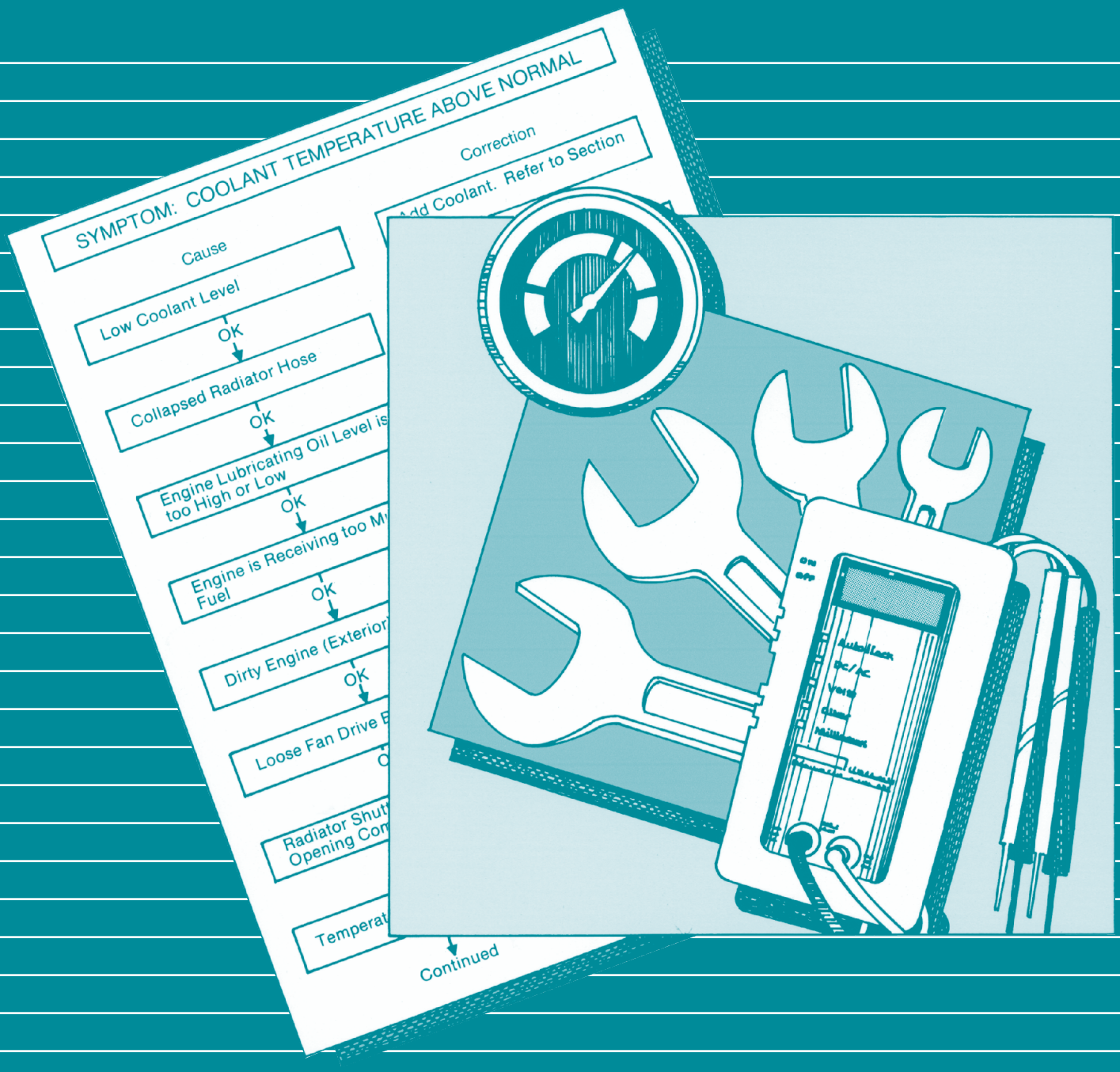
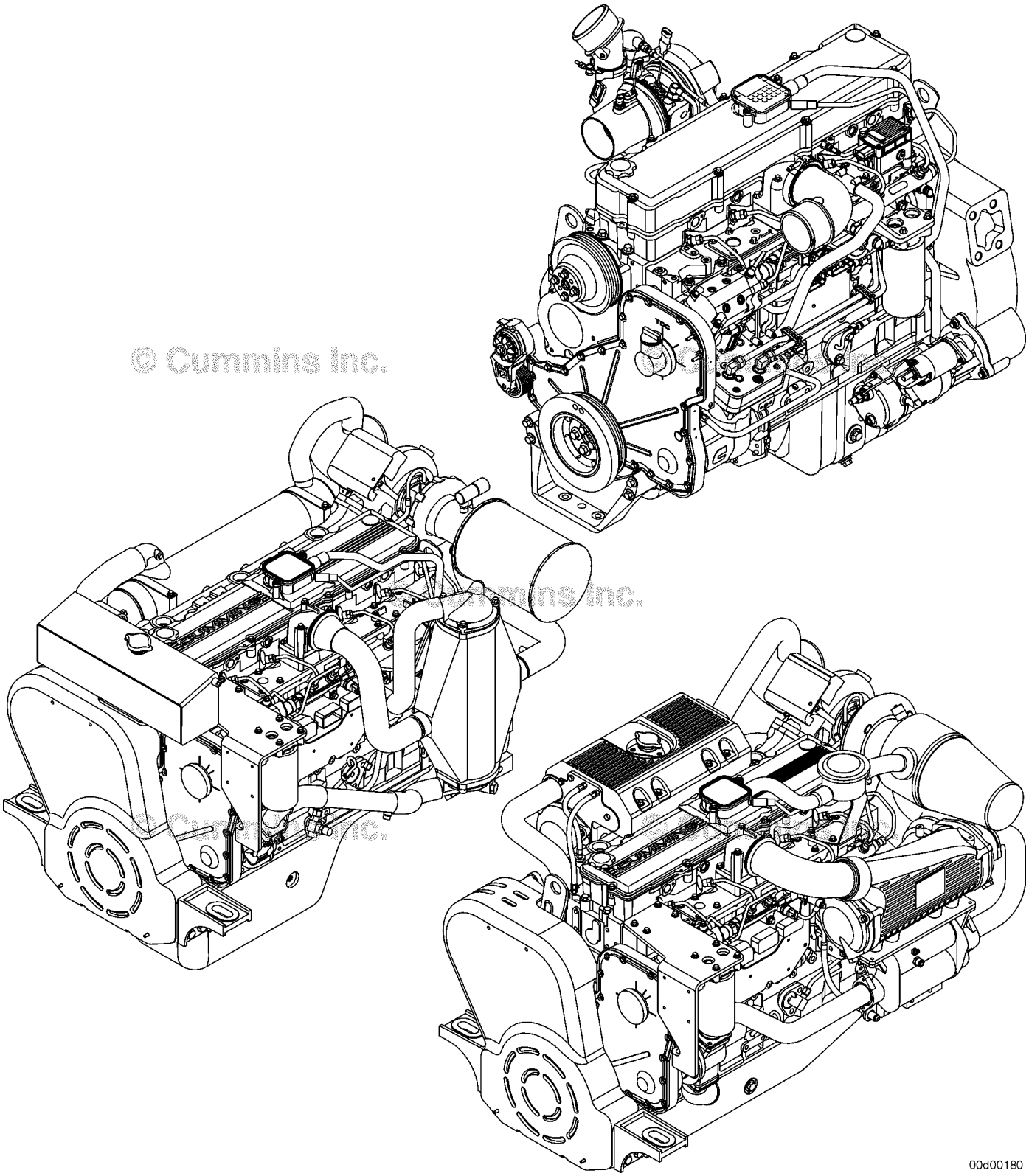
Troubleshooting and Repair Manual ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Volume 2



Troubleshooting and Repair Manual
ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines
Volume 2



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Bulletin 4021418
Printed 23-JULY-2014

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Foreword

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

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

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

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

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

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

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

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

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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.

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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.

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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.

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

INSPECTION is required.

CLEAN the part or assembly.

PERFORM a mechanical or time **MEASUREMENT**.

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LUBRICATE the part or assembly.

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

TIGHTEN to a specific torque.

PERFORM an electrical **MEASUREMENT**.

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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.

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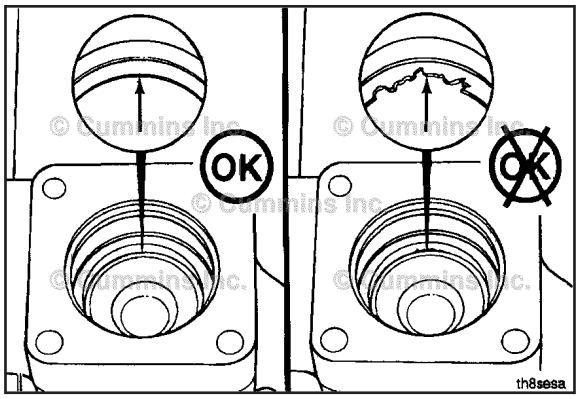
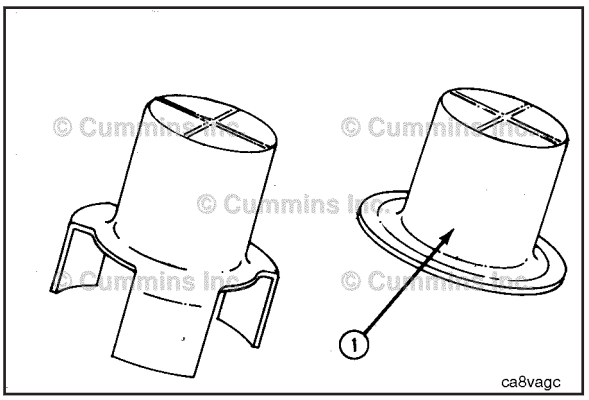
Illustrations

General Information

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



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



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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.

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- 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.

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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

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- 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

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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

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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

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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

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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

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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.

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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

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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

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Section 5 - Fuel System - Group 05

Section Contents

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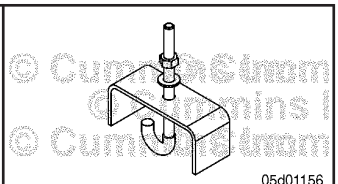
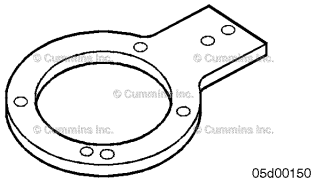
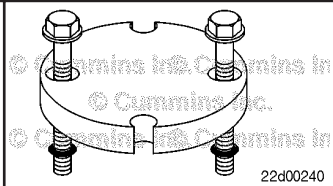
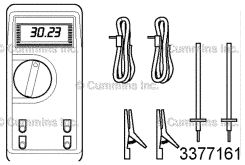
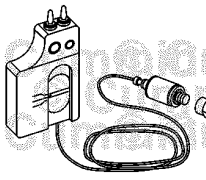
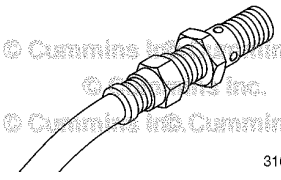
Service Tools

Fuel System

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
2892416	**Remover Fixture** Used to remove the air/fuel mixer venturi from the intake manifold.	 05d01156
3162897	**Fuel Pump Mounting Plate** Used to hold the fuel pump in the ball joint vise during service.	 05d00150
3163381	**Fuel Pump Gear Puller** Used to pull the fuel pump gear. Includes Part Number 3900633, capscrews.	 22d00240
3164488	**Multimeter** Used to measure voltage, resistance, and current in electrical circuits.	 3377161
3164491	**Pressure and Vacuum Module** Used with multimeter, Part Number 3164488, to measure pressures and restrictions in the fuel system.	 22c00252
3164618	**12 mm Banjo Adapter Fitting (Leakage Flow Adapter)** Used to isolate drain flow from the fuel drain lines where they connect to the fuel drain manifold. Allows fuel leakage measurement from the fuel pump, injector, or fuel rail pressure relief valve drain lines.	 3164614

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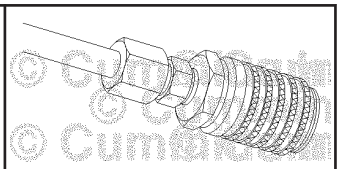
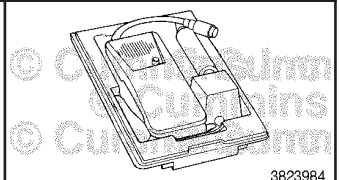
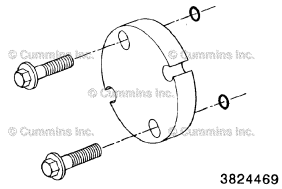
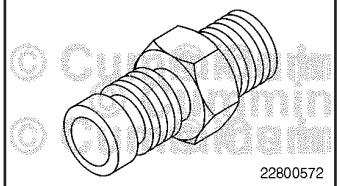
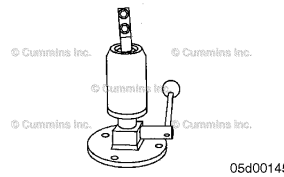
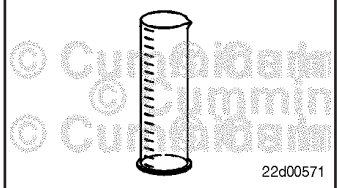
Tool No.	Tool Description	Tool Illustration
3164621	**0.043-Inch Diagnostic Fuel Line** Used to create rated fuel flows through the low-pressure fuel system without loading the engine.	 22c00253
3823984	**Combustible Gas Detector** Used to check for gas leaks at connections.	 3823984
3824469	**Fuel Pump Gear Puller** Fuel pump gear puller, Part Number 3824469, has been obsoleted. This tool can be used with M8-1.25 x 50 capscrews, Part Number 3900633, grade 8.8 flange head capscrews or equivalent.	 3824469
3824510	**Electrical Contact Cleaner** Non-petroleum cleaner used to clean electrical connections and fuel pump internal parts.	 oi8togt
3824842	**M10 Compucheck® Fitting** Used to measure fuel system pressure at the fuel filter head.	 22800572
ST 302	**Ball Joint Vise** Used with the fuel pump mounting plate for holding the fuel pump during service.	 05d00145
Not Applicable	**1000 cc Graduated Cylinder** Used to measure high-pressure pump drain flow (leakage).	 22d00571

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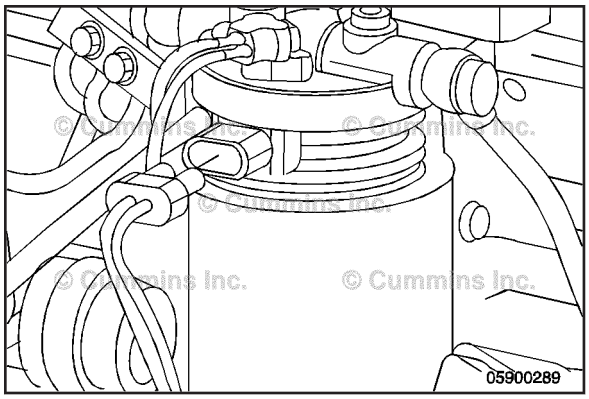
Engine Fuel Heater, Electric (005-008)

Initial Check

The fuel heater is an optional device installed on the fuel filter head. It is held on the filter head by the threaded filter spud.

NOTE: The fuel heater is **not** controlled by the electronic control module (ECM). A bimetallic switch on the filter head acts as a thermostat. The fuel heater will turn on at approximately 1°C [34°F] and turn off at approximately 18°C [65°F].

The switch should register as an open circuit above 18°C [65°F] and register as a closed circuit below 1°C [34°F].

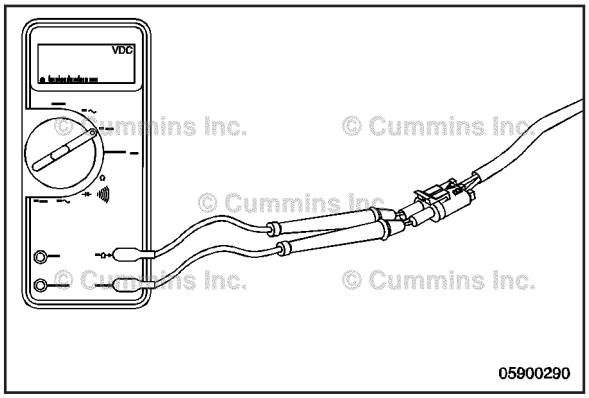


Remove the 2-pin connector from the fuel heater.

Check for proper voltage to the fuel heater.

NOTE: Minimum voltage is 12 VDC with keyswitch ON (separate 24 volt heaters are used on vehicles with a 24-volt charging system).

If the voltage is **not** within specifications, refer to the OEM troubleshooting and repair manual.



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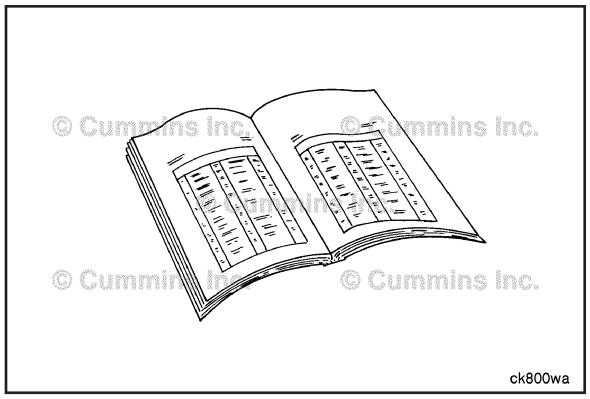


Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

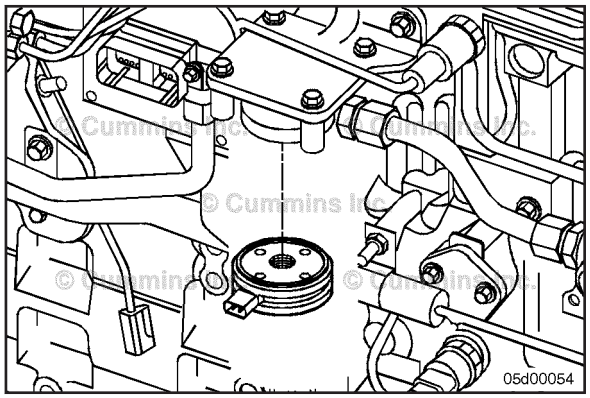
⚠WARNING⚠

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

⚠WARNING⚠

Drain the fuel-water separator into a container, and dispose of contents in accordance with local environmental regulations.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Disconnect the OEM power supply connector from the fuel heater.
- Disconnect the engine harness connector from the water-in-fuel sensor.
- Drain a small quantity of fuel from the filter water drain to reduce fuel spillage during filter removal.
- Remove the spin-on fuel filter. Refer to Procedure 006-015 in Section 6.



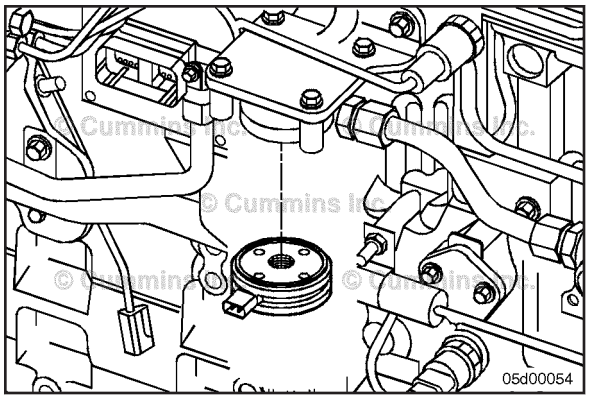
Remove

Remove the threaded filter spud and fuel heater.

Install

Install a new gasket onto the fuel heater.

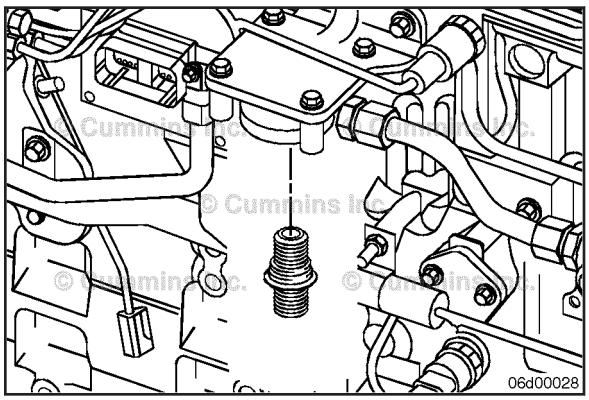
Place the fuel heater, gasket side facing up, against the filter head with the electrical connector facing away from the engine block.



Apply thread-locker, Part Number 3375068, to the filter spud threads where they will engage the filter head.

Install the fuel filter spud.

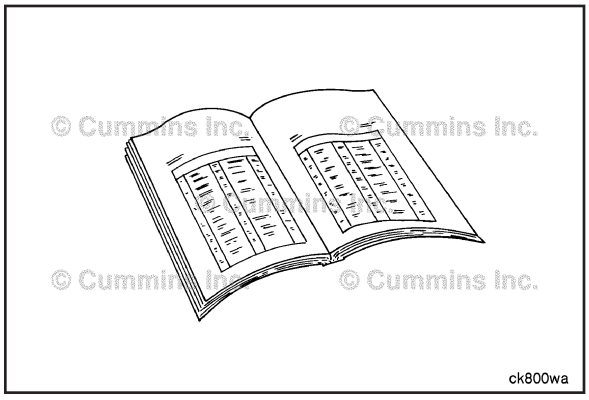
Torque Value: 30 N•m [22 ft-lb]

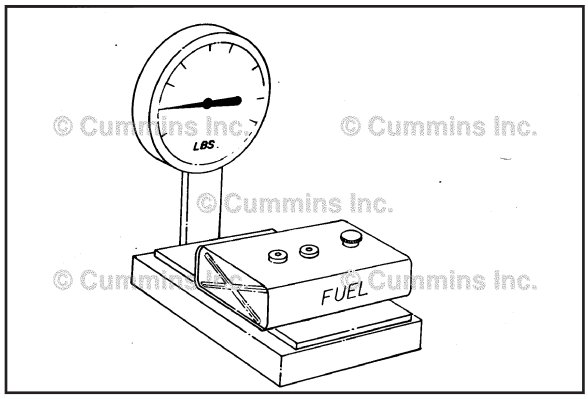


Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the fuel filter. Refer to Procedure 006-015 in Section 6.
- Connect the fuel heater.
- Connect the water-in-fuel sensor.
- Connect the batteries. Refer to Procedure 013-009.





Fuel Consumption (005-010)

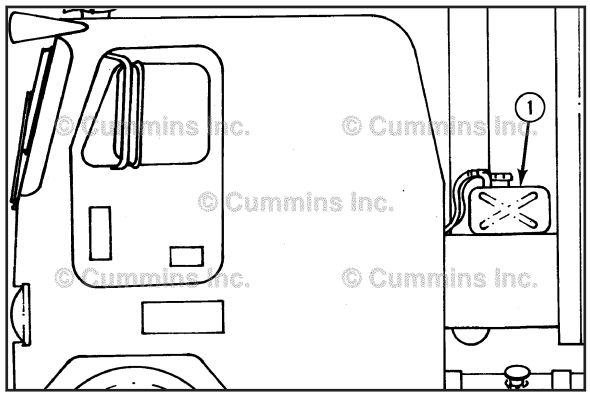
Measure

All Applications Except Marine

See the Fuel Consumption Checklist sheets in Section TS.

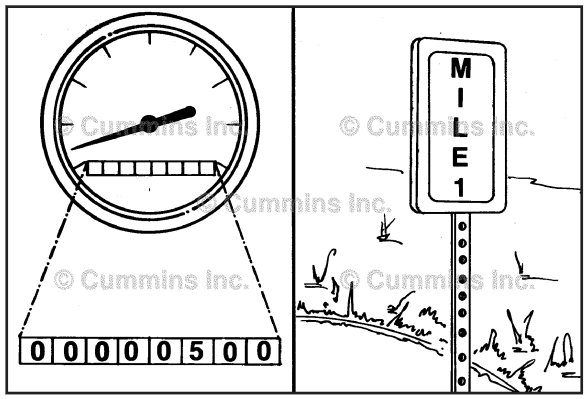
NOTE: The most accurate method to check the fuel consumption is to weigh the fuel used. Use a scale capable of measuring within 0.045 kg [0.1 lb] to weigh the fuel tank. Use a remote mount tank with enough capacity to run 80 km [50 mi].

Fill the fuel tank. Weigh the tank with the fuel. The weight of Number 2 diesel fuel is nominally 0.844 kg per liter [7.03 pounds per gal].

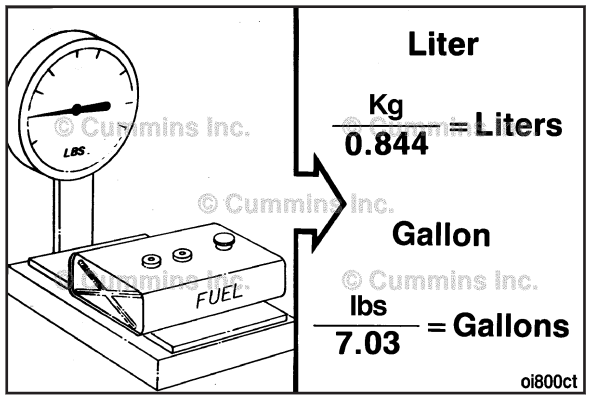


Install the remote tank (1).

Install the return fuel line to the test tank or the results will **not** be accurate.



Measure the distance traveled with an accurate odometer. The odometer accuracy can be checked by using measured kilometers [miles].



After traveling the route, remove the tanks and weigh the fuel remaining. Compute the fuel used in liters [gal] as required.

Compute the kilometers per liter or miles per gallon:

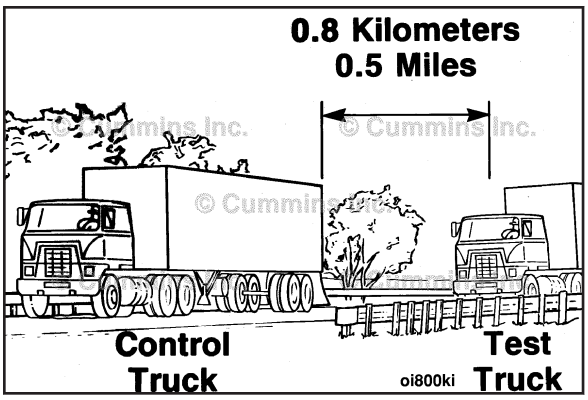
- Miles (÷) Gallons (=) MPG
- Kilometers (÷) Liters (=) KPL

In addition to the measurement of the fuel used, the following factors provide points for running a test similar to the recognized Type II Society of Automotive Engineers Fuel Test.

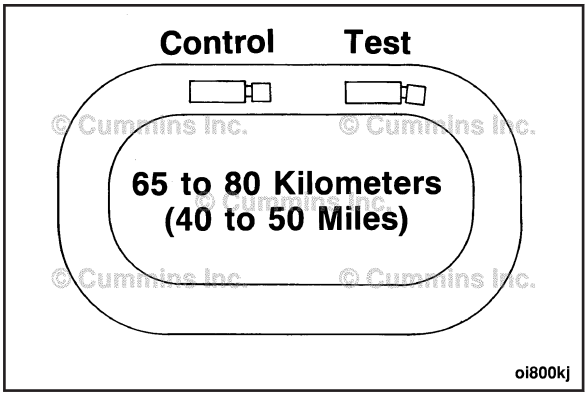
These procedures are helpful to determine differences in fuel consumption between two vehicles under the same environmental, road, and test conditions.

Perform the test with the test vehicle and a control vehicle. The control vehicle compensates for changes in traffic conditions.

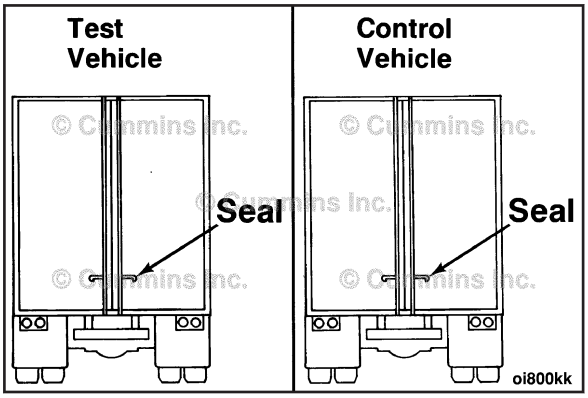
The vehicles **must** stay close together to experience the same varying traffic and weather conditions, but **not** so close as to affect each other's driving or headwind.

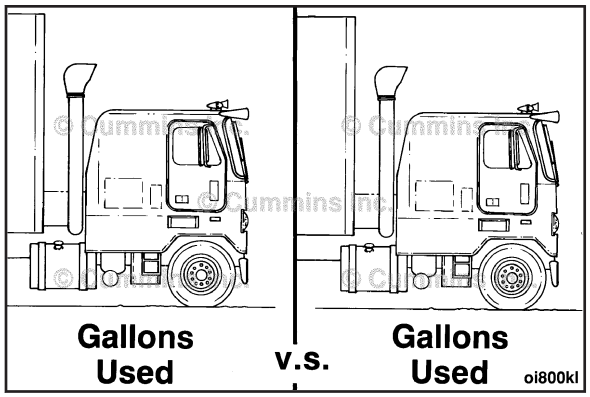


The test course **must** be 65 to 80 km [40 to 50 mi] long.

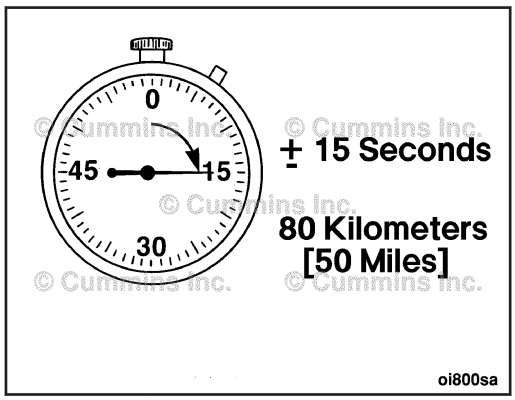


The test route and truck weights **must not** change during the test.





All of the test results are based on comparing the fuel used by the test truck to the fuel used by the control truck.



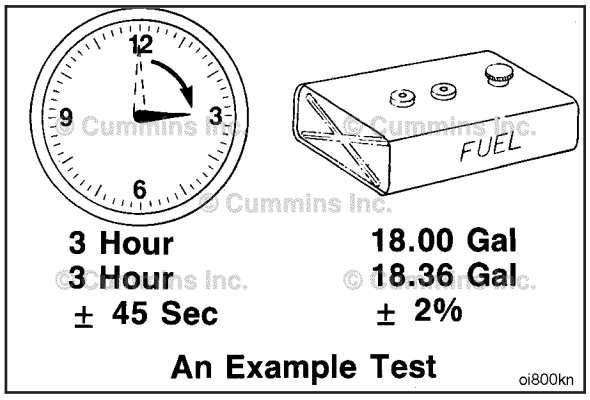
Drive the truck on a warm-up test run. Drive enough tests to achieve:

- The difference in elapsed time between each test run can **only** be ±0.5 percent. This will be ±15 seconds on 80 km [50 mi] at 97 km/h [60 mph].

The fuel usage of the test truck between test drives **must** fall within a 2-percent range, e.g., 2.55 vs. 2.60 km/l [6.00 vs. 6.12 mpg].

The same range also applies between test drives of the control truck.

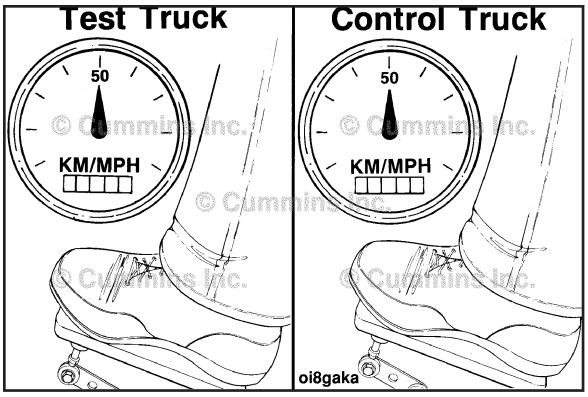
NOTE: The differences in traffic and driving practices can make the test drive fall out of the 2-percent range.



A minimum of three test drives that meet these conditions make a valid test. A single test drive is unreliable.

Use the same experienced drivers for all of the tests.

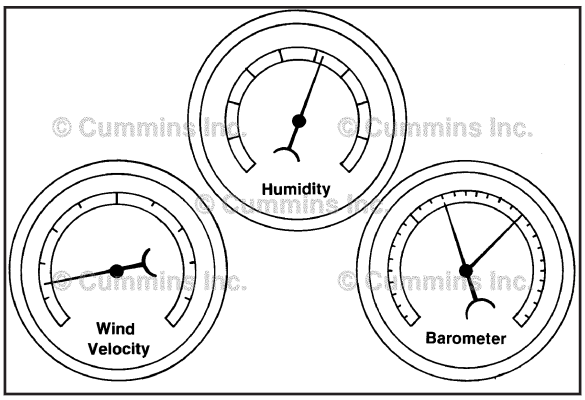
NOTE: The vehicle speeds **must** be representative of a typical operation.



During the test, record the following:

- Ambient temperature
- Humidity
- Barometric pressure
- Wind velocity
- Wind direction.

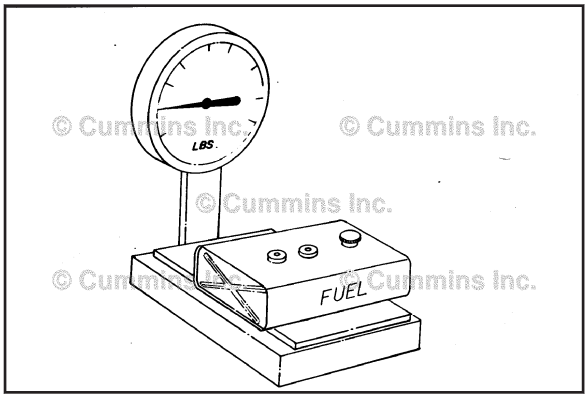
NOTE: Avoid testing under any extreme conditions.

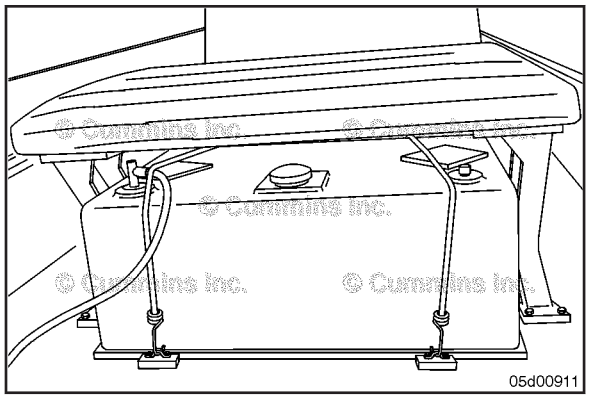


Marine Applications

See the Fuel Consumption Checklist sheets in Section TS.

The most accurate method to check the fuel consumption is to weigh the fuel used.





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

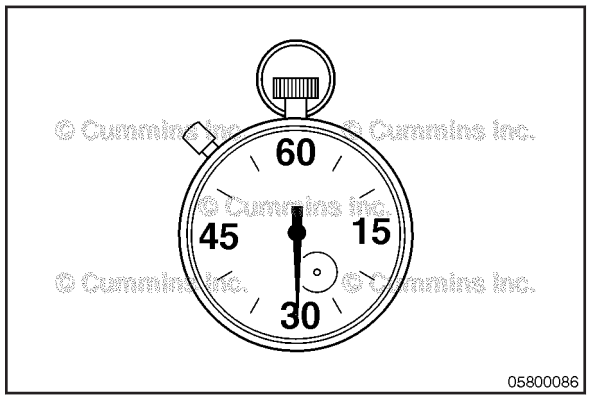
⚠WARNING⚠
Do not vent the fuel system on a hot engine; this can cause fuel to spill onto a hot exhaust manifold, which can cause a fire.

△CAUTION△
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.

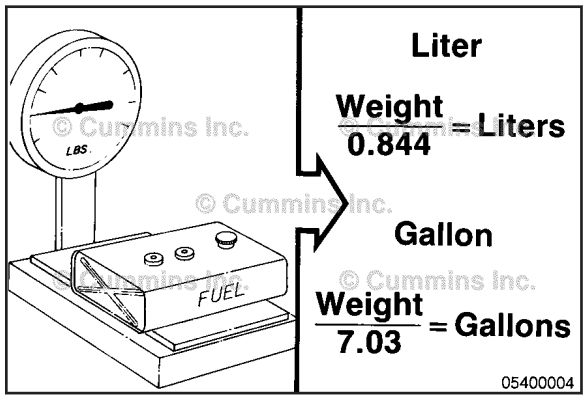
Install a remote fuel tank (1) with enough capacity to run 1 hour.

Fill and weigh the fuel tank. The weight of Number 2 diesel fuel is nominally 0.844 kg per liter [7.03 lb per gallon].

NOTE: Use a scale capable of measuring within 0.045 kg [0.1 lb] to weigh the fuel tank.



Measure the time with a stopwatch.



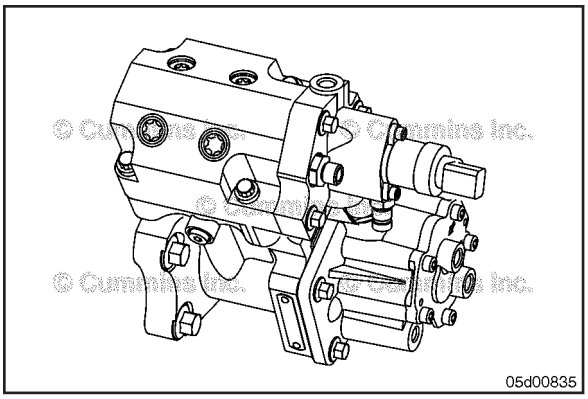
After one hour of operation, weigh the fuel remaining, and compute the fuel used in liters [gallons] as required.

Compute the fuel consumption. Fuel used divided by the time equals the fuel consumption rate.

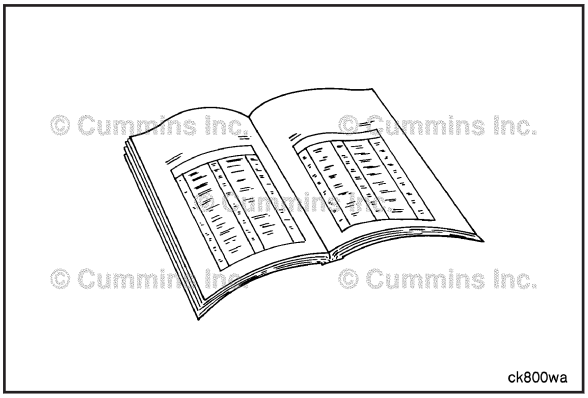
Fuel Pump (005-016)

General Information

This procedure refers to the Cummins® Common Rail fuel system.



Preparatory Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

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

△CAUTION△
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine. Refer to Procedure 000-009 in Section 0.

- Disconnect the batteries. Refer to the OEM service manual.
- Remove the fuel supply lines from the fuel pump. Refer to Procedure 006-024 in Section 6.
- Remove the fuel drain line from the fuel pump. Refer to Procedure 006-013 in Section 6.
- Remove the fuel pump gear access cover.

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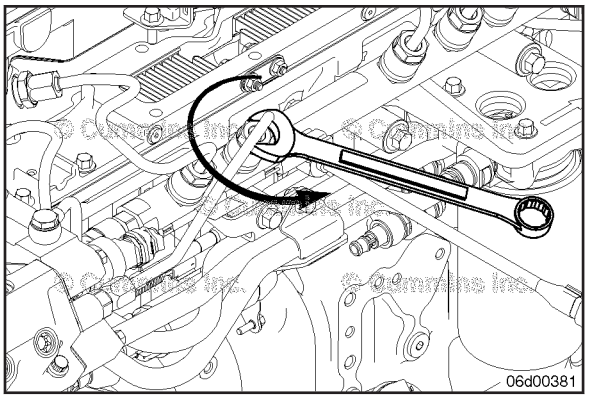


⚠WARNING⚠

Normal engine operation creates highly pressurized fuel in the fuel line which will remain in the fuel line after engine shutdown. Never open the fuel system when the engine is operating. Before servicing the fuel system, always loosen the pump-to-rail fuel line at the rail to vent the pressure. Keep hands clear of the line when loosening. High-pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

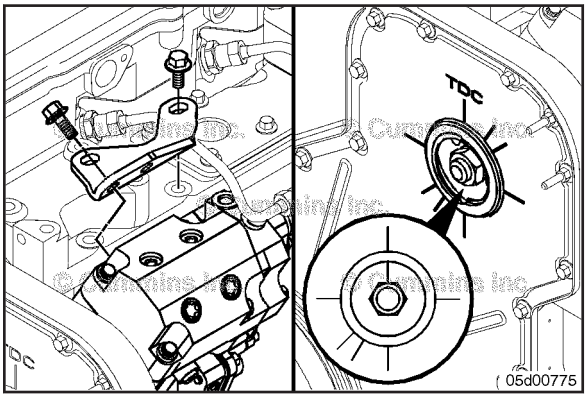
Before servicing the fuel system, loosen the pump-to-rail line at the rail to vent the pressure.

Keep hands clear of the line when loosening.

Tighten the fuel rail nut.

Torque Value: 65 N•m [48 ft-lb]

NOTE: A machined slot in this fitting directs the fuel spray towards the engine block.

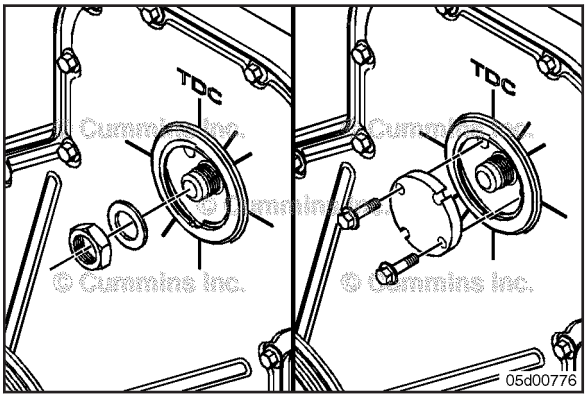


Remove

Remove the fuel pump upper support bracket.

Locate top dead center for cylinder Number 1 by barring the engine until the line on the fuel pump gear aligns with the front cover mark for top dead center.

NOTE: Depending on the build year of the engine, the fuel pump support bracket can be mounted on the fuel pump head or the fuel pump actuator housing.

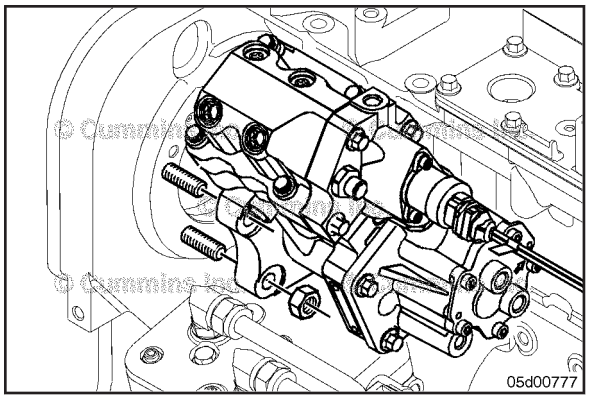


Remove the fuel pump gear nut and washer.

Use fuel pump gear puller, Part Number 3824469, to pull the fuel injection pump drive gear loose from the fuel pump drive shaft.

Remove the four mounting nuts that hold the fuel pump to the gear housing.

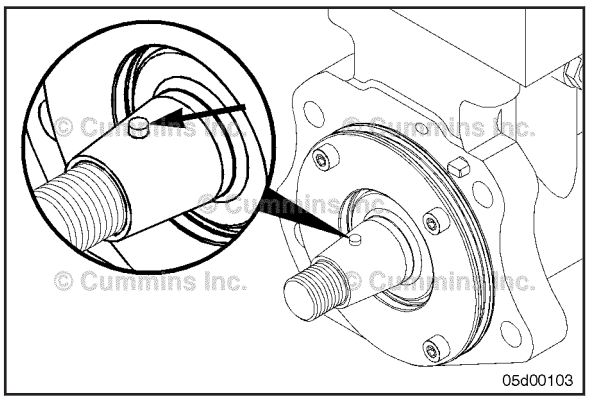
Remove the fuel pump.



Inspect for Reuse

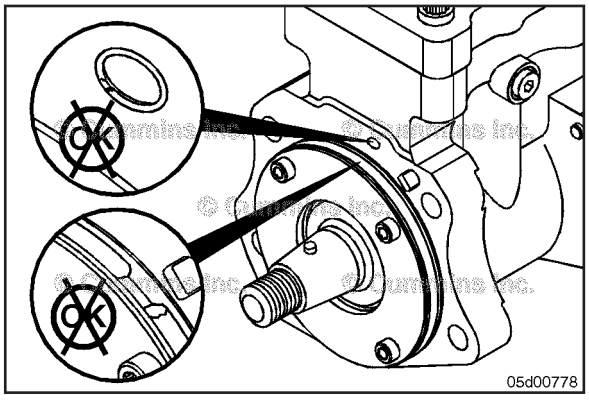
The dowel pin in the fuel pump drive shaft **must not** be sheared.

If the dowel is sheared, the camshaft housing or fuel pump **must** be replaced, and the drive gear **must** be replaced.



Be sure the pilot o-ring is **not** cut or otherwise damaged.

The pump oil supply o-ring **must** be replaced. Make sure it is **not** damaged.



Install

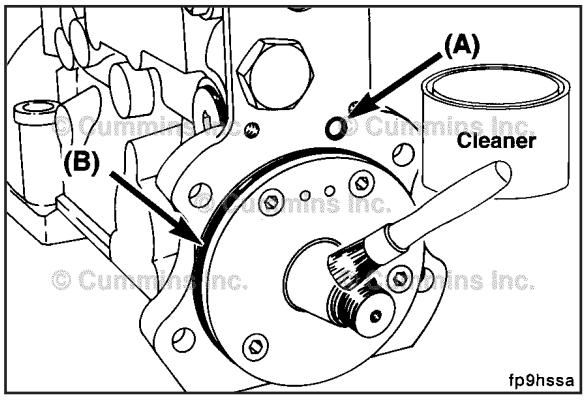
Make sure the engine is at Number 1 cylinder, top dead center. The fuel pump gear timing mark **must** align with the top dead center mark on the front cover.

Make sure the o-ring seals for the oil feed orifice (A) and pilot (B) are installed correctly.

Lubricate the pilot o-ring (B) with clean engine oil.

Clean the nose of the drive shaft and the fuel pump gear inside diameter with electrical contact cleaner, Part Number 3824510, or equivalent.

The fuel pump drive gear inside diameter and the drive shaft outside diameter **must** be clean and dry before installing the gear.



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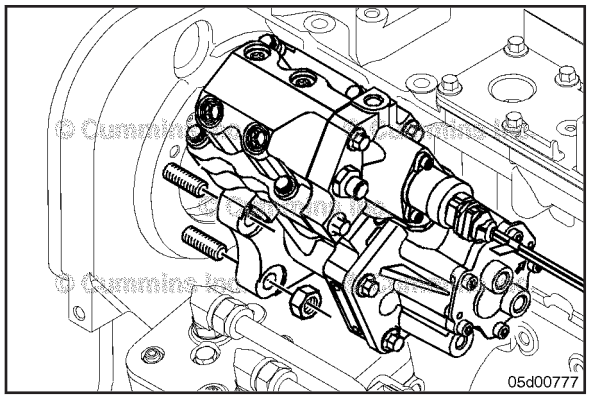
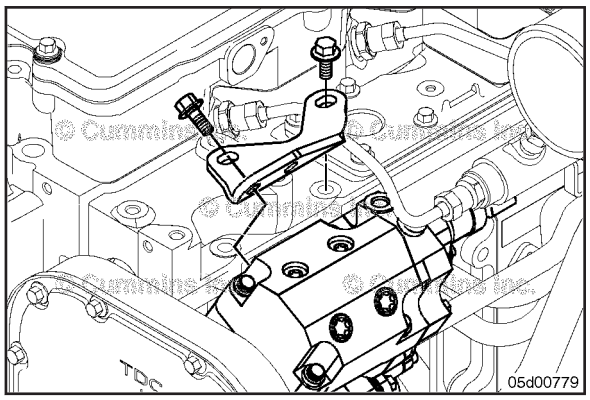


Slide the fuel injection pump shaft through the drive gear and position the fuel injection pump flange onto the mounting studs.

Make sure the dowel pin in the drive shaft lines up with the keyway in the fuel injection pump gear.



Installation sequence for fuel pump head mounted support bracket:

1 Install the pump mounting nuts (leave loose).

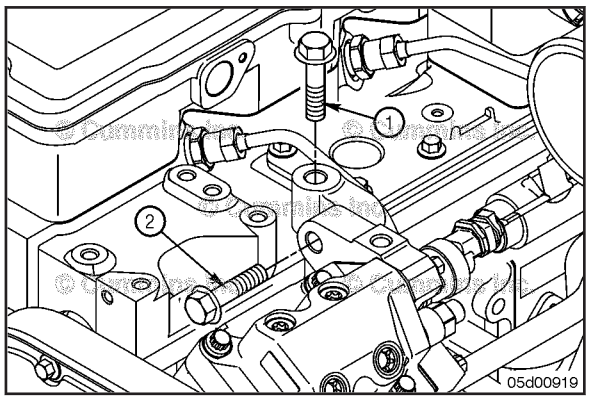
2 Install the support bracket bolts (leave loose).

3 Tighten the pump mounting nuts.

Torque Value: 44 N•m [32 ft-lb]

1 Tighten the support bracket bolts.

Torque Value: 65 N•m [48 ft-lb]



Installation sequence for fuel pump actuator housing mounted support bracket:

1 Install the pump mounting nuts (leave loose).

2 Install the bolt to the cylinder head (1) and the bolt through the pump flange (2) into the support bracket (leave loose).

3 Tighten the pump mounting nuts.

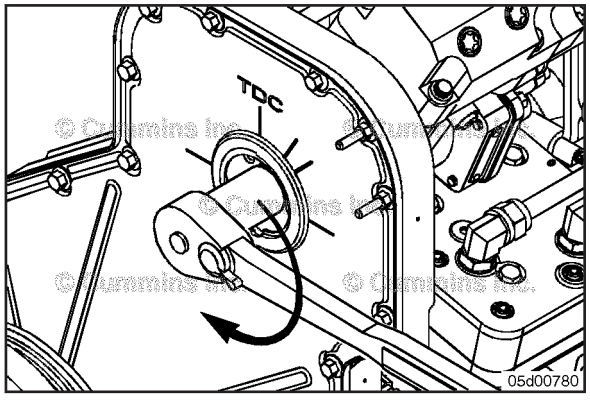
Torque Value: 44 N•m [32 ft-lb]

1 Tighten the bolt into the cylinder head (1).

Torque Value: 65 N•m [48 ft-lb]

1 Tighten the bolt into the pump flange (2).

Torque Value: 80 N•m [59 ft-lb]

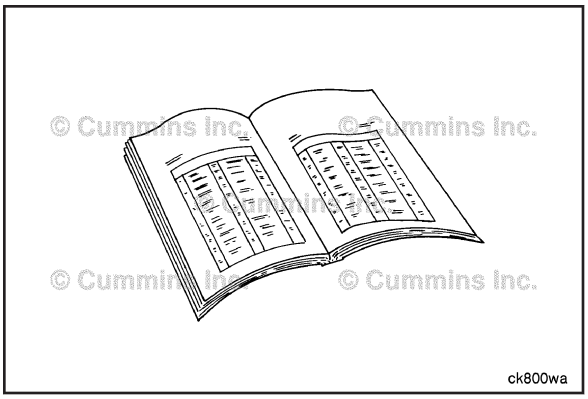


Tighten the fuel injection pump drive gear nut.

Torque Value: 180 N•m [133 ft-lb]

Finishing Steps

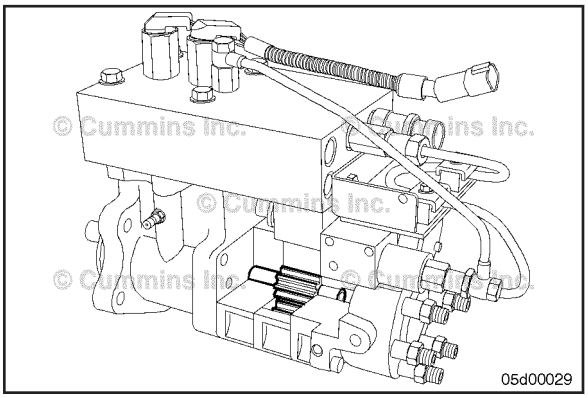
- Install the access cover in the front cover.
- Install the fuel supply lines to the fuel pump. Refer to Procedure 006-024 in Section 6.
- Install the fuel drain line to the fuel pump. Refer to Procedure 006-013 in Section 6.
- Connect the wire harness to the fuel pump actuator.
- Install the fuel filter head bracket (marine applications **only**. Refer to Procedure 006-018 in Section 6.
- Install the system integration module mounting capscrews and nuts (marine applications **only**).
- Connect the batteries. Refer to the OEM service manual.
- Open the fuel supply valve. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Fuel Pump Delivery Valve (005-020)

General Information

This procedure refers to the CAPS fuel system.



Preparatory Steps

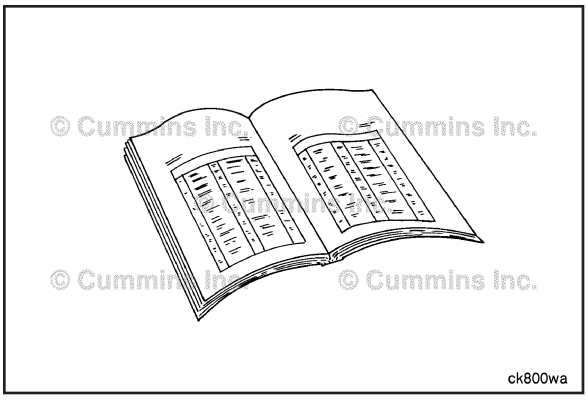
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Thoroughly steam-clean the distributor outlet fitting and fuel pump area.

Dry with compressed air.

Remove the high-pressure fuel supply lines. Refer to Procedure 006-051 in Section 6.



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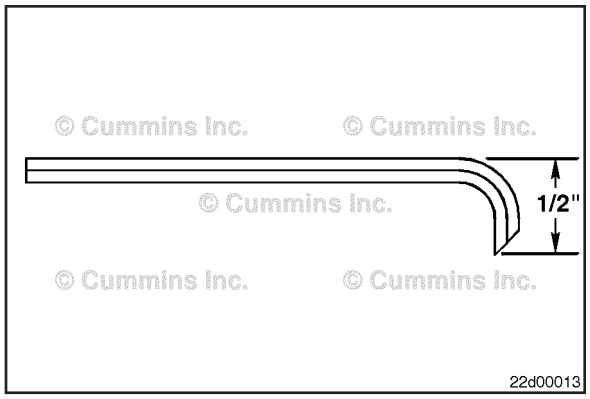
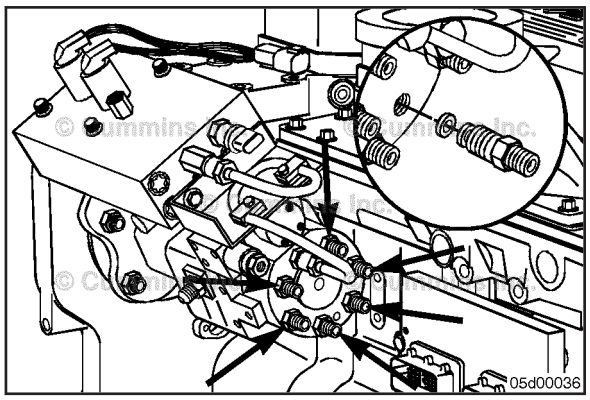


Remove

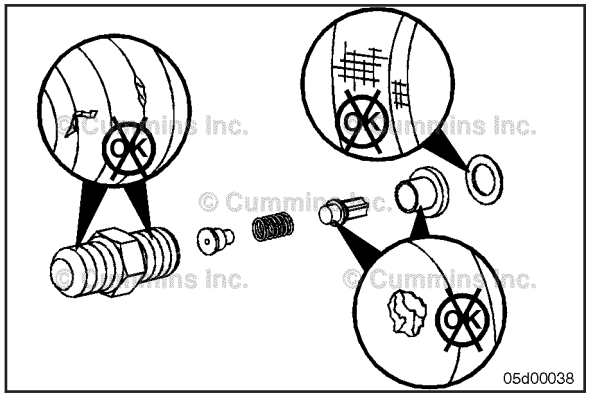
Remove the distributor outlet fitting and the seal disk.

NOTE: A tool like the one shown here can be made from a 1/8 in or 3/16 in allen wrench. Use it to remove the seal disc. Use the following procedure for instructions to make the tool. Refer to Procedure 005-084 in Section 5.



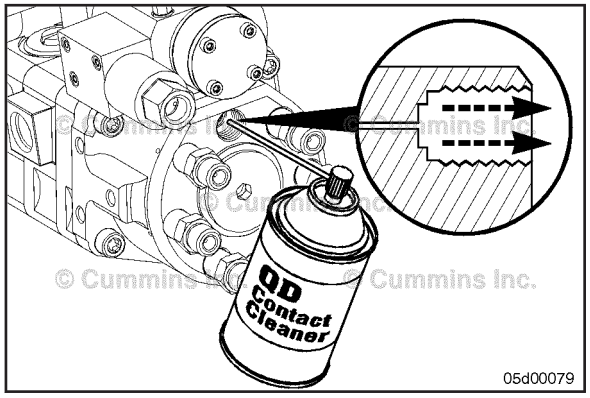
NOTE: The outlet fitting valve and seat are a matched set; do **not** “mix and match” valves and seats with other outlet fitting assemblies.

If either the outlet fitting valve or seat is damaged, the entire outlet fitting assembly **must** be replaced. Also, the seal washers **must always** be replaced.



Clean and Inspect for Reuse

Check for broken parts, debris, or sticking of the outlet fitting valve. Replace the outlet fitting assembly if any parts are damaged. **Always** replace the seal washer.



Use QD™ contact cleaner, Part Number 3824510, to clean the delivery valve port in the distributor.

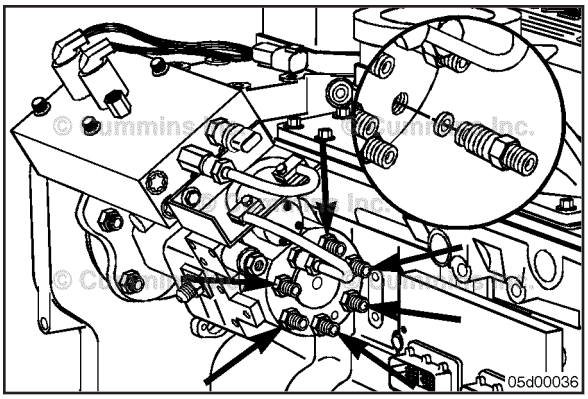
Install

Install a new seal washer into the distributor outlet fitting hole. Make sure the washer is fully seated in the bottom of the hole.

Install the outlet fitting assembly hand tight.

Tighten the outlet fitting assemblies.

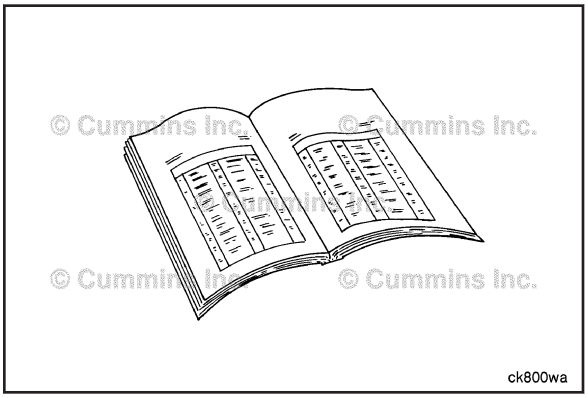
Torque Value: 81 N•m [60 ft-lb]



Finishing Steps

Install the high-pressure fuel supply lines. Refer to Procedure 006-051 in Section 6.

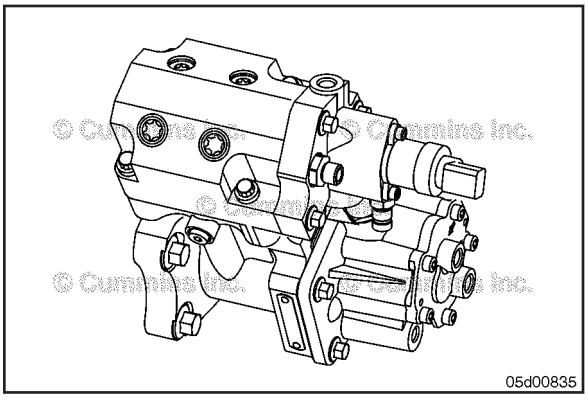
Operate the engine and inspect for fuel leaks.



Fuel Pump Gear Pump (005-025)

General Information

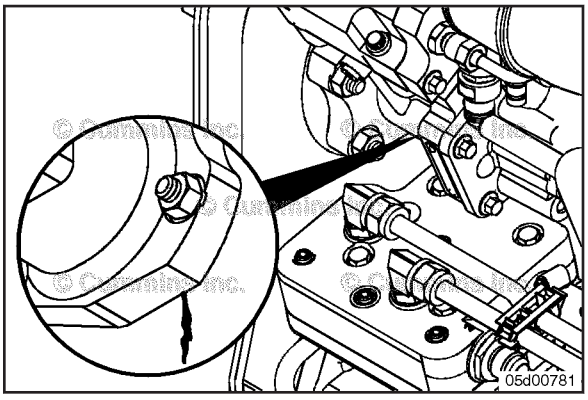
This procedure refers to the Cummins® Common Rail fuel system.



Initial Check

The gear pump shaft incorporates a double seal. The first seals oil in the fuel pump camshaft housing; the second seals fuel in the gear pump. If either seal fails, fluid will drip from the weep hole. The weep hole is located near the gear pump mounting flange on the inboard side (toward the engine block).

A gear pump gasket seals oil at the gear pump to camshaft housing interface.



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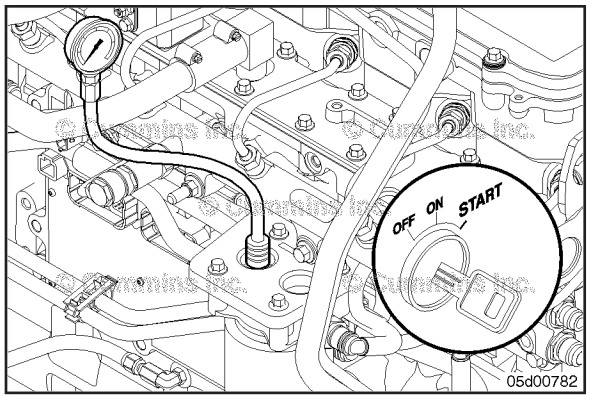


Measuring Gear Pump Pressure with the Engine Cranking (useful if engine will **not** start).

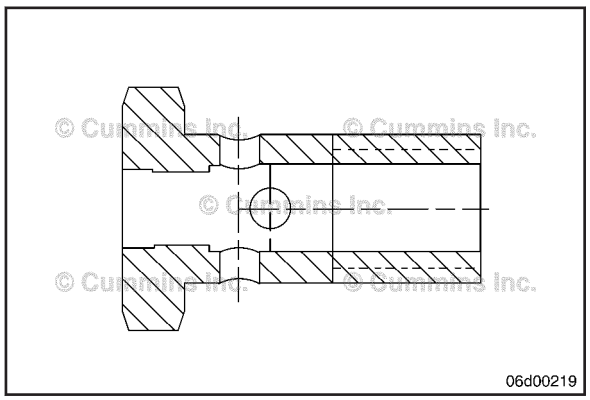
1 Install a pressure gauge at the on engine fuel filter head (M10 x 1.5 Compuchek™ fitting, Part Number 3824842).

NOTE: If there is **not** enough clearance to install the female Compuchek™ fitting, Part Number 3824842, an adapter fitting, Part Number 3932302, and an 1/8-NPT male Compuchek™ fitting, Part Number 3377244, may be used to aid accessibility.

1 Monitor the gear pump pressure while the engine is cranking.

Minimum Gear Pump Pressure at Cranking		
kPa		**psi**
105	MIN	15

If the gear pump pressure is lower than 105 kPa [15 psi] during cranking, make sure that the engine cranking speed is at least 150 rpm. Make sure that the lift pump pressure during cranking is at least 35 kPa [5 psi]. Refer to Procedure 005-045 in Section 5.



NOTE: For optional test points on the fuel system, a banjo pressure gauge adapter can be constructed.

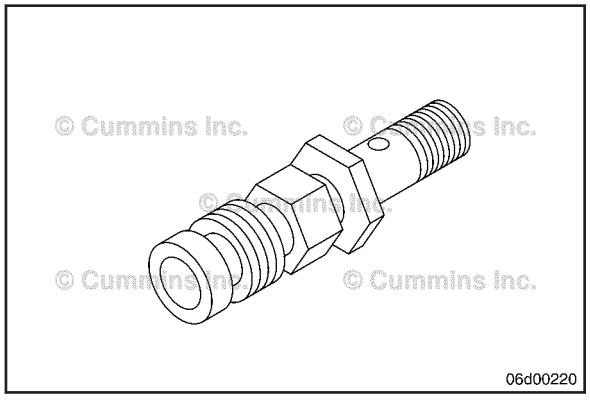
Construction of Banjo Pressure Gauge Adapter

A banjo-style pressure gauge adapter can be used to measure pressure or vacuum at any point in the low-pressure fuel system where a banjo bolt exists at a fuel line.

The ISC and ISL engines with high-pressure common rail fuel systems use a M12 x 7/16-inch banjo bolt connection. This tool can be used for measurement of drain line restriction (pressure) at the fuel drain manifold.

Make a banjo bolt flow adapter tool by drilling and tapping the hex face of an M12 x 7/16-inch banjo bolt, Part Number 3903035, or similar banjo bolt.

Drill and tap the banjo bolt to the size of the Compuchek™ fitting (or other hose union) being used (example 1/8-inch NPT Compuchek™ fitting, Part Number 3377244, or M10 Compuchek™ fitting, Part Number 3824842).



Assemble the banjo pressure gauge adapter as follows.

1 Install the Compuchek™ fitting, or other type fitting, in the hexagonal face of the banjo bolt.

2 Attach a hose or pressure gauge to the banjo pressure adapter.

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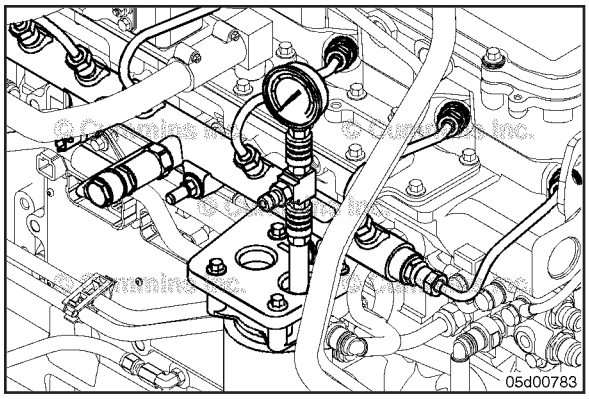
Measuring Gear Pump Pressure at Rated Condition

1 Install a M10 x 1.5 Compuchek™ fitting, Part Number 3824842, at the diagnostic port on the outlet of the fuel filter head.

2 Construct a "T" adapter fitting using one quick-disconnect, Part Number 3376859, and two 1/8-inch NPT Compuchek™ fittings, Part Number 3042618.

3 Install a 0.043-inch orificed diagnostic fuel line, Part Number 3164621, at the outlet of the fuel filter head. Run the fuel hose back to the fuel tank.

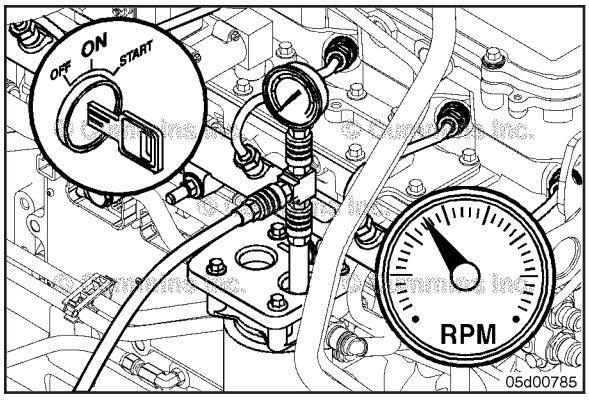
4 Install a 0 to 1034 kPa [0 to 150 psi] pressure gauge at the "T" adapter fitting.

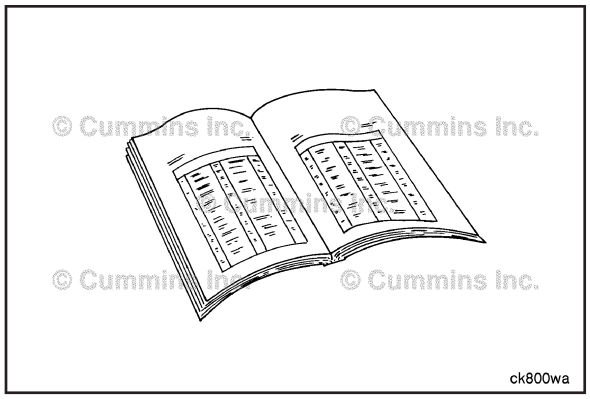


Operate the engine at high idle and observe the gear pump pressure.

Minimum Gear Pump Pressure 483 kPa [70 psi]

If the gear pump pressure is low, check for excessive inlet vacuum. Refer to Procedure 006-020 in Section 6.





Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠

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

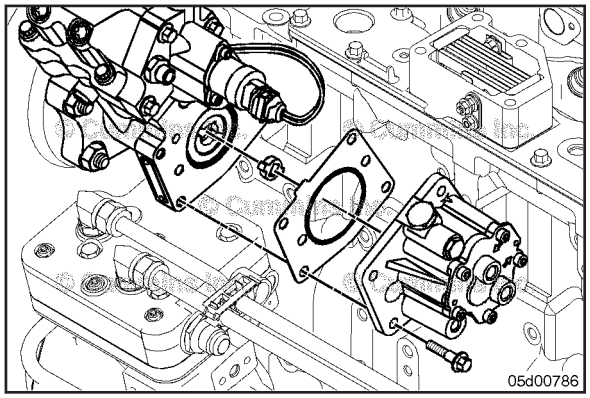
⚠WARNING⚠

Do not vent the fuel system on a hot engine; this can cause fuel to spill onto a hot exhaust manifold, which can cause a fire.

△CAUTION△

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.

- Disconnect the batteries. Refer to the OEM service manual.
- Shut off the fuel supply. Refer to the OEM service manual.
- Clean any fuel, oil, and debris from the gear pump.
- Remove the fuel supply lines from the gear pump. Refer to Procedure 006-024 in Section 6.



Remove

Remove the four bolts that hold the gear pump to the fuel pump.

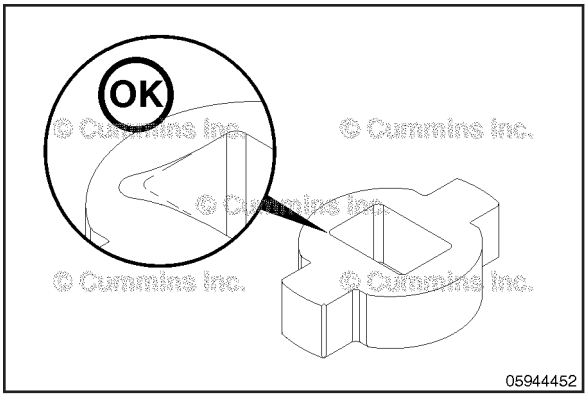
Remove the drive coupling if it remains attached to the rear of the fuel pump camshaft.

Remove the gear pump gasket.

Clean and Inspect for Reuse

Inspect the gear pump for damage.

NOTE: Gear pump coupling wear is normal. The gear pump should **not** be replaced due to coupling or shaft wear.



Install

Install the drive coupling into the back of the high-pressure pump camshaft.

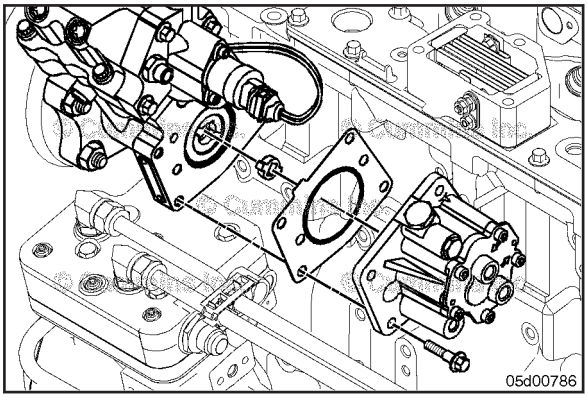
Insert the mounting bolts through the gear pump flange.

Install a new gasket onto the bolts.

Index the gear pump input shaft to engage the drive coupling and install the gear pump.

Install the four gear pump bolts and tighten.

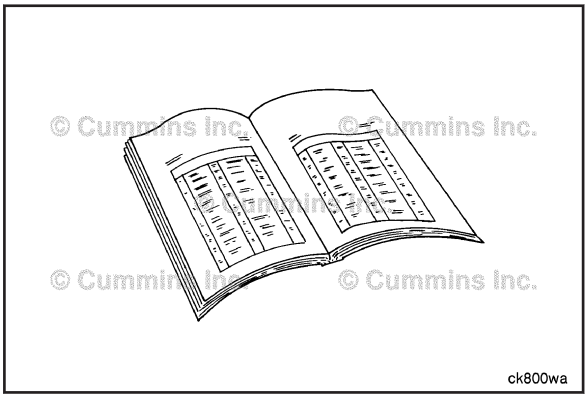
Torque Value: 34 N•m [25 ft-lb]

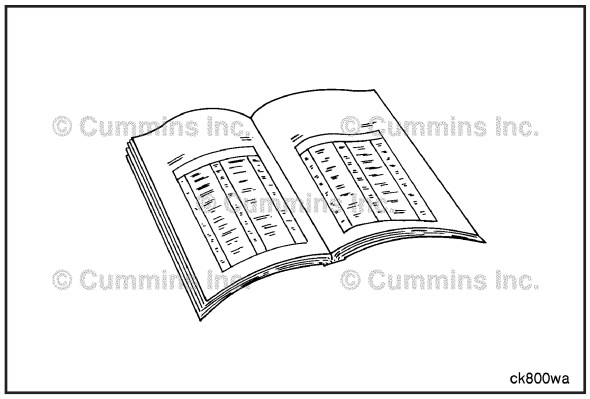


Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Connect the batteries. Refer to the OEM service manual.
- Open the fuel supply valve. Refer to the OEM service manual.
- Operate the engine and check for leaks.





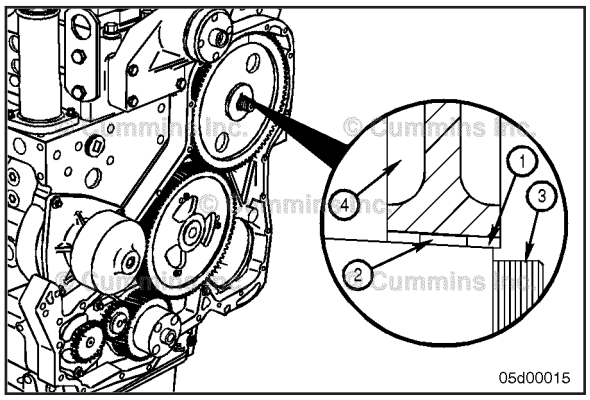
Fuel Pump Timing (005-037)

Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the gear cover. Refer to Procedure 001-031 in Section 1.
- Remove the fuel pump camshaft nut. Refer to Procedure 005-016 in Section 5.



Inspect for Reuse

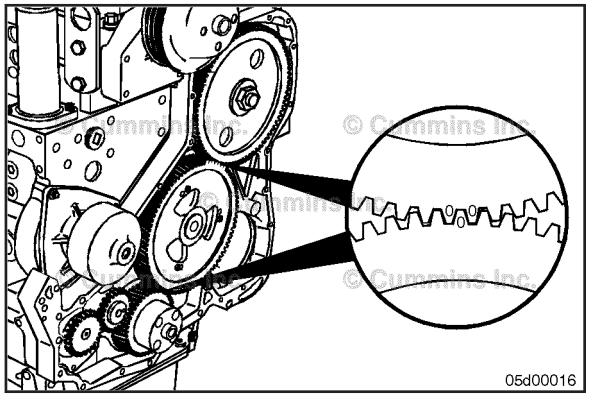
Check that the fuel pump camshaft alignment dowel is present in the fuel pump drive gear keyway. If the alignment dowel is **not** visible, remove the injection pump, determine the cause of misalignment, and repair or replace any damaged components.

1 Fuel pump gear keyway

2 Fuel pump timing dowel pin

3 Fuel pump camshaft

4 Fuel pump gear



If this inspection is being performed due to a performance complaint, and the problem first occurred after gear train removal and replacement, then check the timing of the camshaft gear to the crankshaft gear and the camshaft gear to the fuel pump drive gear.

If this inspection is being performed due to a performance complaint, and the problem first occurred after gear train removal and replacement, then check the timing of the camshaft gear to the crankshaft gear and the camshaft gear to the fuel pump drive gear. Refer to Procedure 001-012 in Section 1.

If the engine camshaft gear is mistimed in relation to the crankshaft gear, intake and exhaust valve events will **not** be optimized. Also, for CAPS injection pump fuel systems, the primary speed sensor reads the tonewheel on the camshaft gear and fuel injection timing will be incorrect.

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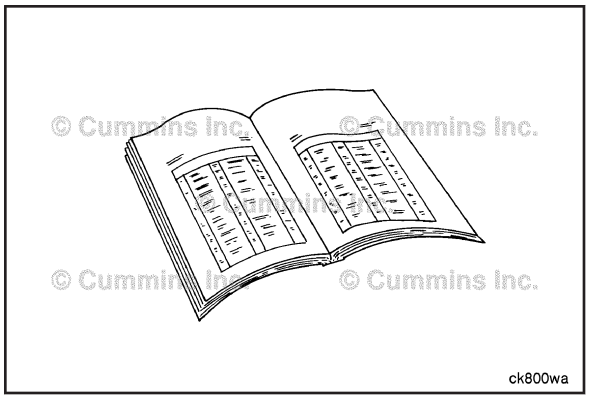
Finishing Steps

Install and tighten the injection pump camshaft nut. Refer to Procedure 005-016 in Section 5. Refer to Procedure 005-229 in Section 5.

Install the front gear cover. Refer to Procedure 001-031 in Section 1.

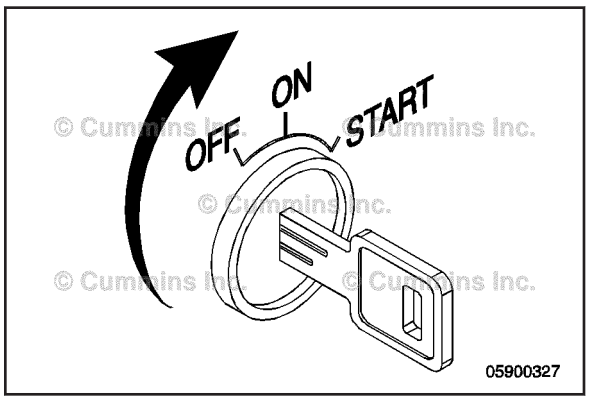


Fuel Lift Pump (005-045)

Initial Check

A malfunctioning electric fuel lift pump can cause slow engine starts or can result in an engine failing to start. The fuel lift pump can be cleaned and repaired to a limited extent.

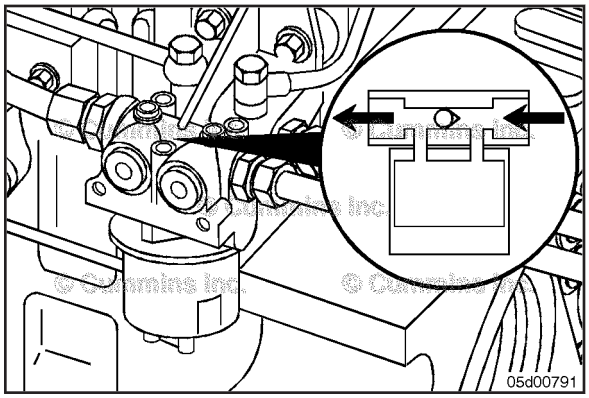
The lift pump will operate for 30 to 60 seconds when the key is switched ON. The lift pump will also operate while the engine is cranking.



Block Mounted Lift Pump

The lift pump is contained in an assembly that includes fuel supply and drain manifolds. These manifolds provide for OEM connection of fuel supply and return hoses. The fuel supply manifold also contains M10 STORM fittings which allow for pressure and vacuum measurement of the fuel supply at the electric lift pump.

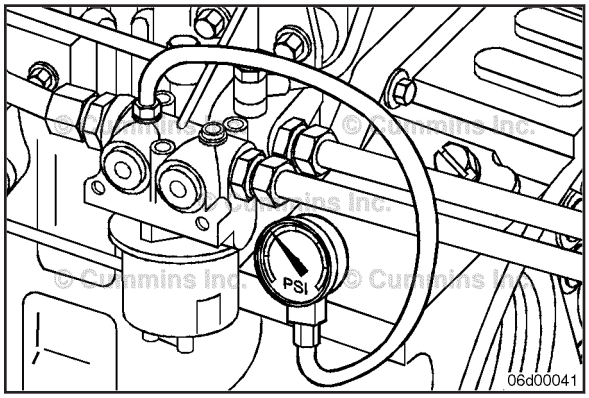
A bypass check valve in the fuel supply manifold makes sure the system is primed by the lift pump. This check valve opens under vacuum created by the fuel injection pump, once the engine is started. High vacuum measured between the electric lift pump and the fuel filter can indicate this check valve has become plugged.

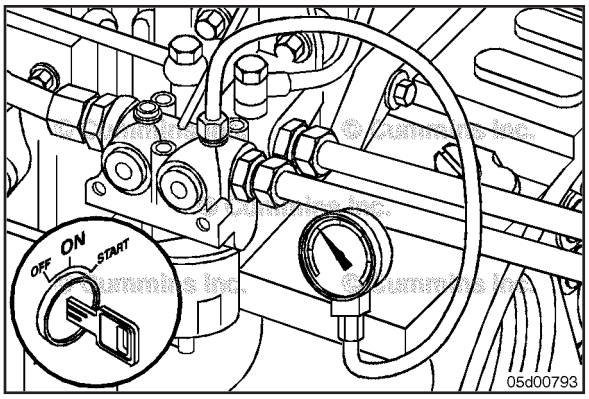


The output of the fuel lift pump can be checked through the following test:

- Measure the output pressure. Use a pressure gauge at the lift pump outlet port.

Fuel Lift Pump Output Pressure		
kPa		psi
35	MIN	5





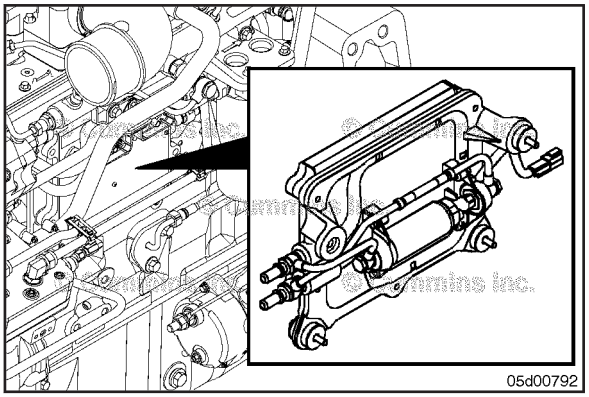
The lift pump check valve restriction can be determined using the following test:

1 Install a 0 to 762 mm Hg [0 to 30 in Hg] vacuum gauge at the inlet and outlet M10 STORM ports on the electric lift pump head

2 Operate the engine at rated power condition

3 Record the inlet restriction at the inlet and outlet of the lift pump. Refer to Procedure 006-020 in Section 6.

Fuel Lift Pump Inlet Restriction		
mm Hg		**in Hg**
102	MAX	4

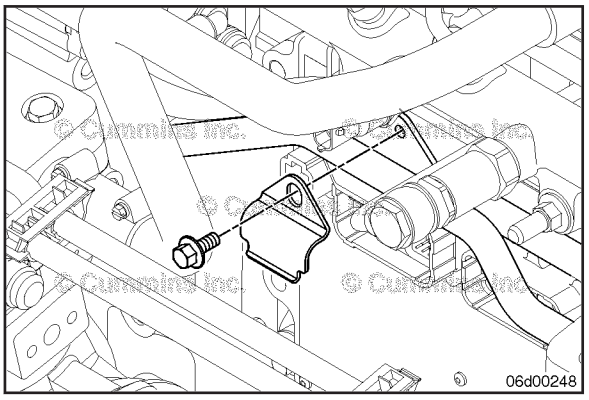


ECM Cooling Plate Mounted Lift Pump

A lift pump is mounted to the back of the ECM cooling plate.

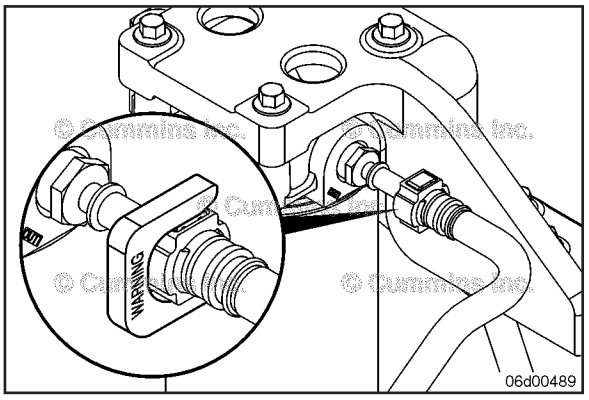
A bypass check valve in the ECM cooling plate makes sure the system is primed by the lift pump. This check valve opens under vacuum created by the gear pump, once the engine is started. High vacuum measured between the electric lift pump and the gear pump can indicate this check valve has become plugged.

The ECM cooling plate check valve is integral with the lower (outlet) fitting of the ECM cooling plate.



Fuel Lift Pump Flow Test Setup

Remove the clasp from the fuel line brace. This will allow the fuel lines to move so that test equipment can be installed properly.

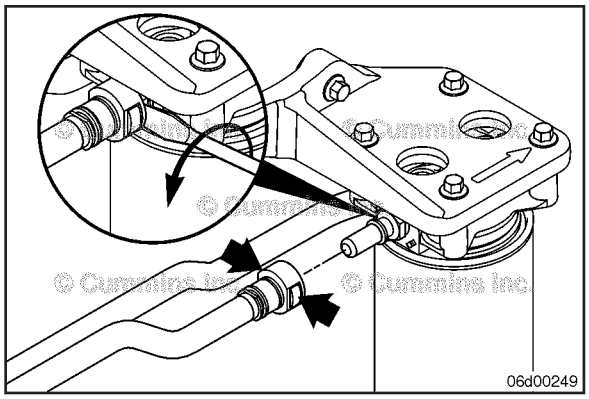


Disconnect the quick disconnect style fuel line from the gear pump inlet by pressing in the locking tangs on both sides of the quick disconnect fitting.

To aid in the removal of quick disconnect style fuel lines, slide removal tools, Part Number 4918878, over the locking tangs. Make sure the tool is removed from the fuel line as soon as possible after the line has been disconnected.

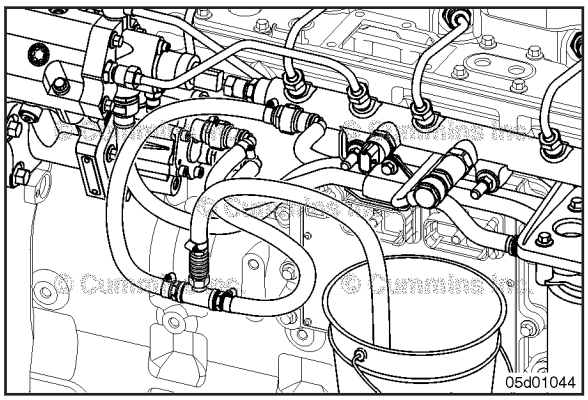
Inadvertently leaving the tool in place can result in fuel leaks.

To aid in removal, a screwdriver may be inserted between the fuel line end and quick disconnect male union. After pressing the opposing locking tangs, twisting the flat blade of the screwdriver helps to remove the fuel line.



Install diagnostic fuel line, Part Number 4918895, between the gear pump fuel supply line and the gear pump innlet.

Connect orifice diagnostic fuel line, Part Number 3164621, to the Compuchek™ fitting on the diagnostic fuel line, Part Number 4918895, and run hose into a collection device.



NOTE: At initial key-on, the lift pump will run for 30 seconds and then stop.

Turn key switch to the "On" position and allow fuel to flow into a collection device for 10 seconds (or until fuel stream is continuous.)

NOTE: It may take longer than 10 seconds for fuel stream to flow continuously during the first key-on cycle due to air in the diagnostic fuel lines.

Once fuel flow is continuous, transfer the orifice diagnostic fuel line to a clear graduated cylinder and allow fuel to flow into the graduated cylinder for 10 seconds.

Remove the orifice diagnostic fuel line from graduated cylinder after 10 seconds and turn key switch to the "Off" position.

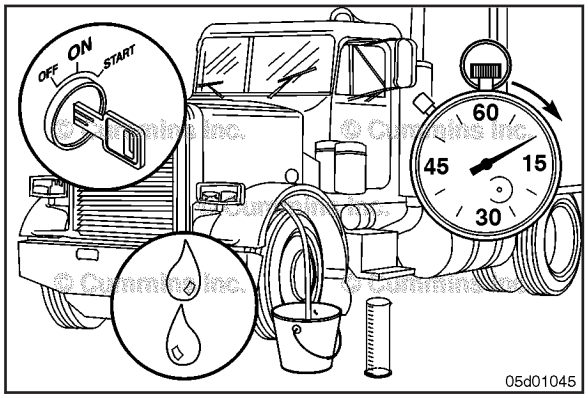
Record the volume of fuel collected over 10 seconds.

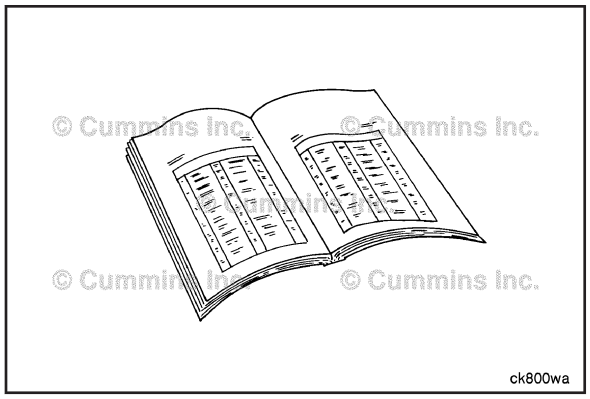
Repeat this test 3 times and take an average of the flow rates.

Minimum volume of fuel during 10 second fuel lift pump flow test 100 ml [3.4 fl-oz]

NOTE: If the lift pump flow is low while the lift pump runs, make sure the ECM cooling plate check valve is not blocked open. Also, make sure the OEM connection inlet restriction is within specification.

NOTE: If the lift pump flow is low while the lift pump runs, make sure fuel is primed. For example, following fuel filter replacement; it is necessary to cycle the fuel lift pump three or four times before the air is purged.





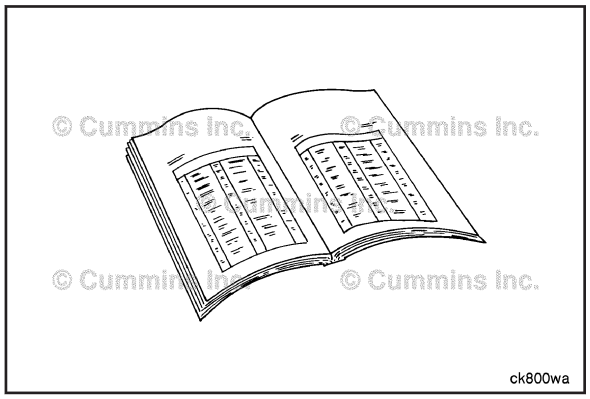
Preparatory Steps

Block Mounted Lift Pump

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery cables. Refer to Procedure 013-009 in Section 13.
- Thoroughly clean the fittings and components before removal. Make sure that debris, water, steam, or cleaning solution do **not** get inside the fuel system.
- Remove the fuel lift pump inlet and outlet fuel lines. Refer to Procedure 006-024 in Section 6.
- Disconnect the fuel pump power lead.



ECM Cooling Plate Mounted Lift Pump

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

△CAUTION△

Use caution when 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.

- Disconnect the negative (-) battery cable first. Refer to Procedure 013-009 in Section 13.
- Disconnect the electric fuel priming pump from the engine wiring harness.
- Shut off the fuel supply valve. Refer to the OEM service manual.

NOTE: Thoroughly clean fittings and components before removal. Make sure that debris, water, steam or cleaning solution do **not** get inside the fuel system.

- Remove the fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Remove the ECM cooling plate. Refer to Procedure 006-006 in Section 6.

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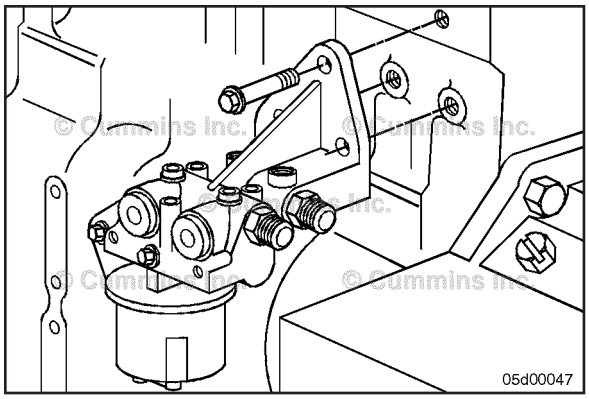
Remove

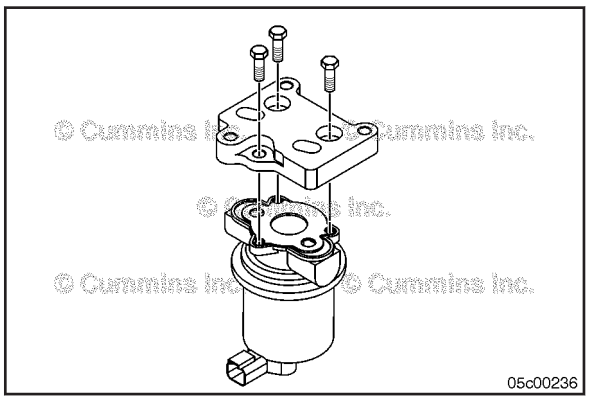
Block Mounted Lift Pump

⚠CAUTION⚠
The lift pump contains loose parts and is sensitive to debris. Use care when removing the lift pump body from the adapter to make sure the parts are intact and the pump is not exposed to any debris. Failing to do so can cause the pump to malfunction or have premature wear.

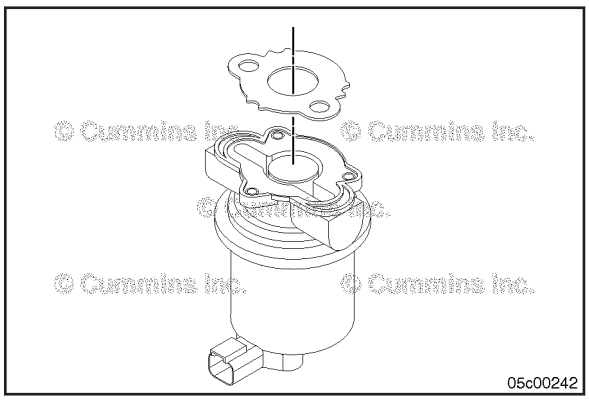
Remove the three capscrews at the top of the lift pump adapter.



Remove the three bolts which connect the adapter to the lift pump body.



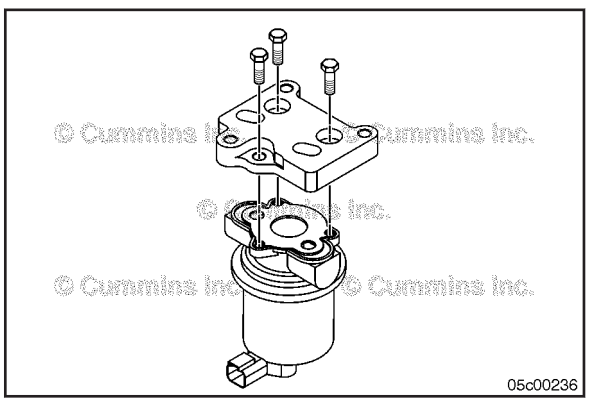
Replace the fuel lift pump gasket.

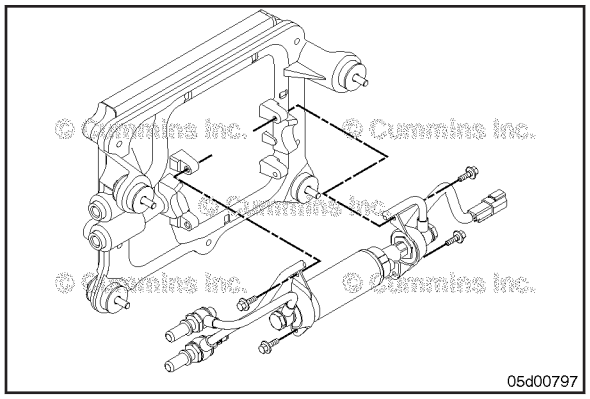


Connect the adapter and lift pump assembly.

Tighten the bolts.

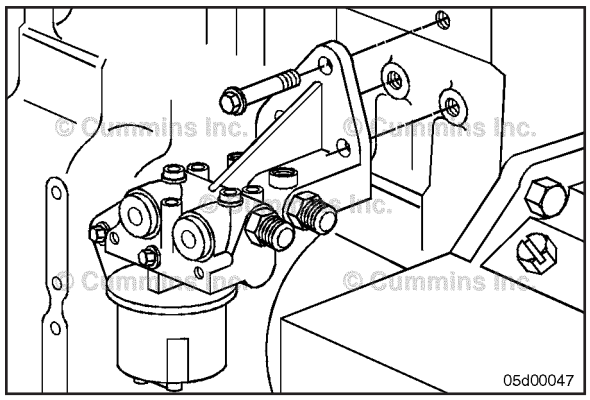
Torque Value: 12.4 N•m [110 in-lb]





ECM Cooling Plate Mounted Lift Pump

Remove the electric lift pump from the ECM cooling plate.



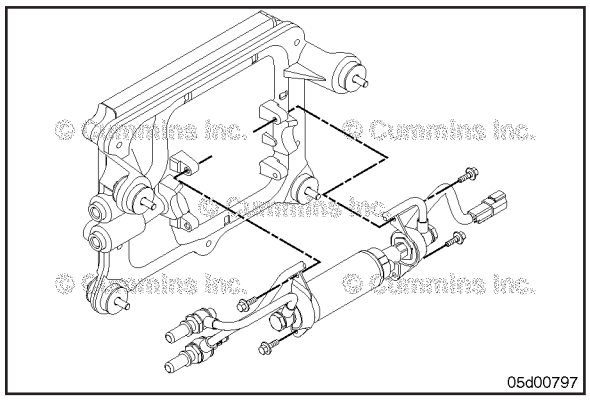
Install

Block Mounted Lift Pump

Install the fuel lift pump adapter to the block. Use the three capscrews.

Tighten the capscrews.

Torque Value: 43 N•m [32 ft-lb]



ECM Cooling Plate Mounted Lift Pump

Install the electric lift pump to the ECM cooling plate.

Tighten the mounting capscrews.

Torque Value: 10 N•m [89 in-lb]

NOTE: The ECM cooling plate check valve **must** be free of debris and installed into the lower ECM cooling plate port (outlet port).

NOTE: Hold the fuel lines, as shown, so they can **not** come into contact with each other or the engine block.

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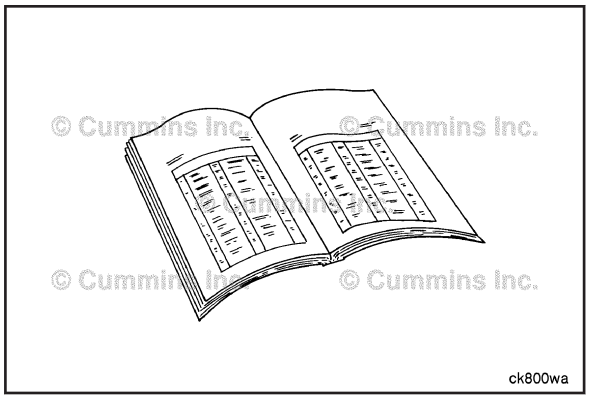
Finishing Steps

Block Mounted Lift Pump

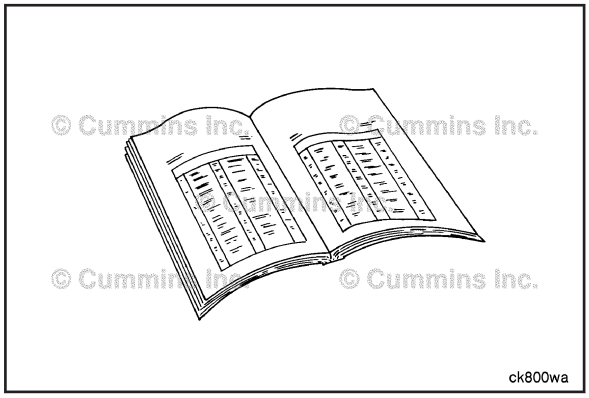


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the power lead to the fuel lift pump.
- Install all removed fuel lines. Refer to Procedure 006-024 in Section 6.
- Connect the battery cables. Refer to Procedure 013-009 in Section 13.
- Turn the key on with the engine off. The lift pump will run for 30 to 60 seconds.

Verify that the lift pump is **not** leaking.

ECM Cooling Plate Mounted Lift Pump



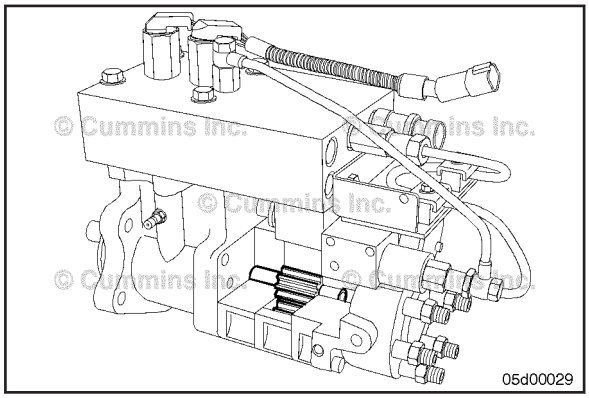
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the ECM cooling plate to the engine block. Refer to Procedure 006-006 in Section 6.
- Install all fuel lines. Refer to Procedure 006-024 in Section 6.
- Connect the battery, negative (-) cable last. Refer to Procedure 013-009 in Section 13.
- Open the fuel valve. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Rotor, CAPS Fuel Injection Pump (005-072)

General Information

This procedure refers to the CAPS fuel system.



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Preparatory Steps

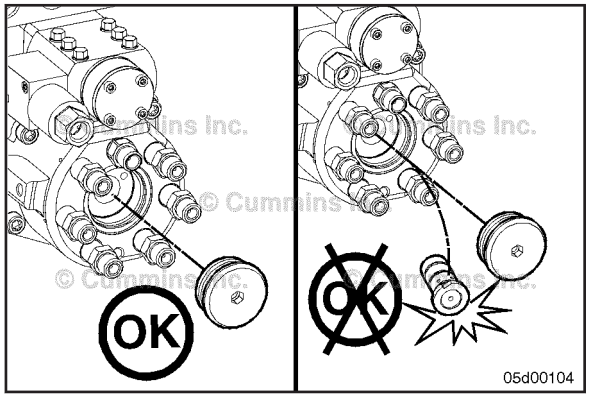
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturers recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠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.

Steam clean the fuel injection pump and the engine in the vicinity of the fuel pump.

Dry with compressed air. Pay special attention to the distributor area.

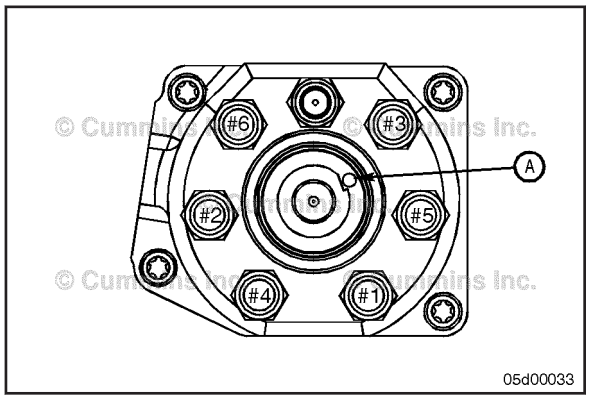


Remove

△CAUTION△
The rotor can slide out during the removal of the distributor plug. If the rotor is dropped, the entire distributor module must be replaced. Do not attempt to start the engine with the distributor plug removed. Doing so can cause the rotor to be ejected from the distributor, causing damage to the rotor.

ISL Only: Remove the air bleed line. Refer to Procedure 006-056.

Remove the distributor plug, being sure the rotor does **not** fall out.



Clean and Inspect for Reuse

Check the position of the notch on the rotor. It **must** line up with the alignment mark (A) on the outside of the distributor (when the engine is barred to top dead center (TDC) for the number 1 cylinder). If the alignment is correct, the rotor is properly timed to the engine.

If a mechanical problem exists, indicated by misalignment of the rotor, the entire fuel pump will have to be replaced; Refer to Procedure 005-016.

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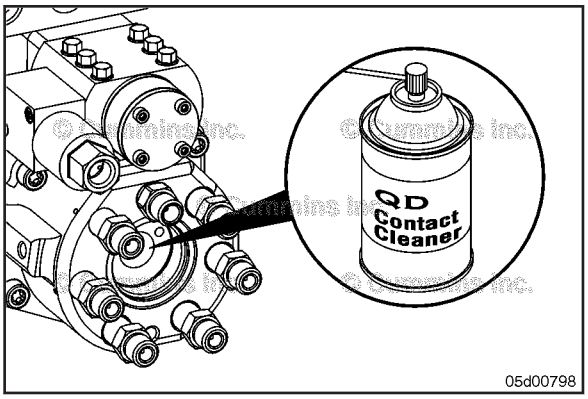
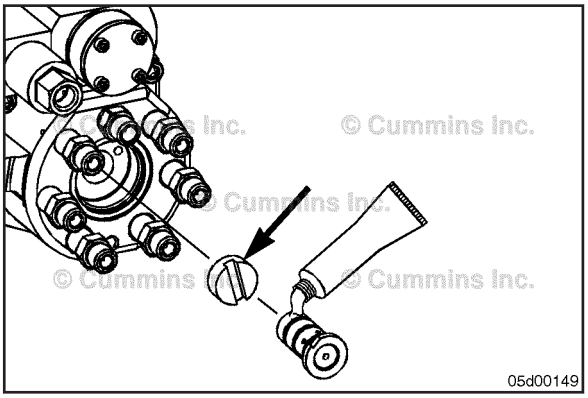
Clean the rotor bore with QD contact cleaner, Part Number 3824510.



Install

Use Lubriplate™ 105, or equivalent, between the drive coupling and the rotor to prevent it from falling off during assembly.



⚠CAUTION⚠
The rotor must be properly timed to the fuel pump camshaft. Improper assembly will cause the rotor to be 180 degrees out of time.

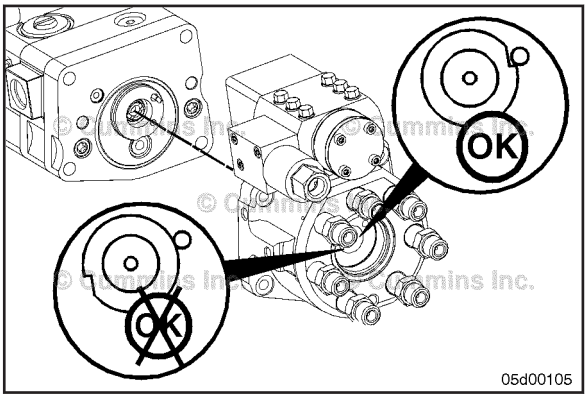
Insert the rotor and coupling into the distributor module completely.

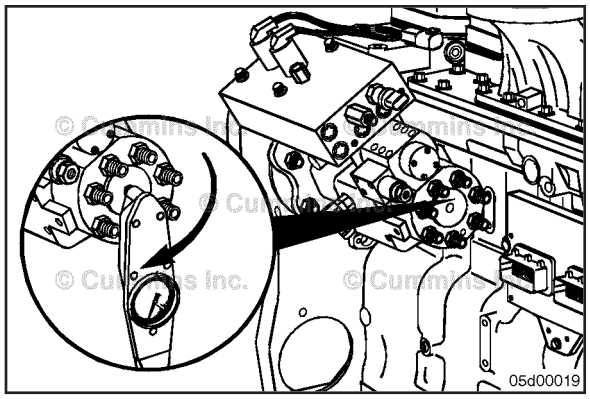
Lightly rotate the rotor with finger-pressure until it drops into the slot in the drive coupling.

When properly engaged, the notch in the rotor will align with the hole in the distributor while the engine is at Number 1 cylinder TDC.

If the rotor will **not** engage, remove the rotor and drive coupling and try again. Do **not** tighten the rotor cap if the coupling will **not** engage.

If **not** properly timed, remove the rotor and drive coupling and repeat the previous step. Make sure the fuel pump camshaft dowel pin is pointing toward the top of the fuel pump before installing.





Install the distributor plug and torque.

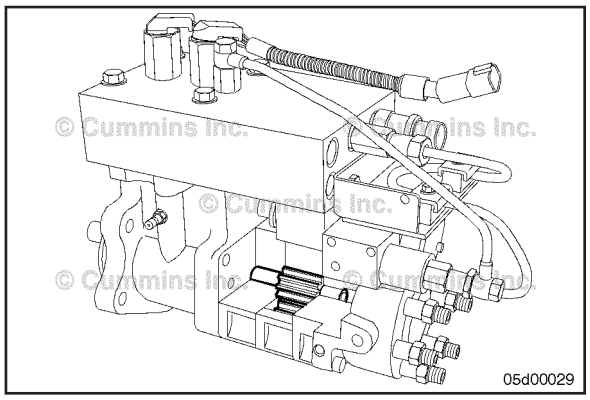
Torque Value: 14 N•m [10 ft-lb]

NOTE: Be sure the rotor is fully engaged before replacing the plug.

ISL Only: Install the air bleed line. Refer to Procedure 006-056 in Section 6.

Finishing Steps

- Operate the engine and check for leaks.

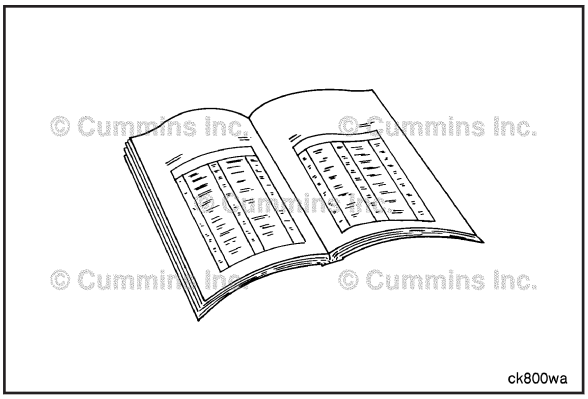


Injection Control Valve (005-078)

General Information

This procedure refers to the CAPS fuel system.

Preparatory Steps



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

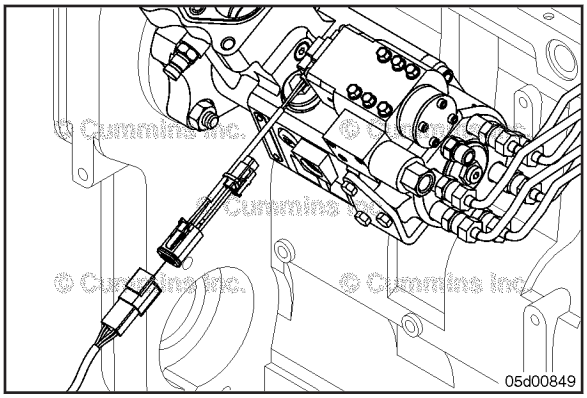
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△
Fault codes can occur if steam sprays directly on the electrical connections on top of the accumulator block.

- Thoroughly steam-clean the entire fuel pump.
- Dry the fuel pump with compressed air.
- Remove the fuel injection pump accumulator. Refer to Procedure 005-085 in Section 5.

Remove

Unplug the engine wiring harness from the injection control valve connector.



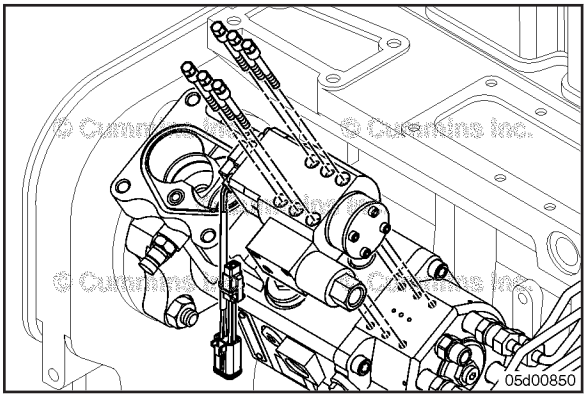
Remove the injection control valve drain line.

Remove the six injection control valve mounting screws.

Remove the injection control valve from the distributor module.

Do **not** misplace parts during disassembly.

Secure the six bolts, sealing plate, and both crush tubes into a parts bag. The parts are to be returned with the core.



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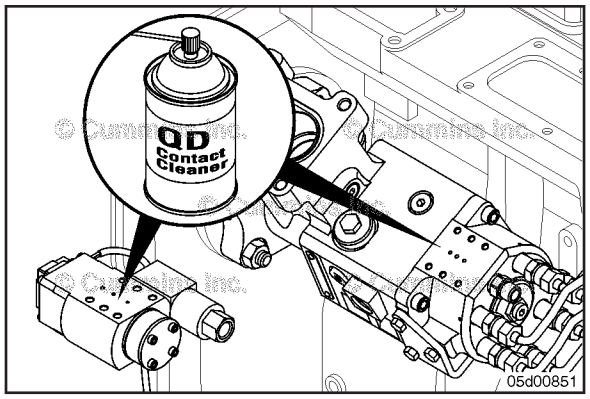


Clean and Inspect for Reuse

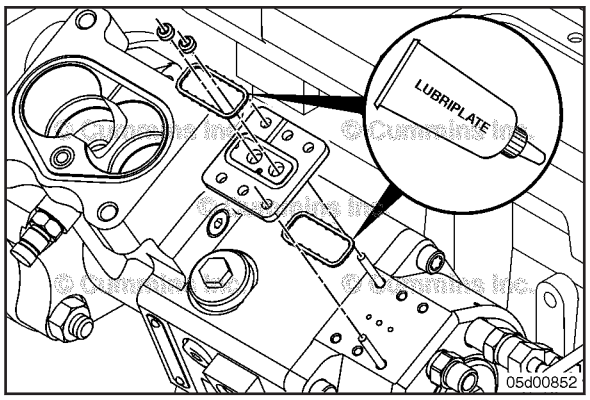
Clean the mounting surface of the distributor module and injection control valve.

Use QD™ contact cleaner, Part Number 3824510.

Spray or wipe debris away from the three distributor module drillings. Do **not** allow debris to enter the distributor module drillings.

Inspect the distributor module sealing face for cracks, indentations, and damage.

Replace the distributor module if damage is found.



Install

Install guide pins, Part Number 3165166, in the upper left and lower right corner of the distributor module.

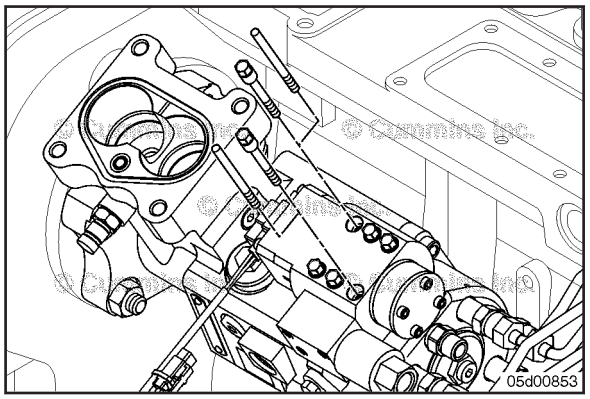
Install the o-rings into the sealing plate using Lubriplate™ to hold them in place.

Slide the sealing plate down over the guide pins.

The o-rings **must** be securely seated in the sealing plate before proceeding.

Insert crush tubes into the sealing plate.

Check the position of the crush tubes. They **must** sit flush on the distributor module and **must not** be installed at an angle.



Install the injection control valve on top of the distributor module using guide pins.

Check that the o-rings are still in their grooves.

Install four bolts through the injection control valve and tighten finger tight.

Remove the two guide pins.

Install the two remaining bolts, finger-tight, through the injection control valve.

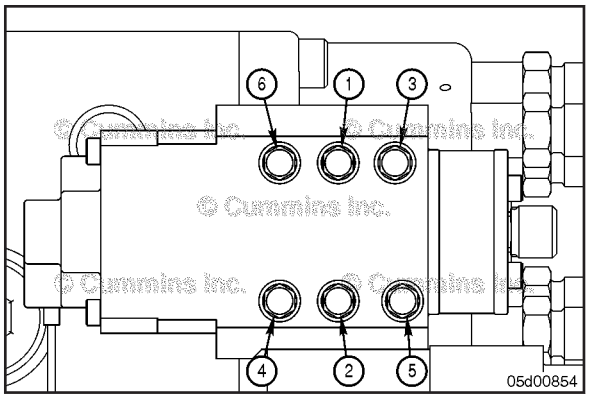
⚠CAUTION⚠

Bolts must be torqued as described or the injection control valve/distributor module will not function properly. Use a high-quality, calibrated torque wrench.

Tighten the bolts in sequence for each step. Refer to the accompanying illustration for the torque sequence.

Torque Value:

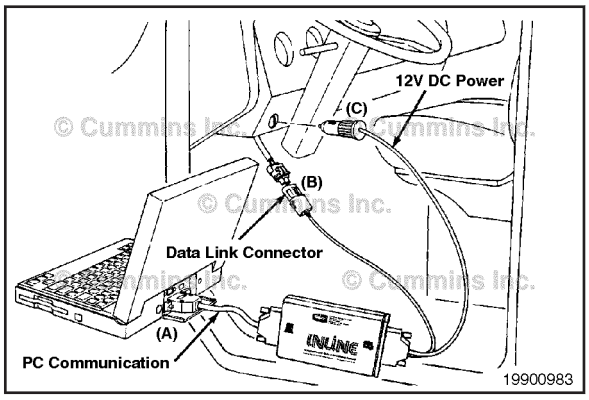
Step 1	1.8 N•m	[16 in-lb]
Step 2	3.6 N•m	[32 in-lb]
Step 3	5.6 N•m	[50 in-lb]
Step 4	Torque to 5.6 N•m [50 in-lb] three more times following the torque sequence	



Install the injection control valve drain line.

Click Test

Use INSITE™ electronic service tool, with the keyswitch in the ON position, to run the Control Valve Click Test.

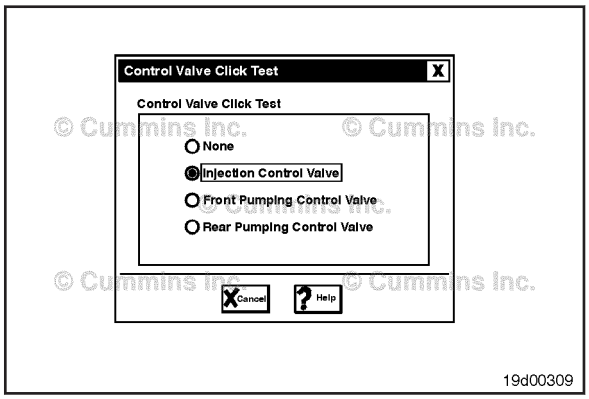


Select Injection Control Valve to initiate the test.

A click will be heard until None is selected on the Control Valve Click Test screen.

If no click is heard, troubleshoot any active fault codes.

The click test will need to be performed after any repairs are made to clear the fault codes.



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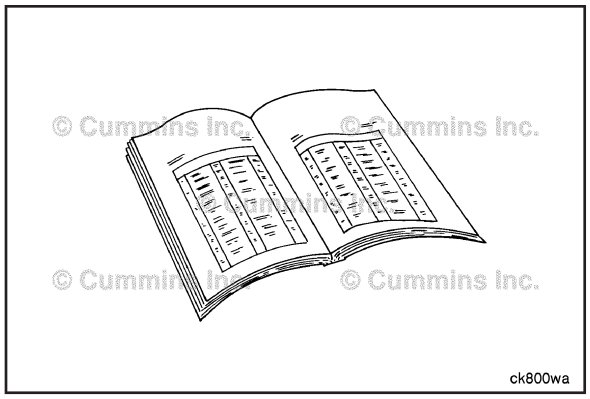
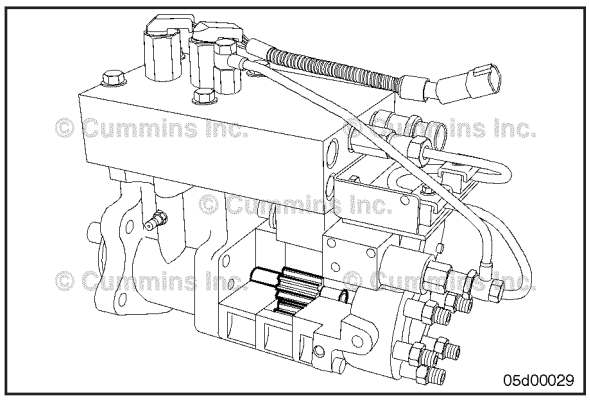


Finishing Steps

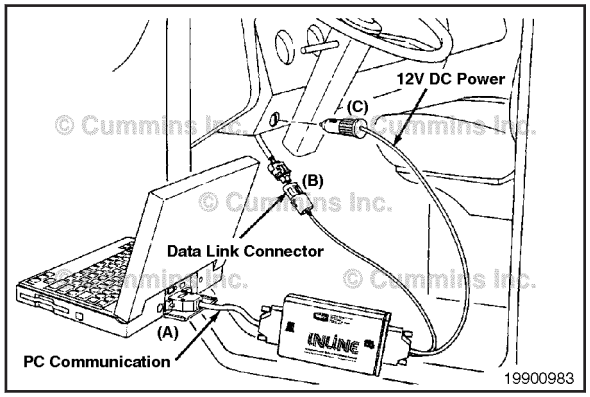
- Install the fuel injection pump accumulator. Refer to Procedure 005-085 in Section 5.
- Install the air bleed line. Refer to Procedure 006-056 in Section 6.
- Install the drive gear cover.
- Connect the fuel pressure sensor and the fuel temperature sensors to the engine harness.
- Connect the pumping control valve connector to the engine harness.
- Connect the stator connector to the engine harness.
- Click test the injection control valve stator to check for proper operation. Refer to click test in this procedure.
- Start the engine and check for fuel leaks or active fault codes.
- Check for fuel leaks or active fault codes.



Pumping Control Valve (005-079)

General Information

This procedure refers to the CAPS fuel system.



Click Test

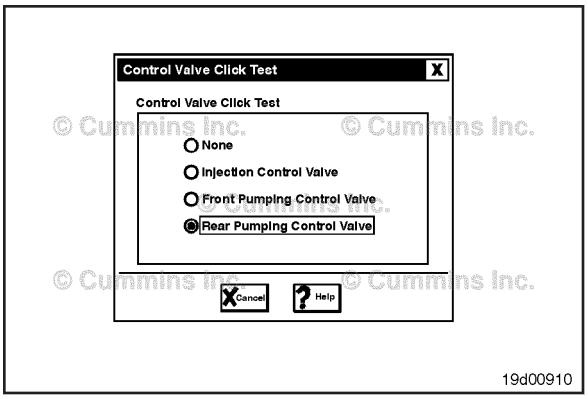
Use INSITE™ electronic service tool, with the keyswitch in the ON position, to run the Control Valve Click Test.

Select the pumping control valve to be tested to initiate the test. Select either front control valve or rear control valve.

A “click” will be heard until the other pumping control valve is selected, or None is selected on the Control Valve Click Test screen.

If no “click” is heard, troubleshoot any active fault codes.

NOTE: The click test will need to be performed after any repairs are made to clear the fault codes.

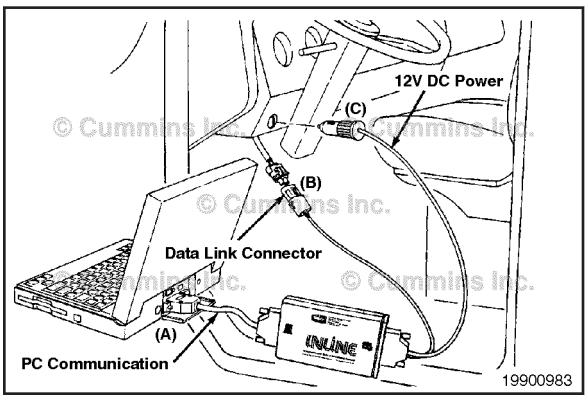


Cutout Test

The Plunger Cutout Test can be used to check performance of the front and rear pumping plungers.

NOTE: When performing this test, the engine load **must** be the same when each pumping plunger is cut out.

Use INSITE™ electronic service tool, with the engine running at idle, to perform this test.



Select the pumping control valve to be cut out.

Select the monitor button and monitor valve close angle, engine speed, and accumulator pressure while the selected plunger is cut out.

Record valve close angle, engine speed, and accumulator pressure after the engine stabilizes.

After testing with one pumping control valve disabled, select “None” so that the engine will run with both valves enabled. Switching directly from “Front” to “Rear” or “Rear” to “Front” will cause the engine to misfire or hesitate.

Cut out the other pumping control valve, and record valve close angle, engine speed, and accumulator pressure after the engine stabilizes.

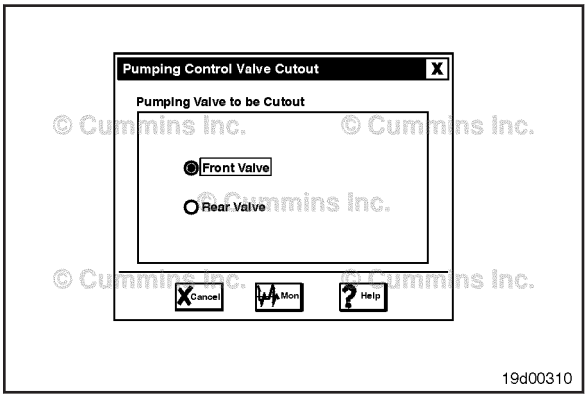
Compare the results when the rear pumping control valve is cut out against the results when the front pumping control valve is cut out.

If the engine dies when one of the pumping control valves is cut out, replace the accumulator. Refer to Procedure 005-085.

NOTE: The valve close angle **must not** vary more than 15 degrees crank angle.

If the valve close angle varies more than 15 degrees between the front and rear valves, then replace the accumulator module. Refer to Procedure 005-085 in Section 5.

NOTE: Troubleshoot any active fault codes before replacing the pump.



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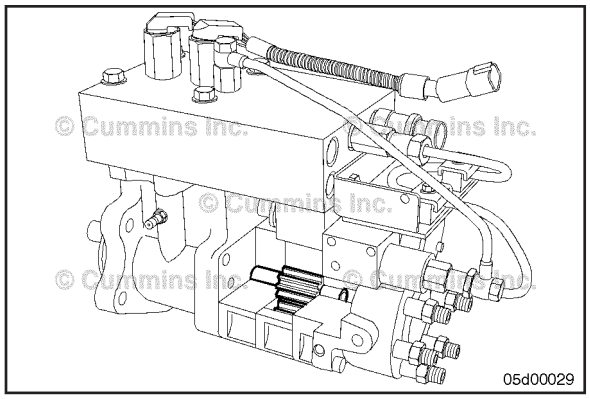
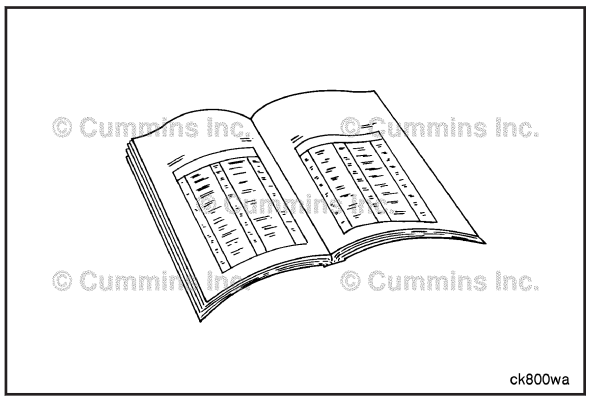


Snubber, Rate Shape (005-081)

General Information

This procedure refers to the CAPS fuel system.



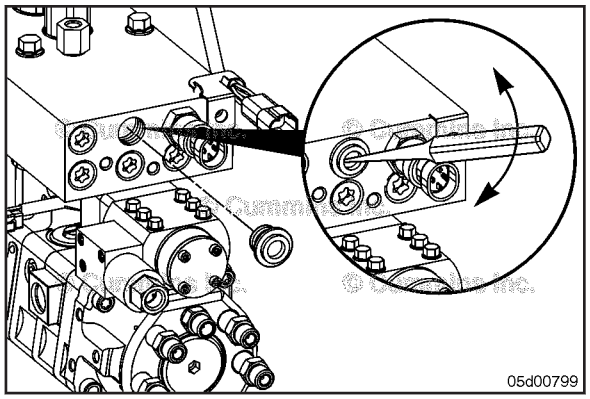
Preparatory Steps

⚠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 steam-clean the rate shape tube and fuel pump area.
- Dry with compressed air.
- Remove the rate shape tube assembly. Refer to Procedure 005-090 in Section 5.

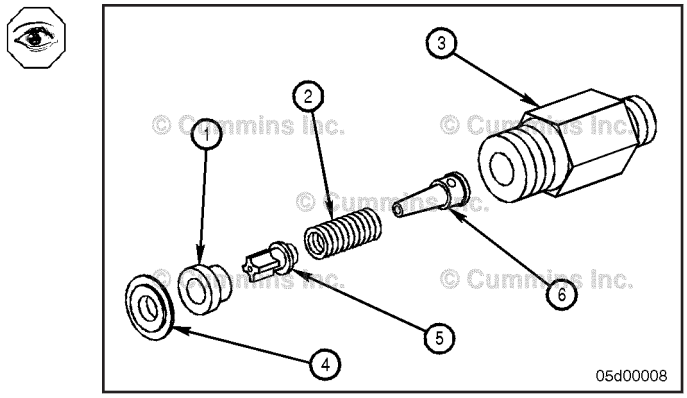


Remove

Remove the rate shape snubber assembly.

Use a center punch to pry the seal disc from the accumulator.

Inspect for Reuse



The parts in the assembly are as shown:

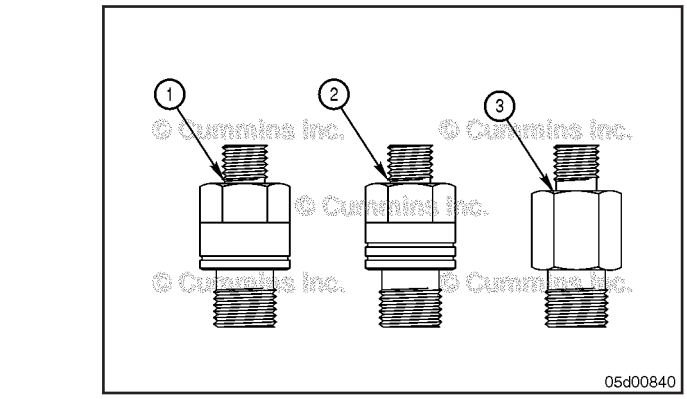
1 Snubber valve seat
2 Spring
3 Rate shape snubber body
4 Seal disc
5 Snubber valve
6 Spring post.

Replace the snubber assembly if the snubber spring is broken.

Do **not** reuse snubber seal discs.

Early design snubber valves are **not** reusable.

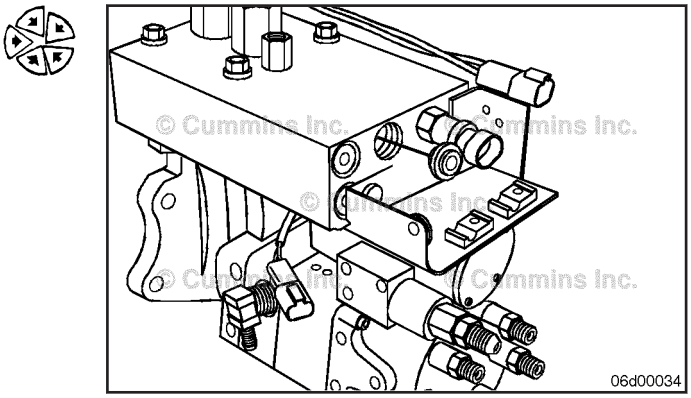
1 Part Number 3800351, first snubber valve assembly released for CAPS (one groove, **not** reusable)
2 Part Number 3800764, second snubber valve assembly released for CAPS (two grooves, **not** reusable)
3 Part Number 4010544, current snubber valve assembly released for CAPS (no grooves, may be reused); always replace the seal disk.



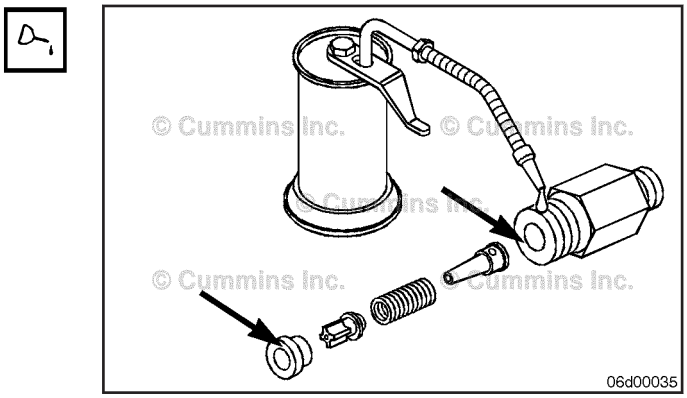
Install

Clean the bore for the distributor outlet fitting with QD cleaner prior to installation of the new snubber assembly.

Install a new seal disc into the accumulator.



Apply lubricating oil to the face of the snubber seat and to the face and threads of the snubber fitting.



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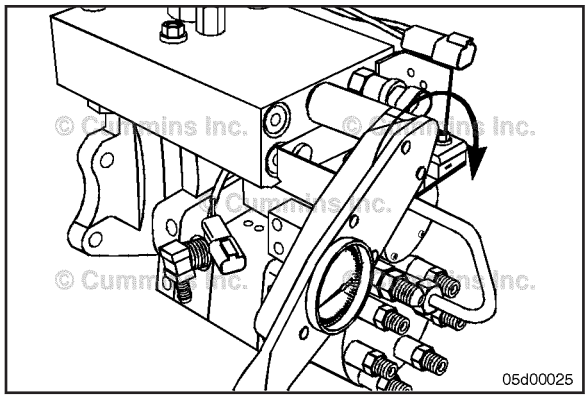
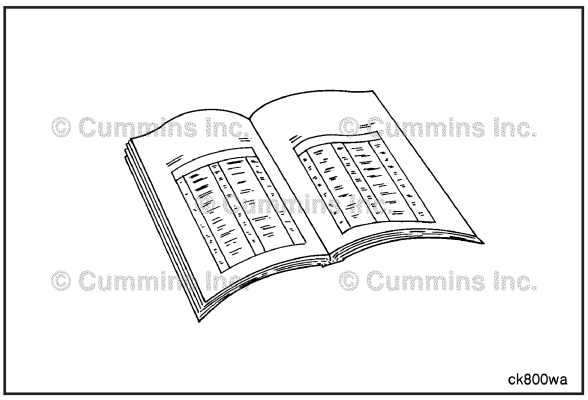


Install the snubber assembly.

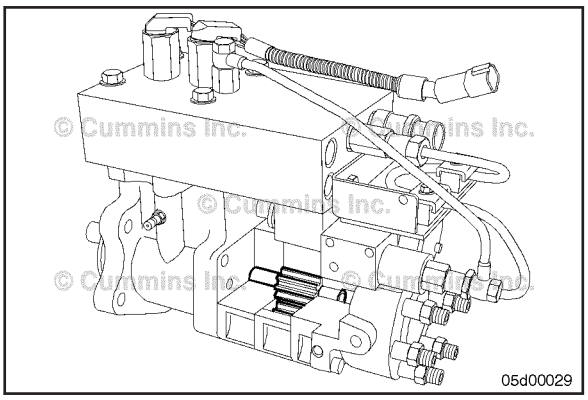
Torque Value:

Step 1	14 N•m	[124 in-lb]
Step 2	Rotate 80 degrees	



Finishing Steps

- Install the rate shape tube assembly. Refer to Procedure 005-090 in Section 5.
- Operate the engine and check for leaks.

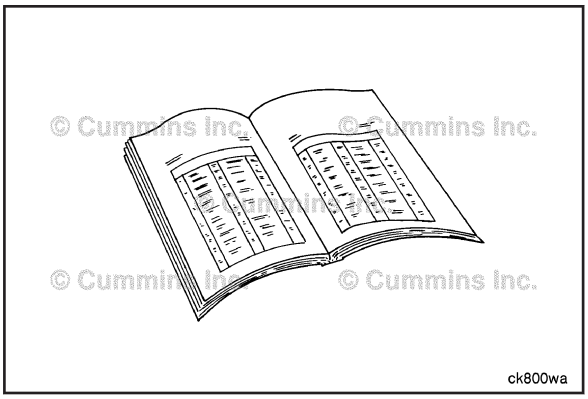


Fuel Pump Distributor Inlet Fitting (005-084)

General Information

This procedure refers to the CAPS fuel system.

Preparatory Steps



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

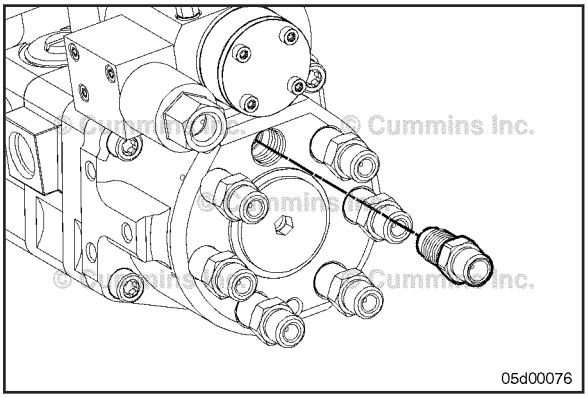
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△
Fault codes can occur if steam sprays directly on the electrical connections on top of the accumulator block.

- Thoroughly steam-clean the distributor inlet fitting and fuel pump area.
- Dry with compressed air.
- Remove the fuel pump distributor and injection control valve module assembly. Refer to Procedure 005-086 in Section 5.

NOTE: Injection control valve does not need to be removed from the distributor module.

Remove

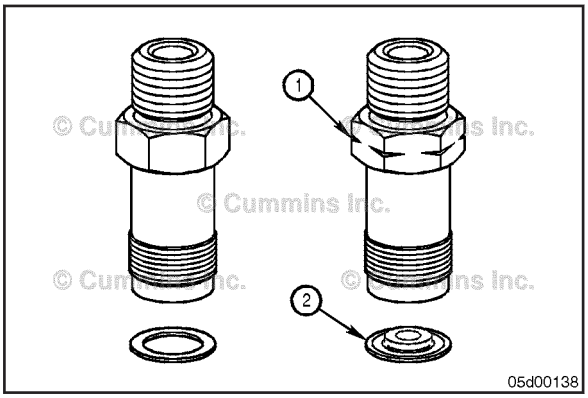


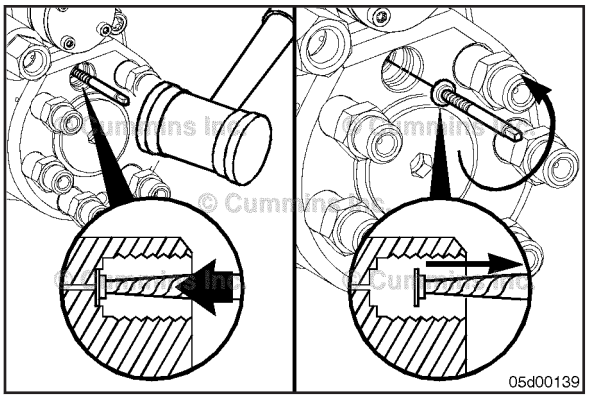
Remove the distributor inlet fitting and the seal disc.

NOTE: A tool like the one shown in this procedure can be made from a 1/8-inch or 3/16-inch Allen wrench. Use it to remove the seal disc.

Two types of inlet fittings and sealing washers may be in use. A flat washer will be installed in most new pumps and a piloted washer (2) will be installed in some ReCon® pumps.

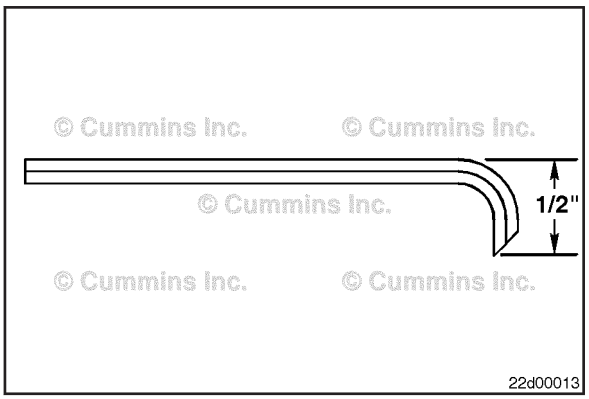
Different removal techniques are necessary based on the type of sealing washer being removed.





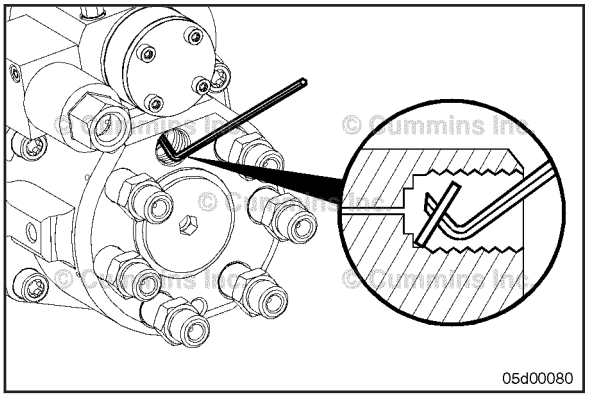
Removal of “piloted seal washer”

Use a plastic hammer to tap a spiral easy out into the center hole of the sealing washer. Turn the easy out **counterclockwise** to dislodge the washer.



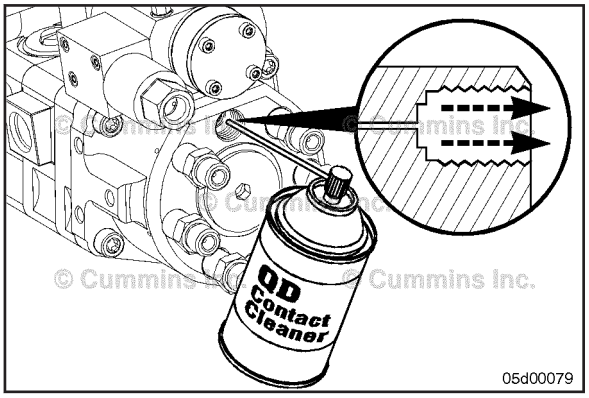
Removal of a “flat washer”

The flat sealing washer is swaged into the inlet fitting bore during installation. A special tool can be made to aid in its removal by grinding the short leg of a 1/8-inch or 3/16-inch Allen wrench so that the wrench is no longer than 13-mm [1/2-in] long (measured from the outside of the long leg). This tool acts as a mini heel bar to pry out the sealing washer without damaging the back of the hole.



Pry out the old sealing washer with the modified Allen wrench.

Substantial of force is required to remove the sealing washer.

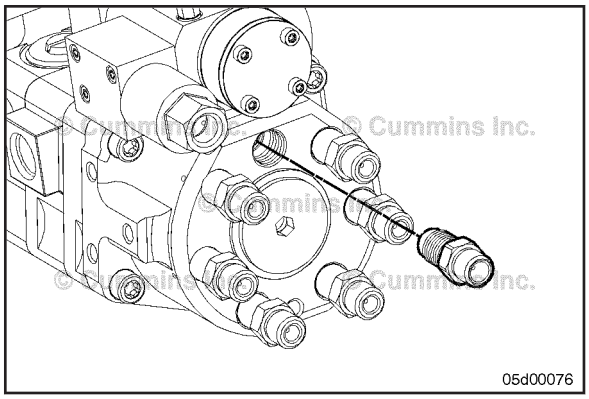


Clean and Inspect for Reuse

△CAUTION△
Any debris left in this fitting during assembly will run through the fuel pump. Damage to the fuel pump can occur.

Use QD™ contact cleaner, Part Number 3824510, to clean the inlet fitting bore from the bottom of the bore outward.

Install



⚠CAUTION⚠
Any dirt trapped in this fitting during assembly will run through the fuel pump. Damage to the fuel pump can occur.

Install the sealing washer into the distributor. Make sure the sealing washer is seated correctly in the distributor bore before installing the inlet fitting.

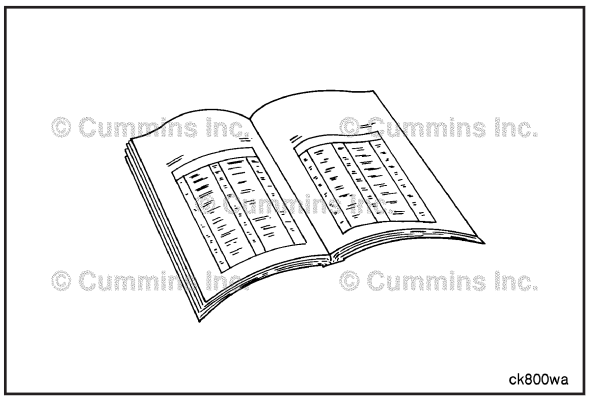
Install the new inlet fitting.

Torque Value:

Step 1	5.7 N•m	[50 in-lb]
Step 2	Rotate 120 degrees clockwise	

Finishing Steps

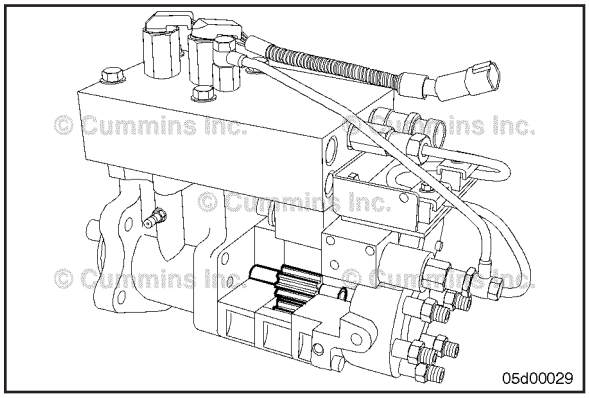
- Install the fuel pump distributor and injection control valve module assembly. Refer to Procedure 005-086 in Section 5.
- Start the engine and check for fuel leaks at the rate shape tube connections.
- Road-test the vehicle. Check again for fuel leaks or active fault codes.



Fuel Pump Accumulator Module (005-085)

General Information

This procedure refers to the CAPS fuel system.



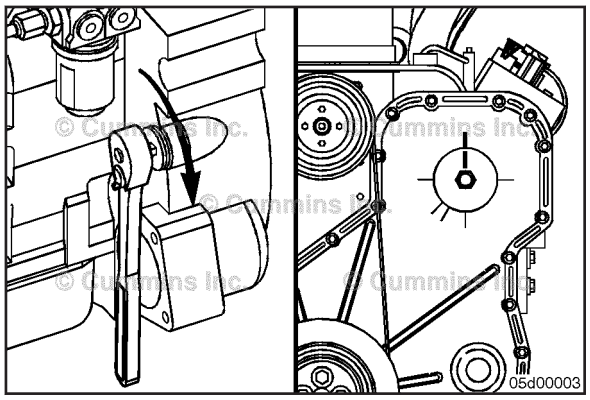
Preparatory Steps

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

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△
Make sure that steam does not spray directly on the electrical connections on the top of the accumulator block, or fault codes will possibly occur.

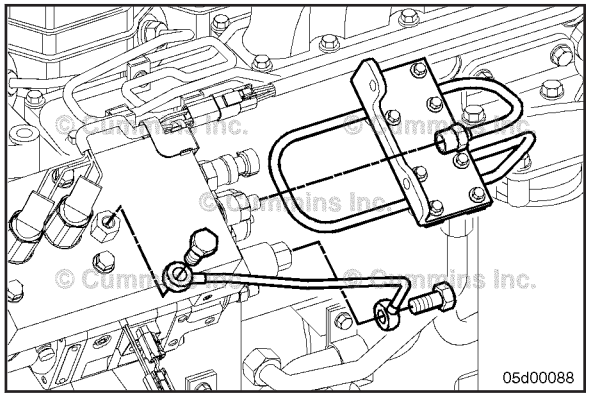
- Thoroughly steam-clean the entire fuel pump.
- Dry the fuel pump with compressed air.



Remove

Remove the fuel pump drive gear cover.

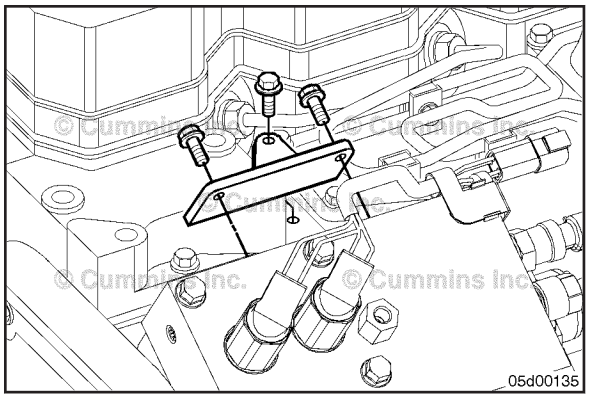
Locate top dead center for cylinder number 1 by barring the engine slowly until the line on the pump gear lines up with the line on the gear cover.



Remove the rate shape tube assembly. Refer to Procedure 005-090 in Section 5.

Remove the air bleed line. Refer to Procedure 006-056 in Section 6.

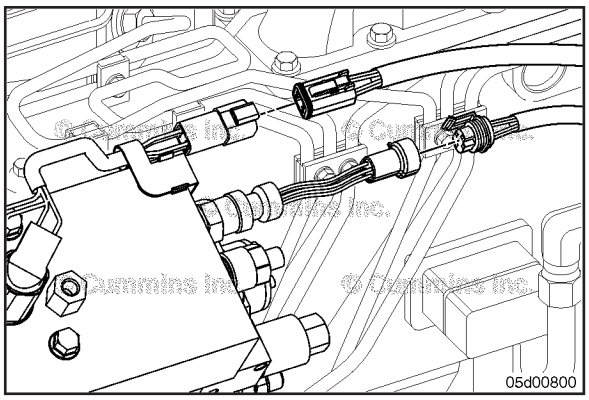
Remove the fuel pump upper support bracket.



