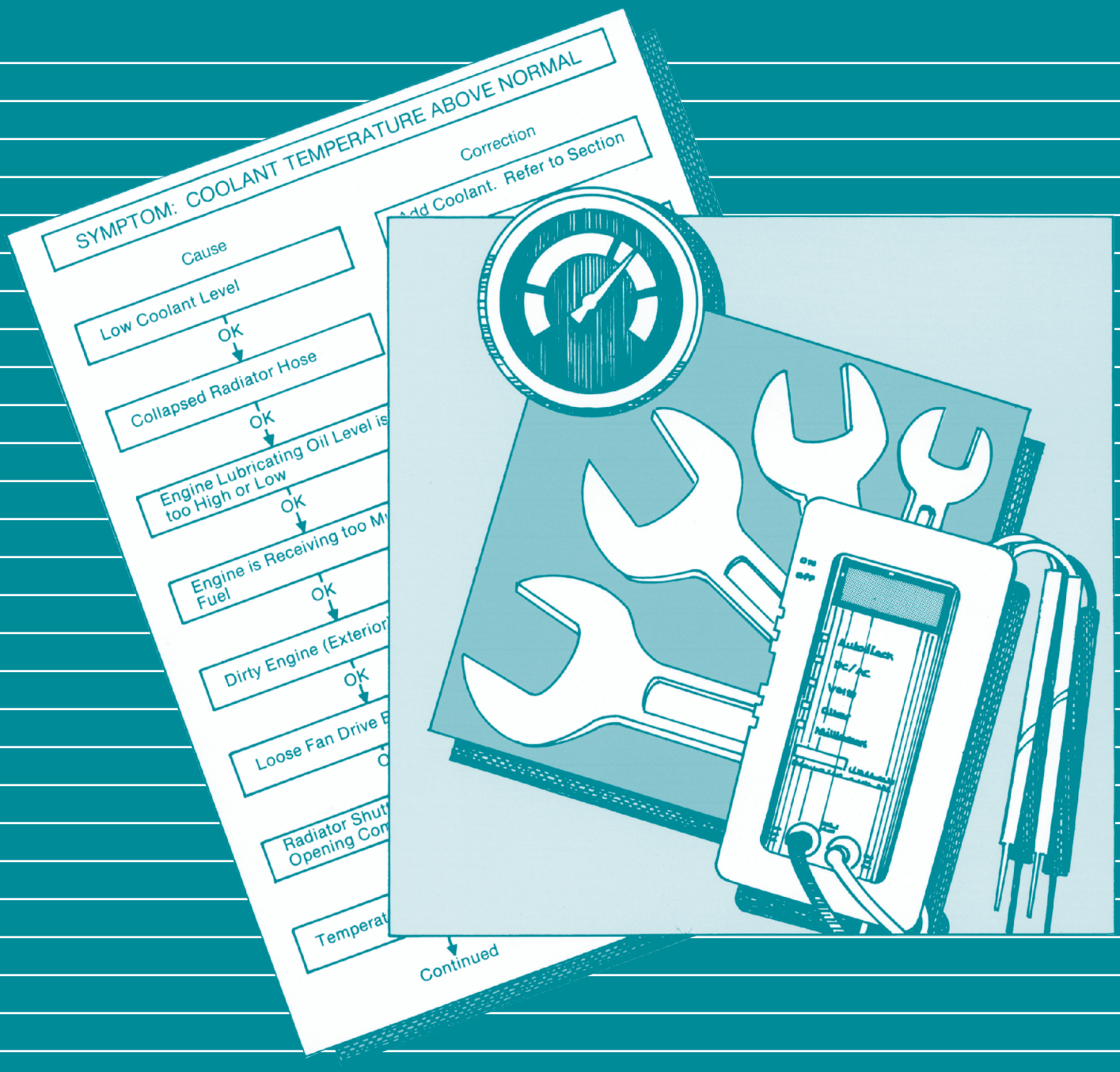
Troubleshooting and Repair Manual ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Volume 1



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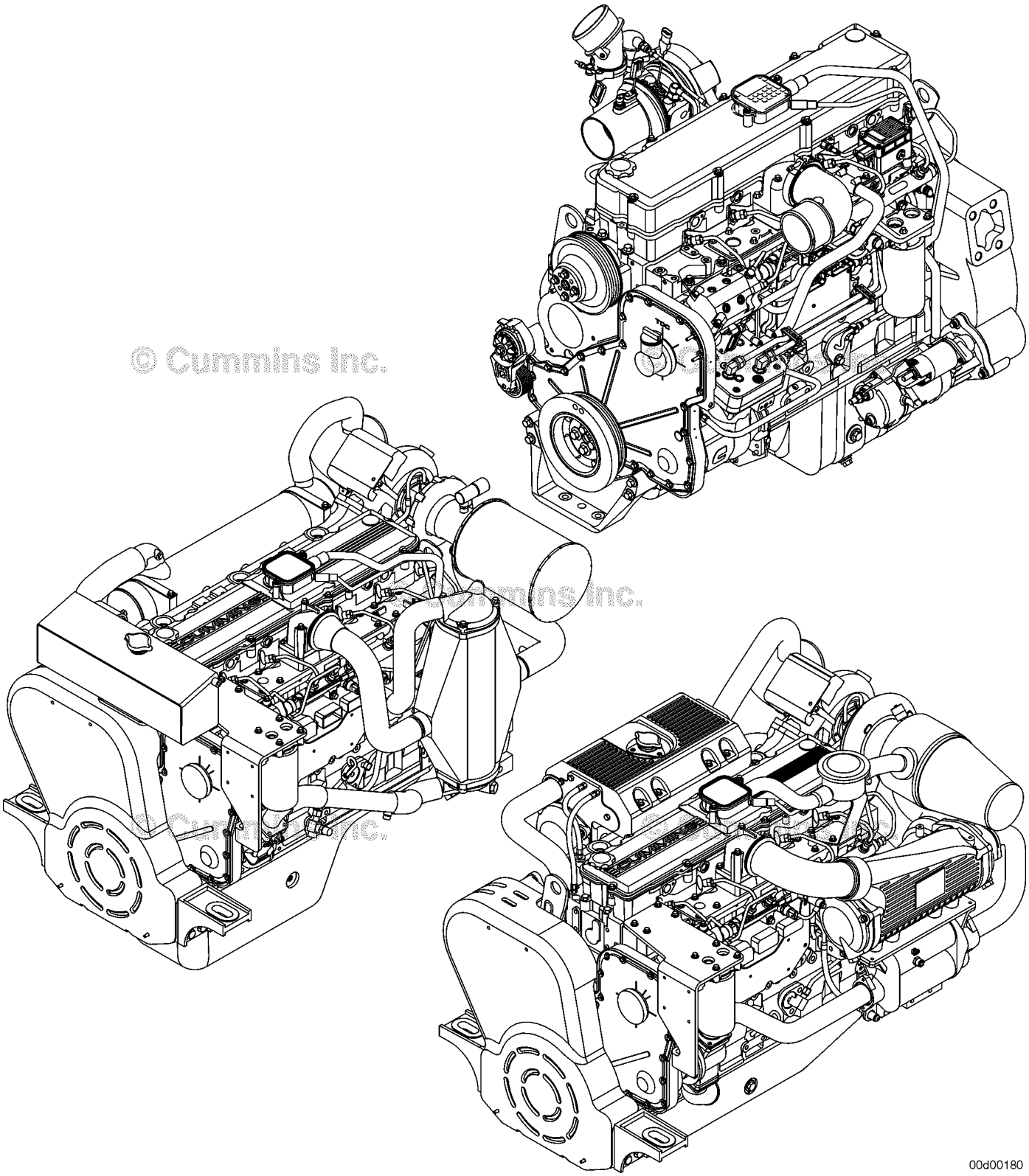

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Foreword

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

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

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

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

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

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

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

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

Table of Contents

Section i - Introduction

Section Contents

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About the Manual

General Information

This Troubleshooting and Repair Manual is intended to aid in determining the cause of engine related problems and to provide recommended repair procedures.

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.

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 organized to provide an easy flow from problem identification to problem correction.

A list of troubleshooting symptoms containing the most common problems is in the Troubleshooting Symptoms, Section (TS). The manual is designed to use the Troubleshooting Symptoms as a guide to locating the problem and directing the end user to the correct procedure for making the repair. Complete the following steps to locate and correct the problem.

1 Locate the symptom on the Section Contents pages of Section TS.
   - Reference to the page number where the Troubleshooting Symptom Tree is found is made to the right of the symptom tree title.

2 The left column of boxes in the Troubleshooting Symptom Charts indicates a probable cause of the problem, starting at the top with the simplest and easiest to repair, and continuing downward to the most difficult.
   - The right column of boxes provides a brief description of the corrective action with a reference number to the correct procedure used to make the repair.

3 Locate the probable cause in the left column then turn to the procedure referenced in the right column.

4 The Troubleshooting Symptom Charts are based on the following assumptions:
   - The components have been installed according to the manufacturer's specifications.
   - The easiest repairs are done first.
   - All generic solutions are designed for the most common applications and Original Equipment Manufacturer (OEM).

Refer to the Original Equipment Manufacturer's service manual for their specifications.

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**.

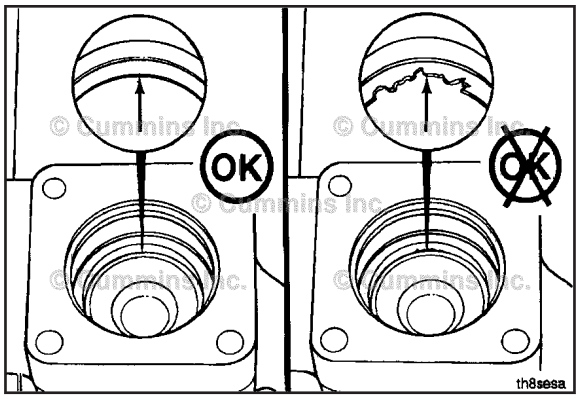
Refer to another location in this manual or another publication for additional information.

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.

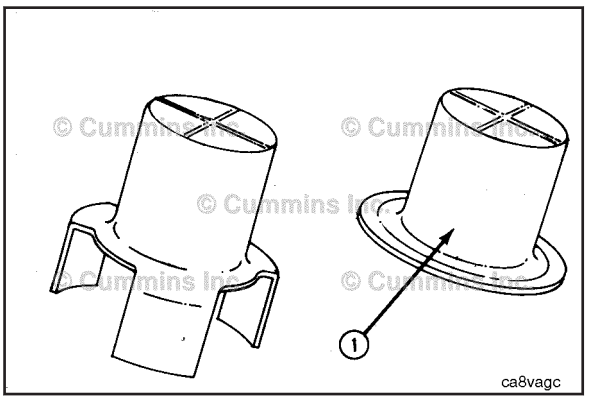
Illustrations

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 or Cummins ReCon® components. All of the repair services described in this manual are available from all Cummins Distributors and most Dealer locations.
- Follow the specified disassembly and assembly procedures to reduce the possibility of damage to the components

Welding on a Vehicle with an Electronic Controlled Fuel System

⚠CAUTION⚠

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

General Cleaning Instructions

Definition of Clean

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

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

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

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

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

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

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

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

Abrasive Pads and Abrasive Paper

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

⚠ 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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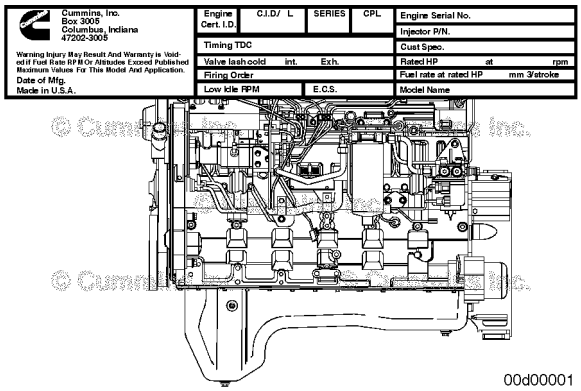
Engine Identification

Engine Dataplate

All Applications Except Marine



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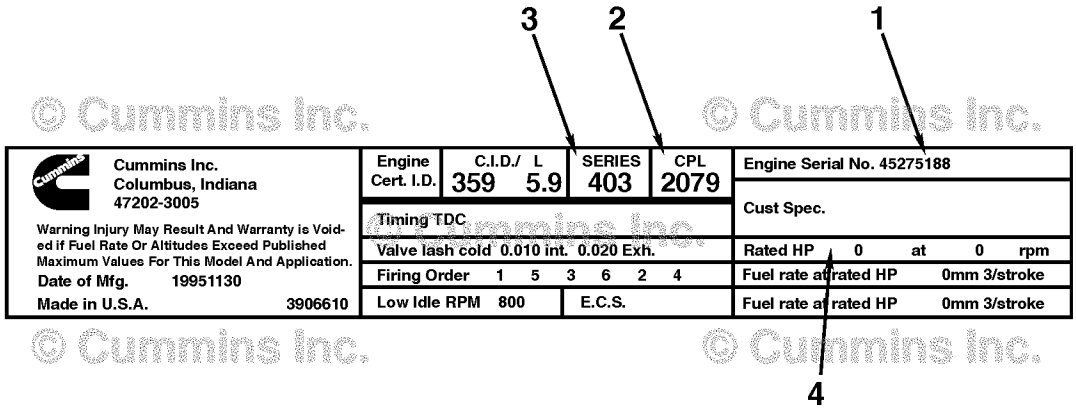
The engine dataplate provides important information about the engine. The engine serial number (ESN) and control part list (CPL) provide information for service and for ordering parts. The engine dataplate **must not** be changed unless approved by Cummins Inc.



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Have the following engine data available when communicating with a Cummins® Authorized Repair Location:

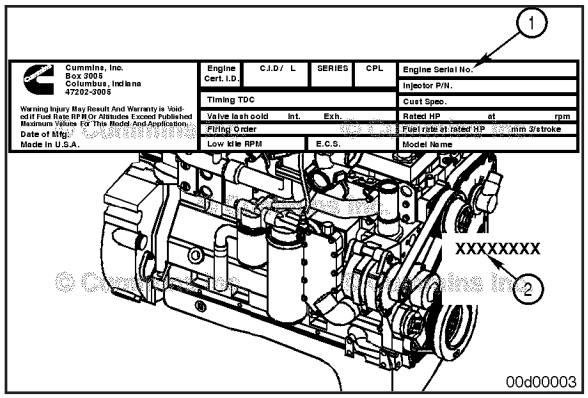
1 Engine serial number (ESN)

2 Control parts list (CPL)

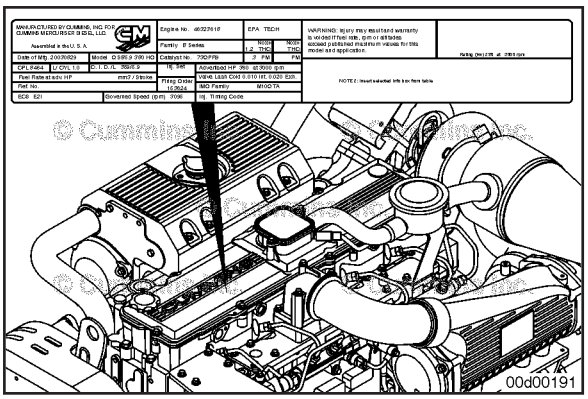
3 Model

4 Horsepower and rpm rating.

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



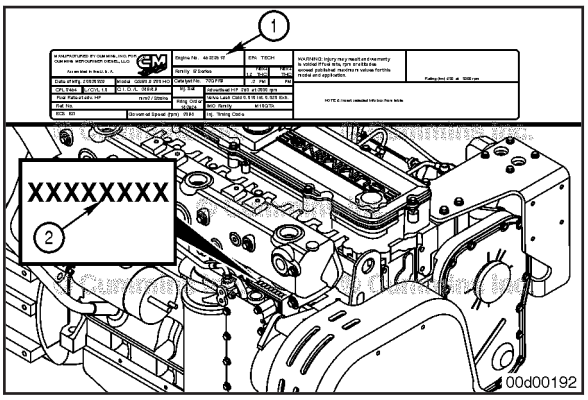
If the engine dataplate (1) is **not** legible, the engine serial number (ESN) (2) can be found on the engine block, on top of the lubricating oil cooler housing. Additional engine information is on the ECM dataplate.



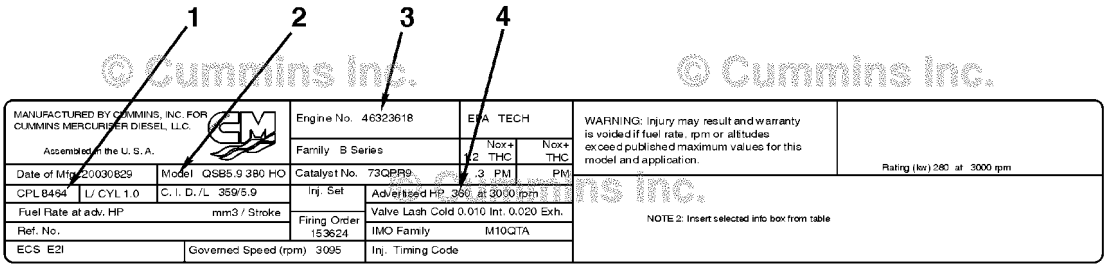
Marine Applications

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

The dataplate for marine engines is located on the top front of the valve cover for both the QSC and QSL engines.



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



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Have the following engine data available when communicating with a Cummins® Authorized Repair Location:

1 Control parts list (CPL)

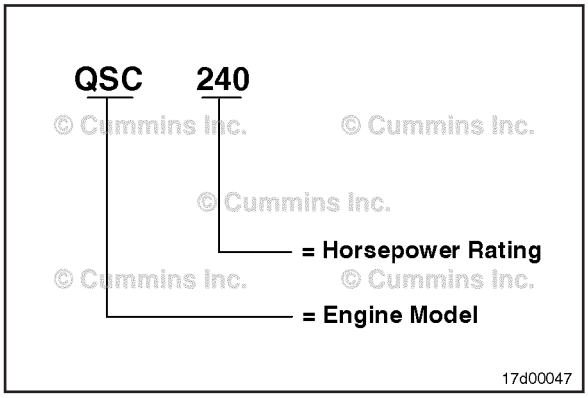
2 Model

3 Engine serial number (ESN)

4 Horsepower and rpm rating.

Cummins® Engine Nomenclature

The Cummins® engine nomenclature provides the engine model and horsepower rating.



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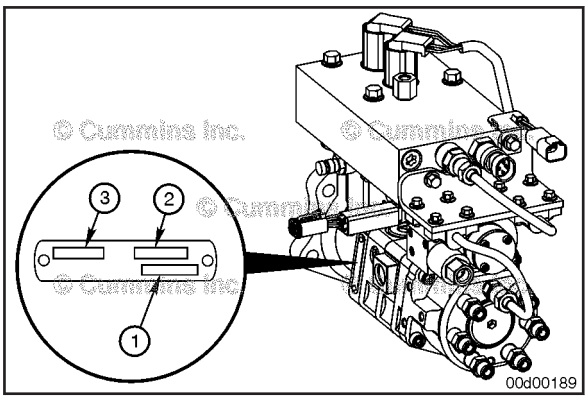
Fuel Injection Pump Dataplate

The Cummins® Accumulator Pump System (CAPS) fuel injection pump dataplate is located on the side of the injection pump. The dataplate contains the following information:

1 Cummins® part number

2 Pump serial number

3 Factory code.



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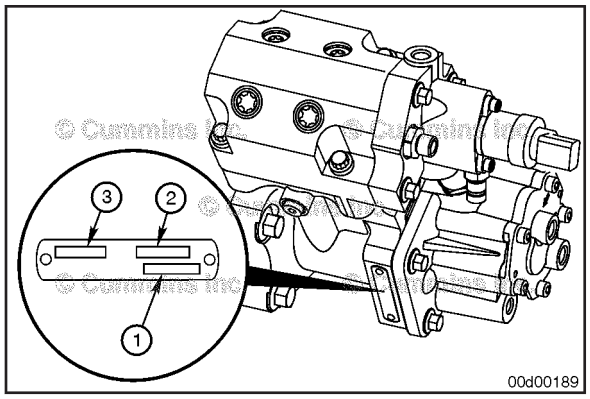
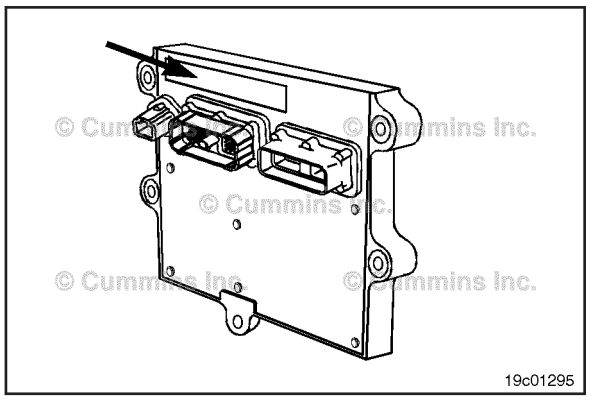


The Cummins® Common Rail Fuel System dataplate is located on the side of the high-pressure pump. The dataplate contains the following information:

1 Cummins® part number

2 Pump serial number

3 Factory code.



ECM Dataplate

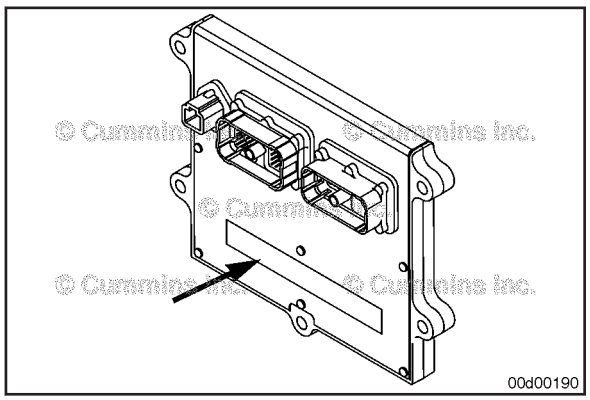
All Applications Except Marine

The ECM dataplate is located on the front of the ECM.

The following information is found on the ECM dataplate:

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

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



Marine Applications

The ECM dataplate is located on the front of the ECM.

The following information is found on the ECM dataplate:

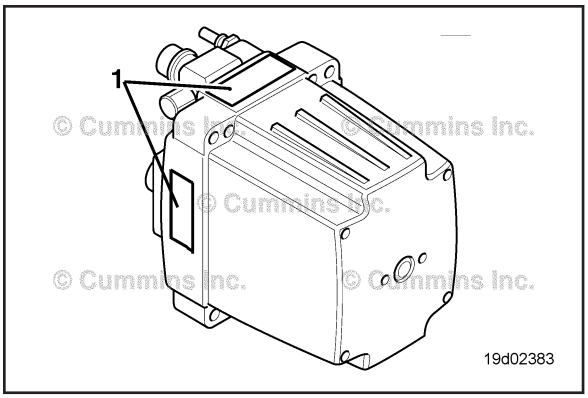
- ECM part number (PN)
- ECM serial number (SN)
- ECM date code (DC)
- Engine serial number (ESN)
- ECM Code (identifies the software in the ECM).

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

Dosing Control Unit Dataplate

ISLe4 engines are fitted with a dosing control unit which is part of the aftertreatment system. The dosing control unit dataplate is located on the front edge of the dosing control unit, as shown (1). The dataplate contains the following information:

- Type
- Ref.
- S/N.
- Cummins® part number.



Engine Diagrams

Engine Views

All Applications Except Marine

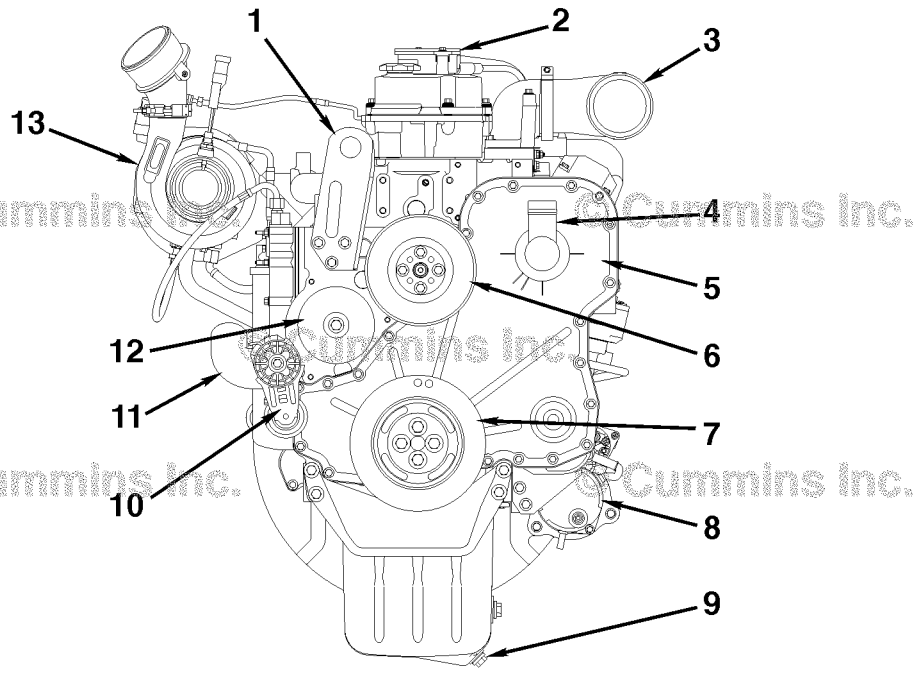
The following illustrations provide the locations of the major external engine components, filters, and other service and maintenance points. Some external components will be different locations for different engine models.

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

Engine Diagrams

Engine Views

All Applications Except Marine



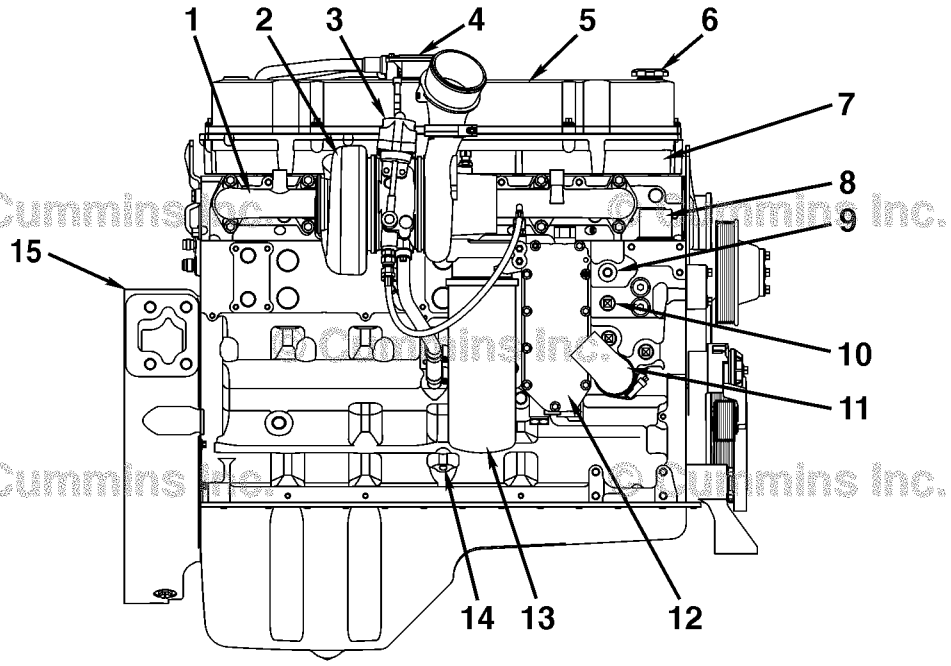
Front Engine View (Cummins® Common Rail Fuel System)

1 Engine lifting bracket
2 Crankcase breather
3 Air intake connection
4 Engine oil fill
5 Front gear cover
6 Fan pulley
7 Vibration Damper
8 Starter
9 Engine oil pan drain plug
10 Automatic belt tensioner
11 Coolant inlet connection
12 Water pump
13 Turbocharger (variable geometry turbocharger shown).

Engine Diagrams

Engine Views

All Applications Except Marine



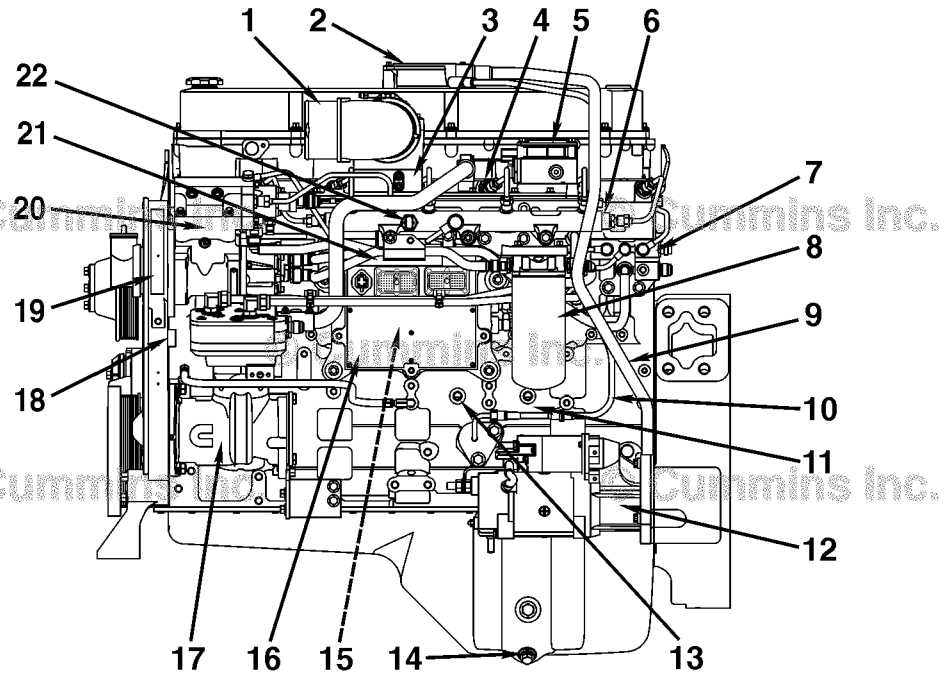
Exhaust Side Engine View (Cummins® Common Rail Fuel System)

1 Exhaust manifold
2 Turbocharger (variable geometry turbocharger shown)
3 Variable geometry turbocharger actuator (variable geometry turbocharger **only**)
4 Crankcase breather
5 Rocker lever cover
6 Engine oil fill
7 Rocker lever housing
8 Coolant outlet connection
9 Coolant heater port
10 Coolant inlet connection
11 Lubricating oil cooler
12 Lubricating oil filter
13 Dipstick location
14 Flywheel housing.

Engine Diagrams

Engine Views

All Applications Except Marine



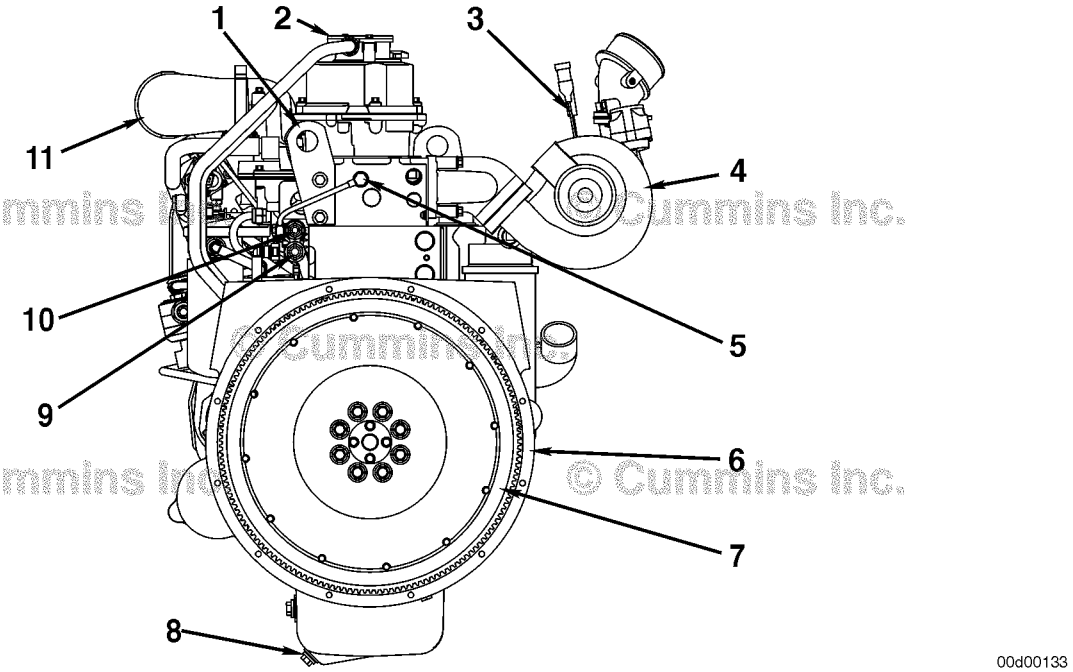
Intake Side Engine View (Cummins® Common Rail Fuel System)

1 Air intake connection
2 Crankcase breather
3 Intake air heater
4 Intake manifold pressure and temperature sensor
5 Turbocharger control valve
6 Fuel rail
7 Fuel drain manifold
8 Fuel filter
9 Crankcase breather draft tube
10 Crankcase breather oil drain tube
11 Crankshaft speed sensor
12 Starter
13 Lubricating oil pressure sensor
14 Engine oil drain plug
15 Fuel lift pump (behind ECM)
16 Electronic control module (ECM)
17 Air compressor
18 Camshaft speed sensor
19 Engine data plate
20 High-pressure fuel pump
21 Ambient air pressure sensor
22 Fuel rail pressure sensor.

Engine Diagrams

Engine Views

All Applications Except Marine



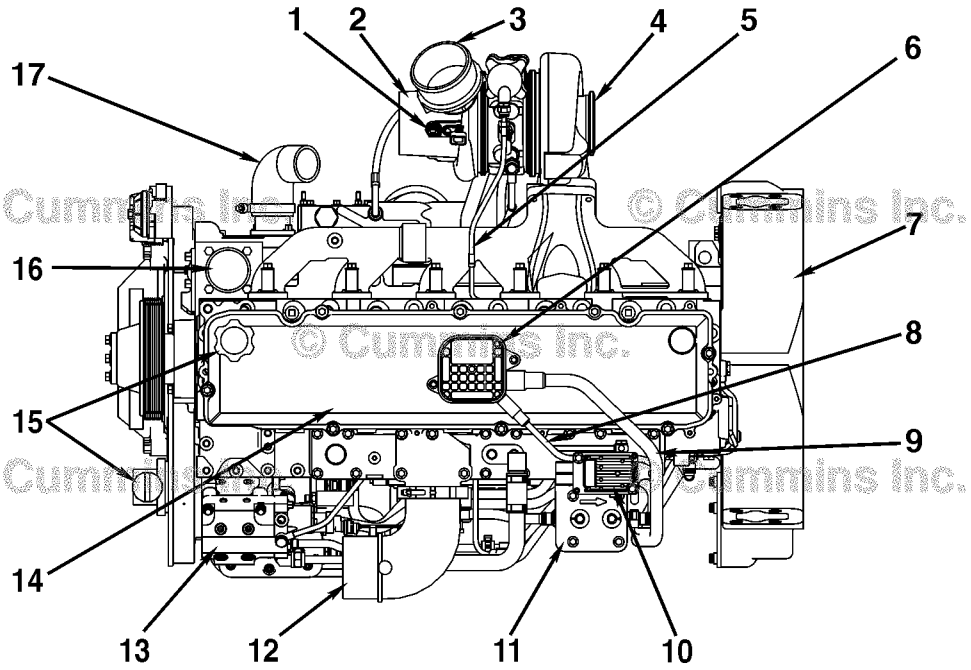
Rear Engine View (Cummins® Common Rail Fuel System)

1 Engine lifting bracket
2 Crankcase breather
3 Turbocharger (VGT shown)
4 Injector drain line connection
5 Flywheel housing
6 Flywheel
7 Engine oil drain plug
8 OEM fuel supply line connection
9 OEM fuel drain line connection
10 Air intake connection.

Engine Diagrams

Engine Views

All Applications Except Marine



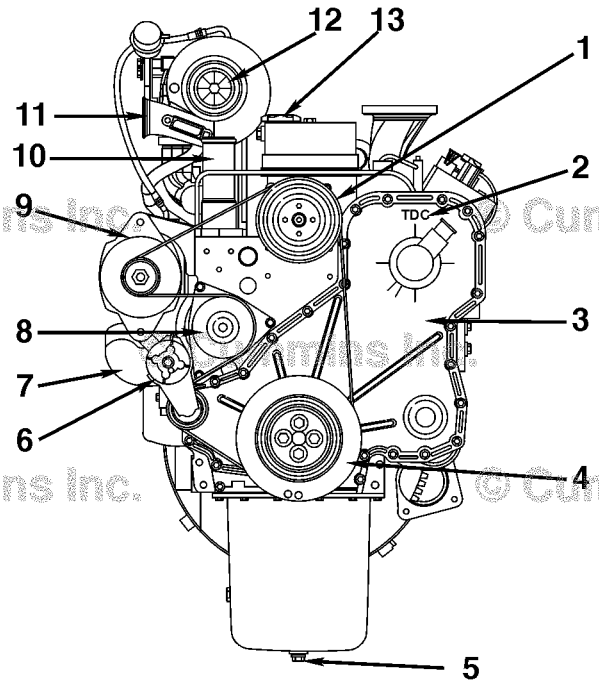
Top Engine View (Cummins® Common Rail Fuel System)

1 Coolant inlet connection
2 Turbocharger air inlet
3 Turbocharger air outlet
4 Turbocharger exhaust outlet
5 Turbocharger actuator air line (variable geometry turbocharger **only**)
6 Crankcase breather
7 Flywheel housing
8 Crankcase breather oil drain tube
9 Crankcase breather draft tube
10 Turbocharger control valve (variable geometry turbocharger **only**)
11 Fuel filter bracket
12 Air inlet connection
13 High-pressure pump
14 Engine oil fill
15 Coolant outlet connection.

Engine Diagrams

Engine Views

All Applications Except Marine



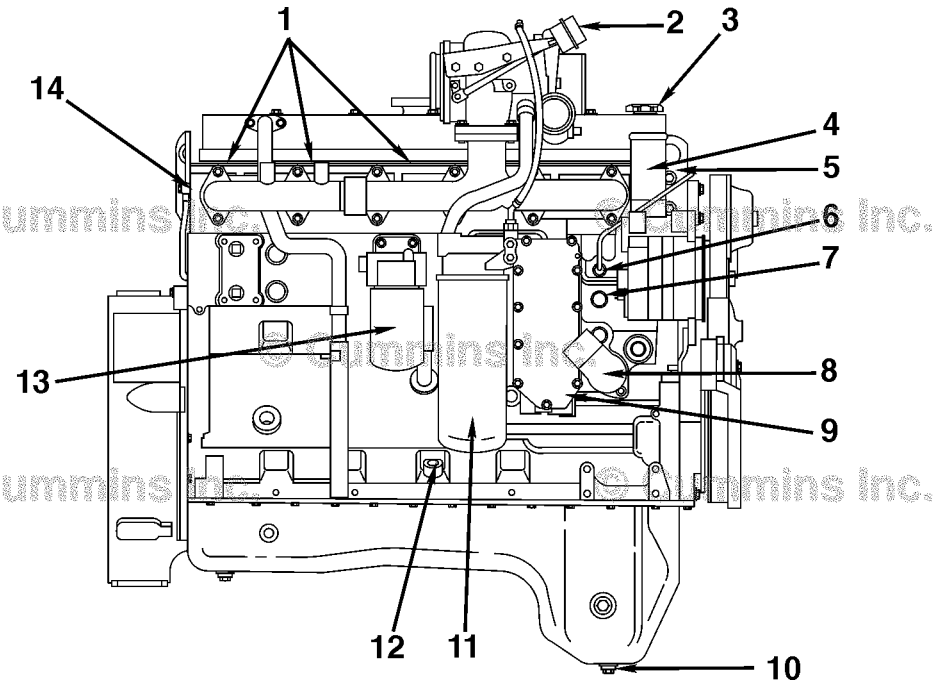
Front View (CAPS Fuel System)

1 Fan pulley
2 Top dead center (TDC) mark
3 Front gear cover
4 Vibration damper
5 Engine oil pan drain plug
6 Automatic belt tensioner
7 Water inlet
8 Water pump
9 Alternator
10 Water outlet
11 Turbocharger air outlet
12 Turbocharger air inlet
13 Engine oil fill.

Engine Diagrams

Engine Views

All Applications Except Marine



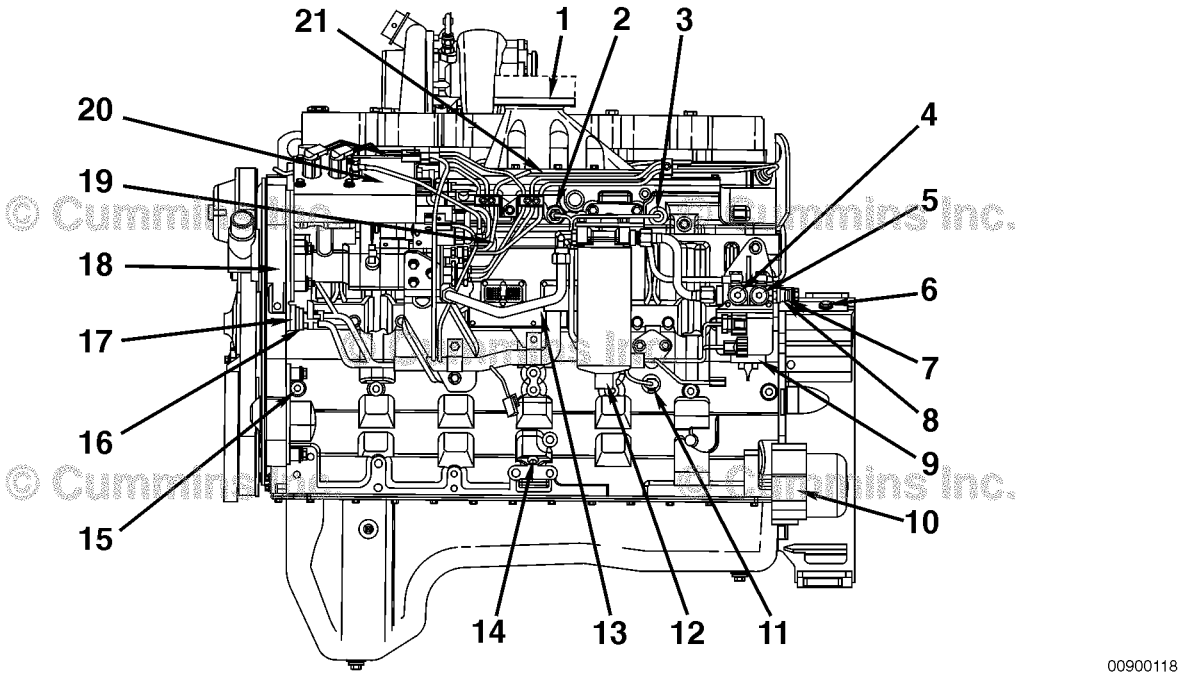
Exhaust Side View (CAPS Fuel System)

1 1/2-inch (NPTF) coolant taps
2 Turbocharger wastegate actuator
3 Engine oil fill
4 Coolant outlet
5 Front engine lifting bracket
6 Coolant temperature sensor
7 Coolant heater port
8 Coolant inlet
9 Lubricating oil cooler
10 Engine oil pan drain plug
11 Lubricating oil filter
12 Dipstick location
13 Coolant filter
14 Injector drain fuel outlet connection.

Engine Diagrams

Engine Views

All Applications Except Marine



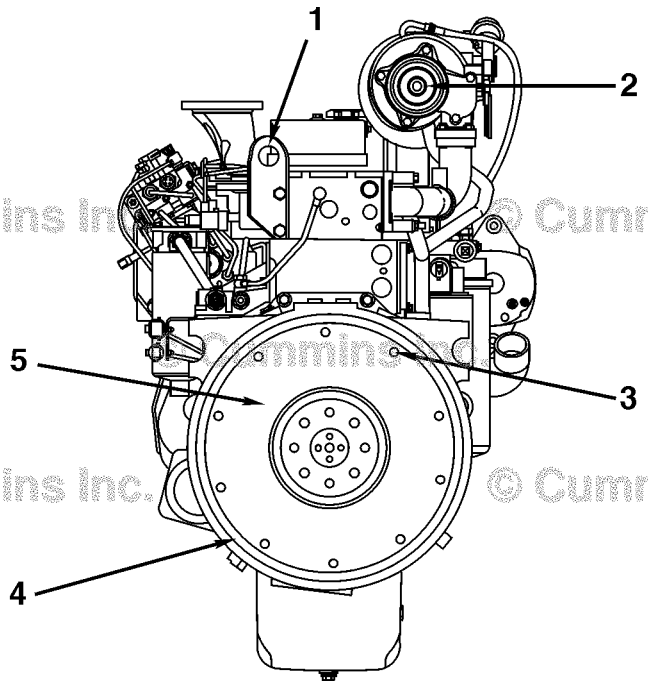
Fuel Pump Side View (CAPS Fuel System)

1 Engine air inlet
2 Intake manifold pressure sensor
3 Intake manifold temperature sensor
4 M10 (STOR) fuel pressure after-lift pump
5 M10 (STOR) fuel pressure before-lift pump
6 Magnetic pickup location 3/4-16 UNF
7 Fuel return connection
8 Fuel inlet connection
9 Fuel lift pump
10 Starter mounting flange
11 Oil pressure sensor
12 Fuel filter/water separator
13 Electronic control module (ECM)
14 Dipstick location
15 M10 (STOR) oil pressure port
16 Engine position sensor (EPS) - (inboard)
17 Engine speed sensor (ESS) - (outboard)
18 Engine dataplate
19 High-pressure fuel lines
20 Cummins® Accumulator Pump System (CAPS) injection pump
21 Intake air heater.

Engine Diagrams

Engine Views

All Applications Except Marine



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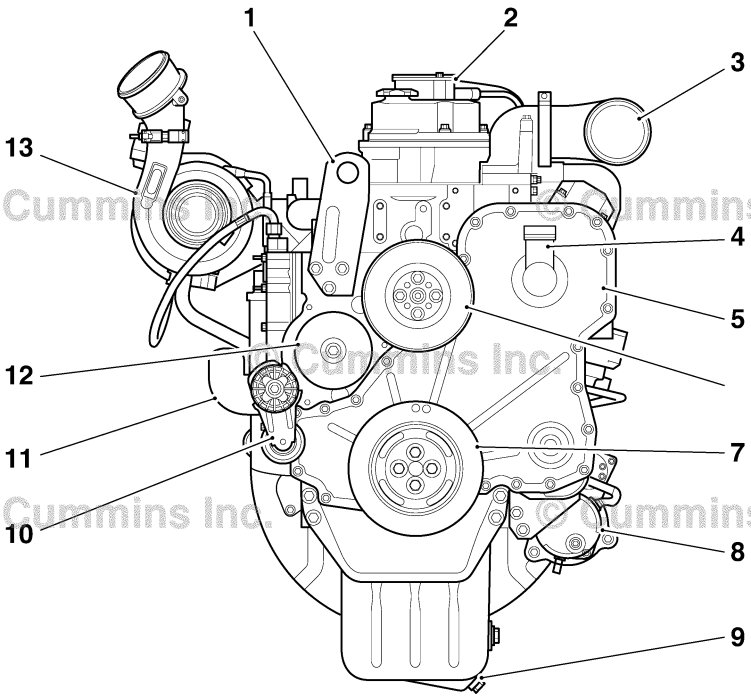
Rear View (CAPS Fuel System)

1 Rear engine lifting bracket
2 Turbocharger exhaust outlet
3 Clutch mounting holes
4 Flywheel housing
5 Flywheel.

Engine Diagrams

Engine Views

All Applications Except Marine



00d00230

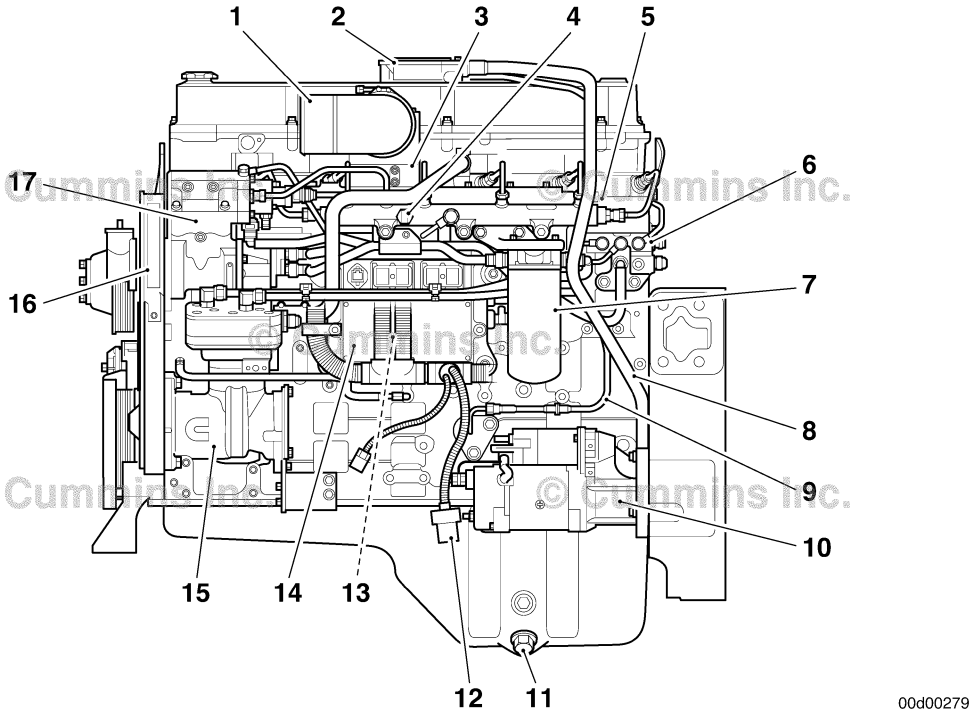
Front - ISLe3 and ISLe4 - (CM850 Electronic Control Module)

1 Engine lifting bracket
2 Crankcase breather
3 Air intake connection
4 Engine oil fill
5 Front gear cover
6 Fan pulley
7 Vibration Damper
8 Starter
9 Engine oil pan drain plug
10 Automatic belt tensioner
11 Coolant inlet connection
12 Water pump
13 Turbocharger.

Engine Diagrams

Engine Views

All Applications Except Marine



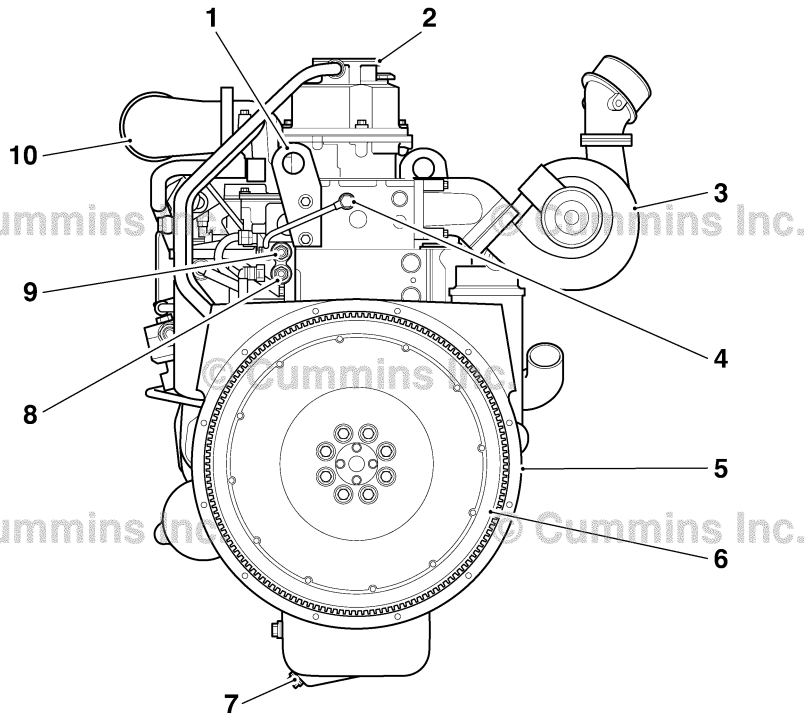
Left - ISLe3 and ISLe4 - (CM850 Electronic Control Module)

1 Air intake connection
2 Crankcase breather
3 Intake air heater
4 Fuel rail pressure sensor
5 Fuel rail
6 Fuel drain manifold
7 Fuel filter
8 Crankcase breather draft tube
9 Crankcase breather oil drain tube
10 Starter
11 Engine oil drain plug
12 Aftertreatment interface connection (ISLe4)
13 Fuel lift pump
14 Electronic control module (ECM)
15 Air compressor
16 Engine data plate
17 High-pressure pump.

Engine Diagrams

Engine Views

All Applications Except Marine



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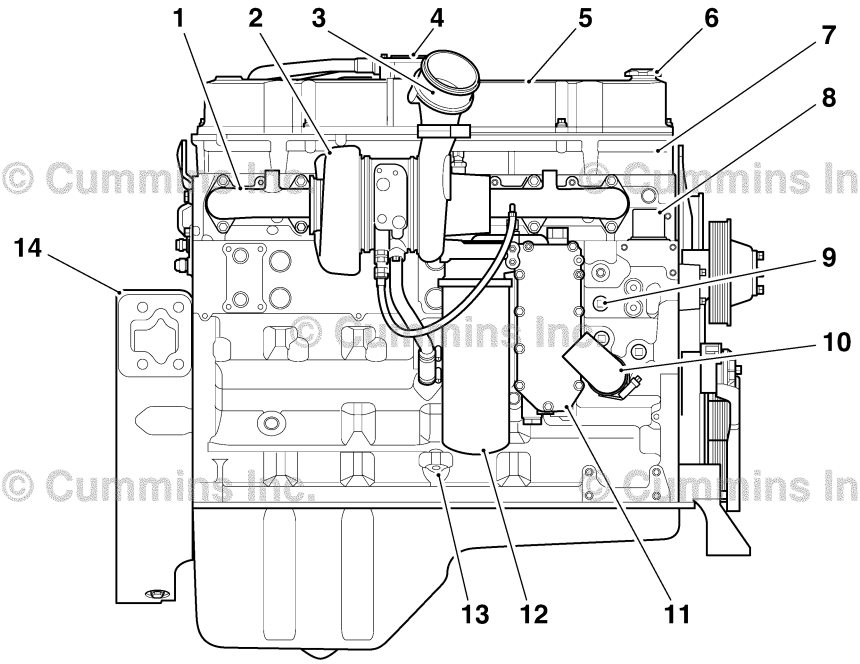
Rear - ISLe3 and ISLe4 - (CM850 Electronic Control Module)

1 Engine lifting bracket
2 Crankcase breather
3 Turbocharger
4 Injector drain line connection
5 Flywheel housing
6 Flywheel
7 Engine oil drain plug
8 OEM fuel supply line connection
9 OEM fuel drain line connection
10 Air intake connection.

Engine Diagrams

Engine Views

All Applications Except Marine



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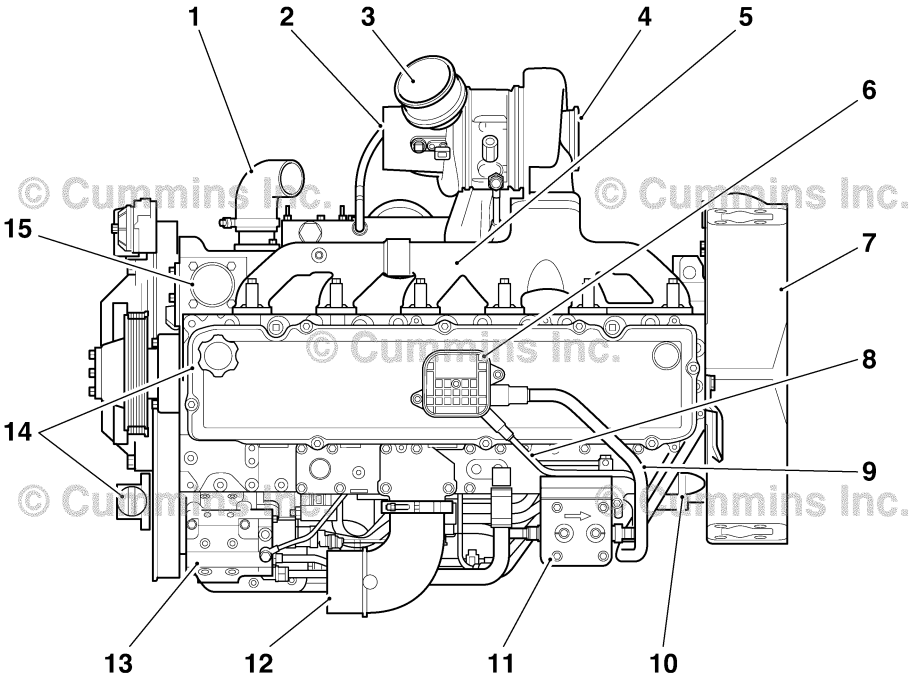
Right - ISLe3 and ISLe4 - (CM850 Electronic Control Module)

1 Exhaust manifold
2 Turbocharger
3 Turbocharger air inlet
4 Crankcase breather
5 Rocker lever cover
6 Engine oil fill
7 Rocker lever housing
8 Coolant outlet connection
9 Coolant heater port
10 Coolant inlet connection
11 Lubricating oil cooler
12 Lubricating oil filter
13 Dipstick location
14 Flywheel housing.

Engine Diagrams

Engine Views

All Applications Except Marine



Top - ISLe3 and ISLe4 - (CM850 Electronic Control Module)

1 Coolant inlet connection
2 Turbocharger air inlet
3 Turbocharger air outlet
4 Turbocharger exhaust outlet
5 Exhaust manifold
6 Crankcase breather
7 Flywheel housing
8 Crankcase breather oil drain tube
9 Crankcase breather draft tube
10 Starter motor location
11 Fuel filter bracket
12 Air inlet connection
13 High-pressure pump
14 Engine oil fill
15 Coolant outlet connection.

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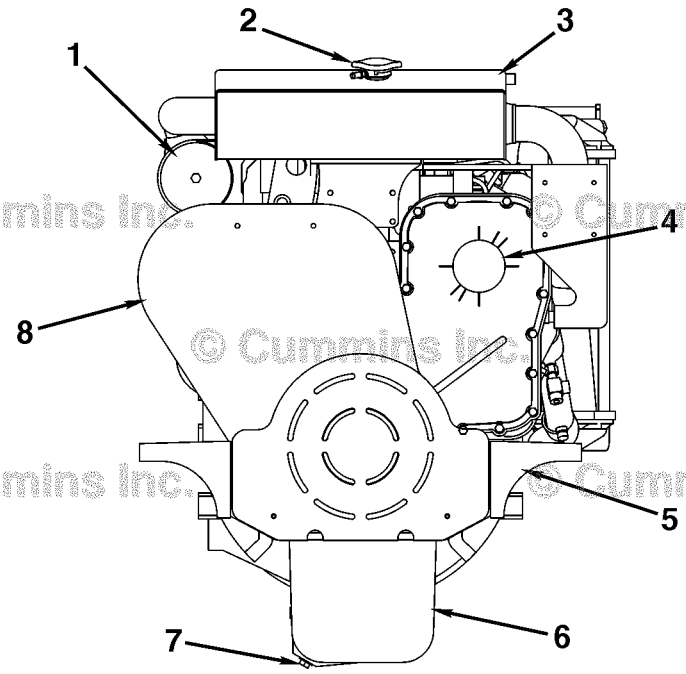
Marine Applications



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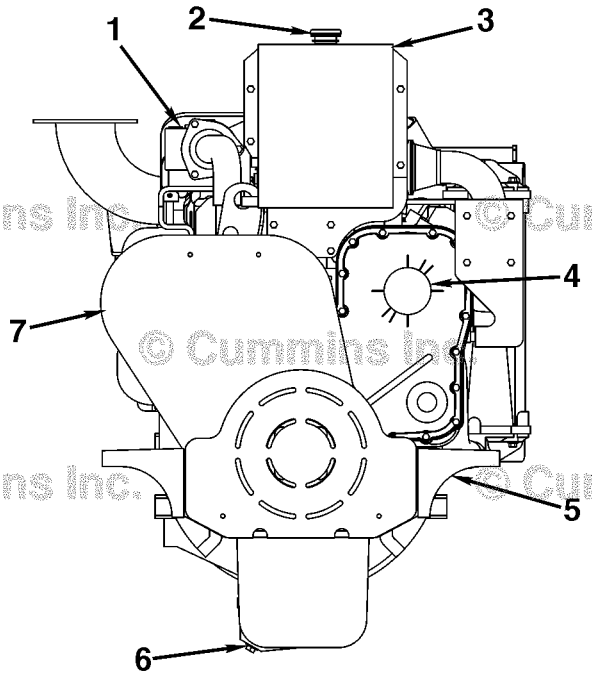
Front View QSL9 Marine (Sea water cooled)

1 Heat exchanger
2 Coolant fill cap
3 Expansion tank
4 Timing case cover
5 Engine mounting bracket
6 Oil pan
7 Oil pan drain plug
8 Belt and pulley guard.

Marine Applications



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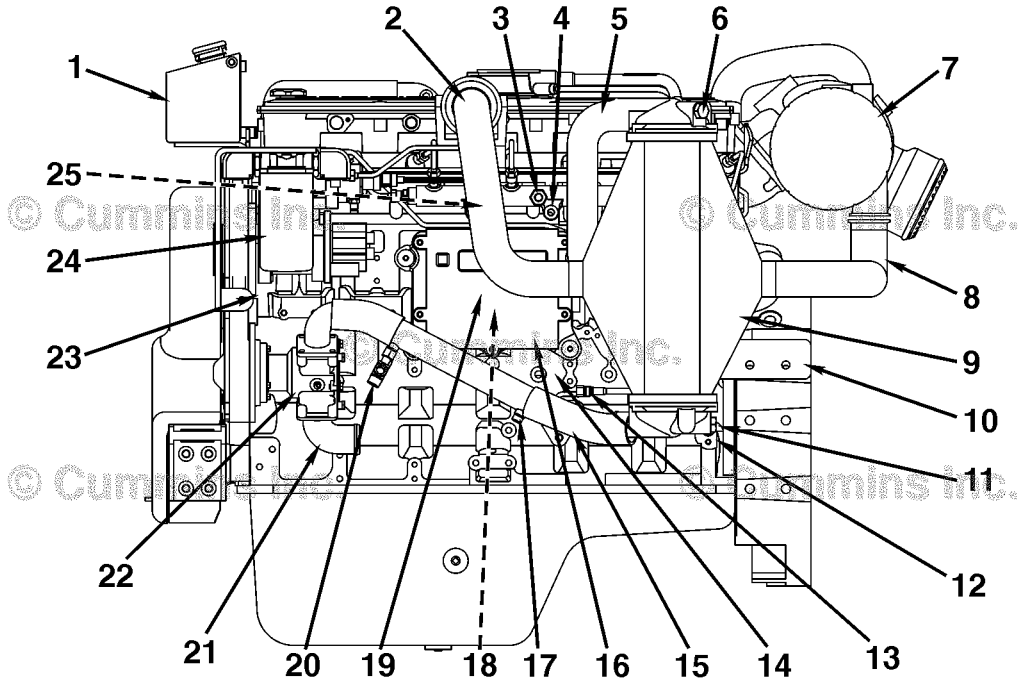
Front View QSL9 Marine (Keel Cooled)

1 Keel cooler thermostat housing
2 Coolant fill cap
3 Expansion tank
4 Timing case cover
5 Engine mounting bracket
6 Oil pan drain plug
7 Belt and pulley guard.

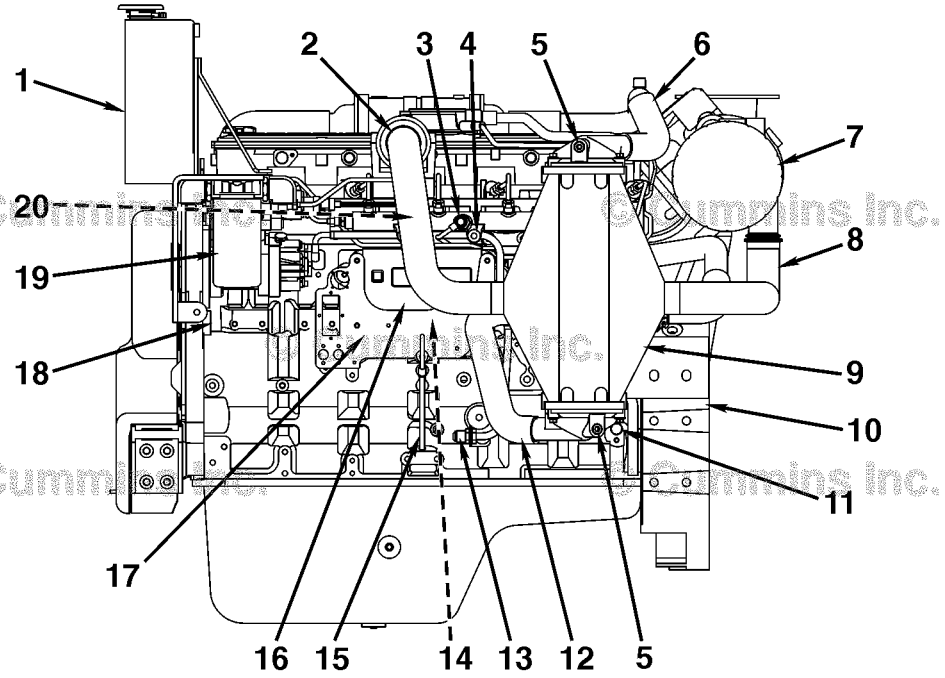
Marine Applications



Left View (Port) QSL9 Marine (Sea Water Cooled)

1 Expansion tank
2 Aftercooler air outlet
3 Intake manifold temperature sensor
4 Intake manifold pressure sensor
5 Aftercooler sea water outlet
6 Zinc anode
7 Air cleaner or filter
8 Aftercooler air inlet
9 Aftercooler housing
10 Flywheel housing
11 Zinc anode
12 Crankshaft speed sensor
13 Fuel inlet from fuel tank
14 Oil pressure sensor
15 Aftercooler sea water inlet
16 Electronic control module (ECM)
17 Fuel return from engine to fuel cooler
18 Fuel lift pump (behind ECM)
19 SIM module (mounted on ECM bracket)
20 Fuel return to fuel tank
21 Sea water pump inlet
22 Sea water pump
23 Camshaft position sensor
24 Fuel filter
25 Fuel rail pressure sensor (behind aftercooler air outlet).

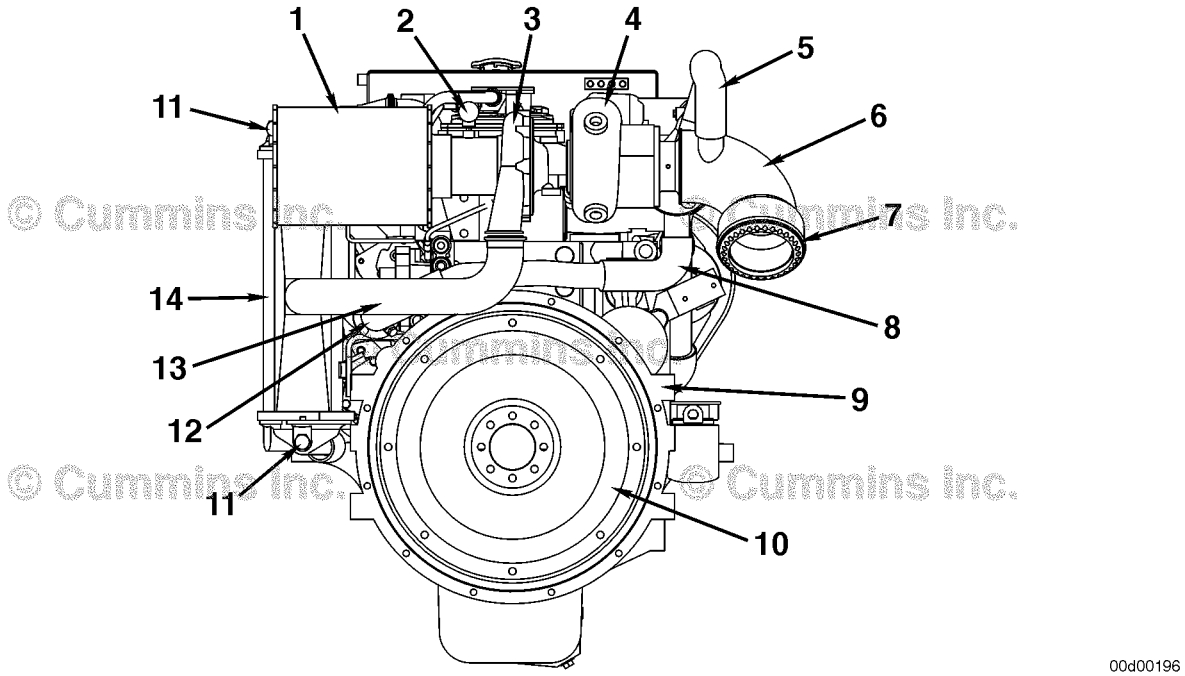
Marine Applications



Left View (Port) QSL9 Marine (Keel Cooled)

1 Expansion tank
2 Aftercooler air outlet
3 Intake manifold temperature sensor
4 Intake manifold pressure sensor
5 Zinc anode
6 Aftercooler coolant inlet
7 Air cleaner or filter
8 Aftercooler air inlet
9 Aftercooler housing
10 Flywheel housing
11 Crankshaft speed sensor
12 Aftercooler coolant outlet
13 Fuel inlet from fuel tank
14 Fuel lift pump (behind ECM)
15 Engine oil dipstick
16 SIM module (mounted on ECM bracket)
17 Electronic control module (ECM)
18 Camshaft position sensor
19 Fuel filter
20 Fuel rail pressure sensor (behind aftercooler air outlet).

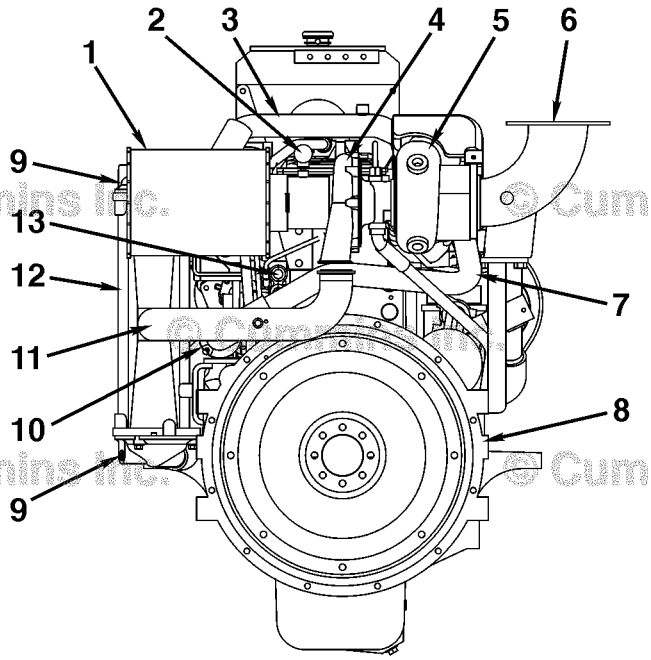
Marine Applications



Rear View QSL9 Marine (Sea Water Cooled)

1 Air cleaner and filter
2 Air cleaner restriction indicator
3 Turbocharger compressor side
4 Turbocharger turbine side
5 Sea water from heat exchanger to exhaust elbow
6 Water cooled exhaust elbow
7 Sea water discharge
8 Sea water to heat exchanger
9 Flywheel housing
10 Flywheel
11 Aftercooler zinc anode
12 Marine gear oil cooler
13 Aftercooler air inlet
14 Aftercooler.

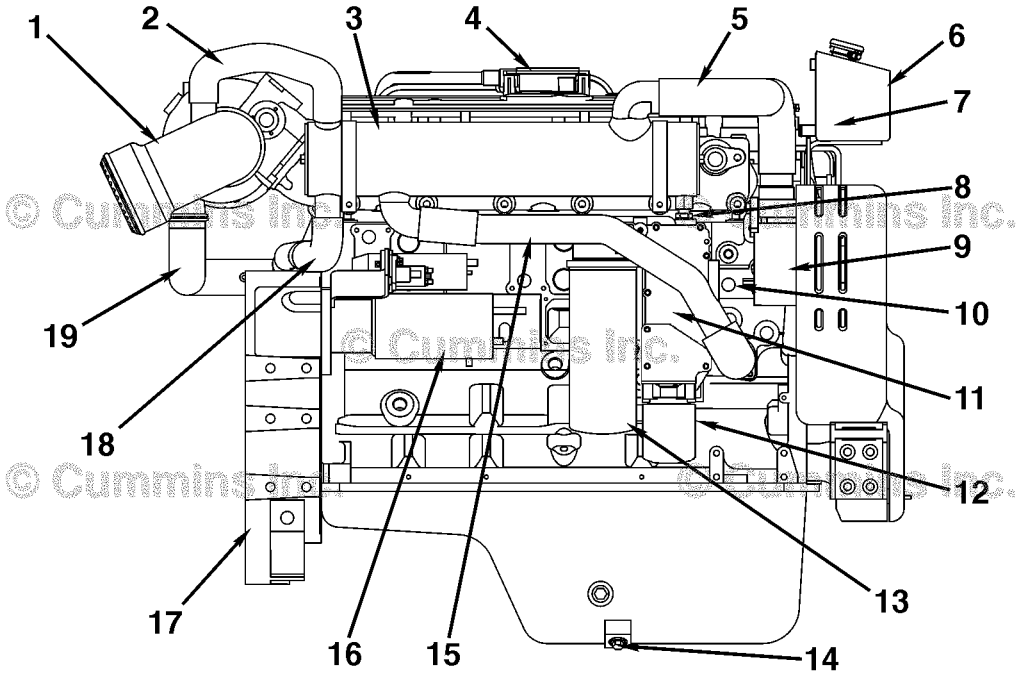
Marine Applications



Rear View QSL9 Marine (Keel Cooled)

1 Air cleaner and filter
2 Air cleaner restriction indicator
3 Coolant outlet from thermostat housing to aftercooler
4 Turbocharger compressor side
5 Turbocharger turbine side
6 Exhaust elbow
7 Coolant return from marine gear oil cooler to water pump
8 Flywheel housing
9 Zinc anode
10 Marine gear oil cooler
11 Aftercooler air inlet
12 Aftercooler
13 Fuel return to fuel tank.

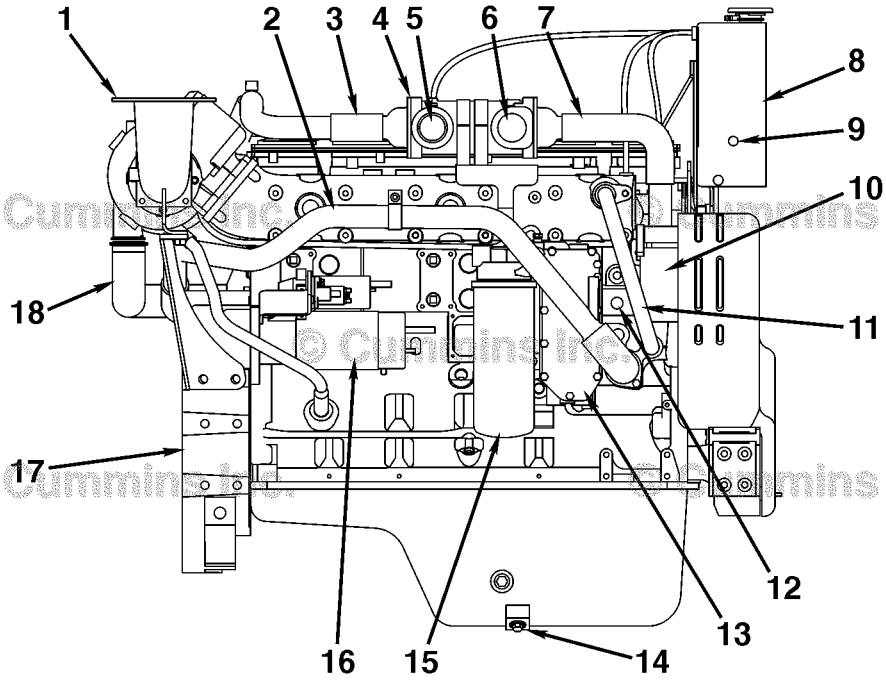
Marine Applications



Right View (Starboard) QSL9 Marine (Sea Water Cooled)

1 Water cooled exhaust elbow
2 Sea water from heat exchanger to exhaust elbow
3 Heat exchanger
4 Crankcase breather
5 Heat exchanger coolant inlet
6 Expansion tank
7 Coolant level sensor
8 Zinc anode
9 Alternator
10 Coolant temperature sensor
11 Lubricating oil cooler
12 Coolant filter
13 Lubricating oil filter
14 Oil pan drain plug
15 Heat exchanger coolant outlet
16 Starter motor
17 Flywheel housing
18 Heat exchanger sea water inlet
19 Intake air from turbocharger to aftercooler.

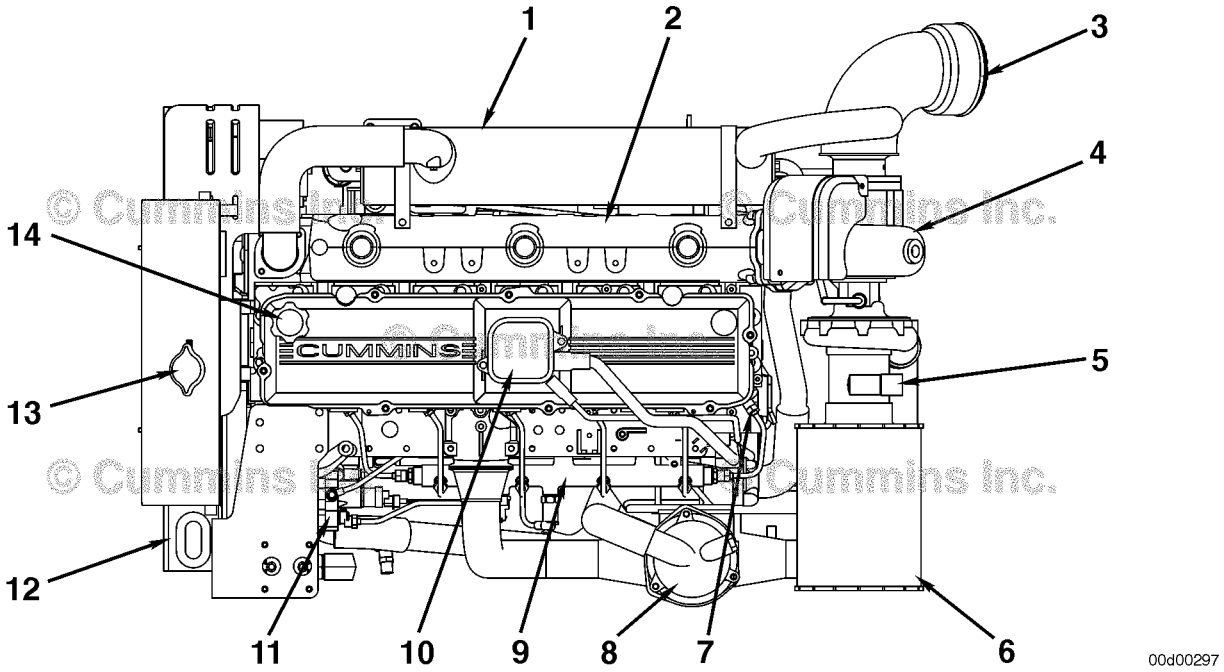
Marine Applications



Right View (Starboard) QSL9 Marine (Keel Cooled)

1 Exhaust elbow
2 Coolant return from marine gear oil cooler to water pump
3 Coolant outlet from thermostat housing to aftercooler
4 Keel cooler thermostat housing
5 Coolant from keel cooler to engine
6 Coolant from engine to keel cooler
7 Coolant return from engine to keel cooler thermostat housing
8 Expansion tank
9 Coolant level sensor
10 Alternator
11 Coolant return from exhaust manifold to water pump
12 Coolant temperature sensor
13 Lubricating oil cooler
14 Oil pan drain plug
15 Lubricating oil filter
16 Starter motor
17 Flywheel housing
18 Intake air from turbocharger to aftercooler.

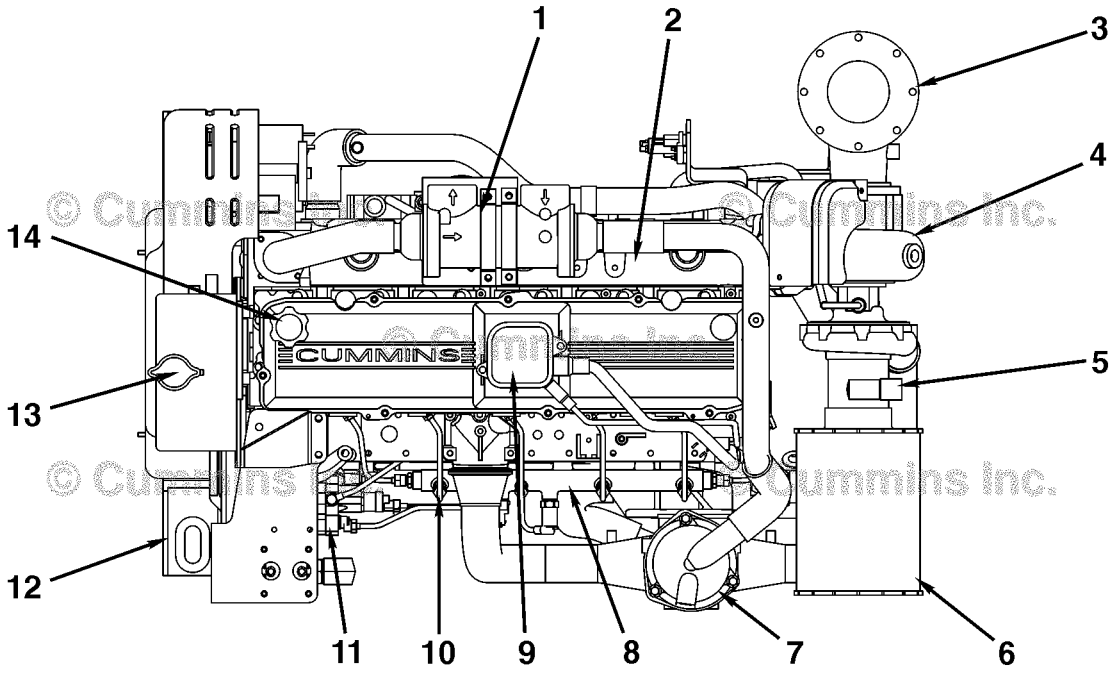
Marine Applications



Top View QSL9 Marine (Sea Water Cooled)

1 Heat exchanger
2 Exhaust manifold
3 Exhaust outlet
4 Turbocharger
5 Air inlet restriction indicator
6 Air filter
7 High-pressure injector supply line
8 Aftercooler
9 Fuel rail
10 Crankcase breather
11 Fuel pump
12 Front engine mount
13 Expansion tank coolant fill cap
14 Oil fill cap.

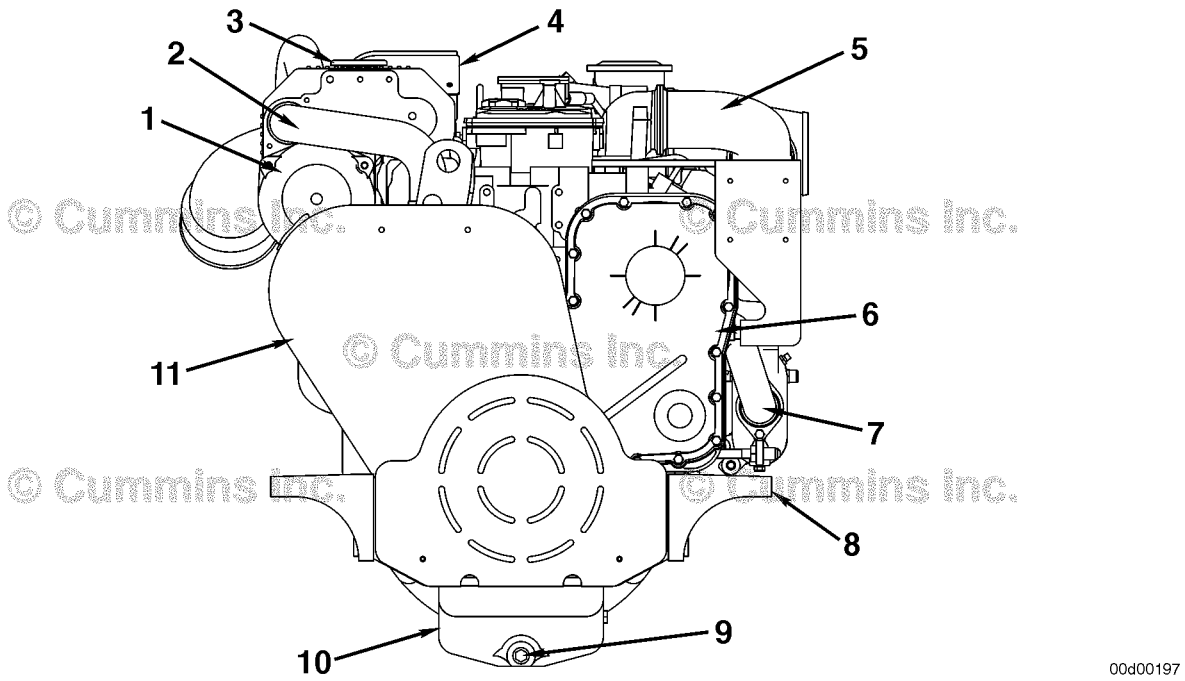
Marine Applications



Top View QSL9 Marine (Keel Cooled)

1 Thermostat housing (keel cooled)
2 Exhaust manifold
3 Exhaust outlet
4 Turbocharger
5 Air inlet restriction indicator
6 Air filter
7 Aftercooler
8 Fuel rail
9 Crankcase breather
10 High pressure injector supply line
11 Fuel pump
12 Front engine mount
13 Expansion tank coolant fill cap
14 Oil fill cap.

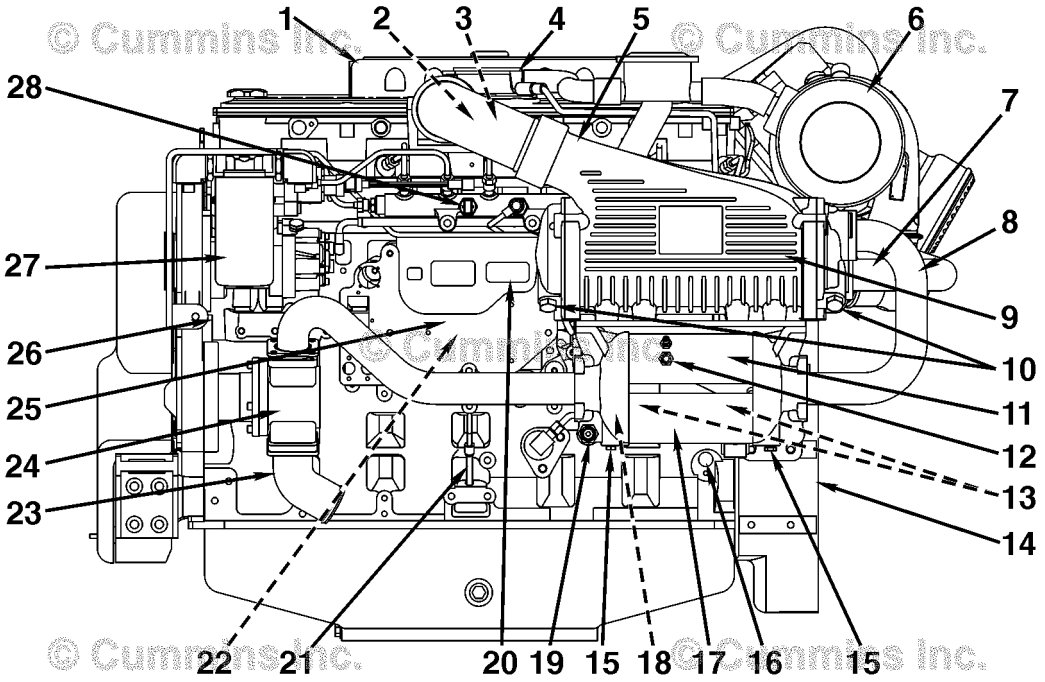
Marine Applications



Front View QSC8.3 Marine (Sea Water Cooled)

1 Heat exchanger
2 Engine coolant to heat exchanger
3 Coolant fill cap
4 Expansion tank
5 Intake air inlet from aftercooler
6 Timing case cover
7 Sea water pump discharge
8 Engine mounting bracket
9 Oil pan drain plug
10 Oil pan
11 Belt and pulley guard.

Marine Applications



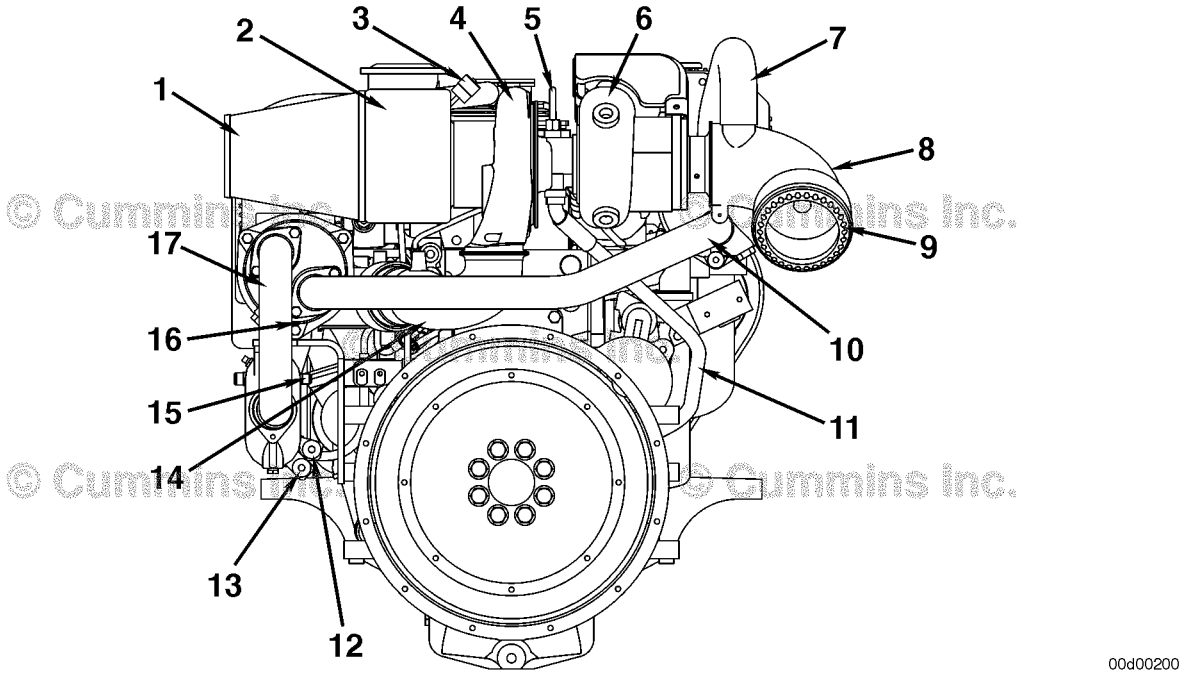
Left View (Port) QSC8.3 Marine (Sea Water Cooled)

1 Expansion tank
2 Intake manifold temperature sensor (behind aftercooler air outlet)
3 Intake manifold pressure sensor (behind aftercooler air outlet
4 Crankcase breather
5 Aftercooler air outlet
6 Air cleaner or filter
7 Aftercooler sea water outlet
8 Aftercooler sea water inlet
9 Aftercooler housing
10 Zinc anodes
11 Fuel cooler
12 Fuel outlet to fuel tank
13 Marine gear oil cooler connection (behind gear oil cooler x 2)
14 Flywheel housing
15 Zinc anode
16 Crankshaft speed sensor
17 Marine gear oil cooler
18 Oil pressure sensor (behind marine gear oil cooler)
19 Fuel inlet from fuel tank
20 Electronic control module (ECM)
21 Lubricating oil dipstick
22 Fuel lift pump (behind ECM)
23 Sea water inlet
24 Sea water pump
25 SIM module (mounted on ECM bracket)
26 Camshaft position sensor

27 Fuel filter

28 Fuel rail pressure sensor.

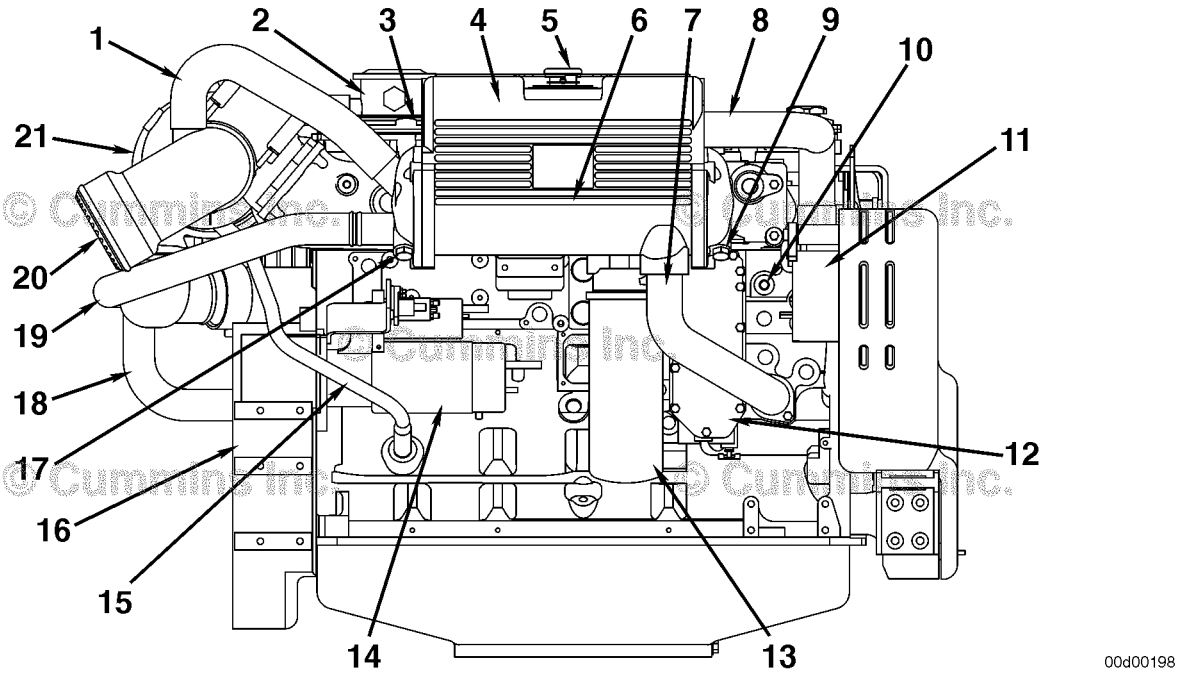
Marine Applications



Rear View QSC8.3 Marine (Sea Water Cooled)

1 Air cleaner or filter
2 Closed crankcase ventilation canister/filter
3 Intake air restriction indicator
4 Turbocharger compressor side
5 Turbocharger oil supply
6 Turbocharger exhaust side
7 Heat exchanger sea water outlet
8 Sea water cooled exhaust elbow
9 Sea water discharge
10 Heat exchanger sea water inlet
11 Turbocharger oil drain tube
12 Marine gear oil cooler connection
13 Marine gear oil cooler connection
14 Aftercooler air inlet
15 Fuel cooler inlet from engine
16 Aftercooler drain valve
17 Aftercooler sea water inlet.

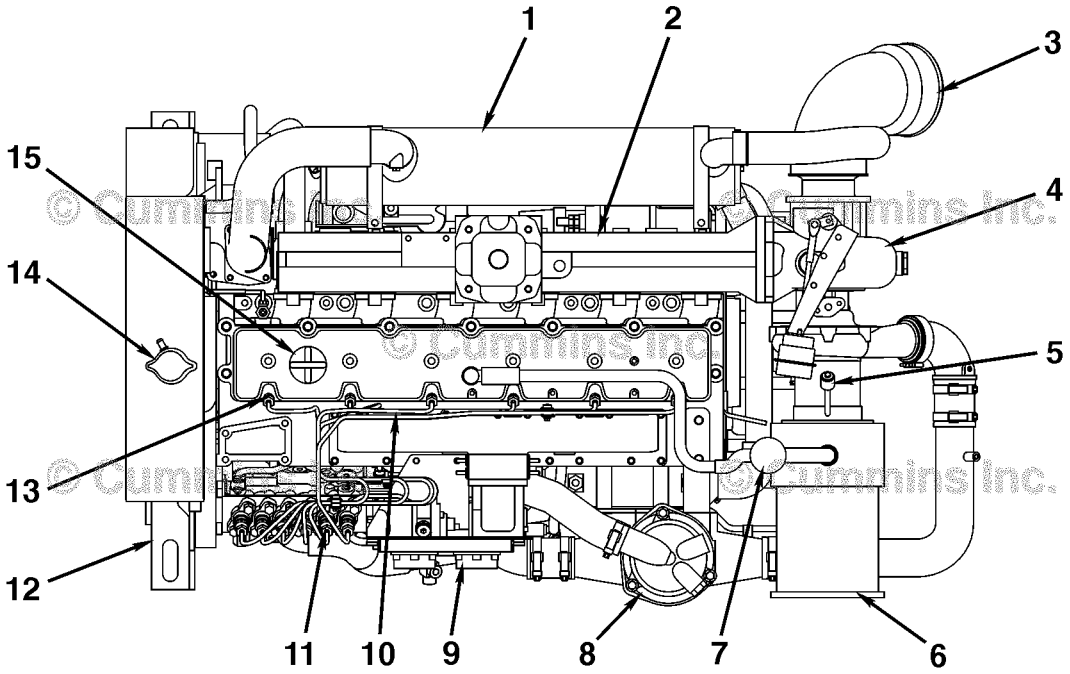
Marine Applications



Right View (Starboard) QSC8.3 Marine (Sea Water Cooled)

1 Sea water outlet from heat exchanger
2 Vacuum regulator for air filter
3 Coolant level sensor
4 Expansion tank
5 Coolant fill cap
6 Heat exchanger
7 Coolant outlet from heat exchanger
8 Coolant inlet to heat exchanger
9 Zinc anode
10 Coolant temperature sensor
11 Alternator
12 Lubricating oil cooler
13 Lubricating oil filter
14 Starter motor
15 Turbocharger oil drain
16 Flywheel housing
17 Zinc anode
18 Sea water inlet to aftercooler
19 Sea water inlet to heat exchanger
20 Exhaust elbow/sea water discharge
21 Turbocharger.

Marine Applications



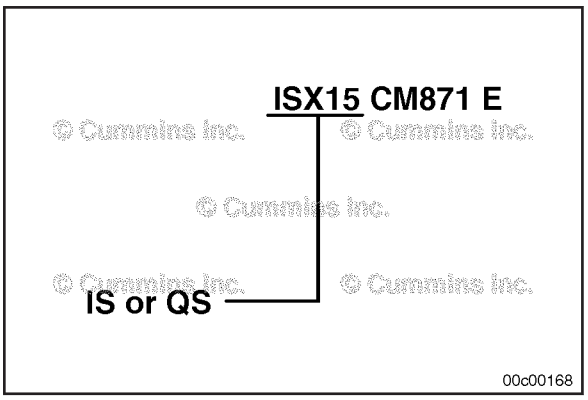
Top View QSC8.3 Marine (Sea Water Cooled)

1 Heat exchanger
2 Exhaust manifold
3 Exhaust outlet
4 Turbocharger
5 Air inlet restriction indicator
6 Air filter
7 Crankcase breather
8 Aftercooler
9 Electronic control module (ECM)
10 High pressure injector supply line
11 Fuel pump
12 Front engine mount
13 Injector
14 Expansion tank coolant fill cap
15 Oil fill cap.

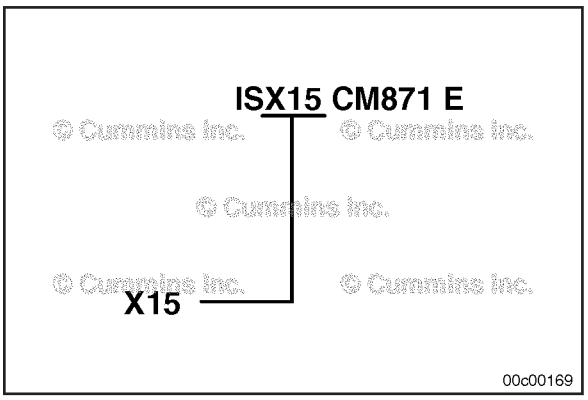
Cummins® Service Engine Model Product Identification

General Information

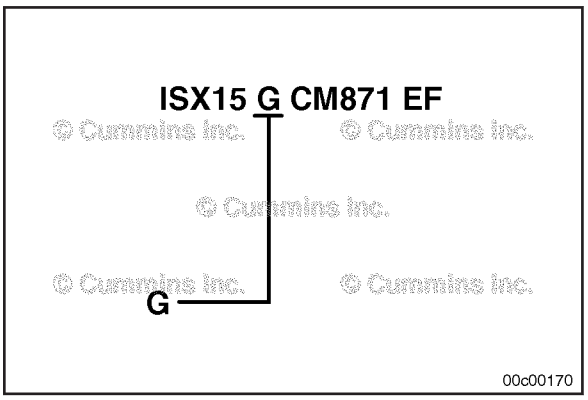
The Cummins® Service Engine Model Nomenclature procedure describes how engines are identified within Cummins service organization. This method was introduced for models after and including manufacture year 2007.



Electronic engines are identified by the first two letters, either an "IS" for On-Highway automotive or "QS" for Off-Highway industrial market applications.

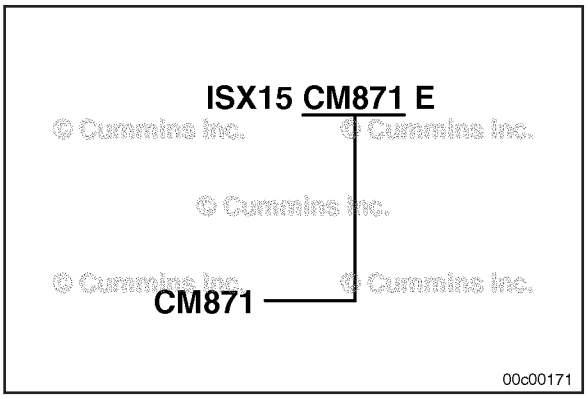


The third letter is the engine platform designation followed by the engine liter size.

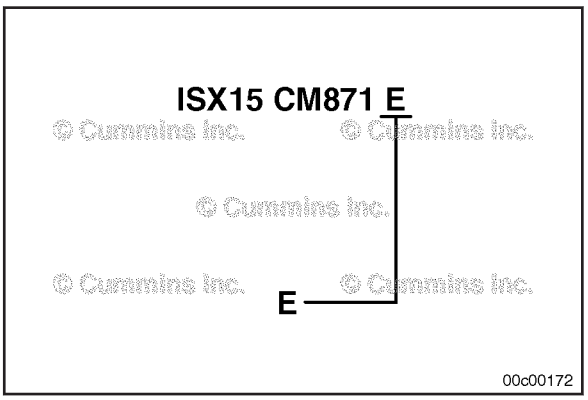


If the engine operates on a fuel type other than diesel, the type will be identified after the liter size.

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



The technology identifier after the control system designates the prevailing technology used with the engine. (See table in this procedure for letter designations.)

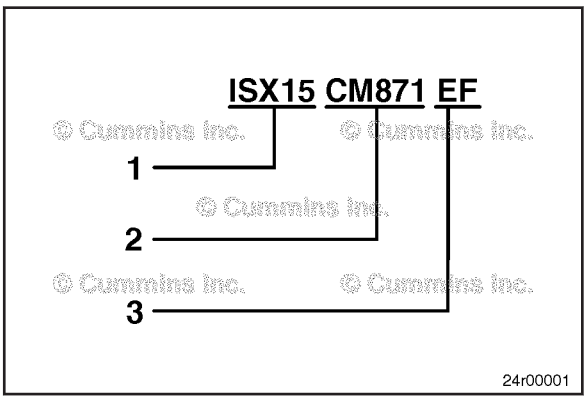


Example:

1 On-Highway automotive "X" 15 liter engine

2 Control system number 871

3 Technology supported; Electric EGR and Diesel Particulate Filter



Technology	Name	Suffix
Exhaust Gas Recirculation	Not used	None
	Pneumatic	P
	Electric	E
Diesel Particulate Filter (DPF)	Not used	None
	Full Flow DPF	F
	Partial Flow DPF	F2
Diesel Oxidation Catalyst	Not used	None
	DOC	C
3-Way Oxidation Catalytic Converter	Not used	None
	3-Way Catalyst	J
Selective Catalytic Reduction System	Not used	None
	Air Driven	S
	Airless	A
Nox Sensor	Not used	None
	Nox Sensor	N
Modular Common Rail System	Used only on QSK19, 38, 50 , 60 HHP Engines	MCRS
Integrated Dosing Control Unit	Not Used	None
	Integrated	I

Section F - Familiarization

Section Contents

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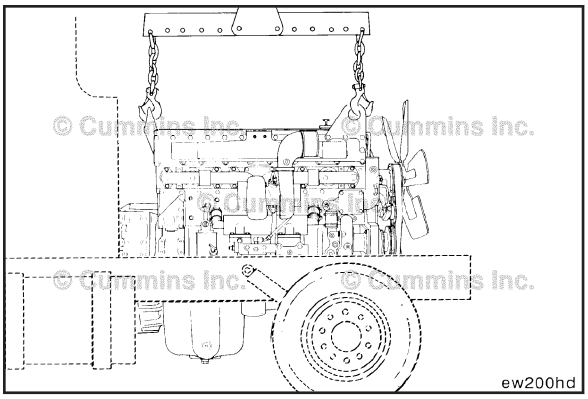
Complete Engine - Overview (000-999)

General Information

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

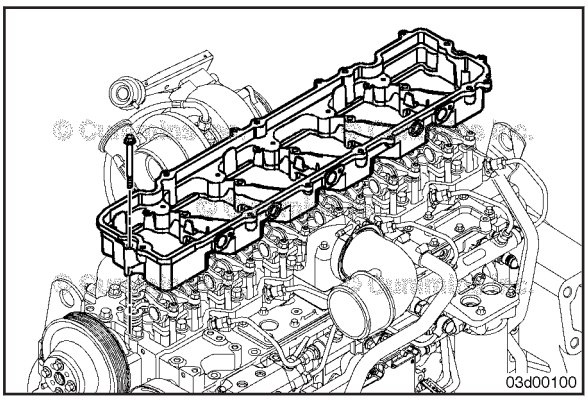
All replacement steps will **not** apply to all types of equipment. Complete **only** the steps that apply to the equipment involved. Use the equipment manufacturer's recommendations and precautions for removal of chassis parts to gain access to the engine.



Rocker Levers - Overview (003-999)

General Information

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

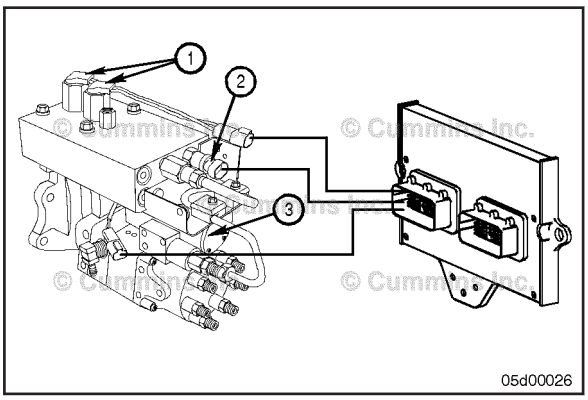


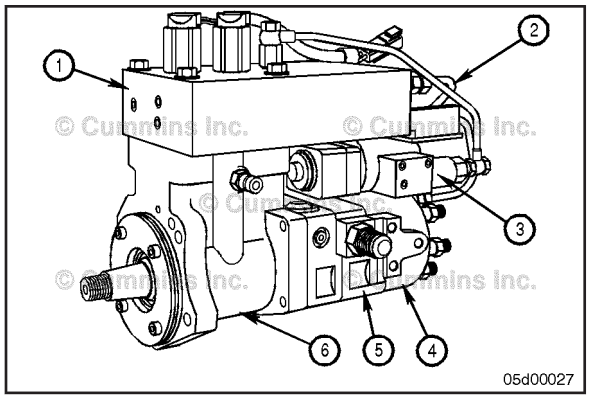
Fuel System - Overview (005-999)

General Information

CAPS Fuel System

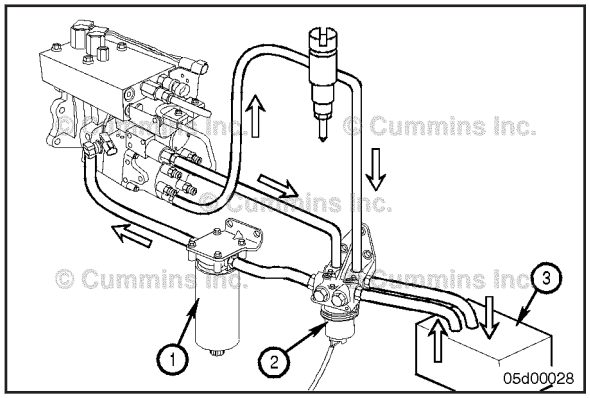
The Cummins accumulator pump system (CAPS) fuel system is a distributor-type injection system. An accumulator is used to store pressurized fuel for the injection event. There are four components that provide or receive input to the electronic control module (ECM). There are two pumping control valves (1) that are controlled by the ECM. These valves control the pressure in the accumulator. The accumulator fuel pressure/ temperature (2) sensor is located on the accumulator and provides the ECM with pressure and temperature information. The injection control valve (3) is also controlled by the ECM and regulates fuel injected into the cylinder.



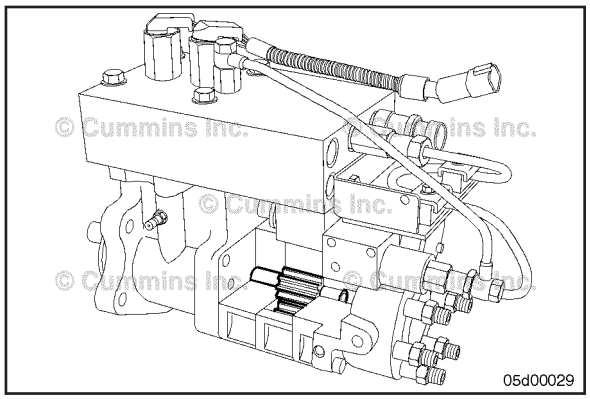


The CAPS injection pump can be divided into six distinct units/modules. They are the gear pump, cam housing, accumulator, rate shape tube, injection control valve (ICV), and distributor. Fuel flows through the modules in the following order:

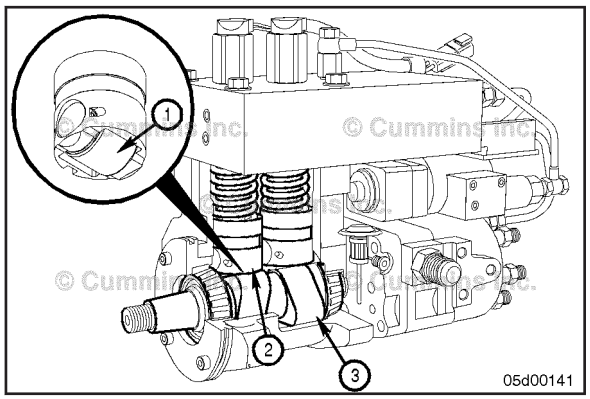
- Gear pump - 5
- Cam housing - 6
- Accumulator - 1
- Rate shape tube - 2
- Injector control valve (ICV) - 3
- Distributor - 4.



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

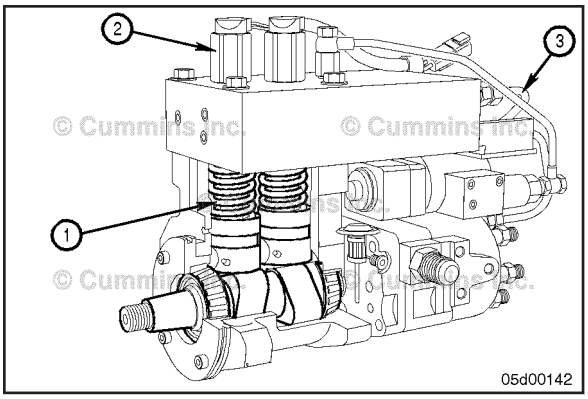


The gear pump supplies fuel to the pumping plungers through internal drillings in the cam housing. The gear pump also supplies fuel to the distributor for lubrication. The fuel pressure is regulated to approximately 160 psi at rated engine rpm. The gear pump has an internal filter to catch any debris generated downstream of the main, external fuel filter. The pump camshaft is driven off the engine camshaft; therefore, pump rpm is one-half engine rpm. The gear pump is driven by the pump camshaft through an internal coupling. The gear pump shaft then turns the distributor rotor through a second internal coupling.

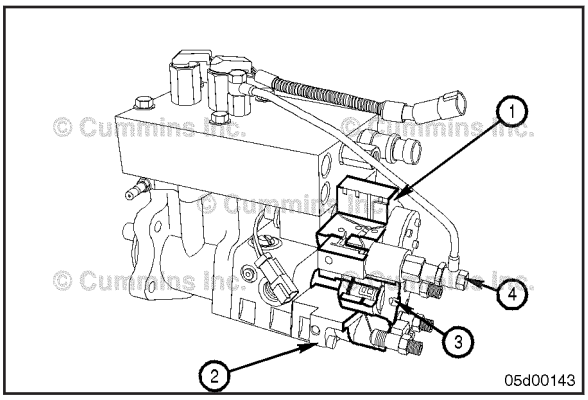


Each of the two pumping plungers is driven by a three lobed camshaft (3). The camshaft is located in the cam housing module by tapered roller bearings. The bearings that support the camshaft, as well as the tappets (2), rollers (1), and camshaft itself are lubricated with engine oil. These are the **only** components in the pump lubricated with engine oil.

A pumping control valve (2) is located above each pumping plunger (1). The supply fuel from the gear pump flows around the plunger of this normally open valve into the chamber above the plunger. The volume above each pumping plunger is filled, by the gear pump, as the plungers travel downward. As the plunger starts to move upward, the fuel is pushed backward into the gear pump. When the pumping control valve closes, the fuel is pushed into the accumulator and then held by check valves. The time when the pumping control valve is energized (closed) is based on engine speed, accumulator pressure, and throttle position. A 0- to 24,000-psi pressure sensor is located in the accumulator. The pressure sensor provides direct feedback to the ECM, so the desired accumulator pressure is maintained. This pressure sensor also has temperature sensing capabilities built into it. Fuel moves from the accumulator to the distributor and through the rate shape tube (3).

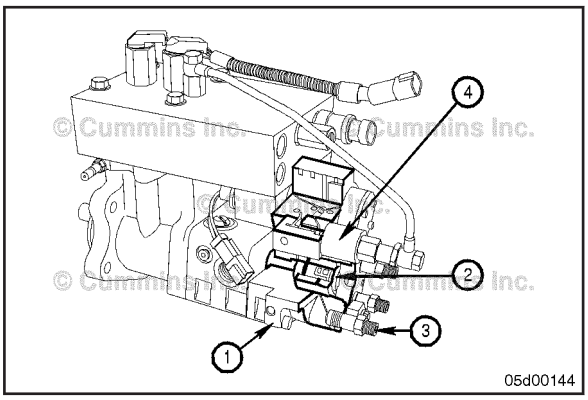


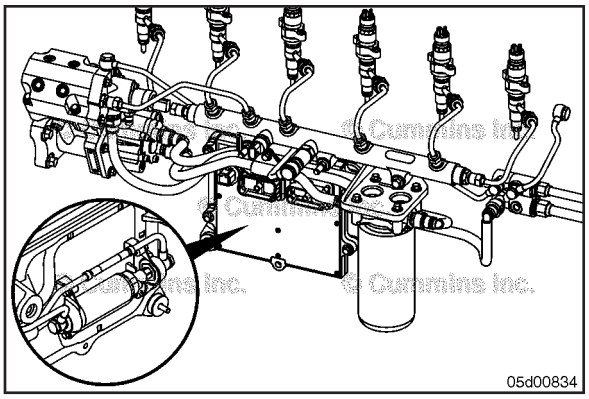
Fuel is delivered to the injection control valve (1) by the rate shape tube and through a drilling in the distributor (2). The ICV controls both fueling and timing. The injection control valve contains an inner pin and outer valve. The outer valve is moved by magnetic force generated inside the ICV by a current from the ECM. The inner pin is moved by spring force and fuel pressure. When the two pins are in the closed position, no fuel flows through the control valve. The position of these internal parts controls fuel flow to the distributor rotor (3) and to the drain (4). The injection control valve opens and closes once for each injection event.



The distributor (1) directs the fuel to the correct injector using the rotor. The drain fuel from the ICV is routed through the ICV pressure regulator (4) and is returned to the tank.

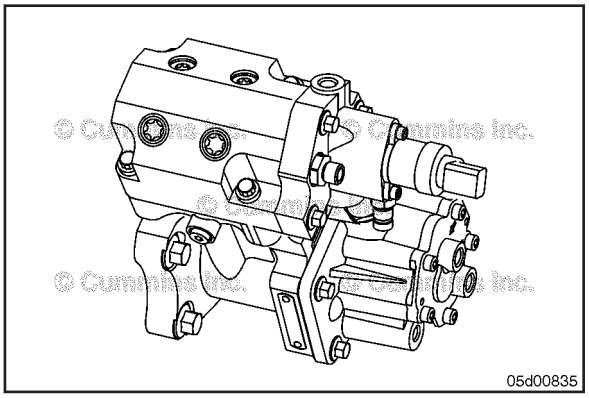
The position of the rotor directs the fuel to one of six drillings in the distributor housing. These drillings communicate the fuel to six fuel pump delivery valves (3). There is one injector line per delivery valve. The injection line carries the fuel to the injector.



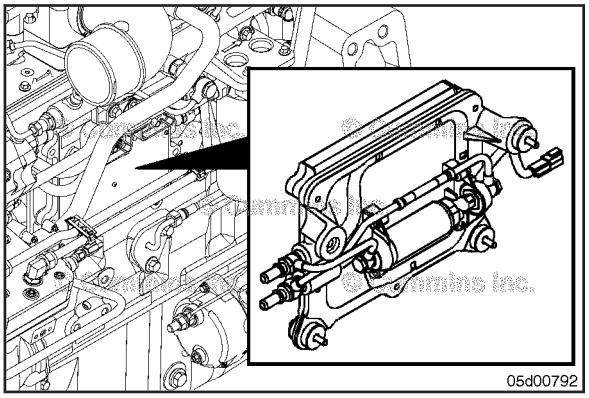


Cummins® Common Rail Fuel System

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

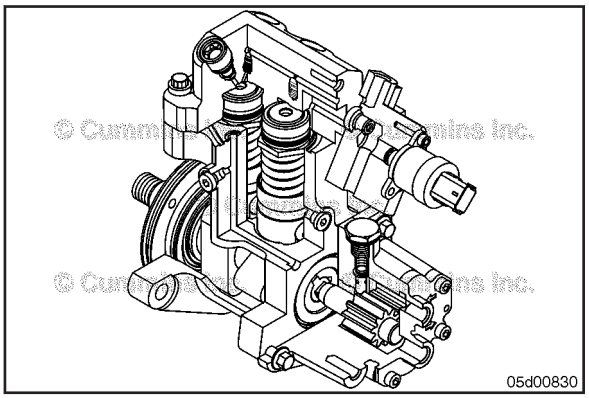


The high-pressure fuel pump can be divided into four distinct assemblies. They are the fuel gear pump, fuel pump actuator housing, cam housing, and high-pressure fuel pump head. Fuel flows through the gear pump to a 2-micron pressure-side filter. After the pressure-side filter, fuel enters the fuel pump actuator housing. The fuel pump actuator housing includes an air-bleed fitting and the fuel pump actuator. Some fuel continuously returns to drain through the air-bleed orifice fitting. Fuel that is metered through the fuel pump actuator enters the high-pressure fuel pump head where it is pumped to fuel rail pressure and exits at the high-pressure outlet fitting.



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

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

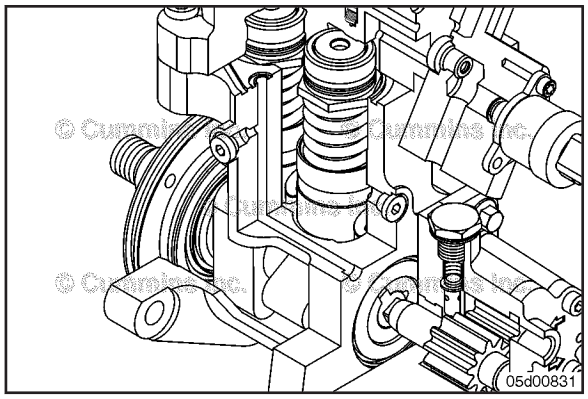


The gear pump output is routed to a 2-micron fuel filter. The filtered fuel returns to the fuel pump actuator housing.

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

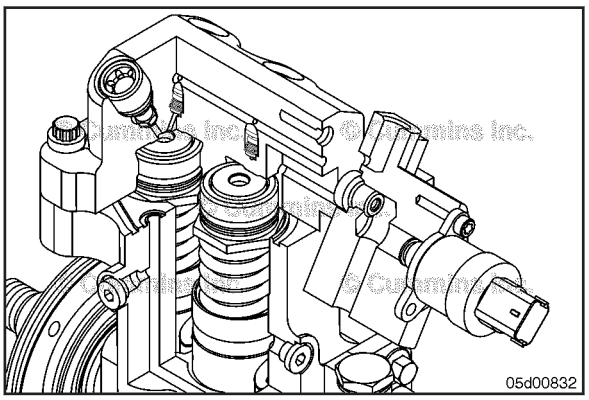
Each of the two pumping plungers is driven by a three lobed camshaft. The camshaft is located in the cam housing module by tapered roller bearings. The bearings that support the camshaft, as well as the tappets, rollers and camshaft itself are lubricated with engine oil. These are the only components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

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

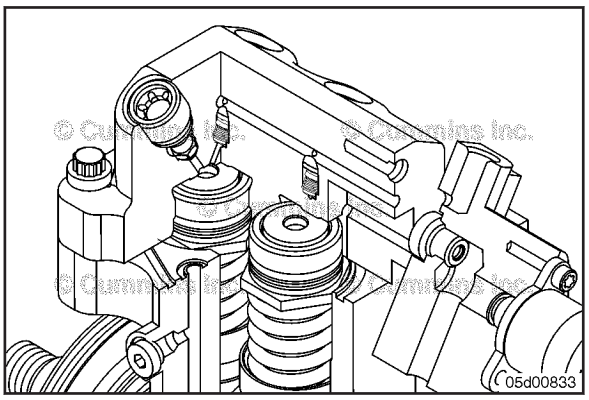


Pressurized fuel from the gear pump is supplied to the fuel pump actuator. The fuel pump actuator is opened or closed by the ECM to maintain the appropriate fuel rail pressure.

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

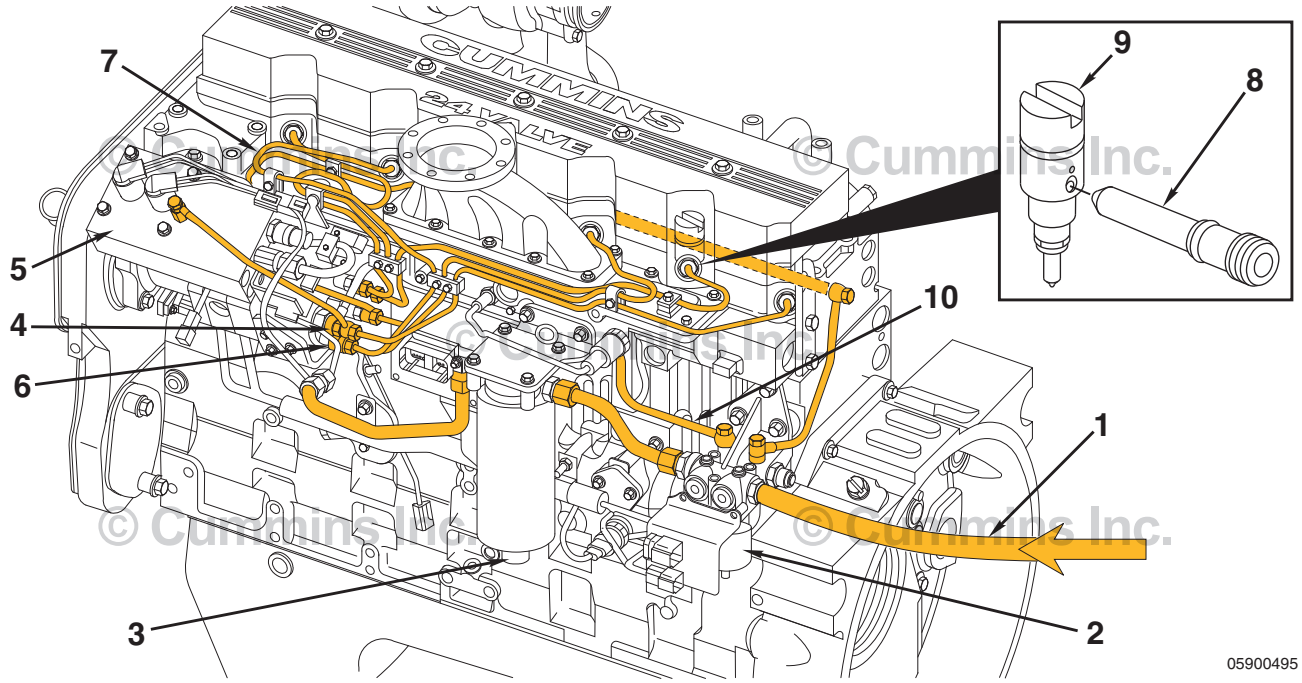


Fuel that is metered past the fuel pump actuator enters the high-pressure fuel pump inlet drilling, past the inlet check valve and fills the pumping chamber by pressing the pumping plunger downward. When the camshaft pushes the pumping plunger upward, fuel reaches rail pressure and causes the outlet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



Flow Diagram, Fuel System (200-001)

General Information

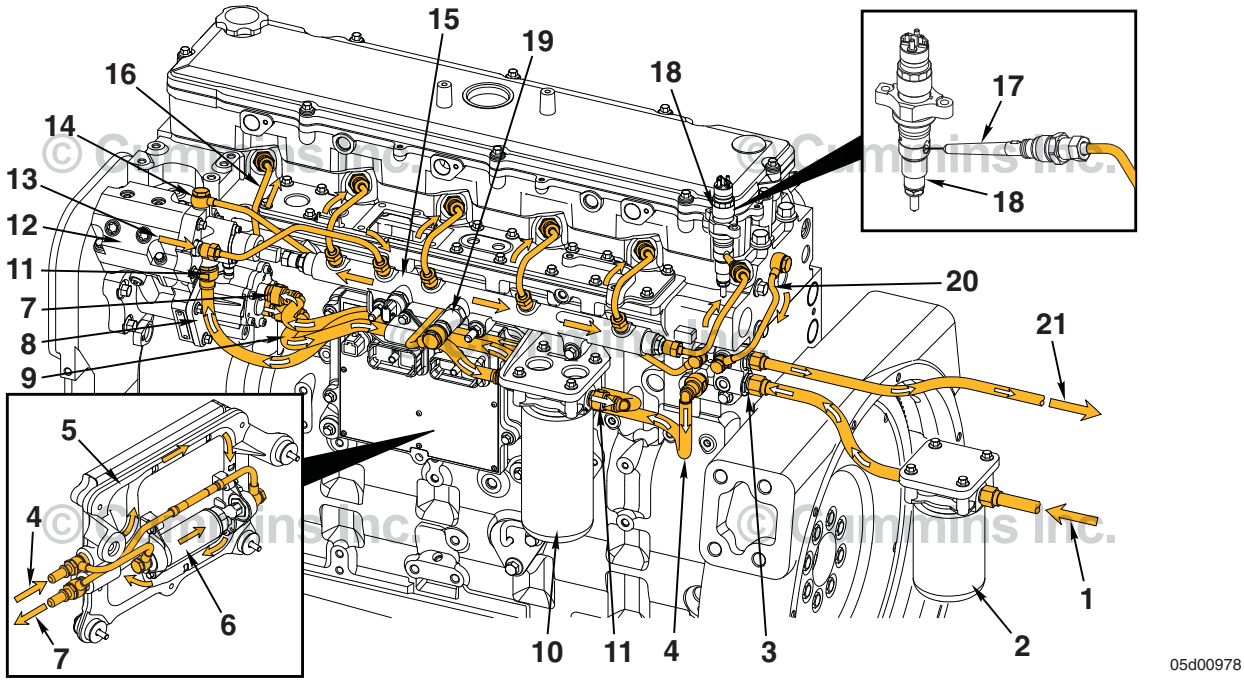


CAPS Fuel System

1 Fuel from supply tank
2 Electronic lift pump
3 Suction side fuel filter and water separator
4 Fuel drain line
5 CAPS injection pump
6 Distributor outlet fitting
7 High-pressure supply lines
8 Fuel connector
9 Injectors
10 Fuel return to supply tank

Flow Diagram, Fuel System (200-001)

General Information

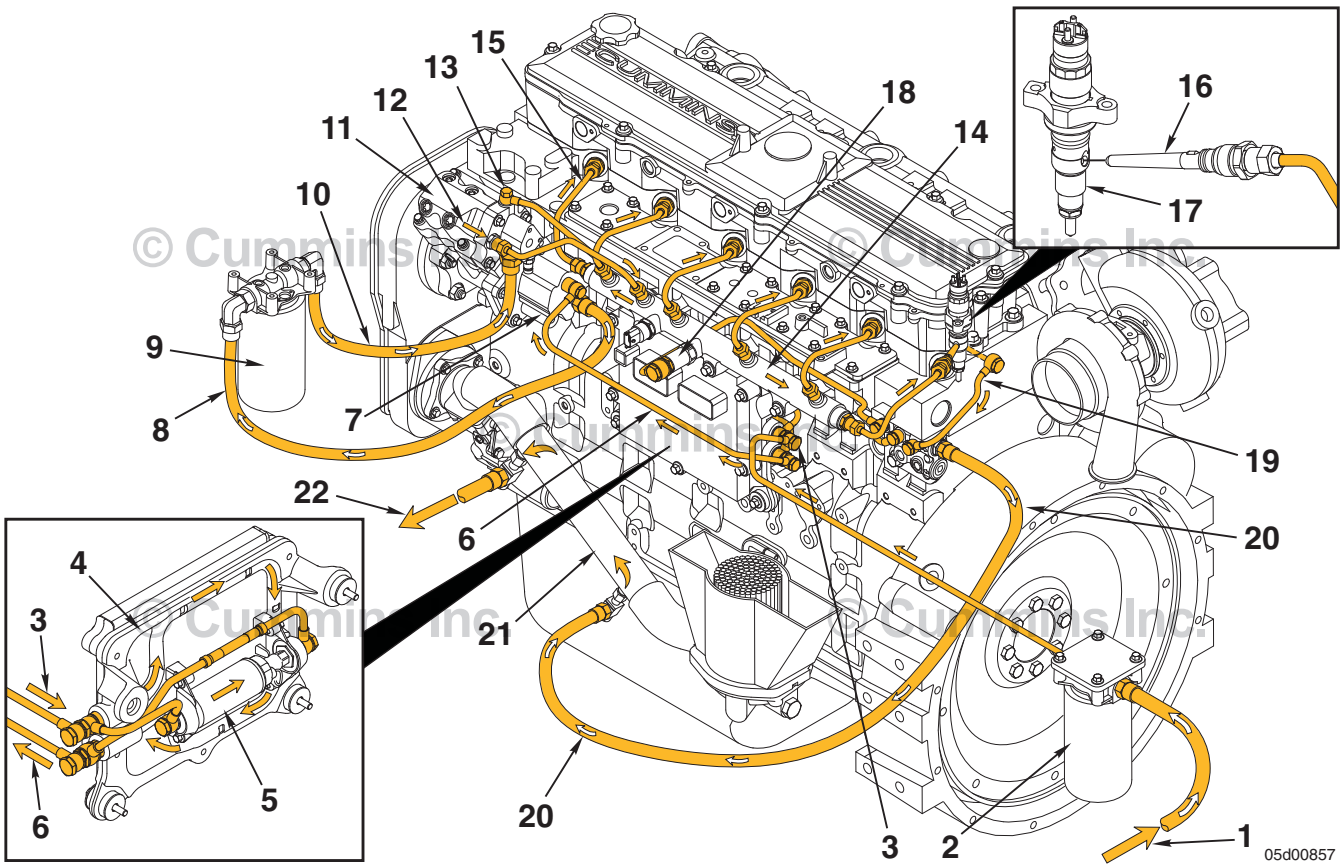


Cummins® Common Rail Fuel System

1 Fuel from supply tank
2 Fuel filter and water separator
3 OEM fuel supply connection
4 Fuel supply to ECM mounted fuel lift pump
5 ECM cooling plate
6 ECM mounted fuel lift pump
7 Fuel outlet from ECM mounted fuel lift pump
8 Fuel gear pump
9 Fuel from gear pump to fuel filter
10 Pressure side fuel filter
11 Fuel inlet to fuel pump actuator
12 High-pressure fuel pump
13 Fuel outlet from high-pressure pump
14 High-pressure pump drain flow connection
15 Fuel rail
16 High-pressure injector supply lines
17 High-pressure fuel connector
18 Fuel injector
19 Fuel pressure relief valve
20 Fuel injector drain flow line
21 Fuel return to supply tanks

Flow Diagram, Fuel System (200-001)

General Information

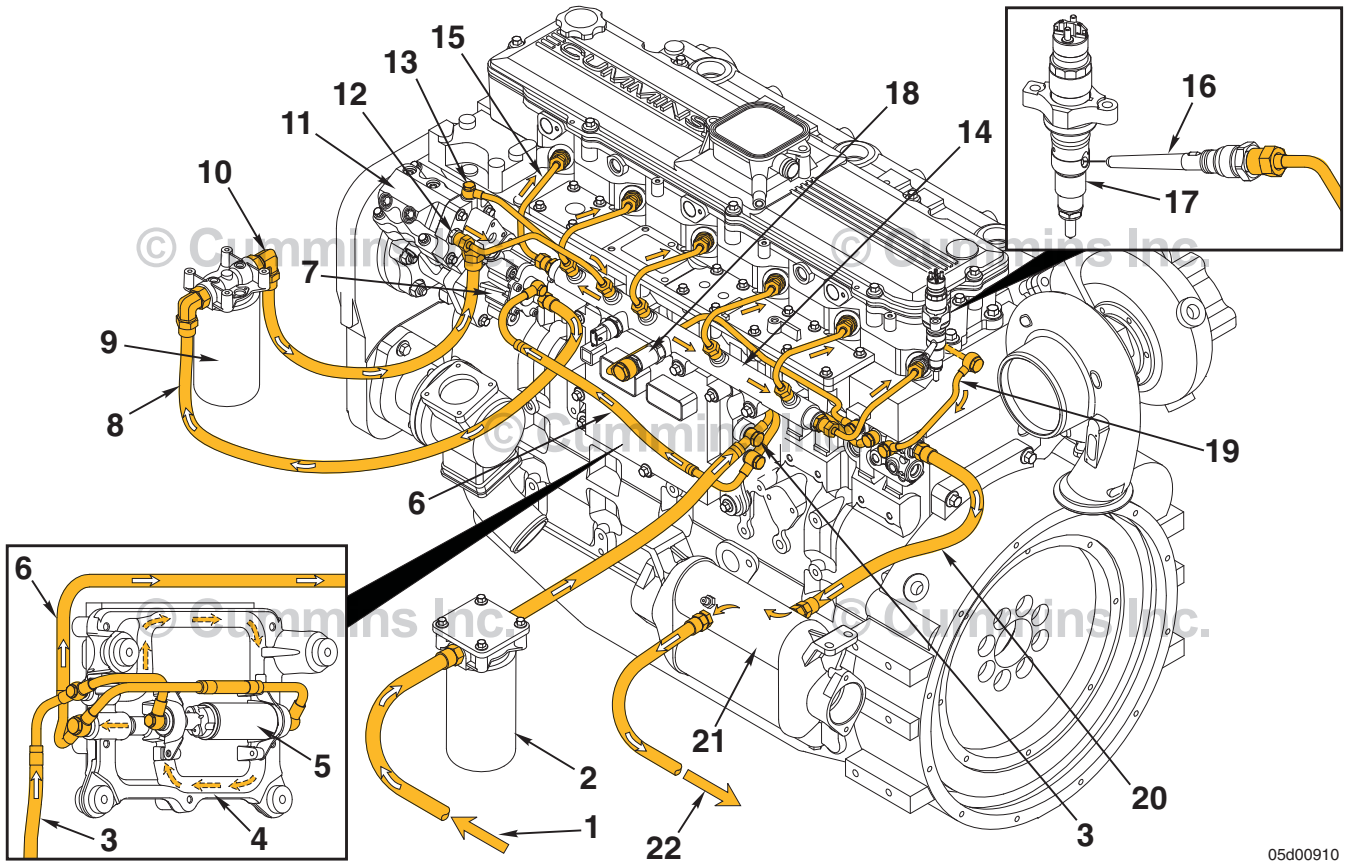


QSL9 Marine Applications, Cummins® Common Rail Fuel System

1 Fuel from supply tank
2 Fuel filter and water separator
3 Fuel supply to ECM mounted fuel lift pump
4 ECM cooling plate
5 ECM mounted fuel lift pump
6 Fuel outlet from ECM mounted fuel lift pump
7 Fuel gear pump
8 Fuel from gear pump to fuel filter
9 Pressure side fuel filter
10 Fuel inlet to fuel pump actuator
11 High-pressure fuel pump
12 Fuel outlet from high-pressure pump
13 High-pressure pump drain flow connection
14 Fuel rail
15 High-pressure injector supply lines
16 High-pressure fuel connector
17 Fuel injector
18 Fuel pressure relief valve
19 Fuel injector drain flow line
20 Fuel return to fuel cooler on sea water cooled engines **only**; fuel return to tank on keel cooled engines
21 Fuel cooler (sea water cooled engines **only**)
22 Fuel return to fuel tank (sea water cooled engines **only**).

Flow Diagram, Fuel System (200-001)

General Information

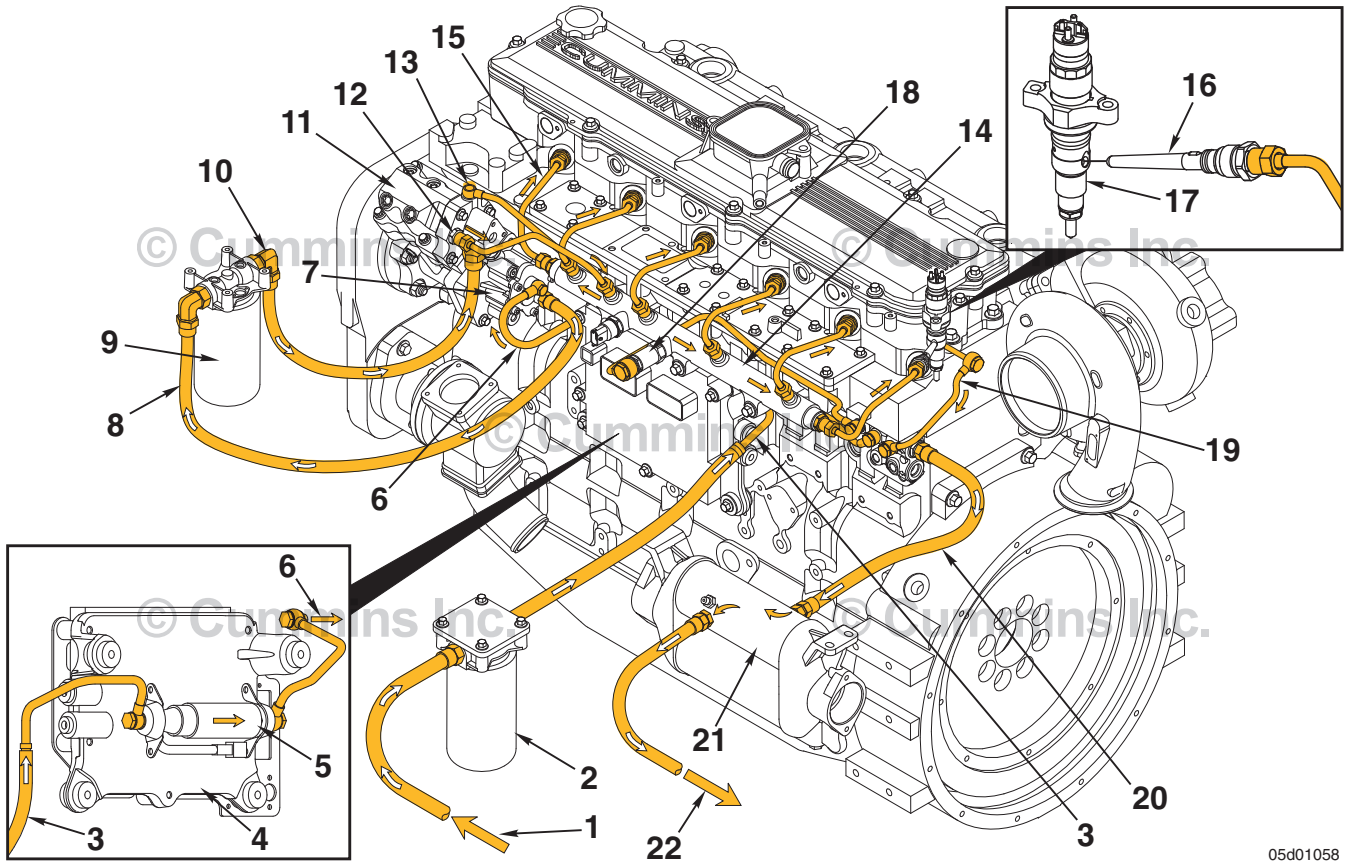


QSC8.3 Marine Applications (Sea Water Cooled), Cummins® Common Rail Fuel System With ECM Fuel Cooling

1 Fuel from supply tank
2 Fuel filter and water separator
3 Fuel supply to ECM mounted fuel lift pump
4 ECM cooling plate
5 ECM mounted fuel lift pump
6 Fuel outlet from ECM mounted fuel lift pump
7 Fuel gear pump
8 Fuel from gear pump to fuel filter
9 Pressure side fuel filter
10 Fuel inlet to fuel pump actuator
11 High-pressure fuel pump
12 Fuel outlet from high-pressure pump
13 High-pressure pump drain flow connection
14 Fuel rail
15 High-pressure injector supply lines
16 High-pressure fuel connector
17 Fuel injector
18 Fuel pressure relief valve
19 Fuel injector drain flow line
20 Fuel return to fuel cooler
21 Fuel cooler
22 Fuel return to fuel tank.

Flow Diagram, Fuel System (200-001)

General Information



QSC8.3 Marine Applications (Sea Water Cooled), Cummins® Common Rail Fuel System Without ECM Fuel Cooling

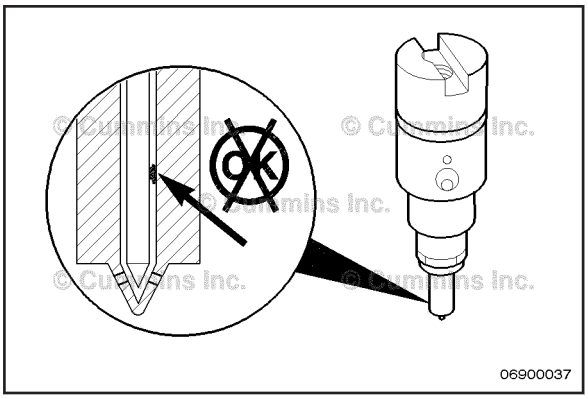
1 Fuel from supply tank
2 Fuel filter and water separator
3 Fuel supply to ECM mounted fuel lift pump
4 ECM plate
5 ECM mounted fuel lift pump
6 Fuel outlet from ECM mounted fuel lift pump
7 Fuel gear pump
8 Fuel from gear pump to fuel filter
9 Pressure side fuel filter
10 Fuel inlet to fuel pump actuator
11 High-pressure fuel pump
12 Fuel outlet from high-pressure pump
13 High-pressure pump drain flow connection
14 Fuel rail
15 High-pressure injector supply lines
16 High-pressure fuel connector
17 Fuel injector
18 Fuel pressure relief valve
19 Fuel injector drain flow line
20 Fuel return to fuel cooler
21 Fuel cooler
22 Fuel return to fuel tank.

Injectors and Fuel Lines - Overview (006-999)

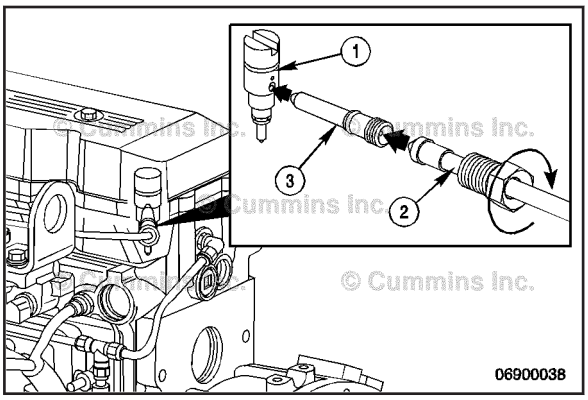
General Information

CAPS Fuel System

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



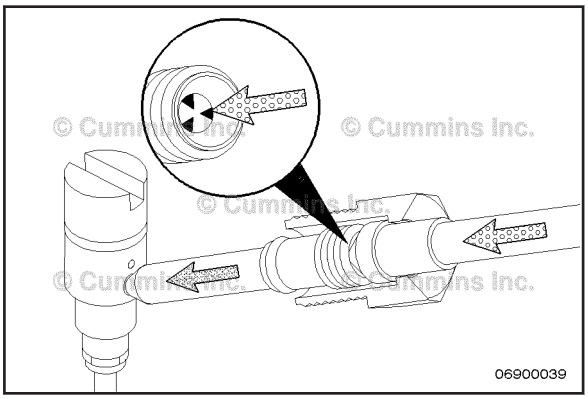
Injectors used in the ISC and ISL engines have hole type nozzles. High pressure fuel flows into the side of the injector and causes the needle to lift and fuel to be injected. The clearances in the nozzle bore are extremely small and any sort of dirt or contaminants will cause the injector needle valve to stick. This is why it is important to clean the area around any fuel connection before servicing it. Also, cap or cover any open fuel connections before a fuel system repair is performed.



High pressure fuel is supplied to the injector (1) from the fuel pump via an injector supply line (2) and a fuel connector (3). The end ferrule on the injector supply line pushes against the fuel connector when the fuel line nut is torqued in the cylinder head. This force provides the sealing pressure between both the injector supply line to the fuel connector and the connector to the injector.

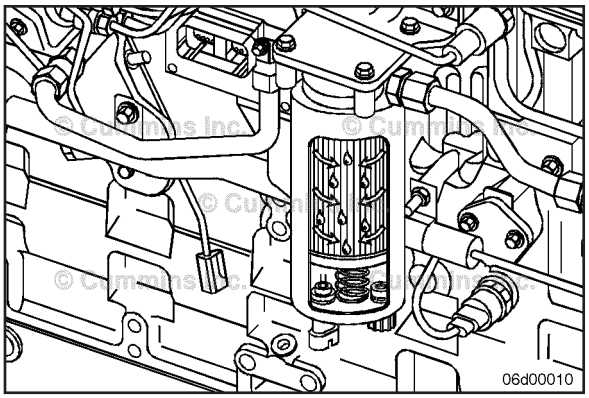
The torque on this line is critical. If the nut is under torqued, the surfaces will **not** seal and a high pressure fuel leak will result. If the nut is over torqued, the connector and injector will deform and also cause a high pressure leak. The leak may result in an injector misfire and low power.

Always lubricate the threads of the high pressure line nuts with engine oil before tightening. Always make sure the proper torque is used on the high pressure line nuts.



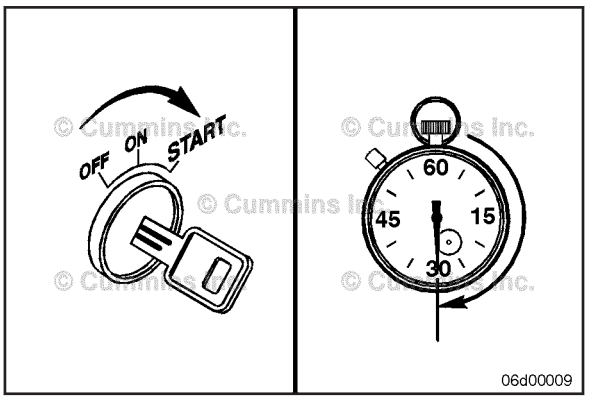
The fuel connector contains an edge filter that breaks up small contaminants that enter the fuel system. The edge filter uses the pulsating high pressure to break up most particles so they are small enough to pass through the injector.

NOTE: The edge filters are **not** a substitute for cleaning and covering all fuel system connections during repair. Edge filters are **not** a substitute for maintaining the recommended engine mounted fuel filter.

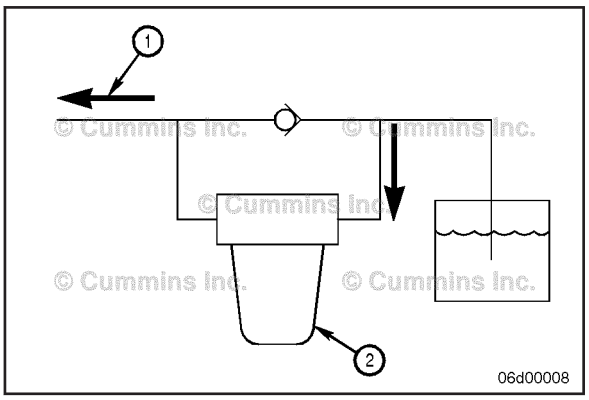


The fuel filter is a spin-on type.

Fuel flows around the outside of the filter and back up through the middle. The filtering media is a 10 micron Stratapore™ design for efficient debris removal. The filter also strips the water and collects it at the bottom of the filter to be drained daily.

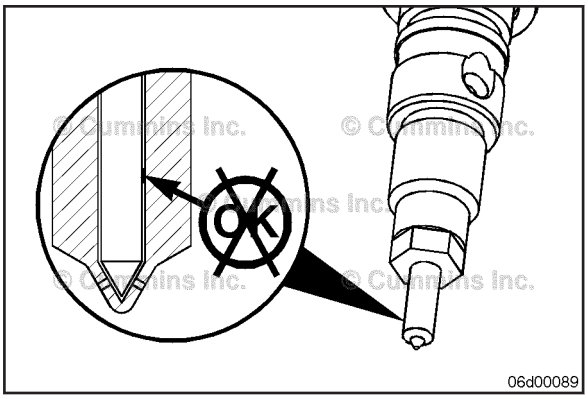


The ISC and ISL lift pump will run for 30 seconds after the key is switched on to assist with fuel priming. The lift pump will run during cranking and while the engine is running until the 30 seconds has lapsed. The lift pump will shut off anytime the key is switched “OFF”. The 30 second timer is reset after each key switch cycle and ECM power down.



Once the engine is started, additional fuel is drawn through the lift pump head via the gear pump. A valve in the head opens when the gear pump requires more flow than the lift pump can provide or when the lift pump is shut off.

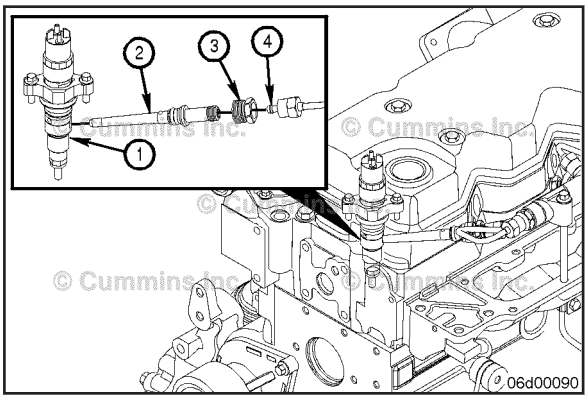
Cummins® Common Rail Fuel System



⚠WARNING⚠

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

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

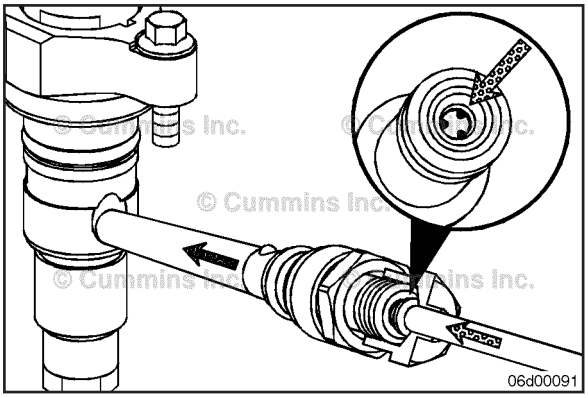


△CAUTION△

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

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

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

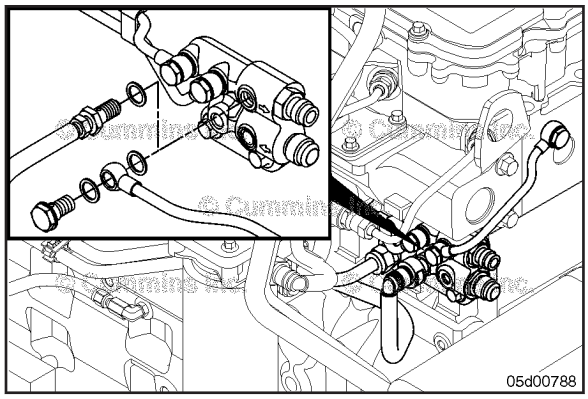


If the injector is **not** fully seated prior to the installation of the high-pressure connector, the joint will **not** seal.

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

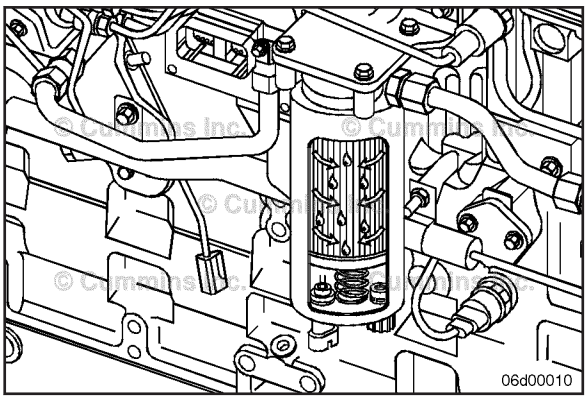
The edge filters are **not** a substitute for cleaning and covering all fuel system connections during repair.

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



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

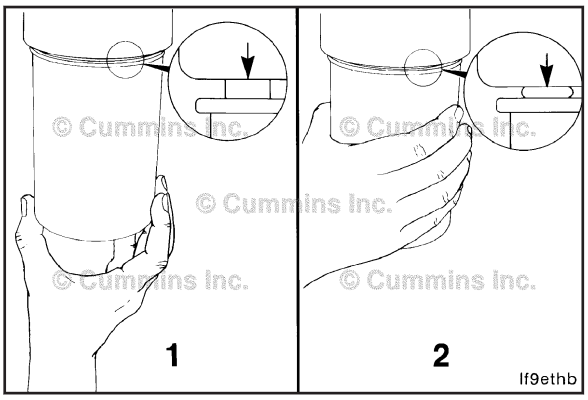
The electronic control module (ECM) controls the fueling and timing of the engine by actuating the injector solenoids. An electronic pulse is sent to the solenoids to lift the needle and start the injection event. By electronically controlling the injectors, there is a more precise and accurate control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



Fuel Filters

The engines covered in this manual require original equipment manufacturers (OEM's) to mount a 10-micron suction filter prior to the OEM fuel supply connection at the rear of the engine block. The 10-micron filter performs water stripping and includes a water-in-fuel sensor. The water-in-fuel sensor **must** be installed. If **not**, a fault code warning lamp will be active.

The engines covered in this manual also include a 2-micron pressure-side fuel filter. The pressure-side filter will be located downstream of the gear pump before the high-pressure fuel pump inlet. If a water-in-fuel fault is experienced, drain the water stripping filter and replace the pressure side fuel filter.



Lubricating Oil System - Overview (007-999)

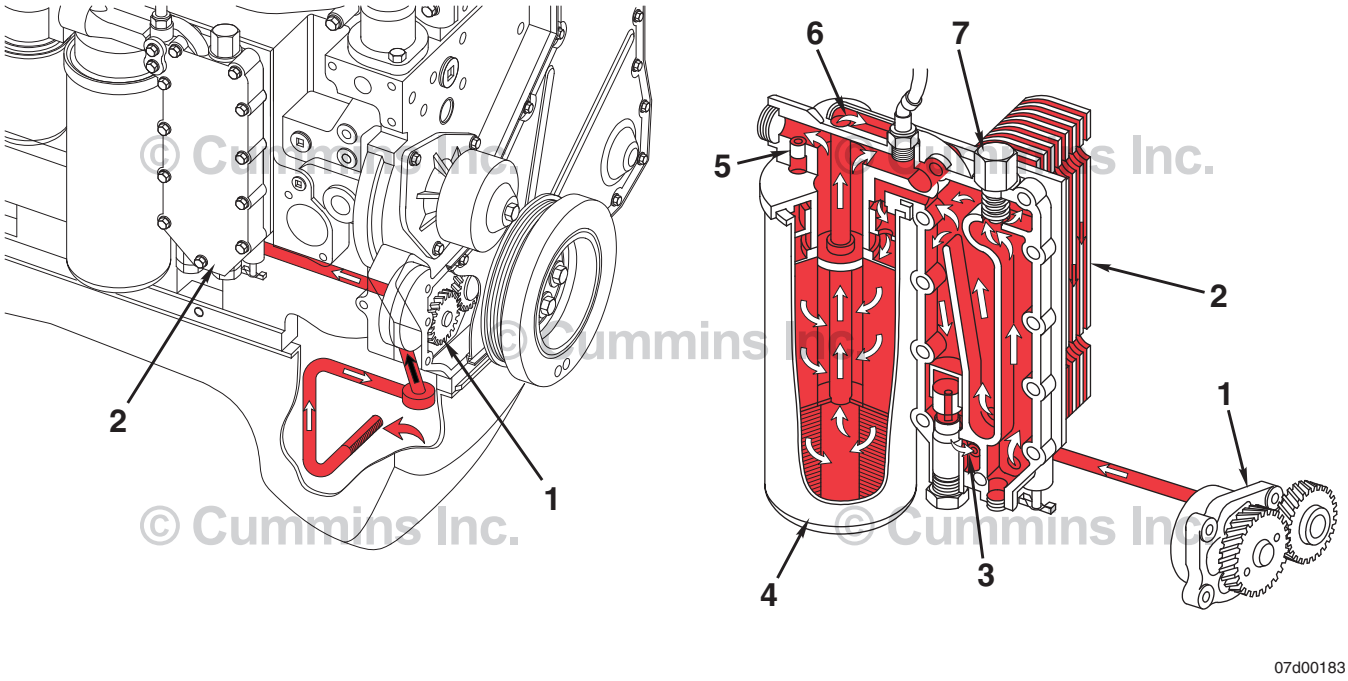
General Information

Lubricating Oil Filters

The LF9009 oil filter is used on all ISC, QSC8.3, ISL, and QSL9 with CM850 engines. This filter is a spin-on element and contains an internal venturi that provides filter bypass oil flow through a stacked disk section of the filter. Lubricating oil filters **must** be of the venturi style. Using a lubricating oil filter without a venturi will result in premature engine wear.

