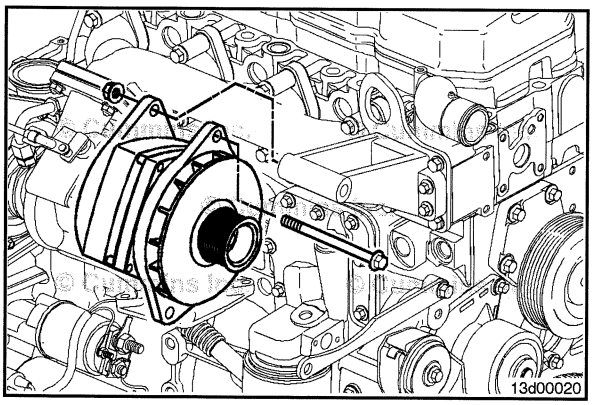
Pad Mount

- Remove the alternator mounting capscrews.
- Remove the alternator.



Hinge Mount

- Remove the alternator link capscrew.



- Remove the alternator mounting capscrew.
- Remove the alternator.

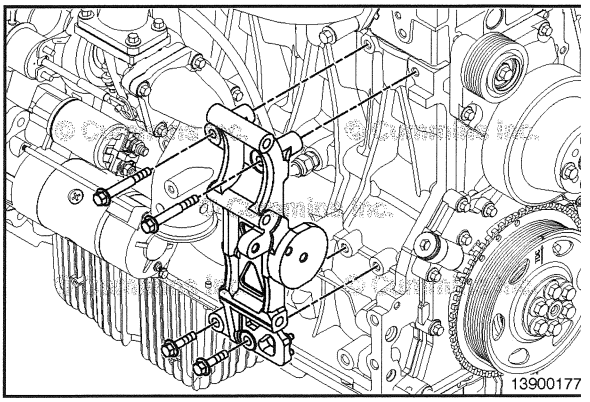
Charging System Alternator Bracket (013-003)

Remove

Remove the upper alternator bracket mounting capscrews.

Remove the lower alternator bracket mounting capscrews.

Remove the alternator bracket.

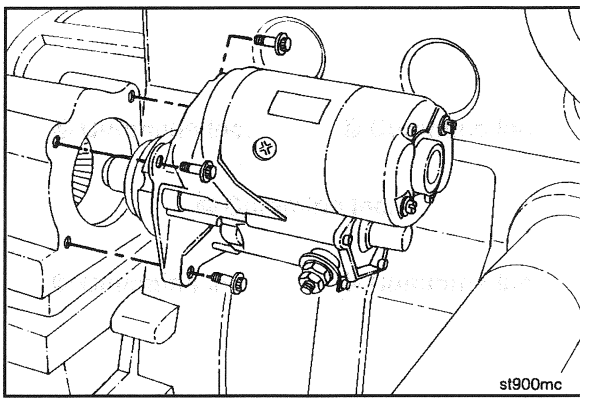


Starting Motor (013-020)

Remove

Remove the three capscrews and the starting motor.

NOTE: 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.

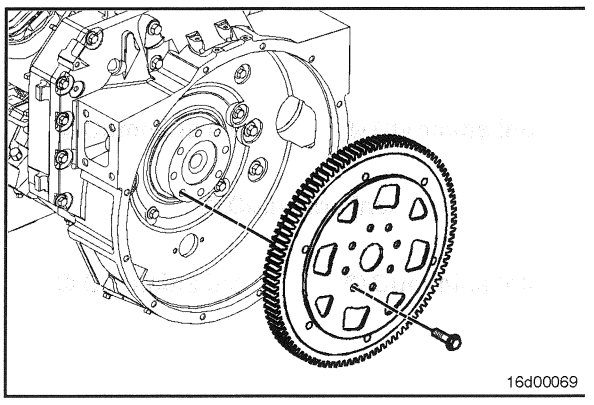


Flexplate (016-004)

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, Cummins® Part Number 3824591, to hold the flywheel to prevent rotation.

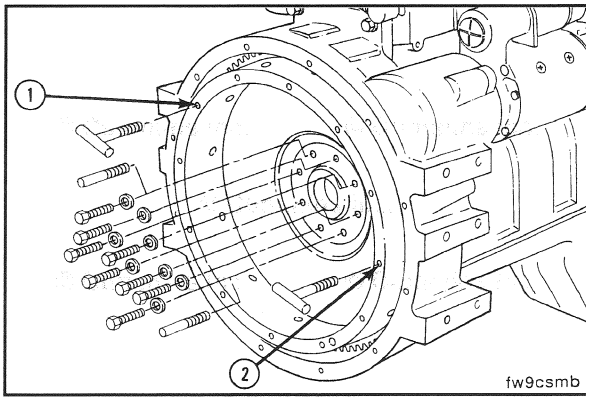
Remove two capscrews 180 degrees apart.

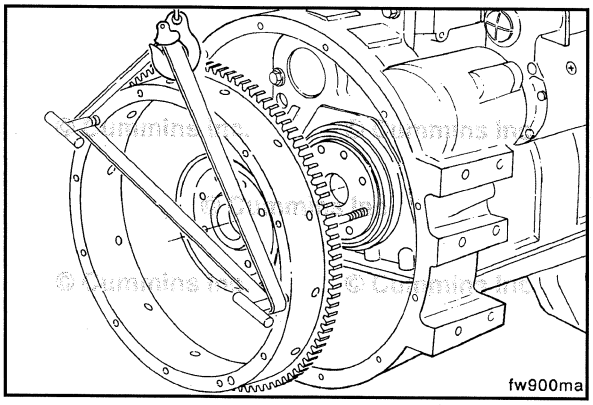
Install two M12 x 1.25 x 90-mm guide pins.

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).

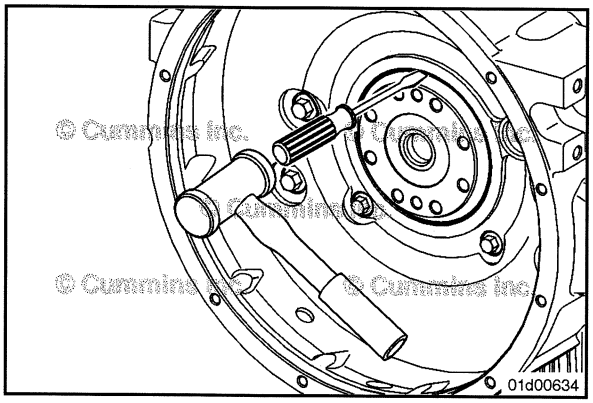
Remove the remaining six flywheel mounting capscrews.





⚠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

Lip Seal

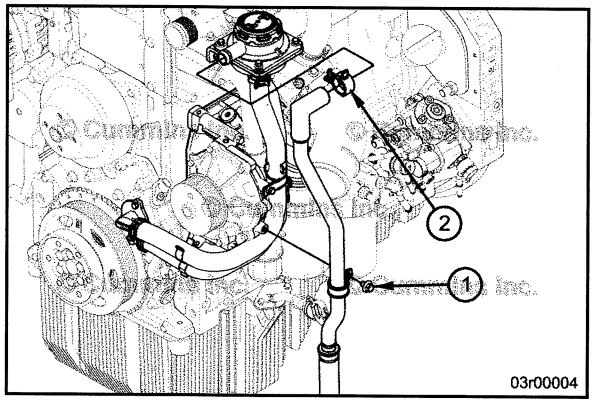
Clean the surface area around the rear crankshaft seal.

NOTE: For engines equipped with a lip style rear crankshaft seal, the seal can be removed using the following method.

Use a suitable round bar or screwdriver. Carefully tap the seal at the 12 o'clock position toward the front of the engine, so it begins to pivot and the lower part of the seal at the 6 o'clock position begins to tilt outward.

Use the screwdriver to carefully pry the seal off the crankshaft.

Discard the crankshaft seal when removed.



Crankcase Breather Tube (003-018)

Remove

Remove capscrew (1) from the P-clip securing the crankcase breather tube to the water pump housing.

Remove the spring clamp (2) and disconnect the crankcase breather tube.

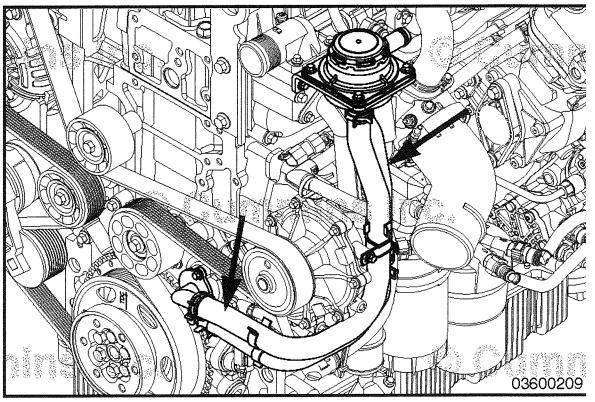
Remove the crankcase breather tube.

Crankcase Breather Adapter (003-031)

Remove

Remove the open crankcase ventilation hoses and open crankcase oil drain line from the crankcase breather adapter.

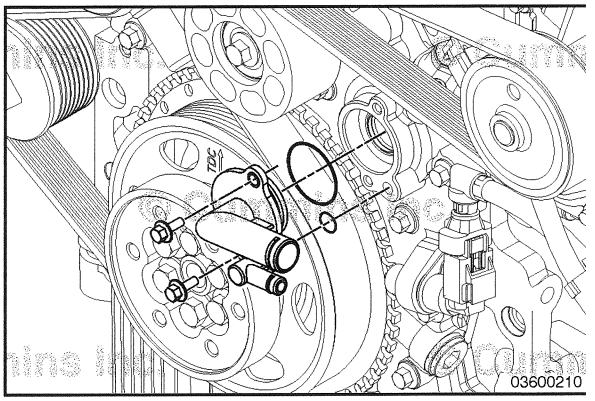
- Refer to Procedure 003-026 in Section 3.
- Refer to Procedure 003-037 in Section 3.



Remove the two mounting capscrews from the crankcase breather adapter.

Remove the crankcase breather adapter from the front cover.

Discard the o-rings.

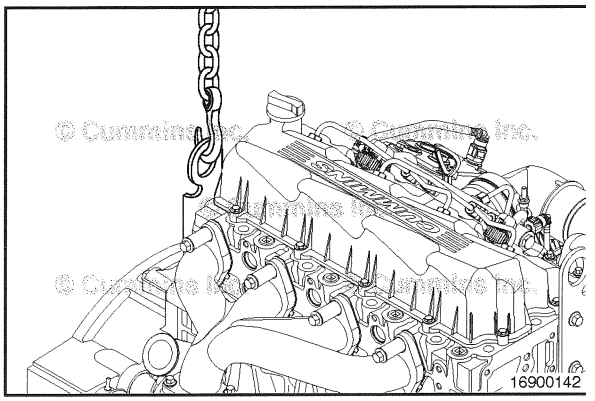


Flywheel Housing (016-006)

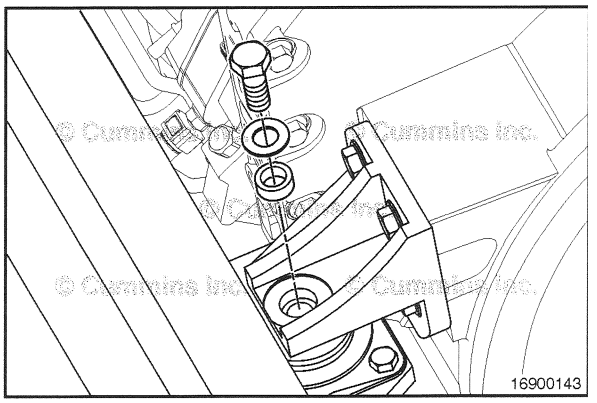
Remove

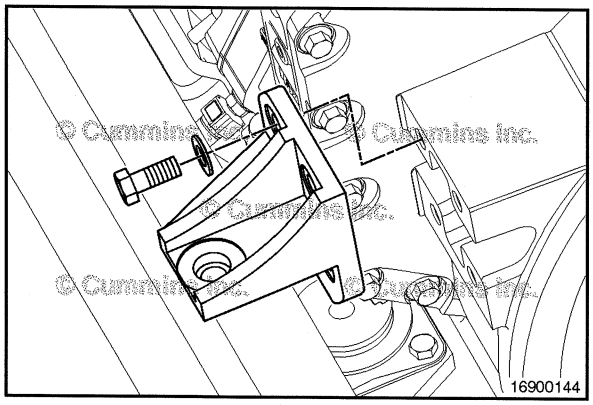
⚠WARNING⚠
The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

Use a hoist or lifting fixture to support the rear of the engine.

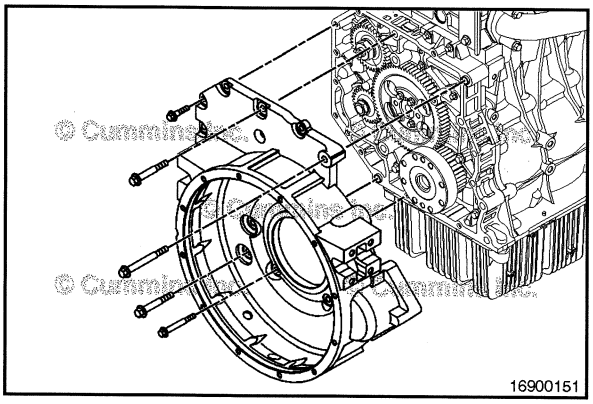


Remove the rear engine supports. Refer to Procedure 016-003 in Section 16.





Remove the rear engine brackets. Refer to Procedure 016-003 in Section 16.



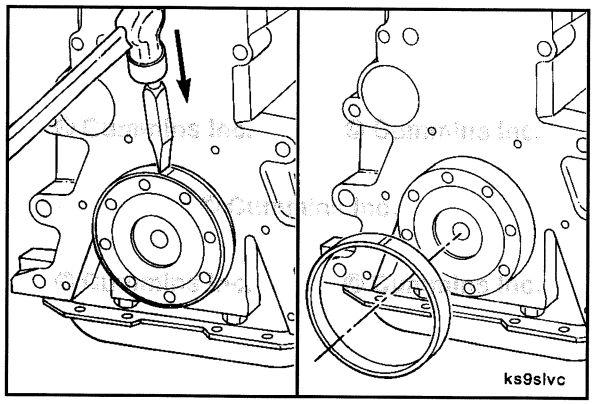
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Loosen the flywheel housing capscrews, but do **not** remove.

Use a rubber hammer to loosen the flywheel housing so that the seal is broken between the flywheel housing and rear gear housing.

While supporting the flywheel housing, remove the mounting capscrews and the flywheel housing.

Note the location of the flywheel housing capscrews as removed. Some of the capscrews are different length/size fasteners and **must** be installed in the same location as removed.



Crankshaft Wear Sleeve, Rear (001-067)

Remove

△CAUTION△
Do not nick or gouge the crankshaft with the chisel. If the crankshaft is damaged, it must be replaced.

NOTE: If a wear sleeve has previously been installed, the flywheel housing **must** be removed to remove the wear sleeve. After removing the wear sleeve, reinstall the flywheel housing. Refer to Procedure 016-006 in Section 16.

If a wear sleeve has previously been installed, use a dull chisel that is **only** as wide as the wear sleeve.

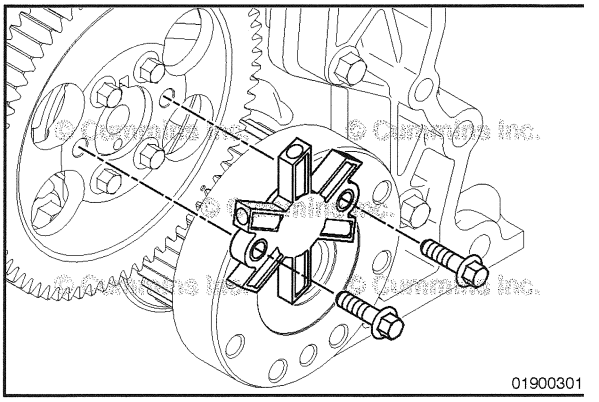
Make one or two soft blows with a hammer to make chisel marks across the wear sleeve. This will expand the wear sleeve, allowing the sleeve to be removed.

Crankcase Breather (Internal) (003-002)

Remove

Remove two mounting capscrews and the crankcase breather disc mounting capscrews.

Remove the breather disc from the camshaft gear.

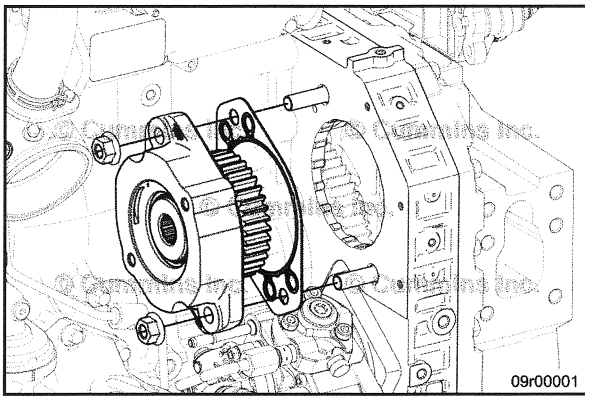


Accessory Drive (009-001)

Remove

Remove the two nuts from the studded screws securing the accessory drive to the rear gear housing.

Remove the accessory drive and gasket.



Rocker Lever Cover (003-011)

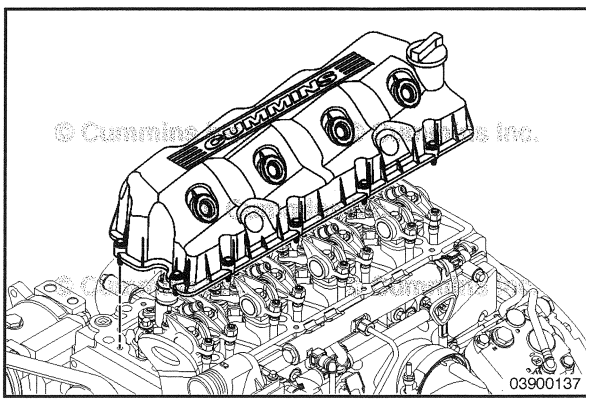
Remove

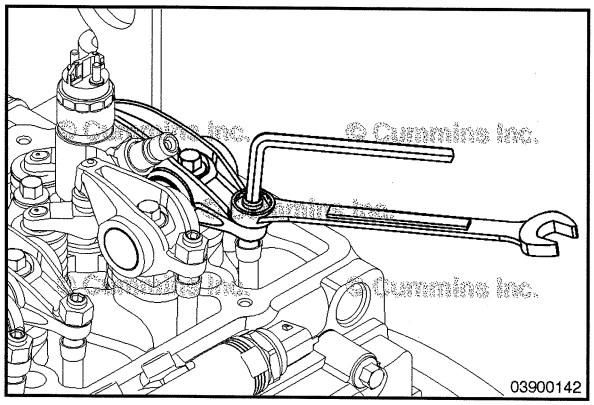
⚠CAUTION⚠
Be sure to remove the injector wiring harness pass-through connector locking rings before attempting to remove the rocker lever cover. Refer to Procedure 019-063 in Section 19.

The mounting capscrews and compression limiters are part of the rocker lever cover. The capscrews are the captive design and will be held in place in the rocker lever cover.

Loosen the rocker lever cover capscrews.

Pull the rocker lever cover gently. Leave the injector wiring harness and support brace attached to the cylinder head.



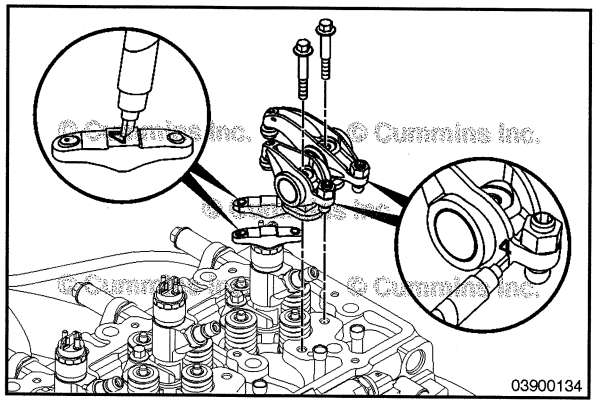


Rocker Lever (003-008)

Remove

Loosen the adjusting screw locknuts.

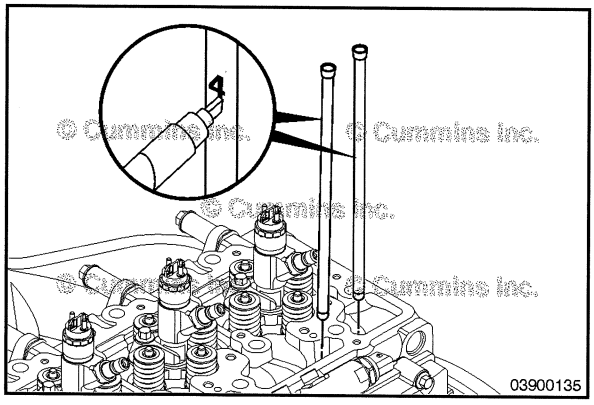
Loosen the adjusting screws until they stop.



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.

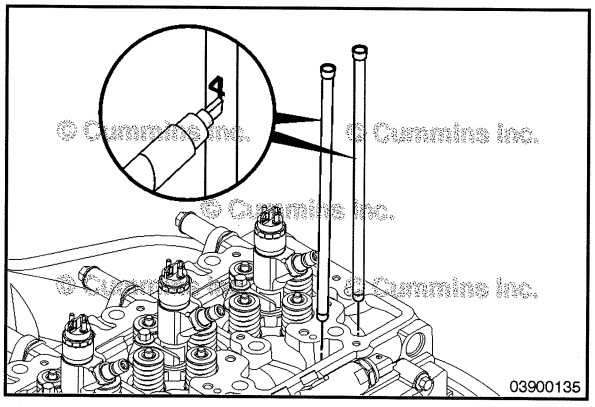
Remove and mark the crossheads one at a time as to their location and position. The crossheads and rocker assembly **must** be installed in their original location and position when reused.



NOTE: The push rods **must** be installed in their original location and position.

Mark the push rods to identify their location.

Remove the push rods. Refer to Procedure 004-014 in Section 4.



Push Rods or Tubes (004-014)

Remove

NOTE: The push rods **must** be installed in their original location and position.

Mark the push rods to identify their location.

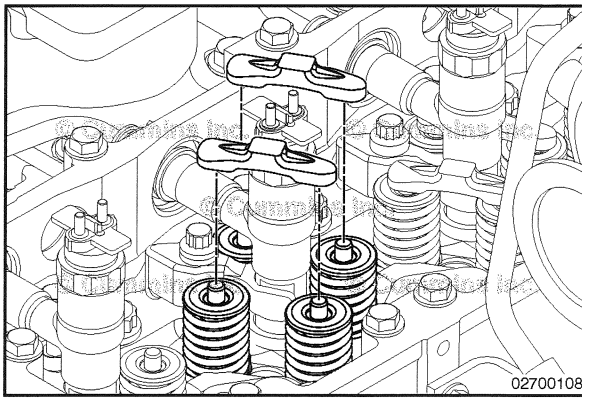
Remove the push rods.

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.

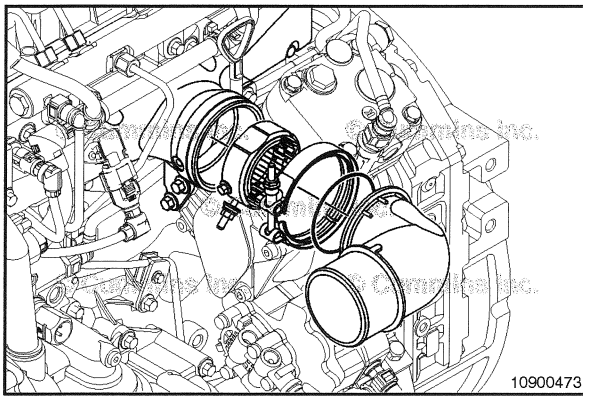
Remove the crossheads.



Air Intake Connection (010-080)

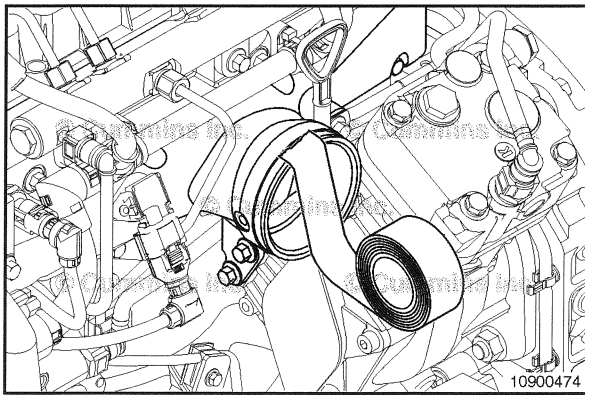
Remove

Remove the mounting V-band clamp, air intake connection, o-ring seal, and cold starting aid, if equipped. Refer to Procedure 010-029 in Section 10.



NOTE: Make sure to leave manifold inlet edges exposed so that mounting surfaces can be properly cleaned.

Tape off the intake manifold cover opening or place a clean rag in the intake to prevent debris from entering the intake system.



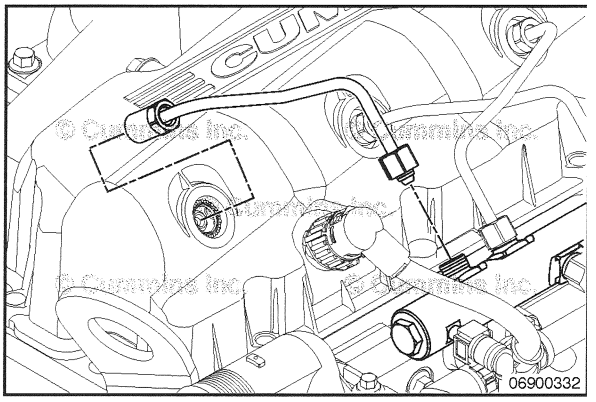
Injector Supply Lines (High Pressure) (006-051)

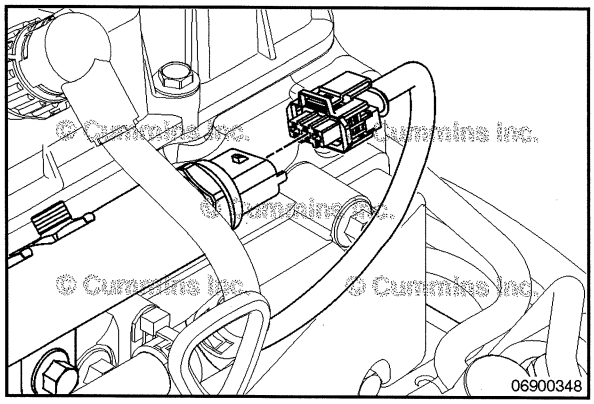
Remove

Disconnect the high-pressure fuel line from both ends of the number 4 fuel line. Cover the end of the line immediately.

Use the appropriate protective cap from the fuel system Clean Care Kit, Cummins® Part Number 5298815.

Repeat the steps for all four injectors, removing and capping the connection one at a time.



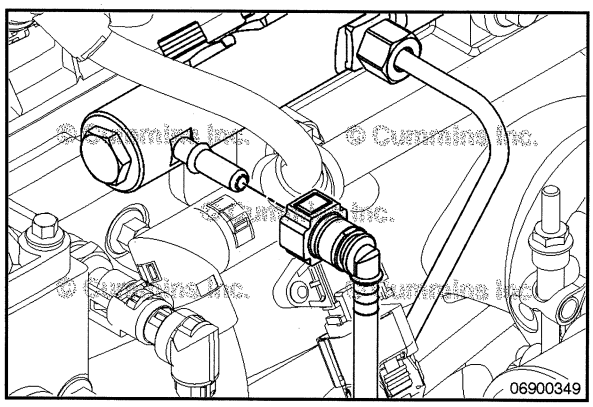


Fuel Rail (006-060)

Remove

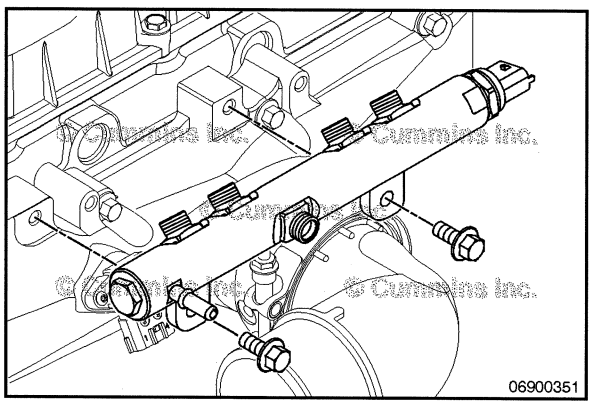
NOTE: Do **not** remove the fuel rail pressure sensor unless it is being replaced. The fuel pressure sensor **must** be replaced if it is removed from the fuel rail.

Disconnect the fuel rail pressure wiring harness sensor connector.



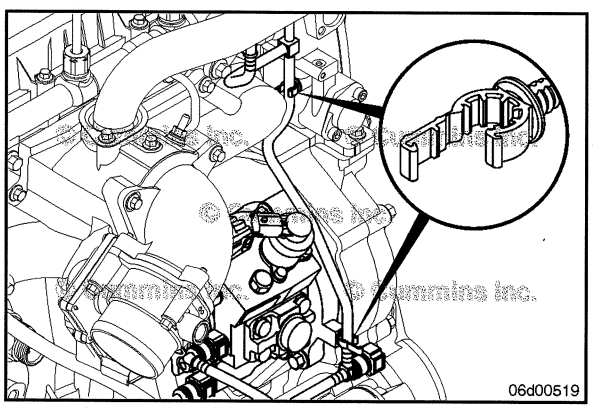
⚠WARNING⚠
Depending on the circumstance, diesel fuel is flammable. When inspecting or performing service or repairs on the fuel system, to reduce the possibility of fire and resulting severe personal injury, death or property damage, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area.

Disconnect the fuel pressure relief valve drain line.



Remove the fuel rail mounting capscrews.

Remove the fuel rail.



Fuel Drain Lines (006-013)

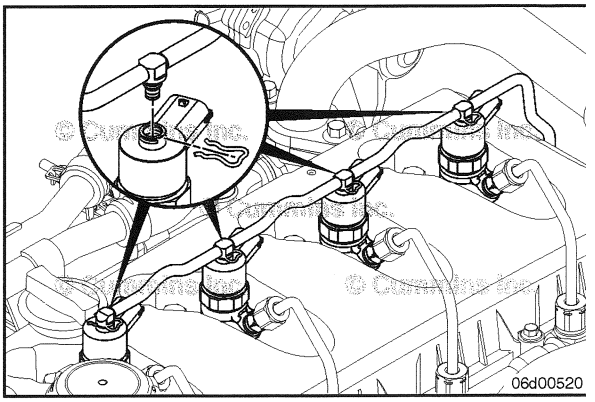
Remove

NOTE: Mark the location of all p-clips, and routing of fuel drain lines, to make sure that they are replaced in the correct location during reassembly.

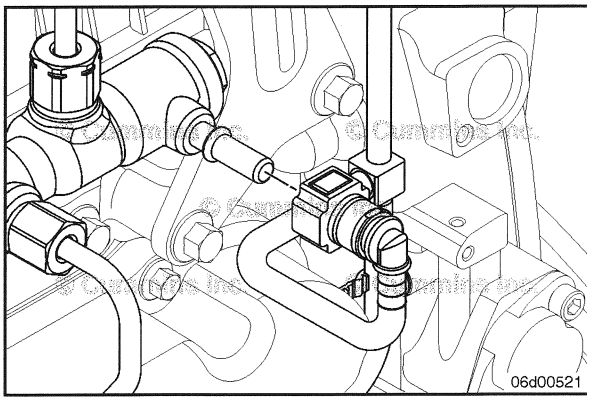
Remove the fuel drain line connector from the OEM vehicle fuel drain line.

Any open fuel connectors **must** be closed immediately with protection caps.

Remove the fuel drain connector from each of the injectors, taking care **not** to lose the retaining spring clips.

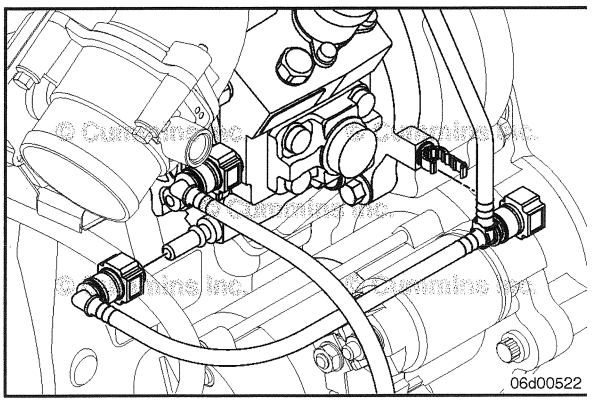


Remove the fuel drain connector from the high pressure fuel rail.



Remove the fuel drain connector from the high pressure fuel pump.

Carefully remove the fuel drain line from each fir tree clip location.



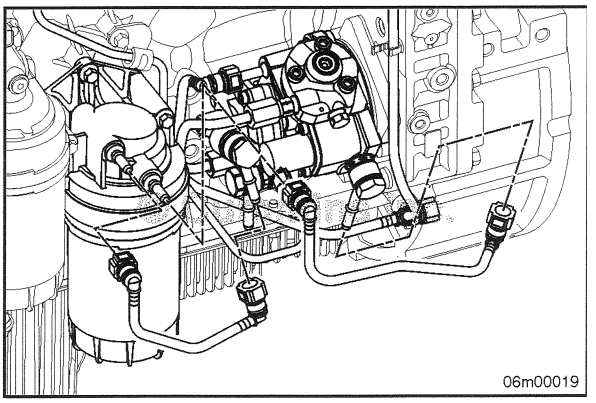
Fuel Supply Lines (006-024)

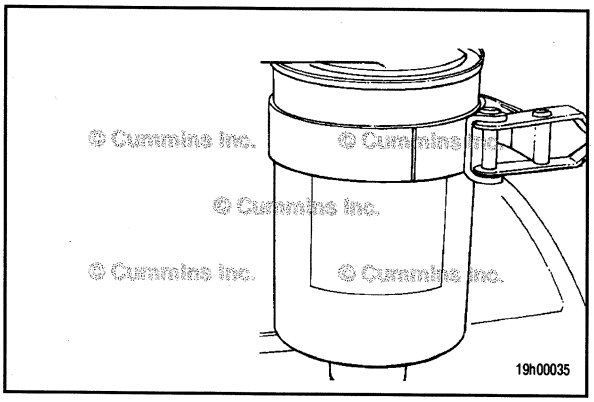
Remove

Mark the location of all P-clips and routing of fuel supply lines to make sure that they are replaced in the correct location during assembly.

Remove the fuel supply line connecting the gear pump to the fuel filter head.

Remove the fuel supply line connecting the fuel filter head to the inlet of the high-pressure fuel pump.

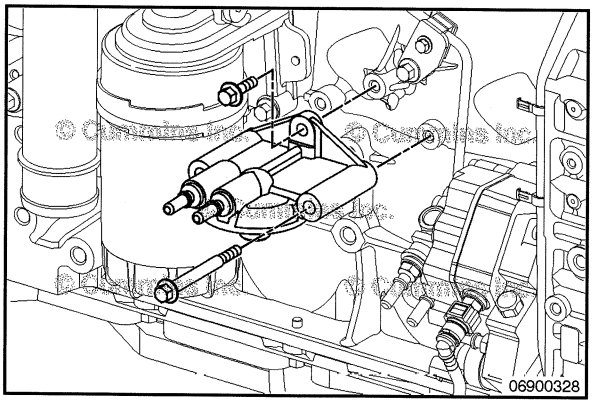




Fuel Filter (Spin-On Type) (006-015)

Remove

Remove the fuel filter from the filter head with filter wrench, Cummins® Part Number 3398231, or equivalent.



Fuel Filter Head (006-017)

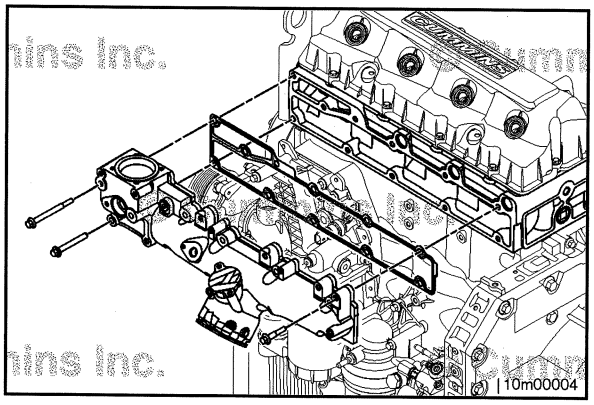
Remove

NOTE: The following steps can beused for replacing the pressure side and suction-side fuel filter.

The fuel filter head is marked with IN and OUT arrows to indicate flow. Be sure to note the orientation of the fuel filter head before removal.

Remove the fuel filter head mounting capscrews.

Remove the fuel filter head.

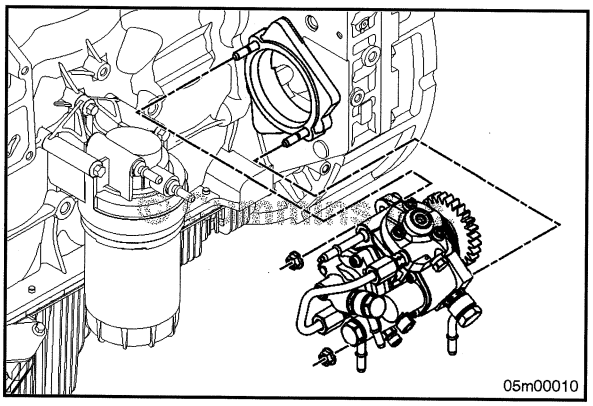


Air Intake Manifold (010-023)

Remove

Cover the intake opening with tape to keep foreign material out of the manifold and intake system.

Remove the air intake manifold capscrews and remove the air intake manifold.



Fuel Pump (005-016)

Remove

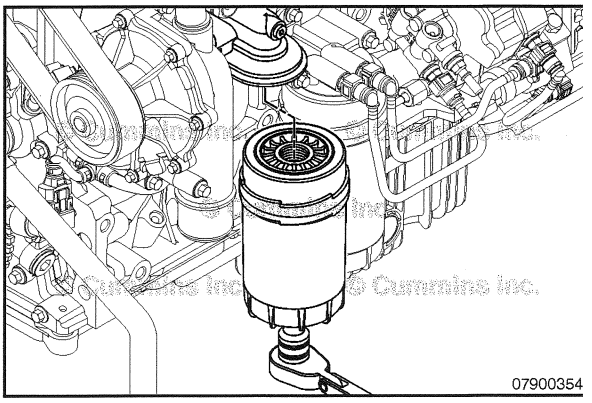
Remove the two flanged fuel pump mounting nuts.

Remove the fuel pump from the gear housing.

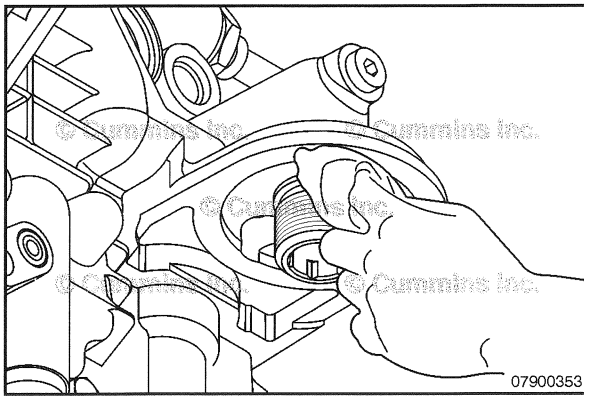
Lubricating Oil Filter (Spin-On) (007-013)

Remove

Use the ½-inch drive socket in the bottom of the filter to remove the oil filter.



Clean the sealing surface of the filter head.



Turbocharger Oil Supply Line (010-046)

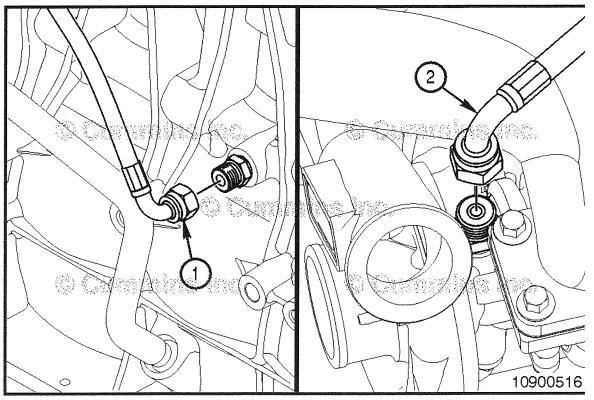
Remove

NOTE: Use a wrench to hold the fitting at the oil rifle connection (1) while loosening the oil supply line fitting. This will help prevent accidental loosening of the fitting.

Remove the oil supply line from the engine block fitting in the oil rifle on the side of the cylinder block (1).

Remove the oil supply line from the turbocharger bearing housing (2).

Remove the banjo screw and two sealing washers from the turbocharger oil supply line at the bearing housing (2).



Turbocharger Oil Drain Line (010-045)

Remove

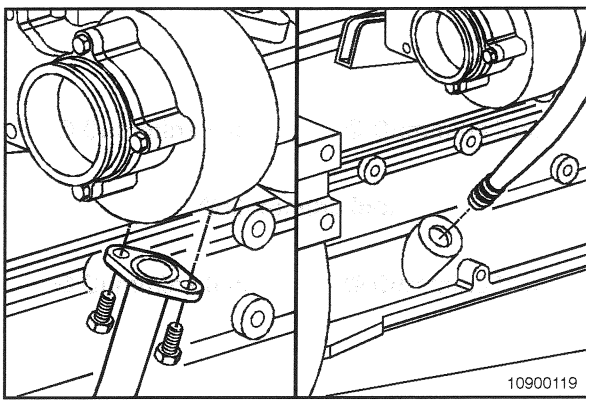
Remove the capscrews from the turbocharger oil drain line.

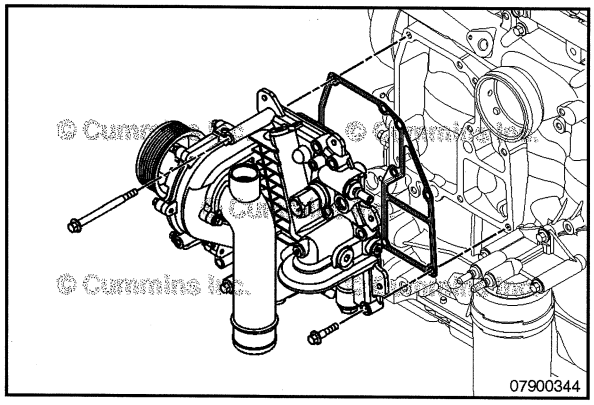
Remove the hose spring clamps from the oil drain hose connections, if applicable.

Pull the drain line out of the oil drain hose connections, if applicable.

Pull the oil drain line connection out of the cylinder block.

Remove and discard the o-rings.

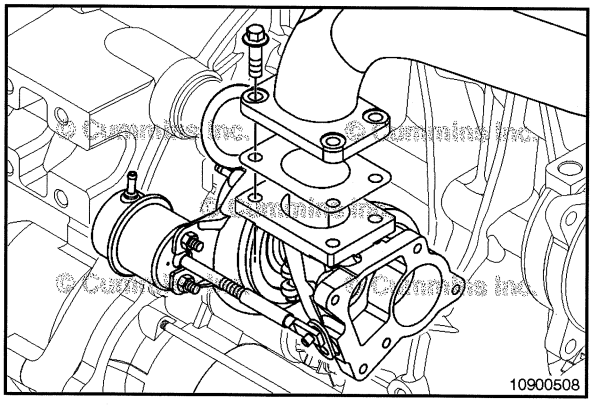




Lubricating Oil Cooler (007-003)

Remove

Remove the mounting capscrews and the water pump/ lubricating oil cooler housing from the side of the engine.



Turbocharger (010-033)

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.

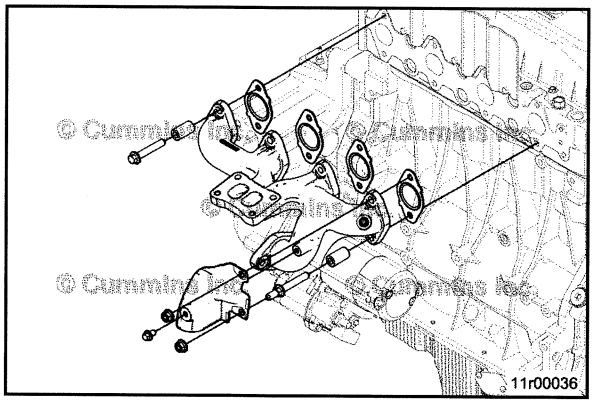
△CAUTION△
Before discarding the turbocharger mounting gasket, identify the type of gasket removed. Some turbocharger mounting gaskets have a divider down the middle of the gasket and some do not. Only replace the gasket with a like gasket. Use of the incorrect gasket will result in turbocharger damage.

Remove the turbocharger compressor outlet connection, V-band clamp, and o-ring from the turbocharger compressor outlet. Refer to Procedure 010-132 in Section 10.

Remove the four turbocharger mounting nuts.

Remove the turbocharger and gasket.

Discard the gasket.



Exhaust Manifold, Dry (011-007)

Remove

Remove the two upper mounting capscrews and install two guide studs, Cummins® Part Number 3163934, into the top center section mounting location.

Remove the heat shield, remaining exhaust manifold mounting capscrews, and spacers.

Remove the exhaust manifold.

Remove and discard the gaskets.

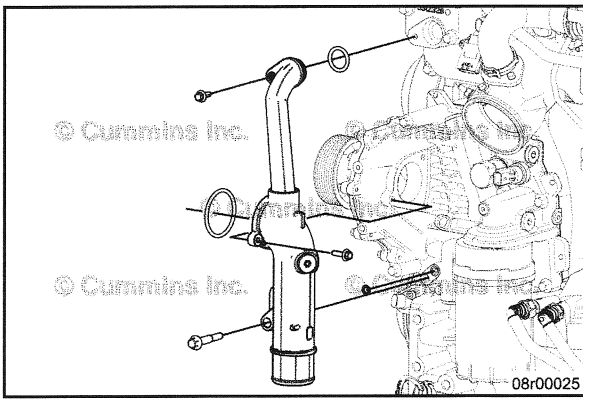
Cover open points in the exhaust manifold and cylinder head with heavy tape, if the repair is delayed.

Water Inlet Connection (008-082)

Remove

Remove the coolant hose(s).

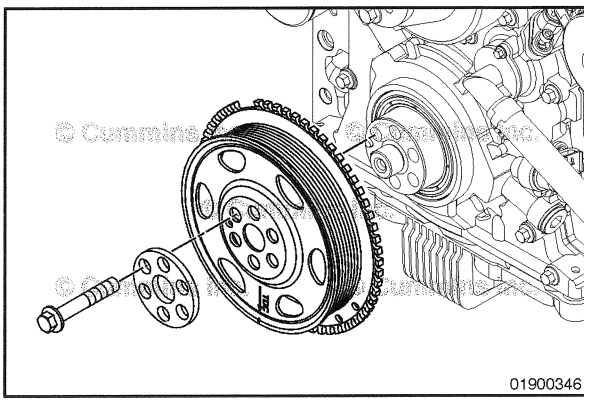
Remove the capscrews, water inlet connection, and o-rings.



Crankshaft Speed Indicator Ring (001-071)

Remove

Remove the six capscrews that hold the crankshaft speed indicator ring/pulley to the nose of the crankshaft.



Crankshaft Seal, Front (001-023)

Remove

Use tool, Cummins® Part Number 4919660, to remove the front crankshaft seal from the front gear cover.

NOTE: The front gear cover does **not** need to be removed to remove and install the crankshaft seal.

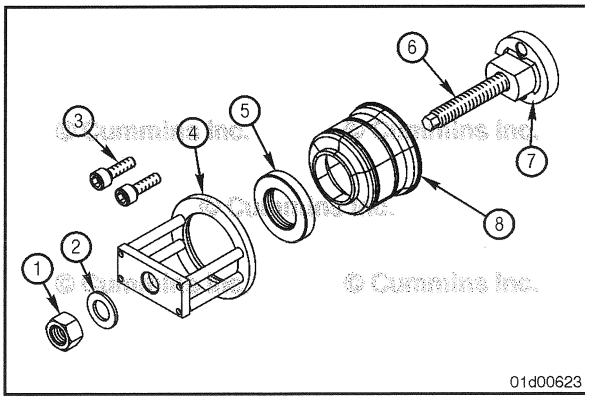
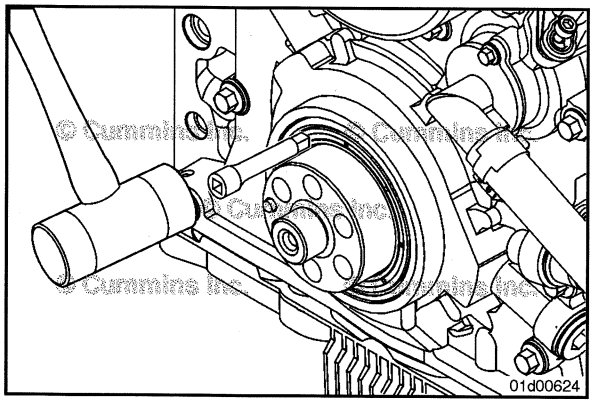
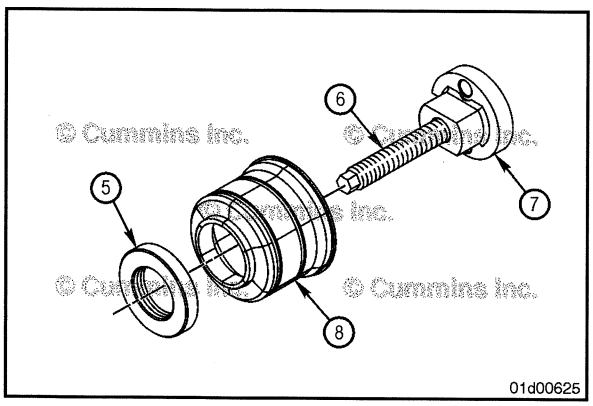


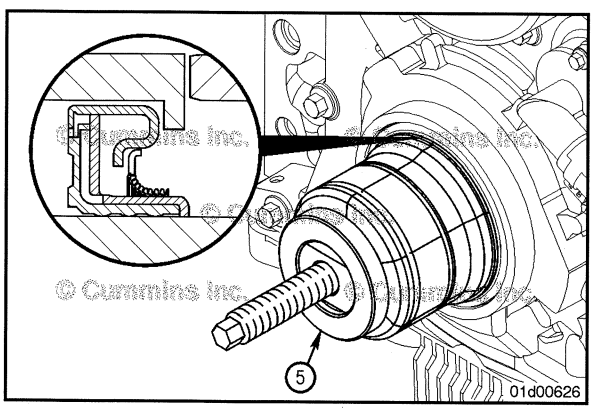
Table 1. Front Crankshaft Seal Replacer, Cummins® Part Number 4919660			
Item Number	**Part Number**	**Description**	**Quantity**
1	3276934	Nut, regular hexagon	1
2	4919675	Washer, plain	1
3	3625554	Screw, socket head cap	2
4	4909665	Installer, seal	1
5	4919676	Nut, adjusting	1
6	4919673	Screw, replacer	1
7	4919674	Adapter, mounting	1
8	4919664	Remover, seal	1
Not shown	4919668	Spring tension	2



To prepare the seal assembly for the insertion of the seal remover (8) carefully tap the inner seal casing with a 3/8th drive bar, so as to create a 1 to 2 mm [0.039 to 0.079 inches] gap between the inner and outer seal casing.



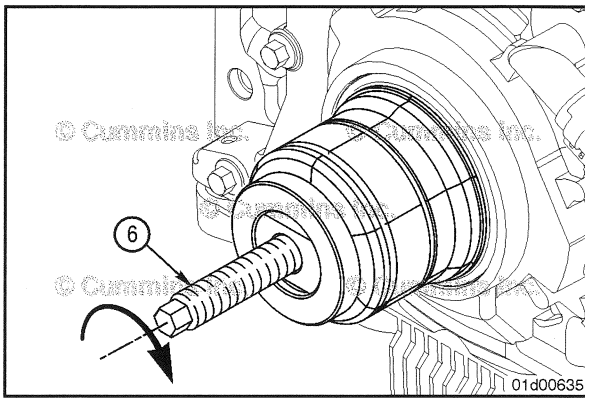
Loosely assemble the mounting adaptor (7) though the seal remover (8) and the adjusting nut (5) in preparation for removal of the crankshaft seal.



Align the seal remover assembly over the front of the crankshaft and carefully insert the front lip of the tool into the 1 to 2 mm [0.039 to 0.079 inches] gap created earlier between the inner and outer seal casing. Make sure that front lip of the tool engages under the full circumference of the seal casing outer lip, and hand-tighten the adjusting nut (5) to secure. Take care to support the seal remover assembly in the horizontal axis.

Use a wrench to slowly rotate the replacer screw (6) in a clockwise direction to remove the seal cartridge from the front gear cover. Do **not** exceed torque value of 45 N•m [35 ft lb].

Discard seal assembly when removed.



Gear Cover, Front (001-031)

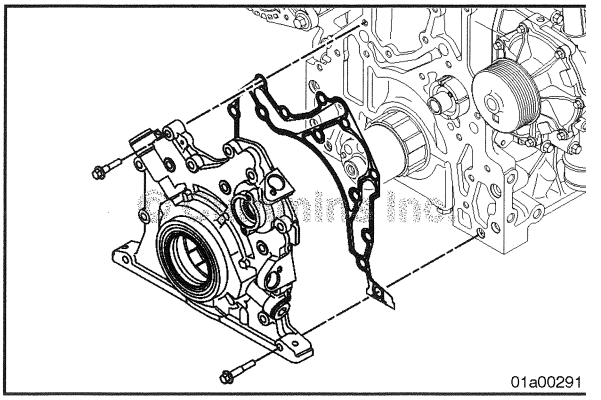
Remove

⚠CAUTION⚠
To break the seal, pry the front gear cover away from the cylinder block. Be careful not to damage the front gear cover when breaking the seal to the cylinder block.

NOTE: Document the location of the three longer mounting capscrews upon removal.

Remove the front gear cover mounting capscrews.

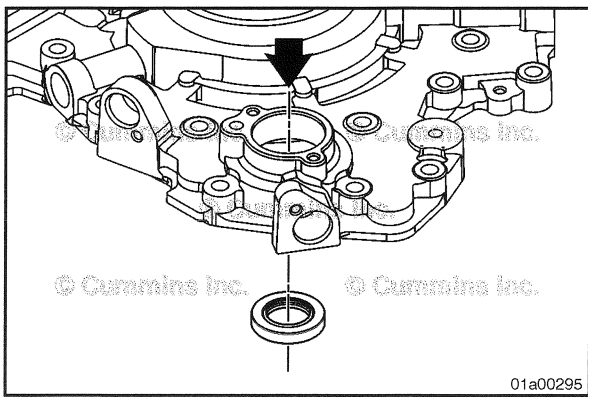
Remove the front gear cover.



Support the front gear cover on a flat work surface with wooden blocks.

Use a suitable seal driver and hammer to drive the old camshaft seal out of the rear of the front gear cover.

Discard the camshaft seal.



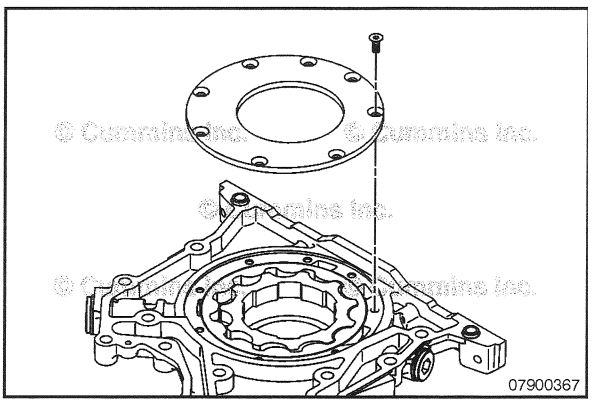
Lubricating Oil Pump (007-031)

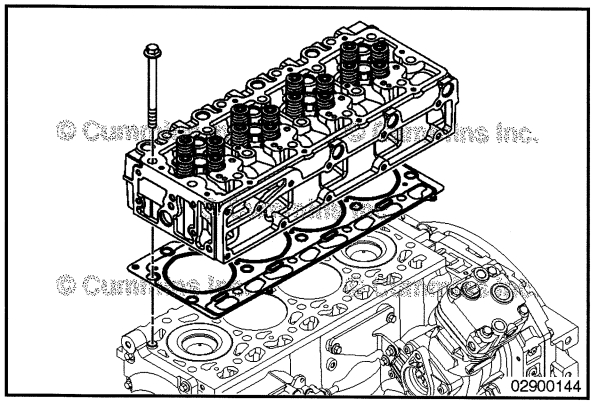
Remove

Place the front gear cover on a flat surface, front face down.

Remove the eight lubricating oil pump cover mounting capscrews on the rear of the gear cover.

Remove the cover.



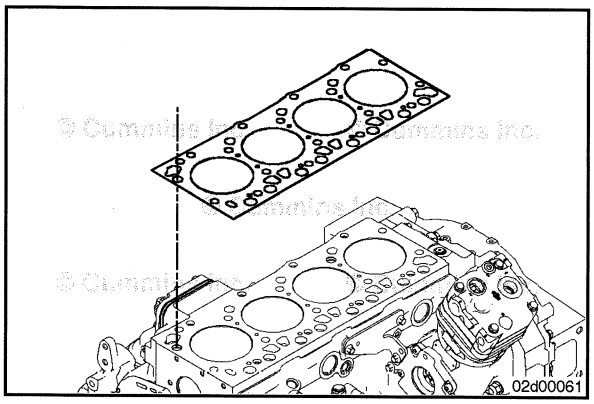


Cylinder Head (002-004)

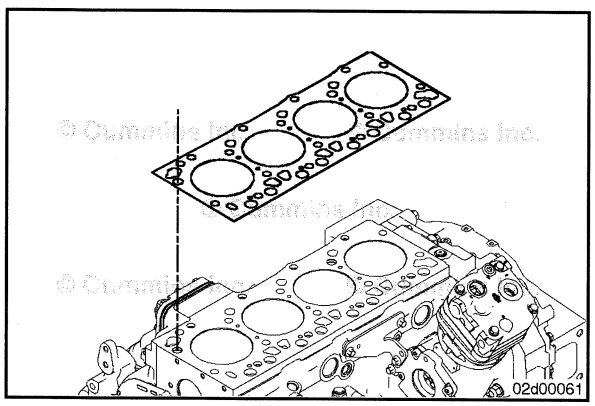
Remove

⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To reduce the possibility of serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Remove the cylinder head capscrews and cylinder head.



Remove the cylinder head gasket from the cylinder block.



Cylinder Head Gasket (002-021)

Remove

Remove the cylinder head gasket.

Injector (006-026)

Remove

⚠WARNING⚠
The pressure of the fuel in the line is sufficient to penetrate the skin and cause serious personal injury. Wear gloves and protective clothing.

△CAUTION△
When removing the injector, care must be taken not to damage the injector tip.

Disconnect the injector wiring harness from the injector.

Remove the injector actuator wire nuts and wires from the injector.

Loosen and remove the injector hold-down capscrew.

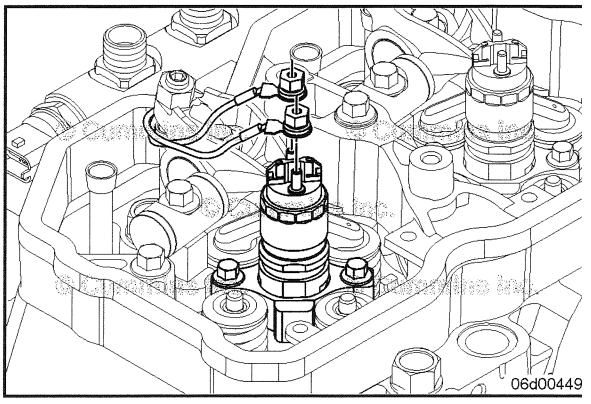
A small heel pry bar can also be used to pry up the injector. Pry up the injector hold-down flange (part of the injector body just above the cylinder head casting).

Remove the injector hold-down clamp from the injector.

Remove the injector from the cylinder head.

Apply a protective cap to the injector nozzle.

Insert a blind plug to prevent dust or debris from entering the engine through the cylinder head.



Loosen and remove the injector hold-down capscrew.

A small heel pry bar can also be used to pry up the injector. Pry up the injector hold-down flange (part of the injector body just above the cylinder head casting).

Remove the injector hold-down clamp from the injector.

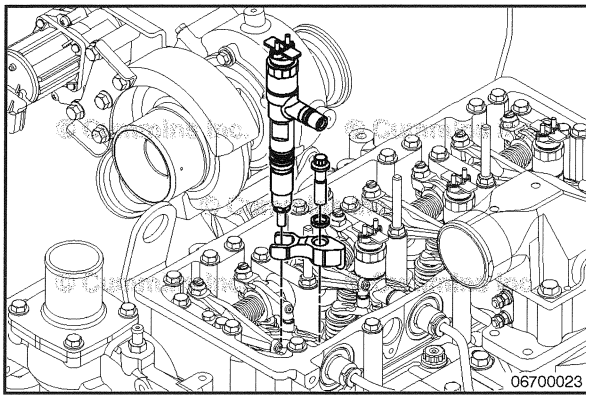
Remove the injector from the cylinder head.

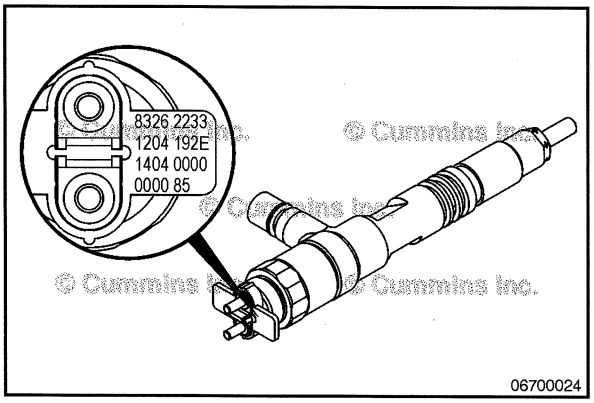
Apply a protective cap to the injector nozzle.

Insert a blind plug to prevent dust or debris from entering the engine through the cylinder head.

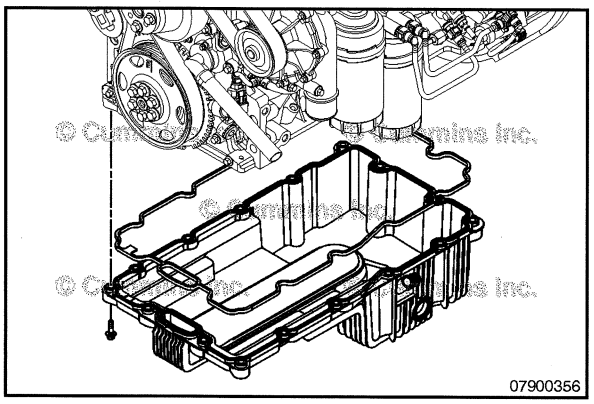
With the injector removed, verify that the injector o-ring is attached to the bottom of the injector. If the injector o-ring remained in the injector bore, it **must** be removed.

A double stacked or incorrect o-ring can cause high-pressure fuel leaks and/or performance problems because of incorrect injector protrusion.





NOTE: Record the cylinder location where each injector was installed. If new injectors are **not** being installed, the injectors **must** be installed in their original location.

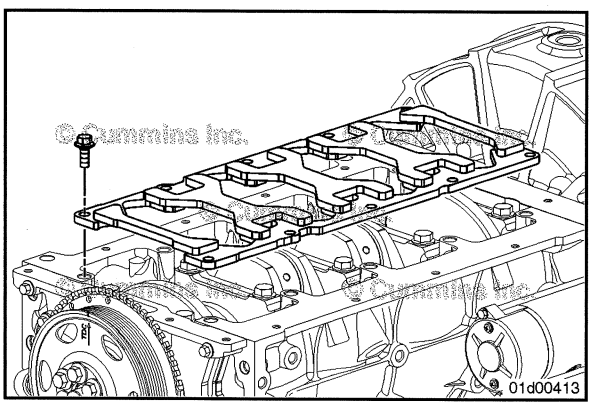


Lubricating Oil Pan (007-025)

Remove

NOTE: The oil pan seal should remain in the oil pan during the removal step, if possible.

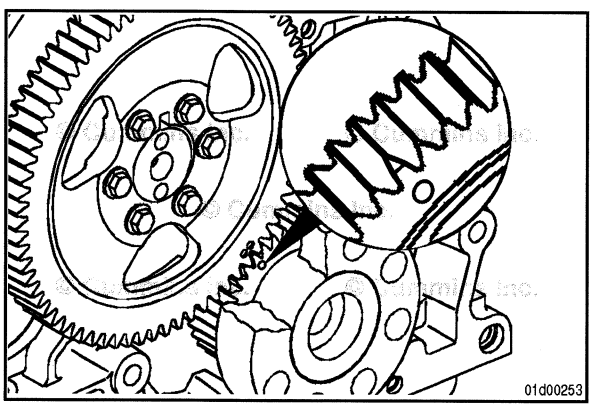
Remove the lubricating oil pan and gasket.



Block Stiffener Plate (001-089)

Remove

Remove the capscrews and block stiffener plate.



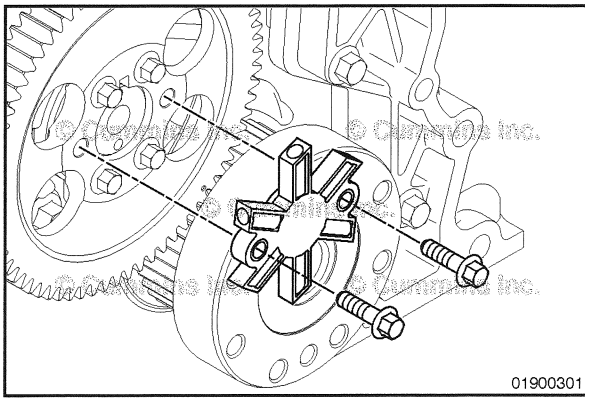
Camshaft Gear (Camshaft Installed) (001-012)

Remove

Rotate the crankshaft to allow the camshaft timing marks to align.

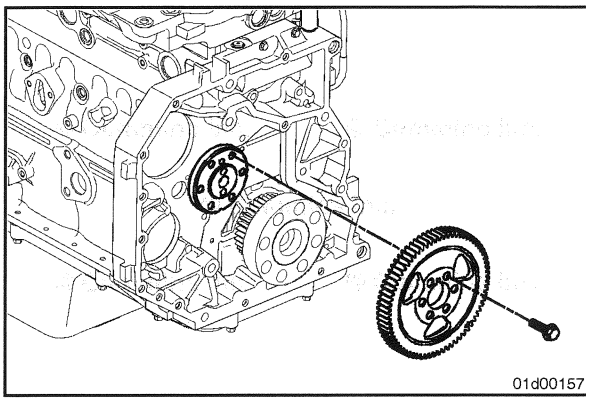
NOTE: Crankshaft timing tooth is beveled at flange end.

Remove the crankcase breather disc. Refer to Procedure 003-002 in Section 3.



Remove the camshaft gear capscrews.

Remove the camshaft gear.



Camshaft (001-008)

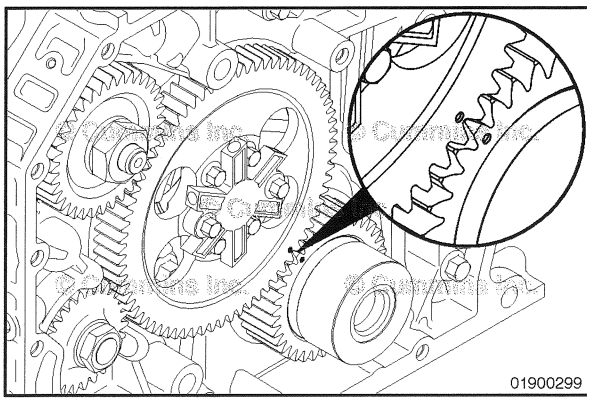
Remove

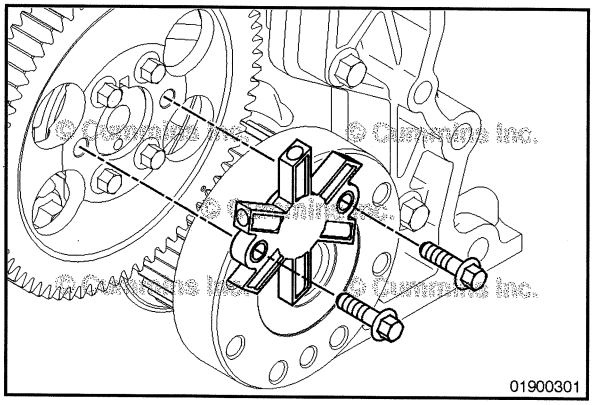
NOTE: Any time the camshaft is removed from the engine, the camshaft seal behind the crankcase breather tube flange mounting **must** be replaced. Refer to Procedure 003-031 in Section 3 to replace the seal after the camshaft has been installed into the engine.

NOTE: The engine can have either a mark on the crankshaft gear or a chamfered tooth.

Rotate the crankshaft to align the timing marks on the camshaft and crankshaft gear.

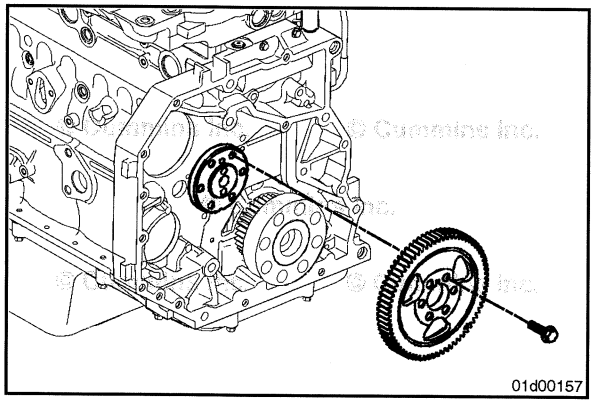
Service Tip: The crankshaft can be rotated by installing two of the flywheel/flexplate mounting capscrews half way. Then use a pry bar in between the two capscrews to rotate the engine.





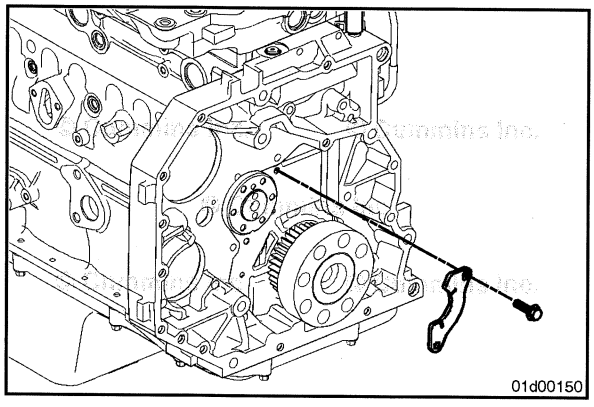
Remove the mounting capscrews and the crankcase internal breather from the camshaft gear.

NOTE: The two capscrews used to hold the crankcase breather disc to the camshaft gear are longer than the four camshaft gear mounting capscrews.

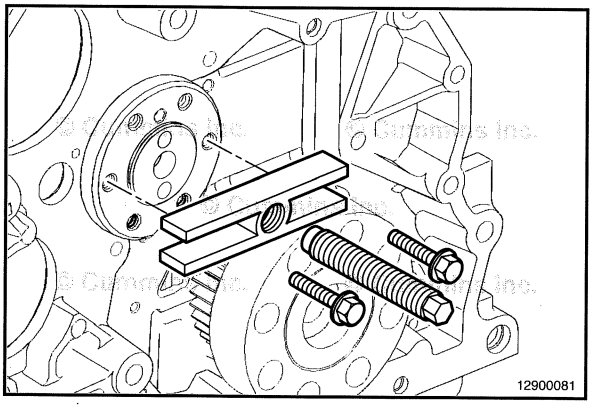


Remove the camshaft gear capscrews and remove the camshaft gear.

Refer to Procedure 001-012 in Section 1.



Remove the thrust plate capscrews and remove the thrust plate.



△CAUTION△
The camshaft will drop once the camshaft clears the last bushing if not supported. This can cause damage to the camshaft journal or, if equipped, the camshaft speed indicator ring.

Use a gear puller, Cummins® Part Number ST-647 or equivalent, to attach to the end of the camshaft, where the camshaft gear mounts, to act as a handle. This will give proper leverage and ease in removing the camshaft.

Slide the camshaft out of the bore, use the installed gear puller.

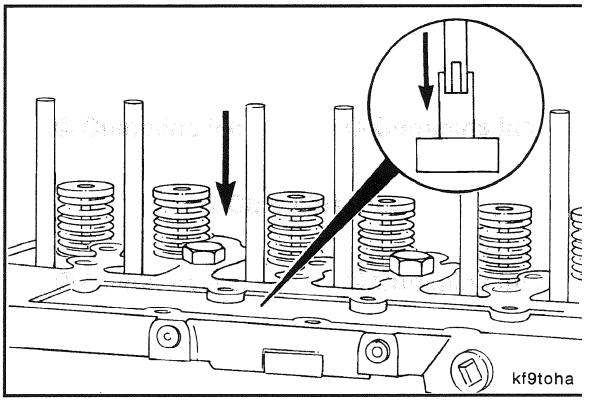
Tappet (004-015)

Remove

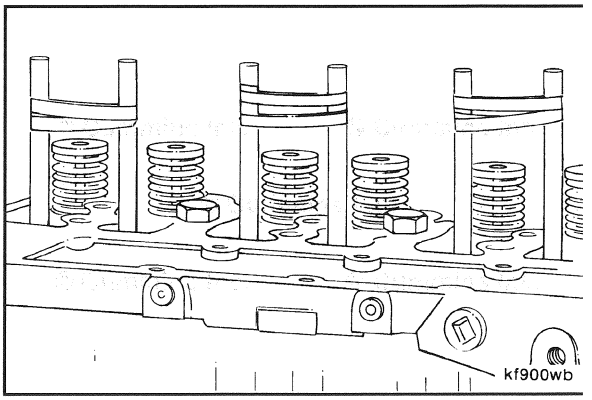
Use tappet removal tool kit, Cummins® Part Number 3822513, to remove the tappets.

Push a wooden dowel rod into each tappet. It will probably be necessary to push the dowel into the tappet with a soft-face hammer.

NOTE: When properly installed, the dowels can be used to pull the tappets up and should require considerable effort to be pulled out.

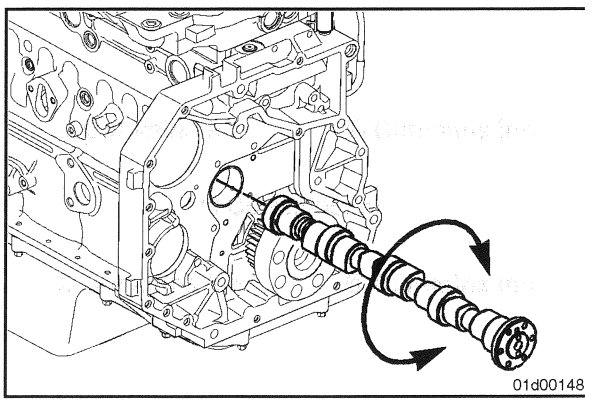


Pull each valve tappet up until it makes contact with the cylinder block. Put a rubber band around two dowels. This will hold the tappets up off the camshaft.



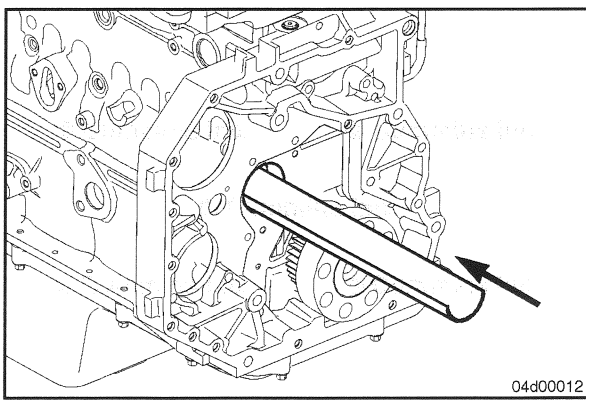
NOTE: The camshaft **must** be removed from the flywheel end of the engine.

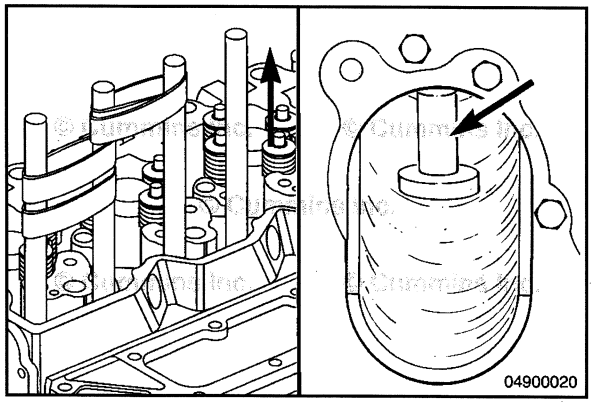
Remove the camshaft. Refer to Procedure 001-008 in Section 1.



NOTE: Make sure the trough is positioned so that it will catch the tappet when the wooden dowel is removed.

Insert the trough from the tappet replacement kit, Cummins® Part Number 3822513, to the full length of the cam bore.



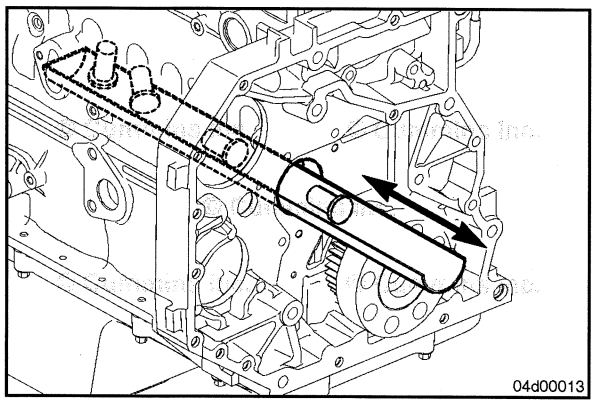


Only remove one tappet at a time.

Mark the position of the tappets as they are removed. The tappets **must** be installed in the same position when the engine is assembled.

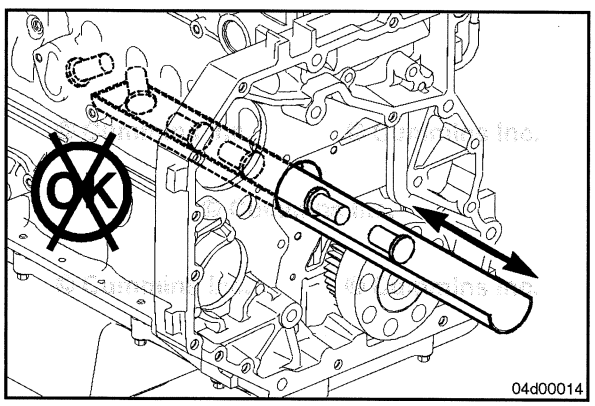
Remove the rubber band from the two companion tappets.

Secure the tappet that is **not** to be removed with the rubber band.

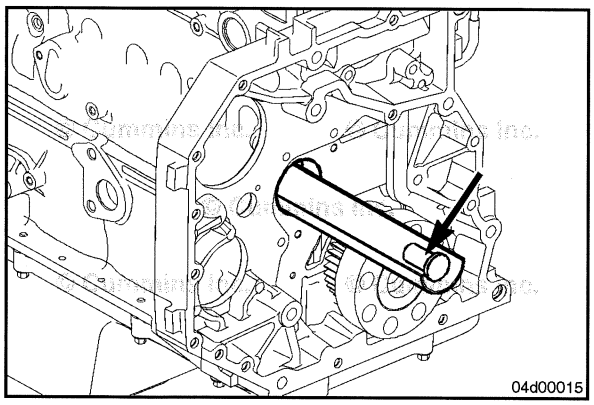


NOTE: When the tappet is dropped into the trough, most of the time it will fall over. However, if it does **not**, gently shake the trough just enough to allow the tappet to fall over before removing.

Pull the wooden dowel from the tappet bore, allowing the tappet to fall into the trough.



Take special care **not** to knock or shake the tappets over the end of the trough.



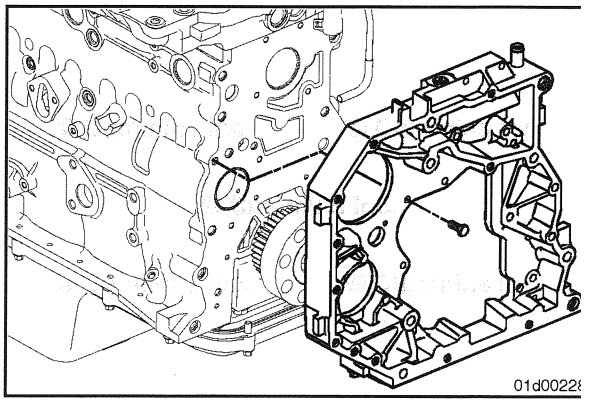
Carefully pull the trough and tappet from the camshaft bore, and remove the tappet. Repeat the process until all tappets are removed.

Gear Housing, Rear (001-034)

Remove

NOTE: The rear gear housing is mounted to the engine with three different length and size of capscrews. Note the location and size of the capscrews when they are removed to be sure they are installed in the same locations.

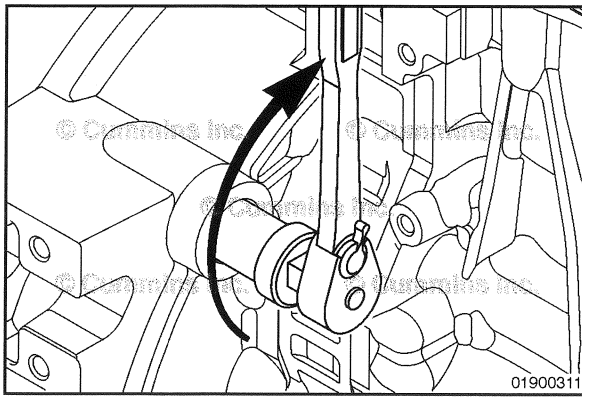
Remove the rear gear housing capscrews and housing.



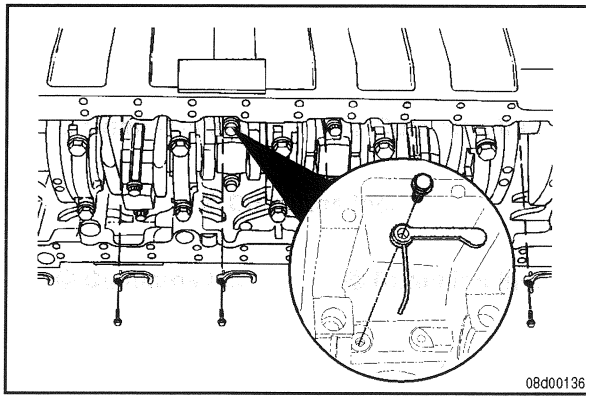
Piston Cooling Nozzle (001-046)

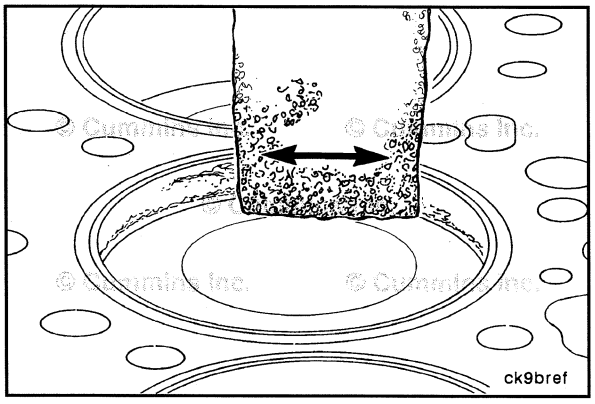
Remove

Use the engine barring tool, Cummins® Part Number 3824591, to rotate the crankshaft to various positions to access each piston cooling nozzle and/or capscrew.



Remove the piston cooling nozzles and/or capscrews.





Piston and Connecting Rod Assembly (001-054)

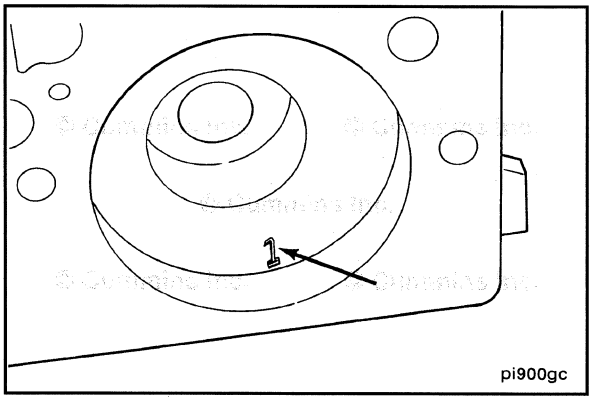
Remove

⚠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.

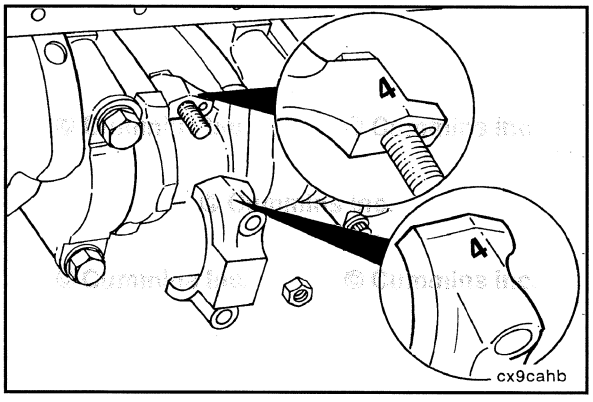
Rotate the crankshaft until the pistons are below the carbon deposits that are found above the ring travel area.

Use a fine fibrous abrasive pad, Cummins® Part Number 3823258, or equivalent, and solvent to remove the carbon.



Mark each piston according to the cylinder location.

NOTE: On pistons with anodized coatings, do **not** stamp on the anodized coating or on the outer rim. Do **not** stamp on the aluminum piston crown above the piston pin axis.



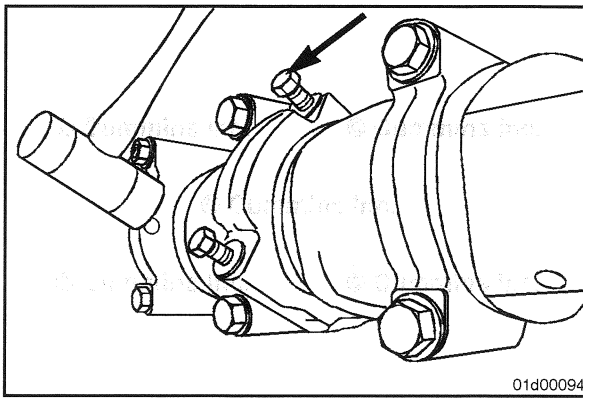
Rotate the crankshaft to position the rod caps at bottom dead center for removal.

Mark each connecting rod and rod cap according to the cylinder number location.

Loosen the connecting rod capscrews.

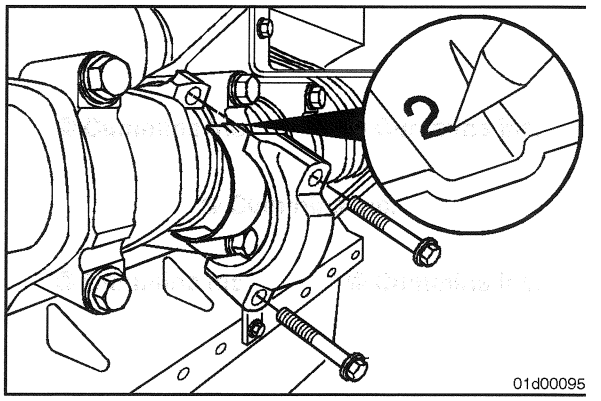
Do **not** remove the capscrews from the rods at this time.

Use a rubber hammer to hit the connecting rod capscrews to loosen the caps.



⚠CAUTION⚠
Do not damage the fractured split surface on the connecting rod or connecting rod cap while the connecting rod cap is removed. If the fractured split surface is damaged, the connecting rod and connecting rod cap must be replaced to help reduce the possibility of engine damage. Incorrect assembly can damage the rod.

⚠CAUTION⚠
When setting the rod cap down, do not set the cap down on the fractured split surface. Damage to the fractured split surface can result.



Remove the connecting rod capscrews.

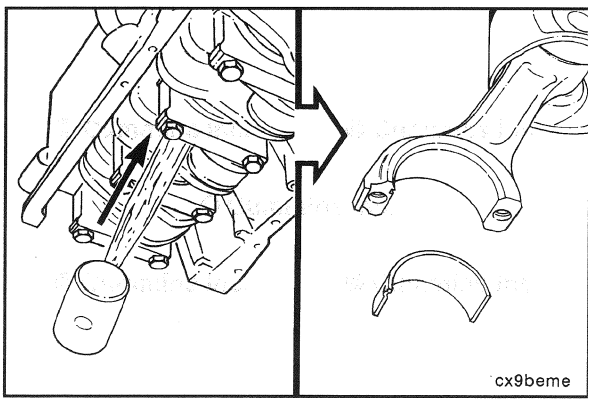
Remove the rod cap.

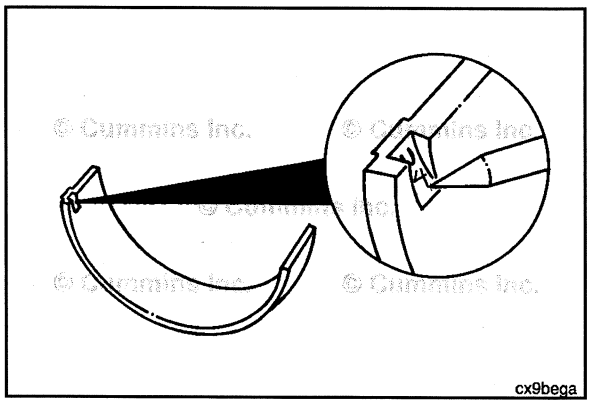
Remove the lower rod bearing.

Mark the cylinder number and the letter “L” (lower) on the flat surface of the bearing tang.

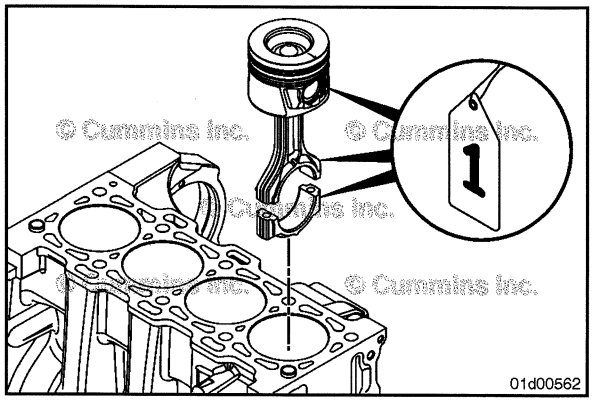
Push the connecting rod and piston assembly out of the cylinder bore. Care **must** be taken **not** to damage the connecting rod or bearing.

Remove the upper rod bearing.





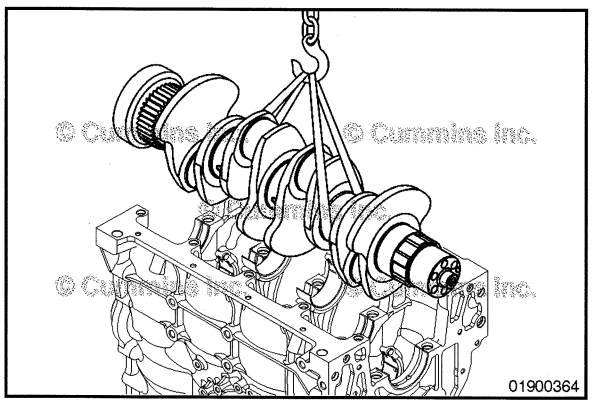
Mark the cylinder number and the letter “U” (upper) on the flat surface of the bearing tang.



The piston and connecting rod assemblies **must** be installed in the same cylinder number they were removed from to provide for proper fit of worn mating surfaces if parts are reused.

Use a tag to mark the piston and rod assembly with the cylinder number.

Place the rod and piston assemblies in a container to protect them from damage.

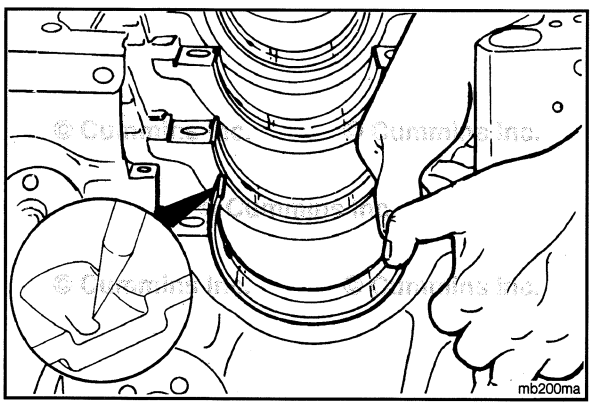


Crankshaft (001-016)

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 crankshaft.



Remove the upper main bearings.

Use an awl to mark the bearing's position in the tang area.

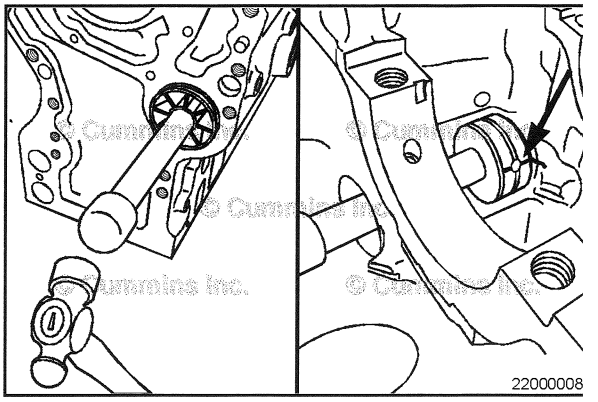
NOTE: Marking the bearing's position is for future identification or possible failure analysis.

Camshaft Bushings (001-010)

Remove

Use the camshaft bushing replacer kit, Cummins® Part Number 3165045, to remove the camshaft bushings. The tool will drive the camshaft bushing to the inside of the block. The camshaft bushing can be retrieved from the bottom of the engine.

NOTE: Once removed, camshaft bushings can **not** be reused.



Notes

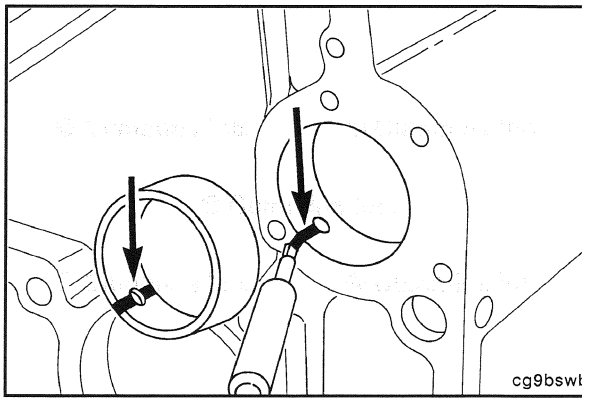
Section AS - Engine Assembly - Group 00

Section Contents

Camshaft Bushings (001-010)

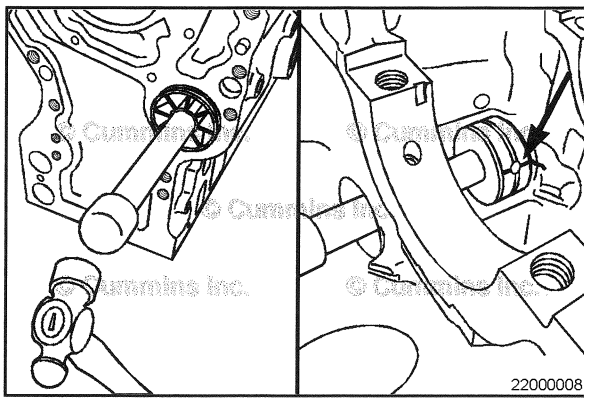
Install

Mark the camshaft bushing and cylinder block with a felt tip pin to aid in the alignment of the lubricating oil hole in the cylinder block with the large lubricating oil hole in the bushing.



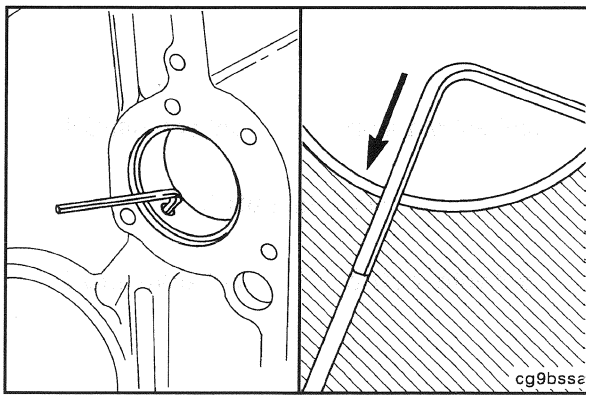
Slide the camshaft bushing on the replacer tool. Align the marks on the camshaft bushing and the cylinder block.

Drive the camshaft bushing to the correct installed depth. The correct installed depth is when the camshaft bushing end is flush with the machined face of the block and the oil hole aligns with the cylinder block oil hole.



Be sure the large lubricating oil hole is aligned.

A 3.2 mm [0.128 in] diameter rod **must** be able to pass through the lubricating oil hole.

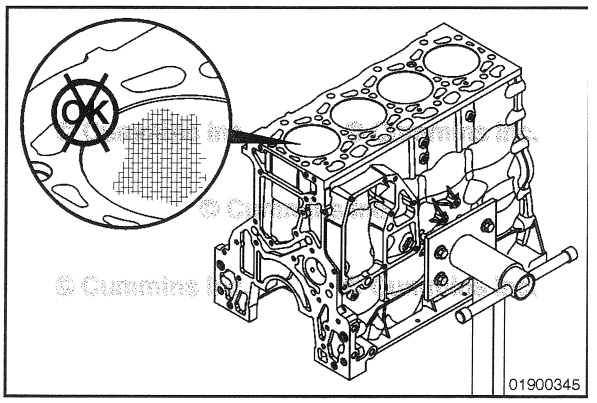


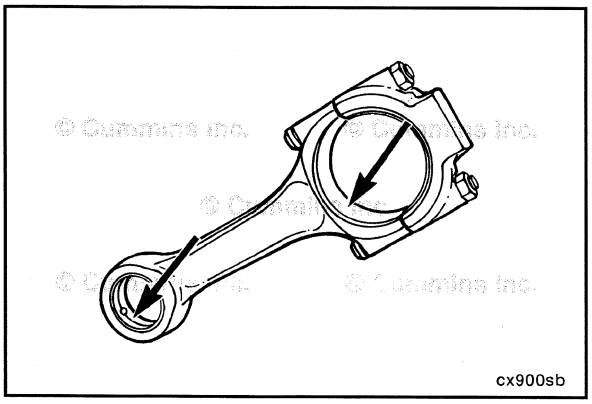
Piston and Connecting Rod Assembly (001-054)

Install

The cylinder block and all parts **must** be clean before assembly. Refer to Procedure 001-026 in Section 1 to inspect the cylinder walls of the cylinder block.

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.

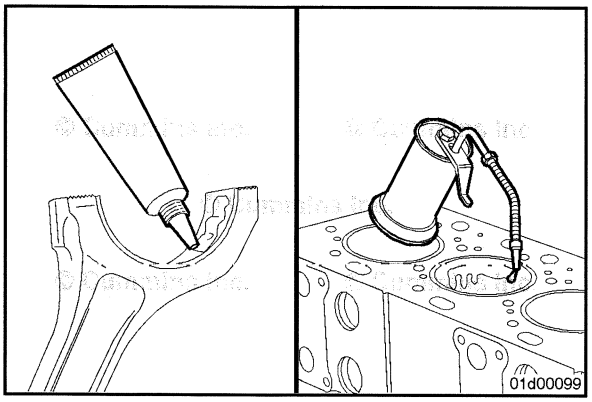
Make sure the connecting rod and backside of the connecting rod bearing surfaces are clean and free of debris. Do **not** lubricate the backside of the connecting rod bearings.

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.

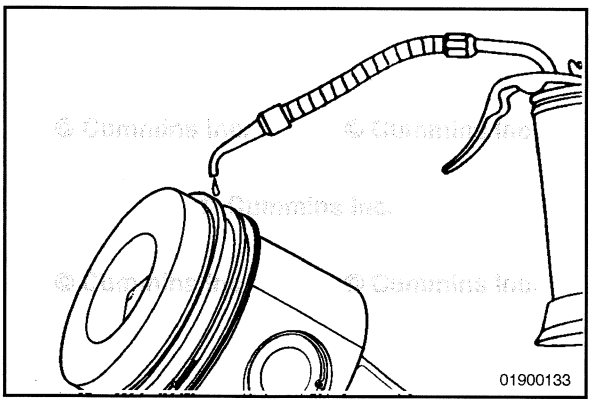
The upper and lower rod bearing shells are **not** interchangeable on fracture split connecting rods.

NOTE: If the connecting rod bushing is removed for any reason, a new bushing **must** be used.



Use assembly lube, Cummins® Part Number 3163087, or equivalent, to coat the inside circumference of the bearing shell.

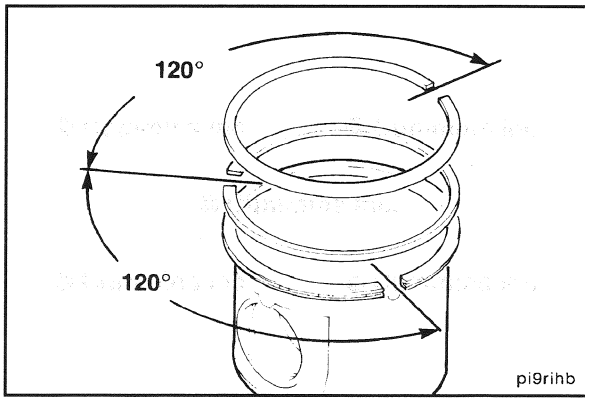
Apply a film of clean 15W-40 oil to the cylinder block wall.



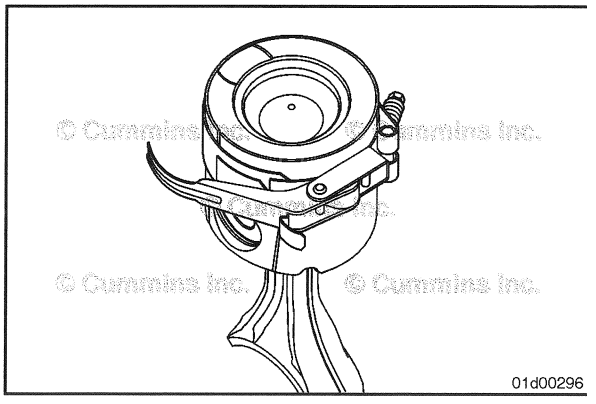
Lubricate the rings and piston skirts with clean engine lubricating oil.

Rotate the rings to position the ring gaps as shown.

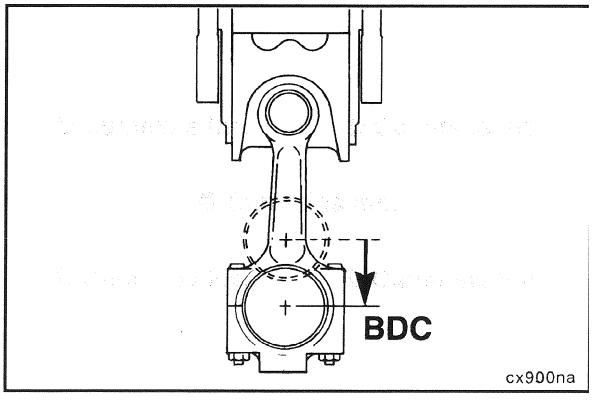
The ring gap of each ring **must not** be aligned with the piston pin, or with any other ring. If the ring gaps are **not** aligned correctly, the rings will **not** seal properly.



Use piston ring compressor, Cummins® Part Number 3164330, to compress the rings.



Rotate the crankshaft so the connecting rod journal of the connecting rod being installed is at bottom dead center.

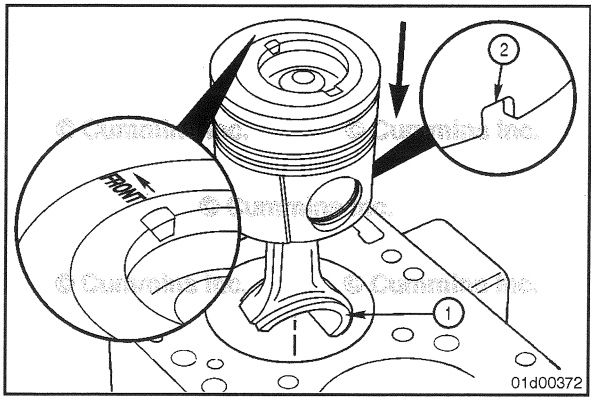


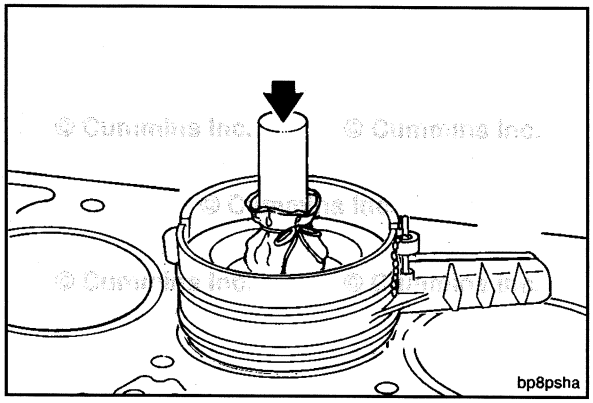
⚠CAUTION⚠
Failure to follow this step will result in extensive engine damage.

NOTE: The piston and connecting rod assembly **must** be installed with the correct orientation.

Align the "Front" marking and/or arrow on the top of the piston so that it points towards the front of the engine. Insert the connecting rod through the cylinder bore until the ring compressor contacts the top of the cylinder block.

The long end of the connecting rod (1) and the notch in the piston skirt (2) will be on the exhaust side of the engine. If **not**, verify the piston is installed correctly onto the connecting rod.



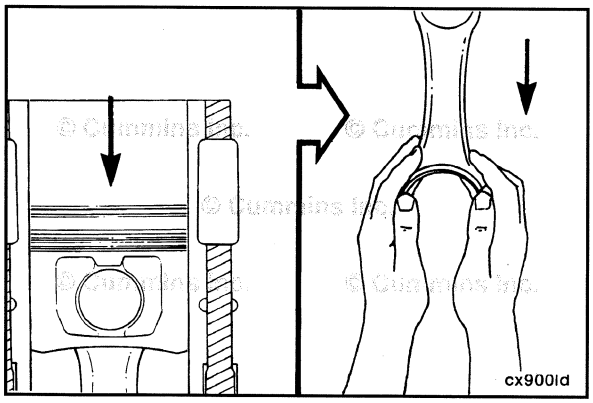


Hold the ring compressor against the cylinder block.

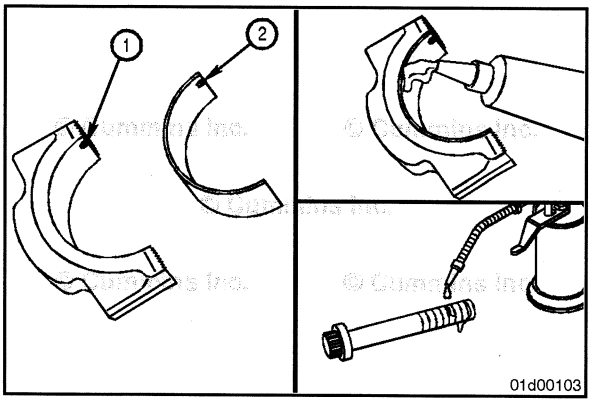
Push the piston through the ring compressor and into the cylinder bore.

Push the piston until the top ring is completely in the cylinder bore.

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.



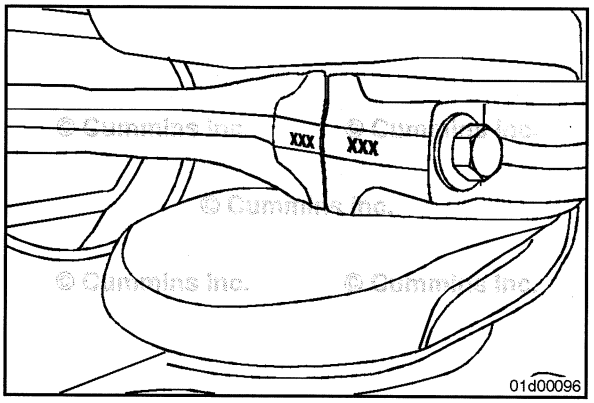
NOTE: If new bearings are **not** used, the used bearings **must** be installed on the same connecting rod cap from which they were removed.

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 lube, Cummins® Part Number 3163087, or equivalent, to coat the inside diameter of the bearing shell.

Use clean 15W-40 oil to lubricate the connecting rod capscrew threads and the underside of the connecting rod capscrew threads.



⚠CAUTION⚠
Do not damage the fractured split surface on the connecting rod or connecting rod cap while the connecting rod cap is removed. If the fractured split surface is damaged, the connecting rod and connecting rod cap must be replaced to help reduce the possibility of engine damage.

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.

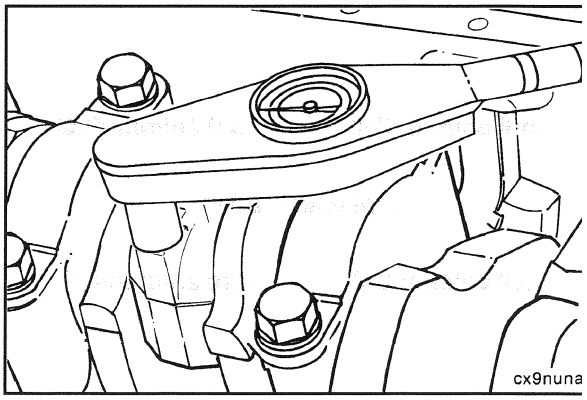
Install the connecting rod cap and capscrews.

Use a marked socket and torque wrench to tighten the rod capscrews.

Use the torque plus angle method, to tighten the connecting rod capscrews in alternating sequence.

Torque Value:

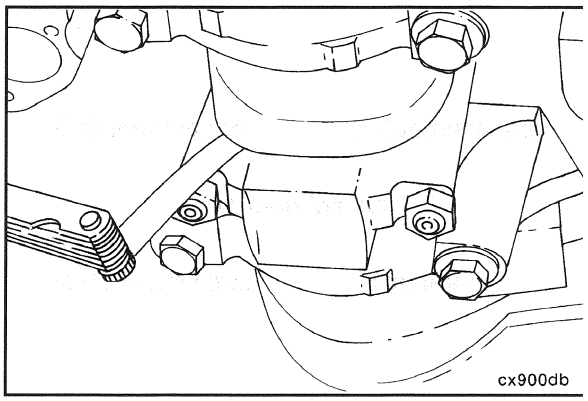
Step 1	30 N•m	[22 ft-lb]
Step 2	60 N•m	[44 ft-lb]
Step 3	Rotate 60 degrees clockwise	



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**
0.125	MIN	0.005
0.275	MAX	0.011

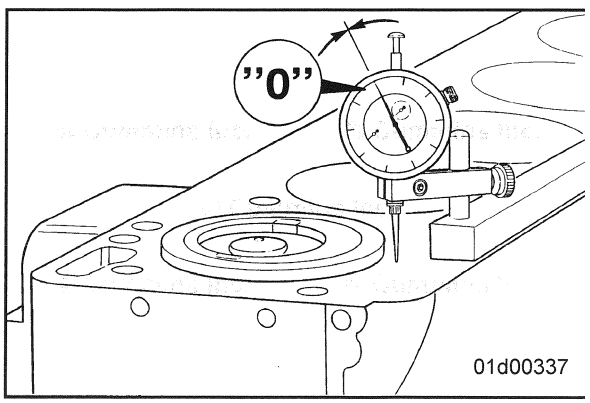


Measure piston protrusion above the cylinder block combustion deck.

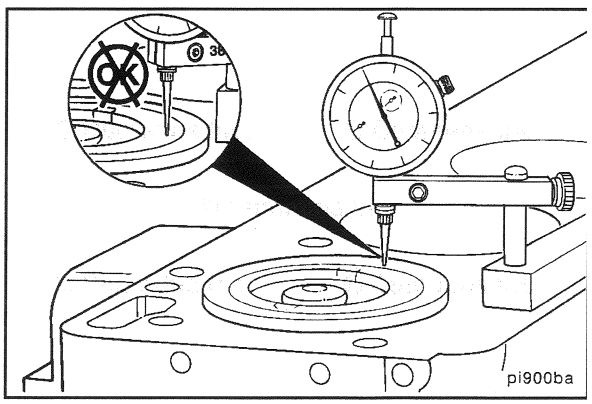
NOTE: This procedure is only required after a piston, crankshaft, connecting rod, or block modification/ replacement.

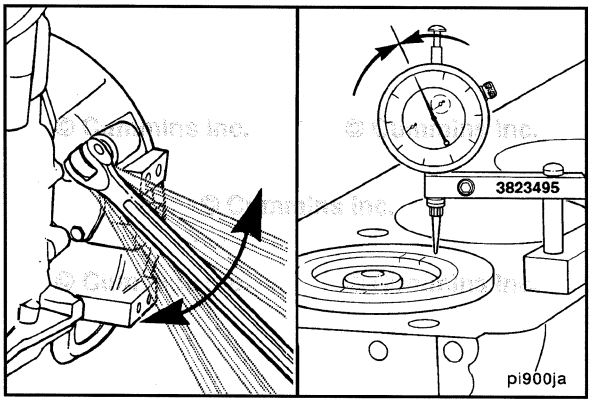
Measure the piston protrusion. Use depth gauge assembly, Cummins® Part Number 3823495. No piston or head gasket grading is required.

Install the dial indicator on the cylinder head and zero.



Move the dial indicator directly over the piston pin to eliminate any side-to-side movement. Do **not** place the indicator tip on the anodized area.

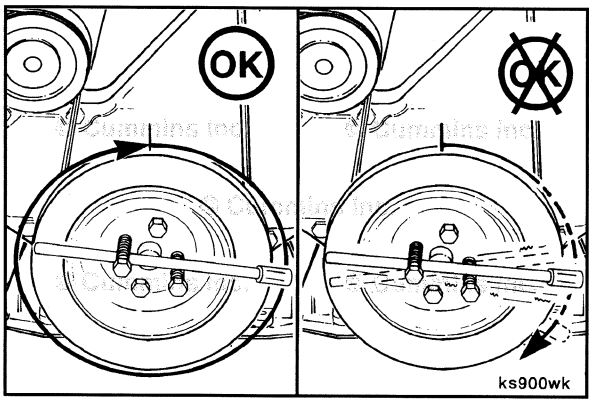




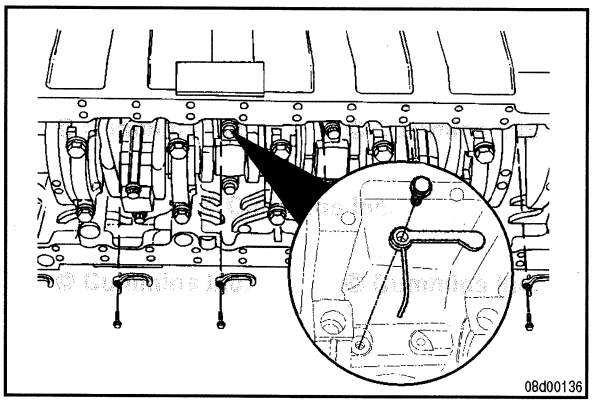
Rotate the crankshaft to top dead center. Rotate the crankshaft **clockwise** and **counterclockwise** to find the highest dial indicator reading. Record the reading.

Piston Protrusion		
mm		**in**
0.25	MIN	0.010
0.52	MAX	0.020

If the piston protrusion is **not** within specification, verify that the correct parts are installed and/or the cylinder block combustion deck has been machined improperly. Refer to Procedure 001-026 in Section 1.



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

⚠CAUTION⚠
Slight bending of the piston cooling nozzles can result in severe engine damage. Replace piston cooling nozzle if it is bent or damaged during disassembly or assembly.

Install the piston cooling nozzle and/or capscrew one cylinder at a time, rotate the crankshaft, as necessary, for access.

Use a long extension to guide the capscrew and/or piston cooling nozzle into place.

NOTE: The locator pin on the piston cooling nozzle **must** engage the locating hole in the block for proper alignment.

Tighten the capscrew.

Torque Value:
Cooling Nozzle Capscrew 15 N•m [133 in-lb]

Gear Housing, Rear (001-034)

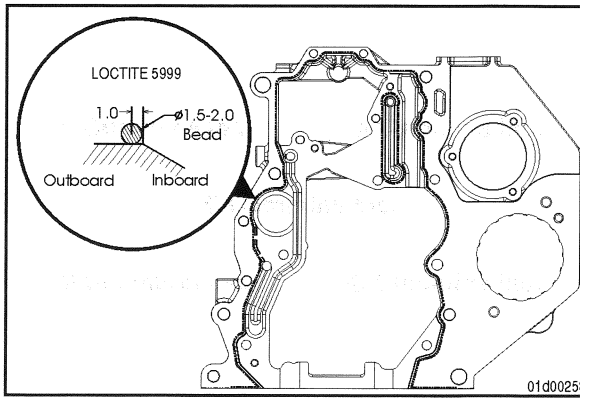
Install

⚠CAUTION⚠
Make sure to only apply sealant to the areas specified. Failure to do so may block oil passages to the accessory drive and/or cause a loss of oil pressure. This will result in severe engine damage.

Apply a 1.5 to 2.0 mm [0.06 to 0.08 in] wide bead of sealant, Cummins® Part Number 3164070, to the block side of the gear housing in the path illustrated and install the rear gear housing capscrews and housing.

Be sure there is a bead of sealant at the intersection joint of the cylinder block, oil pan, and gear housing.

NOTE: Install the gear housing within 10 minutes of applying the sealant or the sealant will **not** seal correctly. Once installed, allow the sealant to dry for 30 minutes before running the engine.

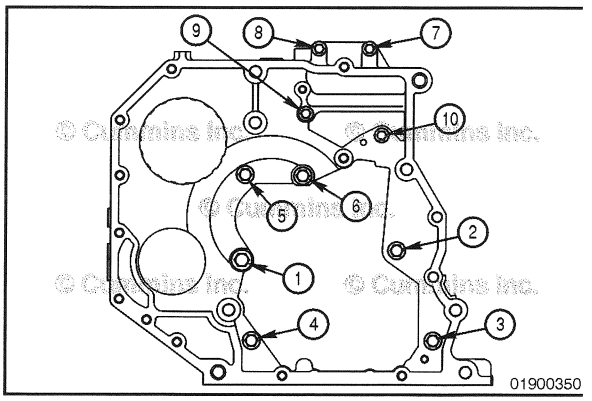


Tighten the capscrews as shown.

Torque Value:
M12 77 N•m [57 ft-lb]

Torque Value:
M10 47 N•m [35 ft-lb]

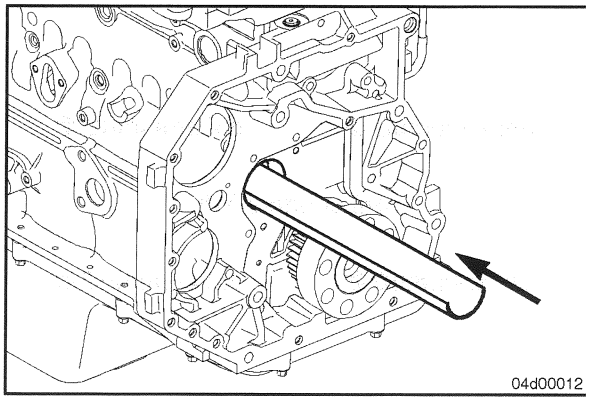
Torque Value:
M8 24 N•m [212 in-lb]

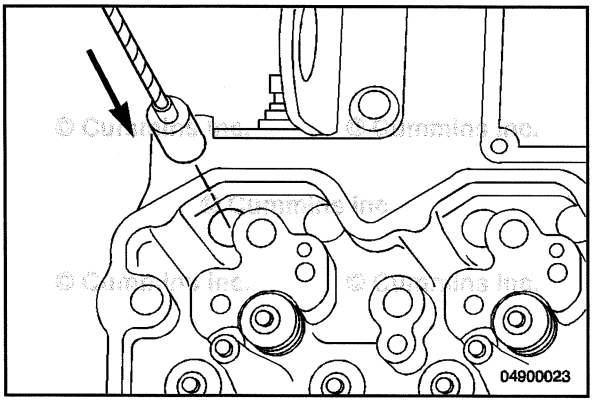


Tappet (004-015)

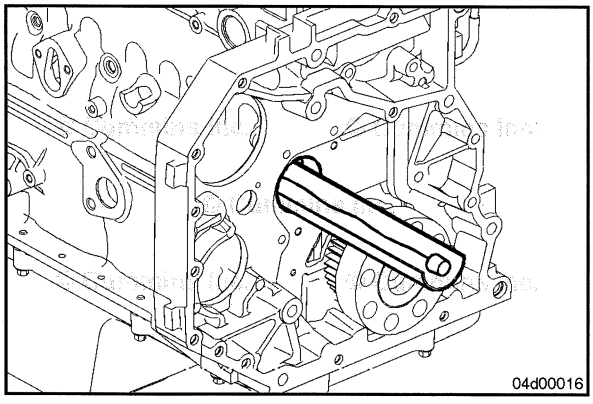
Install

Insert the trough from the tappet replacement kit, Cummins® Part Number 3822513, the full length of the cam bore.

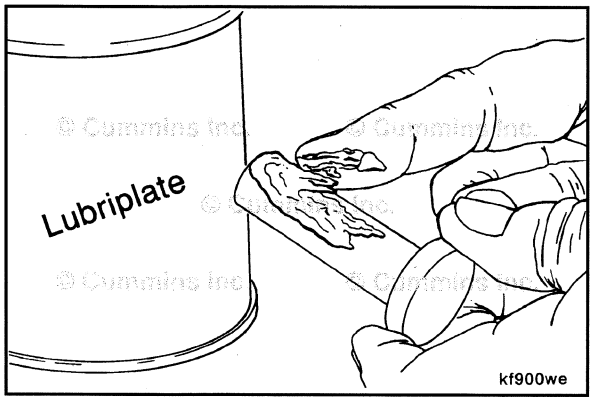




Lower the tappet installation tool down through the push tube hole, through the tappet bore, and into the trough.

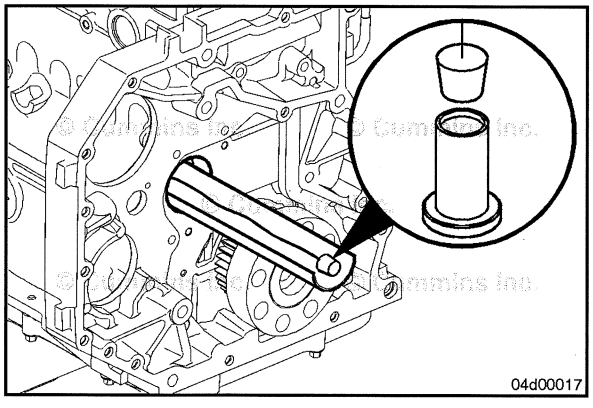


Feed the installation tool through the camshaft bores by carefully pulling the trough/installation tool out the rear of the engine. The barrier at the rear of the trough will pull the tool out **most** of the time.



NOTE: The tappets must be installed in the same positions as removed.

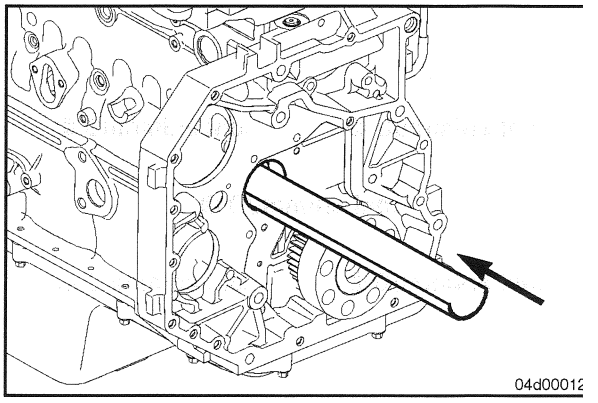
Lubricate the tappets with assembly lubricant, Cummins® Part Number 3163087, or equivalent.



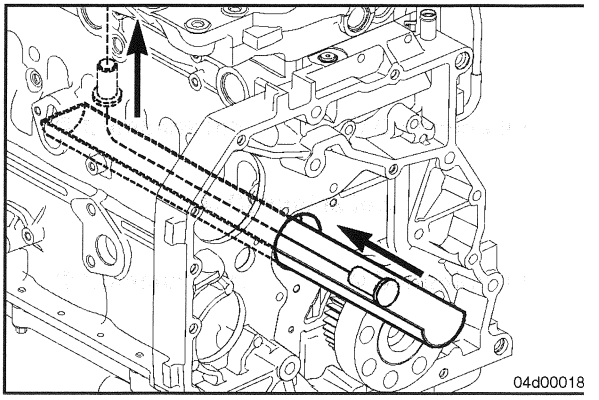
To aid in removing the installation tool after the tappet is installed, work the tool in and out of the tappet several times **before** installing the tappets.

Insert the installation tool into the tappet.

Slide the trough into the camshaft bore.

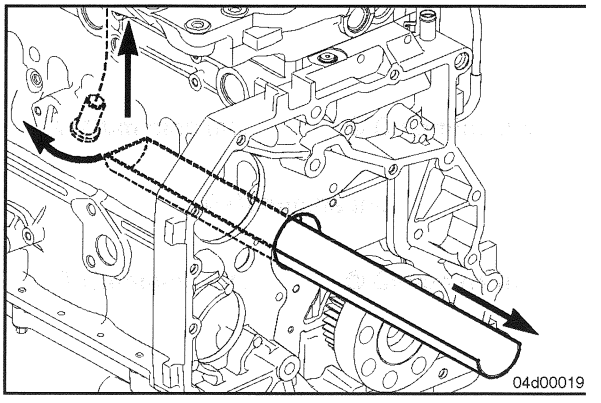


Pull the tool and tappet through the camshaft bore and up into the tappet bore.

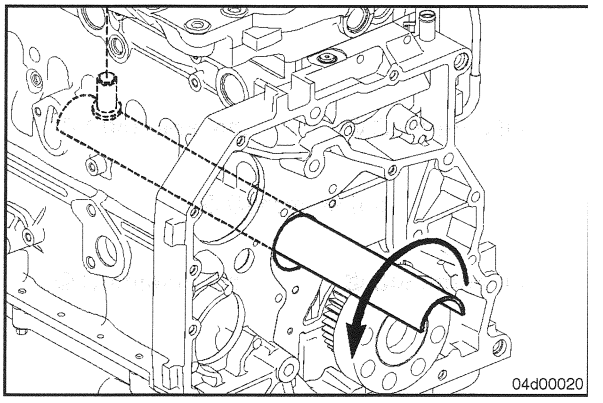


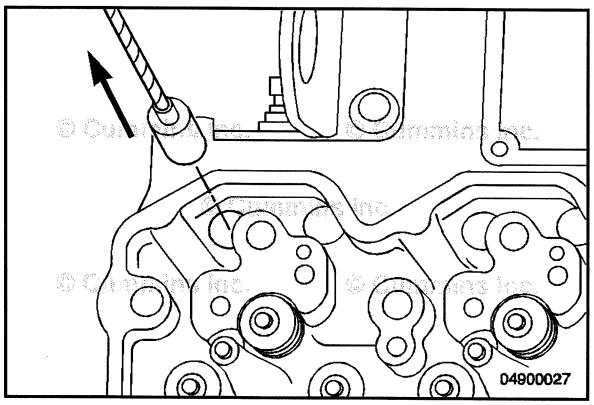
If difficulty is experienced in getting the tappet to make the bend from the trough up to the tappet bore, pull the trough out enough to allow the tappet to drop down and align itself.

Pull the tappet up into the bore.

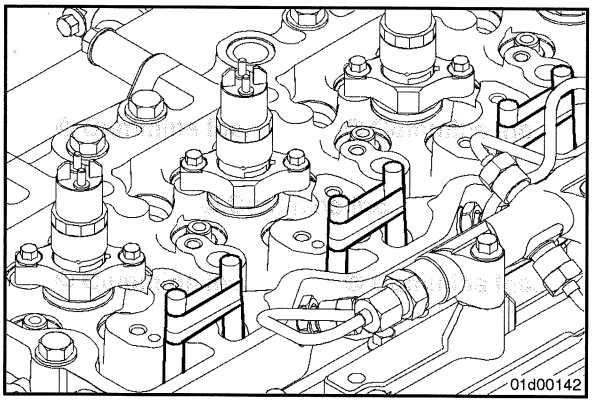


After the tappet has been pulled up into position, slide the trough back into the camshaft bore, and rotate it ½ of a turn. This will position the round side of the trough up, which will hold the tappet in place.





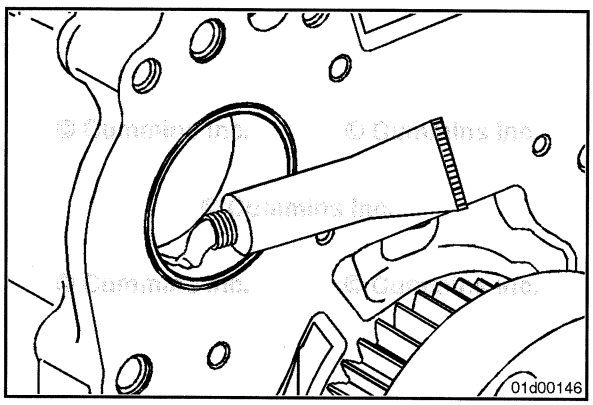
Remove the installation tool from the tappet.



Install a wooden dowel into the top of the tappet.

Wrap rubber bands around the wooden dowels to secure the tappets.

Repeat this process until all tappets have been installed.

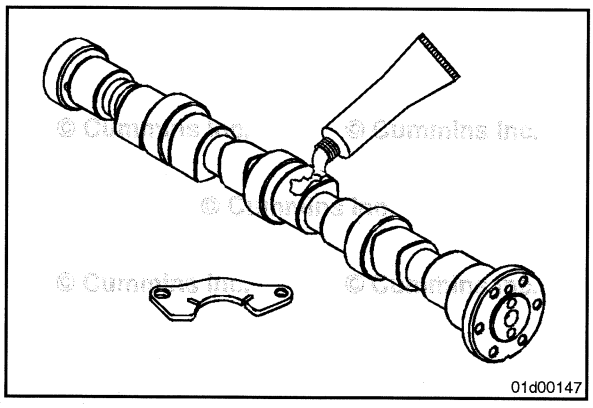


Camshaft (001-008)

Install

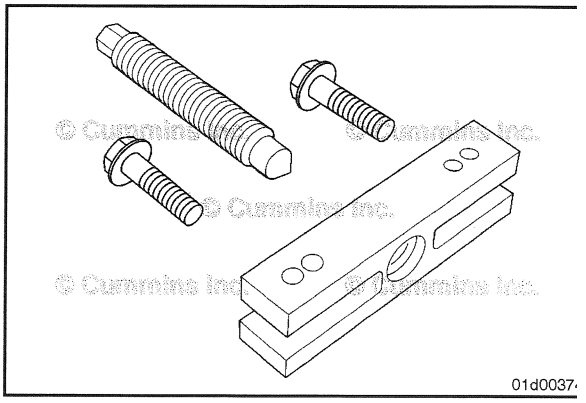
Apply assembly lubricant, Cummins® Part Number 3163087, to the rear camshaft bore.

NOTE: Any time the camshaft is removed from the engine, the camshaft seal behind the crankcase breather tube flange mounting **must** be replaced. Refer to Procedure 003-018 in Section 3 to replace the seal after the camshaft has been installed into the engine.



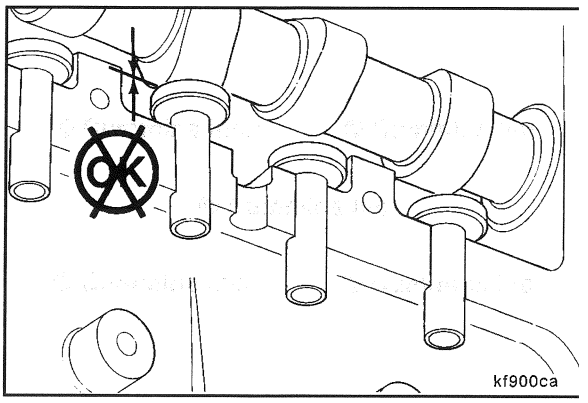
Lubricate the camshaft lobes, journals, and thrust washer with assembly lubricant, Cummins® Part Number 3163087.

Use a gear puller, Cummins® Part Number ST-647 or equivalent, to attach to the end of the camshaft, where the camshaft gear mounts, to act as a handle. This will give proper leverage and ease in installing the camshaft.



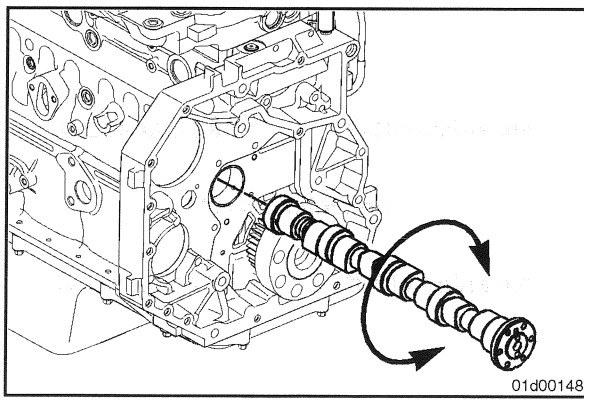
⚠CAUTION⚠
Before the camshaft is installed, verify the tappets are fully inserted into the tappet bores. If the tappets are not fully inserted, the camshaft and/or tappets may be damaged during installation.

NOTE: The following illustrations show the engine in the upright position for clarity.



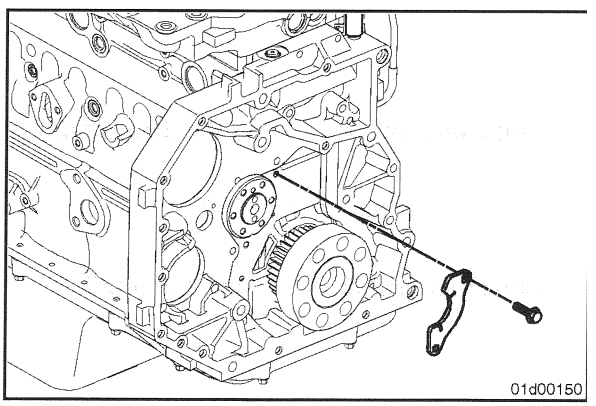
⚠CAUTION⚠
Do not force the camshaft into the camshaft bore as damage to the camshaft bushing can result.

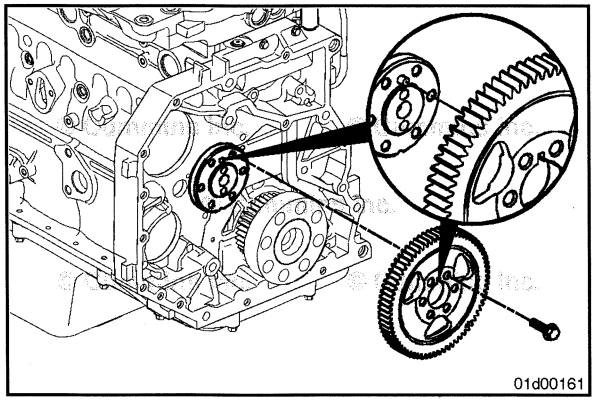
Install the camshaft. While pushing in slightly, rotate the camshaft and carefully work the camshaft through the camshaft bushings. As each camshaft journal passes through a bushing, the camshaft will drop slightly and the camshaft lobes will catch on the bushings. Rotating the camshaft will free the lobe from the bushing and allow the camshaft to be installed.



Install the thrust plate.

Torque Value: 24 N•m [212 in-lb]





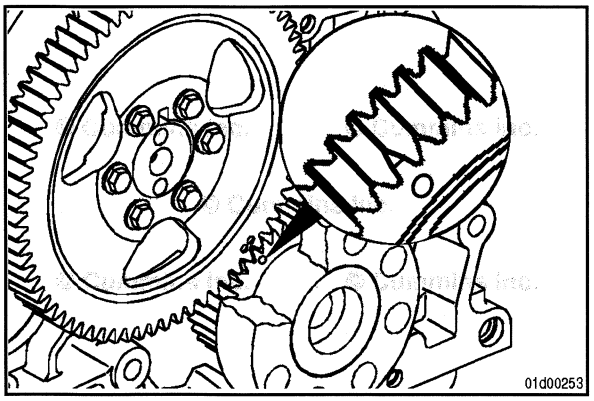
Camshaft Gear (Camshaft Installed) (001-012)

Install

⚠CAUTION⚠
To reduce the possibility of engine damage, make sure the camshaft rotates freely.

Align the camshaft gear with the pin in the camshaft and the mark on the crankshaft gear.

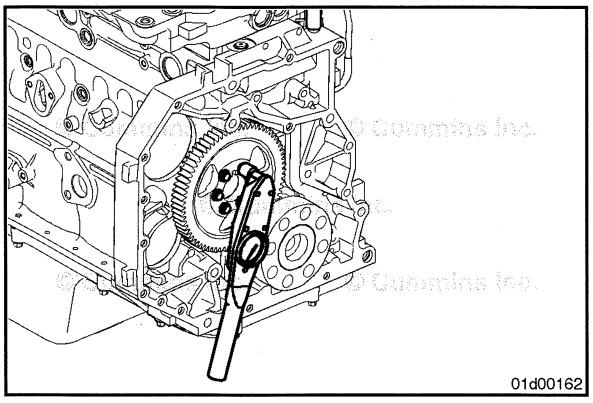
Install the camshaft gear onto the camshaft.



Check to make sure the timing marks on the camshaft gear align with the timing marks on the crankshaft gear.

NOTE: Crankshaft timing tooth is beveled at the flange end.

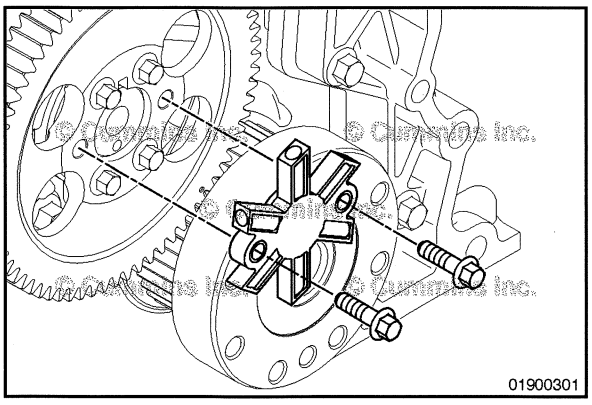
Mesh camshaft gear timing marks with crankshaft timing tooth and align pin in camshaft with key slot in the camshaft gear.



Install the camshaft gear capscrews and tighten.

Torque Value: 15 N•m [133 in-lb]

Tighten an additional 35 degrees.



Install the crankcase breather disc. Refer to Procedure 003-002 in Section 3.

Block Stiffener Plate (001-089)

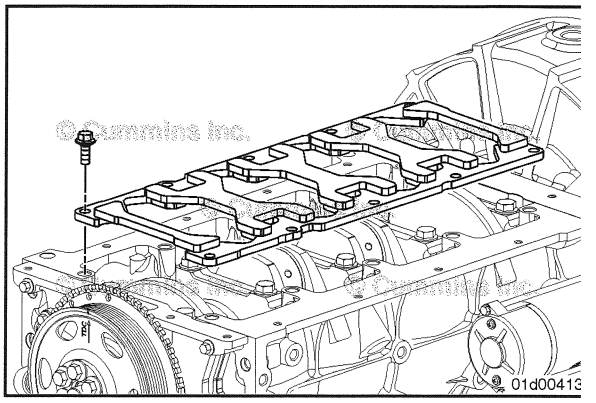
Install

NOTE: The block stiffener plate **must** be installed so the center ribs are bent away from the block, to make sure there is proper clearance from the block main caps.

Install the block stiffener plate.

Install the block stiffener plate mounting capscrews.

Torque Value:
Block Stiffener Plate Capscrews 43 N•m [32 ft-lb]

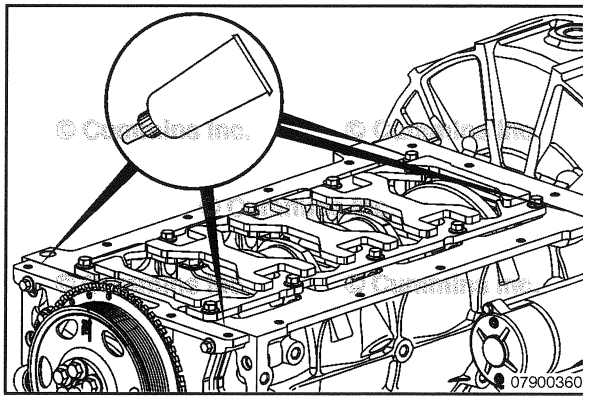


Lubricating Oil Pan (007-025)

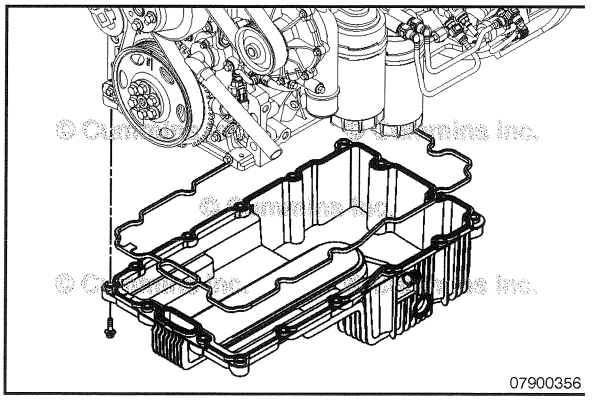
Install

NOTE: If a new front cover gasket has been installed, do **not** scrape away the sealant which is extruded from the new front cover gasket. Additional sealant is **only** required at the T-joint between the cylinder block and rear housing.

Apply a 2-mm [1/16-in] bead of sealant, Cummins® Part Number 3164070, to the oil pan mounting surfaces at the cylinder block to front gear cover joints and the cylinder block to rear gear housing joints.

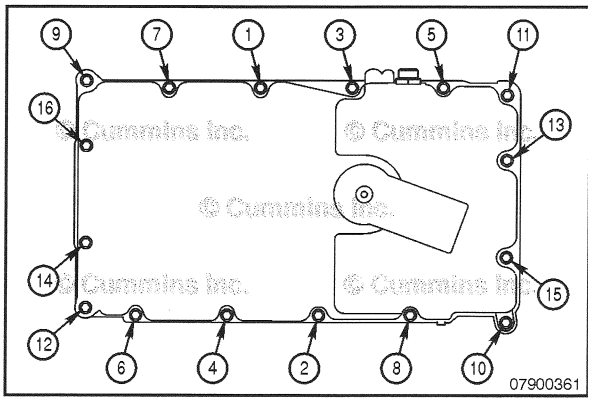


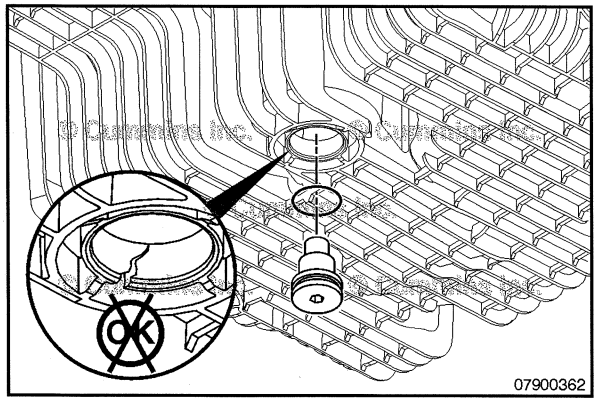
Confirm the seal is located in the groove around the perimeter of the oil pan and the seal is free of oil.



Tighten all sixteen mounting capscrews in the sequence shown in the accompanying graphic.

Torque Value: 24 N•m [212 in-lb]





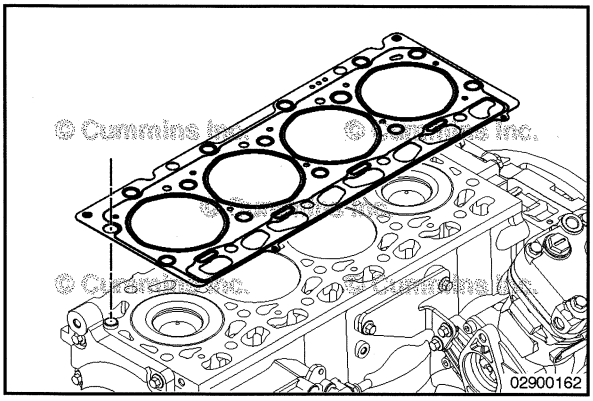
⚠CAUTION⚠
Do not overtighten the oil drain plug. The plug and/or oil pan can be damaged by overtightening.

Clean and check the oil drain plug threads and sealing surface.

Lubricate the oil drain plug o-ring with clean engine oil prior to installing the drain plug.

Install and tighten the oil pan drain plug.

Torque Value: 24 N•m [212 in-lb]

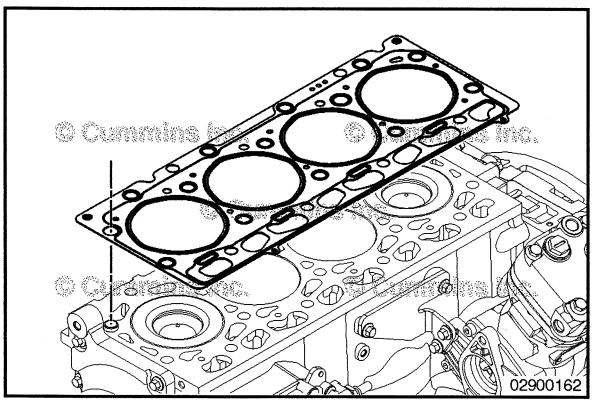


Cylinder Head Gasket (002-021)

Install

A new gasket **must** be installed. Do **not** reuse an old gasket.

Install the head gasket.

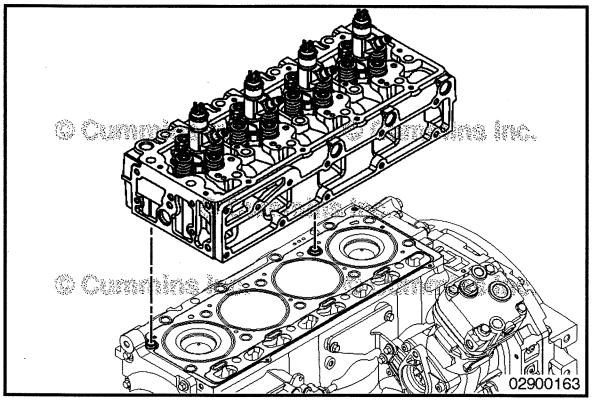


Cylinder Head (002-004)

Install

⚠CAUTION⚠
Make sure the gasket is correctly aligned with the holes in the cylinder block. Damage to the cylinder block can occur if the gasket is not aligned correctly.

Install the cylinder head gasket. Refer to Procedure 002-021 in Section 2.

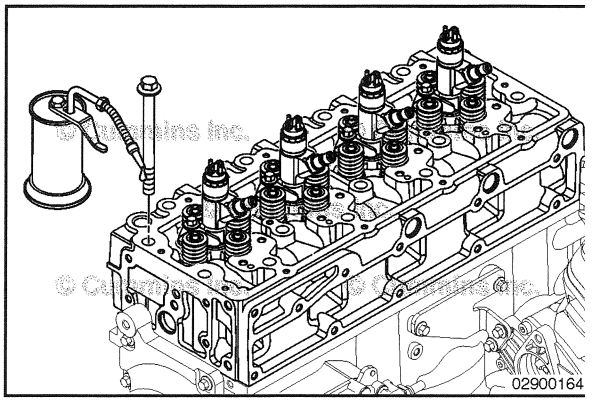


⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To reduce the possibility of serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Carefully place the cylinder head on the cylinder block, and seat it onto the dowels.

Lubricate the threads and under the heads on the cylinder head mounting capscrews with clean engine oil.

Install the capscrews and tighten finger-tight.

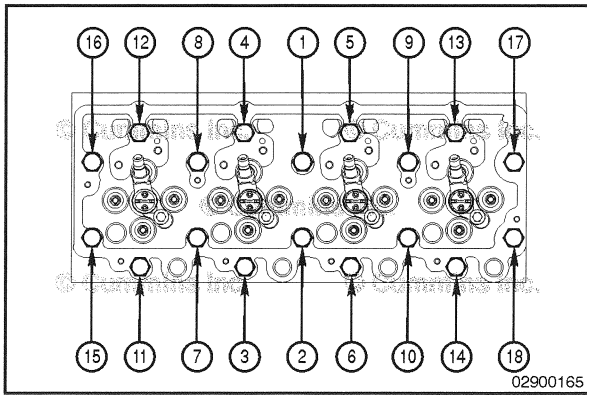


Use the illustrated sequence to tighten the cylinder head capscrews.

Tighten the capscrews.

Torque Value:

Step 1	70 N•m	[52 ft-lb]
Step 2	Loosen 180 degrees	
Step 3	60 N•m	[44 ft-lb]
Step 4	Repeat 60 N•m [44 ft-lb] torque, rotate capscrews 90 degrees clockwise, and then rotate capscrews an additional 90 degrees clockwise.	



Fuel Pump (005-016)

Install

NOTE: Timing of the high-pressure pump with the crankshaft is **not** required.

Install the fuel pump on the gear housing.

Position the fuel pump to the mounting flange on the gear housing while aligning the fuel pump and the gear housing through the fuel pump mounting studs.

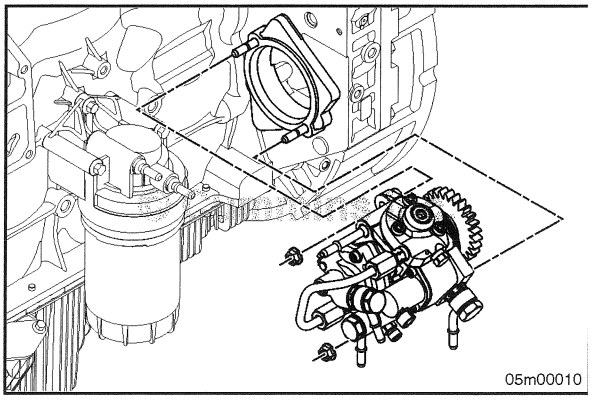
Tighten the mounting nuts evenly and press the fuel pump into the gear housing bore, and hand-tighten **only**.

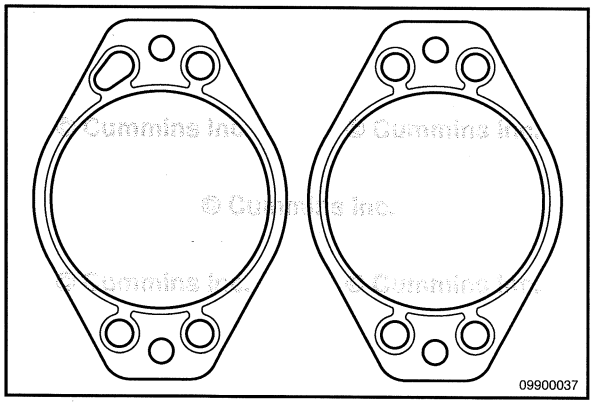
NOTE: Do **not** attempt a final tightening at this time. Do **not** attempt to tighten (pull) the pump to the gear housing using the mounting nuts. Damage to the pump or gear housing can occur.

The pump **must** be positioned flat to the mounting flange before attempting to tighten the two mounting nuts.

Tighten the fuel pump mounting nuts.

Torque Value: 24 N•m [212 in-lb]





Accessory Drive (009-001)

Install

NOTE: If oil supply to the accessory drive is **not** required and the gasket does **not** have oil passages, this check is **not** required. If the accessory drive uses o-rings for seals, this check is **not** required.

Prior to installing the accessory drive, identify which gasket is going to be installed so that, if necessary, the gasket can be properly oriented.

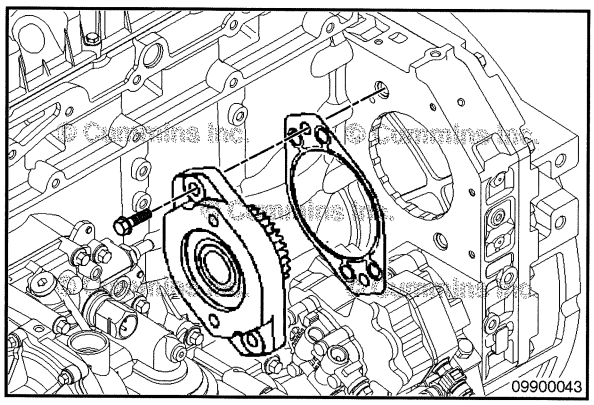
There are two types of accessory drive gasket:

1 Three round oil supply passages and one elongated oil supply passage

2 Four round oil supply passages.

It is preferred that, when installing the accessory drive, the gasket with the four round oil supply passages be used. The gasket can be installed in any orientation.

If only the gasket with the one elongated oil supply passage is available, install the gasket so that the elongated oil supply passage is **not** over the oil supply hole in the gear housing.



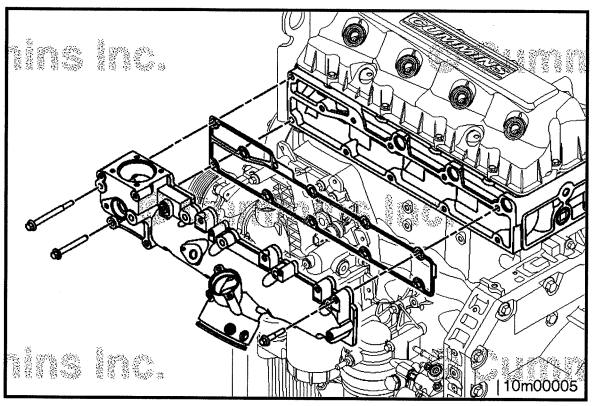
⚠CAUTION⚠
Failure to align the oil supply hole to the accessory drive properly will result in accessory drive damage.

Install the accessory drive and new gasket.

If required, when installing the accessory drive and gasket, make sure the oil supply hole in the gear housing is lined up with the holes in the accessory drive and gasket. The accessory drive is marked for “Top” and “Bottom”.

Install and tighten the two capscrews securing the accessory drive to the rear gear housing.

Torque Value: 77 N•m [57 ft-lb]



Air Intake Manifold (010-023)

Install

Remove the tape from the intake manifold opening before continuing with the installation process.

Install the air intake manifold and capscrews. Apply a light coating of thread sealant, Cummins® Part Number 3824041, to the capscrews before installation.

If the air intake manifold was originally equipped with a gasket, replace the gasket. If the air intake manifold was originally equipped with sealant, seal the intake with RTV sealant, Cummins® Part Number 3164070 or equivalent.

Torque Value: 24 N•m [212 in-lb]

Fuel Filter Head (006-017)

Install

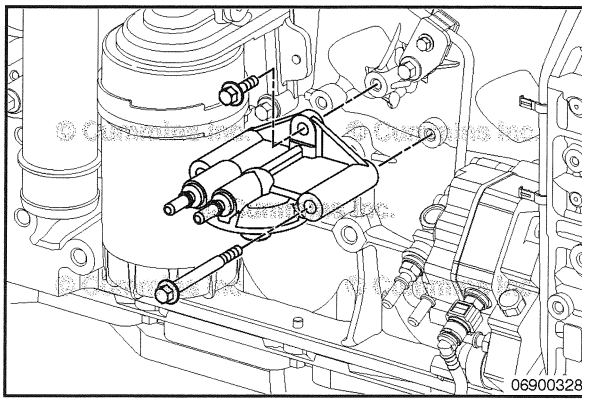
Pressure Side Fuel Filter

- The fuel filter head is marked with IN and OUT arrows to indicate flow. Be sure the fuel filter head is installed in the same way as it was removed.

Install the fuel filter head.

Install the fuel filter head mounting capscrews.

Torque Value: 24 N•m [212 in-lb]



Fuel Filter (Spin-On Type) (006-015)

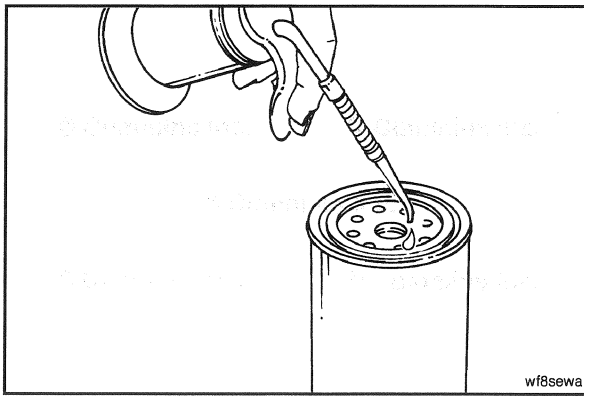
Install

⚠CAUTION⚠
Do not pre-fill the suction side fuel filter with fuel unless a clean side block off plug is used. The system must be primed after the fuel filter is installed. Pre-filling the pressure side fuel filter can result in debris entering the fuel system and damaging fuel system components.

NOTE: If available, pre-fill new filters, with clean fuel prior to assembly using the clean side block-off plug packed with the filter. Do **not** pour fuel directly into the center of the filter as this will allow unfiltered fuel to enter the system and can cause damage to fuel system components.

Use the correct fuel filter.

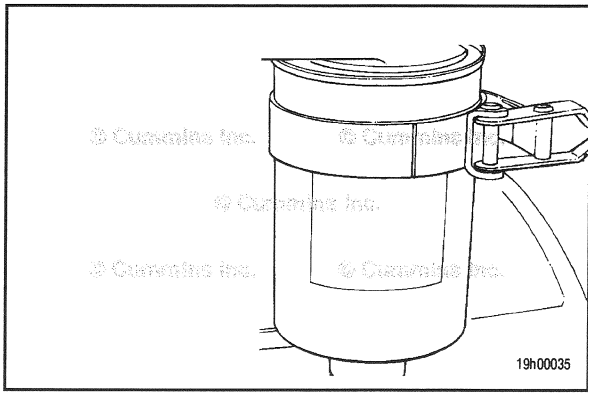
Lubricate the fuel filter o-ring seal with clean lubricating oil.

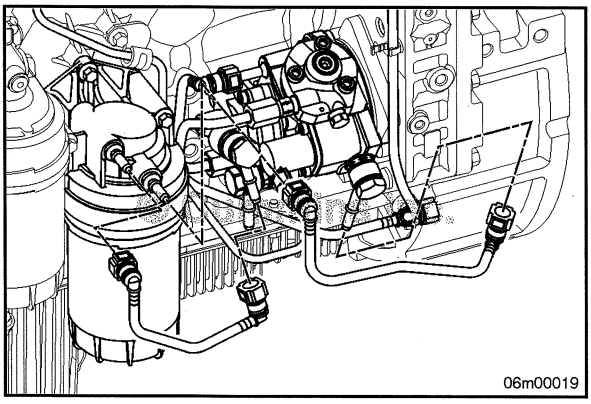


⚠CAUTION⚠
Mechanical overtightening can distort the threads the threads as well as damage the filter element seal or filter can.

Install the filter on the filter head. Use filter wrench, Cummins® Part Number 3398231, or equivalent. Tighten the filter until the gasket contacts the filter head surface.

Tighten the fuel filter an additional 3/4 turn after contact or see equipment manufacturer service information.





Fuel Supply Lines (006-024)

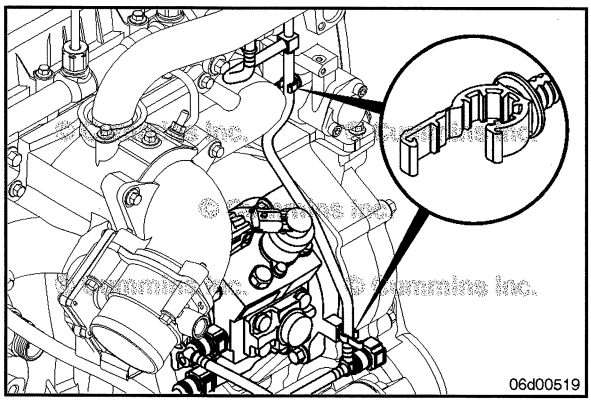
Install

Without Electric Lift Pump

Install the fuel supply line connecting the gear pump to the fuel filter head.

Install the fuel supply line connecting the fuel filter head to the inlet to the high-pressure pump.

Install the P-clips and P-clip mounting capscrews in locations noted during removal.



Fuel Drain Lines (006-013)

Install

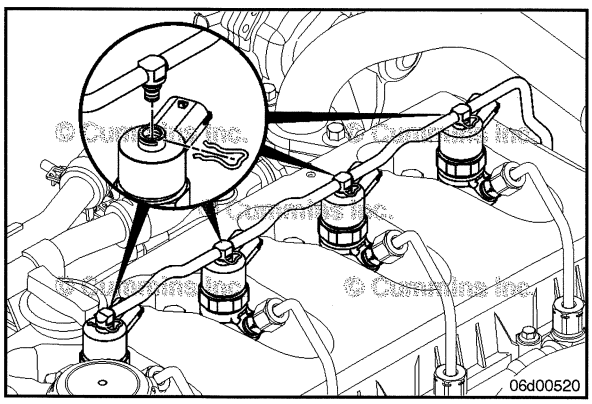
During installation, each quick disconnecting connector **must** be securely locked in position.

There **must** be no unwanted kinks or bends in the fuel drain lines during installation.

Remove the protective caps from the open fuel lines just prior to installing each of the fuel drain line connectors.

Install the fuel drain lines according to the routing noted during removal.

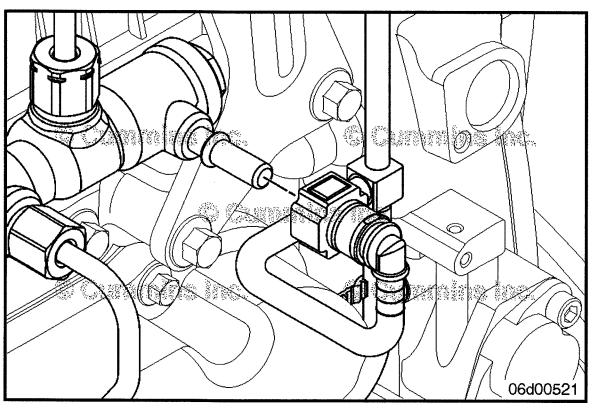
Each fuel drain line **must** be secured correctly at each fir tree clip location.



Install the fuel drain connector to each of the injectors with a new seal, if required, and make sure the seal is fully installed into the injector housing.

Secure the fuel drain connector in position with the retaining spring clip. A click should be heard when fitted correctly.

To make sure the connectors are installed correctly, apply a slight upward force to the fuel drain line connector at each injector.

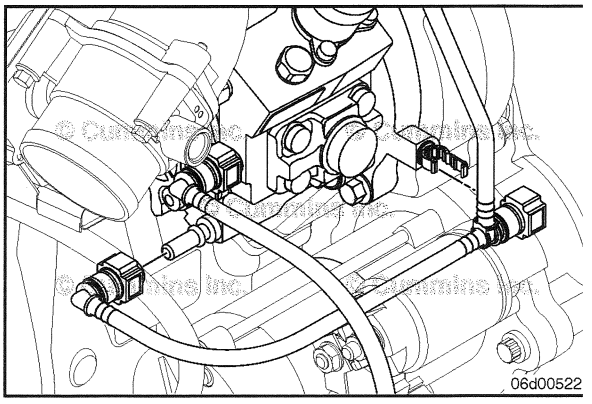


Install the fuel drain connector to the high pressure fuel rail.

NOTE: The fuel pump drain connector is the lowest of the two identical connection tubes on the pump.

Install the fuel drain line connector to the high pressure fuel pump.

Install the fuel line drain connector to the OEM vehicle fuel drain line.



Injector (006-026)

Install

⚠CAUTION⚠
The incorrect sealing washer can cause high-pressure fuel leaks and/or performance problems due to incorrect injector protrusion.

⚠CAUTION⚠
When installing the injector, care must be taken not to damage the injector tip.

NOTE: If the injector solenoid shipping cap is **not** used to install the injector, be careful that pressure is **not** placed on the wire terminals. Wire terminals can break off if they are used to push on the injector.

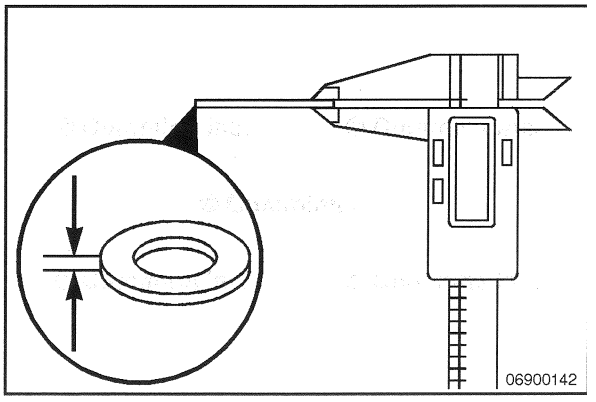
A replacement copper sealing washer **must** be used when installing the injectors.

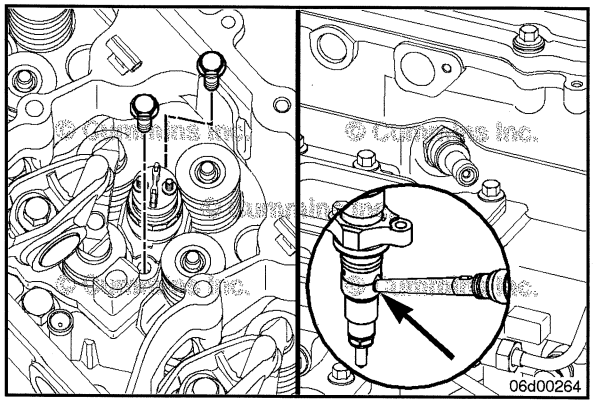
Verify the correct thickness of the new injector sealing washer.