Disconnect the 4-pin Deutsch™ connector for the pumping control valves.

Disconnect the pressure and temperature sensors.

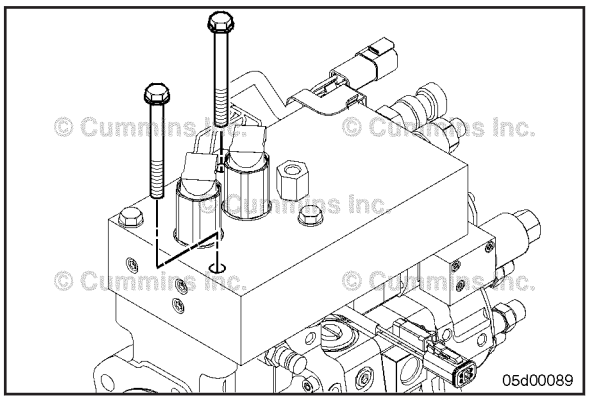
NOTE: The pressure sensor connector has a potted pigtail connector. This sensor can **only** be disconnected at the engine harness end of the pigtail harness.



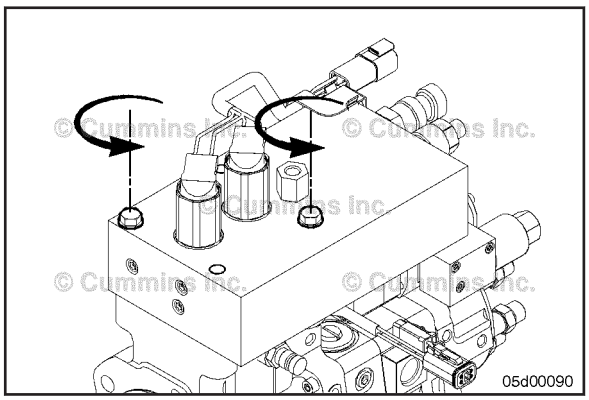
⚠WARNING⚠
The accumulator module weighs 11 kg [25 lb] and is free to move once the capscrews are removed. Do not drop; personal injury can occur.

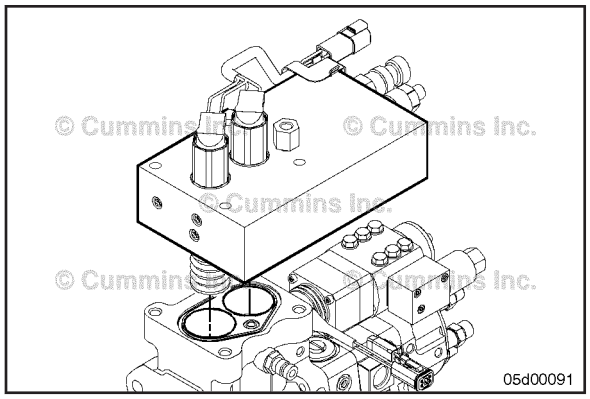
△CAUTION△
Do not use air tools. The use of air tools will possibly damage the fuel pump.

Remove two of the four capscrews that are located diagonally from one another.



Remove the last two capscrews. Alternately loosen the capscrew to avoid binding. Loosen each capscrew about one turn at a time.

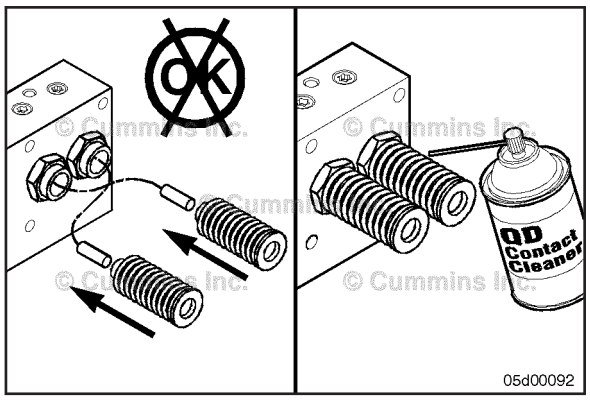




⚠WARNING⚠
The accumulator module weighs 11 kg [25 lb] and is free to move once the capscrews are removed. Do not drop; personal injury can occur.

Remove the accumulator module.

Use as much care as possible to avoid dislodging the springs from the bottom of the accumulator.



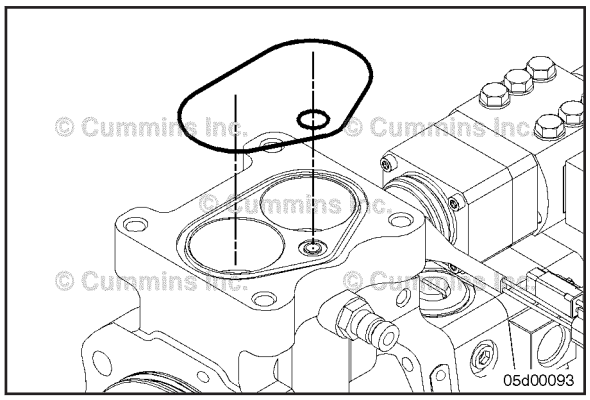
If the springs are dislodged, the ceramic plungers can fall out. The plungers are matched to each bore.

Reseat the springs fully onto plunger barrels.

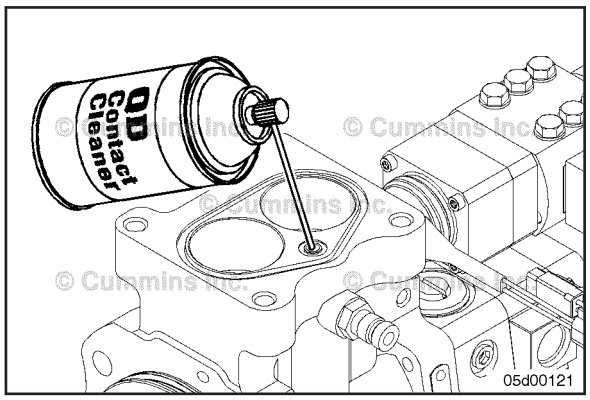
Do **not** interchange the plungers.

NOTE: Before replacing a ceramic plunger, special care needs to be taken to clean it.

Use QD™ contact cleaner, Part Number 3824510, to clean the plunger.



Remove the oil seal ring and fuel passage o-rings.



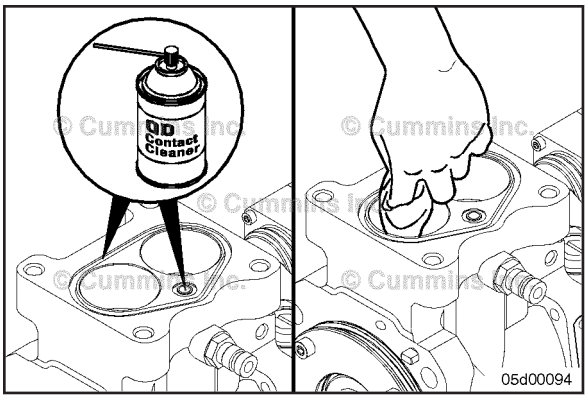
Clean and Inspect for Reuse

Clean the small fuel passage using the plastic tube provided with the contact cleaner.

Use QD™ contact cleaner, Part Number 3824510.

Clean the o-ring groove and mounting surface on the cam housing and the accumulator.

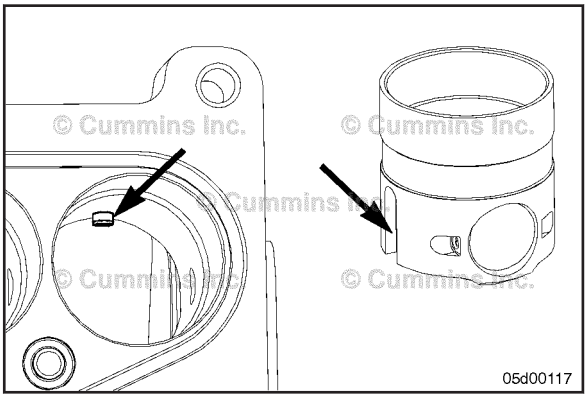
Make sure the top of the tappets in the camshaft housing are clean. Wipe out debris with a clean towel.



Check the tappets for proper alignment.

The tappets have a slot on the side that engages a pin on the engine side of the camshaft housing. The pin keeps the roller aligned with the camshaft. Make sure the tappet assembly is properly aligned. Make sure the tappet guide pins and guide pin grooves are **not** worn excessively.

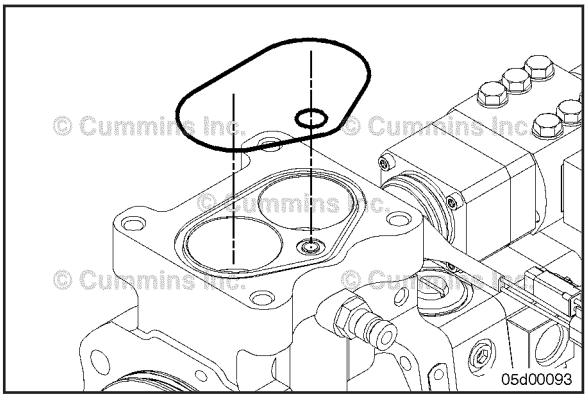
With the tappets removed, the tappet rollers and camshaft can be inspected. Linear scratches on the camshaft and rollers is expected; pitting on the nose of the camshaft is **not**.



Install

Install a new oil ring seal and fuel passage o-ring.

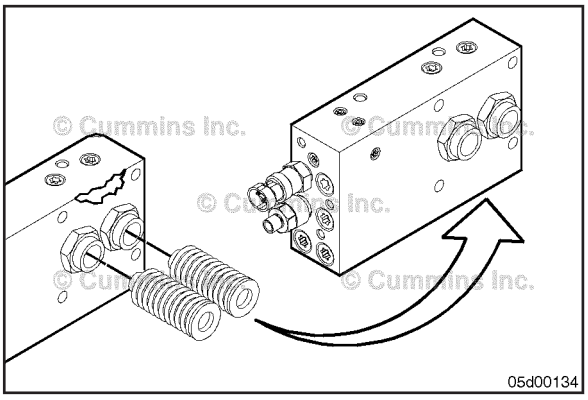
Apply Lubriplate™ 105, or equivalent, to the o-ring grooves to hold the o-rings in place.

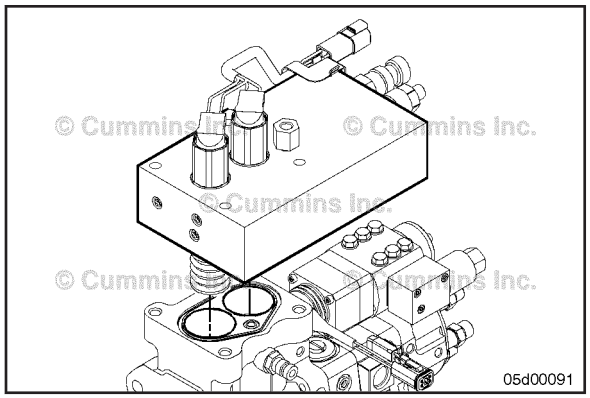


⚠CAUTION⚠
The ceramic plungers can fall out when removing the plastic caps or old springs. Do not interchange the plungers. If they fall out, use QD™ contact cleaner, Part Number 3824510, to clean the plungers thoroughly before replacing them.

If replacing the accumulator module with a new one, remove the springs from the old accumulator module.

Fully install the springs on the plunger barrels of the new accumulator module.

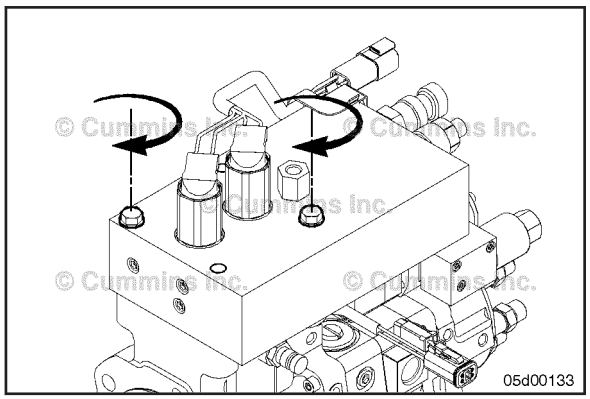




NOTE: The use of two 10-mm x 80-mm studs will aid in the installation.

Install the accumulator module.

NOTE: Use care to avoid dislodging the springs on the accumulator and the o-rings on the camshaft housing.

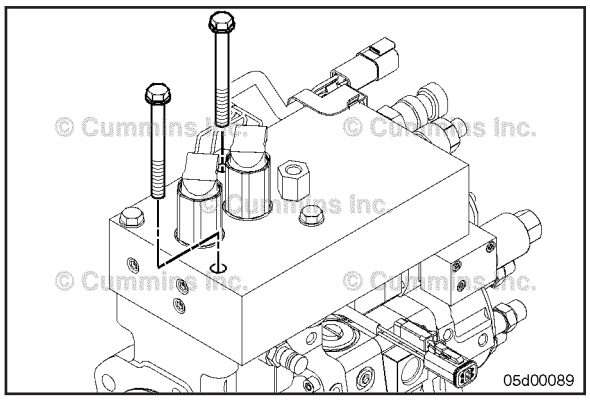


⚠CAUTION⚠
Do not use air tools. The use of air tools will possibly damage the fuel pump.

Install two of the four capscrews.

Draw the accumulator module down evenly. **Only** turn each capscrew about one turn at a time.

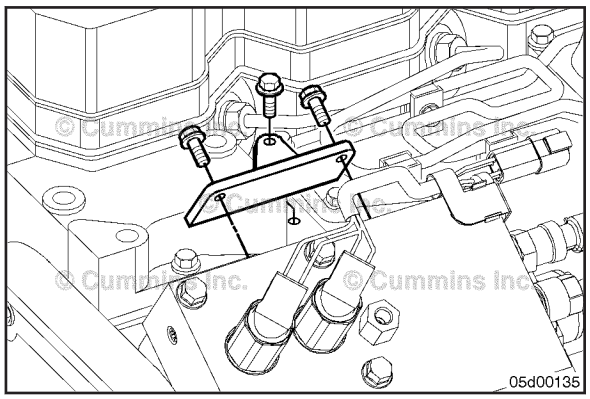
Make sure the o-rings are still in their grooves before the accumulator is fully tightened to the camshaft housing. Use a mirror if necessary.



Install the remaining two capscrews.

Tighten the four capscrews.

Torque Value: 68 N•m [50 ft-lb]



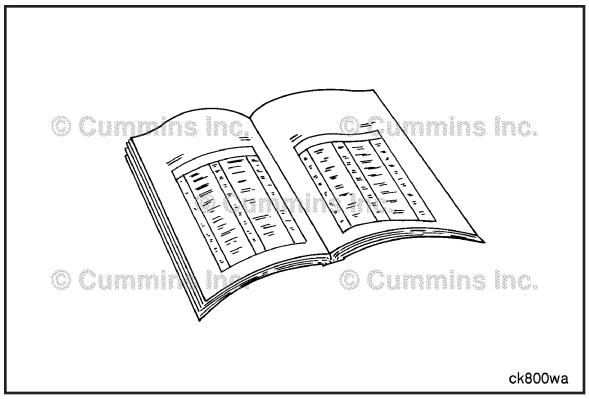
Install the upper support bracket.

Tighten the capscrews.

Torque Value: 44 N•m [32 ft-lb]

Finishing Steps

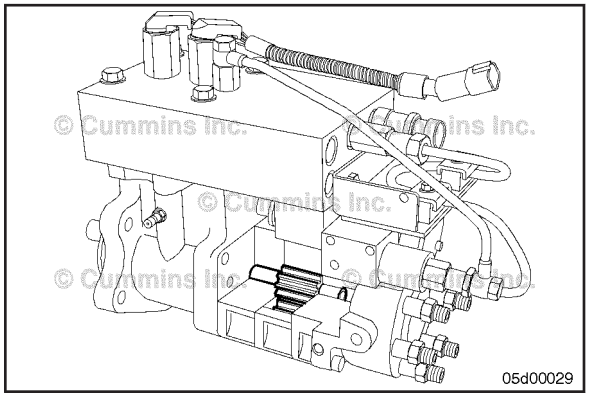
- Install rate shape tube assembly. Refer to Procedure 005-090 in Section 5.
- Install the air bleed line. Refer to Procedure 006-056 in Section 6.
- Install the drive gear cover.
- Connect the fuel pressure sensor and the fuel temperature sensors to the engine harness.
- Connect the pumping control valve connector to the engine harness.
- Start the engine and check for fuel leaks or active fault codes.
- Road-test the vehicle.
- Check for fuel leaks or active fault codes.

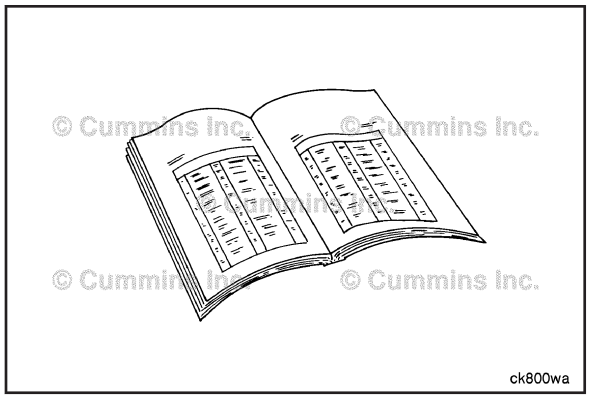


Fuel Pump Distributor and Injection Control Valve Module (005-086)

General Information

This procedure refers to the CAPS fuel system.





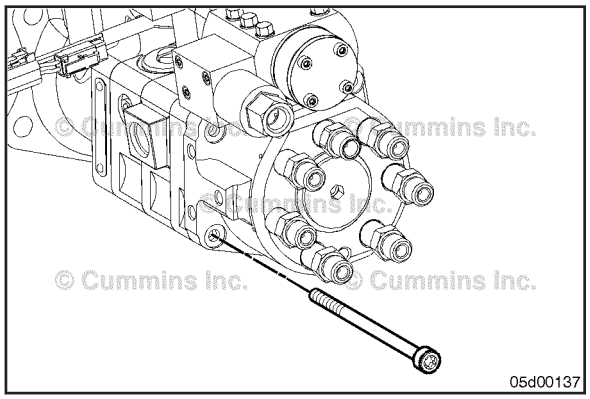
Preparatory Steps

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

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△
Fault codes can occur if steam sprays directly on the electrical connections on top of the accumulator block.

- Thoroughly steam clean the entire fuel pump.
- Dry the fuel pump with compressed air.
- Remove the air bleed line. Refer to Procedure 006-056 in Section 5.
- Remove the fuel pump from the engine, if necessary. Refer to Procedure 005-016 in Section 5.
- Mount the fuel pump in the vise ring if removed. Orient the pump with the distributor facing upward to aid in disassembly.
- Remove the rate shape tube assembly. Refer to Procedure 005-090 in Section 5.

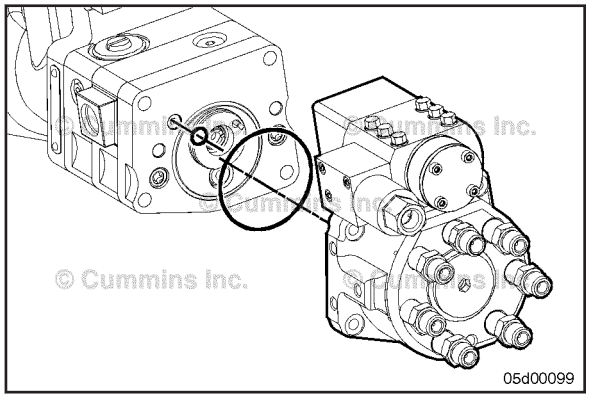


Remove

△CAUTION△
The capscrews also fasten the gear pump module. The gear pump is free to move after the capscrews are removed.

Loosen, but do **not** remove, the distributor plug.

Remove the four mounting capscrews on the distributor.



Remove the injection control valve/distributor module.

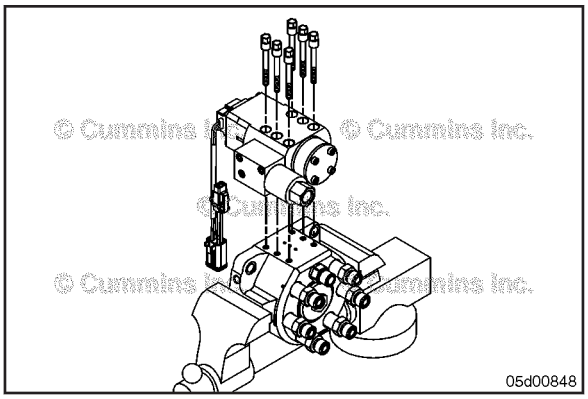
Remove the drive coupling.

Discard the two o-rings.

Place the injection control valve/distributor module in a clean bench vise.

Remove the injection control valve from the distributor module and install the injection control valve on the new distributor module. Refer to Procedure 005-078 in Section 5.

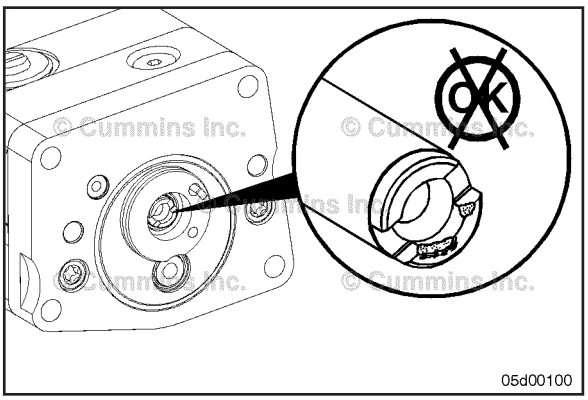
NOTE: Injection control valves built before January, 2001 are **not** reusable. If removing an injection control valve built before January, 2001, use the appropriate injection control valve kit to complete the repair.



Clean and Inspect for Reuse

Inspect coupling and gear pump shaft ends for excessive wear. Wear could be found on the inside corners of the coupling groove; such wear, however, is **not** common.

A polished surface is acceptable.

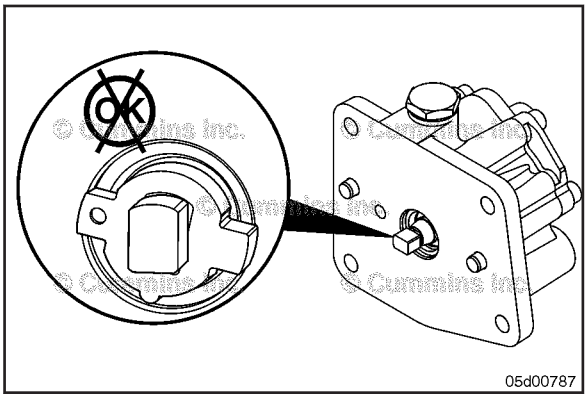


⚠CAUTION⚠
A distributor rotor seizure can cause damage to the gear pump.

If rotor seizure is suspected, inspect the gear pump. Refer to Procedure 005-089 in Section 5.

Replace the gear pump module if wear is visible.

Replace the gear pump module if the gear pump driveshaft is damaged.

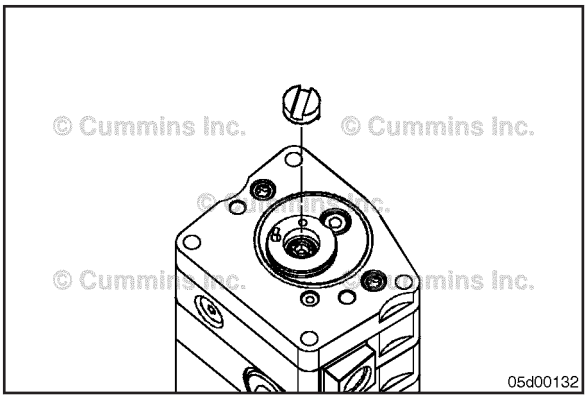


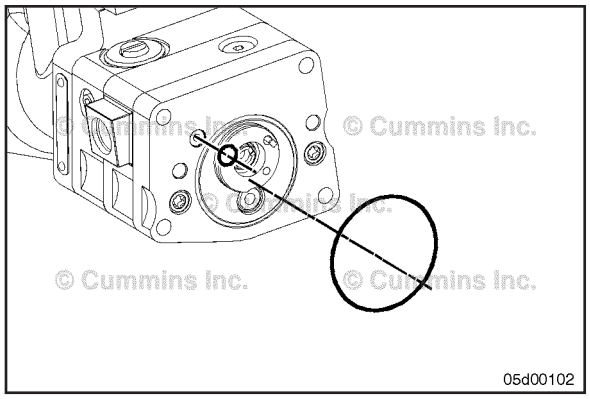
Install

Install the drive coupling.

Center the coupling on the gear pump shaft.

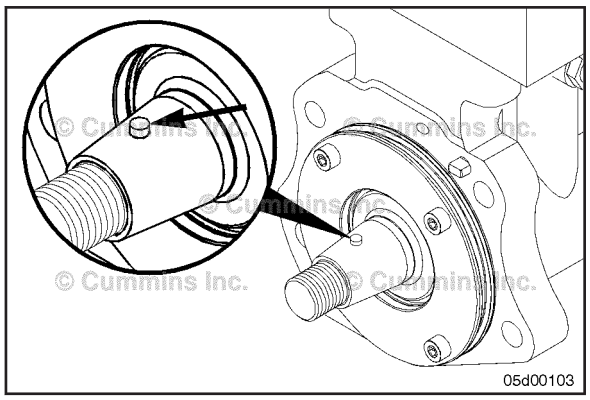
Apply Lubriplate™ 105, or equivalent, to the coupling to keep it from sliding in the shaft groove during assembly.





Install new o-rings.

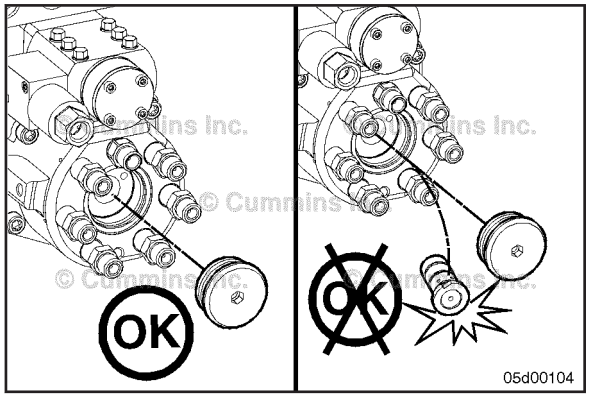
Apply Lubriplate™ 105, or equivalent, to the o-rings to keep them from falling out during assembly.



NOTE: This step is **not** necessary if you replace the distributor without removing the fuel pump from the engine.

The dowel pin **must** be facing up toward the top of the pump.

If the shaft needs to be rotated, install the fuel pump drive nut onto the shaft to provide a means for rotating the shaft.

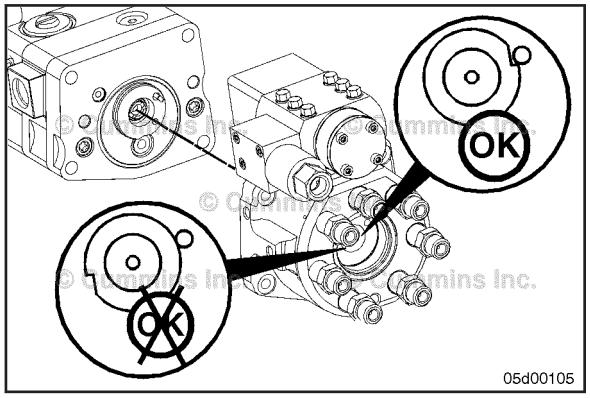


CAUTION
The rotor can slide out once the distributor plug is removed.

CAUTION
Do not drop the rotor. Damaging the rotor will necessitate replacement of the entire distributor module.

Remove the large plug from the end of the distributor.

Do **not** remove the rotor.



Install the distributor module.

Lightly rotate the rotor with finger pressure until it drops into the slot in the drive coupling.

When properly engaged, the notch in the rotor will align with the hole in the distributor (when the engine is at top dead center for number 1 cylinder).

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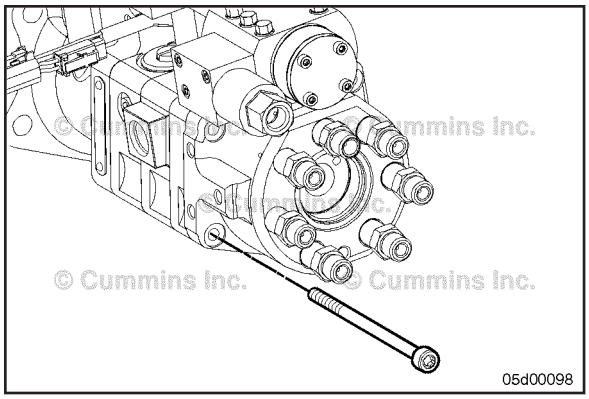
Do **not** pinch the o-rings.

Install the four distributor capscrews.

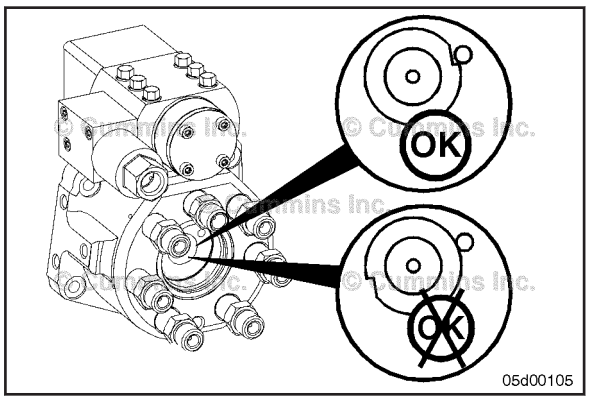
Tighten the capscrews.

Torque Value: 48 N•m [35 ft-lb]



⚠CAUTION⚠
The rotor must be properly timed to the fuel pump camshaft. Improper assembly will cause the rotor to be 180 degrees out of time.

If **not** properly timed, install the drive coupling and rotor again. Refer to Procedure 005-072 in Section 5.

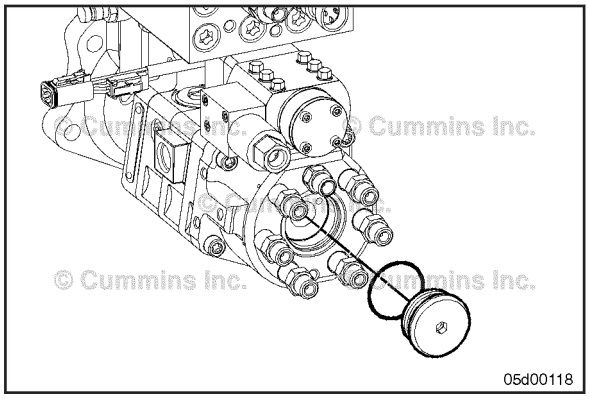


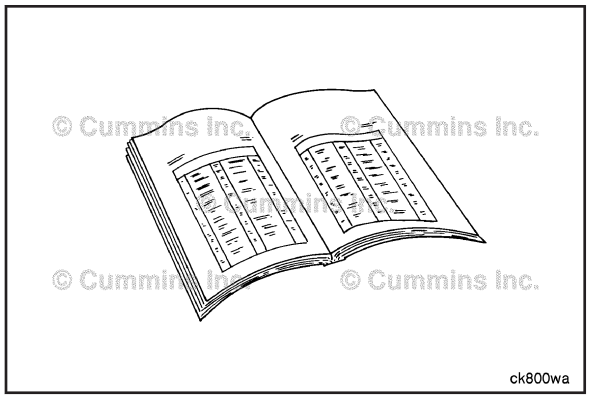
Install a new o-ring on the distributor plug.

Install the large plug at the end of the distributor.

Tighten the distributor plug.

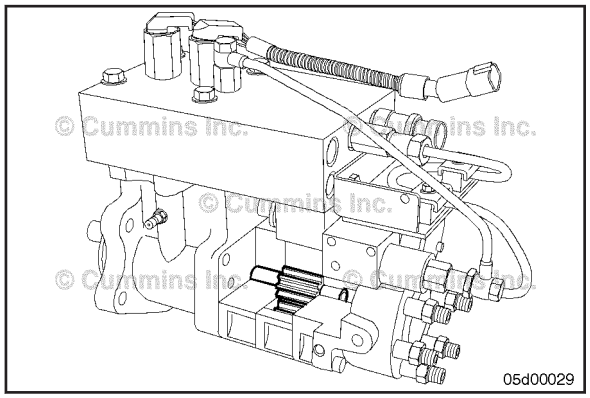
Torque Value: 14 N•m [120 in-lb]





Finishing Steps

- Install the rate shape tube assembly. Refer to Procedure 005-090 in Section 5.
- Install the fuel pump on the engine, if removed. Refer to Procedure 005-016 in Section 5.
- Install the air bleed line. Refer to Procedure 006-056 in Section 6.
- Use INSITE™ electronic service tool to run the Injection Control Valve Click Test. Refer to Procedure 005-078 in Section 5.
- Start the engine and check for fuel leaks or active fault codes.
- Road-test the vehicle for at least 1 mile. Check for fuel leaks or active fault codes.



Fuel Pump Cam Housing Module (005-088)

General Information

This procedure refers to the CAPS fuel system.

Preparatory Steps

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

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△
Make sure that steam does not spray directly on the electrical connections on the top of the accumulator block, or fault codes will possibly occur.

Thoroughly steam-clean the entire fuel pump.

Dry the pump with compressed air.

Bar the engine to top dead center (TDC).

Remove

CAPS Fuel System

Remove the air bleed line (1). Refer to Procedure 006-056 in Section 6.

Remove the fuel pump from the engine. Refer to Procedure 005-016 in Section 5.

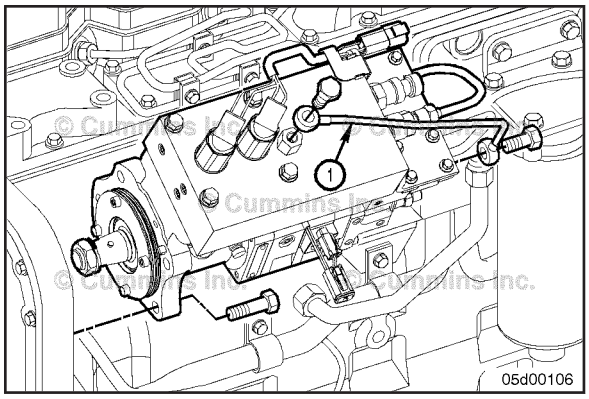
Mount the fuel pump to the mounting plate, Part Number 3162897, and orient the fuel pump with the distributor facing upward to aid in disassembly.

Remove the rate shape tube assembly. Refer to Procedure 005-090 in Section 5.

Remove the accumulator module. Refer to Procedure 005-085 in Section 5.

Remove the distributor module. Refer to Procedure 005-086 in Section 5.

Remove the gear pump module. Refer to Procedure 005-089 in Section 5.

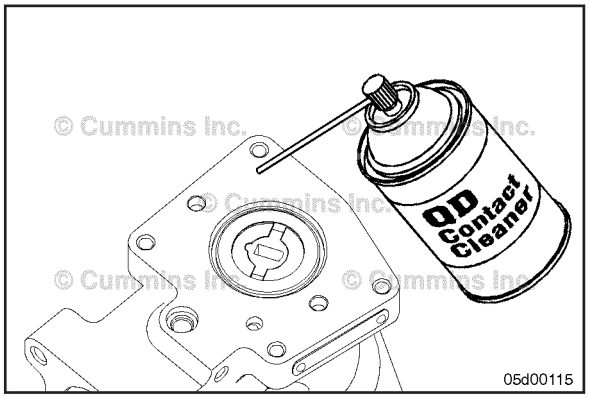


Clean and Inspect for Reuse

Clean the mounting surfaces of the cam housing.

Use QD™ contact cleaner, Part Number 3824510.

Inspect the camshaft coupling interface for wear. If the camshaft is worn excessively, replace the camshaft housing module.



⚠CAUTION⚠
If the tappets are removed, be sure to install them in the same bore they were removed from.

Remove the roller tappets from the camshaft housing bores.

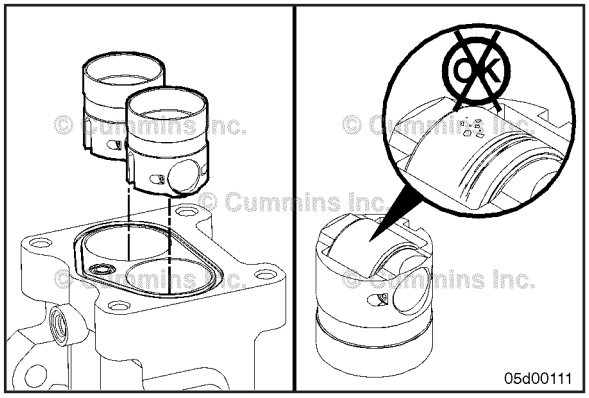
Inspect the roller surfaces for pitting and wear.

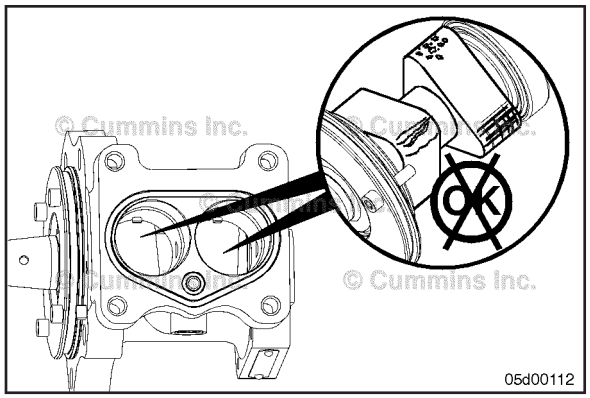
Make sure the roller rotates freely and smoothly.

Replace the camshaft housing module if the rollers are worn.

NOTE: It is normal to see lines (scratches) worn in the direction of roller travel. The camshaft housing or tappets should be replaced if the rollers are pitted.

Examine the tappets guide pin slots. If the guide pin slot is worn more than 25-percent of its original width, the tappet **must** be replaced.

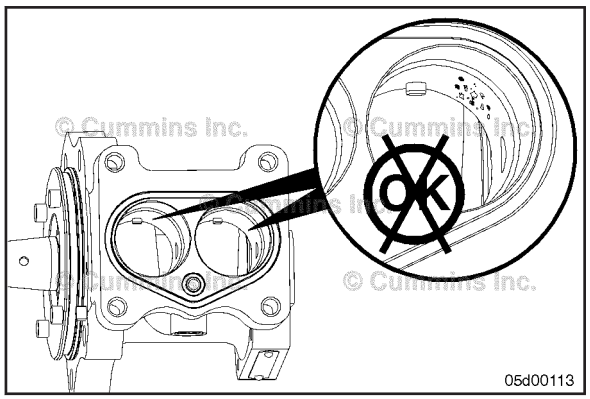




Inspect the guide pins. If the guide pins are worn or if oil leaks at the cam housing guide pin press fit, the camshaft housing **must** be replaced.

Inspect the camshaft lobes for pitting and wear. Replace the camshaft housing if there is any pitting or wear.

Inspect for raised burrs in the tappet bore. Replace the camshaft housing if raised burrs are present. Scratching or polishing is normal.

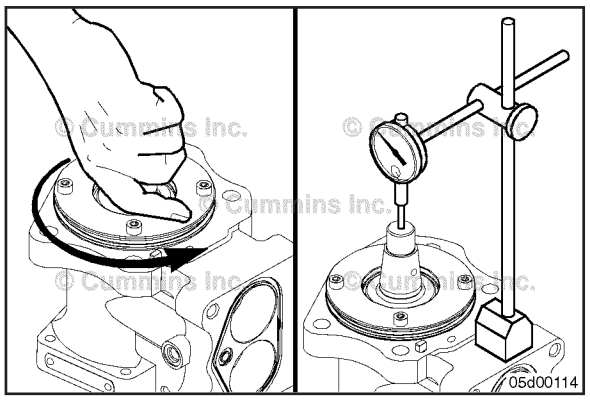


Inspect the tappet bores for scuffing or wear leading into the housing.

Polishing will occur in vertical bands at many places around the inside of the bores.

Polish in the bores is acceptable.

Replace the camshaft housing if there is severe tappet guide pin wear (more than 25-percent of tappet pin is worn).

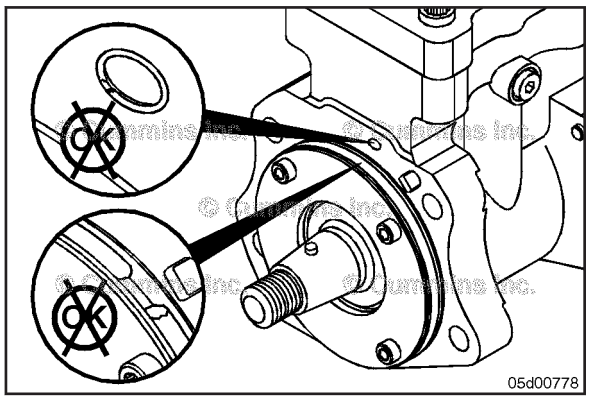


Using fingers, make sure the camshaft turns freely. The bearings **must** turn smoothly and freely during rotation.

Replace the camshaft housing if the bearings are tight or rough.

Check the camshaft for end clearance.

Camshaft End Clearance		
mm		**in**
0.05	MAX	0.002

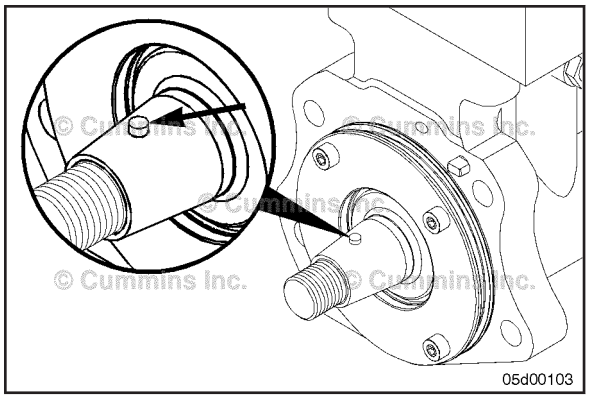


Inspect the oil feed and pump mounting o-ring.

Install

CAPS Fuel System

Make sure the timing dowel pin in the camshaft points toward the top of the fuel pump.

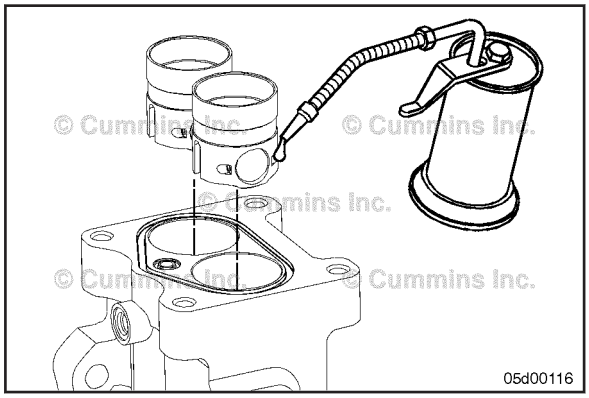


Lubricate the tappets and camshaft lobes with clean 15W-40 engine oil.

Install the roller tappets into the camshaft housing. Be sure that the tappets guide grooves are oriented correctly onto the tappet guide pins. Also, be sure that the tappet assemblies are installed in their original bores.

Check the tappets for proper alignment.

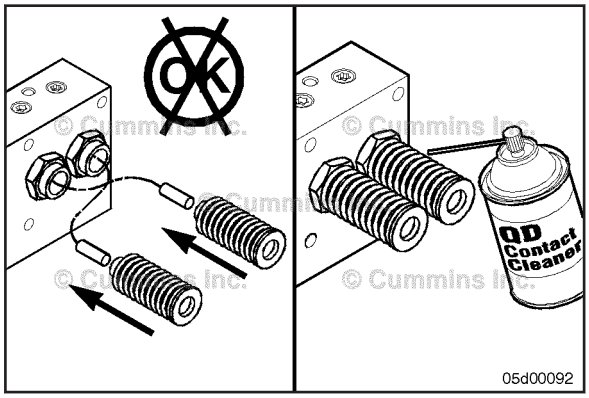
The tappets have a slot on the side that engages a pin on the engine side of the camshaft housing. The pin keeps the roller aligned with the camshaft. Make sure the tappet is properly aligned.



⚠CAUTION⚠
The ceramic plungers will possibly fall out when removing the springs. Do not interchange the plungers or change their upward orientation. If the plungers are removed, use QD™ contact cleaner, Part Number 3824510, to clean them before replacing.

NOTE: When assembling the fuel injection pump, take care to keep the ceramic pumping plungers in their original orientation in the accumulator module.

If **not** already done, install the spring and tappet retainers onto the accumulator or fuel pump barrel assemblies.



Install the gear pump module. Refer to Procedure 005-089 in Section 5.

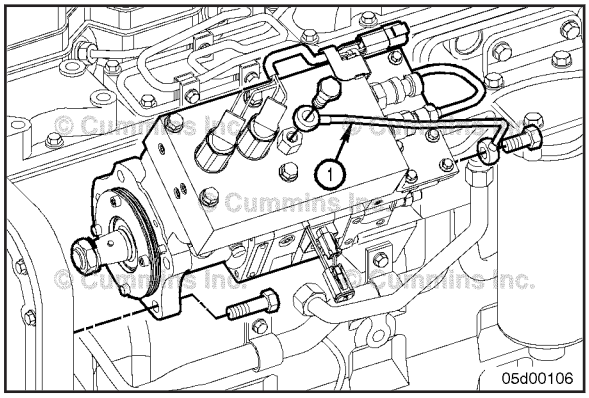
Install the distributor module. Refer to Procedure 005-086 in Section 5.

Install the accumulator module. Refer to Procedure 005-085 in Section 5.

Install the rate shape tube assembly. Refer to Procedure 005-090 in Section 5.

Install the fuel pump onto the engine. Refer to Procedure 005-016 in Section 5.

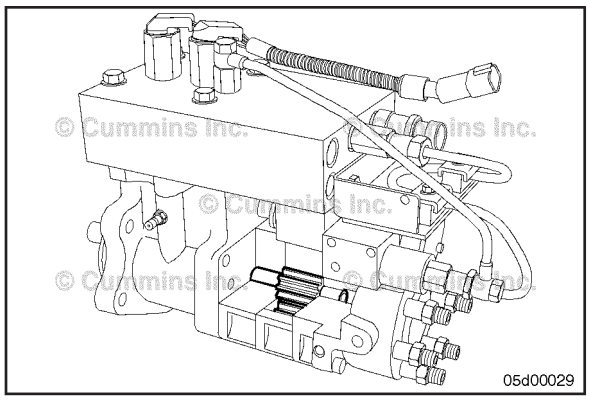
Install the air bleed line. Refer to Procedure 006-056 in Section 6.



Finishing Steps

Start the engine and check for fuel leaks or active fault codes.

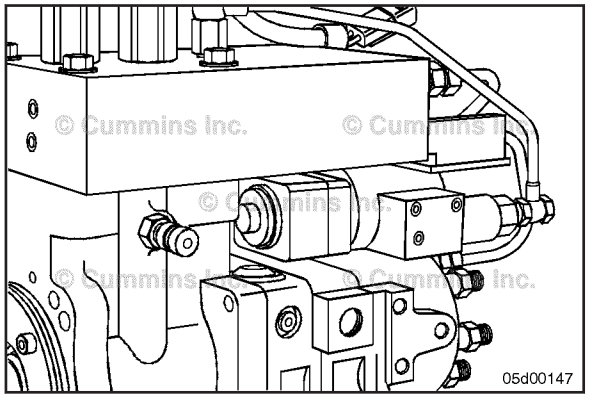
Perform repeat throttle snaps to create increased accumulator or fuel rail pressure.



Fuel Pump Gear Pump Module (005-089)

General Information

This procedure refers to the CAPS fuel system.



Initial Check

Measure the outlet pressure at the diagnostic fitting on the CAPS pump at a rated flow condition and compare to the following chart.

Engine Speed (rpm)	Gear Pump Pressure kPa [psi]
200	14 [2]
700	138 [20]
1300	379 [55]
2200	827 [120]

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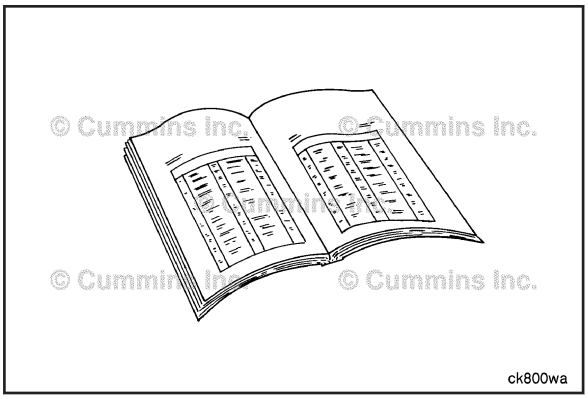
Preparatory Steps



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

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris or dirt can cause personal injury.

△CAUTION△
Make sure that steam does not spray directly on the electrical connections on the top of the accumulator block, or fault codes will possibly occur.

Thoroughly steam-clean the entire fuel pump.

Dry the fuel pump with compressed air.

Remove the air bleed line. Refer to Procedure 006-056 in Section 6.

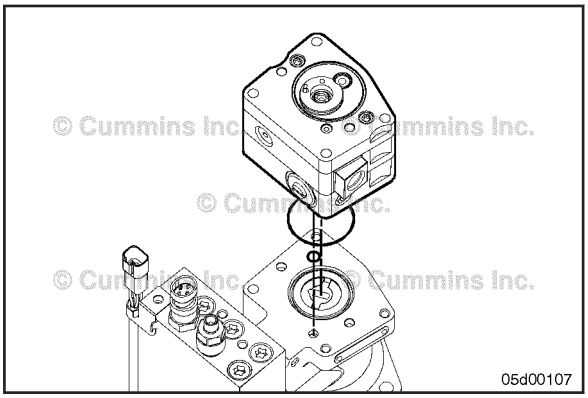
Remove the fuel pump from the engine. Refer to Procedure 005-016 in Section 5.

Mount the fuel pump in a vise ring. Orient the pump with the distributor facing upward to aid in disassembly.

Remove the rate shape tube. Refer to Procedure 005-090 in Section 5.

Remove the distributor module. Refer to Procedure 005-086 in Section 5.

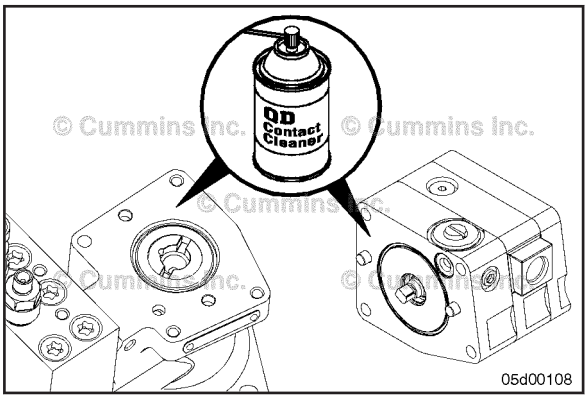
Remove



Remove the gear pump module.

NOTE: Do **not** remove the two capscrews. The gear pump will slide off the dowel pins once the distributor is removed.

Clean and Inspect for Reuse



Clean the mounting surfaces of the gear pump and camshaft housing.

Use QD™ contact cleaner, Part Number 3824510.

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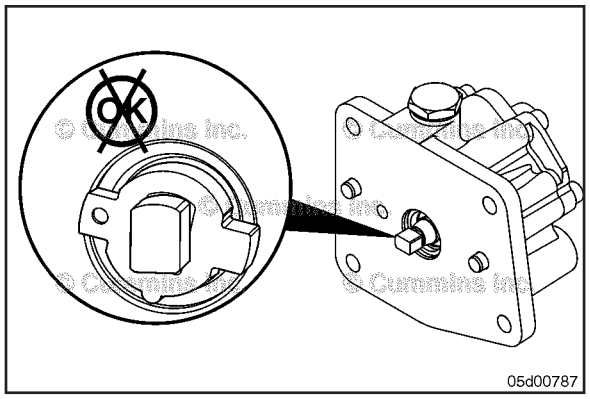
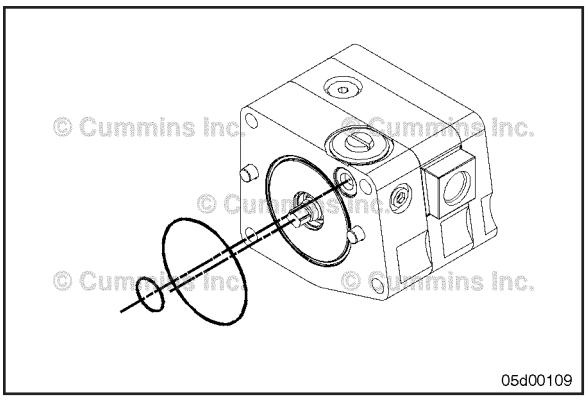


Inspect the drive coupling and shaft ends for excessive wear.

A polished surface is acceptable.

Replace the coupling if wear is visible.



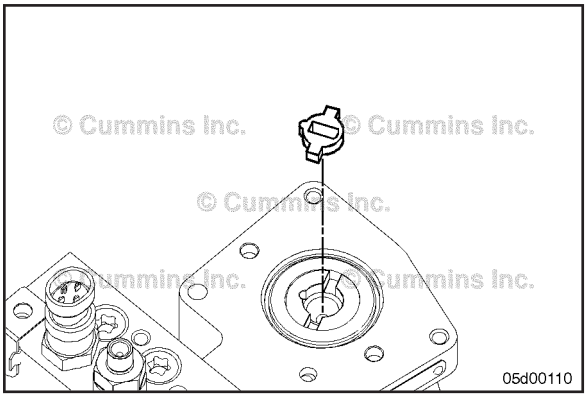
Install

⚠CAUTION⚠

The larger o-rings on either end of the gear pump differ in size. The longer o-ring goes to the side facing the camshaft housing.

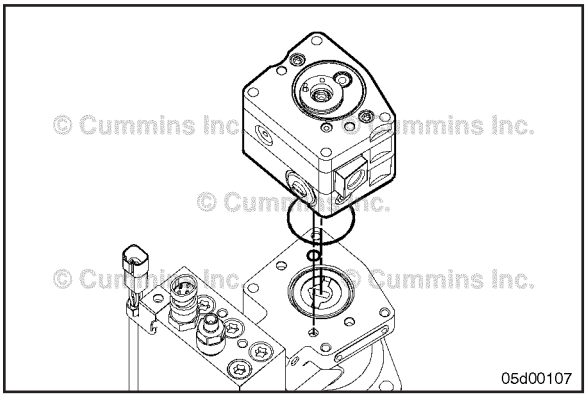
Install new o-rings.

Apply Lubriplate™ 105, or equivalent, to the o-rings to keep them from falling out during assembly.



Install the drive coupling.

Center the coupling in the shaft.



Align the gear pump shaft with the drive coupling and install the gear pump module.

Make sure the o-rings are **not** pinched.

Make sure the timing dowel pin is facing toward the top of the fuel pump.

Finishing Steps

Install the distributor module. Refer to Procedure 005-086 in Section 5.

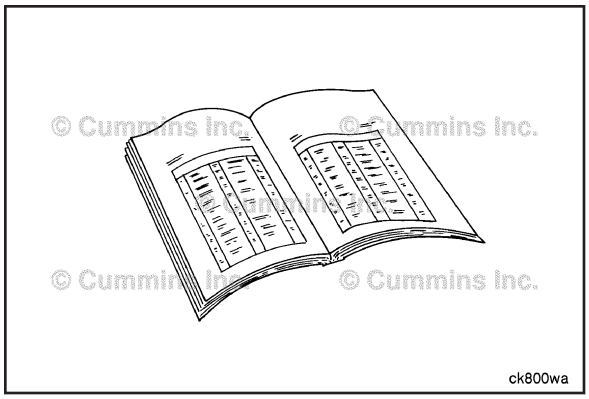
Install the rate shape tube. Refer to Procedure 005-090 in Section 5.

Install the fuel pump on the engine. Refer to Procedure 005-016 in Section 5.

Install the air bleed line. Refer to Procedure 006-056 in Section 6.

Start the engine and check for fuel leaks or active fault codes.

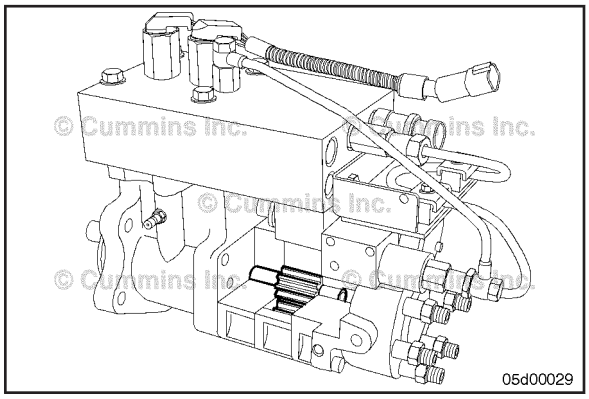
Road-test the vehicle for at least one mile. Recheck for fuel leaks or active fault codes.



Fuel Pump Rate Shape Tube (005-090)

General Information

This procedure refers to the CAPS fuel system.



Preparatory Steps

⚠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.

△CAUTION△
Make sure that direct steam spray stream does not contact the electrical connections on the top of the accumulator block; fault codes will possibly occur.

Thoroughly steam-clean the entire fuel pump.

Dry the fuel pump with compressed air.

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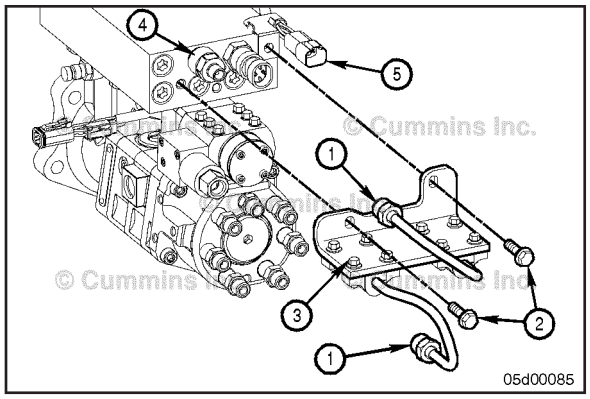


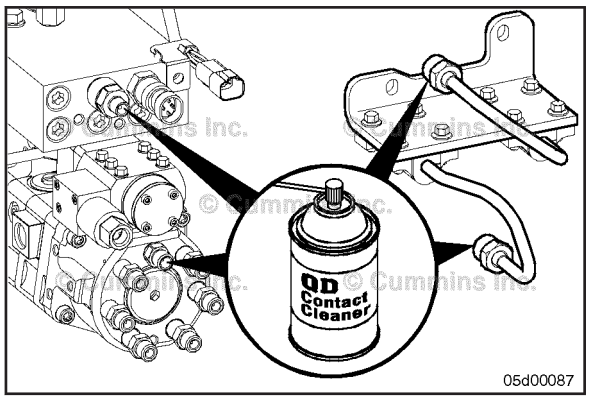
Remove

Loosen the two rate shape tube nuts (1).

Remove the two bracket capscrews (2).

Remove the rate shape tube assembly.

Do **not** loosen or remove the isolator capscrews (3).



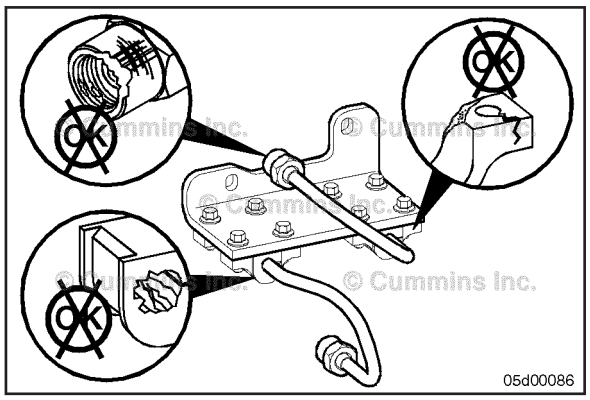
Clean and Inspect for Reuse

Clean the ends of the rate shape tube.

Clean out the rate shape tube with contact cleaner if debris is suspected of entering the tube.

Flush any dirt from the snubber fitting and distributor inlet fitting.

Use QD™ contact cleaner, Part Number 3824510.



Inspect isolators for signs of wear or cracks.

Replace the rate shape tube assembly if any isolator is worn, cracked, or missing.

Inspect the ends of the rate shape tube for damage.

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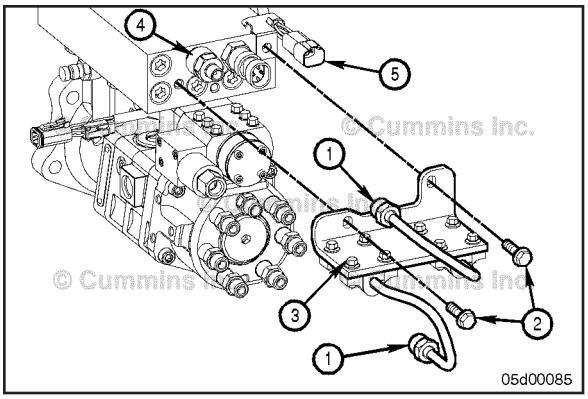
Install



Install the rate shape tube assembly using the following steps:

1 Install the tube nuts (1) and capscrews (2) finger-tight

2 Tighten the rate shape tube nuts (1)

Torque Value: 46 N•m [34 ft-lb]

1 Tighten the two bracket capscrews (2).

Torque Value:
Capscrew
Step 1 41 N•m [30 ft-lb]

Torque Value:
Thermistor Adapter
Step 1 34 N•m [25 ft-lb]

NOTE: If any force is required to flex the rate shape tube in order to start the tube nuts, the rate shape tube **must** be replaced with a new tube.

NOTE: Make sure the harness clip is installed between the bracket and capscrew, **not** between the bracket and accumulator.

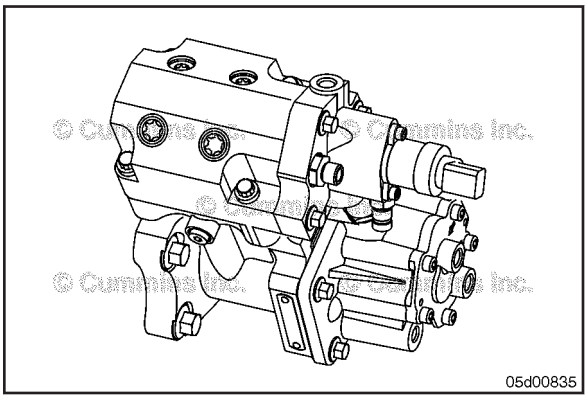
Finishing Steps

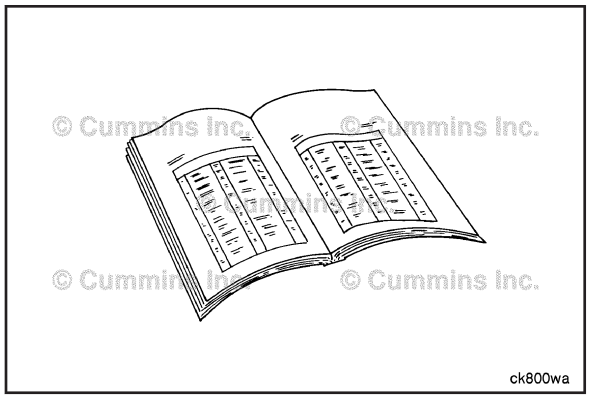
Start the engine and check for fuel leaks at the rate shape tube connections.

Fuel Pump Head Outlet Fitting (005-226)

General Information

This procedure refers to the Cummins® Common Rail fuel system.





Preparatory Steps

⚠WARNING⚠
The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris or dirt can cause personal injury.

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

⚠WARNING⚠
Do not vent the fuel system on a hot engine; this can cause fuel to spill onto a hot exhaust manifold, which can cause a fire.

△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.

- Disconnect the batteries. Refer to the OEM service manual.
- Thoroughly clean the entire fuel pump. Dry the fuel pump with compressed air.
- Close the fuel supply valve. Refer to the OEM service manual.
- Remove the high-pressure fuel line from the fuel pump actuator housing. Refer to Procedure 006-051 in Section 6.
- Remove the fuel drain line from the actuator housing. Refer to Procedure 006-013 in Section 6.
- Remove the fuel supply line from the fuel pump actuator housing. Refer to Procedure 006-024 in Section 6.
- Remove the fuel pump actuator housing from the high-pressure fuel pump. Refer to Procedure 005-228 in Section 5.

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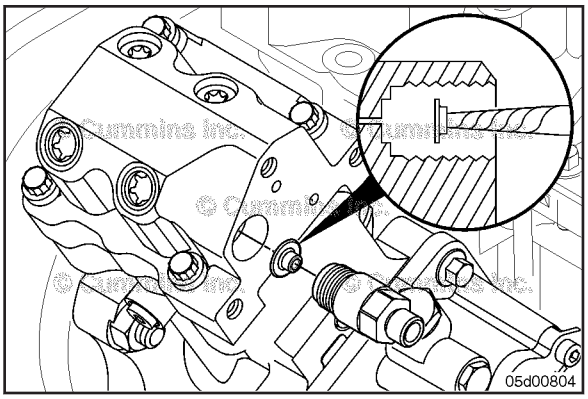
Remove

Remove the fuel pump head outlet fitting and the seal washer from the threaded hole in the back of the high-pressure pump head.

NOTE: It is necessary to remove the seal washer with the aid of a tapered punch. Insert a tapered punch into the center of the seal washer and work the seal out from the bore in the back of the high-pressure pump head.



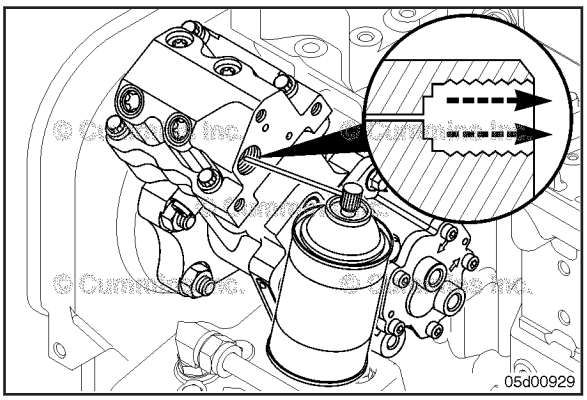
Clean and Inspect for Reuse

Clean the threaded hole in the high-pressure pump head with electrical contact cleaner, Part Number 3824510, or equivalent.

Inspect the threads and cavity in the high-pressure pump head for burrs or debris.

Inspect the seal washer end of the outlet fitting. There should be a polished crown that is free of nicks or inclusions. If the crown is damaged or severely flattened, the male union **must** be replaced.

Clean any burrs with a wire brush, then flush the bore clean.



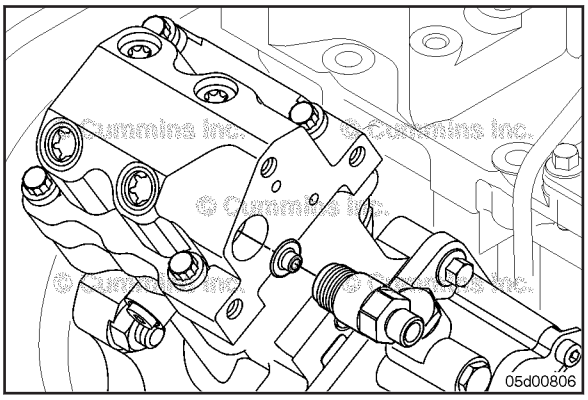
Install

NOTE: This joint is designed to seal in excess of 179,264 kPa [26,000 psi]. Seal washers **must not** be reused.

Install a new seal washer onto the outlet fitting. The seal washer should pilot into the outlet fitting. A small amount of clean grease, such as assembly lubricant, will help in keeping the seal attached to the outlet fitting during installation.

Torque Value:

Step 1	13.6 N•m	[120 in-lb]
Step 2	Rotate 90 degrees	



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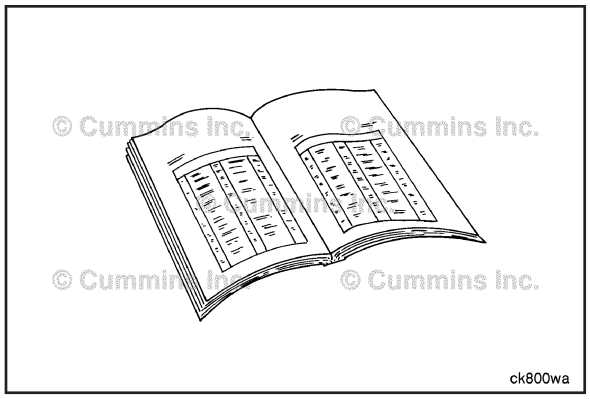
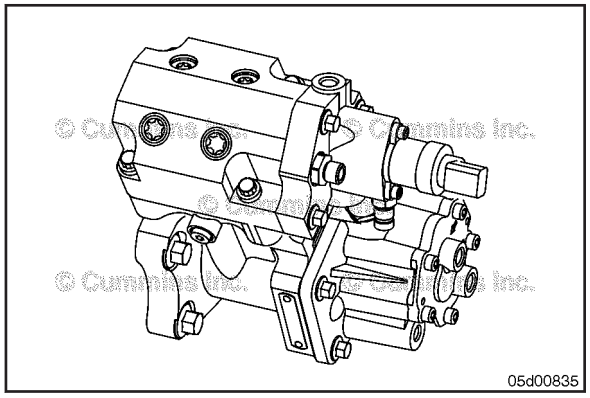


Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the fuel pump actuator housing to the high-pressure fuel pump. Refer to Procedure 005-228 in Section 5.
- Install the high-pressure fuel line to the fuel pump actuator housing. Refer to Procedure 006-051 in Section 6.
- Install the fuel drain line to the actuator housing. Refer to Procedure 006-013 in Section 6.
- Install the fuel supply line to the fuel pump actuator housing. Refer to Procedure 006-024 in Section 6.
- Open the fuel supply valve. Refer to the OEM service manual.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.
- Perform several throttle snaps so that increased fuel rail pressure will be developed.

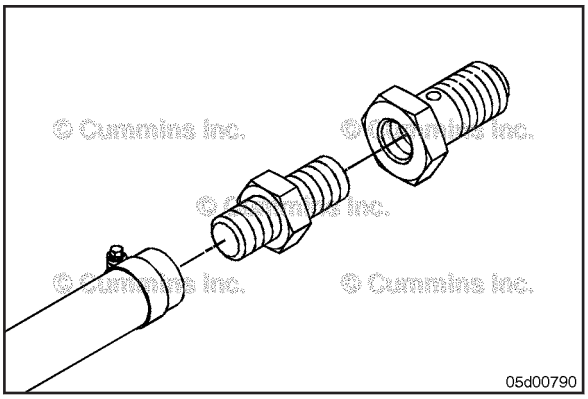


Fuel Pump Head (005-227)

General Information

This procedure refers to the Cummins® Common Rail fuel system.

Initial Check



⚠WARNING⚠
The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.

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

⚠CAUTION⚠
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.

This fuel pump head leakage test uses a flow adapter fitting. The purpose of the flow adapter fitting is to route the drain flow of the fuel pump **only** into a collection device so that leakage may be measured.

Perform the Fuel Pump Head Leakage Test described below.

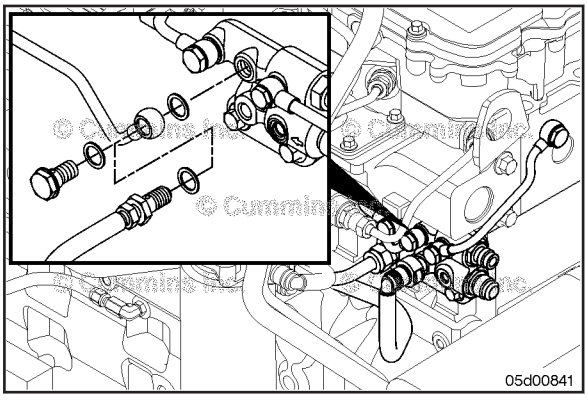
This tool, Part Number 3164618, can be purchased or constructed according to provided instructions. Refer to Procedure 006-026 in Section 6.

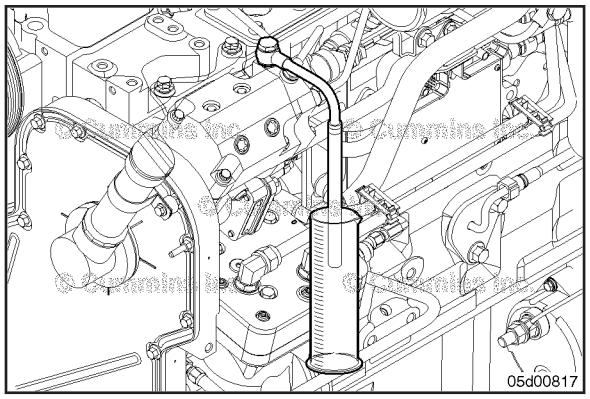
Fuel Pump Head Leakage Test Setup

Remove the banjo bolt from the fuel pump drain line at the fuel drain manifold.

Install a banjo flow adapter fitting at the fuel drain manifold and route a hose from this adapter to a bucket or the vehicle's fuel tanks.

The pump drain line connects at the center connection point on the fuel drain manifold.

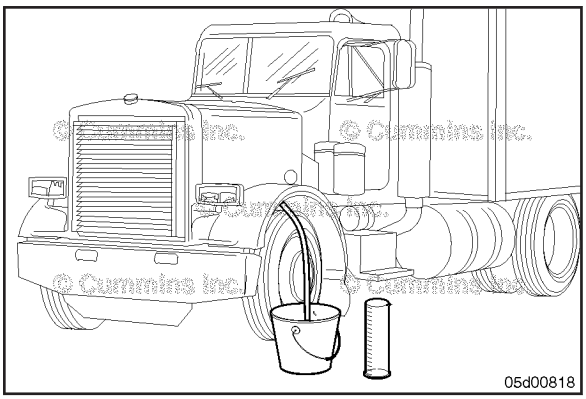




Fuel Pump Head Leakage Alternate Test Setup

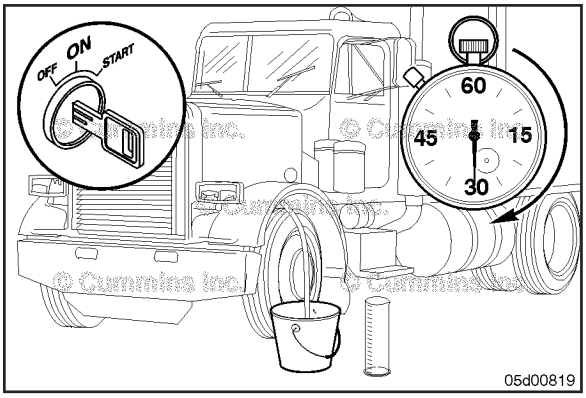
If the drain manifold is **not** easily accessed, an M14 banjo may be attached at the pump head drain port with a fuel hose that is routed to the collection container.

In this setup, a bolt, nut, and washers are needed to prevent fuel from flowing backwards and leaking from the unused drain line.



⚠CAUTION⚠
The high-pressure leakage test in INSITE™ electronic service tool will cause the engine to operate at elevated pressures while the engine idles. The engine noise will change when this test is being performed due to the higher fuel injection pressures. Safety glasses should be worn while working near the running engine. Fuel lines should not be adjusted while performing this test.

Close the engine cover(s) while performing these tests.

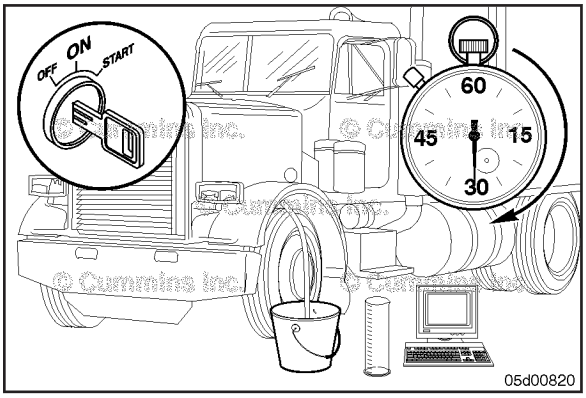


Fuel Pump Head Leakage Test (Engine Will Not Start)

Turn the keyswitch ON and allow the lift pump to complete its cycle. After the cycle is completed, begin cranking the engine until fuel exits the drain line.

When fuel begins to exit the drain line, route the drain flow to a graduated cylinder and continue cranking for 30 seconds.

Maximum Volume of Fuel During Cranking	
cc [oz]	**seconds**
200 [7]	30



Fuel Pump Head Leakage Test (Engine Will Start)

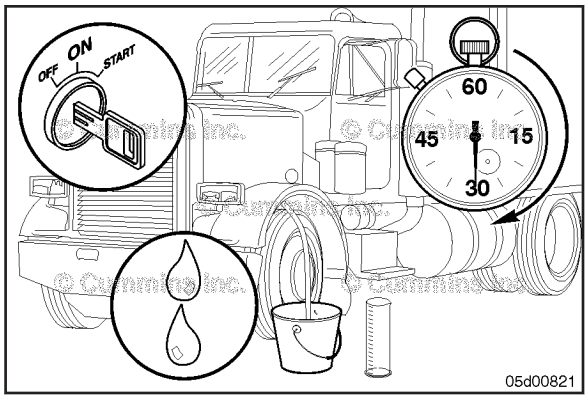
If the engine will start, perform INSITE™ electronic service tool High-Pressure Leakage Test.

- Connect INSITE™ electronic service tool.
- Start the engine and allow the engine to idle with fuel flowing into a collection device.
- Begin the High-Pressure Leakage Test.
- Measure the time necessary to collect 300 cc [10 oz] of fuel pump head drain flow while performing the High-Pressure Leakage Test.

Use a graduated cylinder for this measurement.

This specification is valid for engines operating on diesel fuels. Low fuel viscosity will increase the leakage rate; for example, kerosene or aviation fuels will result in excessive leakage. Verify the fuel type before replacing a fuel pump head for excessive leakage.

Maximum Volume of Fuel During Fuel Pump Head Leakage Test	
cc [oz]	**seconds**
300 [10]	30



Fuel Pump Head Flow Test

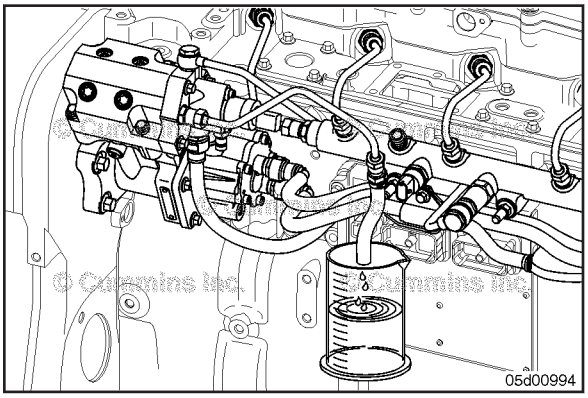
Disconnect the high-pressure fuel line from the fuel rail at the fuel rail connector.

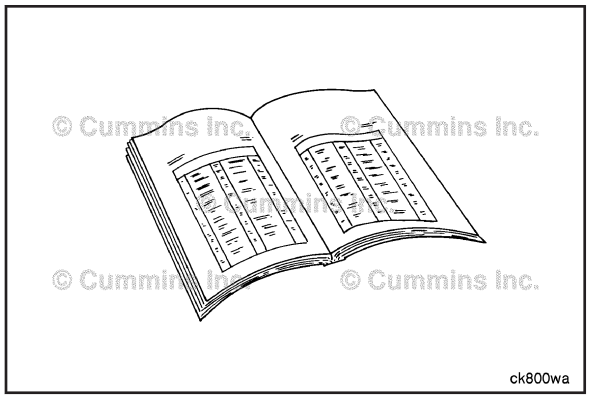
Clamp a hose to the end of the fuel line.

Route a hose into a clean graduated cylinder.

Crank the engine for 30 seconds.

The fuel pump head flow **must** be greater than 100 cc [3.4 oz] in 30 seconds of cranking.





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

⚠WARNING⚠
Do not bleed the fuel system of a hot engine; this can result in fuel spilling onto a hot exhaust manifold, which can cause a fire.

- Disconnect the batteries. Refer to the OEM service manual.
- Close the fuel supply and drain valves. Refer to the OEM service manual.
- Remove the high-pressure fuel line from the high-pressure pump. Refer to Procedure 006-051 in Section 6.
- Remove the fuel drain line from the fuel pump actuator housing. Refer to Procedure 006-013 in Section 6.
- Remove the fuel supply line from the fuel pump actuator housing. Refer to Procedure 006-024 in Section 6.
- Disconnect the wire harness from the fuel pump actuator.
- Remove the fuel pump actuator housing. Refer to Procedure 005-228 in Section 5.

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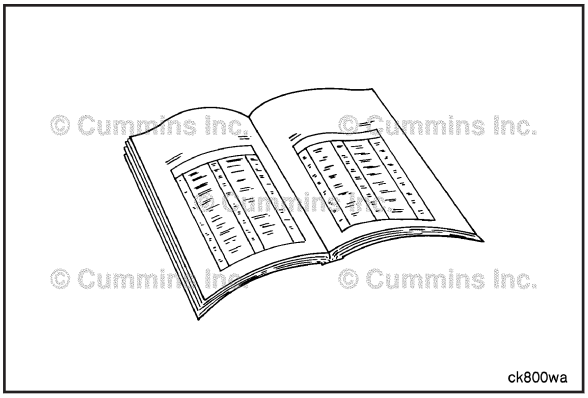
Marine Applications



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Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

⚠WARNING⚠
Do not bleed the fuel system of a hot engine; this can result in fuel spilling onto a hot exhaust manifold, which can cause a fire.

△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.

- Disconnect the batteries. Refer to the OEM service manual.
- Close the fuel supply and drain valves. Refer to the OEM service manual.
- Remove the high-pressure fuel line from the high-pressure pump. Refer to Procedure 006-051 in Section 6.
- Remove the fuel drain line from the fuel pump actuator housing. Refer to Procedure 006-013 in Section 6.
- Remove the fuel supply line from the fuel pump actuator housing. Refer to Procedure 006-024 in Section 6.
- Disconnect the wire harness from the fuel pump actuator.
- Remove the fuel filter head bracket. Refer to Procedure 006-018 in Section 6.
- Remove the fuel pump actuator housing. Refer to Procedure 005-228 in Section 5.

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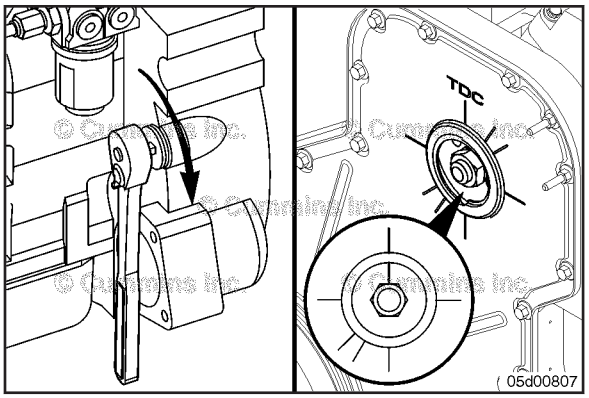
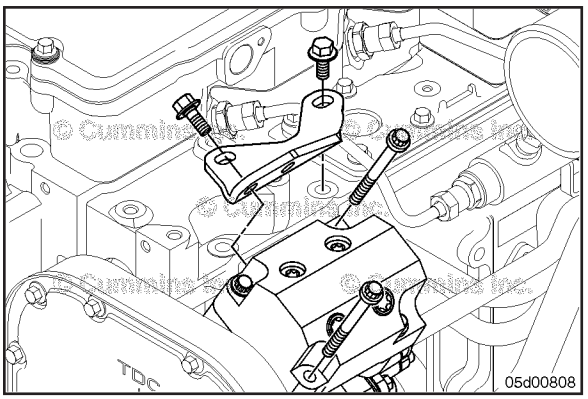


Remove

Remove the fuel pump drive gear cover.

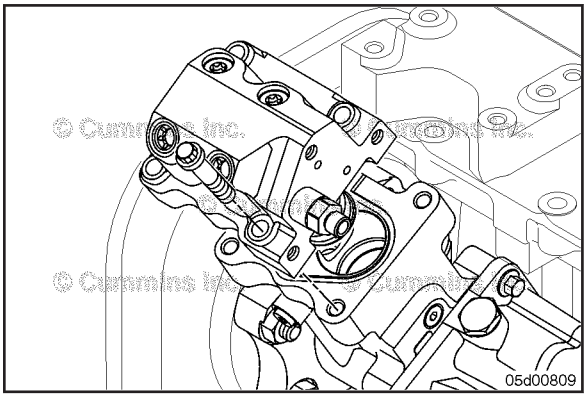
Locate top dead center for cylinder number 1 by barring the engine slowly until the line on the pump gear lines up with the line on the gear cover.



△CAUTION△
Do not use air tool. The use of air tools will possibly damage the fuel pump.

Remove the upper support bracket.

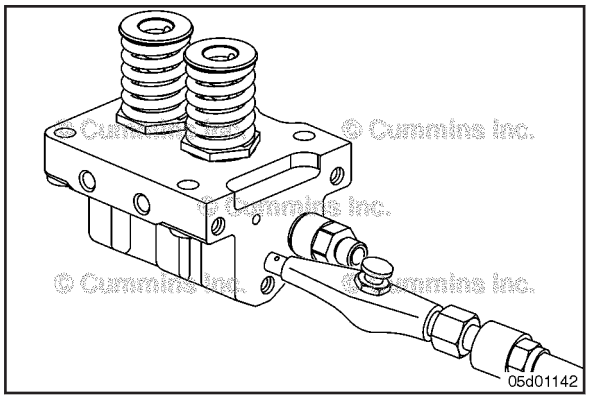
Remove two of the four capscrews that are located diagonally from one another.



Remove the last two capscrews. Alternately loosen the capscrews to avoid binding. Loosen each capscrew about one turn at a time.

Carefully lift the fuel pump head from the camshaft housing, being careful to keep the tappet springs attached to the pump head. Place the head on a clean surface.

Clean and Inspect for Reuse



⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Special care **must** be taken to be sure these parts are kept extremely clean if removed. Cover the camshaft housing with a clean shop towel while the head is removed.

Do **not** use cleaning agents, other than contact cleaner, on pump components.

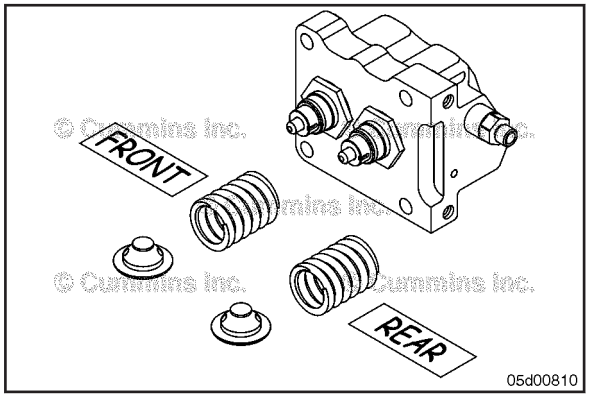
NOTE: Do **not** perform the following test without the springs and spring retainers installed.

With the springs and spring retainers installed, blow compressed air (at least 138 kPa [20 psi]) into the fuel inlet port of the fuel pump head.

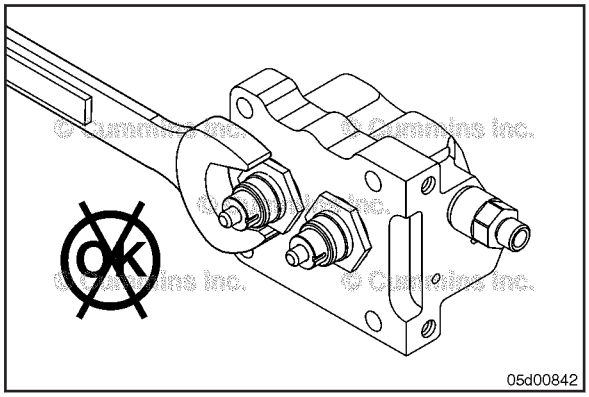
The plungers should extend to the tappet spring retainers. If the pumping plungers are stuck and do **not** extend to the tappet spring retainers, replace the fuel pump head.

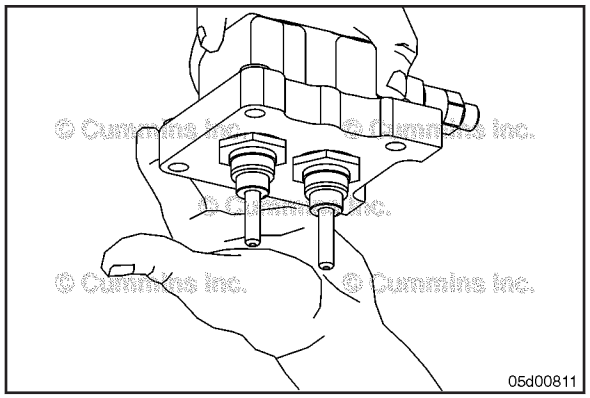
Remove the springs and spring retainers from the barrel retainers.

Make certain to keep track of which springs came from the front and rear. It is recommended that these parts be installed in the same location, even if a new high-pressure pump head is installed.



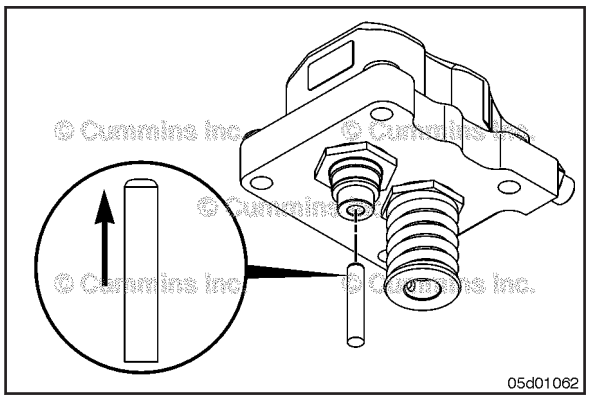
△CAUTION△
Do not remove the barrel retainers. Damage to the pump head and barrel retainers will result.





Press on the pumping plungers to make sure they are **not** binding in the barrel.

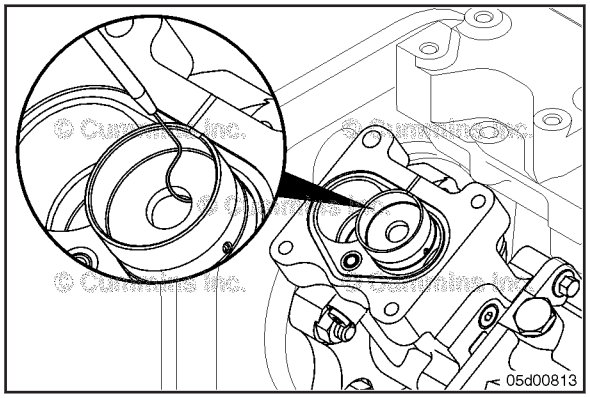
If the pump head check valves are working correctly, the pumping plungers will spring back to their original position. If the plungers do **not** spring back, replace the fuel pump head.



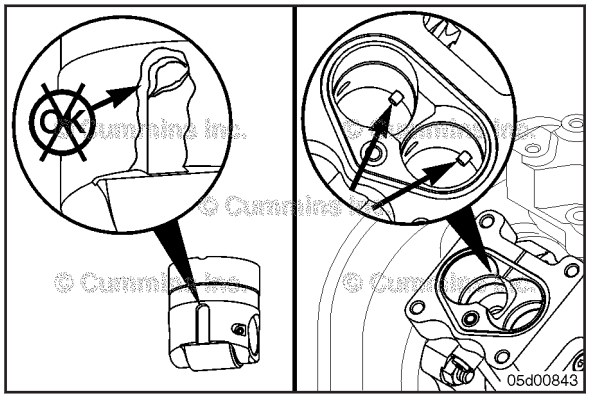
⚠CAUTION⚠
Each plunger must be installed in the same orientation and in the same barrel, or engine damage can result. Marking the bottoms of the plungers with a felt tip marker will help to make sure that correct orientation is maintained.

If the plungers are removed, inspect the plungers. Slight discoloration can be evident. Deep scoring **must not** be present. If scoring or scratches exist that can be felt, the fuel pump head **must** be replaced.

NOTE: Some fuel pump heads are built with non-symmetric pumping plungers. The crowned end of the pumping plunger **must** be installed into the barrel. If the plunger is installed in the wrong orientation, fuel pump head damage will result.



While the fuel pump head is removed, inspect the camshaft housing. The tappets can be removed. Use an o-ring pick as the removal tool.



Inspect the tappet guide pins and tappet guide pin grooves for excessive wear. If more than 25-percent guide pin or groove wear is observed, the fuel pump **must** be replaced.

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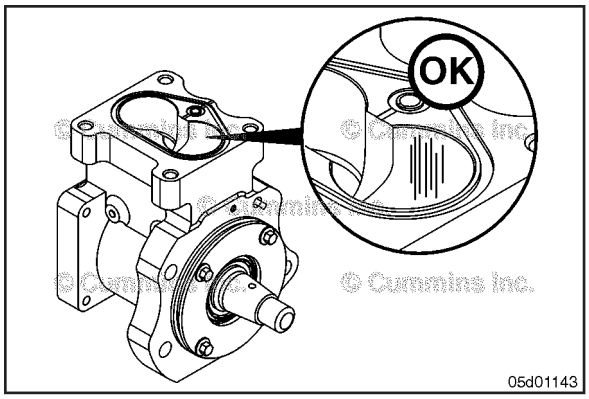
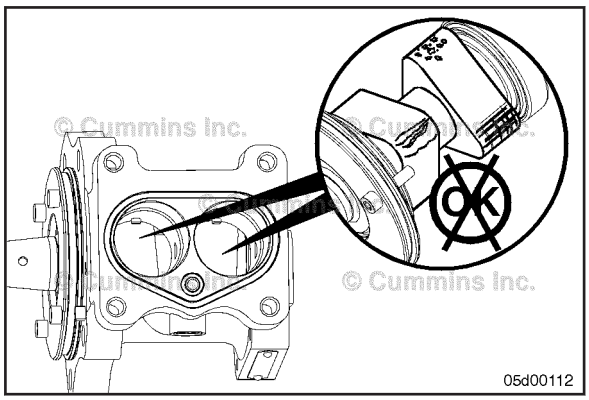
Normal operation creates vertical grooves in the cylinder bores of the fuel pump camshaft housing. These grooves are **not** an indication of a malfunction.

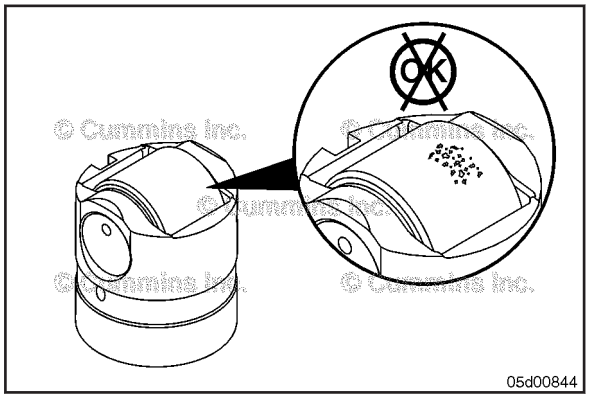
Camshaft housings with grooves are acceptable for reuse.



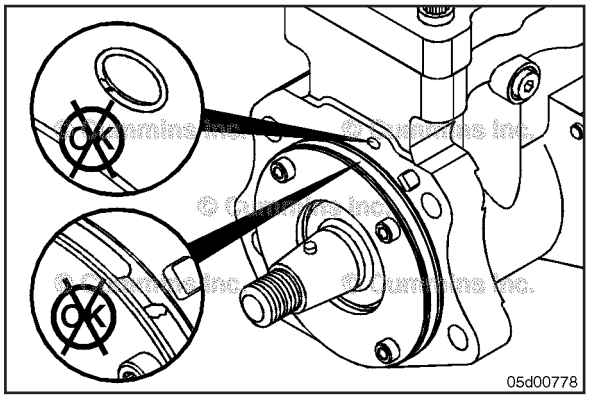
With the camshaft housing tappets removed, inspect the camshaft for wear. If excessive pitting on the nose of the camshaft is observed, the fuel pump **must** be replaced.

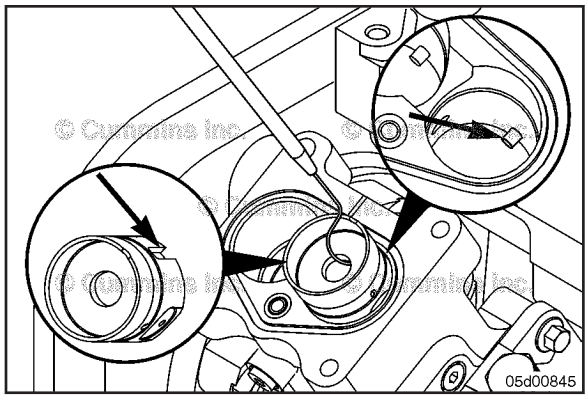


Inspect the tappet rollers for wear. If excessive pitting on the rollers is observed, the tappet(s) **must** be replaced.



If damage to the camshaft, tappets, or camshaft housing is observed, it is possible the fuel pump is **not** receiving adequate lubricating oil. When replacing the fuel pump, inspect the gear housing to make sure no blockages exist in the oil supply to the fuel pump.



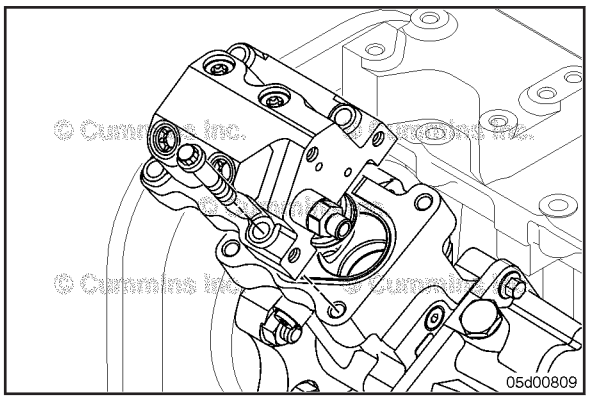


Install

Install the tappets in the original tappet bores.

Be certain the tappets are installed in the original locations.

Be certain that the tappet guide pins engage the guide pin grooves.



Install new fuel pump head o-rings onto the camshaft housing.

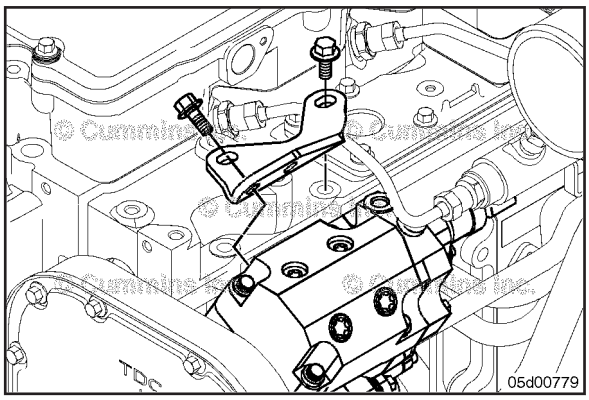
If installing a new or rebuilt pump head, install the new tappet springs and retainers provided with the pump head.

Place the high-pressure pump head onto the high-pressure pump camshaft housing.

Draw the high-pressure pump head down by alternately tightening the four high-pressure pump head capscrews until the head just contacts the camshaft housing.

Tighten the four high-pressure pump head capscrews to the final torque.

Torque Value: 68 N•m [50 ft-lb]



Connect the upper support bracket to the high-pressure pump head in the following order:

- Connect the upper support bracket capscrews to the high-pressure pump head and tighten hand-tight.
- Connect the upper support bracket capscrews to the cylinder head and tighten to the final torque.

Torque Value: 43 N•m [32 ft-lb]

- Tighten the capscrews that attach to the high-pressure pump head to the final torque.

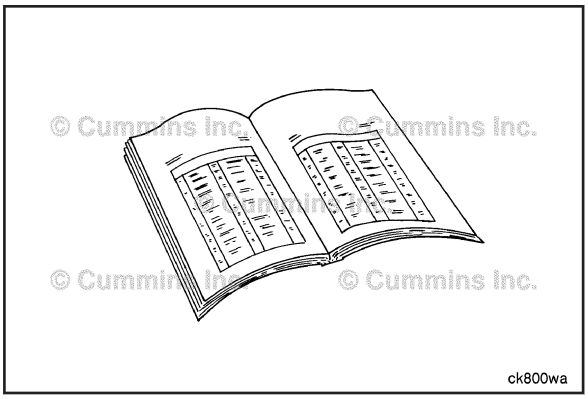
Torque Value: 43 N•m [32 ft-lb]

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.

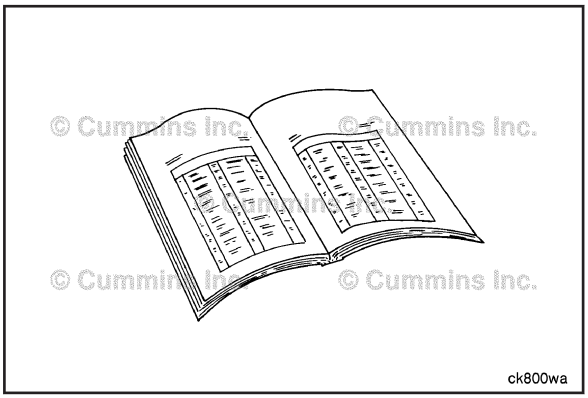
- Install the fuel pump actuator housing. Refer to Procedure 005-228 in Section 5.
- Connect the high-pressure fuel supply line. Refer to Procedure 006-051 in Section 6.
- Connect the fuel drain line to the fuel pump actuator housing. Refer to Procedure 006-013 in Section 6.
- Connect the fuel supply line to the fuel pump actuator housing. Refer to Procedure 006-024 in Section 6.
- Connect the engine harness to the fuel pump actuator.
- Connect the batteries. Refer to the OEM service manual.
- Open the fuel supply and drain valves. Refer to the OEM service manual.
- Operate the engine and check for leaks.

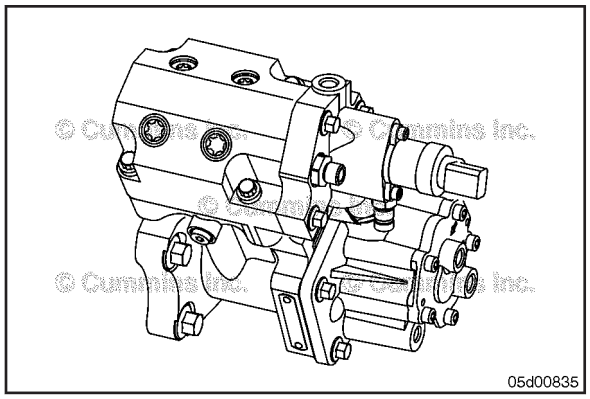


Marine Applications

⚠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 fuel pump actuator housing. Refer to Procedure 005-228 in Section 5.
- Connect the high-pressure fuel supply line. Refer to Procedure 006-051 in Section 6.
- Connect the fuel drain line to the fuel pump actuator housing. Refer to Procedure 006-013 in Section 6.
- Connect the fuel supply line to the fuel pump actuator housing. Refer to Procedure 006-024 in Section 6.
- Connect the engine harness to the fuel pump actuator.
- Install the fuel filter head bracket. Refer to Procedure 006-018 in Section 6.
- Connect the batteries. Refer to the OEM service manual.
- Open the fuel supply and drain valves. Refer to the OEM service manual.
- Operate the engine and check for leaks.

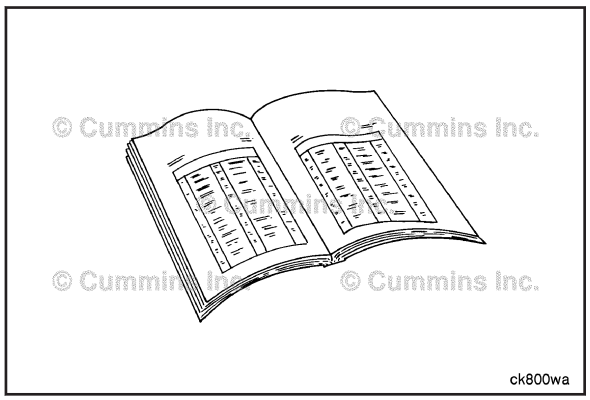




Fuel Pump Actuator Housing (005-228)

General Information

This procedure refers to the Cummins® Common Rail fuel system.



Preparatory Steps

⚠WARNING⚠

The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Disconnect the wire harness from the fuel pump actuator.
- Disconnect the fuel supply line from the fuel pump actuator housing. Refer to Procedure 006-024 in Section 6.
- Disconnect the high-pressure fuel line from the fuel pump actuator housing. Refer to Procedure 006-051 in Section 6.
- Disconnect the fuel drain from the fuel pump actuator housing. Refer to Procedure 006-013 in Section 6.
- Remove the upper support bracket from the fuel pump actuator bracket. Refer to Procedure 005-016 in Section 5.

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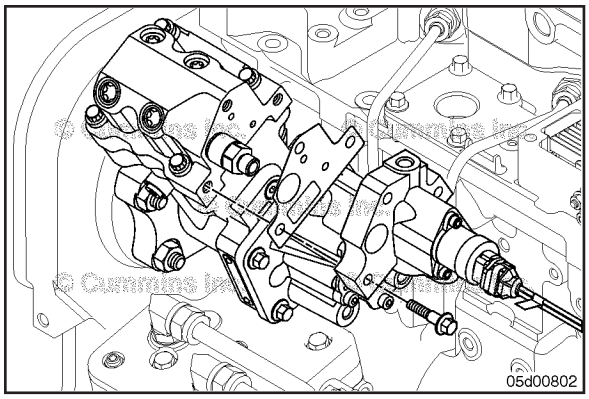
Remove

Remove the three bolts that hold the fuel pump actuator housing to the high-pressure fuel pump head.

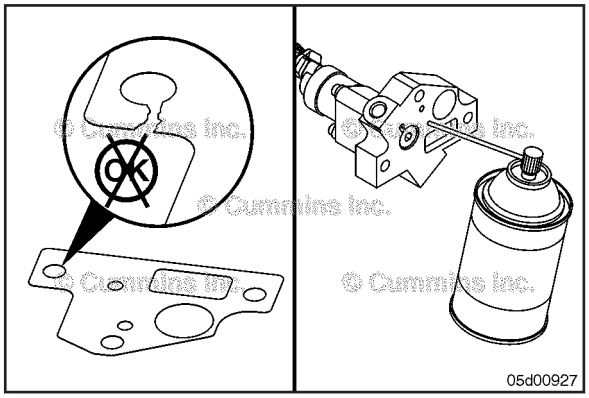
Remove the fuel pump actuator housing and the gasket.



Clean and Inspect for Reuse

Inspect the fuel pump actuator housing gasket. Do **not** reuse the gasket if the material is cracked, torn, or otherwise damaged.

Be sure that the mounting surfaces of the high-pressure pump head and the fuel control valve adapter block are clean. Use contact cleaner to clean these surfaces.



Install

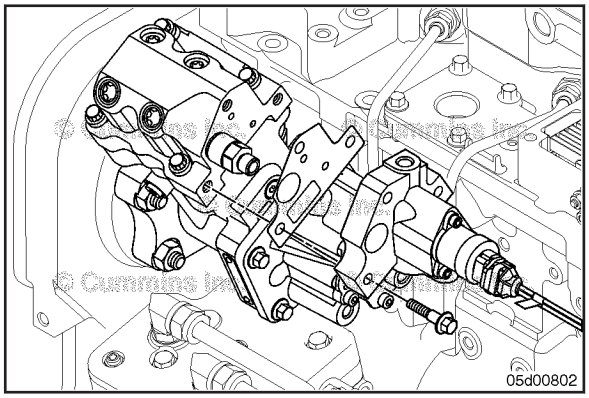
Insert the three mounting bolts through the fuel pump actuator housing.

Install the gasket over the bolts. The gasket **must** be installed dry.

Install the actuator housing.

Tighten the mounting bolts.

Torque Value: 34 N•m [25 ft-lb]



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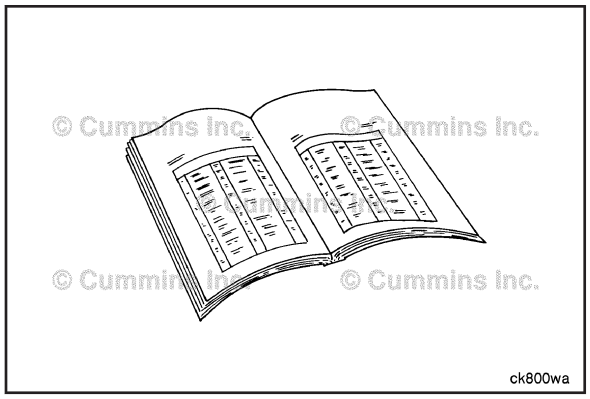
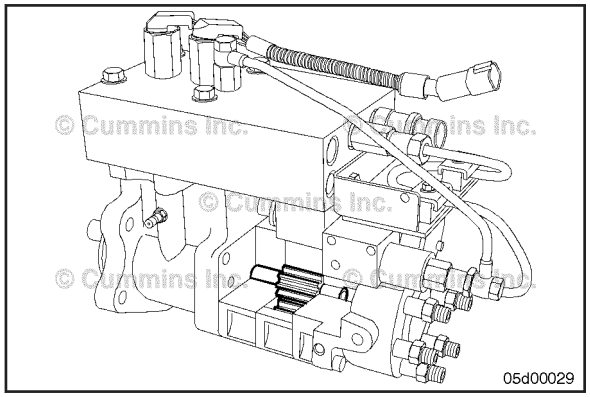


Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

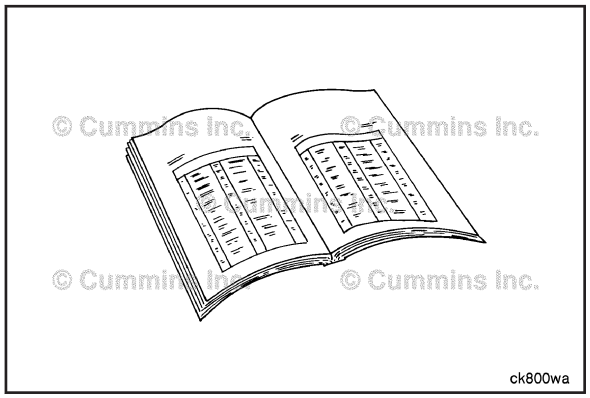
- Install the upper support bracket. Refer to Procedure 005-016 in Section 5.
- Connect the high-pressure fuel line to the fuel pump. Refer to Procedure 006-051 in Section 6.
- Connect the fuel supply line to the fuel pump. Refer to Procedure 006-024 in Section 6.
- Connect the fuel drain line to the fuel pump. Refer to Procedure 006-013 in Section 6.
- Connect the wire harness to the fuel pump actuator.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Fuel Injection Pump (005-229)

General Information

This procedure refers to the CAPS fuel system.



Preparatory Steps

- Disconnect the injection pump supply line. Refer to Procedure 006-024 in Section 6.
- Remove the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Disconnect the fuel drain line. Refer to Procedure 006-013 in Section 6.
- Disconnect the pumping control valve 4-pin Deutsch™ connector.
- Disconnect the injection control valve 4-pin Deutsch™ connector.
- Disconnect the accumulator pressure sensor.
- Disconnect the accumulator temperature sensor.

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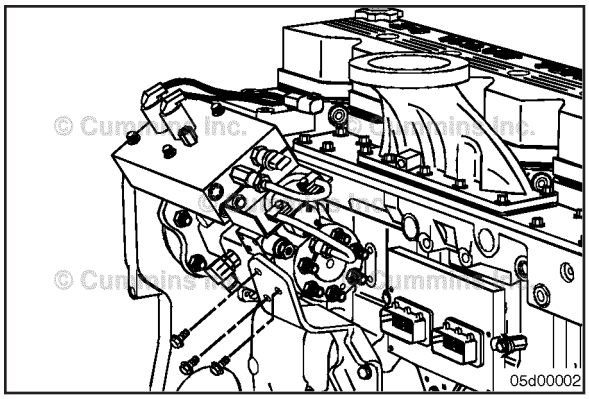
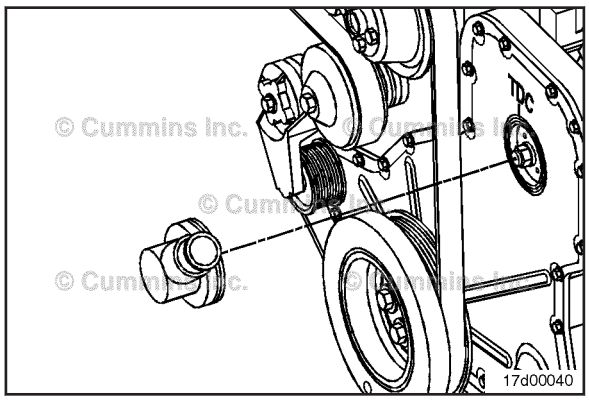
Remove

Remove the injection pump upper support bracket.

Remove the injection pump tail support bracket.

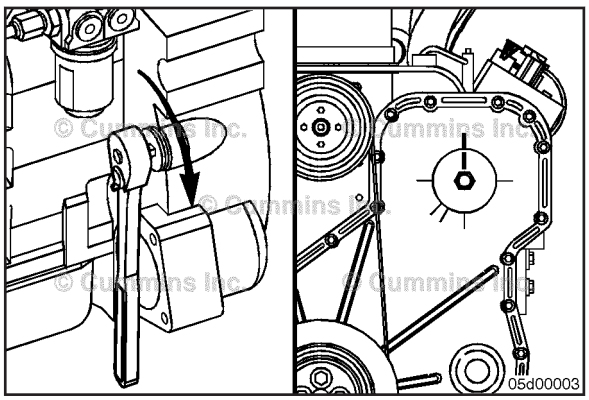


Remove the fuel pump gear access plug.

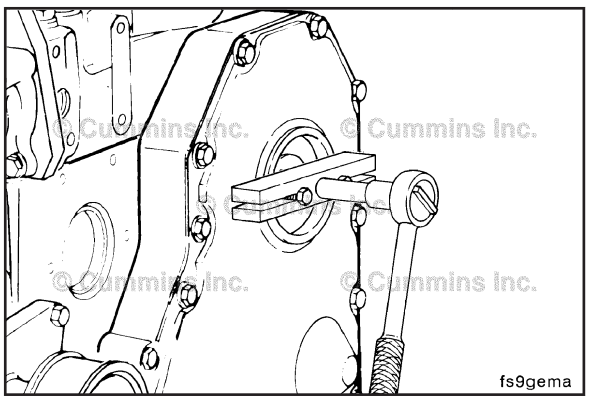


Locate top dead center for cylinder number 1 by barring the engine slowly until the line on the pump gear lines up with the line on the gear cover.

Remove the fuel pump drive gear retaining nut and washer.



Pull the fuel injection pump drive gear loose from the pump driveshaft.



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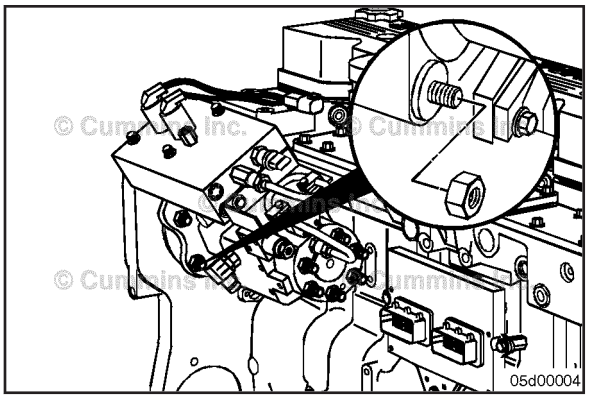
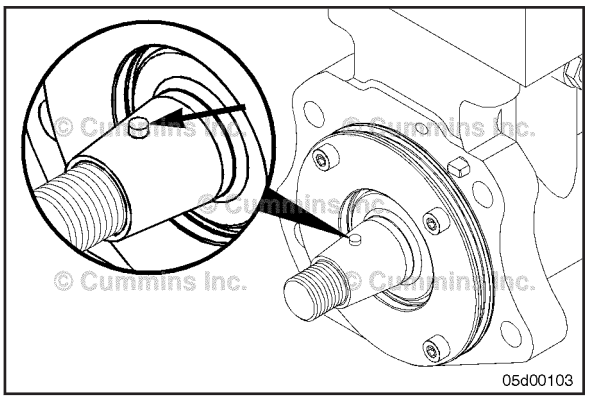


Remove the four mounting nuts.

Remove the fuel injection pump.

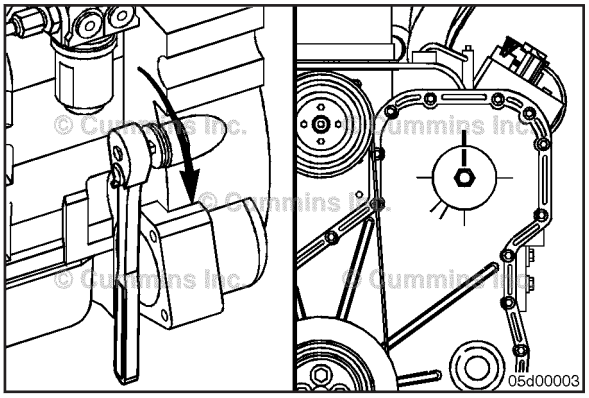


Clean and Inspect for Reuse

The fuel pump driveshaft key **must not** be sheared.

If the key is sheared, the camshaft housing module of the fuel pump **must** be replaced and the drive gear **must** be replaced.

Check that the locating dowel is installed in the camshaft housing.



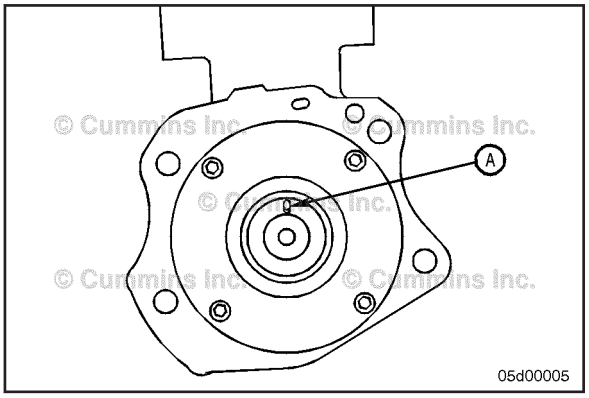
Install

Be sure the engine is at number 1 cylinder top dead center. The fuel pump gear timing mark should align with the top dead center mark on the gear housing.

Clean the fuel injection pump drive shaft with an evaporative cleaner.

Clean the fuel pump gear inside diameter with an evaporative cleaner.

The fuel pump drive gear inside diameter and the drive shaft outside diameter **must** be clean and dry before installing the gear.



Make sure the fuel injection pump is at its top dead center position.

The fuel injection pump is at number 1 cylinder top dead center when the dowel pin in the shaft (A) is perpendicular to the top of the accumulator.

Be sure that the dowel is installed in the pump driveshaft.

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Make sure the o-ring seals for the oil feed orifice (A) and pilot (B) are correctly installed and are **not** damaged.

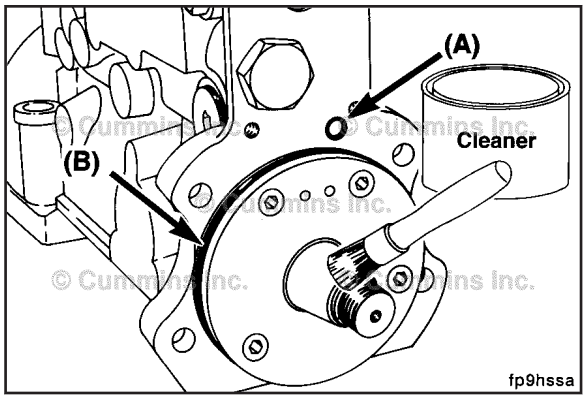
Lubricate the mounting flange with cleaner.

The fuel pump drive gear inside diameter and the shaft outside diameter **must** be clean and dry before installing the gear.

Slide the fuel injector pump shaft through the drive gear and position the fuel injection pump flange onto the mounting studs.

Make sure the dowel pin in the shaft (A) lines up with the keyway in the fuel injection pump gear.

Make sure the dowel pin in the fuel injection pump flange lines up with the hole in the gear housing.



Install the mounting nuts.

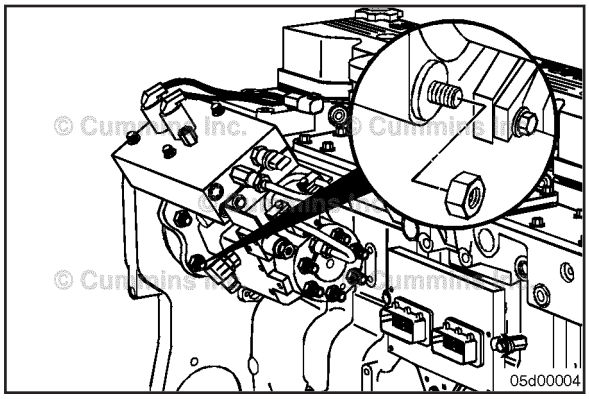
Install the fuel injection pump upper support bracket.

Install the fuel injection pump tail support bracket.

Torque Value:
Fuel Pump Mounting Nuts 44 N•m [32 ft-lb]

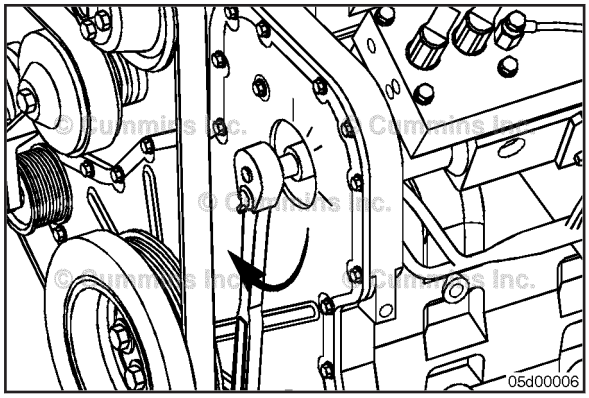
Torque Value:
Fuel Pump Upper Support Brackets (8.8 or 9.8 bracket capscrews) 44 N•m [32 ft-lb]

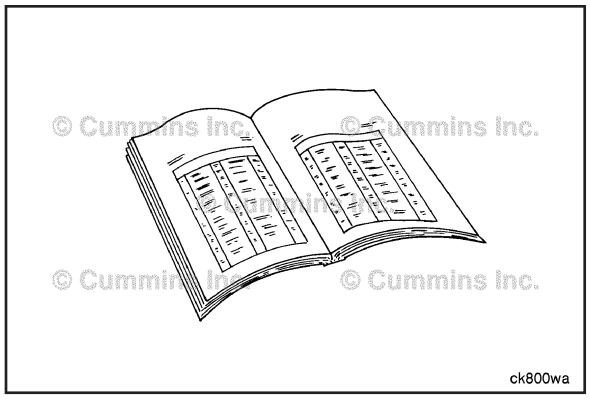
Torque Value:
Fuel Pump Tail Support Bracket (10.9 capscrews) 68 N•m [48 ft-lb]



Tighten the fuel injection pump drive gear nut.

Torque Value: 180 N•m [132 ft-lb]





Finishing Steps

- Install the gear cover access cap hand tight.
- Connect the injection pump supply line. Refer to Procedure 006-024 in Section 6.
- Connect the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Connect the fuel drain line. Refer to Procedure 006-013 in Section 6.
- Connect the pumping control valve 4-pin Deutsch™ connector.
- Connect the injection control valve 4-pin Deutsch™ connector.
- Connect the accumulator pressure sensor to the engine harness.
- Connect the accumulator temperature sensor to the engine harness.
- Operate the engine and check for leaks.

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Section 6 - Injectors and Fuel Lines - Group 06

Section Contents

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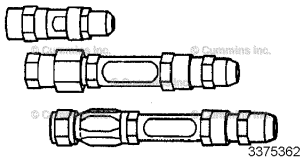
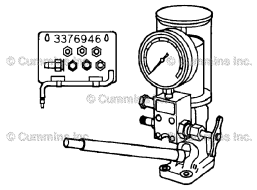
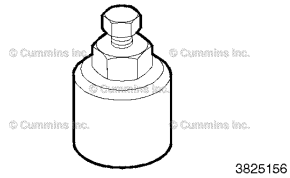
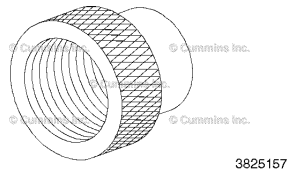
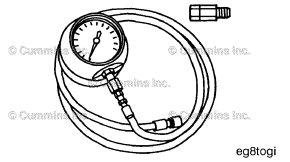
Service Tools

Injectors and Fuel Lines

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3164383	**Fuel Sight Glass Assembly, Number 10 SAE** Used to observe fuel flow to detect air in fuel.	
3376946	**Injector Nozzle Tester** Used to test opening pressure, leakage, chatter and spray pattern.	
3822509	**Injector Bore Brush** Used to clean the injector bore.	
3825156	**Injector Puller** Used to pull the injectors on CAPS fuel system.	
3825157	**Fuel Connector Puller** Used to pull the fuel connector.	
ST-1273	**Pressure Gauge (0 to 1905 mm Hg [0 to 75 in Hg])** Used to measure engine intake manifold pressure, exhaust restriction, lift pump output pressure, and pressure drop across fuel filter.	

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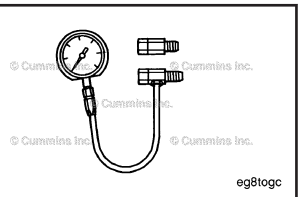
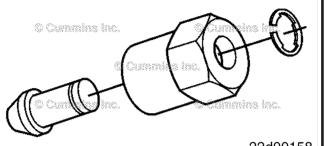
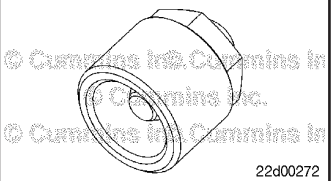
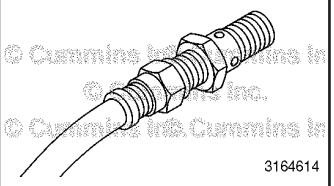
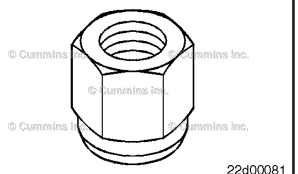
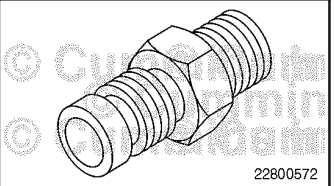
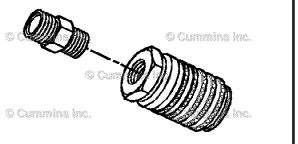
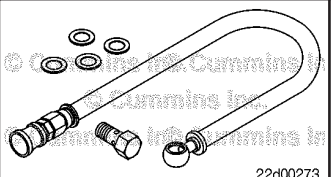
Tool No.	Tool Description	Tool Illustration
ST-434	**Vacuum Gauge (0 to 762 mm Hg [0 to 30 in Hg])** Used to measure lift pump inlet restriction. Hose adaptor, Part Number ST-434-2 and vacuum gauge, Part Number ST-434-12 are used to perform the test.	 eg8togc
3164325	**Fuel System Leak Tester** Used to block a single injector and high pressure fuel connector from pressurized fuel. This tool helps identify a failed injector when injector return flow is excessive.	 22d00158
4918563	**Fuel System Leak Tester** Used to block a single injector and high pressure fuel connector from pressurized fuel. This tool helps identify a failed injector when injector return flow is excessive.	 22d00272
3164618	**Fuel Return Flow Hose** This tool uses a special fitting to connect to the fuel return circuits to measure return flow from the injectors and fuel pump.	 3164614
3164025	**Fuel Connector Remover** Used to pull the fuel connector.	 22d00081
3824842	**M10 STORM Compuchek™ Diagnostic Fitting** Used to measure fuel pressure or vacuum wherever STORM M10 diagnostic ports exist.	 22800572
3164621	**Fuel line with 1.09 mm [0.043 in] orifice.** Used in procedures to create rated flow through the low pressure fuel system without the need to operate the engine under load.	 3164621
4918324	**Fuel Pressure Test Kit** Used with a vacuum gauge, Part Number ST-434 or equivalent, along with quick-disconnect fitting, Part Number 3972088, to check the fuel inlet restriction.	 22d00273

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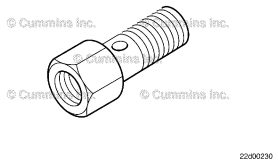
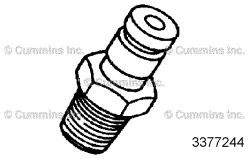
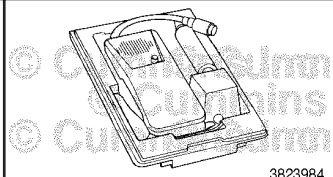
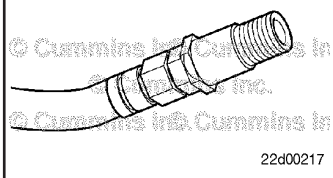
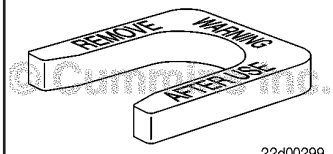
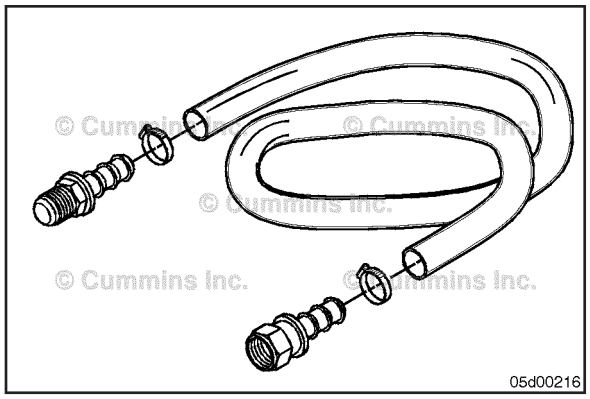
Tool No.	Tool Description	Tool Illustration
4918413	**Banjo Fitting** A banjo-style pressure gauge adapter may be used to measure pressure or vacuum at any point in the low-pressure fuel system where a banjo bolt exists at a fuel line.	
3377244	**Fitting, Quick-Disconnect Male** Used to perform a pressure-side air-in-fuel test.	
3823984	**Combustible Gas Detector** Use to check for gas leaks at connections.	
3164617	**Fuel Return Flow Hose (fuel pressure relief valve)** The tool uses a special banjo fitting to connect to the fuel return circuit to measure the return flow from the fuel pressure relief valve.	
4918878	**Fuel Line Quick Disconnect Tool** Used to remove 3/8 quick disconnect fittings female connectors.	



Air in Fuel (006-003)

Setup

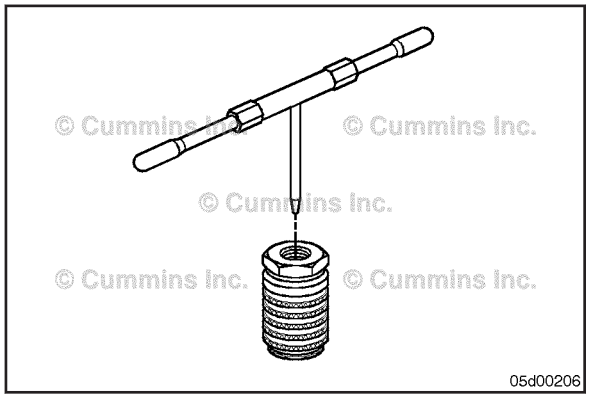
Obtain a 1.09 mm [0.043 in] orificed diagnostic fuel line, Part Number 3164621.

A 1.09 mm [0.043-inch] orificed diagnostic fuel line is used in procedures to create rated flow through the low pressure fuel system, without the need to operate the engine under load.

Obtain a container suitable for collection of fuel that exits the diagnostic fuel line (a 19 liter [5 gal] bucket is recommended).

Construct a sight tube (CAPS) fuel systems **only**):

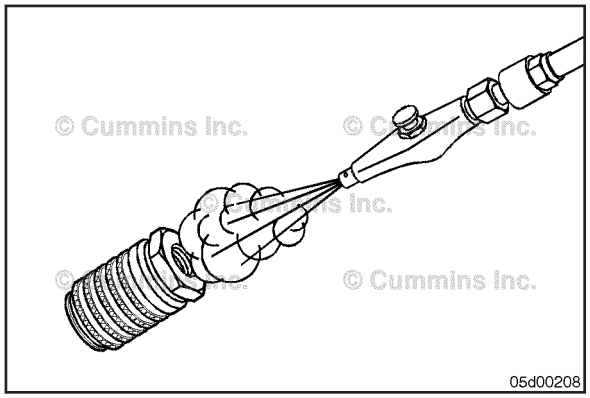
Assemble two (one male and one female, 7.8-14 thread barb-tite fittings and hose clamps to a 61 cm [2 ft] long number-10 clear hose approved for use with diesel fuel.



If 1.09 mm [0.043 in] orificed diagnostic fuel line, Part Number 3164621 can **not** be obtained, construct a 1.09 mm [0.043 in] orificed diagnostic fuel line, use the following steps:

Tap a female quick connect, Part Number 3376859.

Tap size 8-36 national fine (U.S.).



⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the female quick connect, Part Number 3376859, with compressed air.

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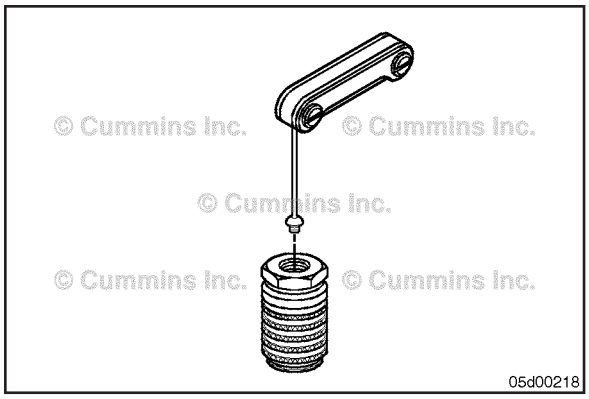
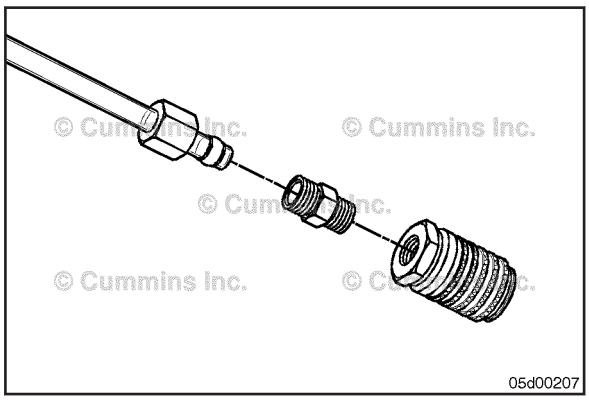
Assemble a 1.09 mm [0.043 in] injector orifice, Part Number 3045018, with washer, to the female quick connect, Part Number 3376859.

NOTE: To obtain correct flow, use a 1.09 mm [0.043 in] injector orifice, Part Number 3045018.



Attach the orifice to an appropriate length (it **must** reach from the fuel pump to the fuel tank) of 1/4-inch, or larger, tubing.

NOTE: It is recommended that this tool be marked and identified as having a 1.09 mm [0.043 in] orifice installed. This is to make sure that there is no confusion when using this tool in the future.

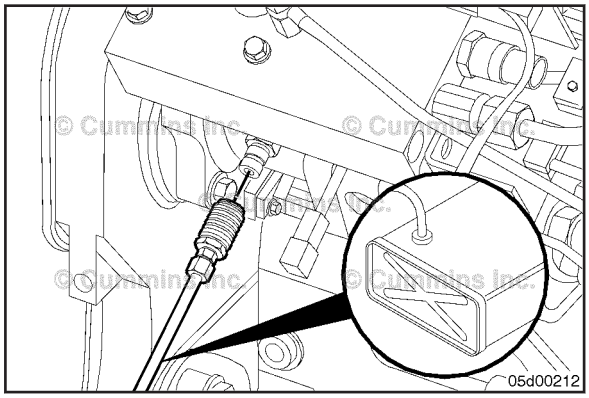


Measure

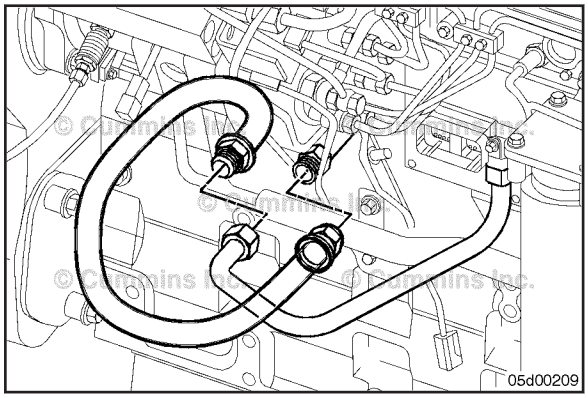
CAPS Fuel System

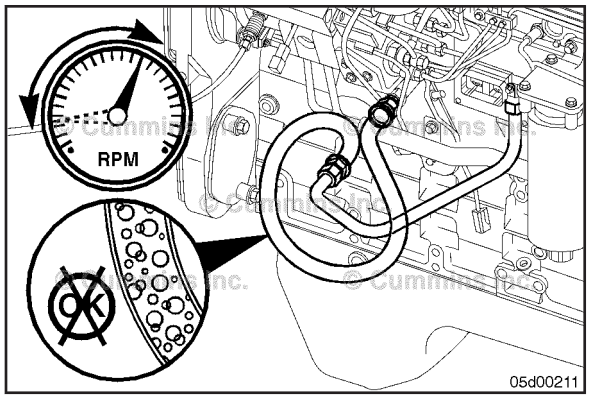
Attach the 1.09 mm [0.043 in] diagnostic fuel line at the fuel injection pump's diagnostic fitting.

Run the outlet of the diagnostic fuel line into the fuel collection container (or the vehicles fuel tank).



Install the sight glass between the fuel filter head and the fuel injection pump inlet.





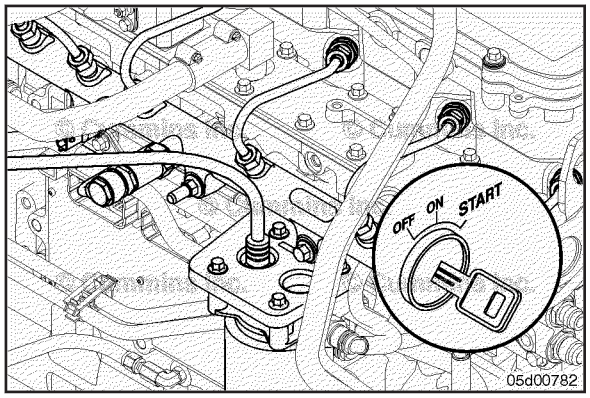
Run the engine from idle to high idle several times to purge the air induced while installing the diagnostic fuel line.

Run the engine up to high idle while another technician checks for air in the system.

NOTE: A small amount of air in the inlet line is acceptable. Ignore any air that is observed in the tube running back to the fuel tank.

Operate the engine at idle and observe any air in the fuel supply. If air is observed, isolate the air to the following components:

- Fuel filter assembly
- Fuel heater
- Fuel lift pump assembly
- OEM fuel plumbing
- Fuel tank stand-pipe.



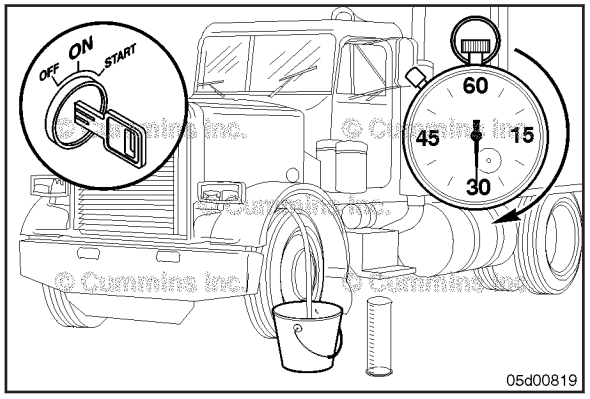
Cummins® Common Rail Fuel System

NOTE: A symptom of air-in-fuel for the engines equipped with a common rail fuel system is an audible surge associated with fuel system pressure fluctuations, due to air in the fuel supply.

The following test method will simulate rated fuel flow through the system so that air in fuel problems may be diagnosed.

Install a Compuchek™ fitting, Part Number 3824842, at the inlet to the 2 micron fuel filter and attach the 1.09 mm [0.043 in] diagnostic fuel line.

NOTE: If there is **not** enough clearance to install the female Compuchek™ fitting, Part Number 3824842, an adapter fitting, Part Number 3932302, and an 1/8-NPT male Compuchek™ fitting, Part Number 3377244, can be used to aid accessibility.



Route the outlet of the 1.09 mm [0.043 in] diagnostic fuel line into a collection device of suitable size (a 19 liter [5 gal] bucket is recommended).

Start the engine and operate the engine speed from idle to high idle several times to purge the air introduced while installing the diagnostic fuel line.

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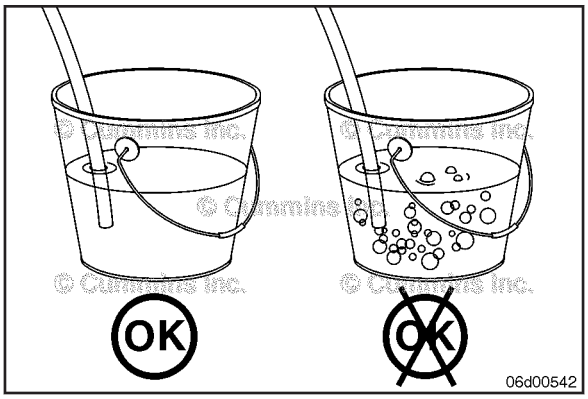
Observe the fuel flow exiting the diagnostic fuel line while the engine operates at idle speed.

Bubbles are an indication of a leak that allows air to enter, a severe inlet restriction that causes cavitation, or a system that is **not** yet primed. Refer to Procedure 006-020 Section 6.

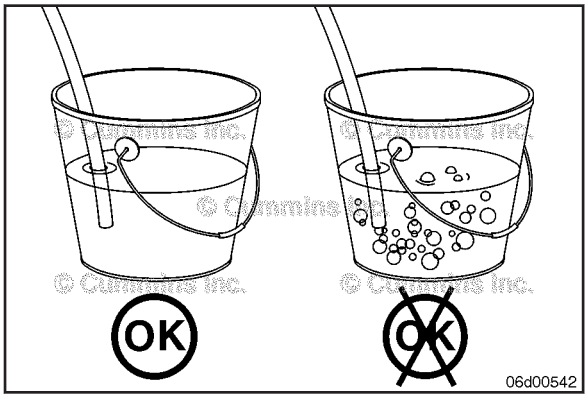
- Suction fuel lines
- ECM cooling plate assembly
- OEM fuel lines
- Suction-side fuel filter assemblies
- Stand-pipe(s) in the fuel tank(s).



If diagnostic fuel lines, Part Number 4918895, are unable to be installed, observe the fuel flow exiting the diagnostic fuel line while the engine operates at idle speed.

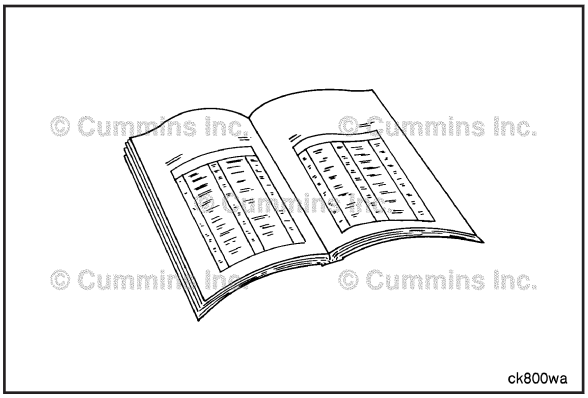
Bubbles are an indication of a leak that allows air to enter, a severe inlet restriction that causes cavitation, or a system that is **not** yet primed. Refer to Procedure 006-020 Section 6.

- Suction fuel lines
- ECM cooling plate assembly
- OEM fuel lines
- Suction-side fuel filter assemblies
- Stand-pipe(s) in the fuel tank(s).
- Gear pump shaft seal leak.



Finishing Steps

- Remove all test fuel lines. Refer to Procedure 006-024 in Section 6.
- Operate the engine and check for leaks.

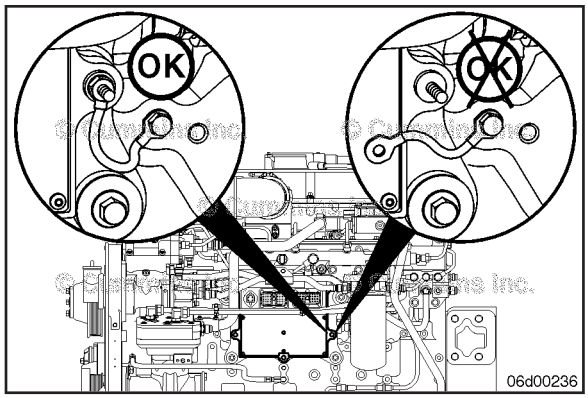


Engine Control Module Cooling Plate, Fuel Cooled (006-006)

Initial Check

The ECM cooling plate assembly provides a vibration isolated mounting location for the ECM. The cooling plate also provides ECM cooling and incorporates the fuel lift pump. A check valve at the outlet port in the ECM cooling plate makes sure that the fuel system is primed while the fuel lift pump is running.

Check the ECM cooling plate for damaged vibration isolators, loose capscrews, or fuel leaks.



Make sure that the ground strap is properly installed. A missing or poorly connected ground strap may cause intermittent engine performance problems.

The ground strap **must** be connected between the head of the ECM mounting bolt and the ECM.

The ground strap **must** be connected to an unpainted block surface that is free of corrosion.

Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

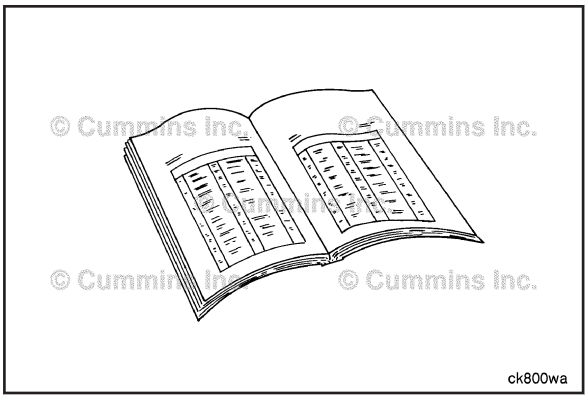
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

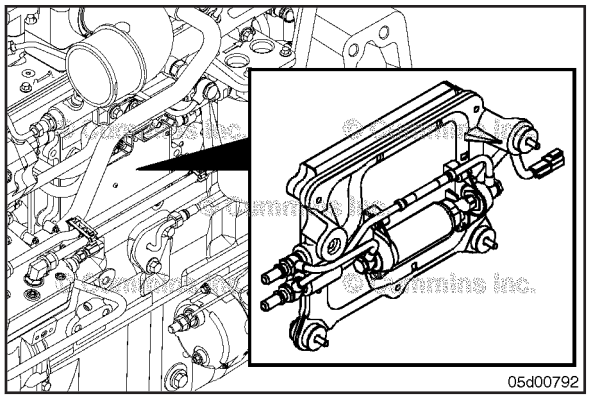
△CAUTION△
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system that fuel is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The fuel and fuel filters must be discarded in accordance with local environmental regulations.

△CAUTION△
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Disconnect the harness connections from the ECM.
- Disconnect the unswitched battery power at the batteries, marine engines **only**.
- Disconnect the unswitched ECM power connection on the SIM mounting plate, marine engines **only**.
- Disconnect the ECM ground strap.
- Disconnect the engine harness from the electric fuel priming pump.
- Close the fuel supply and drain valves, if equipped.
- Disconnect the fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Remove the ECM from the cooling plate. Refer to Procedure 019-031 in Section 19.

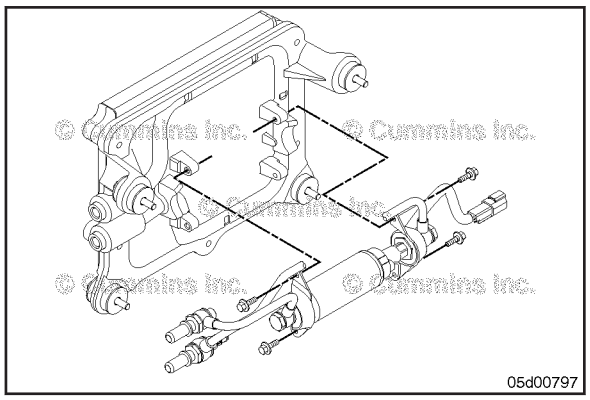




Remove

NOTE: The electric fuel priming pump and priming pump fuel lines will be attached to the ECM cooling plate while the cooling plate is being removed.

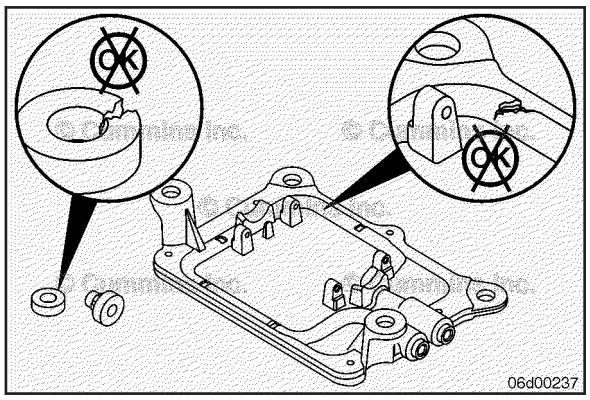
Remove the ECM cooling plate capscrews and the ECM cooling plate from the engine block.



Disassemble

Remove the following components from the ECM cooling plate:

- Male banjo quick disconnect fitting
- Male banjo check valve fitting
- Fuel lift pump supply lines
- Fuel lift pump brackets
- Fuel lift pump.



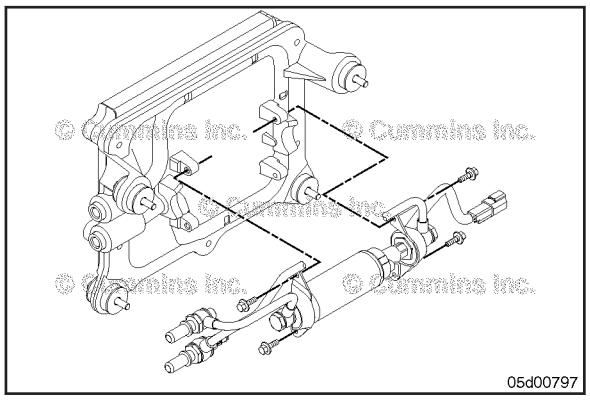
Inspect for Reuse

Inspect the ECM cooling plate for leaks (note that the fuel passages are contained in a tube that is cast into the cooling plate).