Flow Diagram, Lubricating Oil System (200-002)

General Information



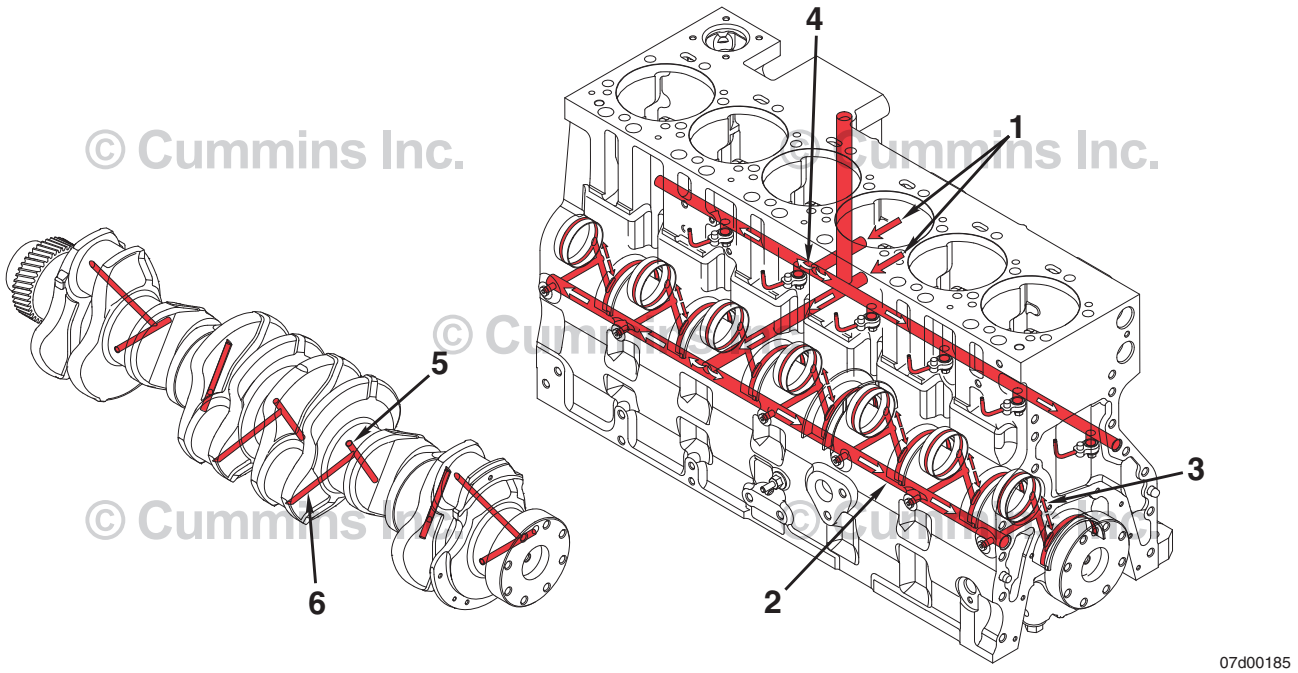
07d00183

Lubricating Oil Cooler Flow

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

Flow Diagram, Lubricating Oil System (200-002)

General Information

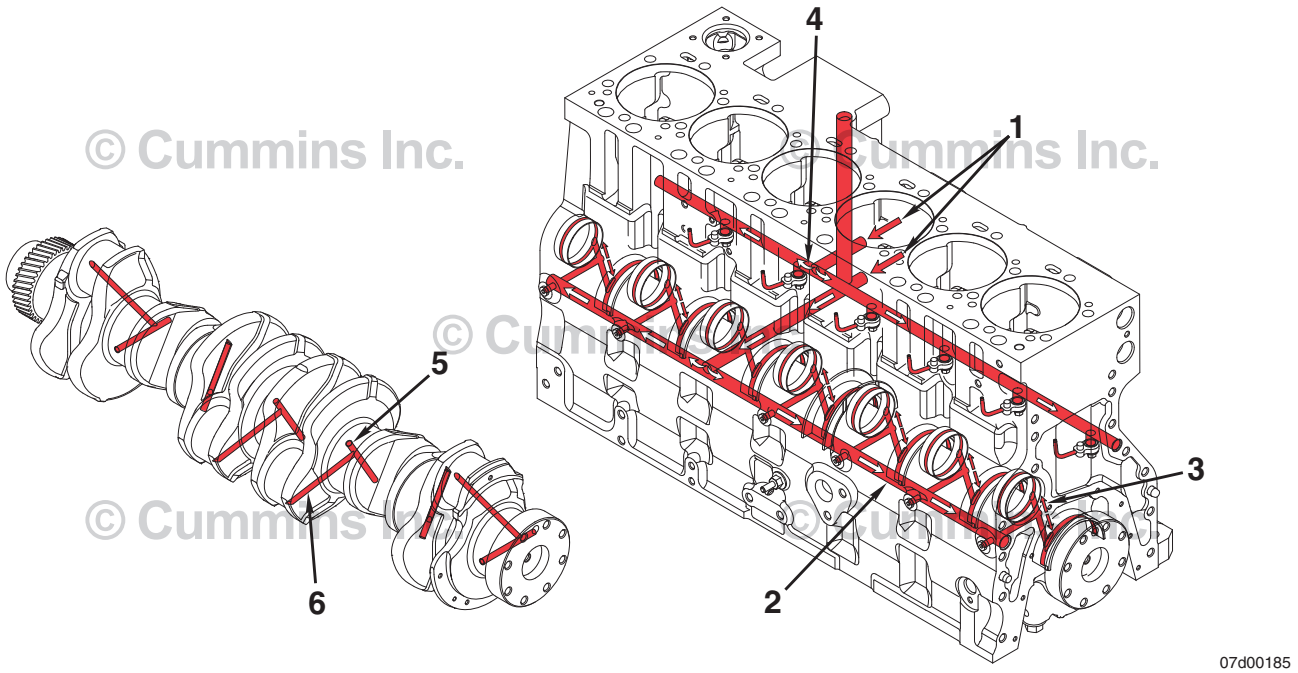


Lubrication for Power Components

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

Flow Diagram, Lubricating Oil System (200-002)

General Information

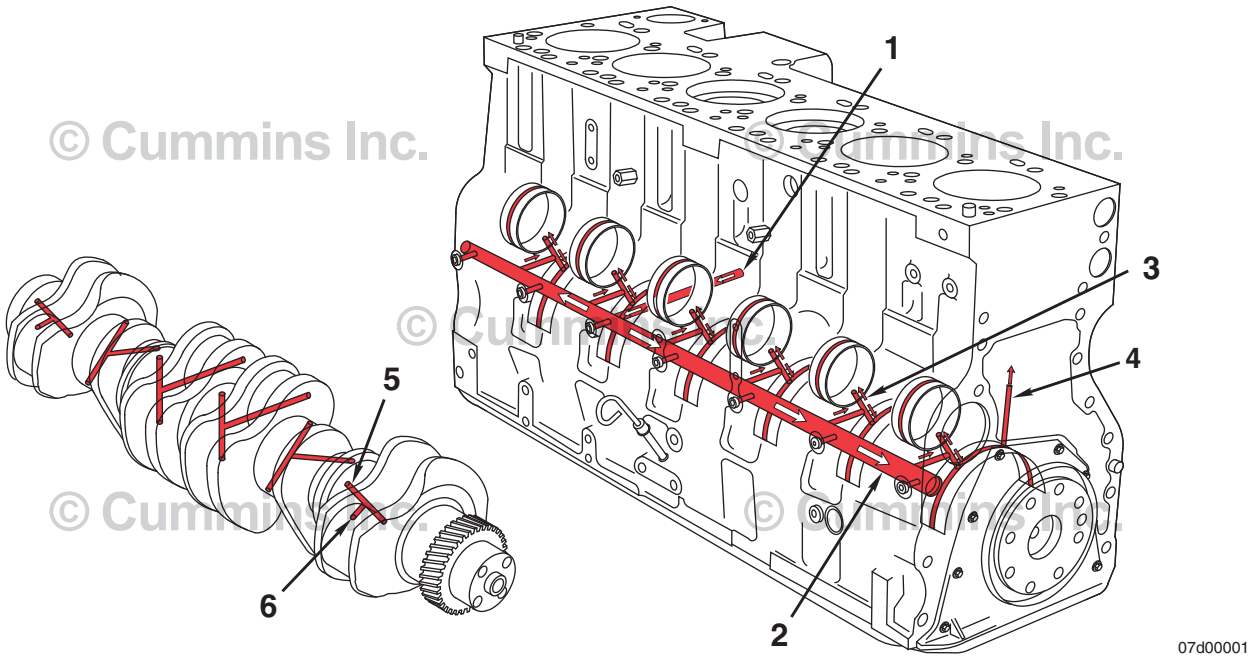


Lubrication for Power Components (All ISL engines and ISC engines with CM850 Electronic Control Module)

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

Flow Diagram, Lubricating Oil System (200-002)

General Information

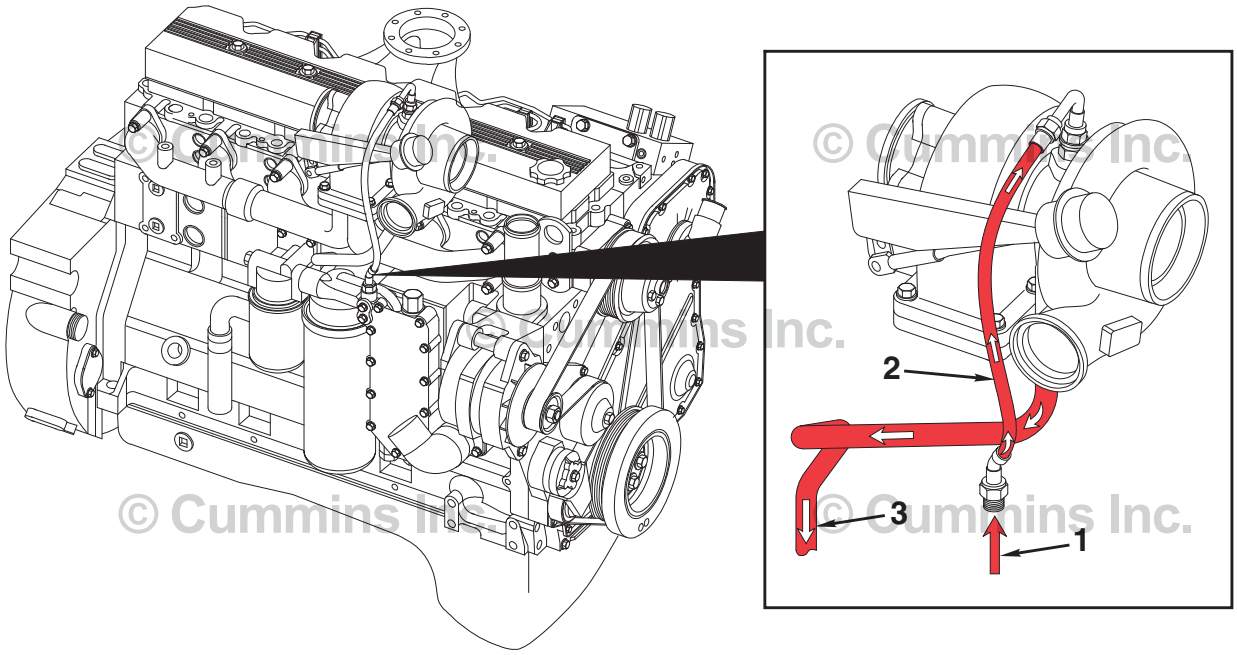


Lubrication for Power Components (ISC engines without CM850 Electronic Control Module)

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

Flow Diagram, Lubricating Oil System (200-002)

General Information



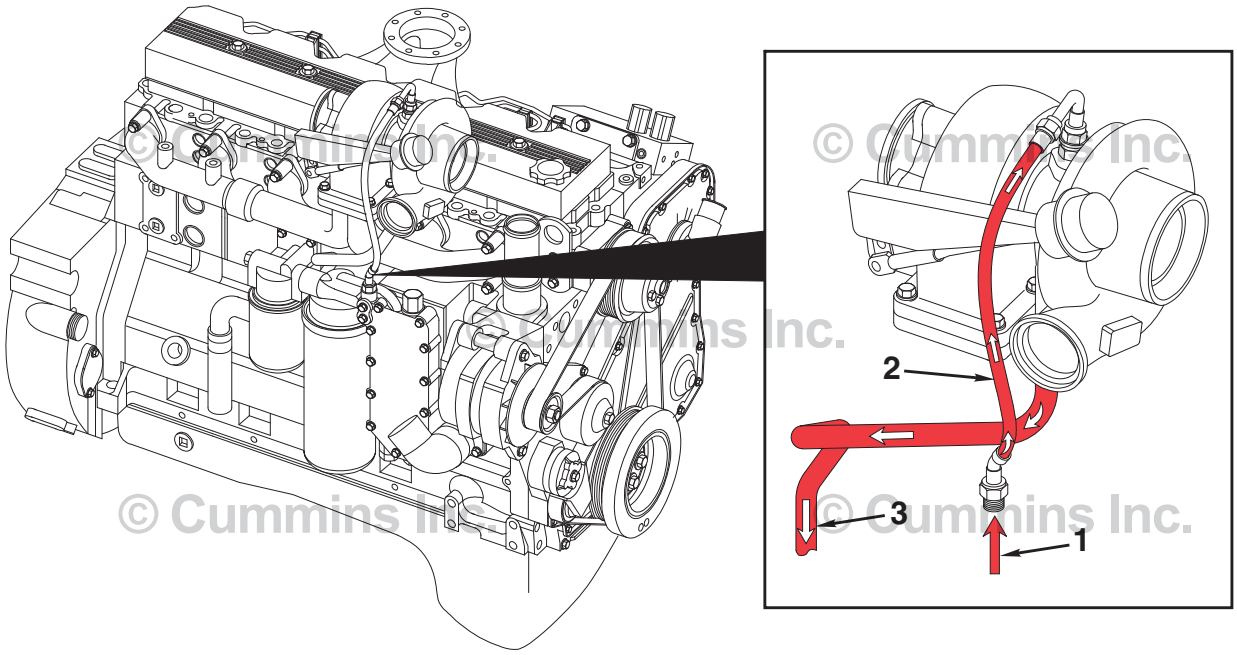
07d00184

Lubrication for Turbocharger (All Applications Except Marine)

1 Lubricating oil supply from filter
2 Turbocharger lubricating oil supply
3 Turbocharger lubricating oil drain

Flow Diagram, Lubricating Oil System (200-002)

General Information



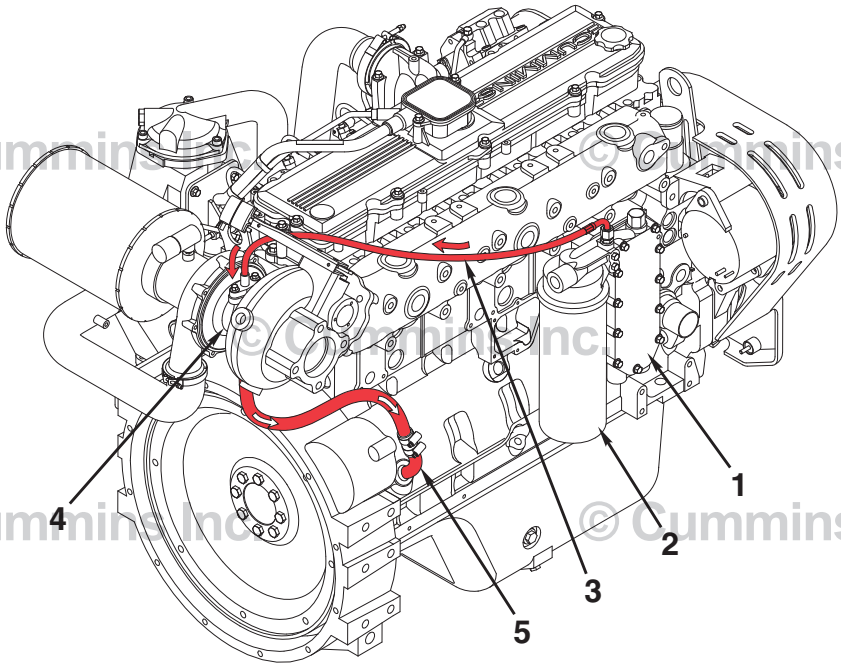
07d00184

Lubrication for Turbocharger

1 Lubricating oil supply from filter
2 Turbocharger lubricating oil supply
3 Turbocharger lubricating oil drain

Flow Diagram, Lubricating Oil System (200-002)

General Information



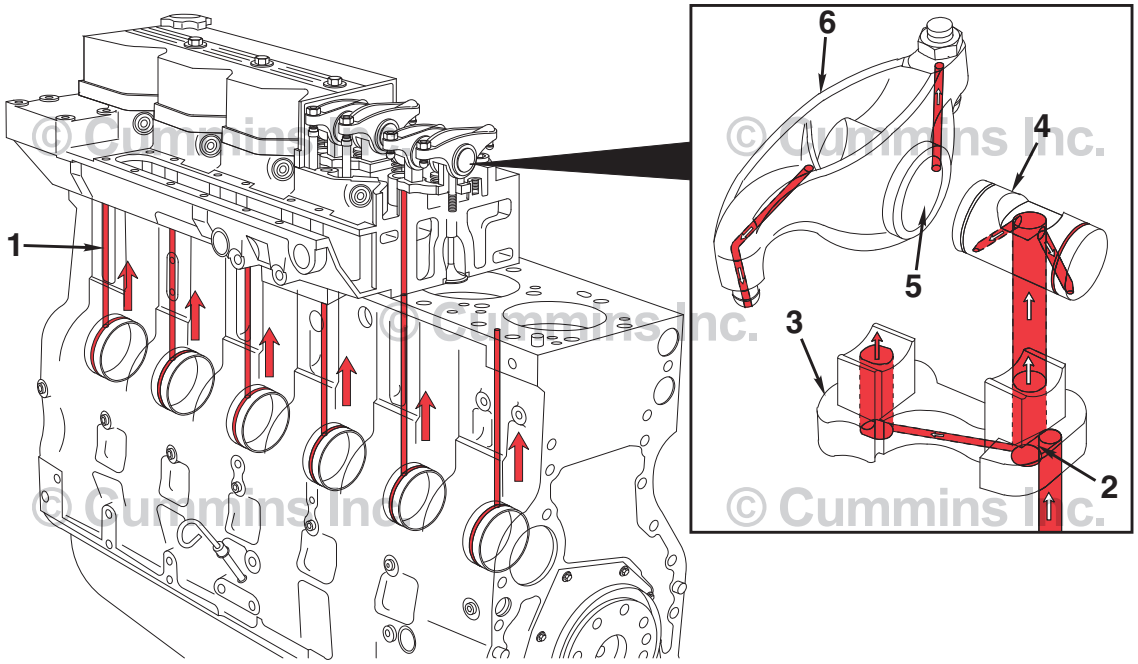
07d00189

Lubrication for Turbocharger (Marine Applications)

1 Lubricating oil cooler
2 Lubricating oil filter
3 Turbocharger lubricating oil supply
4 Turbocharger
5 Turbocharger lubricating oil drain.

Flow Diagram, Lubricating Oil System (200-002)

General Information



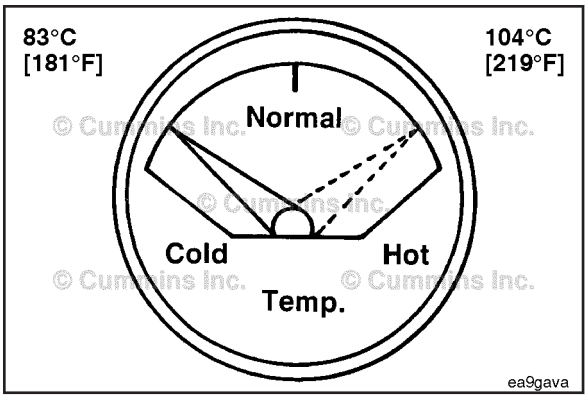
Lubrication for the Overhead

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

Cooling System - Overview (008-999)

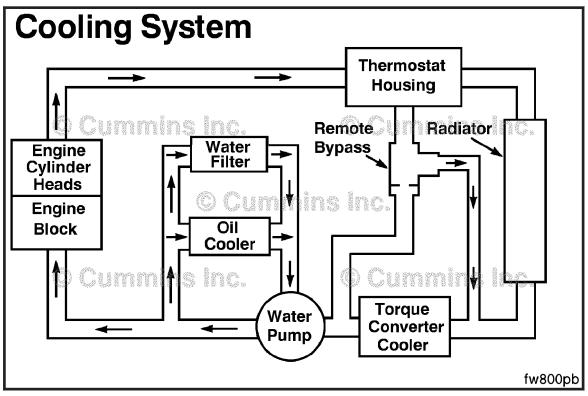
General Information

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



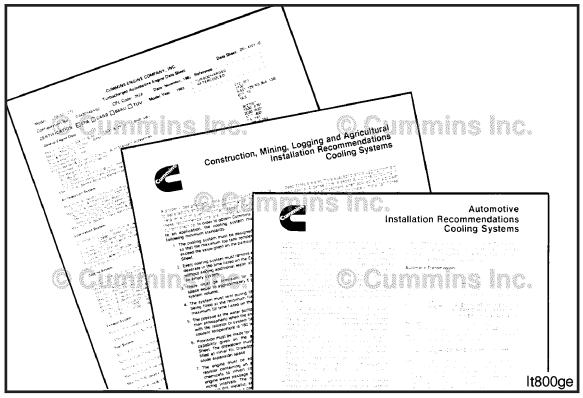
Conventionally cooled engines with automatic transmissions typically use oil-to-water transmission torque converter coolers plumbed between the radiator and the engine water pump.

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

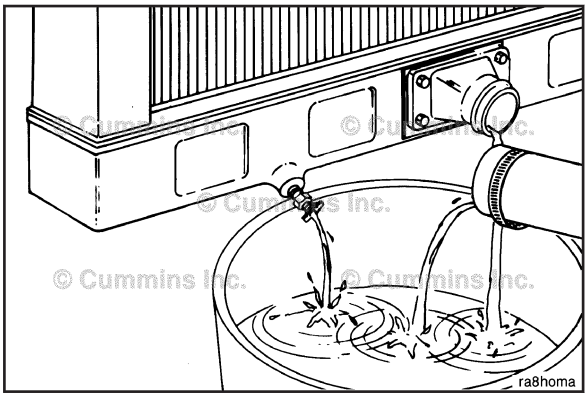


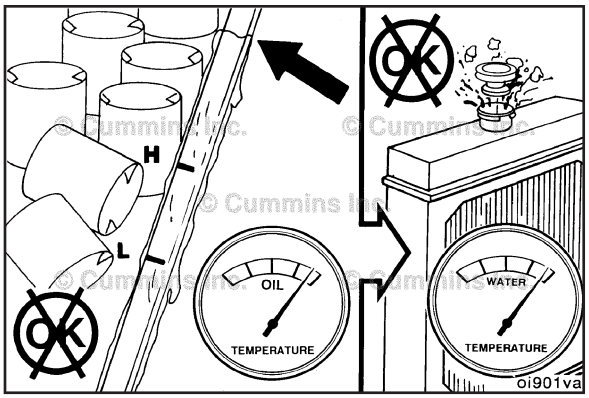
The following publications, available through Cummins Distributors or Cummins Dealers, provide cooling system installation recommendations and specifications approved by Cummins Inc.:

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

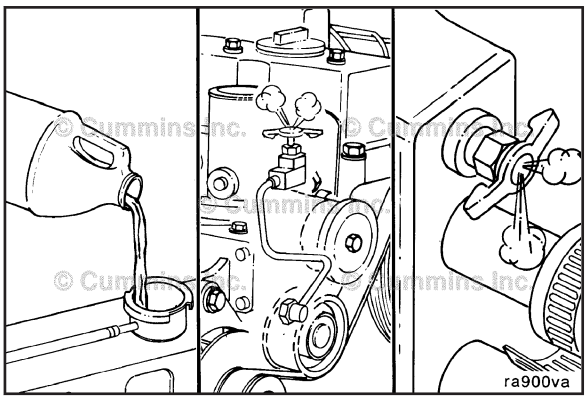


Open the petcocks at the bottom of the radiator and at the bottom of the oil cooler housing. Remove the lower radiator hose. A 20 liter [4 gal] drain pan will contain the coolant in most applications.



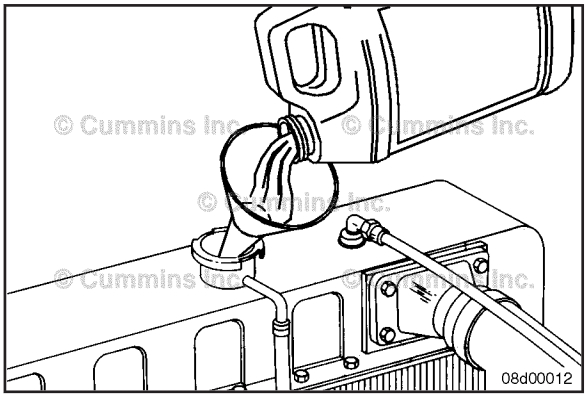


When troubleshooting overheating, remember that too much oil in the oil pan can cause additional heat from friction when the rod journals are submerged in oil. Overfilling with oil raises the oil temperature that is transferred to the cooling system at the oil cooler.

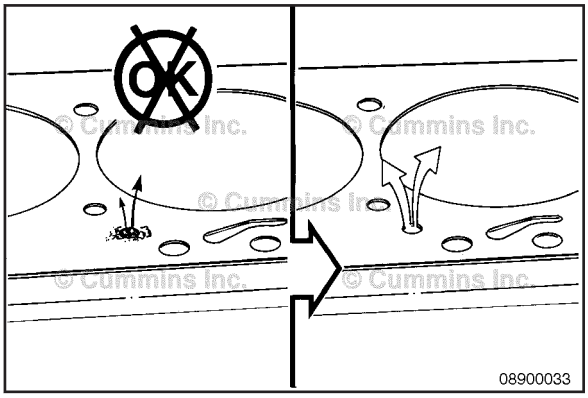


The system is designed to use a specific quantity of coolant. If the coolant level is low, the engine will run hot.

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



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



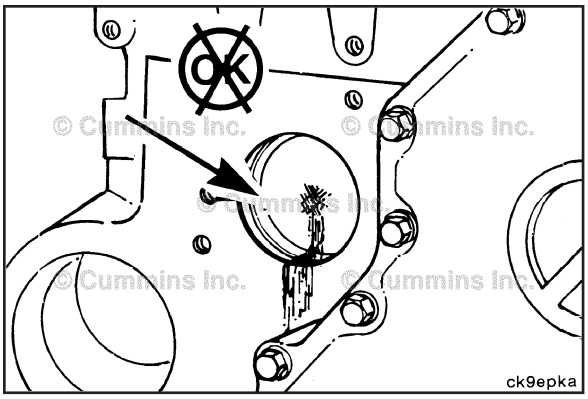
Obstructions in the coolant passages will reduce coolant flow, which can lead to overheating.

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

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

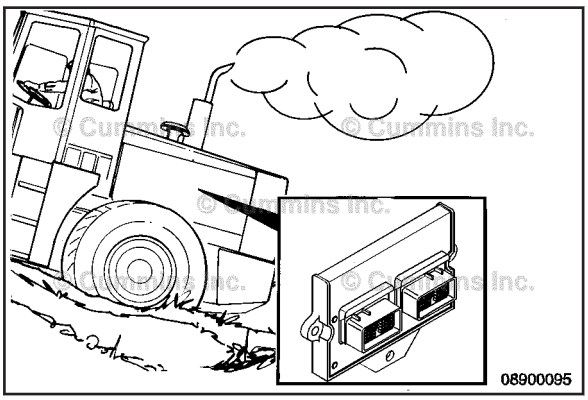
Also, water used as a coolant for even a relatively short period can result in the expansion plugs rusting through, which will allow the coolant to leak.

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

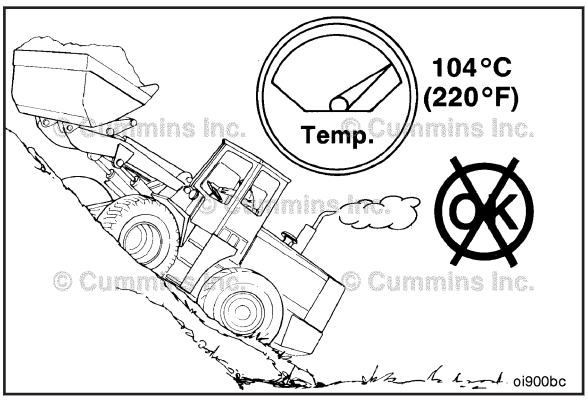


Overfueling and Loading

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

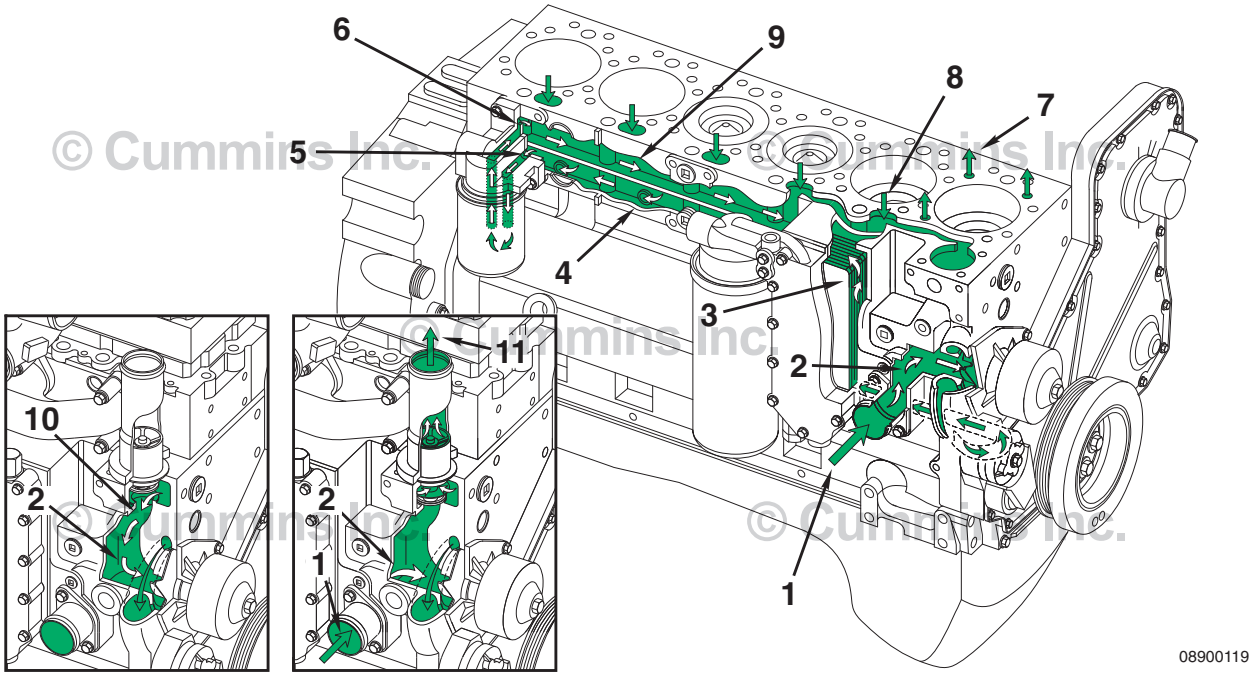


Constant overloading (lugging) can cause the engine to run hot.



Flow Diagram, Cooling System (200-003)

General Information



Internal Engine Coolant Flow, All Applications

⚠CAUTION⚠

Never operate the engine without a thermostat. Without a thermostat, the coolant will not flow to the radiator, and the engine will overheat.

NOTE: The thermostat flow shown is **not** for QSL9 keel cooled engines. On QSL9 keel cooled marine engines, the thermostat is located in the keel cooled thermostat housing. See flow diagram below.

1 Coolant inlet from radiator

2 Water pump suction

3 Coolant flow through lubricating oil cooler

4 Block lower water manifold (to cylinders)

5 Coolant filter inlet (optional)

6 Coolant filter outlet (optional)

7 Coolant supply to cylinder head

8 Coolant return from cylinder head

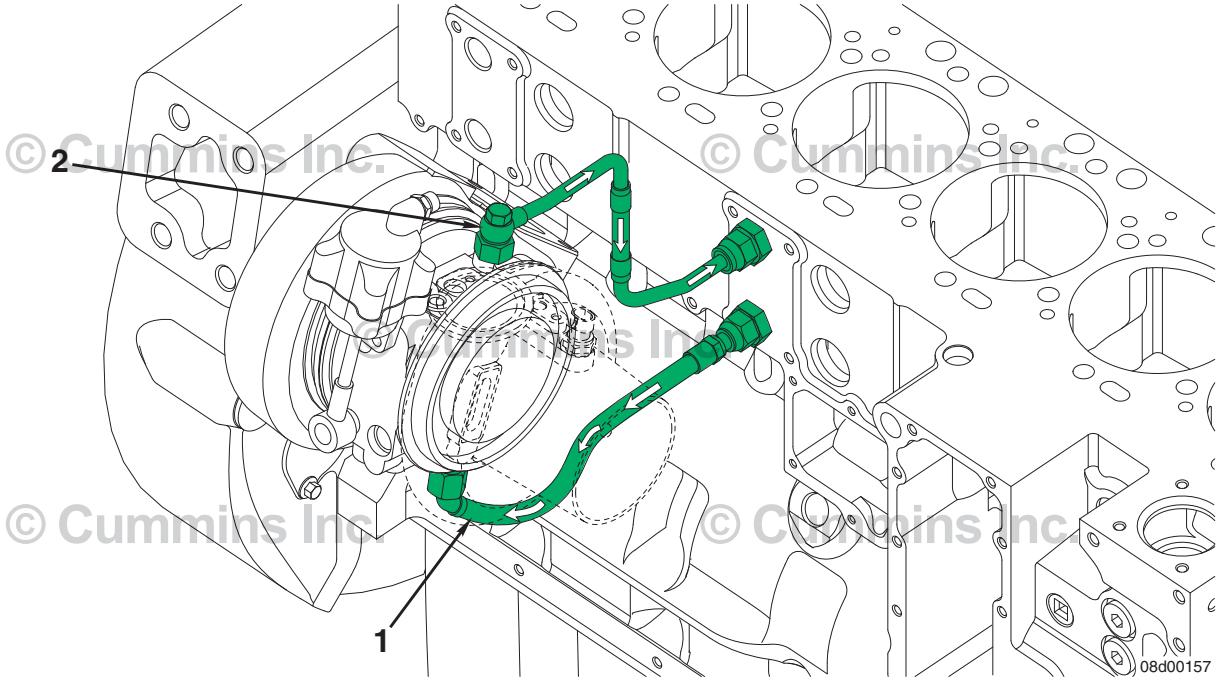
9 Block upper water manifold

10 Thermostat bypass

11 Coolant return to radiator

Flow Diagram, Cooling System (200-003)

General Information



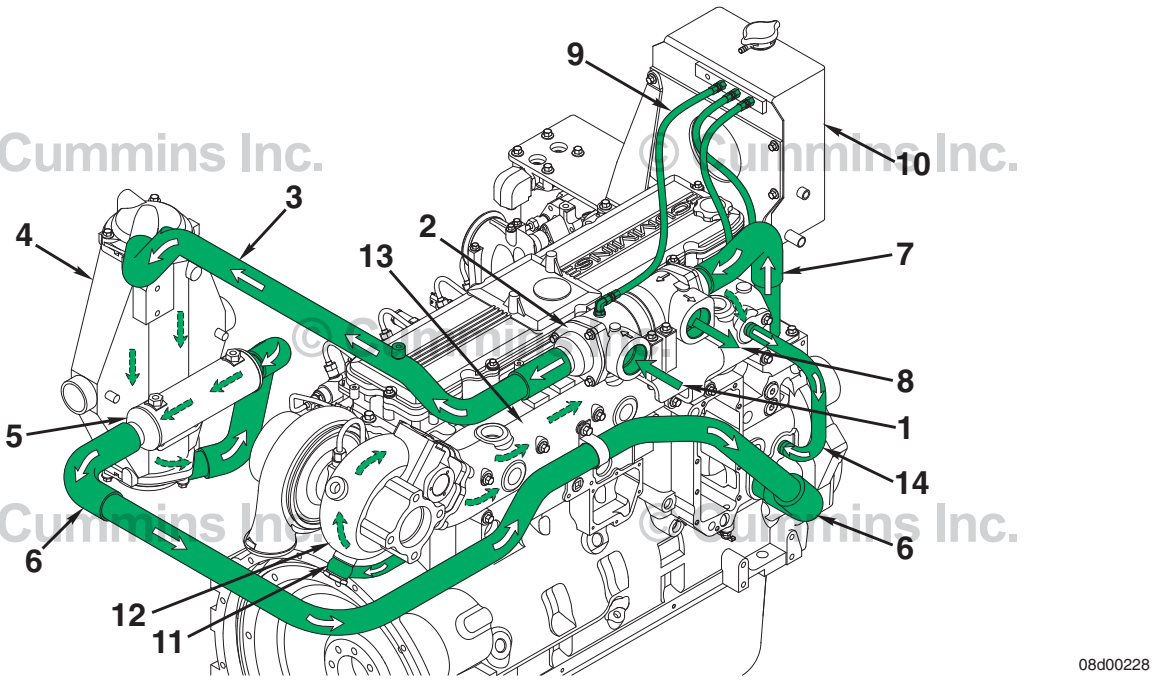
All Applications

1 Turbocharger coolant supply

2 Turbocharger coolant drain

Flow Diagram, Cooling System (200-003)

General Information

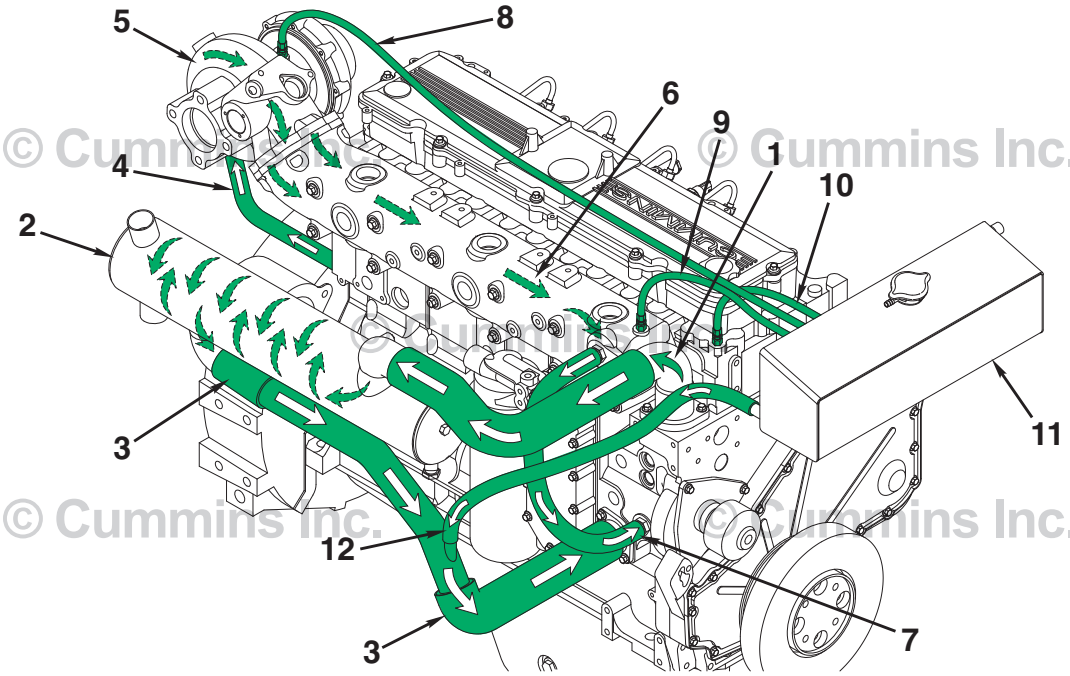


QSL9 with Keel Cooled (Engine Coolant)

1 Engine coolant return from keel cooler
2 Keel cooler thermostat housing
3 Engine coolant to aftercooler
4 Aftercooler
5 Engine coolant through marine gear oil cooler
6 Engine coolant to water pump
7 Engine discharge to keel cooler thermostat
8 Engine coolant to keel cooler
9 Cooling system housing vent line
10 Expansion tank
11 Engine coolant from engine to turbocharger
12 Turbocharger turbine housing
13 Exhaust manifold
14 Engine coolant return from exhaust manifold to water pump.

Flow Diagram, Cooling System (200-003)

General Information

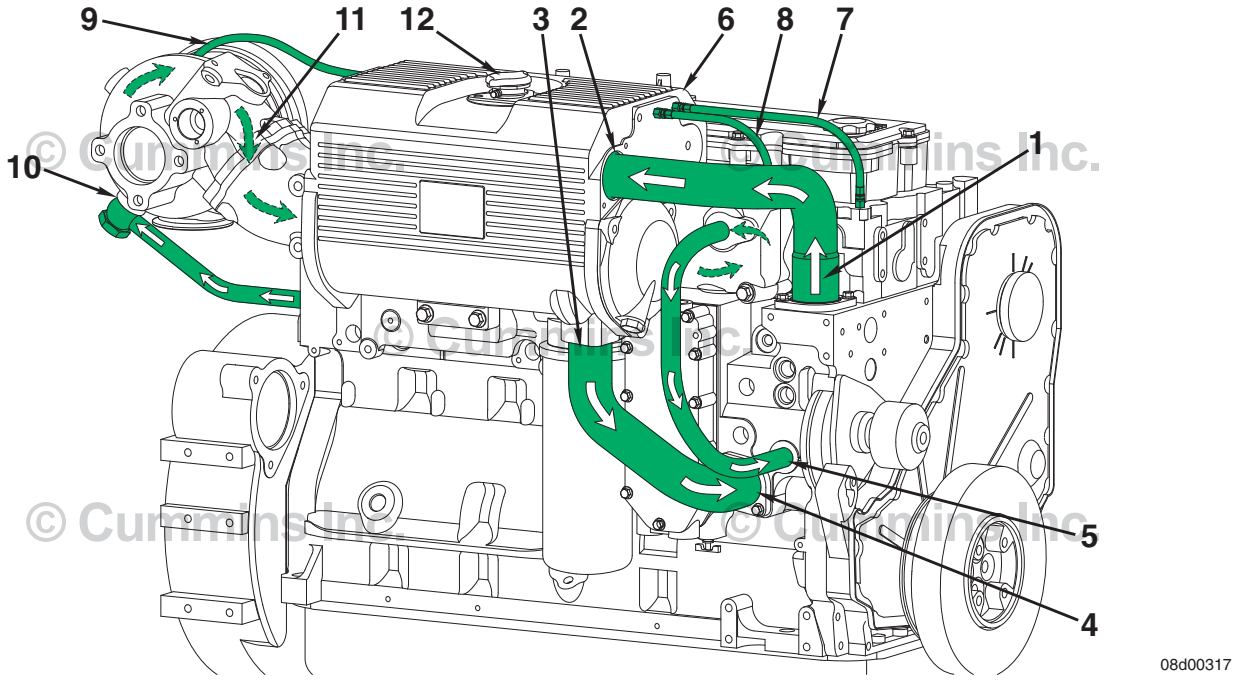


QSL9 with Heat Exchanger (Engine Coolant)

1 Coolant from thermostat to heat exchanger
2 Heat exchanger
3 Coolant return from heat exchanger to water pump
4 Turbocharger coolant supply from cylinder block
5 Turbocharger with water cooled turbine housing
6 Water cooled exhaust manifold
7 Coolant return from exhaust manifold to water pump
8 Turbocharger coolant vent line
9 Exhaust manifold coolant vent line
10 Cylinder head coolant vent line
11 Expansion tank
12 Coolant makeup to water pump from expansion tank.

Flow Diagram, Cooling System (200-003)

General Information

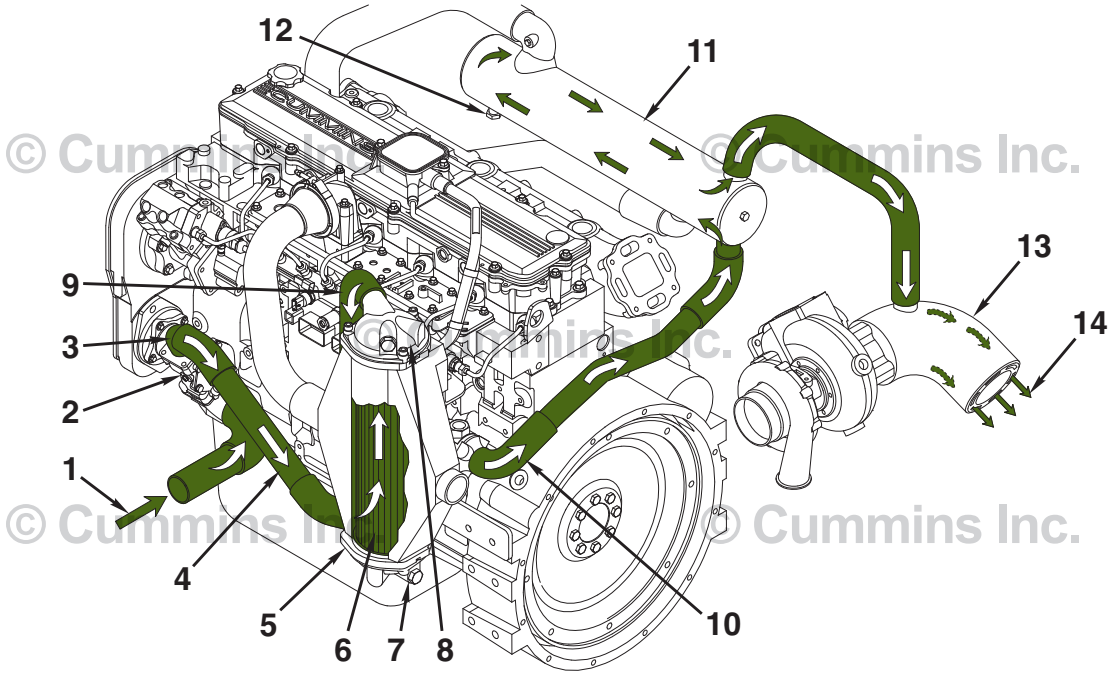


QSC8.3 Engine Coolant

1 Coolant from thermostat
2 Heat exchanger coolant inlet
3 Heat exchanger coolant outlet
4 Water pump coolant inlet from heat exchanger
5 Water pump coolant inlet from exhaust manifold
6 Expansion tank
7 Coolant vent line from cylinder head to expansion tank
8 Coolant vent line from exhaust manifold to expansion tank
9 Coolant vent line from turbocharger to expansion tank
10 Turbocharger coolant inlet from cylinder block
11 Coolant from turbocharger to exhaust manifold
12 Expansion tank fill cap.

Flow Diagram, Cooling System (200-003)

General Information

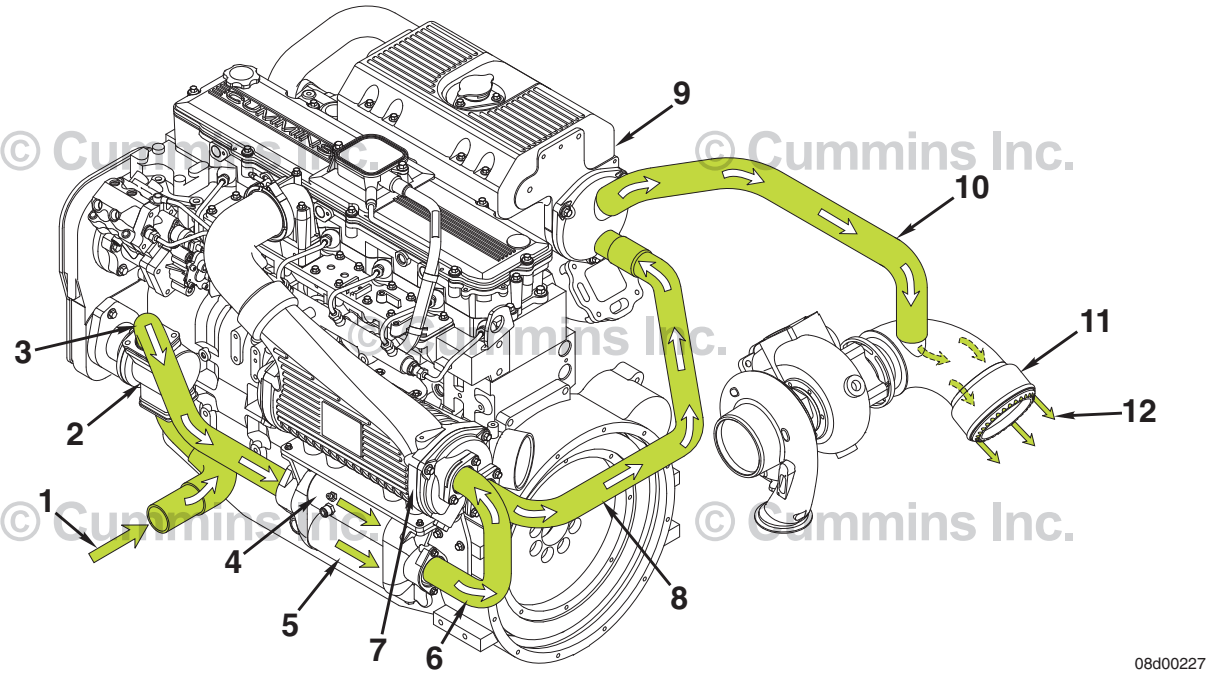


QSL9 Sea Water Cooled (Heat Exchanger), Marine Applications

1 Sea water pump inlet
2 Sea water pump
3 Sea water pump discharge to fuel cooler
4 Fuel cooler
5 Aftercooler sea water inlet
6 Aftercooler
7 Aftercooler lower zinc anode
8 Aftercooler upper zinc anode
9 Aftercooler sea water outlet to marine gear oil cooler
10 Marine gear oil cooler sea water outlet to heat exchanger
11 Heat exchanger
12 Heat exchanger zinc anode
13 Exhaust elbow
14 Sea water discharge.

Flow Diagram, Cooling System (200-003)

General Information



QSC8.3 Sea Water Cooled (Heat Exchanger), Marine Applications

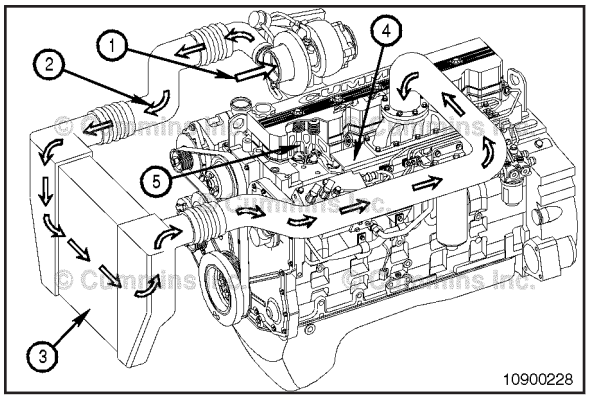
1 Sea water pump inlet
2 Sea water pump
3 Sea water pump discharge to combination marine gear oil and fuel cooler
4 Fuel cooler
5 Marine gear oil cooler
6 Combination marine gear oil cooler and fuel cooler discharge to aftercooler inlet
7 Aftercooler
8 Aftercooler discharge to heat exchanger
9 Heat exchanger/expansion tank assembly
10 Heater exchanger discharge to exhaust elbow
11 Exhaust elbow
12 Sea water discharge.

Air Intake System - Overview (010-999)

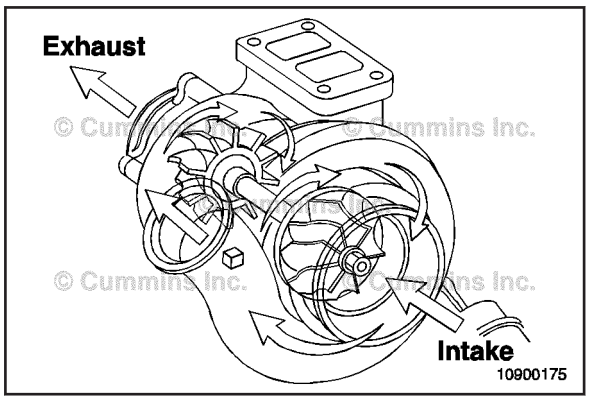
General Information

The combustion air system on the engine consists of an air cleaner, intake air piping, turbocharger, charge-air piping, charge-air cooler, and intake air heater.

Air is drawn through the air cleaner and into the compressor side of the turbocharger (1). It is then forced through the charge-air cooler piping (2), to the charge-air cooler (3), the intake air heater (if applicable), and into the intake manifold (4). From the intake manifold, air is forced into the cylinders (5) and used for combustion.

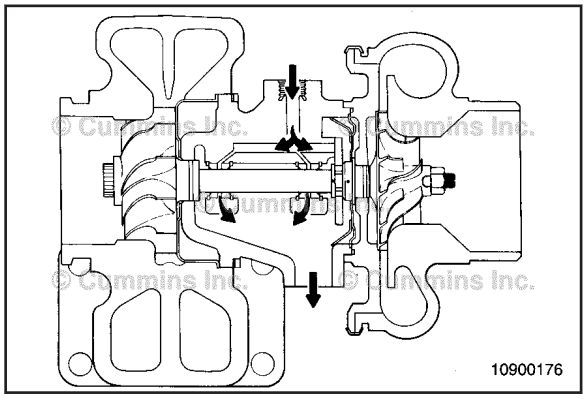


The turbocharger uses exhaust gas energy to turn the turbine wheel. The turbine wheel drives the compressor impeller that provides pressurized air to the engine for combustion. The additional air provided by the turbocharger allows more fuel to be injected to increase the power output from the engine.



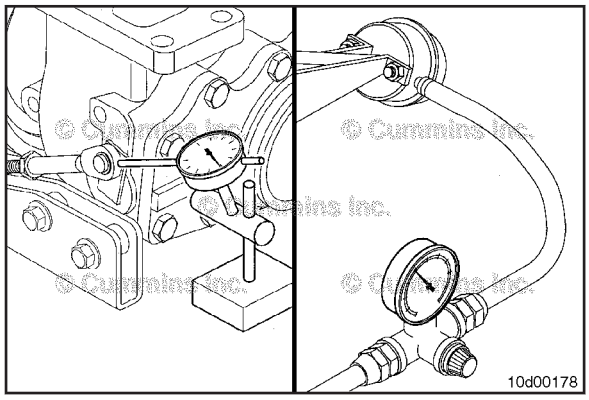
The turbine, compressor wheels, and shaft are supported by two rotating bearings in the bearing housing. Passages in the bearing housing direct filtered, pressurized engine oil to the shaft bearings and thrust bearings. The oil is used to lubricate and cool the rotating components. Oil then drains from the bearing housing to the engine sump, through the oil drain line.

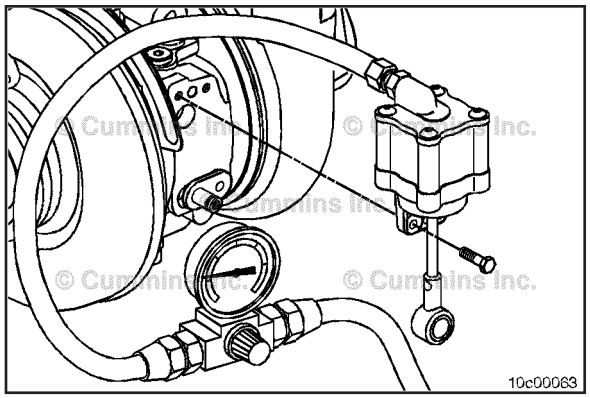
An adequate supply of good, filtered oil is very important to the life of the turbocharger. Make sure a high-quality oil is used and that the oil and the oil filter are changed according to maintenance recommendations.



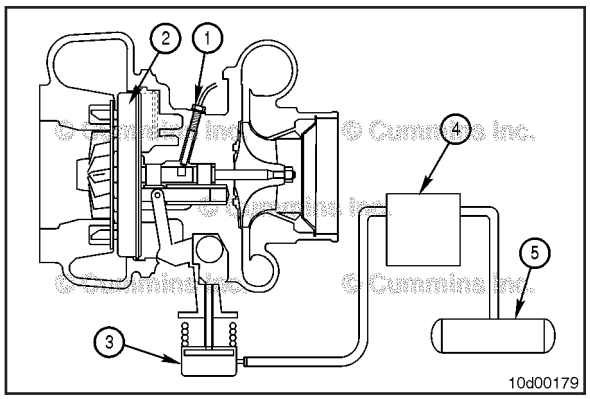
Wastegated turbochargers are used to optimize performance. The wastegated design allows maximum boost to be developed quickly, while making sure that the turbocharger does **not** overspeed at higher engine rpm.

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.



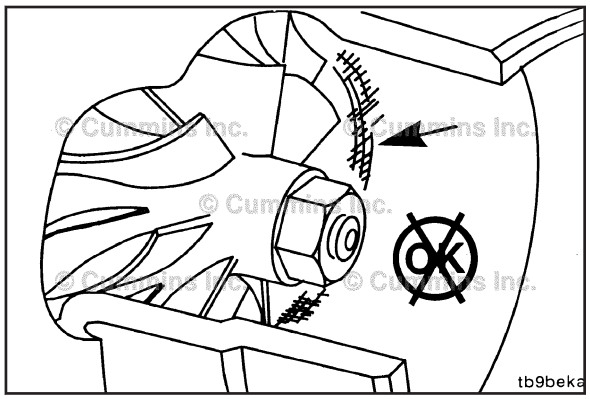


Variable geometry turbocharger (VGT) is used to improve engine performance by building boost more quickly during acceleration or transient conditions. A VGT does **not** use a wastegate actuator. A pneumatic or electric actuator is used to vary the turbine exit area. By closing the variable geometry nozzle (reducing the turbine exit area), turbocharger speeds are increased and boost pressure increases more rapidly. By opening the variable geometry nozzle (increasing the turbine exit area), turbocharger speeds are lower and less boost pressure is produced.



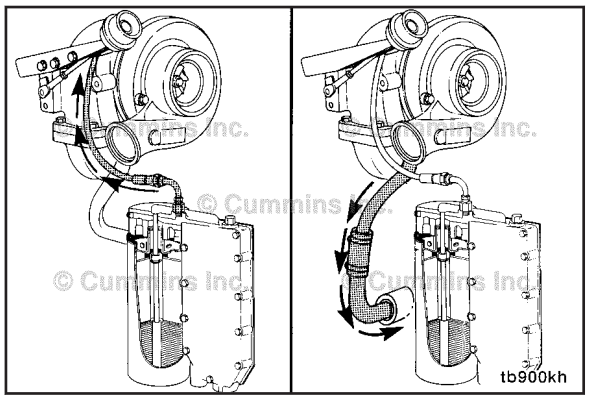
The VGT functions as a standard turbocharger with the addition of the following:

- A speed sensor (1) in the bearing housing to monitor turbocharger operation
- Water-cooled bearing housings (in addition to oil lubrication)
- The sliding nozzle (2) is actuated by a pneumatic actuator attached to the vehicle (brake) air supply system
- The pneumatic actuator (3) operated by an air control valve (4) and receives air from the air supply tank (5)
- When the VGT mechanism opens, a noise can be heard as air is released from the actuator (3) through the control valve (4).



Failure of the internal components of a malfunctioning turbocharger can reduce its effectiveness and also cause excessive smoke and low power. A bearing failure can produce friction that will slow the speed of the rotor assembly. Failed bearings can also allow the blades of the rotor assembly to rub the housings, thus reducing the rotor assembly speed.

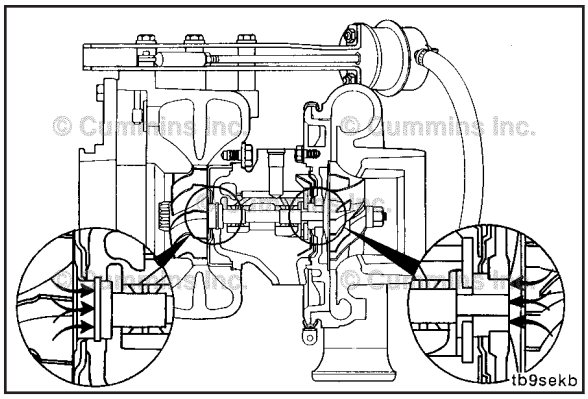
A malfunctioning turbocharger wastegate , VGT actuator, VGT actuator controller, or miscalibration of the turbocharger wastegate can result in excessively high or low boost pressures. Low boost pressures can cause excessive smoke and low power. High boost pressures can cause major engine damage.



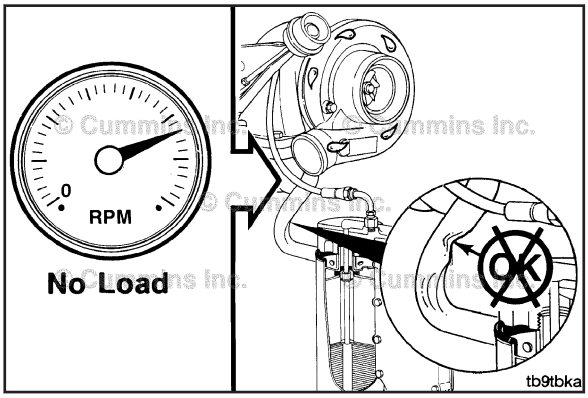
Engine lubricating oil is used to lubricate the bearings and provide some cooling for the turbocharger. The lubricating oil supplied to the turbocharger through the supply line is at engine operating pressure. A return line connected to the bottom of the turbocharger routes the lubricating oil back to 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 it can occur.

Excessive crankcase pressure can prevent oil from draining to the oil pan. This can load the bearing housing and cause lubricating oil to leak past the compressor seals and into the engine.

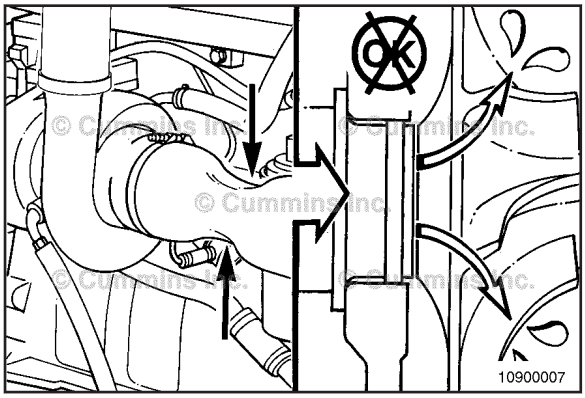


A restricted or damaged lubricating oil return line will cause the turbocharger housing to be pressurized, causing lubricating oil to migrate past the seals.



Additionally, high intake or exhaust restrictions can cause a vacuum between the compressor and the turbocharger housing, resulting in oil leaking past the seals.

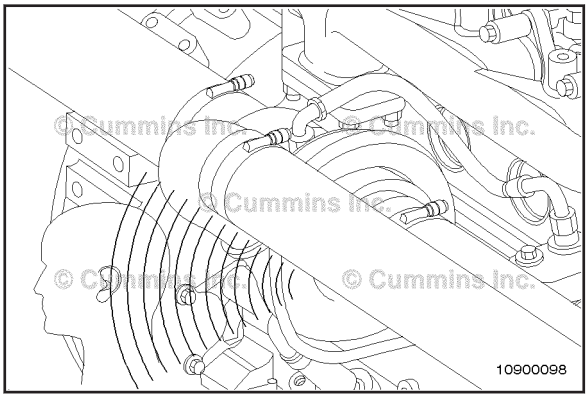
If oil leaks past the compressor housing seal, it is necessary to flush the charge air cooler to clean oil from the intake system. Refer to Procedure 010-027 in Section 10. Refer to Procedure 010-033 in Section 10.

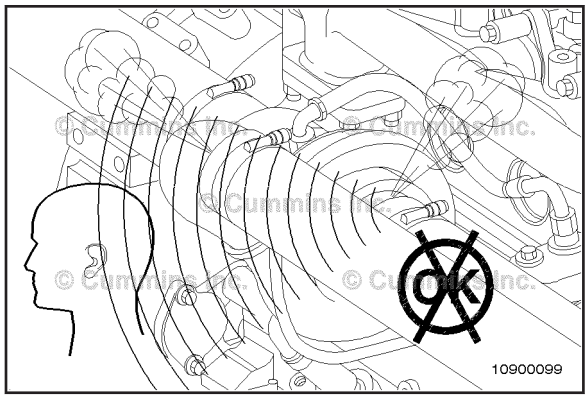


It is normal for the turbocharger to emit a whining sound that varies in intensity depending on engine speed and load. The sound is caused by the very high rotational speed of the rotor assembly and the method used to balance the rotor assembly during manufacturing. Consequently, the sound will be louder at full speed.

If possible, operate the engine at full speed to verify the noise level.

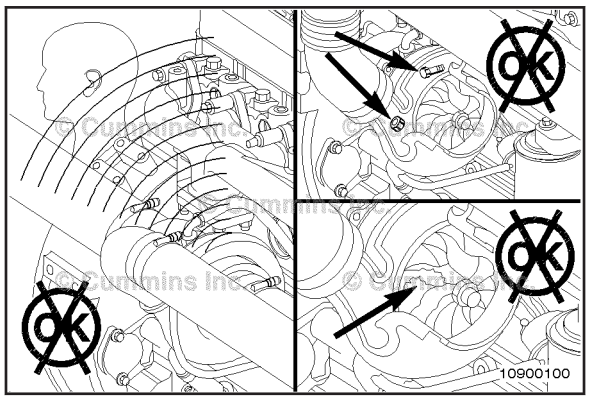
VGTs can also emit a snorting or chuffing sound when the turbocharger operates under certain conditions. An example of this is when the turbocharger is at high speed and the throttle is rapidly closed. These sounds are normal and do **not** cause damage to or decrease the life of the turbocharger.





Leaks in the air system intake and/or exhaust components can produce excessive engine noise. Leak noise is typically a high pitched whine or sucking sound.

Check for leaks in the intake and exhaust system. Check to make sure all hose clamps are tight. Refer to Procedure 010-024 in Section 10.

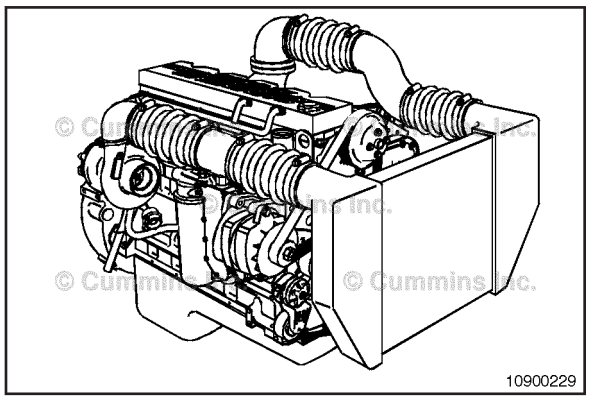


Lower pitched sounds or rattles at lower engine speeds can indicate debris in the system or that the rotor assembly is touching the housings.

Remove the turbocharger inlet and check for foreign objects.

If suspect, check for turbocharger blade damage and bearing clearance. Refer to Procedure 010-033 in Section 10.

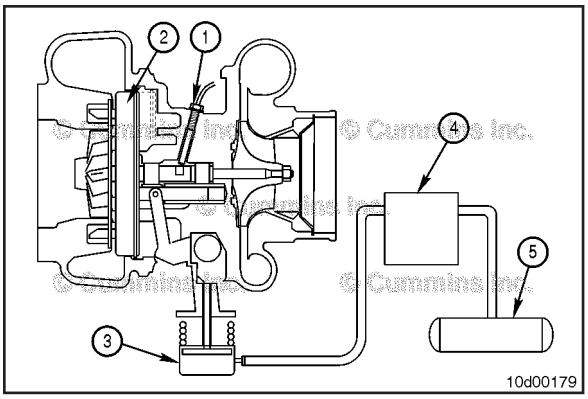
If leaks, blade damage, or improper clearances are found, replace the turbocharger. Refer to Procedure 010-033 in Section 10.



Automotive engines use 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, then returns the air from the charge-air cooler to the engine intake manifold.

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

All ISL with CM850 engines utilize a VGT to improve engine performance by building boost more quickly during acceleration or transient conditions. A pneumatic actuator is used to vary the turbine exit area allowing various boost levels based on performance needs. By closing the variable geometry nozzle (reducing turbine exit area), turbocharger speeds are increased and boost pressure increases more rapidly. By opening the variable geometry nozzle (increasing the turbine exit area), turbocharger speeds are lower and less boost pressure is produced.



The VGT functions as a standard turbocharger with the addition of the following:

- A speed sensor (1) in the bearing housing to monitor turbocharger operation
- The sliding nozzle (2) is activated by a pneumatic actuator attached to the vehicle (brake) air supply system
- The pneumatic actuator (3) operated by an air control valve (4) and receives air from the supply tank (5)
- When the VGT mechanism opens, a noise can be heard as the air is released from the actuator (3) through the control valve (4)
- Water-cooled bearing housing in addition to oil lubrication.

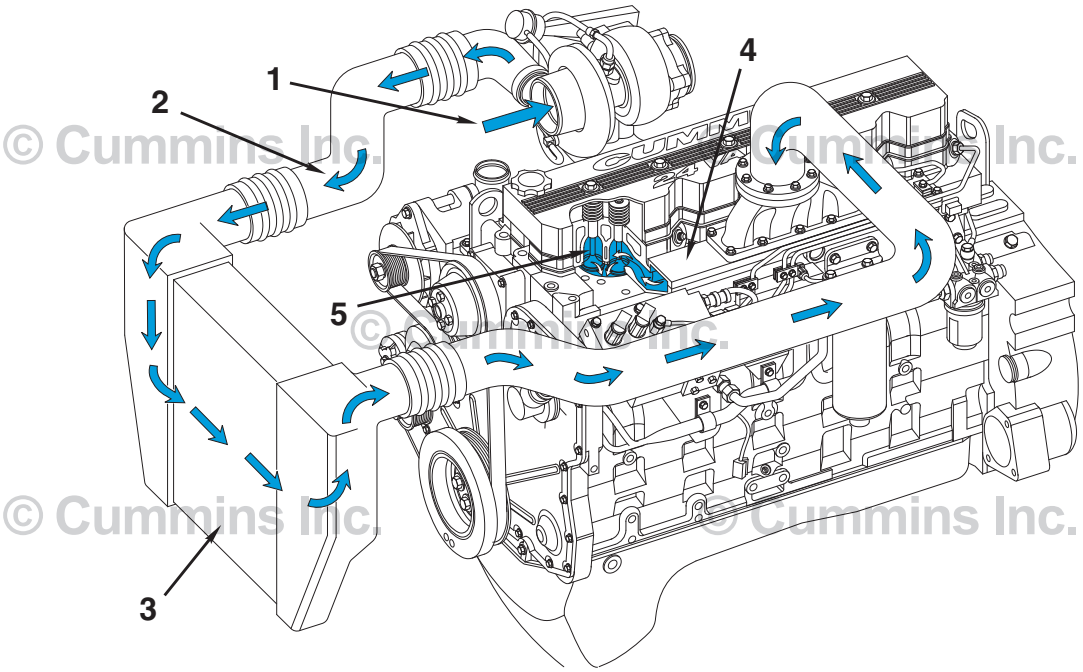
It is normal for the turbocharger to emit a whining sound that varies in intensity depending on engine speed and load. The sound is caused by the very high rotational speed of the rotor assembly and the method used to balance the rotor assembly during manufacturing. Consequently, the sound will be louder at full speed. Also, the pneumatic actuator can emit a slight air leak at key-on position.

The VGT control valve modulates air pressure to the variable geometry actuator. The engine control module (ECM) sends a pulse width modulated signal to the turbocharger control valve to control the VGT. As the signal increases, more air pressure is applied to the variable geometry actuator. Conversely, when the signal decreases, less air pressure is applied to the variable geometry actuator. The turbocharger control valve has both low and high voltage fault codes.

All ISC, QSC8.3, and QSL9 with CM850 engines utilize a Holset® wastegated turbocharger. The wastegate is pneumatically controlled by intake manifold pressure and factory calibrated. The wastegates are **not** adjustable in the field.

Flow Diagram, Air Intake System (200-004)

General Information

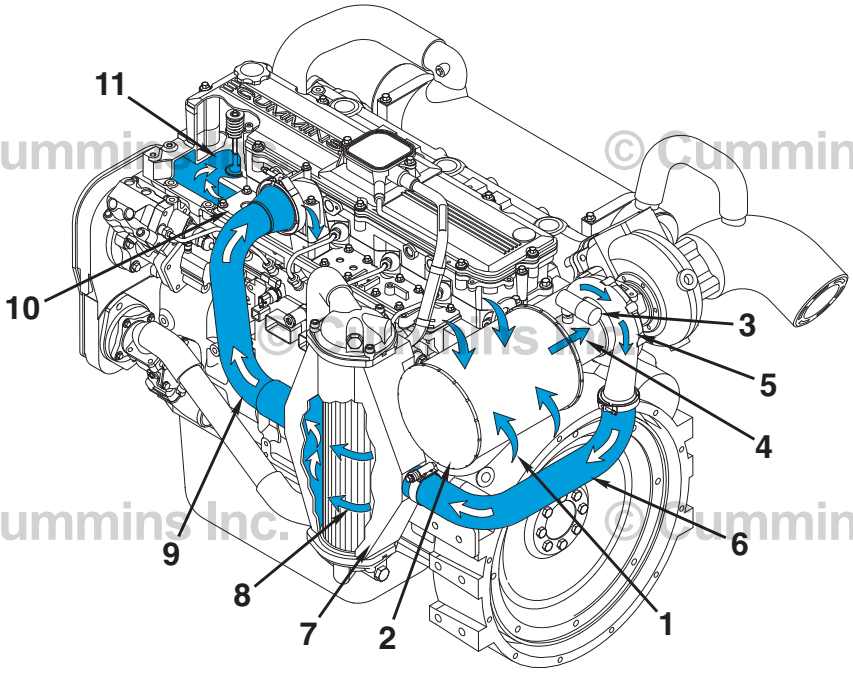


Charge Air Cooled Engines

1 Intake Air Inlet to Turbocharger
2 Turbocharger Air to Charge Air Cooler
3 Charge Air Cooler
4 Intake Manifold (integral part of cylinder head)
5 Intake Valve.

Flow Diagram, Air Intake System (200-004)

General Information



10d00192

QSC8.3 and QSL9 Marine Aftercooled Engines

NOTE: The graphic above is the QSL9 engine configuration. The aftercooler on the QSC8.3 engine mounts to the engine differently, but the air flow from the air inlet to the combustion chamber is the same.

1 Air inlet to air filter

2 Air filter assembly

3 Intake air restriction indicator

4 Air inlet to turbocharger compressor

5 Turbocharger compressor discharge

6 Air discharge from turbocharger compressor to aftercooler inlet

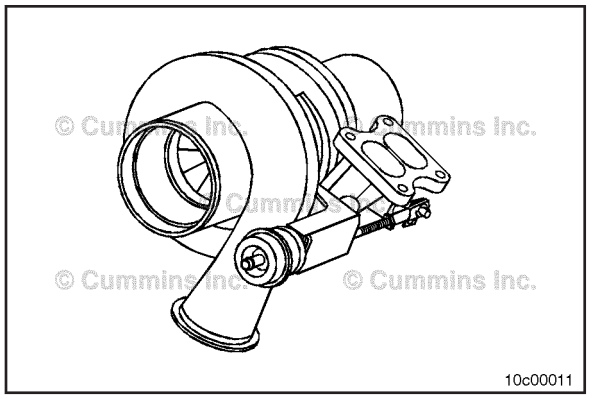
7 Aftercooler air inlet

8 Aftercooler

9 Air discharge from aftercooler to intake manifold

10 Air manifold

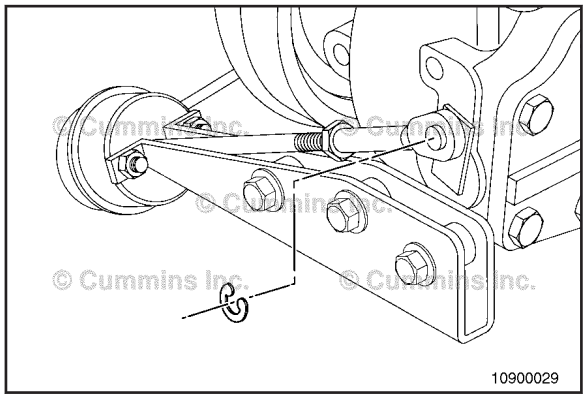
11 Intake valve.



Exhaust System - Overview (011-999)

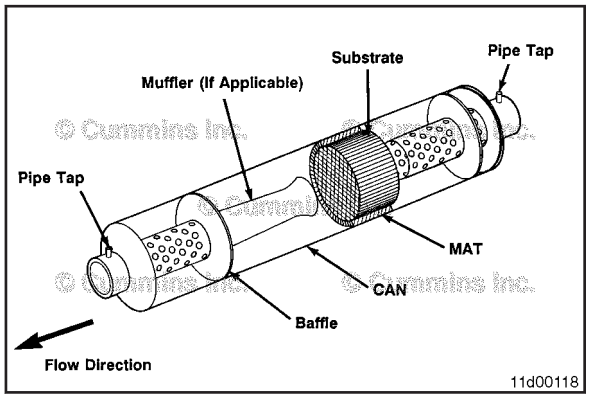
General Information

The wastegated turbocharger is a Holset® Model HX40. It is comprised of a turbocharger, wastegate actuator, and wastegate valve in the turbine housing. A wastegated turbocharger provides improved response at low engine speeds without sacrificing turbocharger durability at high speeds. This is accomplished by allowing the exhaust gases to bypass the turbine wheel during certain modes of engine operation. During low rpm operation, the turbocharger operates as a closed-system turbocharger where the energy of the gas is transferred to the compressor wheel and used to compress intake air. During high rpm operation however, the turbocharger becomes an open-system turbocharger and allows exhaust gas to bypass the turbine. Since the exhaust gas is gated around the turbine wheel, less energy is absorbed through the turbine and transferred to the compressor, reducing the intake manifold pressures and turbine speeds.



The wastegate actuator is mounted on the turbocharger and consists of a pressure canister, diaphragm, and rod. As the pressure changes in the canister, as dictated by the wastegate controller, the actuator rod adjusts the wastegate valve accordingly.

The wastegate valve is mounted inside the turbocharger in the turbine housing. As the valve opens, exhaust gas is allowed to bypass the turbine wheel, lowering turbine speed to adjust the intake manifold pressure.



Some engines are equipped with a diesel oxidation catalyst to reduce exhaust emissions.

Typically, the diesel oxidation catalyst is contained within the muffler assembly and consists of a ceramic substrate that is treated with a chemical coating to oxidize particles of unburned fuel and oil.

The ceramic substrate is held in place in the muffler by a mat, which is a high temperature pad that surrounds the ceramic substrate within the metal muffler housing.

Some transit bus engines are equipped with an exhaust gas filter system, which is used to reduce the amount of particulate matter emitted from the exhaust.

The exhaust gas filter system consists of several components:

1 Exhaust catalyst

2 Exhaust gas temperature sensor

3 Exhaust gas pressure sensor

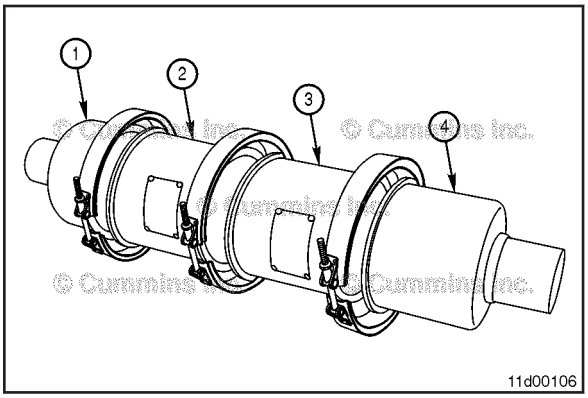
4 Exhaust gas treatment monitor unit and the exhaust gas treatment monitor unit harness

5 Exhaust gas treatment fault code and maintenance lamps.

The exhaust catalyst is a modular assembly consisting of an inlet section (1), a catalyst section (2), an exhaust gas filter section (3), and an outlet section (4). All the sections are joined together with gaskets and v-band clamps.

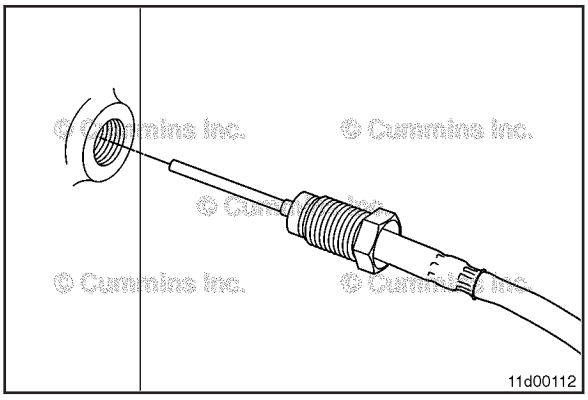
The exhaust gas filter section captures the particulate matter in the exhaust, and then uses the heat generated by the reaction of the unburned fuel and oil particles in the catalyst section to oxidize the particulate matter.

The exhaust gas filter requires periodic maintenance to remove the ash that accumulates when the particulate matter oxidizes.



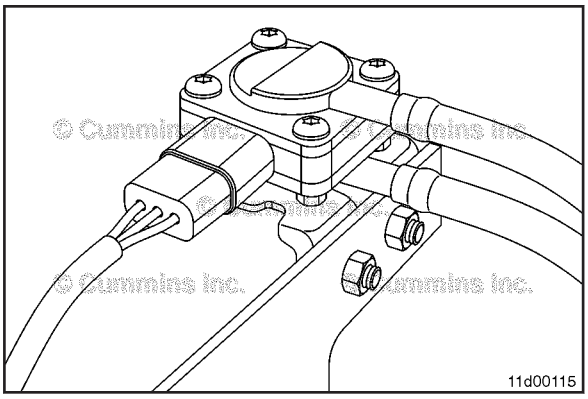
The exhaust gas temperature sensor is typically mounted in the inlet of the exhaust catalyst, however, it can be placed in the vehicle exhaust piping between the turbocharger and the exhaust catalyst inlet.

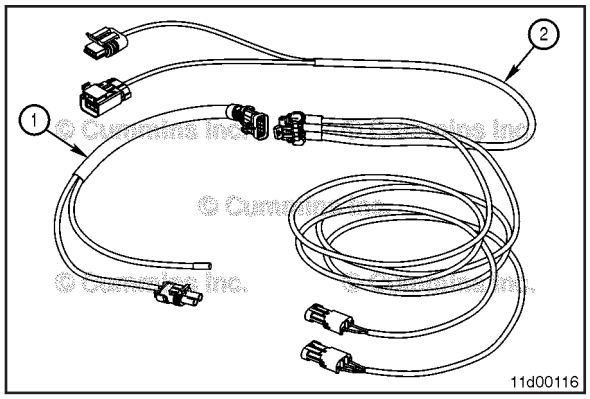
The exhaust gas temperature sensor monitors the temperature of the exhaust gas entering the exhaust catalyst.



The exhaust gas pressure sensor is typically mounted to the vehicle near the exhaust catalyst and is connected to the inlet of the exhaust catalyst by a length of stainless steel flex tubing.

The exhaust gas pressure sensor monitors the exhaust restriction.

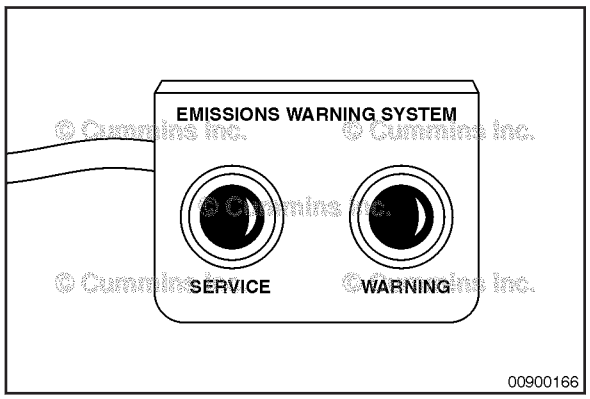




The exhaust gas treatment monitor unit and wiring harness are typically installed in the engine compartment of the vehicle.

The exhaust gas treatment monitor unit (1) monitors the exhaust restriction and exhaust temperature and provides the vehicle operator with feedback via the exhaust gas treatment fault code and maintenance lamps.

The exhaust gas treatment monitor unit harness (2) connects the exhaust gas treatment monitor unit to the exhaust gas temperature sensor, the exhaust gas pressure sensor, and the exhaust gas treatment fault code and maintenance lamps.



The exhaust gas treatment fault code and maintenance lamps are typically located on the vehicle dashboard within sight of the vehicle operator.

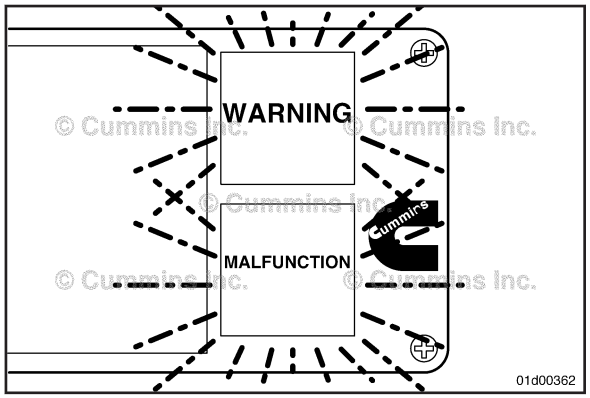
The exhaust gas treatment fault code and maintenance lamps alert the operator to electrical faults within the exhaust gas filter system. The lamps can also alert the operator to either excessive exhaust gas temperature or excessive exhaust restriction.

Both lamps will flash twice upon engine startup to signify that the exhaust gas filter system is operating properly.

The WARNING lamp is red and indicates the need to stop the engine as soon as it can be done safely. The engine **must** remain shutdown until the exhaust gas filter system can be repaired.

The SERVICE lamp is yellow. When it illuminates, the exhaust gas filter system is in need of maintenance at the first available opportunity.

If a fault exists within the exhaust gas filter system, both lamps will continuously flash the number of the recorded fault code with a short one or two second pause between each sequence.

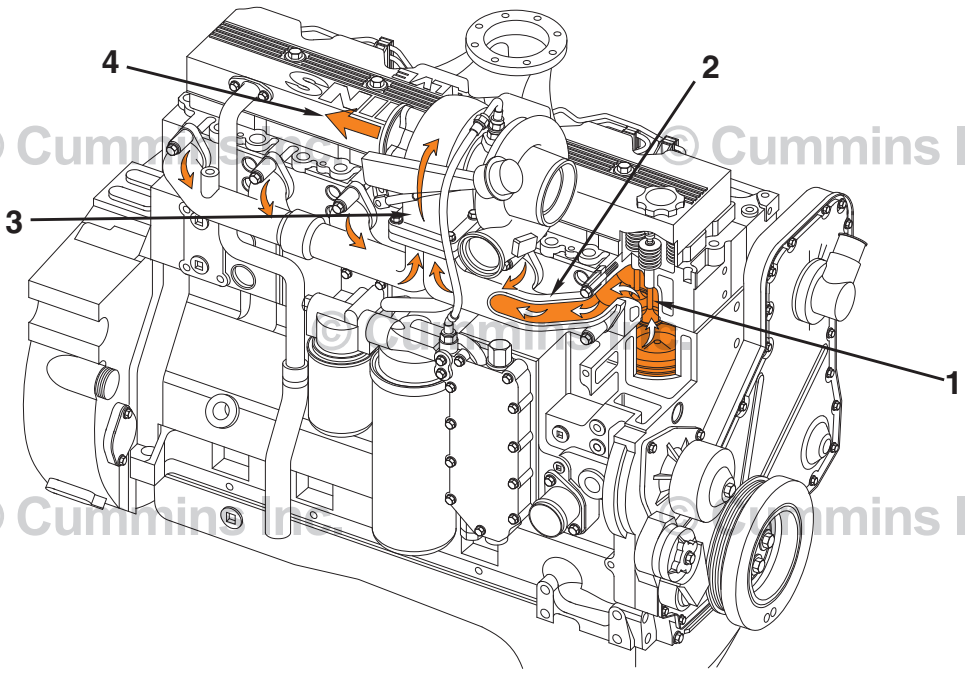


On ISLe4 engines the "MALFUNCTION" or "ENGINE MALFUNCTION" lamp is a blue lamp and indicates that the vehicle may be exceeding emission level limits. When illuminated, the MALFUNCTION or ENGINE MALFUNCTION lamp (blue lamp) indicates the engine or exhaust gas treatment system is need of repair at the first available opportunity.

Another function of the MALFUNCTION or ENGINE MALFUNCTION lamp (blue lamp) is to flash when the urea (commonly referred to as AdBlue™) tank is empty.

Flow Diagram, Exhaust System (200-005)

General Information

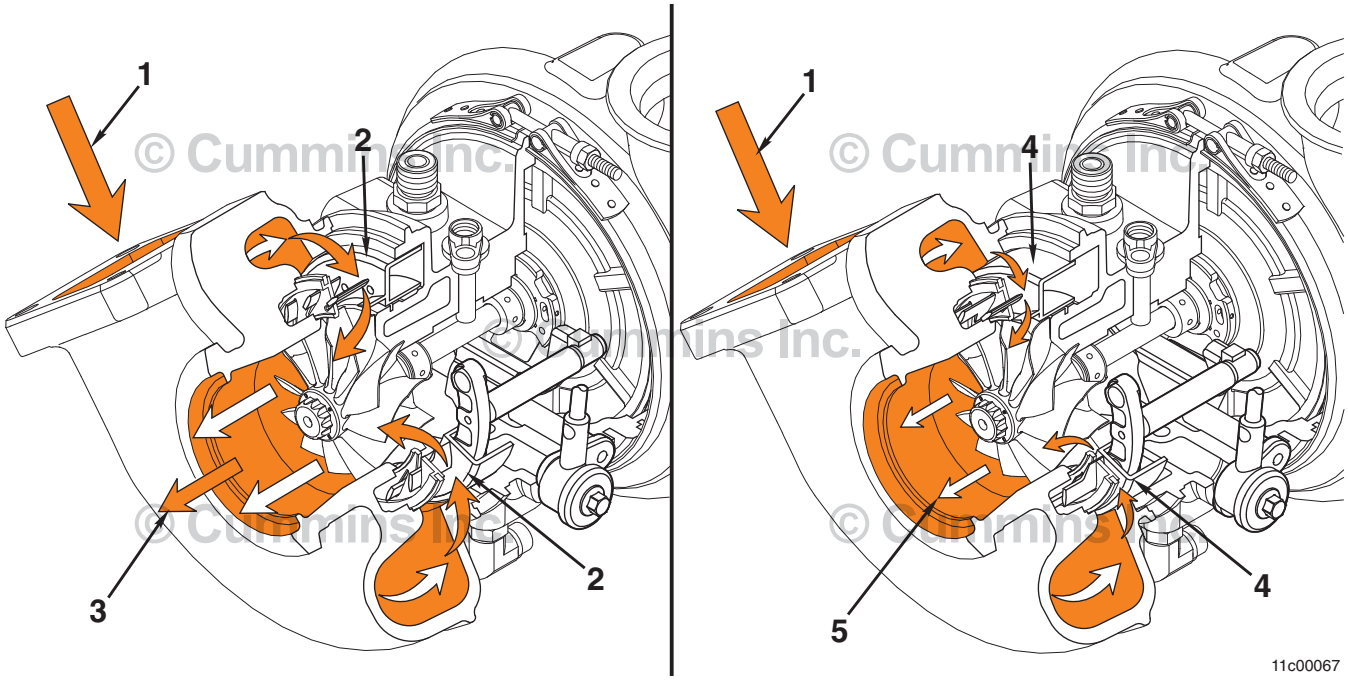


All Applications Except Marine

1 Exhaust valve
2 Exhaust manifold (pulse type)
3 Dual-entry turbocharger
4 Turbocharger exhaust outlet.

Flow Diagram, Exhaust System (200-005)

General Information

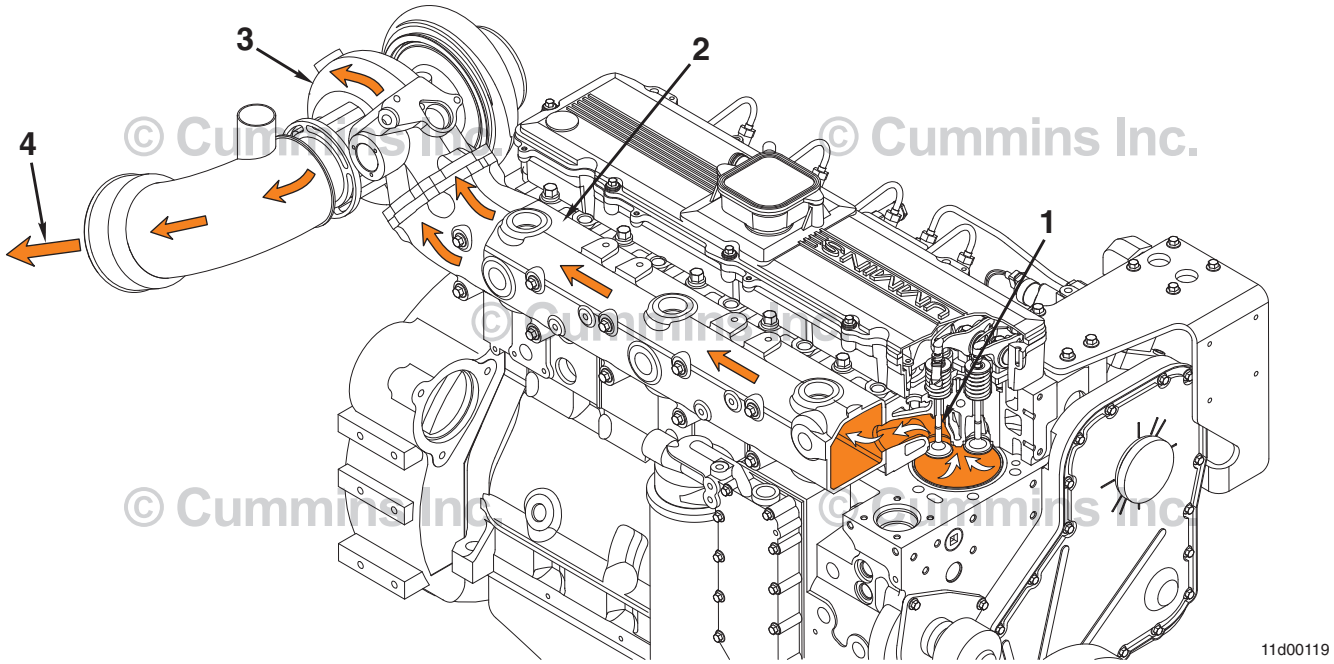


Variable Geometry Turbocharger

1 Exhaust gas in
2 Sliding nozzle open
3 Exhaust gas low velocity flow
4 Sliding nozzle closed
5 Exhaust gas high velocity flow

Flow Diagram, Exhaust System (200-005)

General Information

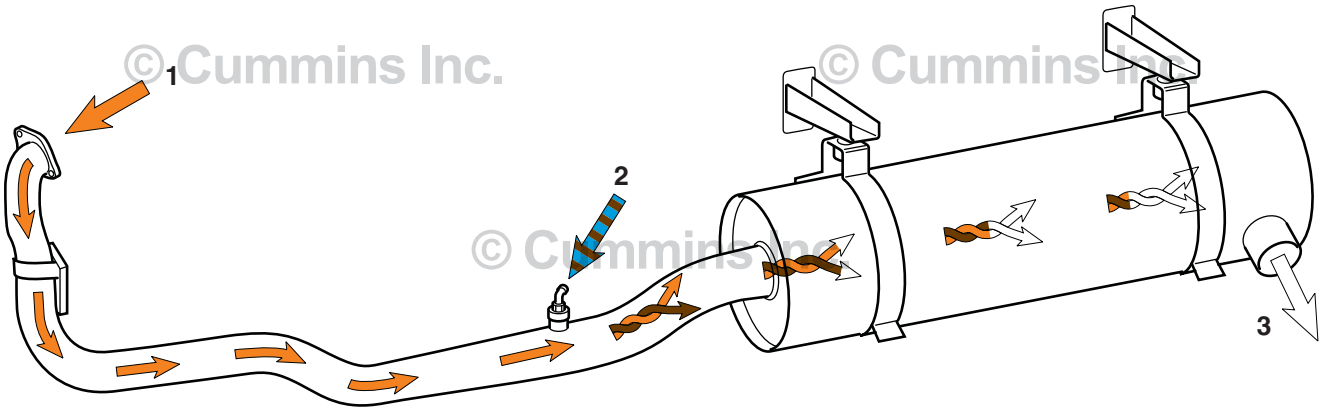


Marine Applications

1 Exhaust valve
2 Exhaust manifold
3 Turbocharger turbine housing
4 Engine exhaust.

Flow Diagram, Exhaust System (200-005)

General Information



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Flow Through Catalyst (ISLe4)

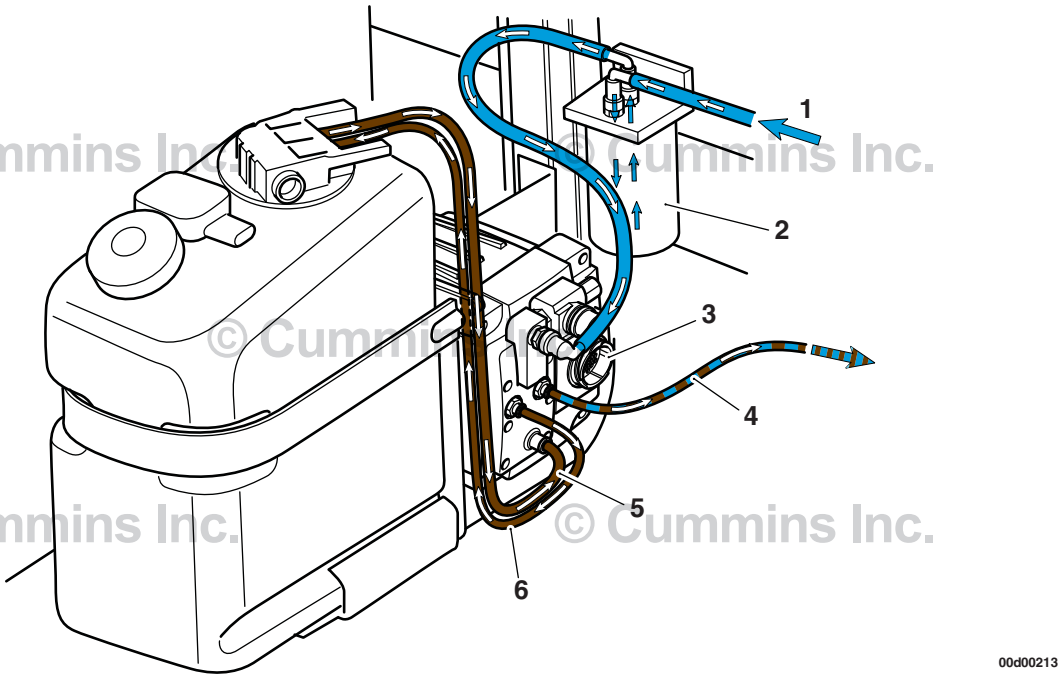
1 Exhaust gas in

2 Urea and air mixture. Injected into the exhaust stream

3 Exhaust gas outlet.

Flow Diagram, Exhaust System (200-005)

General Information



Flow Through Dosing Control Unit (ISLe4)

1 Air feed line from OEM supply
2 Inline air filter
3 Dosing control unit
4 Air and urea mix to nozzle
5 Urea supply from tank.
6 Urea return to tank

Compressed Air System - Overview (012-999)

General Information

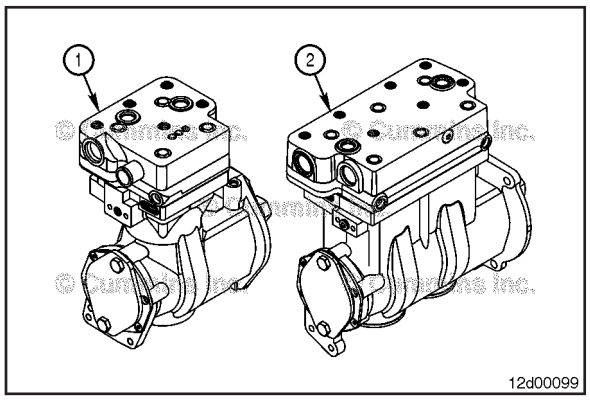
The compressed air system normally consists of a gear-driven air compressor, an air governor, air tanks, and all necessary plumbing.

The compressor operates continuously but has a “loaded” and “unloaded” operating mode. The operating mode is controlled by a pressure activated governor and the compressor unloader assembly. When the air system reaches a predetermined pressure, the governor applies an air signal to the unloader assembly, causing the unloader to either hold open or shutoff the compressor's intake valve, which causes compressed air to stop flowing into the air system. As the system is used, the pressure drops. At a predetermined pressure, the governor exhausts the air signal to the compressor unloader assembly, allowing the compressor to again pump compressed air into the system.

Air compressors are available in an air cooled or water cooled version. The **only** significant difference is that changes have been made to the cylinder head to incorporate a water passage.

Various brands of compressors can be used on the ISC and ISL engines. Troubleshooting procedures are very similar for these air compressors, but see the compressor manufacturer's manual for information including detailed repair information and torque values.

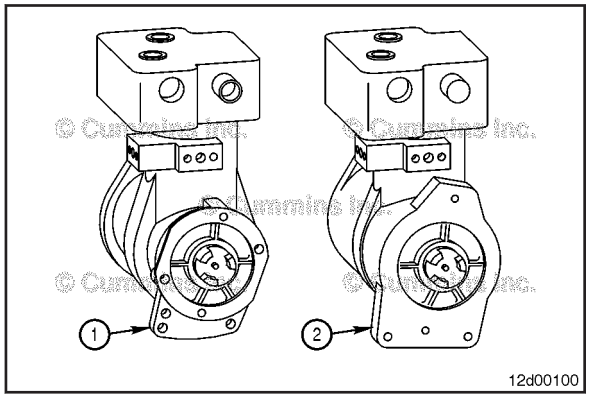
Most air compressor cylinder head and unloader valve assemblies can be serviced without removing the compressor from the engine. This manual will cover servicing of the unloader assembly and cylinder head with the compressor installed on the engine. All other servicing and repair of the compressor internal components **must** be done after the compressor has been removed from the engine.



Air Compressor

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

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

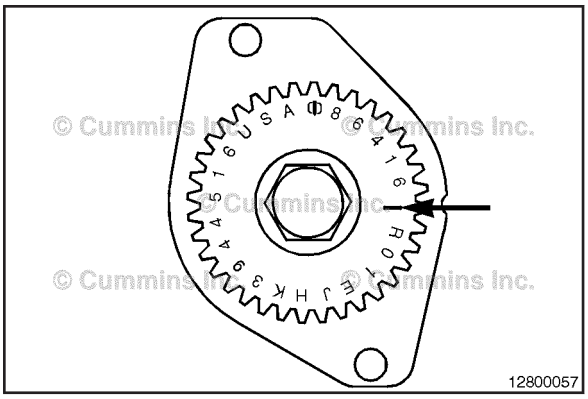


The air compressor can also be a low throughput torque or high throughput torque model, depending on the application.

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

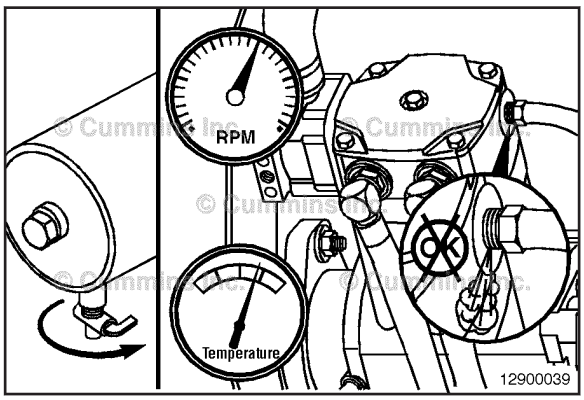
High throughput torque models have an SAE B rear flange (2).

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



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

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



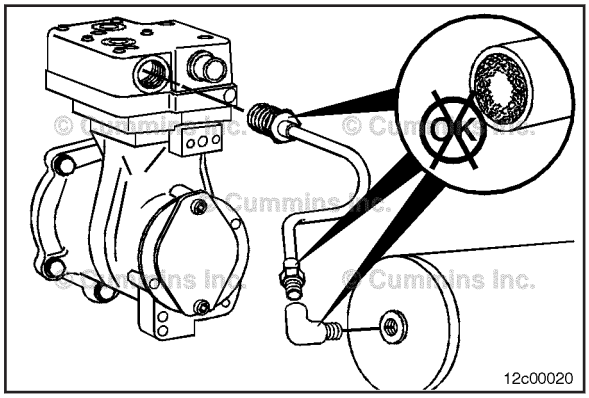
Compressed air system maintenance/servicing can help minimize air compressor duty cycle and ensure reliability and durability of the air compressor. These item include but are **not** limited to:

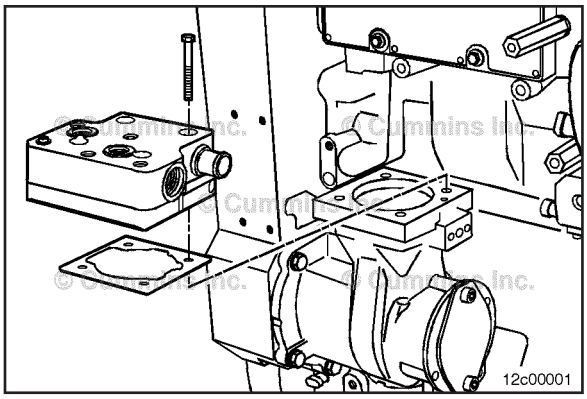
1 Find and stop all leaks in the system. Air leaks can double or triple operating duty cycles. Close attention to correcting air system leaks is critical.

2 Checking the air compressor exhaust port, discharge line, and fittings for carbon build up. If the carbon buildup is greater than 1.6 mm [0.06 in], clean or replace as necessary.

3 Check the air lines and fittings between the outlet port of the air dryer and the first tank after the air dryer for any water or oil. The tank should be dry. If oil is present, replace the dryer desiccant and clean the downstream system and components as required.

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



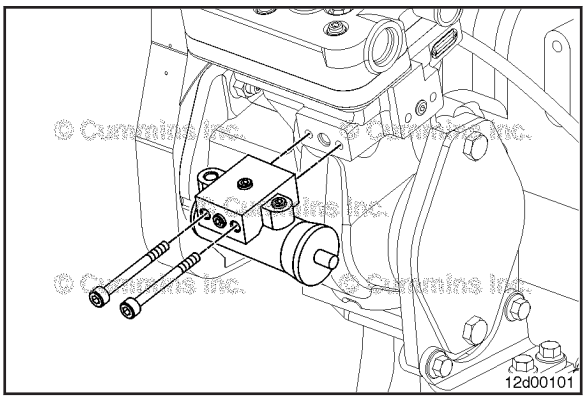


Air Compressor Cylinder Head

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

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

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



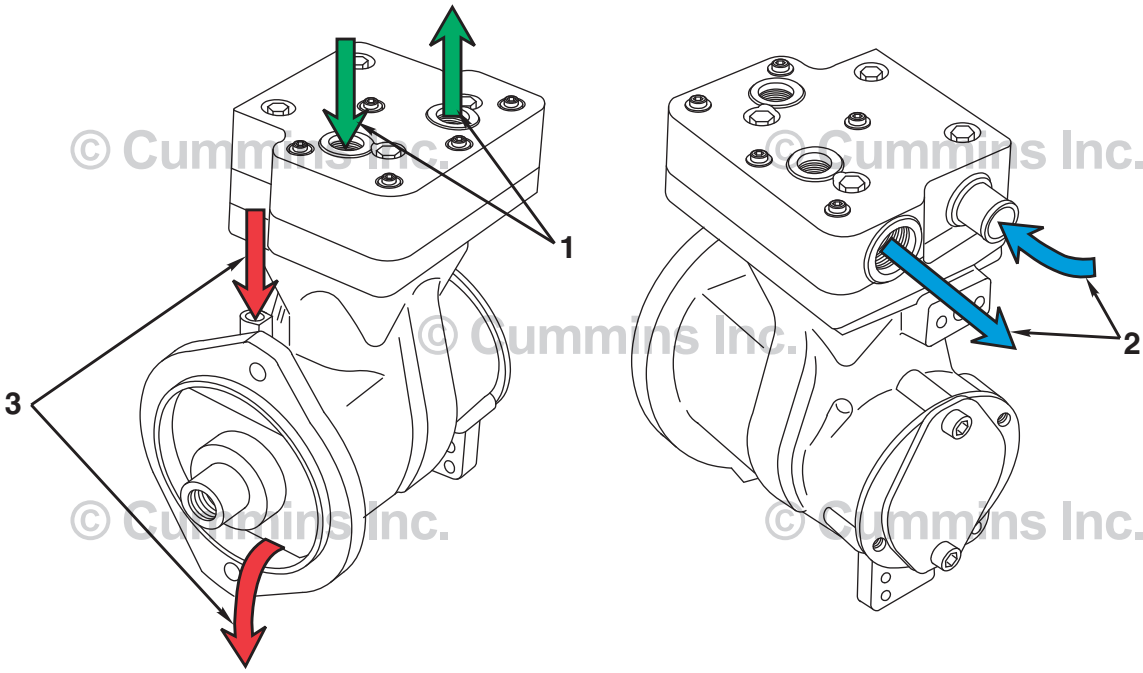
The compressor operates continuously, but has a ”loaded" and ”unloaded" operating mode. The operating mode is controlled by a pressure activated air governor and the air compressor unloader assembly. The air governor can be located on the air compressor or remotely on the vehicle.

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

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

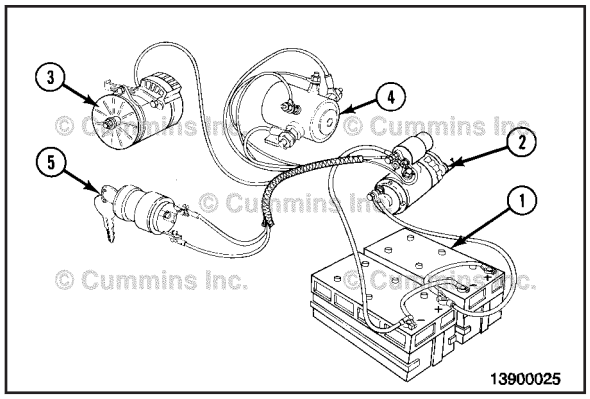
Flow Diagram, Compressed Air System (200-006)

General Information



12d00033

1. Coolant
2. Air
3. Lubricant.



Electrical Equipment - Overview (013-999)

General Information

The basic heavy-duty electrical system consists of:

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

Engine Testing - Overview (014-999)

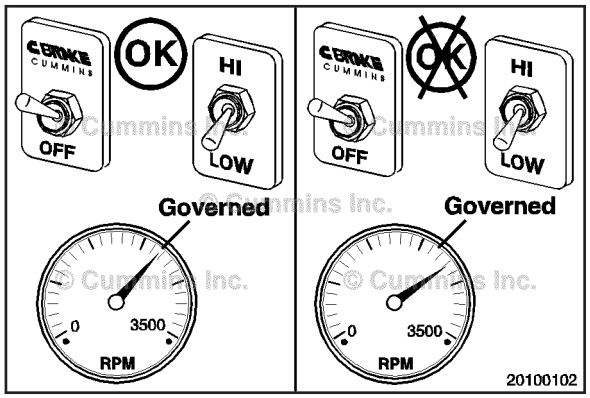
General Information

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

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

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

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



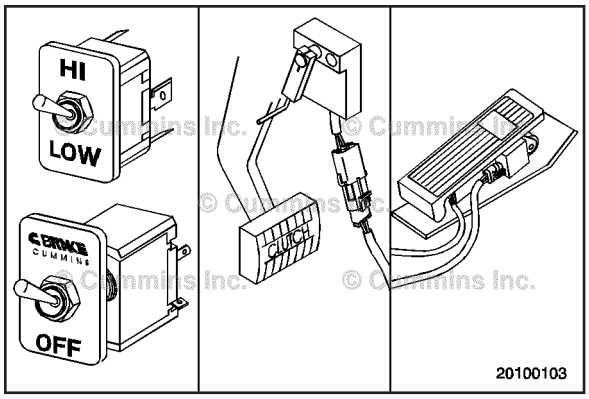
Vehicle Braking - Overview (020-999)

General Information

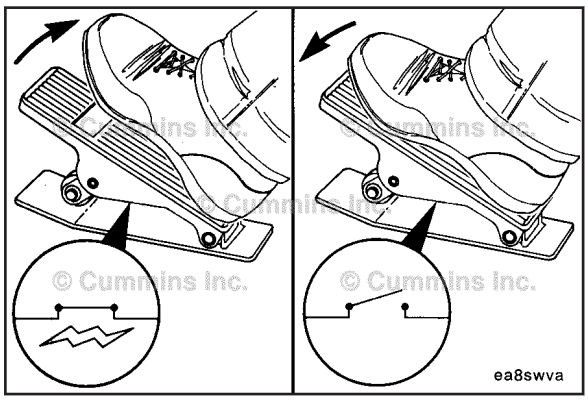
NOTE: The engine brake is comprised of two assemblies. The following instructions apply to both of the engine brake assemblies.

Engine brake controls consist of the following:

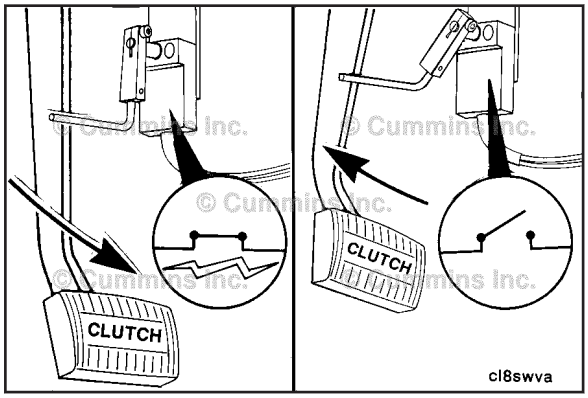
- An ON/OFF switch
- Clutch switch
- Throttle sensor
- Two-position selector switch (optional).



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

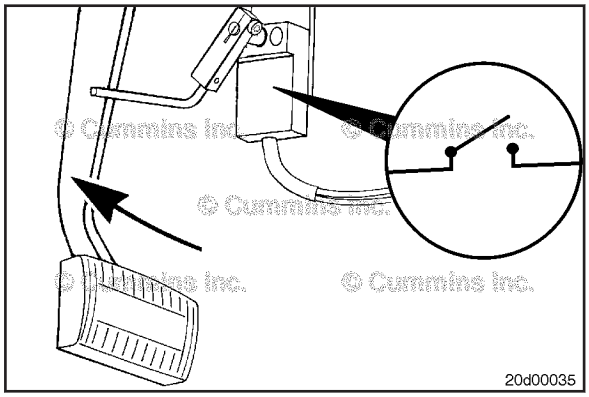


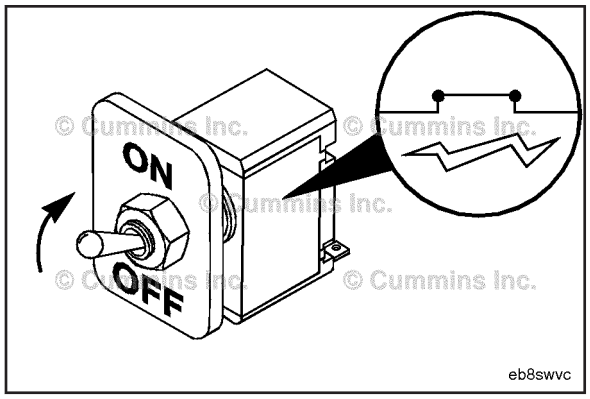
The clutch switch uses the motion of the clutch linkage to deactivate the engine brakes when the clutch pedal is depressed. Depressing the clutch while in cruise control will disengage the cruise control.



The service brake switch is attached to the service brake.

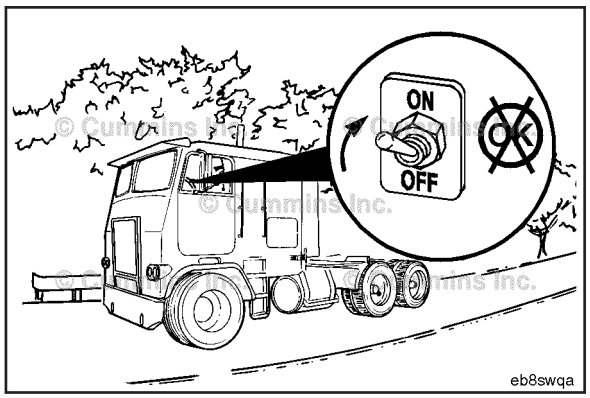
Applying the service brakes while in cruise control will disengage the cruise control and enable the engine brakes.





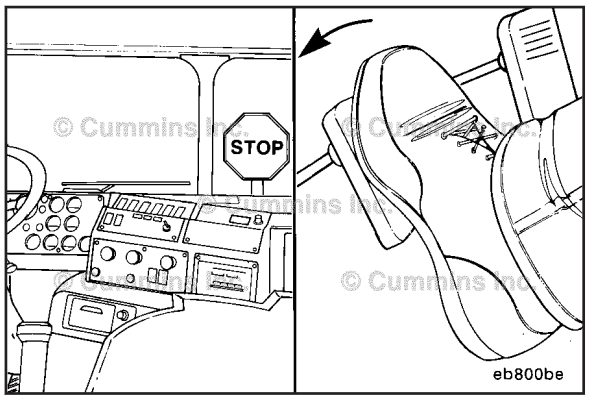
NOTE: See the appropriate pages in this section for specific information about engine brake operation under certain road conditions.

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



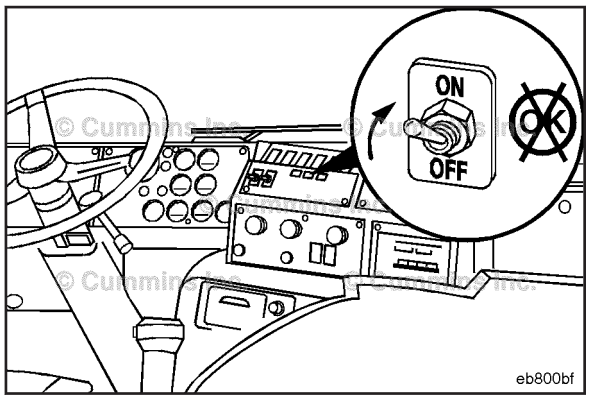
⚠WARNING⚠
Do not use the engine brakes while bobtailing or pulling an empty trailer. With the engine brakes in operation, wheel lockup can occur more quickly when the service brakes are applied, especially on vehicles with single-drive axles.

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



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

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

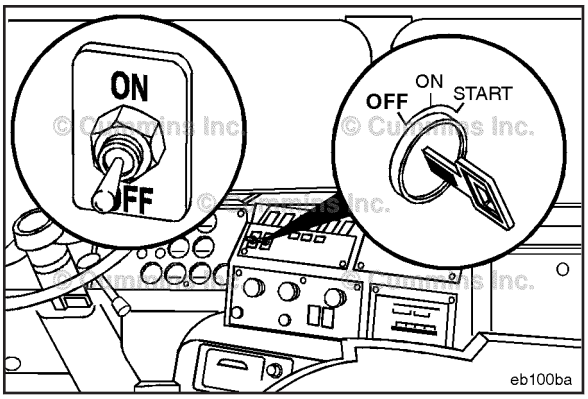


△CAUTION△
Do not use the engine brakes to aid clutchless gearshifting. This can cause the engine to stall or lead to engine damage.

⚠CAUTION⚠

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

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



Notes

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. Refer to Procedure 014-008 in Section 14. If the volume of the noise decreases or the noise disappears, it is related to that particular engine cylinder.

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

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

Main Bearing Noise

(See Engine Noise Excessive - Main Bearing symptom tree)

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

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

An irregular noise can indicate worn crankshaft thrust bearings.

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

Connecting Rod Bearing Noise

(See Engine Noise Excessive - Connecting Rod symptom tree)

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

Piston Noise

(See Engine Noise Excessive - Piston symptom tree)

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

Driveability - General Information

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

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

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

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

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

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

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

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

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

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

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

Driveability/Low Power - Customer Complaint Form

Customer Name/Company/Driver_____Date_____

- Describe Problem/Complaint_____
- Symptoms of the Problem/Complaint
- When cranking:
- ____Cranks too slowly
- ____Cranks OK but does **not** start easily
- ____Cranks OK but does **not** start
- ____Slow start; _____ seconds
- ____Starts then dies
- ____Idle RPM is rough when engine is cold
- ____Idle RPM is rough when engine is hot
- When driving
- ____Misses or hesitates during acceleration
- ____Misses or hesitates during deceleration
- ____Stalls (dies) during acceleration
- ____Stalls (dies) during deceleration
- ____Smokes: ___ black ___ white
- ____Low power

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

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

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

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

- A B C D E F
- Can the vehicle obtain the expected road speed? Yes _____ No _____
- What is desired speed? rpm/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 no was the answer to the previous questions, fill out the Driveability/Low Power/Excessive Fuel Consumption Checklist and go to the Low Power performance tree.

A B C D E F

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

When?

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

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

Additional Comments:

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Driveability/Low Power/Excessive Fuel Consumption - Checklist

Vehicle/Equipment Specifications

Year, Type, and Model: _____

Transmission (RT 14609, and so forth): _____,

Duty Cycle:_____,

Rear Axle Ratio, Number of Axles: _____, Application: Industrial ____, Marine ____, Genset ____, Automotive ____

Typical Gross Vehicle Weight: _____, Engine Rating: _____

Trailer Type and Size: _____, Height: _____, Weight: _____

Tire Size (11R x 24.5, low profile, and so forth) _____

Tire Type: Radial _____, Standard Tread _____, Extra Tread _____

Fan Type: Direct Drive _____, Viscous _____, Clutch _____

Power Steering: Yes _____ No _____Air Conditioner: Yes _____ No _____Air Shield: Yes _____ No _____Freon Compressor: Yes _____ No _____

General Information					
DO Number:			SC Number:		
Fuel Pump Code:			Fuel Pump Serial Number:		
Mileage:			Engine Serial Number:		
Date in Service:			Engine Model and Rating:		
Cruise Speed and rpm:			Rated Speed and rpm:		
Road Speed Governor:	Yes	No	Type:		
Engine Brake:	Yes	No	Type/Brand:		
Chassis and Other Related Items					
Tank Vents:	OK	**Not** OK	Obvious Fuel Leaks:	Yes	No
Brake Drag:	OK	**Not** OK	Axle Alignment:	OK	**Not** OK
Altitude:	Ambient Temperature:				
Fuel Heater:	Conditions (Wind, Rain, Snow):				
Fuel Type:	Number 1D	Number 2D	Other		

General Information					
Typical Terrain:	Flat	Hilly	Percent of Asphalt	Percent of Concrete	

Additional Comments:
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 3048 meters [10,000 feet] _____, Above 3048 meters [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 Oil 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	HRS PER QT	HRS PER LITER	HOURS PER IMPERIAL QUART	MILES PER QUART	MILES PER LITER	MILES PER IMPERIAL QUART	KM PER QUART	KM PER LITER	KM PER IMPERIAL QUART
A	10.0	10.6	12.0	400	425	475	650	675	775
4B	10.0	10.6	12.0	400	425	475	650	675	775
6B	10.0	10.6	12.0	400	425	475	650	675	775
6C	10.0	10.6	12.0	400	425	475	650	675	775

V/VT-378	4.0	4.3	5.0	-	-	-	-	-	-
V/VT-504	4.0	4.3	5.0	250	265	310	400	425	485
V/VT-555	4.0	4.3	5.0	250	265	310	400	425	485
L Series	4.0	4.3	5.0	250	265	310	400	425	485
M Series	4.0	4.3	5.0	250	265	310	400	425	485
N Series	4.0	4.3	5.0	250	265	310	400	425	485
V/VT/ VTA-903	4.0	4.3	5.0	250	265	310	400	425	485
KT/ KTA-19	3.0	3.2	3.75	200	210	250	320	340	390
V/VT/ VTA28	2.0	2.1	2.5	-	-	-	-	-	-
KT/ KTA38	1.5	1.6	1.8	-	-	-	-	-	-
KTA50	1.1	1.2	1.3	-	-	-	-	-	-

Acceptable Oil Usage

(Transit Bus, Shuttle Bus, and School Bus)

Any Time During Coverage Period

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

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

Acceptable Oil Usage

Any Time During Coverage Period

ENGINE FAMILY	HRS PER QT	HRS PER LITER	HOURS PER IMPERIAL QUART	MILES PER QUART	MILES PER LITER	MILES PER IMPERIAL QUART	KM PER QUART	KM PER LITER	KM PER IMPERIAL QUART
A	10.0	10.6	12.0	400	425	475	650	675	775
4B	10.0	10.6	12.0	400	425	475	650	675	775
6B	10.0	10.6	12.0	400	425	475	650	675	775
6C	10.0	10.6	12.0	400	425	475	650	675	775
V/VT-378	4.0	4.3	5.0	-	-	-	-	-	-
V/VT-504	4.0	4.3	5.0	250	265	310	400	425	485
V/VT-555	4.0	4.3	5.0	250	265	310	400	425	485
L Series	4.0	4.3	5.0	250	265	310	400	425	485
M Series	4.0	4.3	5.0	250	265	310	400	425	485
N Series	4.0	4.3	5.0	250	265	310	400	425	485
V/VT/ VTA-903	4.0	4.3	5.0	250	265	310	400	425	485
KT/ KTA-19	3.0	3.2	3.75	200	210	250	320	340	390
V/VT/ VTA28	2.0	2.1	2.5	-	-	-	-	-	-
KT/ KTA38	1.5	1.6	1.8	-	-	-	-	-	-
KTA50	1.1	1.2	1.3	-	-	-	-	-	-

Acceptable Oil Usage									
(Transit Bus, Shuttle Bus, and School Bus)									
Any Time During Coverage Period									
ENGINE FAMILY	HRS PER QT	HRS PER LITER	HOURS PER IMPERIAL QUART	MILES PER QUART	MILES PER LITER	MILES PER IMPERIAL QUART	KM PER QUART	KM PER LITER	KM PER IMPERIAL QUART
B	10.0	10.6	12.0	200	210	240	320	340	385
C	8.0	8.5	10.0	150	160	180	240	255	290
L, M, N	4.0	4.3	5.0	100	105	120	160	170	195

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

15200020

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

Coolant Loss Pre-Troubleshooting Guide

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

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

Driver Interview Questions

Drivers Name:

Engine Serial Number (ESN):

What is your complaint?

How is this engine used?

What sort of load factors?

Where is the vehicle driven?

1 How often do you add coolant?

2 How do you fill the radiator?

3 Do you fill to the High or Low mark when the engine is cold (less than 60°C [140°F]?

4 What type of coolant is added?

5 Any coolant on the ground under the truck?

6 Any green or white streaks on the engine or near the coolant overflow hose?

7 Is there any specific condition when indications of coolant loss (weather, altitude, or load)?

8 Does the engine ever overheat?

9 Does the warning light flash?

10 Under what condition?

11 What temperature does the coolant run at normally?

12 Does the cooling fan operate correctly?

13 Seen any white smoke at operating temperature, or has anyone told you that white smoke is coming out of the exhaust?

14 Has any oil analysis been performed as part of the maintenance?

15 Are there elevated levels of sodium or potassium?

16 Noticed any increase in moisture condensation on the dipstick or oil fill cap, or moisture in the blowby?

17 Noticed a milky appearance in the lube that might indicate coolant is present?

18 What other comments exists that might help Cummins® make the right repair?

Service History Review

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

Look at the engine's warranty claims history:

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

At this point, where is the coolant is going?

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

Air Compressor Air Pressure Rises Slowly

This is symptom tree t004

Cause		Correction
STEP 1 Air intake system restriction to air compressor is excessive	.....	Replace the air compressor air cleaner (if installed). Check the air intake piping. Check the engine air intake restriction if the air compressor air inlet is plumbed to the vehicle or equipment intake system. Refer to Procedure 010-031 in Section 10, to measure the intake restriction.

OK
Go To Next Step

STEP 2 Air system leaks	.....	Block the vehicle wheels and check the air system for leaks with spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, tanks, and valves. Check for air system leaks in the catalyst dosing control unit. Refer to the OEM service manual. For applications fitted with selective catalytic reduction exhaust systems, check the air supply line to the dosing control unit. Procedure 012-019 in Section 12.

OK
Go To Next Step

STEP 3 Air governor is malfunctioning or **not** set correctly	.....	Check the air governor for correct operation. Some OEM installations may **not** utilize an air governor, therefore frequent cycling may be expected and normal. Refer to Procedure 012-016 in Section 12 and the OEM service manual.

OK
Go To Next Step

STEP 4 Carbon buildup is excessive in the air discharge line or downstream air valves	.....	Check for carbon buildup. Clean or replace the air compressor discharge line, as necessary. Check the turbocharger for oil leaks. Check the air compressor intake tube for oil. Refer to Procedure 012-003 in Section 12.

OK
Go To Next Step

STEP 5 Unloader valve is malfunctioning	.....	Check the unloader valve and unloader body seal. Refer to Procedure 012-013 in Section 12 and the OEM service manual. If required, clean the air compressor cylinder head. Refer to Procedure 012-003 in Section 12.

OK
Go To Next Step

STEP 6 Air compressor intake or exhaust valve system leaks air	.....	Leak Test the air compressor head assembly intake and exhaust valve. Refer to Procedure 012-014 in Section 12. The intake and exhaust valves on the air compressor head are **not** serviceable, replace the air compressor cylinder head. Procedure 012-007 in Section 12.

OK
Go To Next Step

Air Compressor Air Pressure Rises Slowly

This is symptom tree t004

Cause	Correction
STEP 7 Air system component is malfunctioning	Check the operation of check valves, alcohol evaporators, air dryers, and other OEM-installed air system components. Refer to the OEM service manual.

Air Compressor Cycles Frequently

This is symptom tree t005

Cause	Correction
STEP 1 Air system leaks	Block the vehicle wheels and check the air system for leaks with service brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, tanks, and valves. For applications fitted with selective catalytic reduction exhaust systems, check the air supply line to the dosing control unit. Refer to Procedure 012-019 in Section 12 and the OEM service manual.
OK Go To Next Step	
STEP 2 Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Make sure the air governor is located less than 0.6 m [2 ft] from the air compressor. Refer to Procedure 012-016 in Section 12 and the OEM service manual.
OK Go To Next Step	
STEP 3 Air system component is malfunctioning	Check the operation of check valves, alcohol evaporators, air dryers, and other OEM-installed air system components. Refer to the manufacturer's instructions.
OK Go To Next Step	
STEP 4 E-type system is **not** plumbed correctly	Install an Econ valve, a check valve, and system hoses. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Air compressor intake or exhaust valve system leaks air	Leak Test the air compressor head assembly intake and exhaust valve. Refer to Procedure 012-014 in Section 12. The intake and exhaust valve on the air compressor head are **not** serviceable, replace the air compressor cylinder head. Refer to Procedure 012-007 in Section 12.
OK Go To Next Step	
STEP 6 Air compressor pumping time is excessive	Replace the desiccant cartridge on the Turbo/CR 2000 air dryer. Refer to the OEM service manual. Check the air compressor duty cycle. Install a larger air compressor, if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Air dryer outlet check valve is sticking	Lubricate or replace the air dryer outlet check valve assembly. Refer to the manufacturer's instructions.

Air Compressor Noise is Excessive

This is symptom tree t006

Cause	Correction
STEP 1 Carbon buildup is excessive in the air discharge line or downstream air valves	Check for carbon buildup. Clean or replace the air compressor discharge line, as necessary. Check the turbocharger for oil leaks. Check the air compressor intake tube for oil. Refer to Procedure 012-003 in Section 12.
OK Go To Next Step	
STEP 2 Ice buildup in the air system components	For all models, check for ice in low spots of the air discharge line, dryer inlet, and elbow fittings. On Holset® models, also check the Econ valve, if equipped. Refer to the original equipment manufacturer (OEM) instructions.
OK Go To Next Step	
STEP 3 Air compressor mounting hardware is loose, worn, or broken	Check the air compressor mounting hardware. Refer to Procedure 012-014 in Section 12.
OK Go To Next Step	
STEP 4 Air compressor is sending air pulses into the air tanks	Install a ping tank between the air dryer and the wet tank. Refer to the OEM instructions.
OK Go To Next Step	
STEP 5 Splined drive coupling or gear is excessively worn	Check the coupling for wear. Refer to Procedure 012-014 in Section 12 if equipped.
OK Go To Next Step	
STEP 6 Air compressor drive gear or engine gear train is worn or damaged	Inspect the drive gears and gear train. Repair as necessary. Refer to Procedure 012-014 in Section 12 to remove the air compressor and inspect the air compressor drive gear. Repair as necessary.
OK Go To Next Step	
STEP 7 Air compressor is excessively worn or internally damaged	Inspect the air compressor for internal damage. Refer to Procedure 012-007 in Section 12. Replace the desiccant element on the air dryer, if equipped. Reference the OEM service manual.

Air Compressor Pumping Excess Lubricating Oil into the Air System

This is symptom tree t007

Cause	Correction
STEP 1 Lubricating oil drain interval is excessive	Verify the correct lubricating oil drain interval. Refer to the oil drain interval in Section 2 of the Operation and Maintenance Manual of the engine being serviced.
OK Go To Next Step	
STEP 2 Lubricating oil is contaminated with coolant or fuel	Refer to the Lubricating Oil Contaminated symptom tree in Section TS.
OK Go To Next Step	
STEP 3 Air intake system restriction to air compressor is excessive	Check the air compressor intake piping. Check the engine air intake restriction. Refer to Procedure 010-031 in Section 10.
OK Go To Next Step	
STEP 4 Contaminants are **not** being drained from the system on a regular basis	Drain the reservoirs daily. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Air compressor pumping time is excessive	Check for all air system leaks and repair if found. Refer to Procedure 012-014 and Procedure 012-019 in Section 12, and the OEM service manual.
OK Go To Next Step	
STEP 6 Air compressor pumping too high	Check the air governor for correct operation. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Carbon buildup is excessive in the air discharge line, air system valves, or cylinder head	Check for carbon buildup. Clean or replace the air compressor discharge line if necessary. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer toProcedure 012-003 in Section 12.
OK Go To Next Step	
STEP 8 Perform oil carry-over test, Inspect Intake system for restriction.	Perform air compressor carry-over test. Refer to Procedure 012-020 in Section 12. If compressor passes the test, inspect compressor intake system for restrictions.
OK Go To Next Step	

Air Compressor Pumping Excess Lubricating Oil into the Air System

This is symptom tree t007

Cause		Correction
STEP 9 Engine angularity during operation exceeds specification	.....	Refer to the Engine Specification data sheet.
OK Go To Next Step		
STEP 10 Crankcase pressure is excessive	.....	Check for excessive blowby. Refer to the Crankcase Gases (blowby) Excessive symptom tree in Section TS.
OK Go To Next Step		
STEP 11 Lubricating oil pressure is above specification	.....	Check the oil pressure. Refer to the Lubricating Oil Pressure High symptom tree in Section TS.
OK Go To Next Step		
STEP 12 Air compressor runs hot	.....	If coolant temperature is above normal, refer to the Coolant Temperature Above Normal - Gradual Overheat symptom tree in Section TS.
OK Go To Next Step		
STEP 13 Lubricating oil drain line is restricted	.....	Remove the air compressor and check the oil drain holes in the air compressor and the accessory drive. Refer to Procedure 012-014 in Section 12.
OK Go To Next Step		
STEP 14 Air compressor drive gear or engine gear train is worn or damaged	.....	Inspect the drive gears and gear train. Repair as necessary. Refer to Procedure 012-014 in Section 12.
OK Go To Next Step		
STEP 15 Air compressor is excessively worn or internally damaged	.....	Inspect the air compressor. Refer to Procedure 012-014 in Section 12.

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

This is symptom tree t008

Cause		Correction
STEP 1 Air system leaks	.....	Block the vehicle wheels and check the air system for leaks with service brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, tanks, and valves. For applications fitted with selective catalytic reduction exhaust systems, check the air supply line to the dosing control unit. Refer to Procedure 012-019 in Section 12 and the OEM service manual.

OK
Go To Next Step

STEP 2 Air governor is malfunctioning or **not** set correctly	.....	Check the air governor for correct operation. Refer to Procedure 012-016 in Section 12 and the OEM service manual.

OK
Go To Next Step

STEP 3 Air compressor unloader and valve assembly is malfunctioning	.....	Check the unloader valve operation and unloader body seal. Refer to Procedure 012-013 in Section 12 and the OEM service manual. If required, clean the air compressor cylinder head. Refer to Procedure 012-003 on Section 12.

OK
Go To Next Step

STEP 4 Air compressor intake or exhaust valve system leaks air	.....	Leak Test the air compressor head assembly intake and exhaust valve. Refer to Procedure 012-014 in Section 12. The intake and exhaust valve on the air compressor head are **not** serviceable, replace the air compressor cylinder head. Refer to Procedure 012-007 in Section 12.

Air Compressor Will Not Pump Air

This is symptom tree t009

Cause	Correction
STEP 1 Air system leaks	Block the vehicle wheels and check the air system for leaks with spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, tanks, and valves. Refer to OEM service manual. For applications fitted with selective catalytic reduction exhaust systems, check the air supply line to the dosing control unit. Procedure 012-019 in Section 12.
OK Go To Next Step	
STEP 2 Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Refer to Procedure 012-016 in Section 12 and the OEM service manual.
OK Go To Next Step	
STEP 3 Air compressor unloader and valve assembly is malfunctioning	Check the unloader valve operation and unloader body seal. Refer to Procedure 012-013 in Section 12 and the OEM service manual. If required, clean the air compressor cylinder head. Refer to Procedure 012-003 in Section 12 .
OK Go To Next Step	
STEP 4 Air compressor intake or exhaust valve system leaks air	Leak Test the air compressor head assembly intake and exhaust valve. Refer to Procedure 012-014 in Section 12. The intake and exhaust valves on the air compressor head are **not** serviceable, replace the air compressor cylinder head. Procedure 012-007 in Section 12.
OK Go To Next Step	
STEP 5 Splined drive coupling or gear is excessively worn	Check the coupling for wear. Refer to Procedure 012-014 in Section 12.
OK Go To Next Step	
STEP 6 Air compressor is excessively worn or internally damaged	Inspect the air compressor. Refer to Procedure 012-014 in Section 12.

Air Compressor Will Not Stop Pumping

This is symptom tree t010

Cause	Correction
STEP 1 Air system leaks	Block the vehicle wheels and check the air system for leaks with service brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, tanks, and valves. For applications fitted with selective catalytic reduction exhaust systems, check the air supply line to the dosing control unit. Refer to Procedure 012-019 in Section 12 and the OEM service manual.

OK
Go To Next Step

STEP 2 Air governor is malfunctioning or **not** set correctly	Check the air governor for correct operation. Refer to Procedure 012-016 in Section 12 and the OEM service manual.

OK
Go To Next Step

STEP 3 Air compressor unloader and valve assembly is malfunctioning	Check the unloader valve operation and unloader body seal. Refer to Procedure 012-013 in Section 12. If required, clean the air compressor cylinder head. Refer to Procedure 012-003 in Section 12.

OK
Go To Next Step

STEP 4 Air governor signal line or actuator line is plugged	Inspect the signal line and actuator line. Refer to the manufacturer's instructions.

OK
Go To Next Step

STEP 5 Air system component is malfunctioning	Check the operation of check valves, alcohol evaporators, air dryers, and other OEM-installed air system components. Refer to the manufacturer's instructions.

OK
Go To Next Step

STEP 6 Air compressor intake or exhaust valve system leaks air	Leak Test the air compressor head assembly intake and exhaust valve. Refer to Procedure 012-014 in Section 12. The intake and exhaust valve on the air compressor head are **not** serviceable, replace the air compressor cylinder head. Refer to Procedure 012-007 in Section 12.

Alternator Not Charging or Insufficient Charging

This is symptom tree t013

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Read the fault codes with an electronic service tool. Refer to Section TF in Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416 or Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 2 Vehicle gauge is malfunctioning	Check the vehicle gauge. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Engine speed too low for charging	Move throttle to raise engine speed to 1200 rpm to excite the alternator. Refer to the Operation and Maintenance Manual, ISC and ISL Series Engines, Bulletin 4021428 or Operation and Maintenance Manual, QSC8.3 and QSL9 Engines, Bulletin 4021518.
OK Go To Next Step	
STEP 4 Alternator belt is loose	Check the alternator belt tension. Refer to Procedures 013-001.
OK Go To Next Step	
STEP 5 Electrical system is "open" (blown fuses, broken wires, or loose connections)	Check the fuses, wires, and connections. Refer to the OEM service manual and the manufacturer's wiring diagrams.
OK Go To Next Step	
STEP 6 Battery cables or connections are loose, broken, or corroded (excessive resistance)	Check the battery cables and connections. Refer to Procedure 013-009.
OK Go To Next Step	
STEP 7 Batteries have malfunctioned	Check the condition of the batteries. Replace the batteries, if necessary. Refer to the OEM service manual.
OK Go To Next Step	

Alternator Not Charging or Insufficient Charging

This is symptom tree t013

Cause	Correction
STEP 8 Alternator pulley is loose on the shaft	Tighten the pulley. Refer to the Operation and Maintenance Manual, ISC and ISL Series Engines, Bulletin 4021428 or Operation and Maintenance Manual, QSC8.3 and QSL9 Engines, Bulletin 4021518.

OK
Go To Next Step

STEP 9 Battery temperature is above specification	Position the batteries away from heat sources. Refer to the OEM service manual.

OK
Go To Next Step

STEP 10 Alternator noise is excessive	Refer to Procedure 013-001.

OK
Go To Next Step

STEP 11 Alternator or voltage regulator is malfunctioning	Test the alternator output. Replace the alternator or voltage regulator if necessary. Refer to Procedure 013-001 and the OEM service manual.

OK
Go To Next Step

STEP 12 Alternator is overloaded, or alternator capacity is below specification	Install an alternator with a higher capacity. Refer to Procedure 013-001 and the OEM service manual.

Alternator Overcharging

This is symptom tree t014

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Read the fault codes with an electronic service tool. Refer to Section TF in Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416 or Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.

OK
Go To Next Step

STEP 2 Battery cables or connections are loose, broken, or corroded (excessive resistance)	Check the battery cables and connections. Refer to Procedure 013-009.

OK
Go To Next Step

STEP 3 Battery cell is damaged (open circuit)	Check the condition of the batteries. Replace the batteries, if necessary. Refer to the OEM service manual.

OK
Go To Next Step

STEP 4 Voltage regulator is malfunctioning	Check the voltage regulator. Replace the voltage regulator, if necessary. Refer to the OEM service manual.

OK
Go To Next Step

STEP 5 Battery isolator failed (if equipped)	Refer to boat manufacturer's specification and wiring.

OK
Go To Next Step

STEP 6 Alternator is malfunctioning	Test the alternator output. Refer to Procedure 013-001 or the OEM service manual if a non-Cummins alternator.

Coolant Loss - External

This is symptom tree t020

Cause		Correction
STEP 1 Coolant level is above specification	.....	Check the coolant level. Refer to the OEM service manual.
OK Go To Next Step		
STEP 2 External engine leak	.....	Inspect the engine and its components for seal, gasket, or draincock leaks. Inspect the radiator, heat exchanger, cab heater, hoses, and connections. Pressurize the cooling system if necessary to determine source of leak. Refer to Procedure 008-018.
OK Go To Next Step		
STEP 3 Cooling system hose are collapsed, restricted, or leaking	.....	Inspect the cooling system hoses for restrictions, obstructions, and leaks. Refer to Procedure 008-045.
OK Go To Next Step		
STEP 4 Cooling system pressure cap is **not** correct, is malfunctioning, or has a low-pressure rating	.....	Inspect the pressure cap. Refer to Procedure 008-047 and the OEM service manual.
OK Go To Next Step		
STEP 5 Engine is overheating	.....	Refer to Coolant Temperature Above Normal, Gradual Overheat or Coolant Temperature Above Normal, Sudden Overheat symptom trees.
OK Go To Next Step		
STEP 6 Coolant loss through radiator overflow	.....	Check and review OEM plumbing to make sure no high-pressure coolant can cause backflow. Check vent lines and fill line for restriction. Refer to the OEM service manual.
OK Go To Next Step		
STEP 7 Transmission oil cooler or torque converter cooler is leaking	.....	Check the transmission oil cooler and torque converter cooler for coolant leaks. Refer to the OEM service manual.
OK Go To Next Step		
STEP 8 Wet exhaust manifold and turbine housing leaking coolant	.....	Pressure-test the coolant system. Refer to Procedure 008-103.

Coolant Loss - Internal

This is symptom tree t021

Cause	Correction
STEP 1 Coolant is leaking into the lubricating oil	Check for coolant in the oil. Refer to the Coolant in the Lubricating Oil symptom tree.
OK Go To Next Step	
STEP 2 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 3 Lubricating oil cooler is leaking	Check the lubricating oil cooler for coolant leaks. Refer to Procedure 007-003 in Section 7.
OK Go To Next Step	
STEP 4 Air compressor cylinder head is cracked or porous, or has a leaking gasket	Inspect the air compressor air inlet and outlet tubes for signs of coolant. Refer to Procedure 012-007 in Section 12.
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 Coolant is leaking into the combustion chamber	Remove the cylinder head and inspect the cylinder head, gasket, and pistons for evidence of coolant. Refer to Procedure 002-004 in Section 2.
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 head expansion plugs leaking or misassembled	Inspect the cylinder head. Refer to Procedure 002-004 in Section 2.
OK Go To Next Step	
STEP 9 Cylinder block is cracked or porous	Remove the oil pan. Pressure-test the cooling system to check for leaks. Refer to Procedure 008-020 in Section 8.
OK Go To Next Step	

Coolant Loss - Internal

This is symptom tree t021

Cause	Correction
STEP 10 Aftercooler is leaking	Inspect and pressure-test the aftercooler for leaks. Refer to Procedure 010-005 in Section 10.

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	Read the fault codes with an electronic service tool. Refer to Section TF in Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416 or Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 2 Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure 008-027.
OK Go To Next Step	
STEP 3 Cold weather radiator cover or winterfront is closed	Open the cold weather radiator cover or the winterfront. Maintain a minimum of 384 cm^2 [60 in^2] or approximately 19.6 x 19.6 cm [7.5 x 7.5 in] of opening at all times.
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 and the OEM service manual.
OK Go To Next Step	
STEP 5 Coolant level is below specification	Inspect the engine and cooling system for external coolant leaks. Repair if necessary. Add coolant. Refer to Procedures 008-018 and 008-020.
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 Sea water cooling system is malfunctioning	Troubleshoot the sea water system. Refer to the Coolant Temperature Above Normal - Sea Water Cooling System symptom tree.
OK Go To Next Step	

Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

Cause		Correction
STEP 8 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, if necessary. Refer to Procedure 008-038.

OK
Go To Next Step

STEP 9 Fan drive belt is broken or loose	.....	Check the fan drive belt. Replace the belt if necessary. Refer to Procedure 008-002.

OK
Go To Next Step

STEP 10 Keel cooler or heat exchanger is malfunctioning or **not** adequately sized	.....	Refer to Procedures 008-052, 008-053 or 008-083.

OK
Go To Next Step

STEP 11 Coolant temperature gauge is malfunctioning	.....	Test the temperature gauge. Repair or replace the gauge, if necessary. Refer to the OEM service manual.

OK
Go To Next Step

STEP 12 Radiator cap is **not** correct, is malfunctioning, or has low-pressure rating	.....	Check the radiator pressure cap. Refer to Procedure 008-047.

OK
Go To Next Step

STEP 13 Thermostat is **not** correct or is malfunctioning	.....	Check the thermostat for the correct part number and for correct operation. Refer to Procedure 008-013 for ISC, QSC8.3 (industrial and marine engines), ISL, and QSL9 industrial engines, or Procedure 008-014 for QSL9 marine keel cooled engines.

OK
Go To Next Step

STEP 14 Cooling system hose is collapsed, restricted, or leaking	.....	Inspect the hoses. Refer to Procedure 008-045.

OK
Go To Next Step

STEP 15 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 restriction. Refer to the OEM service manual.

OK
Go To Next Step

Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

Cause	Correction
STEP 16 Intake manifold air temperature is above specification	Refer to the Intake Manifold Air Temperature Above Specification symptom tree.
OK Go To Next Step	
STEP 17 Lubricating oil level is above or below specification	Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-009.
OK Go To Next Step	
STEP 18 Cooling system is contaminated with dirt, scale, or sludge	Clean the cooling system. Refer to Procedure 008-018.
OK Go To Next Step	
STEP 19 Lubricating oil is contaminated with coolant or fuel	Refer to the Lubricating Oil Contaminated symptom tree.
OK Go To Next Step	
STEP 20 Coolant is contaminated with lubricating oil	Refer to the Lubricating Oil or Transmission Oil in Coolant symptom tree.
OK Go To Next Step	
STEP 21 Coolant pump is malfunctioning	Check the water pump for correct operation. Replace the water pump, if necessary. Refer to Procedure 008-062.
OK Go To Next Step	
STEP 22 Radiator core is internally obstructed or damaged, or the check valve or J-tube is malfunctioning	Inspect the radiator and clean if necessary. Refer to Procedure 008-042.
OK Go To Next Step	
STEP 23 Torque converter is malfunctioning	Check the torque converter. Refer to the OEM service manual.
OK Go To Next Step	
STEP 24 Torque converter cooler or hydraulic oil cooler is malfunctioning	Remove and inspect the cooler cores and o-rings. Refer to the OEM service manual.
OK Go To Next Step	

Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

Cause	Correction
STEP 25 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 26 Air or combustion gases are entering the cooling system	Check for air or combustion gases in the cooling system. Refer to Procedure 008-020.
OK Go To Next Step	
STEP 27 Cylinder head gasket is leaking	Check the cylinder head gasket. Refer to Procedure 002-021.
OK Go To Next Step	
STEP 28 Engine is overfueled	Check the engine fuel rate. Refer to the Fuel Consumption Excessive symptom tree.
OK Go To Next Step	
STEP 29 Plugged cooling passages in the cylinder head, head gasket, or cylinder block	Pressure-test the cooling system. Refer to Procedure 008-020.

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	Read the fault codes with an electronic service tool. Refer to Section TF in Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416 or Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 2 Coolant level is below specification	Inspect the engine and cooling system for external coolant leaks. Repair if necessary. Add coolant. Refer to Procedures 008-018 and 008-020.
OK Go To Next Step	
STEP 3 Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure 008-027.
OK Go To Next Step	
STEP 4 Fan drive belt is broken or loose	Check the fan drive belt. Replace the belt if necessary. Refer to Procedure 008-002.
OK Go To Next Step	
STEP 5 Cold weather radiator cover or winterfront is closed	Open the cold weather radiator cover or the winterfront. Maintain a minimum of 384 cm^2 [60 in^2] or approximately 19.6 x 19.6 cm [7.5 x 7.5 in] of opening at all times.
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.
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 for ISC, QSC8.3 (industrial and marine engines), ISL, and QSL9 industrial engines, or Procedure 008-014 for QSL9 marine keel cooled engines.
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 the OEM service manual.
OK Go To Next Step		
STEP 9 Sea water cooling system is malfunctioning	.....	Troubleshoot the sea water system. Refer to the Coolant Temperature Above Normal - Sea Water Cooling System symptom tree.
OK Go To Next Step		
STEP 10 Cooling system hose is collapsed, restricted, or leaking	.....	Inspect the hoses. Refer to Procedure 008-045.
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 restriction. Refer to the OEM service manual.
OK Go To Next Step		
STEP 12 Coolant pump is malfunctioning	.....	Check the water pump for correct operation. Replace the water pump, if necessary. Refer to Procedure 008-062.
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.
OK Go To Next Step		
STEP 14 Torque converter cooler or hydraulic oil cooler is malfunctioning	.....	Remove and inspect the cooler cores and o-rings. Refer to the OEM service manual.
OK Go To Next Step		
STEP 15 Air or combustion gases are entering the cooling system	.....	Check for air or combustion gases in the cooling system. Refer to Procedure 008-020.
OK Go To Next Step		

Coolant Temperature Above Normal - Sudden Overheat

This is symptom tree t023

Cause	Correction
STEP 16 Plugged cooling passages in the cylinder head, head gasket, or cylinder block	Pressure-test the cooling system. Refer to Procedure 008-020.

OK
Go To Next Step

STEP 17 Cooling system component is malfunctioning	Perform the cooling system diagnostics test. Refer to Procedure 008-020.

OK
Go To Next Step

STEP 18 Cooling system has insufficient capacity	Refer to the OEM service manual.

Coolant Temperature Below Normal

This is symptom tree t024

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Read the fault codes with an electronic service tool. Refer to Section TF in Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416 or Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 2 Coolant temperature gauge or sensor is malfunctioning	Test the gauge and the sensor. Repair or replace, if necessary. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Excessive coolant flow through OEM plumbing and heater cores	Close valves to heater cores. Run engine. If engine operates at normal temperature, refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Thermostat is **not** correct or is malfunctioning	Check the thermostat for the correct part number and for correct operation. Refer to Procedure 008-013 for ISC, QSC8.3 (marine and industrial engines), ISL, and QSL9 industrial engines, or Procedure 008-014 for QSL9 marine keel cooled engines.
OK Go To Next Step	
STEP 5 Engine is operating at low ambient temperature	Check the winterfront, shutters, and under-the-hood air. Use under-the-hood intake air in cold weather. Refer to the OEM service manual.
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.
OK Go To Next Step	
STEP 7 Cooling system component is malfunctioning	Perform the cooling system diagnostics test. Refer to Procedure 008-020.
OK Go To Next Step	

Coolant Temperature Below Normal

This is symptom tree t024

Cause	Correction
STEP 8 Engine idle time is excessive	Low oil and coolant temperatures can be caused by long idle time (greater than 10 minutes). Shut off the engine rather than idle for long periods. If idle time is necessary, raise the idle speed. Procedure 008-020

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.
OK Go To Next Step		
STEP 2 Air compressor cylinder head is cracked or porous, or has a leaking gasket	.....	Inspect the air compressor cylinder head and gasket. Refer to Procedure 012-014.
OK Go To Next Step		
STEP 3 Cylinder head core and expansion plugs leaking or misassembled	.....	Check cylinder head. Refer to Procedure 002-004.
OK Go To Next Step		
STEP 4 Cylinder head gasket is leaking	.....	Check the cylinder head gasket. Refer to Procedure 002-021.
OK Go To Next Step		
STEP 5 Cylinder head is cracked or porous	.....	Pressure-test the cylinder head. Refer to Procedure 002-004.
OK Go To Next Step		
STEP 6 Cylinder block is cracked or porous	.....	Remove the oil pan. Pressure-test the cooling system to check for leaks. Refer to Procedure 008-020.

Coolant Temperature Above Normal - Sea Water Cooling System

This is symptom tree t026-156

Cause	Correction
STEP 1 Sea water inlet valve is **not** open or is partially open	Check sea water inlet valve. Refer to Procedure 008-103.
OK Go To Next Step	
STEP 2 Sea water strainer clogged	Clean sea water strainer. Refer to Procedure 008-067.
OK Go To Next Step	
STEP 3 Sea water hose(s) collapsed	Check sea water system hose(s). Refer to Procedure 008-104.
OK Go To Next Step	
STEP 4 Sea water inlet restriction is excessive	Determine cause of inlet restriction. Refer to Procedure 008-103.
OK Go To Next Step	
STEP 5 Sea water pump outlet pressure is excessive	Determine cause of sea water system blockage. Refer to Procedures 008-057 and 008-103.
OK Go To Next Step	
STEP 6 Sea water pump is **not** pumping water	Inspect the sea water pump impeller. Refer to Procedure 008-057.

Crankcase Gases (Blowby) Excessive

This is symptom tree t027

Cause	Correction
STEP 1 Crankcase ventilation system is plugged	Check and clean the crankcase breather and vent tube. Refer to Procedure 003-002 in Section 3 and Procedure 003-018 in Section 3.
OK Go To Next Step	
STEP 2 Air compressor is malfunctioning	Check the air compressor engine blow-by contribution. Refer to Procedure 014-010 in Section 14. If blowby contribution is out of specification, rebuild or replace the air compressor. Refer to Procedure 012-014 in Section 12.
OK Go To Next Step	
STEP 3 Exhaust or engine brake is malfunctioning	Check the exhaust or engine brake for correct operation. Refer to Procedure 020-004 in Section 20.
OK Go To Next Step	
STEP 4 Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedure 010-033 in Section 10. Check the turbocharger blowby contribution. Refer to Procedure 014-010 in Section 14. If the blowby contribution is out of specification, replace the turbocharger. Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	
STEP 5 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 6 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 7 Piston or piston rings are worn or damaged	Check for air intake system leaks. Refer to Procedure 010-024 in Section 10. Check the pistons and piston rings for wear or damage. For piston cleaning and reuse; Refer to Procedure 001-043 in Section 1. For cylinder liner inspection and reuse; Refer to Procedure 001-028 in Section 1. For piston ring inspection; Refer to Procedure 001-047 in Section 1.

Engine Brake Does Not Operate

This is symptom tree t036

Cause		Correction
STEP 1 Engine brake on/off switch is off	.....	Turn on the switch.

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 Section 1 of the Operation and Maintenance Manual, ISC, ISC^e, and ISL Engines, Bulletin 4021428 or the Operation and Maintenance Manual, QSC8.3 and QSL9 Engines, Bulletin 4021518.

OK
Go To Next Step

STEP 3 Electronic fault codes active or high counts of inactive fault codes	.....	Refer to Section TF in the Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3, and QSL Engines, Bulletin 3666271 for fault code troubleshooting.

OK
Go To Next Step

STEP 4 Engine brake on/off switch or circuit is malfunctioning	.....	Check the engine brake on/off switch and circuit. Refer to Procedures 020-012, 020-015, or Procedures 019-034 and 019-035 in the Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Procedures 019-034 and 019-035 in Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.

OK
Go To Next Step

STEP 5 Engine brake harness connectors are loose or broken	.....	Check the engine brake harness connectors. Check the engine brake harness for continuity.

OK
Go To Next Step

STEP 6 Clutch switch or circuit is malfunctioning	.....	Check the clutch switch adjustment, switch, and circuit. Refer to Procedures 019-009 and 019-010 in the Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Procedure 019-009 in Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.