Injector Sealing Washer Thickness 2.5 mm [0.098 in]

Only one copper sealing washer **must** be installed on the injector.

Remove the blind plug installed to prevent dust or debris from entering the engine.





Record the injector trim codes that are listed on each injector.

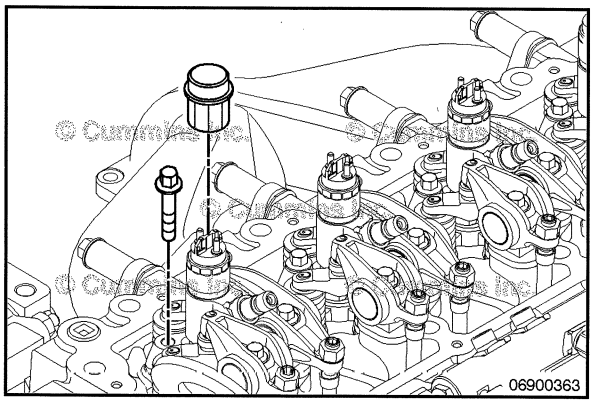
NOTE: The injector trim codes are located on the solenoid at the top of the injector.

Make sure the injector bore is clean.

Lubricate the injector o-ring with clean engine oil.

Install the injector hold-down clamp on the injector before installing the injector into the bore.

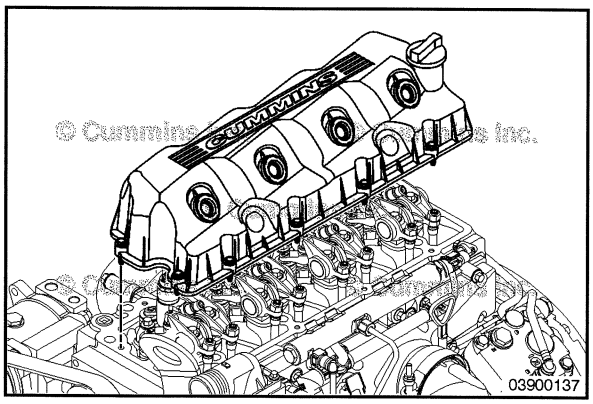
Align the injector in the cylinder head in the proper orientation (fuel inlet toward the high-pressure fuel connector).



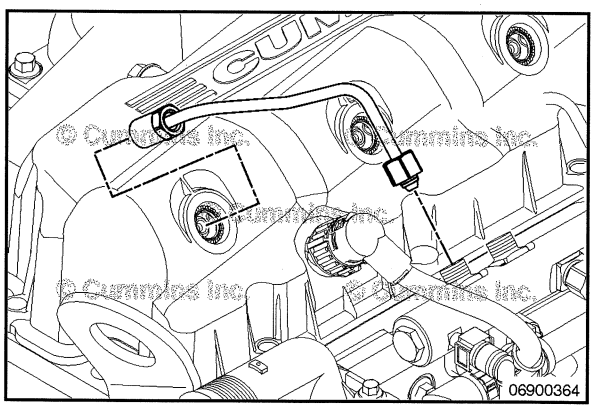
Use the injector solenoid shipping cap to make sure the injector is seated in the injector bore.

Install the injector hold-down capscrew. Do **not** tighten beyond hand-tight at this time.

Repeat the process to loosely install the other three injectors.



Install the rocker lever cover without the seal. Tighten one mounting capscrew on each side of the cover.



Connect the injector end of one of the high-pressure fuel lines to the injector. Use the injector end nut as a guide and center the injector in the grommet.

Remove the high-pressure fuel line from the injector and repeat the process for all four injectors.

Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.

NOTE: Alternate between the capscrews turning each 90 degrees per turn until reaching the final torque.

Tighten the injector hold-down clamp capscrews.

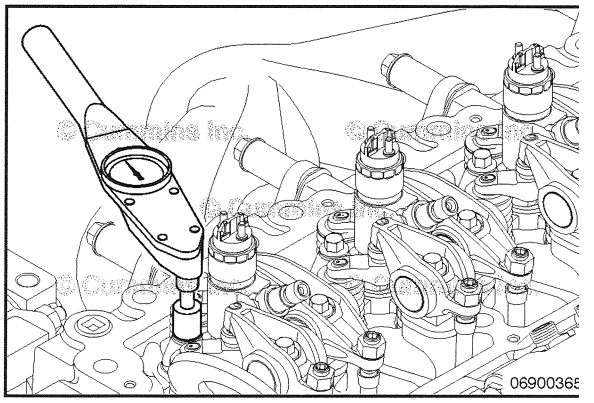
Torque Value:
Injector Hold-down Clamp Capscrews 40 N•m [30 ft-lb]

Install the injector actuator wires and nuts onto the injector.

NOTE: Align the injector wires so they will **not** interfere with each other or the rocker levers. If a 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.

Tighten the nuts.

Torque Value:
Injector Actuator Wire Nuts 1.5 N•m [13 in-lb]

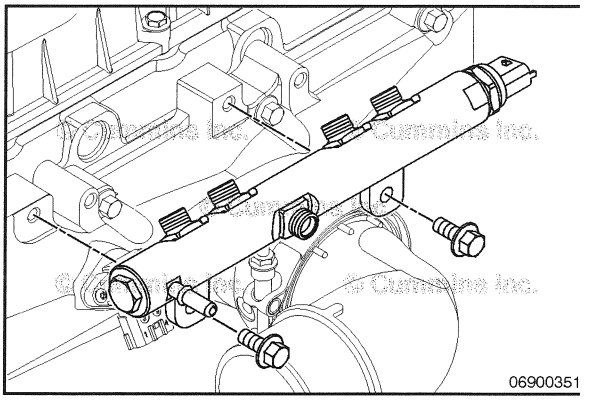


Fuel Rail (006-060)

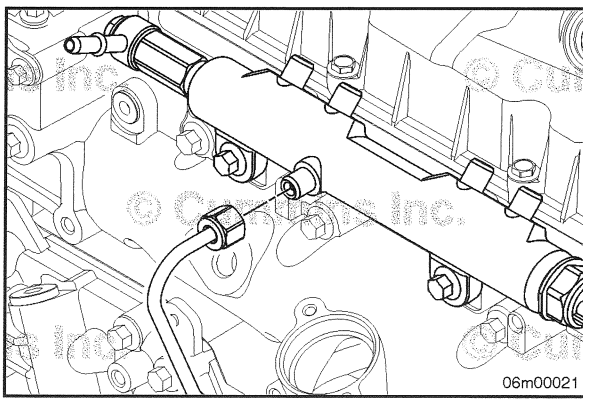
Install

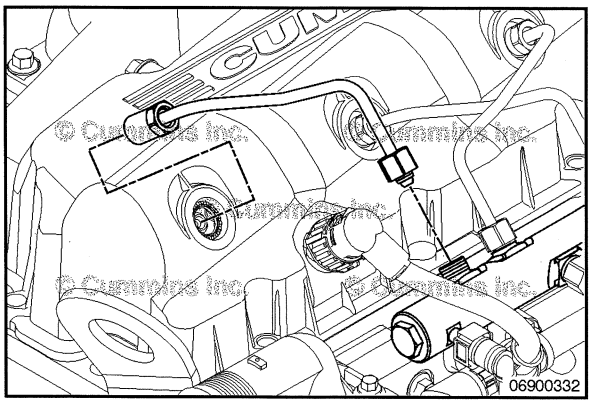
Install the fuel rail on the engine.

Hand-tighten the fuel rail capscrews.



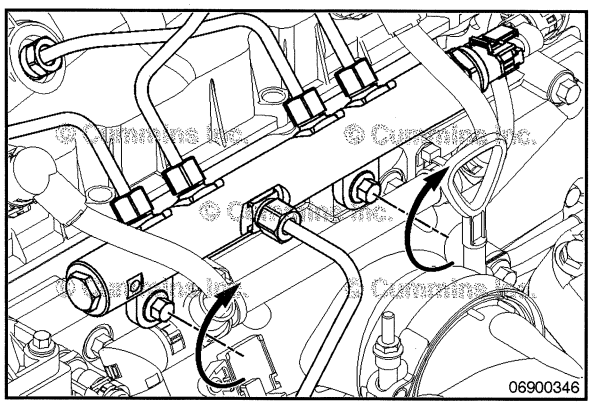
Install the high-pressure supply line that connects the fuel pump to the fuel rail. Refer to Procedure 006-071 in Section 6.





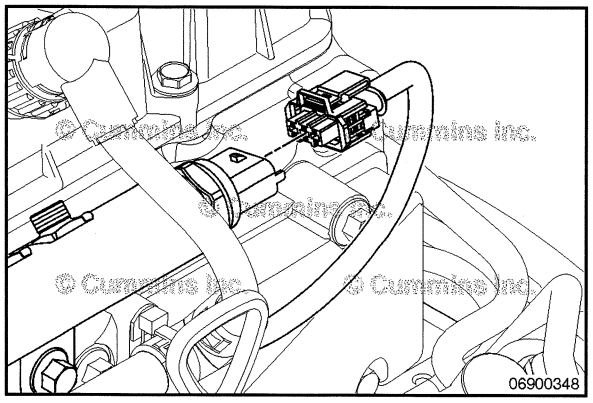
⚠CAUTION⚠
Injector supply lines and the high-pressure supply line must be torqued prior to tightening the fuel rail cap screws.

Install the injector supply line(s) that connect the fuel rail to the fuel injectors. Refer to Procedure 006-051 in Section 6.



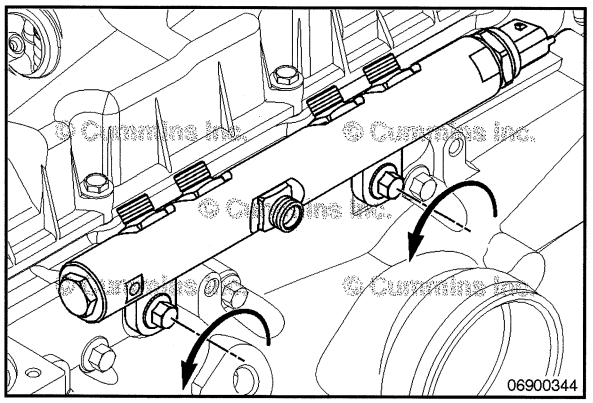
Tighten the fuel rail capscrews.

Torque Value: 24 N•m [212 in-lb]



Connect the fuel rail pressure wiring harness sensor connector.

If the fuel rail pressure sensor was removed, the fuel rail pressure sensor **must** be replaced. Refer to Procedure 019-115 in Section 19.



Injector Supply Lines (High Pressure) (006-051)

Install

Loosen but do **not** remove the capscrews that secure the fuel rail to the intake manifold. The capscrews are loosened to allow proper alignment of the fuel rail after installing the new fuel line(s).

NOTE: Using clean 15W-40 engine oil, lubricate the four injector fuel supply line seals in the rocker cover before installing the fuel supply lines.

The fuel lines **must** be aligned correctly. The process below should be followed to avoid any problems.

Hand tighten the injector fuel line union. Make sure the line is central within the union.

Hand tighten fuel line union at the rail end. Make sure the pipe is central within the union.

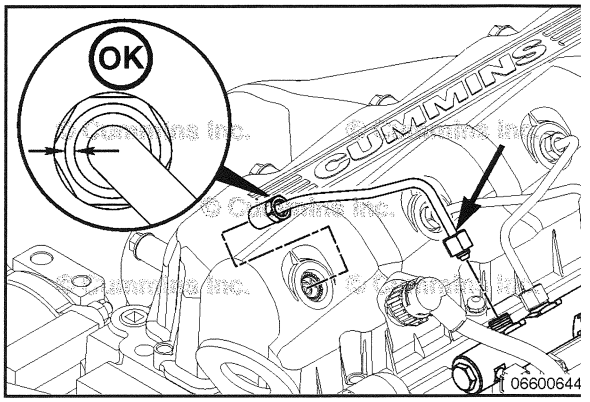
Tighten the injector end, making sure there is no contact between the line and the union at either end.

Torque Value: 35 N•m [26 ft-lb]

Tighten the injector fuel line union.

Torque Value: 35 N•m [26 ft-lb]

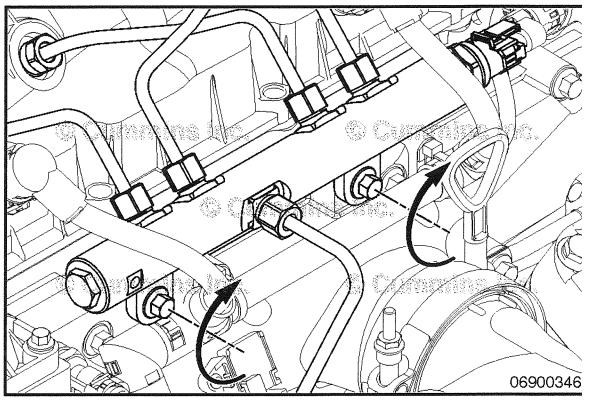
Repeat this process for the other three lines.



NOTE: Check the injector fuel line seals in the rocker cover to make sure they were **not** damaged during assembly of the fuel lines.

Tighten the capscrews for the fuel rail.

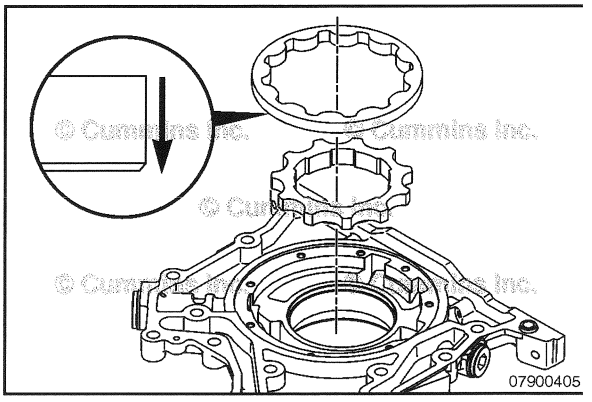
Torque Value: 24 N•m [212 in-lb]



Lubricating Oil Pump (007-031)

Install

Install the lubricating oil pump gears into the front cover.

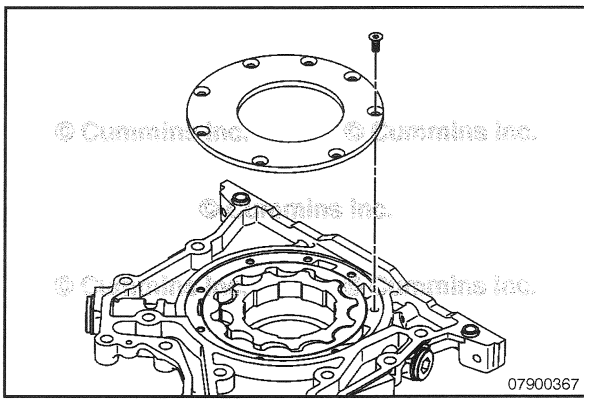


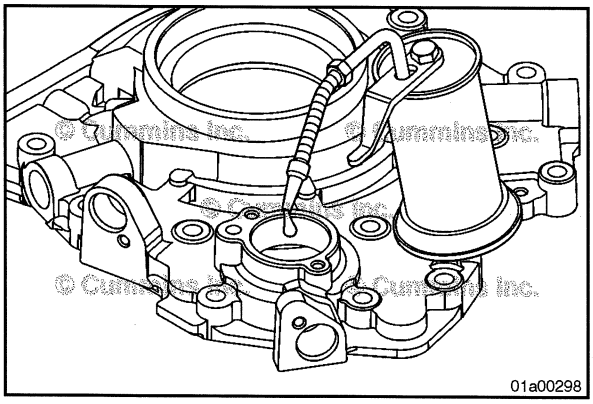
Apply Loctite™ 243, or equivalent, thread sealant to the oil pump cover mounting capscrew threads.

Install the lubricating oil pump cover and the eight mounting capscrews.

Tighten the lubricating oil pump cover capscrews.

Torque Value: 8.5 N•m [75 in-lb]

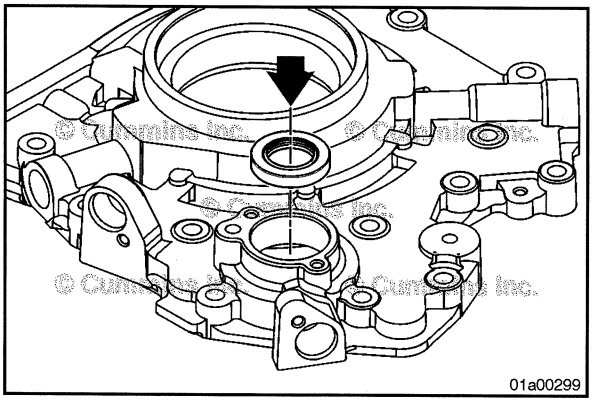




Gear Cover, Front (001-031)

Install

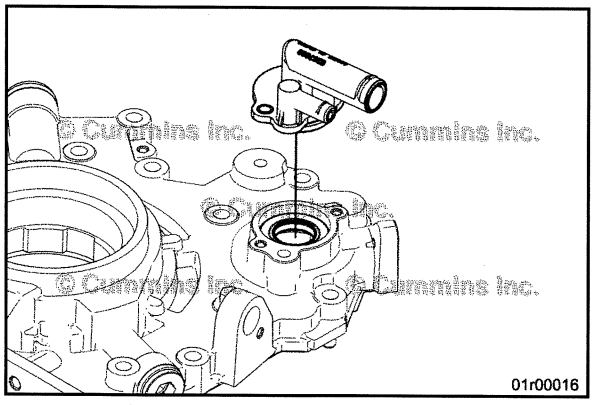
Lubricate the inside surface of the camshaft seal bore with a small amount of clean engine oil.



Install a new camshaft seal into the front gear cover

Start the seal into the bore by hand. Be sure the camshaft seal is inserted equally on all sides.

Apply slight pressure to push it deeper into the bore until the camshaft seal front is at the same level as the front gear cover.

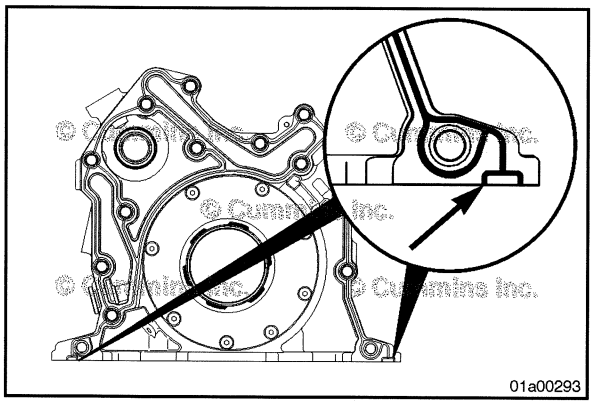


NOTE: Do **not** install the camshaft breather adaptor at this time.

Use the crankcase breather adaptor to push the seal in to the bore to the correct depth.

The seal should be installed approximately 12 mm [0.48 in] into the bore.

Lubricate the outside surface of the camshaft and crankshaft nose with clean engine oil.



When installing the front gear cover gasket, take care **not** to damage the rubber seal on the bottom edges of the gasket.

NOTE: If needed, apply a small amount of sealant, Cummins® Part Number 3164070, to the front gear cover gasket to help hold the gasket in place.

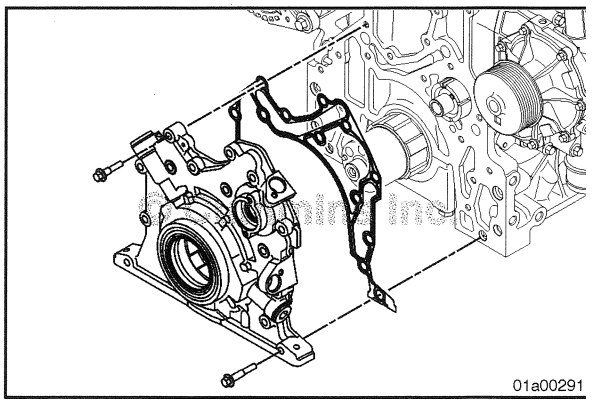
Install the front gear cover gasket. Use the dowel rings in the cylinder block to locate and temporarily hold the front gear cover gasket in place.

NOTE: If needed, rotate the lubricating oil pump in the front gear cover to align with the lubricating oil pump drive gear on the crankshaft.

Install the front gear cover. Take care to align the camshaft seal with the nose of the camshaft upon installation. Use the dowel rings in the cylinder block to locate the front gear cover.

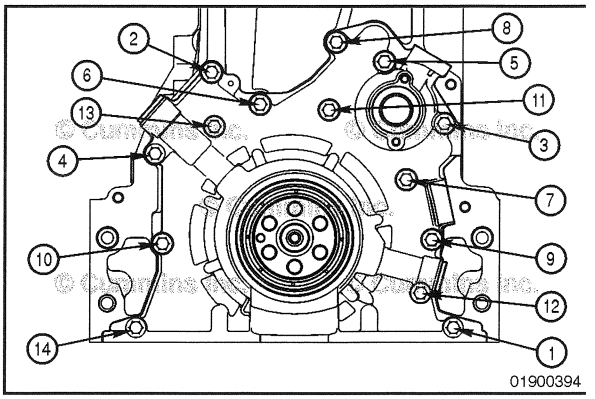
NOTE: As documented during removal, make sure to install the three longer mounting capscrews in the correct locations. If **not** documented during removal, the three longer mounting capscrews go in locations 1, 14, and 12, as shown in the graphic in the next step.

Install the front gear cover mounting capscrews.



Tighten the front gear cover to the cylinder block mounting capscrews in the order indicated.

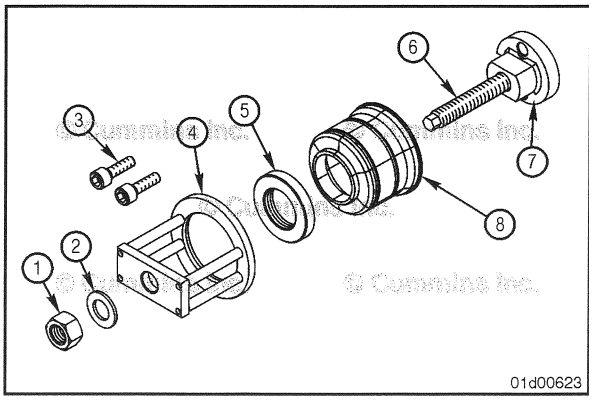
Torque Value: 24 N•m [212 in-lb]

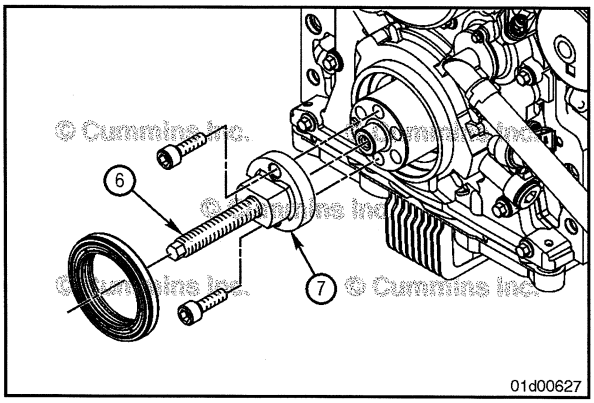


Crankshaft Seal, Front (001-023)

Install

Use tool, Cummins® Part Number 4919660, to install the oil seal into the front gear cover.

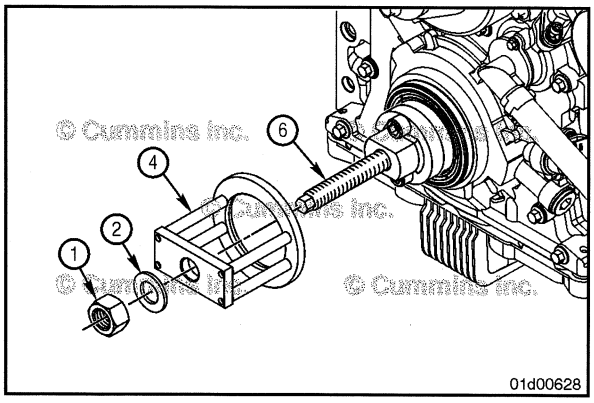




Install the mounting adapter (7) onto the crankshaft nose.

Install the two M12 x 1.25 x 60 mm socket head capscrews.

Place the new front crankshaft seal over the replacer screw (6) and onto the crankshaft nose, and slide the seal assembly by hand toward the front gear cover as far as possible.

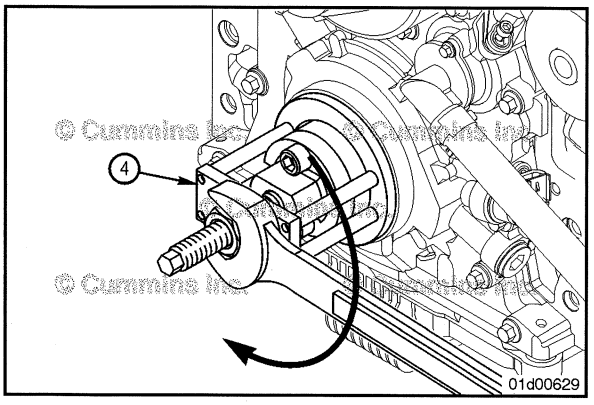


△CAUTION△
Do not use an impact wrench or air tools. Doing so can damage the tool.

NOTE: Make sure the seal is positioned squarely with the crankshaft.

Assemble the crankshaft seal installer (4) over the replacer screw (6) and crankshaft nose and advance the seal installer toward the seal until it is positioned squarely against the seal.

Place the plain washer (2) and the hexagon nut (1) onto the replacer screw (6) and tighten by hand until secure.



△CAUTION△
Do not overtighten the replacer screw assembly after the crankshaft seal replacer contacts the front cover. Doing so can damage the tool.

While holding the crankshaft seal installer (4), use a wrench to rotate the hexagon nut in a clockwise direction until the crankshaft seal installer contacts the front gear cover.

Remove the components of the service tool and inspect the seal for correct engagement. Make sure there are no irregularities

Crankshaft Speed Indicator Ring (001-071)

Install

NOTE: Be sure the dowel pin in the crankshaft is aligned with the tone wheel correctly.

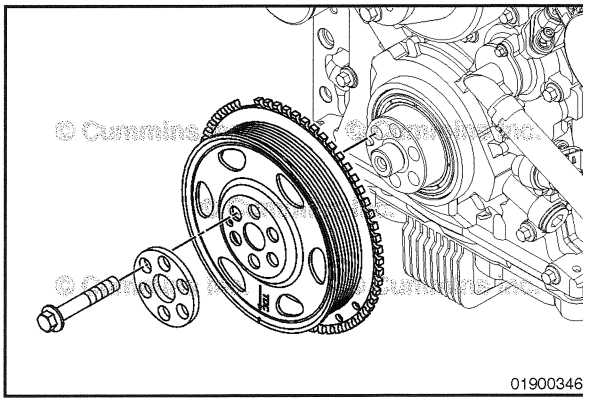
Install the six capscrews that hold the crankshaft speed indicator ring/pulley to the nose of the crankshaft.

Tighten crankshaft speed indicator ring/pulley capscrews in a criss-cross pattern.

Torque Value:

Step 1	55 N•m	[41 ft-lb]
Step 2	Loosen capscrews 180 degrees.	
Step 3	55 N•m	[41 ft-lb]
Step 4	Rotate 90 degrees.	

NOTE: The final torque value should be 125 N•m [92 ft-lb]

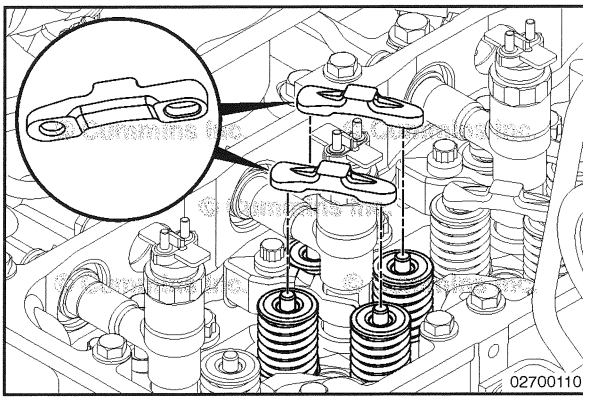


Crosshead (002-001)

Install

NOTE: The crosshead has a round and oval hole. The oval hole is pointed toward the exhaust side. The round hole is pointed toward the intake side. If crossheads are being reused, make sure to install them in their original location and orientation.

Install the crossheads on the valve stems.



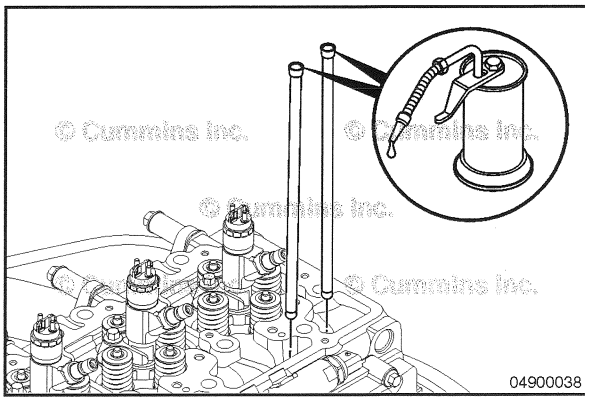
Push Rods or Tubes (004-014)

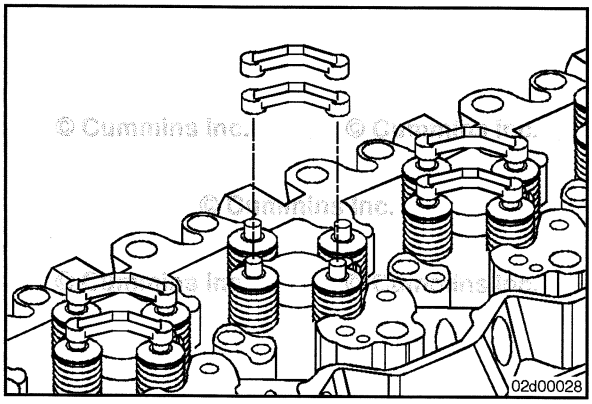
Install

NOTE: The push rods **must** be installed in their original location and position.

Install the push rods into the sockets of the valve tappets.

Lubricate the push rod sockets with clean 15W-40 engine oil.

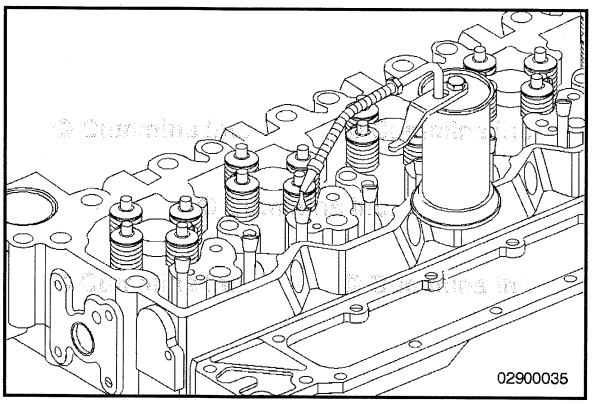




Rocker Lever (003-008)

Install

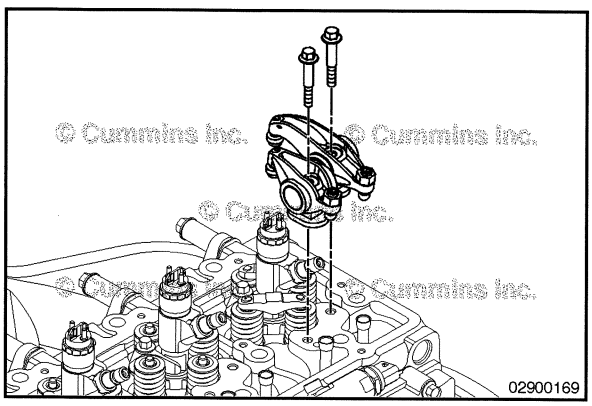
Install the crossheads in their original location and position.



Install the push rods as marked during removal.

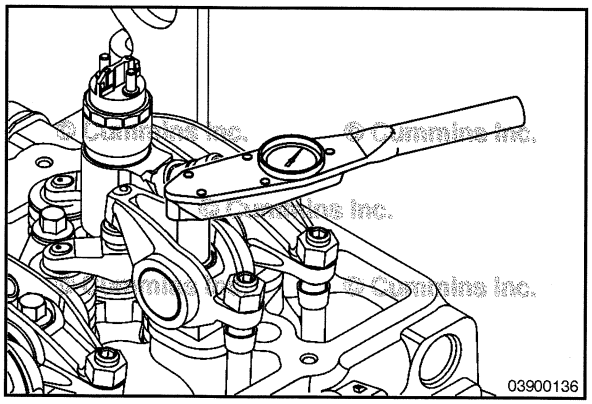
Install the push rods into the sockets of the valve tappets.

Lubricate the push rod sockets with clean 15W-40 lubricating engine oil.



Install the rocker lever assemblies and pedestals in their original position.

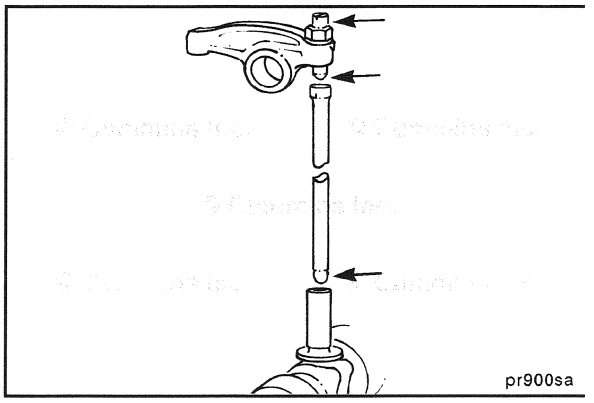
Install the pedestal mounting capscrews.



Tighten the pedestal mounting capscrews.

Torque Value: 36 N•m [27 ft-lb]

⚠CAUTION⚠
Rotate the adjusting screws until the adjusting screw contacts the socket of the push rod. This will ensure the push rod stays in contact with the tappet and adjusting screw when the engine is rotated to set valve lash. If not completed, the push rods may be bent or damaged.

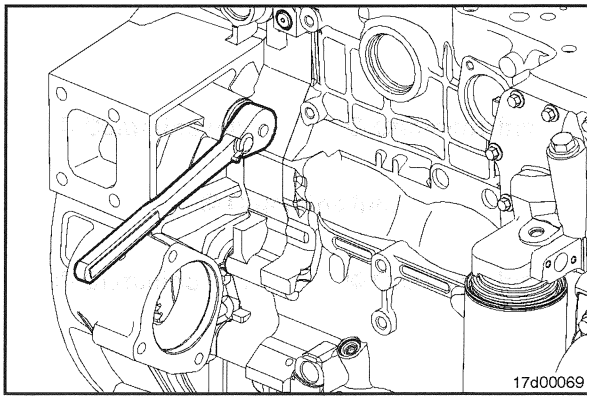


Overhead Set (003-004)

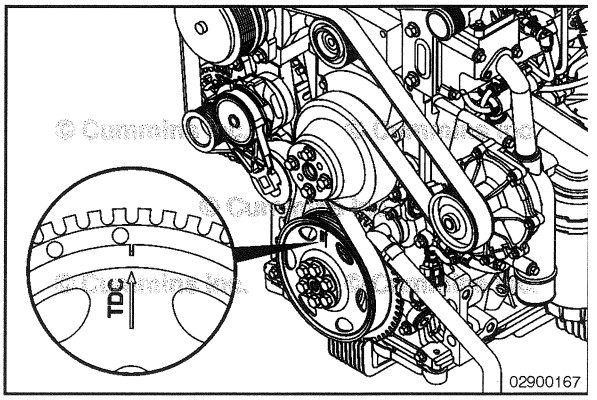
Adjust

NOTE: Engine coolant temperature **must** be less than 60°C [140°F].

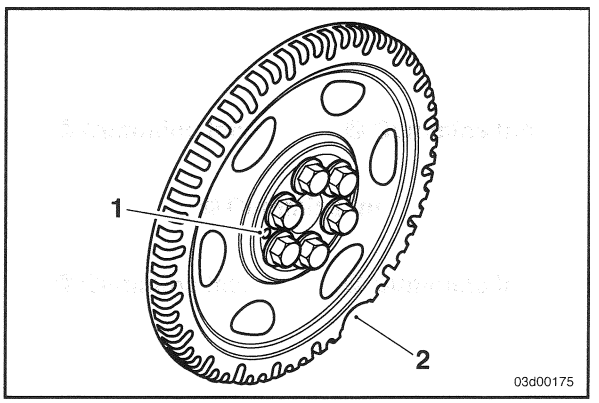
Use the barring tool, Cummins® Part Number 3824591, to rotate the crankshaft until the number 1 cylinder is at top dead center (TDC).

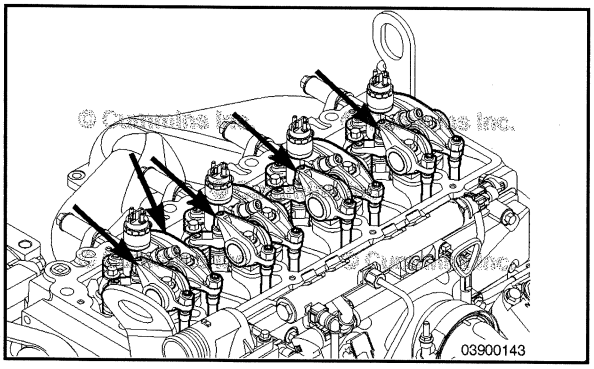


The TDC indicator is on the crankshaft speed indicator ring.



NOTE: If no TDC mark is present on either the crankshaft speed indicator ring, align the large gap in the crankshaft speed indicator ring to the 5 o'clock position (2). The dowel pin could also be visible in the 9 o'clock position (1). Check that both number 1 cylinder rocker levers are loose. If they are **not** loose, rotate the crankshaft 360 degrees and check the proper levers again.

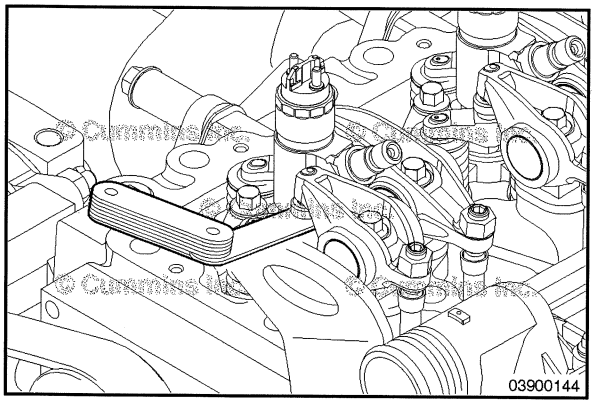




With the engine in this position, lash can be measured on the following rocker levers:

(E = Exhaust, I = Intake)

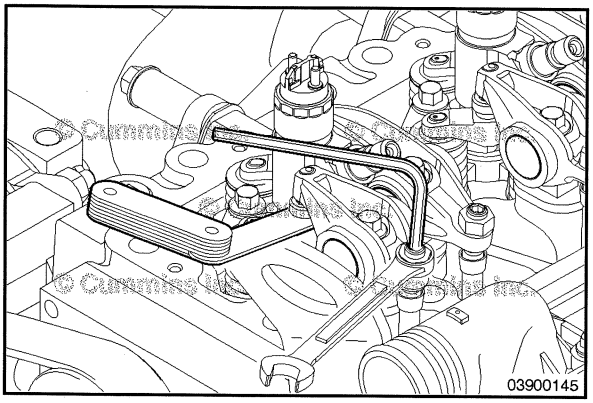
1I, 1E, 2I, and 3E:



Lash Check Limits

	mm		in
Intake	0.28	MIN	0.011
	0.381	MAX	0.015
Exhaust	0.53	MIN	0.021
	0.63	MAX	0.025

NOTE: Checking the overhead setting is usually performed as part of a troubleshooting procedure, and resetting is **not** required during checks as long as the lash measurements are within the above ranges.



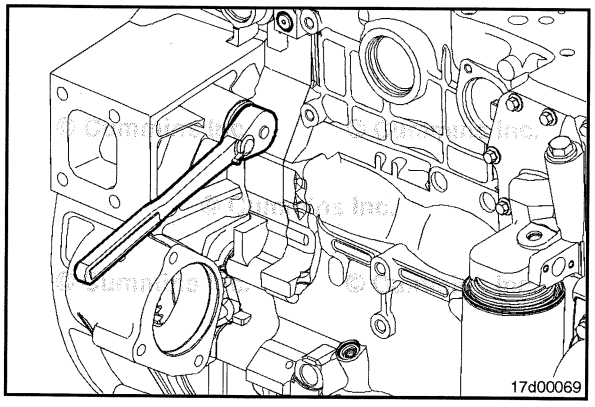
NOTE: The clearance is correct when some resistance is "felt" when the feeler gauge is slipped between the crosshead and the rocker lever socket.

Measure lash by inserting a feeler gauge between the crosshead and the rocker lever socket. If the lash measurement is out of specification, loosen the locknut and adjust the lash to nominal specifications.

Valve Lash Specifications (Nominal)	
	mm
Intake	0.33
Exhaust	0.58

Tighten the locknut and measure the lash again.

Torque Value: 24 N•m [212 in-lb]



Use barring tool, Cummins® Part Number 3824591, to rotate the crankshaft 360 degrees.

Following the same steps and specifications as previously stated, measure lash for the following rocker levers:

(E = exhaust, I = Intake)

2E, 3I, 4E, and 4I

Adjust the lash, if out of specification.

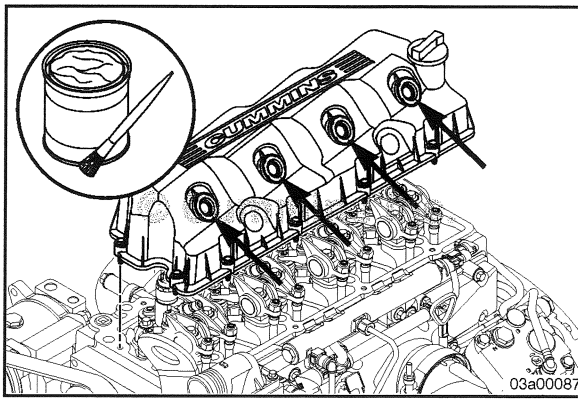
Rocker Lever Cover (003-011)

Install

Use 15W-40 lubricating oil or Lubriplate® #4 to lubricate the fuel line pass-through grommet seals.

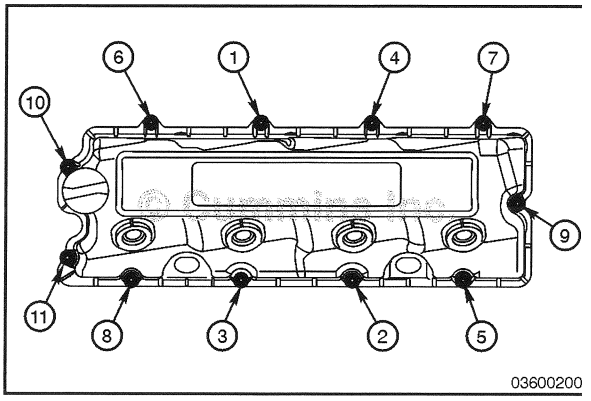
Install the rocker lever cover.

Install the mounting capscrews.



Tighten the mounting capscrews in the sequence shown.

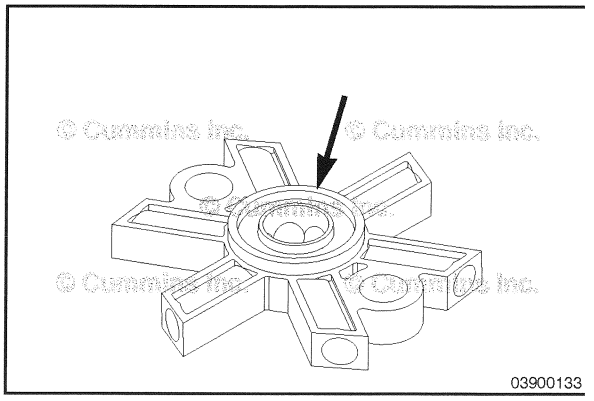
Torque Value: 9 N•m [80 in-lb]



Crankcase Breather (Internal) (003-002)

Install

Be sure the seal is in place on the front face of the breather disc nose.

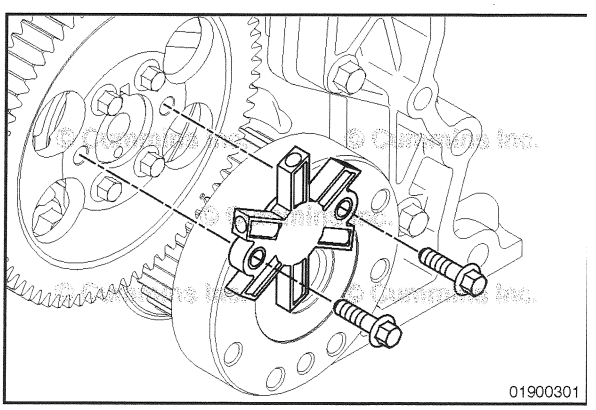


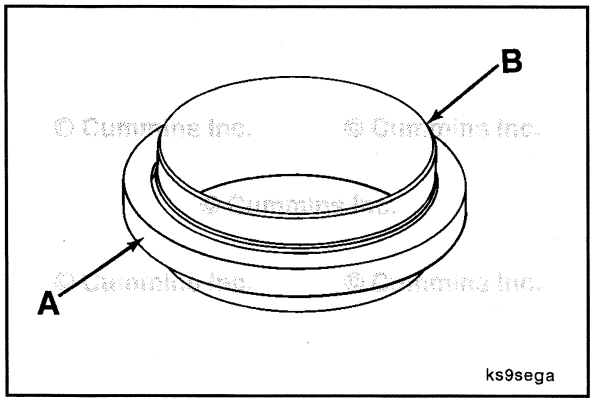
Install the breather disc onto the camshaft gear.

Lubricate the capscrew threads with clean lubricating oil.

Install the two mounting capscrews and tighten.

Torque Value: 28 N•m [248 in-lb]





Crankshaft Wear Sleeve, Rear (001-067)

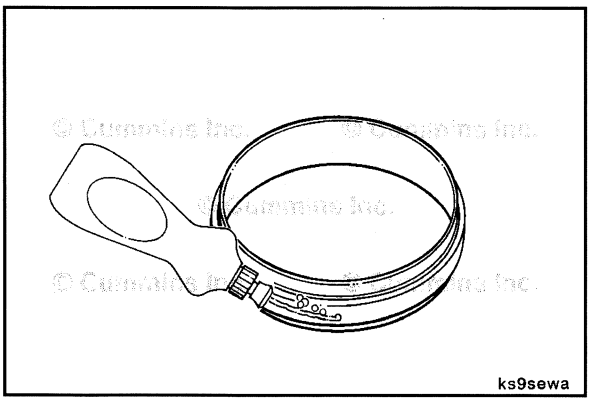
Install

NOTE: The replacement oversize seal may appear different than the standard size seal.

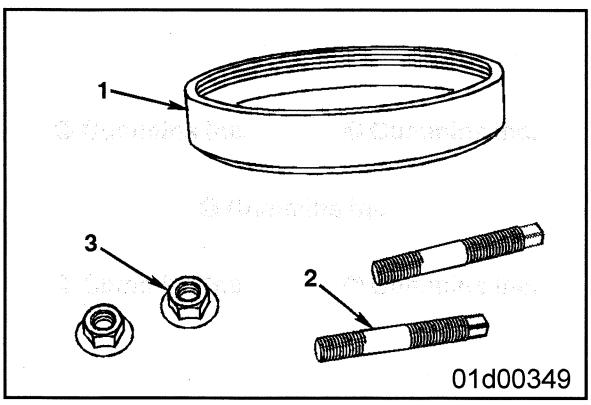
⚠CAUTION⚠
The new rear crankshaft seal should not be removed from the crankshaft rear seal wear sleeve. Damage to the sealing lips may occur when reinstalling the seal onto the wear sleeve.

The new oversize seal and wear sleeve comes pre-assembled and will be installed on the crankshaft as an assembly.

- Crankshaft oil seal.
- Wear sleeve.



To aid in installation, the lubricating oil seal requires the application of a mild soap on the outside diameter of the seal case.



Use service tool, Cummins® Part Number 3824078, to install the crankshaft seal/wear sleeve assembly.

Reference Number	Part Number
1	3163734
2	3163628
3	3163741

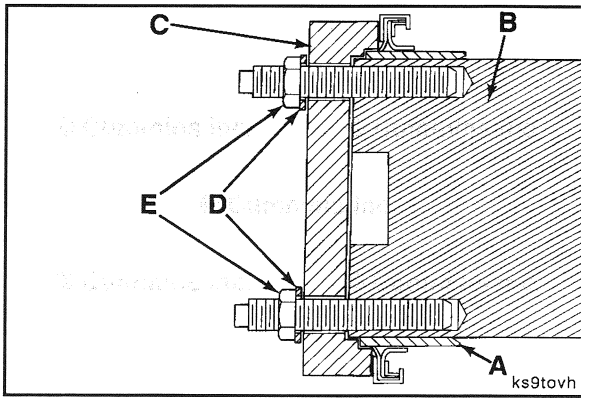
Install two (2) threaded studs into the crankshaft capscrew holes.

Apply a small amount of clean 15W-40 engine oil to the crankshaft, threaded studs, and inside 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.

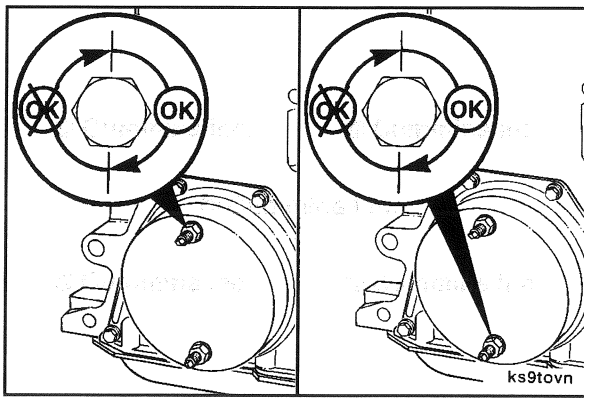


Alternately tighten the nuts ½ of a turn until the installation tool contacts the end of the crankshaft.

Do **not** exceed ½ of a turn of each nut to prevent wear sleeve binding and irregular stretch.

Torque Value: 20 N•m [180 in-lb]

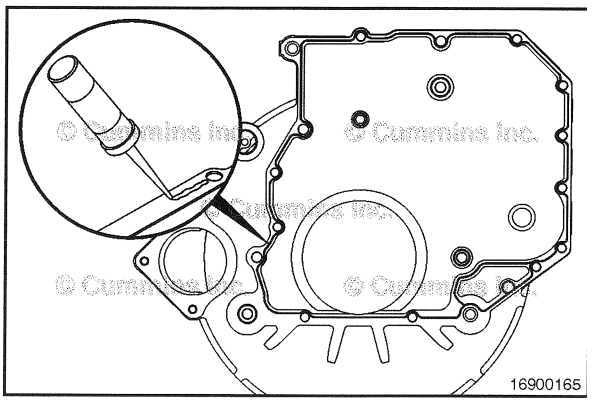
Remove the installation tool and threaded studs.



Flywheel Housing (016-006)

Install

Apply a silicon bead of Loctite™ 509, or equivalent, to the flywheel mounting surface, as shown.



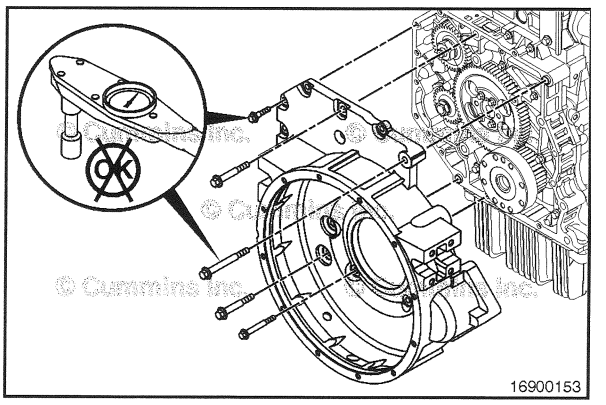
NOTE: Before installing the flywheel housing, make sure any locating dowel rings are in the same position as when the flywheel housing was removed.

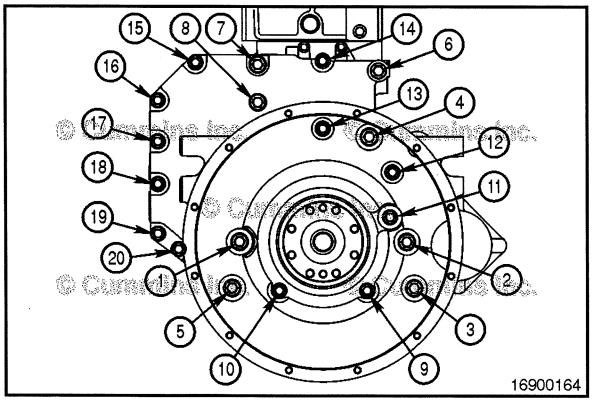
Install a new gasket between the gear housing and the flywheel housing.

Install the flywheel housing and capscrews.

Tighten the flywheel housing capscrews finger tight.

NOTE: Some engines are equipped with one additional capscrew **not** shown in the illustration. Tighten this capscrew last in the sequence.

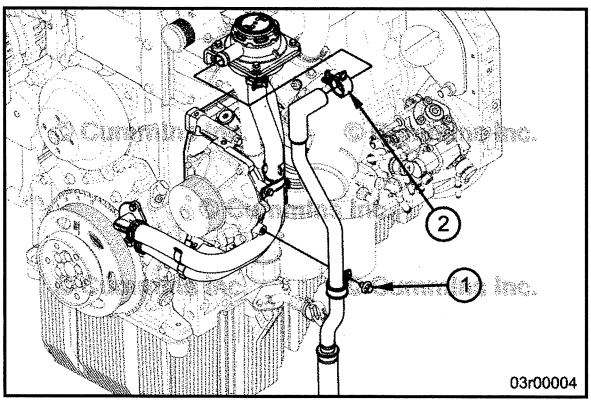




See the illustration for the flywheel housing capscrew torque sequence.

Torque Value:
M10 49 N•m [36 ft-lb]

Torque Value:
M12 85 N•m [63 ft-lb]



Crankcase Breather Tube (003-018)

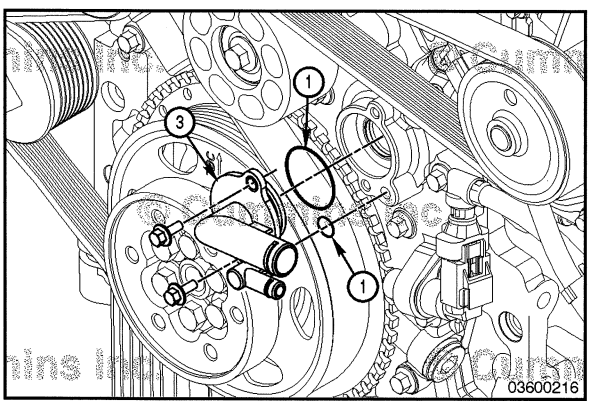
Install

Install the crankcase breather tube.

Secure the crankcase breather tube with a spring clamp (2).

Install the P-clip and capscrew (1).

Torque Value: 18 N•m [159 in-lb]



Crankcase Breather Adapter (003-031)

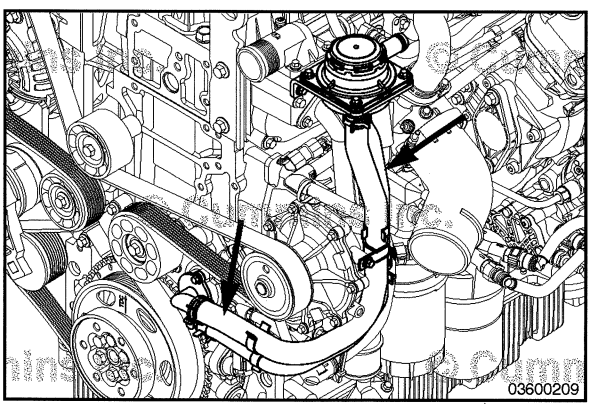
Install

Lubricate the o-ring (1) with clean lubricating oil and install it into the groove of the crankcase breather adapter (3).

Apply Loctite™ 406 or equivalent, to the o-ring (2) and bond it to the crankcase breather adapter (3).

Install the breather adapter to the front cover and tighten the two capscrews.

Torque Value: 7.5 N•m [66 in-lb]



Install the crankcase breather adapter hoses and crankcase oil drain line to the open crankcase ventilation valve.

- Refer to Procedure 003-026 in Section 3.
- Refer to Procedure 003-037 in Section 3.

Crankshaft Seal, Rear (001-024)

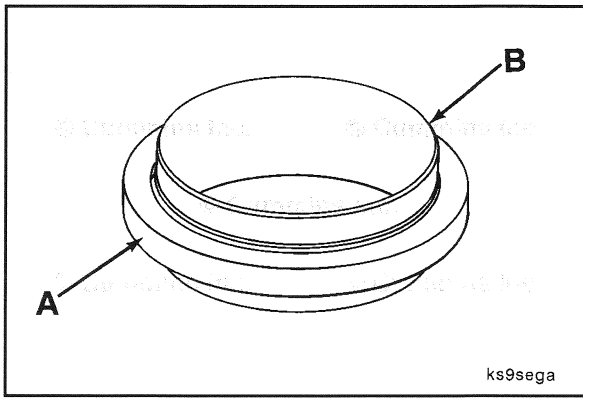
Install

⚠CAUTION⚠
Always replace the rear crankshaft seal with the same style seal as was previously installed to prevent oil leaks.

⚠CAUTION⚠
The seal lip/bore and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

To aid in installation, apply a mild soap solution to the outside diameter of the seal case (A).

NOTE: A seal pilot (B) is provided with the new seal. The seal **must** be left on the seal pilot while installing the seal onto the rear crankshaft flange. This will make sure the lips of the seal are **not** damaged during installation.

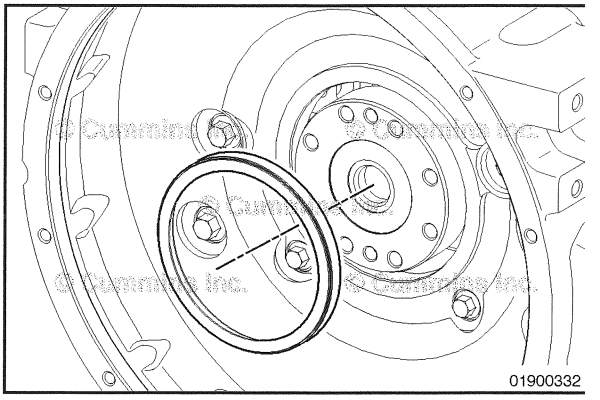


⚠CAUTION⚠
Always replace the rear crankshaft seal with the same style seal as was previously installed to prevent oil leaks.

Place the new rear crankshaft seal, with the seal pilot if required, over the crankshaft flange and slide it by hand toward the flywheel housing.

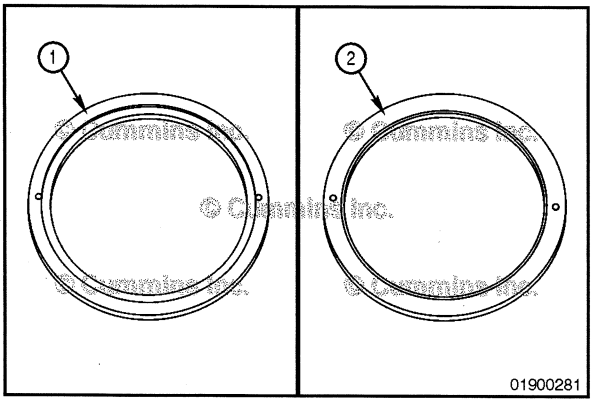
NOTE: Make certain the seal is positioned squarely with the crankshaft.

If used, remove the seal pilot.



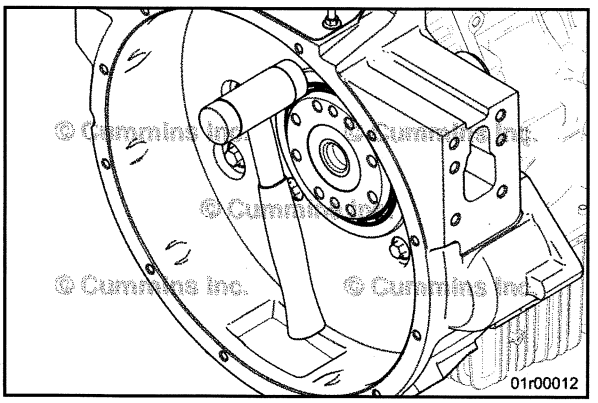
Each new lip style crankshaft seal comes with a disposable seal driver.

- The seal driver for rear gear train engines, which is typically a plastic ring, will install the crankshaft seal to the proper depth in the flywheel housing bore.



The disposable plastic driver that comes with the new rear crankshaft seal is designed to be used with two types of seals.

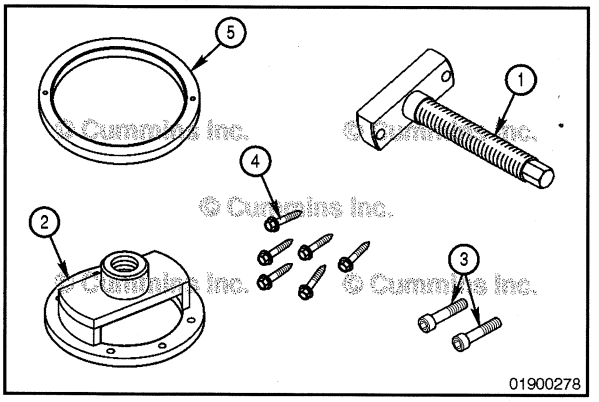
- A double outer dust lip rear crankshaft seal - for this type of seal, the side of the disposable driver (1) with the large chamfer on the inner diameter **must** be used to contact the seal.
- A single outer dust lip rear crankshaft seal - for this type of seal, the side of the disposable driver (2) with the small chamfer on the inner diameter **must** be used to contact the rear crankshaft seal.



NOTE: It can be necessary to lightly tap the rear crankshaft seal with a plastic hammer, without the disposable seal driver, to help start the rear crankshaft seal in the flywheel housing bore.

With the rear crankshaft seal installed onto the crankshaft flange as described earlier in this procedure, use the appropriate disposable seal driver that comes with each new rear crankshaft seal to install the crankshaft seal to the correct depth in the housing.

Use a plastic hammer to drive the crankshaft seal into the housing until the alignment tool stops against the housing. Hit the tool at 12, 3, 6 and 9 o'clock positions to drive the crankshaft seal evenly and to prevent bending the seal carrier.



Optional Method

The disposable plastic driver that comes with the new rear crankshaft seal has been designed with two holes in the outer ring. These holes are provided so the driver can be used in conjunction with the Rear Crankshaft Seal Replacer Kit, Cummins® Part Number 4919533.

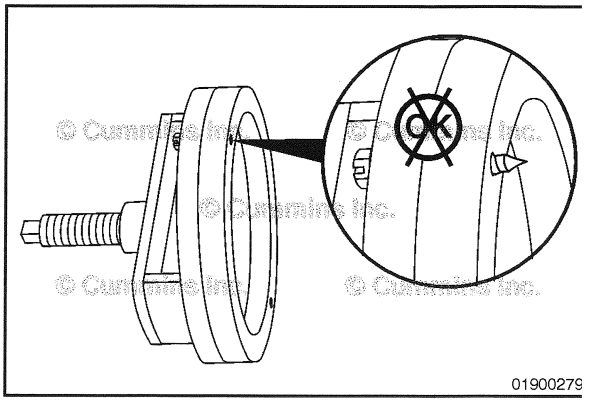
Table 2. Rear Crankshaft Seal Replacer Kit, Cummins® Part

Item Number	Part Number	Descr
1	3164666	Repla
2	4919534	Crank
3	3164174	Soc M12 x
4	3164217	Sheet 10 x 2
Not shown	3164218	Drill. 3
5	—	Disp (p cranks

⚠CAUTION⚠
Do not use the sheet metal screws that come with the Rear Crankshaft Seal Replacer Kit, service tool Cummins® Part Number 4919533. The sheet metal screws are too long. When selecting the correct sheet metal screw, make sure the tip of the sheet metal screw does not protrude past the face of the driver. Damage to the crankshaft seal will result.

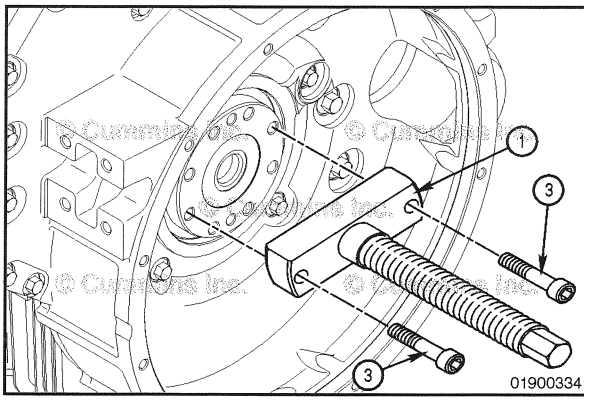
With the correct side of the disposable driver facing outwards for the type of seal that will be installed, center the disposable driver on the crankshaft seal replacer.

Attach the disposable driver to the crankshaft seal replacer using two sheet metal screws (number 10 by 19 mm [0.75 in] long).



With the rear crankshaft seal installed onto the crankshaft flange as described earlier in this procedure, mount the replacer screw assembly (1) onto the rear of the crankshaft.

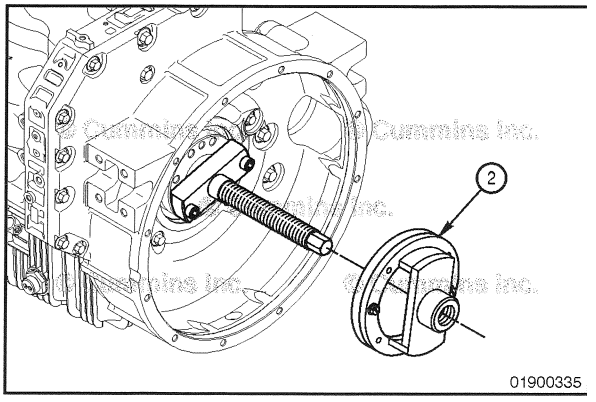
Install the two M12 x 1.25 x 60-mm socket head capscrews (3).



⚠CAUTION⚠
Do not use an impact wrench or air tools. Doing so can damage the tool.

Lubricate the replacer screw with anti-seize compound or a suitable grease.

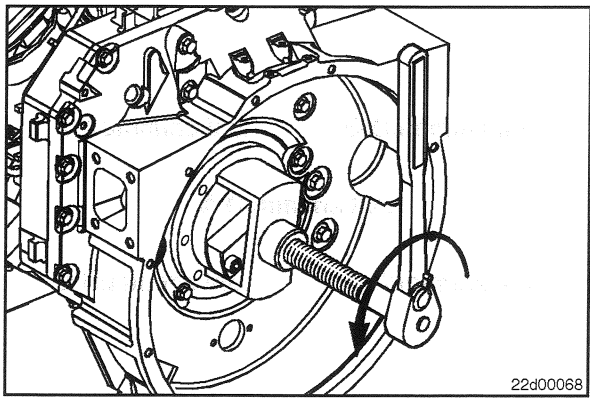
Hold the replacer screw and install the crankshaft seal replacer (2) onto the replacer screw assembly. Advance the crankshaft seal replacer toward the seal by rotating it **clockwise** until the attached disposable driver is positioned against the rear crankshaft seal.

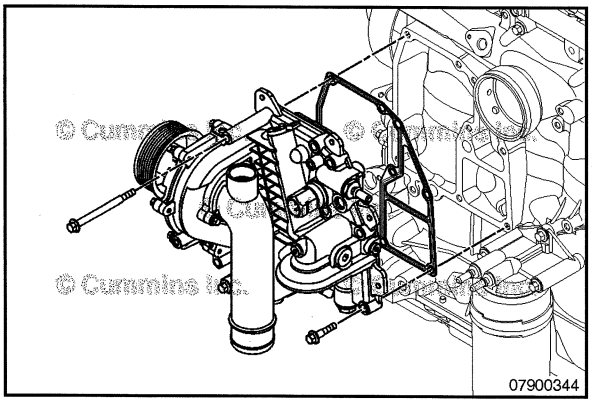


⚠CAUTION⚠
Do not overtighten the replacer screw assembly after the crankshaft seal replacer contacts the flywheel housing. Doing so can damage the tool.

While holding the crankshaft seal replacer, rotate the replacer screw counterclockwise until the disposable driver attached to the crankshaft seal replacer makes contact with the flywheel housing.

Remove the service tools.

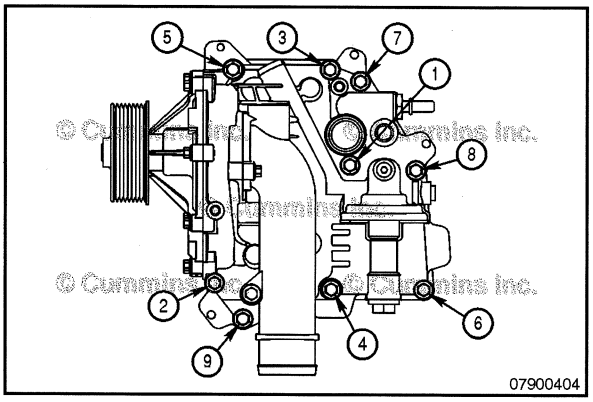




Lubricating Oil Cooler (007-003)

Install

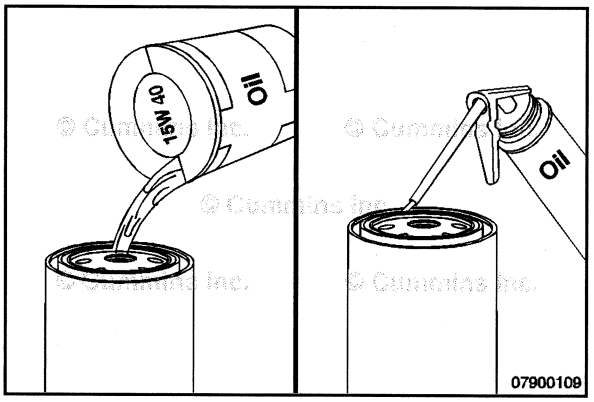
Install the water pump/lubricating oil cooler housing and the mounting capscrews to the side of the engine.



Tighten the capscrews in the sequence shown.

NOTE: Snug capscrew numbers six and eight, then tighten in the sequence shown.

Torque Value: 27 N•m [239 in-lb]



Lubricating Oil Filter (Spin-On) (007-013)

Install

⚠CAUTION⚠
The lack of lubrication during the delay until the filter is pumped full of oil at start-up can damage the engine.

Use clean 15W-40 oil to coat the gasket surface of the filter.

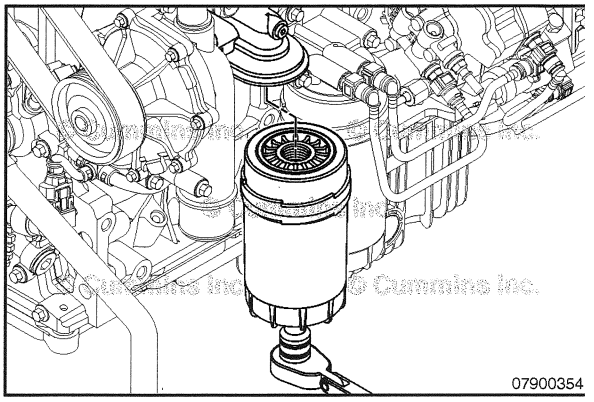
Fill the filter with clean 15W-40 oil.

NOTE: Be careful that no debris is 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 create debris in the oil container.

⚠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.

Tighten 3/4 turn to 1 turn after gasket makes contact with the filter head.



Water Inlet Connection (008-082)

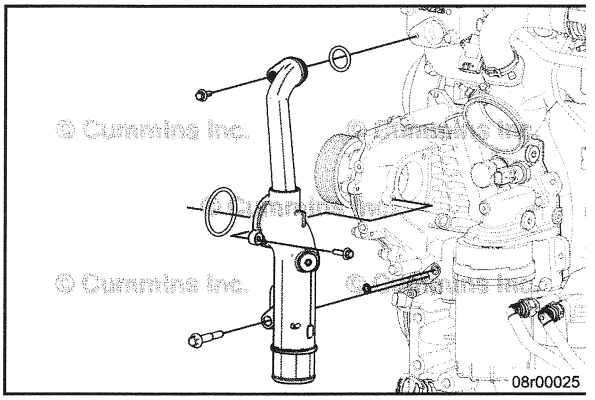
Install

Install the capscrews, water inlet connection, and o-rings.

Torque Value:
M6 9 N•m [80 in-lb]

Torque Value:
M8 13 N•m [115 in-lb]

Install the coolant hose(s).



Exhaust Manifold, Dry (011-007)

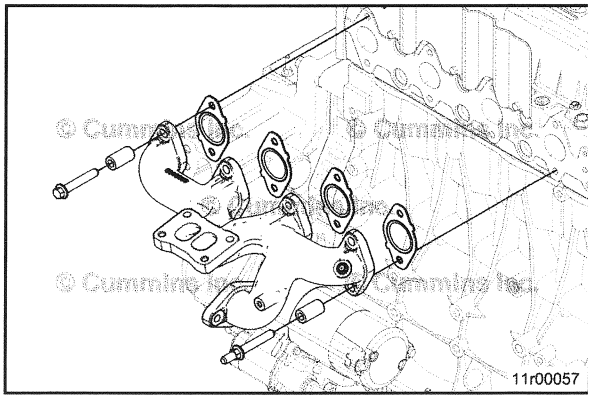
Install

Remove the tape from the open exhaust ports and cylinder head. Install two guide studs, Cummins® Part Number 3163934, into the center section mounting location.

Apply high-temperature anti-seize compound to the exhaust manifold capscrew threads.

Install new lockplates, if equipped.

Install the new gaskets, exhaust manifold, and spacers.



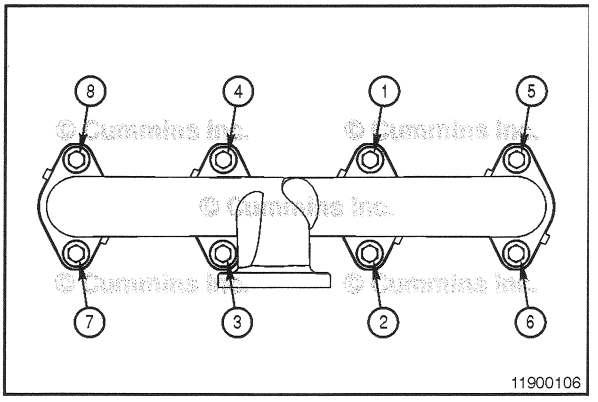
Follow the tightening sequence shown in the illustration.

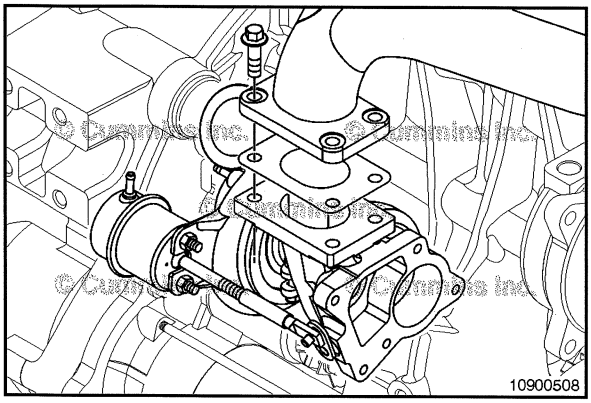
Tighten the exhaust manifold mounting capscrews.

Torque Value: 53 N•m [39 ft-lb]

Install heat shield.

Torque Value: 23 N•m [204 in-lb]





Turbocharger (010-033)

Install

⚠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.

△CAUTION△
The new gasket must match the one that was removed. Use of the incorrect gasket will result in turbocharger damage. Never reuse a turbocharger mounting gasket.

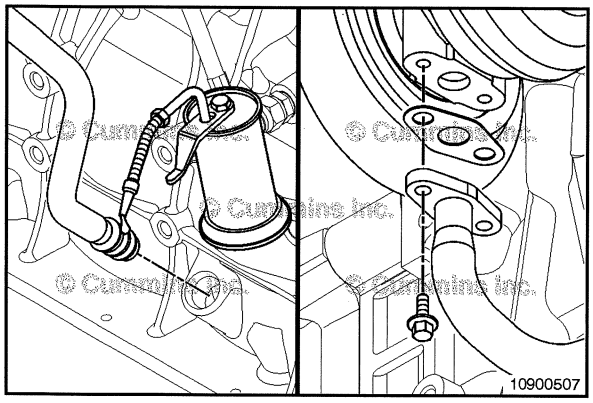
Apply a film of high-temperature anti-seize compound to the turbocharger mounting studs.

Use a new gasket and install the turbocharger.

Install and tighten the four mounting nuts.

NOTE: The torque values given have been established with the use of anti-seize compound as a lubricant.

Torque Value: 24 N•m [212 in-lb]



Turbocharger Oil Drain Line (010-045)

Install

Install new o-rings onto the turbocharger oil drain line.

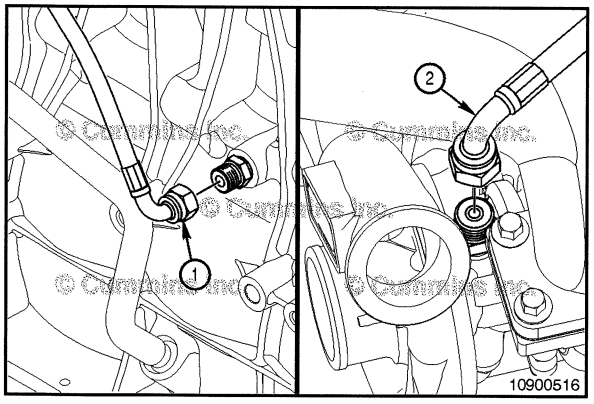
Apply a thin film of oil to the drain line o-rings.

Push the drain line into the drain line boss. Be sure both o-rings are completely seated in the bore.

Install the hose and two spring clamps. Make sure spring clamps or oriented outward.

Install the drain line to the turbocharger bearing housing. Use a new gasket. Install and tighten the drain line capscrews at the bottom of the turbocharger.

Torque Value: 10 N•m [89 in-lb]



Turbocharger Oil Supply Line (010-046)

Install

Use new copper sealing washers or o-ring seals.

Install the oil supply line onto the engine block fitting located at the oil rifle connection (1).

NOTE: A wrench will be required to prevent the fitting from rotating in the cylinder block.

Tighten the oil supply line (1)

Torque Value: 35 N•m [26 ft-lb]

Install the turbocharger oil supply line at the bearing housing (2) using two sealing washers and banjo screw.

Torque Value: 16 N•m [142 in-lb]

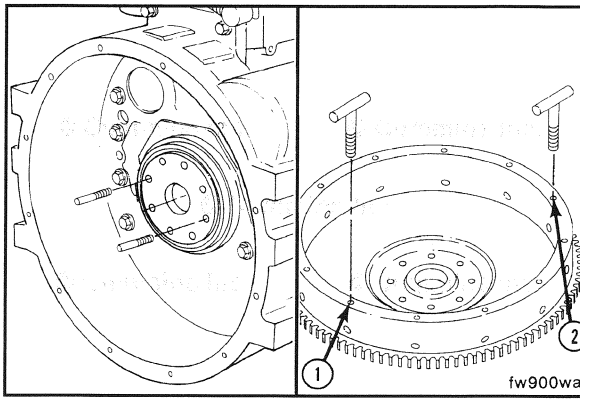
Flywheel (016-005)

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.

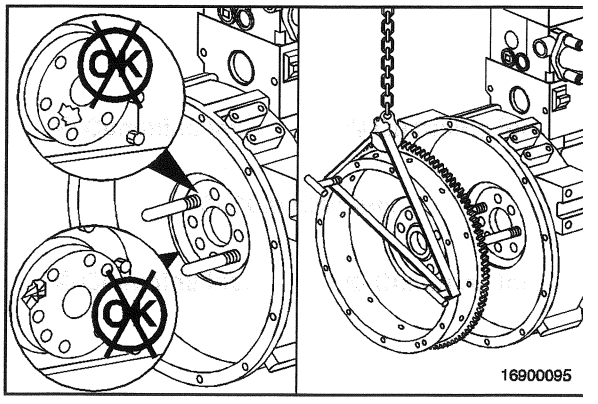
Determine the capscrew thread design and size, and install two T-handles into the flywheel (at points 1 and 2).



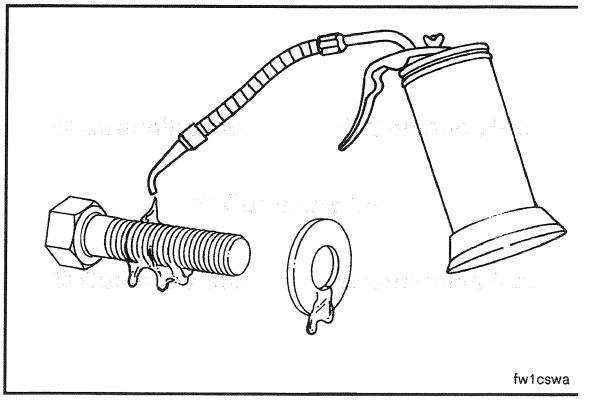
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Inspect the rear face of crankshaft and flywheel mounting flange for cleanliness and raised nicks or burrs.

Install the flywheel on the guide pins.



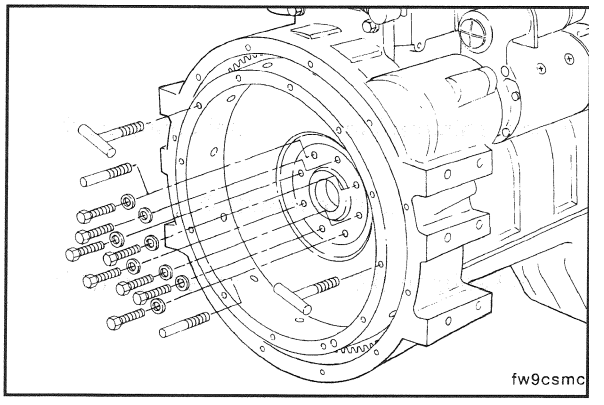
Lubricate the threads of the capscrews and the surface of the washers with clean lubricating engine oil.

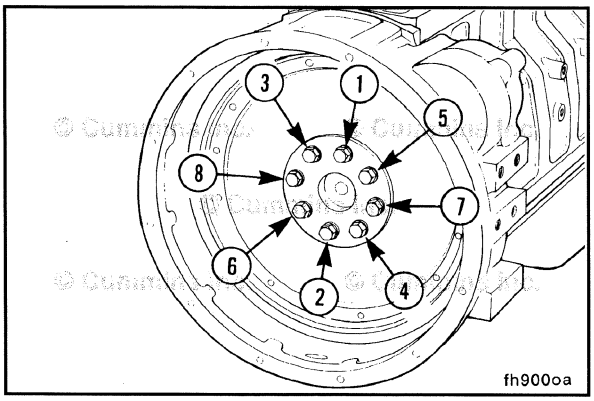


Install the six capscrews.

Remove the T-handles and guide pins.

Install the remaining capscrews into the holes from which the guide pins were removed.



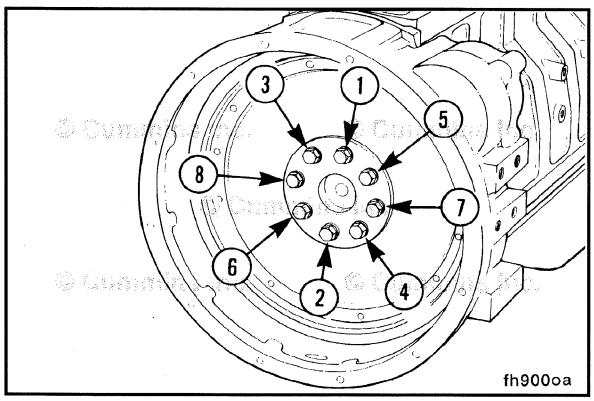


NOTE: Use the barring tool, Cummins® Part Number 3824591, to hold the flywheel to prevent rotation.

Tighten the capscrews in a star pattern.

Torque Value:

Step 1	30 N•m	[22 ft-lb]
Step 2	Plus 90-degree turn	



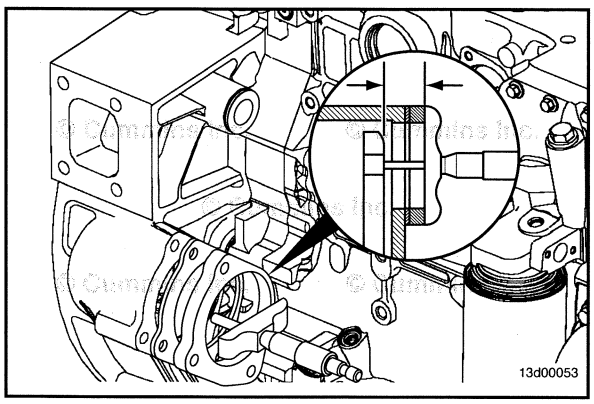
Flexplate (016-004)

Install

NOTE: Some flexplates require mounting plates and/or clamp rings. It will be necessary to install any mounting plates and/or clamp rings prior to or with the flexplate as noted during removal.

Install the flexplate capscrews and flexplate, and tighten the capscrews.

Torque Value:
Flexplate Capscrews 30 N•m [22 ft-lb]



Starting Motor (013-020)

Measure

Use an inside micrometer or a vernier caliper to measure the distance from the starting motor mounting flange to the forward face of the front side of the flywheel ring gear.

NOTE: Include any spacers previously removed when completing the measurement.

Starting Motor Spacing

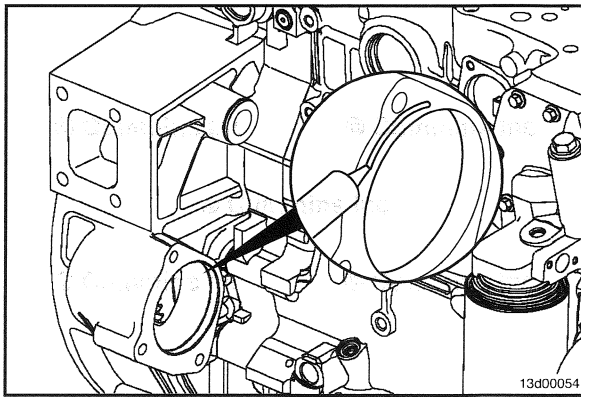
mm		in
49.28	MIN	1.94
52.32	MAX	2.06

Add or remove spacers as necessary to achieve the correct starting motor spacing.

Install

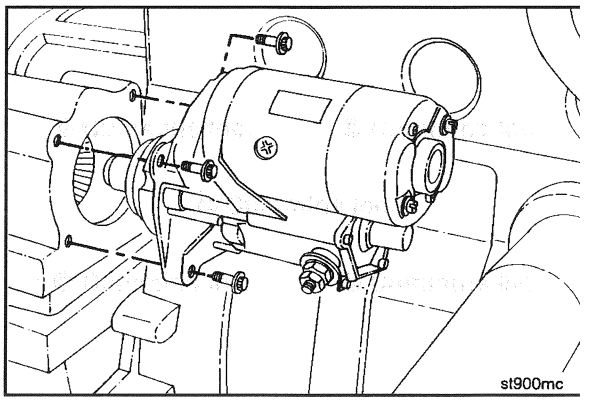
For engines with wet flywheel housings, apply a 1.5 to 2.0 mm [0.06 to 0.09 in] wide bead of sealant, Cummins® Part Number 3164067, to the flywheel housing starting motor mounting flange.

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

⚠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△
Do not overtighten the electrical connections. Starter damage can result.

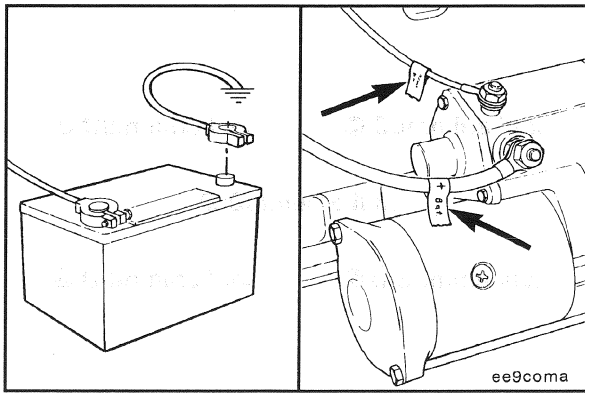
NOTE: Use the location tags to help identify where each wire connection goes.

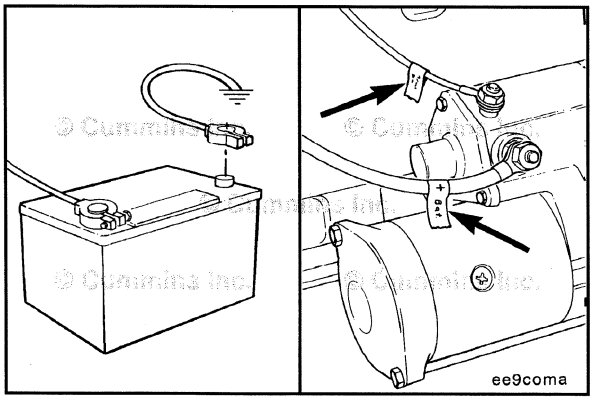
Connect the electrical connections to the starter motor.

Torque Value:
M5 4 N•m [35 in-lb]

Torque Value:
M10 21 N•m [186 in-lb]

Connect the ground cable to the battery terminal.





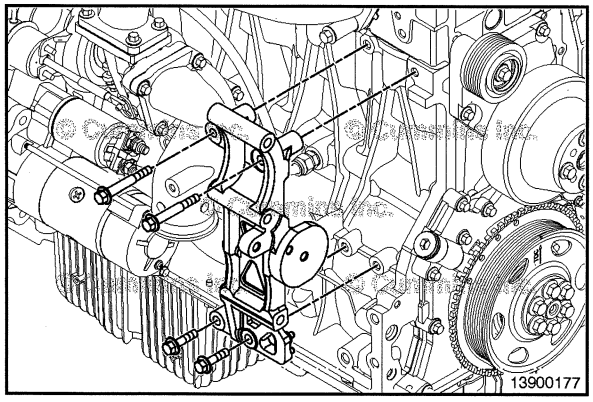
Non-Cummins® Branded Starters

⚠CAUTION⚠
Do not overtighten the electrical connections. Starter damage can result.

NOTE: Use the location tags to help identify where each wire connection goes.

Install the starter motor electrical connections.

For Non-Cummins® branded starters, see equipment manufacturer service information for torque specifications.



Charging System Alternator Bracket (013-003)

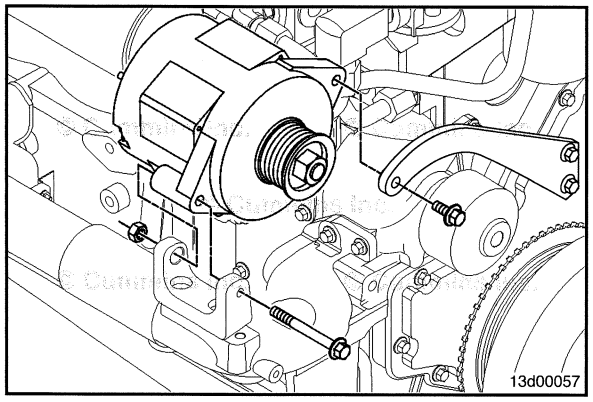
Install

Install the upper alternator bracket and mounting capscrews.

Install the lower alternator bracket and mounting capscrews.

Tighten the upper and lower alternator bracket mounting capscrews.

Torque Value: 45 N•m [33 ft-lb]



Charging System Alternator (013-001)

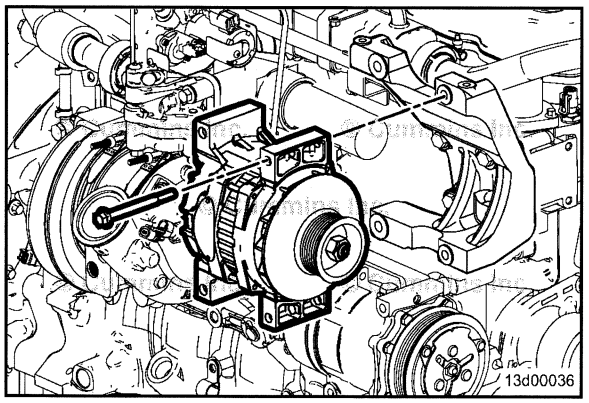
Install

Spool Mount

- Install the alternator and the bottom alternator mounting capscrew and nut.
- Install the upper alternator link mounting capscrew at the top of the alternator.
- Tighten the capscrews.

Torque Value:
Lower Mounting Capscrew 40 N•m [30 ft-lb]

Torque Value:
Upper Link Mounting Capscrew 24 N•m [212 in-lb]



Pad Mount

- Install the alternator.
- Install and tighten the alternator mounting capscrews.

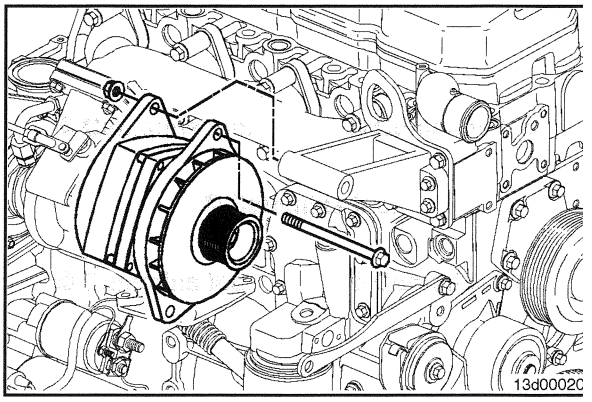
Torque Value:
M10 Capscrew 36 N•m [27 ft-lb]

Torque Value:
M12 Capscrew 64 N•m [47 ft-lb]

Hinge Mount

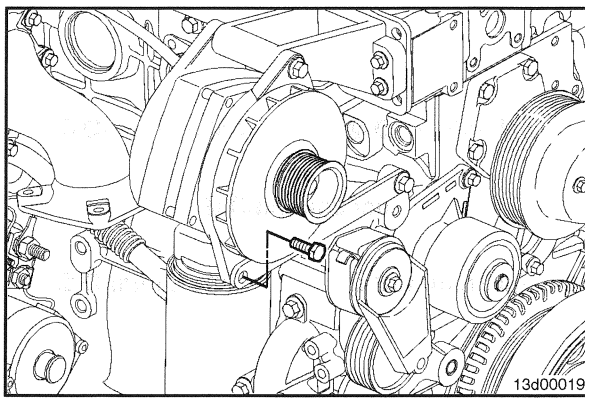
- Install the alternator.
- Install and tighten the alternator mounting capscrew.

Torque Value: 40 N•m [30 ft-lb]



- Install the alternator link capscrew.

Torque Value: 24 N•m [212 in-lb]

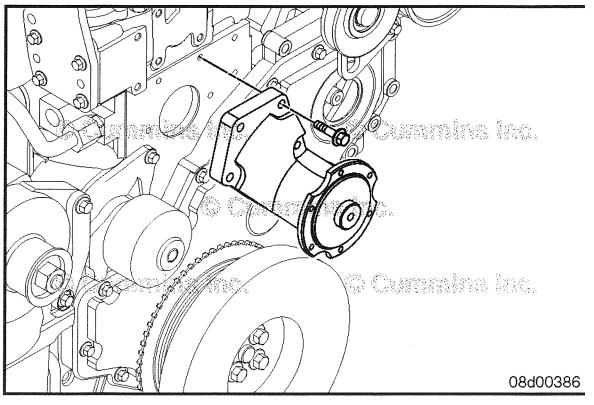


Fan Hub, Belt Driven (008-036)

Install

Install the fan hub and four capscrews.

Torque Value: 32 N•m [24 ft-lb]



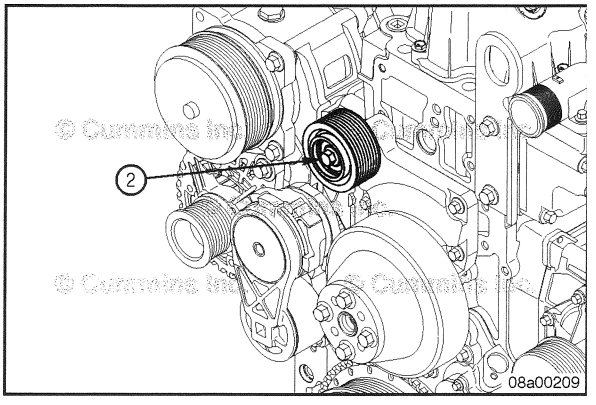
Pulley, Fan Idler (008-111)

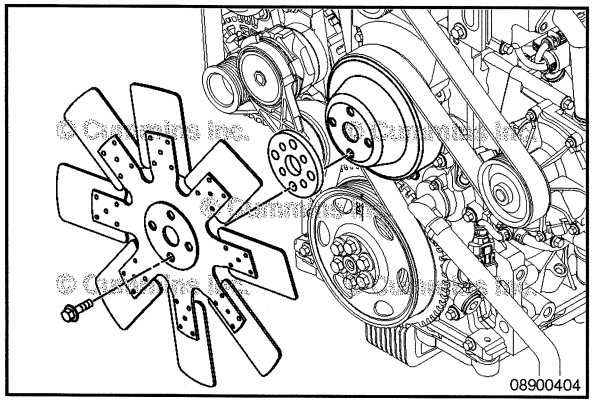
Install

Install the idler pulley and idler pulley mounting capscrew.

Tighten the idler pulley mounting capscrew (2).

Torque Value: 43 N•m [32 in-lb]





Fan Spacer and Pulley (008-039)

Install

Install the fan pulley.

Install the cooling fan and drive belt. Refer to Procedure 008-002 in Section 8.

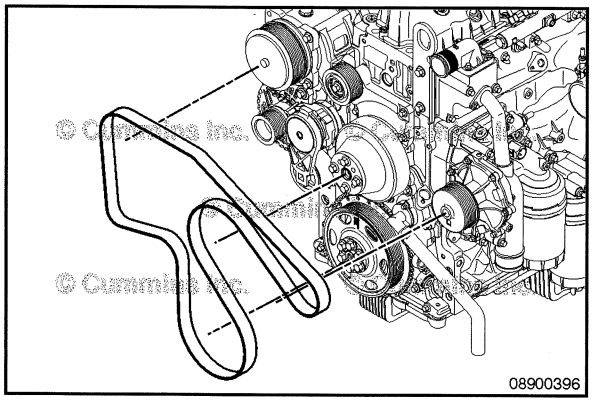
Install the spacer, fan, and fan capscrews.

Torque Value:
M6
Step 1 10 N•m [89 in-lb]

Torque Value:
M10
Step 1 43 N•m [32 ft-lb]

Torque Value:
M12
Step 1 77 N•m [57 ft-lb]

NOTE: Use the tension of the drive belt to hold the cooling fan in place when tightening the mounting capscrews. Do **not** hold the fan blades to keep the cooling fan from rotating.



Drive Belt, Cooling Fan (008-002)

Install

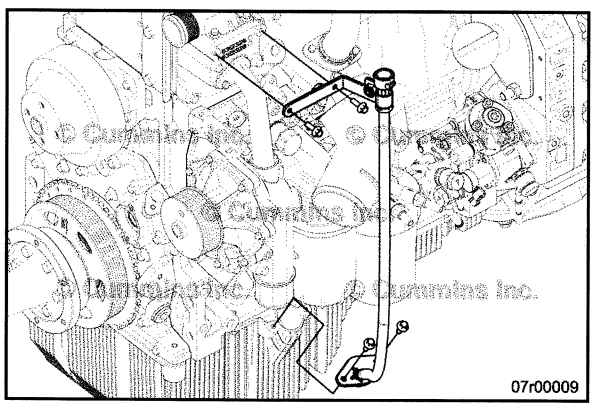
⚠CAUTION⚠
The belt tensioner is spring-loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

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.

Pivot the tensioner in the direction of the spring tang and install the drive belt, slipping the belt over the water pump pulley last.

Release the tensioner to apply tension to the drive belt.

Check the alignment of the belt with the tensioner and the rest of the front-end auxiliary drive.



Lubricating Oil Dipstick Tube (007-011)

Install

Long dipstick with front oil pan sump:

Install dipstick tube into lubricating oil pan.

Tighten the dipstick tube retaining capscrew.

Torque Value: 5 N•m [44 in-lb]

Install dipstick support bracket mounting capscrew.

Torque Value: 24 N•m [212 in-lb]

Long dipstick with rear oil pan sump:

Install dipstick tube into lubricating oil pan.

Tighten the dipstick tube retaining capscrew.

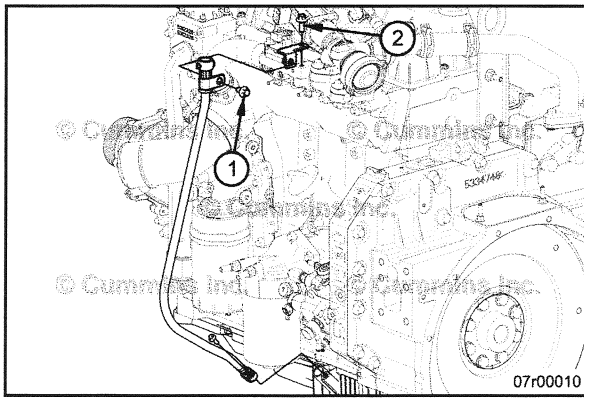
Torque Value: 5 N•m [44 in-lb]

Install dipstick tube support bracket capscrew on the air transfer tube (2).

Install dipstick tube brace capscrew onto dipstick tube support (1).

Torque Value:

Step 1	Capscrew 24 N•m	[212 in-lb]
Step 2	Capscrew 18 N•m	[159 in-lb]

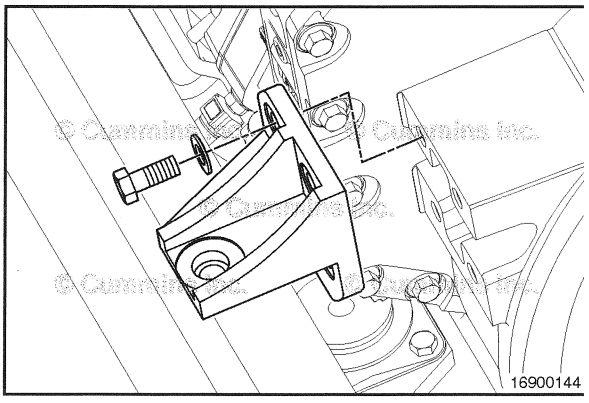


Engine Support Bracket, Rear (016-003)

Install

Install the support bracket and mounting capscrews.

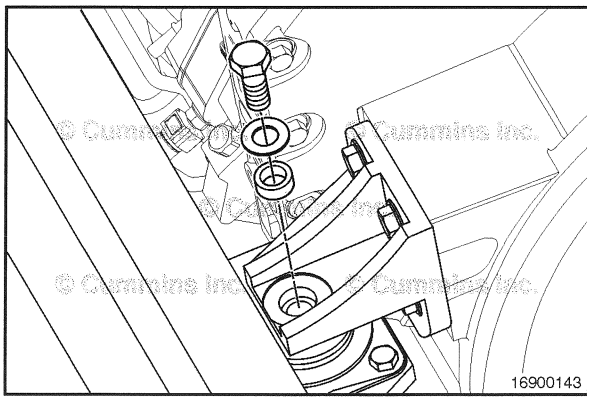
Torque Value: 77 N•m [57 ft-lb]



Install the rear engine mount fasteners.

Tighten to the original equipment manufacturer (OEM) specifications.

Remove the lifting fixture or hoist from the rear of the engine.



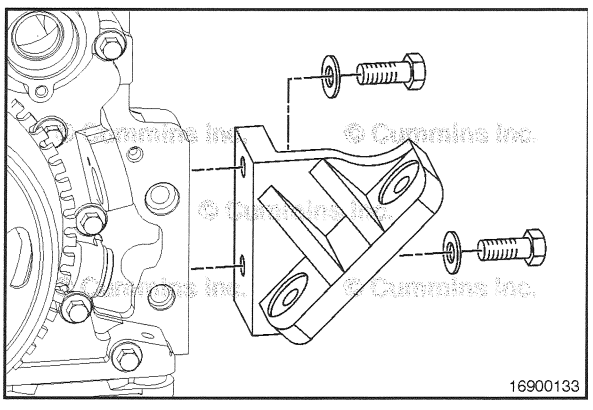
Engine Support Bracket, Front (016-002)

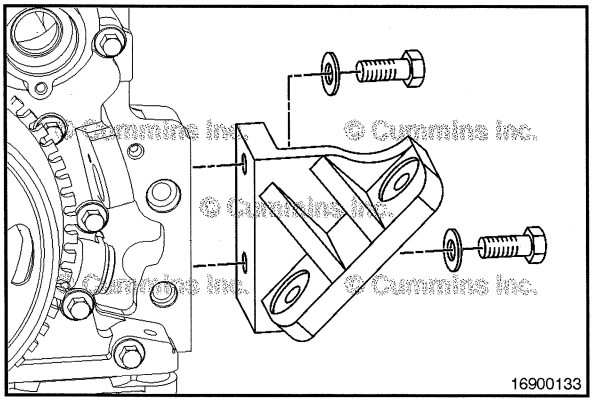
Install

For front mount, install the front mount bracket and capscrews.

Torque Value:
Grade 8.8 80 N•m [60 ft-lb]

Torque Value:
Grade 12.9 125 N•m [95 ft-lb]





For side mount, install the side mount brackets and capscrews.

Torque Value:
Grade 8.8 80 N•m [60 ft-lb]

Torque Value:
Grade 10.9 115 N•m [85 ft-lb]

Torque Value:
Grade 12.9 125 N•m [95 ft-lb]

Section 0 - Product - Group 00

Section Contents

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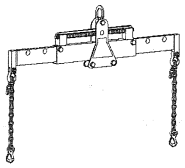
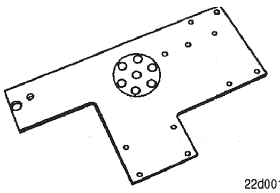
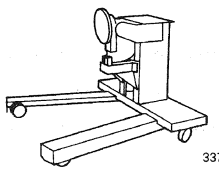
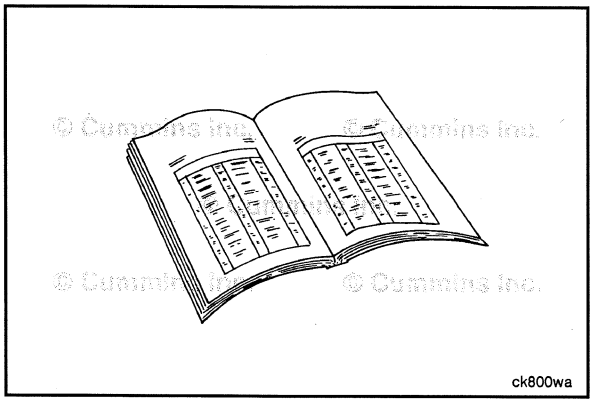
Service Tools

Engine Removal and Installation

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.

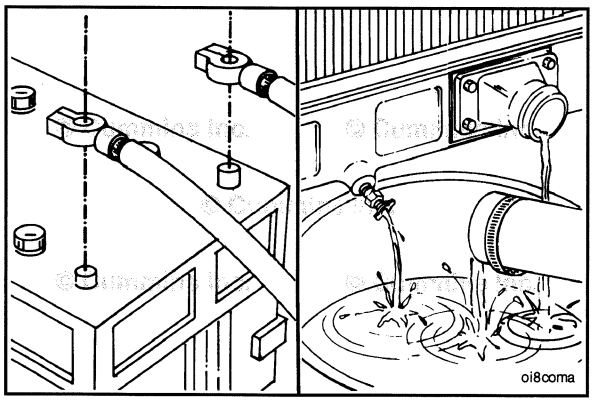
Tool No.	Tool Description	Tool Illustration
3162871	**Engine Lifting Fixture** Used to remove and install the engine.	 3162871
3163625	**Engine Stand Adapter Plate** Used to mount the engine to the rebuild stand.	 22d00144
3375194 or 3375193	**Engine Rebuild Stand** Tilt type of engine rebuild stand: 3375194 - Portable, 3375193 - Stationary	 3375194



Engine Removal (000-001)

General Information

Installations can vary from original equipment manufacturer (OEM) to OEM. Use the following steps as a guideline. See equipment manufacturer service information when necessary.



Remove

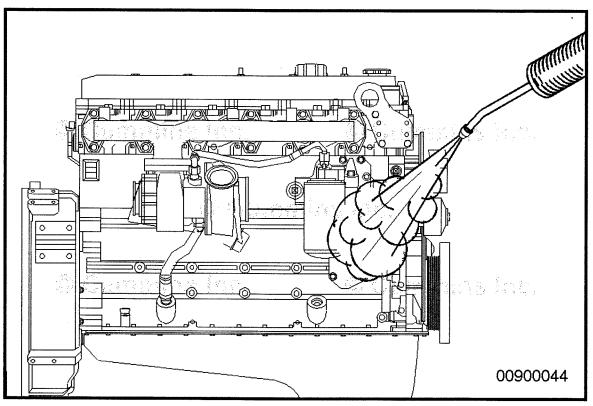
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Coolant is toxic. Keep away from pets and children. 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 temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

Disconnect the battery cables, negative (-) cable first.

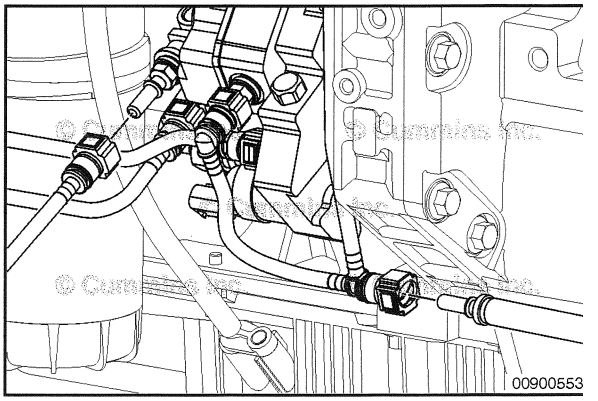
Drain the engine coolant. Refer to Procedure 008-018 in Section 8.



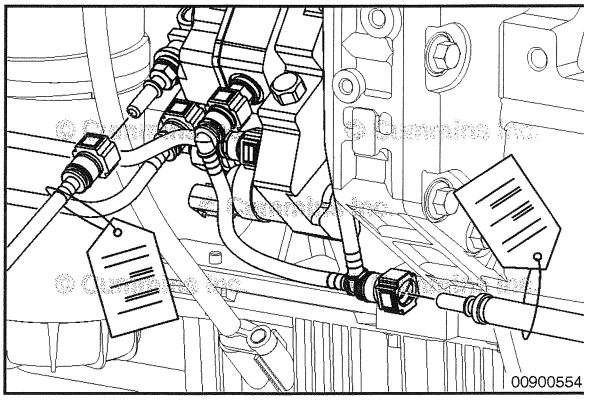
Steam clean the engine. Refer to Procedure 000-009 in Section 0.

⚠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.

Shut off and cap the fuel supply line and fuel return line.



Place a tag on all hoses, lines, linkage, and electrical connections as they are removed to identify their locations.

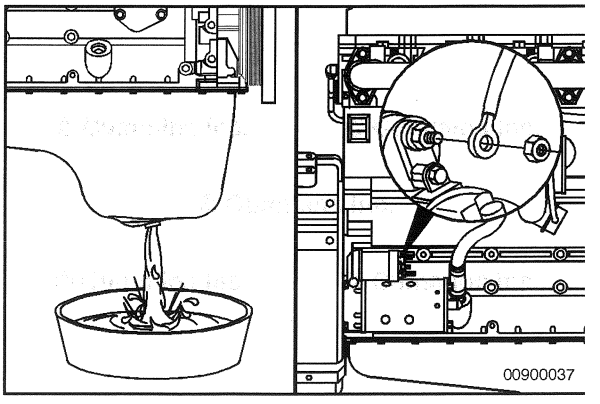


⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.

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

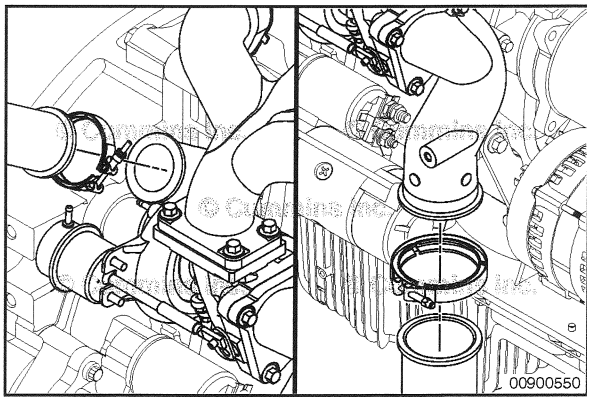
Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.

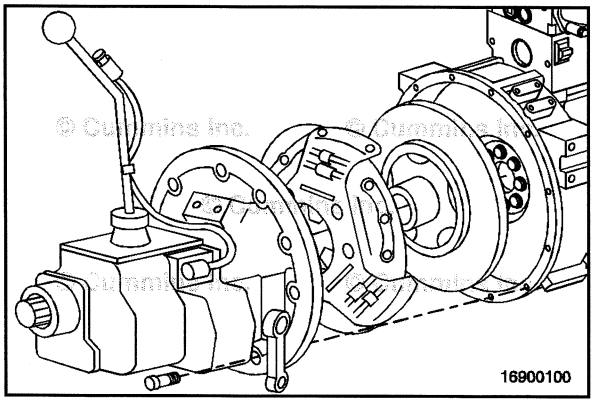
Disconnect the starter cable, engine ground straps, cab or chassis to engine hoses, tubing, electrical wires, wire harnesses, and hydraulic lines.



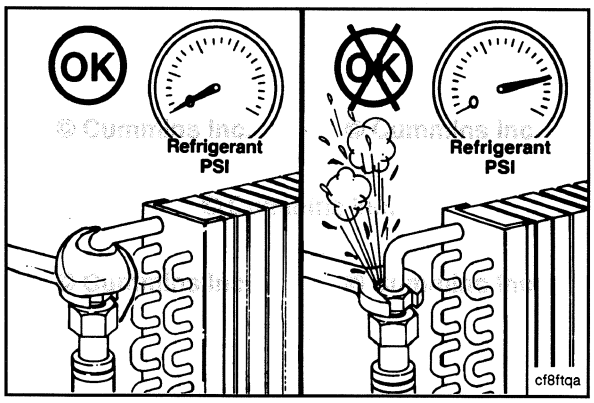
Disconnect the intake and exhaust pipes from the turbocharger. Refer to Procedure 010-022 in Section 10.

Disconnect all chassis-mounted engine-driven accessories.



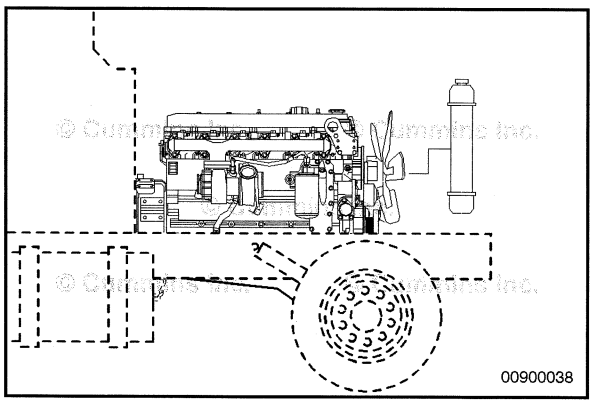


Disconnect the drive units from the flywheel housing. See equipment manfacturer service information for instructions.

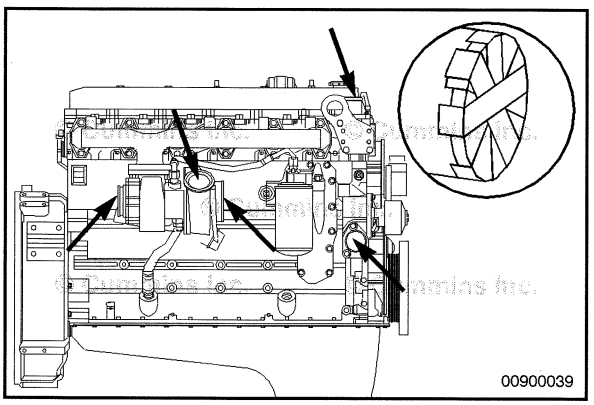


⚠WARNING⚠
If a liquid refrigerant system (air conditioning) is used, wear eye and face protection, and wrap a cloth around the fittings before removing. Liquid refrigerant can cause serious eye and skin injury.

NOTE: For environmental protection, federal regulations require that liquid refrigerant be recycled and **not** vented into the atmosphere. If equipped with a refrigerant compressor, check if there is enough refrigerant hose length to tie and support the compressor on the chassis to prevent the need to evacuate the refrigerant system for engine removal.



Remove all chassis components necessary to remove the engine from the equipment.



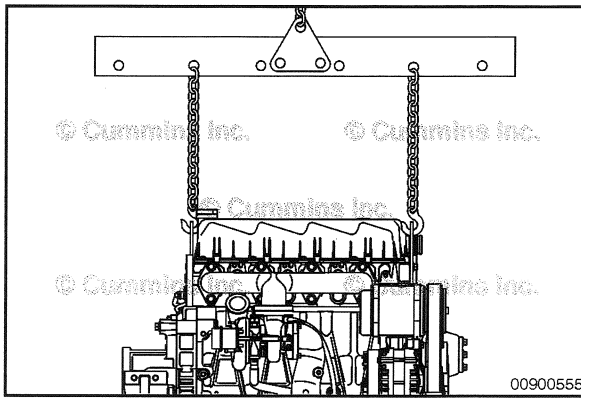
Cover all engine openings to prevent dirt and debris from entering the engine.

⚠WARNING⚠
The engine lifting equipment must be designed to lift the engine and transmission safely as an assembly without causing personal injury. The dry weight of the standard 4 cylinder engine without accessories is 280 kg [617 lb].

△CAUTION△
If the transmission is not removed, place a support under the transmission to prevent it from falling before removing the engine.

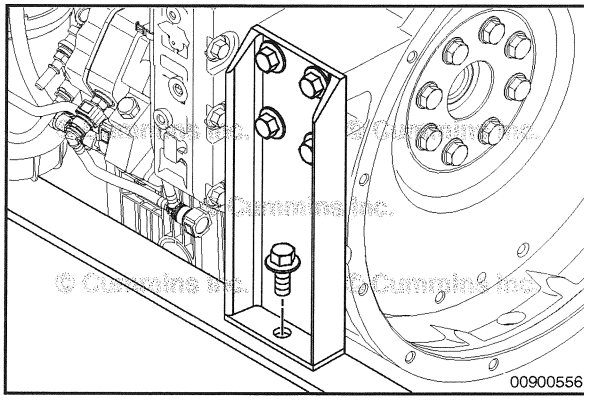
Refer to Procedure 018-015 in Section V.

Use a properly rated hoist and engine lifting fixture, Cummins® Part Number 3162871, attached to the engine-mounted lifting brackets, to remove the engine.



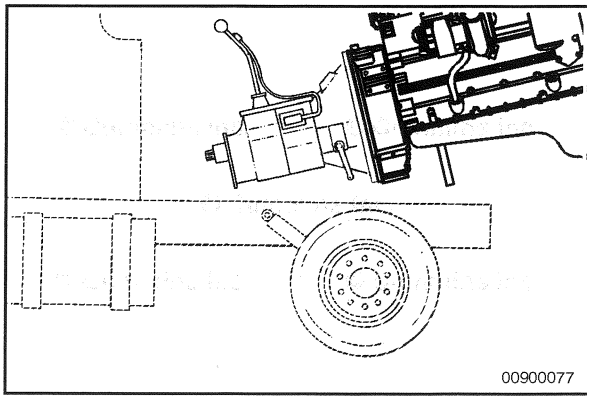
NOTE: When removing the rear engine mount fasteners, keep track of the location of any shims or spacers used.

Remove the engine mount fasteners.



NOTE: On applications in which the rear engine mounts are attached to the transmission, it is often necessary to remove the engine and transmission as an assembly. See equipment manufacturer service information for instructions.

Remove the engine from the vehicle.

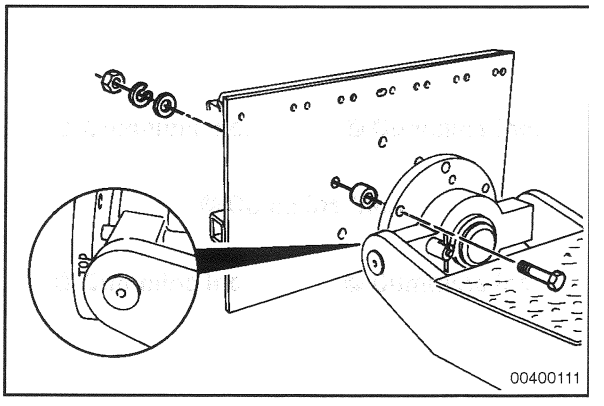


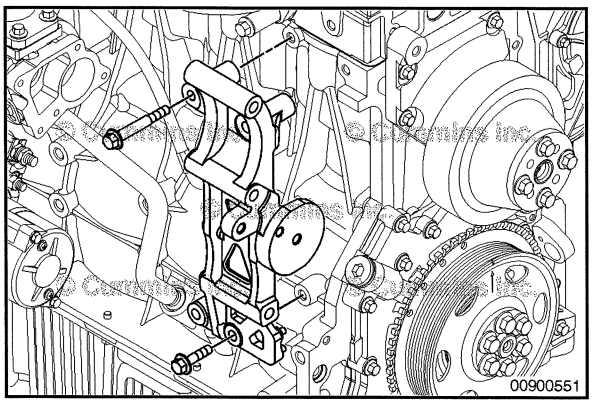
If the engine will be repaired, mount the engine stand adapter plate, Cummins® Part Number 3163625, to the exhaust side of the engine.

NOTE: The turbocharger may need to be removed to install the engine stand adapter plate. Refer to Procedure 010-033 in Section 10.

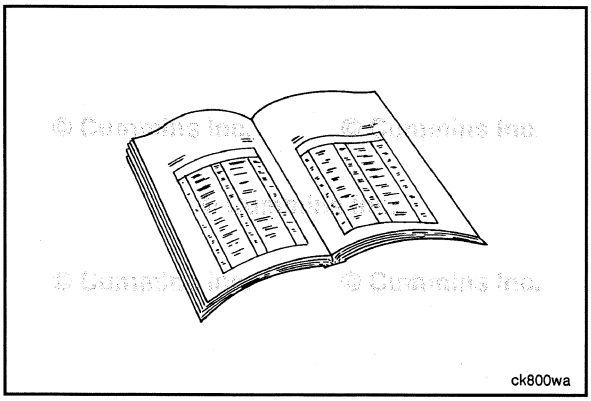
Mount the engine stand adapter plate to the Portable tilt type of engine rebuild stand, Cummins® Part Number 3375194 or 3375193.

If the engine will be replaced, mount the engine on an appropriate shipping pallet.





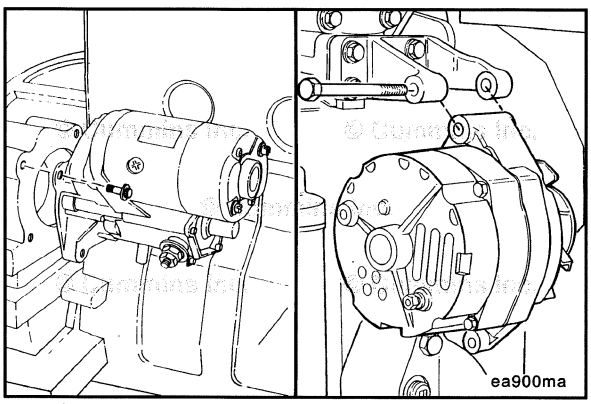
If the engine is to be replaced, remove all remaining accessories, brackets, and drive units that will be used with the replacement engine.



Engine Installation (000-002)

General Information

Installations can vary from original equipment manufacturer (OEM) to OEM. Use the following steps as a guideline. See equipment manufacturer service information when necessary.

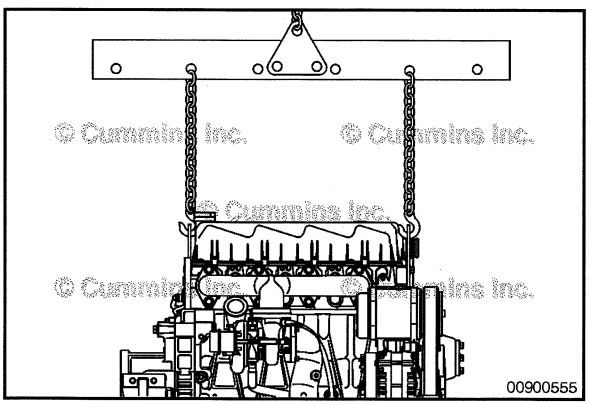


Install

Install all accessories and brackets that were removed from the engine during engine removal.

For engine supplied components, reference the corresponding procedure in this manual.

For vehicle installed components, see equipment manufacturer service information.



⚠WARNING⚠
The engine lifting equipment must be designed to lift the engine and transmission safely as an assembly without causing personal injury. The dry weight of the standard 4 cylinder engine without accessories is 280 kg [617 lb].

Refer to Procedure 018-015 in Section V.

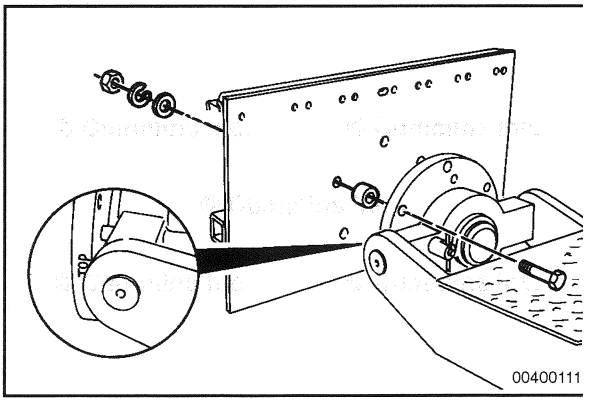
Use a properly rated hoist and engine lifting fixture, Cummins® Part Number 3162871, attached to the engine-mounted lifting brackets, to install the engine.

If the engine was repaired, lift the engine and engine stand adapter plate from the engine rebuild stand.

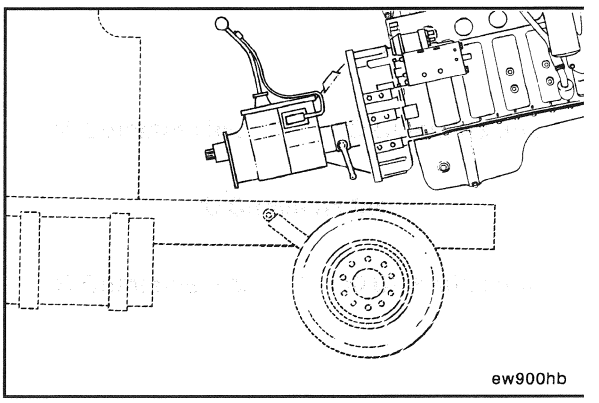
Remove the engine stand adapter plate.

NOTE: The turbocharger may need to be installed after the engine stand adapter plate is removed. Refer to Procedure 010-033 in Section 10.

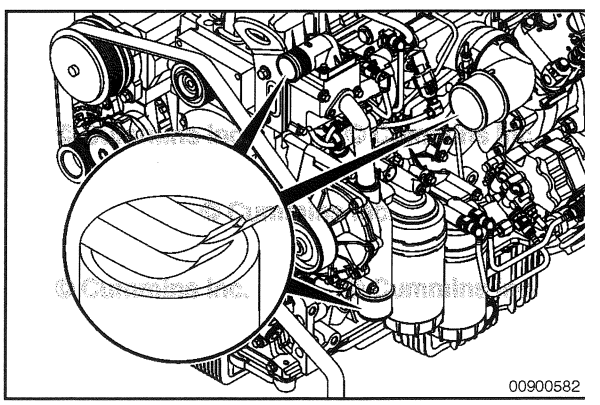
If the engine is a replacement, lift the engine from the shipping pallet.



NOTE: On applications in which the rear engine mounts are attached to the transmission, it is often necessary to install the engine and transmission as an assembly. See equipment manufacturer service information for instructions.



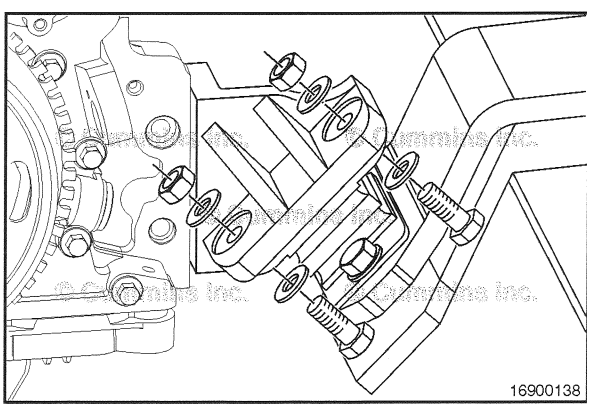
Remove covers from all openings that were covered during removal.

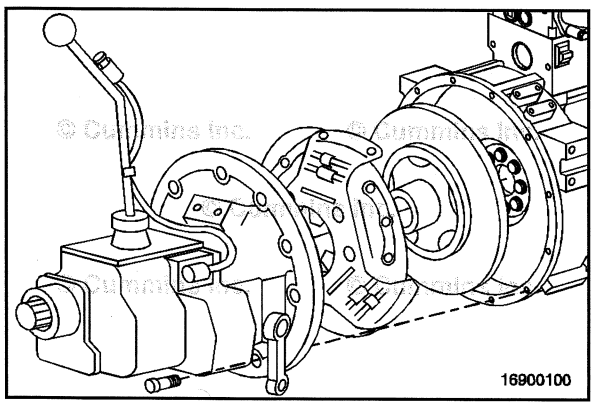


Align the engine in the chassis, and tighten the engine mounting capscrews. See equipment manufacturer service information for torque specifications.

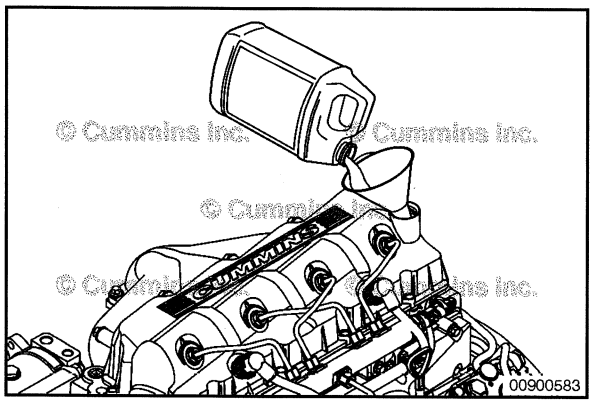
Connect all engine- and chassis-mounted accessories that were removed.

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.

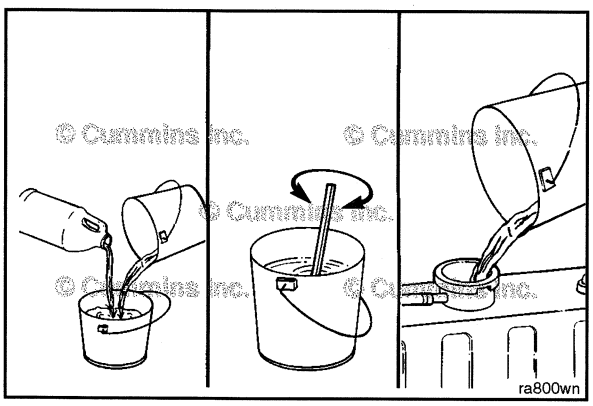




If **not** installed with the engine, connect the drive units to the flywheel housing. See equipment manufacturer service information for instructions.

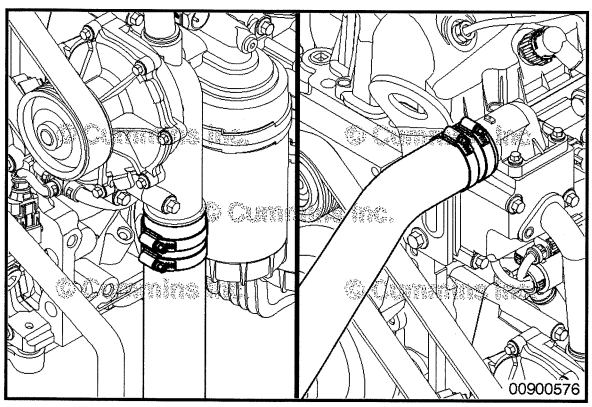


Fill the engine with clean 15W-40 engine oil. Refer to Procedure 007-037 in Section 7.



NOTE: The total coolant capacity of the engines varies. Refer to the original equipment manufacturer's instructions to determine the capacity of the whole cooling system.

Fill the cooling system with new coolant. Refer to Procedure 008-018 in Section 8.

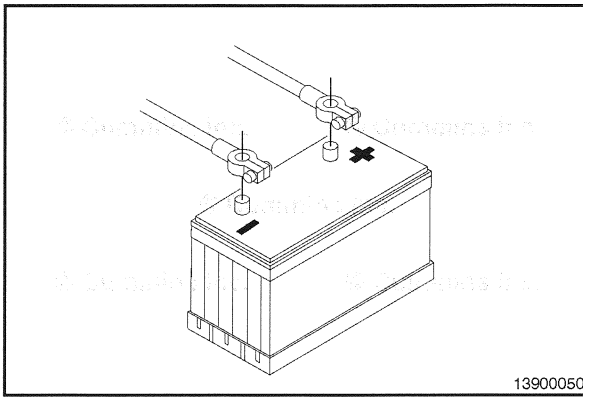


⚠CAUTION⚠
Installation of the cooling system pressure cap at this point is critical for proper purging of air trapped in the cooling system. Improper purging of air from the cooling system will result in engine damage from overheating.

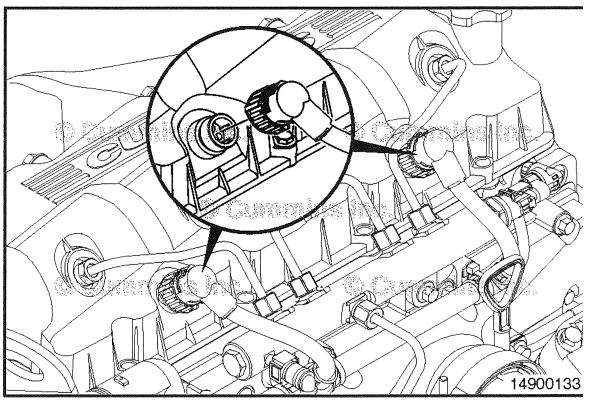
Perform a final inspection to make sure all hoses, wires, linkages, and components have been properly installed and tightened.

⚠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. See equipment manufacturer service information.



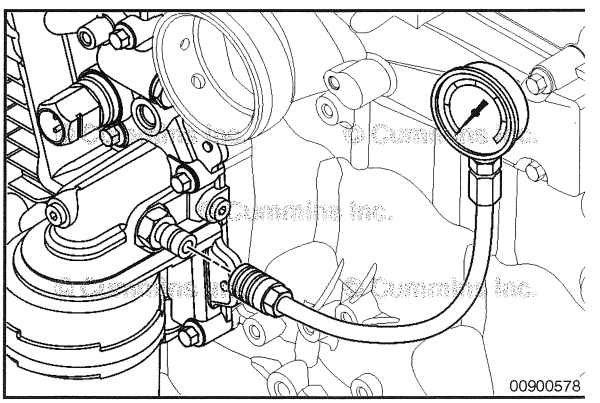
Disconnect the engine injector harness connectors at the rocker housing to make sure the engine will **not** start.



⚠CAUTION⚠
The lubricating oil system must be primed before operating the engine after it has been repaired or rebuilt to avoid internal damage.

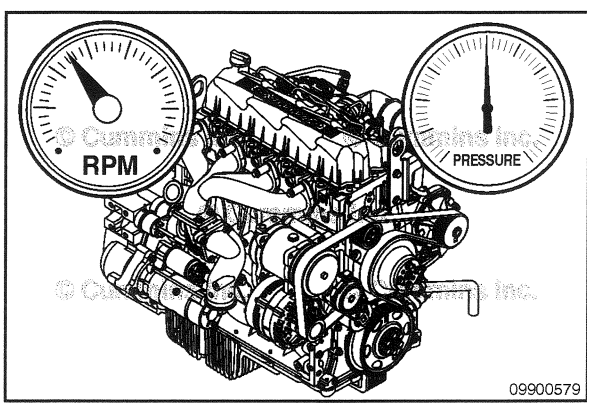
Install a pressure gauge in the main oil rifle on the intake side of the engine to measure oil pressure.

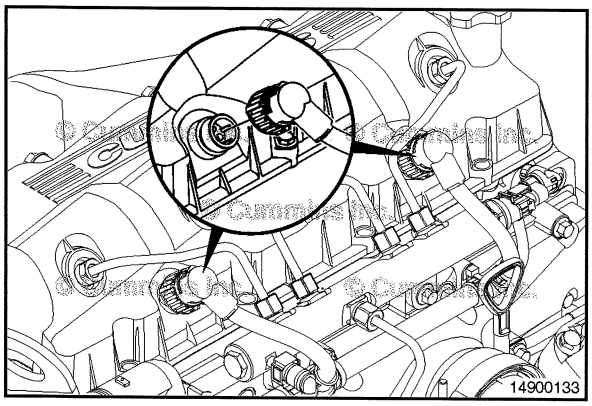
If a port on the main oil rifle is **not** available, install a pressure gauge at the top of the oil filter head.



⚠CAUTION⚠
Do not engage the starting motor for more than 30 seconds. To reduce the possibility of engine damage, wait 2 minutes between starter engagements to cool the starting motor.

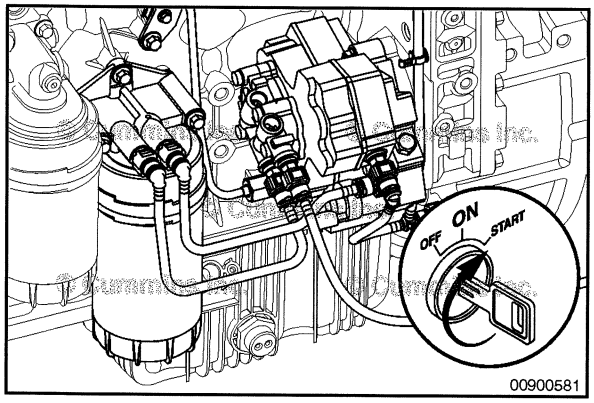
Crank the engine until the lubricating oil pressure gauge indicates a positive pressure.



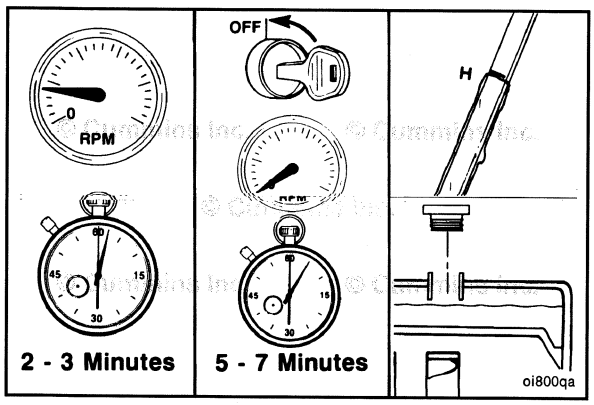


After pressure is observed, connect the engine harness injector connector at the rocker housing.

Remove the pressure gauge.



Prime the fuel system. Refer to Procedure 005-016 in Section 5.

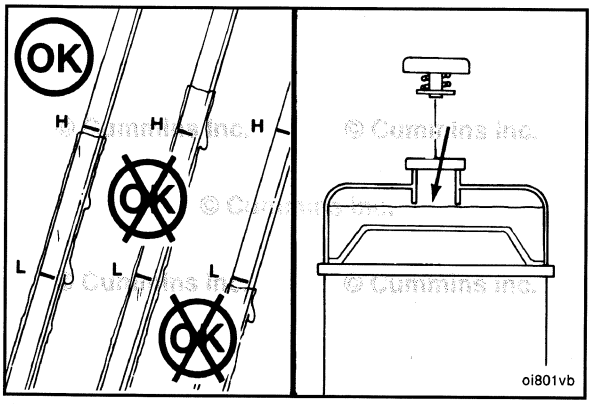


⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

Operate the engine at low idle for 2 to 3 minutes.

Shut off the engine and wait 5 to 7 minutes for the lubricating oil to drain to the lubricating oil pan.

Check the lubricating oil and coolant levels again.



Fill the engine to the correct lubricating oil and coolant levels, if necessary.

Refer to Procedure 007-037 in Section 7.

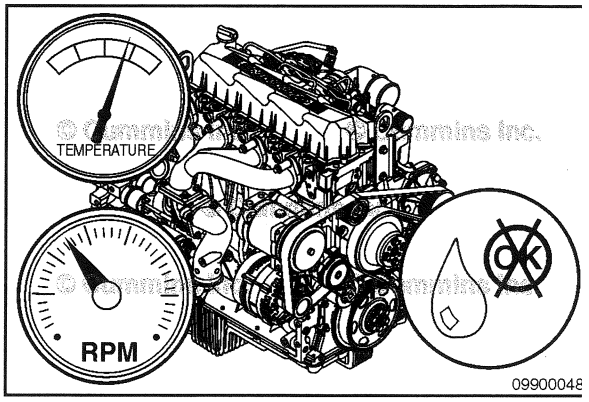
Refer to Procedure 008-018 in Section 8.

Operate the engine at 1000 to 1200 rpm for 8 to 10 minutes.

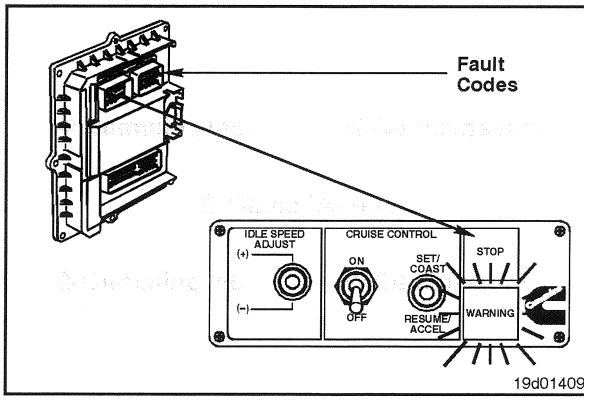
Check for proper operation, unusual noises, and coolant, fuel, or lubricating oil leaks.

Repair all leaks and component problems.

See Section 14 for the Engine Run-In and Test Procedures.



Use INSITE™ electronic service tool to read and clear any fault codes. See the appropriate electronic controls manual for the engine being serviced.



Engine Storage - Long Term (000-005)

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.

⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

△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.

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.

Prepare the Engine for Long Term Storage

△CAUTION△

DO NOT use fuel system preservative oil on Natural Gas or Propane Engines.

- Operate the engine at high idle until the coolant temperature is 70°C [158°F].
- Turn the engine off.
- Drain the oil.
- Install the drain plugs.
- Fill the engine oil pan sump 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.

Internal Preservation of the Fuel System with Mechanically and Electronically Actuated Injectors.

⚠CAUTION⚠

DO NOT use diesel fuel containing bio components for internal preservation of fuel system for engine storage. Fuel properties degradation may cause damages and lead to premature failure of fuel system components.

- Disconnect the fuel lines to the engine fuel filter and the injector return line.
- Use Diesel Pump and Injector calibration fluid that meets ISO 4113 standard, SAE J967d standard and Bosch VS 15665-OL standard.

NOTE: Using calibration fluid allows storage for up to 12 months. After 12 months the engine fuel system **must** be drained and flushed again with fresh calibration fluid. Repeat after each 12-month period.

Alternatively you can use the diesel fuel with 0 percent bio components content for Internal Preservation of the Fuel System.

NOTE: Using diesel fuel with 0 percent bio components content allows storage for up to 6 months. After 6 months, the engine fuel system **must** be drained and be flushed again with fresh diesel fuel with 0 percent bio components content. Repeat after each 6-month period.

- Start the engine.
- After the engine is operating smoothly, transfer the fuel supply line to the container of calibration fluid or the container of diesel fuel with 0 percent bio components content.
- 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 and that the calibration fluid or the diesel fuel with 0 percent bio components content flows out of the injector return line.
- Turn the engine "OFF".
- Connect the fuel lines to the fuel filter and the injector return line.
- Drain all the preservative oil from the engine oil pan sump, the air compressor (if applicable), and drain all the oil filters and all the fuel filters.
- Install the drain plugs.

⚠CAUTION⚠

Before starting another Internal Preservation of the Fuel System procedure again (after passing a storage period) it is required to fill the engine oil pan sump to the high mark using Tectyl™ 910 or equivalent engine preservative oil.

- 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 componen 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 external 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.

Remove the Engine from Long Term Storage

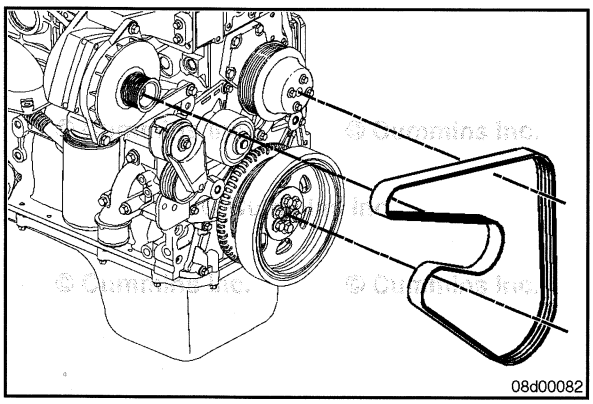
To remove the engine from long term storage, follow the following steps:

⚠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. See the Coolant Recommendations and Specifications procedure in Section V of the corresponding owners and/or operation and maintenance manual 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. See the Coolant Recommendations and Specifications procedure in Section V of the corresponding owners and/or operation and maintenance manual 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. See the Coolant Recommendations and Specifications procedure in Section V of the corresponding owners and/or operation and maintenance manual for antifreeze, water, and SCA specifications.
- Adjust the engine brake (if applicable) and valve clearances. Reference 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 external drive belts that were removed.
- Replace all spark plugs. Reference the Spark Plugs procedure in the corresponding base Troubleshooting and Repair Manual or Service Manual for engine being serviced(if applicable).

- 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 if 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).



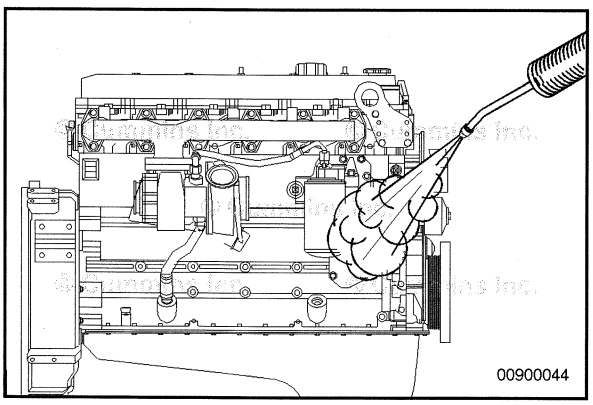
Engine Painting (000-007)

Preparatory Steps

Remove the cooling fan drive belt. Refer to Procedure 008-002 in Section 8.

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.

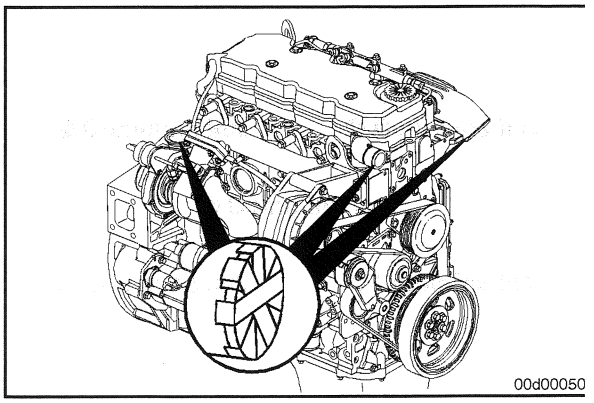
△CAUTION△
To reduce the possibility of engine component damage, avoid prolonged, direct steam or water spray on electrical components.

Use steam to clean the engine and dry with compressed air.

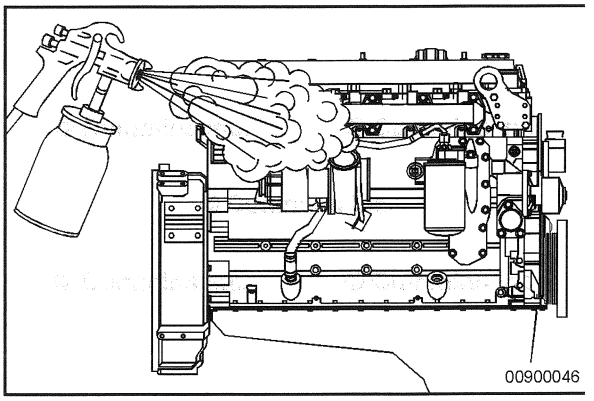
NOTE: Make sure all engine surfaces are clean and dry before painting the engine.

Protect the following components from paint:

- All dataplates (engine, fuel pump, 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.



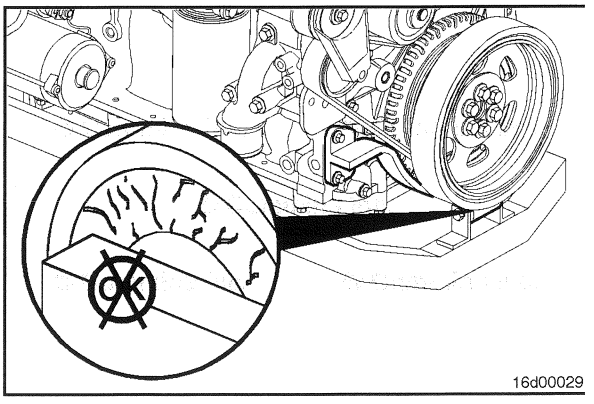
Engine Mounting Bolts (000-008)

Inspect for Reuse

⚠CAUTION⚠
Damaged engine mounts and brackets can cause engine misalignment. Drivetrain component damage can result in excessive vibration complaints.

Inspect all rubber-cushioned mounts for cracks or damage.

Inspect all mounting brackets for cracks or damaged bolt holes.



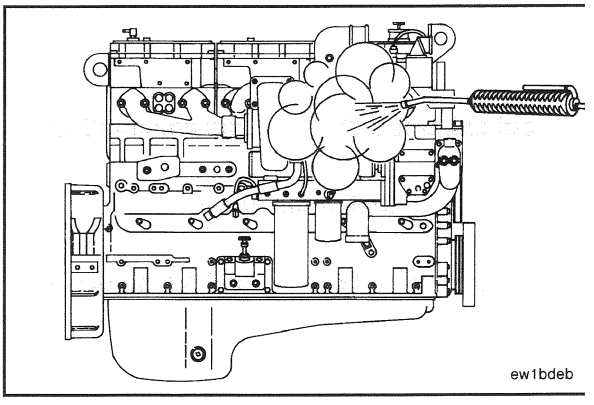
Engine Steam Cleaning (000-009)

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.



Notes

Section 1 - Cylinder Block - Group 01

Section Contents

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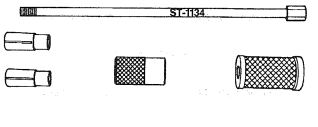
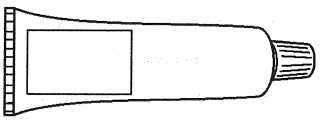
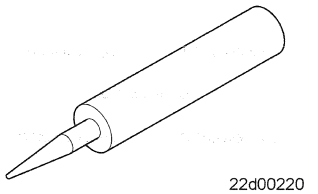
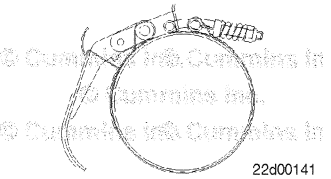
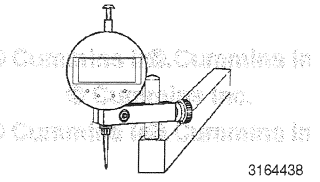
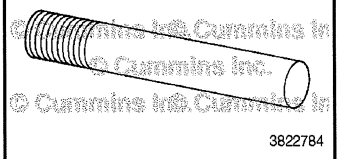
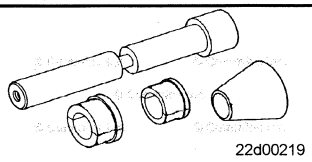
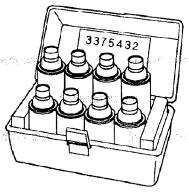
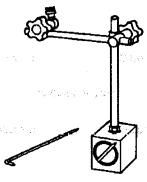
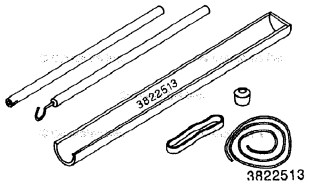
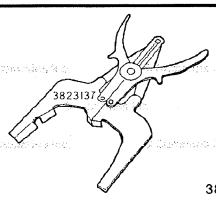
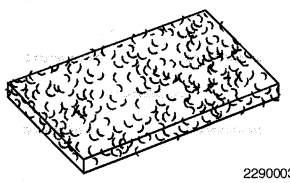
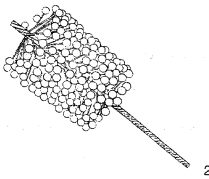
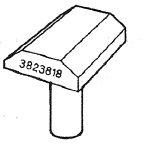
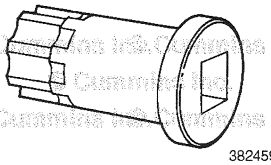
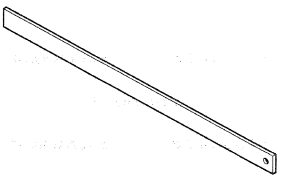
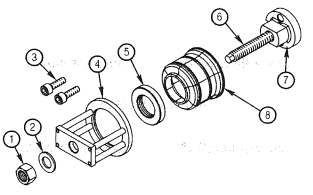
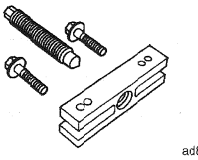
Service Tools

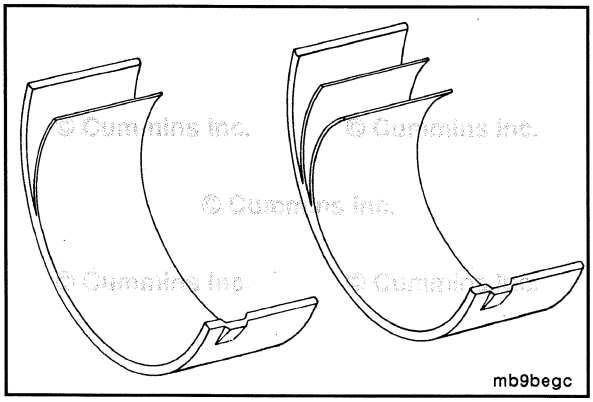
Cylinder Block

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
3163720	**Dowel Pin Extractor** Use to remove solid locating pins from cylinder block. Kit includes SAE and Metric sizes.	 ST-1134
3163934, 3163935, 3163936	**Assembly Guide Pins** Used to aid in assembly. Part Number 3163934 - M12 x 1.75, Part Number 3163935 - M10 x 1.25, and Part Number 3163936 - M8 x 1.0	 3822784
3164067	**RTV Sealant** Used in most locations requiring RTV sealant.	 22d00152
3164070	**RTV Sealant** Used to seal rear gear housing to block, front cover to block, and intake manifold to cylinder head joints.	 22d00220
3164330	**Piston Ring Compressor** Used to install piston with rings into the cylinder bore. For 102 mm bore engines.	 22d00141
3164438	**Depth Gauge Assembly** Used to measure liner protrusion, cylinder block counterbore depths, and valve intrusion and/or protrusion. Equipped with digital, electronic, indicator.	 3164438

Tool No.	Tool Description	Tool Illustration
3164977	**Assembly Guide Pins** Used to aid in assembly. Part Number3164977 - M8 x 1.25	
3165045	**Camshaft Bushing Tool** Used to replace camshaft bushings.	
3375432	**Crack Detection Kit** Used to locate cracks in cylinder blocks, cylinder heads, as well as other engine components.	
3377399	**Magnetic Base Indicator Holder** Used in conjunction with dial indicator, Part Number Metric - 3824564, or SAE - 4918289.	
3822513	**Tappet Removal Tool Kit** Used to remove and install valve tappets.	
3822709	**Thread Insert Kit** Blind metric inserts can be used to repair several different size cylinder block threads.	
3823137	**Piston Ring Expander** Used to install piston rings onto pistons without damaging or distorting the rings.	
3823258	**Abrasive Pad** Used to remove small nicks and burrs from the edges of the bearing shells, connecting rods, main bearing caps, and other components during inspection.	

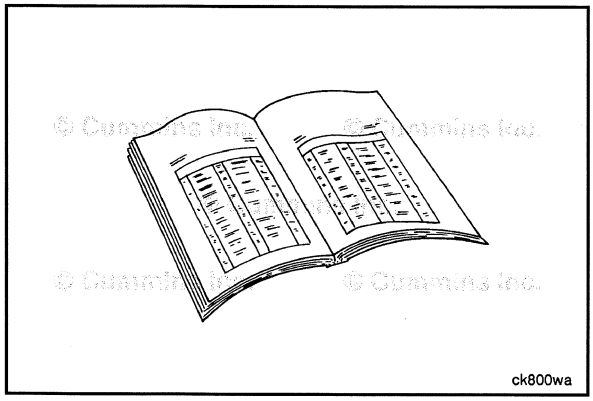
Tool No.	Tool Description	Tool Illustration
3823612	**Flexible Hone** Used to deglaze the engine block cylinder walls.	
3823818	**Main Bearing Rollout Tool** Used to remove and install main bearings with crankshaft installed.	
3824591	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	
4918219	**Precision Straightedge** Used to check cylinder blocks and cylinder heads for flatness.	
4919660	**Oil Seal Replacer (front)** Used to remove/install the front crankshaft seal.	
ST 647	**Standard Gear Puller** Used to remove pulleys, impellers, and/or counterweights. Also used to assist in the removal of the camshaft gear.	



Bearings, Connecting Rod (001-005)

General Information

Reference the appropriate Part Information resources when replacing the connecting rod bearings, so the correct connecting rod bearings are 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.

⚠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.

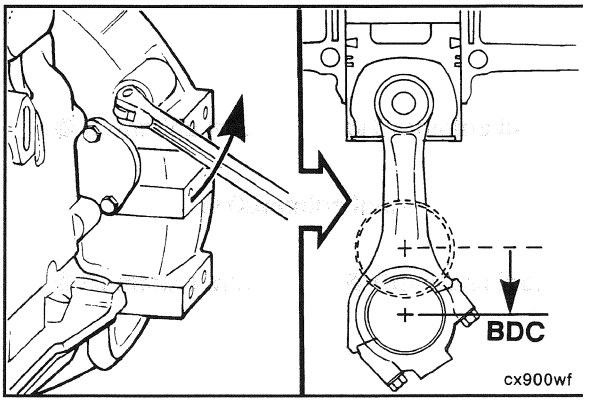
- Disconnect the batteries. See equipment manufacturer service information.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the oil pan and oil pan gasket. Refer to Procedure 007-025 in Section 7.
- Remove the block stiffener plate. Refer to Procedure 001-089 in Section 1.

Remove

⚠CAUTION⚠
Be careful not to damage the fractured split surface on the connecting rod or connecting rod cap while the connecting rod cap is removed. If the fractured split surface is damaged, the connecting rod and connecting rod cap must be replaced to help reduce the possibility of engine damage.

NOTE: The cylinder head does **not** need to be removed if the connecting rod bearings are being inspected or replaced.

Use the barring tool, Cummins® Part Number 3824591, to bar the engine over to bottom dead center of the connecting rod bearing to be removed.



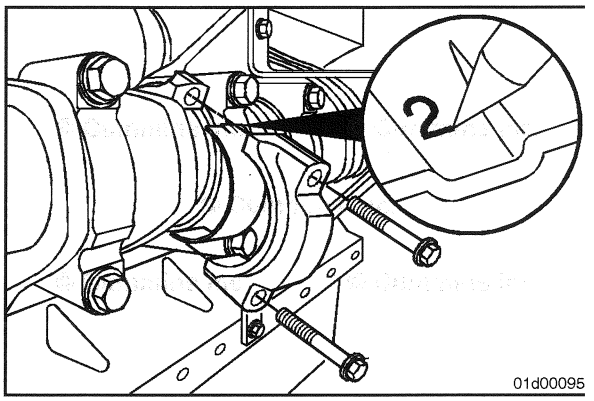
Mark each connecting rod and cap to identify cylinder location.

Remove and install **only** one connecting rod cap at a time to avoid mismatching connecting rods and rod caps.

Remove the connecting rod bolts and connecting rod cap.

Remove the lower end bearing.

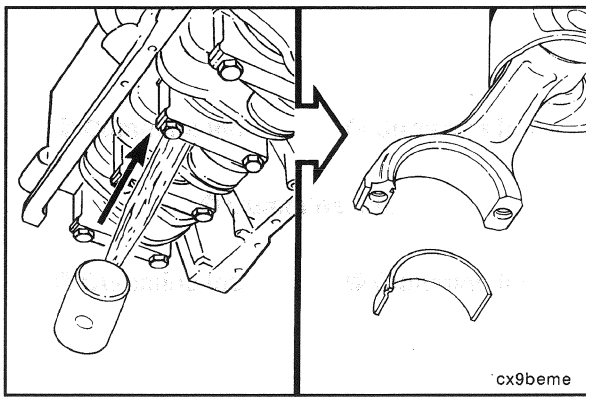
Mark the cylinder number and the letter "L" (lower) on the flat surface of the bearing tang.



⚠CAUTION⚠
Do not damage the J-jet piston cooling nozzles when sliding the connecting rod into the cylinder away from the crankshaft. Engine damage can result.

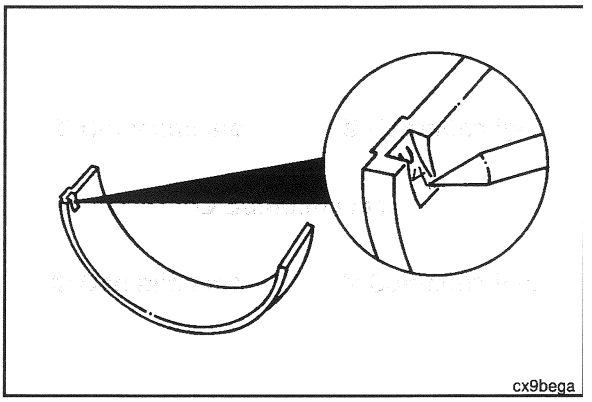
NOTE: Slight bending of the j-jet piston cooling nozzles can result in severe engine damage. Replace piston cooling nozzles if any are bent or damaged during assembly or disassembly.

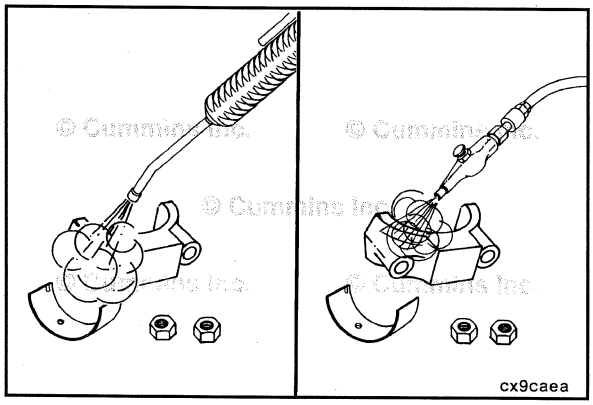
Push the connecting rod into the cylinder, away from the crankshaft, to allow the upper bearing shell to be removed.



Mark the connecting rod bearings for position and cylinder number as they are removed.

Example: U1 - upper rod bearing for cylinder number 1.





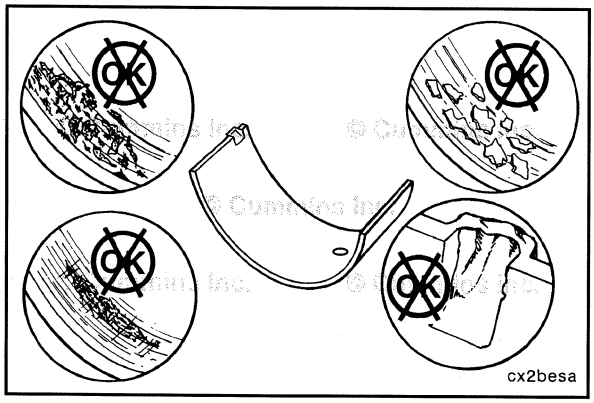
Clean and Inspect for Reuse

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the bearing and connecting rod caps.

Dry with compressed air.

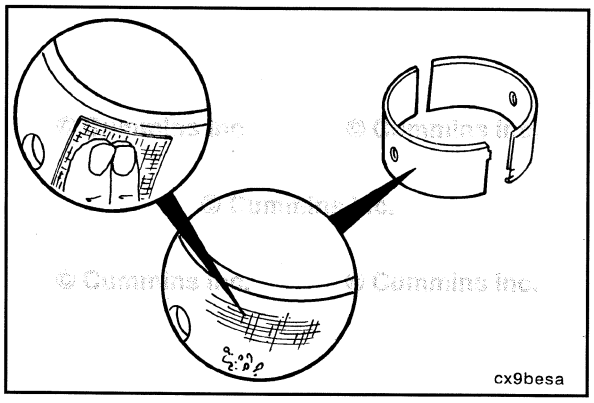
Inspect the connecting rod caps, connecting rod bearing saddles, and capscrews for nicks, cracks, burrs, scratches, or fretting.



Inspect the bearings for damage.

Replace any bearings with the following damage.