Replace any damaged vibration isolators.

Inspect for leaks in the electric fuel supply pump priming circuit. Look for cracked fuel tubes, damaged o-rings, or damaged seal washers.

Inspect the check valve for debris or damage.



Assemble

Install the electric fuel priming pump and the priming circuit fuel lines. Refer to Procedure 005-045 in Section 5.

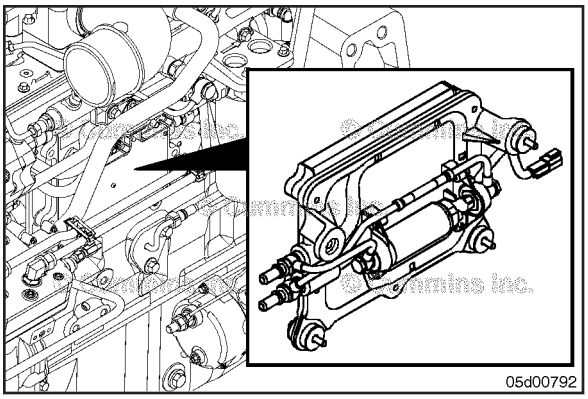
Be sure the lines are supported while tightening the banjo screws. The lines **must not** be permitted to bind.

Be sure the ECM check valve is installed into the bottom (outlet) fitting of the ECM cooling plate.

Install

Install the ECM cooling plate assembly on the engine block. Tighten the capscrews.

Torque Value: 24 N•m [212 in-lb]



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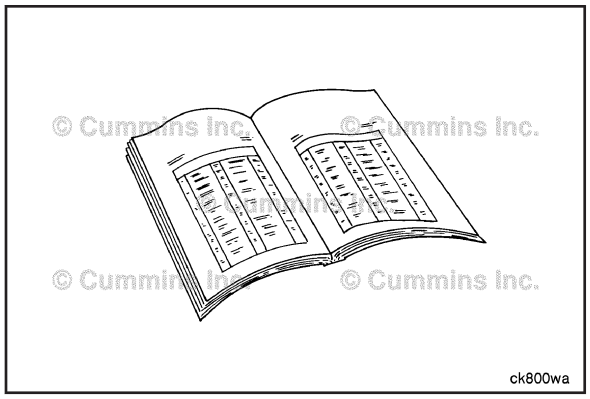

Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠CAUTION⚠
Failure to properly install the ECM ground strap may cause intermittent engine symptoms including intermittent engine stalls. One end of the ground strap must be installed between the ECM housing and the head of the bottom most ECM mounting capscrew. The other end of the ground strap must be tightly bolted to an unpainted block surface that is free from corrosion.

NOTE: Be sure the vibrations isolators are installed correctly. The isolators fit in a single direction into the chamfered locators.

- Install the ECM on the ECM cooling plate. Refer to Procedure 019-031 in Section 19.
- Install the suction fuel lines, if removed.
- Connect the fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Connect the engine harness to the electric fuel priming pump.
- Connect the ECM ground strap.
- Connect the unswitched ECM power connection on the SIM mounting plate, marine engines **only**.
- Connect the harness connections to the ECM.
- Connect the unswitched battery power at the batteries, marine engines **only**.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Open the fuel supply valves, if equipped.
- Cycle the keyswitch and allow the lift pump to operate for 30 seconds. Afterwards, turn the keyswitch OFF and back ON again allowing the lift pump to operate again.
- Allow the lift pump to operate for three or four 30-second cycles before attempting to start the engine.
- Operate the engine and check for leaks.

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Fuel Drain Line Restriction (006-012)

Preparatory Steps

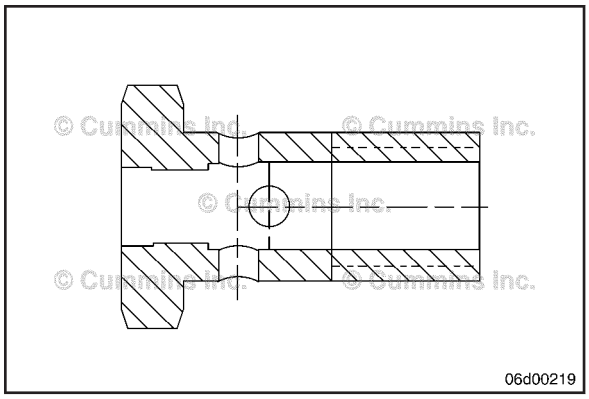
Obtain a M12 banjo pressure gauge tool, Part Number 4918413.

A banjo-style pressure gauge adapter may be used to measure pressure or vacuum at any point in the low-pressure fuel system where a banjo bolt exists at a fuel line.

The engines use M12 x 1.5 banjo bolt connections. Part Number 4918413 may be used for measurement of drain line restriction (pressure) at the fuel drain manifold.

Make a banjo bolt pressure gauge tool by drilling and tapping the hex face of a M12 x 1.5 banjo bolt, Part Number 3903035, or equivalent.

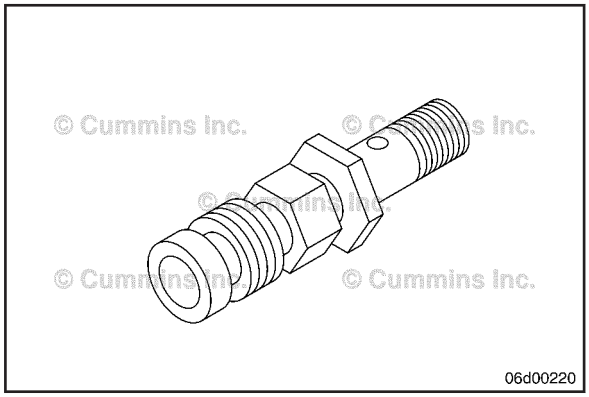
Drill and tap the banjo bolt to the size of Compuchek™ fitting, or other hose union, being used (example 1/8-inch NPT Compuchek™ fitting, Part Number 3377244, or M10 Compuchek™ fitting, Part Number 3824842).



Assemble the banjo pressure gauge adapter.

1 Install the Compuchek™ fitting, Part Number 3377244, or other type fitting in the hex face of the banjo bolt.

2 Attach a hose or pressure gauge to the banjo pressure adapter.

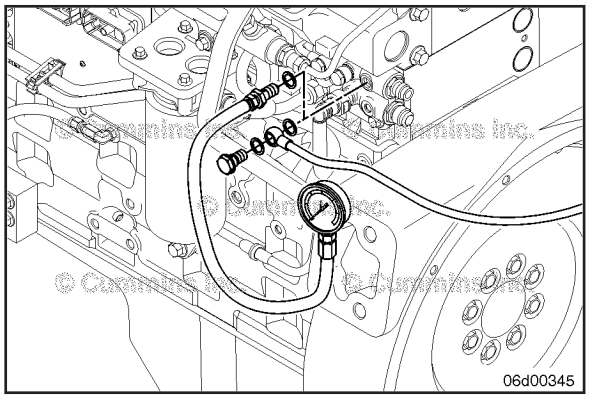


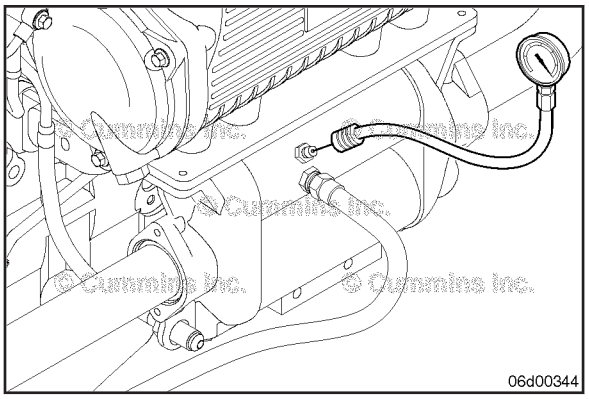
All Applications Except Marine

Install the M12 banjo pressure gauge adapter in place of the injector drain line banjo at the fuel drain manifold.

Install the M12 banjo pressure gauge adapter in place of the banjo bolt that attaches the injector drain line to the electric lift pump drain manifold (CAPS fuel systems).

Install a 0 to 762 mm Hg [0 to 30 in Hg] pressure gauge at the M12 banjo pressure gauge adapter.



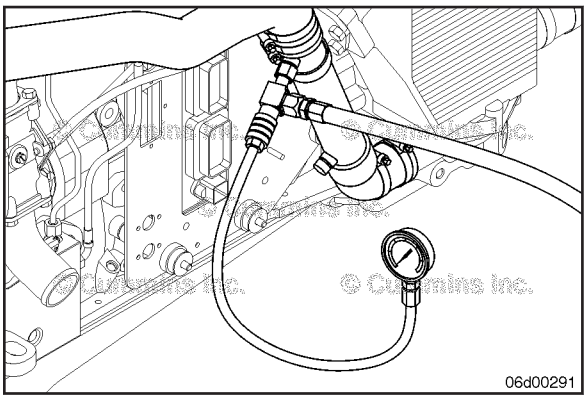


Marine Applications

⚠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.

On QSC8.3 engines, install a Compucheck™, or other type fitting, in the fuel outlet side of the fuel cooler, if one is **not** already installed.

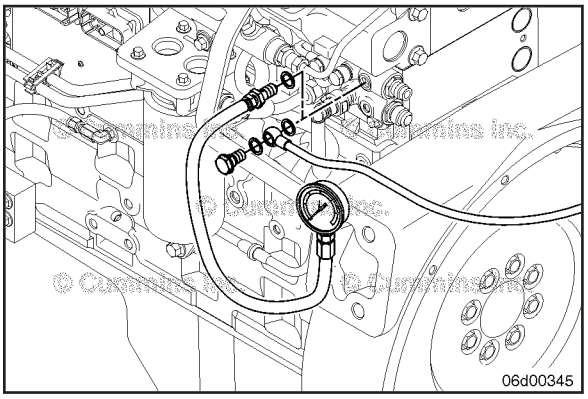
Connect a 0 to 762 mm Hg [0 to 30 in Hg] pressure gauge with a flexible hose at the fuel outlet fitting.



⚠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.

On QSL9 engines with sea water cooling, install a Compucheck™, or other type fitting, in the fuel outlet side of the fuel cooler, if one is **not** already installed.

Connect a 0 to 762 mm Hg [0 to 30 in Hg] pressure gauge with a flexible hose at the fuel outlet fitting.



⚠CAUTION⚠
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system that fuel is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The fuel and fuel filters must be discarded in accordance with local environmental regulations.

NOTE: QSL9 engines with keel coolers do **not** have fuel coolers.

On QSL9 engines with keel cooling, install the M12 banjo pressure gauge adapter in place of the injector drain line banjo at the fuel drain manifold.

Connect a 0 to 762 mm Hg [0 to 30 in Hg] pressure gauge with a flexible hose at the M12 banjo pressure gauge adapter.

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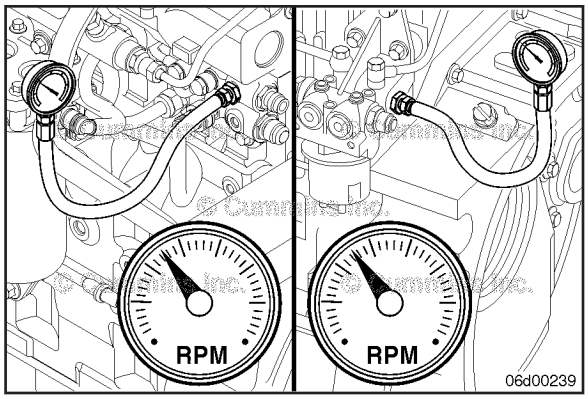
Measure

Operate the engine at rated speed and no load.

Observe the reading on the gauge.

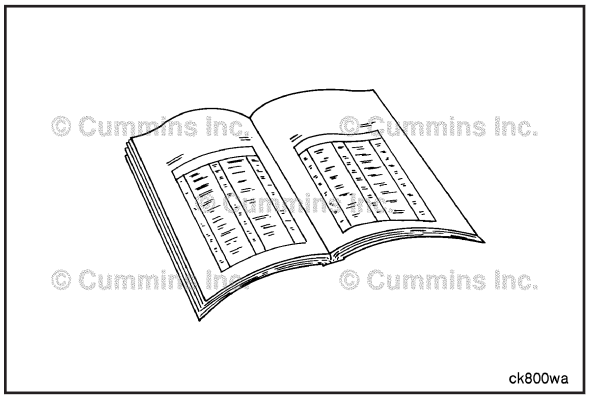
Fuel Drain Line Pressure	mm Hg		in Hg
All Applications Except Marine	254.0	MAX	10.0
Marine Applications	101.6	MAX	4.0

If the drain line pressure is out of specification, check for bends or kinks in the drain lines. Look for places where the OEM fuel lines may be pinched by wire ties or p-clips. Check for blocked fuel tank vents.



Finishing Steps

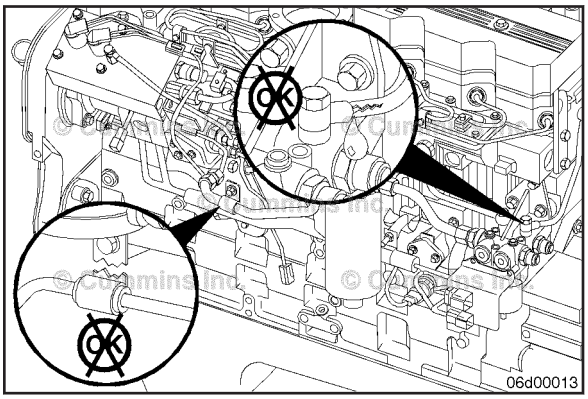
- Remove all test fittings and install the drain lines. Refer to Procedure 006-013 in Section 6.



Fuel Drain Lines (006-013)

Initial Check

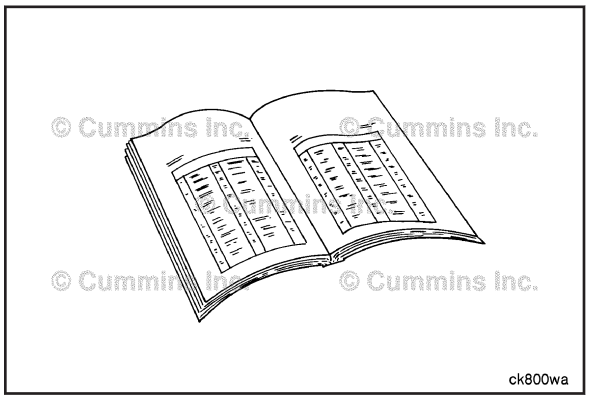
Inspect the drain lines for any signs of leaks, cracks, chafing, or loose or broken brackets.

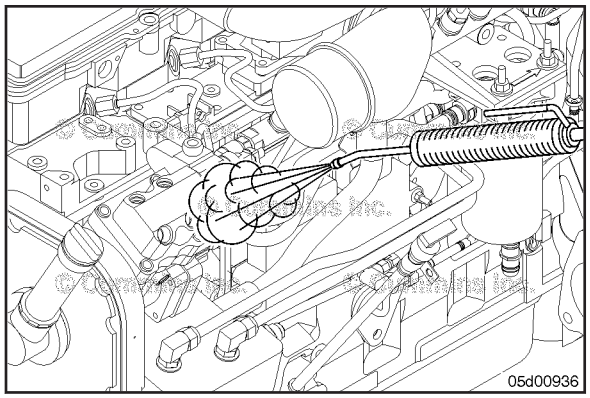


Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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.



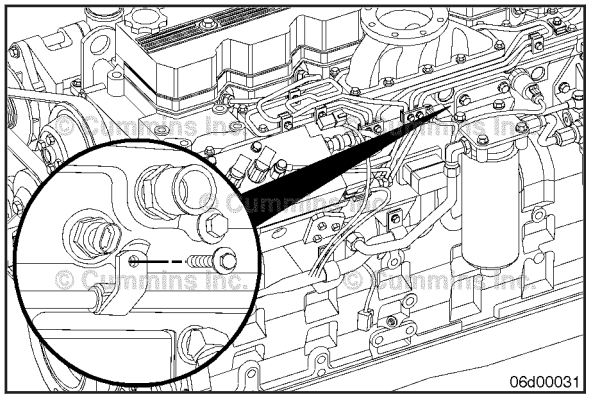


⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

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

△CAUTION△
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine. Refer to Procedure 000-009 in Section 0.



Remove

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.

⚠WARNING⚠
Do not vent the fuel system on a hot engine; this can cause fuel to spill onto a hot exhaust manifold, which can cause a fire.

There are two drain lines on the engine:

1 The fuel injection pump drain line routes fuel from the fuel injection pump to the fuel lift pump drain manifold. This line has a p-clip brace that attaches to the cylinder head.

2 The injector drain line which routes fuel from the rear of the cylinder head to the fuel lift pump drain manifold.

These lines are removed by removing the banjo bolts and sealing washers.

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.

⚠WARNING⚠
Do not vent the fuel system on a hot engine; this can cause fuel to spill onto a hot exhaust manifold, which can cause a fire.

△CAUTION△
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.

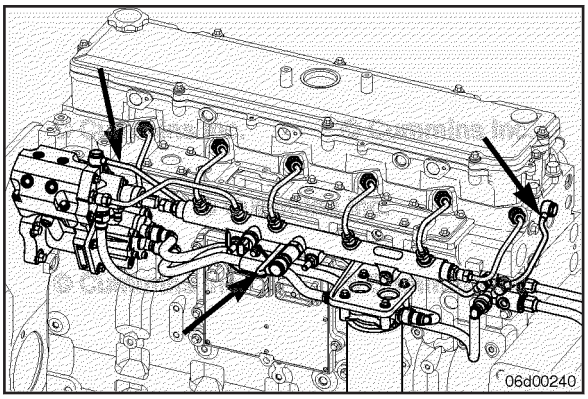
There are three drain lines on the engine:

1 The fuel pump drain line connects the fuel pump to the fuel drain manifold. This line has a p-clip brace that attaches to the engine cylinder head.

2 The fuel rail pressure relief valve drain line connects the fuel rail pressure relief valve to the fuel drain manifold.

3 The injector drain line connects the back of the cylinder head to the fuel drain manifold.

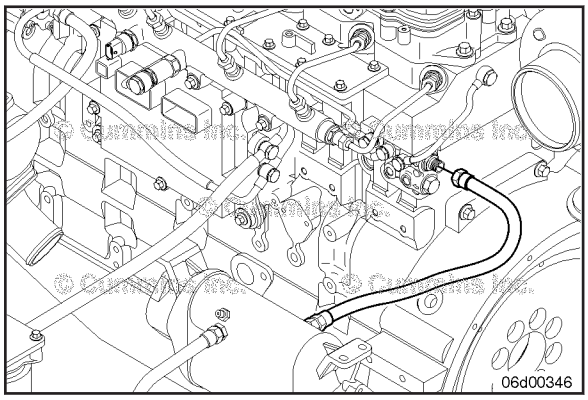
These lines are removed by removing the banjo bolts and sealing washers.

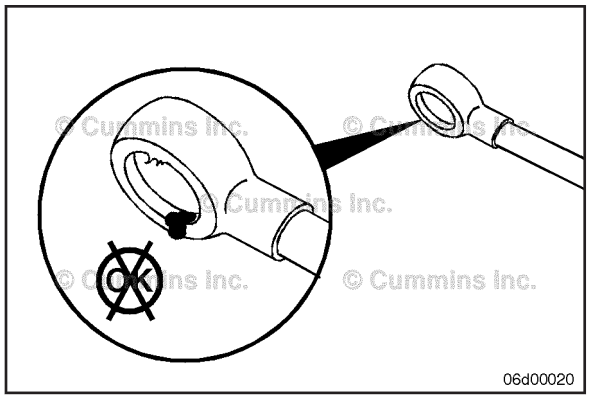


NOTE: QSL9 marine applications, which are keel cooled, do **not** have fuel coolers.

QSC8.3 and QSL9 marine applications, which are sea water cooled, have an additional drain line which transfers the fuel from the fuel drain manifold to the fuel cooler.

This line is removed by loosening the compression nuts.

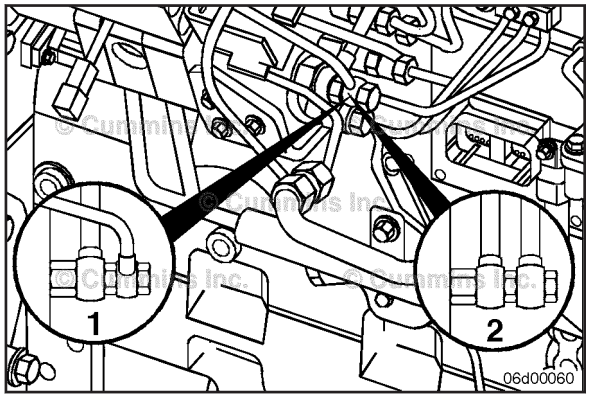




Inspect for Reuse

Inspect the lines for damage.

Inspect the banjo seal washers for damage.



Install

CAPS Fuel System

Connect the fuel drain line at the fuel pump banjo fitting at the rear of the cylinder head and at the lift pump. Use two (2) wrenches when installing the drain line at the fuel pump return.

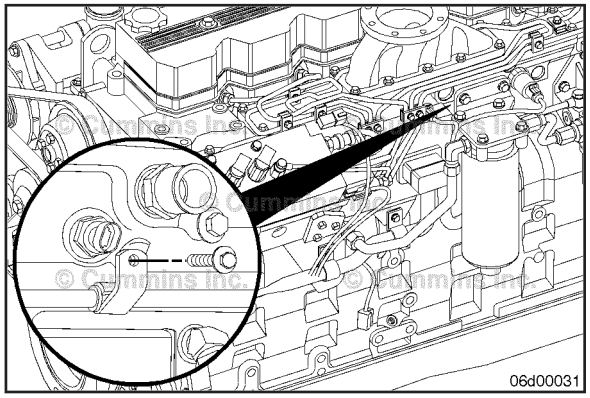
Torque Value:
Style One (1)

Step 1	24 N•m	[212 in-lb]

Torque Value:
Style Two (2)

Step 1	24 N•m	[212 in-lb]

Use the following procedure for air bleeding installation. Refer to Procedure 006-056 in Section 6.



Install and tighten the clamp capscrews.

Torque Value:
M12 banjo bolts

Step 1	24 N•m	[212 in-lb]

Torque Value:
P-clip capscrew

Step 1	24 N•m	[212 in-lb]

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Cummins® Common Rail Fuel System

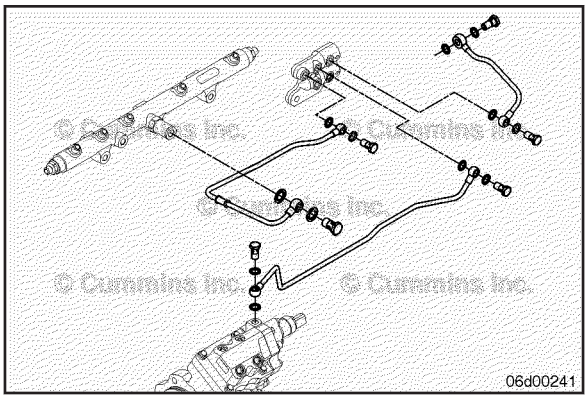
Install the three drain lines on the engine.

High pressure fuel pump drain:

- Install the p-clip bracket
- Install the banjo bolt at the fuel drain manifold
- Install the banjo bolt at the fuel pump.

Pressure relief valve drain line:

- Install the banjo bolt at the fuel drain manifold
- Install the banjo bolt at the pressure relief valve. Hold the line so that it will **not** twist and wear against the bottom of the cylinder head.



Injector drain line.

Torque Value:
M12 banjo bolts

Step 1	24 N•m	[212 in-lb]

Torque Value:
M16 banjo bolts

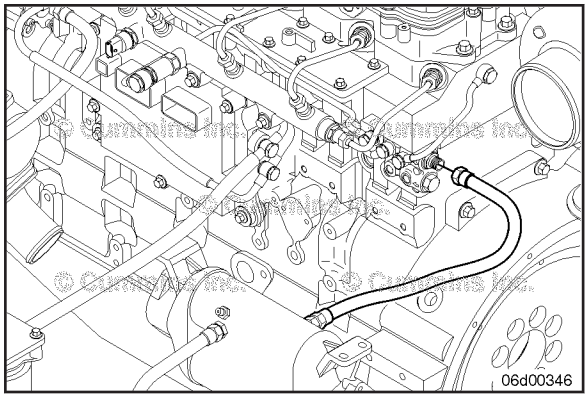
Step 1	43 N•m	[32 ft-lb]

Torque Value:
P-clip capscrew

Step 1	24 N•m	[212 in-lb]

On marine applications, install the additional fuel drain line from the fuel drain manifold to the fuel cooler.

Torque Value: 37 N•m [27 ft-lb]

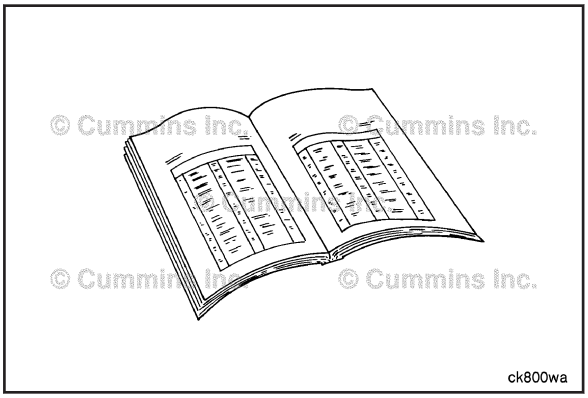


Finishing Steps

⚠ 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 the OEM service manual.
- Operate the engine and check for leaks.



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

General Information

CAPS Fuel System

The CAPS fuel system requires the use of a single fuel filter. The filter **must** have the following characteristics:

- Water-separating
- 10-micron rating
- Water-in-fuel sensor
- Water drain valve
- Engine mounted or chassis mounted.

Fleetguard® FS1022 meets these requirements.

Cummins® Common Rail Fuel System

The Cummins® Common Rail fuel system requires the use of two fuel filters. The suction-side filter **must** have the following characteristics:

- Water-separating
- 10-micron rating
- Water-in-fuel sensor with shunt resistor
- Water-drain valve
- **Always** chassis mounted.

Fleetguard® FS1003 meets these requirements.

Racor™ model 1000MA meets these requirements for marine applications.

The pressure-side filter **must** have the following characteristics:

- 3-micron rating
- Engine mounted or chassis mounted.

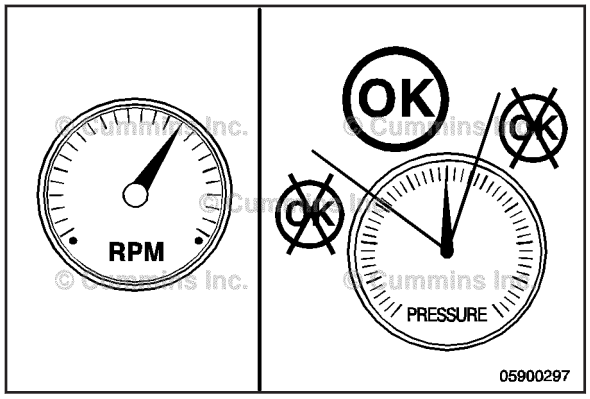
Fleetguard® FF5488 meets these requirements.

The fuel supply and return valves **must** be closed when servicing the fuel filters on marine applications.

Identify the engine for the correct filters.

Refer to Procedure 100-001 in Section E.

The CM554 engine uses the CAPS fuel system.



Measure

Operate the engine at high idle and record the fuel pressure at the inlet and outlet of the fuel filter. Subtract the outlet reading from the inlet reading to determine the restriction.

Maximum Allowable Pressure Drop Across Fuel Filter		
kPa		psi
80	MAX	11.7

If the pressure drop is greater than the specified value, the fuel filter **must** be replaced.

Remove the Compuchek™ fittings and install the threaded plugs into the diagnostic ports. See Section 17 for the correct torque value.

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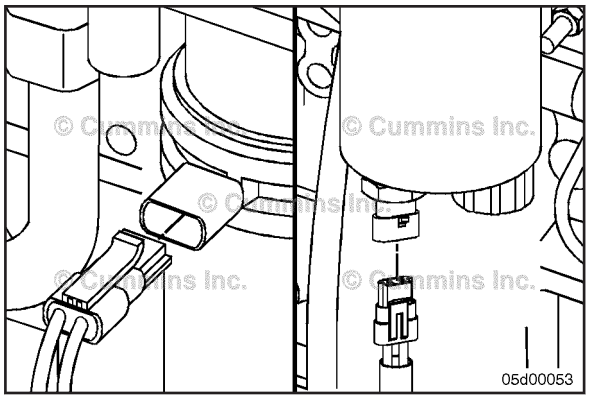
Remove



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

Close the fuel supply and return valves, if equipped.

Disconnect the wiring harness from the water-in-fuel sensor, if equipped.

Disconnect the wiring harness from the fuel heater, if equipped.

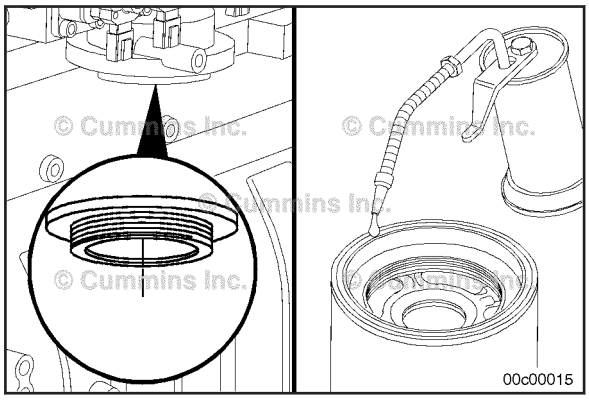
Loosen and remove the fuel filter.

Make sure the seal ring does **not** stick to the filter head.

Remove the ring with an o-ring pick, if necessary.

Install

CAPS Fuel System



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

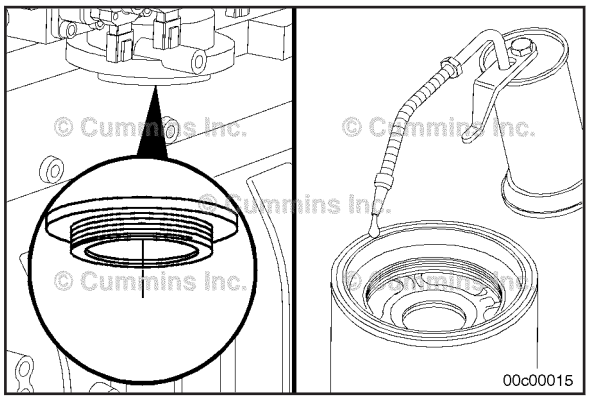
Do **not** fill the fuel filter with fuel before installation; instead, prime the fuel system using the fuel lift pump.

Be sure the center seal ring is installed onto the filter spud.

Install the filter as specified by the filter manufacturer.

Connect the water-in-fuel sensor and the fuel heater, if equipped.

Cummins® Common Rail Fuel System



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

It will be necessary to fill the 10-micron water stripping (suction-side) fuel filter with fuel.

Do **not** fill the 3-micron (pressure-side) fuel filter with fuel before installation; instead, prime the fuel system using the fuel lift pump.

Make sure the center seal ring is installed onto the filter spud.

Install the filter as specified by the filter manufacturer.

Connect the water-in-fuel sensor and the fuel heater, if equipped.

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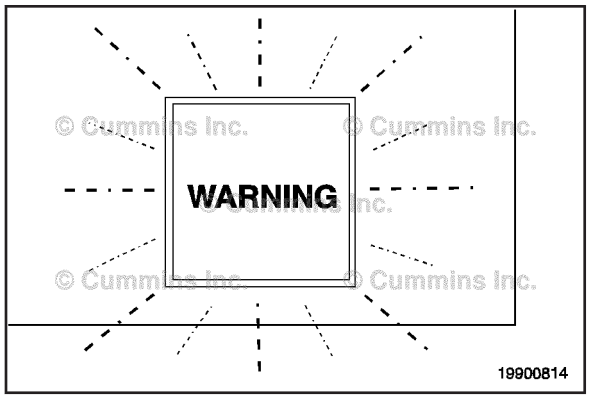
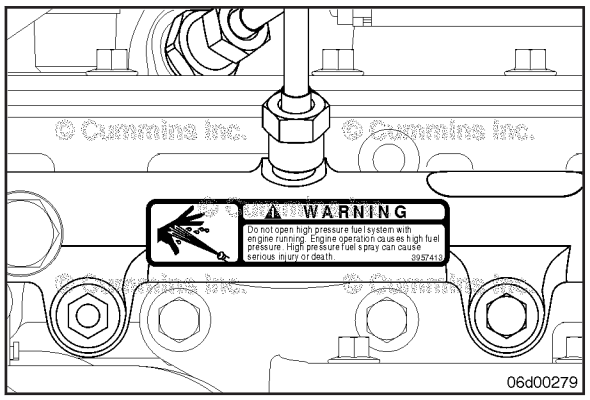


The Cummins® Common Rail fuel system is capable of detecting the presence of the correct water-in-fuel sensor.

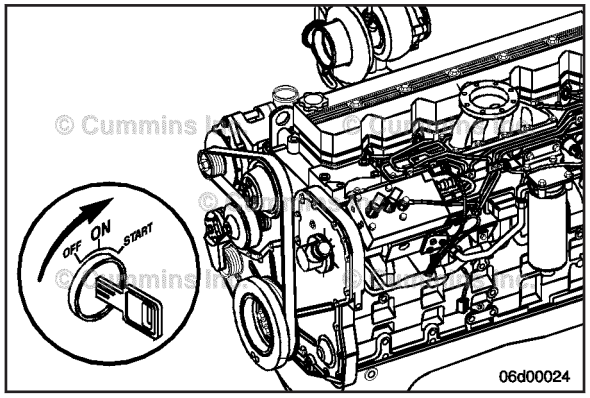
If the water-in-fuel sensor is incompatible or disconnected, the engine WARNING lamp will illuminate.



Prime

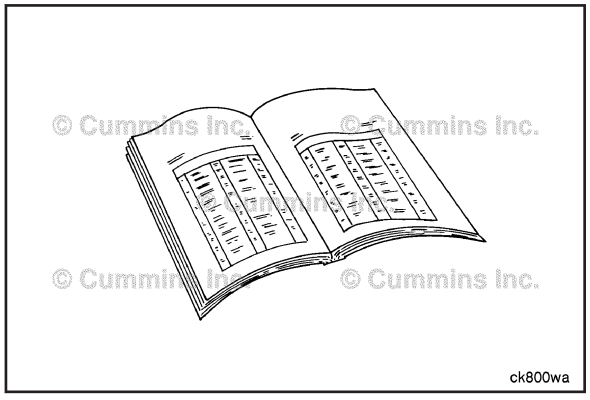
⚠WARNING⚠
Do not open the high-pressure fuel system with the engine running. Engine operation causes high fuel pressure. High-pressure fuel spray can cause serious injury or death.

Open the fuel supply and return valves, if equipped.



Cycle the keyswitch and allow the lift pump to operate for 30 seconds. Then turn the keyswitch OFF and back ON again, allowing the lift pump to operate again.

Allow the lift pump to operate for three or four 30-second cycles before attempting to start the engine.



Finishing Steps

- Operate the fuel lift pump to help prime the fuel system. Turn the keyswitch to RUN, but do **not** attempt to start the engine. This will cause the engine control module (ECM) to operate the fuel lift pump through a priming cycle which lasts at least 30 seconds. Cycle the lift pump several times by keying OFF, waiting 10 seconds, and keying ON again.
- Once the engine is started, slowly increase the engine speed while air is purged from the fuel plumbing.

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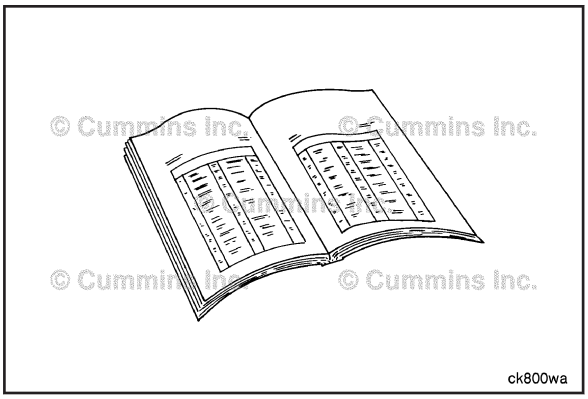
Fuel Filter Head (006-017)

Preparatory Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

⚠WARNING⚠
Drain the fuel-water separator into a container, and dispose of contents 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.

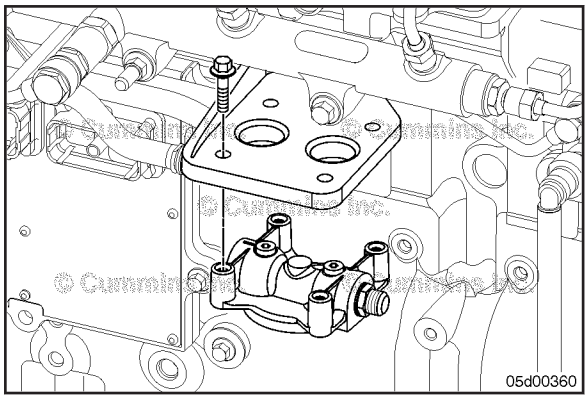
NOTE: Some of the graphics used in this procedure may **not** match all applications. However, the procedure is the same except where noted.

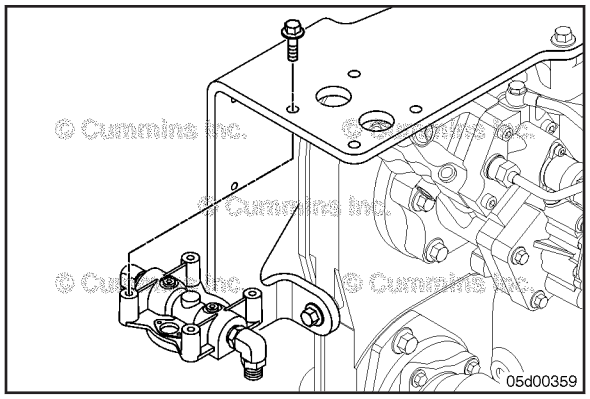
- Disconnect the batteries. See equipment manufacturer service information.
- Close the fuel supply valve, if equipped. See equipment manufacturer service information.
- Remove the fuel filter. Refer to Procedure 006-015 in Section 6.

Remove

All Applications Except Marine

Remove the fuel filter head mounting capscrews.

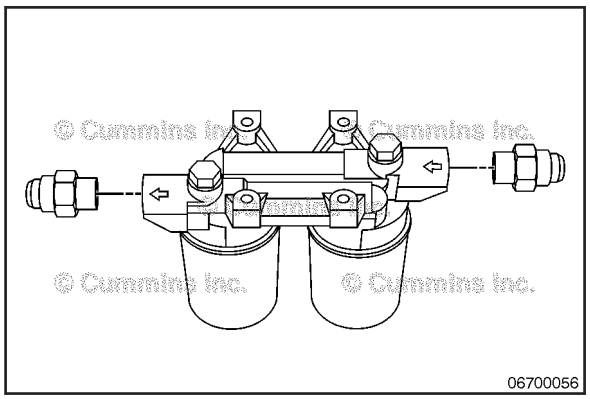




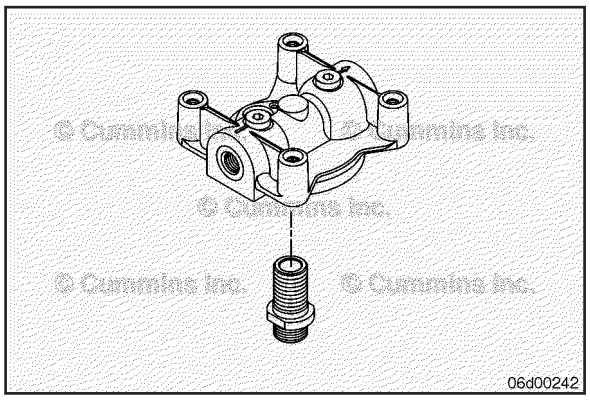
Marine Applications

NOTE: Mark the location of the fuel inlet port to aid in the installation.

Remove the four filter head mounting capscrews and the fuel filter head.



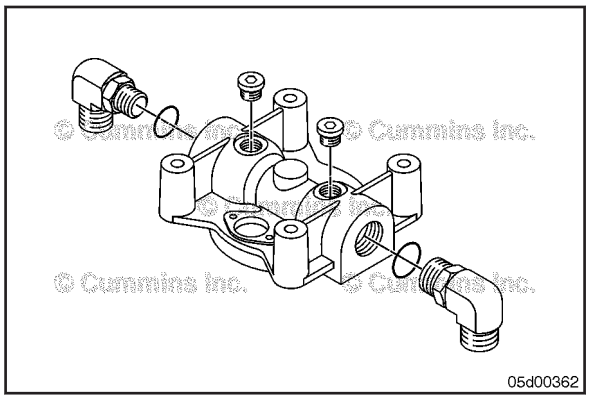
Disconnect the fuel inlet and outlet lines from the filter head.



Disassemble

All Applications Except Marine

Remove the fuel heater, if equipped. Refer to Procedure 005-008 in Section 5.



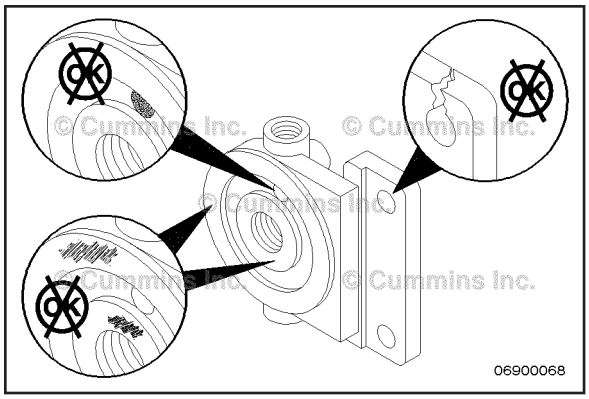
Marine Applications

Remove the fuel line connections and compression o-ring seals.

Remove the test port access plugs.

Inspect for Reuse

Inspect the fuel filter head for cracks, passage blockage, and material or debris on the sealing surfaces.



Assemble

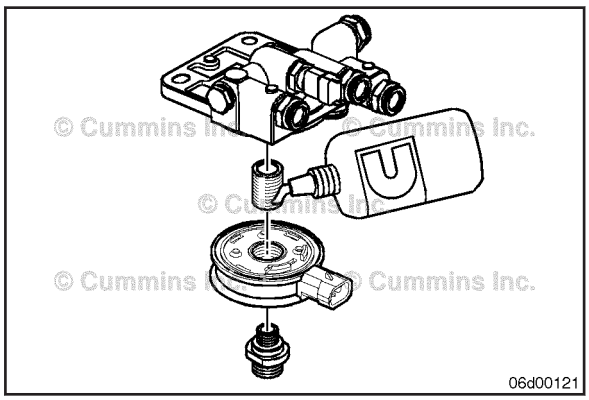
All Applications Except Marine

Apply thread locker, Part Number 3375068, or equivalent to **only** the filter adapter threads that are engaging the fuel filter head.

Install the fuel filter adapter and fuel heater. Refer to Procedure 005-008 in Section 5.

Torque Value: 30 N•m [22 ft-lb]

NOTE: Make sure there is an o-ring between the fuel filter head and the heater.



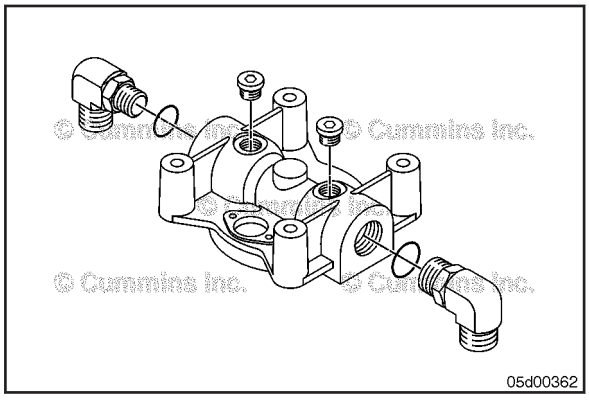
Marine Applications

Use new compression seal rings and install the 90-degree straight thread o-ring elbows in the fuel filter head. Tighten the elbows.

Torque Value: 27 N•m [239 in-lb]

Use new compression seal rings and install the test port plugs. Tighten the plugs.

Torque Value: 14 N•m [124 in-lb]



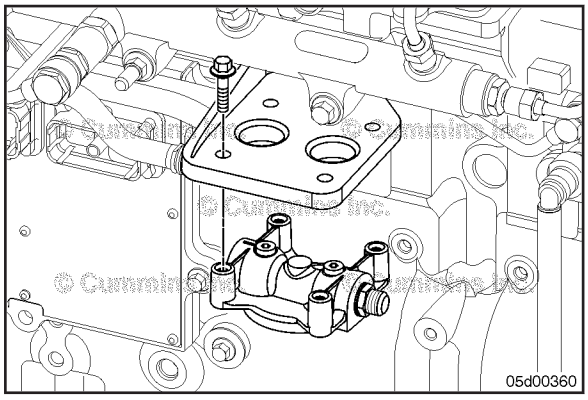
Install

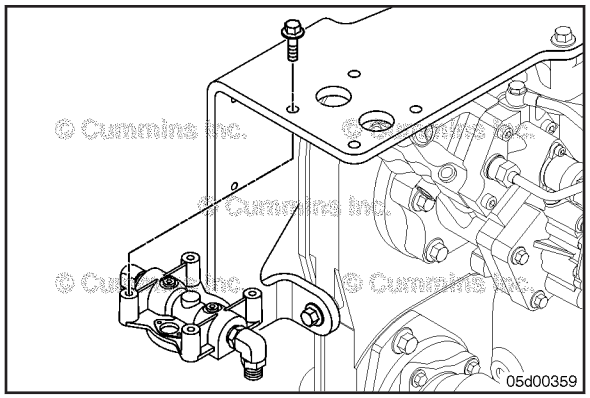
All Applications Except Marine

Install the fuel filter head.

Tighten the retaining capscrews.

Torque Value: 24 N•m [212 in-lb]





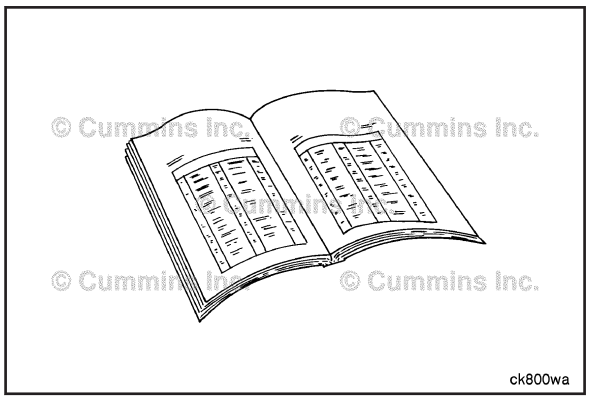
Marine Applications

Align the installation markings for the fuel inlet port.

Install the fuel filter head.

Tighten the retaining capscrews.

Torque Value: 30 N•m [22 ft-lb]



Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the fuel return and supply lines. Refer to Procedure 006-024 in Section 6.
- Install the fuel filter. Refer to Procedure 006-015 in Section 6.
- Open the fuel supply valve, if equipped. See equipment manufacturer service information.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.

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Fuel Filter Head Bracket (006-018)

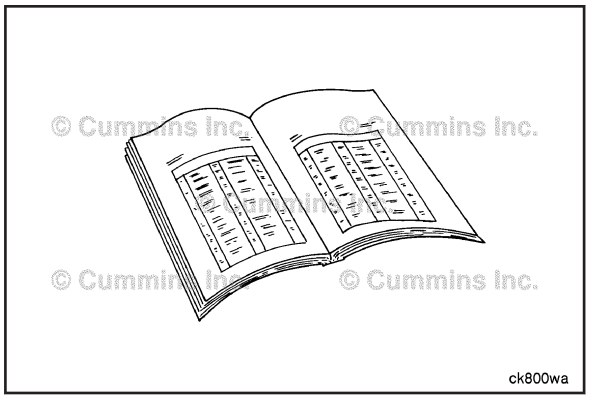
Preparatory Steps

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. See equipment manufacturer service information.
- Remove the fuel filter. Refer to Procedure 006-015 in Section 6.
- Remove the fuel supply lines from the filter head. Refer to Procedure 006-024 in Section 6.
- Remove the fuel filter head. Refer to Procedure 006-017 in Section 6.

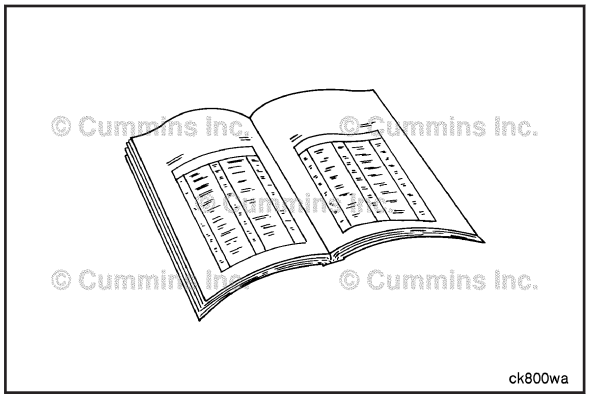


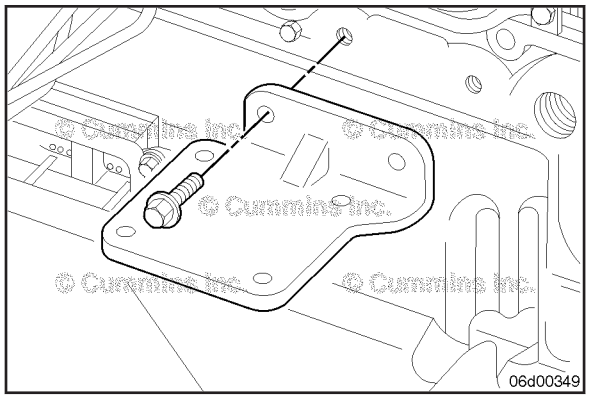
Marine Applications

⚠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 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.

- Close the fuel supply and drain valves. See equipment manufacturer service information.
- Remove the fuel filter. Refer to Procedure 006-015 in Section 6..
- Disconnect the fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Remove the fuel filter head; note the port location (in and out) marking. Refer to Procedure 006-017 in Section 6.

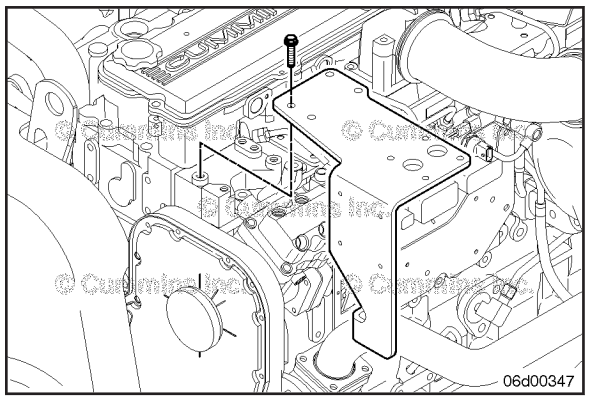




Remove

All Applications Except Marine

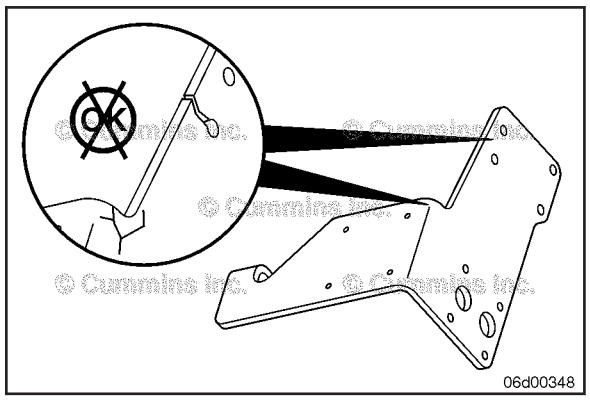
Remove the filter head bracket from the engine.



Marine Applications

Remove the fuel filter head bracket mounting capscrews from the cylinder head.

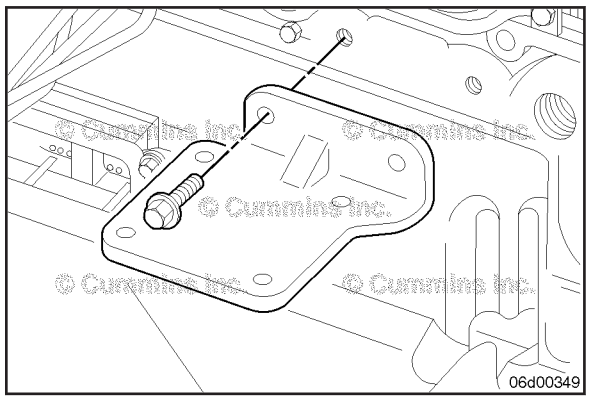
Remove the bracket mounting capscrew, if equipped, from the gear housing.



Inspect for Reuse

Inspect the filter head bracket mounting for cracks and signs of fretting on the mounting holes.

Replace the bracket if it is cracked or has signs of fretting.



Install

All Applications Except Marine

Install the fuel filter head bracket and filter head.

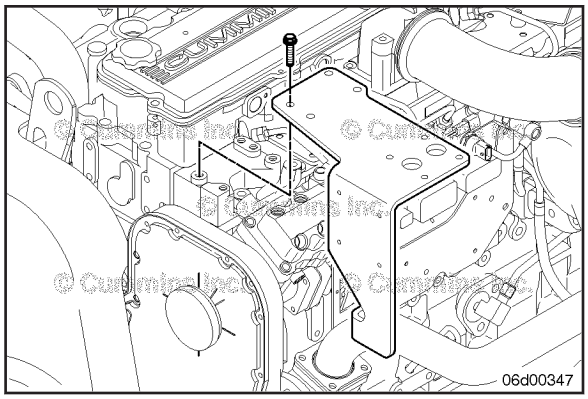
Tighten the retaining capscrews.

Torque Value: 43 N•m [32 ft-lb]

Marine Applications

Install the fuel filter head bracket. Tighten the retaining capscrews.

Torque Value: 43 N•m [32 ft-lb]

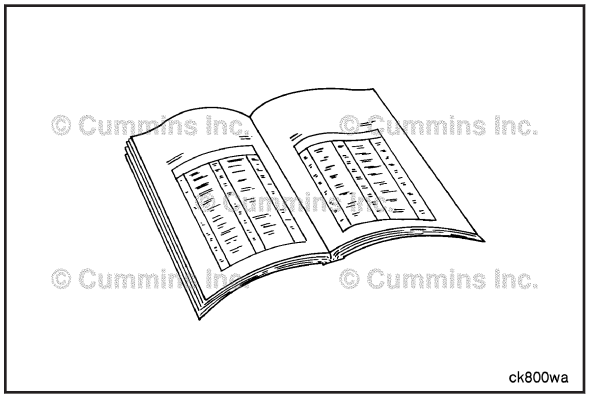


Finishing Steps

All Applications Except Marine

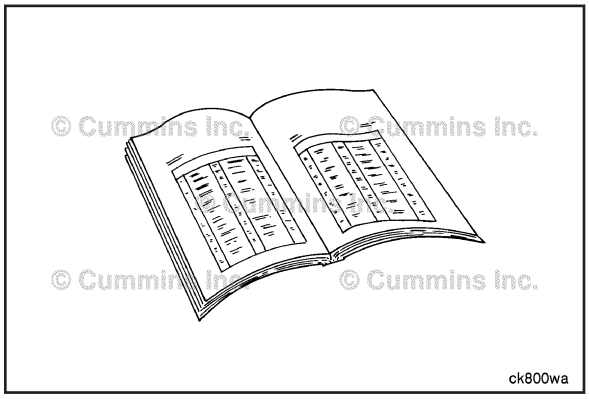
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

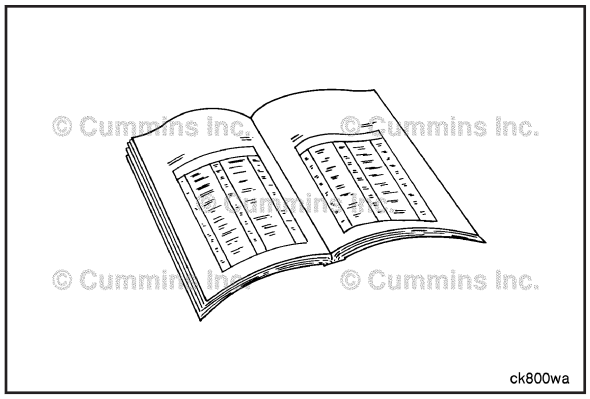
- Install the fuel filter head. Refer to Procedure 006-017 in Section 6.
- Install the fuel filter. Refer to Procedure 006-015 in Section 6.
- Install the fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.



Marine Applications

- Install the fuel filter head with the fuel inlet and outlet ports in the original location. Refer to Procedure 006-017 in Section 6..
- Connect the fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Open the fuel supply and drain valves. Refer to the OEM service manual.
- Operate the engine and check for leaks.



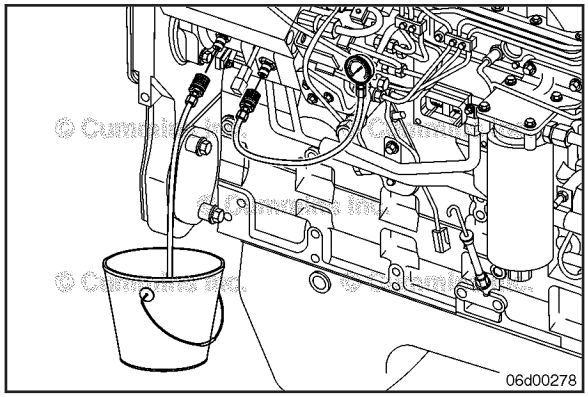


Fuel Inlet Restriction (006-020)

Preparatory Steps

CAPS Fuel System

- Obtain a 1.09-mm [0.043-in] orifice diagnostic fuel line, Part Number 3164621. This tool can also be constructed. Refer to Procedure 006-003 in Section 6.
- Obtain a container suitable for collection of fuel that exits the diagnostic fuel line. A 19-liter [5-gal] bucket is recommended.



Install a 1/8-inch NPT Compuchek™ diagnostic fitting, Part Number 3042618, at the inlet to the fuel injection pump (Cummins® Accumulator Pump System **only**).

Attach the 1.09-mm [0.043-in] orifice diagnostic fuel line at the fuel injection pump cam housing Compuchek™ fitting. Route this hose into a collection container or into the fuel tank.

Attach a 0 to 762 mm-Hg [0 to 30 in-Hg] vacuum gauge at the gear pump inlet Compuchek™ port.

Cummins® Common Rail Fuel System

⚠CAUTION⚠
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system. The fuel and fuel filters must be discarded in accordance with local environmental regulations.

Automotive and Industrial Applications

Obtain a 1.09-mm [0.043-in] orifice diagnostic fuel line, Part Number 3164621.

Obtain a pressure gauge adapter, Part Number 4918324.

Obtain fuel line connector fitting, Part Number 3972088.

Obtain a container suitable for collection of fuel that exits the diagnostic fuel line. A 19-liter [5-gal] bucket is recommended.

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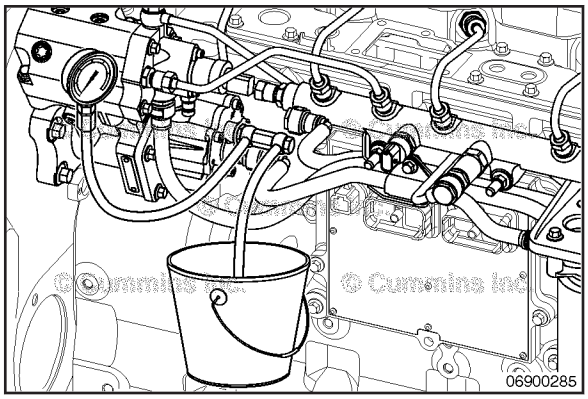
Install a pressure gauge adapter, Part Number 4918324. Use fuel line connector fitting, Part Number 3972088, at the inlet to the gear pump.

Install a vacuum gauge that has a range of at least 0 to 762 mm-Hg [0 to 30 in-Hg] onto the pressure gauge adapter.

Install an M10 Compuchek™ fitting, Part Number 3824842, at the fuel filter head.

NOTE: If there is **not** enough clearance to install the female Compuchek™ fitting, Part Number 3824842, an adapter fitting, Part Number 3932302, and an 1/8-NPT male Compuchek™ fitting, Part Number 3377244, may be used to aid accessibility.

Attach the 1.09-mm [0.043-in] orificed diagnostic fuel line at the fuel filter head Compuchek™ fitting. Route this hose into a collection container or into the vehicle fuel tank.

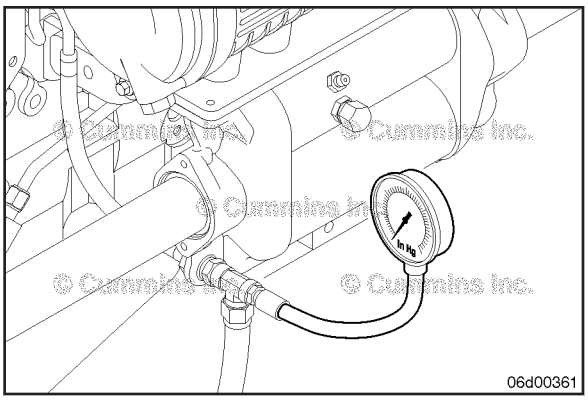


Marine Applications

⚠CAUTION⚠
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system such 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.

Cummins® Common Rail Fuel System

Attach a 0 to 762 mm-Hg [0 to 30 in-Hg] vacuum gauge at the Compuchek™ port at the OEM fuel inlet connection.



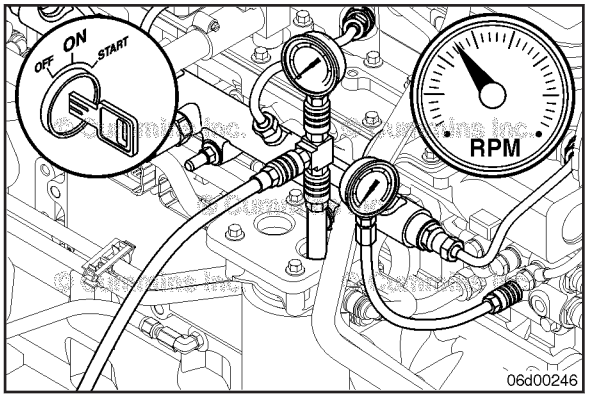
Measure

All Applications Except Marine

Operate the engine at high idle and measure the inlet vacuum.

Maximum Fuel Inlet Restriction (CAPS Fuel Systems)		
mm-Hg	**-**	**in-Hg**
102.0	At OEM connection	4.0
254.0	At inlet to fuel gear pump (dirty filter)	10.0

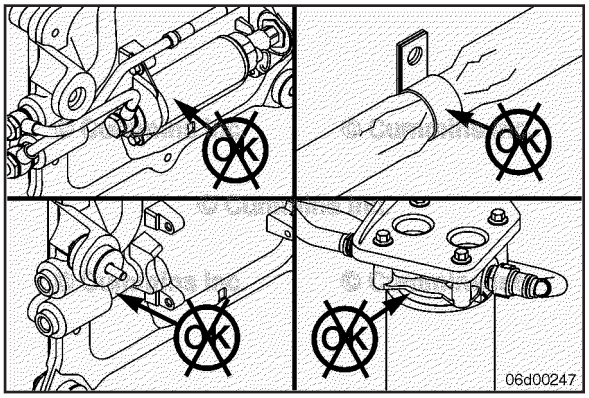
Maximum Fuel Inlet Restriction (Cummins® Common Rail Fuel System)		
mm-Hg	**-**	**in-Hg**
203.2	At OEM connection (dirty filter) loaded condition	8.0
304.8	At inlet to fuel gear pump (dirty filter) loaded condition	10.0



Marine Applications

Operate the engine at rated rpm and measure the inlet vacuum.

Maximum Fuel Inlet Restriction (Cummins® Common Rail Fuel System)		
mm-Hg	**-**	**in-Hg**
102	Dirty filter (rated speed and load)	4.0
63.5	Clean filter (rated speed and load)	2.5



If the inlet restriction is excessive, look for the root cause:

- Suction side fuel filters plugged
- Fuel heater valves restricted
- ECM cooling plate plugged
- ECM cooling plate check valve restricted
- OEM fuel lines pinched or restricted
- Fuel tank stand pipes restricted.

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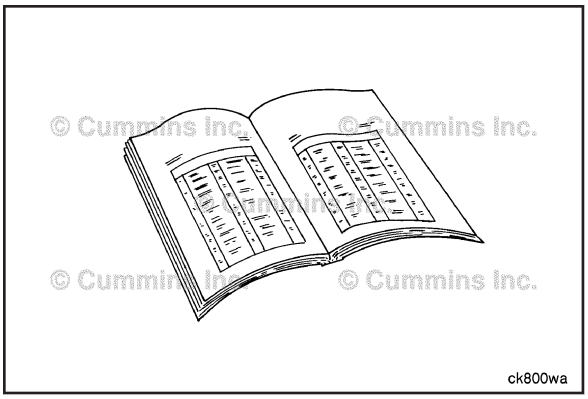
Finishing Steps

All Applications Except Marine

NOTE: Do **not** leave Compuchek™ fittings installed on the suction side of the gear pump. A Compuchek™ fitting on the suction side of the gear pump can allow air to enter the fuel flow, resulting in performance problems.

- Disconnect all diagnostic test fittings and install all components removed during testing.



Marine Applications

- Disconnect the vacuum gauge from the Compuchek™ fitting. Leave the Compuchek™ fitting installed.

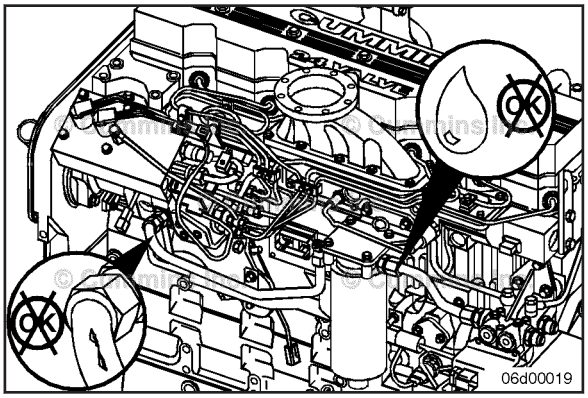
Fuel Supply Lines (006-024)

Initial Check

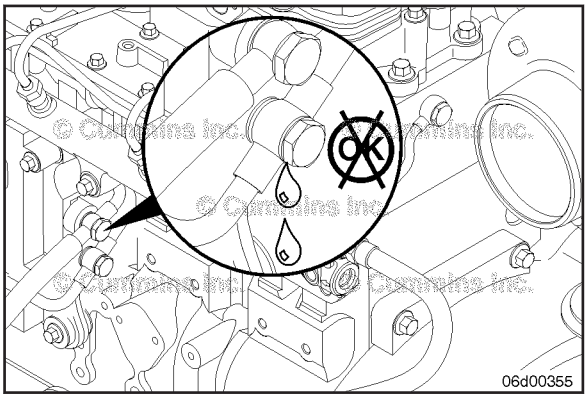
Inspect all fuel supply lines and fittings. Look for cracks in the lines or leaking fittings.

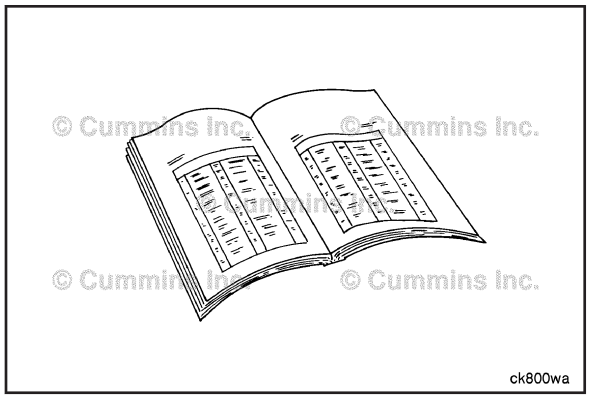
Inspect the straight thread o-ring metric hose fitting. Make sure the lock nuts tighten against the o-ring rather than bottom out against the end of the fitting's threads (example: Cummins® Accumulator Pump System fuel pump inlet and Cummins® Accumulator Pump System fuel filter head).

Inspect the quick-disconnect style fittings for damaged o-ring connections or broken locking tangs.



Inspect the banjo style fittings for leaks at the sealing washers.



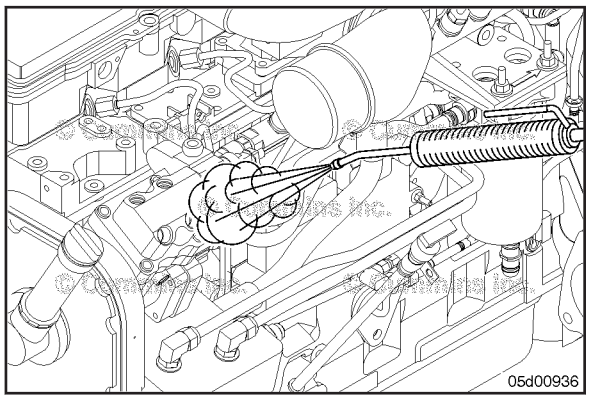


Preparatory Steps

⚠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.
- Close the fuel supply and return valves. Refer to the OEM service manual.
- Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.



⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

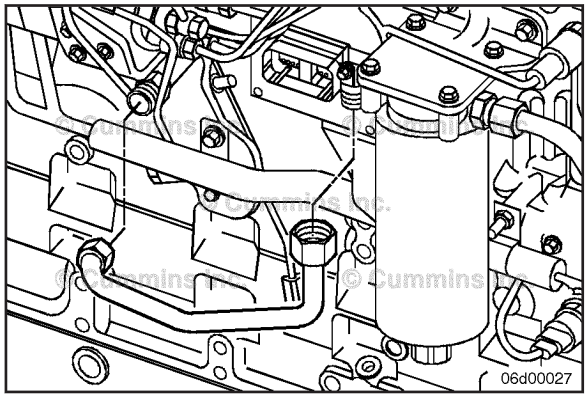
⚠WARNING⚠

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

△CAUTION△

Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which can expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine. Refer to Procedure 000-009 in Section 0.



Remove

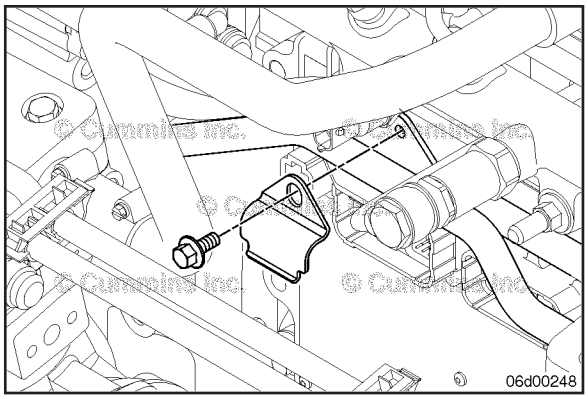
All Applications Except Marine

⚠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.

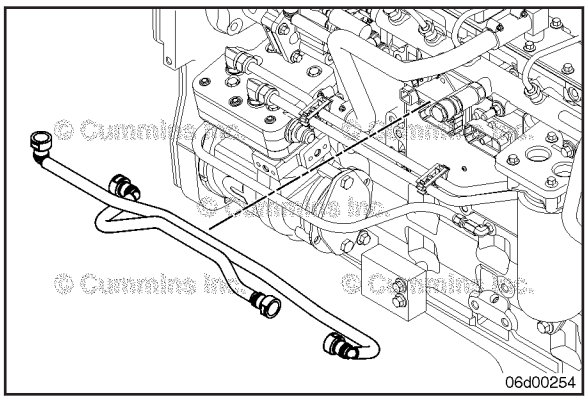
Remove the fuel supply lines.

For quick disconnect style fuel lines, remove the clasp from the fuel line brace. This will allow the lines to move so they can be disconnected.



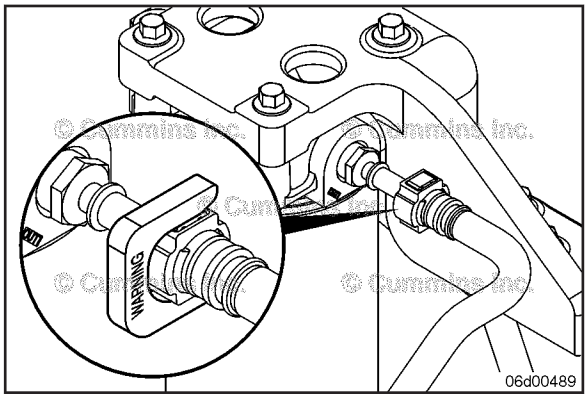
Loosen all quick disconnect lines from the brace.

To remove the gear pump outlet line, the gear pump inlet line **must** be removed first.

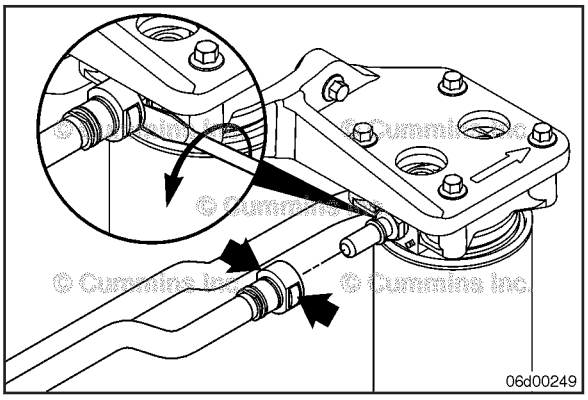


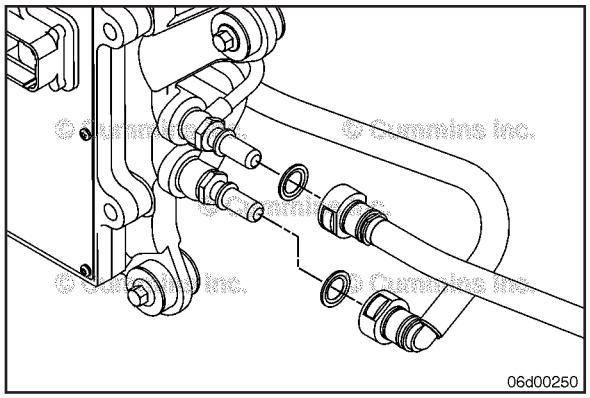
Remove the quick disconnect style fuel lines by pressing in the locking tangs on both sides of the quick disconnect fitting.

To aid in the removal of quick disconnect style fuel lines, slide removal tool, Part Number 4918878, over the locking tangs. Make sure the tool is removed from the fuel line as soon as possible after the line has been disconnected. Inadvertently leaving the tool in place can result in fuel leaks.

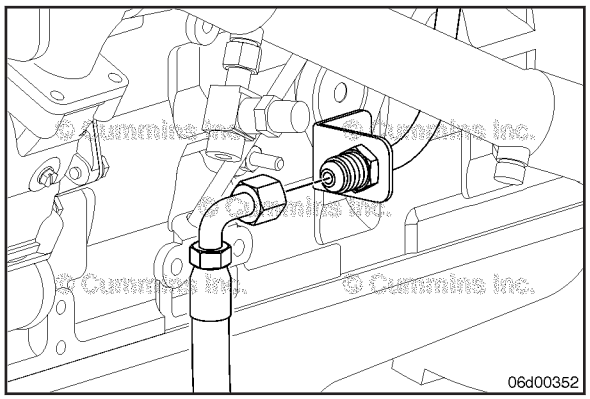


To aid removal, a screwdriver may be inserted between the fuel line end and quick disconnect male union. After pressing the opposing locking tangs, twisting the flat blade of the screwdriver helps to remove the fuel line.





If fuel leaks or suction-side air entry is suspected, remove the fuel hoses or quick disconnect fittings.



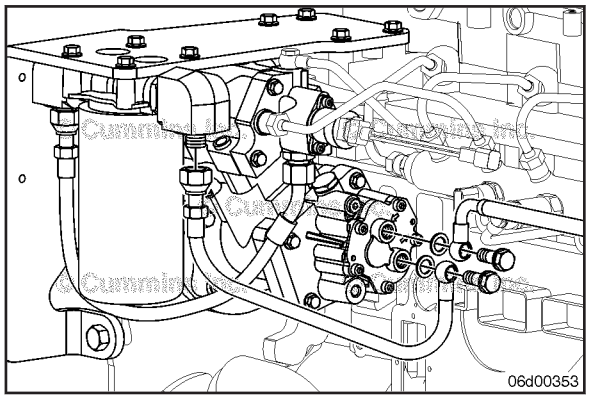
Marine Applications

⚠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 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.

Disconnect the OEM fuel supply line.

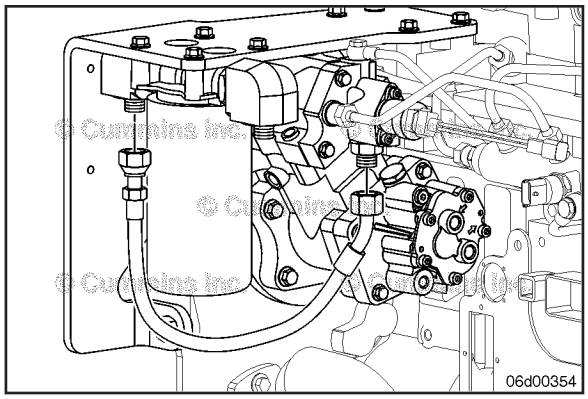
Disconnect the fuel line from the fuel line mounting bracket and the upper ECM cooler fuel connection.



Disconnect the fuel supply line from the lower ECM cooler connection and the upper gear pump connection.

Disconnect the fuel supply line from the lower gear pump connection and the inlet to the fuel filter head.

Disconnect the fuel supply line from the fuel filter head outlet connection and the high-pressure pump connection.



Inspect for Reuse

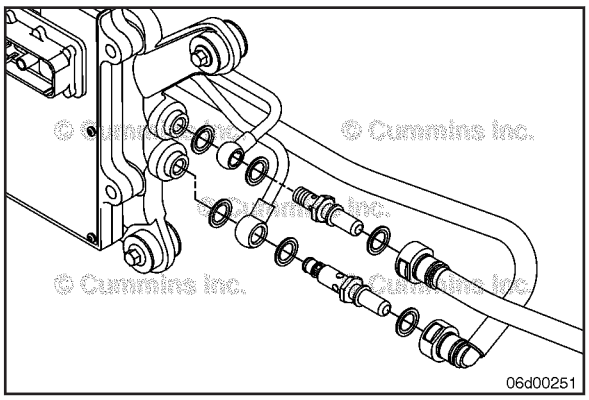
Inspect for burrs or debris on metal connectors that may cause leaks.

On straight thread o-ring metric connectors, be certain the o-rings are **not** frayed or cut.

On quick disconnect style fittings, be certain the o-rings are **not** frayed or cut, and the lock tangs are **not** damaged.

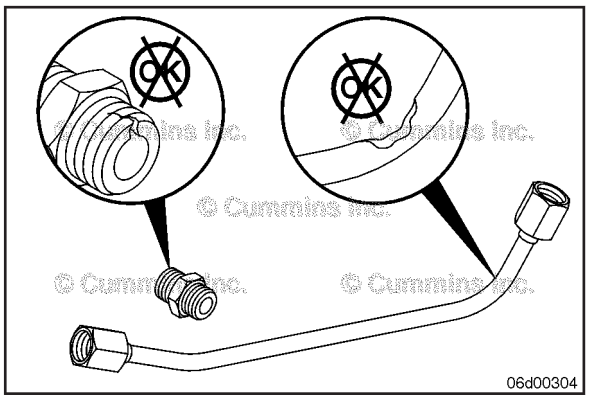
The lower quick disconnect fitting on the cooling plate has a check valve built in to it.

- Inspect the anti-drain back valve for damage or improper sealing. Replace if necessary.
- Verify that the anti-drain back valve seats properly and is free of damage or debris. If damage is found, replace the valve.



Inspect the face of the banjo connector for sealing surface damage.

Replace the banjo bolts, sealing washers, or fuel lines, as necessary.



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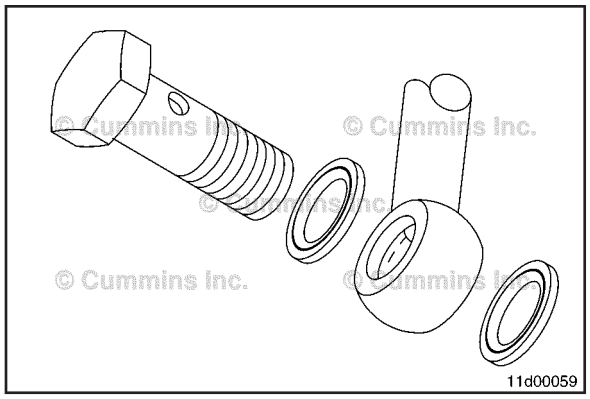
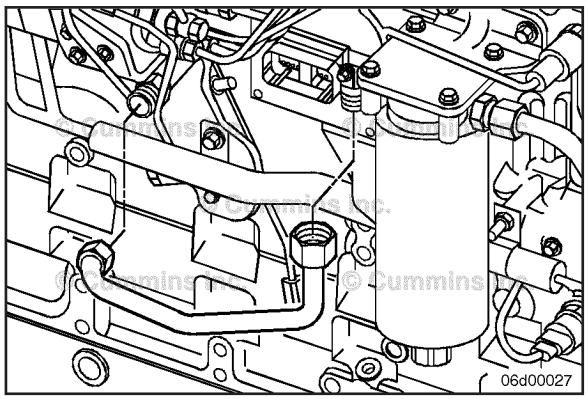


Inspect the straight thread fittings and fuel lines for cracks, bends, or any other damage.

Replace the fuel lines as necessary.



Install

All Applications Except Marine

Install the fuel supply lines.

Torque Value:
Number 10 Flare Fitting 37 N•m [27 ft-lb]

Torque Value:
M12 Quick Disconnect Union 24 N•m [212 in-lb]

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Install the quick disconnect fuel lines (Cummins® Common Rail Fuel Systems **only**).

Install the quick disconnect fittings.

Torque Value: 24 N•m [212 in-lb]

Make sure the quick disconnect style fuel lines clasp onto the quick disconnect fittings.

Make sure the lines are routed and connected correctly. If the lines are connected incorrectly, the engine will **not** operate.

For quick disconnect style lines used with the Cummins® Common Rail Fuel System, fuel lines are routed in the following order:

1 OEM connection to the upper fitting at the ECM cooling plate.

2 Lower ECM cooling plate fitting to the upper gear pump fitting.

3 Lower gear pump fitting to the pressure-side fuel filter inlet.

4 Pressure-side fuel filter outlet to the fuel pump fuel control actuator housing.

The fuel supply line brace holds the fuel lines in the following order:

1 The inside line connects the upper gear pump fitting to the lower ECM cooling plate fitting.

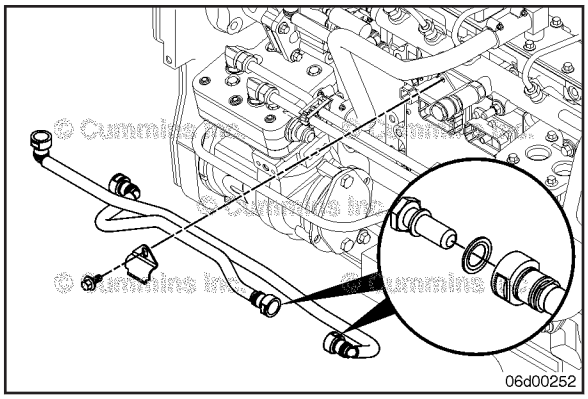
2 The middle line connects the pressure-side fuel filter outlet to the fuel pump fuel control actuator housing.

3 The outside line connects the lower gear pump fitting to the pressure-side fuel filter inlet.

Install the fuel line brace clasp (quick disconnect style fuel lines **only**) and the brace, if necessary.

Torque Value:
Fuel Line Brace 24 N•m [212 in-lb]

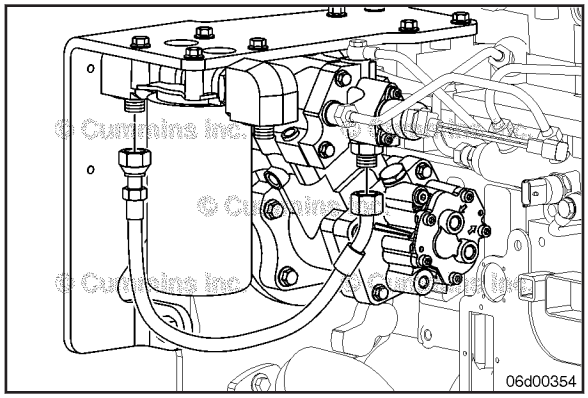
Torque Value:
Fuel Line Brace Clasp 24 N•m [212 in-lb]

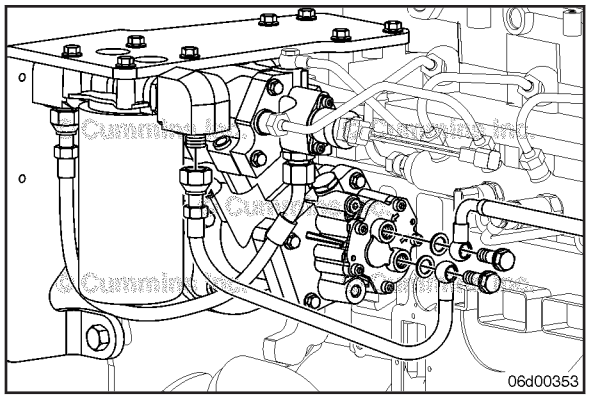


Marine Applications

Connect the fuel supply hose to the fuel pump and the outlet of the fuel filter. Use new sealing washers as needed

Torque Value: 37 N•m [27 ft-lb]





Connect the supply hose from the inlet side of the fuel filter and the lower gear pump connection. Use new sealing washers as needed.

Tighten the filter connection.

Torque Value: 37 N•m [27 ft-lb]

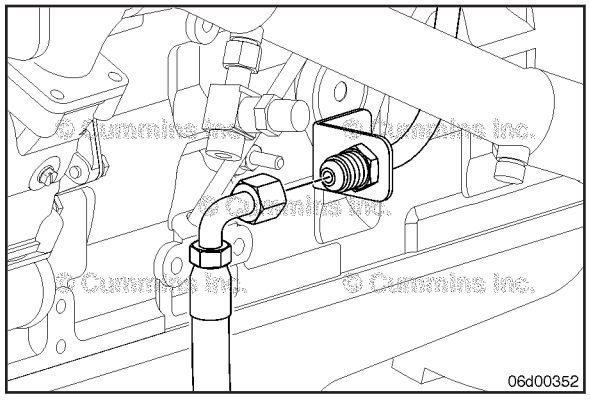
Tighten the gear pump connection.

Torque Value: 37 N•m [27 ft-lb]

Connect the supply line to the upper gear pump connection and the lower ECM cooler connection. Use new sealing washers as needed.

Tighten the connection.

Torque Value: 24 N•m [212 in-lb]



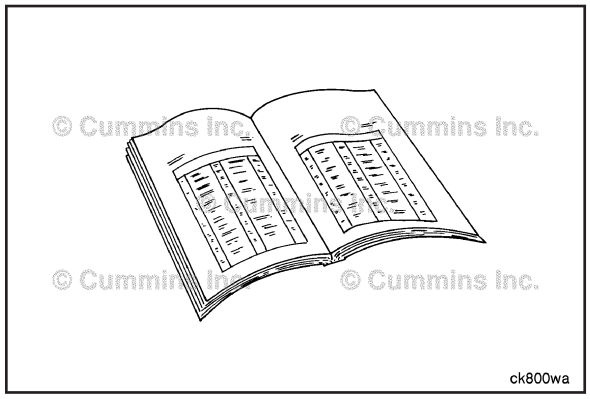
Connect the fuel supply line to the upper ECM cooling plate connection.

Torque Value: 24 N•m [212 in-lb]

Install the fuel supply line on the fuel line connector bracket.

Torque Value: 37 N•m [27 ft-lb]

Connect the OEM fuel supply hose. Refer to the OEM service manual.



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 arching, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Open the fuel supply and return valves, if equipped.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Prime the fuel system. Refer to Procedure 006-015 in Section 6.
- Operate the engine and check for leaks.

Injector (006-026)

Initial Check

Cummins® Common Rail Fuel System

⚠WARNING⚠

The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is operating. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.

△CAUTION△

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.

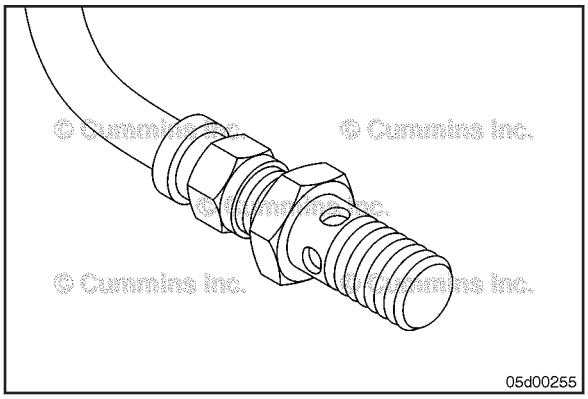
△CAUTION△

Installation of the banjo flow adapter at any place other than the fuel drain manifold can cause damage to high pressure fuel system components.

Return fuel is routed from the injectors, the fuel rail pressure relief valve, and the fuel pump head through three different drain lines.

Measurement of fuel injector leakage requires the use of a fuel return hose, Part Number 3164618.

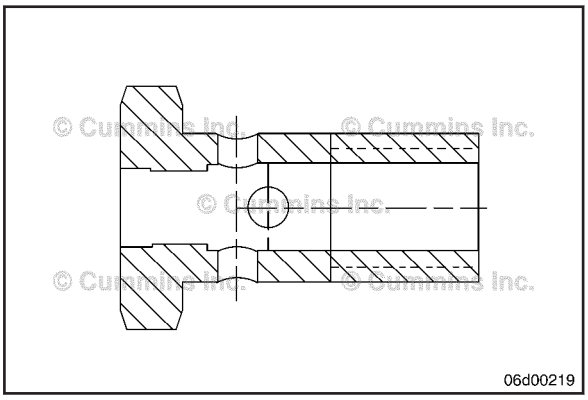
The tool is used to isolate the leakage from just the injectors, so it can be measured with a graduated cylinder.

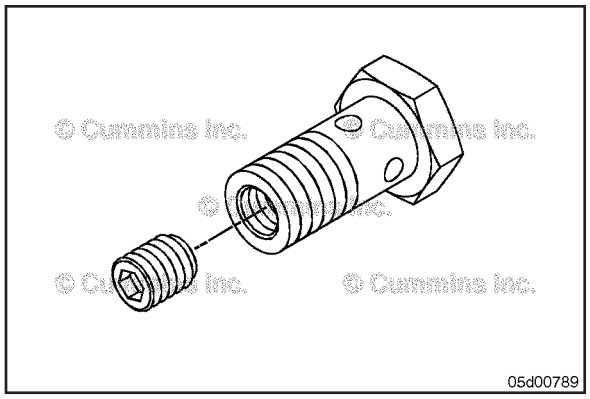


If necessary, this tool can be constructed using the steps outlined below.

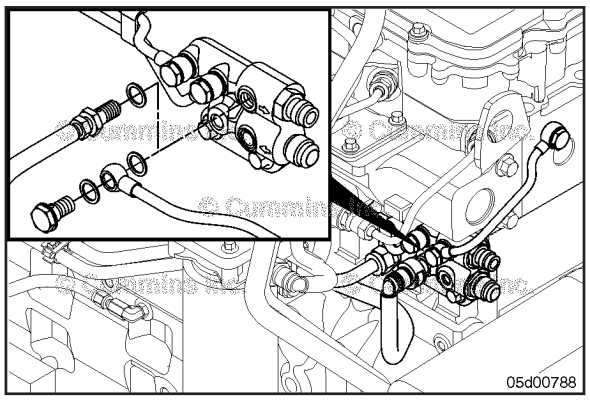
To make a banjo bolt flow adapter tool, drill and tap the hex face of a M12 x 1.5 banjo bolt, Part Number 3903035, or equivalent.

Drill and tap the hex face of the banjo bolt to the size of a male union (or other hose fitting) being used (example 1/8-inch NPT hose barb).





Drill and tap the open end of the banjo bolt for the installation of a 5/16-24 set screw.



⚠WARNING⚠

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

△CAUTION△

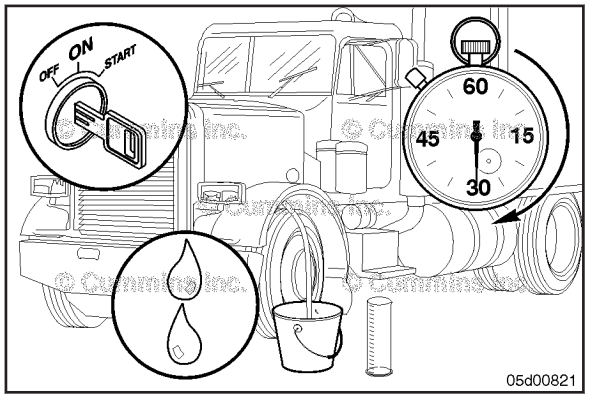
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system that fuel is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The fuel and fuel filters must be discarded in accordance with local environmental regulations.

Remove the M12 banjo bolt that connects the fuel injector drain line to the fuel drain manifold.

Install the M12 fuel return hose, Part Number 3164618, at the fuel drain manifold.

Route the fuel return hose into a collection device.

Obtain a graduated cylinder that is marked in cubic centimeters; example: graduated beaker, Part Number 3823705, or equivalent. A kitchen style measurement cup that is marked in cubic centimeters (cc's) also works well.



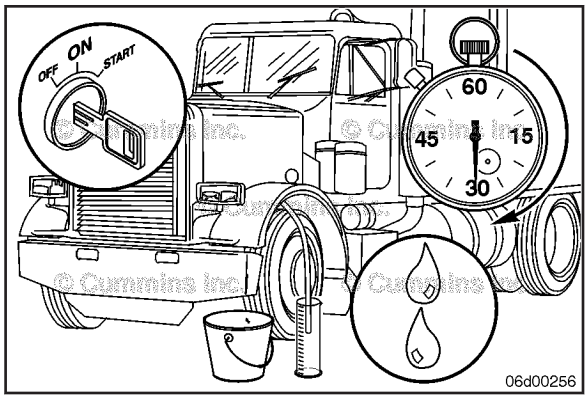
Start the engine and allow the engine to idle until drain fuel from the injector drain line begins to flow into the collection container.

Connect INSITE™ electronic service tool.

If the engine will **not** start, these procedures are still valid; however, the pass/fail specification is different.

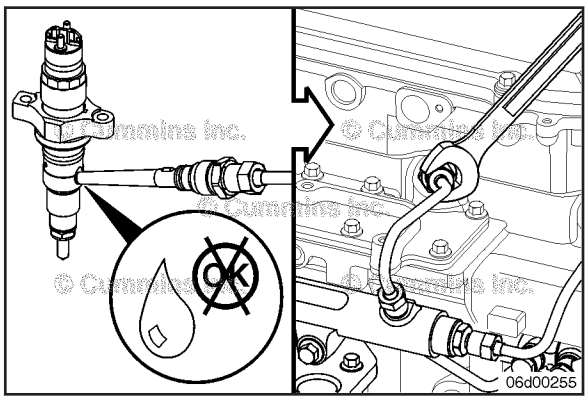
If the engine will **not** start, drain flow **must** be measured while engaging the starter for 30 seconds at a time.

Leakage Specification if Engine Will Not Start	
Maximum Leakage During 30 Seconds of Cranking	100 cc [3.38 oz]



If the injector leakage is excessive during cranking and the engine will **not** start, check the following:

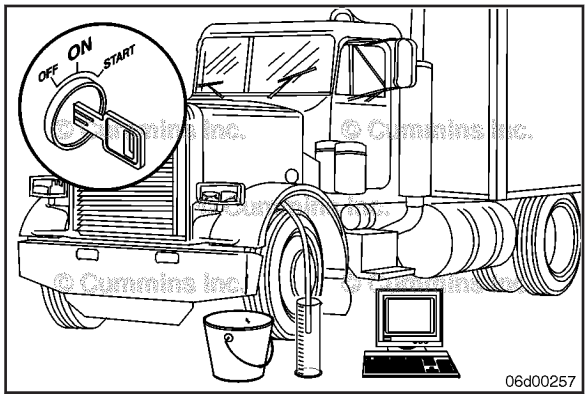
- High pressure fuel connector installation. Refer to Procedure 006-052 in Section 6.
- High pressure fuel connector damage. Refer to Procedure 006-052 in Section 6.
- Use the fuel leak test tool, Part Number 3164325, to isolate injectors from the fuel rail, one at a time.

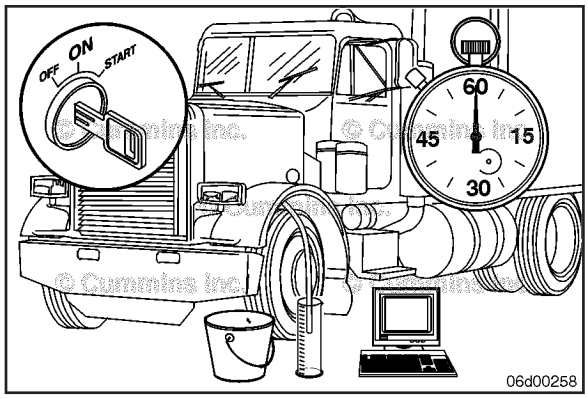


⚠CAUTION⚠
Fuel is at high pressure during this test. After connecting the test fitting, close the engine cover and stand clear of high-pressure fuel lines.

If the engine will start, the following steps will determine if the injector drain flow is excessive.

While the engine is operating at idle, use INSITE™ electronic service tool High Pressure Leak Test to create high fuel rail pressure. INSITE™ electronic service tool will command 1500 BAR [21,756 psi] fuel rail pressure while the engine is at idle during this test.





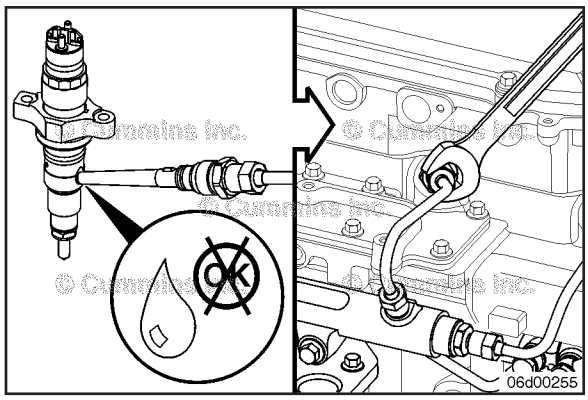
Record the amount of time it takes for 300 cc [10.1 oz] of fuel to flow from the injector drain line when performing INSITE™ electronic service tool High Pressure Leak Test.

Leakage Specification With Engine operating	
Maximum Leakage During 45 Seconds	300 cc [10.1 oz]

If 300 cc [10.1 oz] of fuel leaks from the injectors in less than 45 seconds, there is at least one loose or damaged high pressure fuel connector and/or injector.

NOTE: Fuel temperature and fuel type will influence this measurement. For example; as the engine is warmed up and the injectors become hot, the leakage rate will increase. Also, low viscosity fuels, such as kerosene, will cause the leakage rate to increase. The above specification is correct for on-highway diesel fuels where fuel inlet temperature is less than 49°C [120°F].

After recording the fuel leakage rate, stop INSITE™ electronic service tool High Pressure Leak Test and turn the keyswitch to OFF.

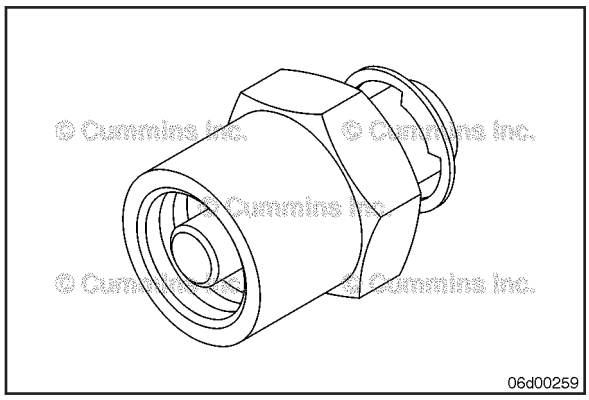


If injector drain flow is excessive, it will be necessary to isolate the injector(s) or fuel connector(s) that are damaged or worn.

A loose fuel connector retaining nut results in a poor seal at the interface between the fuel connector and the injector. This loose condition will result in a leak of high-pressure fuel to the injector drain.

Verify first that the fuel connectors are properly tightened. Refer to Procedure 006-052 in Section 6.

If loose retaining nut(s) are found, test for leakage after tightening the retaining nut(s).



⚠CAUTION⚠
Do not install the isolation tool at the high pressure pump outlet fitting. Severe engine damage will result. This tool must only be installed at the fuel rail for the purpose of isolating the high-pressure fuel supply from individual injectors.

⚠CAUTION⚠
Make certain the keyswitch is in the OFF position (engine not operating) when loosening or tightening high-pressure fuel lines.

Use leak test isolation tool, Part Number 3164325, to isolate excessive fuel drainage from injectors or fuel connectors.

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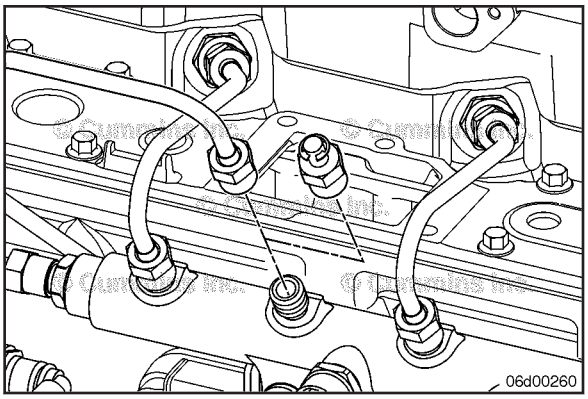
Isolate the injector and fuel connector for each cylinder by installing the isolation tool at the fuel rail in place of the high-pressure fuel line that supplies the fuel connector.

Torque Value: 38 N•m [28 ft-lb]



Record the amount of time it takes for 300 cc [10.1 oz] of fuel to flow from the injector drain line while the engine is operating. Use INSITE™ electronic service tool High Pressure Leak Test. Do this up to six (6) times, once while each line is isolated.

If isolating a single injector and high-pressure fuel connector causes the leakage time to increase significantly compared to the rest of the set, that injector and fuel connector **must** be inspected.

Inspect the suspect fuel connector. Refer to Procedure 006-052 in Section 6. If the fuel connector is **not** damaged, replace both the injector and the fuel connector.

Cylinder	Time
1	
2	
3	
4	
5	
6	

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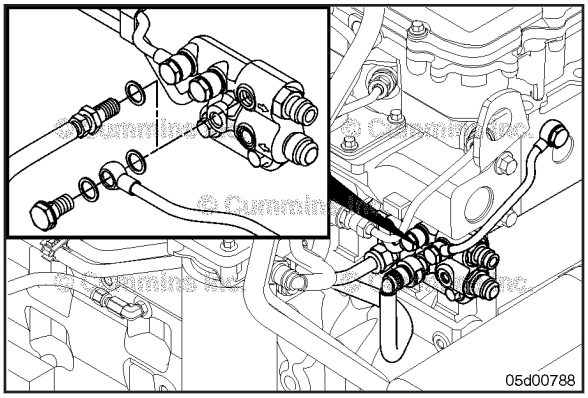
Remove the M12 diagnostic flow adapter from the fuel drain manifold and install the M12 banjo. Refer to Procedure 006-013 in Section 6.

Install all high-pressure fuel lines. Refer to Procedure 006-051 in Section 6.

Operate the engine and check for leaks.

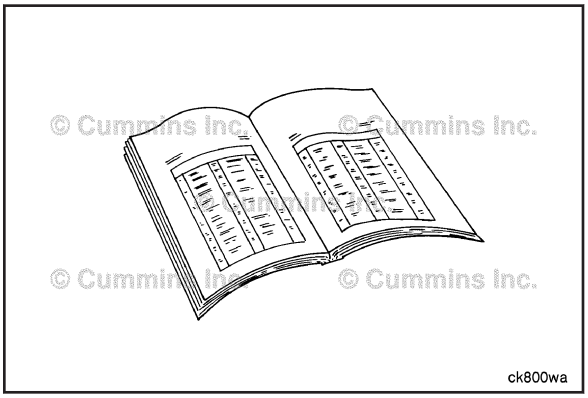


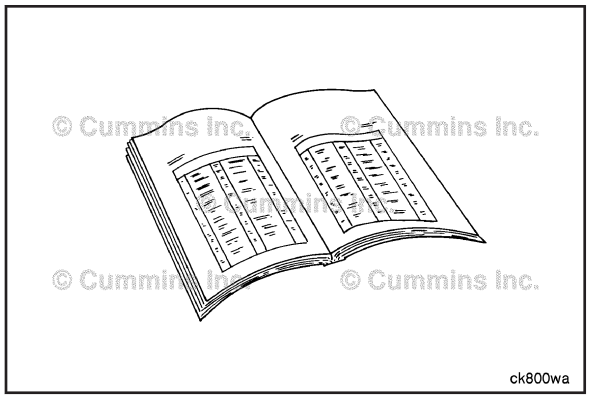
Preparatory Steps

CAPS Fuel System

⚠CAUTION⚠
Attempting to remove the injector without first removing the fuel connector will cause damage to the injector body and/or fuel connector.

- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the engine brake, if equipped. Refer to Procedure 020-004 in Section 20.
- Remove the fuel connector. Refer to Procedure 006-052 in Section 6.





Cummins® Common Rail Fuel System

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠CAUTION⚠

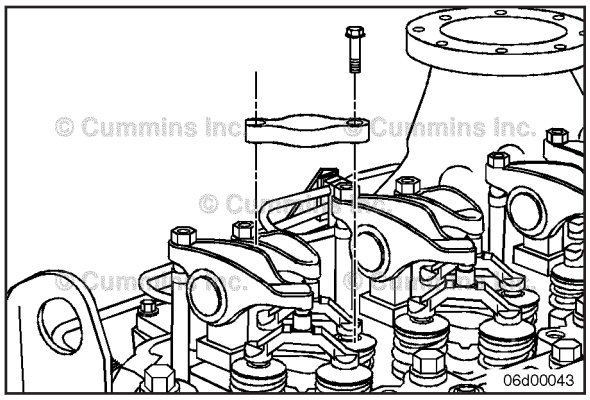
Use caution when disconnecting or removing fuel lines, replacing filters, and priming the fuel system, that fuel is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The fuel and fuel filters must be discarded in accordance with local environmental regulations.

⚠CAUTION⚠

Attempting to remove the injector without first removing the fuel connector will cause damage to the injector body and/or fuel connector.

NOTE: All fuel system diagnostics procedures and component specifications have been moved. Refer to Procedure 005-236 in Section 5.

- 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 high-pressure fuel line. Refer to Procedure 006-051 in Section 6.
- Remove the engine brake, if equipped. Refer to Procedure 020-004 in Section 20.
- Remove the fuel connector. Refer to Procedure 006-052 in Section 6.
- Remove the exhaust rocker lever assembly. Refer to Procedure 003-008 in Section 3.



Remove

CAPS Fuel System

Remove the injector hold-down clamp capscrew that is nearest the exhaust manifold side of the engine.

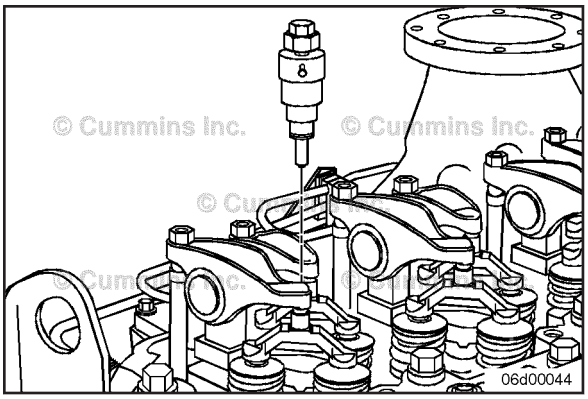
Remove the injector hold-down clamp.

Remove the high-pressure fuel connector. Refer to Procedure 006-051 in Section 6.

Use the injector puller, Part Number 3825156, to pull the injector out of the head.

Alternatively, a rocker cover capscrew can be installed into the top of the injector and used to pull the injector from the cylinder head.

Be sure the injector seal washer is removed from the injector bore.

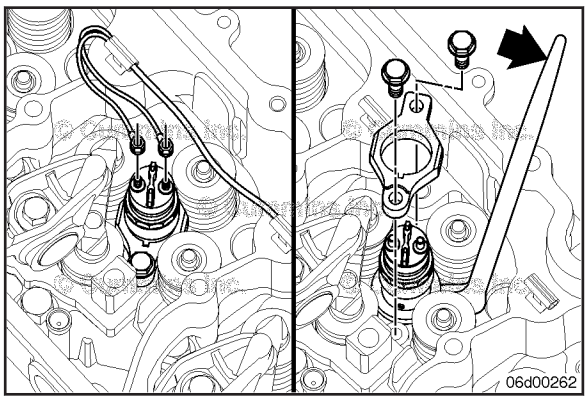


Cummins® Common Rail Fuel System

Disconnect the injector wire harness from the injector.

Remove the two injector hold-down clamp capscrews and remove the injector hold-down clamp.

Use a small heel-bar to pry up on the injector clamp hold-down flange (part of the injector body just above the cylinder head casting).



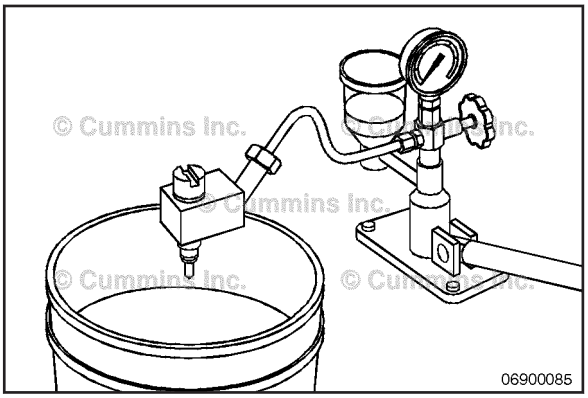
Test

Mechanical Injectors

⚠WARNING⚠
While testing the injectors, keep hands and body parts away from the injector nozzle. Fuel coming from the injector is under extreme pressure and can cause serious injury by penetrating the skin.

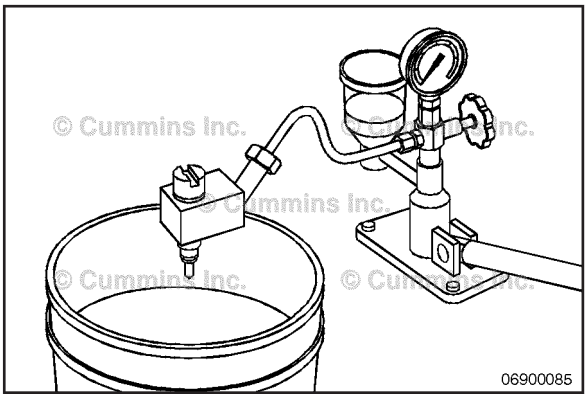
Install the injectors on an injector test stand. Open the bypass valve for the pressure gauge, so the spray pattern can be checked.

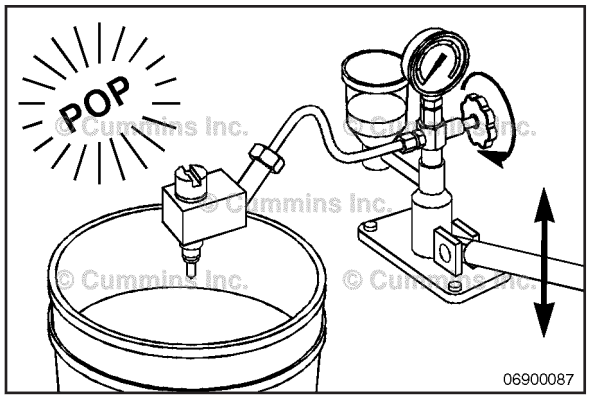
Use the injector test fixture, Part Number 3162269, with the injector nozzle test, Part Number 3376946.



Operate the test stand lever quickly several times to check the spray pattern of the injectors. Verify that the correct number of plumes are present for the number of holes in the injector. Also pay close attention to the size and shape of each plume. If possible, compare the spray pattern to that of a new injector with the same assembly number.

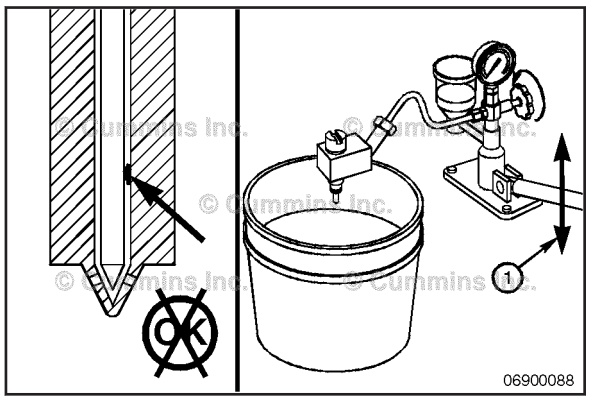
NOTE: The injector spray pattern is an excellent indicator of the nozzle hole condition. Check each plume carefully. It is possible that **only** a single hole has been damaged, resulting in degraded engine performance.





Close the bypass valve for the pressure gauge and operate the test stand lever to check the nozzle opening pressure. There **must** be a good crisp "pop" when the nozzle opens and the pressure **must** be within the specification for the assembly number.

The injector will pop between 275 bar [3,989 psi] and 300 bar [4,351 psi].

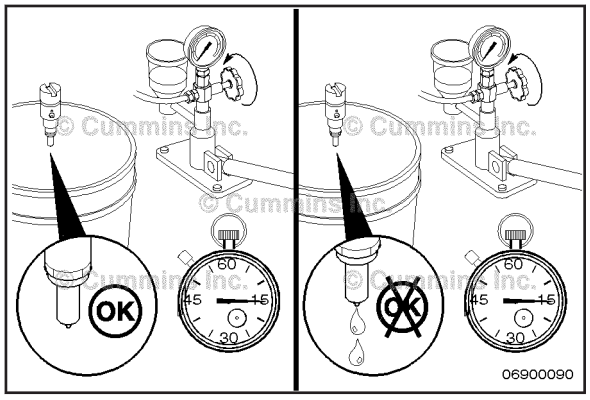


If the nozzle opening pressure is excessively low and/or the nozzle sprays excessive fuel, the injector needle can be sticking. The needle can be stuck due to poor lubrication or debris.

Sometimes it is possible to unstick an injector needle by using the injector test stand. Open the bypass valve for the pressure gauge and operate the test stand lever rapidly for 10 to 20 strokes.

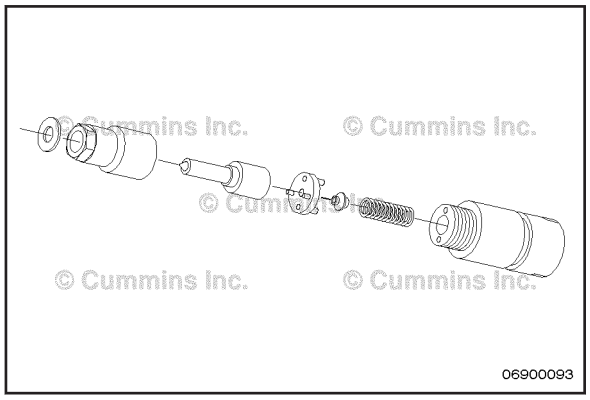
Recheck the nozzle opening pressure and spray pattern to see if the injector has returned to normal operation.

If the injector is still out of specification, replace the injector.



Check the injector for drip and/or excessive leak down. Close the bypass valve for the pressure gauge and build pressure to within 10 bars [145 psi]of the opening pressure of the nozzle.

A drop of fuel **must not** form within 15 seconds.



Disassemble

Mechanical Injectors

Place the injector in the injector clamp and remove the nozzle retaining nut.

NOTE: Injectors covered under warranty by the manufacturer **must not** be repaired. See the manufacturer's warranty instructions.

Remove the nozzle, intermediate plate, spring, and shims from the injector.

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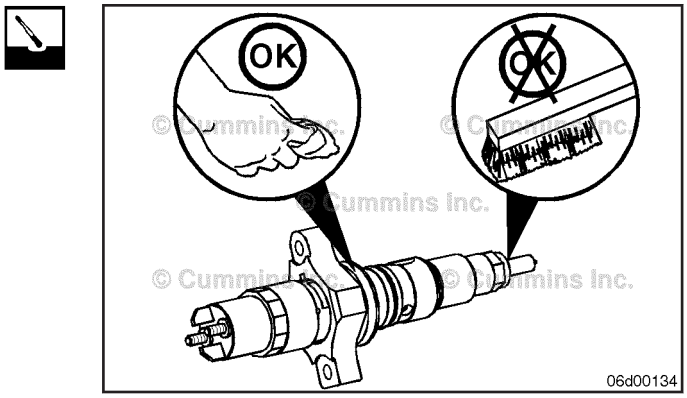
Clean and Inspect for Reuse



⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

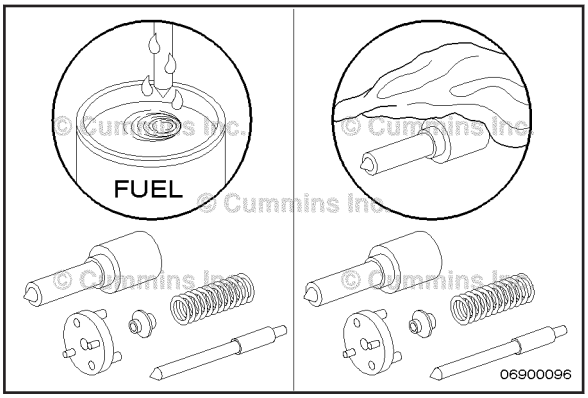
△CAUTION△
Do not use any abrasives (such as glass beading, sand paper, emery cloth, Scotch-Brite™ pads, etc) or metallic items (including wire brushes made of any metallic material) to clean the injectors. The use of any cleaning method other than safety solvent and a soft, clean, lint-free cloth will damage the nozzle holes and cause performance issues.

Clean the injector tip and body with safety solvent and a soft, clean cloth.

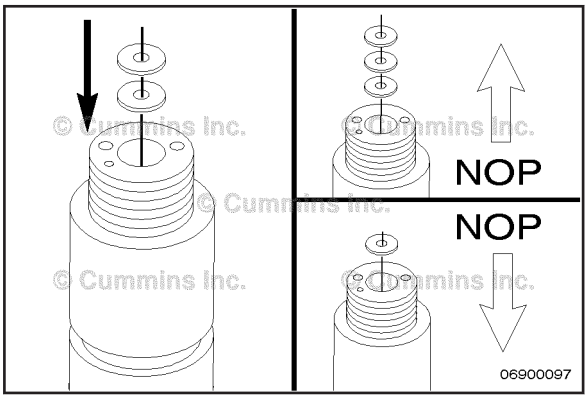
Assemble

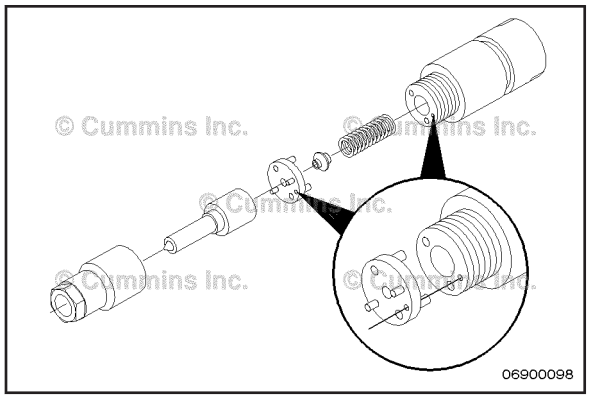
Mechanical Injectors

Clean the injector internal components with clean diesel fuel and a clean cloth. Make sure there is no debris in the internal parts of the injector.



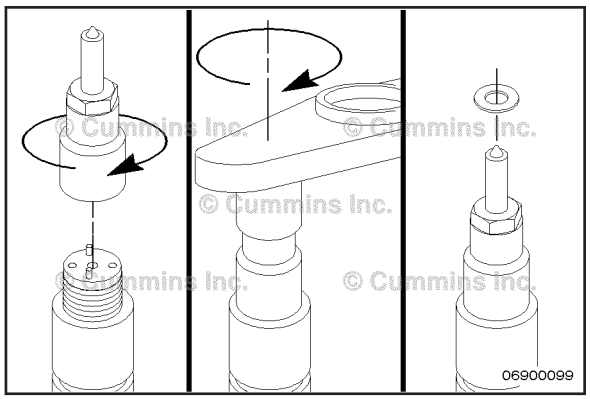
Install shims, as necessary, to modify the nozzle opening pressure. More shims raise the nozzle opening pressure, fewer shims lower the nozzle opening pressure.





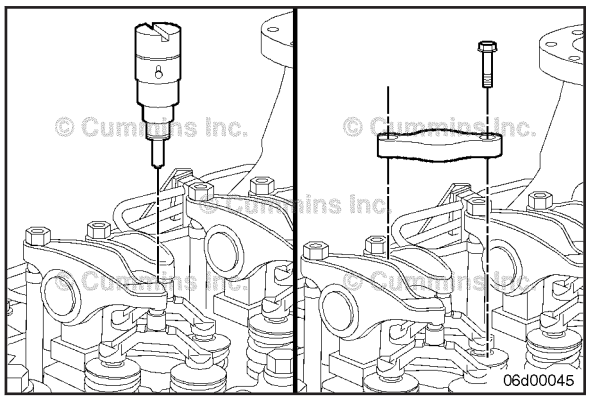
Install the spring, button, intermediate plate, and nozzle/ needle.

Make sure the intermediate plate is in the correct orientation with the supply hole on the plate lining up with the supply hole on the holder.



Install the retaining nut finger tight. Place the injector in the injector clamp and tighten the retaining nut. Install the sealing washer and body o-ring.

Torque Value: 47 N•m [35 ft-lb]



Install

CAPS Fuel System

NOTE: If a new injector is being installed, a new fuel connector **must** be used

Make sure the injector bore is clean and that **only** one (1) sealing washer is installed on the injector nozzle.

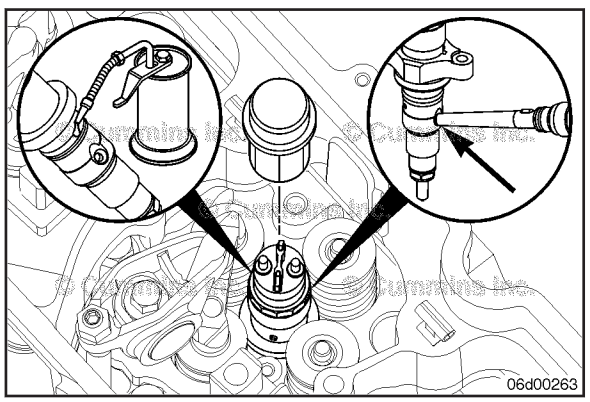
Lubricate the injector o-ring with clean engine oil.

Place the injector in the head in the proper orientation.

Place the injector hold-down clamp on top of the injector and make sure the injector is fully seated in the injector bore.

Install the injector hold-down clamp and tighten.

Torque Value: 10 N•m [89 in-lb]



Cummins® Common Rail Fuel System

Make sure the injector bore is clean and that **only** one (1) sealing washer is installed on the injector nozzle.

Lubricate the injector o-ring with clean engine oil.

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

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

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NOTE: If a new injector is being installed, a new fuel connector **must** be used.

Start the injector hold-down clamp capscrews, and tighten hand-tight.

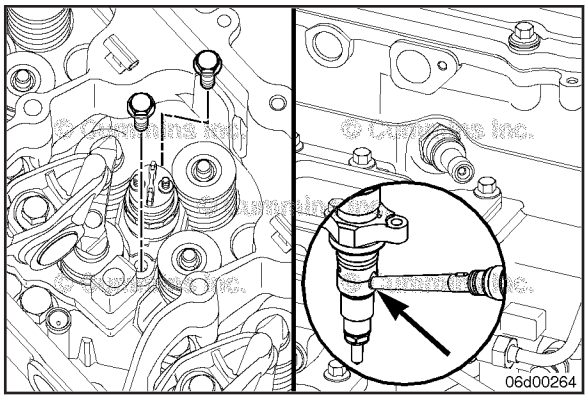
Install the high-pressure fuel connector, making sure the end of the high-pressure fuel connector is in the injector inlet port.

NOTE: The high-pressure fuel connector should click into place if it is seated in the injector inlet port correctly.

Start the high-pressure fuel connector retaining nut and tighten partially.

Torque Value: 15 N•m [133 in-lb]

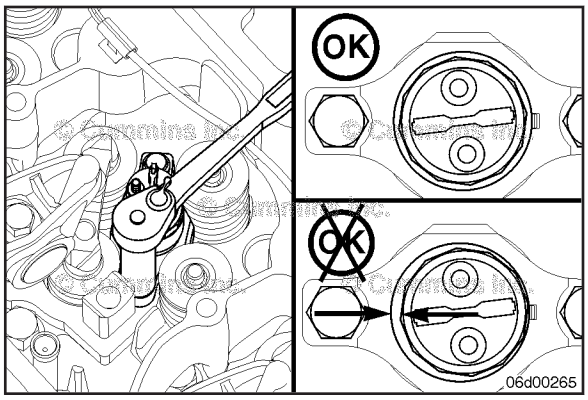
NOTE: This is **not** the final torque for the high-pressure fuel connector retaining nut.



Tighten the injector hold-down clamp capscrews.

NOTE: Make sure to tighten the hold-down clamp capscrews evenly. Check to make sure the gap between the hold-down clamp and the injector is equally spaced around the injector body.

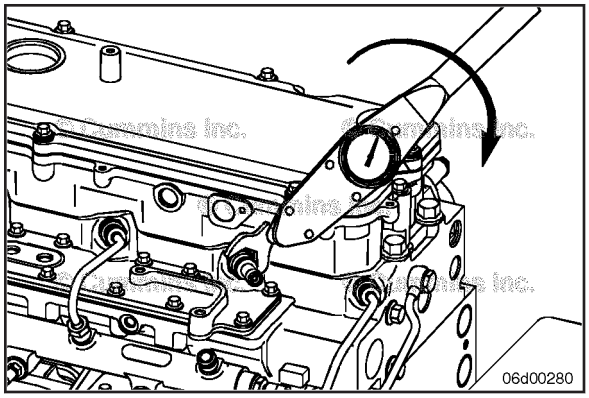
Torque Value: 10 N•m [89 in-lb]

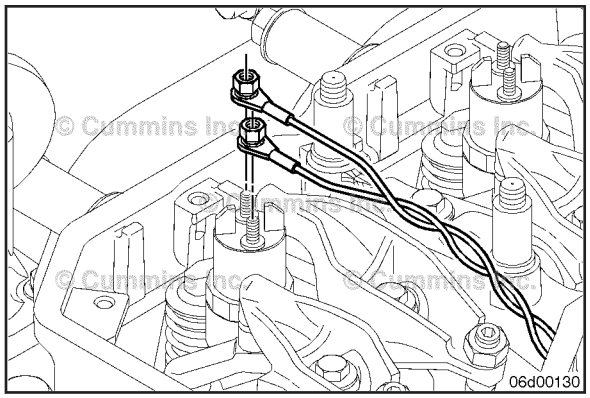


Tighten the high pressure fuel connector retaining nut.

Use the following procedure for the final torque value. Refer to Procedure 006-052 in Section 6.

NOTE: The high-pressure fuel connector **must** be properly tightened or an internal fuel leak can result, causing poor engine performance. A torque wrench **must** be used.





CAUTION

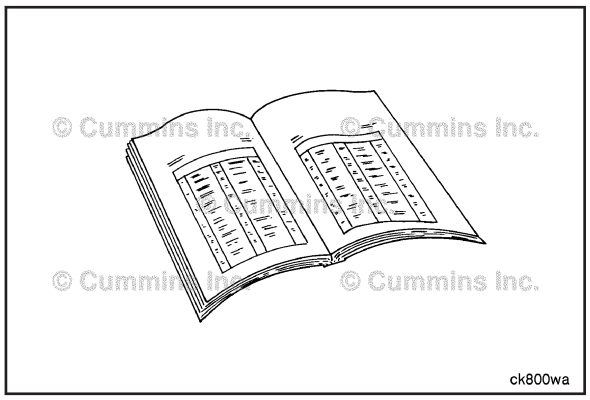
Do not overtighten the injector harness. The injector terminals will be damaged if excessively overtightened.

Install the injector wiring harness to the injector.

Torque Value: 1.25 N•m [11 in-lb]

NOTE: Orient the injector wires so they will **not** interfere with a rocker lever or engine brake housing. If the rocker lever is able to come into contact with the injector harness, it will rub through the wire insulation and cause injector circuit fault codes.

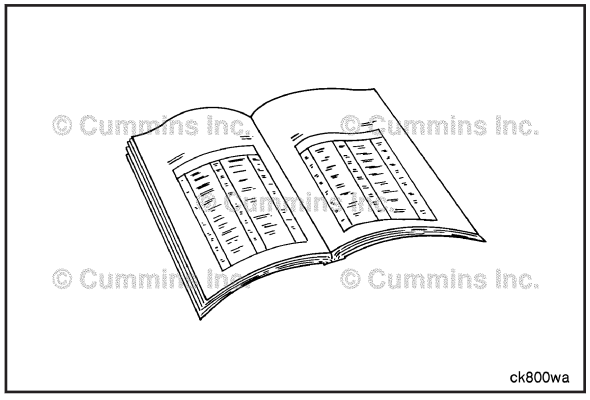
NOTE: Polarity of the wiring is **not** significant. The signal and return wires can be connected to either injector terminal.



Finishing Steps

CAPS Fuel System

- Install the fuel connector. Refer to Procedure 006-052 in Section 6.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the high pressure fuel lines. Refer to Procedure 006-051 in Section 6.
- Operate the engine and check for leaks.



Cummins® Common Rail Fuel System

WARNING

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the exhaust rocker lever assembly. Refer to Procedure 003-008 in Section 3.
- Install the engine brake, if equipped. Refer to Procedure 020-004 in Section 20.
- Install the high pressure fuel lines. Refer to Procedure 006-051 in Section 6.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Open the fuel supply and return valves. Refer to the OEM service manual.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

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

Initial Check

CAPS Fuel System

Inspect the lines for cracks, chafing, or leaks. Make sure the lines are tightened to the proper specification.

Check the fuel pump connections.

Torque Value: 24 N•m [212 in-lb]

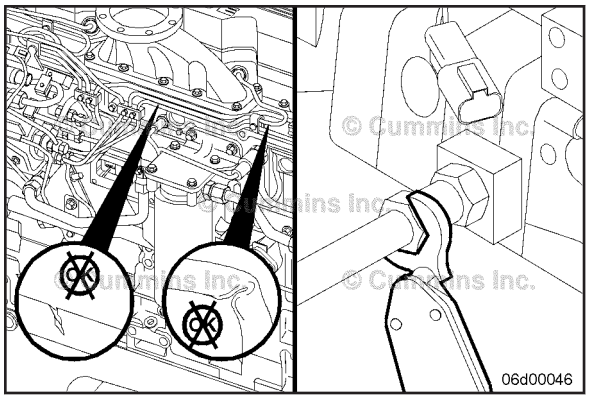
Check the cylinder head connections.

Torque Value: 38 N•m [28 ft-lb]

Check the fuel line isolators for loose capscrews.

Torque Value: 3 N•m [27 in-lb]

If the capscrew is loose, replace the isolator capscrew and bracket. The isolator capscrew and bracket can **not** be used twice.



Cummins® Common Rail Fuel System

Check the fuel pump connection.

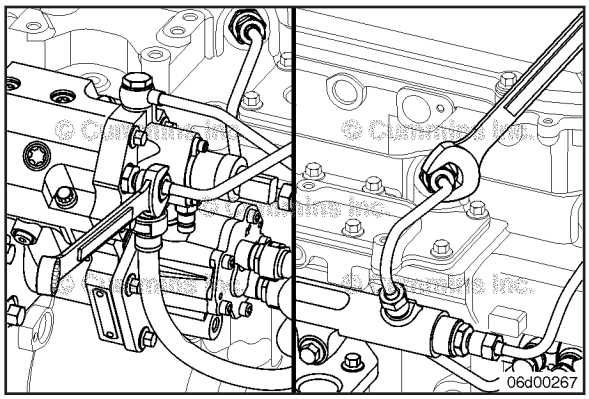
Torque Value: 38 N•m [28 ft-lb]

Check the cylinder head connections.

Torque Value: 38 N•m [28 ft-lb]

Check the fuel rail connections.

Torque Value: 38 N•m [28 ft-lb]

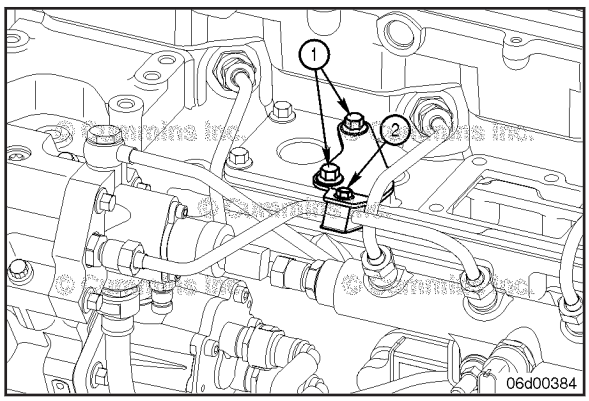


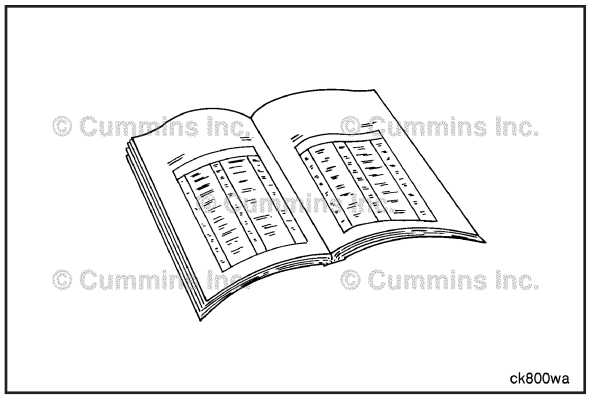
Check the bracket capscrews that support the high-pressure rail supply line.

Torque Value:
High-Pressure Fuel Supply Line Bracket Capscrew (1) 24 N•m [212 in-lb]

Check the bracket isolator capscrew.

Torque Value:
Bracket Isolator Capscrew (2) 9 N•m [80 in-lb]





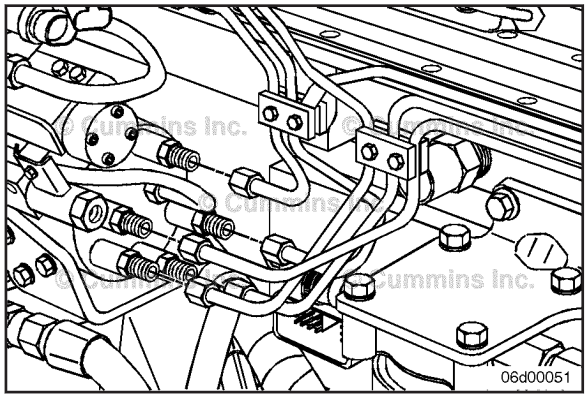
Preparatory Steps

⚠WARNING⚠
The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Clean the area around the fuel lines with solvent.
- Close the fuel supply and drain valves. Refer to the OEM service manual.



Remove

CAPS Fuel System

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

Remove the fuel lines from the fuel pump.

NOTE: Use two (2) wrenches to prevent the outlet fitting from turning.

Remove the fuel line clamp capscrews from the intake cover. This **must** be done before the injection lines can be pulled loose from the cylinder head.

Remove the fuel lines from the cylinder head.

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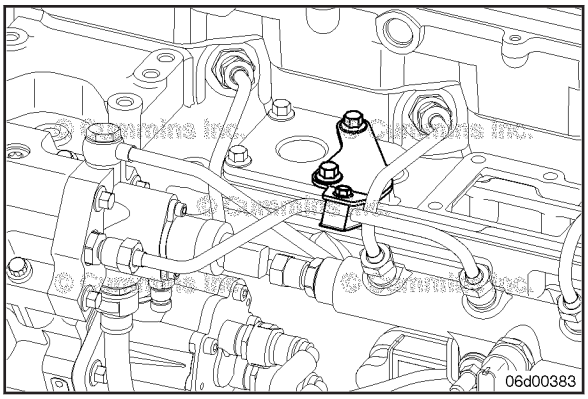
Cummins® Common Rail Fuel System



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

△CAUTION△
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system that fuel is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The fuel and fuel filters must be discarded in accordance with local environmental regulations.

If necessary, remove the air intake connection or turbocharger control actuator.

Loosen the fuel lines at the fuel rail, the fuel connector, and the high-pressure fuel pump outlet fitting.

Loosen the capscrews on the fuel line support bracket and isolator.

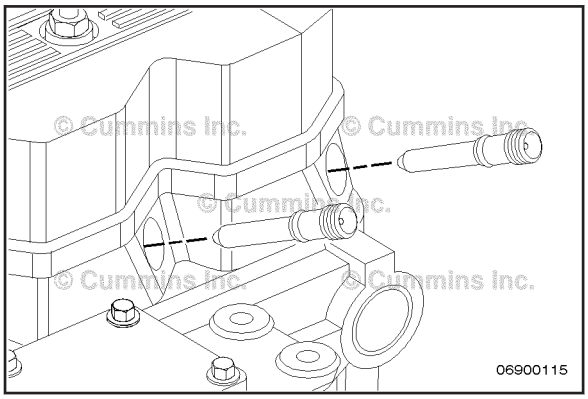
Remove the high-pressure fuel lines.

Install

CAPS Fuel System

Before installing the injector supply lines, make sure the fuel connector is fully and properly seated against the injector.

Refer to Procedure 006-052 in Section 6.



Install the fuel lines in the reverse order of removal.

Tighten the fuel pump connection.

Torque Value: 24 N•m [212 in-lb]

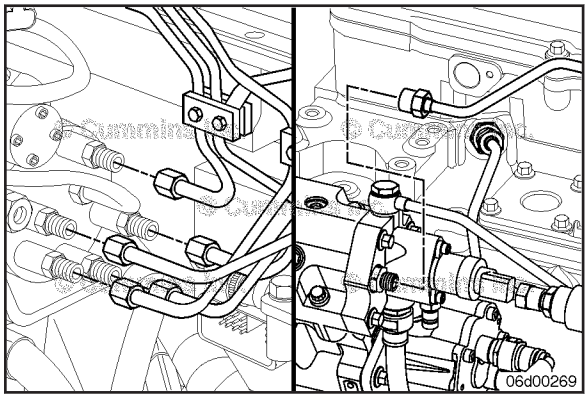
Tighten the cylinder head connection.

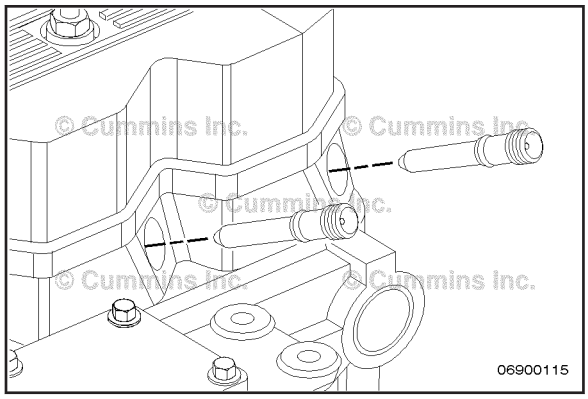
Torque Value: 38 N•m [28 ft-lb]

Tighten the fuel line isolators.

Torque Value: 3 N•m [27 in-lb]

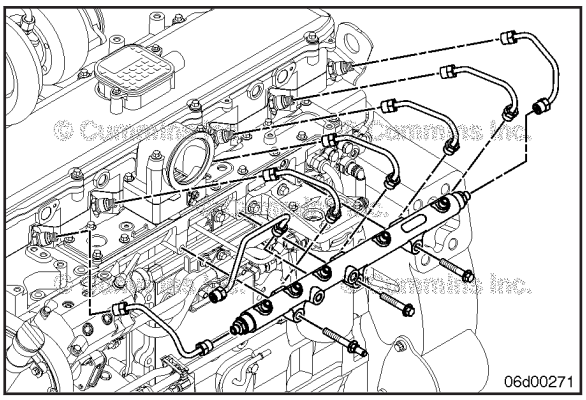
If the capscrew is loose, replace the isolator capscrew and bracket. The isolator capscrew and bracket can **not** be used twice.





Cummins® Common Rail Fuel System

Before installing the injector supply lines, make sure the fuel connector is fully and properly seated against the injector. Make sure the high-pressure connector retaining nut is tightened. Refer to Procedure 006-052 in Section 6.



Install the fuel lines in the reverse order of removal.

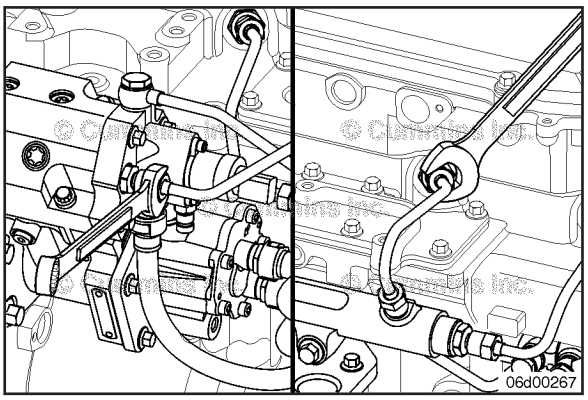
Position the fuel lines from the fuel rail to the cylinder head and tighten the lines finger tight.

Tighten the fuel rail connections.

Torque Value: 38 N•m [28 ft-lb]

Tighten the cylinder head connections.

Torque Value: 38 N•m [28 ft-lb]



Position the fuel line from the pump to the rail and tighten the line finger tight.

Install the fuel line bracket and bracket isolator capscrews finger tight.

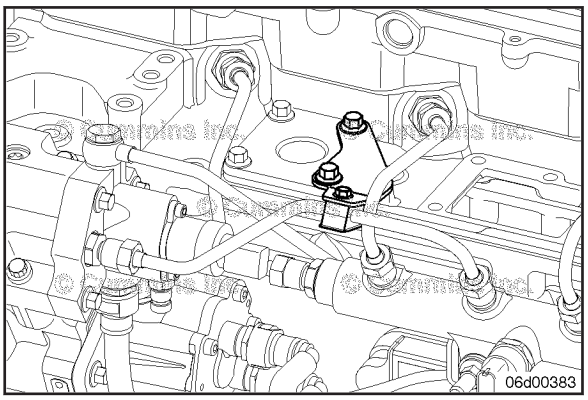
Tighten the fuel line from the fuel pump to the fuel rail at the fuel rail end first.

Tighten the fuel rail connections.

Torque Value: 38 N•m [28 ft-lb]

Tighten the fuel pump connections.

Torque Value: 38 N•m [28 ft-lb]



Tighten the fuel line bracket capscrews.

Torque Value: 24 N•m [212 in-lb]

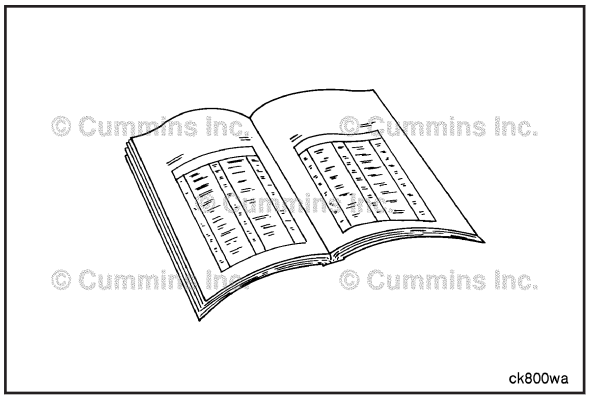
Tighten the fuel line bracket isolator capscrew.

Torque Value: 9 N•m [80 in-lb]

Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the air intake connection and turbocharger control actuator, if removed. Refer to Procedure 010-022 in Section 10.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Open the fuel supply and drain valves. Refer to OEM service manual.
- Operate the engine and check for leaks.



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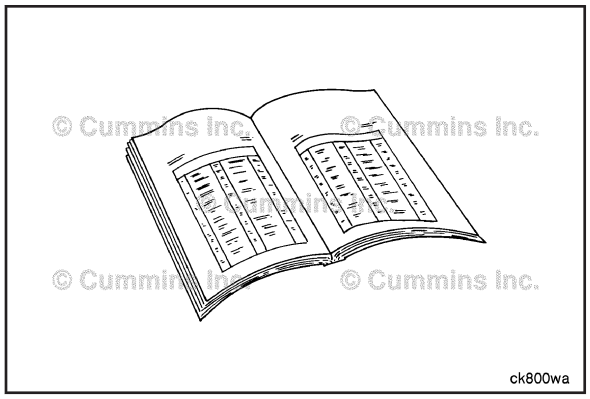


Fuel Connector (Head Mounted) (006-052)

Preparatory Steps

⚠WARNING⚠
The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.

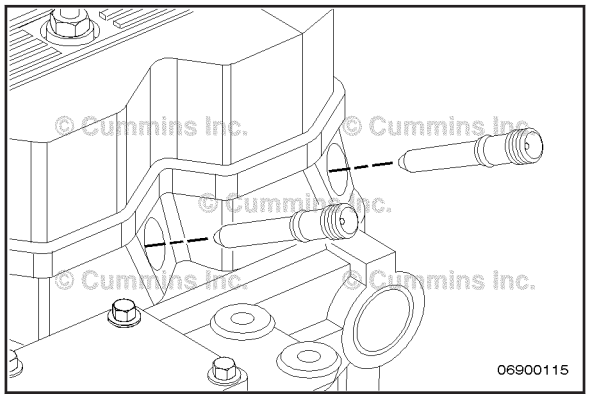
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

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

△CAUTION△
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.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Shut off the fuel supply and drain valves. Refer to the OEM service manual.
- Remove the high-pressure fuel supply lines. Refer to Procedure 006-051 in Section 6.



Remove

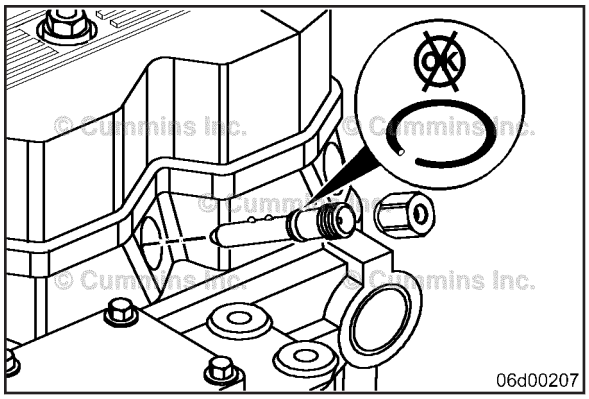
CAPS Fuel System

Use fuel connector puller, Part Number 3825157, to remove the fuel connector from the cylinder head.

Cummins® Common Rail Fuel System

Remove the fuel connector retaining nut.

Use fuel connector puller, Part Number 3164025, to remove the fuel connector from the cylinder head.



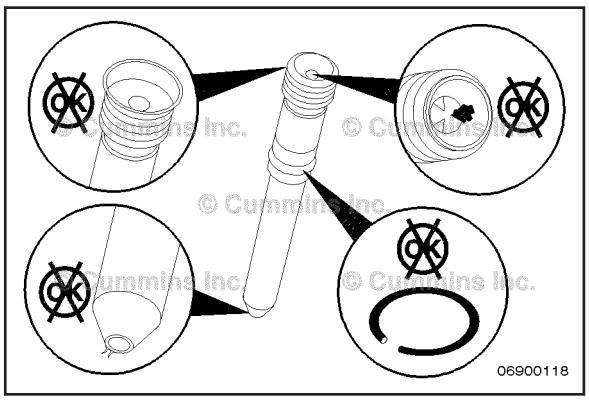
Inspect for Reuse

A new high-pressure connector **must** be installed if a new injector is being installed.

Inspect the fuel connector. Look for burrs or deformation around the inlet and outlet sides of the connector.

Check the edge filter for signs of plugging or material contamination. Do **not** reuse a high-pressure fuel connector if debris is present.

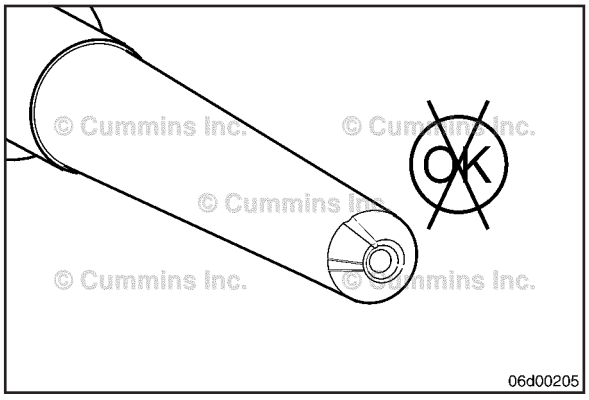
Check the o-ring for tearing or deterioration.



Inspect the outlet sealing surface of the high-pressure connector for wear, an uneven seating surface, or signs of leakage.

When a high-pressure fuel leak is present, small lines or cuts in the connector will be eroded into the seating surface.

The high-pressure connector and injector **must** be replaced when this condition is observed.



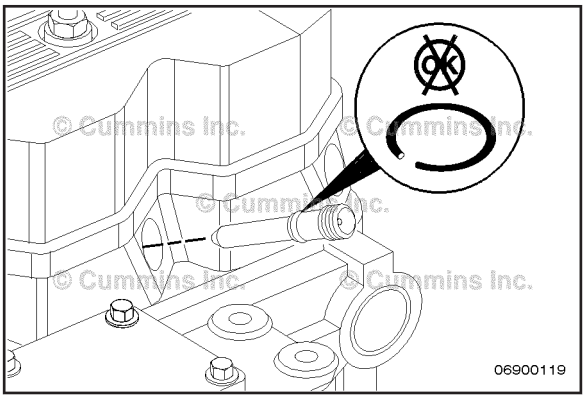
Install

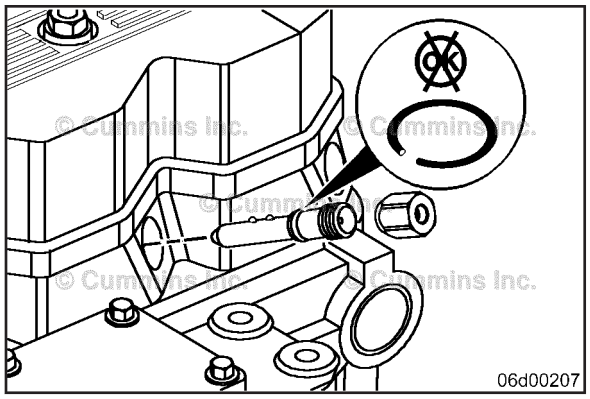
CAPS Fuel System

Coat the fuel connector o-ring with clean engine oil.