OK
Go To Next Step

Engine Brake Does Not Operate

This is symptom tree t036

Cause		Correction
STEP 7 Accelerator pedal or lever position sensor or circuit is malfunctioning	.....	Check for foot pedal restriction. Check the accelerator pedal or lever position sensor and circuit. Refer to Procedures 019-085 and 019-086 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Procedures 019-085 and 019-086 in Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.

OK
Go To Next Step

STEP 8 Service brake pressure switch or circuit is malfunctioning	.....	Check the service brake pressure switch and circuit. Refer to the OEM service manual.

OK
Go To Next Step

STEP 9 Engine electrical ground is malfunctioning	.....	Check engine ground to chassis and chassis ground to battery negative (-) post. Refer to the OEM service manual and Procedure 013-009.

OK
Go To Next Step

STEP 10 Lubricating oil leak (internal)	.....	Check the engine brake control valve and the engine brake piston. Refer to Procedures 020-004.

OK
Go To Next Step

STEP 11 Engine brake lubricating oil passage is restricted	.....	Check the engine brake assembly for restriction. Refer to Procedure 020-004.

OK
Go To Next Step

STEP 12 Engine brake adjustment is **not** correct	.....	Adjust the engine brakes. Refer to Procedure 020-004.

Engine Brake - Low Retarding Power or Slow to Activate

This is symptom tree t037

Cause	Correction
STEP 1 Interview the operator to verify the complaint	Refer to Procedure t00-004 Driveability-General Information, the Driveability/Low-Power Customer Complaint Form, and the Driveability Checklist at the end of Section TS. Follow the instructions on the forms before continuing with this tree.
OK Go To Next Step	
STEP 2 Electronic fault codes active or high counts of inactive fault codes	Refer to Section TF in the Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 3 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 Section 1 in the Operation and Maintenance Manual, ISC, ISC^e, ISL Engines, Bulletin 4021428 or Operation and Maintenance Manual, QSC8.3 and QSL9 Engines, Bulletin 4021518.
OK Go To Next Step	
STEP 4 Engine is cold	Allow the engine to warm to operating temperature. If the engine will **not** reach operating temperature, refer to the Coolant Temperature Below Normal symptom tree.
OK Go To Next Step	
STEP 5 Engine brake adjustment is **not** correct	Adjust the engine brakes. Refer to Procedure 020-004.
OK Go To Next Step	
STEP 6 Engine brake harness connectors are loose or broken	Check the engine brake harness connectors. Check the engine brake harness for continuity.
OK Go To Next Step	
STEP 7 Air in the lubricating oil system	Check the oil level. If level is high, check for a cracked suction tube. Refer to Procedure 007-025.
OK Go To Next Step	

Engine Brake - Low Retarding Power or Slow to Activate

This is symptom tree t037

Cause	Correction
STEP 8 Lubricating oil leak (internal)	Check the engine brake control valve and the engine brake piston. Refer to Procedures 020-004.
OK Go To Next Step	
STEP 9 Engine brake solenoid(s) is malfunctioning	Refer to the Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416, or Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 10 Engine brake control valve(s) is malfunctioning	Check the engine brake control valve(s). Replace the engine brake control valve(s) if necessary. Refer to Procedure 020-004.
OK Go To Next Step	
STEP 11 Engine brake lubricating oil passage is restricted	Check the engine brake assembly for restriction. Refer to Procedure 020-004.
OK Go To Next Step	
STEP 12 Turbocharger is malfunctioning	Monitor the turbocharger boost pressure with an electronic service tool. Refer to the Engine Performance Troubleshooting tree in Section TT.

Engine Noise Excessive

This is symptom tree t047

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

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Read the fault codes with an electronic service tool. Refer to Section TF in Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416 or Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.

OK
Go To Next Step

STEP 2 Fan drive belt is loose	Check the belt tension and tighten, if necessary. Refer to Procedure 008-002.

OK
Go To Next Step

STEP 3 Fan is loose, damaged, or **not** balanced	Check the fan. Refer to Procedure 008-040.

OK
Go To Next Step

STEP 4 Fan clutch, hydraulic pump, or refrigerant compressor noise is excessive	Isolate each component and check for noise. Refer to s Procedure 008-040, Procedure 009-016, or the OEM service manual.

OK
Go To Next Step

STEP 5 Air intake or exhaust leaks	Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.

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 the OEM service manual.

OK
Go To Next Step

STEP 7 Lubricating oil level is above or below specification	Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-037.

OK
Go To Next Step

STEP 8 Lubricating oil is thin or diluted	Refer to Procedure 007-083. If the oil pressure is low, refer to the Lubricating Oil Pressure Low troubleshooting symptom tree in Section TS.

OK
Go To Next Step

Engine Noise Excessive

This is symptom tree t047

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

Cause	Correction
STEP 9 Lubricating oil pressure is below specification	Check the oil pressure. If the pressure is low, Procedure 007-037.
OK Go To Next Step	
STEP 10 Vibration damper is damaged or loose	Inspect the vibration damper. Refer to Procedure 001-051 or Procedure 001-052.
OK Go To Next Step	
STEP 11 Coolant temperature is above specification	Refer to the Coolant Temperature Above Normal - Gradual Overheat symptom tree.
OK Go To Next Step	
STEP 12 Drivetrain noise is excessive	Disconnect the drivetrain. Check for engine noise. Refer to the OEM service manual.
OK Go To Next Step	
STEP 13 Engine mounts are worn, damaged, or **not** correct	Check the engine mounts. Refer to Procedure 016-002 or Procedure 016-003.
OK Go To Next Step	
STEP 14 Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.
OK Go To Next Step	
STEP 15 Overhead components are damaged	Inspect the rocker levers, rocker shafts, and valves for damage or excessive wear. Refer to Procedure 003-008.
OK Go To Next Step	
STEP 16 Injector(s) are malfunctioning	Perform diagnostics to find the malfunctioning injector(s). Replace the injector(s) as necessary. Refer to Procedure 006-026 or Procedure 014-008.
OK Go To Next Step	
STEP 17 Air compressor noise is excessive	Refer to the Air Compressor Noise Excessive symptom tree.
OK Go To Next Step	

Engine Noise Excessive

This is symptom tree t047

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

Cause	Correction
STEP 18 Torque converter is loose	Check the torque converter. Refer to the OEM service manual.
OK Go To Next Step	
STEP 19 Flywheel or flexplate capscrews are loose or broken	Check the flywheel or flexplate and the mounting capscrews. Refer to the OEM service manual.
OK Go To Next Step	
STEP 20 Gear train backlash is excessive or the gear teeth are damaged	Check the gear backlash and the gear teeth. Refer to Procedure 001-008.
OK Go To Next Step	
STEP 21 Main bearing or connecting rod bearing noise	Refer to the Engine Noise Excessive - Connecting Rod symptom tree or the Engine Noise Excessive - Main Bearing.
OK Go To Next Step	
STEP 22 Turbocharger noise	Refer to the Engine Noise Excessive - Turbocharger symptom tree.
OK Go To Next Step	
STEP 23 Combustion noise excessive	Refer to the Engine Noise Excessive - Combustion Knocks symptom tree.
OK Go To Next Step	
STEP 24 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 or Procedure 001-047.

Engine Noise Excessive — Combustion Knocks

This is symptom tree t048

Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Read the fault codes with an electronic service tool. Refer to Section TF in Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416 or Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
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 high-quality fuel. Refer to the Fuel for Cummins Engines, Bulletin 3379001.
OK Go To Next Step	
STEP 3 Air in the fuel system	Check for air in the fuel system. Vent air from the system. Refer to Procedure 006-003.
OK Go To Next Step	
STEP 4 Coolant temperature is above specification	Refer to Procedures 008-018, 008-020, or 008-103.
OK Go To Next Step	
STEP 5 Injector is malfunctioning	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedures 006-026 and 014-008.
OK Go To Next Step	
STEP 6 Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.
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 001-012.

Engine Noise Excessive — Connecting Rod

This is symptom tree t049

Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.

Cause	Correction
STEP 1 Lubricating oil level is below specification	Check the oil level. Verify the dipstick calibration and the oil pan capacity. Fill the system to the specified level. Refer to Procedures 007-037 and 007-009.
OK Go To Next Step	
STEP 2 Lubricating oil pressure is below specification	Check the oil pressure. If the pressure is low, refer to Procedure 007-037.
OK Go To Next Step	
STEP 3 Lubricating oil is thin or diluted	Refer to Procedure 007-083. If the oil pressure is low, refer to the Lubricating Oil Pressure Low symptom tree.
OK Go To Next Step	
STEP 4 Block stiffener plate is misassembled	Remove and inspect block stiffener plate. Refer to Procedure 001-089.
OK Go To Next Step	
STEP 5 Lubricating oil suction or transfer tube misassembled	Remove and inspect the lubricating oil suction or transfer tube. Refer to Procedure 007-035.
OK Go To Next Step	
STEP 6 Crankshaft journals are damaged or out of round	Inspect the crankshaft journals. Refer to Procedure 001-016.
OK Go To Next Step	
STEP 7 Connecting rod capscrews are loose or **not** tightened correctly	Check the torque on the connecting rod capscrews. Refer to Procedure 001-014.
OK Go To Next Step	
STEP 8 Connecting rod is bent or out of alignment	Remove and inspect the connecting rods. Refer to Procedure 001-014.
OK Go To Next Step	

Engine Noise Excessive — Connecting Rod

This is symptom tree t049

Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.

Cause	Correction
STEP 9 Connecting rod and bearings are damaged or worn, are **not** assembled correctly, or are the wrong bearings	Inspect the connecting rod and bearings. Refer to Procedure 001-014.

Engine Noise Excessive — Main Bearing

This is symptom tree t050

Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.

Cause	Correction
STEP 1 Lubricating oil pressure is below specification	Check the oil pressure. If the pressure is low, refer to Procedure 007-037.
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 Procedures 007-037 and 007-009.
OK Go To Next Step	
STEP 3 Lubricating oil is thin or diluted	Refer to Procedure 007-083. If the oil pressure is low, refer to the Lubricating Oil Pressure Low symptom tree.
OK Go To Next Step	
STEP 4 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.
OK Go To Next Step	
STEP 5 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.
OK Go To Next Step	
STEP 6 Crankshaft journals are damaged or out of round	Inspect the crankshaft journals. Refer to Procedure 001-016.
OK Go To Next Step	
STEP 7 Flywheel or flexplate capscrews are loose or broken	Check the flywheel or flexplate and the mounting capscrews. Refer to Procedure 016-005.

Engine Noise Excessive — Piston

This is symptom tree t051

Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Read the fault codes with an electronic service tool. Refer to Section TF in Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416 or Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
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 high-quality fuel. Refer to the Fuels for Cummins Engines, Bulletin 3379001.
OK Go To Next Step	
STEP 3 Overhead adjustments are **not** correct	Measure and adjust the overhead settings. Refer to Procedure 003-004.
OK Go To Next Step	
STEP 4 Injector is malfunctioning	Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedures 006-026 and 014-008.
OK Go To Next Step	
STEP 5 Connecting rod is bent or out of alignment	Remove and inspect the connecting rods. Refer to Procedure 001-014.
OK Go To Next Step	
STEP 6 Connecting rod is misassembled	Remove and inspect the connecting rod. Refer to Procedure 001-014.
OK Go To Next Step	
STEP 7 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 001-043.
OK Go To Next Step	
STEP 8 Piston is misassembled	Remove and inspect the piston. Refer to Procedure 001-043 or 001-054.
OK Go To Next Step	

Engine Noise Excessive — Piston

This is symptom tree t051

Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.

Cause		Correction
STEP 9 Piston pin or bushing is loose, worn, or **not** installed correctly	.....	Remove the pistons and inspect the piston pin and bushing for damage, wear, and correct installation. Refer to Procedure 001-043 or 001-054.

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 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 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 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 4 Air intake or exhaust piping is contacting the chassis or cab	Inspect the air piping, chassis, and cab for contact points. Refer to the original equipment manufacturer (OEM) service manual.
OK Go To Next Step	
STEP 5 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 6 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 7 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 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 Section TF in Troubleshooting and Repair Manual, ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9, CM850 Electronic Control System, Bulletin 4021416.
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	Refer to Procedure 013-007 in Section 13. Replace the batteries if necessary.
OK Go To Next Step	
STEP 5 OEM starter interlock devices engaged	Check the starter interlock devices. Refer to the OEM service manual.
OK Go To Next Step	
STEP 6 Starting circuit component is malfunctioning	Check the starting circuit components. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Starter solenoid does **not** make an audible sound	Check the magnetic switch and starter solenoid. Refer to Procedures 013-017 and 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 the OEM service manual.
OK Go To Next Step	
STEP 9 Engine-driven units are engaged	Disengage 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 the OEM service manual.
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 Section TF in Troubleshooting and Repair Manual, ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9, CM850 Electronic Control System, Bulletin 4021416.
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	Refer to Procedure 013-007 in Section 13. Replace the batteries if necessary.
OK Go To Next Step	
STEP 6 OEM starter interlock devices engaged	Check the starter interlock devices. Refer to the OEM service manual.
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 the OEM service manual.
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 the OEM service manual.
OK Go To Next Step	

Engine Cranks Slowly — (Electric Starter)

This is symptom tree t074-010

Cause	Correction
STEP 9 Engine-driven units are engaged	Disengage engine-driven units.
OK Go To Next Step	
STEP 10 Starting circuit component is malfunctioning	Check the starting circuit components. Refer to the OEM service manual.
OK Go To Next Step	
STEP 11 Starter motor malfunction	Check the voltage drop at the starting motor. Refer to Procedure 013-020 in Section 13.
OK Go To Next Step	
STEP 12 Starting motor pinion or ring gear is damaged	Remove the starting motor, and inspect the gear. Refer to Procedure 013-020 in Section 13.
OK Go To Next Step	
STEP 13 Lubricating oil level is above specification	Check the oil level. Verify the dipstick calibration and oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-009 in Section 7.
OK Go To Next Step	
STEP 14 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Procedure 018-003 in Section V. This procedure can be found in the appropriate Operation and Maintenance Manual, to verify the correct lubricating oil is being used.
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 Crank or Cranks Slowly (Air Starter)

This is symptom tree t077

Cause	Correction
STEP 1 Air pressure is low in the air tanks	Increase air pressure with an external air source. Refer to the OEM service manual.
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 Section TF in Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416 or Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 3 OEM starter interlock devices engaged	Check the starter interlock devices. Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Lubricating oil pressure switch, gauge, or sensor is malfunctioning or is **not** in the correct location	Check the oil pressure switch, gauge, or sensor for correct operation and location. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 Engine-driven units are engaged	Disengage engine-driven units.
OK Go To Next Step	
STEP 6 Starting motor is malfunctioning or starting motor is **not** correct	Check the starting motor operation. Compare the starting motor with the engine and vehicle specifications. Refer to the OEM service manual.
OK Go To Next Step	
STEP 7 Starting motor pinion or ring gear is damaged	Remove the starting motor, and inspect the gear. Refer to Procedure 013-020.
OK Go To Next Step	
STEP 8 Lubricating oil level is above specification	Check the oil level. Verify the dipstick calibration and oil pan capacity. Fill the system to the specified level. Refer to Procedures 007-009 and 007-037.
OK Go To Next Step	

Engine Will Not Crank or Cranks Slowly (Air Starter)

This is symptom tree t077

Cause		Correction
STEP 9 Lubricating oil does **not** meet specifications for operating conditions	.....	Change the oil and filters. Refer to Cummins Engine Oil Recommendations and Specifications, Bulletin 3810340.

OK
Go To Next Step

STEP 10 Crankshaft rotation is impaired	.....	Check the crankshaft for ease of rotation. Refer to Procedure 001-016.

OK
Go To Next Step

STEP 11 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.

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.

Engine Will Not Shut Off

This is symptom tree t081

Cause	Correction
STEP 1 Keyswitch circuit is malfunctioning	Check the vehicle, equipment, or vessel keyswitch circuit. Refer to Procedure 019-064 in Section 19 in ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416, or Procedure 019-064 in Section 19 in ISC, QSC8.3, and ISL Electronic Control System Troubleshooting and Repair Manual, Bulletin 3666271.
OK Go To Next Step	
STEP 2 Starting aid is malfunctioning	Check for correct operation of cold-starting aid. Refer to Procedure 005-008 in Section 5 and Procedure 010-029 in Section 10.
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 the OEM service manual.
OK Go To Next Step	
STEP 5 Engine control module (ECM) is malfunctioning	Replace the ECM. Refer to Procedure 019-031 in Section 19 in ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416, or Procedure 019-031 in Section 19 in ISC, QSC8.3, and ISL Electronic Control System Troubleshooting and Repair Manual, Bulletin 3666271.

Fuel in the Sea Water

This is symptom tree t90

Cause	Correction
STEP 1 Fuel return restriction excessive	Inspect the fuel return lines for restrictions. Refer to Procedure 006-012. Check to make sure the fuel return valve is open.

OK
Go To Next Step

STEP 2 Fuel cooler is malfunctioning (if equipped)	Check the fuel cooler. Refer to Procedure 006-062 for QSL9 marine sea water cooled engines or Procedure 008-129 for QSC8.3 marine engines.

Fuel in Coolant

This is symptom tree t091

Cause	Correction
STEP 1 Bulk coolant supply is contaminated	Check the bulk coolant supply. Drain the coolant and replace with noncontaminated coolant. Replace the coolant filters. Refer to Procedure 008-018.

OK
Go To Next Step

STEP 2 Cylinder head is cracked or porous	Remove intake and exhaust manifolds. Check for evidence of coolant leak. If necessary, operate engine at low idle. Pressure-test the cylinder head. Refer to Procedure 002-004.

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. Replace the oil filters. Refer to Procedure 007-037 in Section 7.
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 Section TF, Troubleshooting and Repair Manual.
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 off the engine rather than idle for long periods. If idle time is necessary, raise the idle speed. Refer to 101-015 in Section 1, in the Operation and Maintenance Manual, ISC, ISCe, and ISL Engines, Bulletin 4021428.
OK Go To Next Step		
STEP 4 Smoke (white or black) is excessive	.....	Troubleshoot for excessive smoke. Refer to the appropriate Engine Performance Troubleshooting Repair Manual.
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. Check or replace the fuel lines, check valves, or tank vents as needed.
OK Go To Next Step		
STEP 6 Injector is malfunctioning (Cummins Common Rail)	.....	Perform a High Pressure Injector Return Flow Test. Refer to Procedure 006-026 in Section 6. Replace injectors as necessary.
OK Go To Next Step		
STEP 7 Internal fuel leaks	.....	Inspect for fuel leaks. Add fluorescent tracer dye to the fuel system. Refer to Procedure 007-044 in Section 7.
OK Go To Next Step		
STEP 8 Injector is malfunctioning (CAPS)	.....	Perform Injector Mechanical Tests. Refer to Procedure 006-026 in Section 6. Replace injectors as necessary.
OK Go To Next Step		

Fuel in the Lubricating Oil

This is symptom tree t092

Cause	Correction
STEP 9 Troubleshooting tree has been exhausted	Refer to Technical Support or Local Distributor/ Dealer.

Intake Manifold Air Temperature Above Specification

This is symptom tree t096

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Refer to Section TF in ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416, or the ISC, QSC8.3, and ISL Electronic Control System Troubleshooting and Repair Manual, Bulletin 3666271.

OK
Go To Next Step

STEP 2 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 3 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 4 Cold weather radiator cover or winterfront is closed	Open the cold weather radiator cover or the winterfront. Maintain a minimum of 387 cm2 [60 in2] of opening at all times. Refer to Section 1 of the ISC, ISCe, and ISL Operation and Maintenance Manual, Bulletin 4021428, or the QSC8.3 and QSL9 Operation and Maintenance Manual, Bulletin 4021518.

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 Aftercooler restricted, if equipped	Inspect for plugged passages in the aftercooler. Refer to Procedure 010-005 in Section 10.

OK
Go To Next Step

STEP 7 Intake manifold temperature gauge is malfunctioning, if equipped	Refer to the OEM service manual.

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 in ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416, or Procedure 019-078 in Section 19 in the ISC, QSC8.3, and ISL Electronic Control System Troubleshooting and Repair Manual, Bulletin 3666271.
OK Go To Next Step	
STEP 9 Fan drive or fan controls are malfunctioning	Check the fan drive and controls. Refer to Procedure 019-045 in Section 19 in ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416, or Procedure 019-045 in Section 19 in the ISC, QSC8.3, and ISL Electronic Control System Troubleshooting and Repair Manual, Bulletin 3666271.
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 Procedure 008-038 in Section 8.
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 Engine is operating at high ambient temperature	Measure the temperature of the ambient air in the engine enclosure. Reroute the air intake, if necessary.
OK Go To Next Step	

Intake Manifold Air Temperature Above Specification

This is symptom tree t096

Cause	Correction
STEP 14 Exhaust system leaking hot air into engine compartment	Check the exhaust plumbing for leaks or broken components. Refer to Procedure 010-024.
OK Go To Next Step	
STEP 15 Malfunctioning intake air heater	Connect INSITE™ electronic service tool. From the list of ”ECM Diagnostic Tests“, select ”Grid Heater Override”. Follow the instructions on the screen to determine if the cold starting aid is working properly. If the intake air heater is **not** functioning properly, troubleshoot the intake air heater wiring and relay circuits. Refer to Procedure 019-408 in Section 19.
OK Go To Next Step	
STEP 16 Intake manifold pressure sensor is malfunctioning	Check the intake manifold pressure sensor. Refer to Procedure 019-061 in Section 19 in ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416, or Procedure 019-061 in Section 19 in the ISC, QSC8.3, and ISL Electronic Control System Troubleshooting and Repair Manual, Bulletin 3666271.
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 Electronic fault codes active or high counts of inactive fault codes	Read the fault codes with an electronic service tool. Refer to Section TF in the ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416 or the ISC, QSC8.3, and ISL Electronic Control System Troubleshooting and Repair Manual, Bulletin 3666271.
OK Go To Next Step	
STEP 2 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 3 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 4 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 5 Intake manifold pressure sensor is malfunctioning	Check the intake manifold pressure sensor. Refer to Procedure 019-159 in Section 19 in the ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416 or Procedure 019-061 in Section 19 in the ISC, QSC8.3, and ISL Electronic Control System Troubleshooting and Repair Manual, Bulletin 3666271.
OK Go To Next Step	
STEP 6 Air compressor connection is loose or damaged	Check the connection between the manifold and the air compressor. Repair or replace if necessary.
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	

Intake Manifold Pressure (Boost) is Below Normal

This is symptom tree t097

Cause		Correction
STEP 8 Turbocharger wastegate is damaged or is stuck open	.....	Check the wastegate for freedom of movement. Inspect the wastegate for damage. Refer to Procedure 010-050 in Section 10.

OK
Go To Next Step

STEP 9 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 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 Performance Troubleshooting symptom tree in Section TT.

OK
Go To Next Step

STEP 12 Excessive load for engine horsepower rating	.....	Reduce vehicle load or use low gear if the engine is industrial. If engine is marine, change propeller(s).

Lubricating Oil Consumption Excessive

This is symptom tree t102

Cause	Correction
STEP 1 Verify the oil consumption rate	Check the amount of oil added versus the mileage. Refer to the Oil Consumption Report form in the Troubleshooting Overview of Section TS.
OK Go To Next Step	
STEP 2 Lubricating oil leak (external)	Inspect the engine for external oil leaks. Tighten the capscrews, pipe plugs, and fittings. Replace gaskets, if necessary. Refer to the following procedures in Section 7. Procedure 007-001, Procedure 007-003, Procedure 007-013, Procedure 007-025, and Procedure 007-037 in Section 7.
OK Go To Next Step	
STEP 3 Crankcase ventilation system is plugged	Check and clean the crankcase breather and vent tube. Refer to Procedure 003-018 and Procedure 003-002 in Section 3.
OK Go To Next Step	
STEP 4 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Procedure 007-037 and Procedure 007-013 in Section 7. Also see the lubricating oil recommendations and specifications procedure in the Operation and Maintenance Manual, ISC and ISL Series Engines, Bulletin 4021428 or the Operation and Maintenance Manual, QSC8.3 and QSL9 Engines, Bulletin 4021518. 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 Section 2 in the Operation and Maintenance Manual, ISC and ISL Series Engines, Bulletin 4021428 or the Operation and Maintenance Manual, QSC8.3 and QSL9 Engines, Bulletin 4021518.
OK Go To Next Step	
STEP 6 Air compressor is pumping lubricating oil into the air system	Check the air lines for carbon buildup and lubricating oil. Refer to Procedure 012-003 in Section 12.
OK Go To Next Step	
STEP 7 Lubricating oil cooler is leaking oil	Check the lubricating oil cooler for oil leaks. Refer to Procedure 007-003 in Section 7.
OK Go To Next Step	

Lubricating Oil Consumption Excessive

This is symptom tree t102

Cause	Correction
STEP 8 Lubricating oil level is above specification	Check the oil level. Verify the dipstick calibration and oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-009 in Section 7.
OK Go To Next Step	
STEP 9 Engine angularity during operation exceeds specification	Refer to Recreational Installation Directions for Marine Engines, Bulletin 3884649.
OK Go To Next Step	
STEP 10 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 11 Valve seals are worn	Inspect the valve seals. Replace the valve seals, if necessary. Refer to Procedure 002-004 in Section 2.
OK Go To Next Step	
STEP 12 Piston rings are **not** seated correctly (after an engine rebuild or piston installation)	Check blowby. Refer to 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 13 Lubricating oil is contaminated with coolant or fuel	Refer to the Lubricating Oil Contaminated troubleshooting symptom tree.
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.
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 007-083 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.
OK Go To Next Step	
STEP 3 Internal coolant leaks	Refer to the Coolant Loss - Internal troubleshooting symptom tree.
OK Go To Next Step	
STEP 4 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 Coolant temperature is below specification	Refer to the Coolant Temperature Below Normal troubleshooting symptom tree in Section TS.
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 and Procedure 007-013 in Section 7. Use the oil type recommended in Section V of the operation and maintenance manual.
OK Go To Next Step	
STEP 3 Lubricating oil pressure switch, gauge, or sensor is malfunctioning or is **not** in the correct location.	Check the oil pressure switch, gauge, or sensor for correct operation and location. Refer to the OEM service manual.
OK Go To Next Step	
STEP 4 Lubricating oil pressure sensor or circuit is malfunctioning (electronic controlled fuel system)	Check the lubricating oil pressure sensor and circuit. Refer to Procedure 019-066 in Section 19 in the ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416, or Procedure 019-066 in Section 19 in the ISC, QSC8.3, and ISL Electronic Control System Troubleshooting and Repair Manual, Bulletin 3666271.
OK Go To Next Step	
STEP 5 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	Read the fault codes with an electronic service tool. Refer to Section TF in Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416, or Section TF in Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 2 Lubricating oil pressure switch, gauge, or sensor is malfunctioning or is **not** in the correct location.	Check the oil pressure switch, gauge, or sensor for correct operation and location. Refer to the OEM service manual.
OK Go To Next Step	
STEP 3 Lubricating oil level is above or below specification	Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-009 in Section 7 and Procedure 007-037 in Section 7.
OK Go To Next Step	
STEP 4 Lubricating oil leak (external)	Inspect the engine for external oil leaks. Tighten the capscrews, pipe plugs, and fittings. Replace gaskets, if necessary. Refer to Procedure 007-001 in Section 7, Procedure 007-003 in Section 7, Procedure 007-013 in Section 7, Procedure 007-025 in Section 7, and Procedure 007-037 in Section 7.
OK Go To Next Step	
STEP 5 Lubricating oil filter is plugged	Measure the differential pressure drop across the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
OK Go To Next Step	
STEP 6 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Procedure 007-013 in Section 7 and Procedure 007-037 in Section 7. Use the oil type recommended in Section V of the operation and maintenance manual.
OK Go To Next Step	

Lubricating Oil Pressure Low

This is symptom tree t105

Cause	Correction
STEP 7 Lubricating oil filter is **not** correct	Make sure the correct oil filter is being used. Refer to the Operation and Maintenance Manual, ISC and ISL Series Engines, Bulletin 4021428, or Operation and Maintenance Manual, QSC8.3 and QSL9 Engines, Bulletin 4021518.
OK Go To Next Step	
STEP 8 Lubricating oil is contaminated with coolant or fuel	Refer to the Lubricating Oil Contaminated symptom tree.
OK Go To Next Step	
STEP 9 Engine angularity during operation exceeds specification	Refer to the engine performance curves and data sheet.
OK Go To Next Step	
STEP 10 Lubricating oil pressure sensor or circuit is malfunctioning (electronic controlled fuel system)	Check the lubricating oil pressure sensor and circuit. Refer to Procedure 019-066 in Section 19 in Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416, or Procedure 019-066 in Section 19 in Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 11 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 12 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 13 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 14 Lubricating oil pump is malfunctioning	Inspect the lubricating oil pump. Refer to Procedure 007-031 in Section 7.
OK Go To Next Step	

Lubricating Oil Pressure Low

This is symptom tree t105

Cause		Correction
STEP 15 Lubricating oil cooler is plugged	.....	Check the oil cooler. Refer to Procedure 007-003 in Section 7.
OK Go To Next Step		
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 lubricating oil. Inspect the oil filter. Check the main bearings, rod bearings, camshaft bushings, and rocker lever bushings for excessive wear. Refer to Procedure 001-005 in Section 1, Procedure 001-006 in Section 1, Procedure 001-010 in Section 1, and Procedure 007-083 in Section 7.
OK Go To Next Step		
STEP 18 Instant loss of lubricating engine oil	.....	Inspect the connecting rod bearings, main bearings, turbocharger, lubricating oil pump, and lubricating oil cooler. Refer to Procedure 001-005 in Section 1, Procedure 001-006 in Section 1, Procedure 007-003 in Section 7, Procedure 007-031 in Section 7, Procedure 010-033 in Section 10, Procedure 010-050 in Section 10, and Procedure 010-113 in Section 10.
OK Go To Next Step		
STEP 19 Significant connecting rod and main bearing damage as a result of instant loss of lubricating engine oil	.....	Inspect the air compressor bushings, camshaft bushings, connecting rods, crankshaft, pistons and cylinder liners. Refer to Procedure 001-010 in Section 1, Procedure 001-014 in Section 1, Procedure 001-016 in Section 1, Procedure 001-028 in Section 1, Procedure 001-043 in Section 1, and Procedure 012-014 in Section 12.

Lubricating Oil Sludge in the Crankcase Excessive

This is symptom tree t106

Cause	Correction
STEP 1 Bulk oil supply is contaminated	Check the bulk oil supply. Drain the oil and replace with noncontaminated oil. Replace the oil filters. Refer to Procedures 007-013 and 007-083.
OK Go To Next Step	
STEP 2 Lubricating oil does **not** meet specifications for operating conditions	Change the oil and filters. Refer to Procedure 007-013 and 007-037. Use the oil type recommended in Section V of the engine operation and maintenance manual.
OK Go To Next Step	
STEP 3 Lubricating oil drain interval is excessive	Verify the correct lubricating oil drain interval. Refer to the Operation and Maintenance Manual, ISC and ISL Series Engines, Bulletin 4021428 or Operation and Maintenance Manual, QSC8.3 and QSL9 Engines, Bulletin 4021518.
OK Go To Next Step	
STEP 4 Crankcase ventilation system is plugged	Check and clean the crankcase breather and vent tube. Refer to Procedure 003-008.
OK Go To Next Step	
STEP 5 Fuel grade is **not** correct for the application or the fuel quality is poor	Operate the engine from a tank of high-quality fuel. Refer to the Fuel for Cummins Engines, Bulletin 3379001.
OK Go To Next Step	
STEP 6 Coolant temperature is below specification	Refer to the Coolant Temperature is Below Normal symptom tree.
OK Go To Next Step	
STEP 7 Lubricating oil is contaminated with coolant or fuel	Refer to Lubricating Oil Contaminated symptom tree.
OK Go To Next Step	
STEP 8 Crankcase pressure is excessive	Check for excessive blowby. Refer to Procedure 014-010.
OK Go To Next Step	
STEP 9 Exhaust system restriction is **not** within specification	Check the exhaust system for restrictions. Refer to Procedure 011-009.
OK Go To Next Step	

Lubricating Oil Sludge in the Crankcase Excessive

This is symptom tree t106

Cause	Correction
STEP 10 Coolant temperature is above specification	Refer to the Coolant Temperature Above Normal - Gradual Overheat or Coolant Temperature Above Normal - Sudden Overheat symptom trees.

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	Refer to Section TF in Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416 or Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
OK Go To Next Step	
STEP 2 Coolant temperature is above specification	Refer to the Coolant Temperature Above Normal symptom tree.
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.
OK Go To Next Step	
STEP 4 Lubricating oil temperature switch, gauge, or sensor malfunctioning or **not** in the correct location	Check the oil temperature switch, gauge, or sensor for correct operation and location. Refer to the OEM service manual.
OK Go To Next Step	
STEP 5 OEM components cooled with engine lubricating oil are malfunctioning	Check OEM components. Refer to the OEM service manual.
OK Go To Next Step	
STEP 6 Lubricating oil cooler is plugged	Check the oil cooler. Refer to Procedure 007-003.
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.

Lubricating or Transmission Oil in the Coolant

This is symptom tree t108

Cause	Correction
STEP 1 Bulk coolant supply is contaminated	Check the bulk coolant supply. Drain the coolant and replace with non-contaminated coolant. Replace the coolant filters. Refer to Procedure 008-018 and Procedure 008-006 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 the OEM service manual.
OK Go To Next Step	
STEP 4 Marine gear oil cooler is malfunctioning	Remove and inspect the marine gear oil cooler. Refer to Procedure 008-041 or Procedure 008-129 in Section 8.
OK Go To Next Step	
STEP 5 Turbocharger bearing housing is cracked or porous (if equipped with liquid cooled turbocharger bearing housing)	Check turbocharger bearing housing. Refer to Procedure 010-033 in Section 10.
OK Go To Next Step	
STEP 6 Cylinder head gasket is leaking	Remove the cylinder head and check the cylinder head gasket. Refer to Procedure 002-004 in Section 2.
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	Replace the cylinder block. Refer to Procedure 001-026 in Section 1.

Turbocharger Leaks Engine Oil or Fuel

This is symptom tree t122

Cause	Correction
STEP 1 Engine is operating for extended periods under light- or no-load conditions (slobbering)	Review the engine operating instructions in Section 1 of the Operation and Maintenance Manual, ISC and ISL Series Engines, Bulletin 4021428 or the Operation and Maintenance Manual, QSC8.3 and QSL9 Engines, Bulletin 4021518.
OK Go To Next Step	
STEP 2 White smoke is present	Refer to the Smoke, White - Excessive symptom tree.
OK Go To Next Step	
STEP 3 Lubricating oil lines leak oil	Check all oil lines and fittings for leaks. Tighten loose fittings and replace leaking oil lines if necessary.
OK Go To Next Step	
STEP 4 Turbocharger oil drain line is restricted	Remove the turbocharger oil drain line and check for restriction. Clean or replace the oil drain line. Refer to Procedure 010-045.
OK Go To Next Step	
STEP 5 Crankcase ventilation system is plugged	Check and clean the crankcase breather and vent tube. Refer to Procedure 003-018.
OK Go To Next Step	
STEP 6 Lubricating oil or fuel is entering the turbocharger	Remove the intake and exhaust piping, and check for oil or fuel.
OK Go To Next Step	
STEP 7 Air intake system restriction is above specification	Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031.
OK Go To Next Step	
STEP 8 Exhaust system restriction is **not** within specification	Check the exhaust system for restrictions. Refer to Procedure 011-009.
OK Go To Next Step	
STEP 9 Turbocharger oil seal is leaking	Check the turbocharger compressor and turbine seals. Refer to Procedure 010-033.
OK Go To Next Step	

Turbocharger Leaks Engine Oil or Fuel

This is symptom tree t122

Cause	Correction
STEP 10 Turbocharger wheel clearance is out of specification	Check the radial bearing clearance and axial clearance. Inspect the turbocharger. Repair or replace the turbocharger if necessary. Refer to Procedure 010-033.

OK
Go To Next Step

STEP 11 Worn piston rings	Check for excessive blowby. Refer to Procedure 014-010.

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 Procedures 002-004.

Urea Usage - Abnormal

This is symptom tree t128

Cause	Correction
STEP 1 Electronic fault codes active or high counts of inactive fault codes	Refer to Section TF in Troubleshooting and Repair Manual, ISB, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416.
OK Go To Next Step	
STEP 2 Urea tank empty or incorrect fluid	Verify urea is in the reservoir tank. Fill the tank with urea, if empty. Refer to the progressive damage limits, if fuel, oil, or coolant, were found in the reservoir tank.
OK Go To Next Step	
STEP 3 Urea leak (external)	Inspect for external urea leaks or crystallization at exhaust joints, tailpipe exit, aftertreatment nozzle, or associated plumbing. Repair as necessary. Refer to Procedure 011-036, Exhaust Catalyst, and Procedure 011-040, Aftertreatment Nozzle.
OK Go To Next Step	
STEP 4 Extended operation of the engine in low-duty cycle, extended idling, and/or low ambient temperatures can result in reduced urea usage. Conversely, extended operation of the engine in high-duty cycle and/or high ambient temperatures can result in increased urea usage	Perform Urea Doser Pump Override Test with INSITE™ electronic service tool. Refer to Procedure 019-440 in Troubleshooting and Repair Manual, ISB, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416.
OK Go To Next Step	
STEP 5 Urea leak (internal)	Inspect for internal urea leaks or crystallization between the aftertreatment nozzle and the exhaust catalyst. Repair as necessary. Refer to Procedure 011-036, Exhaust Catalyst, and Procedure 011-040, Aftertreatment Nozzle.

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 and the OEM service manual.
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 008-080 in Section 8.

Notes

Section TT - Troubleshooting Symptoms (New Format)

Section Contents

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Engine Performance Troubleshooting Tree - CM554 Electronic Control System with CAPS Fuel System

This troubleshooting procedure should be followed for the following symptoms:

- Engine Acceleration or Response Poor
- Cranking Fuel Pressure is Low
- Engine Operating Fuel Pressure is Low
- Engine Decelerates Slowly
- Engine Difficult to Start or Will Not Start (Exhaust Smoke)
- Engine Difficult to Start or Will Not Start (No Exhaust Smoke)
- Engine Power Output Low
- Engine Runs Rough at Idle
- Engine Runs Rough or Misfires
- Engine Speed Surges at Low or High Idle
- Engine Speed Surges Under Load or in Operating Range
- Smoke, Black - Excessive
- Smoke, White - Excessive
- Engine Shuts Off or Dies Unexpectedly or Dies During Deceleration
- Engine Starts But Will Not Keep Running
- Engine Will Not Reach Rated Speed (RPM)
- Intake Manifold Pressure (Boost) is Below Normal

How to Use This Troubleshooting Procedure:

This symptom tree can be used to troubleshoot all of the performance-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 symptom. Perform the list of troubleshooting in the sequence shown in the Specifications/Repair section of the tree.

Shop Talk:

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 problem or if it simply does **not** meet driver expectations.

Low power is a term that is used in the field to describe many different performance problems. 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.

Poor acceleration or response is described 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 because it can be caused by several factors.

TROUBLESHOOTING SUMMARY

STEPS		SPECIFICATIONS	SRT CODE
STEP 1:	**Perform basic troubleshooting procedures.**		
STEP 1A:	Check for active fault codes or high counts of inactive fault codes.	Active fault codes or high counts of inactive fault codes?	
STEP 1B:	Perform basic troubleshooting checks.	All steps have been verified to be correct?	
STEP 2:	**Determination of engine symptom.**		
STEP 2A:	Low power, poor acceleration, or poor response.	Is the engine symptom low power, poor acceleration, or poor response?	
STEP 2B:	Engine misfire, engine speed surge, or engine speed unstable.	Is the engine symptom engine misfire, engine speed surge, or engine speed unstable?	
STEP 2C:	Excessive white or black smoke.	Is the engine symptom excessive white or black smoke?	
STEP 2D:	Low intake manifold pressure.	Is the engine symptom low boost pressure?	
STEP 2E:	Engine will not start or difficult to start, or engine shuts off unexpectedly.	Is the symptom engine will not start or difficult to start, or engine shuts off unexpectedly?	
STEP 3:	**No-start troubleshooting procedures.**		
STEP 3A:	Check the ECM keyswitch voltage.	Is the keyswitch voltage equal to battery voltage?	
STEP 3B:	Check the ECM battery supply voltage.	Is the ECM battery supply voltage equal to the battery voltage?	
STEP 3C:	Verify the operation of cold weather starting aids.	If equipped, are cold weather starting aids operating correctly?	
STEP 3D:	Check the fuel lift pump pressure.	Is the fuel lift pump pressure greater than the specifications outlined in Procedure 005-045 (Fuel Lift Pump) in the ISC, ISCe, QSC8.3, ISL and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418?	
STEP 3E:	Verify fuel pressure sensor accuracy.	Is the accumulator pressure value less than 34.5 bar [500 psi]?	
STEP 3F:	Check the accumulator pressure.	Is accumulator pressure greater than 293 bar [4250 psi] while cranking?	
STEP 3G:	Use INSITE™ electronic service tool to check the CPS crank state.	Does CPS state read Valid Sync while cranking?	
STEP 3G-1:	Check and adjust speed/ position sensor air gap.	Are the sensor(s) depth measurements within specification?	

STEP 3H:	**Measure gear pump pressure.**	**Is the fuel gear pump pressure greater than the specifications outlined in Procedure 005-089 (Fuel Pump Gear Pump Module) in the ISC, ISCe, QSC8.3, ISL and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418?**
STEP 3I:	**Perform the injection control valve (IVC) click test.**	**Does the injection control valve pass the click test?**
STEP 3J:	**Perform the pumping control valve (PCV) click test.**	**Do the pumping control valves pass the click test?**
STEP 3K:	**Check the distributor rotor timing.**	**Distributor rotor timing is correct as outlined in Procedure 005-072 (Rotor, CAPS Fuel Injection Pump) in the ISC, ISCe, QSC8.3, ISL and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418?**
STEP 3L:	**Inspect the gear pump coupling for wear.**	**Is the gear pump drive shaft or coupling worn?**

STEP 4: Fuel system troubleshooting procedures.

STEP 4A:	**Check for fault codes.**	**Are fuel system fault codes active?**
STEP 4B:	**Check the CAPS fuel pump wiring.**	**All fuel pump wiring is undamaged and is properly connected?**
STEP 4C:	**Check transorb diode.**	**Does the rough running, black smoke, or surge complaint continue?**
STEP 4D:	**Check for air in the high-pressure pump fuel supply.**	**Is air present in the fuel supply?**
STEP 4E:	**Measure the fuel inlet restriction.**	**Is the fuel inlet restriction less than the specifications outlined in Procedure 006-020 (Fuel Inlet Restriction) in the ISC, ISCe, QSC8.3, ISL and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418?**
STEP 4F:	**Measure the fuel gear pump pressure.**	**Is the fuel gear pump pressure greater than the specifications outlined in Procedure 005-089 (Fuel Pump Gear Pump Module) in the ISC, ISCe, QSC8.3, ISL and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418?**
STEP 4G:	**Perform the injection control valve click test.**	**Does the injection control valve pass the click test?**
STEP 4H:	**Perform the pumping control valve click test.**	**Do the pumping control valves pass the click test?**
STEP 4I:	**Measure fuel drain line restriction.**	**Is the drain line restriction less than specification?**

STEP 4J:	**Perform the single cylinder cutout test.**	**Can the miss or excessive smoke be attributed to a single cylinder?**
STEP 4K:	**Verify the fuel temperature sensor is within specification.**	**Is the fuel temperature sensor within specification?**
STEP 4L:	**Check for excessive injector drain leakage.**	**Are only a few drops of fuel per minute draining from the back of the cylinder head?**
STEP 4M:	**Pop test the injectors.**	**The injector spray pattern is correct and the injectors pop between 275 and 300 bar [3989 and 4351 psi]?**
STEP 4N:	**Inspect the gear pump coupling for wear.**	**Is the gear pump drive shaft or coupling worn?**

STEP 5: Air handling troubleshooting procedures.

STEP 5A:	**Inspect the turbocharger blades for damage.**	**Damage found on turbocharger blades?**
STEP 5B:	**Check the turbocharger axial and radial clearances.**	**Are the turbocharger axial and radial bearing clearances within specification?**
STEP 5C:	**Inspect the wastegate actuator rod for travel.**	**Does the wastegate actuator rod move?**
STEP 5C-1:	**Inspect the wastegate actuator rod for travel.**	**Does the wastegate actuator rod move?**

STEP 6: Electronic feature troubleshooting procedures.

STEP 6A:	**Verify throttle pedal travel.**	**Does the throttle position read zero when the throttle is released and 100 percent when the throttle is depressed?**
STEP 6B:	**Check ambient air pressure sensor accuracy (if equipped).**	**Is the reading within 50.8 mm-Hg [2 in-Hg] of local barometric pressure?**
STEP 6C:	**Check intake manifold pressure sensor accuracy.**	**Is the intake manifold pressure reading less than 102 mm-Hg [4 in-Hg]?**
STEP 6D:	**Verify electronic feature settings are correct.**	**Are the electronic features set correctly?**

STEP 7: Base engine troubleshooting procedures.

STEP 7A:	**Verify overhead adjustments are correct.**	**Are the overhead settings within the reset limits?**
STEP 7B:	**Verify engine brake adjustment (if equipped).**	**Are the engine brake settings within the reset limits?**
STEP 7C:	**Inspect the charge air cooler.**	**Is the charge air cooler free of cracks, holes, or other damage?**
STEP 7D:	**Check air intake restriction.**	**Is air intake restriction greater than 635 mm-H $_2$O [25 in-H $_2$O]?**
STEP 7E:	**Check exhaust restriction.**	**Is exhaust back pressure less than 72 mm-Hg [3 in-Hg]?**
STEP 7F:	**Check engine blowby.**	**Are the engine blowby measurements within specification?**

STEP 7F-1:	**Verify turbocharger contribution to engine blowby.**	**Has the total engine blowby dropped more than 30 percent of the total?**

TROUBLESHOOTING STEP

STEP 1: Perform basic troubleshooting procedures.

STEP 1A: 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 for active fault codes. • Use INSITE™ electronic service tool to read the fault codes.	Active fault codes or high counts of inactive fault codes? **YES**	Go to appropriate fault code troubleshooting tree
	Active fault codes or high counts of inactive fault codes? **NO**	1B

STEP 1B: Perform basic troubleshooting checks.

Condition:

Action	Specification/Repair	Next Step
The following items must be checked or verified before continuing: • Verify the fuel level in the tanks, regardless of what the gauge reads. • Verify there have **not** been any changes to CPL components on the engine. • Verify fuel grade is correct for the application. • Verify the engine is operating within the recommended altitude. • Verify engine oil is at the correct level. • Verify engine parasitics have **not** changed. • Verify engine duty cycle has **not** changed. • Verify engine cranking speed is greater than 150 rpm. • Verify battery voltage is adequate.	All steps have been verified to be correct? **YES**	2A
	All steps have been verified to be correct? **NO** **Repair:** Correct the condition and verify complaint is no longer present after repair.	Repair complete

STEP 2: Determination of engine symptom.

STEP 2A: Low power, poor acceleration, or poor response.

Condition:		
Action	**Specification/Repair**	**Next Step**
Interview the driver and verify the complaint.	Is the engine symptom low power, poor acceleration, or poor response? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 4 - Fuel System Checks • Step 5 - Air Handling Checks • Step 6 - Electronics Checks • Step 7 - Base Engine Checks.	Perform the troubleshooting steps suggested in the repair procedure
	Is the engine symptom low power, poor acceleration, or poor response? **NO**	2B

STEP 2B: Engine misfire, engine speed surge, or engine speed unstable.

Condition:		
Action	**Specification/Repair**	**Next Step**
Interview the driver and verify the complaint.	Is the engine symptom engine misfire, engine speed surge, or engine speed unstable? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 4 - Fuel System Checks • Step 5 - Air Handling Checks • Step 6 - Electronics Checks • Step 7 - Base Engine Checks.	Perform the troubleshooting steps suggested in the repair procedure.
	Is the engine symptom engine misfire, engine speed surge, or engine speed unstable? **NO**	2C

STEP 2C: Excessive white or black smoke.

Condition:		
Action	**Specification/Repair**	**Next Step**
Interview the driver and verify the complaint.	Is the engine symptom excessive white or black smoke? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 5 - Air Handling Checks • Step 4 - Fuel System Checks • Step 7 - Base Engine Checks.	Perform the troubleshooting steps suggested in the repair procedure
	Is the engine symptom excessive white or black smoke? **NO**	2D

STEP 2D: Low intake manifold pressure.

Condition:		
Action	**Specification/Repair**	**Next Step**
Interview the driver and verify the complaint.	Is the engine symptom low boost pressure? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 5 - Air Handling Checks • Step 4 - Fuel System Checks • Step 7 - Base Engine Checks.	Perform the troubleshooting steps suggested in the repair procedure
	Is the engine symptom low boost pressure? **NO**	2E

STEP 2E: Engine will not start or difficult to start, or engine shuts off unexpectedly.

Condition:		
Action	**Specification/Repair**	**Next Step**
Interview the driver and verify the complaint.	Is the symptom engine will not start or difficult to start, or engine shuts off unexpectedly? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 3 - No Start Checks • Step 4 - Fuel System Checks • Step 7 - Base Engine Checks • Step 5 - Air Handling Checks • Step 6 - Electronics Checks.	Perform the troubleshooting steps suggested in the repair procedure
	Is the symptom engine will not start or difficult to start, or engine shuts off unexpectedly? **NO**	Return to correct symptom tree

STEP 3: No-start troubleshooting procedures.

STEP 3A: Check the ECM keyswitch voltage.

Condition: • Disconnect the OEM harness from the ECM. • Turn keyswitch ON.		
Action	**Specification/Repair**	**Next Step**
Measure the signal voltage from the keyswitch input SIGNAL wire of the OEM harness to the engine block ground. Measure the keyswitch voltage with the keyswitch in the ON position and also with the keyswitch in the START position. Refer to the wiring diagram for connector pin identification.	Is the keyswitch voltage equal to battery voltage? **YES**	3B
	Is the keyswitch voltage equal to battery voltage? **NO** **Repair:** Repair or replace the OEM power harness or keyswitch, or check the battery connections.	Repair complete

STEP 3B: Check the ECM battery supply voltage.

Condition:
- Turn keyswitch OFF.
- Disconnect the ECM power harness from the ECM.

Action	Specification/Repair	Next Step
Measure the voltage from the ECM battery supply (+) to the ECM battery supply (-) pins in the OEM harness connector. Refer to the wiring diagram for connector pin identification.	Is the ECM battery supply voltage equal to the battery voltage? **YES**	3C
	Is the ECM battery supply voltage equal to the battery voltage? **NO** **Repair:** Repair or replace the ECM power harness. Check the battery connections and fuse terminals.	Repair complete

STEP 3C: Verify the operation of cold weather starting aids.

Condition:

Action	Specification/Repair	Next Step
Make sure the intake air heater and other cold starting aids are operational, if equipped. Refer to Procedure 008-011 (Coolant Heater) in Section 8, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 010-029 (Cold Starting Aid) in Section 10, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	If equipped, are cold weather starting aids operating correctly? **YES**	3D
	If equipped, are cold weather starting aids operating correctly? **NO** **Repair:** Repair cold weather starting aids. Refer to Procedure 010-029 (Cold Starting Aid) in Section 10, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 3D: Check the fuel lift pump pressure.

Condition:
- Refer to Procedure 005-045 (Fuel Lift Pump) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.

Action	Specification/Repair	Next Step
Measure the fuel lift pump output pressure. Refer to Procedure 005-045 (Fuel Lift Pump) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418. At initial key-on, the lift pump will run for 30 seconds, then it will stop. Lift pump pressure can be low if fuel prime was lost. Multiple keyswitch cycles can be necessary to prime the fuel system using the electric lift pump.	Is the fuel lift pump pressure greater than the specifications outlined in Procedure 005-045 (Fuel Lift Pump) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418? **YES**	3E
	Is the fuel lift pump pressure greater than the specifications outlined in Procedure 005-045 (Fuel Lift Pump) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418? **NO** **Repair:** Find and repair the cause of low lift pump pressure. Refer to Procedure 005-045 (Fuel Lift Pump) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 3E: Verify fuel pressure sensor accuracy.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to monitor accumulator pressure. The engine speed **must** be zero for at least 1 minute before performing this test.	Is the accumulator pressure value less than 34.5 bar [500 psi]? **YES**	3F
	Is the accumulator pressure value less than 34.5 bar [500 psi]? **NO** **Repair:** Replace the fuel pressure sensor. Refer to Service Bulletin, CAPS Fuel Pressure Sensor Kit, 4021293 or 4021294.	Repair complete

STEP 3F: Check the accumulator pressure.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to read accumulator pressure while cranking the engine.	Is accumulator pressure greater than 293 bar [4250 psi] while cranking? **YES**	3L
	Is accumulator pressure greater than 293 bar [4250 psi] while cranking? **NO**	3G

STEP 3G: Use INSITE™ electronic service tool to check the CPS crank state.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to monitor CPS state while cranking the engine.	Does CPS state read Valid Sync while cranking? **YES**	3H
	Does CPS state read Valid Sync while cranking? **NO** **Repair:** Troubleshoot the engine speed sensor circuit. See Fault Codes 115 and 121.	3G-1

STEP 3G-1: Check and adjust the speed/position sensor air gap.

Condition:
- Install the sensors.

Action	Specification/Repair	Next Step
Check and adjust the speed/position sensor air gap. • Check the air gap between the ESS/EPS and the camshaft ring gear. Since the EPS and ESS are mounted on the same boss, the air gap can be measured using the outside sensor bore. This measurement can usually be taken without removing the air compressor. • Bar the engine over 2 full revolutions (**clockwise** facing the front of the engine). • Use a depth micrometer and measure the distance from the face of the gear housing boss to the face of the camshaft ring gear. Record this measurement “A”. • Measure the gap in 45 degree camshaft rotation increments. If the measurements “A” varies by more than 0.051 mm [0.002 in] the tone wheel is warped, or the camshaft gear is walking. • Next measure the sensor. Use a depth micrometer to measure the distance from the bottom of the sensor mounting flange to the tip of the threaded end of the sensor. Record this as measurement “B”. The air gap can be calculated by subtracting B from A (air gap measurement equals A minus B). If the air gap is less than 0.406 mm [0.016 in] add a 0.508 mm [0.020 in] shim to sensor. • Minimum Air Gap: 0.406 mm [0.016 in] • Maximum Air Gap: 1.020 mm [0.040 in]	Are the sensor(s) depth measurements within specification? **YES** **Repair:** No Repair.	3H
	Are the sensor(s) depth measurements within specification? **NO** **Repair:** Replace the engine speed/position sensor(s). Refer to Procedure 019-042 (Engine Speed Sensor (ESS)) in Section 19, ISC, QSC8.3, and ISL Electronic Control System, Troubleshooting and Repair Manual, Bulletin 3666271.	Repair Complete

STEP 3H: Measure gear pump pressure.

Condition:
- Connect a fuel pressure gauge to the Compuchek™ fitting on the cam housing.

Action	Specification/Repair	Next Step
Measure the gear pump pressure while cranking the engine. Refer to Procedure 005-089 (Fuel Pump Gear Pump Module) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Is the fuel gear pump pressure greater than the specifications outlined in Procedure 005-089 (Fuel Pump Gear Pump Module) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418? **YES**	3I
	Is the fuel gear pump pressure greater than the specifications outlined in Procedure 005-089 (Fuel Pump Gear Pump Module) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418? **NO**	3K

STEP 3I: Perform the injection control valve (ICV) click test.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to perform the ICV click test. Refer to Procedure 005-078 (Injection Control Valve) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Does the injection control valve pass the click test? **YES**	3J
	Does the injection control valve pass the click test? **NO** **Repair:** Replace the injection control valve stator. Refer to Procedure 019-430 (Injection Control Valve Stator) in Section 19, in the Electronic Control System ISC, QSC8.3, and ISL Troubleshooting and Repair Manual, Bulletin 3666271.	Repair complete

STEP 3J: Perform the pumping control valve (PCV) click test.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to perform the front and rear PCV test. Refer to Procedure 005-079 (Pumping Control Valve) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Do the pumping control valves pass the click test? **YES** **Repair:** Replace the injection control valve module. Refer to Procedure 005-086 (Fuel Pump Distributor and Injection Control Valve Module) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete
	Do the pumping control valves pass the click test? **NO** **Repair:** Replace the accumulator module. Refer to Procedure 005-085 (Fuel Pump Accumulator Module) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 3K: Check the distributor rotor timing.

Condition:
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
Inspect the distributor rotor timing and check for a seized rotor. Refer to Procedure 005-072 (Rotor, CAPS Fuel Injection Pump (Rotor, CAPS Fuel Injection Pump) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Distributor rotor timing is correct as outlined in Procedure 005-072 (Rotor, CAPS Fuel Injection Pump Rotor, CAPS Fuel Injection Pump) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418? **YES**	3L
	Distributor rotor timing is correct as outlined in Procedure 005-072 (Rotor, CAPS Fuel Injection Pump-Rotor, CAPS Fuel Injection Pump) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418? **NO** **Repair:** Replace the fuel injection pump. Refer to 005-229 (Fuel Injection Pump) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 3L: Inspect the gear pump coupling for wear.

Condition:
- Turn keyswitch OFF.
- Remove the gear pump module.

Action	Specification/Repair	Next Step
Inspect the gear pump drive shaft coupling and shaft for wear. Refer to Procedure 005-089 (Fuel Pump Gear Pump Module) in Section 5 in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Is the gear pump drive shaft or coupling worn? **YES** **Repair:** Replace the gear pump module. Refer to Procedure 005-089 (Fuel Pump Gear Pump Module) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete
	Is the gear pump drive shaft or coupling worn? **NO** **Repair:** Replace the injection control valve. Refer to Procedure 005-086 (Fuel Pump Distributor and Injection Control Valve Module) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 4: Fuel system troubleshooting procedures.

STEP 4A: Check for fault codes.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to read the fault code information. Check for active fuel system fault codes related to the complaint.	Are fuel system fault codes active? **YES** **Repair:** Follow the appropriate troubleshooting tree.	Repair complete
	Are fuel system fault codes active? **NO**	4B

STEP 4B: Check the CAPS fuel pump wiring.

Condition:		
Action	**Specification/Repair**	**Next Step**
Check the injection control valve, pressure control valve, fuel pressure sensor, and fuel temperature sensor wiring for damage, cuts, and loose connections.	All fuel pump wiring is undamaged and is properly connected? **YES**	4C
	All fuel pump wiring is undamaged and is properly connected? **NO** **Repair:** Replace the malfunctioning fuel system component.	Repair complete

STEP 4C: Check the transorb diode.

Condition: • Unplug the fuel pressure sensor.		
Action	**Specification/Repair**	**Next Step**
Unplug the fuel pressure sensor.	Does the rough running, black smoke, or surge complaint continue? **YES**	4D
	Does the rough running, black smoke, or surge complaint continue? **NO** **Repair:** Replace the transorb diode. Refer to Procedure 019-184 (Transient Suppressor) in Section 19, in the Electronic Control System ISC, QSC8.3, and ISL Troubleshooting and Repair Manual, Bulletin 3666271.	Repair complete

STEP 4D: Check for air in the high-pressure pump fuel supply.

Condition:
- Refer to Procedure 006-003 (Air in Fuel) in Section 6, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.

Action	Specification/Repair	Next Step
Check for air in the fuel. Refer to Procedure 006-003 (Air in Fuel) in Section 6, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Is air present in the fuel supply? **YES** **Repair:** Locate and correct the cause of air ingestion in the fuel supply system. Sources of air ingestion include loose fuel filters, loose fuel line fittings, loose or cracked fuel tank stand-pipes, and severe restrictions in the fuel supply lines and filters.	Repair complete
	Is air present in the fuel supply? **NO**	4E

STEP 4E: Measure the fuel inlet restriction.

Condition:
- Perform this check during the complaint.

Action	Specification/Repair	Next Step
Measure the fuel inlet restriction. Refer to Procedure 006-020 (Fuel Inlet Restriction) in Section 6, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Is the fuel inlet restriction less than the specifications outlined in Procedure 006-020 (Fuel Inlet Restriction) in Section 6, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418? **YES**	4F
	Is the fuel inlet restriction less than the specifications outlined in Procedure 006-020 (Fuel Inlet Restriction) in Section 6, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418? **NO** **Repair:** Locate the cause of the high inlet restriction. Check the OEM fuel inlet plumbing, fuel filters, and lift pump check valve.	Repair complete

STEP 4F: Measure the fuel gear pump pressure.

Condition:
- Connect a fuel pressure gauge to the Compuchek™ fitting on the cam housing.

Action	Specification/Repair	Next Step
Measure the gear pump pressure while the engine is at the rated condition. Refer to Procedure 005-089 (Fuel Pump Gear Pump Module) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Is the fuel gear pump pressure greater than the specifications outlined in Procedure 005-089 (Fuel Pump Gear Pump Module) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418? **YES**	4G
	Is the fuel gear pump pressure greater than the specifications outlined in Procedure 005-089 (Fuel Pump Gear Pump Module) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418? **NO** **Repair:** Replace the fuel gear pump module. Refer to Procedure 005-089 (Fuel Pump Gear Pump Module) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 4G: Perform the injection control valve (ICV) click test.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to perform the ICV click test. Refer to Procedure 005-078 (Injection Control Valve) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Does the injection control valve pass the click test? **YES**	4H
	Does the injection control valve pass the click test? **NO** **Repair:** Replace the injection control valve stator. Refer to Procedure 019-430 (Injection Control Valve Stator) in Section 19, in the Electronic Control System ISC, QSC8.3, and ISL Troubleshooting and Repair Manual, Bulletin 3666271.	Repair complete

STEP 4H: Perform the pumping control valve (PCV) click test.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to perform the front and rear PCV click test. Refer to Procedure 005-079 (Pumping Control Valve) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Do the pumping control valves pass the click test? **YES**	4I
	Do the pumping control valves pass the click test? **NO** **Repair:** Replace the accumulator module. Refer to Procedure 005-085 (Fuel Pump Accumulator Module) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 4I: Measure fuel drain line restriction.

Condition:
- Refer to Procedure 006-012 (Fuel Drain Line Restriction) in Section 6, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.
- Perform this check during the complaint.

Action	Specification/Repair	Next Step
Check the fuel drain line restriction. Refer to Procedure 006-012 (Fuel Drain Line Restriction) in Section 6, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Is the drain line restriction less than specification? **YES**	4J
	Is the drain line restriction less than specification? **NO** **Repair:** Look for causes of high drain line restriction, such as kinked or blocked fuel lines.	Repair complete

STEP 4J: Perform the single cylinder cutout test.

Condition:
- Turn keyswitch ON.
- Engine running at low idle.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
Operate the engine at loaded conditions. • Use INSITE™ electronic service tool to perform the single cylinder cutout test to disable individual injectors.	Can the miss or excessive smoke be attributed to a single cylinder? **YES** **Repair:** Replace the fuel injector in the cylinder that was identified using the single cylinder cutout test. Refer to Procedure 006-026 (Injector) in Section 6, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete
	Can the miss or excessive smoke be attributed to a single cylinder? **NO**	4K

STEP 4K: Verify the fuel temperature sensor is within specification.

Condition:
- Turn keyswitch to the OFF position.
- Disconnect the engine harness from the fuel temperature sensor.
- Install the fuel pressure/temperature sensor breakout cable, Part Number 3162982.

Action	Specification/Repair	Next Step
Check the resistance of the fuel temperature sensor. • Measure the resistance from pin B to pin D of the fuel temperature sensor.	Is the fuel temperature sensor within specification? **YES**	4L
Refer to Procedure 019-119 (Engine Fuel Temperature Sensor) in Section 19, in the Electronic Control System ISC, QSC8.3, and ISL Troubleshooting and Repair Manual, Bulletin 3666271.	Is the fuel temperature sensor within specification? **NO** **Repair:** Replace the fuel temperature sensor. Refer to Procedure 019-119 (Engine Fuel Temperature Sensor) in Section 19, in the Electronic Control System ISC, QSC8.3, and ISL Troubleshooting and Repair Manual, Bulletin 3666271.	Repair complete.

STEP 4L: Check for excessive injector drain leakage.

Condition:
- Remove the fuel injector drain banjo fitting from the back of the cylinder head.

Action	Specification/Repair	Next Step
Run the engine at low idle while monitoring the amount of fuel draining from the back of the cylinder head.	Are **only** a few drops of fuel per minute draining from the back of the cylinder head? **YES**	4M
	Are **only** a few drops of fuel per minute draining from the back of the cylinder head? **NO** **Repair:** A damaged connection between the high-pressure connector and an injector has been detected. Remove all high-pressure connectors and check for burrs or deformation around the tip of the injector. Refer to Procedure 006-052 (Fuel Connector (Head Mounted)) in Section 6, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 4M: Pop test the injectors.

Condition:
- Remove the injectors. Refer to Procedure 006-026 (Injector) in Section 6, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.

Action	Specification/Repair	Next Step
Pop test the injectors and check for proper spray pattern. Refer to Procedure 006-026 (Injector) in Section 6, the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	The injector spray pattern is correct and the injectors pop between 275 and 300 bar [3989 and 4351 psi]? **YES**	4N
	The injector spray pattern is correct and the injectors pop between 275 and 300 bar [3989 and 4351 psi]? **NO** **Repair:** Replace the malfunctioning injector. Refer to Procedure 006-026 (Injector) in Section 6, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 4N: Inspect the gear pump coupling for wear.

Condition:
- Turn keyswitch OFF.
- Remove the gear pump module.

Action	Specification/Repair	Next Step
Inspect the gear pump drive shaft coupling and shaft for wear.	Is the gear pump drive shaft or coupling worn? **YES** **Repair:** Replace the gear pump module. Refer to Procedure 005-089 (Fuel Pump Gear Pump Module) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete
	Is the gear pump drive shaft or coupling worn? **NO** **Repair:** Replace the injection control valve. Refer to Procedure 005-086 (Fuel Pump Distributor and Injection Control Valve Module) in Section 5, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 5: Air handling troubleshooting procedures.

STEP 5A: Inspect the turbocharger blades for damage.

Condition:
- Turn keyswitch OFF.
- Remove the intake and exhaust pipes from the turbocharger.

Action	Specification/Repair	Next Step
Inspect the compressor and turbine blades for damage or wear. Refer to Procedure 010-033 (Turbocharger) in Section 10, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Damage found on turbocharger blades? **YES** **Repair:** Replace the turbocharger assembly. Refer to Procedure 010-033 (Turbocharger) in Section 10, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete
	Damage found on turbocharger blades? **NO**	5B

STEP 5B: Check the turbocharger axial and radial clearance.

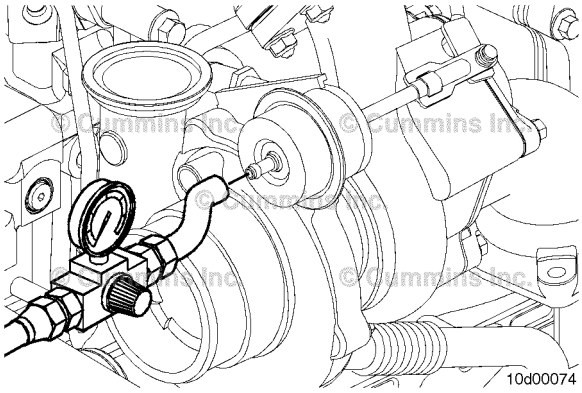
Condition:
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
Check the turbocharger for correct axial and radial clearance. Refer to Procedure 010-033 (Turbocharger) in Section 10, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Are the turbocharger axial and radial bearing clearances within specification? **YES**	5C
	Are the turbocharger axial and radial bearing clearance within specification? **NO** **Repair:** Replace the turbocharger. Refer to Procedure 010-033 (Turbocharger) in Section 10, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 5C: Inspect the wastegate actuator rod for travel.

Condition:
- Turn keyswitch OFF.
- Remove the integral boost line from the wastegate actuator.

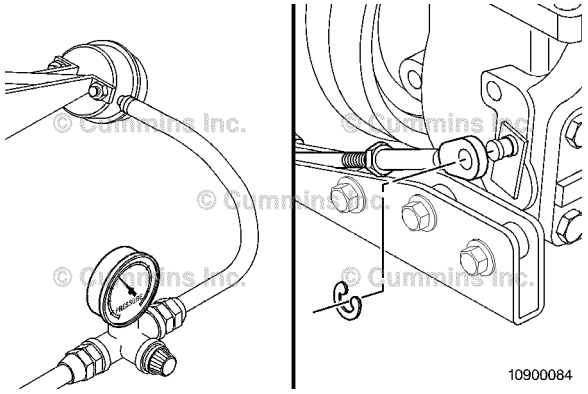
Action	Specification/Repair	Next Step
Apply a regulated air supply of 138 kPa [20 psi] to the actuator and check for actuator movement.	Does the wastegate actuator rod move? **YES**	Repair complete
	Does the wastegate actuator rod move? **NO**	5C-1



STEP 5C-1: Inspect the wastegate actuator rod for travel.

Condition:
- Turn keyswitch OFF.
- Remove the e-clip from the wastegate pin and disconnect the actuator rod.

Action	Specification/Repair	Next Step
Apply a regulated air supply of 138 kPa [20 psi] to the actuator and check for actuator movement.	Does the wastegate actuator rod move? **YES** **Repair:** Move the wastegate lever on the turbocharger back and forth to check for smooth operation. Replace the turbocharger assembly if the wastegate is seized. Refer to Procedure 010-033 (Turbocharger) in Section 10, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete
	Does the wastegate actuator rod move? **NO** **Repair:** Replace the wastegate actuator. Refer to Procedure 010-050 (Turbocharger Wastegate Actuator) in Section 10, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete



STEP 6: Electronic feature troubleshooting procedures.

STEP 6A: Verify throttle pedal travel.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to monitor the throttle position while fully depressing and releasing the throttle pedal.	Does the throttle position read zero when the throttle is released and 100 percent when the throttle is depressed? **YES**	6B
	Does the throttle position read zero when the throttle is released and 100 percent when the throttle is depressed? **NO** **Repair:** Determine and correct the cause of the throttle pedal restriction.	Repair complete

STEP 6B: Check ambient air pressure sensor accuracy (if equipped).

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

Action	Specification/Repair	Next Step
Start INSITE™ Data Monitor/Logger and compare INSITE™ reading for Barometric Air Pressure to the local barometric pressure using the table below. Refer to Procedure 018-028 (Barometric Pressure at Altitude) in Section V.	Is the reading within 50.8 mm-Hg [2 in-Hg] of local barometric pressure? **YES**	6C
	Is the reading within 50.8 mm-Hg [2 in-Hg] of local barometric pressure? **NO** **Repair:** Replace the barometric pressure sensor. Refer to Procedure 019-004 (Barometric Air Pressure Sensor) in Section 19. in the Electronic Control System ISC, QSC8.3, and ISL Troubleshooting and Repair Manual, Bulletin 3666271.	Repair Complete

STEP 6C: Check intake manifold pressure sensor accuracy.

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

Action	Specification/Repair	Next Step
Start INSITE™ electronic service tool Data/ Monitor/Logger and read the value of intake manifold pressure.	Is the intake manifold pressure reading less than 102 mm-Hg [4 in-Hg]? **YES**	6D
	Is the intake manifold pressure reading less than 102 mm-Hg [4 in-Hg]? **NO** **Repair:** Replace the intake manifold pressure sensor. Refer to Procedure 019-061 (Intake Manifold Pressure Sensor) in Section 19, in the Electronic Control System ISC, QSC8.3, and ISL Troubleshooting and Repair Manual, Bulletin 3666271.	Repair complete

STEP 6D: Verify electronic feature settings are correct.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to verify the following adjustable parameters are set correctly: • Maximum Vehicle Speed • Powertrain Protection • Rear Axle Ratio • Tailshaft Teeth • Tire Revolutions per Mile • Gear-Down Protection • Cruise Control Droop Settings • Cruise Control Maximum Vehicle Speed.	Are the electronic features set correctly? **YES**	2A
	Are the electronic features set correctly? **NO** **Repair:** Use INSITE™ electronic service tool to correct programmable features.	Repair complete

STEP 7: Base engine troubleshooting procedures.

STEP 7A: Verify overhead adjustments are correct.

Condition:
- Turn keyswitch OFF.
- Remove the rocker lever cover. Refer to Procedure 003-011 (Rocker Lever Cover) in Section 3, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.

Action	Specification/Repair	Next Step
Measure the overhead settings. Refer to Procedure 003-004 (Overhead Set) in Section 3, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Are the overhead settings within the reset limits? **YES**	7B
	Are the overhead settings within the reset limits? **NO** **Repair:** Adjust the overhead settings. Refer to Procedure 003-004 (Overhead Set) in Section 3, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 7B: Verify engine brake adjustment (if equipped).

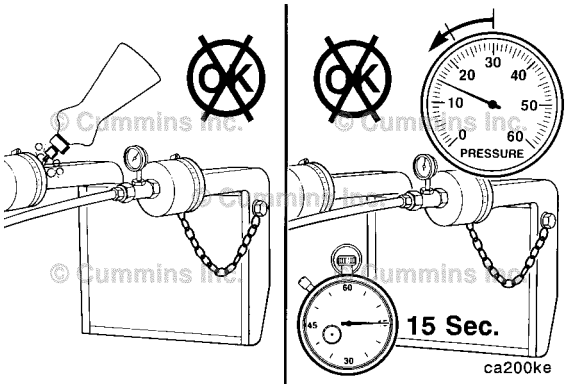
Condition:
- Turn keyswitch OFF.
- Remove the rocker lever cover. Refer to Procedure 003-011 (Rocker Lever Cover) in Section 3, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.

Action	Specification/Repair	Next Step
Verify the engine brakes are operating correctly. • Measure the engine brake settings. Refer to Procedure 020-004 (Engine Brake Assembly) in Section 20, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Are the engine brake settings within the reset limits? **YES**	7C
	Are the engine brake settings within the reset limits? **NO** **Repair:** Adjust the engine brake settings. Refer to Procedure 020-004 (Engine Brake Assembly) in Section 20, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 7C: Inspect the charge air cooler.

Condition:
- Refer to Procedure 010-027 (Charge-Air Cooler) in Section 10, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.

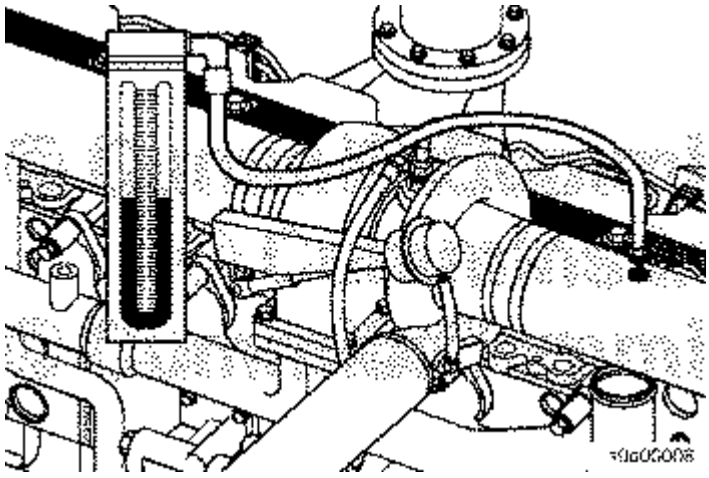
Action	Specification/Repair	Next Step
Inspect the charge air cooler for cracks, holes, or other damage. Refer to Procedure 010-027 (Charge-Air Cooler) in Section 10, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Is the charge air cooler free of cracks, holes, or other damage? **YES**	7D
	Is the charge air cooler free of cracks, holes, or other damage? **NO** **Repair:** Repair the charge air cooler assembly.	Repair complete



STEP 7D: Check air intake restriction.

Condition:
- Refer to Procedure 010-031 (Air Intake Restriction) in Section 10, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.

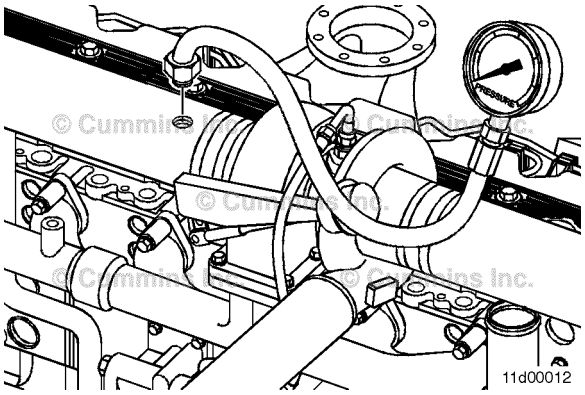
Action	Specification/Repair	Next Step
Check the intake system restriction by installing a vacuum gauge into the air intake system. Refer to Procedure 010-031 (Air Intake Restriction) in Section 10, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Is air intake restriction greater than 635 mm-H_2O [25 in-H_2O]? **YES** **Repair:** Correct the cause of high intake air restriction. Check for a plugged air filter or restricted air intake piping.	Repair complete
	Is air intake restriction greater than 635 mm-H_2O [25 in-H_2O]? **NO**	7E



STEP 7E: Check exhaust restriction.

Condition:
- Refer to Procedure 011-009 (Exhaust Restriction) in Section 11, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.

Action	Specification/Repair	Next Step
Check the exhaust system back pressure by installing a pressure gauge into the exhaust system just past the turbocharger outlet. Refer to Procedure 011-009 (Exhaust Restriction) in Section 11, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Is exhaust back pressure less than 72 mm-Hg [3 in-Hg]? **YES**	7F
	Is exhaust back pressure less than 72 mm-Hg [3 in-Hg]? **NO** **Repair:** Inspect the exhaust system for the source of high restriction.	Repair complete



STEP 7F: Check engine blowby.

Condition:
- Refer to Procedure 014-005 (Engine Testing (Engine Dynamometer)) in Section 14, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.

Action	Specification/Repair	Next Step
Measure the engine blowby. Refer to Procedure 014-005 (Engine Testing (Engine Dynamometer)) in Section 14, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Are the engine blowby measurements within specification? **YES**	Return to Step 2 or contact a Cummins Inc. service representative for further diagnostic and troubleshooting instructions.
	Are the engine blowby measurements within specification? **NO**	Go to Step 7F-1.

STEP 7F-1: Verify turbocharger contribution to engine blowby.

Condition:
- Turn keyswitch OFF.
- Connect the appropriate orifice to the end of the blowby draft tube.
- Remove the turbocharger oil drain line from the block and drain into a bucket.
- Start the engine.

Action	Specification/Repair	Next Step
Load engine to rated rpm on a chassis dynamometer. • Measure the engine blowby as outlined in Procedure 014-005 (Engine Testing (Engine Dynamometer)) in Section 14, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Has the total engine blowby dropped more than 30 percent of the total? **YES** **Repair:** Replace the turbocharger assembly. Refer to Procedure 010-033 (Turbocharger) in Section 10, in the ISC, ISCe, QSC8.3, ISL and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete.
	Has the total engine blowby dropped more than 30 percent of the total? **NO** **Repair:** The engine may need to be rebuilt. See the engine rebuild specifications.	Repair complete.

Engine Performance Troubleshooting Tree - ISC/QSC/ISL/QSL with CM850 Electronic Control System

This troubleshooting procedure should be followed for the following symptoms:

- Engine Acceleration or Response Poor
- Cranking Fuel Pressure is Low
- Engine Operating Fuel Pressure is Low
- Engine Decelerates Slowly
- Engine Difficult to Start or Will Not Start (Exhaust Smoke)
- Engine Difficult to Start or Will Not Start (No Exhaust Smoke)
- Engine Power Output Low
- Engine Runs Rough at Idle
- Engine Runs Rough or Misfires
- Engine Speed Surges at Low or High Idle
- Engine Speed Surges Under Load or in Operating Range
- Smoke, Black - Excessive
- Smoke, White - Excessive
- Engine Shuts Off or Dies Unexpectedly or Dies During Deceleration
- Engine Starts but Will Not Keep Running
- Engine Will Not Reach Rated Speed (RPM)
- Intake Manifold Pressure (Boost) is Below Normal

How to Use This Troubleshooting Procedure:

This symptom tree can be used to troubleshoot all performance 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 symptom. Perform the list of troubleshooting steps in the sequence shown in the Specifications/ Repair section of the tree.

Shop Talk:

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 problem or if it simply does **not** meet driver expectations.

Low power is a term that is used in the field to describe many different performance problems. 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.

Poor acceleration or response is described 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 several factors.

TROUBLESHOOTING SUMMARY

STEPS	SPECIFICATIONS	SRT CODE

STEP 1: Perform basic troubleshooting procedures.

- **STEP 1A:** Check for active fault codes or high counts of inactive fault codes.
- **STEP 1B:** Perform basic troubleshooting checks.

STEP 2: Determination of engine symptom.

- **STEP 2A:** Low power, poor acceleration, or poor response.
- **STEP 2B:** Engine misfire, engine speed surge, or engine speed unstable.
- **STEP 2C:** Excessive white or black smoke.
- **STEP 2D:** Low intake manifold pressure.
- **STEP 2E:** Engine will not start or difficult to start, engine shuts off unexpectedly.

STEP 3: No-start troubleshooting procedures.

- **STEP 3A:** Verify the operation of cold weather starting aids.
- **STEP 3B:** Verify the low-pressure fuel lines are routed correctly.
- **STEP 3C:** Check the ECM keyswitch voltage.
- **STEP 3D:** Check the ECM battery supply voltage.
- **STEP 3E:** Check engine speed during cranking.
- **STEP 3F:** Verify rail fuel pressure sensor accuracy.
- **STEP 3G:** Check for fuel rail pressure while cranking the engine.
  - **STEP 3G-1:** Check fuel gear pump pressure.
  - **STEP 3G-2:** Check fuel lift pump pressure.
- **STEP 3H:** Check for other fault codes that explain a no-start condition.

STEP 4: Fuel system troubleshooting procedures.

- **STEP 4A:** Check for fault codes.
- **STEP 4B:** Check for air in the high-pressure pump fuel supply.
- **STEP 4C:** Measure fuel gear pump pressure.

STEP 4C-1: Measure the fuel inlet restriction.

STEP 4D: Perform single cylinder cutout test.

STEP 4E: Perform cylinder balance diagnostic test.

STEP 4F: Measure fuel drain line restriction.

STEP 4G: Monitor fuel pressure at idle.

STEP 5: Air handling troubleshooting procedures.

STEP 5A: Inspect the turbocharger blades for damage.

STEP 5B: Check the turbocharger axial and radial clearances.

STEP 5C: Determination of turbocharger type.

STEP 5D: Check variable geometry actuator rod for correct travel.

STEP 5D-1: Check for air leaks and inspect air lines.

STEP 5D-2: Check for air pressure at the turbocharger control valve outlet.

STEP 5D-3: Check for air pressure at turbocharger control valve outlet.

STEP 5D-4: Check for vehicle air tank pressure at turbocharger control valve inlet.

STEP 5D-5: Check for correct turbocharger actuator travel.

STEP 5E: Check for broken shaft inside the turbocharger.

STEP 5F: Inspect wastegate actuator - wastegated turbochargers only.

STEP 5G: Inspect wastegate actuator rod for travel.

STEP 5G-1: Inspect the wastegate actuator rod for travel.

STEP 6: Electronic feature troubleshooting procedures.

STEP 6A: Verify throttle pedal travel.

STEP 6B: Check ambient air pressure sensor accuracy.

STEP 6C: Check intake manifold pressure sensor accuracy.

STEP 6D: Verify electronic feature settings are correct.

STEP 7: Base engine troubleshooting procedures.

STEP 7A: **Verify overhead adjustments are correct.**

STEP 7B: **Verify engine brake adjustment.**

STEP 7C: **Inspect charge air-cooler.**

STEP 7D: **Check air intake restriction.**

STEP 7E: **Check exhaust restriction.**

STEP 7F: **Check engine blowby.**

STEP 7F-1: **Verify turbocharger contribution to engine blowby.**

TROUBLESHOOTING STEP

STEP 1: Perform basic troubleshooting procedures.

STEP 1A: 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 for active fault codes. • Use INSITE™ electronic service tool to read the fault codes.	Active fault codes or high counts of inactive fault codes? **YES** **Repair:** Follow the electronic fault code trees for the appropriate troubleshooting procedures.	Repair complete
	Active fault codes or high counts of inactive fault codes? **NO**	1B

STEP 1B: Perform basic troubleshooting checks.

Condition:

None.

Action	Specification/Repair	Next Step
The following items must be checked or verified before continuing: • Verify the fuel level in the tanks • Verify there have **not** been any changes to CPL components on the engine • Verify fuel grade is correct for application • Verify the engine is operating within the recommended altitude • Verify engine oil is at the correct level • Verify engine parasitics have **not** changed • Verify engine duty cycle has **not** changed • Verify engine cranking speed is greater than 150 rpm • Verify battery voltage is adequate.	All steps have been verified to be correct? **YES**	2A
	All steps have been verified to be correct? **NO** **Repair:** Correct the condition and verify complaint is no longer present after repair.	Repair complete

STEP 2: Determination of engine symptoms.

STEP 2A: Low power, poor acceleration, or poor response.

Condition:

None.

Action	Specification/Repair	Next Step
Interview the driver and verify the complaint.	Is the engine symptom low power, poor acceleration, or poor response? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 4 - Fuel System Checks • Step 5 - Air Handling Checks • Step 6 - Electronics Checks • Step 7 - Base Engine Checks.	Perform the troubleshooting steps suggested in the repair procedure
	Is the engine symptom low power, poor acceleration, or poor response? **NO**	2B

STEP 2B: Engine misfire, engine speed surge, or engine speed unstable.

Condition:

None.

Action	Specification/Repair	Next Step
Interview the driver and verify the complaint.	Is the engine symptom engine misfire, engine speed surge, or engine speed unstable? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 4 - Fuel System Checks • Step 5 - Air Handling Checks • Step 6 - Electronics Checks.	Perform the troubleshooting steps suggested in the repair procedure
	Is the engine symptom engine misfire, engine speed surge, or engine speed unstable? **NO**	2C

STEP 2C: Excessive white or black smoke.

Condition:
None.

Action	Specification/Repair	Next Step
Interview the driver and verify the complaint.	Is the engine symptom excessive white or black smoke? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 5 - Air Handling Checks • Step 4 - Fuel System Checks • Step 7 - Base Engine Checks.	Perform the troubleshooting steps suggested in the repair procedure.
	Is the engine symptom excessive white or black smoke? **NO**	2D

STEP 2D: Low intake manifold pressure.

Condition:
None.

Action	Specification/Repair	Next Step
Interview the driver and verify the complaint.	Is the engine symptom low boost pressure? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 5 - Air Handling Checks • Step 4 - Fuel System Checks • Step 7 - Base Engine Checks.	Perform the troubleshooting steps suggested in the repair procedure
	Is the engine symptom low boost pressure? **NO**	2E

STEP 2E: Engine will not start or difficult to start, engine shuts off unexpectedly.

Condition: None.		
Action	**Specification/Repair**	**Next Step**
Interview the driver and verify the complaint.	Is the symptom engine will not start or difficult to start, engine shuts off unexpectedly? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below: • Step 3 - No Start Checks • Step 4 - Fuel System Checks • Step 5 - Air Handling Checks • Step 6 - Electronics Checks.	Perform the troubleshooting steps suggested in the repair procedure
	Is the symptom engine will not start or difficult to start, engine shuts off unexpectedly? **NO**	Return to correct symptom tree

STEP 3: No-start troubleshooting procedures.

STEP 3A: Verify the operation of cold weather starting aids.

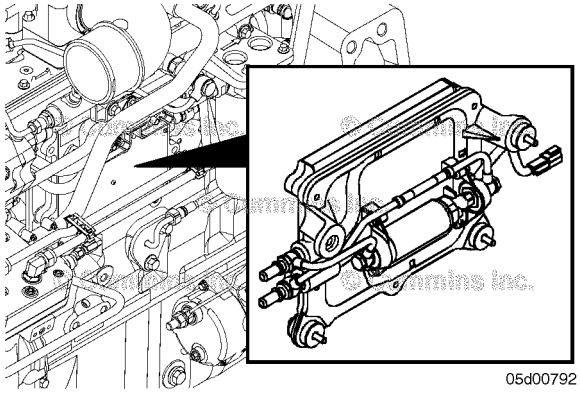
Condition: • Turn keyswitch ON.		
Action	**Specification/Repair**	**Next Step**
Make sure the intake air heater and other cold starting aids are operational. Refer to Procedure 008-011 in Section 8. Refer to Procedure 010-029 in Section 10.	Are necessary cold weather starting aids operating properly? **YES**	3B
	Are necessary cold weather starting aids operating properly? **NO** **Repair:** Install or repair cold weather starting aids. Refer to Procedure 010-029 in Section 10.	Repair complete

STEP 3B: Verify the low-pressure fuel lines are routed correctly.

Condition:

None.

Action	Specification/Repair	Next Step
It is sometimes possible to get the low-pressure fuel lines connected to the ECM cooling plate installed improperly. The top connection to the ECM cooling plate is the inlet and the bottom connection is the outlet. Verify these connections if the low-pressure fuel lines have been removed and installed on the engine.	Are the low-pressure fuel lines connected properly to the ECM cooling plate? **YES**	3C
	Are the low-pressure fuel lines connected properly to the ECM cooling plate? **NO** **Repair:** Properly connect the low-pressure fuel lines to the ECM cooling plate. The fuel inlet is the top connection.	Repair complete



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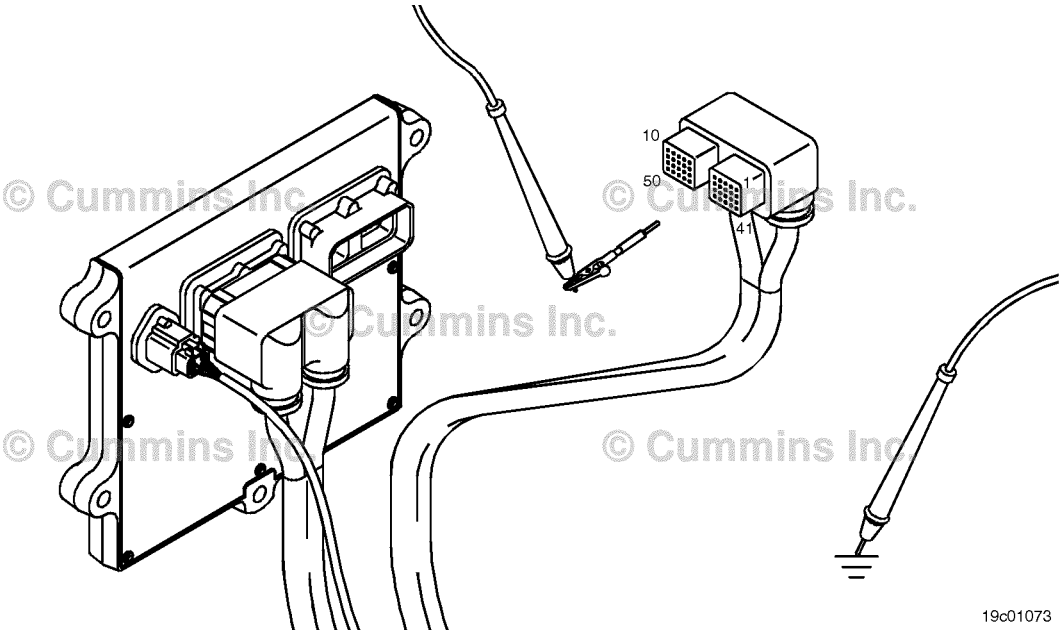
STEP 3C: Check the ECM keyswitch voltage.

Condition:
- Disconnect the OEM harness from the ECM.
- Turn keyswitch ON.

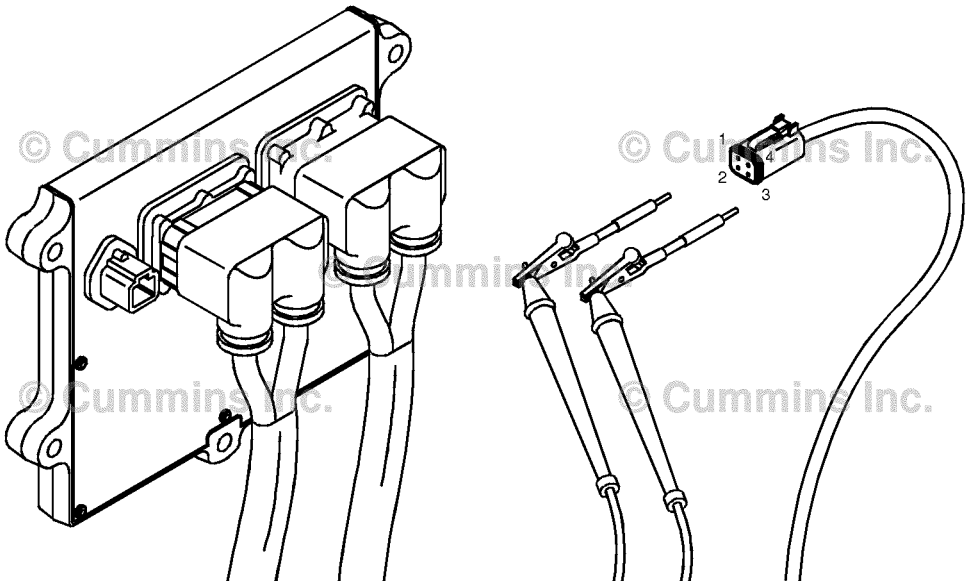
Action	Specification/Repair	Next Step
Measure the signal voltage from the keyswitch input SIGNAL wire of the OEM harness to the engine block ground. Measure the keyswitch voltage with the keyswitch in the ON position and also with the keyswitch in the Cranking position. Refer to the wiring diagram for connector pin identification.	Is the keyswitch voltage equal to battery voltage? **YES**	3D
	Is the keyswitch voltage equal to battery voltage? **NO** **Repair:** Repair or replace the OEM power harness, keyswitch, or check the battery connections.	Repair complete



STEP 3D: Check the ECM battery supply voltage.

Condition:
- Turn keyswitch OFF.
- Disconnect the ECM power harness from the ECM.

Action	Specification/Repair	Next Step
Measure the voltage from the ECM battery SUPPLY (-) pin to the ECM battery SUPPLY (+) pins in the ECM power harness connector. Measure the ECM voltage with the keyswitch in the ON position and also with the keyswitch in the Cranking position. Refer to the wiring diagram for connector pin identification.	Is the ECM battery supply voltage equal to the battery voltage? **YES**	3E
	Is the ECM battery supply voltage equal to the battery voltage? **NO** **Repair:** Repair or replace the ECM power harness. Check the battery connections and fuse terminals.	Repair complete



STEP 3E: Check engine speed during cranking.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to monitor Engine Speed while cranking the engine.	Is the engine cranking speed greater than 150 rpm? **YES**	3F
	Is the engine cranking speed greater than 150 rpm? **NO** **Repair:** Find and correct the cause for low cranking speed. Check the batteries, engine starting motor, and accessory loads.	Repair complete

STEP 3F: Verify rail fuel pressure sensor accuracy.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to monitor the Rail Fuel Pressure Sensor (Measured) with the keyswitch ON and the engine not running.	Is the rail fuel pressure sensor (measured) value less than 30 Bar [435 psi]? **YES**	3G
	Is the rail fuel pressure sensor (measured) value less than 30 Bar [435 psi]? **NO** **Repair:** Replace the rail fuel pressure sensor. Use the following procedure in the Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416. Refer to Procedure 019-115 in Section 19.	Repair complete

STEP 3G: Check for fuel rail pressure while cranking the engine.

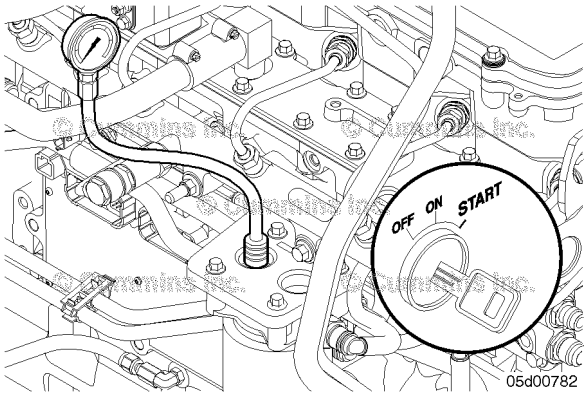
Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
Attempt to start the engine by engaging the engine starting motor for at least 30 continous 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 2215 becomes active, fuel rail pressure is **not** being developed. If the engine starts during this attempt, it is possible that fuel prime to the high pressure pump has been lost. Look for loose fuel lines or filters that allow for loss of fuel prime.	Did Fault Code 2215 become active during the failed the start attempt? **YES**	3G-1
	Did Fault Code 2215 become active during the failed the start attempt? **NO**	3H

STEP 3G-1: Check fuel gear pump pressure.

Condition:
- Install a pressure gauge at the pressure side fuel filter head. Refer to Procedure 005-025 in Section 5.
- Turn keyswitch ON.

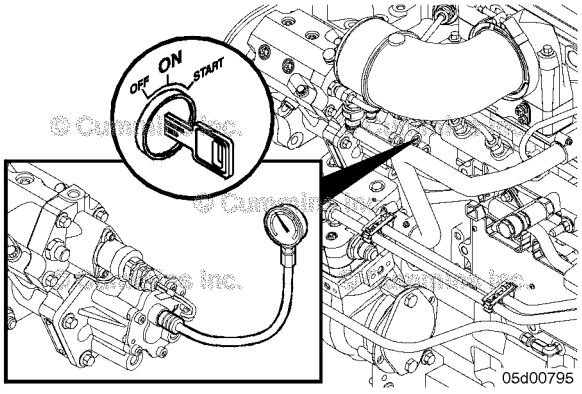
Action	Specification/Repair	Next Step
Measure the fuel gear pump output pressure while cranking the engine. Cranking speed **must** be greater than 150 rpm. Refer to Procedure 005-025 in Section 5.	Is the fuel gear pump pressure while cranking greater than the specification outlined in 005-025? **YES** **Repair:** Follow Fault Code 2215 troubleshooting tree.	Repair complete
	Is the fuel gear pump pressure, while cranking, greater than the specification outlined in 005-025? **NO**	3G-2



STEP 3G-2: Check fuel lift pump pressure.

Condition:
- Install a pressure gauge at the inlet port of the high pressure pump gear pump.
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
Measure the fuel lift pump output pressure. Refer to Procedure 005-045 in Section 5. At initial key ON, the lift pump will run for 30 seconds and then stop.	Is the fuel lift pump pressure greater than the specifications outlined in Procedure 005-045 in the Troubleshooting and Repair Manual, ISC, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418? **YES** **Repair:** Replace the gear pump. Refer to Procedure 005-025 in Section 5.	Repair complete
	Is the fuel lift pump pressure greater than the specifications outlined in Procedure 005-045 in the Troubleshooting and Repair Manual, ISC, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418? **NO** **Repair:** Verify fuel prime by making sure the OEM fuel filter is full or fuel and air is purged from the low pressure fuel lines. Perform INSITE™ electronic service tool Lift Pump Override Test if necessary. If the low pressure fuel system is primed, replace the fuel lift pump. Refer to Procedure 005-045 in Section 5.	Repair complete



STEP 3H: Check for other fault codes that explain a no-start condition.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to read fault code information. Look for fault codes that come active during a failed start attempt that can be the cause for a no-start condition.	Do any fault codes that can cause a no-start condition come active during cranking? **YES** **Repair:** Follow the electronic fault code trees for the appropriate troubleshooting procedures.	Repair complete
	Do any fault codes that can cause a no-start condition come active during cranking? **NO**	4A

STEP 4: Fuel system troubleshooting procedures.

STEP 4A: Check for fault codes.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to read the fault code information. Determine if there are active fuel system fault codes related to the complaint.	Are fuel system fault codes active? **YES** **Repair:** Follow the electronic fault code trees for the appropriate troubleshooting procedures.	Repair complete
	Are fuel system fault codes active? **NO**	4B

STEP 4B: Check for air in the high-pressure pump fuel supply.

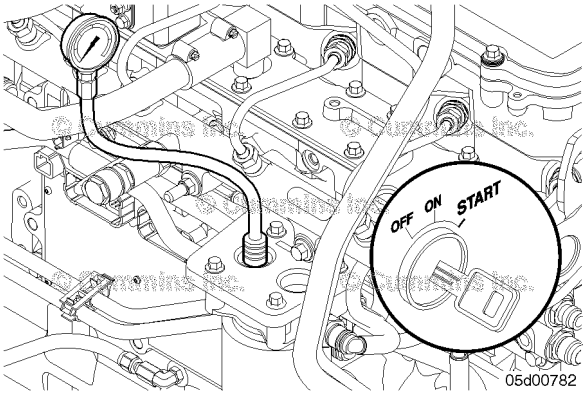
Condition:
- Refer to Procedure 006-003 in Section 6.

Action	Specification/Repair	Next Step
Check for air in the fuel. Refer to Procedure 006-003 in Section 6.	Is air present in the fuel supply? **YES** **Repair:** Locate and correct the cause of air ingestion in the fuel supply system. Sources of air ingestion include loose fuel filters, loose fuel line fittings, loose or cracked fuel tank stand-pipes, or severe restrictions in the fuel supply lines and filters.	Repair complete
	Is air present in the fuel supply? **NO**	4C

STEP 4C: Measure fuel gear pump pressure.

Condition:
- Refer to Procedure 005-025 in Section 5.

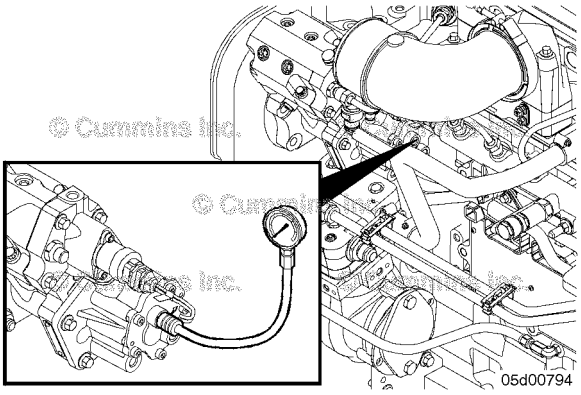
Action	Specification/Repair	Next Step
Check the fuel gear pump pressure. Refer to Procedure 005-025 in Section 5.	Is the fuel gear pump pressure within specification? **YES**	4D
	Is the fuel gear pump pressure within specification? **NO**	4C-1



STEP 4C-1: Measure the fuel inlet restriction.

Condition:
- Measure the fuel pump inlet restriction at the diagnostics port on the fuel gear pump. Refer to Procedure 006-020 in Section 6 .

Action	Specification/Repair	Next Step
Check the fuel inlet restriction. Refer to Procedure 006-020 in Section 6 .	Is the fuel inlet restriction above specification? **YES** **Repair:** Find and correct the cause of high inlet restriction. Look for plugged OEM fuel filters or screens, or a restricted ECM cooler, restricted lift pump bypass check valve (in the ECM cooler), pinched OEM fuel lines or restricted stand-pipe in the OEM fuel tank.	Repair complete
	Is the fuel inlet restriction above specification? **NO** **Repair:** Replace the fuel gear pump. Refer to Procedure 005-025 in Section 5.	Repair complete



STEP 4D: Perform single cylinder cutout test.

Condition:
- Turn keyswitch ON.
- Engine running at low idle.
- Connect INSITE™ electronic service tool.

Action	Specification/Repair	Next Step
Operate the engine at load. Use INSITE™ electronic service tool to perform the Cylinder Cutout Test to disable individual injectors.	Can the miss or excessive smoke be attributed to a single cylinder? **YES** **Repair:** Look for a cause of the complaint including valve lash and excessive crankcase pressure that can indicate power cylinder damage or camshaft lobe wear. If no other damage is found, replace the fuel injector in the cylinder identified by the single cylinder cutout test. Refer to Procedure 006-026 in Section 6.	Repair complete
	Can the miss or excessive smoke be attributed to a single cylinder? **NO**	4E

STEP 4E: Perform cylinder balance diagnostic test.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to run the Cylinder Performance Test to determine if a single cylinder is contributing to the engine symptom.	Does the Cylinder Performance Test identify any cylinder that is contributing to a power imbalance? **YES** **Repair:** Look for a cause of the power imbalance including valve lash and excessive crankcase pressure that can indicate power cylinder damage or camshaft lobe wear. If no other damage is found, replace the fuel injector in the cylinder contributing to the power imbalance. Refer to Procedure 006-026 in Section 6.	Repair complete
	Does the Cylinder Performance Test identify any cylinder that is contributing to a power imbalance? **NO**	4F

STEP 4F: Measure fuel drain line restriction.

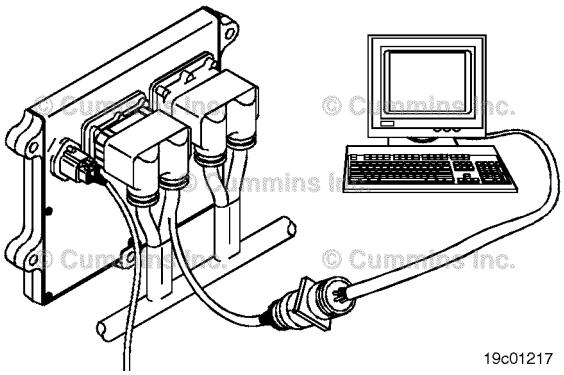
Condition:
- Refer to Procedure 006-012 in Section 6.

Action	Specification/Repair	Next Step
Check the fuel drain line restriction. • Use the following procedure in the Troubleshooting and Repair Manual, ISC, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418. Refer to Procedure 006-012 in Section 6.	Is the drain line restriction less than specification? **YES**	4G
	Is the drain line restriction less than specification? **NO** **Repair:** Look for causes of high drain line restriction, such as kinked or blocked fuel lines.	Repair complete

STEP 4G: Monitor fuel pressure at idle.

Condition:
- Connect INSITE™ electronic service tool.
- Start engine.

Action	Specification/Repair	Next Step
Run engine at idle for at least one minute to purge air induced from previous steps. Use INSITE™ electronic service tool to monitor commanded fuel rail pressure and measured fuel rail pressure for a minimum of 10 seconds. To verify your results, repeat this step with the Fuel System Leakage Test active in the INSITE™ electronic service tool.	Does measured fuel rail pressure deviate more than 200 bar [2900 psi] from commanded pressure and surge at idle, or does the engine start and stall? **YES** **Repair:** Replace the fuel pump actuator. Use the following procedure in the Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416. Refer to Procedure 019-117 in Section 19.	Repair complete.
	Does measured fuel rail pressure deviate more than 200 bar [2900 psi] from commanded pressure and surge at idle, or does the engine start and stall? **NO**	2A



STEP 5: Air handling troubleshooting procedures.

STEP 5A: Inspect the turbocharger blades for damage.

Condition:
- Turn keyswitch OFF.
- Remove the intake and exhaust pipes from the turbocharger.

Action	Specification/Repair	Next Step
Inspect the compressor and turbine blades for damage or wear. Refer to Procedure 010-033 in Section 10.	Damage or wear found on turbocharger blades? **YES** **Repair:** Replace the turbocharger assembly. Refer to Procedure 010-033 in Section 10.	Repair complete
	Damage or wear found on turbocharger blades? **NO**	5B

STEP 5B: Check the turbocharger axial and radial clearances.

Condition:
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
Check the turbocharger for correct axial and radial clearance. Refer to Procedure 010-033 in Section 10.	Are the turbocharger axial and radial bearing clearances within specification? **YES**	5C
	Are the turbocharger axial and radial bearing clearances within specification? **NO** **Repair:** Replace the turbocharger. Refer to Procedure 010-033 in Section 10.	Repair complete

STEP 5C: Determination of turbocharger type.

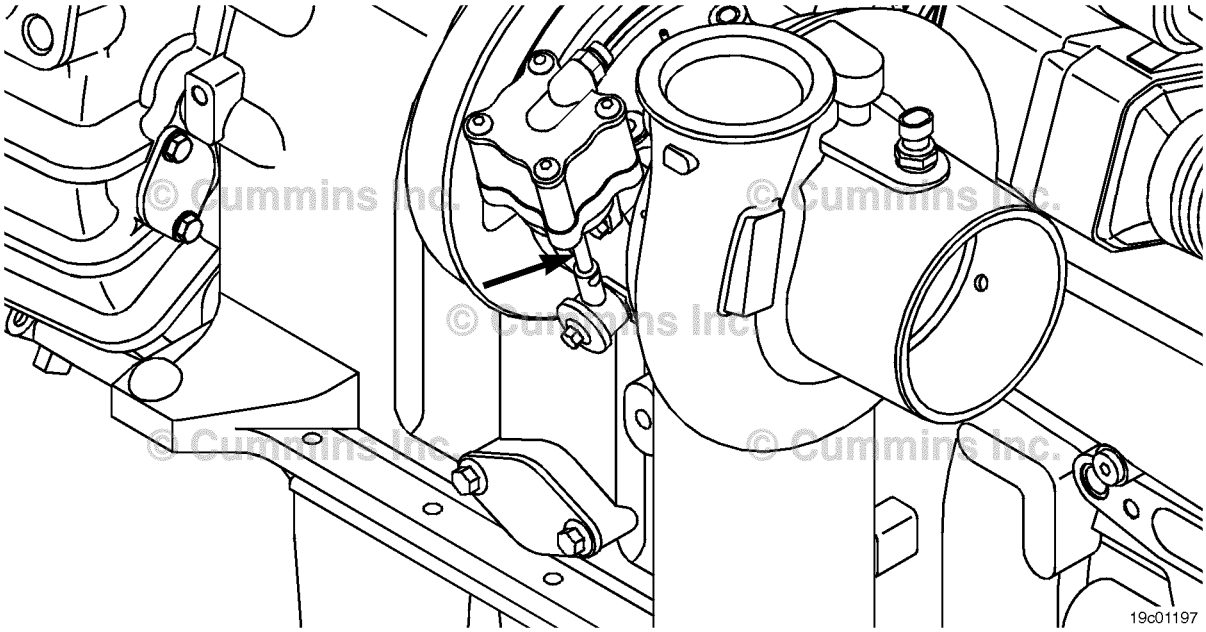
Condition:
None

Action	Specification/Repair	Next Step
Determine if the turbocharger is a wastegated or variable geometry turbo.	Is the turbocharger a variable geometry turbocharger? **YES**	5D
	Is the turbocharger a variable geometry turbocharger? **NO**	5F

STEP 5D: Check variable geometry actuator rod for correct travel.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.
- Verify vehicle air tanks are fully charged (greater than 689 kPa [100 psi]).

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to start the Turbocharger Actuator Test • Adjust the delay timer in the Turbocharger Actuator Test so that the rod movement can be observed. • Select the Retract Actuator position with INSITE™ electronic service tool. • Mark or scribe the variable geometry actuator rod at the base of the actuator. • Select the Extend Actuator position with INSITE™ electronic service tool. • Measure the rod travel by measuring the distance from the base of the variable geometry actuator to the scribe mark. The variable geometry actuator **must** move quickly and crisply. If the actuator rod movement is slow, there could be a problem with the air supply or mechanical problems with the variable geometry turbocharger assembly.	Does the turbocharger actuator rod extend between 8 and 9 mm [0.32 and 0.36 in]? **YES**	5E
	Does the turbocharger actuator rod extend between 8 and 9 mm [0.32 and 0.36 in]? **NO**	5D-1



STEP 5D-1: Check for air leaks and inspect air lines.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.
- Verify vehicle air tanks are fully charged (greater than 689 kPa [100 psi]).

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to perform the Turbocharger Actuator Test. Select the Extended Actuator position and listen for air leaks in the following components: • Turbocharger control valve • Turbocharger control valve inlet connection • Turbocharger control valve outlet connection • Turbocharger actuator inlet connection • Turbocharger actuator • All air lines including OEM supply line to turbocharger control valve and between the turbocharger control valve and the variable geometry turbocharger. A small amount of air will be heard escaping from the turbocharger control valve. This is a normal condition. Do **not** replace the turbocharger control valve for this condition.	Air leaks found in the system or damaged air lines? **YES** **Repair:** Repair air leaks or replace damaged or broken air lines.	Repair complete
	Air leaks found in the system or damaged air lines? **NO**	5D-2

STEP 5D-2: Check for air pressure at the turbocharger control valve outlet.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.
- Verify vehicle air tanks are fully charged (greater than 689 kPa [100 psi]).

Action	Specification/Repair	Next Step
Remove the air line connection at the outlet of the turbocharger control valve. Install a Compuchek™ fitting in the turbocharger control valve outlet. Install an air pressure gauge that is capable of reading at least 1034 kPa [150 psi]. Use INSITE™ electronic service tool to perform the Turbocharger Actuator Test. Select the Extend position.	Is vehicle tank air pressure present at the turbocharger control valve outlet? **YES**	5D-3
	Is vehicle tank air pressure present at the turbocharger control valve outlet? **NO**	5D-4

STEP 5D-3: Check for air pressure at turbocharger control valve outlet.

Condition:
- Turn keyswitch ON.
- Connect INSITE™ electronic service tool.
- Verify vehicle air tanks are fully charged (greater than 689 kPa [100 psi]).

Action	Specification/Repair	Next Step
Remove the air line connection at the outlet of the turbocharger control valve. Install an air pressure gauge that is capable of reading at least 1034 kPa [150 psi]. Use INSITE™ electronic service tool to perform the Turbocharger Actuator Test. Select the Retract position.	Can air be heard escaping from the turbocharger control valve outlet? **YES** **Repair:** The turbocharger control valve is stuck open. It **must not** be allowing air to escape when in the Retract position. Replace the turbocharger control valve. Use the following procedure in the Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416. Refer to Procedure 019-388 in Section 19.	Repair complete
	Can air be heard escaping from the turbocharger control valve outlet? **NO**	5D-4

STEP 5D-4: Check for vehicle air tank pressure at turbocharger control valve inlet.

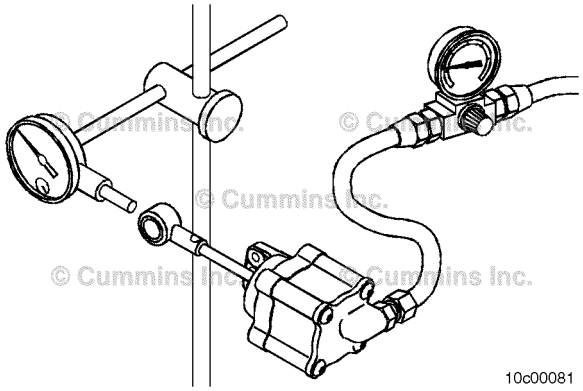
Condition:
- Turn keyswitch ON.
- Verify vehicle air tanks are fully charged (greater than 689 kPa [100 psi]).

Action	Specification/Repair	Next Step
Disconnect the air inlet connection to the turbocharger control valve. Verify vehicle air tank pressure is available at the turbocharger control valve inlet.	Vehicle air tank pressure available at the turbocharger control valve inlet? **YES**	5D-5
	Vehicle air tank pressure available at the turbocharger control valve inlet? **NO** **Repair:** No air pressure available at the turbocharger control valve inlet. Troubleshoot OEM air plumbing and determine why air pressure is **not** present.	Repair complete

STEP 5D-5: Check for correct turbocharger actuator travel.

Condition:
- Remove the variable geometry actuator from the turbocharger assembly. Refer to Procedure 010-113 in Section 10.
- Connect INSITE™ electronic service tool.

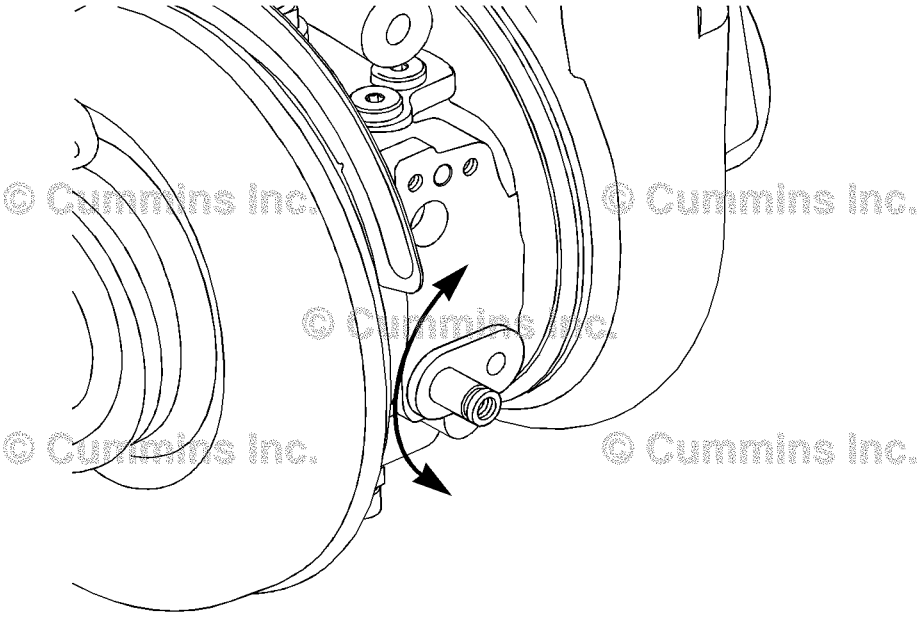
Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to perform the Turbocharger Actuator Test. Select the Extend Actuator position.	Does the variable geometry actuator rod travel at least 12 mm [0.472 in]? **YES** **Repair:** The variable geometry actuator has correct air pressure and correct travel. The variable geometry mechanism in the turbocharger is seized. Replace the turbocharger assembly. Refer to Procedure 010-033 in Section 10.	Repair complete
	Does the variable geometry actuator rod travel at least 12 mm [0.472 in]? **NO** **Repair:** The variable geometry actuator has correct air pressure but the variable geometry actuator rod is **not** extending. Replace the turbocharger actuator. Refer to Procedure 010-113 in Section 10.	Repair complete



STEP 5E: Check for broken shaft inside the turbocharger.

Condition:
- Turn keyswitch OFF.
- Remove the variable geometry actuator from the turbocharger assembly. Refer to Procedure 010-113 in Section 10.

Action	Specification/Repair	Next Step
Check for a broken linkage inside the turbocharger by moving the variable geometry actuator on the turbocharger up and down. The actuator lever **must** move evenly and crisply as it is moved.	Does the sliding nozzle move correctly? **YES**	2A
	Does the sliding nozzle move correctly? **NO** **Repair:** The variable geometry has mechanical damage inside the turbocharger. The actuator moves properly, but the linkage attaching the actuator to the nozzle is broken. Replace the turbocharger assembly. Refer to Procedure 010-033 in Section 10.	Repair complete



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STEP 5F: Inspect wastegate actuator - wastegated turbochargers only.

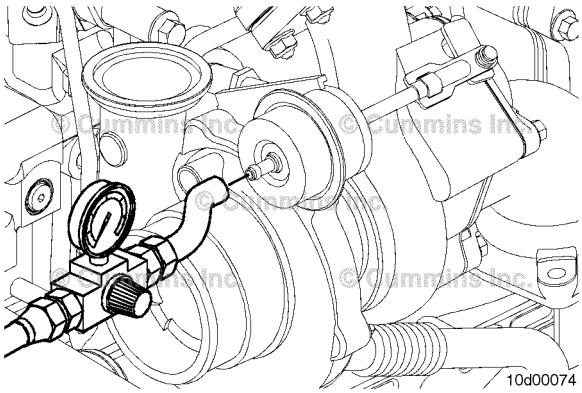
Condition:
- Turn keyswitch OFF.
- Remove the turbocharger if the wastegate actuator is inaccessible.

Action	Specification/Repair	Next Step
Inspect the integral wastegate actuator hose for cracks or holes.	Holes or cracks found in the wastegate actuator hose? **YES** **Repair:** Replace the wastegate actuator hose.	Repair complete
	Holes or cracks found in the wastegate actuator hose? **NO**	5G

STEP 5G: Inspect wastegate actuator rod for travel.

Condition:
- Turn keyswitch OFF.
- Remove the integral boost line from the wastegate actuator.

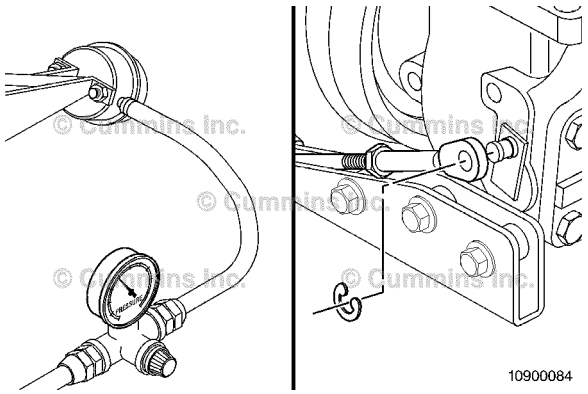
Action	Specification/Repair	Next Step
Apply a regulated air supply of 138 kPa [20 psi] to the actuator and check for actuator movement.	Does the wastegate actuator rod move? **YES**	Repair complete
	Does the wastegate actuator rod move? **NO**	5G-1



STEP 5G-1: Inspect the wastegate actuator rod for travel.

Condition:
- Turn keyswitch OFF.
- Remove the e-clip from the wastegate pin and disconnect the actuator rod.

Action	Specification/Repair	Next Step
Apply a regulated air supply of 138 kPa [20 psi] to the actuator and check for actuator movement.	Does the wastegate actuator rod move? **YES** **Repair:** Move the wastegate lever on the turbocharger back and forth, and check for smooth operation. Replace the turbocharger assembly if the wastegate is seized. Refer to Procedure 010-033 in Section 10.	Repair complete
	Does the wastegate actuator rod move? **NO** **Repair:** Replace the wastegate actuator. Refer to Procedure 010-050 in Section 10.	Repair complete



STEP 6: Electronic feature troubleshooting procedures.

STEP 6A: Verify throttle pedal travel.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to monitor Throttle Position while fully depressing and releasing the throttle pedal.	Does the throttle position read 0 percent when the throttle is released and 100 percent when the throttle is depressed? **YES**	6B
	Does the throttle position read 0 percent when the throttle is released and 100 percent when the throttle is depressed? **NO** **Repair:** Determine and correct the cause of the throttle pedal restriction.	Repair complete

STEP 6B: Check ambient air pressure sensor accuracy.

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

Action	Specification/Repair	Next Step
Start INSITE™ electronic service tool Data Monitor/Logger and compare INSITE™ electronic service tool reading for Barometric Air Pressure to the local barometric pressure. Refer to Procedure 018-028 in Section V.	The INSITE™ electronic service tool reading is within 50.8 mm-Hg [2 in-Hg] of local barometric pressure? **YES**	6C
	The INSITE™ electronic service tool reading is within 50.8 mm-Hg [2 in-Hg] of local barometric pressure? **NO** **Repair:** Replace the barometric pressure sensor. Use the following procedure in the Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416. Refer to Procedure 019-004 in Section 19.	Repair Complete

STEP 6C: Check intake manifold pressure sensor accuracy.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to monitor the value of Intake Manifold Pressure without the engine running.	Intake manifold pressure reading is less than 102 mm-Hg [4 in -Hg]? **YES**	6D
	Intake manifold pressure reading is less than 102 mm-Hg [4 in-Hg]? **NO** **Repair:** Replace the intake manifold pressure sensor. Use the following procedure in the Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416. Refer to Procedure 019-061 in Section 19.	Repair complete

STEP 6D: Verify electronic feature settings are correct.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool; to verify the following adjustable parameters are correctly set: • Maximum Vehicle Speed • Powertrain Protection • Rear Axle Ratio • Tailshaft Teeth • Tire Revolutions per Mile • Gear-Down Protection • Cruise Control Droop Settings • Cruise Control Maximum Vehicle Speed.	Are the electronic features set correctly? **YES**	2A
	Are the electronic features set correctly? **NO** **Repair:** Use INSITE™ electronic service tool to correct programmable features.	Repair complete

STEP 7: Base engine troubleshooting procedures.

STEP 7A: Verify overhead adjustments are correct.

Condition:
- Turn keyswitch OFF.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.

Action	Specification/Repair	Next Step
Measure the overhead setting. Refer to Procedure 003-004 in Section 3.	Are the overhead settings within the reset limits? **YES**	7B
	Are the overhead settings within the reset limits? **NO** **Repair:** Adjust the overhead settings. Refer to Procedure 003-004 in Section 3.	Repair complete

STEP 7B: Verify engine brake adjustment.

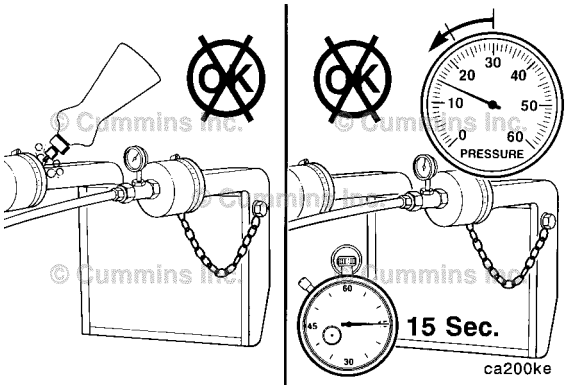
Condition:
- Turn keyswitch OFF.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.

Action	Specification/Repair	Next Step
Verify that the engine brakes are operating correctly. Measure the engine brake settings. Refer to Procedure 020-004 in Section 20.	Are the engine brake settings within the reset limits? **YES**	7C
	Are the engine brake settings within the reset limits? **NO** **Repair:** Adjust the engine brake settings. Refer to Procedure 020-004 in Section 20.	Repair complete

STEP 7C: Inspect charge-air cooler.

Condition:
- Refer to Procedure 010-027 in Section 10.

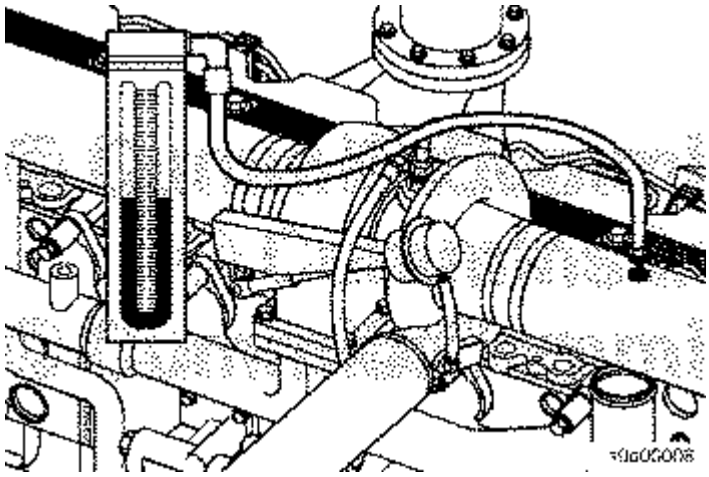
Action	Specification/Repair	Next Step
Inspect the charge-air cooler for cracks, holes, or other damage. Refer to Procedure 010-027 in Section 10.	Is the charge-air cooler free of cracks or other damage? **YES**	7D
	Is the charge-air cooler free of cracks or other damage? **NO** **Repair:** Repair the charge-air cooler assembly.	Repair complete



STEP 7D: Check air intake restriction.

Condition:
- Refer to Procedure 010-031 in Section 10.

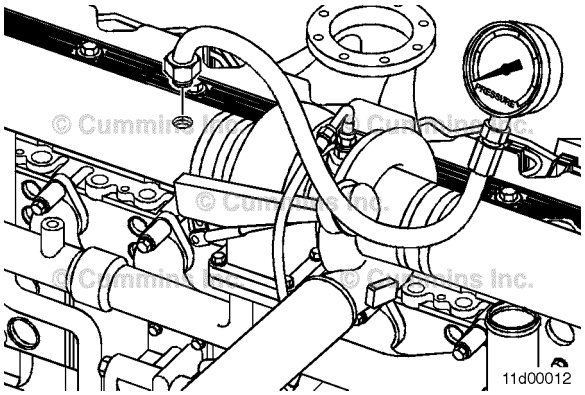
Action	Specification/Repair	Next Step
Check the intake system restriction by installing a vacuum gauge into the air intake system. Refer to Procedure 010-031 in Section 10.	Is air intake restriction greater than 635 mm-H_2O [25 in-H_2O]? **YES** **Repair:** Correct the cause of high intake air restriction. Check for plugged air filter or restricted air intake piping.	Repair complete
	Is air intake restriction greater than 635 mm-H_2O [25 in-H_2O]? **NO**	7E



STEP 7E: Check exhaust restriction.

Condition:
- Refer to Procedure 011-009 in Section 11.

Action	Specification/Repair	Next Step
Check the exhaust system back pressure by installing a pressure gauge into the exhaust system just past the turbocharger outlet. Refer to Procedure 011-009 in Section 11.	Is exhaust back pressure less than 40 in-H $_2$O [3 in-Hg]? **YES**	7F
	Is exhaust back pressure less than 40 in-H $_2$O [3 in-Hg]? **NO** **Repair:** Inspect exhaust system for source of high restriction.	Repair complete



STEP 7F: Check engine blowby.

Condition:
- Refer to Procedure 014-005 in Section 14.

Action	Specification/Repair	Next Step
Measure the engine blowby as outlined in Procedure 014-005.	Are the engine blowby measurements within specification? **YES**	Return to Step 2 or contact a Cummins® Authorized Repair Location for further diagnostic and troubleshooting instructions.
	Are the engine blowby measurements within specification? **NO**	Go to step 7F-1.

STEP 7F-1: Verify turbocharger contribution to engine blowby.

Condition:
- Turn keyswitch OFF.
- Connect the appropriate orifice to the end of the blowby draft tube.
- Remove the turbocharger oil drain line from the block and drain into a bucket.
- Start the engine.

Action	Specification/Repair	Next Step
Load engine to rated rpm on a chassis dynamometer. Measure the engine blowby as outlined in Procedure 014-005 Section 14.	Has the total engine blowby dropped more than 30 percent of the total? **YES** **Repair:** Replace the turbocharger assembly. Refer to Procedure 010-033 in Section 10.	Repair complete
	Has the total engine blowby dropped more than 30 percent of the total? **NO** **Repair:** The engine might need to be rebuilt. See the engine rebuild specifications.	Repair Complete

Engine Performance Troubleshooting Tree for QSC and QSL Marine Engines with CM850 ECM

This troubleshooting procedure should be followed for the following symptoms:

- Engine Acceleration or Response Poor
- Cranking Fuel Pressure is Low
- Engine Operating Fuel Pressure is Low
- Engine Decelerates Slowly
- Engine Difficult to Start or Will Not Start (Exhaust Smoke)
- Engine Difficult to Start or Will Not Start (No Exhaust Smoke)
- Engine Power Output Low
- Engine Runs Rough at Idle
- Engine Runs Rough or Misfires
- Engine Speed Surges at Low or High Idle
- Engine Speed Surges Under Load or in Operating Range
- Smoke, Black - Excessive
- Smoke, White - Excessive
- Engine Shuts Off or Dies Unexpectedly or Dies During Deceleration
- Engine Starts But Will Not Keep Running
- Engine Will Not Reach Rated Speed (rpm)
- Intake Manifold Pressure (Boost) is Below Normal
- Excessive Vibration in Marine Applications

How to Use This Troubleshooting Procedure:

This symptom tree can be used to troubleshoot all performance 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 symptom. Perform the list of troubleshooting in the sequence shown in the Specifications/Repair section of the tree.

Shop Talk:

Operational is a term that in general describes vessel performance on the water. Operational 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 operational problem or if it simply does **not** meet owner expectations.

Low power is a term that is used in the field to describe many different performance problems. Low power is defined as the inability of the engine to produce the power necessary to move the vessel at a speed that can be reasonably expected under the given environment.

Poor acceleration or response is described as the inability of the vessel to accelerate satisfactorily from a stop. It can also be the lag in acceleration at conditions less than rated speed and load. Poor acceleration or response is difficult to troubleshoot, since it can be caused by several factors.

TROUBLESHOOTING SUMMARY

STEPS		SPECIFICATIONS	SRT CODE
STEP 1:	**Perform basic troubleshooting procedures.**		
STEP 1A:	Check for active fault codes or high counts of inactive fault codes.	Active fault codes or high counts of inactive fault codes?	
STEP 1B:	Perform basic troubleshooting checks.	Can the problem be verified?	
STEP 1C:	Perform basic troubleshooting checks.	All steps have been verified to be correct?	
STEP 2:	**Determination of engine symptom.**		
STEP 2A:	Low power, poor acceleration, or poor response.	Is the engine symptom low power, poor acceleration, or poor response?	
STEP 2B:	Engine misfire, engine speed surge, or engine speed unstable.	Is the engine symptom engine misfire, engine speed surge, or engine speed unstable?	
STEP 2C:	Excessive white or black smoke.	Is the engine symptom excessive white or black smoke?	
STEP 2D:	Low intake manifold pressure.	Is the engine symptom low boost pressure	
STEP 2E:	Engine will not start or difficult to start, engine shuts off unexpectedly.	Is the engine symptom engine will not start or difficult to start or engine shuts off unexpectedly?	
STEP 2F:	Engine vibration excessive.	Is the engine symptom Engine Vibration Excessive occurring when the engine is in or out of gear?	
STEP 3:	**Engine starting and running troubleshooting procedures.**		
STEP 3A:	Verify the fuel supply and return valves are open.	Are the fuel supply and return valves in the open position?	
STEP 3A-1:	Check the fuel cooler for damage due to high fuel return back pressure.	Is the fuel cooler damaged or collapsed internally?	
STEP 3B:	Verify the low pressure fuel lines are routed correctly.	Are the low pressure fuel lines connected properly to the ECM cooling plate?	
STEP 3C:	Check the engine speed during cranking.	Is the engine cranking speed greater than 150 rpm?	
STEP 3D:	Check the electronic control module (ECM) keyswitch voltage.	Is the keyswitch voltage equal to battery voltage?	
STEP 3E:	Check the ECM battery supply voltage.	Is the ECM battery supply voltage equal to the battery voltage?	
STEP 3F:	Verify the rail fuel pressure sensor accuracy.	Is the rail fuel pressure sensor (measured) value less than 30 bar [435 psi]?	

STEP 3G:	**Check for fuel rail pressure while cranking the engine.**	**Did Fault Code 2215 or 559 become active during the failed start attempt?**
STEP 3G-1:	**Check the fuel gear pump pressure.**	**Is the fuel gear pump pressure greater than 69 kPa [10 psi]?**
STEP 3G-2:	**Check the fuel lift pump pressure.**	**Is the fuel lift pump pressure greater than the specifications?**

STEP 4: Fuel system troubleshooting procedures.

STEP 4A:	**Check for air in the high-pressure pump fuel supply**	**Is air present in the fuel supply?**
STEP 4B:	**Measure the fuel inlet restriction**	**Is the fuel inlet restriction above specification?**
STEP 4C:	**Perform the single cylinder cutout test.**	**Can the miss or excessive smoke be attributed to a single cylinder?**
STEP 4D:	**Perform the cylinder balance diagnostic test.**	**Does the Cylinder Performance Test identify any cylinder that is contributing to a power imbalance?**
STEP 4E:	**Measure the fuel drain line restriction.**	**Is the drain line restriction within specification?**

STEP 5: Air handling troubleshooting procedures.

STEP 5A:	**Check the intake manifold pressure sensor accuracy.**	**Is the reading within 101.6 mm-Hg [4 in-Hg] of local barometric pressure?**
STEP 5B:	**Check the air intake system for leaks.**	**Were any air intake system leaks found?**
STEP 5C:	**Check the air intake restriction.**	**Is the air intake restriction greater than the specification?**
STEP 5D:	**Inspect the turbocharger blades for damage.**	**Are the turbocharger blades damaged?**
STEP 5E:	**Determine if the turbocharger is a waste gated turbocharger.**	**Is the turbocharger a waste gated turbocharger?**
STEP 5F:	**Inspect the wastegate actuator hose.**	**Are holes or cracks found in the wastegate actuator hose?**
STEP 5G:	**Inspect the turbocharger wastegate capsule for air leaks.**	**Did the wastegate actuator rod move?**
STEP 5G-1:	**Inspect the turbocharger wastegate for proper operation.**	**Did the wastegate actuator rod move?**
STEP 5G-2:	**Inspect the turbocharger wastegate for proper operation.**	**Does the wastegate actuator rod move?**
STEP 5H:	**Measure turbocharger axial and radial clearance.**	**Are the axial and radial clearances within specification?**
STEP 5I:	**Inspect the aftercooler.**	**Is the aftercooler free of cracks or damage?**

STEP 6: Electronic feature troubleshooting procedures.

STEP 6A:	**Verify the throttle travel.**	**Does the throttle position read 0 when the throttle is released and**

		100 percent when the throttle is actuated?

STEP 7: Base engine troubleshooting procedures.

STEP 7A:	Verify the overhead adjustments are correct.	Are the overhead settings within the reset limits?
STEP 7B:	Check the exhaust restriction.	Is the exhaust back pressure less than 75 mm-Hg [3 in-Hg] or 1016 mm-H_2O [40 in-H_2O]?
STEP 7C:	Check the engine blowby.	Are the engine blowby measurements within specification?
STEP 7C-1:	Verify turbocharger contribution to engine blowby.	Has the total engine blowby dropped more than 30% of the total?

STEP 8: Excessive vibration troubleshooting procedures.

STEP 8A:	Check the gear ratio and propeller configuration.	Are the gear ratio and the propeller incorrectly matched to the engine power?
STEP 8B:	Check for correct engine mount isolators and for proper installation requirements.	Are the engine mount isolators correct and installed correctly?
STEP 8C:	Check for damaged engine mounts and isolators.	Are the engine mounts and isolators in good condition?
STEP 8D:	Check the exhaust system.	Is the exhaust system deficient?
STEP 8E:	Check the engine driven accessories.	Is an engine driven accessory malfunctioning?
STEP 8F:	Check the shaft coupling to gear coupling alignment.	Is the shaft coupling to gear coupling misaligned?
STEP 8G:	Check the propeller shaft for proper installation.	Is the propeller shaft installed correctly?
STEP 8H:	Check the propeller shaft for straightness.	Is the propeller shaft straightness within the OEM specification?
STEP 8I:	Isolate the engine.	Does the engine vibration persist?
STEP 8J:	Check for strut/cutlass bearing misalignment.	Is the strut/cutlass bearing misaligned or strut mounting not secure?
STEP 8K:	Check the propeller.	Is the propeller out of balance or propeller not fitted properly to shaft?
STEP 8L:	Check the V-angle on the V-strut.	Does the V-angle on the V-strut match the angle of the blade on the propeller?
STEP 8M:	Check the propeller tunnels.	Does the entry and exit of the propeller tunnel match with the propeller blades?
STEP 8N:	Check the engine to transmission torsional coupling.	Is the torsional coupling incorrect or worn?
STEP 8O:	Check the rudder.	Does the rudder have excessive play in the rudder post?

STEP 8P:	**Check the engine flywheel housing to cylinder block alignment.**	**Is the flywheel housing alignment incorrect?**

TROUBLESHOOTING STEP

STEP 1: Perform basic troubleshooting procedures.

STEP 1A: Check for active fault codes or high counts of inactive fault codes.

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

Action	Specification/Repair	Next Step
Check for any active fault codes. • Use INSITE™ electronic service tool to read the fault codes.	Active fault codes or high counts of inactive fault codes? **YES** **Repair:** Reference Section TF in the Troubleshooting and Repair Manual, ISB, ISBe 4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416 for fault code troubleshooting.	Repair complete
	Active fault codes or high counts of inactive fault codes? **NO**	1B

STEP 1B: Perform basic troubleshooting checks.

Condition:
None.

Action	Specification/Repair	Next Step
Verify the following items. • Is the engine operating within the conditions it was intended to perform? For example, wide open throttle rpm, ambient versus engine room temperatures, load on the vessel, sea conditions, etc. • Are the customer's expectations in line with the engine capability? • Is the engine performing according to the OEM sea trial?	Can the problem be verified? **YES**	1C
	Can the problem be verified? **NO** **Repair:** The problem can **not** be verified and no repair is possible.	Repair complete

STEP 1C: Perform the basic troubleshooting checks.

Condition:

None.

Action	Specification/Repair	Next Step
The following items must be checked or verified before continuing. • Verify the fuel level in the tanks. • Verify there have **not** been any changes to the CPL (turbocharger, injectors, pistons, fuel pump, camshaft, etc.) components on the engine. • Verify the fuel grade is correct for the application. • Verify the engine is operating within the recommended altitude. • Verify the engine oil is at the correct level. • Verify none of the air vents are restricted or obstructed. • Verify the engine parasitics have **not** changed. • Verify the engine duty cycle has **not** changed. • Verify the engine cranking speed is greater than 150 rpm. • Verify the battery voltage is adequate. • Verify the drive train is correctly matched to the engine. • Verify the transmission is correct and is **not** malfunctioning. • Verify the propeller is at the correct pitch and is **not** damaged. • Verify the fuel inlet temperature to the fuel pump is within specification. • Verify the engine throttle and throttle wiring is correct for the engine response issues. • Verify the condition of the hull (clean and no damage).	All steps have been verified to be correct? **YES**	2A
	All steps have been verified to be correct? **NO** **Repair:** Correct the condition and verify the complaint is no longer present after the repair.	Repair complete

STEP 2: Determination of engine symptom.

STEP 2A: Low power, poor acceleration, or poor response.

Condition:

None.

Action	Specification/Repair	Next Step
Determine the engine symptom according to the engine performance.	Is the engine symptom low power, poor acceleration, or poor response? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below. • Step 4 - Fuel System Checks • Step 5 - Air Handling Checks • Step 6 - Electronics Checks • Step 7 - Base Engine Checks	Perform the troubleshooting steps suggested in the repair procedure.
	Is the engine symptom low power, poor acceleration, or poor response? **NO**	2B

STEP 2B: Engine misfire, engine speed surge, or engine speed unstable.

Condition:

None.

Action	Specification/Repair	Next Step
Determine the engine symptom according to the engine performance.	Is the engine symptom engine misfire, engine speed surge, or engine speed unstable? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below. • Step 4 - Fuel System Checks • Step 5 - Air Handling Checks • Step 6 - Electronics Checks	Perform the troubleshooting steps suggested in the repair procedure.
	Is the engine symptom engine misfire, engine speed surge, or engine speed unstable? **NO**	2C

STEP 2C: Excessive white or black smoke.

Condition:

None.

Action	Specification/Repair	Next Step
Determine the engine symptom according to the engine performance.	Is the engine symptom excessive white or black smoke? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below. • Step 5 - Air Handling Checks • Step 4 - Fuel System Checks	Perform the troubleshooting steps suggested in the repair procedure.
	Is the engine symptom excessive white or black smoke? **NO**	2D

STEP 2D: Low intake manifold pressure.

Condition:

None.

Action	Specification/Repair	Next Step
Determine the engine symptom according to the engine performance.	Is the engine symptom low boost pressure? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below. • Step 5 - Air Handling Checks • Step 4 - Fuel System Checks • Step 7 - Base Engine Checks	Perform the troubleshooting steps suggested in the repair procedure.
	Is the engine symptom low boost pressure? **NO**	2E

STEP 2E: Engine will not start or difficult to start, engine shuts off unexpectedly.

Condition:

None.

Action	Specification/Repair	Next Step
Determine the engine symptom according to the engine performance.	Is the engine symptom engine will **not** start or difficult to start, engine shuts off unexpectedly? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below. • Step 3 - No Start Checks • Step 4 - Fuel System checks • Step 5 - Air Handling Checks • Step 6 - Electronics Checks	Perform the troubleshooting steps suggested in the repair procedure.
	Is the engine symptom engine will **not** start or difficult to start, engine shuts off unexpectedly? **NO**	Return to the correct symptom tree.

STEP 2F: Engine vibration excessive.

Condition:

None.

Action	Specification/Repair	Next Step
Determine the engine symptom according to the engine performance.	Is the symptom Engine Vibration is Excessive occurring when the engine is in or out of gear? **YES** **Repair:** Perform the troubleshooting steps in the recommended order listed below. • Step 4 - Fuel System Checks • Step 5 - Air Handling Checks • Step 6 - Electronics Checks • Step 7 - Base Engine Checks • Step 8 - Excessive Vibration Checks	Perform the troubleshooting steps suggested in the repair procedure.
	Is the symptom Engine Vibration is Excessive occurring when the engine is in or out of gear? **NO**	Return to the correct symptom tree.

STEP 3: Engine starting and running troubleshooting procedures.

STEP 3A: Verify the fuel supply and return valves are open.

Condition:
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
Verify the fuel supply and return valves are in the open position. If the vessel is new or work has been completed on the vessel, the fuel valves could have been left in the closed position.	Are the fuel supply and return valves in the open position? **YES**	3B
	Are the fuel supply and return valves in the open position? **NO** **Repair:** Turn the fuel supply and return valve to the open position and verify that no engine damage has occurred.	3A-1

STEP 3A-1: Check the fuel cooler for damage due to high fuel return back pressure.

Condition:

None.

Action	Specification/Repair	Next Step
Remove and inspect the fuel cooler. Check for internal damage, or collapsed internally. For QSL9 engines, refer to Procedure 006-062 (Fuel Cooler) in Section 6 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418. For QSC8.3 engines, refer to Procedure 008-129 (Marine Gear Oil and Fuel Cooler Assembly) in Section 8 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Is the fuel cooler damaged or collapsed internally? **YES** **Repair:** Remove and replace the fuel cooler. For QSL9 engines, refer to Procedure 006-062 (Fuel Cooler) in Section 6 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418. For QSC8.3 engines, refer to Procedure 008-129 (Marine Gear Oil and Fuel Cooler Assembly) in Section 8 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete
	Is the fuel cooler damaged or collapsed internally? **NO**	3B

STEP 3B: Verify the low pressure fuel lines are routed correctly.

Condition:

None.

Action	Specification/Repair	Next Step
It is sometimes possible to get the low pressure fuel lines connected to the ECM cooling plate installed improperly. The top connection to the ECM cooling plate is the inlet and the bottom connection is the outlet. Verify these connections are correct if the low pressure fuel lines have been removed and installed on the engine.	Are the low pressure fuel lines connected properly to the ECM cooling plate? **YES**	3C
	Are the low pressure fuel lines connected properly to the ECM cooling plate? **NO** **Repair:** Properly connect the low pressure fuel lines to the ECM cooling plate. The fuel inlet is the top connection.	Repair complete

STEP 3C: Check the engine speed during cranking.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to monitor Engine Speed while cranking the engine. If the engine does **not** crank at all, reference the Engine Will Not Crank or Cranks Slowly troubleshooting symptom tree in the Troubleshooting and Repair Manual, ISB, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416.	Is the engine cranking speed greater than 150 rpm? **YES**	3D
	Is the engine cranking speed greater than 150 rpm? **NO** **Repair:** Find and correct the cause for low cranking speed. Check the batteries, engine starting motor and accessory loads. Reference the Engine Will Not Crank or Cranks Slowly troubleshooting symptom tree.	Repair complete

STEP 3D: Check the ECM keyswitch voltage.

Condition:
- Turn keyswitch OFF.
- Disconnect the OEM harness from the ECM.
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
Measure the signal voltage. • Measure the signal voltage from the keyswitch input SIGNAL wire of the OEM harness to the engine block ground. Measure the keyswitch voltage with the keyswitch in the “ON” position and also with the keyswitch in the “Cranking” position. Refer to the wiring diagram for connector pin identification.	Is the keyswitch voltage equal to the battery voltage? **YES**	3E
	Is the keyswitch voltage equal to the battery voltage? **NO** **Repair:** Repair or replace the keyswitch harness and/or keyswitch. Check the battery connections. The keyswitch harness can be supplied by the OEM.	Repair complete

STEP 3E: Check the ECM battery supply voltage.

Condition:
- Turn the keyswitch OFF.
- Disconnect the ECM power harness from the ECM.

Action	Specification/Repair	Next Step
Measure the voltage. • Measure the voltage from the ECM battery supply (-) to the ECM battery supply (+) pins in the ECM power harness connector. Measure the ECM voltage with the keyswitch in the ON position and also with the keyswitch in the “Cranking” position. Refer to the wiring diagram for connector pin identification.	Is the ECM battery supply voltage equal to the battery voltage? **YES**	3F
	Is the ECM battery supply voltage equal to the battery voltage? **NO** **Repair:** Repair or replace the ECM power harness. Check the battery connections and fuse terminals.	Repair complete

STEP 3F: Verify the rail fuel pressure sensor accuracy.

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

Action	Specification/Repair	Next Step
Monitor the rail fuel pressure sensor. Use INSITE™ electronic service tool to monitor the rail fuel pressure sensor (measured) with the keyswitch ON and the engine **not** running.	Is the rail fuel pressure sensor (measured) value less than 30 bar [435 psi]? **YES**	3G
	Is the rail fuel pressure sensor (measured) value less than 30 bar [435 psi]? **NO** **Repair:** Replace the rail fuel pressure sensor. Refer to Procedure 019-115 (Rail Fuel Pressure Sensor) in Section 19 in the Troubleshooting and Repair Manual, ISB, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416.	Repair complete

STEP 3G: Check for fuel rail pressure while cranking the engine.

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

Action	Specification/Repair	Next Step
Check for fuel rail pressure. • Attempt to start the engine by engaging the engine starter for at lease 30 continuous seconds. • Use INSITE™ electronic service tool to monitor the 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 either Fault Code 2215 or 559 becomes active, then fuel rail pressure is **not** being developed. Refer to Bulletin 4021416 Troubleshooting and Repair Manual, ISB, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, and QSL9 Engines, CM850 Electronic Control System. If the engine starts during this attempt, it is possible that fuel prime to the high pressure pump has been lost. Look for loose fuel lines or filters that allow for loss of fuel prime.	Did either Fault Code 2215 or 559 become active during the failed start attempt? **YES**	3G-1
	Did either Fault Code 2215 or 559 become active during the failed start attempt? **NO**	4A

STEP 3G-1: Check the fuel gear pump pressure.

Condition:
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
Install a pressure gauge at the pressure side fuel filter head. • Measure the fuel gear pump output pressure while cranking the engine. Refer to Procedure 005-025 (Fuel Pump Gear Pump) in Section 5 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418. Cranking speed **must** be greater than 150 rpm.	Is the fuel gear pump pressure greater than 69 kPa [10 psi] while cranking? **YES** **Repair:** Follow Fault Code 2215 troubleshooting tree. Refer to Bulletin 4021416 Troubleshooting and Repair Manual, ISB, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, and QSL9 Engines, CM850 Electronic Control System.	Repair complete
	Is the fuel gear pump pressure greater than 69 kPa [10 psi] while cranking? **NO**	3G-2

STEP 3G-2: Check the fuel lift pump pressure.

Condition:
- Turn keyswitch ON.

Action	Specification/Repair	Next Step
Install a pressure gauge at the inlet port of the fuel pump. • Measure the fuel lift pump output pressure. Refer to Procedure 005-045 (Fuel Lift Pump) in Section 5 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418. At initial key-on, the lift pump will run for 60 seconds then stop. The lift pump will run for 30 seconds at key-on and 30 seconds after starting the engine.	Is the fuel lift pump pressure greater than the specifications? **YES** **Repair:** Replace the fuel pump. Refer to Procedure 005-025 (Fuel Pump Gear Pump) in Section 5 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete
	Is the fuel lift pump pressure greater than the specifications? **NO** **Repair:** Replace the fuel lift pump. Refer to Procedure 005-045 (Fuel Lift Pump) in Section 5 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 4: Fuel system troubleshooting procedures.

STEP 4A: Check for air in the high pressure pump fuel supply.

Condition:

None.

Action	Specification/Repair	Next Step
Check for air in the fuel. Refer to Procedure 006-003 (Air in Fuel) in Section 6 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Is air present in the fuel supply? **YES** **Repair:** Locate and correct the cause of air ingestion in the fuel supply system. Sources of air ingestion include loose fuel filters, loose fuel line fittings, loose or cracked fuel tank stand-pipes, or severe restrictions in the fuel supply lines and filters.	Repair complete
	Is air present in the fuel supply? **NO**	4B

STEP 4B: Measure the fuel inlet restriction.

Condition:

None.

Action	Specification/Repair	Next Step
Measure the fuel inlet restriction at the customer connection. Refer to Procedure 006-020 (Fuel Inlet Restriction) in Section 6 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418. Maximum fuel inlet restriction at the customer connection. • New filter: 63.5 mm-Hg [2.5 in-Hg] • Dirty Filter: 101.6 mm-Hg [4.0 in-Hg]	Is the fuel inlet restriction above specification? **YES** **Repair:** Find and correct the cause of high fuel inlet restriction. Look for plugged OEM fuel filters or screens, a restricted ECM cooler, restricted lift pump bypass check valve (in the ECM cooler), pinched OEM fuel lines, or a restricted stand pipe in the OEM fuel tank.	Repair complete
	Is the fuel inlet restriction above specification? **NO** **Repair:** Replace the fuel gear pump. Refer to Procedure 005-025 (Fuel Pump Gear Pump) in Section 5 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 4C: Perform the single cylinder cutout test.

Condition:
- Connect INSITE™ electronic service tool.
- Turn keyswitch ON.
- Start the engine and run at low idle.

Action	Specification/Repair	Next Step
Perform the single cylinder cutout test. • Operate the engine at load. • Use INSITE™ electronic service tool to perform the Cylinder Cutout test. Disable individual injectors.	Can the miss or excessive smoke be attributed to a single cylinder? **YES** **Repair:** Look for a cause of the complaint including valve lash and excessive crankcase pressure that can indicate power cylinder damage, or camshaft lobe wear. If no other damage is found, replace the fuel injector in the cylinder that was identified using the single cylinder cutout test. Refer to Procedure 006-026 (Injector) in Section 6 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete
	Can the miss or excessive smoke be attributed to a single cylinder? **NO**	4D

STEP 4D: Perform the cylinder balance diagnostic test.

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

Action	Specification/Repair	Next Step
Perform the cylinder balance diagnostic test. • Use INSITE™ electronic service tool to perform the Cylinder Performance Test. Determine if a single cylinder is contributing to the engine symptom.	Does the Cylinder Performance Test identify any cylinder that is contributing to a power imbalance? **YES** **Repair:** Look for a cause of the power imbalance including valve lash and excessive crankcase pressure that can indicate power cylinder damage or camshaft lobe wear. If no other damage is found, replace the fuel injector in the cylinder contributing to the power imbalance. Refer to Procedure 006-026 (Injector) in Section 6 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete
	Does the Cylinder Performance Test identify any cylinder that is contributing to a power imbalance? **NO**	4E

STEP 4E: Measure the fuel drain line restriction.

Condition:
None.

Action	Specification/Repair	Next Step
Measure the fuel drain line restriction. Refer to Procedure 006-012 (Fuel Drain Line Restriction) in Section 6 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Is the fuel drain line restriction within specification? **YES**	2A
	Is the fuel drain line restriction within specification? **NO** **Repair:** Look for causes of high drain line restriction, such as kinked or blocked fuel lines.	Repair complete

STEP 5: Air handling troubleshooting procedures.

STEP 5A: Check the intake manifold pressure sensor accuracy.

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

Action	Specification/Repair	Next Step
Monitor the reading for intake manifold pressure with the engine off. • Start INSITE™ electronic service tool data/ logger and monitor the INSITE™ electronic service tool reading for intake manifold pressure with the engine off. • Compare the pressure readings observed in INSITE™ electronic service tool to the local barometric pressure. Refer to Procedure 018-028 (Barometric Pressure at Altitude) in Section V.	Is the intake manifold pressure reading less than 50.8 mm-Hg [2 in-Hg] of local barometric pressure? **YES**	5B
	Is the intake manifold pressure reading less than 50.8 mm-Hg [2 in-Hg] of local barometric pressure? **NO** **Repair:** Replace the intake manifold pressure sensor. Refer to Procedure 019-061 (Intake Manifold Pressure Sensor) in Section 19 in the Troubleshooting and Repair Manual, ISB, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416.	Repair complete

STEP 5B: Check the air intake system for leaks.

Condition:

None.

Action	Specification/Repair	Next Step
Check the air intake system for leaks. Refer to Procedure 010-024 (Air Leaks, Air Intake and Exhaust Systems) in Section 10 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Were any air intake system leaks found? **YES** **Repair:** Repair or replace the damaged component.	Repair complete
	Were any air intake system leaks found? **NO**	5C

STEP 5C: Check the air intake restriction.

Condition:
- Install vacuum gauge Part Number ST-1111-3 into the air intake system.
- Turn keyswitch ON.
- Engine operating at rated speed and full load.

Action	Specification/Repair	Next Step
Measure the intake system restriction. Refer to Procedure 010-031 (Intake Air Restriction) in Section 10 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418. Maximum air intake restriction: Clean filter: 381 mm-H_2O [15 in-H_2O] Dirty filter: 635 mm-H_2O [25 in-H_2O]	Is the air intake restriction greater than the specification? **YES** **Repair:** Correct the cause of high intake air restriction. Check for plugged air filter or restricted air intake piping.	Repair complete
	Is the air intake restriction greater than the specification? **NO**	5C

STEP 5D: Inspect the turbocharger blades for damage.

Condition:
- Turn keyswitch OFF.
- Remove the intake and exhaust pipes from the turbocharger.

Action	Specification/Repair	Next Step
Inspect the turbocharger. • Inspect the compressor blades and turbine for damage or wear. Refer to Procedure 010-033 (Turbocharger) in Section 10 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Are the turbocharger blades damaged? **YES** **Repair:** Replace the turbocharger assembly. Refer to Procedure 010-033 (Turbocharger) in Section 10 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete
	Are the turbocharger blades damaged? **NO**	5E

STEP 5E: Determine if the turbocharger is a wastegated turbocharger.

Condition:
None.

Action	Specification/Repair	Next Step
Determine if the turbocharger is a wastegated turbocharger.	Is the turbocharger a wastegated turbocharger? **YES**	5F
	Is the turbocharger a wastegated turbocharger? **NO**	5H

STEP 5F: Inspect the wastegate actuator hose.

Condition:
- Turn keyswitch OFF.
- Remove the turbocharger if the wastegate actuator is inaccessible.

Action	Specification/Repair	Next Step
Inspect the integral wastegate actuator hose for cracks or holes. Refer to Procedure 010-050 (Turbocharger Wastegate Actuator) in Section 10 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Are holes or cracks found in the wastegate actuator hose? **YES** **Repair:** Replace the wastegate actuator hose. Refer to Procedure 010-050 (Turbocharger Wastegate Actuator) in Section 10 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete
	Are holes or cracks found in the wastegate actuator hose? **NO**	5G

STEP 5G: Inspect the turbocharger wastegate capsule for air leaks

Condition:
- Engine OFF.
- Remove the wastegate actuator hose from the wastegate actuator.

Action	Specification/Repair	Next Step
Perform a leak test on the wastegate actuator capsule. Use Wastegate Pressure Test Kit, Part Number 3823799, to apply a regulated air supply of 59 in-Hg to the wastegate actuator capsule. No air should be heard (a leaking noise) through a functional wastegate capsule. Refer to Procedure 010-050 (Turbocharger Wastegate Actuator) in Section 10 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Did the wastegate actuator capsule leak air? **YES** **Repair:** Replace the wastegate actuator. Refer to Procedure 010-050 (Turbocharger Wastegate Actuator) in Section 10 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete
	Did the wastegate actuator capsule leak air? **NO**	5G-1

STEP 5G-1: Inspect the turbocharger wastegate for proper operation.