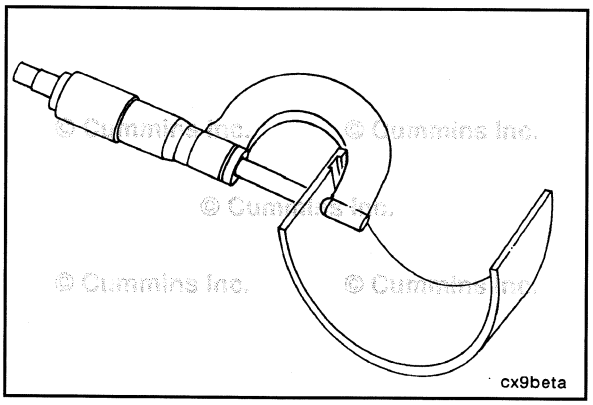
- Pitting.
- Flaking.
- Corrosion.
- Lock tang damage.
- Scratches..



Inspect the bearing shell seating surface for nicks or burrs.

If nicks or burrs can **not** be removed with an abrasive pad, Cummins® Part Number 3823258 or equivalent, the bearings **must** be replaced.

If bearings are damaged, they **must** be replaced as a set.



Measure the rod bearing shell thickness with an outside micrometer that has a ball tip.

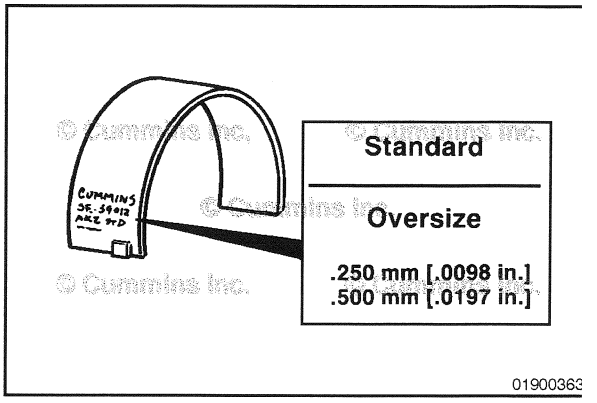
Connecting Rod Bearing Dimensions		
	mm	
Standard	1.955	MIN
	1.968	MAX
0.25 mm [0.010 in]	2.080	MIN
	2.093	MAX
0.50 mm [0.020 in]	2.205	MIN
	2.218	MAX

Discard a bearing shell if its thickness is below the minimum specification.

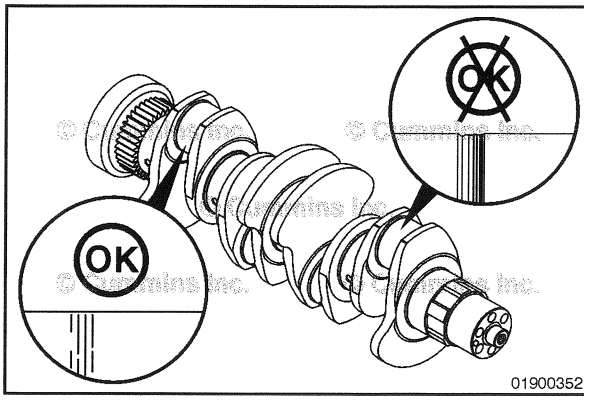
Connecting rod bearings are identified with a part number and size stamped on the back side.

Determine the size of the removed rod bearing and obtain a set of the same size.

Oversize service rod bearings are available for use with crankshafts that have been machined undersized. See the appropriate parts catalog.



Check the rod bearing journals for damage or excessive wear. Minor scratches are acceptable.

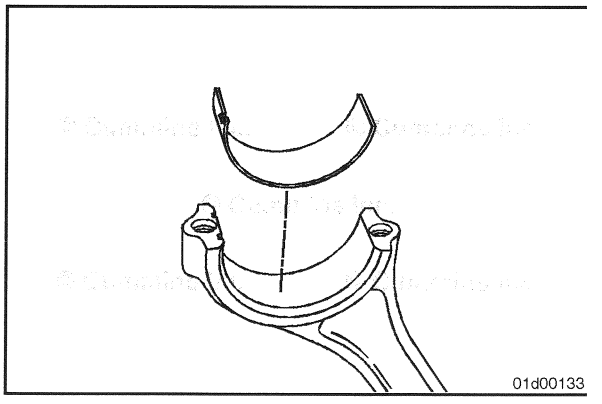


Install

Used connecting rod bearings **must** be installed in their original locations.

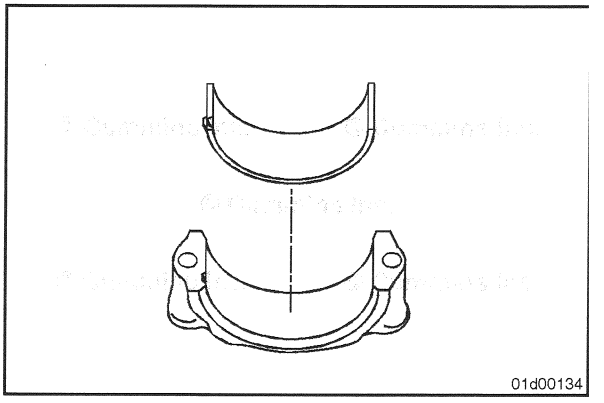
To reduce the possibility of engine damage, make sure the back side of the bearing and connecting rod surface that contacts the bearing is clean and dry.

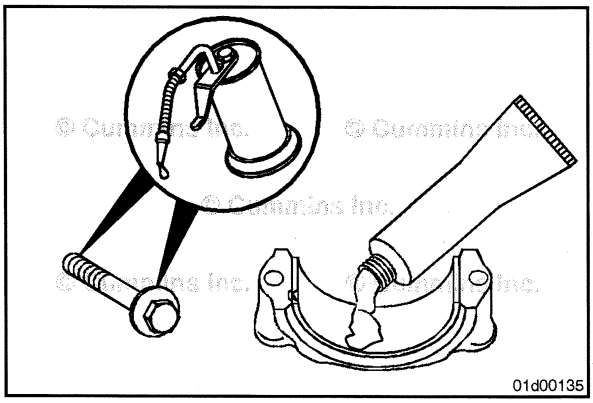
Install the upper bearings in the connecting rod. Make sure the tang is aligned.



Install the lower bearings in the connecting rod caps. Make sure the tang is aligned.

NOTE: With fracture split connecting rods, the upper and lower connecting rod bearings are **not** interchangeable.

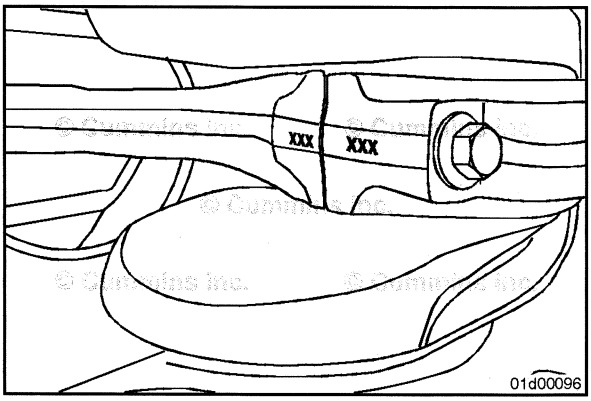




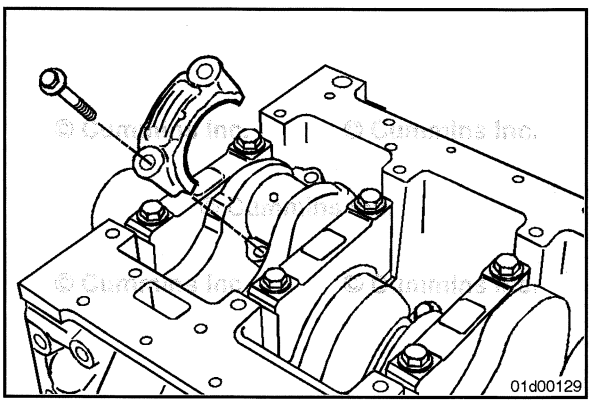
NOTE: With fracture split connecting rods, the fracture split surface on the connecting rod and connecting rod cap **must** be kept dry and clean to be sure of proper mating of the two surfaces.

Lubricate the bearing surfaces with assembly lube, Cummins® Part Number 3163087 or equivalent.

Lubricate the connecting rod bolt threads and under the heads with clean 15W-40 engine oil.

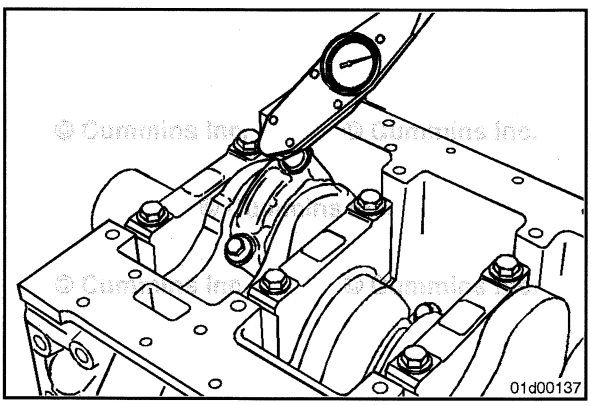


When installing the connecting rod cap, the numbers stamped on the connecting rod cap and connecting rod **must** match and be on the same side of the connecting rod, to prevent engine damage during operation.



Install the connecting rod cap on the corresponding connecting rod.

Install and hand-tighten the connecting rod capscrews.



Tighten the connecting rod capscrews.

Alternately tighten the two capscrews. Refer to Procedure 001-054 in Section 1.

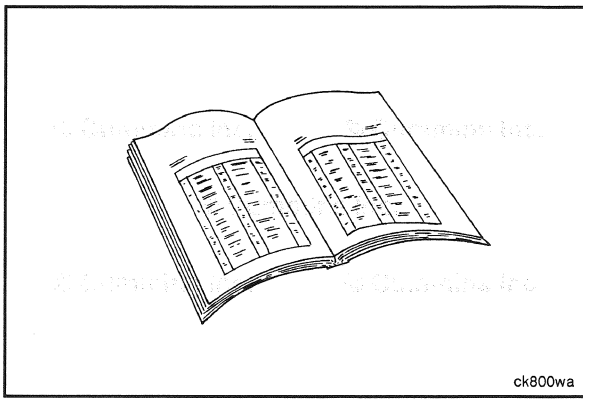
After tightening the capscrews for each connecting rod, rotate the crankshaft 360 degrees to make sure the crankshaft rotates freely.

Measure the connecting rod side clearance. 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 block stiffener plate. Refer to Procedure 001-089 in Section 1.
- Install the oil pan and oil pan gasket. Refer to Procedure 007-025 in Section 7.
- Fill with clean lubricating oil. Refer to Procedure 007-037 in Section 7.
- Connect the battery cables. See equipment manufacturer service information.
- Operate the engine, check for leaks and proper oil pressure.



Bearings, Main (001-006)

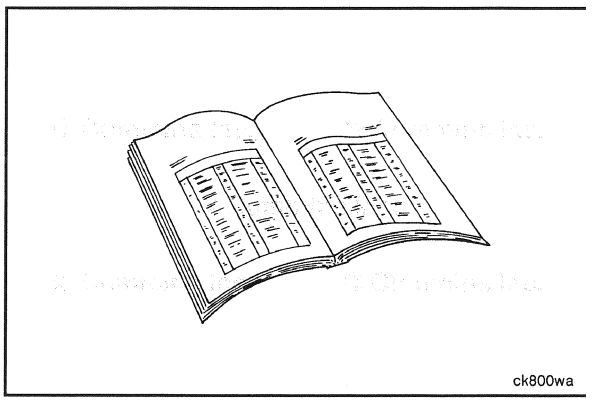
Preparatory Steps

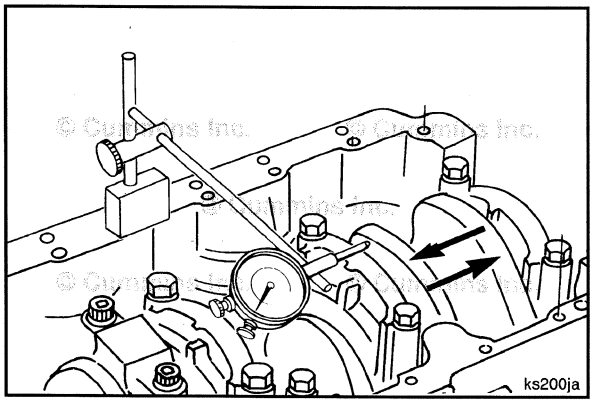
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and 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.

- Disconnect the batteries. See equipment manufacturer service information.
- 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 front gear cover. Refer to Procedure 001-031 in Section 1.
- Remove the block stiffener plate. Refer to Procedure 001-089 in Section 1.





Initial Check

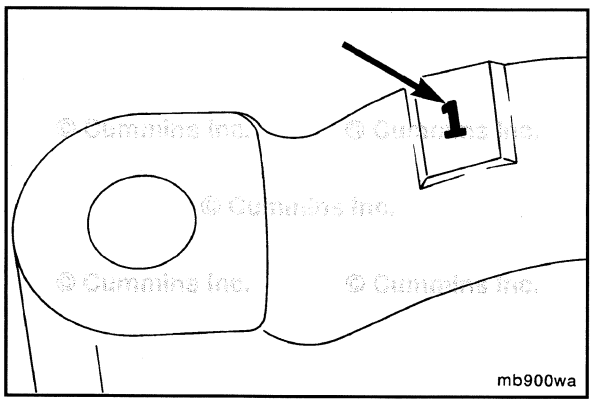
NOTE: The dimensions of the thrust bearing and crankshaft journal determine end play.

Measure the crankshaft end play. Use dial indicator, Cummins® Part Number 3824564 and magnetic base, Part Number 3377399.

Crankshaft End Play

mm		in
0.11	MIN	0.004
0.39	MAX	0.017

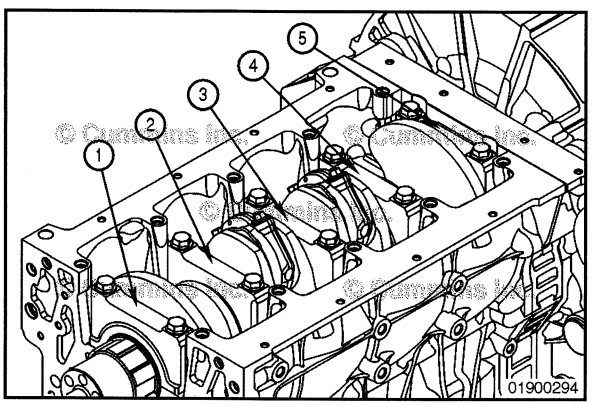
If the crankshaft end play is **not** within specification, make sure to inspect the crankshaft and thrust bearing surfaces for damage.



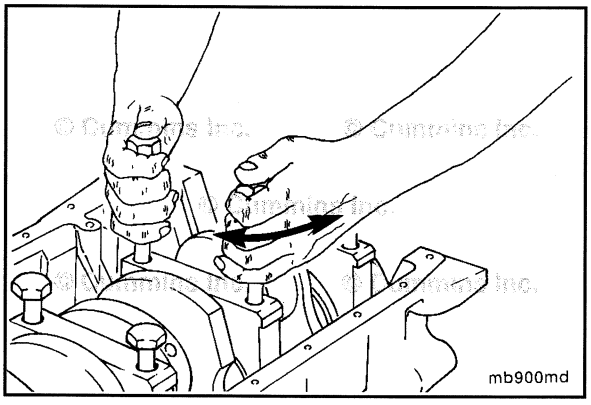
Remove

Before removing the main bearing caps, make certain the caps are clearly marked for their location on the lubricating oil cooler side of the main bearing cap and cylinder block.

The number one cap is at the front of the engine.



NOTE: When replacing bearings in chassis: For four cylinder engines, replace number 2 through 4 while the number 1 and number 5 caps support the crankshaft. After replacing number 2 through number 4, replace number 1 and number 5.



⚠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.

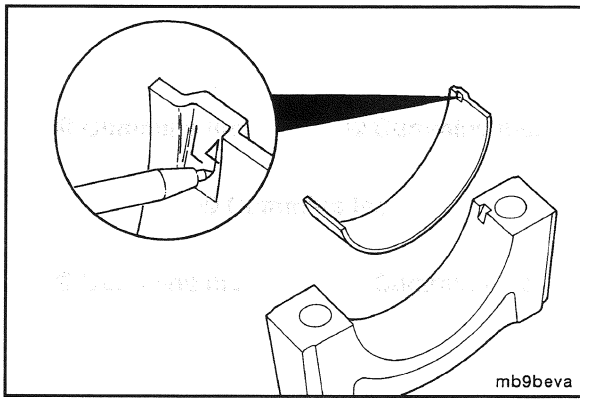
Use two of the main bearing cap bolts to "wiggle" the main bearing cap loose, being careful **not** to damage the bolt threads.

Remove the main bearing cap.

Mark the main bearings for position and number as they are removed.

Use an awl to mark the bearing's position in the tang area.

NOTE: Marking the bearing's position is for future identification or possible failure analysis.



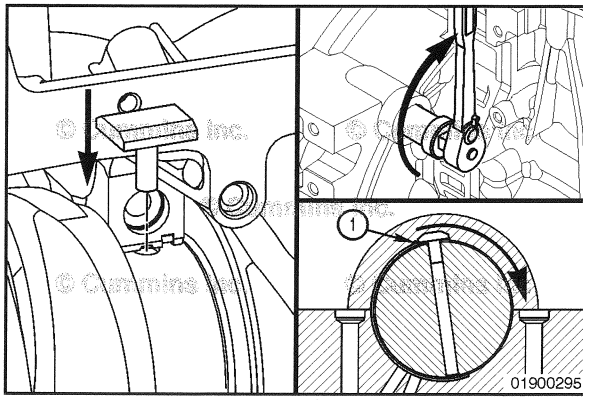
Follow this step to remove the upper main bearings, except for number 1 front main bearing.

To remove the upper main bearing, install the main bearing replacer, Cummins® Part Number 3823818, in the oil hole of the crankshaft main bearing journal.

Use a barring tool, Cummins® Part Number 3824591, to 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.

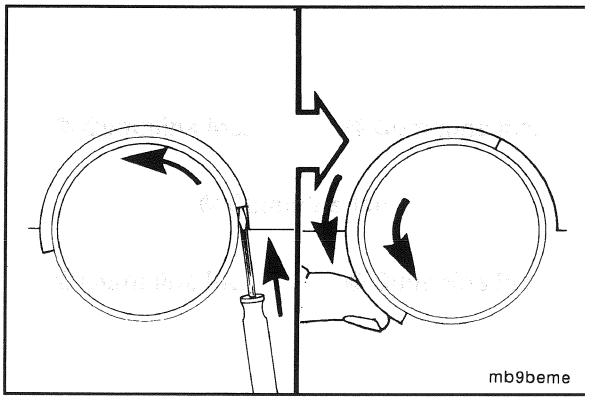
Remove the bearing.



⚠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.



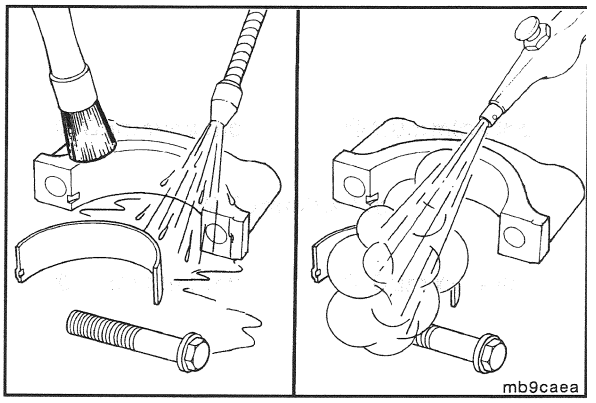
Clean and Inspect for Reuse

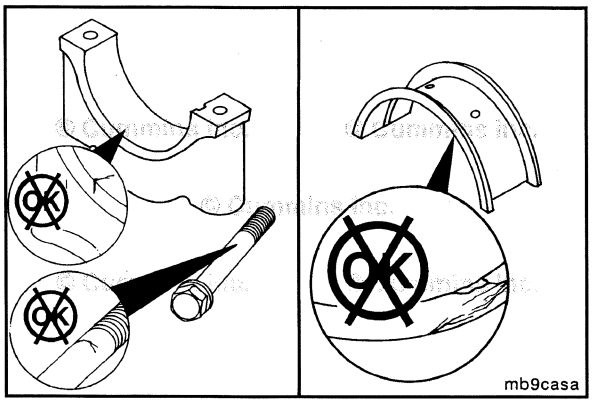
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Steam-clean or use hot, soapy water to clean the main bearing caps.

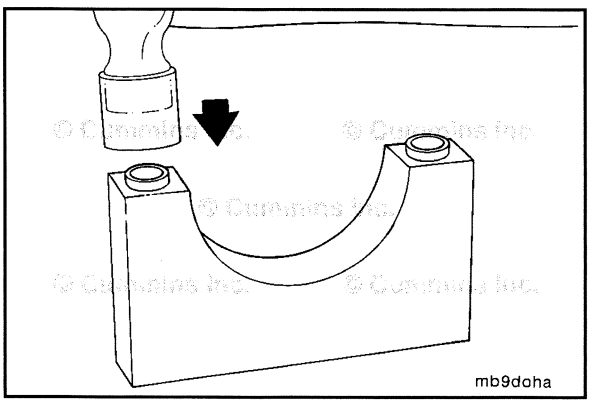
Dry with compressed air.



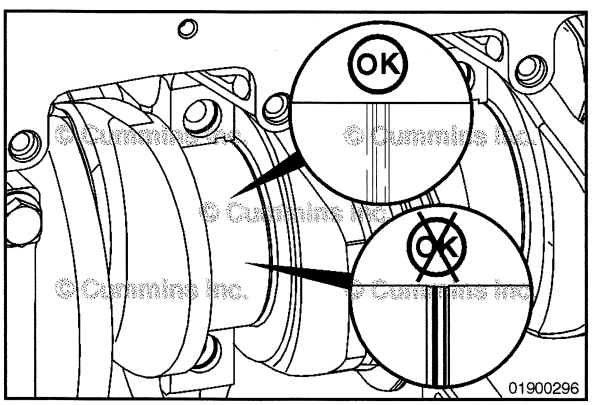


Inspect all main bearing caps, capscrews and thrust bearings for deep scoring, overheating, etc.

Replace any damaged components. If the main bearing cap is damaged, the block **must** be replaced.



Check the main bearing caps to make sure the ring dowels are installed.

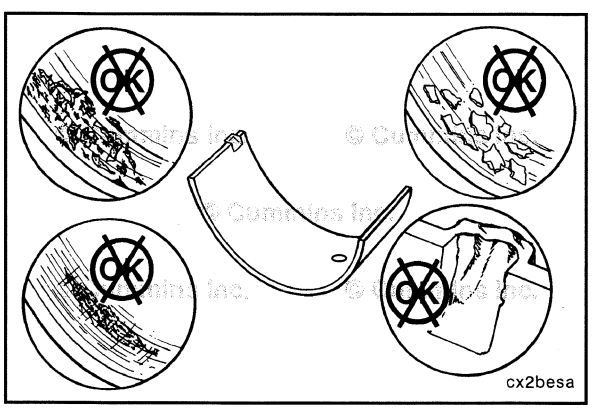


Check the crankshaft main bearing journals for damage or excessive wear. Minor scratches are acceptable.

If crankshaft end play measured during the initial check was found to be out of specification, make sure to check the crankshaft thrust surface for excessive wear or damage. Minor scratches are acceptable.

If damage is found, the crankshaft will need to be removed. Refer to Procedure 001-016 in Section 1.

Also check the thrust bearing surfaces for excessive wear. Replace the thrust bearing(s) if excessive wear is found



Inspect the bearings for damage.

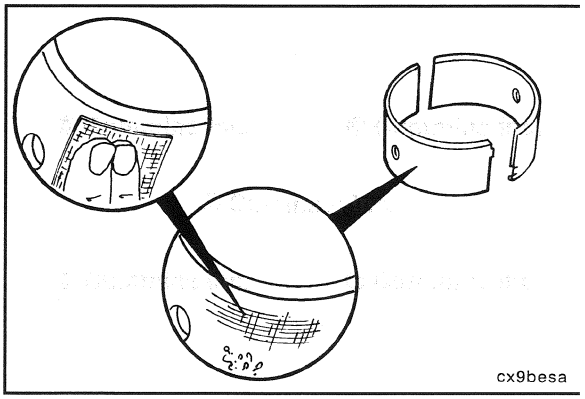
Replace any bearings with the following damage:

- 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, Cummins® Part Number 3823258 or equivalent, the bearings **must** be replaced.

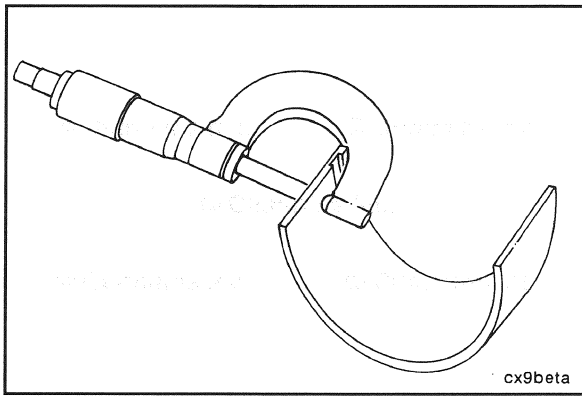
NOTE: If bearings are damaged they **must** be replaced as a set.

NOTE: For more detailed information on bearing damage, refer to Analysis and Prevention of Bearing Failures, Bulletin 3810387.



Measure

Measure the main bearing shell thickness with an outside micrometer that has a ball tip.



Main Bearing Dimensions

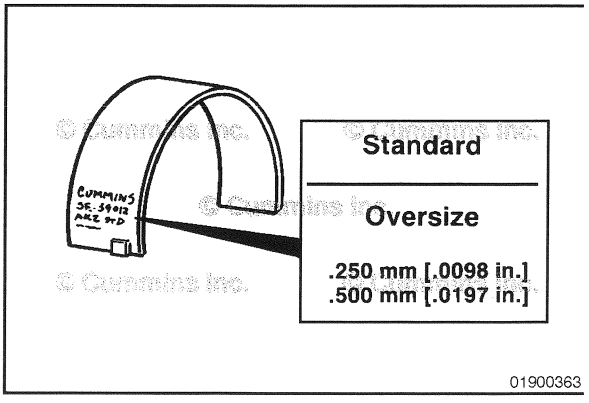
	mm		in
Standard	2.456	MIN	0.0967
	2.464	MAX	0.097
Oversize 0.25 mm [0.010 in]	2.706	MIN	0.1067
	2.714	MAX	0.117
Oversize 0.50 mm [0.020 in]	2.956	MIN	0.1167
	2.964	MAX	0.117

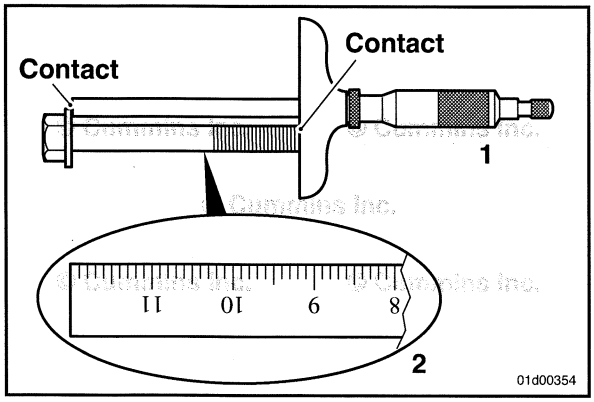
Discard a bearing shell if its thickness is below the minimum specifications.

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.





⚠CAUTION⚠
This step must be completed. Failure to check the main bearing capscrew against reuse guidelines can result in severe engine damage.

Main Bearing Capscrew Reuse Measurement

To check if a main bearing capscrew can be reused, the length **must** be measured by performing the following:

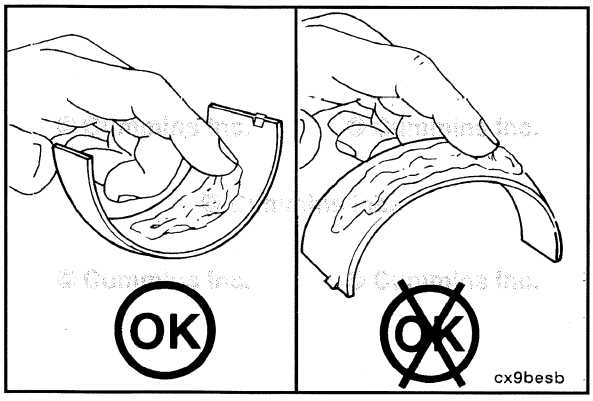
For each main bearing capscrew that has been removed, measure the length from underneath the head of the capscrew to the tip of the capscrew, as illustrated, using one of two methods.

1 A depth micrometer (preferred method for accuracy).

2 A machinist's rule.

If the measurement is above the maximum specification, the main bearing capscrew **must** be replaced.

Main Bearing Underhead Capscrew Length		
mm		in
120.00	MAX	4.724



Install

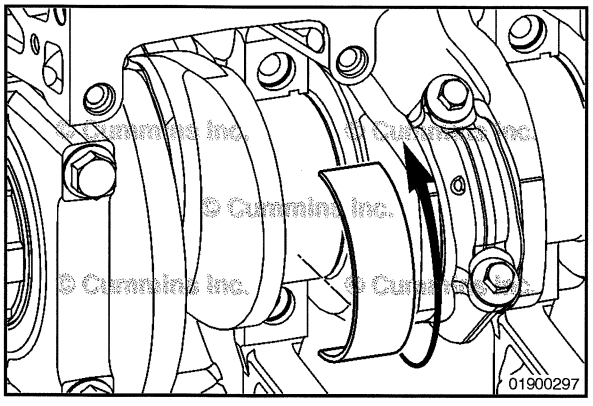
⚠CAUTION⚠
Do not lubricate the side that is against the cylinder block.

Upper Main Bearing

NOTE: Make sure the main bearing being installed is the same size as the main bearing removed, if the crankshaft has not been machined. The size is engraved on the back of the main bearing.

NOTE: Install the upper main bearing cap after each upper main bearing is installed to keep the main bearing in place while the other upper main bearings are installed.

Apply assembly lube, Cummins® Part Number 3163086, to the upper main bearings.



NOTE: The crankshaft thrust bearing **must** be installed in the: The number 4 main bearing position.

NOTE: The upper and lower main bearing shells are not interchangeable. The backs of the main bearings are marked with the proper orientation.

Install the upper main bearings.

Insert the side of the main bearing opposite the tang first in between the crankshaft journal and block. Install the bearing as far as possible by hand.

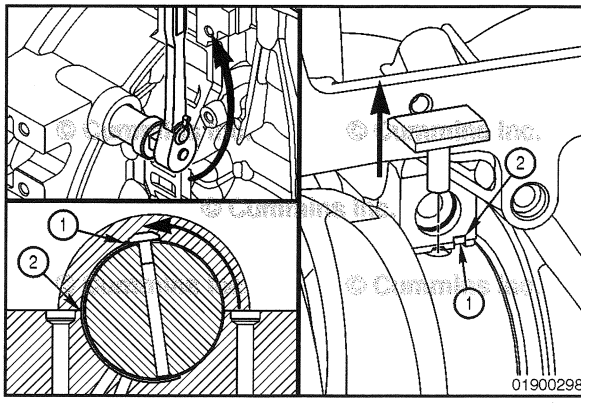
When installing the thrust bearing, it may be necessary to push the crankshaft to the front or rear of the cylinder block.

⚠CAUTION⚠
Make sure the pin does not slide under the bearing.

Follow this step to finish installing the upper main bearings, except for number 1 front main bearing.

Using the main bearing replacer, Cummins® Part Number 3823818, finish installing the main bearing. Rotate the crankshaft, using the barring tool, Cummins® 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.



⚠CAUTION⚠
Use care so the screwdriver does not damage the crankshaft or cylinder block.

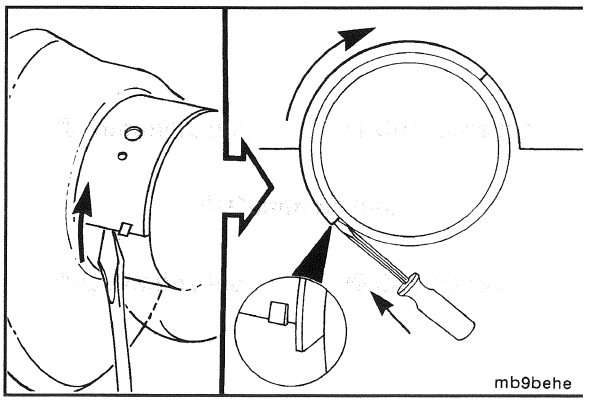
NOTE: The front main, number 1, does **not** have a hole in the journal so the pin can **not** be used to replace the bearing.

Install the number 1 main bearing.

Insert the side of the main bearing opposite the tang first and install as far as possible by hand.

Use a flat blade screwdriver to push the main bearing into position while rotating the crankshaft.

Make sure the tang on the main bearing is located in the notch of the cylinder block.



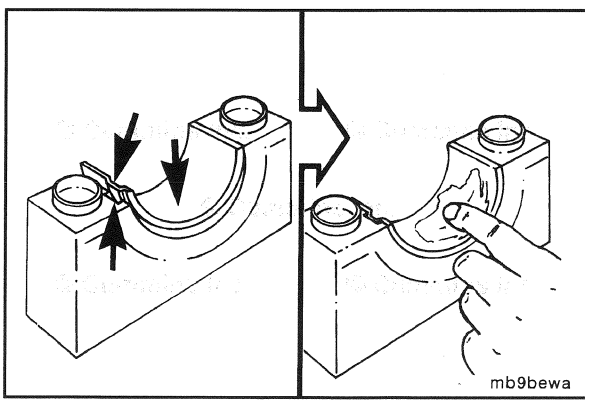
⚠CAUTION⚠
Do not lubricate the back side of the bearing that contacts the main bearing cap.

Lower Main Bearings

Making sure that the backside of the bearings are clean and free of debris, install the lower main bearings into the main bearing caps.

Make sure to align the tangs of the bearings with tangs on the main bearing caps.

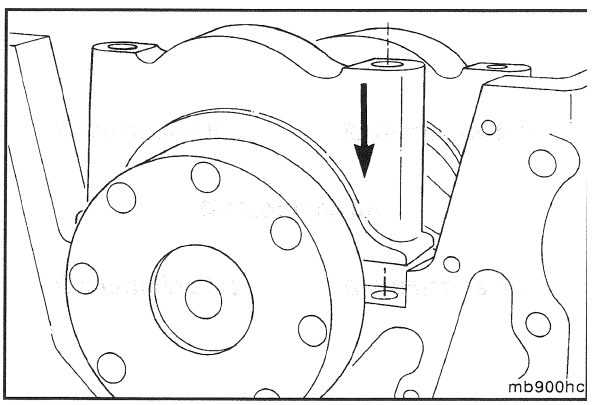
Apply a coat of assembly lube, Cummins® Part Number 3163087, to the crankshaft side of the main bearings and thrust bearing surfaces.

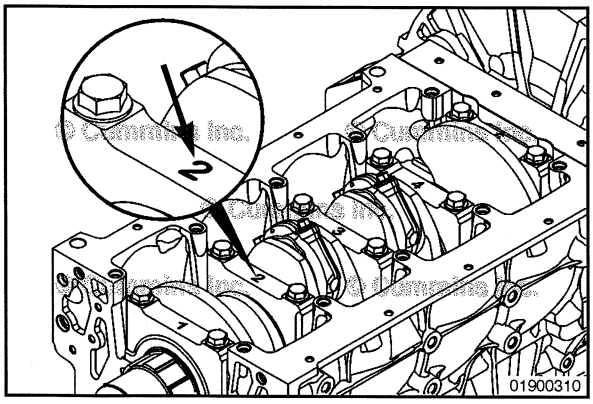


⚠CAUTION⚠
Make sure the caps are correctly installed in the same position as removed, with the number towards the oil cooler side of the engine.

Make sure the main bear cap surfaces between the main bearing cap and block are clean and free of debris.

Install the main bearing cap into position, aligning the main bearing cap dowel rings with the cylinder block.

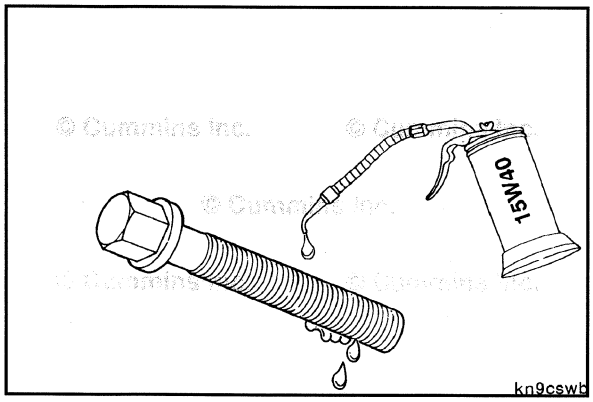




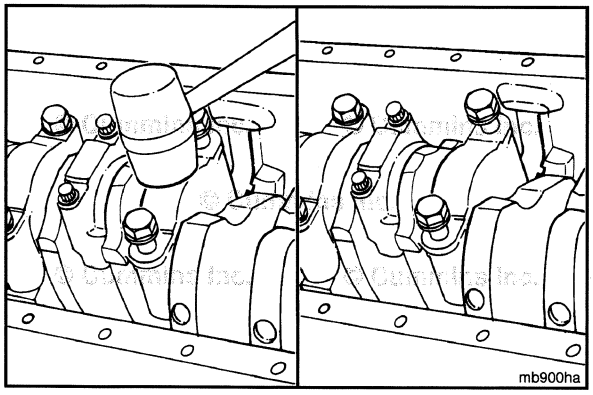
The main bearing caps are/were numbered during the removal process for their location. Number 1 starts with the front of the block.

NOTE: The caps **must** be installed so the numbers on the caps match the bearing saddle in the block. The lock tangs in the main bearing saddle and bearing cap **must** be on the same side.

Install the main bearing caps. Make sure to align the ring dowels on the main bearing cap with the corresponding drillings in the cylinder block.



Lubricate the main bearing capscrew threads and underside of the head with clean engine oil.

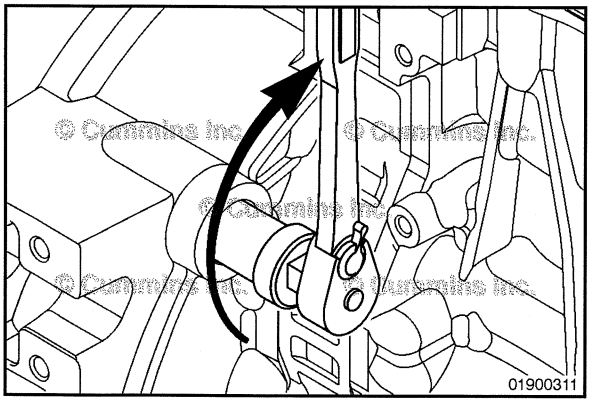


Gently tap the main bearing cap into position with a plastic or rubber mallet.

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. Final torque should be applied after all main bearing caps are installed.



Use the barring tool, Cummins® Part Number 3824591. The crankshaft **must** rotate 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 Check if the crankshaft is contacting one of the connecting rods.

2 Check if the correct main bearing caps where installed correctly.

3 Check if the main bearing cap ring dowels or mounting surfaces were damaged during installation.

4 Check if the correct main bearings where installed.

⚠CAUTION⚠
There is a different torque procedure for new and previously installed main bearing capscrews. Failure to use the correct torque process can result in engine damage.

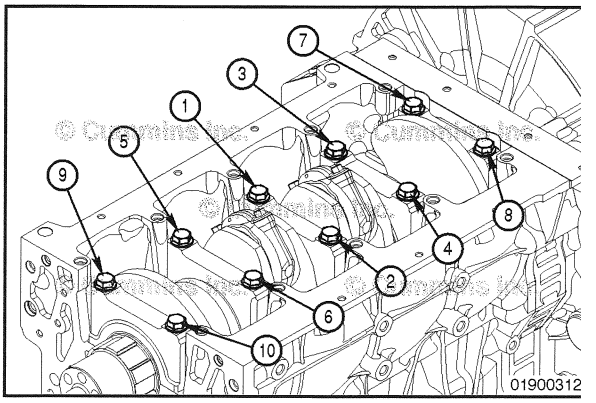
Tighten the main bearing capscrews evenly and in sequence.

Torque Value:
Previously Installed Main Bearing Capscrews

Step 1	60 N•m	[44 ft-lb]
Step 2	80 N•m	[59 ft-lb]
Step 3	Rotate 90 degrees.	

Torque Value:
New Main Bearing Capscrews

Step 1	120 N•m	[89 ft-lb]
Step 2	Loosen completely	
Step 3	60 N•m	[44 ft-lb]
Step 4	85 N•m	[63 ft-lb]
Step 5	Rotate 120 degrees.	

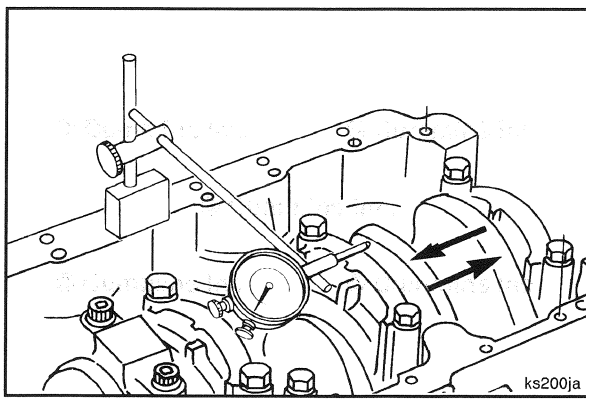


NOTE: The dimensions of the thrust bearing and crankshaft journal determine end play.

Measure the crankshaft end play. Use dial indicator, Cummins® Part Number 3824564 and magnetic base, Part Number 3377399.

Crankshaft End Play

mm		in
0.11	MIN	0.004
0.39	MAX	0.017

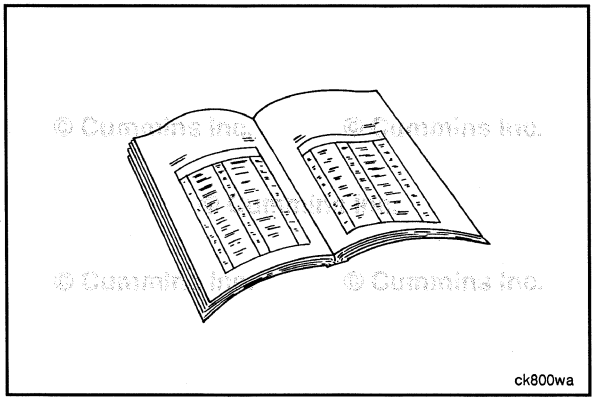


If the crankshaft end play is **not** within specification:

1 If the crankshaft end play 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 play 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 play is **not** within specifications. Oversize thrust bearings of 0.25 to 0.51 mm [0.010 to 0.020 in] are available.



Finishing Steps

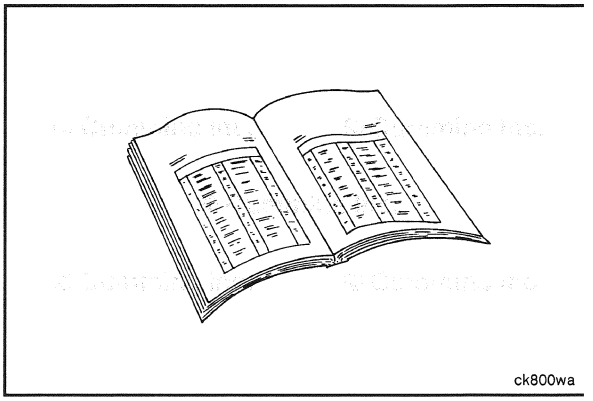
⚠WARNING⚠

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 block stiffener plate. Refer to Procedure 001-089 in Section 1.
- Install the front gear cover. Refer to Procedure 001-031 in Section 1.
- 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. See equipment manufacturer service information.
- Operate the engine at idle for 5 to 10 minutes. Check for leaks and correct oil pressure.

Camshaft (001-008)

Preparatory Steps

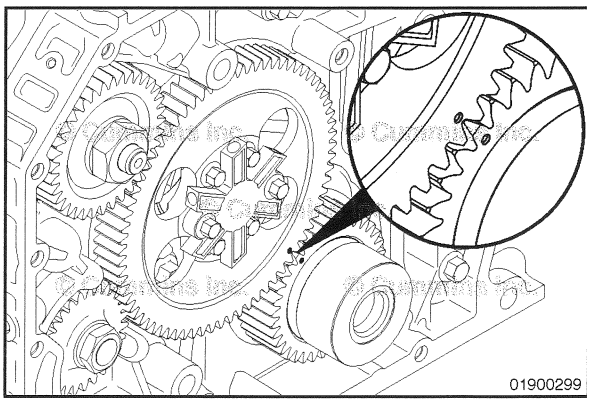


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Support the rear of the engine using the rear support attached to the rear of the cylinder block. Failure to support the engine can cause personal injury.

- Disconnect the batteries. See equipment manufacturer service information.
- The camshaft **must** be removed from the flywheel end of the engine.
- Remove the transmission and all related components, if equipped. See equipment manufacturer service information.
- Remove the engine from the chassis. Refer to Procedure 000-001 in Section 0.
- Remove the flywheel or flexplate. Refer to Procedure 016-005 in Section 16 Refer to Procedure or Procedure 016-004 in Section 16.
- Remove the flywheel housing. Refer to Procedure 016-006 in Section 16.
- 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.
- Raise the tappets. Refer to Procedure 004-015 in Section 4.

Remove

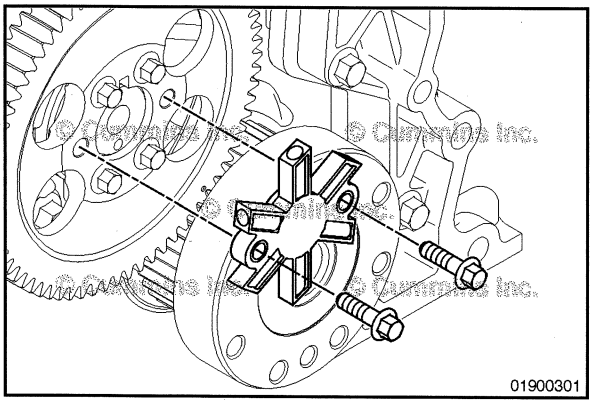


NOTE: Any time the camshaft is removed from the engine, the camshaft seal behind the crankcase breather tube flange mounting **must** be replaced. Refer to Procedure 003-031 in Section 3 to replace the seal after the camshaft has been installed into the engine.

NOTE: The engine can have either a mark on the crankshaft gear or a chamfered tooth.

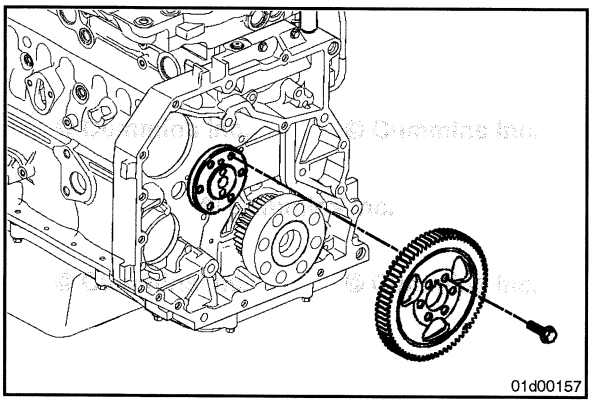
Rotate the crankshaft to align the timing marks on the camshaft and crankshaft gear.

Service Tip: The crankshaft can be rotated by installing two of the flywheel/flexplate mounting capscrews half way. Then use a pry bar in between the two capscrews to rotate the engine.



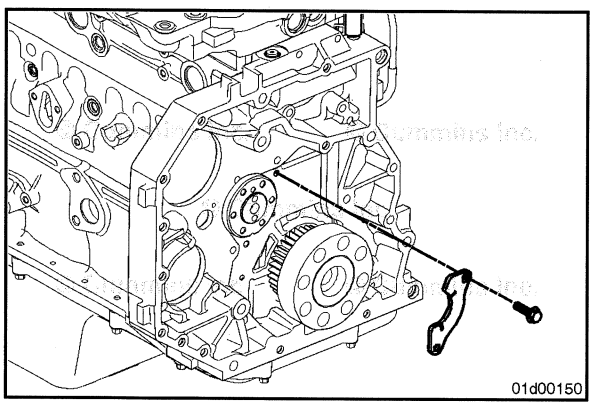
Remove the mounting capscrews and the crankcase internal breather from the camshaft gear.

NOTE: The two capscrews used to hold the crankcase breather disc to the camshaft gear are longer than the four camshaft gear mounting capscrews.

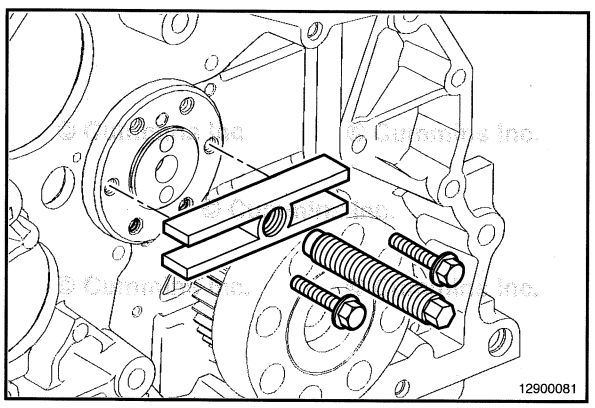


Remove the camshaft gear capscrews and remove the camshaft gear.

Refer to Procedure 001-012 in Section 1.



Remove the thrust plate capscrews and remove the thrust plate.



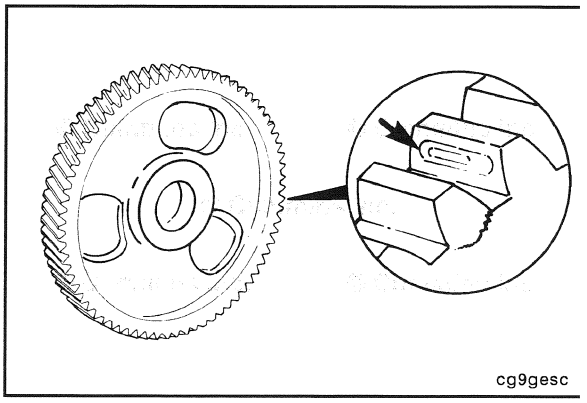
⚠CAUTION⚠
The camshaft will drop once the camshaft clears the last bushing if not supported. This can cause damage to the camshaft journal or, if equipped, the camshaft speed indicator ring.

Use a gear puller, Cummins® Part Number ST-647 or equivalent, to attach to the end of the camshaft, where the camshaft gear mounts, to act as a handle. This will give proper leverage and ease in removing the camshaft.

Slide the camshaft out of the bore, use the installed gear puller.

Clean and Inspect for Reuse

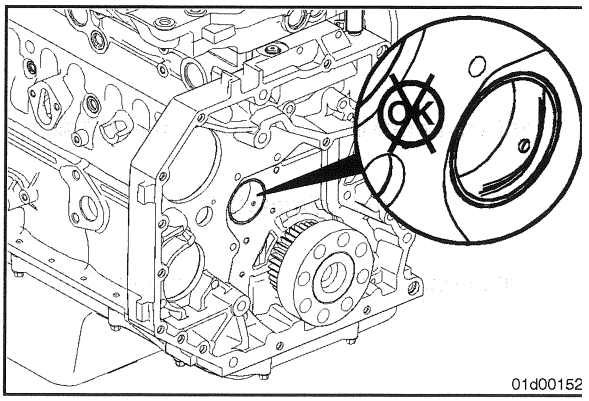
Inspect the camshaft gear. Refer to Procedure 001-012 in Section 1.



Inspect the camshaft bushing. Refer to Procedure 001-010 in Section 1.

NOTE: Rear gear train engines have a rear camshaft bushing.

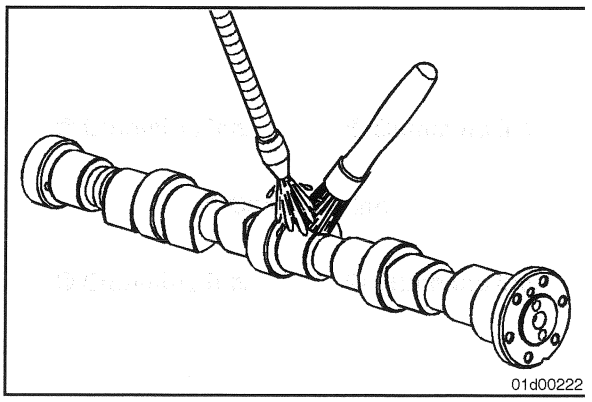
NOTE: Inspection of the rest of the camshaft bushings and camshaft block bores is **not** necessary, unless, during the inspection of the camshaft, damage was noted on the camshaft journals.



⚠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.

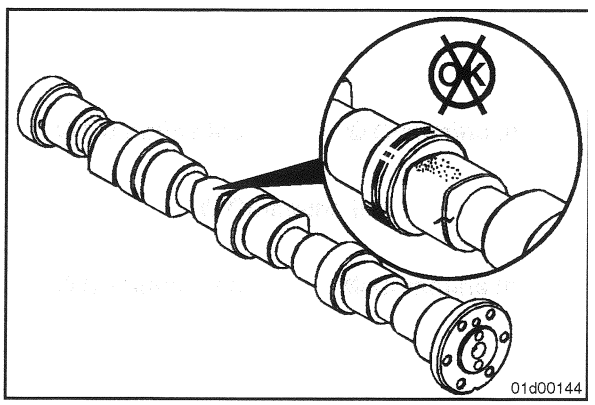
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

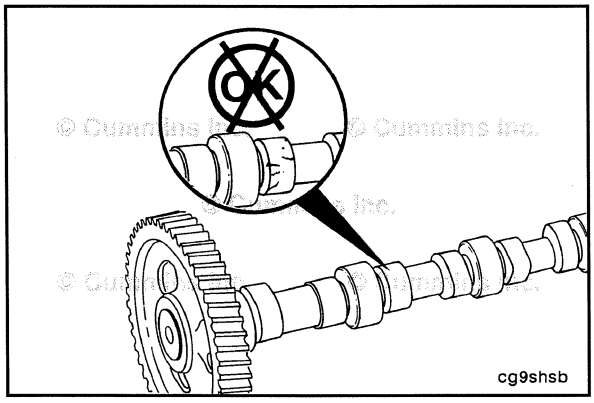
Clean the camshaft with solvents and dry with compressed air.



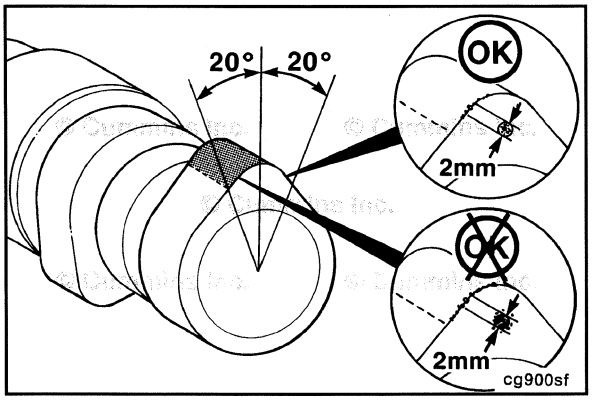
Inspect the valve lobes and bearing journals for cracking, pitting, or scoring.

Inspect the camshaft gear mounting surface on the camshaft to make sure the camshaft gear locating dowel pin is in place and **not** bent, sheared, or cracked.



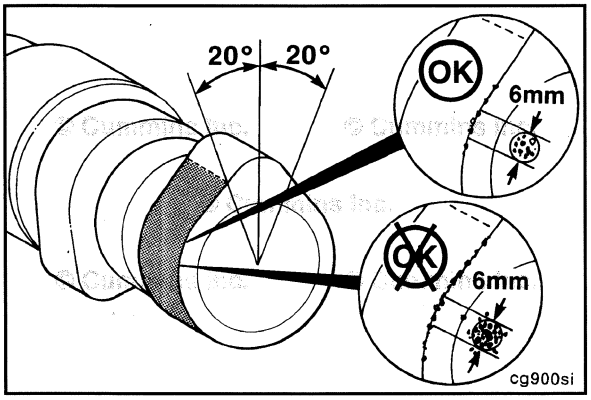


Reference Camshaft and Tappet Reuse Guidelines, Bulletin 3666475, for reuse guidelines for cast iron camshafts.



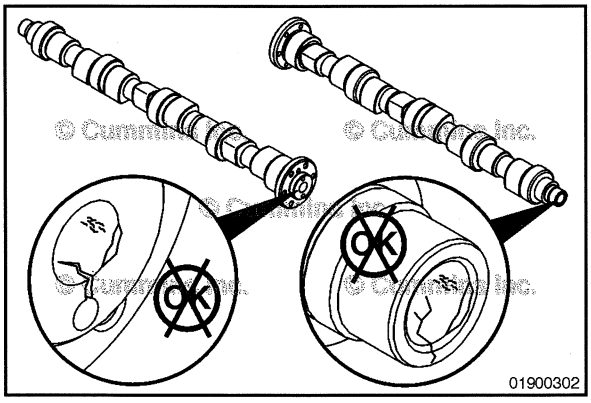
Edge Deterioration (breakdown) Criteria

The area of edge deterioration **must not** be greater than the equivalent area of a 2-mm [0.079-in] circle within ±20 degrees of the nose of the cam lobe.



Outside of the ±20 degrees of the nose of the camshaft lobe, the areas of edge deterioration **must not** be greater than the equivalent area of a 6-mm [0.236-in] circle.

NOTE: If the camshaft shows any pitting or wear, remove and inspect the tappets before installing the camshaft. Refer to Procedure 004-015 in Section 4. If a new camshaft is installed, new tappets also **must** be installed.

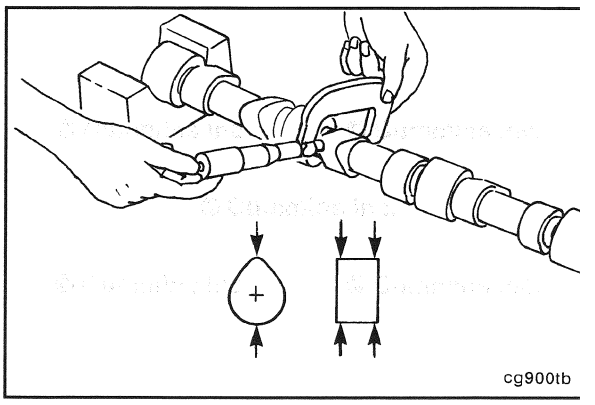


Inspect the inside bore of the camshaft for blockages or oil or sludge buildup on the inside of the camshaft.

Measure

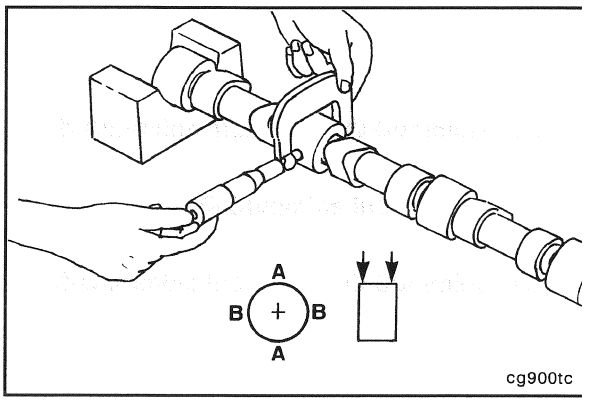
Measure the peak of the camshaft valve lobes.

Diameter of Peak of Lobe			
	mm		in
Intake	47.175	MIN	1.857
	47.855	MAX	1.884
Exhaust	45.632	MIN	1.797
	46.312	MAX	1.823



Measure the camshaft bearing journals.

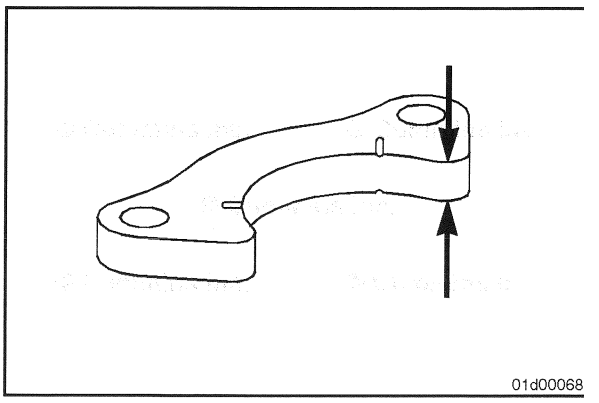
Journal Diameter		
mm		in
53.095	MIN	2.0903
53.995	MAX	2.1257



Measure the camshaft thrust plate thickness.

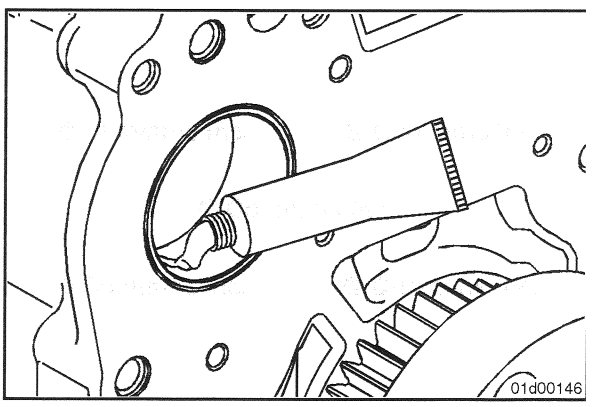
Camshaft Thrust Plate Thickness		
mm		in
5.2	MIN	0.204
5.4	MAX	0.212

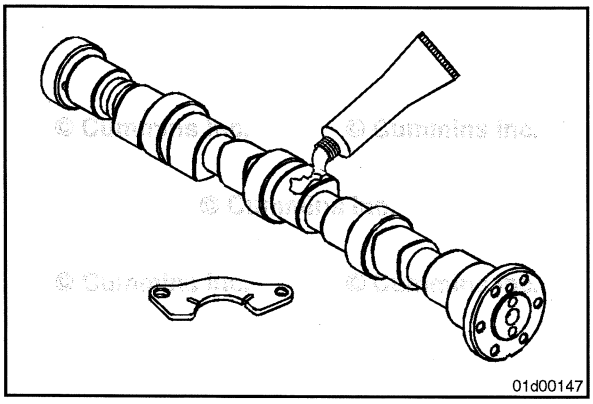
If the camshaft thrust plate is out of specification, replace the thrust plate.



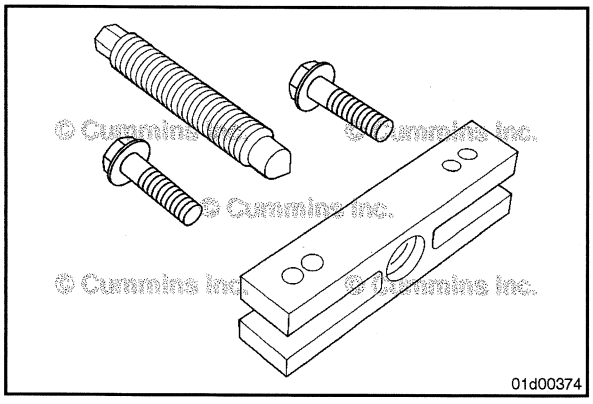
Install

Apply assembly lubricant, Cummins® Part Number 3163087, to the rear camshaft bore.

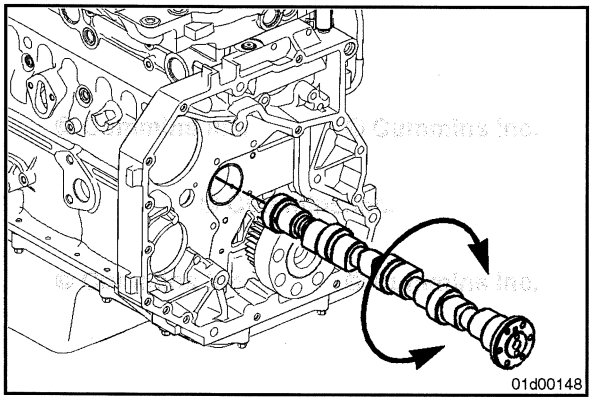




Lubricate the camshaft lobes, journals, and thrust washer with assembly lubricant, Cummins® Part Number 3163087.

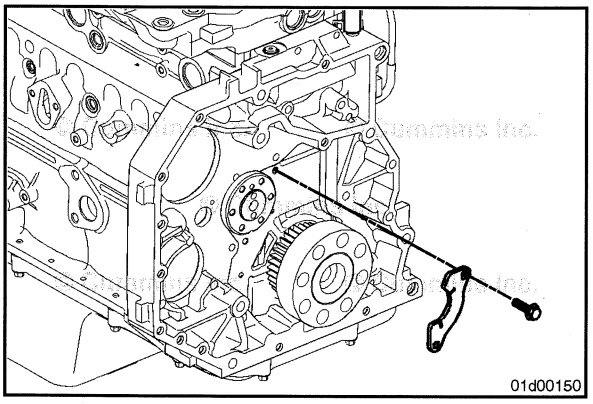


Use a gear puller, Cummins® Part Number ST-647 or equivalent, to attach to the end of the camshaft, where the camshaft gear mounts, to act as a handle. This will give proper leverage and ease in installing the camshaft.



⚠CAUTION⚠
Do not 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.



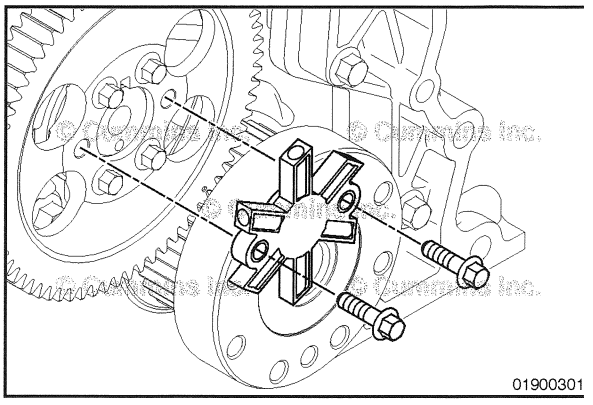
Install the thrust plate.

Torque Value: 24 N•m [212 in-lb]

⚠CAUTION⚠
To reduce the possibility of engine damage, make sure the camshaft rotates freely.

NOTE: The engine can have either a mark on the crankshaft gear or a chamfered tooth.

Align the timing marks on the camshaft gear with the timing marks on the crankshaft gear and tighten the camshaft capscrews.

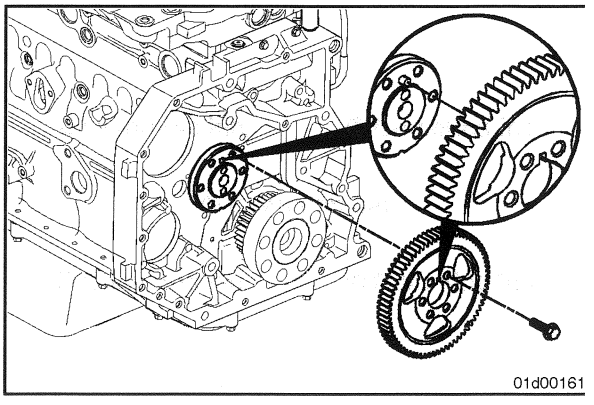


NOTE: The two longer mounting capscrews are used to hold the crankcase internal breather in position.

Rotate the camshaft so the camshaft dowel pin aligns with the slot on the camshaft gear. Lubricate the capscrew threads and nstall the camshaft gear and capscrews.

Tighten the capscrews.

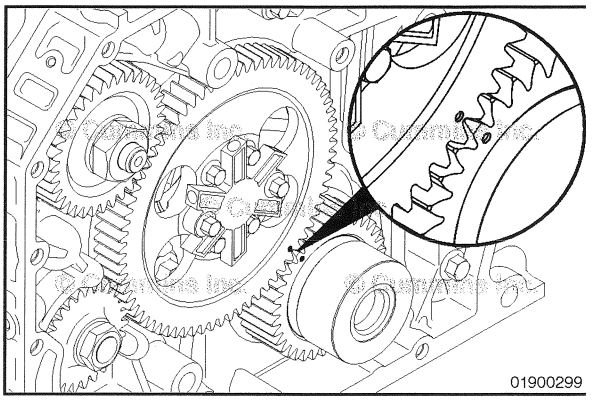
Torque Value: 36 N•m [27 ft-lb]



Install the crankcase breather disc and mounting capscrews.

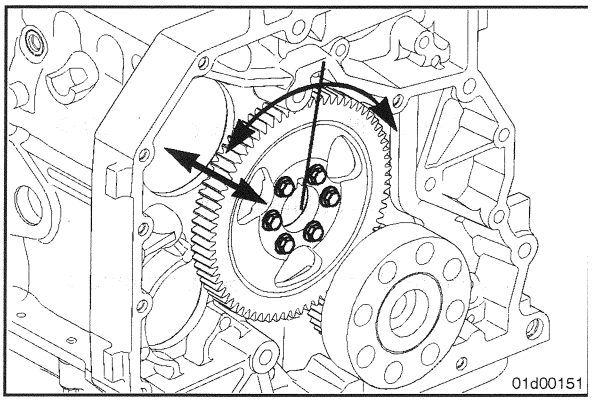
Tighten the mounting capscrews.

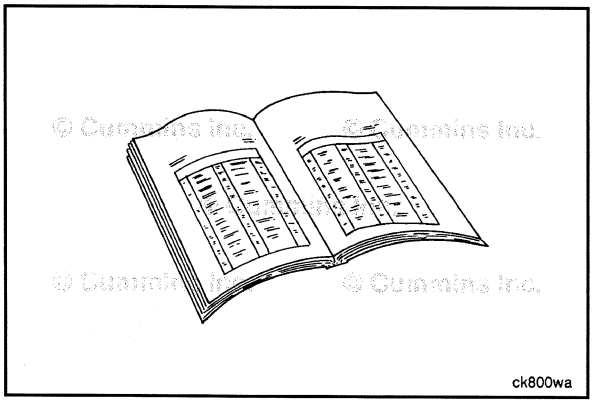
Torque Value: 28 N•m [20 ft-lb]



Use a gauge, Cummins® Part Number 3824564, and magnetic base, Part Number 3377399, to verify the camshaft has proper end play and backlash. Refer to Procedure 001-012 in Section 1.

NOTE: Any time the camshaft is removed from the engine, the camshaft seal behind the crankcase breather tube flange mounting **must** be replaced. Refer to Procedure 003-031 in Section 3 to replace the seal after the camshaft has been installed into the engine.



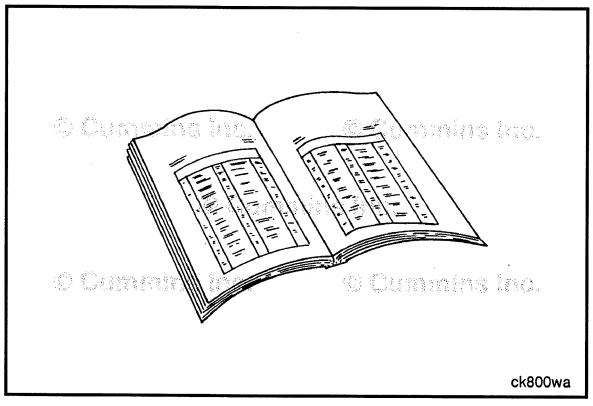


Finishing Steps

⚠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.

- Lower 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 rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Install the flywheel or flexplate. Refer to Procedure To install the flexplate, 016-004 in Section 16. Refer to Procedure To install the flywheel, 016-005 in Section 16
- Install the transmission and all related components, if equipped. See equipment manufacturer service information.
- Install the engine into the application. Refer to Procedure 000-001 in Section 0.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.



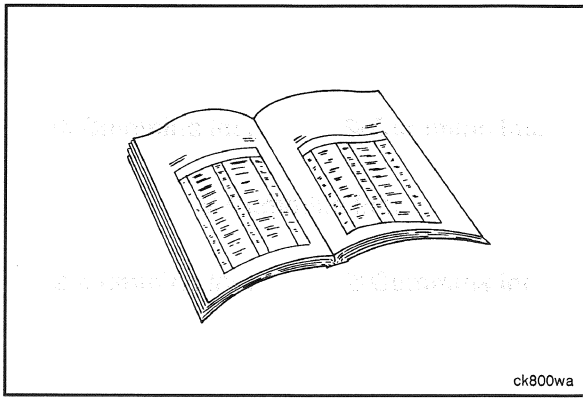
Camshaft Bushings (001-010)

General Information

Some engines are built with a camshaft bushing **only** installed in the first camshaft bore on the same end of the engine that the camshaft is removed and installed.

From production, there are no camshaft bushings installed in the inner block camshaft journal bores.

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

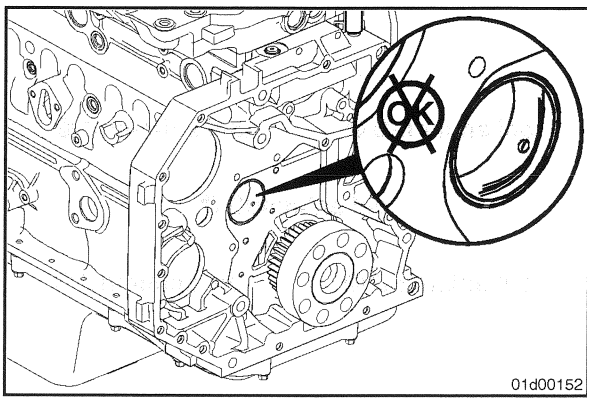
⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the batteries. See equipment manufacturer service information.
- Remove the camshaft. Refer to Procedure 001-008 in Section 1.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the oil pan and oil pan gasket. Refer to Procedure 007-025 in Section 7.

Initial Check

Inspect the camshaft bushing at the end of the engine in which the camshaft was removed for scoring, scuffing or excessive wear.

If damage to the camshaft bushing is found, remove and replace the camshaft bushing.

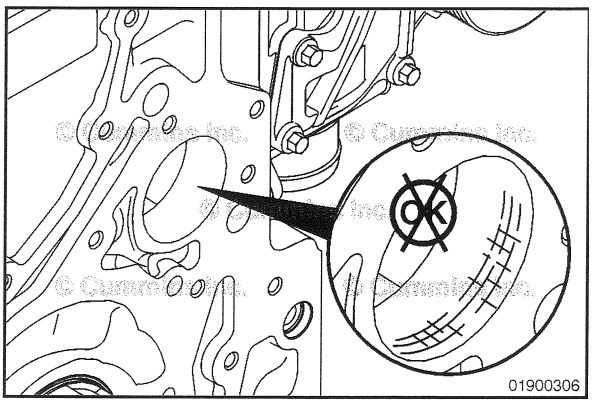


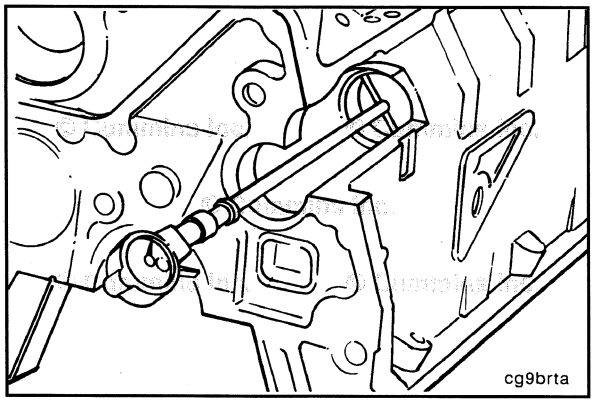
From below the engine, determine if a camshaft bushing is installed at the opposite end of the engine from which the camshaft was removed.

If a camshaft bushing is present, inspect the camshaft bushing for scoring, scuffing, or excessive wear.

If damage to the camshaft bushing is found, remove and replace the camshaft bushing.

To replace the camshaft bushing, you must first:

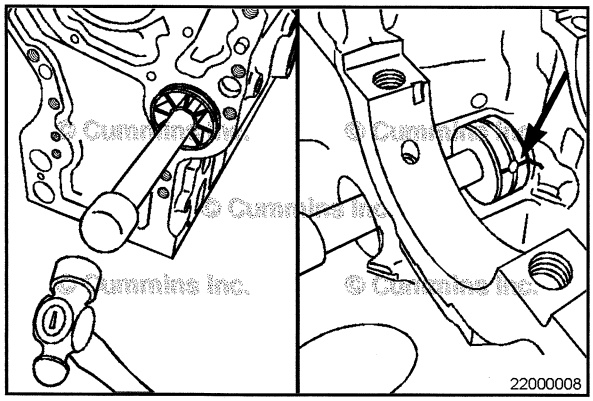




From below the engine, inspect the inner camshaft bores for scoring, scuffing, or excessive wear.

For camshaft bore specifications, reference the Inspect for Reuse section of this procedure.

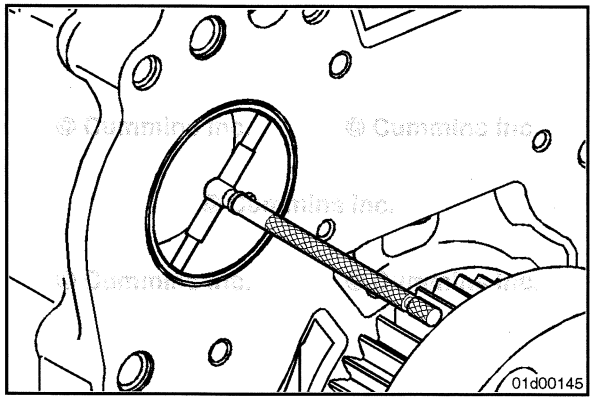
If the damage to the bores is beyond specification, replace the block. Refer to Procedure 001-026 in Section 1.



Remove

Use the camshaft bushing replacer kit, Cummins® Part Number 3165045, to remove the camshaft bushings. The tool will drive the camshaft bushing to the inside of the block. The camshaft bushing can be retrieved from the bottom of the engine.

NOTE: Once removed, camshaft bushings can **not** be reused.

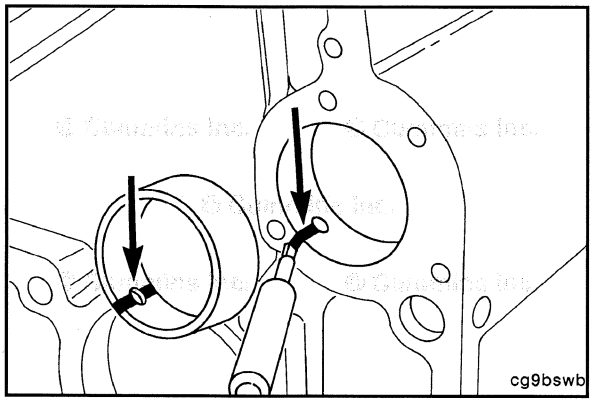


Inspect for Reuse

Measure the camshaft bores **without** the camshaft bushing installed.

Camshaft Bore Diameter without camshaft bushing			
	mm		in
Camshaft Bore (Camshaft Bushing Previously Installed)	59.248	MAX	2.3326
Camshaft Bore (Camshaft Bushing not Previously Installed)	54.164	MAX	2.1324

If a camshaft bushing was previously installed and the camshaft bore is out of specification, replace the block.

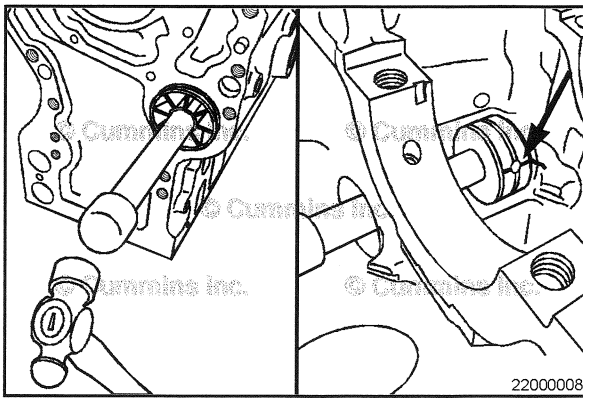


Install

Mark the camshaft bushing and cylinder block with a felt tip pin to aid in the alignment of the lubricating oil hole in the cylinder block with the large lubricating oil hole in the bushing.

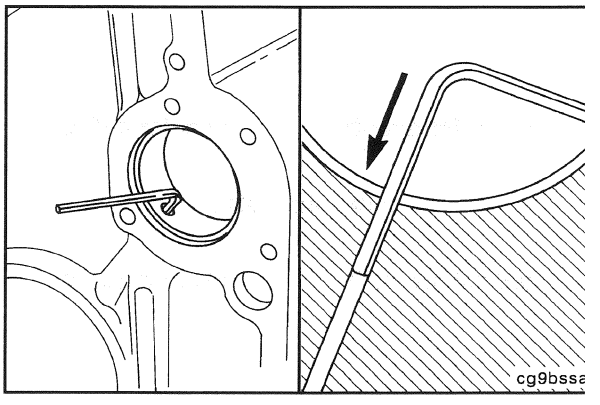
Slide the camshaft bushing on the replacer tool. Align the marks on the camshaft bushing and the cylinder block.

Drive the camshaft bushing to the correct installed depth. The correct installed depth is when the camshaft bushing end is flush with the machined face of the block and the oil hole aligns with the cylinder block oil hole.



Be sure the large lubricating oil hole is aligned.

A 3.2 mm [0.128 in] diameter rod **must** be able to pass through the lubricating oil hole.

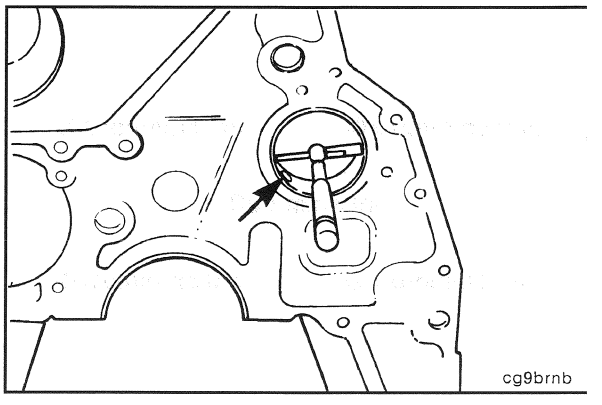


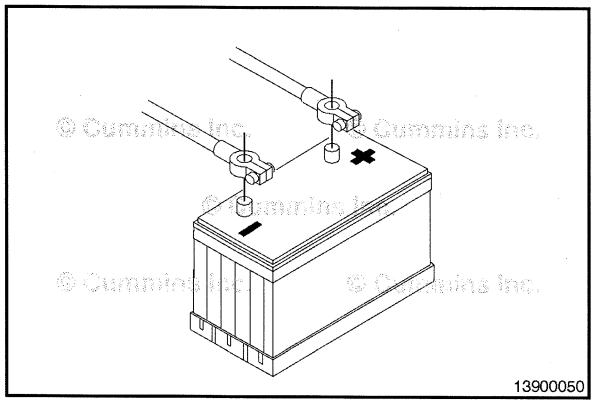
Measure

Measure the installed camshaft bushing.

Camshaft Bore (Bushing Installed)		
mm		in
54.083	MIN	2.1293
54.147	MAX	2.1318

If the camshaft bore with the camshaft bushing installed is out of specification, remove the camshaft bushing and inspect the camshaft bore.

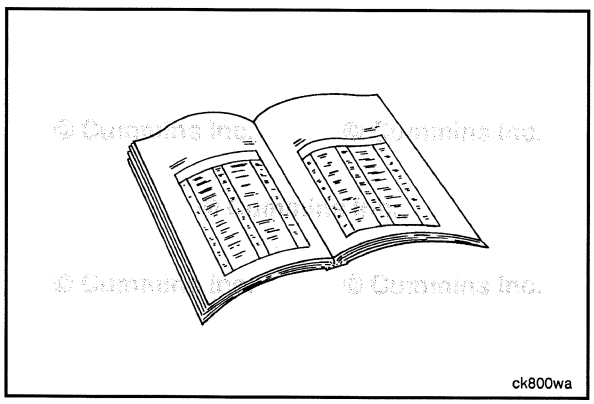




Finishing Steps

⚠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 camshaft. Refer to Procedure 001-008 in Section 1.
- Install the oil pan gasket and oil pan. Refer to Procedure 007-025 in Section 7.
- Fill the engine with clean lubricating oil. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. See equipment manufacturer service information.
- 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.

⚠WARNING⚠
Support the rear of the engine using the rear support attached to the rear of the cylinder block. Failure to support the engine can cause serious personal injury.

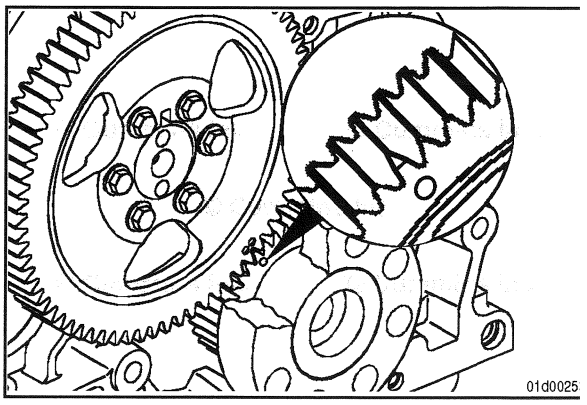
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

- Disconnect the batteries. See equipment manufacturer service information.
- Remove the transmission. See equipment manufacturer service information.
- Remove the starting motor. Refer to Procedure 013-020 in Section 13.
- Remove the flywheel, if installed. Refer to Procedure 016-005 in Section 16.
- Remove the flexplate, if installed. Refer to Procedure 016-004 in Section 16.
- Remove the flywheel housing. Refer to Procedure 016-006 in Section 16.

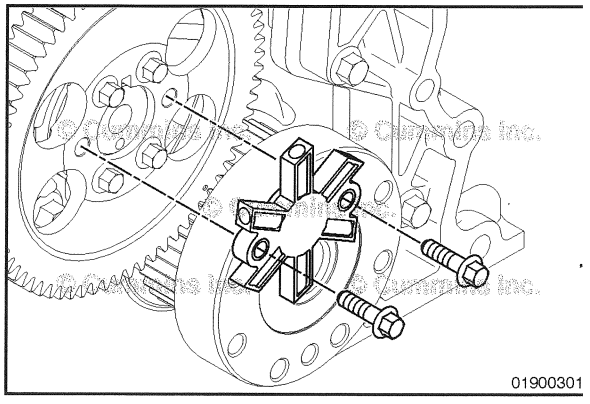
Remove

Rotate the crankshaft to allow the camshaft timing marks to align.

NOTE: Crankshaft timing tooth is beveled at flange end.

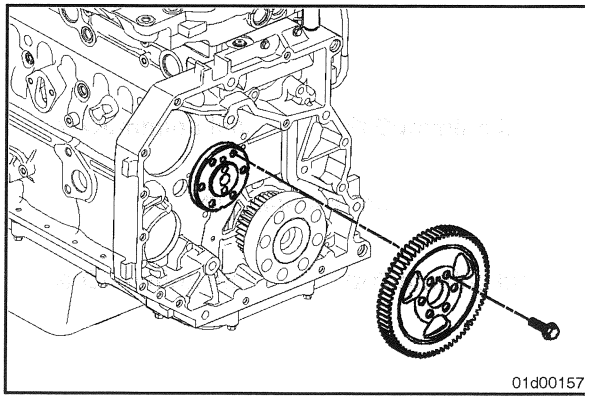


Remove the crankcase breather disc. Refer to Procedure 003-002 in Section 3.



Remove the camshaft gear capscrews.

Remove the camshaft gear.

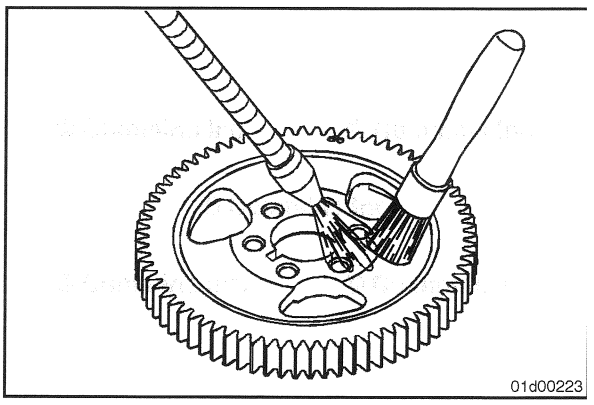


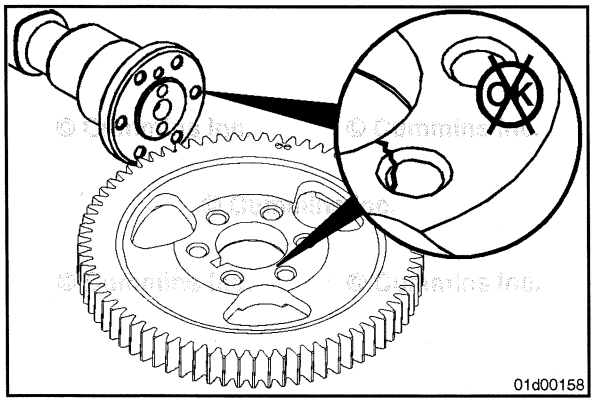
Clean and Inspect for Reuse

⚠ 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.

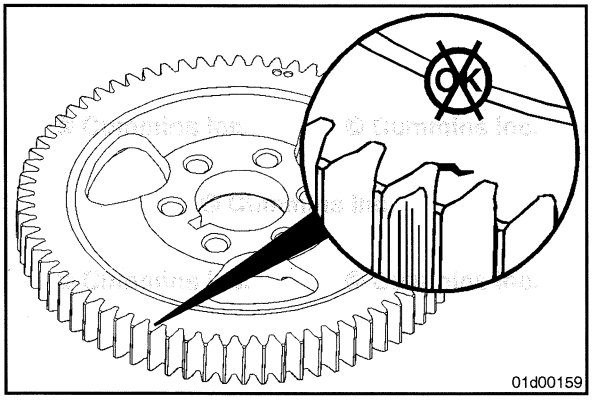
⚠ WARNING ⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the camshaft gear. Dry with compressed air.





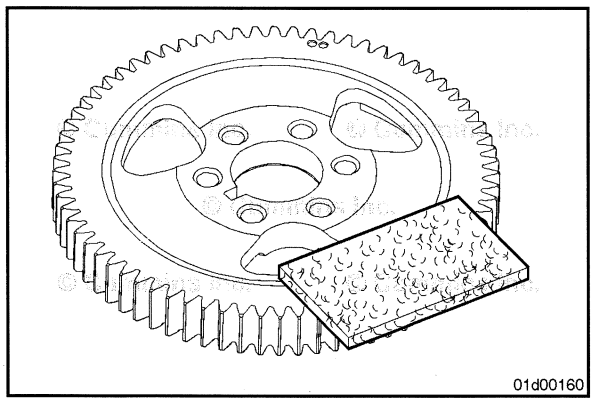
Inspect for cracks and fretting at the capscrew holes on the camshaft and camshaft gear.



Inspect for fretting on the camshaft gear teeth.

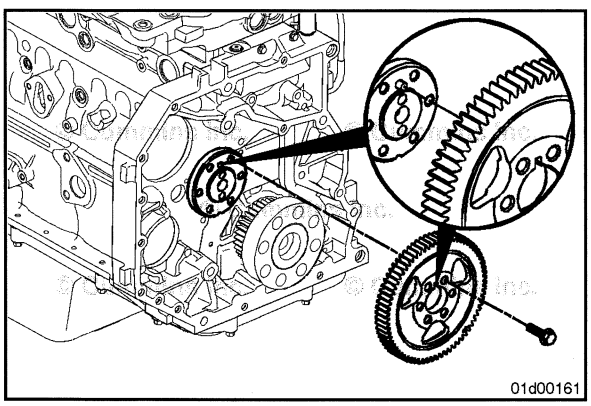
Inspect for cracked or broken teeth on the camshaft gear.

Replace the gear if any damage is found.



Remove any frets, burrs, or raised metal with abrasive pad, Cummins® Part Number 3823258.

If frets, burrs, or raised metal can **not** be removed with abrasive pad, Cummins® Part Number 3823258, replace the gear.



Install

⚠CAUTION⚠
To reduce the possibility of engine damage, make sure the camshaft rotates freely.

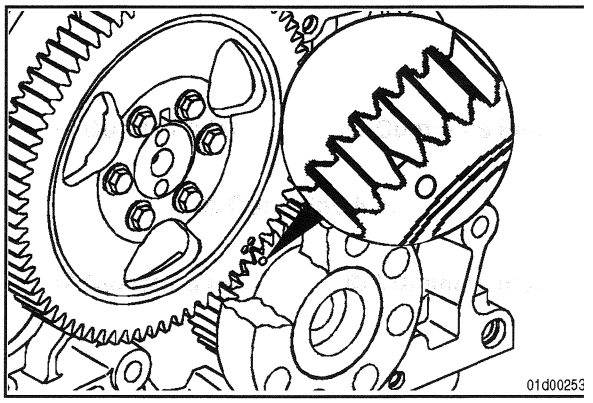
Align the camshaft gear with the pin in the camshaft and the mark on the crankshaft gear.

Install the camshaft gear onto the camshaft.

Check to make sure the timing marks on the camshaft gear align with the timing marks on the crankshaft gear.

NOTE: Crankshaft timing tooth is beveled at the flange end.

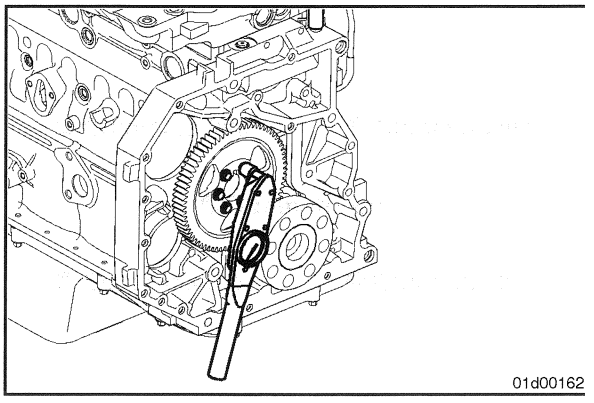
Mesh camshaft gear timing marks with crankshaft timing tooth and align pin in camshaft with key slot in the camshaft gear.



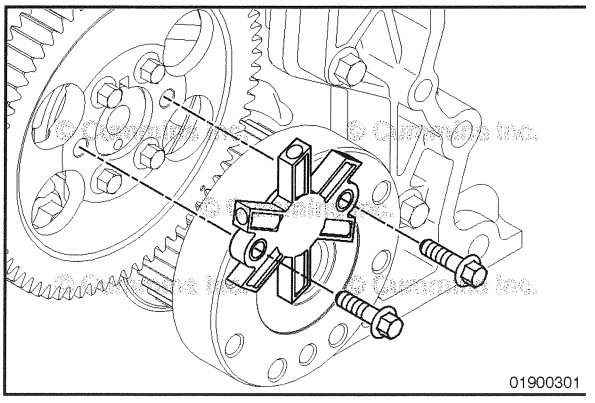
Install the camshaft gear capscrews and tighten.

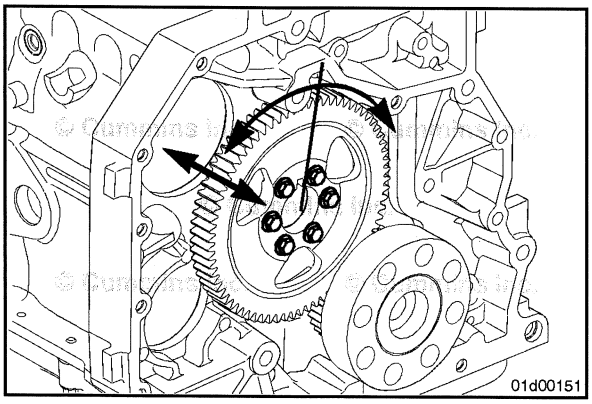
Torque Value: 15 N•m [133 in-lb]

Tighten an additional 35 degrees.



Install the crankcase breather disc. Refer to Procedure 003-002 in Section 3.





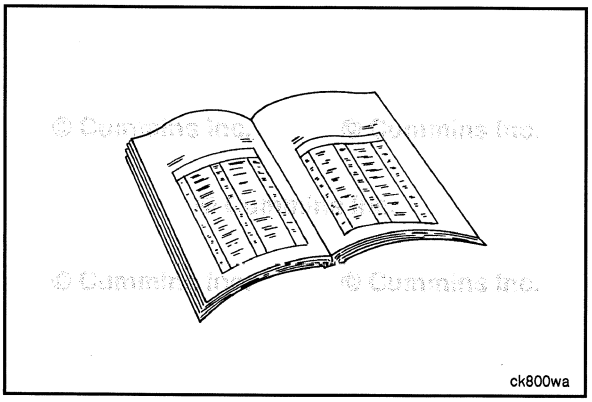
Measure

Use gauge, Cummins® Part Number 3824564, and magnetic base, Part Number 3377399, to check the camshaft end play.

Camshaft End Play		
mm		in
0.070	MIN	0.003
0.330	MAX	0.013

Check the camshaft backlash.

Camshaft Backlash		
mm		in
0.076	MIN	0.003
0.280	MAX	0.011



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⚠
Support the rear of the engine using the rear support attached to the rear of the cylinder block. Failure to support the engine can cause serious personal injury.

⚠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.

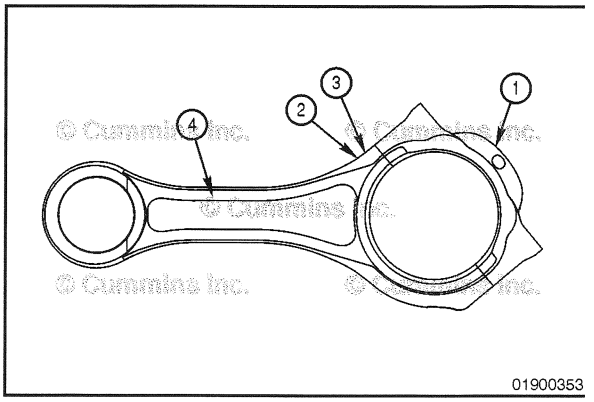
- Install the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Install the flywheel, if installed. Refer to Procedure 016-005 in Section 16.
- Install the flexplate, if installed. Refer to Procedure 016-004 in Section 16.
- Install the starter motor. Refer to Procedure 013-020 in Section 13.
- Install the transmission. See equipment manufacturer service information.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.

Connecting Rod (001-014)

General Information

When replacing a connecting rod, make sure it matches the other connecting rods. All the connecting rods in the engine **must** be the same.

Not all connecting rods have the part number located on the connecting rod. It may be necessary to identify physical characteristics of the connecting rod when matching it to existing connecting rods.



1 Balance weight on the connecting rod cap.

2 Protrusion on short side of connecting rod.

3 Smooth edge on short side of connecting rod.

4 I-Beam design.

Preparatory Steps

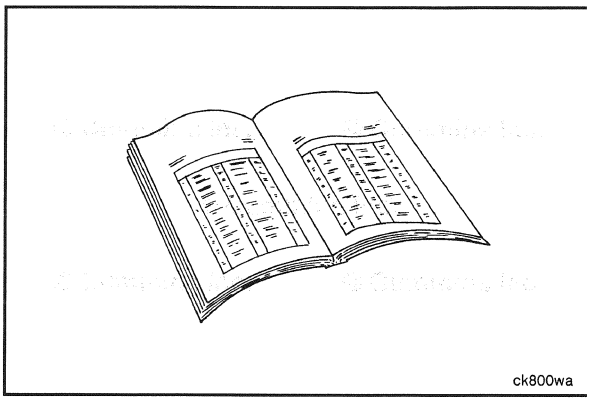
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

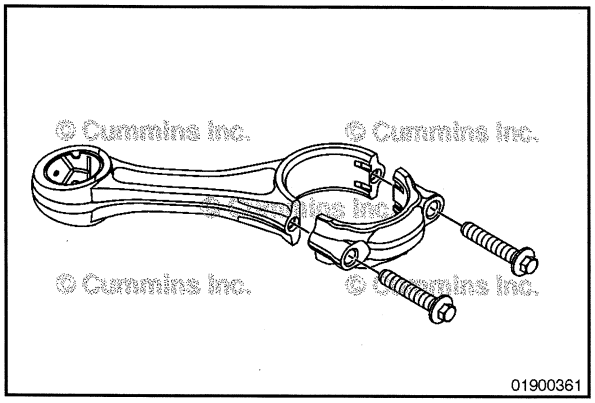
⚠WARNING⚠
Coolant is toxic. Keep away from pets and children. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Wait until the temperature is below 50°C [120°F] to reduce the possibility of personal injury from hot coolant.

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

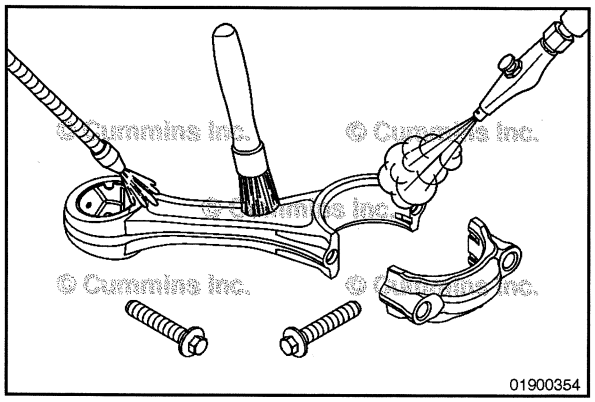
- Disconnect the batteries. See equipment manufacturer service information.
- Remove the piston and connecting rod assemblies from the engine. Refer to Procedure 001-054 in Section 1.
- Disassemble the pistons from the connecting rods. Refer to Procedure 001-054 in Section 1.





Disassemble

Remove the connecting rod capscrews and separate the connecting rod cap from the connecting rod, if assembled.



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⚠
Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Use only with protective clothing, goggles/shield, and gloves.

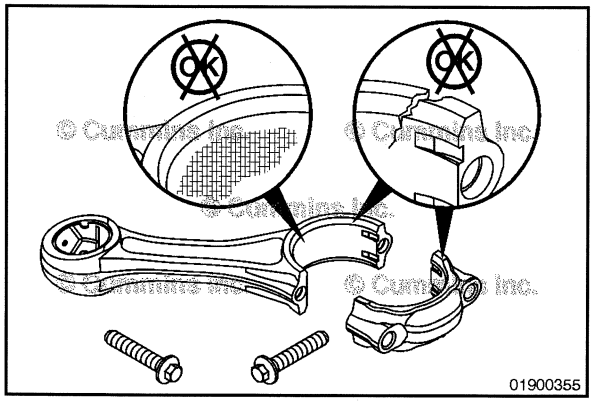
△CAUTION△
The contact surface between the connecting rod and connecting rod cap is not a machined surface. Care should be exercised so these parts are not damaged during handling.

Use solvent to clean the connecting rods.

NOTE: Unless cleaning the contact surface between the connecting rod and connecting rod cap, the rod and cap should be assembled together with the bolts tightened finger tight to prevent damage to the mating surfaces.

Use solvent and a nylon bristle brush to clean the contact surface between the connecting rod and connecting rod cap. Dry the contact surface with compressed air.

Dry the connecting rods with compressed air.

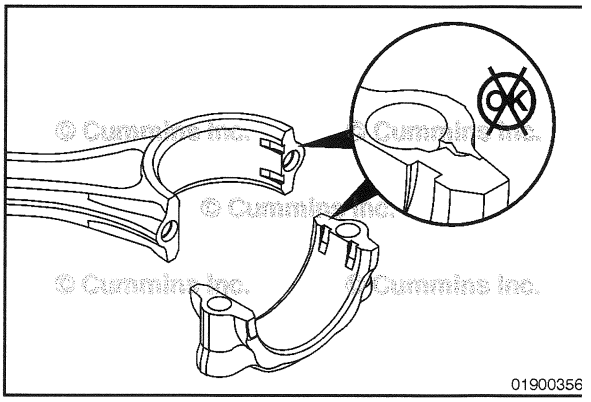


△CAUTION△
The connecting rod and rod cap must be replaced as an assembly if any fretting damage is visible on either piece.

Inspect the rod caps, connecting rod bearing saddles, and capscrews for nicks, cracks, burrs, scratches, and frets.

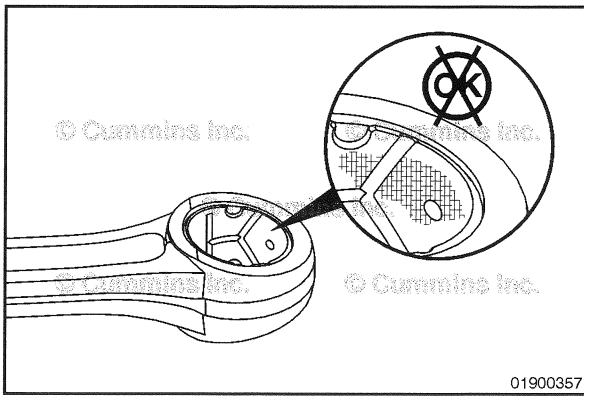
NOTE: The contact surface between the connecting rod and the connecting rod cap is **not** a machined surface. This surface should **not** be considered damaged unless there are deep nicks or cracks across the surface.

Inspect the contact surface between the connecting rod and the connecting rod cap.



Inspect the connecting rod piston pin bore for damage.

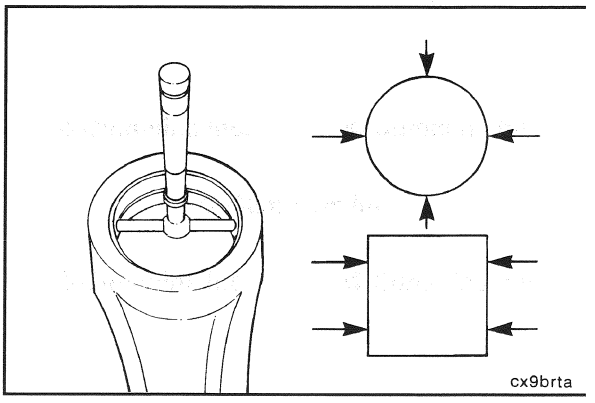
NOTE: The connecting rod small end bore does **not** have an oil drilling that lines up with the hole in the bushing. The hole in the bushing is for manufacturing purposes only.

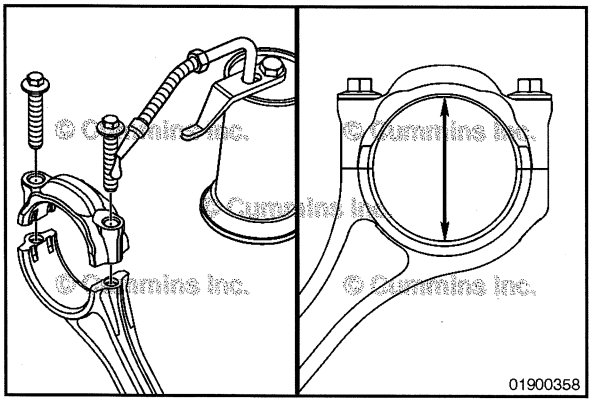


Measure the connecting rod piston pin bushing inside diameter.

Connecting Rod Piston Pin Bushing Diameter		
mm		**in**
40.019	MIN	1.5756
40.042	MAX	1.5765

If the bushing is found to be damaged or out of specification, the bushing can be replaced. Use service tool, Cummins® Part Number 3823902, to remove and install the bushing.





⚠CAUTION⚠
Use a vise with brass jaws to hold the connecting rod. Notches, scratches, or dents in the I-beam area can cause engine damage.

⚠CAUTION⚠
The number on the connecting rod must be the same as the number on the rod cap. Connecting rods and caps are manufactured as an assembly and cannot be interchanged. Engine damage can result.

Use clean 15W-40 engine oil to lubricate the connecting rod capscrews.

Assemble the connecting rod, rod cap, and capscrews.

Tighten the capscrews. Refer to Procedure 001-054 in Section 1 for torque values.

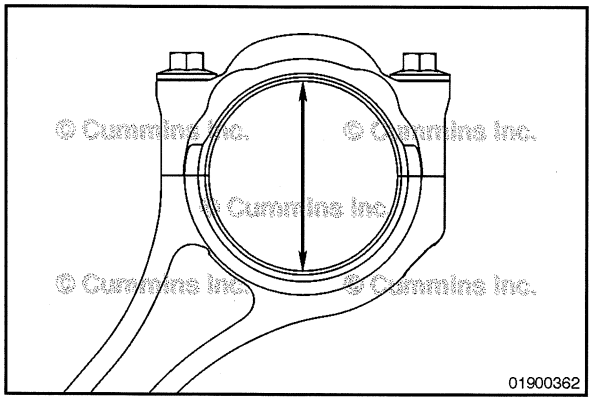
Use a dial bore indicator to measure the inside diameter within a 20-degree arc from each side of the parting line.

Measure the inside diameter at 90 degrees from the parting line.

Connecting Rod Crankshaft Bore Diameter Bearings Removed

mm		in
72.99	MIN	2.873
73.01	MAX	2.875

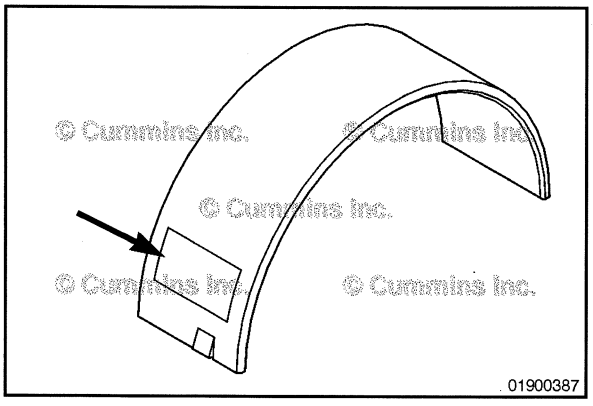
NOTE: If the connecting rod crankshaft bore measurements are **not** within specifications, the connecting rod **must** be replaced.



Repeat the above inspection with the connecting rod bearings installed.

Standard Connecting Rod Crankshaft Bore Diameter with Bearings Installed

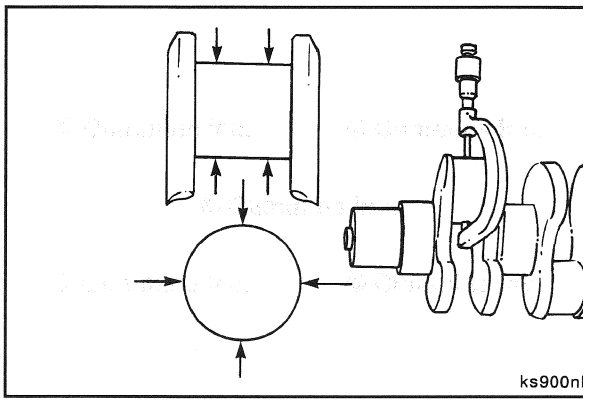
	mm		in
Standard	69.05	MIN	2.719
	69.10	MAX	2.720



Oversize Connecting Rod Crankshaft Bore Diameter with Bearings Installed

	mm		in
Oversize			
0.25 mm [0.010 in]	68.80	MIN	2.709
	68.85	MAX	2.711
0.50 mm [0.020 in]	68.55	MIN	2.699
	68.60	MAX	2.701

Measure the diameter of the connecting rod journal on the crankshaft. Refer to Procedure 001-016 in Section 1.

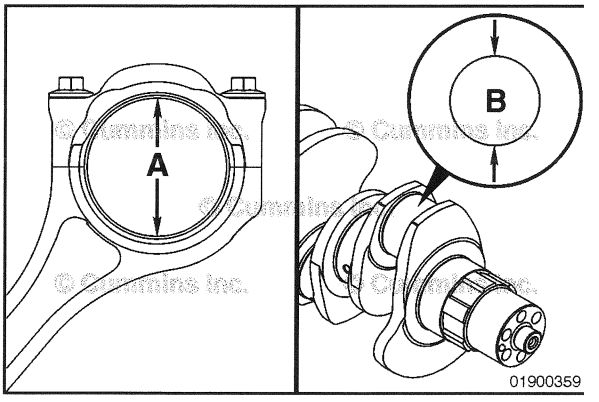


Standard Crankshaft Connecting Rod Journal Diameter			
	mm		in
Standard	68.962	MIN	2.7150
	69.013	MAX	2.7170

Undersize Crankshaft Connecting Rod Journal Diameter			
	mm		in
Undersize			
0.25 mm [0.010 in]	68.712	MIN	2.7052
	68.763	MAX	2.7072
0.50 mm [0.020 in]	68.462	MIN	2.6954
	68.513	MAX	2.6974

NOTE: If crankshaft connecting rod journals are **not** within the given specifications, the crankshaft **must** be reground.

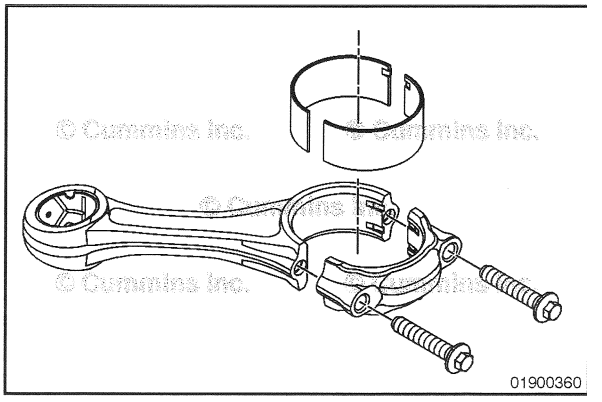
Bearing clearance equals the connecting rod crankshaft bore (with bearing) (A) minus the crankshaft connecting rod journal diameter (B).

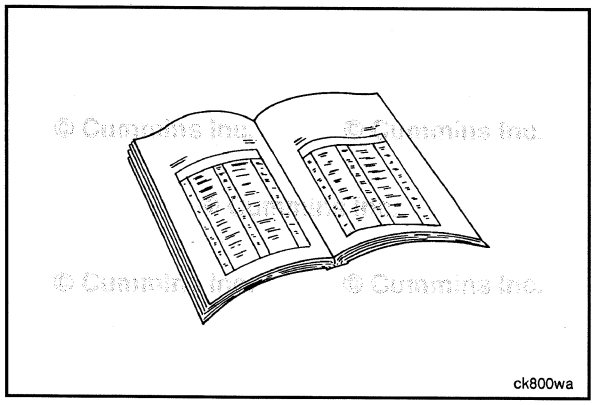


Connecting Rod to Crankshaft Bearing Clearance		
mm		in
0.04	MIN	0.002
0.12	MAX	0.005

Bearing clearance can also be determined with plastigauge during engine assembly.

NOTE: If the clearance is found to be out of specification, use another set of connecting rod bearings.





Finishing Steps

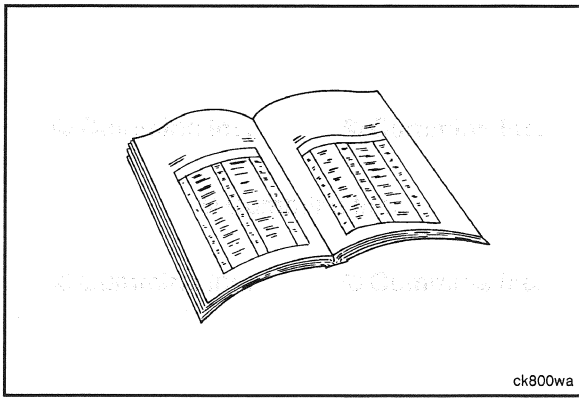
⚠WARNING⚠

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 the pistons on the connecting rods. Refer to Procedure 001-054 in Section 1.
- Install the pistons and connecting rod assembly. Refer to Procedure 001-054 in Section 1.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine to normal operating temperatures and check for leaks.

Crankshaft (001-016)

Preparatory Steps



⚠WARNING⚠
The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

⚠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.

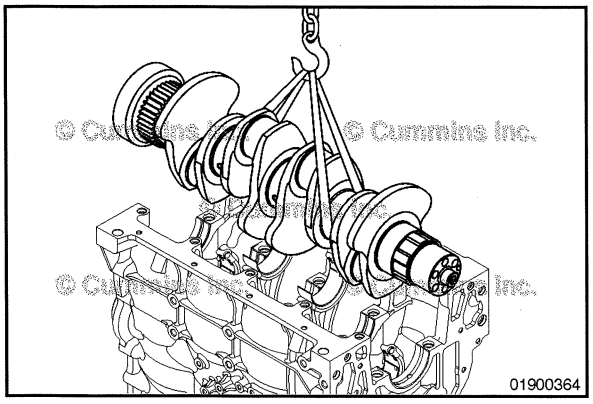
⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠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. See equipment manufacturer service information.
- Remove the engine and place on an engine stand. Refer to Procedure 000-001 in Section 0.
- Remove the cooling fan drive belt. Refer to Procedure 008-002 in Section 8.
- If required, remove the fan hub pulley. Refer to Procedure 008-039 in Section 8.
- Remove the crankshaft speed indicator ring. Refer to Procedure 001-071 in Section 1.
- Remove the front gear cover. Refer to Procedure 001-031 in Section 1.
- Remove the flywheel, if installed. Refer to Procedure 016-005 in Section 16 or
- Remove the flexplate, if installed. Refer to Procedure 016-004 in Section 16.
- Remove the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Remove the camshaft gear. Refer to Procedure 001-012 in Section 1.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the block stiffener plate. Refer to Procedure 001-089 in Section 1.
- Remove the fuel pump and gear. Refer to Procedure 005-016 in Section 5.
- If equipped, remove or disconnect any driven accessories (i.e., hydraulic pump).

Service Tip: With the engine on the engine stand, rotate the engine so that it is upside down. This will allow the tappets to move off of the camshaft and eliminate the need to use tappet replacement kit, Cummins® Part Number 3822513, to raise the tappets.

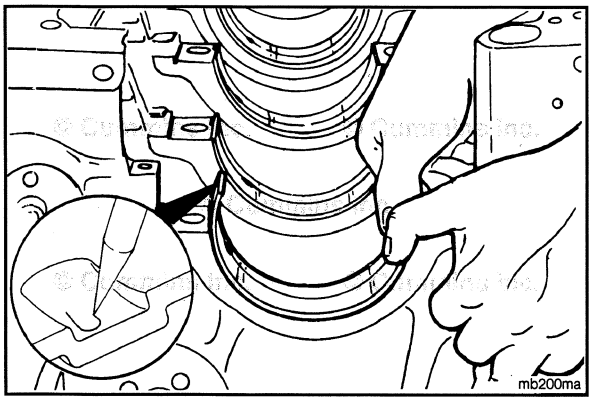
- Remove the rear gear housing. Refer to Procedure 001-034 in Section 1.
- Remove the connecting rod caps. Refer to Procedure 001-005 in Section 1.
- Remove the main bearing caps. Refer to Procedure 001-006 in Section 1.



Remove

⚠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.

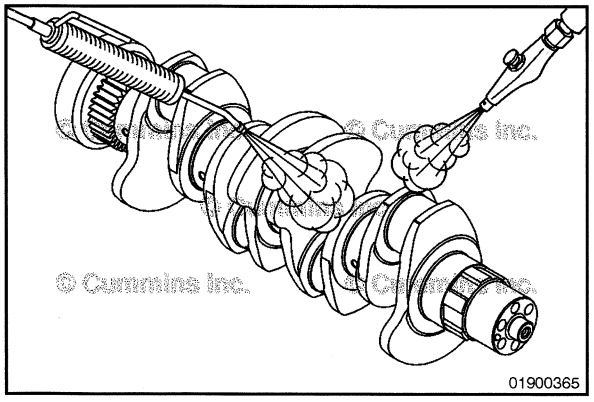
Remove the crankshaft.



Remove the upper main bearings.

Use an awl to mark the bearing's position in the tang area.

NOTE: Marking the bearing's position is for future identification or possible failure analysis.



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.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

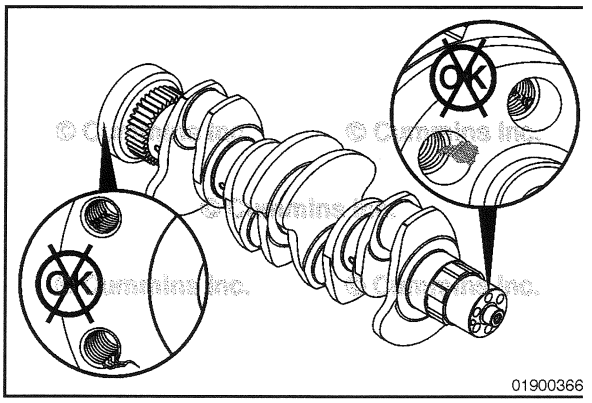
Steam-clean or use hot, soapy water to clean the crankshaft and gear(s).

Use a non-metallic bristle brush to clean the oil drillings. Dry with compressed air. Make sure to blow out the threaded holes on each end of the crankshaft and the oil drillings.

⚠CAUTION⚠
Do not chase threads on the crankshaft. Severe engine damage can occur.

Check the threads for damage at both ends of the crankshaft.

If damage is found, replace the crankshaft.



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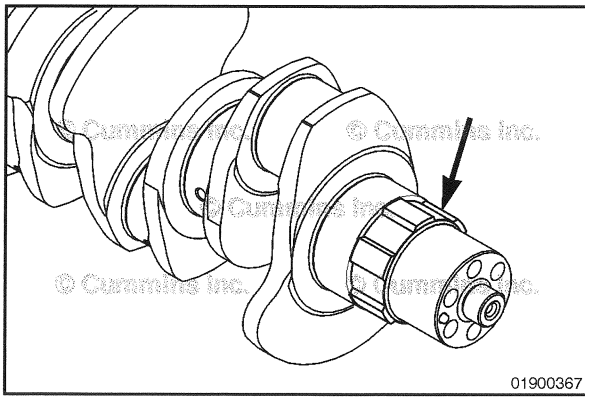
The nose of the crankshaft also serves as the drive shaft for the lubricating oil pump. The inner gear of the oil pump is press fit onto the crankshaft. Refer to Procedure 007-031 in Section 7 for inspection.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Use a fine crocus cloth to polish the machined surfaces.

Inspect the front crankshaft gear.

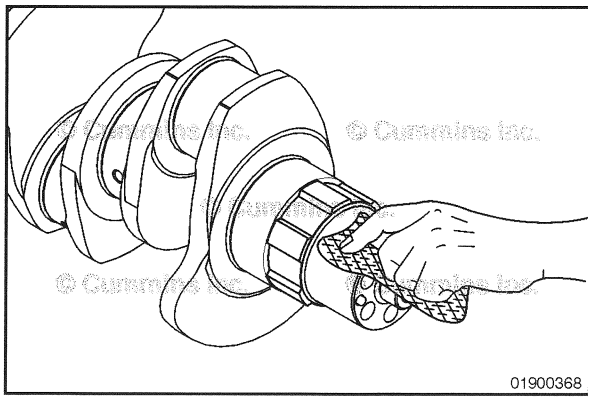
Inspect the front crankshaft seal contact area. Refer to Procedure 001-023 in Section 1.

Inspect the rear crankshaft seal contact area. Refer to Procedure 001-024 in Section 1.

Inspect the connecting rod bearings. Refer to Procedure 001-005 in Section 1.

Inspect the main bearings. Refer to Procedure 001-006 in Section 1.

NOTE: Inspect the rear crankshaft gear. Inspect the crankshaft gear for pitting, fretting, or missing teeth. The rear crankshaft gear is **not** replaceable. If fretting can **not** be removed using abrasive pad, Cummins® Part Number 3823258 or equivalent, the crankshaft **must** be replaced.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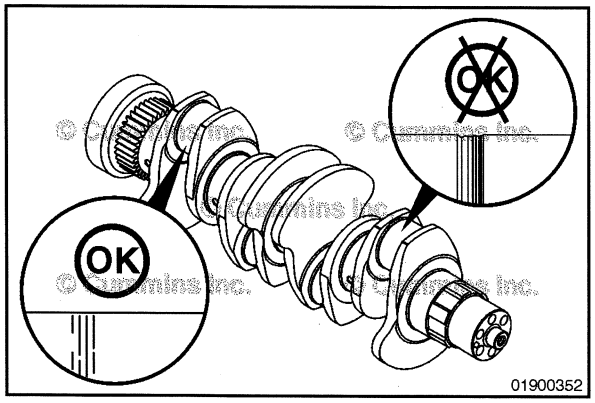
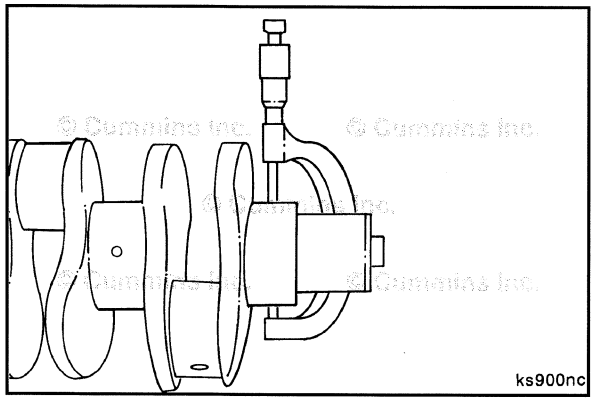


Check the main bearing journals and the rod bearing journals for damage or excessive wear. Minor scratches are acceptable.



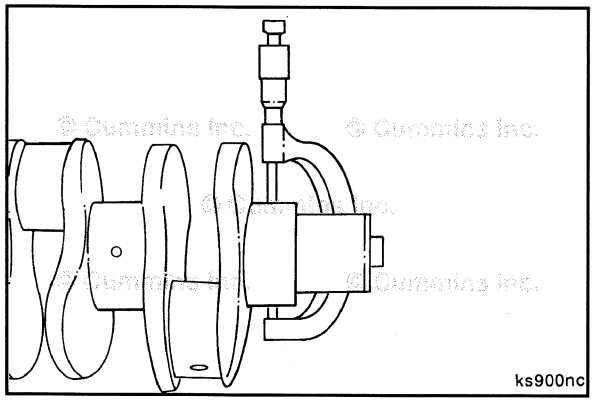
Measure

Measure the crankshaft main and connecting rod journals.

Out-of-Roundness: 0.050 mm [0.002 in].

Taper: 0.013 mm [0.0005 in].

NOTE: If crankshaft journals are **not** within the given specification, the crankshaft **must** be reground. **Always** grind all of the journals when one is **not** within specifications.



Measure and record the diameter of the connecting rod journal on the crankshaft.

Standard Crankshaft Connecting Rod Journal Diameter

	mm		in
Standard	68.962	MIN	2.7150
	69.013	MAX	2.7170

Undersize Crankshaft Connecting Rod Journal Diameter

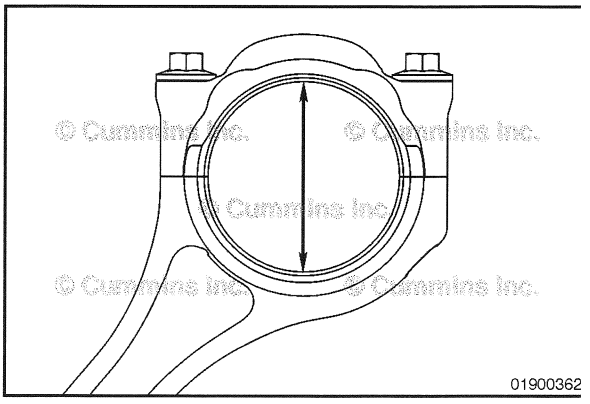
	mm		in
Undersize			
0.25 mm [0.010 in]	68.712	MIN	2.7052
	68.763	MAX	2.7072
0.50 mm [0.020 in]	68.462	MIN	2.6954
	68.513	MAX	2.6974

NOTE: If crankshaft connecting rod journals are **not** within the given specifications, the crankshaft **must** be reground. Machine the crankshaft to the minimum specification of the target undersize bearing. Then finish the crankshaft to the nominal value of the target undersize bearing. **Always** grind all of the journals when one is **not** within specifications.

Measure and record the diameter of the connecting rod crankshaft bore with the bearings installed. Refer to Procedure 001-014 in Section 1 for measuring the connecting rod crankshaft bore (with bearing).

Calculate the connecting rod bearing to crankshaft journal clearance.

Bearing clearance equals the connecting rod crankshaft bore (with bearing) minus the crankshaft connecting rod journal diameter.



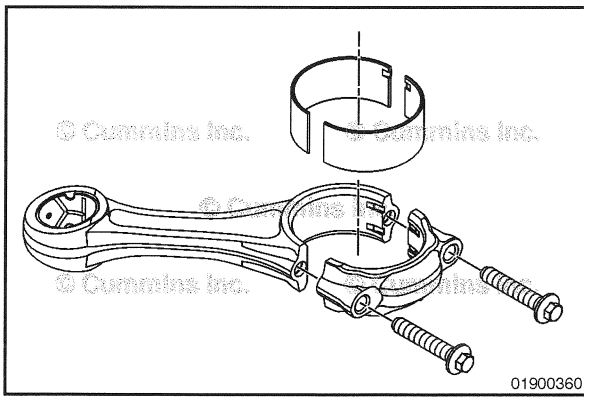
Connecting Rod to Crankshaft Bearing Clearance		
mm		in
0.04	MIN	0.002
0.12	MAX	0.005

Bearing clearance can also be determined with a plastigauge during crankshaft installation.

NOTE: If the clearance is found to be out of specification:

1 Replace or use another set of connecting rod bearings

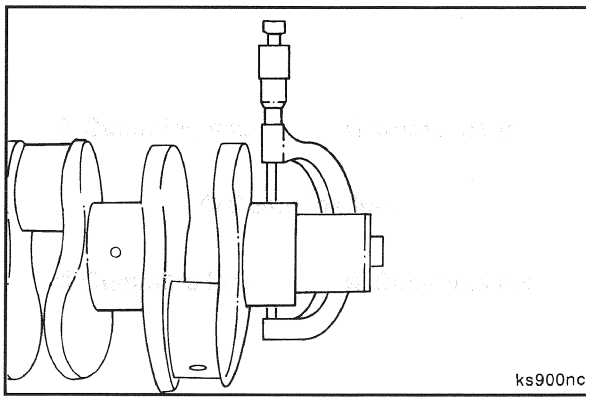
2 Measure and inspect the connecting rod crankshaft bore with the bearings removed. Refer to Procedure 001-014 in Section 1.



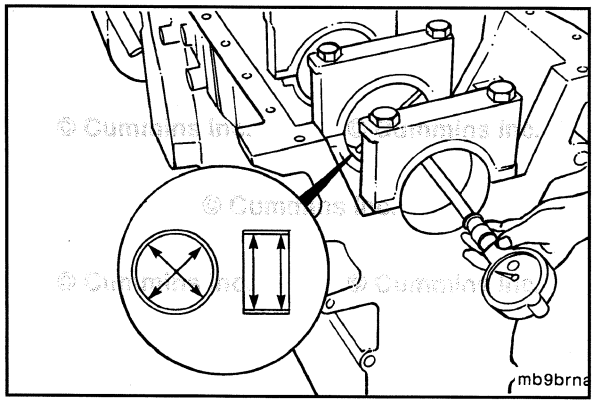
Measure and record the diameter of the main bearing journal on the crankshaft.

Standard Crankshaft Main Bearing Journal Diameter			
	mm		in
Standard	82.962	MIN	3.2662
	83.013	MAX	3.2682

Undersize Crankshaft Main Bearing Journal Diameter			
	mm		in
Undersize			
0.25 mm [0.010 in]	82.712	MIN	3.2564
	82.763	MAX	3.2584
0.50 mm [0.020 in]	82.462	MIN	3.2465
	82.513	MAX	3.2485



NOTE: If crankshaft main bearing journals are **not** within the given specifications, the crankshaft **must** be reground. Machine the crankshaft to the minimum specification of the target undersize bearing. Then finish the crankshaft to the nominal value of the target undersize bearing. **Always** grind all of the journals when one is **not** within specifications.



Install the main bearing caps with the upper and lower main bearings. Refer to Procedure 001-006 in Section 1 for main bearing cap installation.

Tighten the main bearing cap capscrews.

Torque Value: 176 N•m [130 ft-lb]

Measure the main bearing bore with the bearings installed.

Calculate the main bearing to crankshaft journal clearance.

Bearing clearance equals the main bearing crankshaft bore (with bearing) minus the crankshaft main bearing journal diameter.

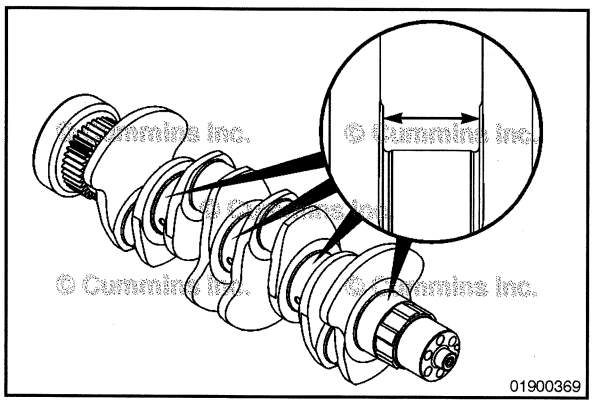
Main Bearing Bore to Crankshaft Bearing Clearance		
mm		**in**
0.04	MIN	0.002
0.12	MAX	0.005

Bearing clearance can also be determined with a plastigauge during engine assembly.

NOTE: If the clearance is found to be out of specification:

1 Replace or use another set of main bearings.

2 Measure and inspect the main bearing bore with the bearings removed. Refer to Procedure 001-026 in Section 1.



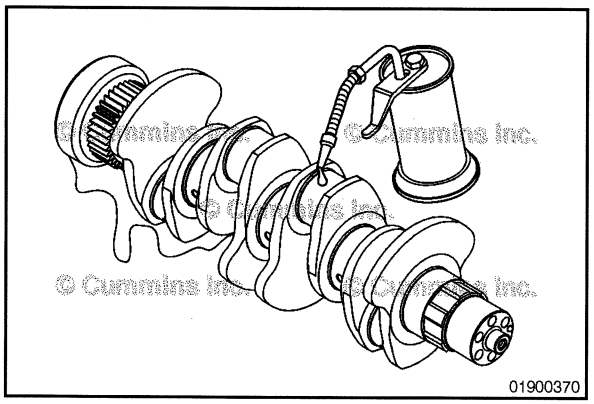
Check the thrust bearing surfaces for damage or excessive wear. Minor scratches are acceptable. Use a fine crocus cloth to polish the machined surfaces.

The thrust bearing surfaces are located at the number 4 crankshaft main bearing journal.

Measure the thrust distance.

Thrust Distance		
mm		**in**
0.065	MIN	0.003
0.432	MAX	0.017

NOTE: Oversize thrust bearings are available if the thrust distance is **not** within specifications. Oversize thrust bearings of 0.25 and 0.50 mm [0.010 to 0.020 in] are available.



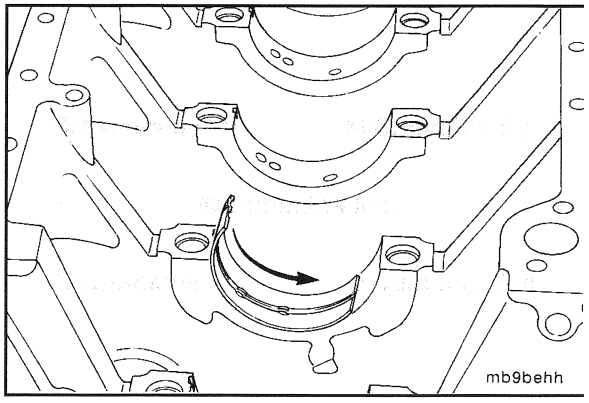
Use a light preservative oil to lubricate the crankshaft to prevent rust.

NOTE: If the crankshaft is **not** going to be used immediately, use a **heavy** preservative oil. Protect the crankshaft with a cover to prevent dirt from sticking to the oil.

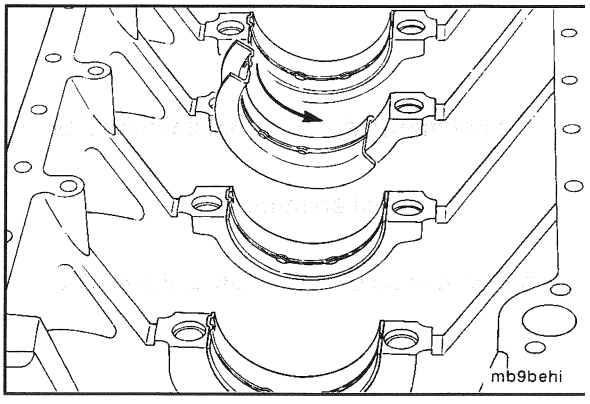
Install

Make sure the backsides of the bearings are clean and free of debris before installing the upper main bearings into the block.

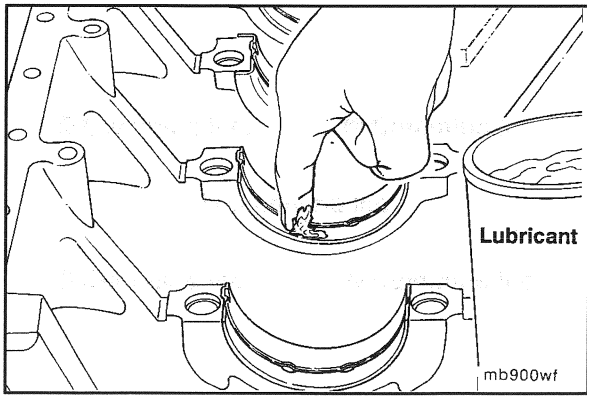
Make sure to align the tangs of the bearings with tangs on the main bearing block saddles.



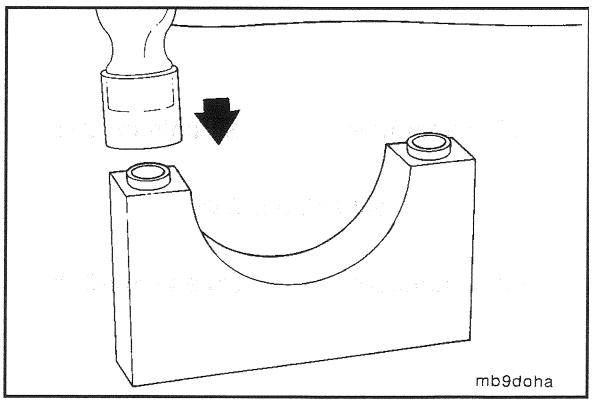
Install the upper crankshaft thrust bearing at the number 4 main bearing.

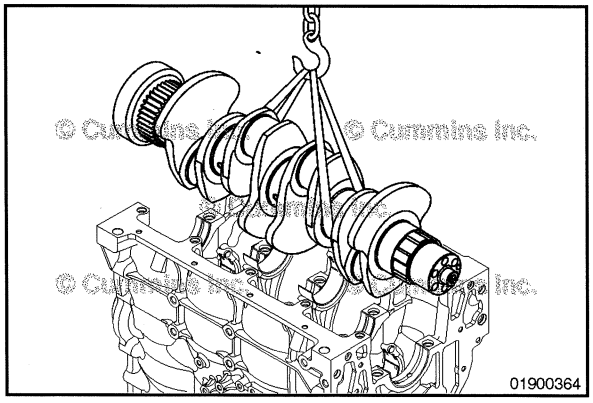


Apply a coat of assembly lubricant, Cummins® Part Number 3163087, to the crankshaft side of the main bearings and thrust bearing surfaces.



Check the main bearing caps to make sure the ring dowels are installed.



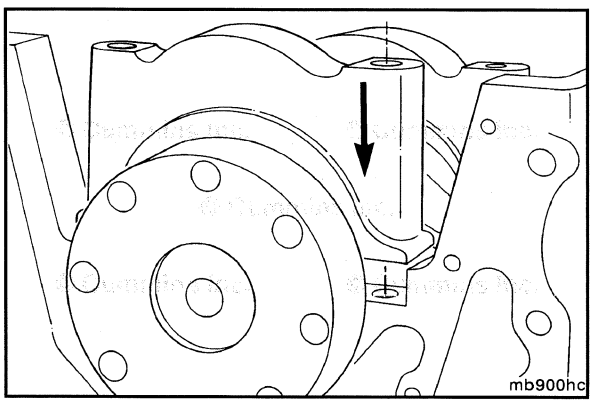


⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

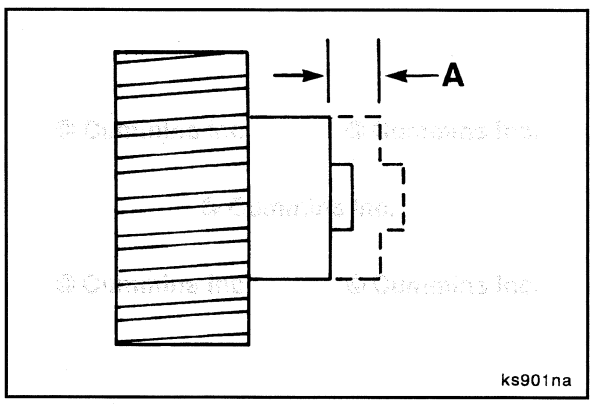
⚠CAUTION⚠
Carefully install the crankshaft to avoid damage to the crankshaft main bearings, especially the thrust/main bearing journals. Engine life will be shortened if damage to the crankshaft occurs.

Install the crankshaft.

NOTE: When setting the crankshaft into the block, make sure the front crankshaft gear meshes with the lubricating oil pump gear (if not previously removed).



Install the main bearing caps. Refer to Procedure 001-006 in Section 1.



NOTE: The dimensions of the thrust bearing and crankshaft journal determine end play.

Measure the crankshaft end play with a dial indicator assembly, Cummins® Part Number 3824564 and magnetic base, Cummins® Part Number 3377399.

Crankshaft End Play		
mm		**in**
0.102	MIN	0.004
0.432	MAX	0.017

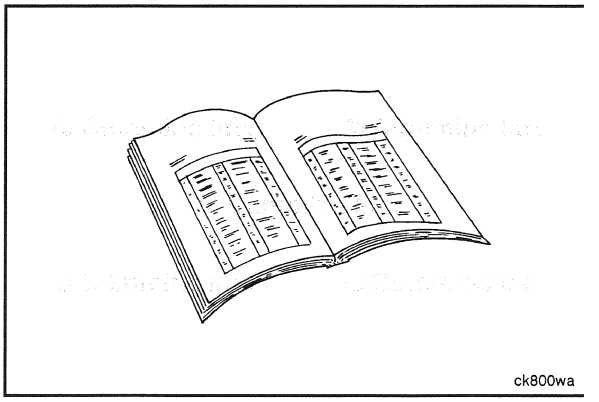
If the crankshaft end play is not within specification:

1 If the crankshaft end play 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 play is above specification, inspect the crankshaft thrust bearing surface. Also check if the correct thrust bearing(s) where installed.

NOTE: Oversize thrust bearings are available if the end play is **not** within specifications. Oversize thrust bearings of 0.25 to 0.51 mm [0.010 to 0.020 in] are available.

Finishing Steps



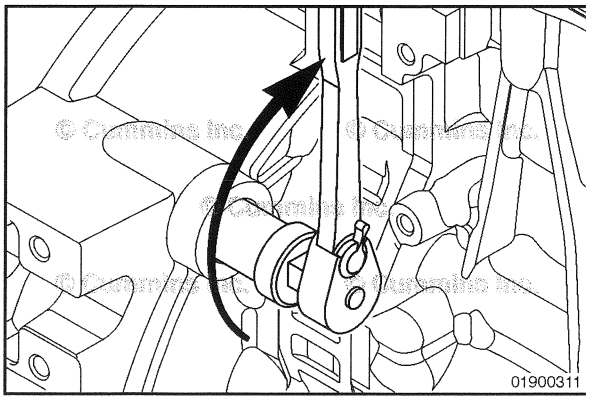
- Install the connecting rod caps. Refer to Procedure 001-005 in Section 1.
- Install the rear gear housing. Refer to Procedure 001-034 in Section 1.
- For rear gear train engines, install the camshaft gear. Refer to Procedure 001-012 in Section 1.
- Install the fuel pump and gear. Refer to Procedure 005-016 in Section 5.
- If equipped, install or connect any driven accessories (i.e., hydraulic pump).
- Install the block stiffener plate. Refer to Procedure 001-089 in Section 1.
- Install the lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7.
- Install the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Install the rear seal. Refer to Procedure 001-024 in Section 1.
- 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 front gear cover. Refer to Procedure 001-031 in Section 1.

Rotation Check

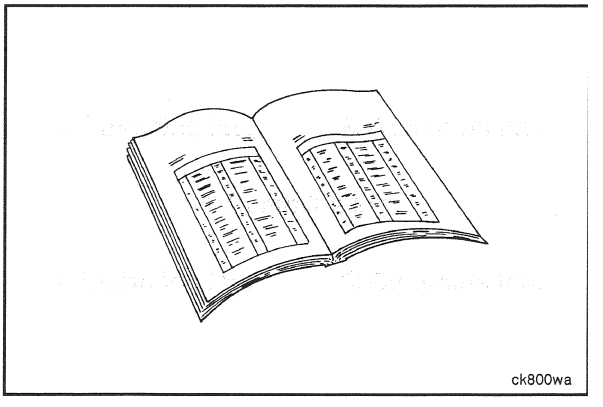
With the engine fully assembled, check that the engine rotates free. Use barring tool, Part Number 3824591.

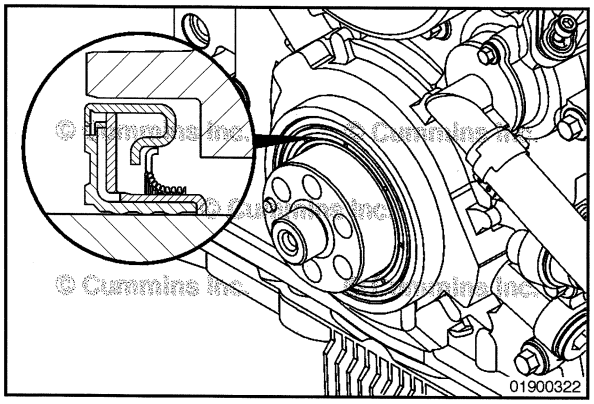
Insert the barring tool into the flywheel housing and engage the flywheel/flexplate ring gear. The crankshaft can then be rotated by hand with a 1/2- inch ratchet or breaker bar.

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.



- Install the engine. Refer to Procedure 000-002 in Section 0.
- Fill the lubricating oil pan. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine to normal operating temperatures and check for leaks and correct engine operation.





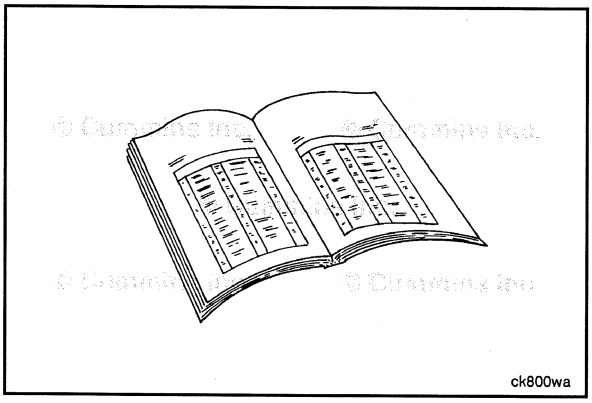
Crankshaft Seal, Front (001-023)

General Information

Unitized/Cartridge

This engine is equipped with a dual or non-lip style seal which utilizes a built-in wear sleeve and a concealed sealing lip. The inner and outer diameters are press-fit onto the crankshaft and the front gear cover respectively, requiring service tool, Cummins® Part Number 4919660, to remove and install. The sealing point is internal to the seal.

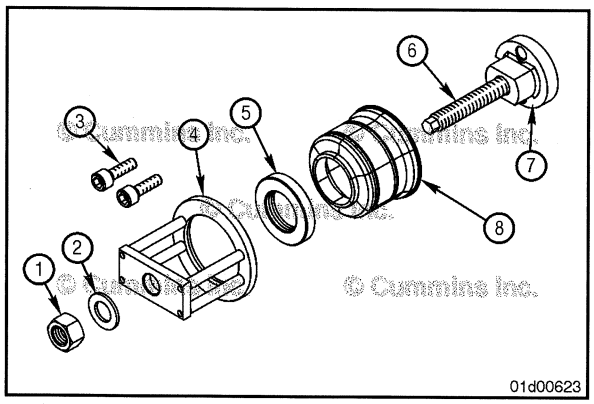
Always replace the front crankshaft seal with the same style seal as was previously installed.



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 batteries. See equipment manufacturer service information.
- Remove the cooling fan drive belt. Refer to Procedure 008-002 in Section 8.



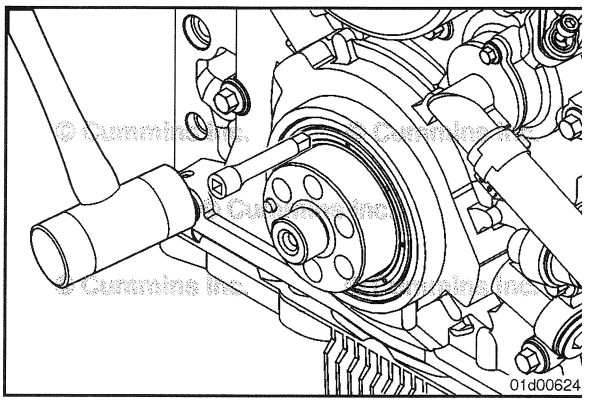
Remove

Use tool, Cummins® Part Number 4919660, to remove the front crankshaft seal from the front gear cover.

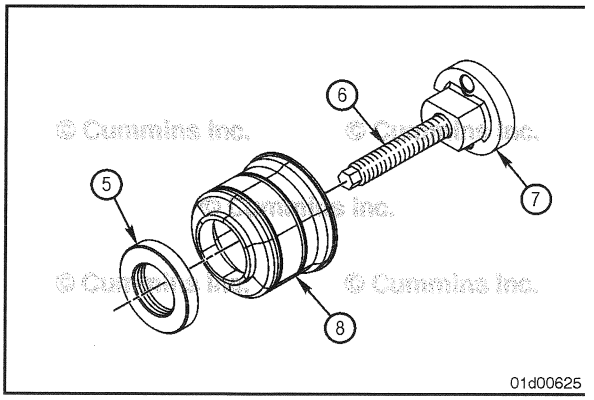
NOTE: The front gear cover does **not** need to be removed to remove and install the crankshaft seal.

Table 1. Front Crankshaft Seal Replacer, Cummins® Part Number 4919660			
Item Number	**Part Number**	**Description**	**Quantity**
1	3276934	Nut, regular hexagon	1
2	4919675	Washer, plain	1
3	3625554	Screw, socket head cap	2
4	4909665	Installer, seal	1
5	4919676	Nut, adjusting	1
6	4919673	Screw, replacer	1
7	4919674	Adapter, mounting	1
8	4919664	Remover, seal	1
Not shown	4919668	Spring tension	2

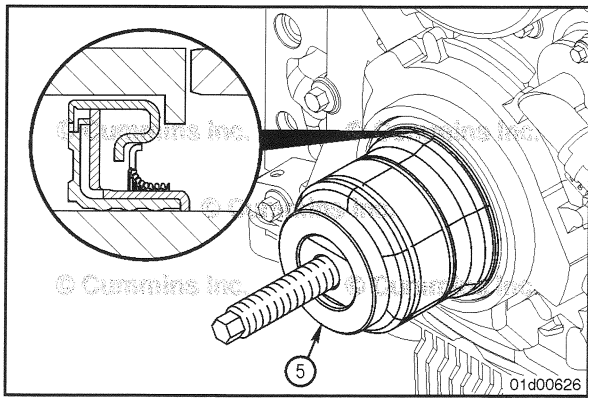
To prepare the seal assembly for the insertion of the seal remover (8) carefully tap the inner seal casing with a 3/8th drive bar, so as to create a 1 to 2 mm [0.039 to 0.079 inches] gap between the inner and outer seal casing.

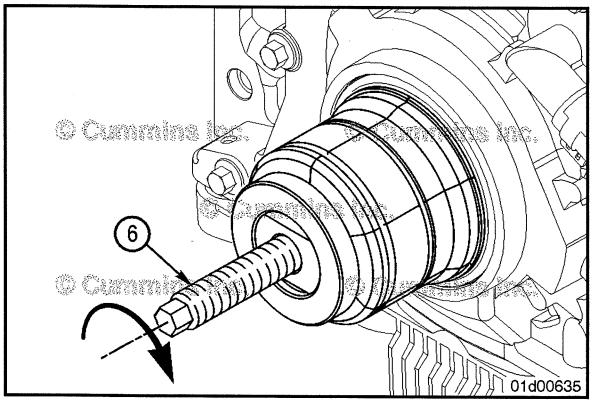


Loosely assemble the mounting adaptor (7) though the seal remover (8) and the adjusting nut (5) in preparation for removal of the crankshaft seal.



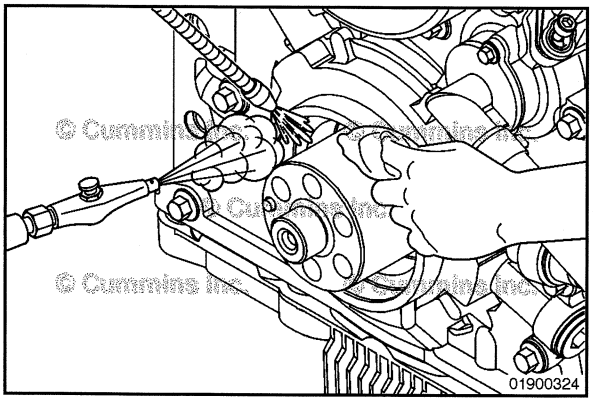
Align the seal remover assembly over the front of the crankshaft and carefully insert the front lip of the tool into the 1 to 2 mm [0.039 to 0.079 inches] gap created earlier between the inner and outer seal casing. Make sure that front lip of the tool engages under the full circumference of the seal casing outer lip, and hand-tighten the adjusting nut (5) to secure. Take care to support the seal remover assembly in the horizontal axis.





Use a wrench to slowly rotate the replacer screw (6) in a clockwise direction to remove the seal cartridge from the front gear cover. Do **not** exceed torque value of 45 N•m [35 ft lb].

Discard seal assembly when removed.



Clean and Inspect for Reuse

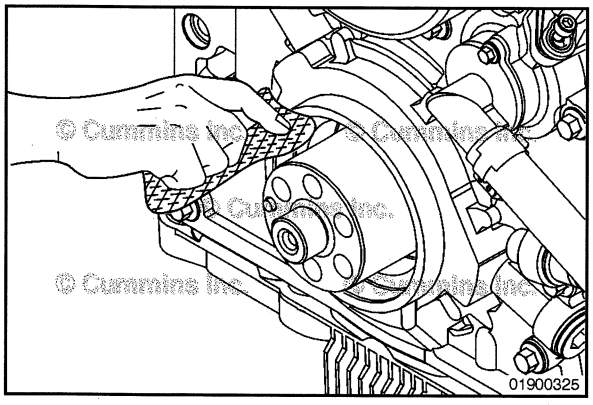
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠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.

Use solvent to clean the oil and seal residue from the crankshaft surface.

Dry with compressed air.



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⚠WARNING⚠
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⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the front gear cover seal bore of any seal residue. Inspect the front gear cover seal bore for nicks or burrs. Use an abrasive pad, Cummins® Part Number 3823258, or equivalent, to remove any minor damage.

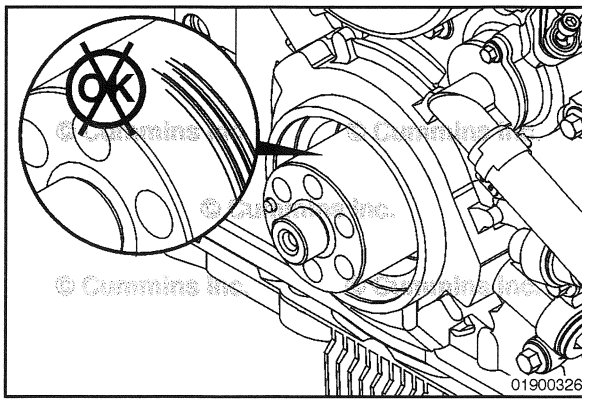
Dry with compressed air.

⚠CAUTION⚠
The seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

Inspect the nose of the crankshaft for excessive wear.

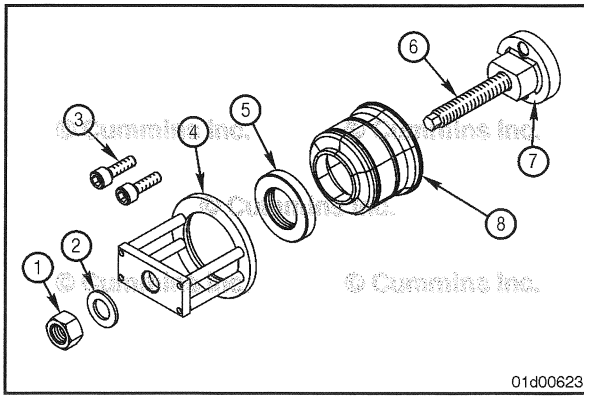
Use a fine crocus cloth to remove any nicks or burrs. No wear sleeve is available if the crankshaft nose sealing surface is damaged.

Inspect the crankshaft seal contact area for a wear groove.



Install

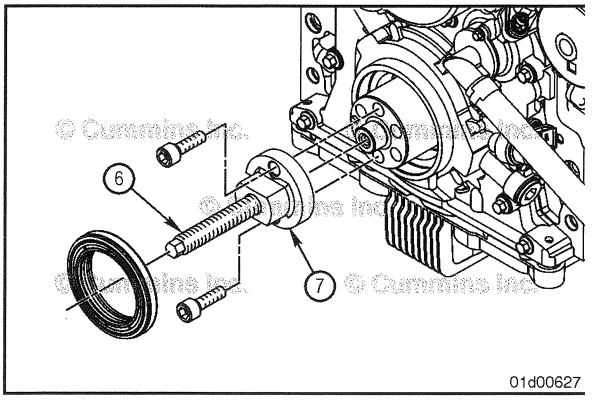
Use tool, Cummins® Part Number 4919660, to install the oil seal into the front gear cover.



Install the mounting adapter (7) onto the crankshaft nose.

Install the two M12 x 1.25 x 60 mm socket head capscrews.

Place the new front crankshaft seal over the replacer screw (6) and onto the crankshaft nose, and slide the seal assembly by hand toward the front gear cover as far as possible.

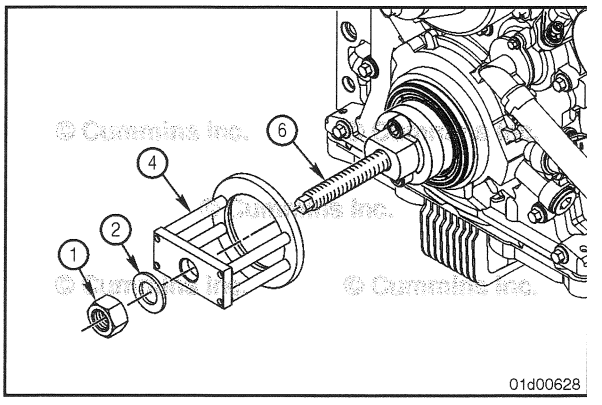


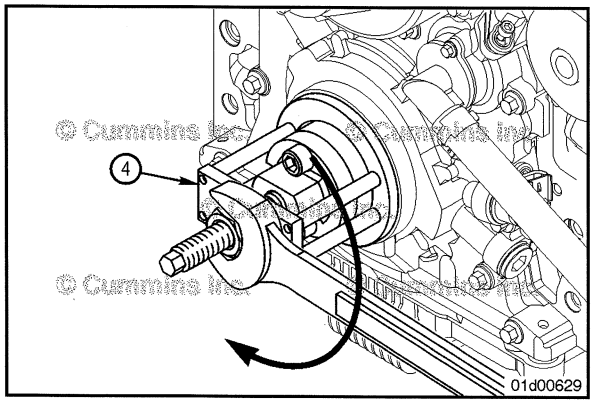
⚠CAUTION⚠
Do not use an impact wrench or air tools. Doing so can damage the tool.

NOTE: Make sure the seal is positioned squarely with the crankshaft.

Assemble the crankshaft seal installer (4) over the replacer screw (6) and crankshaft nose and advance the seal installer toward the seal until it is positioned squarely against the seal.

Place the plain washer (2) and the hexagon nut (1) onto the replacer screw (6) and tighten by hand until secure.

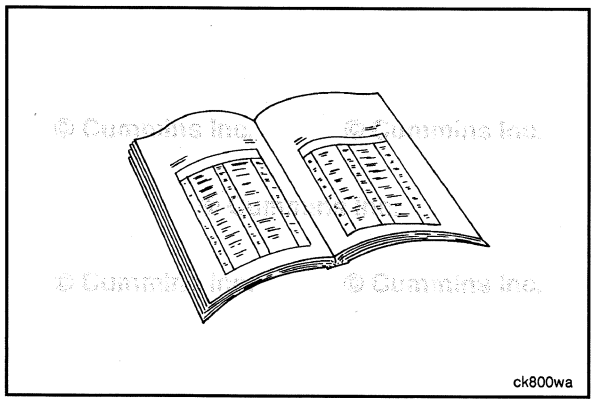




⚠CAUTION⚠
Do not overtighten the replacer screw assembly after the crankshaft seal replacer contacts the front cover. Doing so can damage the tool.

While holding the crankshaft seal installer (4), use a wrench to rotate the hexagon nut in a clockwise direction until the crankshaft seal installer contacts the front gear cover.

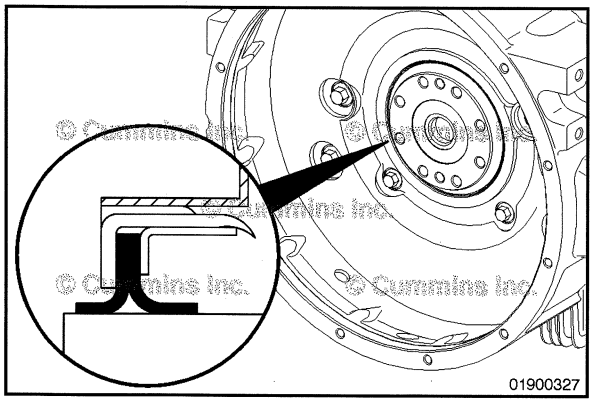
Remove the components of the service tool and inspect the seal for correct engagement. Make sure there are no irregularities



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 crankshaft speed indicator ring. Refer to Procedure 001-071 in Section 1.
- Install the cooling fan drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.



Crankshaft Seal, Rear (001-024)

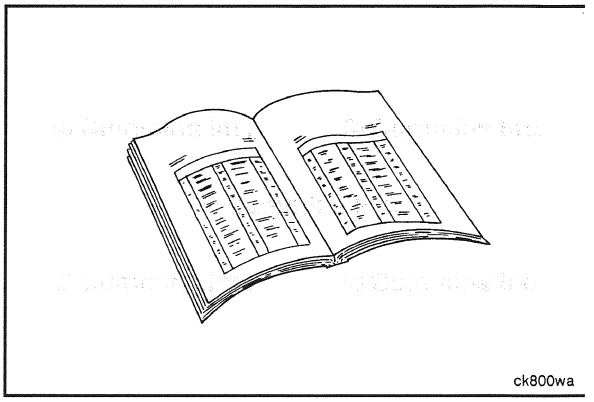
General Information

Lip Seal

This engine is equipped with a lip style rear crankshaft seal, in which the rotating portion of the sealing occurs at the contact surface between the lip of the rear crankshaft seal and the crankshaft.

Always replace the crankshaft seal with the same style crankshaft seal as was previously installed.

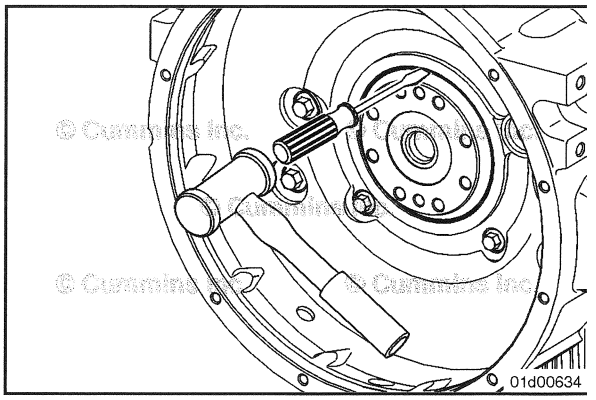
Preparatory Steps



⚠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 batteries. See equipment manufacturer service information.
- Remove the transmission and all related components, if equipped. See equipment manufacturer service information.
- Remove the flywheel, if equipped. Refer to Procedure 016-005 in Section 16.
- Remove the flexplate, if equipped. Refer to Procedure 016-004 in Section 16.

Remove



Lip Seal

Clean the surface area around the rear crankshaft seal.

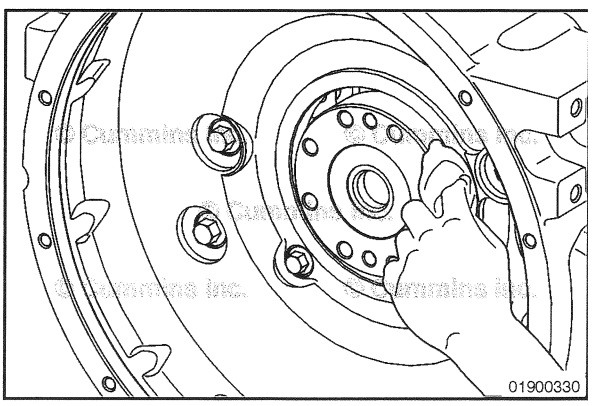
NOTE: For engines equipped with a lip style rear crankshaft seal, the seal can be removed using the following method.

Use a suitable round bar or screwdriver. Carefully tap the seal at the 12 o'clock position toward the front of the engine, so it begins to pivot and the lower part of the seal at the 6 o'clock position begins to tilt outward.

Use the screwdriver to carefully pry the seal off the crankshaft.

Discard the crankshaft seal when removed.

Clean and Inspect for Reuse



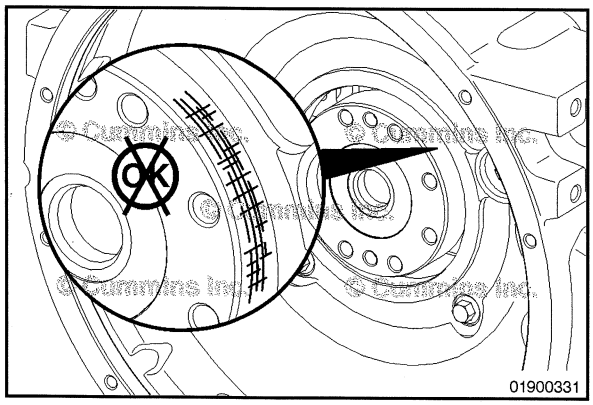
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Use only with protective clothing, goggles/shield, and gloves to reduce the possibility of personal injury.