NOTE: If a new injector has been installed, a new fuel connector **must** be used.

Carefully push the fuel connector into the head until it stops against the injector. Be certain the injector is fully seated in the injector bore before installing the fuel connector. Refer to Procedure 006-026 in Section 6.





Cummins® Common Rail Fuel System

NOTE: If a new injector has been installed, a new fuel connector **must** be used.

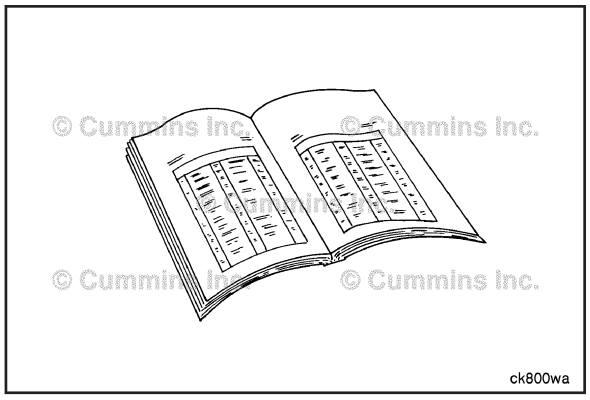
Lubricate the fuel connector o-ring and the threads on the fuel connector retaining nut.

Carefully insert the fuel connector, aligning the guide pin with the slot in the cylinder head at the 12-o'clock position.

NOTE: If the injector was removed along with the high-pressure fuel connector, the installation steps **must** be followed. Refer to Procedure 006-026 in Section 6.

Tighten the fuel connector retaining nut.

Torque Value: 55 N•m [41 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 high-pressure fuel supply lines. Refer to Procedure 006-051 in Section 6.
- Open the fuel supply and drain valves. Refer to the OEM service manual.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

Fuel Pump Air Bleed Line (006-056)

Preparatory Steps

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

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△
Do not use the air bleed line as a handle or step. Doing this may result in cracks or damaged air bleed line that will cause fuel leaks. Make sure that steam does not spray directly on the electrical connections on the top of the accumulator block or fault codes will possibly occur.

Thoroughly steam-clean the entire fuel pump.

Dry the fuel pump with compressed air.

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Remove

ISC and QSC8.3 With CAPS Injection Pump

⚠WARNING⚠
To reduce the possibility of an air bleed line leak due to a broken air bleed line, use two wrenches during removal and installation. Failure to do so may result in a cracked fuel line. In certain applications, with the fuel tank above the head of the engine, this will result in fuel draining from the fuel tank.

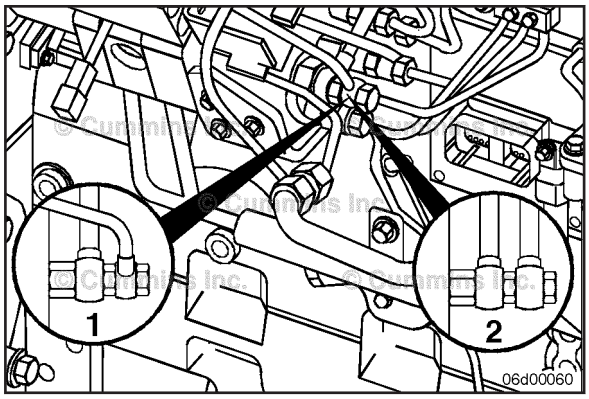
NOTE: There are three styles of air bleed lines. Identify your style and use the appropriate procedures that follow.

Style One (1):

Remove the banjo capscrew at the injection control valve drain fitting of the fuel pump. Use two wrenches to prevent the line from being bent.

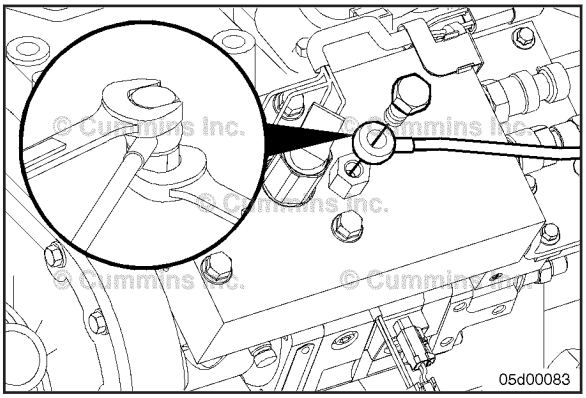
Style Two (2):

Remove the banjo capscrew at the injection control valve drain fitting of the fuel pump. Remove the hollow banjo fitting holding the air bleed line. Use two wrenches to prevent the line from being bent.



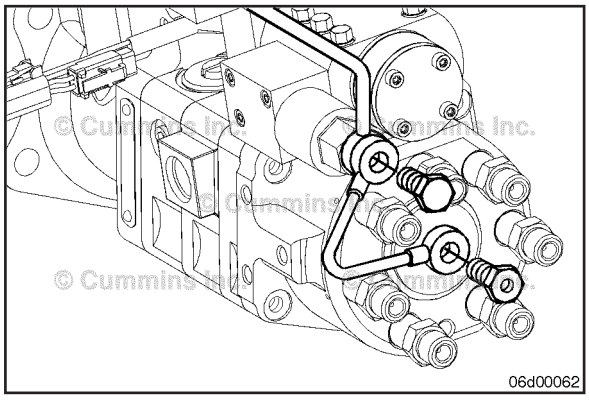
Remove the banjo capscrew at the air bleed fitting on top of the fuel pump. It is located on the accumulator module next to the two pumping control valves.

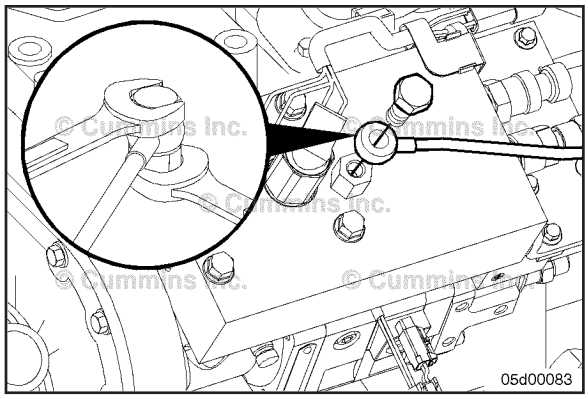
Use two wrenches to prevent the air bleed fitting from turning.



ISL and QSL9 With CAPS Injection Pump

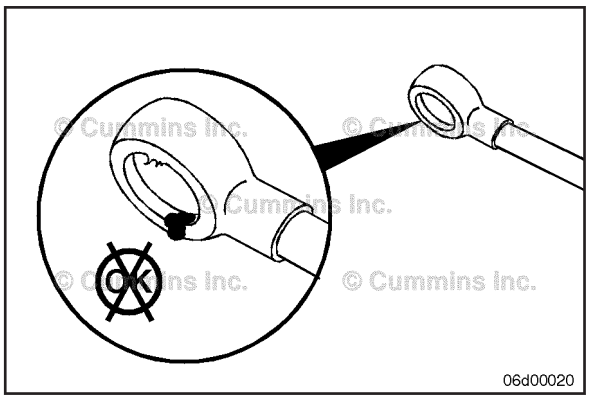
Remove the banjo bolt from the injection control valve drain fitting and the distributor plug.





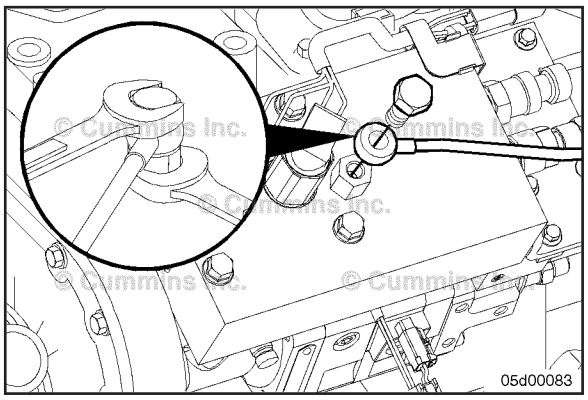
Remove the banjo capscrew at the air bleed fitting on top of the fuel pump. It is located on the accumulator module next to the two pumping control valves.

Use two wrenches to prevent the air bleed fitting from turning.



Inspect for Reuse

Inspect the lines for pinches, bends, or damaged connectors.



Install

ISC and QSC8.3 With CAPS Injection Pump

⚠WARNING⚠
To reduce the possibility of an air bleed line leak due to a broken air bleed line, use two wrenches during removal and installation. Failure to do so may result in a cracked fuel line. In certain applications, with the fuel tank above the head of the engine, this will result in fuel draining from the fuel tank.

Install the banjo capscrew at the air bleed fitting on top of the fuel pump. Use two wrenches to prevent the line from being bent.

Torque Value: 8 N•m [70 in-lb]

NOTE: Use new sealing washers.

Style One (1):

Install the banjo capscrew drain fitting on the fuel pump at the injection control valve. Use two wrenches to prevent the line from being bent.

Torque Value: 8 N•m [70 in-lb]

NOTE: Use new sealing washers.

Style Two (2):

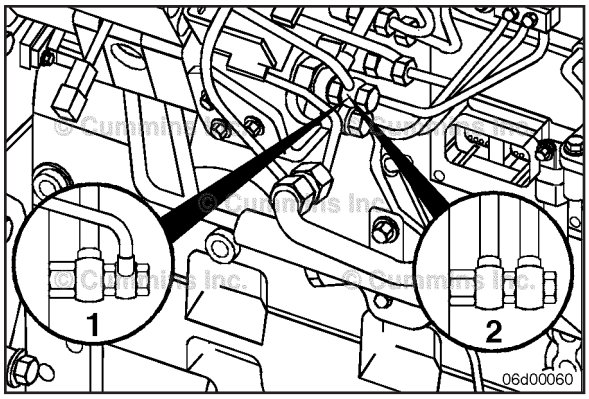
Install the hollow banjo fitting at the injection control valve drain fitting to secure the air bleed line. Use two wrenches to prevent the line from being bent.

Torque Value: 24 N•m [18 ft-lb]

Install banjo capscrew. Use two wrenches to prevent the line from being bent.

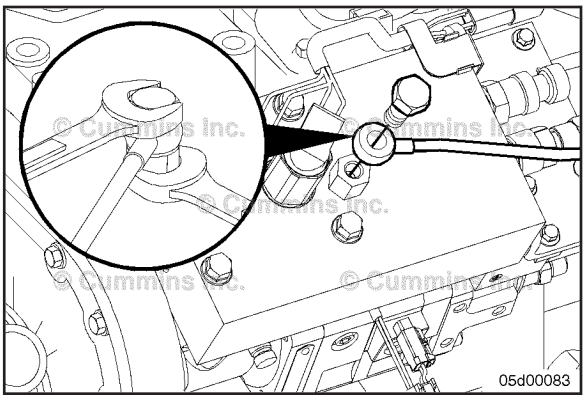
Torque Value: 24 N•m [18 ft-lb]

NOTE: Use new sealing washers.



ISL and QSL9 With CAPS Injection Pump

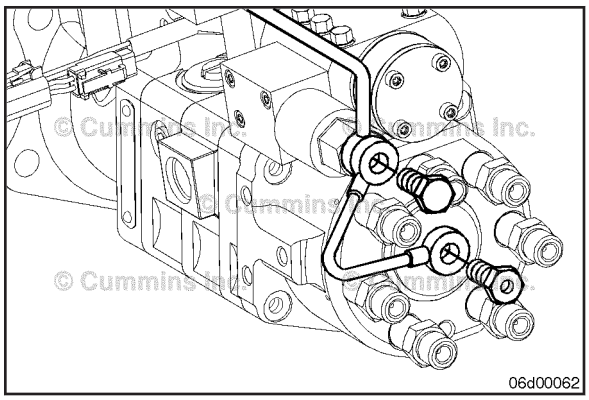
Install the banjo capscrew at the air bleed fitting on top of the fuel pump. Use two wrenches to prevent the air bleed fitting from turning.



Install the banjo capscrew in the injection control valve drain fitting and the distributor plug.

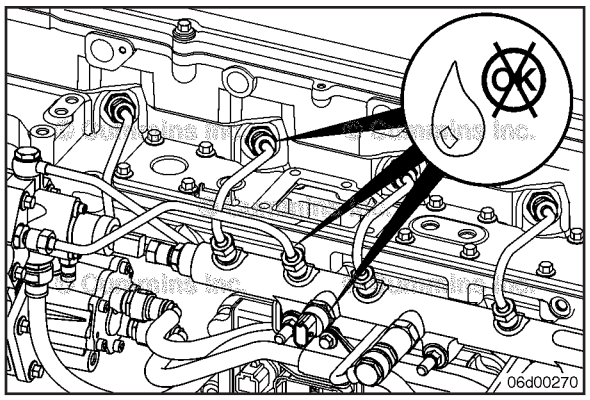
Torque Value: 8 N•m [70 in-lb]

NOTE: Use new sealing washers.



Finishing Steps

Operate the engine and check for leaks.



Fuel Rail (006-060)

Initial Check

⚠WARNING⚠
The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.

⚠WARNING⚠
The pressure within the fuel rail is extremely high. High pressure can penetrate the skin. Stand clear of the engine while it is running.

⚠WARNING⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. To reduce the possibility of personal injury and property damage, never loosen any fittings while the engine is running.

Inspect the fuel pressure sensor, high-pressure fuel line connections, and male unions for leaks.

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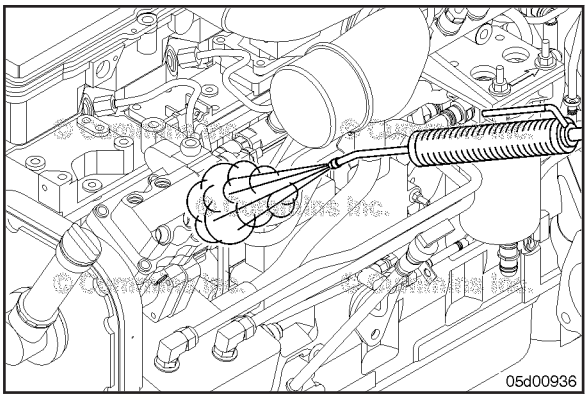
Preparatory Steps

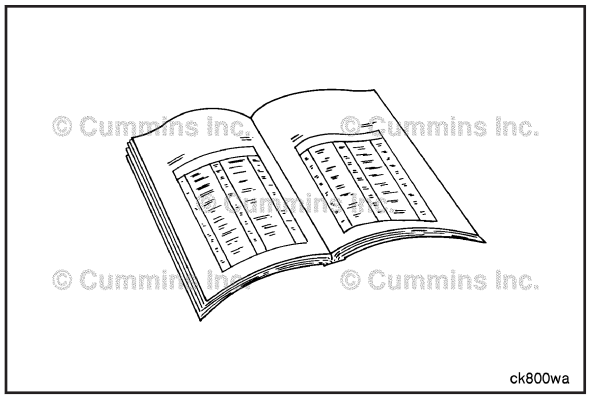
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

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

△CAUTION△
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which can expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine. Refer to Procedure 000-009 in Section 0.



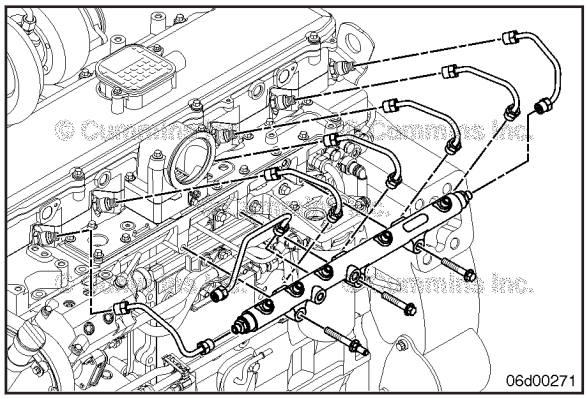


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

⚠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.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Shut off the fuel supply and drain valves. Refer to the OEM service manual.
- Disconnect the fuel pressure sensor from the engine wiring harness. Refer to Procedure 019-115 in Section 19. This procedure is found in the Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416.
- Remove the high-pressure fuel lines from the fuel rail. Refer to Procedure 006-051 in Section 6.
- Remove the fuel drain line from the fuel pressure relief valve. Refer to Procedure 006-013 in Section 6.



Remove

Remove the capscrews that secure the fuel rail to the cylinder head.

Remove the fuel rail assembly.

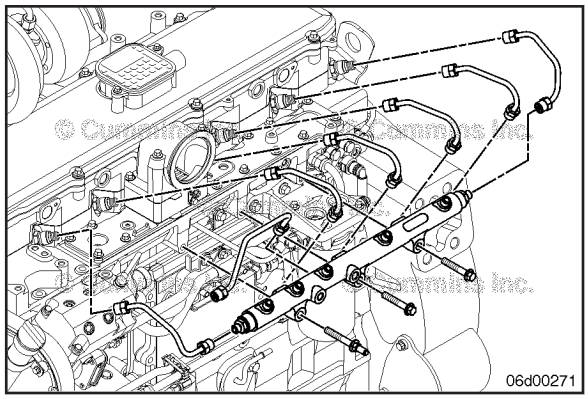
Install

Install the fuel rail assembly. Follow the proper sequence to make sure that high-pressure fuel lines are properly aligned.

- Install the fuel rail assembly capscrews finger-tight.
- Install the high-pressure fuel lines finger-tight.
- Tighten the fuel rail assembly capscrews.

Torque Value: 43 N•m [32 ft-lb]

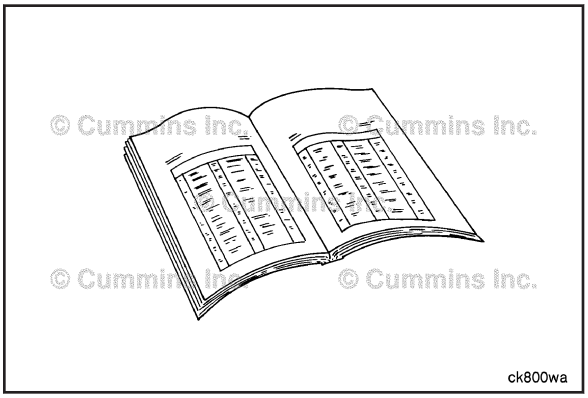
- Tighten the high-pressure fuel lines. Refer to Procedure 006-051

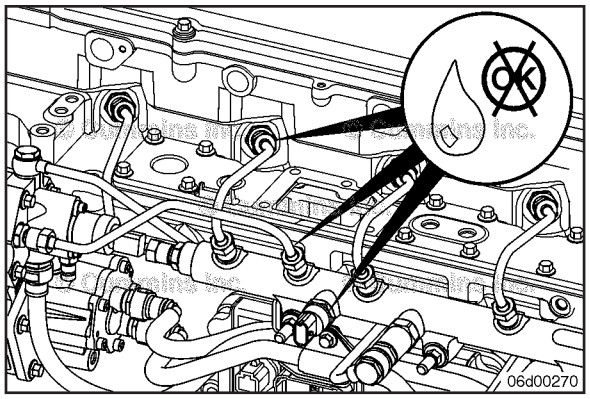


Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the fuel drain line to the fuel pressure relief valve. Refer to Procedure 006-013 in Section 6.
- Install the fuel pressure sensor to the engine wiring harness. Refer to Procedure 019-115 in Section 19. This procedure can be found in the Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416.
- Open the fuel supply and drain valves. Refer to the OEM service manual.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.





Fuel Pressure Relief Valve (006-061)

Initial Check

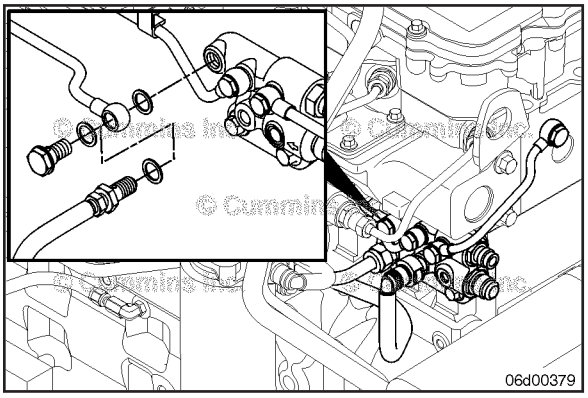
⚠WARNING⚠
The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.

⚠WARNING⚠
The pressure within the fuel rail is extremely high. High-pressure can penetrate the skin. Stand clear of the engine while it is running.

⚠WARNING⚠
The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. To reduce the possibility of personal injury, never loosen any fittings while the engine is running.

△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.

Operate the engine and check for external fuel leaks.



Check for a fuel pressure relief valve that leaks excessive fuel to drain.

The measurement of fuel pressure relief valve leakage requires use of a fuel return flow hose, Part Number 3164618. This tool is used to isolate the leakage from just the fuel pressure relief valve, so the leakage can be measured in a graduated cylinder.

NOTE: If Fault Code 449 or 2311 is active, do **not** replace the fuel pressure relief valve without first determining the cause of the fault condition. See the appropriate troubleshooting tree(s).

Remove the M12 banjo bolt that connects the fuel pressure relief valve drain line to the fuel drain manifold.

Install a fuel return flow hose, Part Number 3164618, at the fuel drain manifold.

Route the fuel return flow hose into a collection device.

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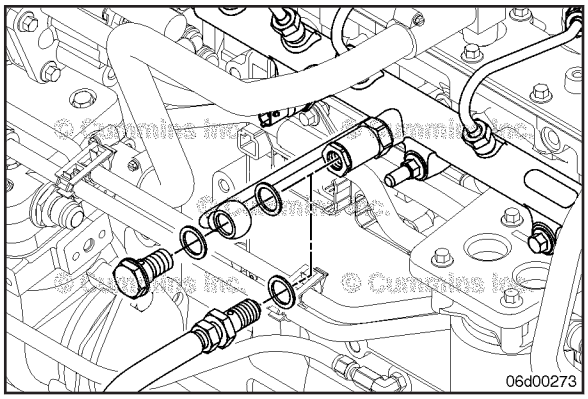
Alternatively, fuel pressure relief valve leakage measurement tool, Part Number 3164617, can be installed at the fuel pressure relief valve.



Test

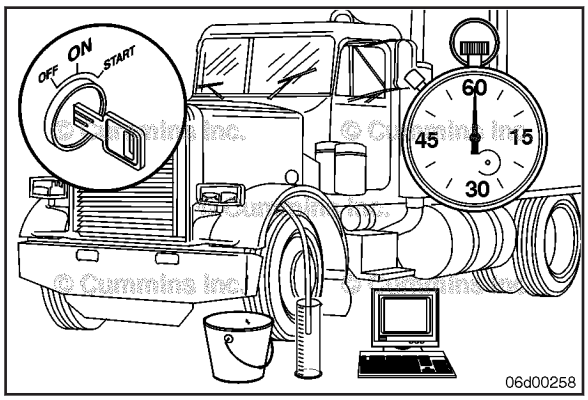
Engine Running

Start the engine and let it idle.

Measure the leakage.

Specification:

Less than 30 drops per minute **must** drain from the fuel pressure relief valve while the engine operates at idle.



⚠CAUTION⚠
Fuel is at high pressure during this test. After connecting the test fitting, close the engine cover and stand clear of high-pressure fuel lines.

Start the engine.

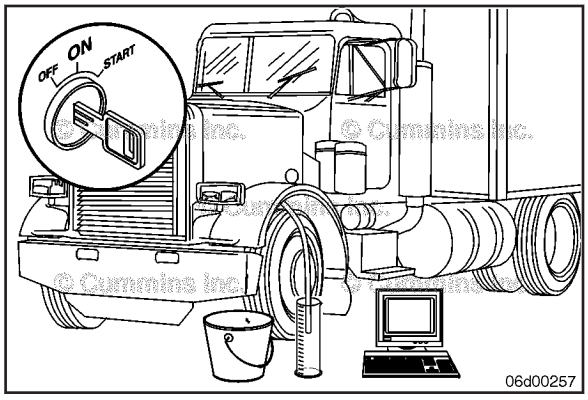
NOTE: Make certain the engine is at operating temperature before running the test.

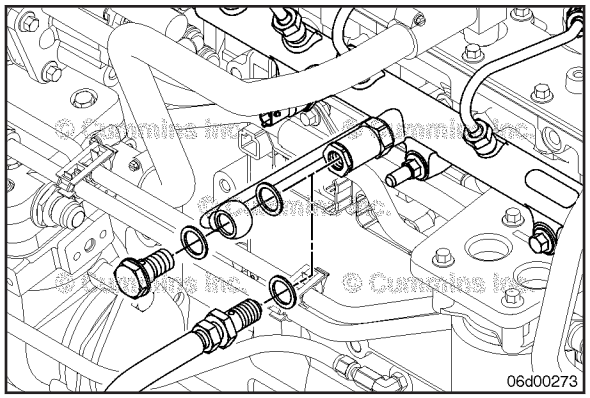
While the engine is operating at idle, use INSITE™ electronic service tool High Pressure Leak Test to create higher fuel rail pressure. INSITE™ electronic service tool will command 1500 BAR fuel rail pressure while the engine is at idle during this test.

Specification:

Less than 30 drops (1.95 ml [0.07 oz]) of fuel per 30 second are permitted to drain from the fuel pressure relief valve.

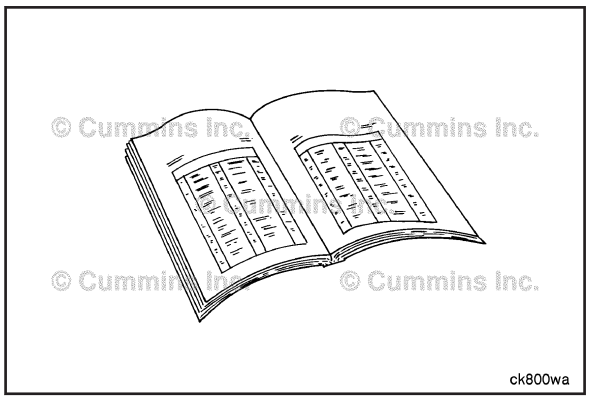
NOTE: For an accurate measurement, collect three different flows and average the results.





Remove the fuel return flow hose and install the fuel drain line banjo bolt. Refer to Procedure 006-013 in Section 6.

Operate the engine and check for leaks.



Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.

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

△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.

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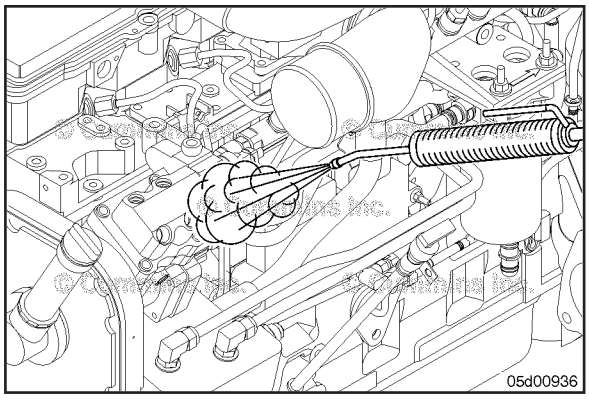
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

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

△CAUTION△
Clean all fittings before disassembly. Dirt or contaminants can damage the fuel system.

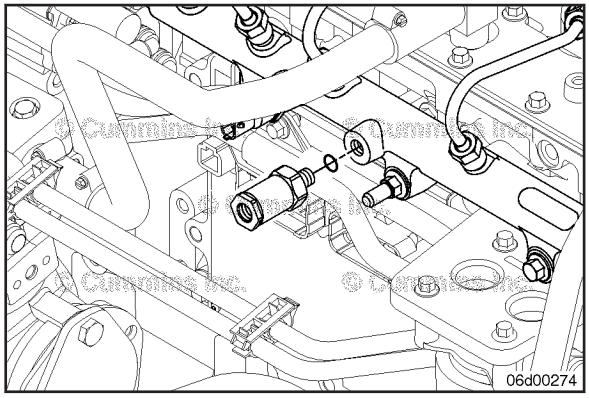
Before servicing **any** fuel system components, (such as fuel lines, fuel pump, injectors, etc.) which would expose the fuel system or internal engine component to potential contaminants prior to disassembly, clean the fittings, mounting hardware, and the area around the component to be removed. Dirt or contaminants can be introduced into the fuel system and engine if the surrounding areas are **not** cleaned, resulting in damage to the fuel system and engine.

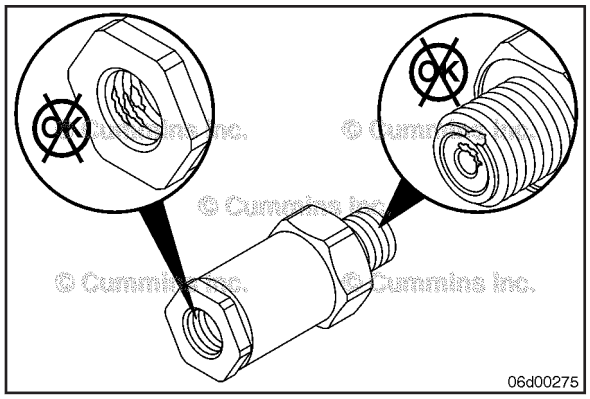
- Clean the engine. Refer to Procedure 000-009 in Section 0.
- Disconnect the batteries. Refer to the OEM service manual.
- Close the fuel supply and drain valves. Refer to the OEM service manual.
- Remove the fuel drain line from the fuel rail pressure relief valve. Refer to Procedure 006-013 in Section 6.
- Remove the fuel pressure relief valve adapter and copper seal washer.



Remove

Remove the fuel pressure relief valve.

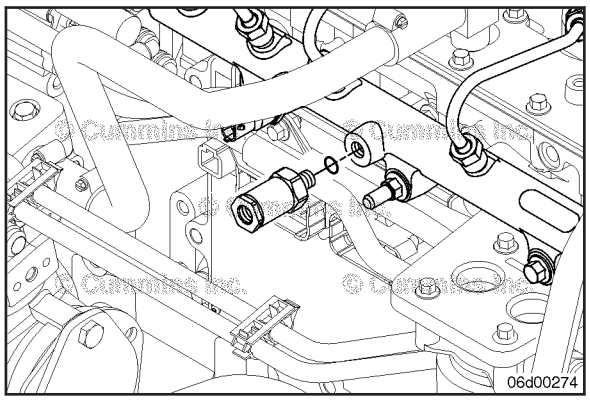




Inspect for Reuse

If the fuel pressure relief valve exhibits excessive leakage to drain, it **must not** be reused.

Inspect the high-pressure seal surface on the fuel pressure relief valve and in the fuel rail for damage. Do **not** reuse components if the high-pressure seal joint is damaged.



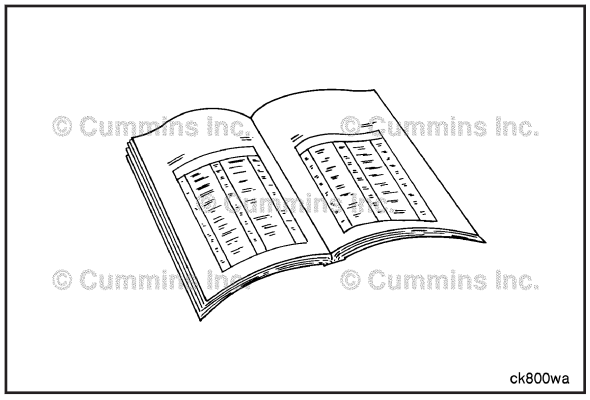
Install

Install the fuel pressure relief valve and a new sealing washer. Use assembly lubricant, Part Number 3163087 or equivalent, on the threads.

Torque Value: 100 N•m [74 ft-lb]

If the reducer has been removed from the fuel rail pressure relief valve, install the reducer with a new copper seal washer.

Torque Value: 37 N•m [27 ft-lb]



Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the fuel drain line to the fuel pressure relief valve. Refer to Procedure 006-013 in Section 6.
- Open the fuel supply and drain valves. Refer to the OEM service manual.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.

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Fuel Cooler (006-062)

General Information

QSL Engines

This procedure applies to QSL9 marine sea water cooled (heat exchanger) engines **only**.

Preparatory Steps

QSL Engines

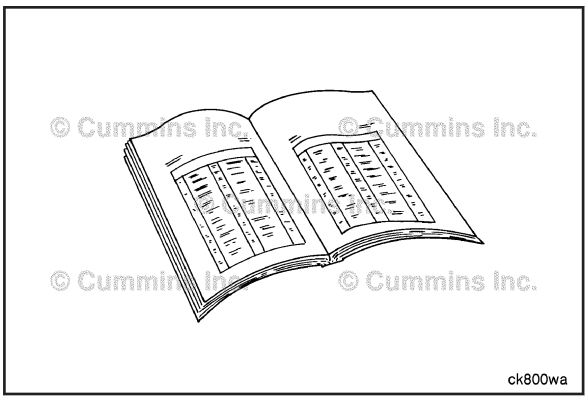
⚠WARNING⚠
Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

⚠CAUTION⚠
Use caution when 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⚠
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.

NOTE: This procedure applies to QSL9 engines **only**. Refer to Procedure 008-129 for QSC8.3 engines.

- Shut off the sea water supply valve(s). Refer to the OEM service manual.
- Drain the sea water system by removing a zinc plug from the aftercooler. Refer to Procedure 010-005.
- Shut off the fuel supply and return valves to the engine. Refer to the OEM service manual.
- Disconnect the fuel drain line from the combined fuel manifold to the fuel cooler at the fuel cooler connection. Refer to Procedure 006-013.
- Disconnect the fuel drain line from the fuel cooler to the fuel tanks.



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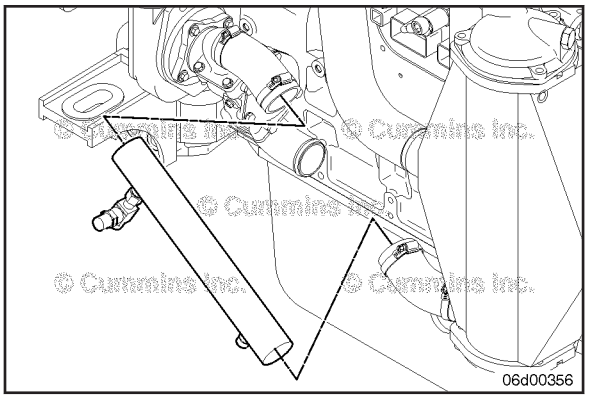
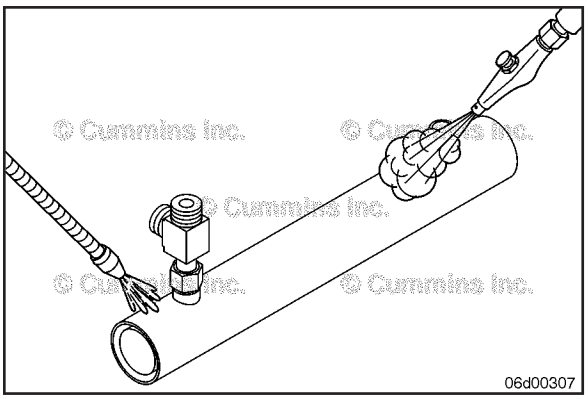


Remove

QSL Engines

Remove the hose clamps at the top and bottom of the fuel cooler.

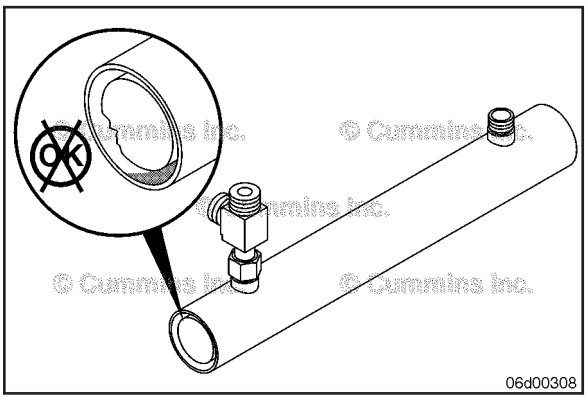
Remove the fuel cooler.



Clean and Inspect for Reuse

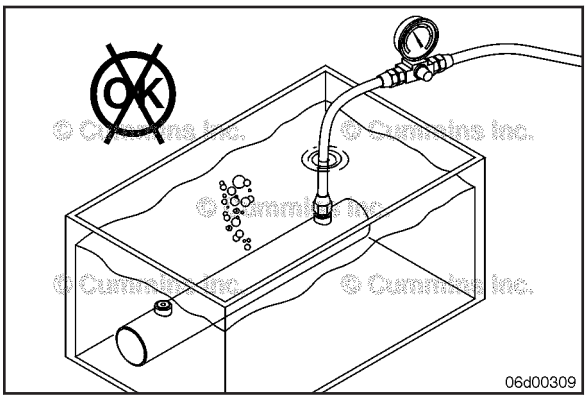
QSL Engines

Clean the hose sealing surfaces of the fuel cooler.



Inspect the core area of the fuel cooler for debris. Clean if required.

Inspect the core for damage to the inter core surfaces.



Pressure test the fuel side of the fuel cooler.

Install a plug in one end of the cooler.

Install fittings and apply shop air pressure.

Air Pressure 172 kPa [25 psi]

Place the cooler in a tank of water and check for leaks.

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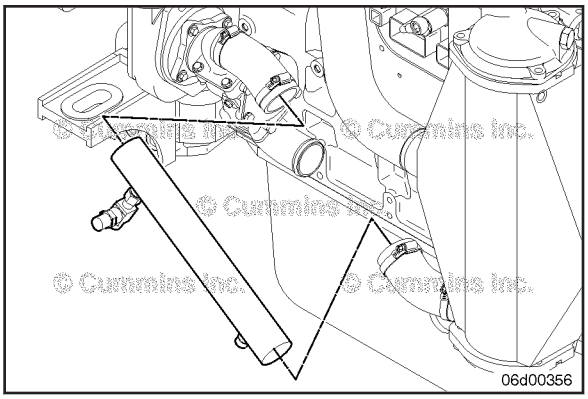
Install

QSL Engines

Install the fuel cooler into the sea water hoses.

Tighten the hose clamps.

Torque Value: 8 N•m [71 in-lb]



Finishing Steps

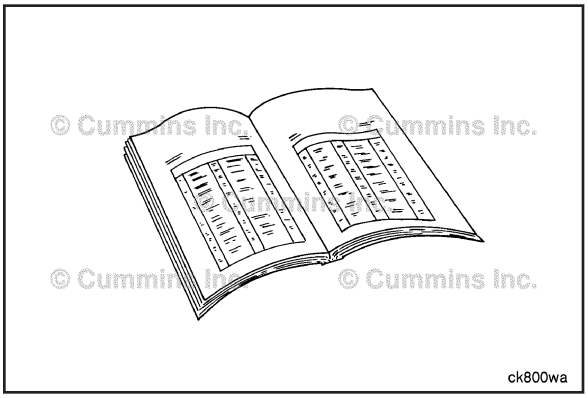
QSL Engines

⚠CAUTION⚠

Failure to properly prime the fuel system on marine engines can result in damage to the fuel cooler. Be sure the drain valve(s) are open. Be sure a good flow of fuel is present through the fuel cooler by cycling the keyswitch at least five times before starting the engine. Refer to Procedure 005-016.

- Connect the fuel drain line from the fuel cooler to the fuel tanks. Refer to the OEM service manual.
- Connect the fuel drain line from the combined fuel manifold to the fuel cooler at the fuel cooler connection. Refer to Procedure 006-013.
- Open the supply and return valves to the engine. Refer to the OEM service manual.
- Open the sea water supply line(s). Refer to the OEM service manual.
- Prime the fuel system. Refer to Procedure 005-016.

Operate the engine and check for leaks.



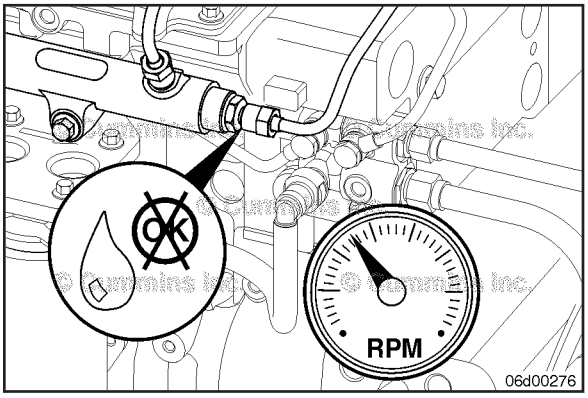
Fuel Rail High Pressure Fitting (006-067)

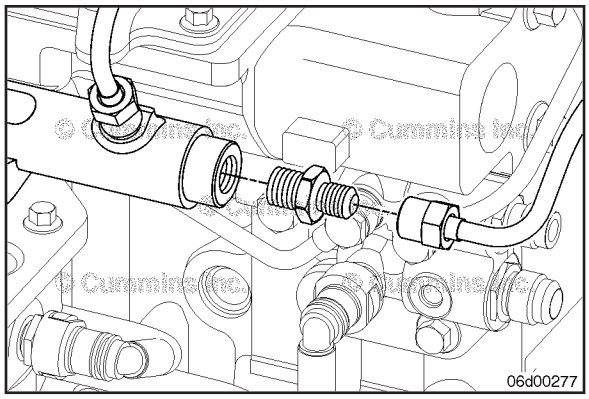
Initial Check

⚠WARNING⚠

The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease to a lower level.

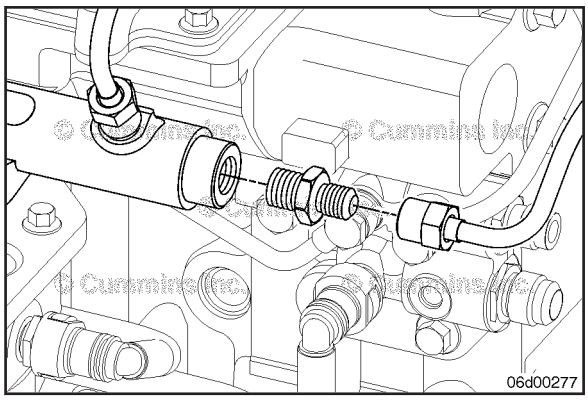
Operate the engine and check for external leaks.





Remove

Remove the high-pressure fitting **only** if a leak is detected.



Install

Flush the outlet fitting using contact cleaner.

Apply Lubriplate™ to the high-pressure fitting threads.

Install the high-pressure fitting.

Torque Value: 100 N•m [74 ft-lb]

Reinstall the high-pressure fuel line. Refer to Procedure 006-051.

Operate the engine and check for leaks. If a leak occurs after replacing the fitting, replace the rail.

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Section 7 - Lubricating Oil System - Group 07

Section Contents

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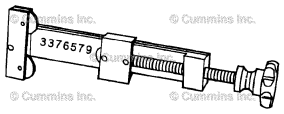
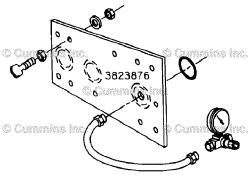
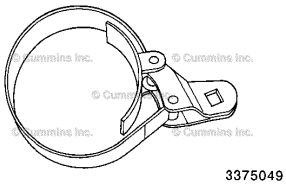
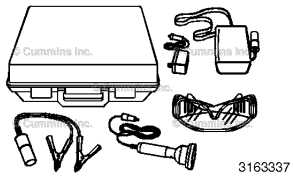
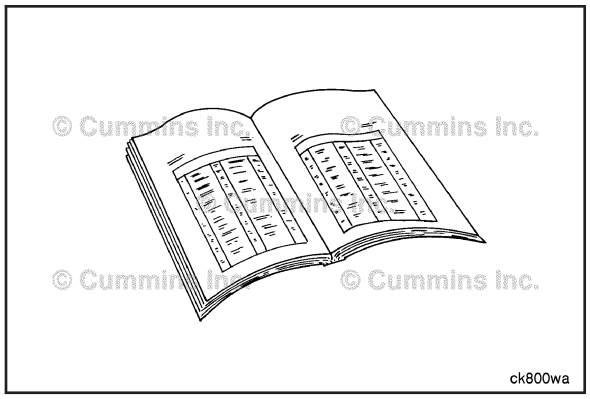
Service Tools

Lubricating Oil System

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3376579	**Tube (Filter) Cutter** Used to cut open the filter to permit inspection of the filter element.	 3376579
3823876	**Lubricating Oil Cooler Pressure Test Kit** Used to seal and pressurize the lube oil cooler to test for leaks. Requires regulated pressure supply, Part Number 3164231, or equivalent (purchased separately).	
3375049	**Oil Filter Wrench** Used to remove the oil filter.	 3375049
3163338	**Black Light Lamp (12 VDC)** Black light with rechargeable battery and charger used with fluorescent tracer, Part Number 3376891, to locate oil leaks.	 3163337



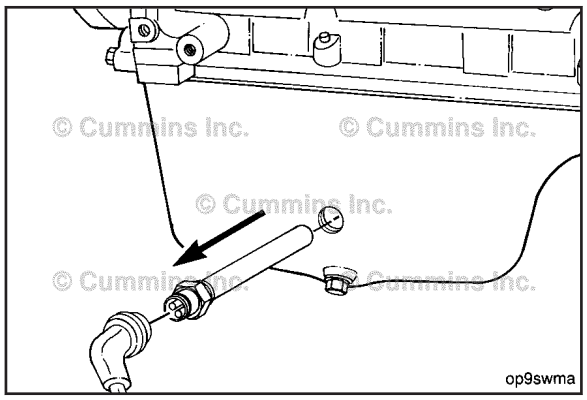
Engine Oil Heater (007-001)

Preparatory Steps

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

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

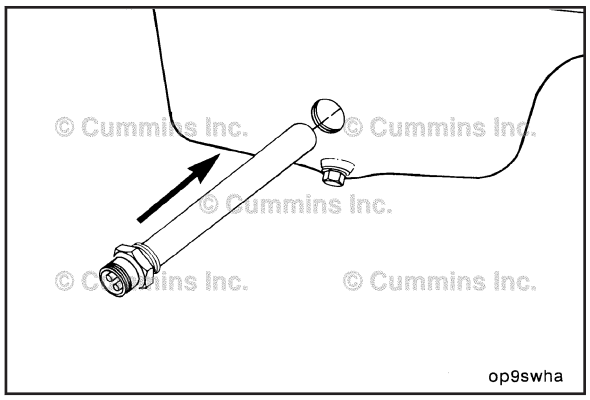
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.



Remove

Disconnect the oil heater electrical cord.

Remove the heater element.



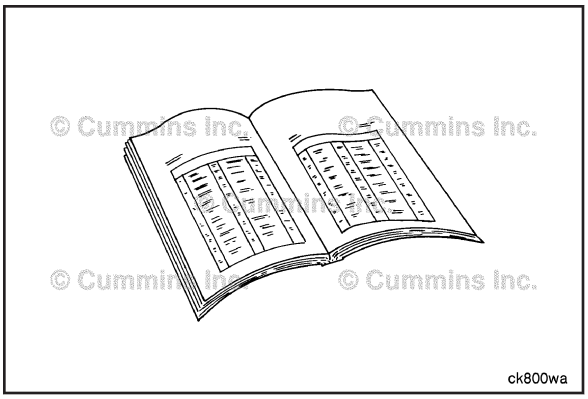
Install

Install the heater element.

Torque Value: 120 N•m [89 ft-lb]

Finishing Steps

- Connect the oil heater electrical cord.
- Fill the engine with lubricating oil. Refer to Procedure 007-037 in Section 7.
- Operate the engine and check for leaks.



Lubricating Oil Cooler (007-003)

Preparatory Steps

All Applications Except Marine

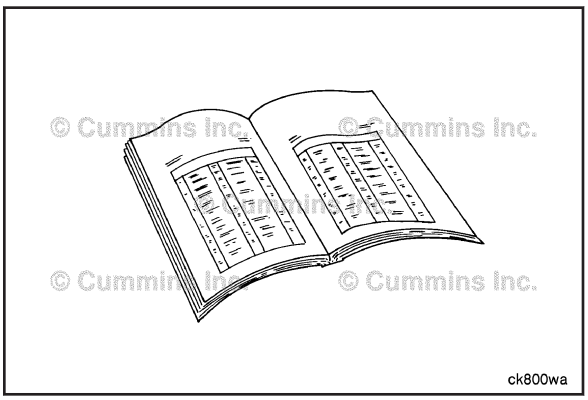
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

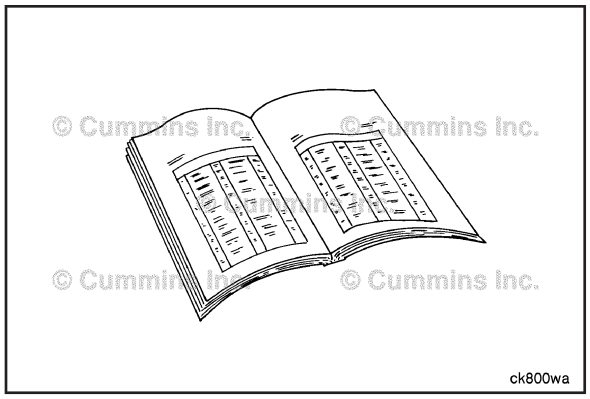
⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

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

⚠WARNING⚠
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.
- Clean the area around the lubricating oil cooler cover.
- Remove the coolant filter head. Refer to Procedure 008-007 in Section 8.
- Remove the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Remove the turbocharger oil supply line. Refer to Procedure 010-046 in Section 10.





Marine Applications

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

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

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

△CAUTION△
Use caution when draining oil or replacing filters that oil is not spilled or drained into the bilge area. The oil and oil filters must be discarded in accordance with local environmental regulations.

- Close the sea water supply and return valves. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the heat exchanger/expansion tank assembly, if equipped. Refer to Procedure 008-053 in Section 8.
- Clean the area around the lubricating oil cover.
- Remove the heat exchanger coolant return connection.
- Remove the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Remove the turbocharger oil supply line. Refer to Procedure 010-046 in Section 10.

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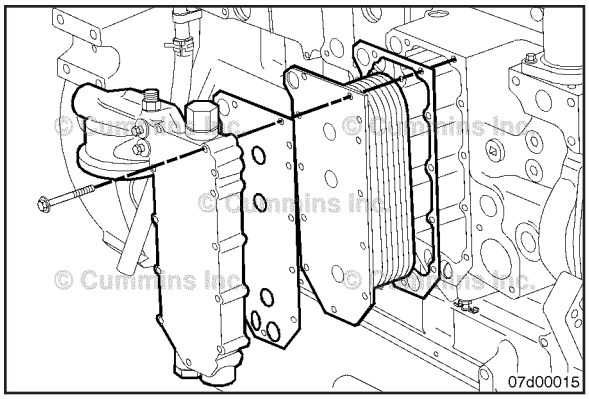
Remove

Remove the lubricating oil cooler cover, gaskets and cooler element.



Clean and Inspect for Reuse

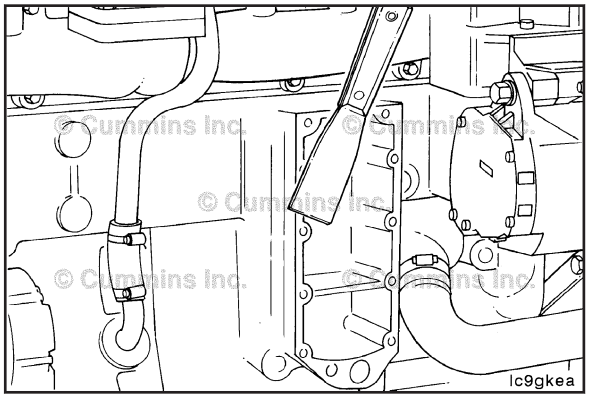
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠CAUTION⚠
Use a solvent that will not harm copper to clean the oil cooler elements.

Use solvent to clean the oil cooler housing and cover.

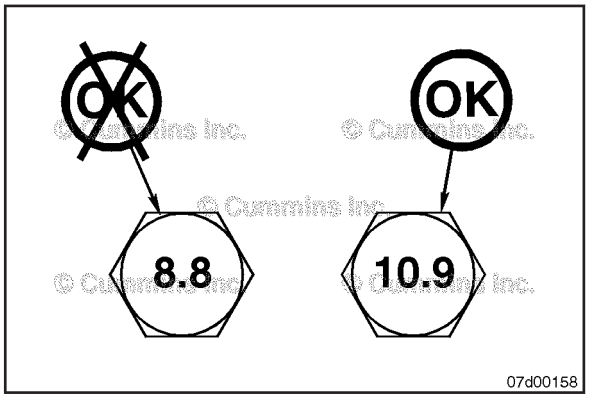
Clean the sealing surfaces of the cylinder block and the oil cooler cover.

NOTE: Replace the elements if any debris is found or the engine has had debris-causing damage.



Inspect the capscrews. If they are Grade 10.9 or higher, they can be reused.

If the capscrews are lower than Grade 10.9, they **must** be replaced with Grade 10.9 or higher capscrews.



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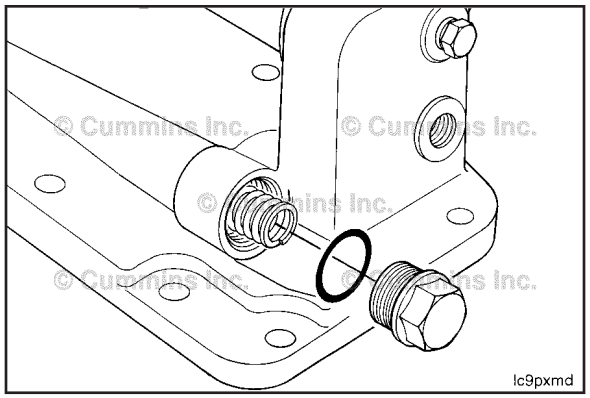
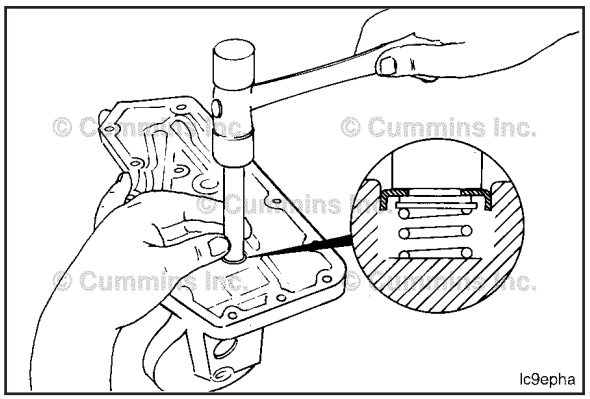


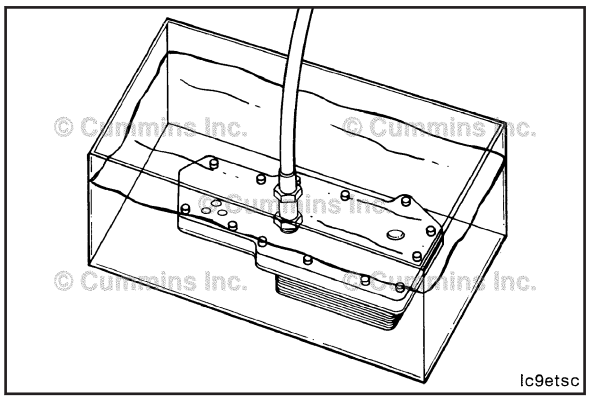
If any debris is suspected to have gone through the engine or if troubleshooting a lubricating oil pressure issue, remove and inspect the lubricating oil pressure regulator located in the lubricating oil cooler cover. Replace if necessary.

- For All Applications Except Marine: Refer to Procedure 007-029 in Section 7.
- For Marine Applications: Refer to Procedure 007-029 in Section 7.



If any debris is suspected to have gone through the engine, inspect the oil filter bypass valve located in the lubricating cooler cover. Make sure the valve is fully seated and opens and closes freely. Replace if necessary.

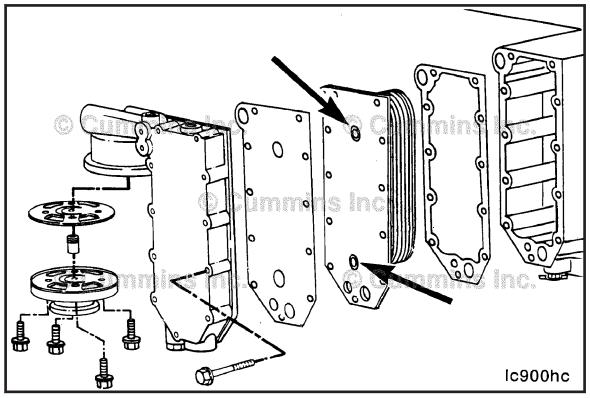
The bypass valve requires a 345 kPa [50 psi] pressure differential to open.



Leak Test

Use leak test kit, Part Number 3823876, to pressure-test the lubricating oil cooler element.

Air Pressure Test		
kPa		**psi**
449	MIN	65
518	MAX	75



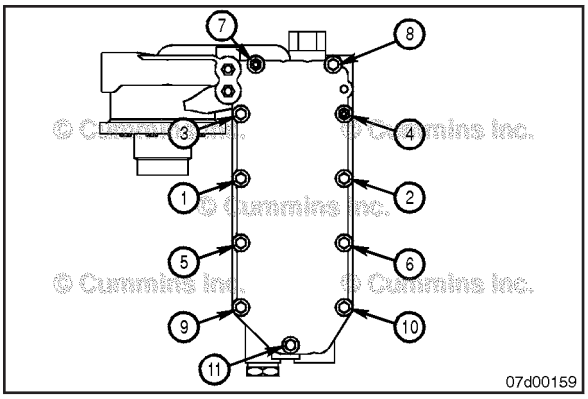
Install

NOTE: Be sure to remove the shipping plugs from a new element.

Assemble the lubricating oil cooler gaskets, element, and cooler cover.

If the oil cooler cover does **not** have a dimple, tighten the capscrews in the sequence shown.

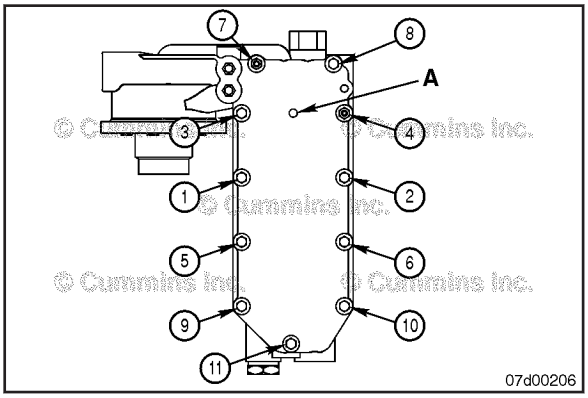
Torque Value: 24 N•m [212 in-lb]



If the oil cooler cover does have a dimple, tighten the capscrews in the sequence shown in the illustration, in two steps. The arrow (A) points to the dimple.

Torque Value:

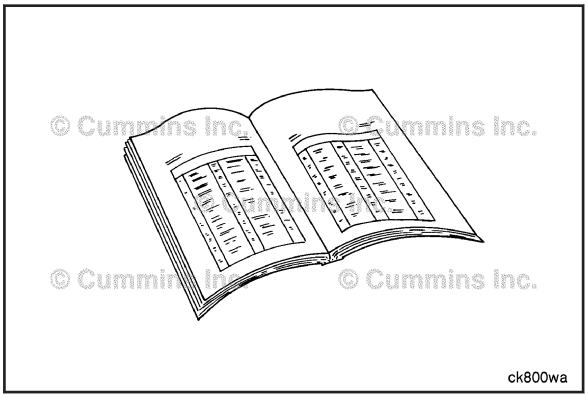
Step 1	24 N•m	[212 in-lb]
Step 2	32 N•m	[24 ft-lb]

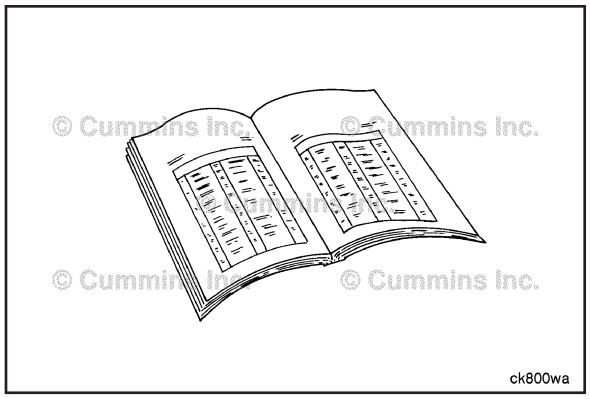


Finishing Steps

All Applications Except Marine

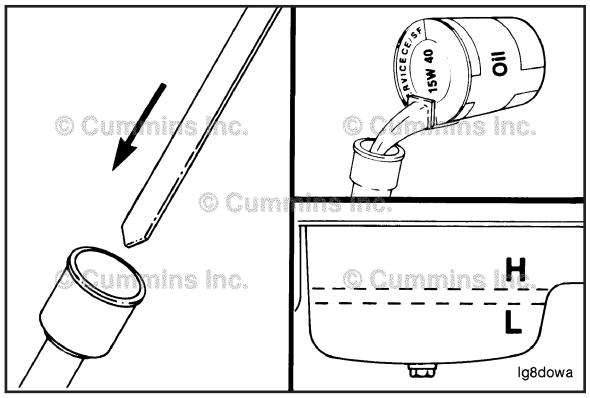
- Install the turbocharger oil supply line. Refer to Procedure 010-046 in Section 10.
- Install the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Install the coolant filter head. Refer to Procedure 008-007 in Section 8.
- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- Operate the engine and check for leaks.
- Stop the engine and check the coolant and lubricating oil level.





Marine Applications

- Install the turbocharger oil supply line. Refer to Procedure 010-046 in Section 10.
- Install the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Install the heat exchanger/expansion tank, if equipped. Refer to Procedure 008-053 in Section 8.
- Install the heat exchanger coolant return line.
- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- Open the sea water supply line valves. Refer to the OEM service manual.
- Operate the engine and check for leaks.
- Stop the engine and check the coolant and lubricating oil levels.



Lubricating Oil Dipstick (007-009)

Calibrate

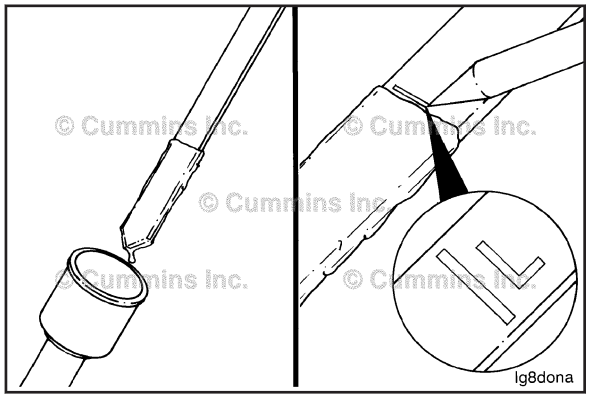
⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

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

Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.

Install the dipstick in the dipstick tube housing.

Use clean lubricating oil to fill the oil pan to the specified LOW oil level. Refer to Procedure 018-017 in Section V.



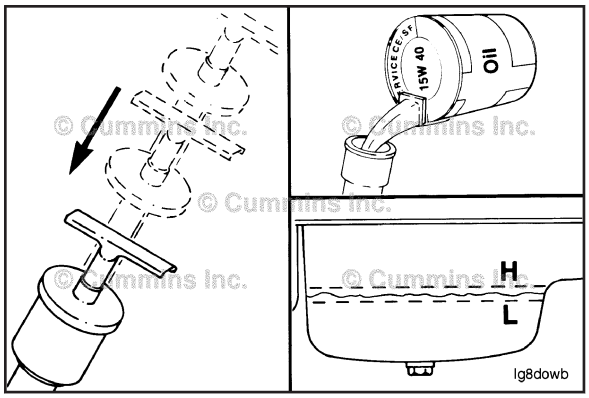
△CAUTION△
Use care when marking the dipstick. The dipstick will break if the scribe mark is too deep.

Remove the dipstick and scribe a mark across the stick at the oil level. Label the mark with an L to indicate the "LOW" oil level.

NOTE: If a new blank dipstick is being used, cut the dipstick off approximately 38 mm [1.5 in] below the LOW oil level mark.

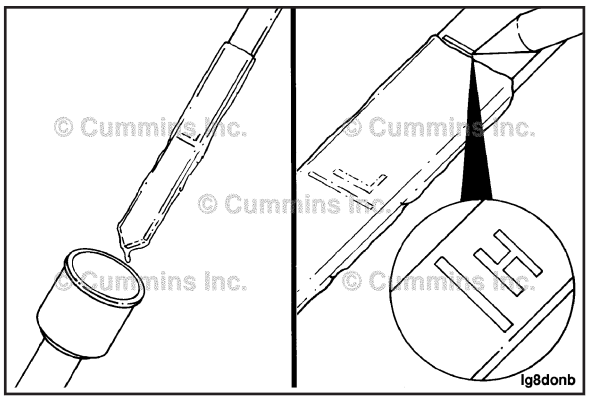
Wipe off the dipstick and install it in the dipstick tube housing.

Use clean lubricating oil to fill the oil pan to the specified HIGH oil level. Refer to Procedure 018-017 in Section V.



⚠CAUTION⚠
Use care when marking the dipstick. The dipstick will break if the scribe mark is too deep.

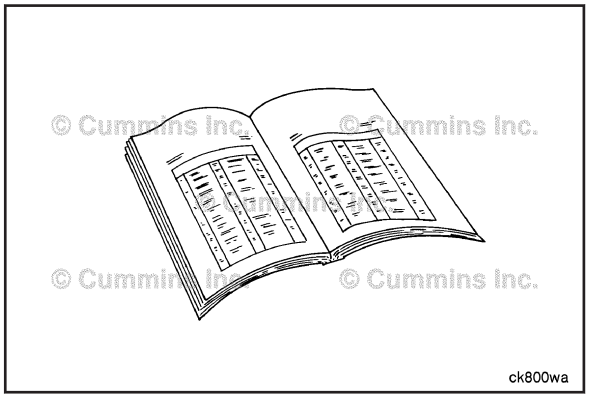
Remove the dipstick and scribe a mark across the stick at the oil level. Label the mark with an H to indicate the HIGH oil level.



Lubricating Oil Dipstick Tube (007-011)

Preparatory Steps

- Clean the area around the dipstick tube before removal to prevent debris from entering the oil system.

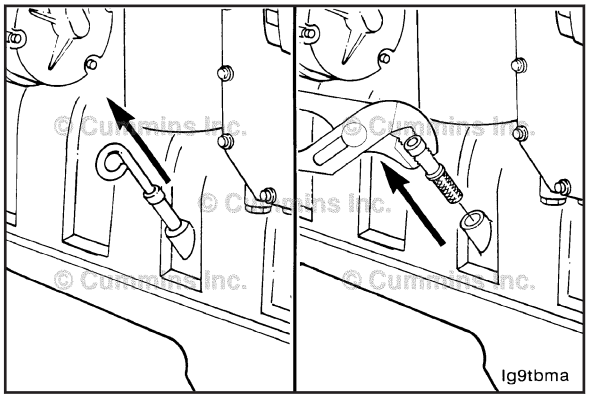


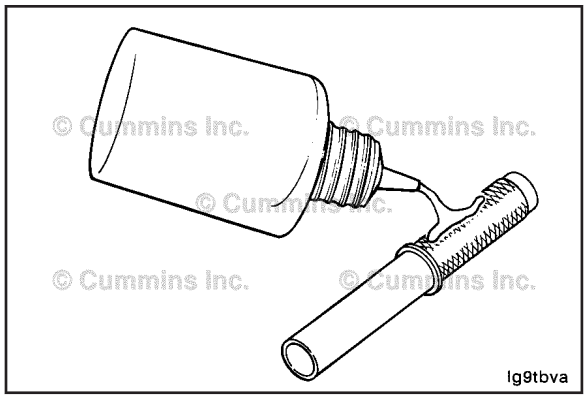
Remove

Remove the dipstick from the dipstick tube.

Remove the dipstick tube from the cylinder block.

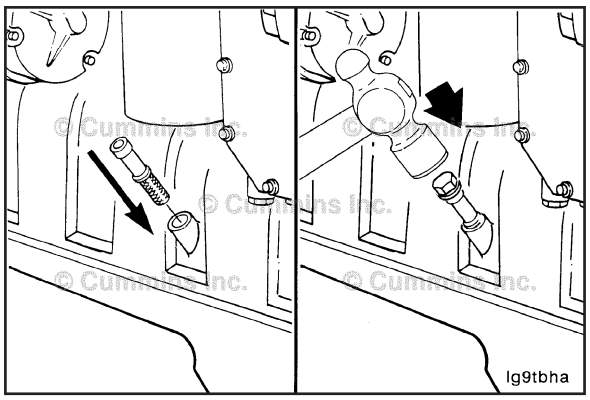
Service Tip: Use a dent puller and a M8 x 1.25 x 21-mm self-tapping capscrew. Thread the capscrew into the dipstick tube and remove the tube.





Install

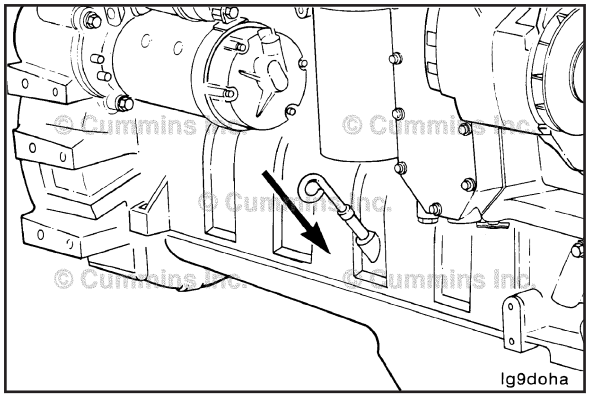
Apply a thin bead of sleeve retaining compound, Part Number 3823718 or equivalent, around the bottom of the knurled end of the tube.



Place the knurled end of the tube into the dipstick tube bore in the cylinder block.

Use a flat washer and hex head capscrew to drive the tube into the cylinder block.

Lightly drive the dipstick tube until it seats against the block casting.



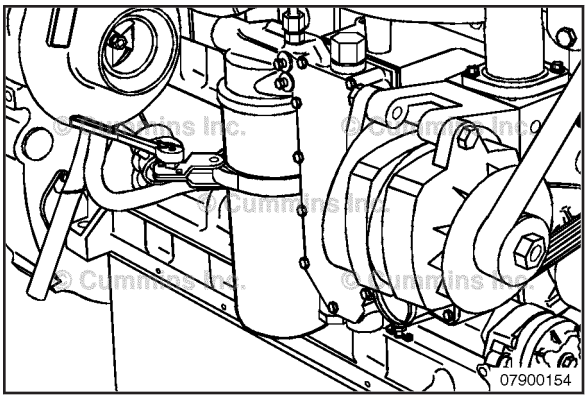
Install the dipstick into the dipstick tube.

Finishing Steps

- Operate the engine and check for leaks.

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

Measure



Remove the oil plugs from the lubricating oil cooler housing at the filter inlet and outlet pressure ports and install manual gauges.

The following parts, or equivalent, are available for use:

Part Number	Description
3377244	Compuchek™ fitting (1/8 inch 27 NPT)
3376920	Compuchek™ coupling (1/4 inch pipe thread)
3164491	Electronic pressure adapter for multimeter (1/4-NPT pipe)
3164488 or 3164489	Electronic digital multimeter

Engine Information	
Oil Filter Type	
Miles on Filter	
Oil Type	

Operate the engine at each rpm indicated and record the corresponding pressure values:

	Engine RPM	Oil Pressure Filter Inlet	Oil Filter Pressure Outlet	Inlet - Outlet = Differential Pressure	INSITE™ electronic service tool
Low Idle					
High Idle					

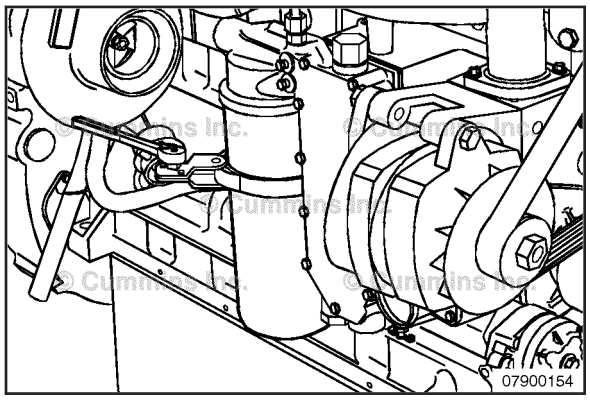
A pressure drop greater than 172 kPa [25 psi], at operating temperature using 15W-40 oil, indicates the filter is plugged.

Identify the causes of a plugged filter. Verify the Cummins Inc. maintenance guidelines are being met.

Use the following procedure to check for possible fluid contamination. Refer to Procedure 007-083 in Section 7.

Change both the lubricating oil and the lubricating oil filter, if the filter is plugged.

See the following bulletin for additional information about lubricating oil filter plugging. Refer to Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340.



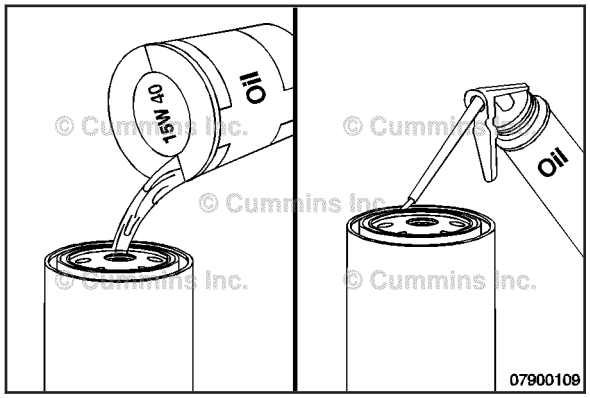
Remove

⚠CAUTION⚠
Use caution when replacing filters that oil is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The oil and oil filters must be discarded in accordance with local environmental regulations.

Clean the area around the lubricating oil filter head.

Use oil filter wrench, Part Number 3375049, to remove the lubricating oil filter.

Clean the gasket surface of the filter head with a clean lint-free cloth.



Install

⚠CAUTION⚠
The lubricating oil filter should be full of oil at start-up to prevent engine damage.

Use clean 15W-40 oil to coat the gasket surface of the filter.

Fill the filter with clean 15W-40 oil.

NOTE: Lubricating oil filters **must** have a filter bypass valve. Using a lubricating oil filter without a filter bypass valve will result in low engine oil pressure if the filter becomes plugged.

Lubricating oil filter recommendations are provided. Refer to Procedure 018-024 in Section V.

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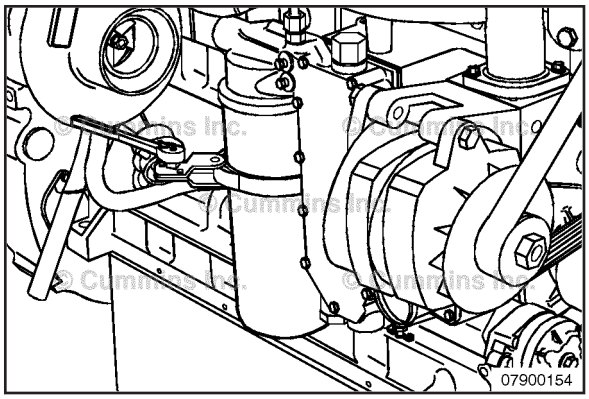
⚠CAUTION⚠

Mechanical overtightening of the filter can distort the threads or damage the filter element seal.

Install the filter on the oil filter head. Tighten the filter until the gasket contacts the filter head surface.

Use an oil filter wrench to tighten the filter. See the filter manufacturer's instructions supplied with the filter.

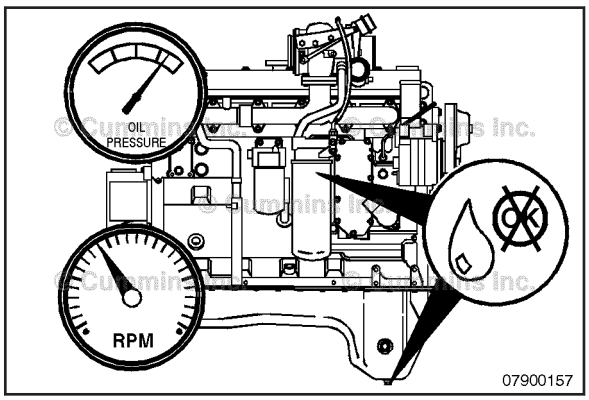


⚠CAUTION⚠

If no oil pressure is noted within 15 seconds after the engine is started, shut down the engine to reduce the possibility of internal engine damage.

NOTE: Confirm that the oil pan has the correct oil level.

Operate the engine and check for leaks.



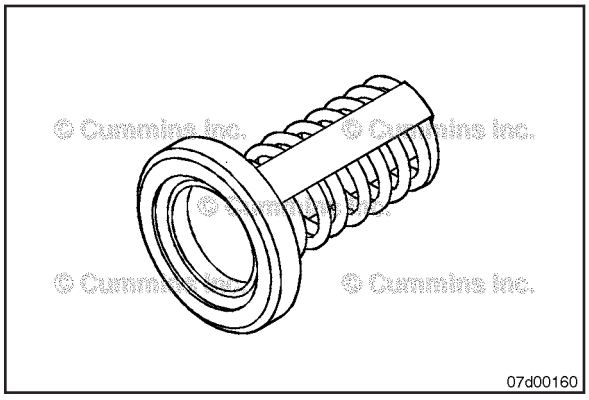
Lubricating Oil Filter Bypass Valve (007-014)

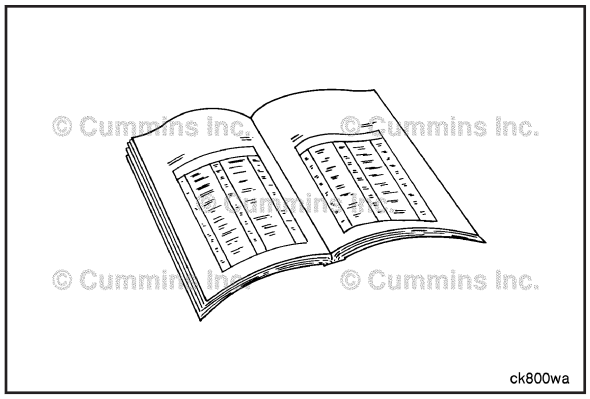
General Information

If the pressure drop across the lubricating oil filter exceeds a predetermined set point, the oil filter bypass valve opens and allows lubricating oil to bypass the lubricating oil filter.

This condition can occur during cold ambient (cold lubricating oil) engine start-ups.

The purpose of the bypass valve is to maintain lubricating oil flow to the engine and to prevent an oil filter collapse.





Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

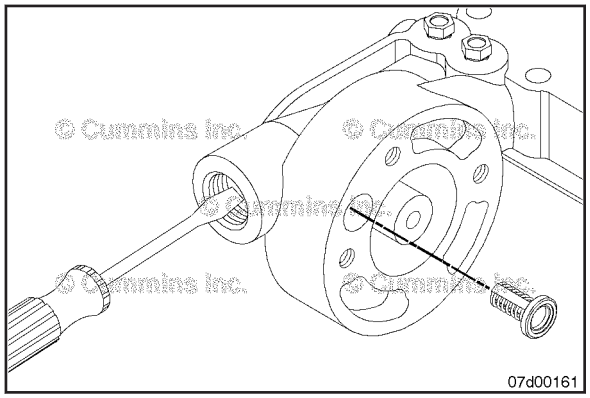
⚠WARNING⚠

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

⚠CAUTION⚠

Use caution when disconnecting or removing oil filters and that oil is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The oil and oil filters must be discarded in accordance with local environmental regulations.

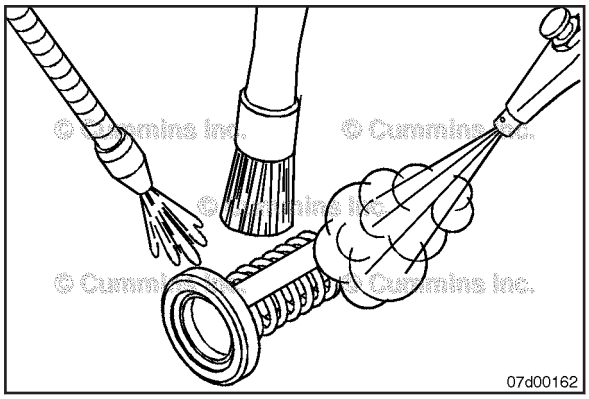
- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Remove the lubricating oil filter head. Refer to Procedure 007-015 in Section 7.
- Remove the 3/4-inch pipe plug from the end of the oil filter head.



Remove

Use a screwdriver to gently push down on the top of the bypass valve to remove it from the bore.

Clean and Inspect for Reuse



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

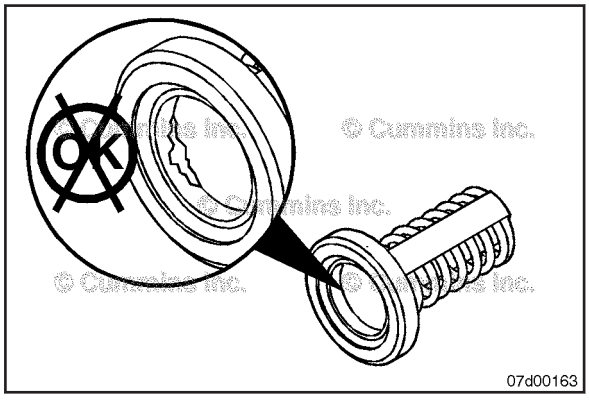
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the bypass valve with solvent.

Dry with compressed air.

Inspect the bypass valve seat for damage. Make sure the valve fully closes.



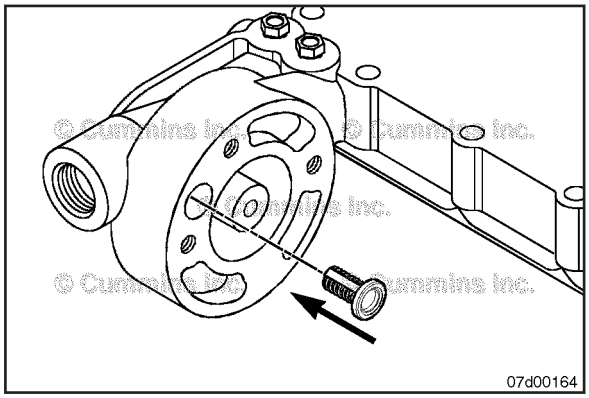
Install

Insert the bypass valve into the bore. The spring should be pointing upward into the bore.

Gently push the bypass valve into the bore until it seats.

Install the 3/4-inch pipe plug into the end of the oil filter head.

Torque Value: 45 N•m [33 ft-lb]



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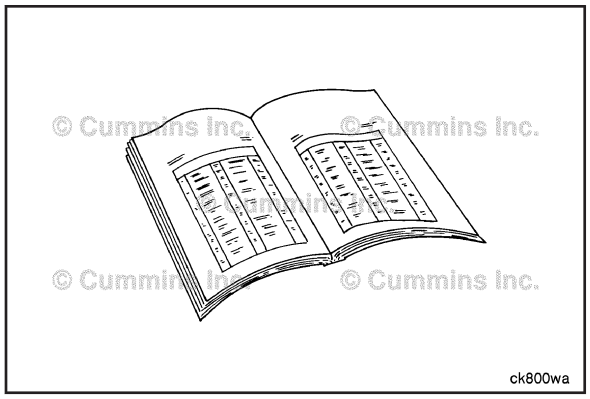

Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the lubricating oil filter head. Refer to Procedure 007-015 in Section 7.
- Install the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

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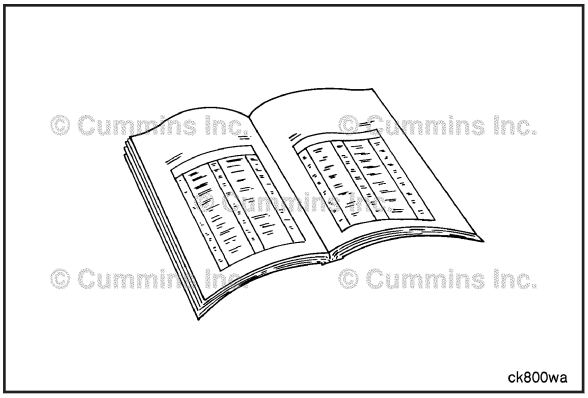
Lubricating Oil Filter Head (007-015)

Preparatory Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

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

△CAUTION△
Use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

△CAUTION△
Use caution when draining oil or replacing filters that oil is not spilled or drained into the bilge area. The oil and oil filters must be discarded in accordance with local environmental regulations.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Remove the lubricating oil cooler. Refer to Procedure 007-003 in Section 7.

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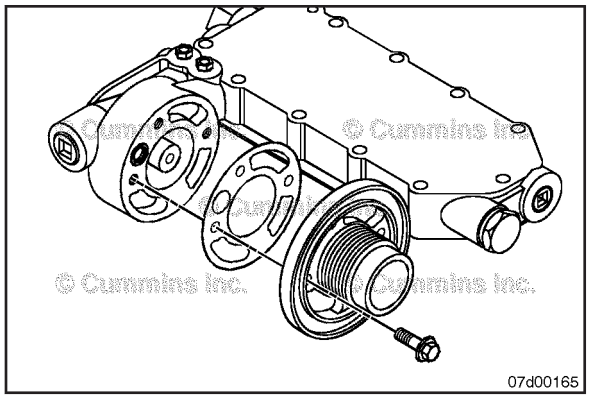
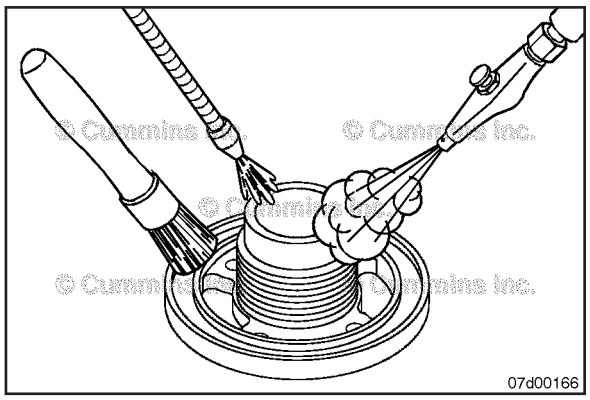


Remove

Remove the lubricating oil filter head adapter capscrews, filter head adapter, and gasket.

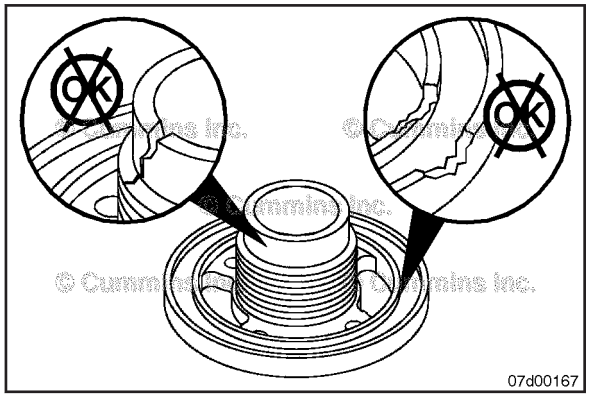


Clean and Inspect for Reuse

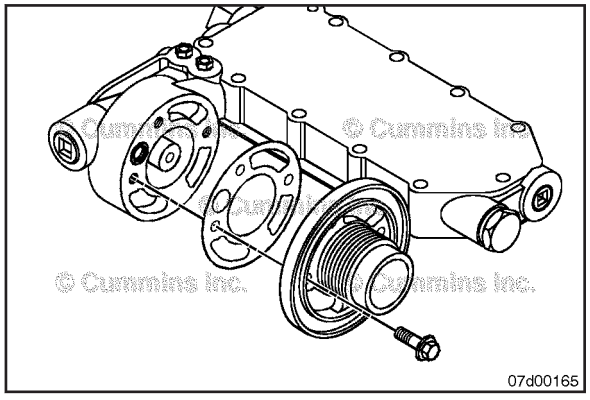
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Use solvent to clean the filter head adapter.



Inspect the filter head adapter for cracks and other damage.

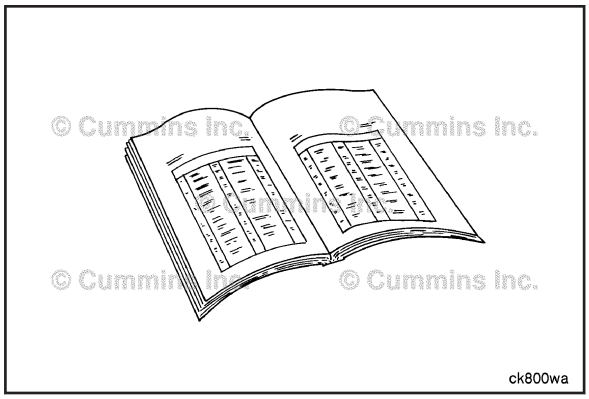


Install

Install the gasket, lubricating oil filter head adapter, and capscrews.

Torque Value: 24 N•m [212 in-lb]

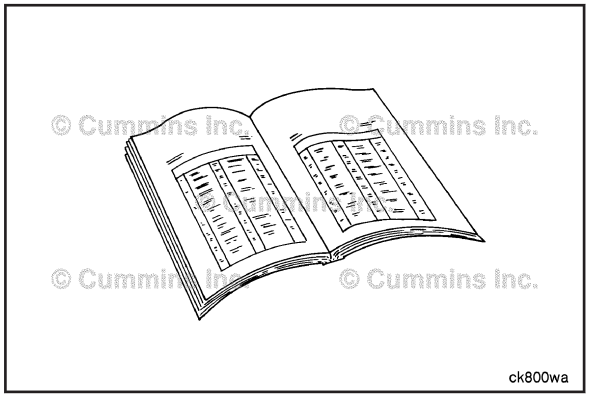
Finishing Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the lubricating oil cooler. Refer to Procedure 007-003 in Section 7.
- Install the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

Lubricating Oil Filter Head (Remote-Mounted) (007-017)



Preparatory Steps

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

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

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

△CAUTION△
Use caution when draining oil or replacing filters that oil is not spilled or drained into the bilge area. The oil and oil filters must be discarded in accordance with local environmental regulations.

- Disconnect the battery. Refer to Procedure 013-009.
- Remove the lubricating oil filter. Refer to Procedure 007-013.
- Disconnect the lubricating oil lines to the filter head. Refer to Procedure 007-092.

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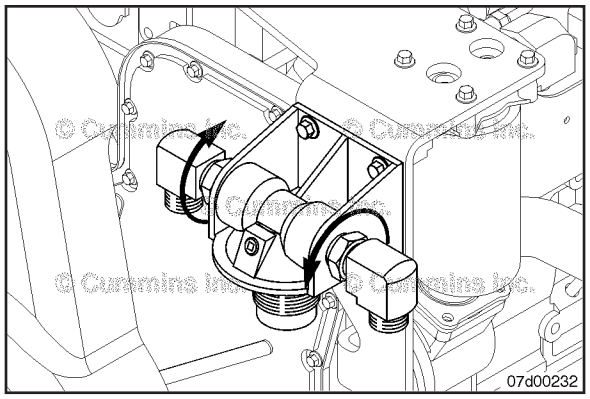
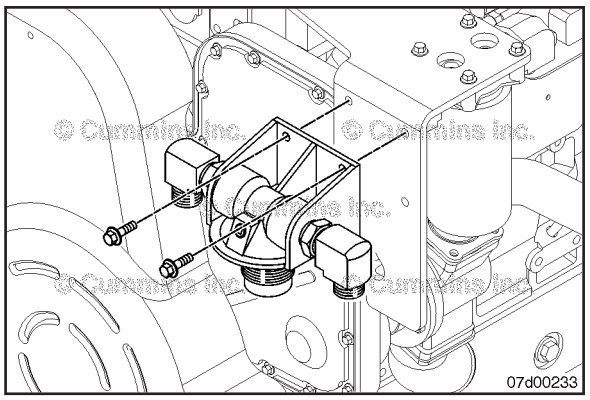
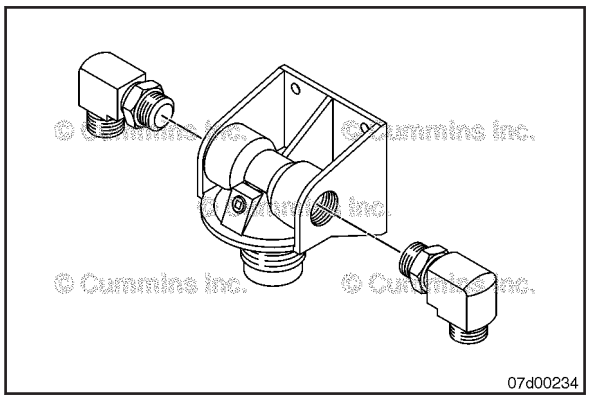


Remove

Loosen, but do **not** remove, the inlet and outlet lubricating oil filter head face seal connection locknuts.



Remove the four mounting capscrews and the lubricating oil filter head.

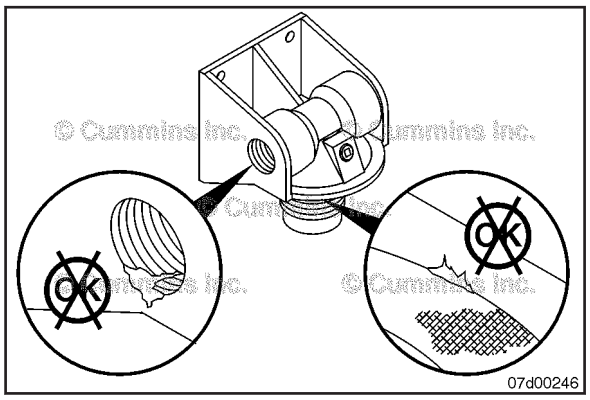


Disassemble

⚠CAUTION⚠
To prevent the possibility of high filter restriction after installation and causing filter damage, be sure to mark the lubricating lines, oil filter head inlet and outlet ports. Failure to do so can cause the center filter media to break up and be pumped through the engine.

Label the filter head connectors to identify the lubricating oil connections and fitting orientation.

Remove the fittings from the lubricating oil filter head.



Inspect for Reuse

Inspect the lubricating oil filter head sealing surfaces and bypass, if equipped.

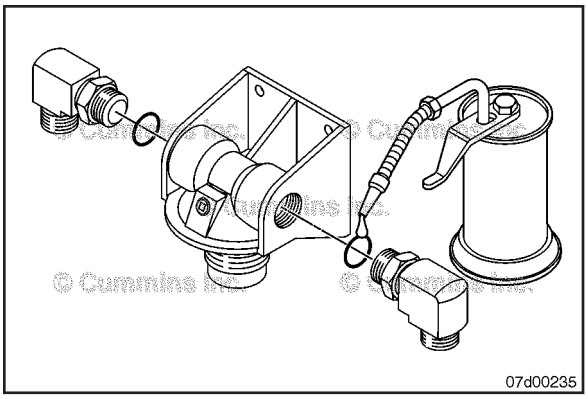
Assemble

Replace the compression o-ring seals and o-rings on all face sealing connections.

Lubricate o-ring with clean engine oil.

Install the inlet and outlet connections into the filter heads. Be sure the lubricating oil connections are orientated correctly and they are installed to their proper depth.

Do **not** torque or tighten the fitting locknuts at this time.

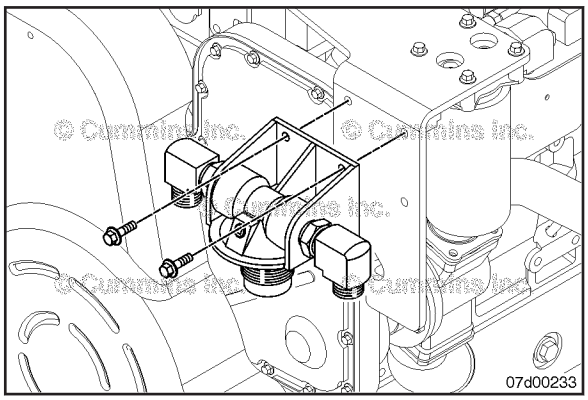


Install

⚠CAUTION⚠
To prevent the possibility of high filter restriction after installation and causing filter damage, be sure the lubricating lines, oil filter head inlet and outlet ports are orientated correctly to the bracket prior to installation. Failure to do so can cause the center filter media to break up and be pumped through the engine.

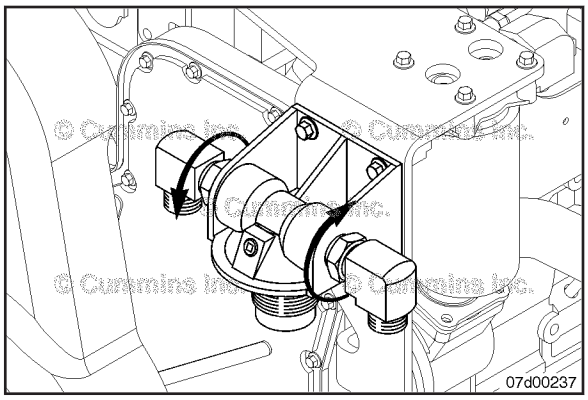
Install the filter head assembly to the bracket and tighten the capscrews.

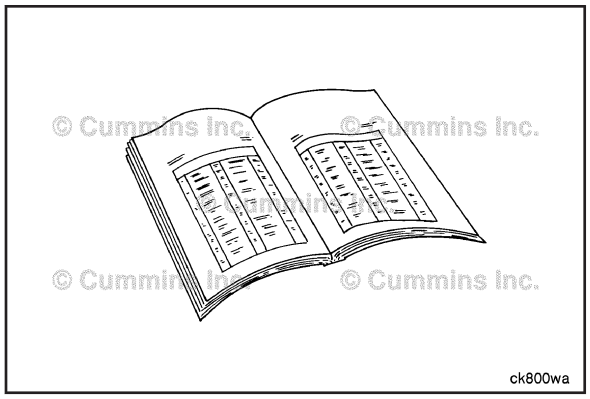
Torque Value: 24 N•m [18 ft-lb]



Tighten the lubricating oil filter inlet and outlet connection locking nuts.

Torque Value: 100 N•m [74 ft-lb]

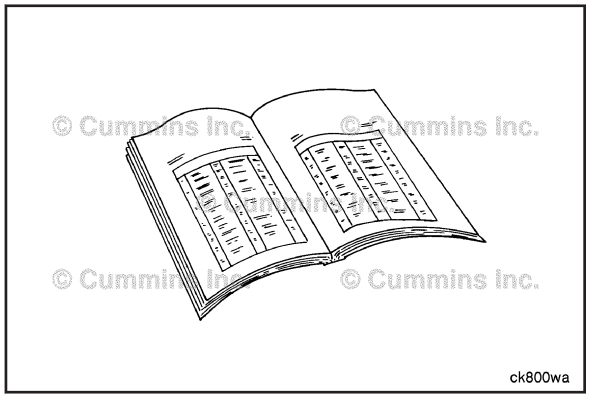




Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the lubricating oil filter flex hoses to the face seal connection and tighten the tube nuts finger tight. Be sure the o-rings are in place and properly located.
- Tighten the lubricating oil supply and return lines. Refer to Procedure 007-092.
- Install a new lubricating oil filter. Refer to Procedure 007-013.
- Connect the battery. Refer to Procedure 013-009.
- Operate the engine and check for leaks and proper oil pressure.
- Check the lubricating oil level.



Lubricating Oil Filter Head Adapter (007-018)

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.

⚠CAUTION⚠
Use caution when disconnecting or removing lubricating oil lines and replacing filters that oil is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The oil and oil filters must be discarded in accordance with local environmental regulations.

NOTE: The face seal washers can fall when removing the oil lines. Use care not to damage or lose the washers.

- Clean the area around the lubricating oil cooler cover.
- Tag for location and remove the lubricating oil lines for the oil filter. Refer to Procedure 007-092.

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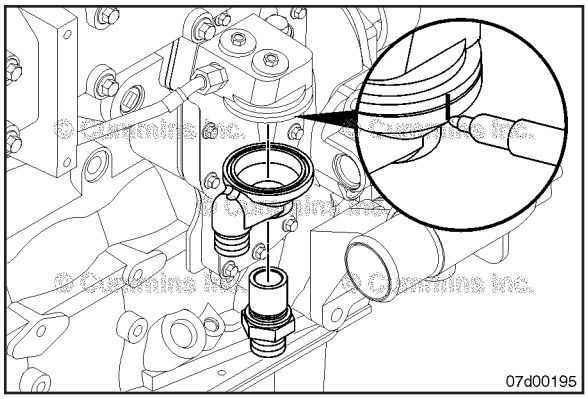
Remove

Make a mark on the lubricating oil cooler housing filter head adapter and the lubricating oil cooler housing to align the filter head adapter during installation.

Remove the lubricating oil filter head adapter by removing the center hose connection.



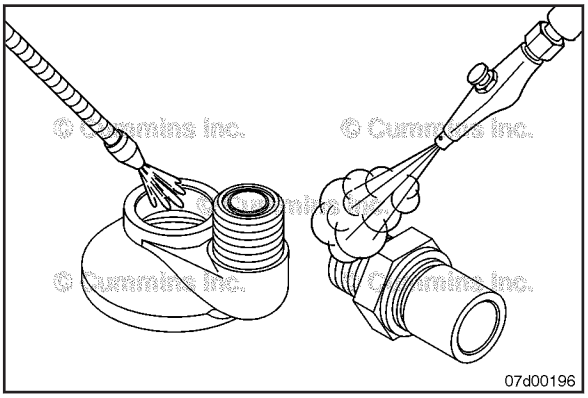
Clean and Inspect for Reuse

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

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

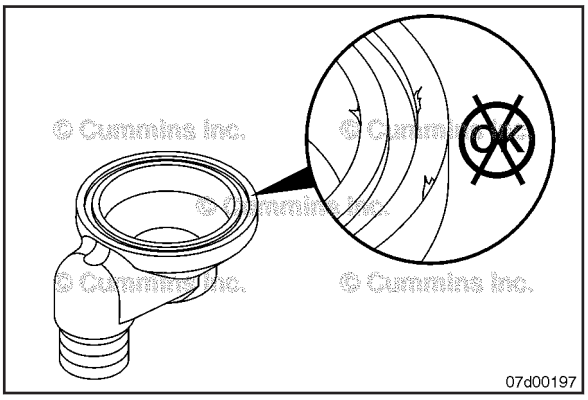
Use solvent to clean the parts.

Dry with compressed air.



Inspect the sealing surfaces for signs of leakage or burrs.

Use a fine crocus cloth to remove burrs.



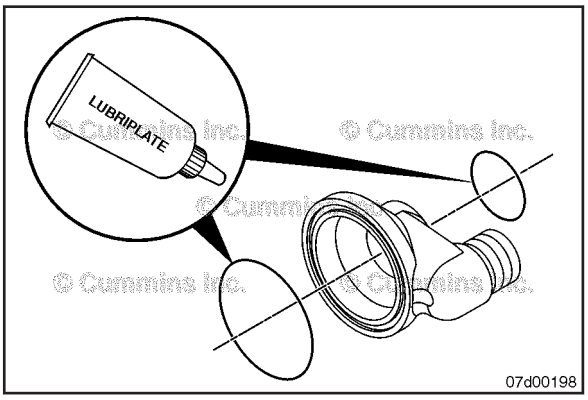
Install

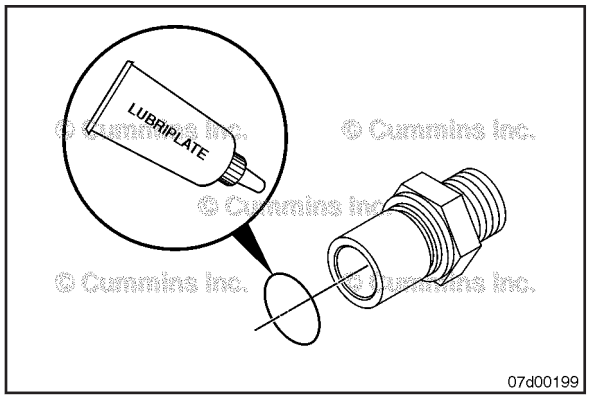
NOTE: Use new o-rings and seal rings when installing the filter head adapter.

Install a new o-ring in the groove on the underside of the filter head cover.

Install a small o-ring in the groove on the other side of the filter head cover.

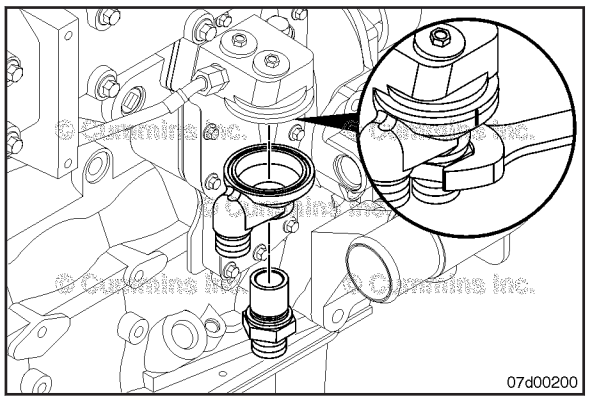
Lubricate the o-rings with clean 15W-40 engine oil or Lubriplate™ multi-purpose lubricant.





Install a new o-ring in the groove of the center hose connector.

Lubricate the o-rings with clean 15W-40 engine oil or Lubriplate™ multi-purpose lubricant.

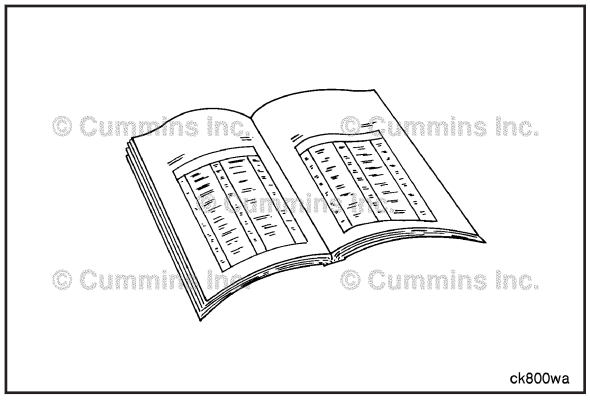


Install the outer hose connector, on the oil filter adapter, to the rear of the engine and align the marks made before removal.

Push the center connector through the adapter and install the filter head adapter to the engine.

Tighten the center connector while keeping the markings made before the removal step aligned.

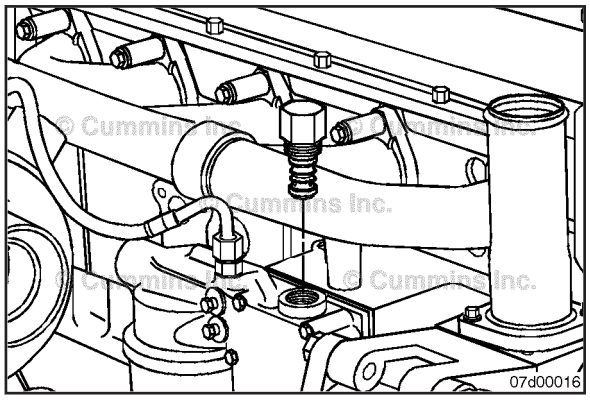
Torque Value: 100 N•m [74 ft-lb]



Finishing Steps

Install the lubricating oil lines for the oil filter. Refer to Procedure 007-092.

Operate the engine and check for leaks.



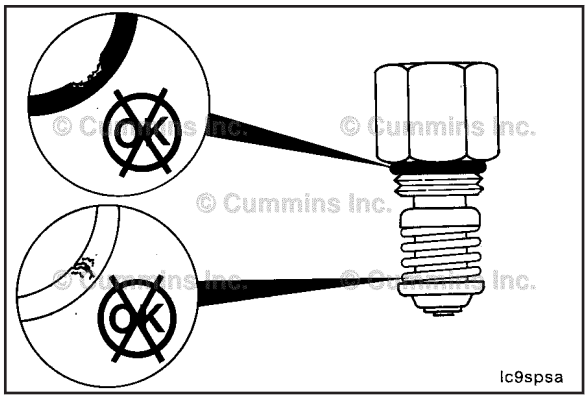
Lubricating Oil High Pressure Relief Valve (007-021)

Remove

Remove the oil cooler bypass valve.

Inspect for Reuse

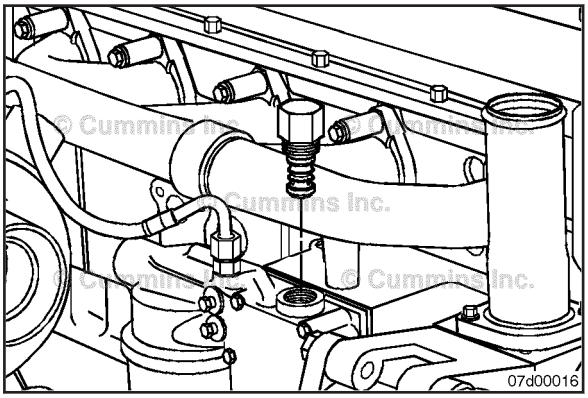
Inspect for a damaged o-ring, broken spring or other damage.



Install

Install the oil cooler bypass valve.

Torque Value: 50 N•m [37 ft-lb]



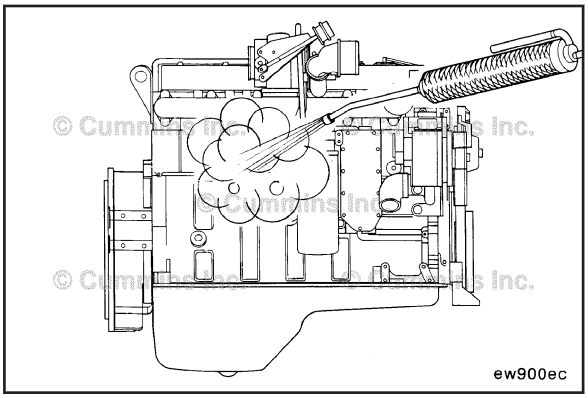
Lubricating Oil Leaks (007-024)

Initial Check

External

⚠WARNING⚠
Wear safety glasses or a face shield, as well as protective clothing, to prevent personal injury when using a steam cleaner or high-pressure water.

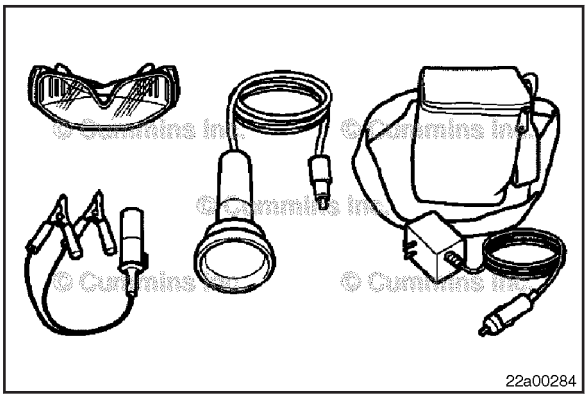
Use a steam cleaner or high-pressure washer to clean the engine.

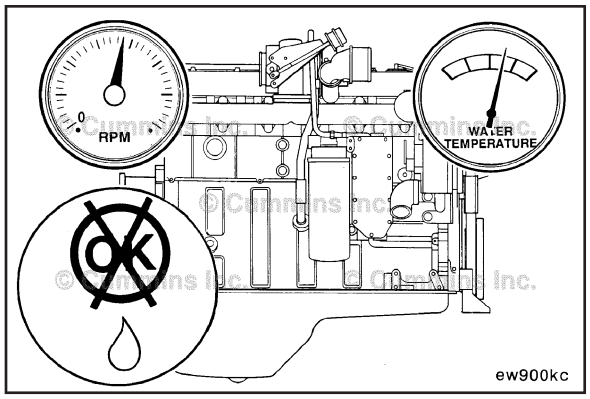


Add fluorescent tracer, Part Number 3376891, before running the engine.

Use black light kit, Part Number 3163338, to help identify the source of an oil leak.

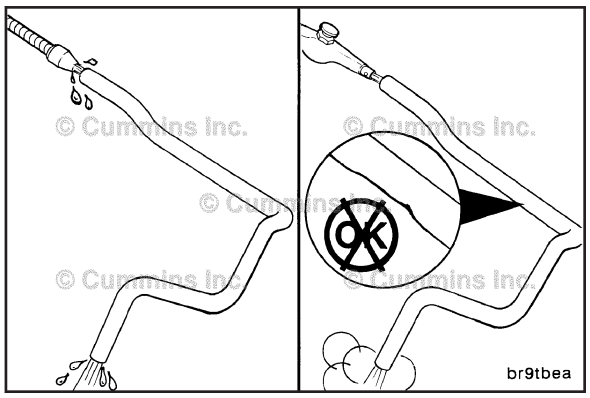
The tracer will be highlighted by the black light to help identify the source of the oil leak.



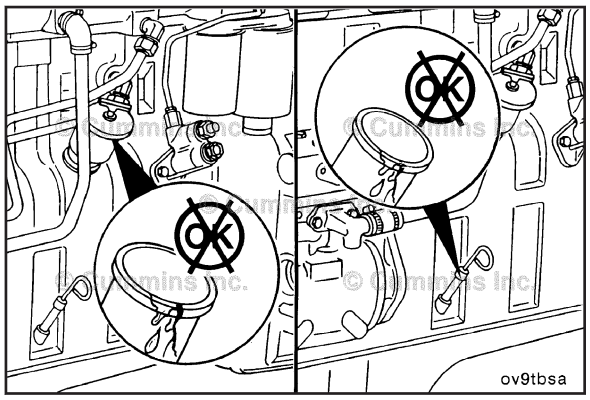


Operate the engine until the coolant temperature reaches 82°C [180°F]. If necessary, run the engine under load to create the conditions of the oil leak. Perform stall tests or a road test. Inspect the exterior of the engine for leaking gaskets, seals, o-rings, pipe plugs, or fittings.

NOTE: Before replacing any gaskets, check the capscrews to make sure they are tightened to the correct torque values.



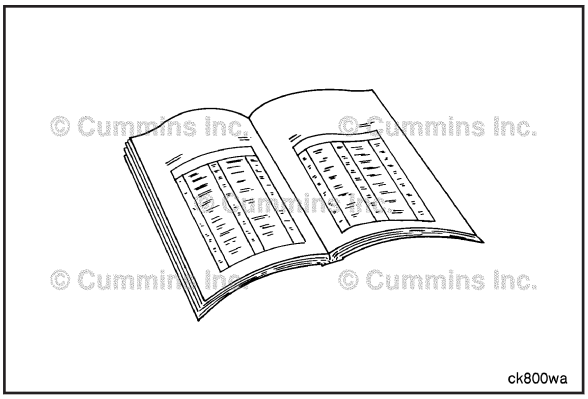
Inspect the engine crankcase breather tube and hose for restriction or leaks. Refer to Procedure 003-018 in Section 3.



Check for a loose or missing oil dipstick tube, dipstick, or oil fill cap.

Lubricating Oil Pan (007-025)

Preparatory Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

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

△CAUTION△
Use caution when draining oil or replacing filters that oil is not spilled or drained into the bilge area. The oil and oil filters must be discarded in accordance with local environmental regulations.

NOTE: The engines use a variety of combinations of gaskets and/or RTV for sealing. When installing the oil pan, use the correct combinations of gaskets and/or RTV that were on the pan.

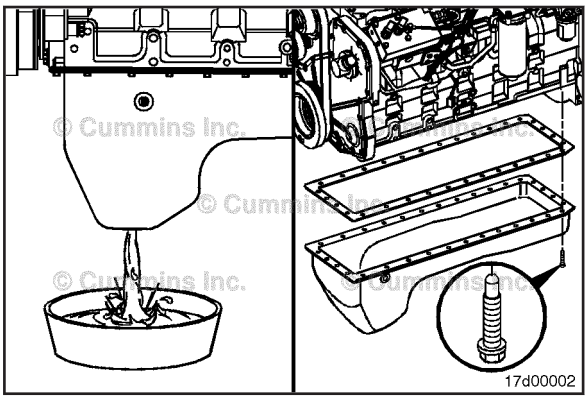
- Disconnect the batteries. See equipment manufacturer service information.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.

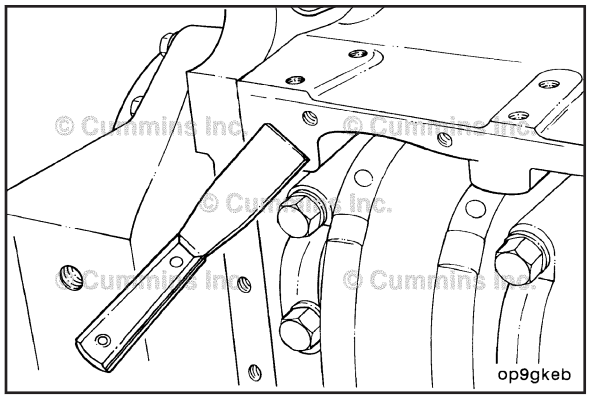
Remove

Remove the lubricating oil pan and gasket/RTV.

Remove the suction tube, if necessary. Refer to Procedure 007-035 in Section 7.

Remove the block stiffener plate. Reference Procedure 001-089 in Section 1, if equipped.





Clean and Inspect for Reuse

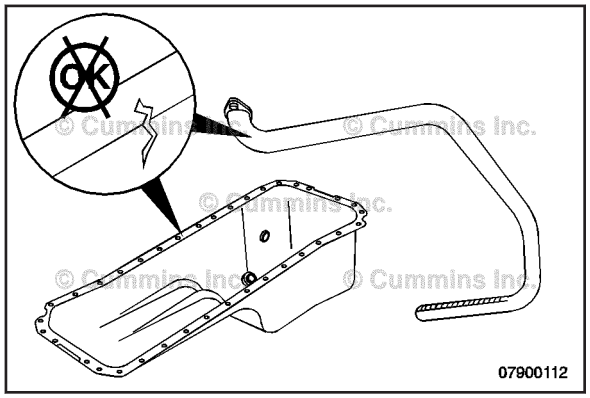
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Remove all gasket material from the cylinder block and lubricating oil pan surface.

Steam clean the lubricating oil pan.

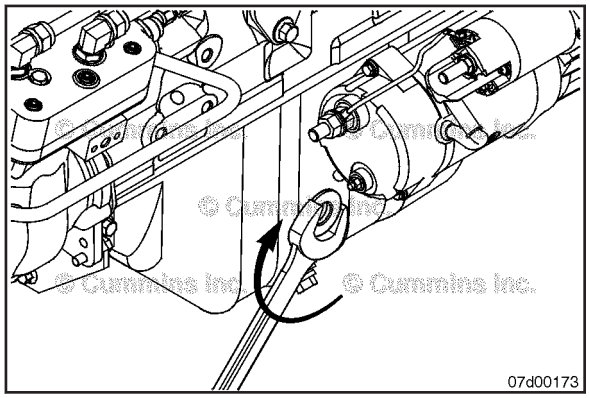
Dry with compressed air.



Inspect the oil pan, suction tube, and tube braces for cracks or other damage.

NOTE: If cracks or other damage is found, replace the damaged part. Do **not** attempt to repair the oil pan by welding.

Use the following procedure if the suction tube **must** be replaced. Refer to Procedure 007-035 in Section 7.



Composite Oil Pan **Only**

Make sure the bulkhead fitting is tight. If it is found to be loose, replace the o-ring and tighten the bulkhead.

Torque Value: 24 N•m [212 in-lb]

Install

NOTE: The engines use a variety of combinations of gaskets and/or RTV for sealing. When installing the oil pan, use the correct combinations of gasket and/or RTV that were on the pan.

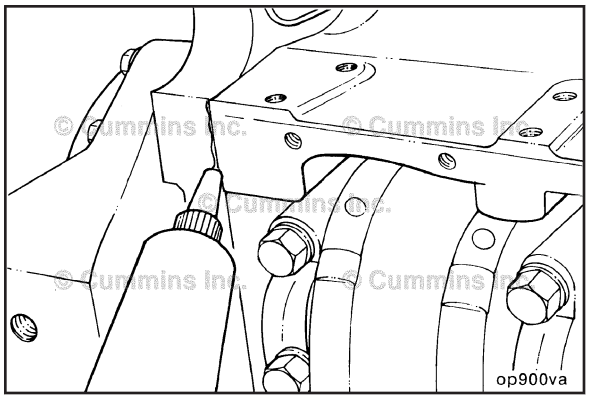
NOTE: To achieve a proper seal, never use an old gasket.

Use RTV sealant, Part Number 3164067, or equivalent, to fill the joints between the lubricating oil pan rail, gear housing, and rear seal housing.

NOTE: Install three guide pins, Part Number 3164977, to improve the alignment of the oil pan sealing components to the cylinder block.

Install the suction tube, if applicable. Refer to Procedure 007-035 in Section 7.

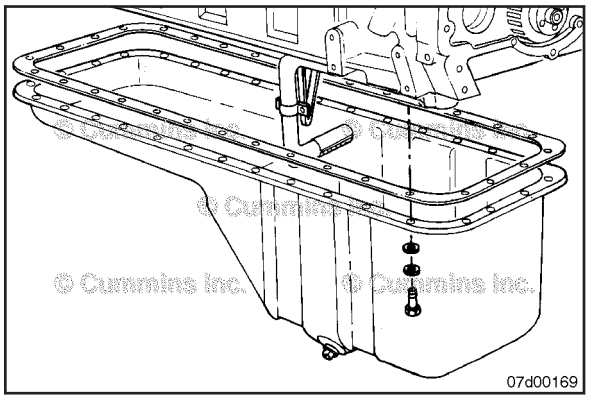
Install the block stiffener plate. Reference Procedure 001-089 in Section 1, if equipped.



Install the gasket and lubricating oil pan.

Install the oil pan corner braces, if equipped.

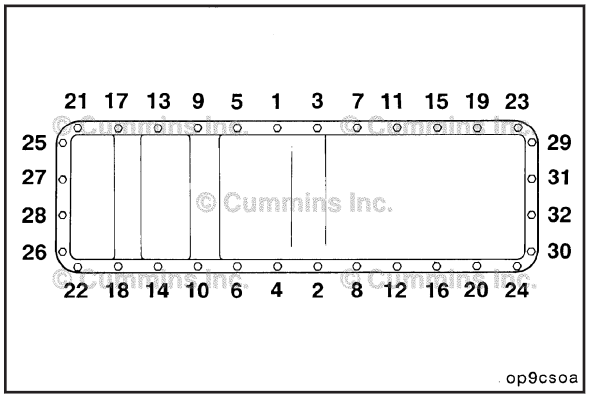
NOTE: New noise isolators **must** be used with oil pans having the isolated gasket system.

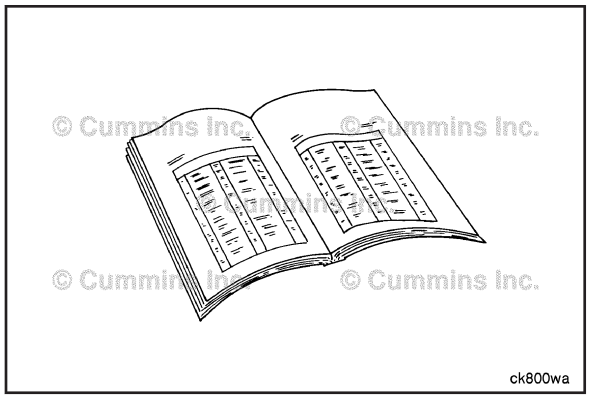


Assemble the washers and capscrews to secure the lubricating oil pan as illustrated.

Tighten all capscrews in the sequence shown in the accompanying chart.

Torque Value: 28 N•m [248 in-lb]

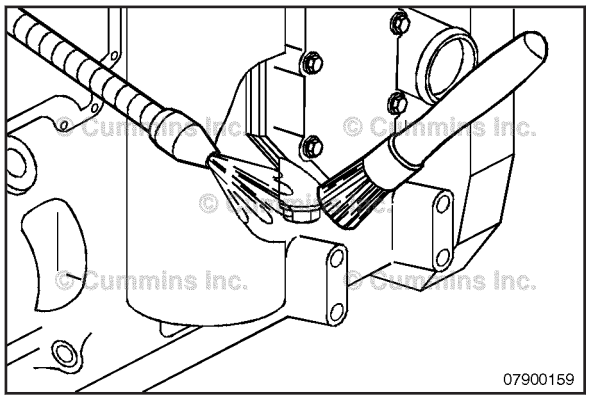




Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Fill the 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.



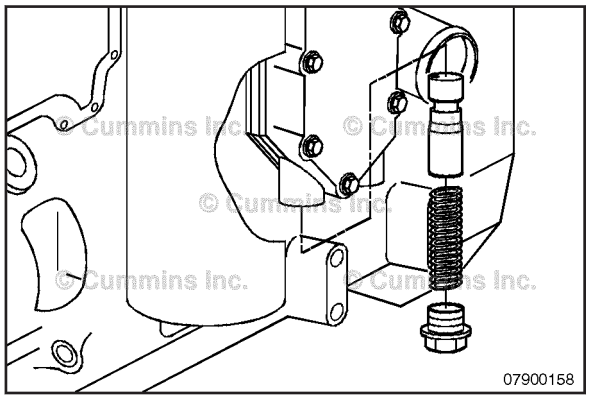
Lubricating Oil Pressure Regulator (Main Rifle) (007-029)

Remove

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

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

Thoroughly clean the area around the pressure regulator plug with clean solvent to prevent debris from falling into the plunger bore when the plug is removed.



Remove the threaded plug, spring, and plunger.

Service Tip: The plunger normally can be removed by inserting one finger into the plunger bore until snug and pulling down. If the plunger can **not** be removed in this manner, the plunger is probably stuck and will require removal of the housing for cleaning the plunger.

Clean and Inspect for Reuse

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

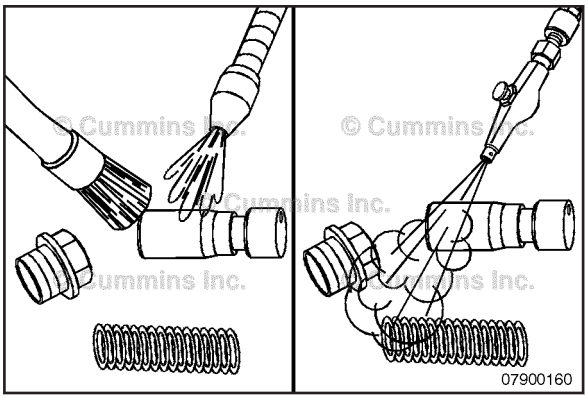
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

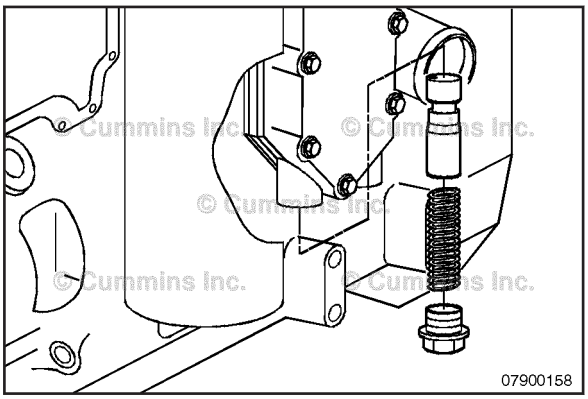
NOTE: If the plunger bore requires cleaning, remove the housing to avoid flushing debris into the engine.

Thoroughly clean all components with clean solvent.

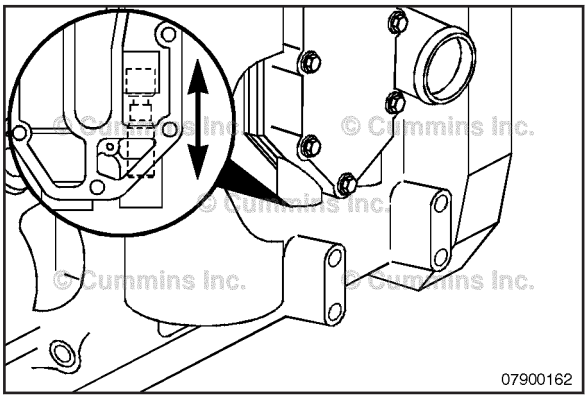
Dry with compressed air.

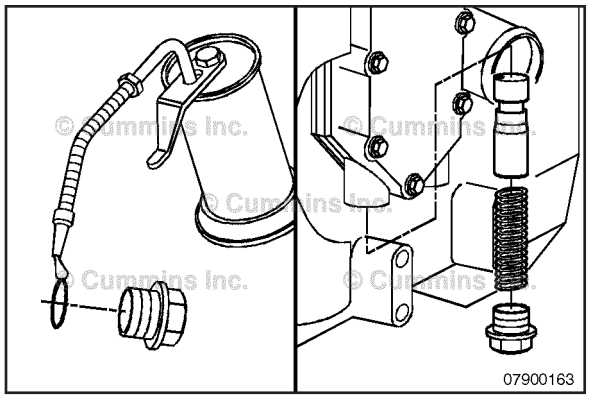


Inspect the plunger and plunger bore. Polished areas on the plunger and bore are acceptable.



Verify that the plunger moves freely in the bore.

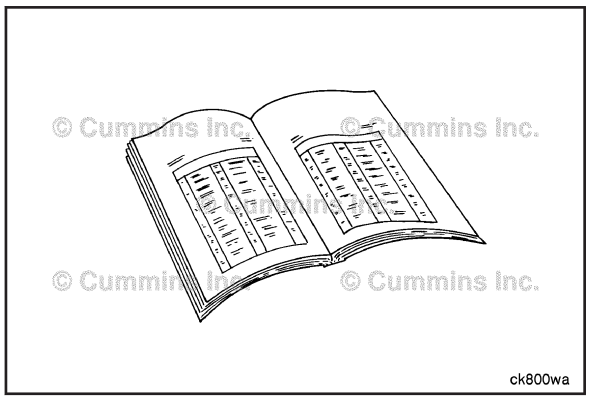




Install

Install a new sealing o-ring on the threaded plug and lubricate with clean engine oil. Install the pressure regulator assembly.

Torque Value: 80 N•m [59 ft-lb]

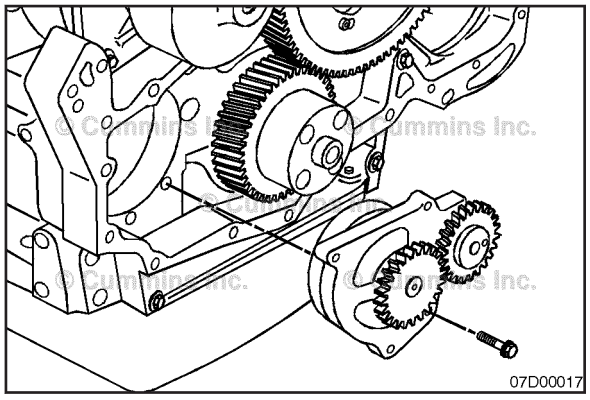


Lubricating Oil Pump (007-031)

Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the 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.
- On Marine engines, remove the belt tensioner. Refer to Procedure 008-080 in Section 8.
- Remove the rubber vibration damper, if installed. Refer to Procedure 001-051 if installed, in Section 1.
- Remove the viscous vibration damper, if installed. Refer to Procedure 001-052 if installed, in Section 1.
- Remove the front cover. Refer to Procedure 001-031 in Section 1.



Remove

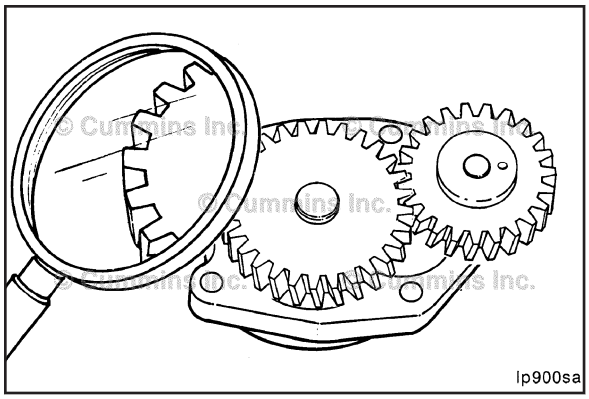
Remove the four mounting capscrews.

Remove the lubricating oil pump from the bore in the cylinder block.

Disassemble

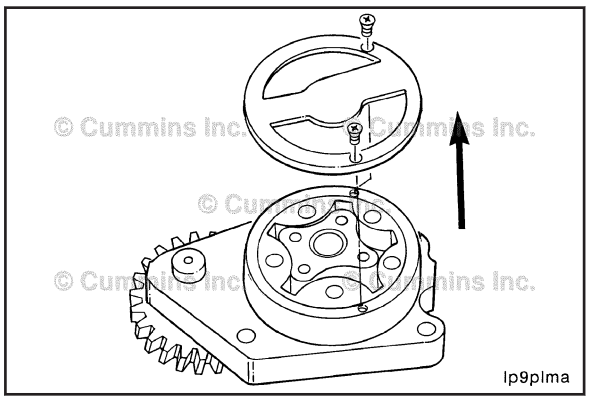
If the lubricating oil pump is to be inspected for reuse, follow these steps.

Inspect the lubricating oil pump gears for chips, cracks, or excessive wear.

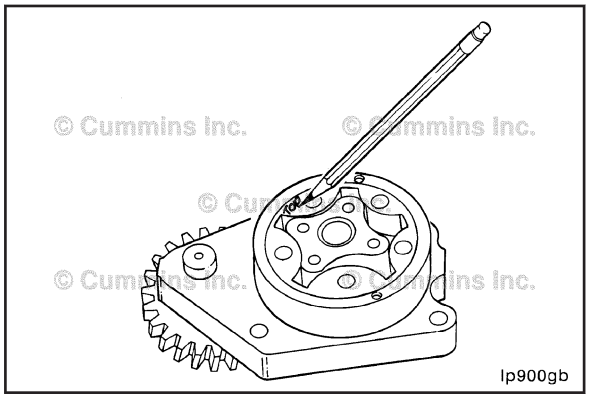


Remove the back plate.

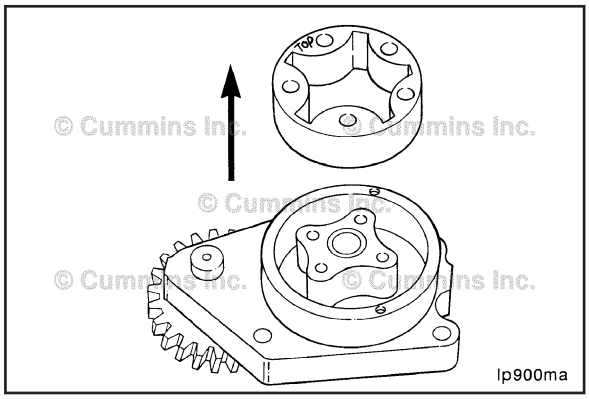
NOTE: The ISC, QSC8.3, ISL, and QSL9 lubricating oil pump uses a large diameter 5/6 rotor set. The graphics in this manual illustrate a 4/5 rotor set.

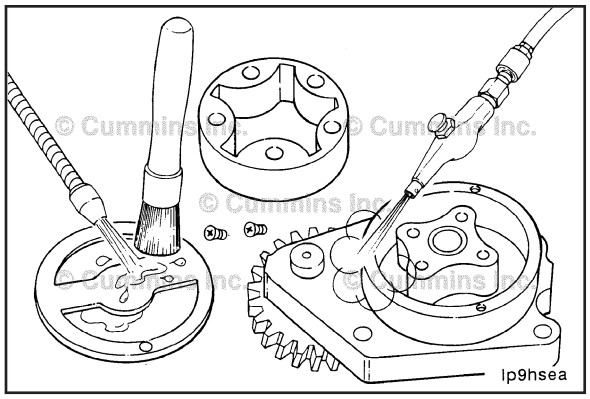


Mark TOP on the gerotor planetary.



Remove the gerotor planetary.





Clean and Inspect for Reuse

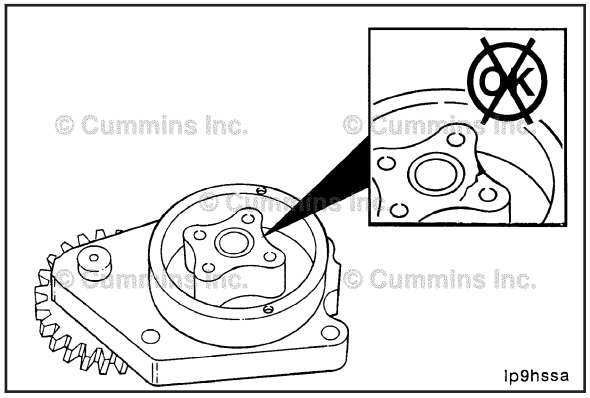
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

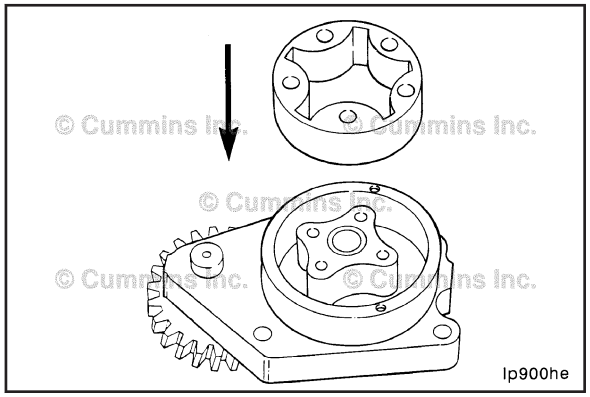
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean all parts in solvent.

Dry with compressed air.



Inspect the lubricating oil pump housing, gerotor drive, and gerotor for damage and excessive wear.



Measure

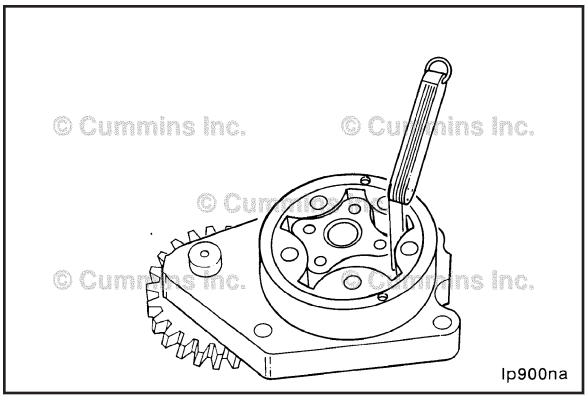
△CAUTION△
Make sure that the gerotor planetary is installed in the original position.

Install the gerotor planetary.

Measure the tip clearance.

Tip Clearance		
mm		**in**
0.0254	MIN	0.001
0.1778	MAX	0.007

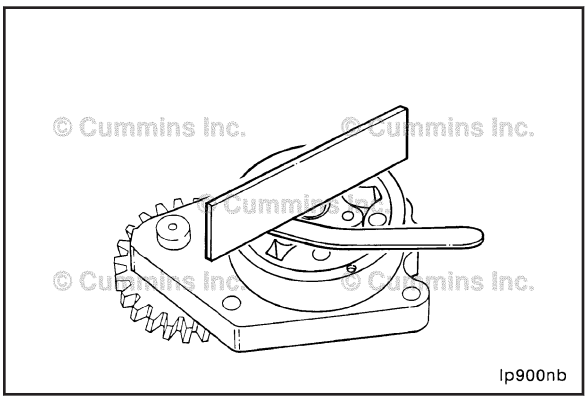
Replace the lubricating oil pump if the tip clearance is out of specification.



Measure the clearance of the gerotor drive/gerotor planetary to port plate.

Gerotor Drive/Gerotor Planetary to Port Plate Clearance		
mm		**in**
0.0254	MIN	0.001
0.1270	MAX	0.005

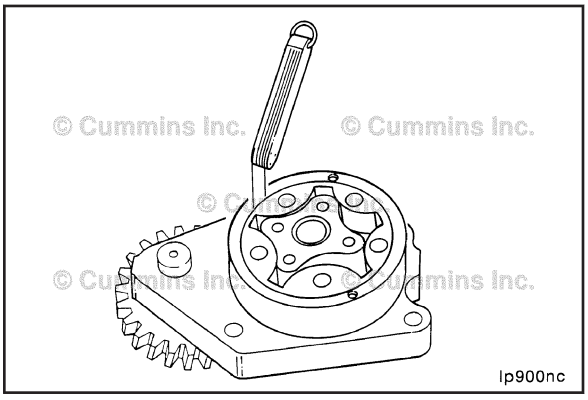
Replace the lubricating oil pump if the geroter drive/ geroter planetary to port plate clearance is out of specification.



Measure the clearance of the gerotor planetary to the body bore.

Gerotor Planetary to Body Bore Clearance		
mm		**in**
0.1778	MIN	0.007
0.3810	MAX	0.015

Replace the lubricating oil pump if the geroter planetary to body bore clearance is out of specification.

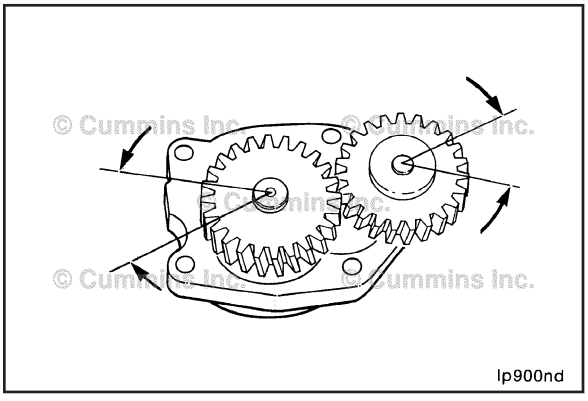


Measure the backlash.

Lubricating Oil Pump Gears Backlash Limits (Used Pump)		
mm		**in**
0.0762	MIN	0.003
0.3302	MAX	0.013

NOTE: Hold the adjoining gears to keep them from moving when checking backlash or else the reading will be the total of both gears.

Replace the lubricating oil pump if the gear backlash is out of specification.



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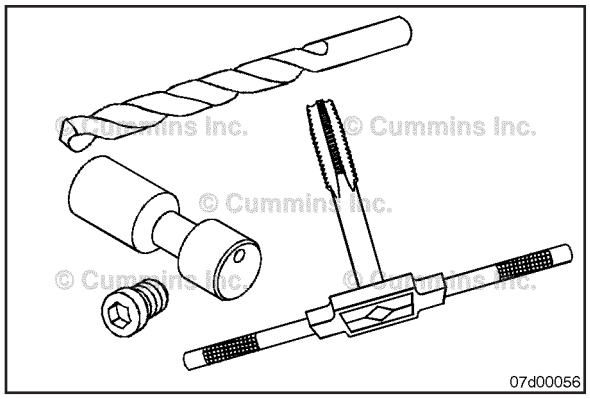


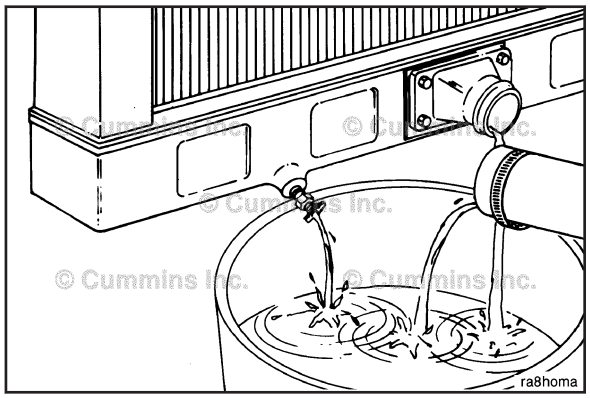
Modify

If a customer reports high oil pressure on an ISC engine with an engine serial number (ESN) less than 45803926, follow the instructions outlined below. If a customer reports high oil pressure on an ISC engine with an ESN greater than 45803925, see the following symptom tree t104 (Lubricating Oil Pressure High) to locate the source of the high lubricating oil pressure in the Troubleshooting and Repair Manual, ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 Engines, Bulletin 4021418.

Instructions to modify the ISC Engine from Dump-to-Pump to Dump-to-Sump.

Required materials:

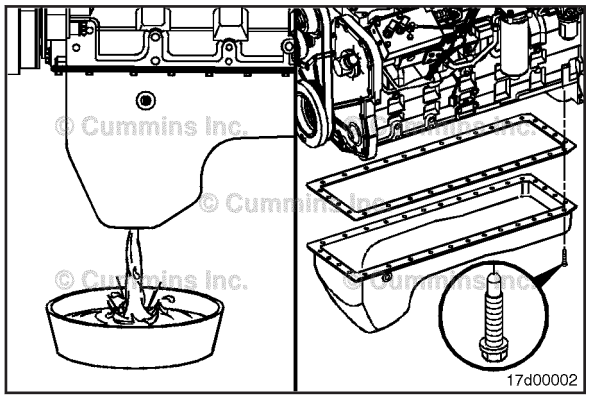
- New pressure regulator plunger
- Long 13 mm [1/2-in] drill bit (preferably 203 mm [8 in])
- Loctite™ Blue, or equivalent (**not** shown)
- 9/16-inch x 18 tap
- 9/16-inch x 18 STOR plug
- Tap Magic or other cutting fluid (**not** shown).



⚠WARNING⚠
Coolant Is toxic. Keep away from pets and children. If not reused, dispose of In accordance with local environmental regulations.

⚠WARNING⚠
Wait until the temperature is below 49°C [120°F] to avoid personal injury from hot coolant.

Drain the coolant. Refer to Procedure 008-018 in Section 8.



⚠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 and then remove the lubricating oil pan and gasket. Refer to Procedure 007-037 and Refer to Procedure 007-025 in Section 7.

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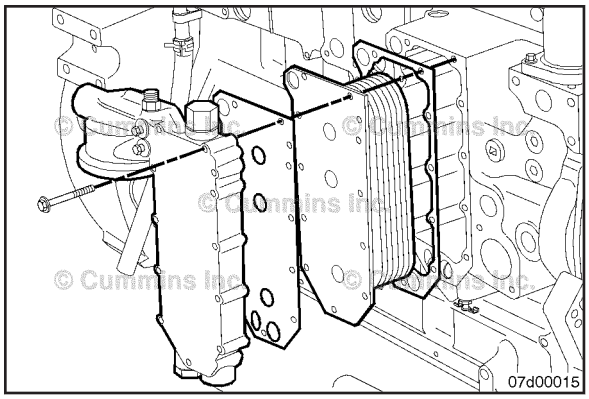
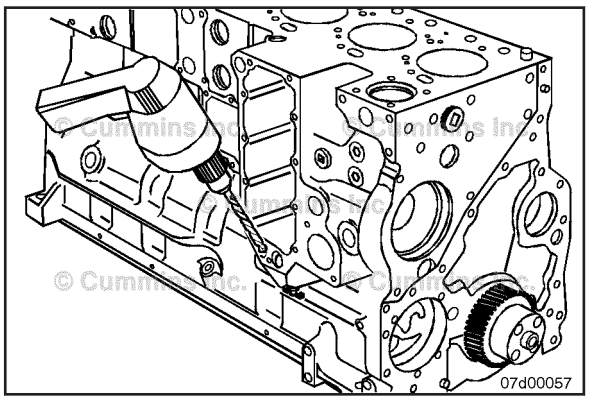
Remove the lubricating oil cooler. Refer to Procedure 007-003 in Section 7.

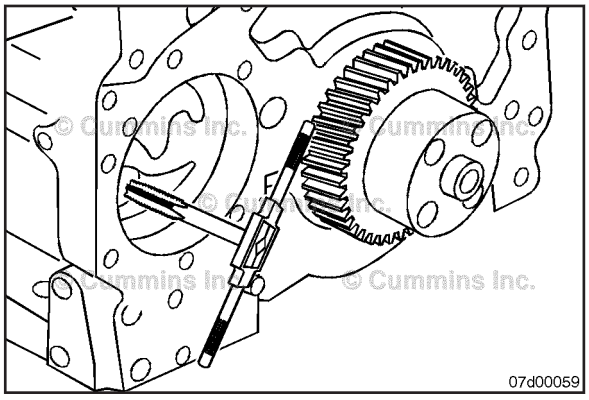


Use a long 1/2-inch drill bit to drill out the angled hole at the bottom of the oil cooler cavity in the block. This is the left most of the two holes located on the bottom of the oil cooler cavity on the gasket surface of the block. Make sure to apply sufficient cutting fluid to cool the bit, and remove the drill frequently to clear debris from the hole. There is approximately 30 mm (1 .18 in) of material to drill through.



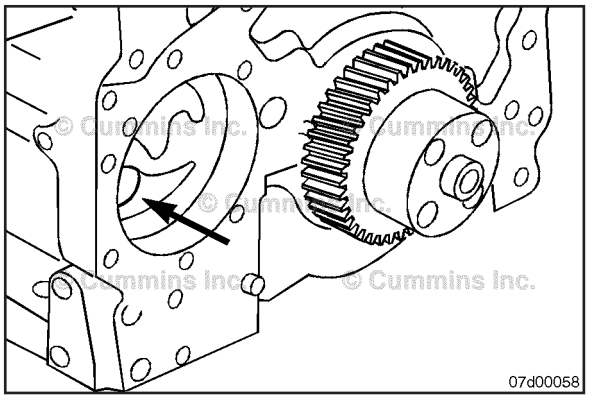
⚠CAUTION⚠
Any burrs or sharp edges must be removed prior to installing the STOR plug so that damage to the o-ring will not occur.

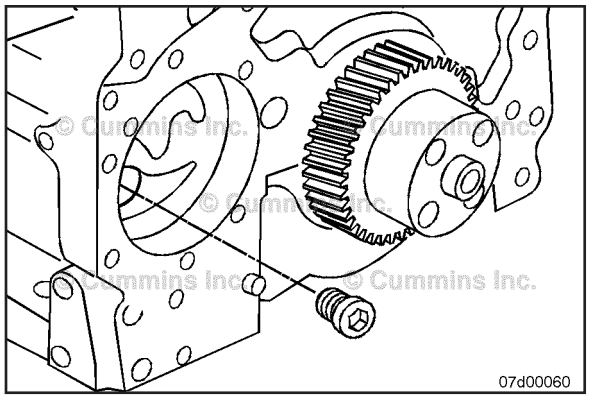
Use a 9/16-inch x 18 tap to tap the hole in the lower lubricating oil pump cavity. This passage is the original dump-to-pump circuit to the lubricating oil pump.



⚠CAUTION⚠
Any material left In the lubricating oil system after this modification will cause engine damage.

Thoroughly clean the angled dump-to-pump drilling, the tapped hole, and the inside block wall.