Condition:
- Engine OFF.
- Remove the wastegate actuator hose from the wastegate actuator.

Action	Specification/Repair	Next Step
Check for wastegate actuator rod for movement. Use Wastegate Pressure Test Kit, Part Number 3823799, to apply a regulated air supply of [29 psi] to the wastegate actuator capsule. Check for wastegate actuator rod for movement. Refer to Procedure 010-050 (Turbocharger Wastegate Actuator) in Section 10 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Did the wastegate actuator rod move? **YES**	5H
	Did the wastegate actuator rod move? **NO**	5G-2

STEP 5G-2: Inspect the turbocharger wastegate for proper operation.

Condition:
- Engine OFF.
- Remove the e-clip from the wastegate pin and disconnect the actuator rod from the wastegate lever.

Action	Specification/Repair	Next Step
Check for wastegate actuator rod movement with it disconnected from the turbocharger wastegate. Use Wastegate Pressure Test Kit, Part Number 3823799, to apply a regulated air supply of [29 psi] to the wastegate actuator capsule. Check for wastegate actuator rod for movement. Refer to Procedure 010-050 (Turbocharger Wastegate Actuator) in Section 10 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Does the wastegate actuator rod move? **YES** **Repair:** Move the wastegate lever back and forth and check for smooth operation. If the wastegate lever does **not** move freely or binds, spray a penetrating oil on the wastegate lever joint and try to free the wastegate lever by working the lever back and forth. If the lever does **not** become free, then replace the turbocharger. Refer to Procedure 010-033 (Turbocharger) in Section 10 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete
	Does the wastegate actuator rod move? **NO** **Repair:** Replace the wastegate actuator. Refer to Procedure 010-050 (Turbocharger Wastegate Actuator) in Section 10 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 5H: Measure turbocharger axial and radial clearance.

Condition:
- Engine OFF.
- Disconnect the exhaust and intake connections from the turbocharger.

Action	Specification/Repair	Next Step
Follow the procedure for measuring the axial and radial clearances of the turbocharger. Refer to Procedure 010-033 (Turbocharger) in Section 10 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Are the axial and radial clearances within specification? **YES**	5I
	Are the axial and radial clearances within specification? **NO** **Repair:** Replace the turbocharger assembly. Refer to Procedure 010-033 (Turbocharger) in Section 10 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 5I: Inspect the aftercooler.

Condition:
None.

Action	Specification/Repair	Next Step
Inspect the aftercooler.	Is the aftercooler free of cracks or damage? **YES**	2A
	Is the aftercooler free of cracks or damage? **NO** **Repair:** Repair or replace the aftercooler assembly. Refer to Procedure 010-005 (Aftercooler Assembly (Sea Water) in Section 10 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 6: Electronic feature troubleshooting procedures.

STEP 6A: Verify the throttle travel.

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

Action	Specification/Repair	Next Step
Verify the throttle travel. • Use INSITE™ electronic service tool to monitor the throttle position while fully depressing and releasing the throttle lever.	Does the throttle position read 0 when the throttle is released and 100 percent when the throttle is actuated? **YES**	2A
	Does the throttle position read 0 when the throttle is released and 100 percent when the throttle is actuated? **NO** **Repair:** Determine and correct the cause of the throttle lever restriction.	Repair complete

STEP 7: Base engine troubleshooting procedures

STEP 7A: Verify the overhead adjustments are correct.

Condition:
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
Measure the overhead settings. • Measure the overhead settings. Refer to Procedure 003-004 (Overhead Set) in Section 3 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Are the overhead settings within the reset limits? **YES**	7B
	Are the overhead settings within the reset limits? **NO** **Repair:** Adjust the overhead settings. Refer to Procedure 003-004 (Overhead Set) in Section 3 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete

STEP 7B: Check the exhaust restriction.

Condition:

None.

Action	Specification/Repair	Next Step
Install a pressure gauge into the exhaust system just past the turbocharger outlet to check the exhaust system back pressure. Refer to Procedure 011-009 (Exhaust Restriction) in Section 11 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Is the exhaust back pressure less than 75 mm-Hg [3 in-Hg] or 1016 mm-H $_2$O [40 in-H $_2$O]? **YES**	7C
	Is the exhaust back pressure less than 75 mm-Hg [3 in-Hg] or 1016 mm-H $_2$O [40 in-H $_2$O]? **NO** **Repair:** Fix or clear the source of high exhaust restriction.	Repair complete

STEP 7C: Check the engine blowby.

Condition:
None.

Action	Specification/Repair	Next Step
Measure the engine blowby. Refer to Procedure 014-010 (Crancase Blowby, Measure) in Section 14 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Are the engine blowby measurements within specification? **YES**	Return to Step 2, or contact an authorized Cummins® service representative for further diagnostic and troubleshooting instructions.
	Are the engine blowby measurements within specification? **NO**	7C-1

STEP 7C-1: Verify the turbocharger contribution to the engine blowby.

Condition:
- Turn keyswitch OFF.
- Start the engine.

Action	Specification/Repair	Next Step
Verify the turbocharger contribution. • Connect the appropriate orifice to the end of the blowby draft tube. • Remove the turbocharger oil drain line from the block and drain into a bucket. • Load the engine to rated rpm. • Measure the engine blowby. Refer to Procedure 014-010 (Crancase Blowby, Measure) in Section 14 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Has the total engine blowby dropped more than 30 percent of the total? **YES** **Repair:** Replace the turbocharger assembly. Refer to Procedure 010-033 (Turbocharger) in Section 10 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete
	Has the total engine blowby dropped more than 30 percent of the total? **NO** **Repair:** The engine may need to be rebuilt. Refer to Procedure 000-001 (Engine Removal) in Section 0 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418 and the engine rebuild specifications.	Repair complete

STEP 8: Excessive vibration troubleshooting procedures.

STEP 8A: 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.	Are the gear ratio and the propeller incorrectly matched to the engine power? **YES** **Repair:** Contact a Cummins® Distributor or Marine District Field Service Manager.	Repair complete
	Are the gear ratio and the propeller incorrectly matched to the engine power? **NO**	8B

STEP 8B: 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.	Are the engine mount isolators correct and installed correctly? **YES**	8C
	Are the engine mount isolators correct and installed correctly? **NO** **Repair:** Check for proper isolator installation requirements. Replace and repair as needed. Refer to Procedure 016-026 (Marine Vibration Isolator) in Section 16 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418. Reference the Engine Mounting Drive Systems section in the Marine Recreational Installation Directions, Bulletin 3884649. If isolators are non-Cummins®, refer to the OEM service manual.	Repair complete

STEP 8C: Check for damaged engine mounts and isolators.

Condition:
None.

Action	Specification/Repair	Next Step
Inspect the engine mounts and isolators for failure.	Are the engine mounts and isolators in good condition? **YES**	8D
	Are the engine mounts and isolators in good condition? **NO** **Repair:** Remove and replace the engine mount isolators. Refer to Procedure 016-026 (Marine Vibration Isolator) in Section 16 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418. Reference the Engine Mounting Drive Systems section in the Marine Recreational Installation Directions, Bulletin 3884649. If the isolators are non-Cummins®, refer to the OEM service manual.	Repair complete

STEP 8D: Check the exhaust system.

Condition:
None.

Action	Specification/Repair	Next Step
Check for exhaust system deficiencies.	Is the exhaust system deficient? **YES** **Repair:** Repair or replace as needed. Reference the OEM service literature and instructions.	Repair complete
	Is the exhaust system deficient? **NO**	8E

STEP 8E: Check the engine driven accessories.

⚠CAUTION⚠

Some sea water pumps are belt driven. Operating the engine when the sea water pump is disconnected can result in engine damage due to overheating.

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

Action	Specification/Repair	Next Step
Check for engine driven accessories malfunctions. Isolate or disconnect the accessories and check for vibration. Do **not** operate the engine if the sea water pump is disconnected.	Is an engine driven accessory malfunctioning? **YES** **Repair:** Determine the cause of the malfunctioning accessories and correct the problem. If the accessory is **not** installed by Cummins Inc., refer to the OEM service manual.	Repair complete
	Is an engine driven accessory malfunctioning? **NO**	8F

STEP 8F: 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.	Is the shaft coupling to gear coupling misaligned? **YES** **Repair:** Repair or replace as needed. Refer to Procedure 016-025 (Propeller Shaft) in Section 16 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418. Reference the Engine Mounting Drive Systems section in the Marine Recreational Installation Directions, Bulletin 3884649. Reference the gear manufacturer's recommendations.	Repair complete
	Is the shaft coupling to gear coupling misaligned? **NO**	8G

STEP 8G: Check the propeller shaft for proper installation.

Condition:
None.

Action	Specification/Repair	Next Step
Check the propeller shaft for proper installation.	Is the propeller shaft installed correctly? **YES**	8H
	Is the propeller shaft installed correctly? **NO** **Repair:** Repair or replace as needed. Refer to Procedure 016-025 (Propeller Shaft) in Section 16 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418. Reference the Engine Mounting Drive Systems section in the Marine Recreational Installation Directions, Bulletin 3884649. Reference the OEM service literature.	Repair complete

STEP 8H: Check the propeller shaft for straightness.

Condition:
None.

Action	Specification/Repair	Next Step
Check the propeller shaft for straightness.	Is the propeller shaft straightness within the OEM specification? **YES**	8I
	Is the propeller shaft straightness within the OEM specification? **NO** **Repair:** Repair or replace the propeller shaft as needed. Refer to an authorized OEM Service Location.	Repair complete

STEP 8I: Isolate the engine.

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

Action	Specification/Repair	Next Step
Run the engine without the drive shaft attached at the coupler.	Does the engine vibration persist? **YES** **Repair:** Check the engine vibration damper for damage. Repair or replace as needed. Refer to Procedure 001-052 (Vibration Damper, Viscous) in Section 1 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete
	Does the engine vibration persist? **NO**	8J

STEP 8J: Check for strut/cutlass bearing misalignment.

Condition:
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
Check for strut/cutlass bearing misalignment or strut mounting is not secure.	Is the strut/cutlass bearing misaligned or strut mounting **not** secure? **YES** **Repair:** Check the strut for mounting stiffness. Repair or replace as needed. Refer to an authorized OEM Service Location.	Repair complete
	Is the strut/cutlass bearing misaligned or strut mounting **not** secure? **NO**	8K

STEP 8K: Check the propeller.

Condition: None.		
Action	**Specification/Repair**	**Next Step**
Check for propeller out-of-balance or propeller not fitted properly to shaft.	Is the propeller out of balance or **not** fitted properly to the shaft? **YES** **Repair:** Check the propeller for accuracy. Repair or replace as needed. Refer to an authorized OEM Service Location.	Repair complete
	Is the propeller out of balance or **not** fitted properly to the shaft? **NO**	8L

STEP 8L: 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.	Does the V-angle on the V-strut match the angle of the blade on the propeller? **YES**	8M
	Does the V-angle on the V-strut match the angle of the blade on the propeller? **NO** **Repair:** Repair or replace as needed. Refer to an authorized OEM Service Location.	Repair complete

STEP 8M: Check the propeller tunnels.

Condition: None.		
Action	**Specification/Repair**	**Next Step**
Check to see if the propeller tunnels are properly matched with the propellers.	Does the entry and exit of the propeller tunnel match with the propeller blades? **YES**	8N
	Does the entry and exit of the propeller tunnel match with the propeller blades? **NO** **Repair:** Repair or replace as needed. Refer to an authorized OEM Service Location.	Repair complete

STEP 8N: Check the engine to transmission torsional coupling.

Condition: None.		
Action	**Specification/Repair**	**Next Step**
Check for an incorrect or worn torsional coupling.	Is the torsional coupling incorrect or worn? **YES** **Repair:** Replace the coupling. Refer to the OEM service literature.	Repair complete
	Is the torsional coupling incorrect or worn? **NO**	8O

STEP 8O: Check the rudder.

Condition:

None.

Action	Specification/Repair	Next Step
Check the rudder for excessive play in the rudder post.	Does the rudder have excessive play in the rudder post? **YES** **Repair:** Repair or replace as needed. Refer to an authorized OEM Service Location.	Repair complete
	Does the rudder have excessive play in the rudder post? **NO** **Repair:** If the engine is **not** damaged, refer to an authorized OEM Service Location.	8P

STEP 8P: 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.	Is the flywheel housing alignment incorrect? **YES** **Repair:** Realign the flywheel housing to cylinder block. Refer to Procedure 016-006 (Flywheel Housing) in Section 16 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418.	Repair complete.
	Is the flywheel housing alignment incorrect? **NO** **Repair:** The engine might have internal damage that has **not** been detected. Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-083 (Lubricating Oil Filter and Analysis) in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418. The engine might need to be rebuilt. Refer to Procedure 000-001 (Engine Removal) in Section 0 in the ISC, ISCe, QSC8.3, ISL, ISLe3 and QSL9 Troubleshooting and Repair Manual, Bulletin 4021418. Refer to the engine rebuild specifications. If the engine is **not** damaged, the problem might be the vessel design. Refer to an authorized OEM service location.	Repair complete.

Fuel Economy Troubleshooting Tree

This troubleshooting procedure should be followed for the following symptoms:

- Fuel Consumption Excessive

How to Use This Troubleshooting Procedure:

This symptom tree is to be used to troubleshoot fuel economy complaints. This tree is used along with the Fuel Consumption - Customer Complaint Form and the Driveability Low Power/Excessive Fuel - Consumption Checklist to help isolate engine, chassis, or driver issues associated with excessive fuel consumption.

Shop Talk:

The Fuel Consumption - General Information section of this manual and Troubleshooting Excessive Fuel Consumption, Bulletin 3666094, should be referenced prior to any troubleshooting being performed on a customer's engine.

The cause of excessive fuel consumption is difficult 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 or 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 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.

Factors to Consider When Troubleshooting Fuel Consumption Complaints	
Excessive Idling Time	Idling the engine can use from 0.5 to 1.5 gallons per hour depending on the engine idle speed
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 mile per gallon
Rolling Resistance	Rolling resistance is the second largest consumer of power on a truck. The type of tire and tread design have a sizeable effect on fuel economy and performance. Changing from a bias ply to a low profile radial tire can reduce rolling resistance by about 36 percent.
Environmental and Seasonal Weather Changes	There can be as much as 1 to 1.5 mile per gallon difference in fuel consumption, depending on the season and the weather conditions.
Truck Route and Terrain	East and west routes experience almost continual crosswinds and head winds. Less fuel can be used on north and south routes where parts of the trip are **not only** warmer, but have less wind resistance.
Driver Technique and Operating Practices	A 1 mile per hour increase in road speed equals a 0.1 mile per gallon increase in fuel consumption. This means that increasing road speed from 50 to 60 mph will result in a loss of fuel mileage of 1 mpg.

Factors to Consider When Troubleshooting Fuel Consumption Complaints	
Result of a Low Power or Driveability Problem	An operator will change driving style to compensate for a low power or driveability problem. Some things the driver is likely to do are: (a) shift to a high engine rpm (b) run on the droop curve in a lower gear instead of upshifting to drive at part-throttle conditions. These changes in driving style will increase the amount of fuel used.

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

TROUBLESHOOTING SUMMARY

STEPS		SPECIFICATIONS	SRT CODE
STEP 1:	**Verify the complaint.**		
STEP 1A:	**Fill out the Fuel Consumption - Customer Complaint Form.**	**Problem caused by vehicle factors, environmental factors, or driver technique?**	
STEP 2:	**Electronic checks using INSITE™ electronic service tool.**		
STEP 2A:	**Check for fault codes.**	**Any active or high counts of inactive fault codes?**	
STEP 2B:	**Confirm Features and Parameters.**	**Features and Parameters set correctly?**	
STEP 2C:	**Check the engine control module (ECM) calibrations.**	**Calibration correct?**	
STEP 2D:	**Monitor vehicle speed.**	**Does vehicle speed read 0 when the vehicle is not moving?**	
STEP 2D-1:	**Inspect the engine and chassis grounds.**	**All grounds present, properly grounded, free of corrosion, and tight?**	
STEP 3:	**Engine performance.**		
STEP 3A:	**Engine performance troubleshooting.**	**Poor fuel economy complaint still exists?**	

TROUBLESHOOTING STEP

STEP 1: Verify the complaint.

STEP 1A: Fill the Fuel Consumption - Customer Complaint Form.

Condition:
N/A

Action	Specification/Repair	Next Step
Fill out the Fuel Consumption - Customer Complaint Form. N/A	Problem caused by vehicle factors, environmental factors, or driver technique? **YES**	Repair complete
	Problem caused by vehicle factors, environmental factors, or driver technique? **NO**	2A

STEP 2: Electronic checks using INSITE™ electronic service tool.

STEP 2A: Check for fault codes.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to read the fault codes. N/A	Any active or high counts of inactive fault codes? **YES**	Troubleshoot fault codes
	Any active or high counts of inactive fault codes? **NO**	2B

STEP 2B: Confirm Features and Parameters.

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

Action	Specification/Repair	Next Step
Confirm the Programmable Features and Parameters are set correctly. N/A	Features and Parameters set correctly? **YES**	2C
	Features and Parameters set correctly? **NO** **Repair:** Reset the Features and Parameters to their appropriate values.	Repair complete

STEP 2C: Check the ECM calibration.

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

Action	Specification/Repair	Next Step
Compare the ECM code with the engine rating and control parts list (CPL). • Verify the calibration is correct.	Calibration correct? **YES**	2D
	Calibration correct? **NO** **Repair:** Calibrate the ECM with the correct ECM code.	Repair complete

STEP 2D: Monitor vehicle speed.

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

Action	Specification/Repair	Next Step
Use INSITE™ electronic service tool to monitor vehicle speed while the vehicle is **not** moving. N/A	Does vehicle speed read 0 when the vehicle is **not** moving? **YES**	3A
	Does vehicle speed read 0 when the vehicle is **not** moving? **NO**	2D-1

STEP 2D-1: Inspect the engine and chassis grounds.

Condition:
- Turn keyswitch OFF.

Action	Specification/Repair	Next Step
Check for loose or corroded engine, chassis, or battery ground connection. • Check the engine ground connection • Check the chassis ground connections • Check the battery terminal connections.	All grounds present, properly grounded, free of corrosion, and tight? **YES** **Repair:** Check the variable speed sensor (VSS) and the VSS circuit. Refer to Procedure 019-091 in Section 19. This procedure is found in the following manuals: • Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3, and ISL Engines, Bulletin 3666271. • Troubleshooting and Repair Manual, CM850 Electronic Control System, ISB, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3 and QSL9 Engines Bulletin 402141. • Troubleshooting and Repair Manual, CM2150 Electronic Control System, ISB, ISC, ISL, ISLe, ISDe, and QSB3.3 Engines Bulletin 4021570.	Repair complete
	All grounds present, properly grounded, free of corrosion, and tight? **NO** **Repair:** Replace, clean, or tighten the grounds.	Repair complete

STEP 3: Engine performance.

STEP 3A: Engine performance troubleshooting.

Condition:

N/A

Action	Specification/Repair	Next Step
Perform the Fuel System Checks, Air Handling Checks, and Base Engine Checks in the Engine Performance Troubleshooting Tree. N/A	Poor fuel economy complaint still exists? **YES** **Repair:** Perform the Fuel System Checks, Air Handling Checks, and Base Engine Checks in the Engine Performance Troubleshooting Tree.	Repair complete
	Poor fuel economy complaint still exists? **NO**	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 0 - Product - Group 00

Section Contents

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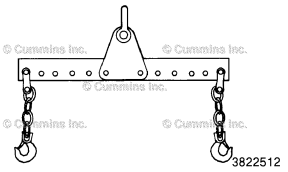
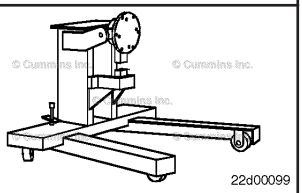
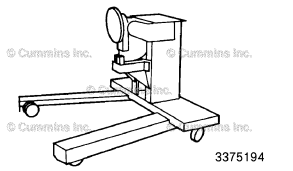
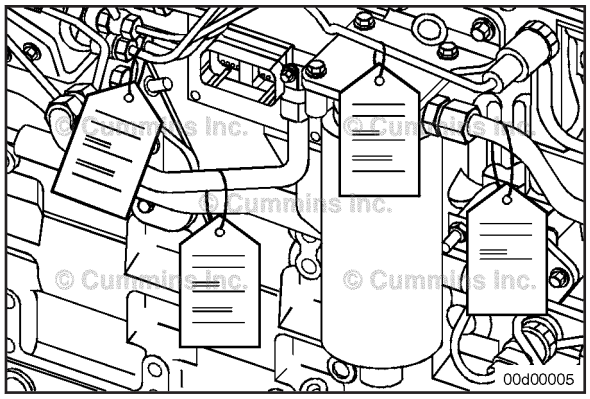
Service Tools

Engine Disassembly/Assembly

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3162871	**Engine Lifting Fixture** Used to lift the engine during removal and installation.	
3822607	**Engine Stand Adapter Plate** Used to mount the engine to the rebuild stand.	
3375194 or 3375193	**Engine Rebuild Stand** Portable tilt type engine rebuild stand.	



Engine Removal (000-001)

Remove

All Applications Except Marine

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

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

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

- Place a tag on all hoses, lines, linkages, and electrical connections as they are removed to identify their locations.
- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Disconnect the starter cable, engine ground straps, cab or chassis to engine hoses, tubing, electrical wires, wire harnesses and hydraulic lines.
- Disconnect the drive units from the flywheel. Refer to the OEM service manual.
- Remove all chassis components necessary to remove the engine from the equipment.
- Cover all engine openings to prevent dirt and debris from entering the engine.

NOTE: On applications where the rear engine mounts are attached to the transmission, it will often be necessary to remove the engine and transmission as an assembly. Refer to the OEM service manual for instructions.

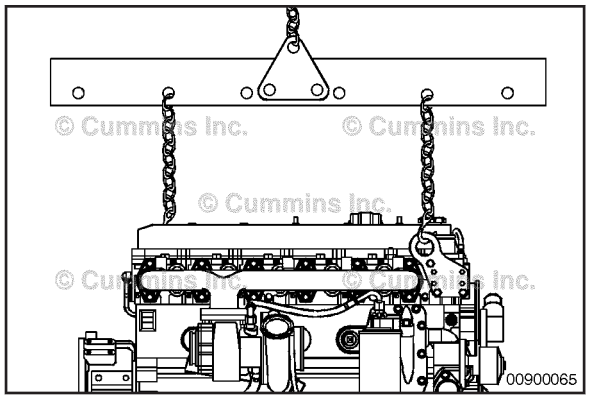
⚠WARNING⚠
The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

Use a properly rated hoist and engine lifting fixture, attached to the engine-mounted lifting brackets, to remove the engine. Refer to Procedure 018-015 in Section V.

NOTE: If the transmission is **not** removed with the engine, place a support under the transmission to prevent it from falling before removing the engine.

Place the engine on suitable engine support stands.

Remove all remaining accessories and brackets to use with the replacement engine.



Marine Applications

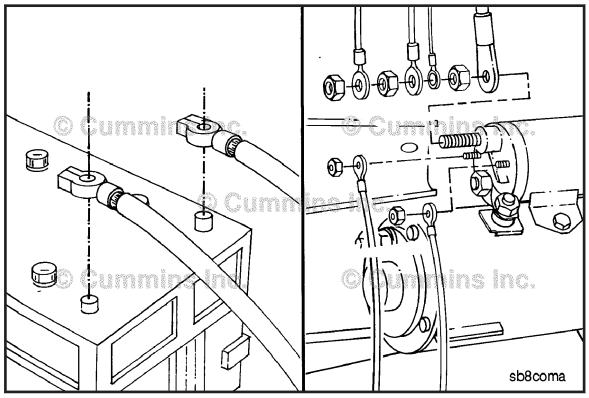
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

△CAUTION△
If the vessel remains in the water while the engine is being removed, make sure all sump or bilge pumps are operational while the engine is removed to prevent the vessel from taking on water and possibly sinking.

NOTE: Some of the graphics used in this procedure will **not** match all applications, but the procedure is the same unless otherwise noted.

Disconnect the battery cables, (-) negative cable first. Disconnect all unswitched power connections from the batteries and engine.

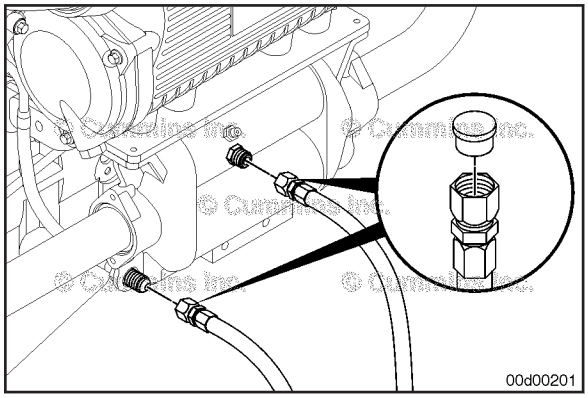
Disconnect and tag the starter cable, engine ground straps, vessel or vessel to engine hoses, tubing, electrical wires, wire harnesses, and hydraulic lines.

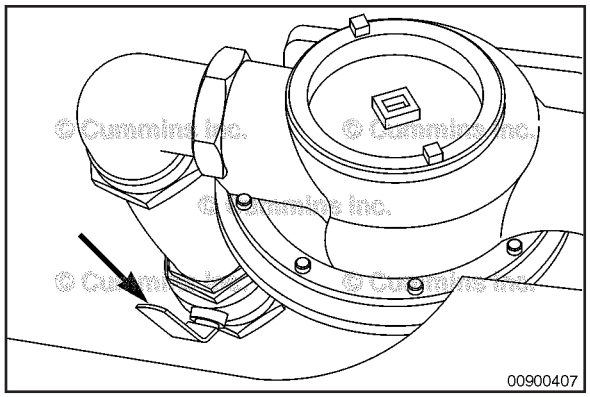


⚠WARNING⚠
Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

△CAUTION△
Use caution when draining the cooling system that coolant is not spilled or drained into the bilge area. The coolant must be disposed of in accordance with local environmental regulations.

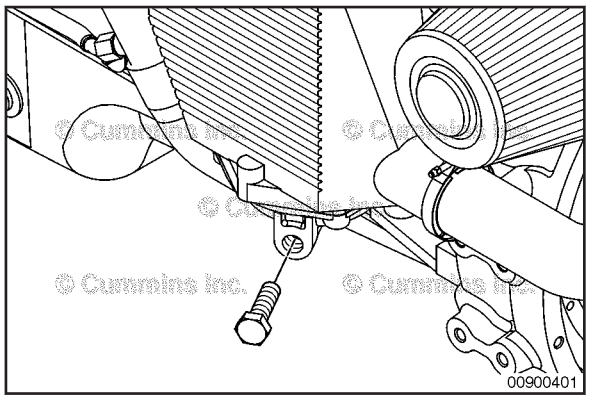
Shut off, disconnect, and cap the fuel supply line and fuel return line from the engine to the fuel tank(s). Refer to Procedure 100-002 in Section E.





NOTE: Some QSL engines are keel cooled and are **not** equipped with sea water supply to the engine.

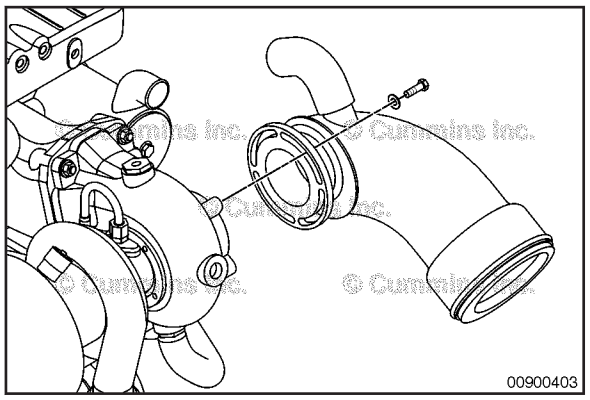
Shut off the sea water supply line(s), if equipped.



⚠CAUTION⚠
Zinc plugs expand and can break off during removal. Inspect the zinc plug to make sure it is in one piece. If not, it must be replaced with a new zinc plug, and the broken pieces must be retrieved from the aftercooler to prevent damage to components downstream in the sea water system.

Drain the sea water system by removing the lower zinc plug from the aftercooler. Refer to Procedure 100-002 in Section E.

Disconnect the sea water supply lines. Refer to Procedure 100-002 in Section E.



⚠CAUTION⚠
Be sure to tie the exhaust piping up above the water line to prevent water from feeding back into the vessel while the exhaust piping is removed. Failure to do so can result in the vessel sinking.

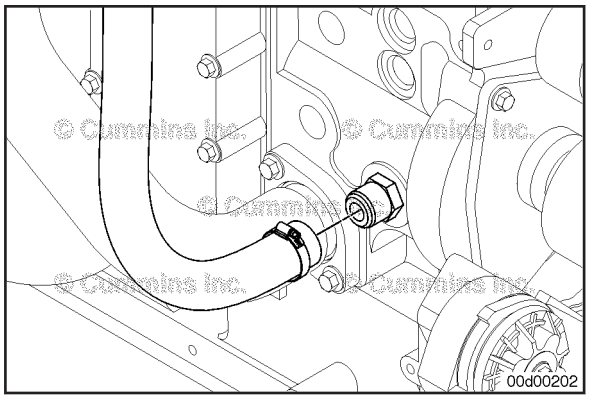
Disconnect the exhaust piping from the exhaust outlet connection on the turbocharger.

⚠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.

⚠CAUTION⚠
Use caution when draining the cooling system that coolant is not spilled or drained into the bilge area. The coolant must be disposed of in accordance with local environmental regulations.

Drain the engine coolant. Refer to Procedure 008-018 in Section 8.

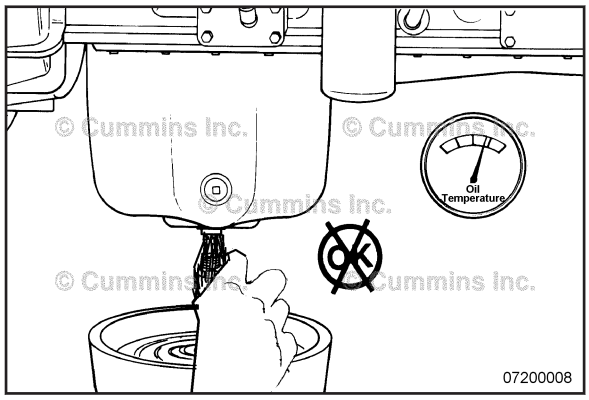


⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.

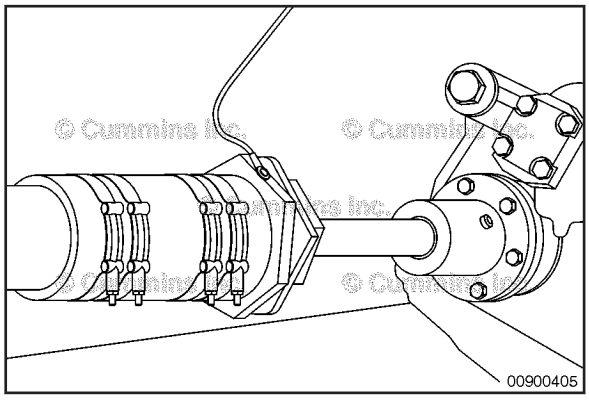
⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

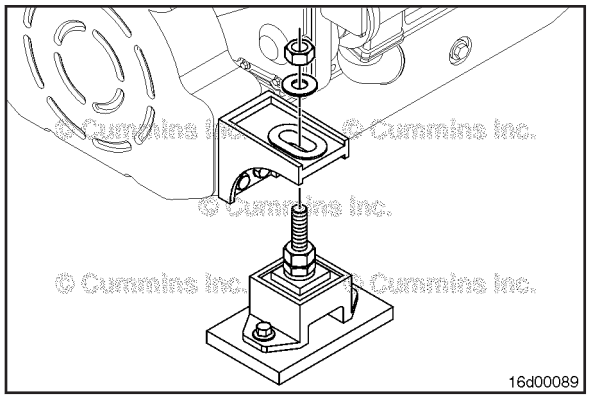
⚠CAUTION⚠
Use caution when draining the lubricating oil system that oil is not spilled or drained into the bilge area. The oil must be disposed of in accordance with local environmental regulations.

Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.



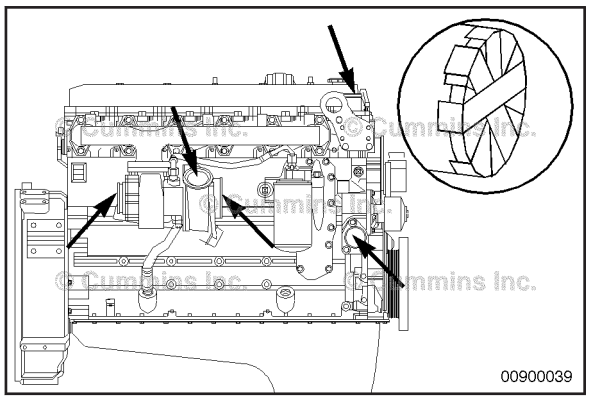
Disconnect the transmission output shaft from the drive coupling. Refer to the OEM service manual.



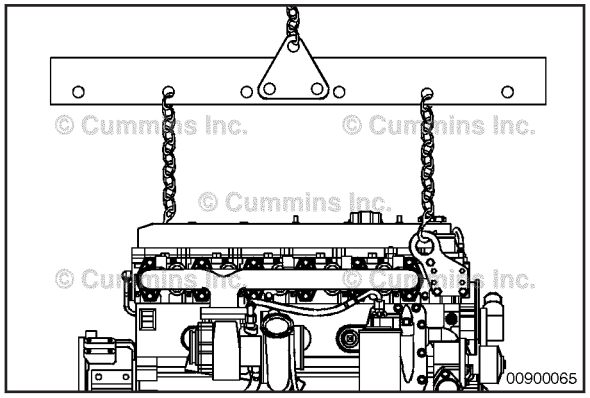


Remove the engine mounting nuts from the engine mounts.

Remove all components necessary to remove the engine from the vessel.



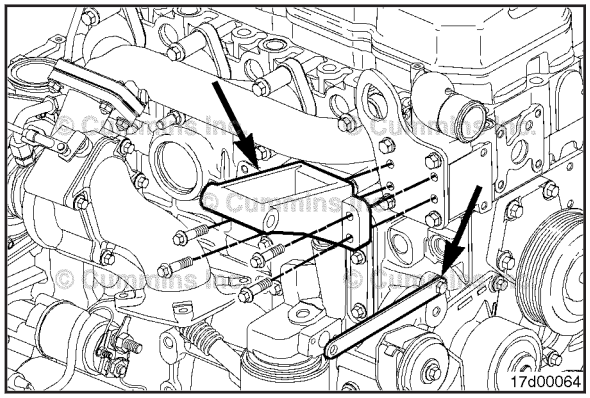
Cover all engine openings to prevent dirt and debris from entering the engine.



⚠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 QSC8.3 marine engine is 896 kg [1975 lb]. The standard weight of the QSL9 marine engine is 907 kg [2000 lb].

Verify the engine weight specifications. Refer to Procedure 018-015 in Section V. Verify the marine gear weight specifications in the Marine Gear OEM service manual .

Use a properly rated hoist and engine lifting fixture, Part Number 3162871, attached to the engine-mounted lifting brackets, to remove the engine.



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)

Install

All Applications Except Marine

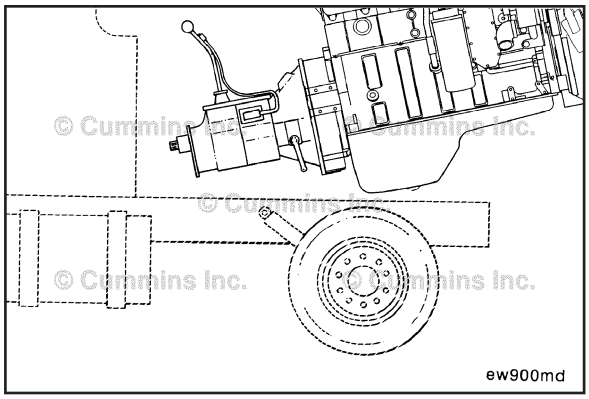
⚠WARNING⚠
The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

Install all accessories and brackets that were removed from the previous engine.

NOTE: On applications where the rear engine mounts are attached to the transmission, it will often be necessary to install the engine and transmission as an assembly.

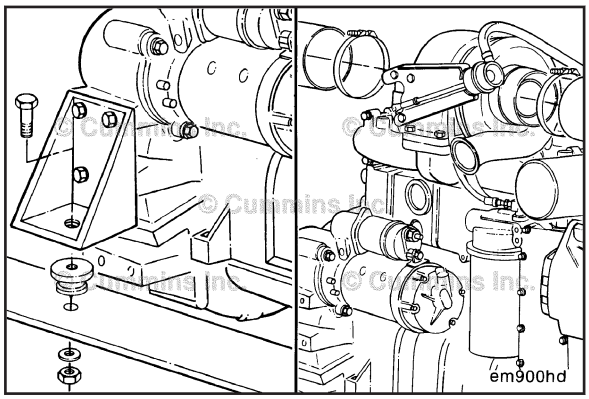
Use a properly rated hoist and engine lifting fixture, attached to the engine-mounted lifting brackets, to install the engine.

For engine weights. Refer to Procedure 018-015 in Section V.



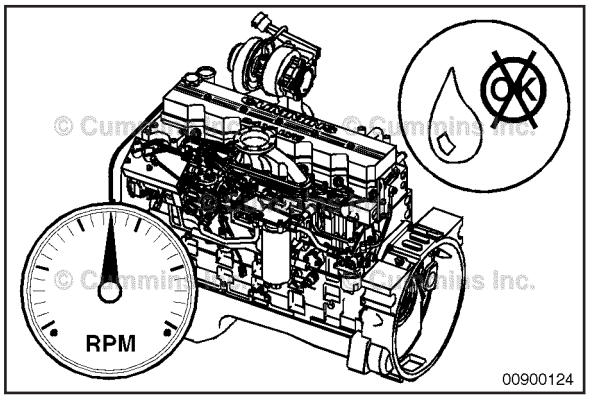
Align the engine in the chassis and tighten the engine-mounting capscrews. Refer to the See equipment manufacturer service information for torque specifications.

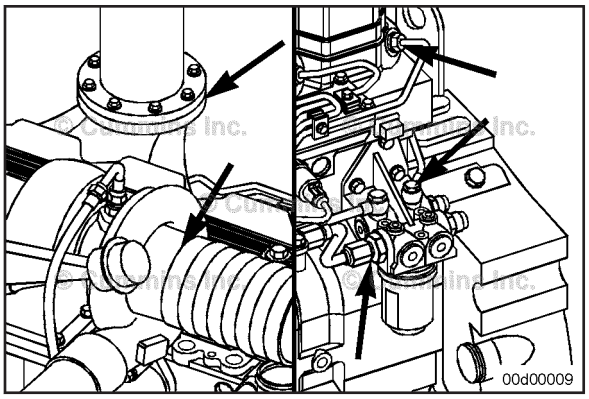
Connect all engine and chassis-mounted accessories that were removed.



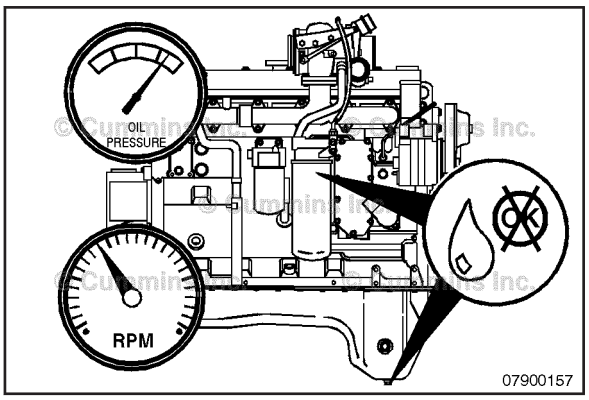
- Uncover all engine openings.
- Connect the drive units to the flywheel. Refer to the OEM service manual.
- Connect the starter cable, engine ground straps, cab or chassis to engine hoses, tubing, electrical wires, wire harnesses and hydraulic lines.
- Fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Fill the engine cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove all tags on all hoses, lines, linkages and electrical connections.

NOTE: Make sure all lines, hoses and tubes are properly routed and fastened to prevent damage. Make sure the air intake and exhaust pipe connections are tight and free of leaks.





Perform a final inspection to make sure that all hoses, wires, linkages, and components have been properly installed and tightened.

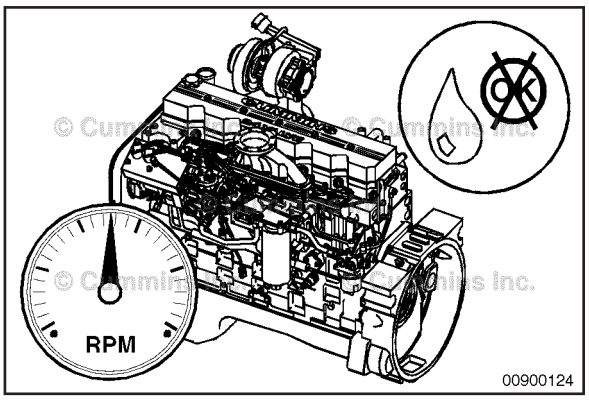


Crank the engine until the oil pressure gauge indicates a positive pressure.

Operate the engine at low idle for 2 to 3 minutes.

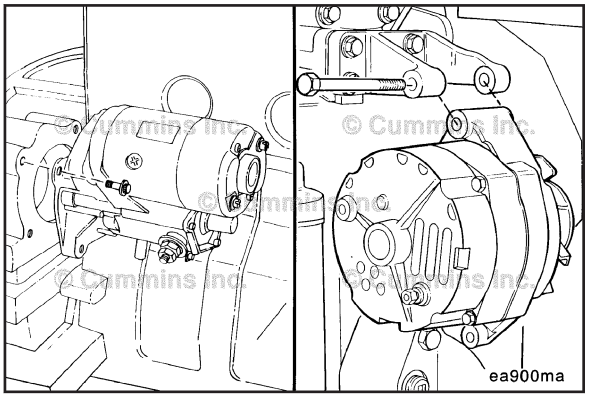
Shut the engine OFF and wait 5 to 7 minutes for the oil to drain to the oil pan, and check the oil and coolant levels again.

Fill the engine to the correct oil and coolant levels, if necessary.



Operate the engine at 1000 to 1200 rpm for eight to 10 minutes. Check for proper operation, unusual noises, and coolant or oil leaks.

Repair all leaks and component problems. Refer to Procedure 014-008 in Section 14.



Marine Applications

NOTE: Installations can vary from OEM to OEM. See Marine Recreational B and C Installation Directions, Bulletin 3884649 for more detailed instructions for various engine and application.

NOTE: Some of the graphics used in this procedure will **not** match all applications, but the procedure is the same unless otherwise noted.

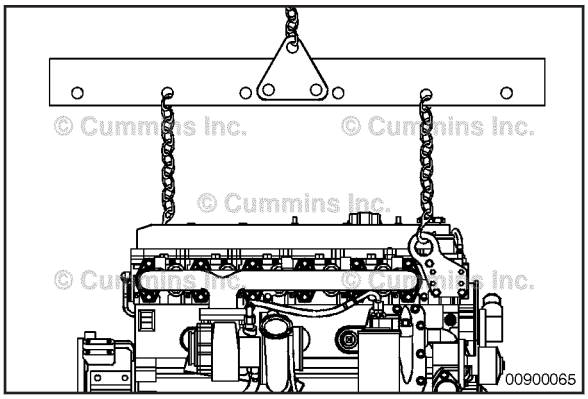
Install all accessories, brackets, and drive units that were removed from the engine, if the engine is being replaced.

⚠WARNING⚠

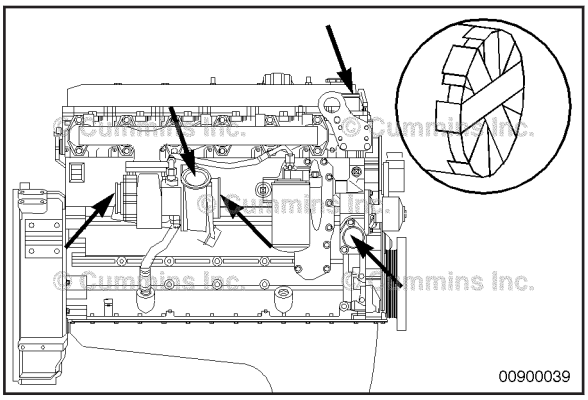
The engine lifting equipment must be designed to lift the engine and transmission safely as an assembly without causing personal injury. The dry weight of the standard QSC8.3 marine engine is 896 kg [1975 lb]. The dry weight of the standard QSL9 marine engine is 907 kg [2000 lb].

For engine weight specifications. Refer to Procedure 018-015 in Section V. Refer to the Marine Gear equipment manufacturer service information for marine gear weight specifications.

Use a properly rated hoist and engine lifting fixture, Part Number 3162871, attached to the engine-mounted lifting brackets, to install the engine.



Remove the covers from all engine openings that were covered during engine removal.

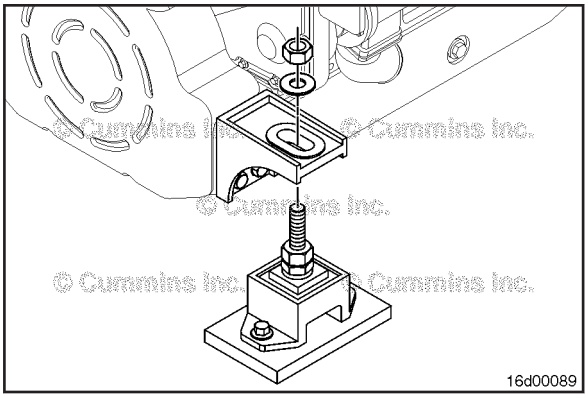


Align the engine in the vessel and tighten the engine mounting capscrews. Refer to the OEM service manual for torque specifications.

See Marine Recreational B and C Installation Directions, Bulletin 3884649.

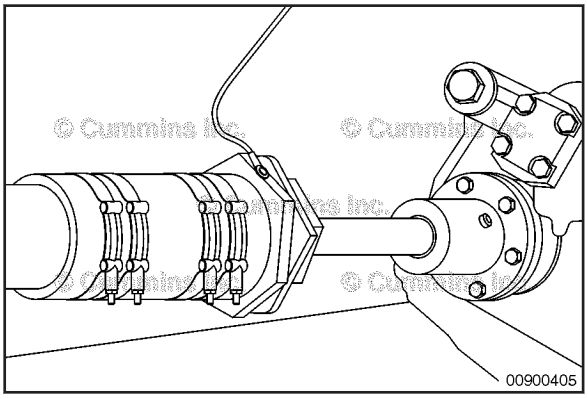
Connect all engine and vessel-mounted components accessories.

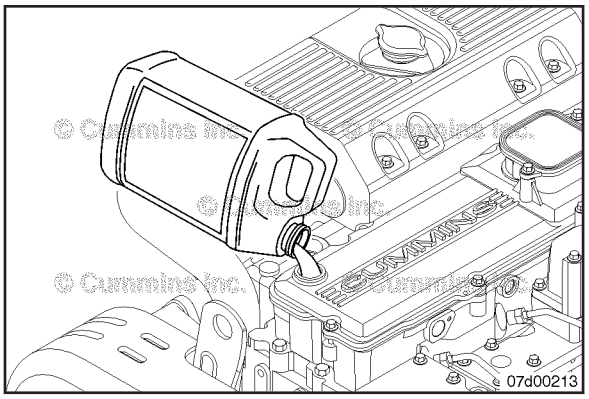
Make sure all sea water lines, fuel lines, hoses, and tubes are properly routed and fastened to prevent damage. Make sure the exhaust pipe connections are tight and free of leaks.



NOTE: The output shaft **must** be aligned when installed. Refer to the equipment manufacturer service information.

Connect the transmission output shaft to the drive coupling. See equipment manufacturer service information.





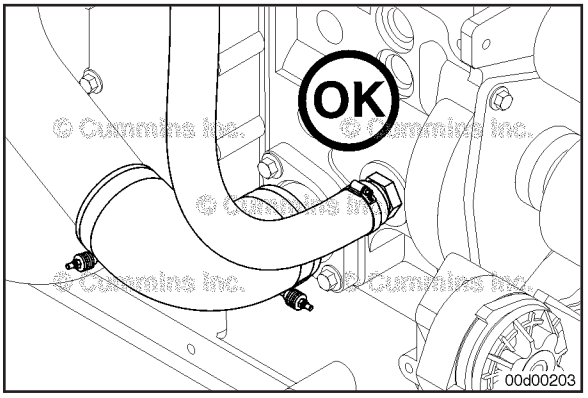
NOTE: If this is a new engine installation, the dipstick will need to be calibrated. Refer to Procedure 007-009 in Section 7.

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 equipment manufacturer service information to determine the capacity of the whole cooling system.

Fill the cooling system with new coolant. Cummins Inc. recommends using Fleetguard® Compleat. It is available in both glycol forms (ethelyne and propylene). Refer to Procedure 008-018 in Section 8.

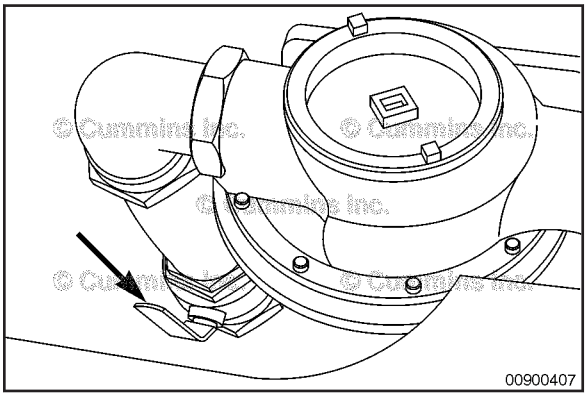
See the engine data sheet to determine the capacity of the whole cooling system.



⚠CAUTION⚠
Leave the pressure cap off or loose until air can be purged out of the cooling system. Improper purging of air from the cooling system will result in engine damage from overheating. If the vessel is equipped with a cabin heater, remote heat exchanger units, or if the engine is keel cooled, it will take longer for the trapped air to purge.

Perform a final inspection to make sure all hoses, wires, linkages, and components have been properly installed and tightened.

Make sure all alarms and lights are working prior to starting the engine.

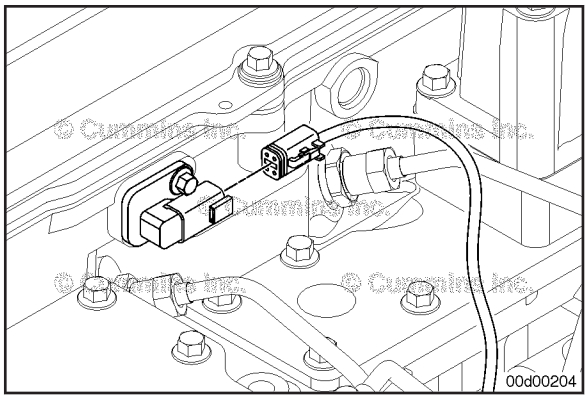


⚠CAUTION⚠
To prevent damage to the sea water pump, open the sea water valves before engaging the starting motor. Rotation of the sea water pump impeller with no water can damage the impeller.

If the engine is cooled by a heat exchanger, open the sea water supply lines.

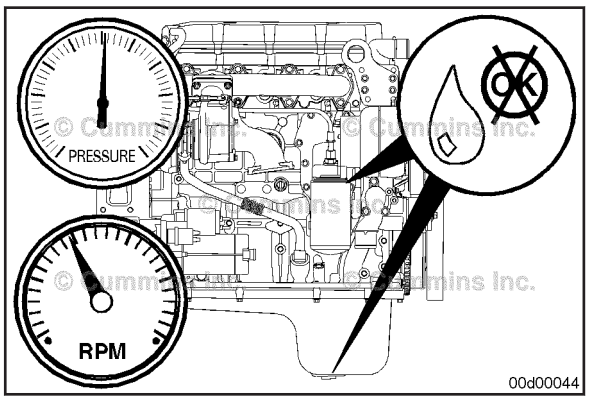
NOTE: This procedure will cause fault codes to be logged in the electronic control module (ECM). These faults will need to be removed prior to placing the engine in service. Reference Section TF of ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416.

Disconnect the engine injector harness connectors at the rocker housing to make sure the engine will **not** start.

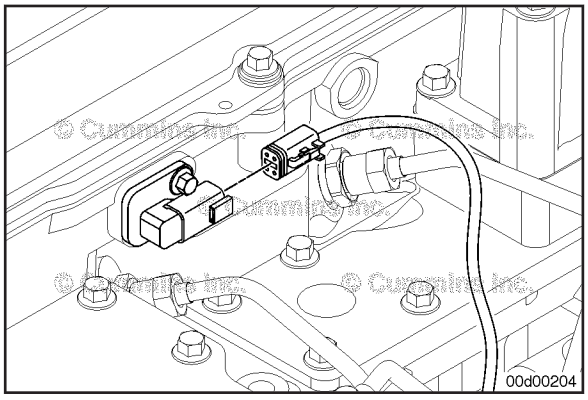


⚠CAUTION⚠
Do not engage the starting motor for more than 30 seconds. To reduce the possibility of engine damage, wait two minutes between starter engagements to cool the starting motor.

Crank the engine until the lubricating oil pressure gauge indicates a positive pressure.

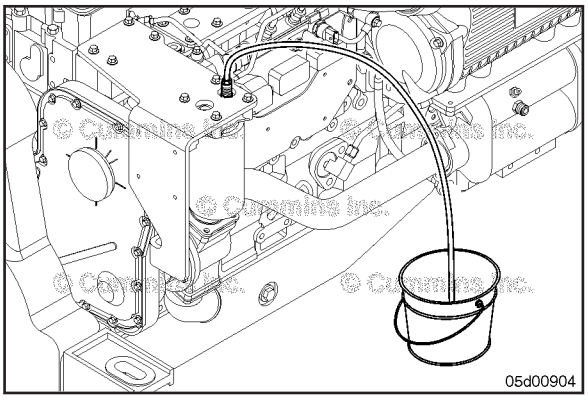


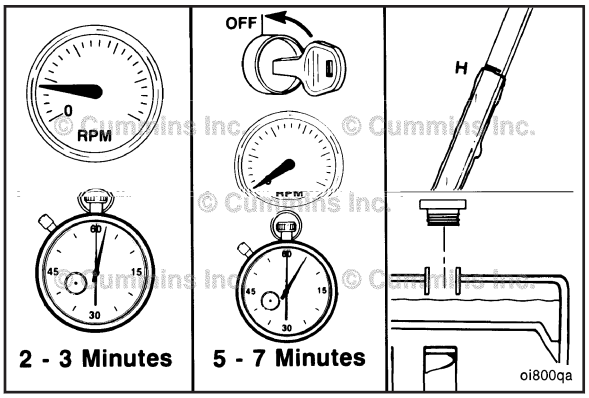
After pressure is observed, connect the engine harness injector connectors at the rocker housing.



⚠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 filter outlet fitting to purge air from the fuel system. Refer to Procedure 005-016 in Section 5.





⚠WARNING⚠

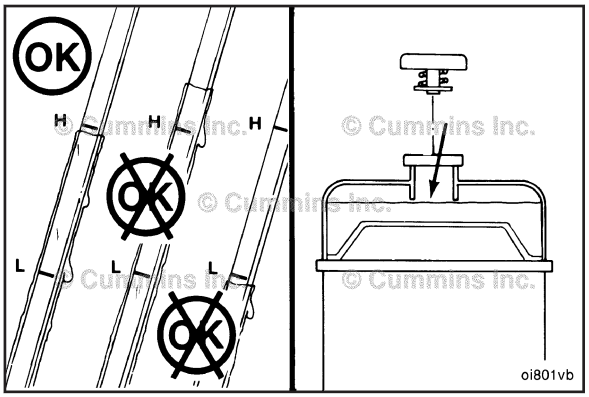
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

Operate the engine and check for sea water flow. Be sure the marine gear is in neutral and the engine can shift in and out of gear.

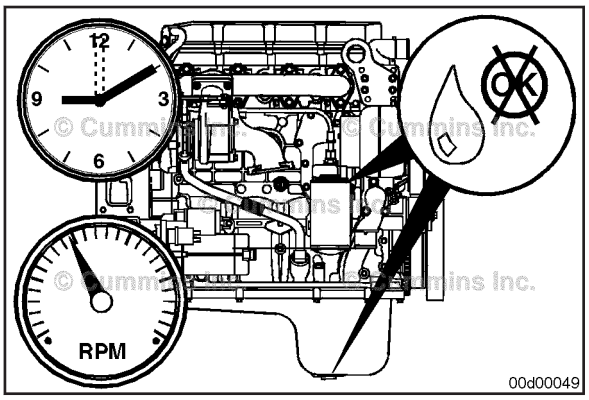
Operate the engine at low idle for two to three minutes.

Shut off the engine and wait five to seven 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.

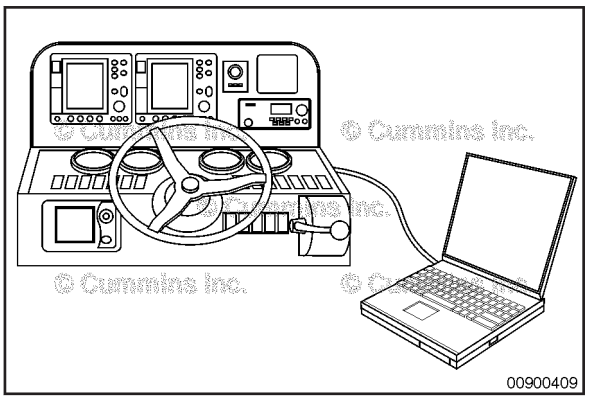


Operate the engine at 1000 to 1200 rpm for eight to ten minutes.

Check for proper operation, unusual noises, and coolant, fuel, or lubricating oil leaks.

Repair all leaks and component problems.

For the Engine Run-In and Test Procedures. Refer to Procedure 014-008 in Section 14.



Use INSITE™ electronic service tool to read and clear any fault codes.

Refer to Section TF of the Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416, to correct any fault codes.

Engine Installation (000-002)

Install

All Applications Except Marine

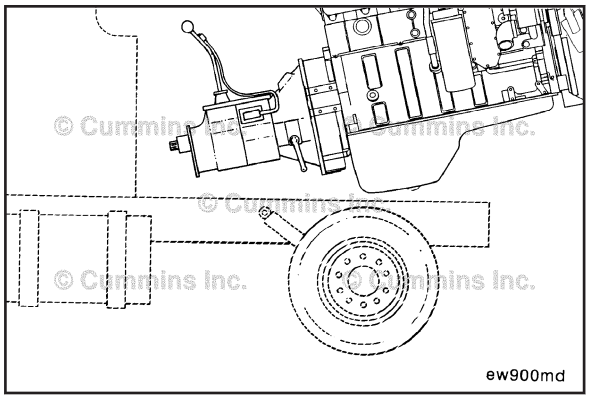
⚠WARNING⚠
The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

Install all accessories and brackets that were removed from the previous engine.

NOTE: On applications where the rear engine mounts are attached to the transmission, it will often be necessary to install the engine and transmission as an assembly.

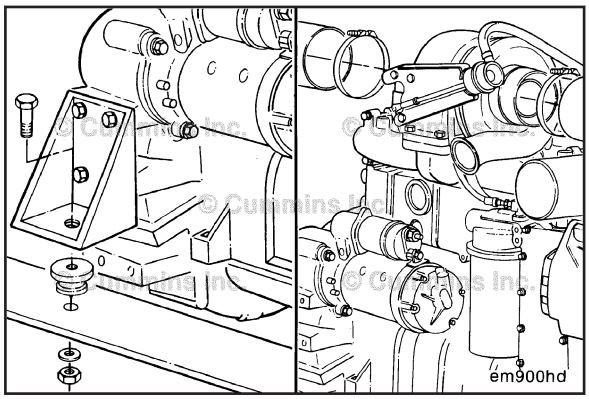
Use a properly rated hoist and engine lifting fixture, attached to the engine-mounted lifting brackets, to install the engine.

For engine weights. Refer to Procedure 018-015 in Section V.



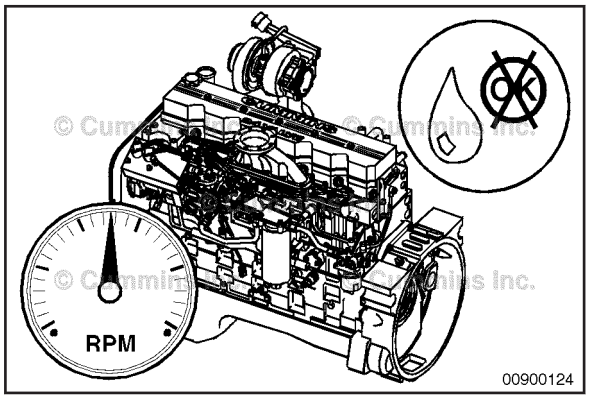
Align the engine in the chassis and tighten the engine-mounting capscrews. Refer to the See equipment manufacturer service information for torque specifications.

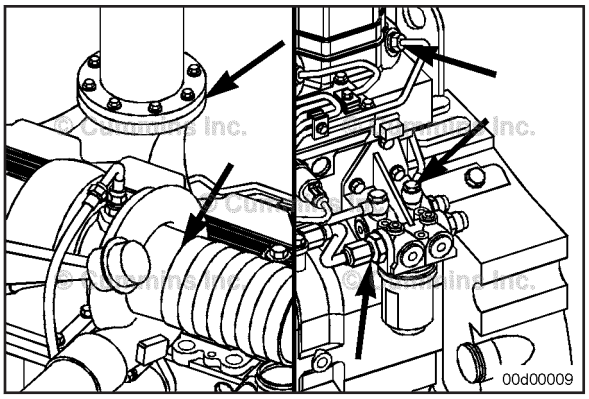
Connect all engine and chassis-mounted accessories that were removed.



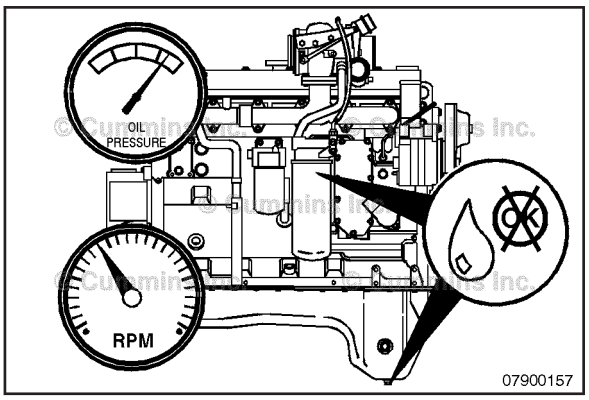
- Uncover all engine openings.
- Connect the drive units to the flywheel. Refer to the OEM service manual.
- Connect the starter cable, engine ground straps, cab or chassis to engine hoses, tubing, electrical wires, wire harnesses and hydraulic lines.
- Fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Fill the engine cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove all tags on all hoses, lines, linkages and electrical connections.

NOTE: Make sure all lines, hoses and tubes are properly routed and fastened to prevent damage. Make sure the air intake and exhaust pipe connections are tight and free of leaks.





Perform a final inspection to make sure that all hoses, wires, linkages, and components have been properly installed and tightened.

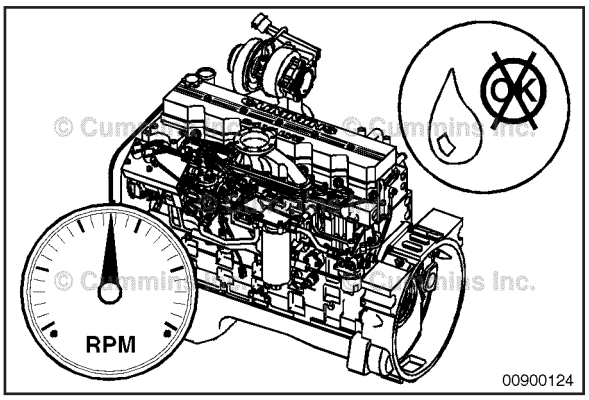


Crank the engine until the oil pressure gauge indicates a positive pressure.

Operate the engine at low idle for 2 to 3 minutes.

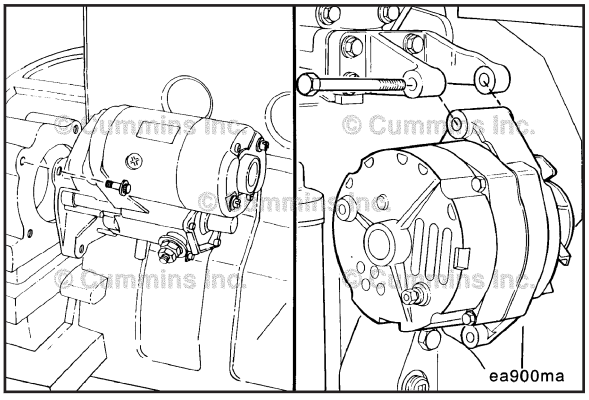
Shut the engine OFF and wait 5 to 7 minutes for the oil to drain to the oil pan, and check the oil and coolant levels again.

Fill the engine to the correct oil and coolant levels, if necessary.



Operate the engine at 1000 to 1200 rpm for eight to 10 minutes. Check for proper operation, unusual noises, and coolant or oil leaks.

Repair all leaks and component problems. Refer to Procedure 014-008 in Section 14.



Marine Applications

NOTE: Installations can vary from OEM to OEM. See Marine Recreational B and C Installation Directions, Bulletin 3884649 for more detailed instructions for various engine and application.

NOTE: Some of the graphics used in this procedure will **not** match all applications, but the procedure is the same unless otherwise noted.

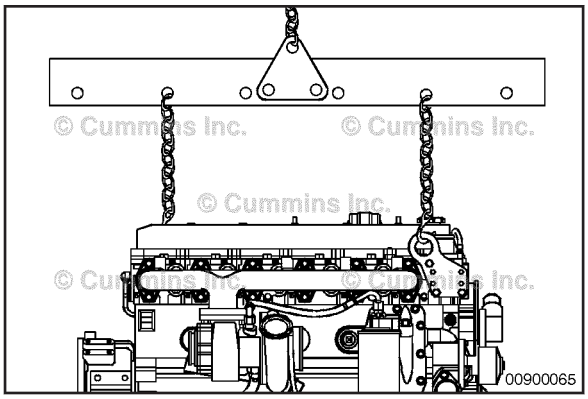
Install all accessories, brackets, and drive units that were removed from the engine, if the engine is being replaced.

⚠WARNING⚠

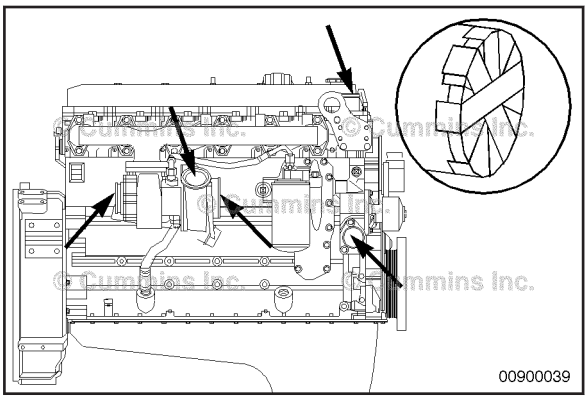
The engine lifting equipment must be designed to lift the engine and transmission safely as an assembly without causing personal injury. The dry weight of the standard QSC8.3 marine engine is 896 kg [1975 lb]. The dry weight of the standard QSL9 marine engine is 907 kg [2000 lb].

For engine weight specifications. Refer to Procedure 018-015 in Section V. Refer to the Marine Gear equipment manufacturer service information for marine gear weight specifications.

Use a properly rated hoist and engine lifting fixture, Part Number 3162871, attached to the engine-mounted lifting brackets, to install the engine.



Remove the covers from all engine openings that were covered during engine removal.

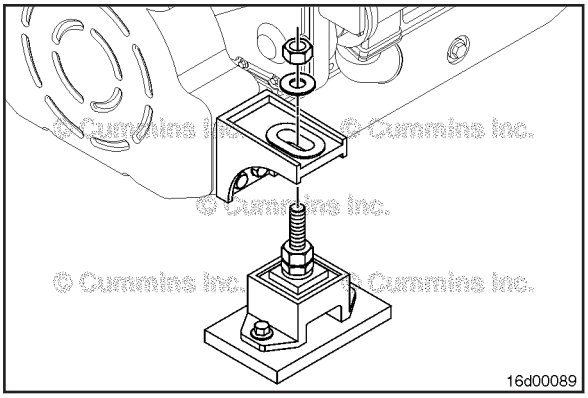


Align the engine in the vessel and tighten the engine mounting capscrews. Refer to the OEM service manual for torque specifications.

See Marine Recreational B and C Installation Directions, Bulletin 3884649.

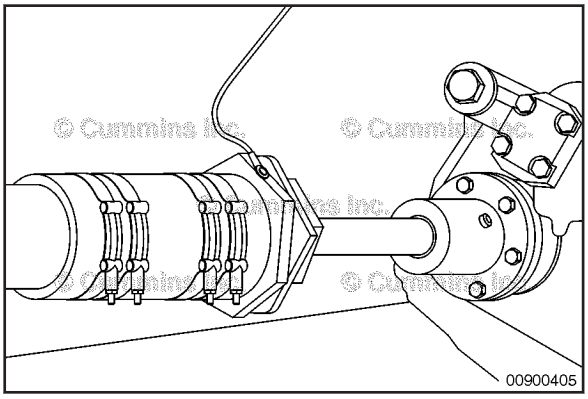
Connect all engine and vessel-mounted components accessories.

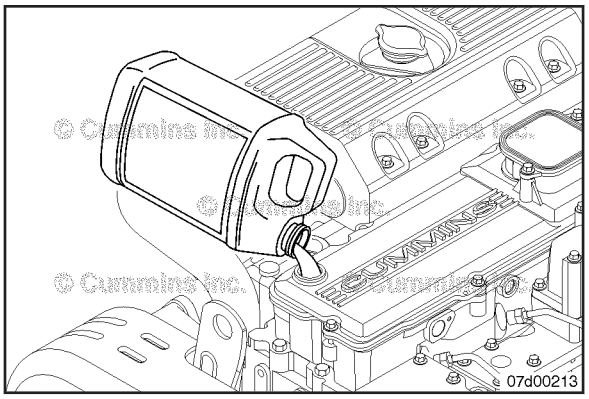
Make sure all sea water lines, fuel lines, hoses, and tubes are properly routed and fastened to prevent damage. Make sure the exhaust pipe connections are tight and free of leaks.



NOTE: The output shaft **must** be aligned when installed. Refer to the equipment manufacturer service information.

Connect the transmission output shaft to the drive coupling. See equipment manufacturer service information.





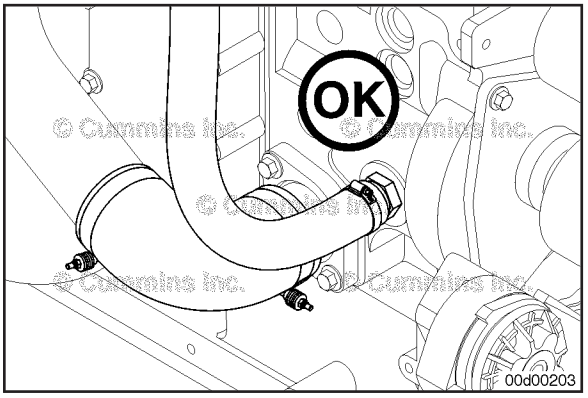
NOTE: If this is a new engine installation, the dipstick will need to be calibrated. Refer to Procedure 007-009 in Section 7.

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 equipment manufacturer service information to determine the capacity of the whole cooling system.

Fill the cooling system with new coolant. Cummins Inc. recommends using Fleetguard® Compleat. It is available in both glycol forms (ethelyne and propylene). Refer to Procedure 008-018 in Section 8.

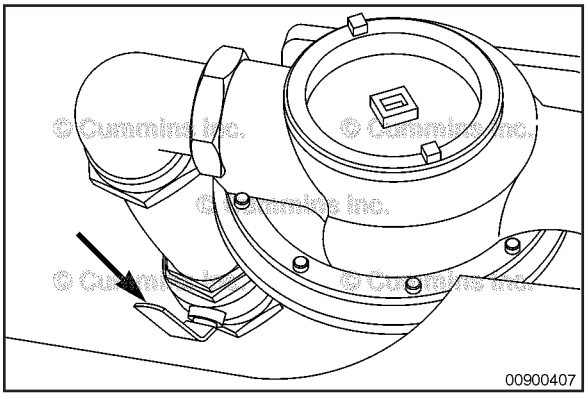
See the engine data sheet to determine the capacity of the whole cooling system.



△CAUTION△
Leave the pressure cap off or loose until air can be purged out of the cooling system. Improper purging of air from the cooling system will result in engine damage from overheating. If the vessel is equipped with a cabin heater, remote heat exchanger units, or if the engine is keel cooled, it will take longer for the trapped air to purge.

Perform a final inspection to make sure all hoses, wires, linkages, and components have been properly installed and tightened.

Make sure all alarms and lights are working prior to starting the engine.

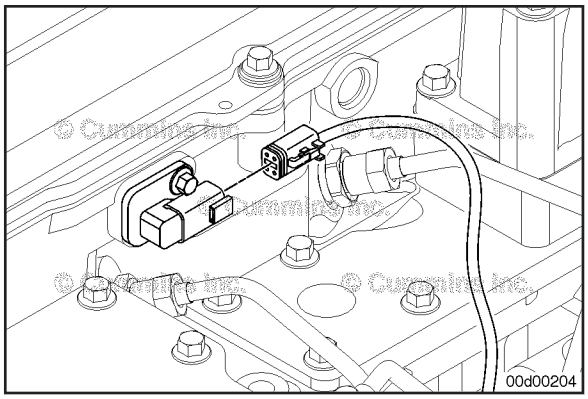


△CAUTION△
To prevent damage to the sea water pump, open the sea water valves before engaging the starting motor. Rotation of the sea water pump impeller with no water can damage the impeller.

If the engine is cooled by a heat exchanger, open the sea water supply lines.

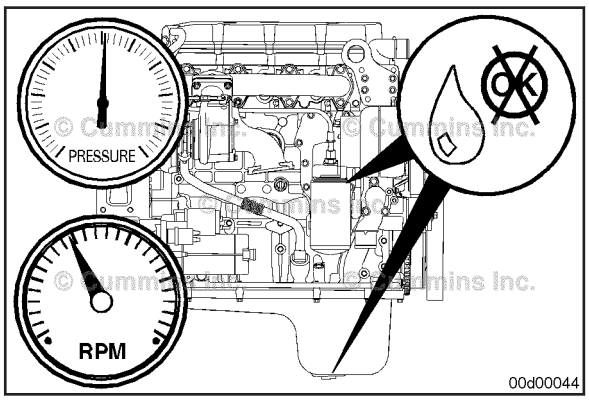
NOTE: This procedure will cause fault codes to be logged in the electronic control module (ECM). These faults will need to be removed prior to placing the engine in service. Reference Section TF of ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416.

Disconnect the engine injector harness connectors at the rocker housing to make sure the engine will **not** start.

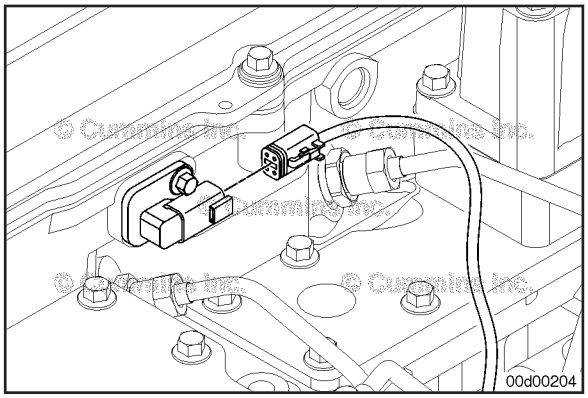


⚠CAUTION⚠
Do not engage the starting motor for more than 30 seconds. To reduce the possibility of engine damage, wait two minutes between starter engagements to cool the starting motor.

Crank the engine until the lubricating oil pressure gauge indicates a positive pressure.

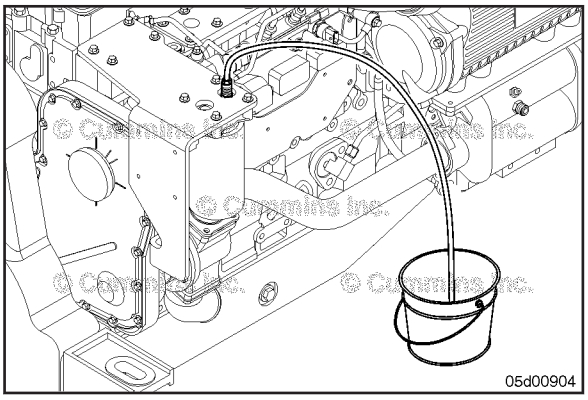


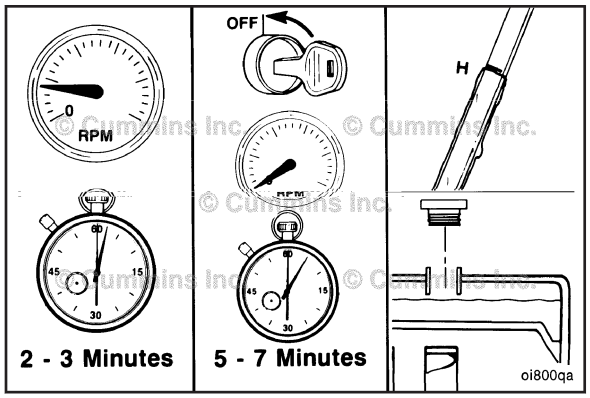
After pressure is observed, connect the engine harness injector connectors at the rocker housing.



⚠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 filter outlet fitting to purge air from the fuel system. Refer to Procedure 005-016 in Section 5.





⚠WARNING⚠

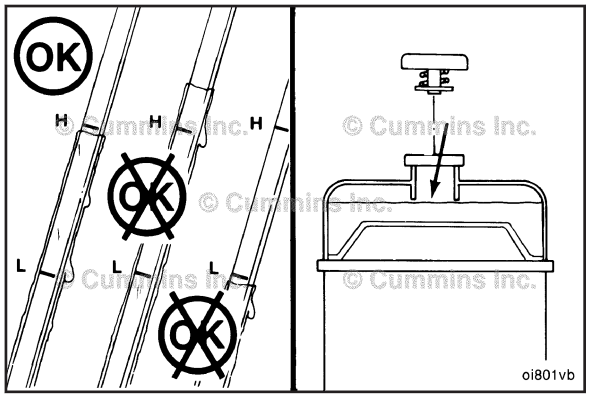
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

Operate the engine and check for sea water flow. Be sure the marine gear is in neutral and the engine can shift in and out of gear.

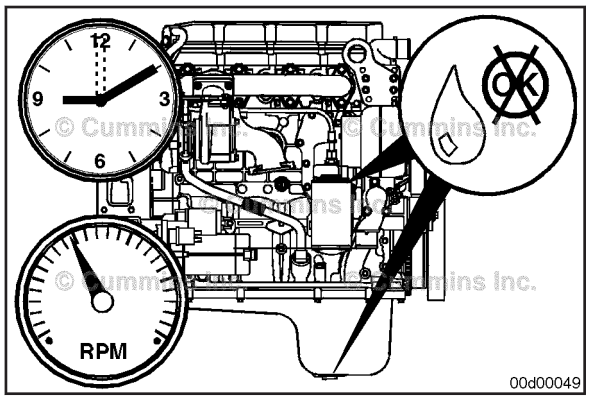
Operate the engine at low idle for two to three minutes.

Shut off the engine and wait five to seven 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.

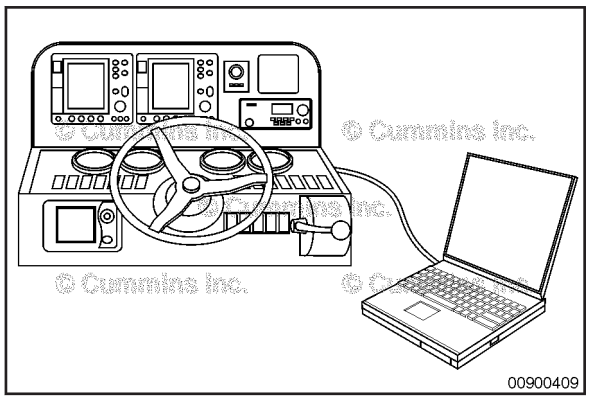


Operate the engine at 1000 to 1200 rpm for eight to ten minutes.

Check for proper operation, unusual noises, and coolant, fuel, or lubricating oil leaks.

Repair all leaks and component problems.

For the Engine Run-In and Test Procedures. Refer to Procedure 014-008 in Section 14.



Use INSITE™ electronic service tool to read and clear any fault codes.

Refer to Section TF of the Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416, to correct any fault codes.

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 component to aid access. Brush or spray preservative oil on all surfaces that are **not** painted and refit the component. Use a rust preservative oil compound that meets military specification, MIL-C-16173C, type P-2, Grade 1 or 2
- Cover all the openings (engine and components) with heavy paper and tape to prevent dirt and moisture from entering the engine. Cover the entire engine with plastic.
- Put a warning tag on the engine. The tag **must** indicate:
- Do **not** operate the engine.
- Do **not** bar the crankshaft.
- The engine has been treated with preservatives.
- The coolant has been removed.
- The date of treatment.
- The date of the 6 week inspection if required.

⚠CAUTION⚠

The engine must be stored in an area that is dry and has uniform temperature.

- Remove any 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 Mounting Bolts (000-008)

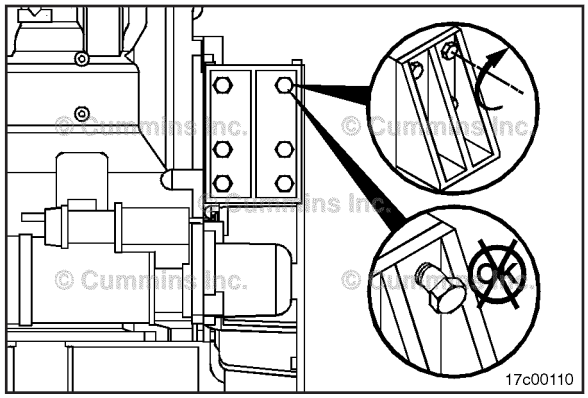
Maintenance Check

⚠CAUTION⚠
Damaged engine mounts and brackets can cause engine misalignment. Driveline component damage can result in vibration complaints.

Inspect all rubber-cushioned mounts for cracks or damage.

Inspect all mounting brackets for cracks or damaged bolt holes.

Check the torque on the engine-mounting nuts and bolts. Tighten any that are loose. Refer to the equipment manufacturer for torque specifications.



Notes

Section 1 - Cylinder Block - Group 01

Section Contents

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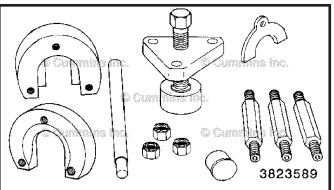
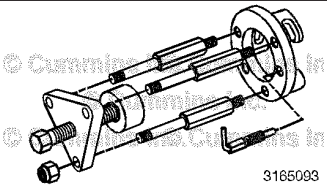
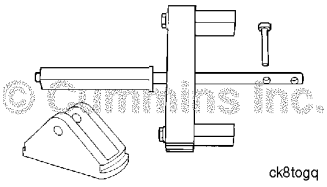
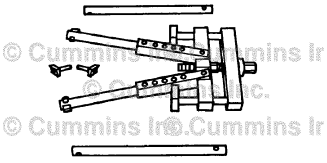
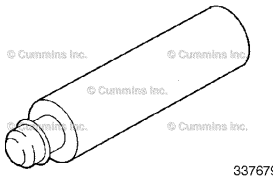
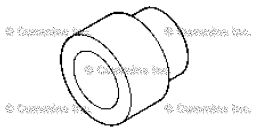
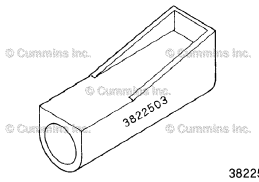
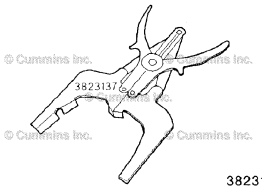
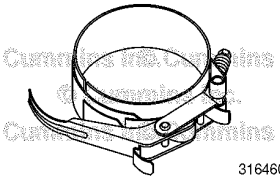
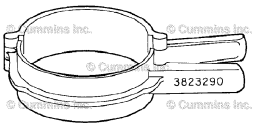
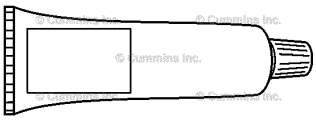
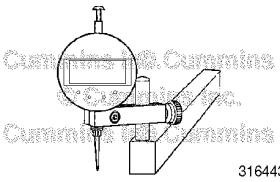
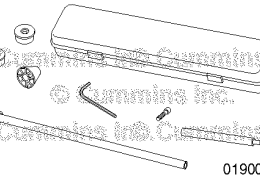
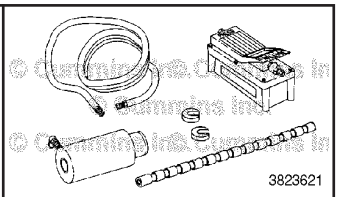
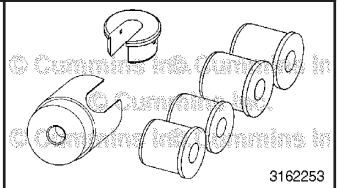
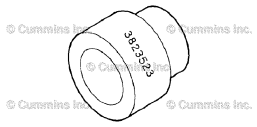
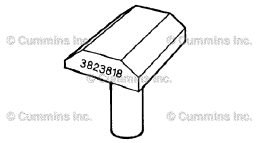
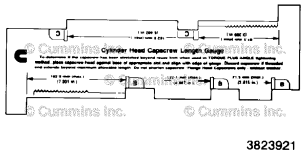
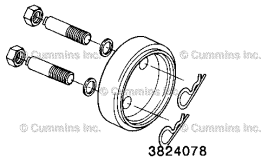
Service Tools

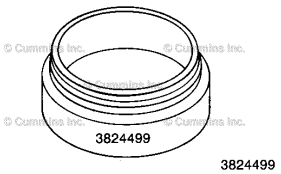
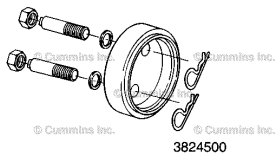
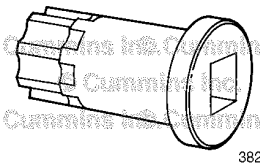
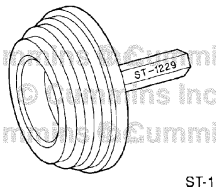
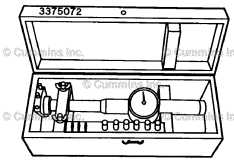
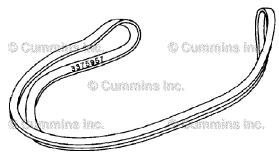
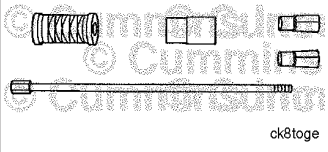
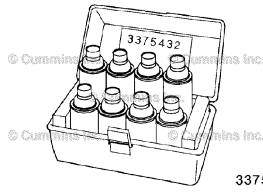
Cylinder Block

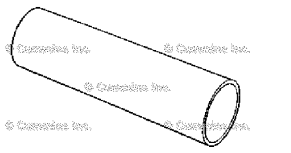
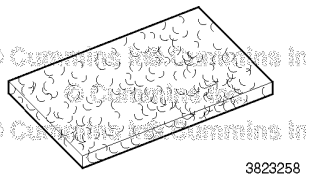
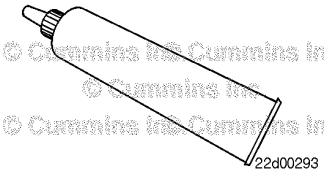
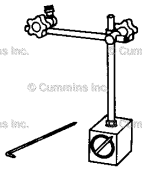
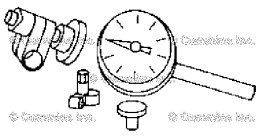
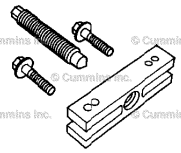
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

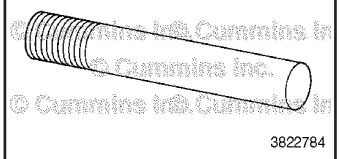
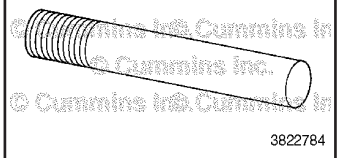
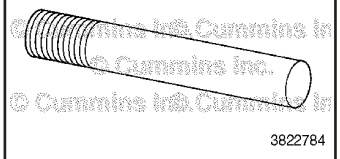
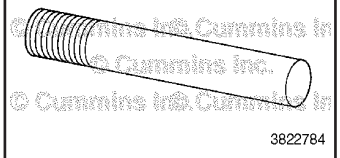
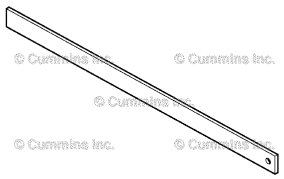
Tool No.	Tool Description	Tool Illustration
3163054	**Camshaft Gear Installation and Removal Tool** Used to remove and install the camshaft gear. Engines without a tapped hole in the camshaft will require partial camshaft removal in order to remove the camshaft gear.	
3165093	**Camshaft Gear Installation and Removal Tool** Used to remove and install the camshaft gear without removing the camshaft. Can **only** be used on engines with a tapped hole in the camshaft. Use with camshaft gear installation and removal tool, Part Number 3163054.	
3375068	**Cup Plug Sealant** Used when installing pipe plugs and cup plugs, to prevent leaks.	
3163745	**Cylinder Liner Puller** Used to remove cylinder liners from the cylinder block. Requires the cylinder liner puller plate, Part Number 3822786.	
3376015	**Cylinder Liner Puller (Universal)** Used to remove cylinder liners from the cylinder block. Requires two puller arm extension feet, Part Number 3376649.	
3164085	**Expansion Plug Driver Handle** Used with all expansion plug drivers larger than 9.525 mm [0.375 in] diameter.	

Tool No.	Tool Description	Tool Illustration
3376816	**Expansion Plug Driver** Used to install 25.4 mm [1.00 in] expansion plug to specified depth. Used with expansion plug driver handle, Part Number 3164085.	 3376816
3822503	**Cylinder Liner Clamp Set** Used to clamp the liner into the bore of the cylinder block. Requires two cylinder head capscrews **not** included in clamp set.	 3822503
3823137	**Piston Ring Expander** Used to install piston rings onto pistons without damaging or distorting the rings.	 3823137
3164604	**Piston Ring Compressor** Used to compress the piston rings while installing the pistons into the cylinder bores.	 3164604
3823290	**Piston Ring Compressor** Used to compress the piston rings while installing the pistons into the cylinder bores.	 3823290
3164067	**RTV Sealant** Used to seal the front gear cover and other joints.	 22d00152
3164438	**Depth Gauge Assembly** Used to measure cylinder liner protrusion, cylinder block counterbore depths, and valve intrusion and or protrusion. Equipped with an electronic digital indicator.	 3164438
3165045	**Camshaft Bushing Tool** Used to remove and install camshaft bushings. NOTE: The following 2 kits are also available for this purpose.	 01900239

Tool No.	Tool Description	Tool Illustration
3823621	**Hydraulic Actuator Kit** Used to remove and install camshaft bushings.	
3162253	**Camshaft Bushing Installation/Removal Kit** Used to remove and install camshaft bushings.	
3823521	**Expansion Plug Driver** Used to install 20.638 mm [0.8125 in] expansion plug to specified depth. Used with expansion plug driver handle, Part Number 3164085.	
3823522	**Expansion Plug Driver** Used to install 30.16 mm [1.1875 in] expansion plug to specified depth. Used with expansion plug driver handle, Part Number 3376795.	
3823523	**Expansion Plug Driver** Used to install 34.925 mm [1.375 in] expansion plug to specified depth. Used with expansion plug driver handle, Part Number 3376795.	
3823818	**Main Bearing Rollout Tool** Used to remove and install main bearings with the crankshaft installed.	
3823921	**Capscrew Length Gauge** Used to measure capscrew free length.	
3824078	**Rear Wear Sleeve Installation Tool** Used to install the rear crankshaft lubricating oil seal wear sleeve.	

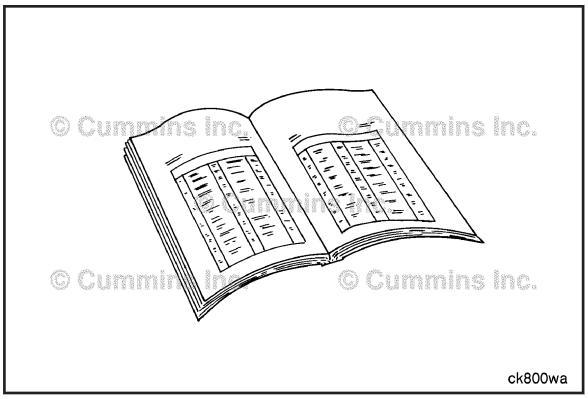
Tool No.	Tool Description	Tool Illustration
3824499	**Lubricating Oil Seal Installation Tool** Used to install the front crankshaft lubricating oil seal in the front cover seal carrier.	
3165112	**Wear Sleeve Installation Tool** Used to install the crankshaft front oil wear sleeves.	
3824591	**Engine Barring Gear** Used to engage the flywheel ring gear to rotate the crankshaft.	
ST-1229	**Cylinder Liner Driver** Used to install cylinder liners into the cylinder block.	
3376619	**Dial Bore Gauge Kit** Used to measure internal diameter bores from 78.5 mm [3.09 in] to 203.2 mm [8.00 in].	
3375957	**Nylon Lifting Sling** Aid in removal and installation of the crankshaft, flywheel, and other heavy components up to 907 kg [2000 lb].	
3163720	**Dowel Pin Extractor Kit** Used to remove solid locating pins from the cylinder block. Kit includes SAE and metric sizes.	
3375432	**Crack Detection Kit** Used to locate cracks in cylinder blocks, cylinder heads; as well as in other engine components.	

Tool No.	Tool Description	Tool Illustration
3824496	**Connecting Rod Guide Pins** Used to prevent damage to the crankshaft during piston installation on engines built with connecting rod studs.	 3824496
3823258	**Abrasive Hand Pad** Used to remove corrosion or carbon buildup.	 3823258
3163087	**Assembly Lubricant** A 10-ounce tube of multi-purpose lubricant.	 22d00293
3822709	**Thread Insert Kit** Used to repair several sizes of cylinder block threads.	 3822709
3377399	**Dial Indicator Magnetic Base** Used in conjunction with dial indicator, Part Number 3824564 (metric), or Part Number 4918289 (SAE).	 3377399
3824564	**Dial Indicator, Metric** Used with indicator base, Part Number 3377399.	 3824564
ST-647	**Standard Puller** Used to remove drive pulleys, impellers, and air compressor counterweights.	 ad8toga
3163934	**Assembly Guide Pin** M12 x 1.75	 3822784

Tool No.	Tool Description	Tool Illustration
3163935	**Assembly Guide Pin** M10 x 1.25	 3822784
3163936	**Assembly Guide Pin** M8 x 1.0	 3822784
3376488	**Assembly Guide Pin** M10 x 1.5	 3822784
3164977	**Assembly Guide Pin** M8 x 1.25	 3822784
4918219	**Precision Straightedge** Used to check cylinder blocks for flatness.	 22d00222

Bearings, Connecting Rod (001-005)

Preparatory Steps



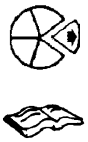
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

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

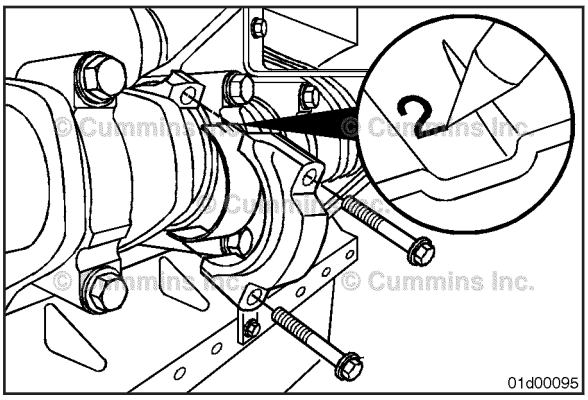
- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Drain the lubricating oil.Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan and gasket.Refer to Procedure 007-025 in Section 7.
- Remove the lubricating oil suction tube.Refer to Procedure 007-035 in Section 7.

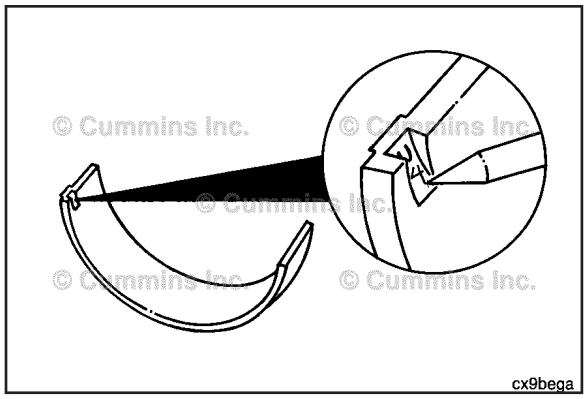
Remove



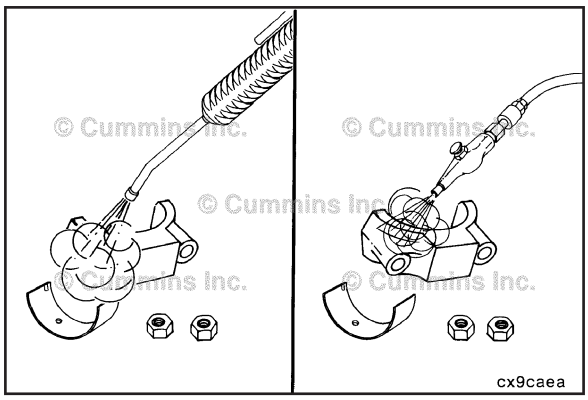
NOTE: The cylinder head does **not** need to be removed if the connecting rod bearings are being inspected or replaced.

Remove the connecting rod caps.Refer to Procedure 001-054 in Section 1.





Remove the upper bearing shell and mark it with the letter "U" (upper) and the cylinder number from where it was removed.



Clean and Inspect for Reuse

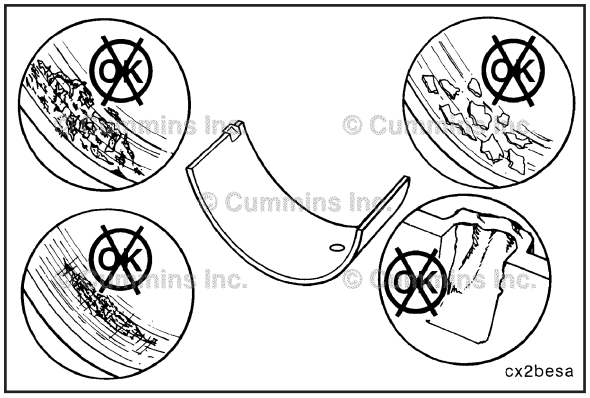
⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Wash the bearing and connecting rod caps.

Dry with compressed air.

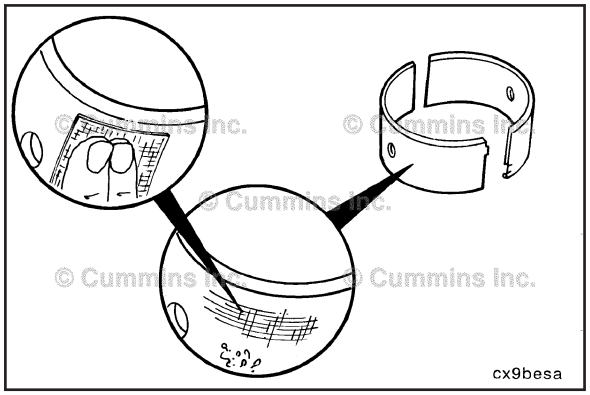
Inspect the connecting rod caps, connecting rod bearing saddles and capscrews for nicks, cracks, burrs, scratches, or fretting.



Inspect the bearings for damage.

Replace any bearings with the following damage:

- Pitting
- Flaking
- Corrosion
- Lock tang damage
- Scratches.



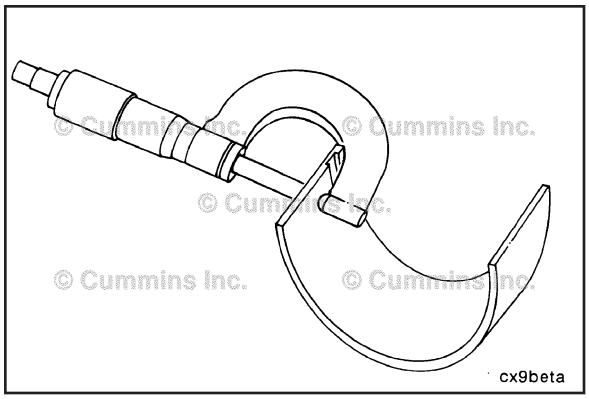
Inspect the bearing shell seating surface for nicks or burrs.

If nicks or burrs can **not** be removed with abrasive pad, Part Number 3823258 or equivalent, the bearings **must** be replaced.

NOTE: If bearings are damaged they **must** be replaced as a set.

NOTE: For more detailed information of bearing damage, see to "Analysis and Prevention of Bearing Failures" Bulletin 3810387.

Measure the rod bearing shell thickness with an outside micrometer that has a ball tip.



Connecting Rod Bearing Dimensions

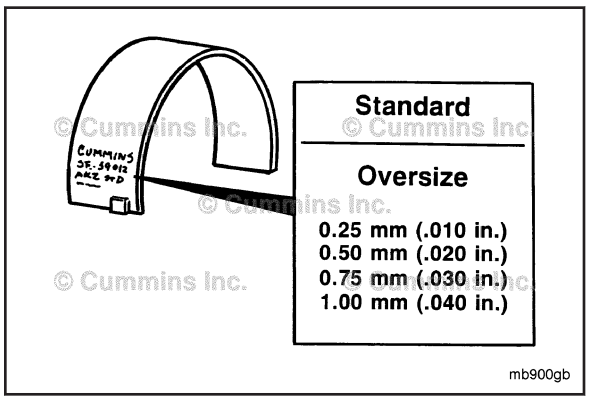
	mm		in
Standard	2.457	MIN	0.0968
	2.469	MAX	0.0972

Discard a bearing shell if its thickness is below the minimum specification.

NOTE: Connecting rod bearings are identified with a part number and size stamped on the back side.

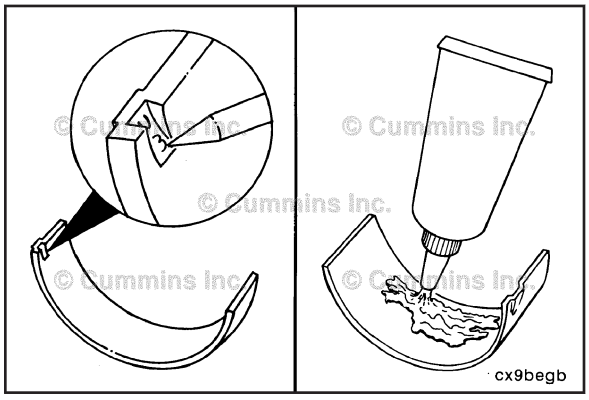
Determine the size of the removed rod bearing and obtain a set of the same size.

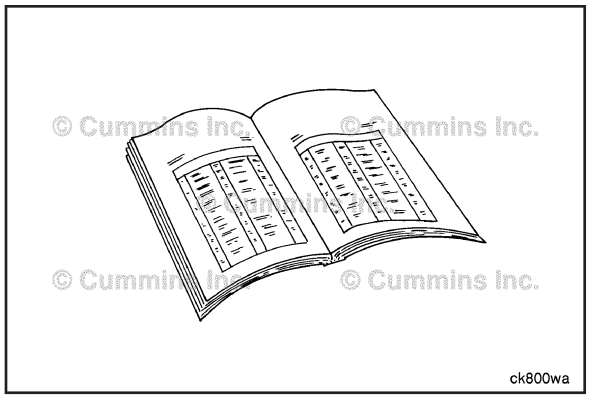
Oversize service rod bearings are available for use with crankshafts that have been machined undersized. See the appropriate parts catalog.



Install

For connecting rod bearing installation instructions use the following. Refer to Procedure 001-054 in Section 1.



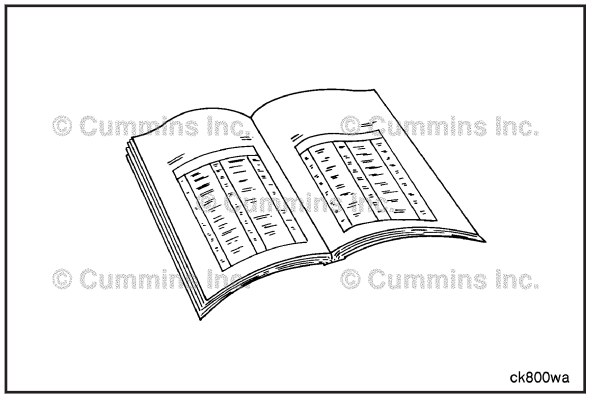


Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7.
- Fill the lubricating oil pan. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.



Bearings, Main (001-006)

Preparatory Steps

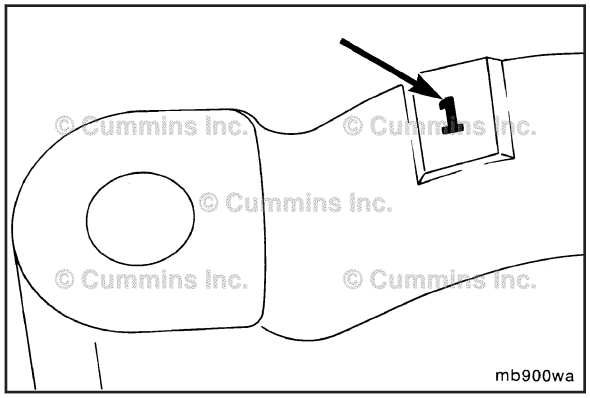
⚠WARNING⚠

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

⚠WARNING⚠

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

- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7.
- Remove the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.

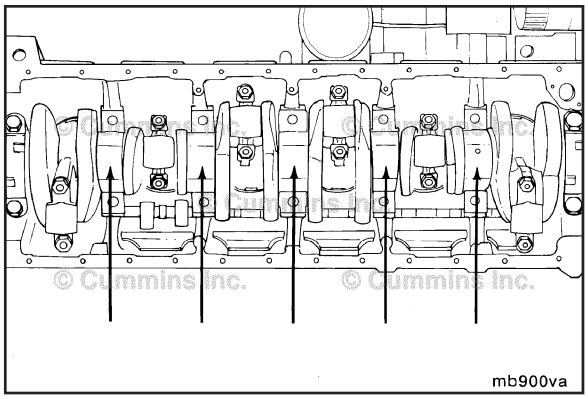


Remove

Before removing the main bearing caps, make certain that the caps are clearly marked for their location on the lubricating oil cooler side of the main bearing cap.

When replacing bearings in chassis, replace number 2 through number 6 while the number 1 and number 7 caps support the crankshaft. After replacing number 2 through number 6, replace number 1 and number 7.

Remove all main bearing caps except the number 1 and number 7 main bearing caps.



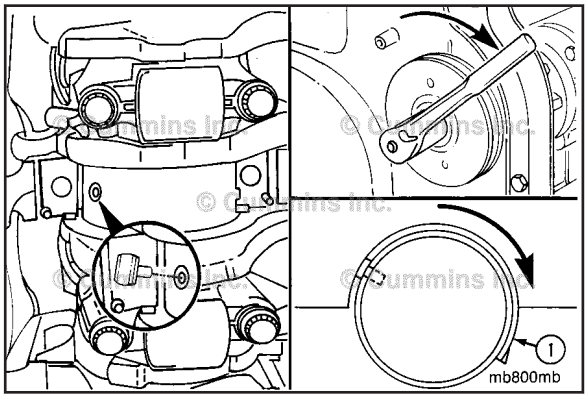
To remove the upper main bearings, install the main bearing replacer, Part Number 3823818, in the oil hole of the crankshaft main bearing journal.

Rotate the crankshaft so that the replacer contacts the upper main bearing on the side opposite the tang.

Continue to rotate the crankshaft in the direction that will remove the tang side (1) of the upper main bearing first.

Remove the bearing.

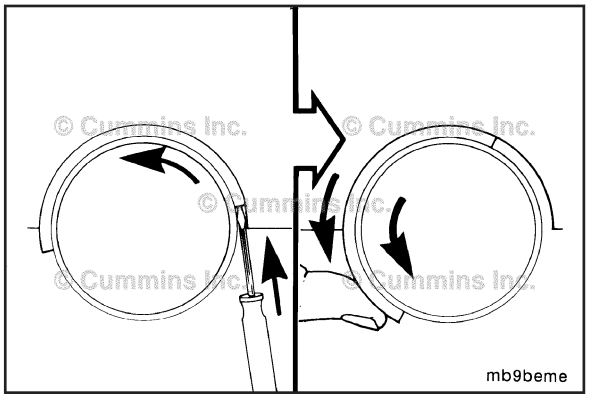
Follow this procedure to remove the other main bearings except for number 1 front main bearing.



CAUTION
Use care so the screwdriver does not damage the crankshaft or cylinder block.

NOTE: The front main bearing, number 1, does **not** have a hole in the journal, so the tool can **not** be used to replace the bearing.

Use a flat blade screwdriver to gently bump the end of the bearing to loosen it from the cylinder block. Then, use finger pressure against the main bearing shell and rotate the crankshaft to roll the main bearing out.



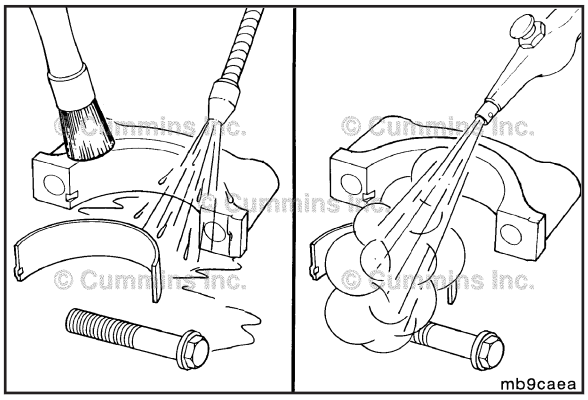
Clean

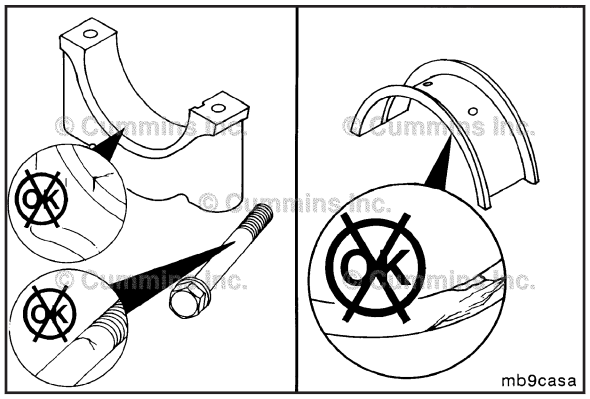
WARNING
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

WARNING
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

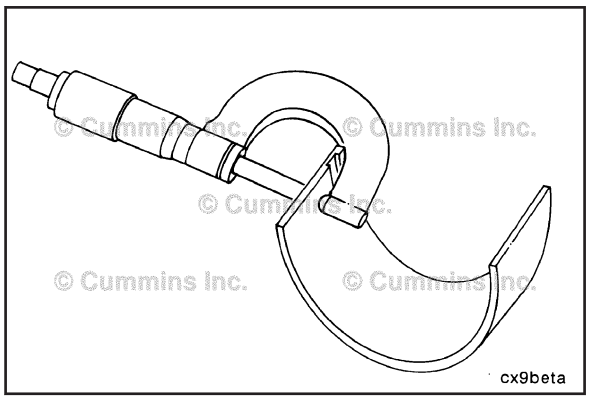
Steam clean the main bearing caps.

Dry with compressed air.





Inspect all main bearing caps and main bearing crankshaft journals for deep scoring, overheating, etc.

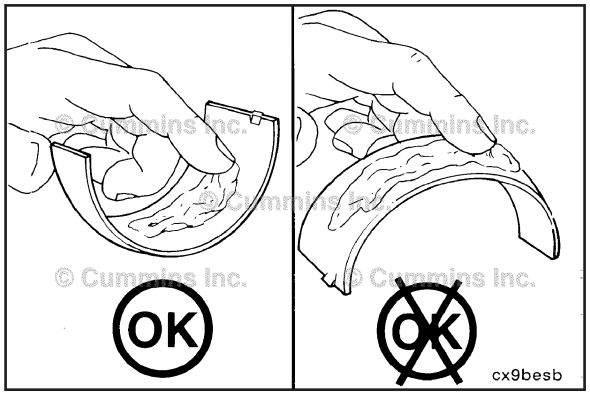


Measure the main bearing shell thickness with an outside micrometer that has a ball tip.

Main Bearing Dimensions

	mm		in
Standard	3.446	MIN	0.1357
	3.454	MAX	0.1360

Discard a bearing shell if its thickness is below the minimum specification.



Install

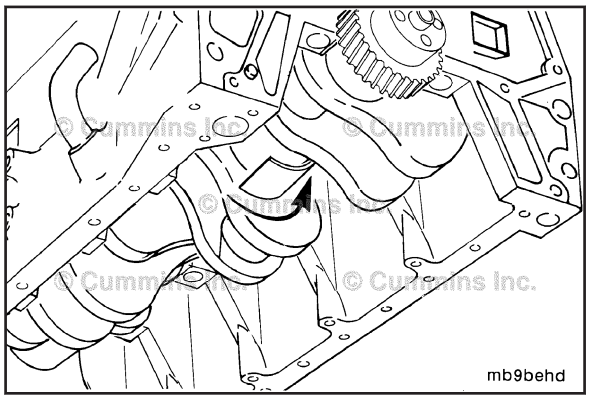
Do **not** lubricate the side that is against the cylinder block.

NOTE: Make sure the main bearing being installed is same size as the main bearing removed. The size is engraved on the back of the main bearing.

Apply a coat of assembly lubricant, Part Number 3163086, or equivalent, to the crankshaft side of the main bearings.

NOTE: The crankshaft thrust bearing **must** be installed in the number four position.

NOTE: The upper and lower main bearing shells of some engines are **not** interchangeable. The backs of the main bearings are marked with the proper orientation, if required.



Insert the side of the main bearing opposite the tang first. Install as far as possible by hand.

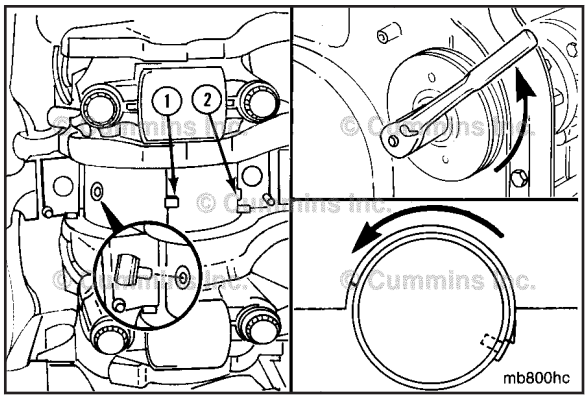
When installing the thrust bearing in the number four journal, it could be necessary to push the crankshaft to the front or rear of the cylinder block.

Make sure the pin does not slide under the bearing.

Using the main bearing replacer, Part Number 3823818, finish installing the main bearing by rotating the crankshaft. Rotate the crankshaft using the barring tool, Part Number 3824591.

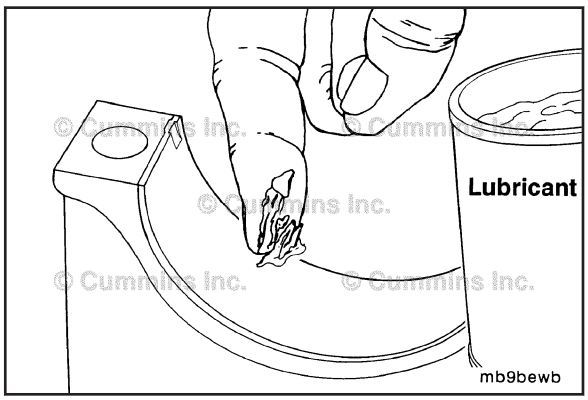
Make sure the tang (1) on the main bearing is located in the notch (2) of the cylinder block.

Finish pushing the main bearing into position.



Install the lower main bearings into the main bearing caps.

Apply a coat of Lubriplate™ 105 multi-purpose lubricant, Part Number 3163086 or equivalent, to the crankshaft side of the main bearings.



NOTE: The main bearing caps are numbered for location. Number 1 starts with the front of the block. Install the cap so that numbers face the intake side of the engine.

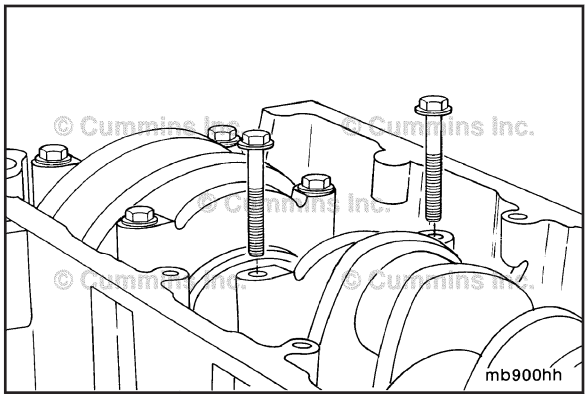
Install a main bearing cap after each upper main bearing is installed to keep the main bearing in place while the other uppers are installed.

Lubricate the main bearing capscrew under the cap and lubricate the main bearing capscrew threads using clean 15W-40 engine oil.

Tighten capscrews.

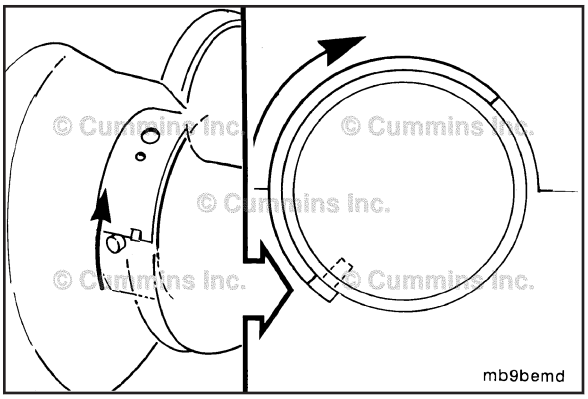
Torque Value: 50 N•m [37 ft-lb]

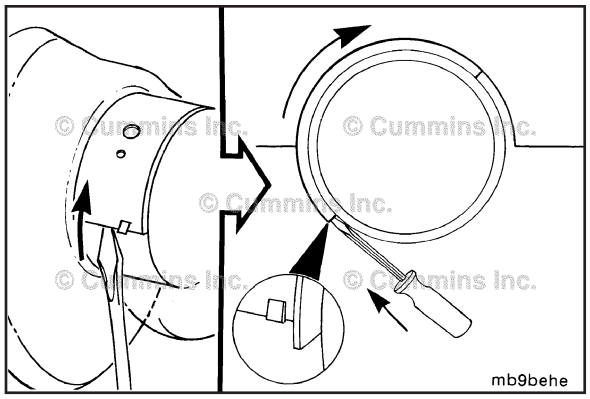
Do **not** tighten to the final torque value at this time.



Repeat this procedure to install the remaining bearing and caps with the exception of main bearing number 1.

The thrust bearing **must** be installed in the number 4 journal.



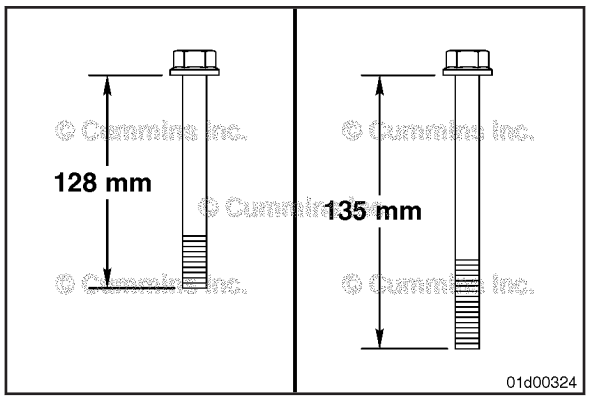


NOTE: The front main, number 1, does **not** have a hole in the journal so the pin can **not** be used to replace the bearing.

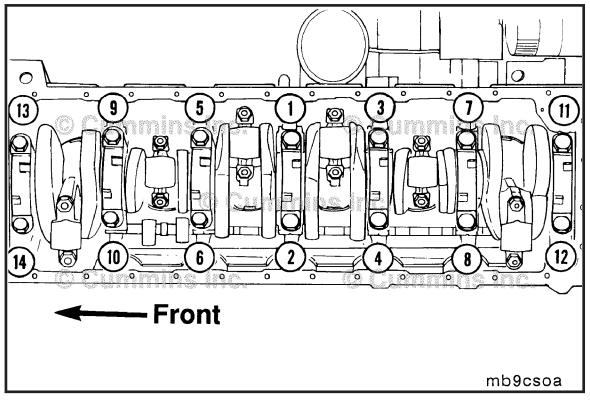
Lubricate and install the number 1 main bearing.

Insert the side of the main bearing opposite the tang first. Install as far as possible by hand.

Use the screwdriver to push the main bearing into position as you rotate the crankshaft.



⚠CAUTION⚠
Some engines use 128 mm [5 in] long main bearing cap capscrews. Others use 135 mm [5.3 in] long main bearing cap capscrews. Failure to use the correct torque value for either size capscrew can result in engine damage.



The crankshaft must rotate freely.

Tighten the main bearing capscrews evenly and in sequence.

Torque Value:
128 mm [5 in] Capscrew

Step 1	50 N•m	[37 ft-lb]
Step 2	95 N•m	[70 ft-lb]
Step 3	Rotate 60 degrees	

Torque Value:
135 mm [5.3 in] Capscrew

Step 1	170 N•m	[125 ft-lb]
Step 2	Loosen all capscrews	
Step 3	50 N•m	[37 ft-lb]
Step 4	Rotate 120 degrees	

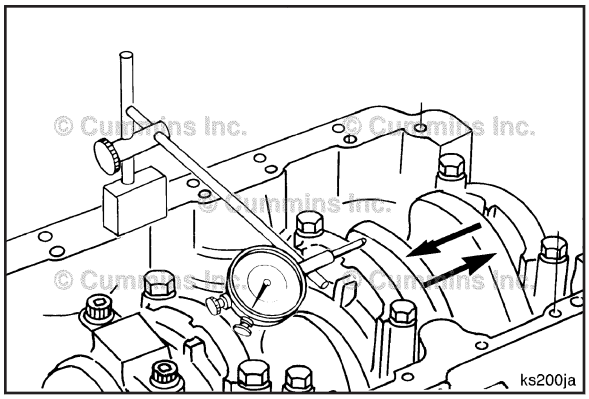
Check the main bearing installation and the size of the main bearings if the crankshaft does **not** rotate freely.

The dimensions of the thrust bearing and crankshaft journal determine end play.

Measure the crankshaft end play using dial indicator, Part Number 3824564 and magnetic base, Part Number 3377399.

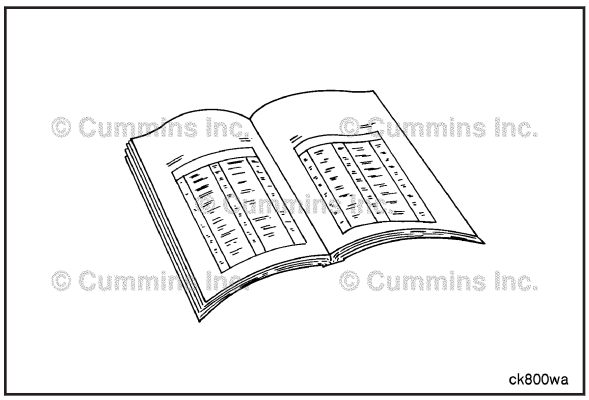
Crankshaft End Play Limits

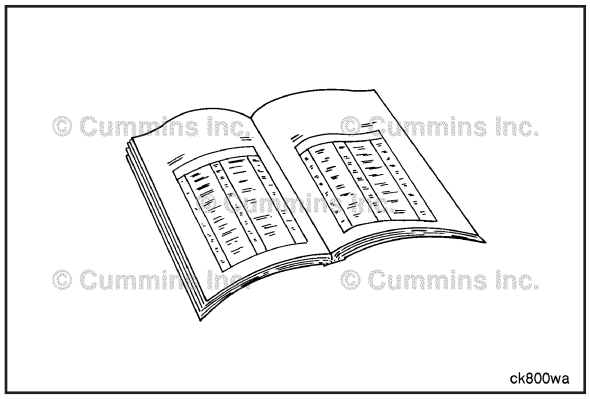
mm		in
0.085	MIN	0.003
0.385	MAX	0.015



Finishing Steps

- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7..
- Fill the lubricating oil pan. Refer to Procedure 007-037 in Section 7.
- Operate the engine and check for leaks.





Camshaft (001-008)

Preparatory Steps

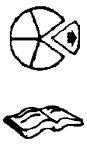
All Applications Except Marine

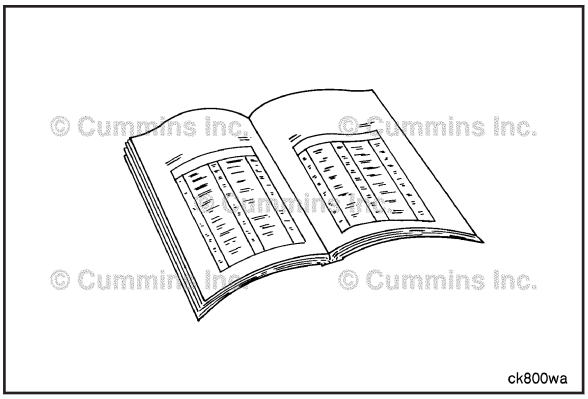
⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the engine brakes, if equipped. Refer to Procedure 020-004 in Section 20.
- Remove the rocker lever housing, if equipped. Refer to Procedure 003-013 in Section 3.
- Remove the rocker levers. Refer to Procedure 003-008 in Section 3.
- Remove the push rods. Refer to Procedure 004-014 in Section 4.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the fan hub, if required. Refer to Procedure 008-039 in Section 8.
- Remove the vibration damper. Refer to Procedure 001-052 in Section 1.
- Remove the gear cover. Refer to Procedure 001-031 in Section 1.
- Raise the tappets. Refer to Procedure 004-015 in Section 4.

Marine Applications





⚠WARNING⚠

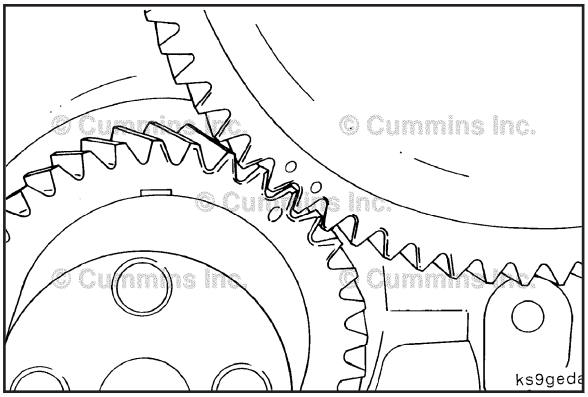
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

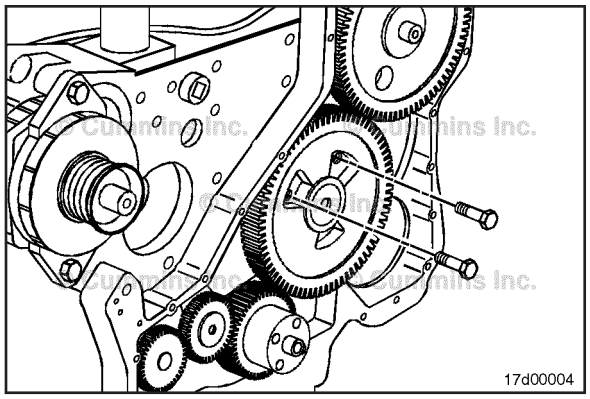
NOTE: Prior to starting this procedure, make sure that there is adequate clearance in front of the engine. Make sure there is plenty of clearance from the front gear housing face to any obstruction in the camshaft area to remove the camshaft. If **not**, the engine **must** be removed from the vessel.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the belt guard. Refer to Procedure 008-001 in Section 8.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the water pump drive belt tensioner. Refer to Procedure 008-080 in Section 8.
- Loosen the fuel filter bracket and move it out of the way. Refer to Procedure 006-018 in Section 6.
- Remove the vibration damper. Refer to Procedure 001-052 in Section 1.
- Remove the gear cover. Refer to Procedure 001-031 in Section 1.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- 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

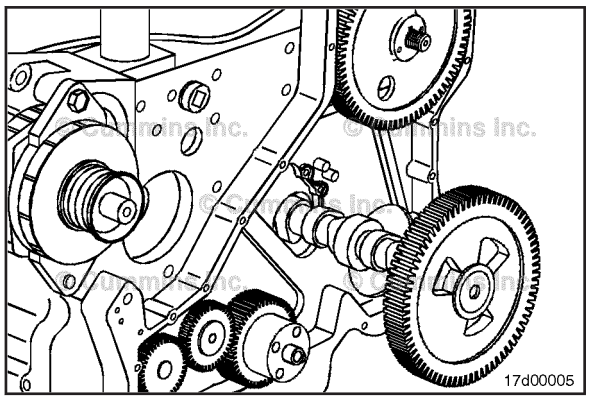
Rotate the crankshaft to align the crankshaft to camshaft timing marks.





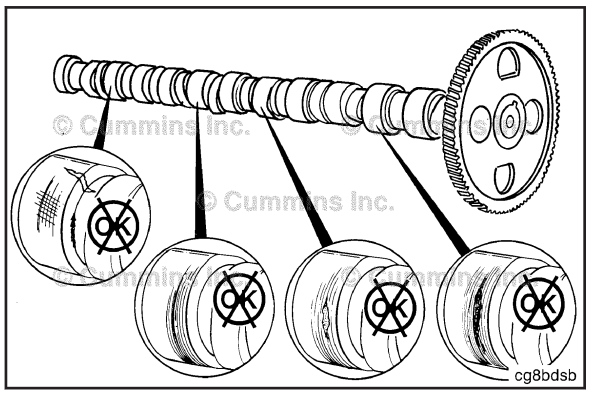
NOTE: Because the thrust plate extends more than 180 degrees around the camshaft, the thrust plate can **only** be removed from the camshaft after removing the cam gear from the camshaft.

Remove the capscrews from the thrust plate.



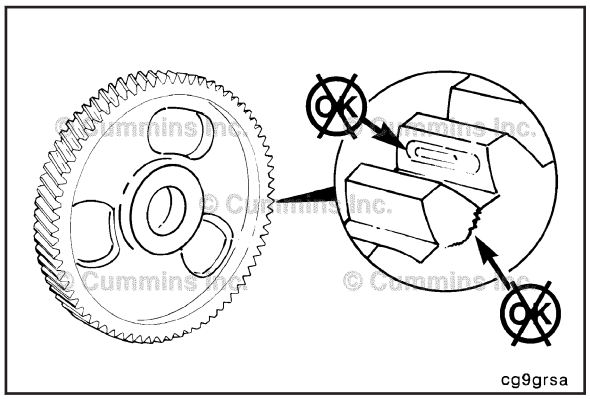
Remove the camshaft and thrust plate together.

NOTE: Rotate the camshaft as it is being removed. Use extreme care to make sure the camshaft bushings are not damaged during the camshaft removal process.



Clean and Inspect for Reuse

Inspect the valve lobes and bearing journals for cracking, pitting, and scoring.

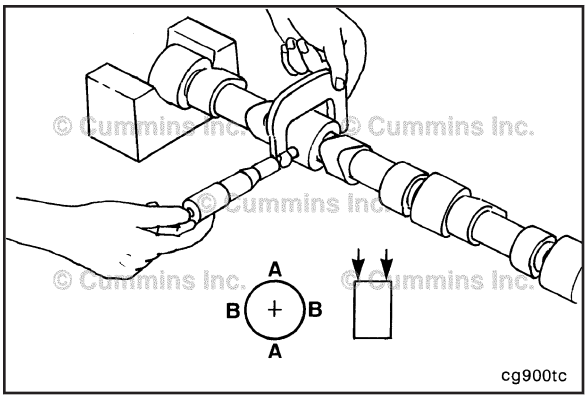


Inspect the camshaft gear teeth for pitting. Look for cracks at the roots of the teeth.

NOTE: Replace the camshaft if the outside diameter of any bearing surface is less than 59.962 mm [2.3607 in].

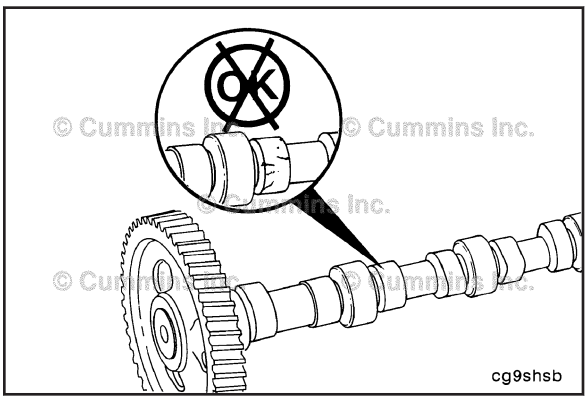
Measure the bearing journals.

Camshaft Bearing Journal Diameter		
mm		in
59.962	MIN	2.3607
60.013	MAX	2.3627



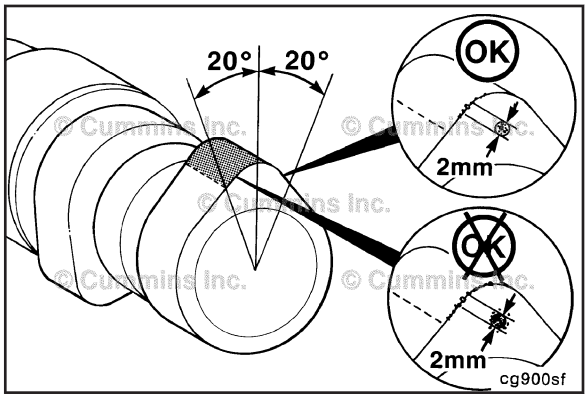
Pitting Reuse Criteria

Refer to Camshaft Reuse Guidelines for Cummins® Engines with Roller Followers or Roller Tappets, Bulletin3666052 for reuse guidelines for roller tappet and steel camshafts.



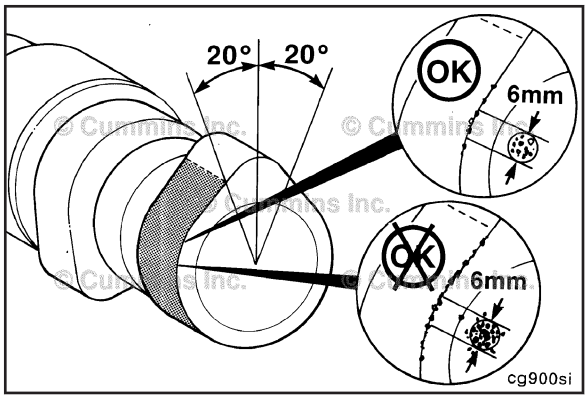
Edge Deterioration (Breakdown) Criteria

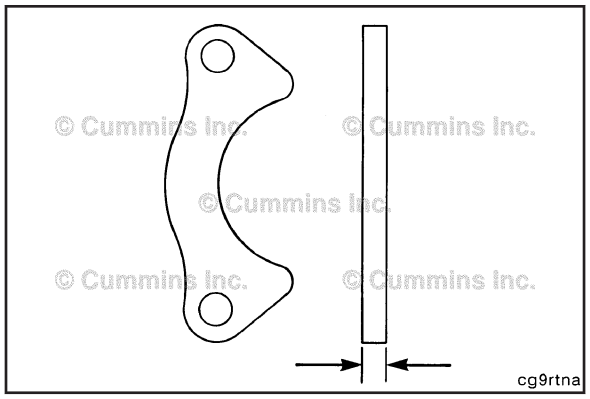
The area of edge deterioration **must not** be greater than the equivalent area of a 2 mm [0.079 in] circle within ± 20 degrees of the nose of the cam lobe.



Outside of the ± 20 degrees of the nose of the cam 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 on an engine that uses slider tappets, new tappets and push tubes also **must** be installed. If a new camshaft is installed on an engine that uses roller tappets, **only** the damaged roller tappets **must** be replaced.

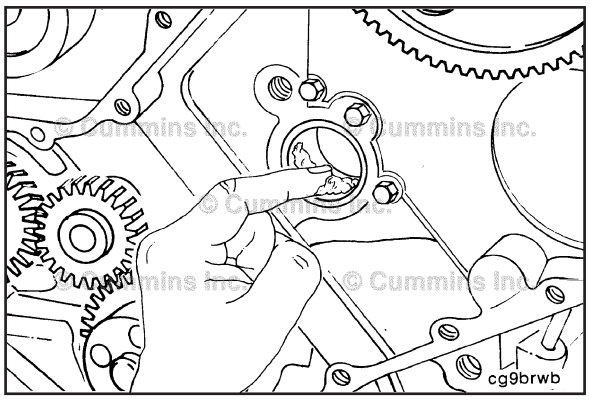




NOTE: It is necessary to remove the camshaft gear to measure the thrust plate thickness. Refer to Procedure 001-013 in Section 1.

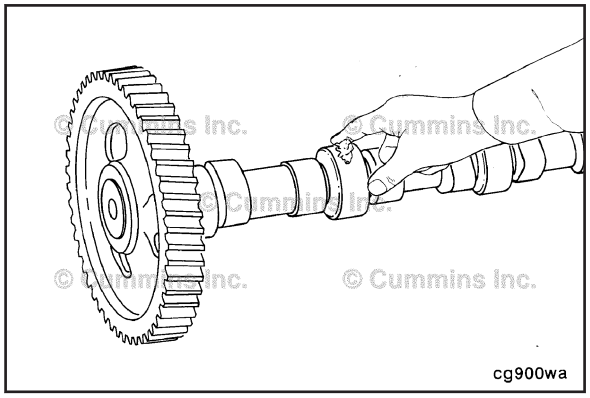
Measure camshaft thrust plate thickness.

Camshaft Thrust Plate		
mm		in
9.40	MIN	0.370
9.60	MAX	0.378

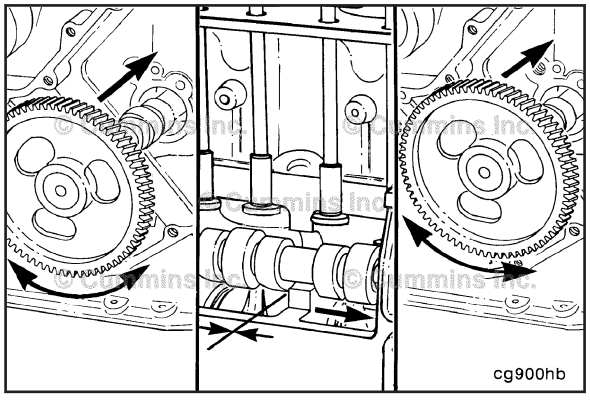


Install

Apply a coat of assembly lubricant, Part Number 3163087, or equivalent, to the front camshaft bore.



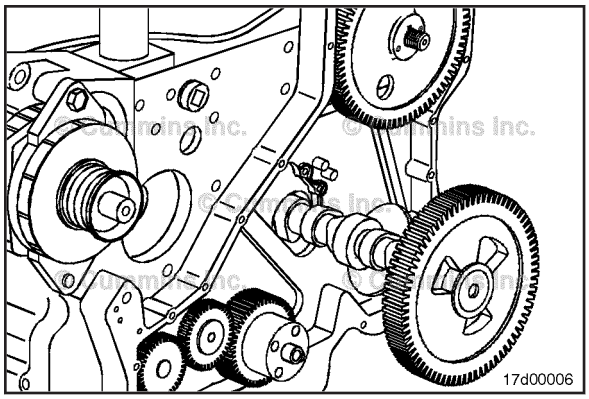
Lubricate the camshaft lobes, journals and thrust plate with assembly lubricant, Part Number 3163087, or equivalent.



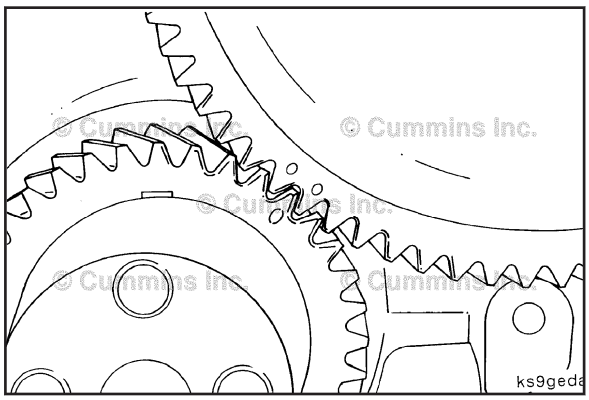
CAUTION
Do not try to force the camshaft into the camshaft bore as damage to the camshaft bushing can result.

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

Before the camshaft gear engages the crankshaft gear, check the camshaft for ease of rotation. When installed properly, the camshaft **must** rotate freely.

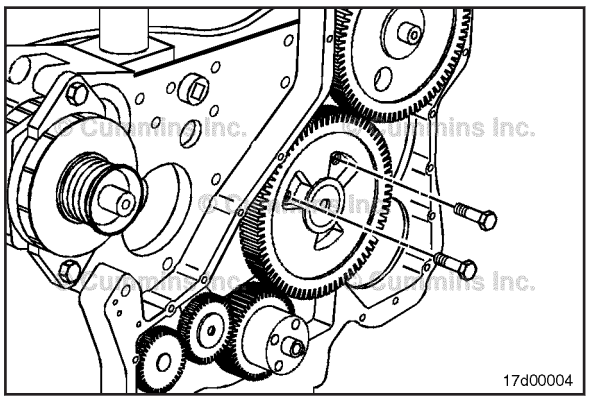


Align the timing marks as illustrated and finish installing the camshaft.



Install the thrust plate capscrews.

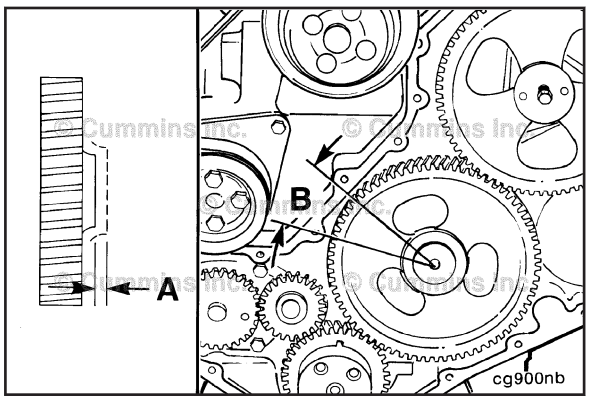
Torque Value: 24 N•m [212 in-lb]

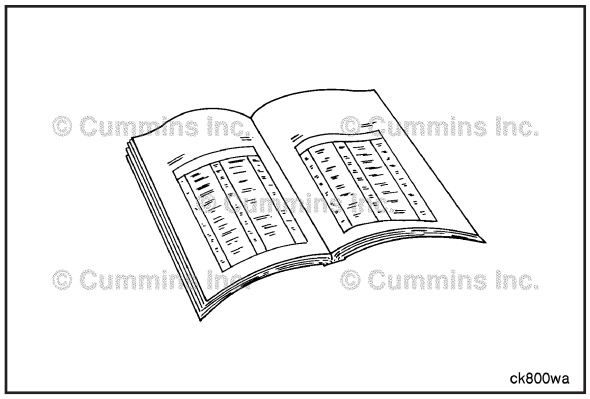


Use gauge, Part Number 3824564, and magnetic base, Part Number 3377399, to verify that the camshaft has proper end play and backlash.

Camshaft End Play (A)		
mm		in
0.12	MIN	0.005
0.50	MAX	0.020

Camshaft Gear Backlash Limits (B)		
mm		in
0.08	MIN	0.003
0.33	MAX	0.013





Finishing Steps

All Applications Except Marine

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

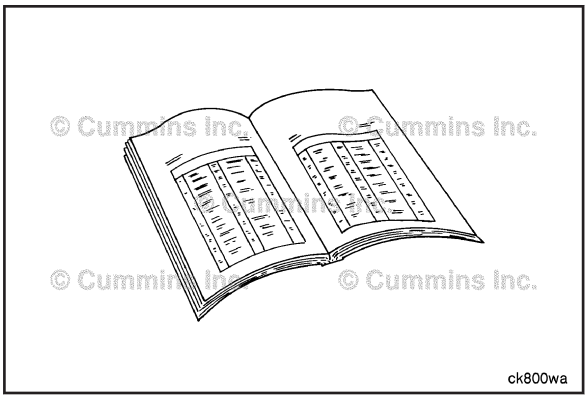
- Install the gear cover. Refer to Procedure 001-031 in Section 1.
- Install the vibration damper. Refer to Procedure 001-051 in Section 1.
- Install the fan hub, if required. Refer to Procedure 008-039 in Section 8.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Release the tappets. Refer to Procedure 004-015 in Section 4.
- Install the push rods. Refer to Procedure 004-014 in Section 4.
- Install the rocker levers. Refer to Procedure 003-008 in Section 3.
- Install the rocker lever housing, if equipped. Refer to Procedure 003-013 in Section 3.
- Adjust the valve lash. Refer to Procedure 003-004 in Section 3.
- Install the engine brakes, if equipped. Refer to Procedure 020-004 in Section 20.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine at idle for 5 to 10 minutes and check for leaks and loose parts.

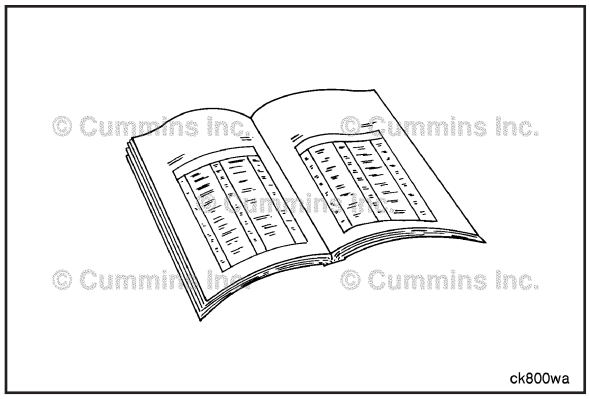
Marine Applications

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the gear cover. Refer to Procedure 001-031 in Section 1.
- Install the automatic belt tensioner. Refer to Procedure 008-080 in Section 8.
- Install the vibration damper, if installed. Refer to Procedure 001-052 in Section 1.
- Install the fuel filter head bracket. Refer to Procedure 006-018 in Section 6.
- Install the water pump drive belt. Refer to Procedure 008-002 in Section 8.
- Install the belt guards. Refer to Procedure 008-001 in Section 8.
- Release the tappets. Refer to Procedure 004-015 in Section 4.
- Install the push rods. Refer to Procedure 004-014 in Section 4.
- Install the rocker levers. Refer to Procedure 003-008 in Section 3.
- Adjust the valve lash. Refer to Procedure 003-004 in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Connect the battery. Refer to Procedure 013-009 in Section 13.
- Operate the engine at idle for 5 to 10 minutes and check for leaks and loose parts.



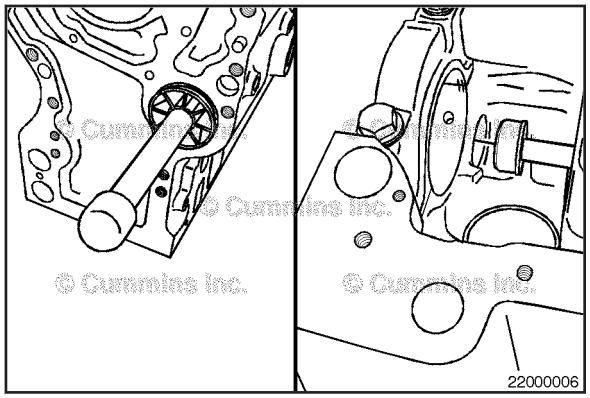


Camshaft Bushings (001-010)

Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the starting motor. Refer to Procedure 013-020 in Section 13.
- Remove the flexplate, if installed. Refer to Procedure 016-004 in Section 16.
- Remove the flywheel, if installed. Refer to Procedure 016-005 in Section 16.
- Remove the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Remove the camshaft. Refer to Procedure 001-008 in Section 1.
- Remove the rear camshaft cup plug. Refer to Procedure 017-002 in Section 17.



Remove

Remove the camshaft bushings. Use the camshaft bushing replacer kit, Part Number 3165045.

The following kits are also available for camshaft bushing installation and removal:

- Hydraulic Actuator Kit, Part Number 3823621
- Camshaft Bushing Kit, Part Number 3162253

Slide the drive bar through the centering guide and insert the drive bar from the rear of the cylinder block through the camshaft bores.

Insert the camshaft bushing replacer and drive the front camshaft bushing from the cylinder block.

Remove the replacer and drive bar from the cylinder block.

Insert the drive bar, camshaft bushing replacer, and centering guide from the front of the cylinder block.

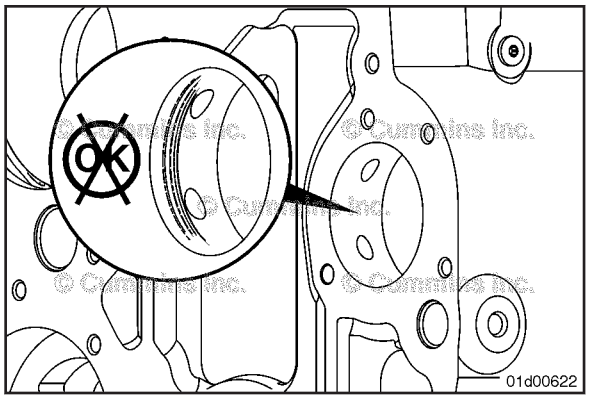
Drive the remaining camshaft bushings from the cylinder block in succession, starting with the number two camshaft bushing.

Remove the drive bar, replacer, and guide from the front of the cylinder block.

Clean and Inspect for Reuse

Inspect the camshaft bore for damage and excessive wear. Refer to Procedure 001-026 in Section 1.

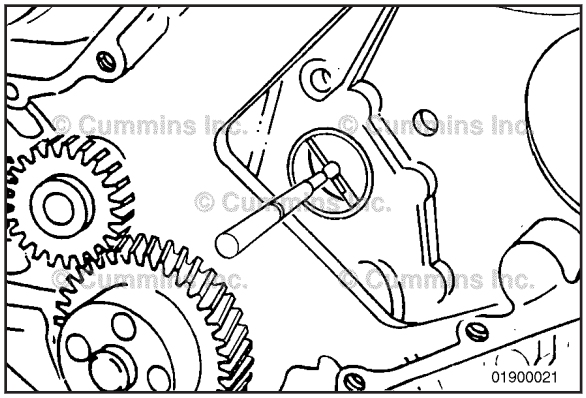
Inspect the camshaft bore for damage and excessive wear. Refer to Procedure 001-026 in Section 1.



Measure the camshaft bore.

Camshaft Bore Diameter (Maximum)

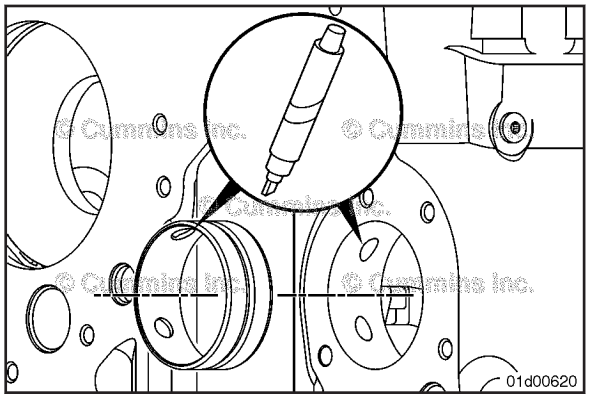
	mm		in
Without bushing	64.013	MAX	2.5202
With bushing	60.120	MAX	2.3669



Install

Mark the oil holes on the camshaft bushing and cylinder block with a felt tip pen. This aids proper alignment of the bushing and bore during installation.

NOTE: The top hole on the front and rear camshaft bushings will **not** line up with the top hole of the cylinder block bores. **Only** the bottom hole will line up for the front and rear camshaft bushings.

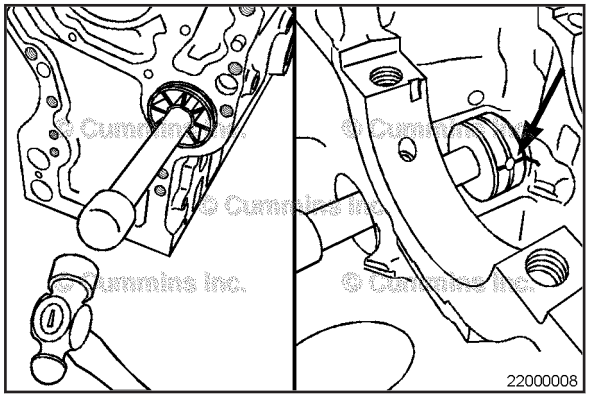


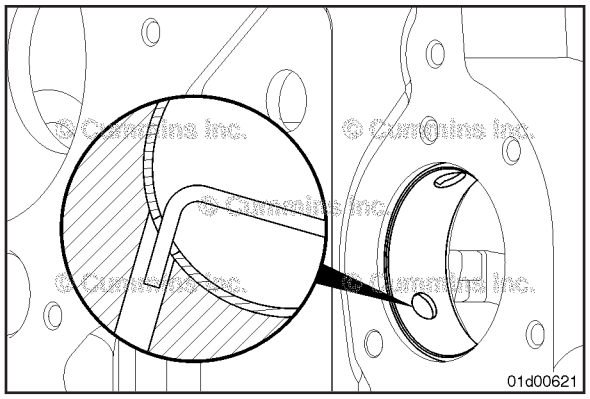
Slide the camshaft bushing on the replacer. Position the notch on the edge of the bushing to the top rear of the block and align the marks on the camshaft bushing and the cylinder block.

Drive the front camshaft bushing to the correct installed depth. The correct installed depth is when the camshaft bushing oil hole aligns with the cylinder block oil hole.

Install the remaining camshaft bushings in succession, starting at the rear of the cylinder block and working toward the front. Remove the drive bar, replacer, and guide from the cylinder block.

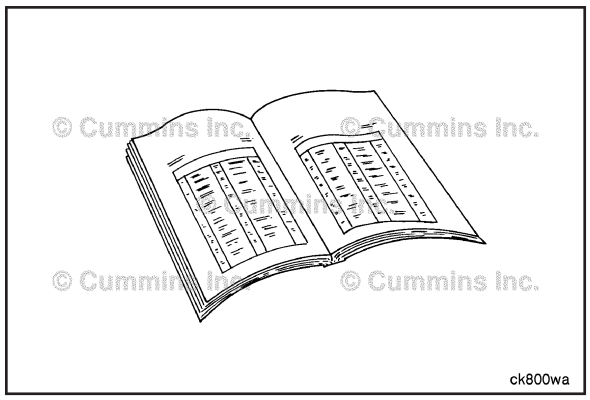
Remove the drive bar, replacer, and guide from the cylinder block.





Make sure the lubricating oil holes in the camshaft bushing are aligned with the oil holes in the camshaft bore. For the front and rear camshaft bushings **only** the bottom hole will line up with the hole in the cylinder block.

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



Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the rear camshaft cup plug. Refer to Procedure 017-002 in Section 17.
- Install the camshaft. Refer to Procedure 001-008 in Section 1.
- Install the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Install the flexplate, if installed. Refer to Procedure 016-004 in Section 16, if installed.
- Install the flywheel, if installed.Refer to Procedure 016-005 in Section 16.
- Install the starting motor. Refer to Procedure 013-020 in Section 13.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

Camshaft Gear (Camshaft Installed) (001-012)

General Information

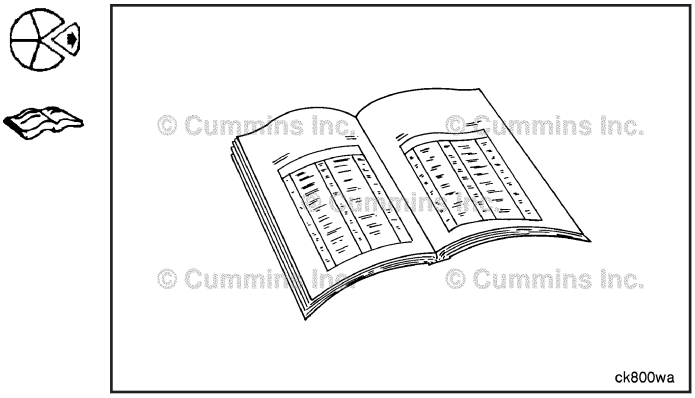
This procedure applies to engines with high-pressure common rail fuel system **only**.

Preparatory Steps

All Applications Except Marine

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the fan hub, if required. Refer to Procedure 008-039 in Section 8.
- Remove the vibration damper. Refer to Procedure 001-052 in Section 1.
- Remove the gear cover. Refer to Procedure 001-031 in Section 1.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Loosen the rocker lever assemblies. Refer to Procedure 003-008 in Section 3.

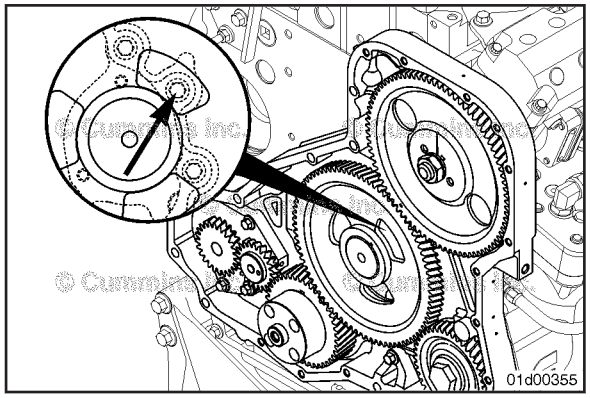


Marine Applications

⚠WARNING⚠

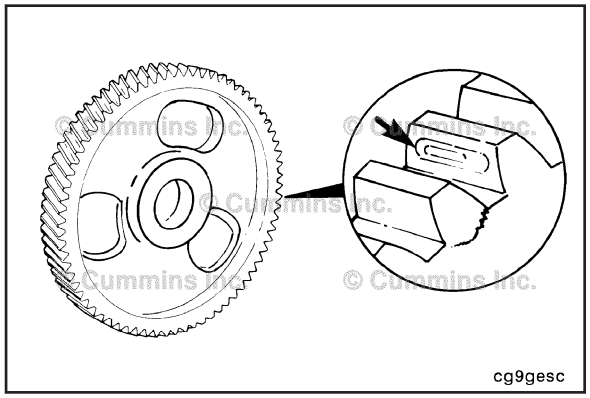
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to Procedure 013-009.
- Remove the belt guard. Refer to Procedure 008-001 in Section 8.
- Remove the water pump drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the water pump drive belt tensioner. Refer to Procedure 008-020 in Section 8.
- Loosen the fuel filter bracket and move it out of the way. Refer to Procedure 006-018 in Section 6.
- Remove the vibration damper. Refer to Procedure 001-052 in Section 1.
- Remove the front gear cover. Refer to Procedure 001-031 in Section 1.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Loosen the rocker lever assemblies. Refer to Procedure 003-008 in Section 3.