⚠CAUTION⚠
The seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

Clean the rear crankshaft sealing surface and bore with solvent.

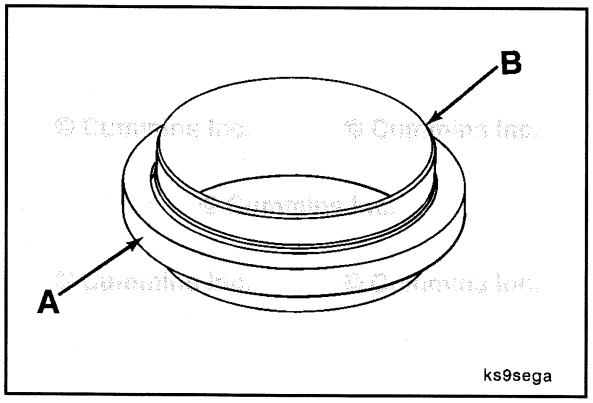
Dry the surface with compressed air.



NOTE: If the crankshaft has excessive wear, a service wear sleeve is available for engines that use a lip style rear crankshaft seal.

Inspect the rear crankshaft flange for damage or excessive wear.

Inspect the crankshaft seal contact area for a wear groove. If the groove is deeper than 0.25 mm [0.010 in], a wear sleeve and oversize seal **must** be used. Refer to Procedure 001-067 in Section 1.



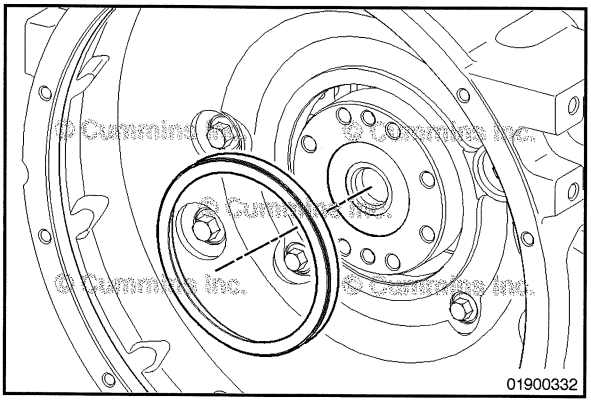
Install

⚠CAUTION⚠
Always replace the rear crankshaft seal with the same style seal as was previously installed to prevent oil leaks.

⚠CAUTION⚠
The seal lip/bore and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

To aid in installation, apply a mild soap solution to the outside diameter of the seal case (A).

NOTE: A seal pilot (B) is provided with the new seal. The seal **must** be left on the seal pilot while installing the seal onto the rear crankshaft flange. This will make sure the lips of the seal are **not** damaged during installation.



⚠CAUTION⚠
Always replace the rear crankshaft seal with the same style seal as was previously installed to prevent oil leaks.

Place the new rear crankshaft seal, with the seal pilot if required, over the crankshaft flange and slide it by hand toward the flywheel housing.

NOTE: Make certain the seal is positioned squarely with the crankshaft.

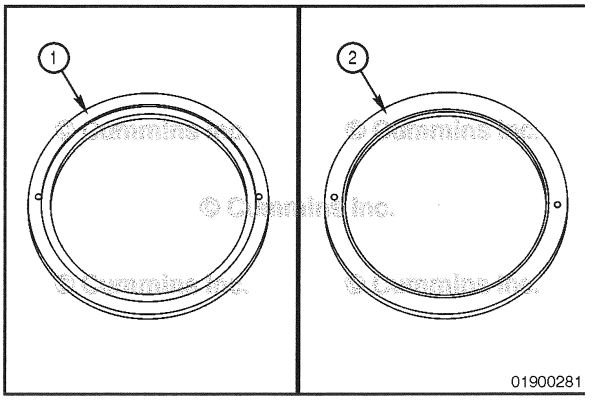
If used, remove the seal pilot.

Each new lip style crankshaft seal comes with a disposable seal driver.

- The seal driver for rear gear train engines, which is typically a plastic ring, will install the crankshaft seal to the proper depth in the flywheel housing bore.

The disposable plastic driver that comes with the new rear crankshaft seal is designed to be used with two types of seals.

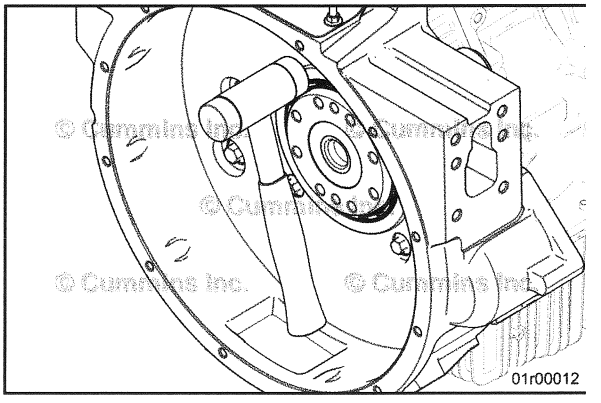
- A double outer dust lip rear crankshaft seal - for this type of seal, the side of the disposable driver (1) with the large chamfer on the inner diameter **must** be used to contact the seal.
- A single outer dust lip rear crankshaft seal - for this type of seal, the side of the disposable driver (2) with the small chamfer on the inner diameter **must** be used to contact the rear crankshaft seal.

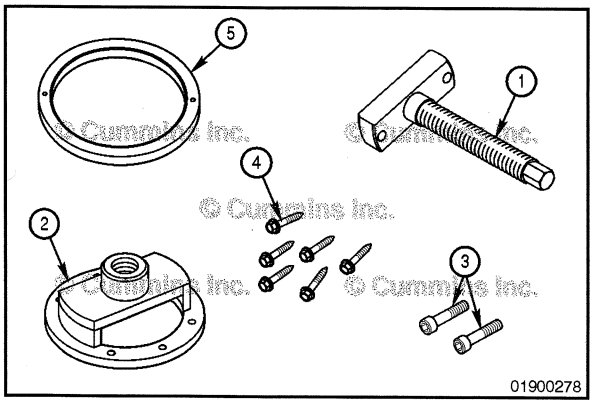


NOTE: It can be necessary to lightly tap the rear crankshaft seal with a plastic hammer, without the disposable seal driver, to help start the rear crankshaft seal in the flywheel housing bore.

With the rear crankshaft seal installed onto the crankshaft flange as described earlier in this procedure, use the appropriate disposable seal driver that comes with each new rear crankshaft seal to install the crankshaft seal to the correct depth in the housing.

Use a plastic hammer to drive the crankshaft seal into the housing until the alignment tool stops against the housing. Hit the tool at 12, 3, 6 and 9 o'clock positions to drive the crankshaft seal evenly and to prevent bending the seal carrier.

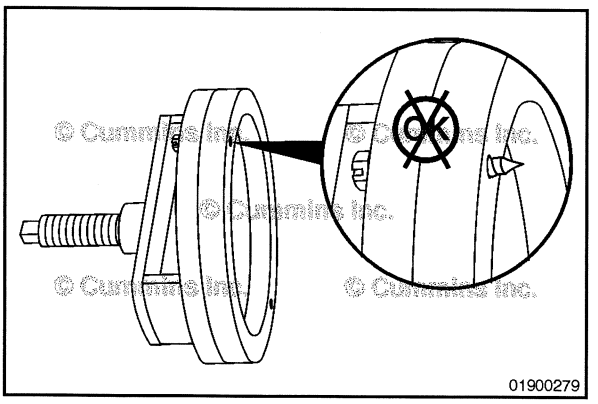




Optional Method

The disposable plastic driver that comes with the new rear crankshaft seal has been designed with two holes in the outer ring. These holes are provided so the driver can be used in conjunction with the Rear Crankshaft Seal Replacer Kit, Cummins® Part Number 4919533.

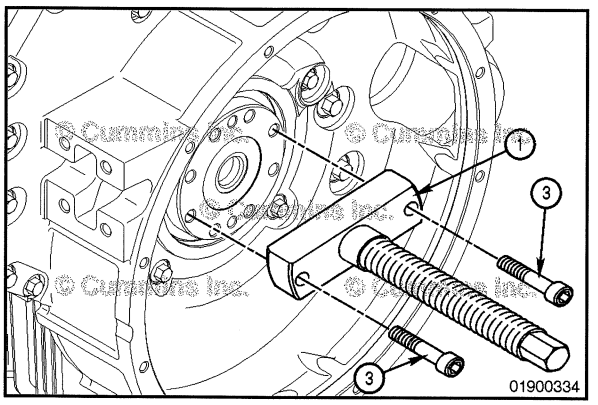
Table 2. Rear Crankshaft Seal Replacer Kit, Cummins® Part		
Item Number	**Part Number**	**Descr**
1	3164666	Repla
2	4919534	Crank
3	3164174	Soc M12 x
4	3164217	Sheet 10 x 2
Not shown	3164218	Drill. 3
5	—	Disp (p crank



⚠CAUTION⚠
Do not use the sheet metal screws that come with the Rear Crankshaft Seal Replacer Kit, service tool Cummins® Part Number 4919533. The sheet metal screws are too long. When selecting the correct sheet metal screw, make sure the tip of the sheet metal screw does not protrude past the face of the driver. Damage to the crankshaft seal will result.

With the correct side of the disposable driver facing outwards for the type of seal that will be installed, center the disposable driver on the crankshaft seal replacer.

Attach the disposable driver to the crankshaft seal replacer using two sheet metal screws (number 10 by 19 mm [0.75 in] long).



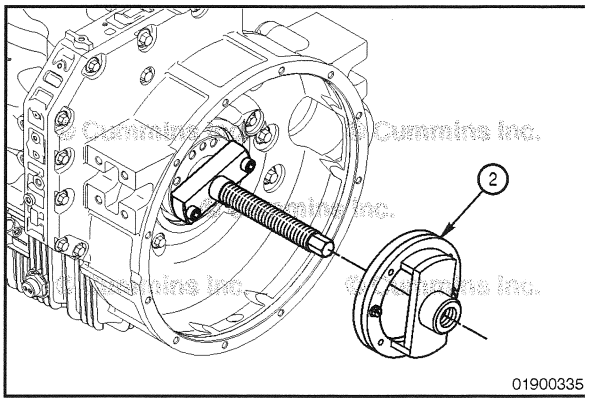
With the rear crankshaft seal installed onto the crankshaft flange as described earlier in this procedure, mount the replacer screw assembly (1) onto the rear of the crankshaft.

Install the two M12 x 1.25 x 60-mm socket head capscrews (3).

⚠CAUTION⚠
Do not use an impact wrench or air tools. Doing so can damage the tool.

Lubricate the replacer screw with anti-seize compound or a suitable grease.

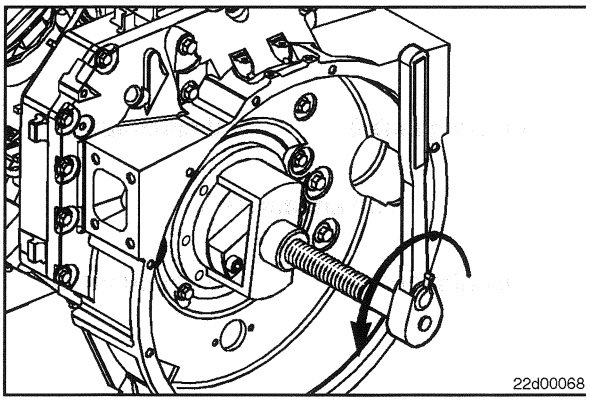
Hold the replacer screw and install the crankshaft seal replacer (2) onto the replacer screw assembly. Advance the crankshaft seal replacer toward the seal by rotating it **clockwise** until the attached disposable driver is positioned against the rear crankshaft seal.



⚠CAUTION⚠
Do not overtighten the replacer screw assembly after the crankshaft seal replacer contacts the flywheel housing. Doing so can damage the tool.

While holding the crankshaft seal replacer, rotate the replacer screw counterclockwise until the disposable driver attached to the crankshaft seal replacer makes contact with the flywheel housing.

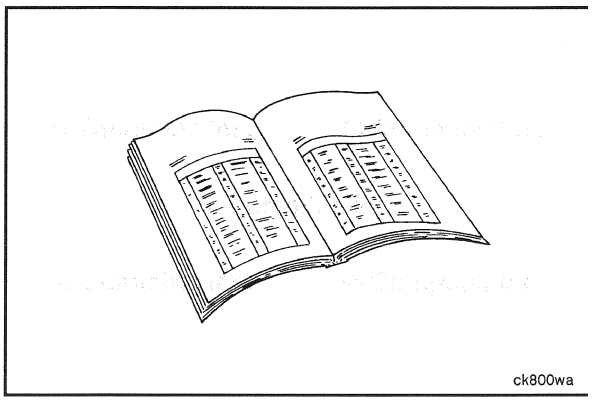
Remove the service tools.

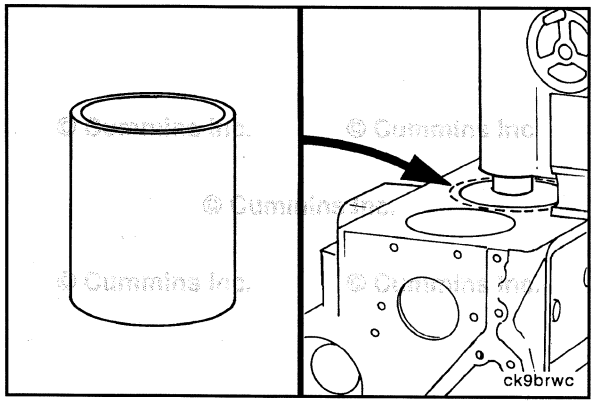


Finishing Steps

⚠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 equipped. Refer to Procedure 016-005 in Section 16.
- Install the flexplate, if equipped. Refer to Procedure 016-004 in Section 16.
- Install the transmission and all related components, if equipped. See equipment manufacturer service information.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.





Cylinder Block (001-026)

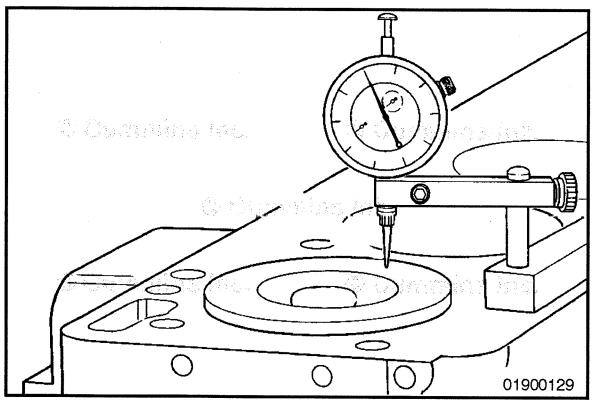
General Information

The cylinder block uses bored cylinders, as opposed to liners. In the event of damage or wear out, the cylinders may be able to be repaired.

The cylinders can be bored oversize twice for the use of oversize pistions and rings (0.5 mm [0.020 in] and 1mm [0.040 in] oversize). See the Overbore section of this procedure.

A specific cylinder head gasket with an increased thickness is **not** available for combustion deck resurfacing of the cylinder block. If the combustion deck can **not** be resurfaced such that the correct specifications of the injector protrusion can be maintained, the cylinder block **must** be replaced.

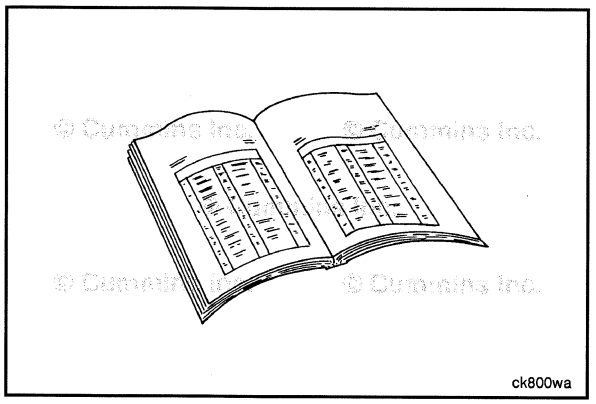
Refer to Procedure 002-004 in Section 2.



Initial Check

Prior to removing the piston and connecting rod assemblies, measure and record piston protrusion. Refer to Procedure 001-054 in Section 1.

Measuring piston protrusion prior to disassembly will aid in determining if the cylinder block, if required, can be resurfaced.



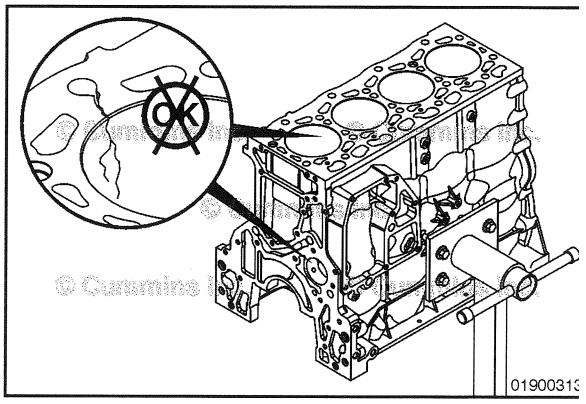
Preparatory Steps

- Remove the engine and place 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. Pay close attention to these areas of the block:

- Main bearing caps and bores.
- Camshaft bores.
- Cylinder bores.
- Tappet bores.
- Cylinder block combustion deck.
- Oil pan mounting surface.
- 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 of damage or leaks.

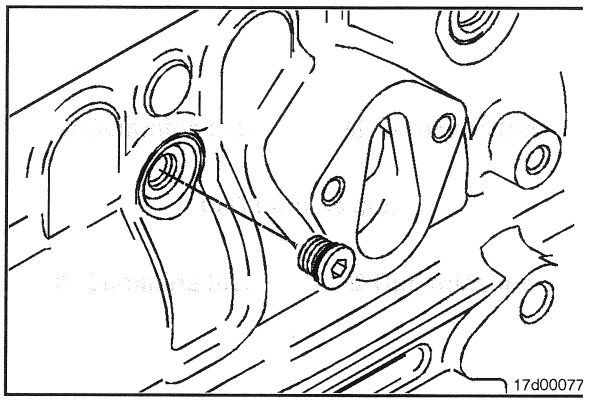
If it is necessary to thoroughly clean the cylinder block for reuse, due to excessive debris or contamination, remove all pipe plugs, expansion plugs, and straight thread plugs as necessary. Make sure all oil and coolant passages are cleaned out.

Use the following procedures for removal and installation.

Refer to Procedure 017-002 in Section 17.

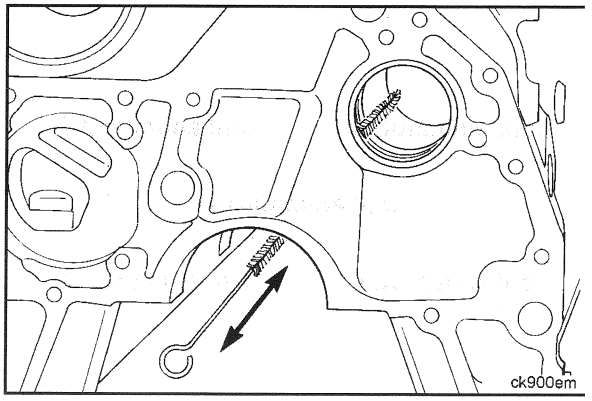
Refer to Procedure 017-007 in Section 17.

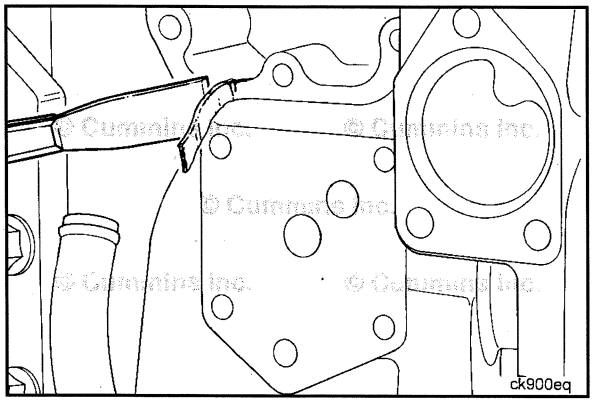
Refer to Procedure 017-011 in Section 17.



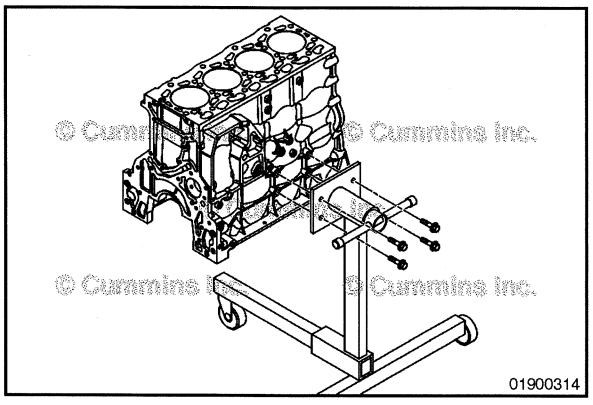
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

Use clean solvent and a nonmetallic brush to clean the block oil drillings.



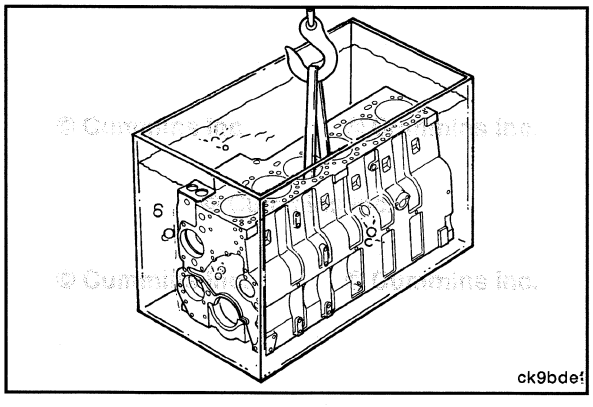


Thoroughly clean all gasket sealing surfaces of any remaining gasket residue.



⚠WARNING⚠
This component or assembly weighs greater than weighs 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 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△
Use a cleaning solution that will not damage the camshaft bushings.

See equipment manufacturer service information 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. The best results are obtained with the use of a cleaning solution that can be heated from 80 to 95°C [176 to 203°F]. A cleaning tank that will mix and filter the cleaning solution will give the best results.

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.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

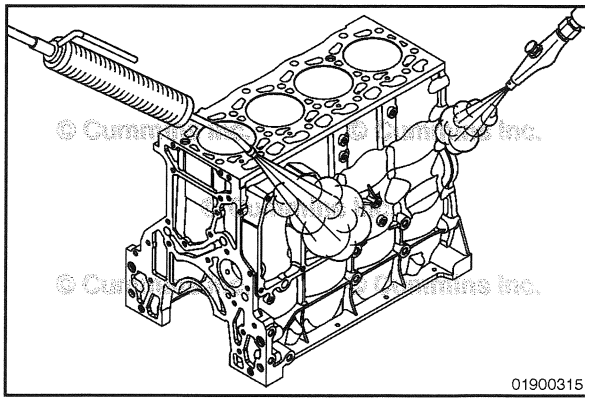
△CAUTION△
To reduce the possibility of engine damage, make sure all debris is removed from the capscrew holes and oil passages.

Remove the block from the cleaning tank.

Use steam to clean the cylinder block thoroughly.

Use compressed air to dry the block.

NOTE: If the cylinder block is **not** going to be used immediately, apply a coating of preservative oil to prevent rust. Cover the block to prevent dirt from sticking to the oil.

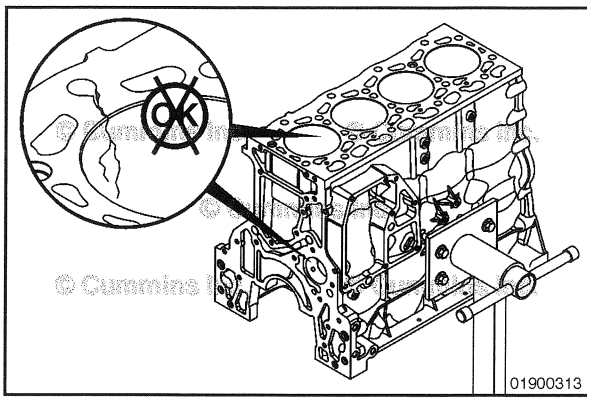


With the cylinder block cleaned, inspect the cylinder block again for signs of cracks, fretting, and discoloration that will prohibit reuse.

To help identify cracks in the cylinder block, use the crack detection kit, Cummins® Part Number 3375432.

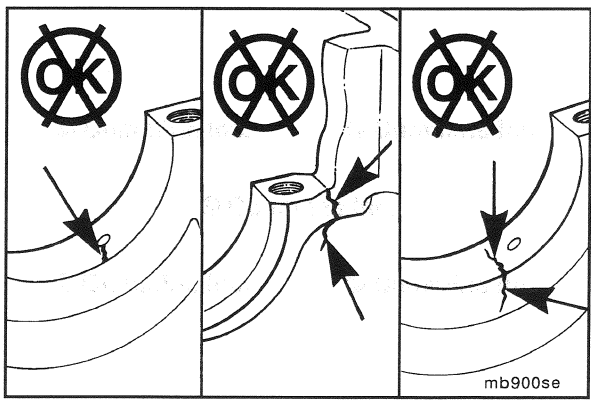
Pay close attention to these areas of the block:

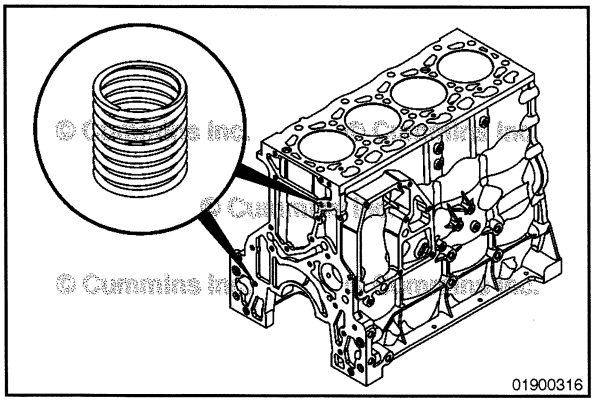
- Main bearing caps and bores.
- Camshaft bores.
- Cylinder bores.
- Tappet bores..
- Cylinder block combustion deck.
- Oil pan mounting surface.
- Front and rear of block sealing surfaces.
- Lubricating oil cooler cavity.



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 cylinder block **must** be replaced.





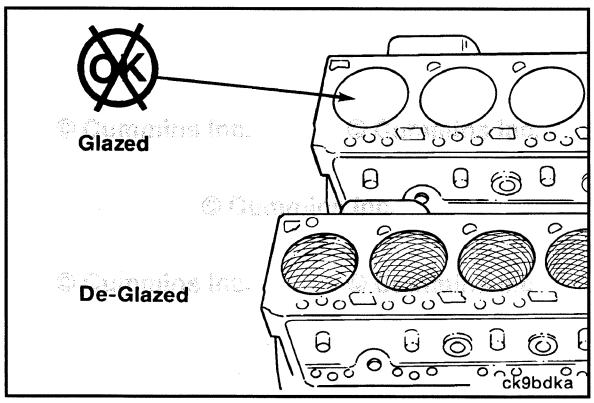
Inspect all threaded capscrew holes for damaged threads. Coiled thread inserts may be used to repair all damaged threads, except main bearing saddle capscrew hole threads.

Service Tool threaded insert kits are available:

1 Cummins® Part Number 3377905, for standard threads

2 Cummins® Part Number 3377903, for metric threads.

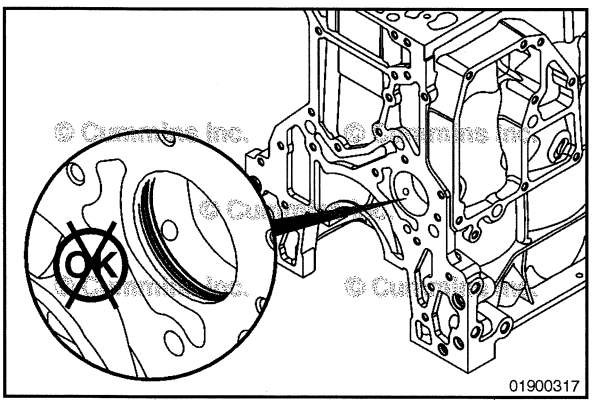
NOTE: Coiled thread inserts **must not** be used to repair main bearing saddle threaded capscrew holes. If damaged, the block **must** be replaced.



Inspect the cylinder bores for glazing.

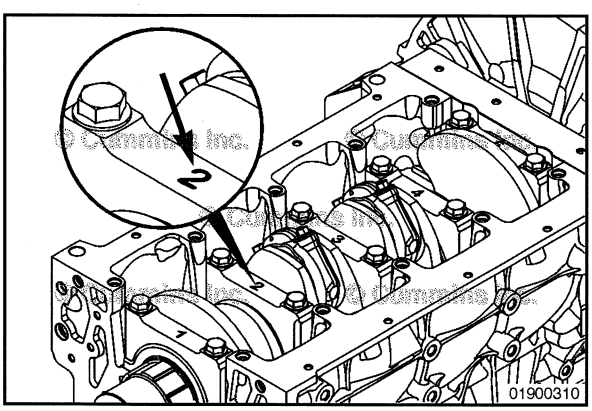
A surface without glaze will have a crosshatched appearance with the lines at 25 to 30 degree angles with the top of the cylinder bore.

If deglazing is required, see the Deglaze information in the Repair section of this procedure.



Inspect the camshaft bores for scoring, scuffing, or excessive wear.

If the is damage to the bore(s) is beyond acceptable limits, the block **must** be replaced. No oversize cam bushings are available.



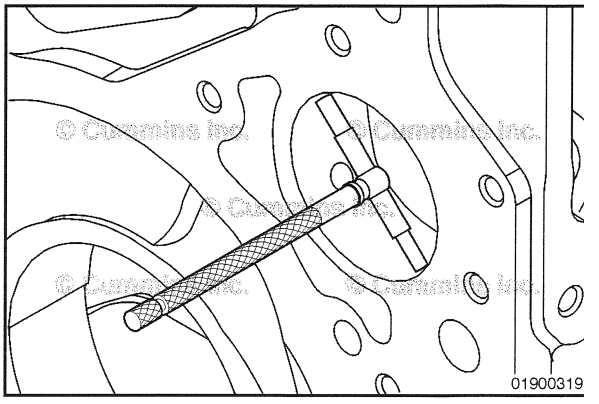
Measure

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 (cylinder bores, main bearing bores, camshaft bores, etc).

Inspect the camshaft bores without the camshaft bushing installed.

Camshaft Bore Diameter without Camshaft Bushing			
	mm		in
Camshaft Bore (Camshaft Bushing Previously Installed)	59.248	MAX	2.3326

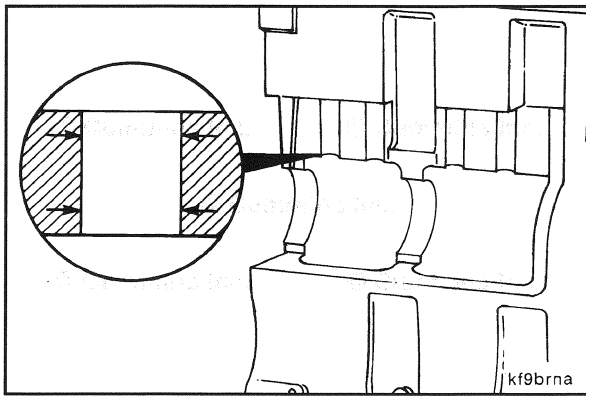


Inspect the tappet bores for scoring or excessive wear.

Measure the tappet bores.

Tappet Bore Diameter		
mm		in
16.000	MIN	0.630
16.055	MAX	0.632

NOTE: If the tappet bores are out of specification, the block **must** be replaced.



Install the main bearing caps without the main bearings. Use the following procedure for main bearing cap installation. Refer to Procedure 001-006 in Section 1.

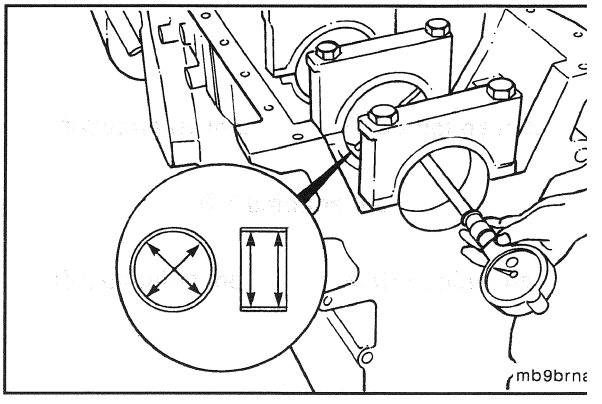
Tighten the main bearing cap capscrews.

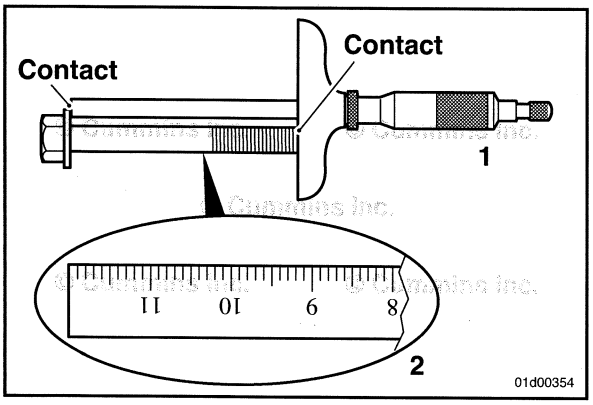
Torque Value: 176 N•m [130 ft-lb]

Measure the main bearing bore with the bearings removed.

Main Bearing Bore Diameter with Bearings Removed		
mm		in
87.983	MIN	3.4639
88.019	MAX	3.4653

NOTE: If the main bearing bore diameters are **not** within specification, check if the main bearing caps where installed in the proper location and orientation. If the main caps are installed properly, the block **must** be replaced.

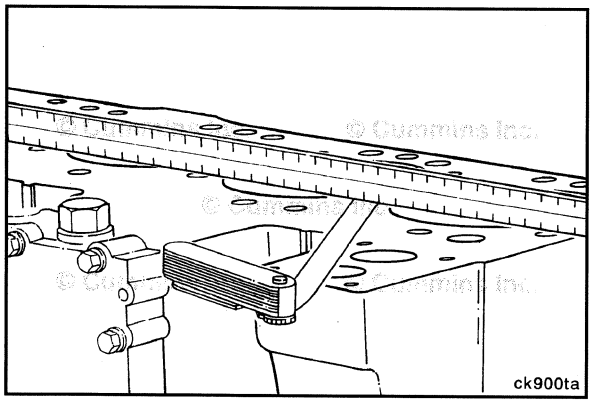




Main Bearing Capscrew Reuse Measurement

To check if a main bearing capscrew can be reused, the length **must** be measured. Use the following procedure to measure the main bearing capscrews. Refer to Procedure 001-006 in Section 1.

If the measurement is beyond the maximum specification, the main bearing capscrew **must** be replaced.



Measure the cylinder block's overall flatness.

Cylinder Block Flatness

	mm		in
End-to-End	0.076	MAX	0.003
Side-to-Side	0.051	MAX	0.002

Inspect for any localized dips or imperfections. If present, the cylinder head deck **must** be resurfaced.

NOTE: The combustion deck of the block can **only** be resurfaced if the following criteria is met:

- After the resurface, the correct piston protrusion can be achieved.

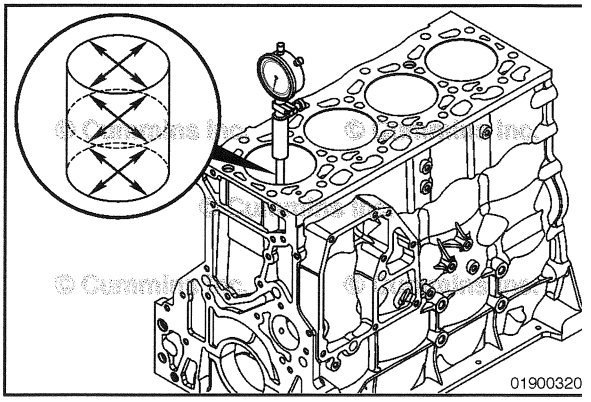
No specific head gasket with an increased thickness is available for combustion deck resurfacing. If the combustion deck can **not** be resurfaced such that the correct piston protrusion can be reached, the cylinder block **must** be replaced.

NOTE: When measuring, deglazing, or boring a cylinder block, make sure all of the main bearing caps are in place and properly torqued. Use the following procedure for torque values. Refer to Procedure 001-006 in Section 1.

Inspect the cylinder bores for damage or excessive wear.

⚠CAUTION⚠
Do not measure the bore diameter within 50 mm (1.97 in) of the block combustion deck. Inaccurate measurements will result.

Use a dial bore gauge to measure the cylinder bore in four places, 90 degrees apart, at the top and bottom of the piston travel area.



Cylinder Bore Diameter (New Cylinder Block)		
mm		**in**
102.010	MIN	4.0161
102.030	MAX	4.0169

Cylinder Bore Diameter (Used Cylinder Block)		
mm		**in**
102.010	MIN	4.0161
102.050	MAX	4.0177

Out-of-Roundness		
mm		**in**
0.038	MAX	0.0015

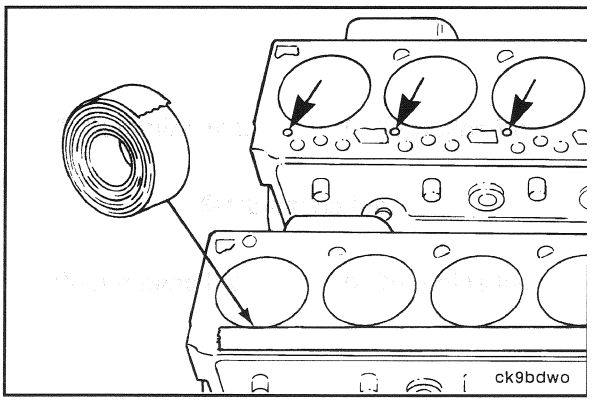
Taper		
mm		**in**
0.076	MAX	0.003

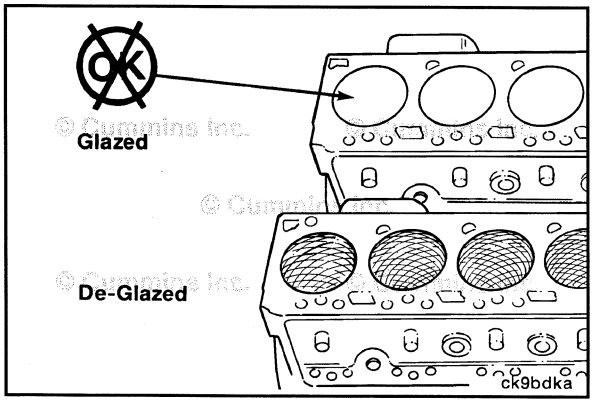
NOTE: The cylinders can be bored oversize twice for the use of oversize pistions and rings (0.5 mm [0.020 in] and 1mm [0.040 in] oversize). See the Overbore section of this procedure.

Repair

⚠CAUTION⚠
Precautions must be taken to prevent debris from any reconditioning operation from entering the lubricating oil passages of the engine. Engine damage will result.

Prior to any reconditioning of the cylinder bores, make sure to cover the lubricating holes and tappet holes in the top of the cylinder block with waterproof tape.

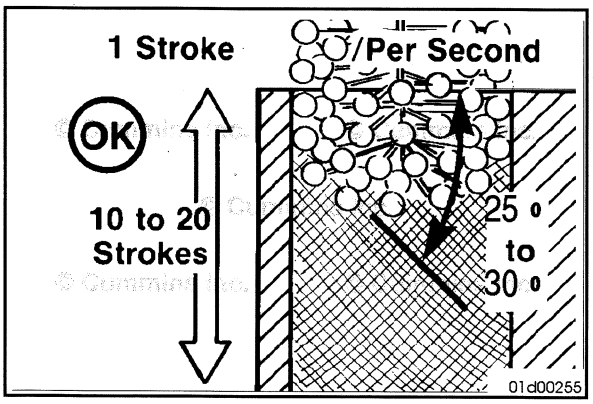




Deglaze:

Deglazing gives the cylinder bore the correct surface finish required to seat the piston rings. Deglazing **must only** be performed if the cylinder bores are still in specification.

NOTE: New piston rings will **not** seat in glazed cylinder bores.



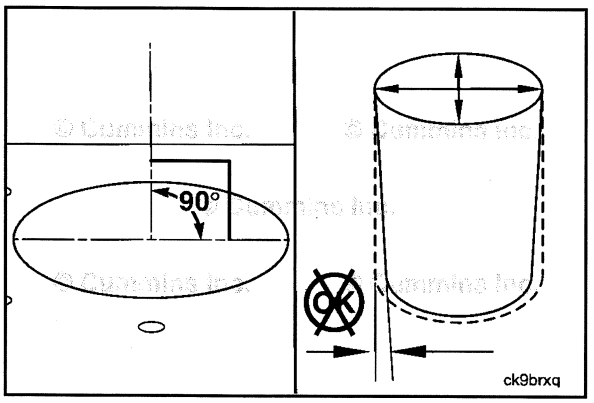
Use a ball type hone and a rotational speed of 300 to 400 rpm, with a stroke frequency of one stroke up and down per second. Make sure to use a good grade of honing oil or a mixture of equal parts SAE 30W engine oil and diesel fuel for a honing lubricant.

NOTE: Vertical strokes **must** be smooth, continuous passes along the full length of the cylinder bore.

Inspect the cylinder bore after 10 strokes.

NOTE: The crosshatch angle is a function of drill speed and how fast the hone is moved vertically. Moving too fast or too slow will give an incorrect crosshatch angle.

A correctly deglazed surface will have a crosshatched appearance with the lines at 25 to 30 degree angles with the top of the cylinder block.

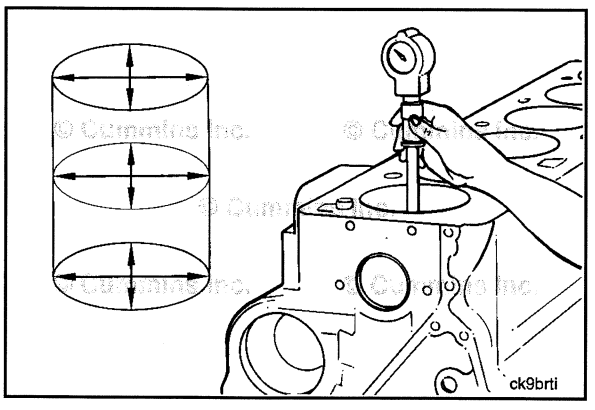


Overbore:

If the cylinder bore was found out of specification or damaged, the cylinder bore can be refinished for oversize pistons and piston rings.

Boring must be done by qualified personnel on a suitable boring machine. Care must be taken to make sure the cylinders are perpendicular to the combustion deck and within taper and out-of-round specification for the cylinder bore.

Follow the boring machine manufacturer's recommendations for machine setup to achieve the best quality bore.



NOTE: The boring diameters given below are not the finished cylinder bore dimensions. The finished cylinder bore diameter will be reached through the final honing operation.

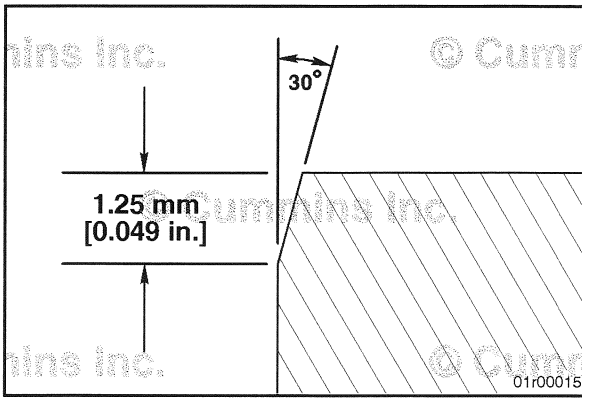
The boring diameter dimensions are as follows:

NOTE: Maximum cutting depth must be limited to 0.228 mm [0.009 in] per cut.

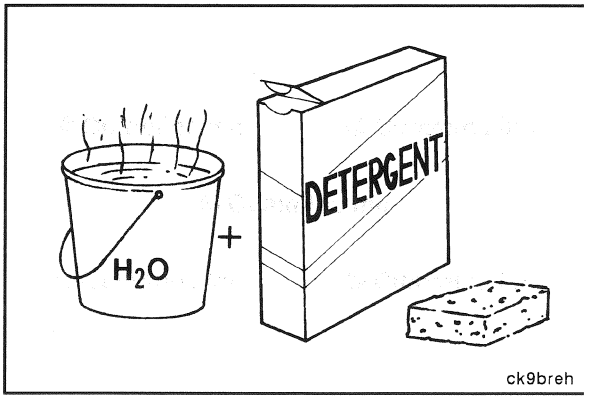
Bore Diameter

	mm		in
First rebore	102.469	NOM	4.0342
Second rebore	102.969	NOM	4.0539

After boring, use a honing stone to break the edge of the bore to approximately 1.25 mm [0.049 in] at 30 degrees.



After deglazing, use a strong solution of hot water and laundry detergent to clean the cylinder bores.

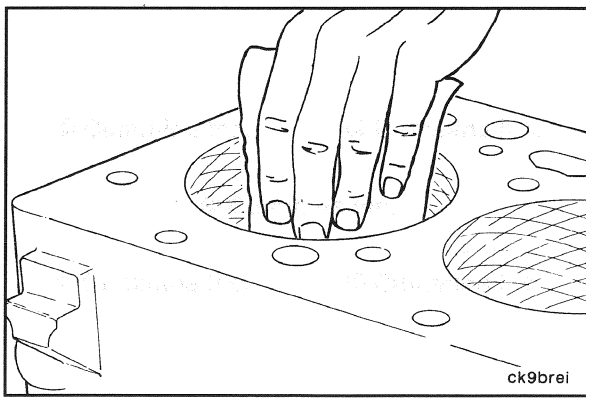


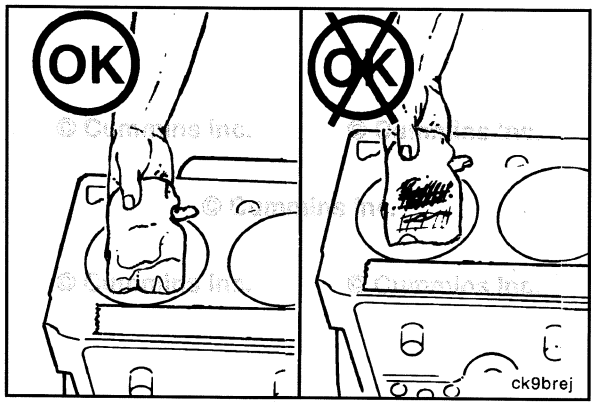
⚠ WARNING ⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△ CAUTION △
Clean the cylinder bores immediately after deglazing/ finish honing. Failure to do so can result in engine damage.

Rinse the cylinder bores until the detergent is removed.

Dry the cylinder block with compressed air.





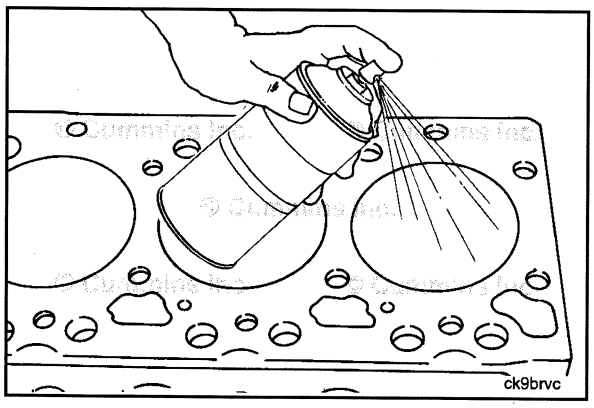
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠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.

△CAUTION△
Be sure to remove the tape covering the tappet holes after the cleaning process is completed. Failure to do so can result in engine damage.

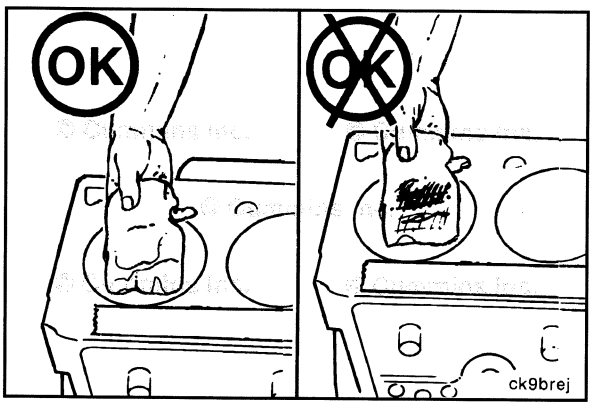
Check the cylinder bore cleanliness by wiping with a white, lint-free, lightly oiled cloth. If grit residue is still present, repeat the cleaning process until all residue is removed.

Wash the cylinder bores with solvent. Dry the cylinder block with compressed air.



If the cylinder block is **not** to be used right away, coat all machined surfaces with a rust preventative solvent.

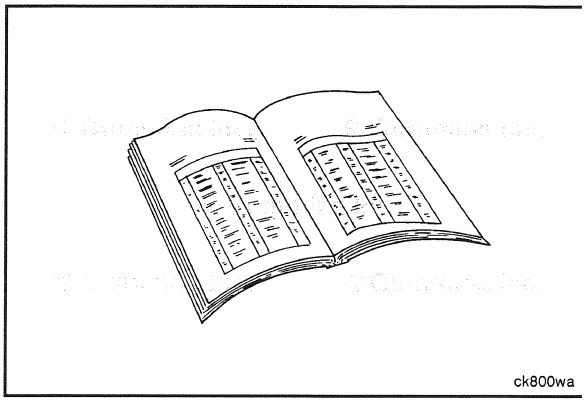
Make sure to cover the cylinder block to prevent dust and debris from collecting on and in the cylinder block.



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 stand and install the engine. Refer to Procedure 000-002 in Section 0.
- Operate the engine to normal operating temperatures and pressures. Check for leaks and proper operation.

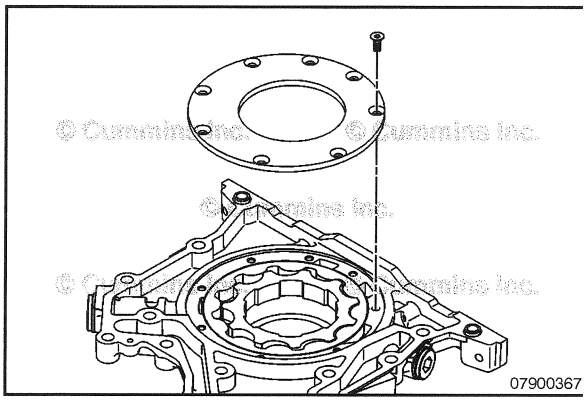


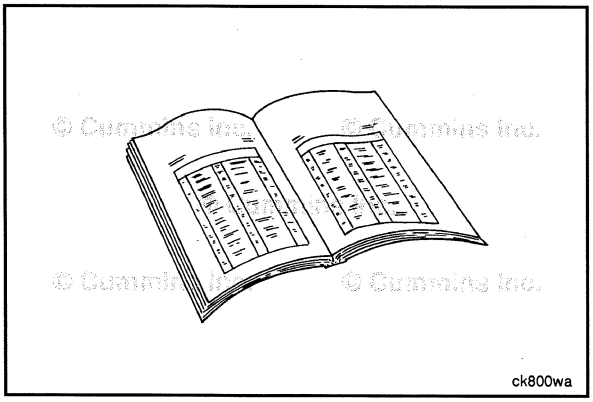
Gear Cover, Front (001-031)

General Information

The lubricating oil pump and lubricating oil high pressure valve are a part of the front gear cover. Use the following procedures for removal and installation instructions, if needed.

- Refer to Procedure 007-031 in Section 7.
- Refer to Procedure 007-029 in Section 7.



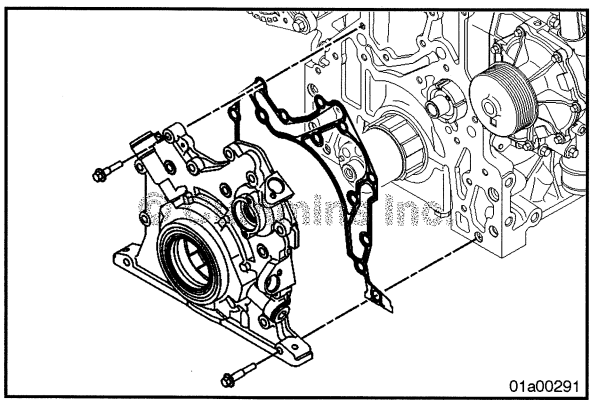


Preparatory Steps

⚠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 batteries. See equipment manufacturer service information.
- Remove the cooling fan drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the cooling fan belt tensioner. Refer to Procedure 008-087 in Section 8.
- Remove the crankshaft speed indicator ring **only**. Refer to Procedure 001-071 in Section 1.
- If required, remove the fan hub pulley. Refer to Procedure 008-039 in Section 8.
- Remove the crankcase breather hose from the crankcase breather adaptor. Refer to Procedure 003-026 in Section 3.
- Remove the crankcase breather adaptor Refer to Procedure 003-031 in Section 1.
- Remove the front crankshaft seal. Refer to Procedure 001-023 in Section 1.
- Disconnect and remove the camshaft position sensor, if required. Refer to Procedure 019-363 in Section 19.
- Disconnect and remove the crankshaft position/speed sensor. Refer to Procedure 019-365 in Section 19.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.



Remove

⚠CAUTION⚠

To break the seal, pry the front gear cover away from the cylinder block. Be careful not to damage the front gear cover when breaking the seal to the cylinder block.

NOTE: Document the location of the three longer mounting capscrews upon removal.

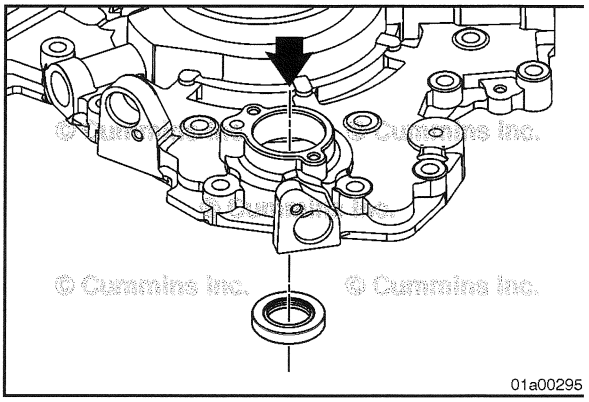
Remove the front gear cover mounting capscrews.

Remove the front gear cover.

Support the front gear cover on a flat work surface with wooden blocks.

Use a suitable seal driver and hammer to drive the old camshaft seal out of the rear of the front gear cover.

Discard the camshaft seal.



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⚠
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.

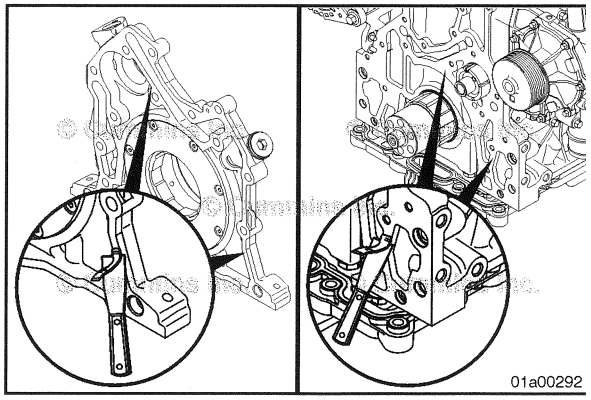
△CAUTION△
If the front gear cover requires steam cleaning, remove the lubricating oil pump and lubricating oil high pressure relief valve. Refer to Procedure 007-031 in Section 7. Refer to Procedure 007-029 in Section 7.

NOTE: If the front gear cover was removed as part of another repair, it is **only** necessary to clean the sealing surfaces.

Clean the sealant or gasket from the front gear cover and from the cylinder block.

Use solvent or steam to clean the front gear cover.

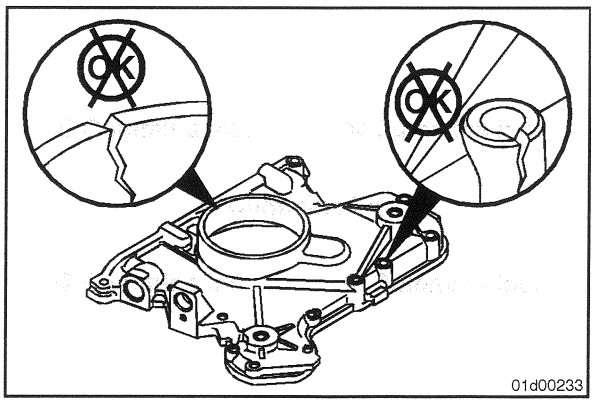
Dry the cover with compressed air.

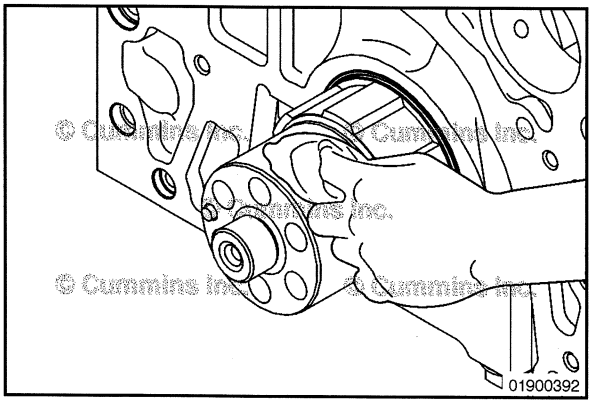


Inspect the front gear cover for cracks or other damage.

Replace the front gear cover if any damage is found.

NOTE: Undamaged parts from the damaged front gear cover can be used again when replacing the front gear cover.



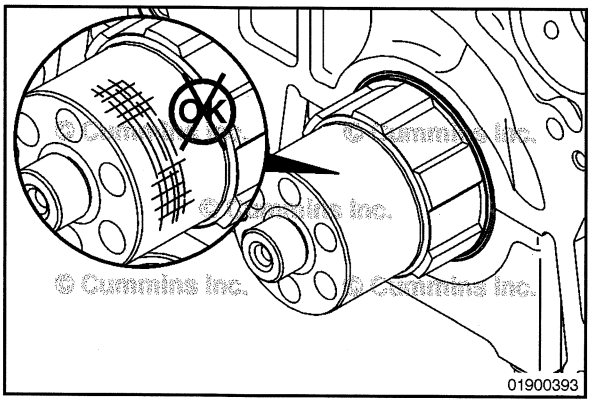


⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

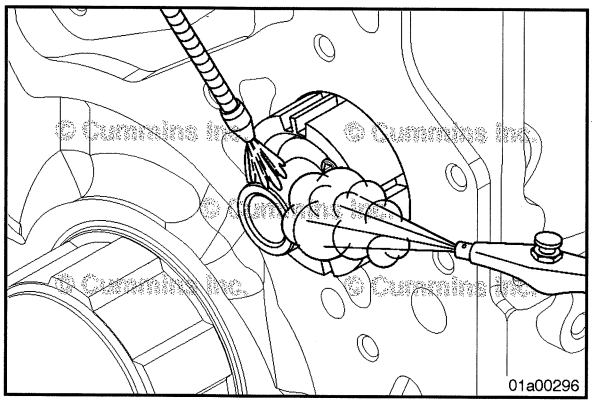
Use solvent to clean the oil and seal residue from the crankshaft surface.

Dry with compressed air.



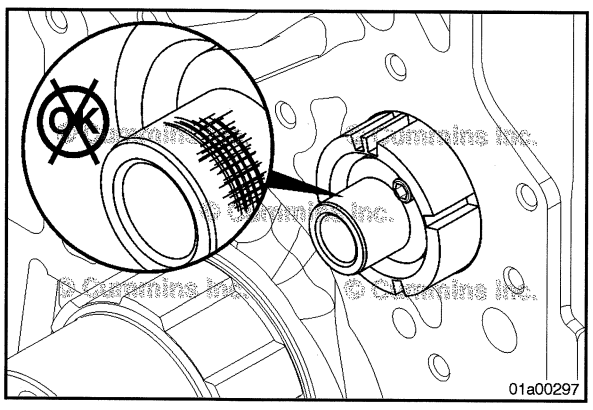
Inspect the nose of the crankshaft for excessive wear.

Use a fine crocus cloth to remove any nicks or burrs. There is **no** wear sleeve available if the crankshaft nose sealing surface is damaged.



Use solvent to clean the oil and seal residue from the camshaft surface.

Dry with compressed air.



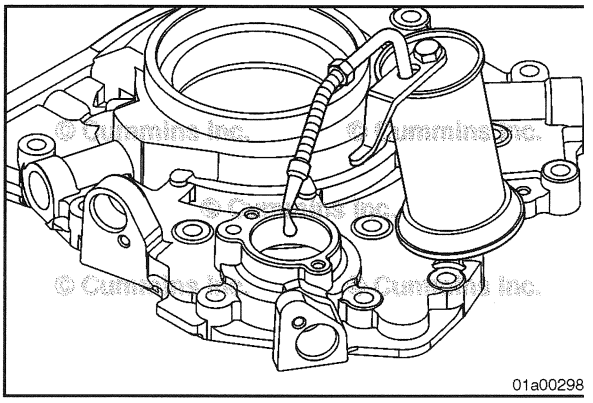
Inspect the nose of the camshaft for excessive wear.

Use a fine crocus cloth to remove any nicks or burrs.

There is no repair option available if the camshaft nose sealing surface is damaged. The camshaft **must** be replaced.

Install

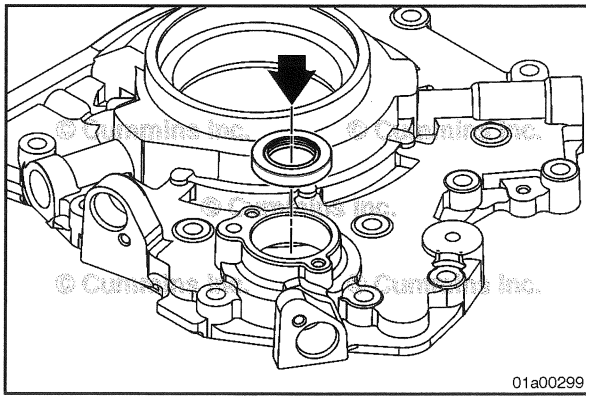
Lubricate the inside surface of the camshaft seal bore with a small amount of clean engine oil.



Install a new camshaft seal into the front gear cover

Start the seal into the bore by hand. Be sure the camshaft seal is inserted equally on all sides.

Apply slight pressure to push it deeper into the bore until the camshaft seal front is at the same level as the front gear cover.

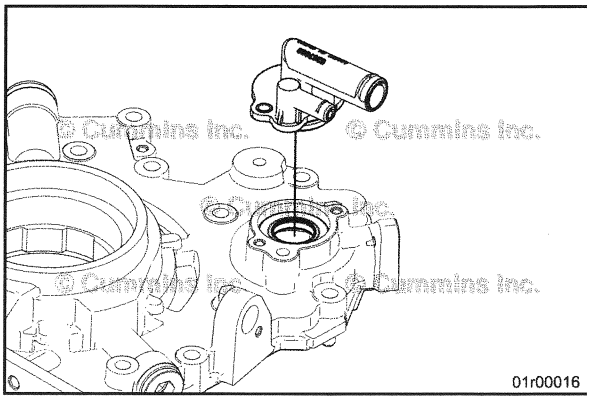


NOTE: Do **not** install the camshaft breather adaptor at this time.

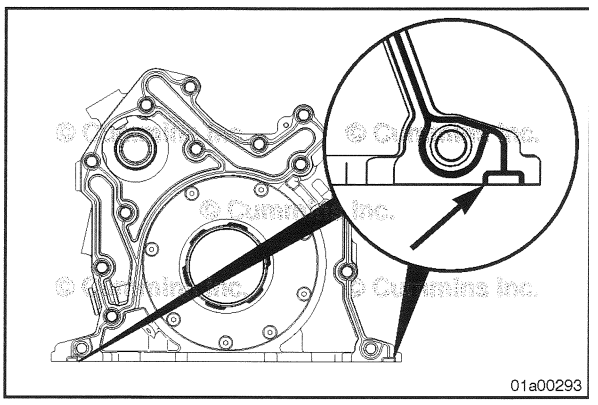
Use the crankcase breather adaptor to push the seal in to the bore to the correct depth.

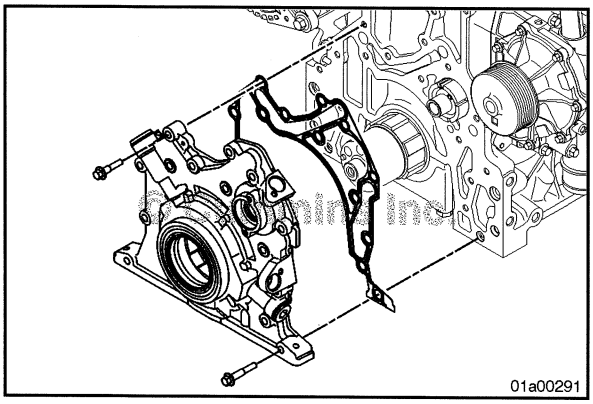
The seal should be installed approximately 12 mm [0.48 in] into the bore.

Lubricate the outside surface of the camshaft and crankshaft nose with clean engine oil.



When installing the front gear cover gasket, take care **not** to damage the rubber seal on the bottom edges of the gasket.





NOTE: If needed, apply a small amount of sealant, Cummins® Part Number 3164070, to the front gear cover gasket to help hold the gasket in place.

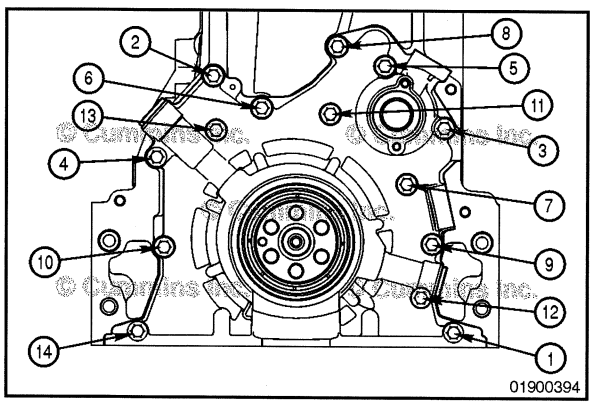
Install the front gear cover gasket. Use the dowel rings in the cylinder block to locate and temporarily hold the front gear cover gasket in place.

NOTE: If needed, rotate the lubricating oil pump in the front gear cover to align with the lubricating oil pump drive gear on the crankshaft.

Install the front gear cover. Take care to align the camshaft seal with the nose of the camshaft upon installation. Use the dowel rings in the cylinder block to locate the front gear cover.

NOTE: As documented during removal, make sure to install the three longer mounting capscrews in the correct locations. If **not** documented during removal, the three longer mounting capscrews go in locations 1, 14, and 12, as shown in the graphic in the next step.

Install the front gear cover mounting capscrews.



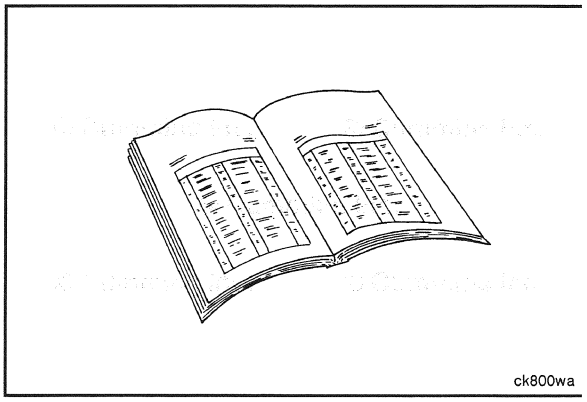
Tighten the front gear cover to the cylinder block mounting capscrews in the order indicated.

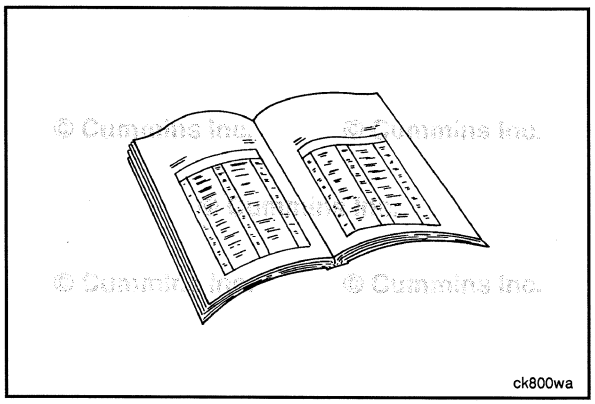
Torque Value: 24 N•m [212 in-lb]

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 lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Install the crankcase breather adaptor. Refer to Procedure 003-031 in Section 1.
- Install and connect the crankshaft position/speed sensor. Refer to Procedure 019-365 in Section 19.
- Install and connect the camshaft position sensor. Refer to Procedure 019-363 in Section 19.
- Install the front crankshaft seal. Refer to Procedure 001-023 in Section 1.
- Install the crankcase breather hose to the crankcase breather adaptor. Refer to Procedure 003-026 in Section 3.
- Install the fan hub pulley. Refer to Procedure 008-039 in Section 8.
- Install the crankshaft speed indicator ring. Refer to Procedure 001-071 in Section 1.
- Install the cooling fan belt tensioner. Refer to Procedure 008-087 in Section 8.
- Install the cooling fan drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the batteries. See equipment manufacturer service information.
- Operate engine and check for leaks.


ck800wa



Gear Housing, Rear (001-034)

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.

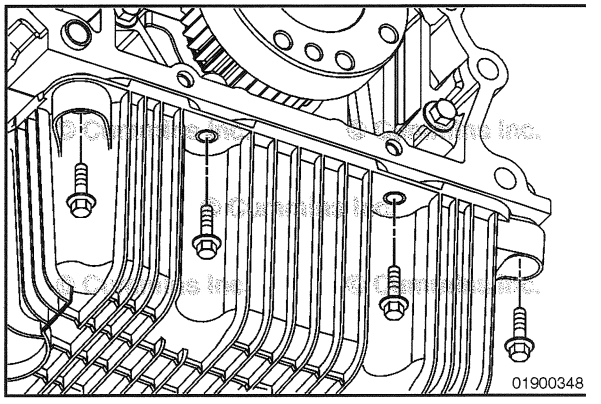
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

⚠WARNING⚠
Support the rear of the engine using the rear support attached to the rear of the cylinder block. Failure to support the engine can cause personal injury.

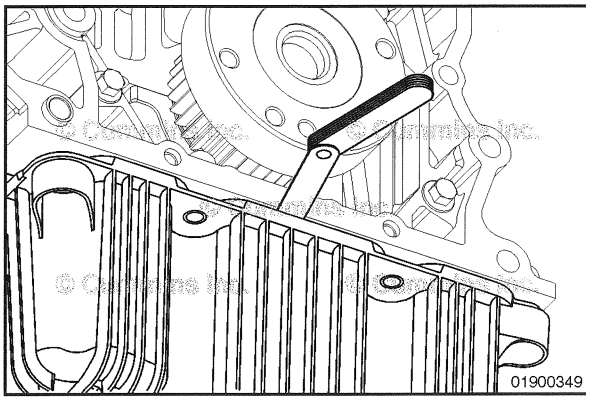
- Disconnect the batteries. See equipment manufacturer service information.
- Remove the transmission. See equipment manufacturer service information.
- Remove flywheel, if installed. Refer to Procedure 016-005 in Section 16.
- Remove the crankcase breather tube. Refer to Procedure 003-018 in Section 3.
- Remove the flexplate, if installed. Refer to Procedure 016-004 in Section 16.
- Remove the rear crankshaft seal. Refer to Procedure 001-024 in Section 1.
- Remove the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Remove the fuel pump. Refer to Procedure 005-016 in Section 5.
- If equipped, remove the hydraulic pump unit. Refer to Procedure 009-016 in Section 9.
- Remove the camshaft gear. Refer to Procedure 001-012 in Section 1.
- Remove the camshaft. Refer to Procedure 001-008 in Section 1.

Remove

Remove the four (4) oil pan to rear gear housing capscrews.

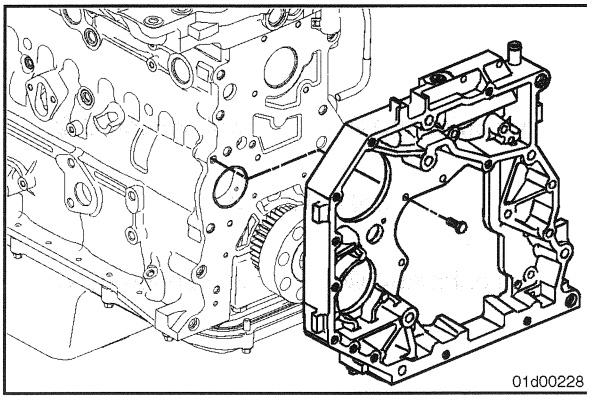


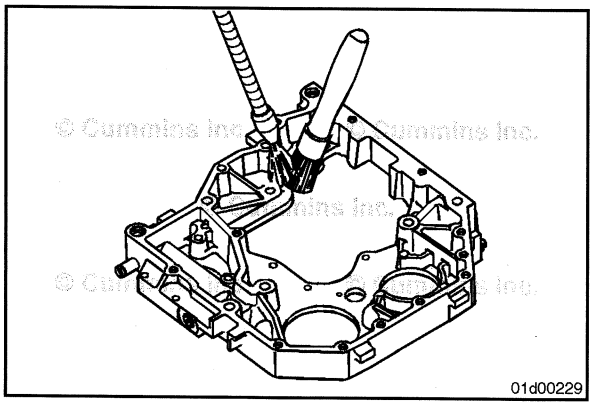
Use a feeler gauge to separate the lubricating oil pan gasket from the gear housing.



NOTE: The rear gear housing is mounted to the engine with three different length and size of capscrews. Note the location and size of the capscrews when they are removed to be sure they are installed in the same locations.

Remove the rear gear housing capscrews and housing.





Clean and Inspect for Reuse

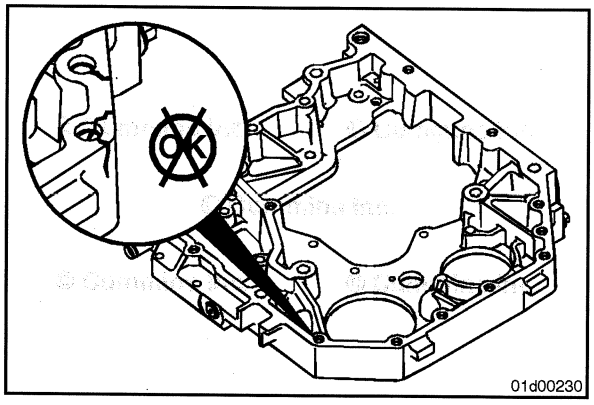
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

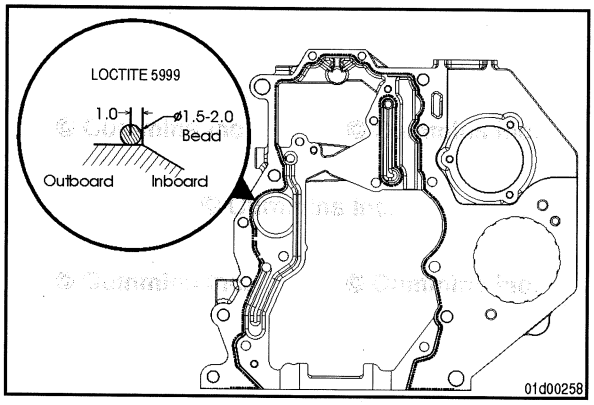
Clean the rear gear housing with solvent. Dry with compressed air.

Clean the oil supply hole for the accessory drive.

NOTE: The rear gear housing has oil drain and supply passages designed into the housing. Make sure these passages are clean and free of debris.



Inspect the rear gear housing for signs of leakage or any other damage.



Install

△CAUTION△
Make sure to only apply sealant to the areas specified. Failure to do so may block oil passages to the accessory drive and/or cause a loss of oil pressure. This will result in severe engine damage.

Apply a 1.5 to 2.0 mm [0.06 to 0.08 in] wide bead of sealant, Cummins® Part Number 3164070, to the block side of the gear housing in the path illustrated and install the rear gear housing capscrews and housing.

Be sure there is a bead of sealant at the intersection joint of the cylinder block, oil pan, and gear housing.

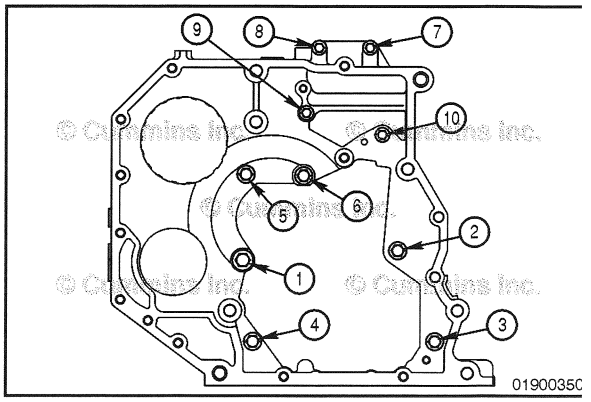
NOTE: Install the gear housing within 10 minutes of applying the sealant or the sealant will **not** seal correctly. Once installed, allow the sealant to dry for 30 minutes before running the engine.

Tighten the capscrews as shown.

Torque Value:
M12 77 N•m [57 ft-lb]

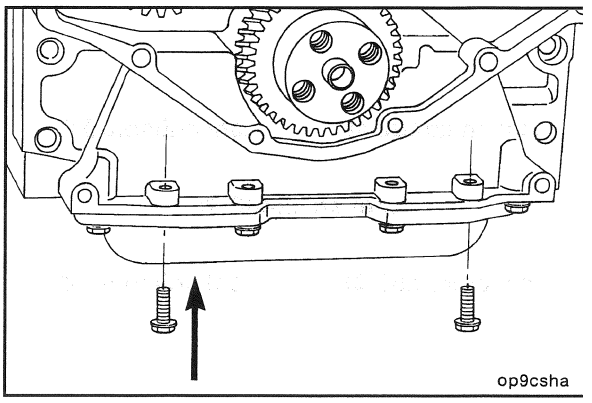
Torque Value:
M10 47 N•m [35 ft-lb]

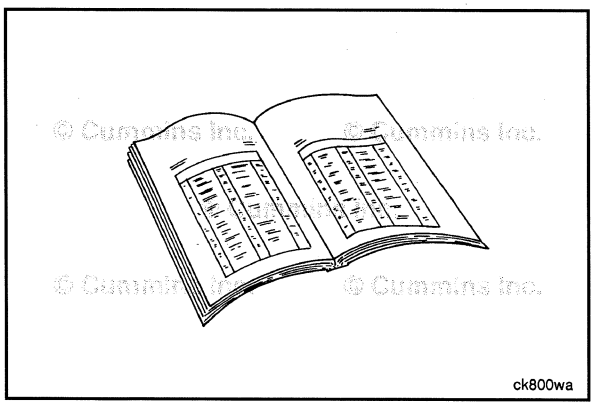
Torque Value:
M8 24 N•m [212 in-lb]



Install the remaining four oil pan capscrews and tighten.

Torque Value: 24 N•m [212 in-lb]





Finishing Steps

⚠WARNING⚠
Support the rear of the engine using the rear support attached to the rear of the cylinder block. Failure to support the engine can cause personal injury.

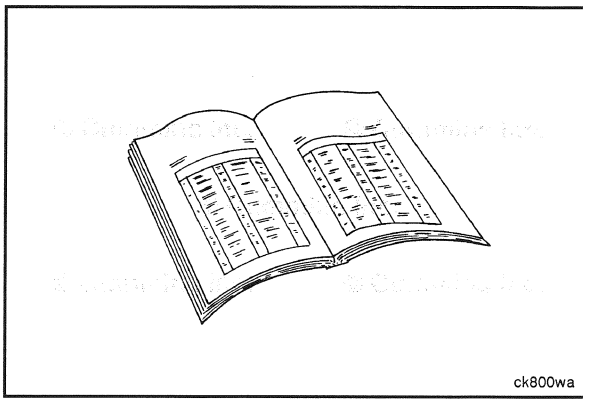
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

⚠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 camshaft. Refer to Procedure 001-008 in Section 1.
- Install the camshaft gear. Refer to Procedure 001-012 in Section 1.
- If equipped, install the hydraulic pump unit. Refer to Procedure 009-016 in Section 9.
- Install the fuel pump. Refer to Procedure 005-016 in Section 5.
- Install the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Install the rear crankshaft seal. Refer to Procedure 001-024 in Section 1.
- 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 crankcase breather tube. Refer to Procedure 003-018 in Section 3.
- Install the transmission. See equipment manufacturer service information.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.

Piston (001-043)

Preparatory Steps


ck800wa

⚠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.

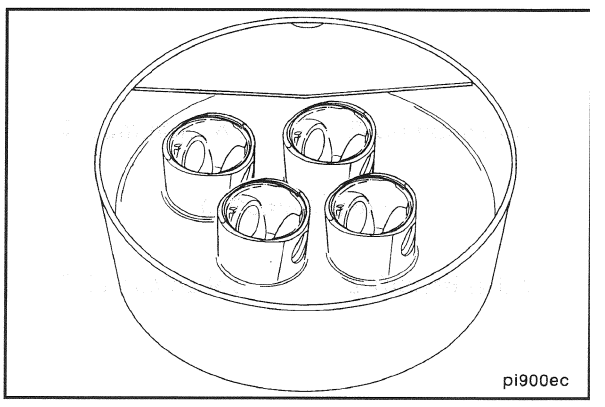
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠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.

- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- 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 cylinder head. Refer to Procedure 002-004 in Section 2.
- Remove and disassemble the piston and connecting rod assemblies. Refer to Procedure 001-054 in Section 1.

Clean and Inspect for Reuse

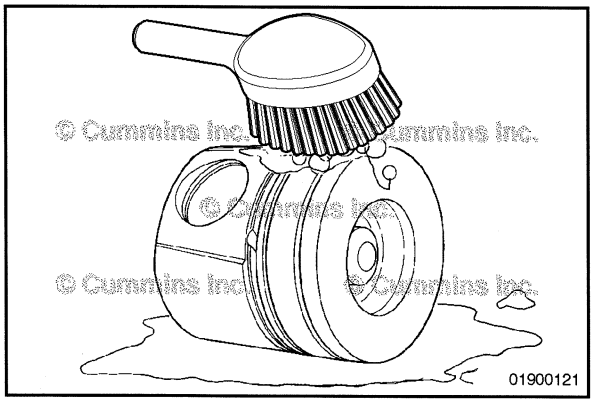

pi900ec

⚠CAUTION⚠
Do not use the bead-blast method to clean the pistons. The pistons will be damaged by blast material embedded in the aluminum.

⚠CAUTION⚠
Do not clean the pistons in an acid tank. Damage to the piston can occur.

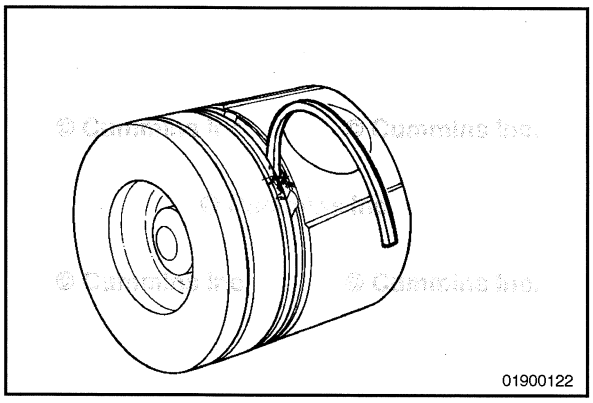
NOTE: Soaking the pistons overnight will usually loosen the carbon deposits.

Soak the pistons in cold parts cleaner.



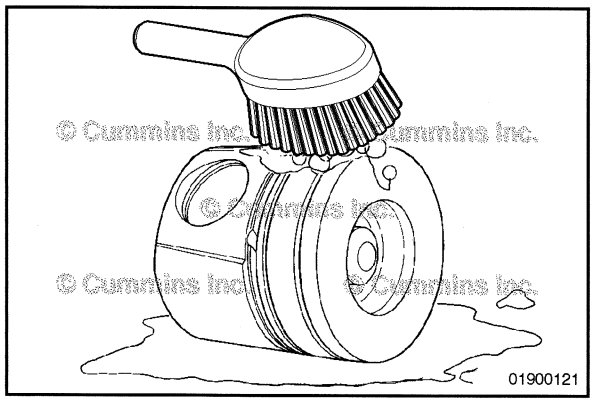
⚠CAUTION⚠
Do not use a metal brush. A metal brush will damage the piston ring grooves.

Wash the pistons in a strong solution of laundry detergent and hot water.



⚠CAUTION⚠
Do not use a ring groove cleaner and make sure 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 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⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

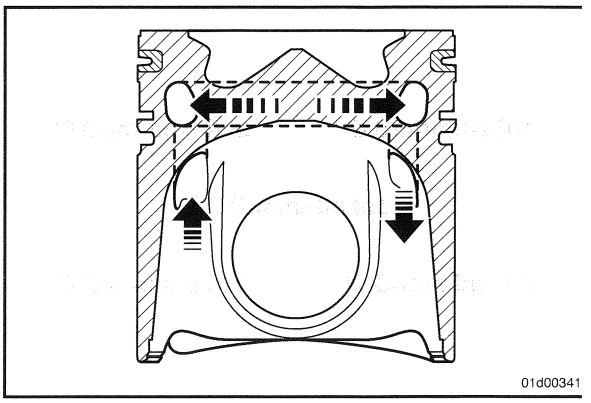
⚠CAUTION⚠
Do not clean the pistons and connecting rods in an acid tank. Damage to the pistons and connecting rods can occur.

Wash the pistons again in a detergent solution or solvent.

Rinse the pistons in clean, hot water.

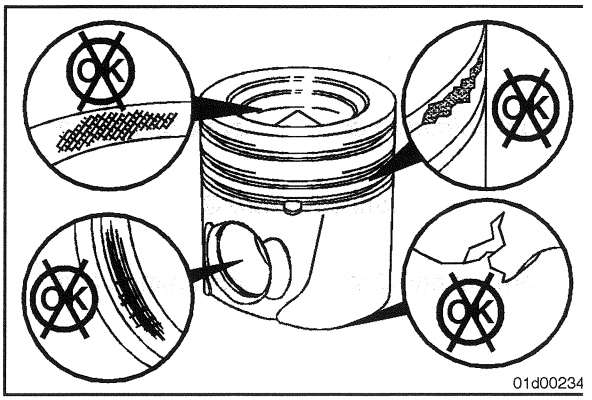
Dry the pistons with compressed air.

Some pistons have an oil passage cast into the top of the piston for cooling purposes. When cleaning the pistons, make sure the oil passage is clean and free of debris.



Inspect the piston for damage and wear to the skirt, pin bore, top, and ring lands.

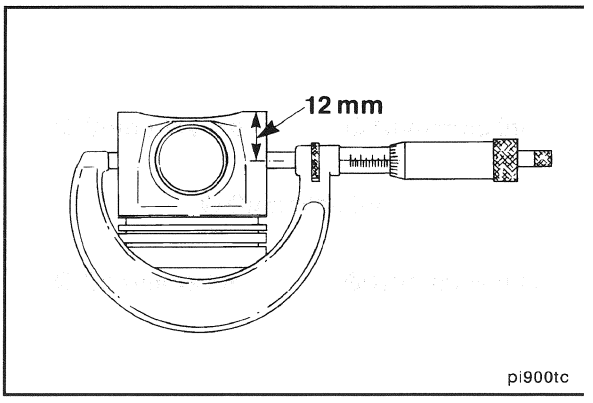
Inspect the piston pin for damage and wear.



Measure

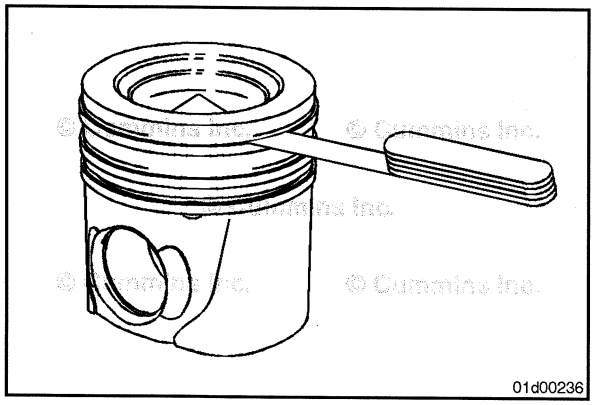
NOTE: For accuracy, the following measurements are to be completed with the components at room temperature, 20°C [68°F]

Measure the piston skirt diameter 12 mm [0.5 in] from the bottom of the piston.



Standard Piston Skirt Diameter		
mm		in
101.871	MIN	4.0107
101.889	MAX	4.0114

Oversize Piston Skirt Diameter			
	mm		in
Oversize			
0.5 mm	102.371	MIN	4.0304
	102.389	MAX	4.0311
1.0 mm	102.871	MIN	4.0501
	102.889	MAX	4.0508

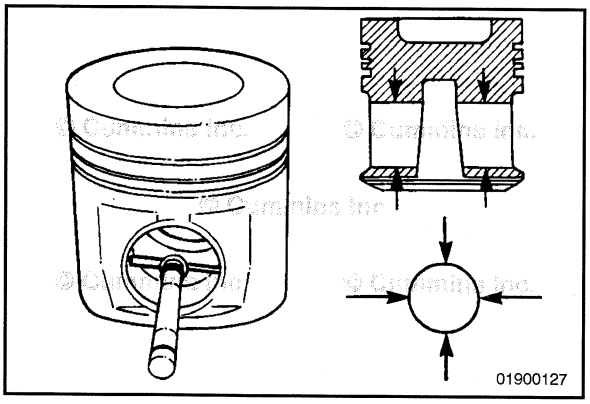


Measure the piston ring clearance. Use a new piston ring to measure the clearance in the ring groove.

Piston Ring Clearance

	mm		in
Intermediate	0.050	MIN	0.0020
	0.100	MAX	0.0039
Oil control	0.040	MIN	0.0016
	0.085	MAX	0.0033

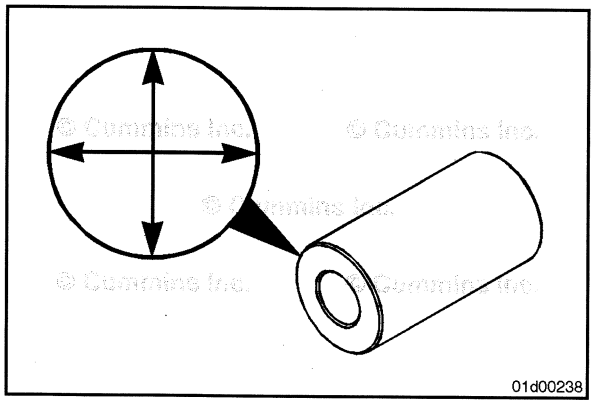
NOTE: The top piston ring clearance is **not** measured due to the type of piston ring used. The clearance can **not** be measured accurately with a typical feeler gauge



Measure the piston pin bore.

Piston Pin Bore

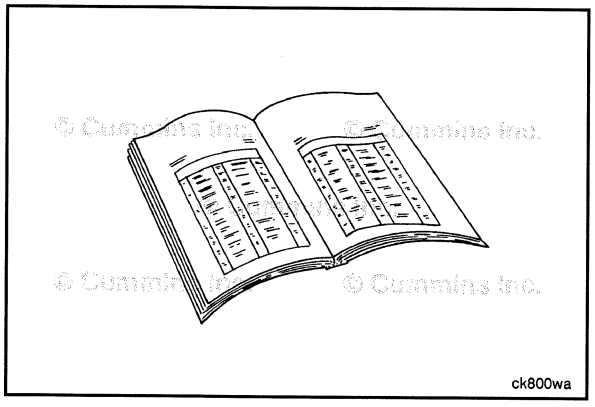
mm		in
40.012	MIN	1.5753
40.019	MAX	1.5756



Measure the piston pin diameter.

Piston Pin Diameter

mm		in
39.997	MIN	1.5747
40.003	MAX	1.5749



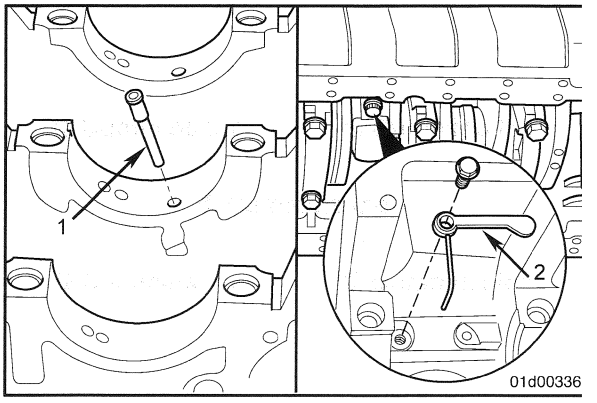
Finishing Steps

- Assemble and install the piston and connecting rod assemblies. Refer to Procedure 001-054 in Section 1.
- 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 coolant. Refer to Procedure 008-018 in Section 8.
- Fill the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Operate the engine and check for leaks.

Piston Cooling Nozzle (001-046)

General Information

J-jet piston cooling nozzles are located in between the main bearing saddles on the exhaust side of the engine. Oil is supplied from an oil gallery in the block on the exhaust side of the engine. Cylinder blocks using J-jet piston cooling nozzles may be machined for saddle jet piston cooling nozzles as well. If this is the case, plugs are required to be installed in the saddle jet piston cooling nozzle location.



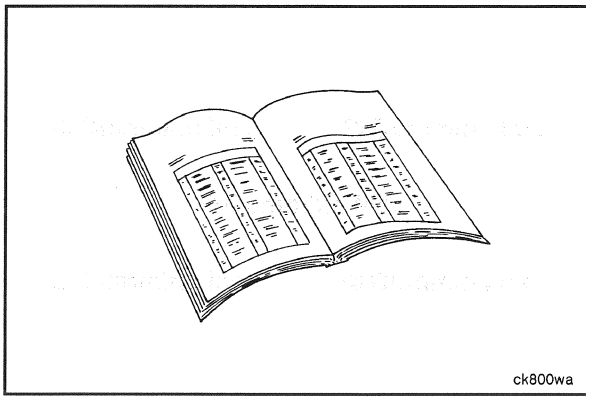
Preparatory Steps

⚠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.

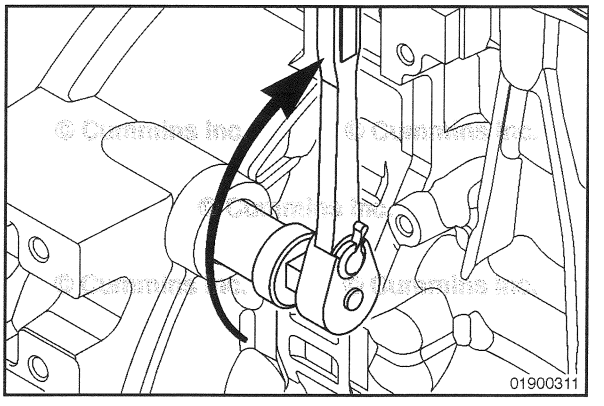
⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

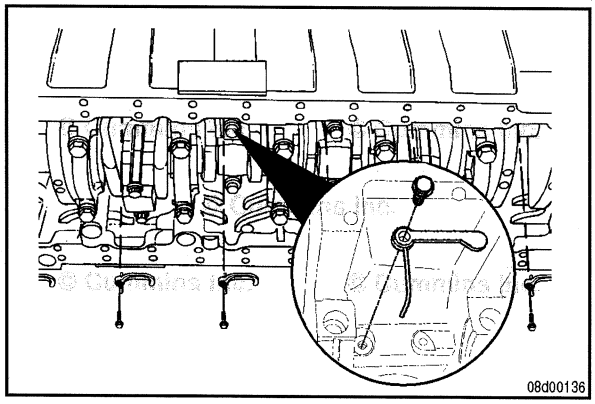
- Disconnect the batteries. See equipment manufacturer service information.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the block stiffener plate. Refer to Procedure 001-089 in Section 1.



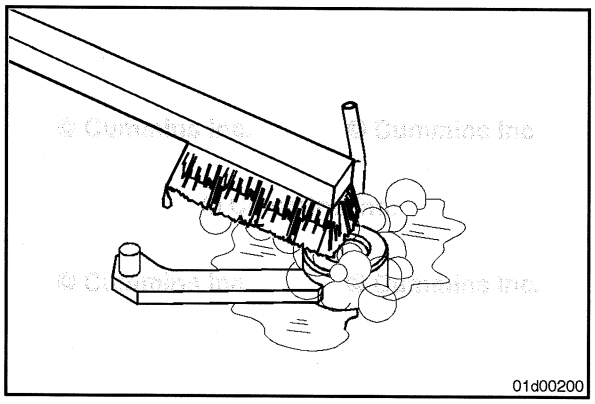
Remove

Use the engine barring tool, Cummins® Part Number 3824591, to rotate the crankshaft to various positions to access each piston cooling nozzle and/or capscrew.





Remove the piston cooling nozzles and/or capscrews.



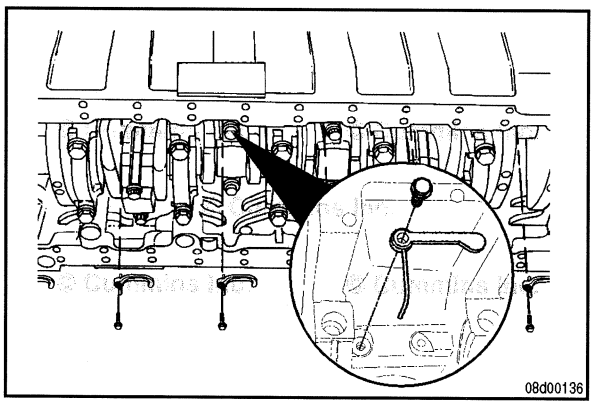
Clean and Inspect for Reuse

⚠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 piston cooling nozzle and oil passage in the block using solvent. Dry with compressed air.

Inspect the capscrew and piston cooling nozzle for damage.



Install

△CAUTION△
Slight bending of the piston cooling nozzles can result in severe engine damage. Replace piston cooling nozzle if it is bent or damaged during disassembly or assembly.

Install the piston cooling nozzle and/or capscrew one cylinder at a time, rotate the crankshaft, as necessary, for access.

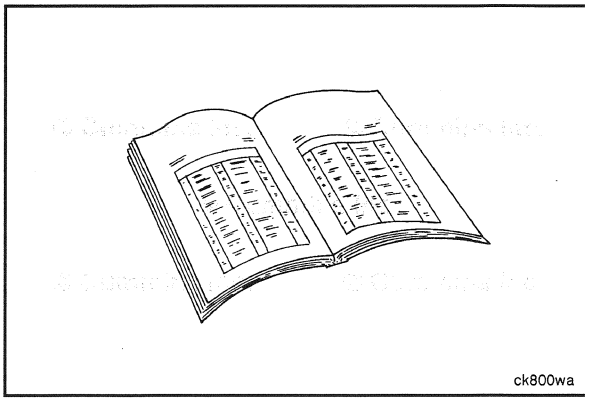
Use a long extension to guide the capscrew and/or piston cooling nozzle into place.

NOTE: The locator pin on the piston cooling nozzle **must** engage the locating hole in the block for proper alignment.

Tighten the capscrew.

Torque Value:
Cooling Nozzle Capscrew 15 N•m [133 in-lb]

Finishing Steps

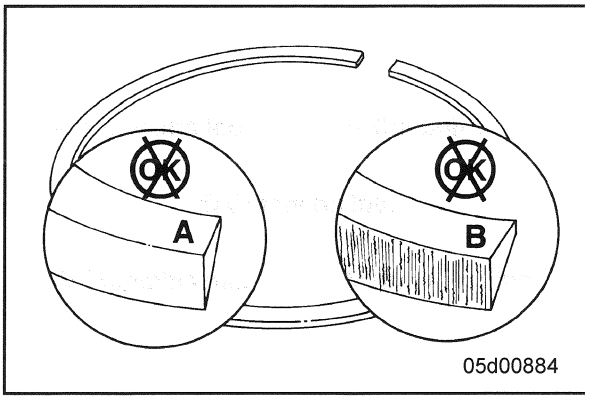


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the block stiffener plate. Refer to Procedure 001-089 in Section 1.
- Install the oil pan and oil pan gasket. Refer to Procedure 007-025 in Section 7.
- Fill the engine with clean lubricating oil. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks and proper oil pressure.

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:

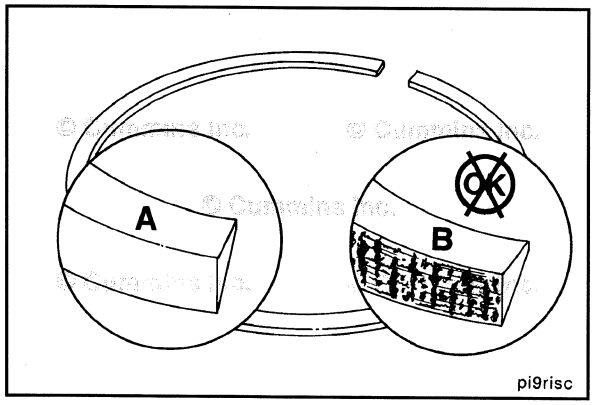
1 Ingested abrasive material.

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.

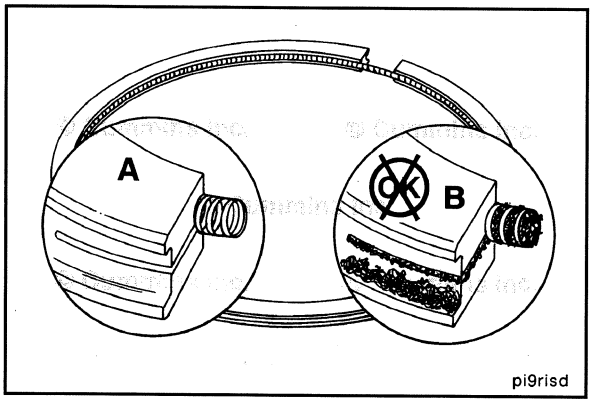
2 Oil dilution.

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:

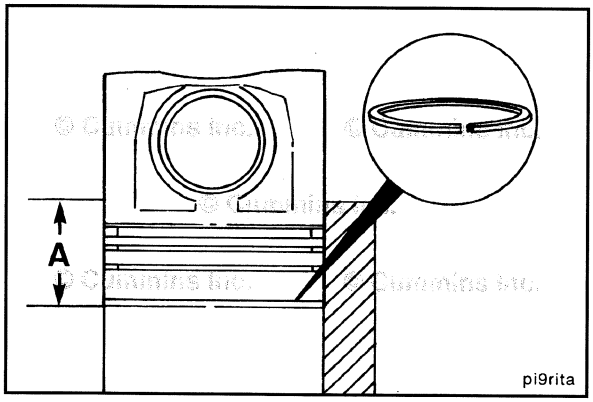
1 Low engine operating temperatures - long periods of idling or a cooling system malfunction.

2 Extended oil change intervals.

3 Use of wrong grade of engine oil.

4 Use of a poor quality engine oil.

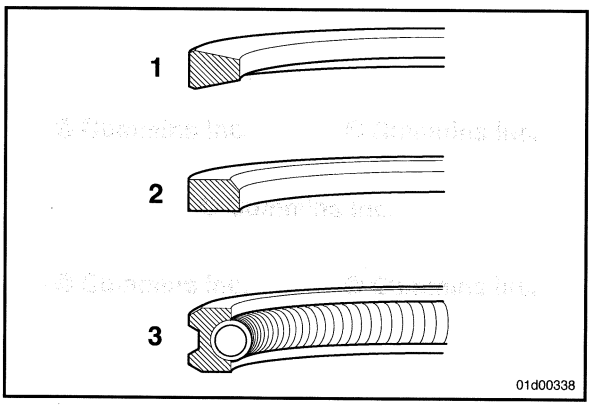
NOTE: Plugging of the oil ring drains restricts oil drain back, which floods the piston ring belt area, resulting in a loss of oil control.



NOTE: The following measurements are intended for inspecting new piston rings.

NOTE: Before completing this inspection, make sure the cylinder bore is within specification. Refer to Procedure 001-026 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), and use a piston to square it with the bore.



The piston ring type and location can be identified by piston ring profile.

1 Top piston ring.

2 Intermediate piston ring.

3 Oil control ring.

Use a feeler gauge to measure the gap.

Piston Ring End Gap Specifications

	mm		in
Top	0.26	MIN	0.010
	0.36	MAX	0.014
Intermediate	0.85	MIN	0.033
	1.15	MAX	0.045
Oil	0.25	MIN	0.010
	0.50	MAX	0.020

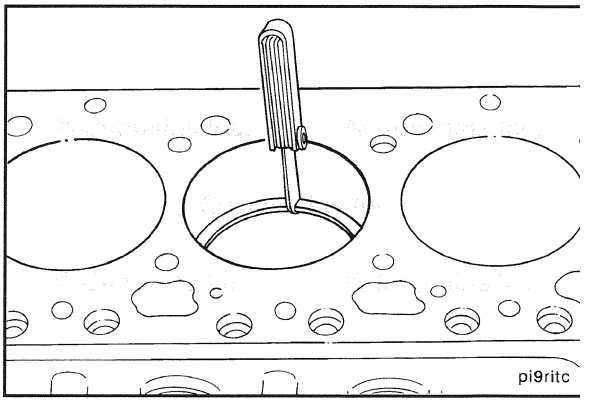
If the piston ring gap is **not** within specification:

1 Verify the correct type and part number piston ring is being used.

2 Verify the cylinder bore is within specification. Refer to Procedure 001-026 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.



Piston and Connecting Rod Assembly (001-054)

General Information

When replacing a connecting rod, make sure it matches the other connecting rods. All the connecting rods in the engine **must** be the same.

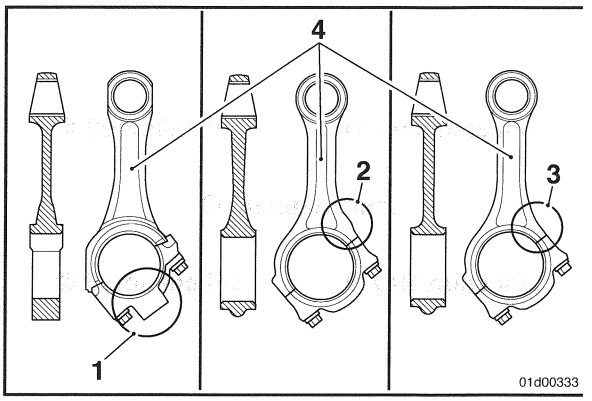
Not all connecting rods have the part number located on the connecting rod. It may be necessary to identify physical characteristics of the connecting rod when matching it to existing connecting rods.

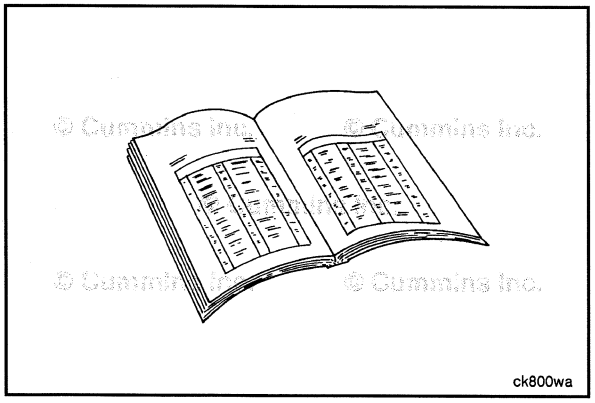
1 Balance weight on the connecting rod cap

2 Protrusion on the short side of the connecting rod

3 Smooth edge on the short side of the connecting rod

4 I-beam design.





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 can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.

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

⚠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.

- Disconnect the batteries. See equipment manufacturer service information.
- 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 block stiffener plate. Refer to Procedure 001-089 in Section 1.
- If the engine is equipped with J-jet piston cooling nozzles, they **must** be removed to prevent component damage. Refer to Procedure 001-046 in Section 1.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the cylinder head. Refer to Procedure 002-004 in Section 2.

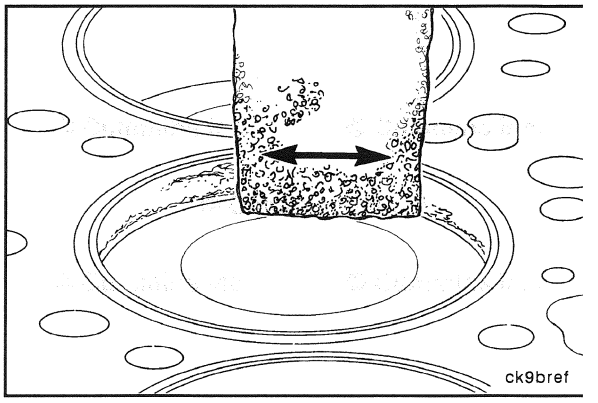
Remove

⚠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.

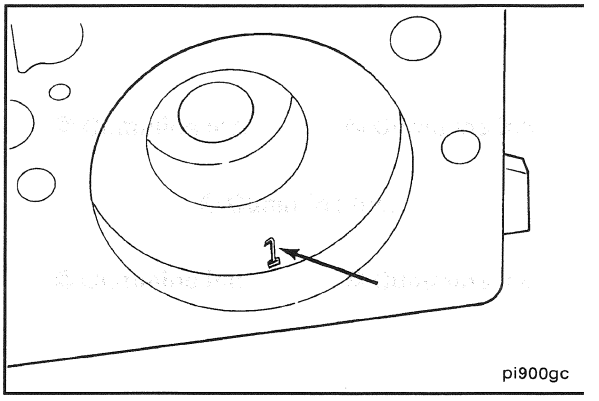
Rotate the crankshaft until the pistons are below the carbon deposits that are found above the ring travel area.

Use a fine fibrous abrasive pad, Cummins® Part Number 3823258, or equivalent, and solvent to remove the carbon.



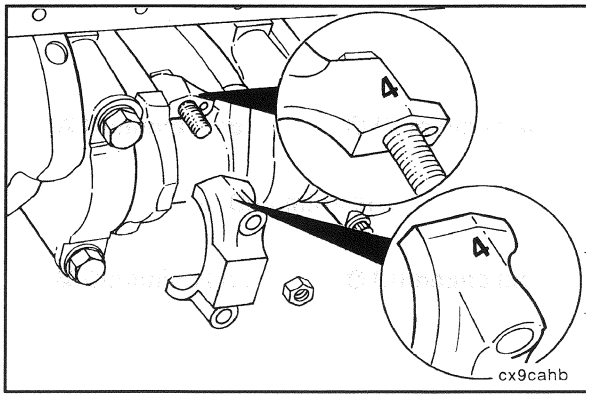
Mark each piston according to the cylinder location.

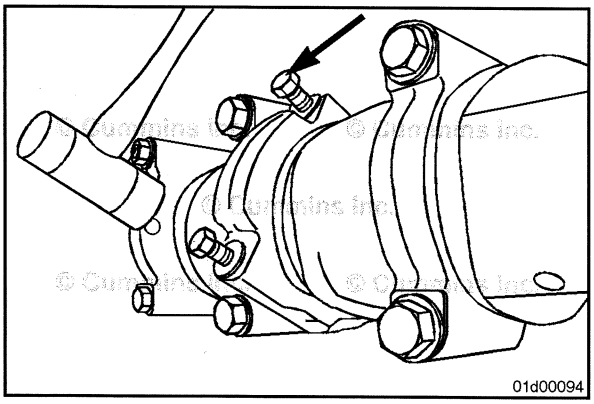
NOTE: On pistons with anodized coatings, do **not** stamp on the anodized coating or on the outer rim. Do **not** stamp on the aluminum piston crown above the piston pin axis.



Rotate the crankshaft to position the rod caps at bottom dead center for removal.

Mark each connecting rod and rod cap according to the cylinder number location.

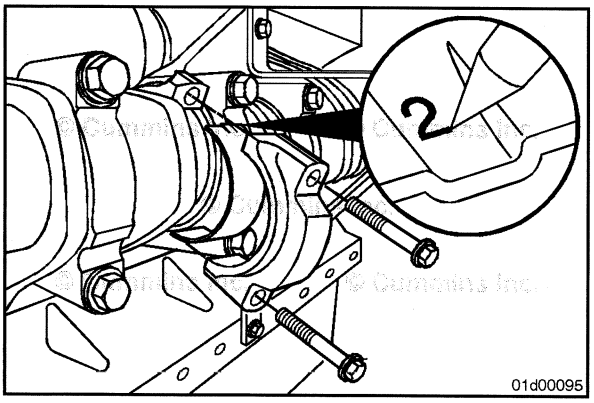




Loosen the connecting rod capscrews.

Do **not** remove the capscrews from the rods at this time.

Use a rubber hammer to hit the connecting rod capscrews to loosen the caps.



⚠CAUTION⚠
Do not damage the fractured split surface on the connecting rod or connecting rod cap while the connecting rod cap is removed. If the fractured split surface is damaged, the connecting rod and connecting rod cap must be replaced to help reduce the possibility of engine damage. Incorrect assembly can damage the rod.

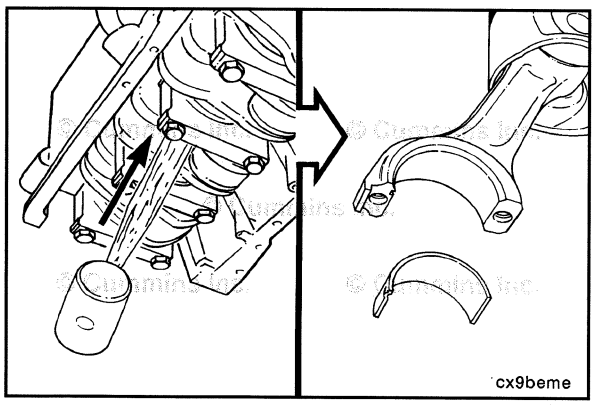
⚠CAUTION⚠
When setting the rod cap down, do not set the cap down on the fractured split surface. Damage to the fractured split surface can result.

Remove the connecting rod capscrews.

Remove the rod cap.

Remove the lower rod bearing.

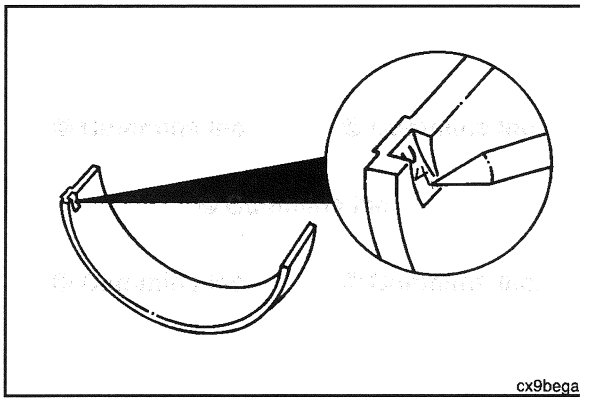
Mark the cylinder number and the letter “L” (lower) on the flat surface of the bearing tang.



Push the connecting rod and piston assembly out of the cylinder bore. Care **must** be taken **not** to damage the connecting rod or bearing.

Remove the upper rod bearing.

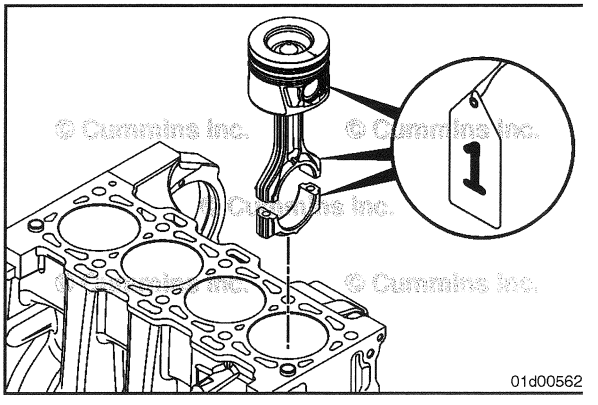
Mark the cylinder number and the letter “U” (upper) on the flat surface of the bearing tang.



The piston and connecting rod assemblies **must** be installed in the same cylinder number they were removed from to provide for proper fit of worn mating surfaces if parts are reused.

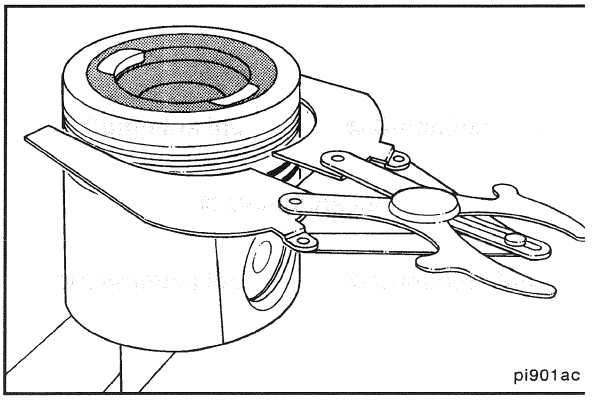
Use a tag to mark the piston and rod assembly with the cylinder number.

Place the rod and piston assemblies in a container to protect them from damage.

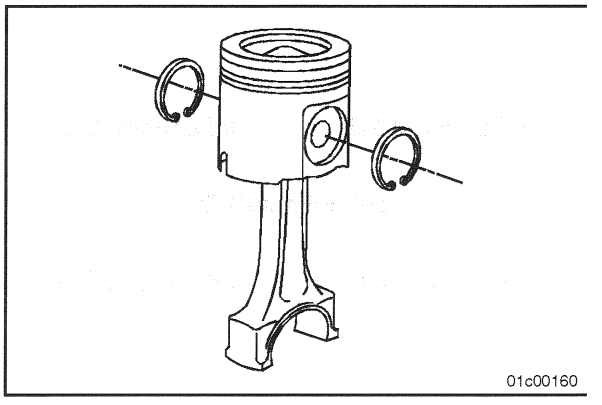


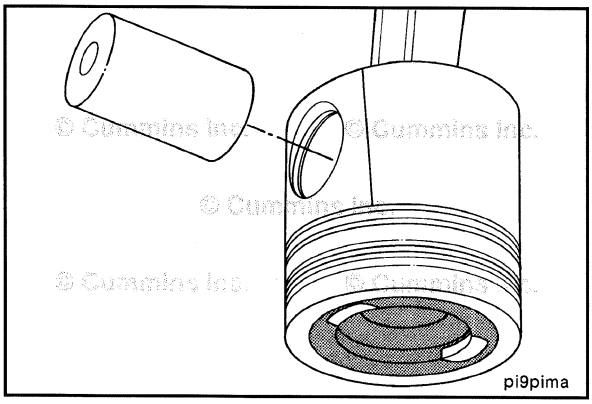
Disassemble

Use a piston ring expander, Cummins® Part Number 3823137, to remove the piston rings.



Use internal snap ring pliers to remove the snap rings from both sides of the piston.

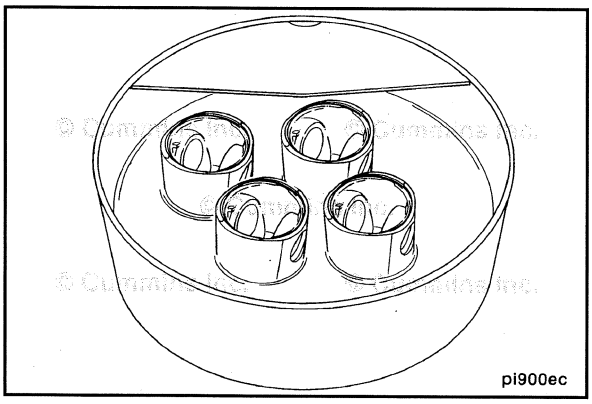




Remove the piston pin.

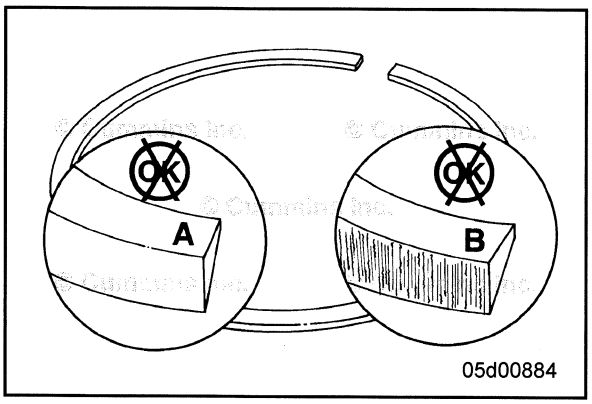
Heating the piston is **not** required.

Remove the connecting rod from the piston.

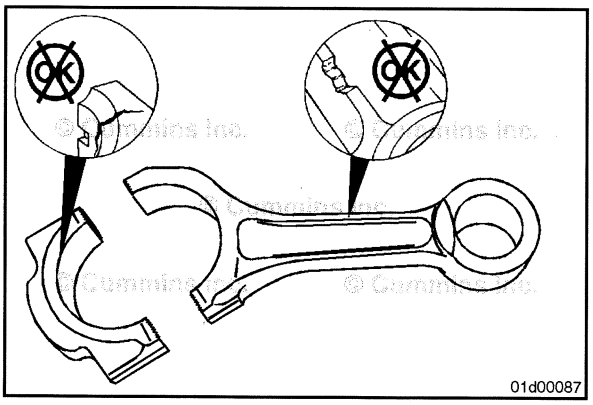


Clean and Inspect for Reuse

Clean and inspect the pistons and piston pins. Refer to Procedure 001-043 in Section 1.

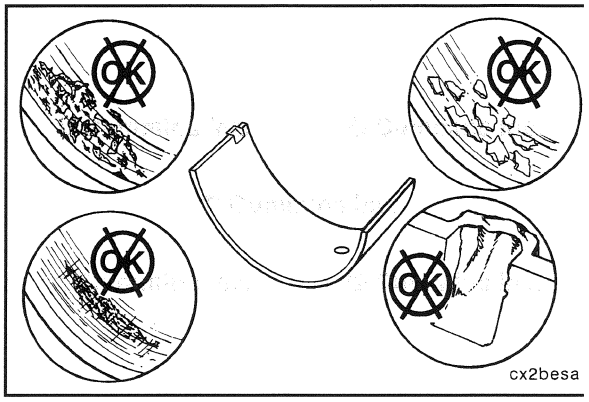


Inspect the piston rings. Refer to Procedure 001-047 in Section 1.



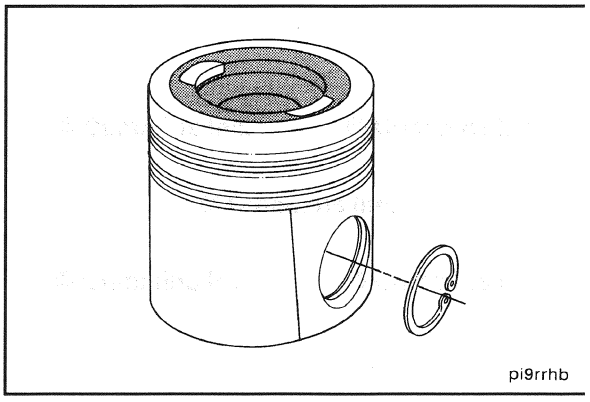
Inspect the connecting rods. Refer to Procedure 001-014 in Section 1.

Inspect the connecting rod bearings. Refer to Procedure 001-005 in Section 1.

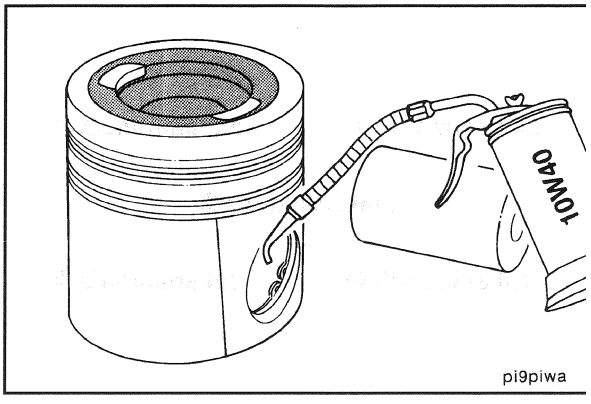


Assemble

Install the retaining ring in the pin groove on one side of the piston.



Lubricate the pin and pin bores with engine lubricating oil.



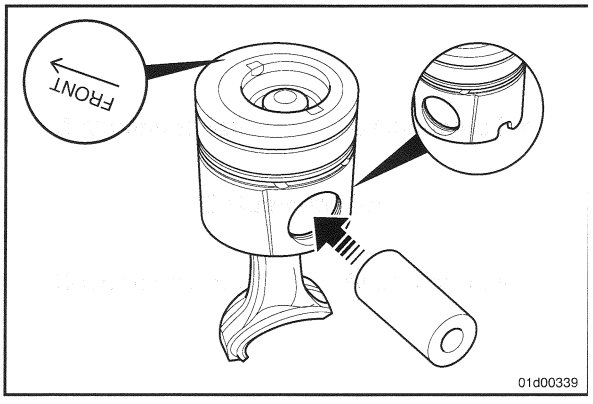
NOTE: The piston **must** be installed onto the connecting rod with the correct orientation.

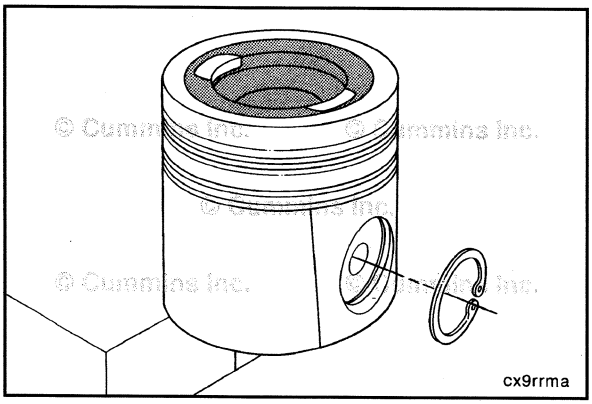
Hold the connecting rod so the angle split of the connecting rod faces away. Install the piston onto the connecting rod so the 'Front' mark and/or arrow are on the left side of the connecting rod. The notch at the bottom of the piston on the piston skirt will face away.

Assemble the piston onto the connecting rod.

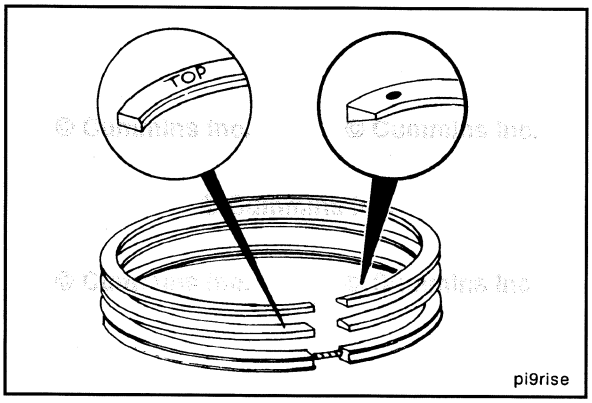
NOTE: Pistons do **not** require heating to install the pin, however, the pistons do need to be at room temperature or above.

Install the pin through the piston and connecting rod.



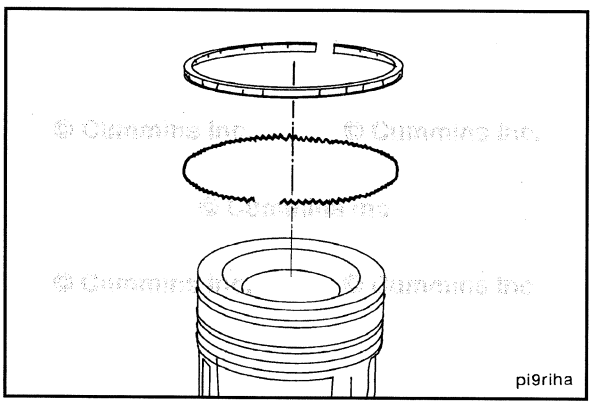


Install the second retaining ring.

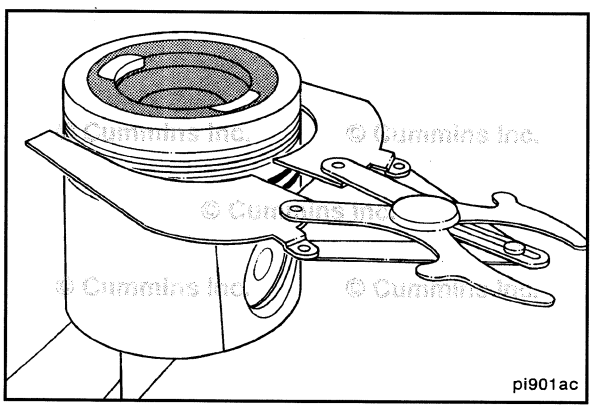


⚠CAUTION⚠
Most piston rings look similar but have significant differences. Make sure the correct part number is being used for the engine.

The top surface of the rings are identified either with the word "TOP" or a supplier identification mark, such as a stamped dot. Assemble with the word "TOP" or the supplier mark facing upward.



The two-piece oil control ring **must** be installed with the expander ring gap 180-degrees from the gap of the oil ring.



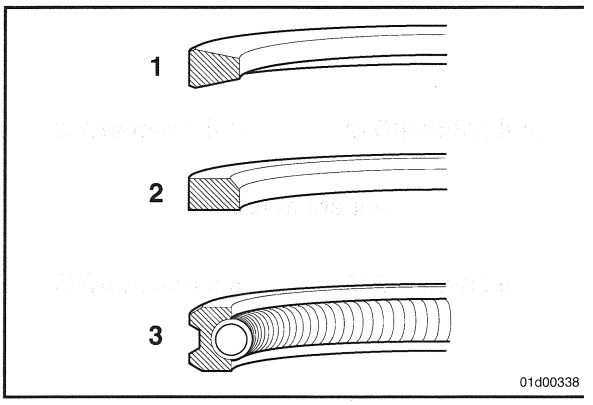
Use a piston ring expander, Cummins® Part Number 3823137, to install the rings on the piston.

The piston ring type and location can be identified by piston ring profile.

1 Top Piston Ring

2 Intermediate Piston Ring

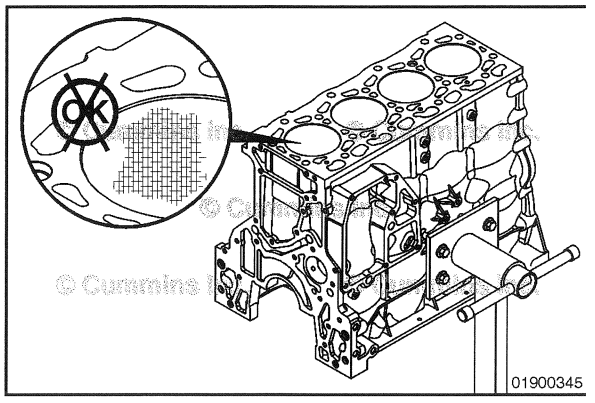
3 Oil Control Ring.



Install

The cylinder block and all parts **must** be clean before assembly. Refer to Procedure 001-026 in Section 1 to inspect the cylinder walls of the cylinder block.

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.

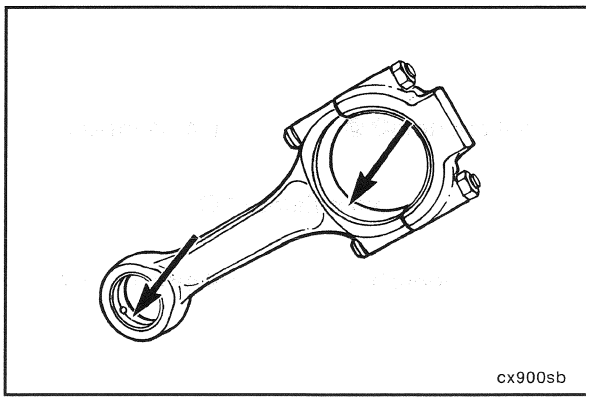
Make sure the connecting rod and backside of the connecting rod bearing surfaces are clean and free of debris. Do **not** lubricate the backside of the connecting rod bearings.

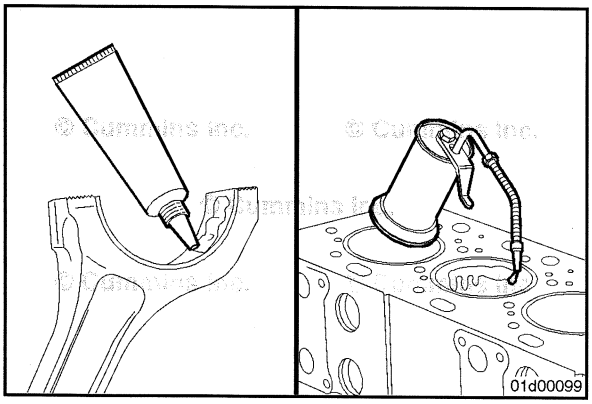
Install the upper bearing shell into the connecting rod.

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.

The upper and lower rod bearing shells are **not** interchangeable on fracture split connecting rods.

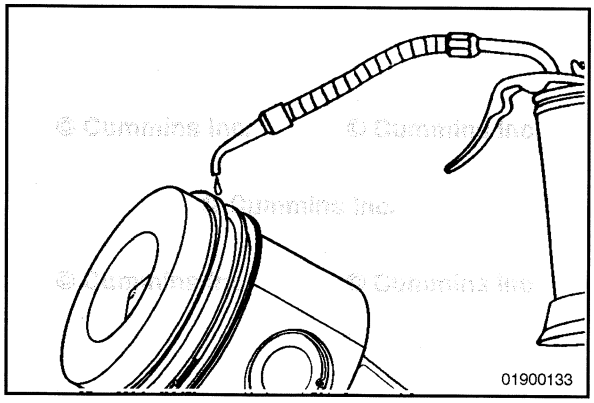
NOTE: If the connecting rod bushing is removed for any reason, a new bushing **must** be used.



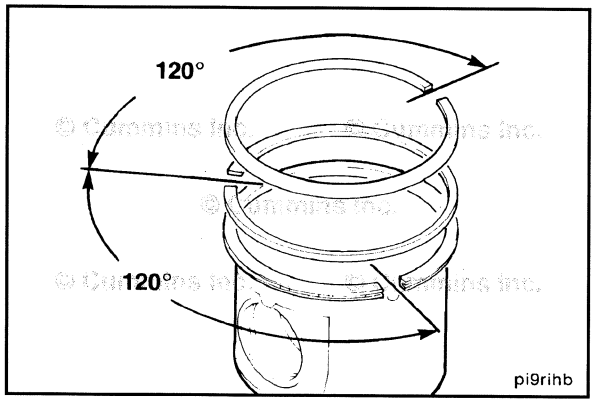


Use assembly lube, Cummins® Part Number 3163087, or equivalent, to coat the inside circumference of the bearing shell.

Apply a film of clean 15W-40 oil to the cylinder block wall.

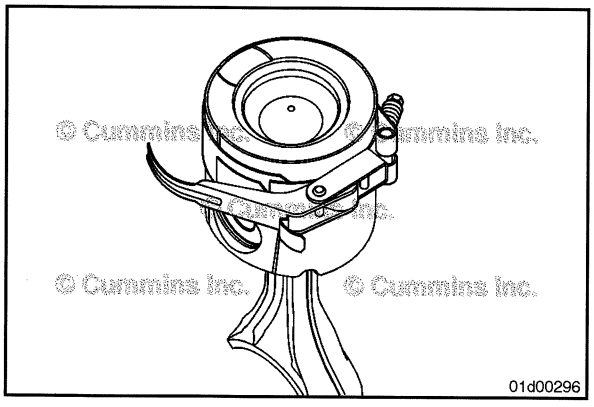


Lubricate the rings and piston skirts with clean engine lubricating oil.



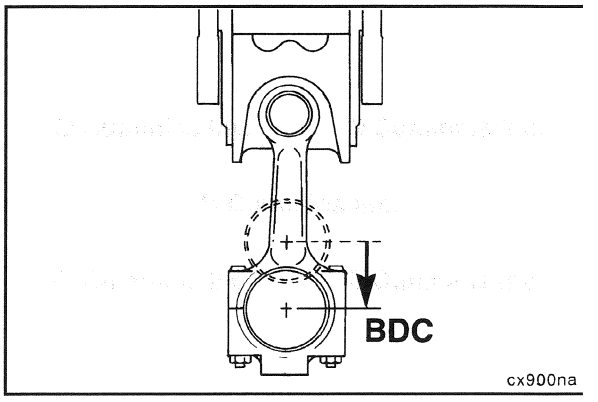
Rotate the rings to position the ring gaps as shown.

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, Cummins® Part Number 3164330, to compress the rings.

Rotate the crankshaft so the connecting rod journal of the connecting rod being installed is at bottom dead center.

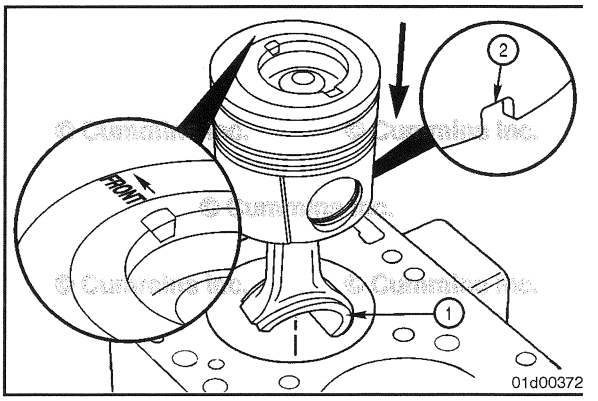


⚠CAUTION⚠
Failure to follow this step will result in extensive engine damage.

NOTE: The piston and connecting rod assembly **must** be installed with the correct orientation.

Align the "Front" marking and/or arrow on the top of the piston so that it points towards the front of the engine. Insert the connecting rod through the cylinder bore until the ring compressor contacts the top of the cylinder block.

The long end of the connecting rod (1) and the notch in the piston skirt (2) will be on the exhaust side of the engine. If **not**, verify the piston is installed correctly onto the connecting rod.

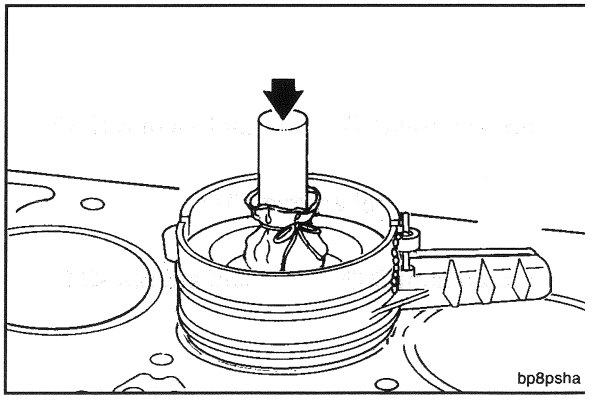


Hold the ring compressor against the cylinder block.

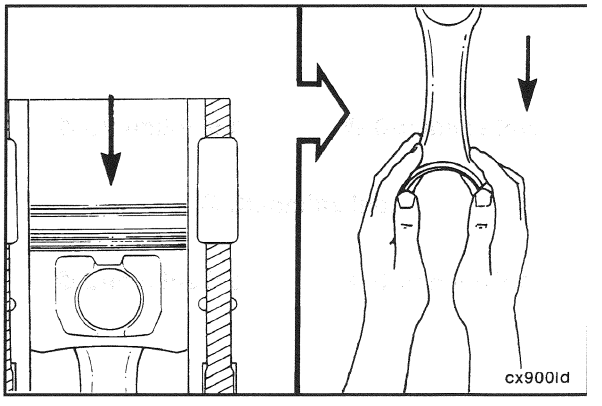
Push the piston through the ring compressor and into the cylinder bore.

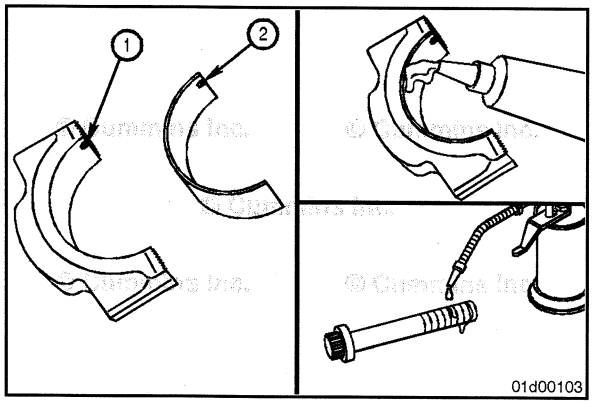
Push the piston until the top ring is completely in the cylinder bore.

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.





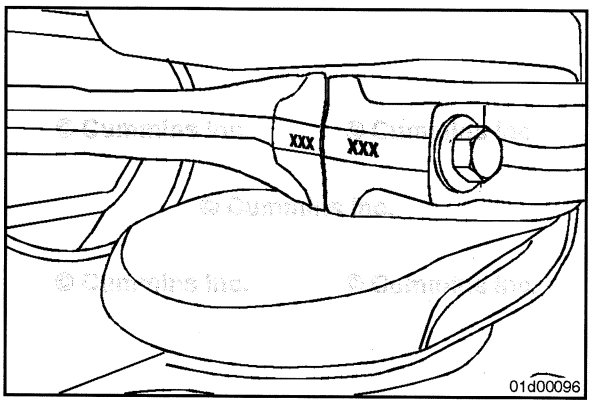
NOTE: If new bearings are **not** used, the used bearings **must** be installed on the same connecting rod cap from which they were removed.

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 lube, Cummins® Part Number 3163087, or equivalent, to coat the inside diameter of the bearing shell.

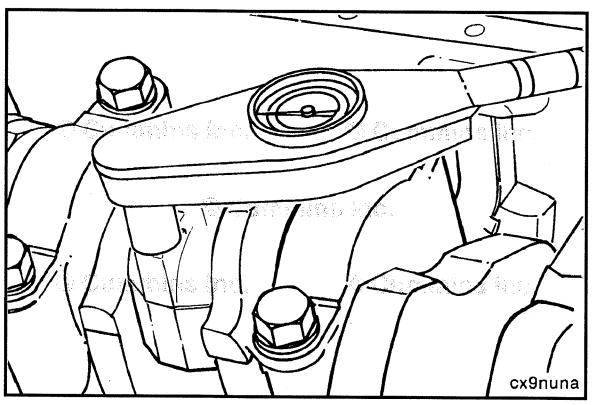
Use clean 15W-40 oil to lubricate the connecting rod capscrew threads and the underside of the connecting rod capscrew threads.



⚠CAUTION⚠
Do not damage the fractured split surface on the connecting rod or connecting rod cap while the connecting rod cap is removed. If the fractured split surface is damaged, the connecting rod and connecting rod cap must be replaced to help reduce the possibility of engine damage.

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.

Install the connecting rod cap and capscrews.

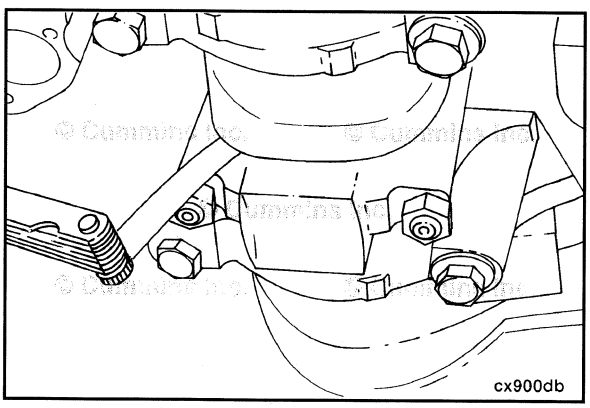


Use a marked socket and torque wrench to tighten the rod capscrews.

Use the torque plus angle method, to tighten the connecting rod capscrews in alternating sequence.

Torque Value:

Step 1	30 N•m	[22 ft-lb]
Step 2	60 N•m	[44 ft-lb]
Step 3	Rotate 60 degrees clockwise	



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

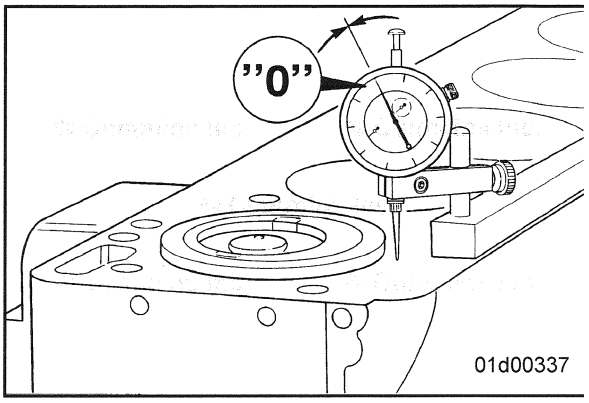
mm		in
0.125	MIN	0.005
0.275	MAX	0.011

Measure piston protrusion above the cylinder block combustion deck.

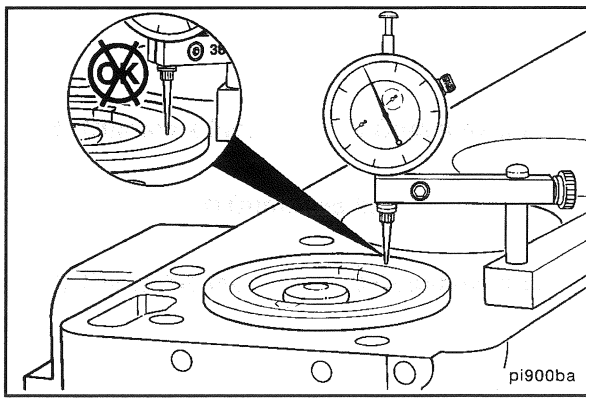
NOTE: This procedure is only required after a piston, crankshaft, connecting rod, or block modification/ replacement.

Measure the piston protrusion. Use depth gauge assembly, Cummins® Part Number 3823495. No piston or head gasket grading is required.

Install the dial indicator on the cylinder head and zero.



Move the dial indicator directly over the piston pin to eliminate any side-to-side movement. Do **not** place the indicator tip on the anodized area.

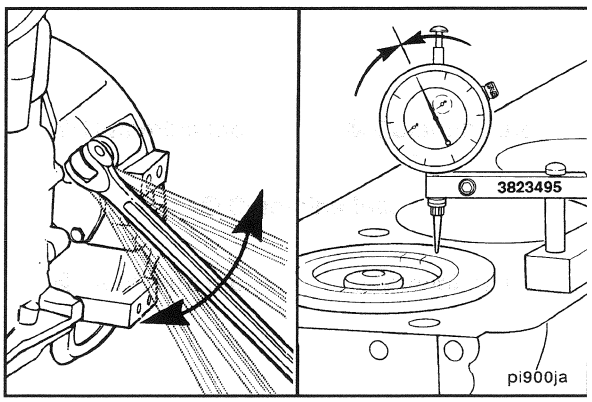


Rotate the crankshaft to top dead center. Rotate the crankshaft **clockwise** and **counterclockwise** to find the highest dial indicator reading. Record the reading.

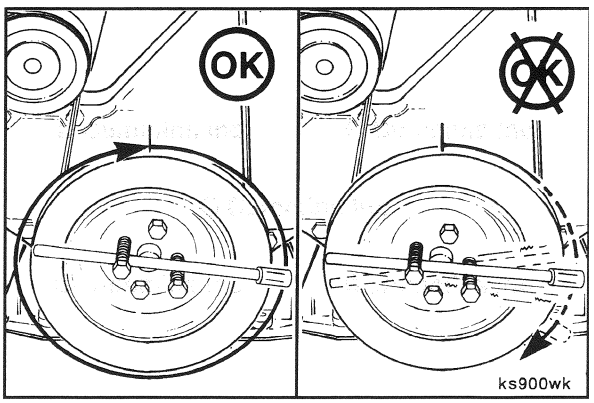
Piston Protrusion

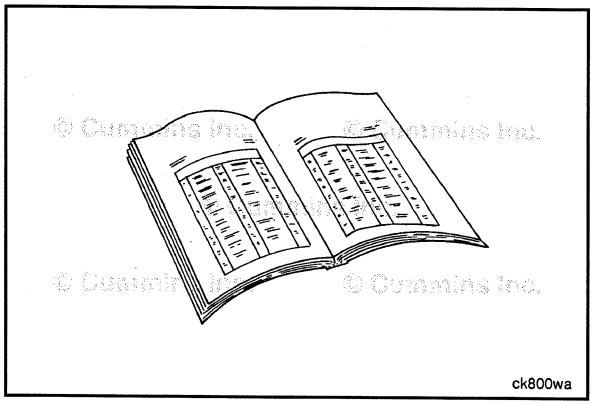
mm		in
0.25	MIN	0.010
0.52	MAX	0.020

If the piston protrusion is **not** within specification, verify that the correct parts are installed and/or the cylinder block combustion deck has been machined improperly. Refer to Procedure 001-026 in Section 1.



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.



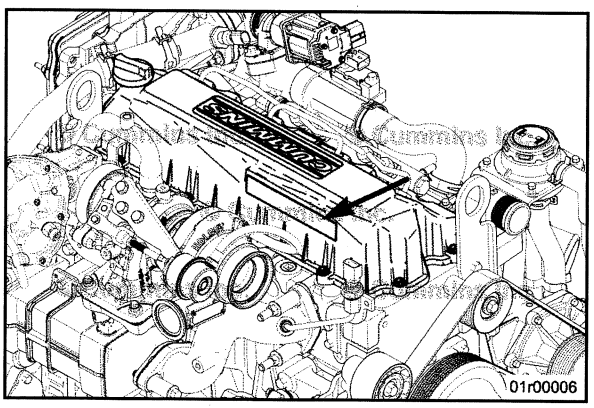


Finishing Steps

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠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 J-jet piston cooling nozzles. Refer to Procedure 001-046 in Section 1.
- Install the block stiffener plate. Refer to Procedure 001-089 in Section 1.
- 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 engine with coolant. Refer to Procedure 008-018 in Section 8.
- Connect the battery cables. See equipment manufacturer service information.
- Operate the engine to normal operating temperature and check for leaks.



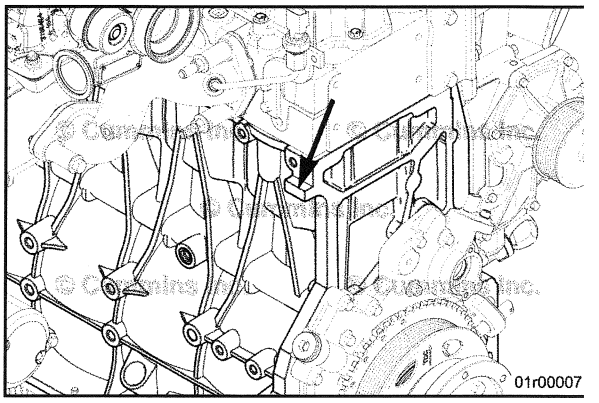
Engine Dataplate (001-057)

General Information

The engine dataplate is typically located on the rocker lever cover and secured with adhesive.

If the dataplate is damaged, missing, or incorrect, contact a Cummins® Authorized Repair location to obtain a new dataplate.

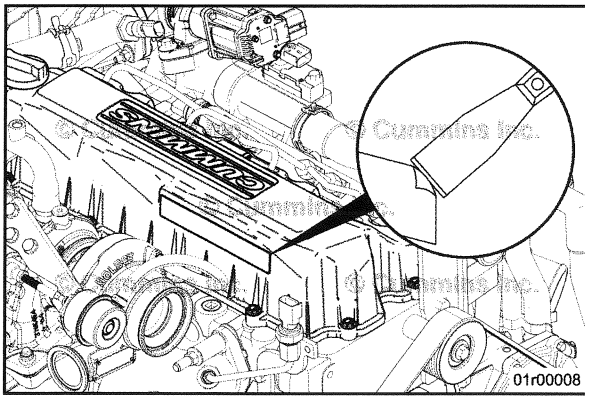
NOTE: If the dataplate is missing, the engine serial number is located on the upper front corner (exhaust side) of the cyliner block.



Remove

For printed plastic dataplates, use the sharp edge of a gasket scraper to peel up a corner of the dataplate. Pull on the corner to remove the dataplate.

NOTE: In most instances, the dataplate will be damaged during removal. Contact a local Cummins® location to obtain a new dataplate.



Clean and Inspect for Reuse

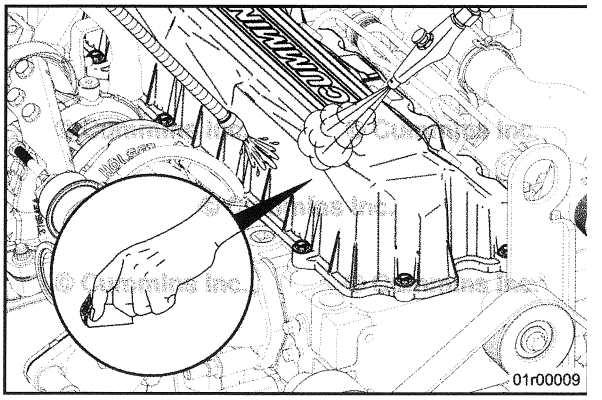
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

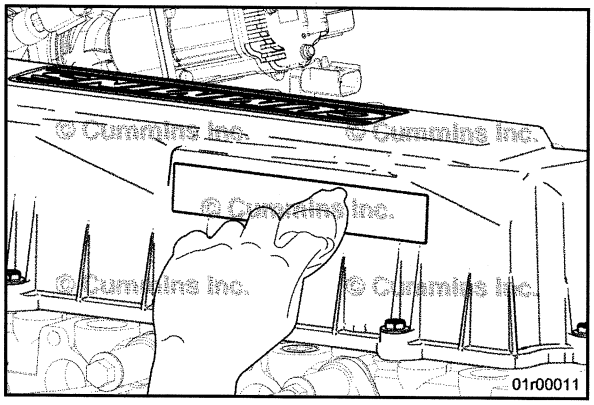
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use solvent to clean the area where the dataplate will be mounted.

Remove any left over adhesive from the printed plastic dataplate. Use solvent with an abrasive pad, Cummins® Part Number 3823258, or equivalent.

Dry with compressed air.

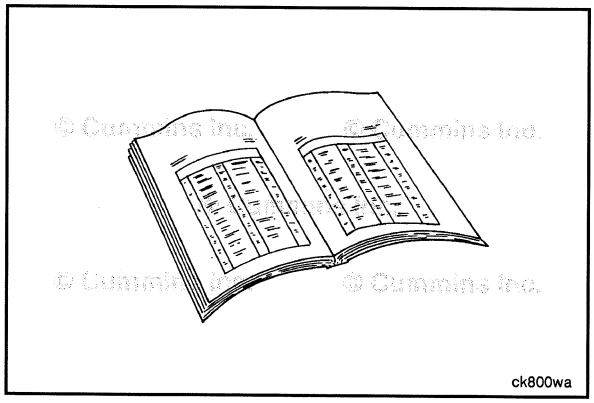




Install

For printed plastic dataplates, peel the backing off the new dataplate. Apply the new dataplate to the appropriate mounting surface. Rub the dataplate with a clean cloth to work out any air bubbles and to adhere the dataplate to the mounting surface.

NOTE: The dataplate must be located in the same area as it was previously installed.



Crankshaft Wear Sleeve, Rear (001-067)

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. See equipment manufacturer service information.

NOTE: Use a container that can hold at least 26 liters [27 qt] of lubricating oil.

- 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. See equipment manufacturer service information.
- 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 rear crankshaft seal. Refer to Procedure 001-024 in Section 1.
- Remove any OEM components (mufflers, shift mechanisms, air filters, etc.) attached to the flywheel housing. See equipment manufacturer service information.

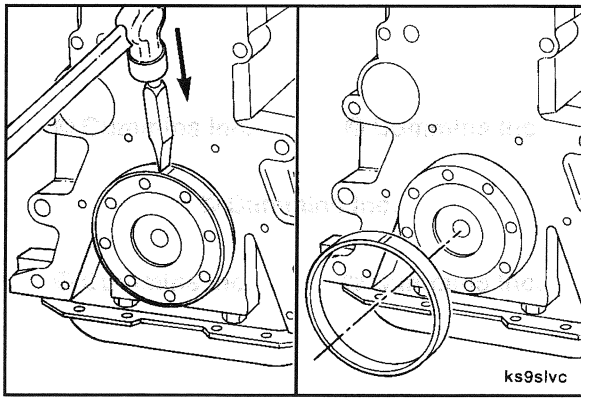
Remove

⚠CAUTION⚠
Do not nick or gouge the crankshaft with the chisel. If the crankshaft is damaged, it must be replaced.

NOTE: If a wear sleeve has previously been installed, the flywheel housing **must** be removed to remove the wear sleeve. After removing the wear sleeve, reinstall the flywheel housing. Refer to Procedure 016-006 in Section 16.

If a wear sleeve has previously been installed, use a dull chisel that is **only** as wide as the wear sleeve.

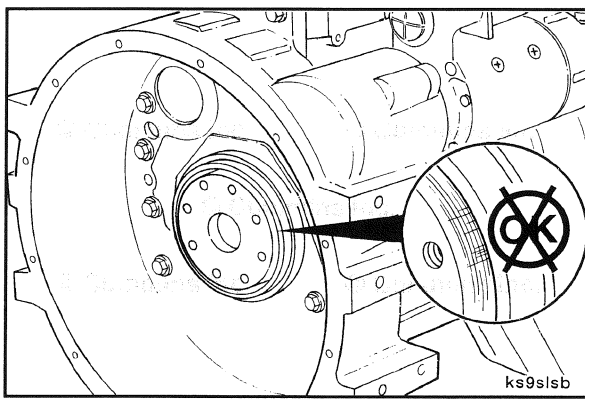
Make one or two soft blows with a hammer to make chisel marks across the wear sleeve. This will expand the wear sleeve, allowing the sleeve to be removed.



Clean and Inspect for Reuse

Clean the flywheel housing bore of any seal residue.

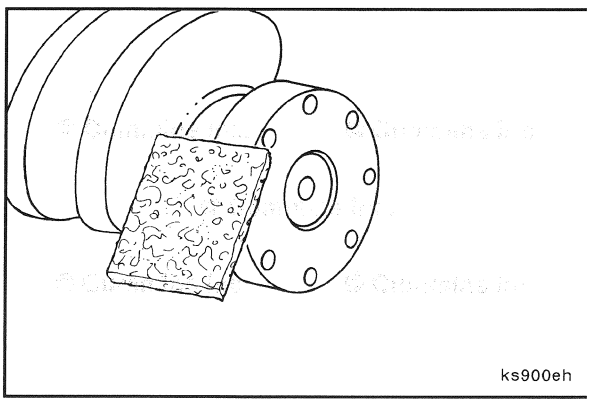
Inspect the flywheel housing bore for nicks or burrs. Use an abrasive pad, Cummins® Part Number 3823258 or equivalent, to remove any minor damage.

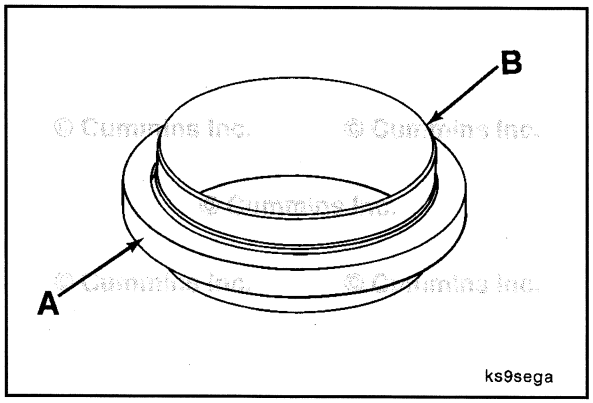


Use a fine crocus cloth to remove any rust or other deposits from the crankshaft flange.

Use a clean cloth and solvent to clean the crankshaft flange.

Inspect the crankshaft flange for nicks or burrs. Use an abrasive pad, Cummins® Part Number 3823258 or equivalent, to remove any minor damage.





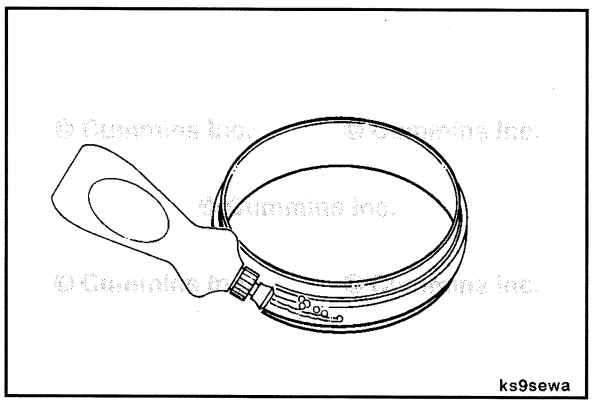
Install

NOTE: The replacement oversize seal may appear different than the standard size seal.

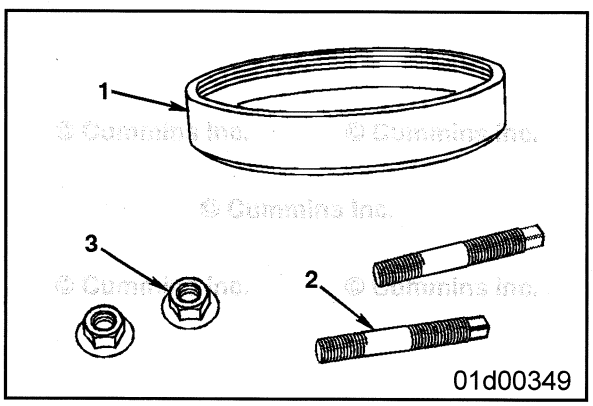
⚠CAUTION⚠
The new rear crankshaft seal should not be removed from the crankshaft rear seal wear sleeve. Damage to the sealing lips may occur when reinstalling the seal onto the wear sleeve.

The new oversize seal and wear sleeve comes pre-assembled and will be installed on the crankshaft as an assembly.

- Crankshaft oil seal.
- Wear sleeve.



To aid in installation, the lubricating oil seal requires the application of a mild soap on the outside diameter of the seal case.

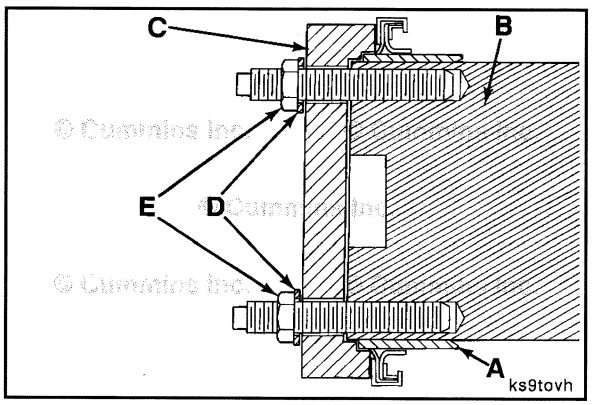


Use service tool, Cummins® Part Number 3824078, to install the crankshaft seal/wear sleeve assembly.

Reference Number	Part Number
1	3163734
2	3163628
3	3163741

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 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.

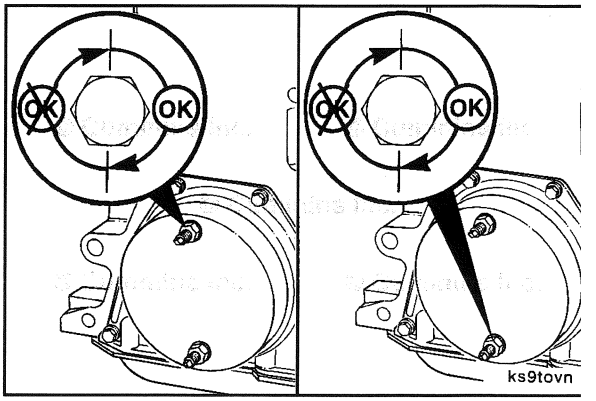
Install the washers (D) and nuts (E) onto the threaded studs.

Alternately tighten the nuts ½ of a turn until the installation tool contacts the end of the crankshaft.

Do **not** exceed ½ of a turn of each nut to prevent wear sleeve binding and irregular stretch.

Torque Value: 20 N•m [180 in-lb]

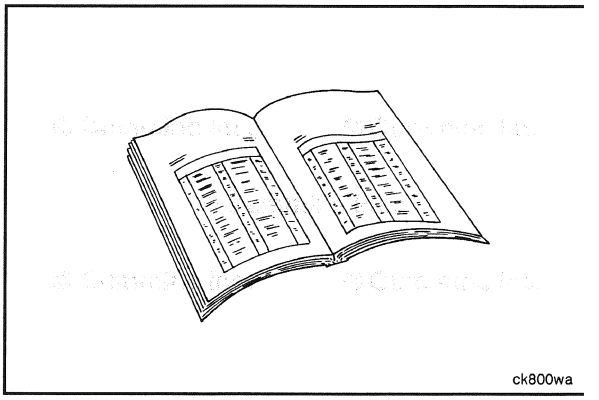
Remove the installation tool and threaded studs.

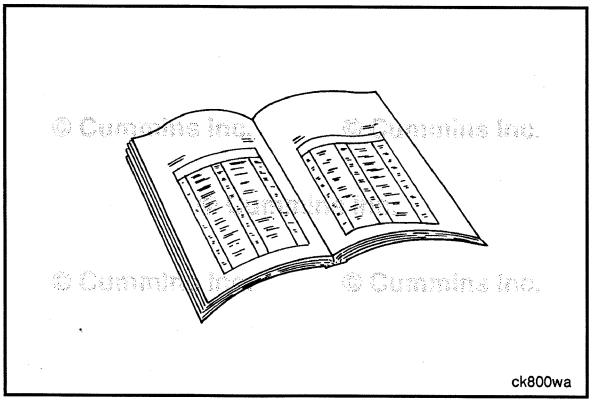


Finishing Steps

⚠ 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. Refer to Procedure 016-005 in Section 16.
- Install the flexplate. 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. See equipment manufacturer service information.
- If equipped with a wet flywheel housing, fill the flywheel housing with oil. Refer to OEM service manual.
- If previously removed, install any OEM components (mufflers, shift mechanisms, air filters, etc.) attached to the flywheel housing. See equipment manufacturer service information.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.