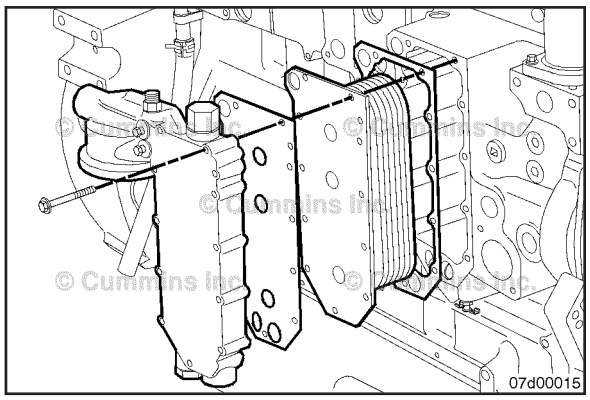




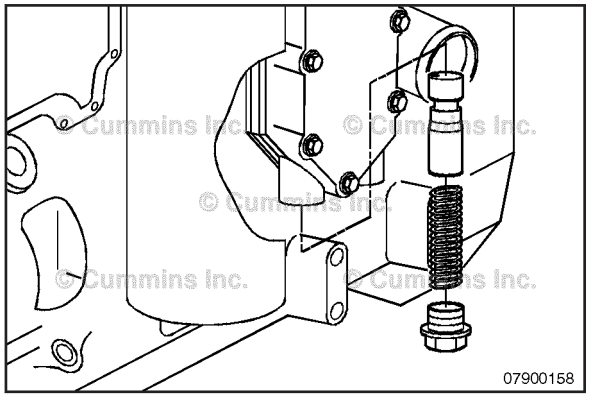
Coat the threads of the 9/16-inch x 18 STOR plug with Loctite™ Blue, or equivalent.

Install the plug in the tapped hole.

Torque Value: 36 N•m [27 ft-lb]

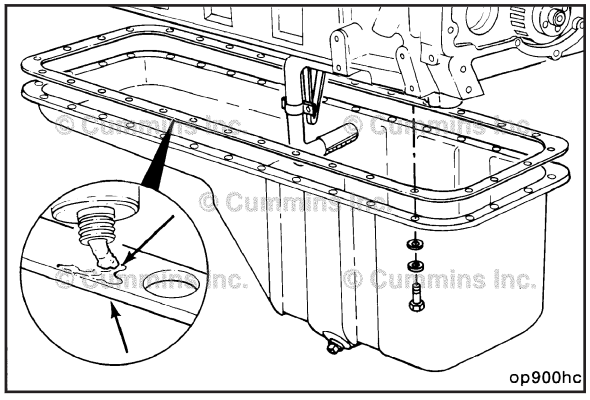


Install the lubricating oil cooler. Refer to Procedure 007-003 in Section 7.



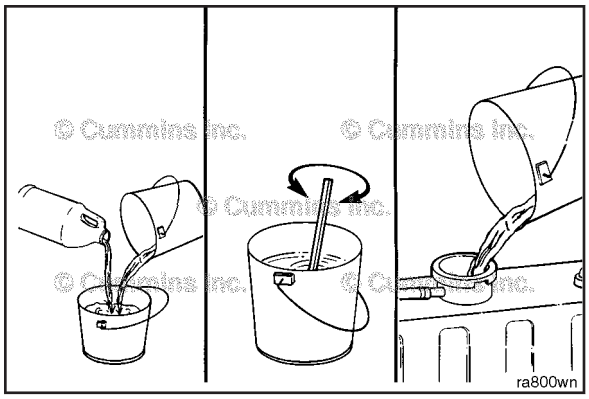
NOTE: The pressure regulator plunger shown in this illustration is the old-style pressure regulator plunger.

Remove the old pressure regulator plunger and install the new plunger. Refer to Procedure 007-029 in Section 7.



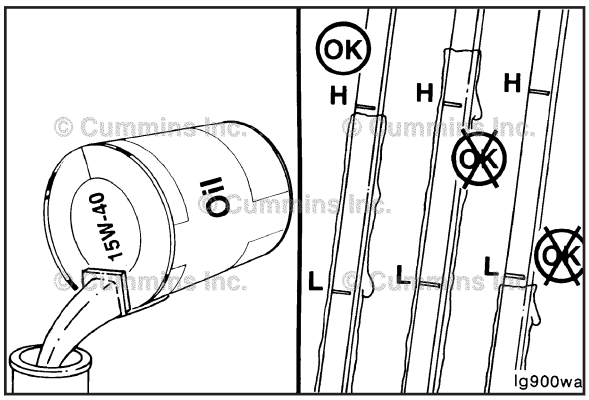
Install the lubricating oil pan and gasket Refer to Procedure 007-025 in Section 7.

Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.



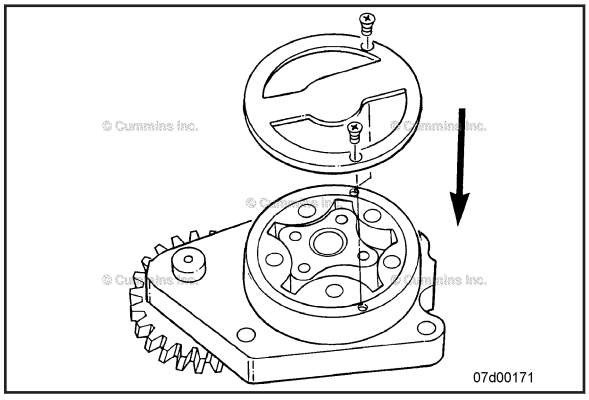
Fill the engine with lubricating oil. Refer to Procedure 007-037 in Section 7.

Crank the engine without starting until lubricating oil pressure registers on the lubricating oil pressure gauge.



Assemble

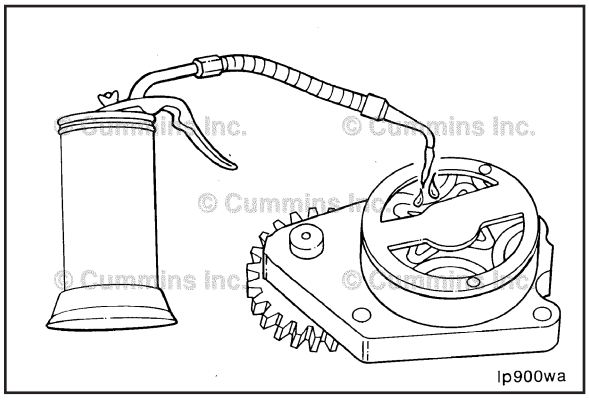
Install the back plate.

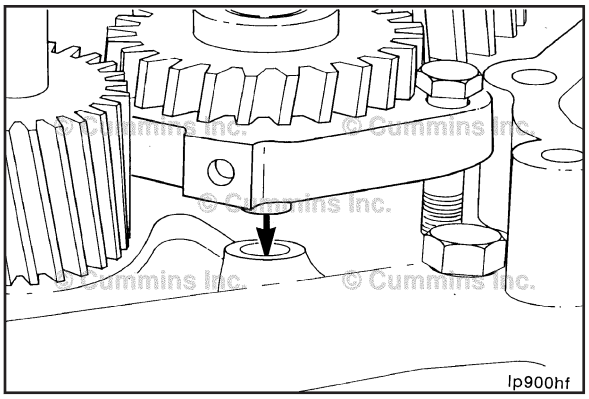


Install

⚠CAUTION⚠
Failure to fill the pump with oil at installation can result in the lubricating oil pump not priming at initial engine start-up, resulting in severe engine damage.

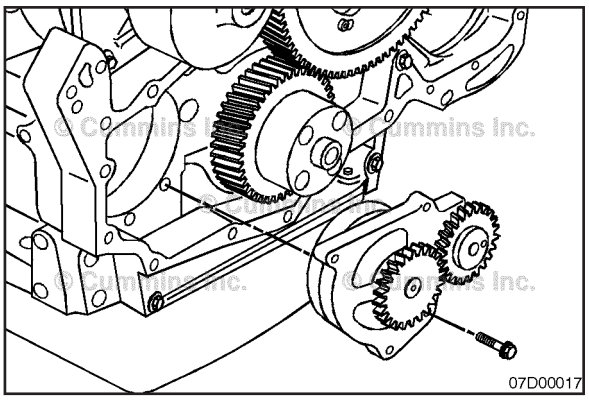
Lubricate the lubricating oil pump with clean 15W-40 engine oil.





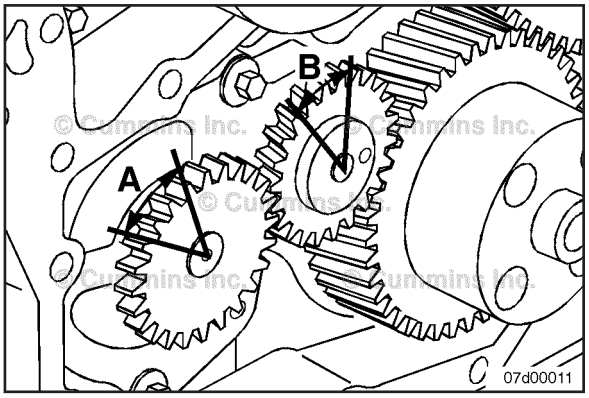
CAUTION
Make sure the idler gear pin is installed in the locating bore in the cylinder block.

Install the lubricating oil pump.



Tighten the capscrews in a crisscross pattern, starting with the upper right capscrew.

Torque Value: 24 N•m [212 in-lb]



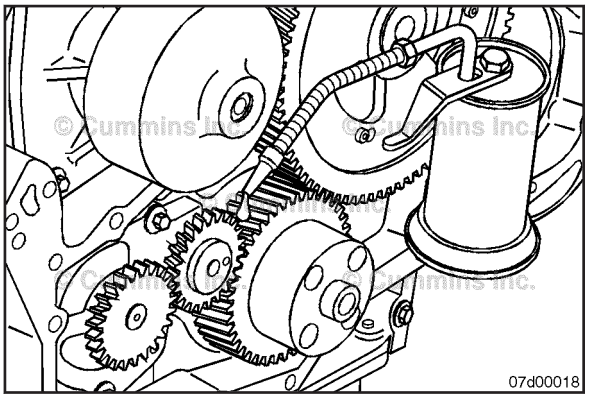
NOTE: Be sure the gear backlash is correct if installing a new lubricating oil pump.

Measure the gear backlash.

Lubricating Oil Pump Gears Backlash Limits (Installed)

	mm		in
A	0.0762	MIN	0.003
	0.3302	MAX	0.013
B	0.0762	MIN	0.003
	0.3302	MAX	0.013

NOTE: If the adjoining gear moves when you measure the backlash, the reading will be incorrect.

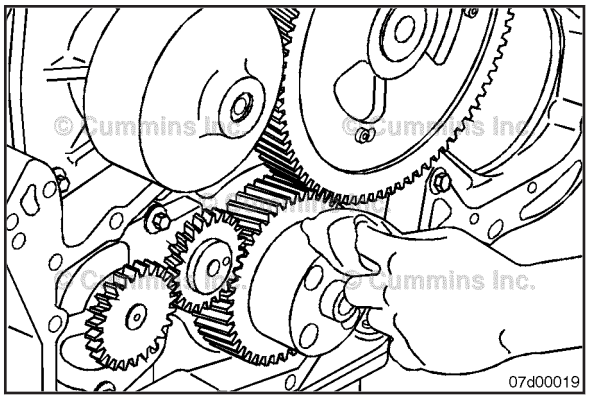


Lubricate the front gear train with clean 15W-40 engine oil.

⚠CAUTION⚠
The seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

Thoroughly clean the front seal area of the crankshaft.

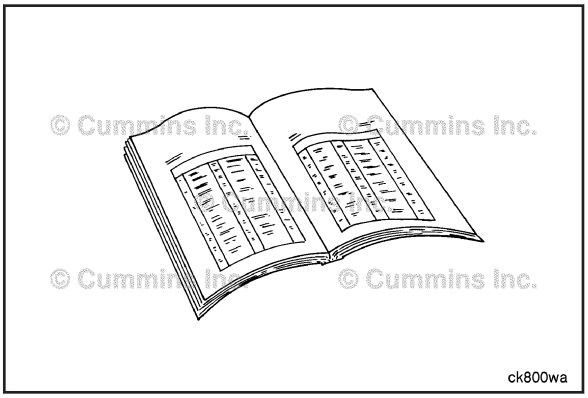
NOTE: Always replace the front seal when removing and installing the front cover. Refer to Procedure 001-031 in Section 1.



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 front cover. Refer to Procedure 001-031 in Section 1.
- Install the rubber vibration damper, if removed. Refer to Procedure 001-051 if installed, in Section 1.
- Install the viscous vibration damper, if removed. Refer to Procedure 001-052 if installed, in Section 1.
- On Marine engines, install the belt tensioner. Refer to Procedure 008-080 in Section 8.
- 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 batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.



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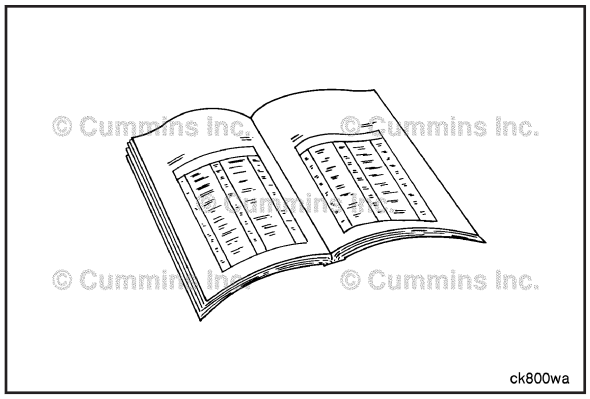


Lubricating Oil Suction Tube (Block-Mounted) (007-035)

Preparatory Steps

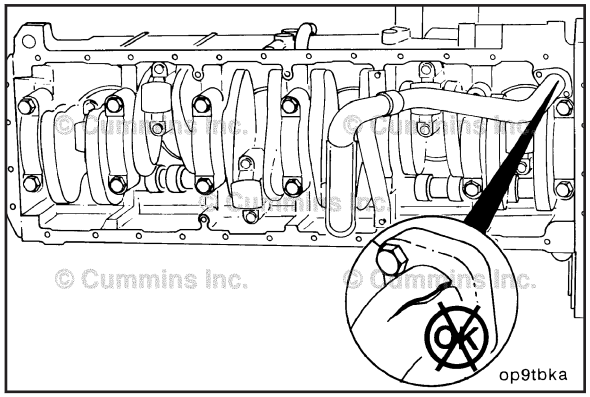
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

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

△CAUTION△
Use caution when draining oil or replacing filters that oil is not spilled or drained into the bilge area. The oil and oil filters must be discarded in accordance with local environmental regulations.

- Disconnect the 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.

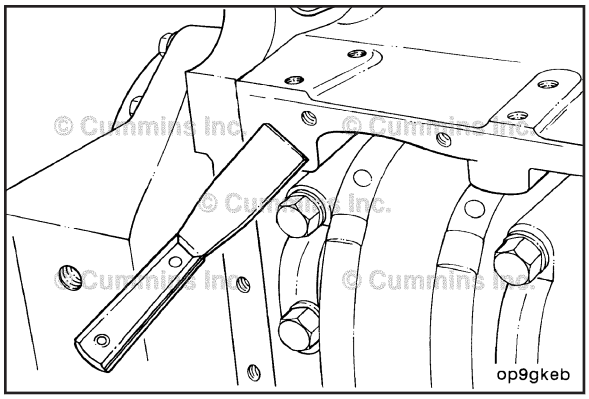


Remove

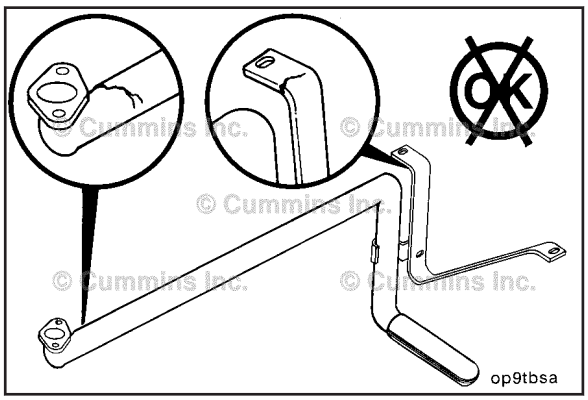
Remove the lubricating oil suction tube.

Clean and Inspect for Reuse

Clean the gasket surfaces.



Inspect the suction tube for cracks.



Install

Install the lubricating oil suction tube and new gasket.

- Install all capscrews finger tight and check for correct alignment.
- Torque the lubricating oil suction tube to the block.

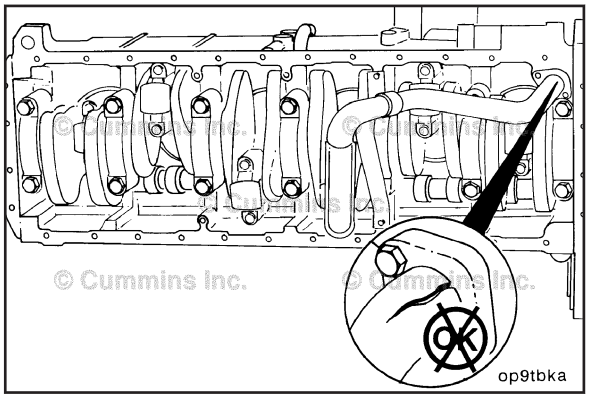
Torque Value: 10 N•m [89 in-lb]

- Torque the lubricating oil suction tube brace to the engine block.

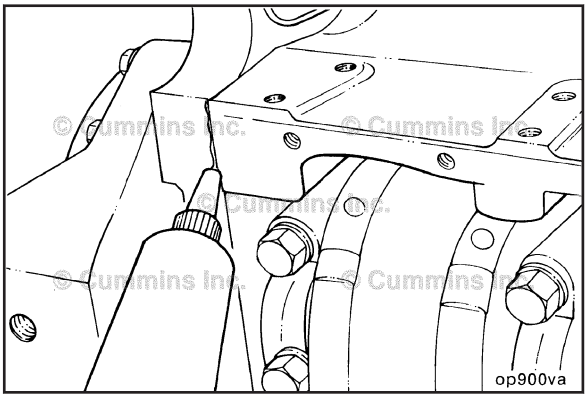
Torque Value: 10 N•m [89 in-lb]

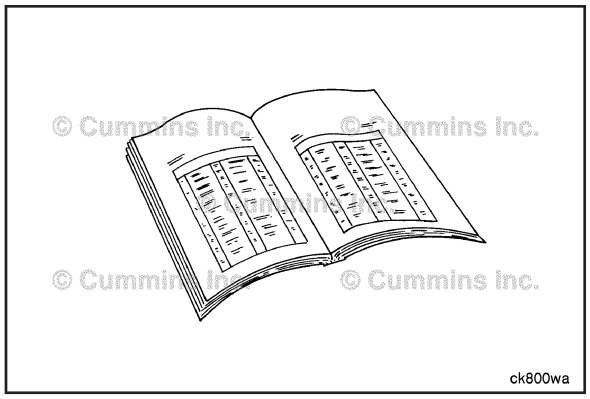
- Torque the lubricating oil suction tube to the brace.

Torque Value: 10 N•m [89 in-lb]



Use RTV sealant, Part Number 3164067, or equivalent, to fill the joints between the lubricating oil pan rail, gear housing, and rear seal housing.

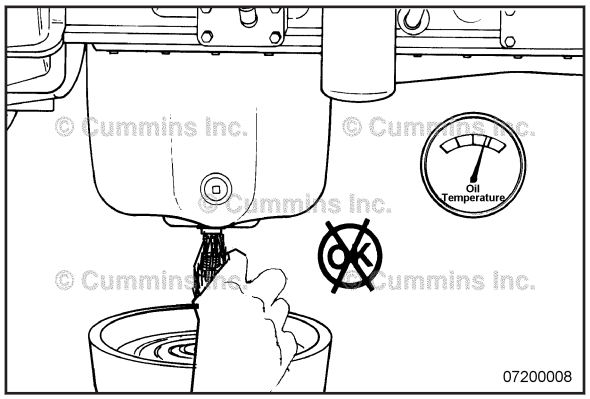




Finishing Steps

⚠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.

- Install the lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7.
- Fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.



Lubricating Oil System (007-037)

Drain

All Applications Except Marine

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

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

NOTE: Use a container that can hold at least 23.6 liters [25 qt] of lubricating oil.

- Operate the engine until the coolant temperature reaches 60°C [140°F]. Shut the engine OFF.
- Remove the oil drain plug.
- Drain the oil immediately to make sure all the oil and suspended contaminants are removed from the engine.
- If performing an oil drain as part of a service maintenance interval, remove and replace the oil filter. Refer to Procedure 007-013 in Section 7.

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Marine Applications

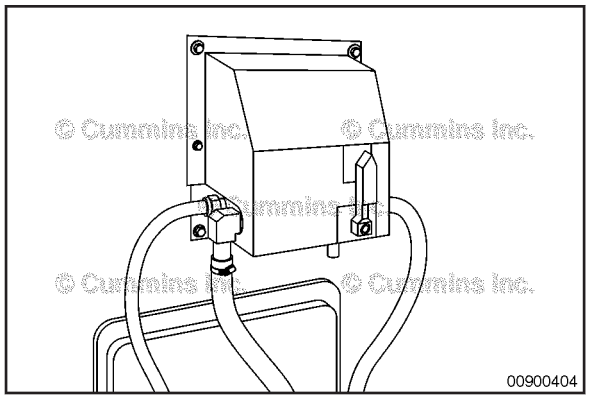
⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

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

△CAUTION△
Use caution when draining oil or replacing filters that oil is not spilled or drained into the bilge area. The oil and oil filters must be discarded in accordance with local environmental regulations.

NOTE: Use a container that can hold at least 23.6 liters [25 qt] of lubricating oil.

- Operate the engine until the coolant temperatures 60°C [140°F]. Shut off the engine.
- Place the lubricating oil pump-out device hose, if equipped, into a suitable container to hold the used lubricating oil.
- Open the inlet valve to the lubricating oil pump-out device.
- Start the pump-out device and drain the lubricating oil from the engine immediately to be sure all of the lubricating oil and suspended contaminants are removed from the engine.
- Shut off the pump-out device after all of oil has been drained.
- If an oil pump-out device was used, close the inlet valve.



Fill

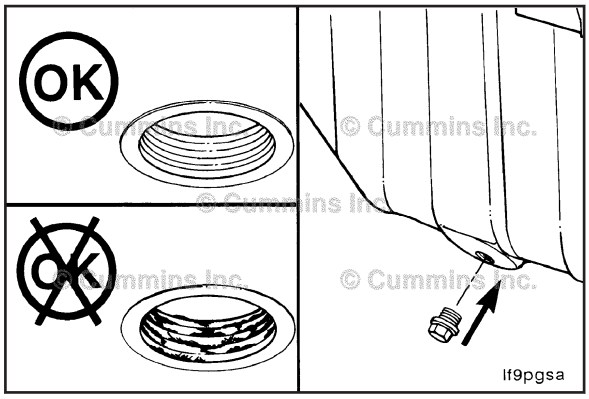
Clean and check the lubricating oil drain plug threads and sealing surface.

Install the lubricating oil pan drain plug.

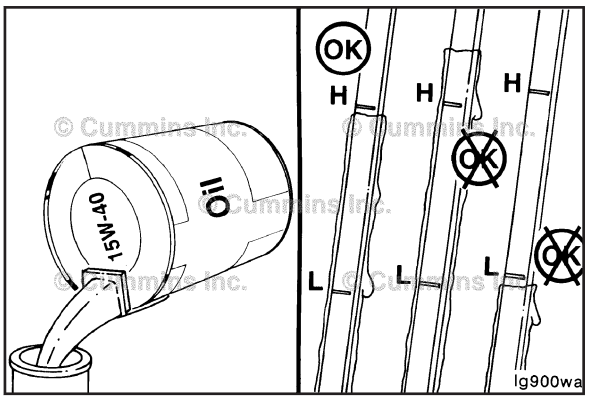
Torque Value:
Steel Oil Pan 80 N•m [59 ft-lb]

Torque Value:
Cast Aluminum Oil Pan 60 N•m [44 ft-lb]

Torque Value:
Composite Oil Pan 60 N•m [44 ft-lb]



NOTE: Use a high quality 15W-40 multi-viscosity oil, such as Cummins® Premium Blue™, or equivalent, in Cummins® engines. Choose the correct oil for your operating climate as outlined in the Section V.

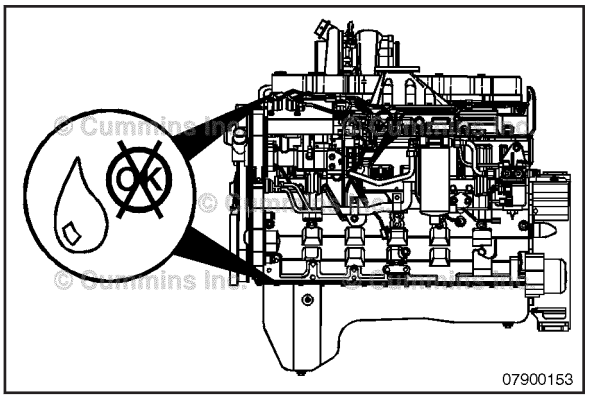


Fill the engine with clean lubricating oil to the proper level.

NOTE: When filling the oil pan, use the fill tube on the side of the engine rather than on top of the rocker lever cover.

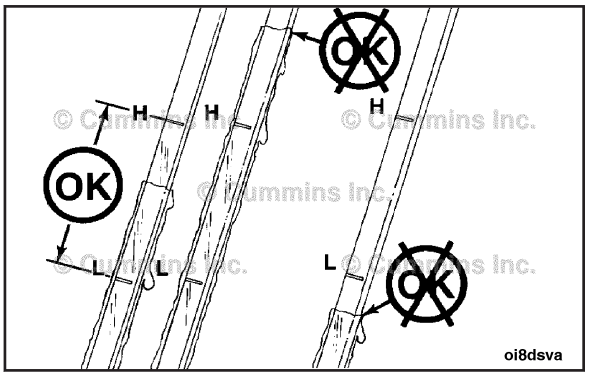
NOTE: White, tan, or brown foam or froth is sometimes found under the oil fill cap, inside the valve cover, or in the crankcase breather. Foam or froth can occur if the engine operates below thermostat opening temperature for sustained periods. This type of foam or froth will **not** affect the function 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.

Verify lubricating oil pan capacities. Refer to Procedure 018-017 in Section V.



⚠CAUTION⚠
If no oil pressure is noted within 15 seconds after the engine is started, shut down the engine to reduce the possibility of internal engine damage.

Idle the engine to inspect for leaks at the drain plug.



Shut the engine OFF. Wait approximately 10 minutes to let the oil drain from the upper parts of the engine. Check the level again.

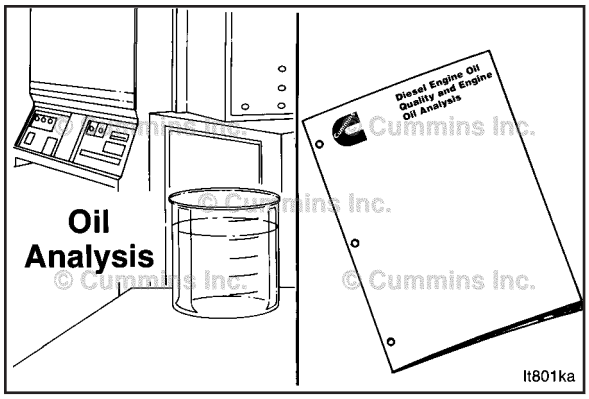
Add oil as necessary to bring the oil level to the "H" (high) mark on the dipstick.

Lubricating Oil Contamination (007-044)

General Information

A used oil analysis can help diagnose internal damage and determine if it was caused by one of the following:

- Oil diluted with coolant
- Oil diluted with fuel.

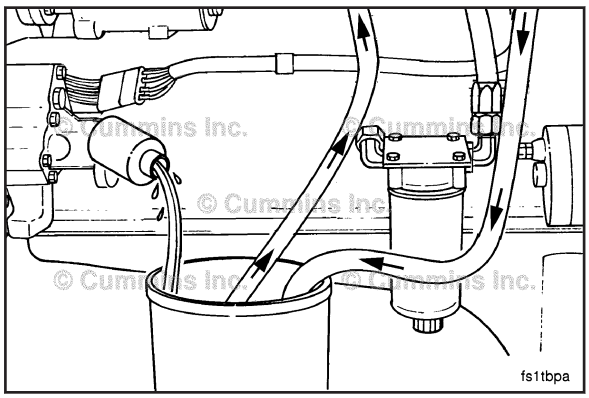


Fluorescent Dye Tracer

NOTE: This test is **not** effective on a cold engine, less than 21°C [70°F] coolant temperature, or with a loose overhead setting.

Install an isolated fuel supply tank at the fuel inlet supply line and at the fuel drain line.

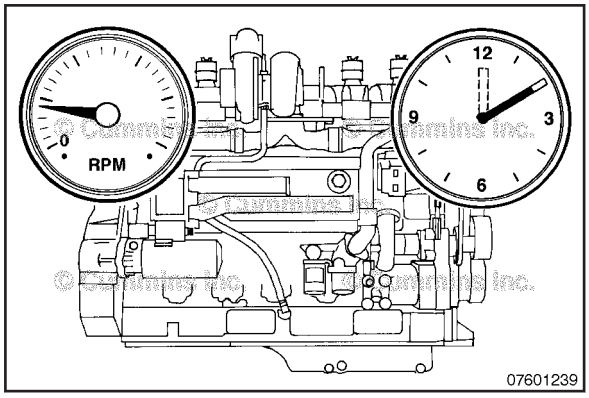
Add fluorescent tracer, Part Number 3376891, to the isolated fuel supply tank. Reference the instructions on the fluorescent tracer bottle for the proper tracer-to-fuel ratio.



CAPS Fuel System

- Start the engine.
- Operate the engine at idle for 6 minutes.
- Shut the engine down.

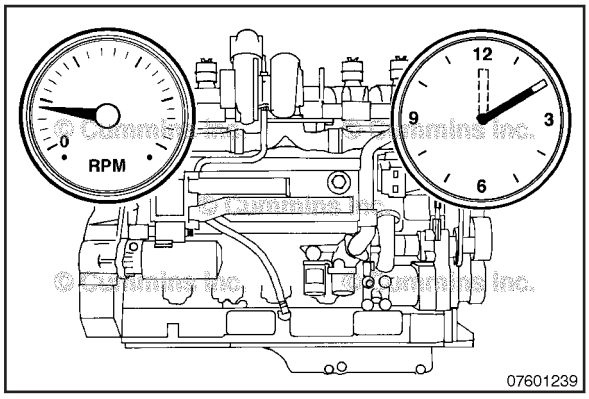
NOTE: Do **not** allow the engine to operate from a remote fuel source for more than 10 minutes.

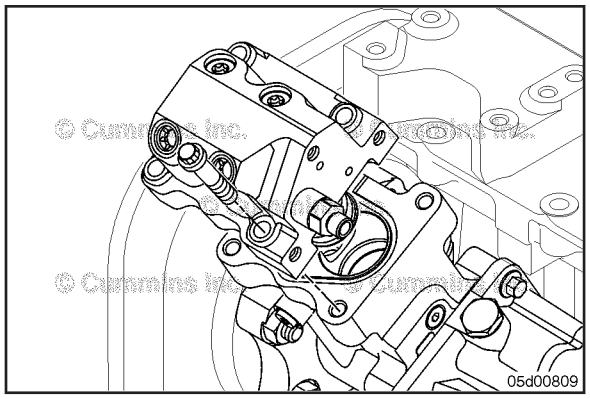


Cummins® Common Rail Fuel System

- Connect INSITE™ electronic service tool.
- Start the engine.
- Operate the engine at idle for 3 minutes.
- After 3 minutes, use INSITE™ electronic service tool High-Pressure Leakage Test to create high fuel rail pressure.
- Operate the engine at high fuel pressure for 3 minutes.
- Shut the engine down.

NOTE: Do **not** allow the engine to operate from a remote fuel source for more than 10 minutes.





⚠WARNING⚠

Normal engine operation creates highly pressurized fuel in the fuel line which will remain in the fuel line after engine shutdown. Never open the fuel system when the engine is operating. Before servicing the fuel system, always loosen the pump to rail fuel line at the rail to vent the pressure. Keep hands clear of the line when loosening. High pressure fuel spray can penetrate the skin, resulting in serious personal injury or death.

Remove the fuel pump head or accumulator.

Use the following procedure for CAPS Fuel System. Refer to Procedure 005-085 in Section 5.

Use the following procedure for Cummins® Common Rail Fuel System. Refer to Procedure 005-227 in Section 5.

Use a black light, Part Number 3163337, to inspect the fuel pump head and camshaft housing for signs of fuel. Fuel will appear to be yellow.

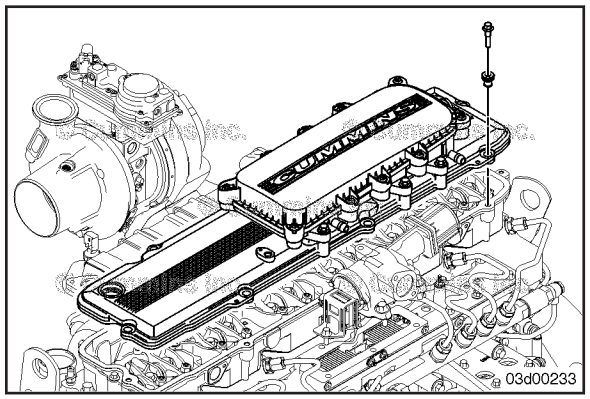
NOTE: A small amount of fuel on the pumping plungers is normal.

If there are signs of a significant amount of fuel in the camshaft housing or on the fuel pump head, replace the fuel pump head.

Install the fuel pump head or accumulator.

Use the following procedure for CAPS Fuel System. Refer to Procedure 005-085 in Section 5.

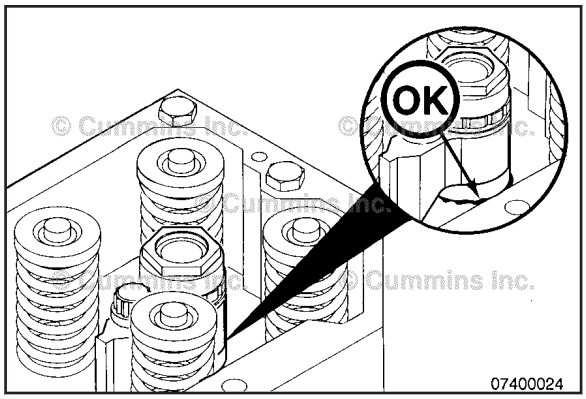
Use the following procedure for Cummins® Common Rail Fuel System. Refer to Procedure 005-227 in Section 5.



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

Use a black light to find fuel leaks from inside or around the injectors.

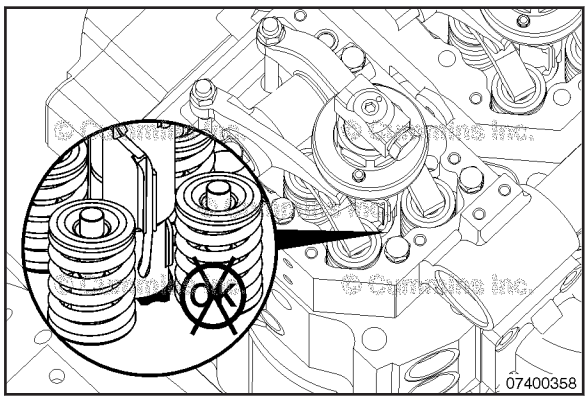
Fuel will appear to be yellow.



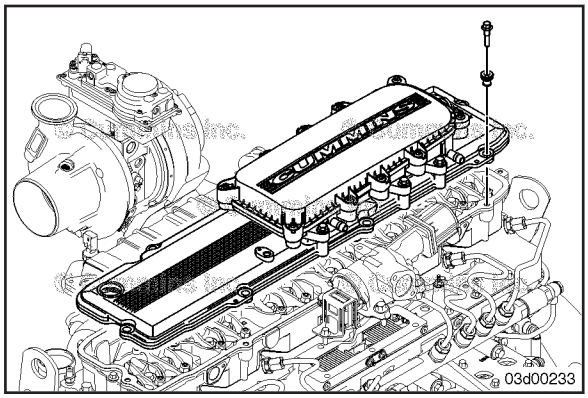
If there is excess leakage around the outside of the injector,

- Check the injector hold-down clamp capscrew torque.
- Remove the injectors and inspect the injector o-rings and injector body for damage.
- Replace the injector o-rings and the injector sealing washers if the injector is reinstalled.
- Replace the injector if injector body damage is present.

Refer to Procedure 006-026 in Section 6.



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

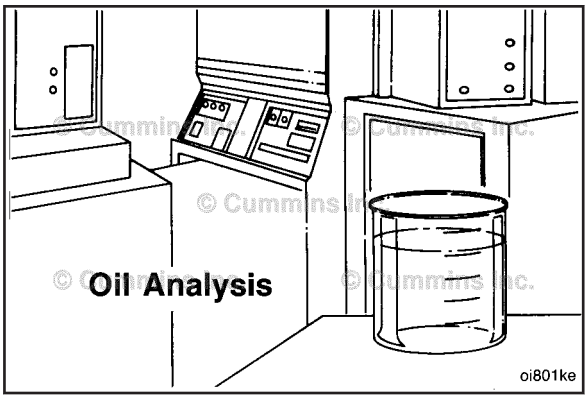


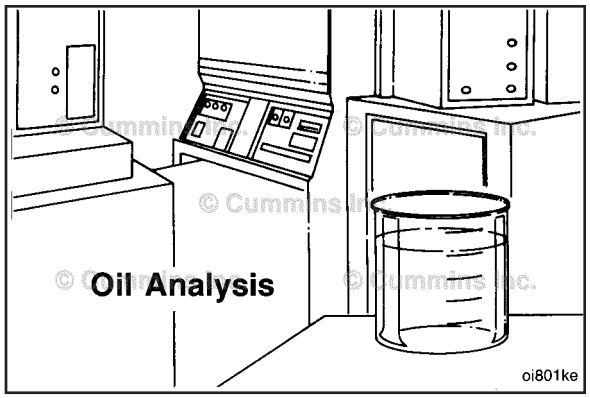
Lubricating Oil and Filter Analysis (007-083)

Inspect

An analysis of used oil can help diagnose internal engine damage and determine if it was caused by one of the following:

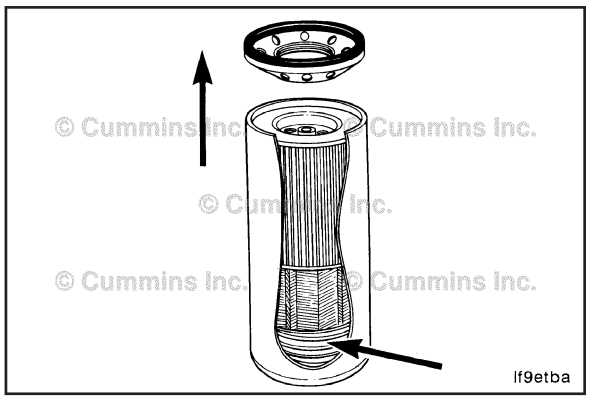
- Intake air filter malfunction
- Coolant leaks
- Oil diluted with fuel
- Metal particles causing wear.



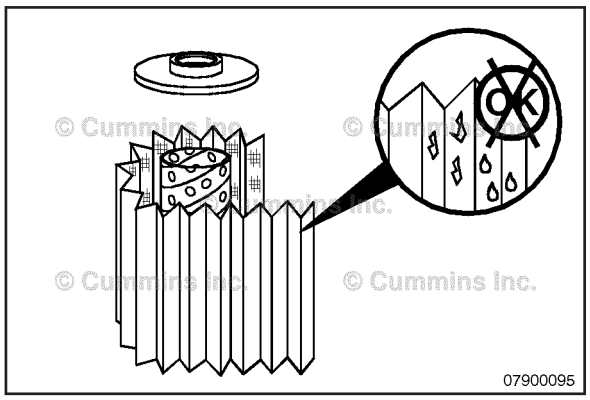


For additional oil analysis information, refer to Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340.

NOTE: Do **not** disassemble an engine for repair based solely on the results of an oil analysis. Inspect the oil filters. If an oil filter shows evidence of internal engine damage, find the source of the problem and repair the damage. Reference the appropriate procedure(s) based on the following oil filter inspection.



⚠WARNING⚠
Restrain the full flow lubricating oil filter and use care when cutting open the upper section of the combination filter. The filter element spring is under compression and can cause personal injury.



Use tube cutter, Part Number 3376579, to open the upper section of the bypass full-flow oil filter.

Inspect the filter element for evidence of moisture or metal particles.

Metal	Possible Source
Copper	Bearings and bushings
Chromium	Piston rings
Iron	Cylinder liners
Lead	Bearing overlay material
Aluminum	Piston wear or scuffing

Lubricating Oil Lines (007-092)

Remove

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

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

△CAUTION△
Use caution when draining oil that oil is not spilled or drained into the bilge area. The oil must be disposed in accordance with local environmental regulations.

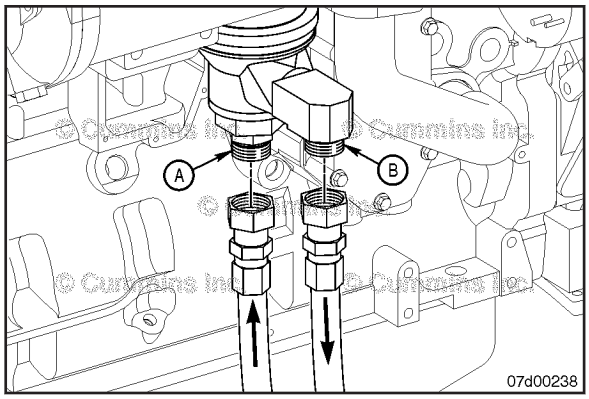
△CAUTION△
Before disconnecting the lubricating oil lines, tag the oil lines for correct location to prevent filter and engine damage due to incorrect installation.

Verify and mark the hoses and adapter head for correct location.

A Oil inlet

B Oil outlet.

Disconnect the lubricating oil lines from the lubricating oil cooler housing filter adapter.



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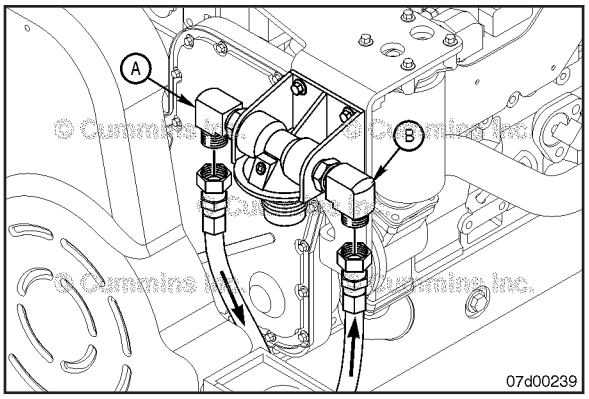


⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

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

△CAUTION△
Use caution when draining oil that oil is not spilled or drained into the bilge area. The oil must be disposed in accordance with local environmental regulations.

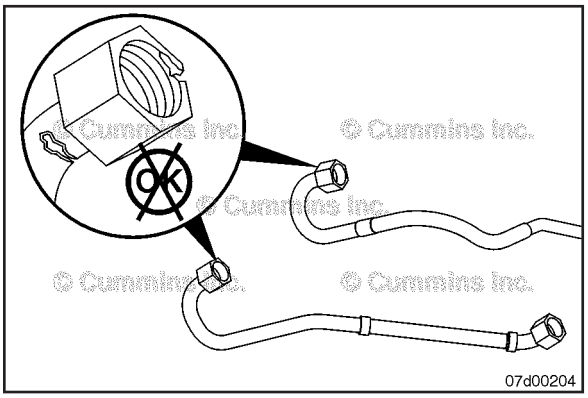
△CAUTION△
Before disconnecting the lubricating oil lines, tag the oil lines for correct location to prevent filter and engine damage due to incorrect installation.

Verify and mark the hoses and oil filter head for correct location.

A Oil outlet

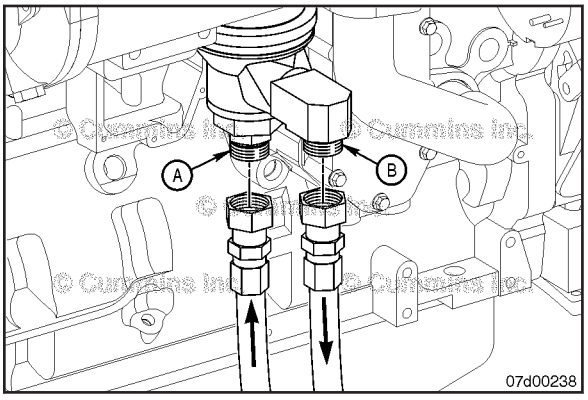
B Oil inlet.

Disconnect the lubricating oil lines from the lubricating oil filter head.



Inspect for Reuse

Inspect the hoses and o-ring sealing surfaces for damage.



Install

△CAUTION△
When installing the lubricating oil lines, make sure the oil lines are not touching or rubbing each other or any other engine parts. Damage to the lines can result in a loss of engine lubricating oil pressure.

Install the hoses to the lubricating oil filter adapter head and tighten finger tight.

A Oil inlet

B Oil outlet.

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Install the hoses on the remote oil filter head and tighten finger tight.

a Oil outlet

B Oil inlet.

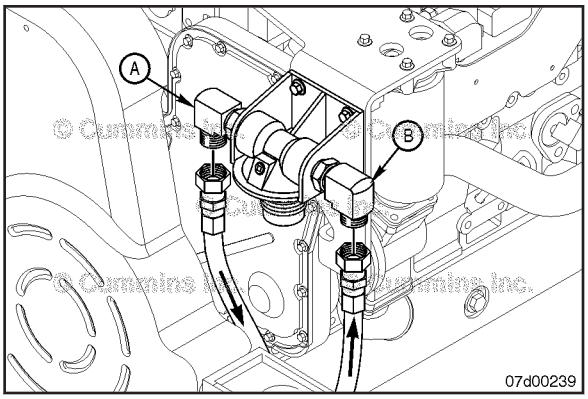
Verify the correct location of the oil lines on the adapter plate and remote oil filter housing.

Torque the hoses on the adapter plate and the remote oil filter head.

Torque Value: 100 N•m [74 ft-lb]

Operate the engine and check for leaks and proper oil pressure.

Shut down the engine and check the oil level; add lubricating oil as necessary.



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Notes

Section 8 - Cooling System - Group 08

Section Contents

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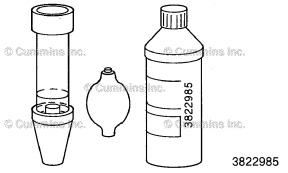
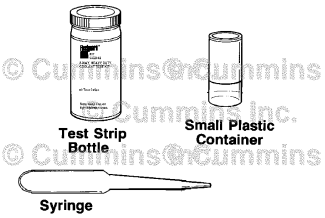
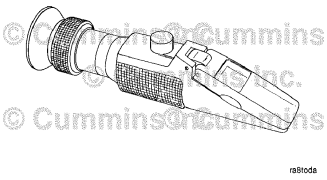
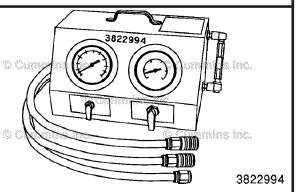
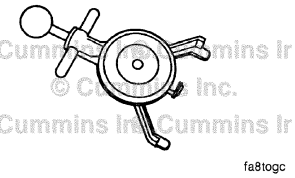
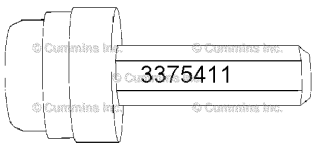
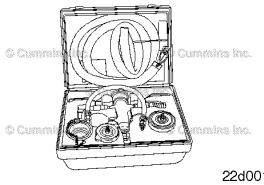
Service Tools

Cooling System

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3822985	**Combustion Gas Leak Test Kit** Used to detect leaks. Includes Part Number 3822986, test fluid, Part Number 3822987, adapter, and Part Number 3877612, instructions.	
CC-2626	**Cooling System Test Kit** The Fleetguard® coolant test kit is used to check the concentration of coolant additives in the cooling system.	
CC-2800	**Refractometer** The Fleetguard® refractometer is used to measure the freezing point protection and antifreeze concentration.	
3822994	**Engine Coolant Analyzer** The Engine Coolant Analyzer is used to troubleshoot pressure loss, restriction, and improper temperature control.	
ST 1293	**Belt Tension Gauge** Used to measure the tension in the drive belt.	
3375411	**Thermostat Seal Mandrel** Used to install new thermostat seals on QSL9 marine keel cooled engines.	

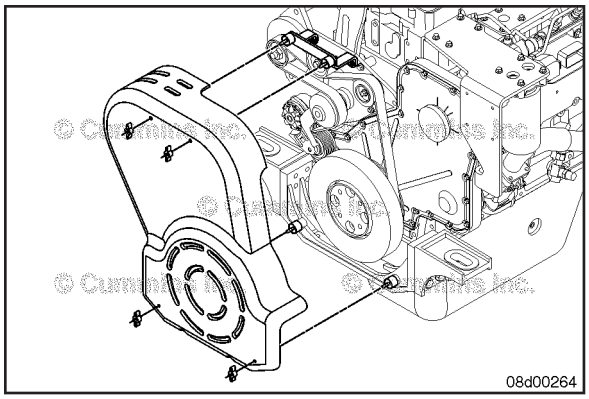
Tool No.	Tool Description	Tool Illustration
3824319	**Coolant Dam/Pressure Tester** Using shop air pressure, the coolant dam creates a vacuum, holding the coolant in with little or no coolant loss.	 22d00167

Belt Guard (008-001)

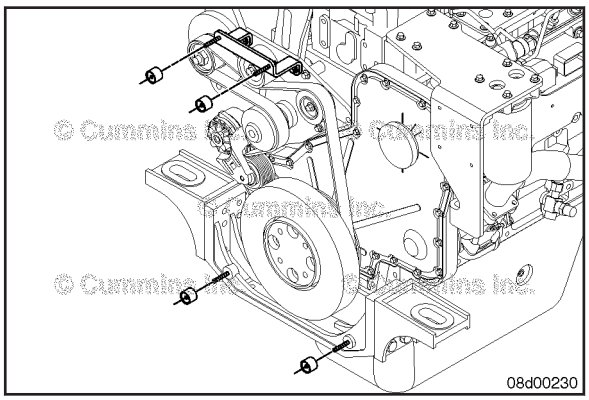
Remove

Remove the four fasteners on the belt guard.

Remove the belt guard.

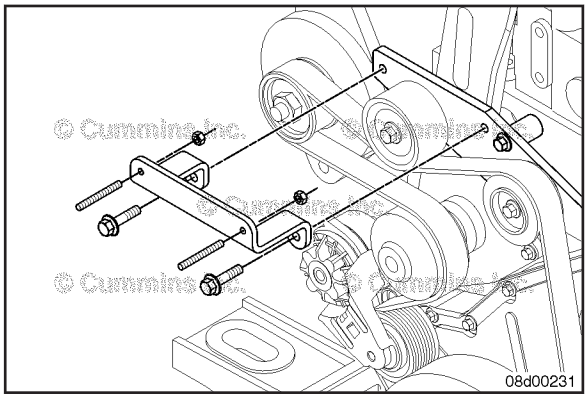


Remove the four rubber isolators from the belt guard mounting studs.



Remove the four studs.

Remove the two mounting capscrews and the belt guard mounting bracket.

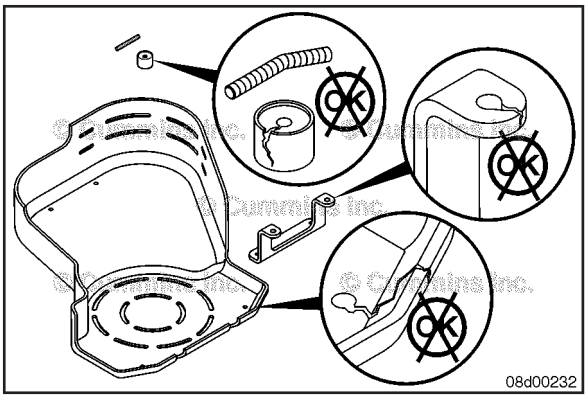


Inspect for Reuse

Inspect the belt guard and bracket for cracks or other damage. If damaged, they **must** be replaced.

Inspect the isolators for damage. If the isolators are hard and brittle, they **must** be replaced.

If damaged or bent, replace the belt guard studs.



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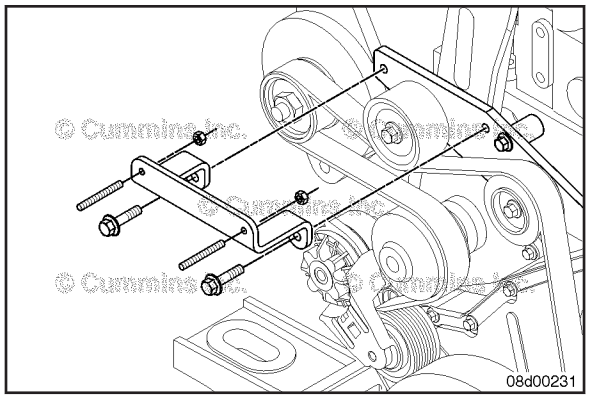


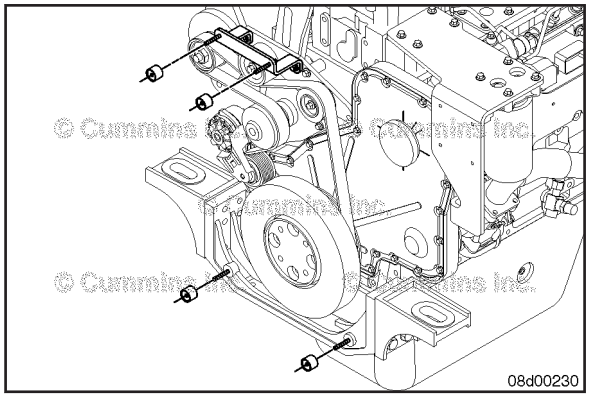
Install

Install the belt guard mounting bracket and tighten the two capscrews.

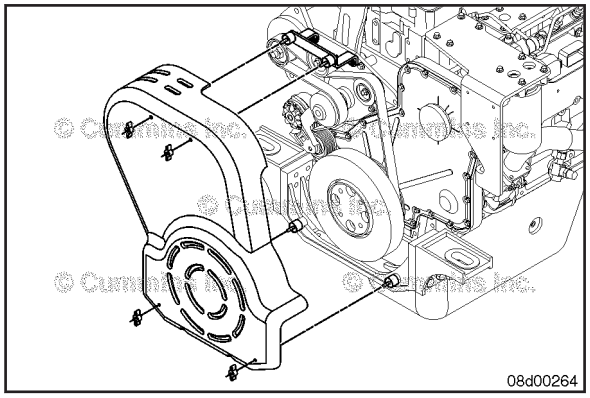
Torque Value: 20 N•m [15 ft-lb]

Install and tighten the four studs.

Torque Value: 15 N•m [133 in-lb]



Install the four rubber isolators onto the four studs.

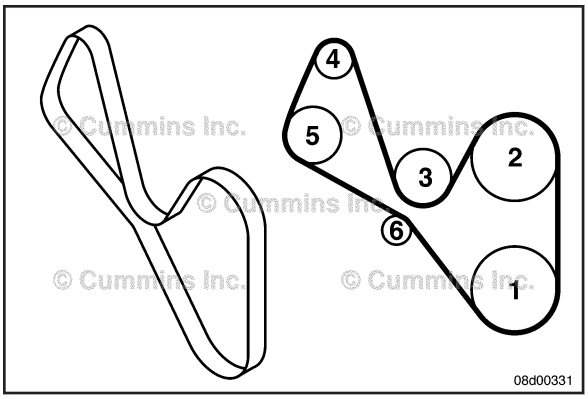


Align the belt guard holes and install the belt guard.

Install and tighten the wing nuts finger tight.

Drive Belt, Cooling Fan (008-002)

General Information



Due to the number of drive belt arrangements, this procedure does **not** cover all available cooling fan drive belt routing.

To make sure the cooling fan drive belt is routed correctly upon installation, make a diagram of the cooling fan belt routing prior to removing the belt, as shown in the illustration.

The cooling fan belt routing typically consists of the following components, but may **not** include all of them:

1 Crankshaft pulley/vibration damper

2 Fan pulley

3 Water pump pulley

4 Refrigerant compressor pulley

5 Alternator pulley

6 Belt tensioner pulley.

NOTE: Some engine-driven belts are installed/supplied by the vehicle original equipment manufacturer (OEM). See the OEM service manual for removal and installation instructions.

Troubleshooting

NOTE: This content in this section is generic and may **not** apply to all available cooling fan drive belt systems.

The following section contains diagnostic information and procedures to aid in identifying drive belt and accessory drive issues. These issues may include:

- Belt noise (squeal and chirp)
- Belt tracking (jumping)
- Belt fraying
- Snub breaks and punctures.

Common causes of drive belt noise, fraying, and breaks are:

- Drive pulley misalignment
- Embedded debris in drive pulley grooves
- Incorrect belt material and/or belt length
- Damaged or incorrect automatic belt tensioner
- Improper drive belt routing
- Improper fan size and/or fan clutch.

The original drive belt and tensioner should be used, if possible, while troubleshooting drive belt issues. Replacement of a belt and/or tensioner prior to troubleshooting may mask the root cause of the issue due to the break-in time required for a belt and tensioner.

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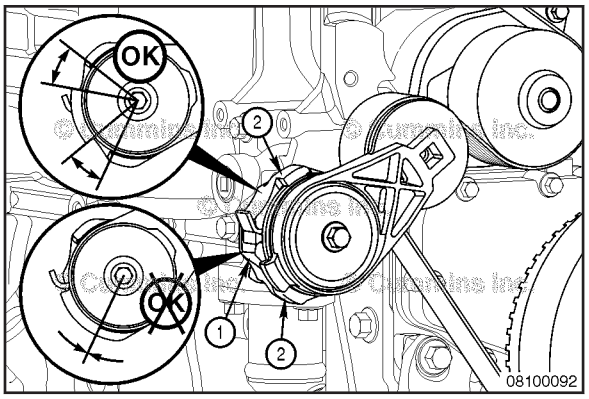
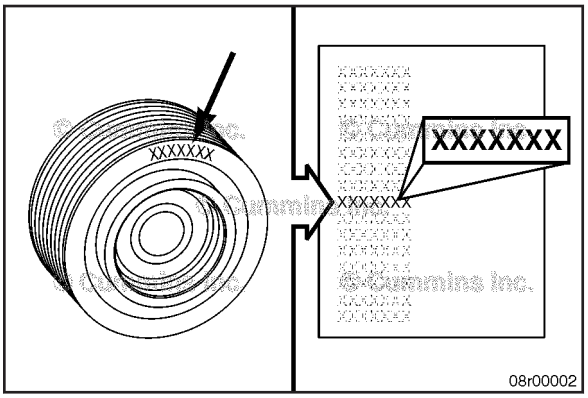


NOTE: A newly installed belt and/or tensioner will **not** come to rest properly until the engine is operated. Always operate the engine for a brief period of time prior to verifying the tensioner resting location.

Inspect the automatic belt tensioner. Refer to Procedure 008-080 in Section 8. If the belt tensioner does **not** meet the reuse criteria, the belt tensioner **must** be replaced.

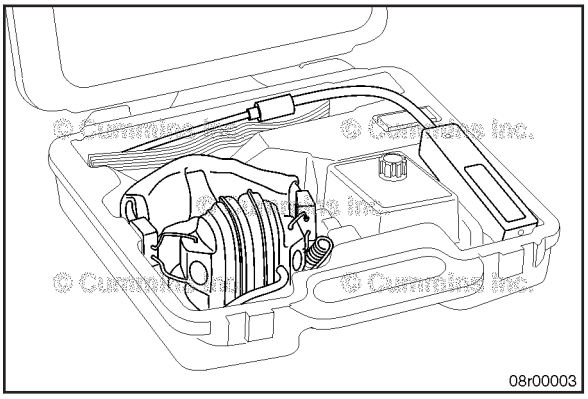
With the belt installed, check the automatic belt tensioner resting position. If the belt tensioner arm stop is contacting either of the spring case stops:

- Verify the correct belt part number is installed
- If the correct belt is installed, replace the belt.

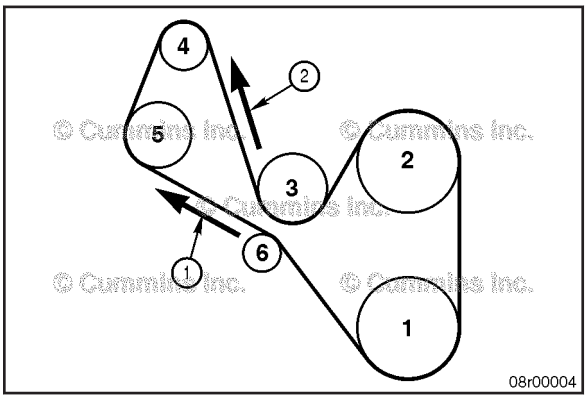


Verify all accessory drive components and pulleys are correct. Components yielding incorrect part numbers, or installed without the appropriate spacers and/or brackets may contribute to gross drive belt misalignment.

Verify proper drive belt routing, if available. Refer to the OEM service manual.



Isolating the source of drive belt noise may be done by use of an electronic stethoscope, or an equivalent device designed to block audible noise other than that desired, by use of a microphone.



Drive belt noise may be difficult to isolate and troubleshoot. The origin of drive belt noise may **not** be located at the pulley out of alignment, rather ‘upstream’ from the noise origin.

Troubleshooting should always be completed in a direction opposite belt travel (i.e. counter clockwise) beginning at the pulley where the noise originates.

Arrow number (1) indicates belt travel direction, whereas arrow number (2) represents the direction in which troubleshooting should be conducted.

- Flat pulleys should be inspected for uneven wear patterns
- Grooved pulleys should be inspected for embedded debris, belt dust buildup, and pulley alignment.

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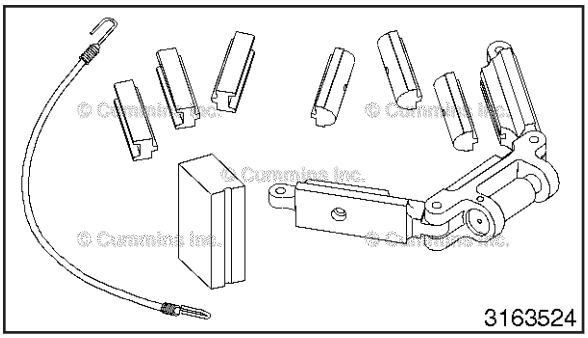
NOTE: The belt alignment laser tool can identify misalignment of pulleys down to ½ of a belt rib. The capability of the alignment fixture is contingent upon proper calibration. Make sure all set-up and calibration procedures are followed before verifying pulley alignment.

Use a Belt Alignment Laser Tool, Part Number 3163524, or equivalent, to verify all pulleys are aligned correctly.

Pulley alignment should always be checked from the fan pulley, and crankshaft pulley to other front end mounted grooved pulleys. Contact a Cummins® Authorized Repair Location for drive belt alignment.

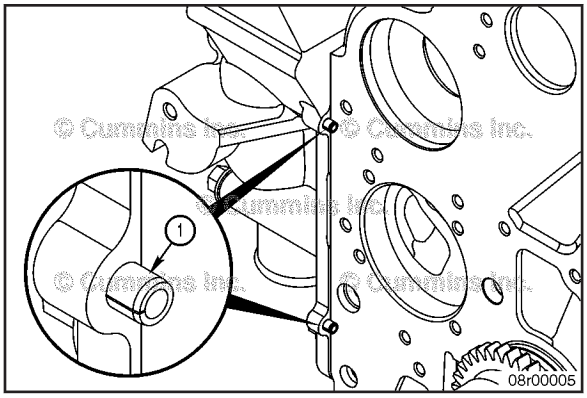


If a pulley is identified as out of alignment, verify the component mounting bracket installation.

Certain engines feature an automatic belt tensioner mounted to the water inlet connection. Verify the locating roll pins (1) are:

- Installed into the connection
- In contact with the cylinder block
- Do **not** appear to be bent or out of place.

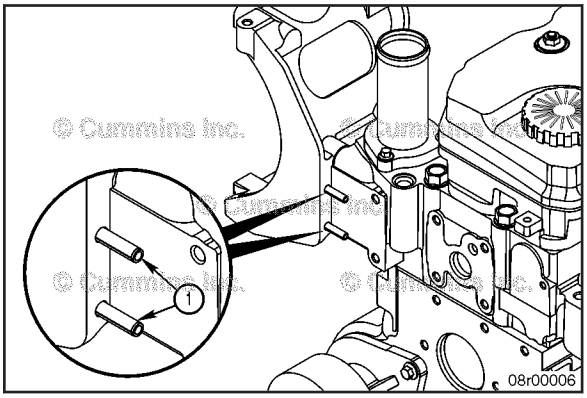
If the water inlet connection and/or roll pins are **not** installed correctly, remount the water inlet connection. Refer to Procedure 008-082 in Section 8.



Certain alternator mounting brackets are aligned to the cylinder head by roll pins. Verify the locating roll pins (1) are:

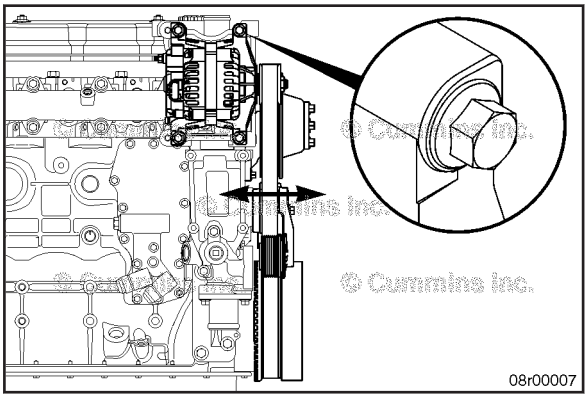
- Installed into the alternator bracket
- In contact with the cylinder head
- Do **not** appear to be bent or out of place.

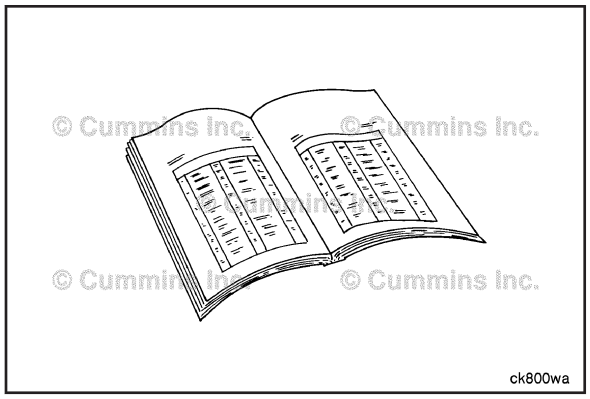
If the alternator bracket and/or roll pins are **not** installed correctly, remount the alternator bracket. Refer to Procedure 013-003 in Section 13.



Check drive pulley alignment with the belt alignment laser tool, Part Number 3163524, or equivalent, after any bracket adjustments are made.

Certain ‘pad mounted’ components which do **not** contain locating features can be positioned on the mounting brackets for fine adjustments.

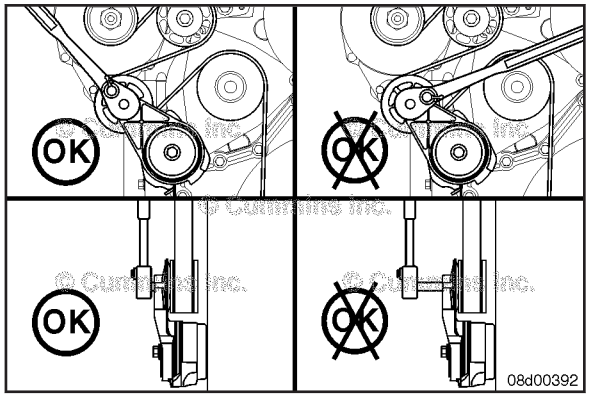




Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.



Remove

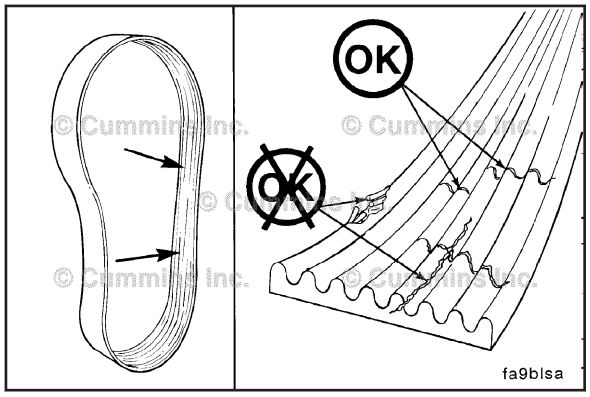
△CAUTION△
The belt tensioner is spring-loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

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

△CAUTION△
Using a socket extension is not recommended because it can cause axial twisting damage to the belt tensioner.

Lift the tensioner to remove the drive belt.

NOTE: If a socket extension is necessary, support the head of the ratchet with one hand to prevent the belt tensioner arm from unintended loading.



Clean and Inspect for Reuse

Inspect the drive belt for damage.

Transverse (across the belt) cracks are acceptable.

Longitudinal (direction of belt ribs) cracks that intersect with transverse cracks are **not** acceptable.

If the belt is frayed, punctured, or material is missing, the belt is unacceptable for reuse and **must** be replaced.

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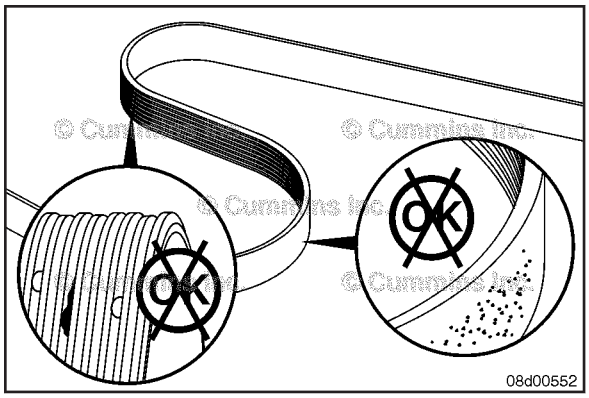
Inspect the belt grooves for:

- Embedded debris
- Uneven/excessive rib wear
- Exposed belt cords.

Inspect the backside of the belt for:

- Glazing (high heat)
- Uneven/excessive rib wear
- Exposed belt cords.

If any of the above conditions are present, the belt is unacceptable for reuse and **must** be replaced.



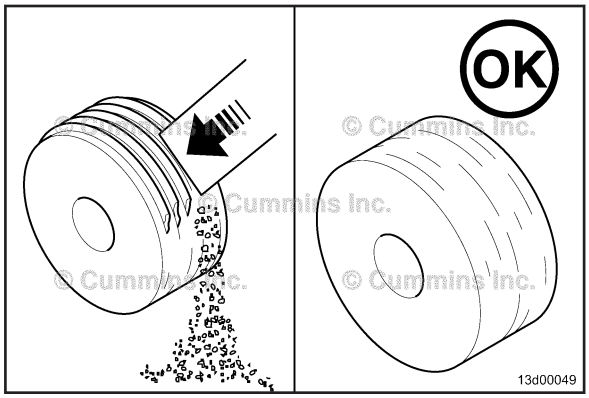
Inspect the idler and drive pulleys for wear or cracks..

Plastic pulleys often have a buildup of road dirt and belt material that is **not** to be confused with wear.

The dirt can be removed with a suitable tool to check for wear.

Clean, check, and reuse all pulleys in the front end accessory drive if **not** damaged, rather than replacing. Pulleys damaged from embedded debris **MUST** be replaced.

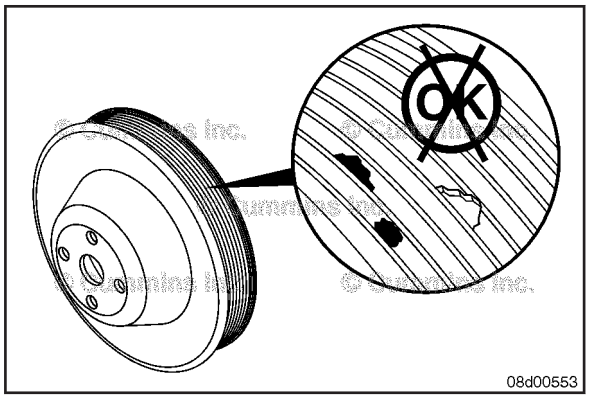
Inspect the tensioner. Refer to Procedure 008-080 in Section 8.



Inspect all system pulleys for embedded debris:

- Rocks, stones
- Metal
- Belt material.

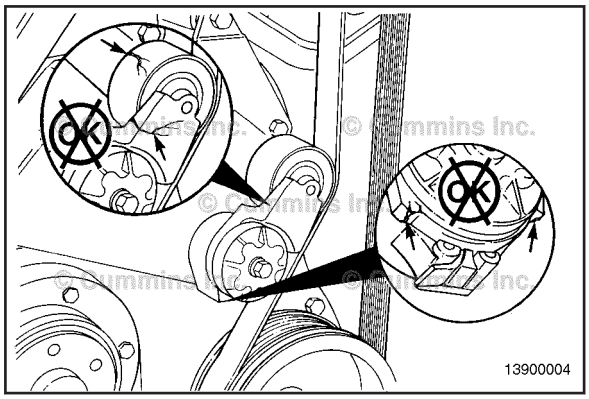
Remove any debris from the grooves of the pulley. If the pulley has been deformed as a result of foreign material embedment, the pulley **MUST** be replaced.

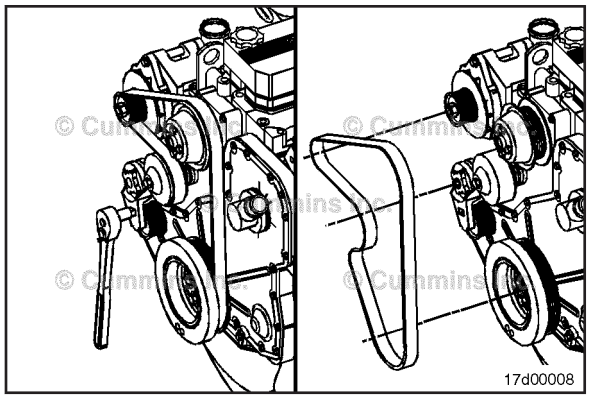


Inspect the drive belt pulleys and idlers for cracked or broken grooves.

Reference the following procedures if a pulley or idler is damaged:

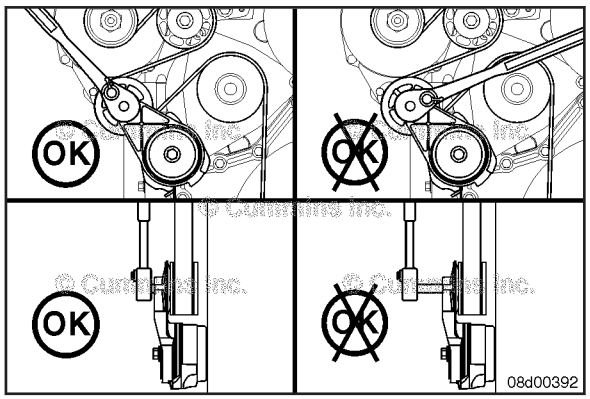
- Inspect the fan pulley. Refer to Procedure 008-039 in Section 8.
- Inspect the crankshaft pulley. Refer to Procedure 001-052 in Section 1.
- Inspect the belt tensioner pulley. Refer to Procedure 008-080 in Section 8.





Install

Route the drive belt on the engine. Use the belt diagram created in the Remove section. Do **not** install the belt over the water pump pulley at this time.



⚠CAUTION⚠
The belt tensioner is spring-loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

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

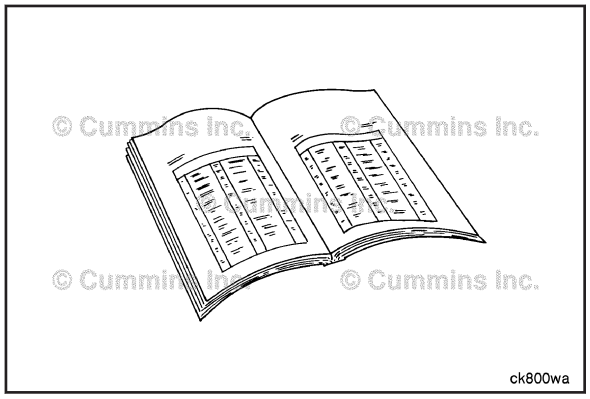
⚠CAUTION⚠
Using a socket extension is not recommended because it can cause axial twisting damage to the belt tensioner.

Pivot the tensioner in the direction of the spring tang and install the drive belt, slipping the belt over the water pump pulley last.

Slowly, release the belt tensioner to apply tension to the drive belt.

NOTE: If a socket extension is necessary, support the head of the ratchet with one hand to prevent the belt tensioner arm from unintended loading.

Check the alignment of the belt with the tensioner and the rest of the front-end accessory drive.



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for belt squeal. Excessive belt squeal indicates excessive belt slip.
- If belt squeal is present, check the routing of the belt to make sure the belt is installed correctly on each pulley.

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Coolant Filter (008-006)

Remove

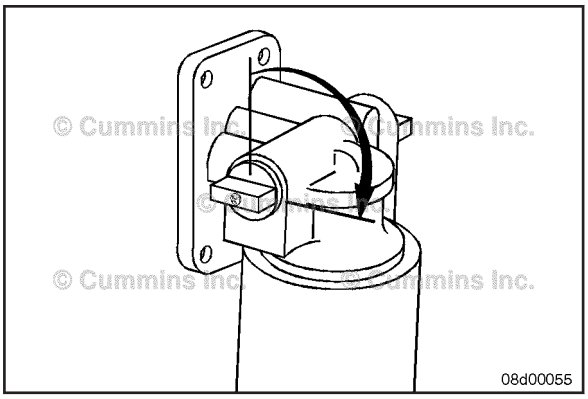
All Applications Except Marine

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

NOTE: Some engine models do **not** require coolant filters.

Remove the coolant system pressure cap.

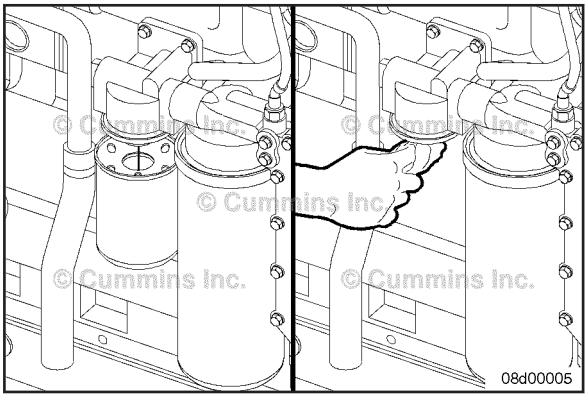
Turn the shutoff valve to the OFF position by rotating the knob from the vertical to the horizontal position, as shown.



⚠WARNING⚠
A small amount of coolant can leak when servicing the coolant filter with the shutoff valve in the OFF position. To reduce the possibility of personal injury, avoid contact with hot coolant.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Remove and discard the coolant filter.



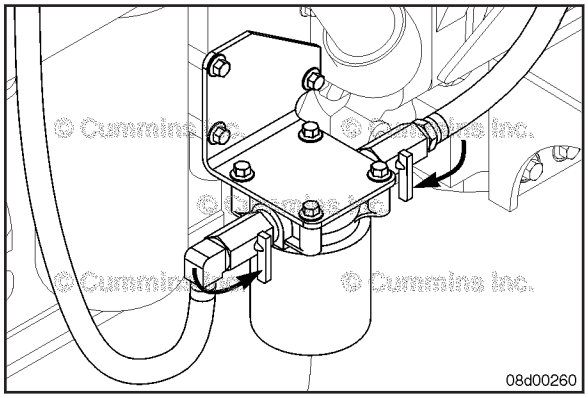
Marine Applications

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

NOTE: It is possible that some marine engine models do **not** have coolant filters.

Remove the coolant system pressure cap.

Turn the inlet and outlet shutoff valves to the OFF position by rotating the knobs from the horizontal to the vertical direction as shown.



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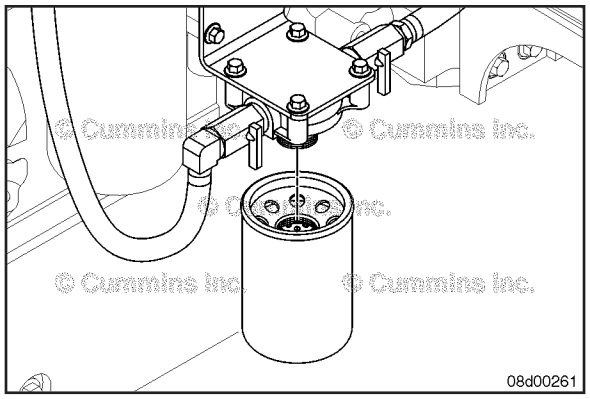
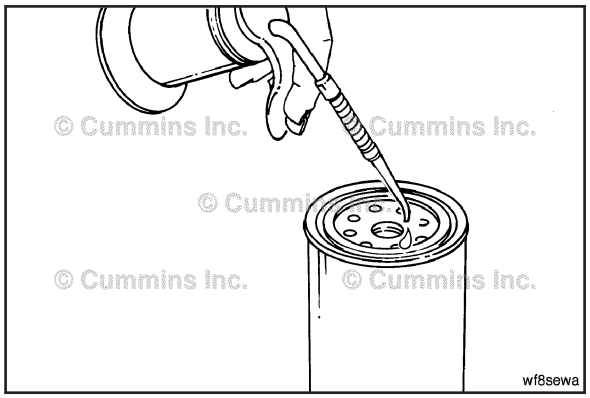


⚠WARNING⚠
A small amount of coolant can leak when servicing the coolant filter with the shutoff valve in the OFF position. To reduce the possibility of personal injury, avoid contact with hot coolant.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠CAUTION⚠
Use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

Remove and discard the coolant filter.



Install

All Applications Except Marine

⚠CAUTION⚠
Do not allow oil to get into the filter. Oil will damage the DCA.

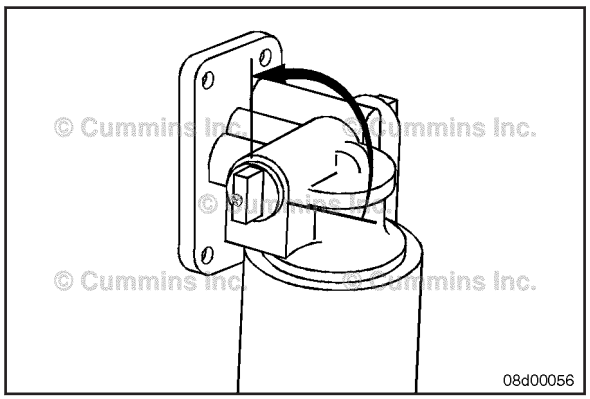
⚠CAUTION⚠
Mechanical over tightening can distort the threads or damage the filter head.

Apply a thin film of lubricating oil to the gasket sealing surface before installing the new coolant filter.

Install the coolant filter on the filter head. Tighten the filter until the gasket contacts the filter head surface.

Tighten the coolant filter an additional 1/2 to 3/4 of a turn, or as specified by the filter manufacturer.

See Section V for coolant filter recommendations.



⚠CAUTION⚠
The valve must be in the ON position to prevent engine damage.

Turn the shutoff to the ON position by rotating the knob from the horizontal to the vertical position, as shown.

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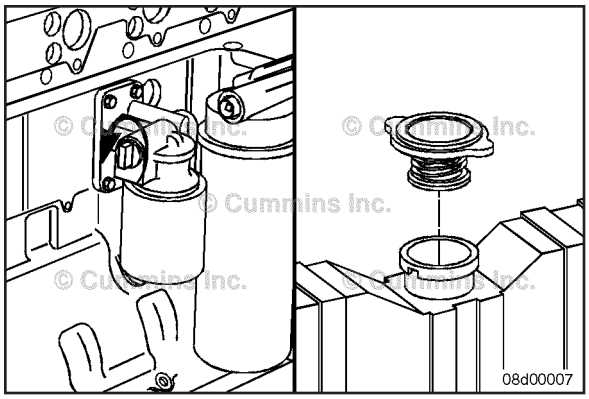
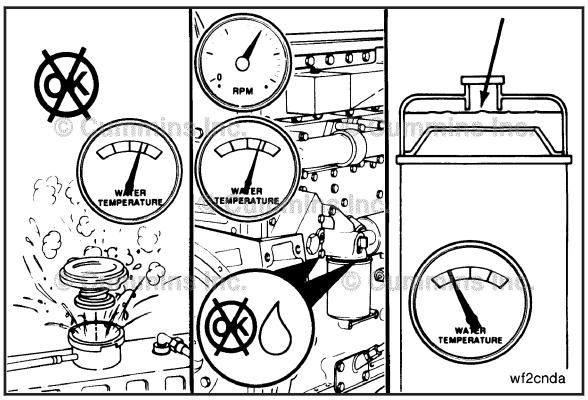
Install the coolant system pressure cap.



Operate the engine and check for coolant leaks.

After the air has been purged from the system, check the coolant level again.



Marine Applications

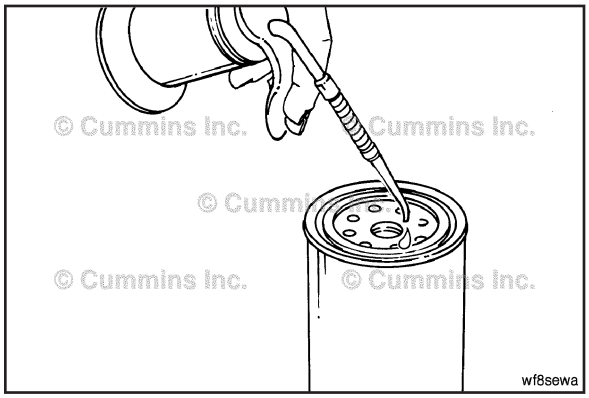
⚠CAUTION⚠
Do not allow oil to get into the filter. Oil will damage the DCA.

⚠CAUTION⚠
Mechanical over tightening can distort the threads or damage the filter head.

Apply a thin film of lubricating oil to the gasket sealing surface before installing the new coolant filter.

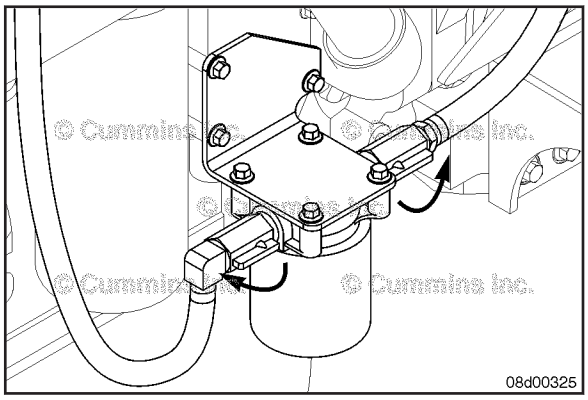
Install the coolant filter on the filter head. Tighten the filter until the gasket contacts the filter head surface.

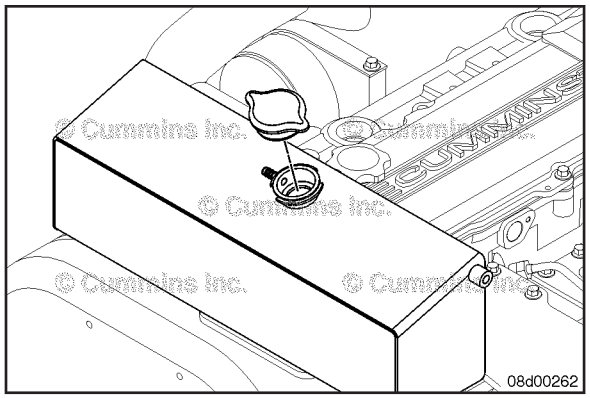
Tighten the coolant filter an additional 1/2 to 3/4 of a turn, or as specified by the filter manufacturer.



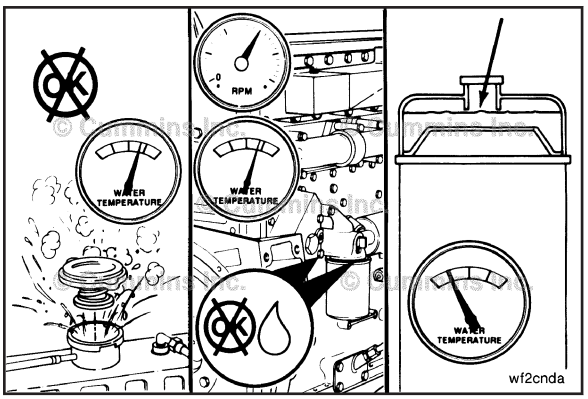
⚠CAUTION⚠
The valve must be in the ON position to prevent engine damage.

Turn the shutoff valves to the ON position by rotating the knobs from the vertical to the horizontal position in the directions shown.



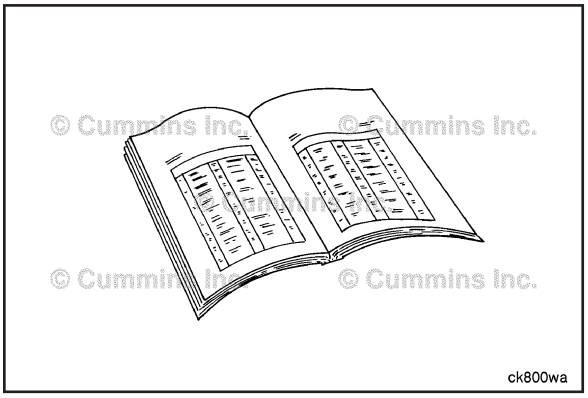


Install the coolant system pressure cap.



Operate the engine and check for coolant leaks.

After the air has been purged from the system, check the coolant level again.



Coolant Filter Head (008-007)

Preparatory Steps

All Applications Except Marine

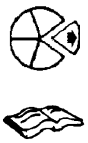
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

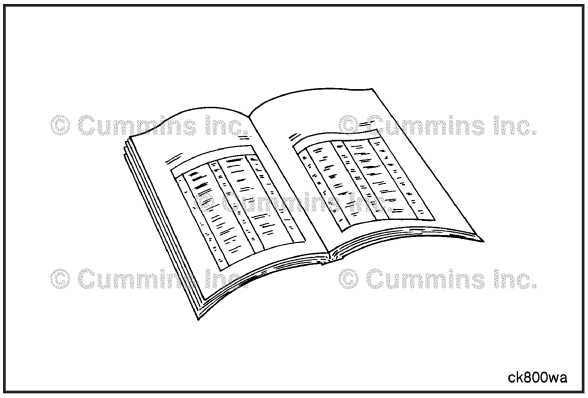
⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the batteries. See equipment manufacturer service information.
- Remove the coolant filter. Refer to Procedure 008-006 in Section 8.

Marine Applications





⚠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 draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

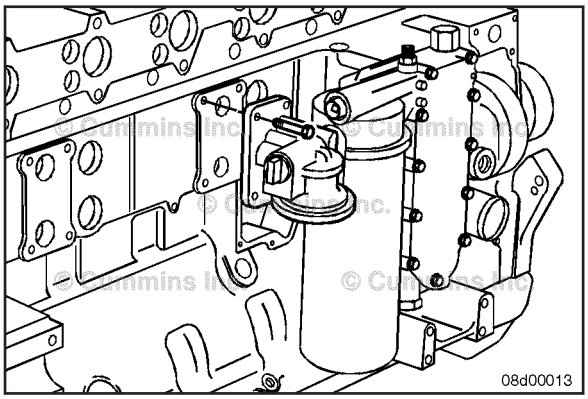
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the coolant filter. Refer to Procedure 008-006 in Section 8.
- Remove the water inlet and outlet hoses from the filter head.
- Remove the water inlet and outlet valves from the filter head.

Remove

All Applications Except Marine

Loosen the four filter head capscrews.

Remove the filter head and gasket.

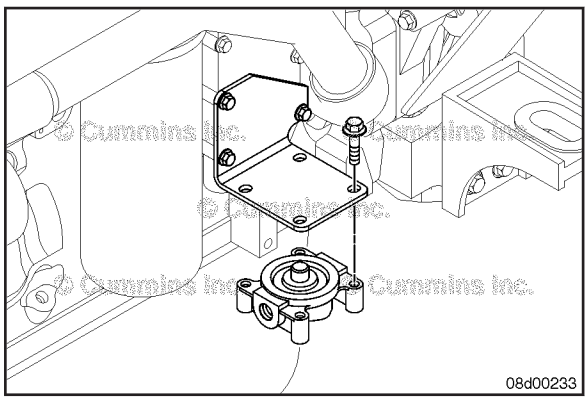


Marine Applications

Mark the inlet and outlet sides of the filter head for correct installation.

Loosen the four filter head mounting capscrews.

Remove the filter head from the mounting bracket.



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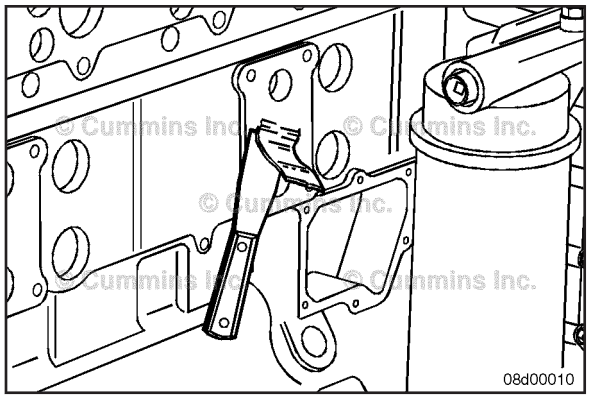
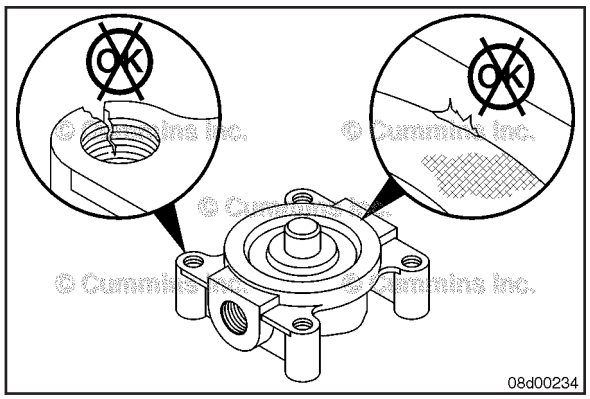


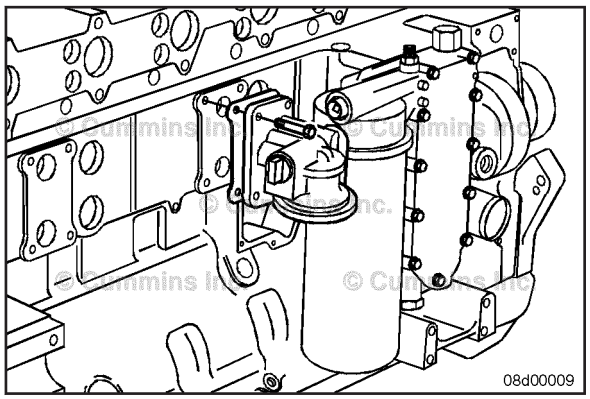
Clean and Inspect for Reuse

Clean the mating surfaces.



Inspect the filter head for cracks, burrs or other damage.

Replace the filter head if it is damaged.



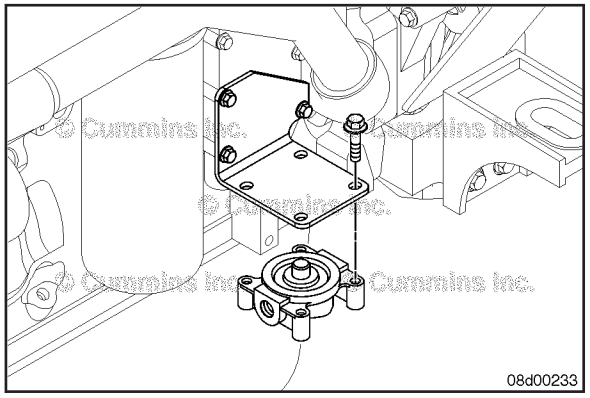
Install

All Applications Except Marine

Install a new gasket and the filter head.

Tighten the four capscrews.

Torque Value: 24 N•m [212 in-lb]



Marine Applications

NOTE: Be sure to install the filter head with the inlet and outlet in the same position as removed.

Install the filter head to the mounting bracket.

Tighten the four mounting capscrews.

Torque Value: 24 N•m [212 in-lb]

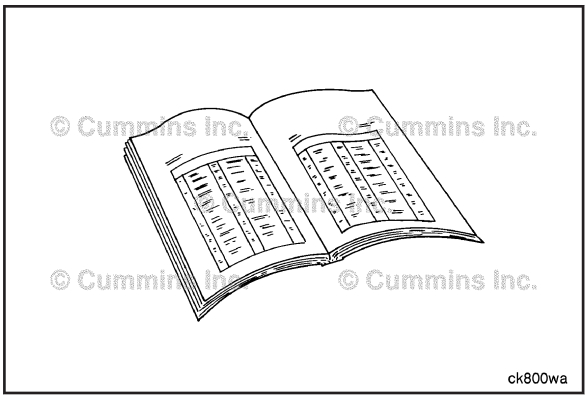
Finishing Steps

All Applications Except Marine

⚠ WARNING ⚠

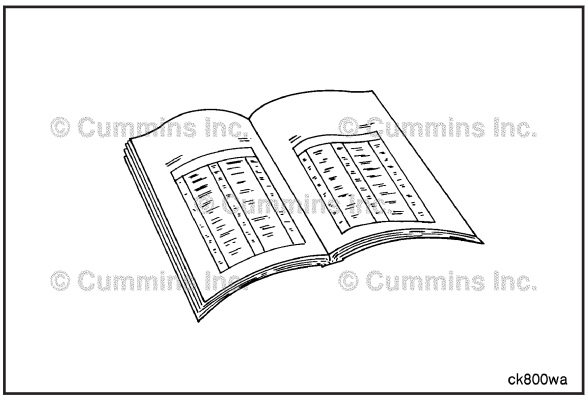
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the coolant filter. Refer to Procedure 008-006 in Section 8.
- Fill the cooling system with either a 50/50 mixture of good-quality water and fully formulated antifreeze or fully formulated coolant. The fully formulated antifreeze or coolant **must** meet ASTM D6210 (EG) and ASTM D6211 (PG) specifications. Refer to Procedure 008-018 in Section 8.
- Connect the battery. See equipment manufacturer service information.
- Operate the engine and check for leaks.



Marine Applications

- Install the coolant inlet and outlet valves to the filter head.
- Install the coolant inlet and outlet hoses and tighten the hose clamps. Refer to the OEM specification.
- Install the coolant filter. Refer to Procedure 008-006 in Section 8.
- Open the inlet and outlet valves.
- Fill the cooling system with either a 50/50 mixture of good-quality water and fully formulated antifreeze or fully formulated coolant. The fully formulated antifreeze or coolant **must** meet ASTM D6210 (EG) and ASTM D6211 (PG) specifications. Refer to Procedure 008-018 in Section 8.
- Operate the engine and check for leaks.



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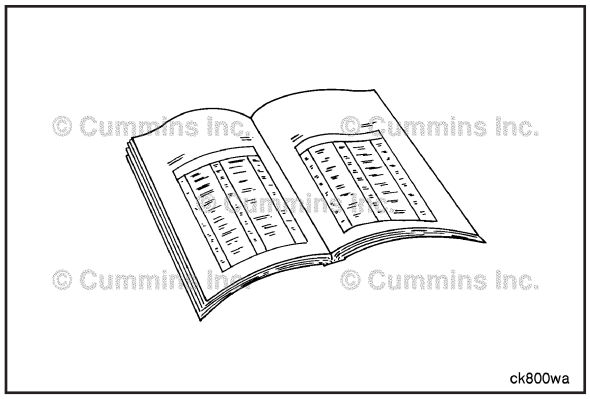


Coolant Filter Valve (008-009)

Preparatory Steps

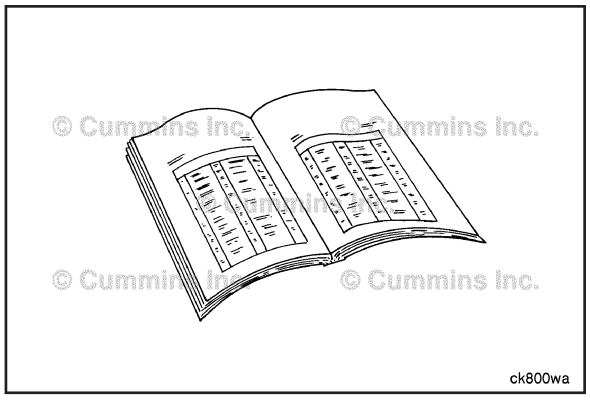
All Applications Except Marine

⚠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.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.
- Remove the coolant filter. Refer to Procedure 008-006 in Section 8.
- Remove the coolant filter head. Refer to Procedure 008-007 in Section 8.



Marine Applications

⚠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 draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.
- Remove the coolant filter inlet and outlet hoses.
- Remove the hose fittings from the shutoff valves.
- Remove the coolant filter head, if necessary. Refer to Procedure 008-007 in Section 8.

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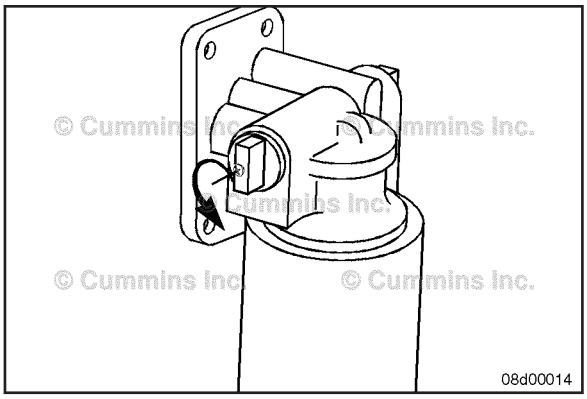
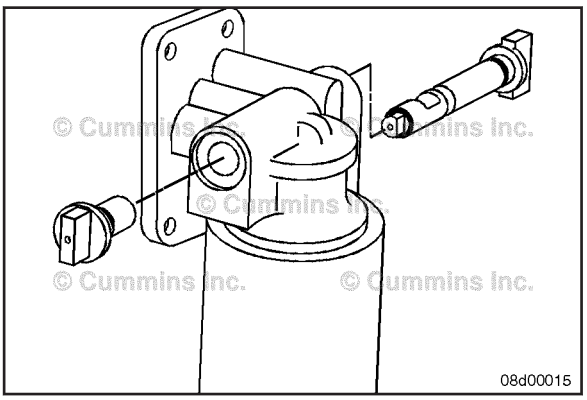
Remove

All Applications Except Marine

Loosen the shutoff valve screw from the end of the valve.

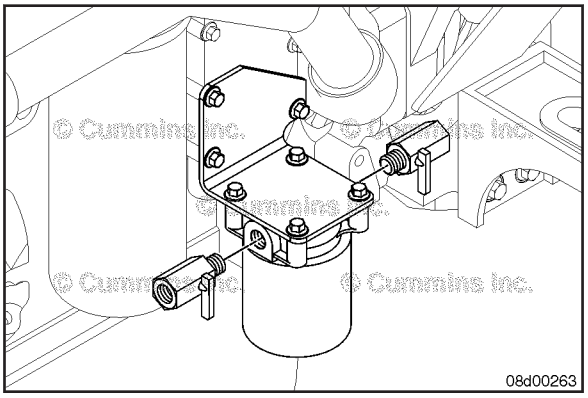


Remove the two pieces of the shutoff valve from both sides of the valve bore.



Marine Applications

Remove the shutoff valves from the filter head.

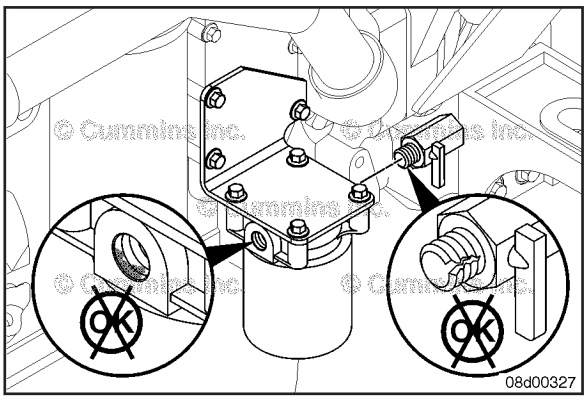


Inspect for Reuse

Marine Applications

Inspect the coolant filter valves and filter head for corrosion, cracks, and damaged threads.

Make sure the valves will fully open and close.



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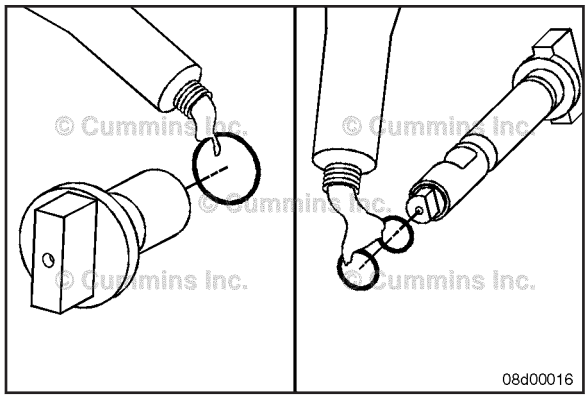
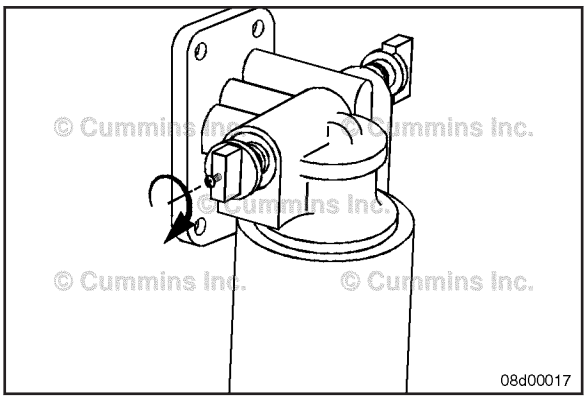


Install

All Applications Except Marine

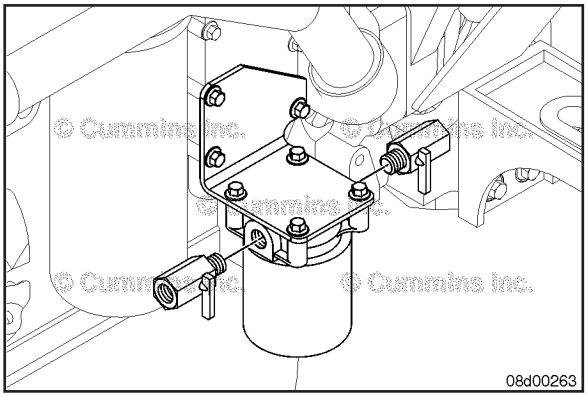
Replace the shutoff valve o-rings.

Lubricate the o-rings before installing the valve pieces back into the bore.



Tighten the shutoff valve screw to tighten the two pieces of the valve together.

Torque Value: 1.5 N•m [12 in-lb]



Marine Applications

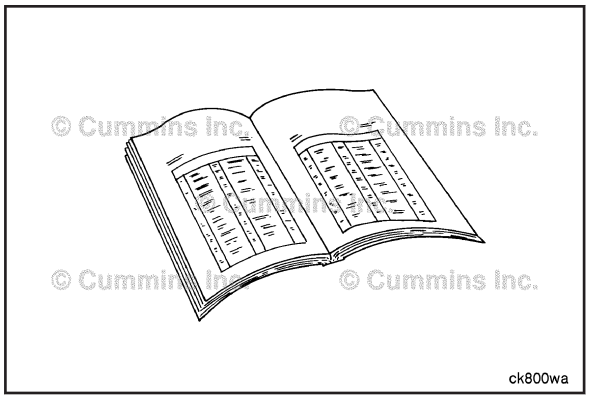
Install the shutoff valves to the filter head.

Finishing Steps

All Applications Except Marine

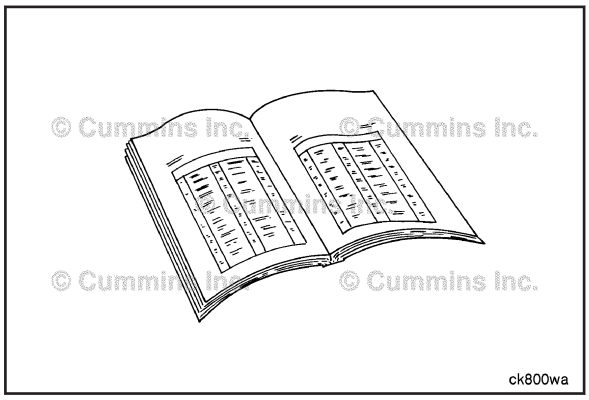
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

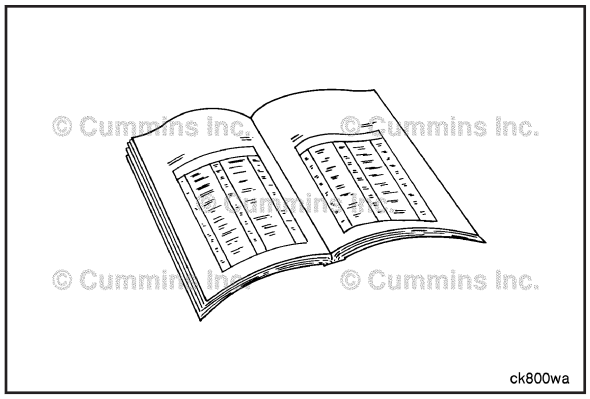
- Install the coolant filter head on the engine. Refer to Procedure 008-007 in Section 8.
- Install the coolant filter. Refer to Procedure 008-006 in Section 8.
- Fill the cooling system with either a 50/50 mixture of good-quality water and fully formulated antifreeze or fully formulated coolant. The fully formulated antifreeze or coolant must meet TMC RP329 or TMC RP330 specifications. Refer to Procedure 008-018 in Section 8.
- Connect the battery. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.



Marine Applications

- Install the coolant filter head, if removed. Refer to Procedure 008-007 in Section 8.
- Install the coolant hose connections to the inlet and outlet valves.
- Connect the coolant inlet and outlet lines and tighten the hose connections.
- Fill the cooling system with either a 50/50 mixture of good-quality water and fully formulated antifreeze or fully formulated coolant. The fully formulated antifreeze or coolant **must** meet TMC RP329 or TMC RP330 specifications. Refer to Procedure 008-018 in Section 8.
- Operate the engine and check for leaks.





Coolant Heater (008-011)

Preparatory Steps

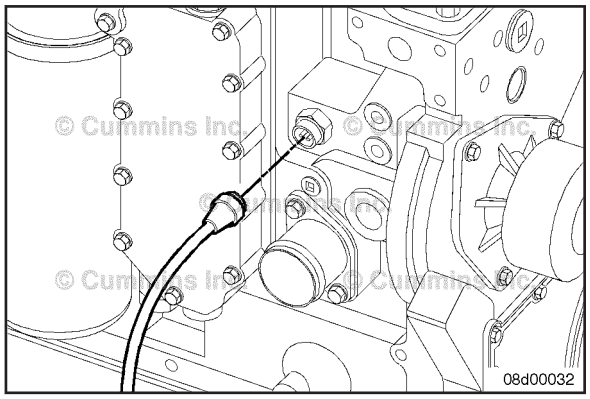
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

△CAUTION△
Use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

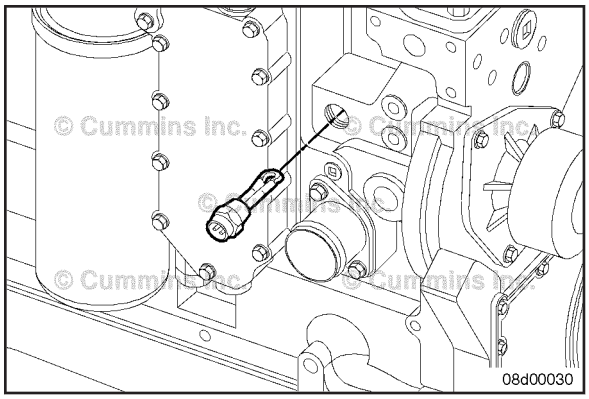
- Disconnect the battery. Refer to Procedure 013-009 in Section 13.
- Drain at least 19 liters [5 U.S. gal] of coolant. Refer to Procedure 008-018 in Section 8.



Remove

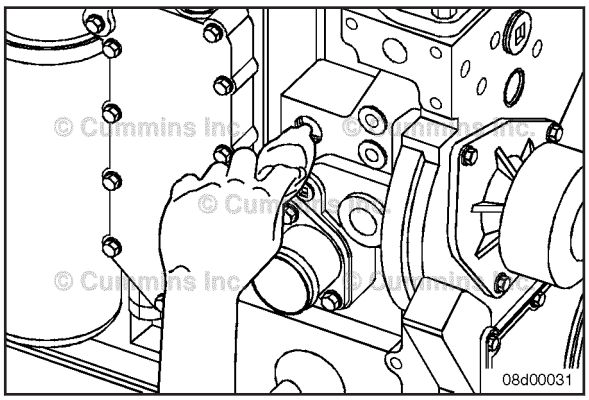
Disconnect the coolant heater electrical cord.

Loosen the coolant heater, and remove it from the cylinder block.



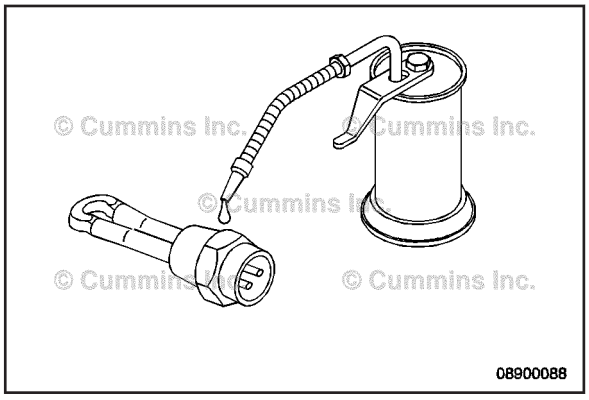
Clean

Clean the coolant heater and block threads thoroughly.



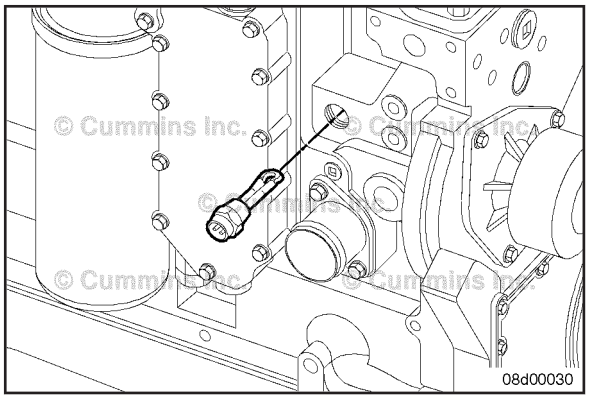
Install

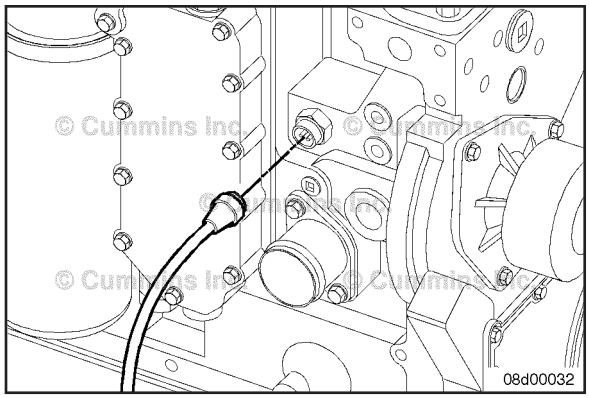
Lubricate the new coolant heater threads with clean engine oil.



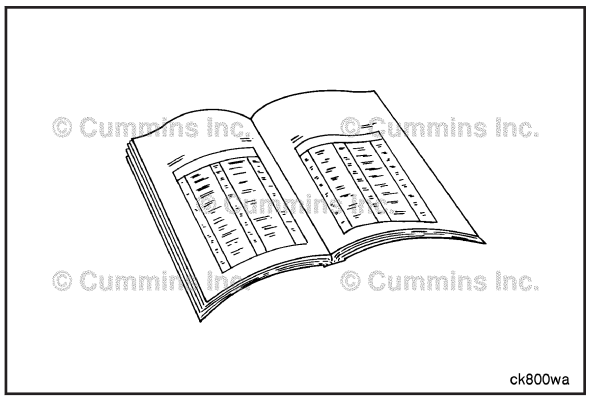
Install the coolant heater.

Torque Value: 75 N•m [55 ft-lb]





Attach the coolant heater electrical cord.

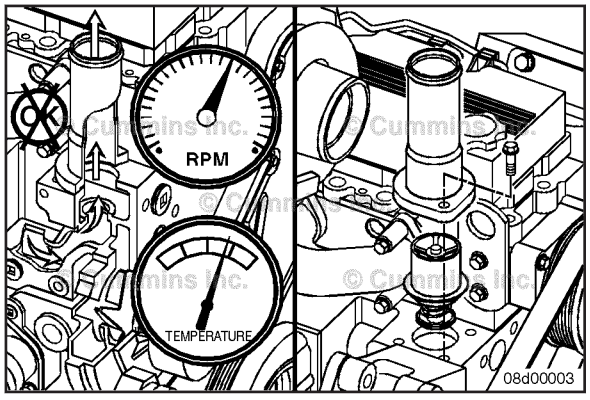


Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the battery. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.



Coolant Thermostat (008-013)

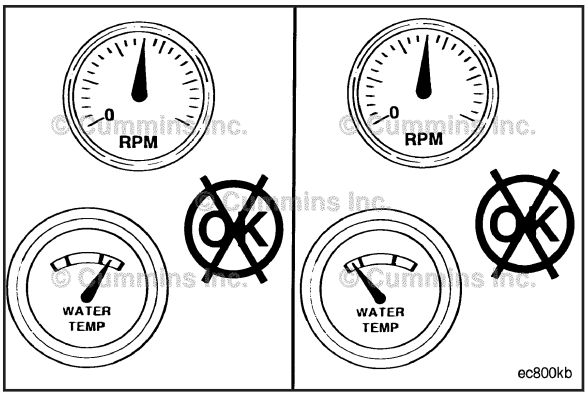
General Information

The thermostat controls the coolant temperature. When the coolant temperature is below operating temperature, coolant is bypassed to the inlet of the water pump. When the coolant temperature reaches the operating range, the thermostat opens, seals off the bypass, and forces coolant to flow to the radiator or the keel cooler on QSL9 marine engines. The thermostat begins opening at 82°C [180°F].

NOTE: Some applications use an original equipment manufacturer (OEM) supplied remote mounted thermostat. Refer to the OEM manual for location. Refer to the OEM service manual for remote mounted thermostat removal and installation instructions.

⚠CAUTION⚠
Never operate the engine without a thermostat. Without a thermostat, the path of least resistance for the coolant is through the bypass to the pump inlet. This will cause the engine to overheat.

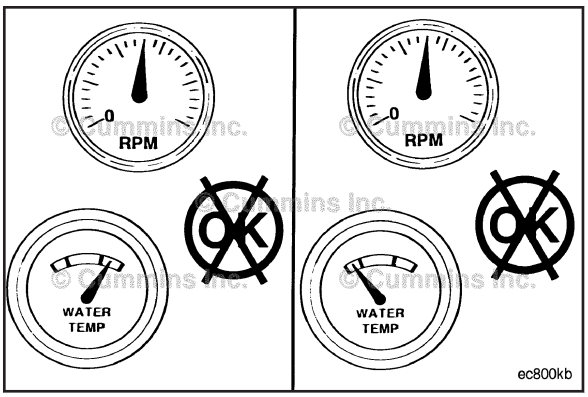
An incorrect or malfunctioning thermostat can cause the engine to run too hot or too cold.



Leak Test

NOTE: The leak test portion of this procedure does **not** apply to QSL9 keel cooled marine engines. To test QSL9 keel cooled engines. Refer to Procedure 008-014 in Section 8.

The engine thermostat and thermostat seal **must** operate properly in order for the engine to operate in the most efficient heat range. Overheating or overcooling will shorten engine life.



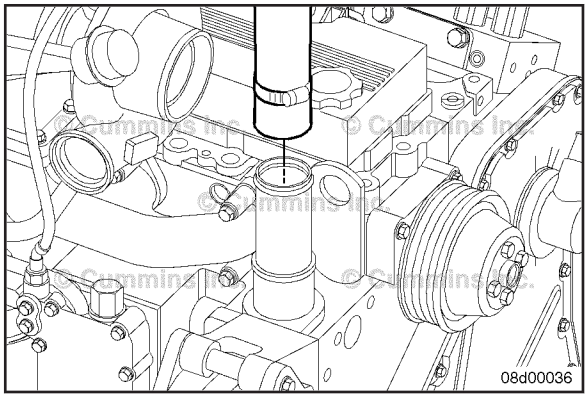
⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

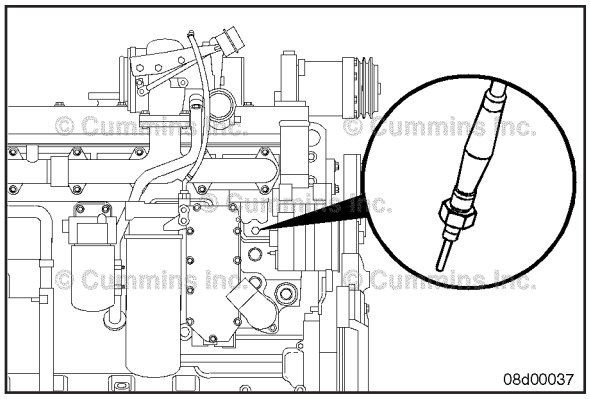
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠CAUTION⚠
On marine engines, use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

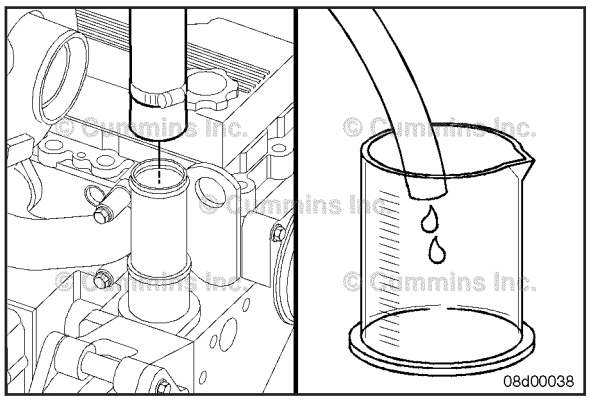
Drain the coolant. Refer to Procedure 008-018 in Section 8.

Remove the radiator hose from the water outlet connection.





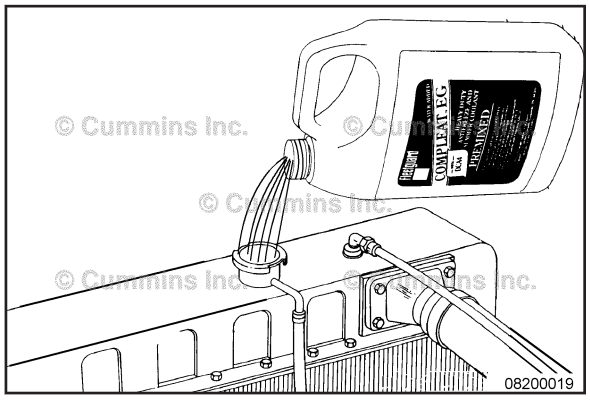
Use an electronic service tool to monitor the coolant temperature, or install a thermocouple or temperature gauge, which is known to be accurate, in the cylinder block on the engine side of the thermostat.



Install a hose of the same size on the water outlet connection. It must be long enough to reach a remote, dry container used to collect coolant.

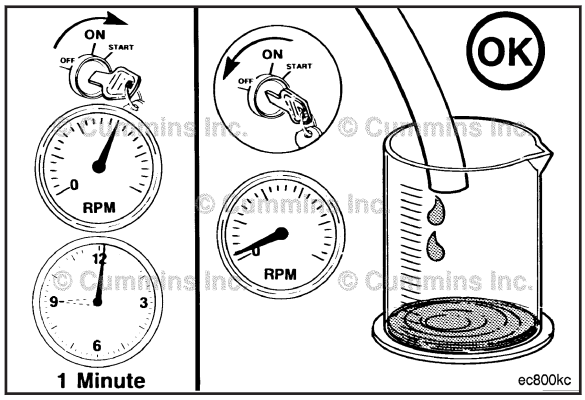
Install and tighten a hose clamp on the housing outlet.

Place the other end of the hose in a dry container.



⚠CAUTION⚠
Always vent the engine and aftercooler during filling to remove air from the coolant system, or overheating will result.

Fill the cooling system. Refer to Procedure 008-018 in Section 8.



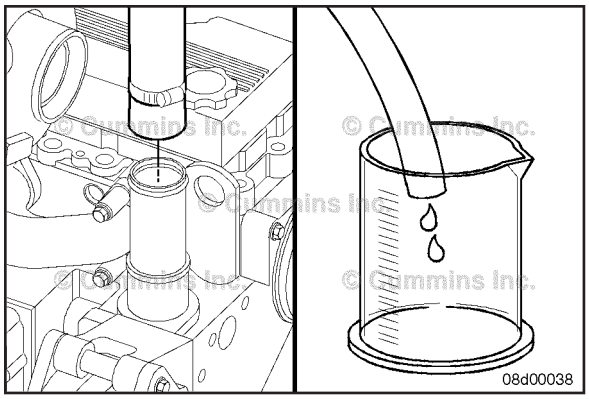
NOTE: The engine coolant temperature **must** be below the thermostat opening temperature to perform this test.

Operate the engine at rated speed for 1 minute.

Shut the engine OFF and measure the amount of coolant collected in the container.

The amount of coolant collected **must not** be more than 100 cc [3.3 fl oz].

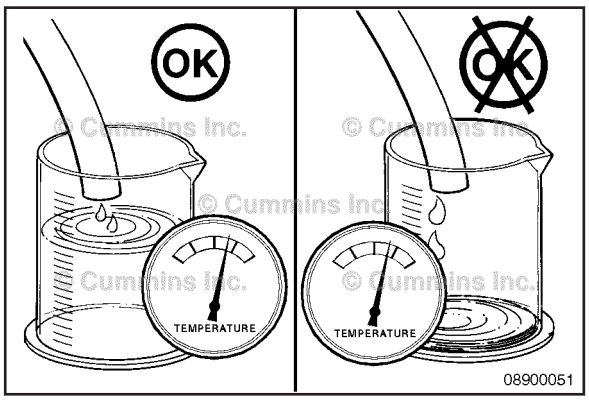
If more than 100 cc [3.3 fl oz] of coolant is collected, the thermostat is leaking and **must** be replaced.



Complete the following test in-chassis to determine the thermostat opening temperature.

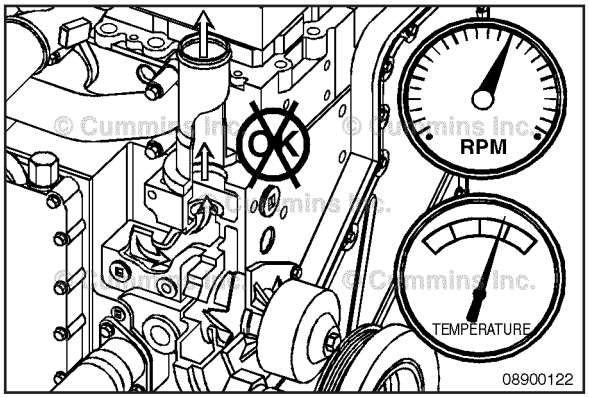
Start the engine and monitor the coolant temperature with INSITE™ electronic service tool or a gauge. Keep the engine speed below 1500 rpm during the test.

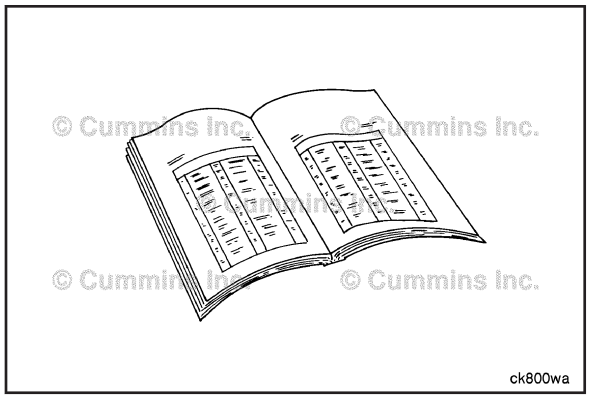
Thermostat Initial Opening Temperature		
°C		°F
81	MIN	178
83	MAX	182



Shut the engine OFF when the coolant starts to flow.

If coolant does **not** start flowing into the container during the initial opening temperature range, the thermostat **must** be replaced.





Preparatory Steps

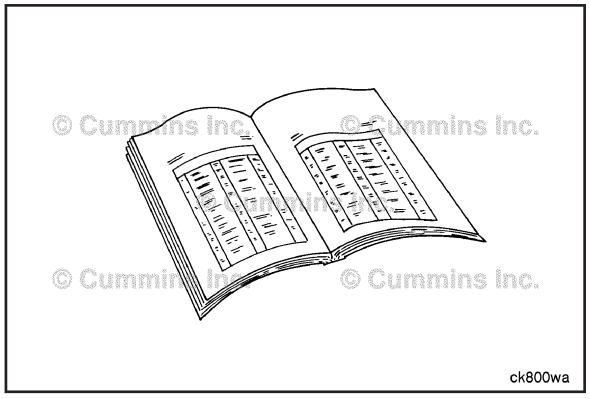
All Applications Except Marine

⚠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.

- Disconnect the batteries. See equipment manufacturer service information.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the radiator hose from the water outlet connection.



Marine Applications

⚠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 draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.
- On QSC8.3 and QSL9 engines with heat exchangers, remove the coolant hose from the water outlet connection.

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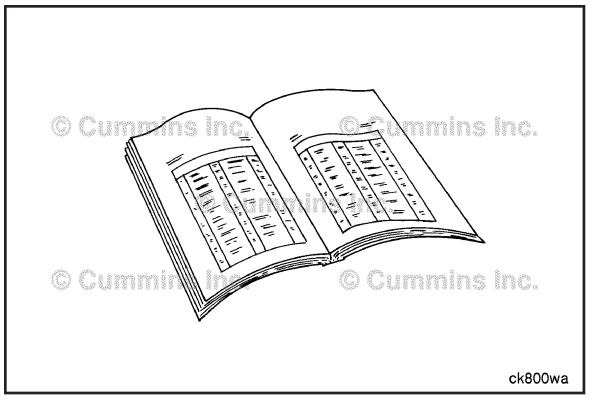
- On QSL9 engines with keel cooling, remove the coolant hose from the inlet side of the keel cooler thermostat housing.

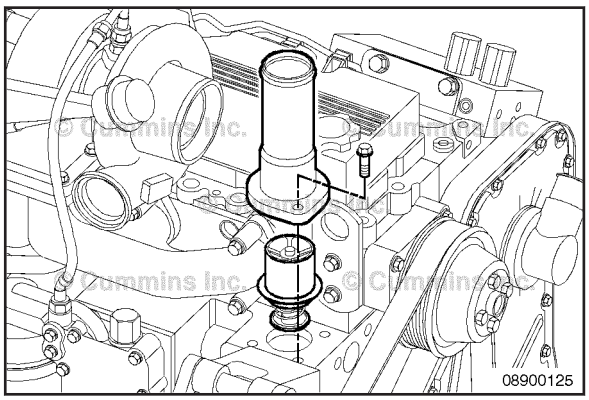


Remove

All Applications Except Marine

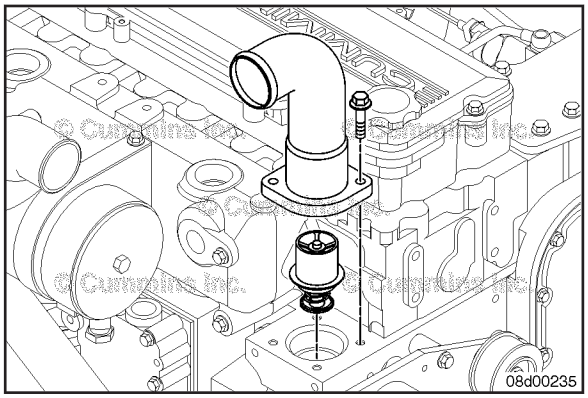
Remove the water outlet connection capscrews and water outlet connection.

Remove the thermostat.

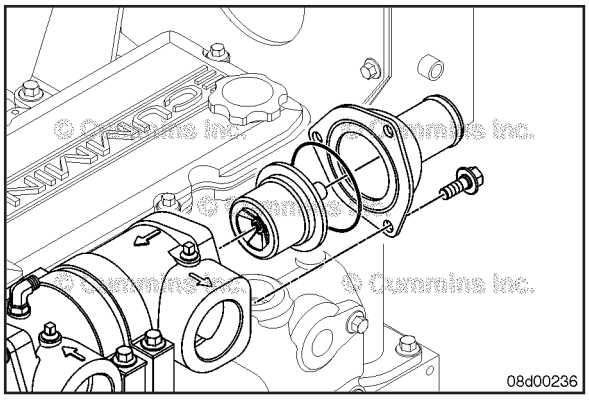


Marine Applications

On marine engines with heat exchangers, remove the water outlet connection capscrews and the water outlet connection from the top of the cylinder head.



On QSL9 engines with keel cooling, remove the water inlet connection capscrews and the water inlet connection from the keel cooled thermostat housing.



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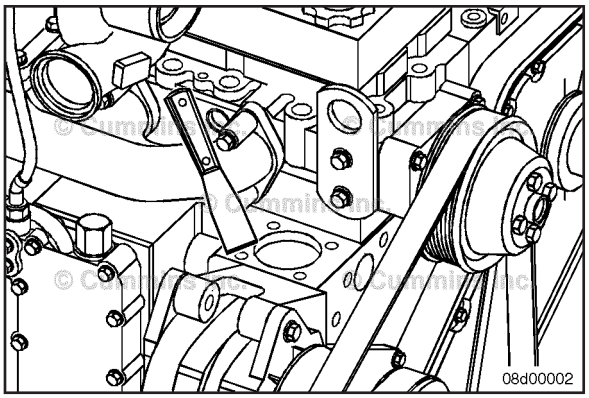
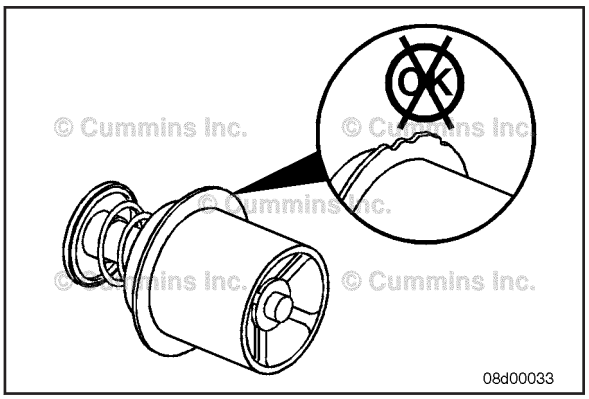


Clean and Inspect for Reuse

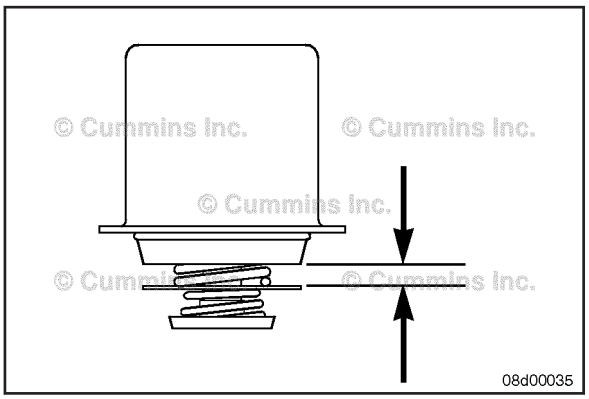
Clean all of the mating surfaces.

NOTE: Do **not** let any debris fall into the thermostat cavity when cleaning the surfaces.



Inspect the thermostat for damage.

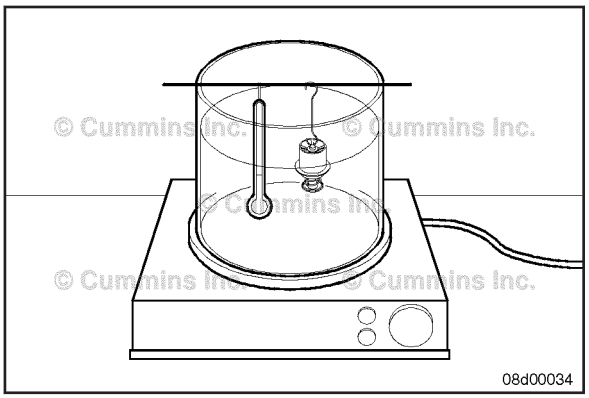
Inspect the thermostat gasket for damage. If the gasket is damaged, it **must** be replaced.



The nominal operating temperature is stamped on the thermostat. The thermostat **must** meet the following criteria:

- The thermostat **must** begin to open within 1°C or 2°F of this nominal temperature.
- The thermostat **must** be fully open within 12°C or 22°F of this nominal temperature.

The fully open distance between the thermostat flange and housing is 9.4 mm [0.370 in].



Heat the water and check the thermostat as follows:

- Suspend the thermostat and a 100°C [212°F] thermometer in a container of water.
- Do **not** allow the thermostat or the thermometer to touch the sides of the container.

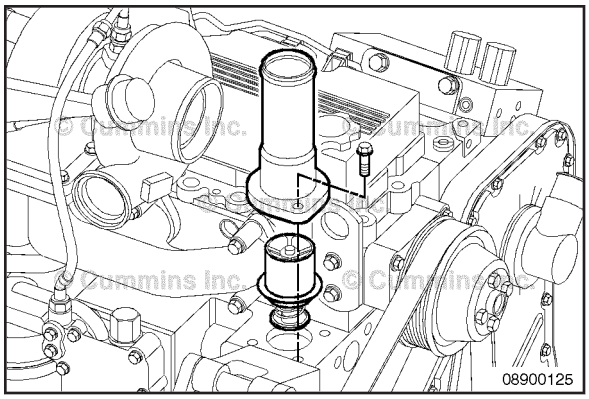
Install

All Applications Except Marine

Install the new thermostat into the water outlet connection. Make sure the top and bottom o-rings are in place. If the o-rings are damaged, replace with new o-rings.

Install the water outlet connection and mounting capscrews.

Torque Value: 24 N•m [212 in-lb]

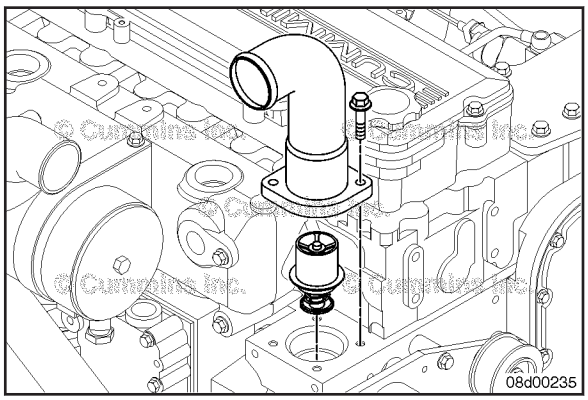


Marine Applications

On QSC8.3 and QSL9 engines with heat exchangers, install the thermostat into the water outlet connection. Make sure that the top and bottom o-rings are in place.

Install the water outlet connection and mounting capscrews.

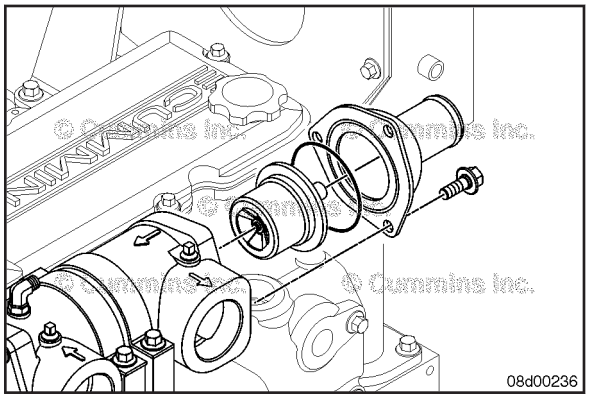
Torque Value: 24 N•m [212 in-lb]

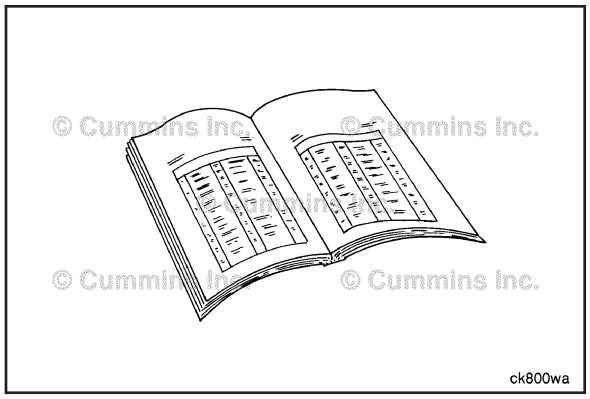


On QSL9 engines with keel cooling, install the thermostat into the water inlet connection of the keel cooled thermostat housing.

Install the water outlet connection.

Torque Value: 24 N•m [212 in-lb]





Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

△CAUTION△

Always vent the engine and aftercooler during filling to remove air from the coolant system, or overheating will result.

- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Reference the equipment manufacturer service information.
- Operate the engine and check for leaks.

Coolant Thermostat Housing (008-014)

General Information

QSL Engines

This procedure applies to QSL9 keel cooled engines **only**.

Preparatory Steps

QSL Engines

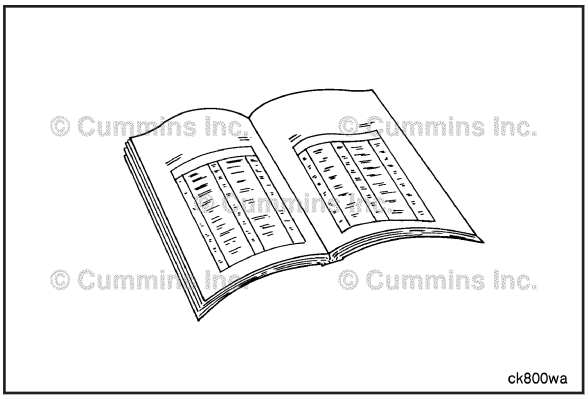
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠CAUTION⚠
Use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

- Disconnect the batteries. Refer to Procedure 013-009.
- Drain the engine coolant. Refer to Procedure 008-018.
- Disconnect the keel cooler inlet and outlet connections. Refer to the OEM service manual.
- Disconnect the coolant vent line from the thermostat housing. Refer to Procedure 008-017.
- Disconnect the thermostat housing coolant inlet and outlet hoses.



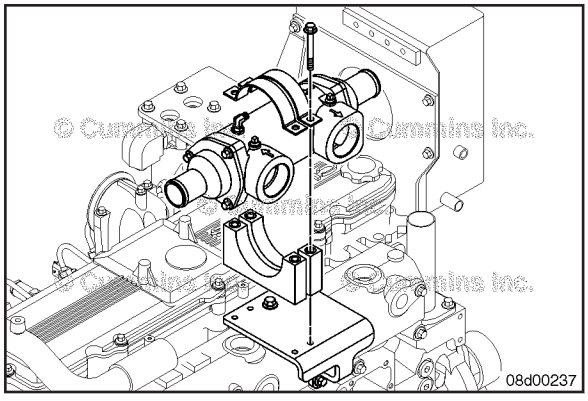
Remove

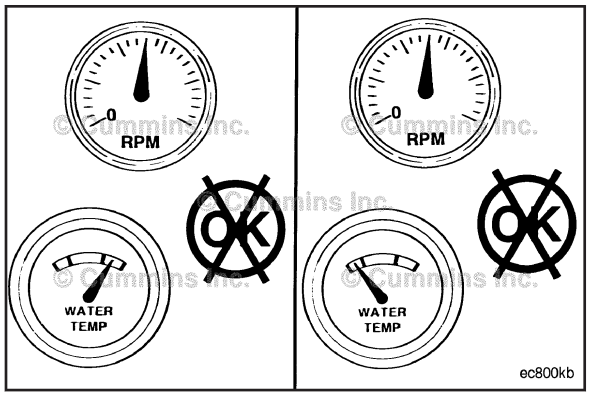
QSL Engines

Remove the four thermostat housing mounting capscrews.

Remove the two clamps and the thermostat housing.

Remove the two vibration isolators.

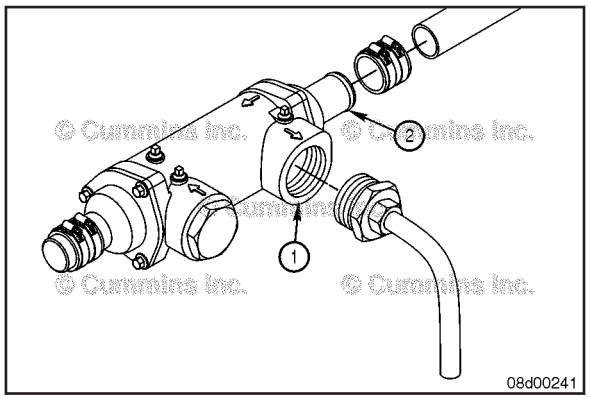




Leak Test

QSL Engines

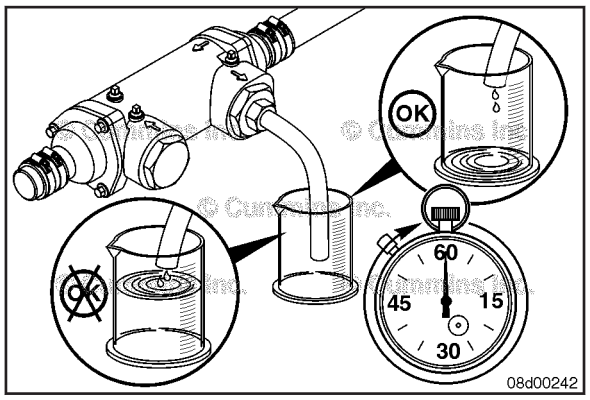
The engine thermostat and thermostat seal **must** operate properly in order for the engine to operate in the most efficient heat range. Overheating or overcooling will shorten engine life.



Fabricate a test fixture to seal all of the water outlet connections except the outlet port to the keel cooler and the inlet port of the thermostat housing.

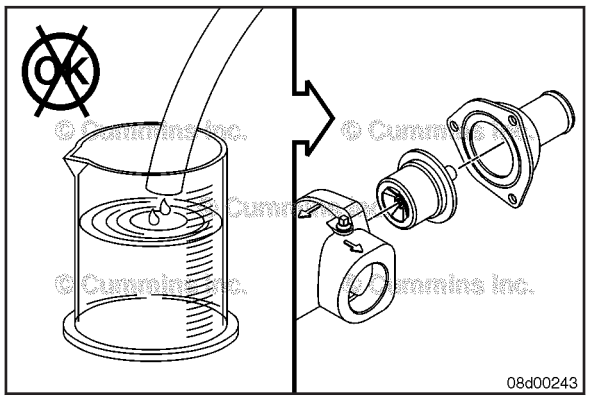
For the outlet port to the keel cooler (1), install a hose long enough to reach a remote, dry container used to collect water. Place the open end of the hose in the dry container.

Connect a water hose to the inlet port (2) of the thermostat housing capable of regulating 152 kPa [22 psi] of filtered tap water.



Apply 152 kPa [22 psi] of water pressure to the thermostat housing for one minute.

The maximum allowable leakage is 100 cc [3.4 fl oz] per minute.



If more than 100 cc [3.4 fl oz] of coolant is collected, the thermostat or thermostat seal is leaking and **must** be replaced. Refer to Procedure 008-016 to replace the thermostat seal.

Disassemble

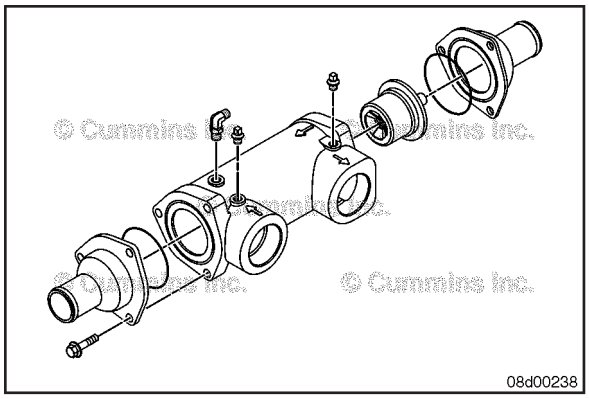
QSL Engines

Remove the three capscrews and hose connections from the ends of the thermostat housing.

Remove the o-rings from the ends of the housing.

Remove the keel cooler hose connections.

Remove the coolant vent fitting and pipe plugs from the housing.

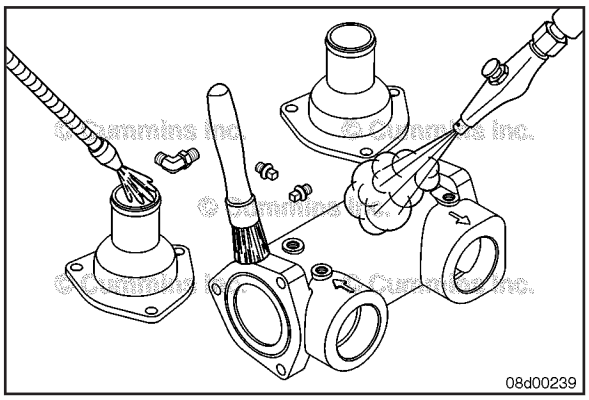


Clean and Inspect for Reuse

QSL Engines

Clean the parts with soap and water.

Dry with compressed air.

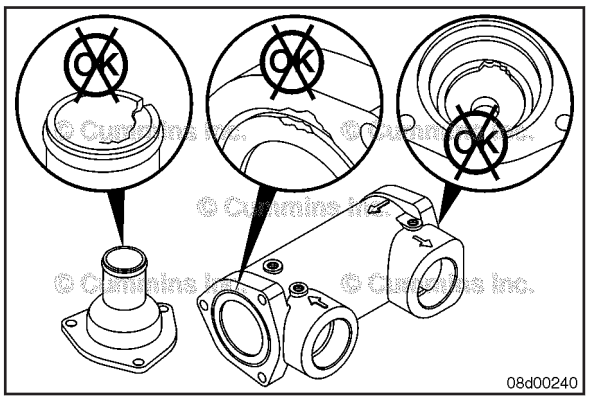


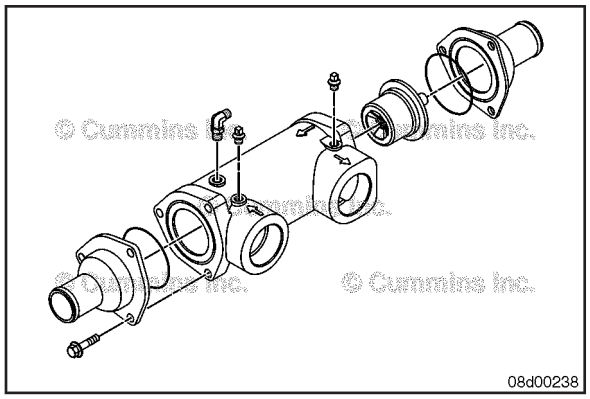
Inspect the components for cracks, nicks, or other damage.

Inspect the thermostat seal for damage. Replace the seal if damaged. Refer to Procedure 008-016.

Inspect the isolators for damage or cracks.

Replace any damaged parts.