Remove

Use cam gear removal and installation tool, Part Number 3163054, and puller assembly, Part Number 3165093, to remove the camshaft gear from the camshaft.



Clean and Inspect for Reuse

Inspect the camshaft gear for cracked, chipped, or broken teeth.

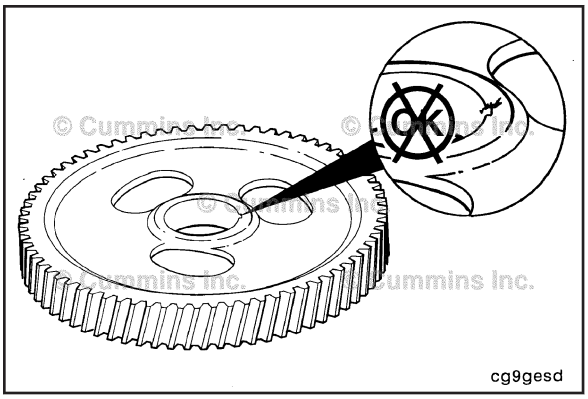
Inspect the camshaft bore for fretting or burrs.

NOTE: If the fretting, burrs, or raised material can **not** be removed with abrasive pad, Part Number 3823258 or equivalent, replace the camshaft gear.

Inspect the camshaft gear keyway for burrs.

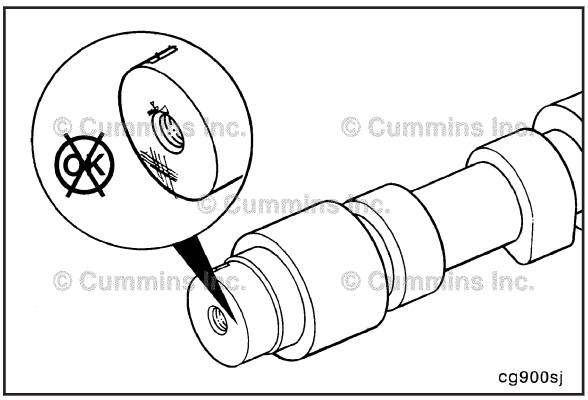
Remove burrs with abrasive pad, Part Number 3823258 or equivalent.

NOTE: If the keyway is damaged or the burrs can **not** be removed, the camshaft gear **must** be replaced.



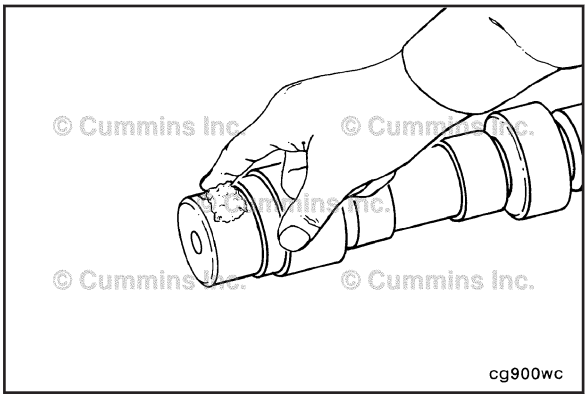
Inspect the camshaft nose for fretting or burrs.

NOTE: If fretting or burrs can **not** be removed with abrasive pad, Part Number 3823258 or equivalent, replace the camshaft. Refer to Procedure 001-008 in Section 1.



Install

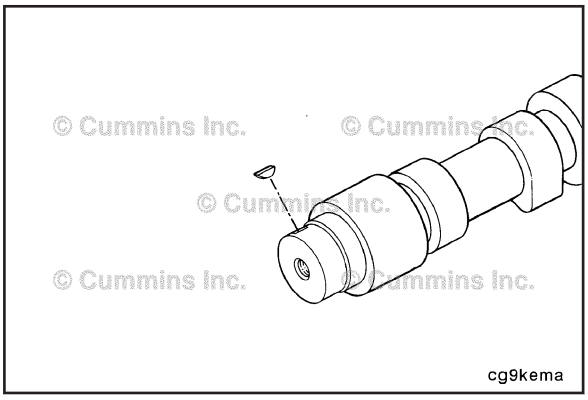
Lubricate the camshaft surface with assembly lubricant, Part Number 3163087, or equivalent.

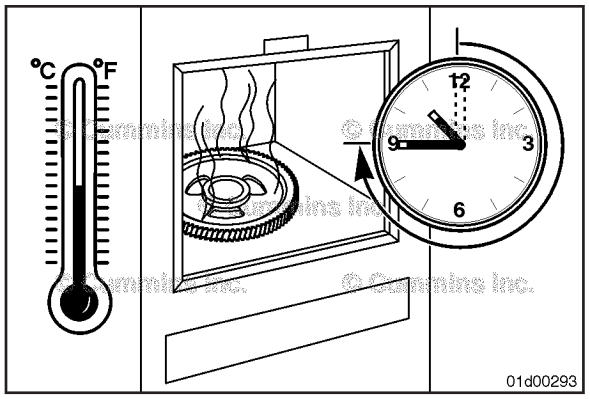


Install the key into the camshaft nose.

Tighten the thrust plate capscrews.

Torque Value: 24 N•m [212 in-lb]





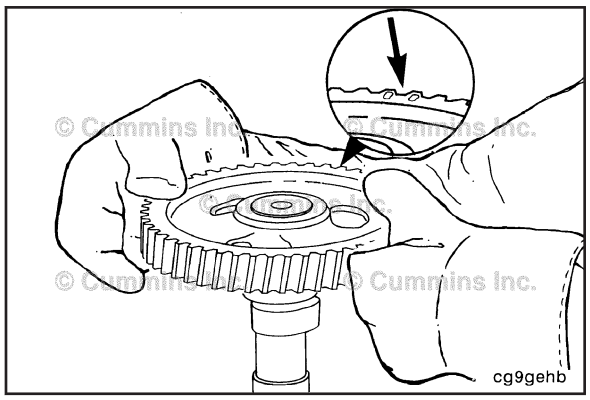
CAUTION

The camshaft gear will be permanently distorted if overheated. The oven temperature should never exceed 204°C [400°F].

Heat the camshaft gear for 45 minutes.

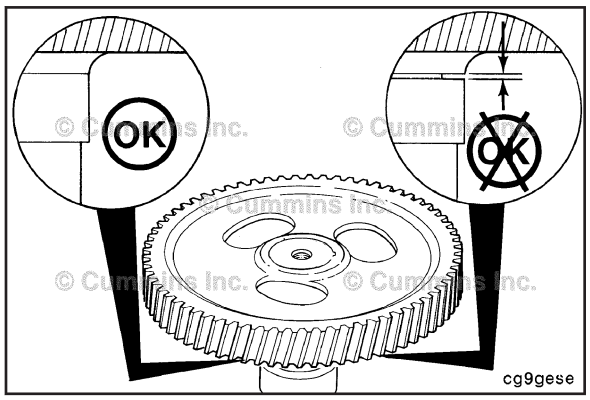
Oven Temperature 204 °C [400 °F]

Use camshaft gear removal and installation tool, Part Number 3163054, and puller assembly, Part Number 3165093, to install the camshaft gear onto the camshaft.



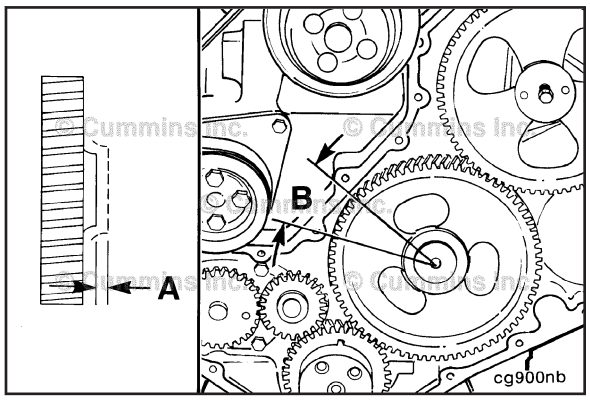
Wear protective gloves to reduce the possibility of personal injury when handling parts that have been heated.

Install the camshaft gear with the timing marks away from the camshaft.



NOTE: Be sure the gear is seated against camshaft shoulder.

Use a 0.02 mm [0.001] feeler gauge, to see if the feeler gauge can be inserted between the camshaft gear and the shoulder on the camshaft. Insert the feeler gauge in multiple locations. If the feeler gauge can be inserted, the camshaft gear is **not** properly seated.



Using gauge, Part Number 3824564, and magnetic base, Part Number 3377399, verify the camshaft has proper backlash and end play.

Camshaft End Play (A)		
mm		**in**
0.12	MIN	0.005
0.50	MAX	0.020

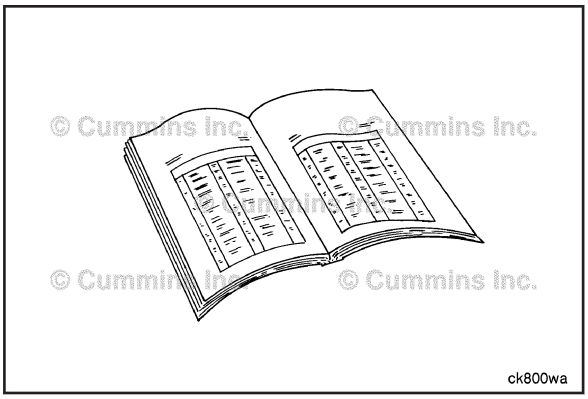
Camshaft Gear Backlash Limits (B)		
mm		**in**
0.08	MIN	0.003
0.33	MAX	0.013

Finishing Steps

All Applications Except Marine

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the gear cover. Refer to Procedure 001-031 in Section 1.
- Install the vibration damper. Refer to Procedure 001-052 in Section 1.
- Install the fan hub, if required. Refer to Procedure 008-039 in Section 8.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Tighten the rocker lever assemblies. Refer to Procedure 003-008 in Section 3.
- Adjust the valve lash. Refer to Procedure 003-004 in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine at idle for 5 to 10 minutes and check for leaks or loose parts.

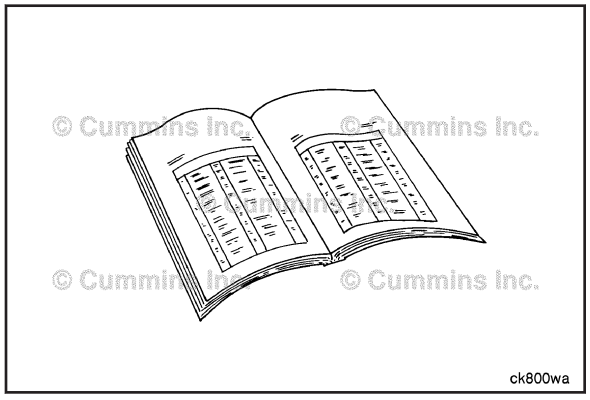


Marine Applications

⚠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.
- Install the automatic belt tensioner. Refer to Procedure 008-080 in Section 8.
- Install the vibration damper. Refer to Procedure 001-052 in Section 1.
- Install the fuel filter head bracket. Refer to Procedure 006-018 in Section 6.
- Install the water pump drive belt. Refer to Procedure 008-002 in Section 8.
- Install the belt guards. Refer to Procedure 008-001 in Section 8.
- Tighten the rocker lever assemblies. Refer to Procedure 003-008 in Section 3.
- Adjust the valve lash. Refer to Procedure 003-004 in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine at idle for 5 to 10 minutes and check for leaks and loose parts.



Camshaft Gear (Camshaft Removed) (001-013)

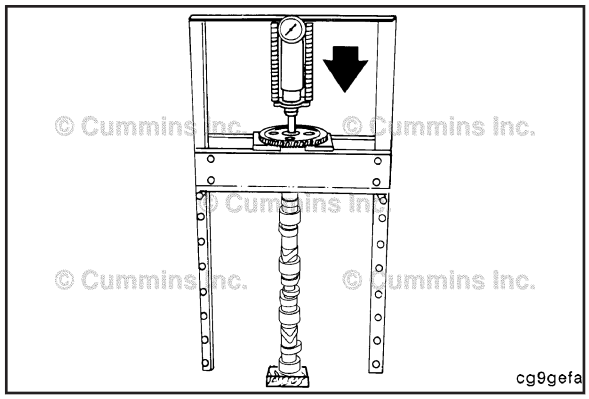
Preparatory Steps

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

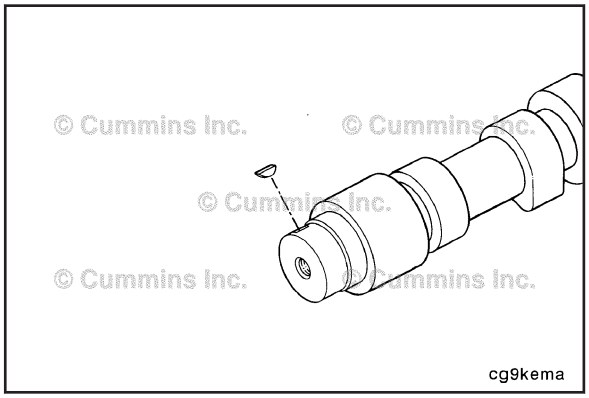
Remove

Remove the gear by using a press.

Remove the thrust plate.



Remove the camshaft key.

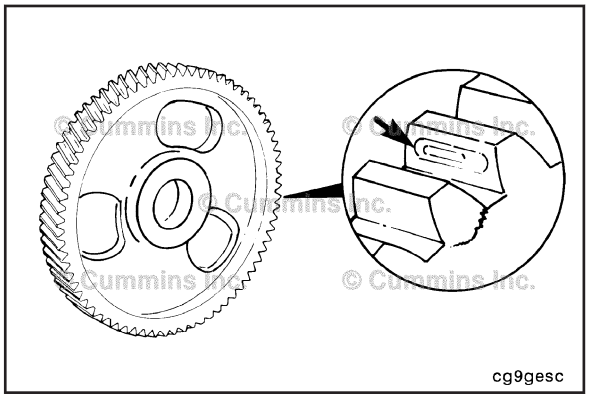


Clean and Inspect for Reuse

Inspect the camshaft gear for cracked, chipped, or broken teeth.

Inspect the camshaft bore for fretting or burrs.

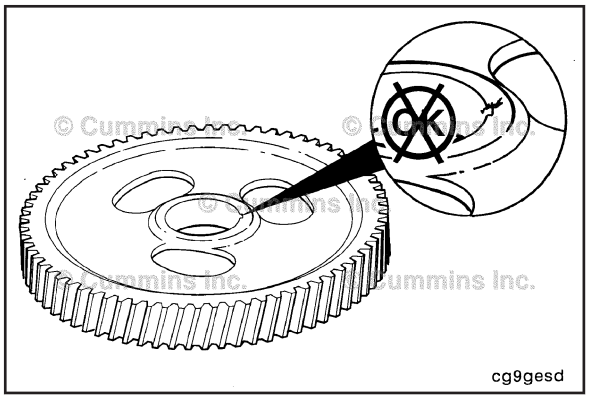
NOTE: If the fretting, burrs, or raised material can **not** be removed with abrasive pad, Part Number 3823258, or equivalent, replace the camshaft gear.

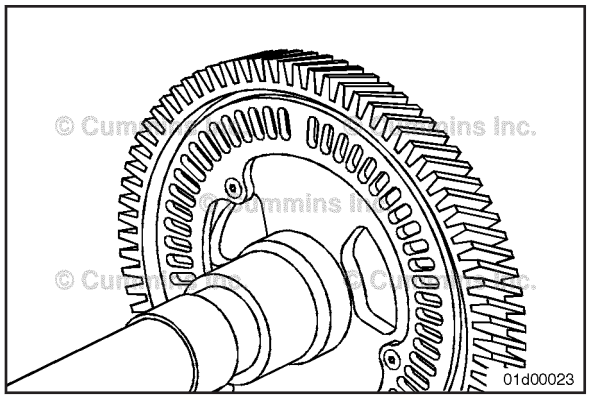


Inspect the camshaft gear keyway for burrs.

Remove burrs with abrasive pad, Part Number 3823258, or equivalent.

NOTE: If the keyway is damaged or the burrs can **not** be removed, the camshaft gear **must** be replaced.





Inspection steps for engines with bolt on speed sensor targets:

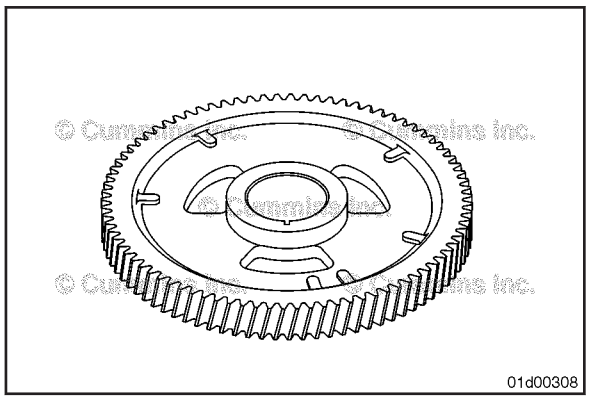
Inspect the cam gear and timing plate for damage.

Inspect the flathead capscrews to make sure they are tight.

If more than one capscrew is loose, replace cam gear.

If **only** one capscrew is loose, tighten all capscrews.

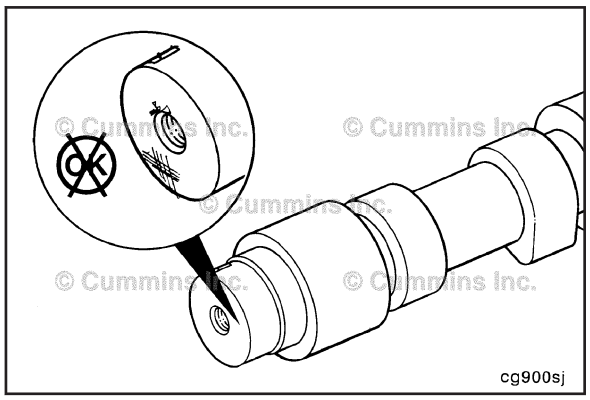
Torque Value: 7 N•m [62 in-lb]



Inspection steps for engines with machined speed sensor targets:

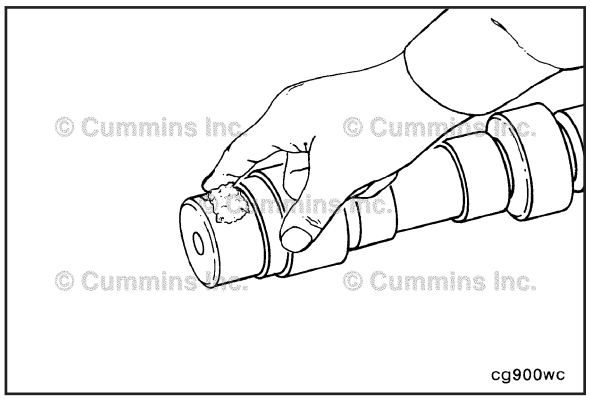
Inspect the camshaft gear and speed sensor targets.

Replace the camshfat gear if any damage is found.



Inspect the camshaft nose for fretting or burrs.

NOTE: If fretting or burrs can **not** be removed with abrasive pad, Part Number 3823258 or equivalent, replace the camshaft.



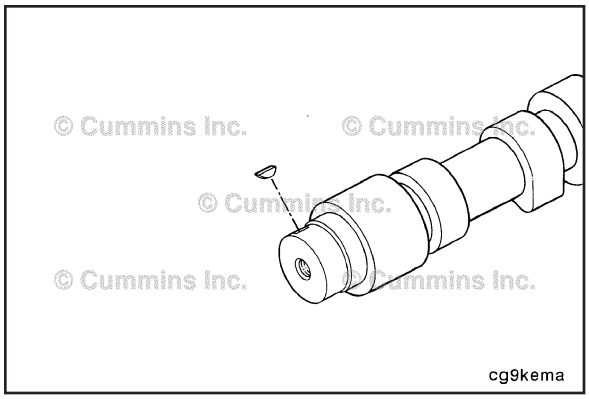
Install

Lubricate the camshaft surface with assembly lubricant, Part Number 3163087, or equivalent.

Install the key.

Install the thrust plate.

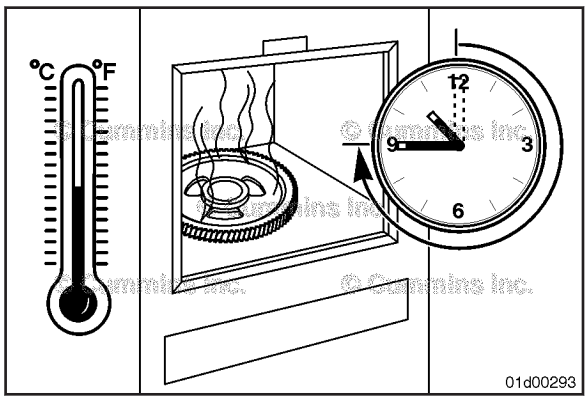
NOTE: Because the thrust plate extends more than 180 degrees around the camshaft, the thrust plate **must** be installed before installing the cam gear on the camshaft.



CAUTION
The camshaft gear will be permanently distorted if overheated. The oven temperature should never exceed 204°C [400°F].

Heat the camshaft gear for 45 minutes.

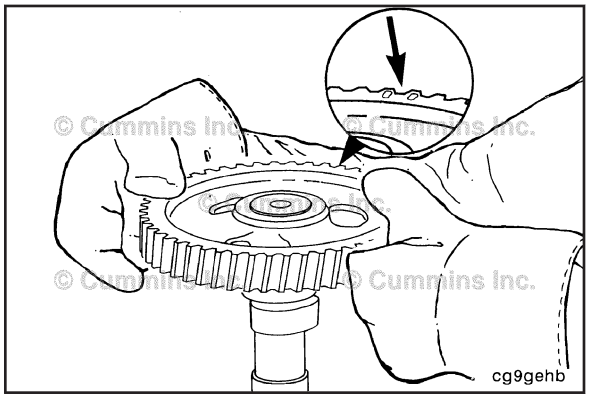
Oven Temperature 204 °C [400 °F]



WARNING
Wear protective gloves to reduce the possibility of personal injury when handling parts that have been heated.

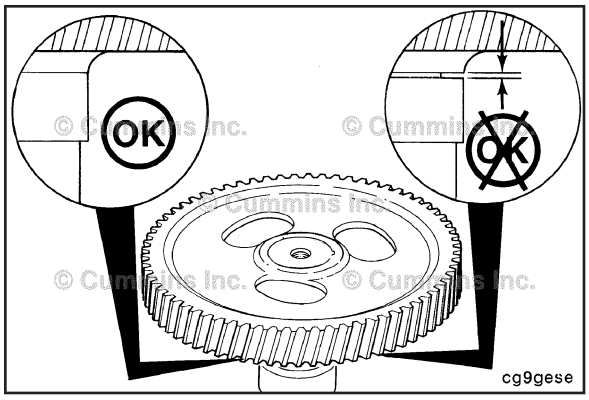
NOTE: When clamping the camshaft to install the gear, do **not** place clamps directly on the camshaft lobes or journals, which could damage the surfaces. Clamp **only** the cast surfaces between the lobes, or place padding between the clamps and the camshaft surfaces.

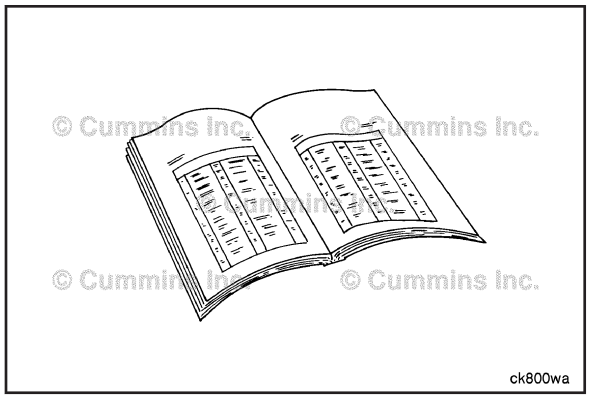
Install the camshaft gear with the timing marks away from the camshaft.



NOTE: Be sure the gear is seated against camshaft shoulder.

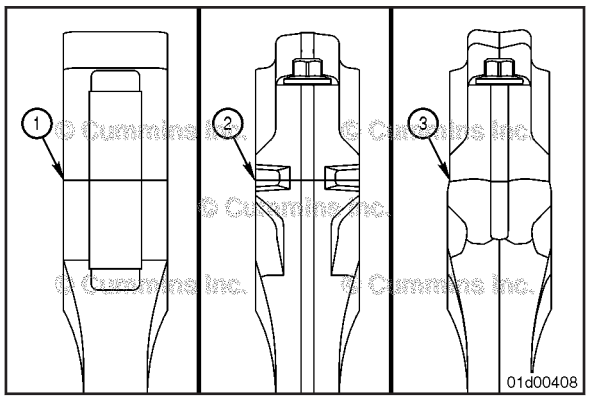
Use a 0.02 mm [0.001 in] feeler gauge, to see if the feeler gauge can be inserted between the camshaft gear and the shoulder on the camshaft. If the feeler gauge can be inserted, the camshaft gear is **not** properly seated.





Finishing Steps

- Install the camshaft. Refer to Procedure 001-008 in Section 1.
- Operate the engine and check for leaks.



Connecting Rod (001-014)

General Information

The connecting rod configuration can change, depending on the engine configuration. Some engines use straight split connecting rods. Other engines use angle split connecting rods. The connecting rod can also have a fracture-split surface or a serrated surface.

Connecting rods with a fracture-split or serrated surface **must** be treated with caution. The two pieces of the connecting rod can **not** be rubbed together, as this will damage the mating surfaces. Use care to **not** drop either piece of the connecting rod.

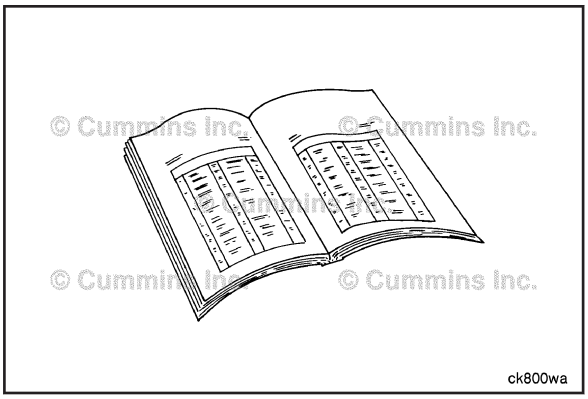
1 C connecting rods are straight, with a smooth machined surface.

2 L fracture-split connecting rods are angled, with a fracture-surface at the crankshaft end.

3 L serrated connecting rods are angled with a serrated machined surface at the crankshaft end.

These connecting rods can **not** be mixed in the same engine.

Preparatory Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

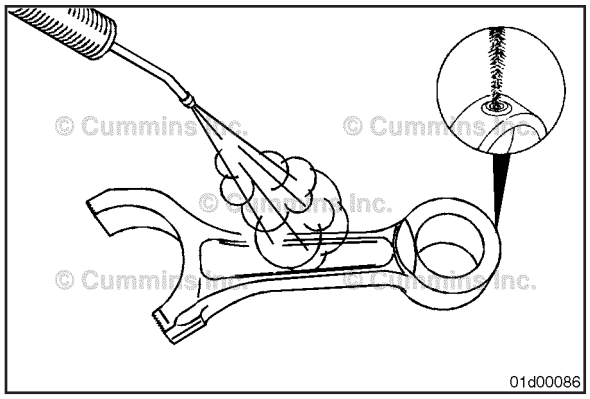
⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

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

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

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the cooling system. Refer to Procedure 008-018 in Section 8.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the cylinder head. Refer to Procedure 002-004 in Section 2.
- Remove the lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7.
- Remove the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Remove the piston and connecting rod, and disassemble. Refer to Procedure 001-054 in Section 1.



Clean and Inspect for Reuse

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

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

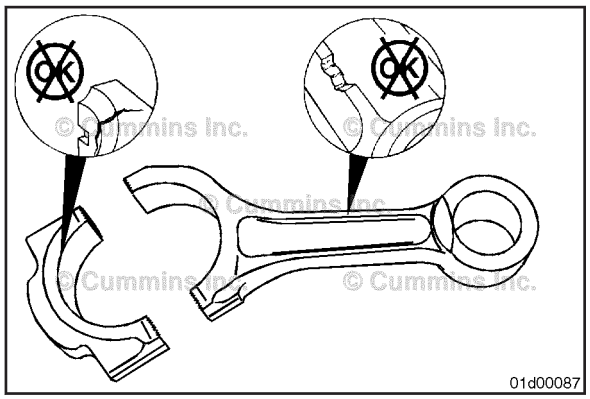
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use a nylon bristle brush to clean the oil drillings.

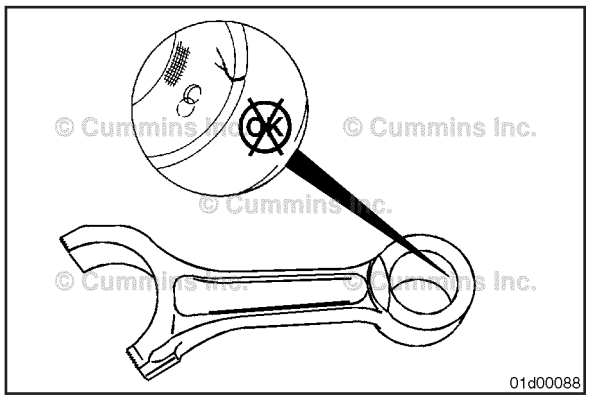
Use steam or solvent to clean the connecting rods.

Dry with compressed air.



Inspect the connecting rods and connecting rod caps for damage.

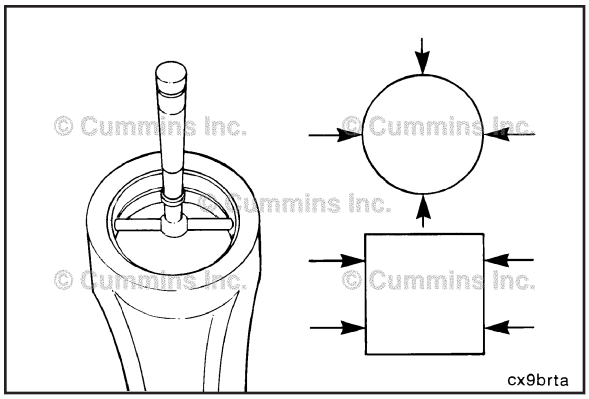
Replace the connecting rod if the “I-beam” is nicked or otherwise damaged.



Inspect the piston pin bore for damage or misalignment of the oil passage and bushing.

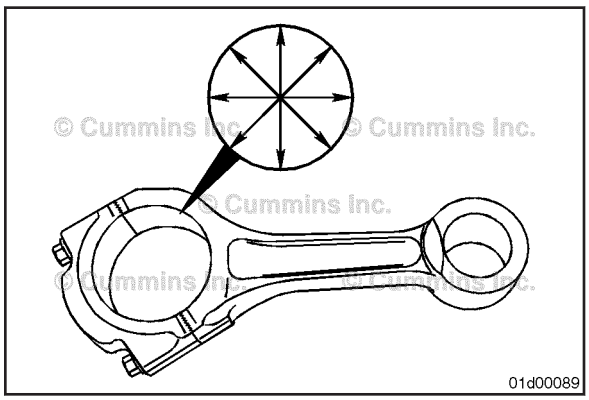
Measure the connecting rod piston pin bushing inside diameter.

Connecting Rod Piston Pin Bushing Diameter		
mm		in
45.023	MIN	1.7726
45.035	MAX	1.7730



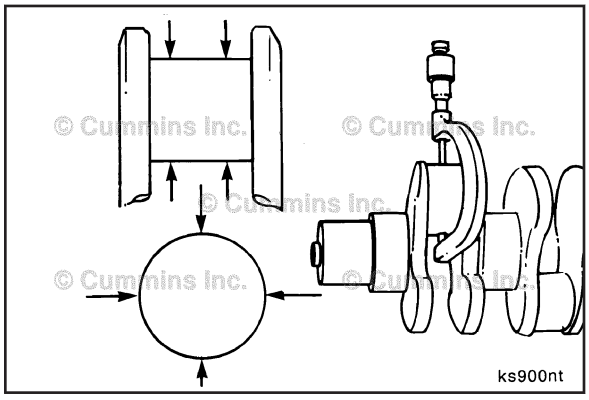
Measure the connecting rod crankshaft bore with the bearing shells removed and the caps tightened to the proper torque value. Refer to Procedure 001-054 in Section 1.

Connecting Rod Crank Bore Diameter (Bearings Removed)		
mm		in
80.987	MIN	3.1885
81.013	MAX	3.1895



Measure the diameter of the rod journal on the crankshaft.

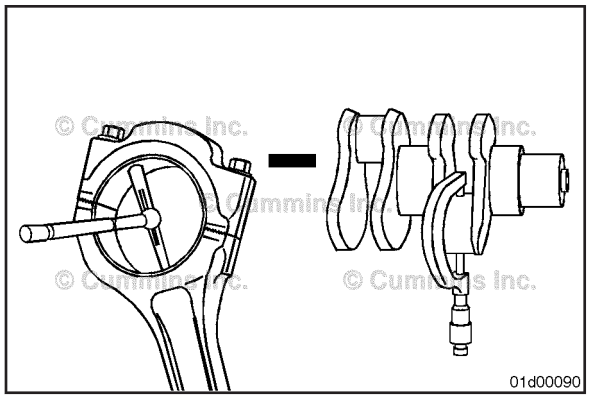
Crankshaft Rod Journal Diameter		
mm		in
CM554 ECM (No Speed Indicator Ring On Crankshaft)		
75.962	MIN	2.9906
76.013	MAX	2.9926
CM850 ECM (Speed Indicator Ring Mounted to Rear of Crankshaft		
76.000	MIN	2.9921
76.026	MAX	2.9931



Out-of-Roundness		
mm		in
0.050	MAX	0.002

Taper		
mm		in
0.013	MAX	0.0005

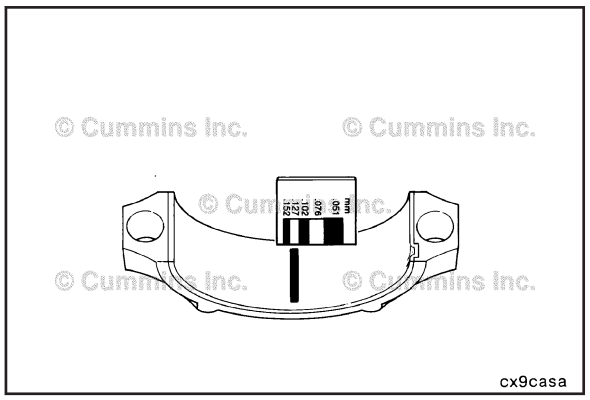
NOTE: If the crankshaft rod journals are **not** within the given specifications, the crankshaft **must** be replaced.



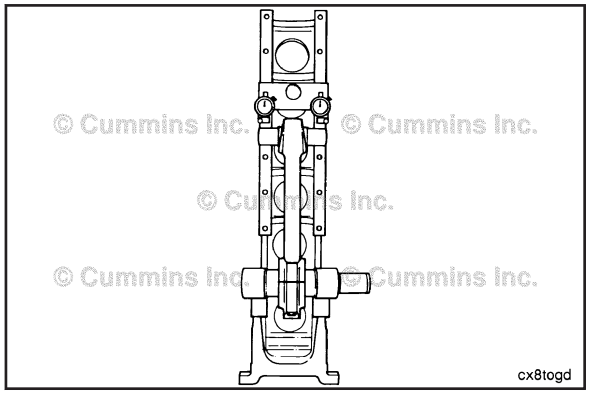
Bearing Clearance

mm		in
0.038	MIN	0.0015
0.116	MAX	0.0045

Bearing clearance: rod inside diameter (with bearing) minus crankshaft journal diameter.



Bearing clearance can also be determined with a plastigauge during engine assembly.



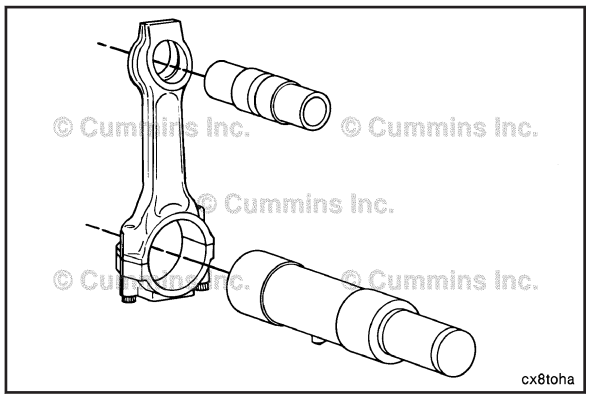
Bend and Twist Inspect

Calibration Procedure

Use a connecting rod checking fixture, Part Number ST-561, and a connecting rod mandrel set, Part Number 3823286, to inspect the bend and twist of the rods.

Calibrate the checking fixture with a new rod that has been measured for correct center to center length, 215.975 to 216.025 mm [8.5029 to 8.5040 in].

Assemble the connecting rod cap to the rod, as described previously in this procedure.



Install the piston pin mandrel from the mandrel set, Part Number 3823286, into the piston pin bore.

NOTE: Use a mandrel, Part Number 3823283, if a piston bushing has been removed or mandrel, Part Number 3823284, if the bushing is still in place.

Install the mandrel, Part Number 3823303, into the crankshaft bore and expand the mandrel.

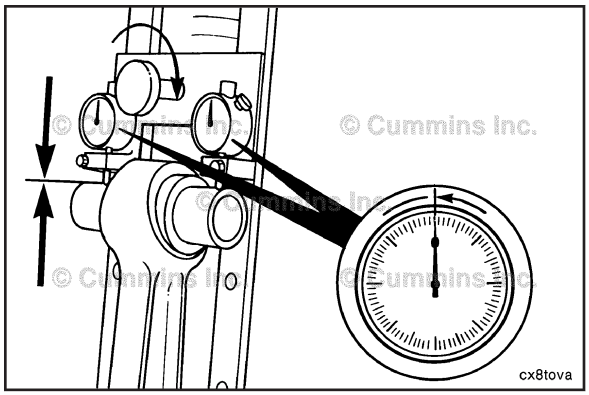
NOTE: Make sure the pin on the mandrel is down and locked in position in the center of the connecting rod.

Install the connecting rod into the fixture.

Move the dial holder to position the contact points of the indicators on the mandrel in the piston pin bore.

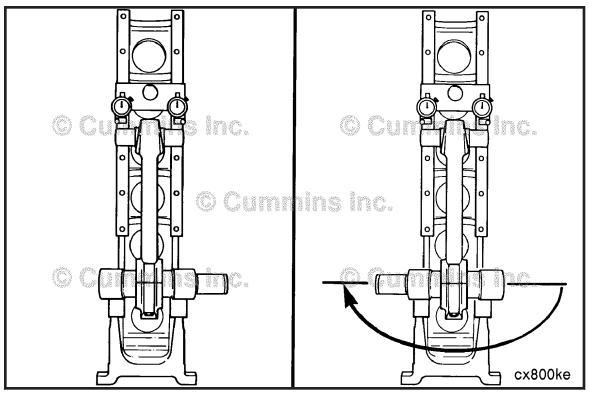
Tighten the bracket to hold the indicators in position.

Set the dial indicators to zero.



Remove the connecting rod from the fixture.

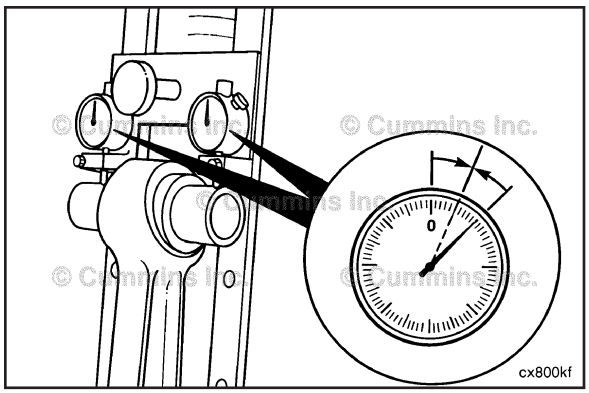
Turn the rod 180 degrees horizontally and install the rod into the fixture again.



Check the dial indicators for zero position again.

If the dial indicators show any change from zero, adjust the dials to half the indicated reading.

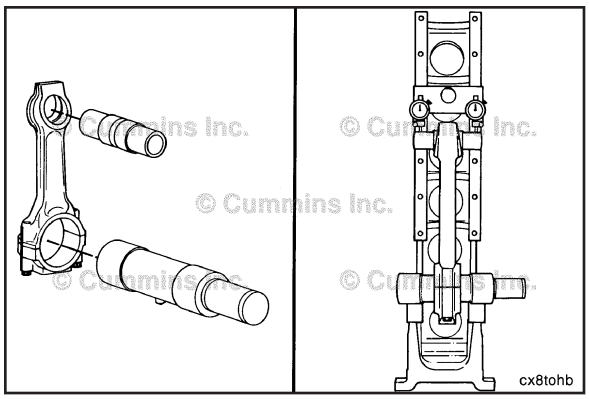
The fixture is now calibrated to allow the connecting rod to be installed into the fixture in either direction and the dials will indicate an equal defection on either side of zero.

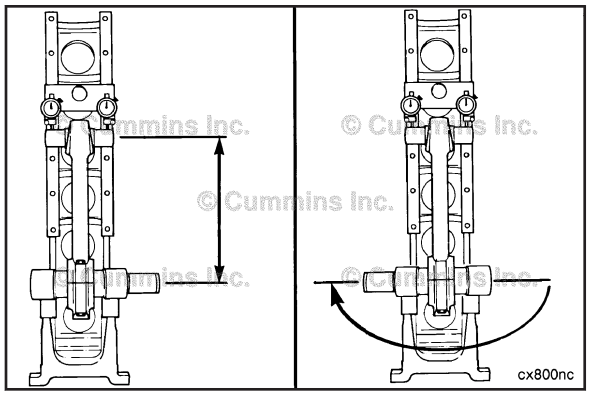


Test

Install the mandrel and arbor into the connecting rod to be inspected.

Install the connecting rod into the fixture.



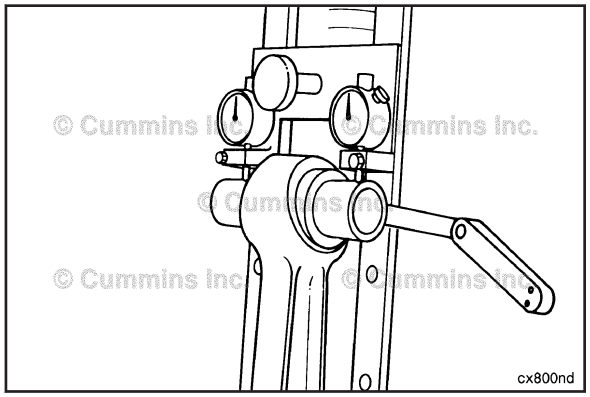


Measure the connecting rod length and bend (alignment).

Straight Split Connecting Rod Length		
mm		in
215.975	MIN	8.5029
216.025	MAX	8.5049

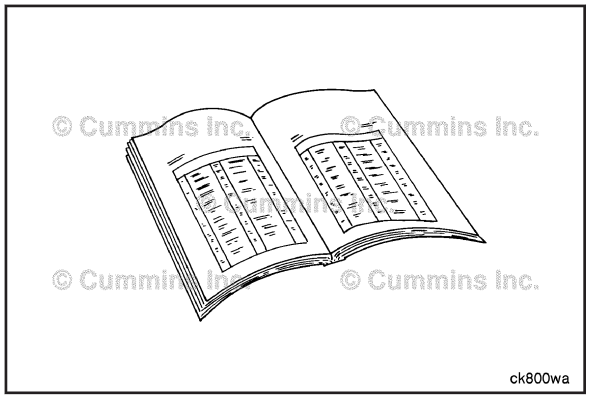
Angle Split Connecting Rod Length		
mm		in
215.950	MIN	8.5020
216.050	MAX	8.5059

Connecting Rod Bend (Alignment)			
	mm		in
Bushing removed	0.20	MAX	0.008
Bushing installed	0.15	MAX	0.006



Install a feeler gauge between the mandrel and the dial indicator holding plate, as shown in illustration.

Connecting Rod Twist			
	mm		in
Bushing removed	0.20	MAX	0.008
Bushing installed	0.30	MAX	0.012



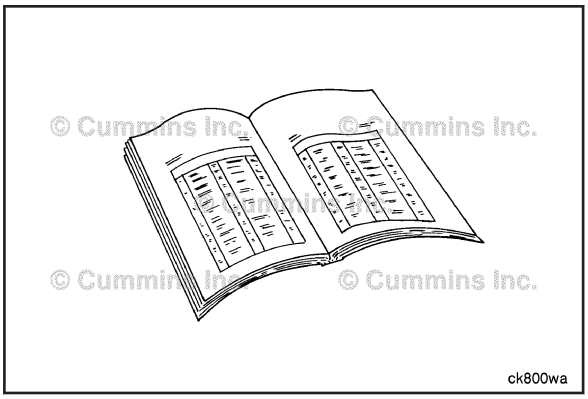
Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Assemble and install the pistons and connecting rod assemblies. Refer to Procedure 001-054 in Section 1.
- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7.
- Install the cylinder head. Refer to Procedure 002-004 in Section 2.
- Fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.

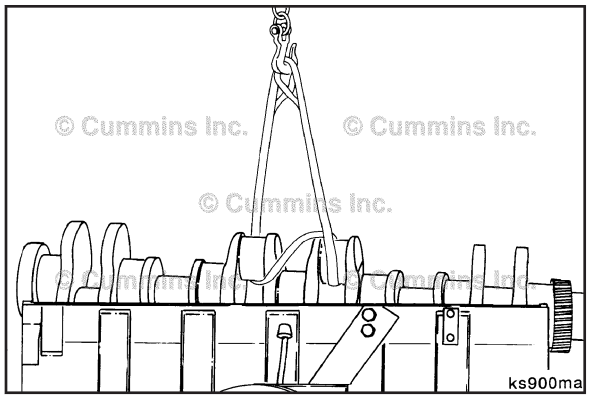
Crankshaft (001-016)

Preparatory Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery. Refer to Procedure 013-009 in Section 13.
- Remove the engine and place it on an engine stand. Refer to Procedure 000-001 in Section 0.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the rubber vibration damper, if installed. Refer to Procedure 001-051 in Section 1.
- Remove the viscous vibration damper, if installed. Refer to Procedure 001-052 in Section 1.
- Remove the front cover. Refer to Procedure 001-031 in Section 1.
- Remove the starter. Refer to Procedure 013-020 in Section 13.
- Remove the flexplate, if installed. Refer to Procedure 016-004 in Section 16.
- Remove the flywheel, if installed. Refer to Procedure 016-005 in Section 16.
- Remove the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Remove the rear crankshaft seal carrier. Refer to Procedure 001-067 in Section 1.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Remove the fuel pump. Refer to Procedure 005-016 in Section 5.
- Remove the air compressor, if required. Refer to Procedure 012-014 in Section 12.
- Remove the installed camshaft gear. Refer to Procedure 001-012 in Section 1.
- Remove the removed camshaft gear. Refer to Procedure 001-013 in Section 1.
- Remove the front gear housing. Refer to Procedure 001-033 in Section 1.
- Remove the connecting rod caps. Refer to Procedure 001-005 in Section 1.
- Remove the main bearing caps. Refer to Procedure 001-006 in Section 1.

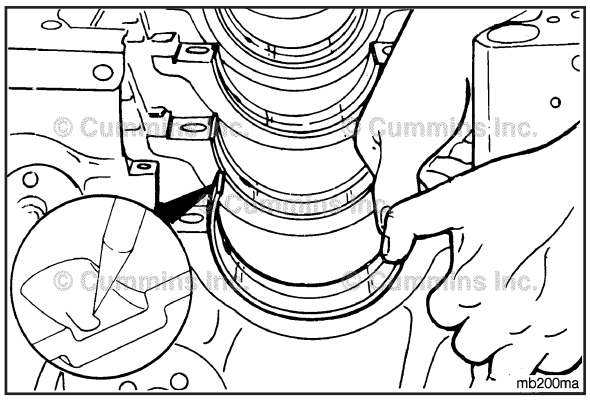


Remove

NOTE: Lift the crankshaft straight up to avoid damage to the crankshaft and cylinder block.

Install nylon lift sling, Part Number 3375957, around the number 3 and number 4 rod bearing journals.

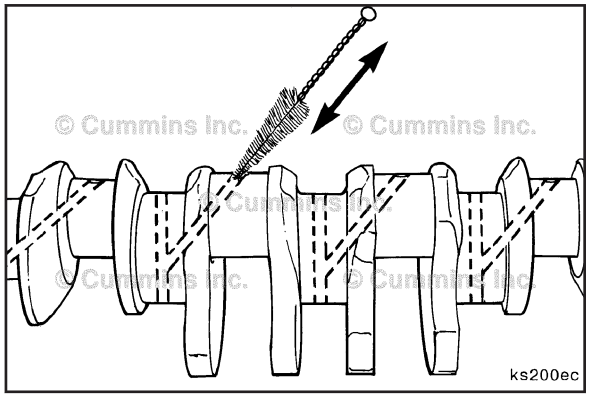
Attach the sling to a hoist and remove the crankshaft.



Remove the upper main bearings.

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

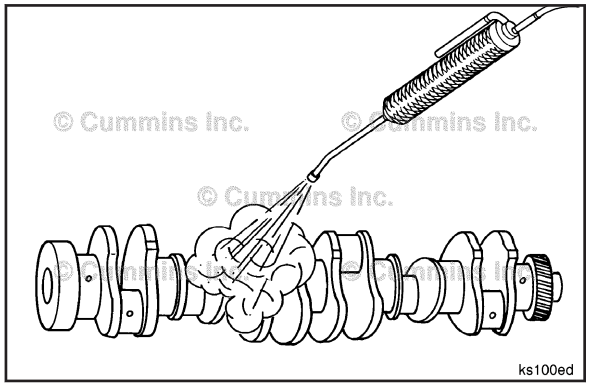
NOTE: Mark the bearing position for future identification or possible failure analysis.



Clean and Inspect for Reuse

Use fine crocus cloth to polish the machined surfaces.

Use a bristle brush to clean the oil drillings.



⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Steam clean the crankshaft and dry with compressed air.

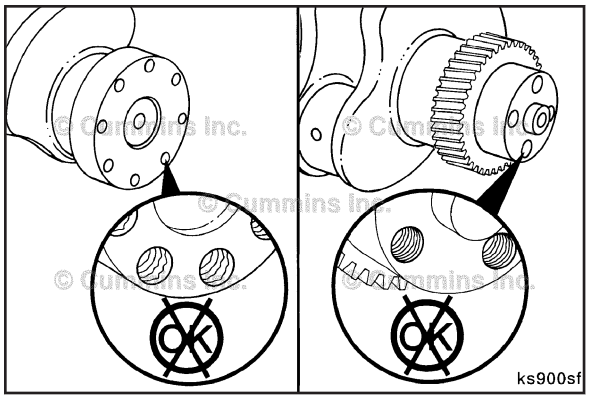
Make sure to blow out the threaded holes on each end of the crankshaft and oil drillings.

Inspect the threaded capscrew holes for damage.

Use one of the following methods to repair any damaged threaded holes:

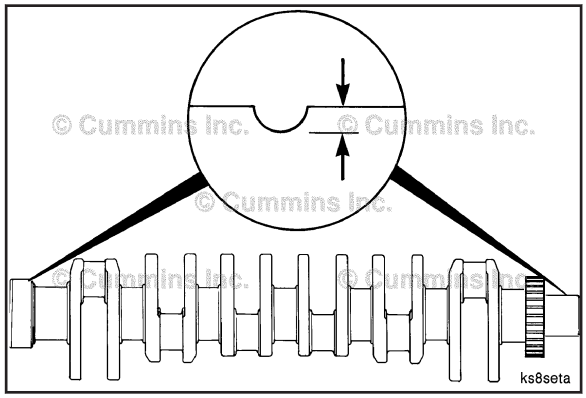
- Chase the threads.
- Use the threaded insert kit, Part Number 3822709.

NOTE: A maximum of one front crankshaft threaded hole and three rear crankshaft holes can be repaired. If more than one threaded hole in the front of the crankshaft or three threaded holes in the rear of the crankshaft requires repair, the crankshaft can **not** be salvaged.

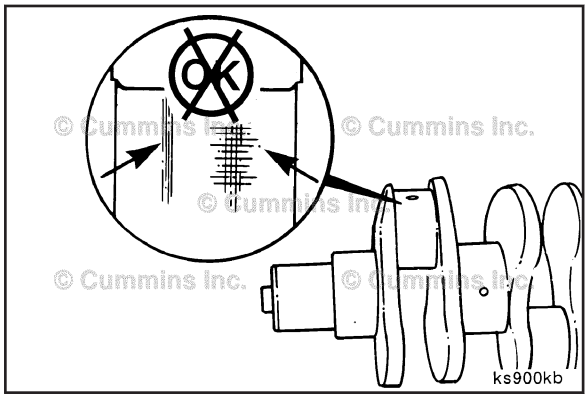


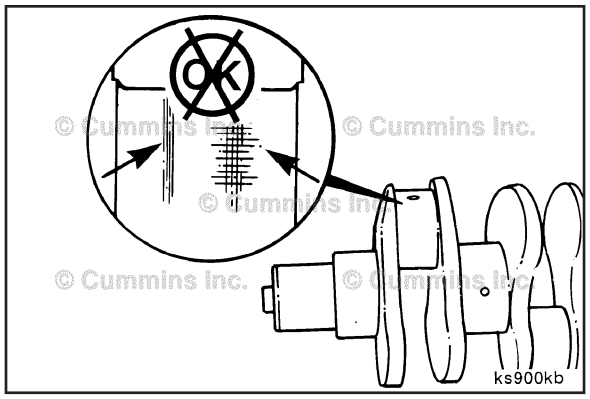
Measure the front and rear oil seal contact areas for a wear groove.

Crankshaft Front and Rear Oil Seal Wear Groove		
mm		in
0.25	MAX	0.010



Inspect the crankshaft connecting rod and main journals for deep scoring, overheating, etc. Minor scratches are acceptable.





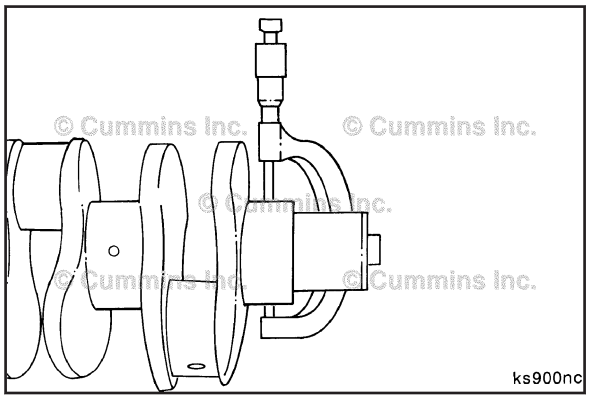
Use a micrometer to measure the connecting rod journals.

Crankshaft Connecting Rod Journal Diameter		
mm		in
76.000	MIN	2.9921
76.026	MAX	2.9931

Crankshaft Connecting Rod Out of Roundness		
mm		in
0.050	MAX	0.002

Crankshaft Connecting Rod Journal Taper		
mm		in
0.013	MAX	0.0005

NOTE: If the crankshaft connecting rod journals are **not** within the given specifications, the crankshaft **must** be reground. Always grind all of the journals when one is **not** within specifications. Oversize connecting rod bearings are available; see the appropriate parts catalog.



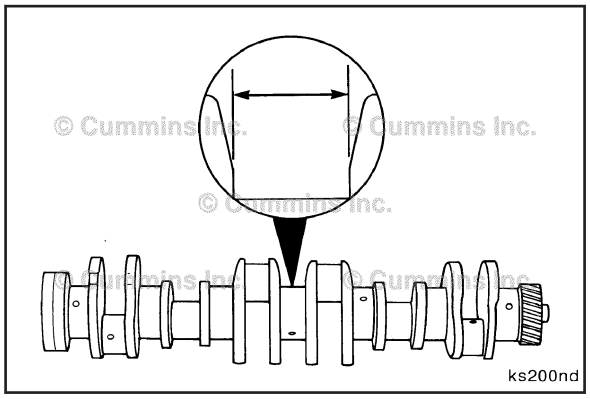
Use a micrometer to measure the crankshaft main bearing journals.

Crankshaft Main Bearing Journal Diameter		
mm		in
98.006	MIN	3.8585
98.032	MAX	3.8595

Crankshaft Main Bearing Journal Out of Roundness		
mm		in
0.050	MAX	0.002

Crankshaft Main Bearing Journal Taper		
mm		in
0.013	MAX	0.0005

NOTE: If the crankshaft main bearing journals are **not** within the given specifications, the crankshaft **must** be reground. Always grind all of the journals when one is **not** within specifications. Oversize connecting rod bearings are available; see the appropriate parts catalog.



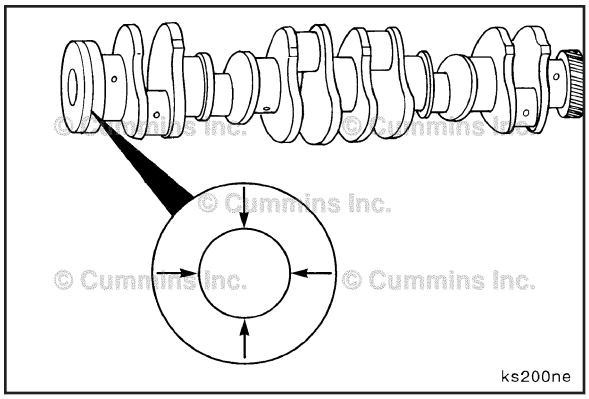
Measure the thrust face width. Minor scratches are acceptable. Use a fine crocus cloth to polish the machined surfaces.

Crankshaft Thrust Face Width (Standard)		
mm		in
42.98	MIN	1.692
43.08	MAX	1.696

NOTE: Oversize thrust bearings are available if the thrust distance is **not** within specifications. See the appropriate parts catalog.

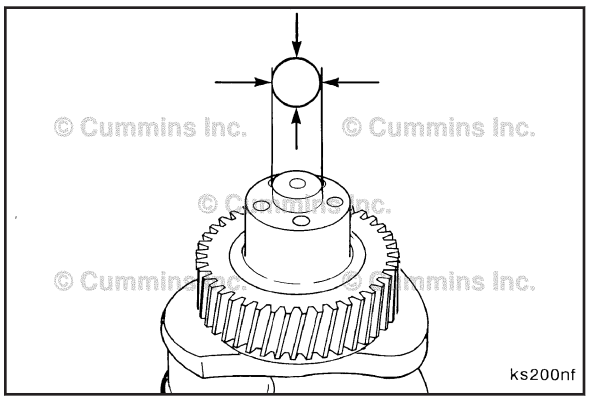
Measure the rear oil seal flange outside diameter.

Crankshaft Rear Oil Seal Flange Outside Diameter		
mm		in
129.98	MIN	5.117
130.03	MAX	5.119



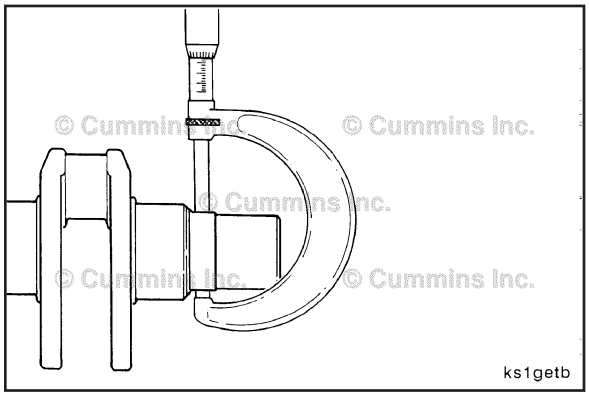
Measure the damper pilot outside diameter.

Crankshaft Damper Pilot Outside Diameter		
mm		in
23.92	MIN	0.942
24.00	MAX	0.945



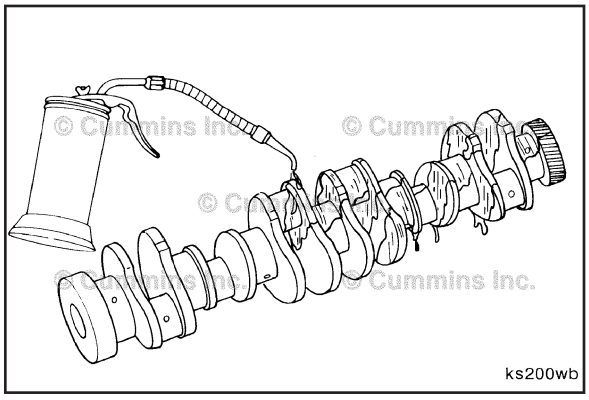
Measure the crankshaft gear journal outside diameter.

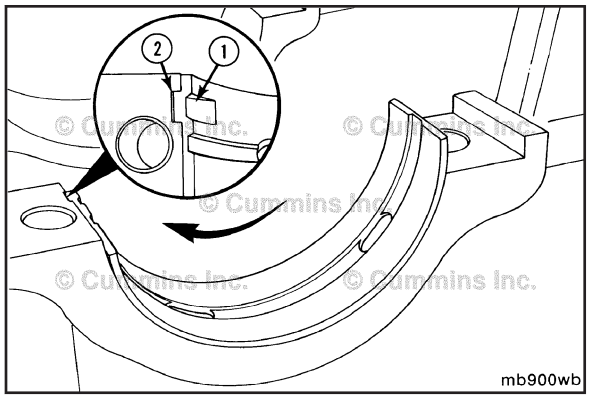
Crankshaft Gear Journal Outside Diameter		
mm		in
75.987	MIN	2.9916
76.006	MAX	2.9924



Use a light preservative oil to lubricate the crankshaft to prevent rust.

NOTE: If the crankshaft is **not** going to be used immediately, protect the part with a plastic cover to prevent dirt from sticking to the oil.





Install

⚠CAUTION⚠
The tang (1) on the bearing shell must be in the slot (2) of the bearing saddle to correctly position the bearing and prevent engine damage.

Upper Main Bearings

Do **not** lubricate the side of the main bearing that is against the cylinder block.

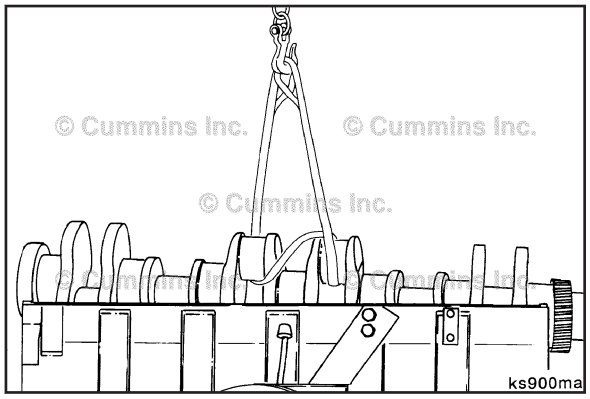
Apply a coat of assembly lubricant, Part Number 3163087 or equivalent, to the crankshaft side of the upper main bearings.

NOTE: Make sure the main bearing being installed is the same size as the main bearing that was removed. The size is engraved on the back of the main bearing.

NOTE: The crankshaft thrust bearing **must** be installed in the number four position.

NOTE: The upper and lower main bearing shells of some engines are **not** interchangeable. The backs of the main bearings are marked with the proper orientation, if required.

NOTE: If used bearing shells are to be installed, they **must** be installed in their original locations, as marked during disassembly.



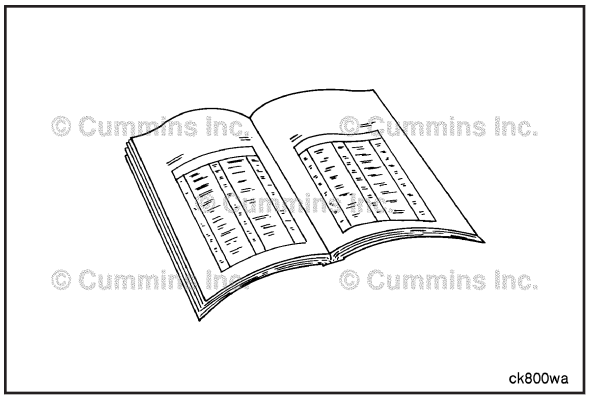
Use a hoist and nylon list sling, Part Number 3375957.

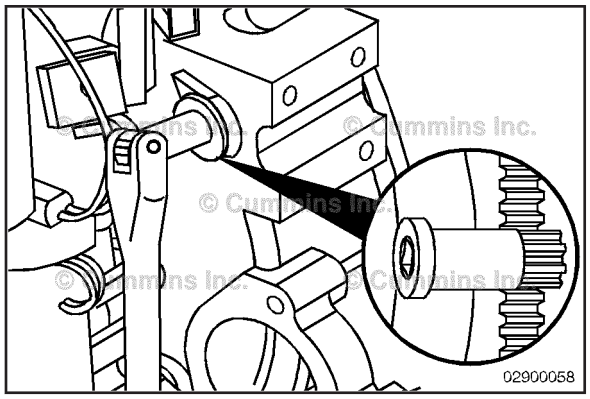
Install the sling around the number 3 and number 4 connecting rod bearing journals.

Install the crankshaft.

Finishing Steps

- Install the main bearing caps. Refer to Procedure 001-006 in Section 1.
- Install the connecting rod caps. Refer to Procedure 001-005 in Section 1.
- Install the rear crankshaft seal carrier. Refer to Procedure 001-067 in Section 1.
- Install the front gear housing. Refer to Procedure 001-033 in Section 1.
- Install the camshaft gear. Refer to Procedure 001-012 in Section 1.
- Install the fuel pump. Refer to Procedure 005-016 in Section 5.
- Install the air compressor, if required. Refer to Procedure 012-014 in Section 12.
- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Install the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Install the flexplate, if removed. Refer to Procedure 016-004 in Section 16.
- Install the flywheel, if removed. Refer to Procedure 016-005 in Section 16.
- Install the front cover. Refer to Procedure 001-031 in Section 1.
- Install the vibration damper, if removed. Refer to Procedure 001-051 in Section 1.
- Install the vibration damper, if removed. Refer to Procedure 001-052 in Section 1.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Check the engine rotation. See the Rotation Check section of this procedure.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.



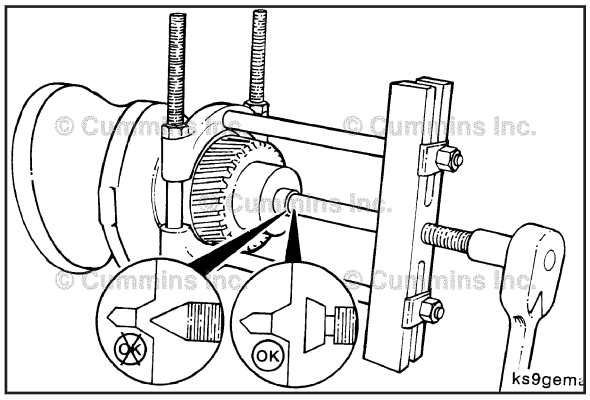


Rotation Check

With the engine fully assembled, check to be sure the engine rotates freely. Use barring tool, Part Number 3824591.

Insert the barring tool into the flywheel housing and engage the flywheel/flexplate ring gear. The crankshaft can then be rotated by hand, using a 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.



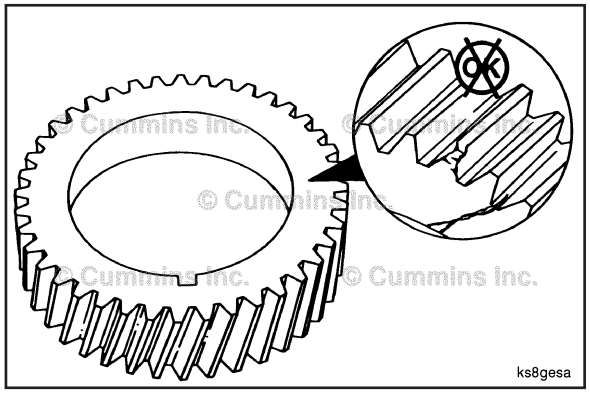
Crankshaft Gear, Front (Crankshaft Removed) (001-019)

Remove

⚠CAUTION⚠
Do not try to split the front crankshaft gear to remove. The gear is made out of steel and will not split. Damage to the tool and the crankshaft can result.

NOTE: If a front crankshaft seal wear sleeve has been installed during a previous repair, it **must** be removed before the crankshaft gear is removed. Refer to Procedure 001-025 in Section 1.

Use a heavy-duty bearing separator, Part Number 316427, or gear puller, as illustrated, to remove the crankshaft gear.



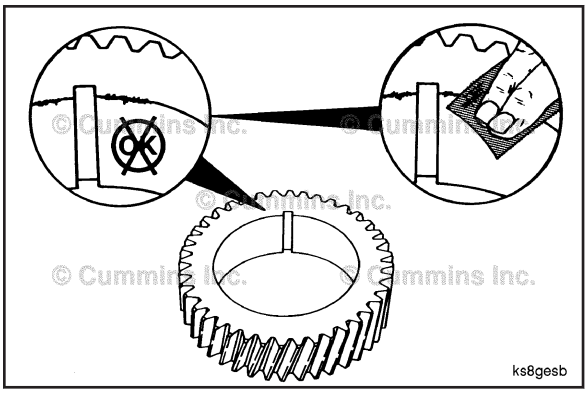
Clean and Inspect for Reuse

Inspect for cracks, broken, or chipped teeth.

The gear **must** be replaced if it is damaged.

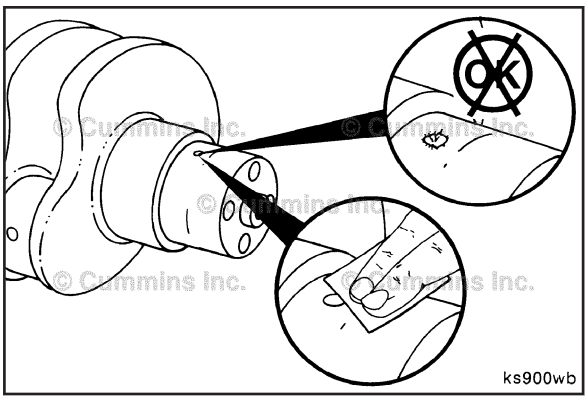
Inspect the gear and keyway for nicks or burrs.

Use fine crocus cloth to remove nicks and burrs.



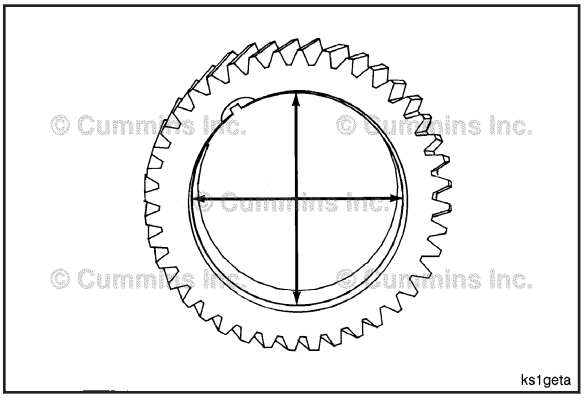
Inspect the crankshaft gear journal and the gear alignment dowel pin hole for burrs or damage.

Use fine crocus cloth to remove burrs.

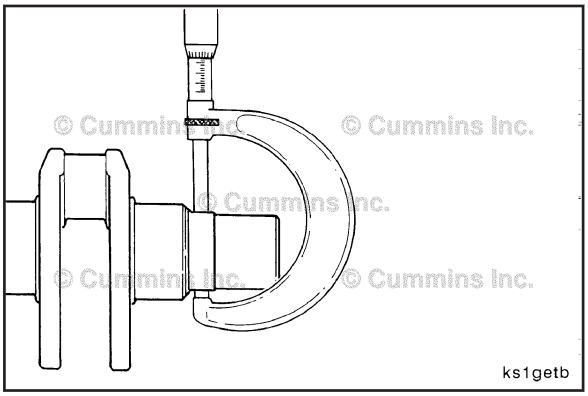


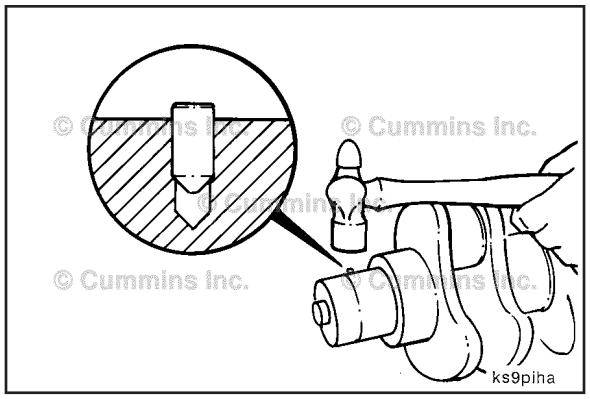
Measure the crankshaft gear bore inside diameter.

Crankshaft Gear Bore Inside Diameter		
mm		in
75.898	MIN	2.9881
75.923	MAX	2.9891



Crankshaft Gear Journal Outside Diameter		
mm		in
75.987	MIN	2.9916
76.006	MAX	2.9924





Install

⚠CAUTION⚠
Do not exceed the specified heating time or temperature. The crankshaft teeth can be damaged.

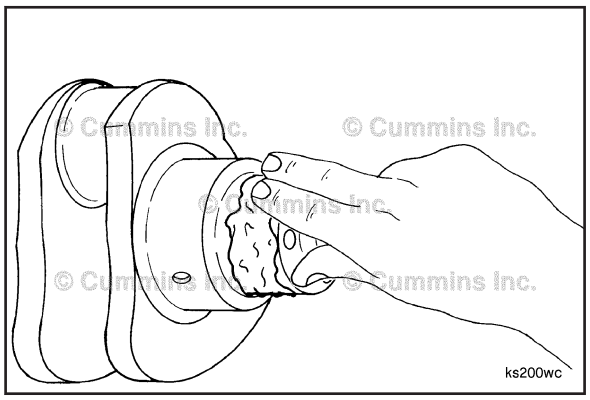
Use a soft hammer to install the gear alignment dowel into the crankshaft.

The pin **must** be 1.02 mm [0.040 in] above the crankshaft surface.

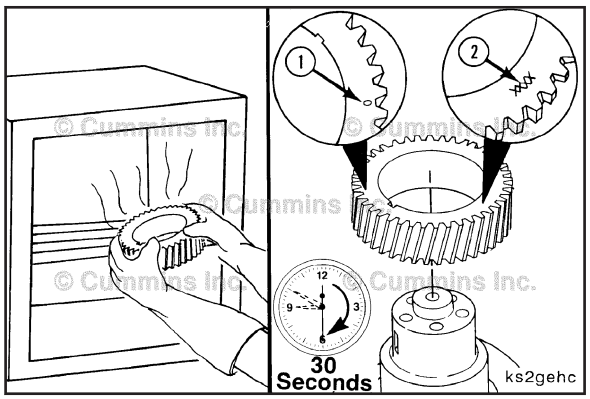
Heat the gear in an oven for a minimum of 45 minutes, but **not** more than 2 hours.

Temperature

Steel Gear	177 °C	[350 °F]



Use assembly lubricant, Part Number 3163087 or equivalent, to lubricate the outside diameter of the crankshaft gear journal.



⚠WARNING⚠
Wear protective gloves to reduce the possibility of personal injury when handling parts that have been heated.

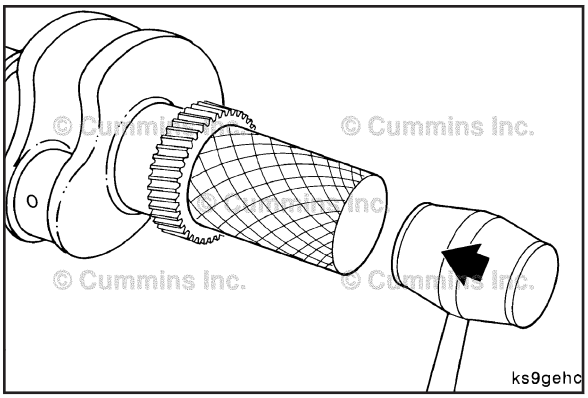
⚠CAUTION⚠
The timing mark (1) and part number (2) on the gear must be facing away from the crankshaft after the gear is installed. Engine damage can result if the gear is installed backwards.

⚠CAUTION⚠
Do not use water or oil to reduce the cooling time. The gear can crack. Allow the gear to air cool.

Remove the gear from the oven.

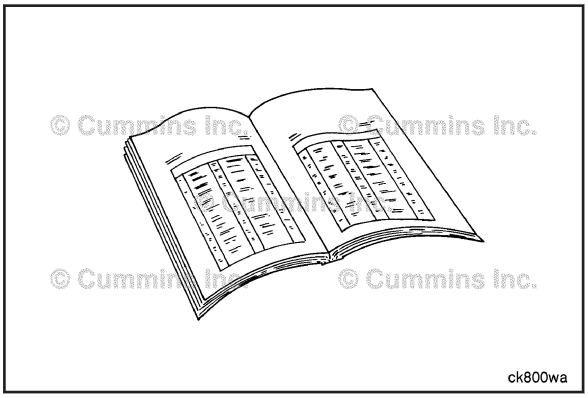
Align the keyway of the gear with the alignment dowel pin in the crankshaft and install the gear within 30 seconds.

If the gear cools and stops on the crankshaft before it is fully installed, use a driver to complete the installation.



Finishing Steps

- Install the crankshaft.
- Operate the engine and check for leaks.

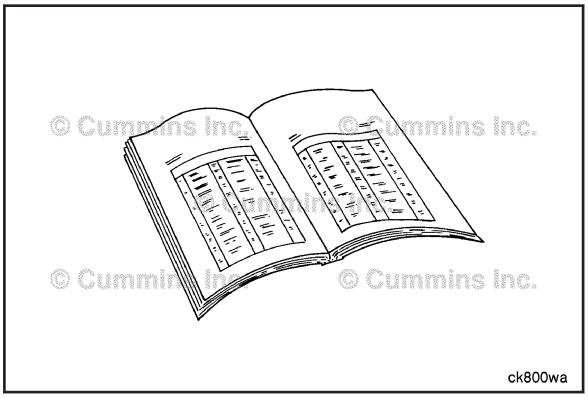


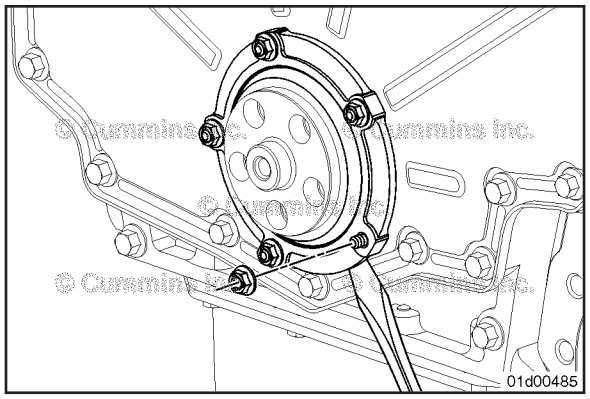
Crankshaft Seal, Front (001-023)

Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery. Refer to Procedure 013-009 in Section 13.
- Remove the belt guard, if equipped. Refer to Procedure 008-001 in Section 8.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the vibration damper, rubber, if installed. Refer to Procedure 001-051 in Section 1.
- Remove the vibration damper, viscous, if installed. Refer to Procedure 001-052 in Section 1.



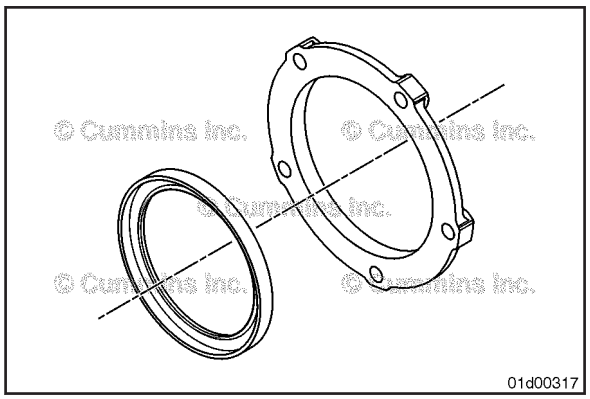


Remove

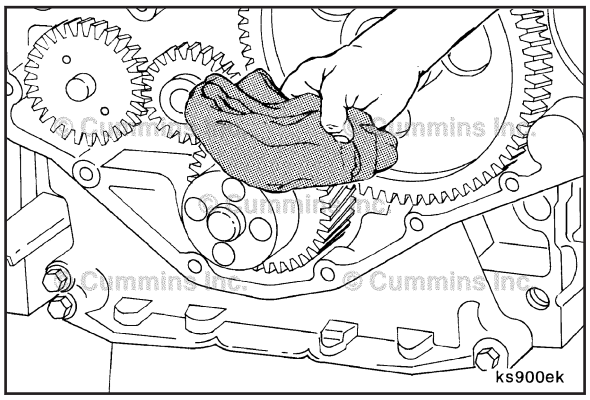
⚠CAUTION⚠
The seal carrier must be removed as shown. Using other areas can cause damage to the front cover.

Remove the mounting nuts from the mounting studs.

Remove the front crankshaft seal carrier.

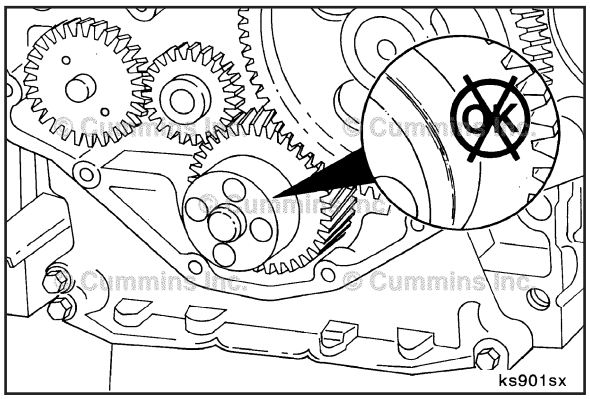


Remove the oil seal from the carrier. Drive the oil seal from the back side of the carrier toward the front side of the carrier, while supporting the carrier. Discard the oil seal.



Clean and Inspect for Reuse

Clean the gear cover seal bore and the crankshaft surface of all oil and seal residue.



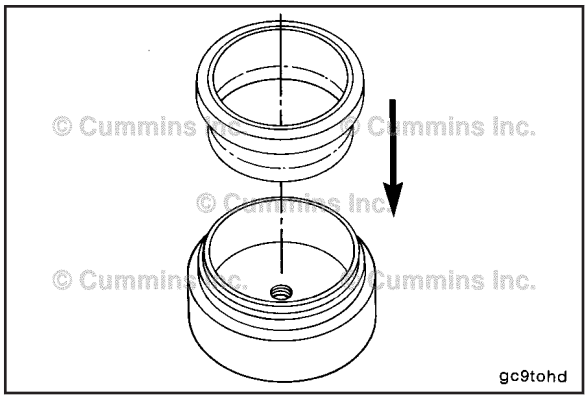
Inspect the crankshaft for excessive wear.

NOTE: If the crankshaft has excessive wear, a service wear sleeve is available. Refer to Procedure 001-025 in Section 1.

Install

Leave the plastic pilot installation tool in the lubricating oil seal.

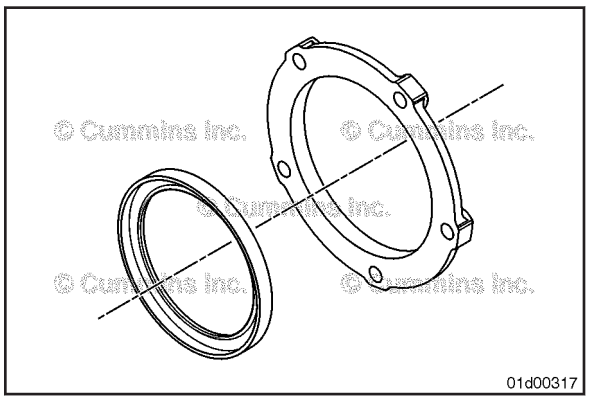
Position the seal on the service tool, Part Number 3824499, with the lubricating oil seal dust lip facing outward.



NOTE: Properly support the carrier lubricating oil seal flange to prevent damage to the lubricating oil seal and carrier.

Press the lubricating oil seal into the carrier from the back side of the carrier toward the front side of the carrier.

Press the lubricating oil seal until the seal is flush on front of the carrier.



Apply a bead of sealant, approximately 4 mm [0.16 in] thick and 4 mm [0.16 in] wide, around the inside of the seal carrier, between the mounting holes and the seal.

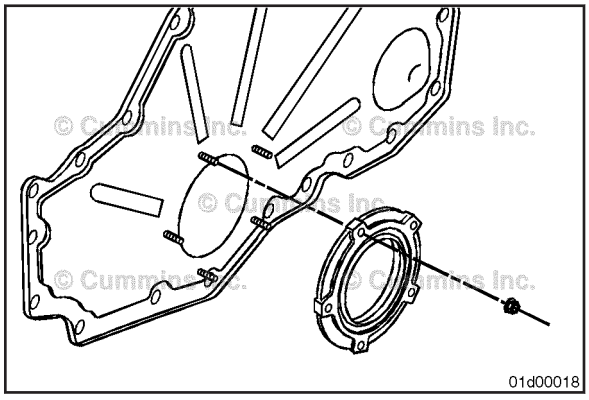
Apply a bead of sealant, approximately 4 mm [0.16 in] thick and 4 mm [0.16 in] wide, around all stud seams on the front cover.

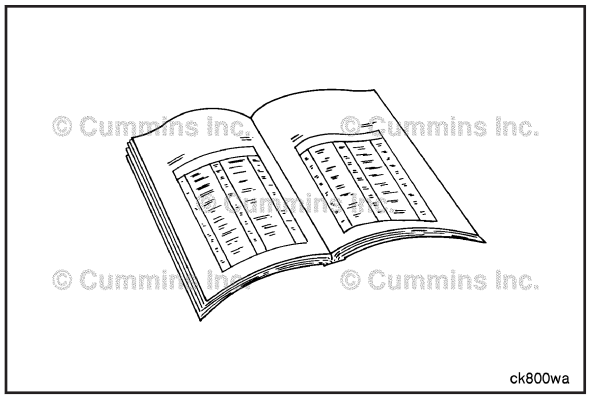
Install the seal carrier on the front gear cover.

Remove the plastic installation tool.

Starting with the upper left stud (as shown in the graphic), tighten the carrier mounting nuts in a star pattern.

Torque Value: 8 N•m [71 in-lb]



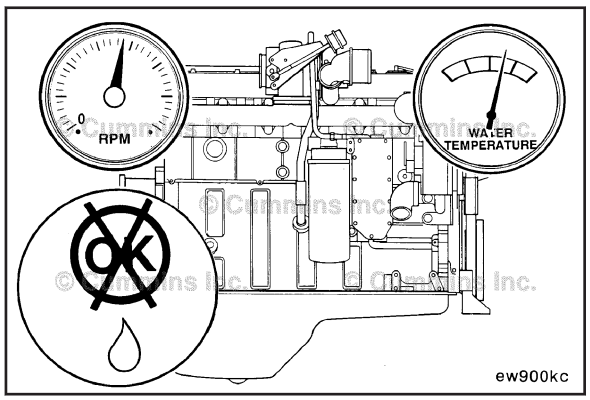


Finishing Steps

⚠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 vibration damper, rubber, if installed. Refer to Procedure 001-051 in Section 1.
- Install the vibration damper, viscous, if installed. Refer to Procedure 001-052 in Section 1.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Install the belt guard, if equipped. Refer to Procedure 008-001 in Section 8.
- Connect the battery. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.



Crankshaft Seal, Rear (001-024)

Initial Check

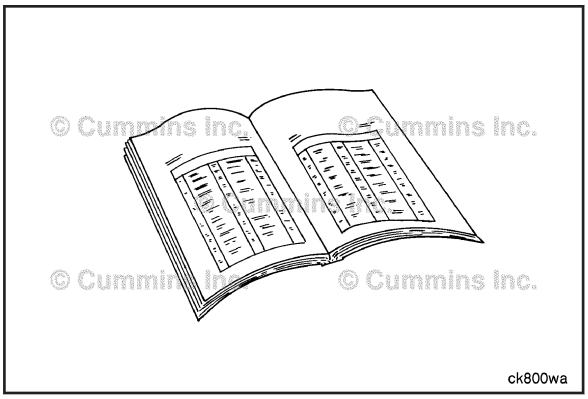
Verify that the rear crankshaft seal is the source of the oil leak by using fluorescent tracer, Part Number 3376891, or equivalent. Refer to Procedure 007-024 in Section 7.

Preparatory Steps

All Applications Except Marine

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the clutch and transmission. Refer to the OEM service manual.
- Remove the starting motor. Refer to Procedure 013-020 in Section 13.
- Remove the flexplate, if installed. Refer to Procedure 016-004 in Section 16.
- Remove the flywheel, if installed. Refer to Procedure 016-005 in Section 16.

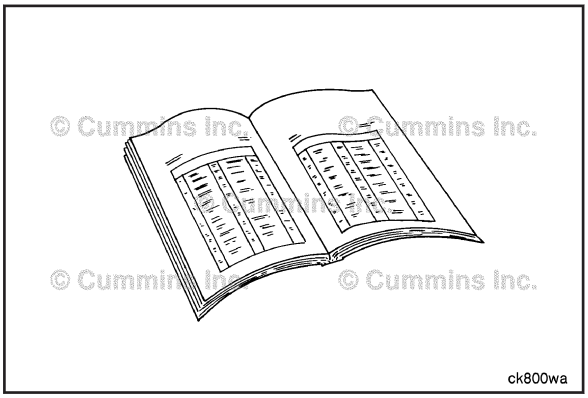


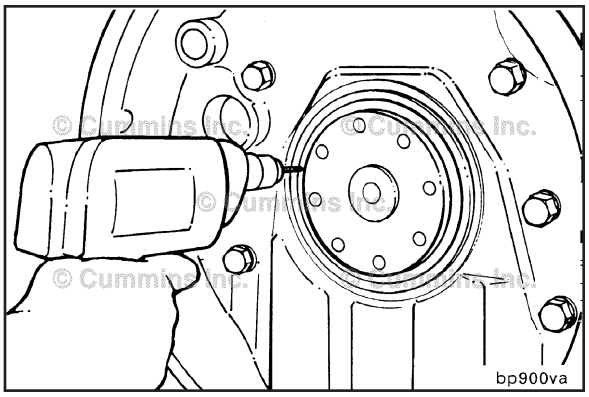
Marine Applications

⚠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: On some vessels, it can be necessary to lift the engine to replace the rear crankshaft seal.

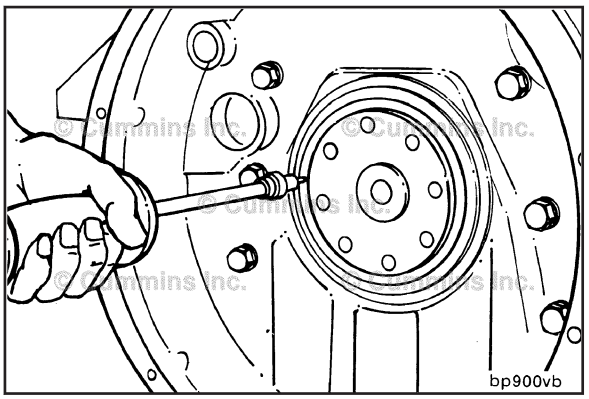
- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Shut off the sea water supply valve. Refer to the OEM service manual.
- Remove the air crossover from the turbocharger to the aftercooler. Refer to Procedure 010-019 in Section 10.
- Remove the propeller driveshaft, marine gear, and drive plate. Refer to the OEM service manual.
- Remove the starting motor. Refer to Procedure 013-020 in Section 13.
- Remove the flywheel. Refer to Procedure 016-005 in Section 16, if installed.
- Remove and seal the exhaust system.



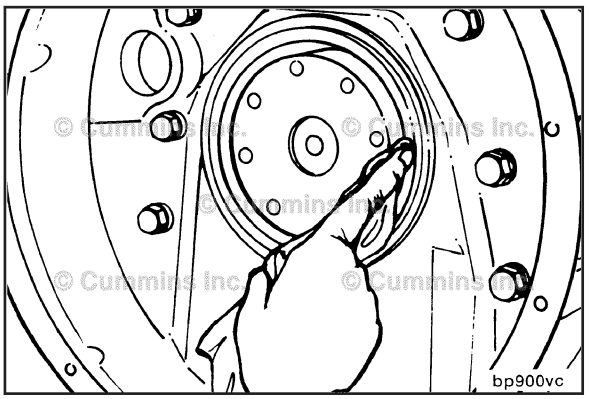


Remove

Drill two holes180 degrees apart into the seal.



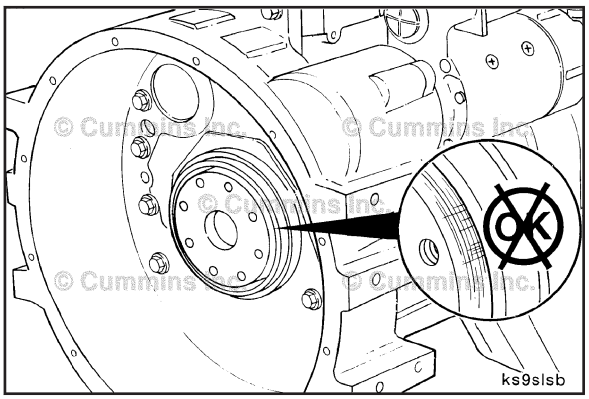
Use a screwdriver and a slide hammer to remove the rear seal.



Clean and Inspect for Reuse

⚠CAUTION⚠
The seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

Clean and dry the rear crankshaft sealing surface.



Inspect the crankshaft for excessive wear.

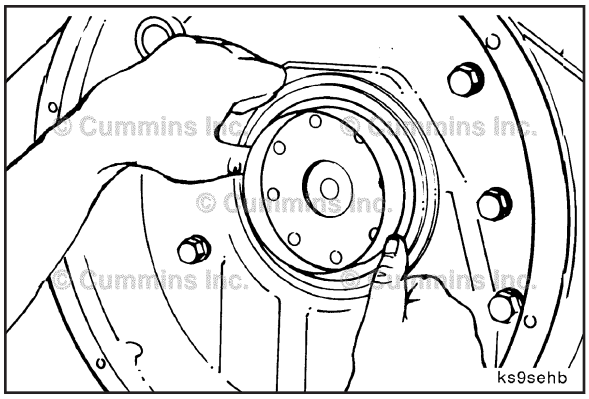
NOTE: If the crankshaft has excessive wear, a service wear sleeve is available. Refer to Procedure 001-067 in Section 1.

Install

NOTE: For installation, the oil seal requires the application of a mild soap solution on the outside diameter of the seal carrier.

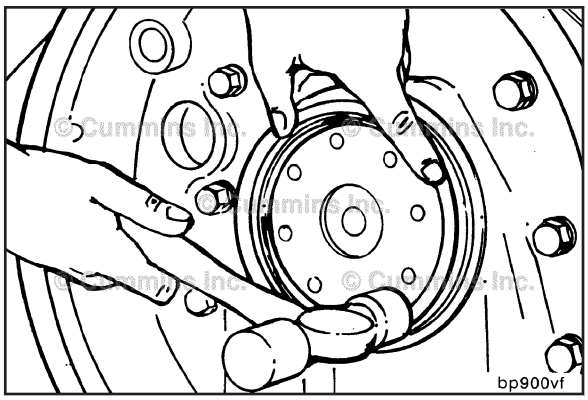
Install the seal pilot, provided in the replacement kit, onto the crankshaft. Push the seal onto the pilot and crankshaft.

Remove the seal pilot.



Use the alignment tool to install the seal to the correct depth in the housing. Use a hammer to drive the seal into the housing until the alignment tool stops against the housing.

Hit the tool at the 12, 3, 6 and 9-o'clock positions to drive the seal evenly and to prevent bending the seal carrier.

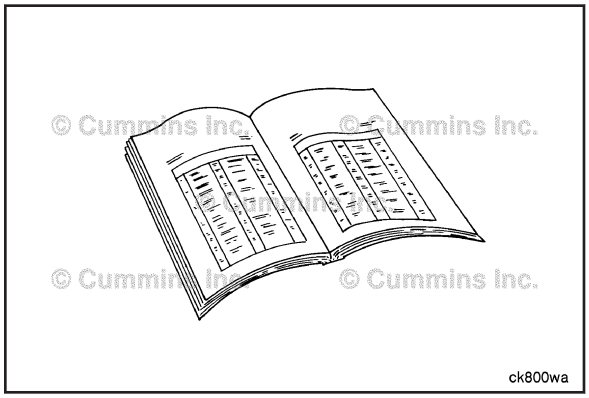


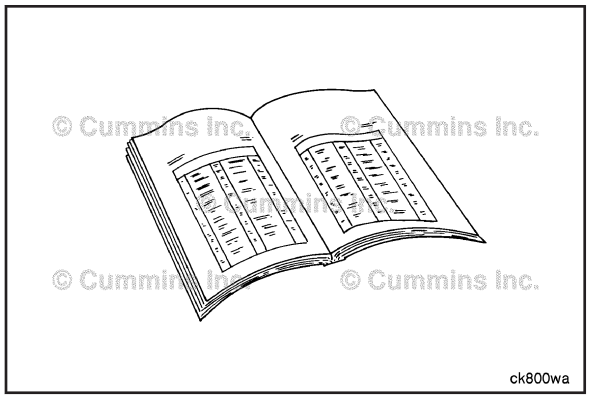
Finishing Steps

All Applications Except Marine

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the flywheel, if installed. Refer to Procedure 016-005 in Section 16.
- Install the flexplate, if installed. Refer to Procedure 016-004 in Section 16.
- Install the starting motor. Refer to Procedure 013-020 in Section 13.
- Install the clutch and transmission. Refer to the OEM service manual.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.



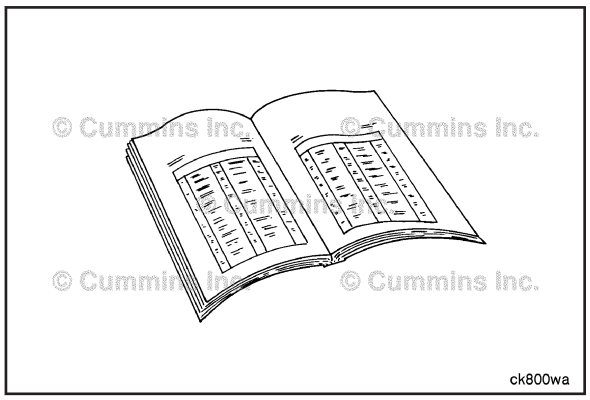


Marine Applications

⚠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 starting motor. Refer to Procedure 013-020 in Section 13.
- Install the drive plate and marine gear. Refer to the OEM service manual.
- Install the air crossover from the turbocharger to the aftercooler. Refer to Procedure 010-019 in Section 10.
- Lower the engine, if the engine was raised to replace the seal. Refer to Procedure 000-002 in Section 0.
- Install the propeller driveshaft. Refer to the OEM service manual.
- Install the exhaust system.
- Open the sea water valve. Refer to the OEM service manual.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.



Crankshaft Wear Sleeve, Front (001-025)

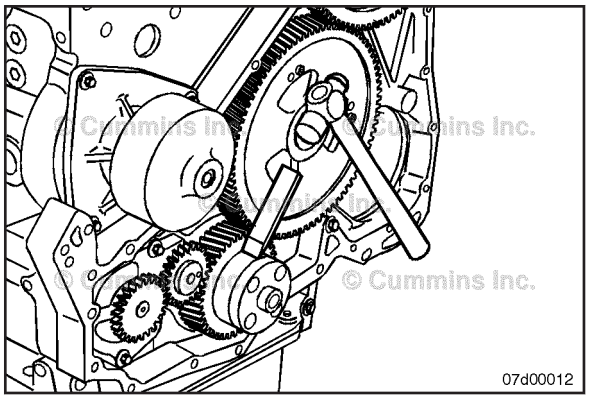
Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) cable first and attach the negative (-) cable last.

- Disconnect the batteries.
- Remove the drive belt.
- Remove the vibration damper.
- Remove the front cover.

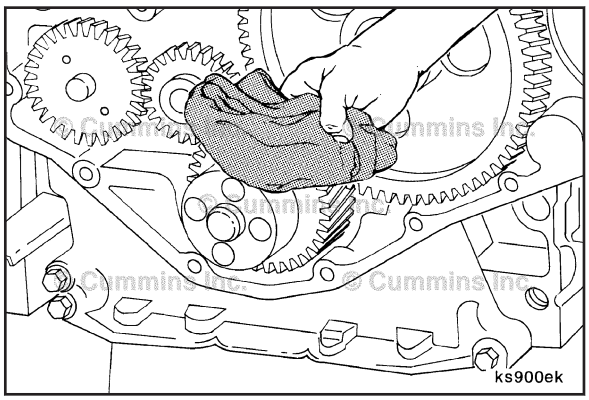
Remove



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

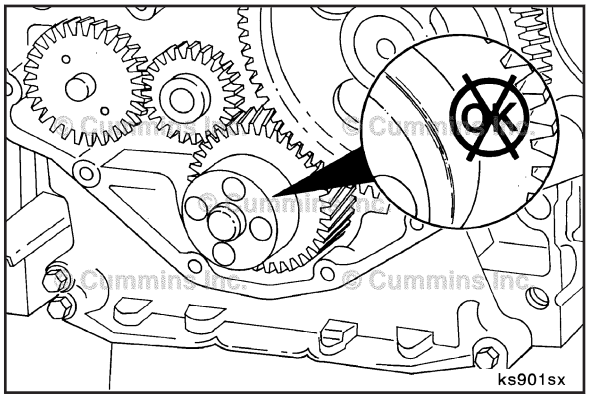
Use a hammer and a chisel that is only as wide as the wear sleeve. Make one or two chisel marks across the wear sleeve. This will expand the wear sleeve allowing the sleeve to be removed.

Clean and Inspect for Reuse



Use a crocus cloth to remove any rust or other deposits from the crankshaft flange.

Use a clean cloth to clean the crankshaft flange.



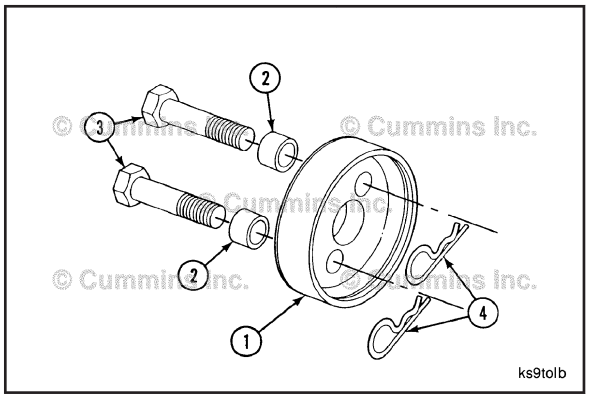
Inspect the seal contact area of the crankshaft for a wear groove. If the seal has worn a groove deep enough to be felt with a sharp object or fingernail, it will be necessary to install a wear sleeve to prevent an oil leak.

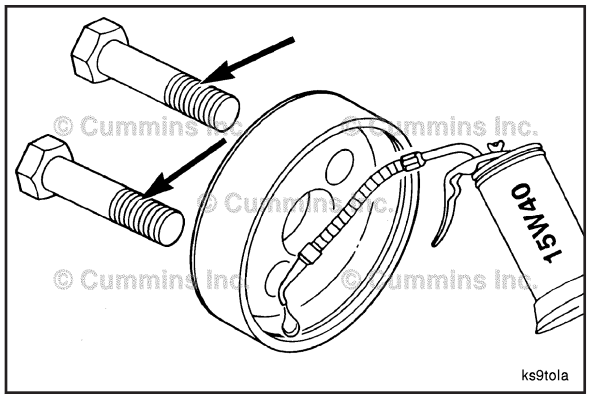
The oil seal used with the wear sleeve has a larger inside diameter than the standard seal. The two seals are **not** interchangeable. See the appropriate parts catalog for the correct part number.

Install

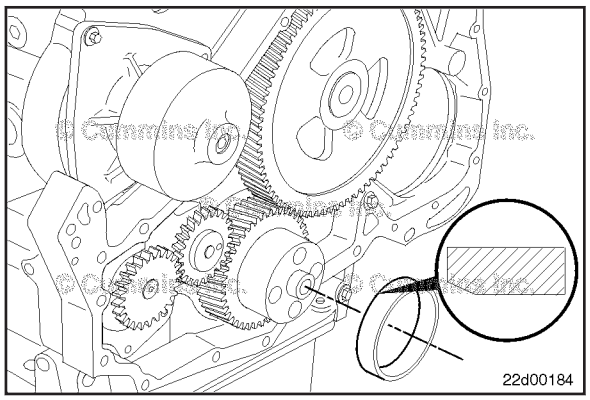
Use the wear sleeve installation kit, Part Number 3165112, to install the wear sleeve to the correct position on the crankshaft. The kit consists of the following:

Reference Number	Description	Quantity
1	Driver	1
2	Spacer	3
3	Capscrew M14x1.5x60 mm	3



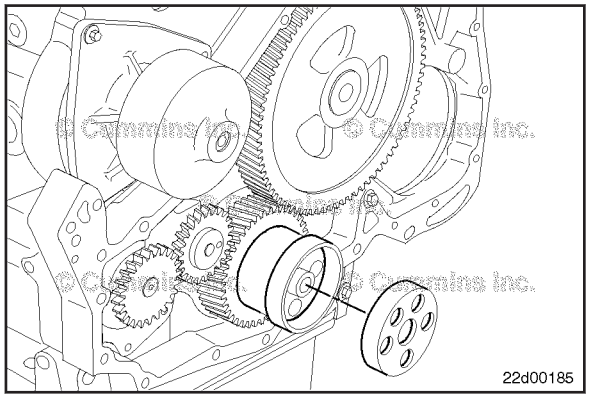


Apply a thin coat of clean 15W-40 lubricating oil to the inside diameter of the driver and to the capscrew threads.

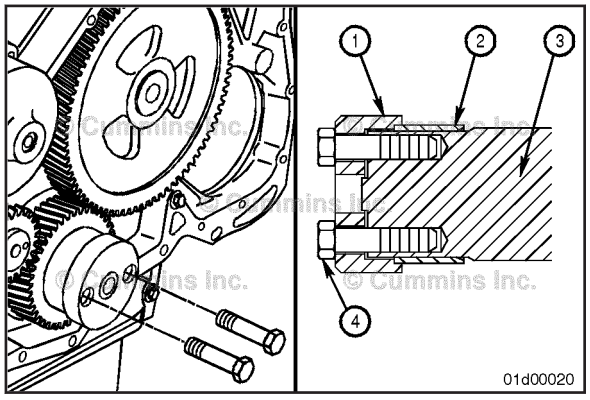


Apply a thin coat of clean 15W-40 lubricating oil to the crankshaft flange.

Position the chamfered end of the wear sleeve onto the end of the crankshaft.



Position the counterbore end of the driver onto the wear sleeve.



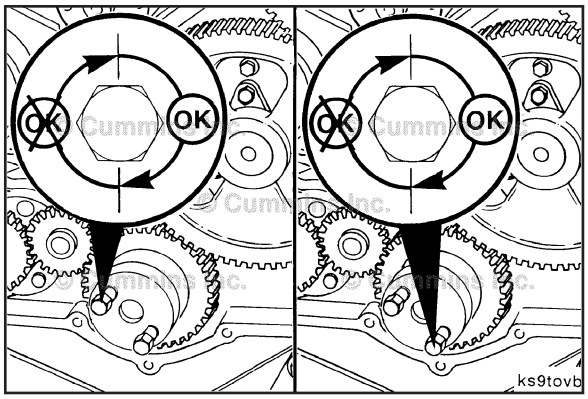
Install the capscrews (without spacers) through the driver and into the crankshaft capscrew holes. Align the wear sleeve and driver perpendicular with the crankshaft. Tighten the capscrews ”finger tight”.

1. Driver
2. Wear Sleeve
3. Crankshaft
4. Capscrew

NOTE: To prevent damage to the wear sleeve, do **not** exceed 1/2 revolution of each capscrew.

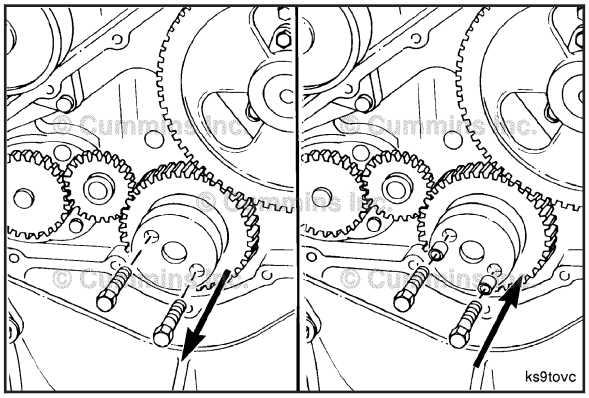
Alternately tighten the capscrews until the sleeve is installed to a depth of approximately 16 mm [0.625 in].

Torque Value: 20 N•m [180 in-lb]

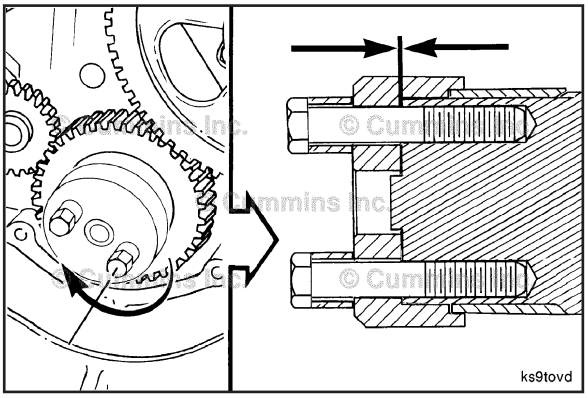


Remove the capscrews and install the spacer on each capscrew.

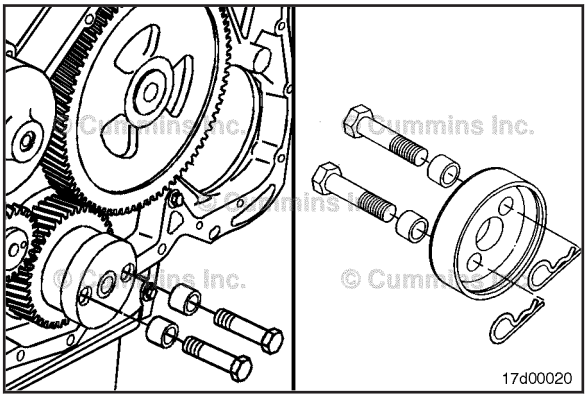
Install the capscrews again.

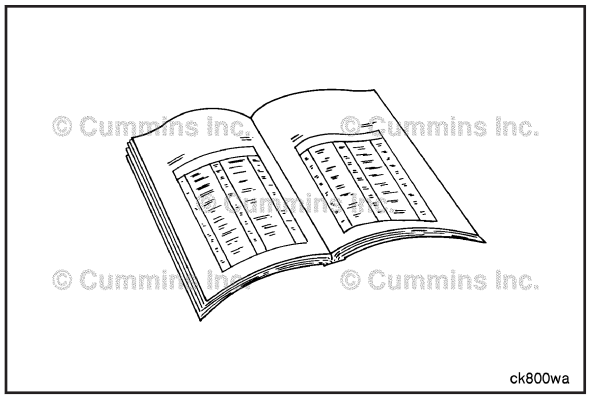


Continue to alternately tighten the capscrews until the bottom of the driver contacts the end of the crankshaft.



Remove the driver.



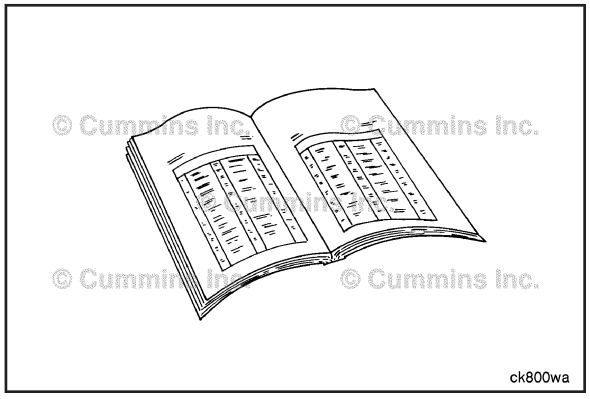


Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) cable first and attach the negative (-) cable last.

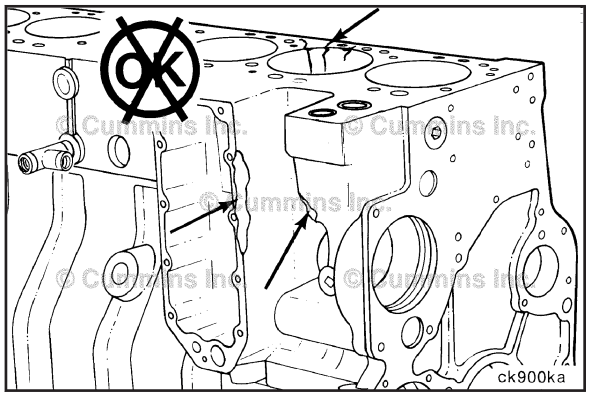
- Install the gear cover.
- Install the vibration damper.
- Install the drive belt.
- Connect the batteries.
- Operate the engine and check for leaks.



Cylinder Block (001-026)

Preparatory Steps

- Remove the engine and place it on an engine stand. Refer to Procedure 000-001 in Section 0.
- Disassemble the engine. See Section DS - Engine Disassembly.



Initial Check

Before cleaning or further disassembly of the block, perform an inspection to see if there is any damage (cracks, fretting, etc.) that would prohibit reuse. Give special attention to areas of the block that include:

- Main bearing caps and bores
- Camshaft bores
- Cylinder bores
- Tappet bores
- Cylinder block combustion deck
- Oil pan mounting surface
- Lubricating oil pump mounting area
- Water pump mounting area
- Front and rear of block sealing surfaces
- Lubricating oil cooler cavity.

Clean and Inspect for Reuse

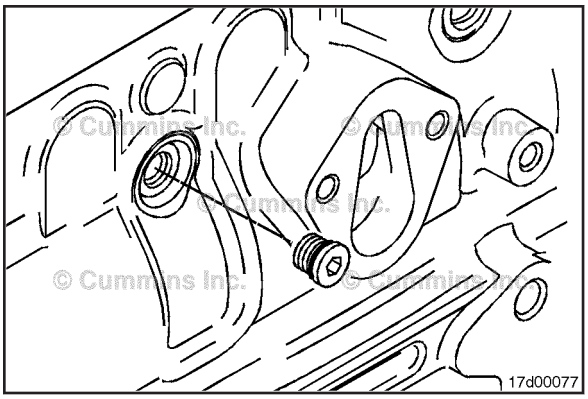
Inspect all pipe plugs, expansion plugs, and straight thread plugs for signs damage or leaks.

If it is necessary to thoroughly clean the cylinder block for reuse, remove all pipe plugs, expansion plugs, and straight thread plugs, as necessary. This will make sure all oil and coolant passages can be cleaned out.

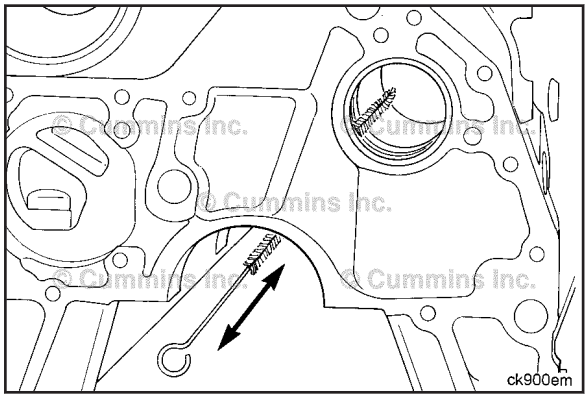
Refer to Procedure 017-002 in Section 17.

Refer to Procedure 017-007 in Section 17.

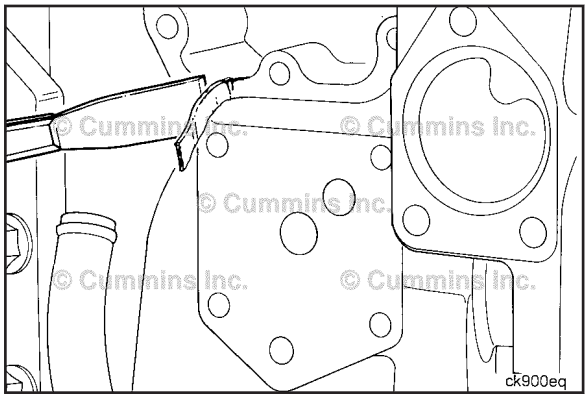
Refer to Procedure 017-011 in Section 17.



Use clean solvent and a non-metallic brush to clean the block oil drillings.

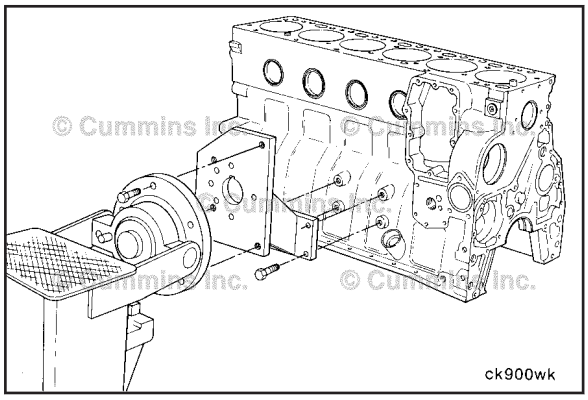


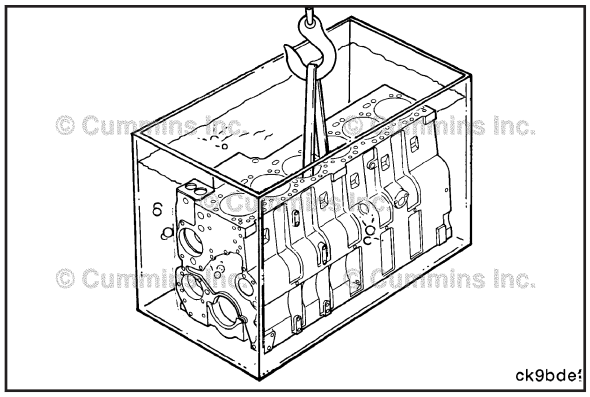
Thoroughly clean all gasket sealing surfaces of any remaining gasket residue.



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

Remove the block from the engine stand.





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

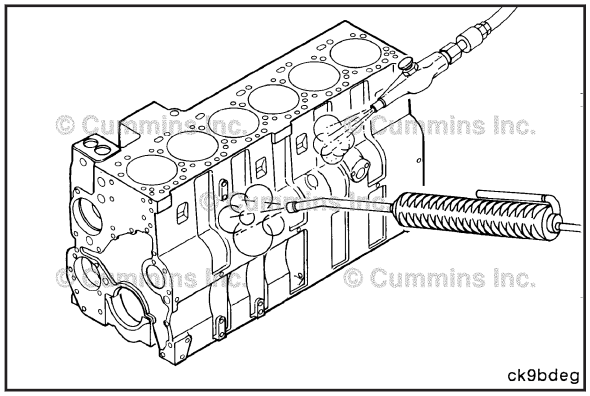
△CAUTION△
If the camshaft bushings have not been removed, make sure to use a cleaning solution that will not damage the camshaft bushing(s).

Follow the manufacturer's operating instructions for the cleaning tank.

Follow the solvent manufacturer's instructions for using the solvent.

NOTE: Cummins Inc. does **not** recommend any specific cleaning solution. Experience has shown the best results are obtained by the use of a cleaning solution that can be heated from 80 to 95°C [176 to 203°F] and a cleaning tank that will mix and filter the cleaning solution.

Clean the cylinder block in the cleaning tank.



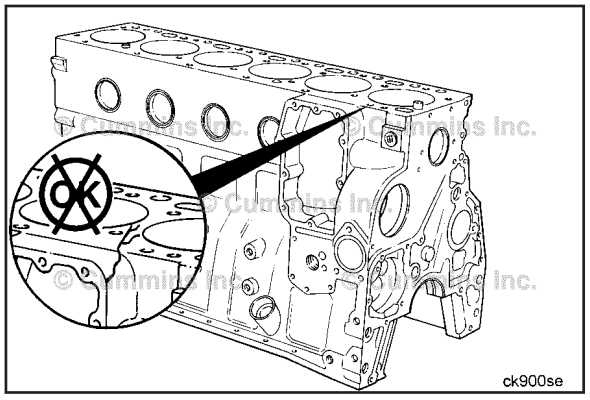
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

△CAUTION△
To reduce the possibility of engine damage, make sure all debris is removed from the capscrew holes and oil passages.

Remove the block from the cleaning tank.

Use steam to clean the block thoroughly.

Use compressed air to dry the block.



With the cylinder block cleaned, inspect the cylinder block for signs of cracks, fretting, and discoloration that would prohibit reuse.

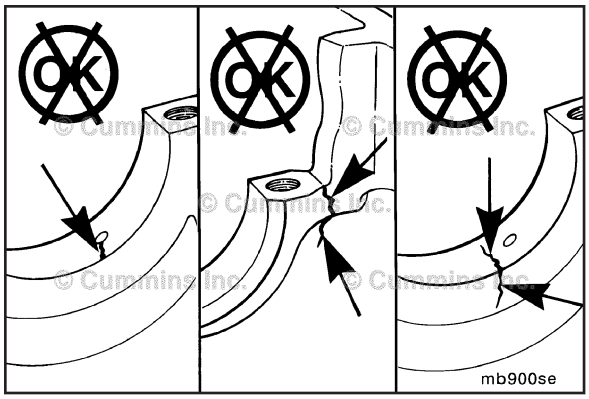
To help identify cracks in the cylinder block, use the crack detection kit, Part Number 3375432.

Give special attention to areas of the block that include:

- Main bearing caps and bores
- Camshaft bores
- Cylinder bores
- Tappet bores
- Cylinder block combustion deck
- Oil pan mounting surface
- Lubricating oil pump mounting area
- Water pump mounting area
- Front and rear of block sealing surfaces
- Lubricating oil cooler cavity.

Make sure to inspect the main bearing caps and main bearing saddle areas for cracks, fretting and signs of discoloration.

If any cracks are found, the block **must** be replaced.



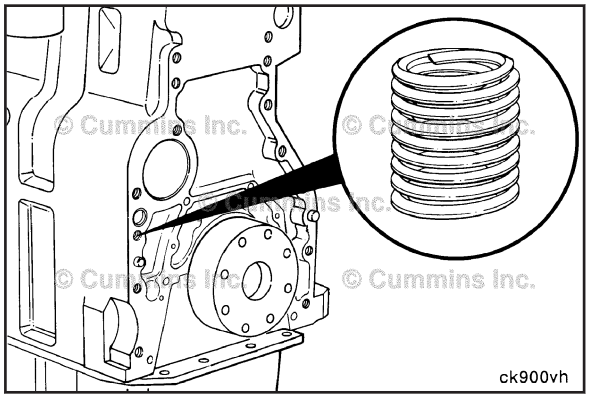
Inspect all threaded capscrew holes for damaged threads. Coiled thread inserts may be used to repair any damaged threads.

Service tool thread repair kits are available:

1 Part Number 3377905 for standard threads.

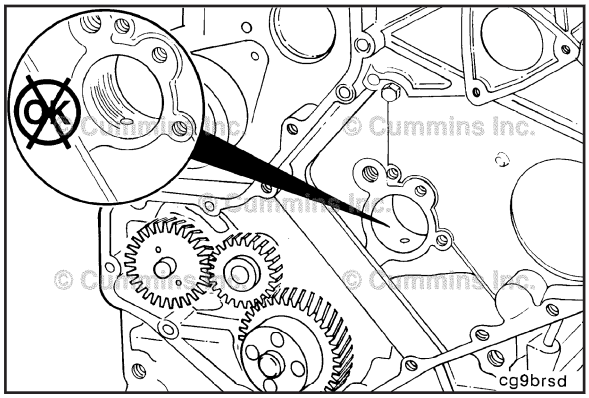
2 Part Number 3377903 for metric threads.

NOTE: Coiled thread inserts should **not** be used to repair main bearing saddle threaded capscrew holes. If damaged, the block **must** be replaced.



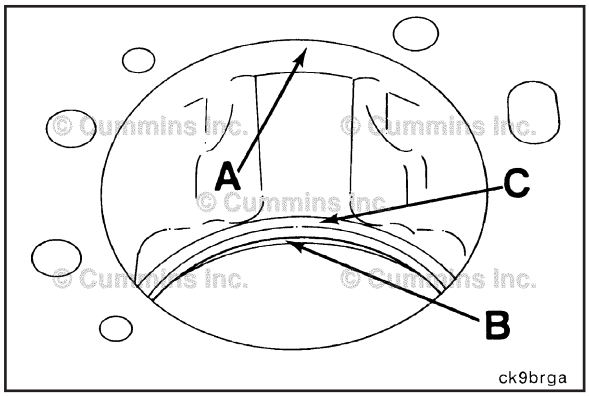
Inspect the camshaft bores for scoring, scuffing, or excessive wear.

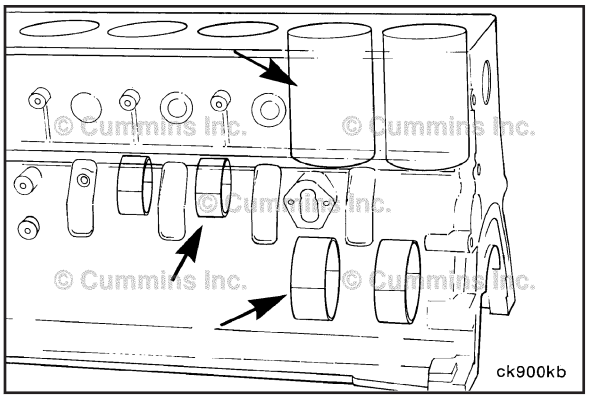
If the camshaft bore is damaged, the cylinder block **must** be replaced. Oversize cam bushings are **not** available.



Inspect the counterbore for extreme wear or cracks.

If surface C has signs of extreme wear, the counterbore will require machining and the installation of shims for the correct liner protrusion. See the Repair section of this procedure.

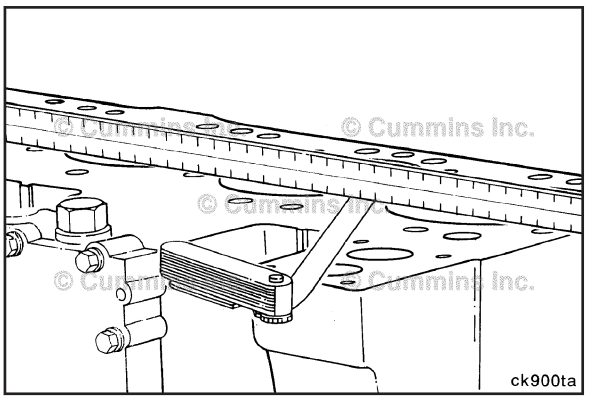




Measure

All measurements of the cylinder block **must** be made when the cylinder block is positioned on a flat surface with the main bearing caps installed.

If the cylinder block is mounted on the engine stand and/or the main bearing caps are **not** installed, the measurements can be incorrect because of distortion to the cylinder bores, main bearing bores, camshaft bores, etc.

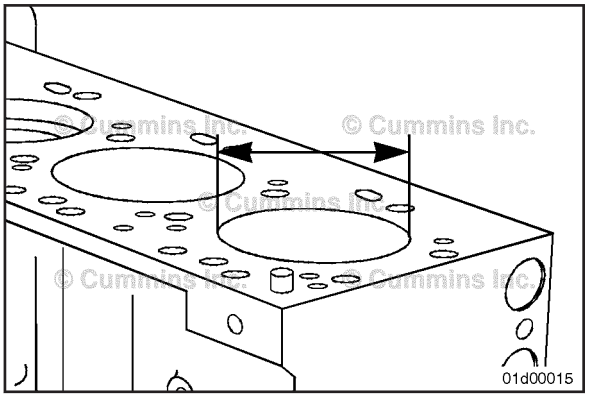


Inspect the cylinder block head deck for damage.

Check the cylinder block head deck for flatness between each cylinder.

Cylinder Block Flatness Specification		
mm		**in**
0.075	End-to-end	0.003
0.075	Side-to-side	0.003

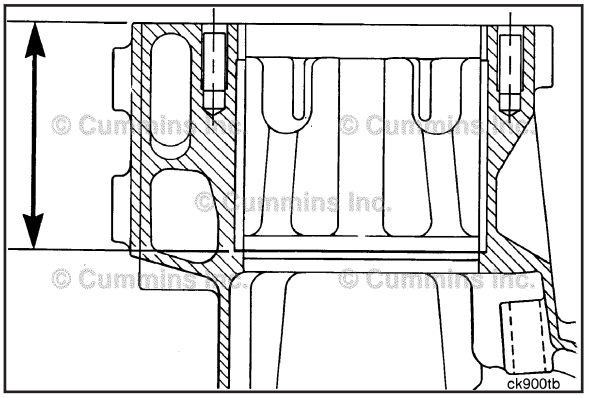
Inspect for any localized dips or imperfections. If any damage is detected, or the flatness is out of specification, the cylinder block **must** be replaced.



Measure the cylinder liner bore in the block.

Cylinder Liner Bore in Block (Press Fit Bore)		
mm		**in**
130.900	MIN	5.1535
130.950	MAX	5.1555

NOTE: If any of the cylinder liner bores are out of specification, the cylinder block **must** be replaced.



Measure the liner counterbore depth.

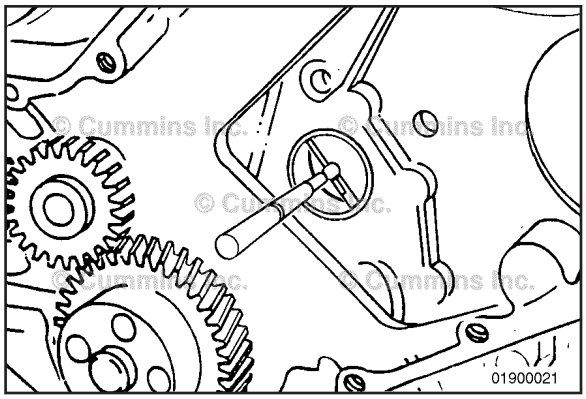
Cylinder Block Counterbore Depth from Cylinder Block Head Deck		
mm		**in**
122.930	MIN	4.8397
123.000	MAX	4.8425

NOTE: If any of the liner counterbore depths are out of specification, the counterbore can be machined and shims installed. See the Repair section of this procedure.

Measure the camshaft bores without the camshaft bushing installed.

Camshaft Bore Diameter (Without Bushing)		
mm		in
64.01	MAX	2.520

NOTE: If any of the camshaft bore diameters are out of specification, the cylinder block **must** be replaced.

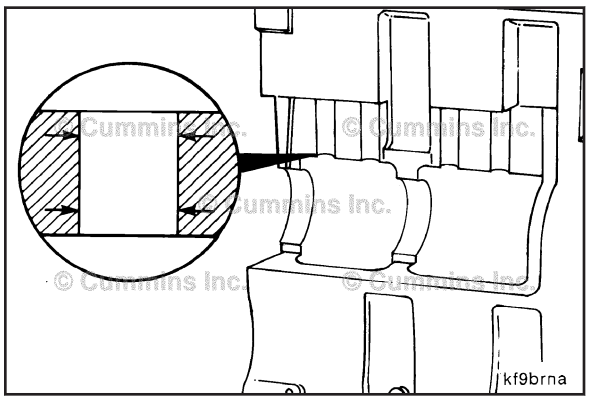


Inspect the tappet bores for scoring or excessive wear.

Measure the tappet bores.

Tappet Bore Diameter		
mm		in
31.295	MIN	1.2321
31.325	MAX	1.2333

NOTE: If any of the tappet bores are out of specification, the cylinder block **must** be replaced.



Install the main bearing caps without the main bearings. Refer to Procedure 001-006 in Section 1.

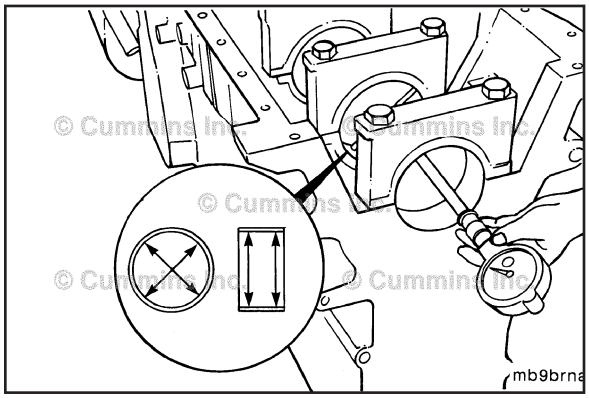
Tighten the main bearing cap capscrews.

Torque Value: 176 N•m [130 ft-lb]

Measure the main bearing bore with the bearings removed.

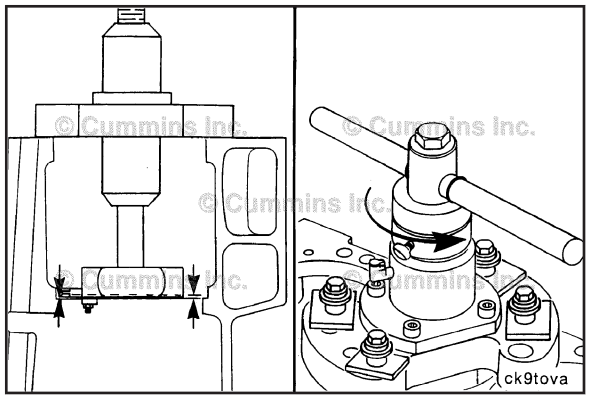
Main Bearing Bore Diameter		
mm		in
104.982	MIN	4.1331
105.018	MAX	4.1346

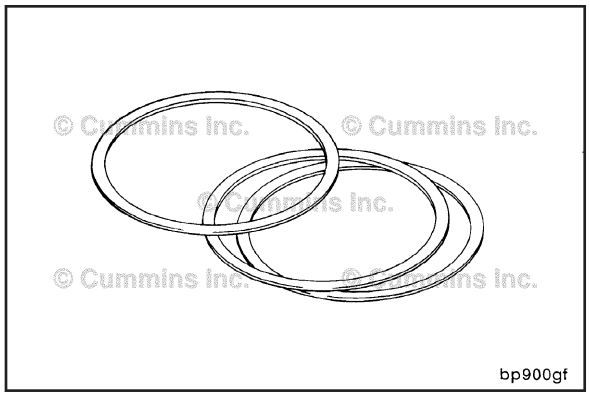
NOTE: The maximum bore misalignment is 0.0127 mm [0.005 in].



Repair

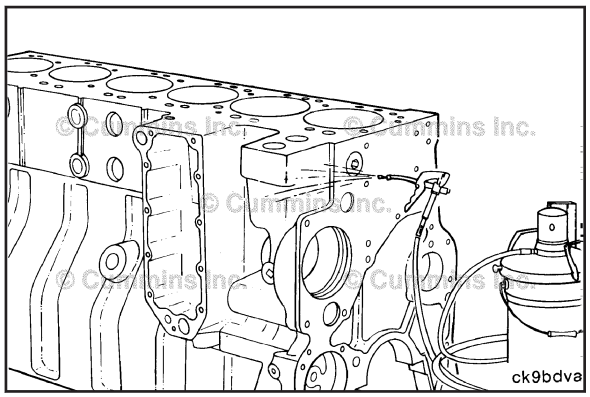
If the counterbores require machining, use counterbore cutter, Part Number 3163785, to machine the counterbore to the proper depth.





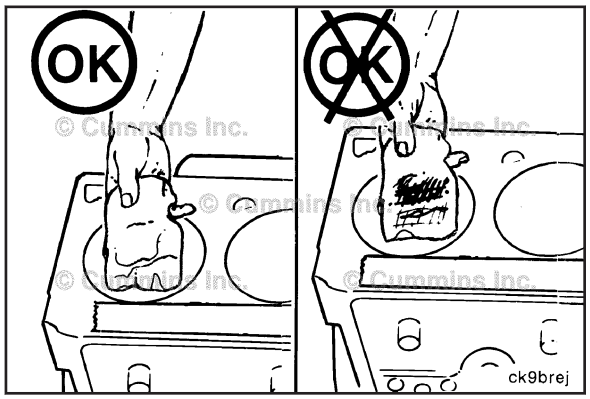
Cylinder liner shims are available in the following thicknesses.

Cylinder Liner Shim Thickness	
mm	**in**
0.25	0.010
0.38	0.015
0.51	0.020
0.76	0.030
1.00	0.040



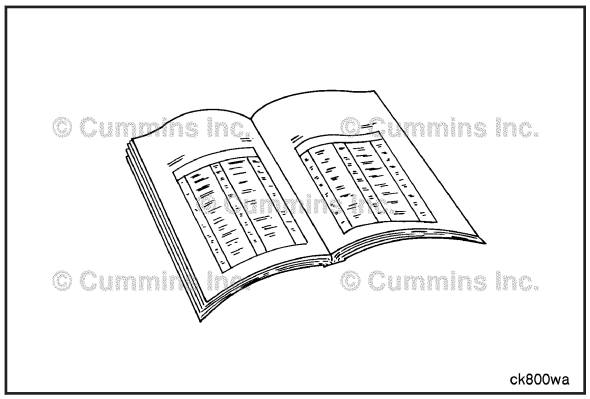
If the cylinder block is **not** to be used right away, coat all machined surfaces with a rust preventative solvent.

Make sure to cover the cylinder block to prevent dust and debris from collecting on and in the cylinder block.



New Cylinder Block

If replacing the cylinder block or using a previously stored cylinder block, make sure to clean any oil/rust preventative solvent from the cylinder bores, gasket sealing areas, and main bearing bores prior to use.



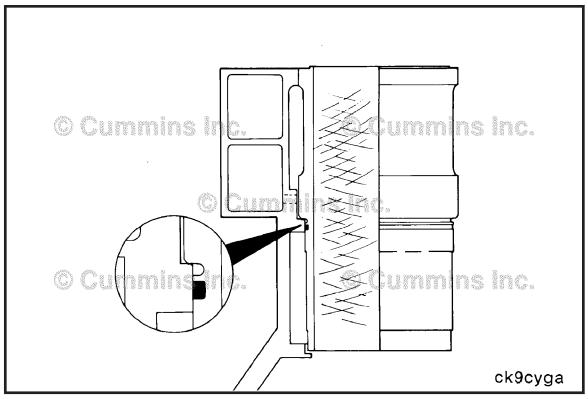
Finishing Steps

- Assemble the engine. See Section AS - Engine Assembly.
- Remove the engine from the engine stand and install the engine. Refer to Procedure 000-002 in Section 0.

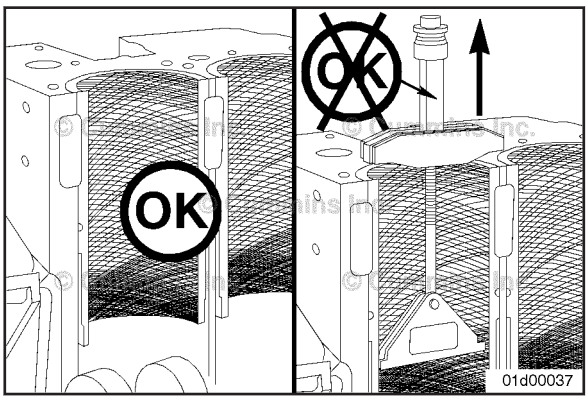
Cylinder Liner (001-028)

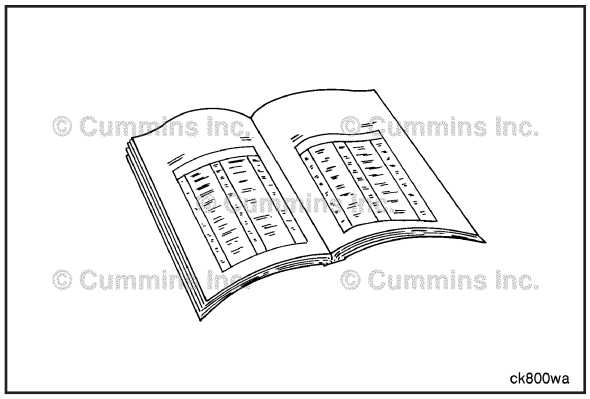
General Information

The cylinder block has a replaceable cylinder liner. A mid-stop design is used to locate the liner in the block. A press fit between the liner and the block provides coolant sealing at the top of the liner. A rectangular ring seal (liner seal) is used for sealing at the mid-stop portion of the liner.



NOTE: Cummins Inc. does **not** recommend removing the cylinder liners to repair an oil consumption problem if the inside diameters of the liners are within the inspection limits included in this procedure. Careful analysis of the condition of the liner bores, piston rings, and pistons can result in the restoration of cylinder sealing with a minimum replacement of parts.





Preparatory Steps

All Applications Except Marine

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

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

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

- Disconnect the batteries. See equipment manufacturer service information.
- Drain the cooling system. Refer to Procedure 008-018 in Section 8.
- Remove rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the cylinder head. Refer to Procedure 002-004 in Section 2.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Remove the piston and connecting rod assemblies. Refer to Procedure 001-054 in Section 1.

Marine Applications

⚠ WARNING ⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ WARNING ⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

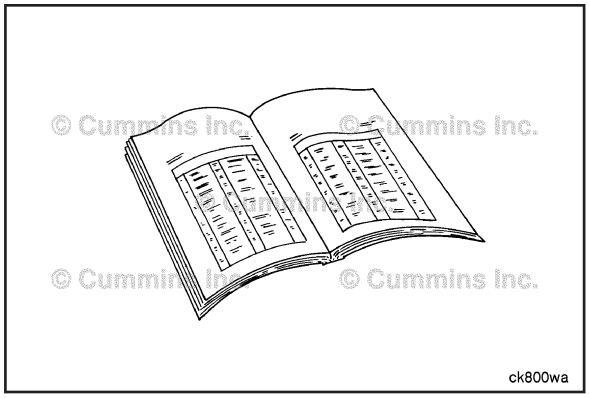
⚠ WARNING ⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

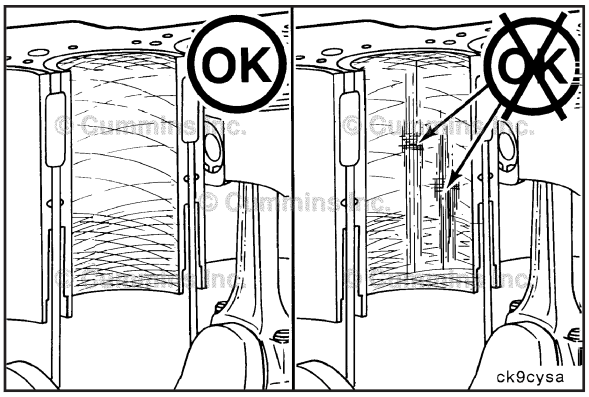
⚠ WARNING ⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

△ CAUTION △
Use caution when disconnecting or removing fuel lines and replacing filters 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 △
Use caution when draining the coolant. Do not spill coolant into the bilge area. Coolant must not be pumped overboard. The coolant must be disposed in accordance with local environmental regulations.

- Disconnect the batteries. See equipment manufacturer service information.
- Shut off the sea water supply. See equipment manufacturer service information.
- Drain the engine coolant system. Refer to Procedure 008-018 in Section 8.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Shut off the fuel supply to the engine. See equipment manufacturer service information.
- Remove the engine from the vessel. Refer to Procedure 000-001 in Section 1.
- Remove the valve cover. Refer to Procedure 003-011 in Section 3.
- Remove the cylinder head. Refer to Procedure 002-004 in Section 2.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Remove the piston and connecting rod assemblies. Refer to Procedure 001-054 in Section 1.





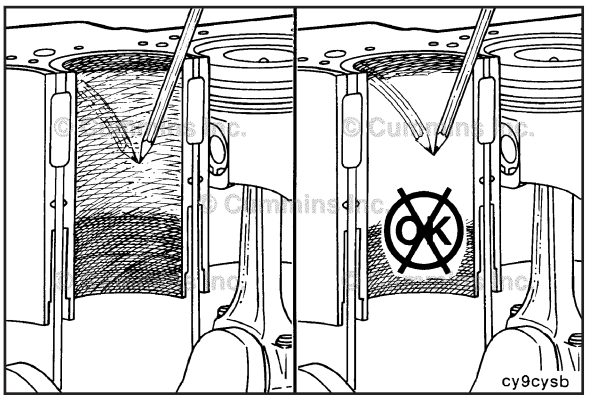
Initial Check

NOTE: Before removing the cylinder liners, inspect the condition to determine reuse.

Inspect the inside diameters of the liners for cracks, scuffing, and scoring.

Inspect the inside diameters for vertical scratches deep enough to be felt with a fingernail.

NOTE: If a fingernail catches in the scratch, the liner **must** be replaced.

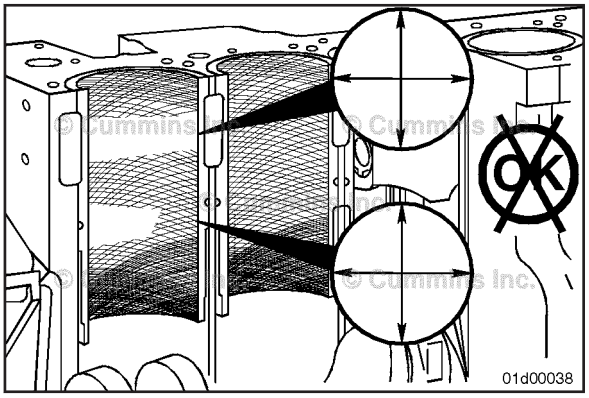


Inspect the inside diameter for liner bore polishing.

A moderate polish produces a bright mirror finish in the worn area with traces of the original hone marks or an indication of an etch pattern.

A heavy polish produces a bright mirror finish in the worn area with no traces of hone marks or an etch pattern.

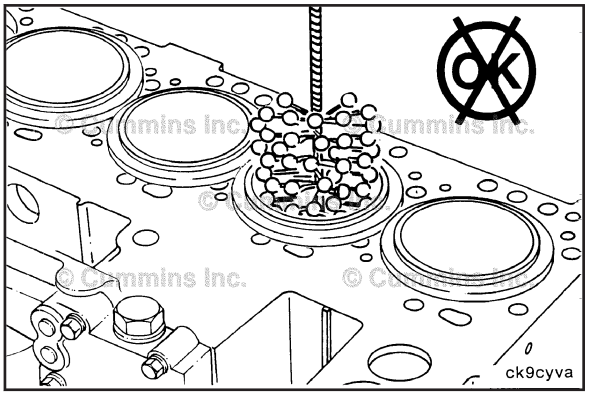
Do **not** reuse liners exhibiting heavy polish or any indications of particle embedment from a failure. Severely worn liners will have a ridge near the top of the liner bore.



If the wear pattern indicates the liner bore is **not** straight or **not** round, use a dial bore gauge to measure the liner inside diameter in four places 90 degrees apart at the top and bottom of the piston travel area.

Cylinder Liner Dimensions

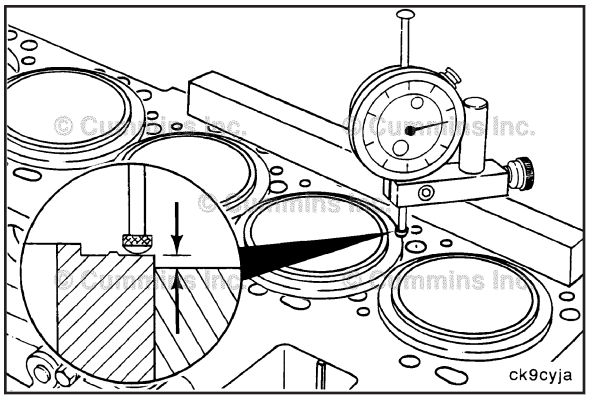
	mm		in
Taper	0.04	MAX	0.0016
Out Of Round	0.04	MAX	0.0016
Bore Diameter	114.04	MAX	4.4898



NOTE: If a liner bore is **not** acceptable for reuse, it **must** be replaced. Damaged liners can **not** be honed or deglazed. This would destroy the cross-hatch pattern needed for oil control.

NOTE: Do **not** remove or disturb the liner seals for liners which pass the inspection criteria.

Liner protrusion is the distance the liner protrudes above the block face. Before removing the liners, check the protrusion in the "unclamped" stage. Use liner protrusion gauge, Part Number 3164438, to measure the liner protrusion.

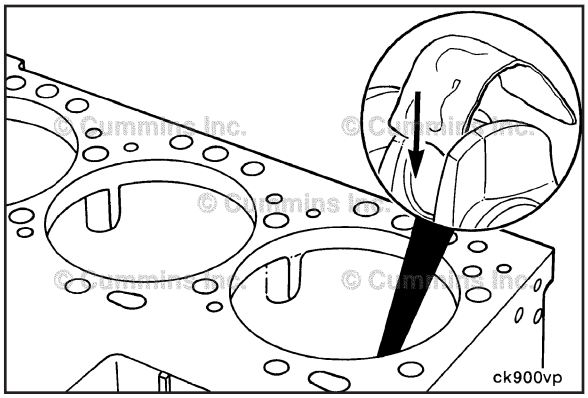


Cylinder Liner Protrusion		
mm		in
0.026	MIN	0.0010
0.122	MAX	0.0048

If the liner was installed correctly and the liner protrusion is out of limits, it will be necessary to machine the counterbore and add shims to restore to the original specifications.

Remove

Use clean shop rags to cover the crankshaft to prevent debris from falling into the main journal area or into the connecting rod journal oil drilling.

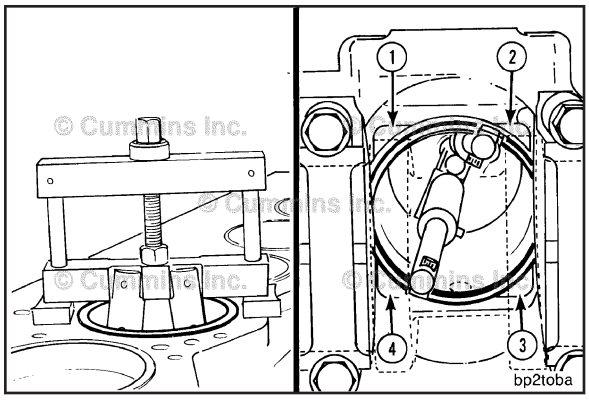


CAUTION
The liner puller must be installed and used as described to avoid damage to the cylinder block. The puller must not contact the block casting at points (1), (2), (3), and (4).

Universal cylinder liner puller method.

Cylinder liner puller, Part Number 3376015.

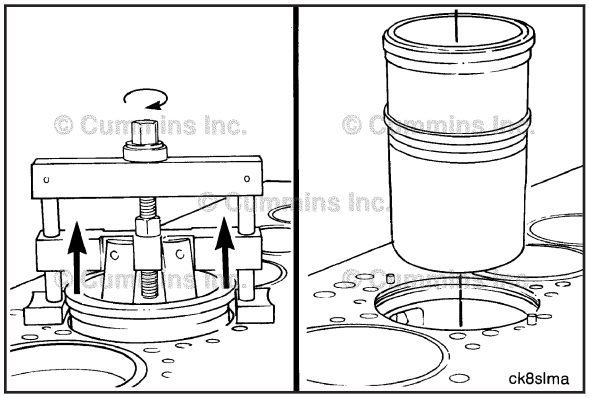
Insert the liner puller into the top of the cylinder block.

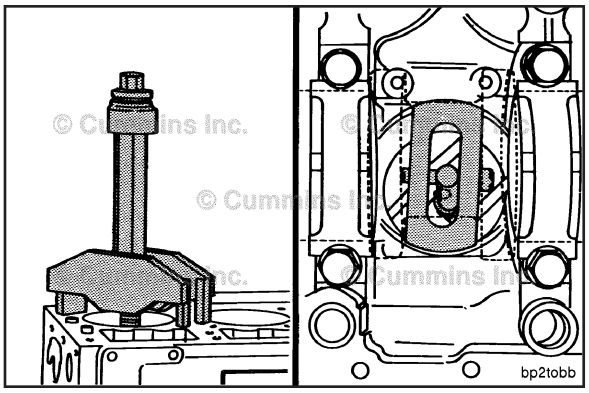


NOTE: The liner puller **must** be centered on the top of the cylinder block.

Turn the puller jackscrew **clockwise** to loosen the liner from the cylinder block.

Use both hands to remove the liner.



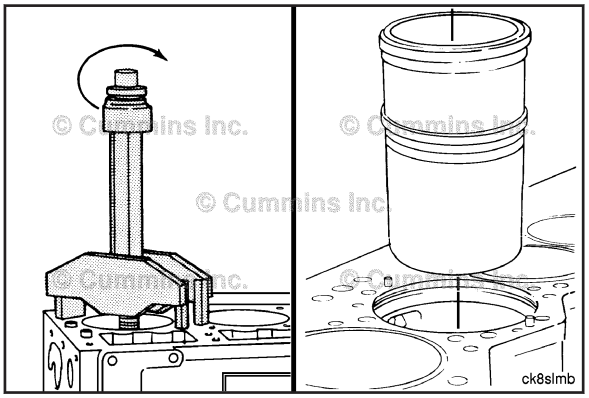


CAUTION
The liner puller must be installed and used as described to reduce the possibility of damage to the cylinder block. The puller plate must be parallel to the main bearing saddles and must not overlap the liner outside diameter.

Standard Liner Puller Method

Liner Puller, Part Number 3163745, may be used as an alternative to the standard puller. The universal puller **must** be used with remover plate, Part Number 3822786.

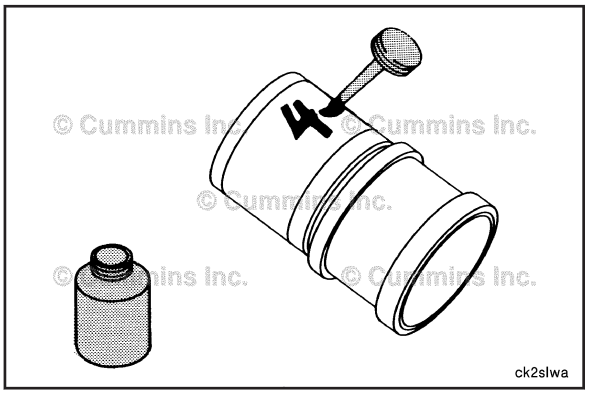
Insert the liner puller into the top of the cylinder block.



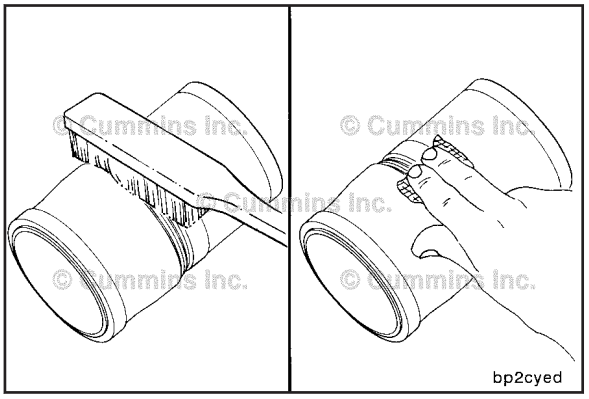
NOTE: The liner puller **must** be centered on the top of the cylinder block.

Turn the puller jackscrew **clockwise** to loosen the liner from the cylinder block.

Use both hands to remove the liner.



Mark the cylinder number on each liner.



Clean and Inspect for Reuse

CAUTION
Do not use any abrasives in the ring travel area of the liner. The liner can be damaged.

Use a soft wire brush or a fine fibrous abrasive pad such as abrasive pad, Part Number 3823258 or equivalent, to clean the flange seating area.

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

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

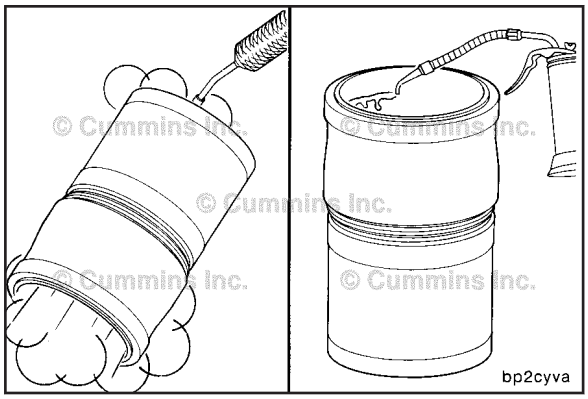
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use solvent or steam clean the liners and dry with compressed air.

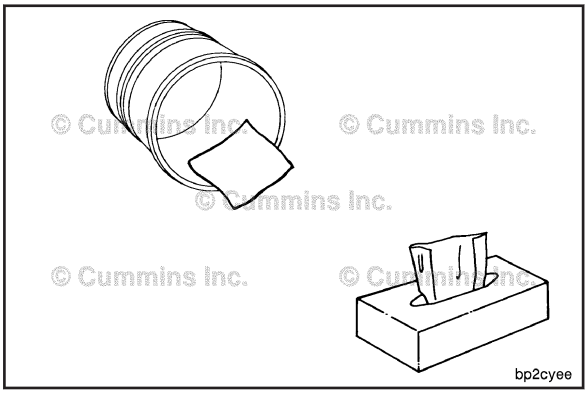
Use clean 15W-40 oil to lubricate the inside diameter of the liners.

Allow the oil to soak in the liner for 5 to 10 minutes.

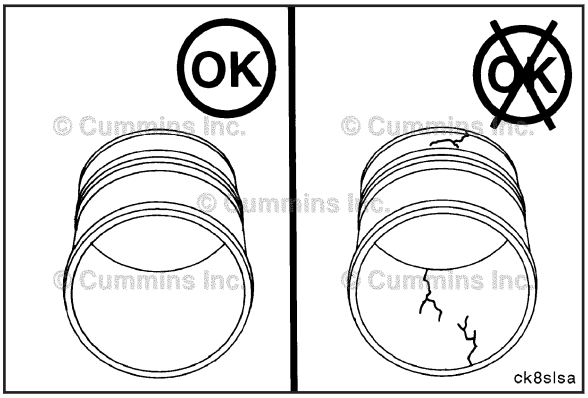


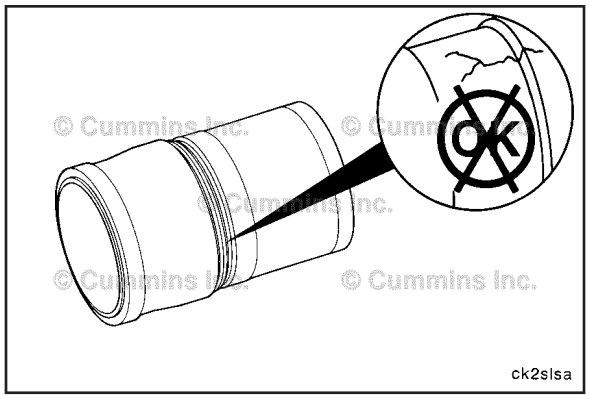
NOTE: Use "lint-free" paper towels to wipe the oil from the inside of the liners.