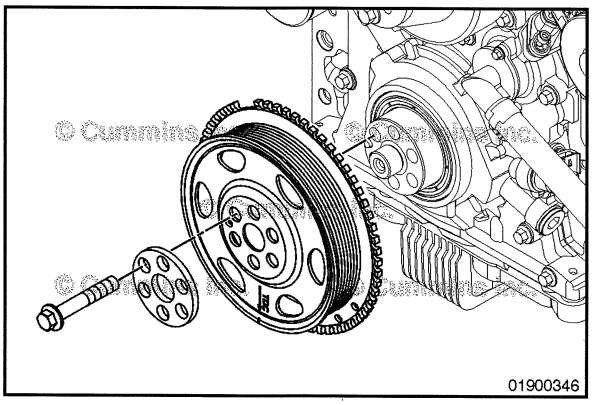

ck800wa

Crankshaft Speed Indicator Ring (001-071)

Preparatory Steps

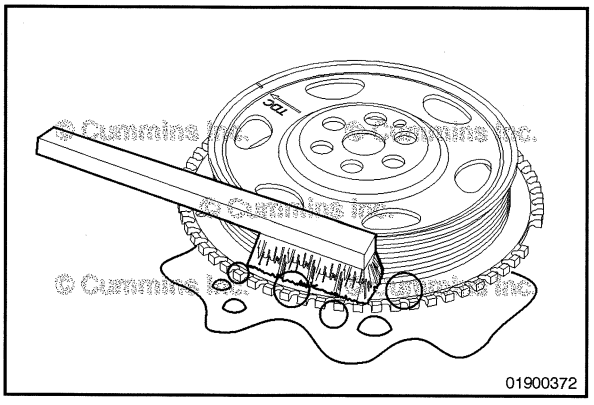
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. See equipment manufacturer service information.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.


01900346

Remove

Remove the six capscrews that hold the crankshaft speed indicator ring/pulley to the nose of the crankshaft.


01900372

Clean and Inspect for Reuse

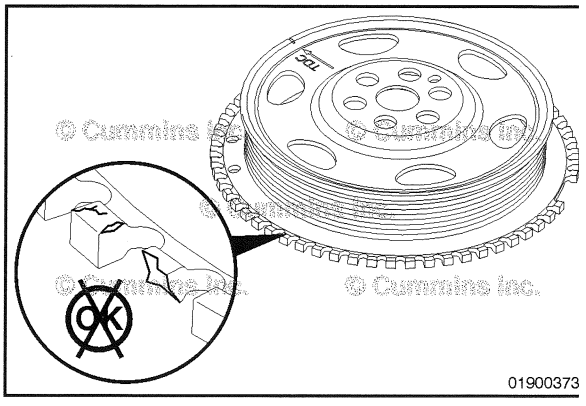
⚠WARNING⚠
Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Wear protective clothing, goggles/ shield, and gloves to reduce the possibility of personal injury.

Use soapy water to clean the oil from the crankshaft speed indicator ring.

Dry the speed indicator ring with compressed air.

Inspect the speed indicator ring for missing teeth, cracks, or damaged surfaces.

If any damage is found, the speed indicator ring **must** be replaced.



01900373

Install

NOTE: Be sure the dowel pin in the crankshaft is aligned with the tone wheel correctly.

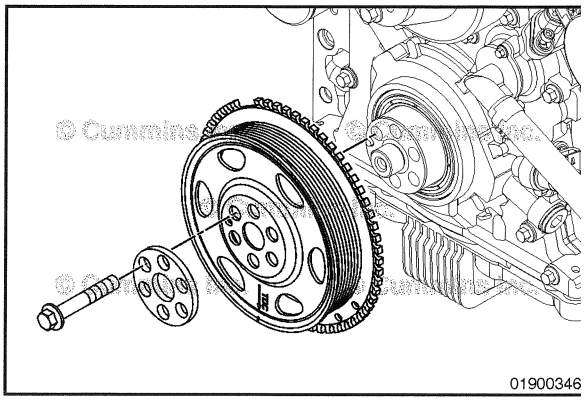
Install the six capscrews that hold the crankshaft speed indicator ring/pulley to the nose of the crankshaft.

Tighten crankshaft speed indicator ring/pulley capscrews in a criss-cross pattern.

Torque Value:

Step 1	55 N•m	[41 ft-lb]
Step 2	Loosen capscrews 180 degrees.	
Step 3	55 N•m	[41 ft-lb]
Step 4	Rotate 90 degrees.	

NOTE: The final torque value should be 125 N•m [92 ft-lb]

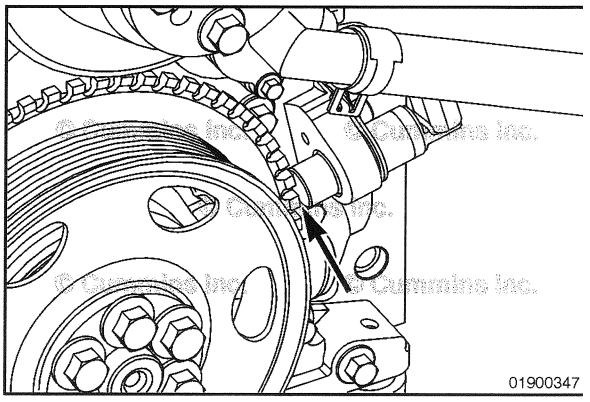

01900346

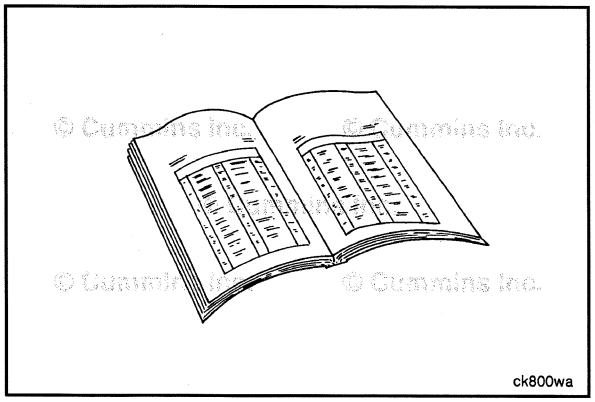
Measure

Measure the crankshaft speed/position sensor air gap between the crankshaft speed/position sensor and the crankshaft speed indicator ring with feeler gauge.

Crankshaft Speed/Position Sensor Air Gap		
mm		**in**
0.8	MIN	0.032
1.5	MAX	0.060

If the air gap is **not** within specification, remove and inspect the crankshaft speed/position sensor for damage.

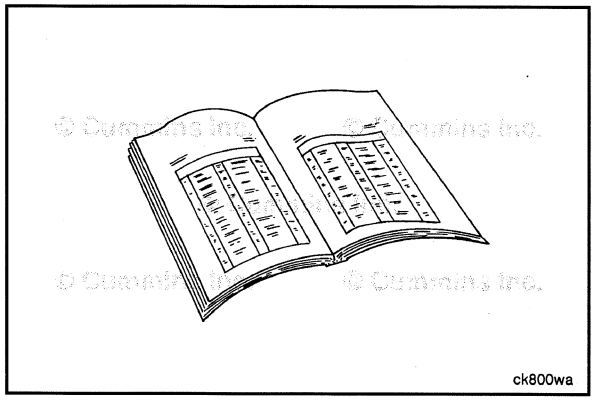

01900347



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 batteries. See equipment manufacturer service information.
- Operate the engine and check for proper operation.



Block Stiffener Plate (001-089)

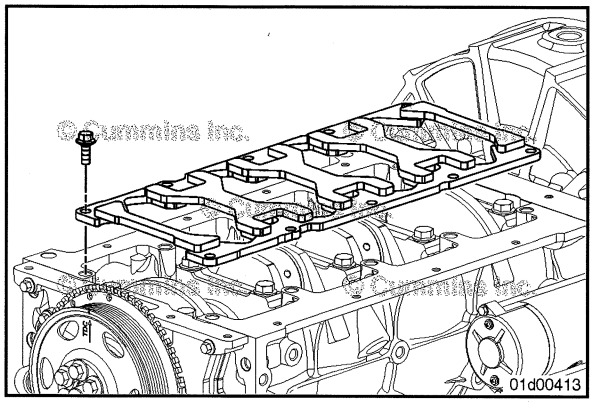
Preparatory Steps

⚠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.

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

- Disconnect the batteries. See equipment manufacturer service information.
- 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

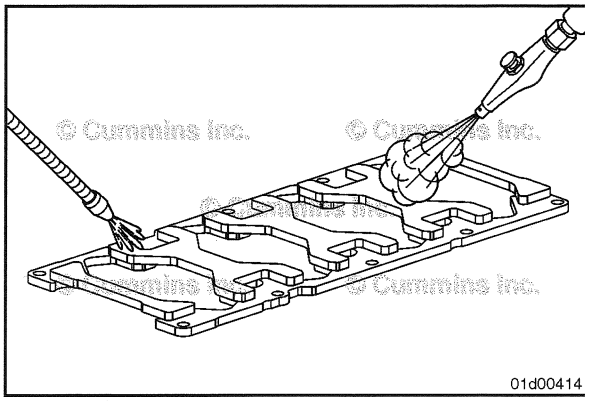
Remove the capscrews and block stiffener plate.

Clean and Inspect for Reuse

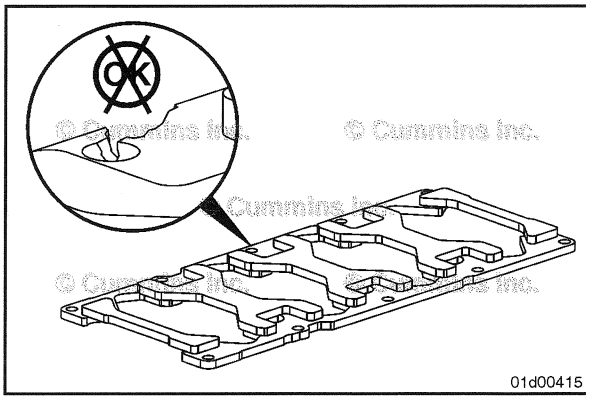
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the block stiffener plate with solvent. Dry with compressed air.



Check the block stiffener plate for cracks. Replace if damage is present.



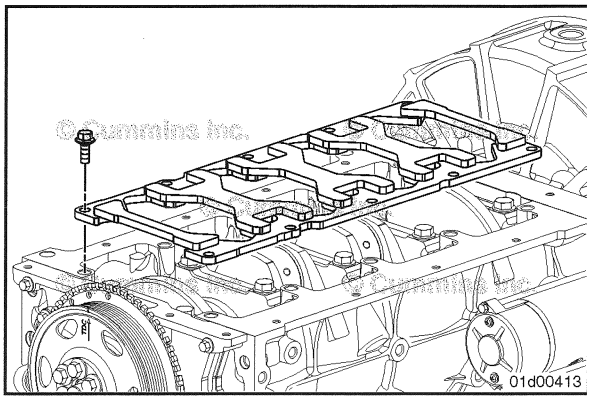
Install

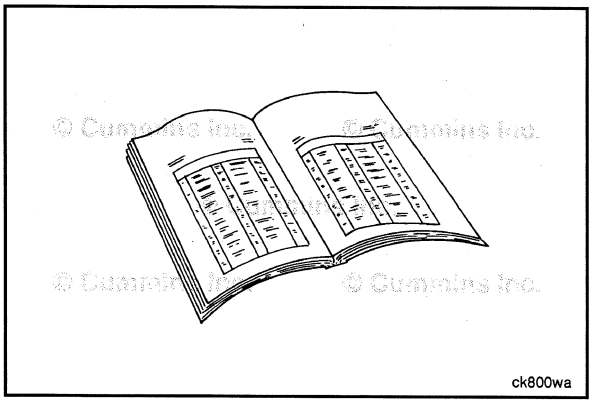
NOTE: The block stiffener plate **must** be installed so the center ribs are bent away from the block, to make sure there is proper clearance from the block main caps.

Install the block stiffener plate.

Install the block stiffener plate mounting capscrews.

Torque Value:
Block Stiffener Plate Capscrews 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 lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Fill the engine with clean lubricating oil. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. See equipment manufacturer service information
- Operate the engine and check for leaks.

Section 2 - Cylinder Head - Group 02

Section Contents

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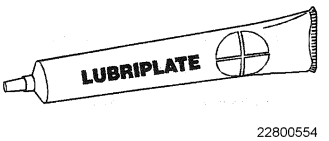
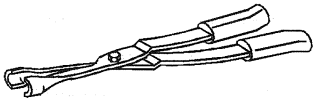
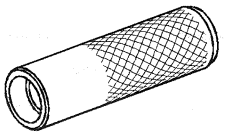
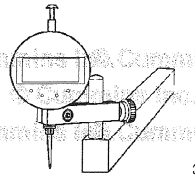
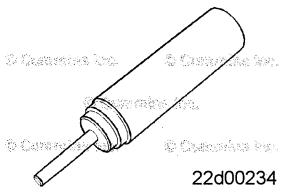
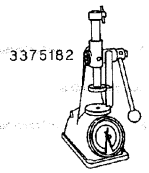
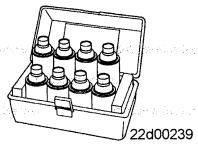
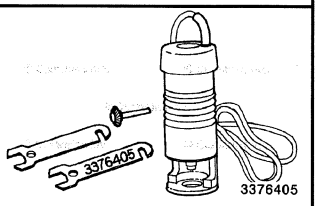
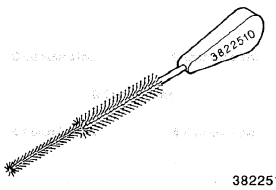
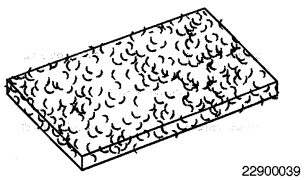
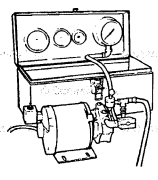
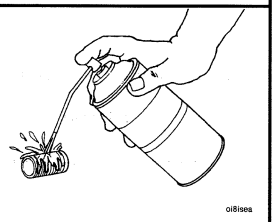
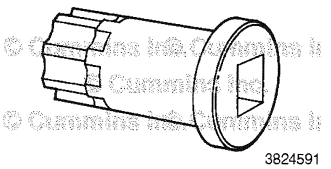
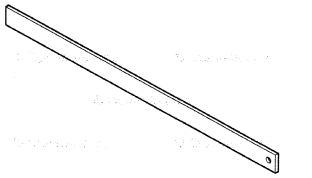
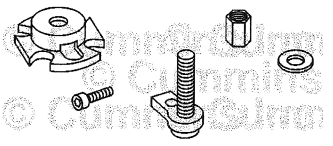
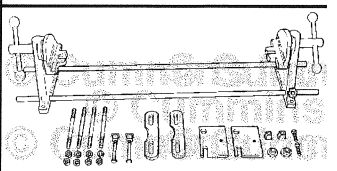
Service Tools

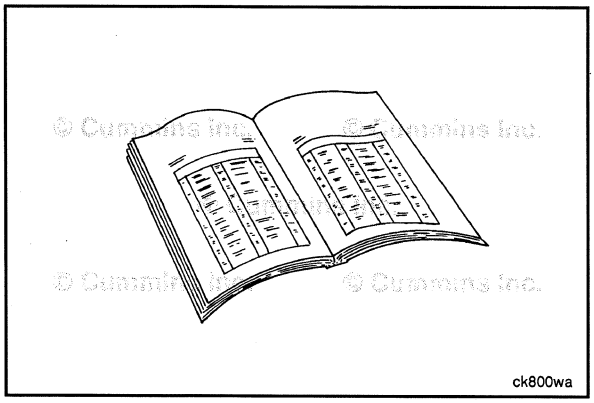
Cylinder Head

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
3163087	**Lubriplate™ Multi-Purpose Lubricant** Used the lubricate engine components.	 22800554
3163293	**Boot Plier** Used to remove the valve seal.	 3163294
3164055	**Valve Stem Seal Installer** Used to install the valve stem seal.	 22d00088
3164057	**Capscrew Length Gauge** Used to measure the length of the cylinder head capscrews.	 22d00085
3164438	**Depth Gauge Assembly** Used to measure liner protrusion, injector protrusion, cylinder block counterbore depths, and valve intrusion and/or protrusion. Equipped with electronic digital indicator.	 3164438
3165170	**Valve Seat Extractor Collet** Used with slide hammer, Part Number 3376617. Slide hammer sold separately.	 3376146

Tool No.	Tool Description	Tool Illustration
3165171	**Valve Seat Installer** Used for installing valve seats.	
3375182	**Valve Spring Tester** Used to check spring tension.	
3375432	**Crack Detection Kit (dye type)** Used to check for cracks in the cylinder head.	
3376405	**Valve Seat Grooving Tool** Cuts groove in valve seat. This is often required prior to use of valve seat extractor. Requires cutter bit Part Number 3376407. Cutter bit is sold separately.	
3822510	**Injector Bore Brush** Used to clean the injector bore in the cylinder head.	
3823258	**Abrasive Pad** Used to clean carbon from the upper liner bores, for removing rust and corrosion, and for scuffing surfaces.	
3824277	**Valve Vacuum Tester (115 V)** Used to test the valve to valve seat connection. Part Number 3824278 is for 220 V. Use with vacuum cup, Part Number 4918162, and vacuum cup seal, Part Number 4918163 to test valves.	
3824510	**Electrical Contact Cleaner** Used to safely clean engine components.	

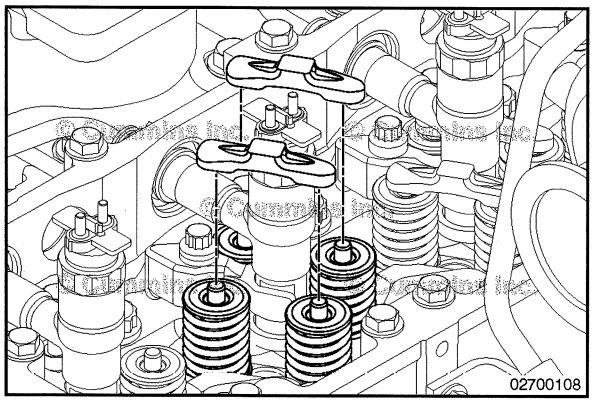
Tool No.	Tool Description	Tool Illustration
3824591	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	 3824591
4918219	**Precision Straightedge** Used to check cylinder head combustion deck for flatness.	 22d00222
4918866	**Valve Spring Compressor Kit** Used to compress the valve springs.	 22d00304
ST 583	**Head Holding Fixture** This fixture is designed to hold and rotate the cylinder to various positions during the rebuild process, as required. The fixture may be adjusted to the desired length by moving the end brackets.	 22d00320



Crosshead (002-001)

Preparatory Steps

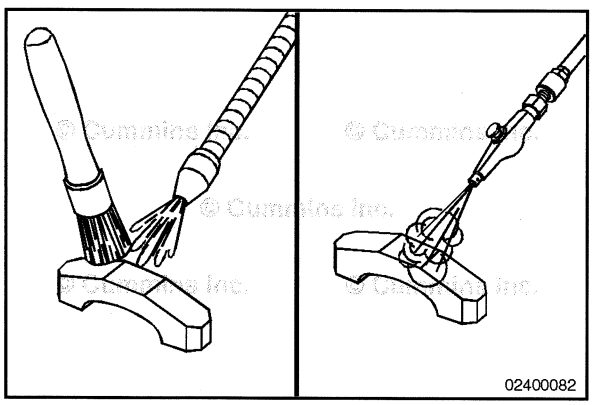
- Remove rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove rocker levers. Refer to Procedure 003-008 in Section 3.



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.

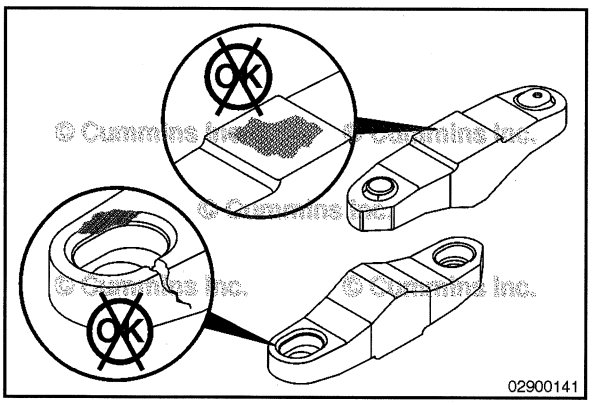


Clean and Inspect for Reuse

⚠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⚠
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 rocker lever and valve tip mating surfaces.

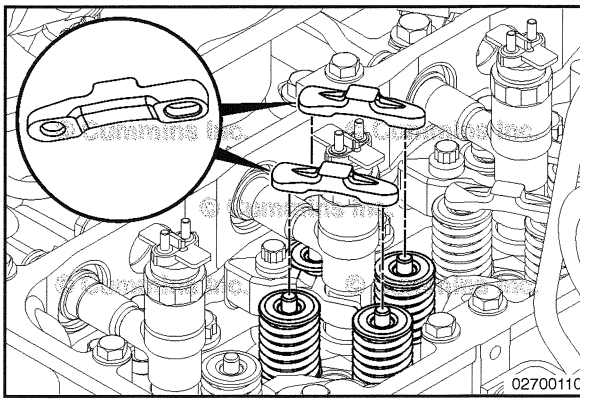
Inspect the contact pads for cracks and other damage.

Replace the crossheads if any damage is found.

Install

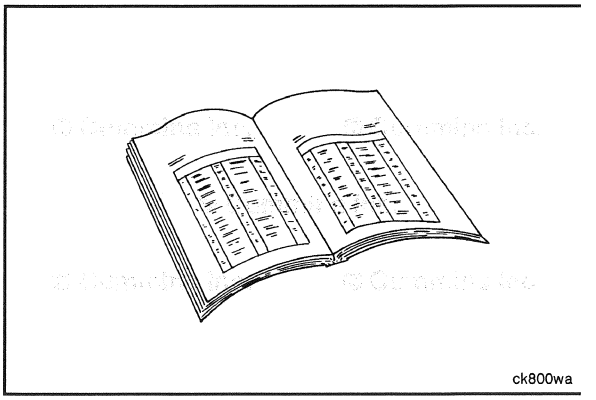
NOTE: The crosshead has a round and oval hole. The oval hole is pointed toward the exhaust side. The round hole is pointed toward the intake side. If crossheads are being reused, make sure to install them in their original location and orientation.

Install the crossheads on the valve stems.



Finishing Steps

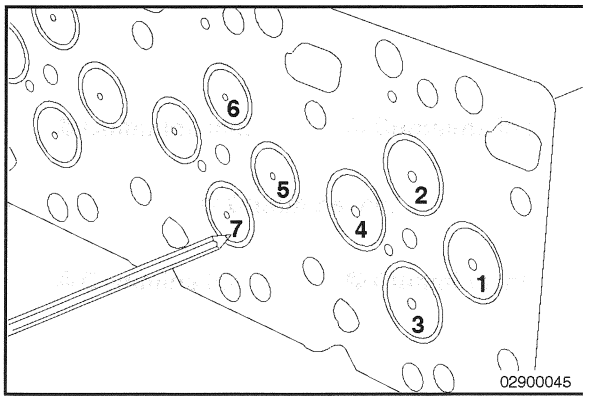
- Install the rocker levers. Refer to Procedure 003-008 in Section 3.
- Adjust the overhead. Refer to Procedure 003-004 in Section 3.
- Install the rocker lever cover and gasket. Refer to Procedure 003-011 in Section 3.
- Operate the engine and check for leaks.



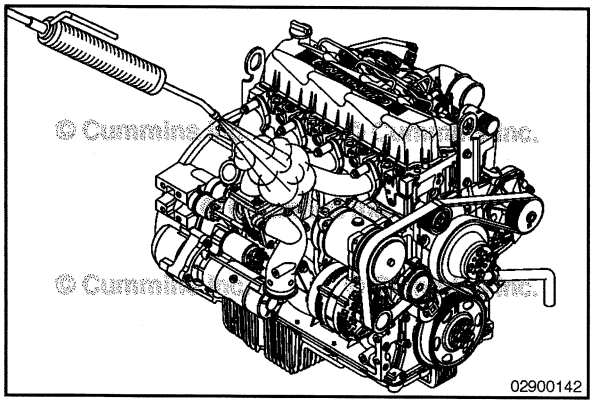
Cylinder Head (002-004)

General Information

The cylinder head group consists of the cylinder head, valves, valve guides, valve springs, valve seat inserts, and crossheads. The exhaust valves are manufactured from a material capable of operating at a higher temperature than the intake valves. In addition to being made from different materials, the intake and exhaust valves are different sizes. Mark, label, or tag the cylinder head parts such as crossheads, valves, and valve springs with the cylinder number and location from which they were removed. It is also recommended that the intake and exhaust valve positions be marked on the combustion face of the cylinder head using a paint pen, to facilitate installing the correct parts in the correct locations.



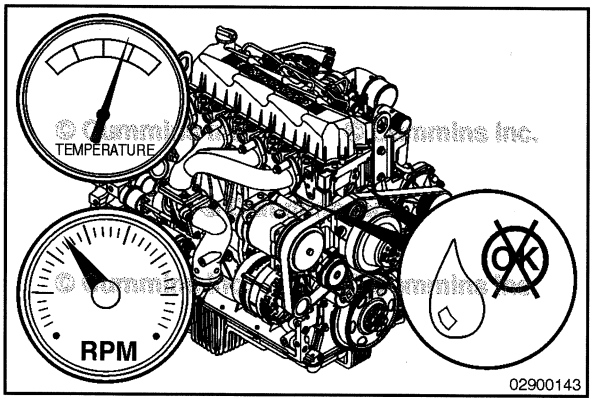
NOTE: A specific cylinder head gasket with an increased thickness is **not** available for combustion deck resurfacing of the cylinder head. If the combustion deck can **not** be resurfaced such that the correct specifications of the injector protrusion and valve depth can be maintained, the cylinder head must be replaced.



Initial Check

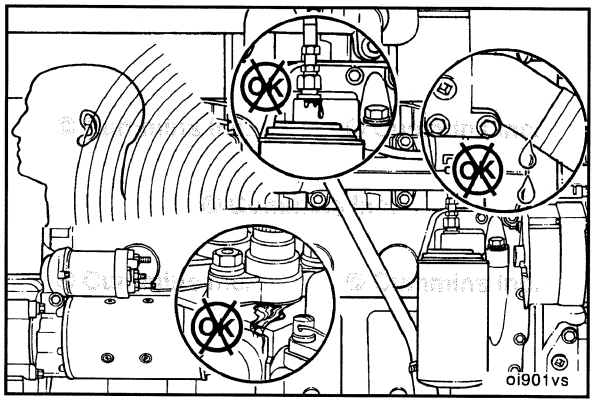
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

Use steam or high-pressure water to clean the exterior of the engine.



Operate the engine at low idle.

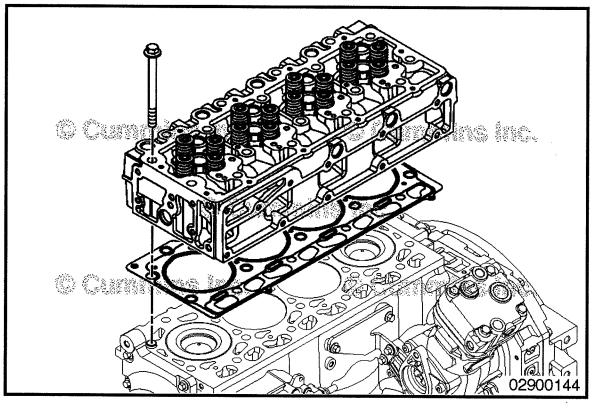
Check for oil or coolant leaks between the cylinder head and the engine block.



Listen for a chirping sound between the cylinder head and engine block.

A chirping sound, usually during acceleration, indicates a combustion leak.

Confirm leaks. Use a transparent bottle half filled with water, immerse the overflow tube from the coolant tank and run the engine at high idle until the thermostat opens and watch for a stream of bubbles in the water. This confirms a combustion leak.



If a leak is found, remove and inspect the cylinder head and all related components.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

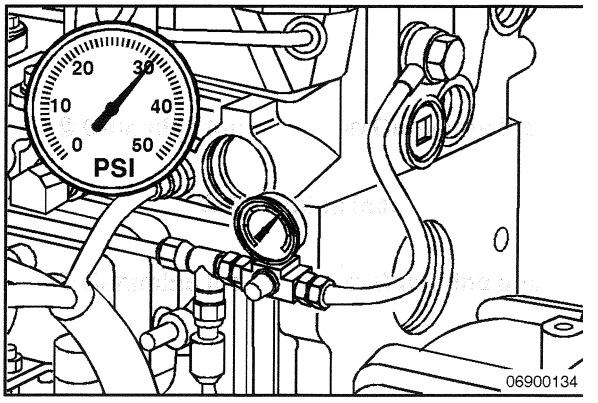
If troubleshooting coolant in fuel, fuel in coolant, or oil in fuel, pressurize the internal fuel drain line in the cylinder head and check for leaks.

Remove the fuel drain line at the back of the cylinder head. Refer to Procedure 006-013 in Section 6.

If equipped with a quick disconnect fitting at the cylinder head, remove the check valve. Refer to Procedure 006-013 in Section 6.

Connect a regulated air supply hose to the cylinder head fuel drain port with a shutoff valve on the air supply side of the pressure gauge.

Apply air pressure.



Air Pressure		
kPa		**psi**
276	NOM	30

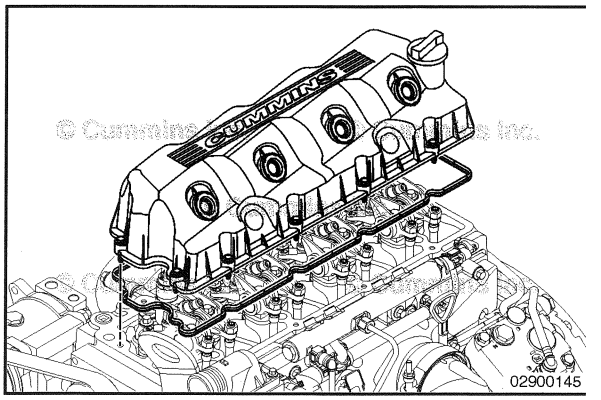
Shut off the air supply to the fuel drain port and monitor the pressure gauge reading. The pressure should hold steady. If the pressure drop rapidly, check for leaks around the:

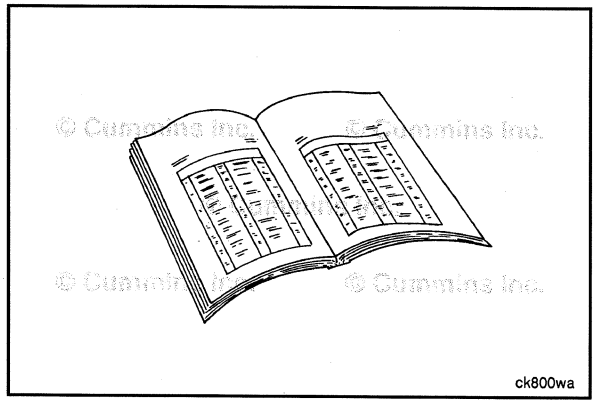
- Test fittings
- Fuel line connections at the injectors.

Remove the rocker lever cover and check for air bubbles around the injectors. Refer to Procedure 003-011 in Section 3.

Remove the radiator cap and check for air bubbles in the cooling system.

If the source of the leak can **not** be determined, remove the cylinder head and pressure test the complete cylinder head. See the Pressure Test step of this procedure. Replace the cylinder head, if necessary.





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 pets and children. If not reused, dispose of in accordance with local environmental regulations.

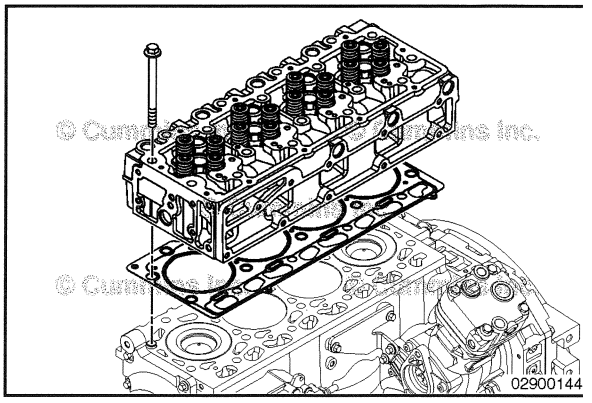
⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

- Disconnect the batteries. See equipment manufacturer service information.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the turbocharger. Refer to Procedure 010-033 in Section 10.
- Remove the exhaust manifold. Refer to Procedure 011-007 in Section 11.
- Remove the coolant bypass tube. Refer to Procedure 008-005 in Section 8.
- Remove the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Remove the combined fuel manifold. Refer to Procedure 006-060 in Section 6.
- Remove the intake manifold. Refer to Procedure 010-023 in Section 10.
- Remove the fuel drain lines. Refer to Procedure 006-013 in Section 6.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the rocker levers. Refer to Procedure 003-008 in Section 2.
- Remove the crossheads. Refer to Procedure 002-001 in Section 2.
- Remove the push rods. Refer to Procedure 004-014 in Section 4.
- Remove the injectors. Refer to Procedure 006-026 in Section 6.

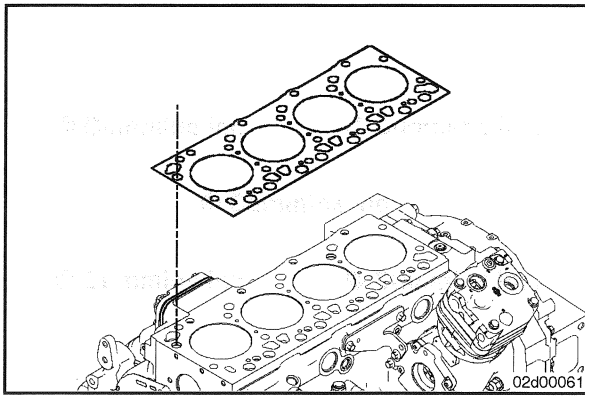
Remove

⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To reduce the possibility of serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Remove the cylinder head capscrews and cylinder head.

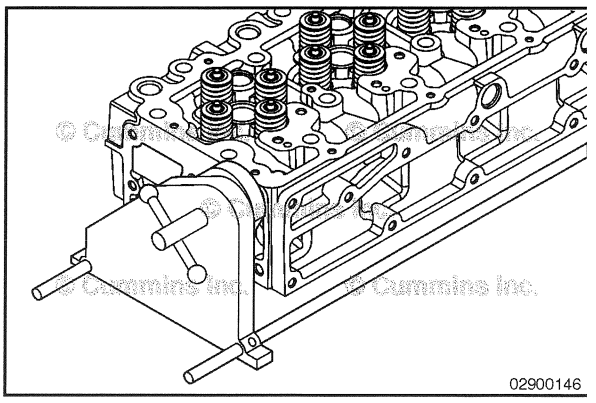


Remove the cylinder head gasket from the cylinder block.

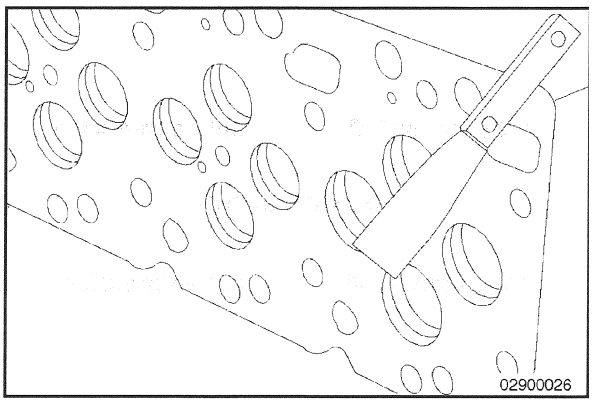


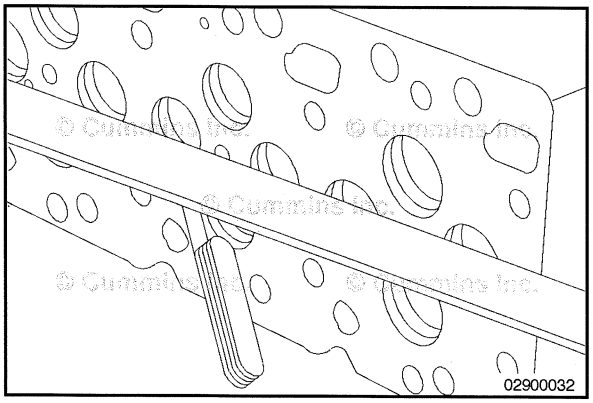
Inspect for Reuse

Install the cylinder head in the cylinder head holding fixture, Cummins® Part Number ST-583.



Clean the combustion deck surfaces on the cylinder block and cylinder head.





Use a straightedge and a feeler gauge to inspect the cylinder head combustion surface for flatness.

Cylinder Head Flatness

	mm		in
End-to-End	0.305	MAX	0.012
Side-to-Side	0.076	MAX	0.003

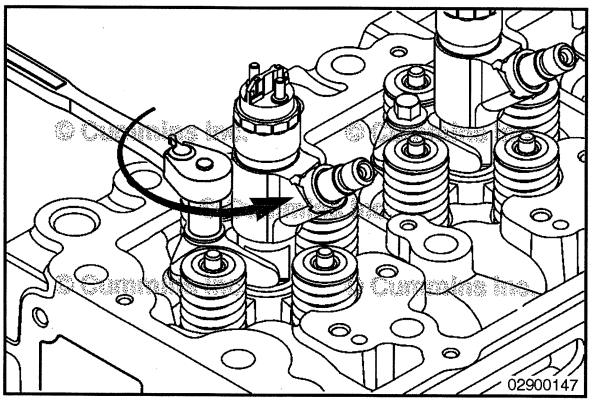
If out of specification, determine if the cylinder head can be resurfaced or if the cylinder head must be replaced by:

1 Measuring and recording valve depth

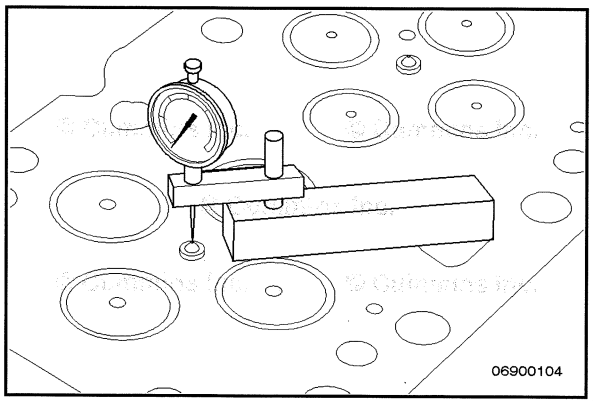
2 Measuring and recording injector protrusion.

NOTE: No specific head gasket with an increased thickness is available for combustion deck resurfacing.

If valve depth and injector protrusion specifications can be maintained, the cylinder head can be resurfaced. If the specifications can **not** be maintained, the cylinder head **must** be replaced.



Install the injectors and hold down clamps. Refer to Procedure 006-026 in Section 6.



Install depth gauge assembly, Cummins® Part Number 3164438, on the cylinder head combustion deck and zero.

Rotate the depth gauge so that it is measuring the injector protrusion at the highest point on the injector.

Record the injector protrusion for each injector.

Injector Protrusion

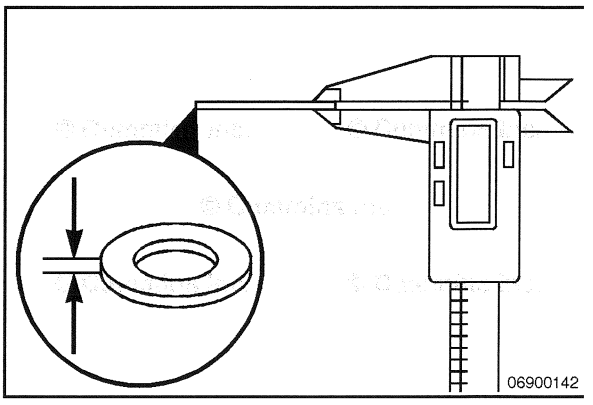
mm		in
1.94	MIN	0.076
2.47	MAX	0.097

NOTE: Do **not** use thicker or double stacked injector sealing washers to correct injector protrusion. This will cause misalignment of the high-pressure fuel connector.

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.

If the injector protrusion is within specification, remove the injector. Refer to Procedure 006-026 in Section 6.



Install depth gauge assembly, Cummins® Part Number 3164438, on the cylinder head combustion deck and zero.

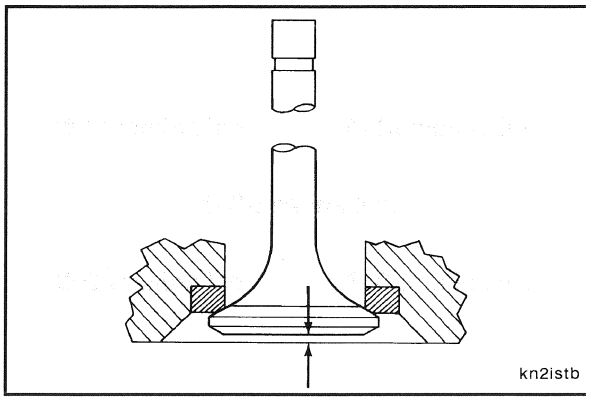
Rotate the depth gauge so that it is measuring the valve recession into the cylinder head (A).

Record the valve depth for each valve.

Intake Valve Depth (Installed)		
mm		in
0.584	MIN	0.023
1.092	MAX	0.043

Exhaust Valve Depth (Installed)		
mm		in
0.965	MIN	0.038
1.473	MAX	0.058

NOTE: Valve depth can be increased slightly on resurfaced cylinder heads by lapping the valves.

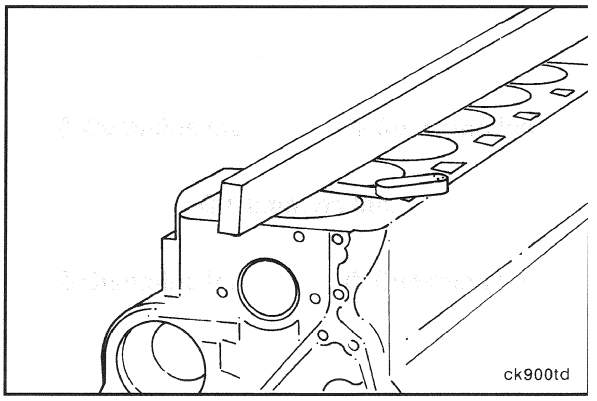


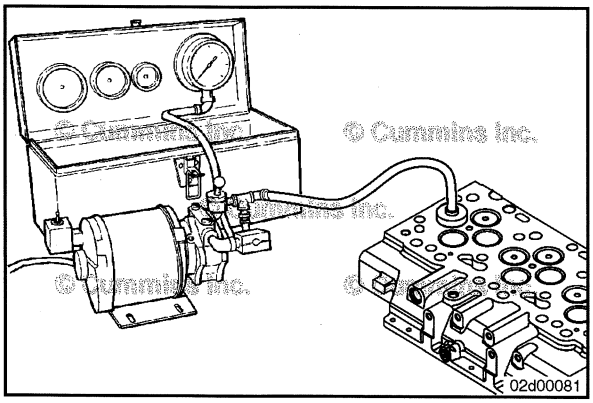
Use a straightedge and feeler gauge to measure the overall flatness of the cylinder block.

Cylinder Block Flatness			
	mm		in
End-To-End	0.075	MAX	0.003
Side-To-Side	0.075	MAX	0.003

Inspect the combustion deck for any localized dips or imperfections.

If out of specification, determine if the cylinder block can be resurfaced or if the cylinder block must be replaced. Refer to Procedure 001-026 in Section 1.





Vacuum Test

If a leaking valve is suspected or if the cylinder head was recently rebuilt, vacuum test the valves and valve seats using valve vacuum tester, Cummins® Part Number 3824277, and cup, Cummins® Part Number ST-1257-6. The vacuum **must not** drop more than 25.4 mm Hg [1.0 in Hg] in five (5) seconds.

NOTE: If a vacuum tester is **not** available, with the valve removed, use a lead pencil or Dykem® 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 to Valve Seat Vacuum

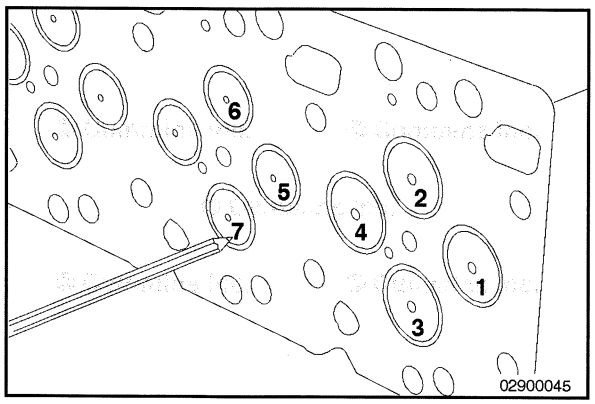
	kPa		in Hg
Used	51	NOM	15
New	69	NOM	20

If out of specification, disassemble the cylinder head and inspect for damaged valves and/or valve seats. Repair as necessary by:

1 Cleaning the valve/valve seat and lapping the valves

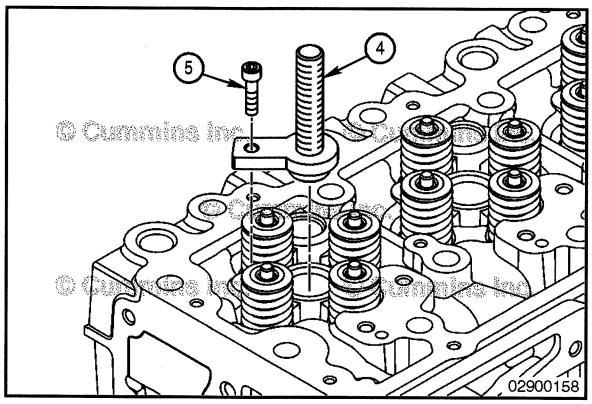
2 Replacing the damaged valve/valve seat, if available

3 Replacing the cylinder head.



Disassemble

Mark the valves to identify their location.



Compress the valve springs using the valve spring compressor service tool, Cummins® Part Number 4918866.

Position the replacer screw (4) above the injector bore and install the capscrew (5) in the cylinder head where the hold-down clamp screws were removed.

Tighten the capscrew (5).

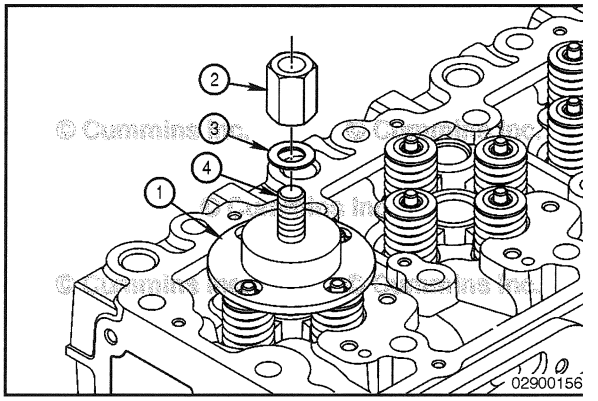
Torque Value: 5 N•m [44 in-lb]

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 lubricant 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).

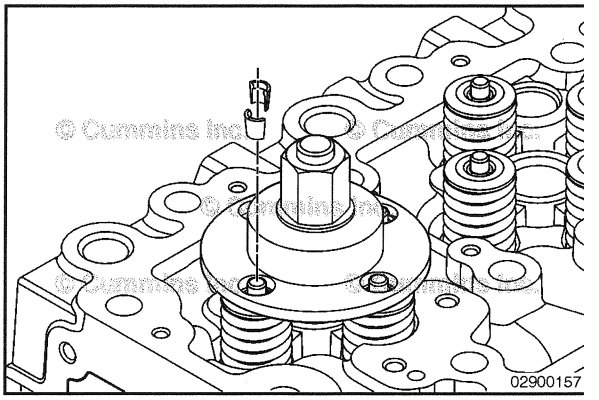


⚠WARNING⚠
Valve springs are under tension and can act as projectiles if released. To reduce the possibility of eye injury, wear safety glasses with side shields.

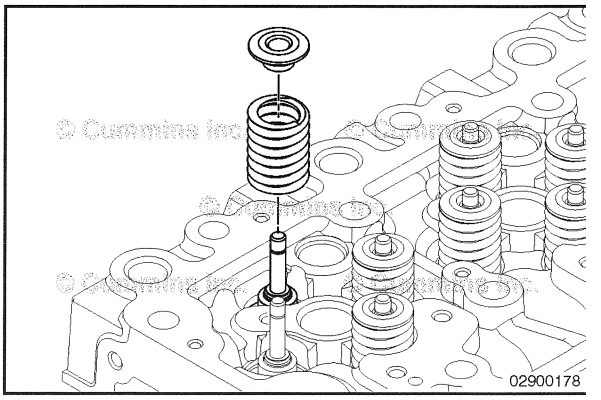
Turn the nut **clockwise** to compress the valve springs.

Continue turning the nut **clockwise** until the valve collets can be removed using a magnetic tool, such as the end of a magnetic screwdriver.

Remove the valve collets and the valve spring compressor service tool.

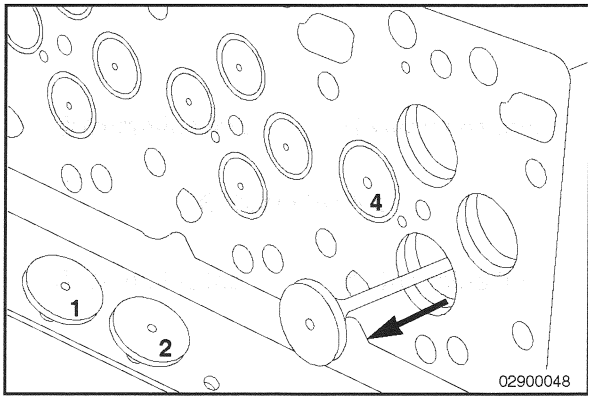


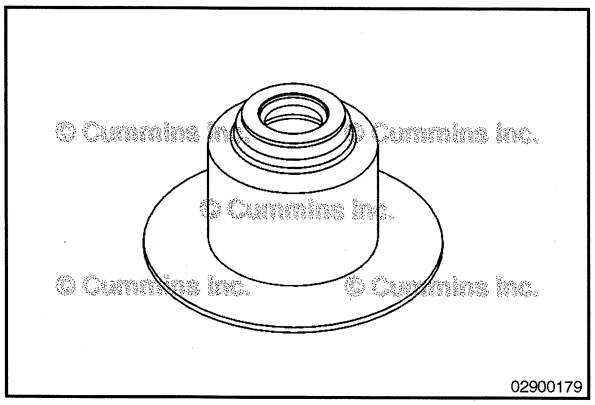
Remove the valve spring retainer and valve springs.



NOTE: Keep the valves in a labeled rack with the associated valve collets, spring retainers and springs. This will aid in assembling the components as a matched set.

Remove the valves.



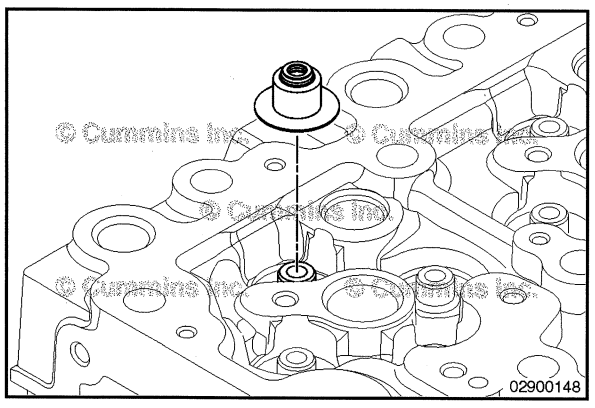


NOTE: Prior to removing the valve stem seals, note the type and color of the valve stem seal installed at each valve location. The same type and color valve stem seal **must** be installed when assembling the cylinder head.

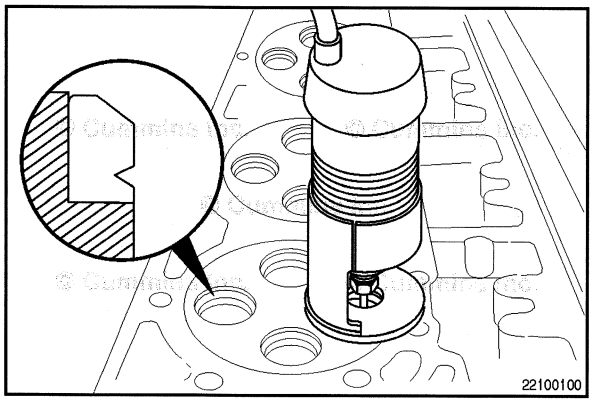
"Top-Hat" Seal

Colors Used:

- Green (Used for exhaust valves)
- Yellow (Used for intake and exhaust valves)
- Brown (Used for intake and exhaust valves)



Use boot pliers, Cummins® Part Number 3163293, to remove the valve stem seals.



NOTE: Prior to removing the valve seat inserts, see the Inspect for Reuse and Clean and Inspect for Reuse steps in this procedure. The condition of the valve, the amount of recess, and the sealing of the valve on the seat insert all help determine whether or **not** a 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 insert groove area, proceed to the next step.

4 If the valve insert groove area is **not** sufficient, use the valve seat insert cutting kit, Cummins® Part Number 3376405, to create a sufficient groove.

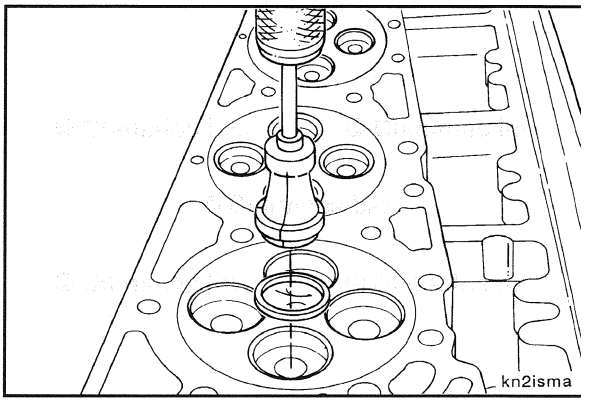
Use the slide hammer remover, Cummins® Part Number 3376617, with valve insert remover, Cummins® Part Number 3165170 to remove the valve seats.

NOTE: Make certain that the valve insert remover assembly is perpendicular to the cylinder head when installed.

Insert the valve insert remover assembly into the valve insert and rotate the T-handle **clockwise** until the remover loosely grips the valve insert.

Position the valve insert remover assembly into the valve insert groove area. Tighten the T-handle firmly, allowing the remover to expand under the valve insert or into the cut groove.

Strike the slide hammer remover against the top nut until the valve insert is removed. Turn the T-handle **counterclockwise** to release the valve insert from the remover.

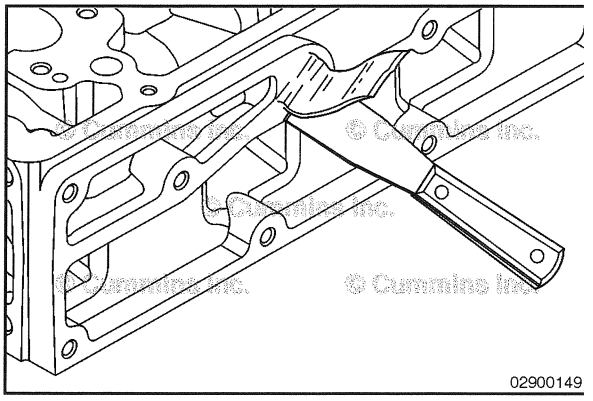


Clean and Inspect for Reuse

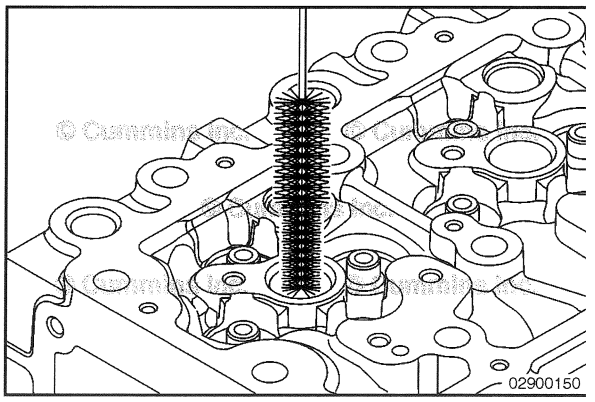
NOTE: Keep the gasket material, and any other material out of the air intake.

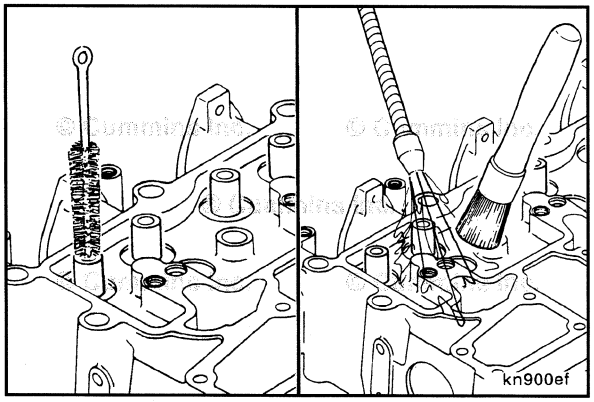
If removed, clean the cylinder head sealing surfaces where the air intake manifold seals.

NOTE: On engines equipped with EGR, it is common to have soot buildup in the air intake section of the cylinder head. If the cylinder head is removed as part of another repair, it is **not** necessary to clean the soot from the intake.



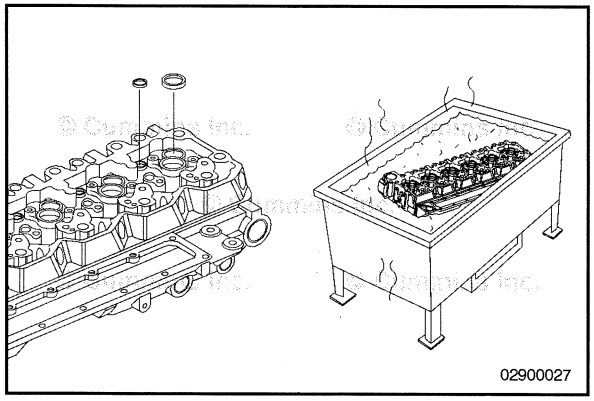
Use an injector bore brush, Cummins® Part Number 3822510, or equivalent, to clean the carbon from the injector seat.





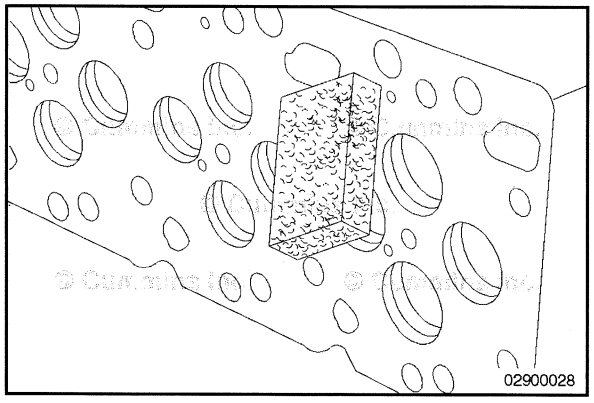
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use a bristle brush to clean the inside diameter of the valve guide bore and blow out with compressed air.



NOTE: Excessive deposits can be cleaned in an acid tank, but the expansion plugs **must** be removed first. Refer to Procedure 017-002 in Section 17.

If required, clean the buildup of deposits in the coolant passages.



⚠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 cylinder head combustion deck with an abrasive hand pad, Cummins® Part Number 3823258, or equivalent, and solvent.

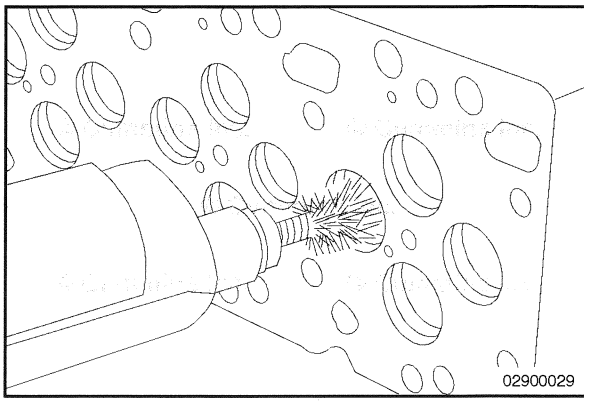
⚠WARNING⚠
Wear protective eye covering while cleaning carbon deposits to reduce the possibility of personal injury.

△CAUTION△
Contacting the valve seat with the wire wheel while it is spinning will damage the valve seat. If this occurs, new valve seats must be cut or new valve seat inserts must be installed.

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.

NOTE: An inferior-quality wire wheel will lose steel bristles during operation, causing additional contamination.

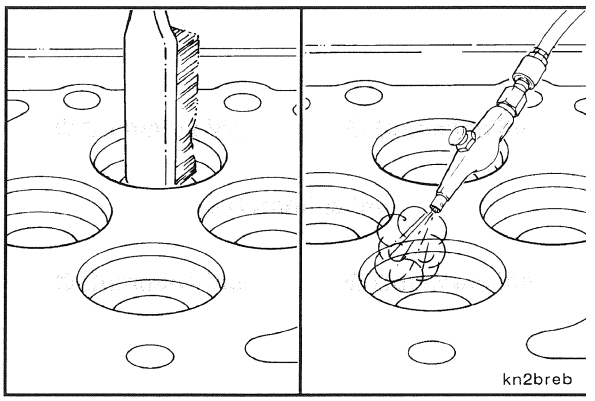
Clean carbon deposits from the valve pockets with a high-quality steel wire wheel installed in a drill or die grinder.



⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

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.

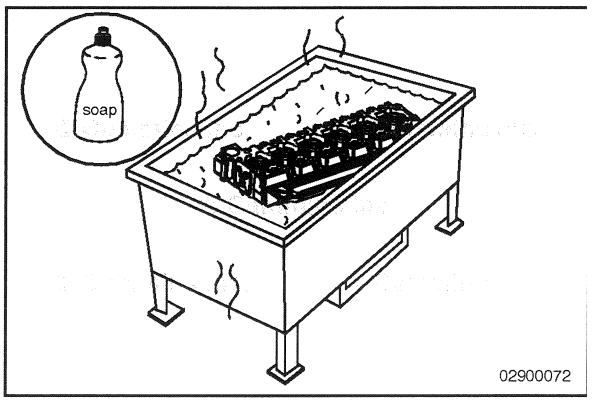


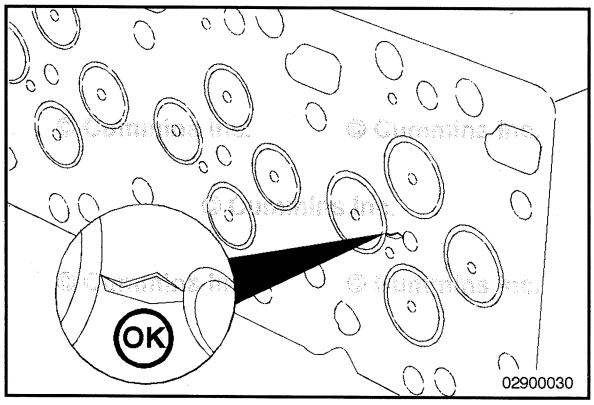
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Wash the cylinder head in a hot, soapy water solution.

Rinse the cylinder head with clean water.

Dry the cylinder head with compressed air.





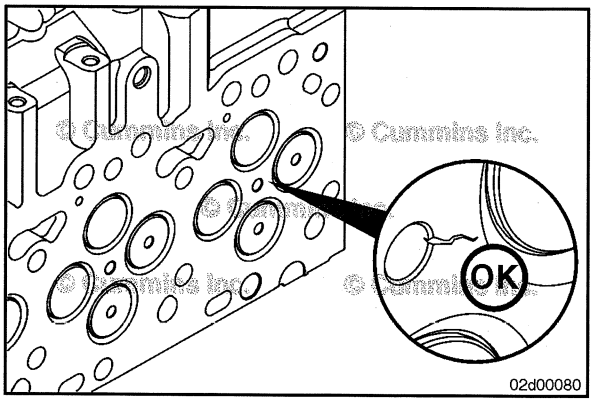
Cylinder Head Cracks - Reuse Guidelines

With the cylinder head cleaned, repeat the inspection of the cylinder head for signs of cracks, fretting, and discoloration that would prohibit reuse.

To help identify cracks in the cylinder block, use the Crack Detection Kit, Cummins® Part Number 3375432.

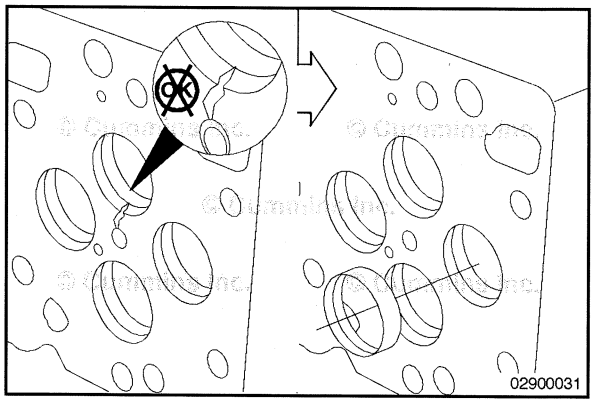
Pay close attention to areas of the cylinder head that include:

- Injector bore
- Combustion face
- Valve seats
- Valve guides



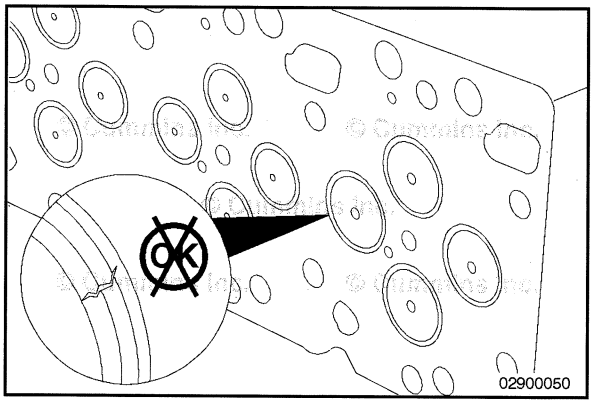
The reuse guidelines for a cylinder head with a crack extending from the injector bore to the intake valve seat are as follows:

- If the crack does **not** extend into the valve seat, the cylinder head is reusable.



- If the crack extends into or through the valve seat, the cylinder head **must** be replaced.

⚠CAUTION⚠
Failure to replace the cylinder head for a crack that extends into or through the valve seat bore will result in a valve seat insert falling out. Engine damage will result.



If still installed, inspect the valve seats for cracks or burnt spots.

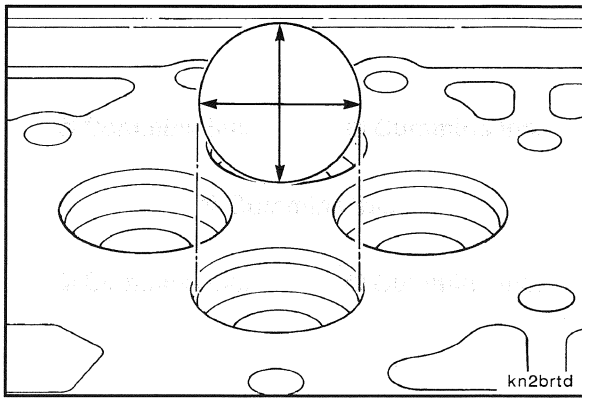
If the valve seat inserts are damaged, for some cylinder heads, the valve seat inserts can be replaced.

1 Verify replacement valve seat inserts are available.

2 If replacement valve seat inserts are available and require placement, see the Disassemble Step.

3 If replacement valve seat inserts are **not** available, the cylinder head **must** be replaced.

If the valve seat insert was removed in the Disassemble Step, measure the inside diameter of the valve seat insert bore in the cylinder head.



Cylinder Head Insert Bore Inside Diameter (I.D.)		
mm		in
34.837	MIN	1.3715
34.863	MAX	1.3726

NOTE: Before cutting the cylinder head, verify valve seat inserts are available for the engine being serviced. If none are available, the cylinder head **must** be replaced.

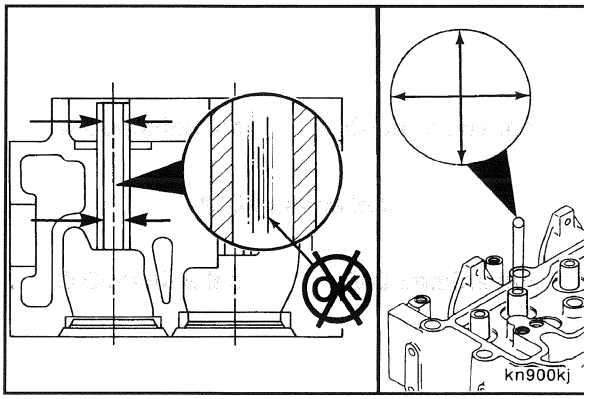
If out of specification, the valve seat insert bore can be oversized 0.254 mm (0.010 in) and/or 0.508 mm (0.020 in).

Use ST257 Valve Seat Insert Tool Kit with valve guide arbor, Cummins® Part Number 3165184, to the cut cylinder head to accept oversize valve seat inserts. Use valve seat cutter, Cummins® Part Numbers 3165183 (0.254 mm (0.010 in) or 3165184 (508 mm (0.020 in).

Valve Guide - Reuse Guidelines

Inspect the valve guides for scuffing or scoring.

Measure the valve guide inner diameter (I.D.)

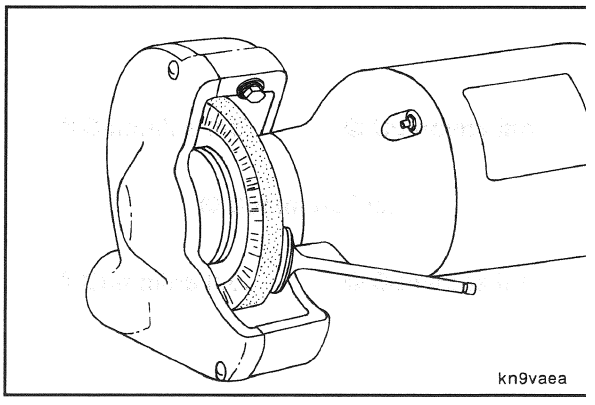


Valve Guide Bore Diameter		
mm		in
7.027	MIN	0.2767
7.077	MAX	0.2786

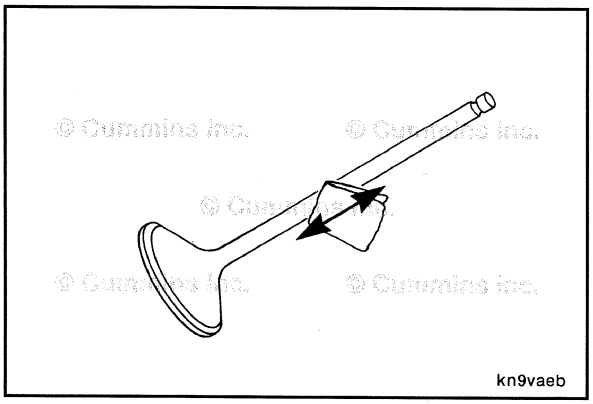
If the valve guide bore is worn larger than the maximum specified or if inspection reveals damaged valve guides, the cylinder head **must** to be replaced.

⚠WARNING⚠
Wear protective eye covering when cleaning the valves with a wire wheel to reduce the possibility of personal injury.

Clean the valve heads with a soft wire wheel.

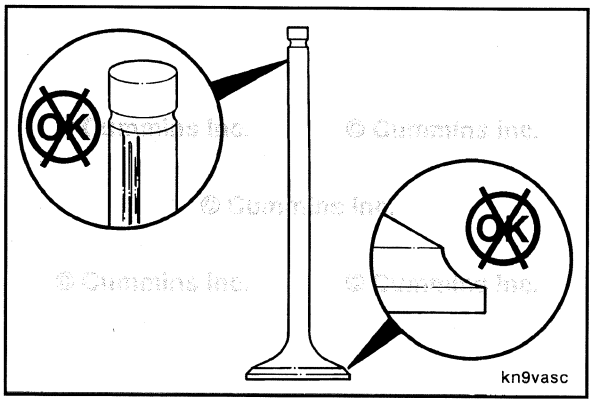


NOTE: Keep the valves in a labeled rack to prevent mixing before taking measurements.



⚠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.

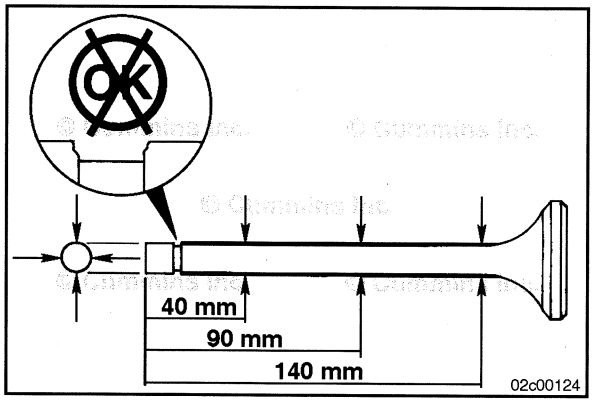
Polish the valve stems with an abrasive pad, Cummins® Part Number 3823258, and solvent.



Valve - Reuse Guidelines

Inspect the valves for:

- excessive wear on the heads and stems
- excessive wear on the valve stem tip
- for bends and distortion.



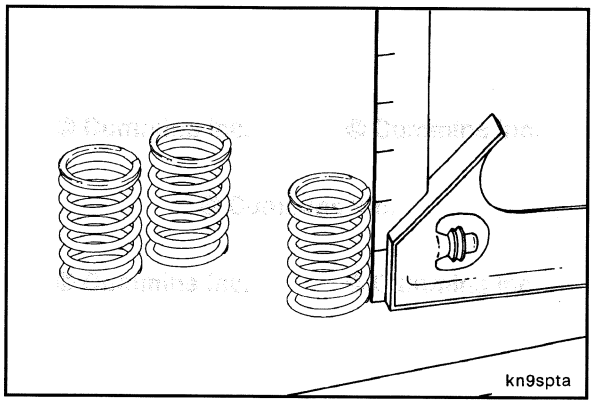
Inspect the valves for damage and the collet grooves for wear.

Measure the outside diameter of the valve stem.

Three measurements must be taken of each valve stem at 40 mm [1.57 in], 90 mm [3.54 in], and 140 mm [5.51 in] from the tip end.

Valve Stem Diameter		
mm		in
6.96	MIN	0.2740
7.01	MAX	0.2760

If the valves are damaged or the stems are worn smaller than the minimum specified, the valves **must** be replaced.



Valve Spring - Reuse Guidelines

Inspect the valve springs.

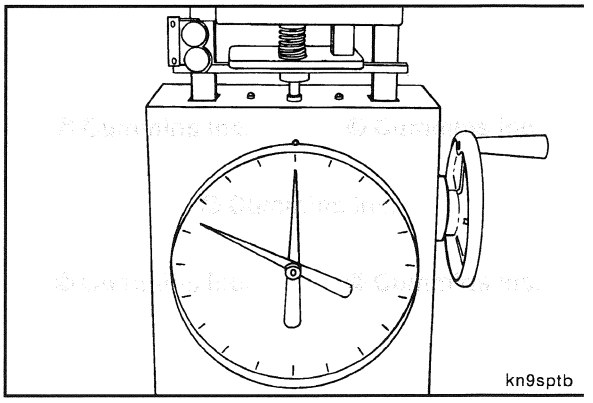
Measure the valve spring. Place a square adjacent to the spring and use a feeler gauge to measure the clearance at the top spring coil.

Approximate Free Length (L): 47.75 mm [1.88 in]

Maximum Inclination: 1.5 mm [0.059 in]

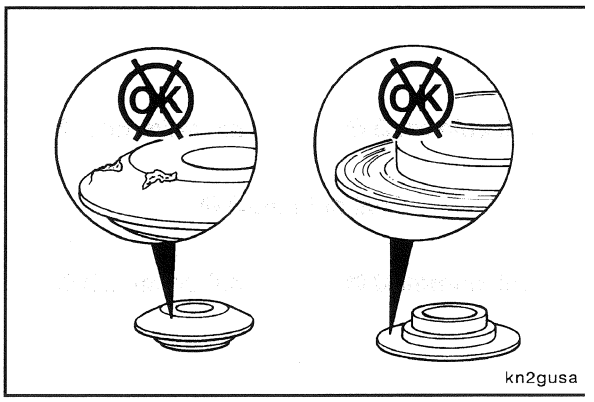
Use valve spring tester, Cummins® Part Number 3375182, to compress the valve spring. A load of 320.8 to 358.8 N [72 to 80.7 lb] is required to compress a spring to a height of 35.33 mm [1.39 in].

NOTE: If the valve spring is **not** within specification, a new valve spring **must** be used.



Inspect the valve spring retainers and valve collets for damage or worn areas.

Discard and replace damaged and worn parts.



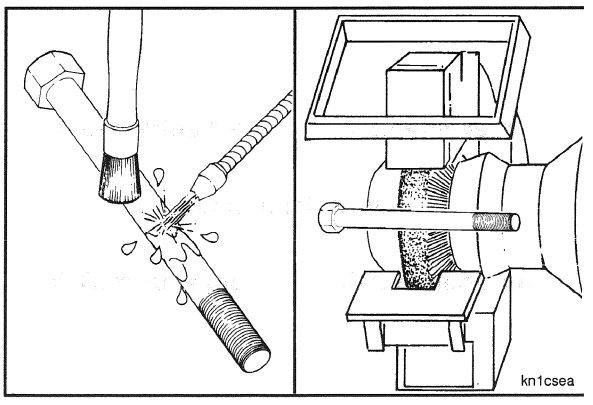
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

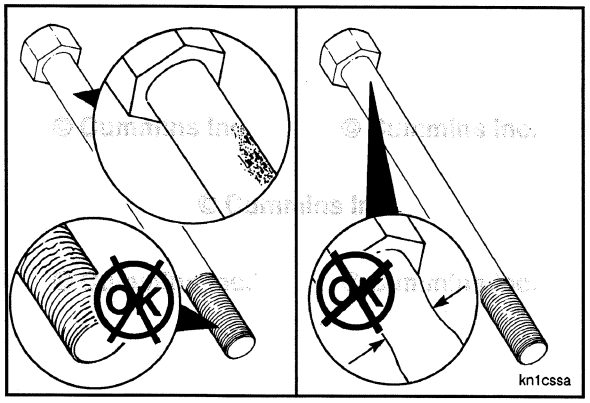
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

△CAUTION△
Do not use caustic or acid solutions to clean the cylinder head capscrews. Component damage can occur.

Use a petroleum-based solvent to clean the capscrews.

Clean the capscrews thoroughly with a wire brush, soft wire wheel, or nonabrasive bead blast to remove deposits from the shank and threads.





Cylinder Head Capscrew - Reuse Guidelines

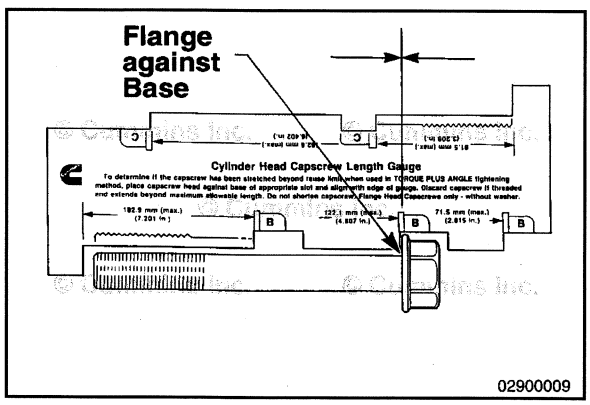
Inspect the cylinder head capscrews for damaged threads, corroded surfaces, or a reduced diameter (due to capscrew stretching).

Do **not** reuse cylinder head capscrews under the following conditions:

- Visible corrosion or pitting exceeding 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 [½ x ½ 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 thread.
- Stretched beyond "free-length" maximum. See the measurement procedure below:

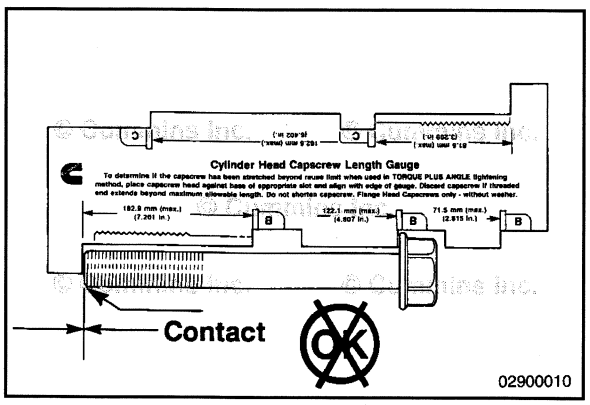


Free-Length Measurement

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 using capscrew length gauge, Cummins® Part Number 3164057, place the head of the capscrew in the appropriate slot with the flange against the base of the slot.

NOTE: Most new cylinder head gaskets and upper engine gasket include the capscrew length gauge, Cummins® Part Number 3164057.



If the end of the capscrew touches the foot of the gauge, the capscrew is too long and **must** be discarded.

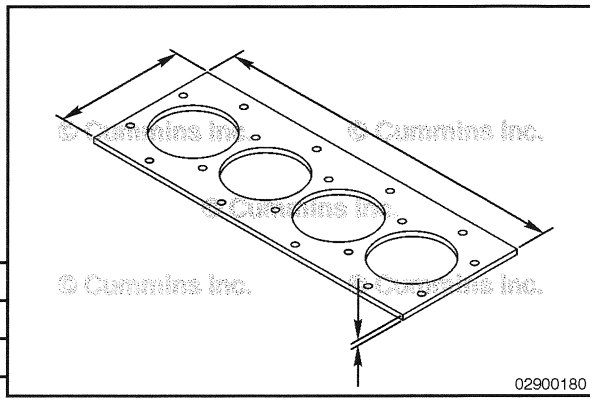
Capscrew Free Length		
mm		in
152.1	MAX	5.99

Pressure Test

If troubleshooting an internal coolant leak or coolant loss symptom, cylinder head test fixtures can be fabricated from a flat piece of steel or aluminum to pressure test the cylinder head.

See the following table for the combustion face test fixture dimensions.

16 mm	Thickness
525 mm	Length
220 mm	Width



NOTE: Use the old cylinder head gasket as a pattern for drilling the capscrew holes.

Fabricate a similar plate and gasket for the coolant outlet on the side of the cylinder head. Measure the cylinder head to determine appropriate dimensions for the plate and gasket.

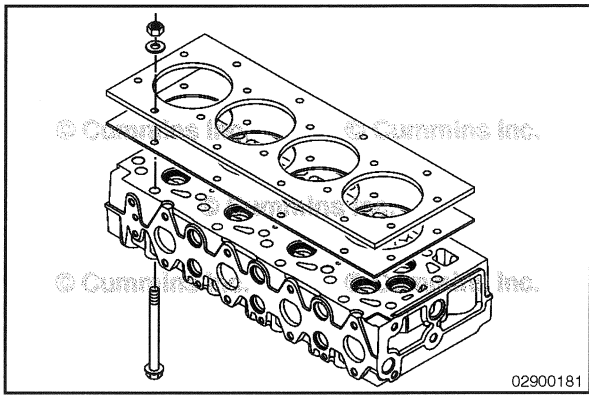
Install the cylinder head combustion face water test fixture.

1 Install a new head gasket.

2 Install the test plate.

3 Install the following:

- 18 - 180-mm-long grade 12.9 flange head capscrews
- 18 - M12 x 1.75 hex flange nuts
- 36 - 12-mm washers

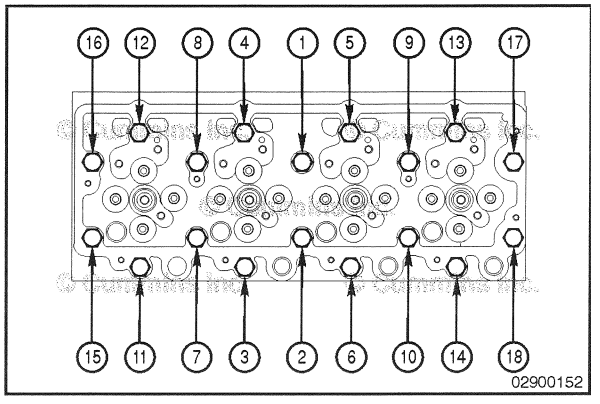


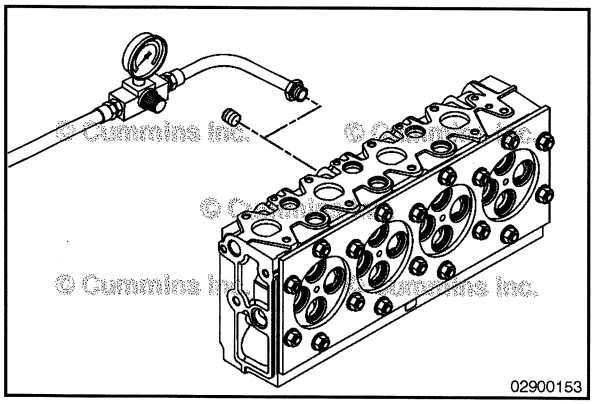
NOTE: Place a washer between each capscrew and the head, and between each nut and test plate. This will prevent mutilation on the surface of the cylinder head.

Install the coolant outlet water test fixture.

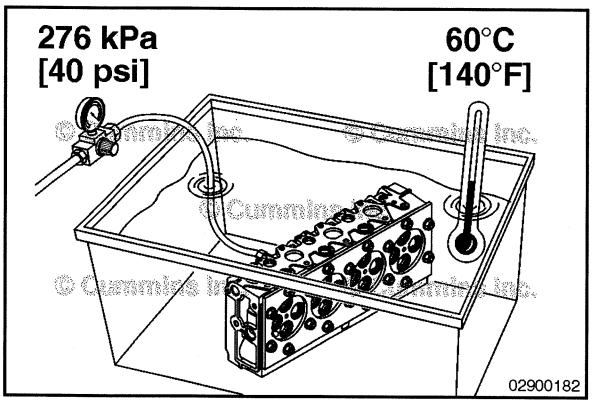
Use the illustrated sequence to tighten the nuts.

Torque Value: 80 N•m [59 ft-lb]





To apply air pressure to the cylinder head, remove one of the pipe plugs located on the exhaust side of the cylinder head. This is the same port used, when the cylinder head is installed, to check cylinder block coolant pressures.



⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To reduce the possibility of serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

NOTE: Make sure to plug or seal any open coolant ports before pressure testing the cylinder head.

Connect a regulated air supply hose, Cummins® Part Number 3164231, to the cylinder head.

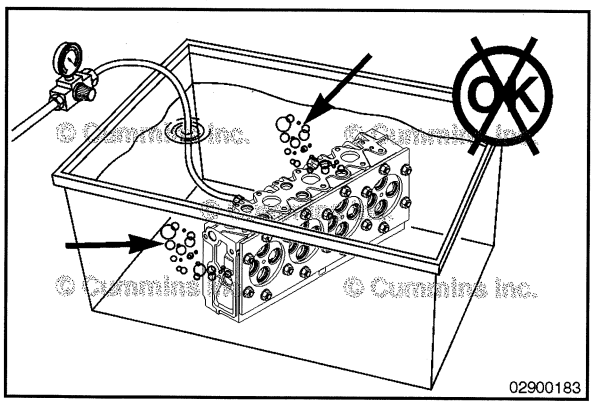
Apply air pressure.

Air Pressure: 276 kPa [40 psi]

Use a nylon lifting strap and a hoist to place the cylinder head in a tank of heated water.

Water Temperature: 60 °C [140 °F]

NOTE: The cylinder head **must** be completely submerged in the water.



Inspect the head. Bubbles indicate an air leak.

If any bubbles exist, verify that the air leak is not coming from:

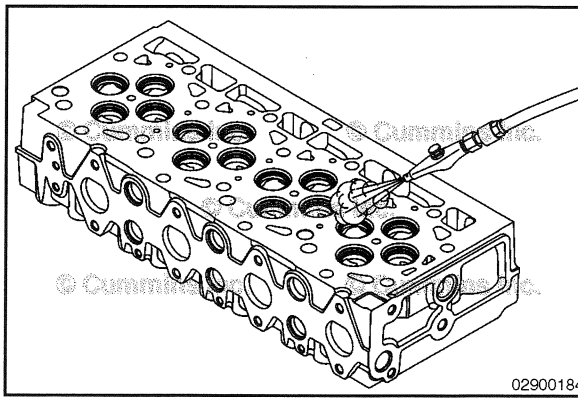
- any cup plugs or fittings installed in the cylinder head
- the test fixture or air line fittings
- the water outlet connection.

If the above checks out okay and bubbles are present, the cylinder head leaks and it **must** be replaced.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Remove the test fixture.

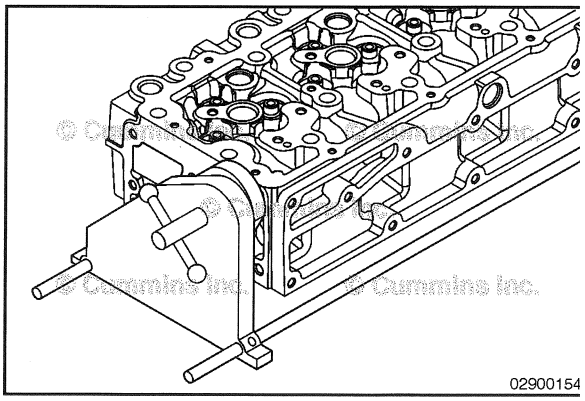
Use compressed air to dry the cylinder head.



Assemble

⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To reduce the possibility of serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Install the cylinder head in the cylinder head holding fixture, Cummins® Part Number ST-583.

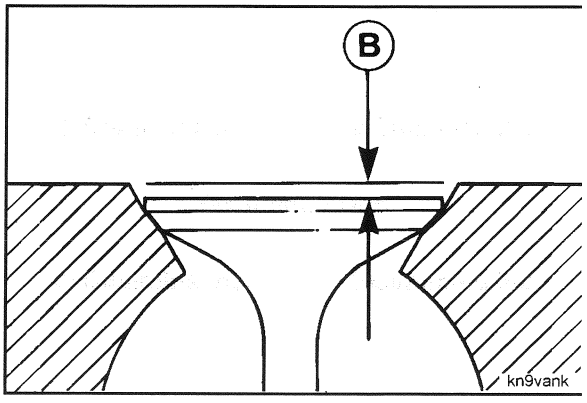


NOTE: When installing the valve seat inserts, the exhaust and intake valve seat inserts are **not** the same.

Valve seat angle:

- Intake 30-degrees
- Exhaust 45-degrees.

If new valve seat inserts are installed, check valve depth and perform a valve leak test. See the Inspect for Reuse section of this procedure.

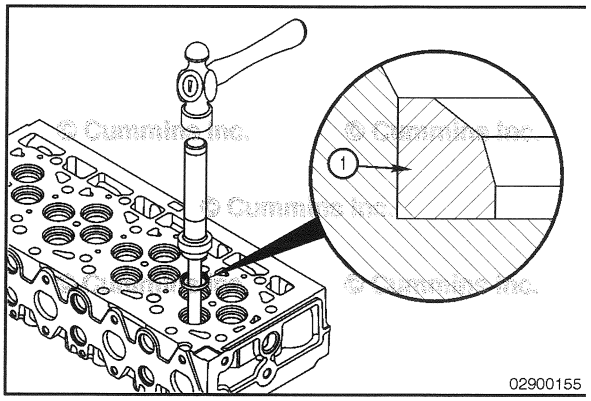


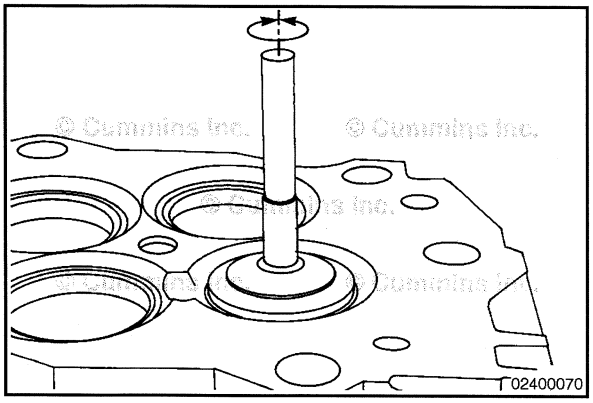
If the valve seat inserts were removed in the Disassemble section, new inserts **must** be installed.

NOTE: The insert chamfer (1) **must** be installed toward the bottom of the counterbore.

Use valve seat installer, Cummins® Part Number 3165171, 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.





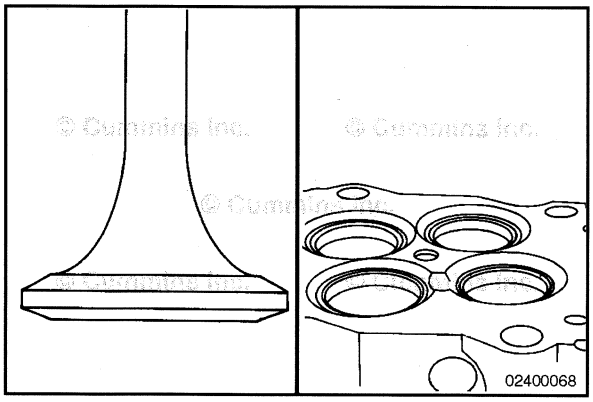
If new valve seat inserts were installed and/or the valve leakage was above specification, the valve seat/valve can be lapped.

NOTE: Lubricate the stems with SAE 15W-40 engine oil before installing the valves.

Use a fine lapping compound, Cummins® Part No. 3375805, or equivalent. Apply a thin and even coating on the valve.

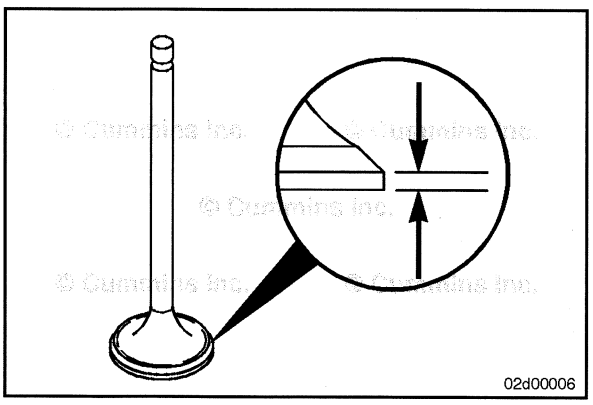
Use a power or a hand suction lapping tool to provide pressure in the center of the valve.

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. Failure will result if the cylinder head, the valves, and the valve seats are not cleaned thoroughly.

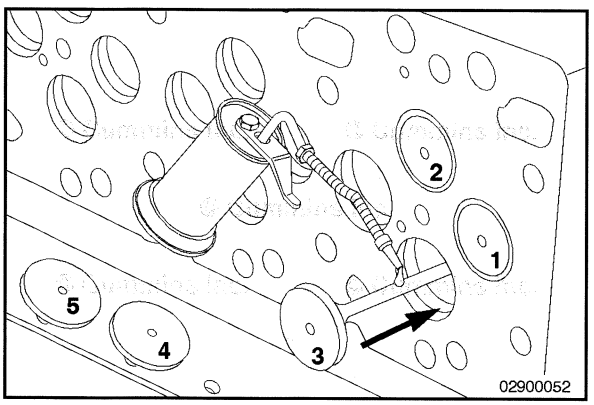
Clean the lapping compound from the parts.



If lapping of the valves was required, measure the rim thickness to determine if there is enough rim material left.

Valve Rim Thickness Limit		
mm		in
0.79	MIN	0.031

If the valve thickness is **not** within the limits, a new valve **must** be used.



⚠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.

Lubricate the stems with SAE 15W-40 engine oil before installing the valves.

NOTE: If installing the same valves as previously removed, make sure to install the valves in the same locations from which the valves were removed.

NOTE: If the cylinder head will **not** be used right away, lubricate the valve stems with assembly lube, Cummins® Part Number 3163087, or equivalent.

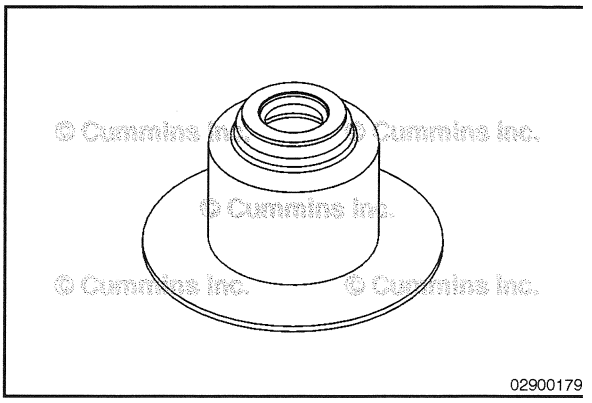
⚠CAUTION⚠
The same type and color valve stem seal must be installed in the same location as removed. Incorrect valve stem seals will result in excessive oil consumption and internal engine damage.

Install new valve stem seals of the same type and color as removed and in the same location.

"Top-Hat" Seal

Colors Used:

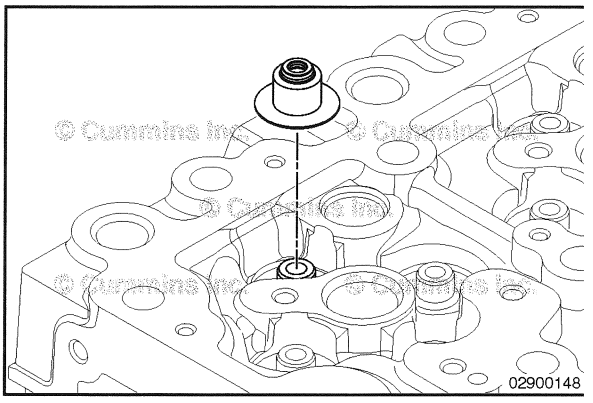
- Green (Used for exhaust valves)
- Yellow (Used for intake and exhaust valves)
- Brown (Used for intake and exhaust valves).



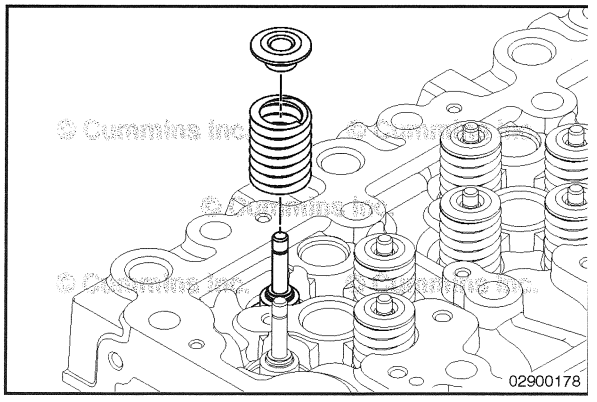
Lubricate the valve stem seals with clean engine oil.

Use a valve stem installation tool, Cummins® Part Number 3164055 or equivalent, to install the new valve stem seals.

Use hand pressure to keep the valves from falling out during installation.



Install the valve springs and valve spring retainers.

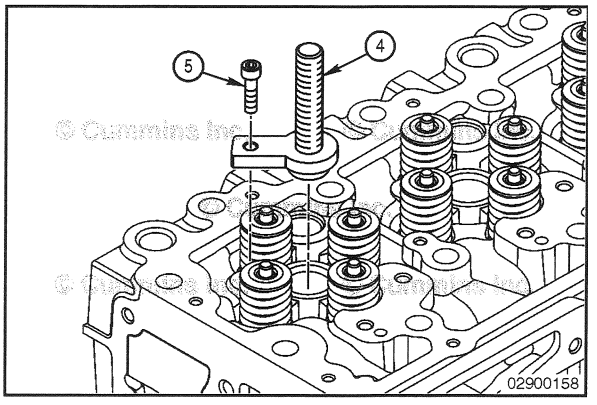


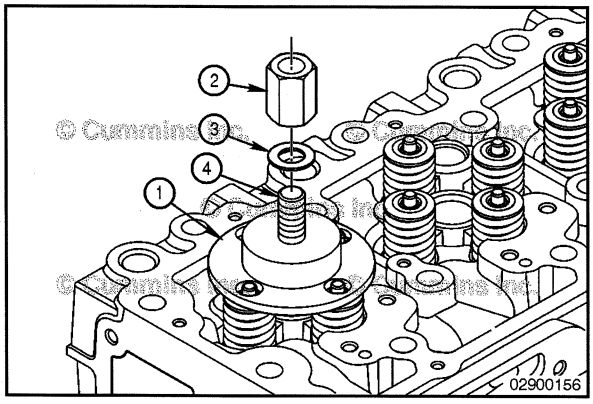
Compress the valve springs using the valve spring compressor service tool, Cummins® Part Number 4918866.

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 (5).

Torque Value: 5 N•m [44 in-lb]



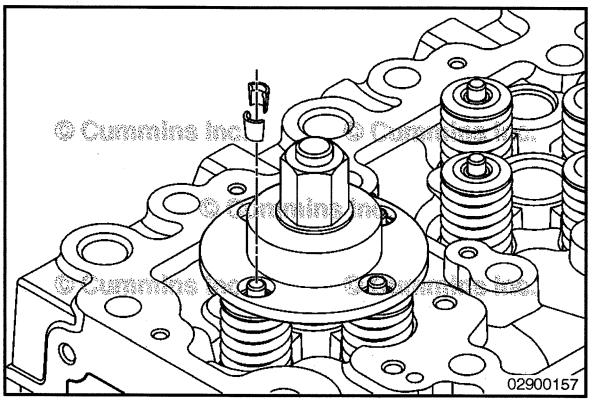


NOTE: The valves are **not** evenly spaced from the injector bore. It is important to align the slots in the valve spring compressor plate with the valve springs.

Apply anti-seize lubricant 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).



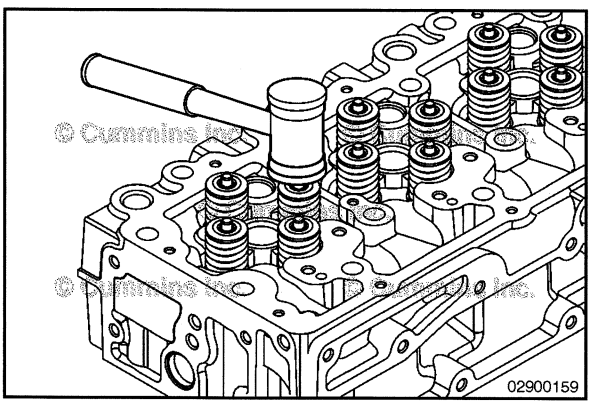
⚠WARNING⚠
Valve springs are under tension and can act as projectiles if released. To reduce the possibility of eye injury, wear safety glasses with side shields.

Compress the valve springs until the valve collets can be installed.

Install the valve collets.

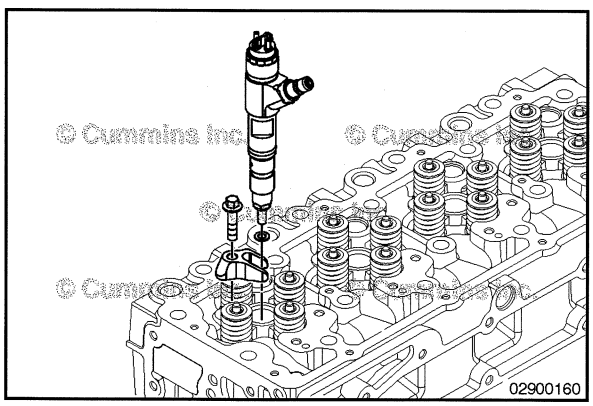
Use assembly lube, Cummins® Part Number 3163087, or equivalent, on the valve collets to help hold them in place until the valve spring compressor is released.

Remove the valve spring compressor service tool.



⚠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.

After assembly, hit the valve stems with a plastic hammer to make sure the collets are seated.



Measure

△CAUTION△
Improper injector protrusion can cause performance problems and high-pressure fuel leaks due to misalignment of the fuel connector.

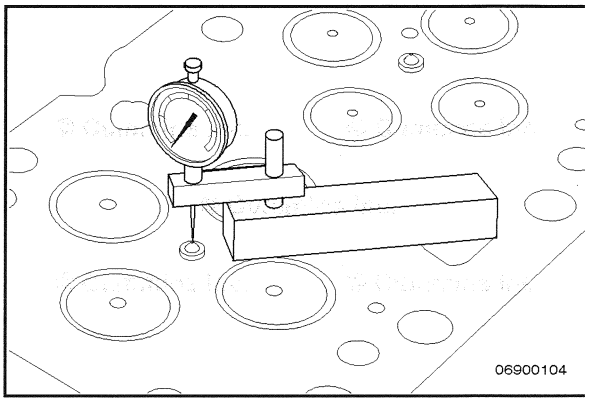
Install the injectors with sealing washers into the cylinder head. Refer to Procedure 006-026 in Section 6.

Measure the injector protrusion.

Install depth gauge assembly, Cummins® Part Number 3164438, on the cylinder head combustion deck and zero.

Rotate the depth gauge so that it is measuring the injector protrusion at the highest point on the injector.

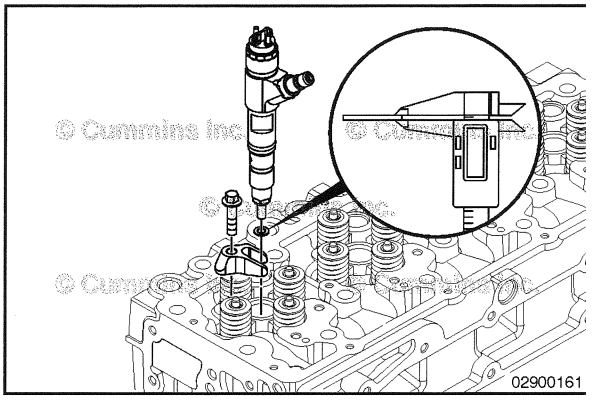
Measure the injector protrusion for each injector.



Injector Protrusion		
mm		**in**
1.94	MIN	0.076
2.47	MAX	0.097

If the injector protrusion is out of specification, check the thickness of the injector sealing washer. Refer to Procedure 006-026 in Section 6.

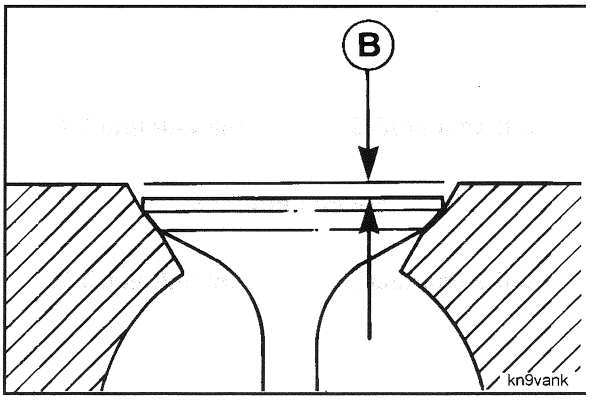
If the sealing washer is the correct thickness, check to make sure the injector bore is clean and free of debris. Also make sure that sealing washers are **not** 'stacked' in the injector bore.



Install depth gauge assembly, Cummins® Part Number 3164438, on the cylinder head combustion deck and zero.

Rotate the depth gauge so that it is measuring the valve recession into the cylinder head (A).

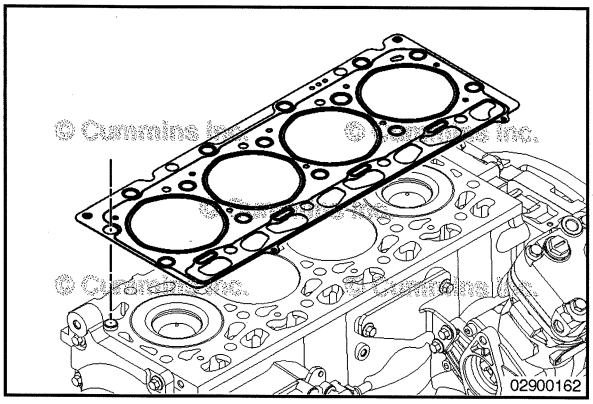
Measure the valve depth for each valve.



Intake Valve Depth (Installed)		
mm		**in**
0.584	MIN	0.023
1.092	MAX	0.043

Exhaust Valve Depth (Installed)		
mm		**in**
0.965	MIN	0.038
1.473	MAX	0.058

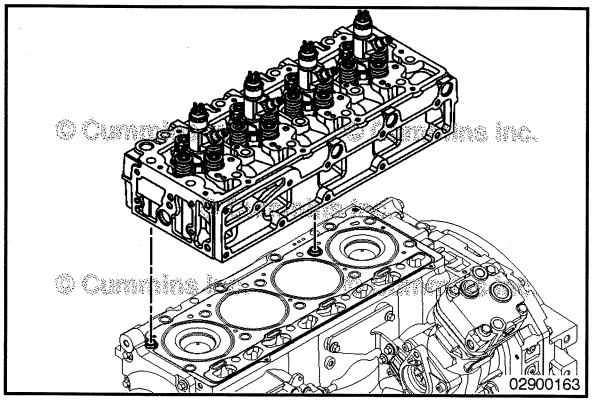
If the valve depth is **not** within specification, check if debris is preventing the valve from closing completely. If no debris is found, remove the valve and inspect the valve seat and valve face for damage.



Install

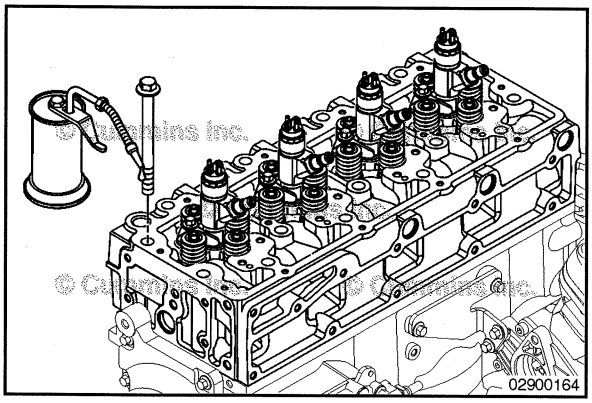
⚠CAUTION⚠
Make sure the gasket is correctly aligned with the holes in the cylinder block. Damage to the cylinder block can occur if the gasket is not aligned correctly.

Install the cylinder head gasket. Refer to Procedure 002-021 in Section 2.



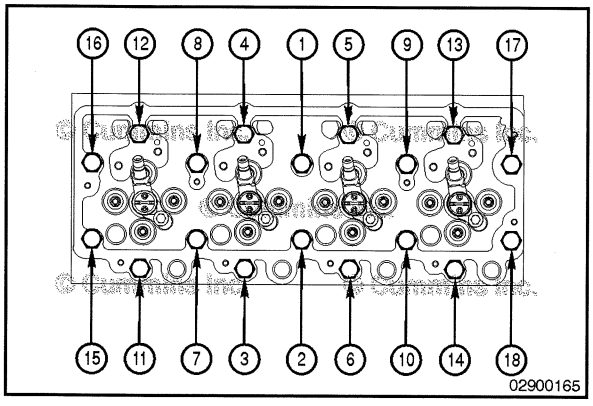
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To reduce the possibility of serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Carefully place the cylinder head on the cylinder block, and seat it onto the dowels.



Lubricate the threads and under the heads on the cylinder head mounting capscrews with clean engine oil.

Install the capscrews and tighten finger-tight.



Use the illustrated sequence to tighten the cylinder head capscrews.

Tighten the capscrews.

Torque Value:

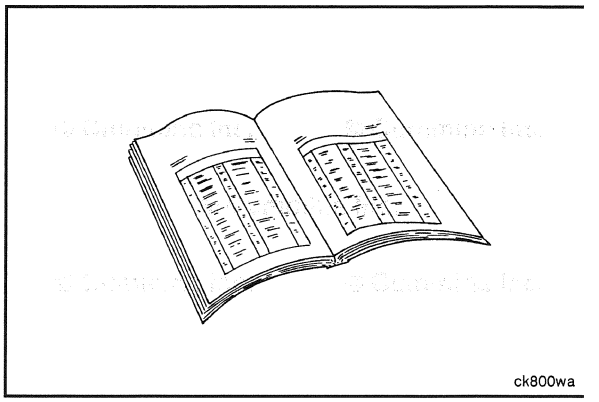
Step 1	70 N•m	[52 ft-lb]
Step 2	Loosen 180 degrees	
Step 3	60 N•m	[44 ft-lb]
Step 4	Repeat 60 N•m [44 ft-lb] torque, rotate capscrews 90 degrees clockwise, and then rotate capscrews an additional 90 degrees clockwise.	

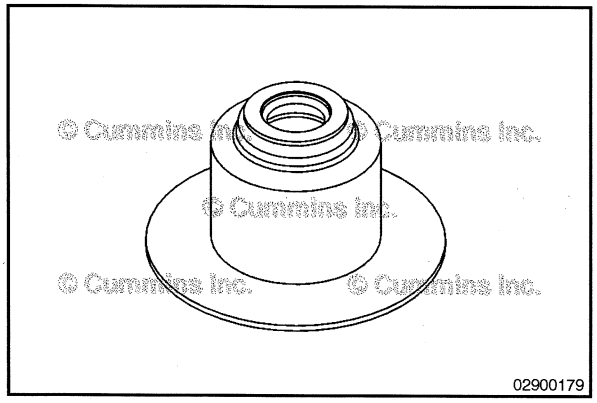
Finishing Steps

⚠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⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Install the injectors. Refer to Procedure 006-026 in Section 6.
- Install the push rods. Refer to Procedure 004-014 in Section 4.
- Install the crossheads. Refer to Procedure 002-001 in Section 2.
- Install the rocker levers. Refer to Procedure 003-008 in Section 2.
- Install the intake manifold. Refer to Procedure 010-023 in Section 10.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the combined fuel manifold. Refer to Procedure 006-060 in Section 6.
- Install the fuel drain lines. Refer to Procedure 006-013 in Section 6.
- Install the high pressure injector supply lines. Refer to Procedure 006-051 in Section 6.
- Install the coolant bypass tube. Refer to Procedure 008-005 in Section 8.
- 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 drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the batteries. See equipment manufacturer service information.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Operate the engine and check for leaks.


ck800wa



Valve Guide Seal, Cylinder Head (002-016)

General Information

The following procedure is for removing the valve stem seals with the cylinder head installed. Use the following procedure 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 valve springs, valve spring retainers and valve collets with the cylinder head installed.

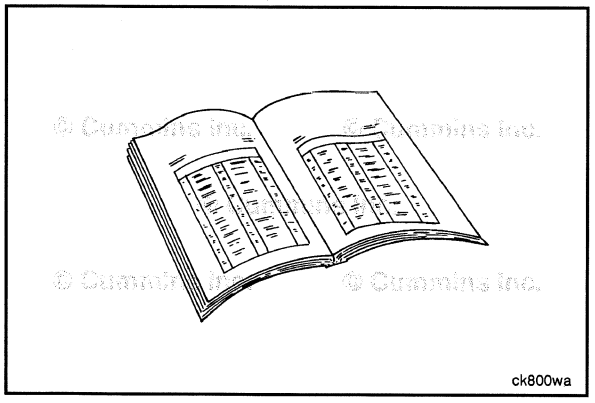
Different color valve stem seals are used. When replacing the valve stem seals, always replace like parts.

There are two colors of valve stem seals used:

"Top-Hat" Seal

Colors Used:

- Green (Used for exhaust valves)
- Yellow (Used for intake and exhaust valves).



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.

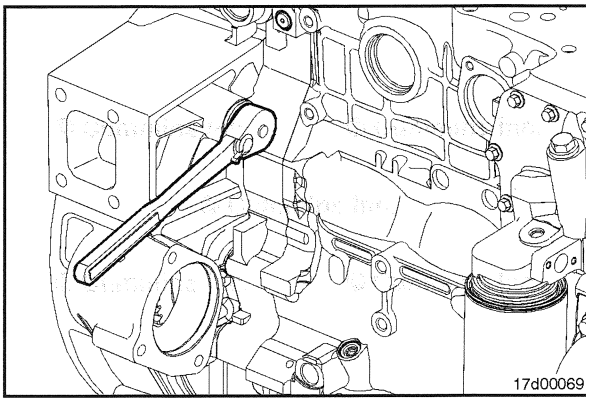
- Disconnect the batteries. See equipment manufacturer service information.
- Remove the injector drain line. Refer to Procedure 006-013 in Section 6.
- Remove the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Remove the fuel rail supply line. Refer to Procedure 006-071 in Section 6.
- Remove the fuel rail. Refer to Procedure 006-060 in Section 6.
- Remove the injectors. Refer to Procedure 006-026 in Section 3.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.

Remove

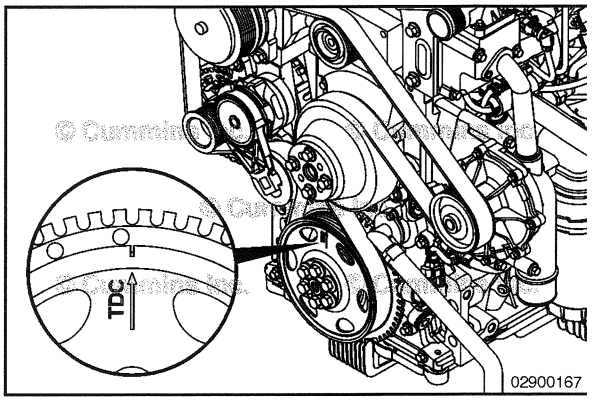
NOTE: In order to remove the valve springs with the cylinder head installed, the piston of the cylinder being worked on **must** be brought to top dead center (TDC) to support the valves.

Use the barring tool, Part Number Cummins® 3824591, rotate the piston to the top dead center on the cylinder being worked on.

TDC can be determined by the following methods:



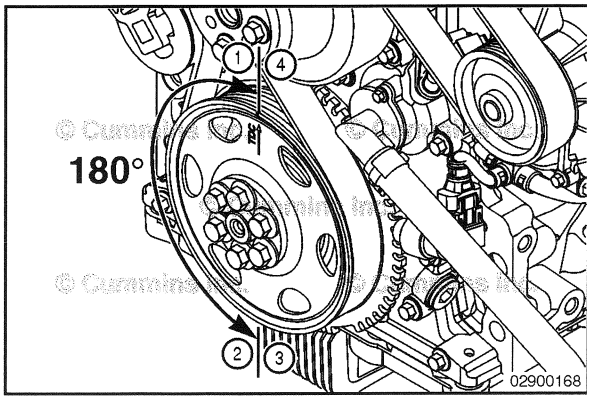
Align the crankshaft speed indicator ring on the front of the crankshaft so the TDC mark on the crankshaft speed indicator ring is at the 12-o'clock position. If both number 1 cylinder rocker levers are loose, move to the following steps. If both number 1 cylinder rocker levers are **not** loose, rotate the crankshaft 360 degrees.



Mark the crankshaft speed indicator ring every 180 degrees with a marker directly on the ring or to a piece of masking tape applied directly around the crankshaft speed indicator ring.

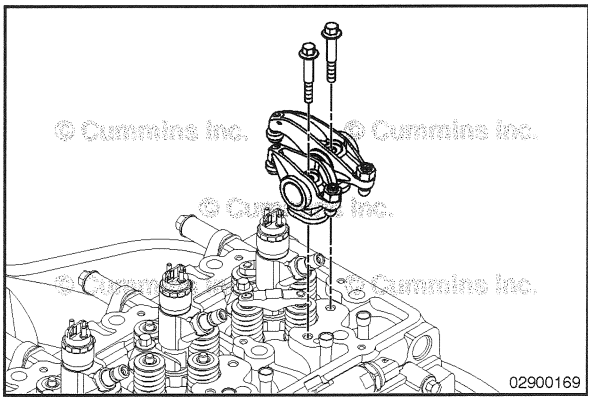
Service Tip: A protractor, camshaft degree wheel or angle/level indicator, Cummins® Part Number 3375855, can be used to locate 180 degree increments around the crankshaft speed indicator ring.

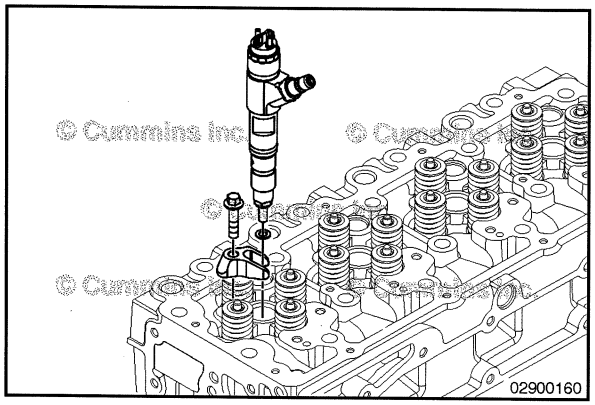
Mark the crankshaft speed indicator ring with the TDC indicator for each cylinder as shown. Two cylinders correspond to each 180-degree line.



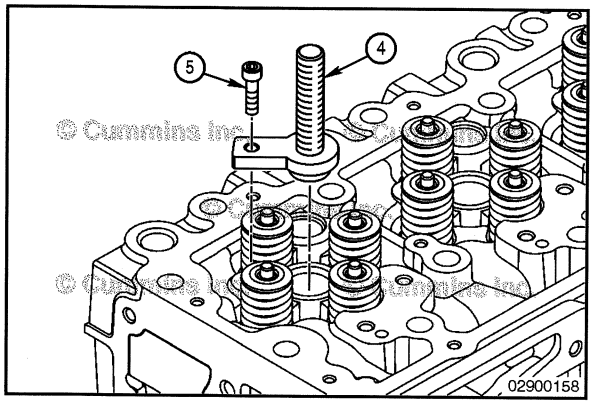
Remove all the crossheads. Refer to Procedure 003-008 in Section 3.

Remove all the rocker lever assemblies. Refer to Procedure 002-004 in Section 2.





Remove all the injectors. Refer to Procedure 006-026 in Section 6.

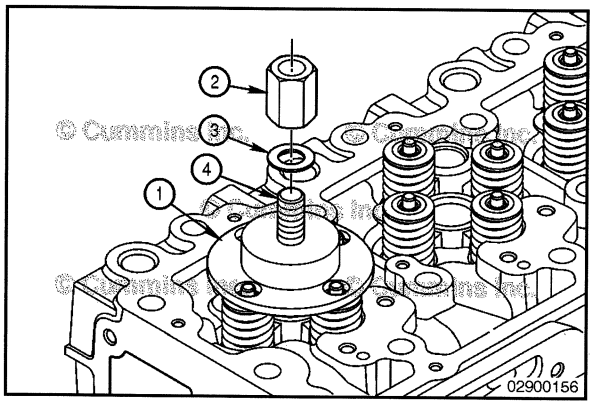


Compress the valve springs. Use the valve spring compressor, Cummins® Part Number 4918866.

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 (5).

Torque Value: 5 N•m [44 in-lb]

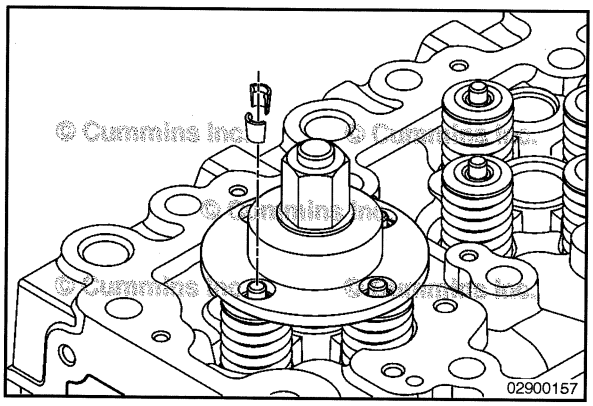


NOTE: The valves are **not** evenly spaced from the injector bore. It is important to align the slots in the valve spring compressor plate with the valve springs.

Apply anti-seize lubricant 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 tension and can act as projectiles if released. To reduce the possibility of eye injury, wear safety glasses with side shields.

Turn the nut **clockwise** to compress the valve springs.

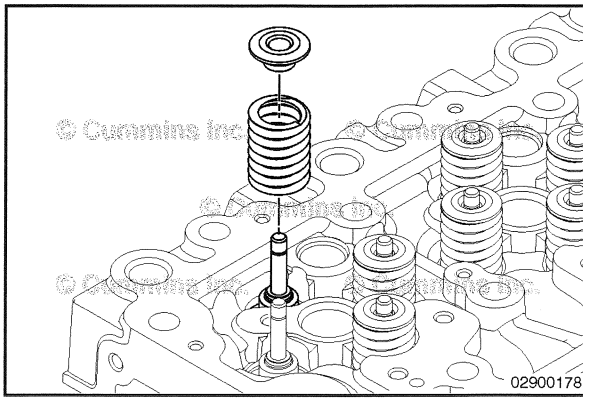
Continue turning the nut **clockwise** until the valve collets can be removed using a magnetic tool, such as the end of a magnetic screwdriver.

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 valve springs.



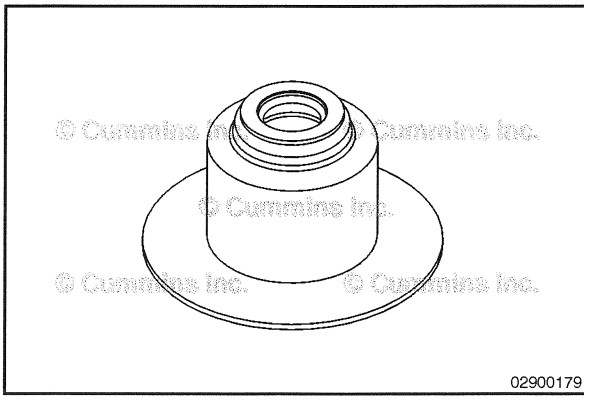
NOTE: Prior to removing the valve stem seals, note the color of the valve stem seal installed at each valve location. The same color valve stem seal **must** be installed when assembling the cylinder head.

There are two colors of valve stem seals used:

"Top-Hat" Seal

Colors Used:

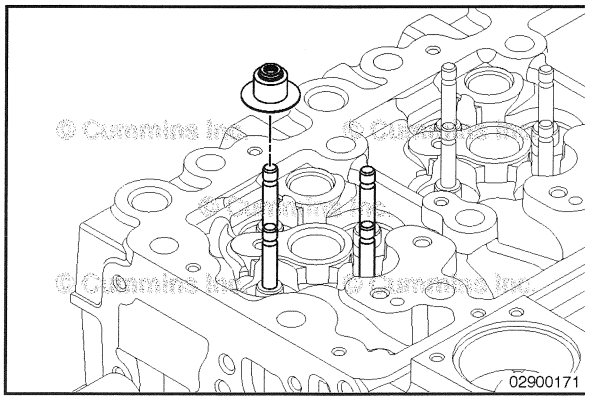
- Green (Used for exhaust valves)
- Yellow (Used for intake and exhaust valves).



Use boot pliers, Cummins® Part Number 3163293, to remove the valve stem seals.

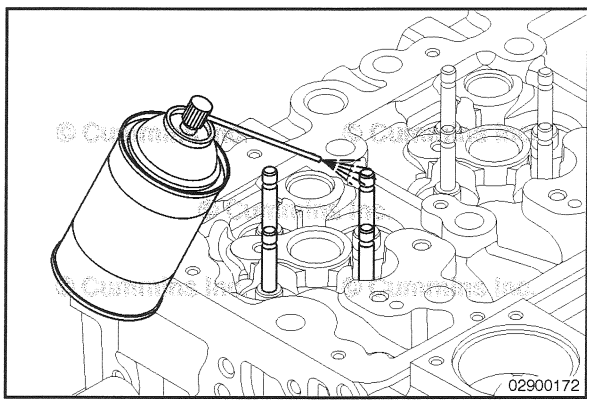
NOTE: The valve stem seals can be installed by hand. The installation tool will aid with installing the valve stem seals, but is **not** mandatory.

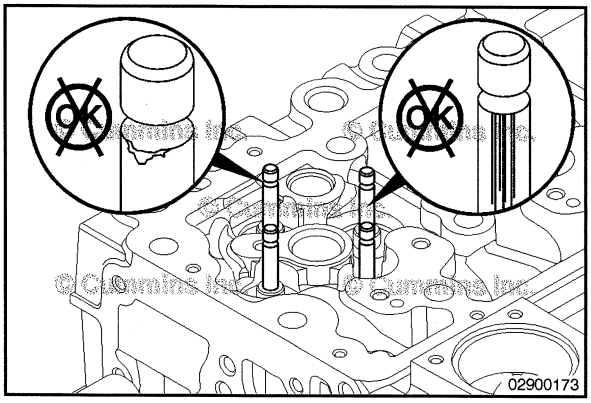
Note color and location of the seal, then discard the old seal.



Clean and Inspect for Reuse

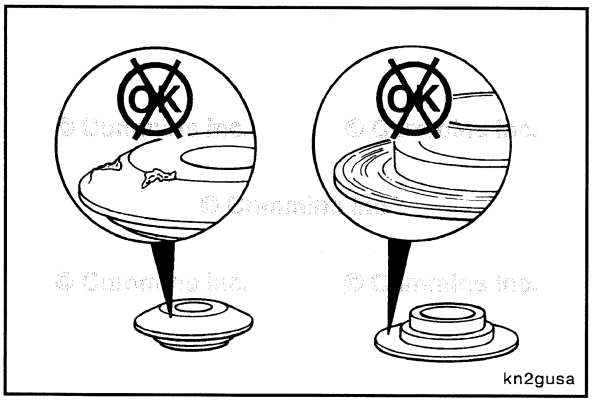
Clean the valve stems with electrical contact cleaner, Cummins® Part Number 3824510.





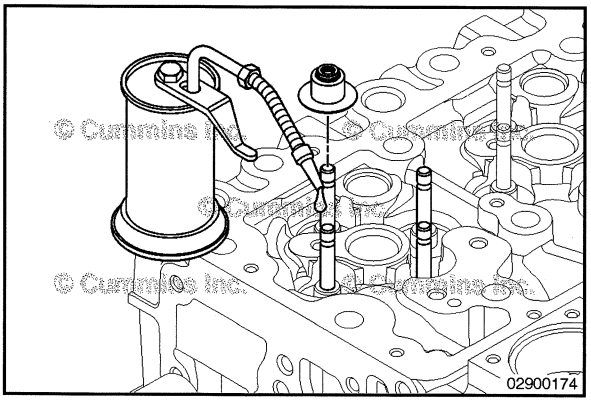
Inspect the exposed valve stem for scoring or heavy polishing. Inspect the valve collet grooves for wear.

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.

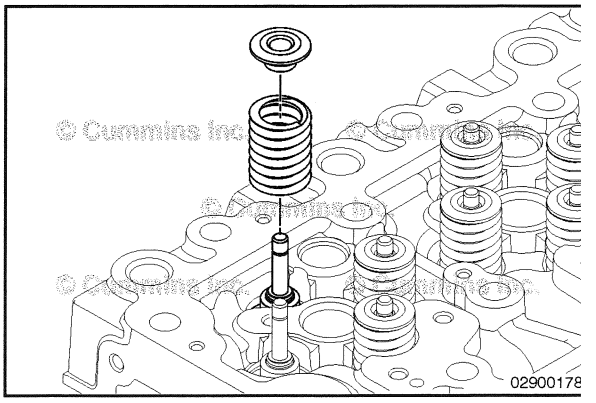
CAUTION
Lubricate all the valve guide bores and valve stems with SAE 15W-40 engine oil. Failure to lubricate the valve guides and valve stems can result in premature valve guide wear.

Install new valve stem seals of the same color as removed and in the same location. See the General Information section of this procedure for valve stem seal identification.

Lubricate the stems with SAE 15W-40 engine oil before installing the valve stem seals.

Install new valve stem seals. Use a valve stem installation tool, Cummins® Part Number 3164055.

Install the valve spring retainer and valve springs.

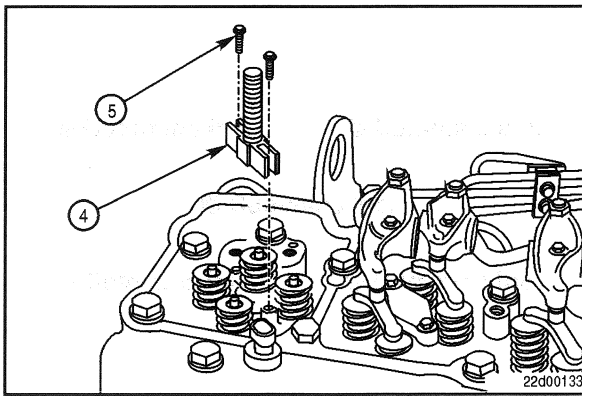


Compress the valve springs. Use the valve spring compressor, Cummins® Part Number 4918866.

Position the replacer screw (4) above the injector bore and install the capscrew (5) in the cylinder head where the hold-down clamp screws were removed.

Tighten the capscrew (5).

Torque Value: 5 N•m [44 in-lb]

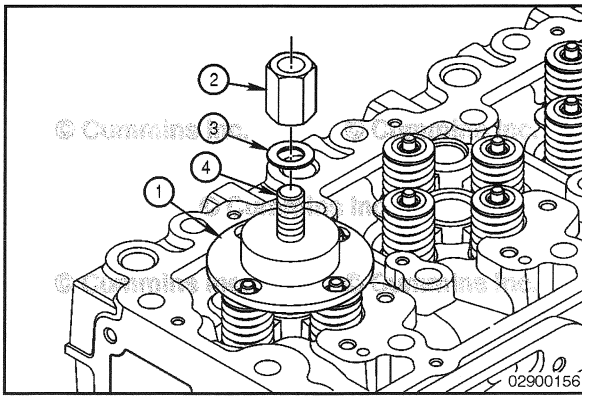


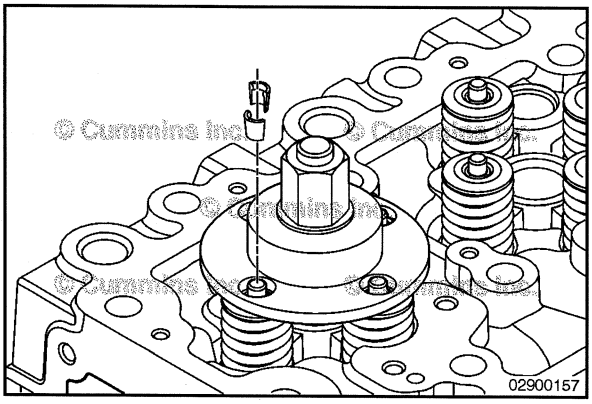
NOTE: The valves are **not** evenly spaced from the injector bore. It is important to align the slots in the valve spring compressor plate with the valve springs.

Apply anti-seize lubricant 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 tension and can act as projectiles if released. To reduce the possibility of eye injury, wear safety glasses with side shields.

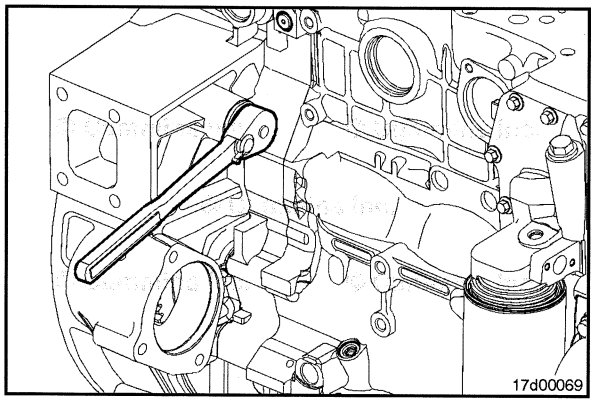
NOTE: Because there is a gap between the top of the piston and the valve face, it may be necessary to use a second magnet to pull the valve stem up to install the valve collets.

Compress the valve springs until the valve collets can be installed.

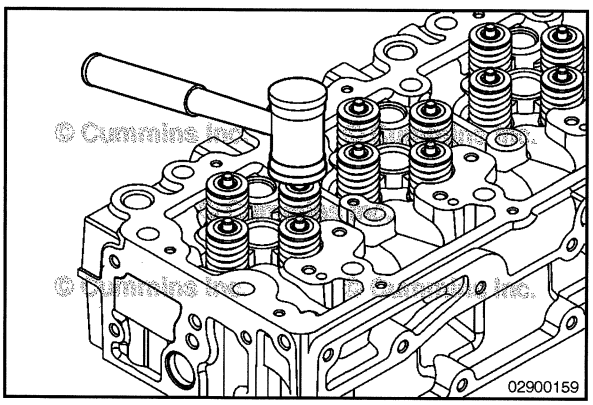
Install the valve collets.

Service Tip: Use assembly lube, Cummins® 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.



Use the marks made previously on the crankshaft speed indicator, rotate the engine **clockwise** to put the next group of cylinders at TDC.



⚠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.

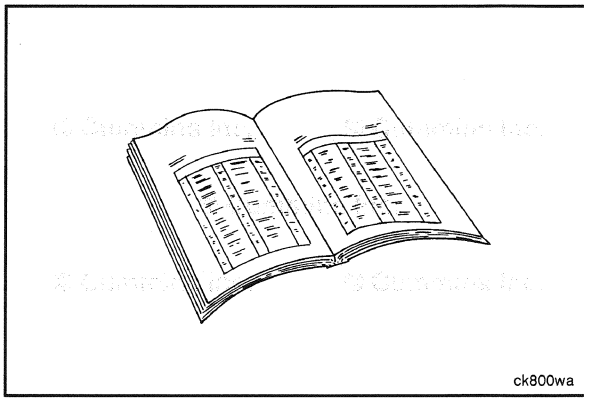
△CAUTION△
Rotate the engine to the next cylinder in the firing order before hitting the valve stem of the cylinder previously worked on. This will ensure that the valve does not contact the piston, resulting in a bent valve and internal engine damage.

After rotating the engine to the next group of cylinders, hit the valve stems of the cylinders 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 are replaced.

Finishing Steps

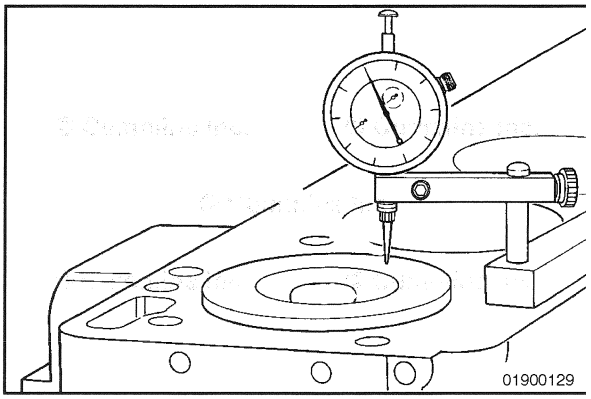
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.



- Install the injectors. Refer to Procedure 006-026 in Section 6.
- Install the cross heads. 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 rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.

Cylinder Head Gasket (002-021)

General Information



A specific cylinder head gasket with an increased thickness is **not** available for combustion deck resurfacing of the cylinder block or cylinder head. If the combustion deck can **not** be resurfaced such that the correct specifications of the injector protrusion and valve depth can be maintained, the cylinder block and/or cylinder head **must** be replaced.

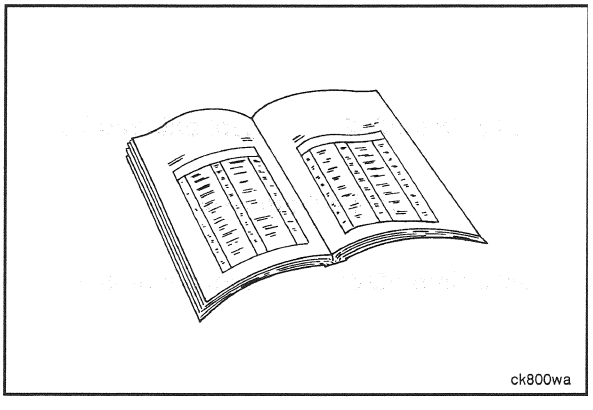
Remove and install instructions and specification can be found in the following procedures.

Refer to Procedure 001-026 in Section 1 for specifications.

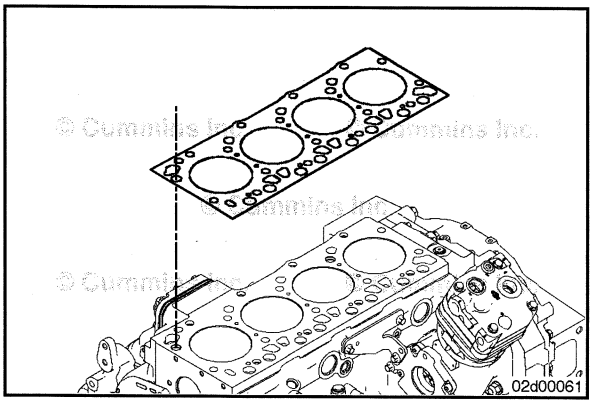
Refer to Procedure 002-004 in Section 2 for specifications.

Preparatory Steps

⚠WARNING⚠
This assembly weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this assembly.

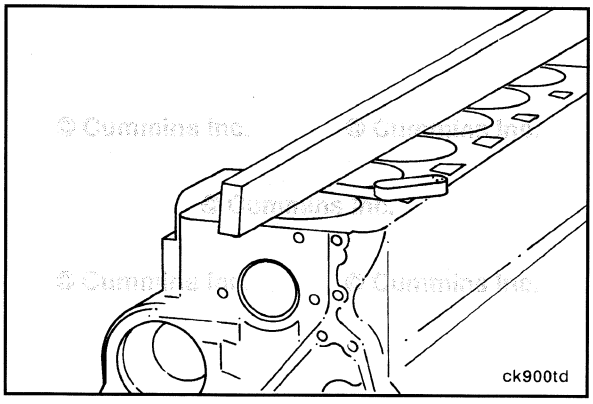


- Remove the cylinder head. Refer to Procedure 002-004 in Section 2.



Remove

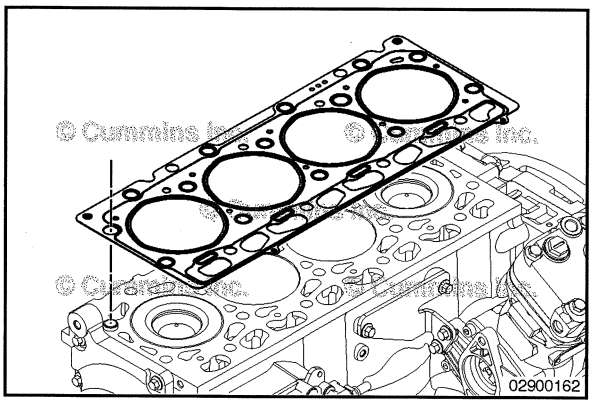
Remove the cylinder head gasket.



Clean and Inspect for Reuse

NOTE: Cylinder head gaskets can **not** be reused. A new cylinder head gasket **must** be used.

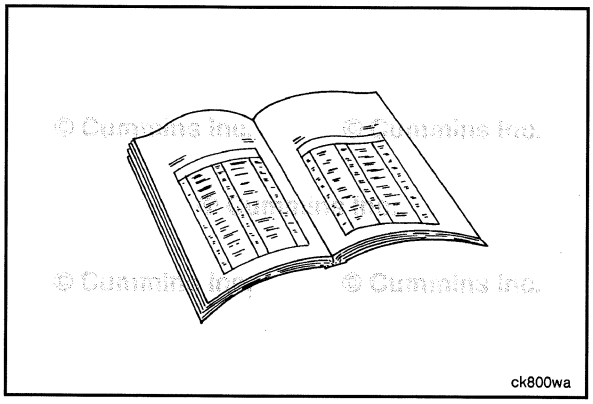
Clean the cylinder block and cylinder head combustion deck. Inspect and measure the cylinder block and cylinder head combustion deck flatness. Refer to Procedure 002-004 in Section 2.



Install

A new gasket **must** be installed. Do **not** reuse an old gasket.

Install the head gasket.



Finishing Steps

⚠WARNING⚠

This assembly weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this assembly.

- Install the cylinder head. Refer to Procedure 002-004 in Section 2.
- Operate the engine and check for leaks.

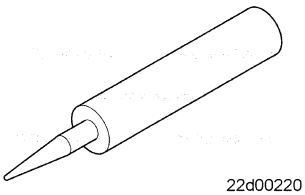
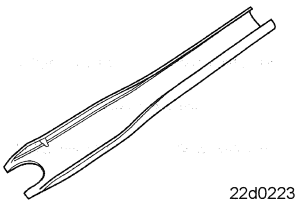
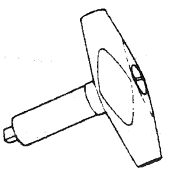
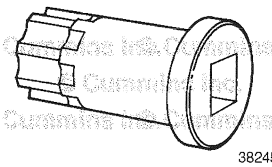
Section 3 - Rocker Levers - Group 03

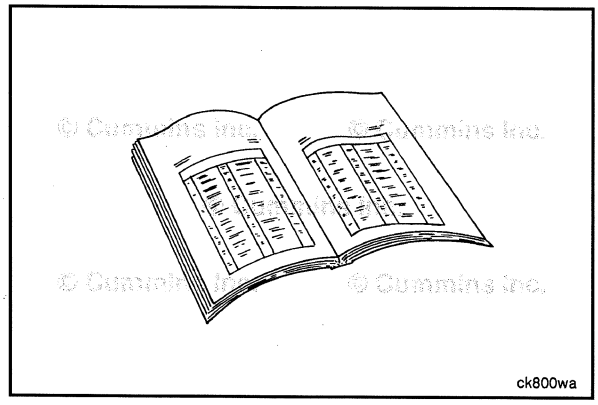
Section Contents

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
3164070	**RTV Sealant** Used to seal crankcase breather cover plate.	 22d00220
3165175	**Barring Plug Remover** Quickly removes stubborn barring plugs from flywheel housing.	 22d0223
3823208	**Torque Wrench - Nm** Used to tighten injector terminal nuts.	 3823208
3824591	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	 3824591


ck800wa

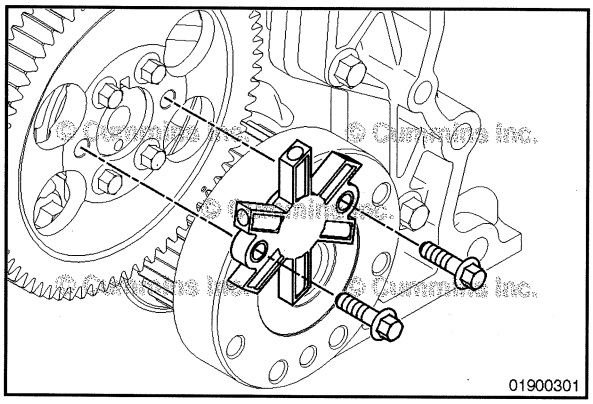
Crankcase Breather (Internal) (003-002)

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⚠
Support the rear of the engine using the rear support attached to the rear of the cylinder block. Failure to support the engine can cause serious personal injury.

- Disconnect the batteries. See equipment manufacturer service information.
- Remove the transmission. See equipment manufacturer service information.
- 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.


01900301

Remove

Remove two mounting capscrews and the crankcase breather disc mounting capscrews.

Remove the breather disc from the camshaft gear.

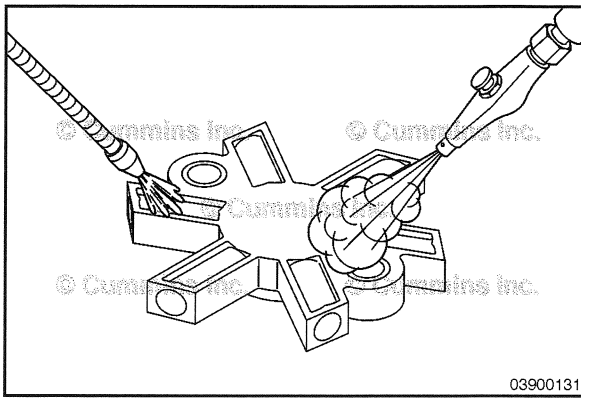
Clean and Inspect for Reuse

⚠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 breather disc with solvent.

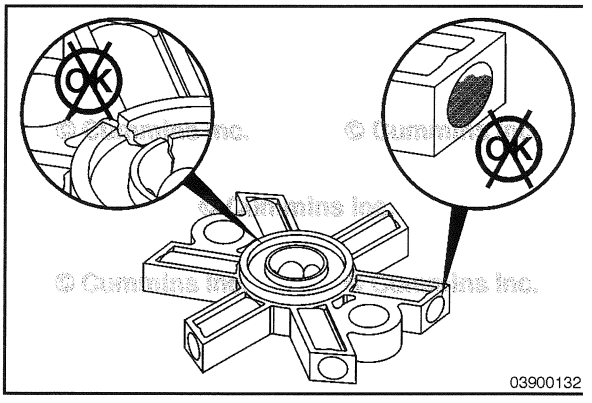
Dry with compressed air.



Inspect the breather disc for cracks and obstructions.

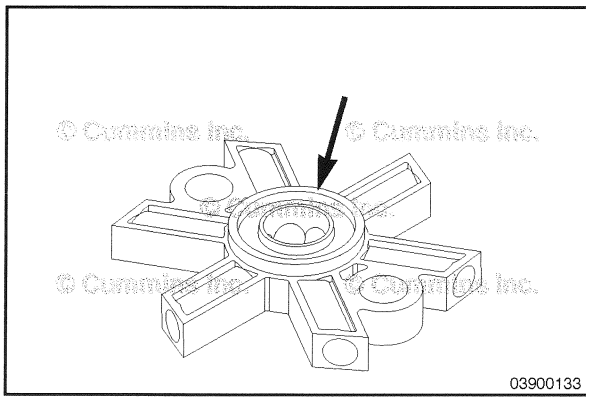
Inspect the camshaft bore for obstructions.

Remove the crankcase breather tube, if necessary. Refer to Procedure 003-018 in Section 3.



Install

Be sure the seal is in place on the front face of the breather disc nose.

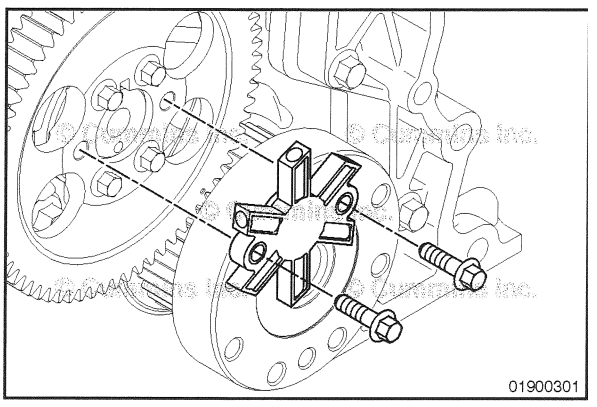


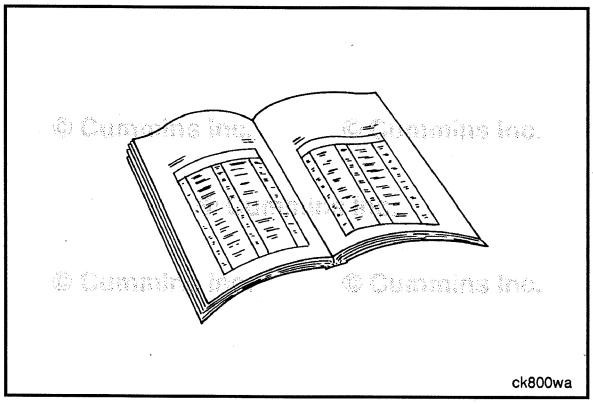
Install the breather disc onto the camshaft gear.

Lubricate the capscrew threads with clean lubricating oil.

Install the two mounting capscrews and tighten.

Torque Value: 28 N•m [248 in-lb]



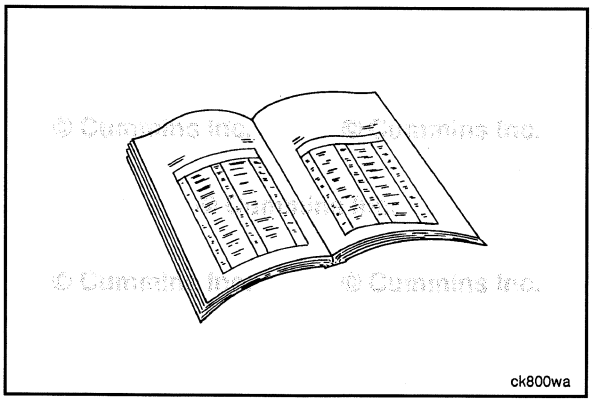


Finishing Steps

⚠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.

⚠WARNING⚠
Support the rear of the engine using the rear support attached to the rear of the cylinder block. Failure to support the engine can cause serious personal injury.

- 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 starting motor. Refer to Procedure 013-020 in Section 13.
- Install the transmission. See equipment manufacturer service information.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.



Overhead Set (003-004)

General Information

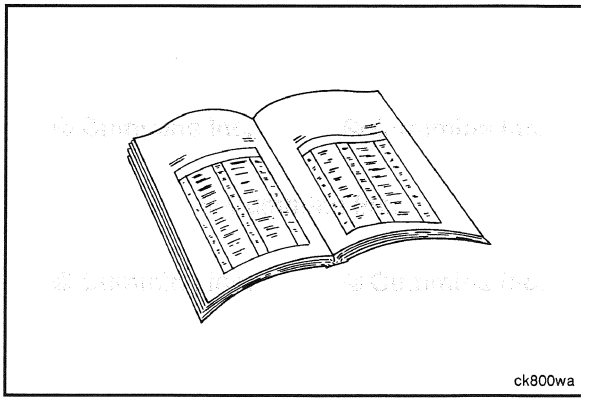
Overhead setting is **only** required at the interval specified in the Operation and Maintenance Manual/Owners Manual or when engine repairs cause removal of the rocker levers and/or loosening of the adjusting screws.

Excessive valve lash prior to this can indicate an overhead set incorrectly from a previous repair, worn valve stems, crossheads, push rods, or rocker levers.

Loose rocker levers and the need to reset the valve clearance frequently can also indicate camshaft lobe or tappet wear. If an inspection of the rocker levers, valve stems, crossheads, and push rod does **not** show wear, then tappet and/or camshaft lobe wear can be suspected.

Refer to Procedure 001-008 in Section 1 to check camshaft wear. Refer to Procedure 004-015 to check for tappet wear.

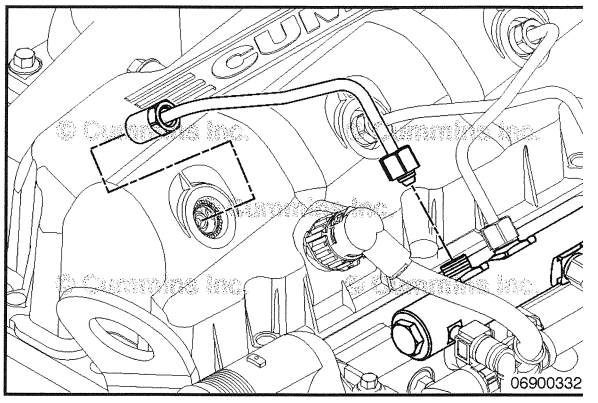
Preparatory Steps



⚠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. See equipment manufacturer service information.
- Clean the area around the fuel lines. Remove the high-pressure injector supply lines. Refer to Procedure 006-051 in Section 6.
- Remove the rocker lever cover and gasket. Refer to Procedure 003-011 in Section 3.

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.

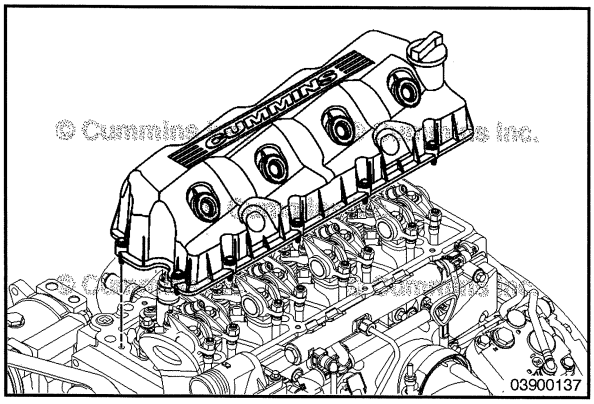
⚠WARNING⚠
Drain the fuel into a container, and dispose of contents in accordance with local environmental regulations.

⚠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 high-pressure line from the rail end of the injector number 4. Cover the end of the line immediately.

Disconnect the line from the number 4 injector. Cover the end of the line and the injector connection immediately.

Repeat the steps for the remaining injectors, removing and capping the connections one at a time.



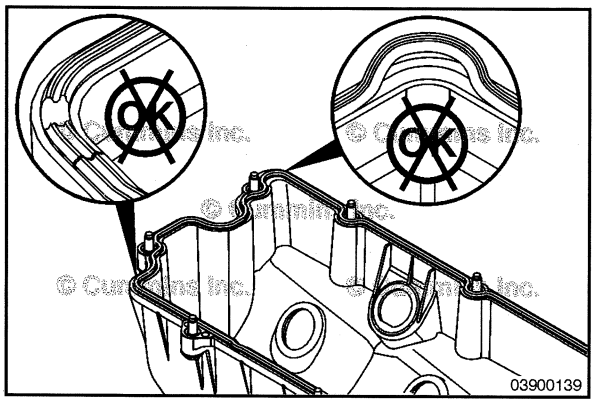
The mounting capscrews and compression limiters are part of the rocker lever cover. The capscrews are the captive design and will be held in place in the rocker lever cover.

Disconnect the wiring harness from the connectors in the rocker lever cover.

Loosen the rocker lever cover capscrews.

Loosen the bracelets that secure the wiring harness plugs to the rocker lever cover.

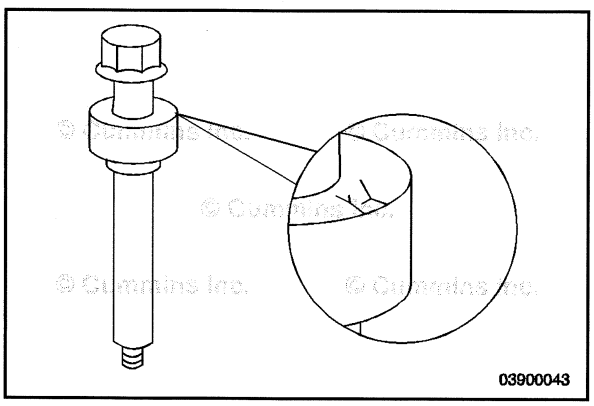
Pull the rocker lever cover gently. Leave the wiring harness plugs on the cylinder head.



NOTE: Check the gasket while it is installed in the valve cover.

Check the gasket for cracks on the sealing surface.

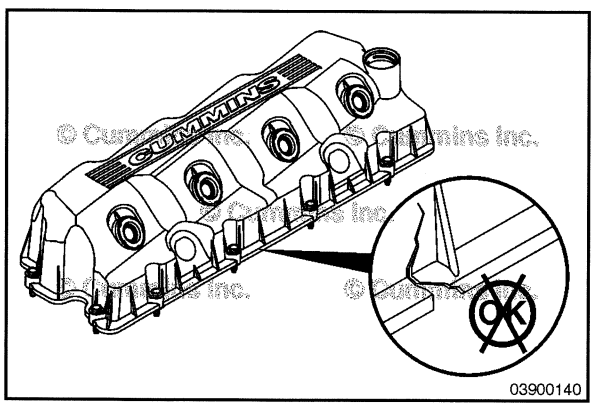
Replace the gasket if damage is present.



NOTE: It may be necessary to replace the capscrew/ compression limiter as an assembly.

Inspect the compression limiters and rocker lever cover edge for cracks or other damage.

The compressions limiters are **not** replaceable.



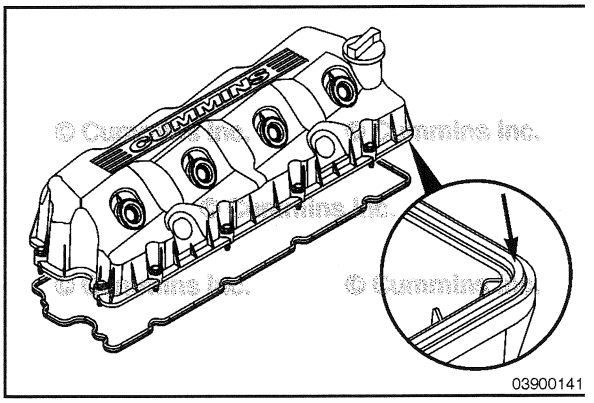
Inspect the rocker lever cover for cracks or other damage.

Replace the rocker lever cover if any damage is found.

If replacing the rocker lever gasket, 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.

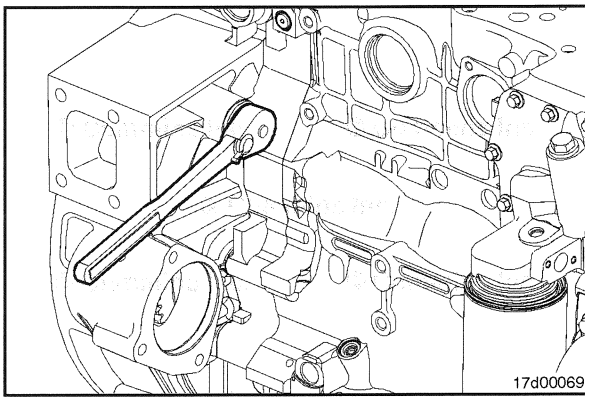
2 Press the remaining gasket into the rocker lever cover.



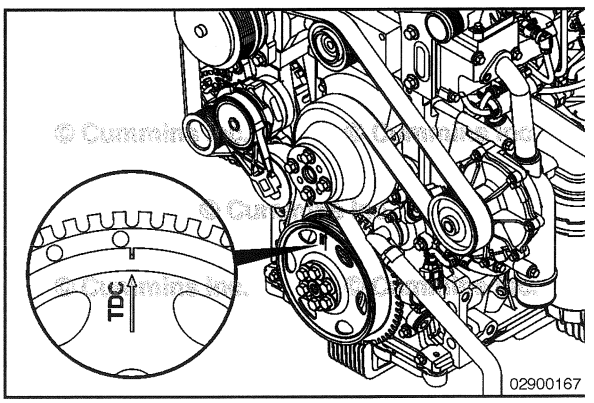
Adjust

NOTE: Engine coolant temperature **must** be less than 60°C [140°F].

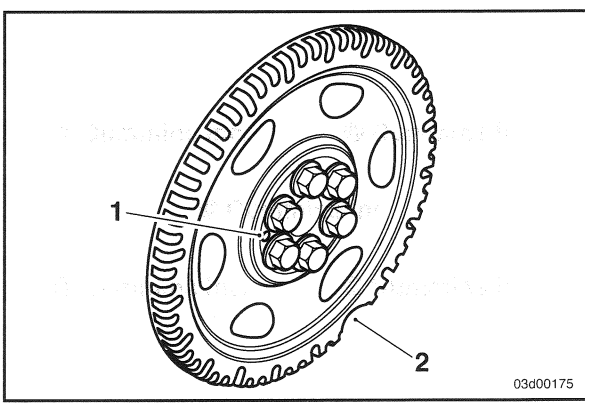
Use the barring tool, Cummins® Part Number 3824591, to rotate the crankshaft until the number 1 cylinder is at top dead center (TDC).

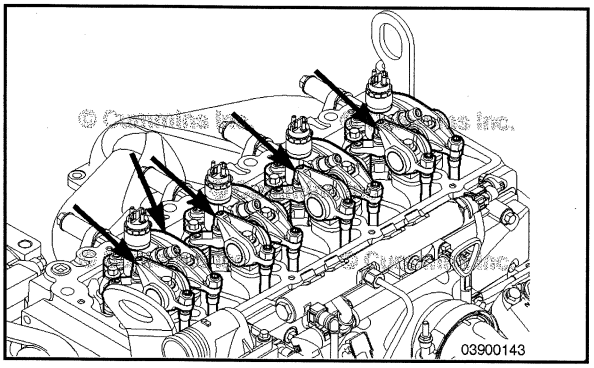


The TDC indicator is on the crankshaft speed indicator ring.



NOTE: If no TDC mark is present on either the crankshaft speed indicator ring, align the large gap in the crankshaft speed indicator ring to the 5 o'clock position (2). The dowel pin could also be visible in the 9 o'clock position (1). Check that both number 1 cylinder rocker levers are loose. If they are **not** loose, rotate the crankshaft 360 degrees and check the proper levers again.

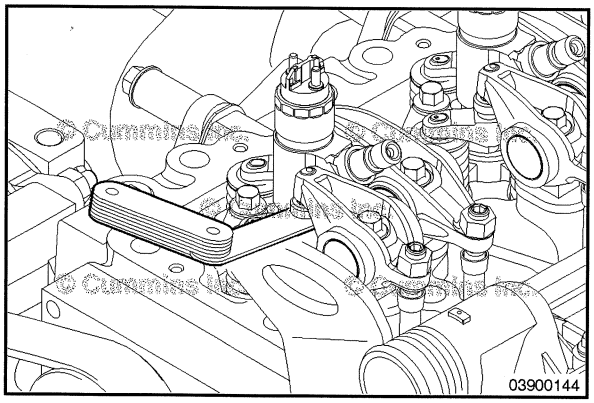




With the engine in this position, lash can be measured on the following rocker levers:

(E = Exhaust, I = Intake)

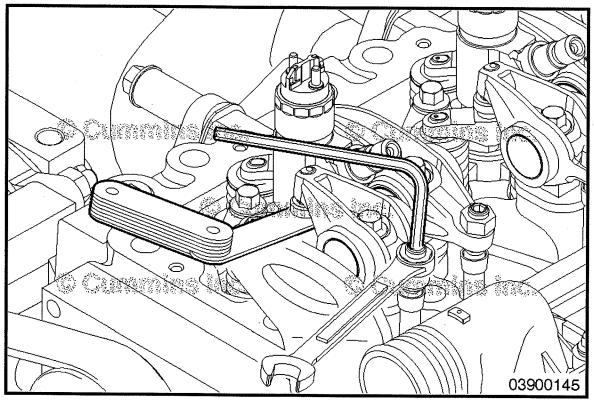
1I, 1E, 2I, and 3E:



Lash Check Limits

	mm		in
Intake	0.28	MIN	0.011
	0.381	MAX	0.015
Exhaust	0.53	MIN	0.021
	0.63	MAX	0.025

NOTE: Checking the overhead setting is usually performed as part of a troubleshooting procedure, and resetting is **not** required during checks as long as the lash measurements are within the above ranges.



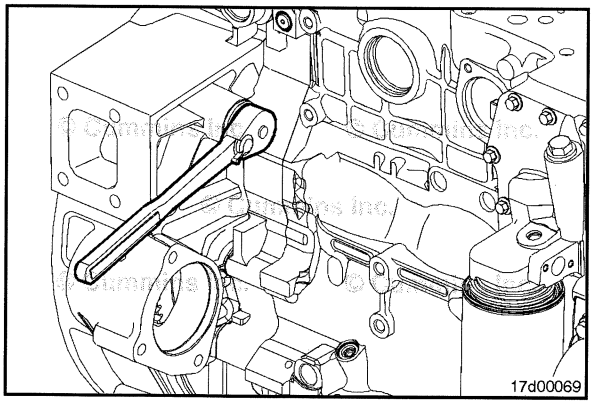
NOTE: The clearance is correct when some resistance is "felt" when the feeler gauge is slipped between the crosshead and the rocker lever socket.