Assemble

QSL Engines

Install the thermostat into the thermostat housing.

Install a new o-ring on the thermostat housing.

Install the water inlet connection and three mounting capscrews. Tighten the capscrews.

Torque Value: 44 N•m [32 ft-lb]

Install a new o-ring on the other end of the thermostat housing and the water outlet connection. Install the three capscrews and tighten.

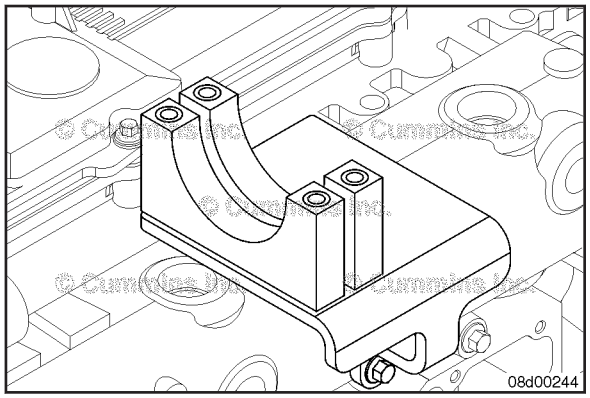
Torque Value: 44 N•m [32 ft-lb]

Install the two pipe plugs and tighten.

Torque Value: 15 N•m [133 in-lb]

Install the coolant vent line fitting. Tighten the fitting so it faces the thermostat housing inlet end.

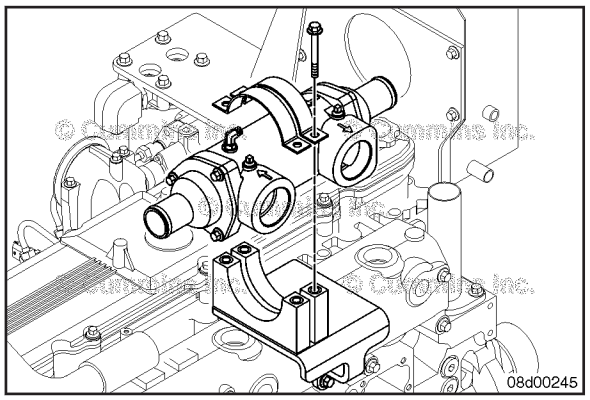
Install the keel cooler inlet and outlet fittings. Refer to the OEM service manual.



Install

QSL Engines

Place the vibration isolators on top of the thermostat housing support bracket.



Install the thermostat housing onto the isolators using clamps and capscrews as shown.

Tighten the capscrews.

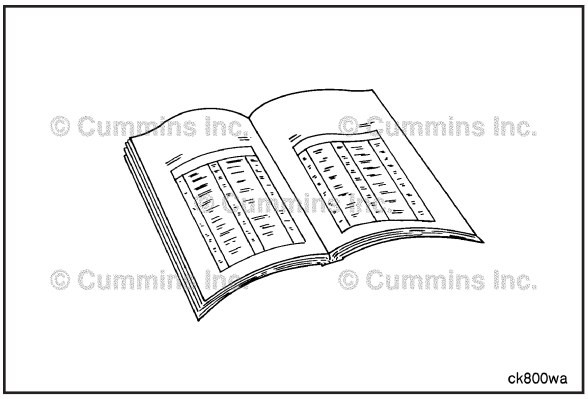
Torque Value: 44 N•m [32 ft-lb]

Finishing Steps

QSL Engines

- Install the coolant inlet and outlet hoses.
- Install the coolant vent line. Refer to Procedure 008-017.
- Install the keel cooler inlet and outlet hoses. Refer to the OEM service manual.
- Fill the engine with coolant. Refer to Procedure 008-018.
- Connect the batteries. Refer to Procedure 013-009.

Operate the engine and check for leaks.



Coolant Thermostat Housing Support (008-015)

General Information

QSL Engines

This procedure applies to marine QSL9 keel cooled engines **only**.

Preparatory Steps

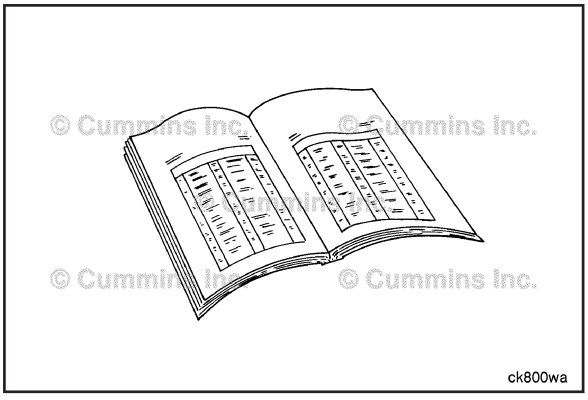
QSL Engines

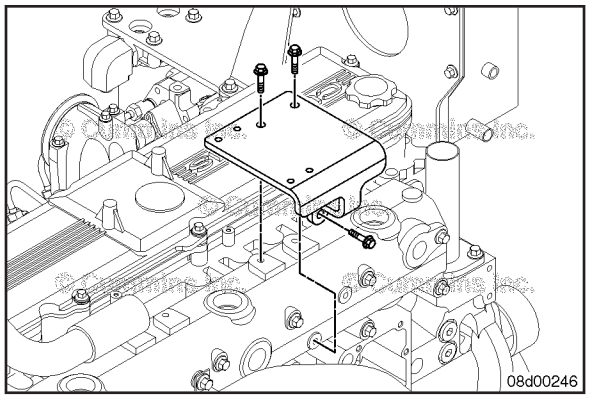
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

△CAUTION△
Use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

- Drain the engine coolant. Refer to Procedure 008-018.
- Remove the thermostat housing. Refer to Procedure 008-014.

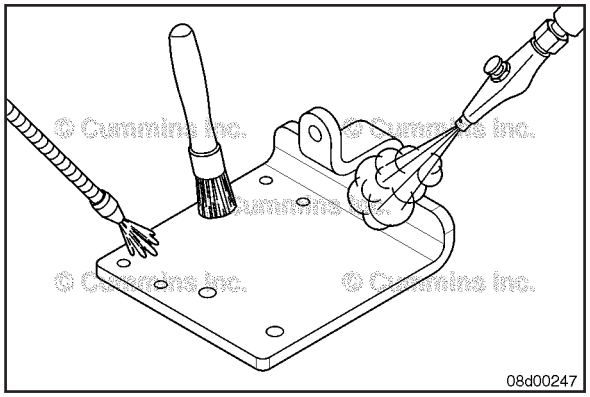




Remove

QSL Engines

Remove the three thermostat housing support mounting capscrews and the thermostat housing support.



Clean and Inspect for Reuse

QSL Engines

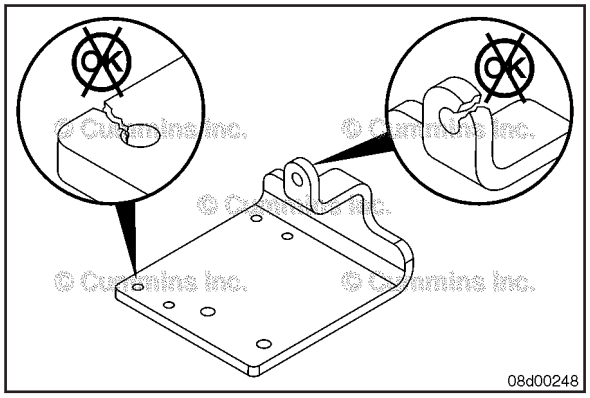
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use solvent to clean the bracket.

Dry with compressed air.



Inspect the bracket for cracks or other damage.

Repair or replace the bracket, if damaged.

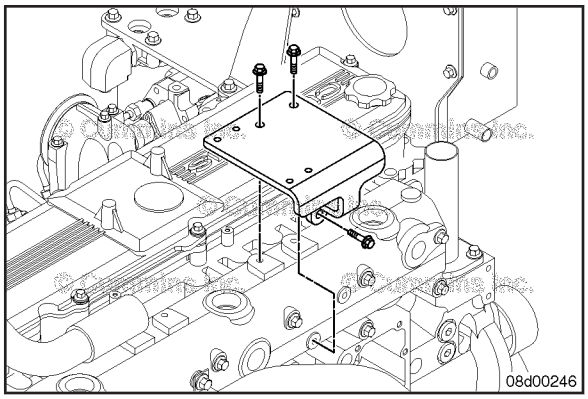
Install

QSL Engines

Install the thermostat housing bracket and mounting capscrews.

Tighten the capscrews.

Torque Value: 44 N•m [32 ft-lb]

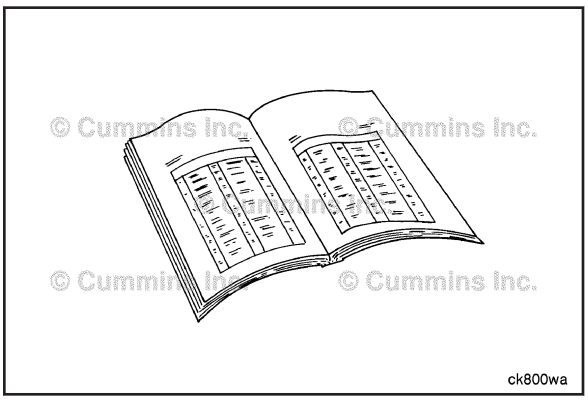


Finishing Steps

QSL Engines

- Install the thermostat housing. Refer to Procedure 008-014.
- Fill the engine with coolant. Refer to Procedure 008-018.

Operate the engine and check for leaks.



Coolant Thermostat Seal (008-016)

Preparatory Steps

Marine Applications

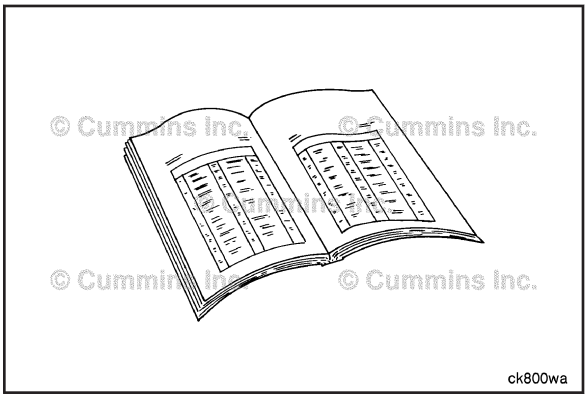
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠CAUTION⚠
Use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

NOTE: This procedure applies **only** to QSL9 engines with keel cooling.

- Drain the engine coolant. Refer to Procedure 008-018.
- Remove the coolant thermostat housing. Refer to Procedure 008-014.
- Remove the coolant thermostat. Refer to Procedure 008-013.



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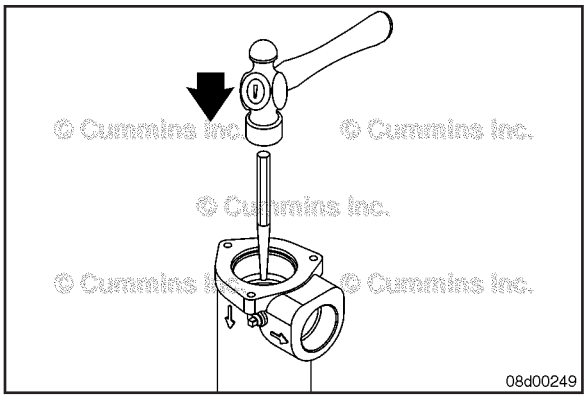
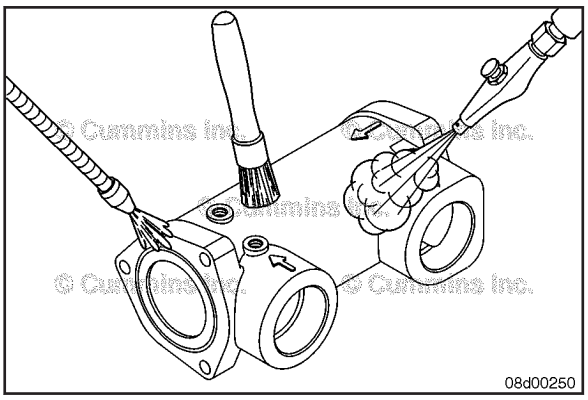


Remove

⚠CAUTION⚠
Use care when removing the thermostat seal, the thermostat housing can be damaged.

Use a punch and hammer to remove the seal from the housing.



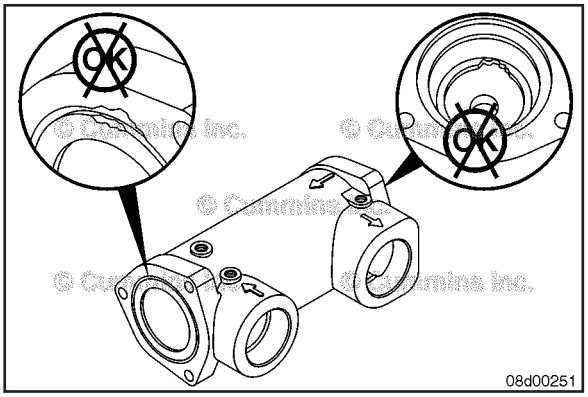
Clean and Inspect for Reuse

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

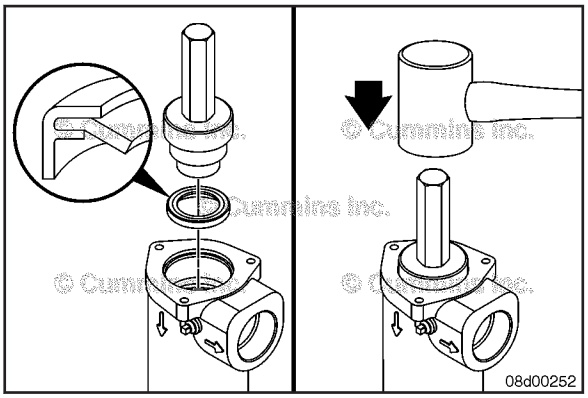
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use solvent to clean the thermostat housing.

Dry with compressed air.



Inspect the thermostat housing for cracks, pits, or other damage.



Install

When installing a new seal, the part number side of the seal **must** be facing the mandrel.

Use thermostat seal mandrel, Part Number 3375411, and a hammer to install the seal.

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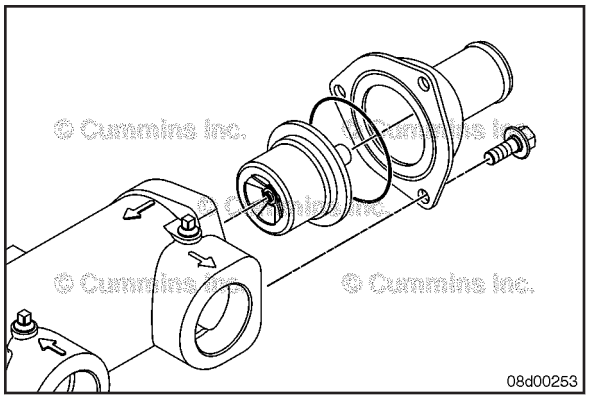
Install the thermostat in the housing.

Install a new o-ring in the groove on the thermostat housing mounting surface.

Install the thermostat housing cap over the end of the housing using three capscrews. Tighten the capscrews.

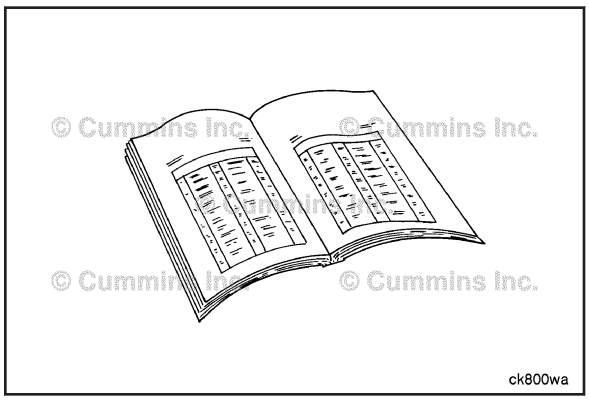
Torque Value: 44 N•m [32 ft-lb]



Finishing Steps

- Install the thermostat housing. Refer to Procedure 008-014.
- Fill the engine with coolant. Refer to Procedure 008-018.

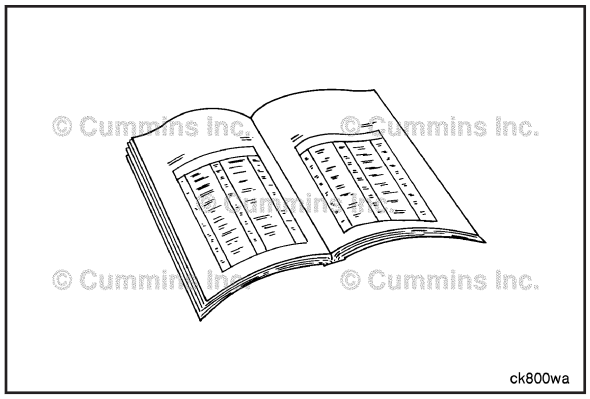
Operate the engine and check for leaks.



Coolant Vent Lines (008-017)

General Information

This procedure applies to the QSL9 and QSC8.3 marine engines **only**.



Preparatory Steps

⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

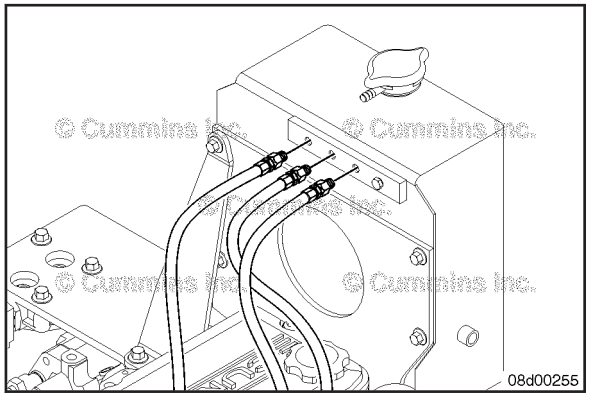
⚠WARNING⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

△CAUTION△

Use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.



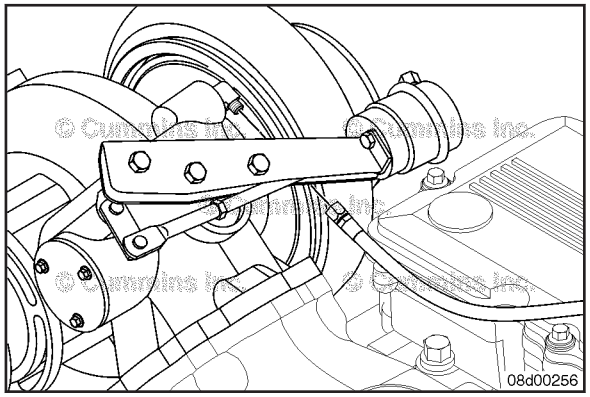
Remove

QSL Engines

Disconnect the exhaust manifold vent line from the expansion tank and the top of the exhaust manifold.

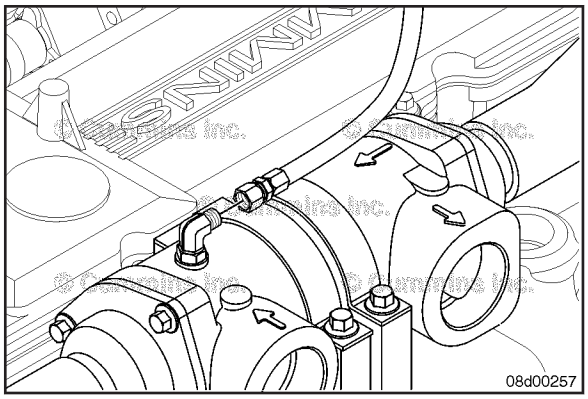
Disconnect the cylinder head vent line from the expansion tank and the top of the cylinder head.

Disconnect the turbocharger vent line from the top of the expansion tank.



Disconnect the turbocharger vent line from the top of the turbocharger.

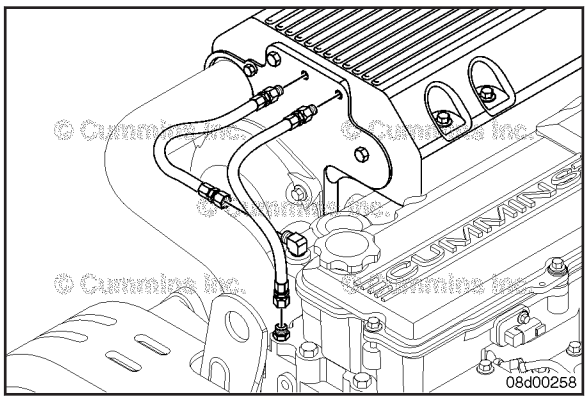
If the engine is keel cooled, disconnect the vent line from the top of the expansion tank and the top of the thermostat housing.



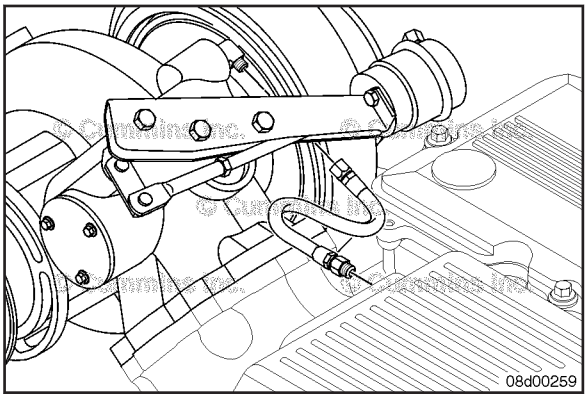
QSC Engines

Disconnect the vent line from the front of the expansion tank and the top of the exhaust manifold.

Disconnect the vent line from the front of the expansion tank and the top of the cylinder head.



Disconnect the vent line from the rear of the expansion tank and the turbocharger.



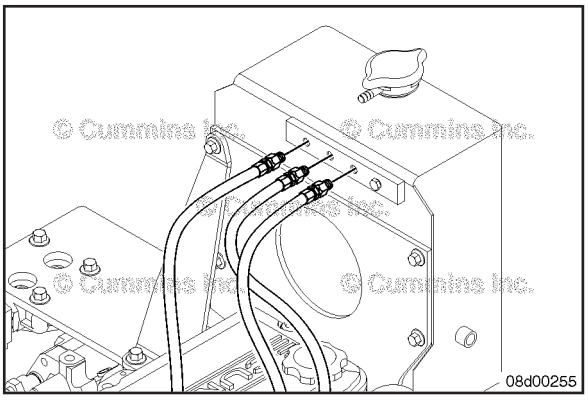
Install

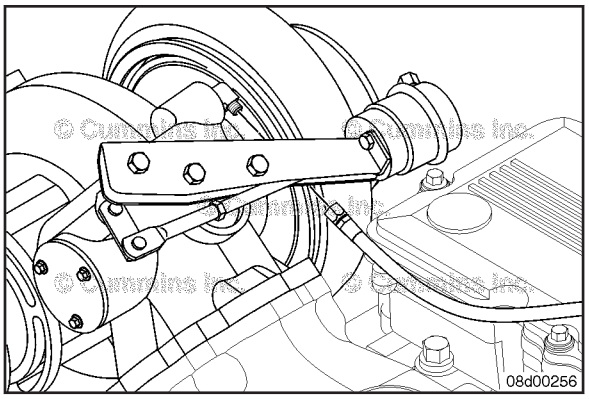
QSL Engines

Connect the vent line at the top of the expansion tank and the top of the exhaust manifold.

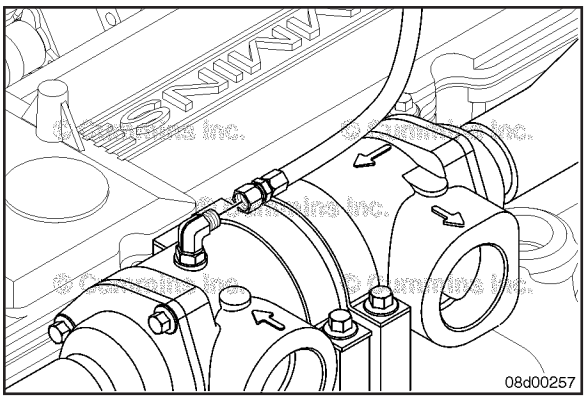
Connect the vent line for the turbocharger at the top of the expansion tank.

Connect the vent line at the top of the expansion tank and the top of the cylinder head.

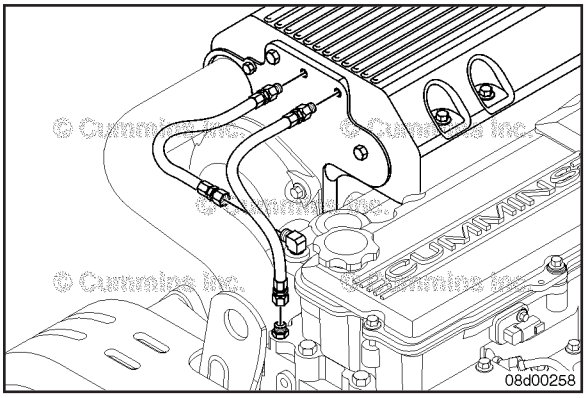




Connect the coolant vent line to the top of the turbocharger.



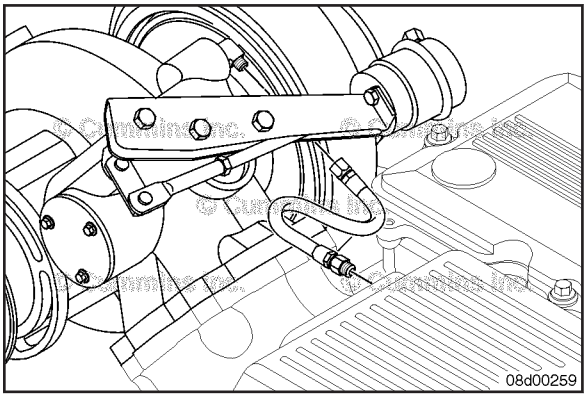
If the engine is keel cooled, connect the vent line from the top of the expansion tank and to the top of the thermostat housing.



QSC Engines

Connect the vent line at the front of the expansion tank and the top of the exhaust manifold.

Connect the vent line at the front of the expansion tank and the top of the cylinder head.



Connect the vent line at the rear of the expansion tank and the turbocharger.

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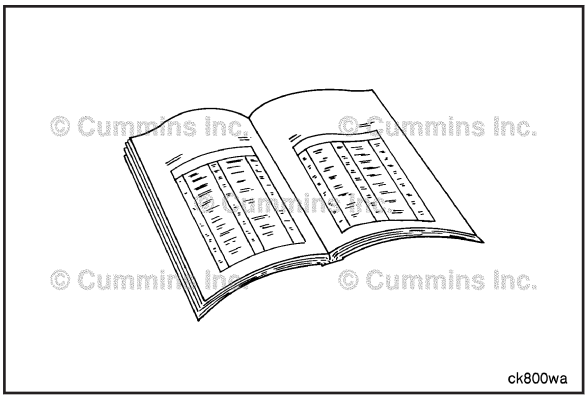
Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Fill the cooling system. Refer to Procedure 008-018 in Section 8.

Operate the engine and check for leaks.



Cooling System (008-018)

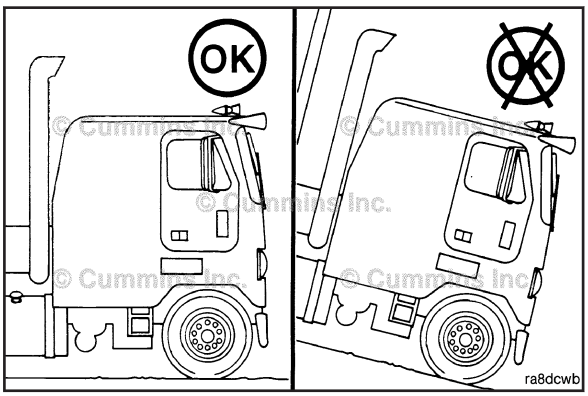
Coolant Replacer Method

Evacuation

The following steps are used to evacuate the cooling system using the coolant replacer tool, Part Number 2892459.

NOTE: When the vehicle/equipment or engine is equipped with a quick disconnect fitting in the cooling system package, the Coolant Replacer Method is the preferred method for coolant removal. Use the coolant replacer tool, Part Number 2892459. If the vehicle/equipment or engine does **not** have a quick disconnect fitting presently installed, one can be installed in the cooling system package to utilize the Coolant Replacer Method; otherwise the coolant drain and fill method **must** be used.

Position the equipment on level ground.



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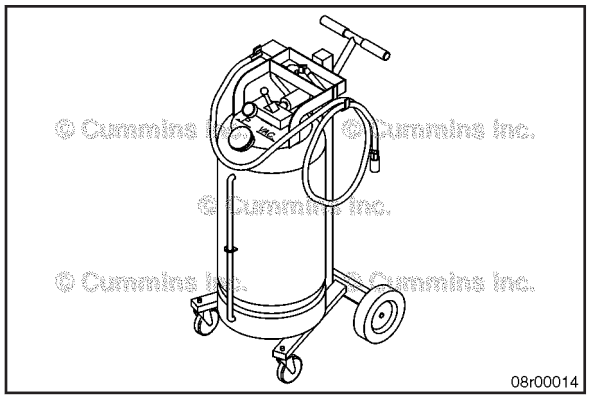


⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

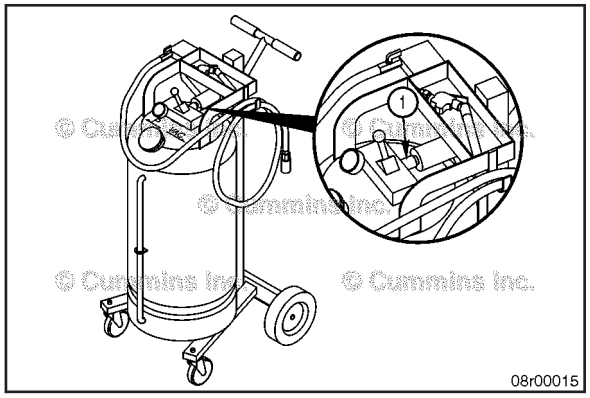
⚠CAUTION⚠
Do not use the coolant replacement tool to evacuate contaminated coolant or a system that is suspected of contamination. This could result in cross contamination of coolant. The coolant drain method should be used for removing contaminated coolant. Refer to the manufacturer's manual for specific instructions on cleaning the tool of contaminants.

NOTE: See equipment manufacturer service information for special coolant drain requirements. Special instructions may also be located near the cooling system access point or fill door on the vehicle.

Isolate the engine from the vehicle cooling system by closing coolant flow valves to the equipment heating systems before starting the repair. This will prevent the heater circuit from draining, minimizing the chance for air pockets to be present during the fill process.

This air can be very difficult to purge in some applications with several feet of plumbing and multiple heater cores.

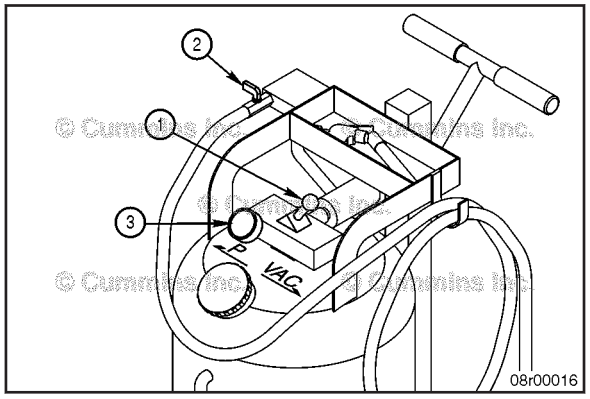
Remove the radiator cap.



⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

The coolant replacement tool tank capacity of 68 Liters [18 gal] is adequate for most applications. An additional storage tank can be used for cooling system packages with more than 68 Liters [18 gal] capacity.

Be sure there is no air pressure in the coolant replacement tool tank by opening the pressure relief valve (1) located on the control block of the coolant replacement tool.



Connect the coolant replacement tool to a shop air supply regulated at 621 kPa [90 psi].

Switch the coolant replacement tool control lever (1) to "VAC" and leave the service hose valve (2) closed. This will create a vacuum in the tank to evacuate coolant from the cooling system package.

Monitor the gauge (3) and build a vacuum of approximately 508 mm-Hg [20 in-Hg] in the coolant replacement tool tank. Once the vacuum has been achieved, move the control valve lever (1) to the middle position.

Maintain approximately a 508 mm-Hg [20 in-Hg] vacuum to achieve a faster drain.

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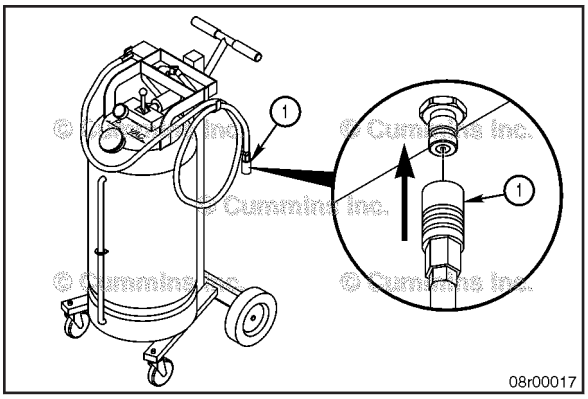
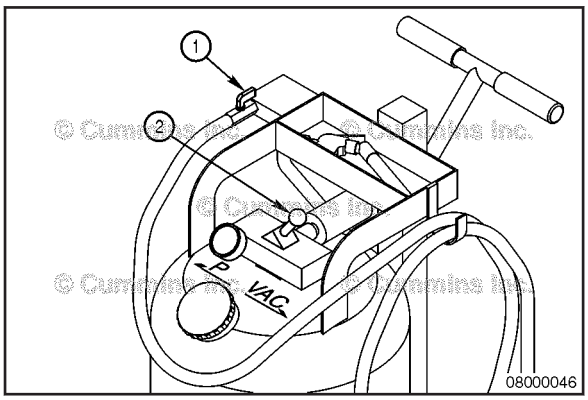
Attach the fill hose quick disconnect coupling (1) of the coolant replacement tool to the quick disconnect fitting. Location of the fitting may vary between OEMs, but the fitting is generally located in the lowest point of the vehicle/equipment cooling system package.

NOTE: Most Volvos are equipped with a different style fitting located in the radiator. An adapter hose is needed to connect the Cummins® coolant replacement tool to the fitting. The adapter hose is included in accessory kit.



Open the service hose valve (1) by turning it **clockwise** until it is completely open (approximately ¼ turn).

Additional shop air may be required to maintain enough of a system vacuum to remove the coolant from the system. This can be done by moving the control valve lever (2) back to the VAC position.

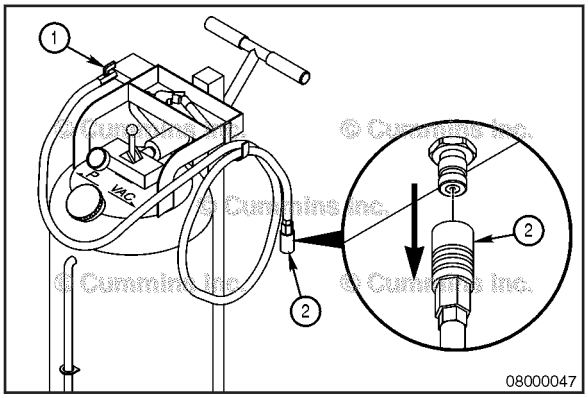


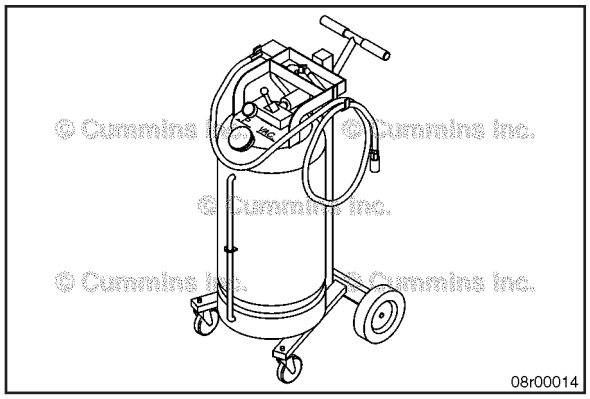
When the cooling system has been evacuated, a coolant and air mixture will be visible in the clear section of the coolant replacement tool fill hose.

NOTE: Some residual coolant will settle in the coolant package as the recessed areas of the block continue to drain down over the next few minutes.

Once the system has been evacuated, turn the service hose valve (1) to the closed position by turning the valve **counterclockwise** a ¼ turn. Disconnect the shop air connection from the coolant replacer tool.

Disconnect the fill hose quick disconnect coupling (2) on the coolant replacement tool from the quick disconnect fitting.





Injection

⚠CAUTION⚠
The cooling system must be filled properly to prevent air locks or serious engine damage can result.

The following steps are used to inject coolant into the cooling system using the coolant replacer tool, Part Number 2892459.

NOTE: When the vehicle/equipment or engine is equipped with a quick disconnect fitting in the cooling system package, the Coolant Replacer Method is the preferred method for coolant removal. Use the coolant replacer tool, Part Number 2892459. If the vehicle/equipment or engine does **not** have a quick disconnect fitting presently installed, one can be installed in the cooling system package to utilize the Coolant Replacer Method; otherwise the coolant drain and fill method **must** be used.

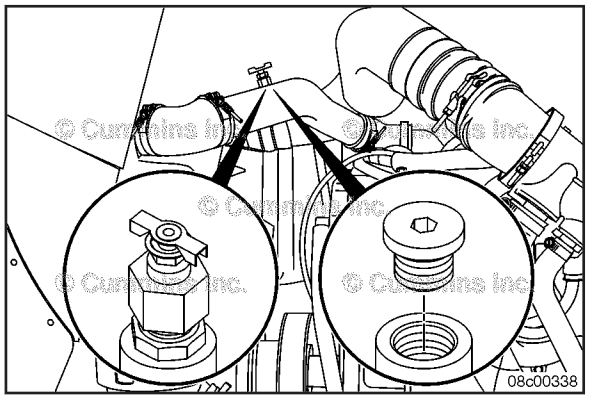
Cummins Inc. recommends the use of either a 50/50 mixture of good quality water and fully-formulated antifreeze, or fully-formulated coolant when filling the cooling system. The fully-formulated antifreeze or coolant **must** meet TMC RP329 or TMC RP330 specifications.

Good quality water is important for cooling system performance. Excessive levels of calcium and magnesium contribute to scaling problems, and excessive levels of chlorides and sulfates cause cooling system corrosion.

Water Quality	
Calcium Magnesium (Hardness)	Maximum 170 ppm as ($CaCO_3$ + $MgCO_3$)
Chloride	40 ppm as (Cl)
Sulfate	100 ppm as (SO_4)

Cummins Inc. recommends the use of Fleetguard® ES COMPLEAT™. It is available in glycol forms (ethylene and propylene) and complies with TMC RP329 and RP330 standards.

Refer to Cummins® Coolant Requirement and Maintenance, Bulletin 3666132, for more engine coolant specifications.



⚠CAUTION⚠
Opening the manual bleed valve or removing the pipe plug on applicable installations is critical. Failure to do so can result in engine damage.

NOTE: Some applications can have a manual bleed valve or pipe plug that is required to be opened to properly fill the system. The upper radiator pipe is a common location.

If applicable, open the manual bleed valve or remove the pipe plug before filling the cooling system.

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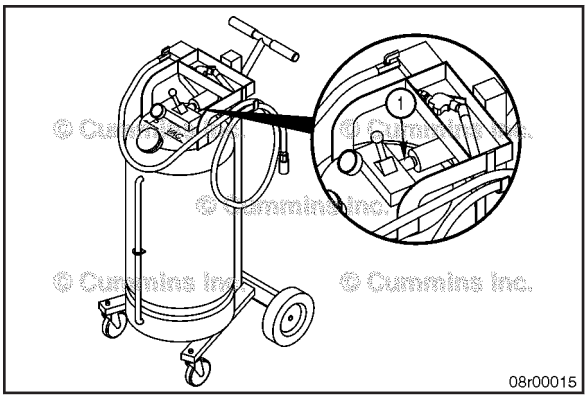
Be sure there is no air pressure in the coolant replacement tool tank by opening the pressure relief valve (1) located on the control block of the coolant replacement tool.



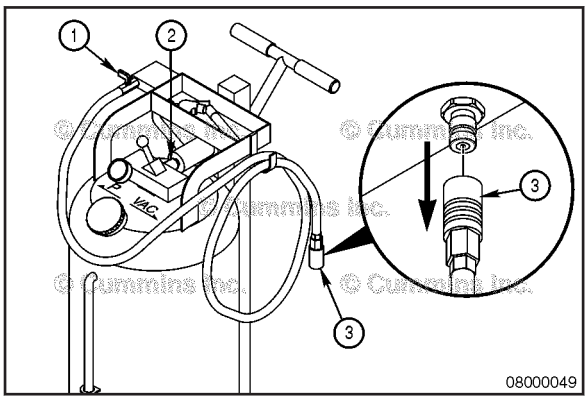
Connect the coolant replacement tool to a shop air supply regulated at 621 kPa [90 psi].

Attach the fill hose quick disconnect coupling (1) of the coolant replacement tool to the quick disconnect fitting located in the vehicle/equipment cooling system package.

With the service hose valve (2) in the closed position, switch the coolant replacement tool control lever (3) to “P” and build 172 kPa [25 psi] pressure on the gauge.

Slowly open the service hose valve (2) part way by turning it **counterclockwise** approximately 1/8 turn.

Do **not** open the ball valve completely as this will increase the coolant flow rate and increase the amount of air pockets created in the cooling system; This will provide a more complete injection of coolant.

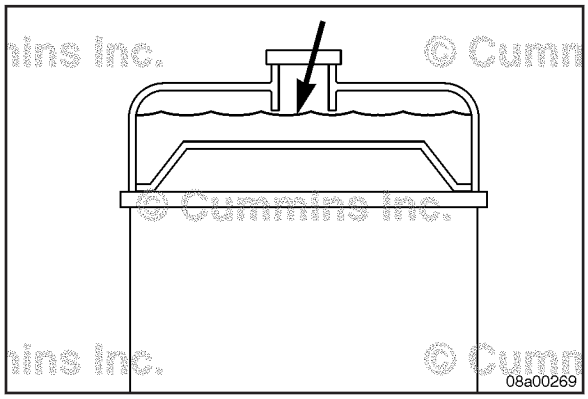


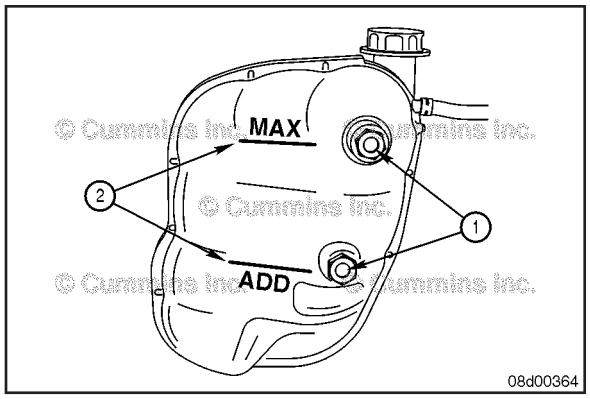
Fill the cooling system with coolant to the bottom of the fill neck in the radiator fill or recovery/expansion tank or until the coolant replacer tool is empty (whichever occurs first).

On applications that use a coolant recovery system, check to make sure the coolant is at the appropriate level in the coolant recovery tank for the engine temperature.

Many coolant recovery/expansion tanks, also called auxiliary tanks, have sight glasses or are made of a clear material (**not** shown) to aid in checking the coolant level without removing the radiator cap.

It is important to understand the impact of temperature on the expansion of the coolant. Most auxiliary tanks do **not** have a provision for a "FULL HOT" coolant level. Filling the "top tank" while hot will result in a low operating level once the system has cooled.





⚠CAUTION⚠

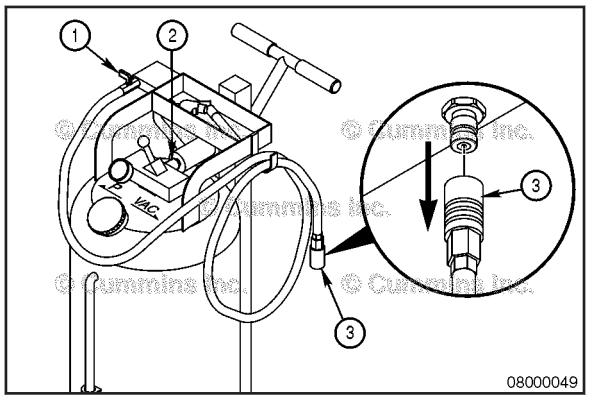
The cooling system must be filled properly to prevent air locks or serious engine damage can result.

NOTE: If all coolant drained from the system was collected, the same volume or more **must** go back into the system. If any drained coolant remains in the tool after filling, this is an indication of an air pocket in the cooling system package which **must** be purged before returning the vehicle to service.

NOTE: Top off of coolant might be necessary for repairs that were performed to correct a coolant loss issue.

If all coolant drained from the system would **not** return to the system or the level is above the maximum level. This is an indication of an air pocket in the cooling system package, which **must** be purged before returning the vehicle to service.

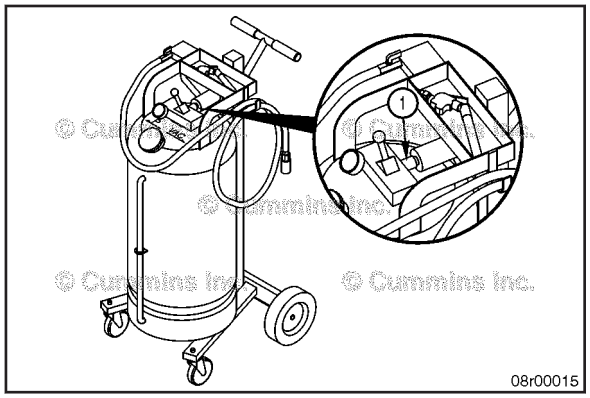
To remove an air pocket from the cooling system, the coolant replacement tool can be used. Refer to the vacuum section of this procedure.



Once the coolant level has been returned to the correct level, close the service hose valve (1) by turning the valve **clockwise** until closed.

Remove pressure from the coolant replacement tool tank by opening the pressure release valve on the back of the control block (2).

Disconnect the service hose quick disconnect coupling (3) from the quick disconnect fitting of the vehicle/equipment.



Vacuum

The following steps are used to place a vacuum on the cooling system using the coolant replacer tool, Part Number 2892459.

Be sure there is no air pressure in the coolant replacement tool tank by opening the pressure relief valve (1) located on the control block of the coolant replacement tool.

Clamp off any vent hoses/connections or overflow to the cooling system.

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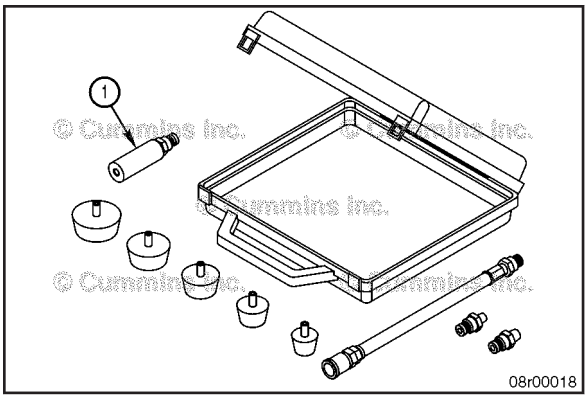
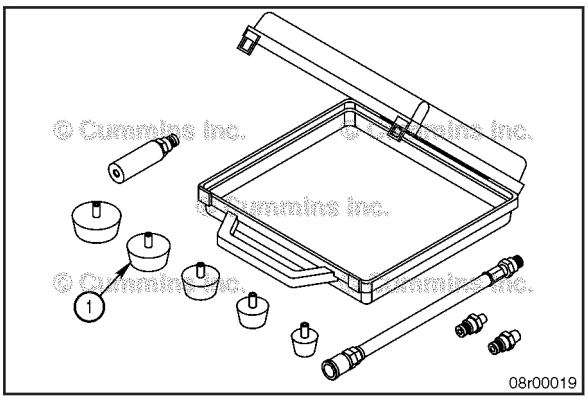
Attach the coolant dam handle (1) to the fill hose of the coolant replacement tool.



Attach the appropriate size coolant dam rubber adapter (1) onto the coolant dam handle.

The size of the fill neck will differ between OEMs choose the appropriate sized coolant dam rubber adapters.

Connect the coolant replacement tool to shop air regulated at 621 kPa [90 psi].



Place the coolant dam over the coolant fill neck in the radiator or overflow tank.

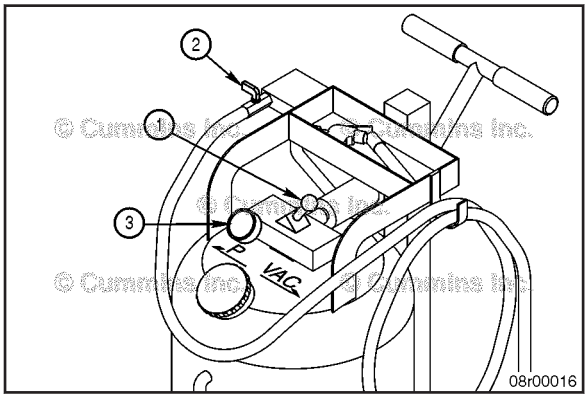
The size of the fill neck will differ between OEMs. Choose the appropriate sized coolant dam rubber adapters.

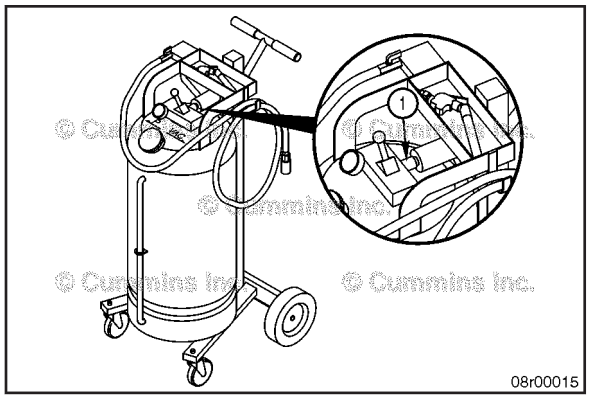
Switch the coolant replacement tool control lever (1) to “VAC” and leave the service hose valve (2) closed. This will create a vacuum in the tank to evacuate coolant from the cooling system package.

Monitor the gauge (3) and build a vacuum of approximately 508 mm-Hg [20 in-Hg] in the coolant replacement tool tank.

Slowly open the service hose valve (2) by turning it **clockwise** until it is completely open approximately ¼ turn.

Once the cooling system is put into a vacuum, any air trapped in the cooling system will be evacuated through the top of the system. This is noticed as air bubbles through the overflow tank or top of the radiator.



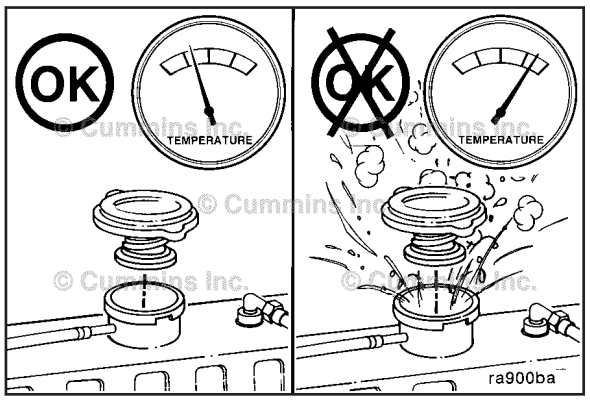


When air bubbles are no longer being drawn to the top of the cooling system move the control lever to the middle position. Remove the vacuum on the coolant replacement tool tank by opening the pressure relief valve located on the control block of the coolant replacement tool (1).

Remove the coolant dam from the radiator fill neck or overflow tank.

Disconnect the coolant replacement tool from the regulated shop air supply.

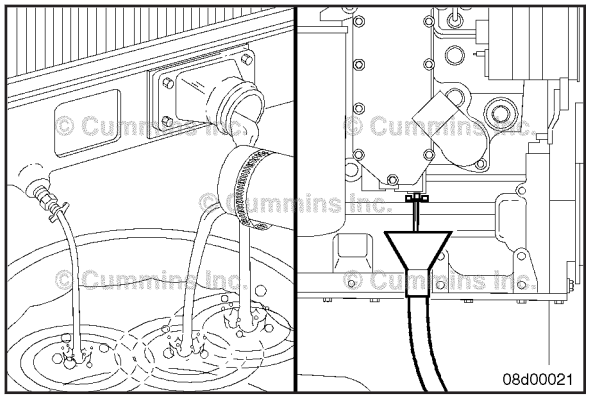
Install the radiator cap.



Drain

⚠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.

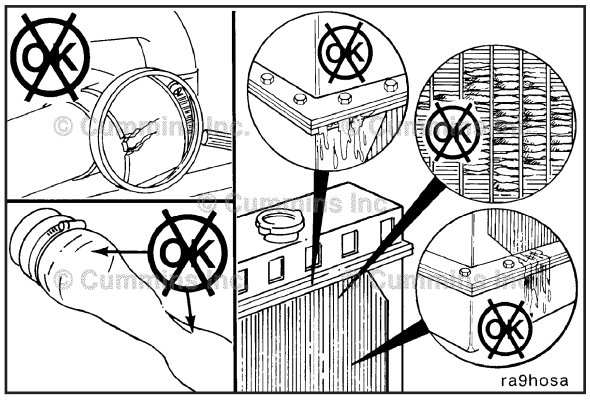
Remove the pressure cap.



⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Drain the cooling system by opening the drain valve on the radiator and by opening the drain valve on the bottom of the engine oil cooler housing. A drain pan with a capacity of 57 liters [15 gal] is adequate in most applications.

After the cooling system is completely drained, close the drain valves. Refer to the equipment manufacturer service information for complete cooling system drain information.

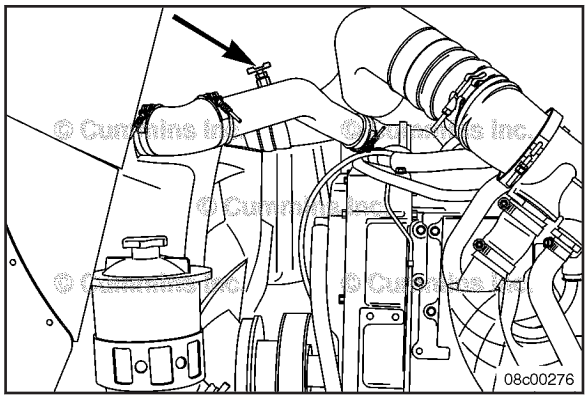


Check for damaged hoses and loose or damaged hose clamps. Replace as required.

Check the radiator for leaks, damage, and buildup of dirt.

Clean and replace as required.

Fill

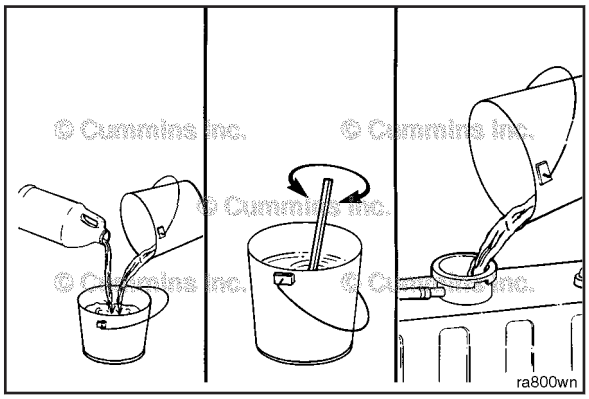


⚠CAUTION⚠
Opening the manual bleed valve on applicable installations is critical. Failure to do so can result in engine damage.

NOTE: Some applications can have a manual bleed valve that is required to be opened to properly fill the system. The upper radiator pipe is a common location for bleed valves. The illustration is for reference **only**.

If applicable, open the manual bleed valve before filling the cooling system.

Once filled, close the manual bleed valve.



⚠CAUTION⚠
The system must be filled properly to prevent air locks or serious engine damage can result. During filling, air must be purged from the engine coolant passages. Be sure to open the petcock on the aftercooler for aftercooled engines. Wait 2 to 3 minutes to allow the air to be vented; then add the mixture to bring the coolant level to the top.

⚠CAUTION⚠
During all coolant fill procedures, all coolant flow valves to equipment heating systems must be opened in order to purge air from those systems as well as from the base engine cooling system. These valves must remain open during the engine cooling system deaeration process. Make sure adequate coolant levels are maintained in the coolant reservoir during the entire fill procedure. Special care must be taken when filling EGR cooler equipped engines to make sure all air is purged from the cooling system or serious engine damage can result.

⚠CAUTION⚠
Never use water alone for coolant. This can result in damage from corrosion.

The system has a designed fill rate of up to 19 liters [5 gal] per minute.

Refer to Procedure 018-018 in Section V.

Flush

Fleetguard® Restore™ is a heavy-duty cooling system cleaner that removes corrosion, silica gel, and other deposits. The performance of Fleetguard® Restore™ is dependent on time, temperature, and concentration levels. An extremely scaled or flow-restricted system, for example, can require higher concentrations of cleaners, higher temperatures, longer cleaning times, or the use of Restore Plus™. Up to twice the recommended concentration levels of Fleetguard® Restore™ can be used safely. Fleetguard® Restore Plus™ **must** be used **only** at its recommended concentration level. Extremely scaled or fouled systems can require more than one cleaning.

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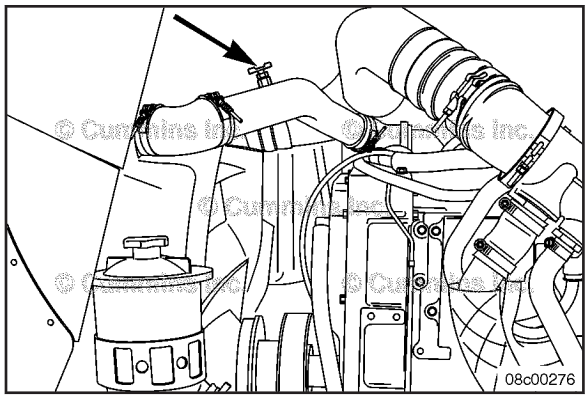

⚠CAUTION⚠
Fleetguard® Restore™ contains no antifreeze. Do not allow the cooling system to freeze during the cleaning operation.

⚠CAUTION⚠
Opening the manual bleed valve on applicable installations is critical. Failure to do so can result in engine damage.

NOTE: Some applications can have a manual bleed valve that is required to be opened to properly fill the system. The upper radiator pipe is a common location for bleed valves. The illustration is for reference **only**.

If applicable, open the manual bleed valve before filling the cooling system.

Once filled, close the manual bleed valve.

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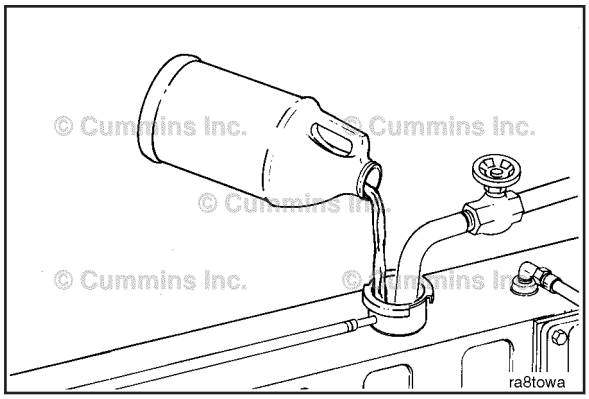
⚠WARNING⚠
Do not stand near the surge tank or radiator while operating the engine with the pressure cap off. If the vehicle is equipped with a fill door on the side of the surge tank, keep it closed due to coolant expansion.

△CAUTION△
Fleetguard® Restore™ contains no antifreeze. Do not allow the cooling system to freeze during the cleaning operation.

△CAUTION△
Opening the manual bleed valve on applicable installations is critical. Failure to do so can result in engine damage.

△CAUTION△
The system must be filled properly to prevent air locks or serious engine damage can result. During filling, air must be purged from the engine coolant passages. Make sure to open the petcock on the aftercooler for aftercooled engines. Wait 2 to 3 minutes to allow the air to be vented; then add the mixture to bring the coolant level to the top.

NOTE: Some applications can have a manual bleed valve that is required to be opened to properly fill the system. The upper radiator pipe is a common location for bleed valves. The illustration is for reference **only.**



If applicable, open the manual bleed valve before filling the cooling system.

Once filled, close the manual bleed valve.

NOTE: Add 3.8 liters [1 gal] of Fleetguard®, Restore™, Restore Plus™, or equivalent for each 38 to 57 liters [10 to 15 gal] of cooling system capacity.

Fill the cooling system to the capacity or level stated in the OEM service manual.

Use plain water.

Open all coolant flow valves to equipment heating systems. See the OEM service manual for valve locations.

Wait 2 to 3 minutes, without starting the engine, to allow the coolant level to stabilize.

Add plain water to bring the level back to FULL.

Turn all cab heater switches to HIGH in order to allow maximum coolant flow through the heater core(s). The blower does **not** have to be ON.

With the pressure cap off:

- Operate the engine at LOW IDLE for 2 minutes.
- Shut the engine OFF and add plain water to bring the level back to FULL.

With the pressure cap off:

- Operate the engine at LOW IDLE for 1 minute to allow adequate oil pressure to build throughout the engine.
- Operate the engine at HIGH IDLE until the thermostat opens.

Operate the engine at low idle 2 minutes before shutting it down. This allows adequate cool down of pistons, cylinders, bearings, and turbocharger components.

Shut the engine OFF and check the coolant level according to the OEM service manual recommendations and add coolant, if necessary, to bring it back to the FULL level.

Install the pressure cap.

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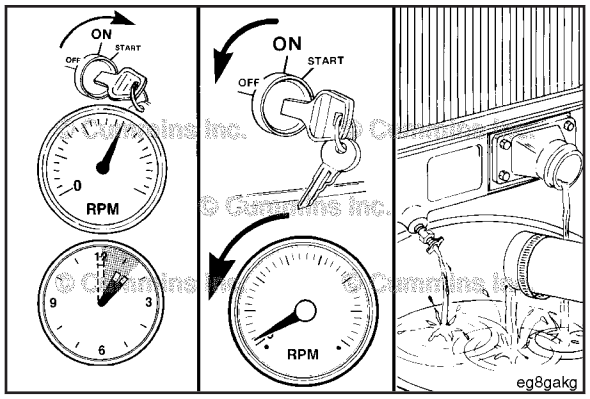
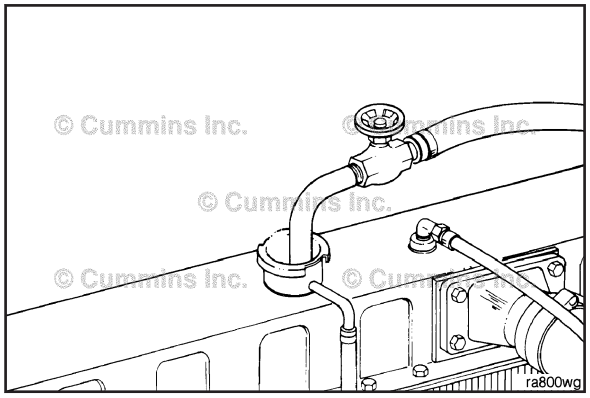


⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Operate the engine at normal operating temperatures, at least 85°C [185°F], for 1 to 1 ½ hours.

Shut the engine OFF allow to cool to 50°C [122°F], and drain the cooling system.



⚠WARNING⚠
Do not stand near the surge tank or radiator while operating engine with the pressure cap OFF. If the vehicle is equipped with fill door on the side of the surge tank, keep it closed due to coolant expansion.

Remove the pressure cap.

Fill the cooling system to the capacity or level stated in the OEM service manual.

Open all coolant flow valves to equipment heating systems. See the OEM service manual for valve locations.

Wait 2 to 3 minutes without starting the engine to allow the system to naturally purge entrained air and the coolant level to stabilize.

Add plain water to bring the level back to FULL.

Turn all cab heater switches to HIGH in order to allow maximum coolant flow through the heater core(s). The blower **must** be turned ON.

With the pressure cap off:

- Operate the engine at LOW IDLE for 2 minutes.
- Shut the engine OFF and add plain water to bring the level back to FULL.

With the pressure cap off:

- Operate the engine al LOW Idle for 1 minute to allow adequate oil pressure to build throughout the engine.
- Operate the engine at HIGH Idle until the thermostat opens.

Continue to operate the engine at HIGH idle for 5 minutes with the coolant temperature above 85°C [185°F].

Allow the engine to idle 2 minutes before shutting it down. This allows adequate cool down of pistons, cylinders, bearings, and turbocharger components.

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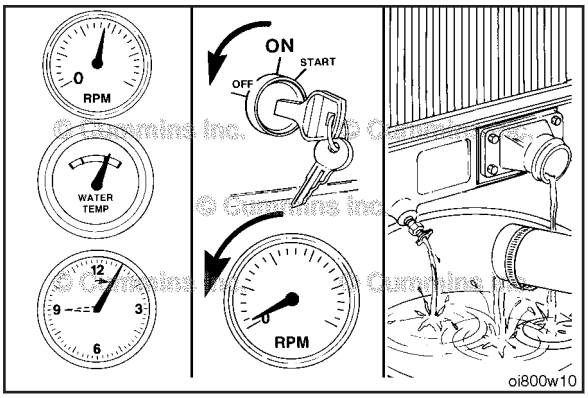
⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Shut the engine OFF. Allow it to cool to 50°C [122°F], and drain the cooling system.

If the water being drained is still dirty, the system **must** be flushed again, until the drained water is clean.



Cooling System Diagnostics (008-020)

General Information

The following procedure covers common troubleshooting steps to help identify:

- Engine overheating causes. See the Initial Check section of this procedure.

NOTE: At the end of this procedure, a worksheet is provided to record any measured values taken during troubleshooting. The worksheet will help in gathering and analyzing the data.

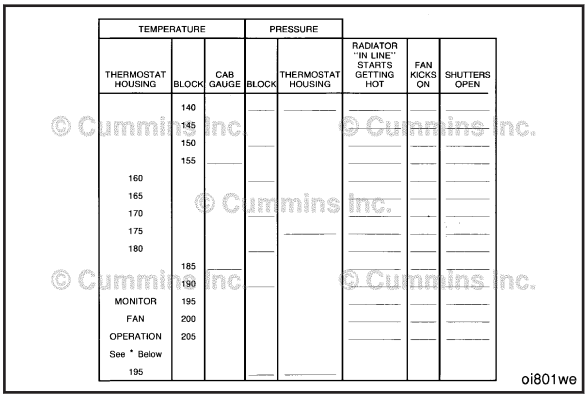
- External and internal coolant leaks/loss. See the Pressure Test section of this procedure.
- Combustion gas leaks into the cooling system. See the Test section of this procedure.

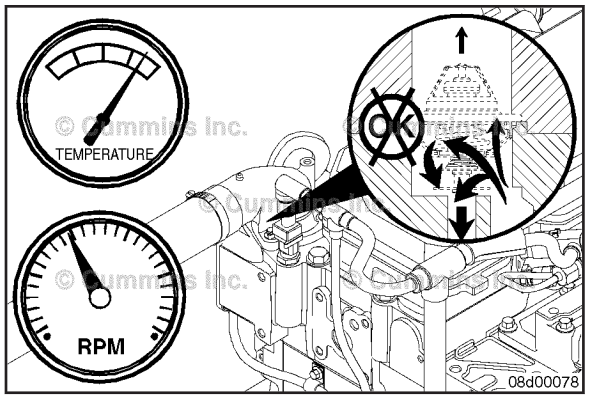
If the coolant reaches an unacceptable level in the recovery/expansion tank, a fault code should become active that will illuminate an instrument lamp and impose a power derate. This low level is detected by a coolant level switch mounted in the coolant surge/recovery tank.

In the event of a cooling system-related malfunction, it is recommended that the coolant level switches be checked for proper operation. Refer to the OEM service manual for operational checks and repairs.

Removal and installation of the coolant level switch for diagnostics is **NOT** recommended. This poses a high likelihood of damage, due to the plastic construction of the switch. The coolant level switch **must only** be removed from the surge/recovery tank when replacing it with a new switch. Be certain **not** to overtighten the switch when installing. Most switches have a very low torque value, which can be found in the OEM service manual.

Coolant level switches are very susceptible to improper pH levels. For this reason, it is imperative that coolant be maintained in accordance with Cummins® Coolant Requirements and Maintenance, Bulletin 3666132.



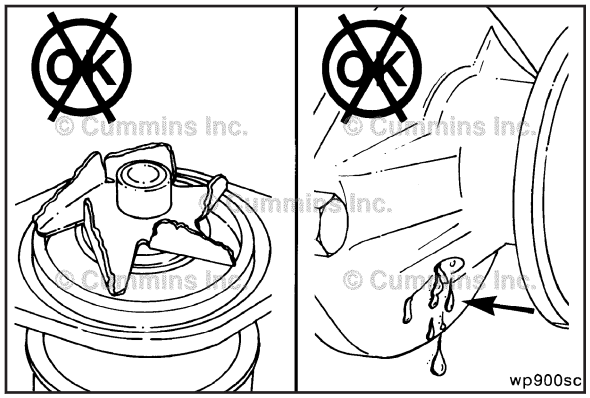


⚠CAUTION⚠

Never operate the engine without a thermostat. Without a thermostat, the path of least resistance for the coolant is through the bypass to the water pump inlet. This can cause the engine to overheat.

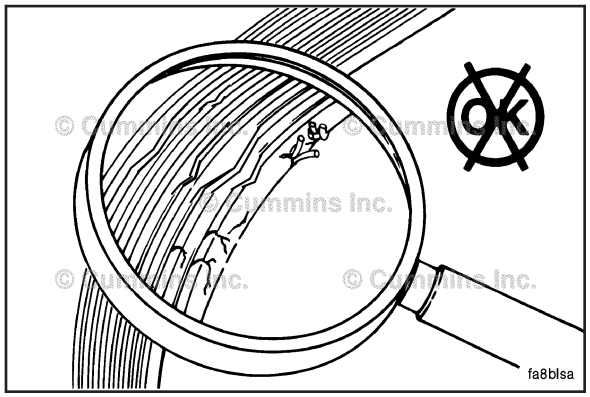
Thermostat

There are different temperature range thermostats available, depending on the engine type and application. The part number and nominal operating temperature are stamped on the thermostat. To verify that the correct temperature range and part number thermostat is installed, make sure to reference the appropriate part information resources. Refer to Procedure 008-013 in Section 8.



Water Pump

A damaged or an incorrect water pump can lead to an engine overheating condition. To verify that the correct water pump is installed, make sure to reference the appropriate parts information resources. Refer to Procedure 008-062 in Section 8.

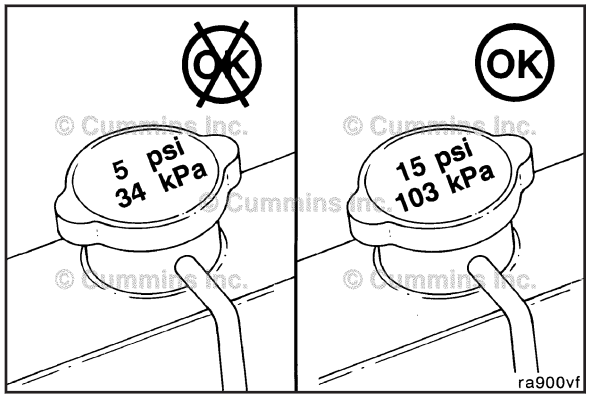


Belt and Belt Tensioner

A worn/incorrect belt, belt tensioner, or misaligned pulley can cause:

- Belt slip
- Belt jump or "walk off"
- Noise
- Belt breaks and shredding
- Component bearing seizure.

Refer to Procedure 008-002 or Refer to Procedure 008-080 in Section 8.



Pressure Cap

A commonly overlooked item when troubleshooting the cooling system is the radiator pressure/expansion tank cap. The cooling system is designed to use a pressure cap to prevent boiling of the coolant. An incorrect, damaged, or malfunctioning cap can result in the loss of coolant and in an engine overheating condition.

For information for pressure cap specifications, refer to the OEM service manual.

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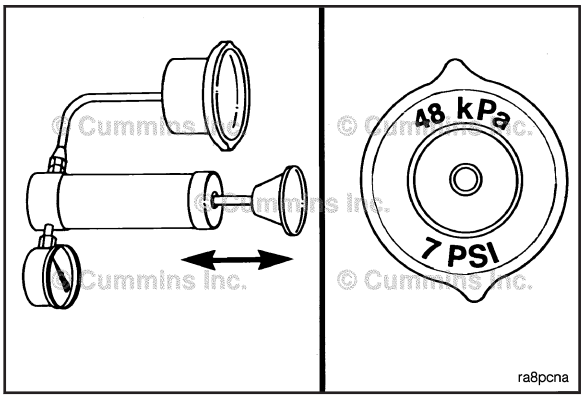
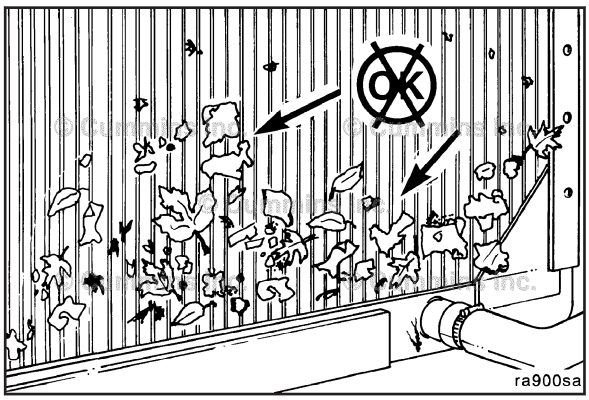
An incorrect or malfunctioning cap can also result in the loss of coolant and in an engine overheat condition.

Pressure test the radiator cap. Refer to the OEM service manual.

The pressure cap **must** seal within 14 kPa [2 psi] of the value stated on the cap, or it **must** be replaced.

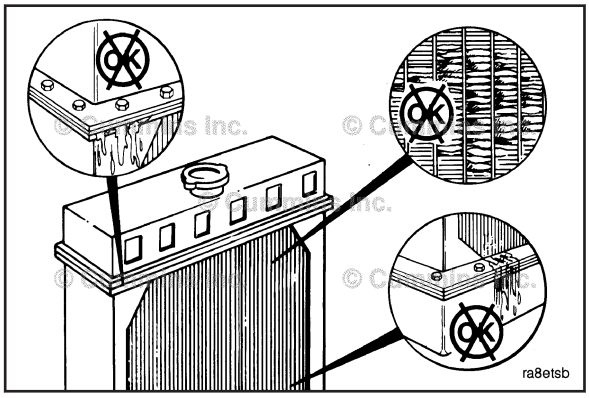


Air forced through the fins of the radiator by a fan cools the coolant pumped through the radiator. Environmental debris (such as paper, straw, lint, and dust) can obstruct the fins and reduce the flow of air, which will reduce the cooling effect of the radiator.



The radiator **must** be inspected for bent/broken fins and coolant leaks periodically.

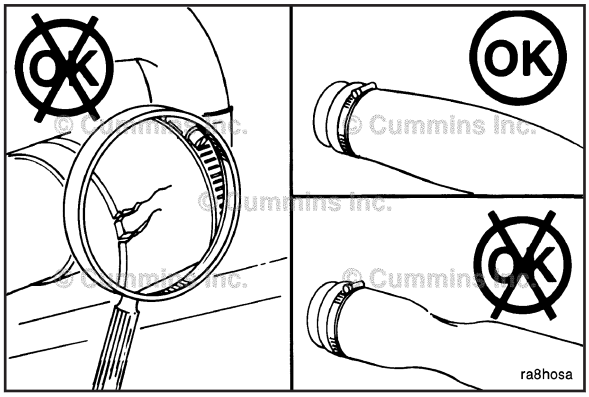
For maintenance, removal, or installation of the radiator, refer to the OEM service manual.

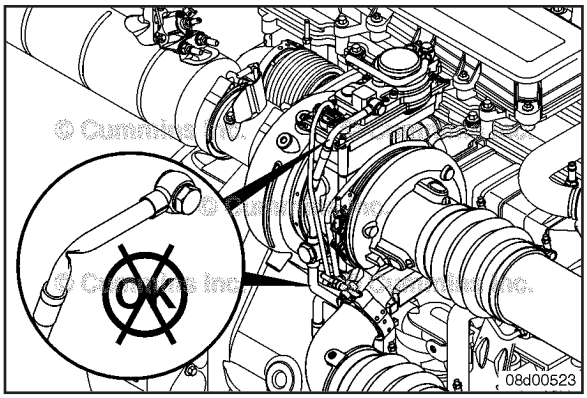


NOTE: The silicone engine coolant hose will exhibit swelling due to the elasticity of the hose.

Coolant Hoses

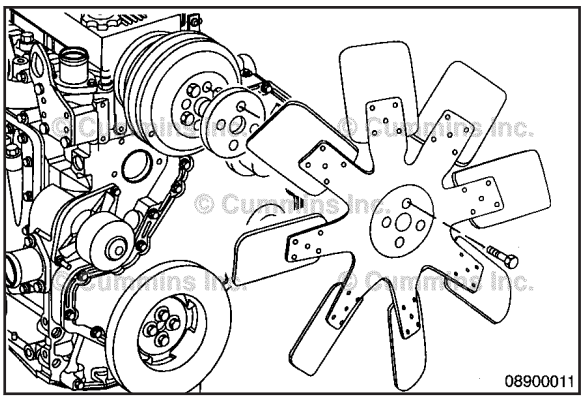
Collapsed or damaged coolant hoses can result in engine heating problems. Make sure to inspect all hoses for cracks, cuts, or collapsing. Replace any damaged hoses.





Inspect the coolant vent lines from the EGR cooler, cylinder head and variable geometry actuator (VGT). Make sure the lines are **not** pinched and that there are no sharp turns or dips in the vent lines from the engine connection point to the surge tank.

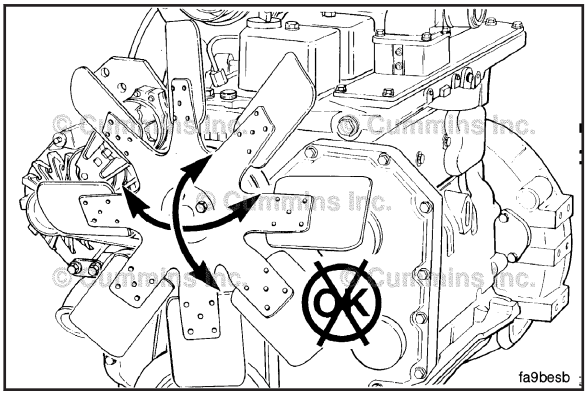
Blow shop air through the suspected lines to make sure there is no excessive restriction inside the lines.



Cooling Fan

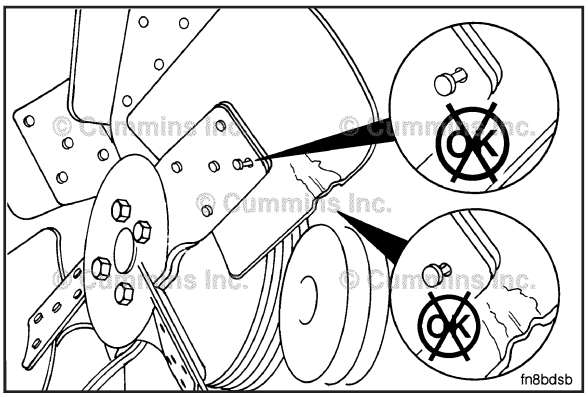
The engine cooling fan is typically driven by a crankshaft driven belt. In some applications, the fan is located off the engine for a remote mounted cooling system.

The cooling fan is supplied by the OEM. The OEM **must** be contacted for any service-related information. This procedure **only** highlights some of the items related to cooling fans.



If the fan is belt-driven, a slipping belt will result in a slower fan speed and reduced cooling. A malfunctioning automatic belt tensioner can be the problem. Refer to Procedure 008-080 in Section 8.

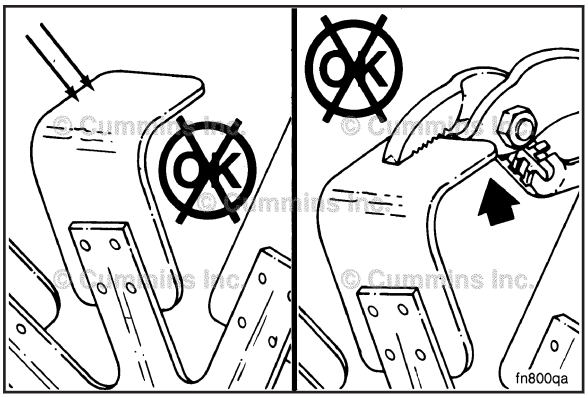
Check the bearings in the fan hub and other pulleys to make sure they are **not** causing excessive belt vibration and slippage. Refer to Procedure 008-036 in Section 8.



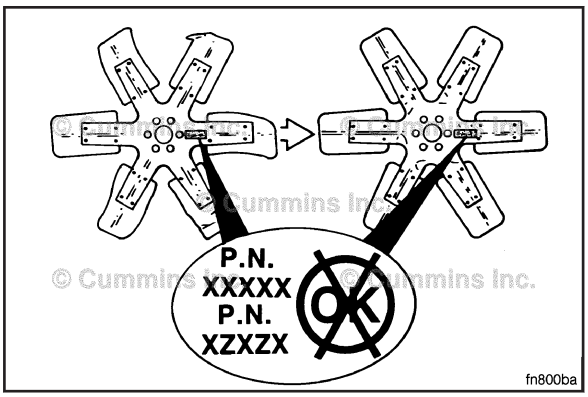
The cooling fan **must** be inspected periodically. Check for cracks, loose rivets, and bent or loose blades.

Check the fan to make sure it is securely mounted. Tighten the capscrews, if necessary.

⚠WARNING⚠
Do not straighten a bent fan blade or continue to use a damaged fan. A bent or damaged fan blade can fail during operation and cause personal injury or property damage.



Only replace a damaged cooling fan with an exact equivalent cooling fan. Although same size cooling fans can appear similar, there can be differences in the blade pitch and profile.



Fan Drive

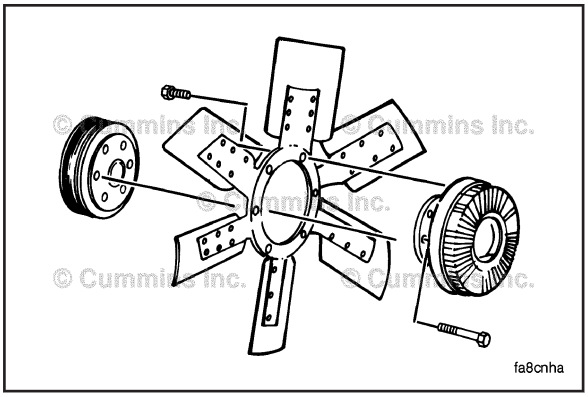
A malfunctioning fan drive can cause engine cooling problems.

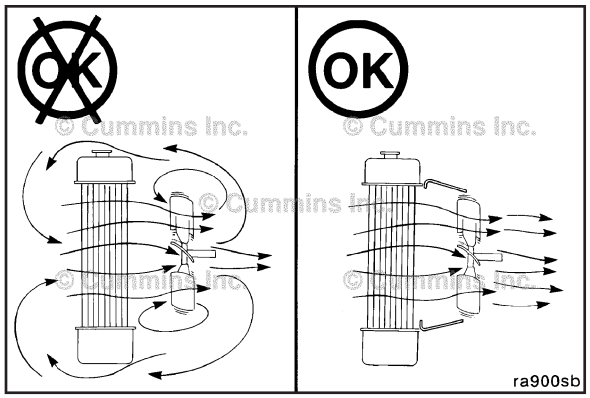
Various fan drive configurations are used to determine when the fan is driven, which include:

- Direct drive - the fan is engaged all of the time
- Air engaged/disengaged clutch
- Electric/electromagnetic clutch
- Viscous clutch
- Hydraulic drive
- Crankshaft/PTO driven.

Use the following procedure for additional information on electromagnetic fan clutches supplied by Cummins Inc. Refer to Procedure 008-026 in Section 8.

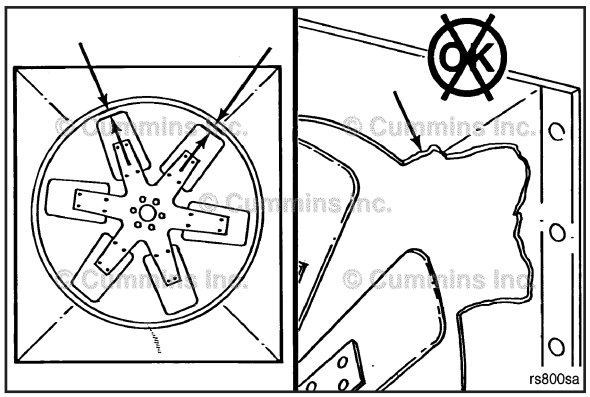
For other fan clutches, refer to the OEM service manual.



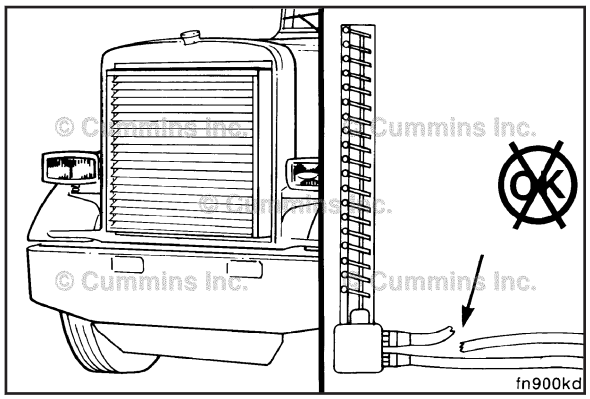


Fan Shroud Assembly

A fan shroud assembly is used to direct air flow provided by the cooling fan. A missing or damaged fan shroud will reduce the amount of air flow provided by the cooling fan and can cause an engine coolant overheating condition.



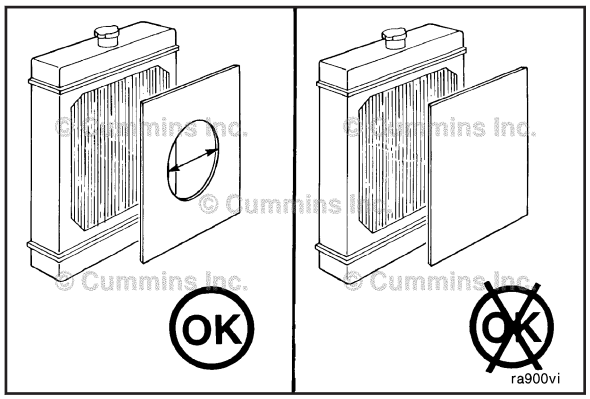
Check the fan shroud for damage and/or contact with the cooling fan. Replace any damaged components. Refer to Procedure 008-038 in Section 8.



Radiator Shutters

NOTE: Make sure the air temperature sensor is functioning correctly. Check the air-operated shutter controls. Check for air leaks. Refer to the OEM service manual.

Radiator shutters are designed to control airflow across the radiator. If the shutters fail to open when needed, the engine can run hot. Inability of the shutters to close can result in too much airflow and the engine running cold.



Winter Fronts

Winter fronts can be used to reduce the engine warm up time and help maintain engine heat in cold climate locations.

The winter fronts should **only** cover part of the frontal area of the cooling system, leaving part of the frontal area open to air flow.

Failure to leave part of the front area open to air flow or leaving the winter fronts installed when ambient temperatures increase can lead to an engine overheating condition.

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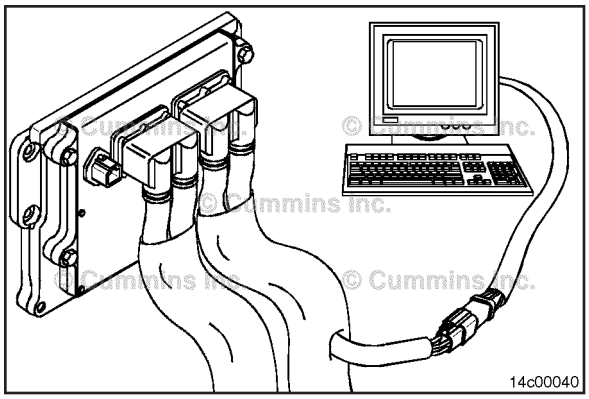
Initial Check

Connect an electronic service tool to the vehicle's data link.

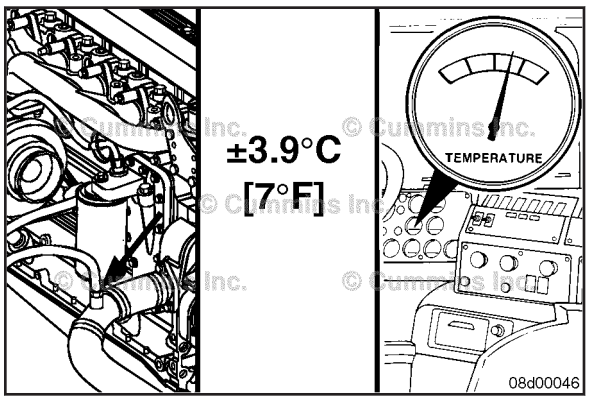
Turn the keyswitch to the ON position.

Monitor the coolant temperature with the electronic service tool.



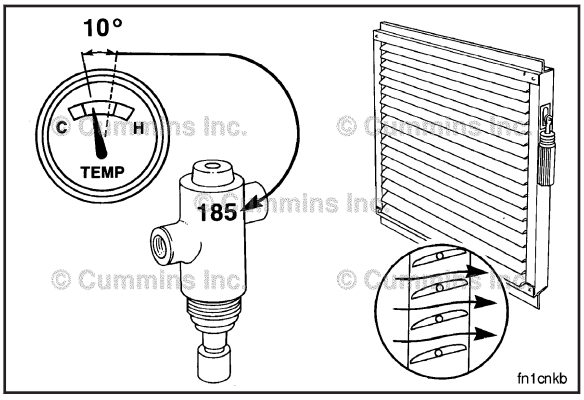
If equipped with an in dash coolant temperature gauge, monitor coolant temperature with an electronic service tool and compare the cab temperature gauge reading. Replace the cab temperature gauge if it is **not** within the manufacturer's specifications of the correct reading.

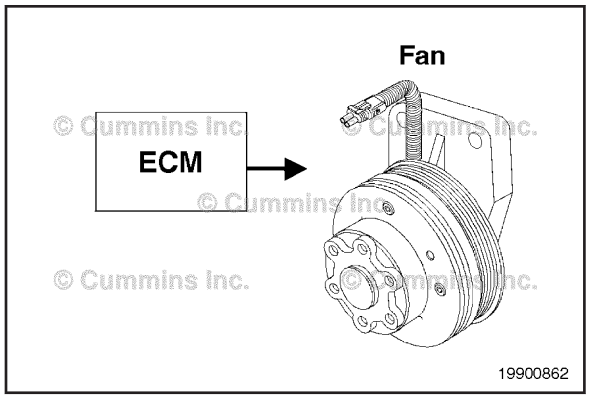
If the manufacturer's specifications are **not** available, replace the gauge if it is **not** within ±3.9°C or ±7°F of the correct reading.



For vehicles equipped with temperature controlled shutters, check the coolant temperature at which the shutters open and close. Compare this value to what is stamped on the shutter control.

Cummins Inc. recommends that the shutters open at 85°C [185°F] engine coolant temperature.





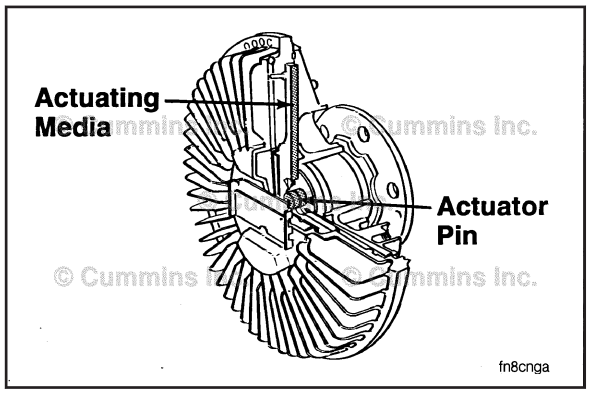
If equipped with a temperature controlled cooling fan clutch, check the coolant temperature at which the fan clutch engages.

If the fan clutch engagement is controlled by a fan control on the vehicle, compare the recorded value to what is stamped on the fan control and/or reference the OEM service manual.

If the fan clutch engagement is controlled by the engine's electronic control module (ECM), the engagement coolant temperature is a set value that can **not** be changed. If the fan clutch does **not** engage, check to make sure the fan control logic parameter is set correctly.

The ECM is capable of using either a zero (“0”) VDC or 12 VDC signal to engage the fan clutch. The exact enable logic can be selected in the Features and Parameters section of INSITE™ electronic service tool.

Cummins Inc. recommends that the fan engage at 96°C [205°F] engine coolant temperature.

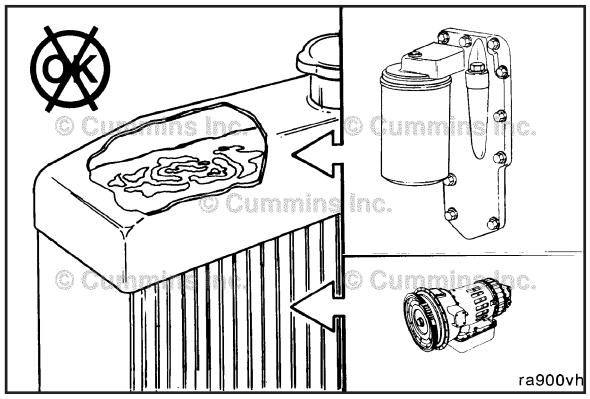


If equipped with a viscous fan drive, check the coolant temperature at which the fan engages. Viscous fan clutches are typically activated by a built-in sensor behind the radiator that monitors air temperature.

NOTE: Some viscous fan drives could possibly be electronically controlled.

When the air temperature reaches a specific level, depending on the temperature setting of the sensor used, the temperature-sensing control moves an actuator that allows viscous fluid to engage the fan drive and increase the fan speed. For more information, refer to the OEM service manual.

Cummins Inc. recommends that the fan engage at 96°C [205°F] engine coolant temperature.



Pressure Test

The operating pressure of the coolant system and the lubricating system can result in the mixing of the fluids if there is a leak between the systems:

- Cylinder head gasket
- Lubricating oil cooler, etc.

Transmission/power steering/hydraulic fluid can also leak into the coolant through radiator fluid coolers, if equipped. Refer to the OEM service manual.

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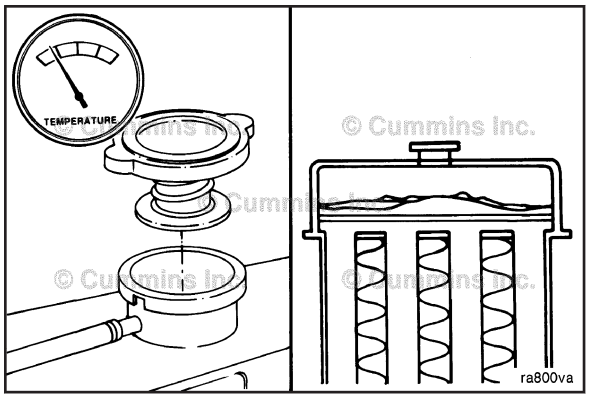
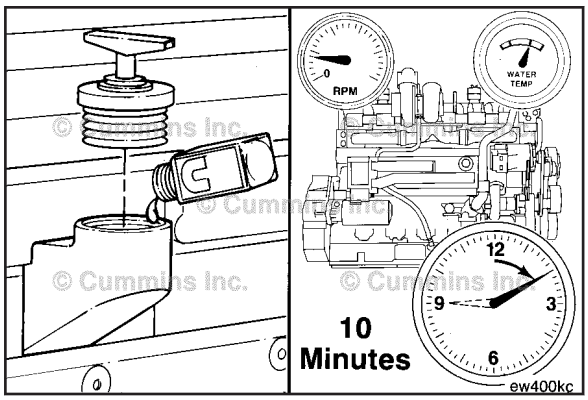
Check the coolant level and fill if necessary. Refer to Procedure 008-018 in Section 8.



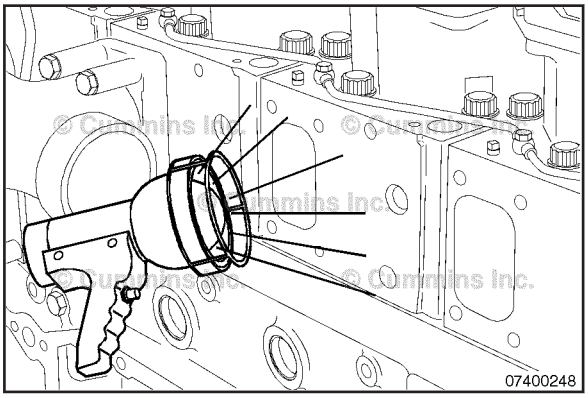
To aid in determining the location of the coolant leak, it may be necessary to add fluorescent tracer, Part Number 3377438, to the coolant.

Add one unit of fluorescent tracer to each 38 liters [10 gal] of coolant .

Idle the engine for 5 to 10 minutes or until normal operating temperature is reached, to allow the dye to circulate through the cooling system.



Use a high intensity black light, Part Number 3163337, or equivalent, to illuminate the dye.

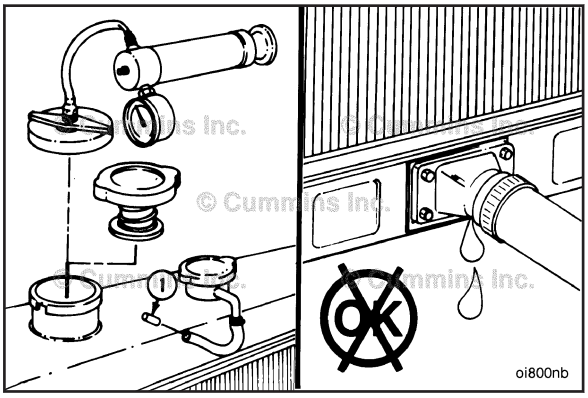


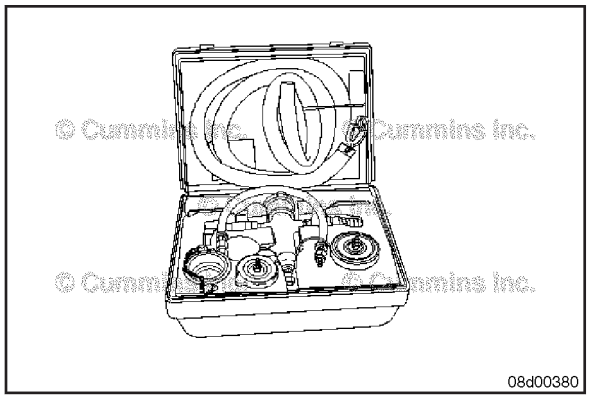
⚠CAUTION⚠
Do not apply more than 138 kPa [20 psi] air pressure to the cooling system or damage to the water pump seal can result.

If the radiator is equipped with a pressure relief valve, plug the overflow line (1).

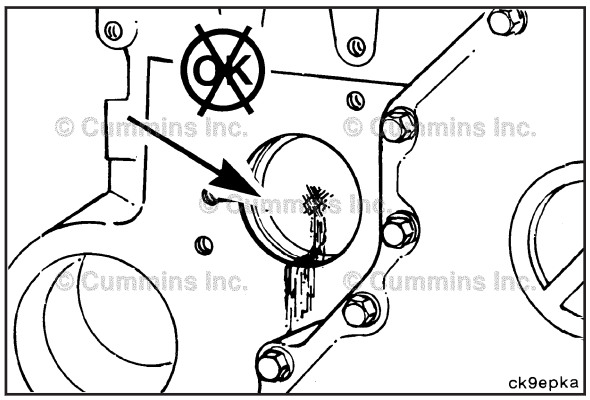
Install the pressure tester to the radiator fill neck or surge tank, if equipped, and apply air pressure.

Air Pressure 138 kPa [20 psi]





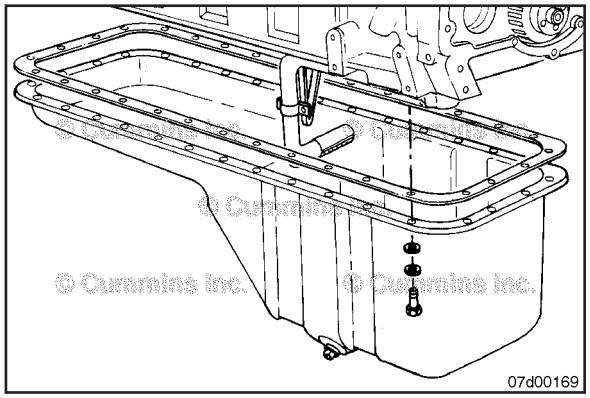
The Coolant Dam™/Pressure Tester service tool, Part Number 3824319, can also be used to pressurize the cooling system. The Coolant Dam™/Pressure Tester uses shop air rather than a hand air pump.



For external coolant leaks, inspect the exterior of the engine and repair if necessary.

Pay close attention to areas around the:

- Lubricating oil cooler. Refer to Procedure 007-003 in Section 7.
- Water pump. Refer to Procedure 008-062 in Section 8.
- Air compressor head gasket. Refer to Procedure 012-014 in Section 12.
- Cup plugs. Refer to Procedure 017-002 in Section 17.
- Pipe plugs. Refer to Procedure 017-007 in Section 17.
- EGR cooler. Refer to Procedure 011-019 in Section 11.
- EGR cooler coolant line. Refer to Procedure 011-031 in Section 11.
- Variable geometry turbocharger. Refer to Procedure 010-033 in Section 10.
- Turbocharger coolant lines. Refer to Procedure 010-041 in Section 10.



For internal coolant leaks, inspect the interior of the engine. It may be necessary to remove the following components to look for signs of a coolant leak:

- Rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Turbocharger oil drain line. Refer to Procedure 010-045 in Section 10.

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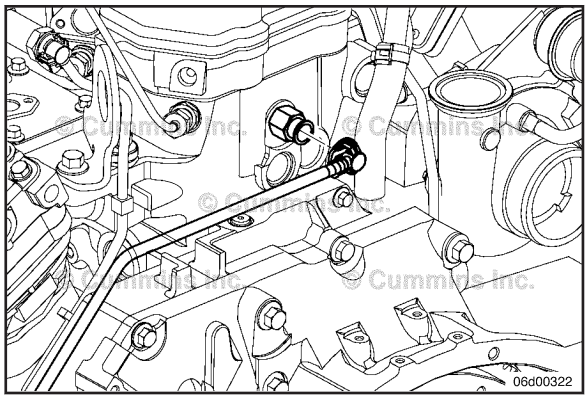
For suspected fuel in the coolant or coolant in the fuel, disconnect the fuel drain connection at the rear of the cylinder head. Refer to Procedure 006-013 in Section 6.

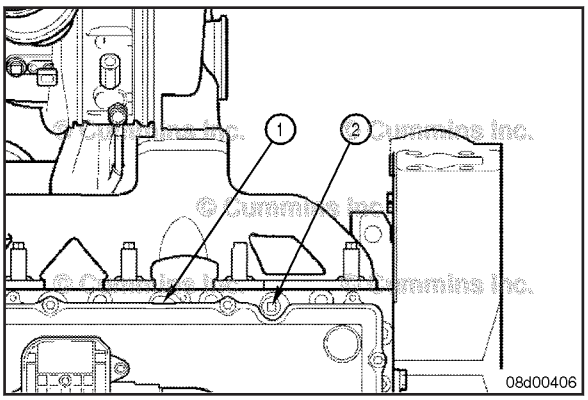


Coolant Pressure Check

Measure the coolant pressure at the coolant tap number 5 (1) or coolant tap number 6 (2) on the exhaust side of the cylinder head.

Coolant pressure can be affected by the following:

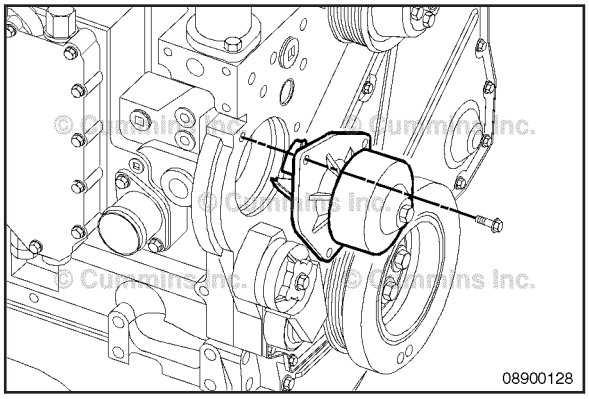
- Radiator pressure cap
- Debris in the cooling system
- OEM cooling options such as in-cab heaters and torque converter cooling
- Air in the cooling system
- Incorrect initial cooling system fill
- Less than 50/50 antifreeze mixture
- Engine operation at high altitude.

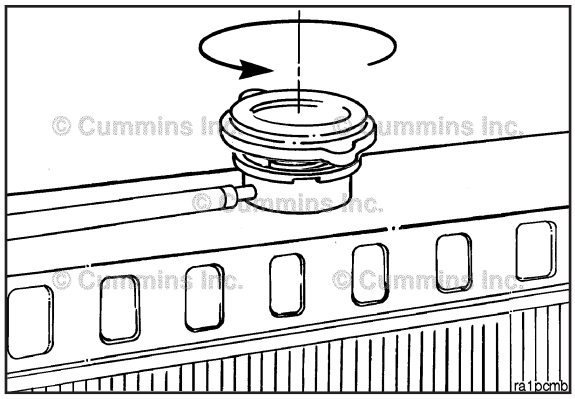


Record the block pressure at 60°C [140°F], closed thermostat, at high idle.

If the block coolant pressure is less than 138 kPa [20 psi] at high idle and without a pressure cap, do the following:

- Check the belt tension and condition
- Remove the water pump, inspect the impeller integrity, and check for slippage on the shaft. Refer to Procedure 008-062 in Section 8.



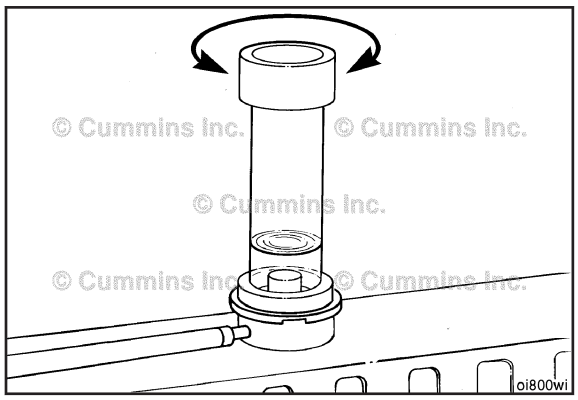


Setup

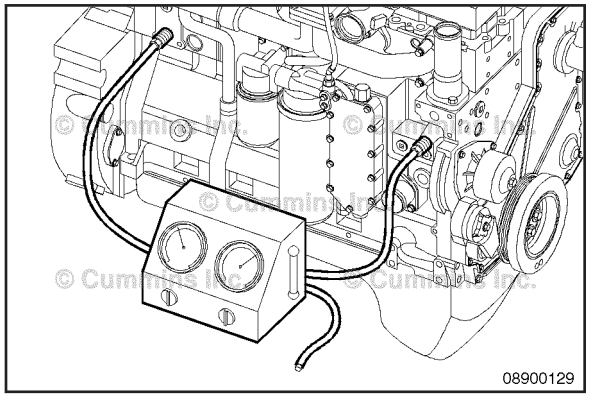
⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

NOTE: All cab heaters and air conditioners **must** be turned to the OFF position, and the engine fan control **must** be turned to the AUTOMATIC position, if applicable.

Remove the radiator cap, and leave it off for the following test.

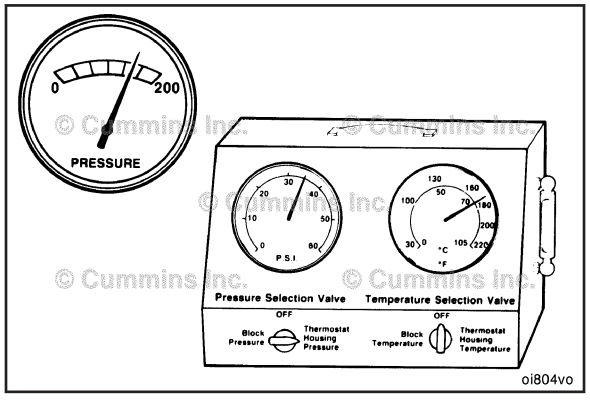


Install the combustion gas leak test instrument, Part Number 3822985, into the radiator cap opening.



Install the analyzer kit, Part Number 3822994.

- Red line - plugged
- Yellow line - cylinder block pressure
- Black line - water pump inlet.



Test

Pressure Readings:

Turn the pressure selection valve to the position corresponding to the desired reading. Turn the temperature selection valve to the OFF position.

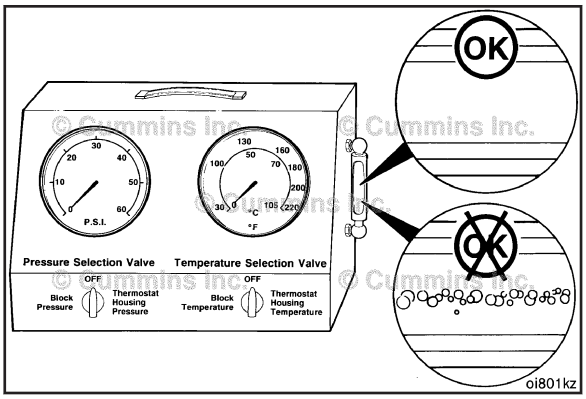
NOTE: When the cylinder block pressure reading is taken, the valve **must** be turned to the thermostat housing pressure location.

Start the engine and run at high idle.

Monitor the sight glass installed on the service tool throughout the test. If air is observed, finish the test, and examine the combustion leak tester. This will determine the origin of the leak.

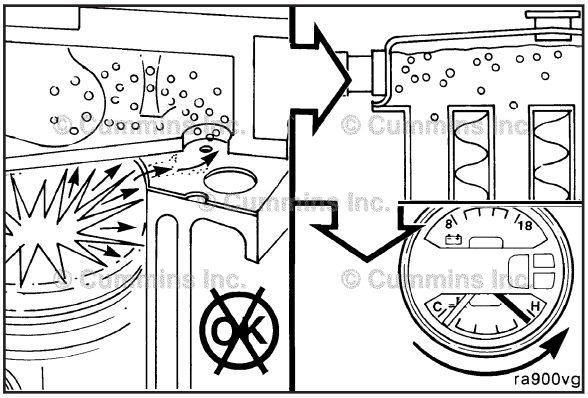
Temperature Readings:

There will be temperature fluctuations when switching the temperature selection valve. This fluctuation is normal and is caused by temperature loss in the line. The temperature will stabilize after a few seconds.



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

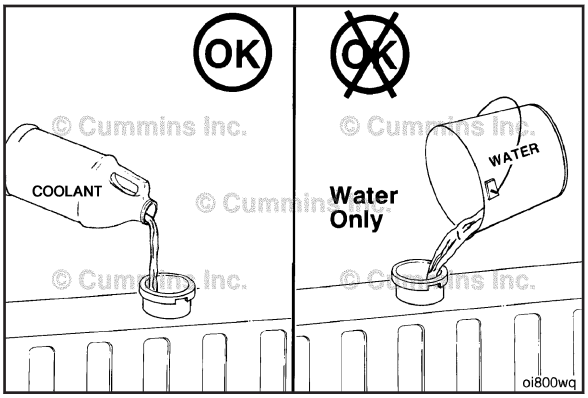
Similarly, coolant can be displaced through the overflow if the head gasket or a crack in the cylinder head leaks compression gases into the cooling system.



Combustion Gas Leak

Use a combustion gas tester, Part Number 3822985, or its equivalent, to test for combustion gases in the cooling system.

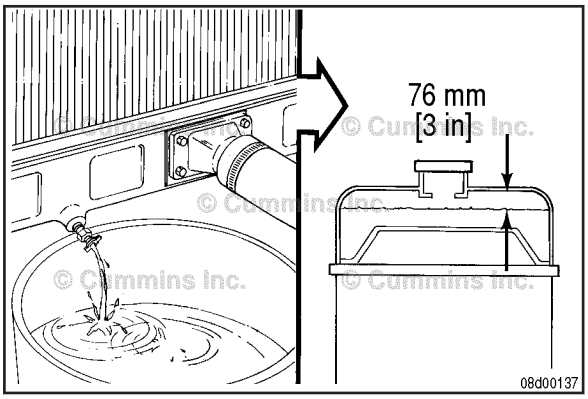
It is recommended that the cooling system contain a mixture of 50 percent antifreeze and 50 percent water during the combustion gas leak test. The use of water **only** can result in a color change in the test fluid from blue to turquoise or light green during the test. This is **not** an indication of a combustion gas leak.

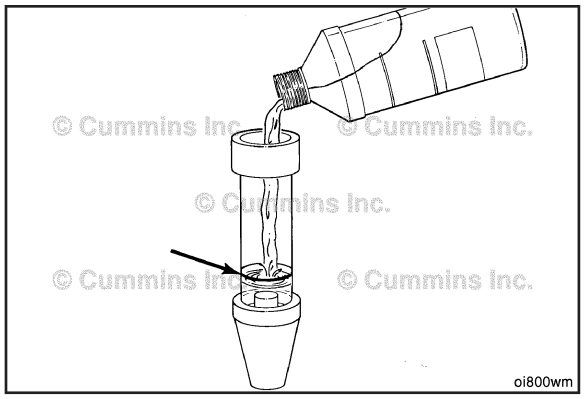


⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

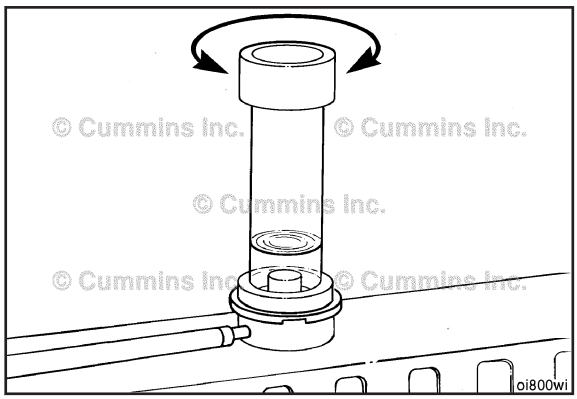
Drain the coolant level down approximately 76 mm [3 in] below the radiator cap seal ledge in the radiator fill neck.

If the coolant is above this point, the coolant can contaminate the test fluid, causing the test to be ineffective.

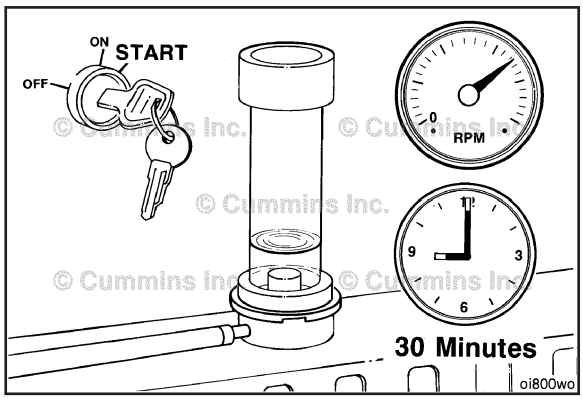




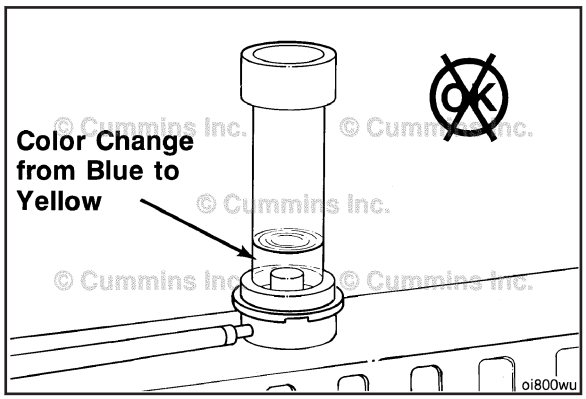
Pour the test fluid into the combustion gas leak test instrument until it is up to the yellow fill line on the instrument.



Insert the rubber tip of the combustion gas leak test instrument into the radiator fill neck. Hold the instrument down firmly and turn back and forth to make certain that an airtight seal is formed between the tester and the radiator fill neck.



Start the engine and run at idle for approximately 30 minutes. Monitor the engine temperature and color of the test fluid during engine operation. Do **not** allow the engine temperature to exceed 100°C [212°F] during the test.



If the color of the test fluid changes from blue to yellow or green anytime during the test, combustion gases are leaking into the cooling system. Discontinue the test if the color of the test fluid changes from blue to yellow or green.

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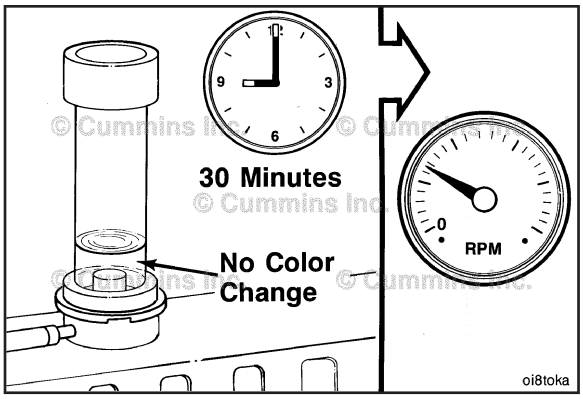
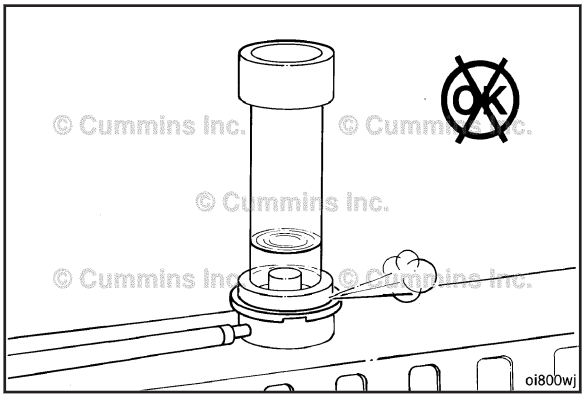
If the color of the test fluid does **not** change from blue to yellow or green during the 30 minute test period, return the engine to low idle.

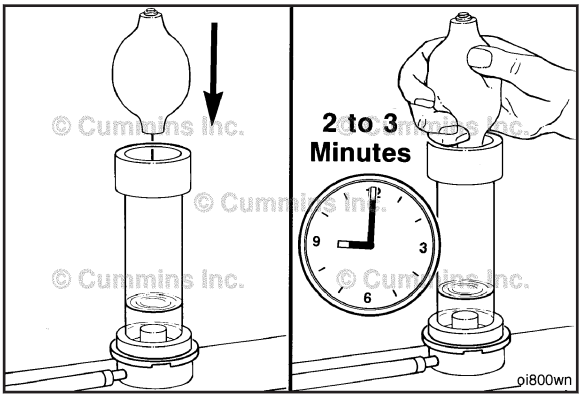


Check the test instrument to make sure it is firmly sealed in the radiator fill neck.

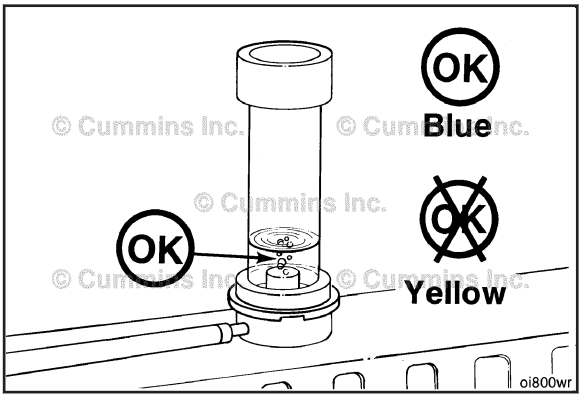


Insert the tip of the rubber ball into the hole in the top of the test instrument. Squeeze the rubber ball 2 to 3 minutes to draw air from the radiator through the test fluid.

If the color of the test fluid remains blue, combustion gases are **not** entering the cooling system. If the color of the test fluid changes from blue to yellow or green, combustion gases are entering the cooling system and further investigation is required to determine the source of the combustion leak.



As the cooling system warms up to operating temperature, air will be expelled through the combustion gas tester in the form of bubbles in the test fluid. This is due to normal expansion of the coolant. Do **not** mistake the presence of air bubbles in the tester as combustion gases or air leaks into the cooling system. A change in the color of the test fluid from blue to yellow or green is the **only** indication of combustion gas in the cooling system.



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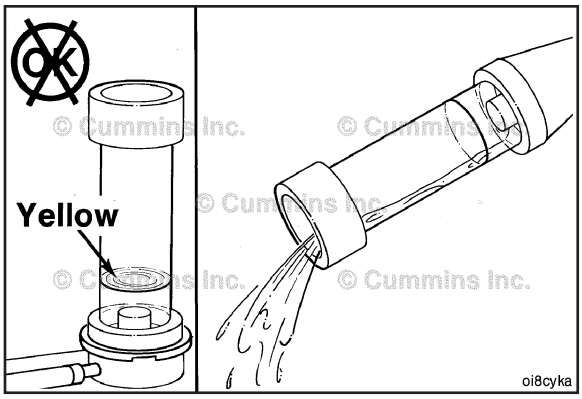
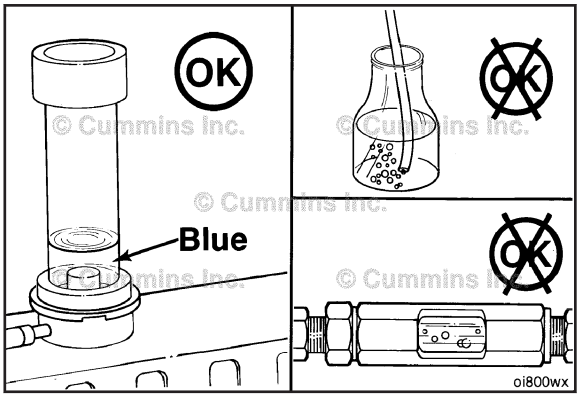


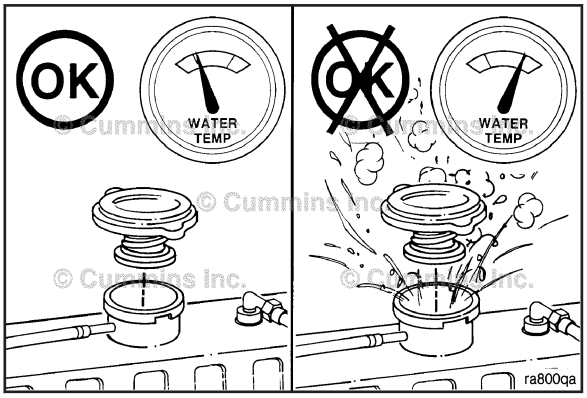
NOTE: Discard the tester fluid if it has indicated positive.

A positive result from the combustion gas leak tester indicates cylinder head gasket or cylinder head casting leakage. Refer to Procedure 002-004 in Section 2.



A negative result from the combustion gas leak tester, coupled with a continuous flow of air bubbles from the previous test, indicates the following:

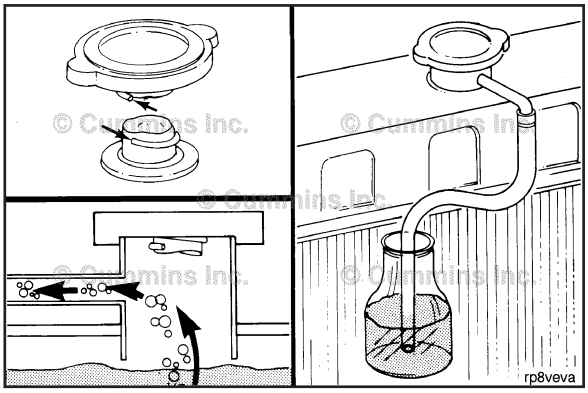
- Damaged fan, shutter, or heater air control valve
- Air compressor head or head gasket leakage



Overflow Method

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

Allow the engine to cool and remove the radiator cap.



Install a radiator pressure cap that has had the spring and the pressure relief valve removed to allow free flow from the overflow tube.

Attach a rubber hose to the radiator overflow connection.

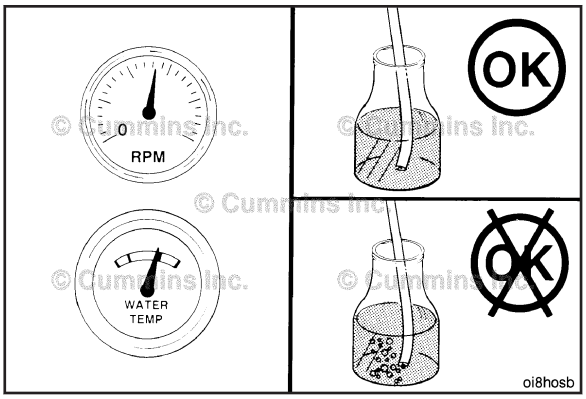
Put the free end of the hose below the water level in a container of water.

NOTE: The pressure cap **must** be tightly sealed in the top of the radiator fill neck.

Operate the engine at rated rpm until it reaches a temperature of 82°C [180°F].

Check for a continuous flow of air bubbles from the hose in the water container.

NOTE: The engine coolant temperature **must** be stable to perform this test. An increasing coolant temperature will give a false indication of air due to expansion of the coolant in the system.

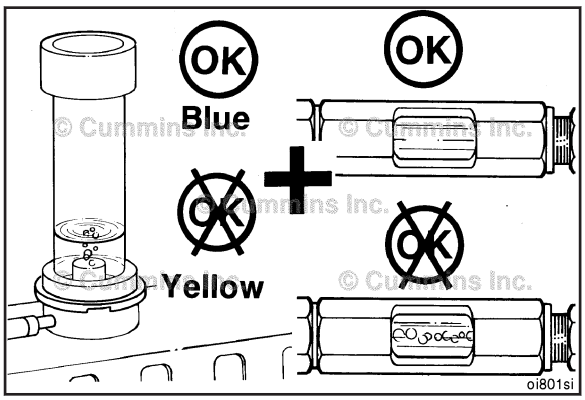


Analyzing the Data

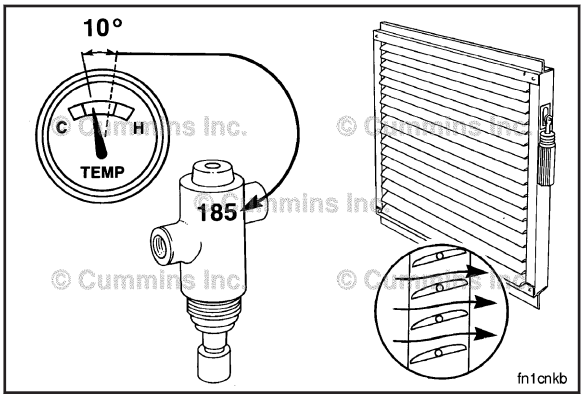
Check the color of fluid in the combustion gas leak tester. A yellow or green (not shown in the illustration) color will indicate a combustion leak. A blue color will indicate there is no leak. This information will help isolate the source of air in the cooling system, if any.

NOTE: The test kit is **not** sensitive enough to detect very small combustion gas leaks.

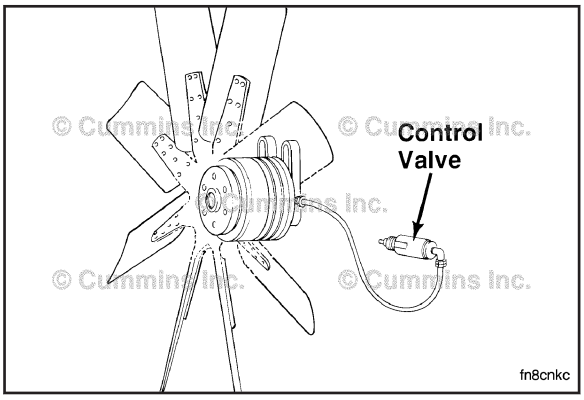
Do **not** rule out combustion gas leaks if the combustion gas leak test does **not** indicate a combustion gas leak.

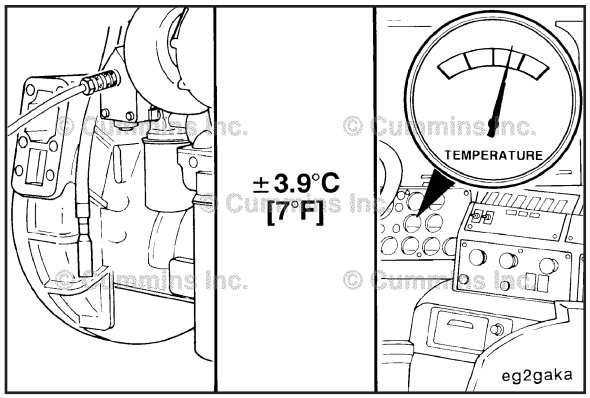


Check the recorded coolant temperature when the shutters are opened. Compare this value to the stamp on the shutter control. Cummins Inc. recommends that the shutters open at 85°C [185°F].

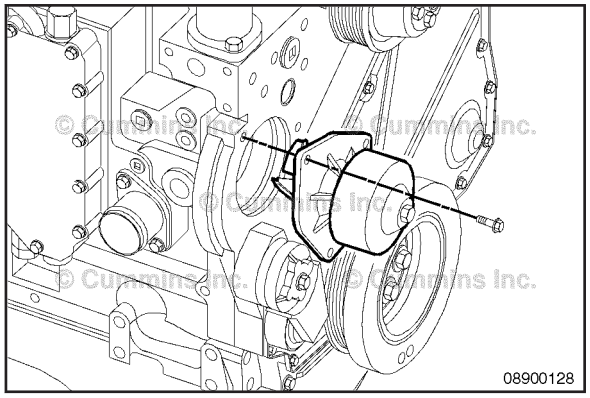


Check the recorded coolant temperature when the fan is engaged. Cummins Inc. recommends that the fan engage at 96°C [205°F].



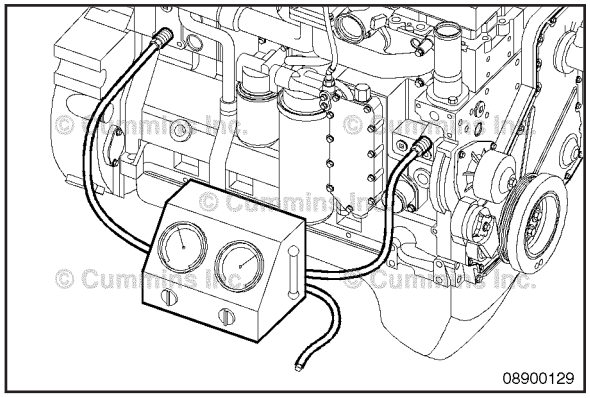


Compare the cab temperature gauge reading with the block temperature. Replace the cab temperature gauge if it is **not** within the manufacturer's specifications for the correct reading. If no manufacturer's specifications are available, replace the gauge if it is **not** within ±3.9°C [7°F] of the correct reading.



Read the recorded block pressure at 60°C [140°F]. If the block pressure is less than 138 kPa [20 psi] at high idle and without a pressure cap, check the following:

- Remove the water pump
- Inspect the impeller's integrity, and for slippage on the shaft
- Check the belt tension and condition.



If there is a drop in block pressure of more than 34 kPa [5 psi] during the test, check the following:

- Air in the system
- Incorrect initial cooling system fill
- Less than 50/50 antifreeze mixture, or the engine is at high altitude.

Worksheet

Fill in the blanks with the test data as the test is being run. Mark when the radiator line gets hot, when the fan starts operating, and when the shutters open.

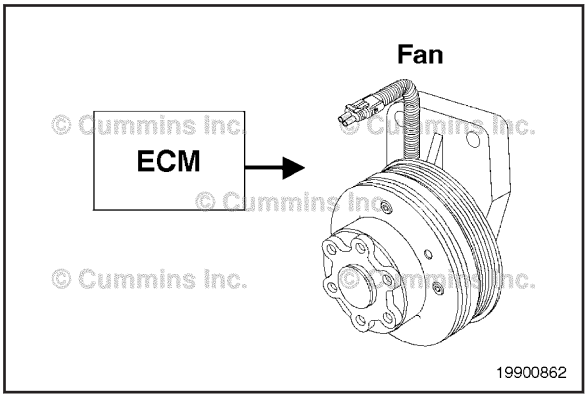
Coolant Temperature (°F)	Pressure					
Thermostat Housing	Cab Gauge	Cylinder Head	Radiator “In Line” Starts Getting Hot	Fan Starts Operating	Shutters Open	Notes
140						Engine at high idle throughout test
145						Monitor for air throughout test

150						Start monitoring radiator “in” line
155						
160						
165						Check water filter
170						
175						
180						
185						
190						
195						
200						
205						Cool engine down

Fan Clutch, On-Off (008-027)

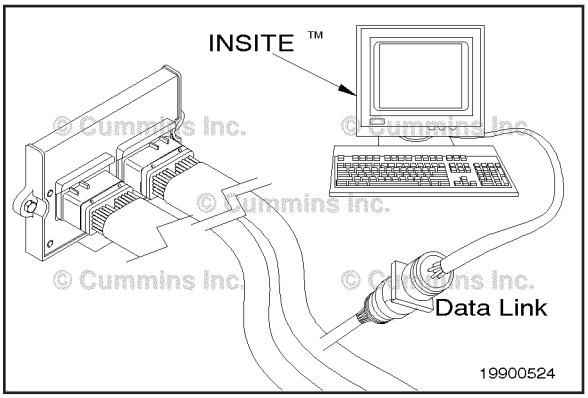
General Information

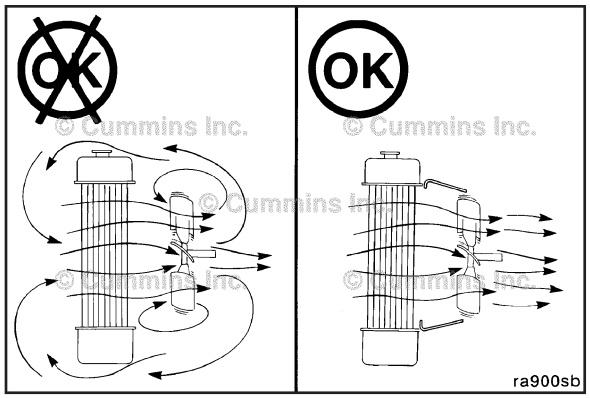
Many fan clutches can be controlled by the engine's electronic control module (ECM). The ECM monitors coolant temperature and intake manifold temperature to determine when to engage the cooling fan. Some applications have additional sensors monitored by the ECM for fan control (for example, air conditioner pressure and transmission temperature). These are various fan clutch types, such as air-engaged, air-disengaged, electric, viscous, and on/off. Refer to the OEM service manual to determine fan clutch type.



The ECM is capable of using either a 0-VDC or 12-VDC signal to engage the fan clutch. The enable logic is contained in the ECM calibration and can be programmed using INSITE™ electronic service tool.

Refer to the OEM service manual for fan clutch troubleshooting and repair information.





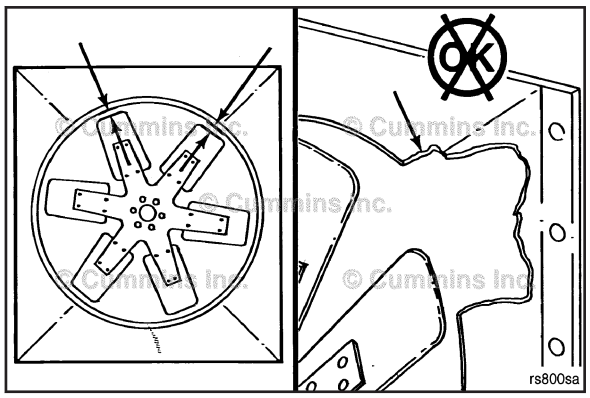
Fan Shroud Assembly (008-038)

General Information

The radiator or fan shroud is used to direct all air-flow across the radiator fins rather than around the edges of the radiator.

An incorrect fan shroud or obstructions can reduce air-flow and cause the engine to run hot.

NOTE: Check to be sure air is **not** recirculating. Check for missing baffles.

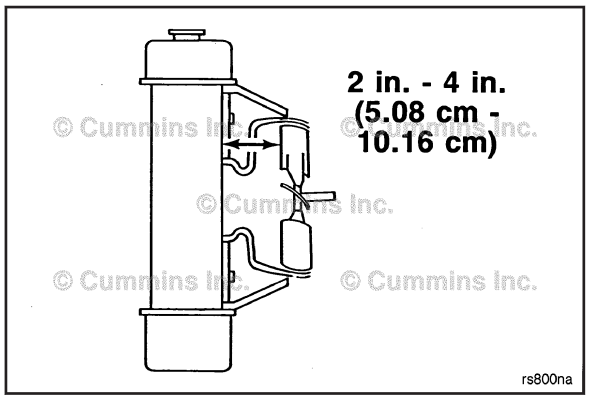


Initial Check

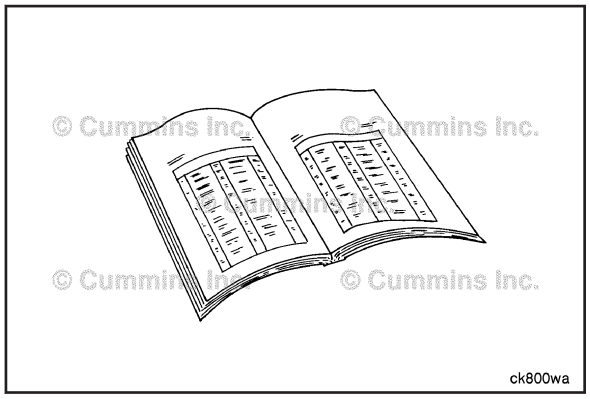
CAUTION

The fan shroud must be installed correctly, be in good condition, and the shroud-to-fan clearance must be within the manufacturer's specifications to allow proper airflow through the radiator to provide adequate engine cooling.

Inspect the fan shroud for proper fan clearance, cracks, air leaks, and damage. Replace if necessary. Refer to the equipment manufacturer's service manual for instructions.



Cummins Inc. recommends that fan clearance be between 5.08 to 10.16 cm [2 to 4 in] from the radiator core. Refer to the equipment manufacturer's service manual for alternative positions.



Fan Spacer and Pulley (008-039)

Preparatory Steps

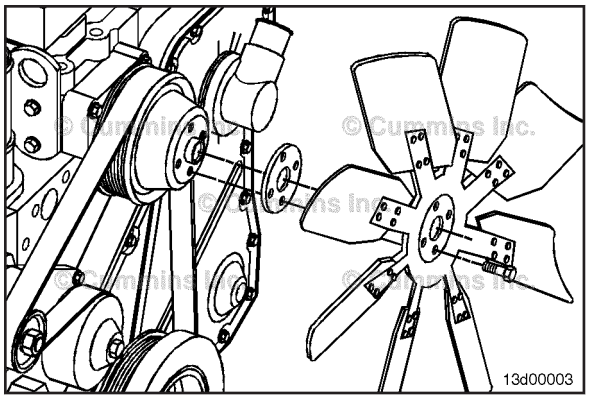
WARNING

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Remove the fan drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the cooling fan. Refer to Procedure 008-040 in Section 8.

Remove

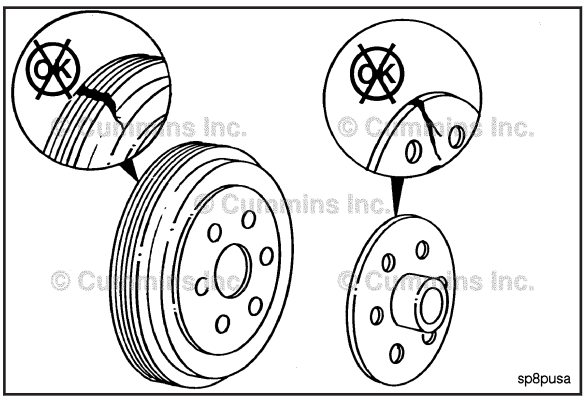
Remove the fan spacer and the fan pulley.



Inspect for Reuse

Check the spacer and pulley for cracks or damage.

If damage is found on the fan pulley, the fan hub **must** also be inspected.

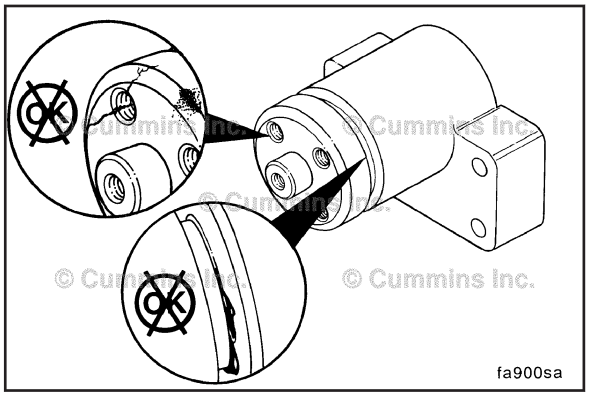


Inspect the fan hub for indications of oil seal leakage.

Inspect the fan hub for cracks or other damage.

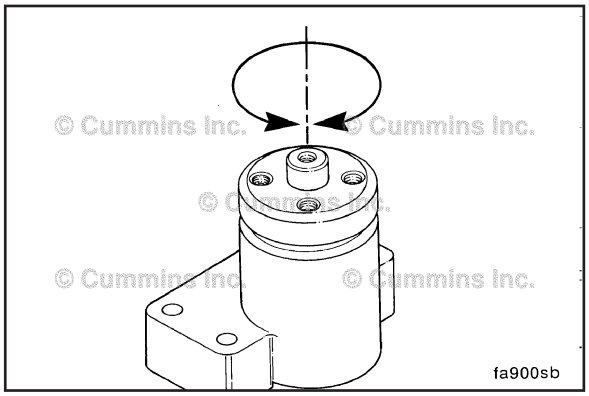
Inspect the fan hub chamfer and fan pulley mating surface for damage.

Replace the fan hub if damage is found.



Turn the fan hub by hand to check for freedom of rotation.

The fan hub **must** spin freely without any wobble or excessive end clearance.



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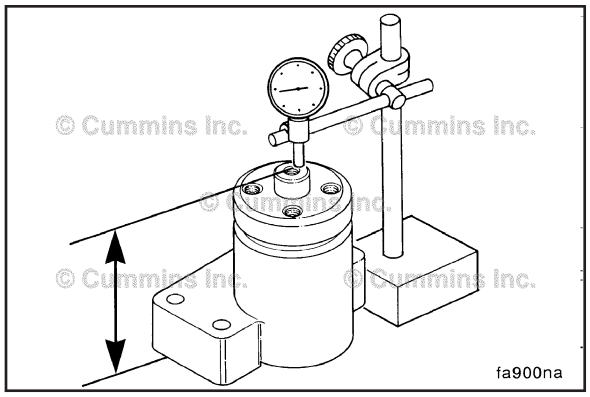


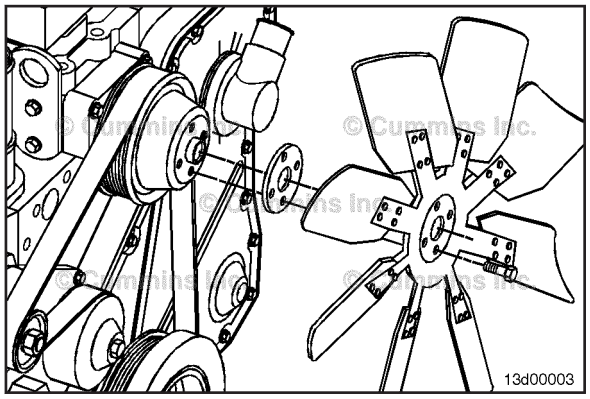
Inspect the fan hub bearing for wear.

The bearing **must** have a minimal amount of side-to-side or end-play movement.

Replace the fan hub if there is more than 0.15 mm [0.006 in] of end play in the fan hub.

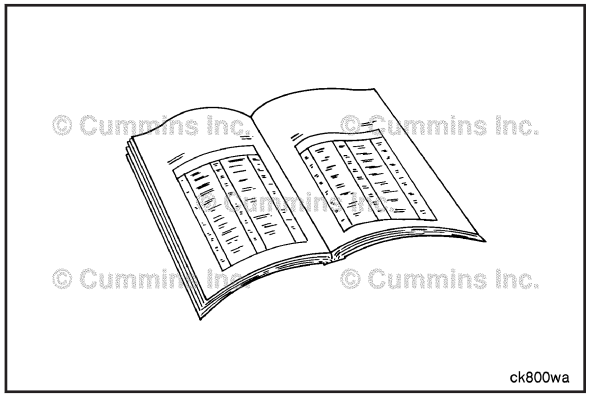
Fan Hub End Play		
mm		in
0.15	MAX	0.006

NOTE: Some fan hub assemblies can be rebuilt with new bearings and related components. Check for part availability before disassembling the fan hub.



Install

Install the fan pulley and the fan spacer.



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 cooling fan. Refer to Procedure 008-040 in Section 8.
- Install the fan drive belt. Refer to Procedure 008-002 in Section 8.
- Operate the engine and check for proper operation.

Fan, Cooling (008-040)

Preparatory Steps

Remove the fan drive belt. Refer to Procedure 008-002.

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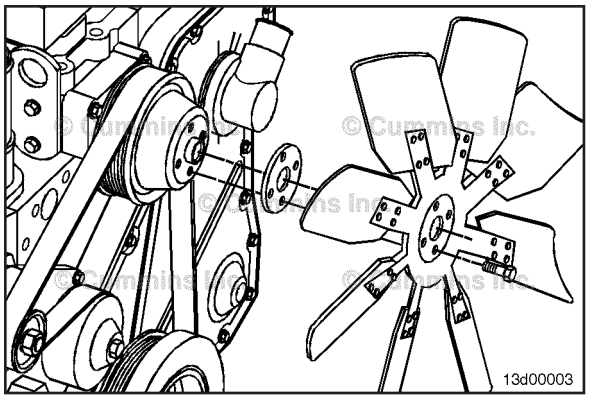
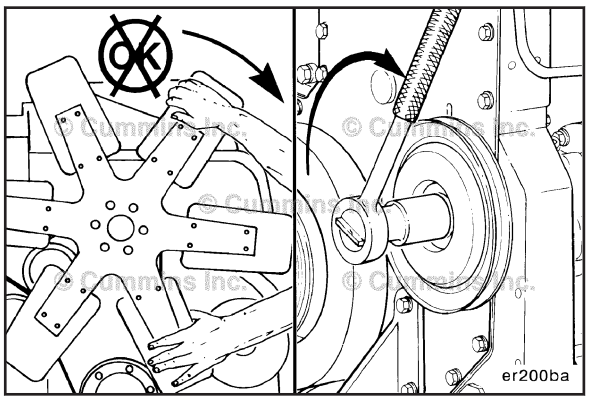
Remove

Remove the fan capscrews, the fan and the spacer.

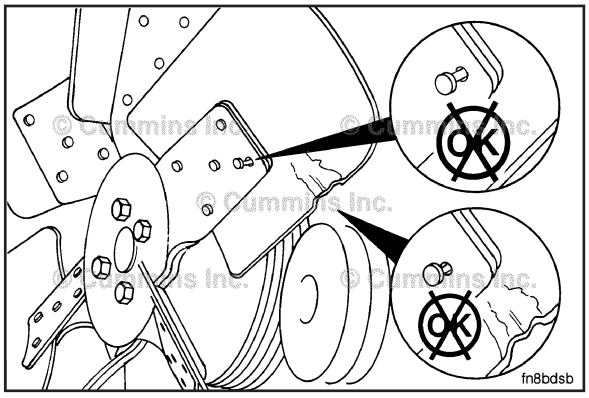


Inspect for Reuse

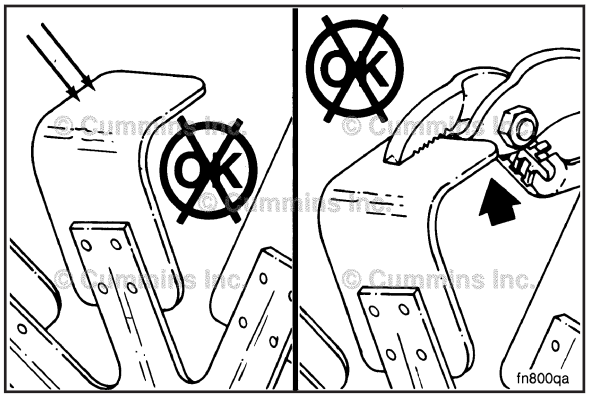
⚠WARNING⚠
Do not rotate the engine by pulling or prying on the fan. The fan blade(s) can be damaged and cause the fan to fail and cause personal injury or property damage. Use the accessory drive shaft or the crankshaft barring tool to rotate the crankshaft.



A visual inspection of the cooling fan is required daily. Check for cracks, loose rivets, and bent or loose blades. Check the fan to make sure it is securely mounted. Tighten the capscrews, if necessary.



⚠WARNING⚠
Do not straighten a bent fan blade or continue to use a damaged fan. A bent or damaged fan blade can fail during operation and cause personal injury or property damage.



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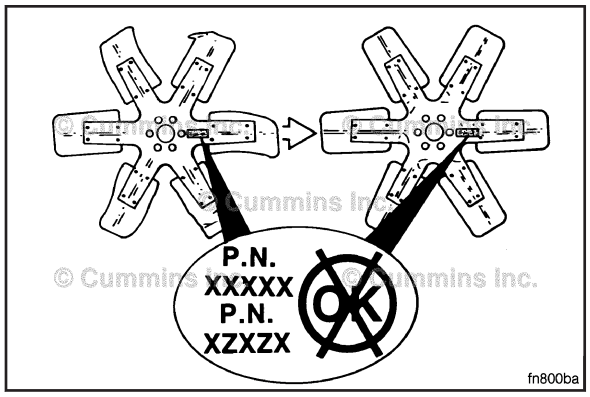
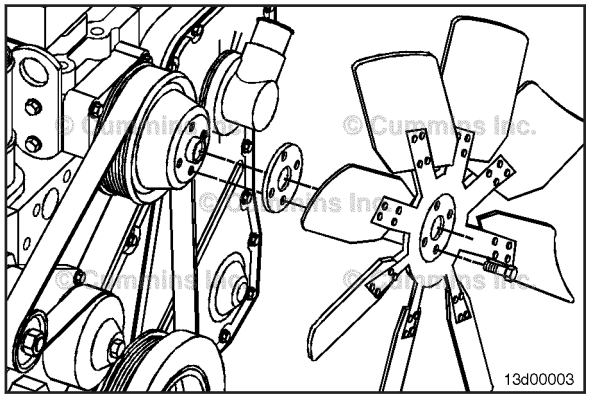


Replace original equipment fan that is damaged with a fan of the identical part number. Cummins Inc. **must** approve any other fan changes to be covered under warranty.

Refer to the vehicle or equipment manufacturer's specifications for capscrew torque.



Install

Install the fan capscrews, the fan and the spacer.