Continue to lubricate the inside of the liners and wipe clean until the paper towel does **not** show gray or black residue.

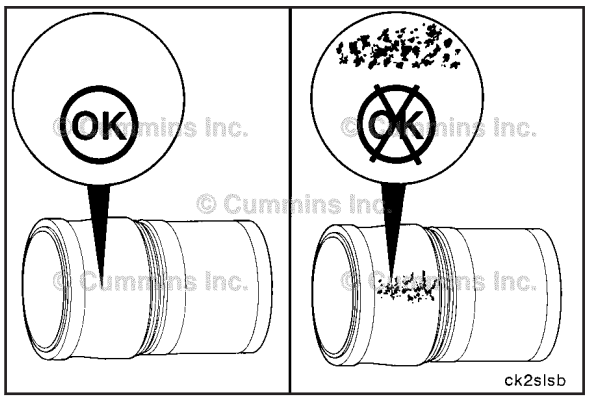


Inspect the liners for cracks on the inside and outside diameters.





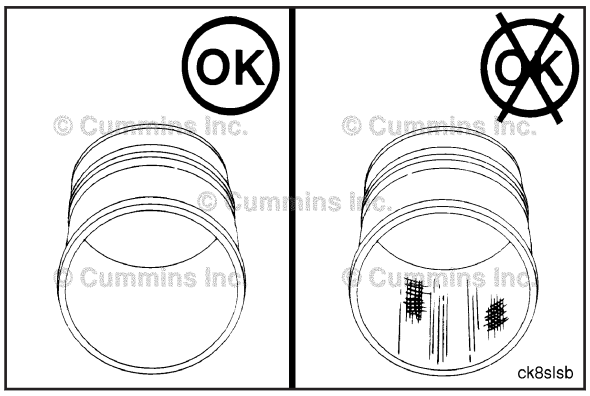
Inspect for cracks under the flange.



Inspect the outside diameter and seat area for excessive corrosion or pitting.

NOTE: Pits must **not** be more than 1.6 mm [0.06 in] deep.

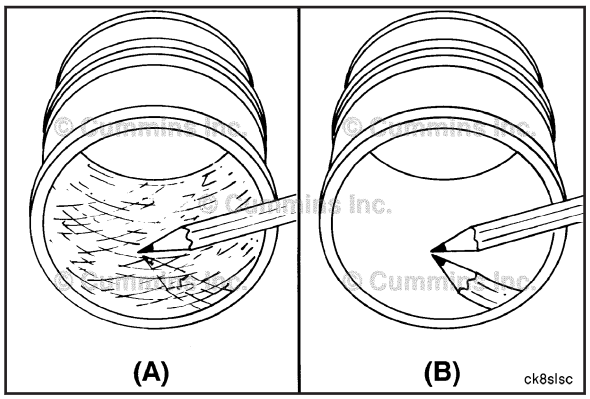
Replace the liner if the pits are too deep or if the corrosion can **not** be removed with fine emery cloth.



Inspect the inside diameters for vertical scratches deep enough to be felt with a fingernail.

NOTE: If a fingernail catches in the scratch, the liner **must** be replaced.

Inspect the inside diameter for scuffing or scoring.



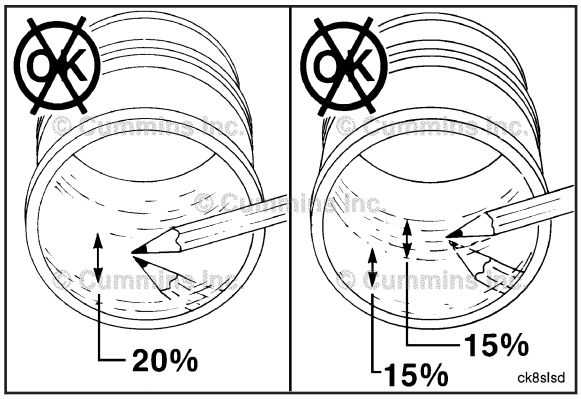
Inspect the inside diameter for liner bore polishing.

A moderate polish produces a bright mirror finish in the worn area with traces of the original hone marks or an indication of an etch pattern.

A heavy polish produces a bright mirror finish in the worn area with no traces of hone marks or an etch pattern.

Replace the liner if:

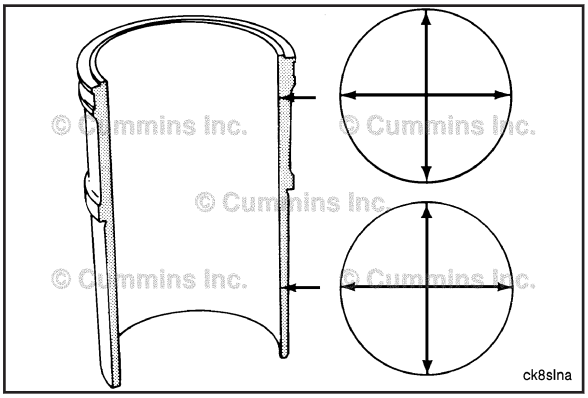
- A heavy polish is present over 20 percent of the piston ring travel area.
- Both moderate and heavy polish over 30 percent of the piston ring travel area and one half (15 percent) is heavy polish.



Dial Bore Gauge, Part Number 3376619.

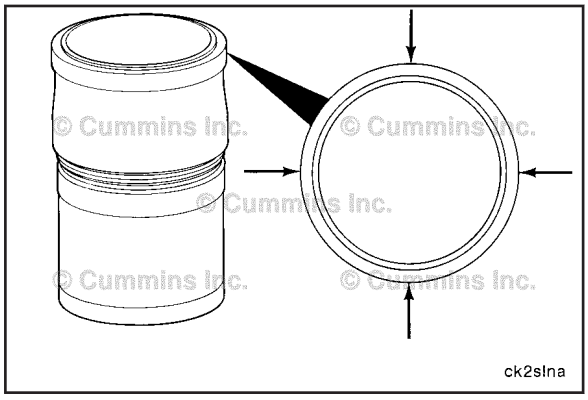
Measure the liner inside diameter in four places 90 degrees apart at the top and bottom of the piston travel area.

Cylinder Liner Inside Diameter		
mm		in
114.000	MIN	4.4882
114.040	MAX	4.4898

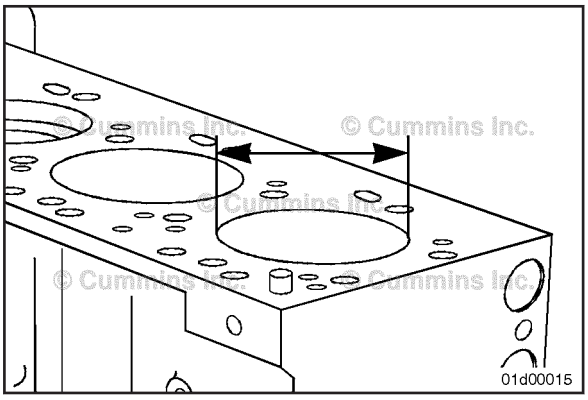


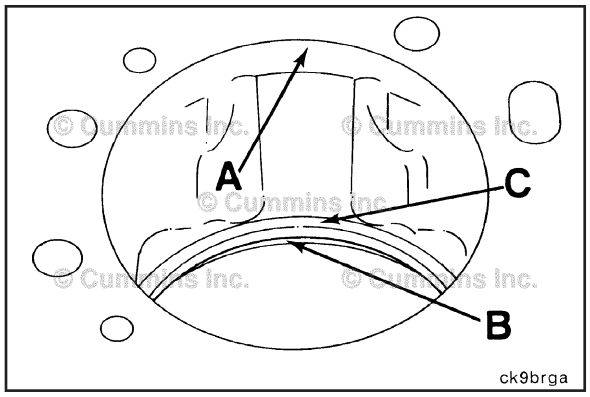
Measure the outside diameter of the liner top press fit area.

Cylinder Liner Out Diameter (Top Press Fit)		
mm		in
130.938	MIN	5.1550
130.958	MAX	5.1558



Cylinder Liner Bore in Block (Press Fit Bore)		
mm		in
130.900	MIN	5.1535
130.950	MAX	5.1555

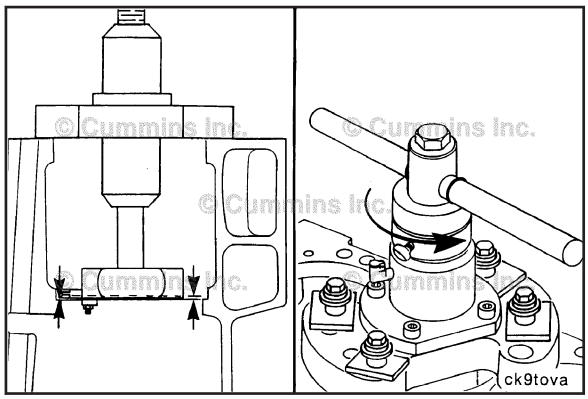




Install

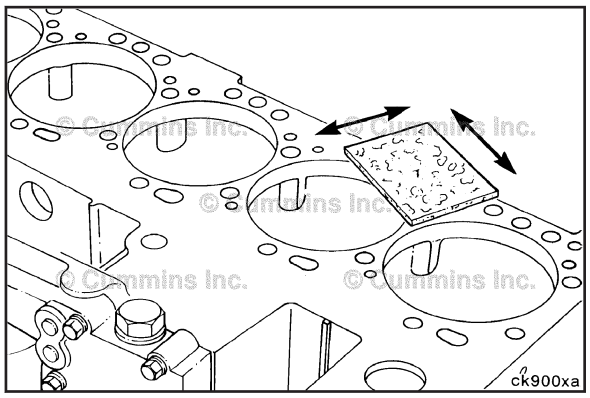
⚠CAUTION⚠
Clean all deposits and debris from sealing surfaces A, B, and C. Use abrasive pad, Part Number 3823258, or equivalent, and cleaning solvent to polish the surfaces. Due to the critical machined tolerances, care should be taken not to remove any additional material.

If surface C has cracks or signs of extreme wear, the counterbore will require machining and the installation of shims for the correct liner protrusion.



Use a counterbore cutter, Part Number 3163785, to machine the counterbore to the proper depth.

NOTE: Part Number 3823567, cutter plate, and Part Number 3823570, cutter bit, **must** be used with the counterbore machining tool.



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

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Clean the combustion deck with a gasket scraper or abrasive pad, Part Number 3823258 or equivalent, and diesel fuel or solvent.

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

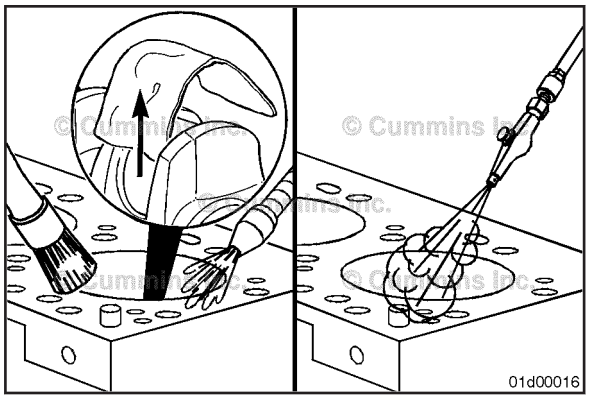
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

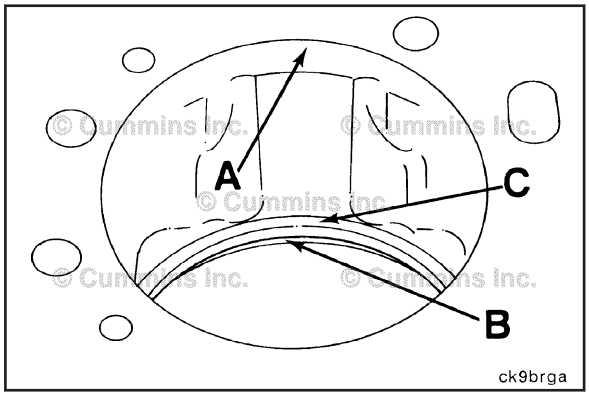
Thoroughly flush the block with mineral spirits or cleaning solvent.

Remove the shop rags and clean the crankshaft with a cleaning solvent.

Blow the cylinder bores and crankshaft dry and wipe them clean with a lint-free cloth.

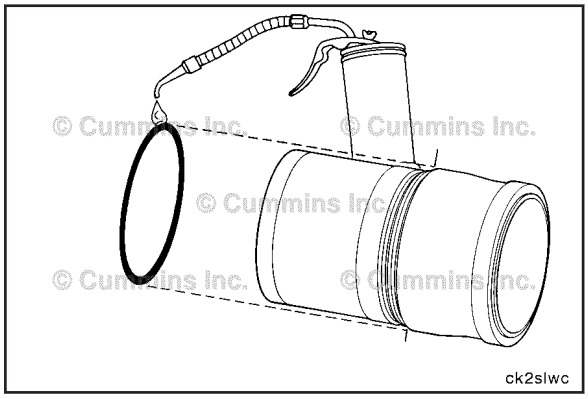


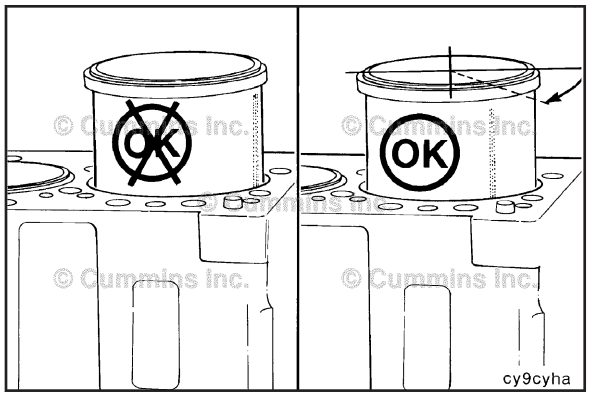
Lubricate surfaces A and B with clean 15W-40 engine oil.



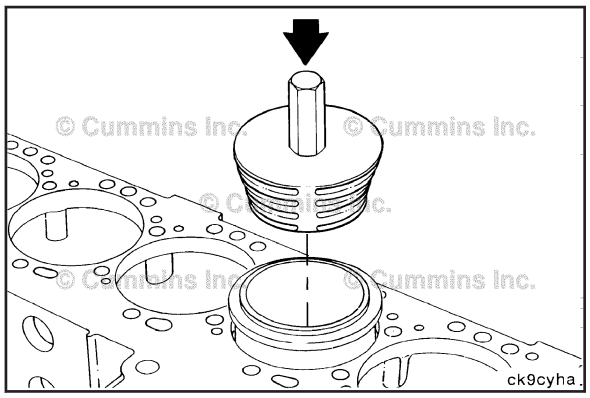
Use clean 15W-40 oil to coat the liner o-ring seals.

Install new o-ring seals on the liners.

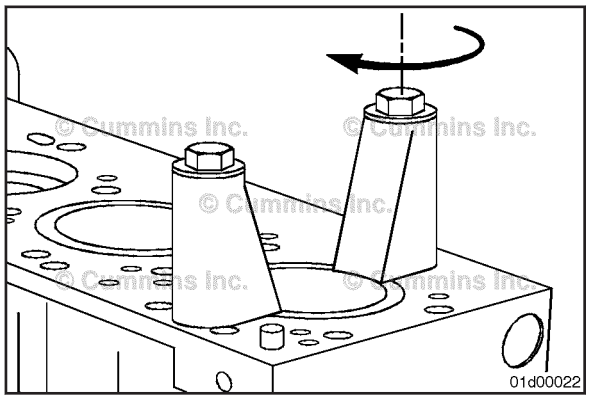




When reusing liners, install them in the same cylinder from where they were removed and rotate them 45 degrees (1/8 turn) from their original position. When correctly installed, any liner pitting **must** be positioned as illustrated so the pitted surface is rotated away from the location where pitting occurs.



Install the liner into the bore of the cylinder block, use liner driver, Part Number ST-1229.

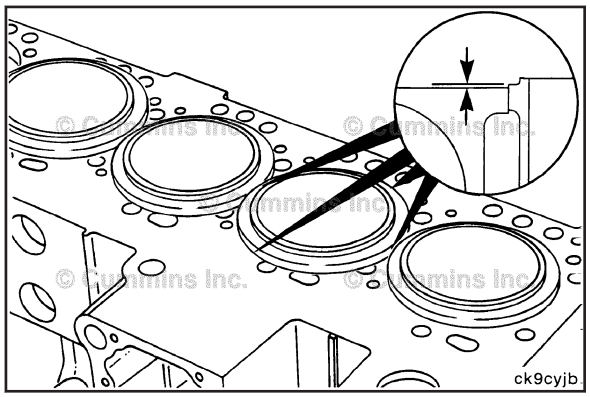


Use two (2) cylinder head capscrews and position the two (2) liner clamps, Part Number 3822503, as illustrated.

Tighten the capscrews.

Torque Value: 68 N•m [50 ft-lb]

Remove the clamps and repeat this procedure until all liners have been clamped and released.



Liner protrusion is the distance the liner protrudes above the block face.

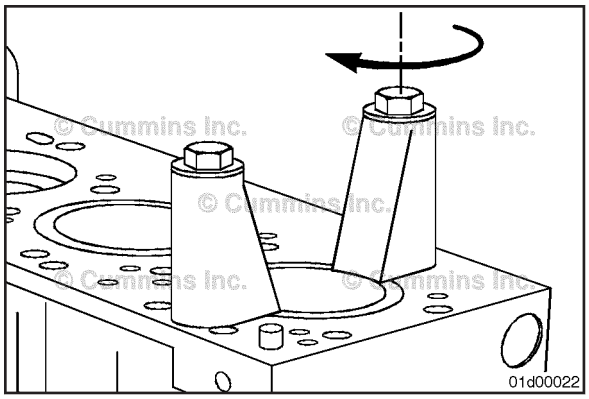
Measure the liner protrusion at four points 90 degrees apart using gauge, Part Number 3164438.

Cylinder Liner Protrusion		
mm		**in**
0.026	MIN	0.0010
0.122	MAX	0.0048

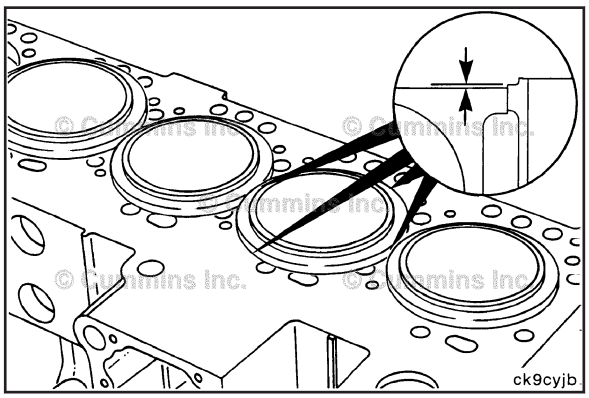
NOTE: If the liner protrusion varies more than 0.025 mm [0.0010 in] for 180 degrees:

- Install and tighten the liner clamps again.

Torque Value: 68 N•m [50 ft-lb]

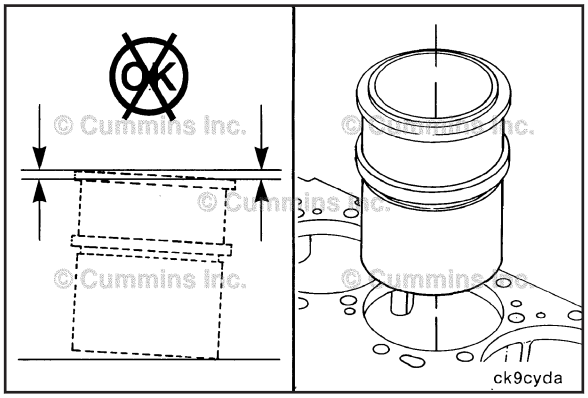


- Measure the liner protrusion again.

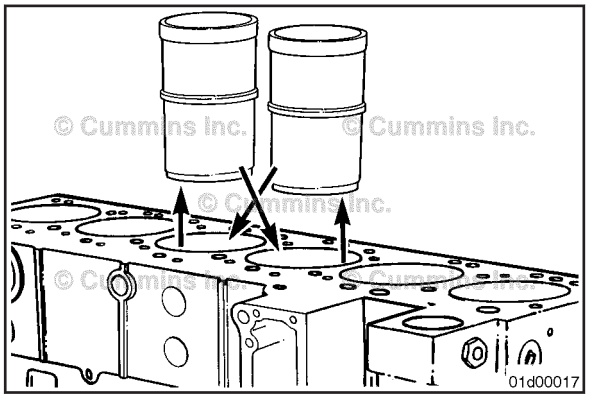


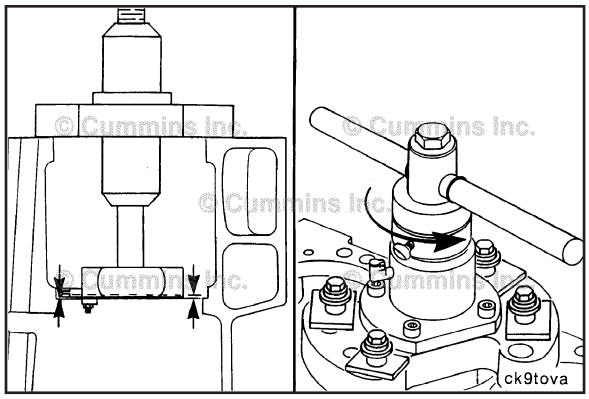
NOTE: If the protrusion still varies more than 0.025 mm [0.0010 in]:

- Remove the liner.
- Inspect the liner sealing edge for burrs, dirt, or damage.
- Replace the liner if it is damaged.
- Install the liner again.
- Measure the liner protrusion.



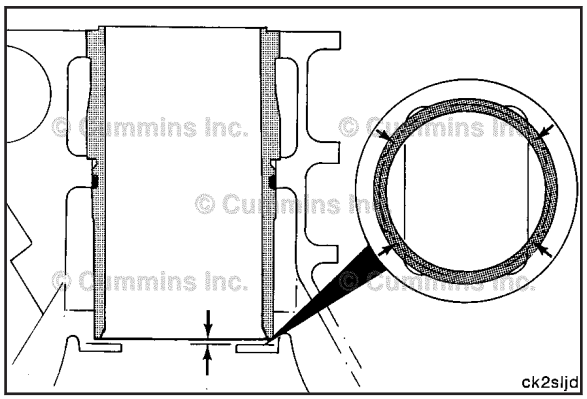
Service Tip: If the out-of-limit condition is minimal, tolerance stack-up may allow the protrusion limits to be obtained by installing other new liners in the out-of-limit bore.





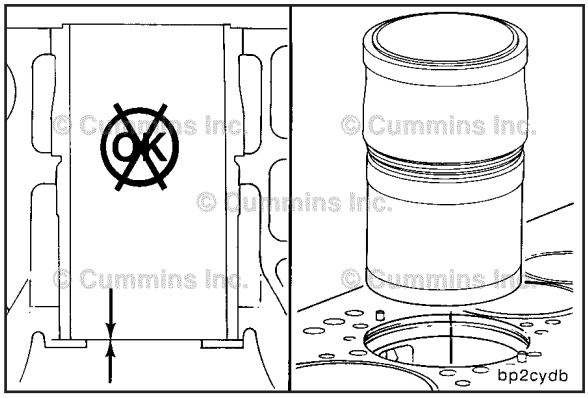
NOTE: If the liner protrusion still does **not** meet the specifications, machine the cylinder block liner bore for shims using the following tools:

- Drive unit, Part Number 3163785.
- Cutter plate, Part Number 3823567.
- Cutter bit, Part Number 3823570.



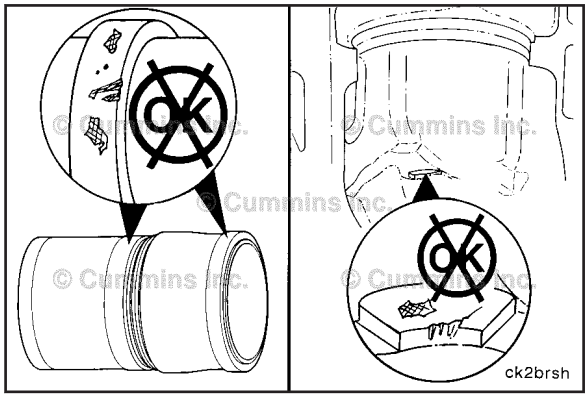
Use a feeler gauge to inspect the liner to block clearance at the four block casting points.

Cylinder Liner to Block Clearance		
mm		**in**
0.229	MIN	0.009



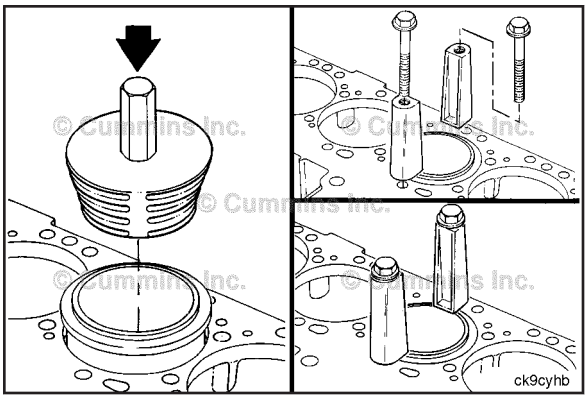
NOTE: If the clearance is **less** than 0.229 mm [0.009 in]:

- Remove the liner.

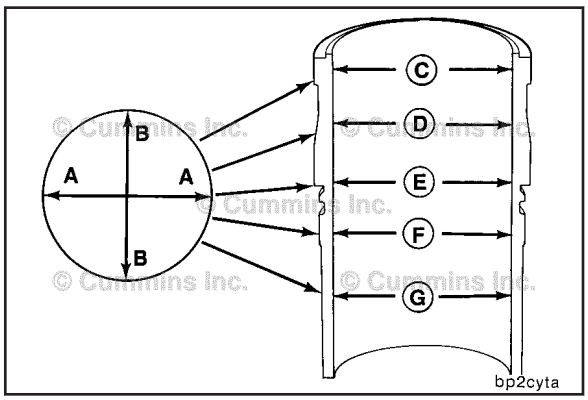


- Inspect the liner and cylinder block for dirt or damage.

- Replace the liner if it is damaged.
- Install the liner again.

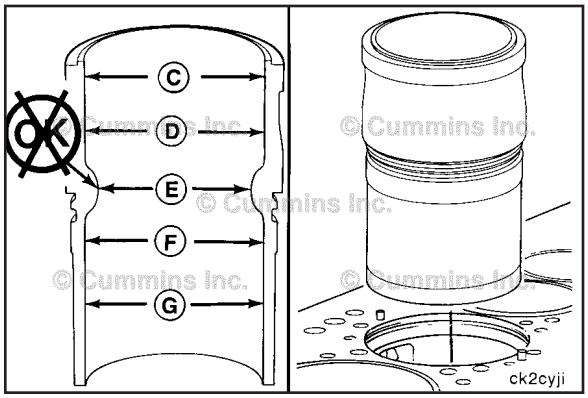


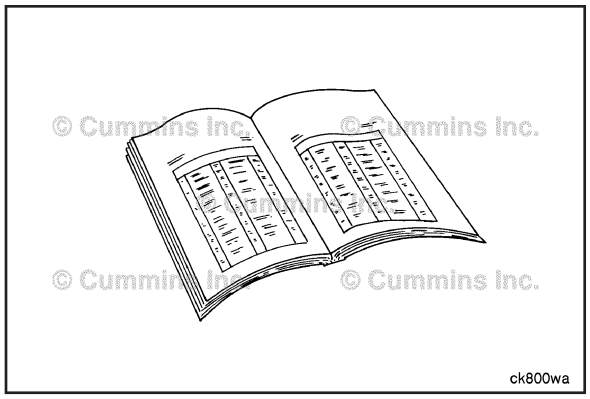
Measure the liner bore for out-of-roundness at points "C", "D", "E", "F", and "G". Measure each point in the direction "AA" and "BB". The bore **must not** be more than 0.04 mm [0.002 in] out-of-round.



NOTE: If the liner bore is more than 0.04 mm [0.002 in] out-of-round:

- Remove the liner so the cylinder block liner bore can be measured.





Finishing Steps

All Applications Except Marine

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

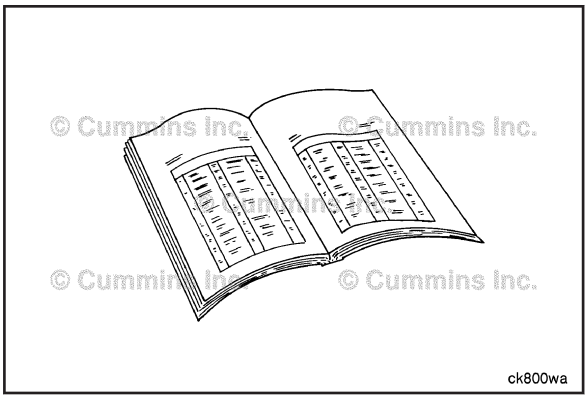
- Install the pistons and connecting rods. Refer to Procedure 001-054 in Section 1.
- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Install the cylinder head. Refer to Procedure 002-004 in Section 2.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Fill lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.

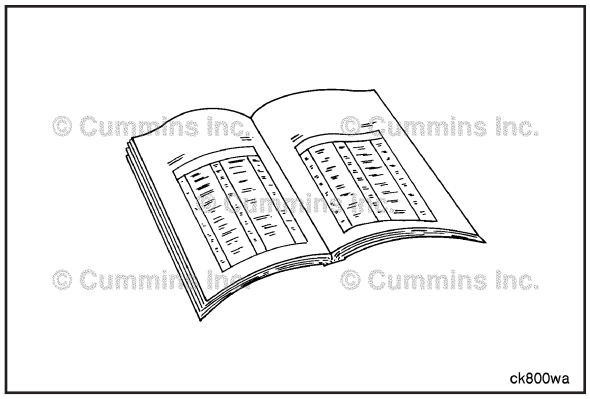
Marine Applications

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the piston and connecting rod assemblies. Refer to Procedure 001-054 in Section 1.
- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Install the cylinder head. Refer to Procedure 002-004 in Section 2.
- Install the valve cover. Refer to Procedure 003-011 in Section 3.
- Install the engine into the vessel. Refer to Procedure 000-002 in Section 1.
- Fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Fill the engine coolant system. Refer to Procedure 008-018 in Section 8.
- Open the sea water supply. See equipment manufacturer service information.
- Open the fuel supply to the engine. See equipment manufacturer service information.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine until the coolant temperature reaches 82°C [180°F] and check for leaks and proper operation.





Gear Cover, Front (001-031)

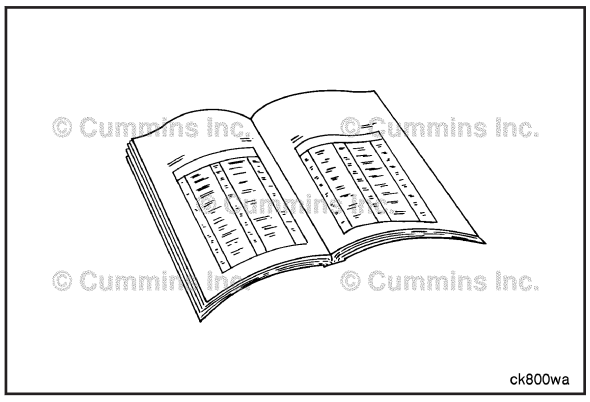
Preparatory Steps

All Applications Except Marine

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the vibration damper (rubber), if installed. Refer to Procedure 001-051 in Section 1.
- Remove the vibration damper (viscous), if installed. Refer to Procedure 001-052 in Section 1.
- Remove the front seal. Refer to Procedure 001-023 in Section 1.
- If required, remove the fan hub pulley. Refer to Procedure 008-039.



Marine Applications

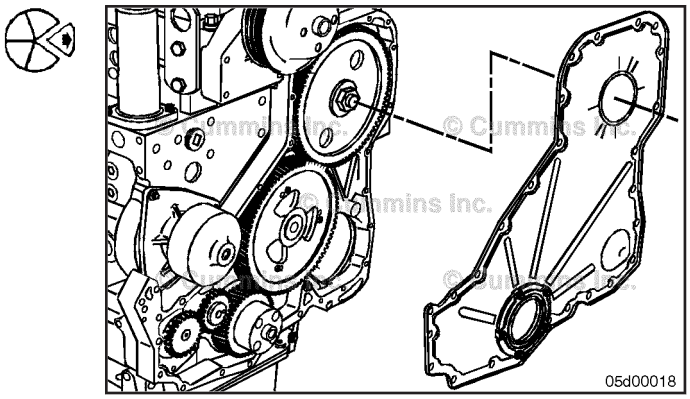
⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the belt guard. Refer to Procedure 008-001 in Section 8.
- Remove the four fuel filter bracket mounting capscrews from the top of the cylinder head and the side of the gear housing. Refer to Procedure 006-018 in Section 6. Push the fuel filter and bracket to the side.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the vibration damper. Refer to Procedure 001-052 in Section 1.
- If required, remove the automatic belt tensioner. Refer to Procedure 008-080 in Section 8.

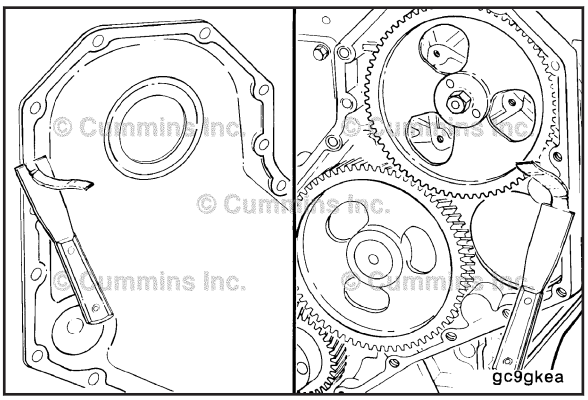
Remove

Remove the front gear cover.

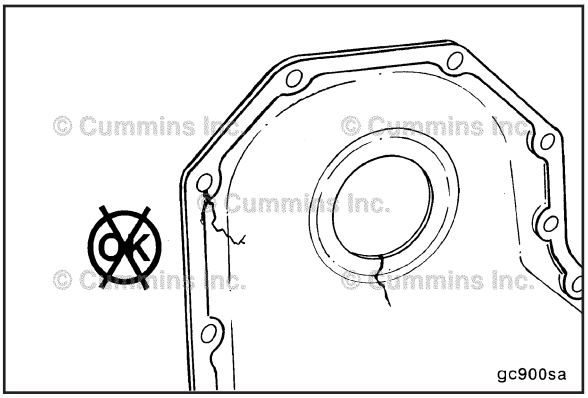


Clean and Inspect for Reuse

Clean the residual sealant from the gear cover and gear housing gasket surface.

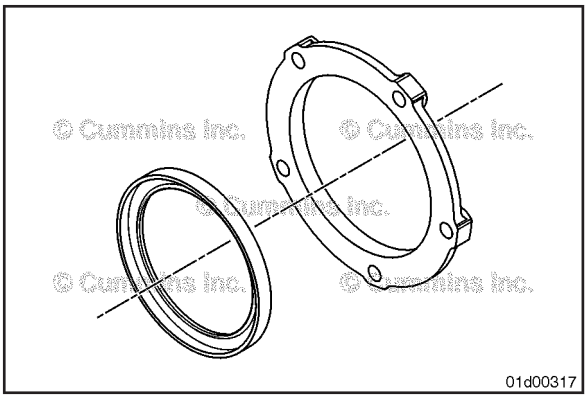


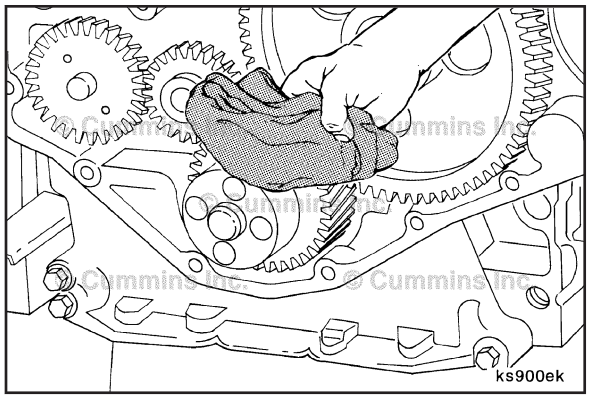
Inspect the gear cover for cracks or other damage.



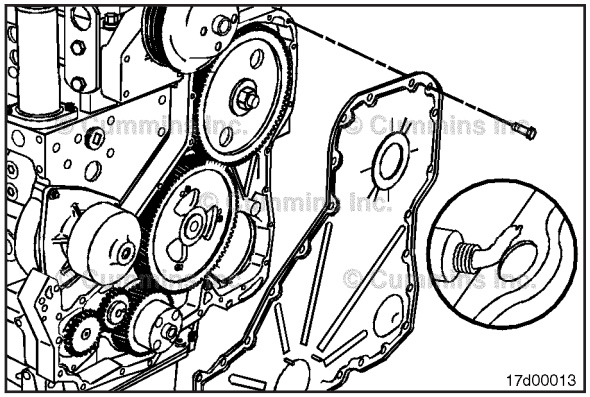
Install

Install a new seal in the carrier. Refer to Procedure 001-023 in Section 1.





⚠CAUTION⚠
The crankshaft must be clean, dry, and oil free before installing the gear cover. Failure to properly clean the sealing surface will result in an oil leak.

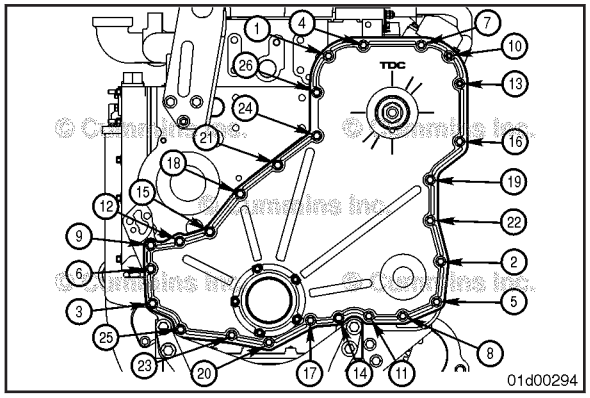


NOTE: Install three guide pins, Part Number 3164977, to improve alignment of the front cover and front seal to the gear housing and crankshaft.

NOTE: Apply sealant to the inside of the bolt holes.

Apply a thin bead of RTV™ sealant 3 to 4 mm [.12 to .16 in] wide, Part Number 3164067 or equivalent, to the engine side of the front cover **only**.

Install the front cover on the engine within 10 minutes.



Tighten the front cover capscrews in the sequence shown.

Torque Value:
10 mm Front Cover Mounting Capscrews
Step 1 30 N•m [22 ft-lb]

Torque Value:
11 mm Front Cover Mounting Capscrews
Step 1 40 N•m [30 ft-lb]

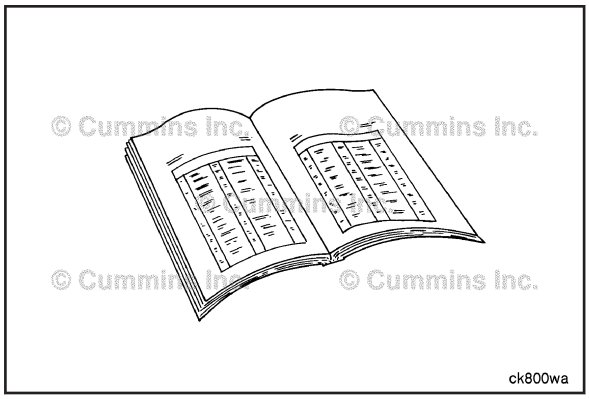
Finishing Steps

All Applications Except Marine

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the seal carrier on the front cover. Refer to Procedure 001-023 in Section 1.
- Install the vibration damper (rubber), if installed. Refer to Procedure 001-051 in Section 1.
- Install the vibration damper (viscous), if installed. Refer to Procedure 001-052 in Section 1.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

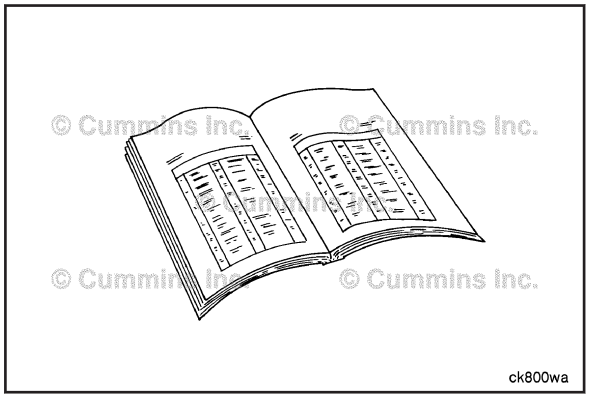


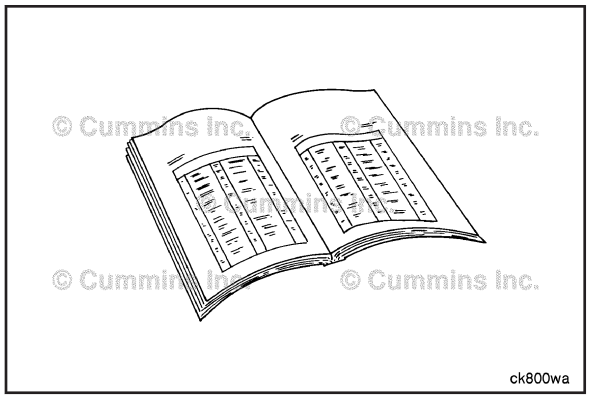
Marine Applications

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the seal carrier on the front cover. Refer to Procedure 001-023 in Section 1.
- Install the automatic belt tensioner, if removed. Refer to Procedure 008-080 in Section 8.
- Install the vibration damper. Refer to Procedure 001-052 in Section 1.
- Install the drive belt. Refer to Procedure 008-001 in Section 8.
- Install the fuel filter bracket. Refer to Procedure 006-018 in Section 6.
- Install the belt guard. Refer to Procedure 008-001 in Section 8.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine at idle for 5 to 10 minutes and check for leaks or loose parts.





Gear Housing, Front (001-033)

Preparatory Steps

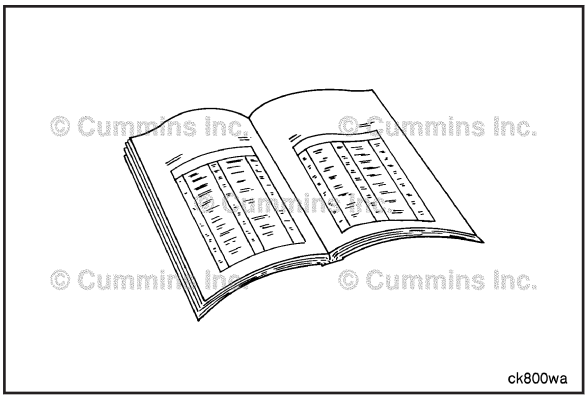
All Applications Except Marine

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Shut off the fuel supply. Refer to the OEM service manual.
- Remove the rubber vibration damper, if installed. Refer to Procedure 001-051 in Section 1.
- Remove the viscous vibration damper, if installed. Refer to Procedure 001-052 in Section 1.
- Remove the gear cover. Refer to Procedure 001-031 in Section 1.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the rocker levers. Refer to Procedure 003-008 in Section 3.
- Remove the push rods. Refer to Procedure 004-014 in Section 4.
- Remove the fuel pump. Refer to Procedure 005-016 in Section 5.
- Remove the camshaft gear. Refer to Procedure 001-012 in Section 1.
- Remove the camshaft if the camshaft gear can **not** be removed. Refer to Procedure 001-008 in Section 1.
- Remove or disconnect gear driven accessories, such as air compressor and hydraulic pump.

Marine Applications

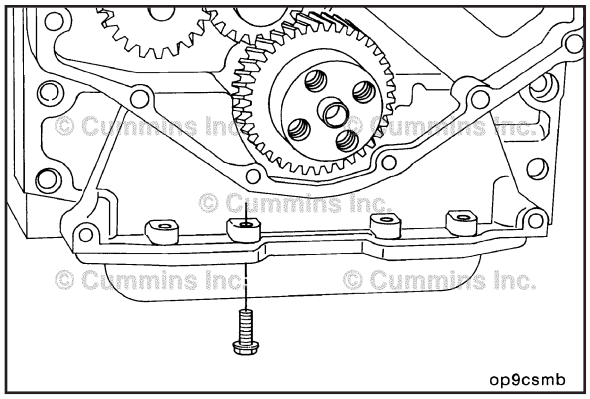


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

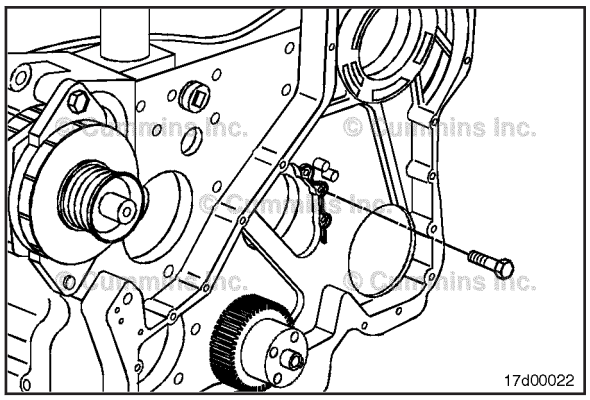
⚠CAUTION⚠
Use caution when draining the fuel system that fuel is not spilled or drained into the bilge area. The fuel must be disposed of in accordance with local environmental regulations.

- Shut off the fuel supply. Refer to the OEM service manual.
- Shut off the sea water supply. Refer to the OEM service manual.
- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the fuel filter mounting bracket. Refer to Procedure 006-018 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 3.
- Remove the push rods. Refer to Procedure 004-014 in Section 4.
- Remove the belt guard. Refer to Procedure 008-001 in Section 8.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the automatic belt tensioner, if required. Refer to Procedure 008-080 in Section 8.
- Remove the vibration damper, if installed. Refer to Procedure 001-052 in Section 1.
- Remove the gear cover. Refer to Procedure 001-031 in Section 1.
- Remove the fuel pump. Refer to Procedure 005-016 in Section 5.
- Remove the camshaft gear. Refer to Procedure 001-012 in Section 1.
- Remove the sea water pump, if equipped. Refer to Procedure 008-057 in Section 8.

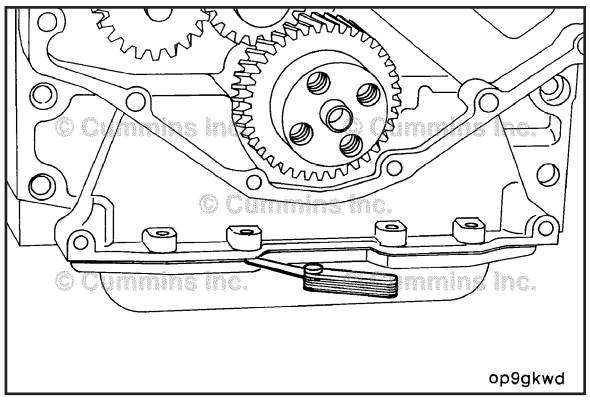


Remove

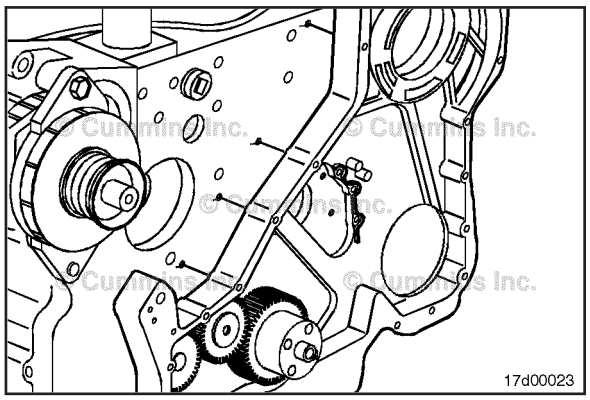
Remove the four front oil pan capscrews.



Remove the gear housing capscrews.



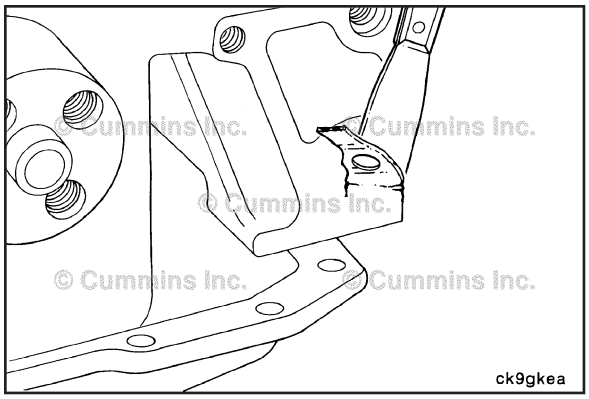
Use a feeler gauge to separate the lubricating oil pan gasket from the gear housing.



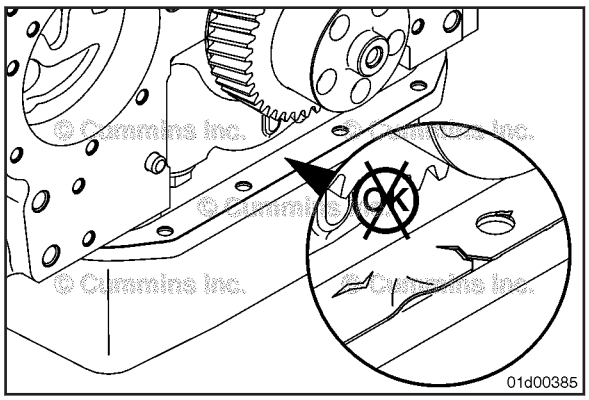
Remove the gear housing capscrews and remove the gear housing.

Clean and Inspect for Reuse

Clean the gasket material from the cylinder block.

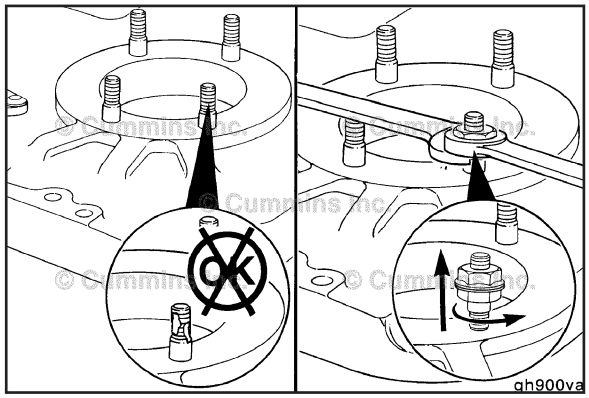


Inspect the lubricating oil pan gasket for tears or other damage. See the Install section of this procedure if the gasket is damaged.

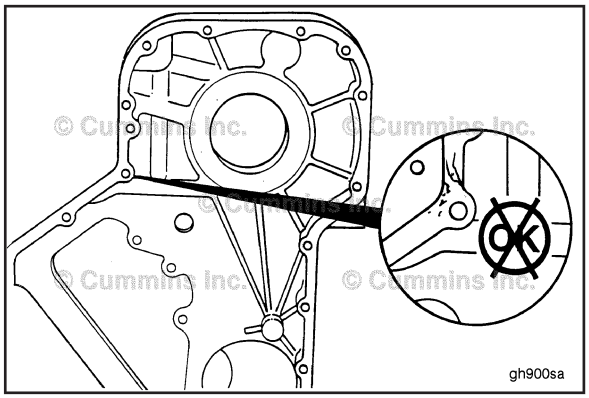


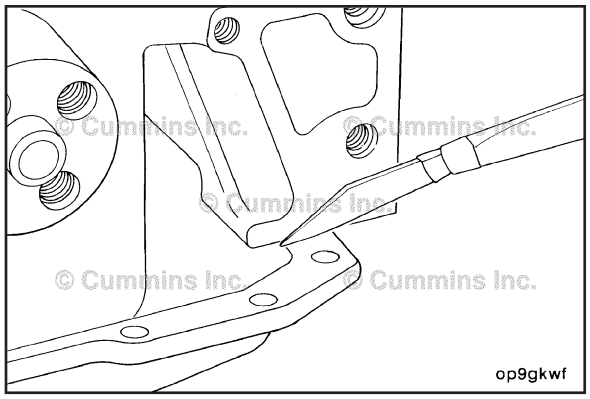
Inspect fuel pump mounting studs for damage.

To install or remove the fuel pump studs, use two nuts locked together on the stud.



Inspect the gear housing sealing surfaces for cracks or other damage. Replace the gear housing if any damage is found.



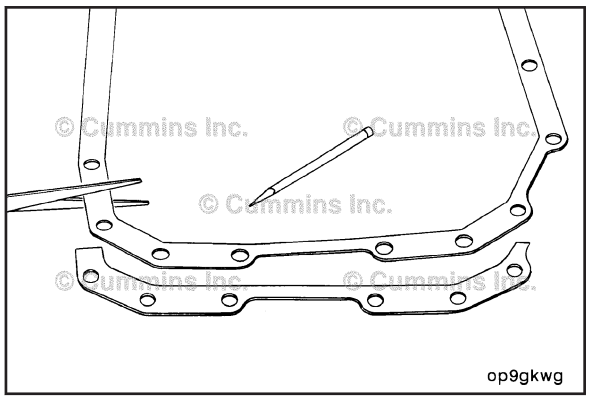


Install

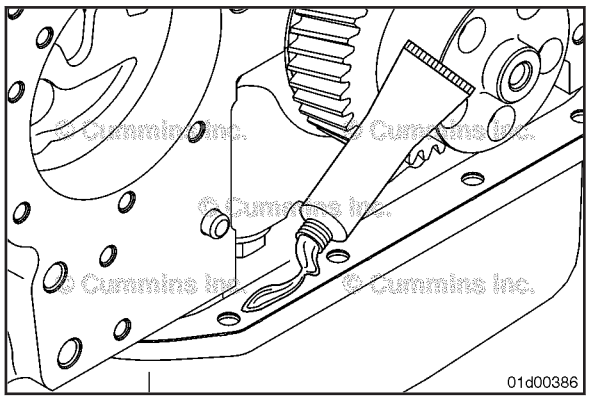
Pan Gasket - Repair

If the lubricating oil pan gasket is damaged, it can be repaired.

Cut the damaged gasket off even with the front of the cylinder block.



Use the old gasket as a template to cut the front section of a new gasket to the same size.

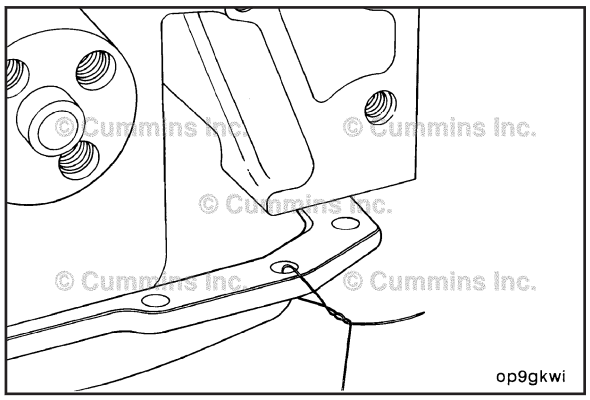


NOTE: The gear housing **must** be installed within 10 minutes of applying the sealant.

Clean the sealing surfaces.

Coat the new gasket on both sides with RTV sealant, Part Number 3823494 or equivalent.

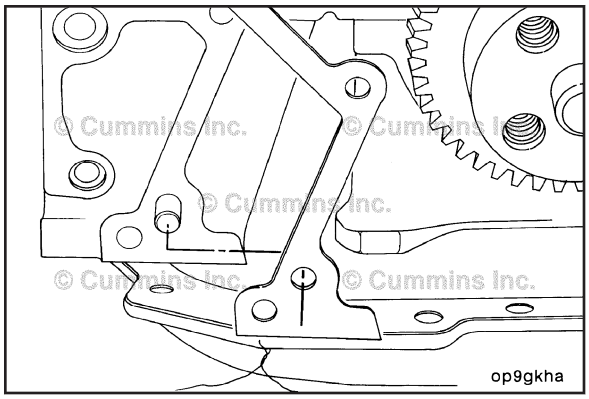
Be sure there is a bead of sealant at the intersecting joint of the cylinder block, oil pan, and gear housing.



Use common thread or a very fine wire to hold the new gasket splice in position as illustrated.

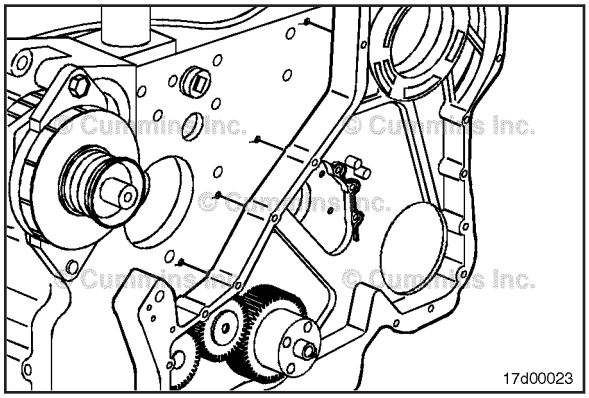
Position the gear housing gasket on the alignment dowels.

Use guide pins (M8 x 1.25 x 50) to assist in aligning the gasket and gear housing. Be sure to remove the guide pins after alignment.

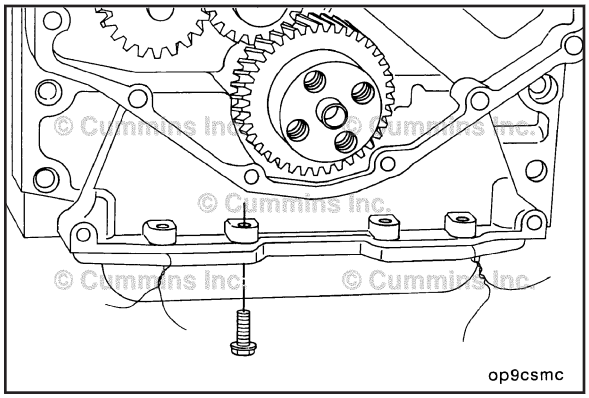


Install the gear housing.

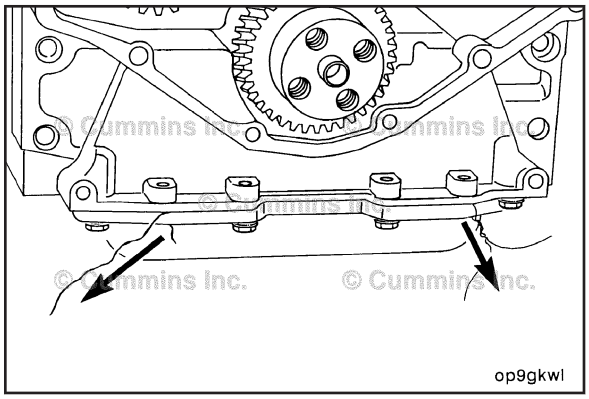
Torque Value: 40 N•m [30 ft-lb]

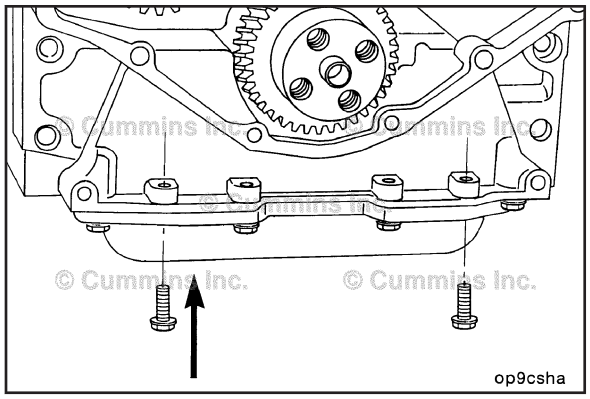


Start the oil pan capscrews in the holes **not** being used to tie the gasket in place.



Remove the thread or wire holding the gasket in place.





Install the remaining two oil pan capscrews and tighten. Refer to Procedure 007-025 in Section 7.

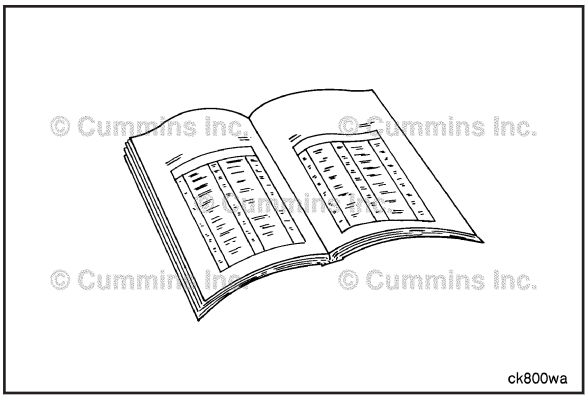
Finishing Steps

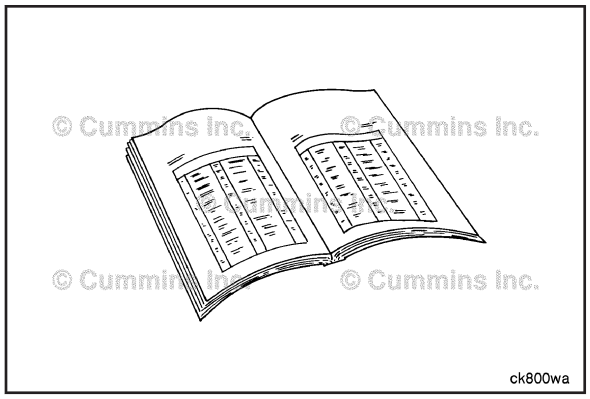
All Applications Except Marine

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

- Install the camshaft, if removed. Refer to Procedure 001-008 in Section 1.
- Install the camshaft gear. Refer to Procedure 001-012 in Section 1.
- Install the push rods. Refer to Procedure 004-014 in Section 4.
- Install the rocker levers. Refer to Procedure 003-008 in Section 3.
- Adjust the overhead. Refer to Procedure 003-004 in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the gear cover. Refer to Procedure 001-031 in Section 1.
- Install the rubber vibration damper, if installed. Refer to Procedure 001-051 in Section 1.
- Install the viscous vibration damper, if installed. Refer to Procedure 001-052 in Section 1.
- Install the fuel pump. Refer to Procedure 005-016 in Section 5.
- Install or connect gear driven or accessories. Refer to the OEM service manual.
- Open the fuel valve. Refer to the OEM service manual.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.





Marine Applications

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠

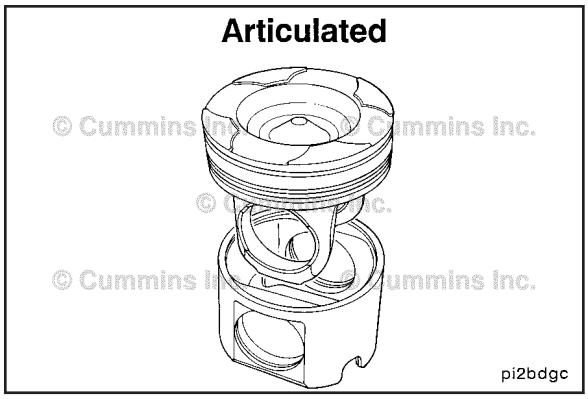
Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

- Install the camshaft gear. Refer to Procedure 001-012 in Section 1.
- Install the sea water pump, if equipped. Refer to Procedure 008-057 in Section 8.
- Install the fuel pump. Refer to Procedure 005-016 in Section 5.
- Install the gear cover. Refer to Procedure 001-031 in Section 1.
- Install the seal carrier on the front cover. Refer to Procedure 001-023 in Section 1.
- Install the vibration damper, if installed. Refer to Procedure 001-052 in Section 1.
- Install the automatic belt tensioner, if removed. Refer to Procedure 008-080 in Section 8.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Install the belt guard. Refer to Procedure 008-001 in Section 8.
- Install the push rods. Refer to Procedure 004-014 in Section 4.
- Install the rocker levers. Refer to Procedure 003-008 in Section 3.
- Adjust the overhead. Refer to Procedure 003-004 in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the fuel filter mounting bracket. Refer to Procedure 006-018 in Section 6.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Open the fuel supply valve. Refer to the OEM service manual.
- Open the sea water supply valve. Refer to the OEM service manual.
- Operate the engine at idle for 5 to 10 minutes and check for leaks or loose parts.

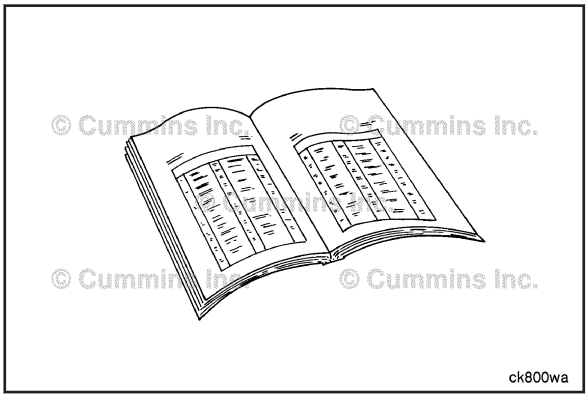
Piston (001-043)

General Information

Some engines are equipped with articulated pistons. The articulated piston is a two (2) piece piston consisting of a forged steel crown and an aluminum skirt. An open chamber oil gallery is located on the underside of the crown of the piston to provide more oil contact with the piston and give better piston cooling.



Preparatory Steps



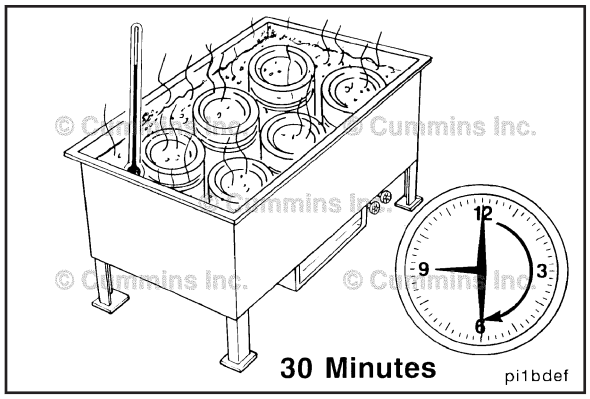
⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠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 lubricating oil suction tube. Refer to Procedure 007-035 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.



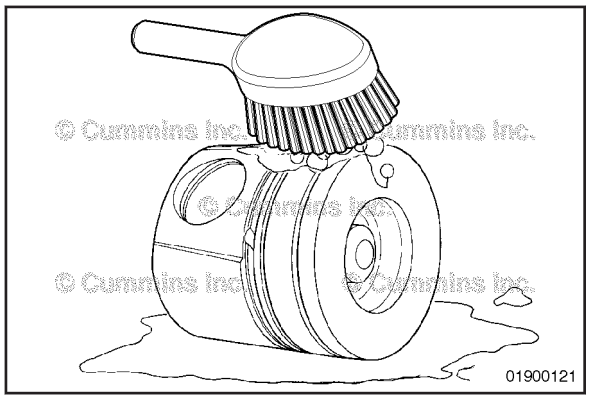
Clean and Inspect for Reuse

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

△CAUTION△
Do not use the bead blast method to clean the piston. The piston will be damaged by blast material embedded in the aluminum.

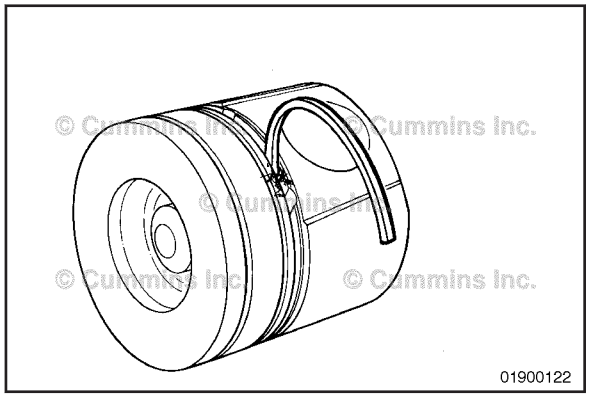
△CAUTION△
Do not clean the pistons and connecting rods in an acid tank.

Allow the piston to soak for a minimum of 30 minutes in a tank containing a cleaning solvent suitable for steel and aluminum.



△CAUTION△
Do not use a metal brush. A metal brush will damage the piston ring grooves.

Wash the pistons and connecting rods in a strong solution of laundry detergent in hot water. Use a non-metallic brush to remove carbon deposits.



△CAUTION△
Do not use a ring groove cleaner to clean the ring grooves. Do not to scratch the ring sealing surface in the piston groove.

Clean the remaining deposits from the ring grooves with the square end of a broken piston ring.

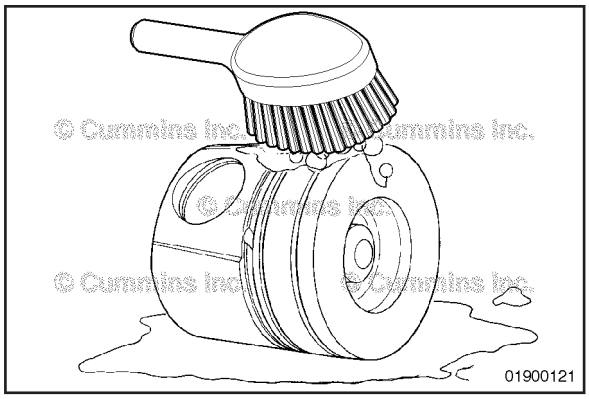
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

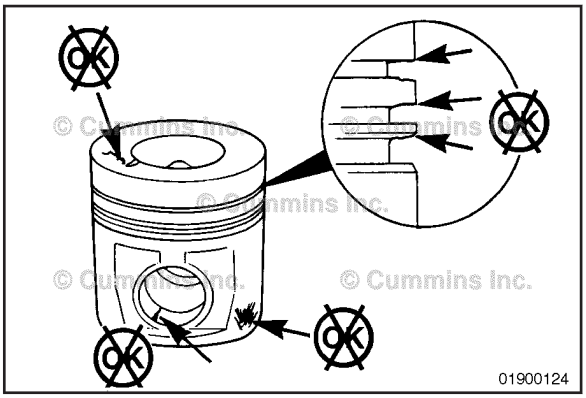
Wash the pistons again in a detergent solution or solvent.

After rinsing, used compressed air to dry.



Inspect the piston for damage and excessive wear. Check the top, ring grooves, skirt, and pin bore for cracks or damage.

NOTE: If severe piston damage has occurred, check the turbocharger and other exhaust components for damage from debris.



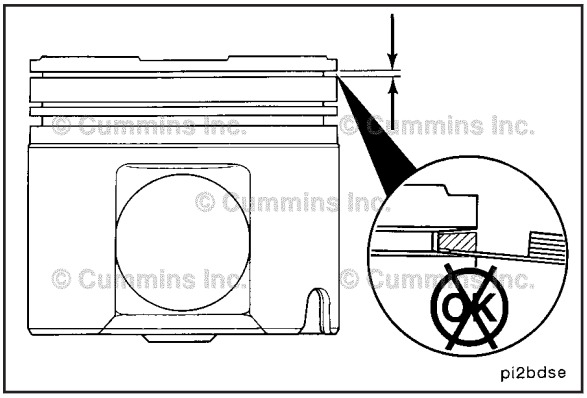
Measure

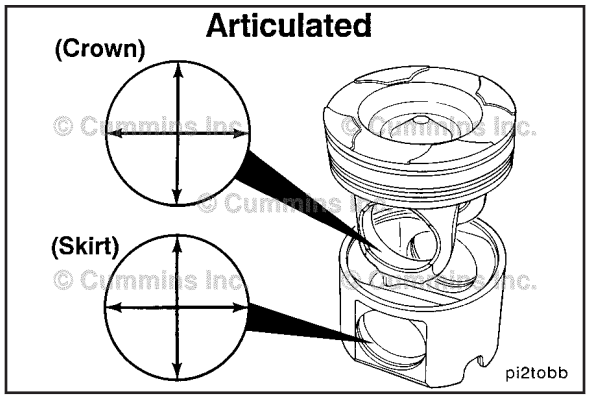
The ring groove can be inspected with a new ring and a feeler gauge.

Hold a new ring in the groove even with the outside diameter of the piston.

Install a 0.15 mm [0.006 in] feeler gauge.

If the feeler gauge enters the groove without resistance, there is too much wear. Replace the piston.



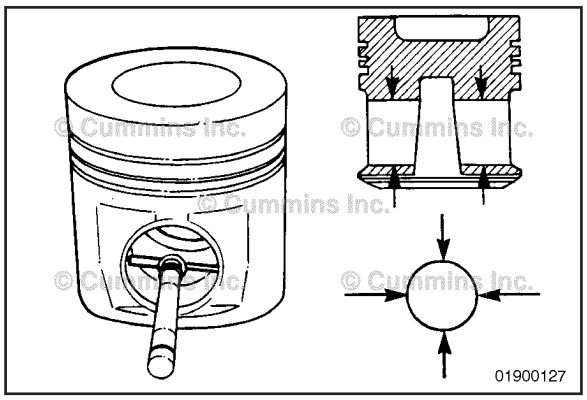


Articulated Pistons

Measure the piston pin bore inside diameter on both the crown and skirt.

Articulated Piston Pin Bore Inside Diameter

	mm		in
Crown	45.016	MIN	1.7723
	45.036	MAX	1.7731
Skirt	45.012	MIN	1.7721
	45.026	MAX	1.7727



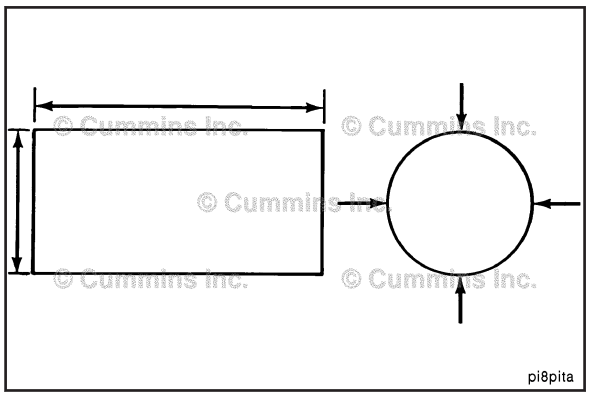
Single Piece Pistons

Measure the pin bore when the piston temperature is at 20°C [68°F].

Piston Pin Bore Diameter

mm		in
45.006	MIN	1.7719
45.012	MAX	1.7721

NOTE: Add 0.013 mm [0.0005 in] to the bore diameter per 5°C [10°F] temperature rise up to 32°C [90°F].



Inspect the piston pin for nicks, gouges, and excessive wear.

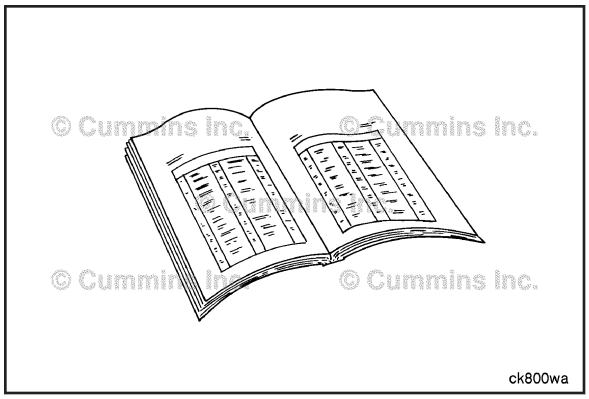
Measure the piston pin outside diameter.

Piston Pin Diameter

mm		in
44.997	MIN	1.7715
45.003	MAX	1.7718

Replace the piston pin if it is more than 0.003 mm [0.0001 in] out of round.

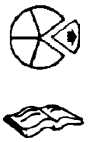
Finishing Steps

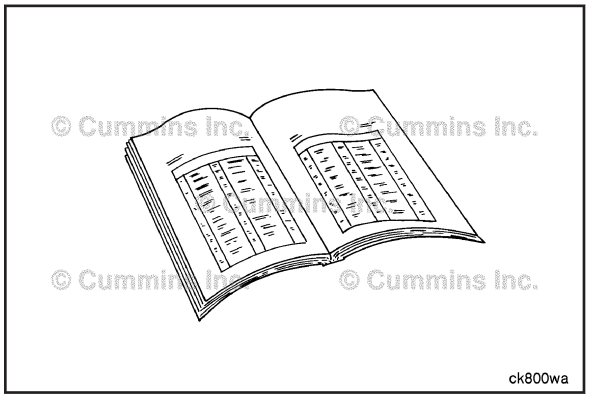


- Assemble and install the piston and connecting rod assemblies. Refer to Procedure 001-054 in Section 1.
- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan. Refer to Procedure 007-037 in Section 7.
- Install the cylinder head. Refer to Procedure 002-004 in Section 2.
- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- Fill the engine with lubricating oil. Refer to Procedure 007-025 in Section 7.
- Operate the engine and check for leaks.

Piston Cooling Nozzle (001-046)

Preparatory Steps



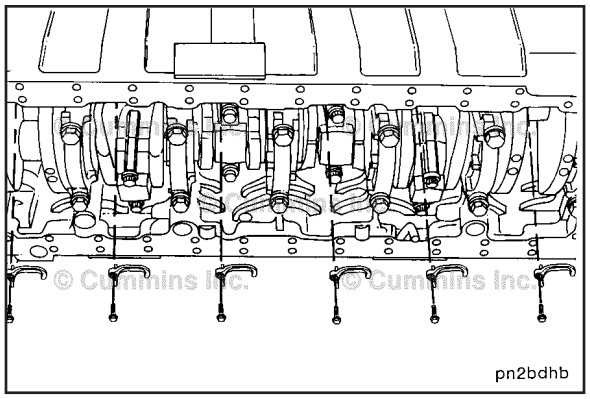


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

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

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.

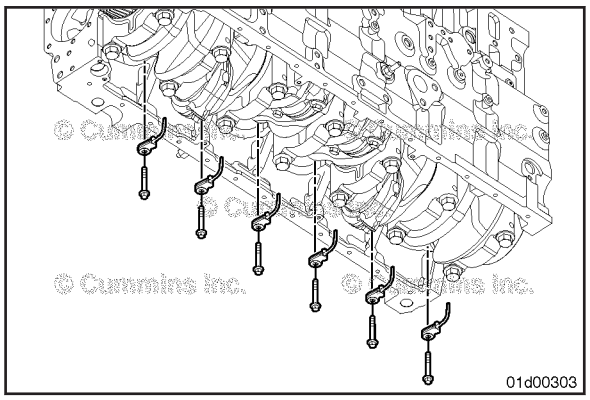


Remove

Banjo Bolt Mounted

Remove the piston cooling nozzle capscrews and nozzles.

NOTE: The crankshaft **must** be rotated to allow access to remove the nozzles.

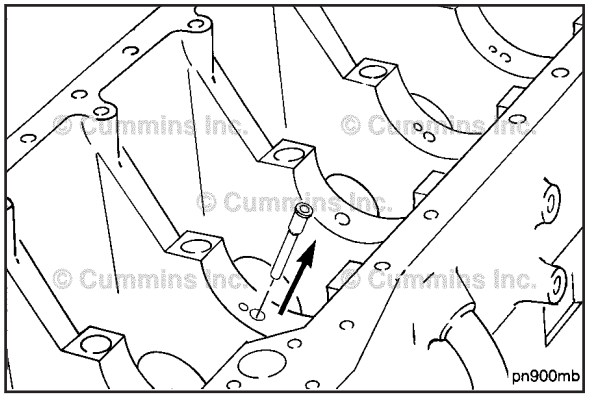


Flange Head Capscrew Mounted

Remove the piston cooling nozzle capscrews and nozzles.

NOTE: The crankshaft **must** be rotated to allow access to remove the nozzles.

NOTE: On engines with the speed indicator ring mounted to the crankshaft, the number six (6) piston cooling nozzle can **not** be removed without first disconnecting the connecting rod from the crankshaft and moving the piston out of the way. Also, a crows foot socket will be required to access the capscrew.



Main Bearing Saddle Mounted

⚠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 block stiffener plate. Refer to Procedure 001-089 in Section 1.

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

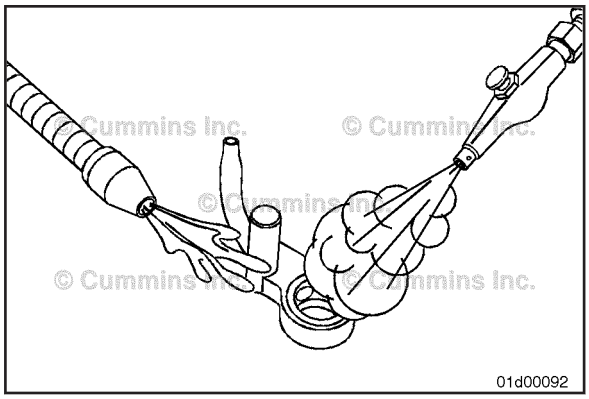
NOTE: Number three saddle does **not** have nozzles.

Remove the piston cooling nozzles or plugs by pressing from the top with an appropriate size punch.

NOTE: Do **not** reuse the saddle jet piston cooling nozzles or plugs once removed.

NOTE: Blocks which use saddle jet piston cooling nozzles may be machined for banjo bolt mounted piston cooling nozzles as well. If this is the case, capscrews will be installed in the banjo bolt mounted piston cooling nozzle location. If it is necessary to remove these capscrews, follow the banjo bolt mounted piston cooling nozzle removal procedure.

Clean and Inspect for Reuse



⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggle and protective clothing to reduce the possibility of personal injury.

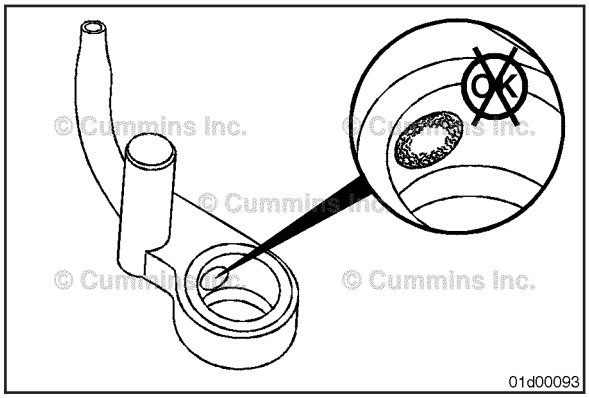
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the piston cooling nozzles and capscrew with solvent.

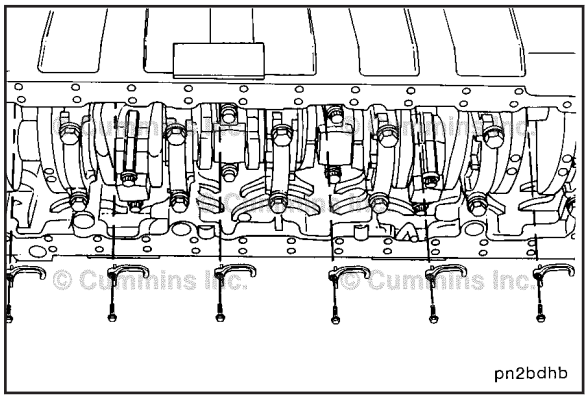
Dry with compressed air.

Inspect the piston cooling nozzles for flow restriction or any other damage. Replace if necessary.



Install

Banjo Bolt Mounted



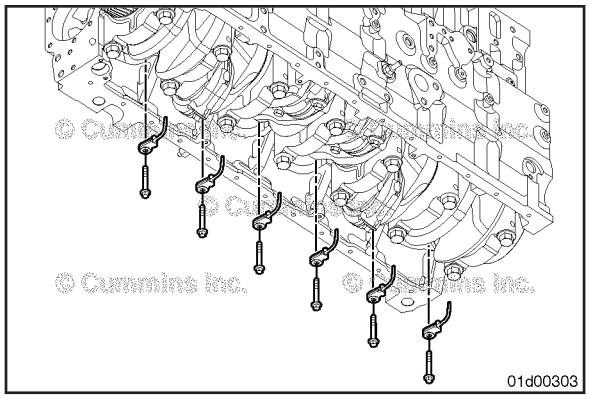
⚠CAUTION⚠
Properly align nozzles in the locator notch before tightening the capscrews.

Install the nozzle, washers and capscrews.

Tighten the capscrews.

Torque Value: 25 N•m [221 in-lb]

NOTE: The crankshaft **must** be rotated to allow access to install all the nozzles.

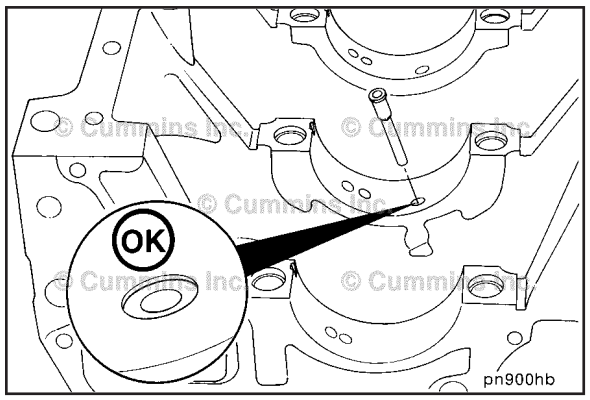


Flange Head Capscrew Mounted

Install the piston cooling nozzles and capscrews.

Tighten the capscrews.

Torque Value: 33 N•m [24 ft-lb]



Main Bearing Saddle Mounted

⚠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.

⚠CAUTION⚠
Do not use a hammer to install the piston cooling nozzles. Use hand pressure only. Use of a hammer can cause component damage.

Install the nozzles, two per saddle.

Push the piston cooling nozzle or plug into place by hand.

Use a flat punch to push the nozzle or plug into the recess.

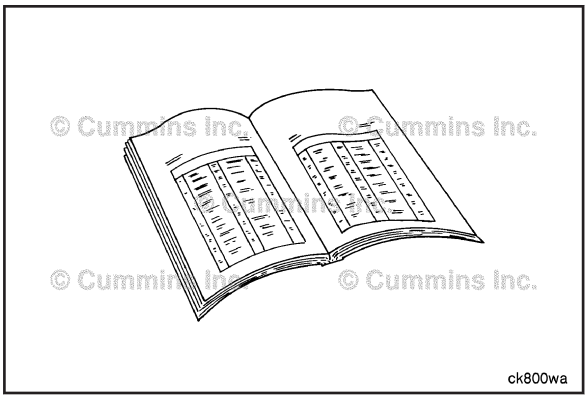
NOTE: Blocks which use saddle jet piston cooling nozzles may be machined for banjo bolt mounted piston cooling nozzles as well. If this is the case, capscrews will be installed in the banjo bolt mounted piston cooling nozzle location. If previously removed, follow the banjo bolt mounted piston cooling nozzle installation procedure.

NOTE: Number three saddle does **not** have nozzles.

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

Install the block stiffener plate. Refer to Procedure 001-089 in Section 1.

Finishing Steps

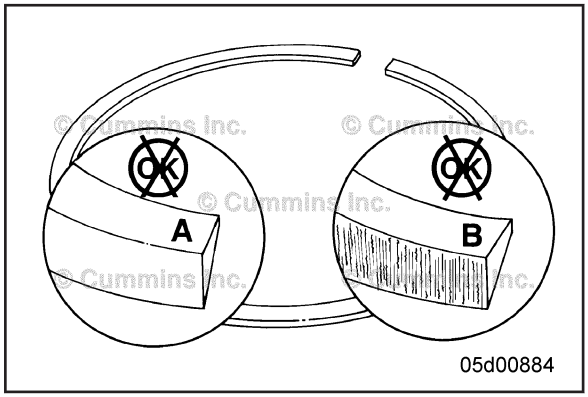


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Fill the engine with lubricating oil. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for oil leaks.

Piston Rings (001-047)

Failure Analysis Inspection



Inspect the piston rings for abrasive wear.

NOTE: Abrasive wear of the intermediate ring can be indicated by a rapid reduction of the dark finish coating on the front face of the ring, in some cases to the point where the dark finish coating is no longer visible (A). This is commonly referred to as full face ring wear. This rapid reduction will typically leave a sharp edge on the bottom of the intermediate ring. Abrasive wear can also be indicated by concentrated vertical scratches on the top ring (B).

Abrasive wear can be caused by:

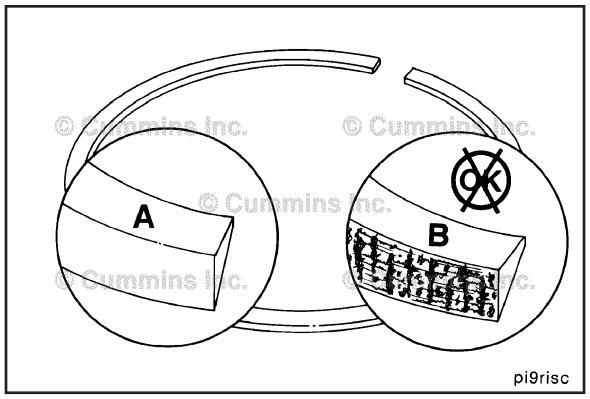
1 Ingested abrasive material

2 Inadequate cleaning during a previous repair

3 Particles embedded in the bore

4 High soot content in the lubricating oil from extended oil drain intervals

5 Scuffing and scoring.



NOTE: Scuffing and scoring is indicated by heavy scratches, metal discoloration, and voids (B).

Scuffing and scoring can be caused by:

1 Engine overheating

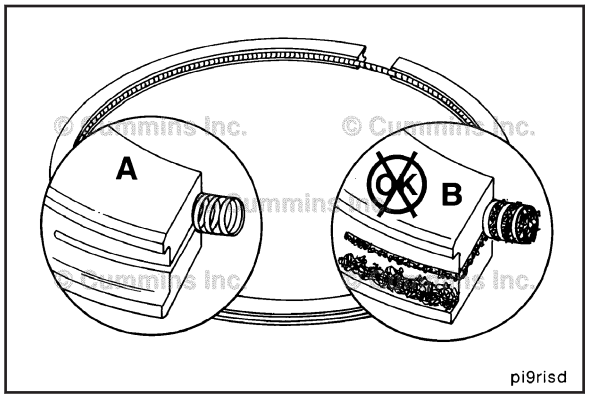
2 Oil dilution

3 Improper maintenance of the lubrication system

4 Piston cooling nozzle malfunction

5 Oil ring plugged by deposits.

NOTE: Scuffing and scoring on the piston rings indicates a breakdown of the oil film on the cylinder bore wall, causing transfer of material from the piston ring face to the cylinder bore.



NOTE: Oil ring plugging is indicated by deposits on the oil ring grooves (B).

Oil ring plugging can be caused by:

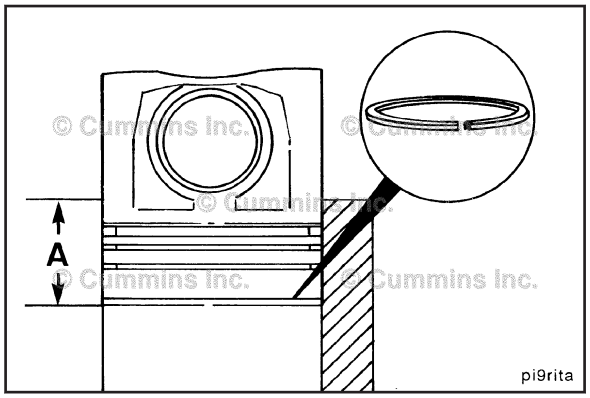
1 Low engine operating temperatures - long periods of idling or a cooling system malfunction

2 Extended oil change intervals

3 Use of the wrong grade of engine oil

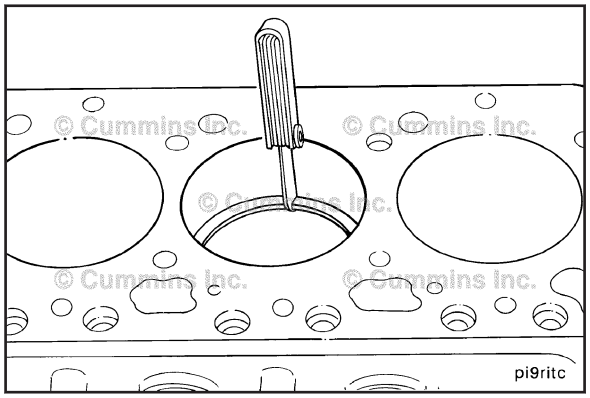
4 Use of a poor quality engine oil.

NOTE: Plugging of the oil ring drains restricts oil drain-back, which floods the piston ring belt area, resulting in a loss of oil control.



NOTE: The following measurements are intended for inspecting new piston rings.

Measure the piston ring gap by installing the piston rings into the cylinder bore in which they will be used. Position the rings below the ring reversal area by positioning each ring in the cylinder 89 mm [3.5 in] below the top deck (A). Use a piston to square the rings with the bore.



Use a feeler gauge to measure the gap.

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 piston ring gap measurement is being taken 89 mm [3.5 in] below the cylinder block deck

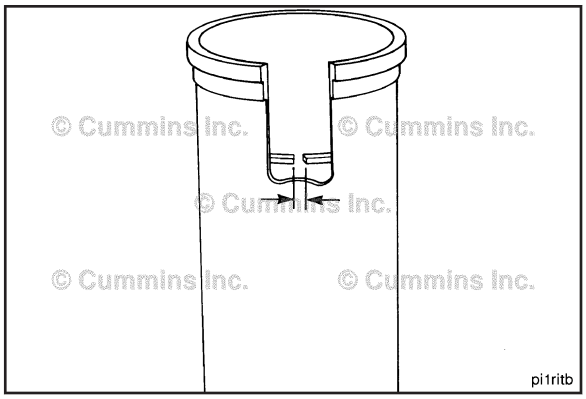
3 Try another set of piston rings.

Ring Gap, ISC CM554 Control Module			
	mm		in
Top Ring	0.35	MIN	0.014
	0.60	MAX	0.024
Intermediate Ring	0.35	MIN	0.014
	0.65	MAX	0.026
Oil Control Ring	0.30	MIN	0.012
	0.60	MAX	0.023

Ring Gap, ISL CM554 Control Module			
	mm		in
Top Ring	0.35	MIN	0.014
	0.50	MAX	0.020
Intermediate Ring	0.85	MIN	0.033
	1.15	MAX	0.045
Oil Control Ring	0.30	MIN	0.012
	0.60	MAX	0.023

Ring Gap, QSC Marine Engines with CM850 Control Module			
	mm		in
Top Ring	0.35	MIN	0.014
	0.45	MAX	0.017
Intermediate Ring	0.40	MIN	0.016
	0.70	MAX	0.027
Oil Control Ring	0.30	MIN	0.012
	0.60	MAX	0.023

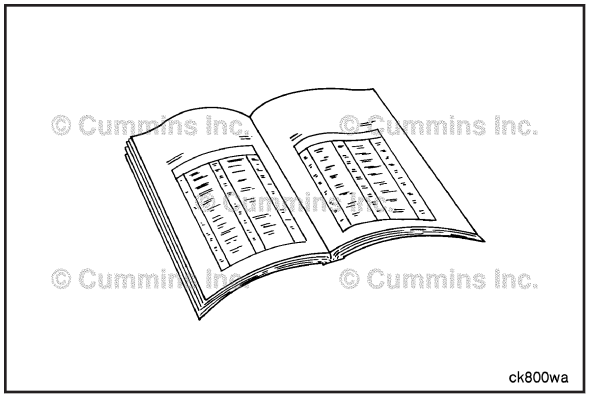
Ring Gap, All Other Engines with CM850 Control Module			
	mm		in
Top Ring	0.30	MIN	0.012
	0.45	MAX	0.018
Intermediate Ring	0.85	MIN	0.033
	1.15	MAX	0.045
Oil Control Ring	0.30	MIN	0.012
	0.60	MAX	0.023

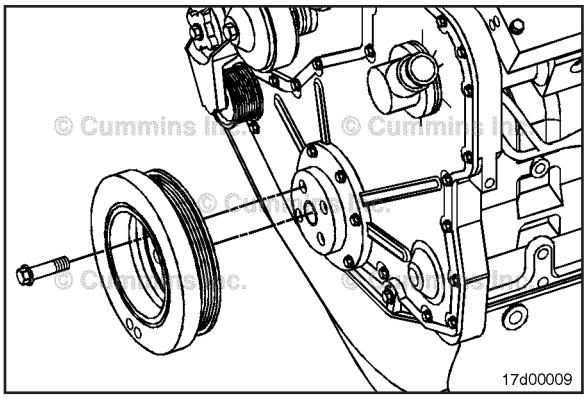


Vibration Damper, Rubber (001-051)

Preparatory Steps

- Disconnect the battery. Refer to Procedure 013-009 in Section 13.
- Remove the belt guard, if equipped. Refer to Procedure 008-001 in Section 8.
- Remove the fan and fan shroud, if necessary.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.

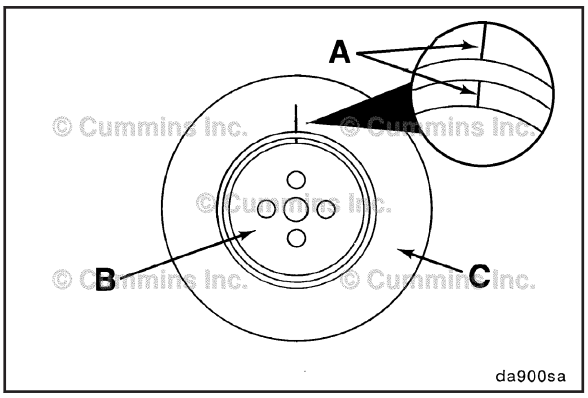




Remove

NOTE: Some engines use four damper capscrews while others use five damper capscrews.

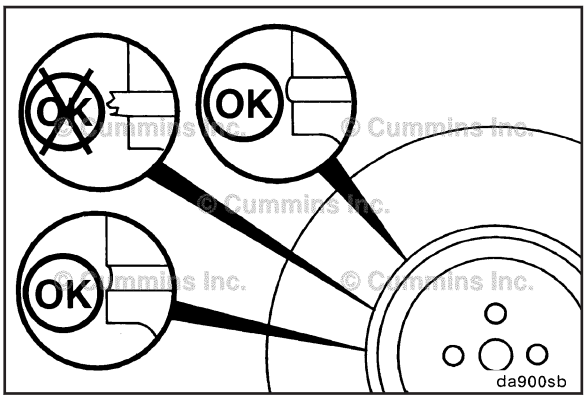
Remove the vibration damper.



Inspect for Reuse

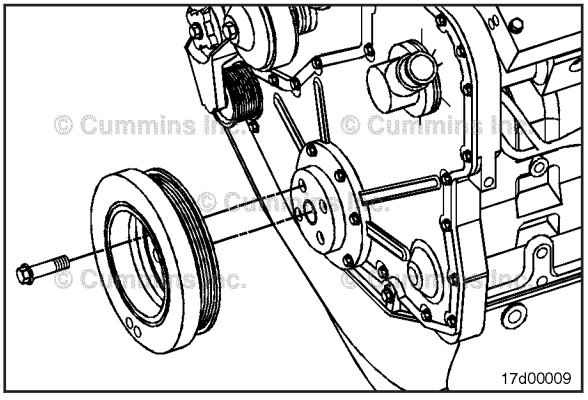
Check the index lines (A) on the damper hub (B) and the inertia member (C). If the lines are more than 1.59 mm [1/16 in] out of alignment, replace the damper.

Inspect the vibration damper hub (B) for cracks. Replace the damper if the hub is cracked.



Inspect the rubber member for deterioration. If pieces of rubber are missing or if the elastic member is more than 3.18 mm [1/8 in] below the metal surface, replace the damper.

NOTE: Also look for forward movement of the damper ring on the hub. Replace the damper if any movement is detected.



Install

NOTE: Some engines use four damper capscrews while others use five damper capscrews.

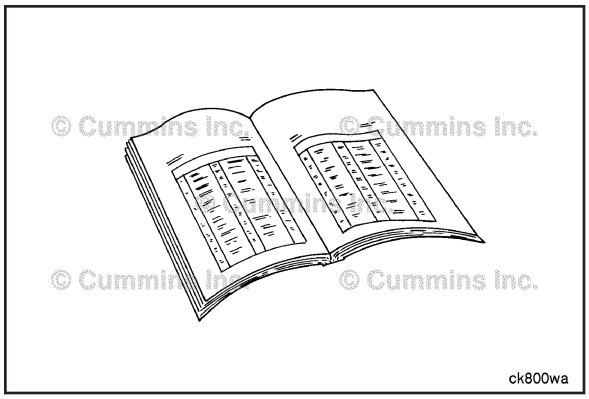
Install the vibration damper.

Tighten the capscrews in a star pattern.

Torque Value: 200 N•m [148 ft-lb]

Finishing Steps

- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Install the fan and fan shroud, if removed.
- Install the belt guard, if equipped. Refer to Procedure 008-001 in Section 8.
- Connect the battery. Refer to Procedure 013-009 in Section 13.
- Start the engine and check for proper operation.

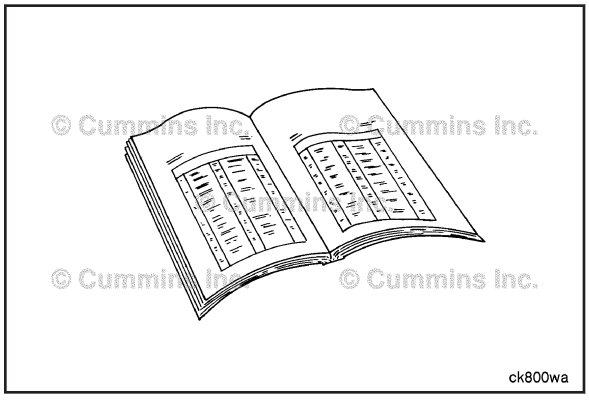


Vibration Damper, Viscous (001-052)

Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

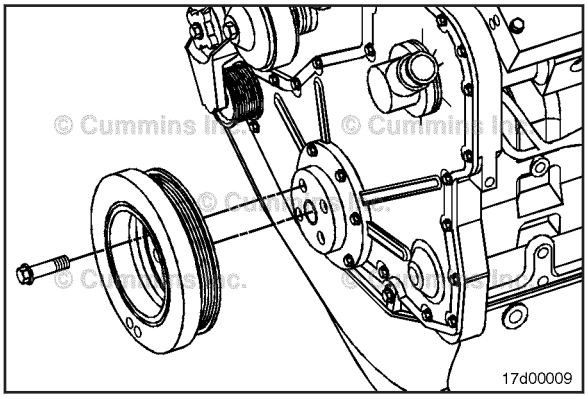
- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the belt guard, if equipped. Refer to Procedure 008-001 in Section 8.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the fan and fan shroud, if necessary.

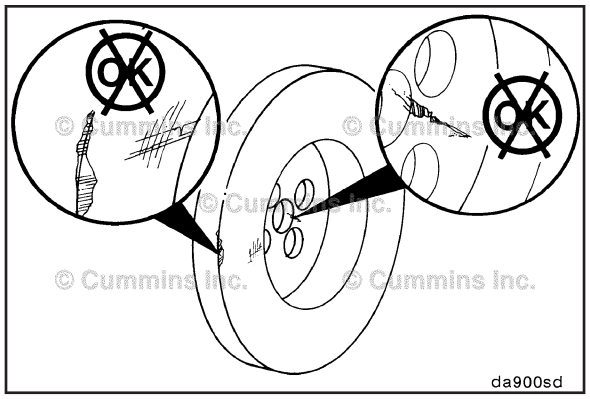


Remove

NOTE: Some engines use four damper capscrews while others use five damper capscrews.

Remove vibration damper.



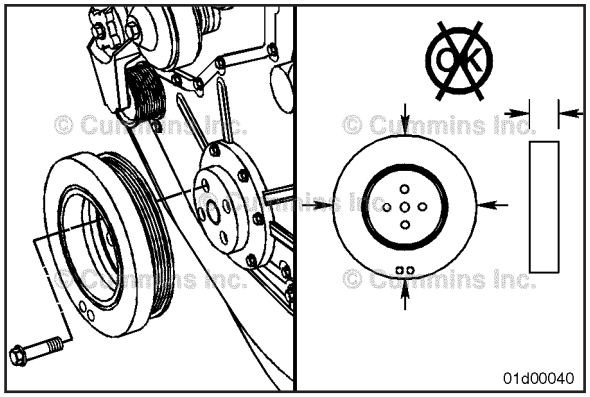


Clean and Inspect for Reuse

Check the mounting web for cracks.

Check the housing for dents or raised surfaces.

Replace the damper if any of these defects are identified.

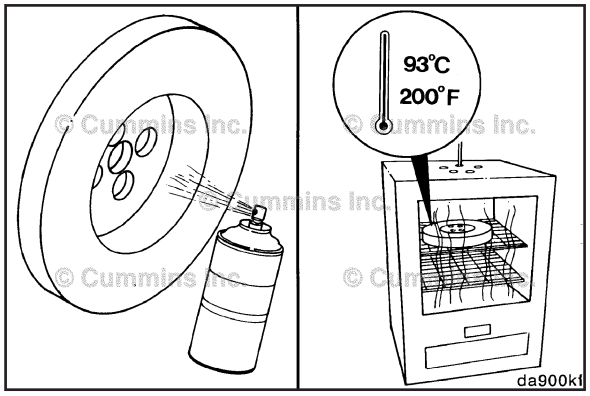


The viscous damper is filled with a silicone fluid. After many hours of use, the silicone fluid may become thicker and expand.

To determine if the damper thickness is correct, remove the paint from the damper in four locations on either side of the damper. Measure and record the thickness of the damper in four places.

Measure the thickness 3.175 mm [0.125 in] from the outside of the damper.

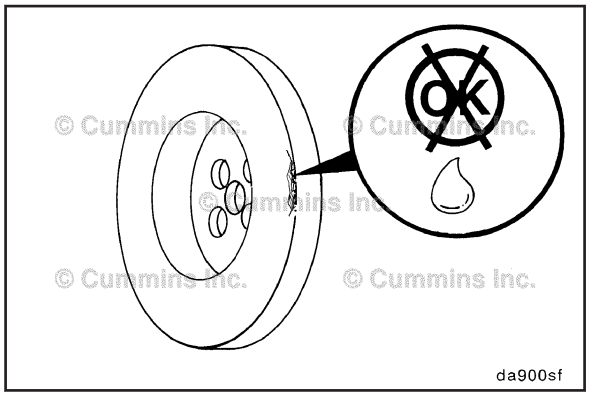
Replace the damper if its thickness varies by more than 0.25 mm [0.010 in].



Spray the damper with spot check developer, type SKD-NF, or equivalent.

Heat the damper in an oven (rolled lip side down) for two (2) hours.

Temperature 93 °C [200 °F]



⚠WARNING⚠
Wear protective gloves to reduce the possibility of personal injury when handling parts that have been heated.

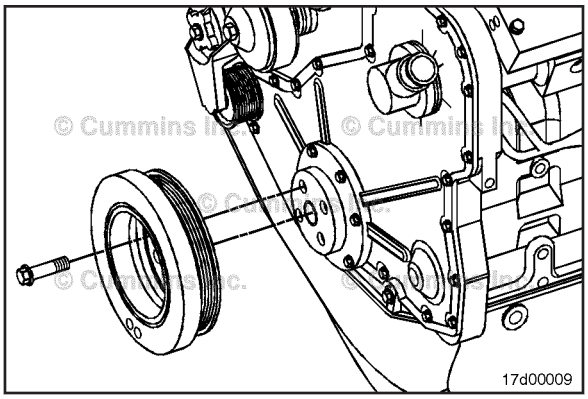
Remove the damper from the oven and check for fluid leakage.

If there is leakage, replace the damper.

Install

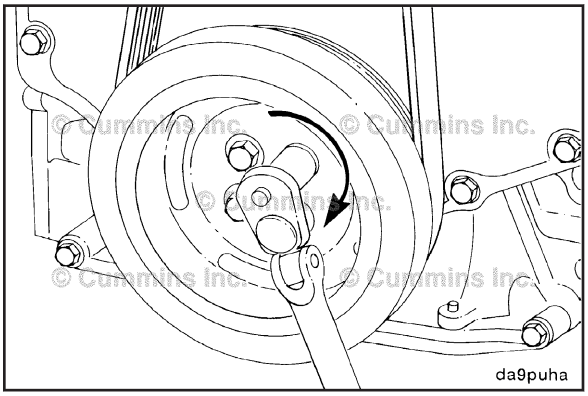
NOTE: Some engines use four damper capscrews while others use five damper capscrews.

Install the vibration damper.



Tighten the capscrews in a star pattern.

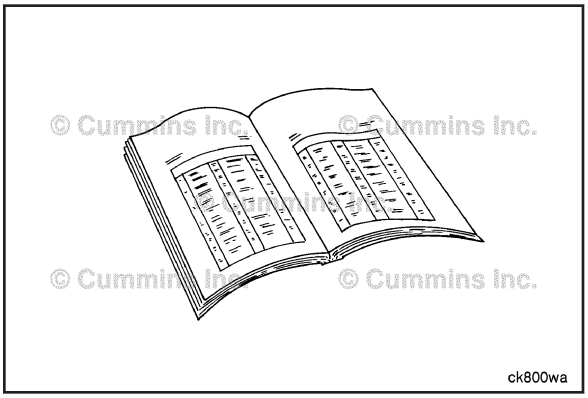
Torque Value: 200 N•m [148 ft-lb]

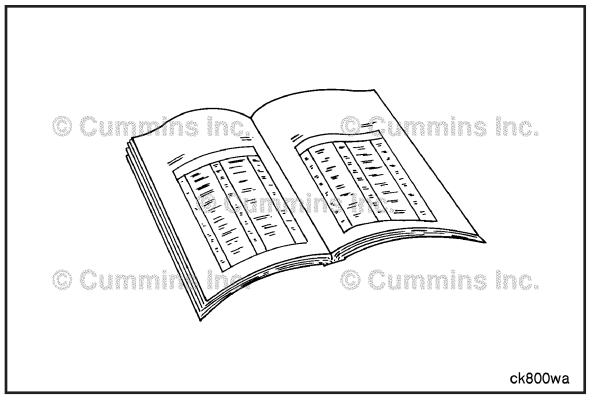


Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Install the fan and fan shroud, if removed.
- Install the belt guard, if equipped. Refer to Procedure 008-001 in Section 8.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for loose parts.





Piston and Connecting Rod Assembly (001-054)

Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

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

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Remove the piston cooling nozzles, if required. Refer to Procedure 001-046 in Section 1.
- Remove the cylinder head. Refer to Procedure 002-004 in Section 2.

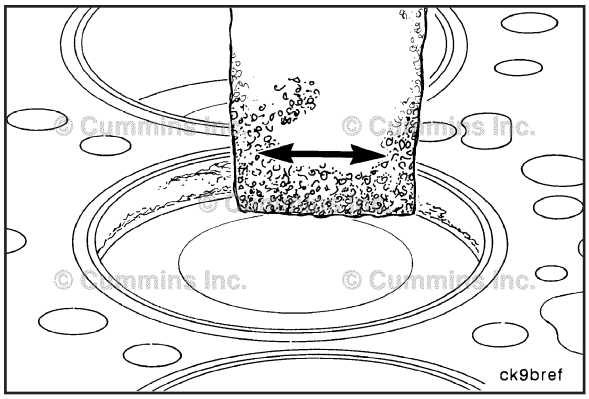
Remove

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

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

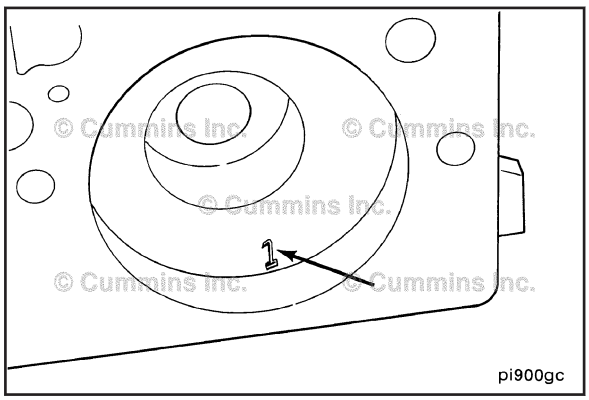
Rotate the crankshaft until the pistons are just below the carbon deposits that are found above the ring travel area.

Use an abrasive pad, Part Number 3823258, or equivalent, and solvent to remove the carbon deposits.



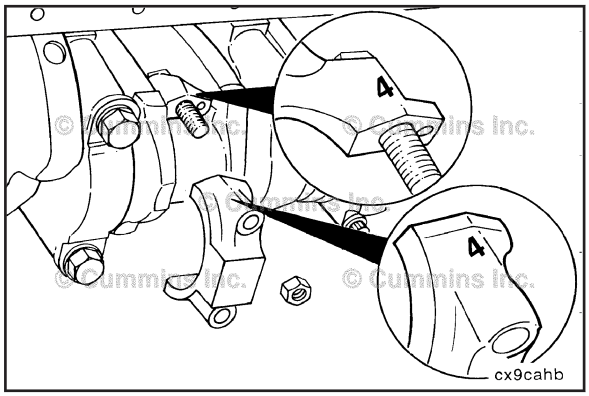
Mark each piston according to the cylinder location.

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.



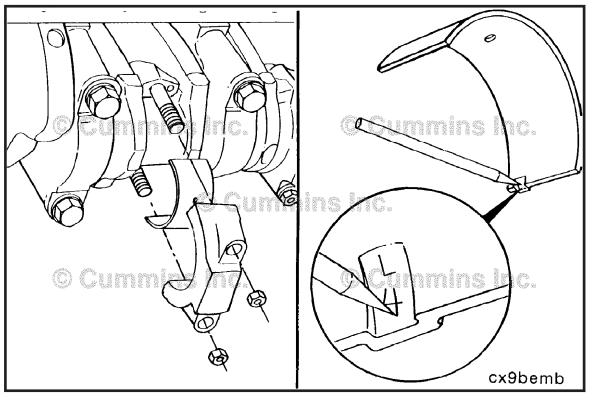
Rotate the crankshaft to position the rod cap at Bottom Dead Center (BDC) for removal.

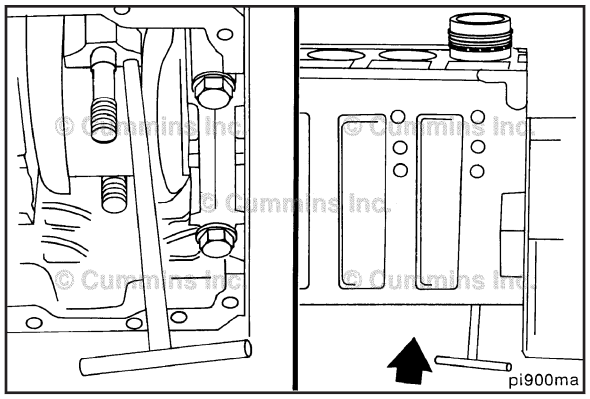
Mark each connecting rod and rod cap according to the cylinder number location.



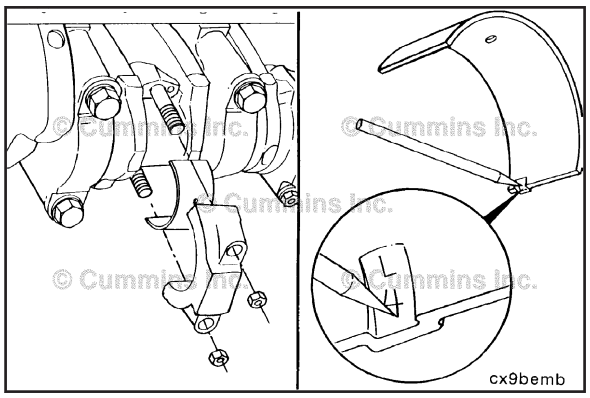
Engines with Horizontal Split Connecting Rods

- Remove the nuts, connecting rod cap, and lower connecting rod bearing.
- Mark the cylinder number and the letter "L" (lower) on the flat surface of the bearing tang.



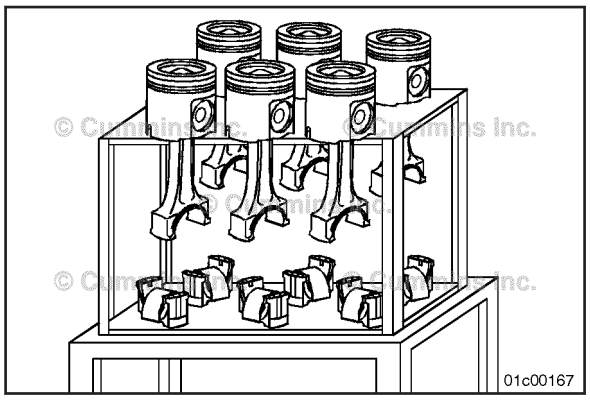


Push the connecting rod and piston assembly out of the cylinder bore. Care **must** be taken to **not** damage the connecting rod or bearing.



Remove the upper rod bearing.

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

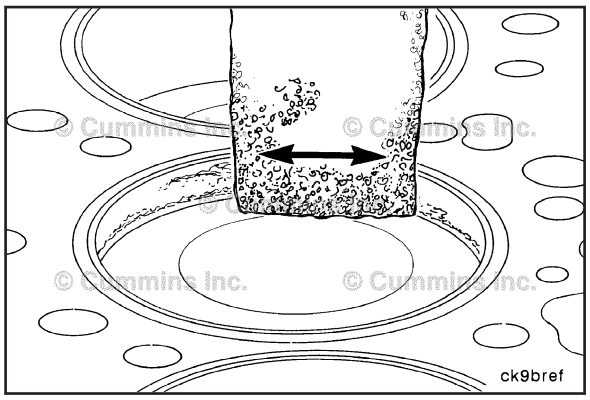


Use both hands to remove the piston and connecting rod assembly.

If parts are reused, the piston and connecting rod assemblies **must** be installed in the same cylinder locations from which they were removed to provide the proper fit of worn mating surfaces.

Use tags to mark the piston and connecting rod assembly locations as they are removed.

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



⚠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.

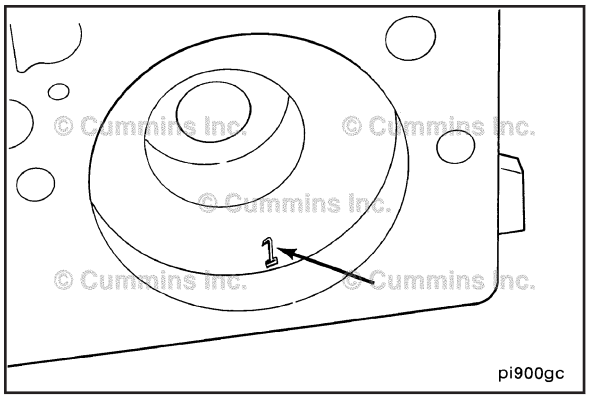
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Engines with Angle Split Connecting Rods

- Rotate the crankshaft until the pistons are just below the carbon deposits that are found above the ring travel area.
- Use an abrasive pad, Part Number 3823258, or equivalent, and solvent to remove the carbon deposits.

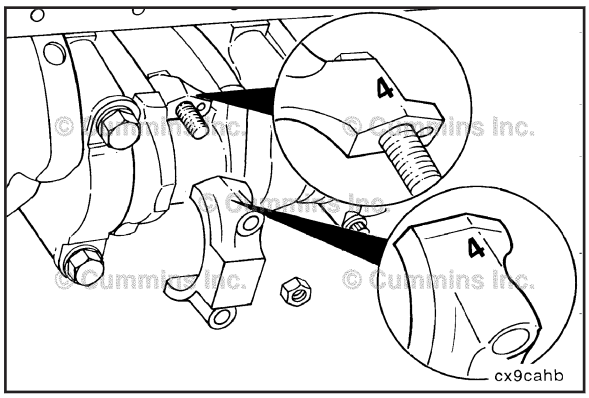
Mark each piston according to the cylinder location.

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 BDC for removal.

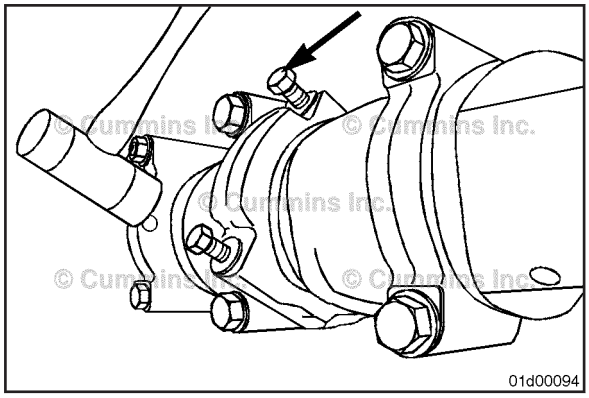
Mark each connecting rod and rod cap according to the cylinder location.



Loosen the connecting rod capscrews.

NOTE: 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 from the dowels.



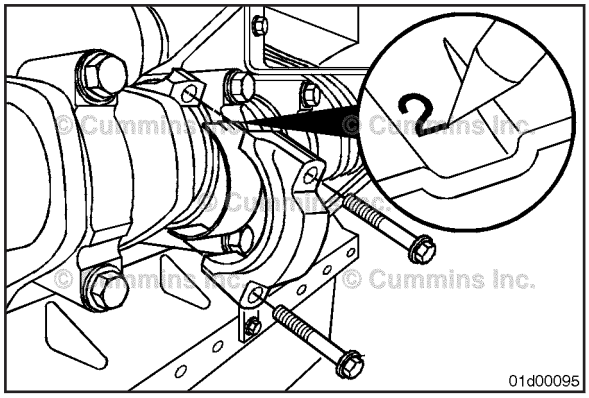
⚠CAUTION⚠
Do not damage the fractured split surface on the connecting rod or connecting rod cap while the connecting rod caps are removed. If the fractured split surface is damaged, the connecting rod and connecting rod cap must be replaced to help reduce the possibility of engine damage. Incorrect assembly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

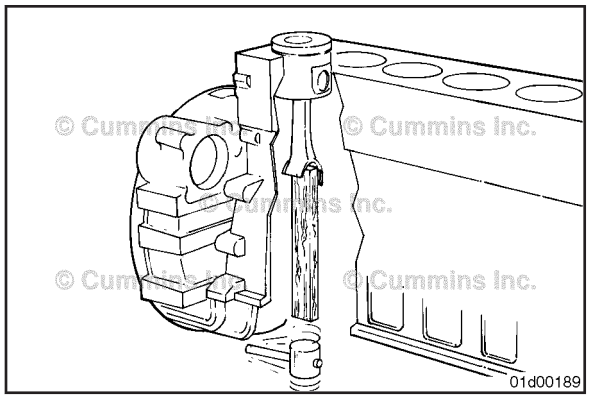
Remove the connecting rod capscrews.

Remove the rod cap.

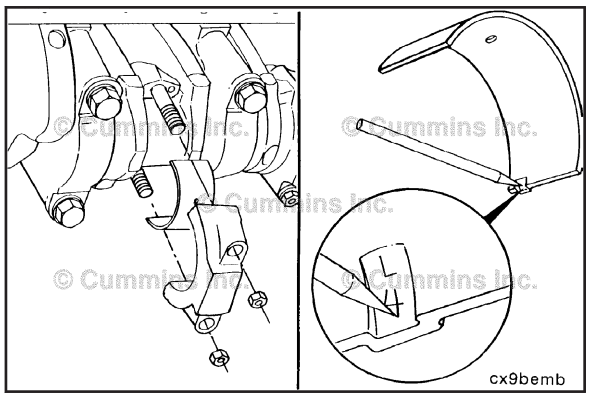
Remove the lower rod bearing.

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



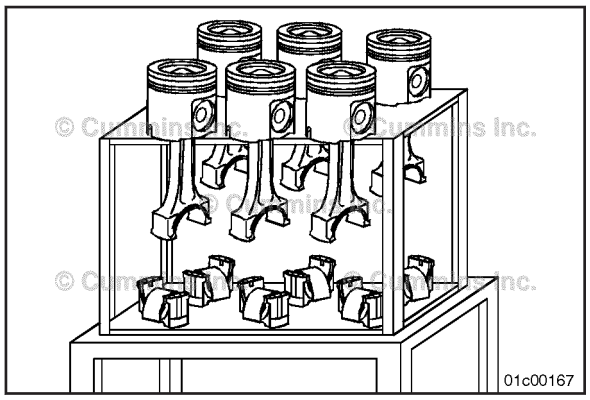


Push the connecting rod and piston assembly out of the cylinder bore. Care **must** be taken to **not** damage the connecting rod or bearing.



Remove the upper rod bearing.

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

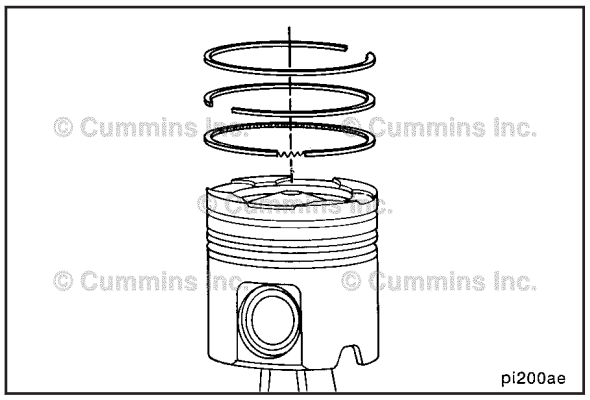


Use both hands to remove the piston and connecting rod assembly.

If parts are reused, the piston and connecting rod assemblies **must** be installed in the same cylinder location from which they were removed, to provide the proper fit of worn mating surfaces.

Use tags to mark the piston and connecting rod assembly locations as they are removed.

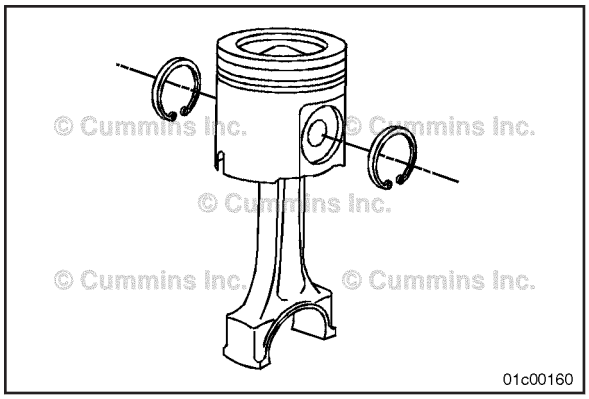
Place the rod and piston assemblies in a container to protect them from damage.



Disassemble

Use piston ring expander, Part Number 3823137, to remove the piston rings.

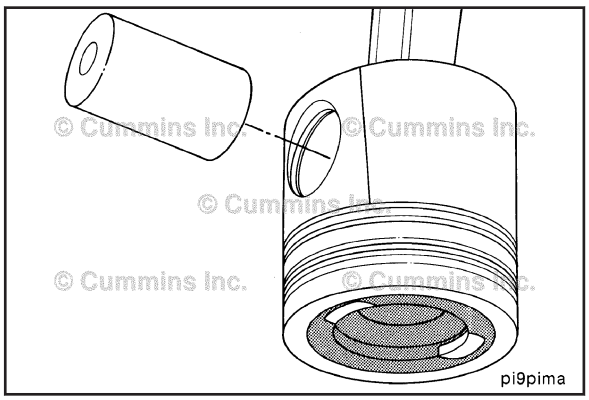
Use internal snap ring pliers to remove the snap rings from both sides of the piston.



Remove the piston pin.

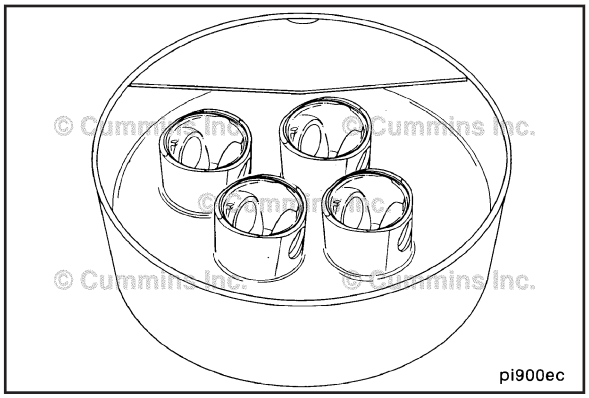
NOTE: Heating the piston is **not** required.

If the parts are to be reused, mark each component (piston, pin, and rings) with the cylinder number from which they were removed. Create an alignment mark on one side of each piston pin, piston, and connecting rod to make sure of the correct orientation during assembly.

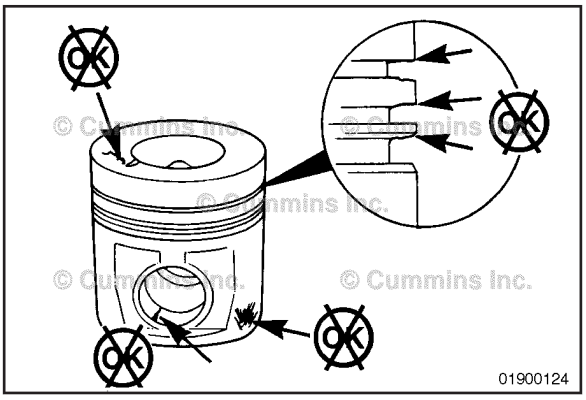


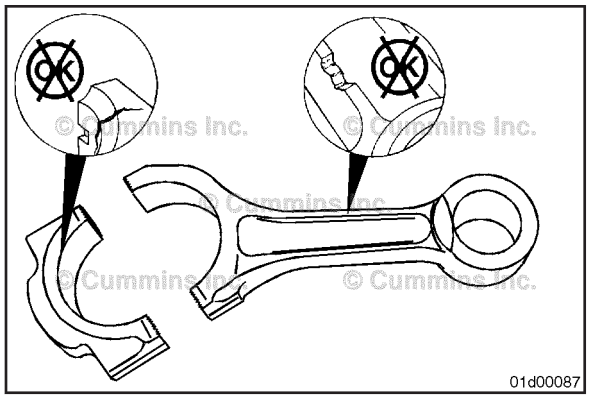
Clean and Inspect for Reuse

Clean the pistons. Refer to Procedure 001-043 in Section 1.

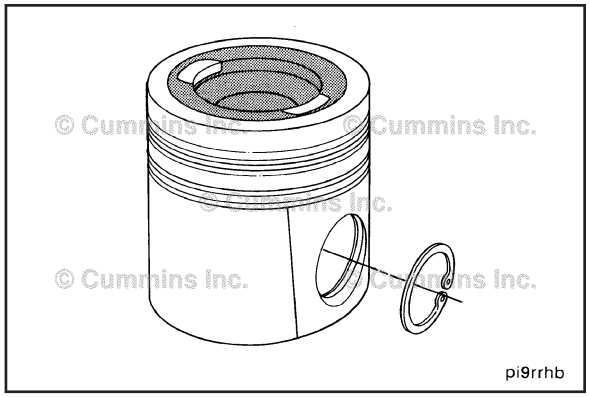


Inspect the pistons. Refer to Procedure 001-043 in Section 1.





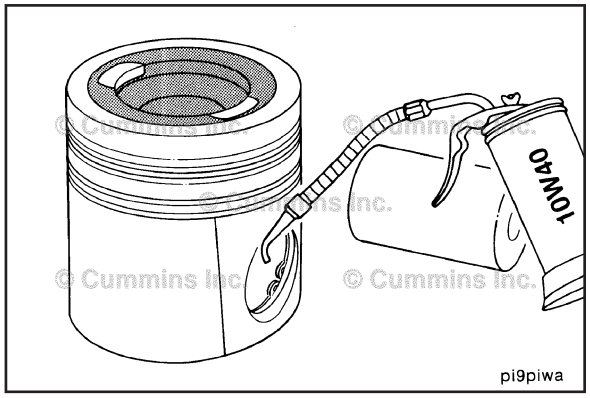
Inspect the connecting rods. Refer to Procedure 001-014 in Section 1.



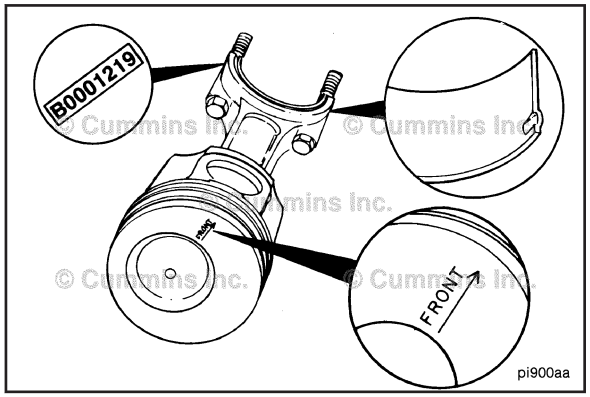
Assemble

Single-Piece Piston

Install the retaining ring in the pin groove on one side of the piston.



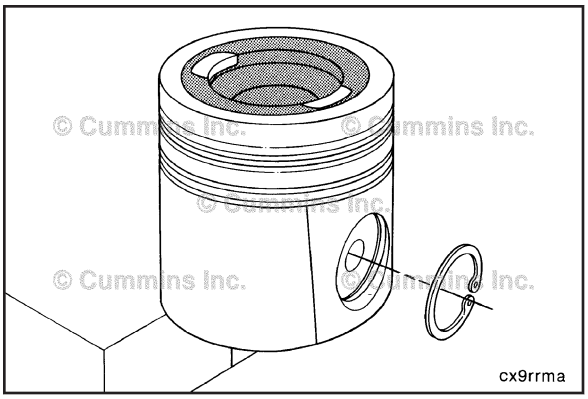
Lubricate the pin and pin bores with engine lubricating oil.



⚠CAUTION⚠
Make sure the "front" marking on the piston and the numbers on the rod and cap are oriented as illustrated.

Align the pin bore of the rod with the pin bore of the piston skirt, and install the piston pin.

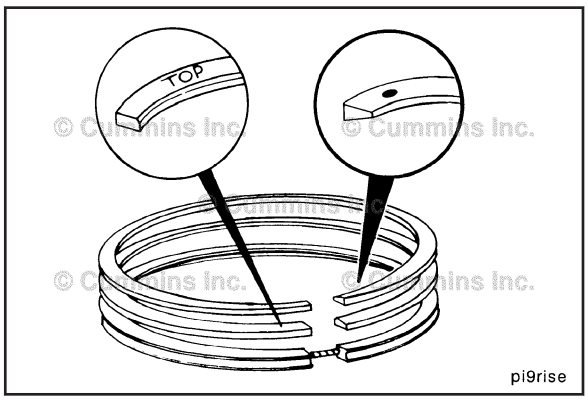
Install the second retaining ring.



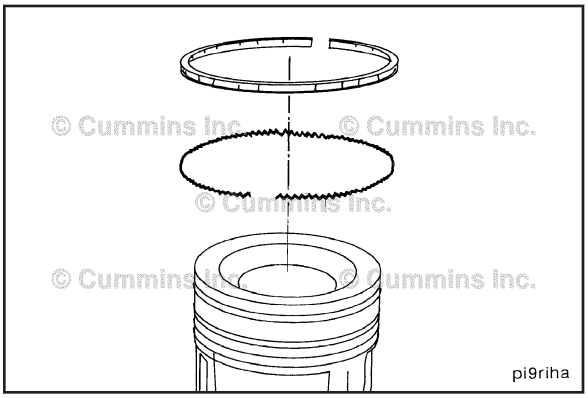
⚠CAUTION⚠
Most piston rings look similar but have significant difference. Make sure the correct part number is being used for the engine.

The top surface of the upper and intermediate rings are identified either with the word "TOP" or a supplier identification mark, such as a dot. Assemble with the word "TOP" or the supplier mark facing upward.

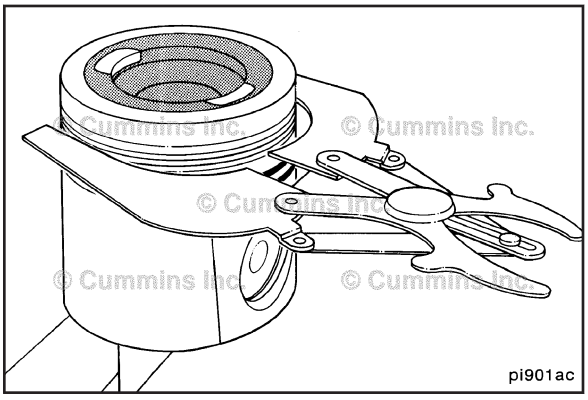
The bottom, or oil control ring, can be installed with either side up.

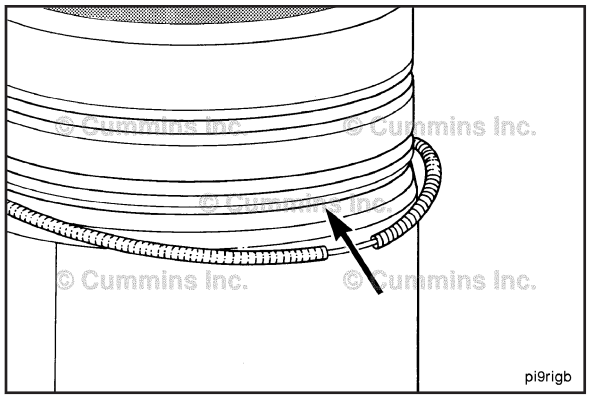


NOTE: The two-piece oil control ring **must** be installed with the expander ring gap 180-degrees from the gap of the oil ring.

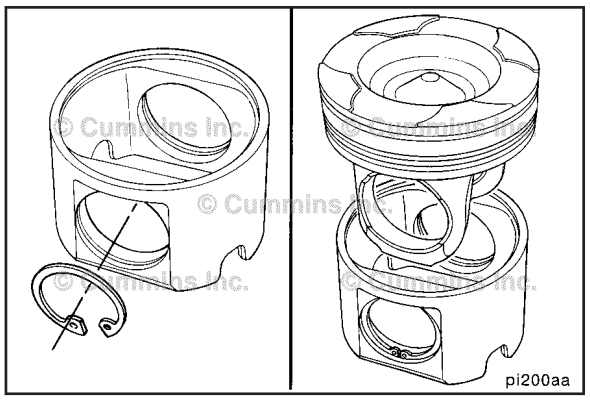


Use piston ring expander, Part Number 3823137, to install the rings on the piston.





Position the oil ring expander in the oil control ring groove.



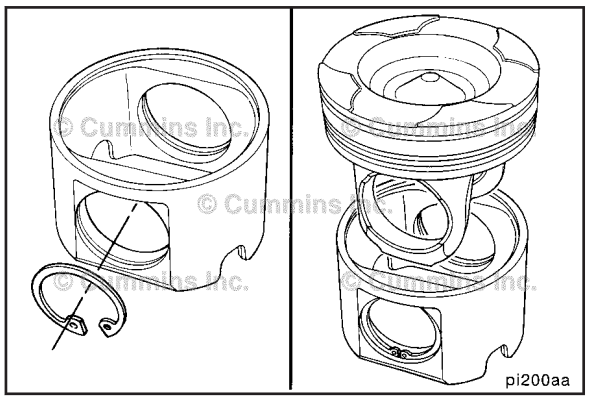
Articulated Piston

NOTE: If the pistons are being reused, the crown, skirt, and pin **must** be matched as they were when they were removed.

Position the skirt over the piston crown.

NOTE: It is **not** necessary to heat the articulated pistons before assembly. The piston pin is a slip fit.

Install the retaining ring in the pin groove on one side of the piston.



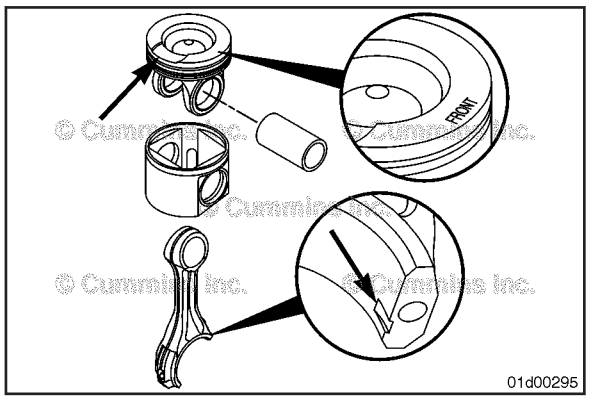
NOTE: If the pistons are being reused, the crown, skirt, and pin **must** be matched as they were when they were removed.

Position the skirt over the piston crown.

NOTE: It is **not** necessary to heat the articulated pistons before assembly. The piston pin is slip fit.

Engines with Angle Split Connecting Rods

- Install the retaining ring in the pin groove on one side of the piston.



△CAUTION△
Do not use a hammer to install the piston pin. The piston can distort, causing it to seize in the liner.

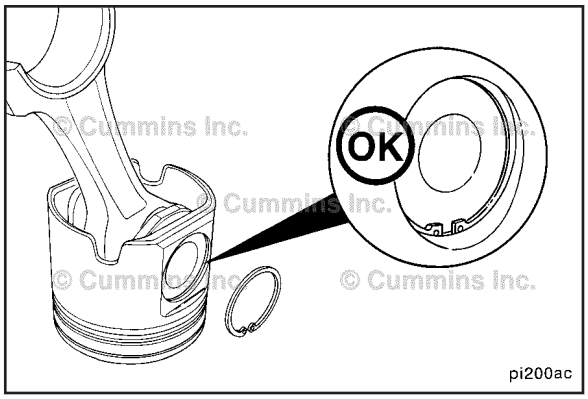
△CAUTION△
The lock tang on the connecting rod must be on the side opposite the deep valve pocket of the piston crown.

Lubricate the pin and pin bores with engine lubricating oil.

Align the pin bore of the rod with the pin bore of the piston skirt and crown, and install the piston pin.

⚠CAUTION⚠
The snap ring must be seated completely in the piston groove to prevent engine damage during engine operation.

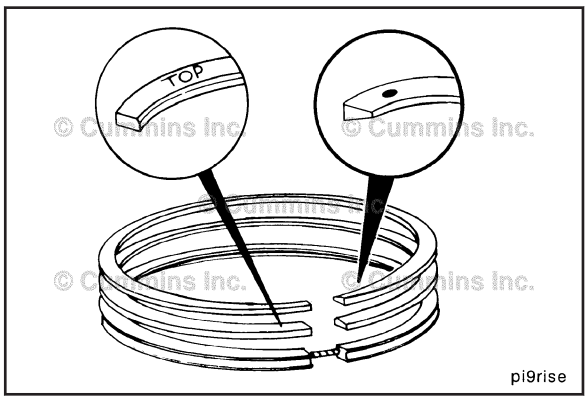
Install the second retaining ring.



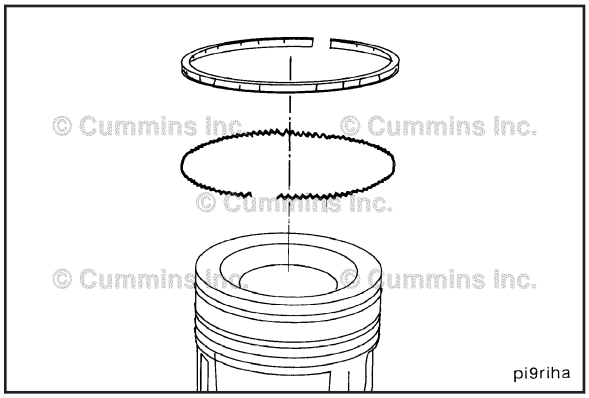
⚠CAUTION⚠
Most piston rings look similar but have significant difference. Make sure the correct part number is being used for the engine.

The top surface of the upper and intermediate rings are identified either with the word "TOP" or a supplier identification mark, such as a dot. Assemble with the word "TOP" or the supplier mark facing upward.

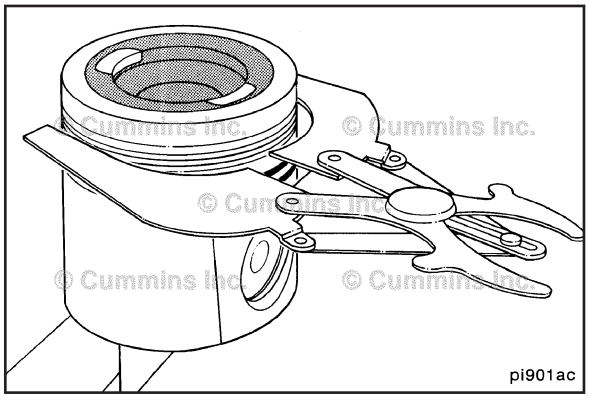
The bottom, or oil control ring, can be installed with either side up.

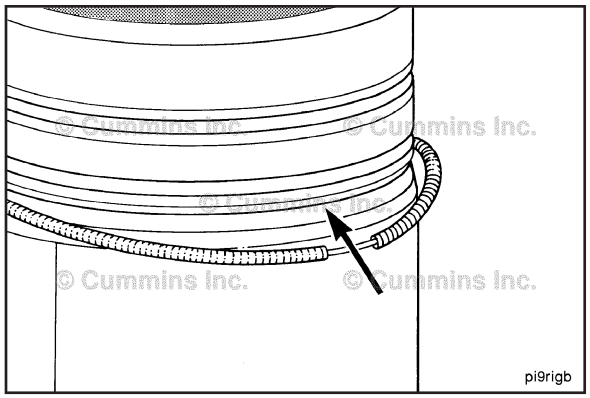


NOTE: The two-piece oil control ring **must** be installed with the expander ring gap 180-degrees from the gap of the oil ring.

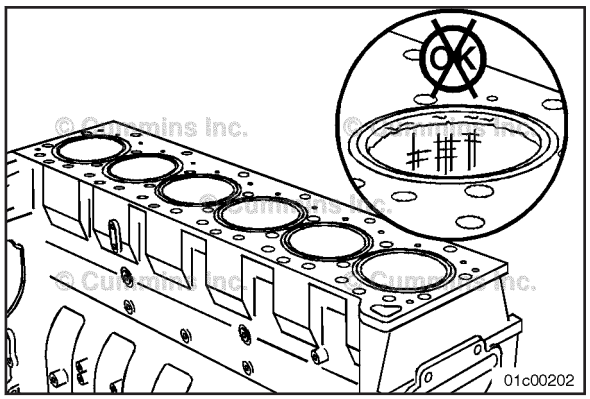


Use piston ring expander, Part Number 3823137, to install the rings on the piston.





Position the oil ring expander in the oil control ring groove.

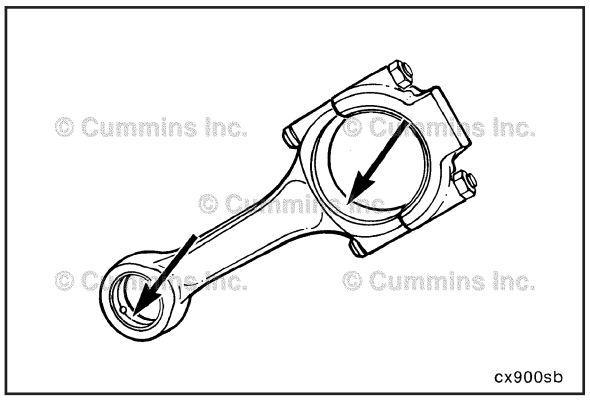


Install

The cylinder block and all parts **must** be clean before assembly. Inspect the cylinder liners for reuse.

Refer to Procedure 001-028 in Section 1.

Use a clean, lint-free cloth to clean the connecting rods and bearing shells.



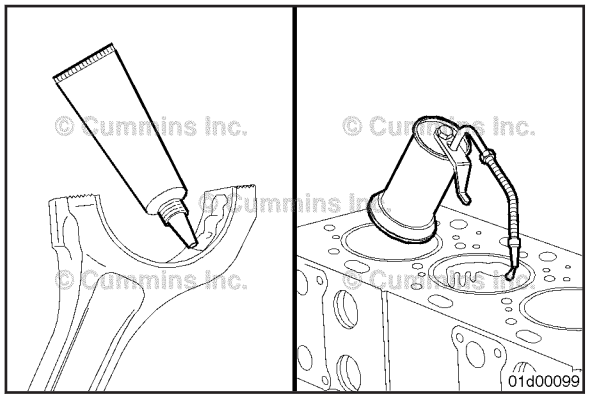
If new bearings are **not** used, the used bearings **must** be installed on the same connecting rod and location from where they were removed.

Install the upper bearing shell into the connecting rod.

The tang of the bearing shell **must** be in the slot of the rod. The end of the bearing shell **must** be even with the cap mounting surface.

NOTE: The upper and lower rod bearing shells are **not** interchangeable on angle split connecting rods. The backs of the bearings are marked with either "UPR" or "LWR" to indicate their location.

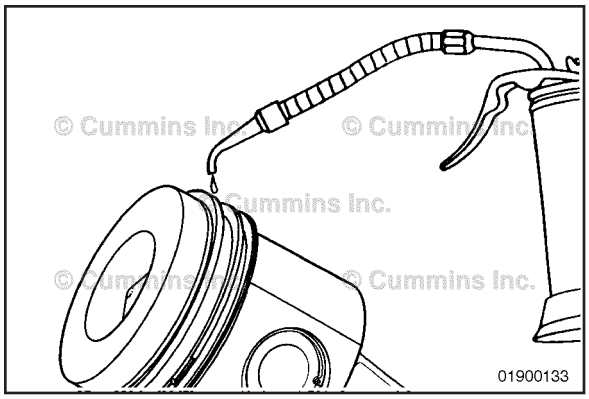
NOTE: If the connecting rod bushing is removed for any reason, a new bushing **must** be used.



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

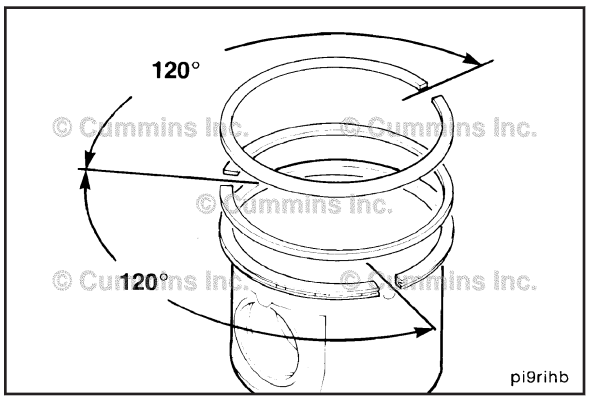
Apply a film of clean 15W-40 oil to the cylinder liner.

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

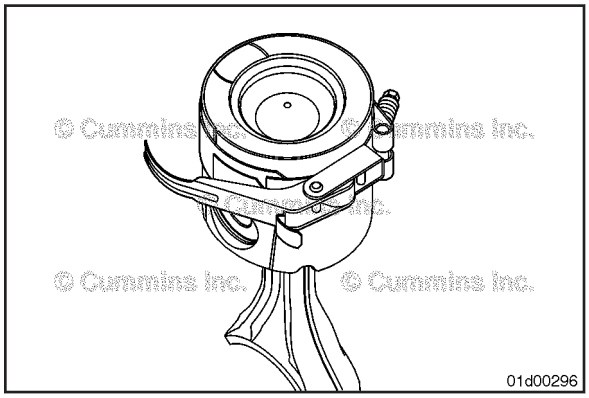


Rotate the rings to position the ring gaps as shown.

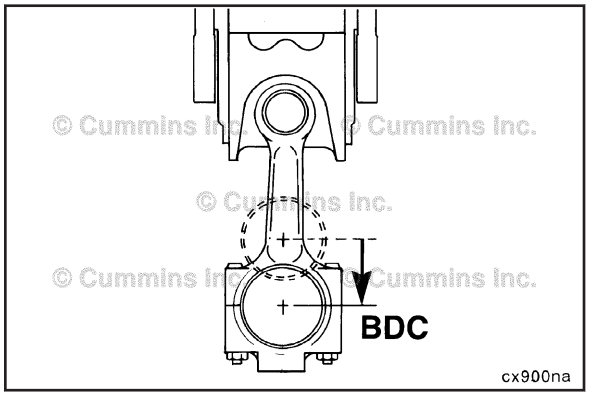
NOTE: The ring gap of each ring **must not** be aligned with the piston pin, or with any other ring. If the ring gaps are **not** aligned correctly, the rings will **not** seal properly.

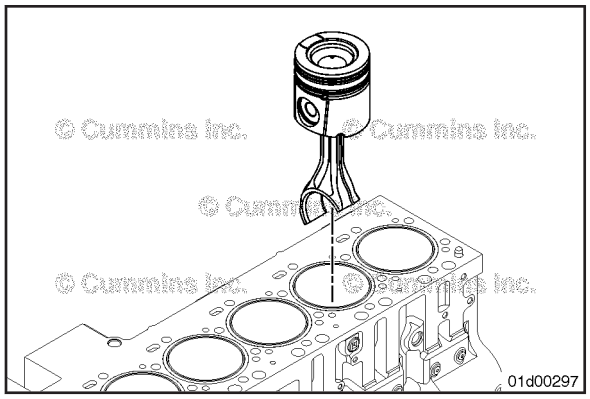


Use piston ring compressor, Part Number 3823290, to compress the rings.



Rotate the crankshaft so the connecting rod journal of the connecting rod being installed is at BDC.





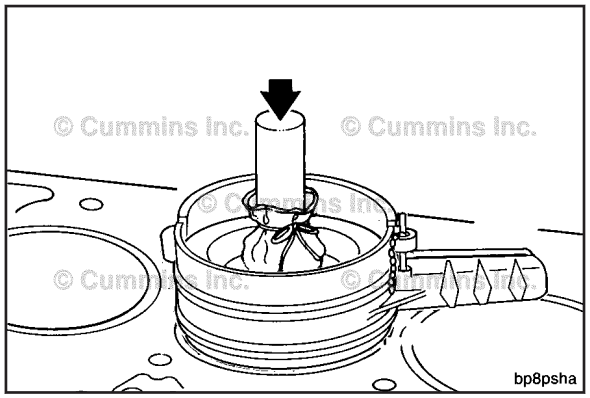
CAUTION

Omission of this step will result in extensive engine damage.

NOTE: For all piston types make sure that the "FRONT" marking on the piston crown is pointed toward the front of the engine block.

Engines with Angle Split Connecting Rods

- Align the piston crown deep valve pocket on the exhaust side of the engine.
- Insert the connecting rod through the cylinder liner until the ring compressor contacts the top of the liner.
- The angle split of the connecting rod should face the intake side.

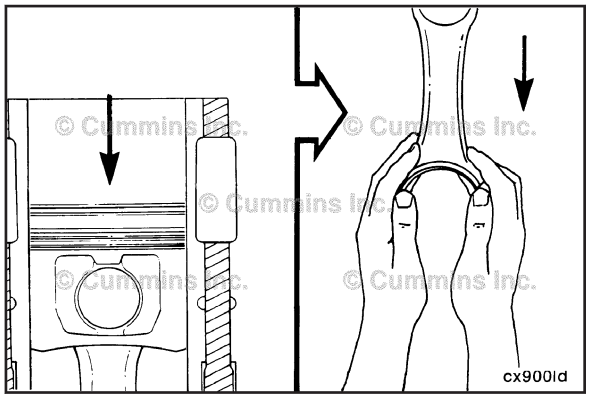


Hold the ring compressor against the cylinder liner.

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

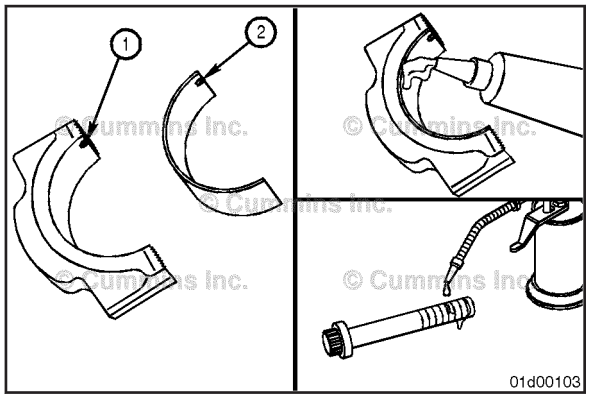
Push the piston until the top ring is completely in the cylinder liner.

NOTE: If the piston does **not** move freely, remove the piston and inspect for broken or damaged rings.



Carefully push the piston into the bore while guiding the connecting rod to the crankshaft journal.

NOTE: Connecting rod guide, Part Number 3824476, can be used to aid installation on engines with connecting rod studs.



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

Install the bearing in the connecting rod cap.

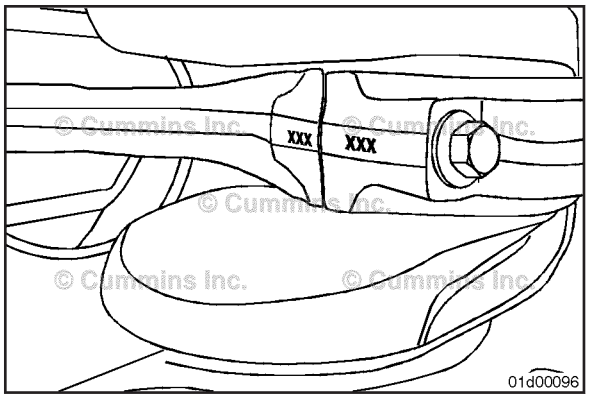
The tang of the bearing (2) **must** be in the slot of the cap (1).

Use assembly lubricant, Part Number 3163087, or equivalent, to coat the inside diameter of the bearing shell.

Use clean 15W-40 oil to lubricate 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.

Engines With Connecting Rod Studs and Nuts

- Install the connecting rod cap and nuts.
- Use a marked socket and torque wrench to tighten the connecting rod nuts.
- Use the torque plus angle method to tighten the connecting rod nuts in alternating sequence.

Torque Value:

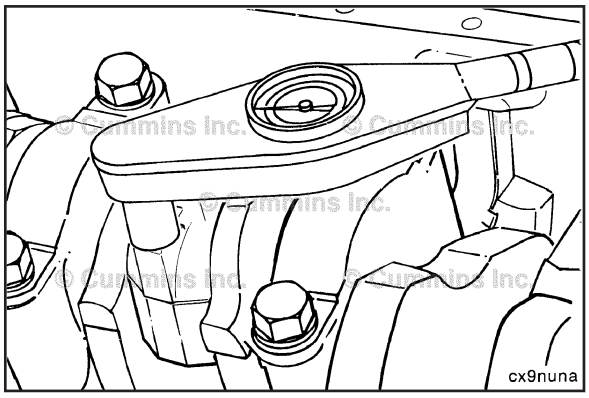
Connecting Rod Nuts		
Step 1	60 N•m	[44 ft-lb]
Step 2	Loosen capscrews	
Step 3	70 N•m	[52 ft-lb]
Step 4	Advance 90 degrees	

Engines With Connecting Rod Capscrews

- Install the connecting rod cap and capscrews
- Use a marked socket and torque wrench to tighten the connecting rod capscrews.
- Use the torque plus angle method to tighten the connecting rod capscrews in alternating sequence.