Measure lash by inserting a feeler gauge between the crosshead and the rocker lever socket. If the lash measurement is out of specification, loosen the locknut and adjust the lash to nominal specifications.

Valve Lash Specifications (Nominal)	
	mm
Intake	0.33
Exhaust	0.58

Tighten the locknut and measure the lash again.

Torque Value: 24 N•m [212 in-lb]



Use barring tool, Cummins® Part Number 3824591, to rotate the crankshaft 360 degrees.

Following the same steps and specifications as previously stated, measure lash for the following rocker levers:

(E = exhaust, I = Intake)

2E, 3I, 4E, and 4I

Adjust the lash, if out of specification.

Install

Install the wiring harness plugs on the cylinder head into the rocker lever cover.

Tighten the bracelets that secure the wiring harness plugs to the rocker lever cover.

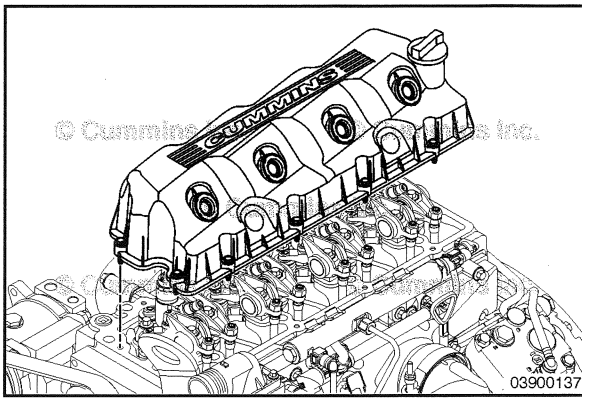
Install the rocker lever cover.

Install the mounting capscrews.

Tighten the mounting capscrews.

Torque Value: 9 N•m [80 in-lb]

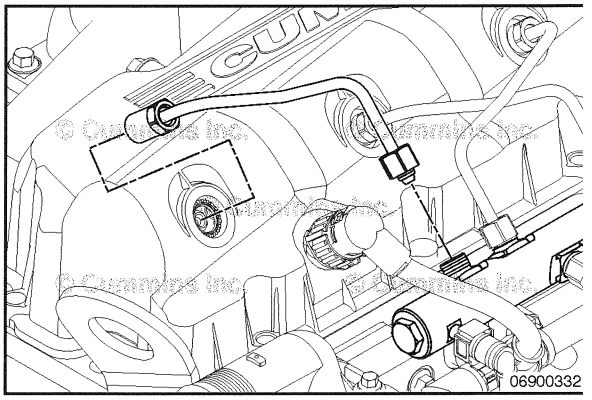
Connect the wiring harness to the connectors in the rocker lever cover.



Install and hand-tighten all of the fuel lines.

Tighten the injector high pressure supply lines:

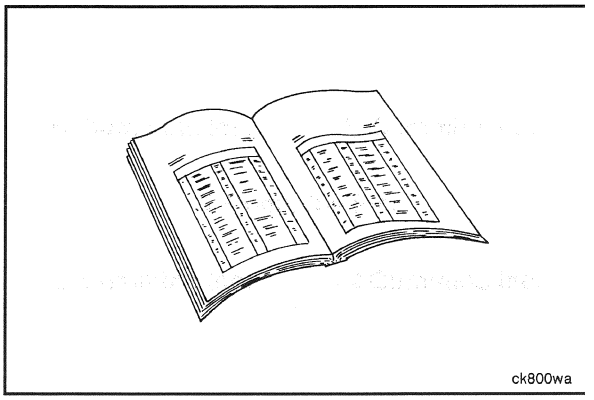
Torque Value: 22 N•m [195 in-lb]

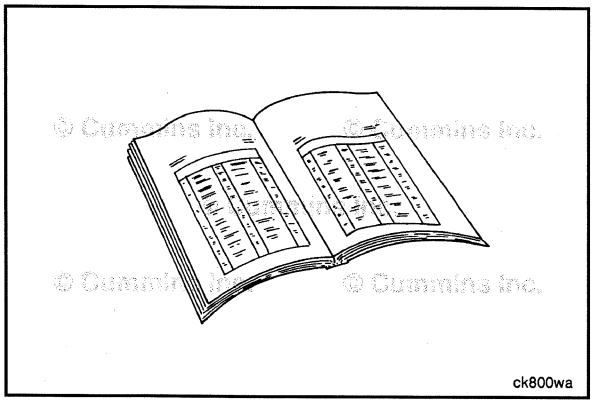


Finishing Steps

⚠ 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.

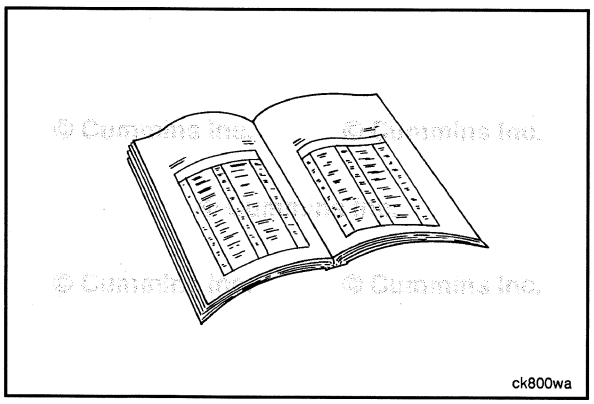
- Install the gasket and rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.





⚠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. See equipment manufacturer service information.
- Operate the engine and check for leaks.

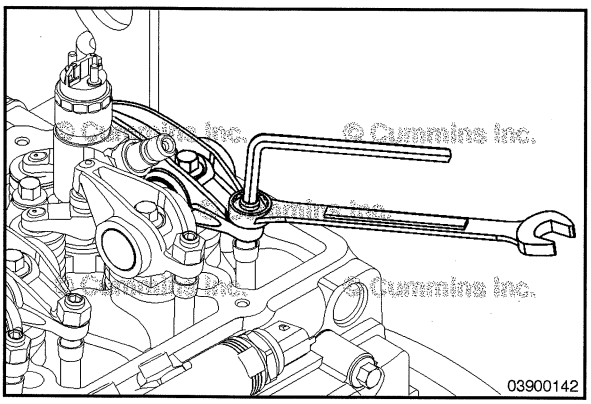


Rocker Lever (003-008)

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 batteries. See equipment manufacturer service information.
- Disconnect engine wiring harness from the injectors. Refer to Procedure 019-043 in Section 19.
- Remove the rocker lever cover and gasket. Refer to Procedure 003-011 in Section 3.



Remove

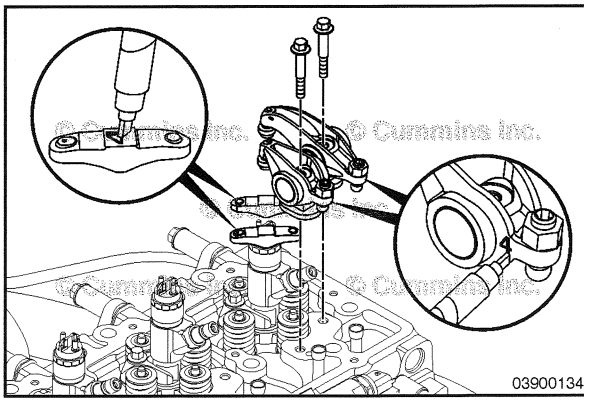
Loosen the adjusting screw locknuts.

Loosen the adjusting screws until they stop.

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.

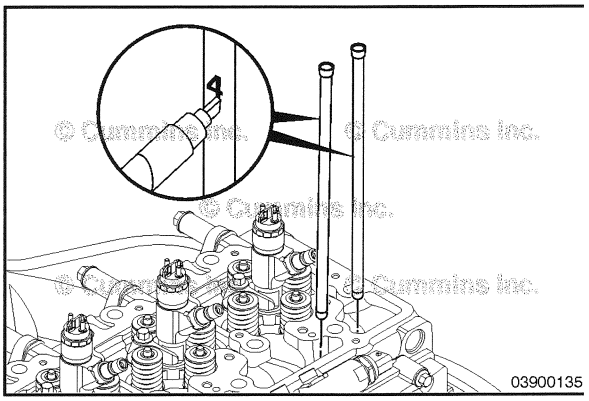
Remove and mark the crossheads one at a time as to their location and position. The crossheads and rocker assembly **must** be installed in their original location and position when reused.



NOTE: The push rods **must** be installed in their original location and position.

Mark the push rods to identify their location.

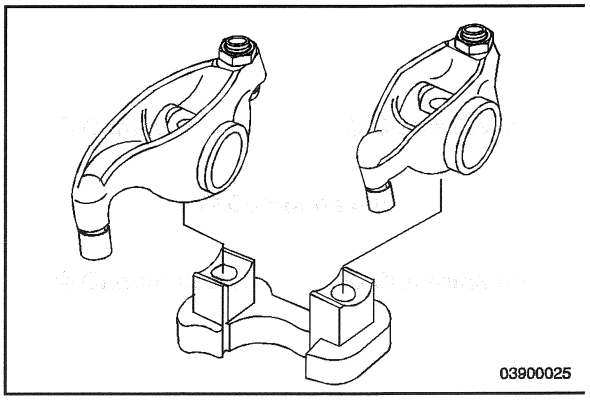
Remove the push rods. Refer to Procedure 004-014 in Section 4.



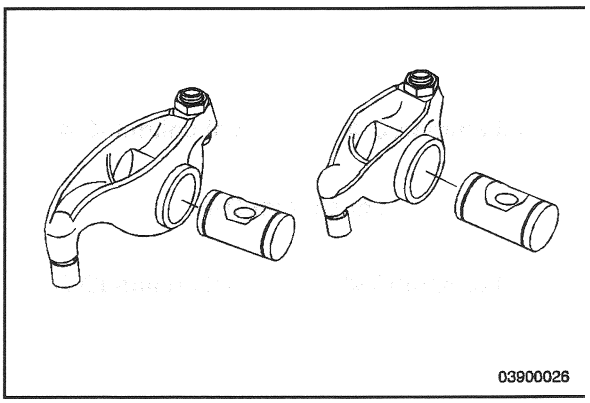
Disassemble

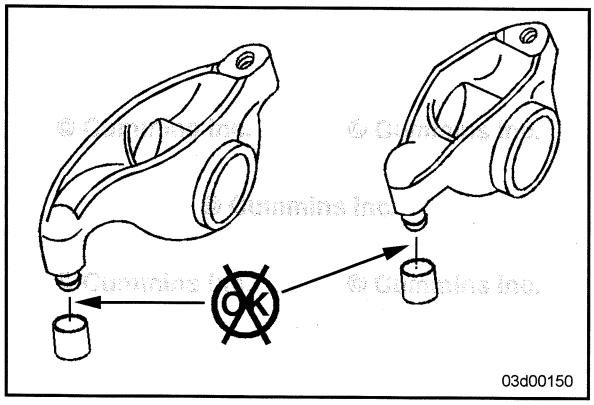
NOTE: All rocker lever components **must** be installed in their original location and position.

Remove the rocker levers from the pedestal.



Remove the rocker lever shafts from the rocker levers.

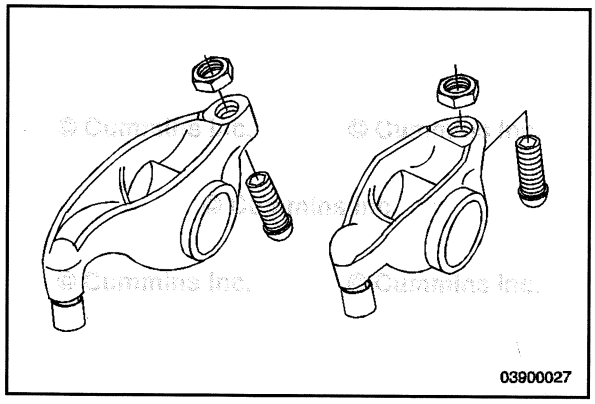




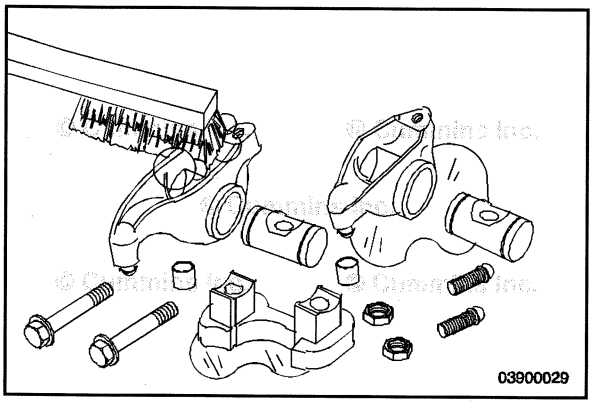
The socket at the tip of the rocker lever should **not** be removed.

This part is **not** serviceable.

If damage to the socket is found, the rocker lever **must** be replaced.

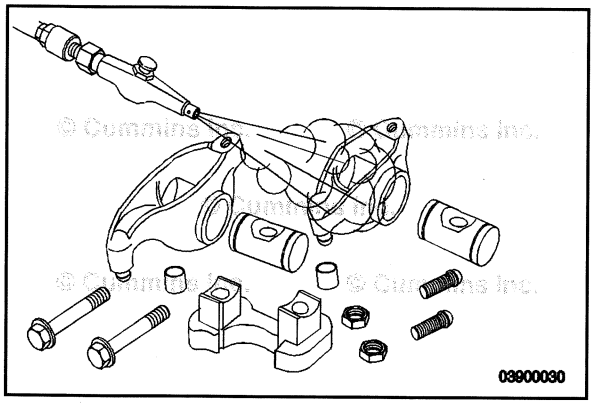


Remove the locknut and adjusting screw.



Clean and Inspect for Reuse

Clean all parts in a strong solution of laundry detergent and 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.

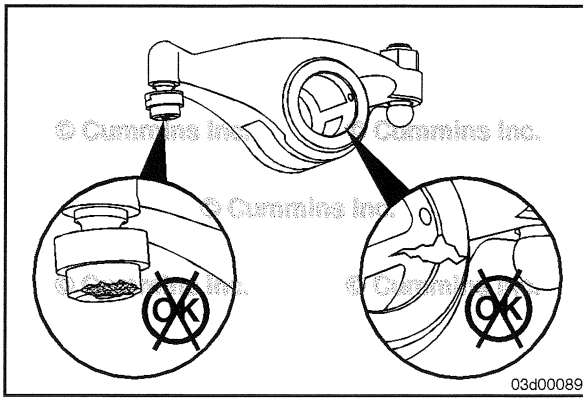
NOTE: The pedestals are made from powdered metal and will appear wet even after they have been cleaned and dried.

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.

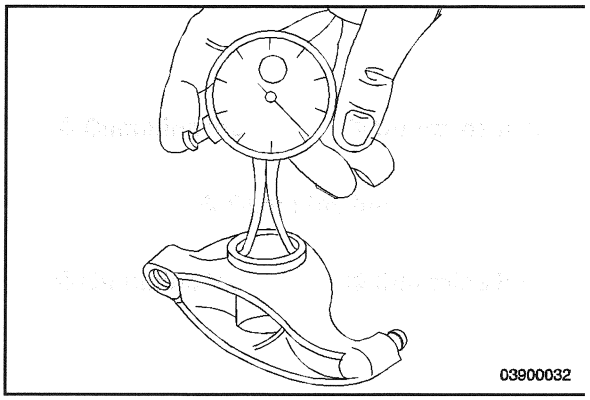
Inspect for wear on the nose of the socket.

NOTE: The socket at the tip of the rocker lever should **not** be removed. This part is **not** serviceable. If damage to the socket is found, the rocker lever **must** be replaced.



Measure the rocker lever bore.

Rocker Lever Bore		
mm		**in**
22.027	MAX	0.867

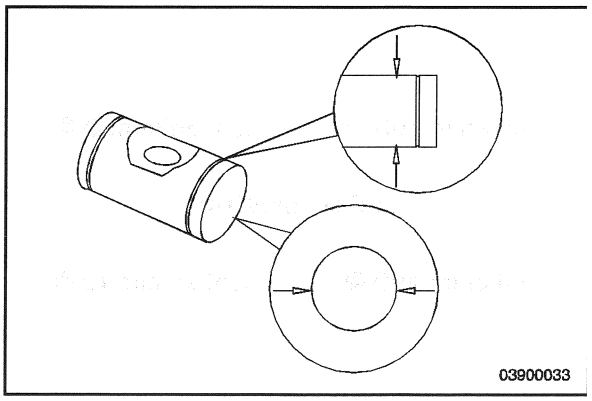


Inspect the rocker lever pedestal and rocker lever shaft.

It is **not** uncommon for the rocker lever shaft to have a polished appearance. Inspect for the following to determine rocker lever shaft reusability.

Measure the rocker lever shaft diameter.

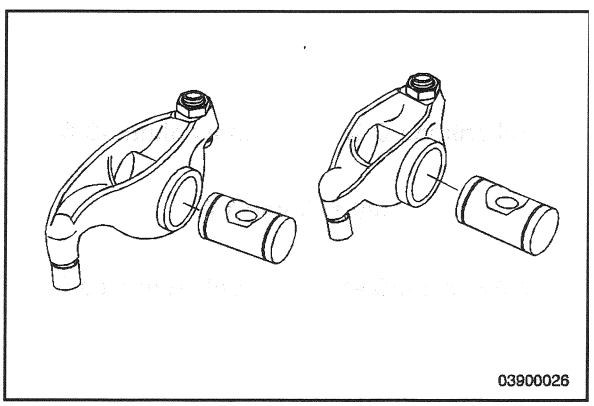
Rocker Lever Shaft		
mm		**in**
21.965	MIN	0.865

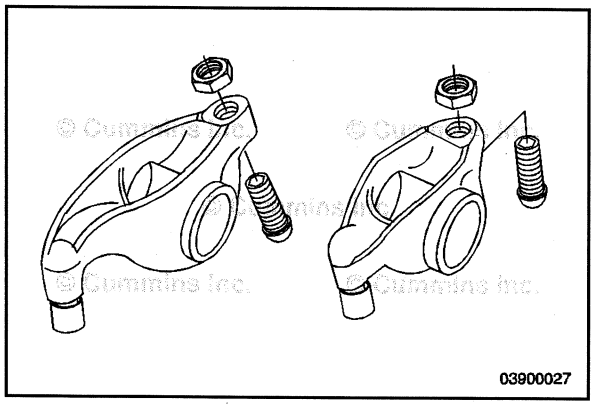


Lubricate the rocker lever shaft with clean 15W-40 engine lubricating oil.

Install the rocker lever shaft into the rocker lever and rotate the rocker lever 180 degrees about the rocker lever shaft. The rocker lever should rotate freely without any binding.

If the rocker lever does **not** rotate freely, replace the rocker lever shaft and rocker lever.

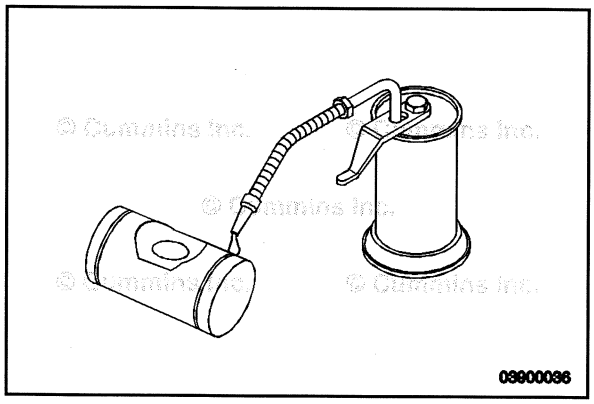




Assemble

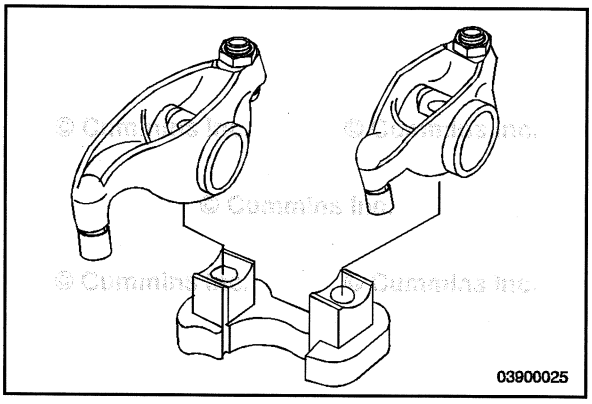
NOTE: All rocker lever components **must** be installed in their original location and position.

Install the adjusting screw until it stops and then install the locknut.

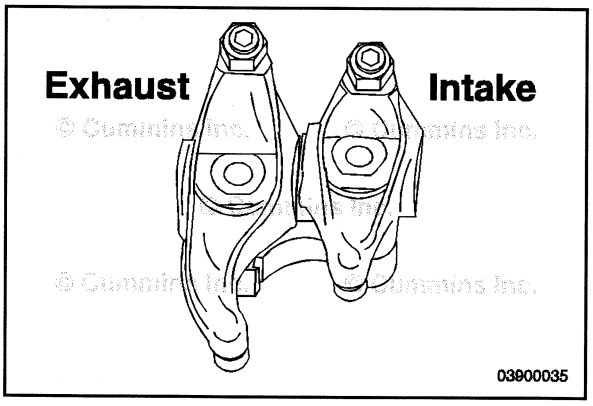


Lubricate the rocker lever shafts with clean 15W-40 engine lubricating oil.

Install the rocker lever shafts into the rocker levers.



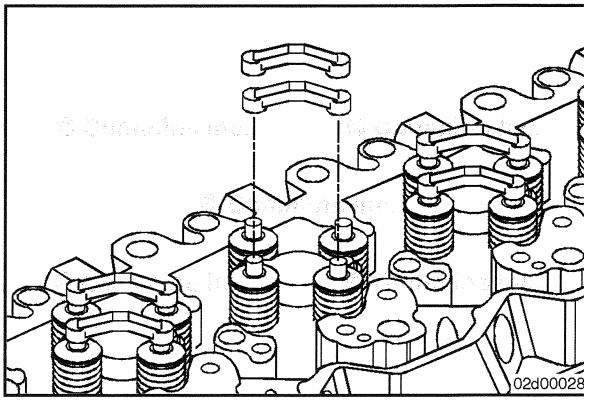
Position the rocker levers on the rocker pedestal.



△CAUTION△
Make sure to assemble the intake and exhaust rocker levers in the correct location. Failure to do so will result in engine damage.

Install

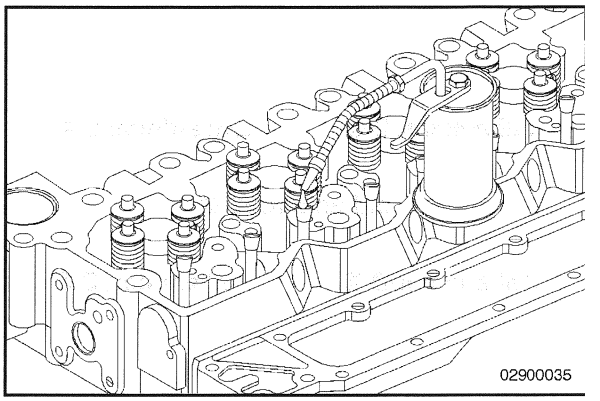
Install the crossheads in their original location and position.



Install the push rods as marked during removal.

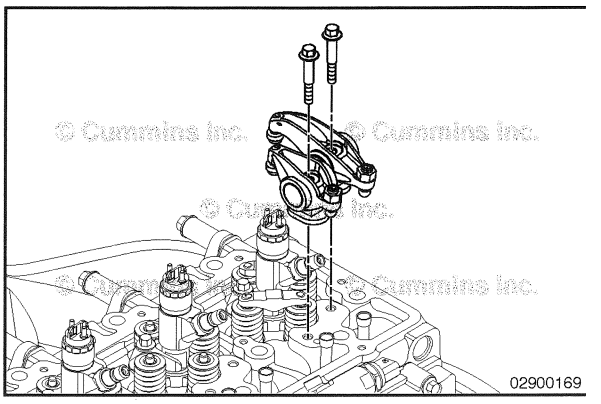
Install the push rods into the sockets of the valve tappets.

Lubricate the push rod sockets with clean 15W-40 lubricating engine oil.



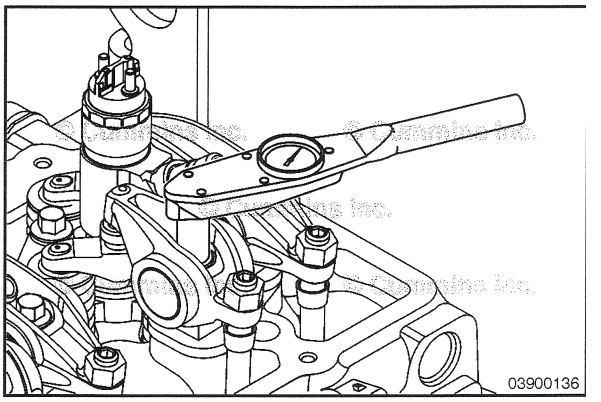
Install the rocker lever assemblies and pedestals in their original position.

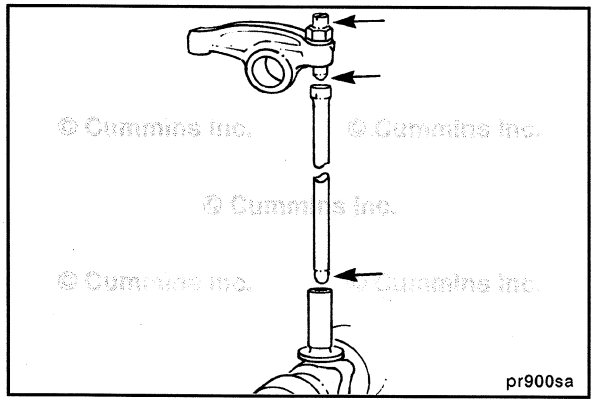
Install the pedestal mounting capscrews.



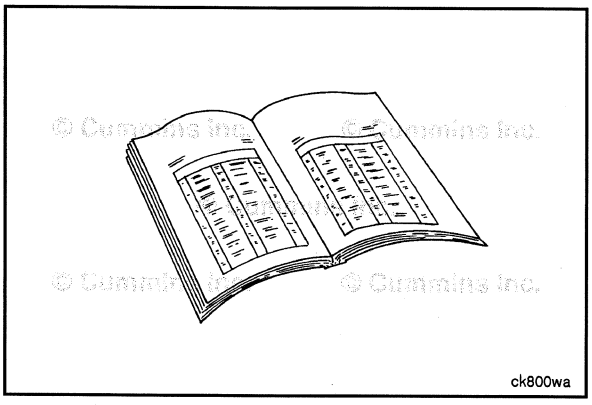
Tighten the pedestal mounting capscrews.

Torque Value: 36 N•m [27 ft-lb]





⚠CAUTION⚠
Rotate the adjusting screws until the adjusting screw contacts the socket of the push rod. This will ensure the push rod stays in contact with the tappet and adjusting screw when the engine is rotated to set valve lash. If not completed, the push rods may be bent or damaged.



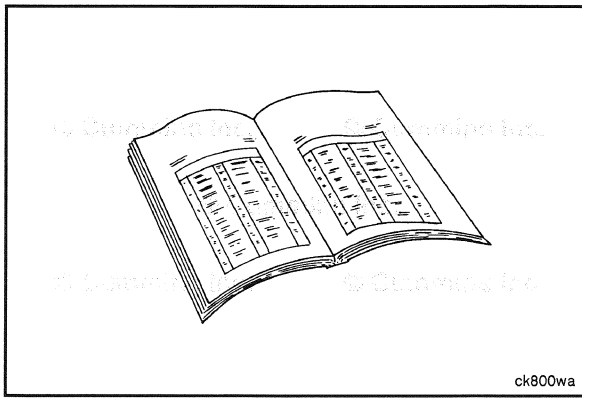
Finishing Steps

⚠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.

- Set valve lash for intake and exhaust valves. Refer to Procedure 003-004 in Section 3.
- Install the rocker lever cover gasket and rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Connect the engine wiring harness to injectors. Refer to Procedure 019-043 in Section 19.
- Connect the batteries. See equipment manufacturer service information.
- Operate engine and check for leaks.

Rocker Lever Cover (003-011)

Preparatory Steps

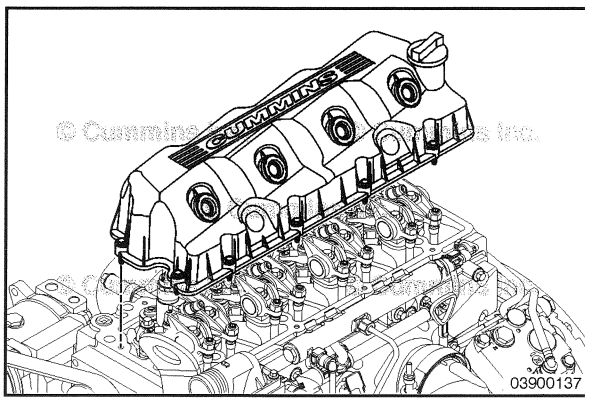


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

- Clean the rocker lever cover surface and injector supply lines before beginning this procedure. Prior to removing any components, clean around the mounting fasteners and sealing joints with compressed air to remove any loose debris.
- Disconnect the batteries. See equipment manufacturer service information.
- Remove the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Disconnect the internal actuator wiring harness. Refer to Procedure 019-063 in Section 19.

Remove

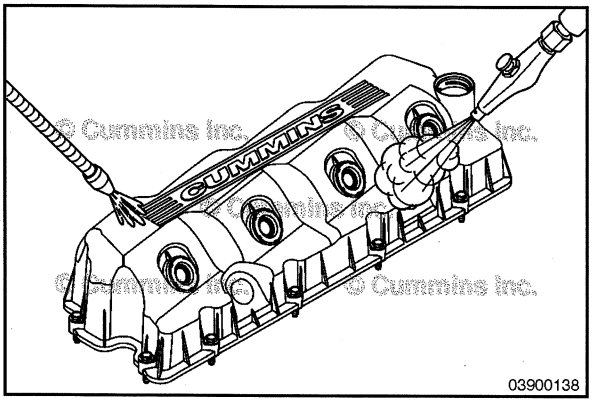


⚠CAUTION⚠
Be sure to remove the injector wiring harness pass-through connector locking rings before attempting to remove the rocker lever cover. Refer to Procedure 019-063 in Section 19.

The mounting capscrews and compression limiters are part of the rocker lever cover. The capscrews are the captive design and will be held in place in the rocker lever cover.

Loosen the rocker lever cover capscrews.

Pull the rocker lever cover gently. Leave the injector wiring harness and support brace attached to 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.

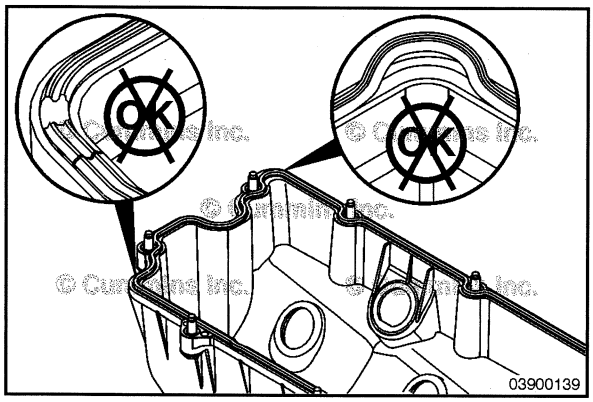
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

NOTE: When cleaning the rocker lever cover, if the rocker lever gasket is still installed in the base of the rocker lever cover, do **not** submerge the rocker lever cover in solvent. Limit the amount of exposure the gasket has to solvent. The gasket is reusable.

Clean the rocker lever cover with solvent.

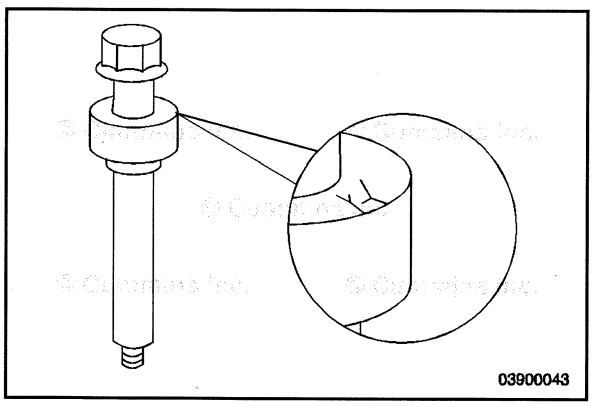
Dry with compressed air.



NOTE: Check the gasket while it is installed in the rocker lever cover.

Check the gasket for cracks on the sealing surface.

Replace the gasket if damage is present.



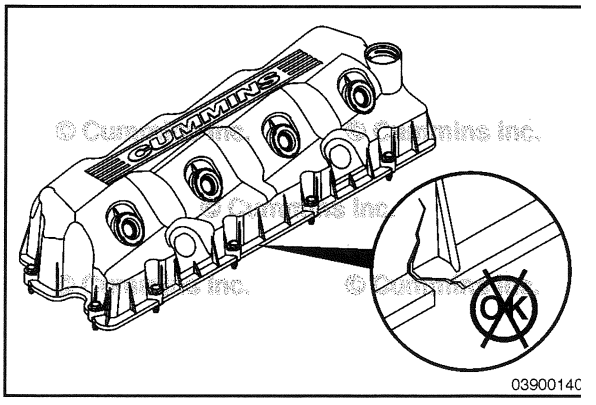
NOTE: It may be necessary to replace the capscrew/ compression limiter as an assembly.

Inspect the compression limiters and rocker lever cover edge for cracks or other damage.

Replace the compression limiters and/or capscrew assembly if damage is found.

Inspect the rocker lever cover for cracks or other damage.

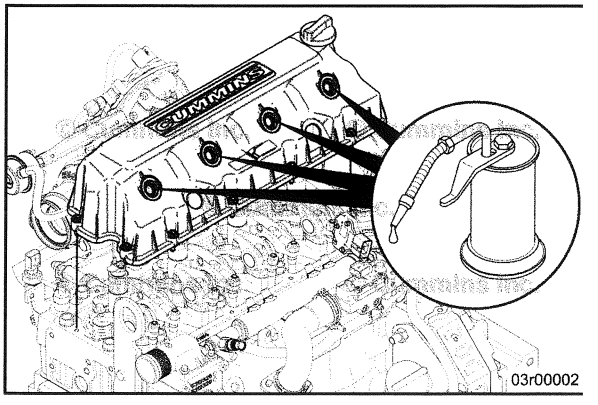
Replace the rocker lever cover if any damage is found.



Inspect the fuel line pass-through grommet seals for cracks, deformity, or other damage. Replace the grommet if damaged.

If it is necessary to replace the pass-through grommet, remove by using a flat tip screwdriver to extend the grommet outward.

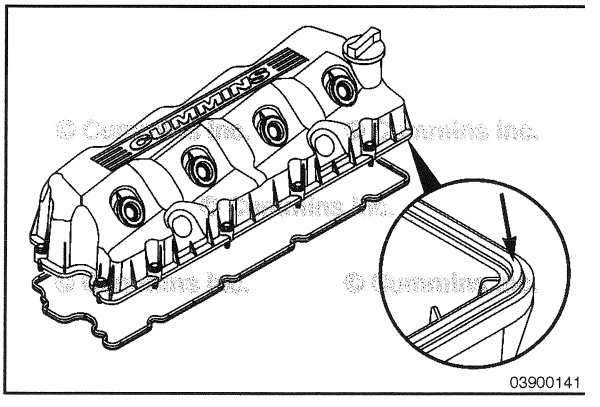
To install the grommet, lubricate with 15W-40 lubricating oil. Hold the valve cover while using a suitable tool (19-mm socket) to lightly tap with a soft hammer to seat into the groove.



If replacing the rocker lever gasket, 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 remaining gasket into the rocker lever cover.

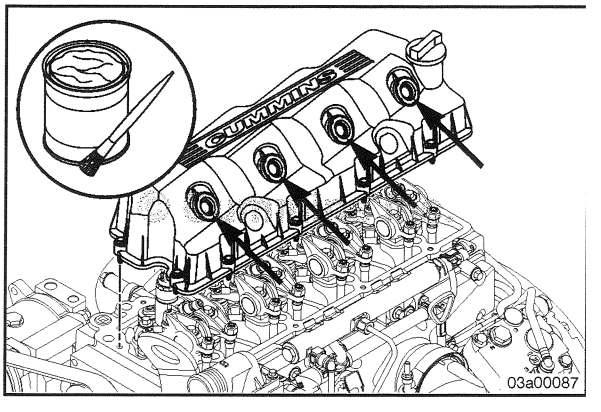


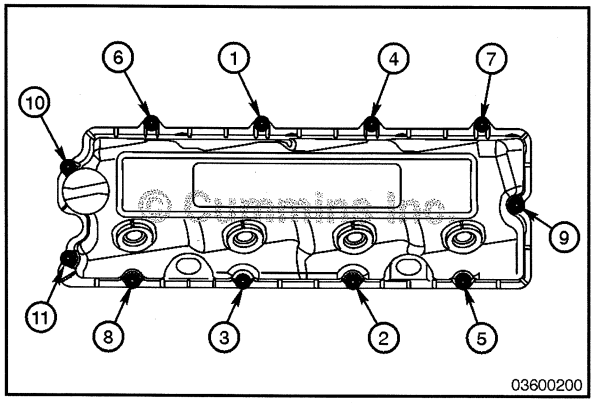
Install

Use 15W-40 lubricating oil or Lubriplate® #4 to lubricate the fuel line pass-through grommet seals.

Install the rocker lever cover.

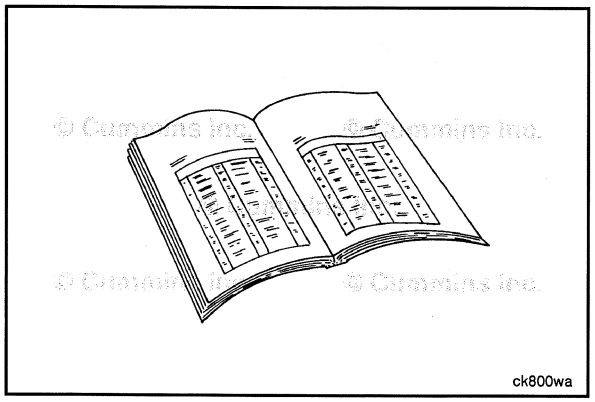
Install the mounting capscrews.





Tighten the mounting capscrews in the sequence shown.

Torque Value: 9 N•m [80 in-lb]

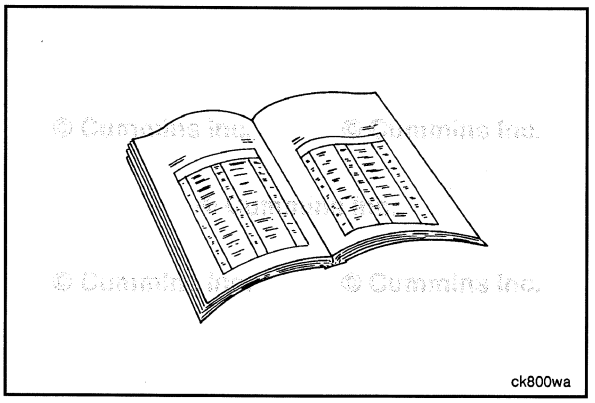


Finishing Steps

⚠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 the internal actuator wiring harness. Refer to Procedure 019-063 in Section 19.
- Install the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.

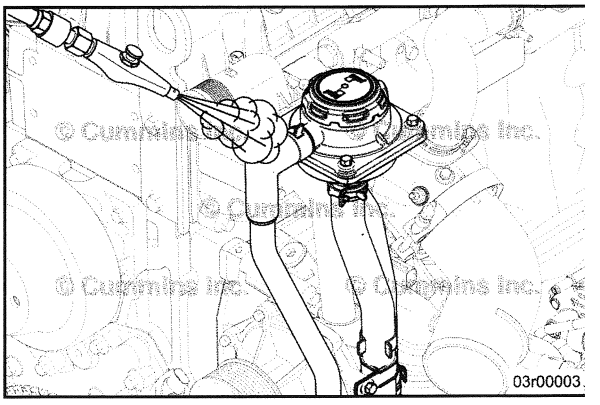


Crankcase Breather Tube (003-018)

General Information

This procedure is **only** intended for engines equipped with an open crankcase ventilation system.

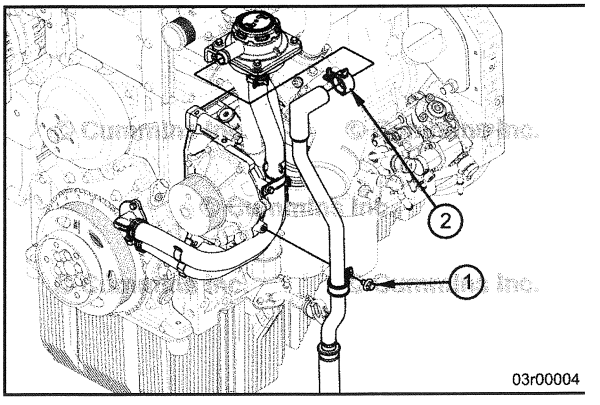
Preparatory Steps



⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

- Clean the area around the breather tube connection with compressed air.

Remove

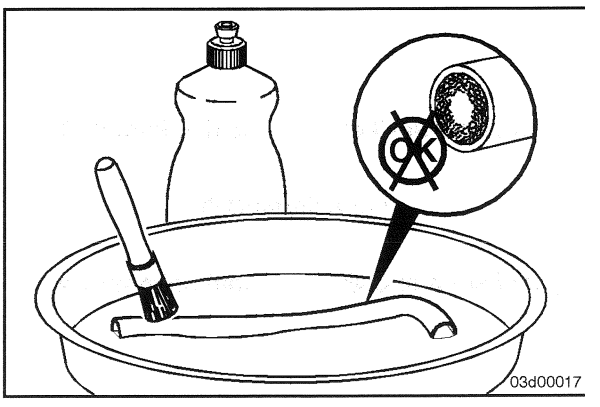


Remove capscrew (1) from the P-clip securing the crankcase breather tube to the water pump housing.

Remove the spring clamp (2) and disconnect the crankcase breather tube.

Remove the crankcase breather tube.

Clean and Inspect for Reuse



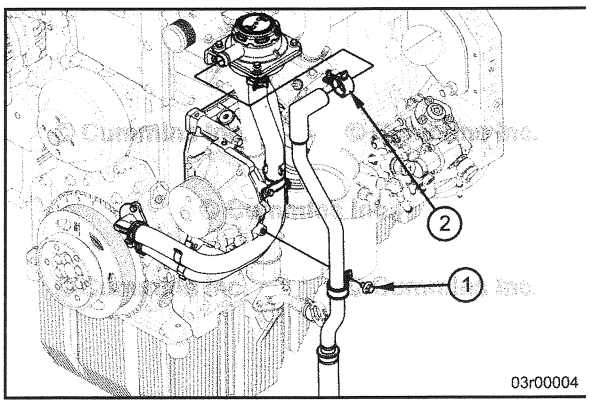
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Check the crankcase breather tube internally for obstructions or sludge buildup.

Clean with hot, soapy, water and a soft brush.

Use compressed air to dry the crankcase breather tube after rinsing in clean water.

Install

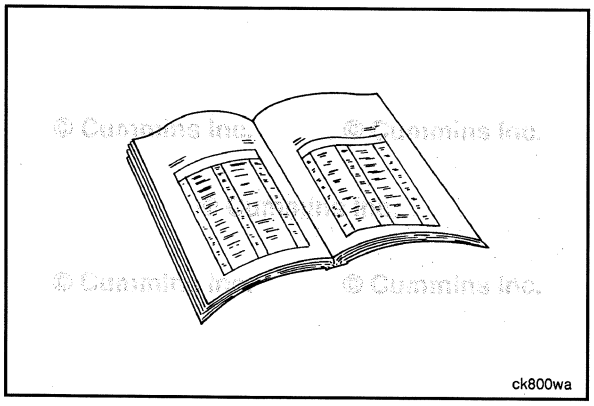


Install the crankcase breather tube.

Secure the crankcase breather tube with a spring clamp (2).

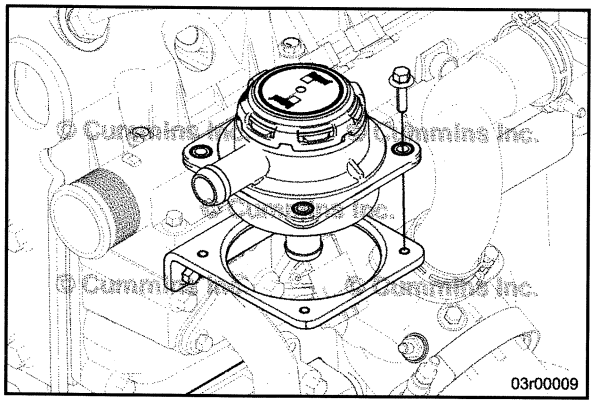
Install the P-clip and capscrew (1).

Torque Value: 18 N•m [159 in-lb]



Finishing Steps

- Operate the engine and check for leaks.

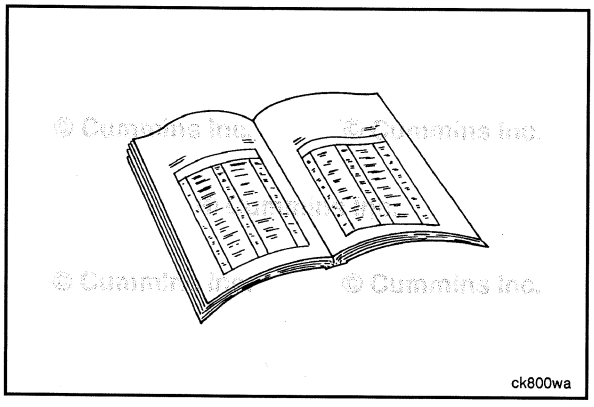


Open Crankcase Ventilation Valve (003-025)

General Information

This engine is equipped with an open crankcase ventilation system. The open crankcase ventilation valve is used to:

- Separate oil from the crankcase gases
- Regulate the pressure in the crankcase
- Prevent the engine and turbocharger from consuming oil in the event that the engine air filter becomes too restricted.

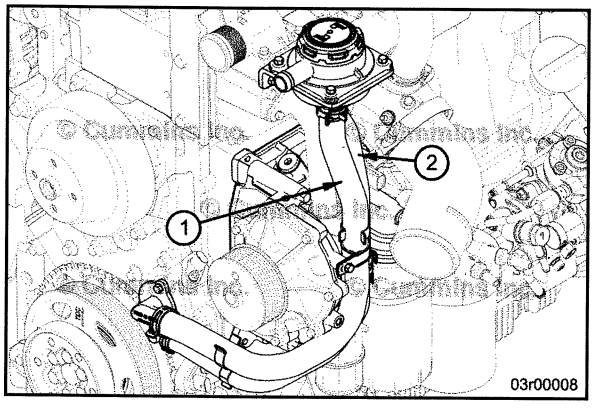


Preparatory Steps

⚠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. See equipment manufacturer service information.



Remove

Remove the crankcase ventilation hoses (1) and crankcase oil drain line (2) from the crankcase breather adapter.

- Refer to Procedure 003-026 in Section 3.
- Refer to Procedure 003-037 in Section 3.

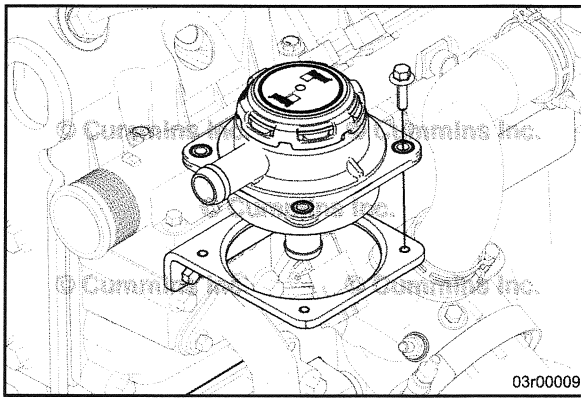
Remove the crankcase breather tube. Refer to Procedure 003-018 in Section 3.

Remove the four capscrews attaching the open crankcase ventilation valve to the bracket.

Remove the ventilation valve from the mounting bracket.

NOTE: Engines equipped with front sump oil pans have the lubricating oil dipstick tube support bracket attached to the crankcase ventilation valve mounting bracket.

Remove the P-clip and mounting capscrew.

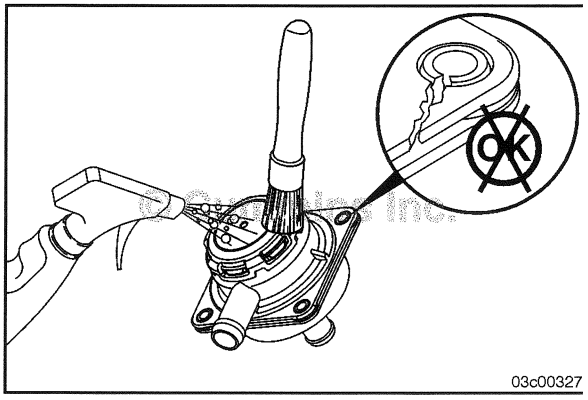


Clean and Inspect for Reuse

Use hot, soapy water and a soft brush to clean the crankcase ventilation valve.

NOTE: Only clean the outside of the valve. Do **not** submerge in water/solvent.

Inspect the crankcase ventilation valve for cracks or other damage. Replace if necessary.



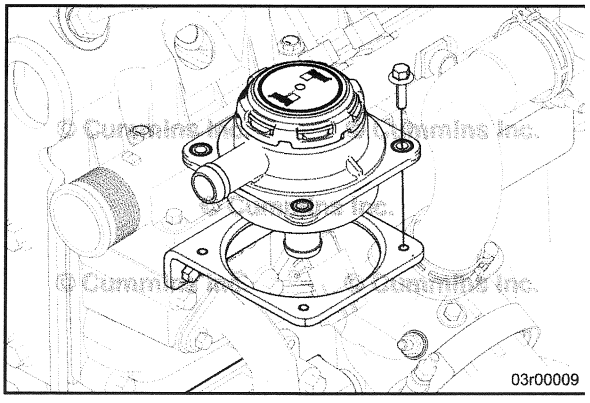
Install

Install the ventilation valve to the mounting bracket and tighten the four capscrews.

NOTE: Make sure to use the proper orientation of the ventilation valve upon installation, as illustrated.

Torque Value: 7.4 N•m [65 in-lb]

NOTE: Engines equipped with front sump oil pans have the lubricating oil dipstick tube support bracket attached to the crankcase ventilation valve mounting bracket.



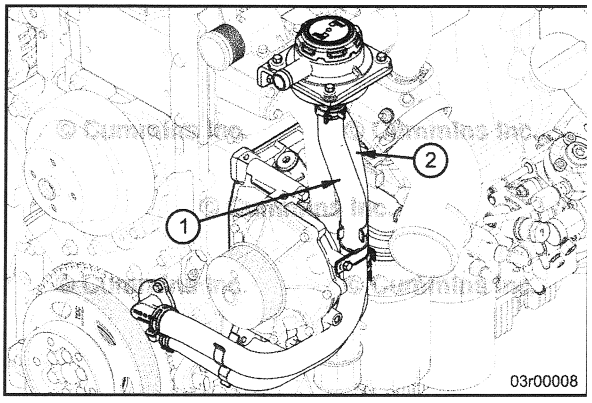
Install the P-clip and mounting capscrew.

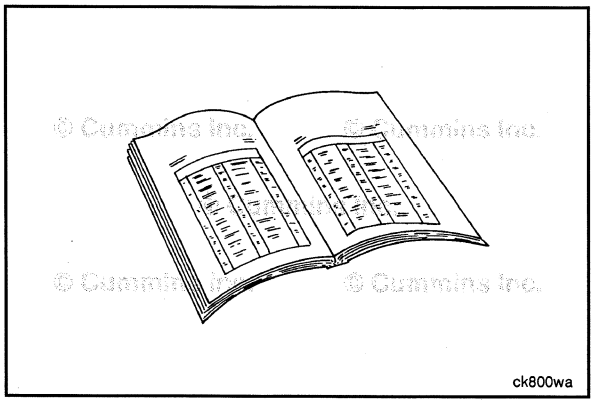
Torque Value: 7.4 N•m [65 in-lb]

Install the crankcase ventilation hoses (1) and crankcase oil drain line (2) to the open crankcase ventilation valve.

- Refer to Procedure 003-026 in Section 3.
- Refer to Procedure 003-037 in Section 3.

Install the crankcase breather tube. Refer to Procedure 003-018 in Section 3.



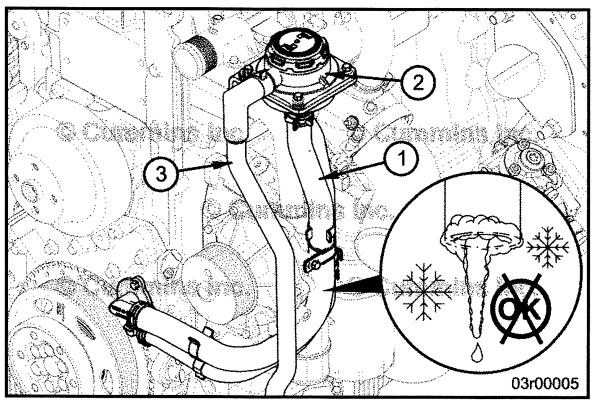


Finishing Steps

⚠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. See equipment manufacturer service information.
- Operate the engine and check for leaks.

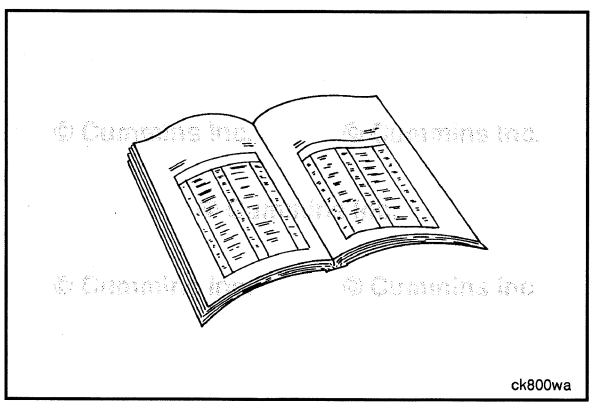


Open Crankcase Ventilation Hoses (003-026)

General Information

The engine uses an external open crankcase ventilation system. The open crankcase ventilation system provides aerosol filtering of crankcase emissions, commonly known as blowby. The open crankcase ventilation system vents the gases back into the atmosphere

The crankcase ventilation hose (1) is connected to the crankcase ventilation valve (2) and is used to vent the filtered crankcase gases to the atmosphere through the crankcase breather tube (3). The breather tube **must** remain free of any obstructions such as sludge, debris or ice buildup in order for the crankcase breather system to function properly. Use the following procedure for information for the open crankcase breather oil drain hose and check valve. Refer to Procedure 003-037 in Section 3.



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. See equipment manufacturer service information.

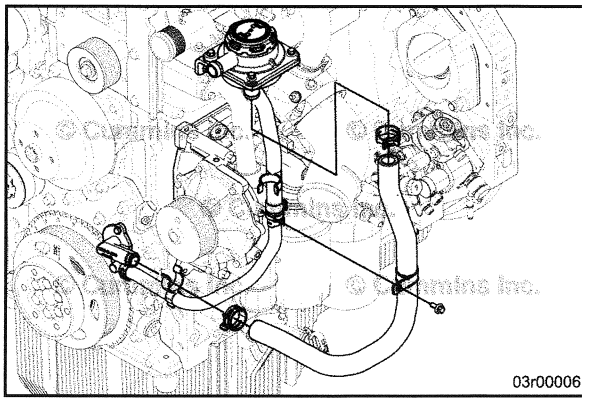
Remove

Remove any fasteners securing the crankcase ventilation hose to the engine.

Remove the spring clamps.

Remove the P-clip mounting capscrew.

Remove the open crankcase ventilation system hose.



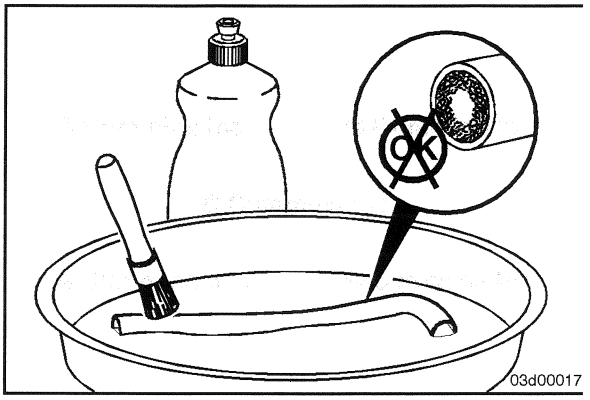
Clean and Inspect for Reuse

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Inspect the crankcase ventilation hose internally for obstructions or sludge buildup. Blockages **must** be removed to reduce the possibility of crankcase pressure buildup.

If a blockage is found, the crankcase ventilation hose(s) **must** be cleaned with a strong solution of detergent and water, or replaced.

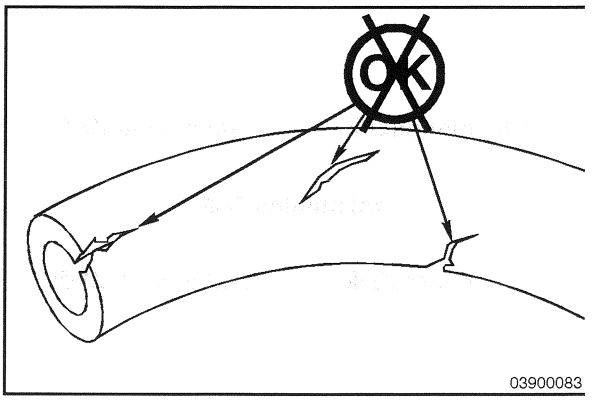
Dry the hose(s) with compressed air.



Check the crankcase ventilation hose(s) for other debris which could obstruct the hose(s).

Check the hose(s) for cracks and other damage.

Replace the crankcase ventilation hose(s) if any damage is found.



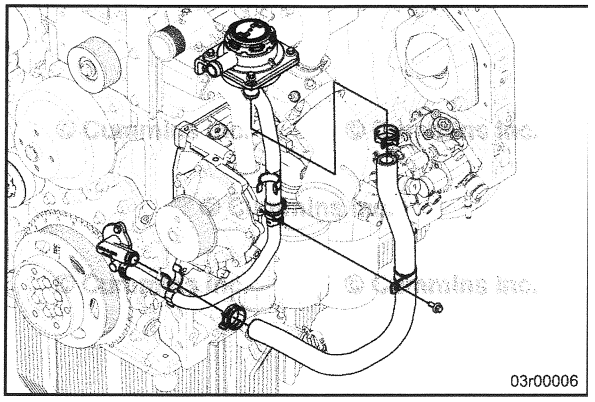
Install

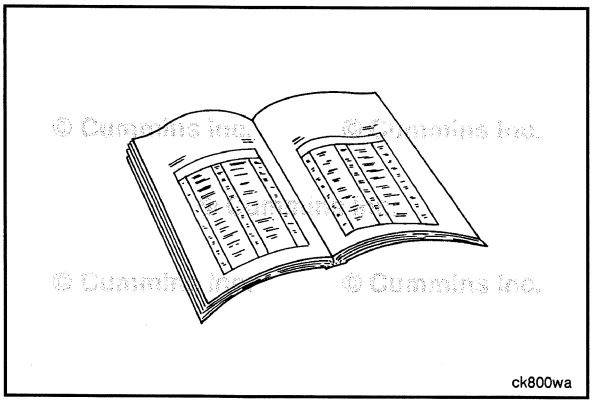
Install the open crankcase ventilation system hose.

Install the spring clamps.

Install the P-clip mounting capscrew.

Torque Value: 7.4 N•m [65 in-lb]



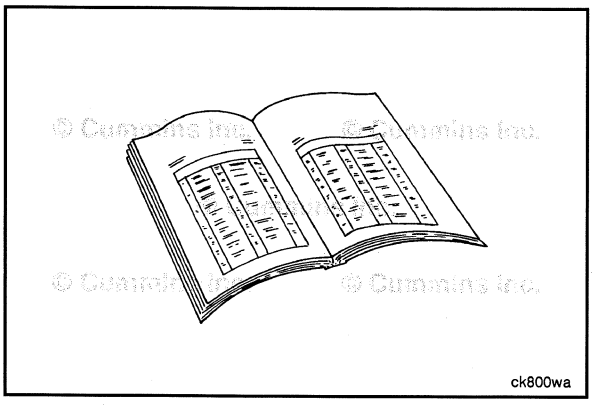


Finishing Steps

⚠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. See equipment manufacturer service information.
- Operate the engine and check for leaks.



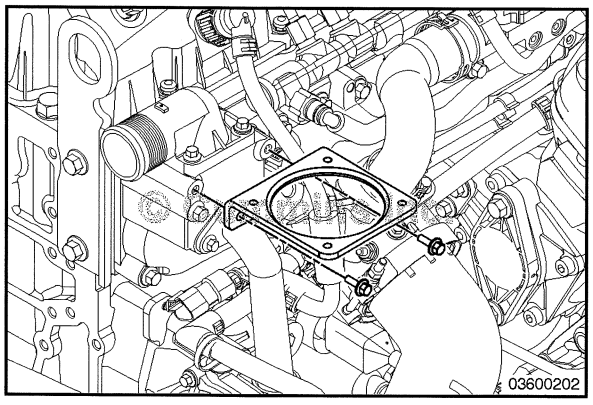
Crankcase Breather Bracket (003-027)

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. See equipment manufacturer service information.
- Remove the crankcase ventilation valve. Refer to Procedure 003-025 in Section 3.



Remove

Remove the two capscrews from the breather mounting bracket and remove the bracket.

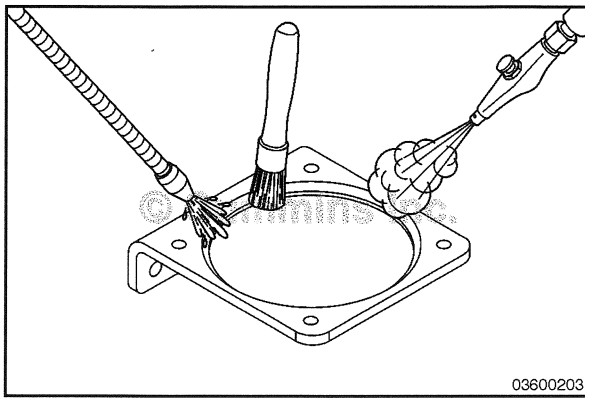
Clean and Inspect for Reuse

⚠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.

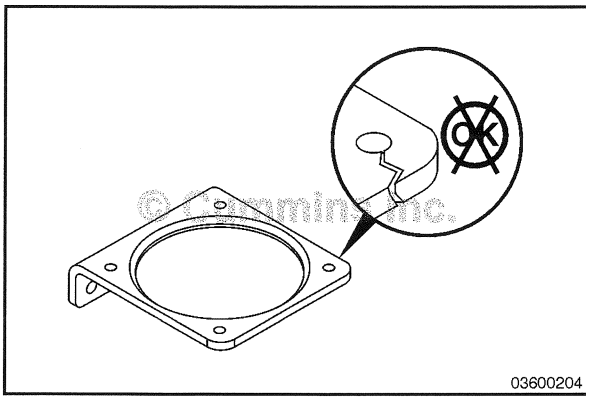
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the crankcase breather mounting bracket with solvent.

Dry with compressed air.



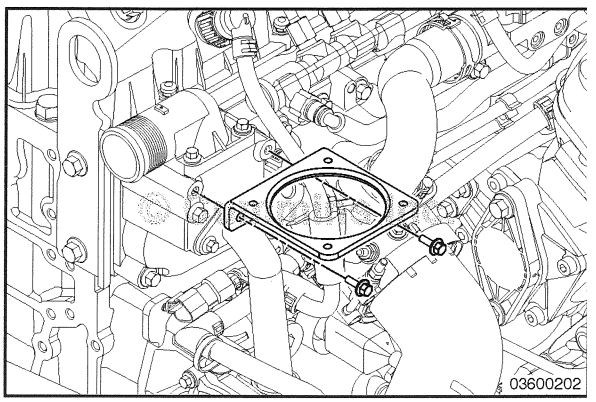
Inspect the crankcase breather mounting bracket for cracks or other damage.

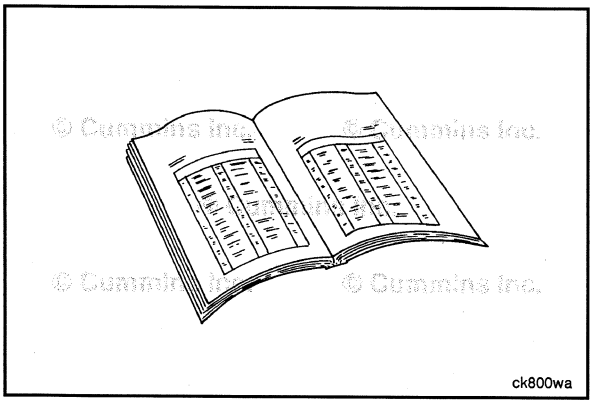


Install

Install the breather bracket onto the intake manifold with two capscrews.

Torque Value: 7.4 N•m [65 in-lb]



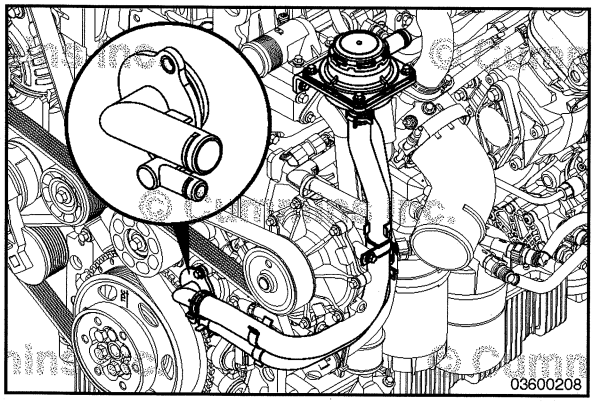


Finishing Steps

⚠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 ventilation valve. Refer to Procedure 003-025 in Section 3.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.



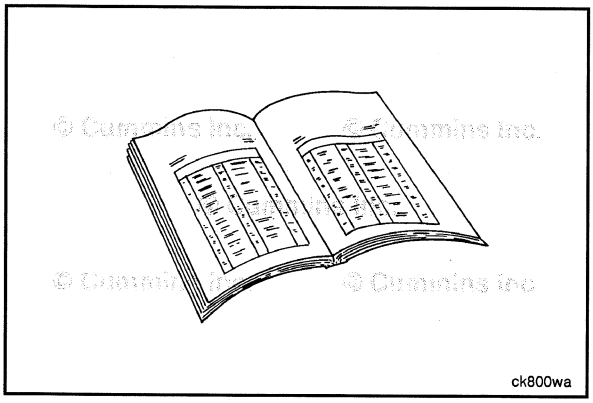
Crankcase Breather Adapter (003-031)

General Information

The engine is equipped with an open crankcase ventilation system. The open crankcase ventilation valve is used to:

- Separate oil from the crankcase gases.
- Regulate the pressure in the crankcase.
- Prevent the engine and turbocharger from consuming oil in the event that the engine air filter becomes too restricted.

NOTE: This component is also used to seal the camshaft to the front cover.



Preparatory Steps

⚠WARNING⚠

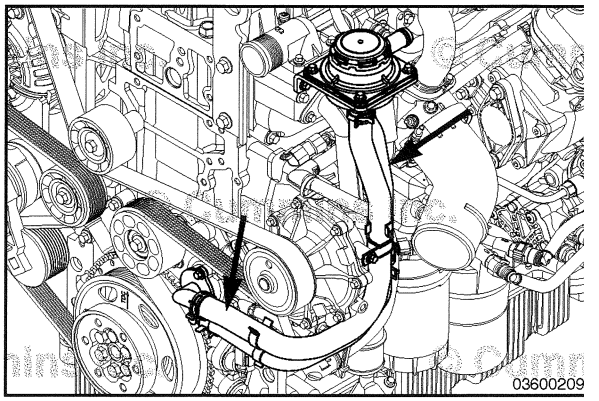
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. See equipment manufacturer service information.

Remove

Remove the open crankcase ventilation hoses and open crankcase oil drain line from the crankcase breather adapter.

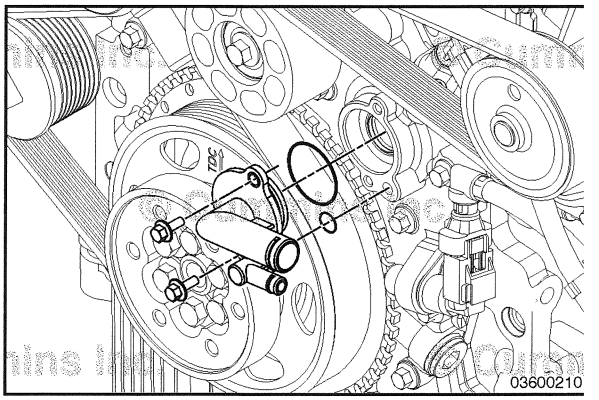
- Refer to Procedure 003-026 in Section 3.
- Refer to Procedure 003-037 in Section 3.



Remove the two mounting capscrews from the crankcase breather adapter.

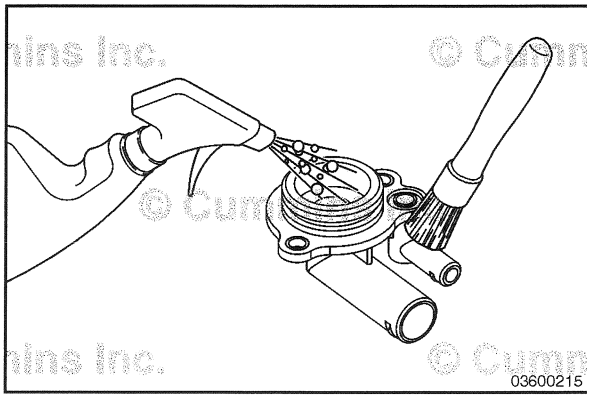
Remove the crankcase breather adapter from the front cover.

Discard the o-rings.

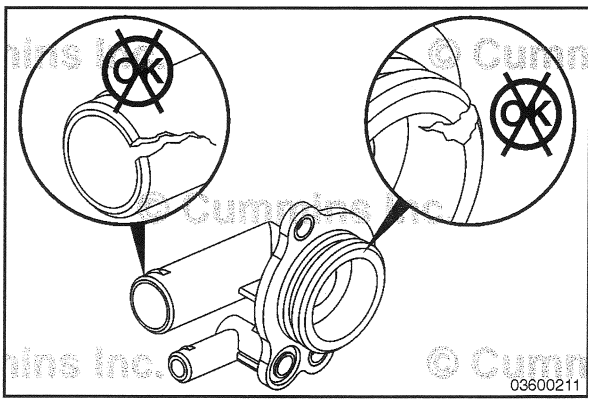


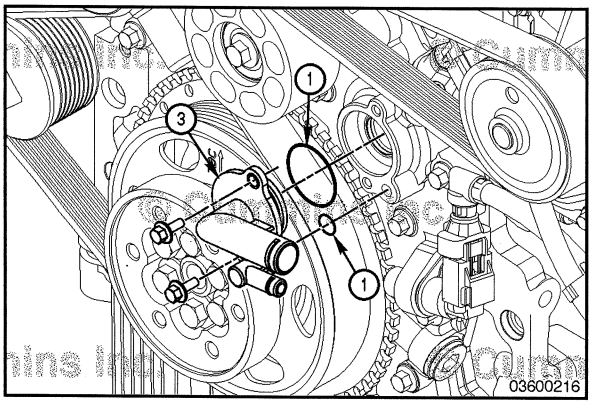
Clean and Inspect for Reuse

Use hot soapy water and a soft brush to clean the crankcase breather adapter.



Inspect the crankcase breather adapter for cracks or other damage. Replace if necessary.





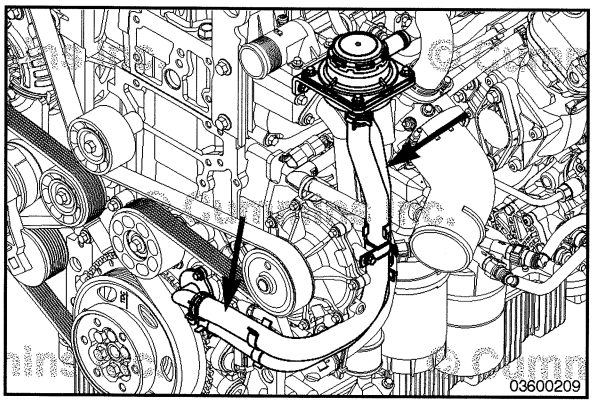
Install

Lubricate the o-ring (1) with clean lubricating oil and install it into the groove of the crankcase breather adapter (3).

Apply Loctite™ 406 or equivalent, to the o-ring (2) and bond it to the crankcase breather adapter (3).

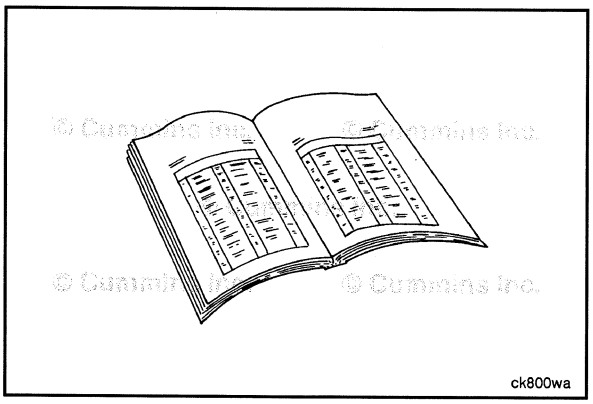
Install the breather adapter to the front cover and tighten the two capscrews.

Torque Value: 7.5 N•m [66 in-lb]



Install the crankcase breather adapter hoses and crankcase oil drain line to the open crankcase ventilation valve.

- Refer to Procedure 003-026 in Section 3.
- Refer to Procedure 003-037 in Section 3.

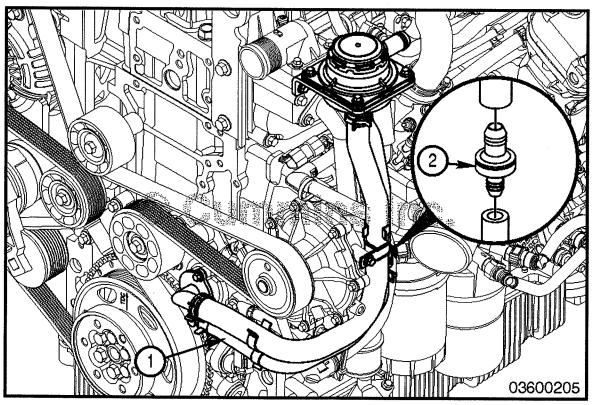


Finishing Steps

⚠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. See equipment manufacturer service information.
- Operate the engine and check for leaks.



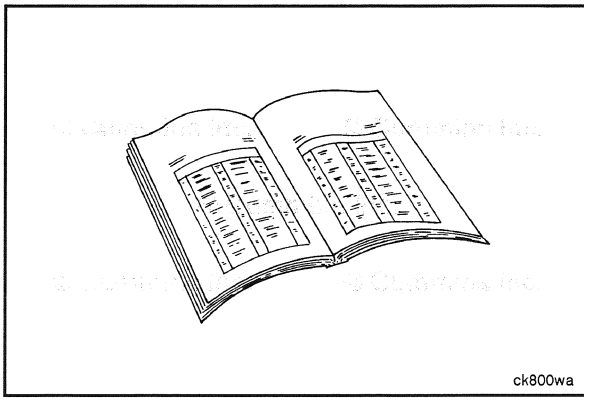
Crankcase Breather Oil Drain Line (003-037)

General Information

The engine is equipped with an open crankcase ventilation system. The closed crankcase oil drain line (1) returns oil to the crankcase through the crankcase breather adapter from the crankcase ventilation valve.

The crankcase ventilation system oil drain line also contains a check valve (2).

Preparatory Steps

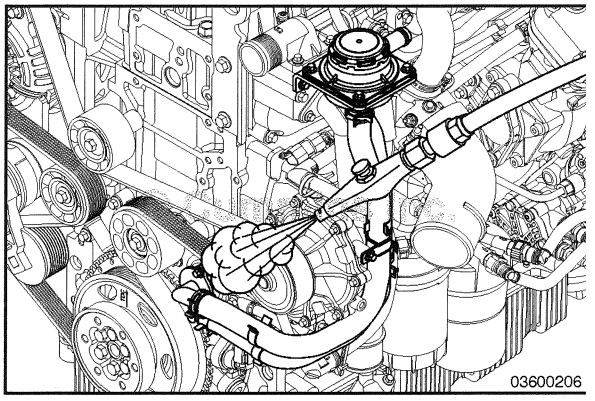


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

- Disconnect the batteries. See equipment manufacturer service information..

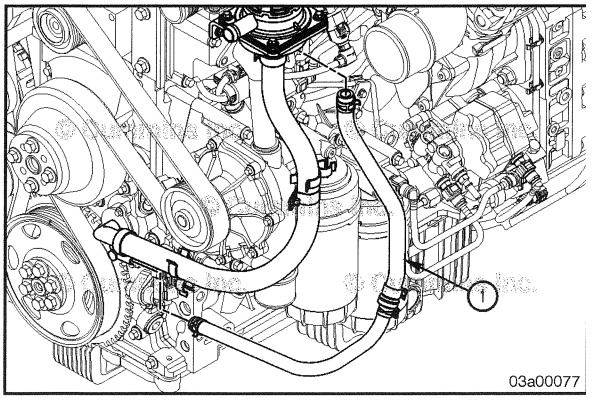
Clean the area around the crankcase breather adapter and crankcase ventilation valve with compressed air.



Remove

Remove all hose clamps attaching the crankcase oil drain line (1) to the engine.

Remove the crankcase oil drain line that attaches to the crankcase breather adapter and crankcase ventilation valve outlet.



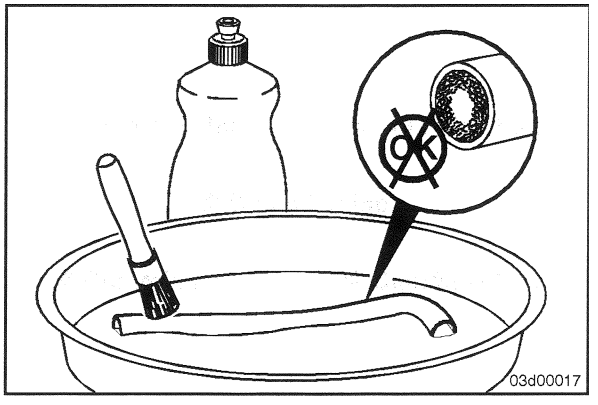
Clean and Inspect for Reuse

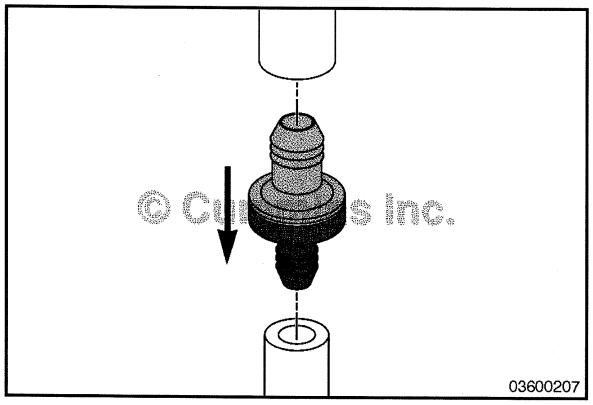
Check the crankcase breather oil drain line internally for obstructions or sludge buildup.

Use hot, soapy water and a soft brush to clean the closed crankcase oil drain. Dry with compressed air.

Inspect the crankcase ventilation oil drain line for cracks or other damage. Replace, if necessary.

NOTE: An obstructed drain line will lead to excessive crankcase pressure.

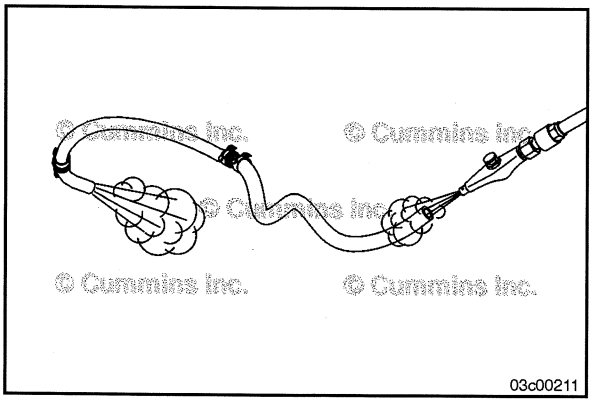




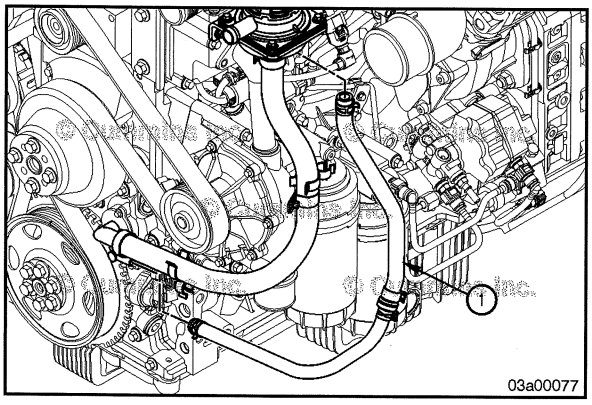
Clean the breather oil drain line check valve with solvent.

Dry with compressed air.

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: If it is necessary to replace the check valve, be sure the direction of the flow arrow is pointed downward.

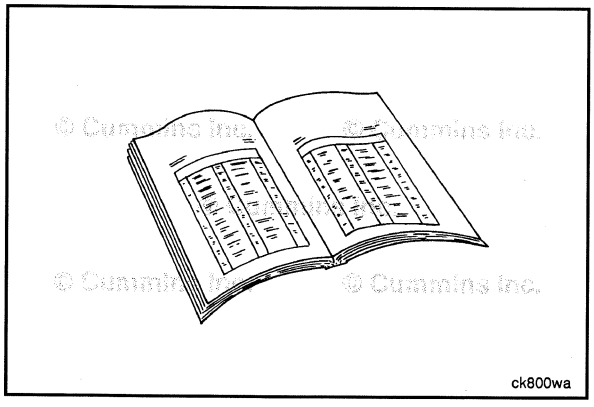


Install

Install the check valve with the black end down (toward the oil pan) and the gray end up (toward the ventilation valve).

Install the crankcase ventilation oil drain line (1) and the clamps that attach to the crankcase breather adapter and the crankcase ventilation valve outlet.

Torque Value: 7.5 N•m [66 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. See equipment manufacturer service information.
- Operate the engine and check for leaks.

Section 4 - Cam Followers/Tappets - Group 04

Section Contents

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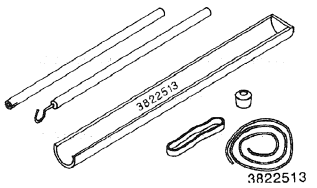
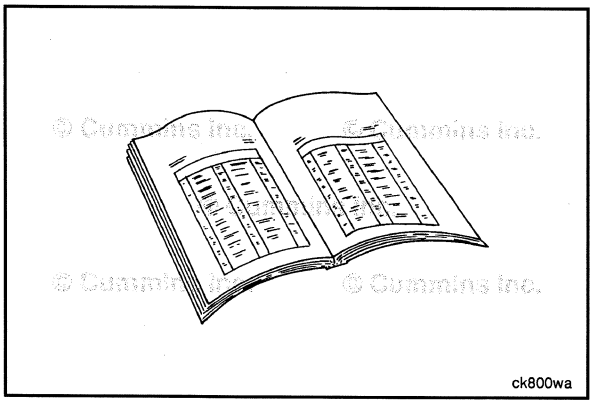
Service Tools

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.

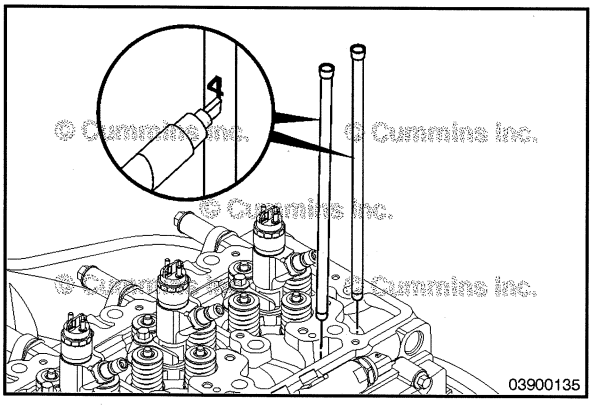
Tool No.	Tool Description	Tool Illustration
3822513	**Tappet Replacement Kit** Used to remove and install valve tappets.	



Push Rods or Tubes (004-014)

Preparatory Steps

- 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.

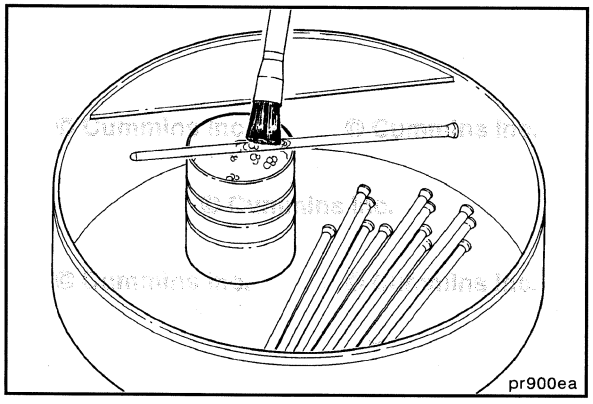


Remove

NOTE: The push rods **must** be installed in their original location and position.

Mark the push rods to identify their location.

Remove the push rods.

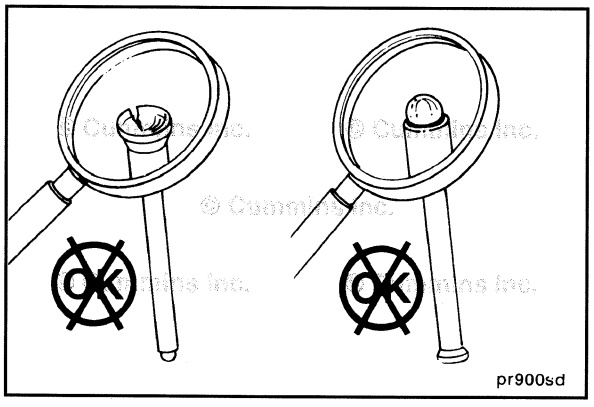


Clean and Inspect for Reuse

⚠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.



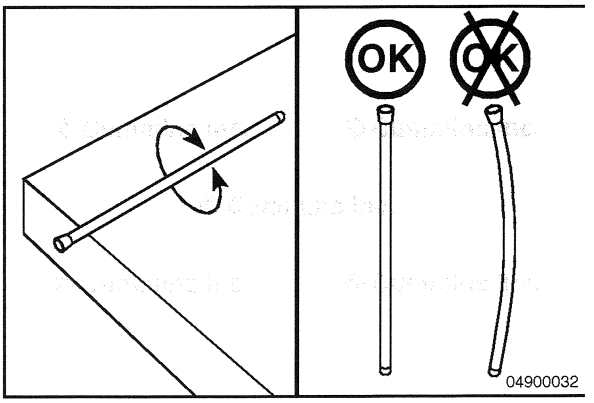
Inspect both ends of the push rods for wear, scoring, or other damage.

Check for cracks where the ball and the socket are pressed into the tube.

⚠CAUTION⚠
Do not use or try to straighten a bent push rod. The use of a bent push rod can cause engine damage.

Check the straightness of the push rod by rolling it on a level surface.

Replace the push rod if it is bent.

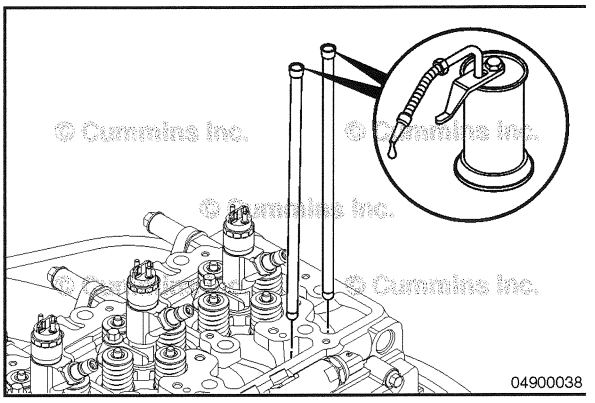


Install

NOTE: The push rods **must** be installed in their original location and position.

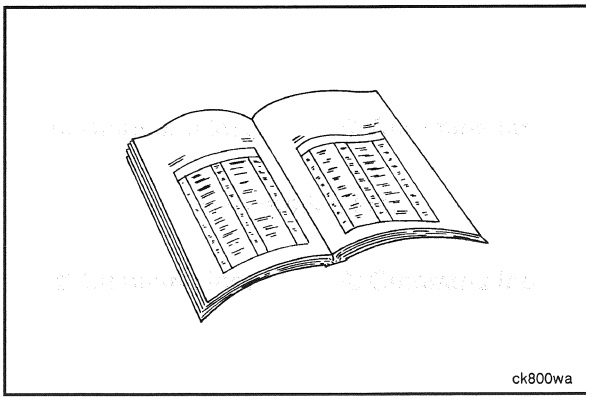
Install the push rods into the sockets of the valve tappets.

Lubricate the push push rod sockets with clean 15W-40 engine oil.



Finishing Steps

- Install the crossheads and rocker levers. Refer to Procedure 003-008 in Section 3.
- Adjust the valves. Refer to Procedure 003-004 in Section 3.
- Install rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Operate the engine and check for leaks.

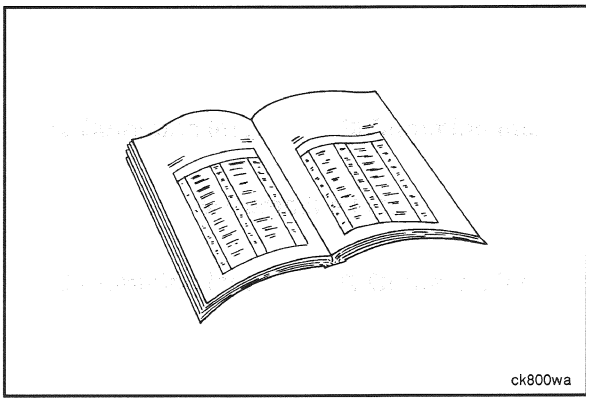


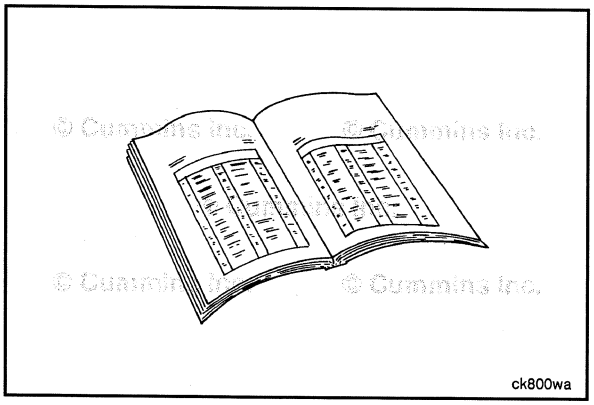
Tappet (004-015)

General Information

NOTE: Due to limited accessibility for camshaft removal, in most applications it will be necessary to remove the engine from the vehicle chassis.

NOTE: The following procedure is for an engine in the upright position and using the standard valve tappet removal tool. If the engine is mounted on an engine rollover stand and inverted with the cylinder head mating surface facing down, the tappets can be replaced without using the special tappet removal tool.

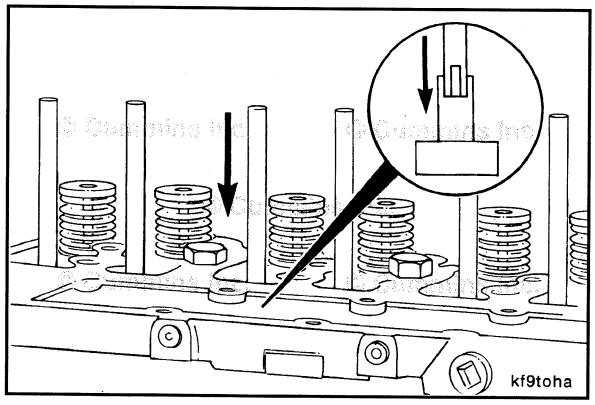




Preparatory Steps

⚠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. See equipment manufacturer service information.
- Remove the engine. Refer to Procedure 000-001 in Section 0.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the push rods or tubes. Refer to Procedure 004-014 in Section 4.

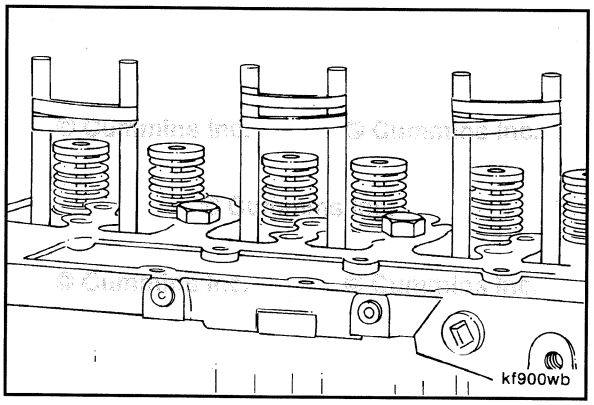


Remove

Use tappet removal tool kit, Cummins® Part Number 3822513, to remove the tappets.

Push a wooden dowel rod into each tappet. It will probably be necessary to push the dowel into the tappet with a soft-face hammer.

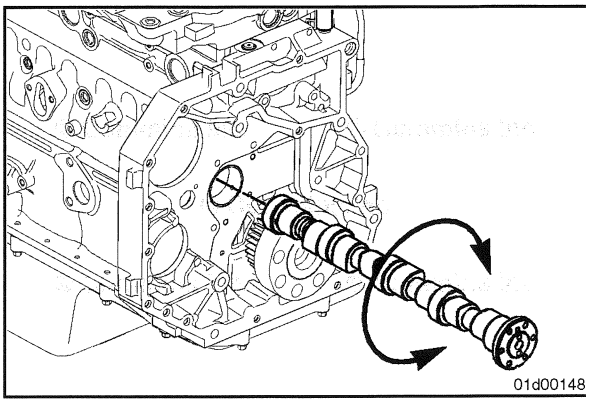
NOTE: When properly installed, the dowels can be used to pull the tappets up and should require considerable effort to be pulled out.



Pull each valve tappet up until it makes contact with the cylinder block. Put a rubber band around two dowels. This will hold the tappets up off the camshaft.

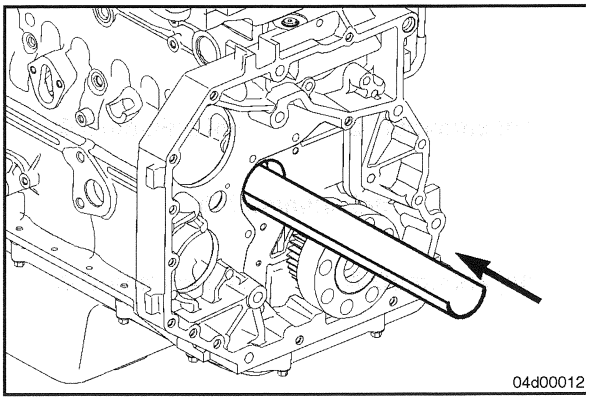
NOTE: The camshaft **must** be removed from the flywheel end of the engine.

Remove the camshaft. Refer to Procedure 001-008 in Section 1.



NOTE: Make sure the trough is positioned so that it will catch the tappet when the wooden dowel is removed.

Insert the trough from the tappet replacement kit, Cummins® Part Number 3822513, to the full length of the cam bore.

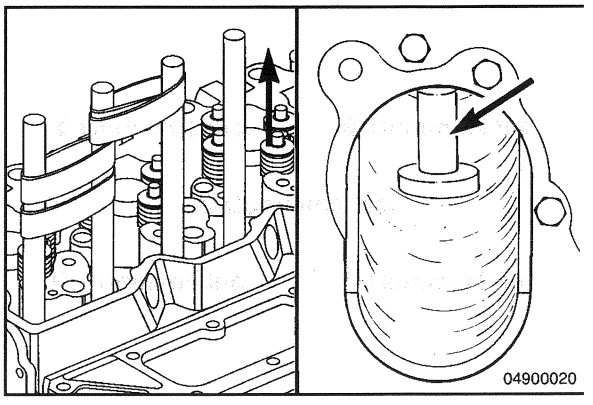


Only remove one tappet at a time.

Mark the position of the tappets as they are removed. The tappets **must** be installed in the same position when the engine is assembled.

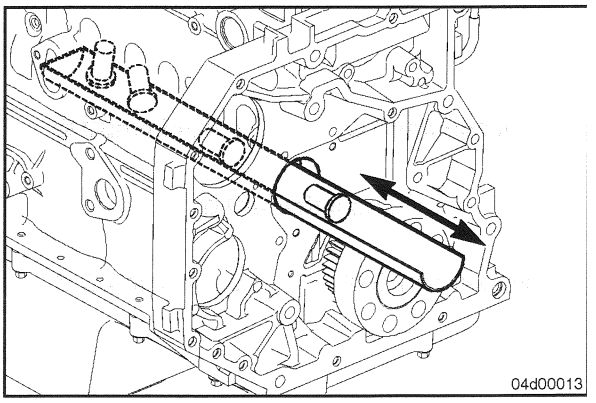
Remove the rubber band from the two companion tappets.

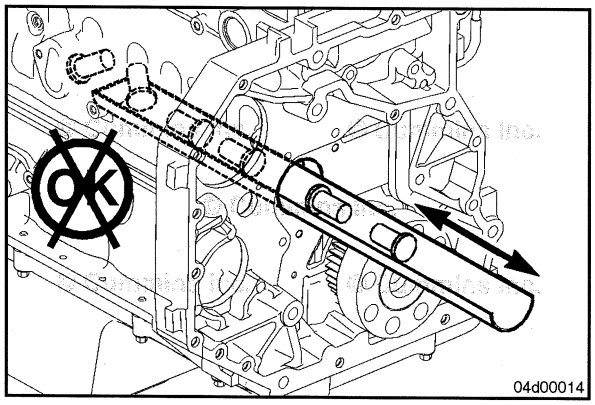
Secure the tappet that is **not** to be removed with the rubber band.



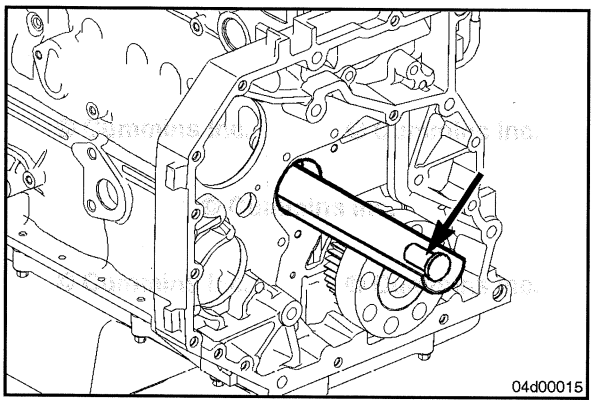
NOTE: When the tappet is dropped into the trough, most of the time it will fall over. However, if it does **not**, gently shake the trough just enough to allow the tappet to fall over before removing.

Pull the wooden dowel from the tappet bore, allowing the tappet to fall into the trough.

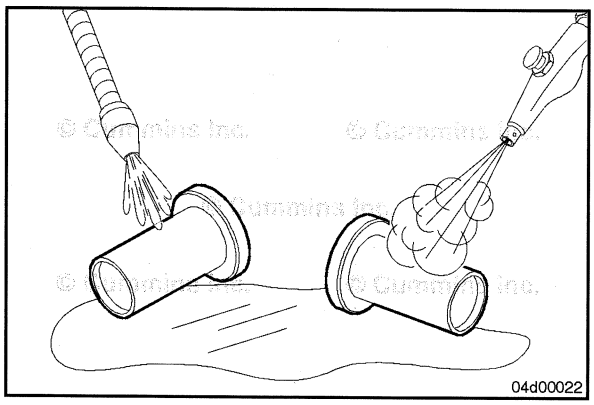




Take special care **not** to knock or shake the tappets over the end of the trough.



Carefully pull the trough and tappet from the camshaft bore, and remove the tappet. Repeat the process until all tappets are removed.



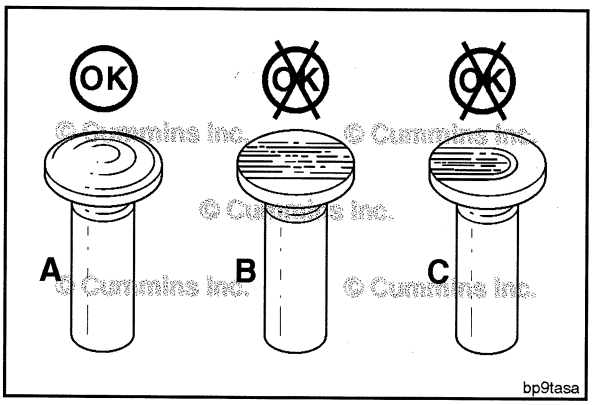
Clean and Inspect for Reuse

⚠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 tappets with solvent.

Dry with compressed air.



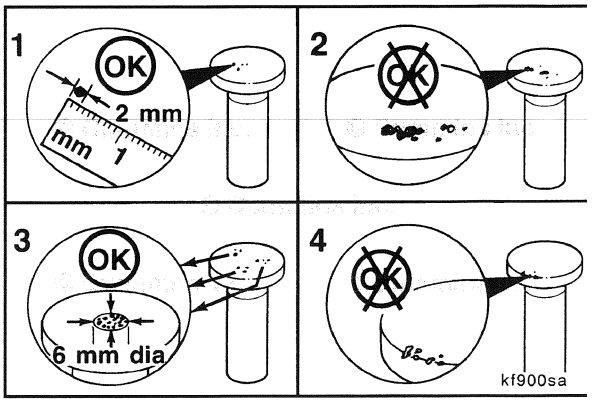
Inspect the socket, stem, and face for excessive wear, cracks, and other damage.

- Normal contact (exaggerated).
- Irregular contact - do **not** reuse.
- Irregular contact - do **not** reuse.

The following criteria define the size of pit marks on the tappet face that are acceptable.

- A single pit can **not** be greater than 2 mm [0.079 in].
- Interconnection of pits is **not** allowed.
- Total pits when added together should **not** exceed 6-mm [0.236-in] diameter or a total of 4 percent of the tappet face.
- No pitting is allowed on the edges of the wear face of the tappet.

For detailed illustrations and reuse guidelines, refer to Service Bulletin, Camshaft and Tappet Reuse Guidelines, Bulletin 3666475.

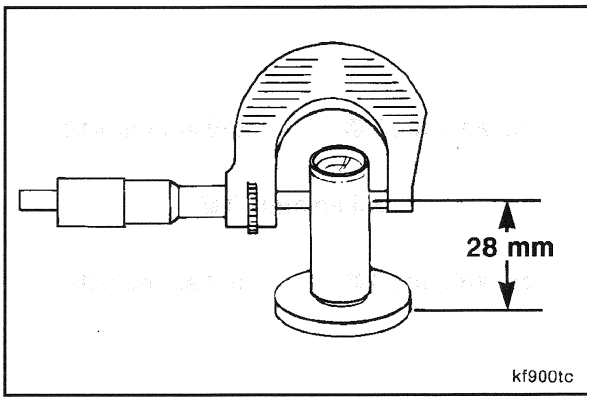


Measure the valve tappet stem.

Valve Tappet Stem Diameter

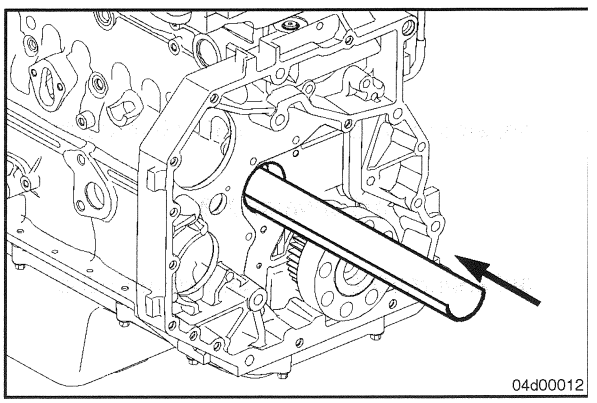
mm		in
15.936	MIN	0.627
15.977	MAX	0.629

If the tappet stem is **not** within specifications, replace the tappet. Make sure to inspect the tappet bore for wear. Refer to Procedure 001-026 in Section 1.

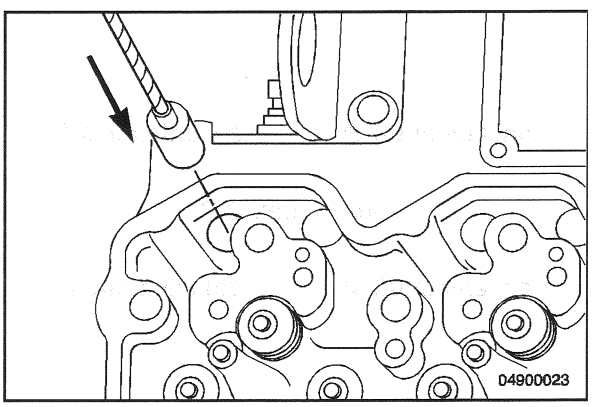


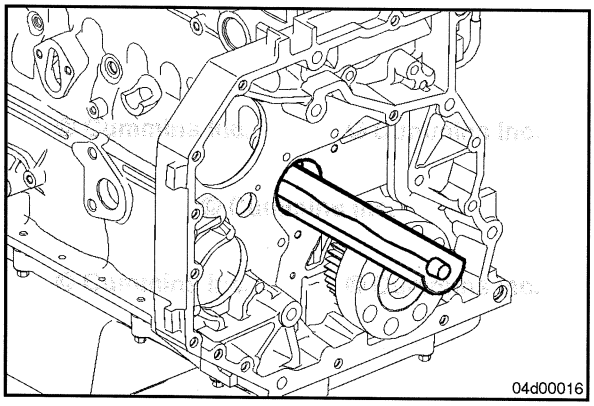
Install

Insert the trough from the tappet replacement kit, Cummins® Part Number 3822513, the full length of the cam bore.



Lower the tappet installation tool down through the push tube hole, through the tappet bore, and into the trough.

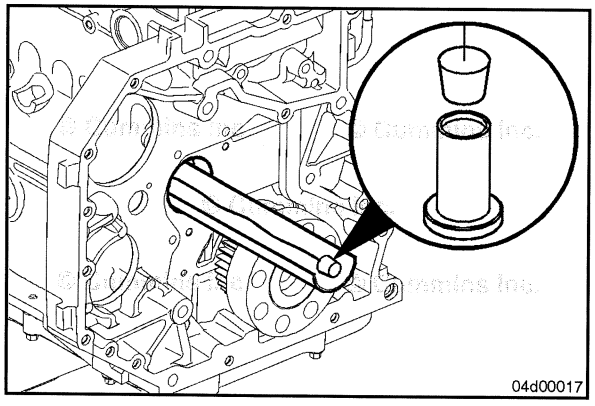




Feed the installation tool through the camshaft bores by carefully pulling the trough/installation tool out the rear of the engine. The barrier at the rear of the trough will pull the tool out **most** of the time.

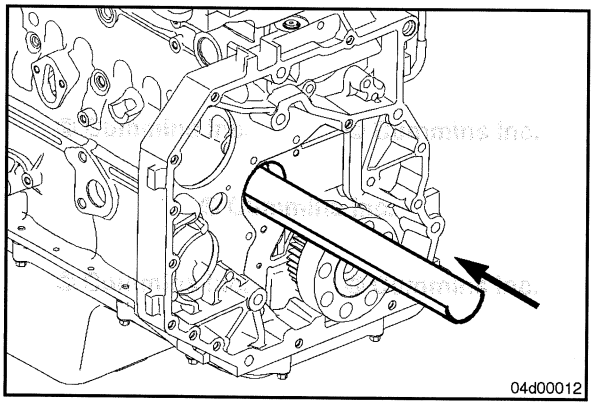
NOTE: The tappets must be installed in the same positions as removed.

Lubricate the tappets with assembly lubricant, Cummins® Part Number 3163087, or equivalent.



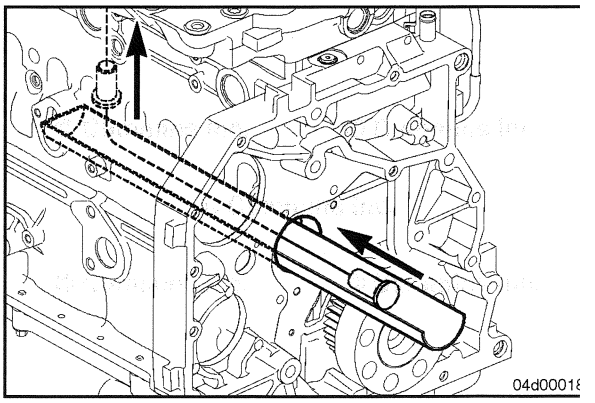
To aid in removing the installation tool after the tappet is installed, work the tool in and out of the tappet several times **before** installing the tappets.

Insert the installation tool into the tappet.



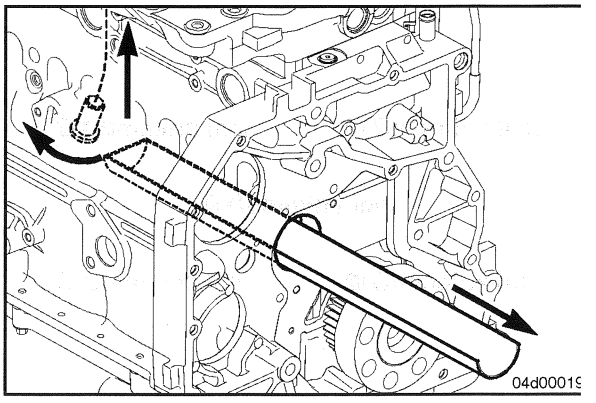
Slide the trough into the camshaft bore.

Pull the tool and tappet through the camshaft bore and up into the tappet bore.

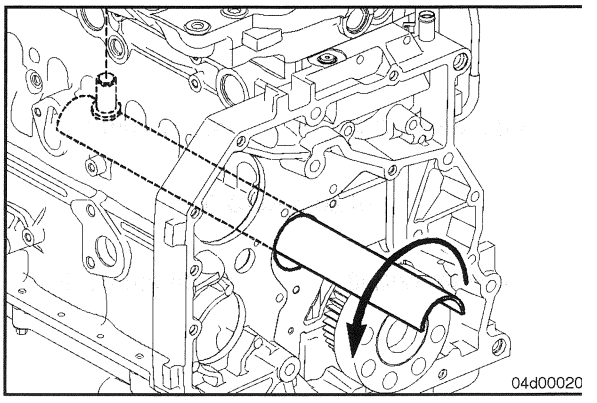


If difficulty is experienced in getting the tappet to make the bend from the trough up to the tappet bore, pull the trough out enough to allow the tappet to drop down and align itself.

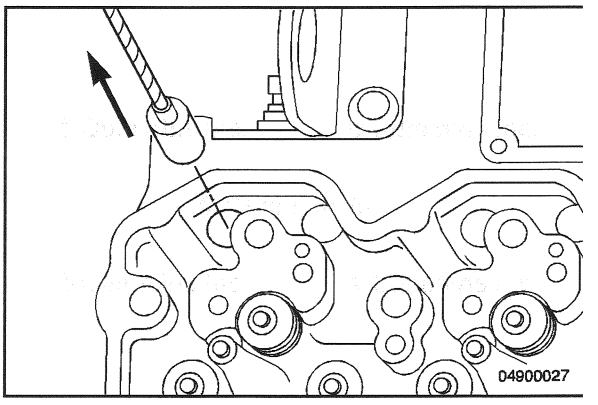
Pull the tappet up into the bore.

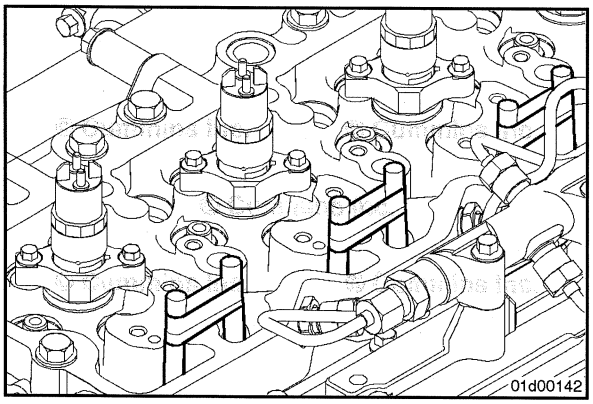


After the tappet has been pulled up into position, slide the trough back into the camshaft bore, and rotate it ½ of a turn. This will position the round side of the trough up, which will hold the tappet in place.



Remove the installation tool from the tappet.

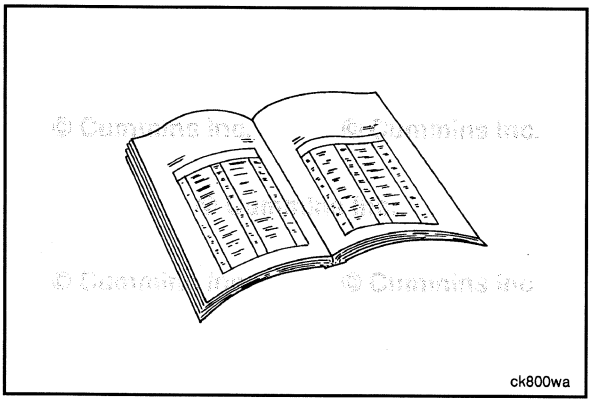




Install a wooden dowel into the top of the tappet.

Wrap rubber bands around the wooden dowels to secure the tappets.

Repeat this process until all tappets have been installed.



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 camshaft. Refer to Procedure 001-008 in Section 1.
- Install the push rods or tubes. Refer to Procedure 004-014 in Section 4.
- 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 engine. Refer to Procedure 000-002 in Section 0.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.

Section 5 - Fuel System - Group 05

Section Contents

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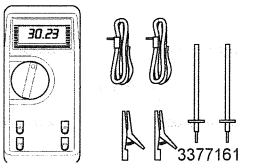
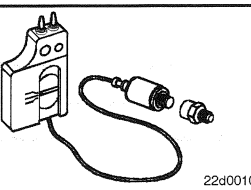
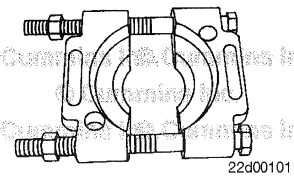
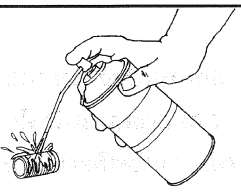
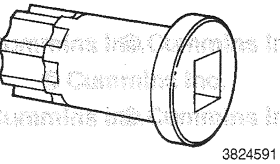
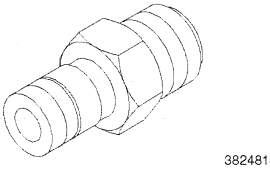
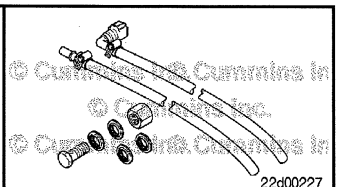
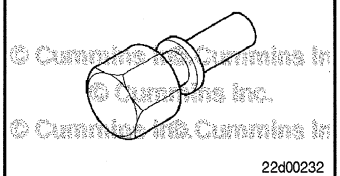
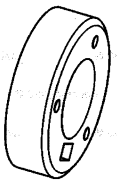
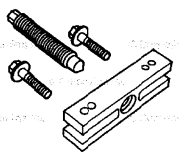
Service Tools

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
3164489	**Digital Multimeter** Used to measure electrical circuits: Voltage (volts), resistance (ohms), and current (amps). 3164489 - Automotive meter with built in temperature adapter and tachometer.	
3164491	**Pressure/Vacuum Module** Used to measure fuel pressure and restriction.	
3375326	**Bearing Separator Tool** Used to remove the fuel pump gear.	
3824510	**Quick Dry (QD™) Cleaner** Used to clean parts and tools safely.	
3824591	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	
3824842	**Compuchek™ Fitting** Used to check fuel pressure/restriction. 10 mm o-ring connection.	

Tool No.	Tool Description	Tool Illustration
4918354	**Fuel Return Flow Tester Kit** Used to check injector and HPCR pump drain flow.	 22d00227
4918464	**Fuel Tube Plug** Used to plug low pressure fuel lines.	 22d00232
4919139	**Graduated Beaker** Used to measure fuel return flows.	 22d00140
5298632	**Fuel Pump Drive Gear Retention Tool** Use to secure fuel pump gear drive while removing or installing drive gear retaining nut.	 22d00147
ST 647	**Standard Gear Puller** Used to remove pulleys, impellers, and/or counterweights. Also used to assist in the removal of the camshaft gear.	 ad8toga

Engine Fuel Heater, Electric (005-008)

General Information

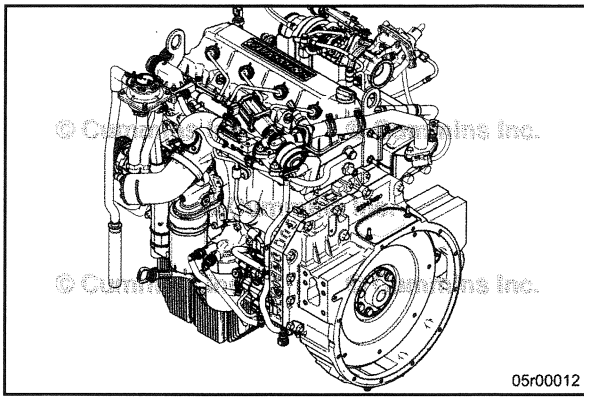
This procedure applies to all engines equipped with Cummins®/Fleetguard® fuel heaters.

NOTE: The fuel heater is **not** controlled by the engine control module (ECM). A bimetallic strip acts as a thermostat.

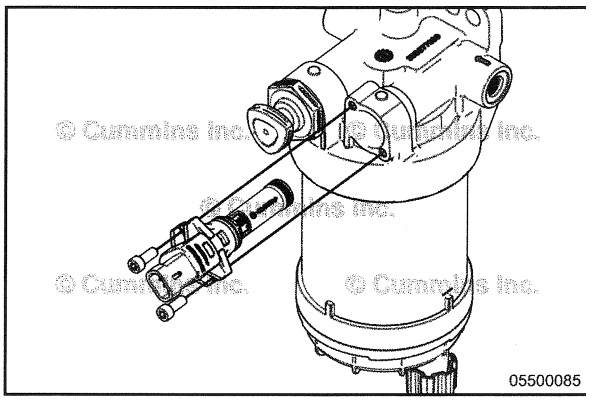
Fuel heater versions include 12 VDC and 24 VDC.

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].

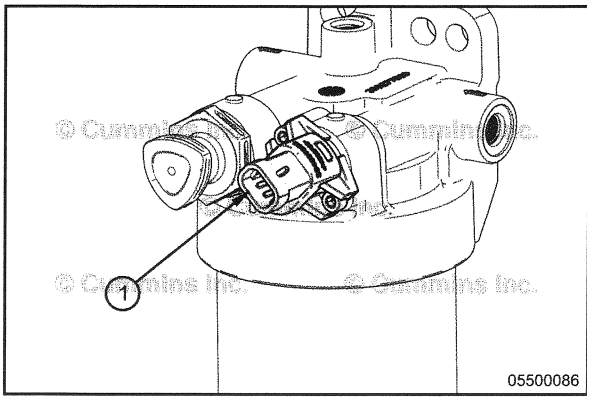


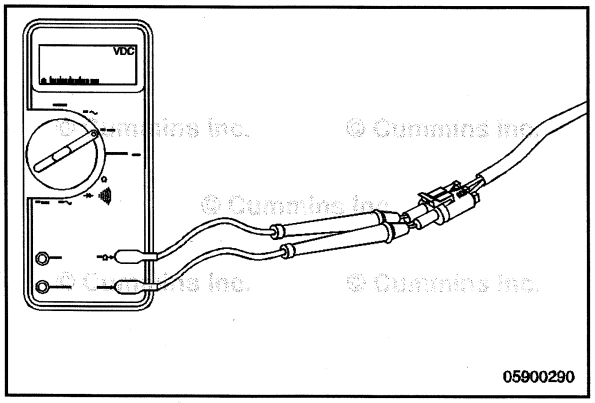
The fuel heater (stick type) is integrated into the remote mounted priming pump and is installed in the fuel filter head. The location of the priming pump/fuel filter will be determined by the original equipment manufacturer (OEM).



Test

Remove the connector from the fuel heater (1).





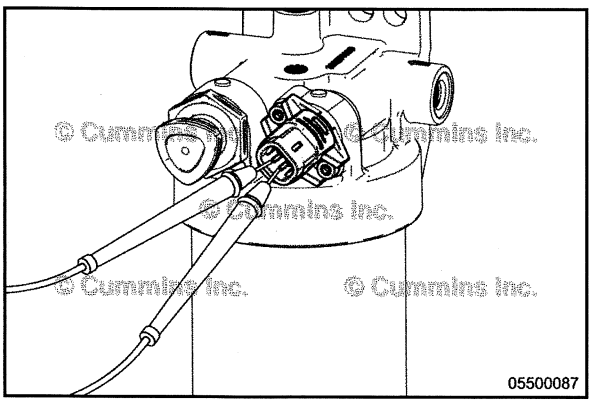
Check for proper voltage to the fuel heater at the OEM connector.

Fuel heater voltage:

12 volt system: 12-VDC

24 volt system: 24-VDC

If the voltage is **not** within specifications, see equipment manufacturer service information.



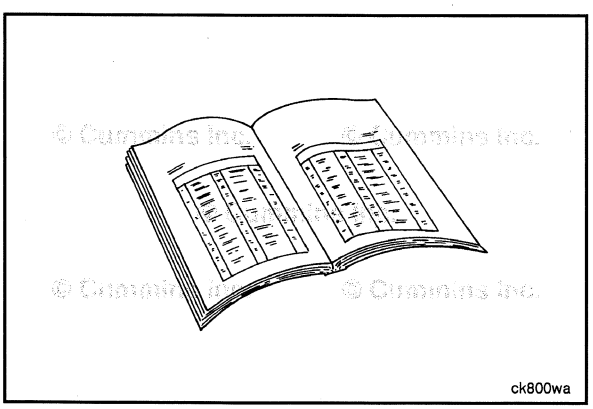
Measure the resistance across the two connector pins on the fuel heater connector.

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 if 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.

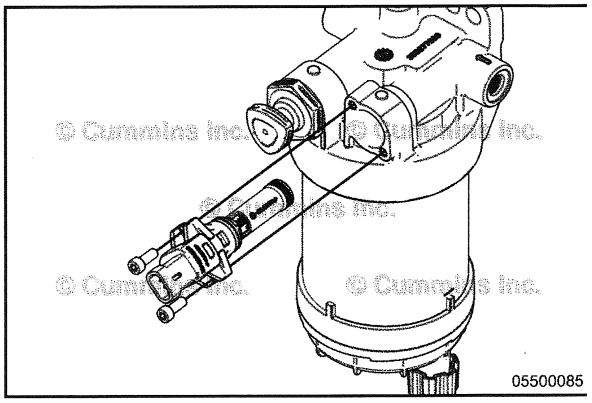
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

- Steam clean the fuel heater and area around the fuel heater. Dry with compressed air.
- Disconnect the battery cables. See equipment manufacturer service information.
- Disconnect all electrical connections.

Remove

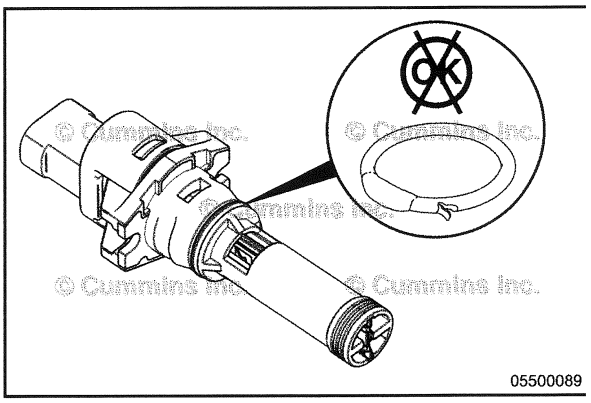
Remove the two bolts holding the fuel heater into the filter head.

Remove the fuel heater by pulling it out of the filter head.

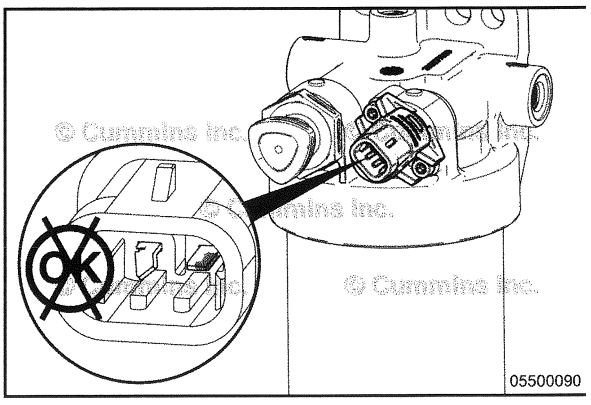


Clean and Inspect for Reuse

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

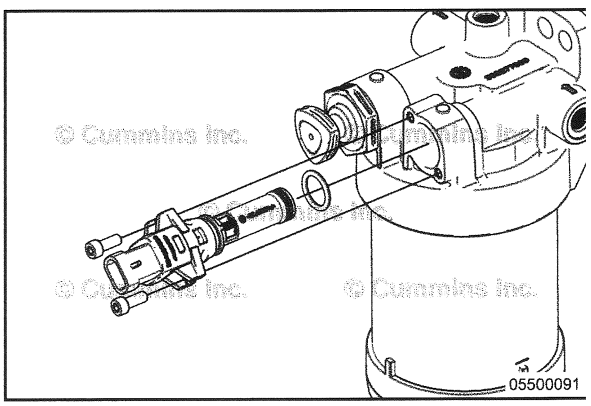
⚠CAUTION⚠
Make sure that no dirt or debris enters the fuel heater to prevent the passing of contaminants to the high-pressure fuel pump and injectors. Small amounts of dirt and debris can cause a malfunction of these components.

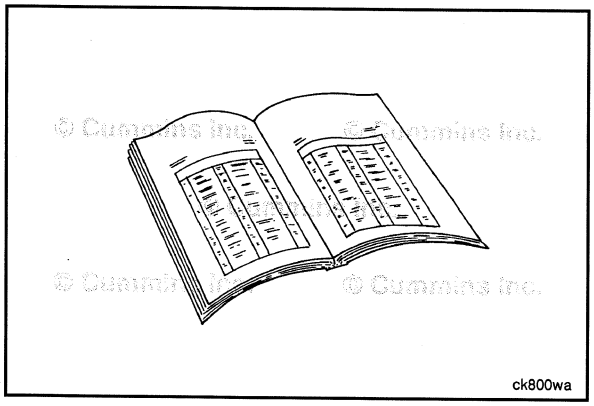
Install a new o-ring onto the fuel heater.

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]



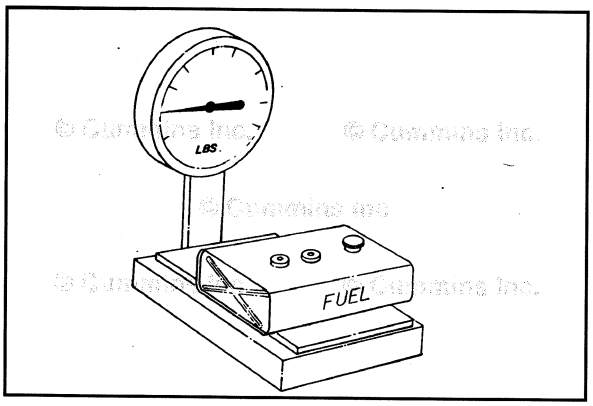


Finishing Steps

⚠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. See equipment manufacturer service information.
- Operate the engine and check for leaks.

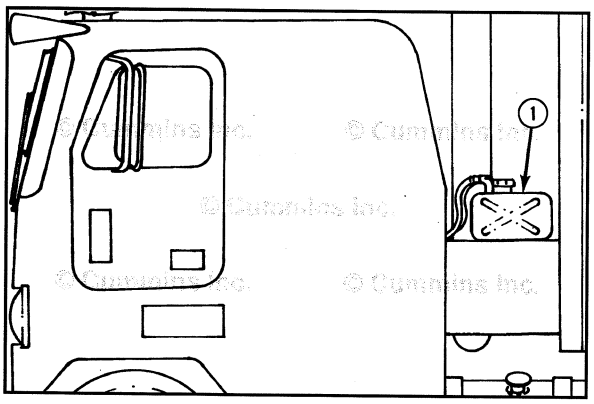


Fuel Consumption (005-010)

Measure

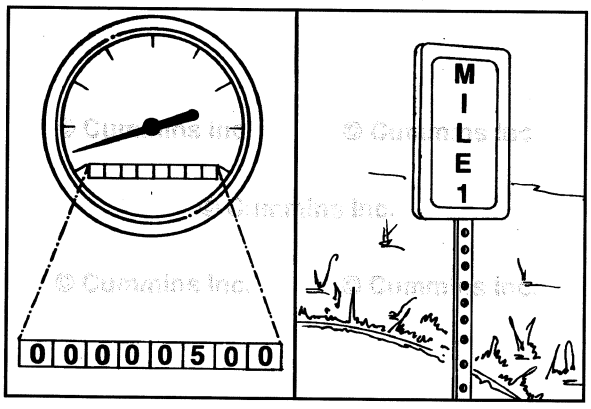
NOTE: The most accurate method of checking fuel consumption is to weigh the fuel used. Use a scale capable of measuring within 0.045 kg [0.1 lb] to weigh the fuel tank. Use a remotely mounted tank with enough capacity to run 80 km [50 mi].

Fill the fuel tank. Weigh the tank with the fuel. The weight of number 2 diesel fuel is nominally 0.844 kg per liter [7.03 lb per gal].



Install the remote tank (1).

Install the return fuel line to the test tank, or the results will **not** be accurate.



Measure the distance traveled with an accurate odometer. The odometer's accuracy can be checked by using measured kilometers [miles].

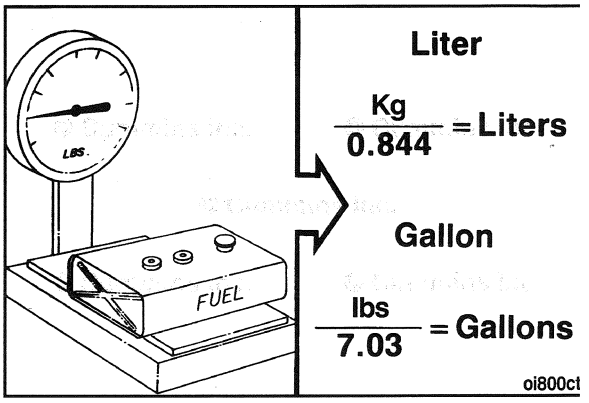
After traveling the route, remove the tanks, and weigh the remaining fuel. Compute the fuel used in liters [gallons] as required.

Compute the kilometers per liter or miles per gallon.

- Miles ÷ gallons = Miles per gallon
- Kilometers ÷ liters = Kilometers per liter

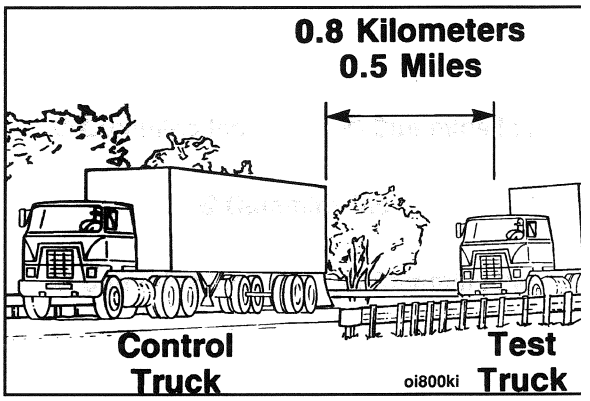
In addition to the measurement of the fuel used, the following factors provide points for running a test similar to the recognized Type II Society of Automotive Engineers (SAE) Fuel Test.

These procedures are helpful in determining differences in fuel consumption between two vehicles under the same environmental, road, and test conditions.

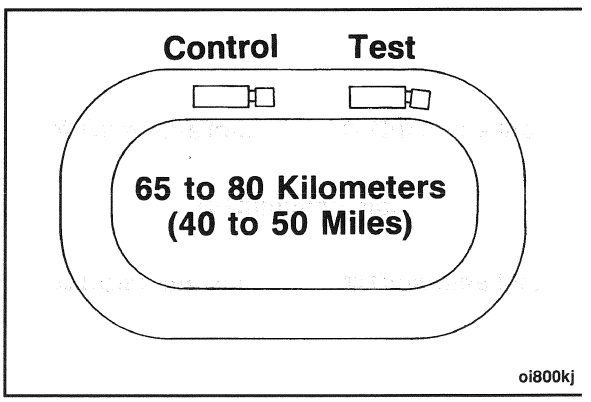


Perform the test with the test vehicle and a control vehicle. The control vehicle compensates for changes in traffic conditions.

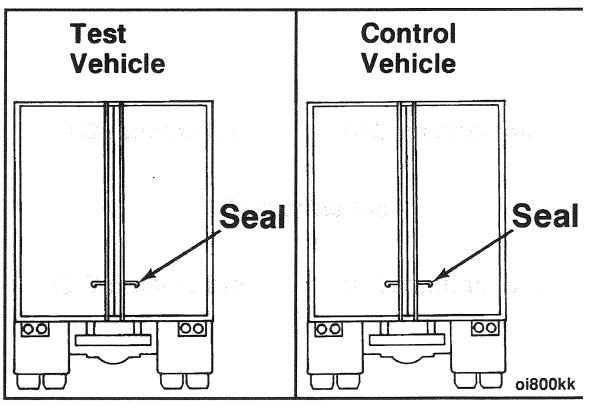
The vehicles **must** stay close enough together to experience the same varying traffic and weather conditions, but **not** so close as to affect each other's driving or headwind.

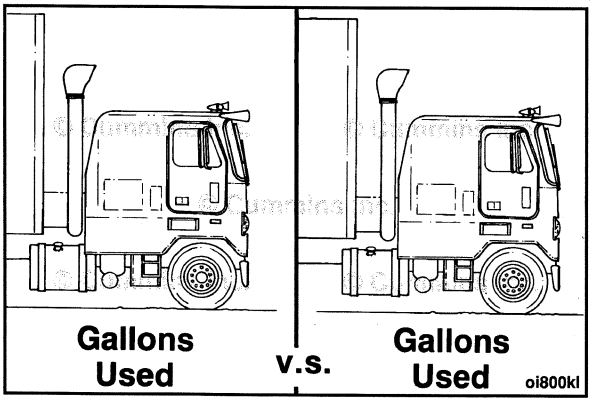


The test course **must** be 65 to 80 km [40 to 50 mi] long.

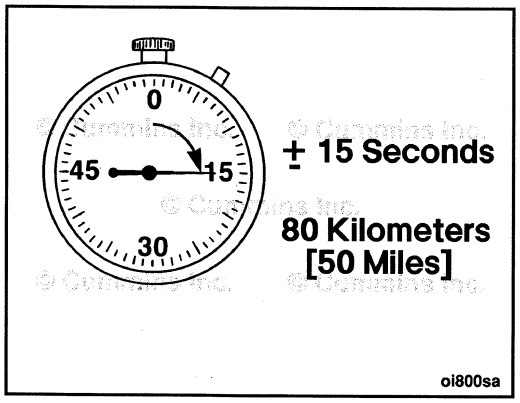


The test route and truck weights **must not** change during the test.





All the test results are based on comparing the fuel used by the test truck to the fuel used by the control truck.



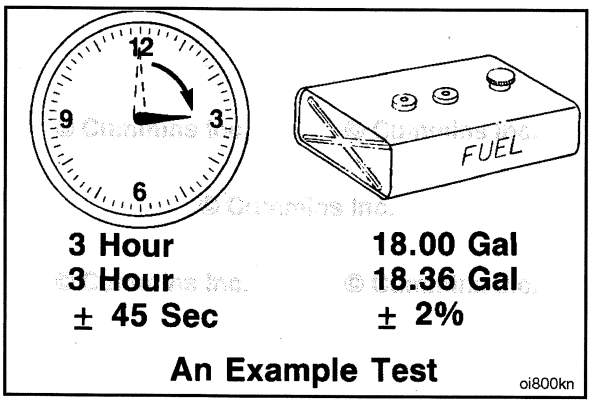
NOTE: The differences in traffic and driving practices can make the test drive fall out of the 2-percent range.

Drive the truck on a warm-up test run. Drive enough tests to achieve the following:

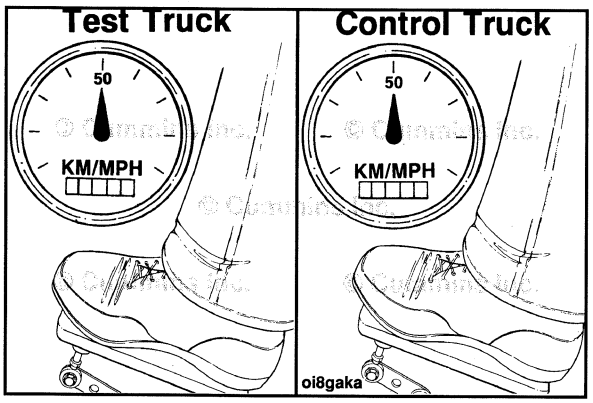
- The difference in elapsed time between each test run can **only** be ±0.5 percent. This will be ±15 seconds over 80 km [50 mi] at 97 km/h [60 mph].

The fuel usage of the test truck between test drives **must** fall within a 2-percent range (e.g., 2.55 versus 2.60 km/liters [6.00 versus 6.12 mpg]).

The same range also applies between test drives of the control truck.



A minimum of three test drives that meet these conditions make a valid test. A single test drive is unreliable.



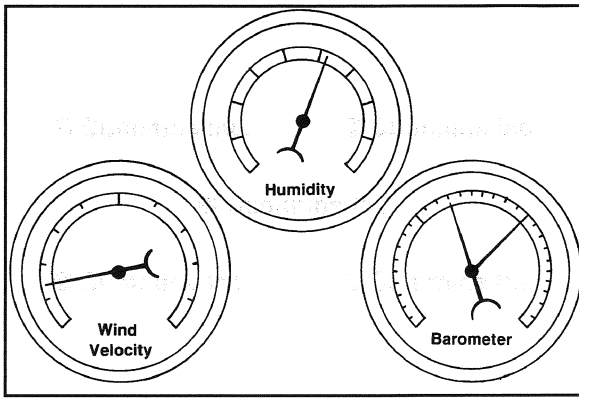
NOTE: The vehicle speeds **must** be representative of a typical operation.

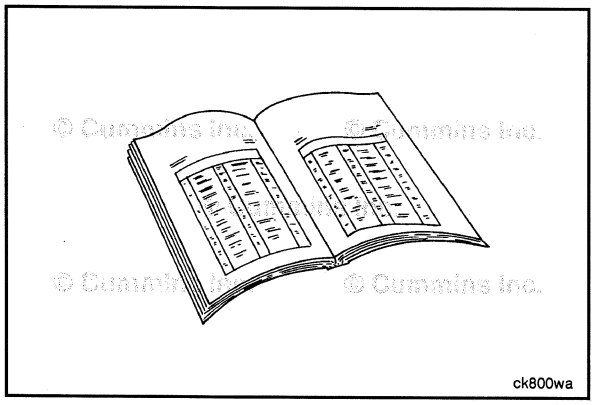
Use the same experienced drivers for all of the tests.

NOTE: Avoid testing under any extreme conditions.

During the test, record the following:

- Ambient temperature.
- Humidity.
- Barometric pressure.
- Wind velocity.
- Wind direction.





Fuel Pump (005-016)

Preparatory Steps

⚠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⚠
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 all fittings before disassembly. Dirt or contaminants can damage the fuel system.

- Disconnect the batteries. See equipment manufacturer service information.
- Disconnect and remove the original equipment manufacturer service information (OEM) fuel supply line at end of the pressure side fuel filter. See equipment manufacturer service information.
- Disconnect and remove the low-pressure fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Disconnect and remove the low-pressure fuel drain lines. Refer to Procedure 006-013 in Section 6.

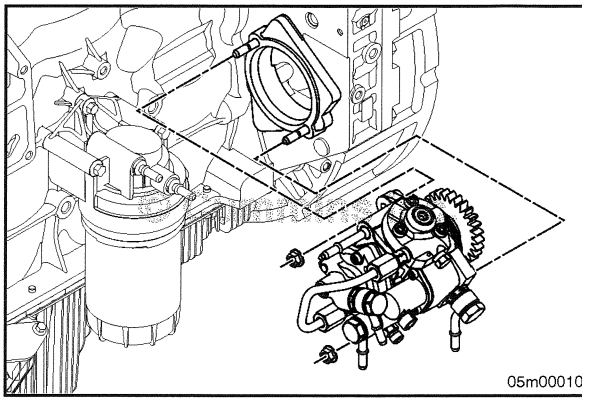
NOTE: Do **not** bend, pry, or kink the fuel rail supply line during the fuel pump removal.

- Disconnect and remove the high-pressure supply line from the fuel pump to the fuel rail (flared connection). Refer to Procedure 006-071 in Section 6.
- Disconnect the fuel pump actuator electrical connector.
- Remove the pressure-side fuel filter. Refer to Procedure 006-015 in Section 6.
- Remove the pressure side fuel filter head. Refer to Procedure 006-017 in Section 6.

Remove

Remove the two flanged fuel pump mounting nuts.

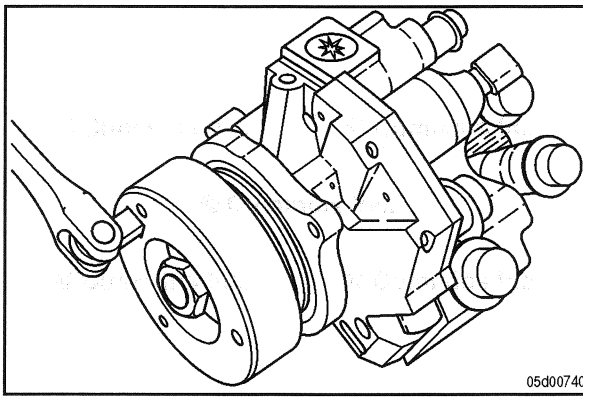
Remove the fuel pump from the gear housing.



Disassemble

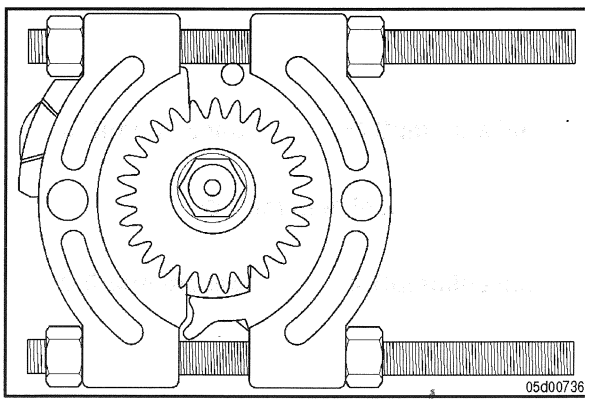
Use a Fuel Pump Drive Gear Retention Tool, Cummins® Part Number 3164707, and a ½-inch breaker bar to retain the fuel pump drive gear.

Loosen the clamp load of the fuel pump drive gear retaining nut by rotating it **counterclockwise**. Do **not** remove it from the shaft.



Install a bearing separator, Snap-On™ Part Number CJ951, or equivalent, between the fuel pump mounting flange and drive gear.

Secure the bearing separator.

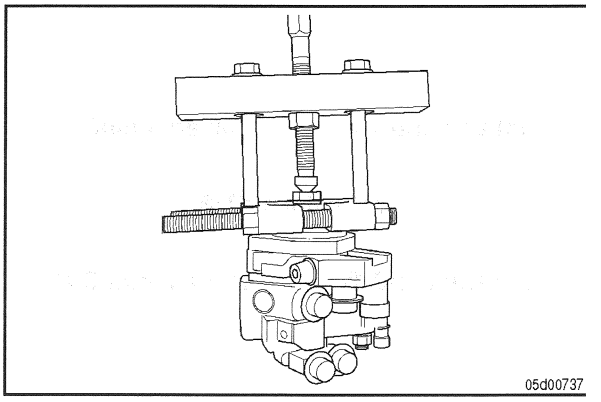


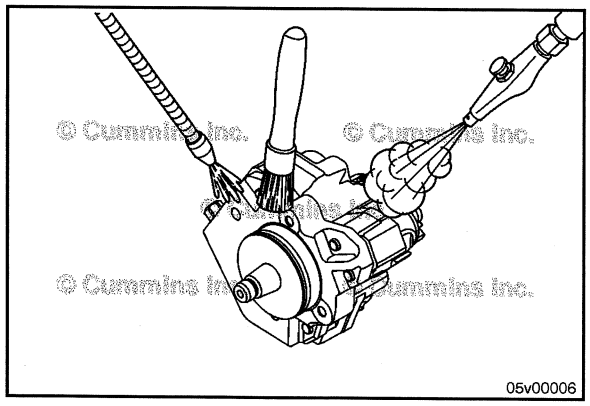
Install a Snap-On™ puller, Part Number CG150, or equivalent, onto the bearing separator, Snap-On™, Part Number CJ951, and the fuel pump driveshaft.

Rotate the puller screw until the drive gear is separated from the driveshaft.

Remove the drive gear retaining nut, lock washer, and drive gear from the fuel pump driveshaft.

NOTE: Temporarily tighten the drive gear retaining nut onto the drive shaft when in transport or long time storage.





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.

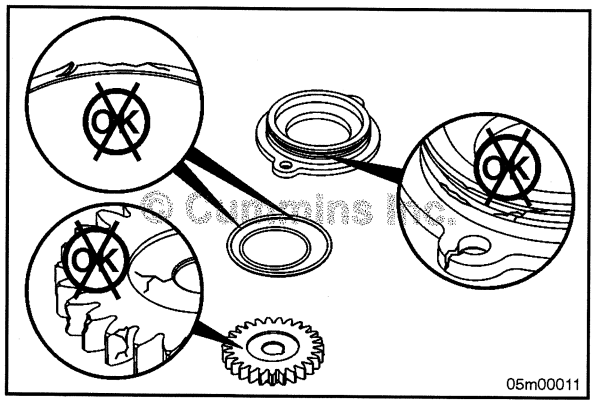
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△
Use solvent or cleaner that will not harm aluminum.

△CAUTION△
Do not allow the cleaner to enter the fuel fittings. Dirt and debris can damage the fuel system.

Clean the fuel pump with solvent.

Dry with compressed air.

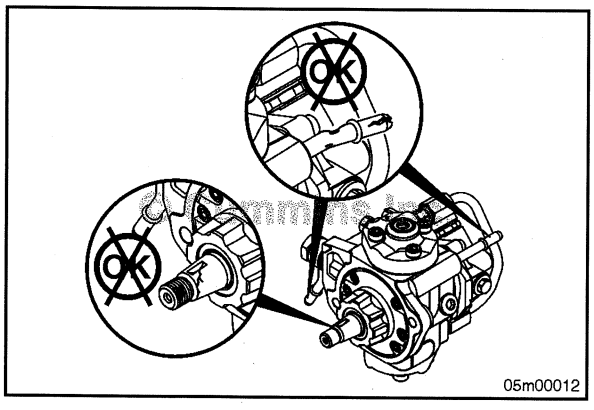


Inspect the drive gear for damage. Replace if damage is found.

Inspect the o-ring seal for damage. Replace if damage is found.

Inspect the o-ring seal area for damage. Clean and repair any burred surfaces.

Inspect the adapter for damage. Replace if any damages is found.



Inspect the driveshaft for damage.

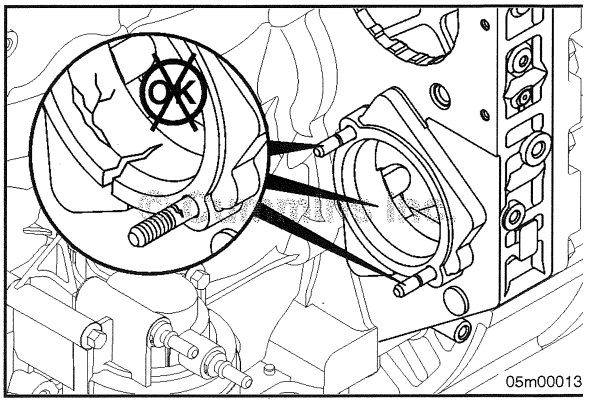
Replace the fuel pump if damage is found.

Inspect the quick connect fittings for cracks, wear, or pinched areas.

Replace the fuel pump assembly, if damage is found.

Inspect the gear housing, high-pressure pump mounting bore, and mounting studs for cracks.

Replace any damaged components.

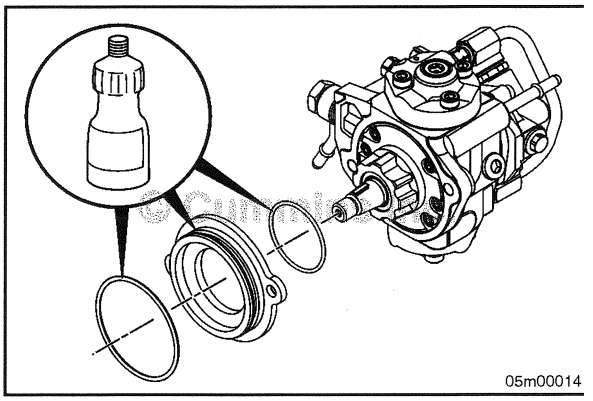


Assemble

Lubricate the outer diameter of the fuel pump mounting adapter with clean vegetable oil.

Lubricate and install new seal rings onto the inner and outer diameters of the fuel pump mounting adapter with clean vegetable oil.

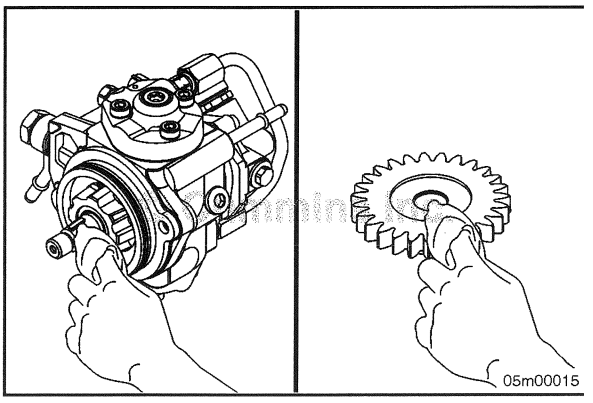
Install the fuel pump adapter onto the fuel pump.



⚠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.

The pump driveshaft nose and drive gear shaft mating surface **must** be clean and dry prior to assembly.

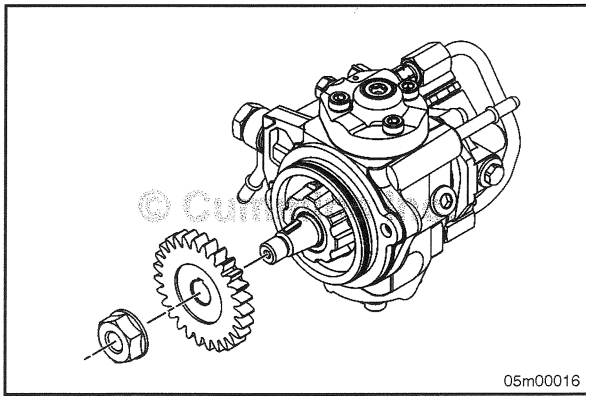
Wipe off the driveshaft and gear with solvent and a lint-free cloth. Do **not** touch the mating surface after wiping.

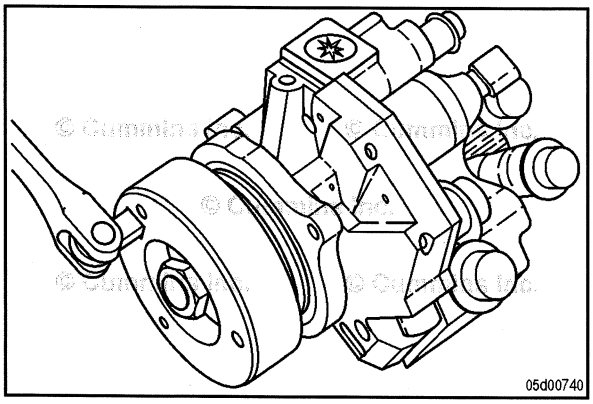


Install the fuel adapter onto the driveshaft.

Install the drive gear onto the driveshaft.

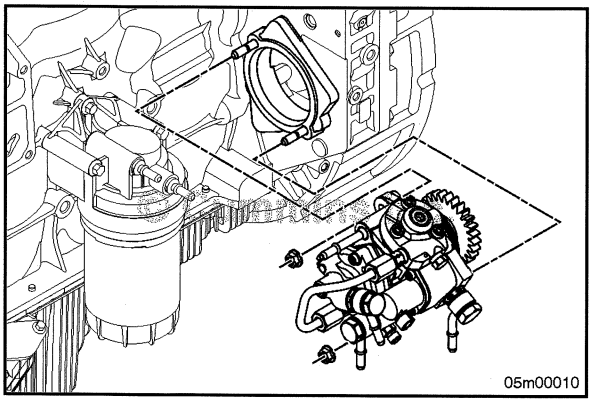
Install the drive shaft lock washer and retaining nut and hand-tighten.





Use the Fuel Pump Drive Gear Retention Tool, Cummins® Part Number 3164707, and a 1/2 inch breaker bar to hold the drive gear in place while tightening the drive gear retaining nut.

Torque Value: 67 N•m [49 ft-lb]



Install

NOTE: Timing of the high-pressure pump with the crankshaft is **not** required.

Install the fuel pump on the gear housing.

Position the fuel pump to the mounting flange on the gear housing while aligning the fuel pump and the gear housing through the fuel pump mounting studs.

Tighten the mounting nuts evenly and press the fuel pump into the gear housing bore, and hand-tighten **only**.

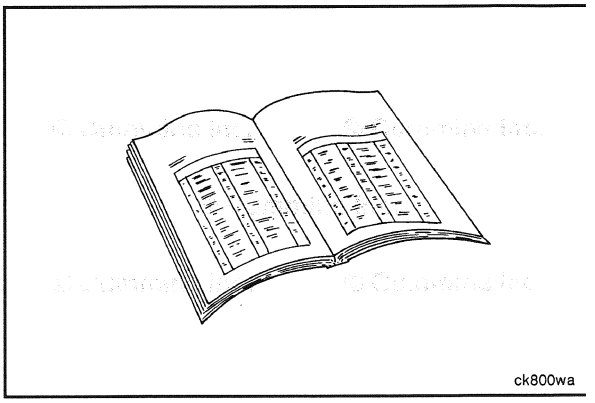
NOTE: Do **not** attempt a final tightening at this time. Do **not** attempt to tighten (pull) the pump to the gear housing using the mounting nuts. Damage to the pump or gear housing can occur.

The pump **must** be positioned flat to the mounting flange before attempting to tighten the two mounting nuts.

Tighten the fuel pump mounting nuts.

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.

⚠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 pressure side fuel filter head. Refer to Procedure 006-017 in Section 6.
- Install the pressure side fuel filter. Refer to Procedure 006-015 in Section 6.
- Connect and install the fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Connect and install the fuel drain lines. Refer to Procedure 006-013 in Section 6.

NOTE: Apply a counter-torque to the fitting on the high-pressure pump using an open end wrench to reduce the possibility of a leak or a loose fitting.

NOTE: Do **not** bend, pry, or kink the fuel rail supply line during the fuel pump installation.

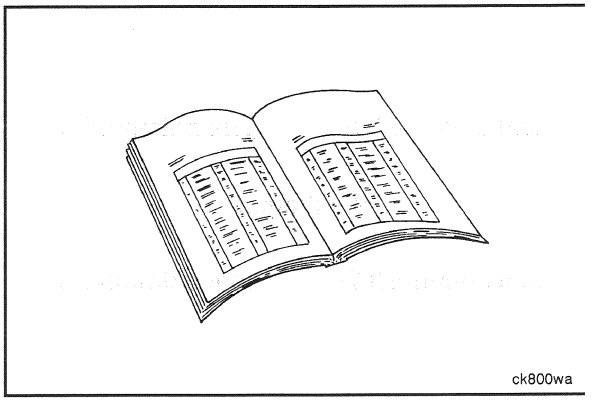
- Connect or install the high-pressure supply line from the fuel pump to the fuel rail (flared connection). Refer to Procedure 006-071 in Section 6.
- Install the OEM fuel supply line. See equipment manufacturer service information.
- Connect the fuel pump actuator electrical connector.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.

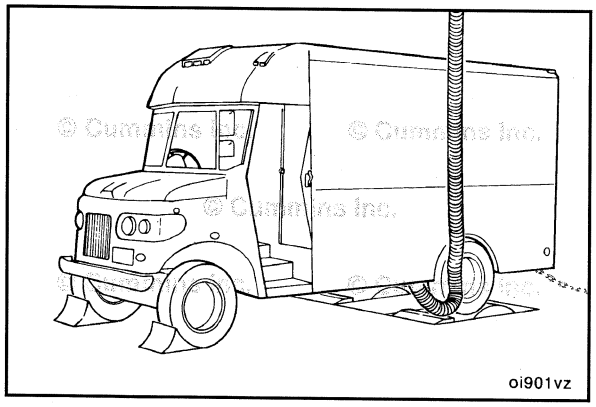
Fuel Lift Pump (005-045)

General Information

The engine uses a hand priming pump to prime the fuel system.

The lift pump is located at the suction side on the fuel filter head. It is **not** a serviceable part. If the lift pump is found to be malfunctioning, replace the suction side fuel filter.





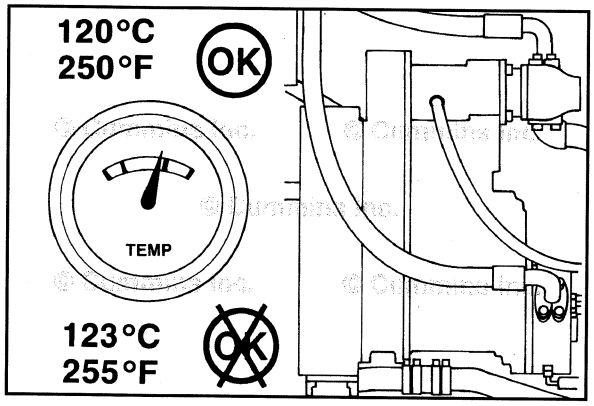
Stall Speed Test (005-054)

Stall Speed Check

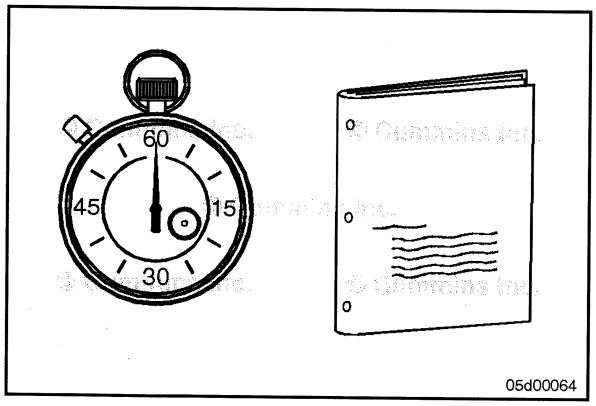
Converter Transmission's Stall Speed:

NOTE: It is possible that the vehicle brakes will **not** hold an electronically controlled transmission.

The stall speed is the engine speed (rpm) obtained at full throttle when the converter output shaft is locked.

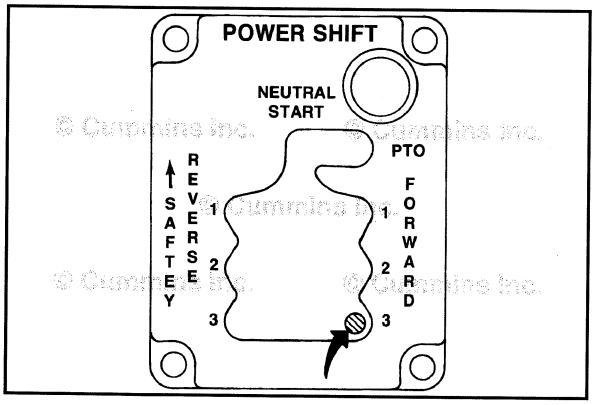


⚠CAUTION⚠
Do not exceed 120°C [248°F] converter oil temperature. Overheating can result and converter damage can occur. If the oil temperature exceeds 120±C [248°F], put the transmission in neutral, and operate the engine until the oil temperature is below 120°C [248°F]. Check the converter oil level.



The following equipment is needed for this check:

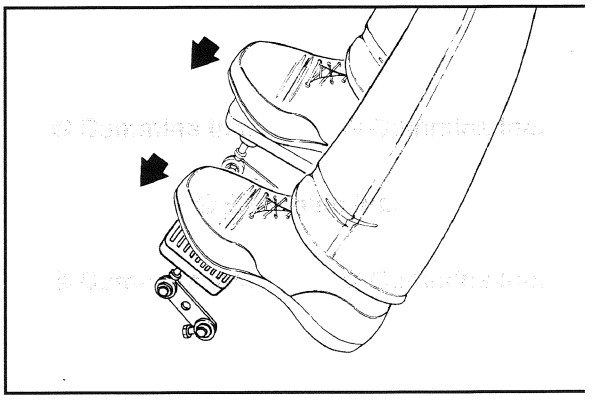
- Stopwatch.
- Equipment manufacturer's stall speed and time-to-stall specifications.



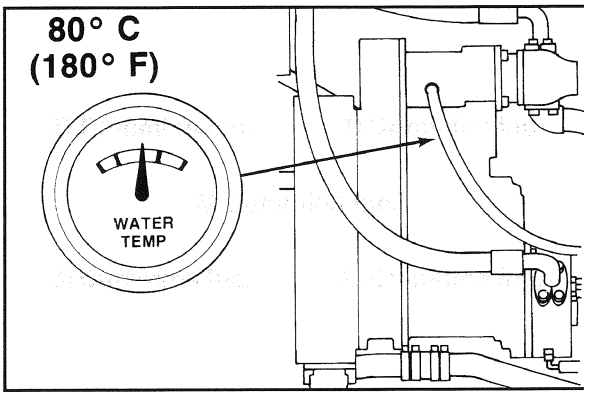
Place the gear selector in the highest gear or full forward.

NOTE: The brakes **must** prevent the vehicle from moving when the engine is at full throttle. Engage the vehicle brakes to keep the vehicle from moving.

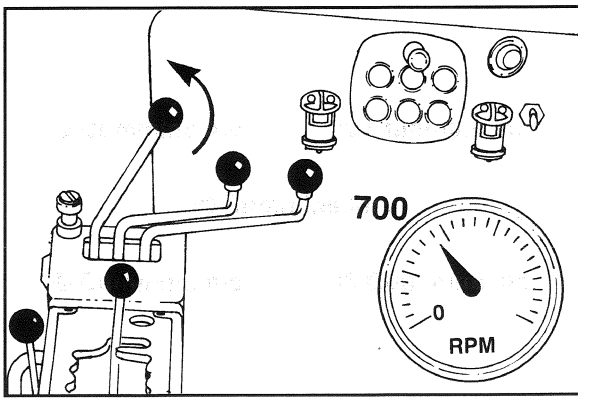
Make sure the vehicle has good brakes and air pressure in the brake system.



Operate the engine until the converter temperature is 80°C [176°F] or above.

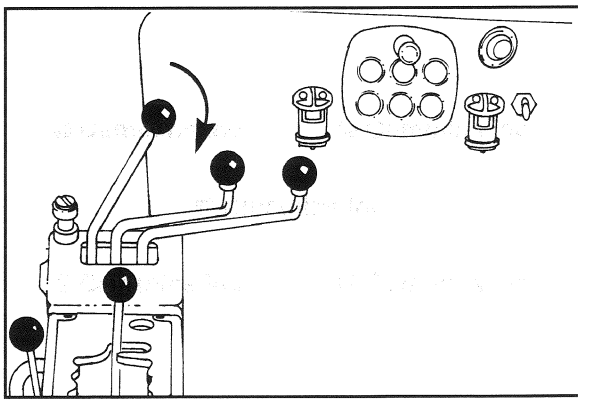


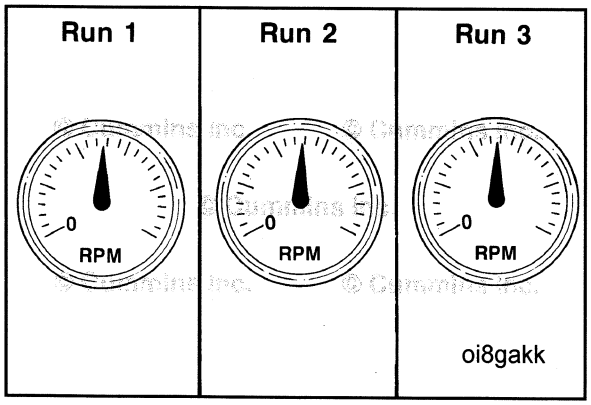
Bring the engine speed back to low idle.



⚠CAUTION⚠
Do not exceed 120°C [248°F] converter oil temperature. Overheating and damage to the converter can occur.

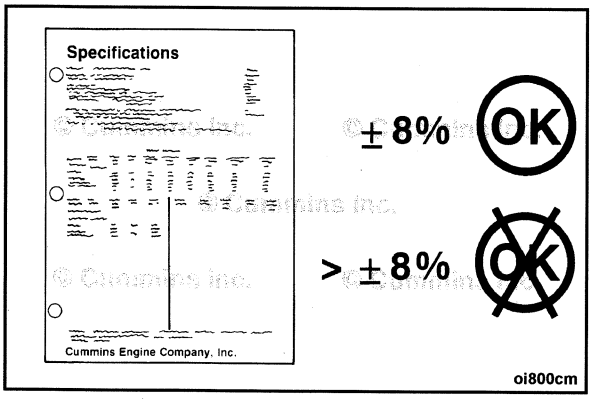
Quickly move the throttle to the full-open position with the vehicle brakes applied.





Check the engine speed (rpm) at the point of stall:

- **Always** hold the speed until it is stable.
- Take several readings.
- Make sure the readings are accurate.