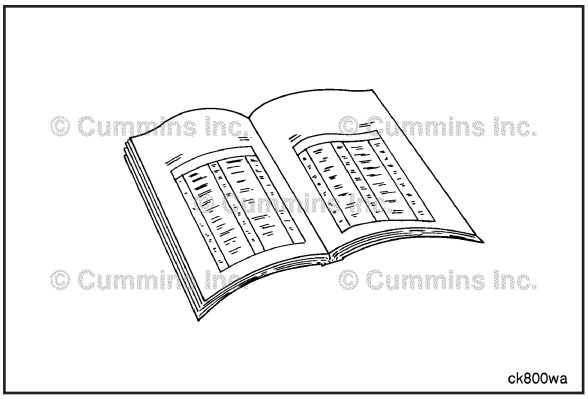
Torque Value: 43 N•m [32 ft-lb]

Finishing Steps

Install the fan drive belt. Refer to Procedure 008-002.

Marine Gear Oil Cooler (008-041)

Preparatory Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠CAUTION⚠
Use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

NOTE: This procedure applies to marine engines **only**.

- Disconnect the batteries. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13.
- Shut off the sea water inlet valve(s) on the vessel hull, if equipped. Refer to the OEM service manual.

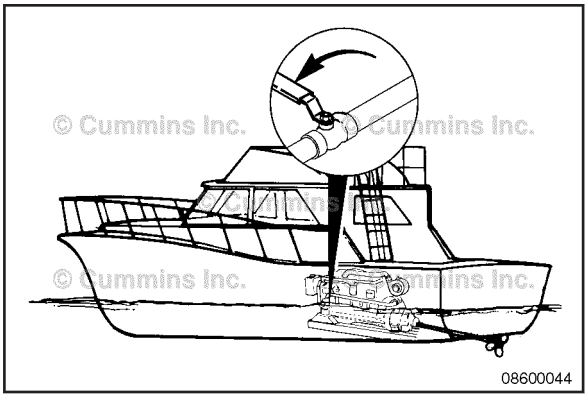
NOTE: This procedure applies to QSL9 and QSC8.3 with oil cooler marine engines **only**. For the QSC engine with combination cooler, refer to Procedure 008-129 (Marine Gear Oil and Fuel Cooler Assembly) in Section 8.

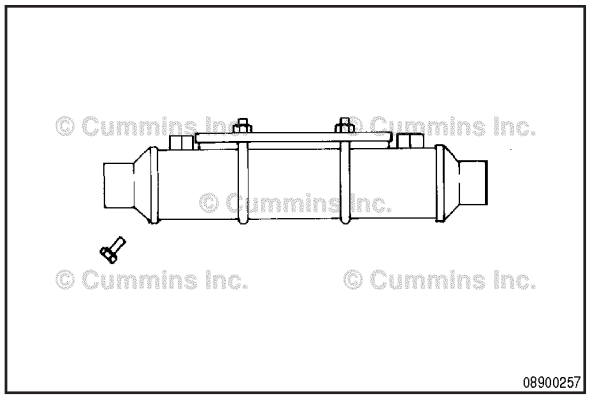
NOTE: Some QSL engines are keel cooled, so **not** all of the steps will apply.

- Disconnect the oil temperature and pressure sensor connectors from the OEM harness.

Flush

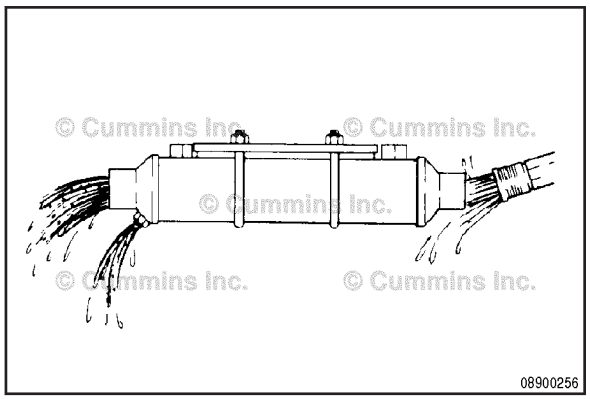
Shut off the sea water inlet valve on the vessel hull, if equipped.





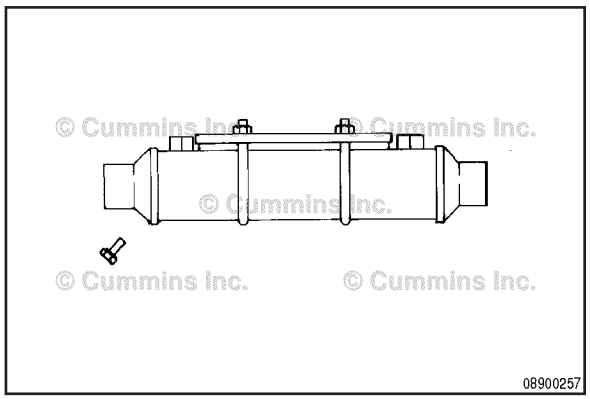
Remove the marine gear oil cooler drain plug and drain the sea water from the marine gear oil cooler.

Disconnect the sea water inlet and outlet connections.

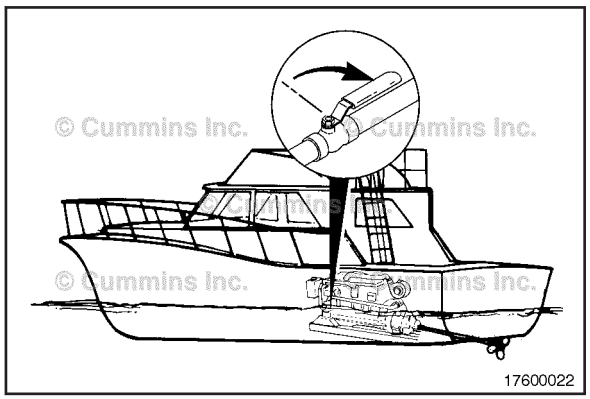


Use clean water to back flush all the debris from the cooler.

Make sure the debris flushed from the cooler does **not** enter the water supply hoses.



Install the drain plug and sea water hose connections.



Open the sea water valve on the vessel hull, if closed.

Remove

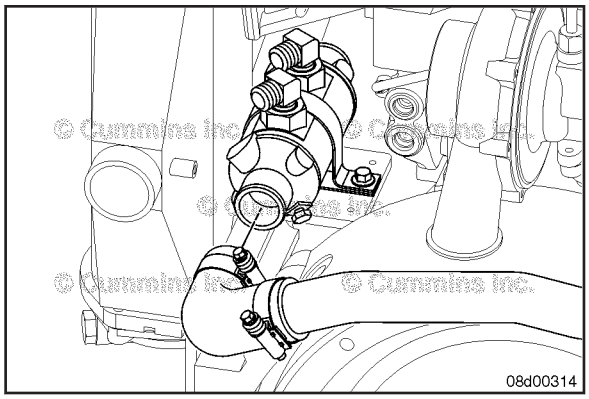
QSL Engines

⚠CAUTION⚠

Removing the sea water supply line for the shaft log seal will allow sea water to leak into the vessel, if the line is not plugged. To reduce the possibility of damage, be sure to plug the supply line and prevent sea water from leaking into the vessel.

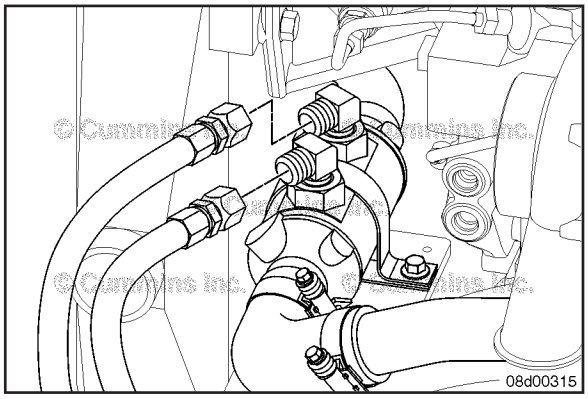
Remove the aftercooler sea water discharge hose from the gear cooler.

Remove the marine gear cooler sea water discharge hose form the gear cooler.



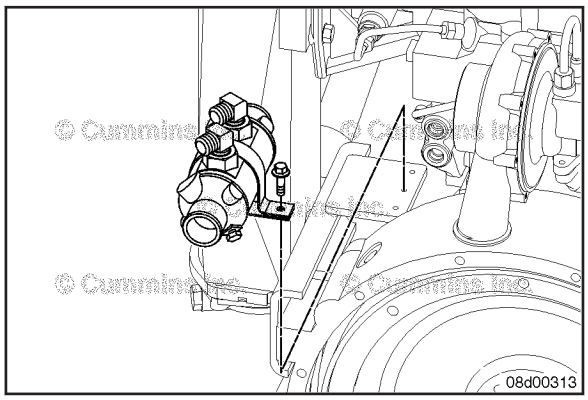
Remove and plug the sea water supply line for the shaft log seal from the gear oil cooler (if equipped).

Remove the transmission oil supply and return lines; mark their locations.



Disconnect the marine gear oil pressure/temperature sensor (if equipped).

Remove the bracket to cooler mounting capscrew.



QSC Engines

Drain the sea water system by removing the two plugs at the bottom of the marine gear oil cooler assembly. Refer to Procedure 008-059 (Zinc Anode) in Section 8.

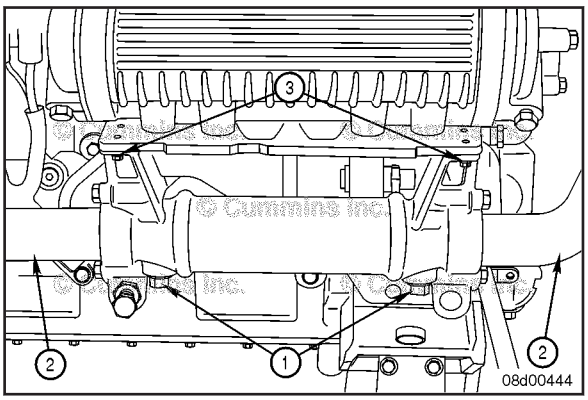
Disconnect the sea water inlet and outlet pipes.

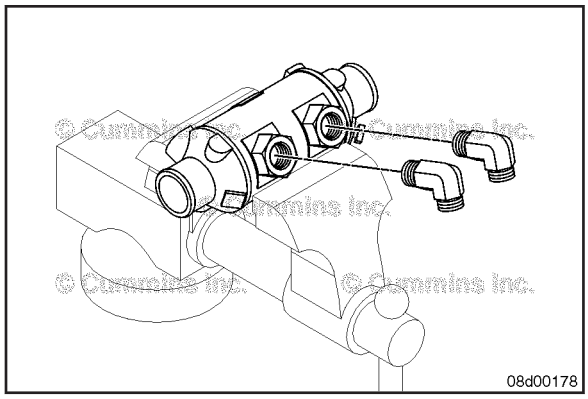
Remove the capscrews mounting the gear cooler to the aftercooler.

Turn the cooler so the transmission oil supply and return lines can be removed.

Remove the transmission oil supply and return lines and mark their locations.

Disconnect the marine gear oil pressure/temperature sensor, if equipped.



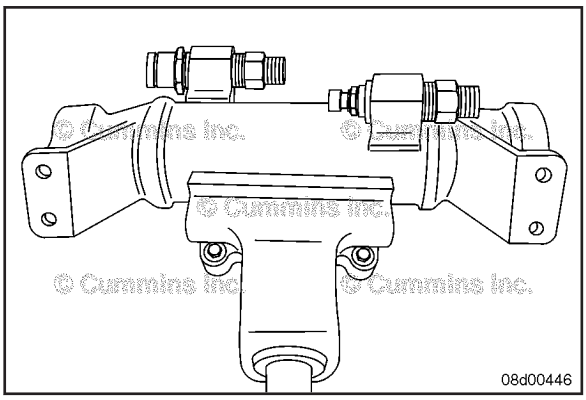


Disassemble

QSL Engines

Place the cooler in a vise and remove the two oil line fittings from the gear cooler, if necessary.

Mark the fitting locations prior to removal.



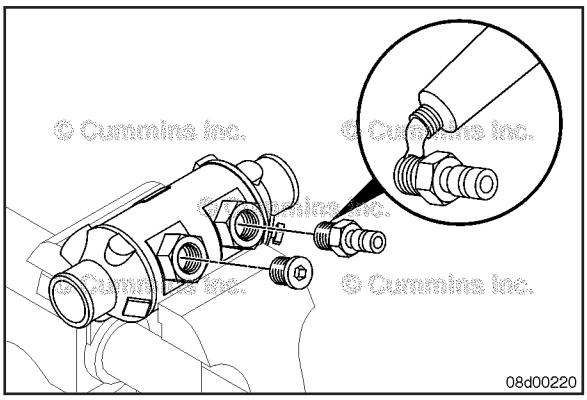
QSC Engines

Place the cooler in a vise and remove the two oil line fittings from the gear cooler, if necessary.

Mark the fitting locations prior to removal.

Remove the sensors, if equipped.

Do **not** tighten the vise to the extent that the cooler case can be damaged.



Inspect for Reuse

QSL Engines

Plug one gear oil port and attach an air supply line to the other gear oil port with a quick disconnect fitting. Apply thread sealant to the threads to prevent leaks. Do **not** allow sealant to enter the gear oil cooler.

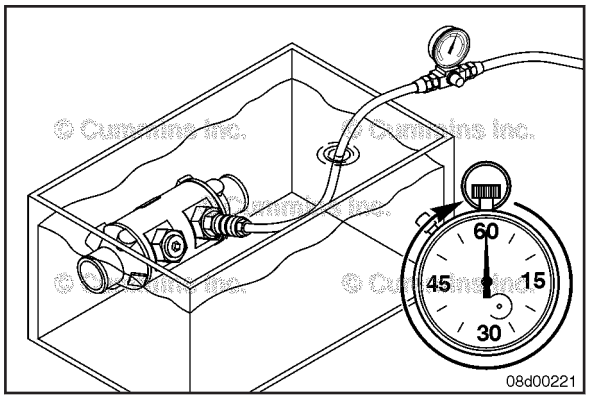
⚠WARNING⚠
Troubleshooting with high pressure air presents the risk of equipment damage, personal injury, or death. Troubleshooting must be performed by trained, experienced technicians.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Attach a high-pressure air supply source (air cylinder or other suitable source) with an air pressure regulator and an inline shutoff valve to the quick disconnect fitting.

Set the regulator test pressure to 276 kPa [40 psi].

Submerge the gear oil cooler into a tank of water. Rotate the cooler to allow any trapped air to escape. Allow the cooler to remain submerged for 1 minute.



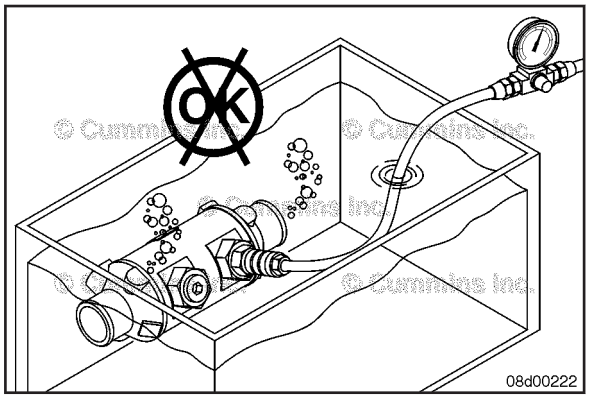
Inspect for air bubbles at the fitting braze joints.

Inspect for air bubbles at the opening at each end of the cooler.

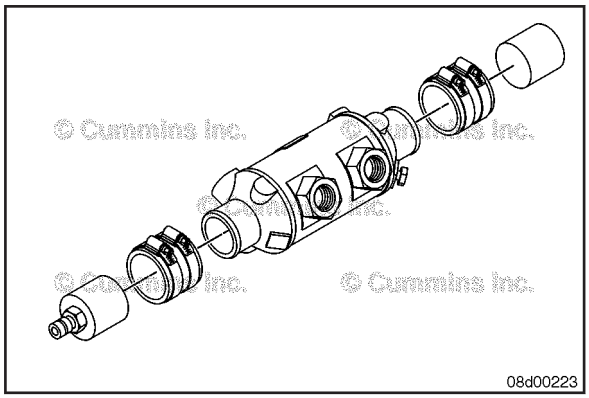
If leaks are detected, replace the gear oil cooler.

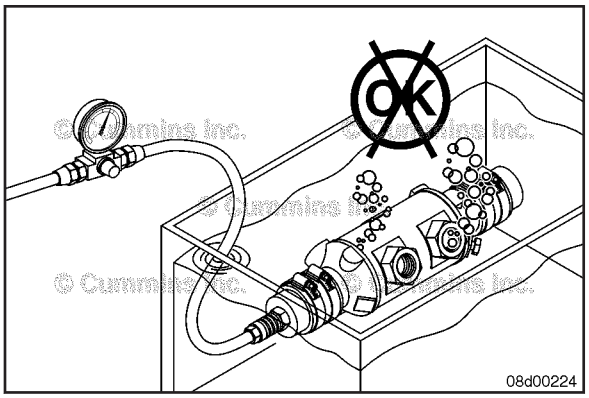
Remove the cooler from the tank. Shut off the air supply and disconnect the air supply.

Remove the plug and test fitting.



Fabricate a test fixture to seal the sea water connections, or use connector hoses with a quick disconnect air connection to supply a regulated test pressure of 276 kPa [40 psi] to the sea water side of the gear oil cooler.





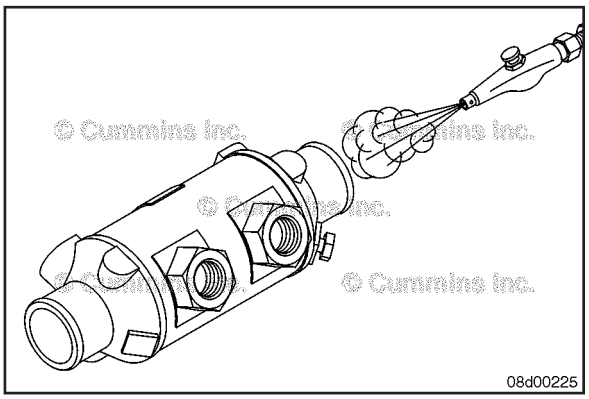
Submerge the cooler into a tank of water for 1 minute.

Inspect for air leaks at the braze joints of the end caps and any bubbles from the gear oil ports. If leaks are detected, replace the gear oil cooler.

Remove the cooler from the tank.

Shut off the air supply and disconnect the air supply.

Remove the test equipment.



⚠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.

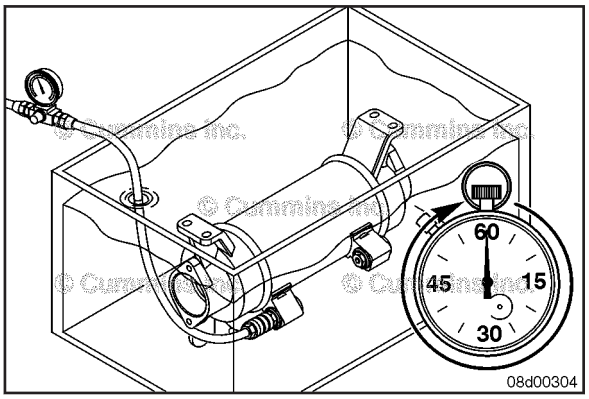
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Drain the water from the cooler.

Flush the oil side of the cooler with clean solvent.

Use compressed air to dry the cooler.



QSC Engines

Plug one gear oil port and sensor ports, as needed.

Attach an air supply line to the other gear oil port with a quick disconnect fitting.

Apply thread sealant to the threads to prevent leaks.

Do **not** allow sealant to enter the gear oil cooler.

Attach a high-pressure air supply source, such as an air cylinder or other suitable source, with an air pressure regulator and an inline shutoff valve to the quick disconnect fitting.

Set the regulator test pressure to 276 kPa [40 psi].

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Submerge the gear oil cooler into a tank of water.

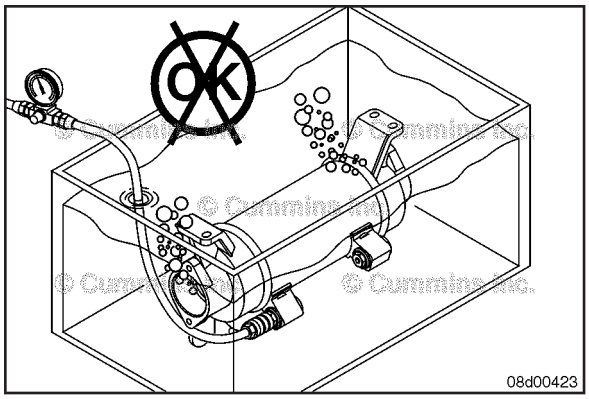
Rotate the cooler to allow any trapped air to escape.

Allow the cooler to remain submerged for 1 minute.

Inspect for air bubbles at the fitting braze joints.

Inspect for air bubbles at the opening at each end of the cooler.

If leaks are detected, replace the gear oil cooler.

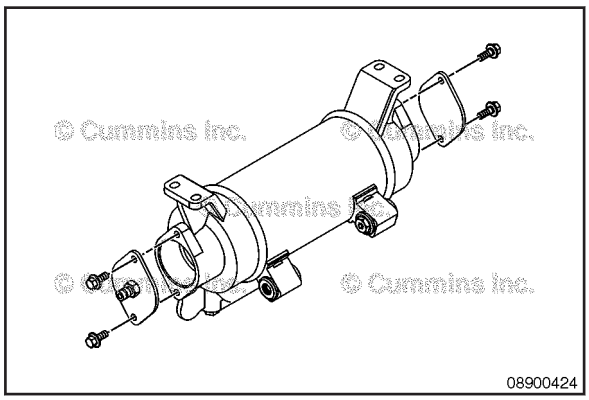


Remove the cooler from the tank.

Shut off the air supply and disconnect the air supply.

Remove the test fitting and install a plug. This is to keep water from contaminating the oil side of the cooler.

Fabricate a test fixture to seal the sea water connections, or use connector hoses with a quick disconnect air connection to supply a regulated test pressure of 276 kPa [40 psi] to the sea water side of the gear oil cooler.



⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Submerge the cooler into a tank of water for 1 minute.

Inspect for air leaks at the braze joints.

If leaks are detected, replace the gear oil cooler.

Remove the cooler from the tank.

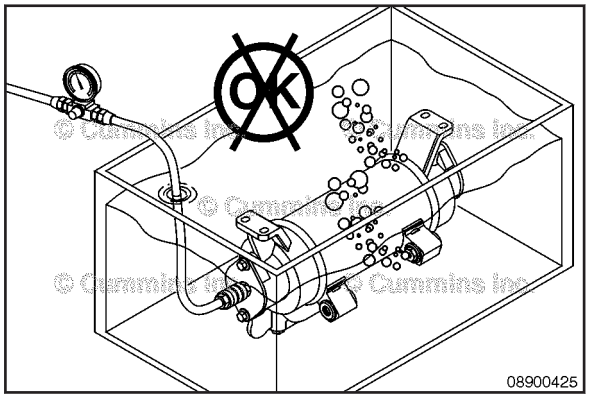
Shut off the air supply and disconnect the air supply.

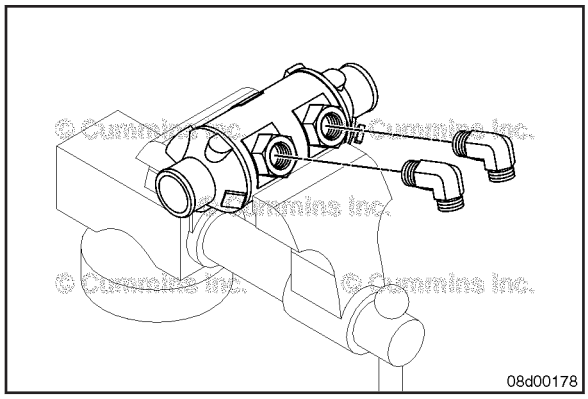
Remove the test equipment.

Drain the water from the cooler.

Flush the oil and fuel sides of the cooler with clean solvent.

Use compressed air to dry the cooler.





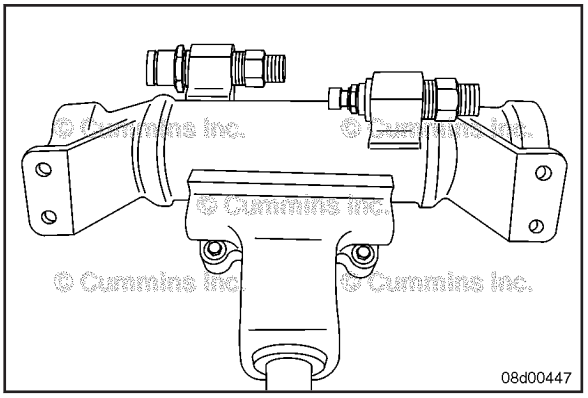
Assemble

QSL Engines

Coat the threads with thread sealant and install the two line fittings into the gear cooler, if removed. Be sure they are oriented in the same direction as they were removed.

Tighten the two locknuts.

Torque Value: 24 N•m [212 in-lb]



QSC Engines

Place the cooler in a vise.

Do **not** tighten the vise to the extent that the cooler case could be damaged.

(1) Coat the threads with thread sealant and install the two line fittings into the gear cooler, if removed. They **must** be oriented in the same direction as they were removed.

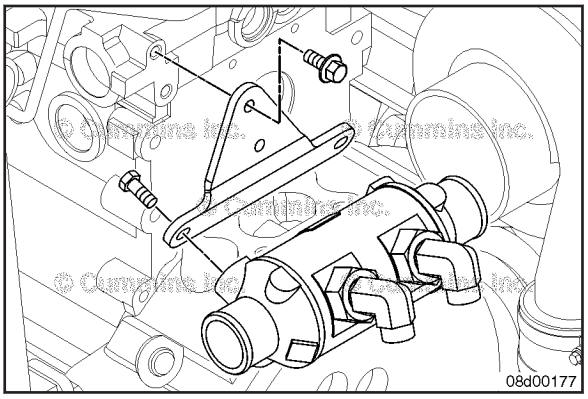
(2) Install the oil temperature sensor on the right and the oil pressure sensor on the left.

Tighten the oil temperature sensor.

Torque Value: 30 N•m [22 ft-lb]

Tighten the oil pressure sensor.

Torque Value: 15 N•m [133 in-lb]



Install

QSL Engines

Install the marine gear oil cooler to the mounting bracket with two mounting capscrews. Tighten the capscrews.

Torque Value: 18 N•m [159 in-lb]

Install the mounting bracket to the engine block with two mounting capscrews. Tighten the capscrews.

Torque Value: 44 N•m [32 ft-lb]

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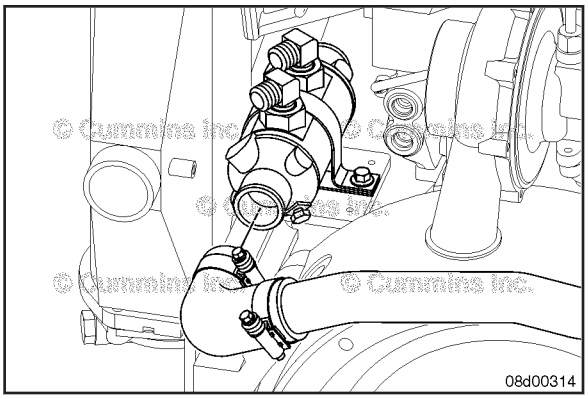
Install the marine gear oil cooler inlet and outlet hoses and tighten the hose clamps.

Torque Value: 8 N•m [71 in-lb]

Install the aftercooler discharge hose and tighten the hose clamp.

Torque Value: 8 N•m [71 in-lb]

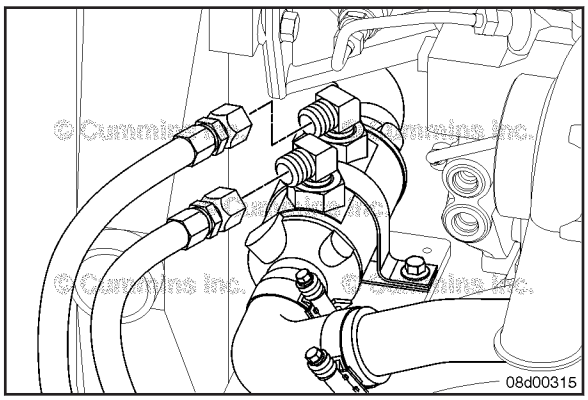


Install the transmission oil supply and return hoses to the gear cooler.

Torque Value: 30 N•m [22 ft-lb]

Install the sea water supply for the shaft log seal to gear oil cooler (if equipped).

Connect the gear oil pressure/temperature sensor wiring harness connector (if equipped).



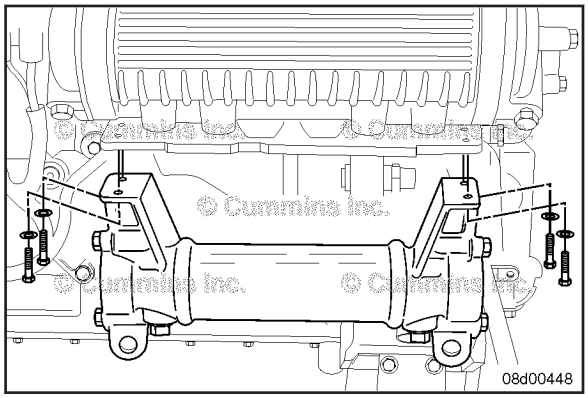
QSC Engines

Connect the transmission oil supply and return lines to their original locations and tighten.

Install the marine gear oil cooler to the aftercooler.

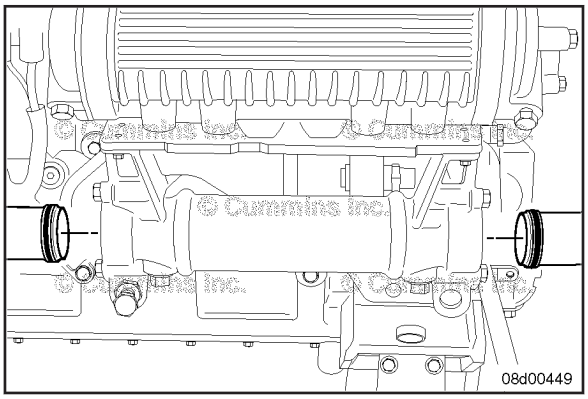
Tighten the capscrews.

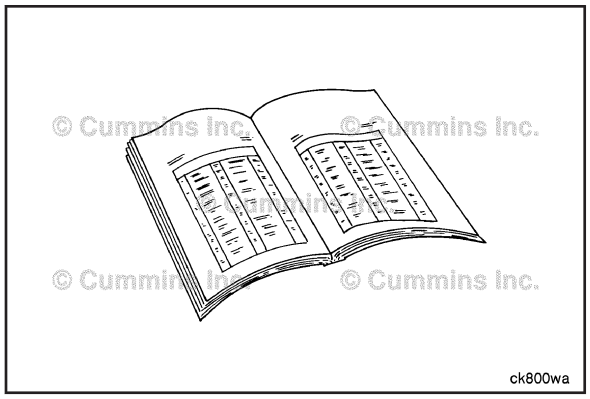
Torque Value: 30 N•m [22 ft-lb]



Connect the sea water inlet and outlet pipe.

Torque Value: 24 N•m [212 in-lb]



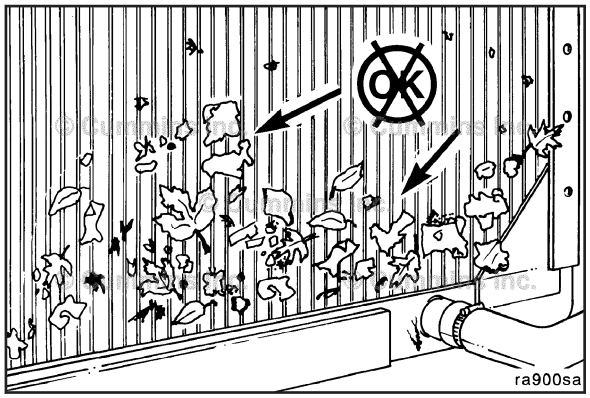


Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

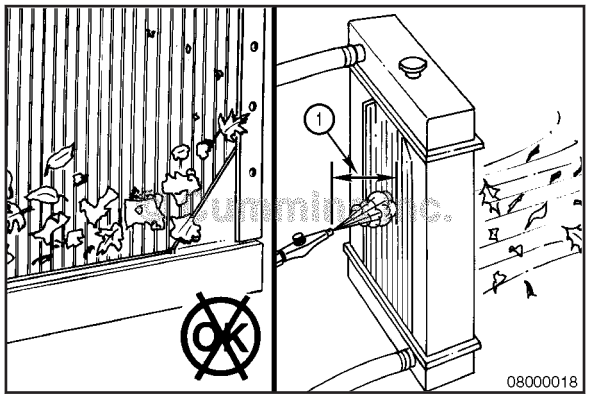
- Connect the aftercooler air inlet connection and air crossover to the aftercooler. Refer to Procedure 010-019 (Air Crossover) in Section 10, and Procedure 010-131 Air Intake Connection Adapter) in Section 10.
- If the engine is sea water cooled, open the sea water valve. Refer to the OEM service manual.
- If the engine is keel cooled, fill the cooling system. Refer to Procedure 008-018 (Cooling System) in Section 8.
- Connect the batteries. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13.
- Operate the engine and check for leaks.



Radiator (008-042)

General Information

Air forced through the fins of the radiator by a fan cools the coolant pumped through the radiator. Environmental debris (such as paper, straw, lint, and dust) can obstruct the fins and stop the flow of air, which will reduce the cooling effect of the radiator.



Initial Check

⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△

Keep the compressed air nozzle a minimum of 15cm [6 in] from the radiator core to avoid damaging the fins. See call out 1 in the illustration

Inspect for plugged radiator fins.

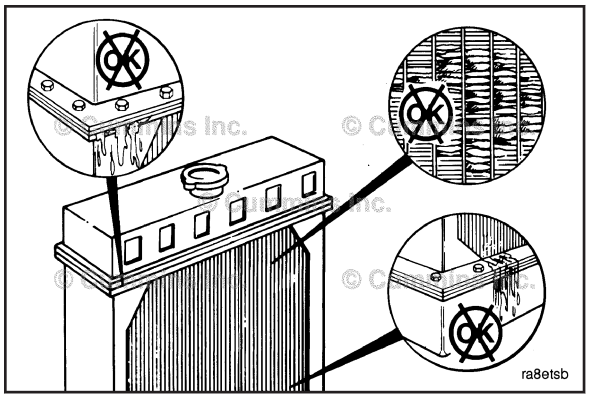
Use compressed air to blow out the dirt and debris.

Air Pressure: 552 kPa [80 psi]

Inspect the radiator for bent or broken fins.

Inspect the radiator core and gasket for leaks.

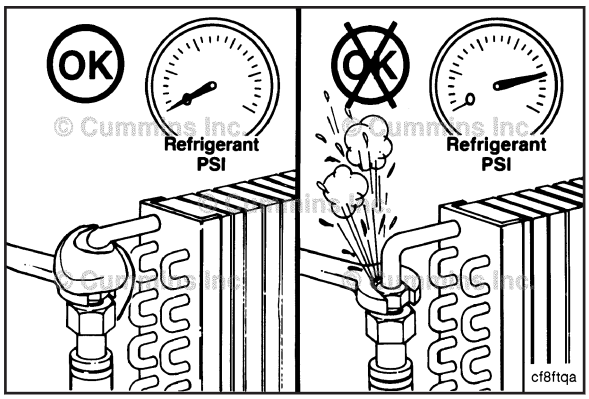
If the radiator **must** be replaced, see equipment manufacturer service information.



⚠WARNING⚠
If a liquid refrigerant system (air conditioning) is used, wear eye and face protection, and wrap a cloth around the fittings before removing. Liquid refrigerant can cause serious eye and skin injuries.

⚠WARNING⚠
To protect the environment, liquid refrigerant systems must be properly emptied and filled using equipment that prevents the release of refrigerant gas into the atmosphere. Federal law requires capturing and recycling the refrigerant.

Use care in removing the refrigerant system, if equipped, before removing the radiator.

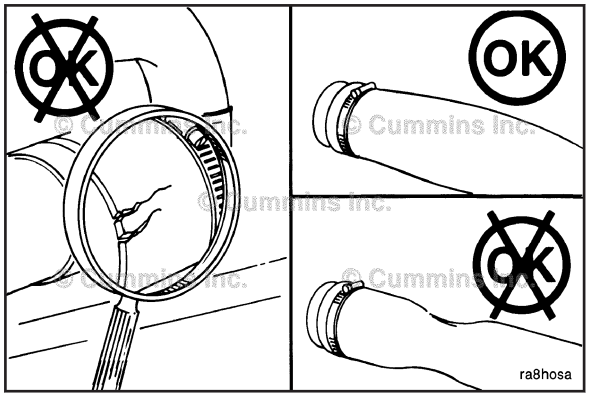


Radiator Hoses (008-045)

Inspect for Reuse

Inspect all hoses for cracks, cuts, or collapsing.

NOTE: The silicone engine coolant hose will exhibit swelling due to the elasticity of the hose.



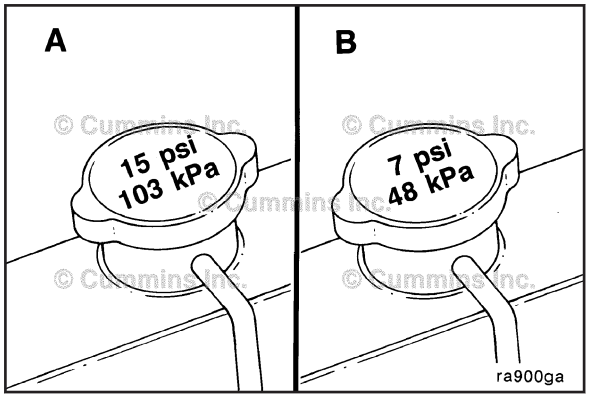
Radiator Pressure Cap (008-047)

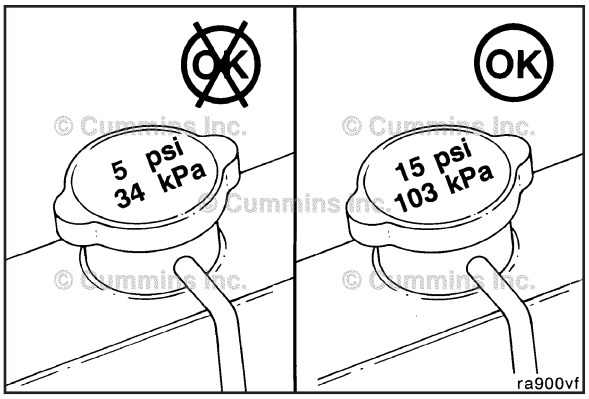
General Information

The system is designed to use a pressure cap to prevent boiling of the coolant.

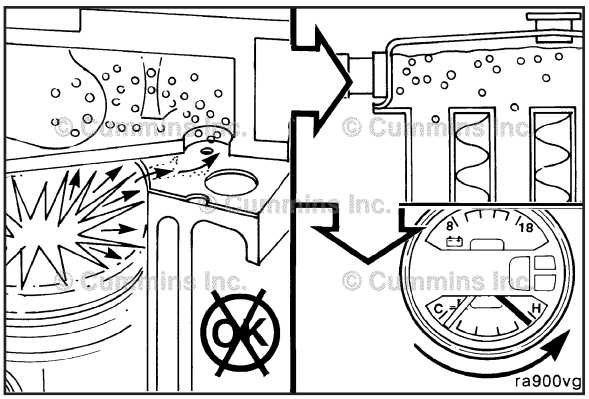
Different caps are specified for the two recommended systems:

Radiator Cap Pressure Test		
	System	**Cap**
A (Normal-Duty)	104°C [220°F]	103 kPa [15 psi]
B (Light-Duty)	99°C [210°F]	48 kPa [7 psi]



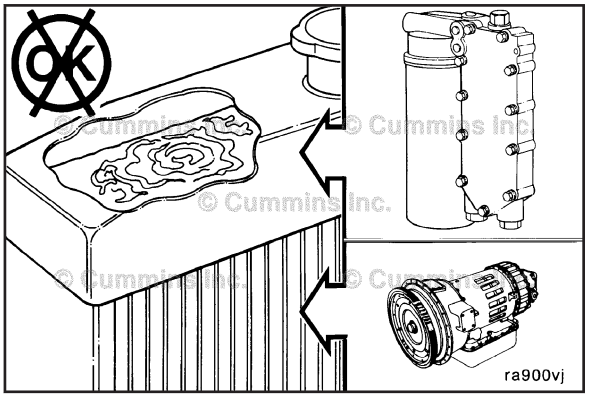


An incorrect or malfunctioning cap can result in the loss of coolant and the engine running hot.



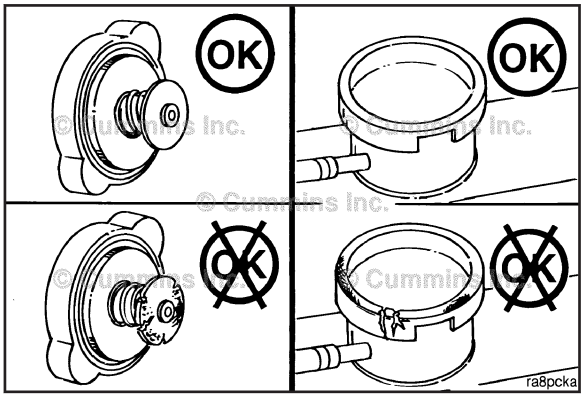
Air in the coolant can result in loss of coolant from the overflow when the aerated coolant is hot. The heated air expands, increasing the pressure in the system, causing the cap to open.

Similarly, coolant can be displaced through the overflow if the head gasket leaks compression gases to the coolant system.



The operating pressure of the cooling system and the lubricating system can result in the mixing of the fluids if there is a leak between the systems such as the head gasket or oil cooler. Refer to Section 7, Lubricating Oil System.

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



Inspect for Reuse

Be sure the correct radiator cap is being used. Refer to the Cooling System Specifications in Section V.

Inspect the rubber seal of the pressure cap for damage.

Inspect the radiator fill neck for cracks or other damage.

Refer to the equipment manufacturer's service manual for instructions if the fill neck is damaged.

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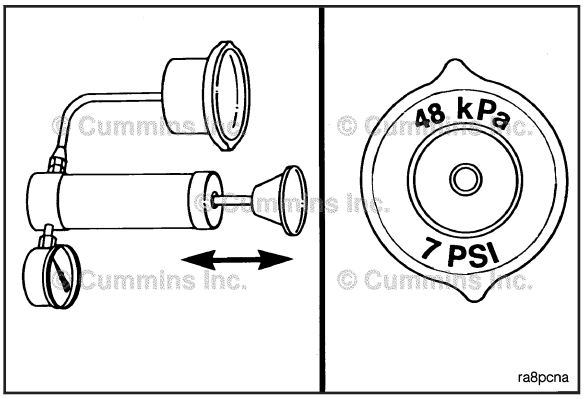
Pressure-test the radiator cap.

The pressure cap **must** seal within 14 kPa [2 psi] of the value stated on the cap, or it **must** be replaced.

Refer to the equipment manufacturer's service manual for radiator cap test procedure.

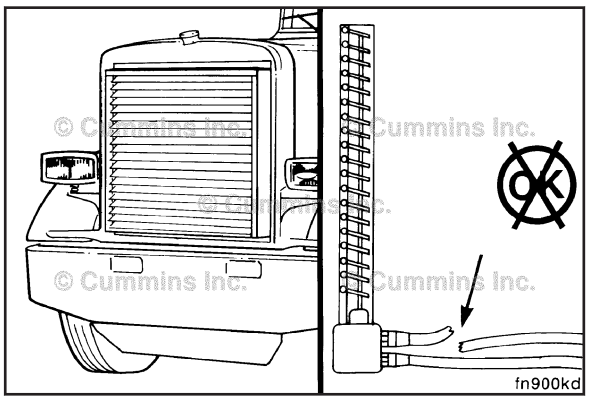


Radiator Shutter Assembly (008-049)

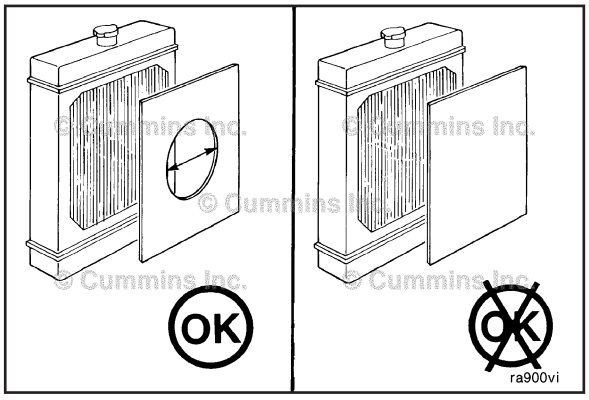
General Information

Shutters are designed to control air-flow across the radiator. If the shutters fail to open when needed, the engine can run hot. Failure of the shutters to close can result in too much air-flow and the engine running cold.

NOTE: Make sure that the air temperature sensor is functioning correctly. Check the air-operated shutter controls. Check for air leaks. Refer to the OEM service manual.



Winterfronts can be used on a charge air cooled engine, but **must** be designed to cover part of the frontal area of the cooling system. A minimum of 77419 sq mm [120 sq in] of charge air cooled frontal area **must** be left open to air-flow.



Expansion Tank (008-052)

General Information

This procedure applies to QSL9 engines **only**. The expansion tank on the QSC8.3 engine is part of the heat exchanger component. Refer to Procedure 008-053.

The graphics in this procedure are of the QSL9 engine with keel cooling. The expansion tank and mounting bracket on the QSL9 engine with sea water cooling (heat exchanger) is different; however, all of the hose and vent line connections are the same.

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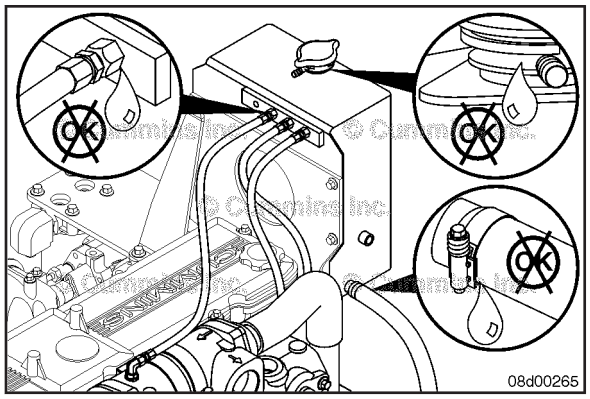
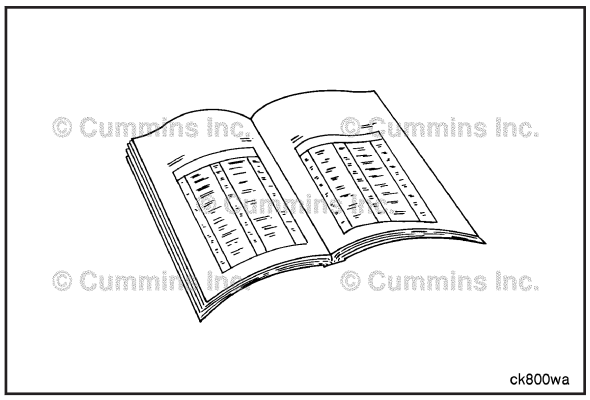


Initial Check

QSL Engines

Check the expansion tank, hoses and vent line connections for signs of leaks.



Preparatory Steps

QSL Engines

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

△CAUTION△
Use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

- Disconnect the batteries. Refer to Procedure 013-009.
- Drain the engine coolant. Refer to Procedure 008-018.
- Disconnect the coolant level sensor connector. Refer to Procedure 019-017 in Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416, or Procedure 019-017 in Troubleshooting and Repair Manual, ISC, QSC8.3, ISL and QSL9 Engines, Bulletin 3666271.

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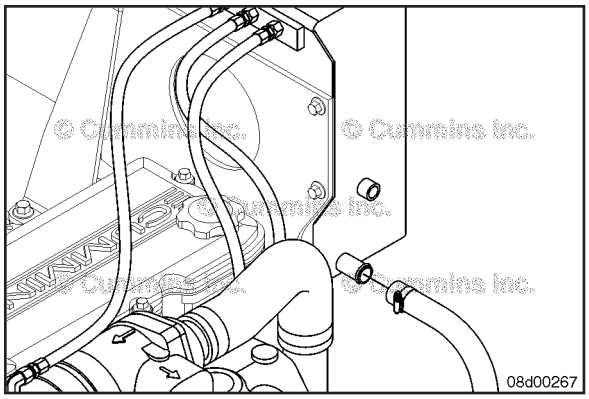
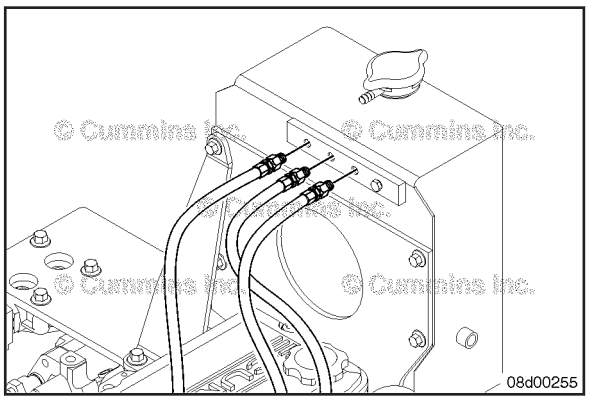
Remove

QSL Engines

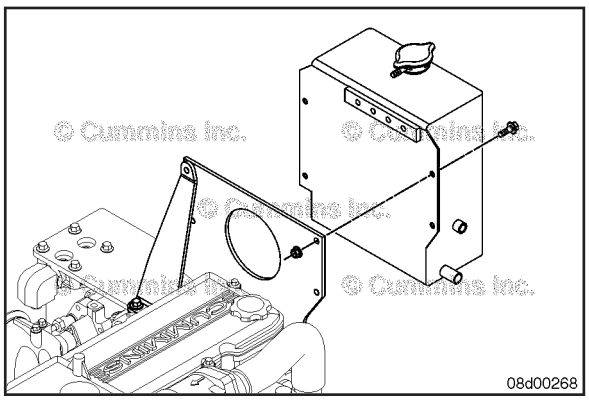
Disconnect the coolant make-up hose from the expansion tank and the coolant transfer tube.



Remove the vent lines from the rear of the expansion tank.

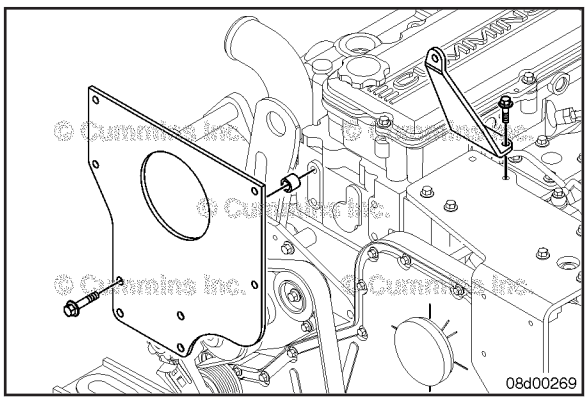


Remove the four mounting capscrews and lift the expansion tank from the engine.



Remove the four bracket mounting capscrews and the expansion tank mounting bracket.

Remove the rubber isolators.



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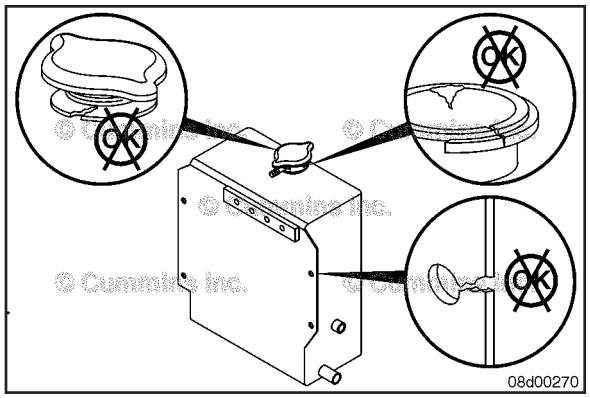


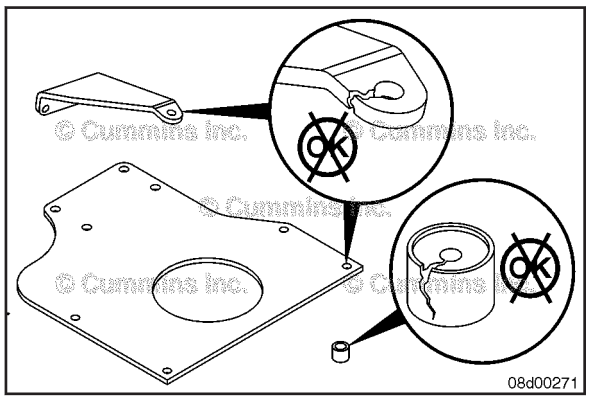
Inspect for Reuse

QSL Engines

Inspect the mounting areas for cracks.

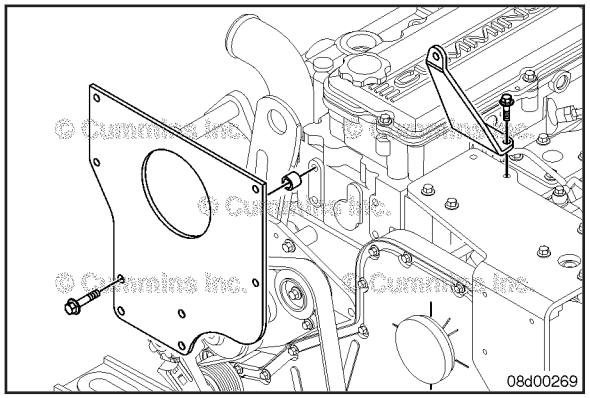
Inspect all connection points for cracks or signs of leakage.

Inspect the fill neck and pressure cap for leakage or cracks.



Inspect the rubber isolators for damage. Replace the isolators, if necessary.

Inspect the mounting bracket for cracks at the bolt hole areas or at the bend in the bracket.

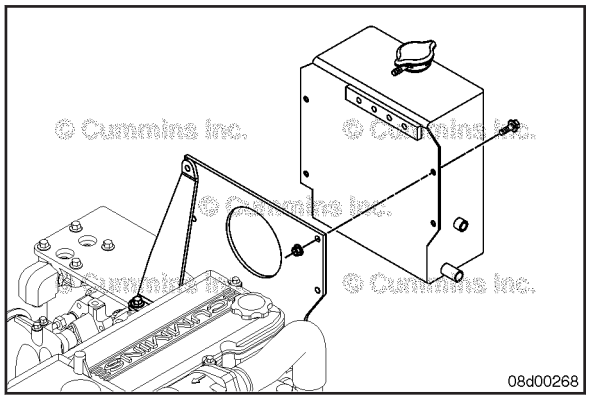


Install

QSL Engines

Install the mounting bracket to the engine. Tighten the four mounting capscrews.

Torque Value: 43 N•m [32 ft-lb]



Install the expansion tank onto the bracket with a rubber vibration isolator and plain washer between the tank and the bracket.

Install the four mounting capscrews, rubber vibrations isolators and plain washers from the bottom of the bracket. Tighten the capscrews.

Torque Value: 43 N•m [32 ft-lb]

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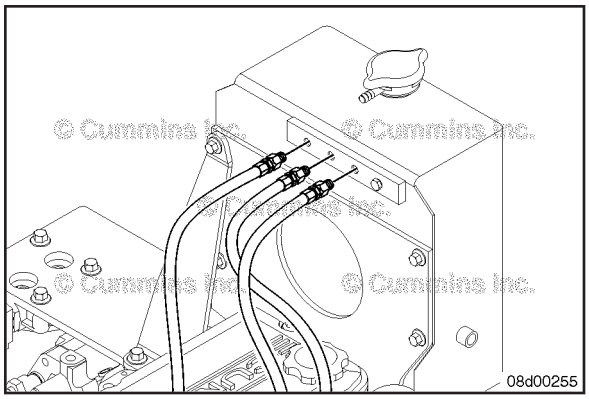
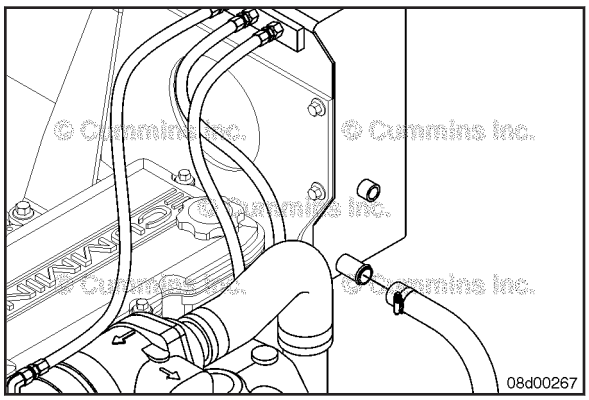
Install the vent line connections at the rear of the expansion tank to the turbocharger, exhaust manifold and thermostat housing.

Torque Value: 14 N•m [124 in-lb]



Install the coolant make-up hose and clamps to the expansion tank and coolant transfer tube. Tighten the hose clamps.

Torque Value: 8 N•m [70 in-lb]

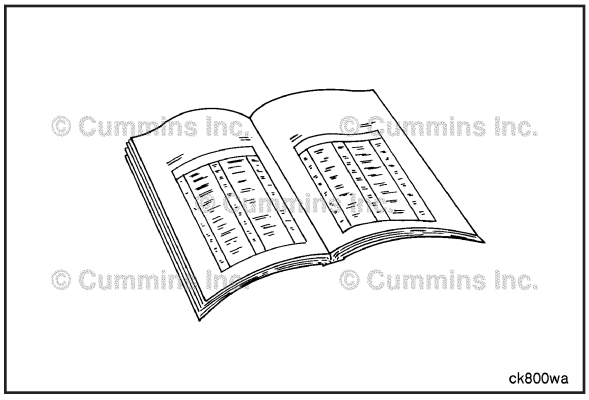


Finishing Steps

QSL Engines

- Connect the coolant level sensor connector. Refer to Procedure 019-017 in Troubleshooting and Repair Manual, ISB, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, QSL9 Engines, CM850 Electronic Control System, Bulletin 4021416, or Procedure 019-017 in Troubleshooting and Repair Manual, ISC, QSC8.3, ISL and QSL9 Engines, Bulletin 3666271.
- Fill the cooling system. Refer to Procedure 008-018.
- Connect the batteries. Refer to Procedure 013-009.

Operate the engine and check for leaks.



Heat Exchanger (008-053)

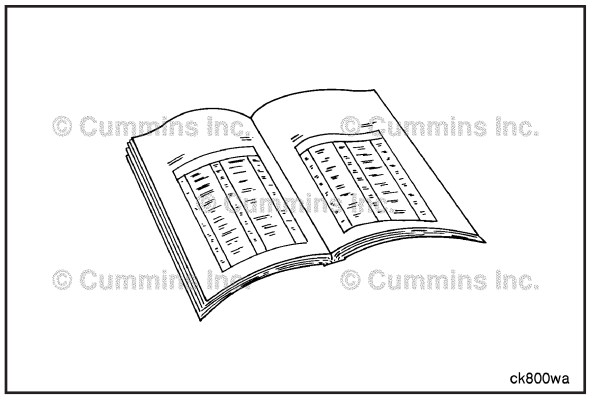
General Information

Marine Applications

This procedure applies to marine engines **only**.

The heat exchanger and the expansion tank is a one piece component on the QSC8.3 marine engine.

The heat exchanger and expansion tank are separate components on the QSL9 marine engine.



Preparatory Steps

QSL Engines

⚠ WARNING ⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ WARNING ⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠ WARNING ⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

△ 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 of in accordance with local environmental regulations.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Shut off the sea water valve. Refer to the OEM service manual.
- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.
- Disconnect the coolant make-up hose from the expansion tank to the coolant transfer tube. Refer to Procedure 008-052 in Section 8.
- Drain the sea water system. Refer to Procedure 010-005 in Section 10.

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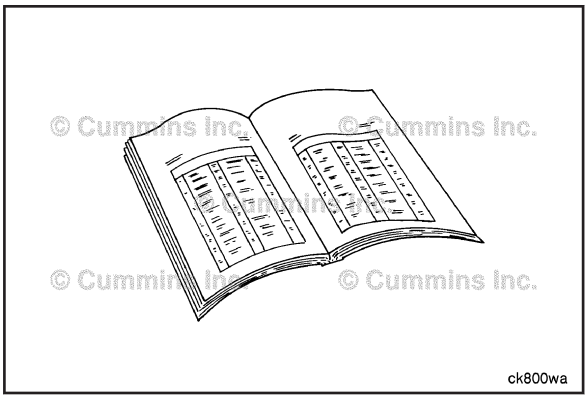
QSC Engines



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

△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 of in accordance with local environmental regulations.

- Disconnect the batteries. Refer to Procedure 013-009.
- Shut off the sea water valve. Refer to the OEM service manual.
- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.
- Drain the sea water system. Refer to Procedure 010-005 in Section 10.
- Disconnect the vent lines from the turbocharger, exhaust manifold, and cylinder head. Refer to Procedure 008-017 in Section 8.

Remove

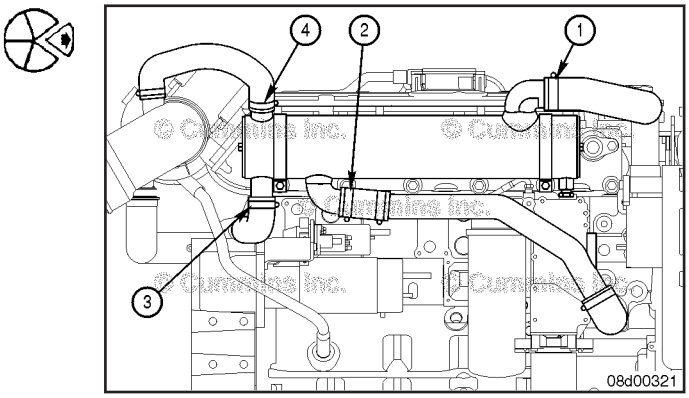
QSL Engines

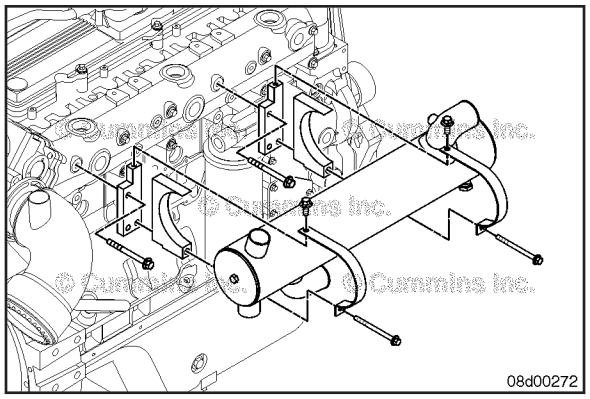
Disconnect the engine coolant heat exchanger inlet hose (1).

Disconnect the engine coolant heat exchanger outlet hose (2).

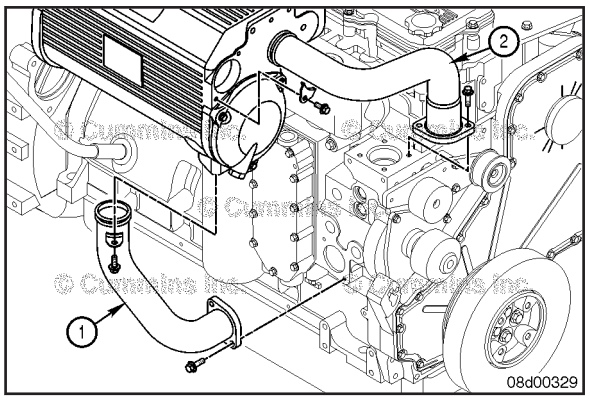
Disconnect the sea water coolant heat exchanger inlet hose (3).

Disconnect the sea water coolant heat exchanger outlet hose (4).



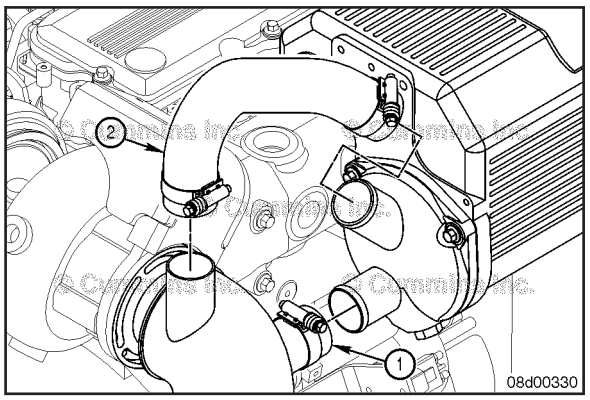


Remove the four mounting capscrews, retaining clamps and isolators, and the heat exchanger.



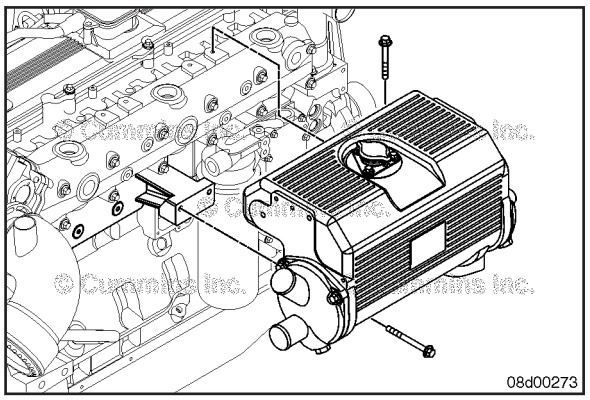
QSC Engines

Remove the engine coolant water inlet (1) and outlet (2) tubes from the heat exchanger.



Disconnect and remove the sea water inlet (1) from the heat exchanger and the aftercooler.

Remove the outlet hose (2) from the heat exchanger.



Remove the two mounting capscrews at the bottom of the heat exchanger and the four mounting capscrews at the heat exchanger to exhaust manifold mounting.

Remove the heat exchanger.

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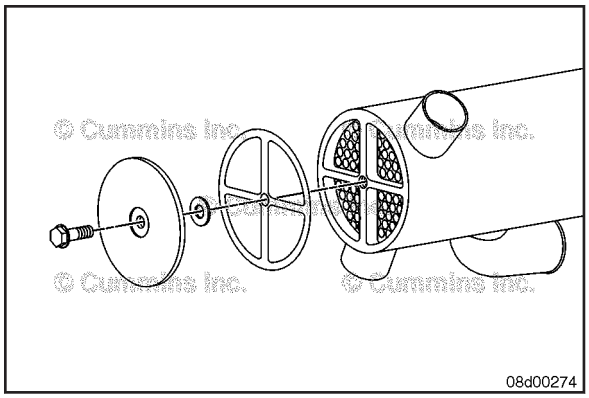
Disassemble

QSL Engines

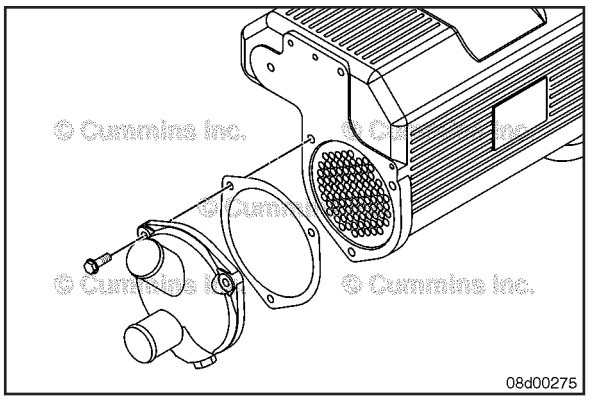
Remove the two end caps from the heat exchanger.



QSC Engines

Note the orientation of the zinc plug locations so they are installed in the same location.

Remove the two end caps from the heat exchanger.



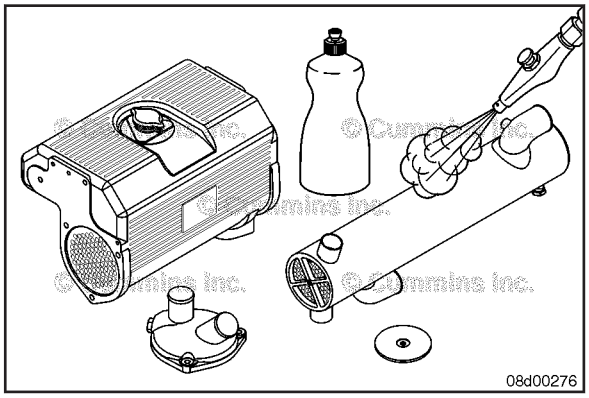
Clean and Inspect for Reuse

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

NOTE: The heat exchanger core can be cleaned and leak tested by a radiator cleaning facility. An ultrasonic cleaner is the preferred method of cleaning.

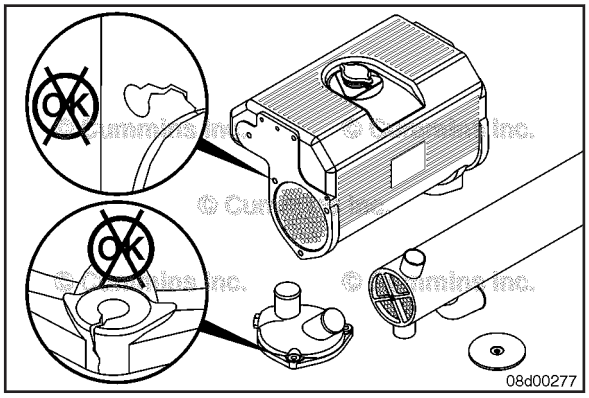
Clean the end caps and the housing with soap and water.

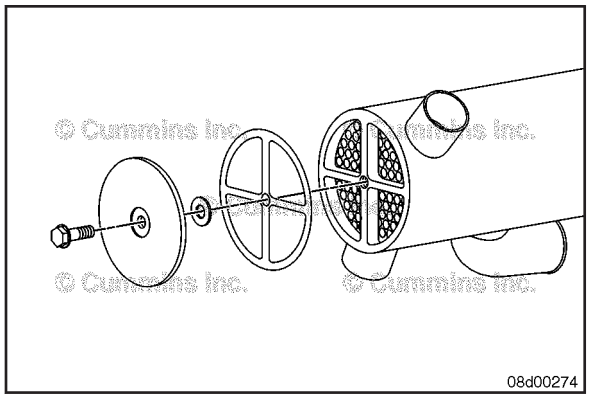
Dry with compressed air.



Inspect the housing and caps for cracks or other damage.

Inspect the housing for deterioration of the sealing surfaces.





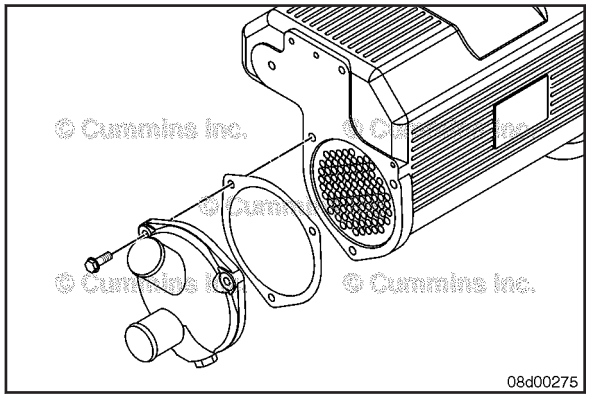
Assemble

QSL Engines

Install a new gasket, seal, spacer and washer.

Install and tighten the end cap mounting capscrews.

Torque Value: 8 N•m [71 in-lb]



QSC Engines

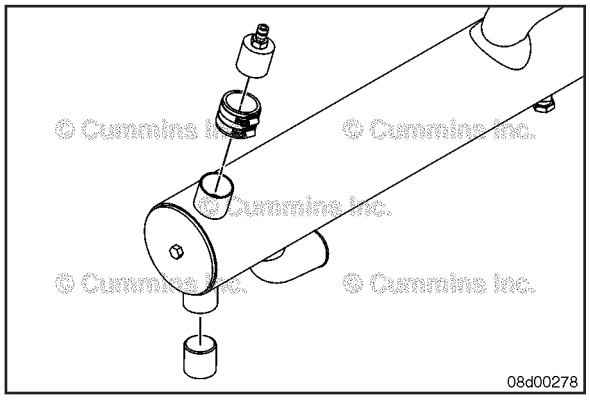
Install new o-rings on both end caps.

Install the end caps with the zinc anodes orientated in the same location as they were removed. Tighten the capscrews.

Torque Value: 44 N•m [32 ft-lb]

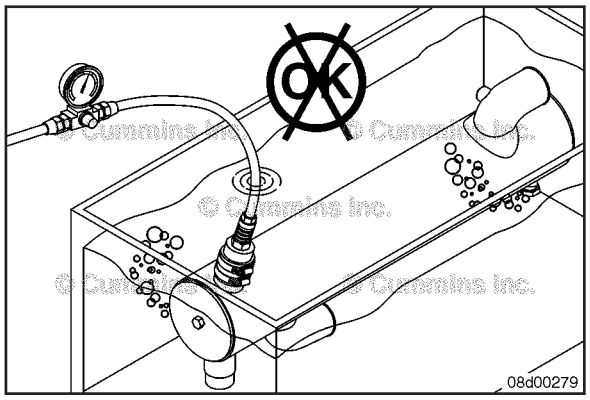
Install the zinc anodes.

Torque Value: 55 N•m [41 ft-lb]



Pressure Test

Fabricate a test fixture to seal the sea water connections, or use connector hoses with a quick disconnect air connection to supply a regulated test pressure of 276 kPa [40 psi] to the sea water side of the heat exchanger.



⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Submerge the expansion tank into a tank of water for one minute. Inspect for air leaks at the end caps and bubbles at the zinc anode plugs. If leaks are detected, replace the cooler.

Remove the cooler from the tank.

Shut off the air supply and disconnect the air supply.

Remove the test equipment and dry the cooler with compressed air.

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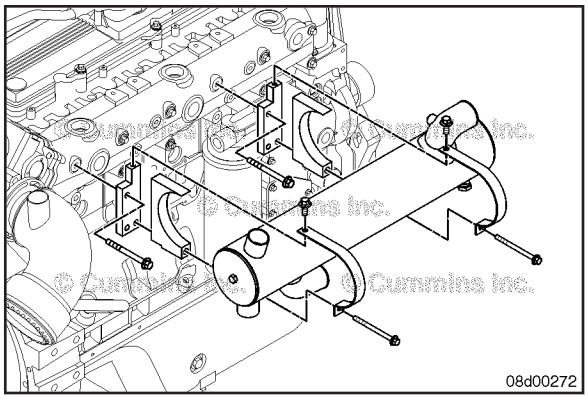
Install

QSL Engines

Install the coolant heat exchanger with the retaining clamps and four mounting capscrews.

Hand-tighten the capscrews at this time.



Connect the engine coolant heat exchanger inlet hose (1).

Connect the engine coolant heat exchanger outlet hose (2) to the heat exchanger and water pump inlet connection.

Connect the sea water coolant heat exchanger inlet hose (3).

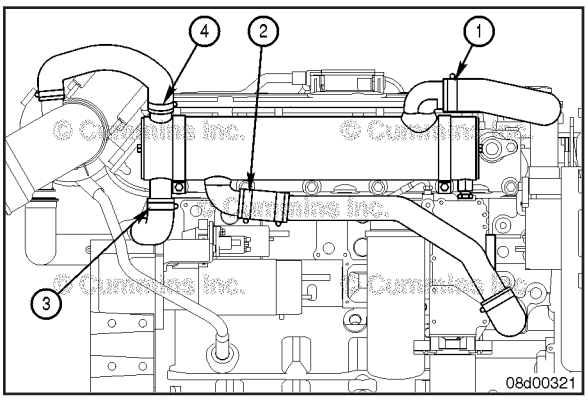
Connect the sea water coolant heat exchanger outlet hose (4).

Tighten all of the hose clamps.

Torque Value: 8 N•m [71 in-lb]

Tighten the heat exchanger mounting capscrews.

Torque Value: 44 N•m [32 ft-lb]



QSC Engines

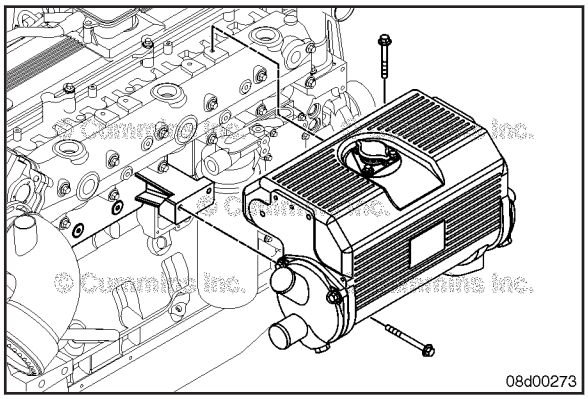
Install the heat exchanger to the exhaust manifold first with the four mounting capscrews. Do **not** tighten these capscrews at this time.

Install the two capscrews at the bottom of the heat exchanger. Tighten the capscrews.

Torque Value: 44 N•m [32 ft-lb]

Tighten the four upper capscrews.

Torque Value: 44 N•m [32 ft-lb]



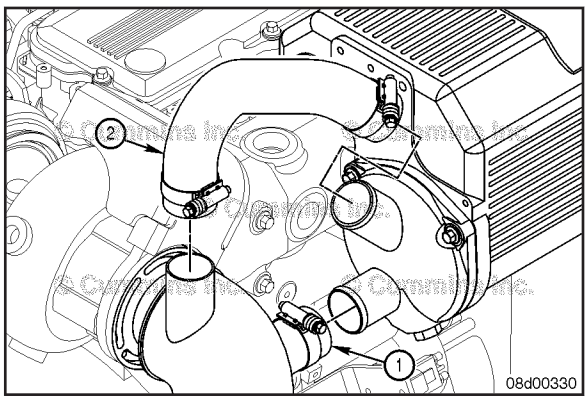
Connect the sea water inlet tube (1) to the heat exchanger and the aftercooler. Tighten the capscrews on the aftercooler connection.

Torque Value: 24 N•m [212 in-lb]

Connect the sea water outlet connection (2) to the heat exchanger and exhaust riser.

Tighten the host clamps on the heat exchanger and the exhaust riser.

Torque Value: 8 N•m [71 in-lb]



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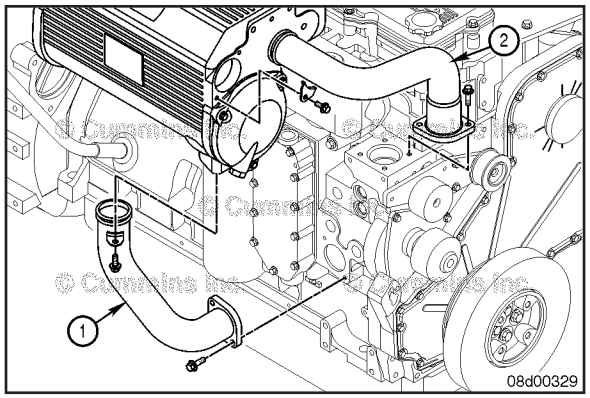
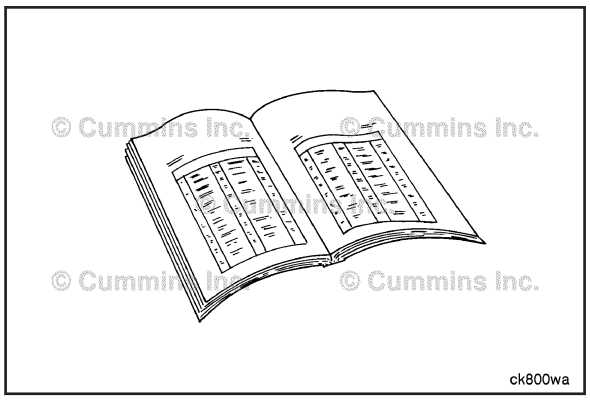


Use new o-rings and install the engine coolant heat exchanger inlet (1) and outlet (2) tubes.

Tighten the capscrews.

Torque Value: 24 N•m [212 in-lb]

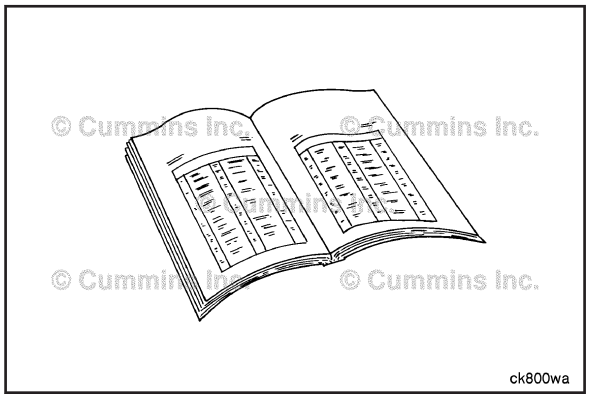


Finishing Steps

QSL Engines

- Connect the coolant make-up hose from the expansion tank to the coolant transfer tube. Refer to Procedure 008-052 in Section 8.
- Fill the engine cooling system. Refer to Procedure 008-018 in Section 8.
- Open the sea water valve. Refer to the OEM service manual.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.

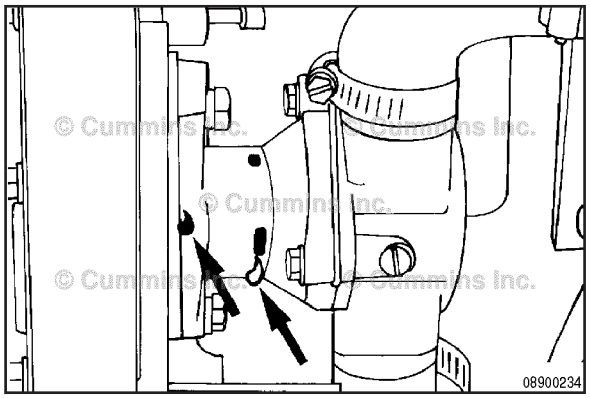
Operate the engine and check for leaks.



QSC Engines

- Connect the vent lines from the turbocharger, exhaust manifold, and cylinder head. Refer to Procedure 008-017 in Section 8.
- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- 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.



Sea Water Pump (008-057)

Initial Check

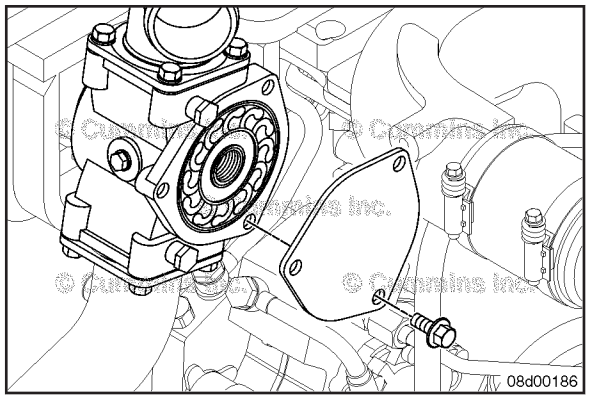
Inspect the sea water pump for evidence of water or oil, indicating seal leakage. If seal leakage is evident, the pump **must** be repaired or replaced.

⚠CAUTION⚠
Zinc plugs expand and can break off during removal. Inspect the zinc plug to make sure it is in one piece. Refer to Procedure 008-059. 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.

Shut off the sea water supply.

Drain the sea water pump by removing the zinc plug from the aftercooler on QSL engines. Refer to Procedure 010-005. On QSC engines, remove the plug at the bottom of the marine gear oil/fuel cooler assembly.

Remove the cover from the back of the sea water pump.



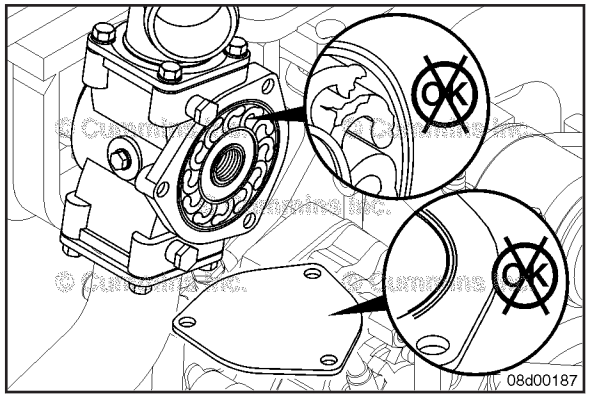
Inspect the cover for signs of grooves worn into the cover surface.

Inspect the impeller for missing, badly worn vanes, or chunks of vanes missing.

If the cover is badly grooved or the impeller is badly damaged, the pump **must** be repaired or replaced. See the Repair step in this procedure for replacing the sea water pump impeller without removing the pump from the engine.

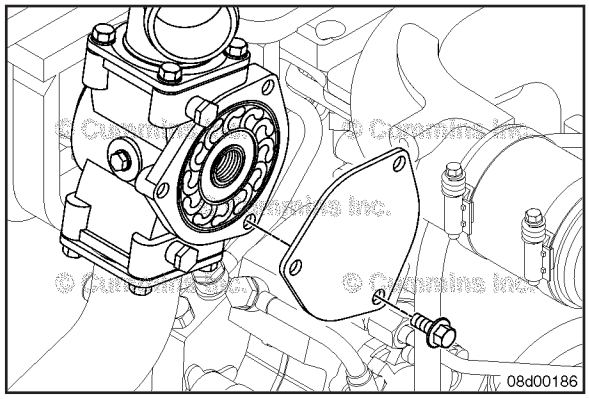
If the impeller is damaged, the sea water circuit down stream (marine gear oil cooler, fuel cooler, aftercooler and aftercooler element) of the pump **must** be checked and cleaned.

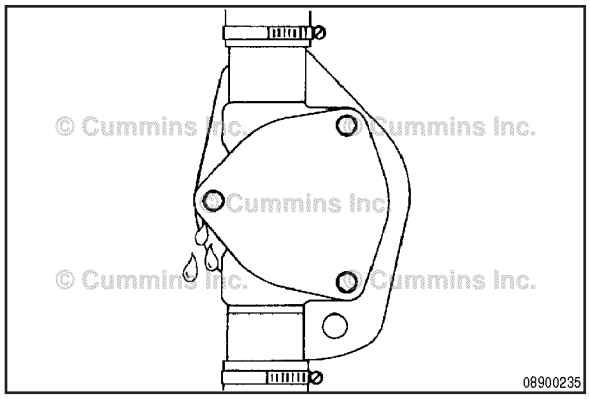
Inspect the cover o-ring for cuts or other damage.



Install the cover on the back of the pump with the three mounting capscrews.

Torque Value: 24 N•m [212 in-lb]



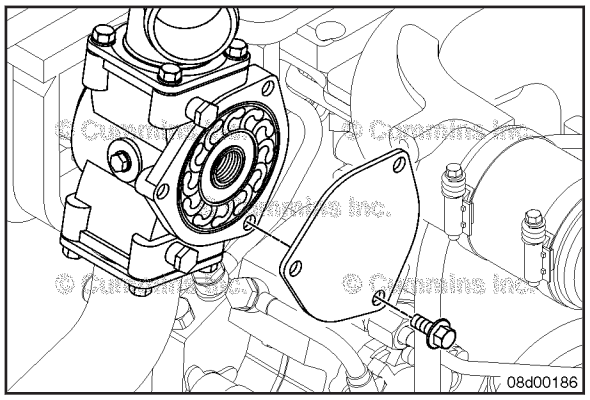


Repair

CAUTION

If the impeller has failed and pieces are missing, all pieces must be retrieved. The engine heat exchanger, marine gear oil cooler, marine gear oil cooler and fuel cooler assembly, and sea water aftercooler must be flushed. Refer to procedures 008-053, 008-041, 008-129, and 010-005 for flushing these components. Failure to do so can result in overheating and damage to engine can occur.

Impeller debris can also drop into the inlet piping. Make sure all debris is removed before installing a new impeller; otherwise, additional impeller failures or engine overheating will occur.



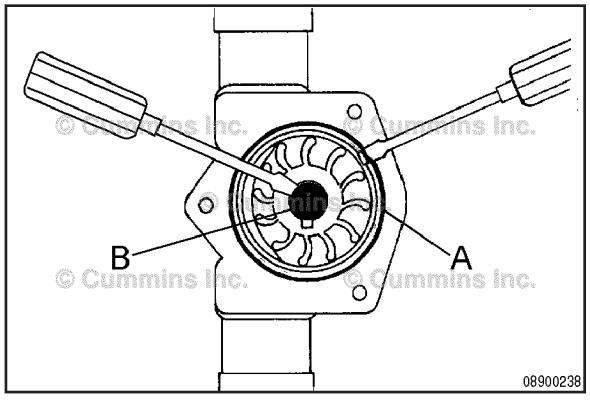
CAUTION

Zinc plugs expand and can break off during removal. Inspect the zinc plug to make sure it is in one piece. Refer to Procedure 008-059. 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.

Shut off the sea water supply.

Drain the sea water pump by removing the zinc plug from the aftercooler on QSL engines. Refer to Procedure 010-005. On QSC engines, remove the plug at the bottom of the marine gear oil/fuel cooler assembly.

Remove the cover from the back of the sea water pump.



Use a small screwdriver to remove the o-ring (A).

Use a small screwdriver to remove the inner cap (B), if equipped.

Clean the o-ring groove.

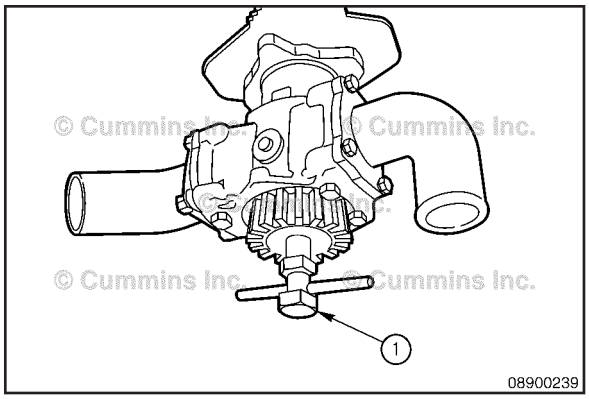
⚠CAUTION⚠

Do not pry against the pump housing to remove the impeller as this can cause damage to the liner.

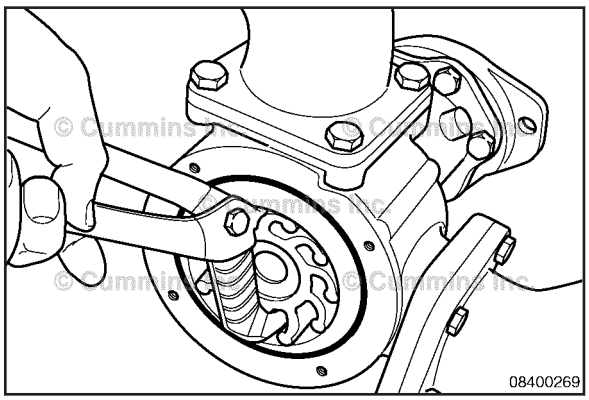
Be sure to note the direction of impeller vanes for proper re-installation. Mark the outer surface.

An impeller removal tool is available from Sherwood Pumps, Part Number 23631.

If the impeller is equipped with a threaded insert, use the special tool or a ¾-NFT bolt (1) to insert in the impeller to pull the impeller out.

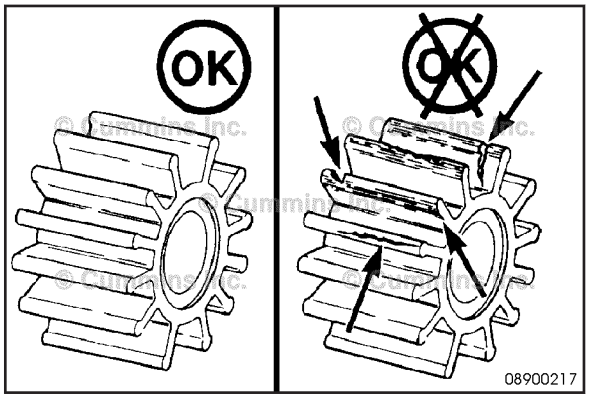


If the impeller does **not** have a threaded bore, grasp the hub of the impeller with pliers and remove the impeller from the impeller bore.



Inspect for damage such as rips, tears, chunks of material missing, or wear on the edges of the vanes.

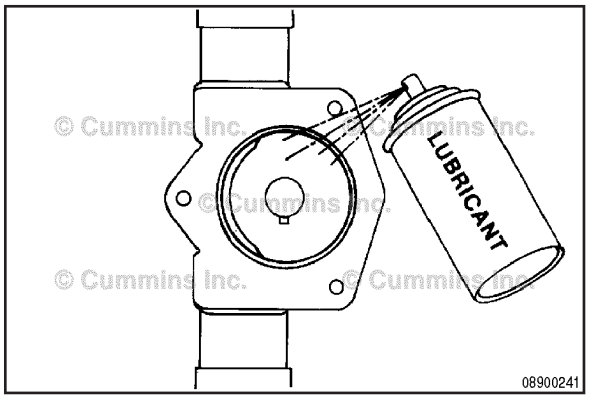
Replace the impeller if damage is found.

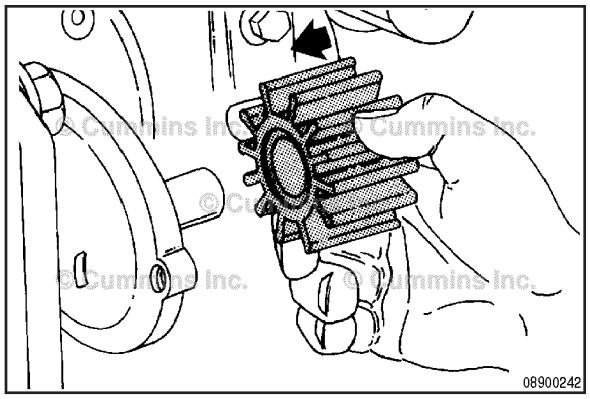


Clean the internal pump surfaces.

Lubricate the housing with silicone or glycerine non-petroleum-based lubricant. Petroleum-based lubricant will damage the rubber impeller.

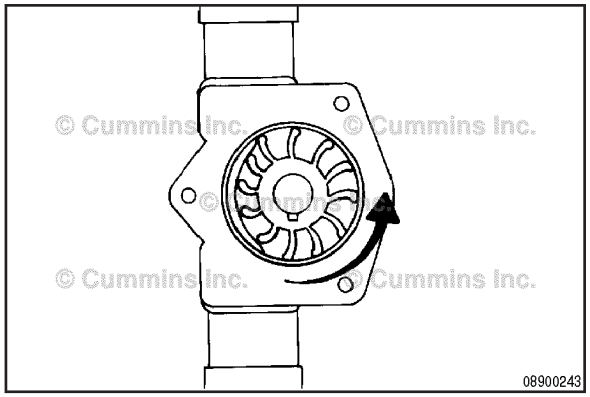
If non-petroleum-based lubricant is **not** readily available, use soapy water to ease installation.





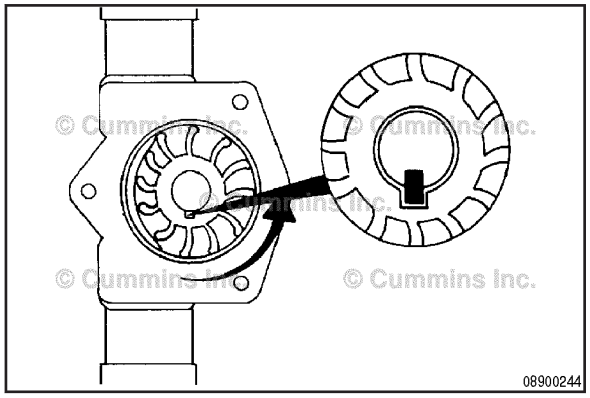
If the impeller is in good shape and will be reused, install it in the same direction from which it was removed. See the mark you made during removal.

If the impeller was **not** marked and the original rotation or direction can **not** be determined, replace the impeller with a new one.

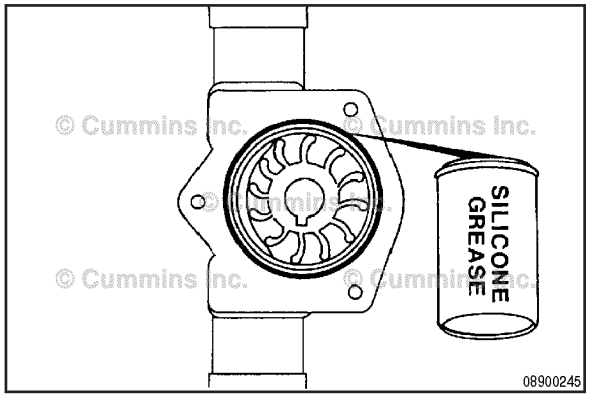


An oil filter strap wrench or even plastic wire straps can be used as an installation aid to hold the vanes.

Guide the impeller into the housing, twisting it **counterclockwise** as it is advanced so that the vanes will be deflected in the proper direction.

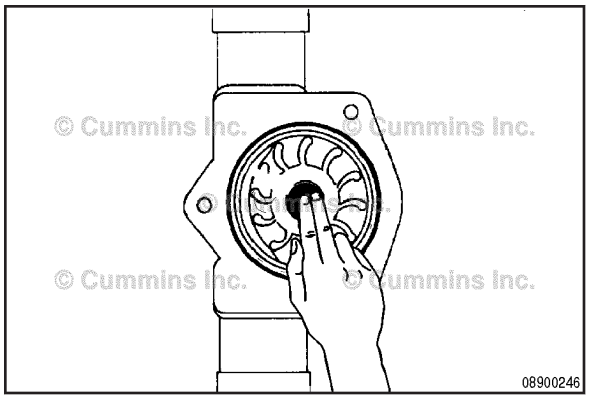


Continue to turn the impeller while pushing it into the housing. It will slide all the way in when the keyway lines up with the key.



Insert the new o-ring into the impeller housing. Use a light coat of silicone grease to hold the o-ring in place.

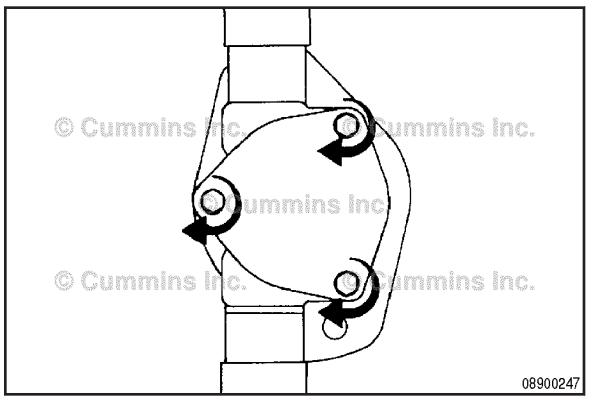
Install the rubber impeller cap into the center hub of the impeller, if equipped.



Install the cover plate and capscrews.

Tighten the capscrews.

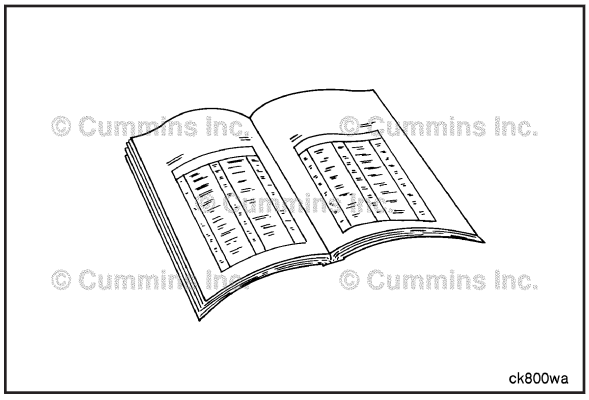
Torque Value: 24 N•m [212 in-lb]



Preparatory Steps

⚠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.

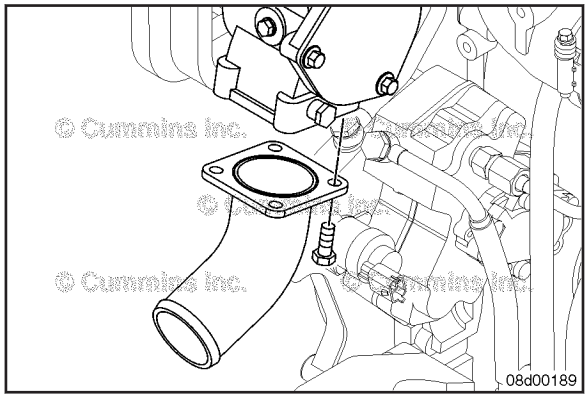
- Shut off the sea water supply. Refer to the OEM service manual.
- Drain the sea water system by removing the zinc plug from the bottom of the aftercooler of QSL engines. Refer to Procedure 010-005. On QSC engines, remove the plug at the bottom of the marine gear oil/fuel cooler assembly.

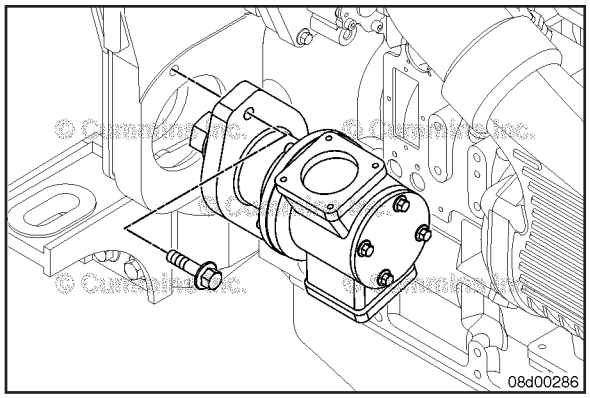


Remove

Remove the upper and lower water connections from the sea water pump.

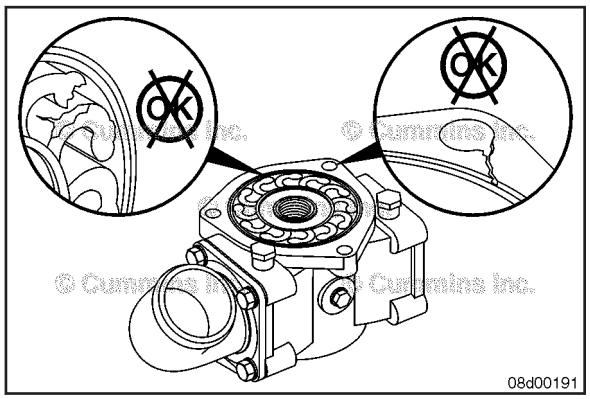
Remove the o-rings.





Remove the sea water pump mounting capscrews.

Remove the sea water pump.



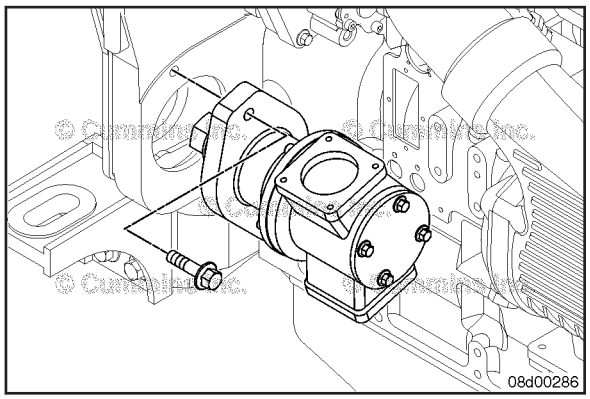
Inspect for Reuse

Inspect the pump for cracks, leakage points or other exterior damage.

Remove the rear cover and inspect the impeller.

Repair or replace the sea water pump if damage is found.

Inspect the water inlet and outlet connection o-rings. Replace if damaged.



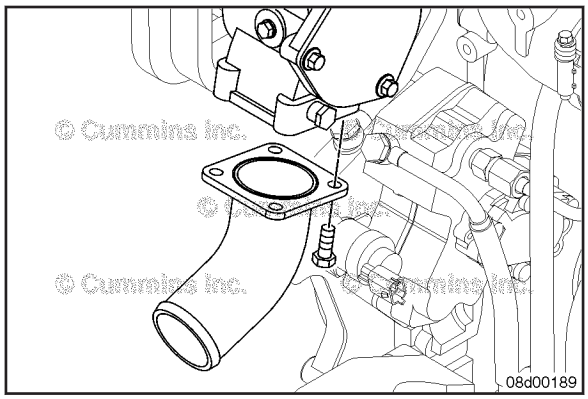
Install

NOTE: If a new sea water pump is being installed, the sea water pump **must** be painted before installation.

Install the sea water pump.

Install the sea water pump mounting capscrews and tighten.

Torque Value: 24 N•m [18 ft-lb]



Install the o-rings onto the water inlet and outlet connections. Use a light coat of silicone grease to hold the o-rings in place.

Install the upper and lower water connections from the sea water pump.

Install the capscrews and tighten.

Torque Value: 133 N•m [15 in-lb]

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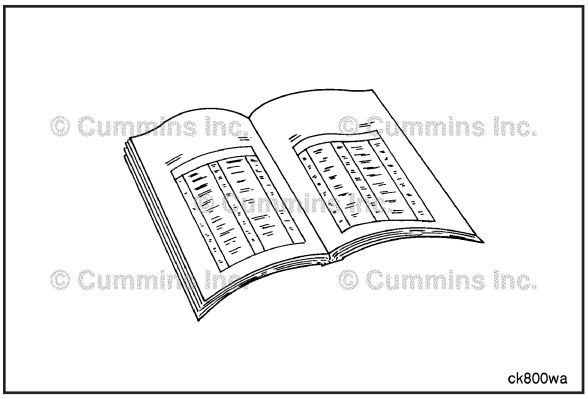
Finishing Steps

- Install the zinc plug in the aftercooler on QSL engines. Refer to Procedure 010-005. On QSC engines, install the plug in the bottom of the marine gear oil/fuel cooler assembly.
- Open the sea water supply.

Operate the engine and check for leaks.



Zinc Anode (008-059)

Remove

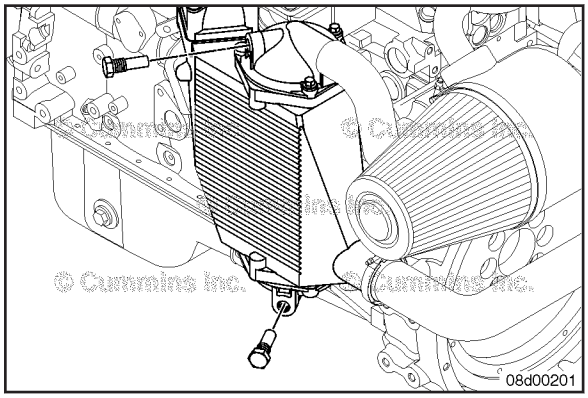
⚠CAUTION⚠
Zinc anode plugs expand and can break off during removal. Inspect the zinc anode plug to make sure it is in one piece. If not, it must be replaced with a new zinc anode plug, and the broken pieces must be retrieved from the aftercooler to prevent damage to components downstream in the sea water system.

⚠CAUTION⚠
In some cases, it will be necessary to hold the welded fitting on the heat exchanger with an additional wrench to prevent damage to the heat exchanger.

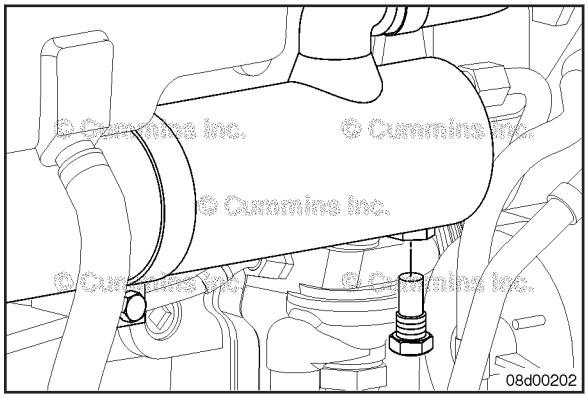
The QSC8.3 marine engine has two zinc anode plugs in the heat exchanger and two in the aftercooler. The QSL9 sea water cooled engine (heat exchanger) has one zinc anode plug in the heat exchanger and two in the aftercooler.

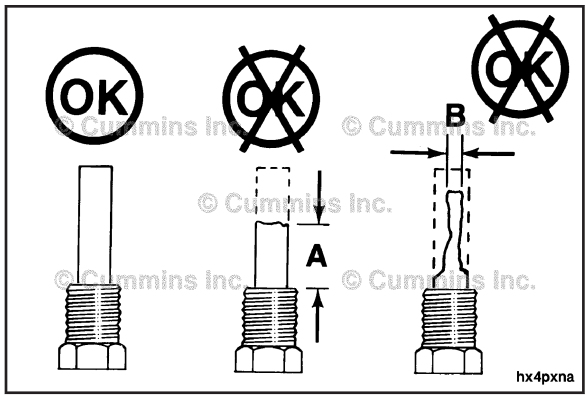
The QSL9 keel cooled marine engine does **not** use zinc anode plugs.

Shut off the sea water supply valve(s) and remove the zinc anode plugs from the bottom and top of the aftercooler assembly.



Remove the zinc anode plug from the bottom of the heat exchanger.





Inspect the sacrificial zinc anode plug and replace as required.

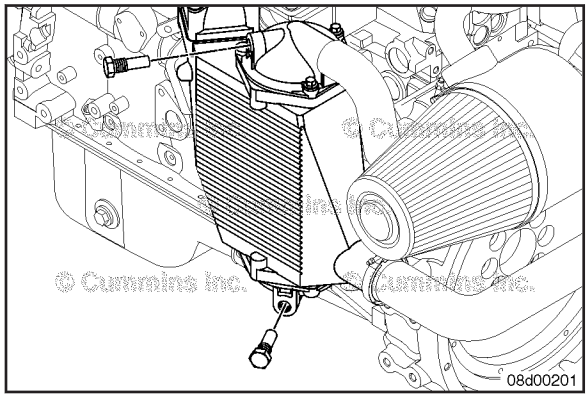
Place the zinc portion of the plug on a metal surface and strike the plug with a small hammer to remove loose material. This will help to determine the actual amount of material remaining.

Check the length of all the zinc anode plugs in the heat exchanger and aftercooler, and replace them if they are 50 percent eroded. Frequency of replacement depends upon the chemical reaction of raw water circulated through the heat exchanger and aftercooler.

Zinc anode Plug Erosion Limits

	mm		in
A	19.0	MIN	0.750
New	51.0	MAX	2.000
B	6.4	MIN	0.250
New	16.0	MAX	0.630

If any zinc anode plug does **not** meet specification, replace it with a new zinc anode plug.



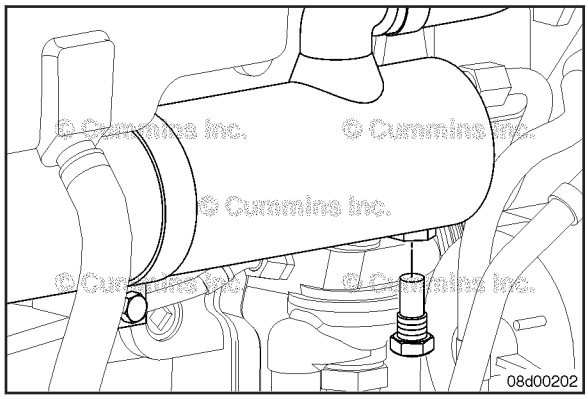
Install

⚠CAUTION⚠

Do not use thread sealant or Teflon™ tape on the zinc anodes. The use of any type of thread sealant will insulate the zinc anode and prevent a good ground.

Install the zinc anode plugs in the aftercooler assembly.

Torque Value: 45 N•m [35 ft-lb]



Install the zinc anode plug in the bottom of the heat exchanger.

Torque Value: 45 N•m [35 ft-lb]

Open the sea water supply valve(s).

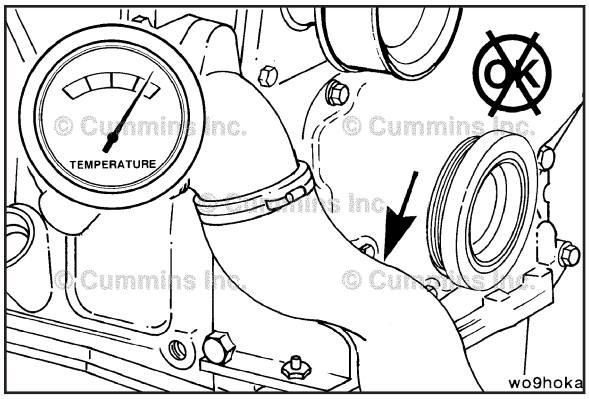
Operate the engine and check for leaks.

Water Pump (008-062)

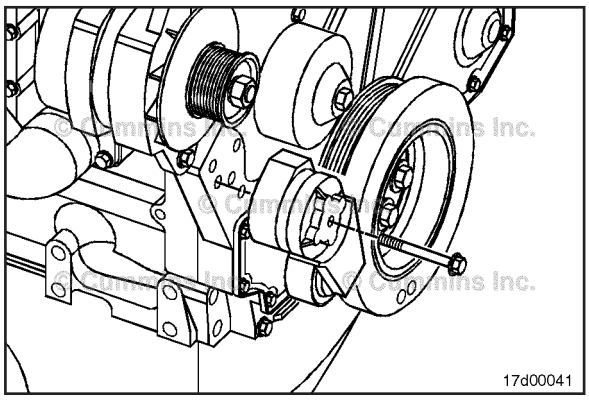
General Information

On all applications except marine, the water pump pulls coolant from the bottom of the radiator and pumps it through the engine and back to the top of the radiator for cooling. Reduced or interrupted flow will result in the engine operating hot.

On marine applications, the water pump pulls water through a coolant return line from the heat exchanger, if equipped, and exhaust manifold. A makeup line from an expansion tank is also plumbed into the coolant return line.

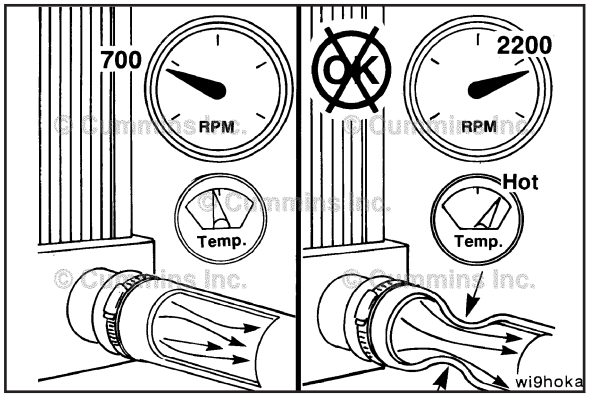


The pump is belt-driven from the crankshaft pulley. An automatic belt tensioner is used to prevent the belt from slipping on the pump pulley. A malfunction of the tensioner will cause the water pump impeller to rotate at a slower speed, reducing the amount of coolant flow.

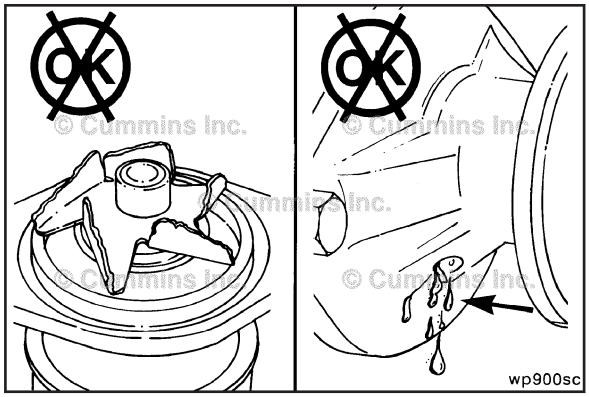


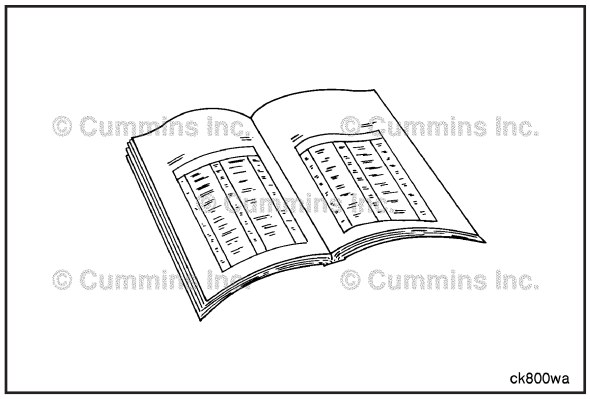
The coolant flow can also be reduced if the inlet hose to the water pump collapses. A hose will usually **not** collapse while the engine is running at low speed. Check the hose while the engine is operating at rated speed.

NOTE: Be sure the engine is warm, a minimum of 91°C [195°F], so the thermostat is open.



A worn or malfunctioning water pump will **not** produce the flow required to prevent the engine from running hot. However, be sure to check the other possibilities indicated in the Coolant Temperature above Normal symptom chart in Section TS before checking the flow or replacing the pump.





Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

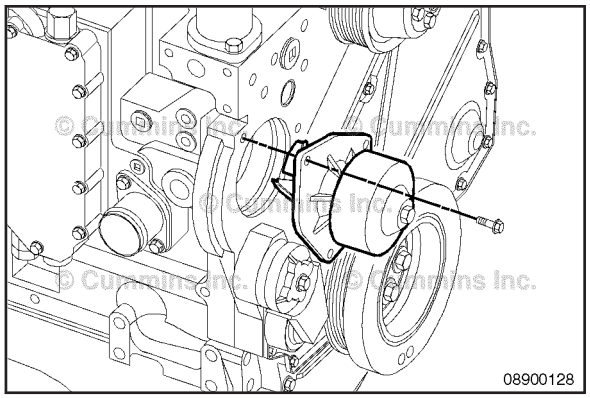
⚠WARNING⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

△CAUTION△

Use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- 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.

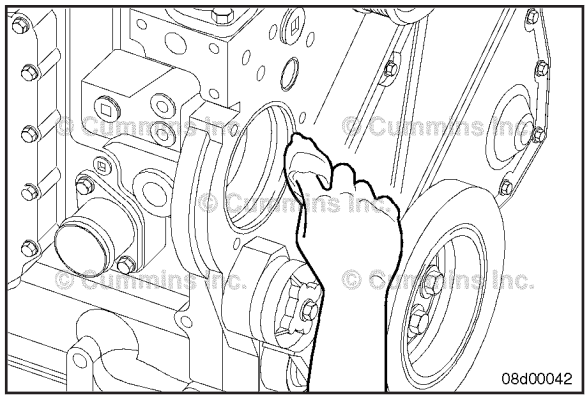


Remove

Remove the water pump capscrews and the water pump.

Clean and Inspect for Reuse

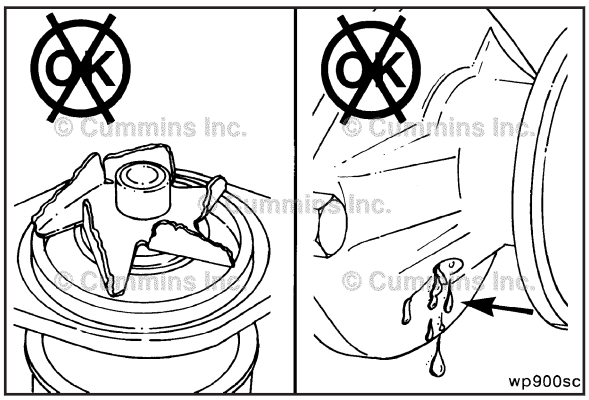
Clean the o-ring sealing surface on the water pump housing and the cylinder block.



Inspect the water pump housing and impeller for cracks or damage.

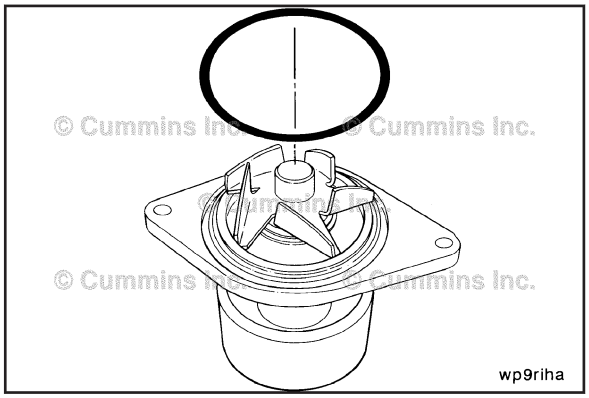
Inspect the water pump weep hole for an indication of a steady leak.

NOTE: A streak or chemical buildup at the weep hole is **not** justification for water pump replacement. If a steady flow of coolant or oil is observed, replace the water pump with a new or rebuilt unit.



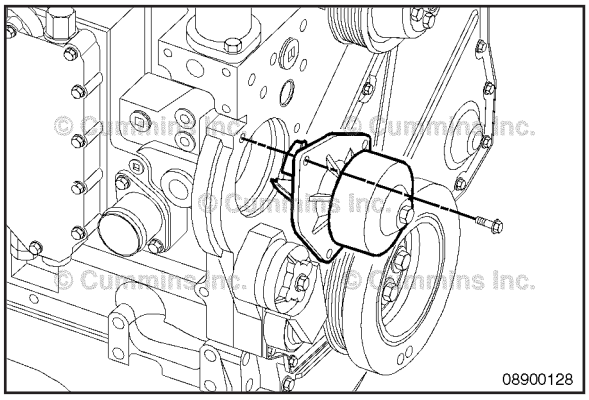
Install

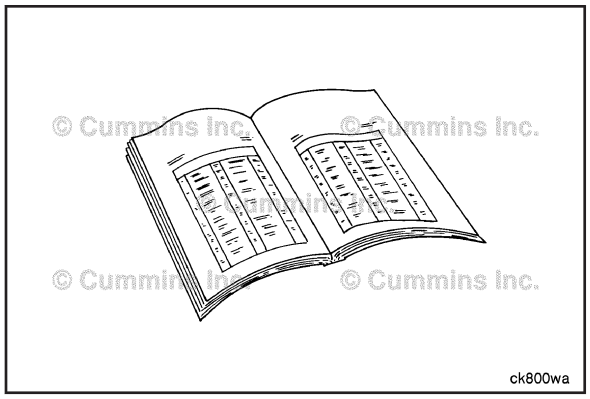
Install a new sealing ring into the groove in the water pump housing.



Install the water pump.

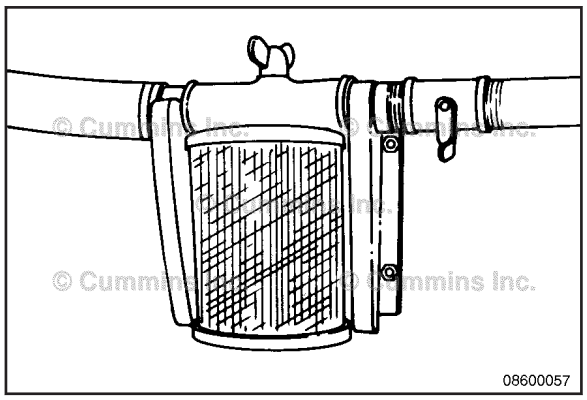
Torque Value: 24 N•m [212 in-lb]





Finishing Steps

- Lift the tensioner and install the belt. Refer to Procedure 008-002 in Section 8.
- Install the belt guard, if equipped. Refer to Procedure 008-001 in Section 8.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

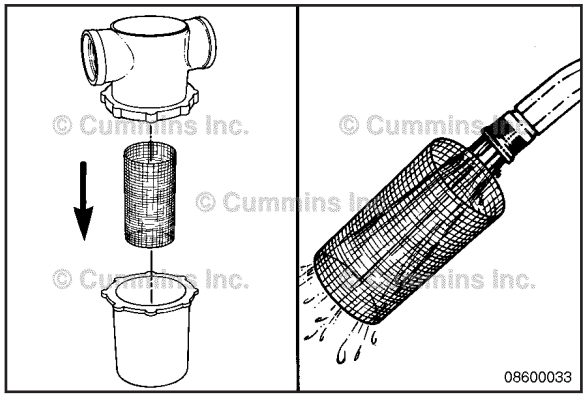


Sea Water Strainer (008-067)

General Information

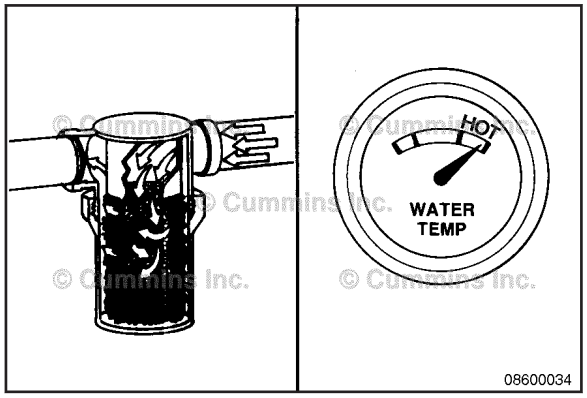
Marine Applications

NOTE: Most sea water systems for heat exchanger cooled engines use a sea water strainer. The strainer removes debris from the sea water before it enters the sea water pump.



NOTE: Sea water strainer arrangements may differ.

Inspect the sea water strainer daily for any foreign objects that could restrict water flow.

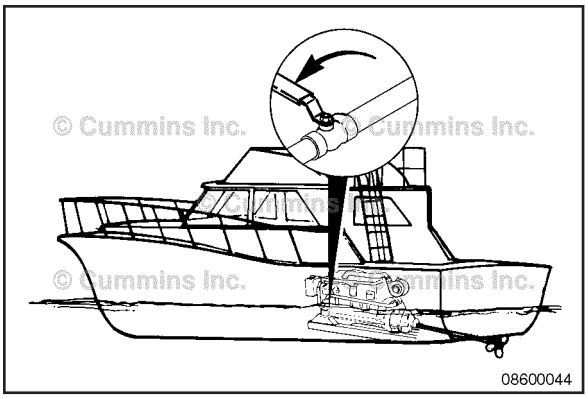


⚠CAUTION⚠

A restricted or clogged sea water strainer can result in hotter than normal, or overheated, engine coolant and marine gear oil temperatures.

For more detailed information, refer to Sea Water Strainer Cleaning in this section.

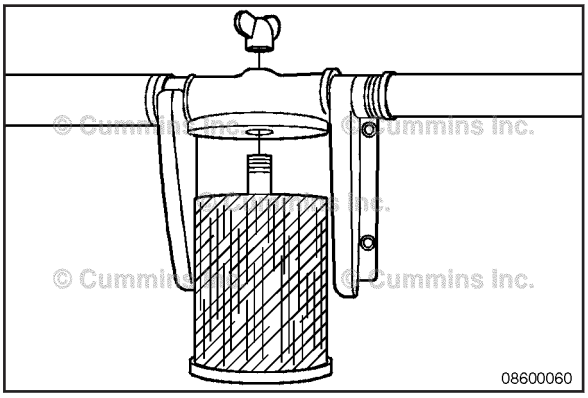
NOTE: If the sea water strainer is below the water level, close the sea water inlet valves before servicing the sea water strainer.



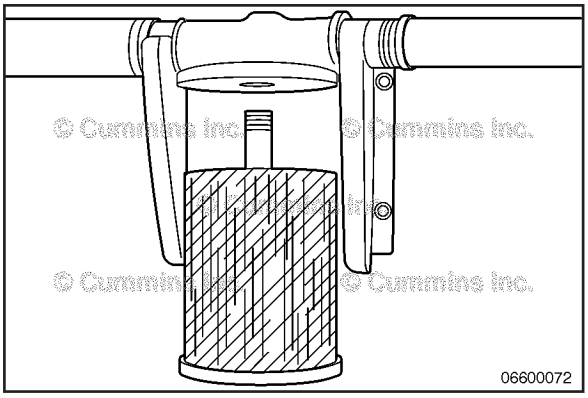
Disassemble

Marine Applications

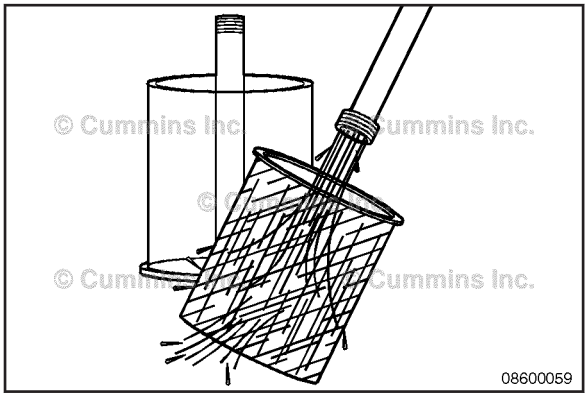
Loosen and remove the sea water strainer wing nut(s) as required.

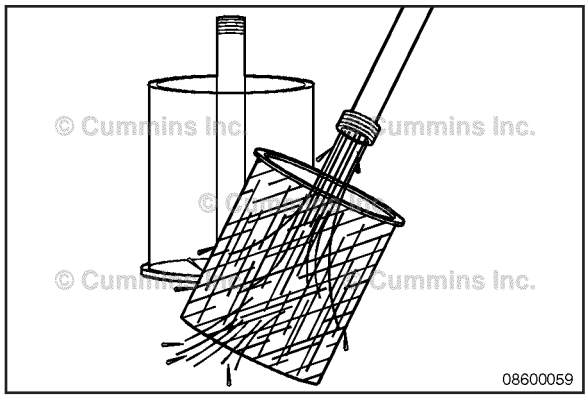


Remove the sea water strainer assembly. Be careful **not** to damage o-ring. Retain and inspect for damage.



Remove the sea water strainer basket.



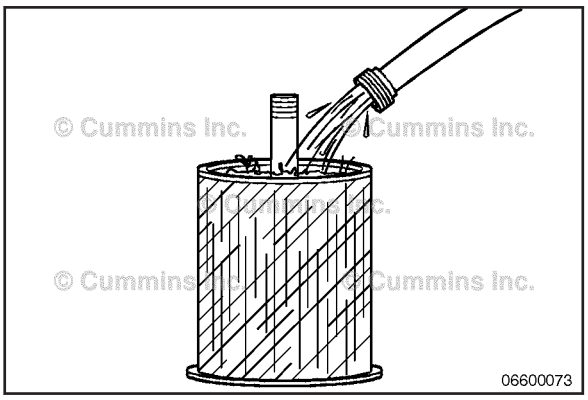


Clean

Marine Applications

Empty all debris from the sea water strainer basket.

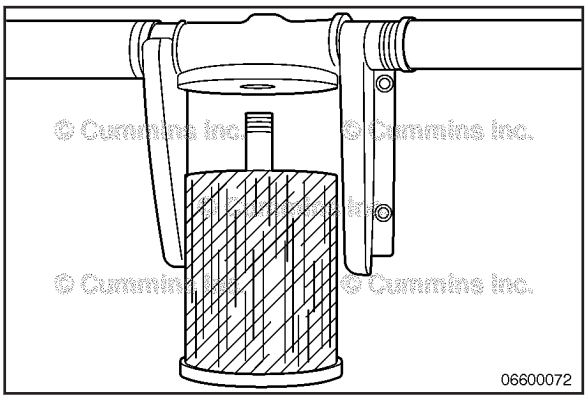
Clean the sea water strainer.



Prime

Marine Applications

Prime the sea water strainer with clean water.

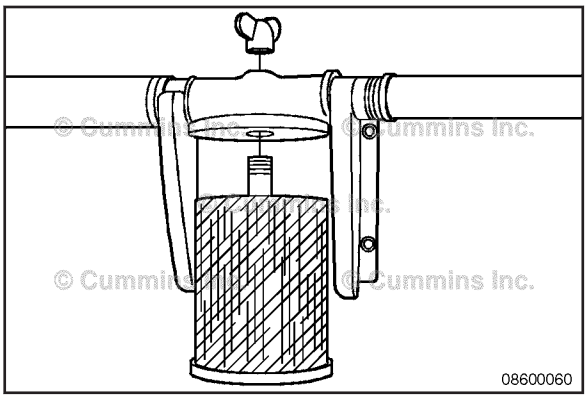


Assemble

Marine Applications

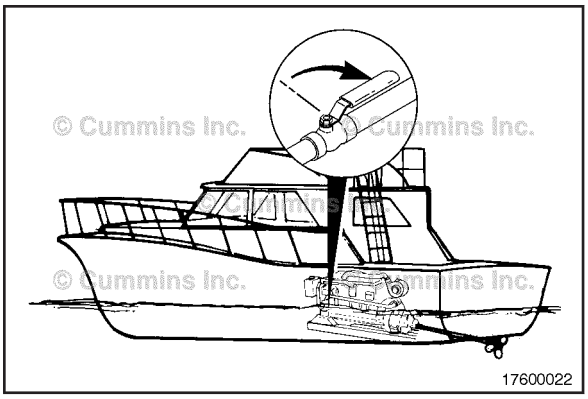
Install the sea water strainer.

Inspect o-ring seal for tears or damage. Replace if necessary. Be sure o-ring is seated properly.



Install and tighten the wing nut(s).

Open the sea water inlet valves.

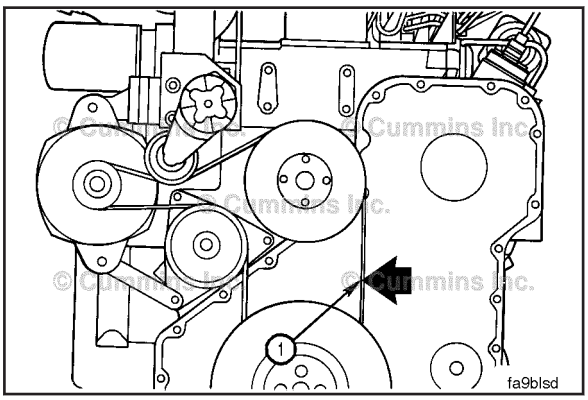


Belt Tensioner, Automatic (Water Pump) (008-080)

Initial Check

Check the belt deflection at the longest span of the belt. The deflection **must** be checked at the center (1) of the span.

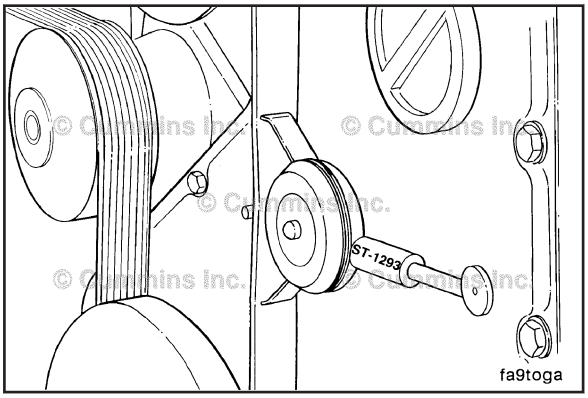
The maximum deflection allowed in the belt is 9.5 to 12.7 mm [3/8 to 1/2-in].



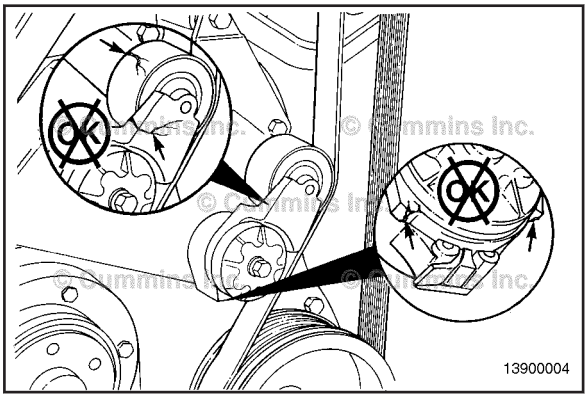
Use belt tensioner gauge, Part Number ST-1293, to measure the tension in the drive belt.

Belt Tension		
N		lbf
356	MIN	80
534	MAX	120

If the measurement is out of the specified range, replace **only** the belt and perform the tension test again. If the measurement is still outside of the specified rang after the new belt has been installed, replace the belt tensioner.



Check the tensioner arm, pulley, and stops for cracks. If any cracks are observed, the tensioner **must** be replaced.



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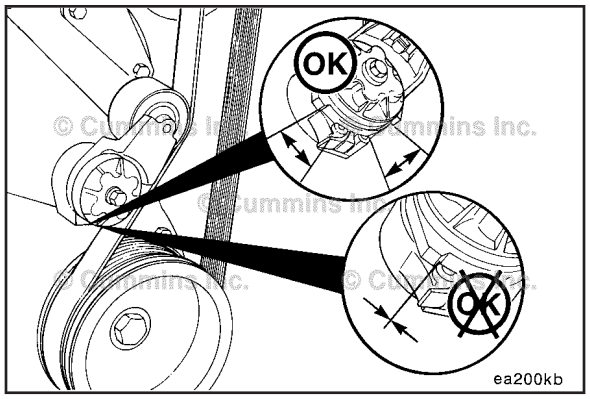
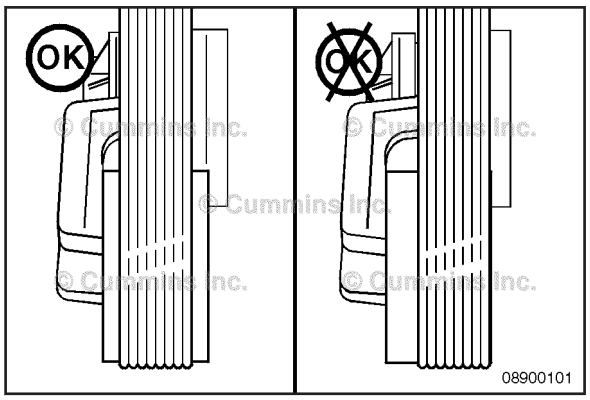
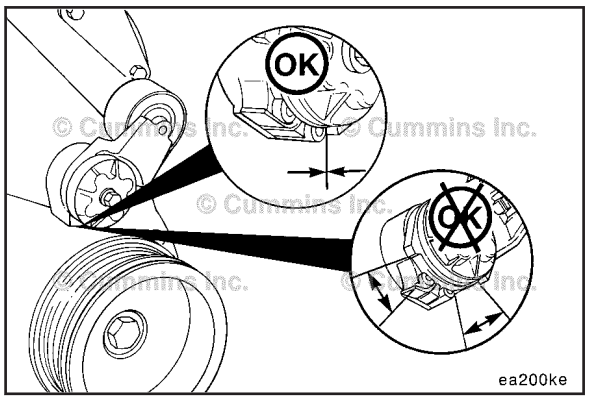


With the belt installed, verify that neither tensioner arm stop is in contact with the spring casing stop. If either stop is touching, replace the drive belt. Refer to Procedure 008-002 in Section 8.

After replacing the belt, if the tensioner arm stops are still in contact with the spring case stop, replace the tensioner.



Check the location of the drive belt on the belt tensioner pulley. The belt **must** be centered on, or close to the middle of, the pulley. Misaligned belts, either too far forward or backward, can cause belt wear, belt roll-off failures, or increase uneven tensioner bushing wear.



Remove the drive belt. Refer to Procedure 008-002 in Section 8.

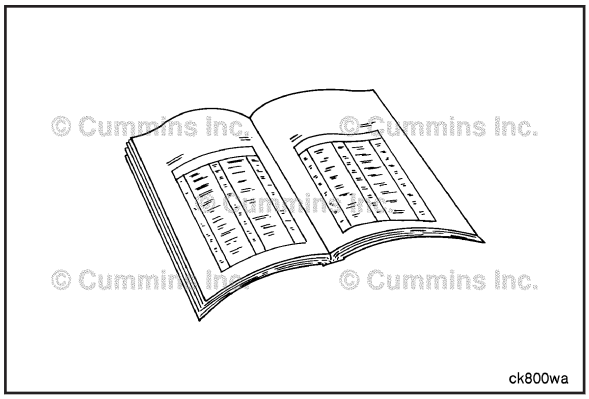
With the belt removed, verify that the tensioner arm stop is in contact with the spring case stop. If they are **not** touching, the tensioner **must** be replaced.

Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

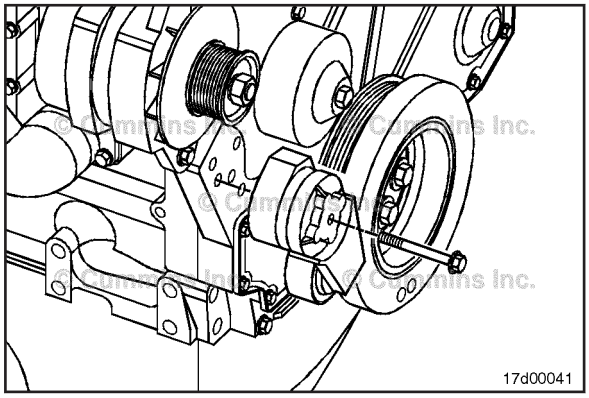
- Disconnect the battery. Refer to Procedure 013-009 in Section 13.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Lift the belt tensioner to relieve tension in the belt.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.



Remove

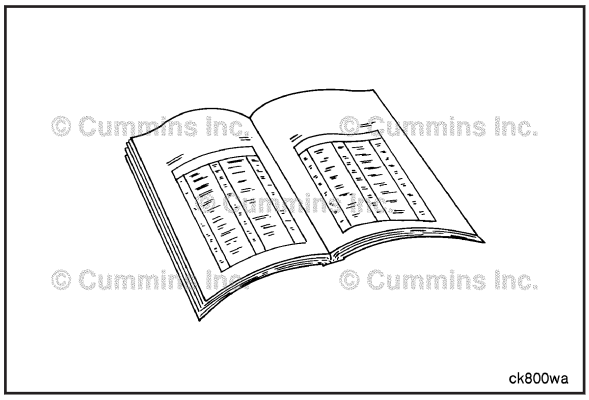
Remove the capscrew and belt tensioner from the bracket.

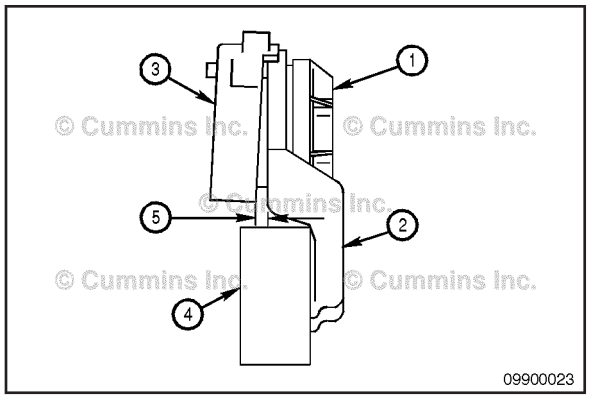
NOTE: Most belt tensioners are mounted to the water inlet connection. Some belt tensioners are mounted to a separate mounting bracket and use internal fasteners for clearance.



Inspect for Reuse

Inspect the cooling fan drive belt for reuse. Refer to Procedure 008-002 in Section 8.





Measure the clearance between the tensioner spring case and the tensioner arm to verify tensioner wear-out and uneven bearing wear. If the clearance at the measurement point 5 exceeds 3 mm [0.12 in], the tensioner is damaged and **must** be replaced as a complete assembly.

Tensioners generally will show a larger clearance gap near the lower portion of the spring case, resulting in the upper portion rubbing against the tensioner arm.

1 Tensioner cap

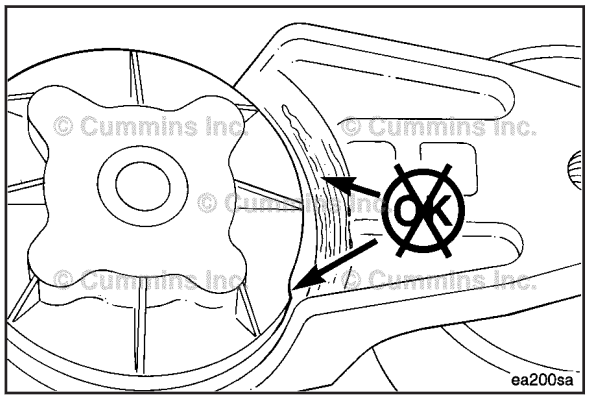
2 Tensioner arm

3 Spring case

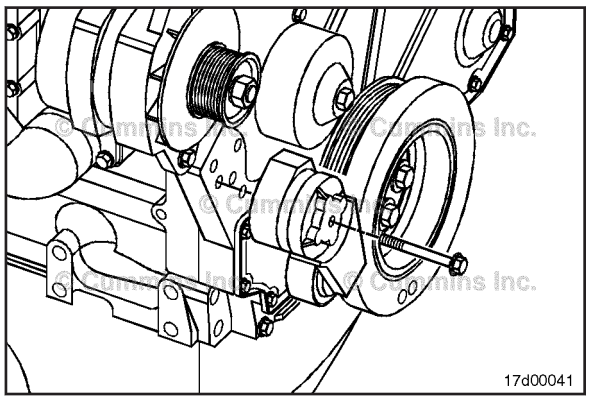
4 Tensioner pulley

5 Clearance gap.

NOTE: Always replace the belt when a tensioner is replaced. However, it is **not always** necessary to replace a tensioner when a belt is replaced.



Inspect the tensioner for evidence of the tensioner arm contacting the tensioner cap. If there is evidence of the two areas making contact, the pivot tube bushing has failed and the tensioner **must** be replaced.



Install

If removed, install the belt tensioner mounting bracket and mounting bracket capscrews.

NOTE: Some belt tensioner mounting brackets use internal fasteners for clearance.

Torque Value: 24 N•m [212 in-lb]

Install the belt tensioner and capscrew.

Torque Value: 43 N•m [32 ft-lb]

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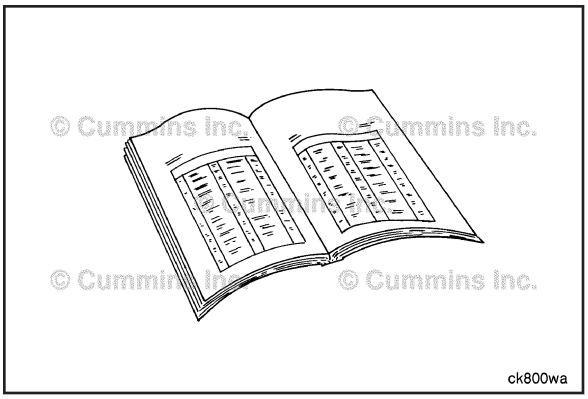
Finishing Steps

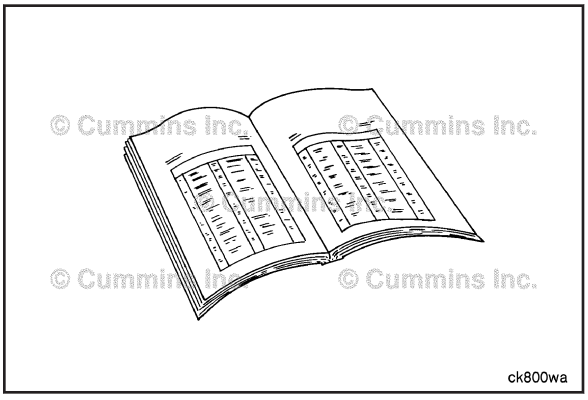


- Lift and hold the tensioner using a 3/8-inch square drive.
- Install the drive belt and release the tensioner.
- Install the belt guard, if equipped. Refer to Procedure 008-001 in Section 8.

Service Tip: If difficulty is experienced installing the drive belt or if the belt seems too short, position the belt over the grooved pulleys first. Then, while holding the tensioner up, slide the belt over the water pump pulley.

Water Inlet Connection (008-082)

Preparatory Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

△CAUTION△
Use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Disconnect the coolant hose to the water inlet connection. Refer to Procedure 008-045 in Section 8.

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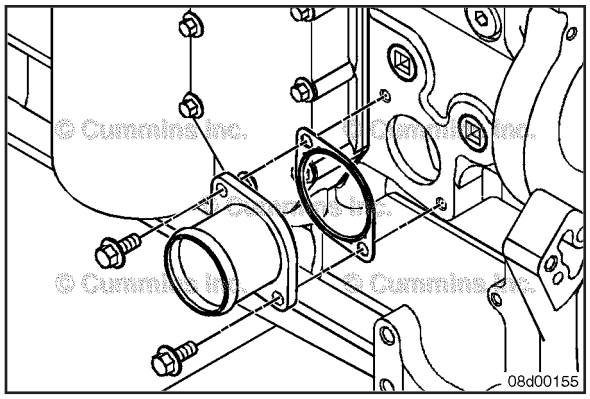
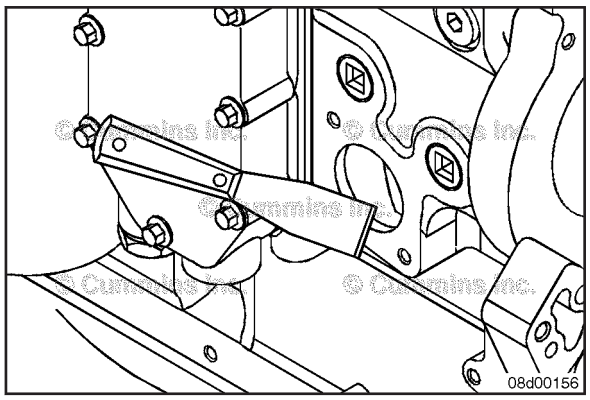


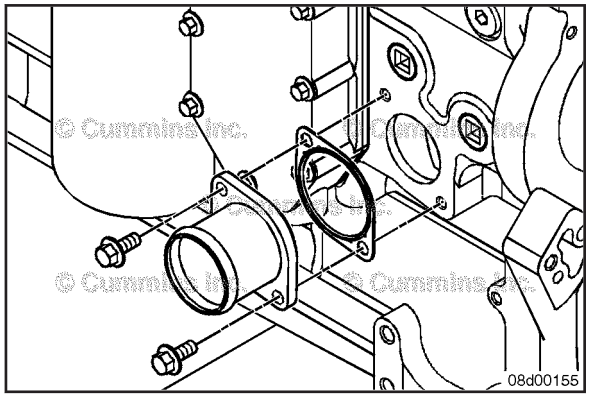
Remove

Remove the water inlet connection capscrews.



Clean and Inspect for Reuse

Clean all the mating surfaces.



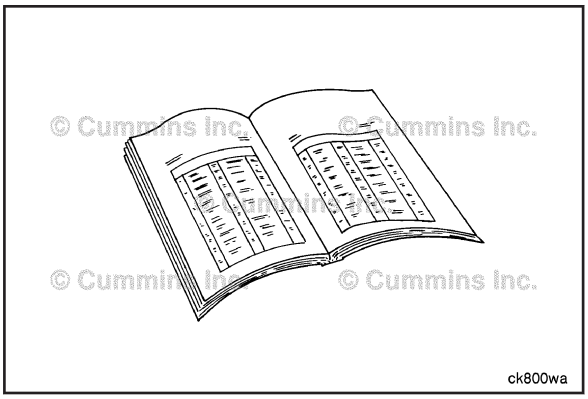
Install

Install a new water inlet connection gasket.

Install the water inlet connection and mounting capscrews.

Torque Value: 24 N•m [212 in-lb]

Finishing Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the coolant hose to the water inlet connection. Refer to Procedure 008-045 in Section 8.
- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

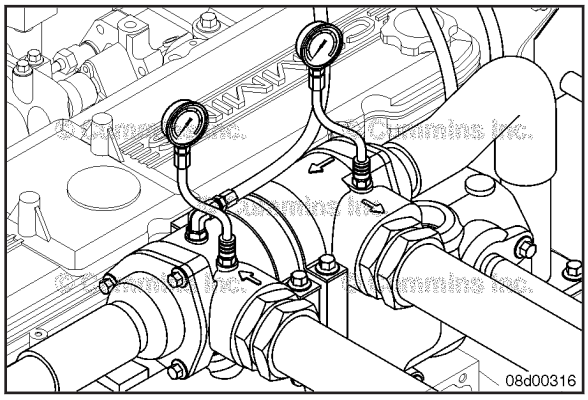
Keel Cooler (008-083)

General Information

QSL Engines

The temperature and pressure differential tests can be conducted at the same time, if the pressure connection allows the temperature probe to enter the coolant flow completely.