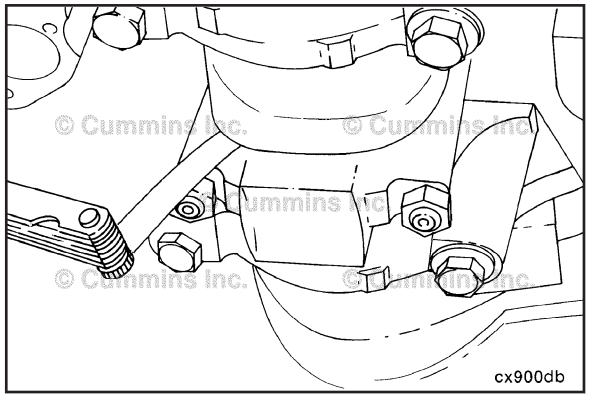
Torque Value:

Connecting Rod Capscrews		
Step 1	60 N•m	[44 ft-lb]
Step 2	Loosen capscrews	
Step 3	70 N•m	[52 ft-lb]
Step 4	Advance 60 degrees	

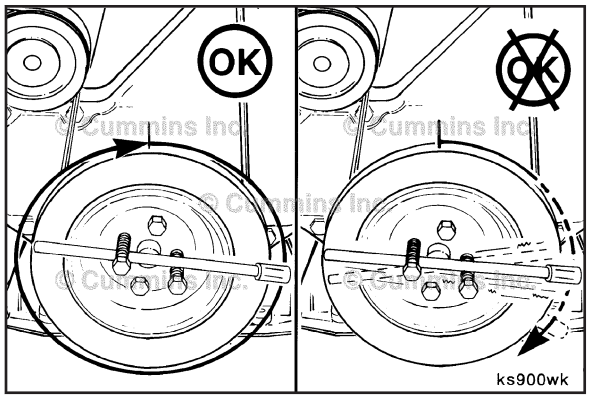


NOTE: Do **not** measure the clearance between the rod cap and crankshaft.

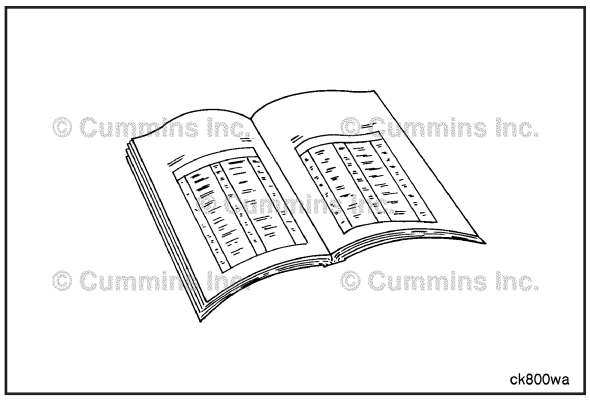
Measure the side clearance between the connecting rod and crankshaft.



Connecting Rod and Crankshaft Side Clearance		
mm		**in**
0.10	MIN	0.004
0.30	MAX	0.012



Check for freedom of rotation as the connecting rod caps are installed. If the crankshaft does **not** rotate freely, check the installation of the connecting rod bearings and the bearing size.

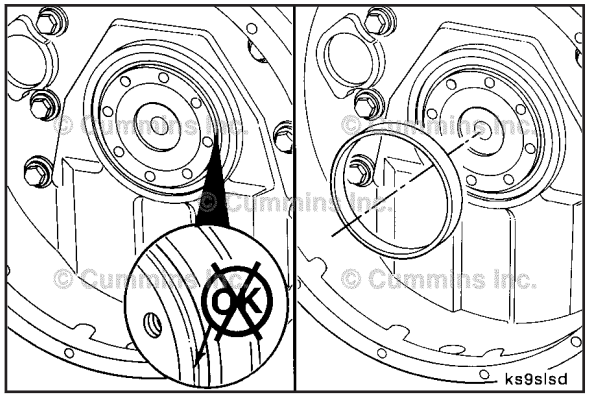


Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the piston cooling nozzles, if required. Refer to Procedure 001-046 in Section 1.
- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Install the cylinder head. Refer to Procedure 002-004 in Section 2.
- Fill the engine with lubricating oil. Refer to Procedure 007-037 in Section 7.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to OEM service manual.
- Operate the engine and check for leaks.



Crankshaft Wear Sleeve, Rear (001-067)

Initial Check

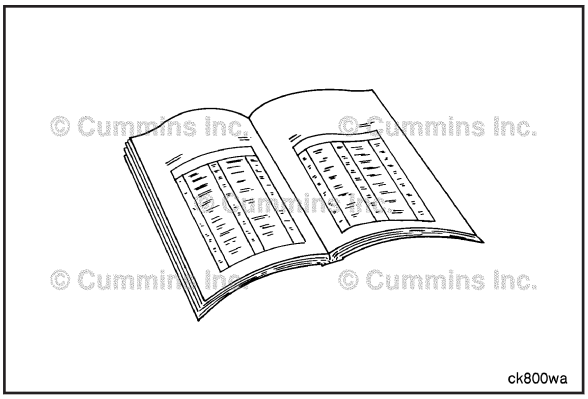
If the crankshaft seal has worn a groove in the crankshaft flange, a wear sleeve **must** be installed to prevent oil leakage.

Preparatory Steps

All Applications Except Marine

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Disconnect the driveline and remove the transmission, if equipped. Refer to the OEM service manual.
- Remove the clutch and flywheel, if equipped. Refer to Procedure 016-005 in Section 16.
- Remove the flywheel housing. 016-006 in Section 16.
- Loosen the lubricating oil pan mounting capscrews four revolutions.

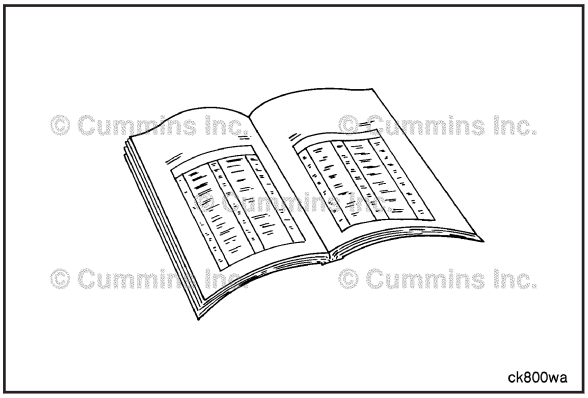


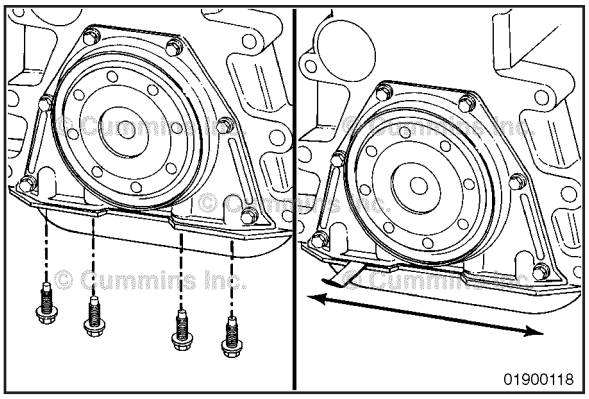
Marine Applications

⚠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: On some vessels, it can be necessary to lift the engine to replace the rear crankshaft seal.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Shut off the sea water supply valve. Refer to the OEM service manual.
- Remove the air crossover from the turbocharger to the aftercooler. Refer to Procedure 010-019 in Section 10.
- Remove the propeller driveshaft, marine gear and drive plate. Refer to the OEM service manual.
- Remove the starting motor. Refer to Procedure 013-020 in Section 13.
- Remove the flywheel. Refer to Procedure 016-005 in Section 16, if installed.
- Remove the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Loosen the lubricating oil pan mounting capscrews four revolutions.





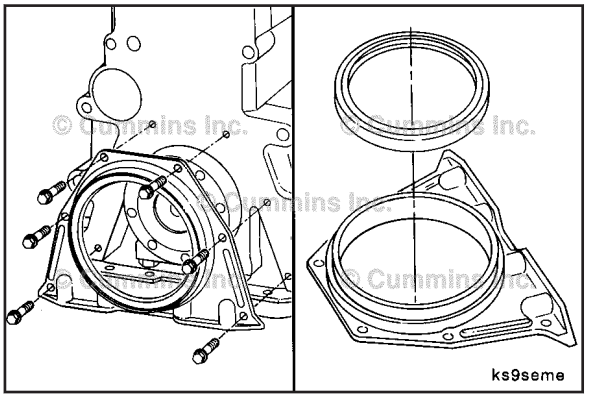
Remove

⚠CAUTION⚠

Use extreme care when releasing the oil pan gasket from the rear cover to prevent damage to the gasket. If the gasket is damaged, the oil pan must be removed and the gasket replaced. 007-025 in Section 7.

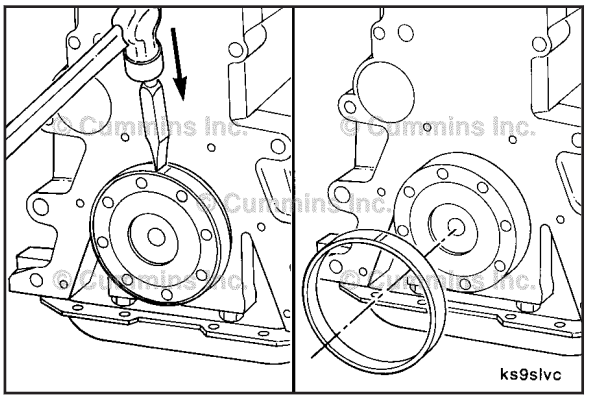
Remove the four lubricating oil pan mounting capscrews which secure the oil pan to the rear cover.

Insert a feeler gauge or shim stock between the rear cover and the oil pan gasket. Move the feeler gauge or the shim stock back and forth to release the gasket from the rear cover.



Remove the capscrews from the rear cover, and remove the cover from the crankshaft flange.

Remove the seal from the rear cover.

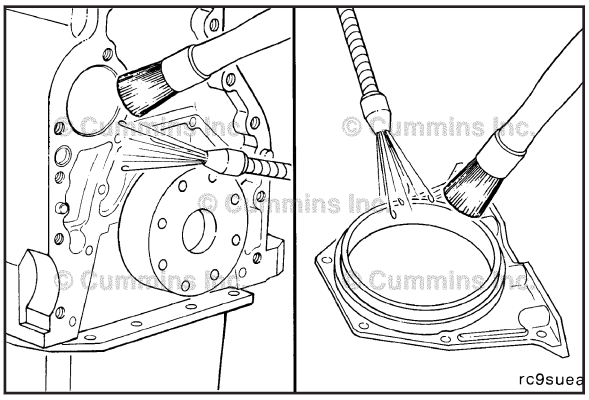


⚠CAUTION⚠

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

Use a dull chisel that is **only** as wide as the wear sleeve.

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



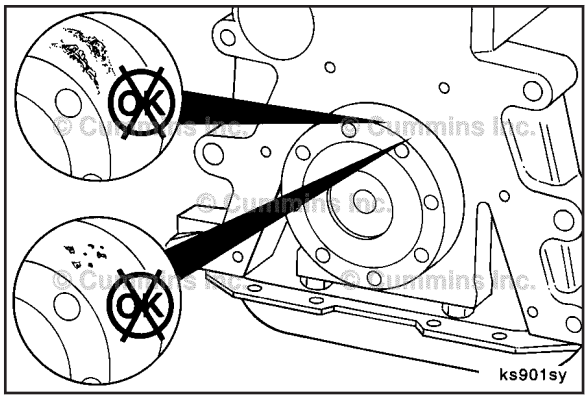
Clean and Inspect for Reuse

Clean the gasket surface of the cylinder block and rear cover.

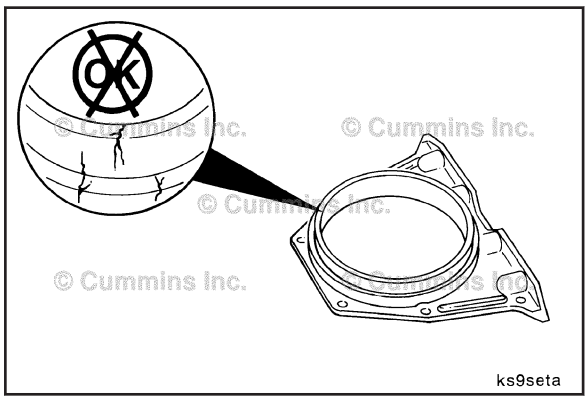
Use a crocus cloth to remove any rust or other deposits from the crankshaft flange.

Use a clean cloth to clean the crankshaft flange.

Inspect the crankshaft flange for dirt or nicks.



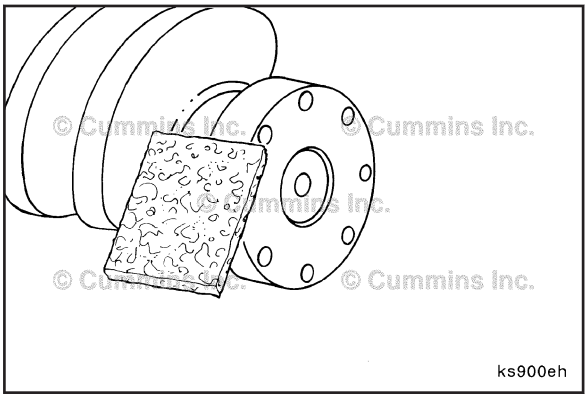
Inspect the rear cover for cracks or other damage.



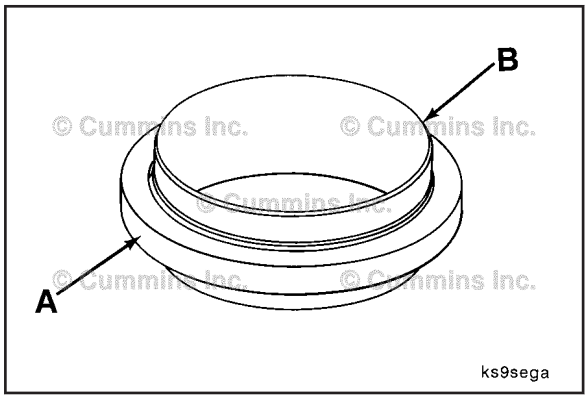
Install

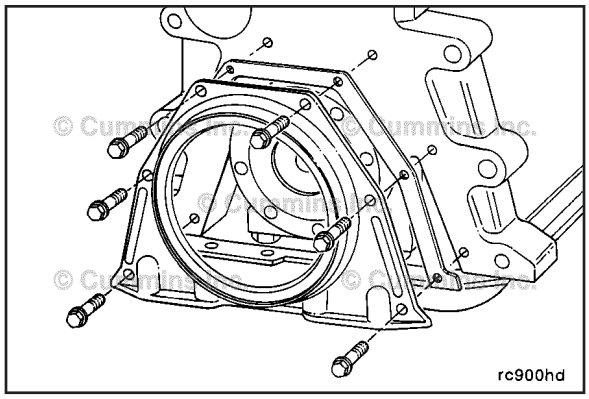
NOTE: Do **not** use any kind of lubricant to install the seal. The oil seal **must** be installed with the lip of the oil seal and the crankshaft clean and dry to make sure of proper oil sealing.

Clean any lubricant from the lip of the oil seal.



The combination crankshaft oil seal (A) wear sleeve (B) replacement kit for service usage is installed on the crankshaft as an assembly. The crankshaft rear oil seal should **not** be removed from the crankshaft rear seal wear sleeve.

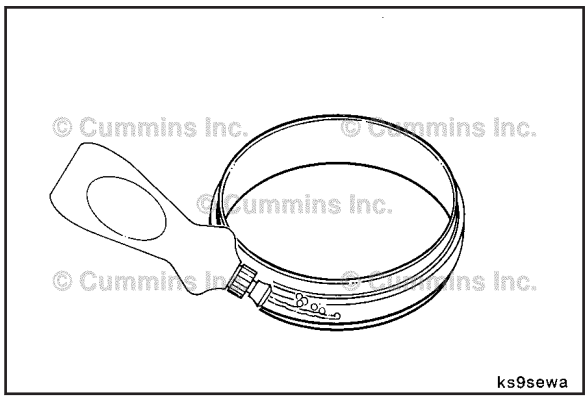




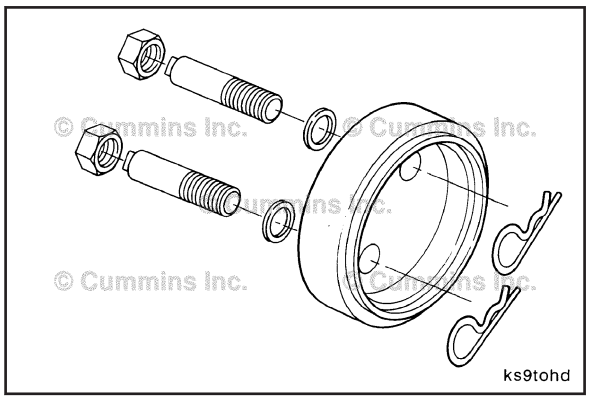
NOTE: If the oil pan is installed, loosen the oil pan capscrews to allow clearance for rear cover and gasket clearance.

Install the rear cover and gasket.

The seal installation is being used to properly align the rear cover. Do **not** push or force the cover in any direction to prevent irregular seal lip position after seal installation.

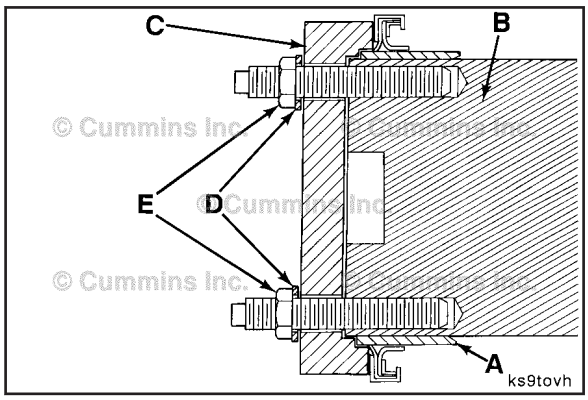


The oil seal for a wet flywheel housing requires soap on the outside diameter of the seal case. Nothing is required on the outside diameter of the seal case for dry housings.



Use a Rear Seal/Sleeve Installer, Part Number 3824078, to install oil seal/wear sleeve assembly. Install two (2) threaded studs into the crankshaft capscrew holes.

Apply a small amount of clean 15W-40 engine oil to the crankshaft, threaded studs, and inside diameter of the crankshaft rear seal/wear sleeve installation tool.



Position the chamfered end of the wear sleeve (A) onto the end of the crankshaft (B).

Position the counterbore end of installation tool (C) over threaded studs and align with wear sleeve, perpendicular to the end of the crankshaft.

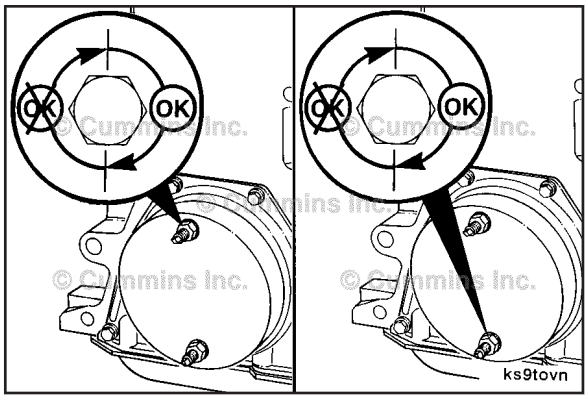
Install the washers (D) and nuts (E) onto the threaded studs.

Alternately tighten the nuts until the installation tool contacts the end of the crankshaft.

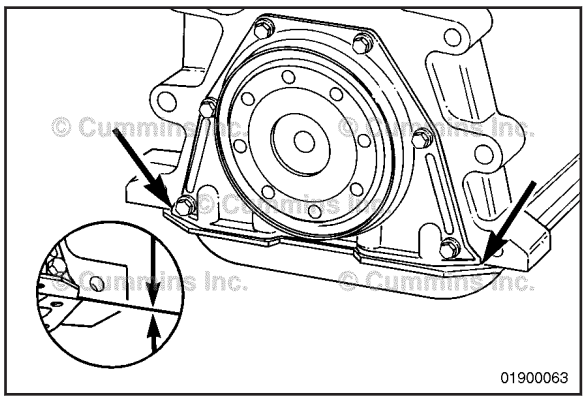
Do **not** exceed 1/2 revolution on each nut to prevent wear sleeve binding and irregular stretch.

Torque Value: 20 N•m [180 in-lb]

Remove the installation tool and threaded studs.



Align the rear cover even with both sides of the oil pan rail on the cylinder block.

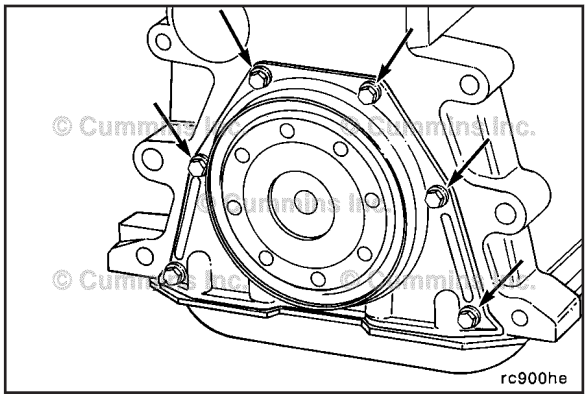


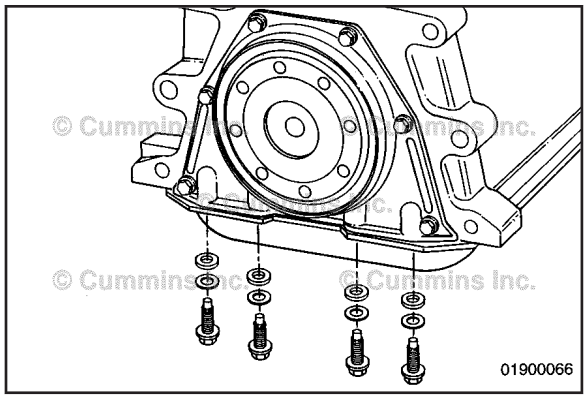
Tighten the rear cover capscrews.

The chart below shows the proper torque value when using either a 9.8 or a 10.9 grade bolt. The grade is embossed on the top of each bolt.

Apply Dri Lock™ to both part numbers below during installation. Dri Lock™ 205 is recommended. Use Dri Lock™ 204 or 211, when 205 is **not** available.

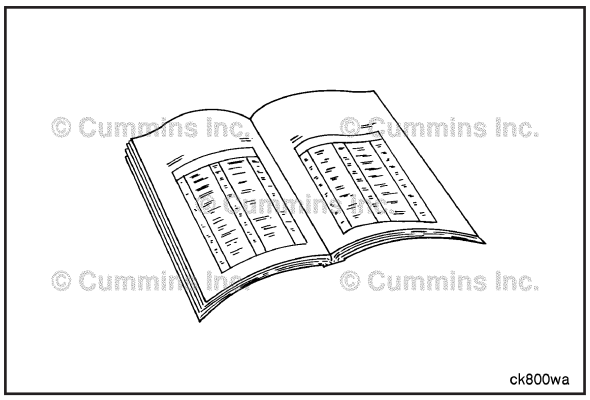
Rear Seal Carrier				
Bolt Number	**Bolt Size**	**Bolt Class**	**Torque**	**Dri-Lock**
3913638	M-6	9.8	10 N•m [88.5 in-lb]	No
3991306	M-6	10.9	13 N•m [115 in-lb]	Yes





Install the four (4) rear oil pan mounting capscrews to the pan.

Tighten the oil pan capscrews. 007-025 in Section 7.



Finishing Steps

All Applications Except Marine

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

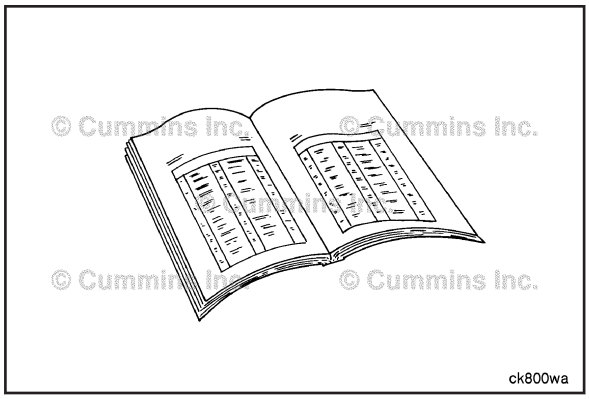
- Install the flywheel housing. 016-006 in Section 16.
- Install the clutch and flywheel, if equipped. Refer to Procedure 016-005 in Section 16, if installed.
- Install the transmission and connect the driveline, if equipped. Refer to the OEM service manual.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

Marine Applications

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

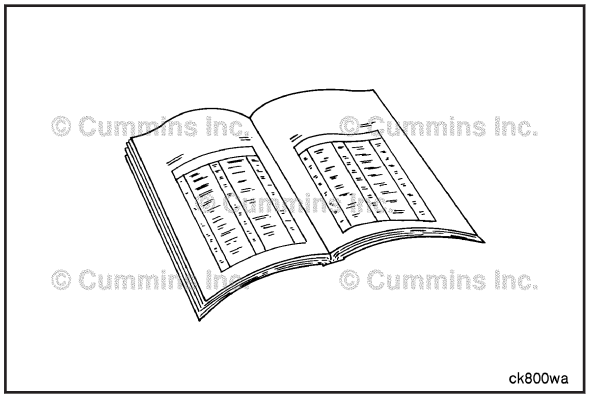
- Install the flywheel housing. Refer to Procedure 016-006 in Section 16.
- Install the flywheel. Refer to Procedure 016-005 in Section 16, if installed.
- Install the starting motor. Refer to Procedure 013-020 in Section 13.
- Install the drive plate, marine gear and propeller shaft. Refer to the OEM service manual.
- Install the air crossover from the turbocharger to the after cooler. Refer to Procedure 010-019 in Section 10.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Open the sea water supply valve. Refer to the OEM service manual.
- Operate the engine it idle for 5 to 10 minutes and check for leaks or loose parts.



Crankshaft Speed Indicator Ring (001-071)

Preparatory Steps

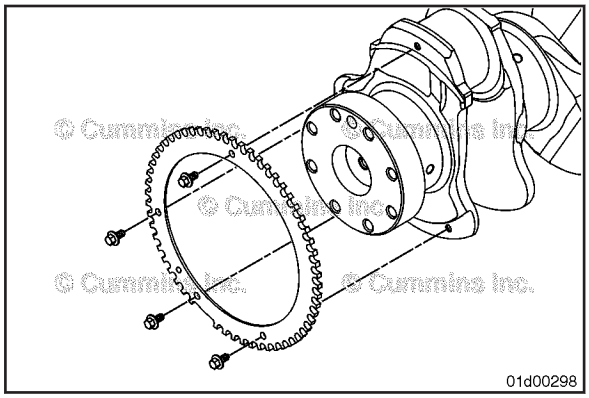
- Remove the crankshaft. Refer to Procedure 001-016 in Section 1.

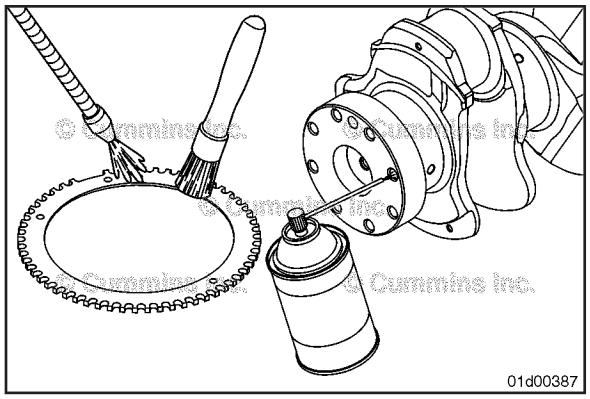


Remove

Remove and discard the four crankshaft speed indicator ring mounting capscrews.

NOTE: The capscrews are one-time use **only**. They can **not** be reused.





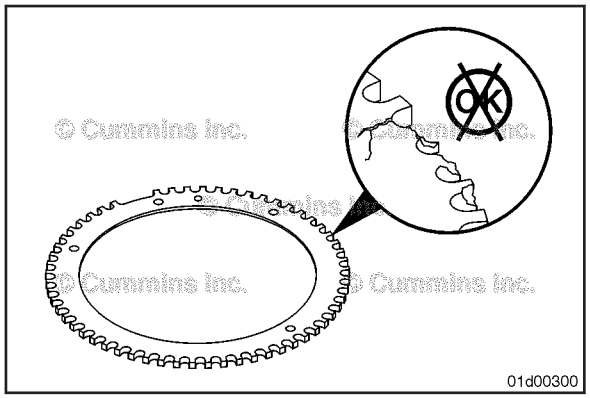
Clean and Inspect for Reuse

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

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Clean any oil from the speed indicator ring.

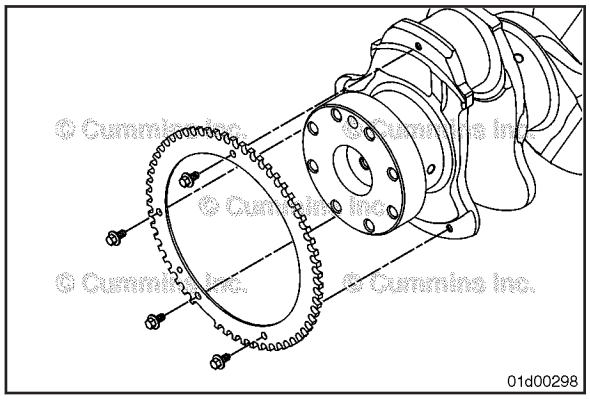
Clean the capscrew holes in the crankshaft. Use degreaser solvent such as contact cleaner, Part Number 3824510.



Inspect the speed indicator ring for missing, bent, or damaged teeth.

Inspect for cracks or damaged surfaces.

If any visual damage is found, the speed indicator ring **must** be replaced.



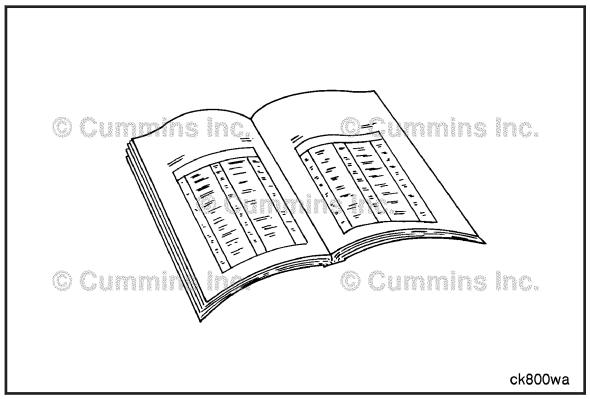
Install

Install the speed indicator ring.

Install new capscrews.

Tighten the capscrews in an alternating pattern.

Torque Value: 8 N•m [71 in-lb]



Finishing Steps

- Install the crankshaft. Refer to Procedure 001-016 in Section 1.
- Operate the engine and check for leaks and proper operation.

Block Stiffener Plate (001-089)

General Information

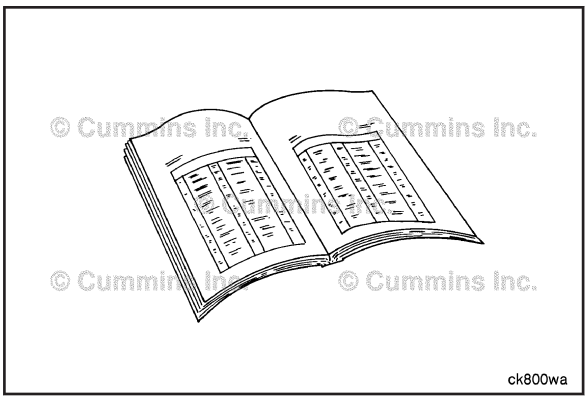
The block stiffener plate will **only** be found on some engines.

Preparatory Steps

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

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

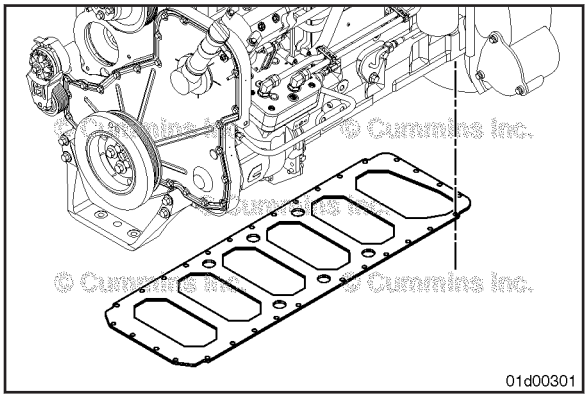
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.

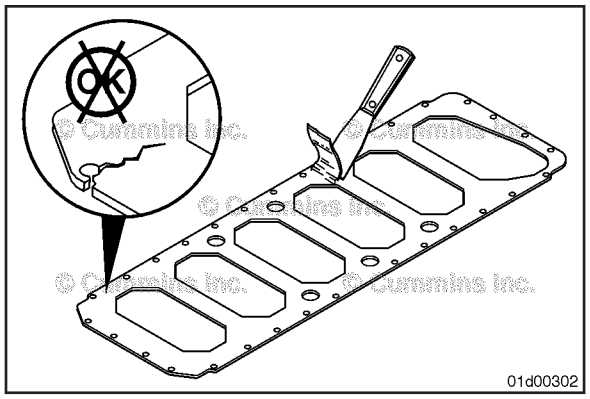


Remove

Remove the block stiffener plate.

NOTE: The plate will be loose after the oil pan capscrews are removed.

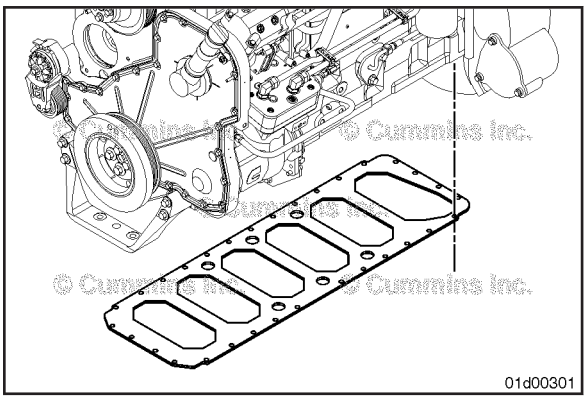




Clean and Inspect for Reuse

Remove all gasket material from both gasket surfaces.

Inspect the block stiffener plate for cracks or other damage.

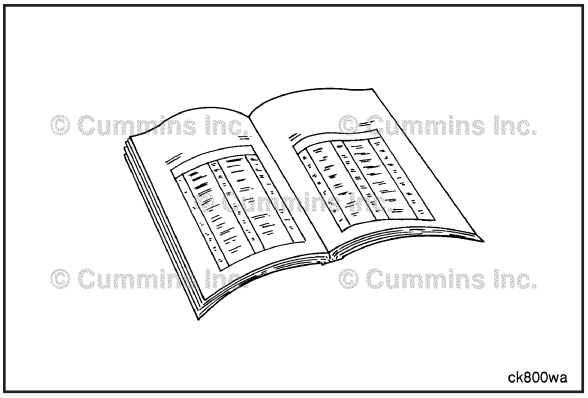


Install

Install the block stiffener plate. Use a new gasket and/or RTV sealant.

NOTE: The engines use a variety of combinations of gaskets and/or RTV sealant. When installing the oil pan and block stiffenter plate, use the same combination of gaskets and/or RTV sealant.

NOTE: The block stiffener **must** be held in place while the lubricating oil suction tube is installed. Use a few lubricating oil pan capscrews or wire ties to accomplish this.



Finishing Steps

- Install the lubricating oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Fill the engine with lubricating oil. Refer to Procedure 007-037 in Section 7.
- Operate the engine and check for leaks.

Section 2 - Cylinder Head - Group 02

Section Contents

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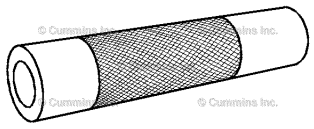
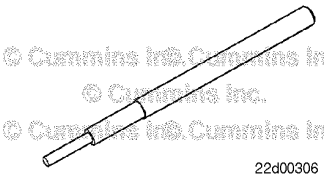
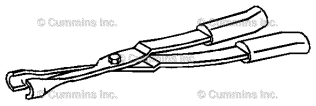
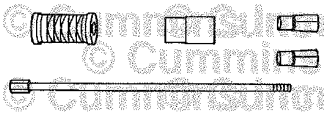
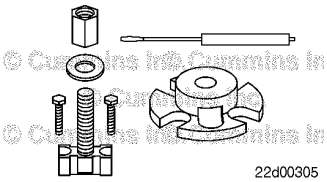
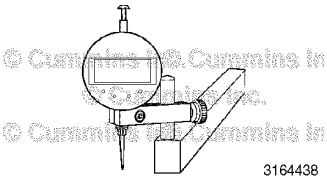
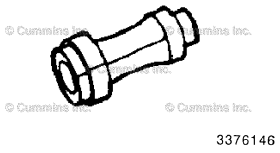
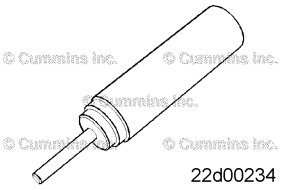
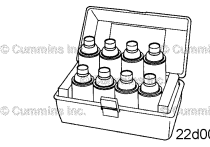
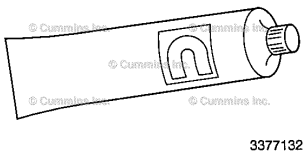
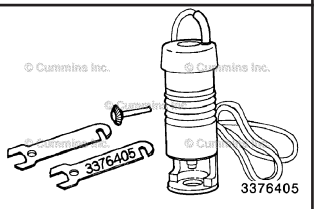
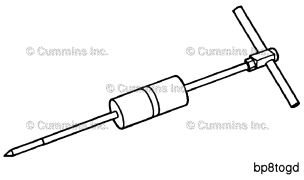
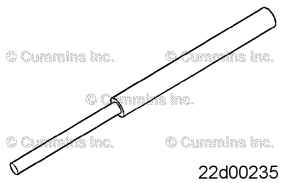
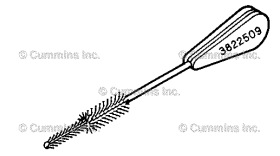
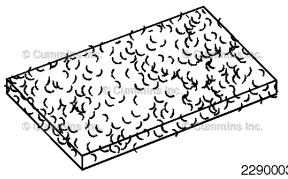
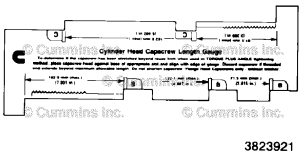
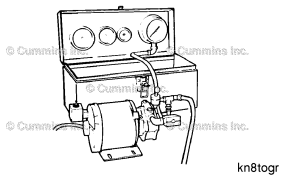
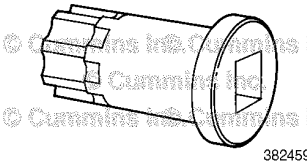
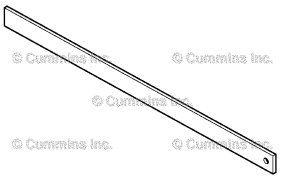
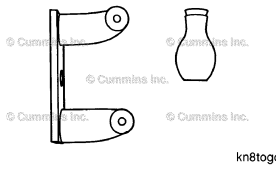
Service Tools

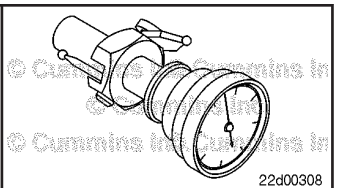
Cylinder Head

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
3163100	**Valve Guide Installer** Used to install valve guides.	 3163293
3163101	**Valve Guide Remover** Used to remove valve guides.	 22d00306
3163293	**Boot Pliers** Used to remove valve stem seals. The twist and pull action frees the boot and the serrated jaws provide a secure grip.	 3163294
3163720	**Dowel Pin Extractor** This puller contains various sized collets to remove crosshead guides or dowels throughout the engine.	 ck8toge
3164329	**Valve Spring Compressor** Used to remove and install valve collets.	 22d00305
3164438	**Depth Gauge Assembly** Used to measure injector protrusion and valve intrusion and/or protrusion. Equipped with electronic digital indicator.	 3164438

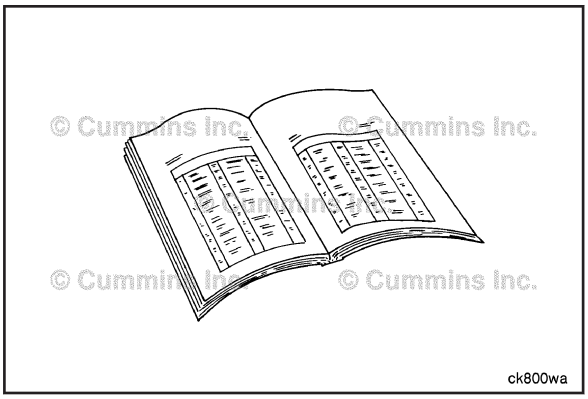
Tool No.	Tool Description	Tool Illustration
3165113	**Intake Valve Seat Extractor Collet** Used with slide hammer, Part Number 3376517. The slide hammer is sold separately.	
3165114	**Exhaust Valve Seat Extractor Collet** Used with slide hammer, Part Number 3376517. The slide hammer is sold separately.	
3165115	**Valve Seat Installer** Used for installing intake and exhaust valve seats.	
3375182	**Valve Spring Tester** Used to check spring tension.	
3375432	**Crack Detection Kit (Dye Type)** Used to clean and inspect components for cracks.	
3375805	**Valve Lapping Compound** An abrasive compound used to lap the valves.	
3376405	**Valve Seat Grooving Tool** Used to cut a groove in the valve seat. This is often required prior to use of the valve seat extractor. It requires cutter bit, Part Number 3376407. The cutter bit is sold separately.	
3376617	**Slide Hammer Assembly** Used with the valve seat extractor to remove the valve seat inserts from the cylinder head.	

Tool No.	Tool Description	Tool Illustration
3823186	**Valve guide Arbor** Used for positioning to valve guide inside diameter, to cut valve seats, and to cut valve seat pockets for oversize seats. It can also be used with gauge, Part Number ST-685-4, to check valve seat concentricity.	
3822509	**Injector Bore Brush** Used to clean carbon from injector bores.	
3823258	**Abrasive Pad** Used to clean carbon from the upper liner bores, remove rust and corrosion, and scuff surfaces.	
3823921	**Capscrew Length Gauge** Used to measure capscrew free length.	
3824277	**Valve Vacuum Tester** Used with vacuum cup, Part Number ST-1257-6, to vacuum test the cylinder head, to determine if the valves are properly seated.	
3824591	**Engine Barring Gear** Used to engage the flywheel ring gear to rotate the crankshaft.	
4918219	**Precision Straightedge** Used to check cylinder head combustion decks for flatness.	
ST-1166	**Magnetic Crack Detector** Used to inspect the cylinder head combustion face for cracks in the injector bore and valve seat areas. The kit includes powder spray bulb, Part Number ST-1166-7, used for spraying the metal powder, Part Number ST-1166-8.	

Tool No.	Tool Description	Tool Illustration
ST-685-4	**Eccentrimeter Gauge** Used to measure the valve seat to valve guide runout.	 22d00308

Crosshead (002-001)

Preparatory Steps



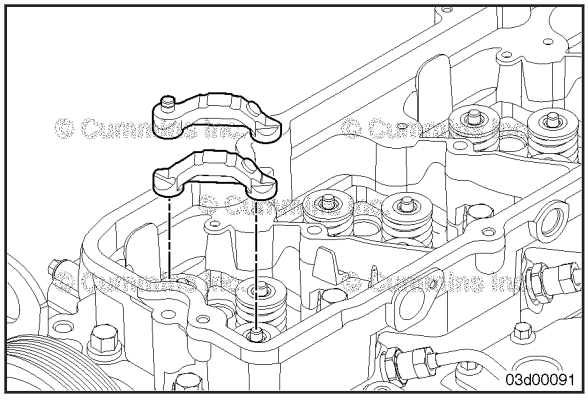
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Remove the rocker lever assembly. Refer to Refer to Procedure 003-008 in Section 3.

Remove

NOTE: Make note of the crosshead location and orientation. If the crossheads are reused, they **must** be installed in their original location and orientation.

Remove the crossheads.



Clean and Inspect for Reuse

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

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

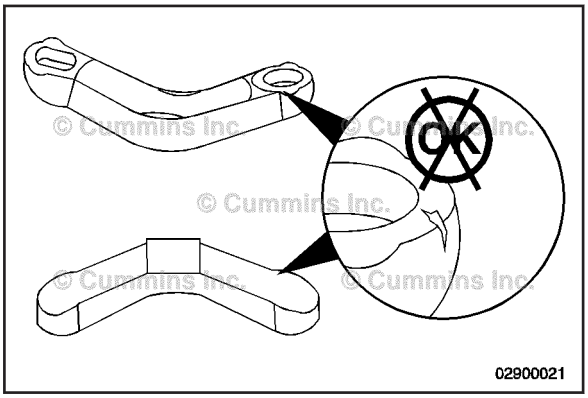
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

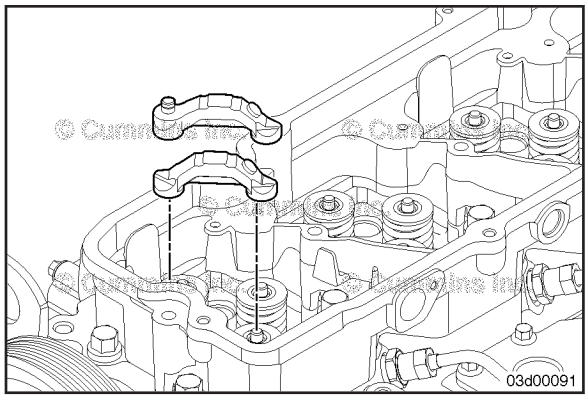
Clean the crossheads with solvent.

Dry with compressed air.

Inspect the crossheads for cracks and/or excessive wear on the rocker lever and valve tip mating surfaces.

Inspect the contact pads for cracks and other damage.



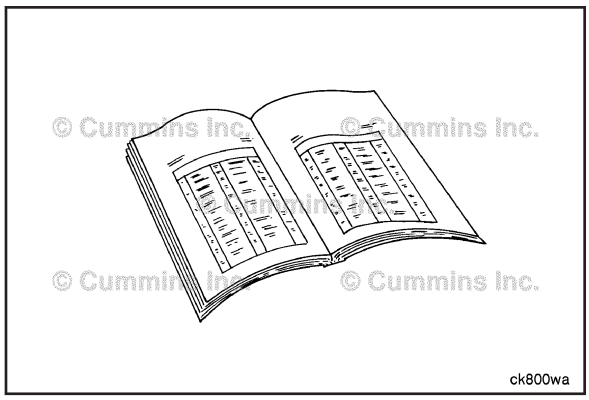


Install

NOTE: The crosshead has a round hole and an oval hole. If installing new crossheads, it is **not** required to place the holes in a particular position.

NOTE: When reusing the crossheads, make sure to install them in their original location and orientation.

Install the crossheads on the valve stems.



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the rocker lever assembly. Refer to Procedure 003-008 in Section 3.
- Install the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

Cylinder Head (002-004)

Initial Check

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠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.

If troubleshooting coolant in the fuel, fuel in the coolant, fuel in the oil, or oil in the fuel, pressurize the internal fuel drain line in the cylinder head and check for leaks.

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.

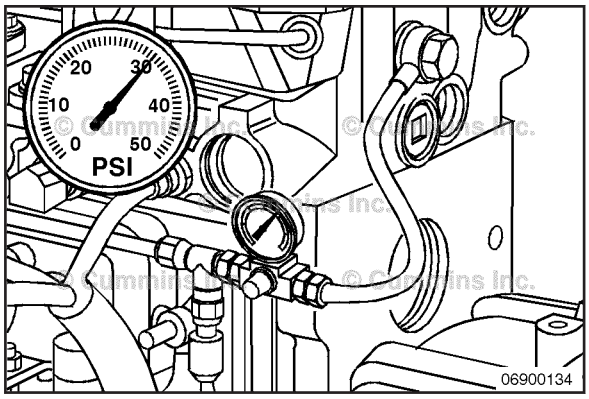
Air Pressure		
kPa		**psi**
276	NOM	30

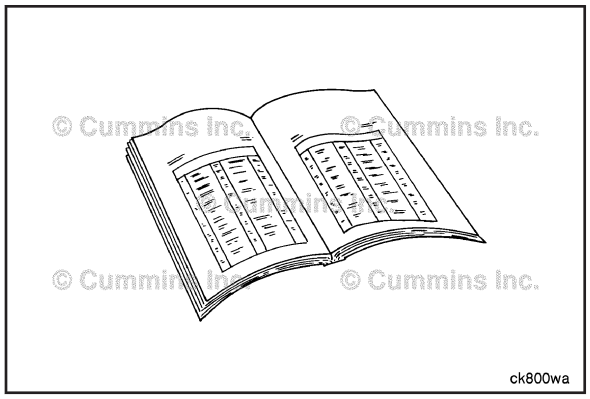
Shut off the air supply to the fuel drain port and monitor the pressure gauge reading. The pressure should hold steady. If the pressure drops rapidly, check for leaks around:

- Test fittings
- Fuel connectors at the cylinder head.

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 section in this procedure. Replace the cylinder head, if necessary.





Preparatory Steps

All Applications Except Marine

⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ WARNING ⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- See equipment manufacturer service information.
- Remove the air crossover tube. Refer to Procedure 010-019 in Section 10.
- Remove the air intake connection adapter. Refer to Procedure 010-131 in Section 10.
- Remove all water and heater hoses. Refer to Procedure 008-045 in Section 8.
- Remove the turbocharger actuator air line, if equipped. Refer to Procedure 010-118 in Section 10.
- Remove the turbocharger control valve, if equipped. Use the following procedure in the ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416. Refer to Procedure 019-388 in Section 19
- Remove the intake manifold cover and intake heater. Refer to Procedure 010-108 in Section 10. Refer to Procedure 010-080 in Section 10.
- Remove the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Remove the fuel rail. Refer to Procedure 006-060 in Section 6.
- Remove the fuel connection tubes. Refer to Procedure 006-052 in Section 6.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the rocker lever housing. Refer to Procedure 003-013 in Section 3.
- Remove the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Remove the rocker lever. Refer to Procedure 003-008 in Section 3.
- Remove the crossheads. Refer to Procedure 002-001 in Section 2.
- Remove the push rods or tubes. Refer to Procedure 004-014 in Section 4.
- Remove the fuel drain lines. Refer to Procedure 006-013 in Section 6.
- Remove the turbocharger. Refer to Procedure 010-033 in Section 10.
- Remove the exhaust manifold. Refer to Procedure 011-007 in Section 11.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.

Marine Applications

WARNING
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

WARNING
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

WARNING
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

CAUTION
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
Use caution when draining the coolant system that coolant is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The coolant and coolant filters must be discarded in accordance with local environmental regulations.

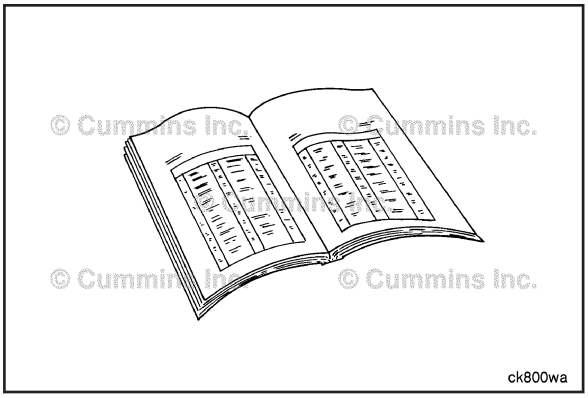
- Shut off the sea water supply, if applicable. See equipment manufacturer service information.
- Shut off the fuel supply and drain valves. See equipment manufacturer service information.
- Disconnect the batteries. See equipment manufacturer service information.
- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.
- Drain the sea water system, if the engine has a heat exchanger. Refer to Procedure 008-053 in Section 8.
- Remove the air crossover from the air intake connection and the aftercooler. Refer to Procedure 010-019 in Section 10.
- Remove the air intake connection. Refer to Procedure 010-080 in Section 10.
- Remove the fuel filter head bracket. Refer to Procedure 006-018 in Section 6.
- Remove the fuel lift pump. Refer to Procedure 005-045 in Section 5.
- Remove the injector fuel lines. Refer to Procedure 006-051 in Section 6.
- Remove the common fuel rail. Refer to Procedure 006-060 in Section 6.
- Disconnect and remove the intake manifold temperature sensor. Use the following procedure in the ISC, QSC8.3, and ISL Electronic Control System Troubleshooting and Repair Manual, Bulletin 3666271. Refer to Procedure 019-059 in Section 19.
- Disconnect and remove the intake manifold pressure sensor. Use the following procedure in the ISC, QSC8.3, and ISL Electronic Control System Troubleshooting and Repair Manual, Bulletin 3666271. Refer to Procedure 019-061in Section 19.
- Disconnect and remove the intake manifold temperature sensor. Use the following procedure in the ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416. Refer to Procedure 019-059 in Section 19.
- Disconnect and remove the intake manifold pressure sensor. Use the following procedure in the ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416. Refer to Procedure 019-061 in Section 19.
- Remove the intake manifold cover. Refer to Procedure 010-108 in Section 10.
- Remove the fuel drain lines from the rear of the cylinder head. Refer to Procedure 006-013 in Section 6.
- This step applies to QSL9 engines **only**. Remove the two aftercooler to cylinder head bracket mounting capscrews. Refer to Procedure 010-005 in Section 10.
- Remove all water and heater hoses. Refer to Procedure 008-045 in Section 8.
- Remove the coolant vent lines from the turbocharger and expansion tank. Refer to Procedure 008-017 in Section 8.

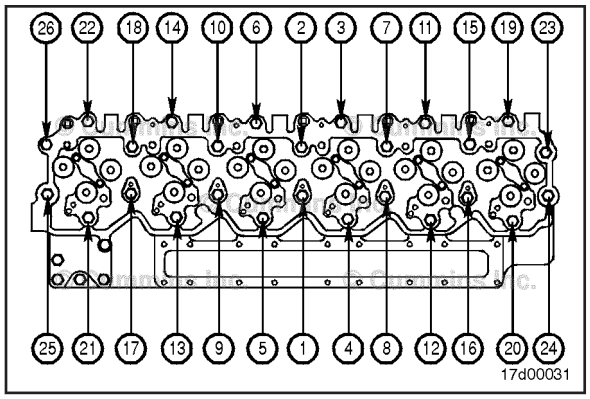
NOTE: This next step applies to QSL9 engines **only**. The expansion tank and heat exchanger on the QSC8.3 engines are a one-piece unit. Refer to Procedure 008-053 in Section 8.

- Remove the expansion tank. Refer to Procedure 008-052 in Section 8.

NOTE: Some QSL9 engines are keel cooled and do **not** have heat exchangers.

- Remove the heat exchanger, if equipped. Refer to Procedure 008-053 in Section 8.
- Remove the turbocharger and exhaust manifold as an assembly. Refer to Procedure 011-008 in Section 11.
- Remove the fuel connection tubes. Refer to Procedure 006-052 in Section 6.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the rocker lever housing. Refer to Procedure 003-013 in Section 3.
- Remove the rocker lever. Refer to Procedure 003-008 in Section 3.
- Remove the crossheads. Refer to Procedure 002-001 in Section 2.
- Remove the push rods or tubes. Refer to Procedure 004-014 in Section 4.





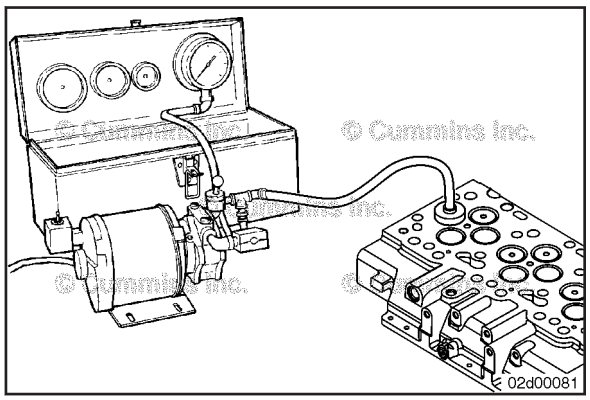
Remove

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

Remove the cylinder head capscrews.

Cylinder Head Weight 71.2 kg [157 lb]

Remove the cylinder head and gasket from the cylinder block.



Vacuum Test

NOTE: If a leaking valve is suspected, use valve vacuum tester, Part Number 3824277, and cup, Part Number ST-1247-6, to vacuum test the valves and valve seats. The vacuum **must not** drop more than 254 mm Hg [10 in Hg] in 10 seconds.

Valve to Valve Seat Vacuum		
457 mm Hg	Used	18 in Hg
635 mm Hg	New	25 in Hg

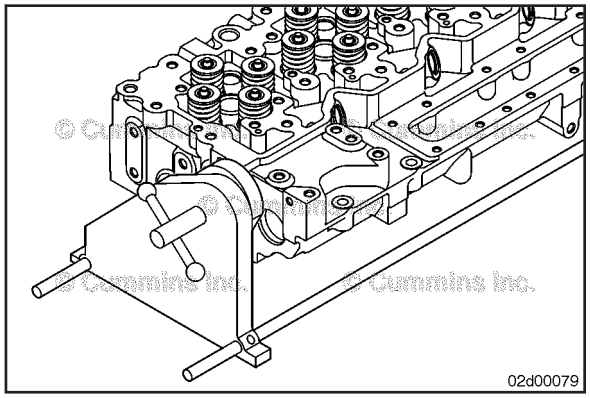
NOTE: If a vacuum tester is **not** available, use a lead pencil or Dykem™ marking pen with the valve removed to mark across the valve face. Install the valve in the valve guide. Hold the valve against the valve seat and rotate the valve backward and forward three or four times. Correct contact against the valve seat will break the marks on the valve face.

If out of specification, disassemble the cylinder head and inspect for damaged valves and/or valve seat inserts. Repair as necessary:

1 Clean the valve, valve seat inserts, and lap the valves.

2 Replace the damaged valve/valve seat inserts, if available.

3 Replace the cylinder head.

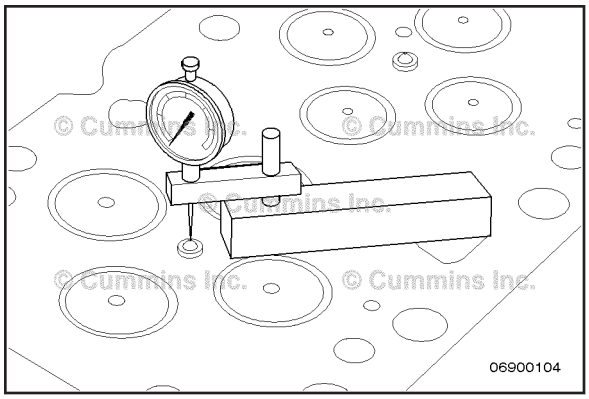


Disassemble

Install the cylinder head in the cylinder head holding fixture, Part Number ST-583.

Before removing the injectors, use gauge block, Part Number 3164438, to measure the injector protrusion.

Place the injector protrusion tool on the flat surface of the head. Measure the injector protrusion to the highest point on the injector. The protrusion **must** be within the following specifications:



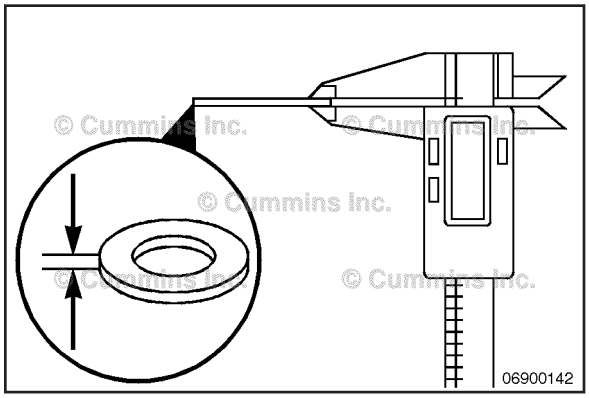
Injector Protrusion (CAPS Fuel System)		
mm		**in**
2.60	MIN	0.102
3.40	MAX	0.134

Injector Protrusion (Cummins® Common Rail Fuel System)		
mm		**in**
2.25	MIN	0.088
2.80	MAX	0.110

Remove the injector. Refer to Procedure 006-026 in Section 6.

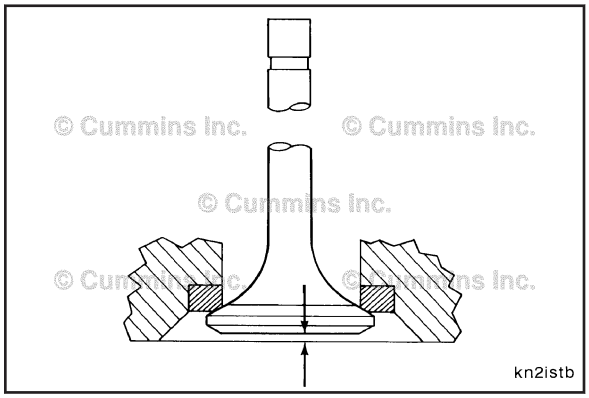
If the injector protrusion is out of specification, check the thickness of the injector sealing washer. Refer to Procedure 006-026 in Section 6.

If the sealing washer is the correct thickness, check to make sure the injector bore is clean and free of debris. Also make sure that sealing washers are **not** "stacked" in the injector bore.



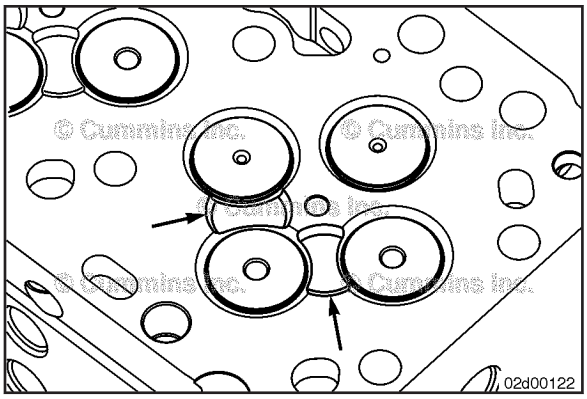
Standard Cylinder Head

Measure the valve recess.



Standard Head Valve Recess in Cylinder Head		
mm		**in**
0.84	MIN	0.033
1.32	MAX	0.052

If the valve recess is outside the specifications, replace the valve. If the valve recess is still outside the specifications, the valve seat insert or cylinder head **must** be replaced.

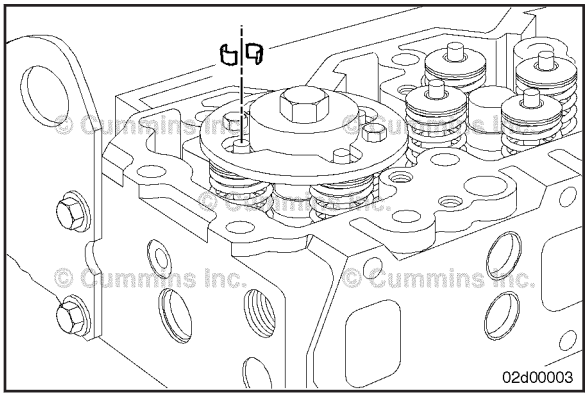


Scallop Cylinder Head

Measure the valve recess.

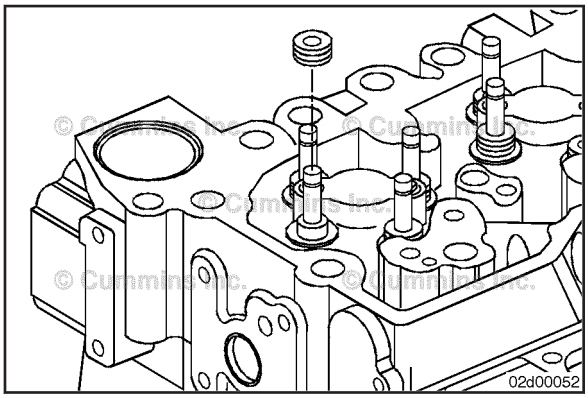
Scallop Head Valve Recess in Cylinder Head		
mm		in
0.69	MIN	0.027
1.17	MAX	0.046

If the valve recess is outside of the specifications, replace the valve. If the valve recess is still outside the specifications, the valve seat insert or cylinder head **must** be replaced.



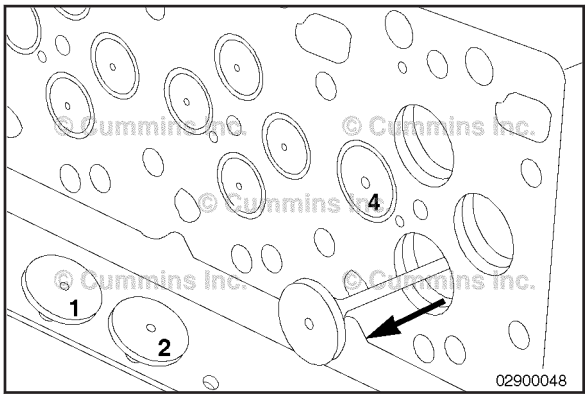
Compress the valve springs and remove the valve stem collets. Use valve spring compressor, Part Number 3164329.

Release the valve springs and remove the spring retainers and springs.



Use the boot pliers, Part Number 3163293, to remove the valve stem seal.

Remove and discard the valve stem seals.



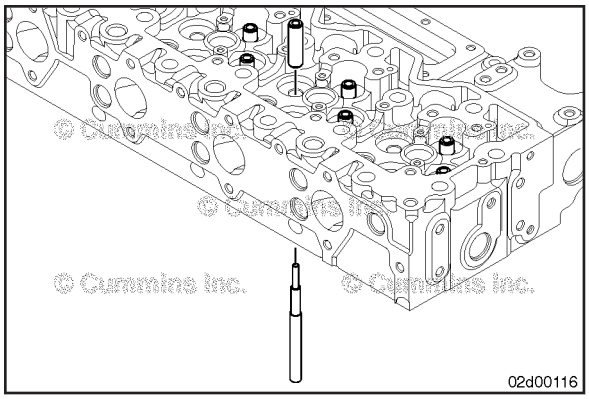
Keep the valves in a labeled rack for a correct match with companion seats while making measurements.

Mark the valves to identify their location. Any numbering system can be used as long as the valves are put back in their original location if they are to be reused.

Remove the valves.

NOTE: Prior to removing the valve guide, reference the Inspect for Reuse section in this procedure. The condition of the valve guide will help to determine if it needs to be replaced.

Use valve guide driver, Part Number 3163101, to remove the old valve guides.



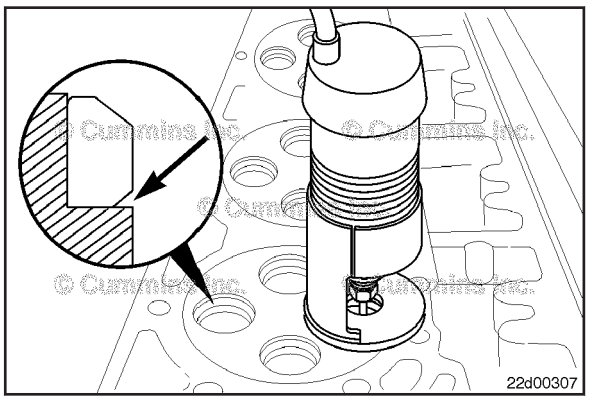
NOTE: Prior to the removal of the valve seat inserts, reference the Clean and Inspect for Reuse section in this procedure. The condition of the valve, the amount of recess, and the sealing of the valve on the seat insert all help to determine if a valve seat insert needs to be replaced.

1 If required, remove the valve seat inserts.

2 Inspect the valve-insert-to-cylinder-head contact area. A sufficient groove for the remover **must** exist.

3 If there is sufficient valve seat insert groove area, proceed to the next step.

4 If the valve seat insert groove area is **not** sufficient, use the valve seat insert cutting kit, Part Number 3376405, to create a sufficient groove.

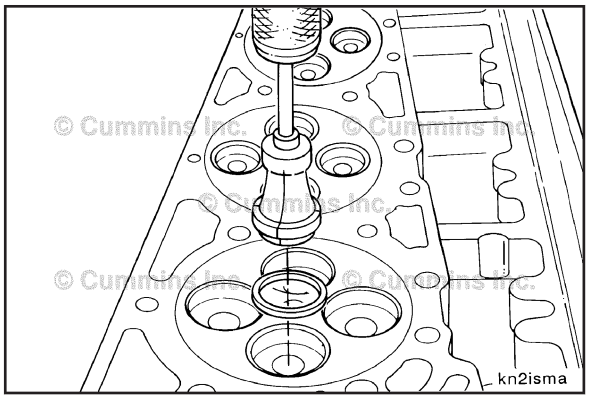


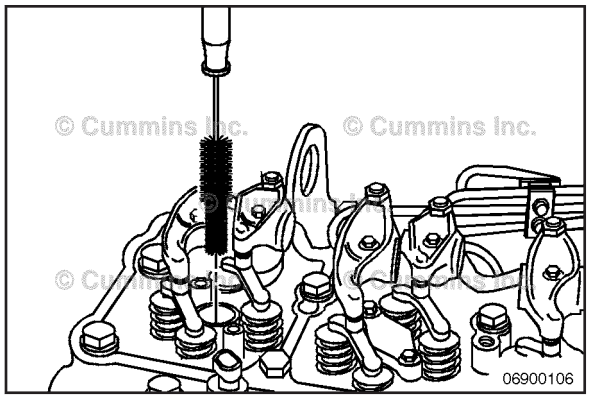
Use the slide hammer remover, Part Number 3376617, with intake valve seat insert extractor, Part Number 3165113, and exhaust valve seat insert extractor, Part Number 3165114, to remove the valve seat inserts.

NOTE: Make certain the valve seat insert remover assembly is perpendicular to the cylinder head when installed. Place the valve seat insert remover assembly into the valve seat insert and rotate the T-handle **clockwise** until the remover loosely grips the valve seat insert.

Position the valve seat insert remover assembly into the valve seat insert groove area. Tighten the T-handle firmly, allowing the remover to expand under the valve seat insert or into the cut groove.

Strike the slide hammer remover against the top nut until the valve seat insert is removed. Turn the T-handle **counterclockwise** to release the valve seat insert from the remover.

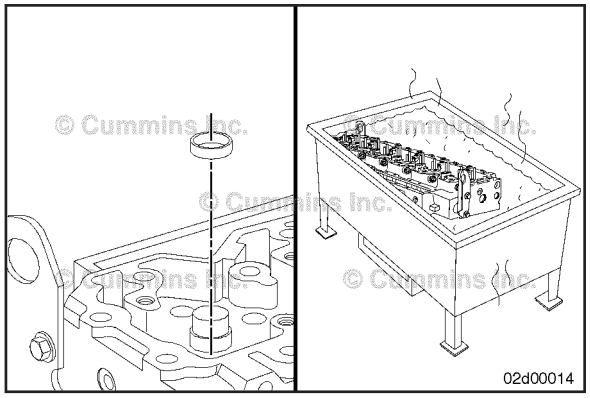




Clean and Inspect for Reuse

Use injector bore brush, Part Number 3822509, to clean the carbon from the injector nozzle seat.

Scrape the gasket material from all gasket surfaces on the block and head.



⚠WARNING⚠
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⚠WARNING⚠
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⚠WARNING⚠
To reduce the possibility of personal injury, wear goggles and protective clothing.

Clean the buildup of deposits from the coolant passages. Excessive deposits can be cleaned in an acid tank, but the expansion plugs **must** first be removed.

Clean the cylinder head combustion deck with an abrasive pad, Part Number 3823258, or equivalent, and diesel fuel or solvent. The surface finish (RA - roughness average) maximum is 3.2 µm [0.0001 in].

Inspect the area within 1/8-inch of the firing ring diameter. Any wear that can be felt with a fingernail within the 1/8-inch area is unacceptable, making the cylinder head **not** reusable.

Wear beyond this 1/8-inch area will have no effect on future combustion sealing and the usability of the cylinder head.

Clean carbon deposits from the valve pockets with a high quality steel wire wheel installed in a drill or a die grinder.

NOTE: An inferior quality wire wheel will lose steel bristles during operation, causing additional contamination.

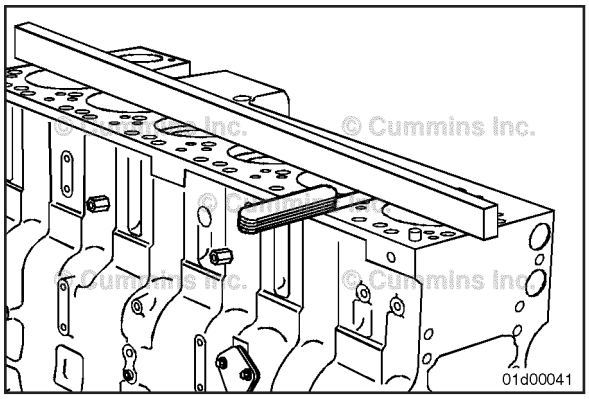
Wash the cylinder head in a hot, soapy water solution.

Dry with compressed air.

Use a straight-edge, Part Number 4918219, and a feeler gauge to measure the overall flatness of the cylinder block.

The overall flatness, end to end and side to side, **must not** exceed 0.075 mm [0.003 in].

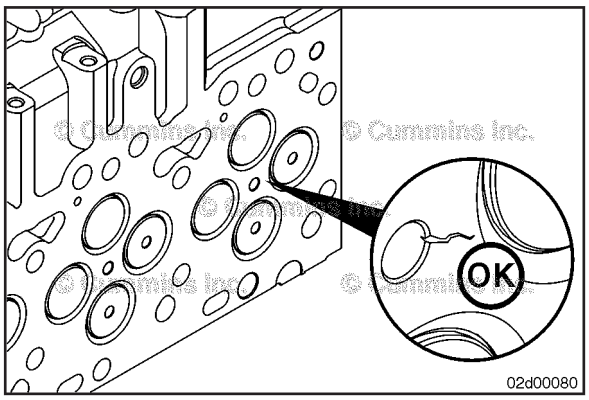
Use a 2-foot straight edge and a 0.0254 mm [0.001 in] feeler gauge to measure local cylinder block combustion surfaces flatness. Check between the cylinder bores and also between the coolant passages. If the 0.0254 mm [0.001 in] feeler gauge fits under the 2-foot straight-edge, or if the cylinder block is pitted, has grooves or other damage, the cylinder block **must** be replaced.



Cylinder Head Cracks - Reuse Guidelines

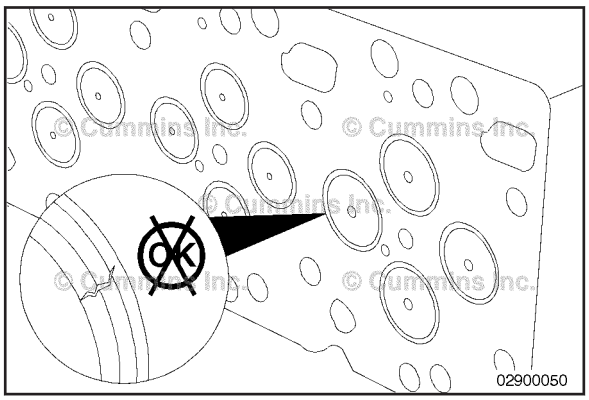
The reuse guidelines for a cylinder head with a crack extending from the injector bore to the intake valve seat are as follows:

- If a crack does **not** extend into the valve seat, the cylinder head is reusable.



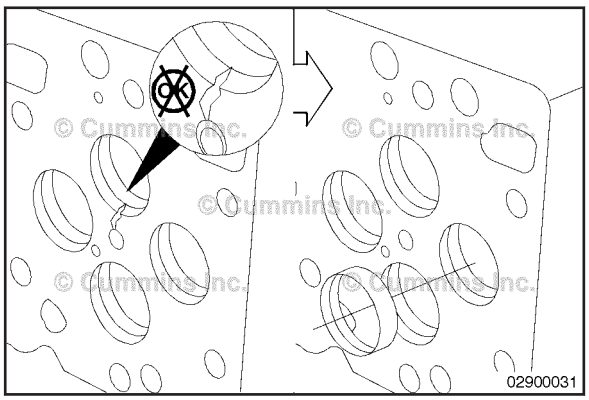
Inspect the valve seats for cracks or burn spots.

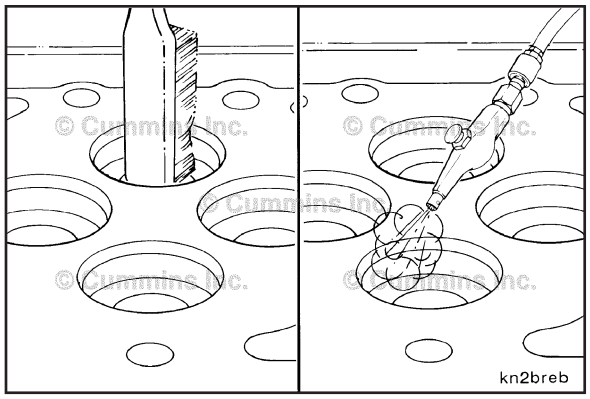
- If the valve seats are cracked or burned, the valve seat **must** be replaced.
- If the valve seat has dropped out and caused damage to the cylinder head combustion face, the cylinder head **must** be replaced.



If a crack extends into or through the valve seat bore, the cylinder head **must** be replaced.

Use crack detection kit, Part Number 3375432, to help identify cylinder head cracks.





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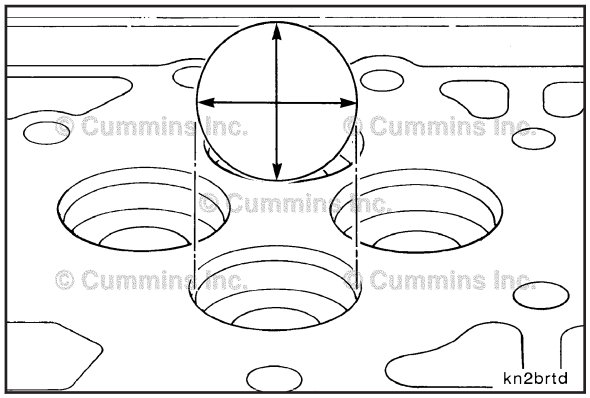
⚠WARNING⚠
To reduce the possibility of personal injury, wear goggles and protective clothing.

Use a wire brush and solvent to clean the deposits from the valve seat insert bores, if it was necessary to remove the valve seat inserts.

Dry with compressed air.



If the valve seat insert was removed in the Disassemble section, measure the inside diameter of the valve seat insert bore in the cylinder head.

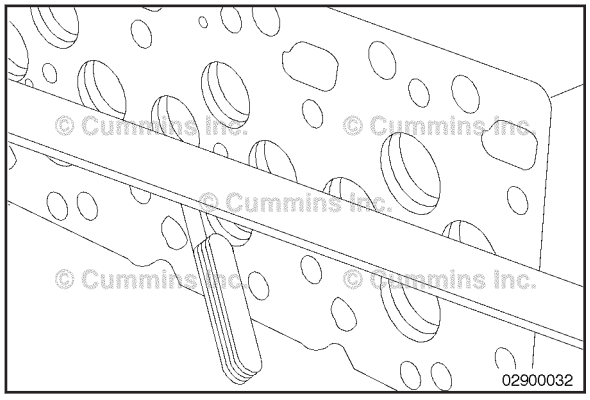
Cylinder Head Insert Bore Inside Diameter		
mm		**in**
39.371	MIN	1.550
39.401	MAX	1.551

NOTE: Before cutting the cylinder head, verify the valve seat inserts are available for the engine being serviced. If none are available, the cylinder head **must** be replaced.

If out of specification, the valve seat insert bore can be oversized 0.254 mm [0.010 in].

Cylinder Head Insert Bore Inside Diameter for Oversized Seats		
mm		**in**
39.625	MIN	1.560
39.655	MAX	1.561

NOTE: It is very important to take precise measurements of the valve seat pocket diameter. A 4-point contact gauge is recommended for this measurement process. By **not** taking a proper diameter measurements will lead to a poor press fit of the valve seat, which may lead to a dropped valve seat and damage to the cylinder head combustion face.



Use a straight-edge, Part Number 4918219, and a feeler gauge to inspect the cylinder head combustion surface for flatness.

Cylinder Head Flatness			
	mm		**in**
End to End	0.203	MAX	0.008
Side to Side	0.075	MAX	0.003

Use a 2-foot straight-edge and a 0.0254 mm [0.001 in] feeler gauge to measure local cylinder head combustion surface flatness. Check between the cylinder bores and also between the coolant passages. If the 0.0254 mm [0.001 in] feeler gauge fits under the 2-foot straight-edge or if the cylinder head is pitted, has grooves or other damage, the cylinder head **must** be replaced.

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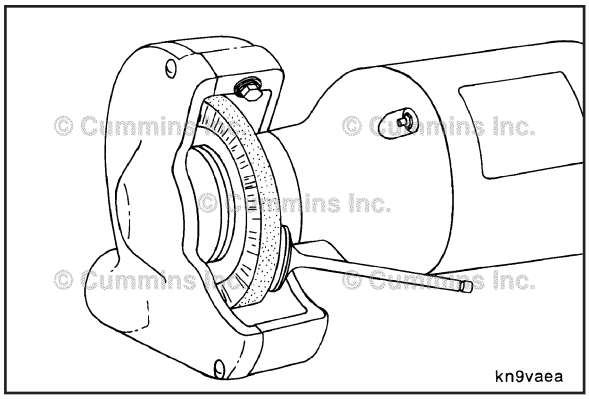
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Clean the valve heads with a soft wire wheel.

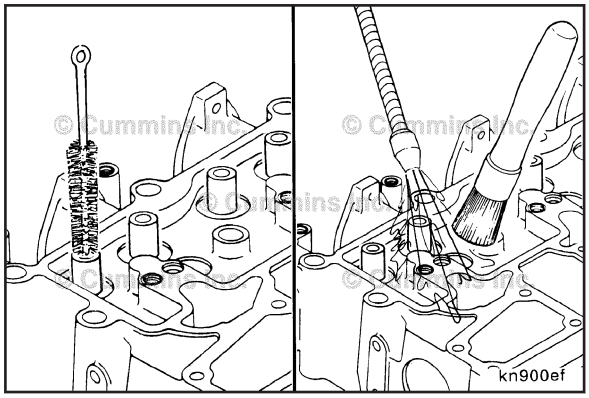
NOTE: Keep the valves in a labeled rack to prevent mixing prior to making measurements.

Polish the valve stems with an abrasive pad, Part Number 3823258, or equivalent, and diesel fuel or solvent.



⚠WARNING⚠
To reduce the possibility of personal injury, wear goggles and protective clothing.

Use a bristle brush to clean the inside diameter of the valve guide bore and blow out with compressed air.

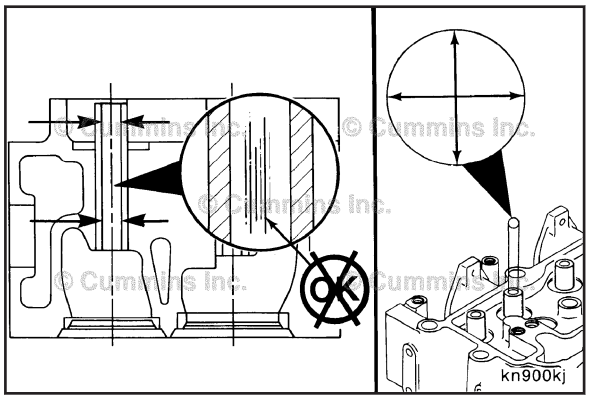


Inspect the valve guides for scuffing, scoring, chips, or cracks.

Measure the valve guide inside diameter.

Valve Guide Inside Diameter		
mm		**in**
8.019	MIN	0.316
8.081	MAX	0.318

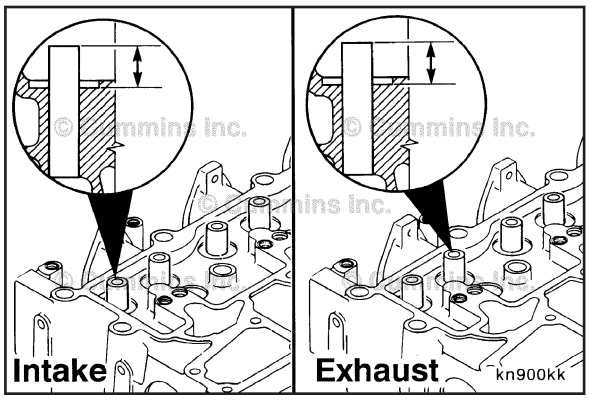
If the valve guide inside diameter is worn larger than the maximum specified, the cylinder head **must** be replaced.

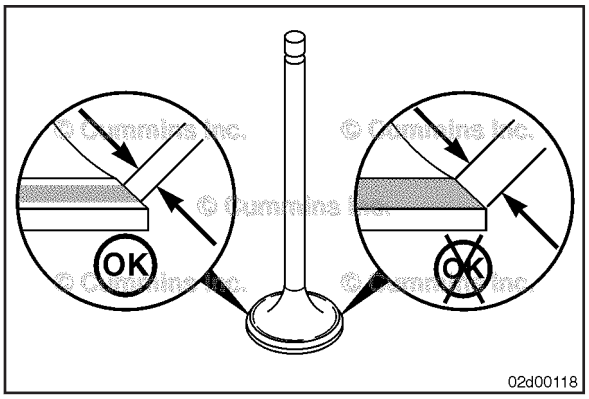


Use a depth micrometer to measure the valve guide installed height. Measure from the top of the valve guide to the bottom of the recessed area.

Valve Guide Height (Installed)		
mm		**in**
13.15	MIN	0.518
13.65	MAX	0.537

If the valve guide height is outside the specification, the cylinder head **must** be replaced.

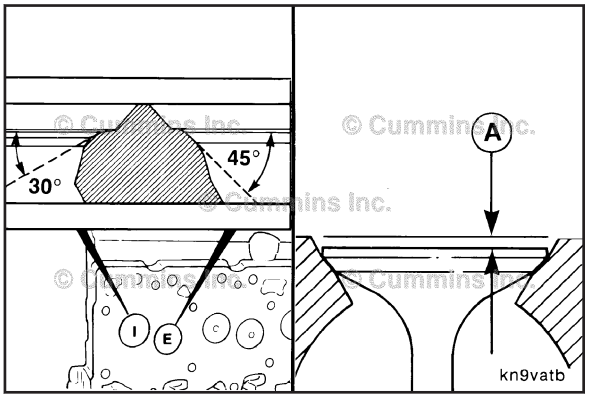




Verify the valve sealing area is in the center of the valve. If the sealing area extends to the top or bottom of the valve, the valve **must** be replaced.

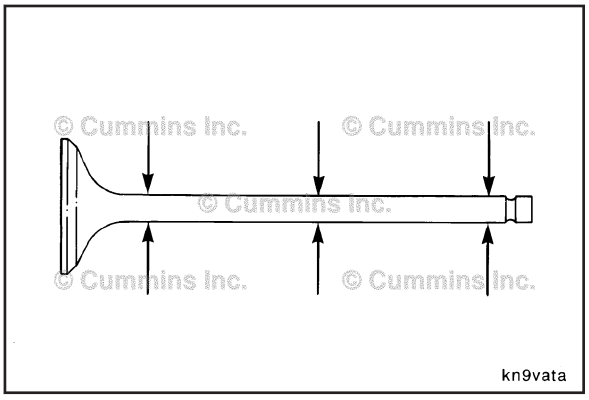
After replacing the valve, recheck the valve sealing area. If the sealing area still extends to the top or bottom of the valve, the valve seat **must** be replaced.

Use a lead pencil or Dykem™ marking pen to mark across the valve face. Install the valve in the valve guide. Hold the valve against the valve seat and rotate the valve backward and forward three or four times. Correct contact against the valve seat will break the marks on the valve face.



Valve seat angle:

- Intake is 30 degrees
- Exhaust is 45 degrees.



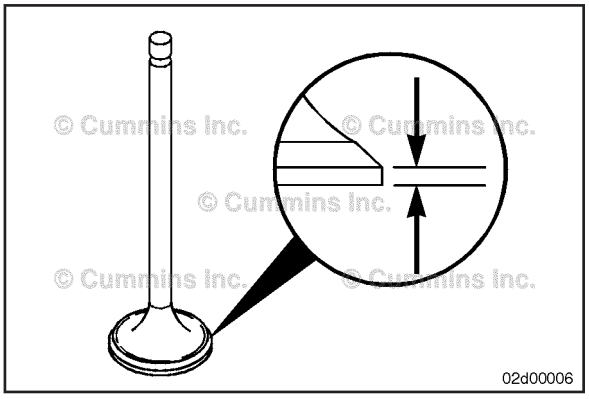
Inspect for abnormal wear or scuffing on the heads and stems.

Measure the valve stem diameter.

Valve Stem Diameter

mm		in
7.96	MIN	0.313
7.98	MAX	0.314

Replace any valve found outside these dimensions.



Check the valve stem tip for flatness.

Inspect for bent valves.

Measure the rim thickness.

NOTE: Measure 90 degrees apart to verify uniformity of lap.

If the valve thickness is **not** within the limits, a new valve **must** be used.

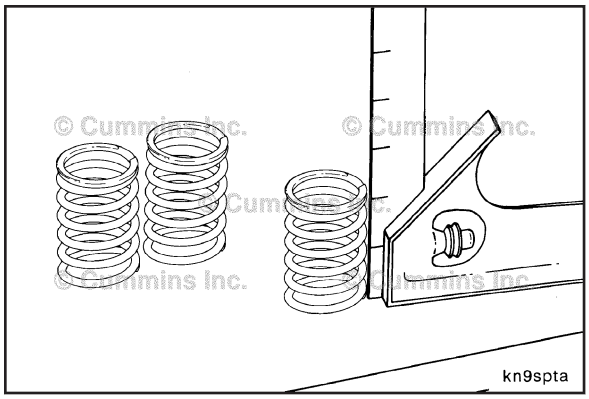
Valve Rim Thickness

	mm		in
Exhaust	1.83	MIN	0.072
Intake	2.20	MIN	0.087

Inspect the valve springs.

Measure the valve spring.

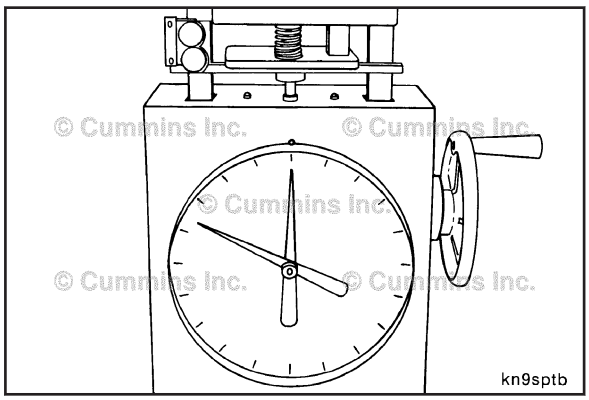
Approximate Free Length 59.18 mm [2.330 in]



A load of 906 to 1007 N [204 to 226 lbf] is required to compress the spring to a height of 30.6 mm [1.20 in]. Use spring compressor tool, Part Number 3375182, to measure spring force.

Replace the valve spring if the load required to compress the spring is outside the specification.

NOTE: Valve springs **must** be replaced in pairs under the same cross head. If one spring does **not** meet the specification, replace both valve springs under the same cross head.



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⚠WARNING⚠
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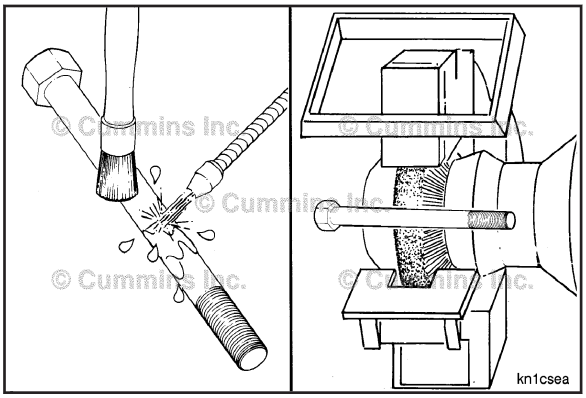
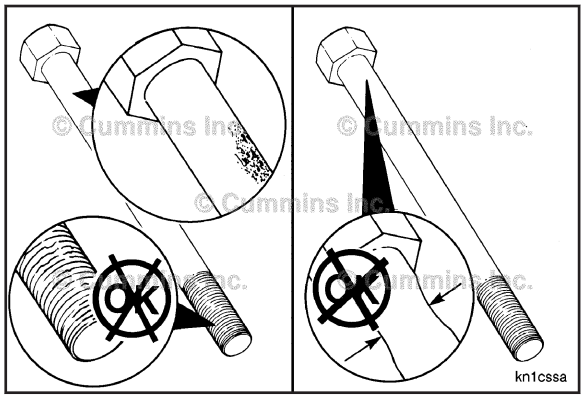
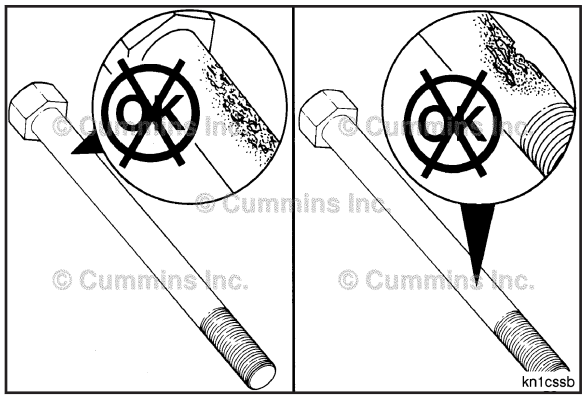
Use a petroleum-based solvent to clean the capscrews.

Clean the capscrews thoroughly with a wire brush or a soft wire wheel. A non-abrasive bead blaster can be used to remove deposits from the shank and the threads.



Inspect the cylinder head capscrews for damaged threads, corroded surfaces, or a reduced diameter (due to capscrew stretching).

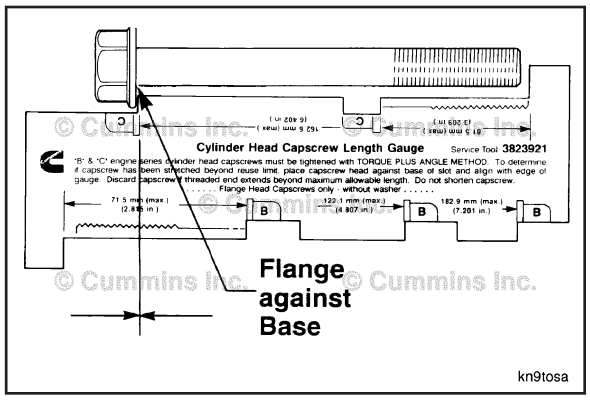




Do **not** reuse cylinder head capscrews under the following conditions:

Visible corrosion or pitting exceeds 1 sq cm [0.155 sq in] in area. Example:

- Acceptable is 9.525 x 9.525 mm [3/8 x 3/8 in].
- Unacceptable is 12.700 x 12.700 mm [1/2 x 1/2 in].
- Visible corrosion or pitting exceeds 0.12 mm [0.005 in] in depth.
- Visible corrosion or pitting is located within 3.2 mm [1/8 in] of the fillet or threads
- Stretched beyond "free length" maximum. Reference the measurement procedure below.

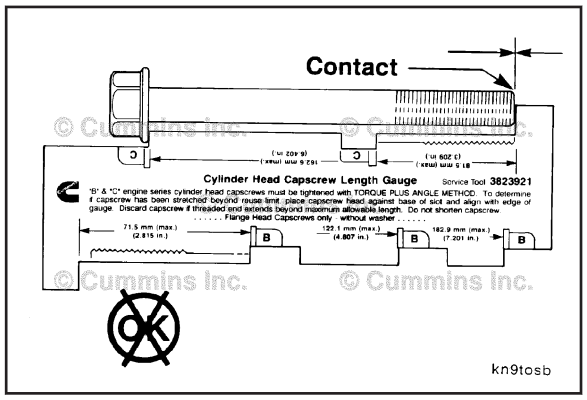


Capscrew Length Gauge, Part Number 3823921

Free Length Measurement

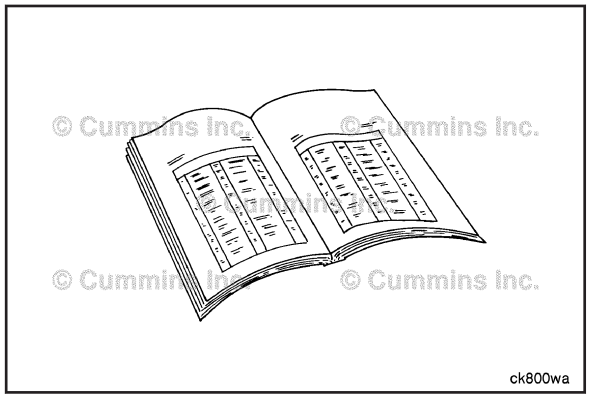
NOTE: If the capscrews are **not** damaged, they can be reused throughout the life of the engine, unless the specified "free length" is exceeded.

To check the capscrew free length, place the head of the capscrew in the appropriate slot with the flange against the base of the slot.



If the end of the capscrew touches the foot of the gauge, the capscrew is too long and **must** be discarded. The maximum capscrew free length is 162.6 mm [6.4 in].

Cylinder Head Capscrew Free Length		
mm		in
162.6	MAX	6.4



Machine

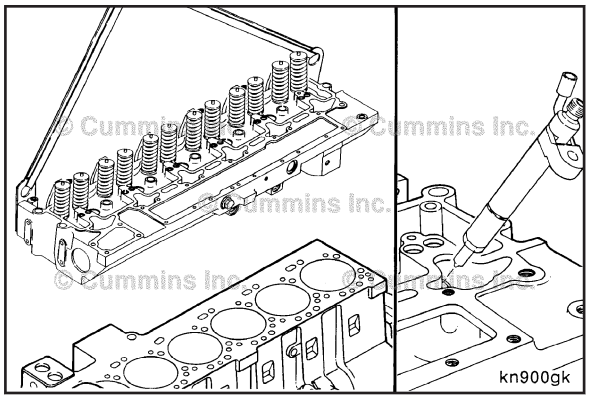
There are two surfaces that require attention when considering machining the cylinder head.

They are the exhaust manifold mounting surface and the combustion surface of the cylinder head.

Use the following information as it applies to these surfaces.

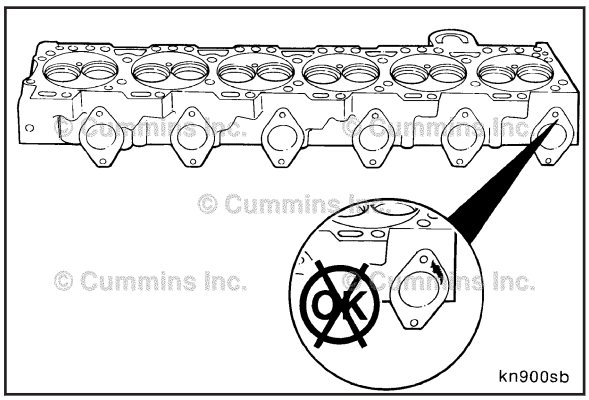
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

For the exhaust manifold mounting surface machining, the cylinder head **must** be removed and completely disassembled to perform this repair.



A maximum of 0.5 mm [0.02 in] can be machined from the exhaust manifold mounting surface of the cylinder head.

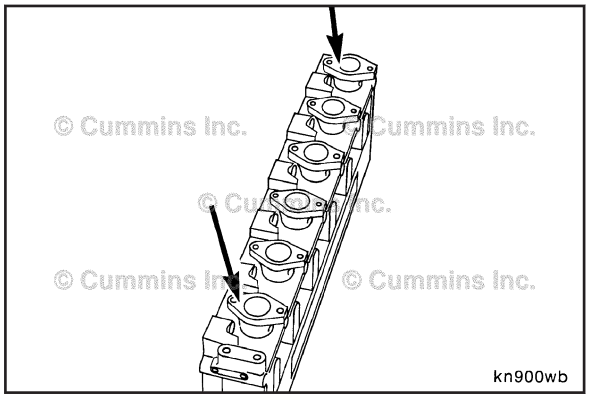
NOTE: If grooves or pits are deeper than 0.5 mm [0.02 in], the mounting surface can **not** be restored by machining.



⚠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.

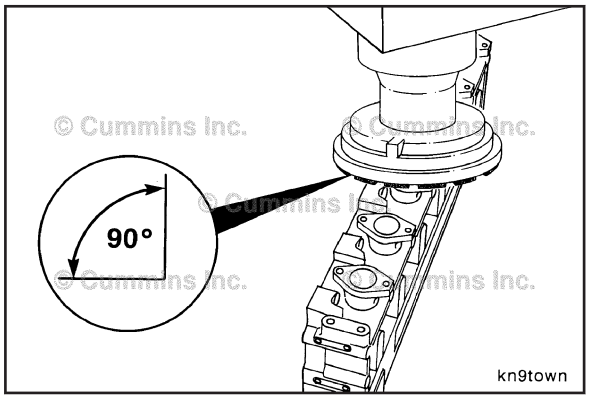
If the exhaust manifold mounting surface is found to be out of specification, install the cylinder head on a resurfacing machine.

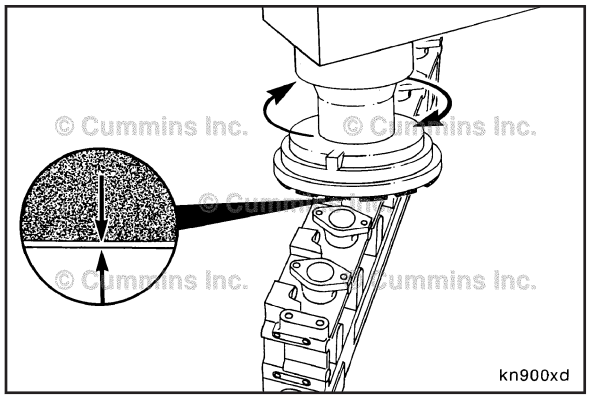
NOTE: Align the cylinder head lengthwise using two undamaged points that are as far apart as possible on the exhaust manifold mounting surface.



Inspect the perpendicularity of the cutting tool with either the top or bottom surface of the cylinder head.

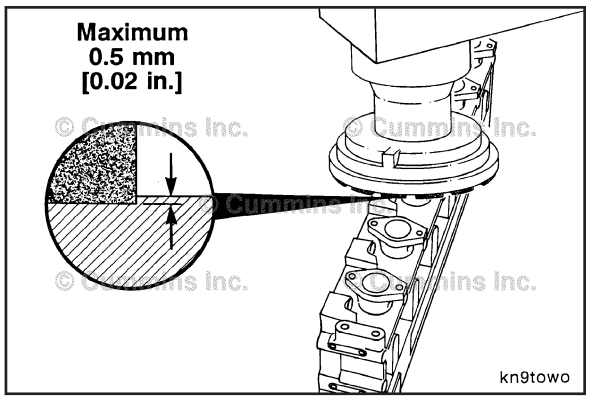
NOTE: The cutting tool **must** be perpendicular to within 0.05 mm [0.002 in] per 25.4 mm [1 in].





Inspect the full length alignment of the cylinder head.

- Move the cutting tool down to within 0.79 mm [1/32 in] of the exhaust manifold mounting surface.
- Rotate the cutting tool by hand while moving the cutting tool the full length of the cylinder head.

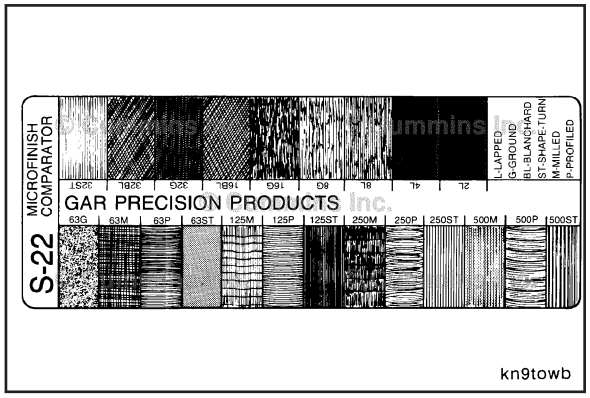


⚠WARNING⚠
To reduce the possibility of personal injury, wear goggles and protective clothing.

Machine the exhaust manifold mounting surface.

Follow the manufacturer's instructions for operating the resurfacing machine.

NOTE: Do **not** remove more than 0.5 mm [0.02 in] from the cylinder head exhaust manifold mounting surface.



Use a surface comparator to inspect the finish of the exhaust manifold mounting surface. A surface finish of 3.2µM [125 µ in] or less **must** be maintained.

⚠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.

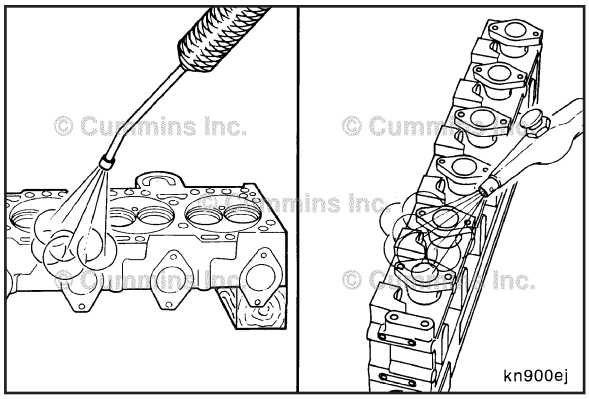
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠WARNING⚠
To reduce the possibility of personal injury, wear goggles and protective clothing.

Remove the cylinder head from the resurfacing machine.

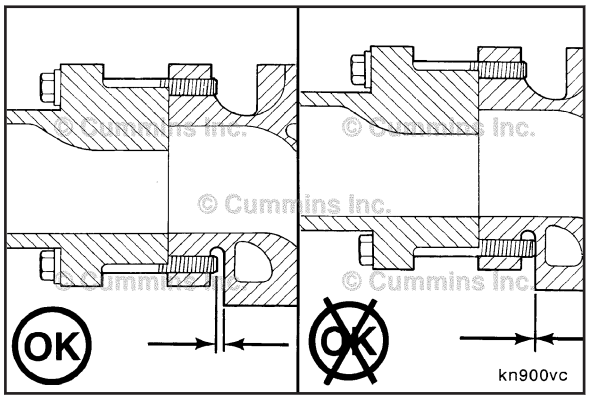
Clean the cylinder head to remove the machining debris.

Dry with compressed air.



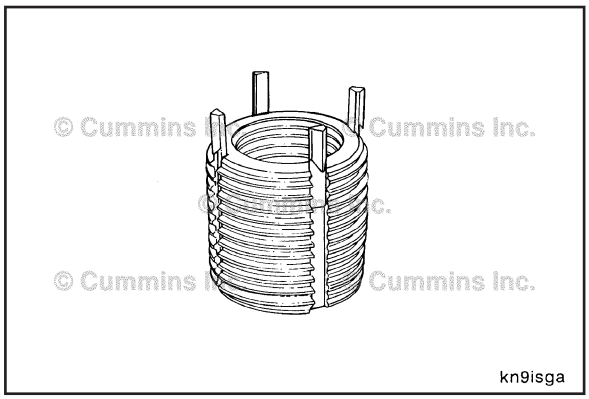
Assemble the exhaust manifold to the cylinder head; including the lockplate and exhaust manifold gasket.

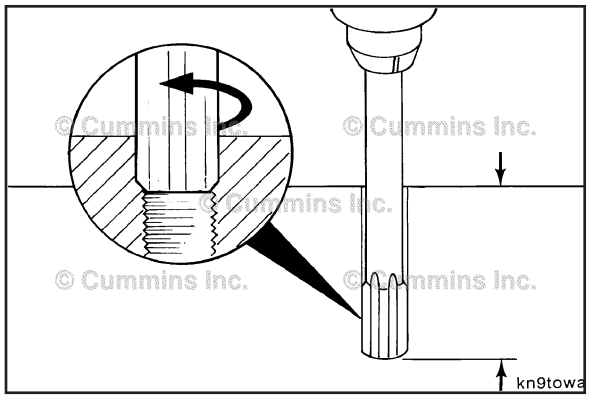
NOTE: The lower capscrew **must not** contact the cylinder head.



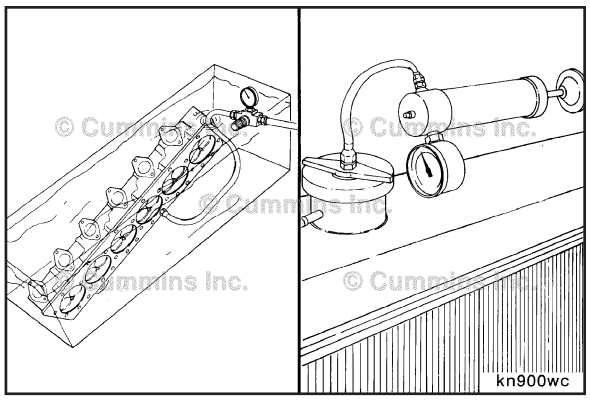
If, during assembly, any threaded holes for the exhaust manifold are found to be damaged, the holes can be repaired with the use of threaded inserts.

NOTE: Keylocking type threaded inserts are recommended.



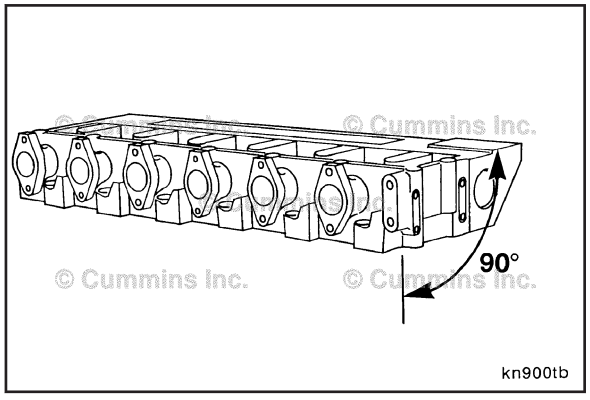


Follow the manufacturer's repair procedure for the type of insert being installed.



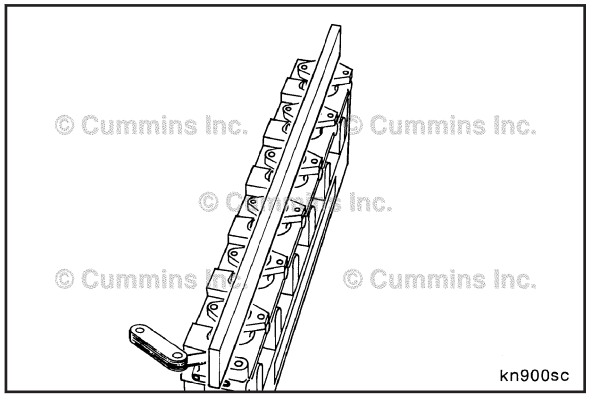
Inspect the cylinder head for coolant leaks after repairing the capscrew holes. Use the Pressure Test section in this procedure.

NOTE: This repair can be accomplished while the engine is still in chassis. If in chassis, pressurize the cooling system to perform the test.



Measure the perpendicularity between the exhaust manifold mounting surface and the combustion surface of the cylinder head.

The surface must be perpendicular within 0.30 mm [0.012 in].



Use a straight-edge and a feeler gauge to measure the flatness of the exhaust manifold mounting surface.

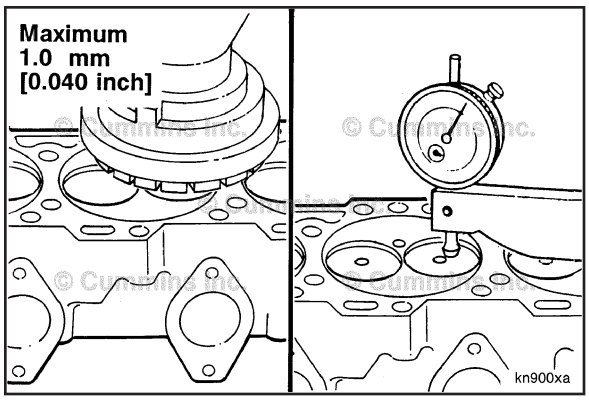
NOTE: The exhaust manifold mounting surface **must** be flat within 0.20 mm [0.008 in], for the full length of the cylinder head.

Exhaust Manifold Mounting Surface - Specifications

	mm		in
Amount of Material Removed	0.5	MAX	0.02
Surface Finish	3.2 µM	MAX	125 µ in
Perpendicularity With Combustion Face	0.30	MAX	0.012
Flatness	0.025 mm per 25.4 mm	MAX	0.001 in per 1.0 in
(Full Length of Cylinder Head)	0.20	MAX	0.008

A maximum of 1 mm [0.040 in] can be machined from the combustion surface of the cylinder head.

If the cylinder head is machined, place the valves in their respective bores and check the valve depth dimension. If the depth is less than the minimum specification, the valve seat will require machining. Go to Valve Seat - Grinding.

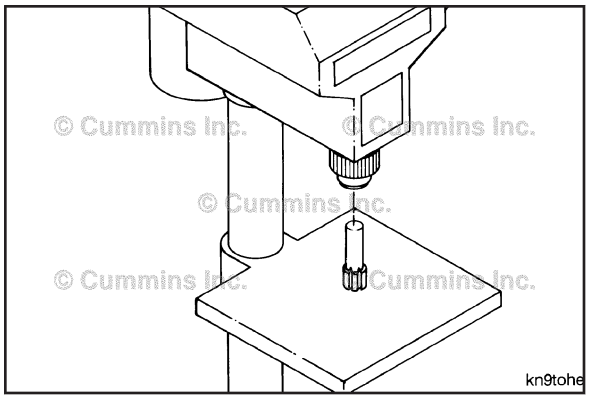


Valve Recess in Cylinder Head

	mm		in
Exhaust	1.09	MIN	0.0430
	1.62	MAX	0.064
Intake	0.59	MIN	0.023
	1.12	MAX	0.044

Valve Guide

When reaming the valve guide bore, use reams that will result in the following specifications.



Oversize Valve Guide Bore Dimensions

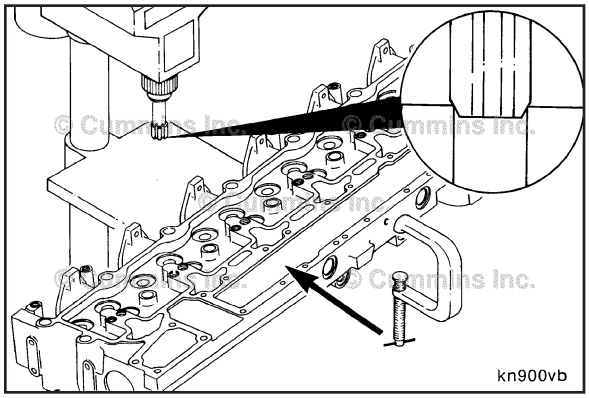
mm		in
16.441	MIN	0.6473
16.481	MAX	0.6489

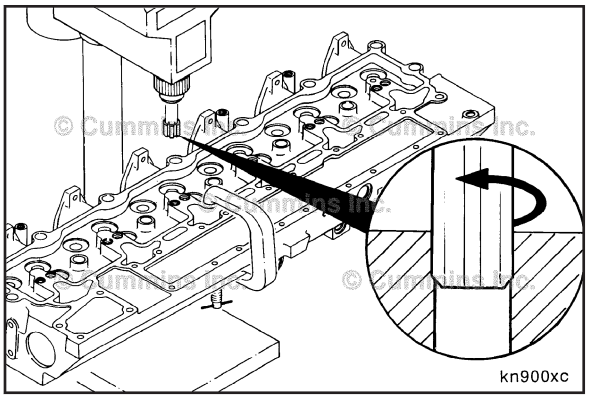
Install the cylinder head on the table of the drill press.

Locate the valve guide bore to be machined under the reamer.

NOTE: Use the taper on the end of the reamer as a pilot when centering the reamer in the bore.

Clamp the cylinder head to the drill press table.



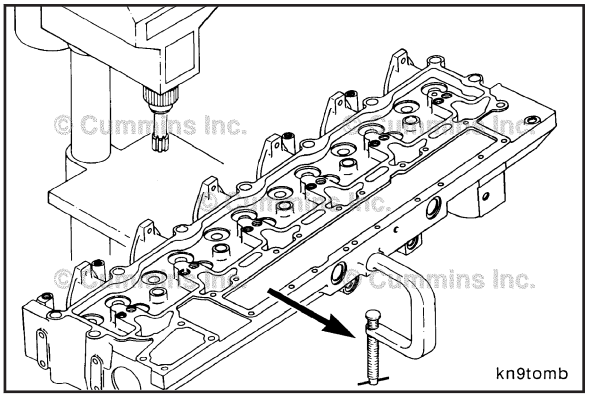


⚠WARNING⚠
To reduce the possibility of personal injury, wear goggles and protective clothing.

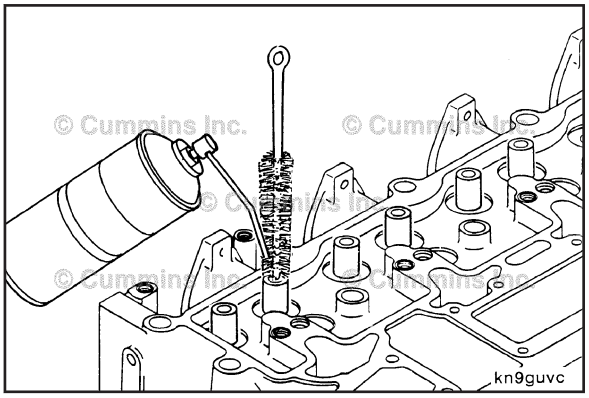
Use cutting oil when drilling or reaming the valve guide bore. Ream the valve guide completely through.

Clean the debris from the valve guide bore.

Inspect the valve guide bore to make sure all damage to the valve guide bore has been removed.



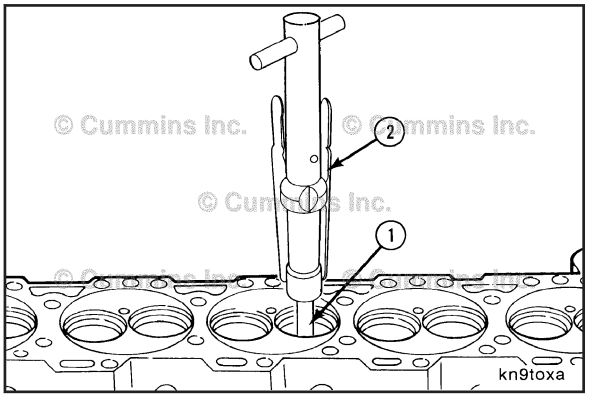
Remove the cylinder head from the drill press.



Valve Seat

NOTE: A clean valve guide is required for successful valve seat insert bore machining.

Clean the inside diameter of the valve guide.

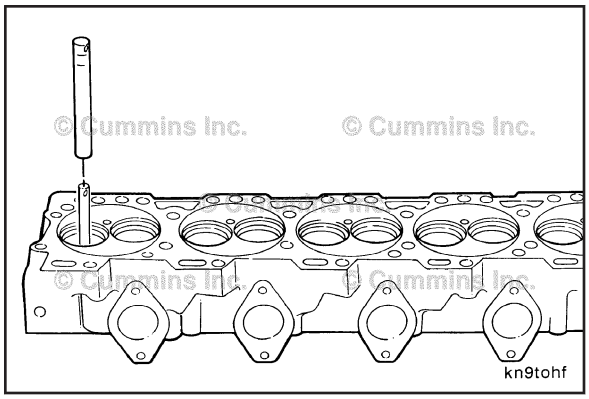


Install valve guide arbor set, Part Number 3823187, in the valve guide.

Install the valve guide arbor (1) in the valve guide with the arbor puller (2).

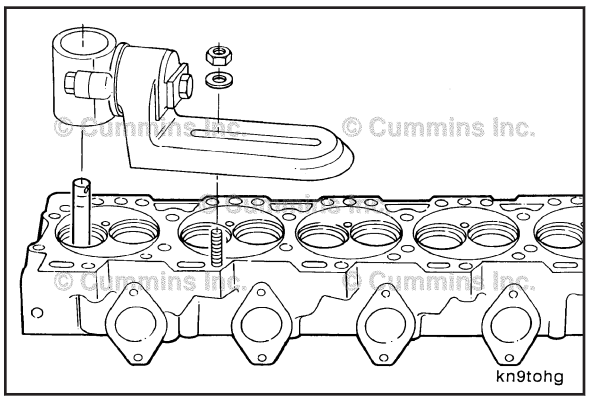
Rotate the arbor to be sure that it is installed correctly.

Remove the arbor puller and install the adapter sleeve from the valve seat insert tool kit over the arbor.

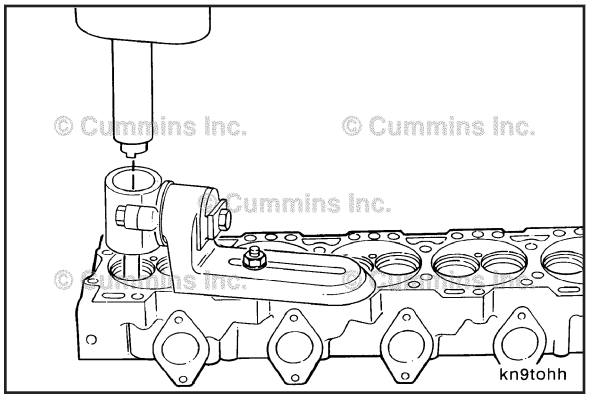


Install the base assembly and gear case swivel from the valve seat insert tool, Part Number ST-257, on the cylinder head.

Clamp the base assembly loosely to the cylinder head using a 14 mm [1/2 in] x 152.4 mm [6 in] capscrew, washer, and nut.

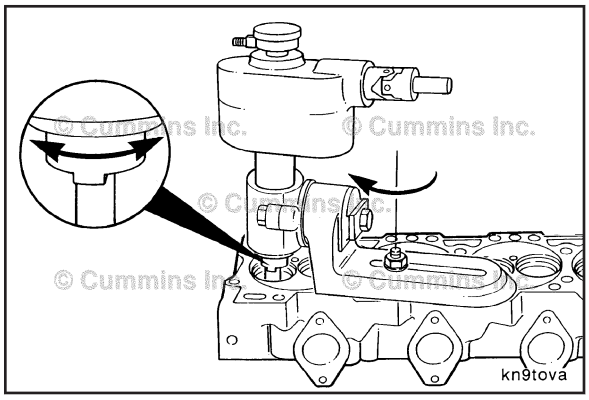


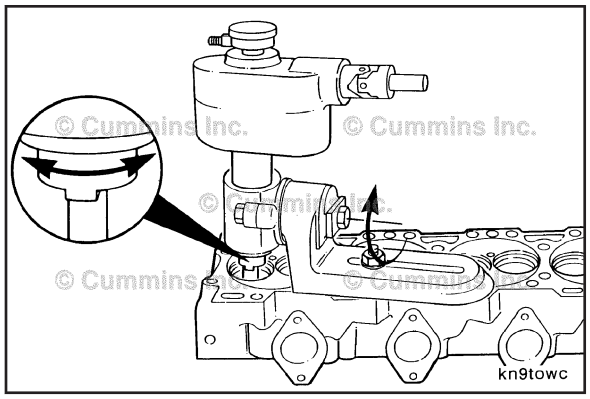
Install the seat cutter drive shaft into the gear case and over the arbor. This will align the base assembly.



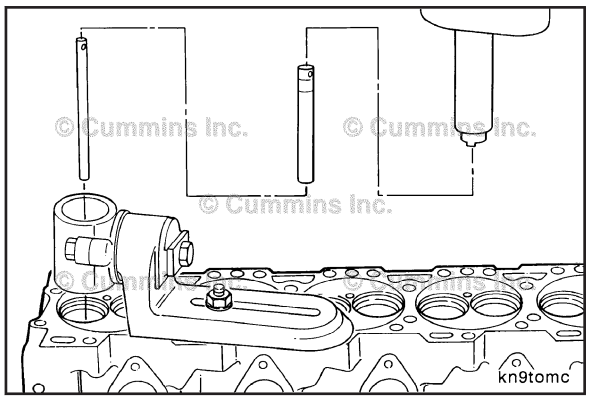
Position the base assembly and gear case swivel so the seat cutter drive shaft turns freely.

Turn the seat cutter drive shaft to make sure it turns freely while tightening the base assembly to the cylinder head.



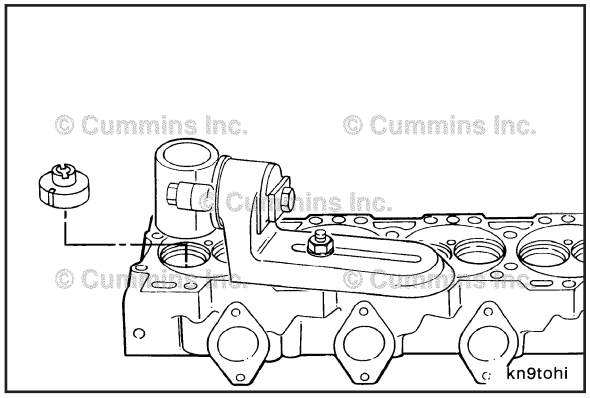


Turn the seat cutter drive shaft to make sure it turns freely while tightening the capscrew that locks the gear case swivel to the base assembly.



Remove the valve seat cutter drive shaft.

Remove the adapter and arbor from the valve guide.



Install the oversize valve seat insert cutter over the bore to be machined. Use the specifications below to determine the oversize cutter required.

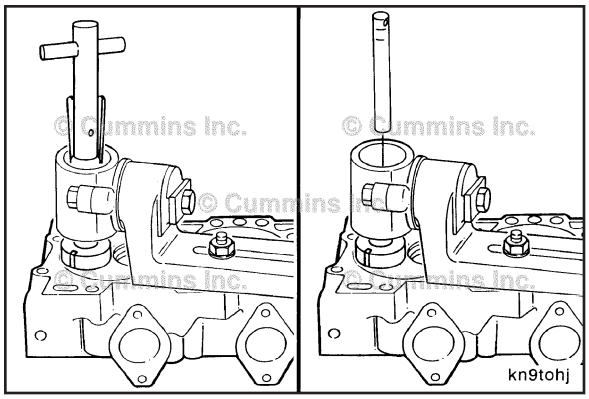
Oversize Valve Seat Cutters and Insert Bore Oversize		
Part Number	**mm**	**Inch**
Intake - 3824058	0.25	0.010
Exhaust - 3824060	0.25	0.010
Intake - 3824059	0.50	0.020
Exhaust - 3824061	0.50	0.020

Insert Bore Inside Diameter

	mm		in
Intake - 3824058	54.151	MIN	2.1319
	54.181	MAX	2.1331
Exhaust - 3824060	47.251	MIN	1.8603
	47.281	MAX	1.8615
Intake - 3824059	54.405	MIN	2.1419
	54.435	MAX	2.1431
Exhaust - 3824061	47.505	MIN	1.8703
	47.535	MAX	1.8715

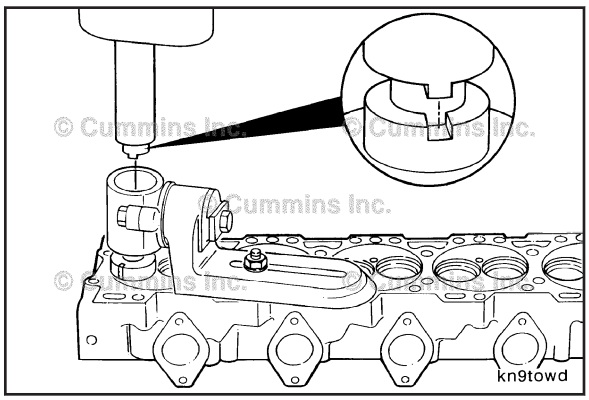
Use the arbor puller to install the arbor through the valve seat cutter, turning the arbor while pressing down to seat the arbor onto the valve guide.

Remove the arbor puller and install the adapter over the arbor and into the center of the valve seat insert cutter.

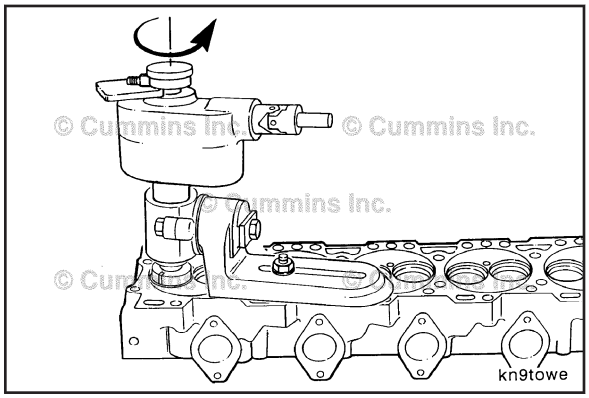


Insert the gear case assembly into the gear case swivel.

Press downward until the driving tangs of the gear case assembly engage with the driving tangs of the valve seat insert cutter.

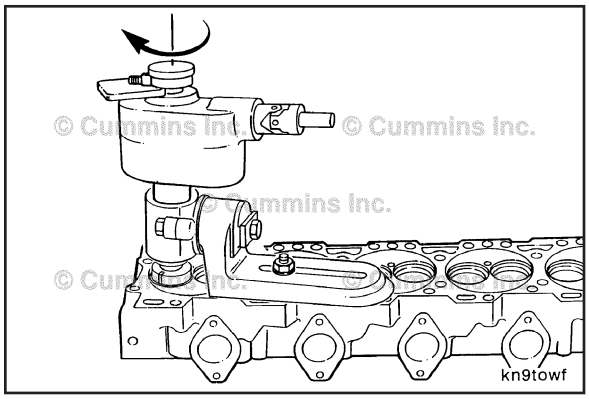


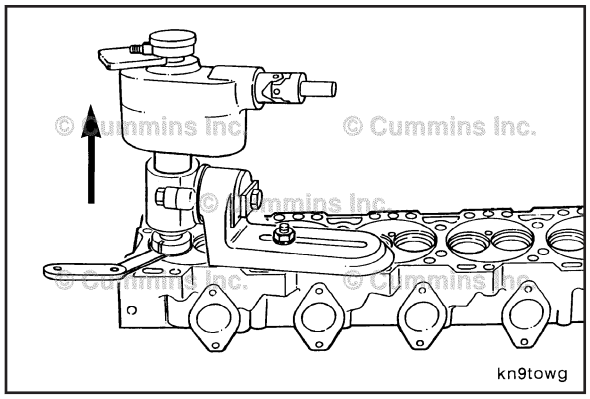
Rotate the knurled hand wheel **counterclockwise** until the oversize valve seat insert to be installed and a 4.52 mm [0.178 in] gauge block will slip in between the knurled hand wheel and the machined surface of the gear case assembly.



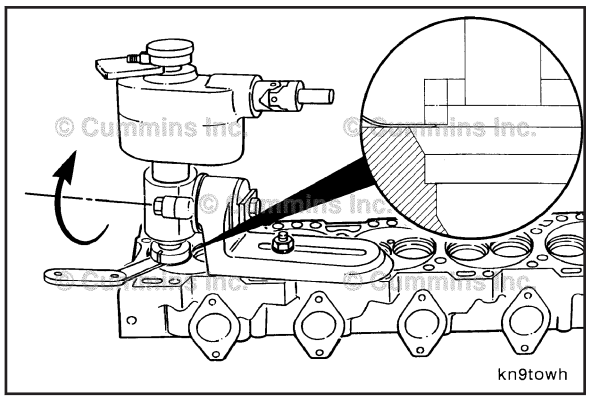
Rotate the knurled hand wheel **clockwise** until the oversize valve seat insert and the gauge block are lightly clamped.

This sets the correct machining depth.

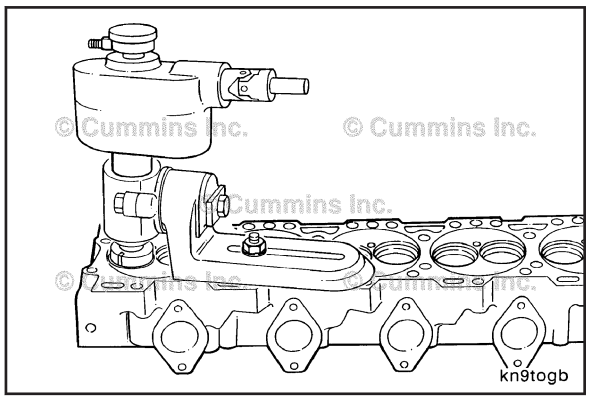




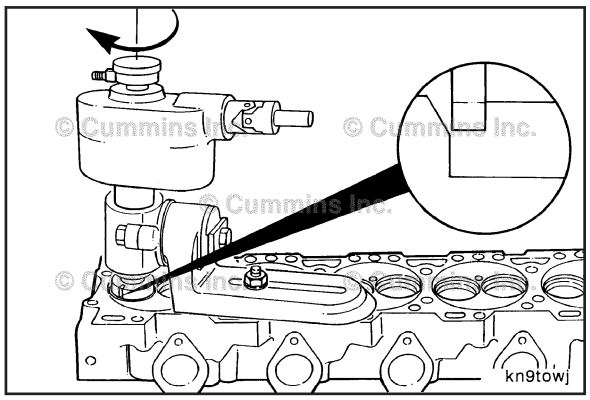
Use a feeler gauge that is **not** bowed to set the vertical location of the gear case assembly by raising the assembly so the bottom edge of the cutter is 0.75 mm [0.030 in] above the combustion surface of the cylinder head.



Tighten the gear case swivel capscrew.



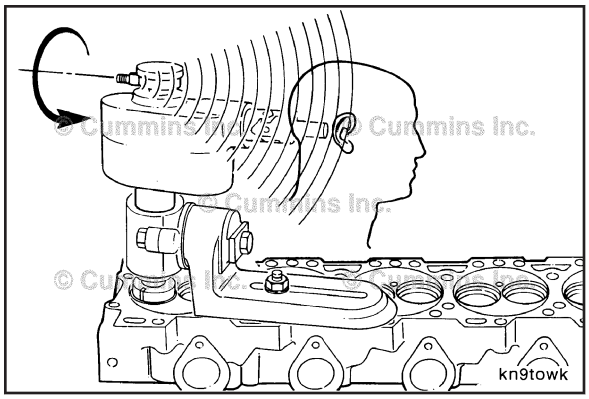
Remove the feeler gauge and the gauge block.



NOTE: Verify that the driving tangs are engaged with the cutter.

Turn the knurled hand wheel **clockwise** to move the cutter down to the cylinder head until the cutter almost touches the valve seat insert bore.

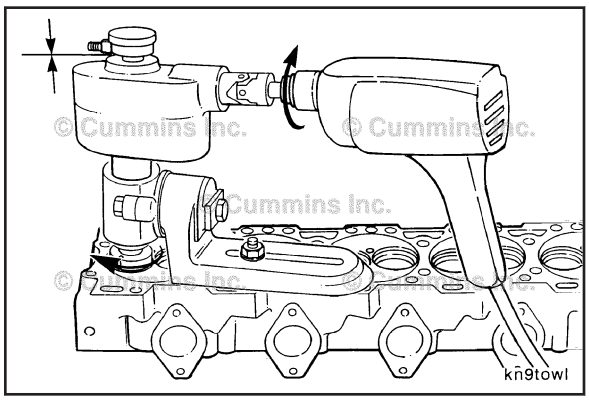
Engage the automatic down feed by rotating the small knurled hand wheel **clockwise** until a click is heard.



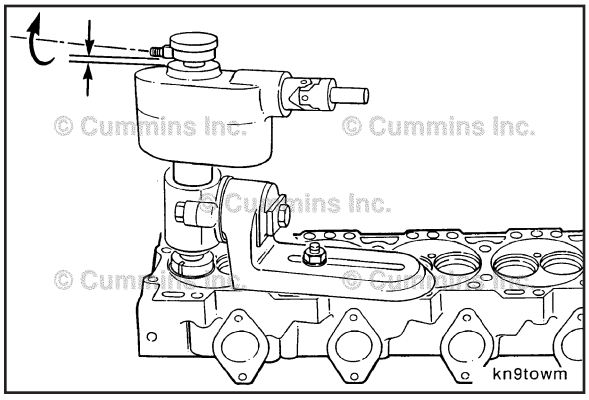
⚠WARNING⚠
To reduce the possibility of personal injury, wear goggles and protective clothing.

Connect a 1/2-inch drill motor to the drive shank of the gear case assembly. Turn the drill motor “ON”. Use cutting oil while machining the valve seat insert bore.

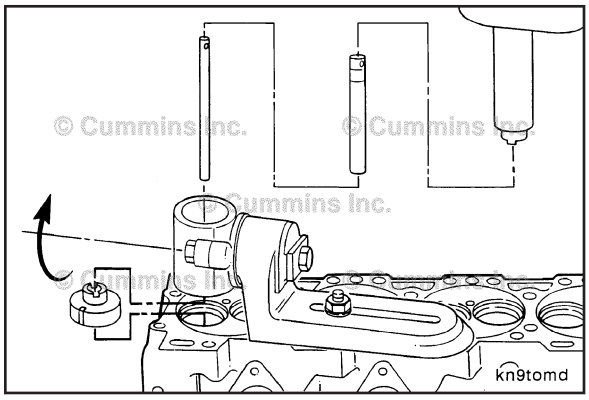
Machine the bore until the feed depth knob is against the gear case. Let the cutter turn two or three more revolutions to make sure the valve seat counterbore surface is machined evenly.

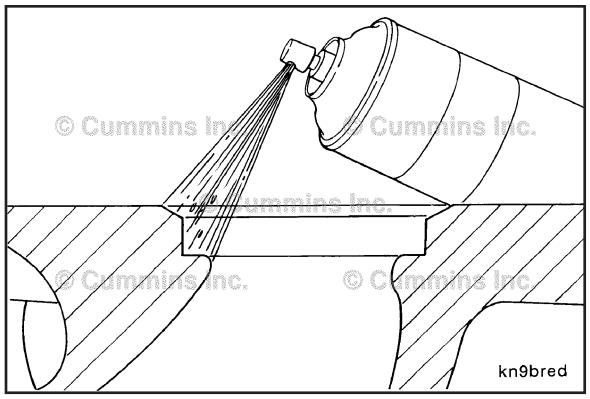


If the feed engagement knob disengages before the knob is against the gear case, turn the knob by hand to complete the cut.

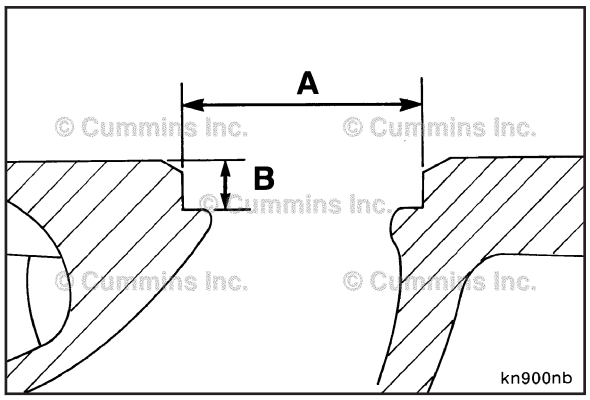


Without removing the base assembly and gear case swivel casting, loosen the swivel capscrew and remove the gear case assembly, arbor, and cutter.





Use a spray cleaner that produces no residue to clean the valve seat insert bore. Remove any machining debris.

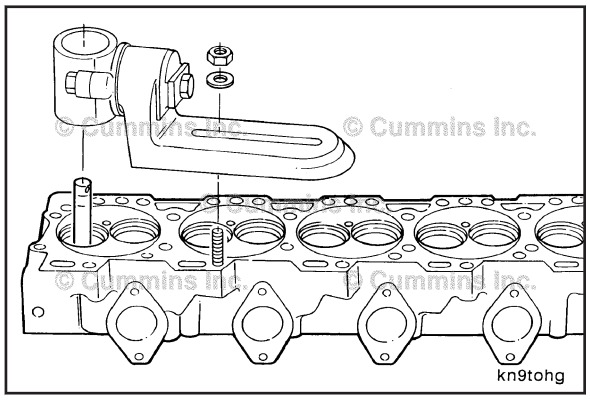


Measure the inside diameter of the valve seat insert bore (A) and the valve seat insert bore depth (B) in the cylinder head. Use the specification below.

If the valve seat insert bore does **not** meet the specifications, the valve seat bore **must** be machined to a larger size or the cylinder head **must** be replaced.

Insert Bore Inside Diameter (A)			
	mm		**in**
Intake - Standard	53.897	MIN	2.1219
	53.927	MAX	2.1231
Exhaust - Standard	46.997	MIN	1.8503
	47.027	MAX	1.8515
Intake - 3824058	54.151	MIN	2.1319
	54.181	MAX	2.1331
Exhaust - 3824060	47.251	MIN	1.8603
	47.281	MAX	1.8615
Intake - 3824059	54.405	MIN	2.1419
	54.435	MAX	2.1431
Exhaust - 3824061	47.505	MIN	1.8703
	47.535	MAX	1.8715

Valve Seat Recession In Cylinder Head (B)			
	mm		**in**
Intake	3.68	MIN	0.145
	4.14	MAX	0.163
Exhaust	3.17	MIN	0.125
	3.63	MAX	0.143



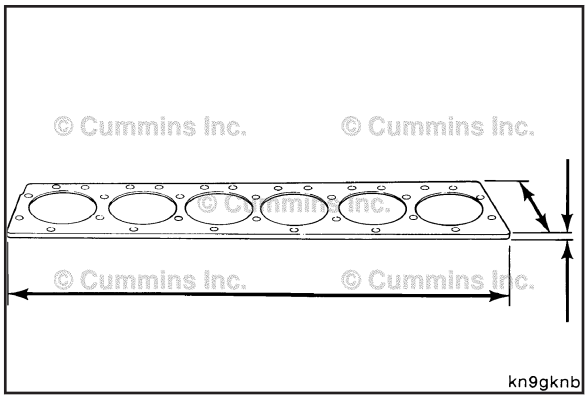
Remove the base assembly and gear case swivel.

Pressure Test

A cylinder head test fixture can be fabricated from a flat piece of steel or aluminum. Reference the following table for test fixture dimensions.

Test Fixture Dimensions		
16 mm	Thickness	0.630 in
749 mm	Length	29.5 in
193 mm	Width	7.6 in

Use a cylinder head gasket as a pattern for drilling the capscrew holes.



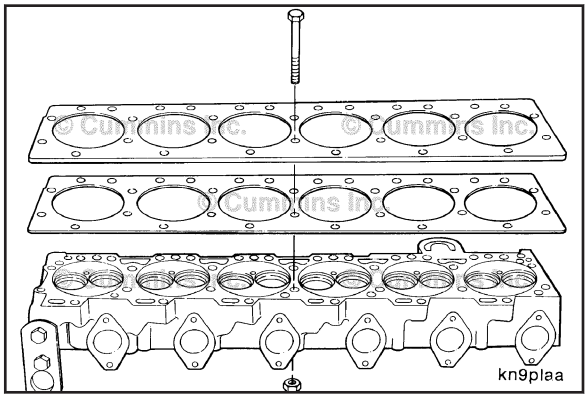
Install the cylinder head water test fixture.

- Install a new head gasket.
- Install the test plate.

Install the following:

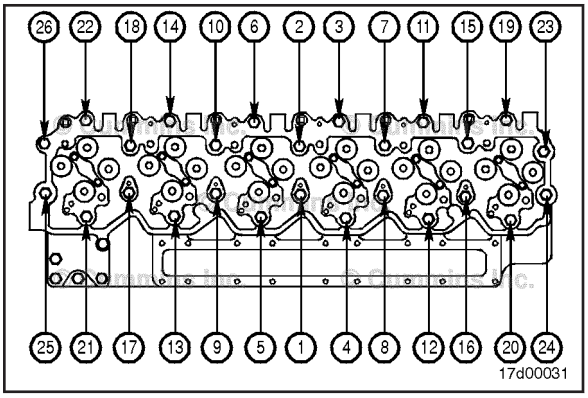
- 26 - 180 mm long head capscrews, Part Number 3920781.
- 26 - M12 x 1.75 hexagon flange nuts.
- 52 - 12 mm washers, Part Number 3900269.

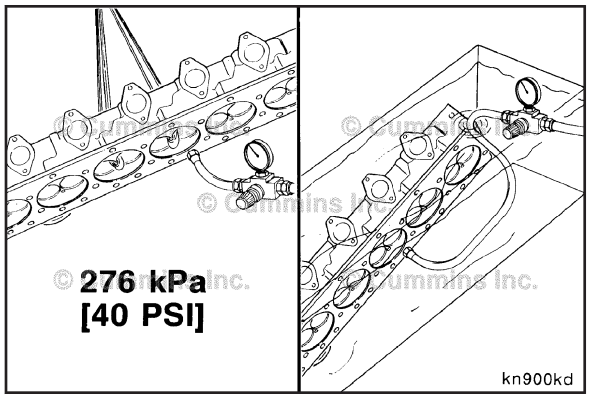
Place a washer between each capscrew and the head, and between each nut and test plate. This will prevent mutilation on the surface of the cylinder head.



Tighten the 26 nuts in the sequence shown in the illustration.

Torque Value: 80 N•m [59 ft-lb]





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

Connect a regulated air supply hose to the test fixture plate.

Apply air pressure.

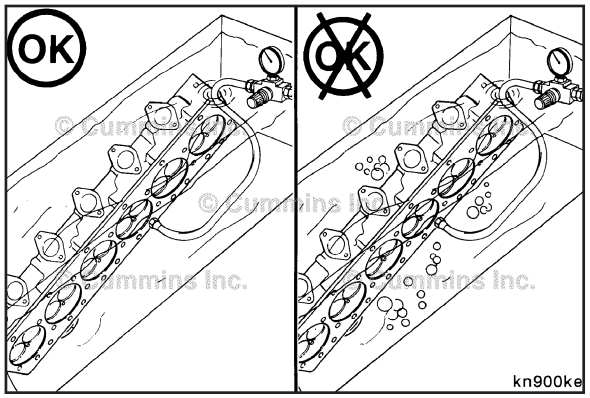
Air Pressure 276 kPa [40 psi]

Use a nylon lifting strap and hoist to place the cylinder head in a tank of heated water.

Water Temperature 60 °C [140 °F]

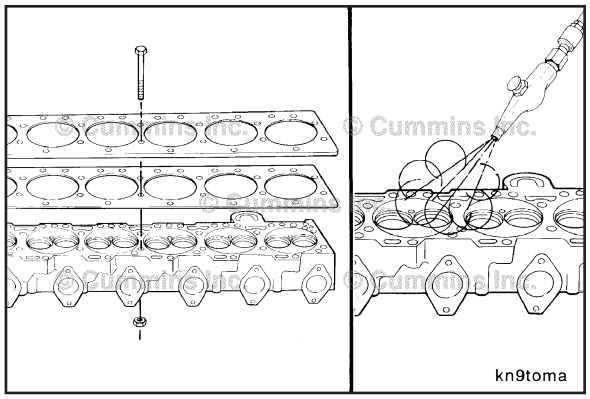
The cylinder head **must** be completely submerged in the water.

If the head leaks, it **must** be replaced.



Inspect the cylinder head. Bubbles indicate an air leak.

If the cylinder head leaks, it **must** be replaced.



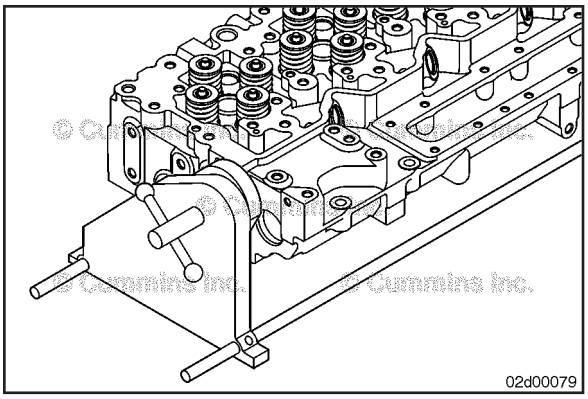
⚠WARNING⚠
To reduce the possibility of personal injury, wear goggles and protective clothing.

Remove the test fixture.

Use compressed air to dry the cylinder head.

Assemble

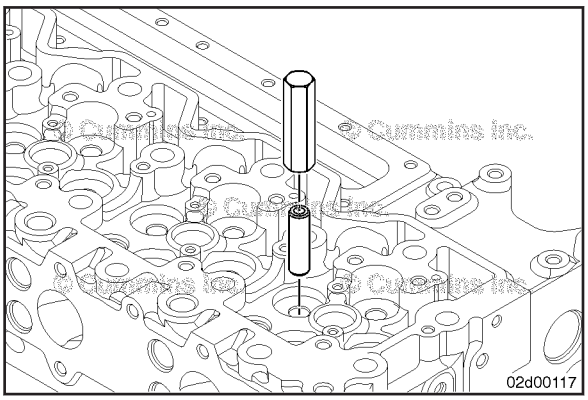
Install the cylinder head in the cylinder head holding fixture, Part Number ST-583.



Use valve guide driver, Part Number 3163100, to install the new valve guides.

Verify the valve slides freely in the valve guide. If **not**, it may be necessary to ream the guide bore.

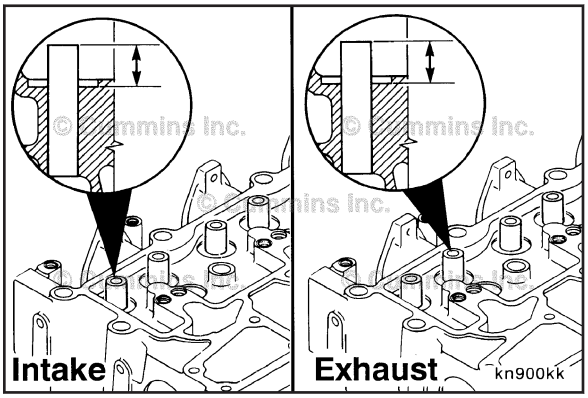
Reference the Clean and Inspect for Reuse step for valve guide inside diameter specifications.



Use a depth micrometer to measure the valve guide installed height. Measure from the top of the valve guide to the bottom of the recessed area.

Valve Guide Height (Installed)		
mm		**in**
13.15	MIN	0.518
13.65	MAX	0.537

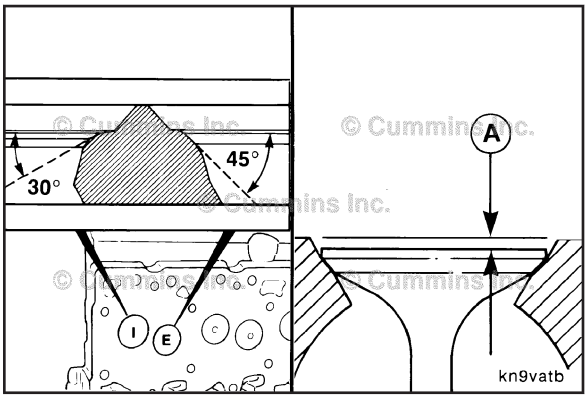
If the valve guide height is **not** within specifications, seat the guide with the installation tool.

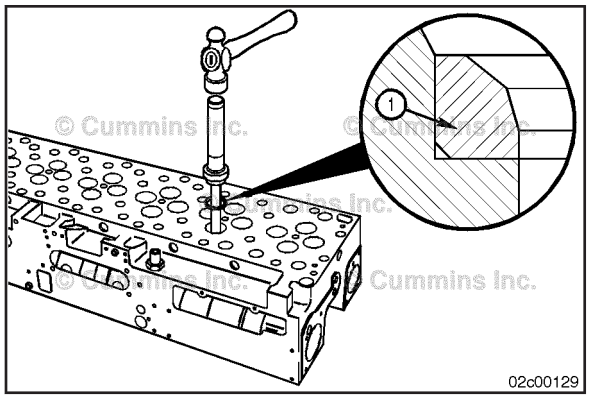


When installing the valve seat inserts, the exhaust and intake valve seat inserts are **not** the same.

Valve seat angle:

- Intake is 30 degrees
- Exhaust is 45 degrees.





If the valve seat inserts were removed in the Disassemble section, new inserts **must** be installed.

NOTE: The valve guide **must** be installed prior to installing the valve seats.

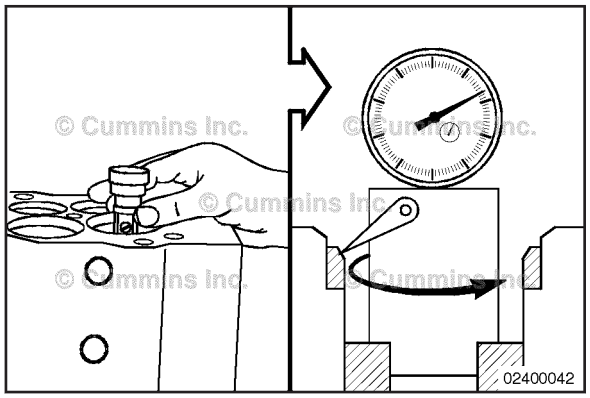
Make sure the valve seat pocket and valve seat is clean before installing.

The insert chamfer (1) **must** be installed toward the bottom of the counterbore.

Use valve seat installer, Part Number 3165115, to drive the intake and exhaust valve seat inserts into the counterbore.

Use a dead blow hammer with the seat drivers to install the new valve seat inserts.

The seats **must** be fully seated into the valve seat pocket. There should **not** be a gap between the seat and the bottom of the pocket.



Measure the valve-seat-to-valve-guide runout. Use arbor set, Part Number 3823186, and eccentrimeter, Part Number ST-685-4, or equivalent.

Valve Seat-to-Valve Guide Runout		
mm		**in**
0.2	MAX	0.008

If the valve seat-to-valve guide runout is **not** within specifications, one of the following actions can be taken:

- Apply Dykem™ marking pen to the valve seat and valve seating surfaces and allow to dry. Install the valve in the valve guide. Hold the valve against the valve seat, and rotate the valve backward and forward three to four times. Verify the contact against the valve seat forms a uniform band on the valve sealing surface. If a uniform band is formed, the assembly is within specifications.
- Clean the valve/valve seat and lap the valves.
- Remove the valve seat and make sure no debris is causing an issue under the seat. Reinstall the valve seat if debris is found.
- Remove the valve seat and machine the valve seat pocket oversize so that an oversize valve seat can be installed. Reference the Clean and Inspect for Reuse section above for valve seat pocket diameter specifications. Use the valve guide ID during machining to help position the valve seat pocket to valve guide ID, to make sure of a proper runout measurement after the oversize valve seat is installed.
- Replace the cylinder head.

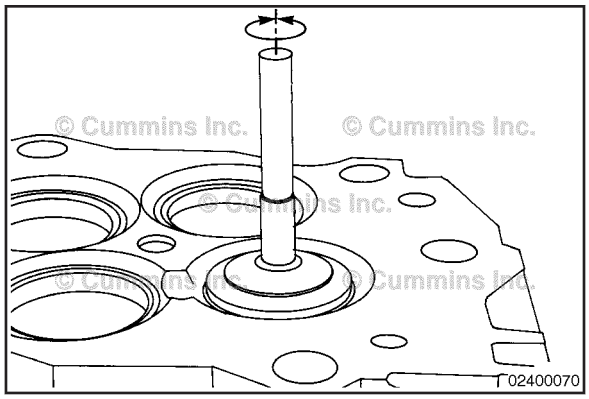
If new valve seat inserts were installed and/or the valve leakage was above specification, the valve seat/valve can be lapped.

Lubricate the stems with SAE 15W-40 engine oil before installing the valves.

Use a fine lapping compound, Part Number 3375805, or equivalent. Apply a thin and even coating on the valve.

Use a power or a hand suction lapping tool to provide pressure in the center of the valve.

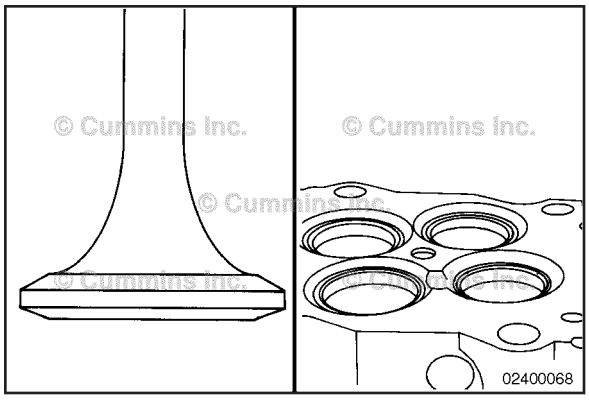
Turn the valve backward and forward. Continue lapping until the compound shows a continuous contact pattern on both the valve seat insert and the valve.



⚠CAUTION⚠
Lapping compound is an abrasive material. Damage will result if the cylinder head, valves, and valve seats are not cleaned thoroughly.

Clean the lapping compound from the parts.

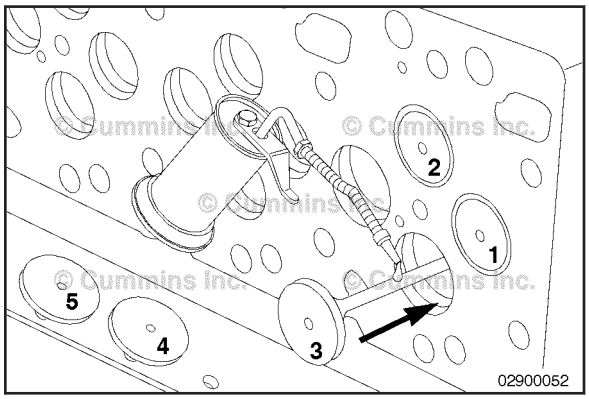
Measure the valve rim thickness. Reference the Clean and Inspect for Reuse section.



Valves that are being reused **must** be installed in the same location from which they were removed.

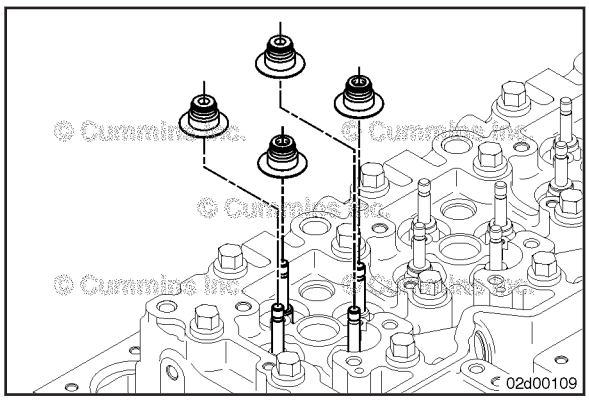
Lubricate the stems with SAE 90W or 15W-40 engine oil before installing the valves.

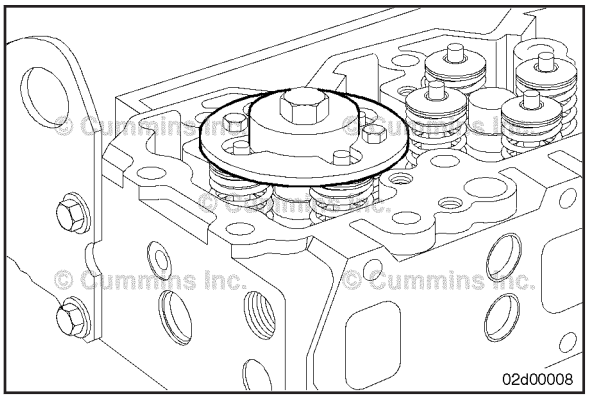
Install the valves.



Install the valve seals over the exhaust valve guides.

Install the valve seals over the intake valve guides.