NOTE: The stall speed for the engine and converter/ transmission can vary ±8 percent from the manufacturer's specifications.

Check the speed (rpm) against the specifications for the equipment, converter, or automatic transmission.

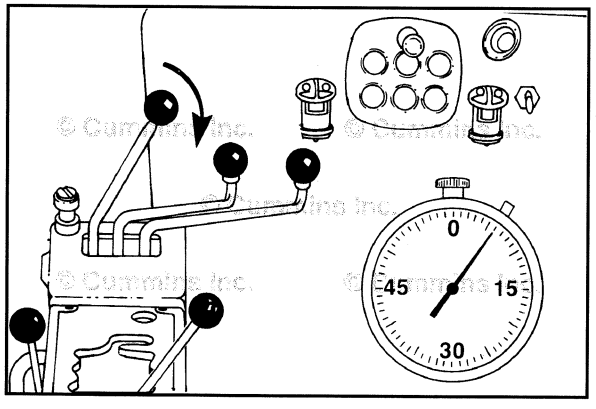
STALL SPEED CHECK LIST

IF THE STALL SPEED IS TOO LOW, CHECK THE FOLLOWING:

	Yes	No	
1.	- - -	- - -	The tachometer is in error.
2.	- - -	- - -	The engine is up to or above 70°C [160°F].
3.	- - -	- - -	The converter oil is up to temperature 80°C [180°F] minimum.
4.	- - -	- - -	The stall has been held long enough for the engine to accelerate to full power.
5.	- - -	- - -	The match curve stall speed was recorded correctly.
6.	- - -	- - -	The converter oil is to the converter manufacturer's recommendation. (SAE 30 instead of SAE 10 for instance.)
7.	- - -	- - -	The engine driven accessory power requirements exceed 10 percent of the gross engine power. Check for abnormal accessory horsepower losses such as hydraulic pumps, large fans, oversize compressors, etc. Either remove the accessory or accurately determine the power requirement and adjust accordingly.
8.	- - -	- - -	The AFC (Air Fuel Control) is propery adjusted.
9.	- - -	- - -	The unit is operating at an altitude high enough to affect the engine power.
10.	- - -	- - -	The converter charging pressure is correct.
11.	- - -	- - -	The tailshaft governor is interfering with and preventing a full throttle opening. (Disconnect the tailshaft governor.)
12.	- - -	- - -	The converter blading is interfering or in a stage of failure. Check the sump or filter for metal particles.
13.	- - -	- - -	The converter stators are free-wheeling instead of locking up.
14.	- - -	- - -	The engine is set for power other than that specified on the power curve.

If the stall speed is **not** within the specifications, reference the Stall Speed Checklist at the end of this section.

Check the equipment manufacturer service information troubleshooting procedures for other reasons for stall speed problems.



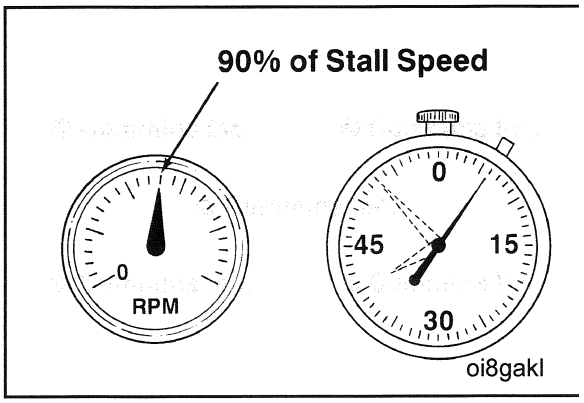
Time Speed Check

Perform the previous Stall Speed Check procedure through the “bring the engine speed back to low idle” step; then:

- Quickly move the throttle to the full-open position, and start the stopwatch at the same time.

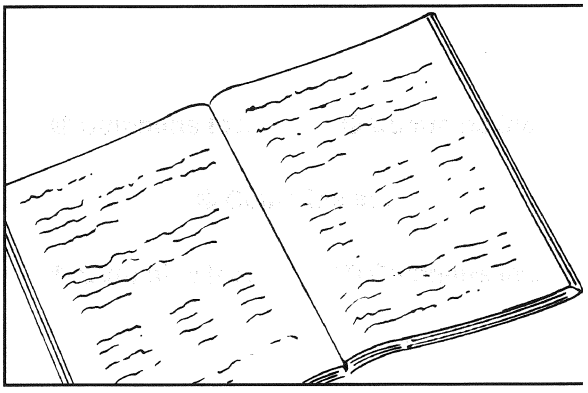
NOTE: The type of unit and the stall speed rpm can make the stall speed time a maximum of 10 seconds.

- When the engine speed is 90 percent of the stall speed rpm, stop the stopwatch.
- Example: Stall speed 2089 [2089 x 0.90 = 1880 rpm]



Check the equipment manufacturer service information for the time to stall or the acceleration time.

If the time is excessive, reference the Stall Speed Checklist at the end of this procedure.



Stall Speed Checklist

Stall Speed Too Low

	Yes	No	
1.			The tachometer is in error.
2.			Engine temperature is up to or above 70°C [160°F].
3.			The converter oil is up to temperature 80°C [180°F].
4.			The stall has been held long enough for the engine to accelerate to full power.
5.			The match curve stall speed was recorded correctly.
6.			The converter oil is to the converter manufacturer's recommendation (SAE 30 instead of SAE 10, for instance).

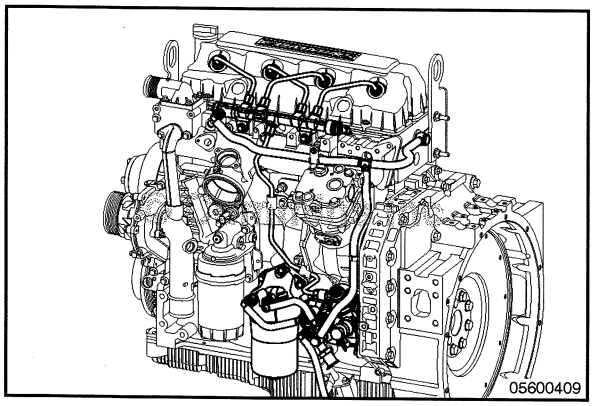
7.			The engine-driven accessory power requirements exceed 10 percent of the gross engine power. Check for abnormal accessory horsepower losses such as hydraulic pumps, large fans, oversized compressors, and so on. Either remove the accessory or accurately determine the power requirement and adjust accordingly.
8.			The unit is operating at an altitude high enough to affect the engine's power.
9.			The converter charging pressure is correct.
10.			The tailshaft governor is interfering with and preventing a full-throttle opening. Disconnect the tailshaft governor. Do **not** exceed the manufacturer's maximum output speed.
11.			The converter blading is interfering or in a stage of failure. Check the sump or filter for particles.
12.			The converter stators are free-wheeling instead of locking up.
13.			The engine is set for power other than that specified on the power curve.
14.			The converter is wrong due to improper build or rebuild of unit.
15.			The converter is performing to the published absorption curve.
16.			The engine and converter match is correct. Check the engine and converter models for the proper match.
17.			The engine is matched to too large of a converter. If this condition is believed to exist, please report the engine-converter-accessory information to the factory.

18.			The engine power is down. The engine torque rise could be less than shown on the standard engine curve. See the fuel setting adjustments and the turbocharger air manifold pressure check.

Stall Speed Too High

	Yes	No	
1.			The engine is high in power.
2.			The tachometer is in error.
3.			The accessory power requirements are less than 10 percent of the gross engine power.
4.			The converter oil is aerating or foaming. Check for low oil level, air leaks in suction line, lack of foam inhibitor in the oil, or suction screen or filter. It would be accompanied by a noticeable loss of machine performance.
5.			The converter is being held at full-stall. Check for slipping front disconnect clutch or a rotating output shaft. On the converter-transmission package, this can be impossible to check.
6.			The converter turbine element is beginning to fail and lose blades, or the converter was originally built with the wrong size element.
7.			The engine and converter match is correct due to a revision in the engine rating or the converter performance.
8.			If the oil level is too high on the transmission-converter units with the oil sump in the transmission, it can cause severe aeration due to parts dipping into the oil.
9.			The converter is performing to the published absorption curve.
10.			The converter charging pressure is correct.

The reasons for abnormal stall speeds listed above are some that have been recorded by Cummins Inc representatives and probably do **not** include all possible causes. The correction of the problem is either covered in the vehicle service manual, the converter service manual, or is self-explanatory.



Fuel System Diagnostics (005-236)

General Information

⚠CAUTION⚠
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

The following procedure contains measurement steps and specifications regarding the engine's fuel system components.

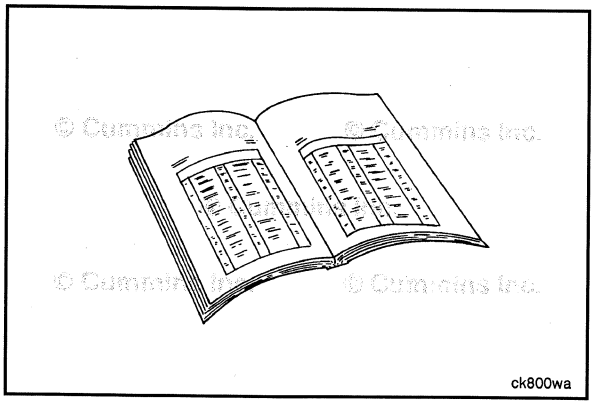
This procedure is **not** intended to take the place of troubleshooting tree repair direction.

Reference the appropriate troubleshooting tree for repair direction.

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.

While collecting data during cranking tests, 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 or triggering the starter protection feature.

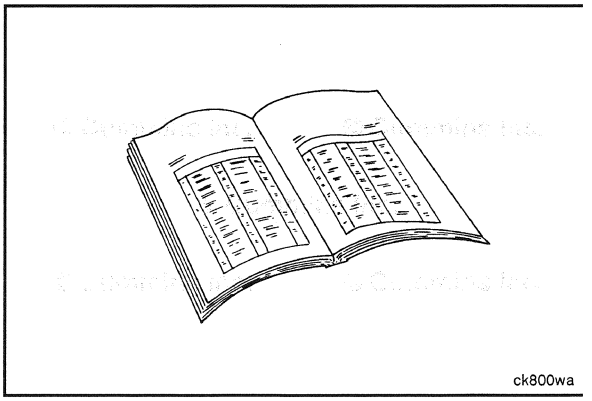
In order to reach engine high idle, it could be necessary to temporarily adjust the "maximum engine speed without vehicle speed source" parameter with INSITE™ electronic service tool to the high idle speed of the engine (2300 rpm for example).



The procedures listed below are important fuel system checks to perform when troubleshooting fuel system related issues. Use the corresponding procedures for additional fuel system diagnostic checks:

- Air in Fuel: Refer to Procedure 006-003 in Section 6
- Fuel Inlet Restriction: Refer to Procedure 006-020 in Section 6
- Fuel Drain Line Restriction: Refer to Procedure 006-012 in Section 6
- Fuel System Priming:
- Fuel System Specifications: Refer to Procedure 018-016 in Section V.

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.

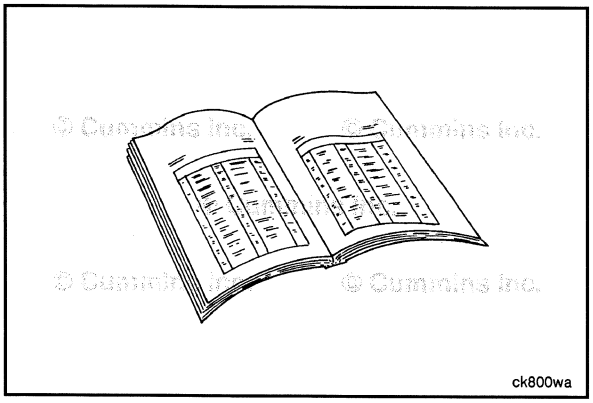
⚠WARNING⚠
The fuel pump, high-pressure fuel lines, and fuel rail contain very high pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.

⚠WARNING⚠
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.

⚠WARNING⚠
Do not bleed the fuel system of a hot engine; This can result in fuel spilling onto a hot exhaust manifold, which can cause a fire.

Before diagnosing any fuel system component, (such as fuel lines, fuel pump, injectors, fuel rail, 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 procedure for cleaning information. Refer to Procedure 000-009 in Section 0.

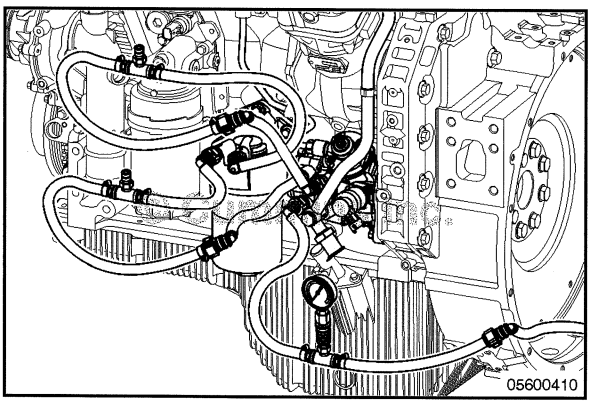


Low-Pressure System Check

⚠CAUTION⚠
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

The low-pressure system check is designed to help troubleshoot the low-pressure side fuel system by taking multiple fuel system checks at one time while the engine is running or cranking.

NOTE: The tool set up for the low-pressure system check may be slightly different than the setup described in the Air in Fuel, Fuel Inlet Restriction, and Fuel Drain Line Restriction procedures. The reason is that the procedures are written to be performed individually and **not** all at once. The difference between those procedures and the low-pressure system setup is the use and location of the 0.043-inch orificed diagnostic fuel line, Cummins® Part Number 3164621. Based on the additional clear lines installed during the low-pressure system check setup, the 0.043-inch orificed diagnostic fuel line, Cummins® Part Number 3164621, can be installed at the fuel filter outlet diagnostic port. Using the 0.043-inch orificed diagnostic fuel line does **not** have a significant effect on the drain line restriction measurement, but it is necessary to use when performing the fuel filter restriction measurement.



Initial Setup

Air in Fuel and Fuel Inlet Restriction Setup

1 Install the diagnostic fuel line, Cummins® Part Number 4918696, between the pressure side fuel filter fuel supply inlet fitting and the fuel line connector. This line will be used to check for air in the fuel before the pressure side filter.

2 Install the diagnostic fuel line, Cummins® Part Number 4918696, or sight glass at the suction side fuel filter inlet connection. This is used to check for air in the fuel. The suction side filter is **not** shown.

3 Install diagnostic fuel line, Part Number 4918462, 4918895, or 4918696, between the gear pump original equipment manufacturer (OEM) fuel supply line and the gear pump inlet fitting. This line will be used to check for fuel inlet restriction at the fuel gear pump and for air in the fuel.

   NOTE: If the fuel gear pump inlet connection or the suction side fuel filter inlet does **not** use quick connect fittings, use the following procedures for the setup instructions. Refer to Procedure 006-003 in Section 6. Refer to Procedure 006-020 in Section 6. A sight glass and test line will need to be installed.

4 Attach a 0 to 762 mm-Hg [0 to 30 in-Hg] vacuum gauge or multimeter pressure transducer, Part Number 3164491, to the diagnostic fuel line.

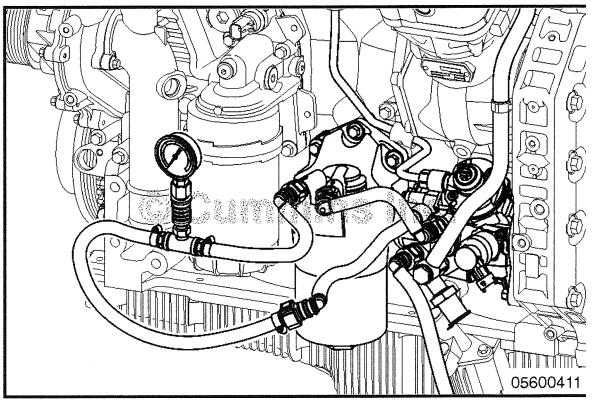
Make certain the test lines are **not** kinked or leaking after installation.

Fuel Filter Restriction Setup

NOTE: The fuel inlet and outlet are labeled on the fuel filter head using text or arrows. The illustrations do **not** necessarily display the true orientation of the inlet or outlet of the fuel filter.

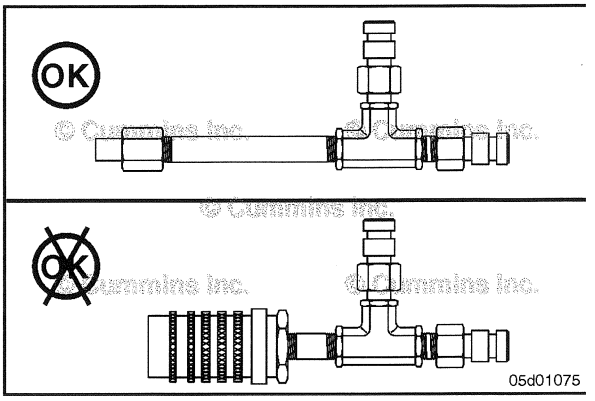
1. Disconnect the inlet fuel line of the fuel filter and install diagnostic fuel line, Cummins® Part Number 4918696.

2. Connect a 0 to 1034 kPa [0 to 150 psi] fuel pressure gauge or multimeter pressure transducer, Cummins® Part Number 3164491, to the Compuchek™ fitting.



Construct a "T" adapter fitting using 1/8 inch NTP pipe (or appropriate length for the application), an 1/8 inch NPT "T" fitting, and two 1/8-inch NPT Compuchek™ fittings, Cummins® Part Number 3377244 or 3042618.

NOTE: Do **not** use a female Compuchek™ fitting when constructing the "T" adapter. If a female Compuchek™ fitting is used, the pressure readings will be inaccurate.



3. Remove the Compuchek™ fitting from diagnostic fuel line, Cummins® Part Number 4918696. Install the "T" adapter fitting into the diagnostic fuel line. Install the diagnostic fuel line onto the outlet of the fuel filter. Connect the fuel filter outlet line to the diagnostic fuel line.

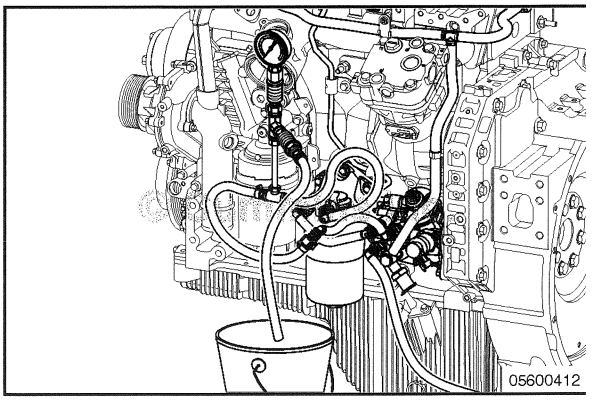
4. Connect a 0.043-inch orificed diagnostic fuel line, Cummins® Part Number 3164621, to the "T" adapter Compuchek™ fitting. Run the fuel hose back to the fuel tank or into a bucket. The diagnostic line is used to simulate running the engine at rated fuel system flow rate.

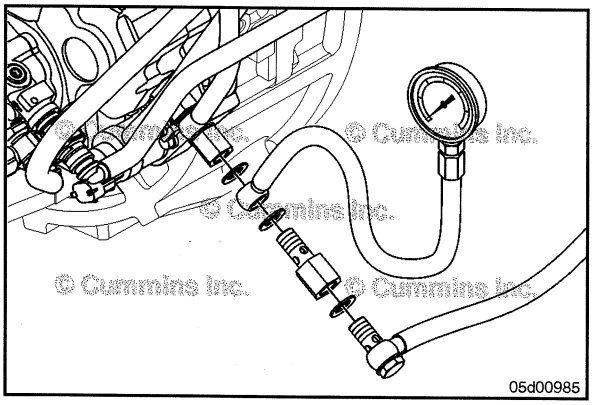
NOTE: If the engine will **not** start, do **not** install the 0.043-inch orificed diagnostic fuel line, Cummins® Part Number 3164621, at the outlet of the fuel filter head.

5. Connect a 0 to 1034 kPa [0 to 150 psi] pressure gauge or multimeter pressure transducer, Cummins® Part Number 3164491, to the "T" adapter Compuchek™ fitting.

Regardless of what type of pressure measurement tool is used (gauge or multimeter pressure transducer), make sure it is calibrated and functioning properly prior to use.

Make certain the test lines are **not** kinked or leaking after installation.



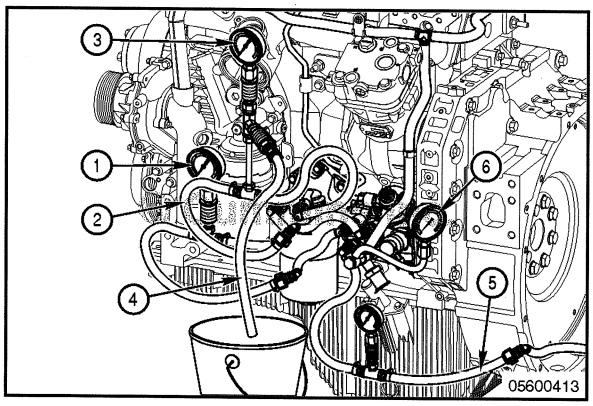


Drain Line Restriction Setup

Remove the OEM fuel drain line from the high-pressure injection pump drain connection.

Install the fuel pressure gauge adapter kit, Cummins® Part Number 4918324, into the drain connection.

Make certain the test lines are **not** kinked or leaking after installation.



Summary of Tools Installed:

1 Diagnostic fuel line between the pressure side fuel filter inlet fitting and the fuel line connector. This line is used to check for air in the fuel before the pressure side filter.

2 Diagnostic fuel line or sight glass before the OEM suction side fuel filter. This line is used to check for air in the fuel. The suction side fuel filter **not** shown.

3 Diagnostic fuel line with pressure gauge to measure outlet fuel filter pressure.

4 0.043-inch orificed diagnostic fuel line, Cummins® Part Number 3164621, attached to the "T" adapter Compuchek™ fitting at the fuel filter outlet. Put the fuel hose back to the fuel tank or into a bucket. The diagnostic line is used to simulate running the engine at rated fuel system flow rate as needed for test purposes. The diagnostic line is **not** used when the engine will **not** start.

5 Diagnostic fuel line between the fuel gear pump OEM fuel supply line and the fuel gear pump inlet fitting. This line is used to check for fuel inlet restriction at the fuel gear pump and for air in the fuel. If the fuel gear pump does **not** use quick connect fittings, a sight glass and pressure gauge adapter kit will need to be used.

6 Fuel pressure gauge adapter kit at the fuel pump outlet drain connection. This line is used to check the fuel drain line restriction.

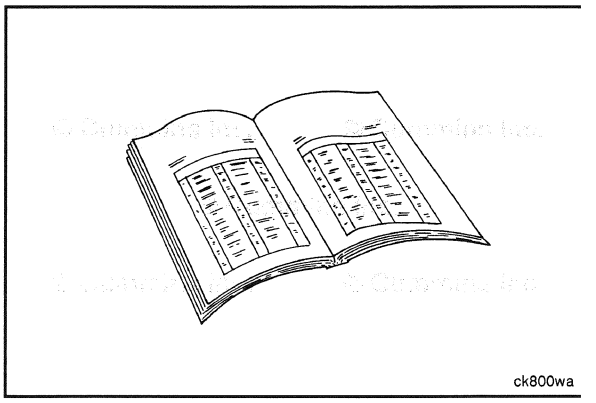
Use the manual priming pump to prime the fuel system and to help remove air from the fuel system introduced while installing the test lines.

Use the following procedure for fuel system priming information. Refer to Procedure 006-014 in Section 6.

NOTE: During fuel system priming, it may be necessary to remove the 0.043-inch orificed diagnostic fuel line, Cummins® Part Number 3164621, at the "T"adapter Compuchek™ fitting to speed up fuel system priming.

If the engine will **not** start, perform low-pressure system checks at engine cranking. Prior to performing the low-pressure system checks, crank the engine for 30 seconds to help purge air from the fuel system due to the newly installed diagnostic fuel lines.

If the engine will start, allow the engine to operate at high idle for 1 minute, or until the air is purged from the newly installed diagnostic fuel lines, then perform the low-pressure system checks.



Measurement - Engine Will Start

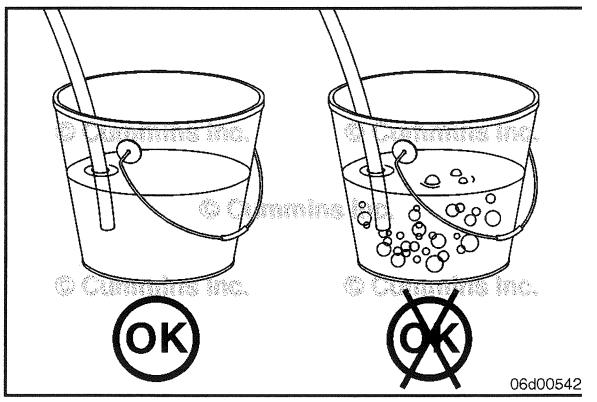
This part of the procedure is for measuring the low-pressure system for an engine that will start.

Check for air in the fuel with the engine running at high idle (2300 rpm).

- Check for air in the fuel in the diagnostic fuel line or sight glass at the suction side fuel filter inlet connection.
- Check for air in the fuel in the diagnostic fuel line between the gear pump OEM fuel supply line and the fuel gear pump inlet.
- Check for air in the fuel in the diagnostic fuel line between the pressure side fuel filter fuel supply inlet fitting and the fuel line connector.
- Check for air in the fuel out of the 0.043-inch orificed diagnostic fuel line, Cummins® Part Number 3164621, (installed at the outlet of the fuel filter head).

There should **not** be any air present.

Reference the appropriate troubleshooting tree for repair direction.

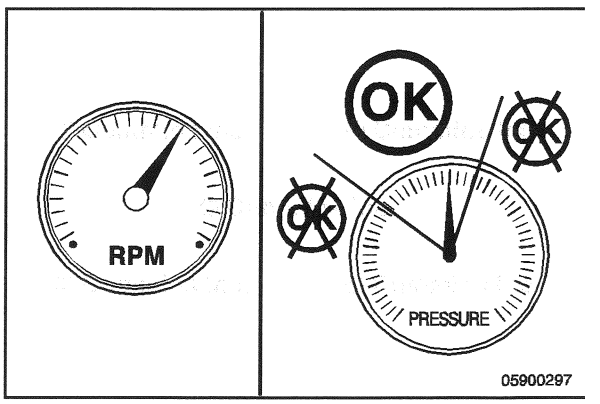


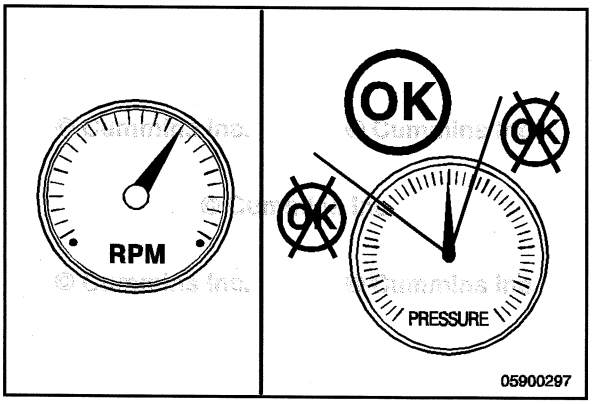
Measure inlet restriction with the engine running at high idle.

Make sure a 0.043-inch orificed diagnostic fuel line, Cummins® Part Number 3164621, is installed at the outlet of the fuel filter head.

Fuel Inlet Restriction at High Idle (2300 rpm)		
mm Hg		in Hg
760	MAX	30

Reference the appropriate troubleshooting tree for repair direction.



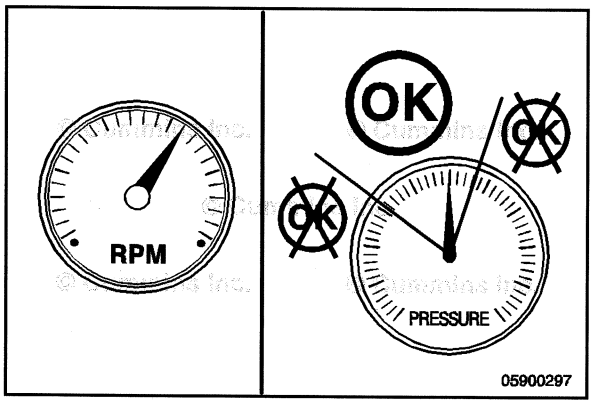


Measure drain line restriction with the engine running at high idle.

Make sure a 0.043-inch orificed diagnostic fuel line, Cummins® Part Number 3164621, is installed at the outlet of the fuel filter head.

Drain Line Restriction at High Idle (2300 rpm)		
kPa		**psi**
20	MAX	2.90

Reference the appropriate troubleshooting tree for repair direction.

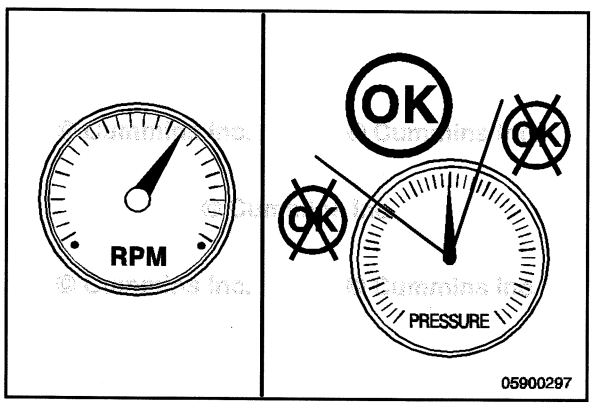


Measure the gear pump pressure at the fuel filter inlet with the engine running at high idle.

Make sure a 0.043-inch orificed diagnostic fuel line, Cummins® Part Number 3164621, is installed at the outlet of the fuel filter head.

Gear Pump Pressure at High Idle (2300 rpm)		
kPa		**psi**
450	MIN	65.3
750	MAX	108.8

Reference the appropriate troubleshooting tree for repair direction.



Measure the fuel filter restriction with the engine running at high idle.

Make sure a 0.043-inch orificed diagnostic fuel line, Cummins® Part Number 3164621, is installed at the outlet of the fuel filter head.

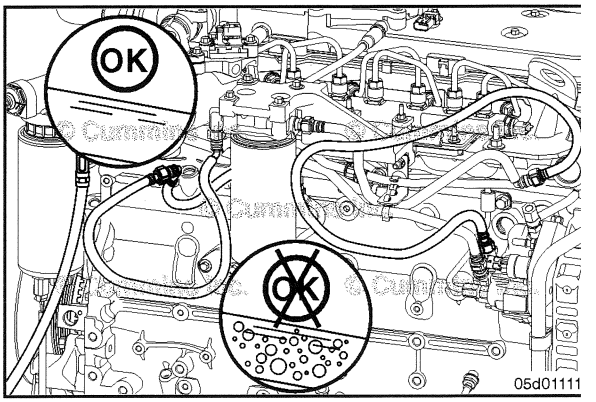
Record the fuel pressure at the inlet and outlet of the fuel filter.

Subtract the outlet reading from the inlet reading to determine the fuel filter restriction.

Pressure Drop Across Fuel Filter at High Idle (2300 rpm)		
kPa		**psi**
81	MAX	11.7

Reference the appropriate troubleshooting tree for repair direction.

Measurement - Engine Will Not Start



This part of the procedure is for measuring the low-pressure system for an engine that will **not** start.

NOTE: If the engine will **not** start, do **not** install 0.043-inch orificed diagnostic fuel line, Cummins® Part Number 3164621, at the outlet of the fuel filter head.

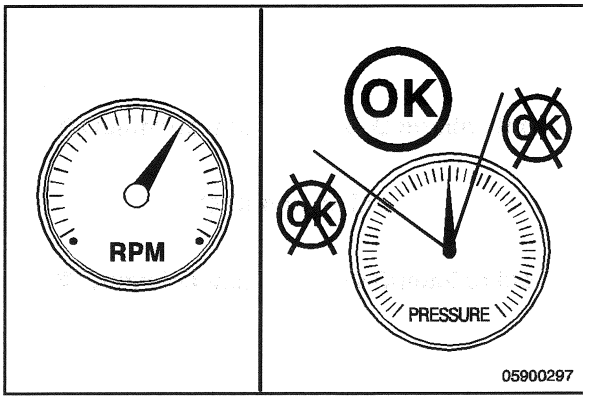
Do **not** crank the engine for 30 seconds continuously. Crank the engine in 15 second intervals with a 15 second break between cranking. This reduces the possibility of overheating the starter motor or triggering the starter protection feature.

Check for air in the fuel with the engine cranking.

- Check for air in the fuel in the diagnostic fuel line or sight glass at the suction-side fuel filter inlet connection.
- Check for air in the fuel in the diagnostic fuel line between the gear pump OEM fuel supply line and the fuel gear pump inlet.
- Check for air in the fuel in the diagnostic fuel line between the pressure side fuel filter fuel supply inlet fitting and the fuel line connector.

There should **not** be any air present.

Reference the appropriate troubleshooting tree for repair direction.



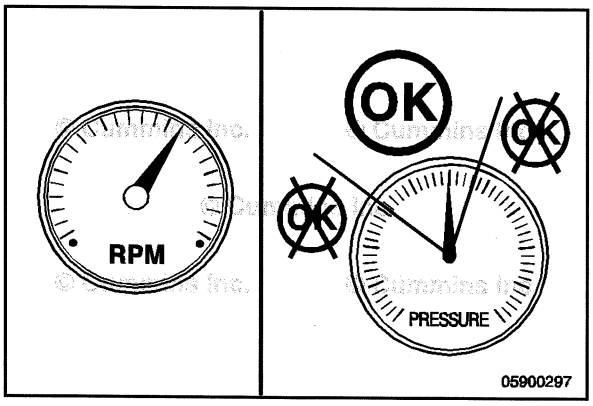
Measure drain line restriction with the engine cranking.

NOTE: If the engine will **not** start, do **not** install 0.043-inch orificed diagnostic fuel line, Cummins® Part Number 3164621, at the outlet of the fuel filter head.

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 or triggering the starter protection feature.

Drain Line Restriction at Engine Cranking (150 rpm minimum)		
kPa		**psi**
20	MAX	2.90

Reference the appropriate troubleshooting tree for repair direction.



Measure the gear pump pressure at the fuel filter inlet with the engine cranking.

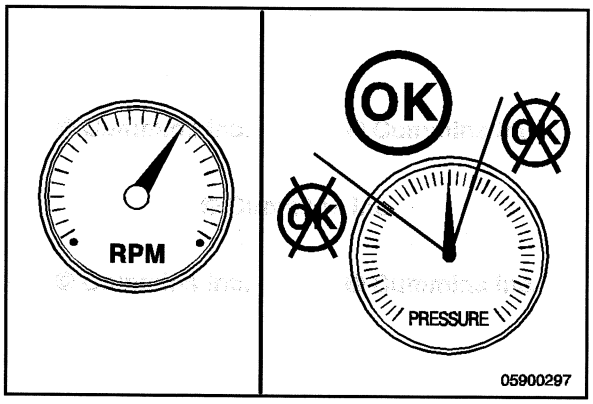
NOTE: If the engine will **not** start, do **not** install 0.043-inch orificed diagnostic fuel line, Cummins® Part Number 3164621, at the outlet of the fuel filter head.

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 or triggering the starter protection feature.

Gear Pump Pressure at Engine Cranking (150 rpm minimum)

kPa		psi
450	MIN	65.3
750	MAX	108.8

Reference the appropriate troubleshooting tree for repair direction.



Measure the fuel filter restriction with the engine cranking.

NOTE: If the engine will **not** start, do **not** install 0.043-inch orificed diagnostic fuel line, Part Number 3164621, at the outlet of the fuel filter head.

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 or triggering the starter protection feature.

Record the fuel pressure at the inlet and outlet of the fuel filter.

Subtract the outlet reading from the inlet reading to determine the fuel filter restriction.

Pressure Drop Across Fuel Filter at Engine Cranking (150 rpm minimum)

kPa		psi
81	MAX	11.7

Reference the appropriate troubleshooting tree for repair direction.

High-Pressure Fuel Pump Supply Flow Test

Initial Setup

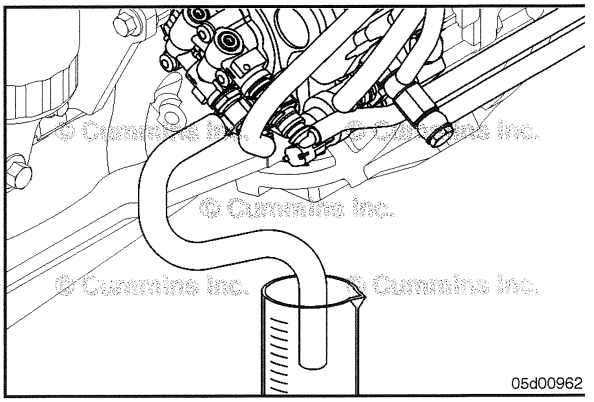
⚠WARNING⚠
The fuel pump, high-pressure fuel lines, and fuel rail contain very high pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high pressure fuel system to allow pressure to decrease to a lower level.

⚠CAUTION⚠
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Disconnect the high-pressure fuel outlet line from the high-pressure injection pump. Refer to Procedure 006-061 in Section 6.

Insert a piece of tubing over the outlet fitting of the fuel pump and route it into a 500 ml graduated beaker, Cummins® Part Number 4919139.

Make certain the test lines are **not** kinked or leaking after installation.

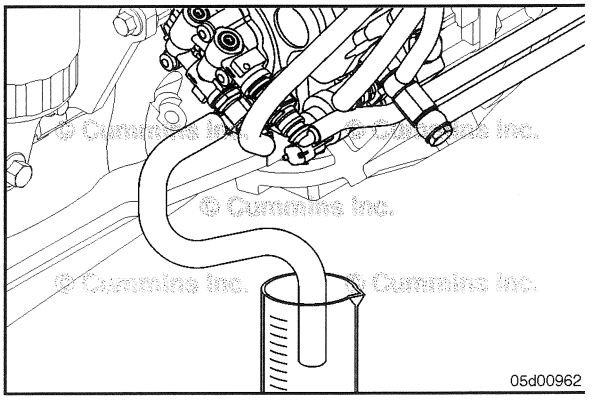


Measurement

Crank the engine and measure the amount of fuel exiting the fuel pump.

Prior to collecting data, crank the engine for 30 seconds to help purge air from the newly installed diagnostic fuel line.

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 or triggering the starter protection feature.

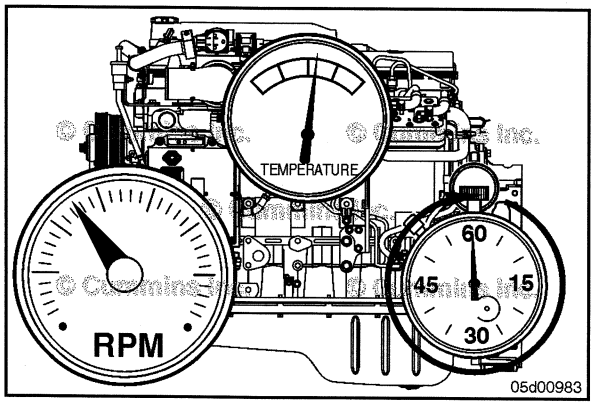


Minimum High-Pressure Fuel Pump Supply Flow with Engine Cranking (150 rpm minimum) in 30 Seconds		
ml		fl-oz
75	MIN	2.5

NOTE: For an accurate measurement, it is a good idea to collect three different flows and average the results.

Use the following procedure to connect the high-pressure fuel outlet line to the high-pressure injection pump. Refer to Procedure 006-061 in Section 6.

Reference the appropriate troubleshooting tree for repair direction.



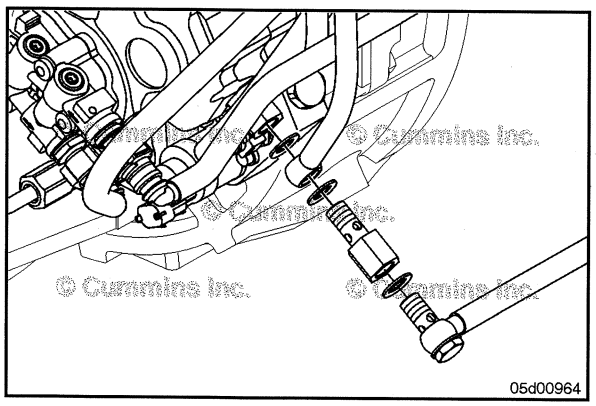
High-Pressure Fuel Pump Return Flow Test

⚠CAUTION⚠
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Measurement of the fuel return drain flow can diagnose a high-pressure fuel pump problem. The following steps describe how to check the high-pressure fuel pump return flow.

NOTE: This test set up is **only** for checking gear pump return flow. If additional troubleshooting will be performed to collect rail and/or injector return flow, reference the Injector section in this procedure. The Injector section will describe the setup required to separate the rail, injector, and gear pump return flows at the same time.

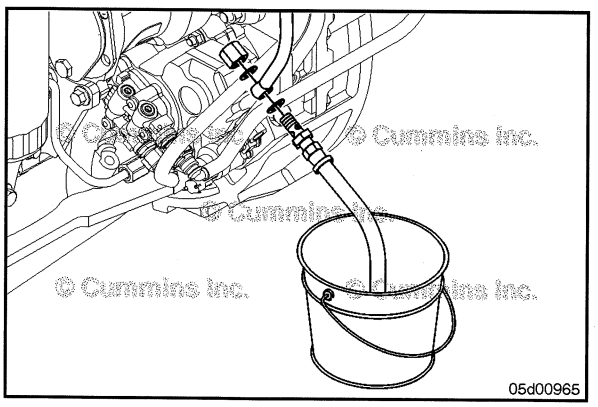
If the engine will start, make certain that the engine is at operating temperature (88°C [190°F] or open thermostat) before connecting the lines and running the test.



Initial Setup

Disconnect the OEM fuel drain line to the tank from the high-pressure fuel pump drain connection.

Disassemble and remove the banjo bolt and eyelet from the drain connection.



Install the fuel drain hose, Cummins® Part Number 3164618, into the eyelet and cap it off with Cummins® Part Number 4918297 (part of kit number 4918295).

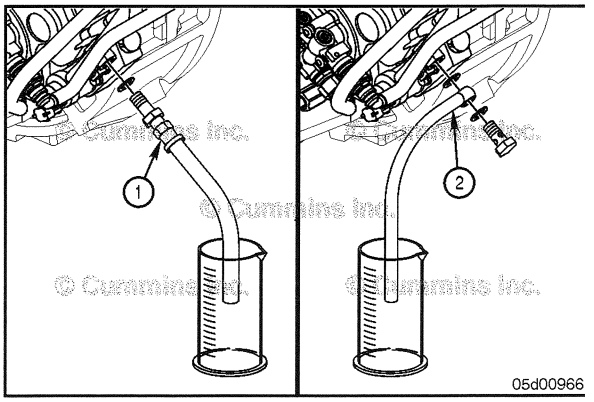
Route the drain hose into a bucket.

This is the injector and high-pressure relief valve combined fuel return flow.

Install the fuel drain flow hose, Cummins® Part Number 4918679 (1) or 4918295 (2), into the threaded drain connection located on the pump.

Route the fuel drain hose into a graduated beaker, Cummins® Part Number 4919139. This is the gear pump return flow.

Make certain the test lines are **not** kinked or leaking after installation.



Measurement - Engine Will Not Start

If the engine will **not** start, measure the fuel pump return flow while cranking the engine.

Prior to collecting data, crank the engine for 30 seconds to help purge air from the newly installed diagnostic fuel line.

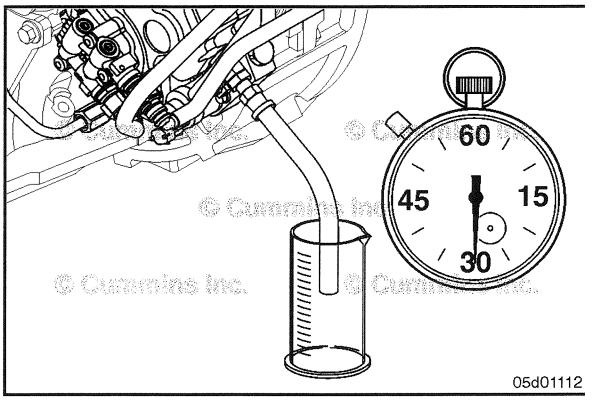
Do **not** crank the engine for 30 seconds continuously. Crank the engine in 15 second intervals with a 15 second break between cranking. This reduces the possibility of overheating the starter motor or triggering the starter protection feature.

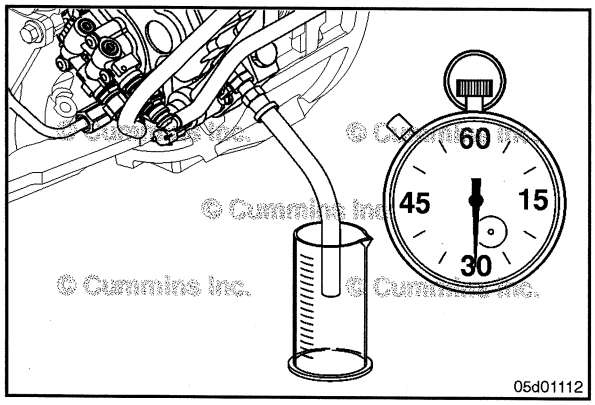
Maximum High-Pressure Fuel Pump Return Flow with Engine Cranking (150 rpm minimum) in 30 Seconds		
ml		fl-oz
317	MAX	11

NOTE: For an accurate measurement, it is a good idea to collect three different flows and average the results.

Reference the appropriate troubleshooting tree for repair direction.

Use the following procedure to connect the OEM drain line to the injection pump. Refer to Procedure 005-016 in Section 6.





Measurement - Engine Will Start

If the engine will start, make certain that the engine is at operating temperature (88°C [190°F] or open thermostat) before connecting the lines and running the test.

Prior to collecting data, operate the engine for 1 minute to help purge air from the newly installed diagnostic fuel line.

The fuel pump return flow can be measured with or without using INSITE™ electronic service tool "Fuel System Leakage Test".

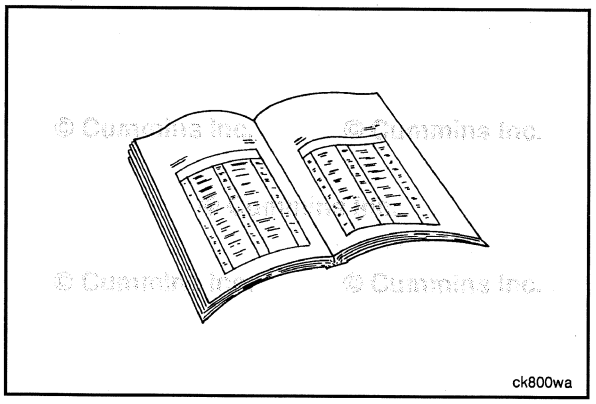
Measure the fuel pump return flow.

Maximum High-Pressure Fuel Pump Return Flow at Standard Idle Conditions in 30 Seconds		
ml		fl-oz
317	MAX	11

NOTE: For an accurate measurement, it is a good idea to collect three different flows and average the results.

Reference the appropriate troubleshooting tree for repair direction.

Use the following procedure to connect the OEM drain line to the injection pump. Refer to Procedure 005-016 in Section 6.



Fuel Pump Gear Pump Pressure Test

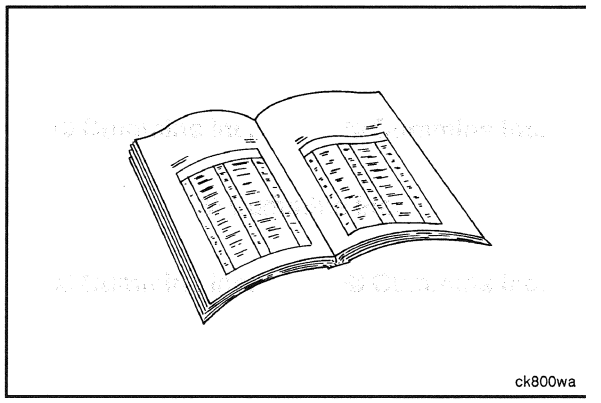
⚠CAUTION⚠
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

If the engine can be started, measurement of the fuel pressure out of the fuel gear pump can diagnose a fuel system or fuel pump problem.

Reference the Fuel Filter Restriction section in this procedure for the setup and measurement of the fuel gear pump pressure into the fuel filter.

Reference the appropriate troubleshooting tree for repair direction.

Fuel Filter Restriction Test



⚠CAUTION⚠
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

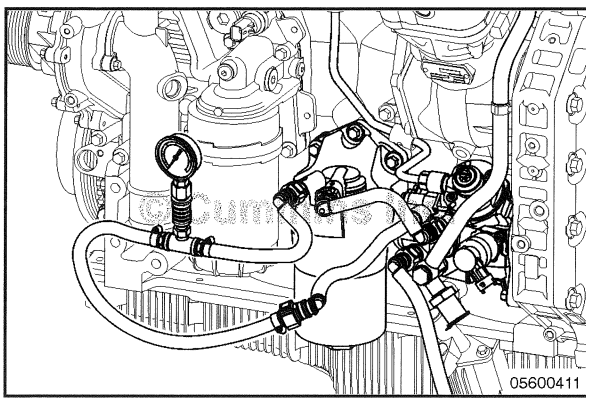
Use the following procedure to check the suction side filter restriction. Refer to Procedure 006-020 in section 6.

Check the pressure side fuel filter restriction by measuring the pressure drop across the fuel filter. Use the following steps:

If the engine will start, make certain that the engine is at operating temperature (88°C [190°F] or open thermostat) before connecting the lines and running the test.

The fuel pressure filter restriction should be measured at rated engine fuel system flow. The 0.043-inch orificed diagnostic fuel line, Cummins® Part Number 3164621, at the outlet of the fuel filter head, is used to simulate running the engine at rated fuel system flow.

Initial Setup



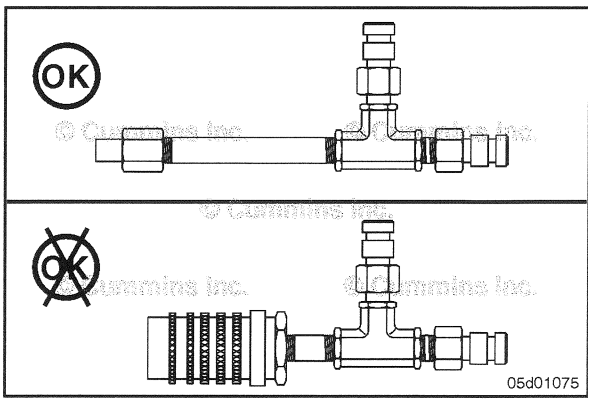
The fuel inlet and outlet are labeled on the fuel filter head with text or arrows. The illustrations do **not** necessarily display the true orientation of the inlet or outlet of the fuel filter.

1. Install an M10 male Compuchek™ fitting, Cummins® Part Number 3824842, into the diagnostic port on the inlet side of the fuel filter.

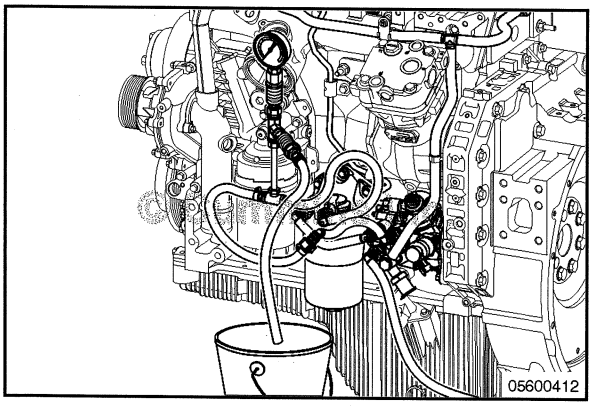
NOTE: The fuel filter head mounting capscrews may need to be loosened in order to center the test ports for attaching to the Compuchek™ fitting. If there is **not** enough clearance to install the Compuchek™ fitting, Cummins® Part Number 3824842, an adapter fitting, Cummins® Part Number 3932302, and an 1/8-NPT male Compuchek™ fitting, Cummins® Part Number 3377244 or 3042618, may be used to aid accessibility.

2. Connect a 0 to 1034 kPa [0 to 150 psi] fuel pressure gauge or multimeter pressure transducer, Cummins® Part Number 3164491, to the Compuchek™ fitting.

Construct a "T" adapter fitting using one adapter fitting, Cummins® Part Number 3932302, a 3 inch long 1/8 inch NTP pipe (or appropriate length for the application), an 1/8 inch NPT "T" fitting, and two 1/8-inch NPT Compuchek™ fittings, Cummins® Part Number 3377244 or 3042618.



NOTE: Do **not** use a female Compuchek™ fitting when constructing the "T" adapter. If a female Compuchek™ fitting is used, the pressure readings will be inaccurate.



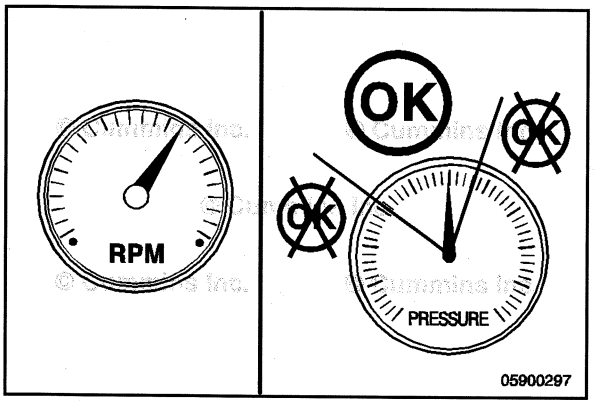
3. Install the "T" adapter fitting into the diagnostic port on the outlet side of the fuel filter.

4. Connect a 0.043-inch orificed diagnostic fuel line, Cummins® Part Number 3164621, to the "T" adapter Compuchek™ fitting. Run the fuel hose back to the fuel tank or into a bucket. The diagnostic line is used to simulate running the engine at rated fuel system flow rate.

5. Connect a 0 to 1034 kPa [0 to 150 psi] pressure gauge or multimeter pressure transducer, Cummins® Part Number 3164491, to the "T" adapter Compuchek™ fitting.

Regardless of what type of pressure measurement tool is used (gauge or multimeter pressure transducer), make sure it is calibrated and functioning properly prior to use.

Make certain the test lines are **not** kinked or leaking after installation.



Measurement - Engine Will Not Start

If the engine will **not** start, measure the fuel pressure while cranking the engine.

NOTE: If the engine will **not** start, do **not** install 0.043-inch orificed diagnostic fuel line, Cummins® Part Number 3164621, at the outlet of the fuel filter head.

Prior to collecting data, crank the engine for 30 seconds to help purge air from the newly installed diagnostic fuel line.

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 or triggering the starter protection feature.

Fuel Pressure Range at Fuel Filter with Engine Cranking (150 rpm minimum)

kPa		psi
207	MIN	30
750	MAX	108

Record the fuel filter outlet pressure value and subtract it from the fuel filter inlet pressure.

Maximum Allowable Pressure Drop Across Fuel Filter while Cranking (150 rpm minimum)

kPa		psi
81	MAX	11.7

Reference the appropriate troubleshooting tree for repair direction.

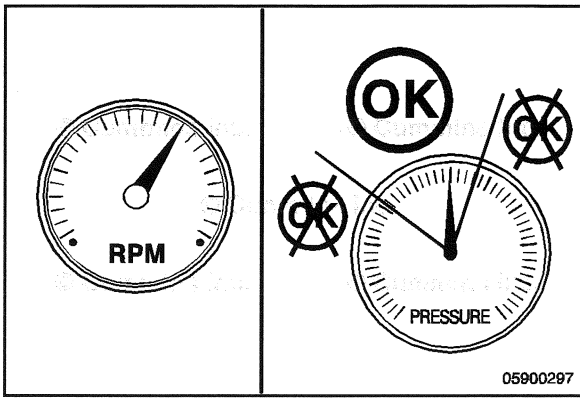
Measurement - Engine Will Start

If the engine will start, make certain that the engine is at operating temperature (88°C [190°F] or open thermostat) before connecting the lines and running the test.

NOTE: Make certain a 0.043 inch orificed diagnostic fuel line, Cummins® Part Number 3164621, is installed at the outlet of the fuel filter head.

Prior to collecting data, operate the engine for 1 minute to help purge air from the newly installed diagnostic fuel line.

Measure the fuel pressure at high idle.



Fuel Pressure Range at Fuel Filter with Engine at High Idle (2300 rpm)		
kPa		**psi**
207	MIN	30
750	MAX	108

Record the fuel filter outlet pressure value and subtract it from the fuel filter inlet pressure.

Maximum Allowable Pressure Drop Across Fuel Filter while Engine Running at High Idle (2300 rpm)		
kPa		**psi**
81	MAX	11.7

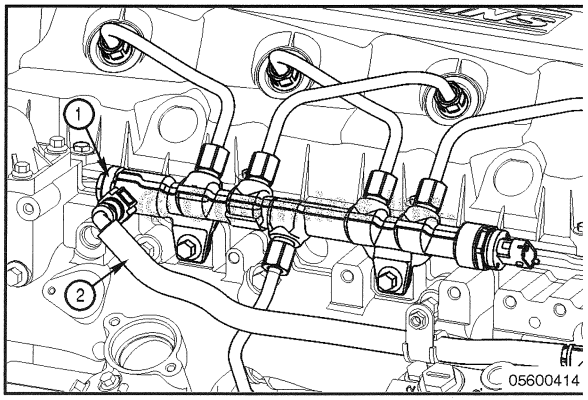
Reference the appropriate troubleshooting tree for repair direction.

High-Pressure Fuel Rail Return Flow Test

⚠CAUTION⚠
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

The purpose of this test is to check for a fuel rail pressure relief valve (1) that leaks excessive fuel to the fuel drain (2) line.

If the engine will start, make certain that the engine is at operating temperature (88°C [190°F] or open thermostat) before connecting the lines and running the test.



Initial Setup

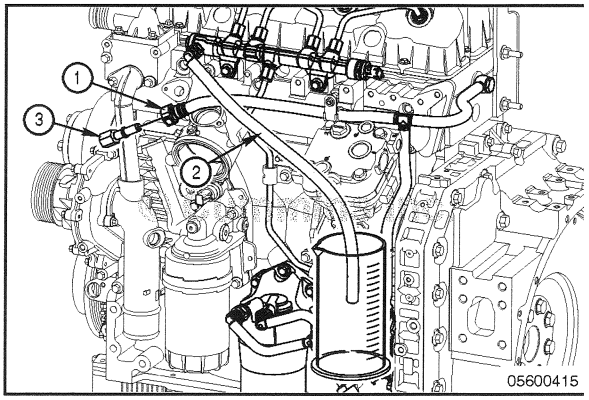
Disconnect the quick connect (1) located at the fuel rail pressure relief valve.

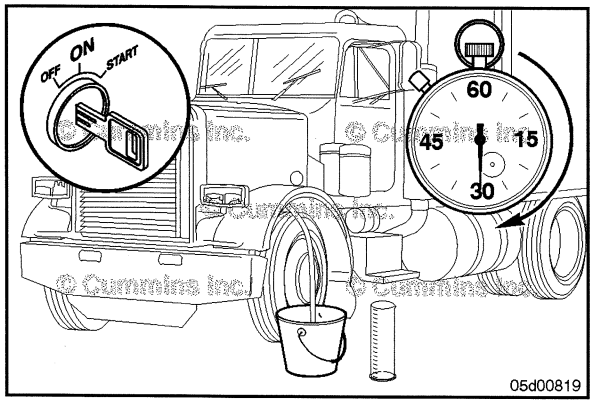
Install the quick disconnect line, Cummins® Part Number 4918434, onto the quick connect (1).

Route the fuel rail drain hose, Cummins® Part Number 4918434, female connector, into a graduated beaker, Cummins® Part Number 4919139.

Insert the fuel block-off tool, Cummins® Part Number 4918464, into the quick connect fitting line (2).

Make certain the test lines are **not** kinked or leaking after installation.





Measurement - Engine Will Not Start

If the engine will **not** start, measure the fuel return flow while cranking the engine.

Prior to collecting data, crank the engine for 30 seconds to help purge air from the newly installed diagnostic fuel line.

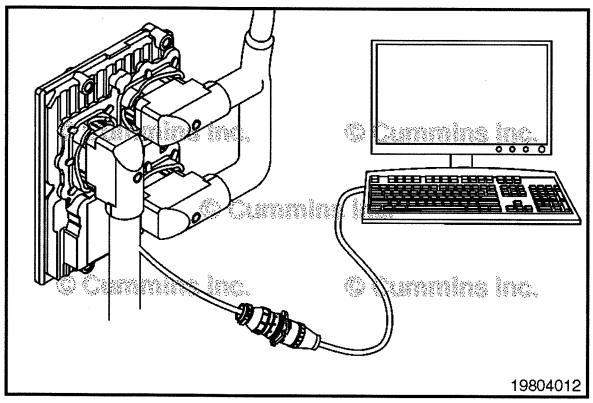
Do **not** crank the engine for 30 seconds continuously. Crank the engine in 15 second intervals with a 15 second break between cranking. This reduces the possibility of overheating the starter motor or triggering the starter protection feature.

High-Pressure Fuel Rail Return Flow at Engine Cranking (150 rpm minimum) in 30 Seconds

Maximum of 5 Drops

NOTE: For an accurate measurement, it is a good idea to collect three different flows and average the results.

Reference the appropriate troubleshooting tree for repair direction.



Measurement - Engine Will Start

If the engine will start, make certain that the engine is at operating temperature (88°C [190°F] or open thermostat) before connecting the lines and running the test.

Prior to collecting data, let the engine run for 1 minute to help purge air from the newly installed diagnostic fuel line.

The "Fuel System Leakage Test" in INSITE™ electronic service tool **must** be used to increase system pressure and therefore increase the ability to detect high leakage.

Start the engine, use INSITE™ electronic service tool "Fuel System Leakage Test" located under "ECM Diagnostic Tests" to start the fuel pressure override test.

Measure the return fuel flow.

High-Pressure Fuel Rail Return Flow at Standard Idle Conditions using INSITE™ electronic service tool "Fuel System Leakage Test" in 30 Seconds

ml		fl-oz
8	MAX	0.27

NOTE: 8 ml [0.27 fl-oz] in 30 seconds equals approximately 1 drop per second.

NOTE: For an accurate measurement, it is a good idea to collect three different flows and average the results.

Reference the appropriate troubleshooting tree for repair direction.

Cutout Test

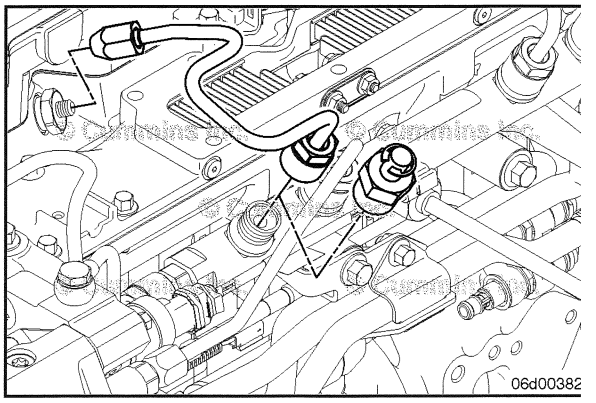
Perform a manual cutout test that will **not** start.

- With the engine **not** operating, disconnect the fuel line routed from the fuel rail to cylinder number 1. Refer to Procedure 006-051 in Section 6.
- Install the injector leakage isolation tool.

Torque Value: 40 N•m [30 ft-lb]

Attempt to start the engine or operate the engine at idle.

Repeat the above test, as necessary, with each cylinder blocked off.



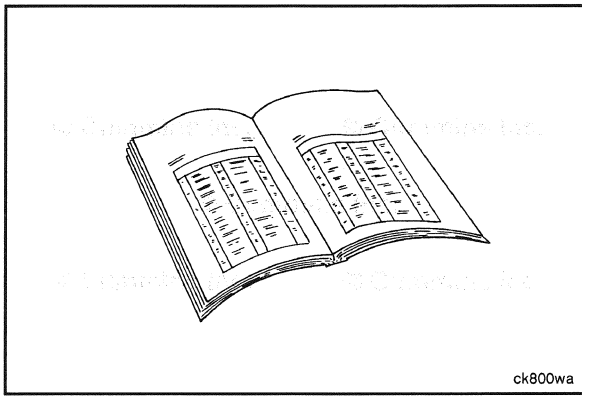
High-Pressure Fuel Injector Return Flow Test

⚠CAUTION⚠
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

The purpose of this test is to check for excessive fuel return (leakage) from the injectors/high-pressure connector to the fuel drain line.

The steps below will describe the set up to separate the rail, injector, and gear pump return flows at the same time. The fuel system return flows must be separated from each other to collect proper data.

If the engine will start, make certain that the engine is at operating temperature (88°C [190°F] or open thermostat) before connecting the lines and running the test.



Initial Setup

Fuel Rail Pressure Relief Valve Return Flow:

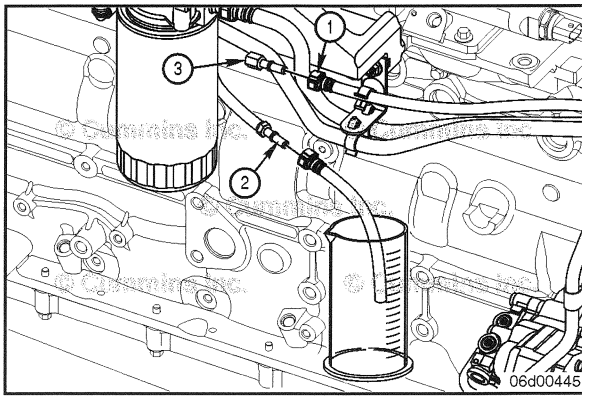
Disconnect the quick connect (1) located at the fuel rail pressure relief valve.

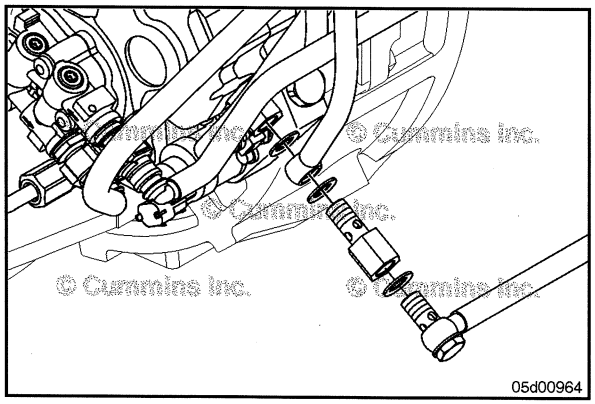
Install the quick disconnect line, Cummins® Part Number 4918462, onto the quick connect fitting line (2).

Route the fuel rail drain hose, Cummins® Part Number 3164617, female connector, into a graduated beaker, Part Number 4919139.

Insert the fuel block-off tool, Cummins® Part Number 4918464, into the quick connect fitting line (3).

Make certain the test lines are **not** kinked or leaking after installation.

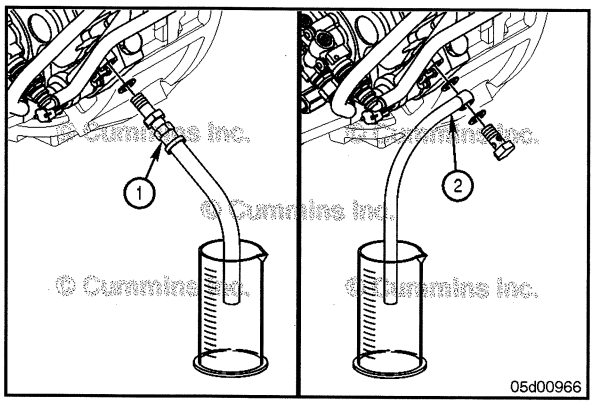




Fuel Pump Return Flow:

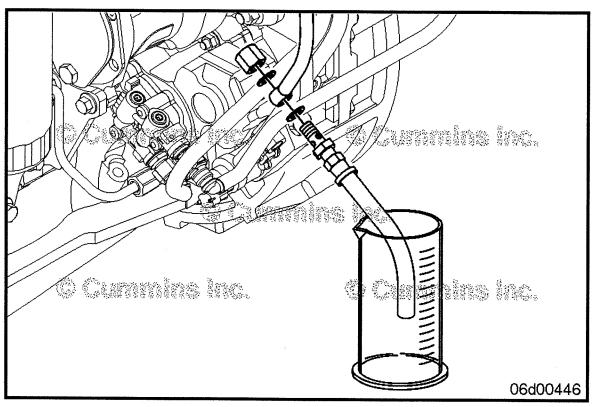
Disconnect the OEM fuel drain line from the gear pump drain connection.

Remove the flow-through banjo bolt from the drain connection eyelet.



Install the fuel drain flow hose, Cummins® Part Number 4918679 (1) or 4918295 (2), into the fuel pump threaded drain connection.

Route the fuel drain hose into a graduated beaker, Cummins® Part Number 4919139.

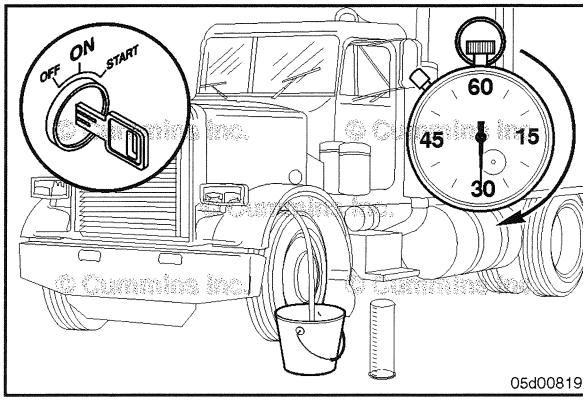


Injector Return Flow:

Install fuel drain hose, Cummins® Part Number 3164618, into the eyelet and cap it off with Cummins® Part Number 4918297 (Part of kit Part Number 4918295).

Route the fuel rail drain hose into a graduated beaker, Cummins® Part Number 4919139.

Measurement - Engine Will Not Start



Make certain the test lines are **not** kinked or leaking after installation.

If the engine will **not** start, crank the engine and measure the amount of fuel returned by the injectors.

Prior to collecting data, operate the engine for 30 seconds to help purge air from the newly installed diagnostic fuel line.

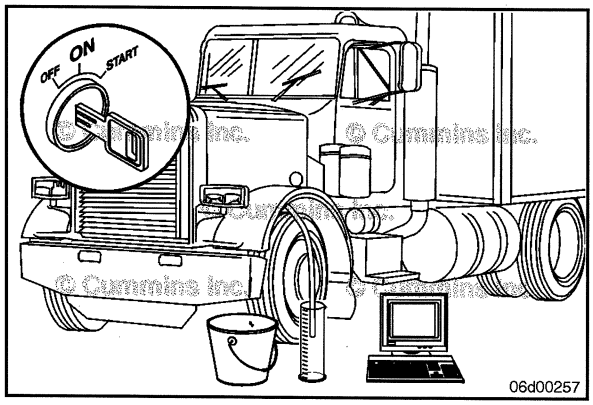
Do **not** crank the engine for 30 seconds continuously. Crank the engine in 15 second intervals with a 15 second break between cranking. This reduces the possibility of overheating the starter motor or triggering the starter protection feature.

Injector Return Flow at Engine Cranking (150 rpm minimum) for 30 Seconds

ml		fl-oz
90	MAX	4

NOTE: For an accurate measurement, it is a good idea to collect three different flows and average the results.

If the fuel return flow is greater than specification, it will be necessary to perform the "Injector Isolation Test" to block off the fuel to one injector at a time to determine the location of the leak. See the following instructions for isolating an injector.



Measurement - Engine Will Start

If the engine will start, make certain that the engine is at operating temperature (88°C [190°F] or open thermostat) before connecting the lines and running the test.

Prior to collecting data, crank the engine for 1 minute to help purge air from the newly installed diagnostic fuel line.

The "Fuel System Leakage Test" in INSITE™ electronic service tool **must** be used to increase system pressure and therefore increase the ability to detect high leakage.

Start the engine, use the INSITE™ electronic service tool "Fuel System Leakage Test" located under "ECM Diagnostic Tests" to start the fuel pressure override test.

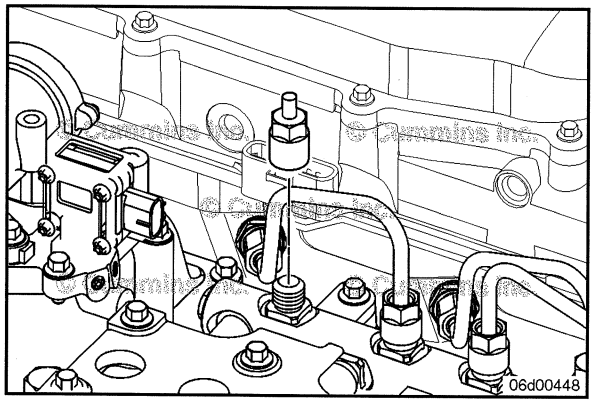
A leak may **not** be detected at standard idle conditions without using INSITE™ electronic service tool "Fuel System Leakage Test".

With the fuel drain hose in a graduated cylinder, measure the injector drain flow for 30 seconds.

Injector Return Flow at Standard Engine Idle Conditions using INSITE™ electronic service tool "Fuel System Leakage Test" in 30 Seconds		
ml		**fl-oz**
120	MAX	4.1

NOTE: For an accurate measurement, it is a good idea to collect three different flows and average the results.

If the fuel return flow is greater than specification, it will be necessary to perform the "Injector Isolation Test" described below to block off the fuel to one injector at a time to determine the location of the leak.



Initial Setup - Injector Isolation

⚠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.

Before attempting to isolate the leak, make sure **all** of the high-pressure fuel connectors are tightened to the correct torque. Refer to Procedure 006-051 in Section 6.

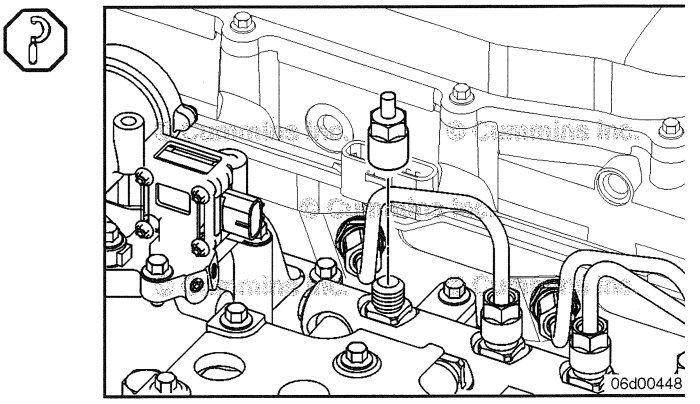
If a connector is **not** tightened to the proper torque, tighten the connector and perform the previous test again. If the injector return flow is greater than the specified flow rate, it will be necessary to block off the fuel to one injector at a time to determine the location of the leak.

With the engine **not** running, remove the fuel injector supply line connecting the fuel rail to cylinder number 1. Refer to Procedure 006-051 in Section 6.

Install the injector leakage isolation tool, Cummins® Part Number 4918298, on the fuel rail where the number 1 cylinder fuel line connects.

Torque Value: 40 N•m [30 ft-lb]

Measurement - Injector Isolation



Repeat the return flow test with cylinder 1 blocked off and record the flow rate.

Install the fuel injector supply line. Refer to Procedure 006-051 in Section 6.

Repeat the return flow test with each cylinder blocked off.

Record the flow rate for each test.

The flow rate will decrease below the maximum specified flow when the cylinder with the leak is blocked.

The following table illustrates an example of a return flow test where a leak is present in cylinder number 5.

Example Return Flow Test Results						
Cylinder Blocked	1	2	3	4	5	6
ml/30 Seconds	210	210	210	210	91	210
fl-oz/30 Seconds	7	7	7	7	3	7

NOTE: For an accurate measurement, it is a good idea to collect three different flows and average the results.

If the measurement does **not** meet the specifications listed, reference the appropriate troubleshooting tree for repair direction.

If this test is performed and there is **not** a significant change in fuel return flow while blocking off one injector, there may be a problem with more than one injector.

Compare the fuel return flow difference across **all** injectors. (If there is more than one injector that caused a noticeable decrease in flow, they could be the leaking injectors).

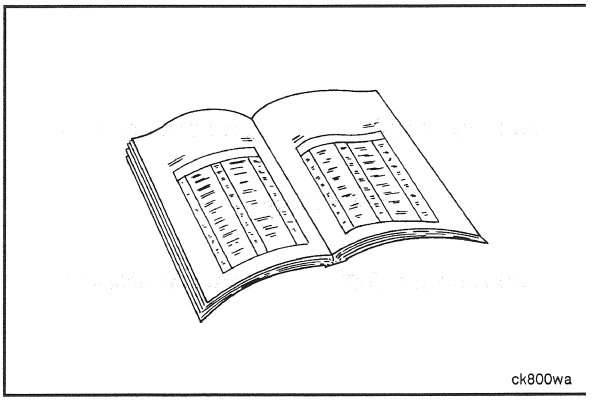
Another cause of this problem could be that the customer is operating on fuels lighter than specified. Fuels with low viscosity will result in higher injector leakage and greater return flow rates.

Use the following procedures for assembly information.

- Fuel Pump: Refer to Procedure 005-016 in Section 5.
- Injector Supply Lines (High-Pressure): Refer to Procedure 006-051 in Section 6.
- Fuel Connector (Head Mounted): Refer to Procedure 006-051 in Section 6.

Finishing Steps

- Remove **all** test equipment.
- Operate the engine and check for leaks.



Notes

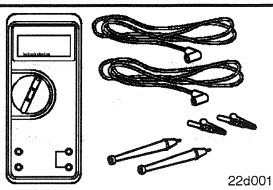
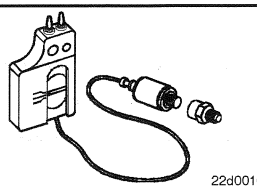
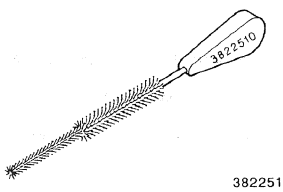
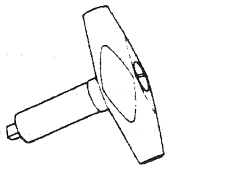
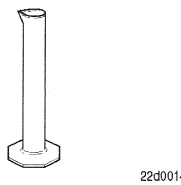
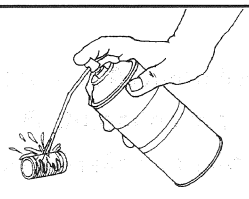
Section 6 - Injectors and Fuel Lines - Group 06

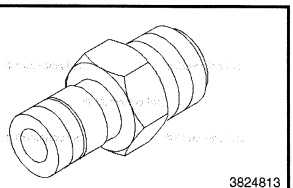
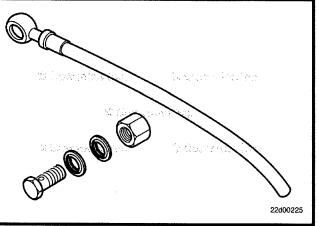
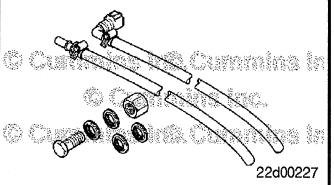
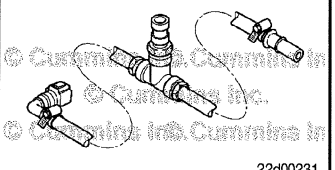
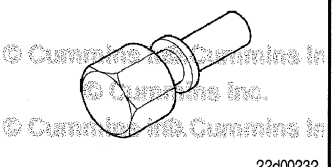
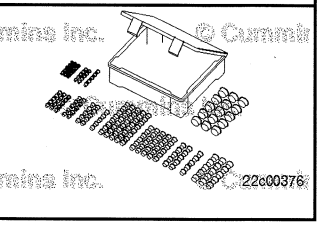
Section Contents

Service Tools

Injectors and Fuel Lines

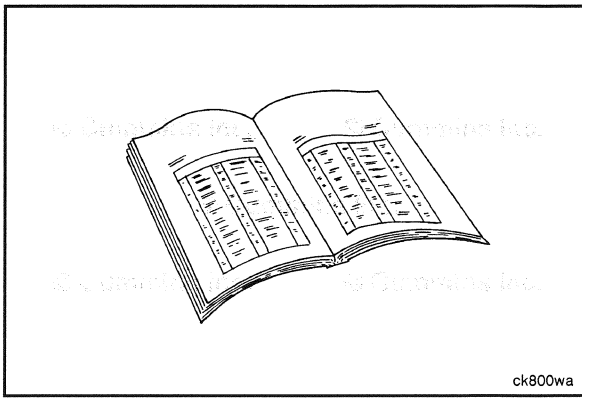
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3164489	**Digital Multimeter** Used to measure electrical circuits: Voltage (volts), resistance (ohms), and current (amps). 3164489 - Automotive meter with built in temperature adapter and tachometer.	 22d00105
3164491	**Pressure/Vacuum Module** Used to measure fuel pressure and restriction. Use with digital multimeter, Part Number 3164488 or 3164489.	 22d00104
3822510	**Injector Bore Brush** Used to clean the injector bore.	 3822510
3823208	**Torque Wrench - Injector Terminal Nuts** This 13 in-lb torque wrench is used to tighten the injector terminal nuts.	 3823208
4919139	**Graduated Beaker** Used to measure fuel return flows.	 22d00140
3824510	**Quick Dry (QD™) Cleaner** Used to clean parts and tools safely.	

Tool No.	Tool Description	Tool Illustration
3824842	**Compuchek™ Fitting** Used to check fuel pressure/restriction. 10 mm o-ring connection.	
4918295	**Fuel Return Flow Hose Kit** Used to check fuel return flow from 12 mm banjo fitting connections.	
4918354	**Fuel Return Flow Tester Kit** Used to check injector and HPCR pump drain flow.	
4918462	**Fuel Pressure Gauge Adapter Kit** Used to check fuel pressure/restriction.	
4918464	**Fuel Tube Plug** Used to plug low pressure fuel lines.	
5298815	**Fuel System Clean Care Kit** Used to cap or plug the fuel system fittings during service to prevent debris from entering the fuel system.	

Air in Fuel (006-003)

General Information



⚠CAUTION⚠
Make sure the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when engine is cranked or started.

The replacement of fuel supply lines, fuel filters, fuel injection pump, high-pressure fuel lines, and injectors will allow air to enter the fuel system. Air in the system can make the engine hard to start, run rough, misfire, produce low power, or produce excessive smoke and a fuel knock.

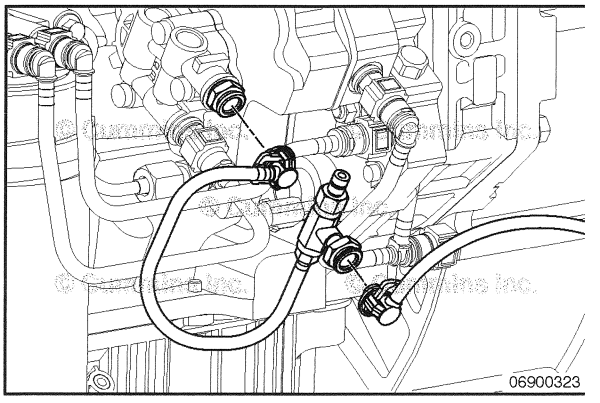
A few bubbles exiting the line during the test is expected. A foamy appearance is an indication of a leak that allows air to enter, a severe inlet restriction that causes cavitation, or a system that is **not** yet primed. If fuel inlet restriction is **not** excessive, the source of air entry should be isolated to one of the following:

- Suction fuel lines.
- Engine control module (ECM) cooling plate assembly, if applicable.
- Original equipment manufacturer (OEM) fuel lines.
- Suction-side fuel filter assemblies.
- Stand-pipe(s) in the fuel tank(s).

Refer to Procedure 006-020 in Section 6.

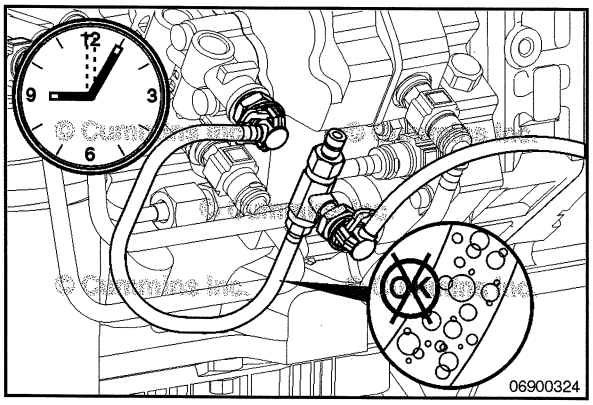
Use the following procedure for additional information. Refer to Procedure 005-999 in Section F.

Test

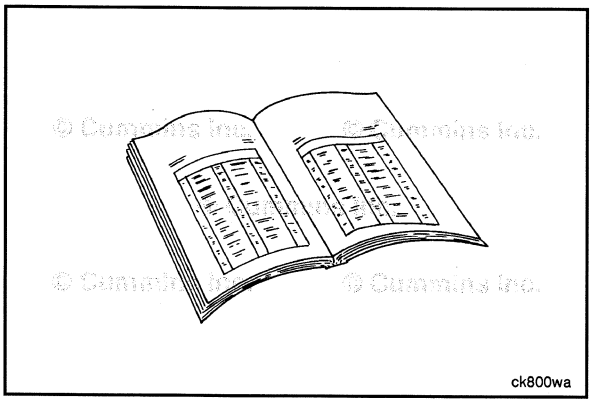


Install the fuel pressure gauge adapter service tool, Cummins® Part Number 4918462, or equivalent, between the ECM cooling plate and the gear pump.

Operate the engine at idle and check for air bubbles in the clear line.



If air continues to bubble through the clear hose for several minutes, an air leak is present.



Fuel Drain Line Restriction (006-012)

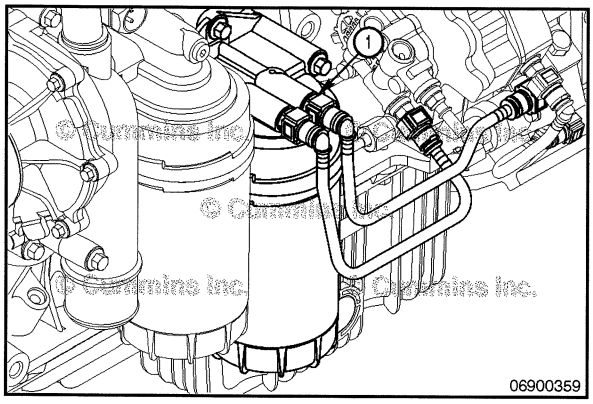
General Information

⚠WARNING⚠
Make sure that the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when ignition is cranked or started. Environmental damage can also occur.

⚠CAUTION⚠
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system that fuel is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The fuel and fuel filters must be discarded in accordance with local environmental regulations.

The fuel drain line restriction is measured at a fuel return manifold located near the point at which the original equipment manufacturer (OEM) connects the vehicle fuel drain line. To locate this manifold, follow the fuel drain lines from their source, (rail pressure relief valve, injector return, or high pressure injector pump return) to their termination point. The termination point will occur at the fuel return manifold.

Refer to Procedure 005-999 in Section F.



Setup

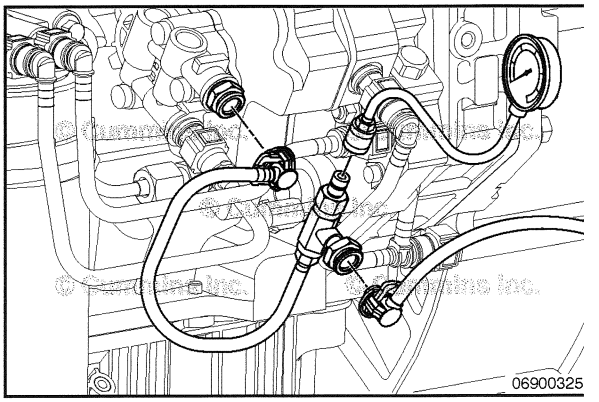
Low Mount Fuel Return Manifold

The integral fuel filter head return manifold (1) is located on the fuel filter head.

Disconnect the fuel drain line connecting the fuel pump drain to the fuel return manifold.

Insert a fuel pressure gauge adapter tool, Cummins® Part Number 4918462, or equivalent, between the fuel return manifold and the fuel drain line.

Attach a pressure gauge to the Compuchek™ fitting on the fuel pressure gauge adapter.

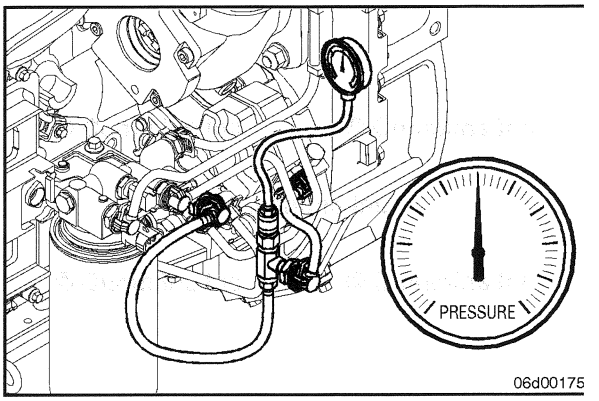


Initial Check

Operate the engine at cranking or low idle and measure the fuel pressure.

Observe the reading on the gauge.

Maximum Drain Line Restriction		
kPa		psi
20.0	MAX	2.9

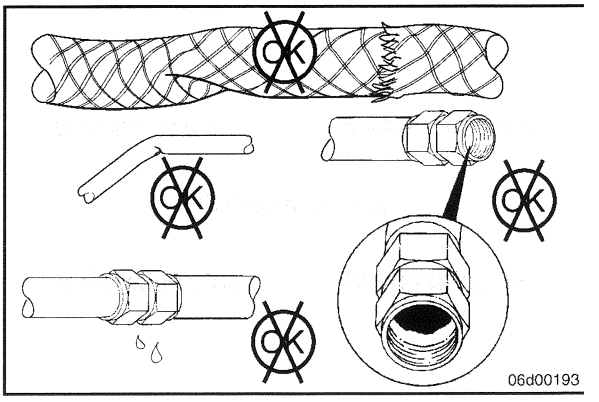


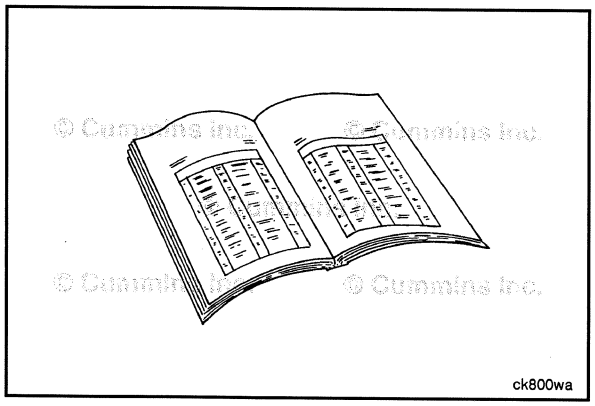
If the fuel drain line restriction is too high, check:

1 OEM fuel lines to the tank for proper size, leaks, bends, or clogs.

2 Fuel drain valves for restrictions or plugging (marine applications only).

3 Fuel tank vents for plugging.





Fuel Drain Lines (006-013)

General Information

⚠CAUTION⚠
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system, that fuel is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The fuel and fuel filters must be discarded in accordance with local environmental regulations.

⚠CAUTION⚠
Be sure that the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the closed position when engine is cranked or started. Environmental damage can also occur. Use the following procedure for general cleaning instructions. Refer to Procedure 005-999 in Section F.

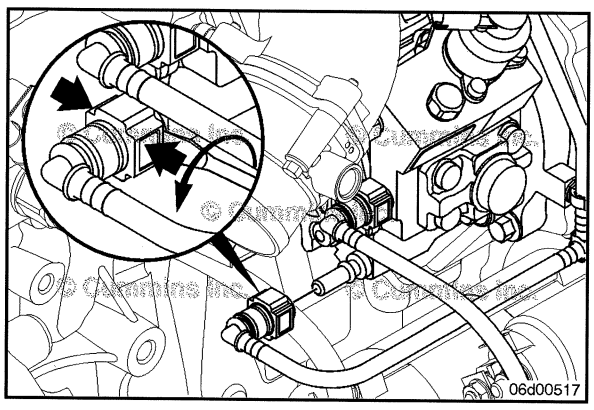
The fuel drain line restriction is measured at a fuel return near the point at which the OEM connects the vehicle fuel drain line. To locate, follow the fuel drain lines from their source (rail pressure relief valve, injector return, and high pressure pump return), to their termination point at the rear of the engine, near the high pressure fuel pump.

The fuel return line uses two types of fittings:

1 The fuel injectors have a push/pull connection fitting to each of the injectors, secured by a removable spring clip.

2 The fuel manifold, fuel pump, and the original equipment manufacturer (OEM) vehicle drain line have a quick disconnect style connection fitting. These are released by pressing in the locking tangs on both sides of the connection fitting.

In addition, the fuel drain line route is secured with fir tree clips.



Directions for service of a two-button, quick-disconnect fitting:

Remove the quick disconnect style fuel lines by pressing in the locking tangs on both sides of the quick disconnect fitting.

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.

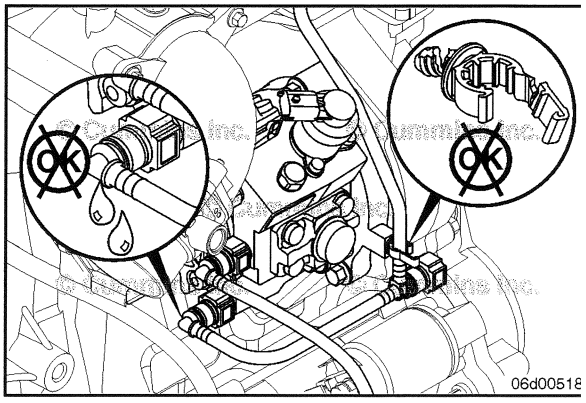
Install the quick-disconnect style fuel lines by pushing the quick-disconnect fitting onto the male union until it clicks.

Initial Check

Inspect the drain lines for any signs of leaks, cracks, chafing, or loose or broken fir tree clips.

NOTE: Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

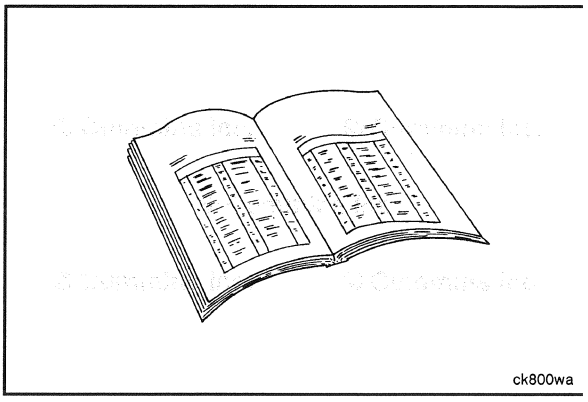
It is essential that maximum cleanliness is observed to reduce the possiblity of contamination of the fuel lines with dust particles or lubricant fluids. Refer to Procedure 204-008 in Section i.



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. See equipment manufacturer service information.

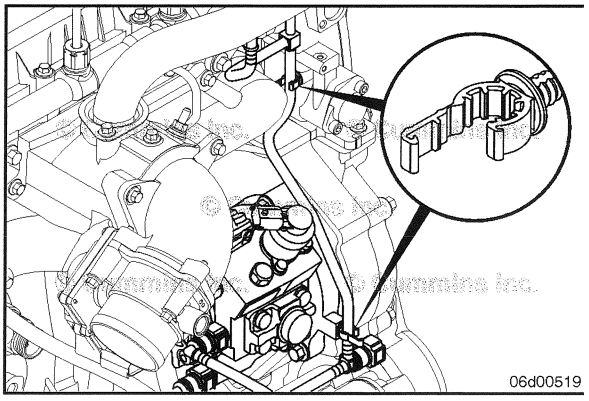


Remove

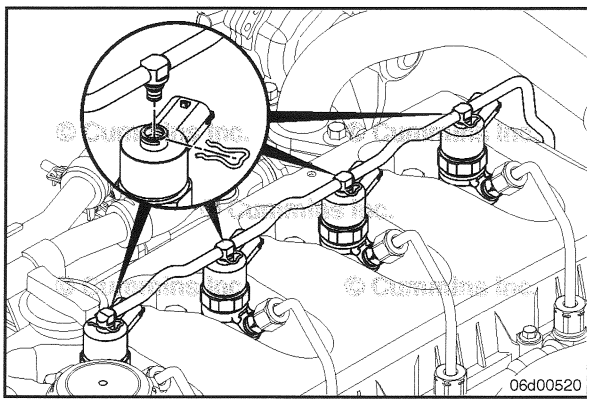
NOTE: Mark the location of all p-clips, and routing of fuel drain lines, to make sure that they are replaced in the correct location during reassembly.

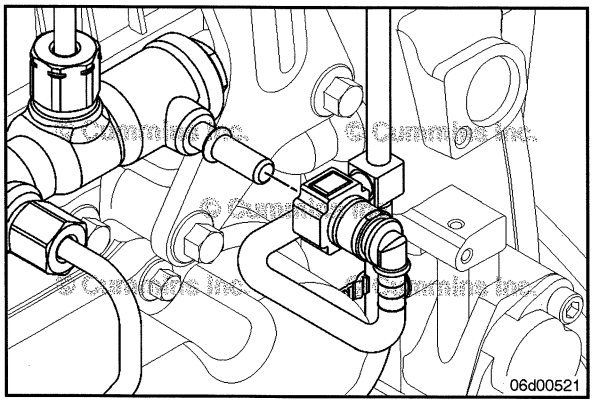
Remove the fuel drain line connector from the OEM vehicle fuel drain line.

Any open fuel connectors **must** be closed immediately with protection caps.

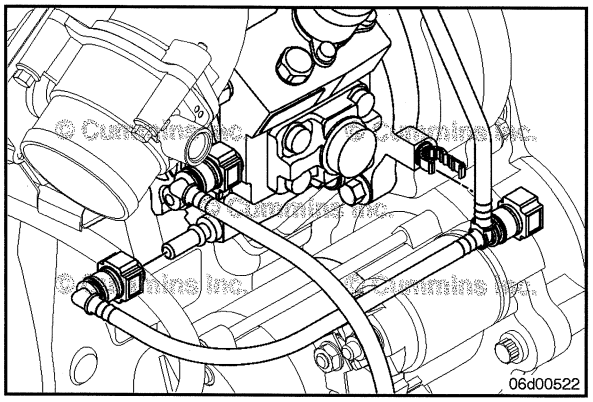


Remove the fuel drain connector from each of the injectors, taking care **not** to lose the retaining spring clips.



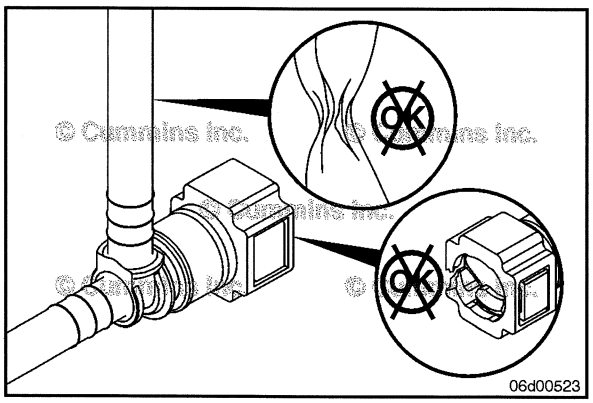


Remove the fuel drain connector from the high pressure fuel rail.



Remove the fuel drain connector from the high pressure fuel pump.

Carefully remove the fuel drain line from each fir tree clip location.

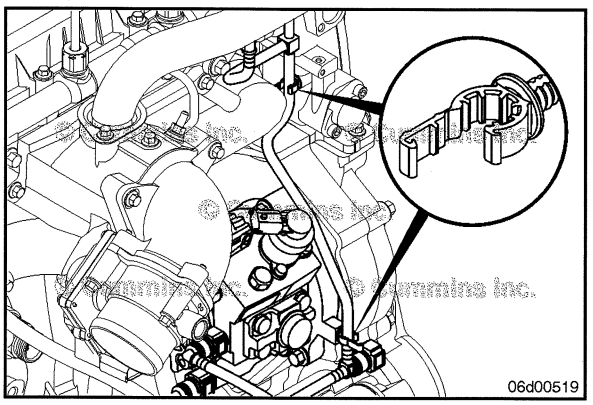


Inspect for Reuse

Inspect the fuel drain lines for clogging and pinched areas.

Check the connector and o-ring for damage.

Replace the fuel line if damaged.



Install

During installation, each quick disconnecting connector **must** be securely locked in position.

There **must** be no unwanted kinks or bends in the fuel drain lines during installation.

Remove the protective caps from the open fuel lines just prior to installing each of the fuel drain line connectors.

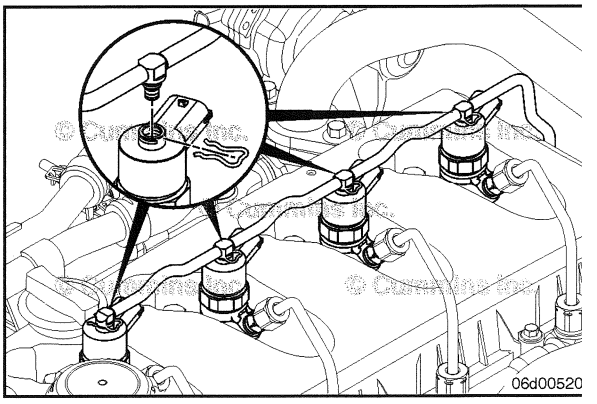
Install the fuel drain lines according to the routing noted during removal.

Each fuel drain line **must** be secured correctly at each fir tree clip location.

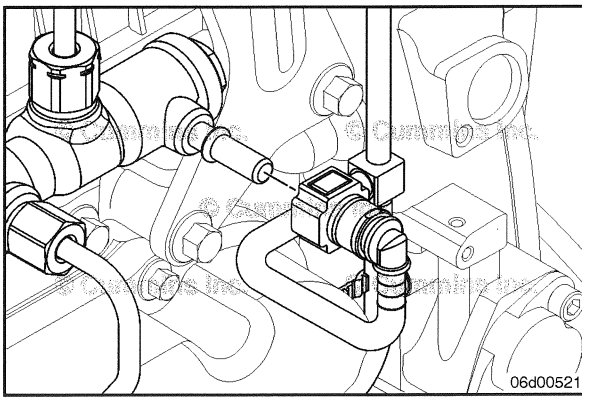
Install the fuel drain connector to each of the injectors with a new seal, if required, and make sure the seal is fully installed into the injector housing.

Secure the fuel drain connector in position with the retaining spring clip. A click should be heard when fitted correctly.

To make sure the connectors are installed correctly, apply a slight upward force to the fuel drain line connector at each injector.



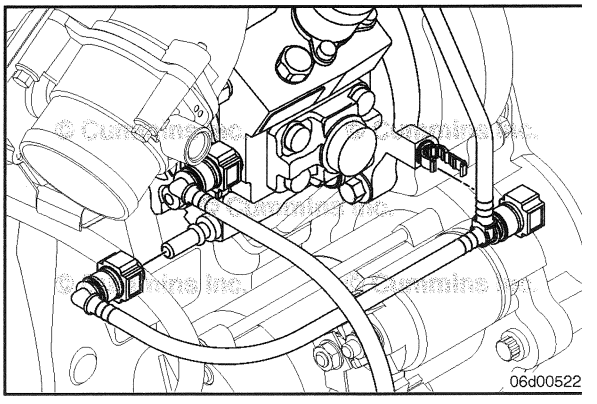
Install the fuel drain connector to the high pressure fuel rail.



NOTE: The fuel pump drain connector is the lowest of the two identical connection tubes on the pump.

Install the fuel drain line connector to the high pressure fuel pump.

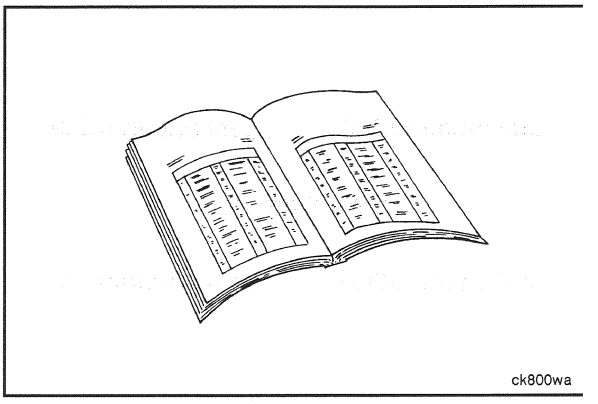
Install the fuel line drain connector to the OEM vehicle fuel drain line.

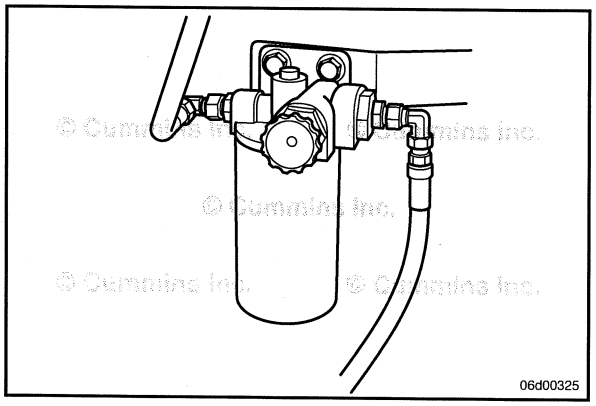


Finishing Steps

⚠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. See equipment manufacturer service information.
- Operate the engine and check for leaks.





Fuel Filter (Spin-On Type) (006-015)

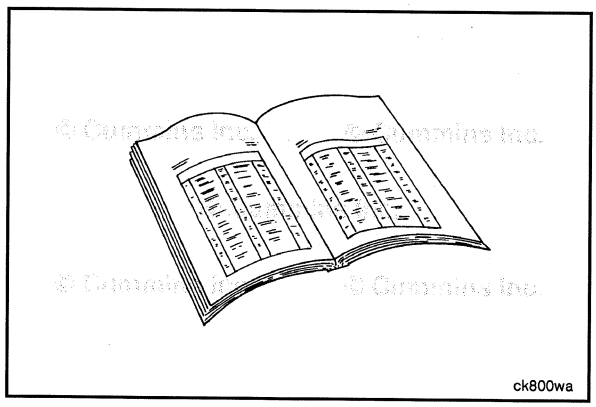
General Information

Fuel System Priming

A certain amount of air becomes trapped in the fuel system when fuel system components on the supply and/or high-pressure side are serviced or replaced. Fuel system priming is accomplished using a manual priming pump. For priming procedures, see the Prime section of this procedure.

NOTE: It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will help prime the fuel system.

NOTE: Use the following procedure for fuel system diagnostics and component specifications. Refer to Procedure 005-236 in Section 5.



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⚠
Do not bleed the fuel system of a hot engine; this can result in fuel spilling onto a hot exhaust manifold, which can cause a fire.

⚠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.

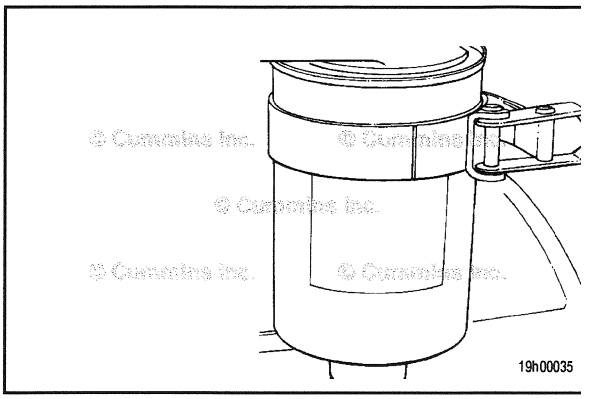
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

- Disconnect the batteries. See equipment maufacturer service information.
- Clean the area around the fuel filter.
- If required, disconnect the wiring harness from the water-in-fuel sensor.

NOTE: Clean all around the filter area before disassembly. Dirt or contaminants can damage the fuel system.

Remove

Remove the fuel filter from the filter head with filter wrench, Cummins® Part Number 3398231, or equivalent.



Install

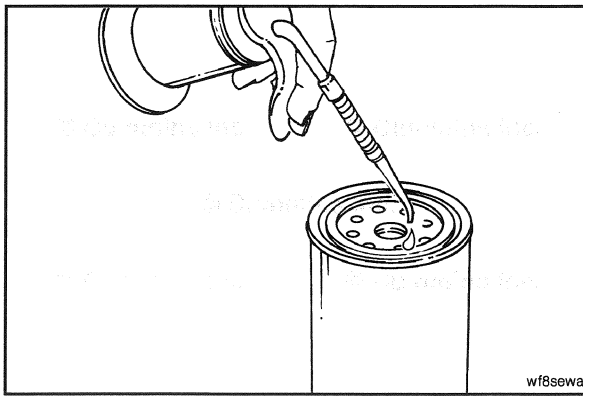
⚠CAUTION⚠
Do not pre-fill the suction side fuel filter with fuel unless a clean side block off plug is used. The system must be primed after the fuel filter is installed. Pre-filling the pressure side fuel filter can result in debris entering the fuel system and damaging fuel system components.

NOTE: If available, pre-fill new filters, with clean fuel prior to assembly using the clean side block-off plug packed with the filter. Do **not** pour fuel directly into the center of the filter as this will allow unfiltered fuel to enter the system and can cause damage to fuel system components.

Use the correct fuel filter.

- Use the following procedure in the QSF3.8 CM2350 F107 Operation and Maintenance Manual, Bulletin 4364317. Refer to Procedure 018-024 in Section V.

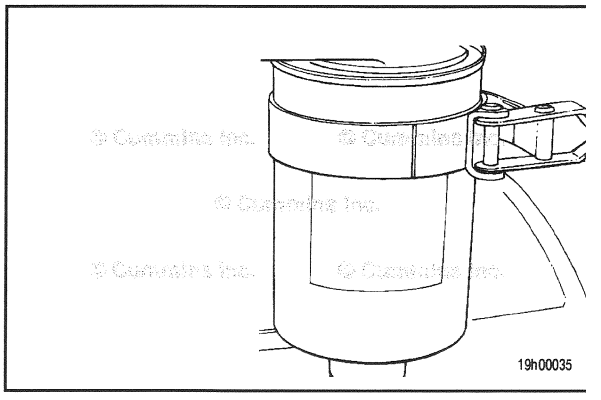
Lubricate the fuel filter o-ring seal with clean lubricating oil.

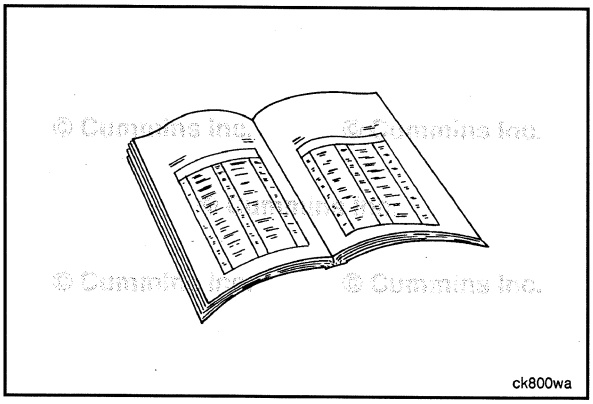


⚠CAUTION⚠
Mechanical overtightening can distort the threads the threads as well as damage the filter element seal or filter can.

Install the filter on the filter head. Use filter wrench, Cummins® Part Number 3398231, or equivalent. Tighten the filter until the gasket contacts the filter head surface.

Tighten the fuel filter an additional 3/4 turn after contact or see equipment manufacturer service information.

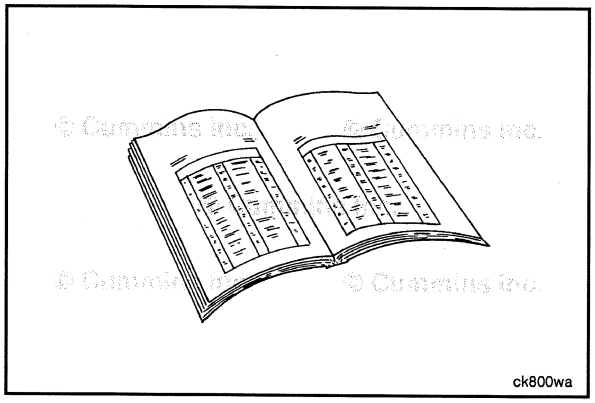




Finishing Steps

⚠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 required, connect the wiring harness to the water-in-fuel sensor.
- Connect the batteries. See equipment manufacturer service information.



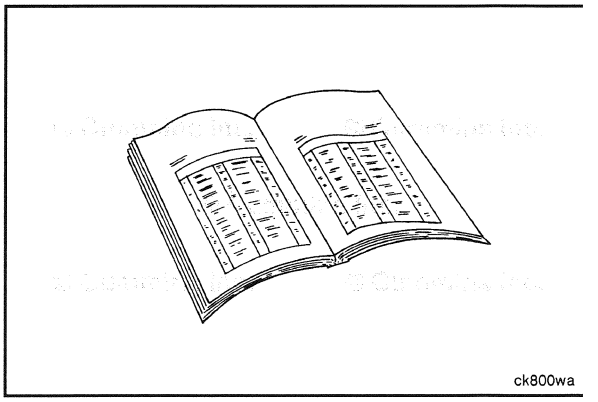
Fuel Filter Head (006-017)

General Information

The pressure side fuel filter head is mounted on the engine. The suction side fuel filter head, with a hand priming lift pump, can be remotely mounted on the vehicle chassis.

Due to the two different fuel filter head designs and mounting locations, the steps in this procedure have been written to be generic.

Preparatory Steps

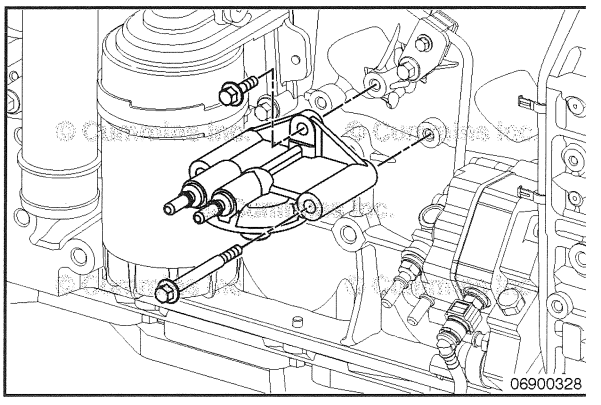


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
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 batteries. See equipment manufacturer service information.
- Drain the fuel-water separator into a container and dispose of contents in accordance with local environmental regulations.
- Disconnect the pressure-side fuel filter head supply and drain line connectors. Refer to Procedure 006-024 in Section 6. Refer to Procedure 006-013 in Section 6.
- Disconnect the suction-side fuel filter head supply and drain line connectors. See equipment manufacturer service information.
- Remove the fuel filter. Refer to Procedure 006-015 in Section 6.
- Remove the fuel heater, if applicable. Refer to Procedure 005-008 in Section 5.

Remove

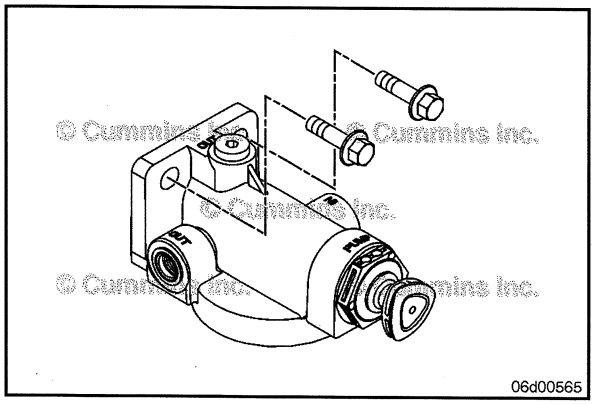


NOTE: The following steps can beused for replacing the pressure side and suction-side fuel filter.

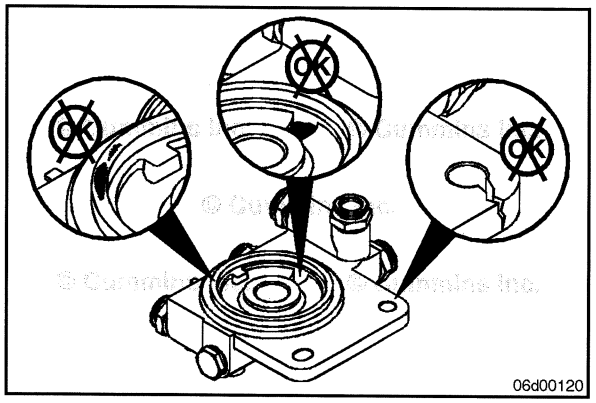
The fuel filter head is marked with IN and OUT arrows to indicate flow. Be sure to note the orientation of the fuel filter head before removal.

Remove the fuel filter head mounting capscrews.

Remove the fuel filter head.

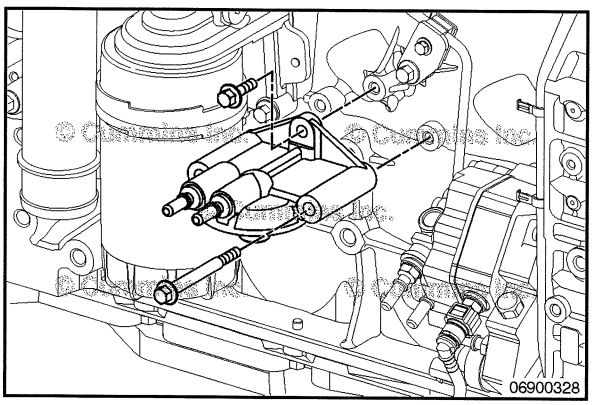


Remove the suction side fuel filter head. See equipment manufacturer service information.



Clean and Inspect for Reuse

Inspect the fuel filter head for cracks, passage blockage, and material or debris on the sealing surfaces.



Install

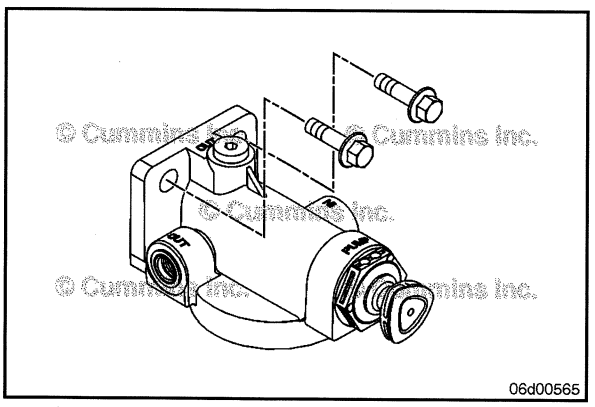
Pressure Side Fuel Filter

- The fuel filter head is marked with IN and OUT arrows to indicate flow. Be sure the fuel filter head is installed in the same way as it was removed.

Install the fuel filter head.

Install the fuel filter head mounting capscrews.

Torque Value: 24 N•m [212 in-lb]

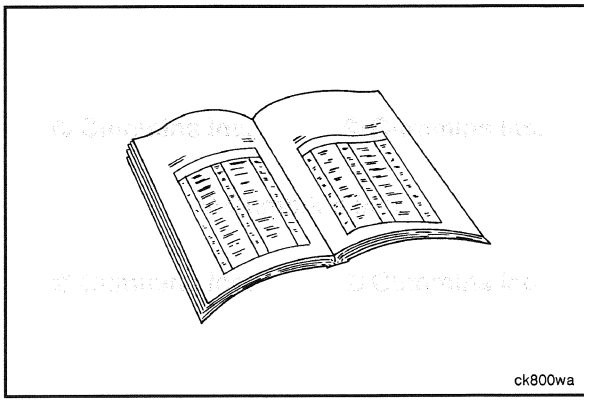


Install the suction side fuel filter head. See equipment manufacturer service information.

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 pressure-side fuel filter head supply and drain line connectors. Refer to Procedure 006-024 in Section 6. Refer to Procedure 006-013 in Section 6.
- Install the suction-side fuel filter head supply and drain line connectors. See equipment manufacturer service information.
- Install the fuel heater, if applicable. Refer to Procedure 005-008 in Section 5.
- Install the fuel filter and prime the system. Refer to Procedure 006-015 in Section 6.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.

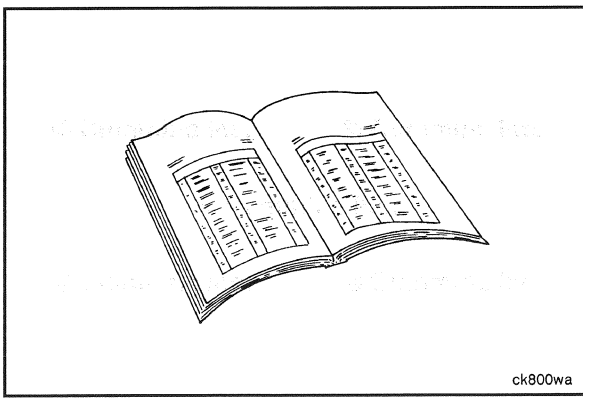


Fuel Inlet Restriction (006-020)

General Information

⚠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.

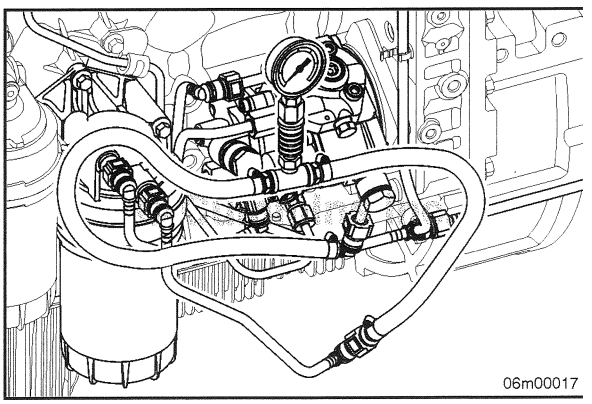
Fuel inlet restriction is measured near the point at which the original equipment manufacturer (OEM) connects the vehicle fuel supply line to the fuel pump (fuel gear pump inlet).

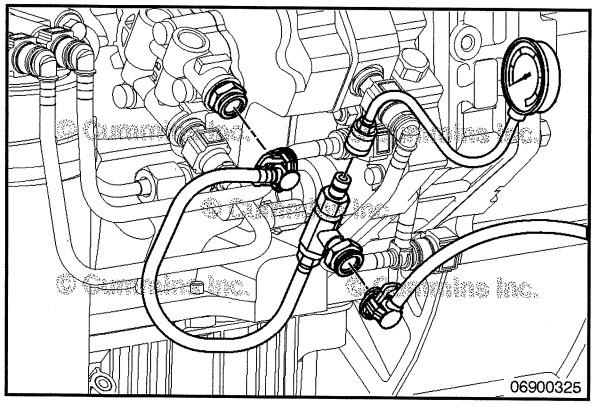


Setup

Use the following instructions if quick connect fittings are **not** installed at fuel gear pump inlet:

- Disconnect the fuel supply line from the gear pump inlet connection.
- Install Fuel Pressure Test Kit, Cummins® Part Number 4919698, between the fuel supply line and the inlet to the gear pump.
- Install a vacuum gauge with a range of at least 0 to 762 mm-Hg [0 to 30 in-Hg] onto the pressure gauge adapter. A pressure/vacuum module, Cummins® Part Number 3164491, and a multimeter can also be used for this measurement.

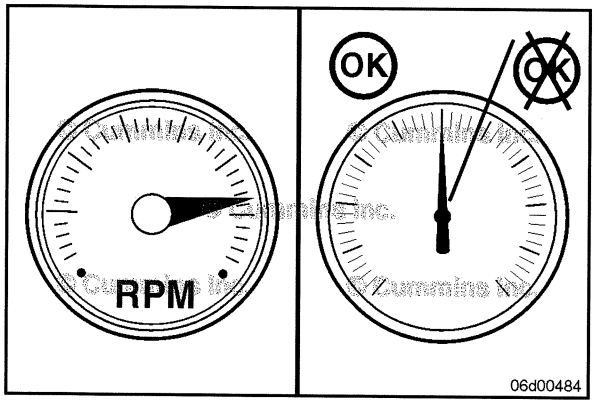




Use the following instructions if quick connect fittings are installed at the fuel gear pump inlet:

- Disconnect the fuel supply line quick connect from the inlet to the gear pump.
- Install a pressure gauge adapter between the fuel supply line and the inlet to the gear pump.
- Pressure gauge adapter, Cummins® Part Number 4918462, for 5/16 inch fittings.

Install a vacuum gauge that has a range of at least 0 to 762 mm-Hg [0 to30 in-Hg] onto the pressure gauge adapter. A pressure/vacuum module, Cummins® Part Number 3164491, and a multimeter can also be used for this measurement.



Measure

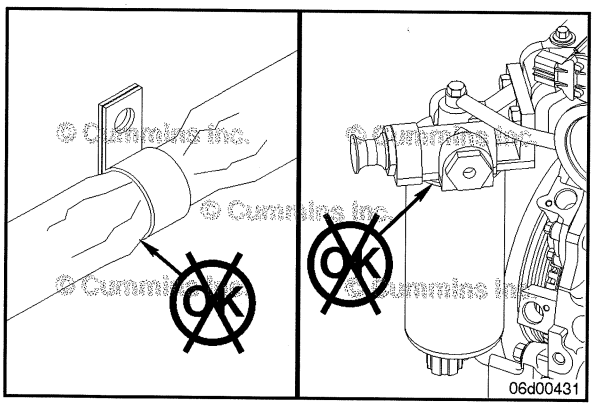
Operate the engine at high idle and measure the fuel inlet restriction.

In order to reach engine high idle, it may be necessary to temporarily adjust the "Maximum engine speed without vehicle speed source" parameter with INSITE™ electronic service tool to the high idle speed of the engine. Refer to the engine dataplate for the value.

Observe the reading on the gauge.

Maximum Fuel Inlet Restriction Vacuum at High Idle		
kPa		in Hg
41	MAX	12.0

With the engine running, there should **not** be any air bubbles in the clear pressure adapter test line at the gear pump inlet. Air bubbles are a sign of severe inlet restriction, loose suction side fittings, or a system that is **not** yet primed.



If the fuel inlet restriction is too high, check the OEM fuel lines from the tank for proper size. Make certain there are no kinks or bends in the fuel lines and that the fuel lines are **not** clogged.

Check the suction side filter head for plugging.

Check the OEM fuel supply tanks for debris (plastic wrappers, paper, etc.) that can intermittently block the fuel pickup tubes.

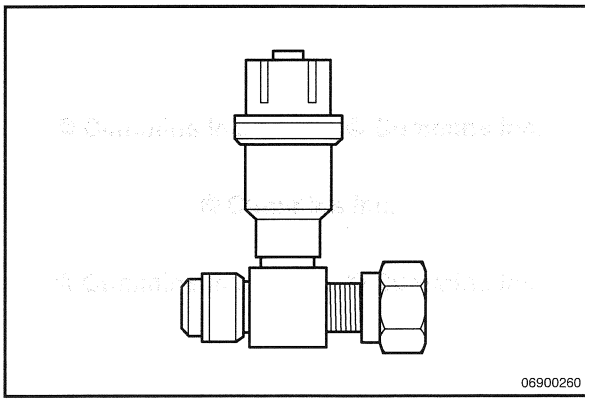
Check the OEM fuel lines for internal damage, such as damaged wall linings, that can intermittently block fuel flow.

Check the fuel tank vents or fill cap vents for plugging.

Make sure there are no clogged OEM fuel strainers or filters, or malfunctioning check valves.

If no issues are found, replace the suction side fuel filter and prime the fuel system. Refer to Procedure 006-015 in Section 6.

If the issue is intermittent and no issues can be found while the engine is being serviced, install a fuel filter minder, Fleetguard® Part Number 3925199S, at the connection between the OEM fuel supply lines and the engine. A fuel filter minder will capture the peak restriction in millimeters and inches of mercury. If the issue occurs again, the fuel filter minder can be checked to see if there is damage or debris on the OEM side causing the high restriction.



Fuel Supply Lines (006-024)

General Information

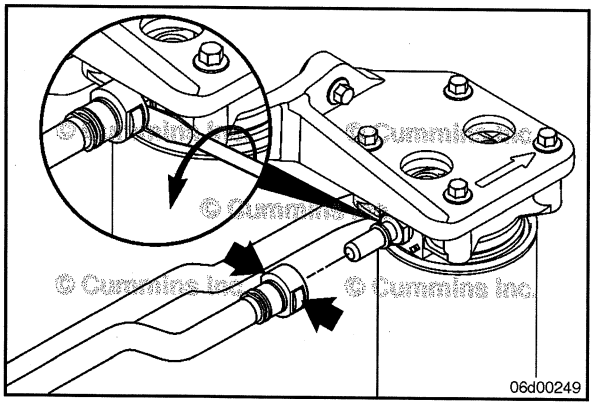
⚠WARNING⚠
Depending on the circumstance, diesel fuel is flammable. When inspecting or performing service or repairs on the fuel system, to reduce the possibility of fire and resulting severe personal injury, death or property damage, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area.

⚠WARNING⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. To avoid the possibility of personal injury, never loosen any fittings while the engine is running.

⚠WARNING⚠
Fuel can be returned at highly elevated temperatures. Wear safety glasses, protective gloves, and clothing when performing this test. Avoid any contact with returned fuel.

△CAUTION△
Be sure the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when engine is cranked or started. Environmental damage can also occur. Refer to Procedure 005-999 in Section F for further information.

Due to the number of different fuel supply line routings and connector styles, the steps in this procedure have been written to be generic. Some of the illustrations may **not** represent the parts being removed or installed.

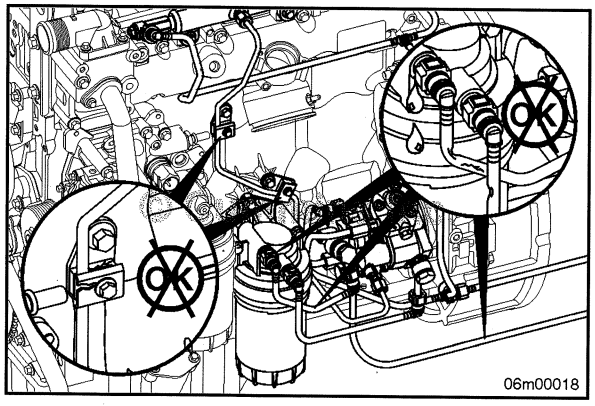


Directions for service of a two-button quick disconnect fitting:

To remove the quick disconnect style fuel lines, press in the locking tangs on both sides of the quick disconnect fitting.

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.

Install the quick disconnect style fuel lines by pushing the quick disconnect fitting onto the male union until it clicks.

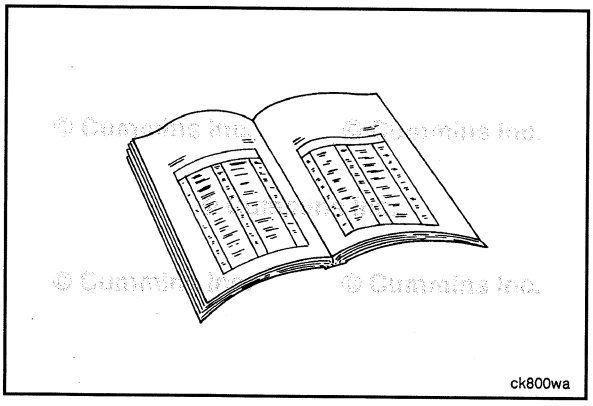


Initial Check

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Inspect all fuel supply line fittings and lines. Look for cracks in the lines or leaks in the fittings.

Check for loose or broken brackets.

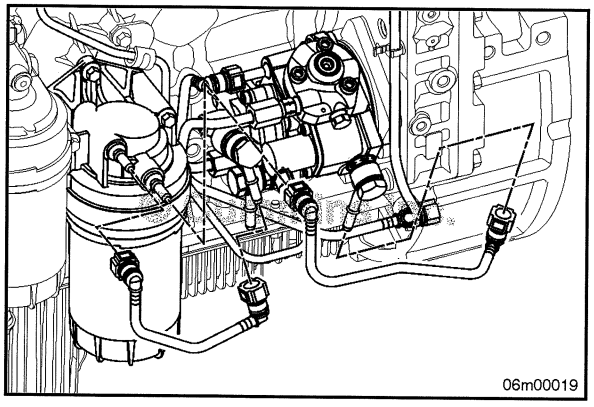


Preparatory Steps

⚠CAUTION⚠
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system, that fuel is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The fuel and fuel filters must be discarded in accordance with local environmental regulations.

NOTE: Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Shut off the fuel supply valve to the engine.



Remove

Mark the location of all P-clips and routing of fuel supply lines to make sure that they are replaced in the correct location during assembly.

Remove the fuel supply line connecting the gear pump to the fuel filter head.

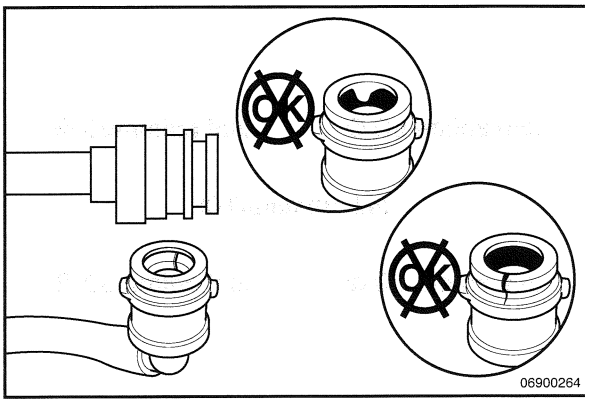
Remove the fuel supply line connecting the fuel filter head to the inlet of the high-pressure fuel pump.

Clean and Inspect for Reuse

Two Button Fitting

Inspect for burrs or debris on metal connectors that can cause leaks.

On quick disconnect fittings, be certain that the o-rings are **not** frayed or cut, and that the lock tangs are **not** damaged.



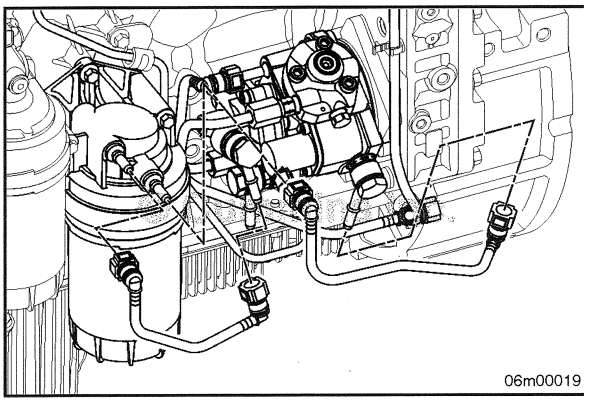
Install

Without Electric Lift Pump

Install the fuel supply line connecting the gear pump to the fuel filter head.

Install the fuel supply line connecting the fuel filter head to the inlet to the high-pressure pump.

Install the P-clips and P-clip mounting capscrews in locations noted during removal.

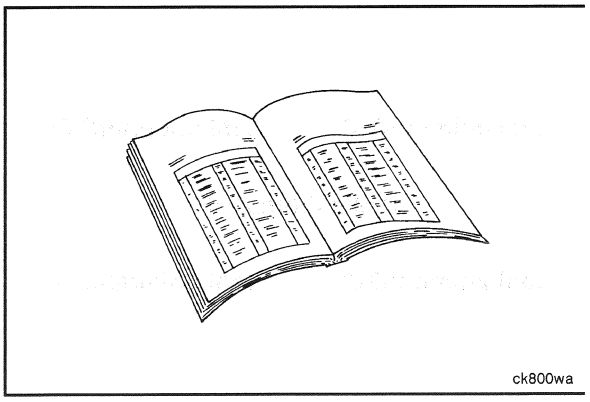


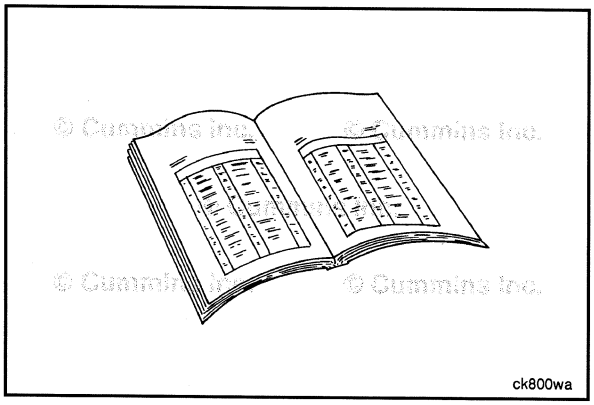
Finishing Steps

⚠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.

⚠CAUTION⚠
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system that fuel is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The fuel and fuel filters must be discarded in accordance with local environmental regulations.

- Open the fuel supply valve.
- Prime the fuel system. Refer to Procedure 005-016 in Section 5.
- Operate the engine and check for leaks.





Injector (006-026)

General Information

⚠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 in 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⚠
Fuel can be be returned at highly elevated temperatures. Wear safety glasses and protective gloves and clothing when performing this test. Avoid any contact with returned fuel.

⚠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⚠
The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. A high-pressure leak can penetrate the skin. Stand clear and do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings on the high pressure fuel system to allow the pressure to decrease to a lower level. High-pressure fuel can cause personal injury.

△CAUTION△
Make sure the fuel inlet and return valves are returned to the open position before cranking the engine. Engine damage can result if valves are in the wrong position when the engine is cranked or started. Environmental damage can also occur.

△CAUTION△
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system. It is essential that maximum cleanliness is observed to reduce the possibility of contamination of the fuel lines with dust particules or lubricant fluids. Refer to Procedure 204-008 in Section i.

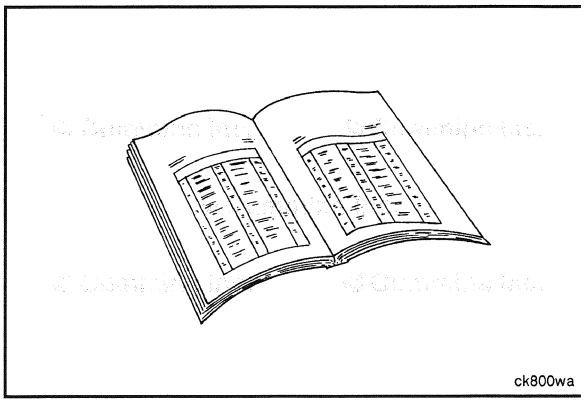
The fuel return manifold is located near the point at which the original equipment manufacturer (OEM) connects the vehicle fuel drain line. To locate this manifold, follow the fuel drain lines from their source, (rail pressure relief valve, injector return, or high pressure injector pump return) to their termination points.

Refer to Procedure 006-999 in Section F for further information.

An internal leak from the fuel injector will result in increased fuel return flow from the cylinder head. The single cylinder cut-out test will **not** be able to isolate this leak because it occurs before it reaches the control needle inside the injector. Because all injectors share the same pressurized fuel supply from the rail, all cylinders will share the reduced fuel flow equally.

Due to the varying engine configurations, the following steps have been established to cover a majority of engine configurations. Some of the illustrations may **not** represent the parts actually being removed or installed.

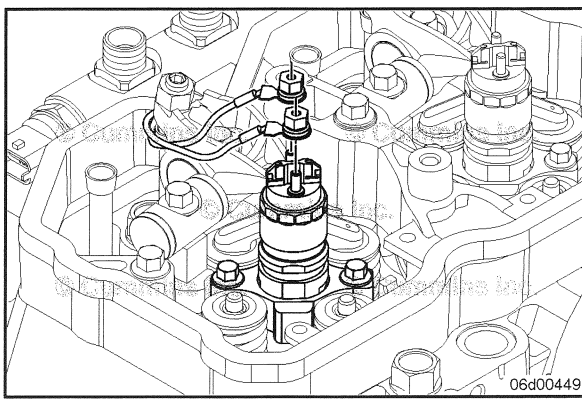
Preparatory Steps



⚠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.

- It is essential that maximum cleanliness is observed to reduce the possibility of contamination of the fuel lines with dust particles or lubricant fluids. Refer to Procedure 204-008 in Section i.
- Disconnect the batteries. See equipment manufacturer service information.
- Close the fuel supply and drain valves. See equipment manufacturer service information.
- Disconnect the fuel rail pressure sensor from the engine wiring harness. Refer to Procedure 019-115 in Section 19.
- Disconnect the high-pressure fuel lines. Refer to Procedure 006-051 in Section 3.
- Remove the exhaust gas recirculation (EGR) crossover tube. Refer to Procedure 011-070 in Section 11.
- Any open fuel connectors **must** be closed immediately with clean protection caps.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.

Remove



⚠WARNING⚠
The pressure of the fuel in the line is sufficient to penetrate the skin and cause serious personal injury. Wear gloves and protective clothing.

⚠CAUTION⚠
When removing the injector, care must be taken not to damage the injector tip.

Disconnect the injector wiring harness from the injector.

Remove the injector actuator wire nuts and wires from the injector.

Loosen and remove the injector hold-down capscrew.

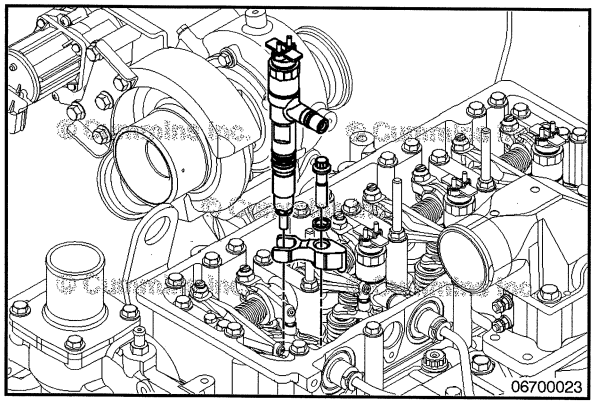
A small heel pry bar can also be used to pry up the injector. Pry up the injector hold-down flange (part of the injector body just above the cylinder head casting).

Remove the injector hold-down clamp from the injector.

Remove the injector from the cylinder head.

Apply a protective cap to the injector nozzle.

Insert a blind plug to prevent dust or debris from entering the engine through the cylinder head.



Loosen and remove the injector hold-down capscrew.

A small heel pry bar can also be used to pry up the injector. Pry up the injector hold-down flange (part of the injector body just above the cylinder head casting).

Remove the injector hold-down clamp from the injector.

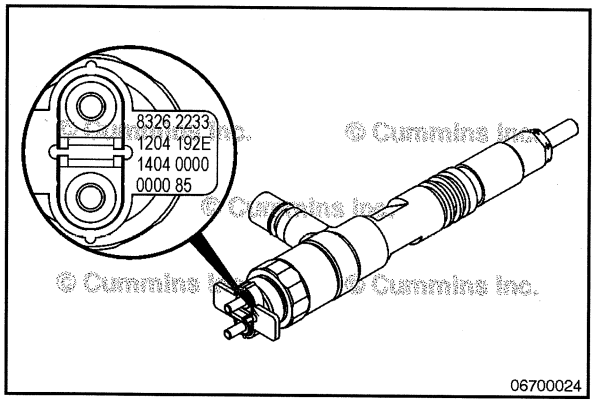
Remove the injector from the cylinder head.

Apply a protective cap to the injector nozzle.

Insert a blind plug to prevent dust or debris from entering the engine through the cylinder head.

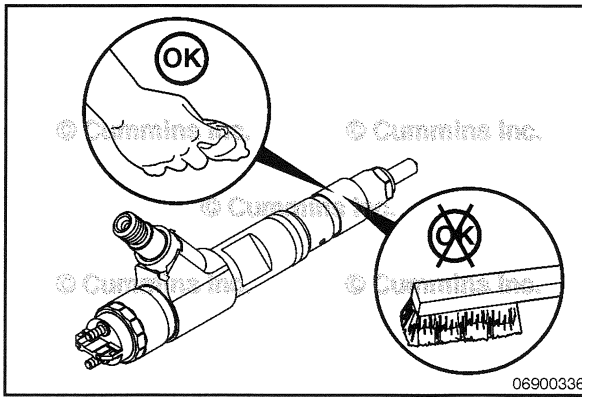
With the injector removed, verify that the injector o-ring is attached to the bottom of the injector. If the injector o-ring remained in the injector bore, it **must** be removed.

A double stacked or incorrect o-ring can cause high-pressure fuel leaks and/or performance problems because of incorrect injector protrusion.



NOTE: Record the cylinder location where each injector was installed. If new injectors are **not** being installed, the injectors **must** be installed in their original location.

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⚠
Overheating will cause the nozzle to turn a dark yellow/tan or blue color resulting in injector damage, depending on the degree of overheating.

⚠CAUTION⚠
Do not use a steel wire brush or glass beading to clean the injectors. Damage to the nozzle holes can result.

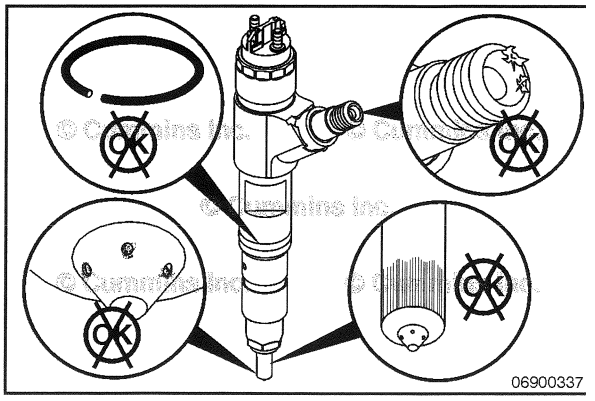
The injector shaft and nozzle should be cleaned in an ultrasonic bath with a safe, aqueous cleaning agent.

Remove the protective cap from the injector nozzle.

Place the injector in the ultrasonic bath in the vertical position. The high-pressure fuel connector and electrical connection **must not** contact the cleaning solution.

A new, fine, lint-free cleaning cloth may also be used to remove any dirt residue.

Do **not** remove the protection caps from the fuel inlet and drain connectors during cleaning.



Inspect the injector tip for carbonization or corrosion.

Check for terminal damage to the solenoid.

Inspect the injector inlet and high-pressure connector tip for damage.

Overheating will cause the nozzle to turn a dark yellow/tan or blue color, depending on the degree of overheating.

Inspect the injector o-rings for damage and replace, if necessary.

Resistance between the terminals **must** be less than 3 ohms.

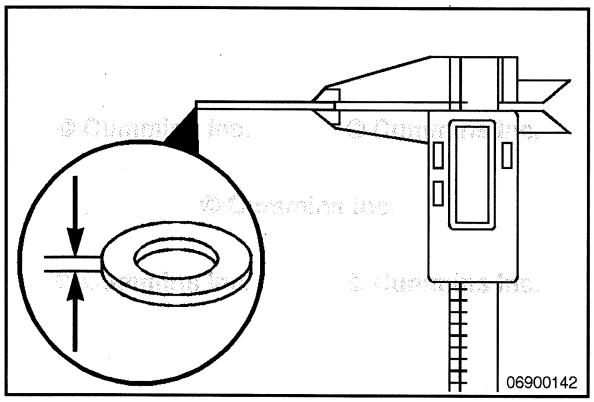
Install

⚠CAUTION⚠
The incorrect sealing washer can cause high-pressure fuel leaks and/or performance problems due to incorrect injector protrusion.

⚠CAUTION⚠
When installing the injector, care must be taken not to damage the injector tip.

NOTE: If the injector solenoid shipping cap is **not** used to install the injector, be careful that pressure is **not** placed on the wire terminals. Wire terminals can break off if they are used to push on the injector.

A replacement copper sealing washer **must** be used when installing the injectors.

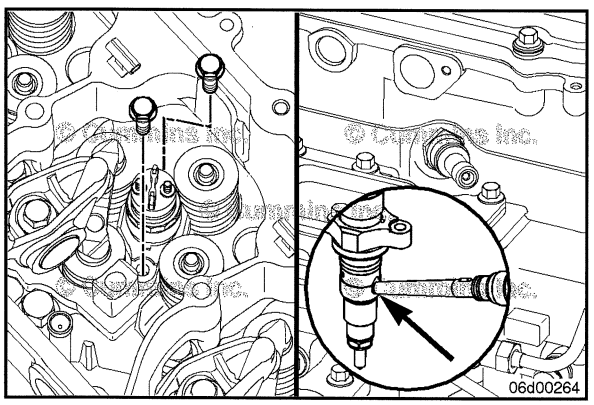


Verify the correct thickness of the new injector sealing washer.

Injector Sealing Washer Thickness 2.5 mm [0.098 in]

Only one copper sealing washer **must** be installed on the injector.

Remove the blind plug installed to prevent dust or debris from entering the engine.



Record the injector trim codes that are listed on each injector.

NOTE: The injector trim codes are located on the solenoid at the top of the injector.

Make sure the injector bore is clean.

Lubricate the injector o-ring with clean engine oil.

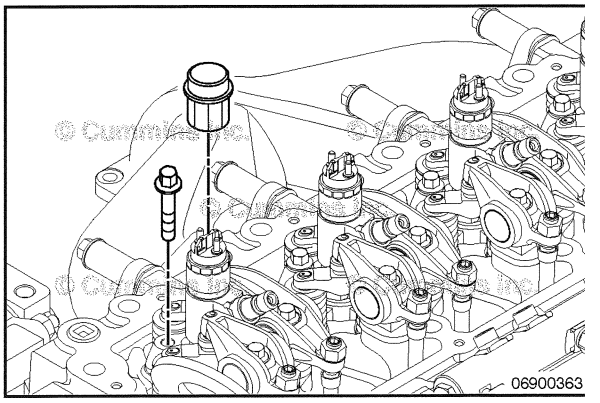
Install the injector hold-down clamp on the injector before installing the injector into the bore.

Align the injector in the cylinder head in the proper orientation (fuel inlet toward the high-pressure fuel connector).

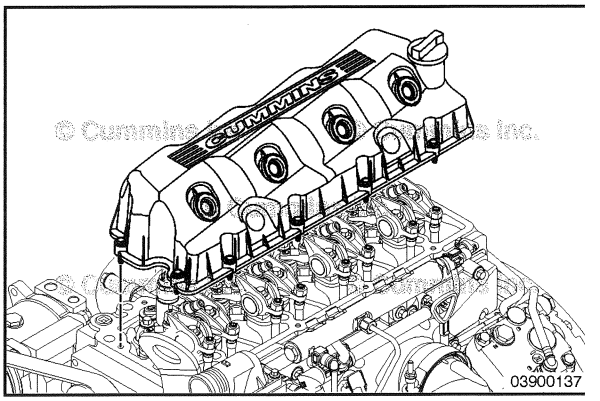
Use the injector solenoid shipping cap to make sure the injector is seated in the injector bore.

Install the injector hold-down capscrew. Do **not** tighten beyond hand-tight at this time.

Repeat the process to loosely install the other three injectors.



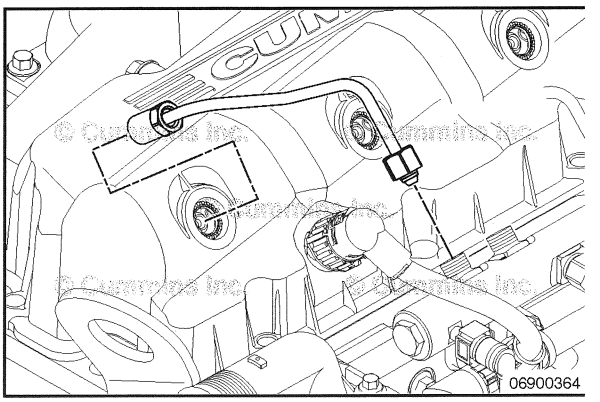
Install the rocker lever cover without the seal. Tighten one mounting capscrew on each side of the cover.

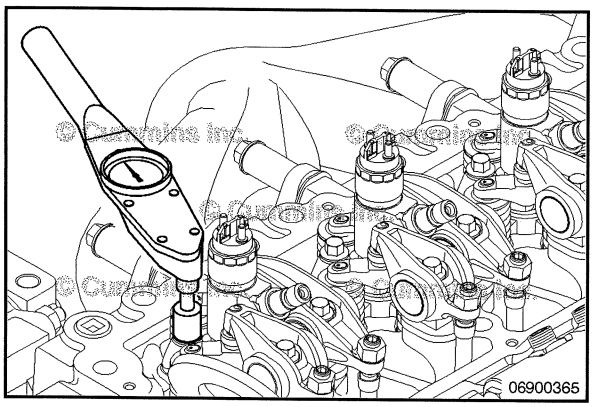


Connect the injector end of one of the high-pressure fuel lines to the injector. Use the injector end nut as a guide and center the injector in the grommet.

Remove the high-pressure fuel line from the injector and repeat the process for all four injectors.

Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.





NOTE: Alternate between the capscrews turning each 90 degrees per turn until reaching the final torque.

Tighten the injector hold-down clamp capscrews.

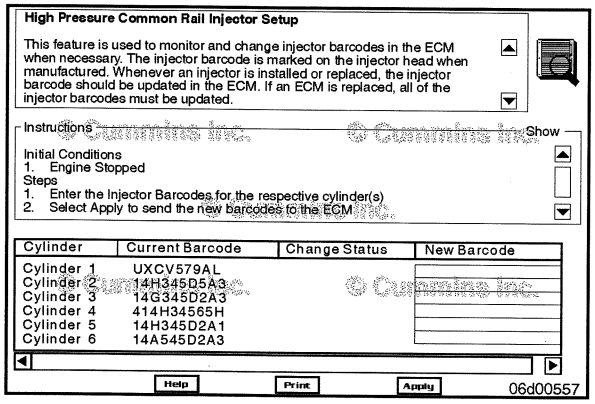
Torque Value:
Injector Hold-down Clamp Capscrews 40 N•m [30 ft-lb]

Install the injector actuator wires and nuts onto the injector.

NOTE: Align the injector wires so they will **not** interfere with each other or the rocker levers. If a 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.

Tighten the nuts.

Torque Value:
Injector Actuator Wire Nuts 1.5 N•m [13 in-lb]



Finishing Steps

Temporarily connect the battery for trim code installation. Refer to the OEM service manual.

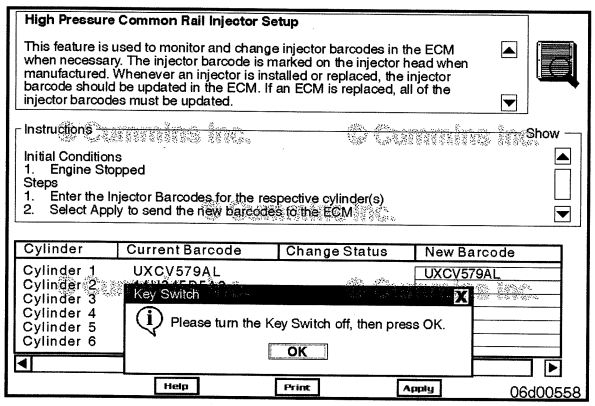
Use the following trim code installation instruction for INSITE™ electronic service tool 7.5 Feature Pack and Newer.

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 in the "High Pressure Comon Rail Injector Setup" and "Instructions" headings.



1 Click on the "New Bar Code" section for the respective cylinder and enter the new bar code.

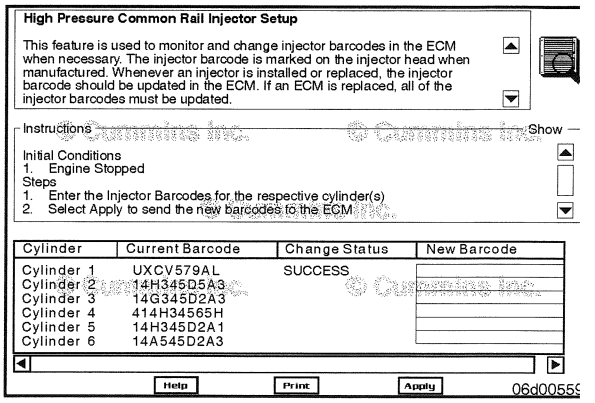
2 After all the injector trim information is entered, select "Apply". Turn the keyswitch OFF, then press the "OK" button to send the new bar code(s) to the ECM.

1. After INSITE™ electronic service tool connects 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:

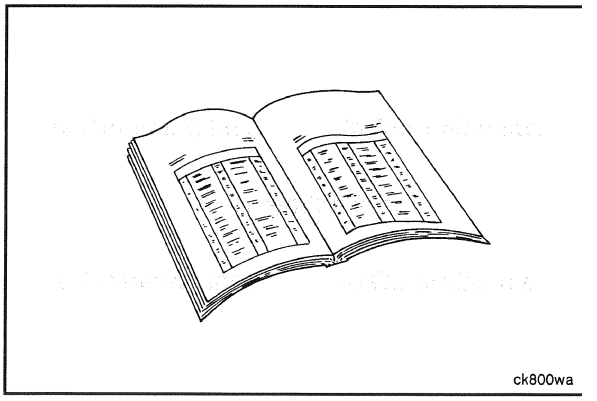
- Verify the correct injector trim code was recorded from each installed injector. Re-enter the trim codes.

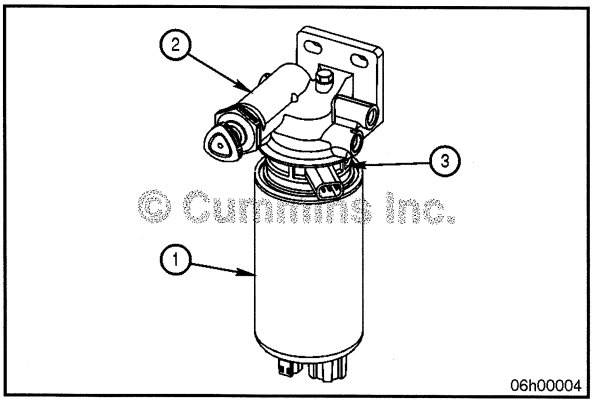
2. Clear the inactive faults.



⚠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.

- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the exhaust gas recirculation (EGR) crossover tube. Refer to Procedure 011-070 in Section 11.
- Install the high-pressure fuel lines. Refer to Procedure 006-051 in Section 3.
- Install the fuel rail pressure sensor to the engine wiring harness. Refer to Procedure 019-115 in Section 19.
- Open the fuel supply and drain valves. See equipment manufacturer service information.
- Connect the batteries. See equipment manufacturer service information..
- Operate the engine and check for leaks.





Fuel-Water Separator (006-043)

General Information

Cummins Inc. requires a fuel-water separator be installed in the fuel supply system.

This Fuel-Water Separator is mounted on the vehicle chassis. The location is determined by the original equipment manufacturer (OEM).

The Fuel-Water Separator is integrated into three components:

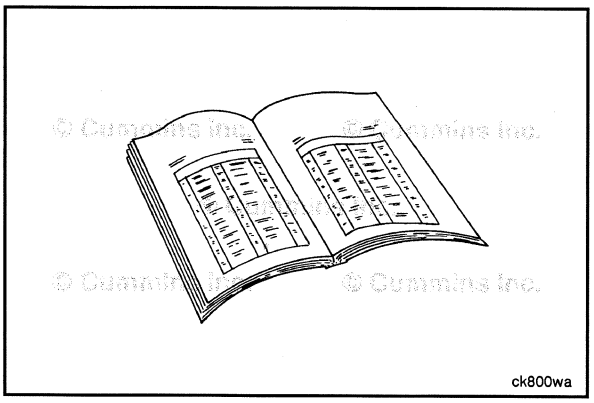
1 Fuel Filter

2 Fuel Filter Head (with priming pump)

3 Fuel Heater.

- Remove the fuel filter head, if necessary. Refer to Procedure 006-017 in Section 6.
- Remove the fuel heater, if necessary. Refer to Procedure 005-008 in Section 5.

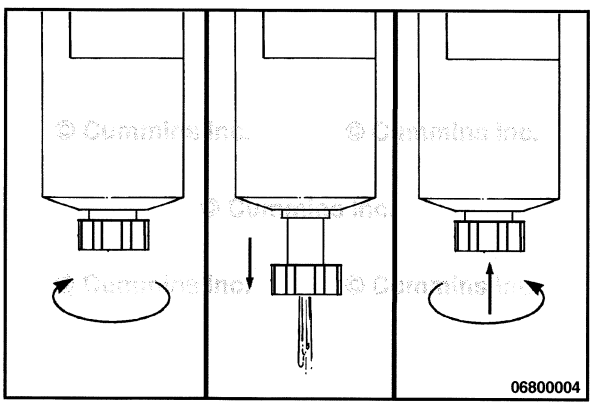
Use the priming pump on the filter head to prime the fuel system, if necessary. Refer to Procedure 006-015 in Section 6.



Drain

⚠WARNING⚠
Drain the water-fuel separator into a container and dispose of in accordance with local environmental regulations.

Drain the water and sediment from the separator daily.



△CAUTION△
When closing the drain valve, do not overtighten the valve. Overtightening can damage the threads.

Shut off the engine.

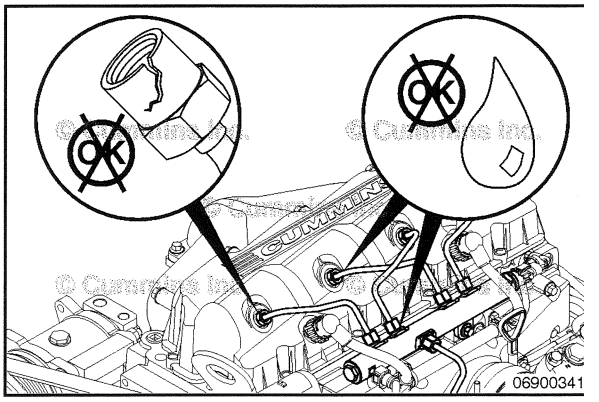
Use your hand to open the drain valve. Turn the valve **counterclockwise** approximately 3½ turns until the valve drops down 25.4mm [1 in] and draining occurs.

Drain the filter sump until clear fuel is visible.

To close the valve, lift the valve and turn **clockwise** until it is hand-tight.

Injector Supply Lines (High Pressure) (006-051)

Initial Check



⚠WARNING⚠
While testing the injectors, keep hands and body parts away from the injector nozzle. Fuel coming from the injector is under extreme pressure and can cause serious injury by penetrating the skin.

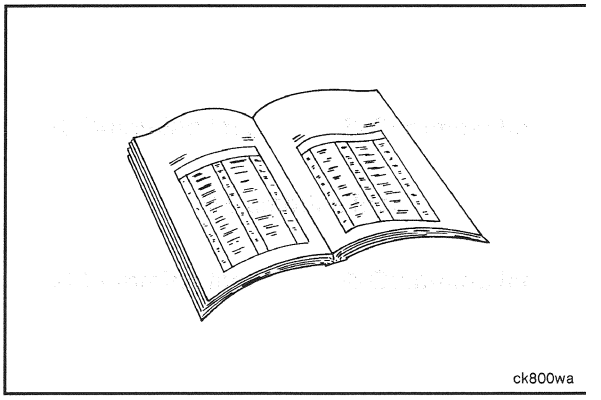
⚠WARNING⚠
Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

⚠WARNING⚠
Drain the fuel into a container, and dispose of contents in accordance with local environmental regulations.

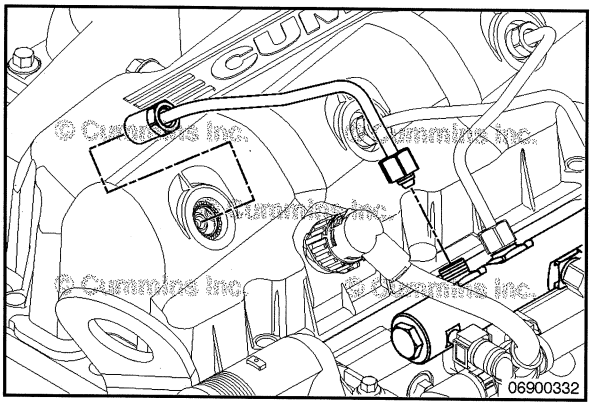
⚠WARNING⚠
The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.

Inspect the injector high-pressure supply lines for cracks, chafing, leaks, and loose or broken brackets.

Preparatory Steps



- See the following procedure for removal and installation of the fuel pump to rail high-pressure line. Refer to Procedure 005-016 in Section 5.
- Before removing any of the high-pressure fuel lines, make sure to have clean caps to cover the ends of the high-pressure fuel lines and the connection on the injectors. This will help to prevent any dirt from entering the fuel lines and the injectors.
- Clean the top of the rocker lever cover and the area around each injector supply line.

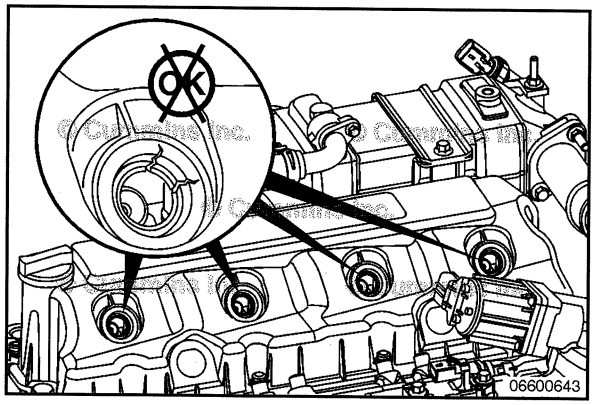


Remove

Disconnect the high-pressure fuel line from both ends of the number 4 fuel line. Cover the end of the line immediately.

Use the appropriate protective cap from the fuel system Clean Care Kit, Cummins® Part Number 5298815.

Repeat the steps for all four injectors, removing and capping the connection one at a time.



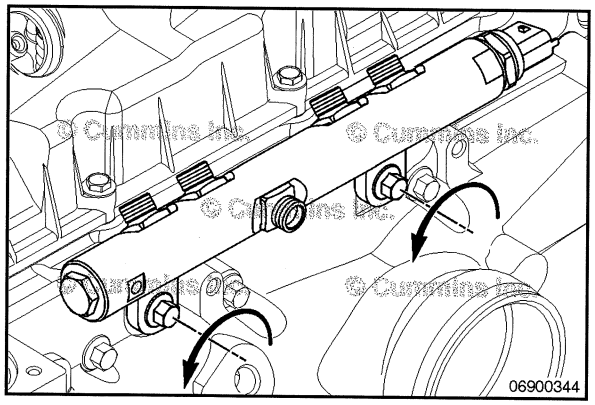
Inspect for Reuse

Inspect the high-pressure fuel supply line ferrules for any signs of burrs, foreign material, rounding, or cracking. Replace, if necessary.

Check the lines for cracks, wear, or pinched areas. Replace, if necessary.

Inspect the ends of the high-pressure lines for damaged sealing surfaces.

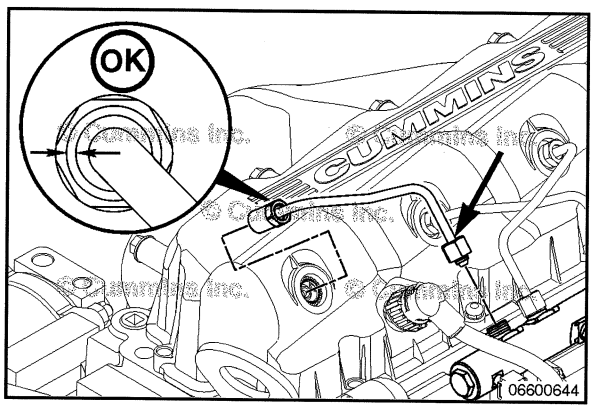
Inspect the four cover seals for dirt, debris, cracks or other damage before assembly of the fuel lines. Clean and replace any seals, as necessary. Refer to Procedure 003-011 in Section 3.



Install

Loosen but do **not** remove the capscrews that secure the fuel rail to the intake manifold. The capscrews are loosened to allow proper alignment of the fuel rail after installing the new fuel line(s).

NOTE: Using clean 15W-40 engine oil, lubricate the four injector fuel supply line seals in the rocker cover before installing the fuel supply lines.



The fuel lines **must** be aligned correctly. The process below should be followed to avoid any problems.

Hand tighten the injector fuel line union. Make sure the line is central within the union.

Hand tighten fuel line union at the rail end. Make sure the pipe is central within the union.

Tighten the injector end, making sure there is no contact between the line and the union at either end.

Torque Value: 35 N•m [26 ft-lb]

Tighten the injector fuel line union.

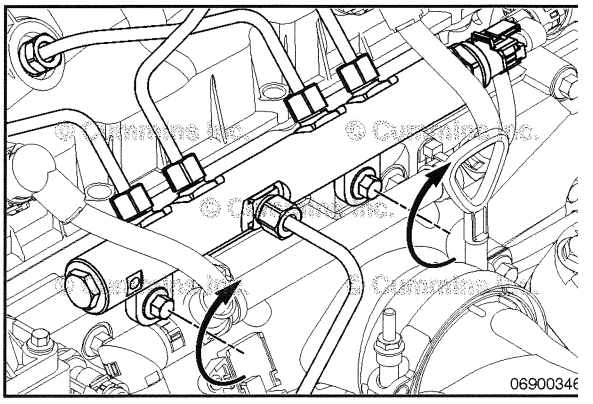
Torque Value: 35 N•m [26 ft-lb]

Repeat this process for the other three lines.

NOTE: Check the injector fuel line seals in the rocker cover to make sure they were **not** damaged during assembly of the fuel lines.

Tighten the capscrews for the fuel rail.

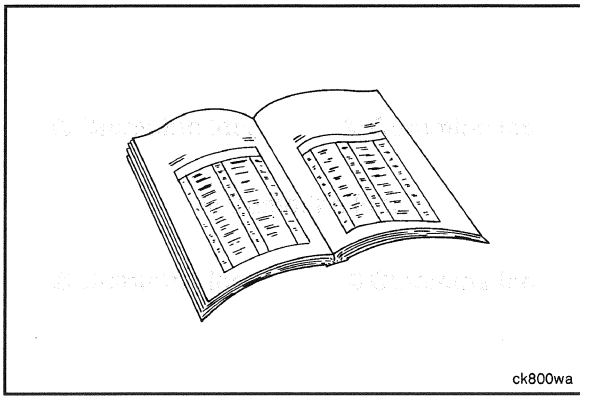
Torque Value: 24 N•m [212 in-lb]



Finishing Steps

⚠WARNING⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

- Install the fuel pump to high-pressure rail line, if removed. Refer to Procedure 005-016 in Section 5.
- It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will prime the fuel system.
- Operate the engine and check for leaks.



Fuel Rail (006-060)

General Information

⚠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.

The fuel rail consists of below components:

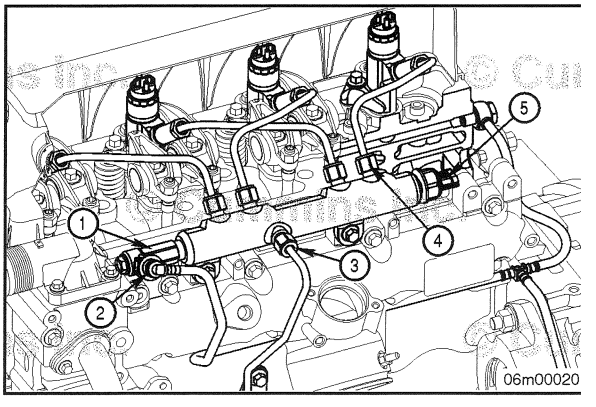
1 Fuel pressure relief valve

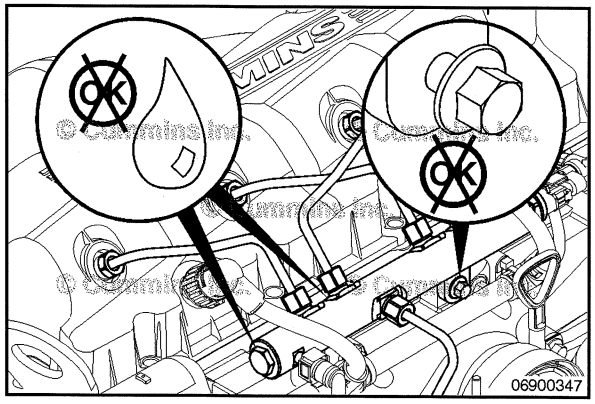
2 Fuel pressure relief valve drain

3 High-pressure fuel supply fitting from fuel pump

4 High-pressure injector supply fitting(s)

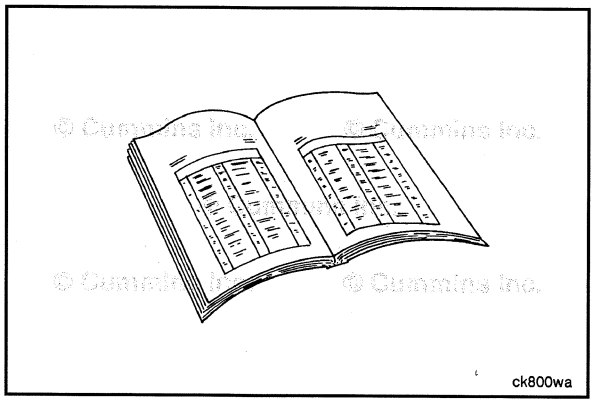
5 Fuel rail pressure sensor.





Initial Check

Check the fuel rail for leaks, loose capscrews, or other damage.



Preparatory Steps

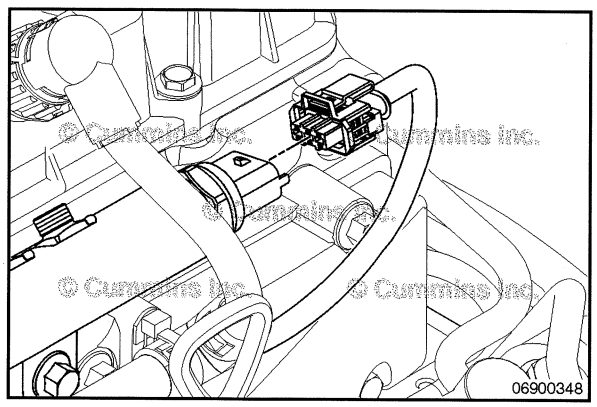
⚠WARNING⚠

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.

NOTE: Note the location of the high-pressure supply lines so they are replaced in the same location during assembly.

- Disconnect the batteries. See equipment manufacturer service information.
- Remove the high-pressure supply lines that connect the fuel rail to the injectors. Refer to Procedure 006-051 in Section 6.
- Disconnect the fuel pressure sensor connector.
- Disconnect the fuel pressure relief drain line. Refer to Procedure 006-013 in Section 6.
- Remove the high-pressure supply line that connects the fuel pump to the fuel rail. Refer to Procedure 006-071 in Section 6.

NOTE: It is **not** necessary to remove the high-pressure supply line from the engine.



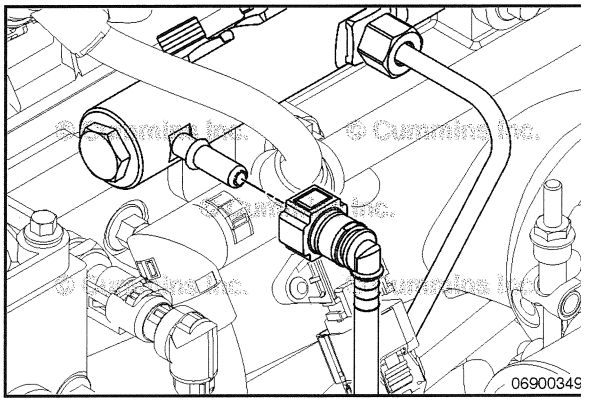
Remove

NOTE: Do **not** remove the fuel rail pressure sensor unless it is being replaced. The fuel pressure sensor **must** be replaced if it is removed from the fuel rail.

Disconnect the fuel rail pressure wiring harness sensor connector.

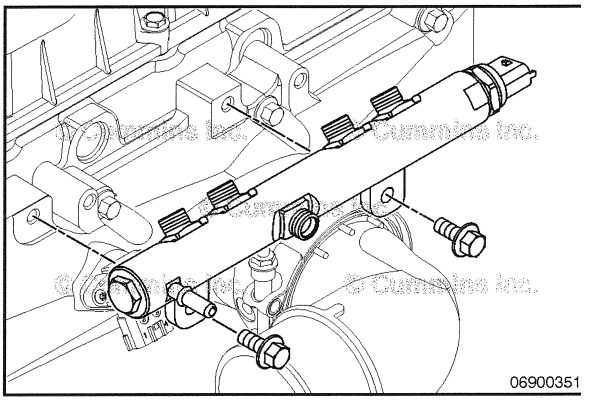
⚠WARNING⚠
Depending on the circumstance, diesel fuel is flammable. When inspecting or performing service or repairs on the fuel system, to reduce the possibility of fire and resulting severe personal injury, death or property damage, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area.

Disconnect the fuel pressure relief valve drain line.



Remove the fuel rail mounting capscrews.

Remove the fuel rail.



Clean and Inspect for Reuse

△CAUTION△
Internal passages of the fuel rail can only be cleaned with contact cleaner, Cummins® Part Number 3824510 or equivalent. Do not use a parts washer to clean the fuel rail. Dirt or contaminants can damage the fuel system.

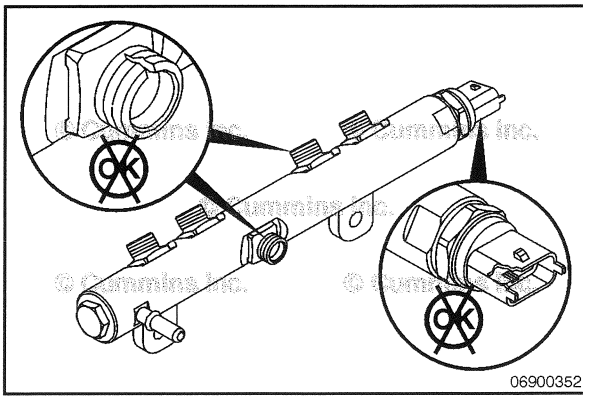
Inspect the fuel line connections at the fuel rail for cracks or scratches.

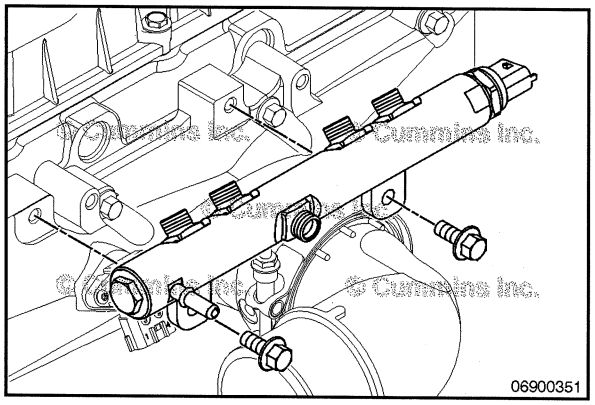
Inspect the inlets of the high-pressure lines for damaged sealing surfaces.

Check for loose or damaged pressure sensors and pressure relief valve.

Inspect the fuel rail pressure sensor for damage. Replace the sensor if any damage is found. Refer to Procedure 019-115 in Section 19.

Inspect the pressure relief valve for damage. Replace the fuel rail assembly if any damage is found.

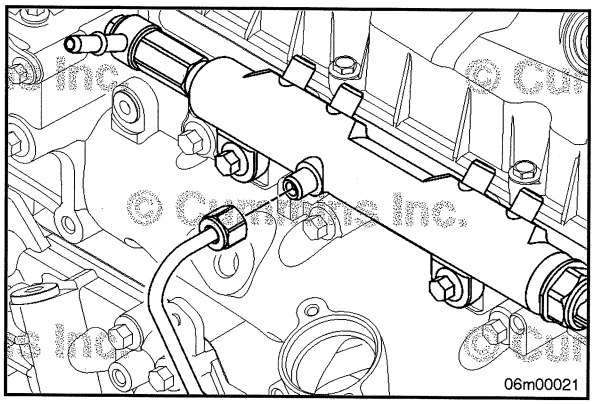




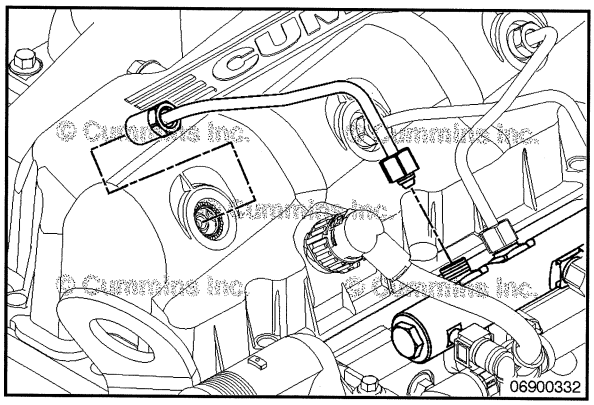
Install

Install the fuel rail on the engine.

Hand-tighten the fuel rail capscrews.



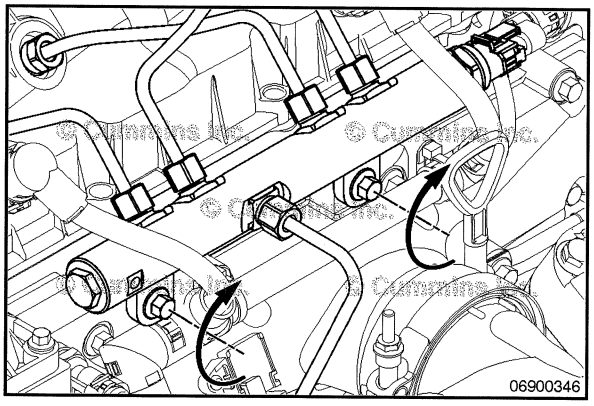
Install the high-pressure supply line that connects the fuel pump to the fuel rail. Refer to Procedure 006-071 in Section 6.



⚠CAUTION⚠

Injector supply lines and the high-pressure supply line must be torqued prior to tightening the fuel rail cap screws.

Install the injector supply line(s) that connect the fuel rail to the fuel injectors. Refer to Procedure 006-051 in Section 6.

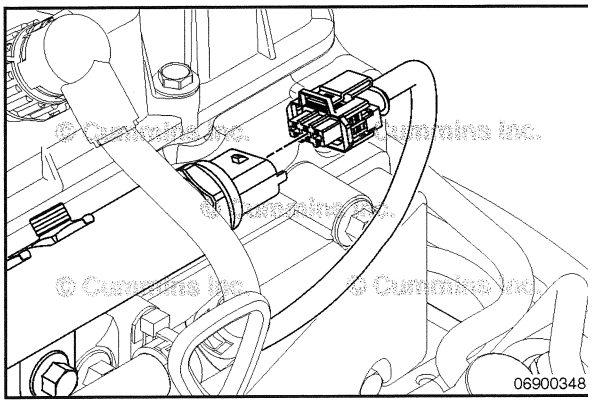


Tighten the fuel rail capscrews.

Torque Value: 24 N•m [212 in-lb]

Connect the fuel rail pressure wiring harness sensor connector.

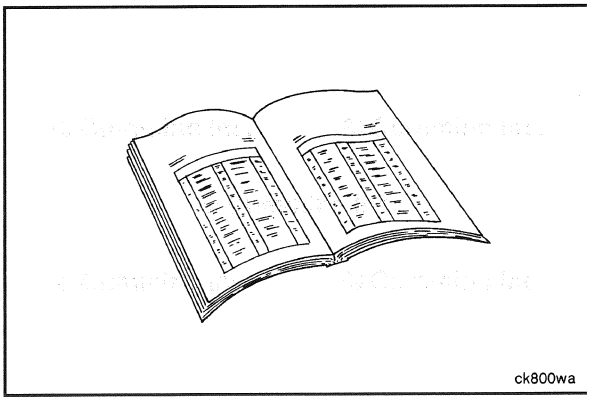
If the fuel rail pressure sensor was removed, the fuel rail pressure sensor **must** be replaced. Refer to Procedure 019-115 in Section 19.



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 pressure sensor connector.
- Connect the fuel pressure relief valve drain line. Refer to Procedure 006-013 in Section 6.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.

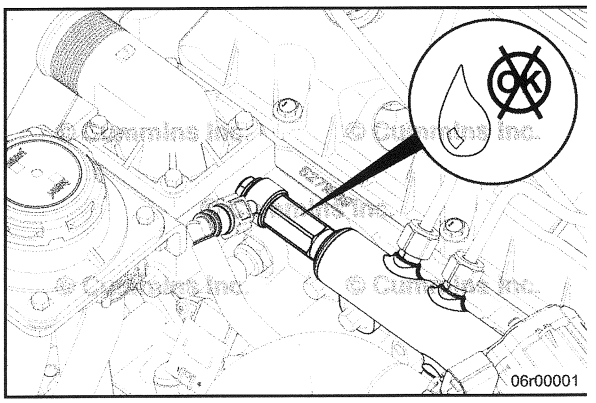


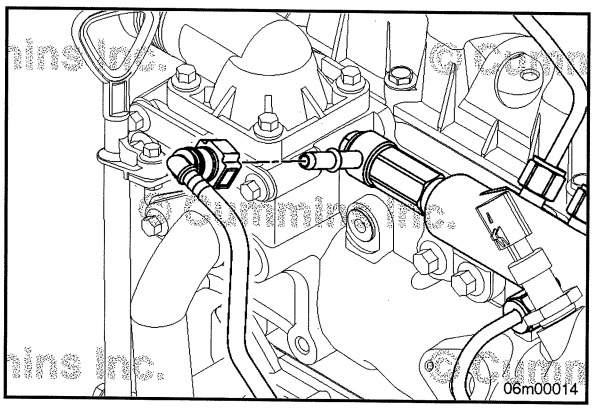
Fuel Pressure Relief Valve (006-061)

Initial Check

⚠CAUTION⚠
Do not overtighten the component in an attempt to stop a leak. Overtightening can result in increased leakage. Always tighten the fuel pressure relief valve to the correct specification.

Check the fuel pressure relief valve for leaks and damage.





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.

⚠CAUTION⚠
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

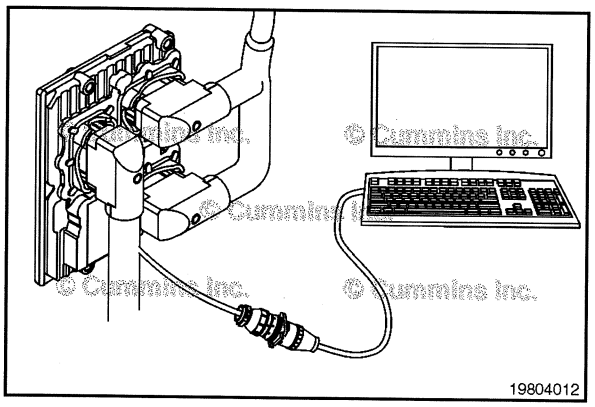
The purpose of this test is to check for a fuel pressure relief valve that leaks excessive fuel to the fuel drain line.

Thoroughly clean the area around the fuel pressure relief valve. Do **not** allow any debris to enter the fuel system.

Remove the quick disconnect fitting from the rail pressure relief valve drain line at the high-pressure fuel rail.

Install a fuel drain hose, Cummins® Part Number 3164617, through the banjo fitting and into the rail pressure relief valve. This hose is designed to block the flow from the fuel line banjo but allow flow from the rail pressure relief valve.

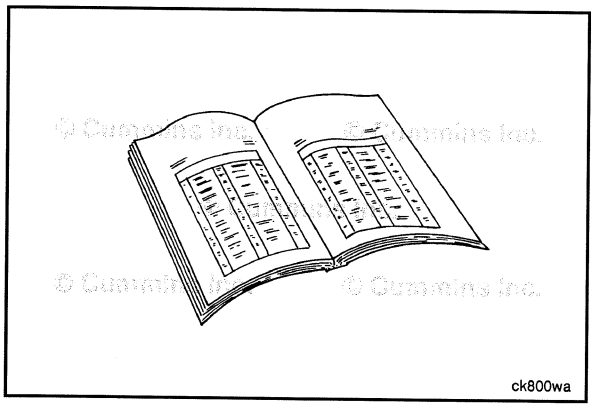
Place the other end of the hose into a graduated beaker, Cummins® Part Number 4919139 or equivalent.



Measurement

If available, operate the engine using INSITE™ electronic service tool fuel leakage test. If INSITE™ electronic service tool is **not** available, operate the engine at idle.

- Specification at idle: No flow.
- INSITE™ electronic service tool override: One drop per second (16 mL per minute [0.5 ounce per minute]).



Preparatory Steps

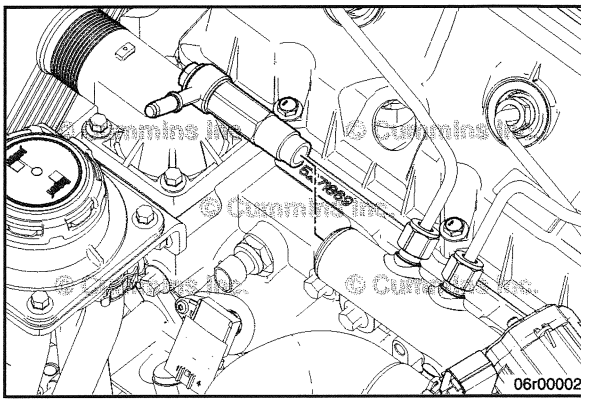
⚠WARNING⚠
Depending on the circumstances, diesel fuel is flammable. When inspecting or performing service or repairs on the fuel system, to reduce the possibility of fire and resulting severe personal injury, death or property damage, never smoke or allow sparks or flames (such as pilot lights, electrical switches, or welding equipment) in the work area.

Remove the fuel drain line from the fuel pressure relief valve. Refer to Procedure 006-013 in Section 6.

Remove

Remove the fuel pressure relief valve from the fuel rail.

NOTE: If the fuel pressure relief valve is malfunctioning or damaged, it **must** be replaced.



Install

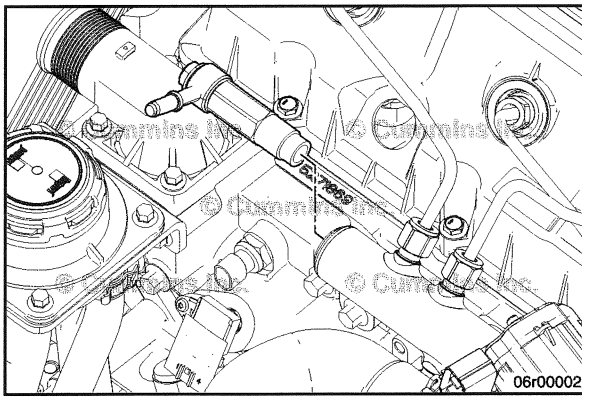
⚠CAUTION⚠
Overtightening the fuel pressure relief valve can result in a fuel leak. Always tighten the fuel pressure relief valve to the correct specification.

Install the fuel pressure relief valve onto the fuel rail.

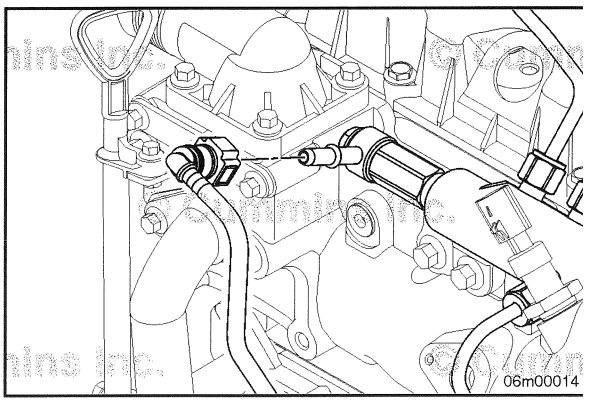
Use the torque plus angle method to tighten the fuel pressure relief valve.

Torque Value:

Step 1	30 N•m	[22 ft-lb]
Step 2	Turn an additional 24 degrees	

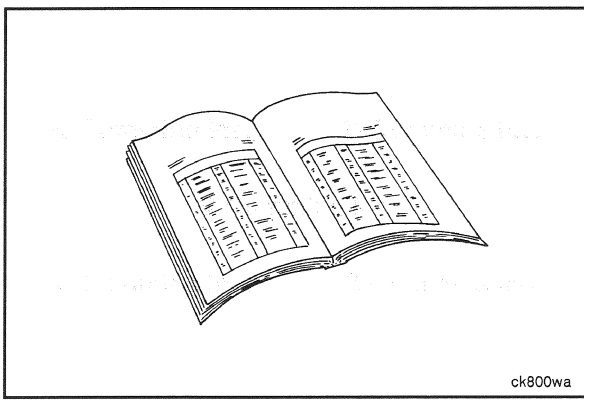


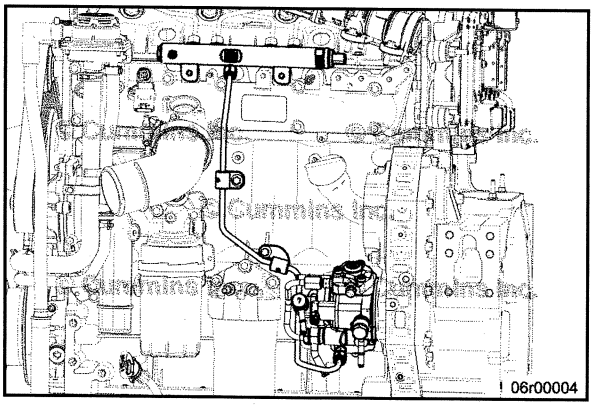
Install the fuel rail drain line and quick disconnect fitting onto the fuel pressure relief valve.



Finishing Steps

- Operate the engine and check the fuel pressure relief valve and fuel line for fuel leaks.



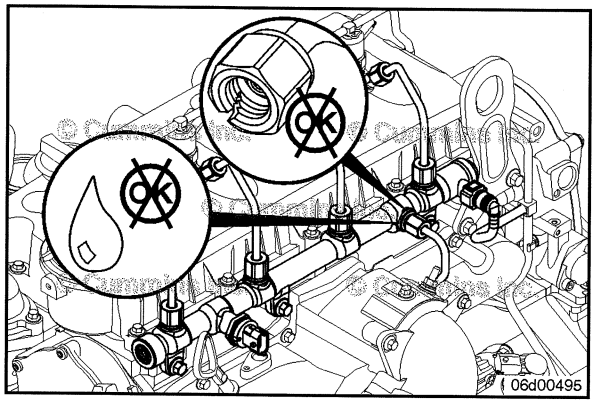


Fuel Rail Supply Line (High Pressure) (006-071)

General Information

⚠WARNING⚠
The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while 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 the pressure to decrease to a lower level.

The fuel rail supply line connects the fuel pump to the fuel rail, containing high-pressure fuel.



Initial Check

⚠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.

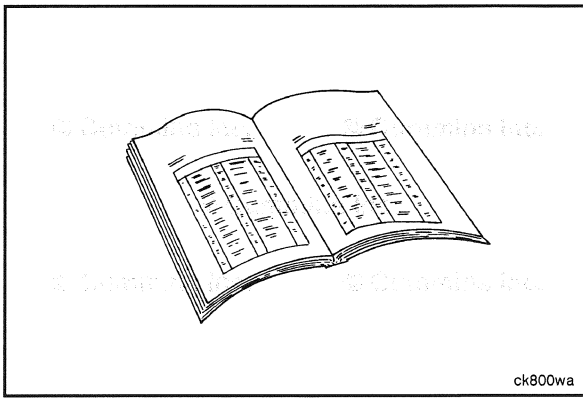
⚠WARNING⚠
Drain the fuel into a container, and dispose of contents in accordance with local environmental regulations.

⚠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.

Inspect the high-pressure supply lines for cracks, chafing, leaks, and loose or broken brackets.

Make certain the fuel line is **not** rubbing on any components.

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

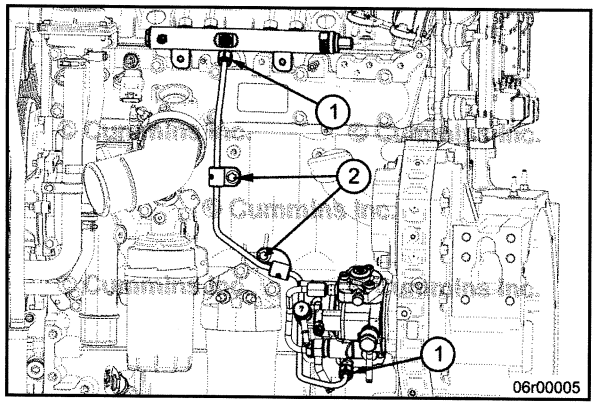
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

△CAUTION△
It is essential maximum cleanliness is observed to reduce the possiblity of contamination of the fuel lines with dust particles or lubricant fluids. Use the following procedure for general cleaning instructions. Refer to Procedure 204-008 in Section i.

- Disconnect the batteries. See equipment manufacturer service information.
- Steam-clean the area around the fuel rail supply line and fittings.
- Dry with compressed air.

Any open fuel connectors **must** be closed immediately with protection caps.



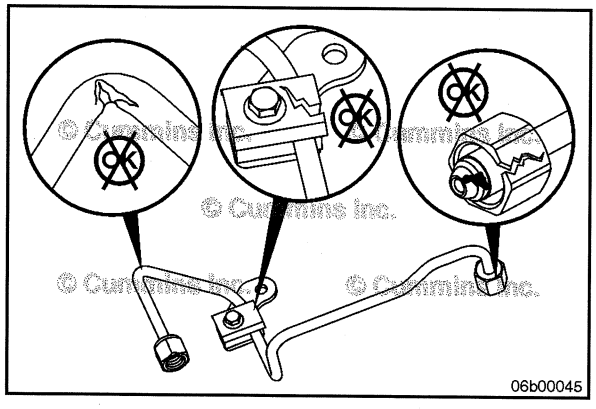
Remove

Disconnect the high-pressure fuel rail supply line fitting (1) from the fuel pump and fuel rail.

Do **not** bend, pry, or kink the fuel rail supply line during removal.

Remove the fuel rail supply line support bracket mounting fastener (2).

Remove the fuel rail supply line.



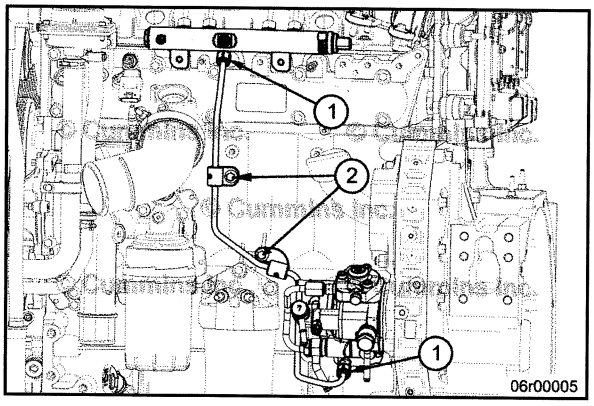
Clean and Inspect for Reuse

Inspect the high-pressure fuel rail supply line ferrules for any sign of burrs, foreign material, rounding, or cracking. Replace if necessary.

Check for cracks, wear, or pinched areas. Replace if necessary.

Inspect the ends of the high-pressure lines for damaged sealing surfaces. Replace any damaged component.

The fuel rail supply line support bracket **must** be inspected for signs of damage.



Install

△CAUTION△

Make certain no dirt or debris enters the fuel rail supply line to prevent the passing of contaminants to the high-pressure fuel rail and injectors. Small amounts dirt or debris can cause a malfunction of these components.

Install the fuel rail supply line (1) at the fuel pump and the fuel rail.

Torque Value: 35 N•m [26 ft-lb]

Install the fuel rail supply line support bracket mounting fastener (2).

Tighten the mounting fastener capscrew (2).

Torque Value: 24 N•m [212 in-lb]

NOTE: Make certain the fuel line is **not** rubbing on any components.

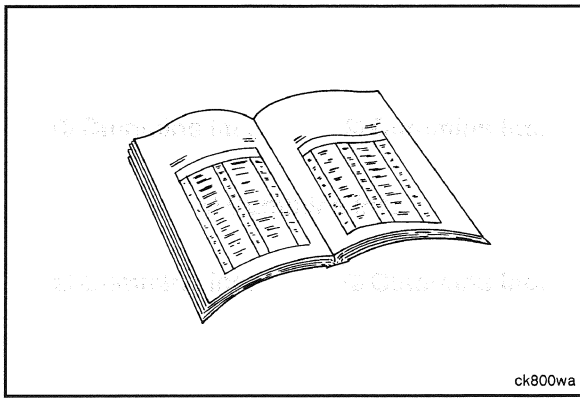
Finishing Steps

⚠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. See equipment manufacturer service information.

NOTE: It is **not** necessary to vent the air from the high-pressure fuel system before starting the engine. Cranking the engine will prime the fuel system.

- Operate the engine and check for leaks.


ck800wa

Notes

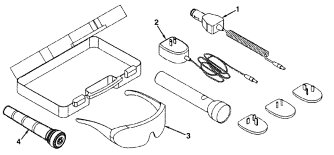
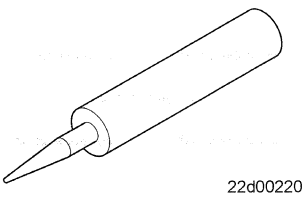
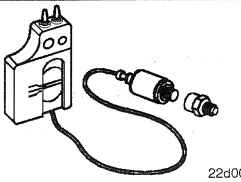
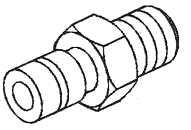
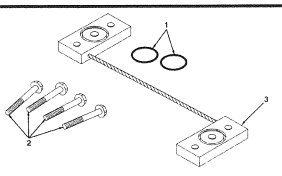
Section 7 - Lubricating Oil System - Group 07

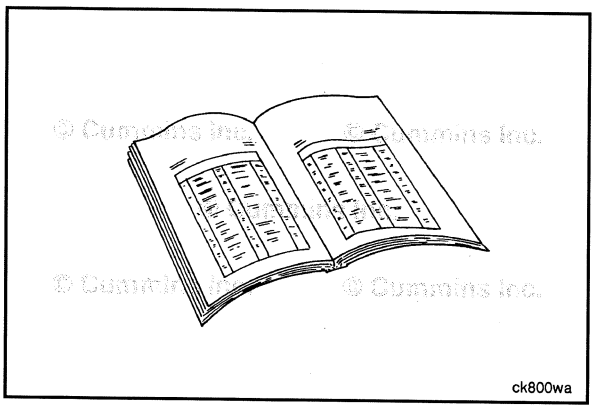
Section Contents

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
2892320	**Black Light Lamp** Used with cordless "True UV" light that will detect the presence of fluorescent dye additive to detect leaks in all engine fluid systems (lubricating oil, coolant, and fuel).	
3164070	**Sealant (Loctite™ 5999)** Used for installing the lubricating oil pan.	 22d00220
3164491	**Pressure/Vacuum Module** Used to measure fuel pressure and restriction. Use with multimeter, Part Number 3164488 or 3164489.	 22d00104
3824842	**Compuchek™ Fitting** Used to measure fuel inlet restriction.	 22d00083
4918868	**Lubricating Oil Cooler Pressure Test Kit** Used with air pressure regulator, Part Number 3164231, to test the lubricating oil cooler.	



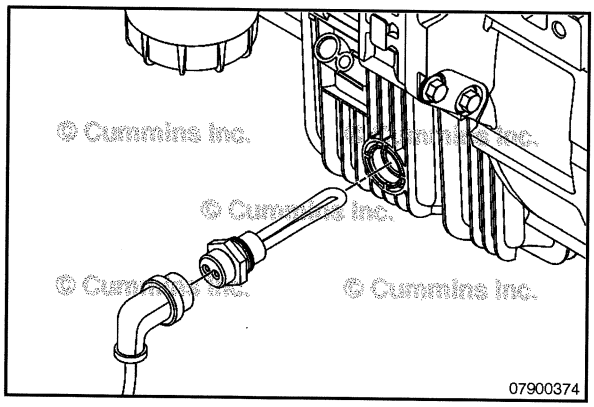
Engine Oil Heater (007-001)

Preparatory Steps

⚠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.

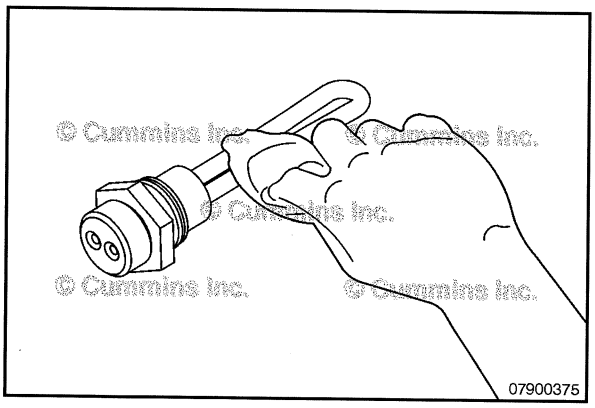
Drain the lubricating oil. Refer to Procedure 007-037 in section 7.



Remove

Disconnect the oil heater electrical cord.

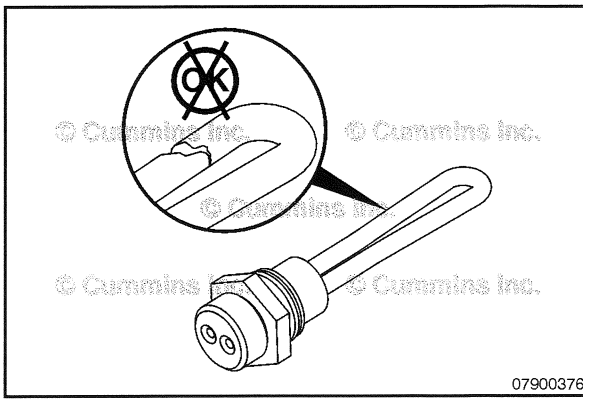
Remove the heater element.



Clean and Inspect for Reuse

Clean the heater element with a dry, clean towel.

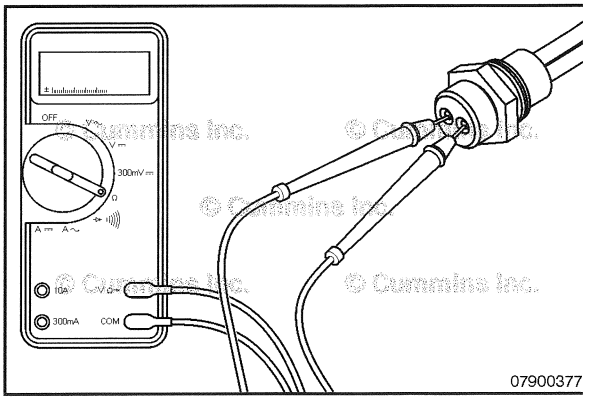
Check for cracks in the heating element.



Test

Perform a resistance test on the engine lubricating oil heater element.

The readings **must** be a minimum of 91 ohms to a maximum 101 ohms.

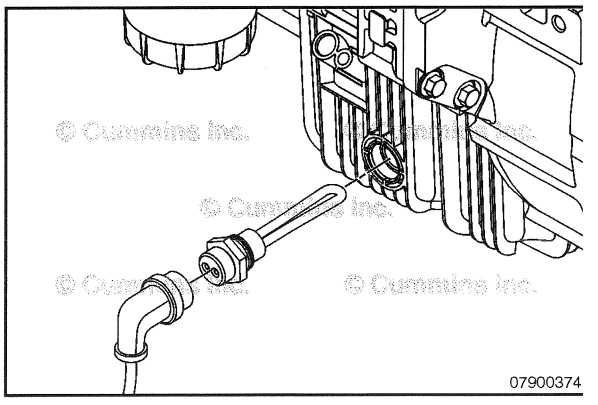


Install

Replace the heater element.

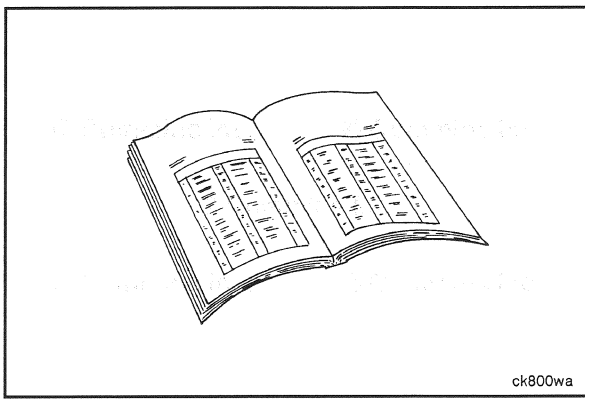
Torque Value: 24 N•m [212 in-lb]

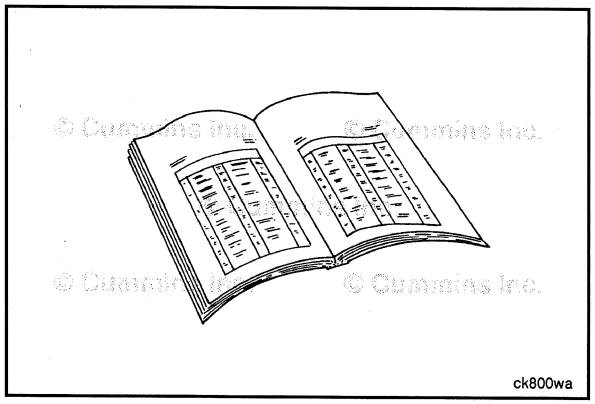
Connect oil heater electrical cord.



Finishing Steps

- Fill the engine with clean oil to the correct level. Refer to Procedure 007-037 in section 7.
- Operate the engine and check for leaks.





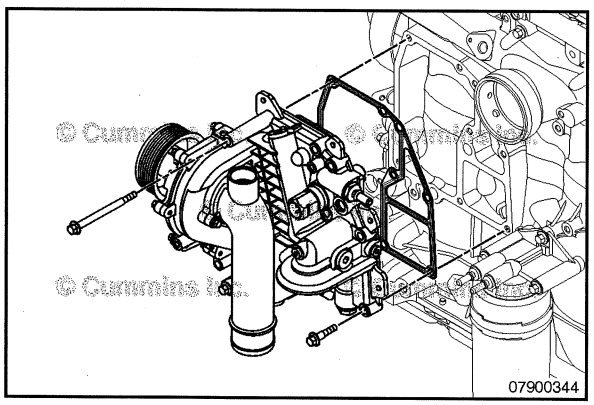
Lubricating Oil Cooler (007-003)

Preparatory Steps

⚠WARNING⚠
Coolant is toxic. Keep away from pets and children. If not reused, dispose of in accordance with local environmental regulations.

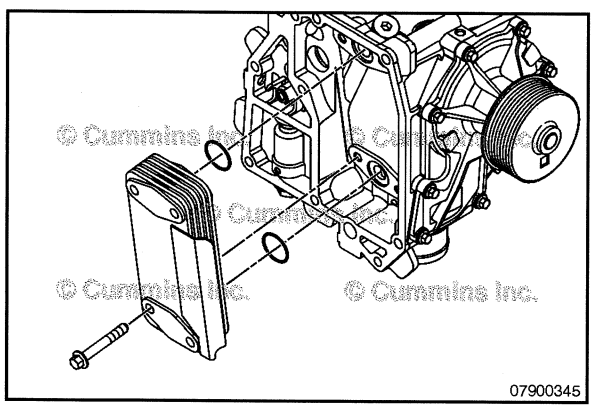
⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the fan drive belt. Refer to Procedure 008-002 in Section 8.
- Disconnect the coolant inlet hose to the water pump. See equipment manufacturer service information.
- Remove the coolant bypass tube. Refer to Procedure 008-005 in Section 8.



Remove

Remove the mounting capscrews and the water pump/ lubricating oil cooler housing from the side of the engine.



Disassemble

Remove the four mounting capscrews and the lubricating oil cooler element from the housing.

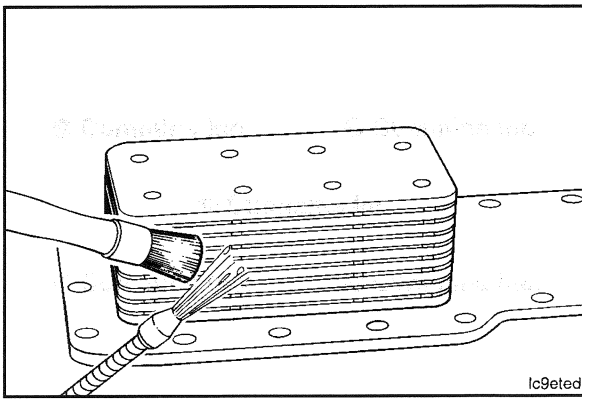
Clean and Inspect for Reuse

⚠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⚠
Use a solvent that will not harm copper to clean the oil cooler elements.

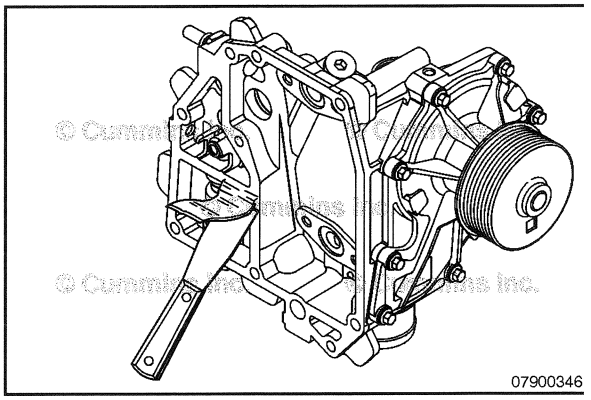
Use solvent to clean the oil cooler housing and cover.

NOTE: Replace the lubricating oil cooler if any debris is found or if the engine has had a debris-causing malfunction.

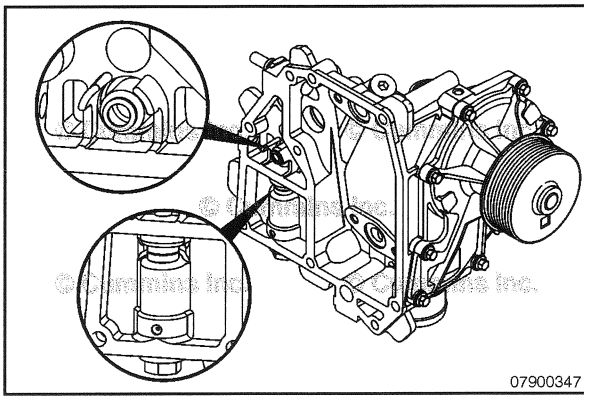


Clean the sealing surfaces.

When cleaning the oil cooler cover, be sure to clean the lubricating oil bypass valve.



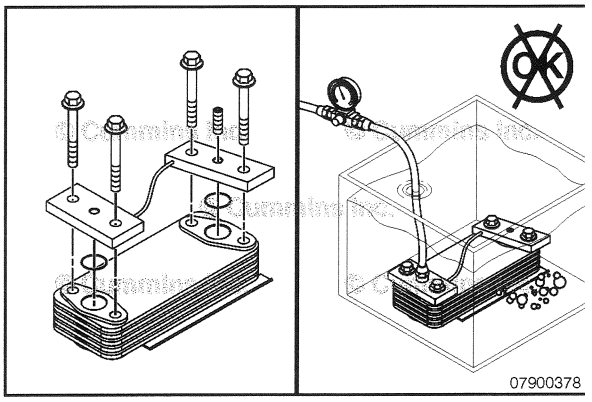
If any debris is suspected to have gone through the engine, or if troubleshooting a lubricating oil pressure issue, remove and inspect the lubricating oil pressure regulator located in the lubricating oil cooler cover. Replace if necessary. Refer to Procedure 007-029 in Section 7.

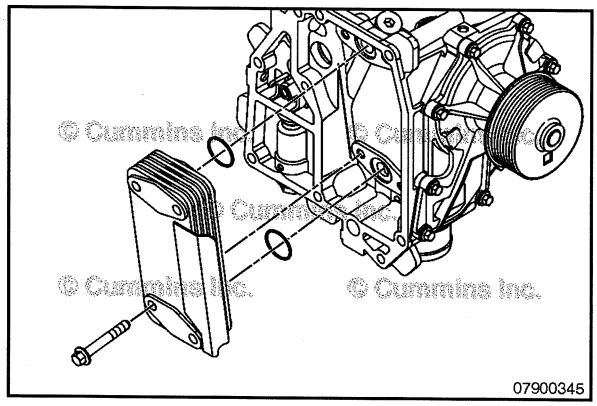


Leak Test

Use the lubricating oil cooler pressure test kit, Cummins® Part Number 4918868, to 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



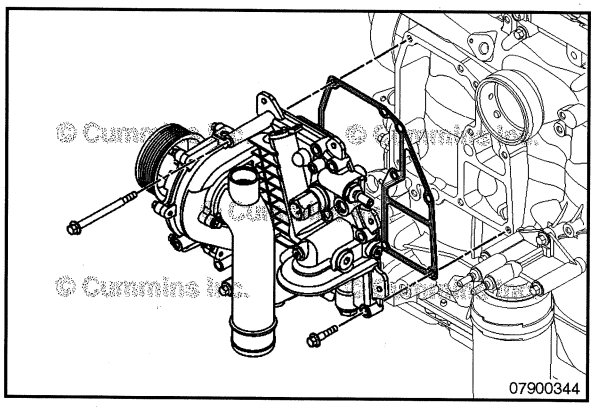


Assemble

Install the lubricating oil cooler element and the four mounting capscrews into the housing.

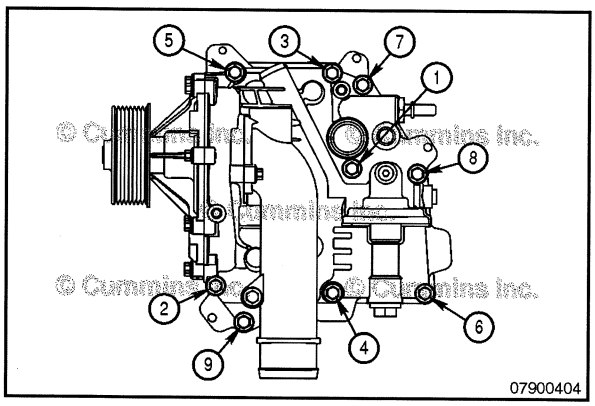
Tighten the capscrews.

Torque Value: 15 N•m [133 in-lb]



Install

Install the water pump/lubricating oil cooler housing and the mounting capscrews to the side of the engine.

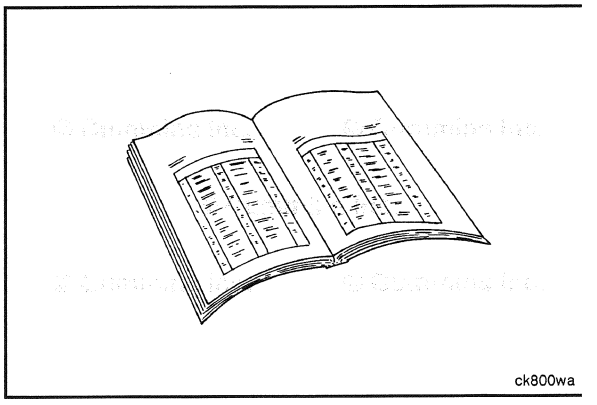


Tighten the capscrews in the sequence shown.

NOTE: Snug capscrew numbers six and eight, then tighten in the sequence shown.

Torque Value: 27 N•m [239 in-lb]

Finishing Steps

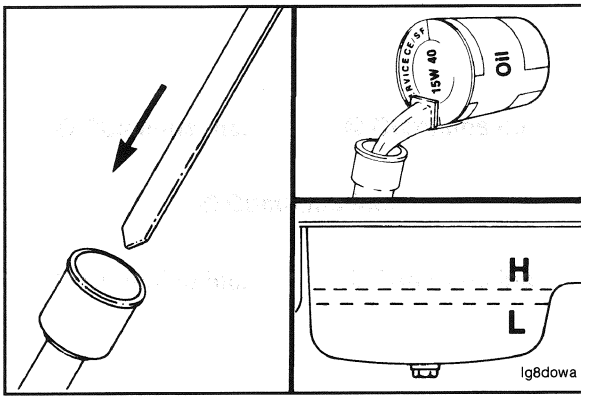


⚠WARNING⚠
Coolant is toxic. Keep away from pets and children. If not reused, dispose of in accordance with local environmental regulations.

- Install the coolant bypass tube. Refer to Procedure 008-005 in Section 8.
- Install the coolant inlet hose to the water pump. See equipment manufacturer service information.
- Install the fan drive belt. Refer to Procedure 008-002 in Section 8.
- Fill the engine the coolant. Refer to Procedure 008-018 in Section 8.
- Operate the engine and check for leaks.

Lubricating Oil Dipstick (007-009)

Calibrate



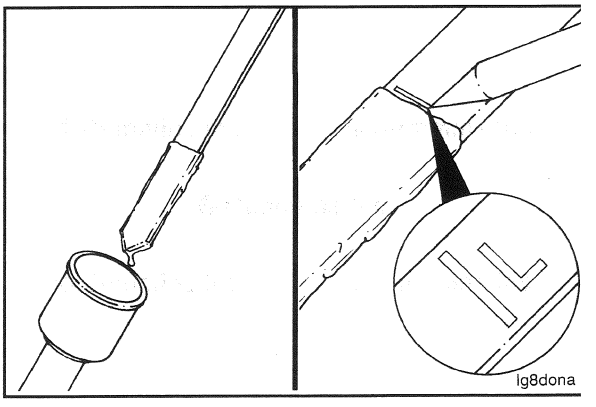
⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.

⚠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.

Wipe off the dipstick and install it in the dipstick tube housing.

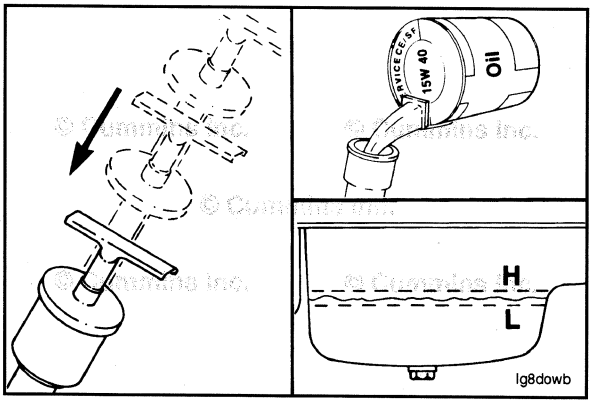
Use clean 15W-40 oil to fill the oil pan to the specified low oil level. Use the following procedure for lubricating oil system specifications in the QSF3.8 CM2350 F107 Operation and Maintenance Manual, Bulletin 4367317. Refer to Procedure 018-003 in Section V.The low oil level can be found by looking up the oil pan option for the engine serial number on QuickServe™ Online.



△CAUTION△
Use care when marking the dipstick, or the dipstick will break if the scribe mark is too deep.

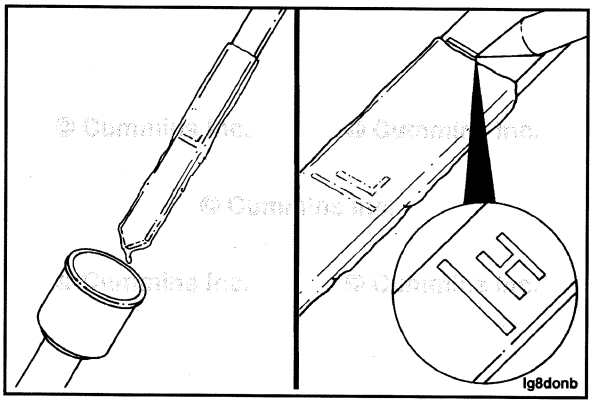
Remove the dipstick, and scribe a mark across the stick at the oil level. Label the mark with an L to indicate the low oil level.

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.

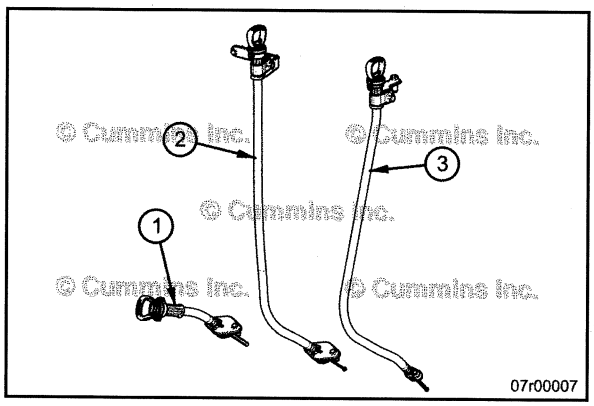


Wipe off the dipstick, and install it in the dipstick tube housing.

Fill the oil pan to the specified high oil level. Use the following procedure for lubricating oil system specifications in the QSF3.8 CM2350 F107 Operation and Maintenance Manual, Bulletin 4367317. The high oil level can be found by looking up the oil pan option for the engine serial number on QuickServe™ Online.



Remove the dipstick, and scribe an mark across the stick at the oil level. Label the mark with an H to indicate the high oil level.

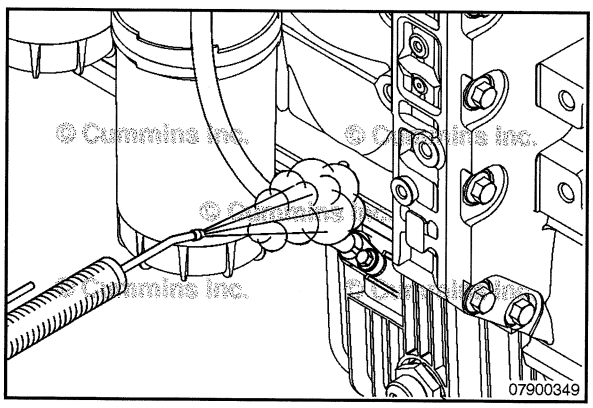


Lubricating Oil Dipstick Tube (007-011)

General Information

There are different design dipsticks to meet the requirements of the original equipment manufacturer (OEM).

- Short dipstick for front or rear sump oil pan (1)
- Long dipstick for front oil pan sump (2)
- Long dipstick for rear oil pan sump (3).



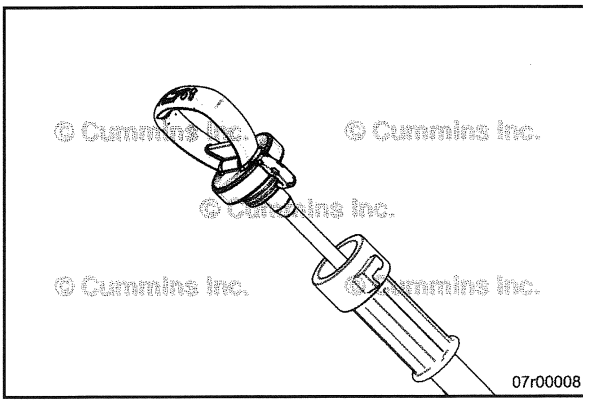
Preparatory Steps

⚠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.

- Clean the area around the dipstick tube before removal to prevent debris from entering the oil system.

Remove

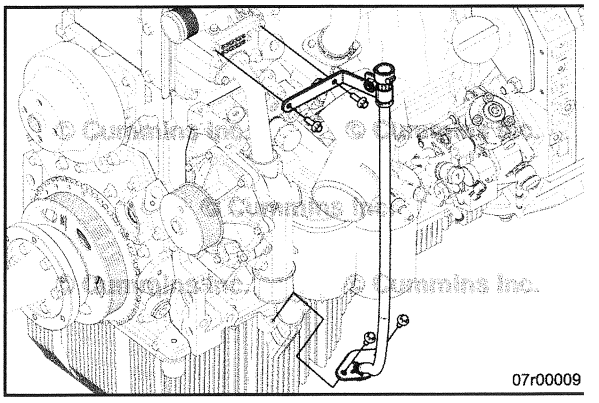
Remove the dipstick from the dipstick tube.



Long dipstick with front oil pan sump:

Remove dipstick tube brace capscrew from dipstick tube support.

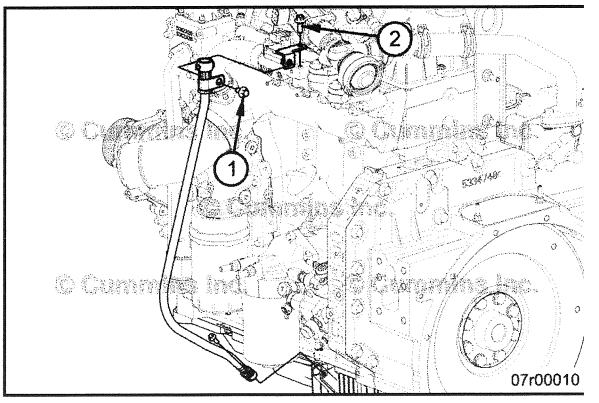
Remove the dipstick tube from the lubricating oil pan.



Long dipstick with rear oil pan sump:

Remove dipstick tube brace capscrew from dipstick tube support (1).

Remove dipstick tube support bracket capscrew from the air transfer tube (2).



Install

Long dipstick with front oil pan sump:

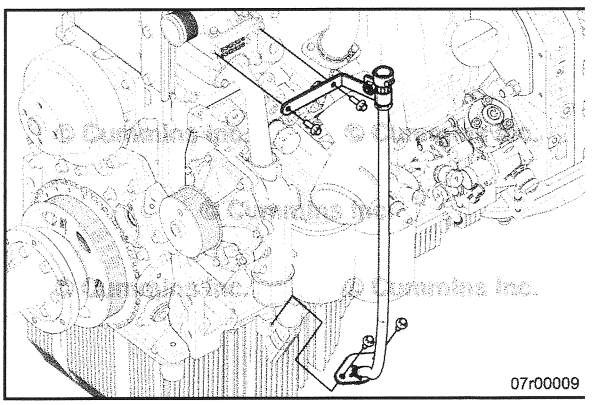
Install dipstick tube into lubricating oil pan.

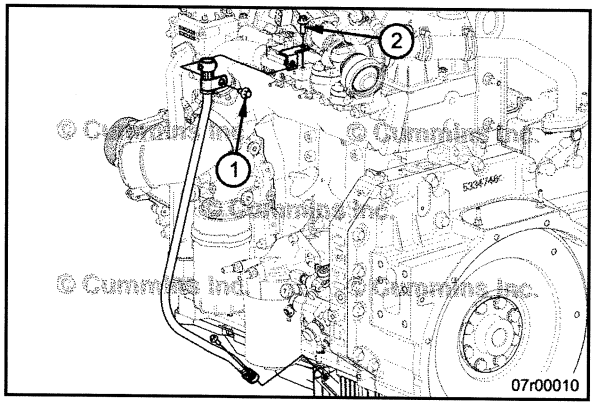
Tighten the dipstick tube retaining capscrew.

Torque Value: 5 N•m [44 in-lb]

Install dipstick support bracket mounting capscrew.

Torque Value: 24 N•m [212 in-lb]





Long dipstick with rear oil pan sump:

Install dipstick tube into lubricating oil pan.

Tighten the dipstick tube retaining capscrew.

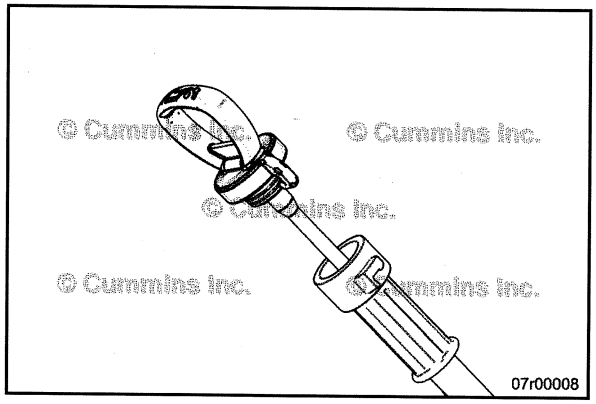
Torque Value: 5 N•m [44 in-lb]

Install dipstick tube support bracket capscrew on the air transfer tube (2).

Install dipstick tube brace capscrew onto dipstick tube support (1).

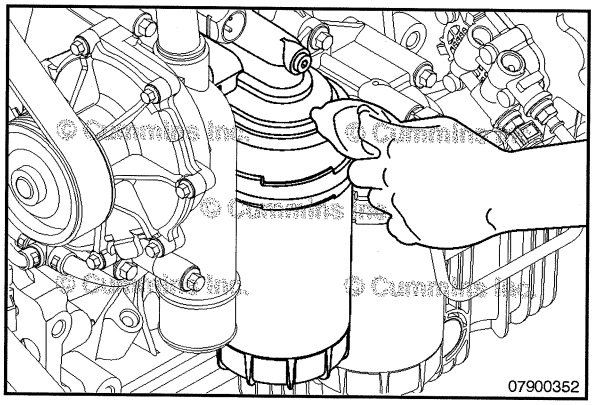
Torque Value:

Step 1	Capscrew 24 N•m	[212 in-lb]
Step 2	Capscrew 18 N•m	[159 in-lb]



Finishing Steps

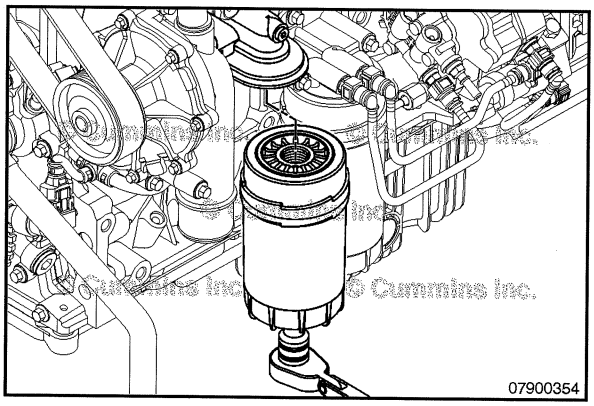
- Install the dipstick into the dipstick tube.



Lubricating Oil Filter (Spin-On) (007-013)

Preparatory Steps

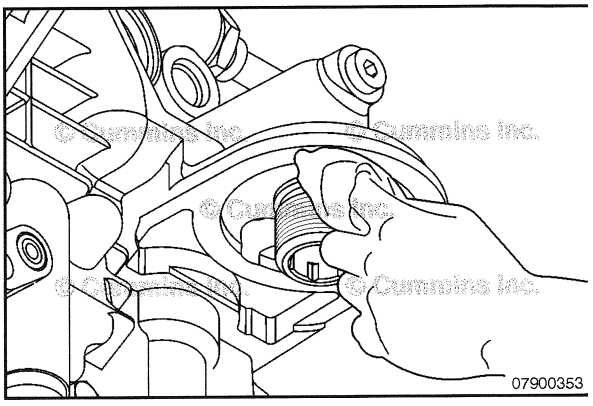
- Clean the area around the lubricating oil filter head.



Remove

Use the ½-inch drive socket in the bottom of the filter to remove the oil filter.

Clean the sealing surface of the filter head.



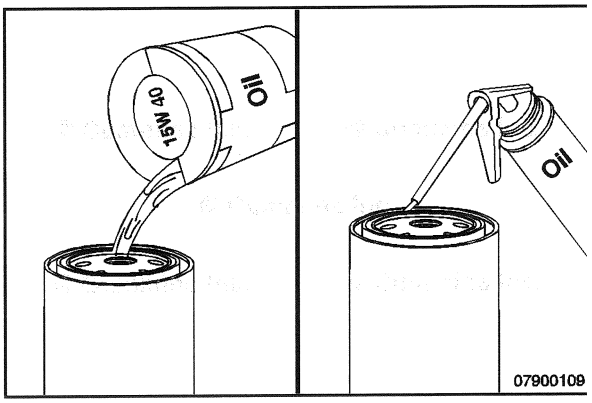
Install

⚠CAUTION⚠
The lack of lubrication during the delay until the filter is pumped full of oil at start-up can damage the engine.

Use clean 15W-40 oil to coat the gasket surface of the filter.

Fill the filter with clean 15W-40 oil.

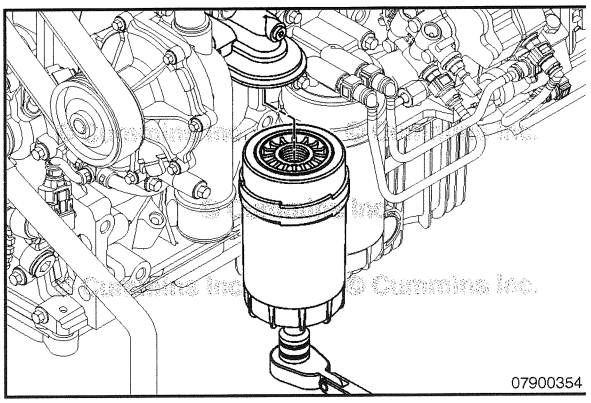
NOTE: Be careful that no debris is poured into the filter. If using an oil supply with a metallic or plastic seal under the cap, be careful to peel the seal back. Puncturing the seal with a knife or sharp object can create debris in the oil container.



⚠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.

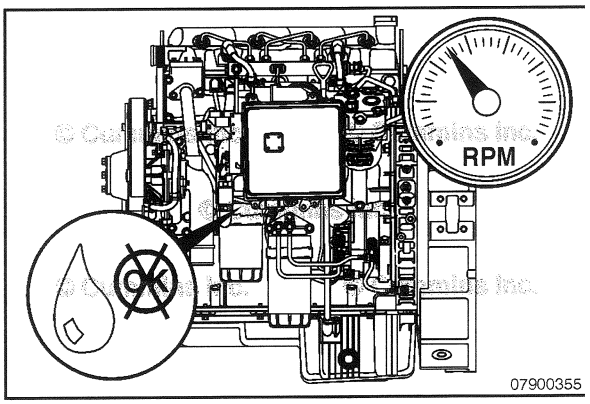
Tighten 3/4 turn to 1 turn after gasket makes contact with the filter head.

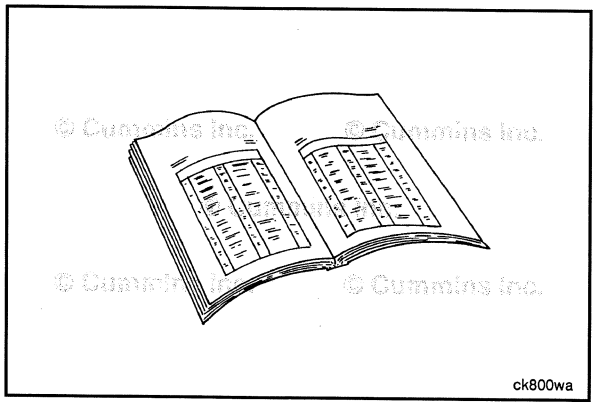


Finishing Steps

⚠CAUTION⚠
If the engine does not produce oil pressure in 15 seconds after starting the engine, shut off the engine to avoid component damage.

- Operate the engine and check for leaks.
- Shut down the engine and check the oil level. Refer to Procedure 007-037 in Section 7.





Lubricating Oil Filter Head (Remote-Mounted) (007-017)

Preparatory Steps

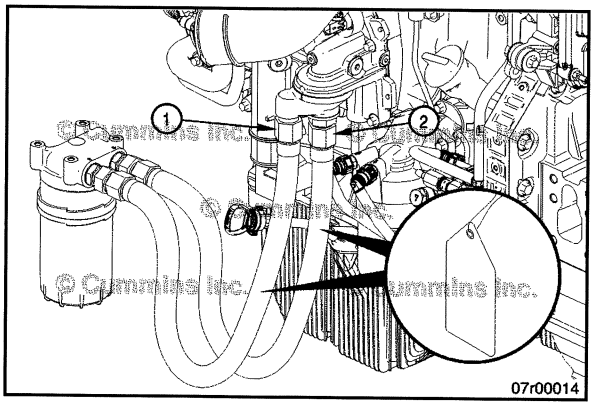
⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠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.

⚠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△
Use caution when draining oil or replacing filters that oil is not spilled or drained into the bilge area. The oil and oil filters must be discarded in accordance with local environmental regulations.

- Disconnect the battery. See equipment manufacturer service information.
- Remove the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Disconnect the lubricating oil lines to the filter head. Refer to Procedure 007-092 in Section 7.



Remove

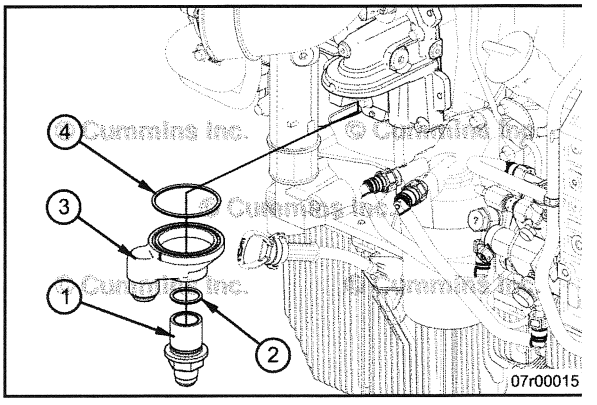
Verify and mark the oil lubricating hoses and the adapter head for proper location.

Loosen, but do **not** remove, the inlet (1) and outlet (2) lubricating oil filter head face seal connection locknuts.

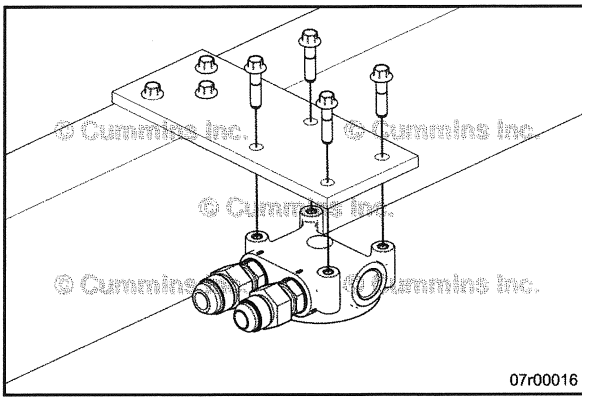
Remove the filter head adapter (1) and discard the o-ring (2).

Remove the filter head cover (3).

Remove and discard the o-ring (4).

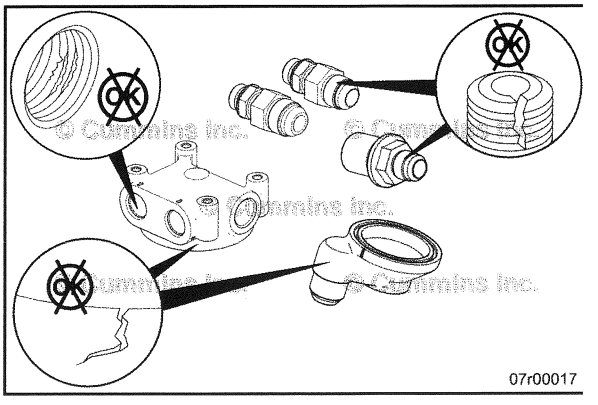


Remove the four mounting capscrews and the lubricating oil filter head.



Inspect for Reuse

Inspect the lubricating oil filter head, adapter, and filter head cover sealing surfaces for cracks or other damage.



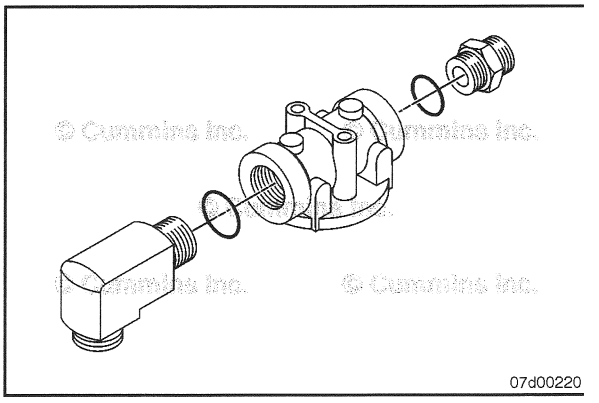
Assemble

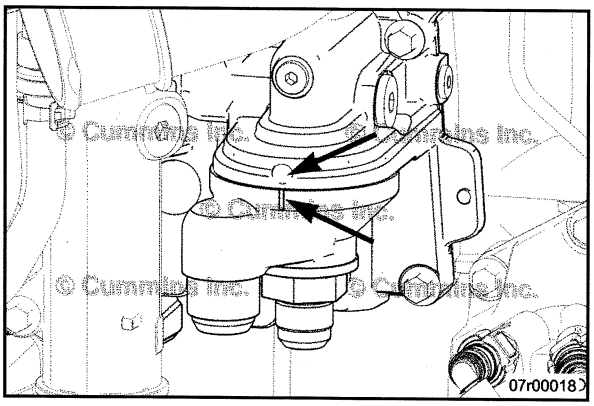
Replace the compression o-ring seals and o-rings on all face sealing connections.

Lubricate the o-rings with clean engine oil.

Install the inlet and outlet connections into the filter head. Be sure the lubricating oil connections are orientated correctly and are installed to their proper depth.

Do **not** tighten the fitting locknuts at this time.





Install

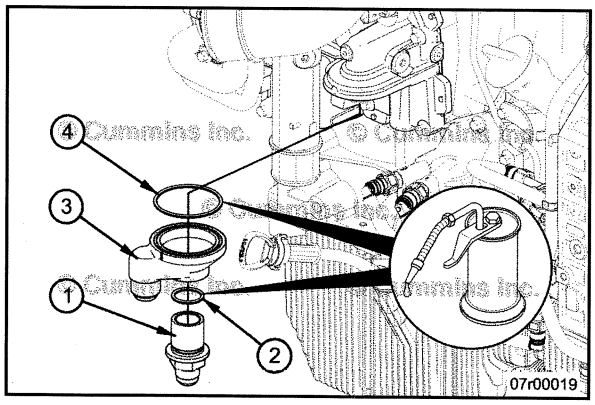
NOTE: The filter head cover has a machined notch that must be aligned with the cast notch on the lubricating oil cooler module.

Replace the compression o-ring seals and o-rings on all face sealing connections.

Lubricate the o-rings with clean engine oil.

Install the inlet and outlet connections into the filter head. Be sure the lubricating oil connections are orientated correctly and are installed to their proper depth.

Do **not** tighten the fitting locknuts at this time.



Lubricate the filter head cover o-ring (2) with clean engine oil.

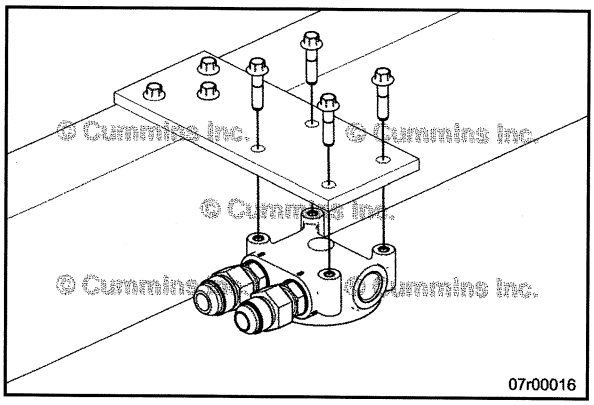
Install the o-ring (2) onto the filter head cover (3).

Lubricate the threads of the filter head adapter (1) and o-ring (4) with clean engine oil.

Assemble the filter adapter (1) onto the filter head cover (3).

Install and tighten the filter head adapter (1).

Torque Value: 100 N•m [74 ft-lb]



Install and tighten the four capscrews into the lubricating oil filter head mounting bracket.

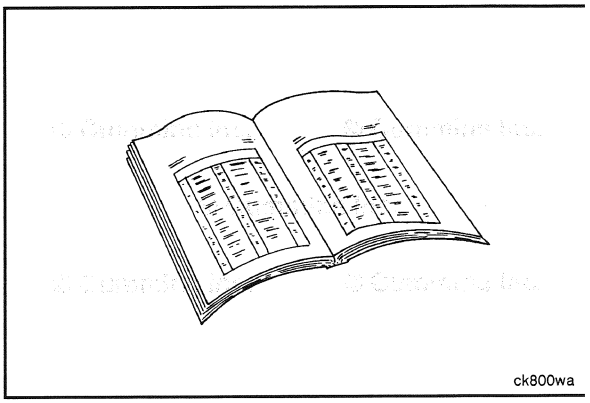
NOTE: The lubricating oil filter head has arrows to indicate the direction of oil flow.

Torque Value: 18 N•m [159 in-lb]

Finishing Steps

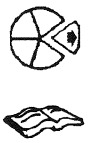
⚠ WARNING ⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Tighten the lubricating oil supply and return lines. Refer to Procedure 007-092 in Section 7.
- Install a new lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Connect the battery. See equipment manufacturer service information.
- Operate the engine and check for leaks and proper oil pressure.
- Shut down the engine and check the lubricating oil level. Add lubricating oil as necessary.



Lubricating Oil Pan (007-025)

Preparatory Steps



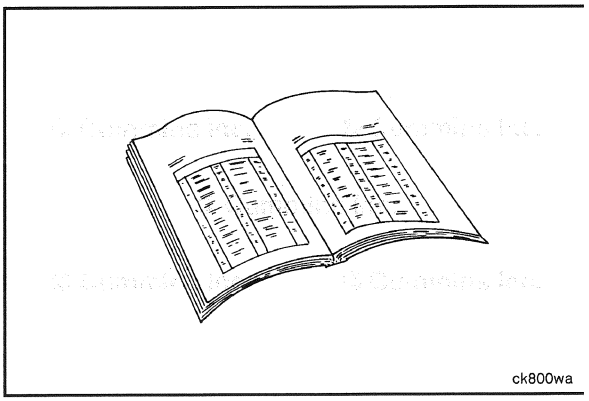
⚠ WARNING ⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

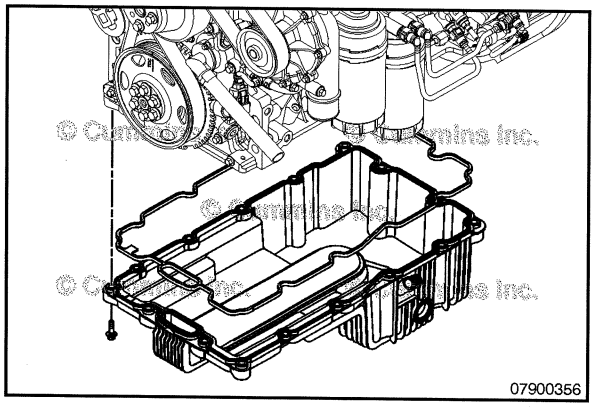
⚠ WARNING ⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

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

- Disconnect the batteries. See equipment manufacturer service information.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.

NOTE: If oil pan is being replaced, remove the lubricating oil dipstick tube. Refer to Procedure 007-011 in Section 7.

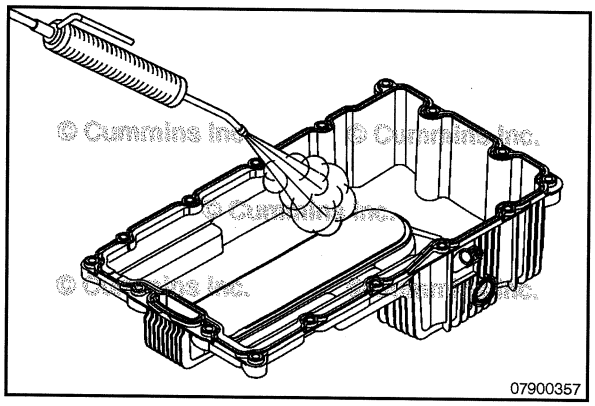




Remove

NOTE: The oil pan seal should remain in the oil pan during the removal step, if possible.

Remove the lubricating oil pan and gasket.



Clean and Inspect for Reuse

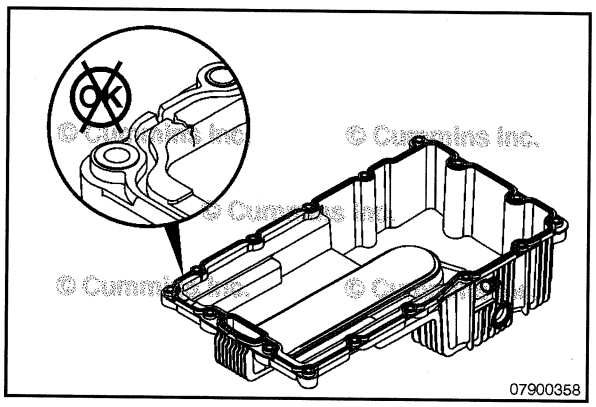
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△
Do not use sharp objects to clean the sealant from the gasket or gasket surface of the oil pan. Damage to the seal can result.

Clean all remaining gasket material from the oil pan and the block.

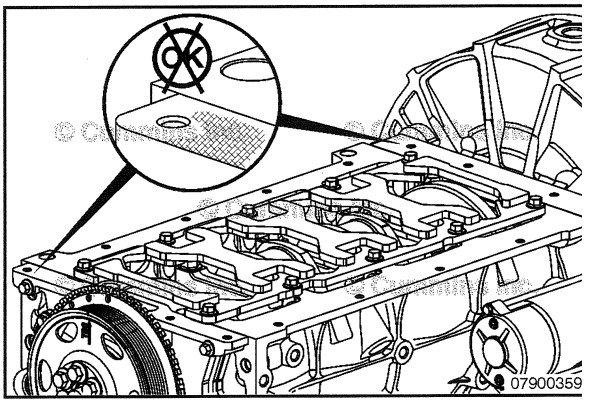
Steam-clean the oil pan. Dry the oil pan with compressed air.



Inspect the oil pan support flange and seal for damage.

NOTE: If cracks are found, replace the damaged part. Do **not** attempt to repair the oil pan by welding.

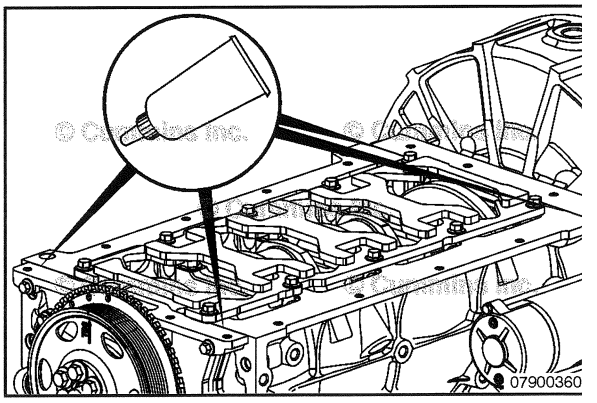
Inspect the underside of the gear housing and front cover for scratches. Scratches in those surfaces can be a cause for leaks.



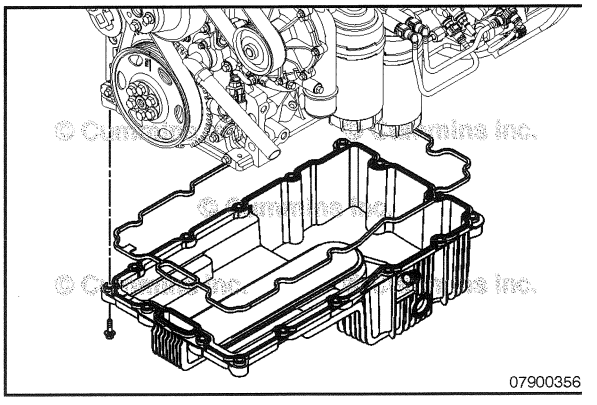
Install

NOTE: If a new front cover gasket has been installed, do **not** scrape away the sealant which is extruded from the new front cover gasket. Additional sealant is **only** required at the T-joint between the cylinder block and rear housing.

Apply a 2-mm [1/16-in] bead of sealant, Cummins® Part Number 3164070, to the oil pan mounting surfaces at the cylinder block to front gear cover joints and the cylinder block to rear gear housing joints.

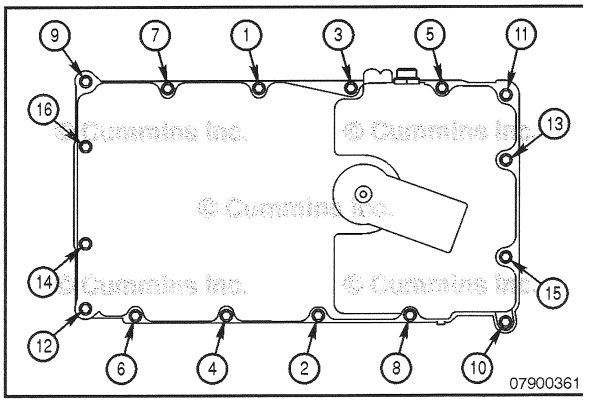


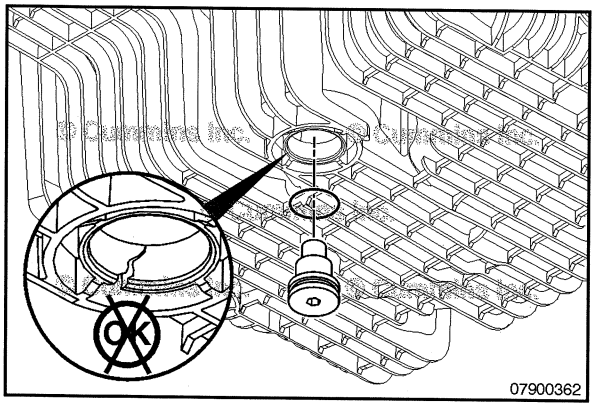
Confirm the seal is located in the groove around the perimeter of the oil pan and the seal is free of oil.



Tighten all sixteen mounting capscrews in the sequence shown in the accompanying graphic.

Torque Value: 24 N•m [212 in-lb]





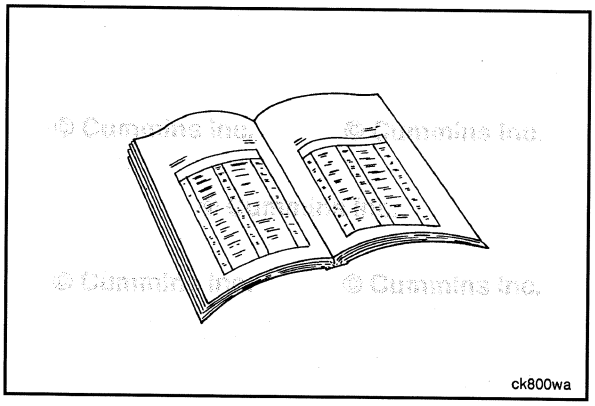
⚠CAUTION⚠
Do not overtighten the oil drain plug. The plug and/or oil pan can be damaged by overtightening.

Clean and check the oil drain plug threads and sealing surface.

Lubricate the oil drain plug o-ring with clean engine oil prior to installing the drain plug.

Install and tighten the oil pan drain plug.

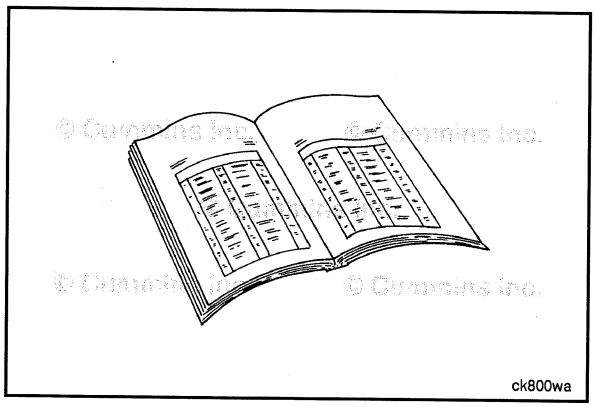
Torque Value: 24 N•m [212 in-lb]



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 lubricating oil dipstick tube, if removed. Refer to Procedure 007-011 in Section 7.
- Fill the engine with clean lubricating oil. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. See equipment manufacturer service information.



Lubricating Oil Pressure Regulator (Main Rifle) (007-029)

Preparatory Steps

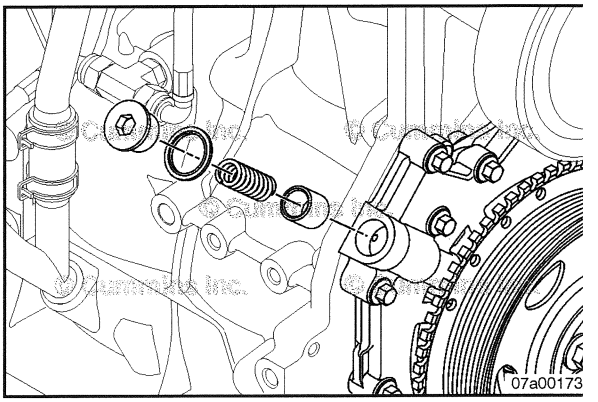
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
When using 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.

- Disconnect the batteries. See equipment manufacturer service information.
- Thoroughly clean the area around the oil pressure regulator plunger with clean solvent to prevent debris from falling into the plunger bore when the plug is removed.

Remove

Remove the threaded plug, oil seal, plunger, and spring.



Clean and Inspect for Reuse

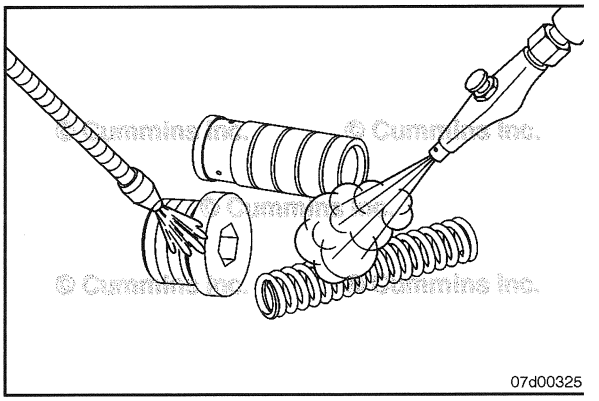
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

If the plunger bore requires cleaning, remove the front gear cover so debris will not be flushed into the engine. Refer to Procedure 001-031 in Section 1.

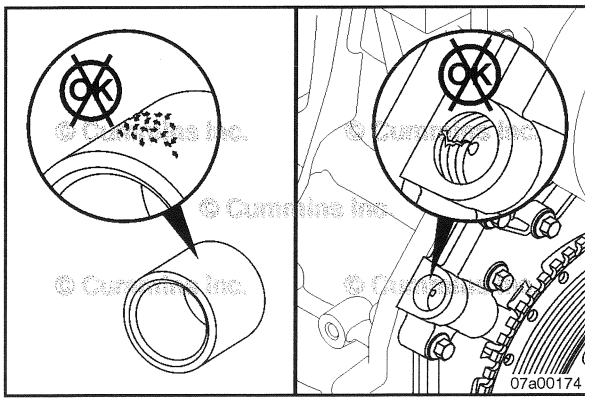
Use solvent to clean the threaded plug, plunger, and spring.

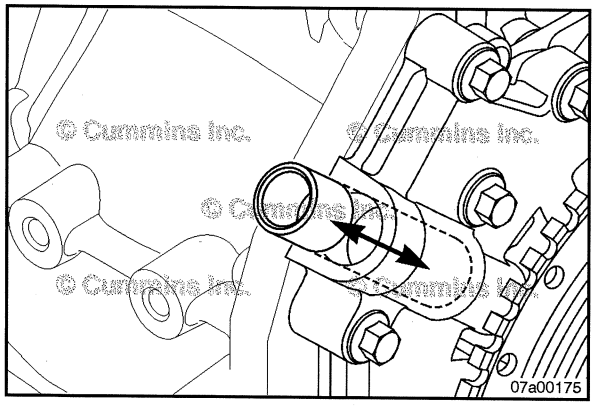
Dry the parts with compressed air.



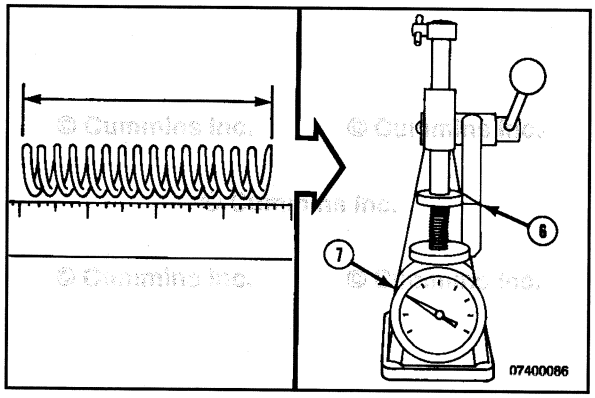
NOTE: Polished areas on the plunger and bore are acceptable.

Inspect the plunger and plunger bore for nicks or scratches.



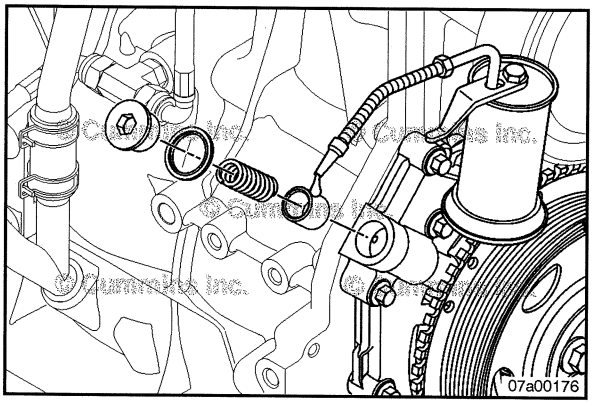


Verify that the plunger moves freely in the bore.



Use valve spring tester, Cummins® Part Number 3375182, to measure the pressure regulator spring at the following heights.

Pressure Regulator Spring Pressure		
Height	N	lbf
42.6 mm [1.677 in]	155 to 165	35 to 37
30.7 mm [1.209 in]	311 to 339	70 to 76



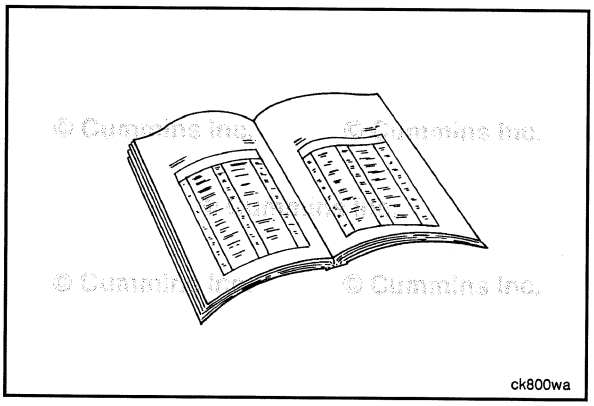
Install

Lubricate the plunger with clean 15W-40 engine oil and install into the front gear cover.

Install the spring, new oil seal, and threaded plug into the front gear cover.

Tighten the threaded plug.

Torque Value: 80 N•m [59 ft-lb]



Finishing Steps

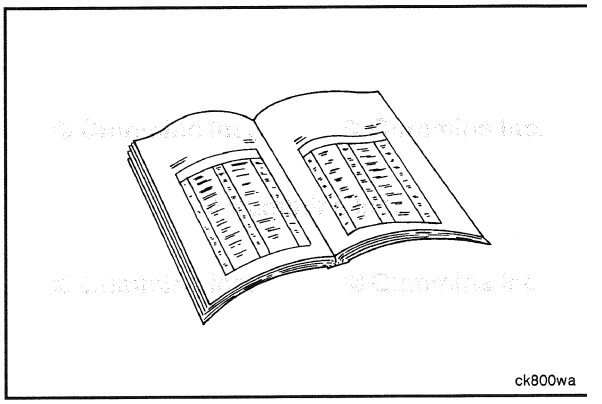
⚠WARNING⚠

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 batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.

Lubricating Oil Pump (007-031)

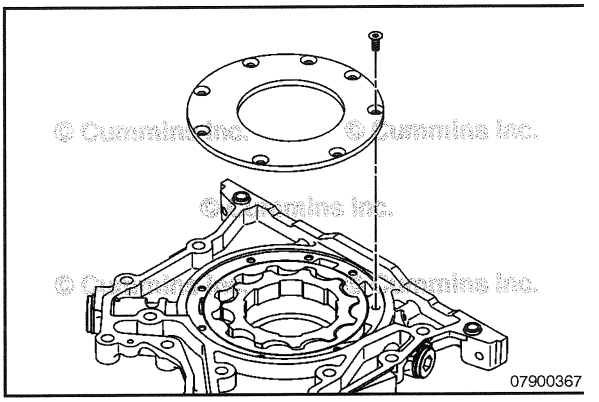
Preparatory Steps



⚠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 batteries. See equipment manufacturer service information.
- Remove the front gear cover. Refer to Procedure 001-031 in Section 1.

Remove

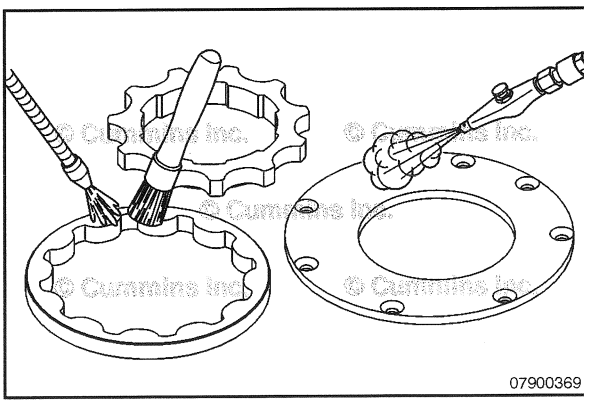


Place the front gear cover on a flat surface, front face down.

Remove the eight lubricating oil pump cover mounting capscrews on the rear of the gear cover.

Remove the cover.

Clean and Inspect for Reuse



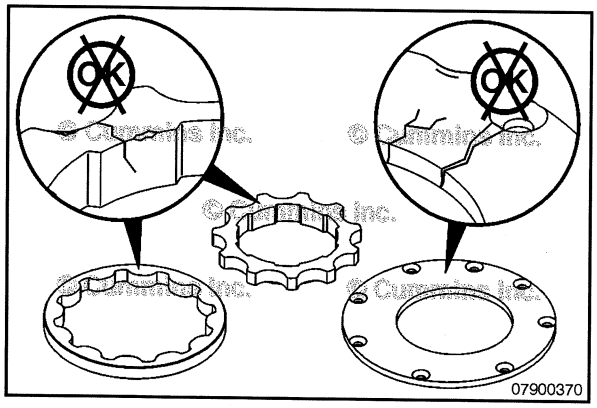
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠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 parts with solvent.

Dry with compressed air.

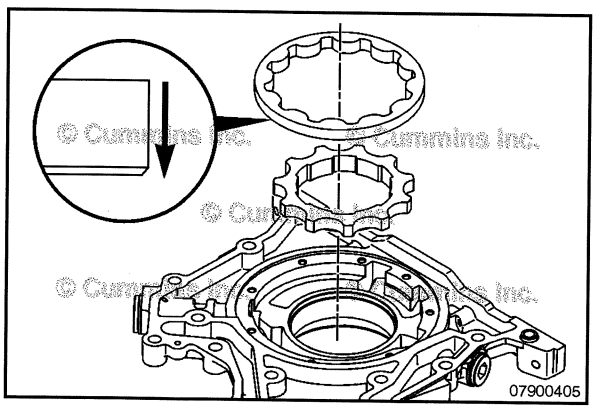


Inspect the components for scratches, cracks, and excessively worn gears.

Inspect the crankshaft nose for damage.

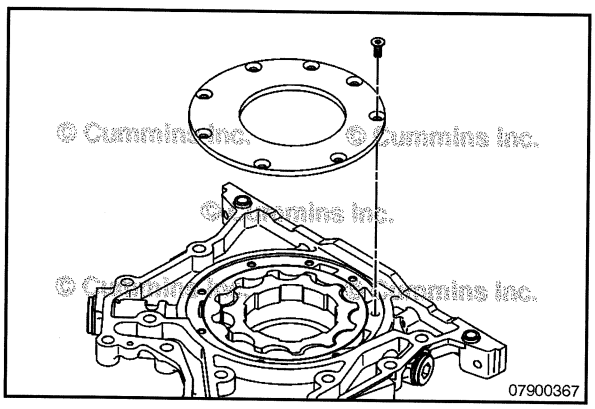
If the gears or the front cover are damaged, it is necessary to replace the front cover. The lubricating oil pump is **not** a serviceable item.

The tip clearance between the oil pump gerotor drive and the planetary **must** remain between 0.12 to 0.22 mm [0.0047 to 0.0087 in]. If the clearance is out of specification, the front cover **must** also be replaced.



Install

Install the lubricating oil pump gears into the front cover.

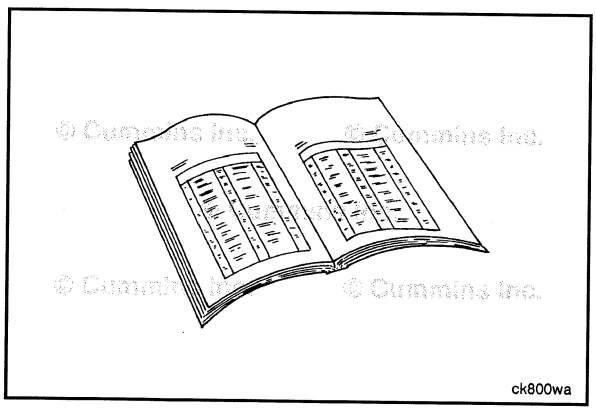


Apply Loctite™ 243, or equivalent, thread sealant to the oil pump cover mounting capscrew threads.

Install the lubricating oil pump cover and the eight mounting capscrews.

Tighten the lubricating oil pump cover capscrews.

Torque Value: 8.5 N•m [75 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 front gear cover. Refer to Procedure 001-031 in Section 1.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.

Lubricating Oil System (007-037)

Measure

⚠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.

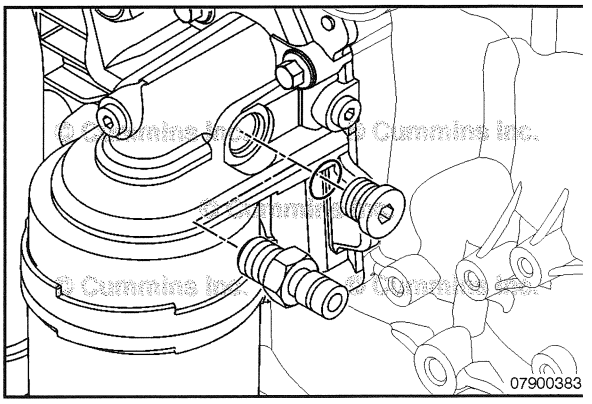
⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

It is preferred that oil pressure be checked at the main oil gallery, if accessible.

Locate the appropriate port for measuring oil pressure. On most engines a port can be found along the main oil gallery. If this port is **not** accessible, another port can be located on the top of the oil filter head.

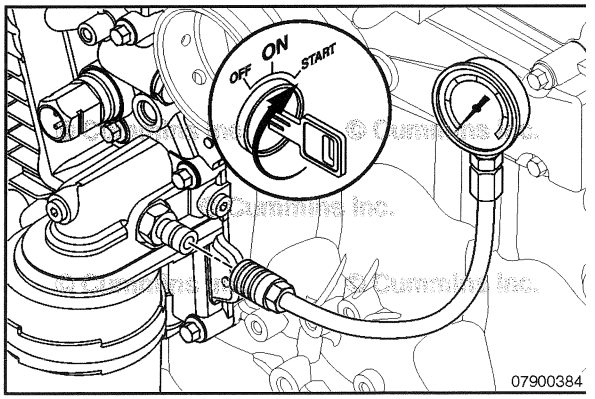
Remove the plug.

Install a Compuchek™ fitting.



△CAUTION△
If the lubricating oil pressure does not develop within 15 seconds, shut down the engine to reduce the possibility of internal damage.

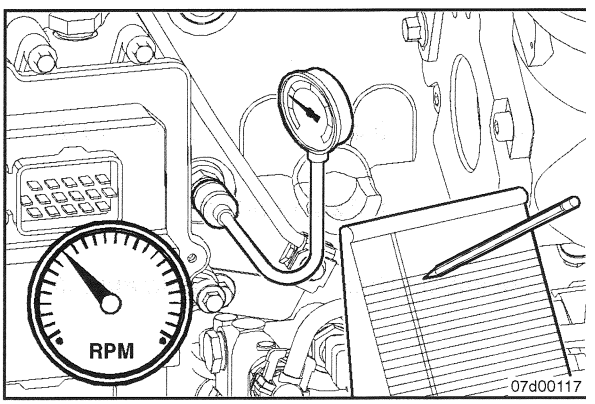
Connect a pressure gauge. Start the engine.

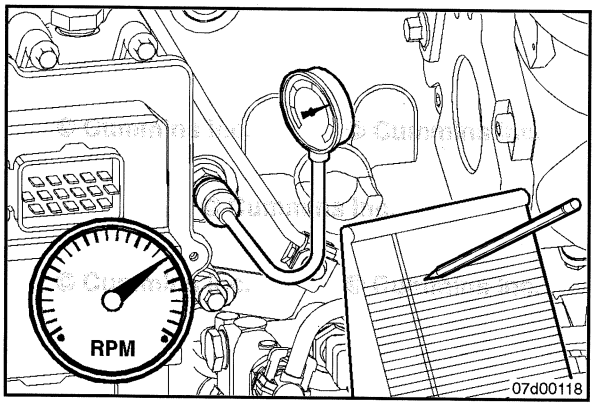


Allow the engine to run and achieve operating temperature. Check for leaks.

Record the lubricating oil pressure readings at idle.

Oil Pressure at Low Idle		
kPa		psi
69	MIN	10

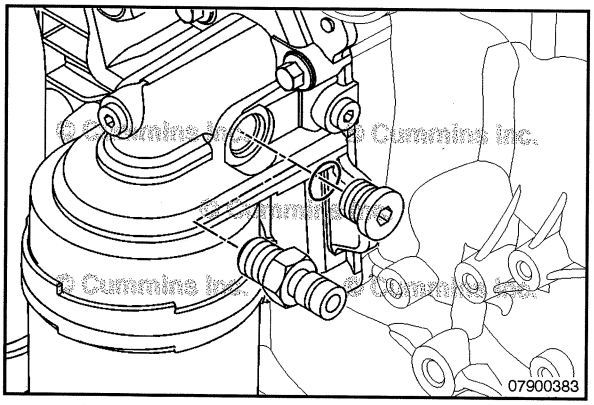




Increase engine speed to rated speed and hold for 30 seconds.

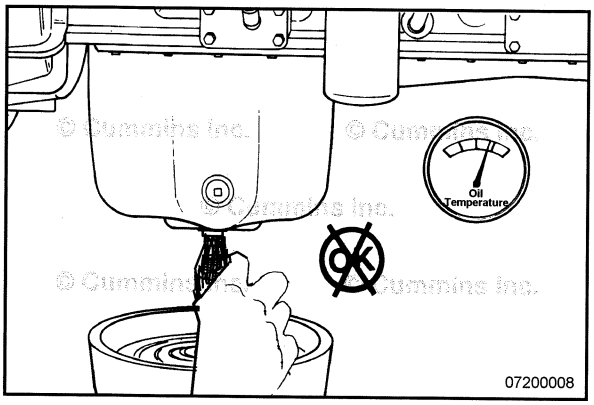
Record the lubricating oil pressure readings at rated engine speed.

Oil Pressure at Rated Engine Speed		
kPa		psi
207	MIN	30



Remove the oil pressure gauge/Compuchek™ fitting and install the previously removed plug.

- Use the following procedure for pipe plug information. Refer to Procedure 017-007 in Section 17.
- Use the following procedure for straight thread plug information. Refer to Procedure 017-011 in Section 17.



Drain

⚠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.

NOTE: For most engines, use a container that can hold at least 20 liters [21 qt] of lubricating oil. Some engines may be equipped with an increased capacity oil pan requiring a container that can hold 28 liters [30 qt] of lubricating oil.

Operate the engine until the coolant temperature reaches 60°C [140°F].

Shut off the engine.

Remove the oil drain plug. Drain the oil immediately to be 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.

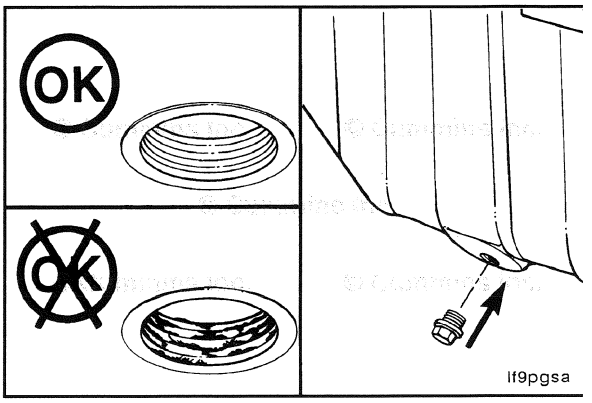
Fill

Clean and check the lubricating oil drain plug threads and sealing surface. Use new sealing washer, if damaged.

Lubricate the oil drain plug o-ring with clean engine oil prior to installing the drain plug.

Install the lubricating oil pan drain plug.

Torque Value:
Lubricating Oil Pan Drain Plug 20 N•m [177 in-lb]



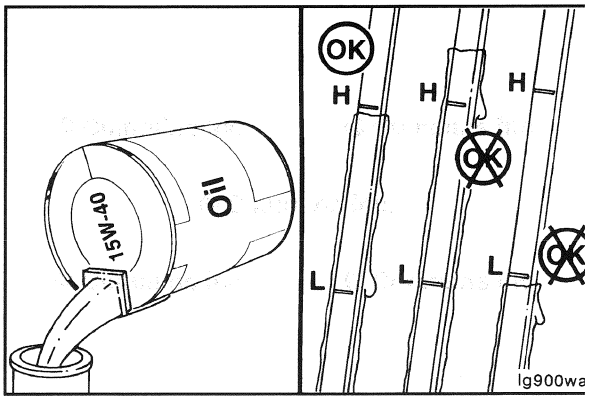
NOTE: Use a high-quality 15W-40 multiviscosity oil, such as Cummins® Premium Blue™, or its equivalent, in Cummins® engines. Choose the correct oil for your operating climate. Reference Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340.

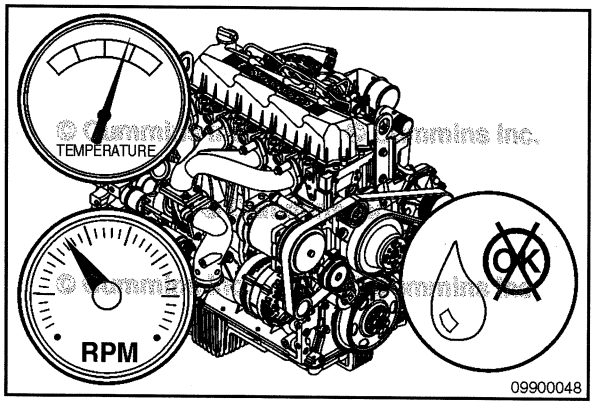
To fill the oil pan, use the fill tube on the side of the engine rather than on top of the rocker lever cover.

If the engine is **not** equipped with a side-fill, wait at least 5 minutes before measuring the oil level with the dipstick to allow the oil to drain to the pan.

Fill the lubricating oil pan with clean 15W-40 lubricating oil to the low level. Use the following procedure for common lubricating oil pan capacities, or look up the oil pan option for the engine serial number on QuickServe™ Online. Refer to Procedure 018-017 in Section V

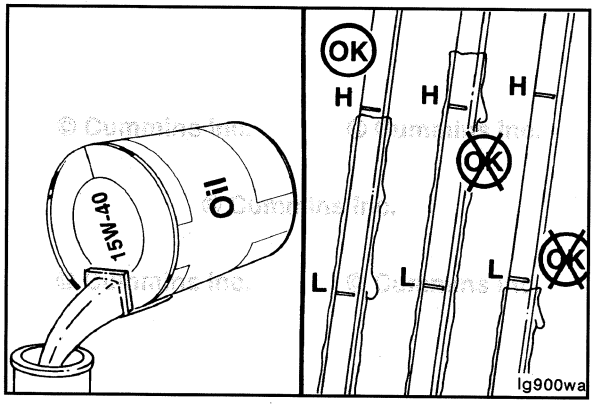
Service Tip: If the oil capacity of the oil pan is **not** known, fill the lubricating oil pan to the lowest oil pan capacity. Refer to Procedure 018-017 in Section V. Add 1 quart of oil at a time until it reaches the high mark on the dipstick. Record the number of quarts added so that capacity is known the next time the oil is drained.





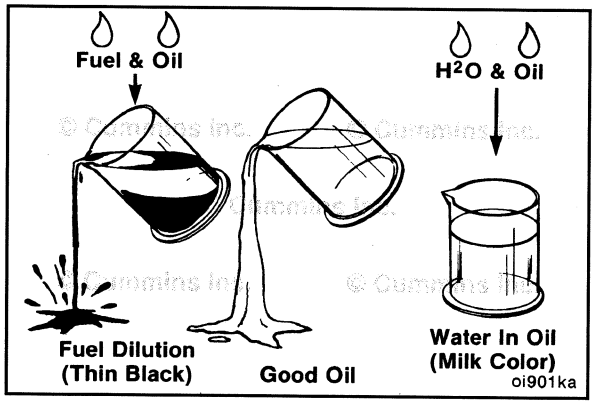
⚠CAUTION⚠
Engine oil pressure must be indicated on the gauge within 15 seconds after starting. If oil pressure is not registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm that the correct oil level is in the oil pan.

Idle the engine to inspect for leaks at the drain plug and, if replaced, the oil filter seal.



Shut off the engine. Wait approximately 5 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 Contamination (007-044)

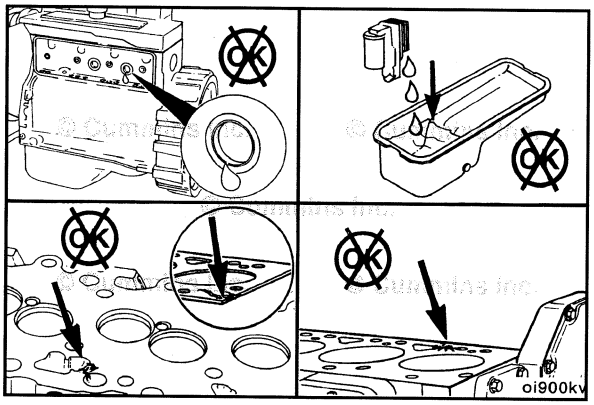
General Information

⚠CAUTION⚠
Diluted oil can cause severe engine damage.

Check the condition of the lubricating oil.

Lubricating Oil Dilution

- Thin, black lubricating oil is an indication of fuel in the oil.
- Milky discoloration is an indication of coolant in the lubricating oil.

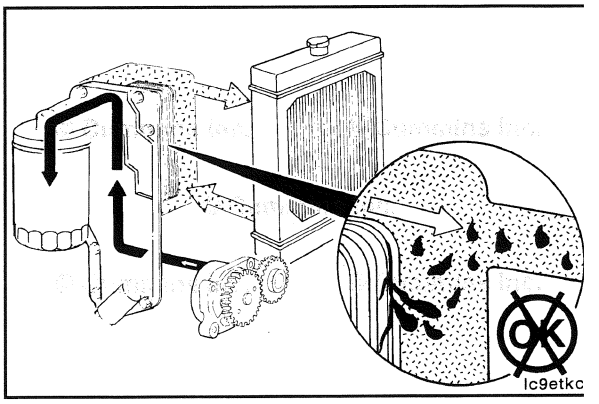


Coolant in the oil can be caused by:

- Expansion plugs leaking.
- Lubricating oil cooler element leaking.
- Damaged cylinder head or gasket.
- Cracked engine block.
- Casting porosity.

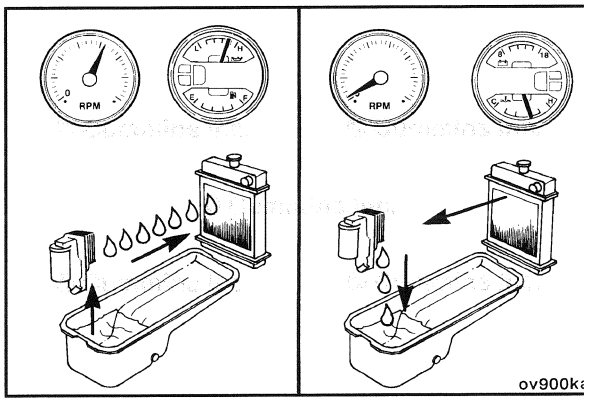
Coolant-Diluted Lubricating Oil

- Since the lubricating oil cooler design does **not** require gaskets or seals to maintain the separation of oil and coolant, the element itself **must** leak to allow mixing of the fluids. Refer to Procedure 007-003 in Section 7.



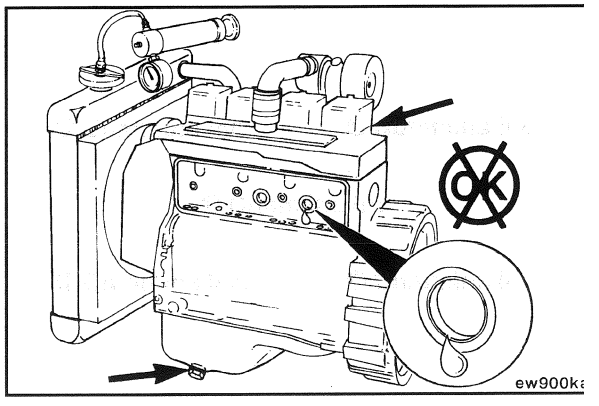
During operation, the lubricating oil pressure will be higher than coolant pressure. A leak in the lubricating oil cooler will show as lubricating oil in the coolant.

However, following an engine shutdown, the residual pressure in the coolant system can cause coolant to seep through the leak path into the lubricating oil.



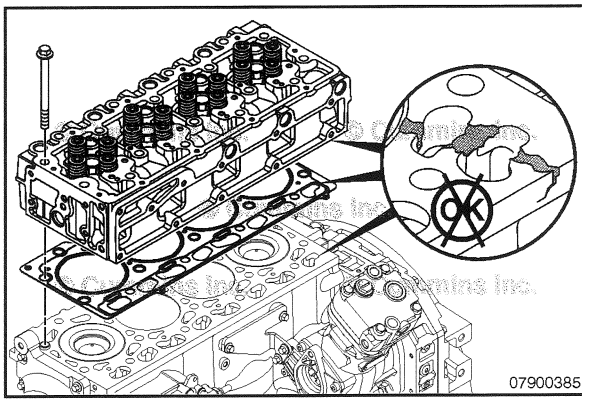
To check for leaks, pressurize the cooling system to 140 kPa [20 psi]. With the system pressurized, remove the following components and inspect for leaks.

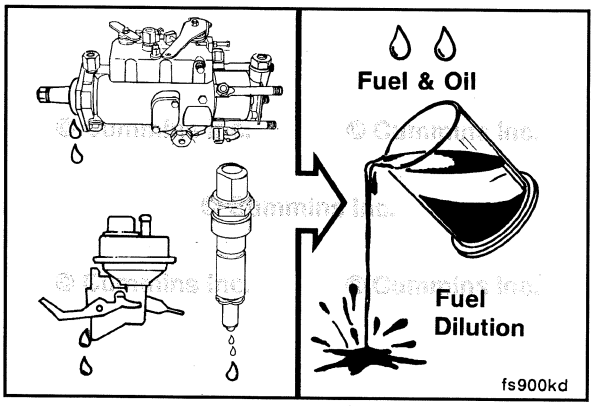
- Valve covers (leaks indicate cracked head).
- Lubricating oil drain plug (leaks indicate damaged lubricating oil cooler or head gasket or a cracked head or block).
- Tappet cover (expansion plug leak).



Coolant in the lubricating oil can be caused by a damaged cylinder head gasket or cracked cylinder head or block.

Remove the cylinder head and gasket, and inspect for cracks or other damage.





Fuel-Diluted Lubricating Oil

Fuel dilution is limited to five sources:

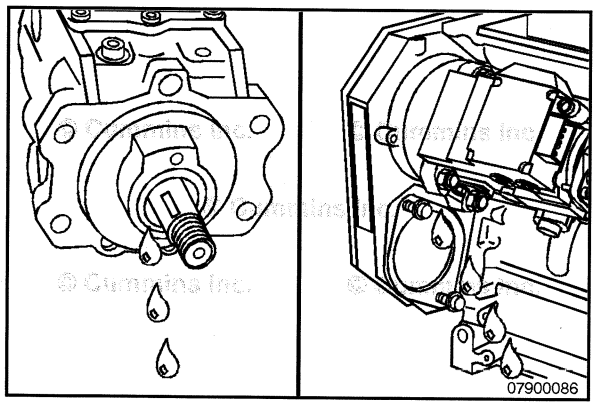
1 Injection pump shaft seal.

2 Fuel leaking by the rings.

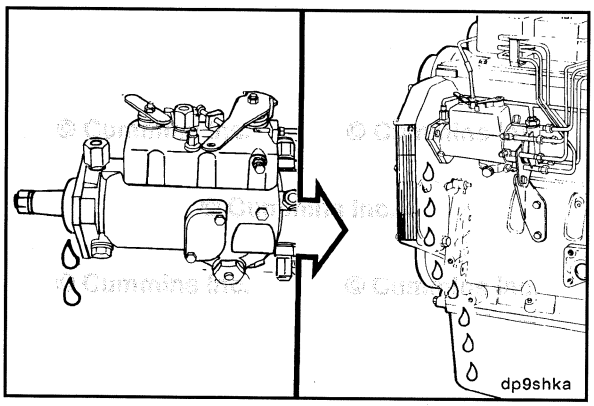
3 Fuel transfer pump.

4 A crack in the cylinder head from the fuel filter location to the air intake.

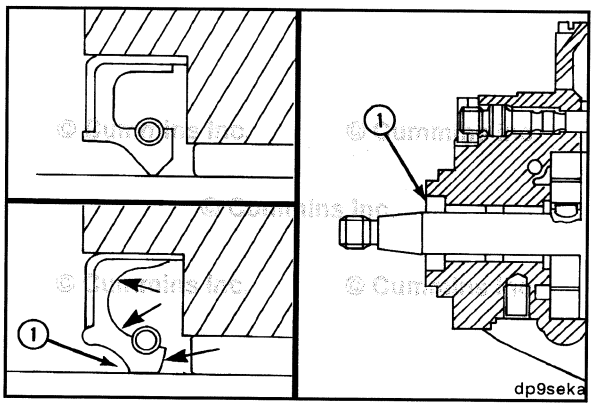
5 Injector leakage.



Use the following logic to determine the source of the lubricating oil diluted with fuel.



A worn or damaged fuel injection pump shaft seal will allow fuel to leak into the gear housing and then into the lubricating oil pan.

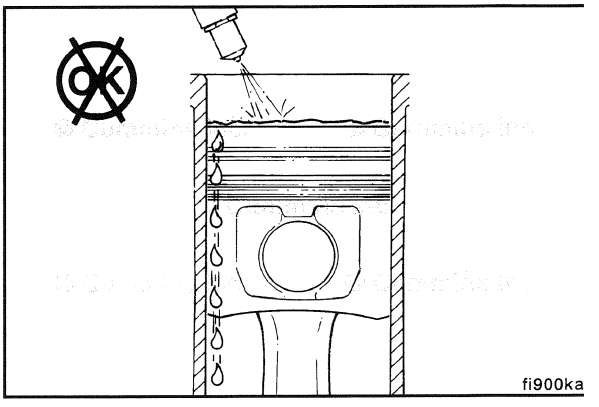


The seal is designed to provide increased sealing as the pump case pressure increases. Pressure forces the lip (1) tighter around the shaft.

A worn seal could leak during start-up and shutdown when case pressure is low. A worn seal can **not** easily be detected by pressurizing the pump.

Incomplete combustion in the cylinders can result in unburned fuel draining into the oil pan.

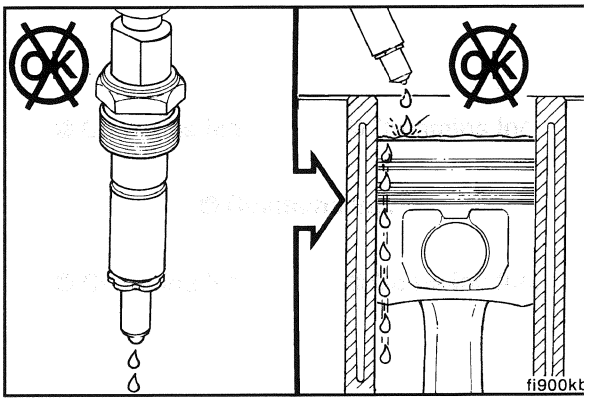
This condition can be caused by a leaking injector or reduced compression caused by inadequate piston ring sealing.



An increase in white exhaust smoke during the first start of the day is a symptom that an injector is leaking.

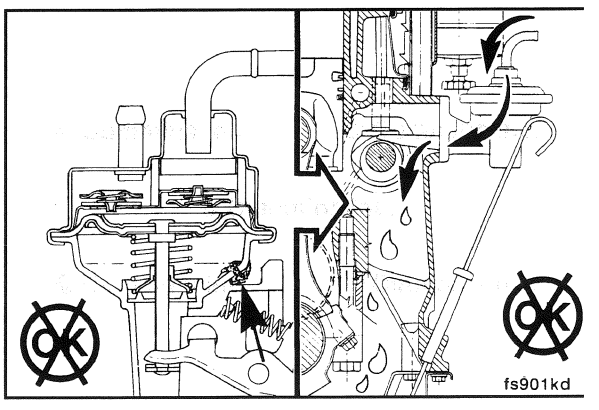
An injector leak will also cause the engine to run rough and have low power.

Remove and repair or replace leaking injectors. Refer to Procedure 006-026 in Section 6.

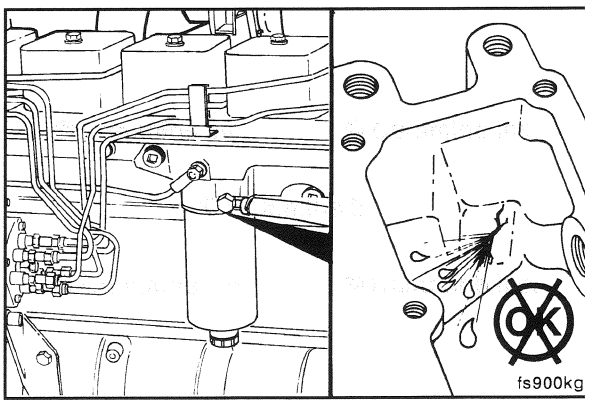


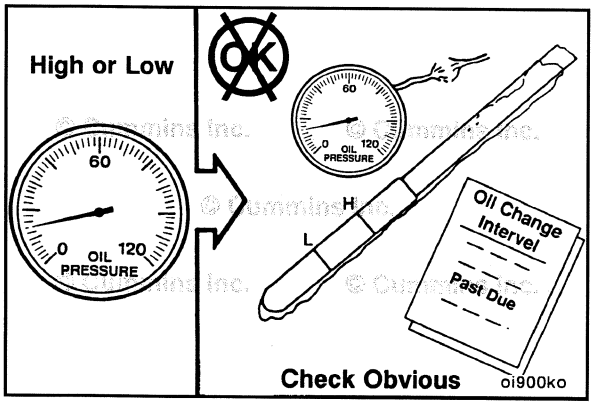
There is a remote possibility for fuel to drain into the oil from the diaphragm-type fuel transfer pump.

For this to happen, the diaphragm in the pump will break and the drain hole will need to be plugged.



Another remote possibility is that a crack or porosity in the head casting will allow fuel to leak to the air intake and into the cylinders.



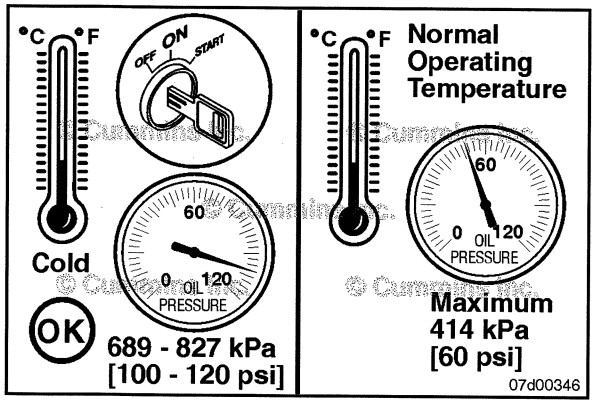


Lubricating Oil System Diagnostics (007-048)

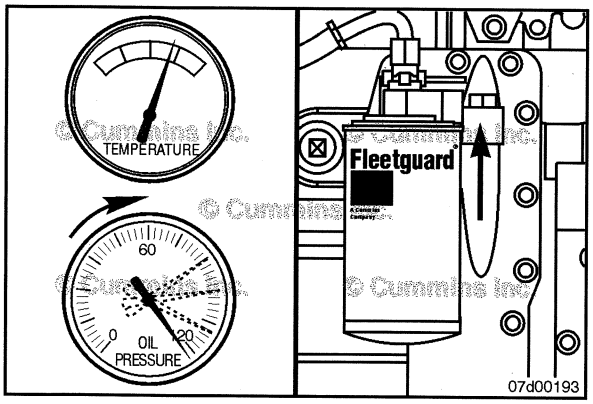
General Information

Lubricating Oil Pressure

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.

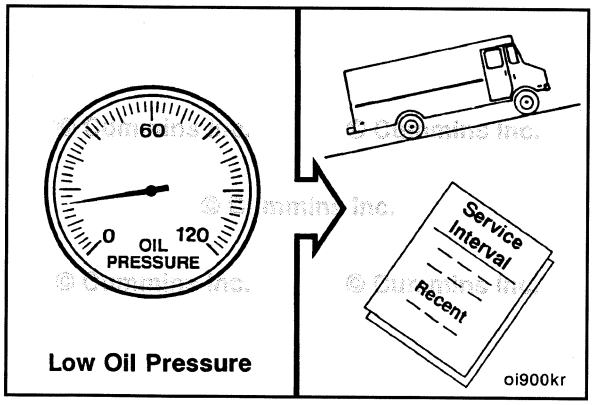


High lubricating oil pressure occurs after the engine is first started in cold weather. Cold-start oil pressure typically will be approximately 689 to 827 kPa [100 to 120 psi]. If the pressure regulator plunger is operating properly, the oil pressure is approximately 414 kPa [60 psi] when normal operating 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.

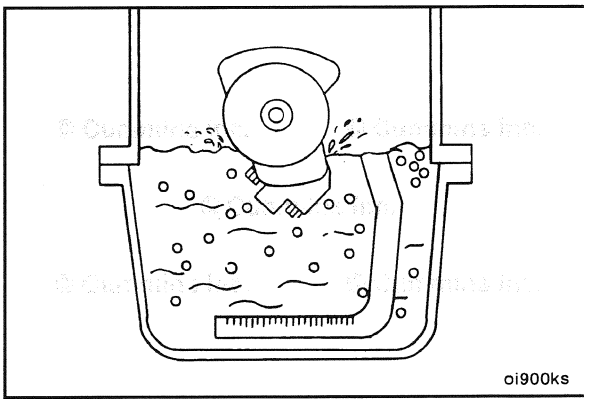
Check the regulator for freedom of movement. Refer to Procedure 007-029 in Section 7.



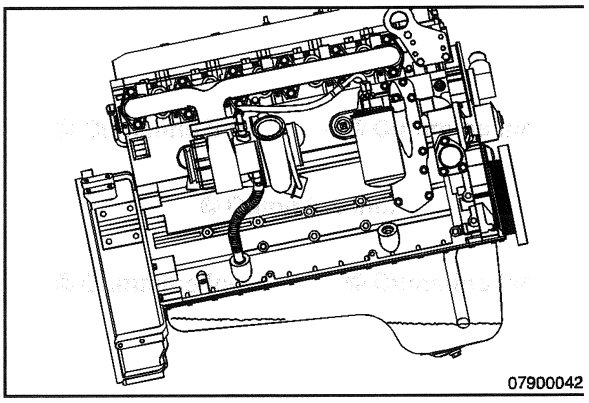
Low lubricating oil pressure (or no oil pressure) can be caused by several lubricating system-related malfunctions. To begin the investigation, determine the engine operating conditions when the low pressure was first observed. The following are conditions of low lubricating oil pressure:

- Following a service interval.
- At idle **only.**
- Operating on a steep grade.
- Operating in rough seas.

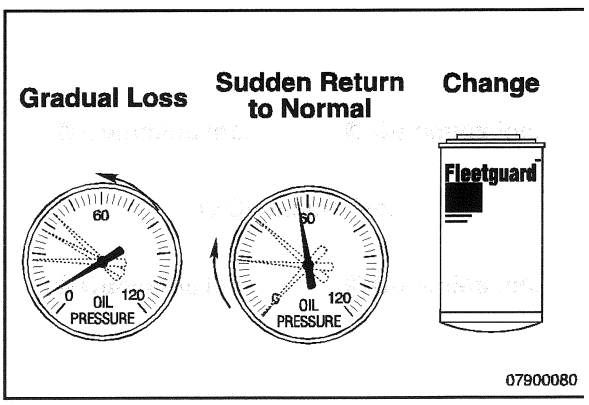
High lubricating oil level can cause low oil pressure. If the oil level is high enough for the connecting rods to dip into the oil while operating, the oil can become aerated, resulting in low oil pressure.



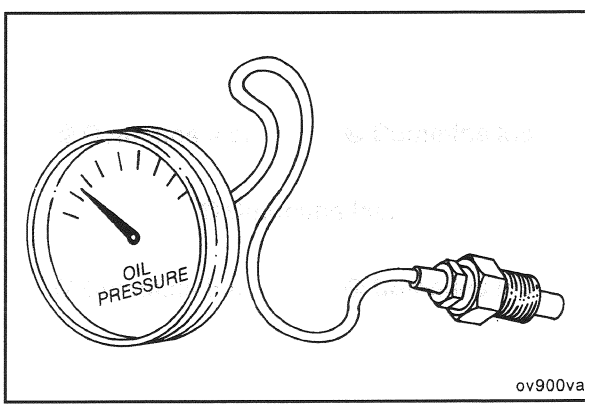
Low oil level will **not** normally appear as low oil pressure. Typically, it will appear as an intermittent loss of oil pressure when rounding a corner or operating on a steep grade. This condition exists when the oil level is extremely low and the suction tube can **not** pick up oil during all modes of operation.

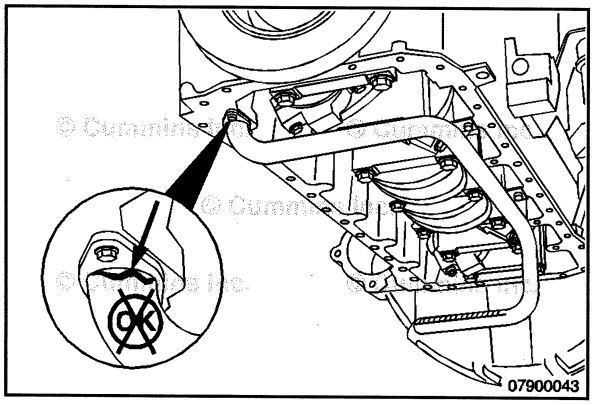


A plugged lubricating oil filter will cause a gradual loss of oil pressure by approximately 69 kPa [10 psi]. The pressure will return to normal when the filter bypass valve opens. If **not** corrected, this will result in severe engine wear, as the engine is running on unfiltered oil when the bypass valve is open.

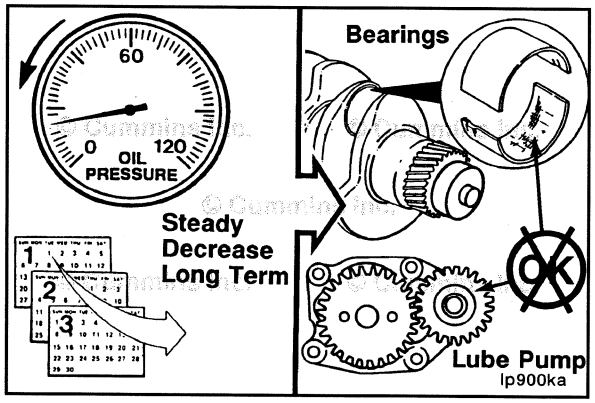


Verify the pressure with a manual gauge to make sure the lubricating oil gauge and the sending unit are operating correctly.

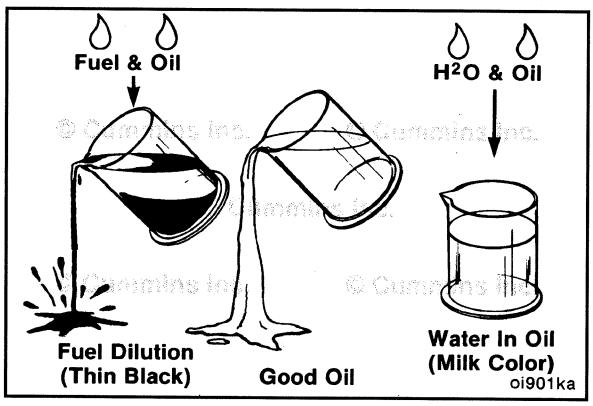




A loose lubricating oil suction tube, damaged gasket, or crack in the suction tube can cause a loss of prime for the oil pump. The engine will have low pressure or no oil pressure during starting, followed by normal oil pressure.



A steady decrease in oil pressure over a long period can be an indication of worn bearings or excessive lubricating oil pump wear.

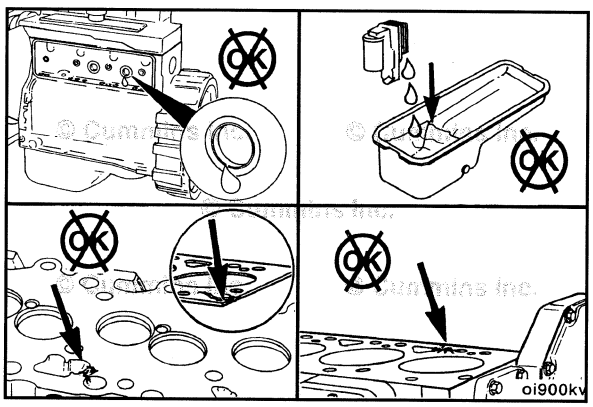


Lubricating Oil Dilution

△CAUTION△
Using diluted oil can cause severe engine damage.

Check the condition of the lubricating oil:

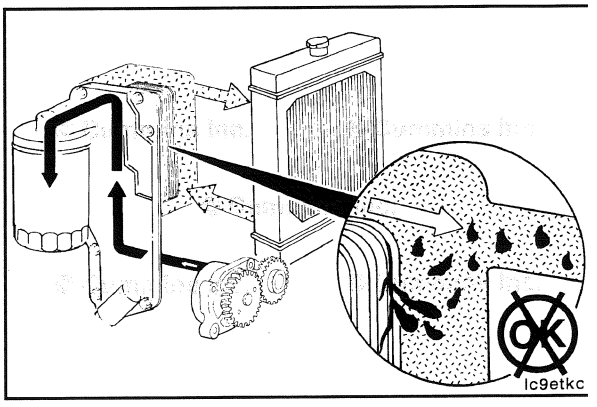
- Thin, black oil is an indication of fuel in the oil.
- Milky discoloration is an indication of coolant in the oil.



Coolant in the oil can be caused by:

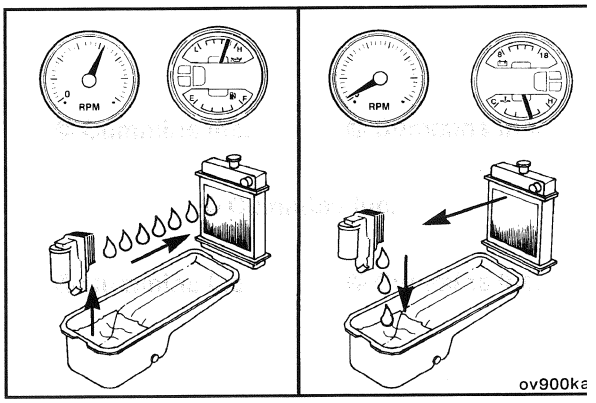
- Expansion plugs leaking.
- Oil cooler element leaking.
- Damaged cylinder head or gasket.
- Cracked engine block.
- Casting porosity.

Since the lubricating oil cooler design does **not** require gaskets or seals to maintain the separation of oil and coolant, a leaking element can allow the fluids to mix. Refer to Procedure 007-003 in Section 7.



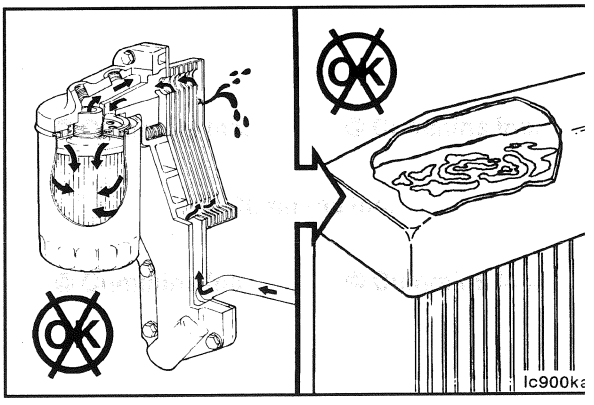
While operating, the oil pressure will be higher than coolant pressure. A leak in the oil cooler will show as oil in the coolant.

However, following an engine shutdown, the residual pressure in the coolant system can cause coolant to seep through the leak path into the oil.



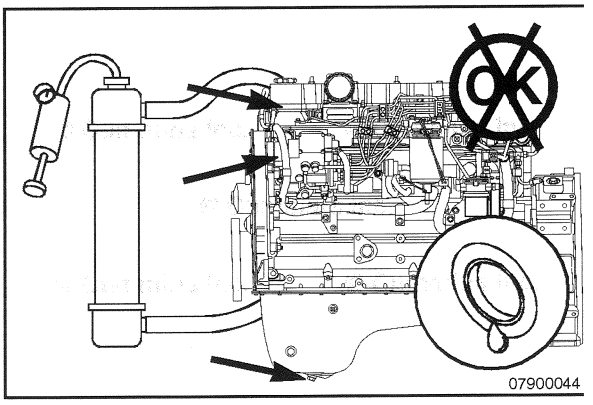
If the oil cooler element ruptures, the oil pressure will force oil into the coolant system.

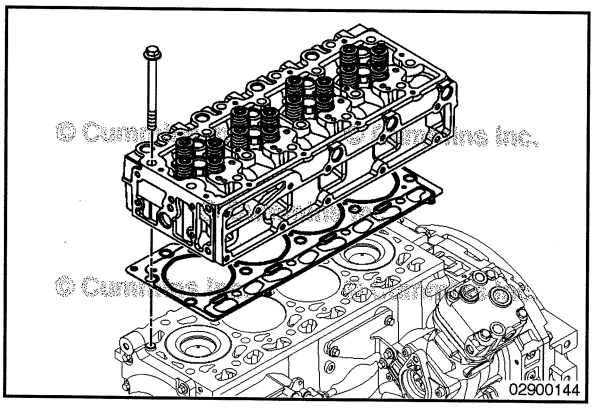
Oil in the coolant will be visible when the radiator cap is removed. Refer to Procedure 007-003 in Section 7.



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. Leaks indicate a damaged oil cooler, cylinder head gasket, or cracked cylinder head or block.Refer to Procedure 007-037 in Section 7.

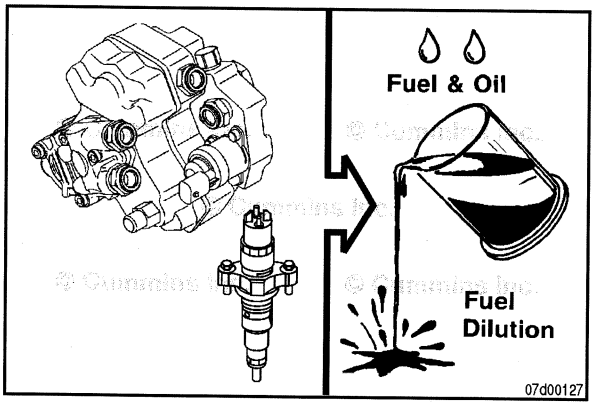




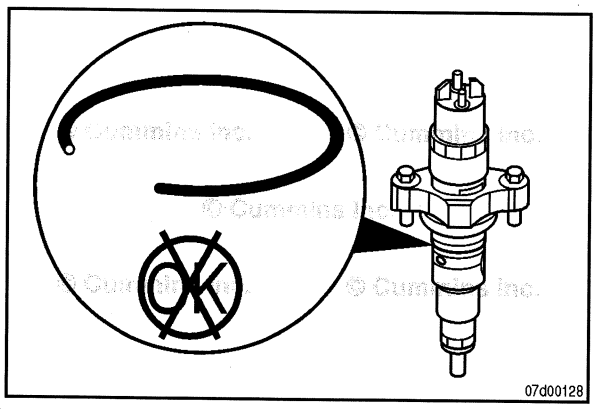
Coolant in the lubricating oil can be caused by a damaged cylinder head gasket or cracked cylinder head or block.

Remove the cylinder head and gasket. Refer to Procedure 002-004 in Section 2.

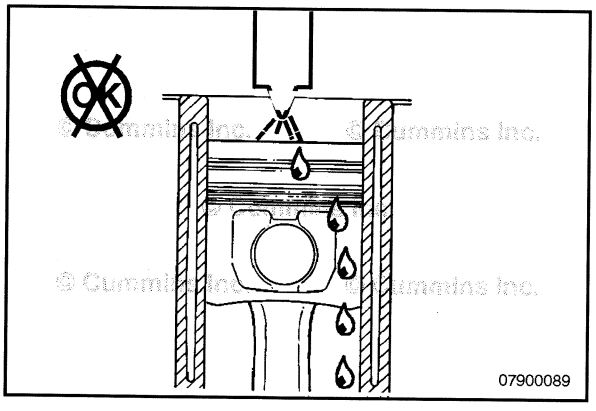
Inspect for cracks or any other damage.



Fuel dilution of the lubricating system is generally due to the injector, but may also be due to internal damage to the high-pressure pump.



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.

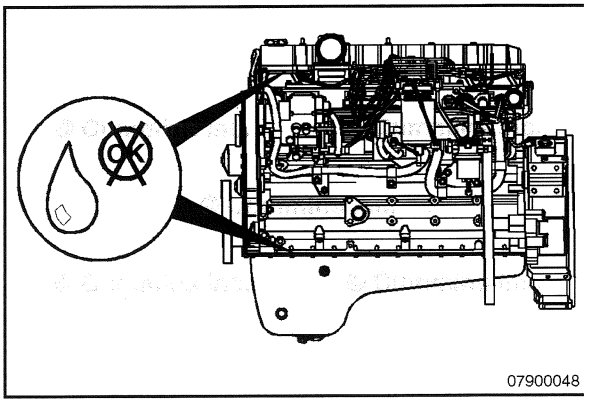


Incomplete combustion in the cylinders can result in unburned fuel draining into the oil pan.

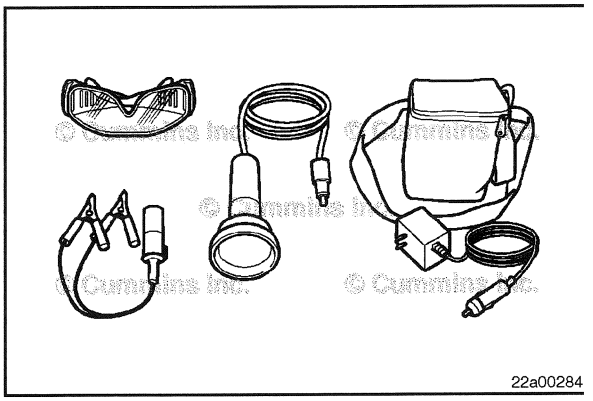
This condition can be caused by a leaking injector or reduced compression caused by inadequate piston ring sealing.

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.



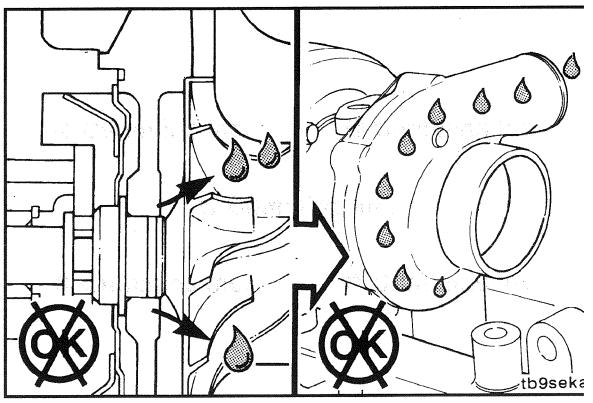
A black light kit, Cummins® Part Number 3163338, and fluorescent tracer, Part Number 3376891, **must** be used to verify the source of an oil leak.



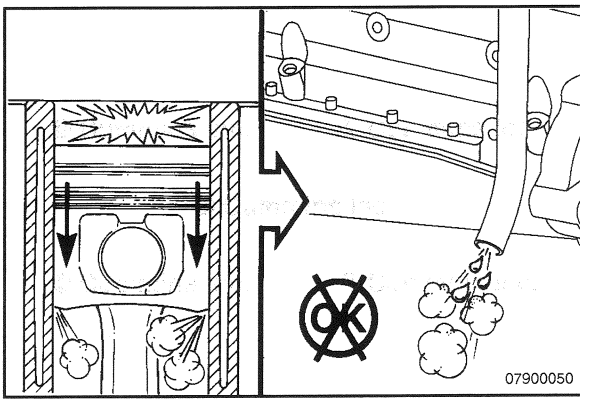
Worn or damaged seals in the turbocharger can also allow oil to leak into the charge-air cooler system and be burned in the engine.

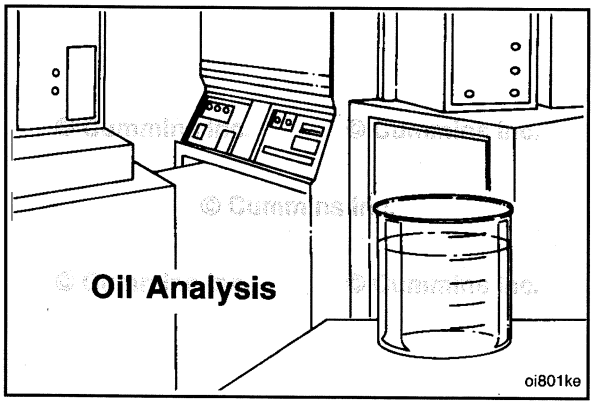
The condition can be verified by removing the air crossover tube or charge-air cooler tubing and looking for oil. Refer to Procedure 010-019 in Section 10. Refer to Procedure 010-027 in Section 10.

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.



Inadequate sealing of the piston rings will result in excessive oil out of the crankcase breather system and/or being consumed by the engine.



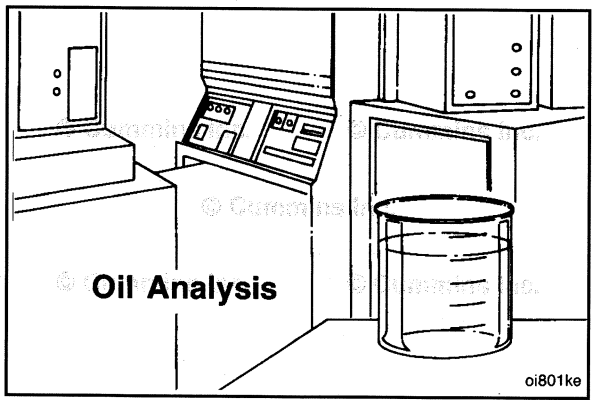


Lubricating Oil and Filter Analysis (007-083)

Inspect

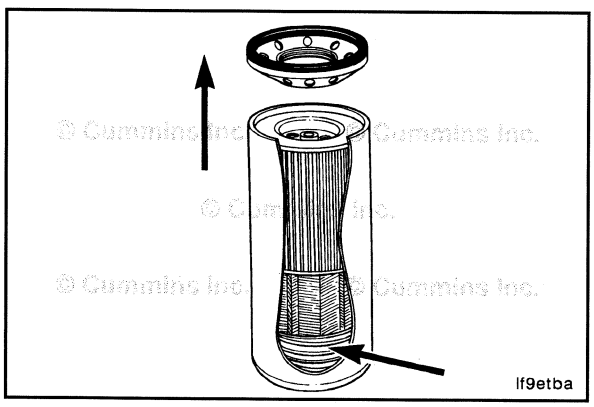
An analysis of used oil can help diagnose internal engine damage and determine if it was caused by one of the following:

- Intake air filter malfunction
- Coolant leaks
- Oil diluted with fuel
- Metal particles causing wear.

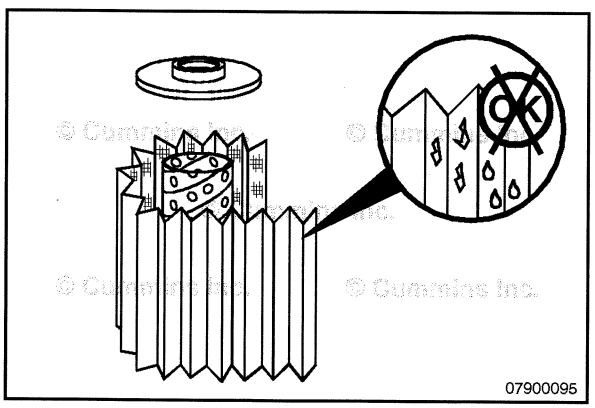


For additional oil analysis information, refer to Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340.

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.

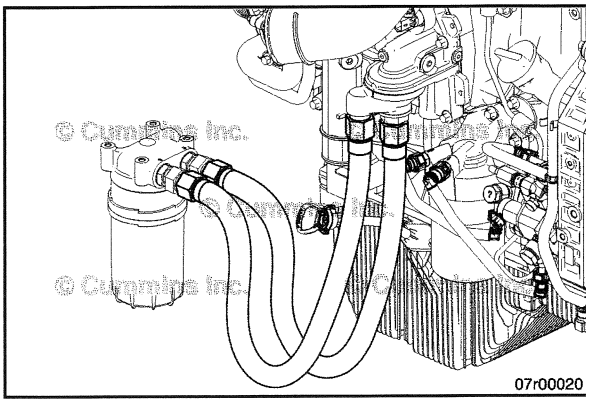
Inspect the filter element for evidence of moisture or metal particles.

Metal	Possible Source
Copper	Bearings and bushings
Chromium	Piston rings
Iron	Cylinder liners
Lead	Bearing overlay material
Aluminum	Piston wear or scuffing

Lubricating Oil Lines (007-092)

General Information

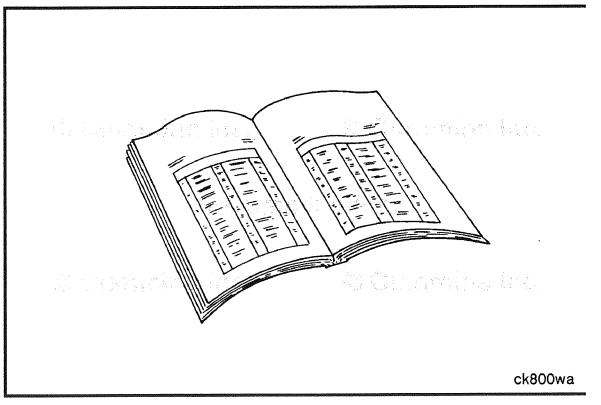
The following procedure is for engines with a remote-mounted oil filter option. The mounting location of the oil filter will vary by application. See equipment manufacturer service information for the location of the remote oil filter.



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. See equipment manufacturer service information.



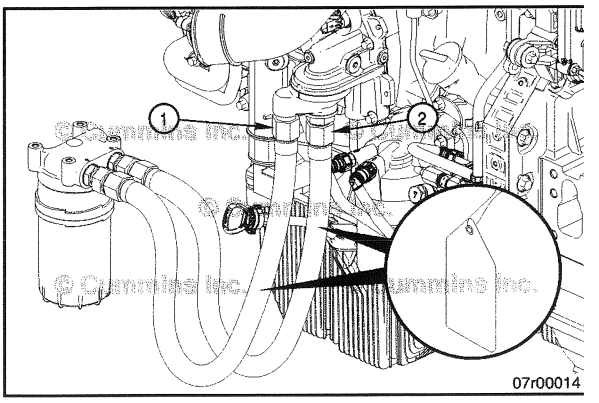
Remove

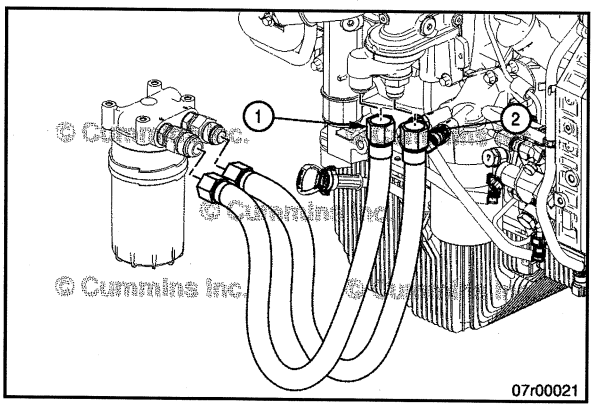
⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠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.

⚠CAUTION⚠
Use caution when draining oil that oil is not spilled or drained into the bilge area. The oil must be disposed in accordance with local environmental regulations.

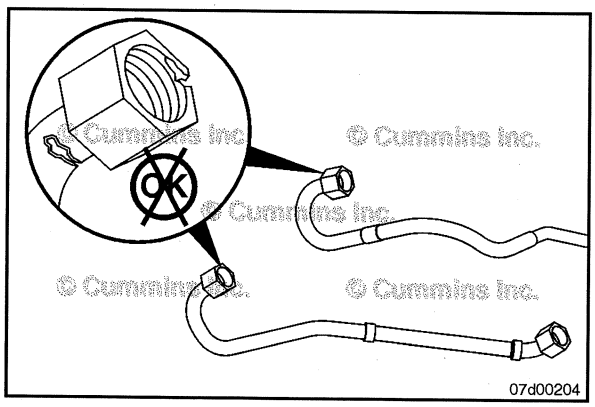
Verify and mark the hoses and adapter head for correct location. The outer hose (1) is the outlet to the filter and the inner hose (2) is the inlet to the filter head.





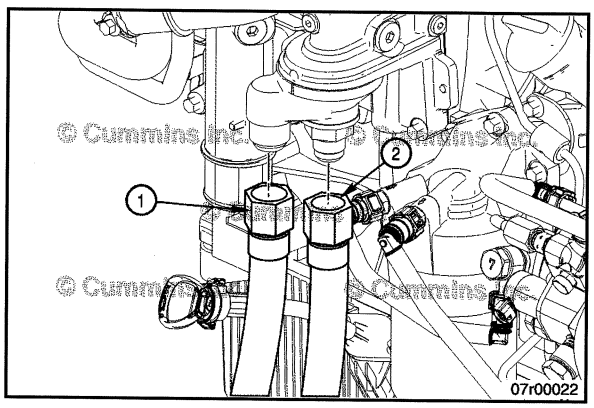
Disconnect the lubricating oil lines from the lubricating oil filter head adapter.

Disconnect the oil lines from the remote-mounted lubricating oil filter head.



Inspect for Reuse

Inspect the hoses and o-ring sealing surfaces for damage.



Install

⚠CAUTION⚠
When installing the lubricating oil lines, make sure the oil lines are not touching or rubbing each other or any other engine parts. Damage to the lines can result in a loss of engine lubricating oil pressure.

Install the hoses to the lubricating oil filter head adapter and finger tighten.

- Adapter outlet (1)
- Adapter inlet (2)

If labels were not applied, the remote-mounted filter head adapter is marked for the inlet (2) and the outlet (1).

Tighten the lubricating oil lines on the remote-mounted filter head adapter.

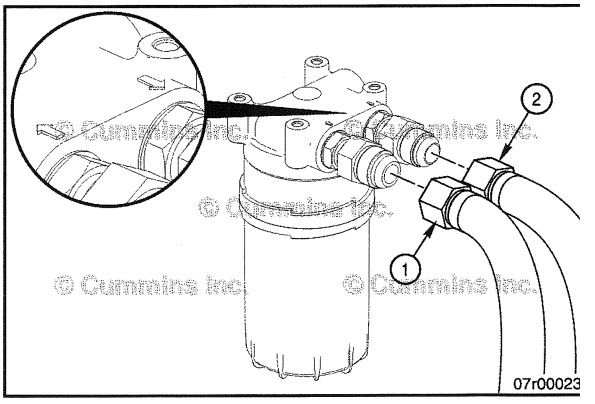
Torque Value: 76 N•m [56 ft-lb]

Use the labels applied in the remove step to align the lubricating oil lines. Install the lubricating oil filter lines to the remote mounted filter head and tighten finger tight.

If labels were **not** applied, the remote-mounted filter head is marked for the remote filter head inlet (2) and the remote filter head outlet (1).

Tighten the lubricating oil lines on the remote-mounted filter head.

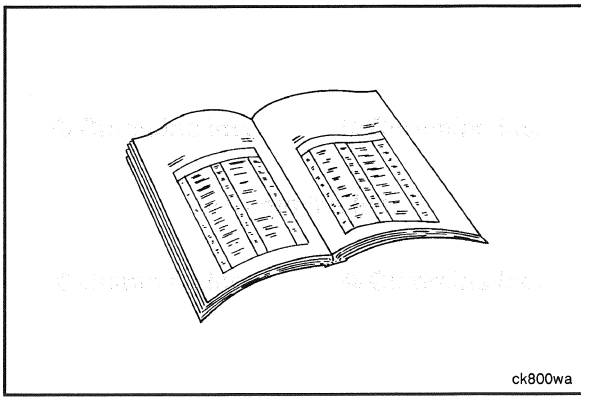
Torque Value: 76 N•m [56 ft-lb]



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 batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.



Notes

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