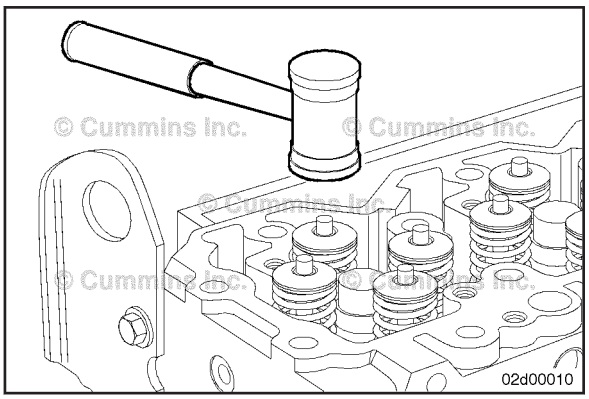




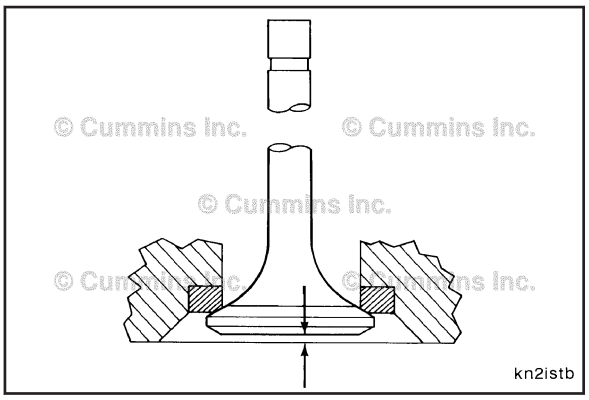
Install the valve spring retainers and valve springs.

Use valve spring compressor, Part Number 3164329, to compress the valve springs.

Install the valve collets and release the spring tension.



After assembly, hit the valve stems with a plastic hammer to make sure the collets are seated.

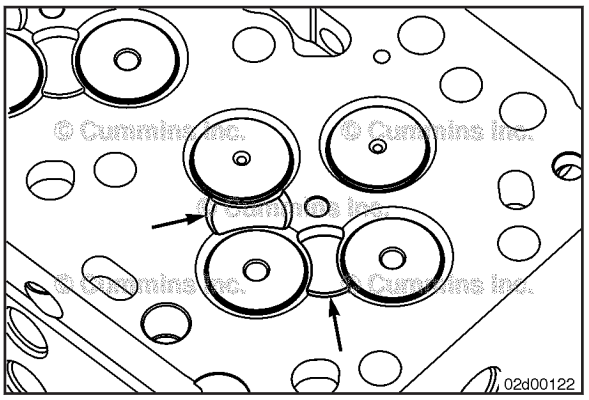


Standard Cylinder Head

Measure the valve recess.

Standard Head Valve Recess in Cylinder Head		
mm		**in**
0.84	MIN	0.033
1.32	MAX	0.052

If the valve recess is outside the specifications, replace the valve. If the valve recess is still outside the specifications, the valve seat insert or cylinder head **must** be replaced.



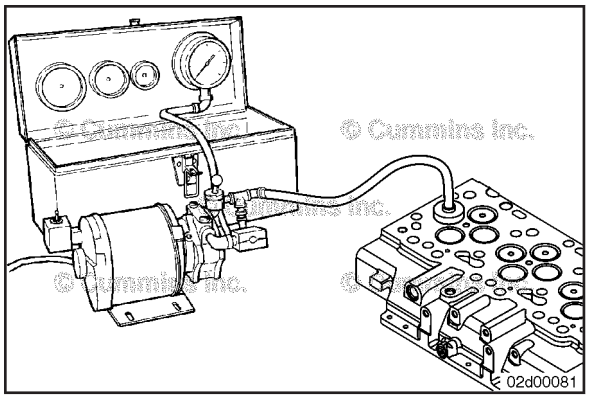
Scallop Cylinder Head

Measure the valve recess.

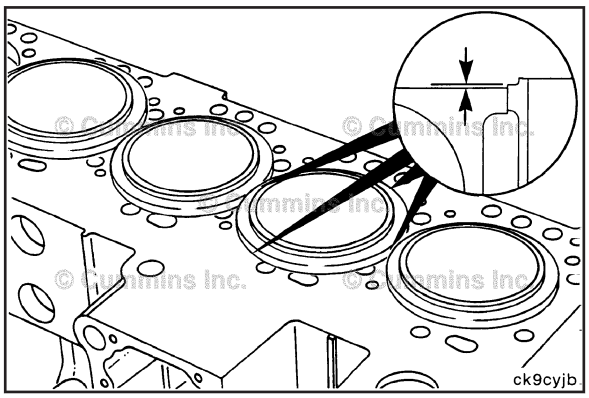
Scallop Head Valve Recess in Cylinder Head		
mm		**in**
0.69	MIN	0.027
1.17	MAX	0.046

If the valve recess is outside the specifications, replace the valve. If the valve recess is still outside the specifications, the valve seat insert or cylinder head **must** be replaced.

Before installing the cylinder head, vacuum test the cylinder head again. Reference the information above in the Vacuum Test section of this procedure.



Before installing the cylinder head, check the cylinder liner protrusion. Refer to Procedure 001-028 in Section 1.

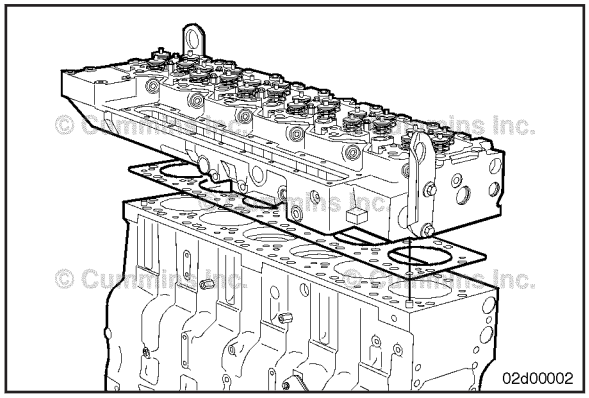


Install

⚠CAUTION⚠
Make sure the cylinder head gasket is correctly aligned with holes in the cylinder block. If not aligned properly, it can cause engine damage.

Do **not** attempt to reuse the cylinder head gasket.

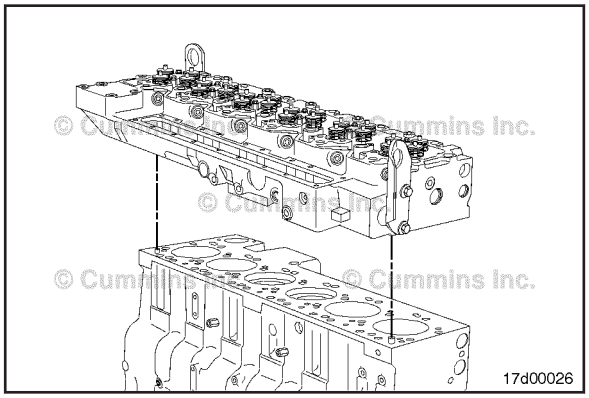
Position the new cylinder head gasket over the dowels.

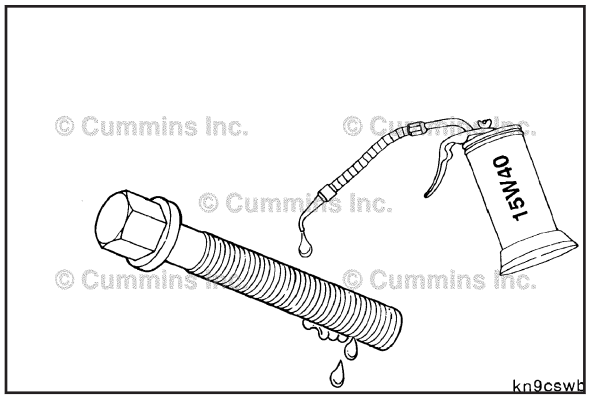


⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Carefully put the cylinder head straight down onto the cylinder block, and seat it onto the dowels.

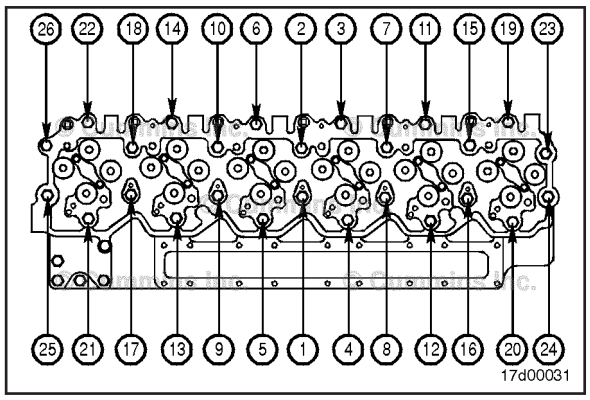
Cylinder Head Weight 71.2 kg [157 lb]





If new capscrews are used, capscrew threads are to be burnished. To burnish new capscrews, tighten the capscrews as described below. Loosen the capscrews and repeat the tightening sequence.

Lubricate the threads and under the heads on the cylinder head capscrews with clean 15W-40 engine lubricating oil.



Tighten the cylinder head capscrews in the sequence shown in the illustration.

Torque Value:
CAPS Fuel System

Step 1	50 N•m	[37 ft-lb]
Step 2	148 N•m	[109 ft-lb]
Step 3	148 N•m	[109 ft-lb]
Step 4	Advance 90 degrees.	

Torque Value:
Cummins® Common Rail Fuel System

Step 1	50 N•m	[37 ft-lb]
Step 2	150 N•m	[111 ft-lb]
Step 3	Loosen all capscrews	
Step 4	115 N•m	[85 ft-lb]
Step 5	115 N•m	[85 ft-lb]
Step 6	Advance 120 degrees.	

Finishing Steps

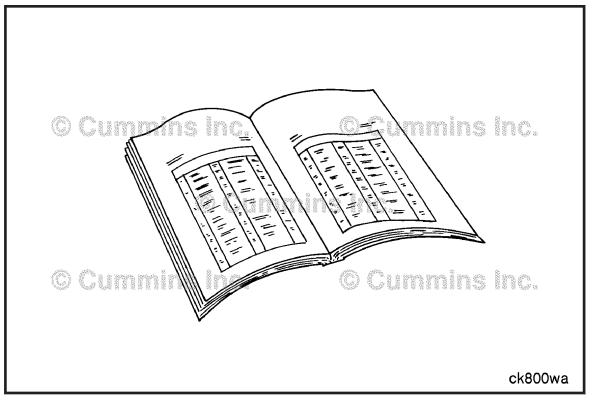
All Applications Except Marine

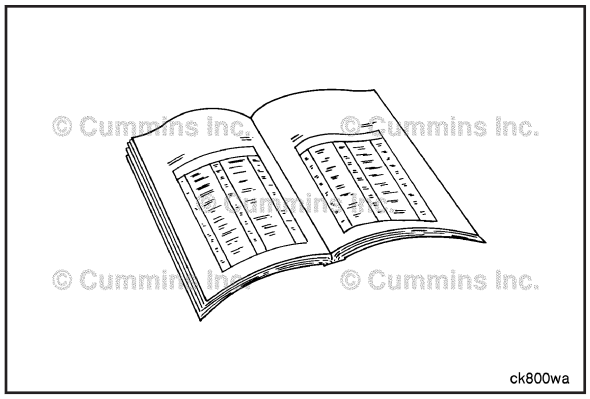
⚠ WARNING ⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠ WARNING ⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠ WARNING ⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- 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 turbocharger control valve, if equipped. Refer to Procedure 019-388 in Section 19 in the Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416.
- Install the fuel drain lines. Refer to Procedure 006-013 in Section 6.
- Install the push rods or tubes. Refer to Procedure 004-014 in Section 4.
- Install the injectors. Refer to Procedure 006-026 in Section 6.
- Install the crossheads. Refer to Procedure 002-001 in Section 2.
- Install the rocker lever. Refer to Procedure 003-008 in Section 3.
- Install the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Install the rocker lever housing. Refer to Procedure 003-013 in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the fuel connection tubes. Refer to Procedure 006-052 in Section 6.
- Install the fuel rail. Refer to Procedure 006-060 in Section 6.
- Install the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Install the turbocharger actuator air line, if equipped. Refer to Procedure 010-118 in Section 10.
- Install all water and heater hoses. Refer to Procedure 008-045 in Section 8.
- Install the intake manifold cover and intake heater. Refer to Procedure 010-108 in Section 10. Refer to Procedure 010-080 in Section 10.
- Install the crankcase breather tube. Refer to Procedure 003-018 in Section 3.
- Install the air crossover tube. Refer to Procedure 010-019 in Section 10.
- Operate the engine and check for leaks.





Marine Applications

WARNING
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

WARNING
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

WARNING
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the push rods or tubes. Refer to Procedure 004-014 in Section 4.
- Install the crossheads. Refer to Procedure 002-001 in Section 2.
- Install the rocker lever assembly. Refer to Procedure 003-008 in Section 3.
- Install the rocker lever housing.Refer to Procedure 003-013 in Section 3.
- Adjust the overhead. Refer to Procedure 003-004 in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the fuel connection tubes. Refer to Procedure 006-052 in Section 6.
- Install the turbocharger and exhaust manifold as an assembly. Refer to Procedure 011-008 in Section 11.

NOTE: This next step applies to QSL9 engines **only**. The expansion tank and heat exchanger on the QSC8.3 engines are a one-piece unit. Refer to Procedure 008-053 in Section 8.

- Install the expansion tank. Refer to Procedure 008-052 in Section 8.

NOTE: Some QSL9 engines are keel cooled and do **not** have heat exchangers.

- Install the heat exchanger, if equipped. Refer to Procedure 008-053 in Section 8.
- Install the coolant vent lines to the turbocharger and expansion tank. Refer to Procedure 008-017 in Section 8.
- Install all water and heater hoses. Refer to Procedure 008-045 in Section 8.
- Install the two aftercooler to cylinder head bracket mounting capscrews. Refer to Procedure 010-005 in Section 10.
- Install the fuel drain lines from the rear of the cylinder head. Refer to Procedure 006-013 in Section 6.
- Install the intake manifold cover. Refer to Procedure 010-108 in Section 10.
- Install the intake manifold temperature sensor. Refer to Procedure 019-059 in Section 19 in the Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
- Install the intake manifold pressure sensor. Refer to Procedure 019-061in Section 19 in the Troubleshooting and Repair Manual, Electronic Control System, ISC, QSC8.3 and ISL Engines, Bulletin 3666271.
- Install the intake manifold temperature sensor. Refer to Procedure 019-059 in Section 19 in the Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416.
- Install the intake manifold pressure sensor. Refer to Procedure 019-061 in Section 19 in the Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL and QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416.
- Install the common fuel rail. Refer to Procedure 006-060 in Section 6.
- Install the injector fuel lines. Refer to Procedure 006-051 in Section 6.
- Install the fuel lift pump. Refer to Procedure 005-045 in Section 5.
- Install the fuel filter head bracket. Refer to Procedure 006-018 in Section 6.
- Install the air intake connection. Refer to Procedure 010-080 in Section 10.
- Install the air crossover from the air intake connection and the aftercooler. Refer to Procedure 010-019 in Section 10.
- Fill the engine coolant. Refer to Procedure 008-018 in Section 8.
- Open the sea water supply, if necessary. See equipment manufacturer service information.
- Open the fuel supply and return valves. See equipment manufacturer service information.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.

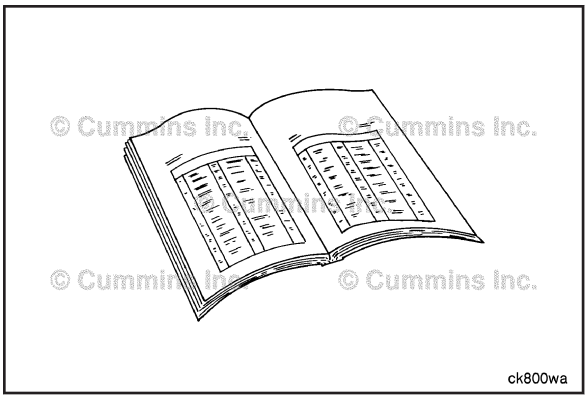
Valve Guide Seal, Cylinder Head (002-016)

General Information

The following procedure is for removing the valve stem seals with the cylinder head installed.

For removing the valve stem seals with the cylinder head removed, Refer to Procedure 002-004 in Section 2.

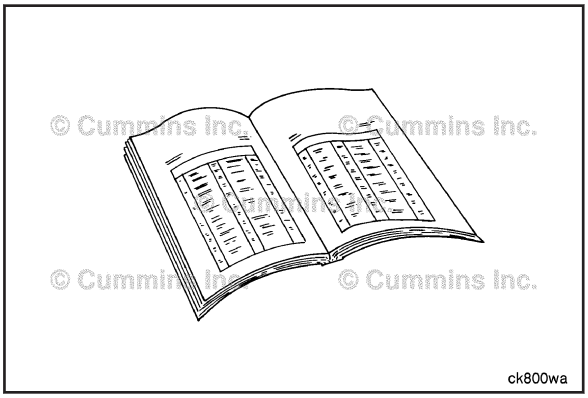
NOTE: This procedure can also be used for removing the valve springs, valve spring retainers, and valve collets with the cylinder head installed.



Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

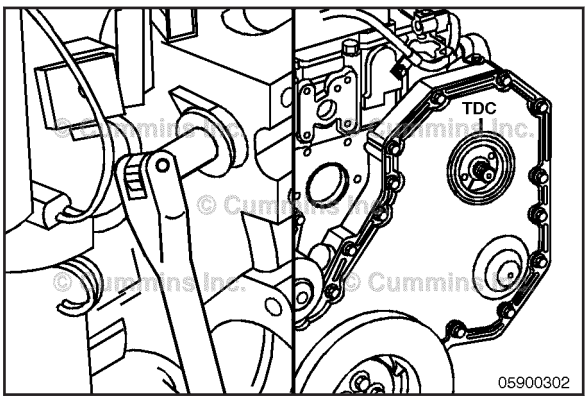
- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- If necessary, remove the engine brake assemblies. Refer to Procedure 020-004 in Section 2.
- Remove the rocker lever assemblies. Refer to Procedure 003-008 in Section 3.
- Remove the crossheads. Refer to Procedure 002-001 in Section 2.
- Remove all injectors. Refer to Procedure 006-026 in Section 6.

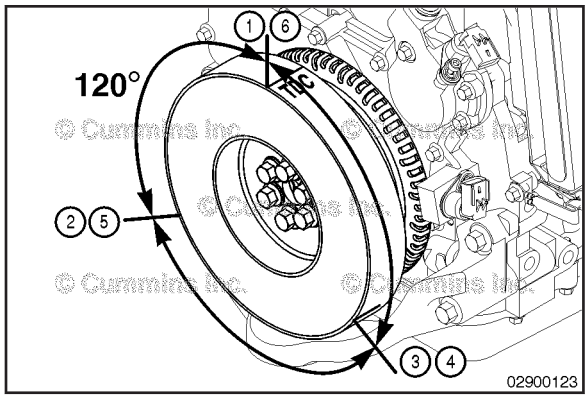


Remove

NOTE: In order to remove the valve springs with the cylinder head installed, the piston of the cylinder being worked on **must** be brought to top dead center (TDC) to support the valves.

Use a barring tool, Part Number 3824591, to rotate the crankshaft to align the (TDC) marks on the gear cover and fuel pump gear.



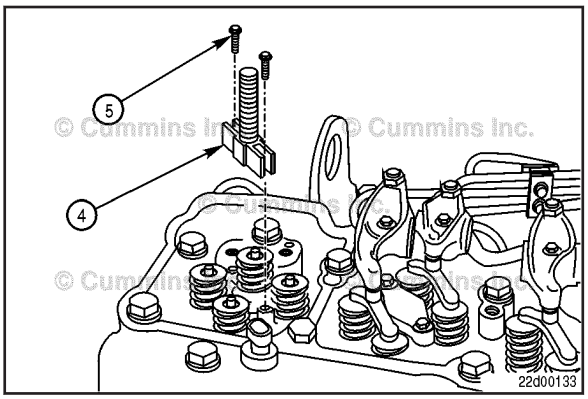


With the (TDC) marks for the number 1 cylinder aligned, mark the vibration damper for the location of (TDC) for the other cylinders.

- Mark the vibration damper every 120 degrees with a marker directly on the damper or to a piece of masking tape applied to the outside diameter of the damper.

Service Tip: A protractor, camshaft degree wheel or angle/level indicator, Part Number 3375855, can be used to locate 120 degree increments around the vibration damper.

- Mark the damper with the TDC indicator for each cylinder as shown. Two cylinders correspond to each 120 degree line.

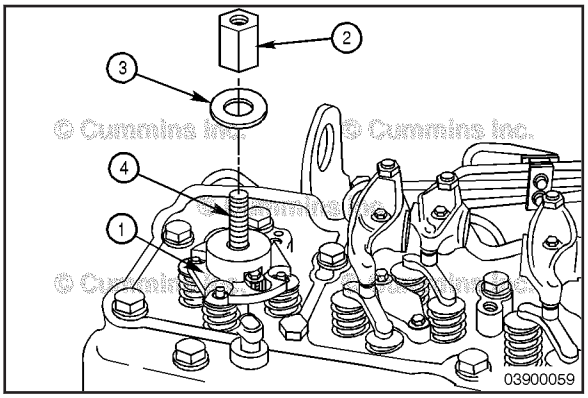


Compress the valve springs using the valve spring compressor service tool, Part Number 3164329.

Position the replacer screw (4) above the injector bore and install the two capscrews (5) in the cylinder head where the hold-down clamp capscrews were removed.

Tighten the capscrews.

Torque Value: 5 N•m [44 in-lb]



NOTE: The valves are **not** evenly spaced from the injector bore. It is important to align the slots in the valve spring compressor plate with the valve springs.

Apply anti-seize compound to the replacer screw (4) threads. **Always** read and follow label precautions.

Position the valve spring compressor plate (1) on the replacer screw (4) and align the slots in the valve spring compressor plate with the valve springs.

Install the washer (3) and nut (2) on the replacer screw (4).

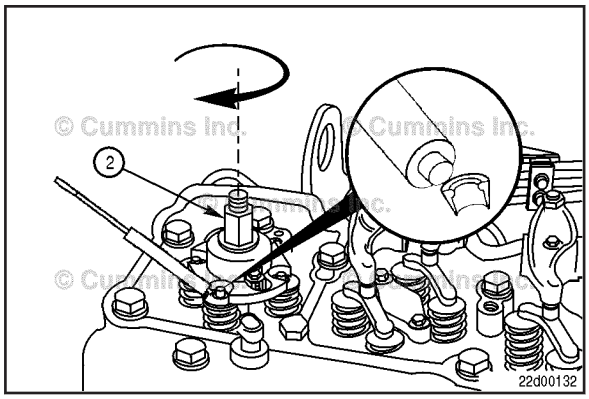
⚠WARNING⚠
Valve springs are under compression and can act as projectiles if released. To reduce the possibility of eye injury, wear safety glasses with side shields.

Turn the nut (2) **clockwise** to compress the valve springs.

Continue turning the nut (2) **clockwise** until the valve collets can be removed using a magnetic tool, such as the end of a magnetic screwdriver.

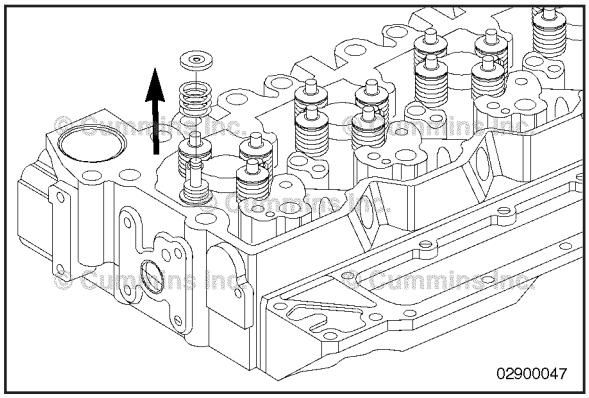
NOTE: Because there is a gap between the top of the piston and the valve face, it may be necessary to use a second magnet to hold the valve stem up to remove the valve collets.

Remove the valve collets and the valve spring compressor service tool.



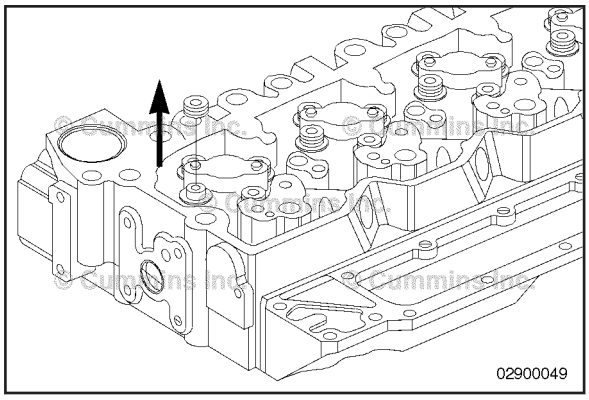
△CAUTION△
With the valve collets, valve springs, and valve spring retainers removed, do not rotate the engine. Rotating the engine will allow the valves to drop into the cylinder requiring the cylinder head to be removed or possible engine damage.

Remove the four valve spring retainers and the valve springs.



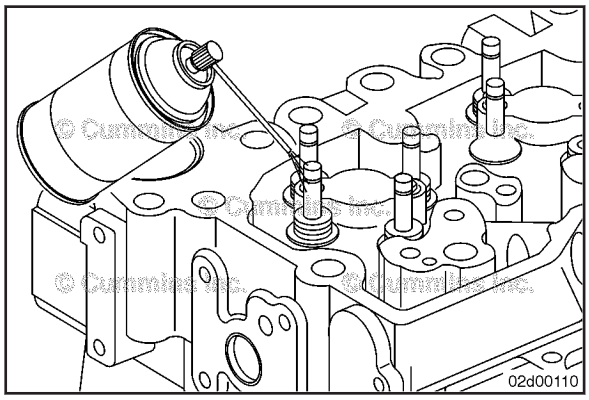
Use boot pliers, Part Number 3163293, to remove the valve stem seals.

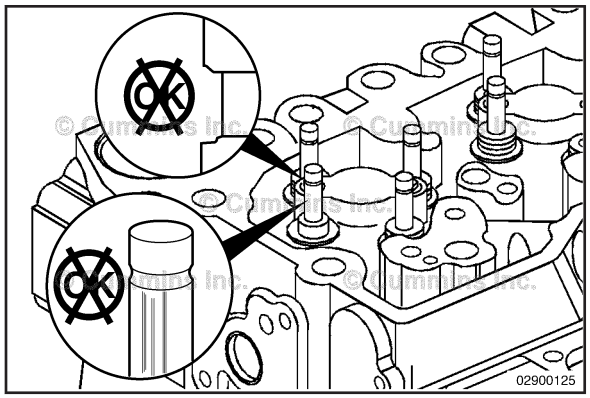
Note the color and location of the seal, and then discard the old seal.



Clean and Inspect for Reuse

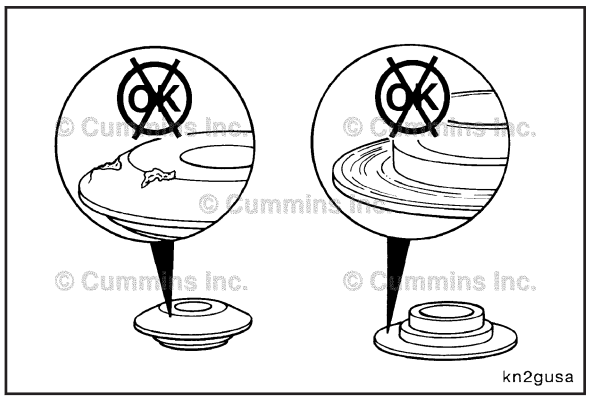
Clean the seal tower and valve stem with contact cleaner, Part Number 3824510.





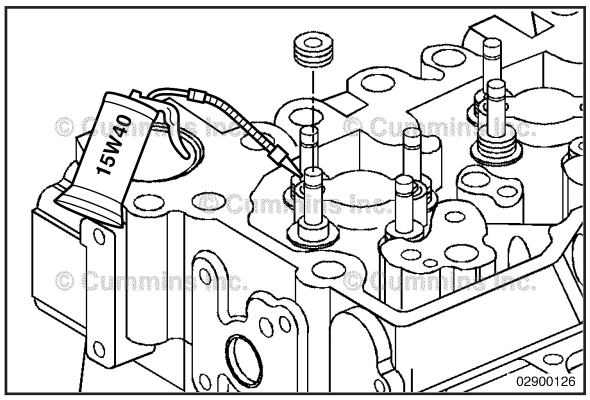
Inspect the exposed valve stem for scoring or heavy polishing. Inspect the valve collet grooves for wear.

If the valve stem is damaged, the cylinder head **must** be removed and the valve replaced. Refer to Procedure 002-004 in Section 2.



Inspect the valve spring retainers and valve collets for damage or worn areas.

Discard and replace damaged and worn parts.



Install

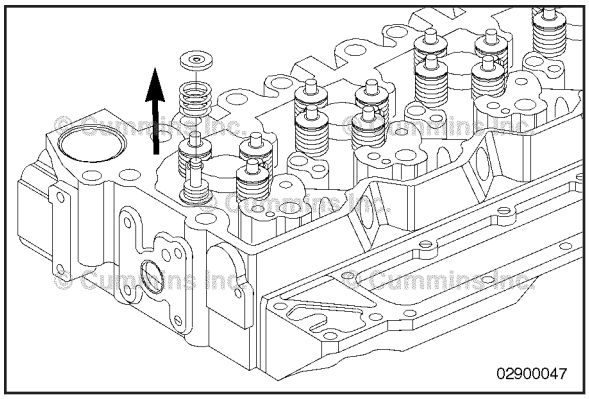
CAUTION
The same color valve stem seal must be installed in the same location as removed. Incorrect valve stem seals will result in excessive oil consumption and internal engine damage.

CAUTION
Lubricate all the valve guide bores and valve stems with SAE 15W-40 engine oil. Failure to lubricate the valve guides and valve stems can result in premature valve guide wear.

Install new valve stem seals of the same color as removed and in the same location. The black valve guide seals are for the exhaust valves; the blue valve guide seals are for the intake valves.

Lubricate the stems with SAE 15W-40 engine oil before installing the valve stem seals.

Install the valve spring retainer and the valve springs.

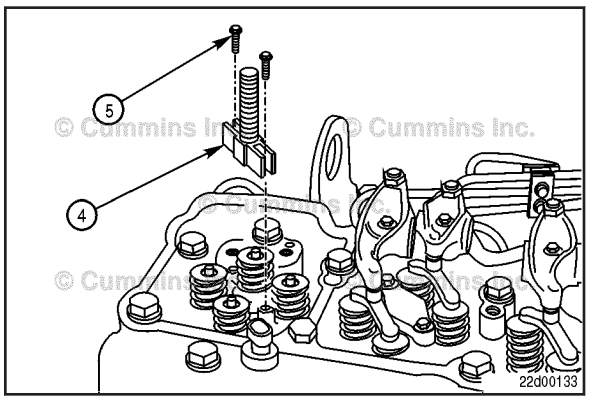


Compress the valve springs using the valve spring compressor service tool, Part Number 3164329.

Position the replacer screw (4) above the injector bore and install the two capscrews (5) in the cylinder head where the hold-down clamp screws were removed.

Tighten the capscrews.

Torque Value: 5 N•m [44 in-lb]

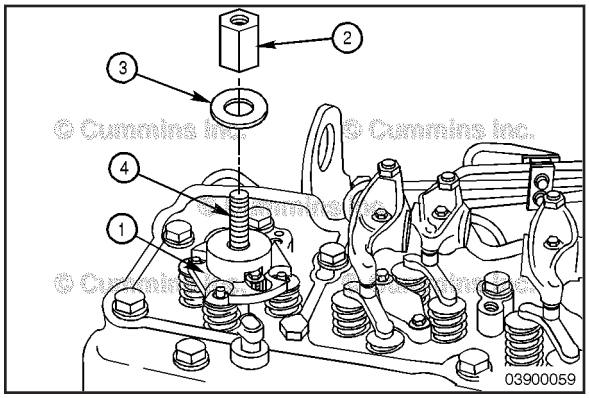


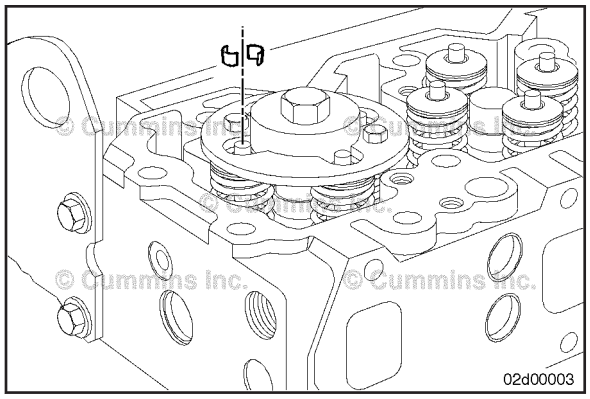
NOTE: The valves are **not** evenly spaced from the injector bore. It is important to align the slots in the valve spring compressor plate with the valve springs.

Apply anti-seize compound to the replacer screw (4) threads. **Always** read and follow label precautions.

Position the valve spring compressor plate (1) on the replacer screw (4) and align the slots in the valve spring compressor plate with the valve springs.

Install the washer (3) and nut (2) on the replacer screw (4).





⚠WARNING⚠
Valve springs are under compression and can act as projectiles if released. To reduce the possibility of eye injury, wear safety glasses with side shields.

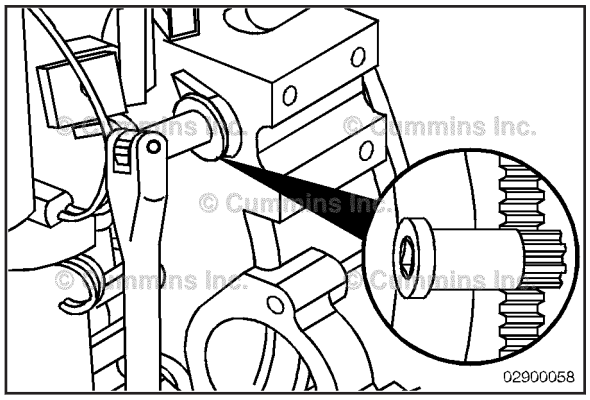
NOTE: Because there is a gap between the top of the piston and the valve face, it may be necessary to use a second magnet to pull the valve stem up to remove the valve collets.

Compress the valve springs until the valve collets can be installed.

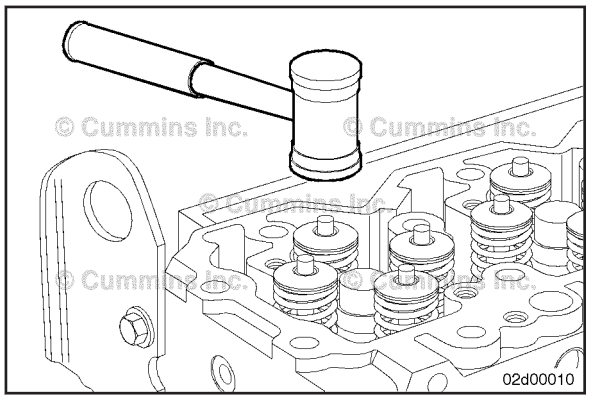
Install the valve collets.

Service Tip: Use assembly lubricant, Part Number 3163087 or equivalent, on the valve collets to help hold them in place until the valve spring compressor is released.

Remove the valve spring compressor service tool.



Using the marks made previously on the vibration damper, rotate the engine to the next mark to replace the valve guide seals on the next pair of cylinders.



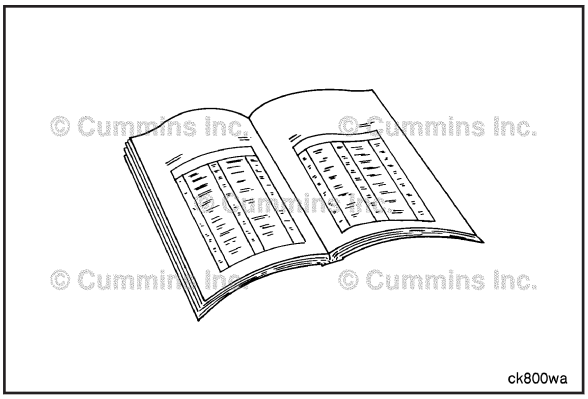
⚠WARNING⚠
To reduce the possibility of personal injury, wear eye protection. If the collets are not correctly installed, they can fly out when the stems are hit with a hammer.

△CAUTION△
Rotate the engine to the next cylinder in the firing order before hitting the valve stem of the cylinder previously worked on. This will ensure the valve does not contact the piston, resulting in a bent valve and internal engine damage.

After rotating the engine to the next cylinder in the firing order, hit the valve stems of the cylinder previously worked on with a plastic hammer to make sure the collets are seated.

Repeat the previous steps until all of the valve stem seals have been replaced.

Finishing Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the injectors. Refer to Procedure 006-026 in Section 6.
- Install the crossheads. Refer to Procedure 002-001 in Section 2.
- Install the rocker lever assemblies. Refer to Procedure 003-008 in Section 3.
- Adjust the overhead. Refer to Procedure 003-004 in Section 3.
- Install the engine brake assemblies, if removed. Refer to Procedure 020-004 in Section 20.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

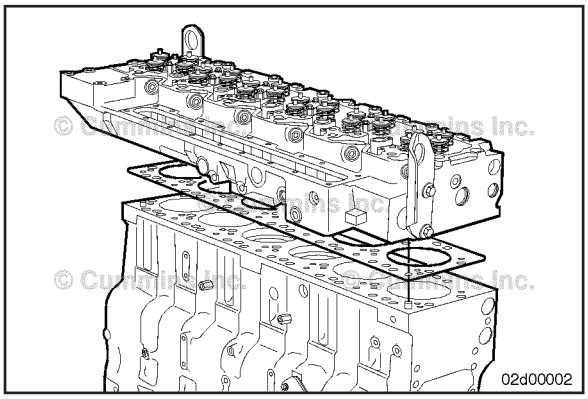
Cylinder Head Gasket (002-021)

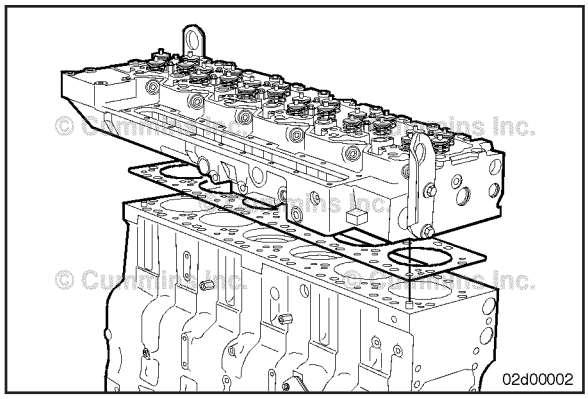
Preparatory Steps

Remove the cylinder head. Refer to Procedure 002-004.

Remove

Remove the cylinder head gasket.





Install

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

Install a new cylinder head gasket.

Finishing Steps

Install the cylinder head. Refer to Procedure 002-004.

Section 3 - Rocker Levers - Group 03

Section Contents

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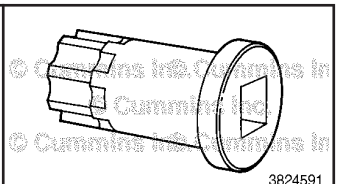
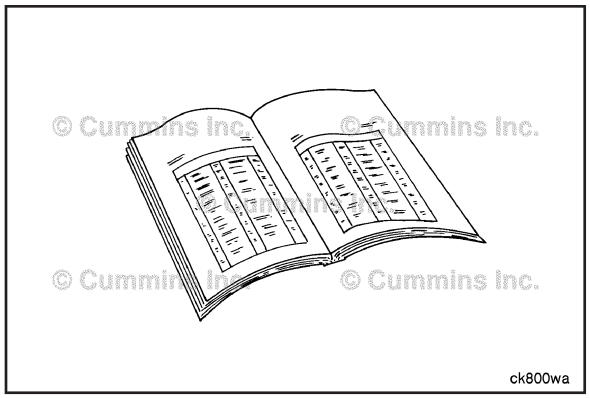
Service Tools

Rocker Levers

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3824591	**Engine Barring Gear** Used to engage the flywheel ring gear to rotate the crankshaft.	

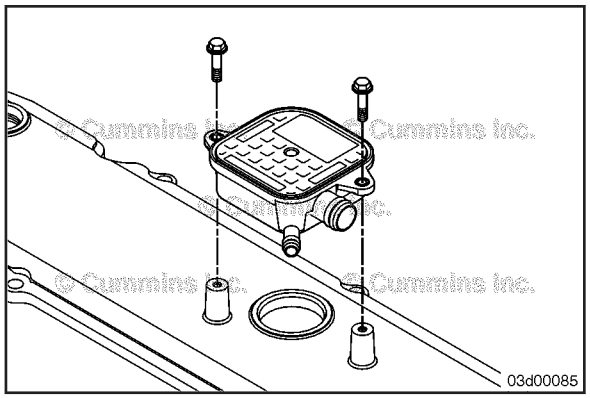


Crankcase Breather (External) (003-001)

Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

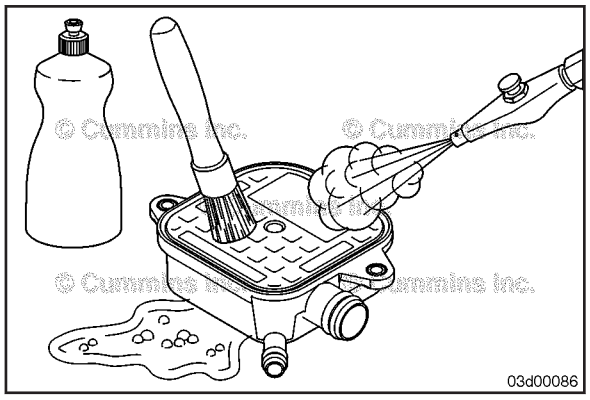
- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the crankcase breather tube and drain tubes. Refer to Procedure 003-018 in Section 3.



Remove

Remove the two mounting capscrews.

Remove the breather from the rocker lever cover by pulling straight up on the breather assembly.



Clean and Inspect for Reuse

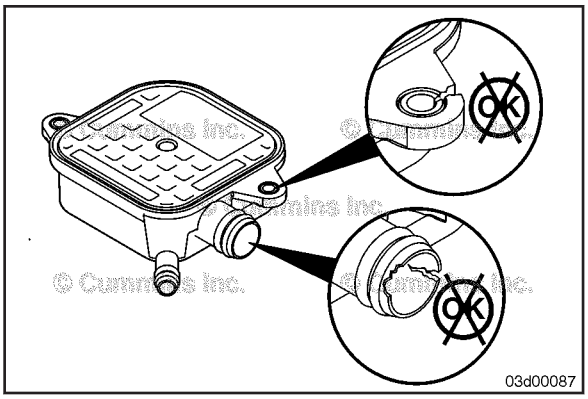
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

NOTE: White, tan, or brown foam or froth is sometimes found under the oil fill cap, inside the valve cover, or in the crankcase breather. Foam or froth can occur if the engine operates below thermostat opening temperature for sustained periods. This type of foam or froth will **not** affect the function of the engine. Foam or froth can also occur if there is an internal coolant leak. If an internal coolant leak is suspected, perform the Coolant Leak - Internal troubleshooting tree.

Use hot soapy water and a soft brush to clean the crankcase breather.

Dry with compressed air.

Inspect the breather for cracks or other damage.



Install

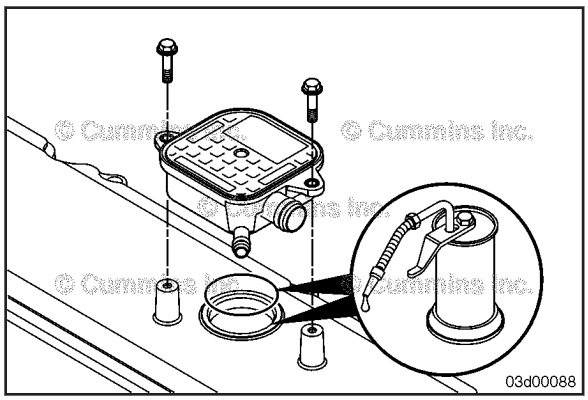
Place a new o-ring on the breather.

Lubricate the o-ring and the valve cover o-ring seat with lubricating oil.

Install the breather into the rocker lever cover.

Tighten the capscrews.

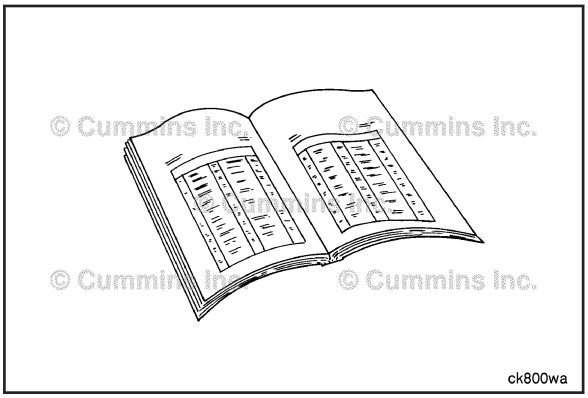
Torque Value: 7 N•m [62 in-lb]



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

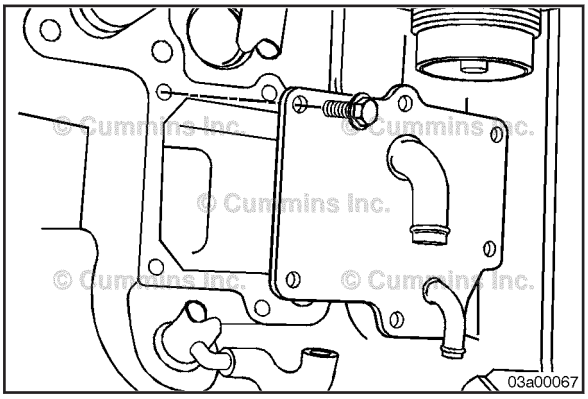
- Install the crankcase breather tube and drain tube. Refer to Procedure 003-018 in Section 3.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

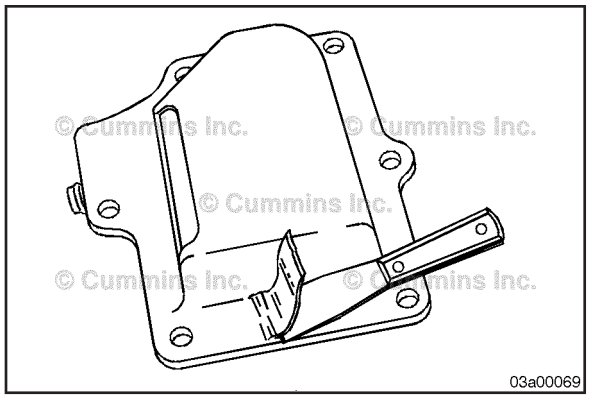


Crankcase Breather (Internal) (003-002)

Remove

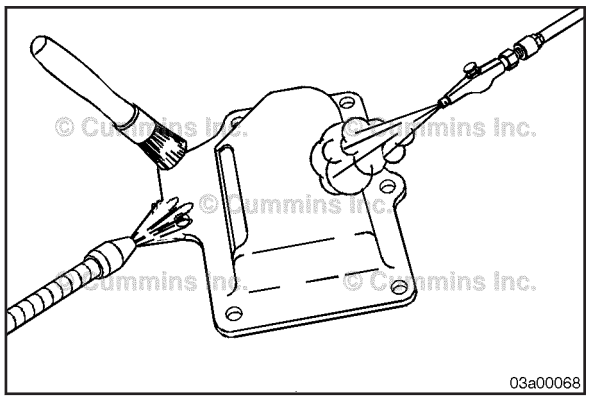
Remove the breather.





Clean and Inspect for Reuse

Remove any gasket material from the breather and the breather mounting surface on the block.



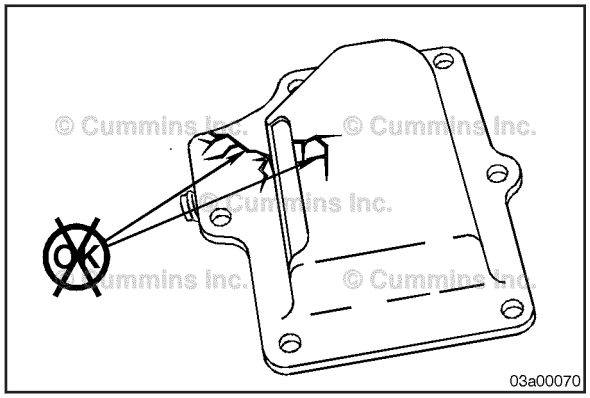
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use a solvent to clean the crankcase breather.

Dry with compressed air.



Inspect the breather for cracks or other damage.

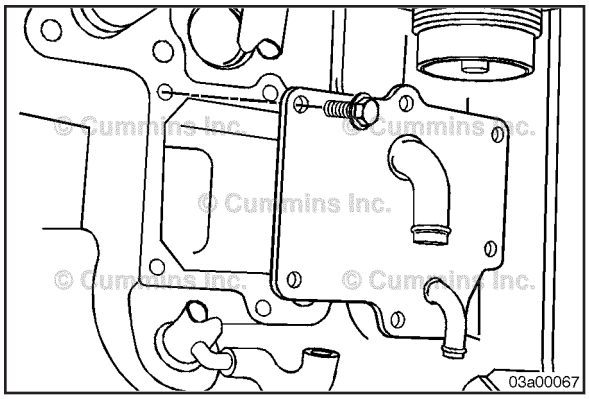
Install

Place a new breather gasket on the breather.

Install the breather into the block.

Tighten the capscrews in a crisscross pattern.

Torque Value: 10 N•m [89 in-lb]

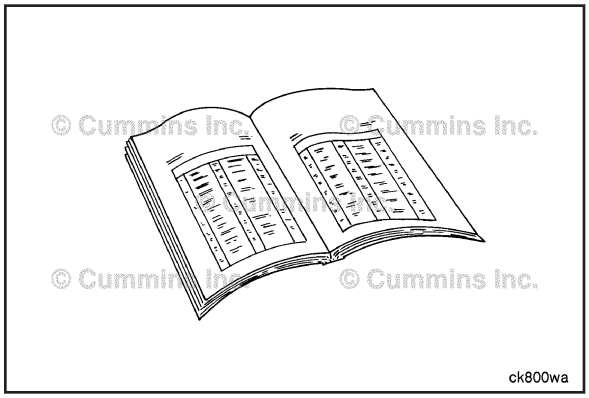


Overhead Set (003-004)

Preparatory Steps

Remove the following:

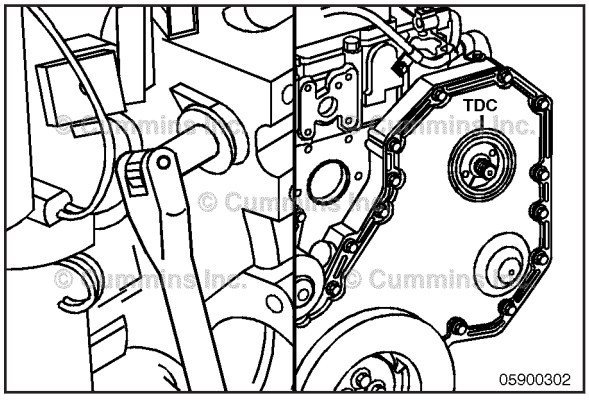
- Crankcase breather tube and drain tube, external crankcase breather **only**. Refer to Procedure 003-018 in Section 3.
- Plastic fuel pump drive cover located on the front of the engine.
- Rocker lever cover and gasket. Refer to Procedure 003-011 (Rocker Lever Cover) in Section 3.
- Engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.



Adjust

⚠CAUTION⚠
Engine coolant temperature should be less than 60°C [140°F].

Use barring tool, Part Number 3824591, or equivalent. Rotate the crankshaft to align the top dead center marks on the gear cover and the fuel pump gear.

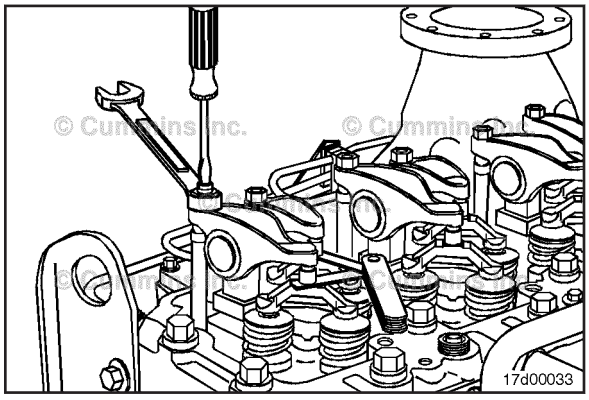


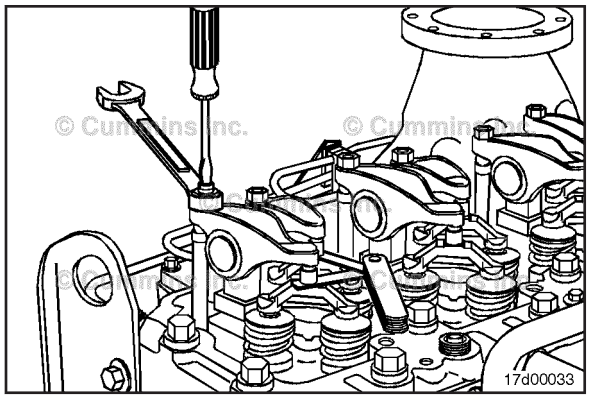
With the engine in this position, lash can be checked on the following rocker arms: 1I, 1E, 2I, 3E, 4I, and 5E.

Lash Check Limits

	mm		in
Intake	0.152	MIN	0.006
	0.559	MAX	0.022
Exhaust	0.381	MIN	0.015
	0.813	MAX	0.032

NOTE: Lash checks are performed as part of a troubleshooting procedure, and resetting is **not** required during checks as long as the lash measurements are within the above limits.





Measure lash by inserting a feeler gauge between the crosshead and the rocker lever ball insert and socket while lifting up on the end of the rocker arm. If the lash measurement is out of specification, loosen the locknut and adjust the lash to the nominal specification.

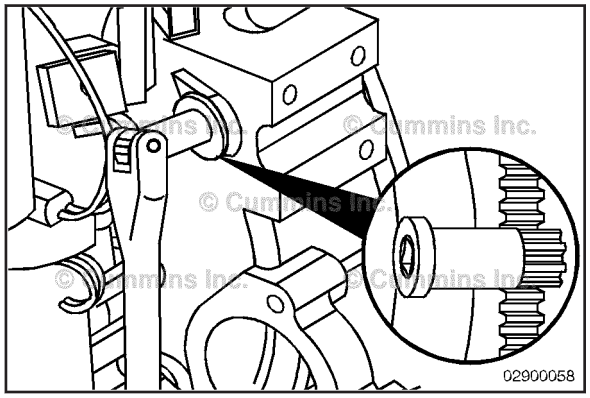
Lash Reset Specifications

	mm		in
Intake	0.305	NOM	0.012
Exhaust	0.559	NOM	0.022

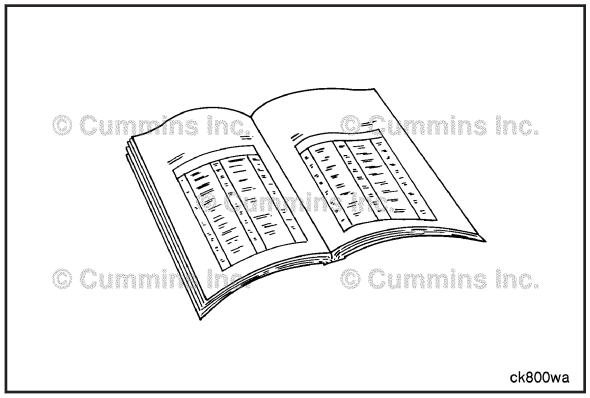
NOTE: Lash resets are **only** required at the interval specified in the appropriate owner's or operation and maintenance manual when lash is measured and found out of specification, or when engine repairs cause removal of the rocker arms and/or loosening of the adjusting screws.

Tighten the locknut and measure again.

Torque Value: 24 N•m [212 in-lb]



Use the barring tool, Part Number 3824591, or equivalent, and rotate the crankshaft 360 degrees and measure lash for rocker arms 2E, 3I, 4E, 5I, 6I, and 6E. Reset the lash, if out of specification.



Finishing Steps

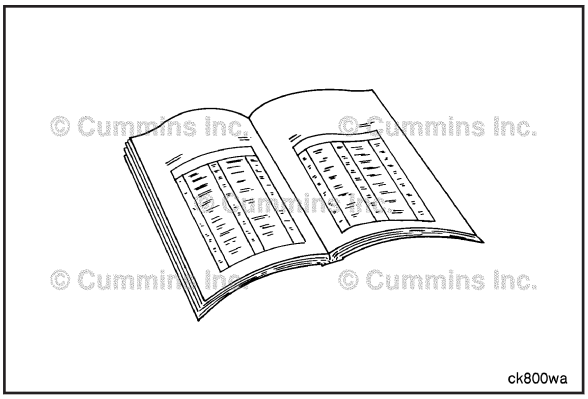
Install the following:

- Engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Gasket and rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Crankcase breather tube and drain tube, external crankcase breather **only**. Refer to Procedure 003-018 in Section 3.
- Plastic fuel pump drive cover located on the front of the engine.

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.

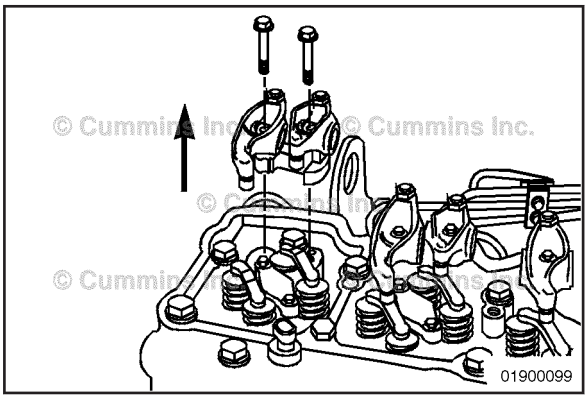
- See equipment manufacturer service information.
- Remove the crankcase breather tube. Refer to Procedure 003-018 in Section 3.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.

Remove

Remove the capscrews from the rocker lever pedestals.

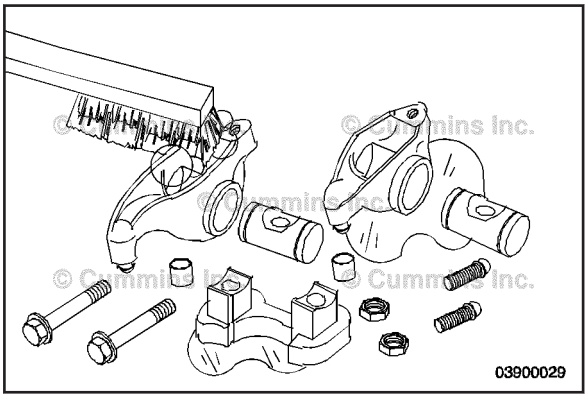
Remove and mark the pedestals and rocker lever assemblies one at a time as to their location and position.

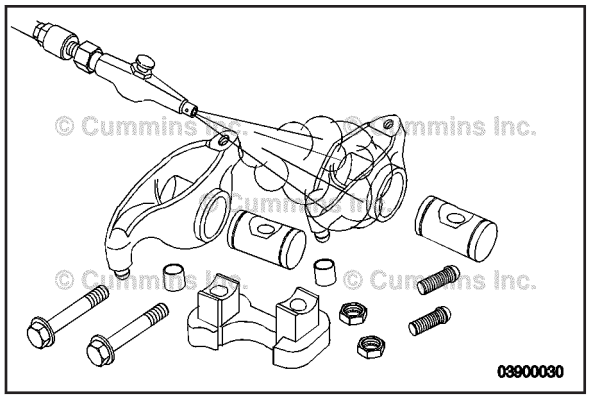
Remove and mark the crossheads one at a time as to their location and position. The crossheads and rocker assemblies **must** be installed in their original location and position.



Clean and Inspect for Reuse

Clean all parts in a strong solution of laundry detergent in hot water.





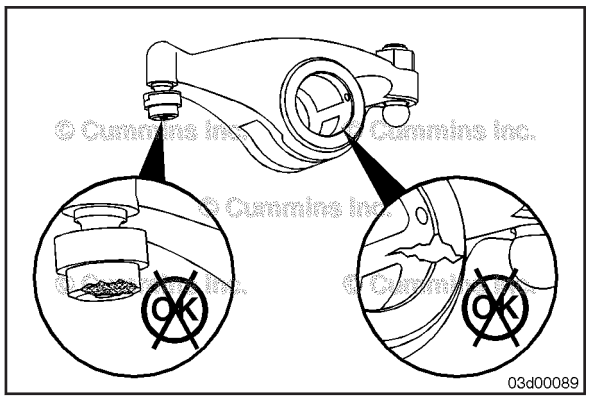
⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use compressed air to dry the parts after rinsing in clean hot water.

The pedestals are made from powdered metal and will continue to show wetness after they have been cleaned and dried.

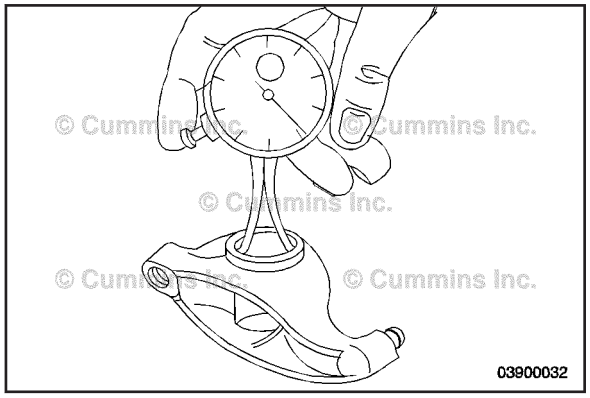
Be sure oil drillings in the rocker arms and shafts are unobstructed.



Inspect for cracks and excessive wear in the bore.

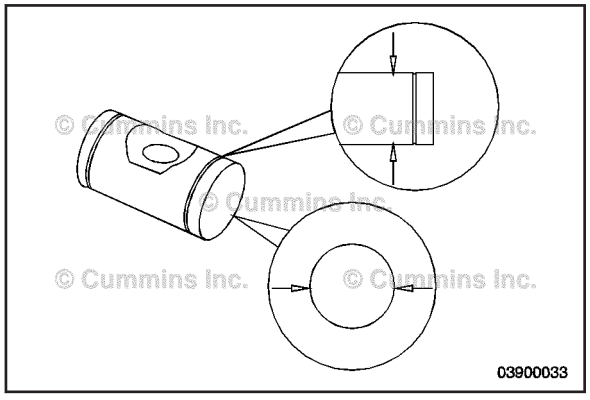
The socket should move freely on the rocker lever and the plastic socket retainer should be in place and **not** cracked.

Inspect for wear on the nose of the socket.



Measure the rocker lever bore.

Rocker Lever Bore		
mm		**in**
24.987	MIN	0.984
25.013	MAX	0.985



Inspect the rocker lever pedestal and rocker lever shaft for cracks.

Measure the rocker lever shaft diameter.

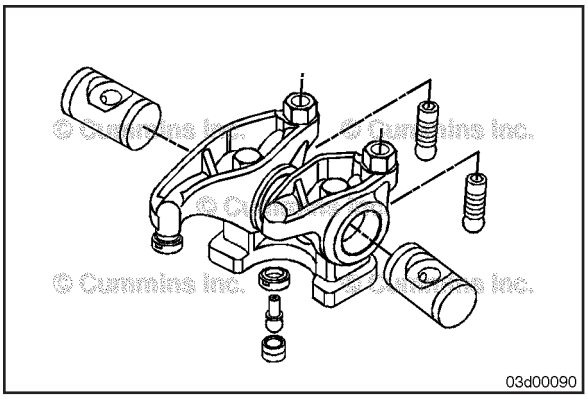
Rocker Lever Shaft		
mm		**in**
24.950	MIN	0.982
24.962	MAX	0.983

Install

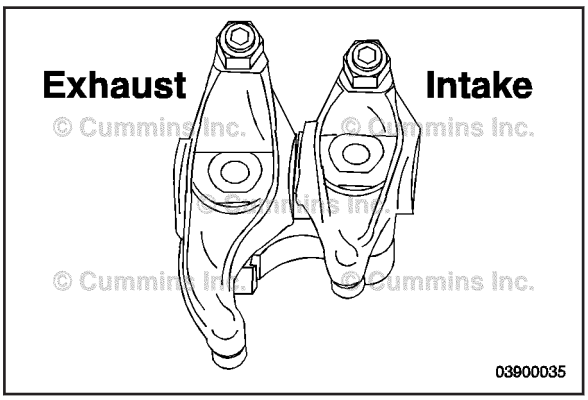
Without Engine Brakes

Different combinations of the adjusting screw, rocker lever shaft, rocker lever, and push rod can exist. Make sure when replacing rocker levers or adjusting screws that the correct part is being used.

Refer to Procedure 004-014 in Section 4.



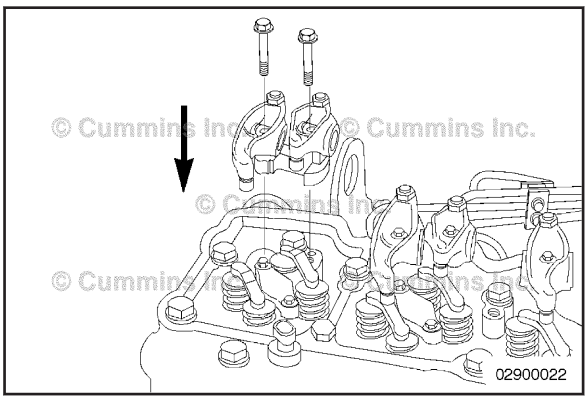
Position the rocker levers on the rocker pedestal.



Install the intake crossheads in their original location and position.

Install the exhaust crossheads in their original location and position.

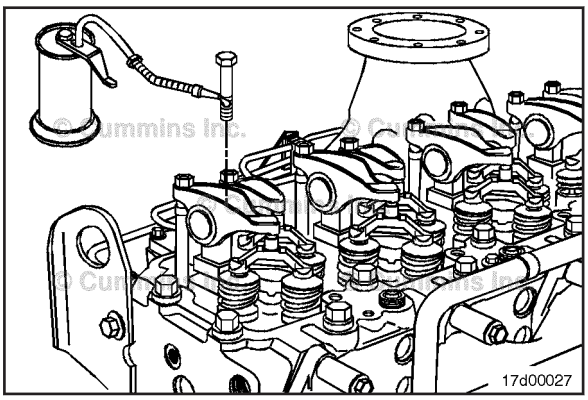
Install the rocker lever assemblies and pedestals in their original locations.

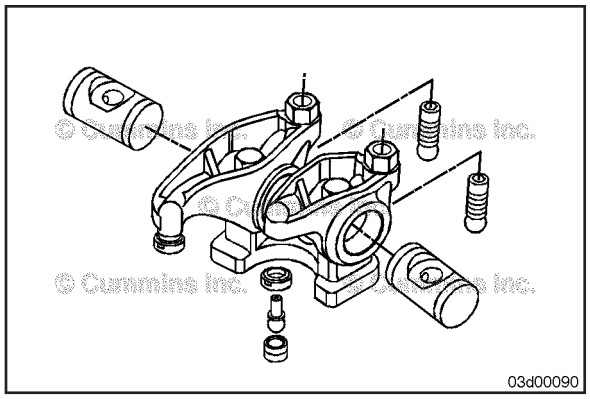


Lubricate the capscrew threads with clean engine oil.

Install and tighten the pedestal capscrews.

Torque Value: 65 N•m [48 ft-lb]

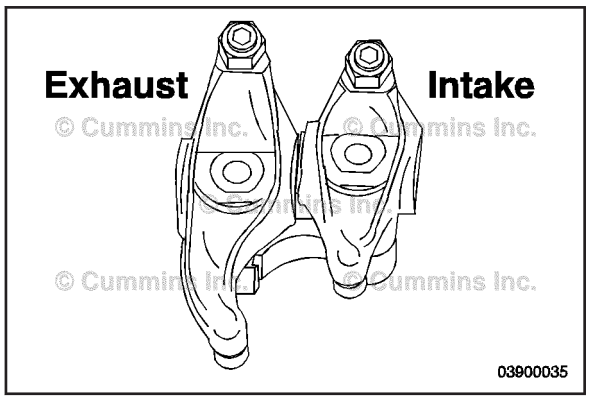




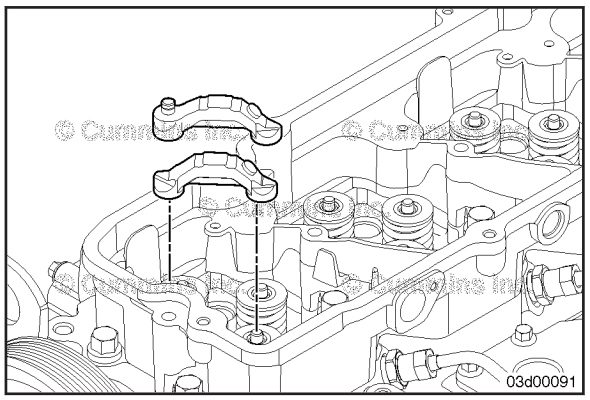
With Engine Brakes

Different combinations of the adjusting screw, rocker lever shaft, rocker lever, and push rod can exist. Make sure when replacing rocker levers or adjusting screws that the correct part is being used.

Refer to Procedure 004-014 in Section 4.

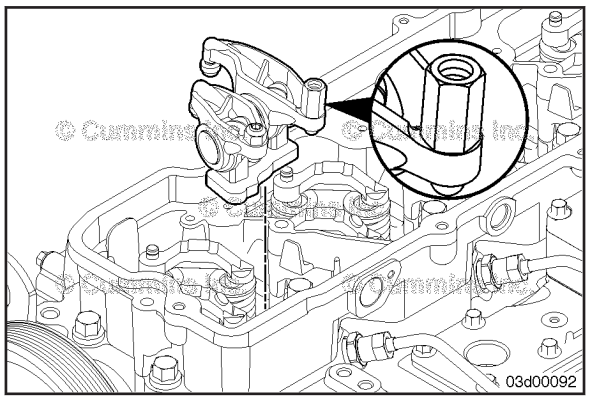


Position the rocker levers on the rocker pedestal.



Install the crossheads in their original location and position.

Install the engine brake compatible exhaust crossheads with the pin facing the exhaust manifold.



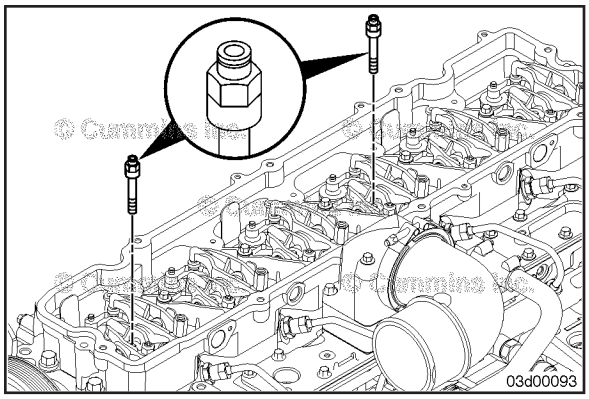
Install the rocker lever assemblies and pedestals in their original location.

Make sure the exhaust rocker levers have the longer adjusting screw locknut installed.

Lubricate the capscrew threads with clean engine oil.

Install the engine brake oil supply capscrews on intake rocker levers 1 and 4.

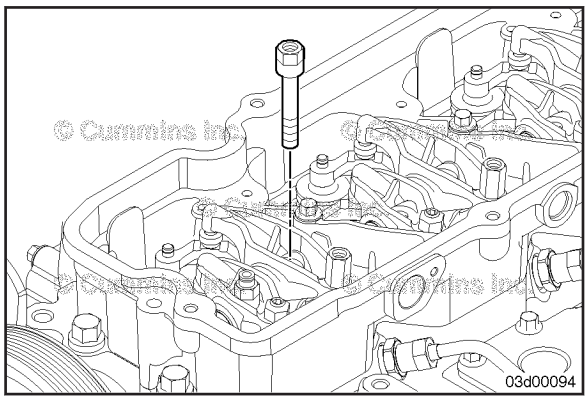
Torque Value: 65 N•m [48 ft-lb]



Lubricate the capscrew threads with clean engine oil.

Install the exhaust rocker lever capscrews into all exhaust levers.

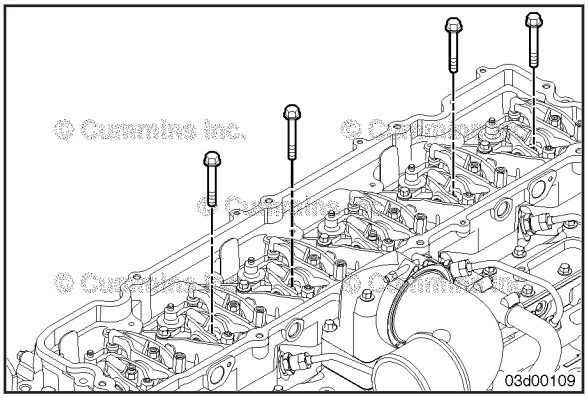
Torque Value: 65 N•m [48 ft-lb]



Lubricate the capscrew threads with clean engine oil.

Install the pedestal capscrews in cylinders 2, 3, 5, and 6 intake rocker pedestals.

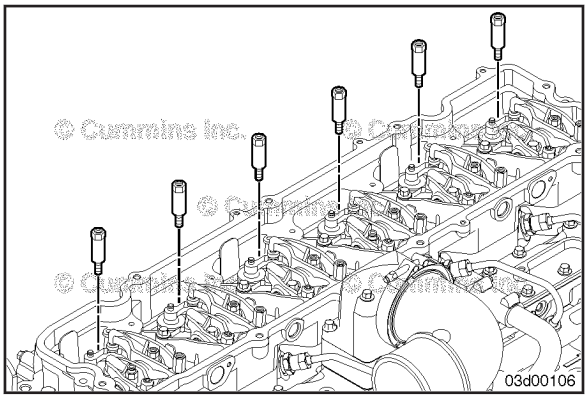
Torque Value: 65 N•m [48 ft-lb]

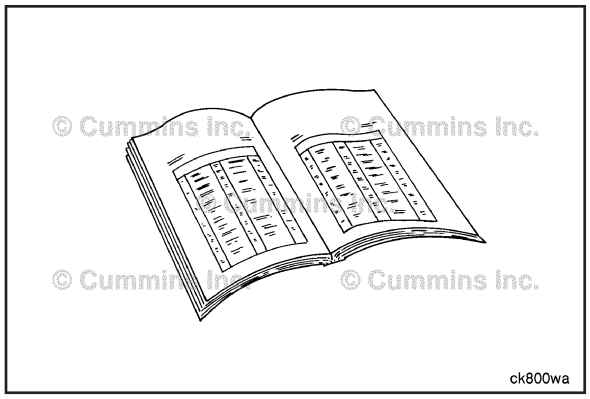


Lubricate the capscrew threads with clean engine oil.

Install the six threaded spacers into the cylinder head.

Torque Value: 24 N•m [212 in-lb]



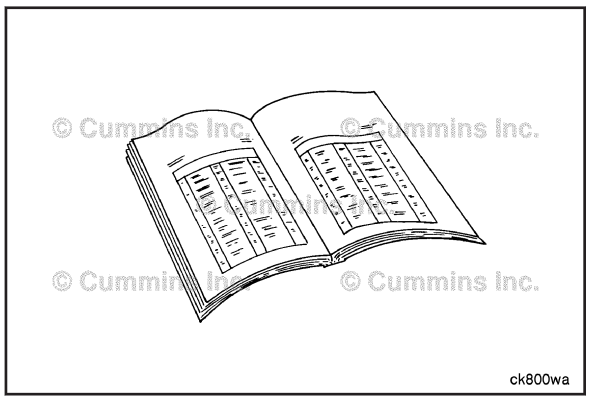


Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Adjust the overhead. Refer to Procedure 003-004 in Section 3.
- Install the engine brake assemblies, if equipped. Refer to Procedure 020-004 in Section 20.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the crankcase breather tube. Refer to Procedure 003-018 in Section 3.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.



Rocker Lever Cover (003-011)

Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

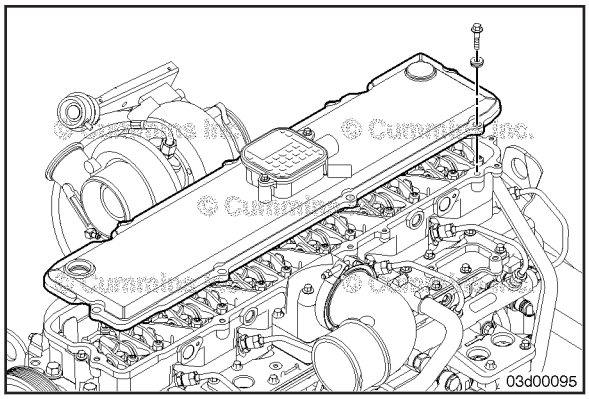
- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Disconnect the crankcase pressure sensor. Refer to Procedure 019-445 in Section 19.
- Remove the crankcase breather tube and drain tube. Refer to Procedure 003-018 in Section 3.
- Remove the turbocharger actuator air supply line. Refer to Procedure 010-118 in Section 10.
- Remove the variable geometry turbocharger (VGT) actuator air supply line. Refer to Procedure 010-118 in Section 10.

Remove

Remove the capscrews.

Remove the rocker lever cover and gasket.

NOTE: Rocker lever cover configurations will be different based upon if the cover is center bolted or perimeter bolted. The rocker lever cover can also be taller if the engine is equipped with engine brakes.

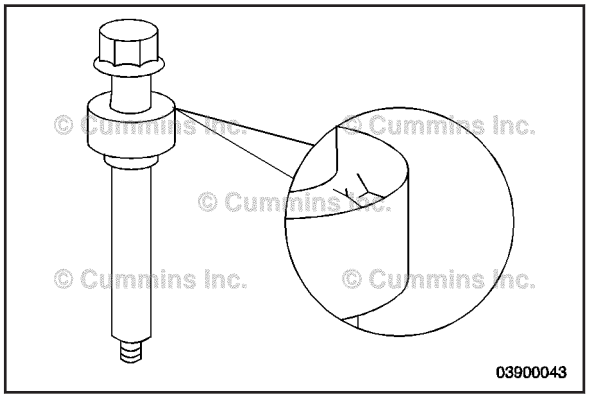


Clean and Inspect for Reuse

Center Bolted Rocker Lever Cover

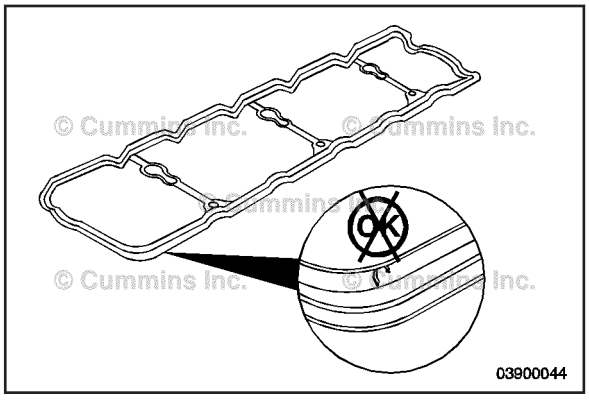
Check the isolators for cracks, tears, or brittleness.

Replace the capscrew assembly if isolators are damaged.



Check the gasket for cracks in the silicone covering.

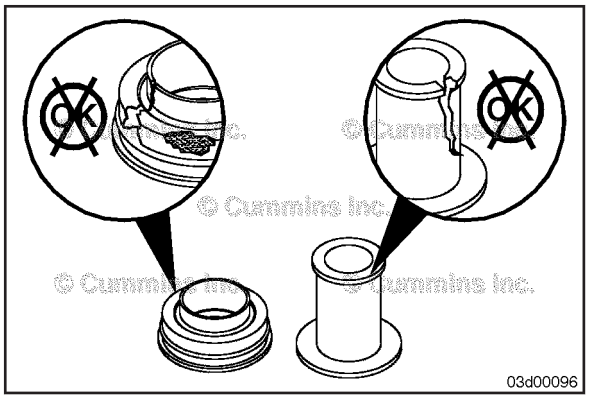
Replace the gasket if cracks are present.

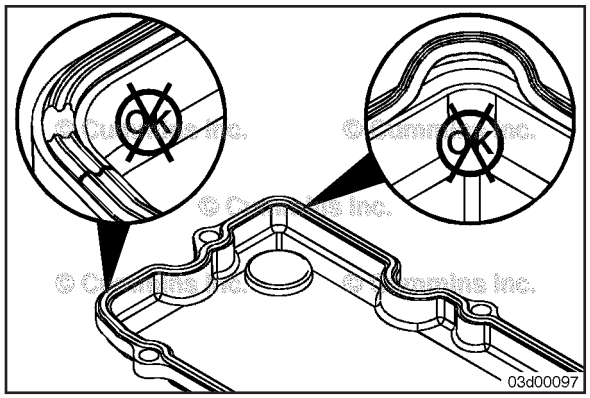


Perimeter Bolted Rocker Lever Cover

Check the isolators for cracks, tears, or brittleness.

Replace the isolators if any damage is found.

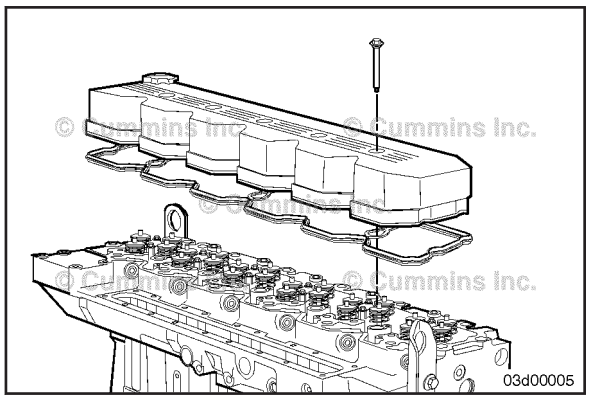




Check the gasket for cracks on the sealing surface.

Replace the gasket if damage is present.

Replace the gasket if it is removed from the groove in the rocker lever cover.

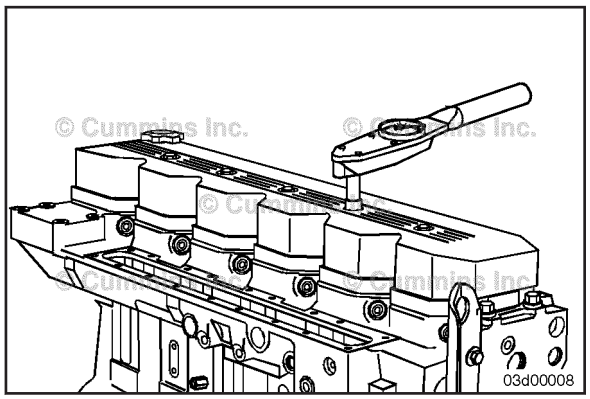


Install

Center Bolted Rocker Lever Cover

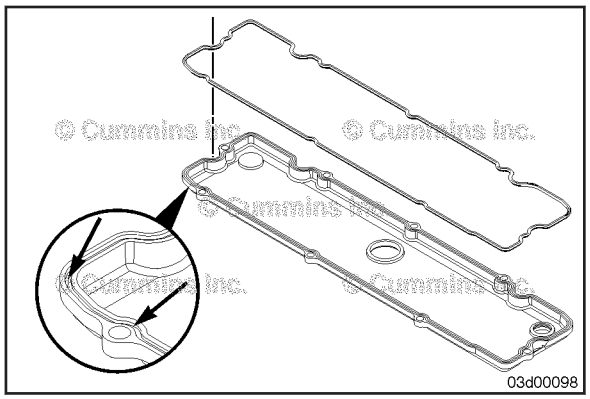
Place the gasket on the cylinder head. Be sure the gasket is properly aligned around the cylinder head capscrews.

Install the rocker lever cover and capscrews.



Tighten the capscrews.

Torque Value: 12 N•m [106 in-lb]



Perimeter Bolted Rocker Lever Cover

NOTE: If the gasket has been removed from the rocker lever cover, a new gasket **must** be installed.

The following installation procedure **must** be used when installing the press in gasket.

1 Press the molded gasket into the corners of the rocker lever cover.

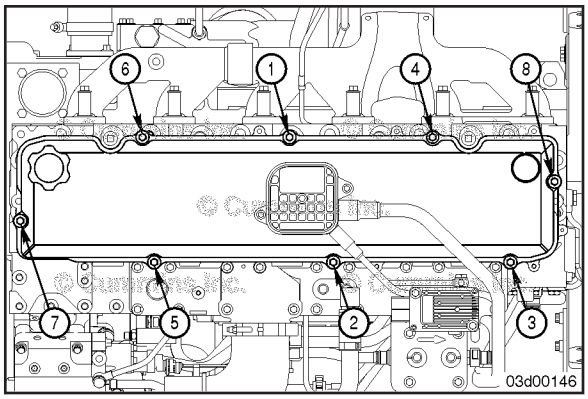
2 Press the gasket around the capscrew mounting holes.

3 Press the remaining gasket into the rocker lever cover.

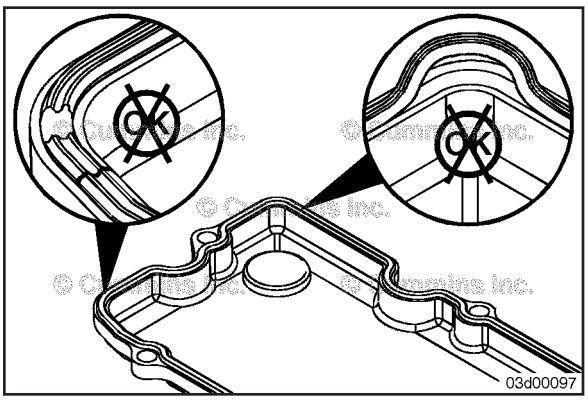
Install the rocker lever cover and capscrews.

Torque Value: 12 N•m [106 in-lb]

Tighten the capscrews in the sequence shown.



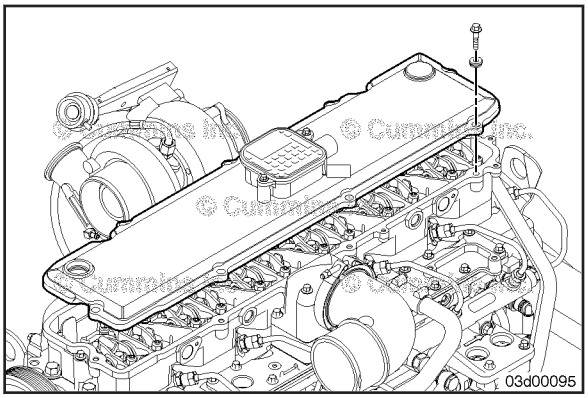
Install the valve cover gasket into the groove of the rocker housing cover. Press the molded gasket into the corners of the valve cover, then press the remaining gasket into the remainder of the groove.

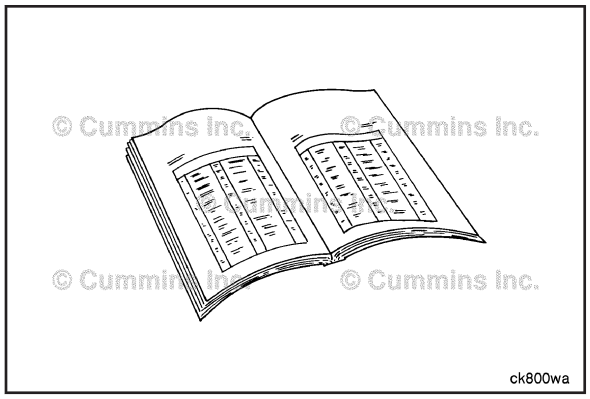


Install the valve cover onto the rocker housing.

Install and tighten the valve cover mounting capscrews. Start with the center capscrews and work outward in a spiral pattern.

Torque Value: 12 N•m [106 in-lb]

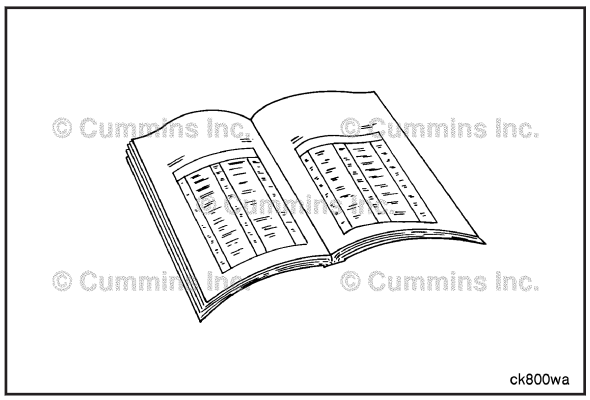




Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the crankcase breather tube and drain tube. Refer to Procedure 003-018 in Section 3.
- Connect the crankcase pressure sensor. Refer to Procedure 019-445 in Section 19.
- Install the turbocharger actuator air supply line. Refer to Procedure 010-118 in Section 10.
- Install the VGT actuator air supply line, if equipped. Refer to Procedure 010-118 in Section 10.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.



Rocker Lever Housing (003-013)

Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

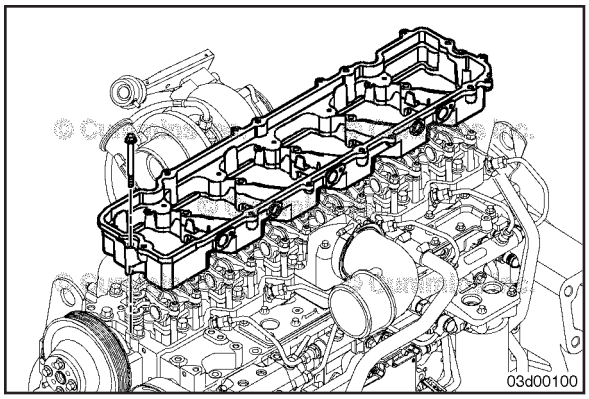
NOTE: This procedure is for engines with a perimeter bolted rocker lever cover. Refer to Procedure 020-007 in Section 20.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the crankcase breather tube and drain tube. Refer to Procedure 003-018 in Section 3.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Disconnect the injector harness pass-through connectors.
- Remove the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Disconnect the injector wiring harness from the injector. Refer to Procedure 006-026 in Section 6.

Remove

Remove the rocker lever housing mounting capscrews.

Remove the rocker lever housing and gasket from the cylinder head.



Clean and Inspect for Reuse

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

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

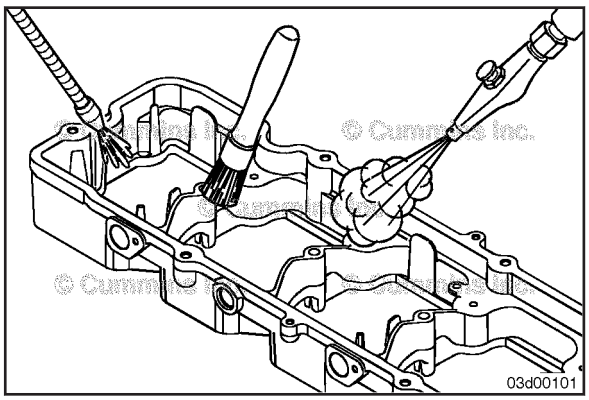
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Remove the rocker lever housing gasket.

Make sure the work surface is clean and free from any oil, dirt, or debris.

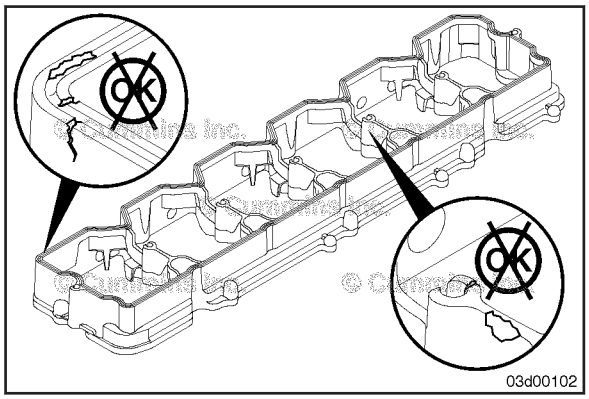
Clean the rocker lever housing with solvent.

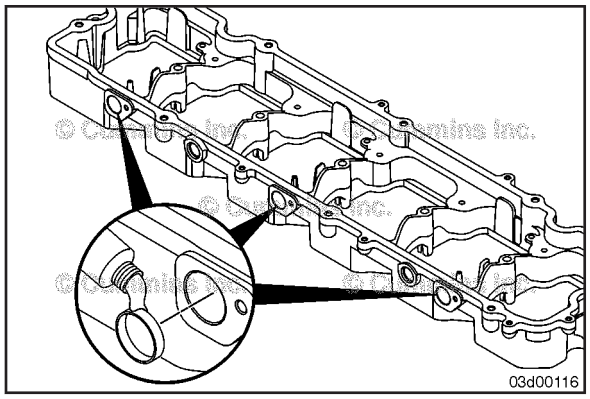
Dry with compressed air.



Inspect the rocker lever housing for cracks or any other damage, especially on the cylinder head mounting surface.

Inspect the bridge area in the center of the rocker lever housing for cracks.



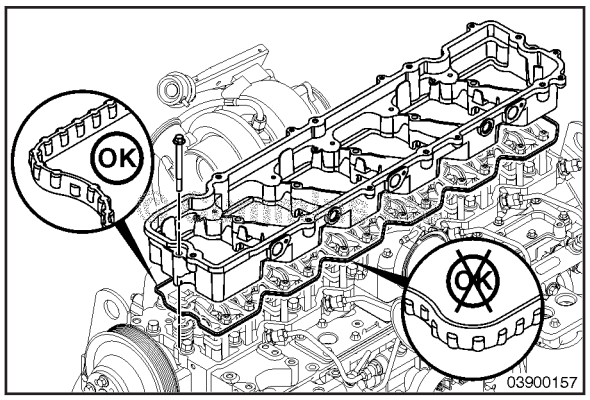


Install

Install the 22 mm cup plugs into the rocker lever housing.

Coat the contact surface of cup plug with Permatex® sealant, or equivalent.

Install the cup plugs flush with the outer surface of the rocker lever housing.



NOTE: A new rocker lever housing gasket **must** be used when the rocker lever housing is removed. Do **not** reuse the old gasket.

NOTE: Unpack the gasket and lay it out in front of the grooved section of the rocker lever housing. Align the gasket in which it will be installed and confirm that the gasket is not twisted.

NOTE: Make sure that the orientation of the gasket matches the corresponding features in the rocker lever housing and that the beaded side of the gasket is installed into the housing.

Install the new rocker lever housing gasket. Start by pressing the beaded side of the gasket into the corresponding features of the rocker lever housing, then press the remaining gasket into the housing.

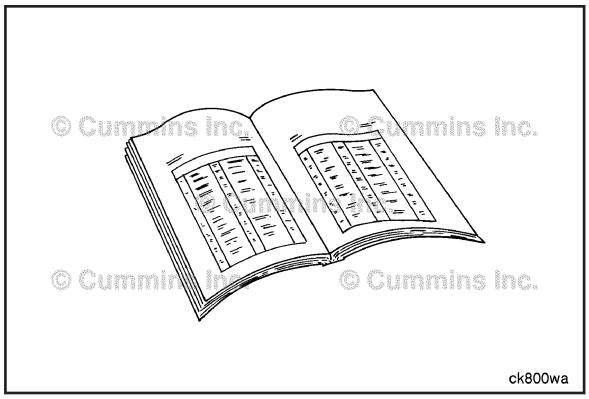
Install the rocker lever housing on the cylinder head.

Install the capscrews and tighten. Start with the center capscrew and work outward in a spiral pattern.

Torque Value: 24 N•m [212 in-lb]

NOTE: Capscrews are not installed in the outer end holes of the rocker lever housing.

Finishing Steps

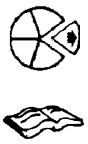


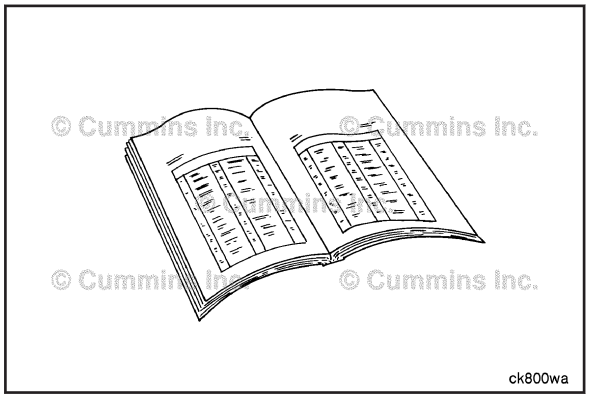
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the injector wiring harness to the injectors. Refer to Procedure 006-026 in Section 6.
- Connect the injector harness pass through connectors.
- Install the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the crankcase breather tube and drain tube. Refer to Procedure 003-018 in Section 3.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

Crankcase Breather Tube (003-018)

Preparatory Steps

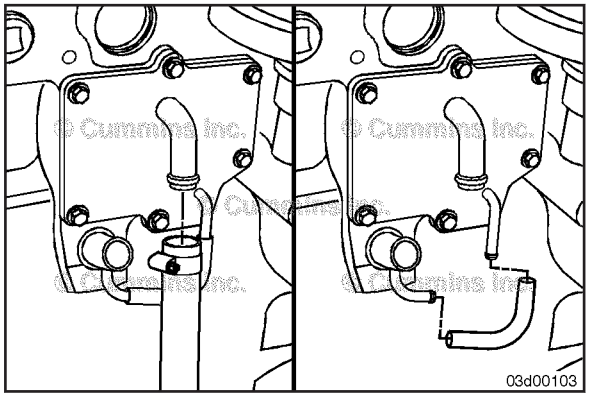




⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.

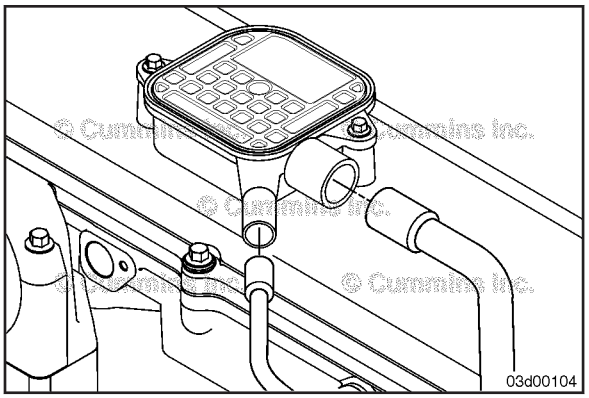
Remove



Block Mounted Crankcase Breather

Remove the crankcase breather tube from the crankcase breather assembly.

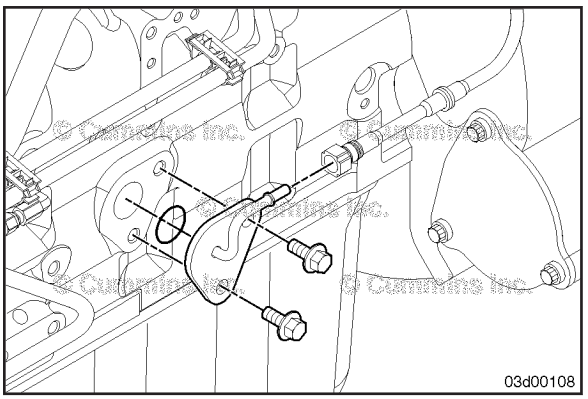
Remove the crankcase drain tube from the crankcase breather assembly.



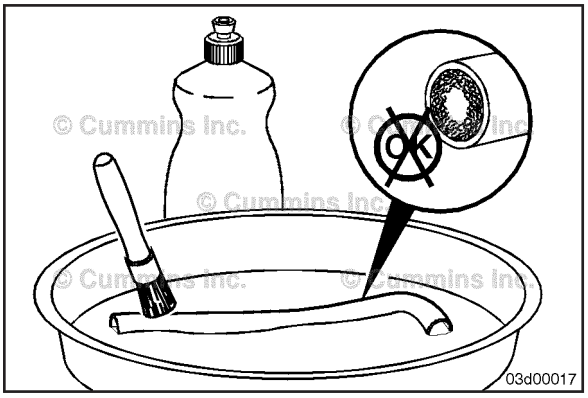
Rocker Lever Cover Mounted Crankcase Breather

Remove the crankcase breather tube from the crankcase breather assembly.

Remove the crankcase drain line from the crankcase breather assembly.



Remove the breather drain line, breather drain line cover, and gasket from the cylinder block.



Clean and Inspect for Reuse

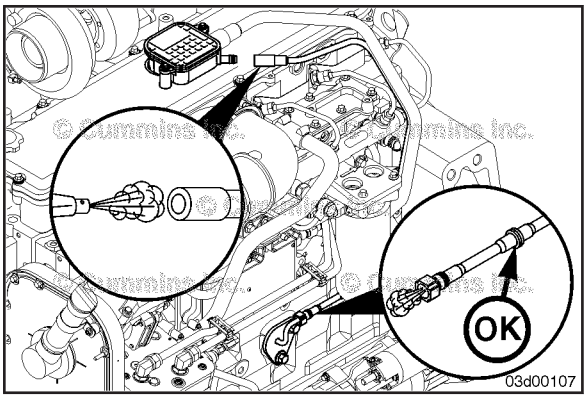
⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Check the tube and lines internally for obstructions or sludge buildup.

Clean the tube and lines with hot, soapy water and a soft brush.

Use compressed air to dry the tube and lines after rinsing in clean water.



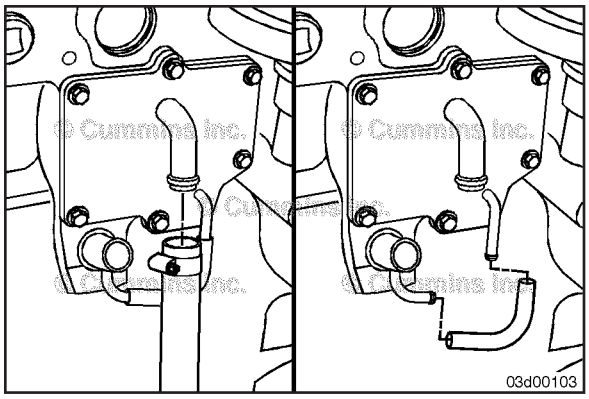
Inspect the breather drain line check valve for correct operation. A small amount of air can be blown through the line (less than 34 kPa [5 psi]) to check the check valve operation.

Install

Block Mounted Crankcase Breather

Install the crankcase breather tube to the crankcase breather assembly.

Install the crankcase drain line to the crankcase breather assembly.

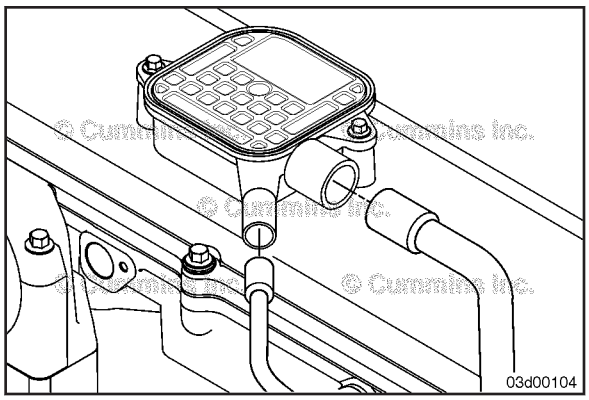


Rocker Lever Cover Mounted Crankcase Breather

NOTE: Make sure the crankcase breather tube or drain line does **not** contact any high pressure fuel lines.

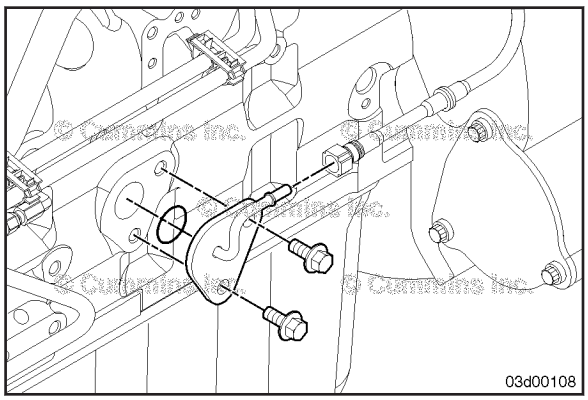
Install the crankcase breather tube to the crankcase breather assembly.

Install the crankcase drain line to the crankcase breather assembly.



Install the breather drain line cover, gasket, and tube to the cylinder block.

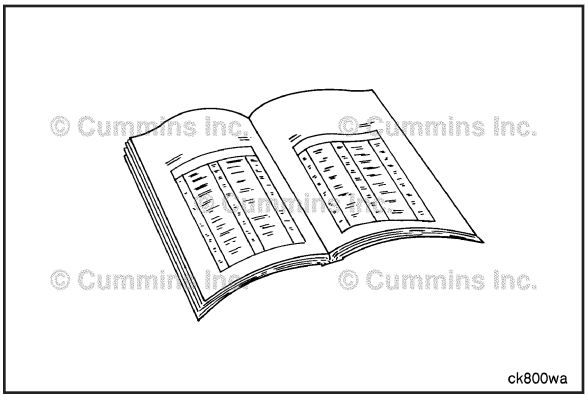
Torque Value: 45 N•m [33 ft-lb]



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

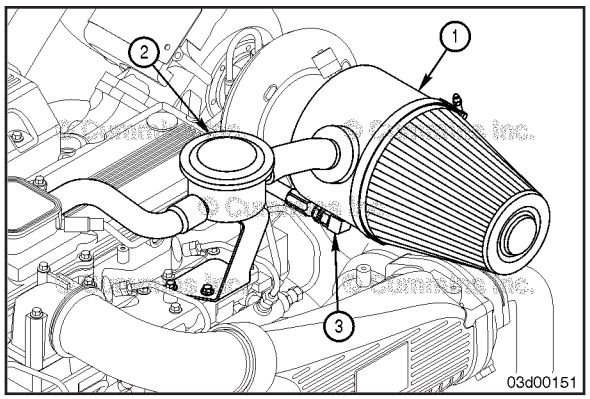
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.



Closed-Crankcase Ventilation System Filter (003-020)

General Information

This procedure applies to Marine Applications **only**.



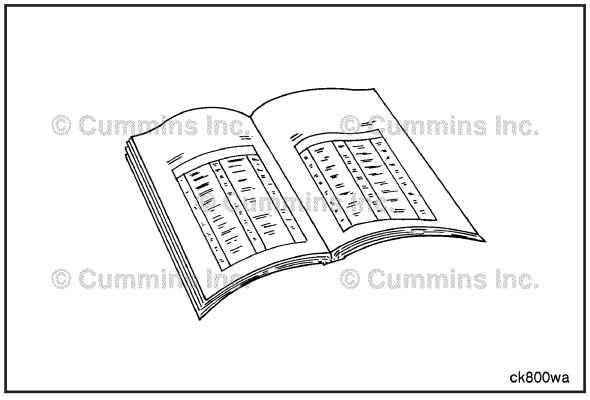
Initial Check

The closed-crankcase system has three major parts.

1. The air cleaner assembly (filters the incoming air) and a oil blow-by filter element called a coalescing filter.
2. Vacuum brake assembly; this keeps the engine from drawing oil directly into the turbocharger if the air cleaner is plugged.
3. Closed-crankcase drain plumbing; this includes the drain hoses and check valve. The check valve prevents crankcase pressure from flowing backwards in the air cleaner.

This procedure covers the closed-crankcase ventilation system filter **only**. Refer to Procedure 010-013 for instructions on removing, cleaning and inspecting, and installing other components of the complete assembly.

Check the restriction gauge on the air filter assembly. If the gauge is red, the air filter element **must** be cleaned or replaced. Refer to Procedure 010-013.

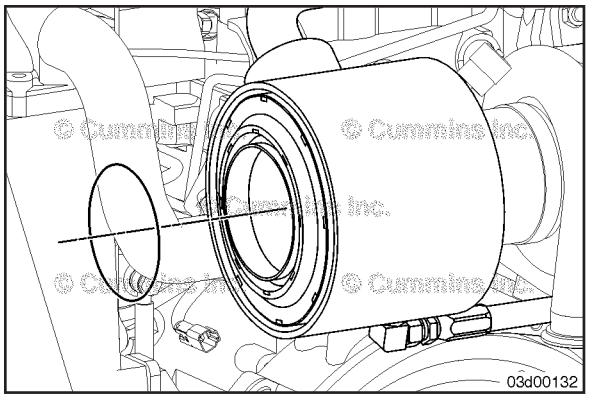


Preparatory Steps

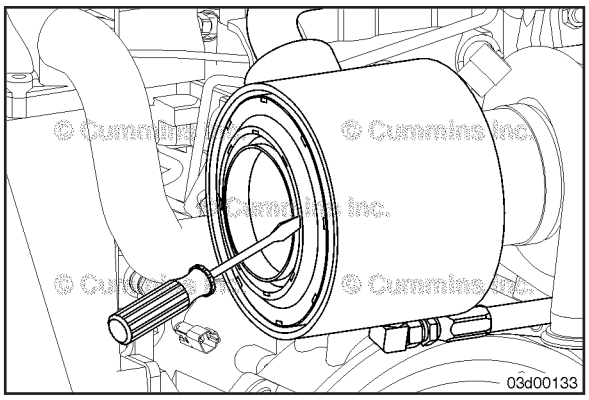
Remove the air filter. Refer to Procedure 010-013.

Remove

Remove the o-ring from the closed-crankcase breather element assembly.

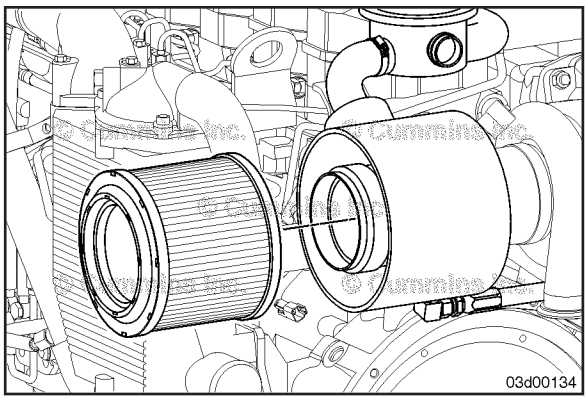


Use a screwdriver in the notches around the element to break the seal and remove the element.



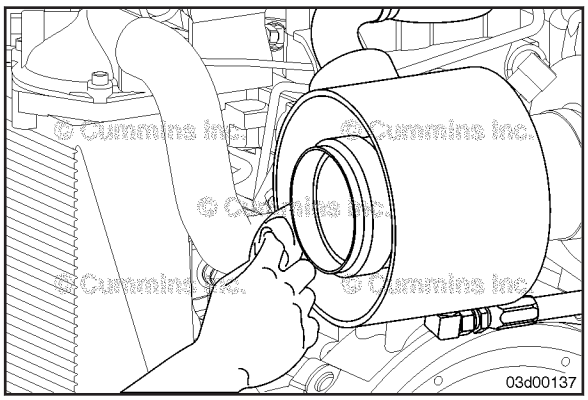
Remove the element from the canister.

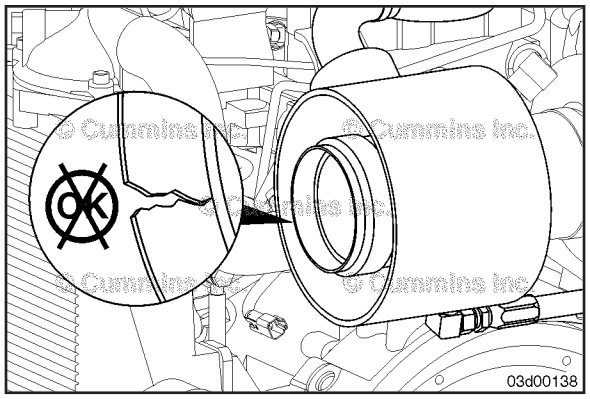
NOTE: The filter will normally be oil soaked. Look for buildup of moisture condensation, sludge, or blockage of the element. Replace the element if it is dirty and oil soaked.



Clean and Inspect for Reuse

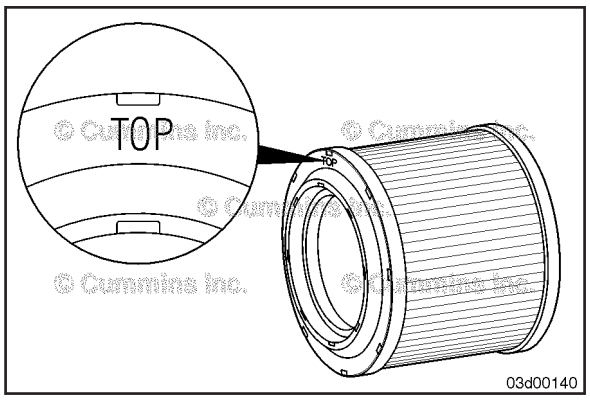
Use a clean rag to wipe the inside of the canister clean.





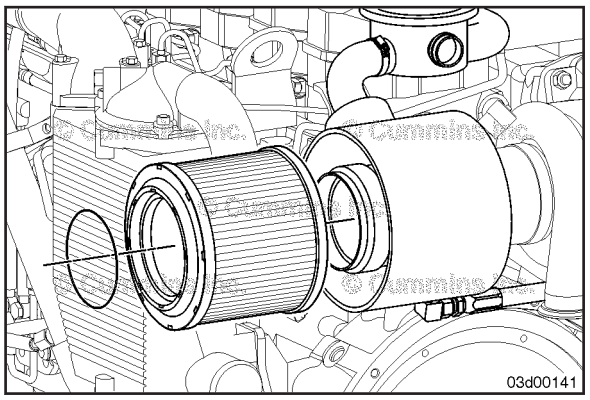
Inspect the canister for damage.

Inspect the o-rings for cuts or other damage.



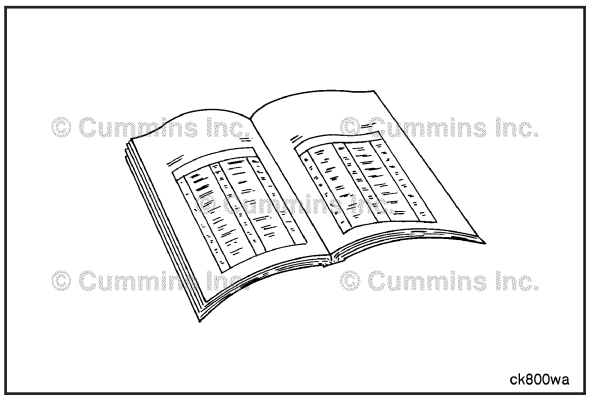
Install

The top of the filter is marked with “TOP” on the outer rim.



Install the clean filter into the canister.

Install the o-ring.



Finishing Steps

Install the air filter. Refer to Procedure 010-013.

Operate the engine and check for leaks.

Section 4 - Cam Followers/Tappets - Group 04

Section Contents

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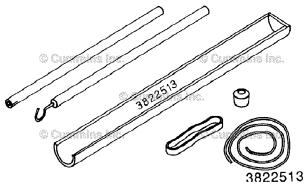
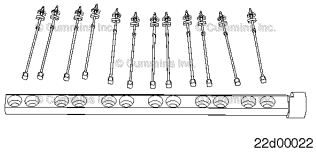
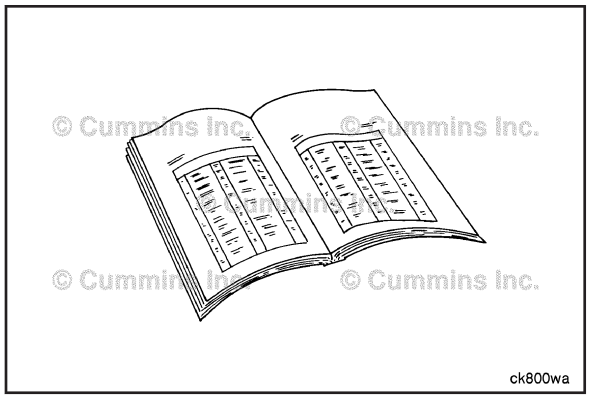
Service Tools

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 Removal Tool Kit** Used to remove and install sliding valve tappets.	
3165088	**Tappet Removal Tool Kit** Used to remove and install roller tappets.	
3165086	**Tappet Removal Tool** Tappet trough for engines using the larger bore tappets. Used to update Tappet Removal Tool Kit, Part Number 3163468.	



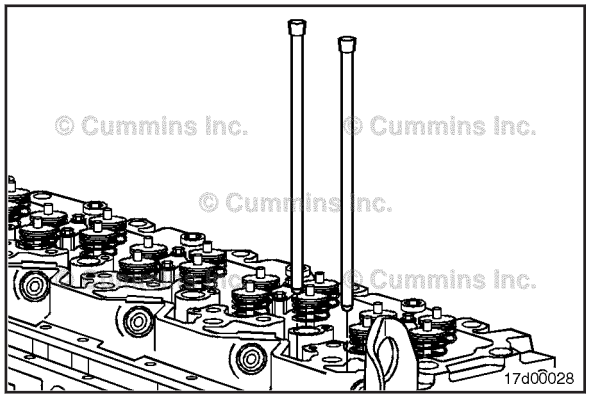
Push Rods or Tubes (004-014)

Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Remove the following:

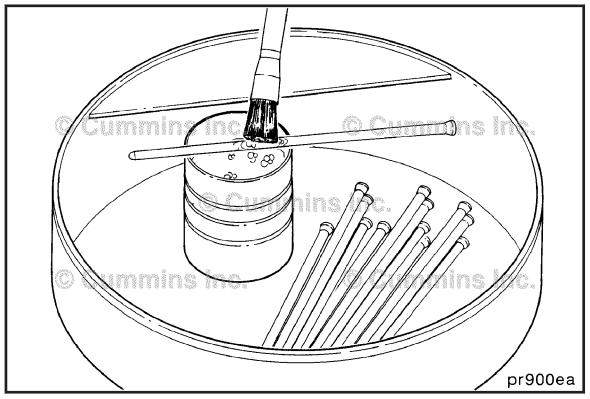
- Disconnect the batteries. See equipment manufacturer service information.
- Crankcase breather tube, external crankcase breather **only**. Refer to Procedure 003-018 in Section 3.
- Rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Rocker levers. Refer to Procedure 003-008 in Section 3.



Remove

Mark the push tubes to identify their location.

Remove the push tubes.



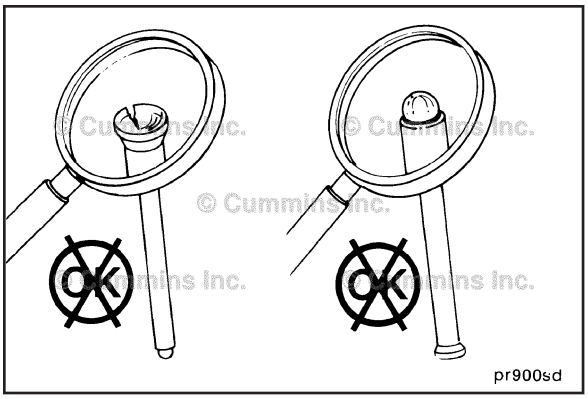
Clean and Inspect for Reuse

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

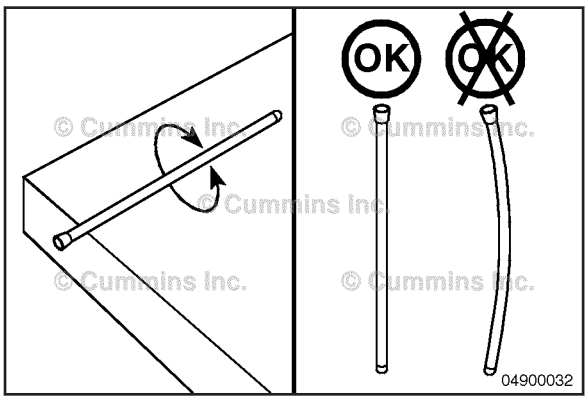
Clean the push tubes in hot soapy water.

Dry with compressed air.

Inspect the push tube ball and socket for signs of scoring. Check for cracks where the ball and the socket are welded into the tube.

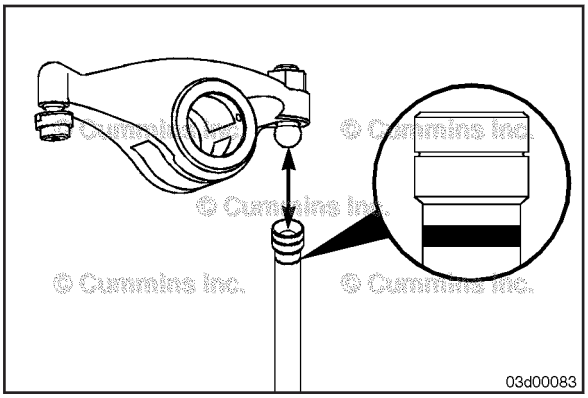


Check the push tubes for straightness.

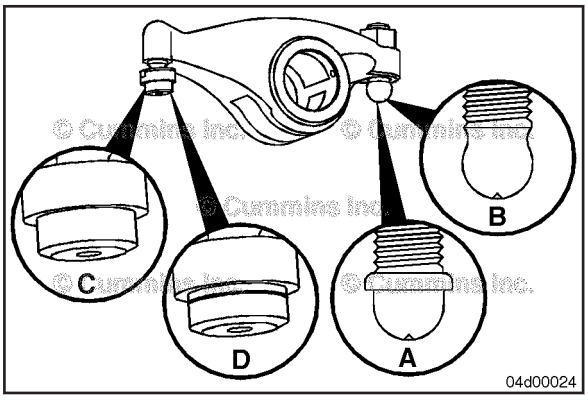


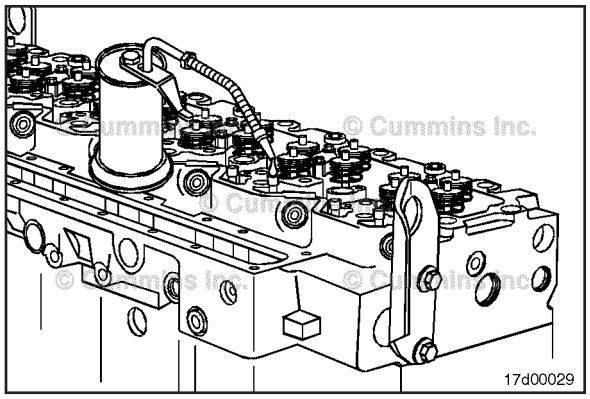
Install

⚠CAUTION⚠
Mismatching push tubes, rocker levers and rocker lever adjusting screws can lead to engine damage. These components are matched depending on the engine configuration. If components are being replaced, make sure the correct part numbers are being installed.



Different adjusting screws are used depending on the engine configuration. Older designs used a collar feature (A) between the adjusting screw threads and the ball. Newer designs (B) have eliminated the collar feature. These components are matched depending on the engine configuration. If components are being replaced, make sure the correct part numbers are being installed.

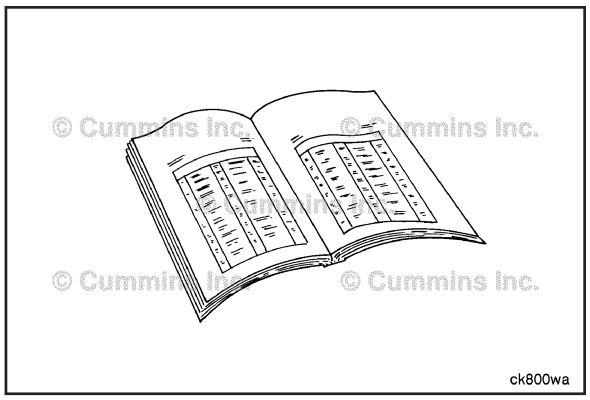




Install the push tubes in their original location.

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

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



Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

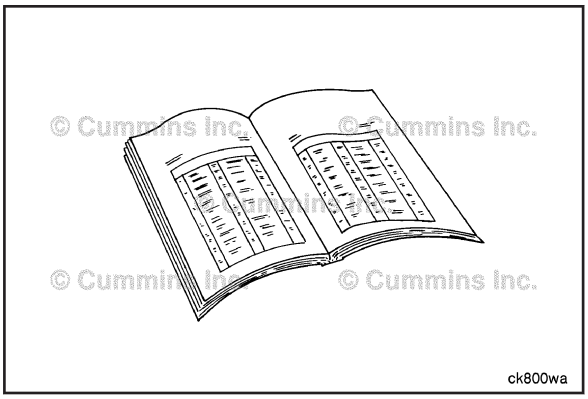
Install the following:

- Crossheads and rocker levers. Refer to Procedure 003-008 in Section 3.
- Adjust the valve lash. Refer to Procedure 003-004 in Section 3.
- Engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Rocker lever cover and associated gasket. Refer to Procedure 003-011 in Section 3.
- Crankcase breather tube and drain tube, external crankcase breather **only**. Refer to Procedure 003-018 in Section 3.
- Connect the battery. See equipment manufacturer service information.

Operate the engine and check for leaks.

Tappet (004-015)

Preparatory Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

NOTE: On Marine applications, prior to starting this procedure, make sure that there is adequate clearance in front of the engine. This procedure requires the camshaft to be removed. Make sure there is adequate clearance from the front gear housing face to any obstruction in the camshaft area to remove the camshaft. If there is **not** enough clearance, the engine **must** be removed from the vessel.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the crankcase breather tube and drain tube, external crankcase breather **only**. Refer to Procedure 003-018 in Section 3.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Remove the rocker levers. Refer to Procedure 003-008 in Section 3.
- Remove the push rods or tubes. Refer to Procedure 004-014 in Section 4.
- Remove the belt guard, if equipped. Refer to Procedure 008-001 in Section 8.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the vibration damper.Refer to Procedure 001-052 in Section 1.
- Remove the gear cover.Refer to Procedure 001-031 in Section 1.

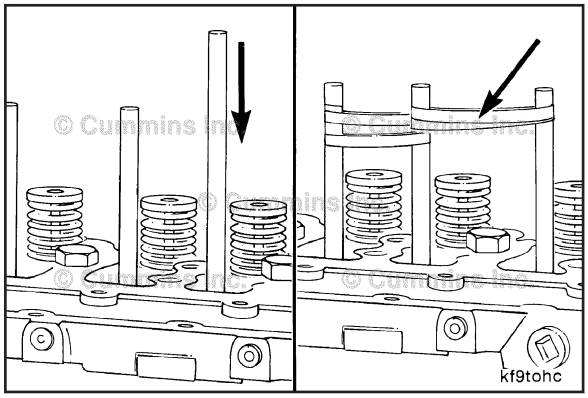
Remove

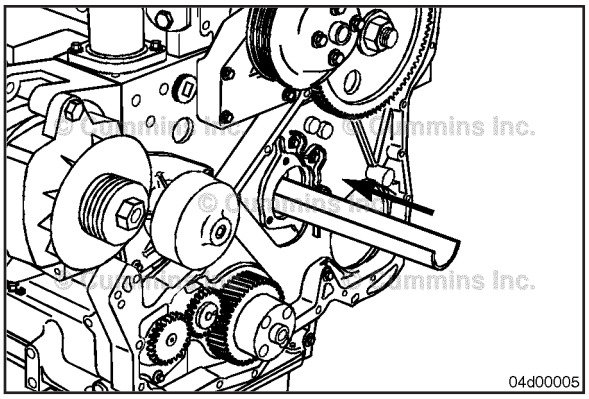
Sliding Tappets

Use tappet removal tool kit, 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.

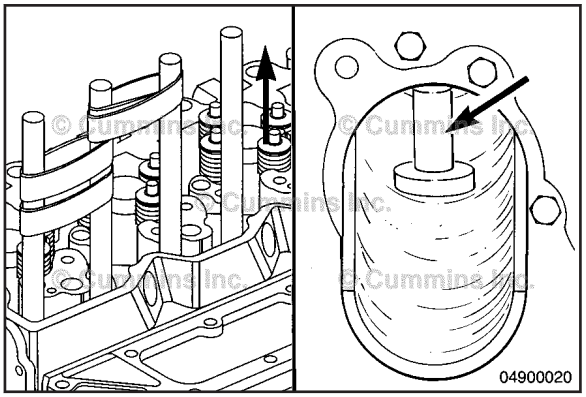
Pull each valve tappet up until it makes contact with the cylinder block. Put a rubber band around two dowels. This will hold the tappets up off the camshaft.



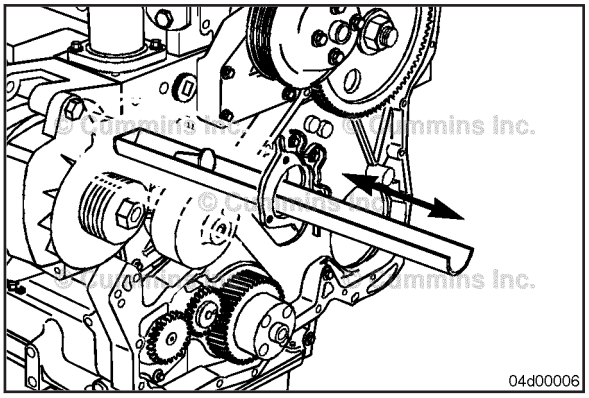


Remove the camshaft. Refer to Procedure 001-008 in Section 1.

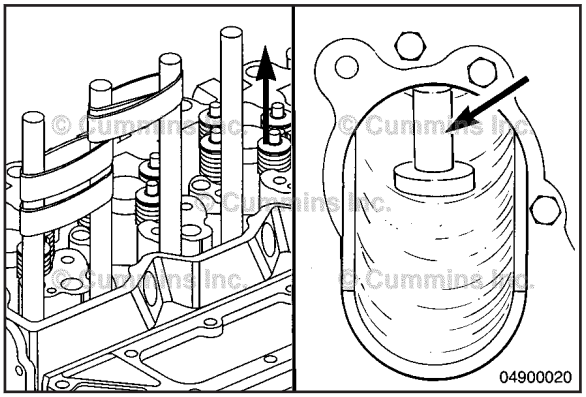
Insert the trough to the full length of the camshaft bore.



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

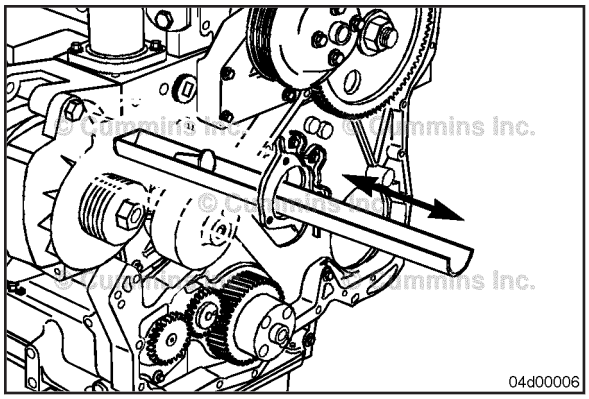


Only remove one (1) tappet at time. Remove the rubber band from the two (2) companion tappets, securing the tappet **not** to be removed with the rubber band.

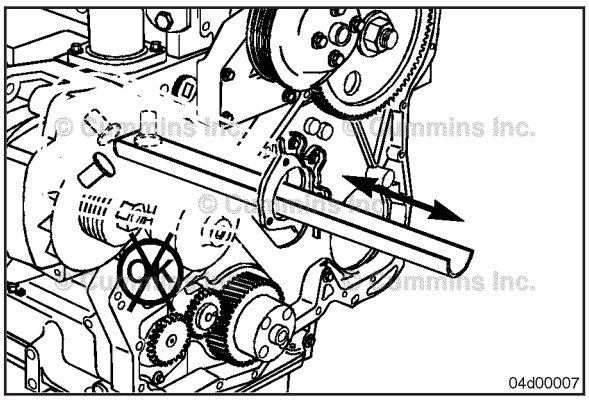


Pull the wooden dowel from the tappet bore and allow the tappet to fall into the trough.

When the tappet is dropped into the trough, most of the time it will fall over. However, if it doesn't, gently shake the trough just enough to allow the tappet to fall over before removing.

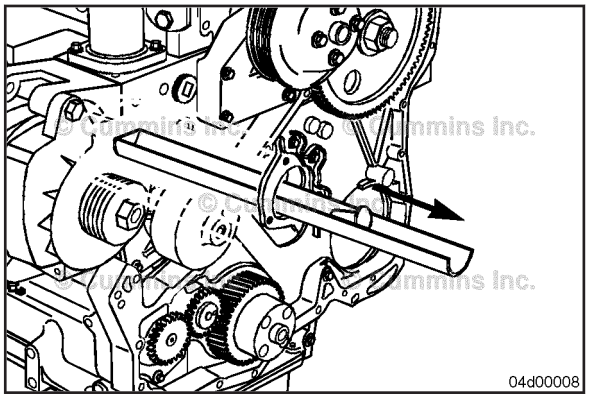


When removing the Number 6 cylinder tappets, special care **must** be taken **not** to knock or shake the tappet over the end of the trough.



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

Mark each tappet to indicate its location if the tappets are to be reused.



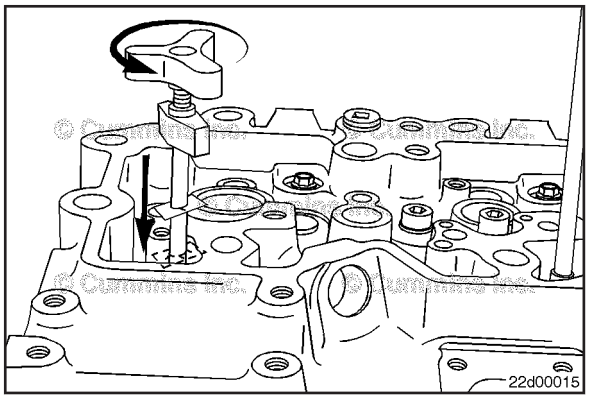
Roller Tappets

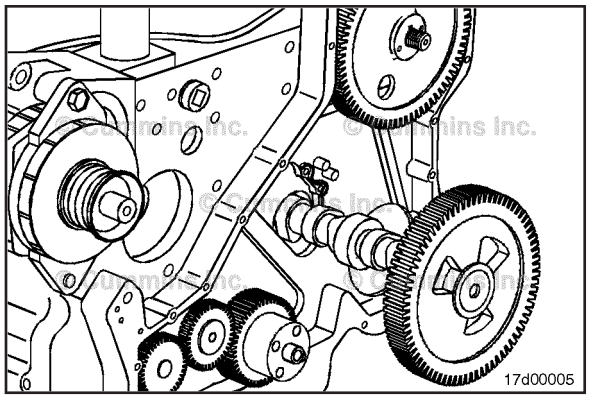
Use tappet removal tool kit, Part Number 3165088, to remove the tappets.

Insert the tappet extractor tool (2) into the tappet bore. Turn the top knob **counterclockwise** while holding the bottom knob to expand and secure the tool into the tappet.

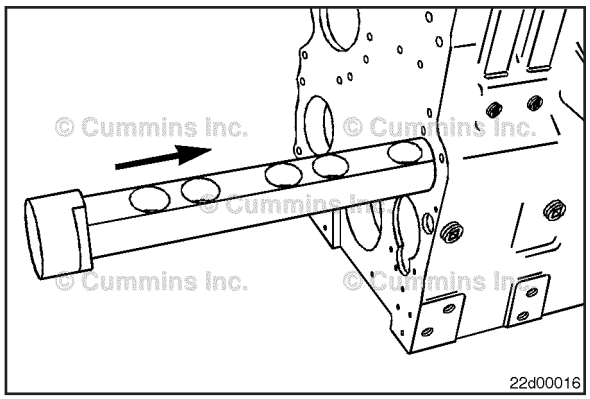
Raise the tappet extractor (2) until it stops, and push the metal tab down against the head surface to secure the tool and captured tappet in the up position.

Repeat for the remaining tappets.



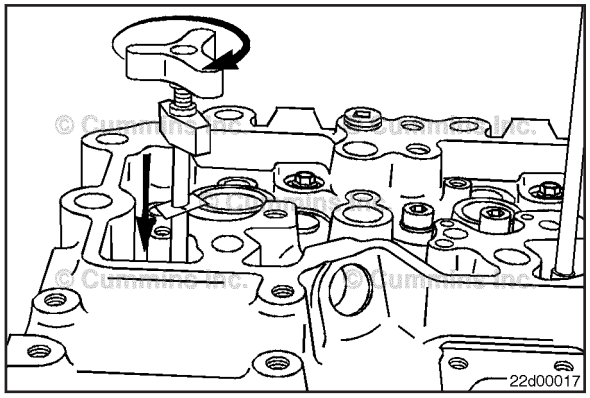


Remove the camshaft. Refer to Procedure 001-008 in Section 1.

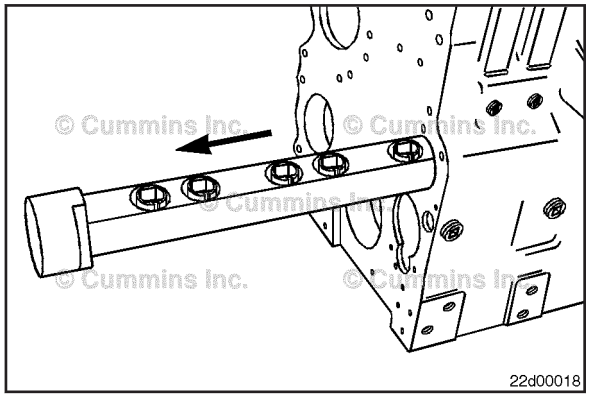


Make sure the holes are in the up position.

Insert the tappet holder to the full length of the camshaft bore.



Lower the tappet extractor, and seat the tappet into the tappet holder. Turn the top knob **clockwise** while holding the bottom knob to disengage the extractor from the tappet. Repeat the step for the remaining tappets.



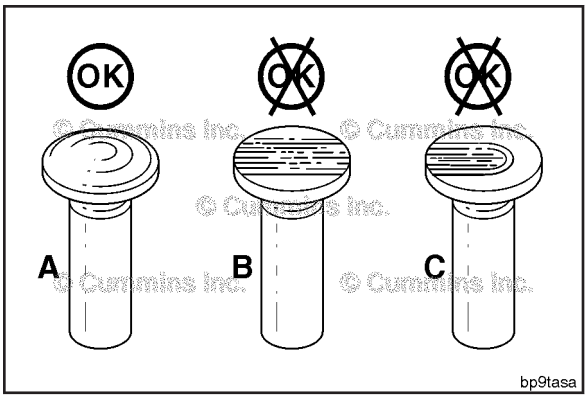
Carefully pull the tappet holder and tappets from the camshaft bore. If the tappets will be reused, be sure to note their position. Do **not** install a tappet in a different position.

Clean and Inspect for Reuse

Sliding Tappets

Inspect the socket, stem and face for excessive wear, cracks and other damage.

Visual Limits
(A) - Normal Contact (exaggerated)
(B) and (C) - Irregular Contact: Do **not** reuse.



Pit marks on the tappet face are acceptable.

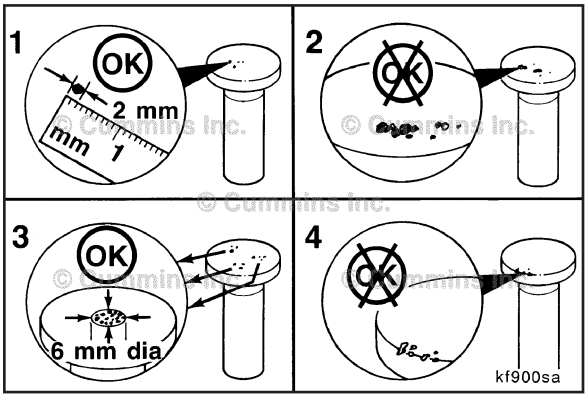
The following criteria defines the size of the pits allowed.

1 A single pit can **not** be greater than 2 mm [0.078 in].

2 Interconnection of pits is **not** allowed.

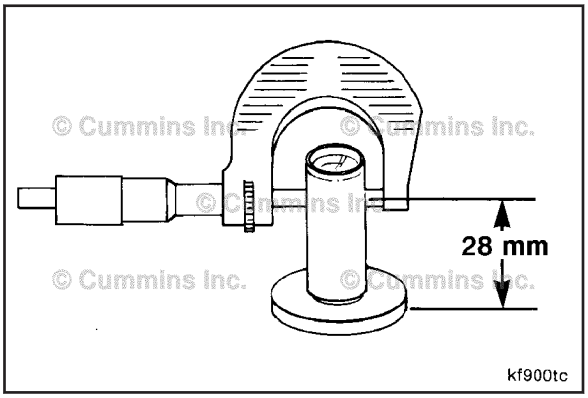
3 Total pits when added together **must not** exceed 6 mm [0.236 in] diameter or a total of 4 percent of the tappet face.

4 No pitting is allowed on the edges of the wear face of the tappet.



Measure the valve tappet stem.

Valve Tappet Stem Diameter		
mm		in
15.936	MIN	0.627
15.977	MAX	0.629

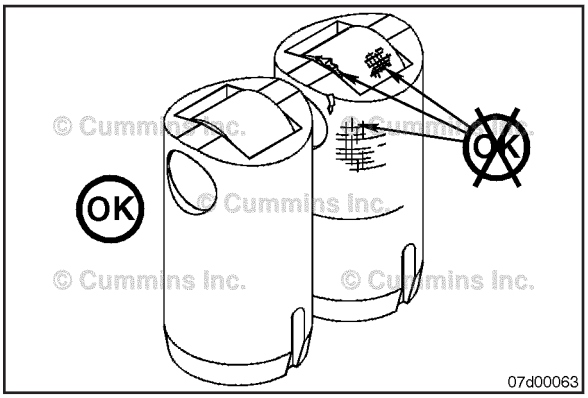


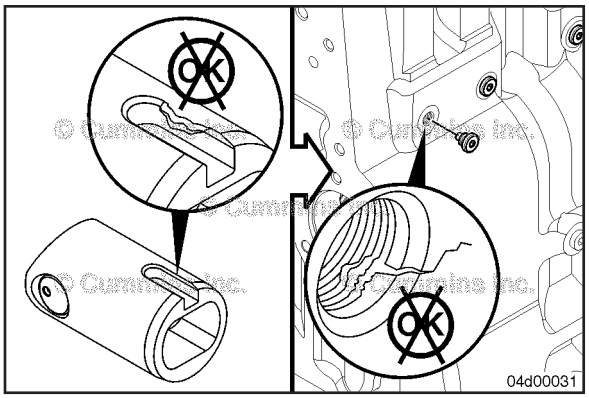
Roller Tappets

Inspect the tappet body for cracks or other damage.

Inspect the roller for flat spots or pitting. Refer to Camshaft Reuse Guidelines for Cummins® Engines with Roller Followers or Roller Tappets, Bulletin 3666052. If excessive wear is found, replace the tappet, and inspect the camshaft.

The roller **must** rotate freely. If it does **not**, replace the tappet.





Inspect the tappet body guide screw groove for damage.

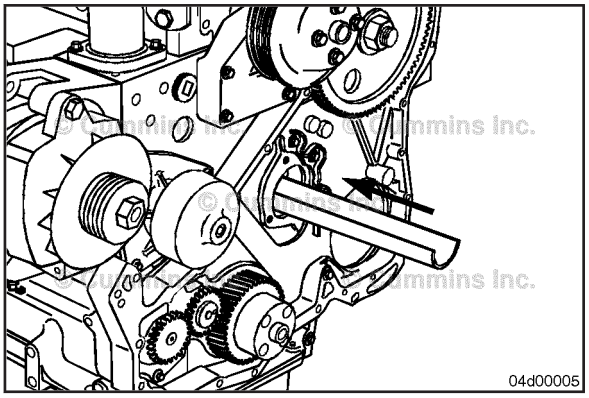
If damage to the groove is found, remove the guide screw from the cylinder block.

Inspect the guide screw and guide screw hole for thread condition and cracks.

NOTE: Damage to the tappet body guide screw is **not** common.

Install the tappet guide screw and tighten.

Torque Value: 10 N•m [89 in-lb]



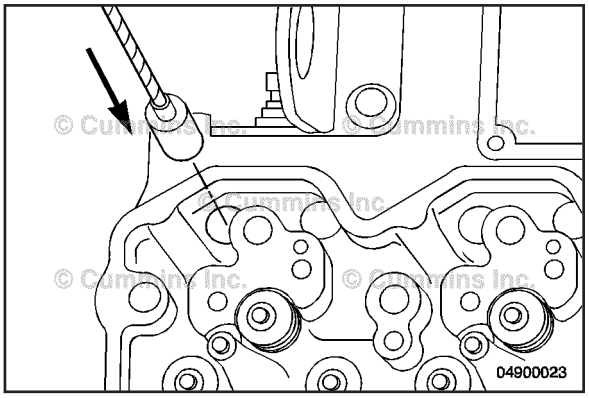
Install

Sliding Tappets

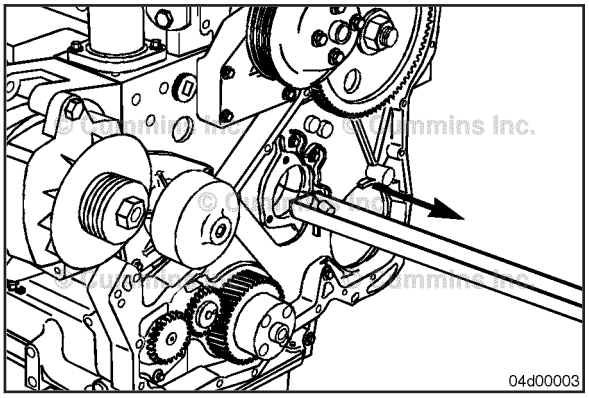
△CAUTION△
Anytime a camshaft or tappets are replaced in a B or C series engine with sliding tappets, that has more than 250 hours or 5000 miles, the camshaft, tappets, and push tubes must be replaced with new.

Insert the trough the full length of the camshaft bore.

Do **not** use worn tappets with a new camshaft.

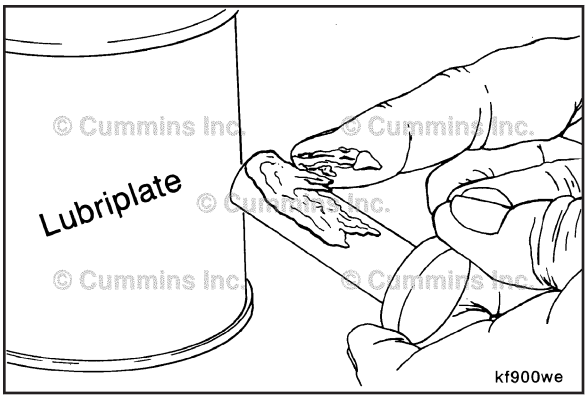


Lower the tappet installation tool down the push tube hole, through the tappet bore, and into the trough.



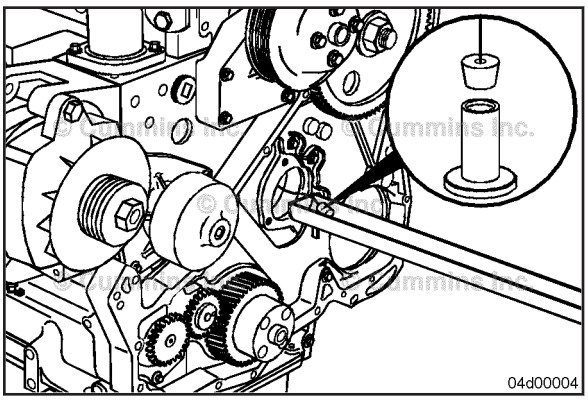
Feed the installation tool through the camshaft bores by carefully pulling the plastic trough or installation tool out the front. The barrier at the rear of the trough will pull the tool out most of the time.

Lubricate the tappets with Lubriplate™ 105, Part Number 3163087, or equivalent.

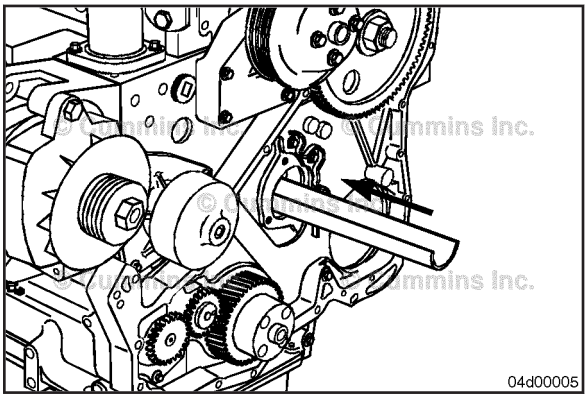


Insert the installation tool into the tappet.

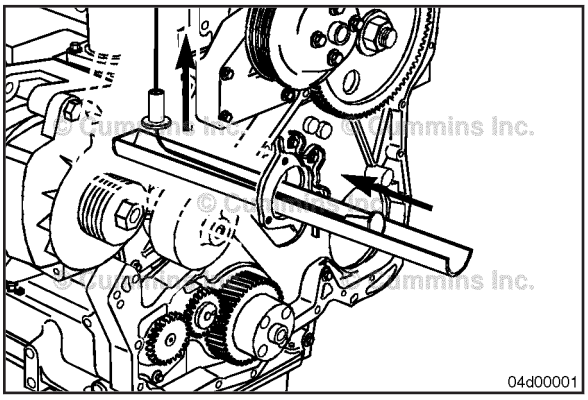
To aid in removing the installation tool after the tappet is installed, work the tool in and out of the tappet several times before installing the tappets.

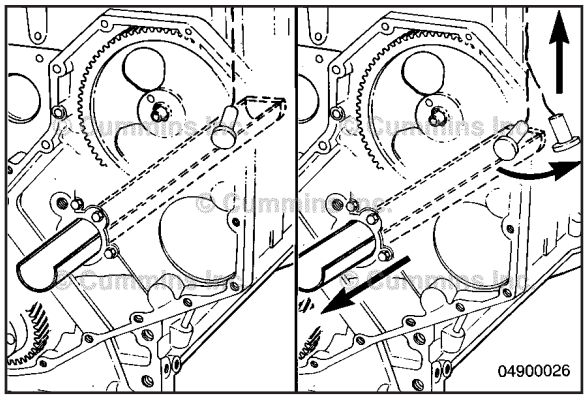


Slide the trough into the camshaft bore.

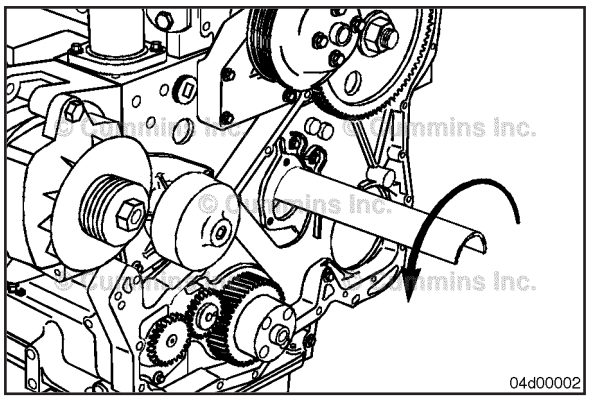


Pull the tool and tappet through the camshaft bore and up into the tappet bore.

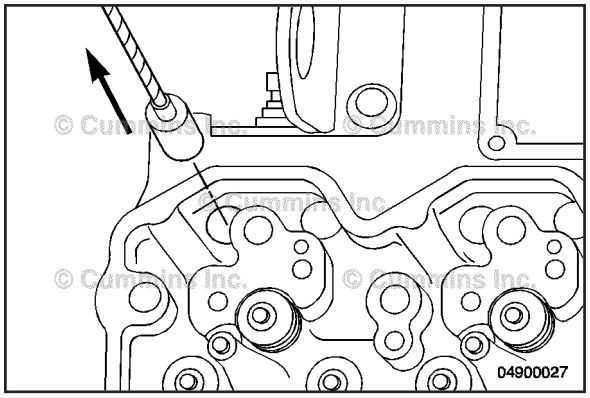




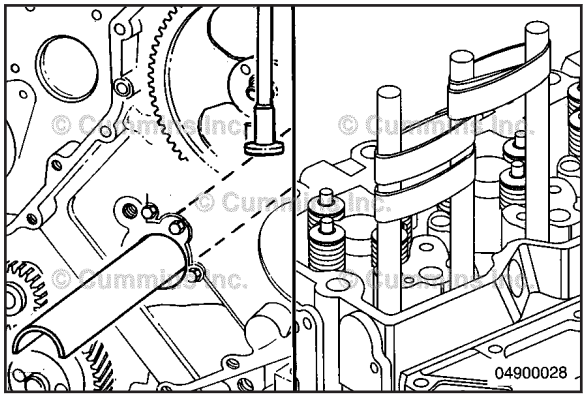
If difficulty is experienced in getting the tappet to make the bend from the trough up to the tappet bore, pull the trough out enough to allow the tappet to drop down and align itself, then pull the tappet up into the bore.



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



Remove the installation tool from the tappet.



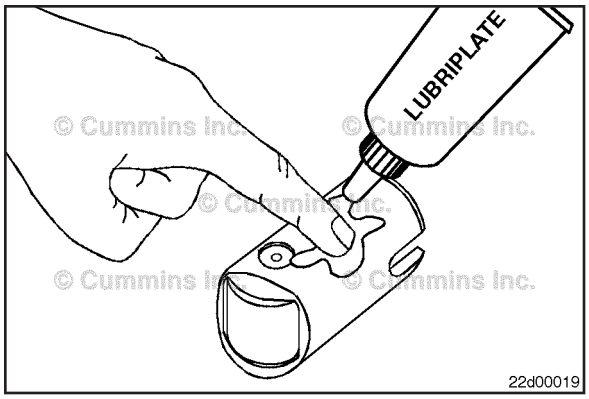
Install a wooden dowel into the top of the tappet. Wrap rubber bands around the wooden dowels to secure the tappets.

Repeat this process until all tappets have been installed.

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

Roller Tappets

Lubricate the tappets with Lubriplate™ 105, Part Number 3163087, or equivalent.

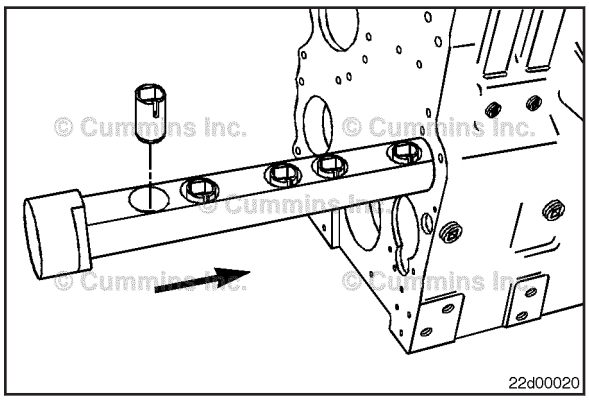


Make sure the tappets are installed with the pin slots toward the outside of the block.

Insert the tappets into the tappet holder.

NOTE: If the tappets are being reused, be sure to install them in their original position.

Insert the tappet holder the full length of the camshaft bore.

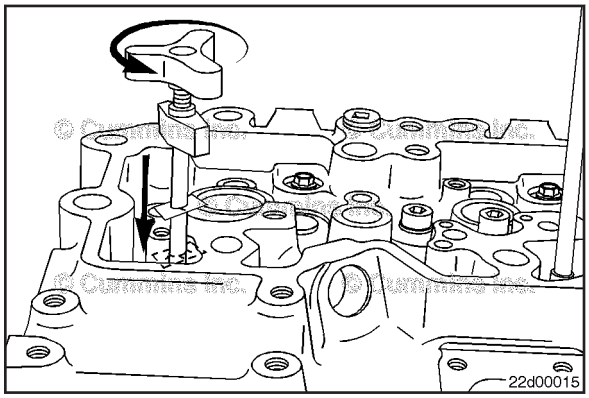


Insert the tappet extractor tool (2) into the tappet bore. Turn the top **counterclockwise** to expand and secure the tool into the tappet.

Raise the tappet extractor (2) until it stops, and push the metal tab down against the head surface to secure the tool in the up position.

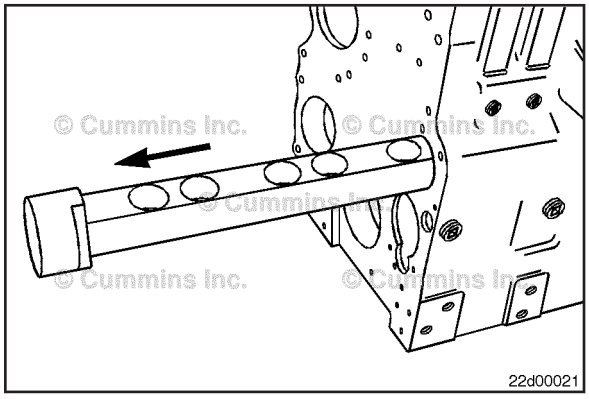
NOTE: Some manipulation may be necessary to get the tappet to enter the bore. When the tappet enters the bore, attempt to rotate the extractor while applying light upward pressure. If the tool will **not** rotate, the tappet has engaged the guide pin. If the tool does rotate, continue until the tappet engages the guide pin.

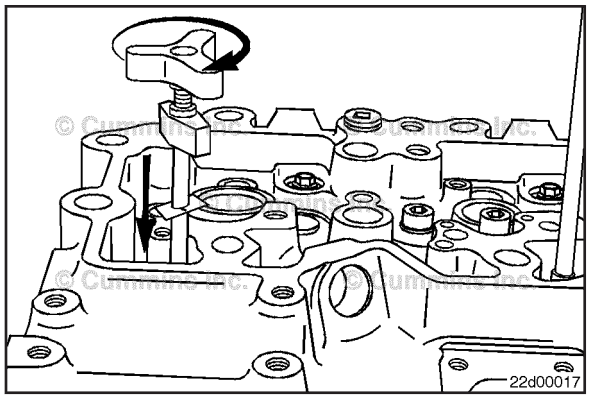
Repeat for the remaining tappets.



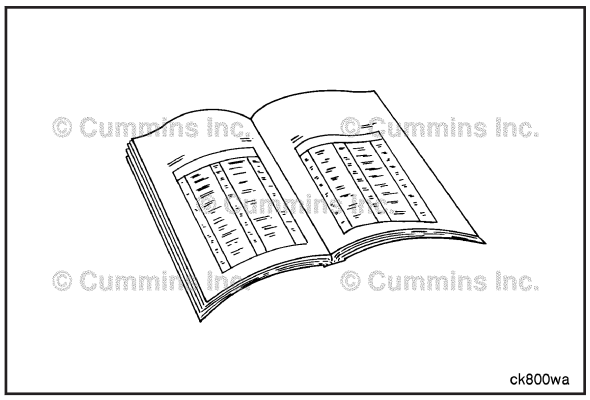
Remove the tappet holder.

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





Lower the tappet extractor, and seat the tappet into the camshaft. Turn the top knob **clockwise** while holding the bottom knob to disengage the extractor from the tappet. Repeat the step for the remaining tappets.



Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the gear cover. Refer to Procedure 001-031 in Section 1.
- Install the vibration damper. Refer to Procedure 001-052 in Section 1.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Install the belt guard, if equipped. Refer to Procedure 008-001 in Section 8.
- Install the push rods or tubes. Refer to Procedure 004-014 in Section 4.
- Install the rocker levers. Refer to Procedure 003-008 in Section 3.
- Adjust the valves. Refer to Procedure 003-004 in Section 3.
- Install the engine brake assembly, if equipped. Refer to Procedure 020-004 in Section 20.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the crankcase breather tube and drain tube, external crankcase breather **only**. Refer to Procedure 003-018 in Section 3.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

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