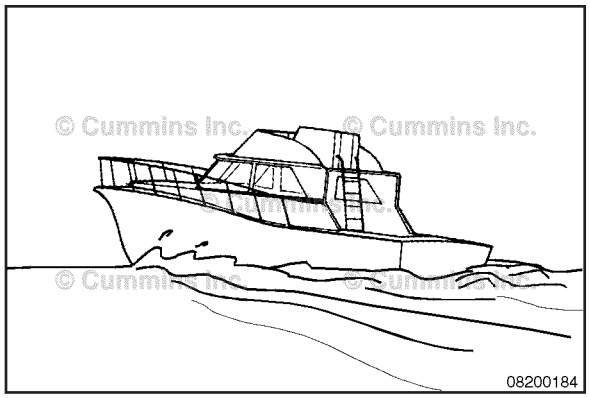
Temperature Differential Test



QSL Engines

NOTE: This test **must** be done using a blocked open thermostat.

Install temperature probes into the inlet and outlet test ports of the keel cooler thermostat housing.



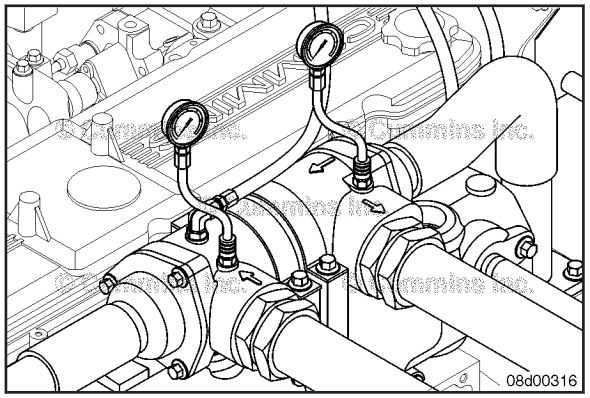
Operate the engine under rated rpm and load until the engine temperature reaches its maximum. Record the inlet and outlet coolant temperature.

A temperature differential of 25°C [45°F] or greater is required for adequate system cooling. If the temperature differential meets this specification, test the coolant pressure differential.

If the temperature difference is less than 25°C [45°F], inspect the vessel's keel coolers. Some problems with keel coolers that can cause a high coolant temperature differential include:

1. keel cooler size is too small
2. seawater temperature is too hot
3. marine growth on the keel cooler
4. fouling to the inside of the keel cooler
5. internal damage to the keel cooler
6. external damage to the keel cooler.

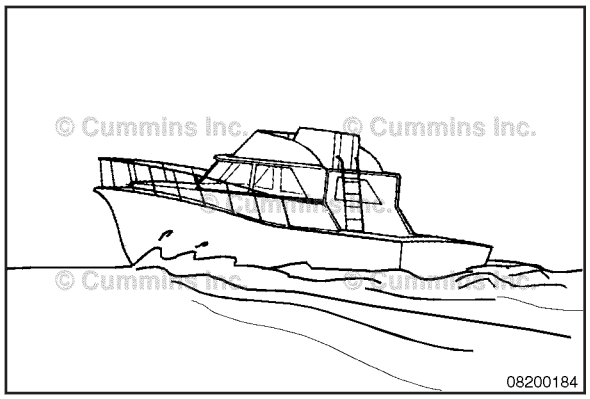
Refer to the keel cooler OEM for troubleshooting and repair manual.



Pressure Differential Test

QSL Engines

Install test fittings and gauges into the inlet and outlet of the keel cooler thermostat housing.



Operate the engine under rated rpm and load until the engine temperature reaches it's maximum. Record the inlet and outlet coolant pressure. If the pressure difference is less than 34 kPa [5 psi], remove and test the keel cooler thermostat. Refer to Procedure 008-014.

If the pressure difference is greater than 34 kPa [5 psi], inspect the vessel's keel coolers. Some problems with keel coolers that can cause high differential pressure are:

1. blockage in the keel cooling system
2. internal damage to the keel cooler.

Refer to the OEM for troubleshooting and repair manual.

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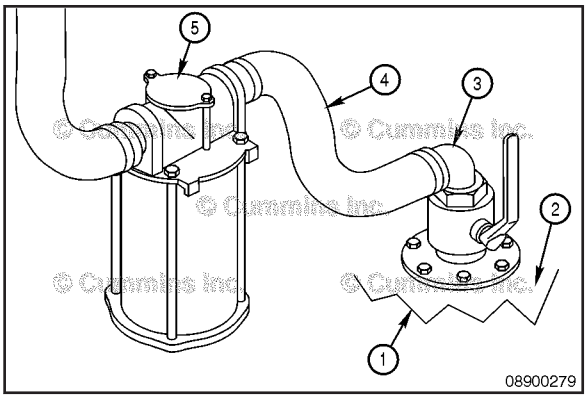
Sea Water System Diagnostics (008-103)

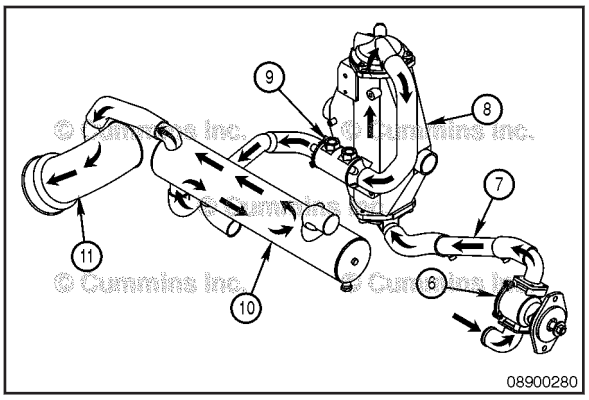
General Information

NOTE: This procedure is for marine applications **only**. Refer to Procedure 008-020 for engine coolant diagnostic procedures.

This is a typical sea water cooling system. For more engine specific system identification, refer to Procedure 200-003.



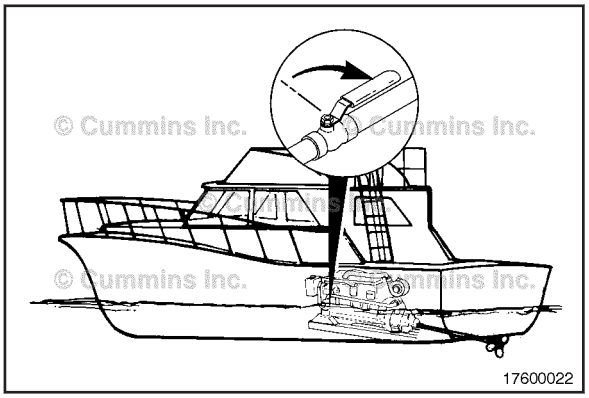
1. Grate-type strainer located on the bottom of the boat hull
2. Vessel bottom/hull
3. Sea water inlet valve
4. Hose
5. Sea water strainer

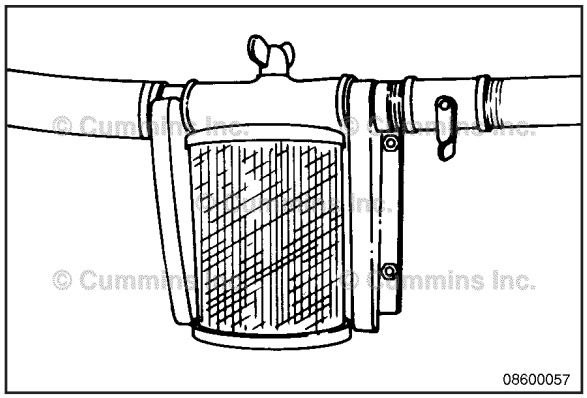


6. Sea water pump
7. Fuel cooler
8. Aftercooler
9. Marine gear oil cooler
10. Heat exchanger
11. Sea water outlet.

Initial Check

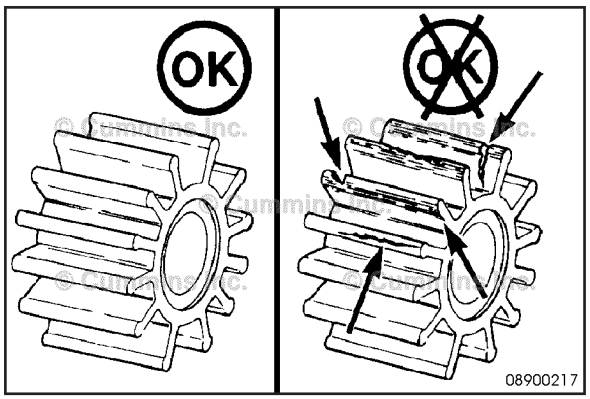
Locate and verify that the sea water inlet valve is in the full open position. If it is closed or partially closed, open the valve and recheck the engine temperature.





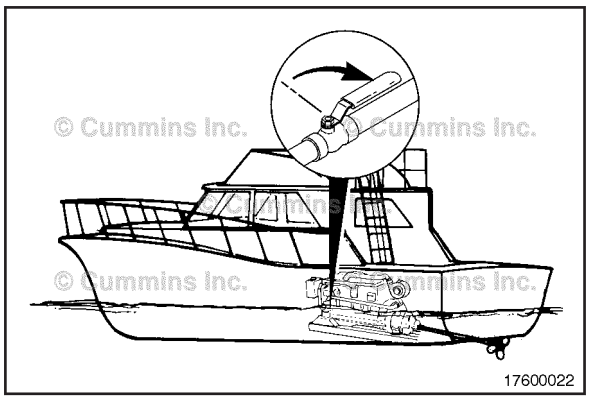
Inspect the sea water strainer for foreign objects that could restrict the water flow.

Some strainers have clear covers for easy inspection. If the strainer has to be opened for inspection, refer to Procedure 008-067.

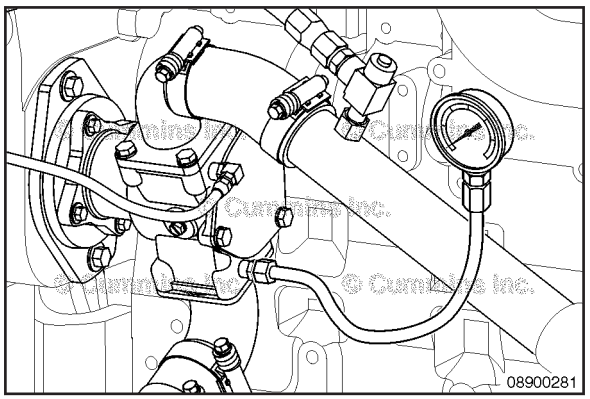


If the engine was in operation with the sea water system highly restricted due to a closed sea water inlet valve or a clogged sea water strainer, the sea water impeller **must** be inspected for damage.

If the hours in service of the sea water impeller is unknown, then inspection of the sea water impeller is advisable. Refer to Procedure 008-057.



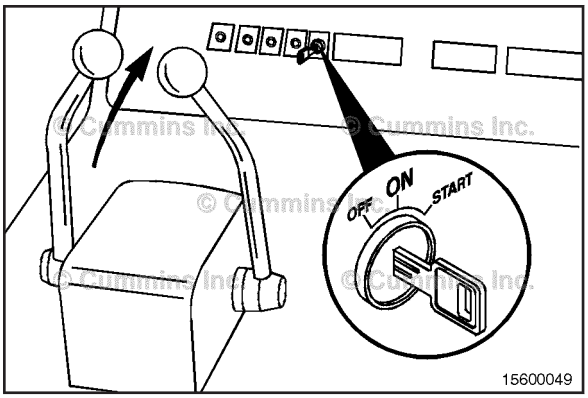
If the engine continues to overheat, perform the following procedures. If the engine does **not** overheat at the dock, perform a sea trial and check for overheating under way.



Test

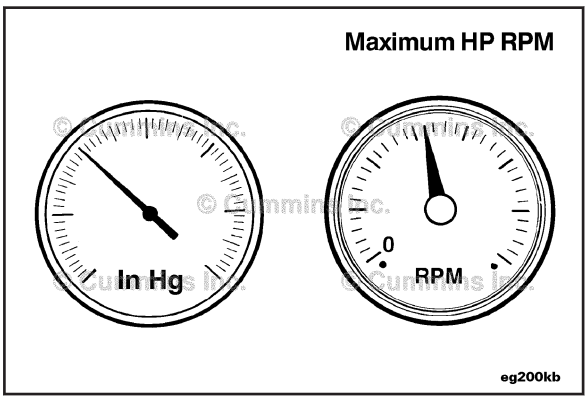
Attach a vacuum gauge to the inlet side of the sea water pump.

Start the engine.



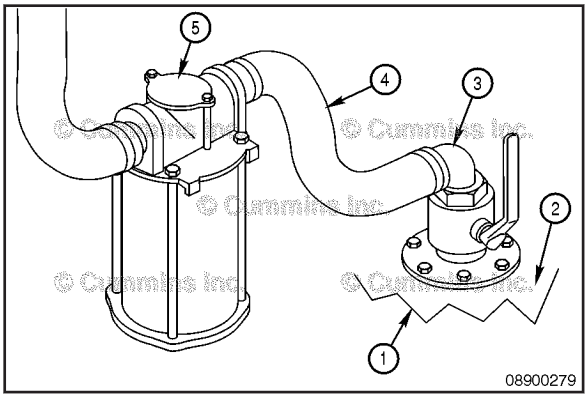
Record the sea water inlet restriction from low idle to rated speed at 500 rpm increments. This test can be conducted while the vessel is at the dock and **not** in gear or underway.

Refer to Procedure 018-018 for Marine engine specifications.



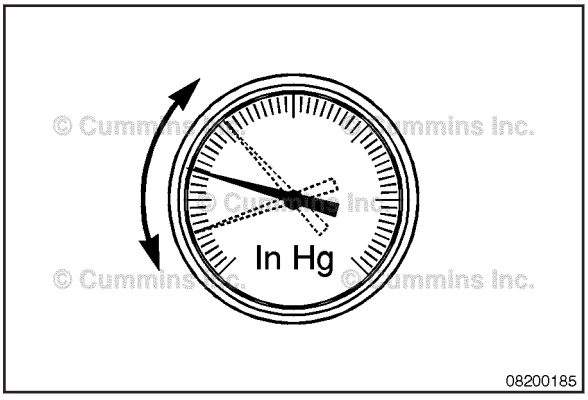
If the sea water inlet restriction is above specification, the source of the restriction **must** be found. Troubleshooting and repair of excessive sea water restriction is a boat manufacturer or boat owner responsibility. Refer to the vessel's OEM service manual. If the inlet restriction is within the specification and the complaint can **not** be verified at the dock, the test **must** be repeated underway.

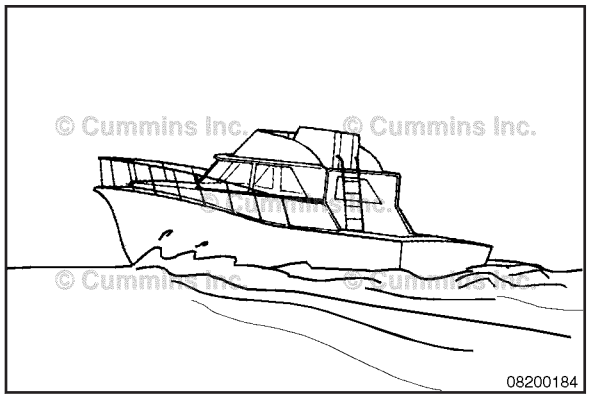
Areas to inspect for restriction are a plugged sea water strainer, sea water valve **not** fully open, defective hose liner in a supply hose, or debris in the inlet hose.



If the sea water inlet restriction readings fluctuate during the test, inspect the sea water supply for leaks or air intrusion. Troubleshooting and repair of excessive sea water restriction is a boat manufacturer or boat owner responsibility. Refer to the vessel's OEM service manual. Troubleshooting and repair for sea water aeration is **not** covered under Cummins warranty.

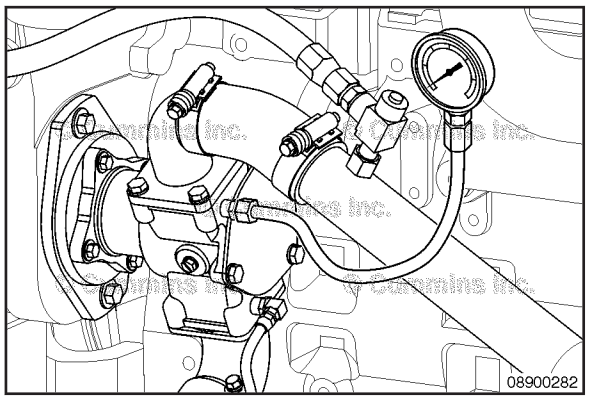
Areas to inspect for a source of air are the sea water strainer inspection cover seal, sea water valve shaft seal packing, or loose hose clamps.





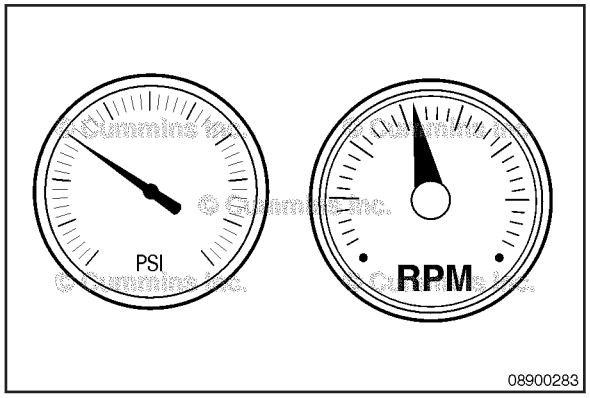
It is possible that aeration (gauge fluctuation) will **only** occur while the vessel is underway due to the introduction of air. Refer to the vessel's OEM service manual.

Areas to inspect for a source of aeration are water inlet scoop installed backwards, incorrect water inlet scoop, or water inlet location on the hull in aerated water flow.



Pressure Test

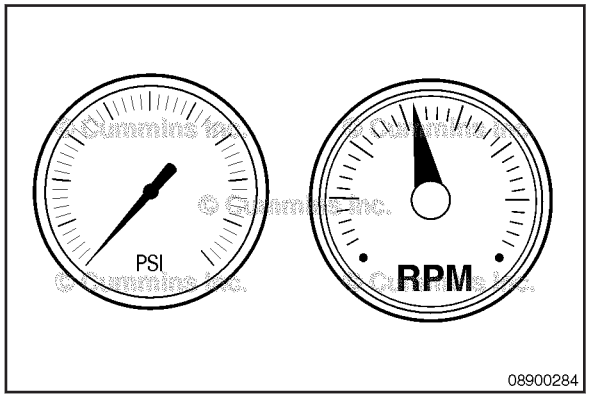
Attach a pressure gauge to the outlet side of the sea water pump to check pump outlet pressure.



Start the engine and record the sea water outlet pressure from low idle to rated speed at 500 rpm increments. This test can be conducted while the vessel is at dock and **not** in gear or underway.

Refer to Procedure 018-018 for Marine engine specifications.

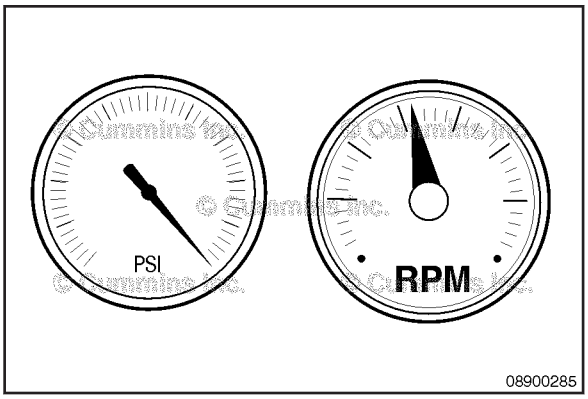
If the sea water pump outlet pressure is within specifications, see the Temperature Differential Test step in this procedure.



If sea water pressure is **not** present, check the pump for damage. Refer to Procedure 008-057.

If the sea water pump outlet pressure is above the maximum specification test the individual sea water system components for excessive pressure drop as described in the Pressure Differential Test step.

Refer to Procedure 018-018 for Marine engine specifications.

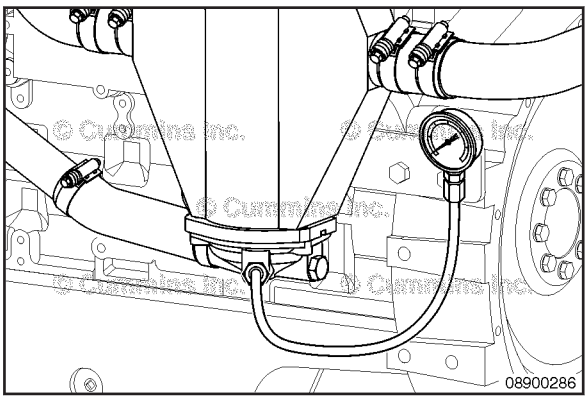


Pressure Differential Test

QSL Engines

Check the sea water pressure at the inlet side of the aftercooler at the rated rpm. Record the reading. If the pressure drop between the sea water pump outlet and the aftercooler inlet exceeds the maximum specification, check or replace the fuel cooler.

Refer to Procedure 018-018 for Marine engine specifications.

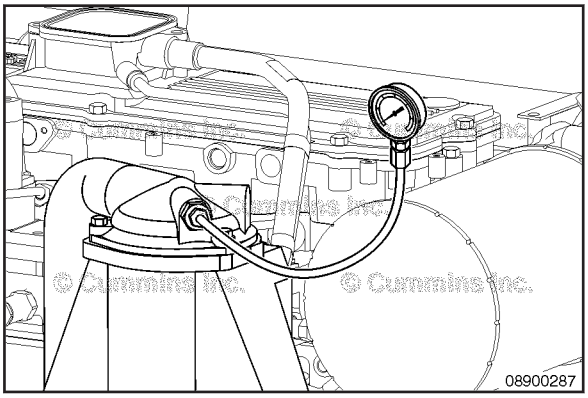


If the pressure drop is within specification, check the sea water pressure at the discharge side of the aftercooler outlet. Record the reading.

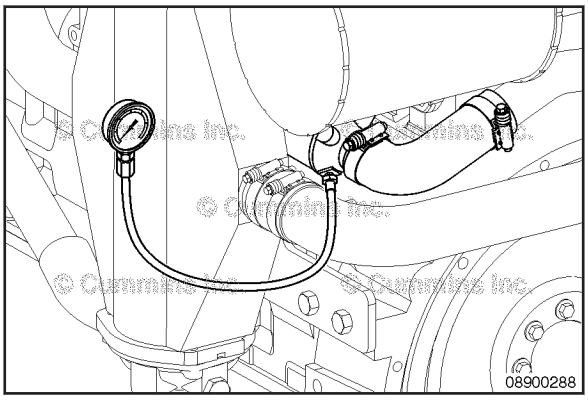
If the pressure drop between the inlet side of the aftercooler exceeds the maximum, check for blockage in the lower cap area of the aftercooler. Clean or replace if necessary. Refer to Procedure 010-005.

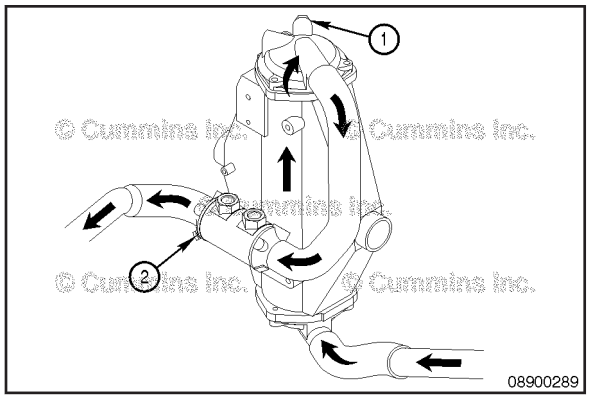
Shut off the sea water supply valve and remove the lower aftercooler sea water supply hose. Clean the debris from the aftercooler and cap. Remove the upper sea water hose and back flush the system.

Refer to Procedure 018-018 for Marine engine specifications.



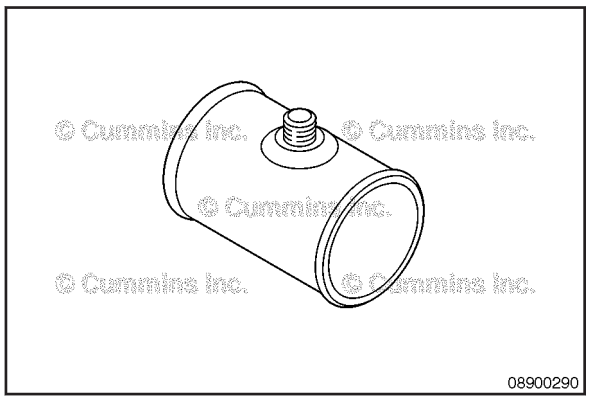
If the pressure drop between the inlet side of the aftercooler and the outlet side of the aftercooler is within specification, attach the pressure gauge to the gear oil cooler drain plug located on the outlet and check for pressure drop across the gear oil cooler.





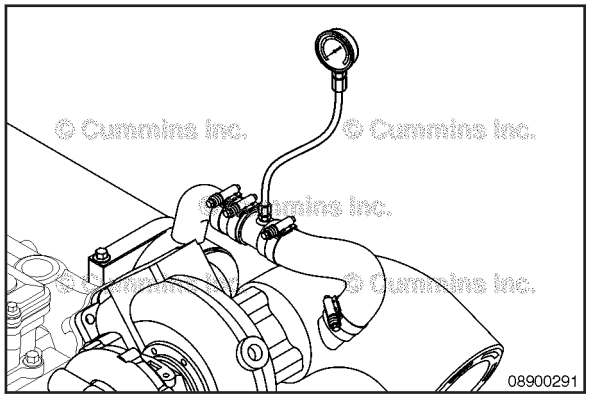
If the pressure drop between the inlet side (1) and the outlet side (2) of the gear cooler is greater than the maximum specification, check for blockage in the gear cooler. Clean or replace if necessary. Refer to Procedure 008-041.

Refer to Procedure 018-018 for Marine engine specifications.



If the pressure drop in the gear oil cooler is within specification, test the pressure drop across the engine heat exchanger.

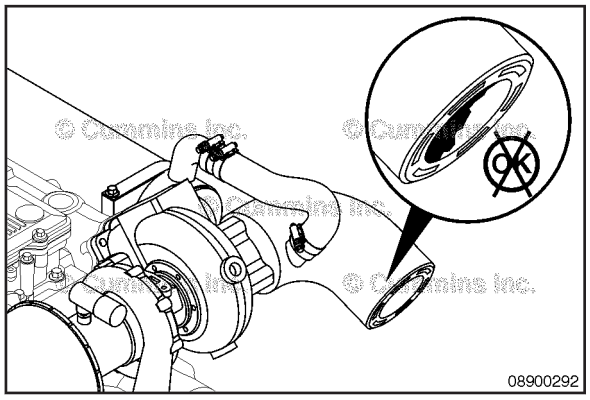
Fabricate a sea water test tool by using a 38 mm [1-1/2 in] pipe with a fitting in the center to connect a pressure gauge.



Install the fabricated test tool between the outlet side of the heat exchanger and the exhaust elbow. Check the pressure drop across the heat exchanger.

If the pressure drop is greater than the maximum specification, check for blockage in the heat exchanger. Clean or replace if necessary.

Refer to Procedure 018-018 for Marine engine specifications.



If the pressure drop across the heat exchanger is within specification, determine the pressure drop across the exhaust elbow (diffuser). This is done by subtracting the heat exchanger outlet pressure form the sea water pump outlet pressure. If this pressure exceeds the maximum specification, check for blockage in the exhaust elbow (diffuser) and exhaust system of the vessel. Clean or replace if necessary.

Refer to Procedure 018-018 for Marine engine specifications.

Some vessels are equipped with a sea water bypass valve to divert sea water flow from the exhaust elbow. If the valve is adjusted to the lowest system pressure, be sure the exhaust piping does **not** overheat under all operating conditions.

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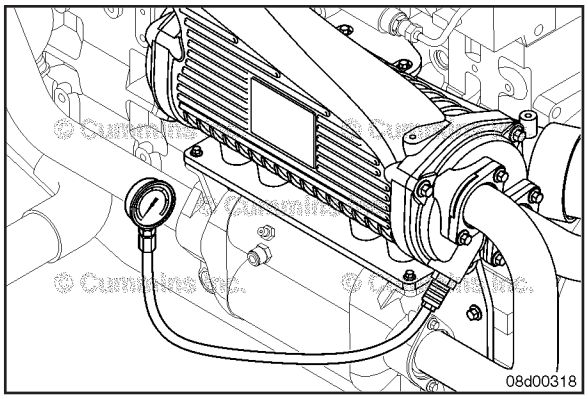
QSC Engines

Check the sea water pressure at the inlet side of the aftercooler at the rated rpm.

Record the reading. Refer to Procedure 018-018 for marine engine specifications.

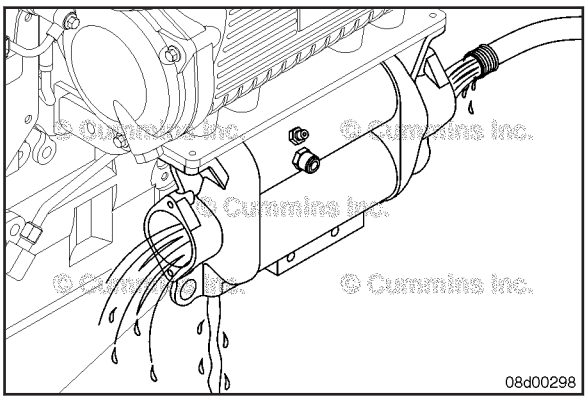
If the pressure drop between the sea water pump outlet and the aftercooler inlet exceeds the maximum specification, check for blockage or damage to the marine gear oil/fuel cooler.



Shut off the sea water supply valve. Refer to the OEM service manual.

Remove the marine gear oil/fuel cooler inlet and outlet hoses. Refer to Procedure 008-129.

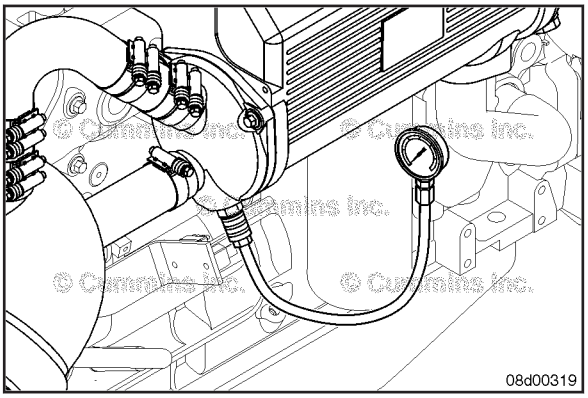
Clean the debris from the inlet side. Use a hose and back flush the cooler. Refer to Procedure 008-129.



If the pressure drop is within specification, check the sea water pressure at the discharge side of the aftercooler outlet. Record the reading.

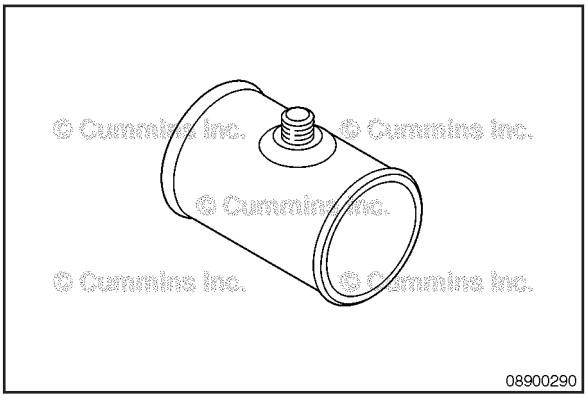
If the pressure drop between the inlet side of the aftercooler exceeds the maximum, check for blockage in the lower cap area of the aftercooler. Refer to Procedure 018-018 for marine engine specifications.

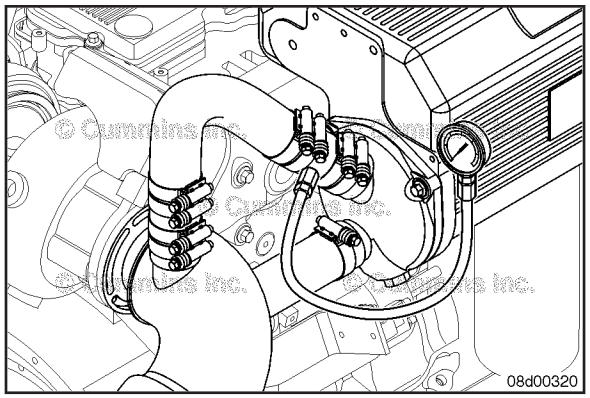
Clean or replace if necessary. Refer to Procedure 010-005.



If the pressure drop between the inlet side of the aftercooler and the outlet side of the aftercooler is within specification, check for pressure drop across the engine heat exchanger.

Fabricate a sea water test tool by using a 38 mm [1-1/2 in] pipe with a fitting in the center to connect a pressure gauge.



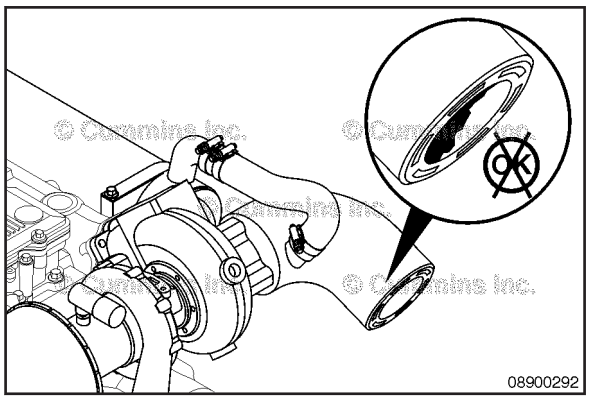


Install the fabricated test tool between the outlet side of the heat exchanger and the exhaust elbow.

Check the pressure drop across the heat exchanger. Refer to Procedure 018-018 for marine specifications.

If the pressure drop is greater than the maximum specification, check for blockage in the heat exchanger.

Clean or replace the heat exchanger if necessary. Refer to Procedure 008-053.

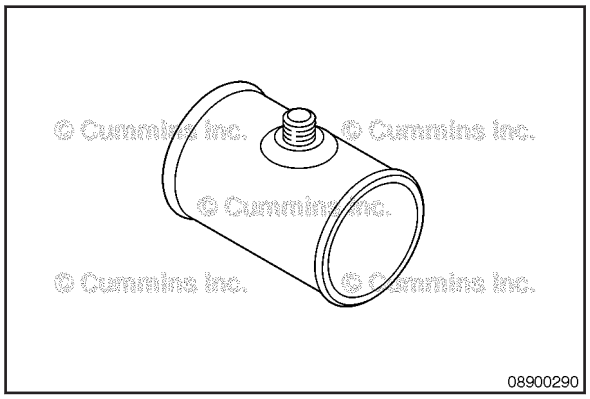


If the pressure drop across the heat exchanger is within specification, determine the pressure drop across the exhaust elbow (diffuser). This is done by subtracting the heat exchanger outlet pressure from the sea water pump outlet pressure. Refer to Procedure 018-018 for marine specifications.

If the pressure exceeds the maximum specification, check for blockage in the exhaust elbow (diffuser) and exhaust system of the vessel.

Clean or replace the elbow if necessary.

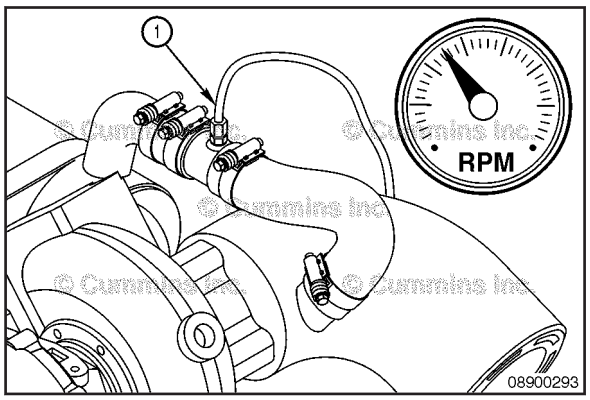
Some vessels are equipped with a sea water bypass valve to divert sea water flow from the exhaust elbow. If the valve is adjusted to the lowest system pressure, be sure the exhaust piping does **not** overheat under all operating conditions.



Temperature Differential Test

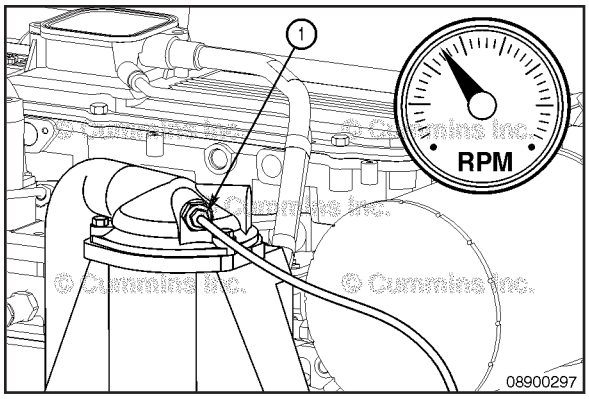
QSL Engines

Fabricate a sea water test tool by using a 38 mm [1-1/2 in] pipe with a fitting in the center to connect a temperature probe.

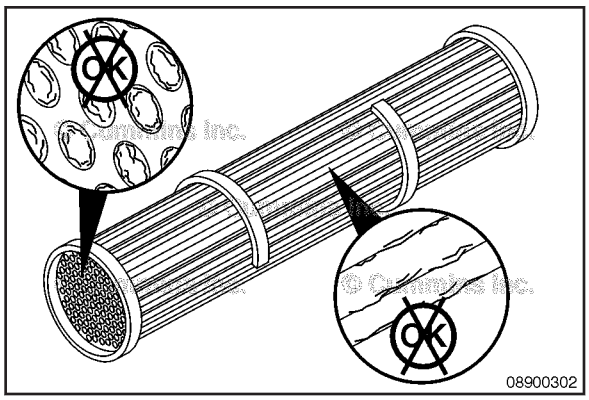


Install the sea water test tool with a temperature probe between the outlet side of the heat exchanger and the exhaust elbow (1). Operate the engine at rated rpm and load and record the temperature.

Install the temperature probe in the outlet side of the aftercooler (1). Operate the engine at the rated rpm and load and record the temperature. If the temperature difference between the aftercooler outlet and the engine heat exchanger outlet is greater than 20°C [40°F], check the sea water pump for water flow problems. Refer to Procedure 008-057.

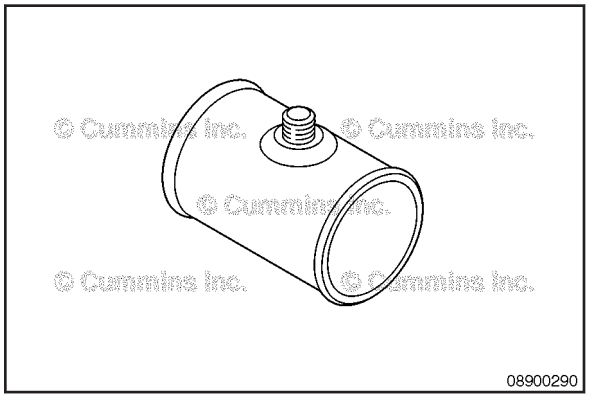


If the sea water temperature difference is less than 3°C [5°F], check the heat exchanger for possible plating to the heat exchanger core. Excessive plating or coating to the inside or outside of the cooling tubes will effect the efficiency of the heat exchanger. Refer to Procedure 008-053.



QSC Engines

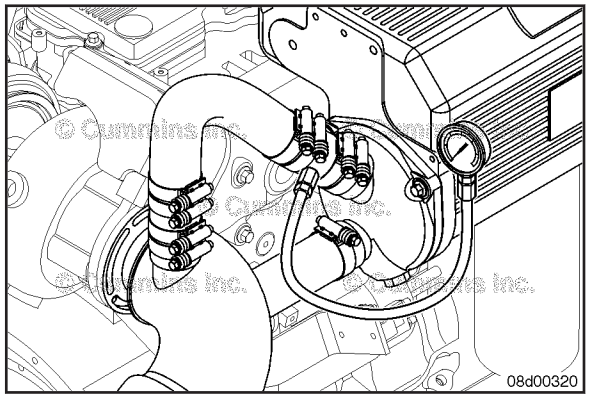
Fabricate a sea water test tool by using a 38 mm [1-1/2 in] pipe with a fitting in the center to connect a temperature gauge.

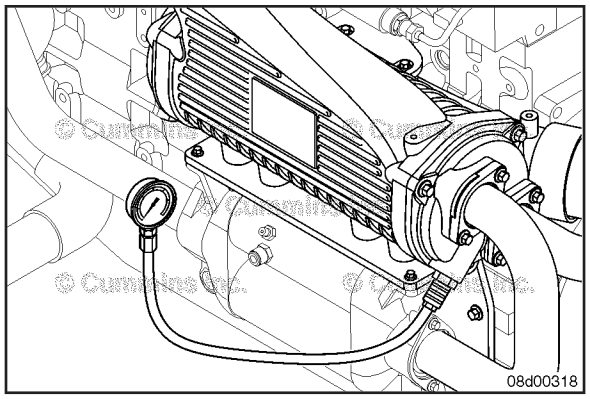


Install the fabricated test tool between the outlet side of the heat exchanger and the exhaust elbow.

Operate the engine at rated rpm and load and record the temperature.

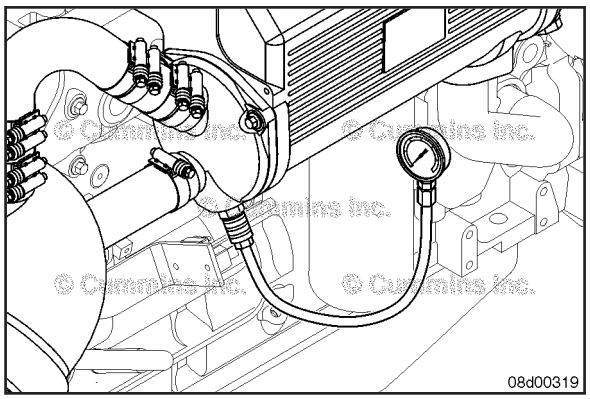
Refer to Procedure 018-018 for marine specifications.





Install the temperature probe in the outlet side of the marine gear oil/fuel cooler. Operate the engine at the rated rpm and load.

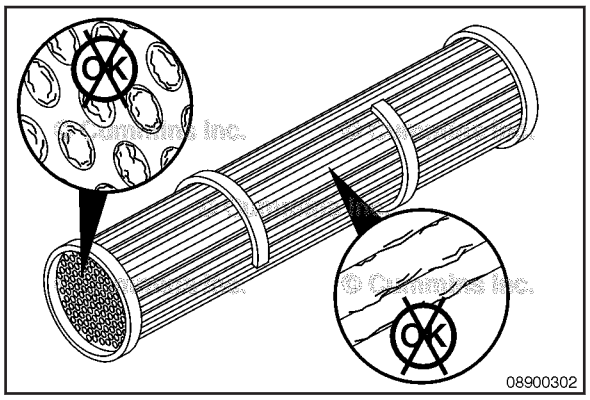
Record the reading. Refer to Procedure 018-018 for marine engine specifications.



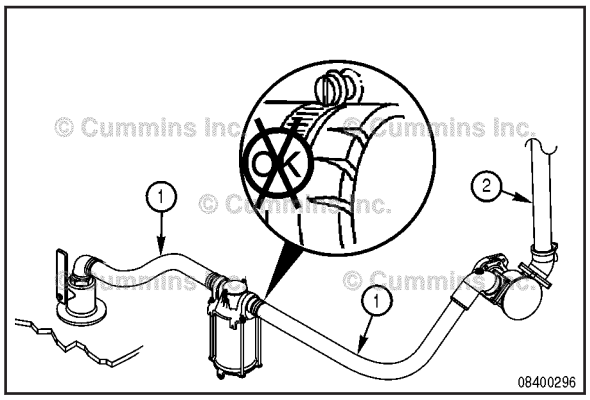
Install the temperature probe in the outlet side of the aftercooler. Operate the engine at the rated rpm and load.

Record the reading. Refer to Procedure 018-018. for marine engine specifications.

If the temperature difference between the marine gear oil/fuel cooler outlet and heat exchanger outlet, or the aftercooler outlet and the marine gear oil/fuel cooler outlet is greater than 20°C [40°F], check the sea water pump for water flow problems. Refer to Procedure 008-057.



If the sea water temperature difference is less than 3°C [5°F], check the heat exchanger and marine gear oil/fuel cooler for possible plating to the cores. Excessive plating or coating to the inside or outside of the cooling tubes will effect the efficiency.



Sea Water Hoses (008-104)

Inspect

Start engine, and inspect all hoses and connections for deterioration. Particles of deteriorated hose can be carried through the sea water system and restrict or clog small passages, especially the heat exchanger, and partially stop circulation. Replace as necessary.

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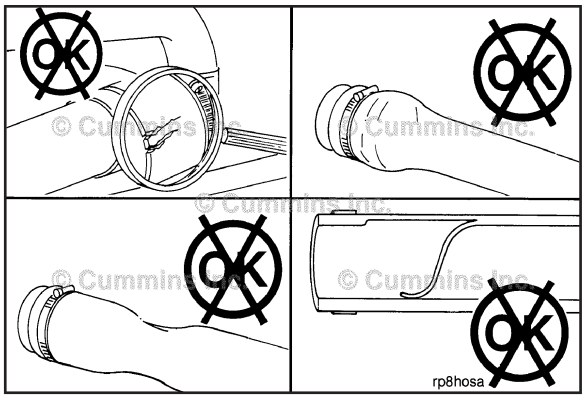
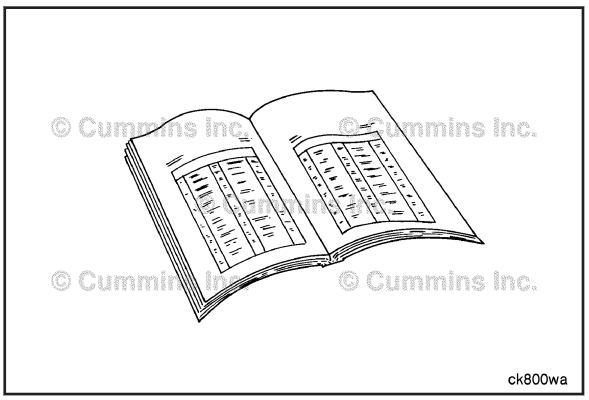
Inspect the sea water system hoses and hose connections for leaks. Replace damaged hoses and clamps, if necessary.



Pulley, Fan Idler (008-111)

Preparatory Steps

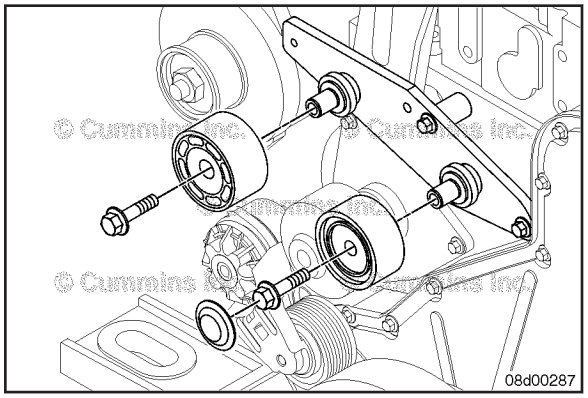
- Remove the belt guard. Refer to Procedure 008-001.
- Remove the fan drive belt. Refer to Procedure 008-002.



Remove

Remove the dust shield.

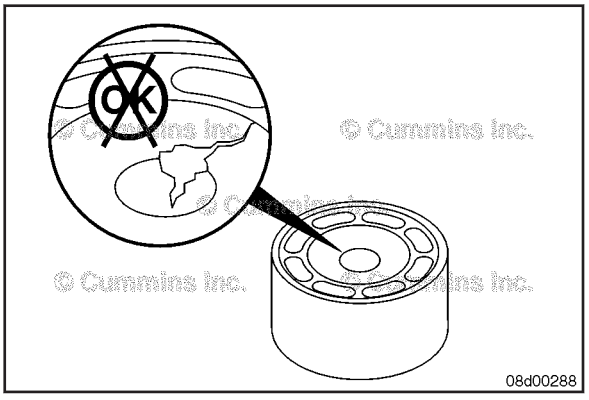
Remove the fan idler pulley capscrew and the fan idler pulley.



Inspect for Reuse

Inspect the pulley for nicks, cracks or any other type of damage.

Replace the pulley if it is damaged.



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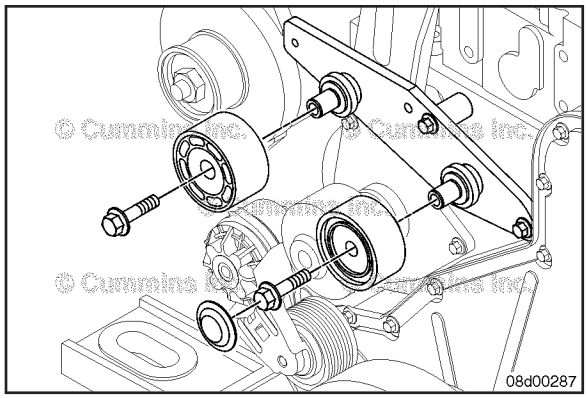
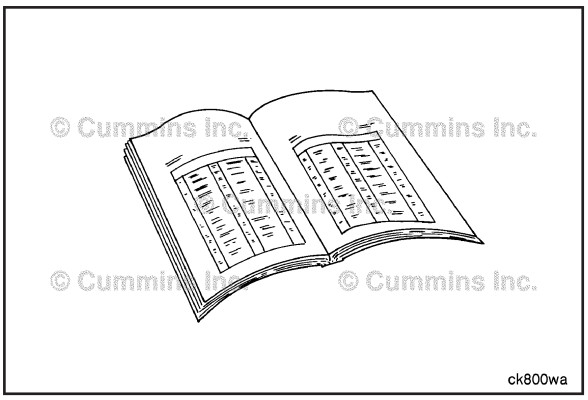


Install

Install the fan idler pulley and capscrew.

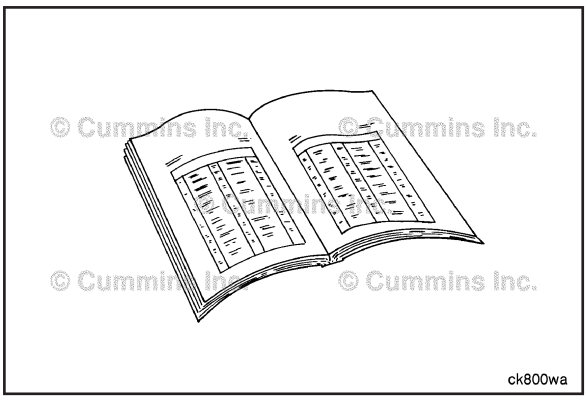
Tighten the capscrew.

Torque Value: 52 N•m [38 ft-lb]



Finishing Steps

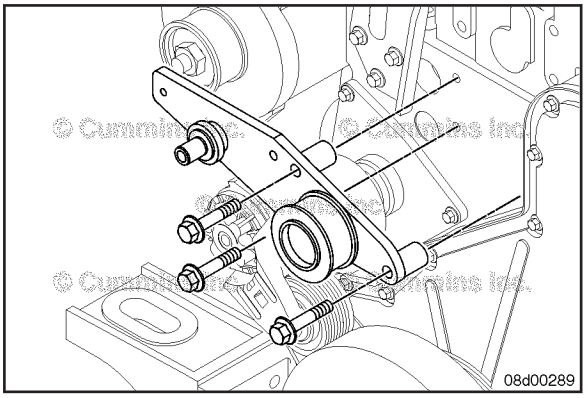
- Install the fan drive belt. Refer to Procedure 008-002.
- Install the belt guard. Refer to Procedure 008-001.



Bracket, Fan Idler Pulley (008-112)

Preparatory Steps

- Remove the belt guard. Refer to Procedure 008-001.
- Remove the fan drive belt. Refer to Procedure 008-002.
- If necessary, remove the fan idler pulley(s). Refer to Procedure 008-111.



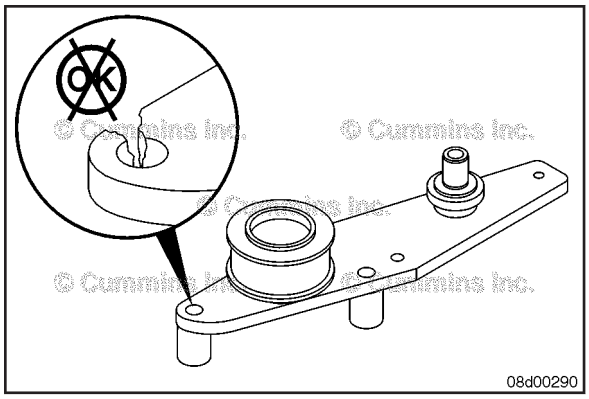
Remove

Remove the mounting capscrews and the pulley bracket.

Inspect for Reuse

Inspect the bracket for cracks near the bolt holes or any other type of damage.

Replace the bracket if it is cracked or damaged.

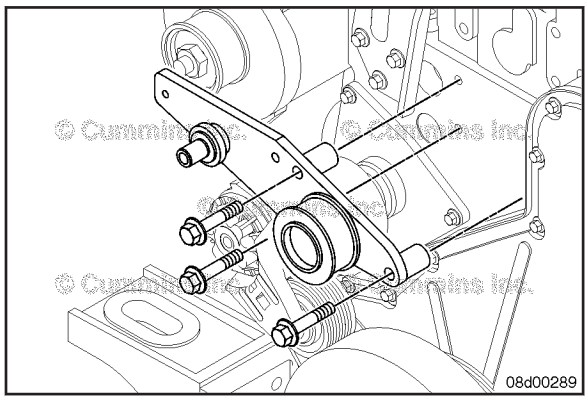


Install

Install the fan idler pulley bracket and mounting capscrews.

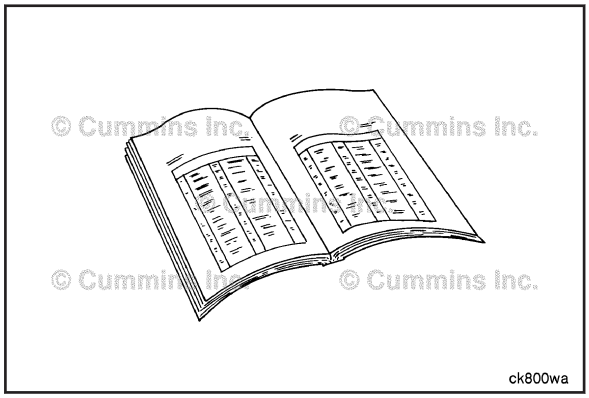
Tighten the capscrews.

Torque Value: 52 N•m [38 ft-lb]



Finishing Steps

- Install the fan idler pulley(s), if removed. Refer to Procedure 008-111.
- Install the fan drive belt. Refer to Procedure 008-002.
- Install the belt guard. Refer to Procedure 008-001.



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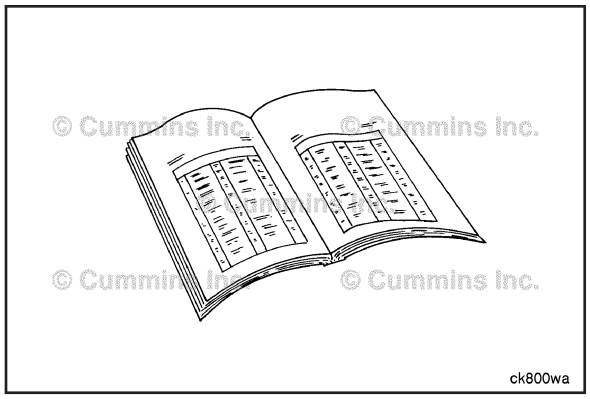


Coolant Return Junction Block (008-113)

Preparatory Steps

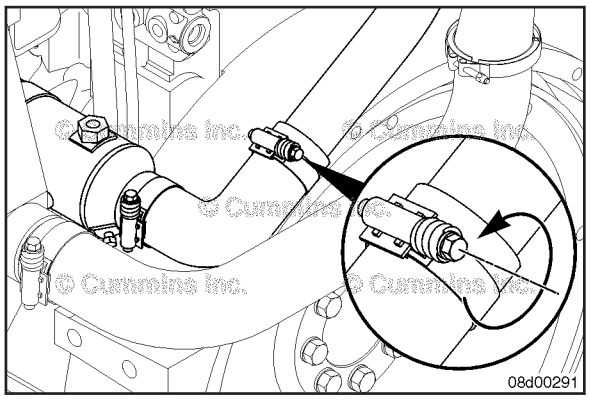
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠CAUTION⚠
Use caution when draining the coolant system that coolant is not spilled or drained into the bilge area. The coolant must be disposed of in accordance with local environmental regulations.

- Disconnect the batteries. Refer to Procedure 013-009.
- Drain the engine coolant. Refer to Procedure 008-018.



Remove

QSL Engines

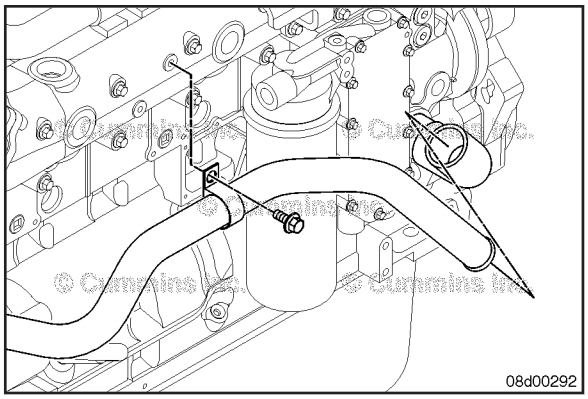
NOTE: Some QSL9 marine engines are keel cooled and some are sea water (heat exchanger) cooled. These first two steps apply to the keel cooled engine.

Loosen the hose clamps at the marine gear oil cooler.

Remove the expansion tank coolant fill tube from the coolant return junction.

Loosen the hose clamps at the water pump inlet connection.

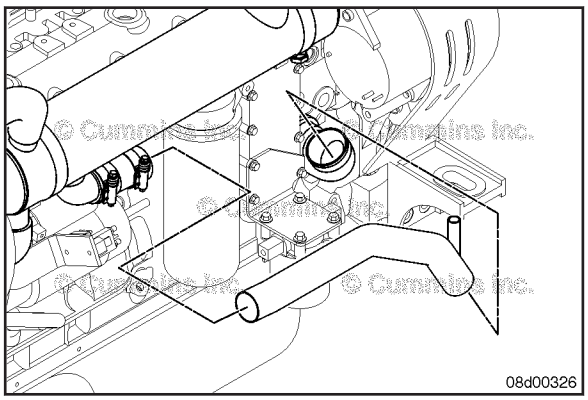
Remove the p-clip and the coolant return tube from the engine.



NOTE: This step applies to the QSL9 sea water (heat exchanger) cooled engine.

Disconnect the engine coolant return from the heat exchanger and the water pump inlet port.

Remove the coolant return pipe.

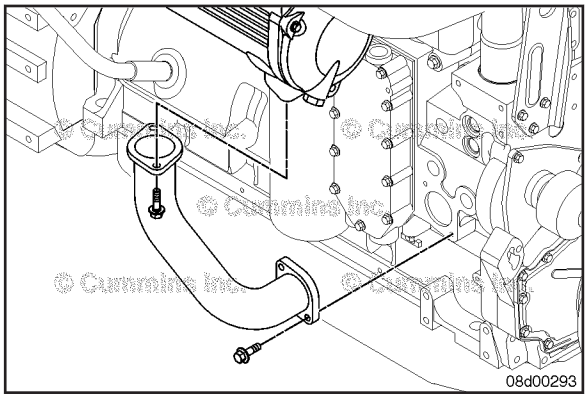


QSC Engines

Remove the two capscrews at the water pump inlet port.

Loosen the clamps at the heat exchanger connection.

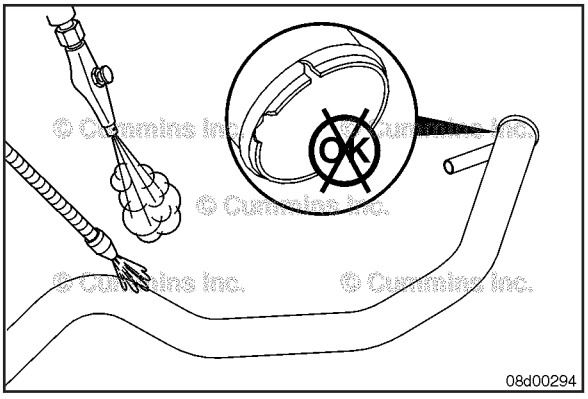
Remove the coolant return tube from the water pump inlet port and the heat exchanger.

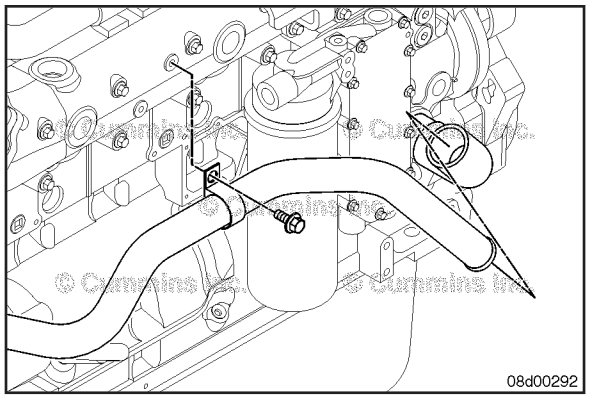


Clean and Inspect for Reuse

Clean the inlet connection of the coolant return junction.

Inspect the connection ends for cracks or other damage.





Install

QSL Engines

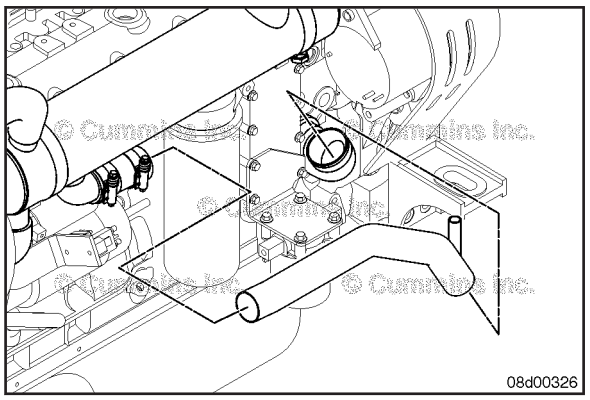
NOTE: These steps apply to the QSL9 keel cooled engine.

Install the coolant return tube to the water inlet connection and the marine gear oil cooler.

Install the p-clip over the tube and to the exhaust manifold.

Position the hose clamps and tighten.

Torque Value: 8 N•m [71 in-lb]

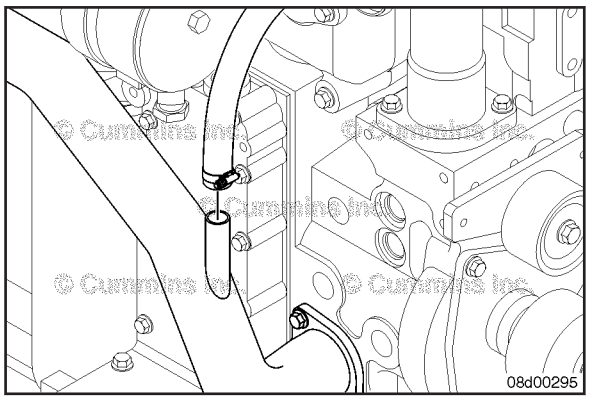


NOTE: This step applies to the QSL9 sea water (heat exchanger) cooled engine.

Install the coolant return to the water pump inlet port and heat exchanger outlet.

Tighten the hose clamps.

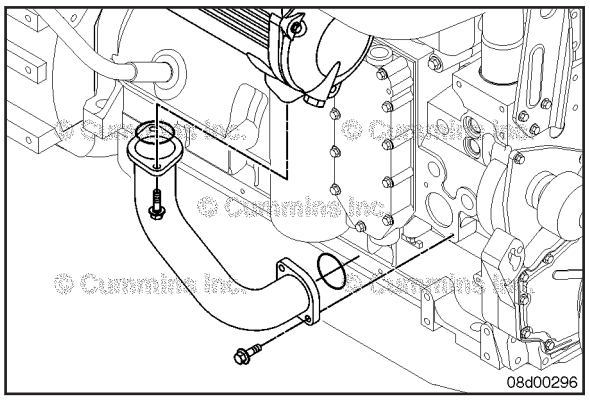
Torque Value: 8 N•m [71 in-lb]



NOTE: This step applies to the QSL9 sea water (heat exchanger) cooled engine and the QSL9 keel cooled engine.

Install the expansion tank fill line tube to the coolant return junction and tighten the hose clamp.

Torque Value: 8 N•m [71 in-lb]



QSC Engines

Install a new o-ring onto the coolant tube, if a flanged tube.

Install the tube onto the heat exchanger first.

Install the tube onto the water pump inlet port.

Install the two mounting capscrews and tighten.

Torque Value: 24 N•m [18 ft-lb]

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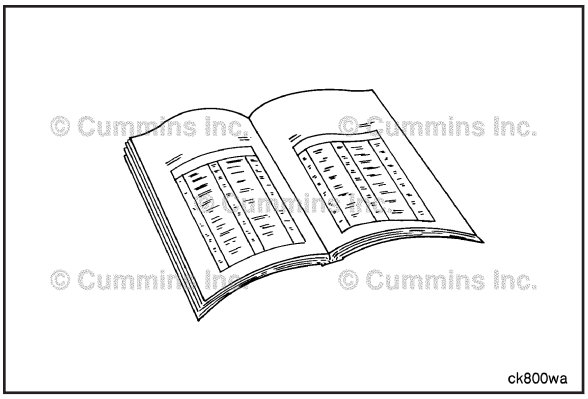
Finishing Steps

- Fill the engine with coolant. Refer to Procedure 008-018.
- Connect the batteries. Refer to Procedure 008-113.

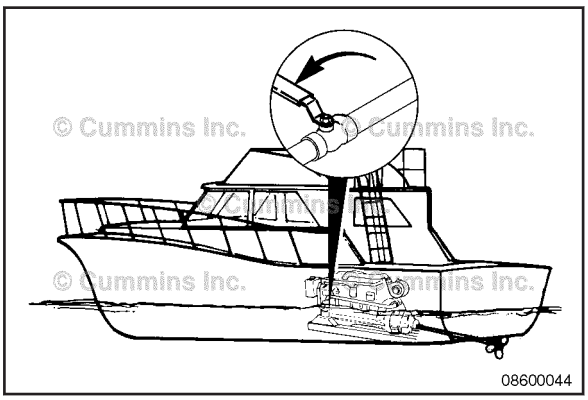
Operate the engine and check for leaks.



Marine Gear Oil and Fuel Cooler Assembly (008-129)

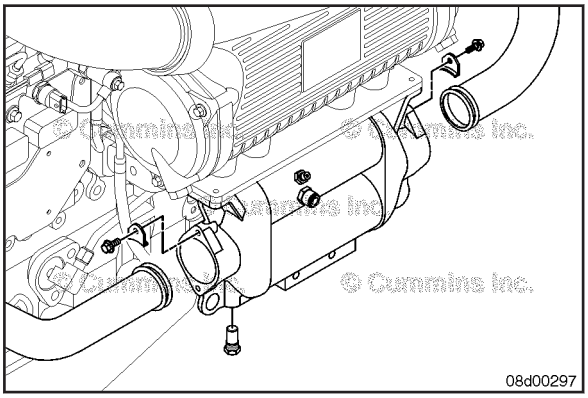
Flush

Shut off the sea water inlet valve on the vessel hull, if equipped.



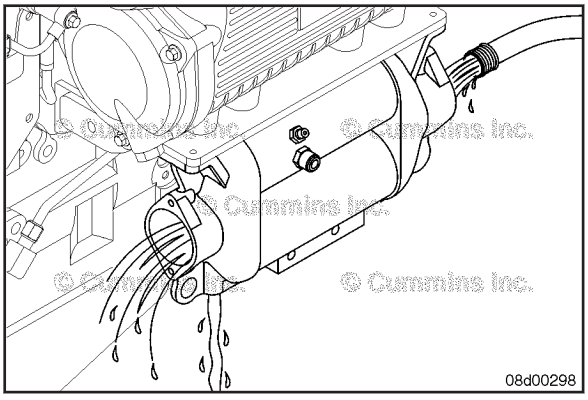
Remove the marine gear oil cooler drain plug and drain the sea water from the gear oil cooler.

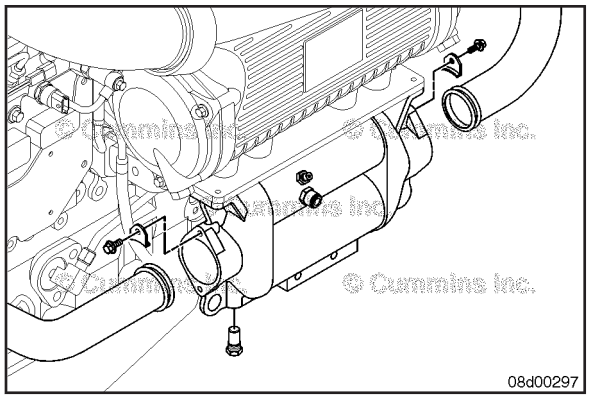
Disconnect the sea water inlet and outlet connections. Refer to Procedure 008-056.



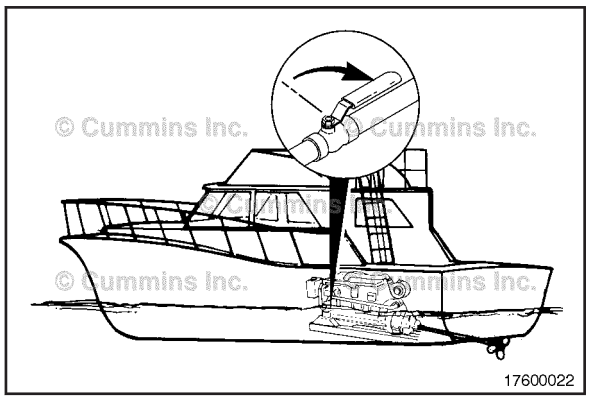
Use clean water to back flush all the debris from the cooler.

Make sure the debris flushed from the cooler does **not** enter the water supply hoses.



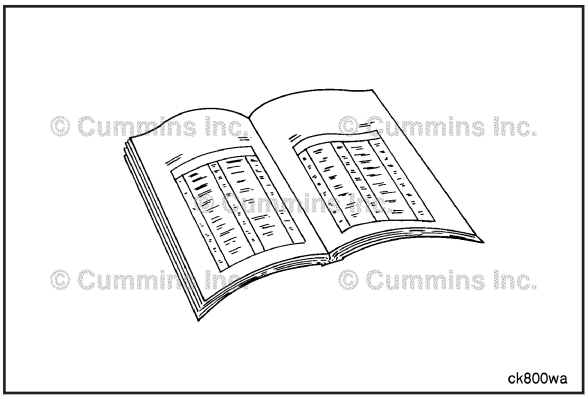


Install the drain plug and sea water hose connections.



Open the sea water valve on the vessel hull, if equipped.

Preparatory Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

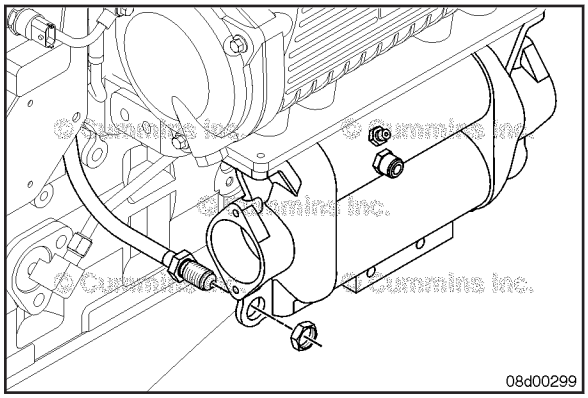
⚠CAUTION⚠
Use caution when disconnecting or removing oil lines that oil is not spilled or drained into the bilge area. The oil must be drained into a suitable container and disposed of in accordance with local environmental regulations.

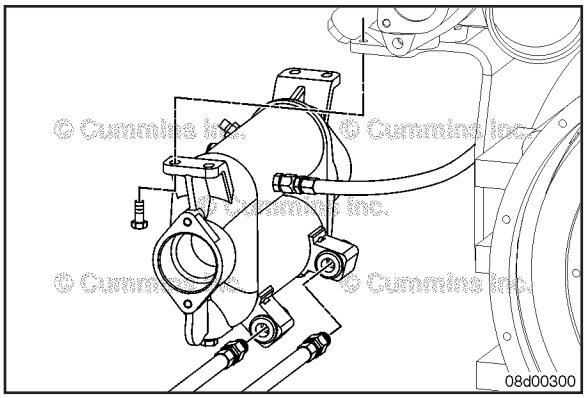
NOTE: This procedure applies to QSC8.3 marine engine only. Refer to Procedure 008-041 for QSL9 marine engines.

- Disconnect the batteries. Refer to Procedure 013-009.
- Shut off the fuel supply and drain valves. Refer to the OEM service manual.
- Disconnect the OEM fuel supply and OEM drain lines from the fuel cooler side of the assembly.
- Shut off the sea water inlet valve(s) on the vessel hull, if equipped. Refer to the OEM service manual.
- Disconnect the oil temperature and pressure sensor connectors from the OEM harness.
- Drain the sea water system by removing the two plugs at the bottom of the marine gear oil and fuel cooler assembly. Refer to Procedure 008-059.
- Disconnect the sea water inlet and outlet pipes. Refer to Procedure 008-056.

Remove

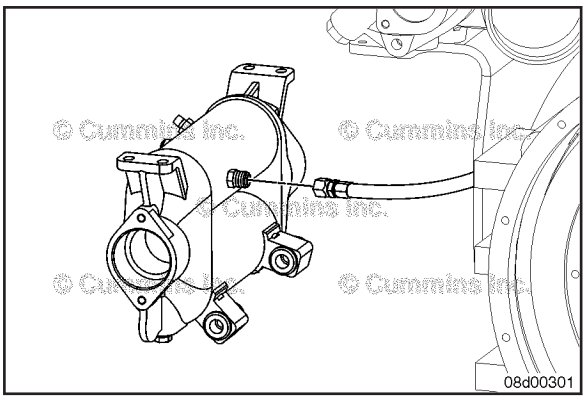
Disconnect the fuel supply hose from the lift pump to the fuel cooler at the fuel cooler.





Remove the mounting capscrews from the gear cooler to aftercooler.

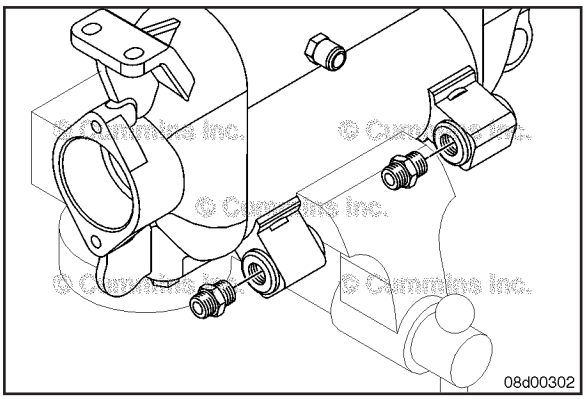
Twist the cooler so the transmission oil supply and return lines can be removed.



Remove the transmission oil supply and return lines; mark their locations.

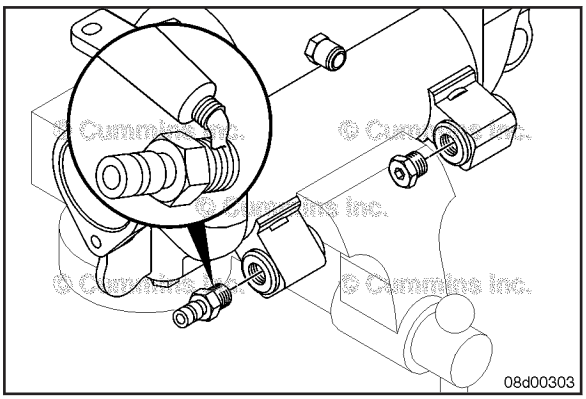
Disconnect the marine gear oil pressure/temperature sensor (if equipped).

Disconnect the braided fuel return hose from the rear of the cooler.



Disassemble

Place the cooler in a vise and remove the two oil line fittings from the gear cooler, if necessary. Mark the fitting locations prior to removal.



Inspect for Reuse

Plug one gear oil port and attach an air supply line to the other gear oil port with a quick disconnect fitting. Apply thread sealant to the threads to prevent leaks. Do **not** allow sealant to enter the gear oil cooler.

Repeat the leak test for the fuel side of the cooler assembly.

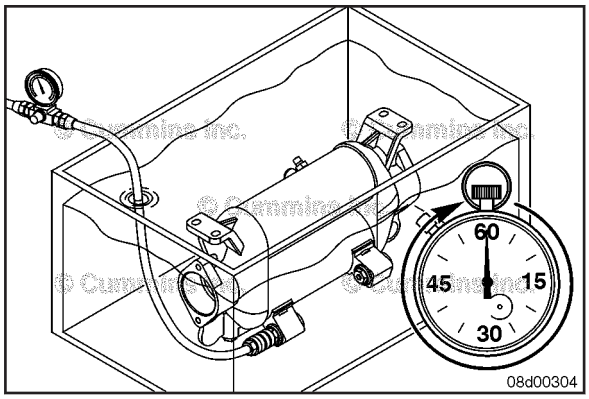
⚠WARNING⚠
Troubleshooting with high pressure air presents the risk of equipment damage, personal injury, or death. Troubleshooting must be performed by trained, experienced technicians.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Attach a high-pressure air supply source (air cylinder or other suitable source) with an air pressure regulator and an inline shutoff valve to the quick disconnect fitting.

Set the regulator test pressure to 1724 kPa [250 psi].

Submerge the gear oil cooler into a tank of water. Rotate the cooler to allow any trapped air to escape. Allow the cooler to remain submerged for one minute.



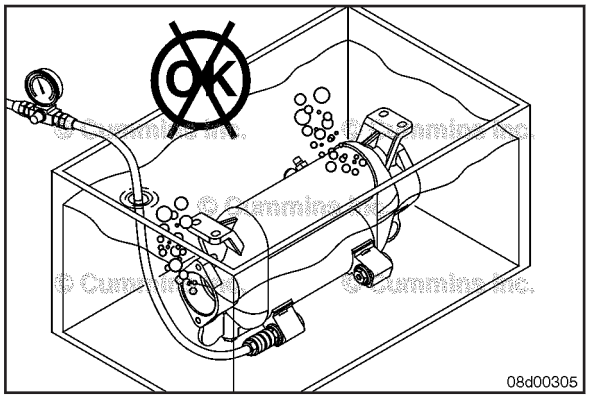
Inspect for air bubbles at the fitting braze joints.

Inspect for air bubbles at the opening at each end of the cooler.

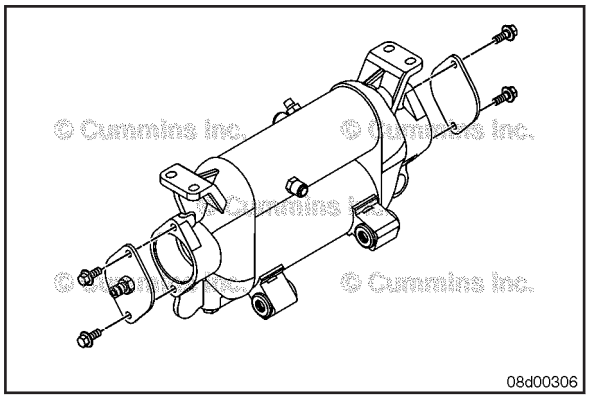
If leaks are detected, replace the gear oil cooler.

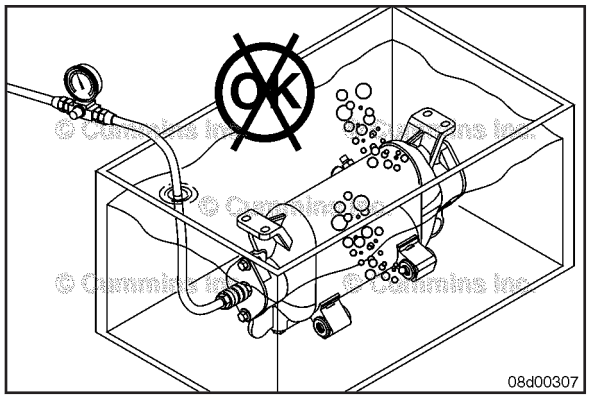
Remove the cooler from the tank. Shut off the air supply and disconnect the air supply.

Remove the plug and test fitting.



Fabricate a test fixture to seal the sea water connections, or use connector hoses with a quick disconnect air connection to supply a regulated test pressure of 276 kPa [40 psi] to the sea water side of the gear oil cooler.





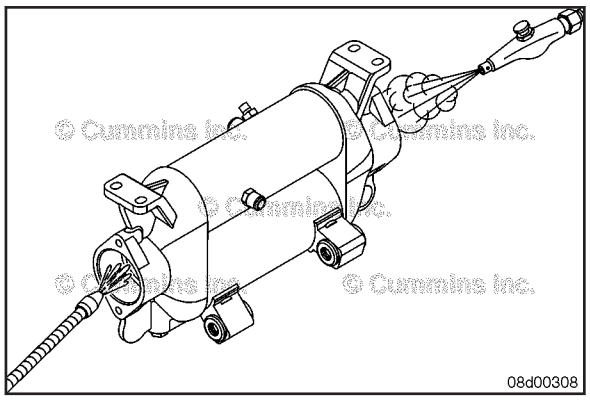
Submerge the cooler into a tank of water for one minute.

Inspect for air leaks at the braze joints of the end caps and any bubbles from the gear oil ports. If leaks are detected, replace the gear oil cooler.

Remove the cooler from the tank.

Shut off the air supply and disconnect the air supply.

Remove the test equipment.



⚠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.

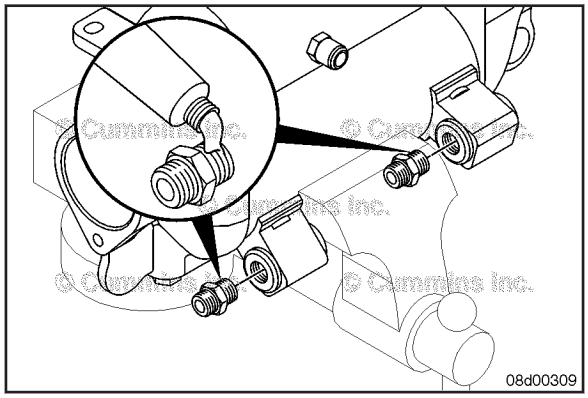
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Drain the water from the cooler.

Flush the oil and fuel sides of the cooler with clean solvent.

Use compressed air to dry the cooler.



Assemble

Coat the threads with thread sealant and install the two line fittings into the gear cooler, if removed. Be sure they are oriented in the same direction as they were removed.

Torque Value: 30 N•m [22 ft-lb]

Install the oil temperature sensor on the right and the oil pressure sensor on the left. Tighten the sensors.

Torque Value: 15 N•m [133 in-lb]

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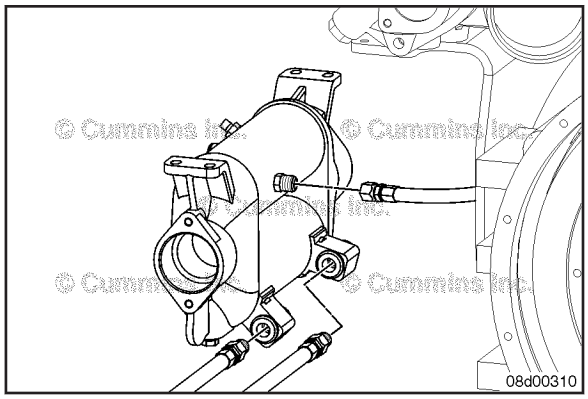
Install

Connect the transmission oil supply and return lines to their original locations and tighten.

Torque Value: 30 N•m [22 ft-lb]

Connect the braided fuel return line to the fuel cooler and tighten.

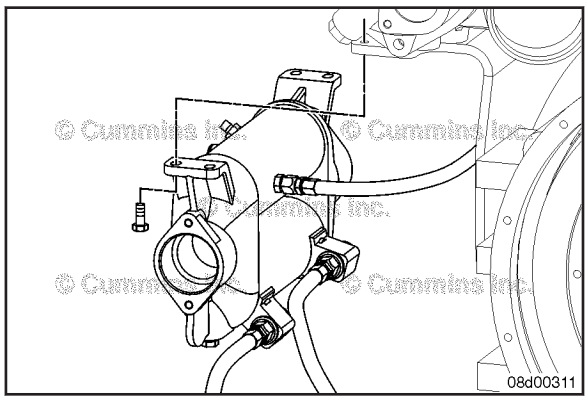
Torque Value: 24 N•m [18 ft-lb]



Install the marine gear oil cooler to the aftercooler.

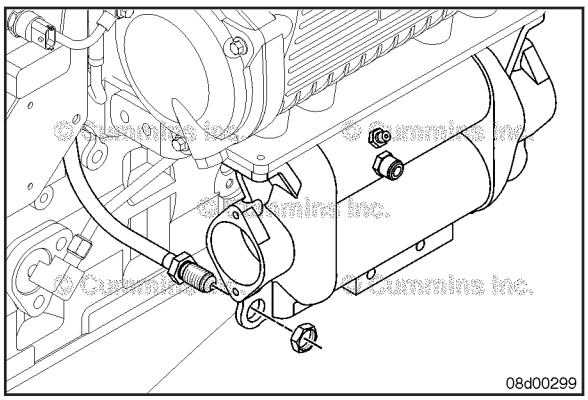
Tighten the capscrews.

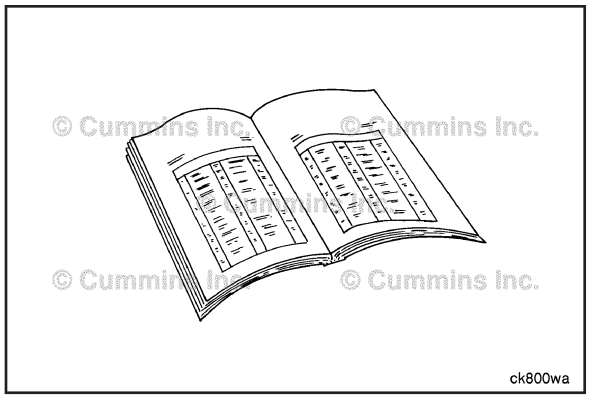
Torque Value: 30 N•m [22 ft-lb]



Install the fuel supply hose from the lift pump through the cooler housing using two jam nuts.

Torque Value: 30 N•m [22 ft-lb]





Finishing Steps

- Connect the oil temperature and pressure sensor connectors from the OEM harness.
- Connect the sea water inlet and outlet pipe. Refer to the OEM service manual.
- Connect the OEM fuel supply and drain lines to the fuel cooler.
- Install the plugs in the bottom of the marine gear oil and fuel cooler assembly. Refer to Procedure 008-059.
- Open the sea water inlet valve(s). Refer to the OEM service manual.
- Open the fuel supply and drain valves. Refer to the OEM service manual.
- Connect the batteries. Refer to Procedure 013-009.

Operate the engine and check for leaks.

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Section 9 - Drive Units - Group 09

Section Contents

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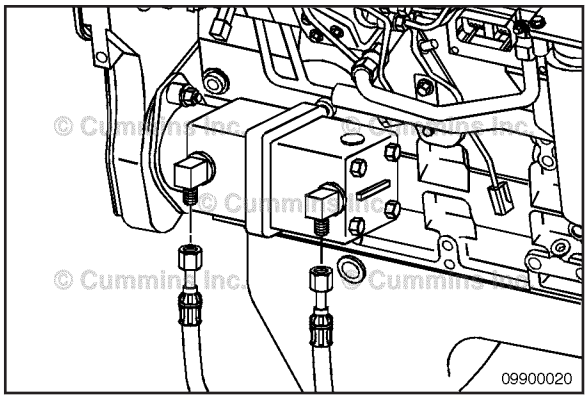
Hydraulic Pump Drive (009-016)

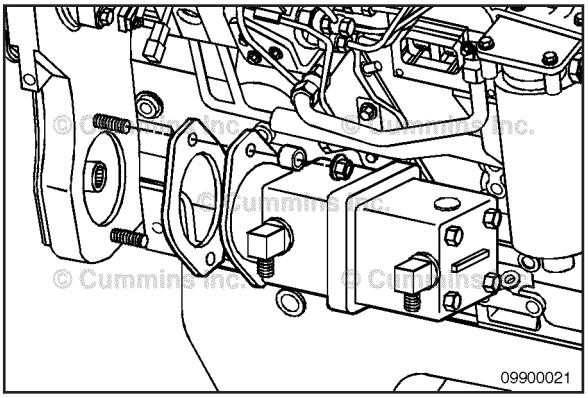
Remove

Disconnect all hydraulic lines from the pump.



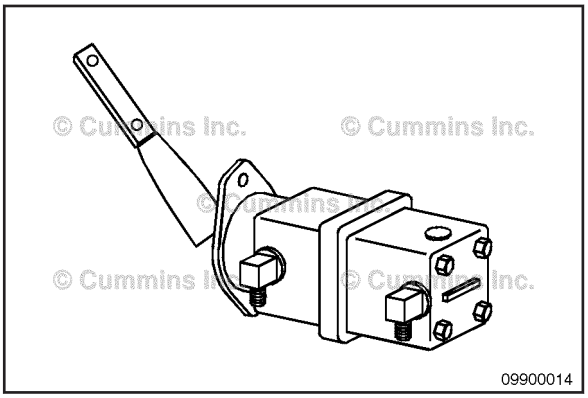
Remove the hydraulic pump and gear assembly.

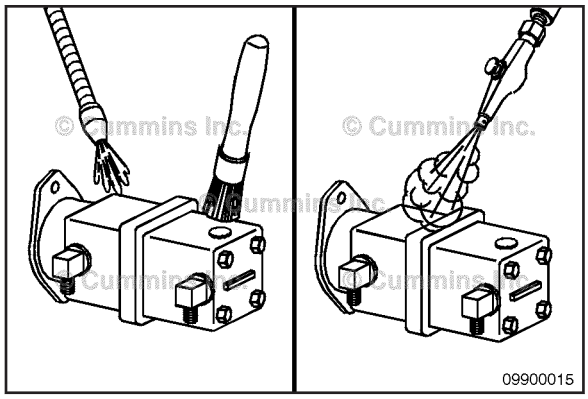
Refer to the equipment manufacturer's service manual for removal procedures.



Clean

Clean the gasket material from the hydraulic pump.





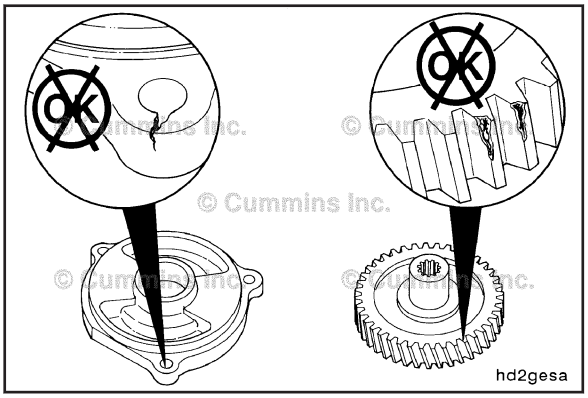
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠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.

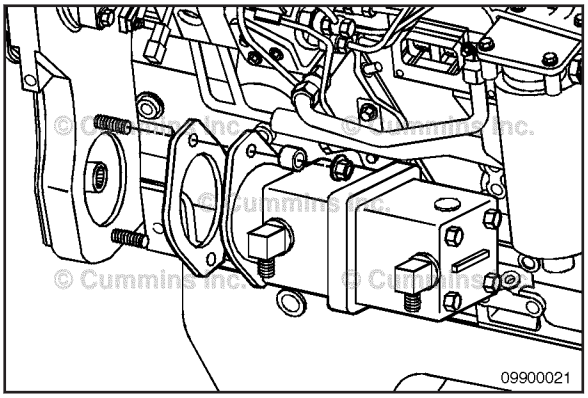
Clean the hydraulic pump gear with solvent.

Dry with compressed air.



Inspect for Reuse

Inspect the hydraulic pump drive gear for damage.



Install

Use a new gasket and install the hydraulic pump.

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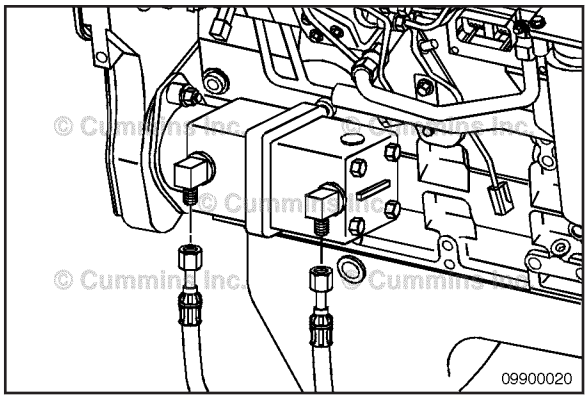
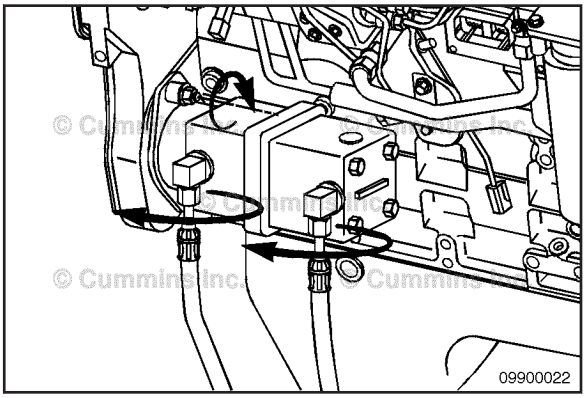
Connect all hydraulic lines to the pump.



Tighten mounting bolts.

Torque Value: 43 N•m [32 ft-lb]

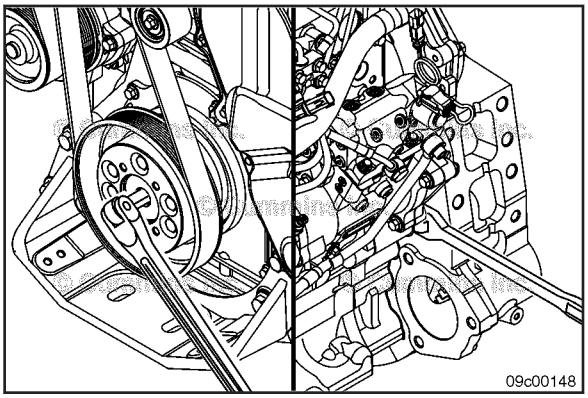


Engine Barring Device (009-035)

Install

Rear Barring

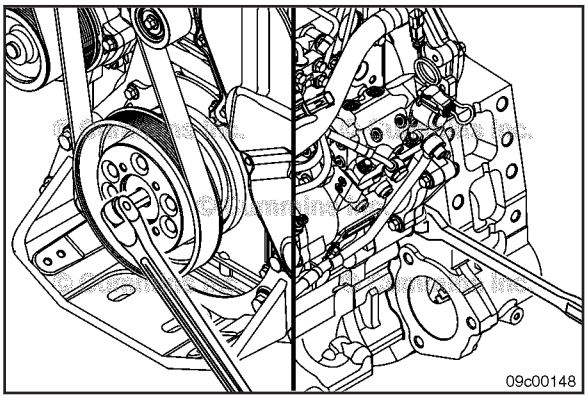
- Remove the plastic cover in the flywheel housing. Insert Cummins® service tool, Part Number 3824591, into the flywheel housing. Use a 1/2-inch breaker bar and rotate it **counterclockwise,** when viewed from the front of the engine.

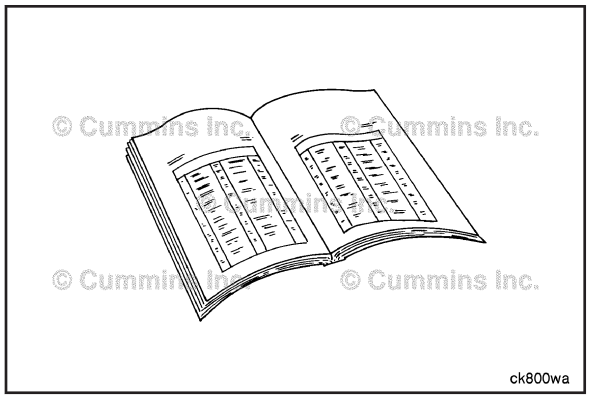


Finishing Steps

Rear Barring

- Make sure that the Cummins® service tool, Part Number 3824591, has been removed from the flywheel housing and the plug has been installed.





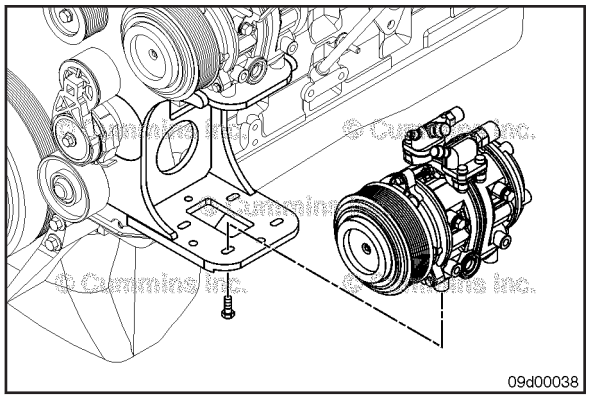
Refrigerant Compressor (009-051)

Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418.
- Remove the belt guard, if equipped. Refer to Procedure 008-001 (Belt Guard) in Section 8 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 008-001 (Belt Guard) in Section 8 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418.
- Remove the drive belt from the refrigerant compressor pulley. Refer to Procedure 009-052 (Drive Belt, Refrigerant Compressor) in Section 9.

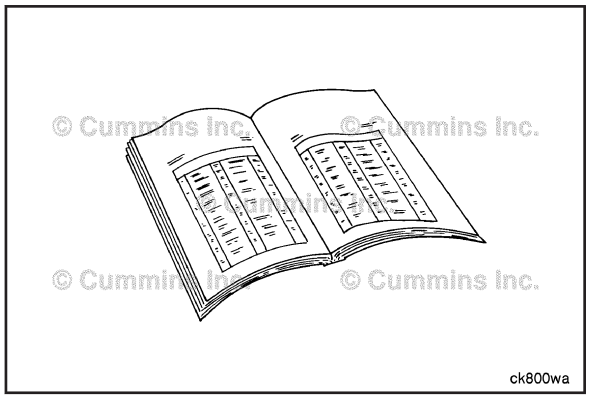


Remove

Remove the refrigerant compressor mounting capscrew.

Remove the refrigerant compressor.

Refer to the OEM service manual for information on disconnecting refrigerant lines.



Inspect for Reuse

Refer to the OEM service manual for refrigerant compressor cleaning and inspection procedures.

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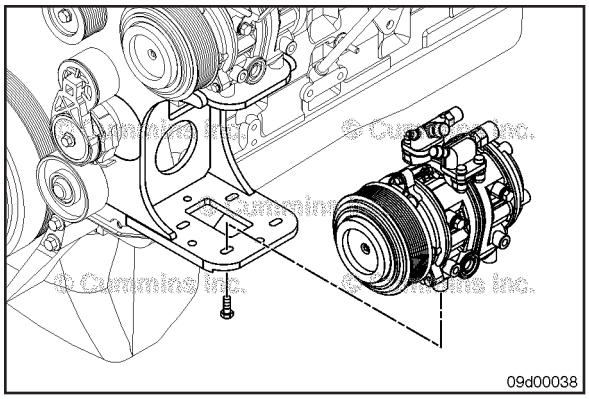
Install

Install the refrigerant compressor and the refrigerant compressor mounting capscrews.

Reference the compressor manufacturer's guidelines for torque values.

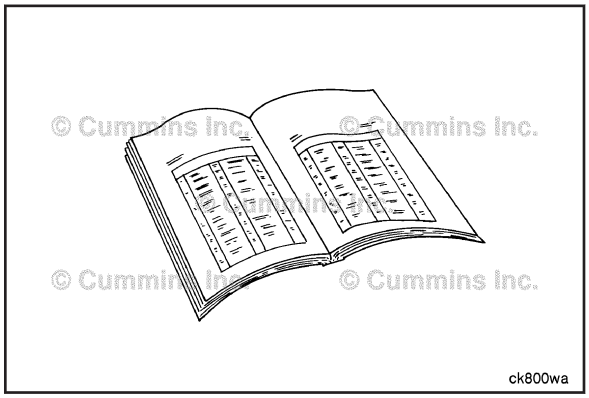
NOTE: Due to the availability of different front end accessory drive configurations, this procedure is meant to be generic. Some front end accessory drive configurations may require the refrigerant compressors to be aligned with the other pulleys. Make sure all drive pulleys and idler pulleys are in alignment with one another. The components with shorter belt spans are the most critical and require special attention. Cummins Inc. recommends the use of the laser alignment tool, Part Number 3163524.

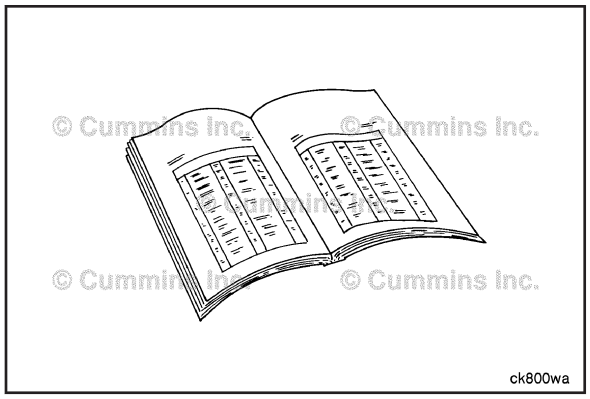


Finishing Steps

⚠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 009-052 (Drive Belt, Refrigerant Compressor) in Section 9.
- Install the belt guard, if equipped. Refer to Procedure 008-001 (Belt Guard) in Section 8 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 008-001 (Belt Guard) in Section 8 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418.
- Connect the battery. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418.



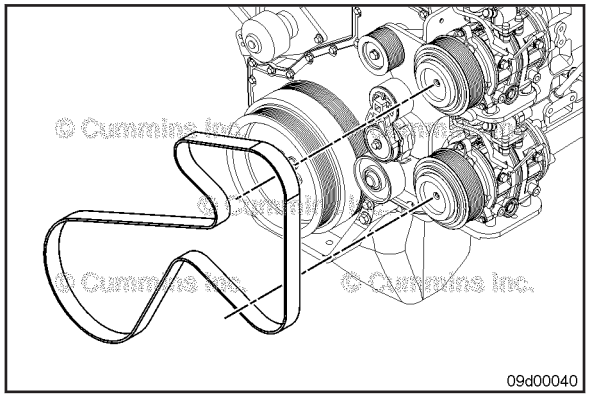


Drive Belt, Refrigerant Compressor (009-052)

Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418.
- Remove the belt guard, if equipped. Refer to Procedure 008-001 (Belt Guard) in Section 8 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 008-001 (Belt Guard) in Section 8 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418.



Remove

△CAUTION△
The belt tensioner is spring-loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

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

△CAUTION△
The use of a socket extension is not recommended because it can cause axial twisting damage to the belt tensioner.

Lift the tensioner to remove the refrigerant compressor drive belt.

NOTE: If a socket extension is necessary, support the head of the ratchet with one hand to prevent the belt tensioner arm from unintended loading.

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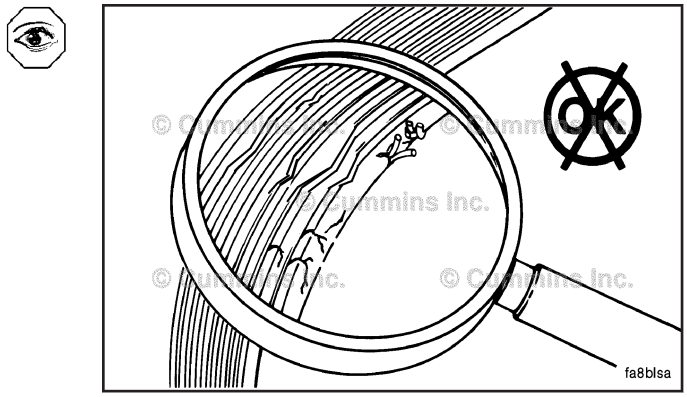
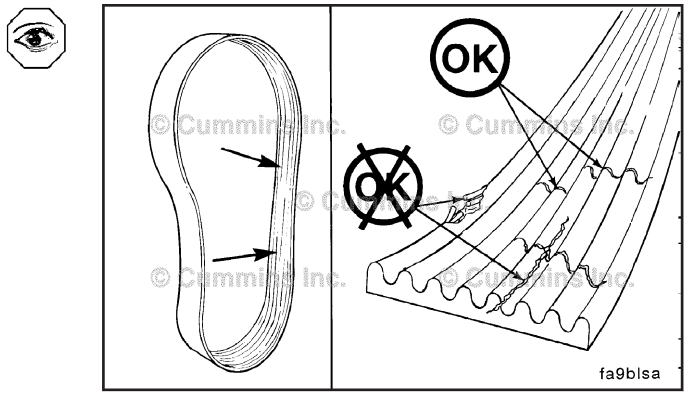
Inspect for Reuse



Inspect the belt for:

- Cracks
- Glazing
- Tears or cuts
- Hardening
- Excessive wear.



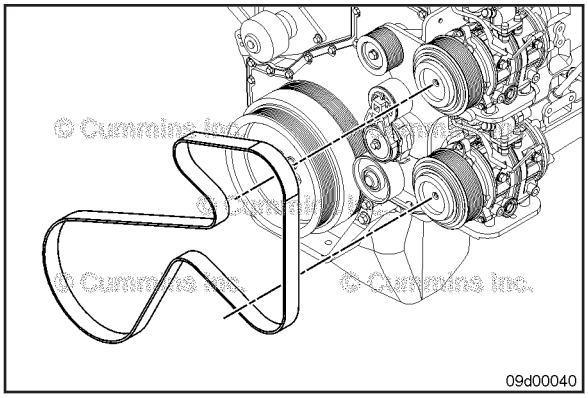
Check the belt for damage.

Transverse (across the belt width) cracks are acceptable.

Longitudinal (direction of the belt length) cracks that intersect with transverse cracks are **not** acceptable.

If the belt is frayed or has any piece of material missing, the belt is unacceptable and **must** be replaced.

Install



⚠CAUTION⚠
The belt tensioner is spring-loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

Lift and hold the belt tensioner.

Install the drive belt and release the tensioner.

NOTE: Due to the availability of different belt run configurations, this procedure is meant to be generic. Reference the application manufacturer's manuals for the correct belt run.

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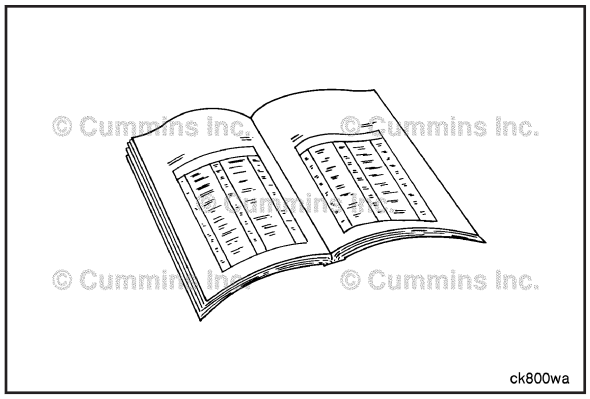
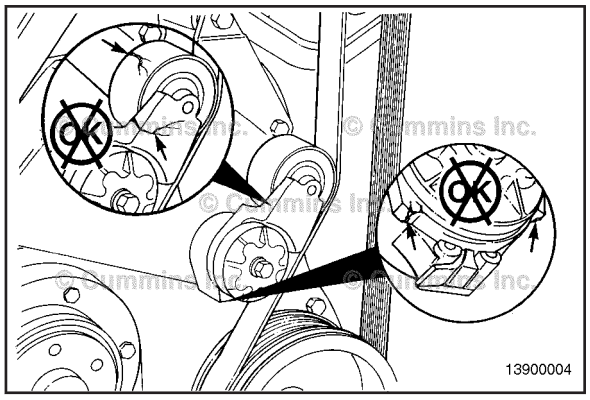


Finishing Steps

⚠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 belt guard, if equipped. Refer to Procedure 008-001 (Belt Guard) in Section 8 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 008-001 (Belt Guard) in Section 8 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418.
- Connect the battery. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418.

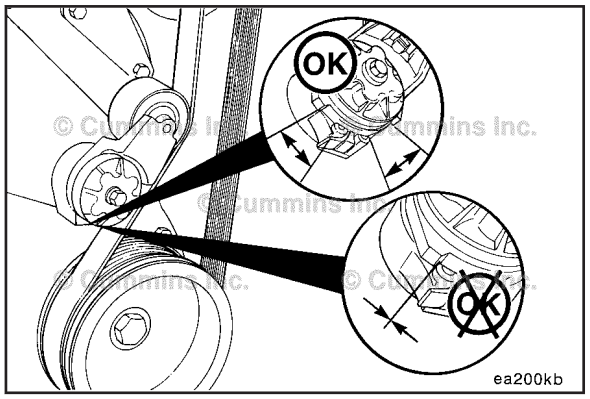


Belt Tensioner, Refrigerant Compressor, Automatic (009-053)

Initial Check

Check the tensioner arm, pulley, and stops for cracks.

If cracks are found, the tensioner **must** be replaced.



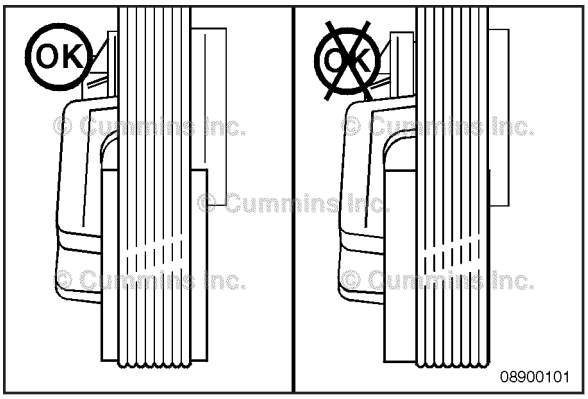
With the belt on, verify that neither of the tensioner arm stops are in contact with the spring casing stop.

If either stop is touching, the drive belt **must** be replaced.

If the tensioner arm stops are still in contact with the spring case stop after replacing the belt, replace the tensioner.

Check the location of the drive belt on the belt tensioner pulley. The belt should be centered on, or close to the middle of, the pulley.

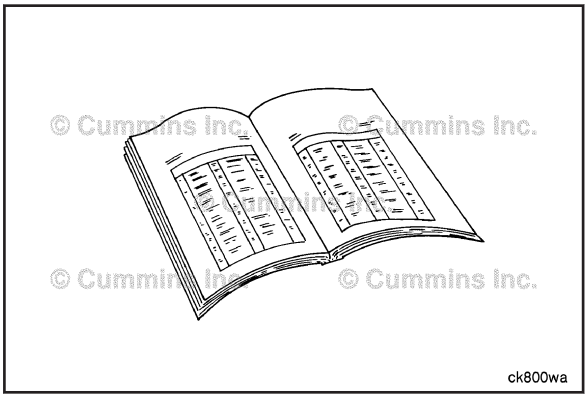
Misaligned belts, either too far forward or backward, can cause belt wear, belt roll-off failures, or increase uneven tensioner bushing wear.



Preparatory Steps

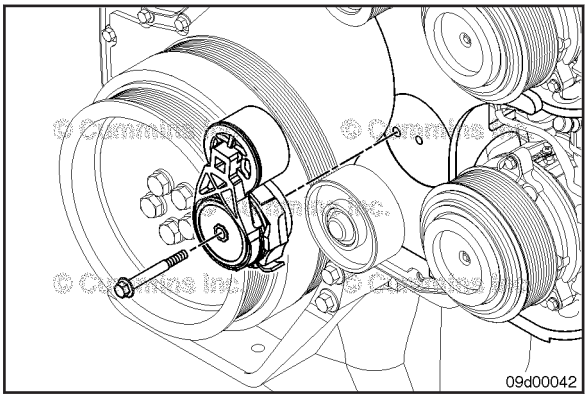
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

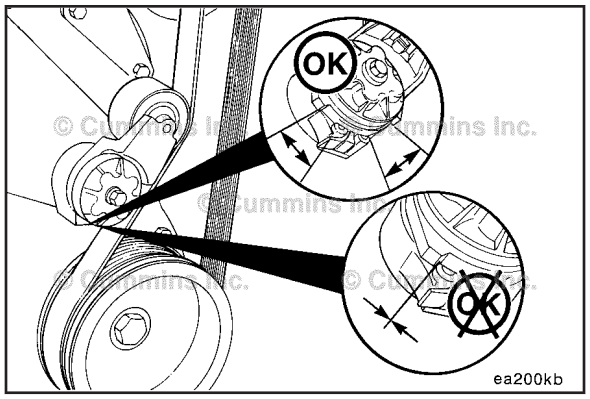
- Disconnect the battery. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418.
- Remove the belt guard, if equipped. Refer to Procedure 008-001 (Belt Guard) in Section 8 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 008-001 (Belt Guard) in Section 8 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418.
- Remove the drive belt. Refer to Procedure 009-052 (Drive Belt, Refrigerant Compressor) in Section 9.



Remove

Remove the capscrew and belt tensioner from the mounting location.

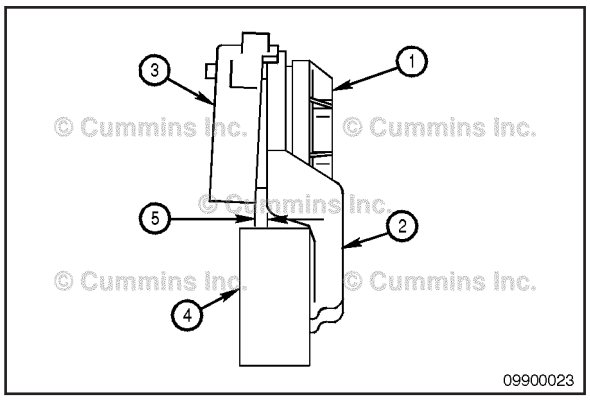




Install

With the belt removed, verify the tensioner arm stop is in contact with the spring casing stop.

If these two are **not** touching, the tensioner **must** be replaced.

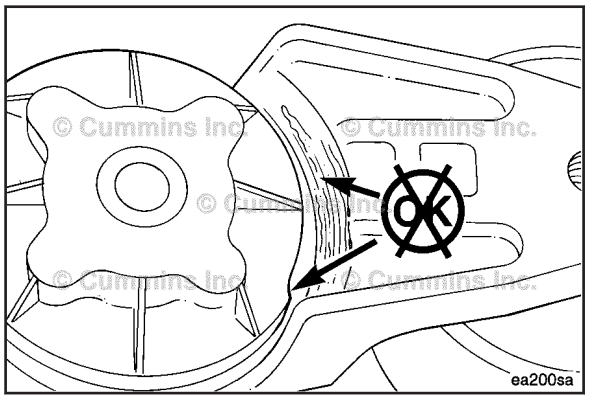


Measure the clearance between the tensioner spring casing and the tensioner arm to verify tensioner wear-out and uneven bearing wear.

If the clearance exceeds 3 mm [0.12 in] at any point, the tensioner **must** be replaced as a complete assembly.

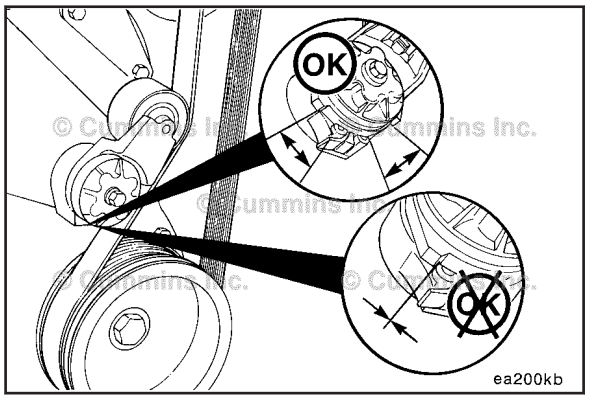
Tensioners usually show a larger clearance gap near the lower portion of the spring casing, resulting in the upper portion rubbing against the tensioner arm. **Always** replace the belt when a tensioner is replaced.

1. Tensioner cap
2. Tensioner arm
3. Spring case
4. Tensioner pulley
5. Clearance gap.



Inspect the tensioner for evidence of the tensioner arm contacting the tensioner cap.

If there is evidence of the two areas making contact, the pivot tube bushing has failed and the tensioner **must** be replaced.

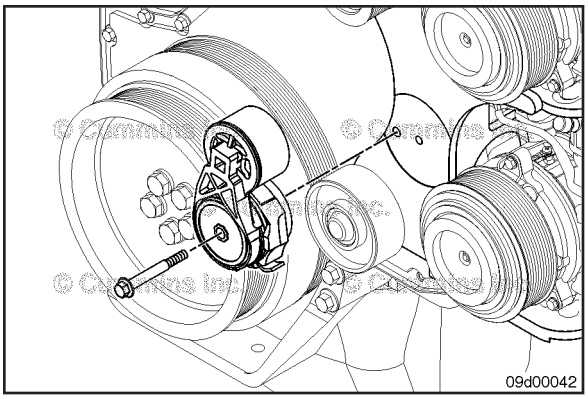


Inspect the mating surface for debris. The tensioner can become misaligned if particles are trapped between the mating surfaces.

Install

Install the belt tensioner and capscrew.

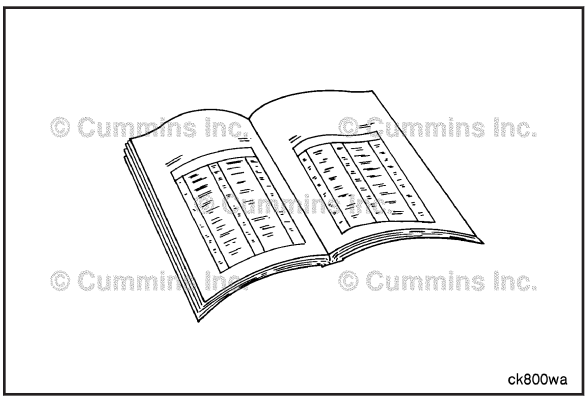
Torque Value: 43 N•m [32 ft-lb]

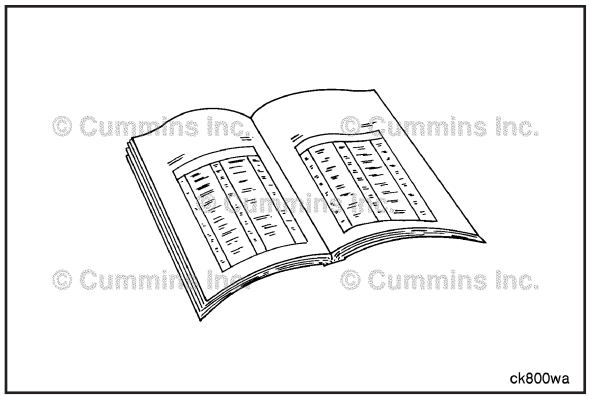


Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Lift and hold the tensioner, use a 3/8-inch square drive.
- Install the drive belt and release the tensioner. Refer to Procedure 009-052 (Drive Belt, Refrigerant Compressor) in Section 9.
- Install the belt guard, if equipped. Refer to Procedure 008-001 (Belt Guard) in Section 8 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 008-001 (Belt Guard) in Section 8 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418.
- Connect the battery. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418.



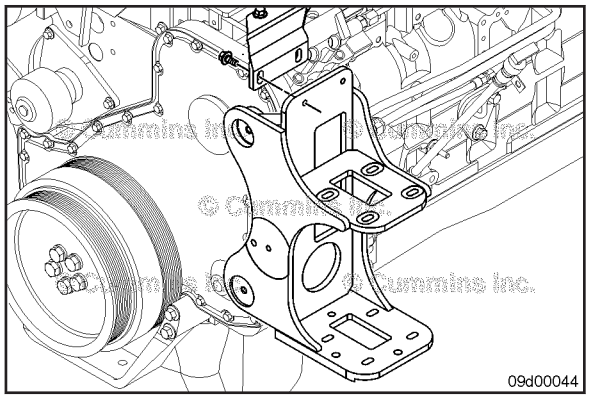


Refrigerant Compressor Mounting Bracket (009-055)

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 (Battery Cables and Connections) in Section 13 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418.
- Remove the belt guard, if equipped. Refer to Procedure 008-001 (Belt Guard) in Section 8 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 008-001 (Belt Guard) in Section 8 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418.
- Remove the drive belt from the refrigerant compressor. Refer to Procedure 009-052 (Drive Belt, Refrigerant Compressor) in Section 9.
- Remove the refrigerant compressor. Refer to Procedure 009-051 (Refrigerant Compressor) in Section 9.



Remove

Remove the refrigerant compressor bracket mounting capscrews and bracket.

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.

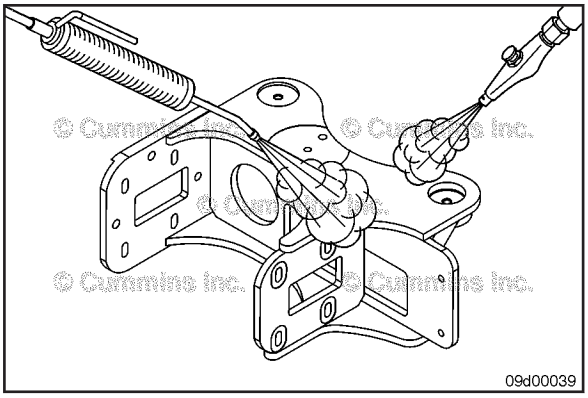
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use steam or solvent to clean the refrigerant compressor mounting brackets.

Dry with compressed air.

Inspect the refrigerant compressor mounting brackets for cracks or damage.

If cracks are found on the refrigerant compressor mounting brackets, they **must** be replaced.

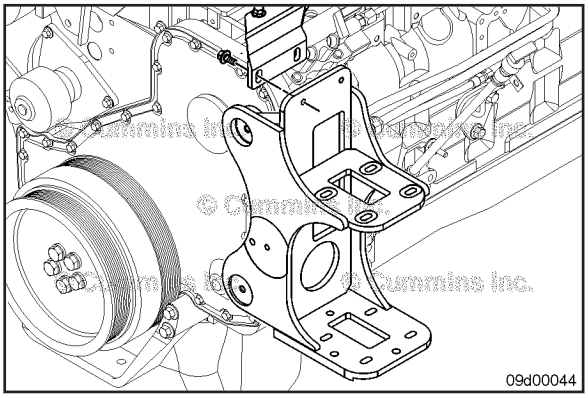


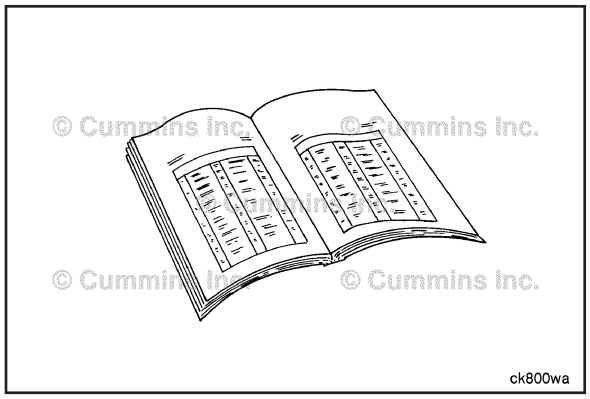
Install

Install the refrigerant compressor mounting bracket and bracket mounting capscrews.

Torque Value: 46 N•m [34 ft-lb]

NOTE: Due to the availability of different bracket configurations, this procedure is meant to be generic. Note any knife edges or alignment pins on the bracket that need to be used and make sure the mating or alignment features are free from debris.





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 refrigerant compressor. Refer to Procedure 009-051 (Refrigerant Compressor) in Section 9.
- Install the drive belt from the refrigerant compressor. Refer to Procedure 009-052 (Drive Belt, Refrigerant Compressor) in Section 9.
- Install the belt guard, if equipped. Refer to Procedure 008-001 (Belt Guard) in Section 8 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 008-001 (Belt Guard) in Section 8 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418.
- Connect the battery. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418.

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Section 10 - Air Intake System - Group 10

Section Contents

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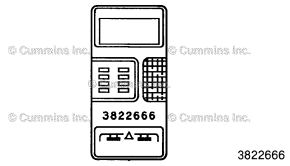
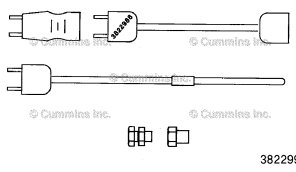
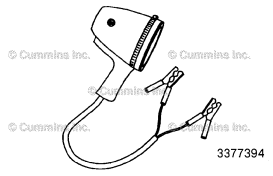
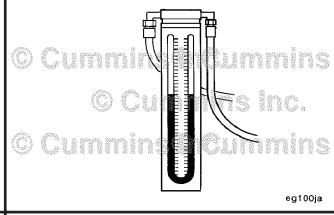
Service Tools

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
3376891	**Fluorescent Tracer** Add to oil. Used with black light, Part Number 3163338 to find oil leaks.	
3822666	**Fluke Digital Thermometer** Used to measure voltage.	
3822988	**Thermocouple Wire Kit** Used to check temperature. Used with fluke digital multimeter, Part Number 3164488.	
3163338	**Black Light (VDC)** Used to inspect for oil or fuel leak.	
ST-1111-3	**Manometer** Used to measure pressure, restriction (0 to 10 in H_2O) with more accuracy.	
ST-1273	**Pressure Gauge (0 to 75 in Hg)** Used to measure the intake manifold pressure and exhaust back pressure.	

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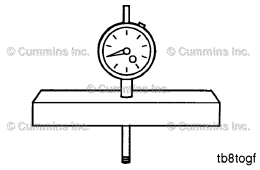
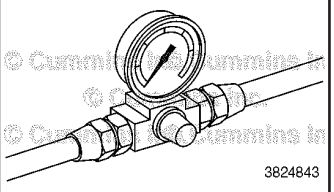
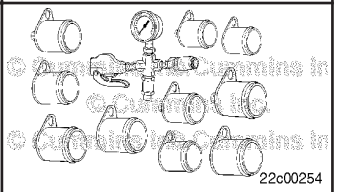
Tool No.	Tool Description	Tool Illustration
ST-537	**Dial Depth Gauge** Used to measure turbocharger axial motion.	
3824843	**Coupling** Used to apply regulated shop air pressure to variable geometry turbocharger actuator.	
3824556	**Charge Air Cooler Tester** Used to pressure test the charge air cooler.	

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Aftercooler Assembly (Sea Water) (010-005)

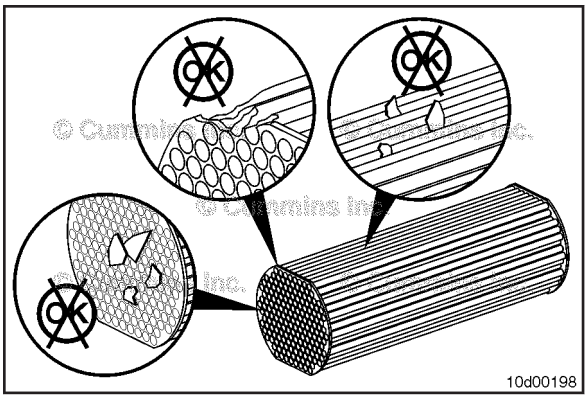
Initial Check

A turbocharger or sea water pump failure can cause damage to the aftercooler assembly.

If a turbocharger failure or a sea water pump failure has occurred, remove the aftercooler element and inspect the element and housing for damage.

Inspect the zinc anodes to make sure they are still in one piece and have **not** broken.

See the Inspect step within this procedure.



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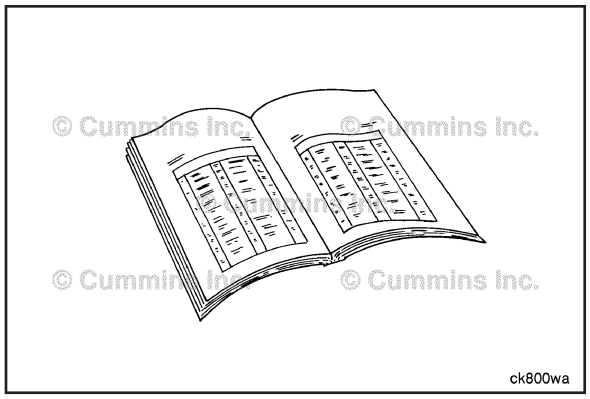

Preparatory Steps

QSL Engines

⚠ WARNING ⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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 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 △
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.

- Shut off the sea water supply and return line(s). Refer to the OEM service manual.
- Shut off the fuel supply and return lines. Refer to the OEM service manual.
- Disconnect the battery power from the engine. Refer to Procedure 013-009.
- Drain the sea water by removing the zinc anode plug at the bottom of the aftercooler. Refer to Procedure 008-059.
- Loosen the aftercooler top and bottom air connection hose clamps.
- If necessary, remove the aftercooler air discharge connection. Refer to Procedure 010-131.
- Disconnect the aftercooler air inlet connection. Refer to Procedure 010-019.
- If necessary, remove the fuel drain flex hoses at the fuel cooler.
- Remove the fuel cooler clip and mounting capscrew.
- Remove the fuel cooler lower molded sea water hose from the aftercooler. Support the cooler to prevent damage to the fuel lines.
- Loosen the hose clamp on the upper water transfer connection and remove the aftercooler sea water discharge hose.

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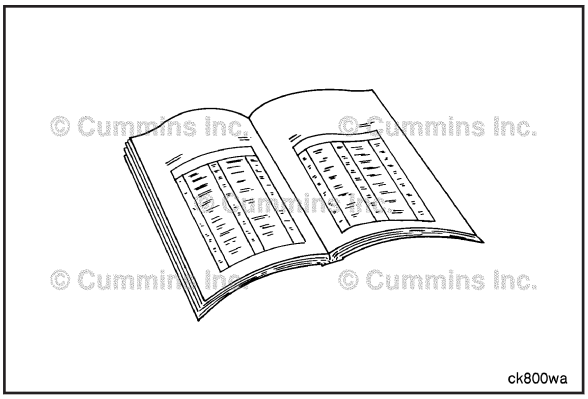
QSC Engines



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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 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⚠
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.

- Shut off the sea water supply and return lines. Refer to the OEM service manual.
- Shut off the fuel supply and return lines. Refer to the OEM service manual.
- Disconnect the batteries. Refer to Procedure 013-009.
- Drain the sea water system by removing the plugs at the bottom of the marine gear oil and fuel cooler.
- Remove the aftercooler air box drain plug and drain the condensation from the aftercooler housing core.
- Remove the air crossover and air outlet tube. Refer to Procedure 010-019.
- Remove the sea water lines. Refer to Procedure 008-056.
- Remove the marine gear oil and fuel cooler assembly. Refer to Procedure 008-129.

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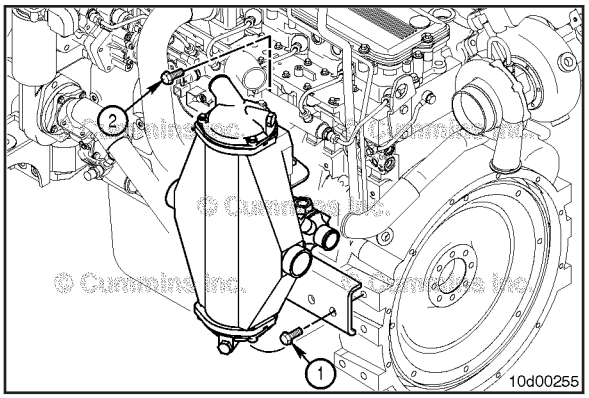
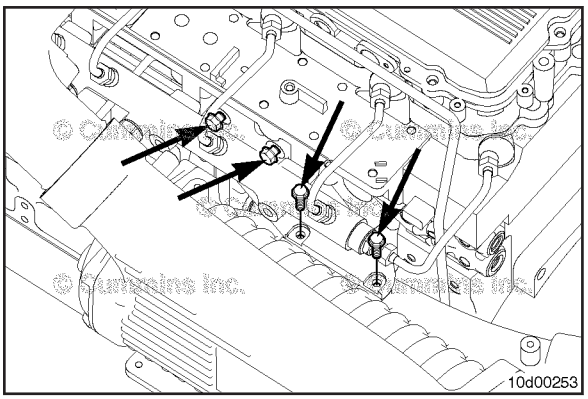


Remove

QSL Engines

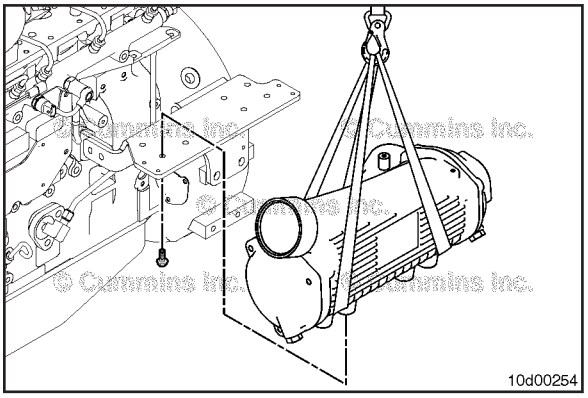
Loosen the aftercooler mounting capscrews at the flywheel housing (1), the cylinder block (2), and the cylinder head (3).

Remove the aftercooler assembly.



QSC Engines

Remove the upper mounting capscrews and loosen the bracket mounting capscrews in the cylinder block.

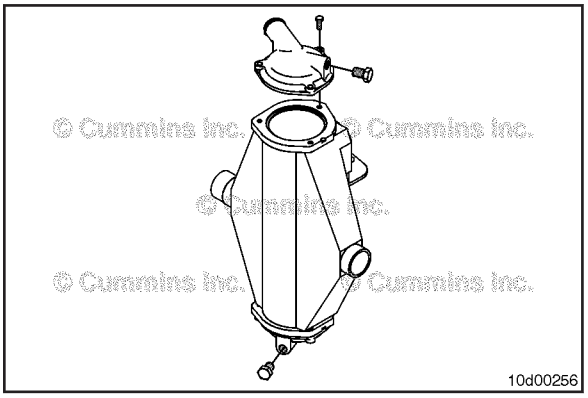


⚠WARNING⚠
This component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this component.

Attach a lifting strap and use a suitable hoist to lift the assembly.

Remove the lower mounting capscrews.

Slide the assembly from the bracket and away from the engine.



Disassemble

NOTE: Although the QSC8.3 and QSL9 aftercoolers look different, the following steps will apply to both.

Mark or note the aftercooler inlet and outlet water connection locations.

Remove the zinc plugs from the upper water transfer connection.

Remove the three capscrews and the upper water connection.

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⚠CAUTION⚠

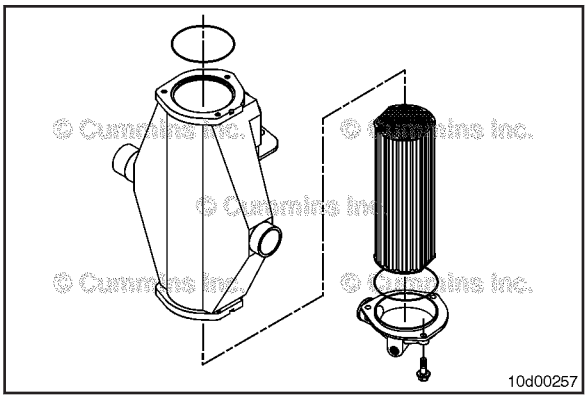
The aftercooler core assembly will slide out of the cooler housing when removing the lower aftercooler water connection. To reduce the possibility of damaging the core, lay the aftercooler assembly on its side to remove the connection and the core.

Lay the aftercooler assembly on its side.

The core assembly has two flat sides which must be orientated toward the aftercooler air intake and outlet sides of the aftercooler.

Remove the lower connection cover and the core.

Remove the upper and lower sealing o-rings.



Clean and Inspect for Reuse

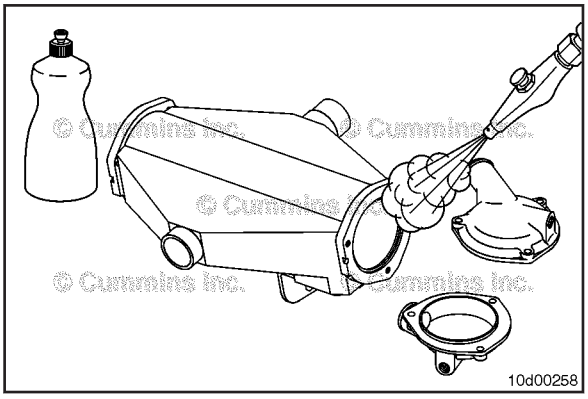
⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

NOTE: The aftercooler core can be cleaned and tested by a radiator cleaning facility. Ultrasonic cleaner is the preferred method of cleaning.

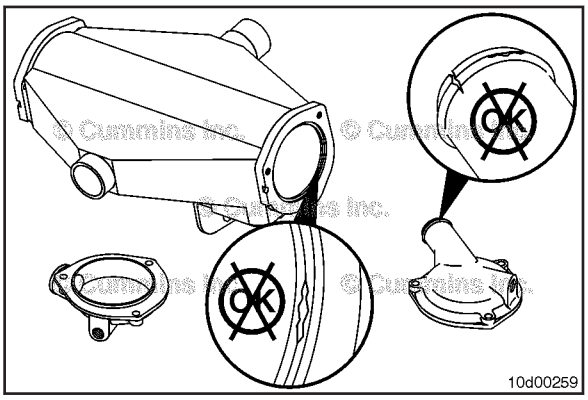
Use soap and water to clean the aftercooler and end caps.

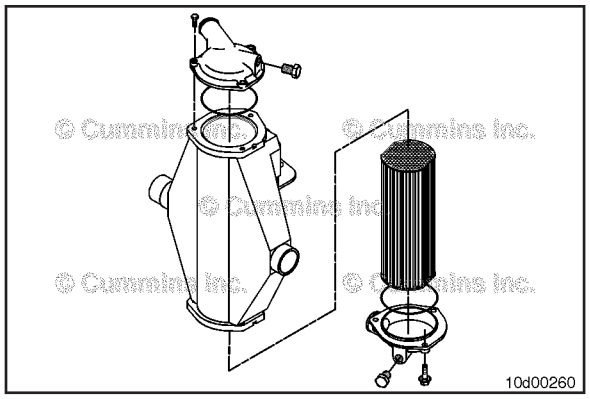
Dry with compressed air.



Inspect the housing and caps for cracks or other damage.

Inspect the aftercooler housing for deterioration of the sealing surfaces.





Assemble

Assemble the aftercooler in a vertical position. Install the aftercooler core into the aftercooler housing. Align the marks so one flat side of the core is facing the air inlet side of the housing.

Install a new o-ring around the lower core O.D. Install the water end cap and tighten the capscrews.

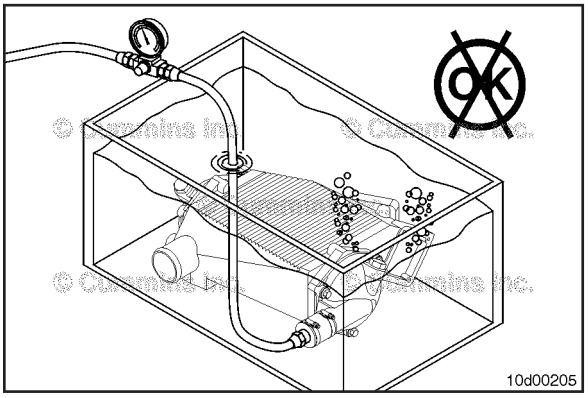
Torque Value: 43 N•m [32 ft-lb]

Install a new o-ring around the upper core O.D. Install the water end cap and tighten the capscrews.

Torque Value: 43 N•m [32 ft-lb]

Install the zinc plugs and tighten.

Torque Value: 55 N•m [41 ft-lb]



Pressure Test

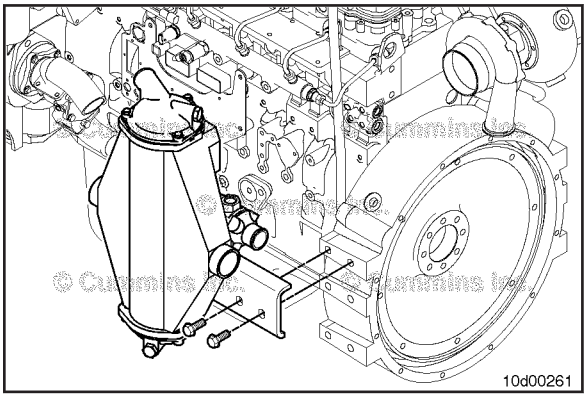
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Pressure test the sea water side of the aftercooler assembly.

Apply 276 kPa [40 psi] air pressure.

Lower the assembly into a tank of water and check for leaks.

Completely dry the aftercooler with compressed air.

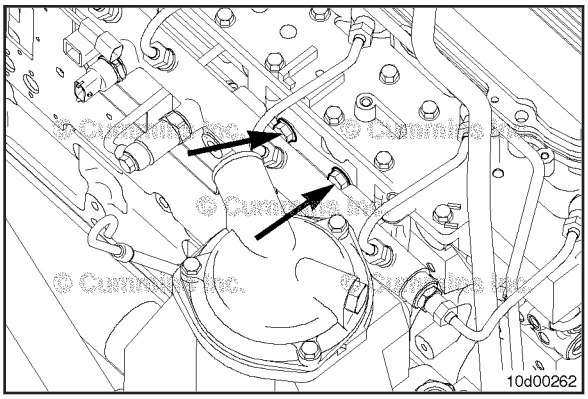


Install

QSL Engines

Loosely install the aftercooler assembly to the flywheel housing first using two mounting capscrews.

Install the upper capscrews first.

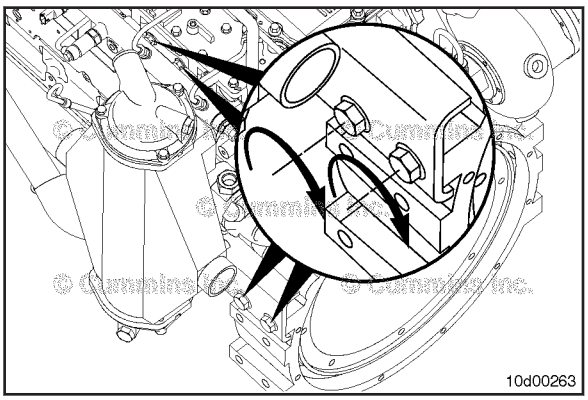


Install the aftercooler to bracket mounting capscrews.

Tighten all capscrews.

Torque Value:

Bracket to Flywheel Housing	to100 N•m	[74 ft-lb]
Bracket to Cylinder Head	to44 N•m	[32 ft-lb]
Aftercooler Bracket	to35 N•m	[26 ft-lb]



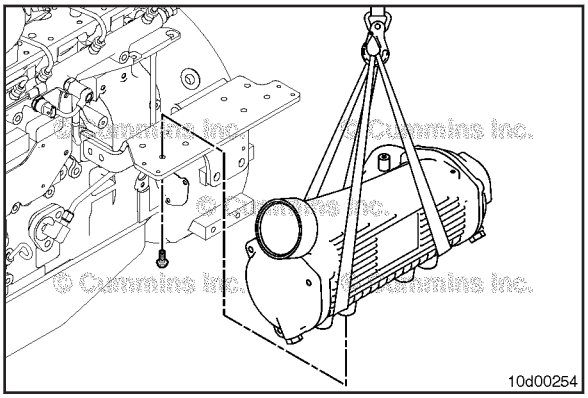
QSC Engines

Attach a lifting strap and use a suitable hoist to lift the aftercooler assembly into place.

Slide the assembly onto the lower support bracket and install the lower mounting capscrews.

Tighten the capscrews.

Torque Value: 35 N•m [26 ft-lb]



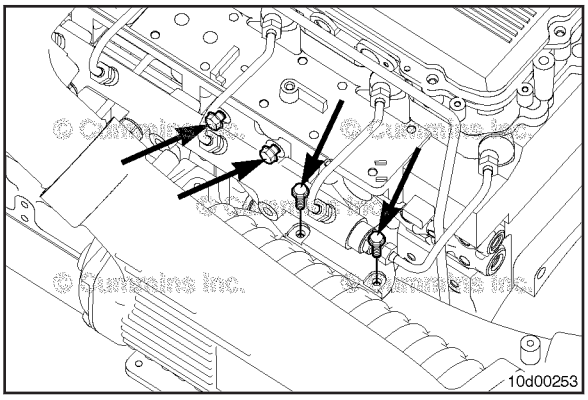
Install the upper bracket to the aftercooler mounting capscrews. Tighten all of the upper bracket mounting capscrews finger tight.

Tighten the bracket to the cylinder block mounting capscrews.

Torque Value: 44 N•m [32 ft-lb]

Tighten the bracket to aftercooler mounting capscrews.

Torque Value: 35 N•m [26 ft-lb]



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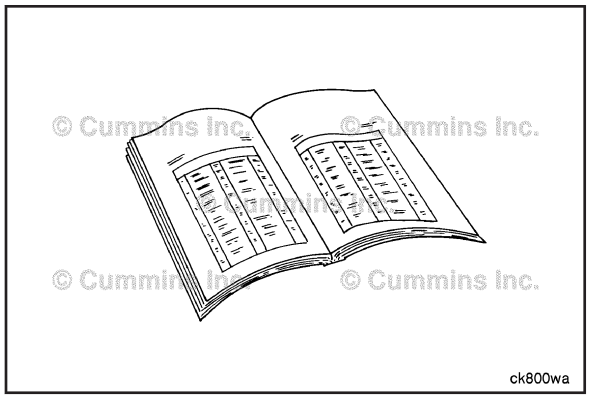
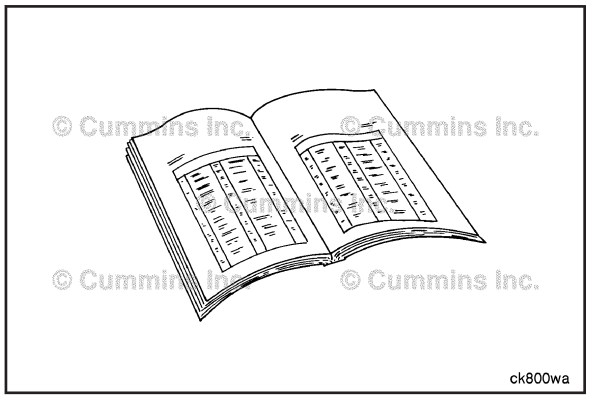


Finishing Steps

QSL Engines

- Install the fuel cooler lower molded sea water hose to the aftercooler.
- Install the fuel cooler clip and mounting capscrew.
- If removed, install the fuel drain flex hoses at the fuel cooler.
- Connect the aftercooler air inlet connection from the turbocharger.
- Install the aftercooler sea water discharge to marine gear cooler hose and tighten the hose clamps.
- If removed, install the aftercooler air discharge to the intake air connection. Refer to Procedure 010-131.
- Tighten the aftercooler top and bottom air connection hose clamps.
- Connect the battery power to the engine. Refer to Procedure 013-009.
- Open the sea water supply and return line(s). Refer to the OEM service manual.
- Open the fuel supply and return lines. Refer to the OEM service manual.

Operate the engine and check for leaks.



QSC Engines

- Install the marine gear oil and fuel cooler assembly. Refer to Procedure 008-129.
- Install the sea water lines. Refer to Procedure 008-056.
- Install the air crossover and air outlet tube. Refer to Procedure 010-019.
- Open the fuel supply and return valves. Refer to the OEM service manual.
- Open the sea water supply and return valves. Refer to the OEM service manual.
- Connect the batteries. Refer to Procedure 013-009.

Operate the engine and check for leaks.

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Air Cleaner Assembly (Engine-Mounted) (010-013)

General Information

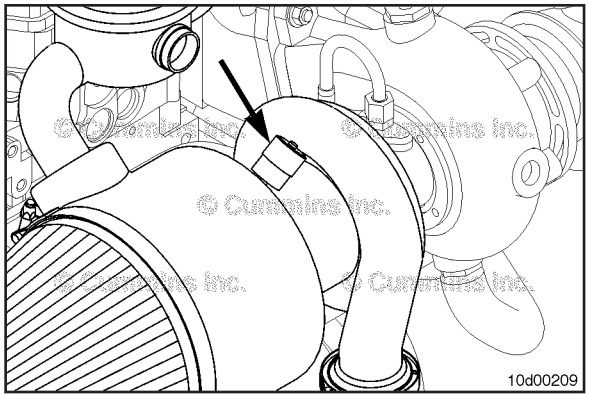
Some marine engines are equipped with a factory installed closed crankcase breather system which is connected to the engine intake air cleaner. Aftermarket (non-factory installed) closed crankcase breather systems can **not** be installed on Cummins marine engines. Installing such non-factory devices will void the warranty.

The closed crankcase system has three major parts.

1. The air cleaner assembly; this 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.

Initial Check

Check the restriction gauge on the air filter assembly. If the gauge is red, the air filter element **must** be cleaned or replaced.

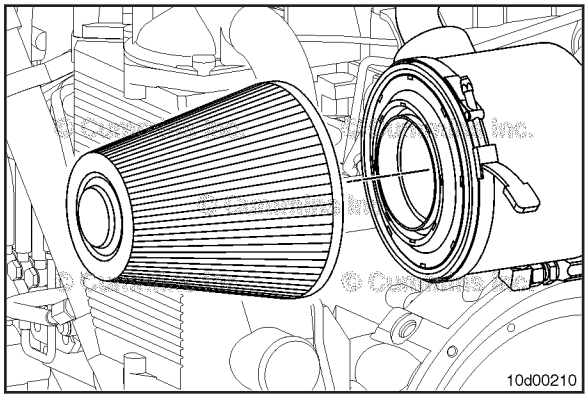


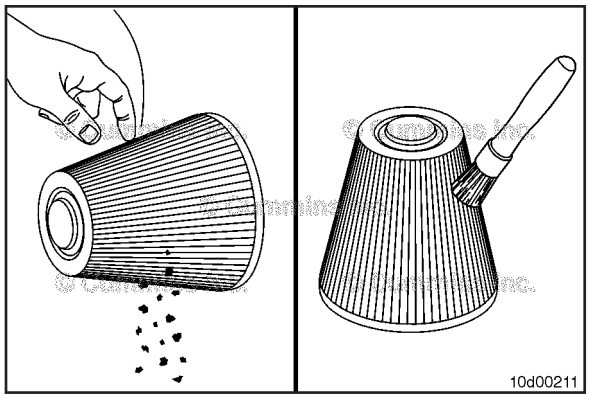
Remove

⚠CAUTION⚠
Use caution when disconnecting or removing oil lines, or replacing filters that oil is not drained into the bilge area. Do not drop or throw filter elements into the bilge area. The oil and filters must be discarded in accordance with local environmental regulations.

Release the clamp and remove the air cleaner element.

Remove the turbocharger silencer cone from inside of the filter element.



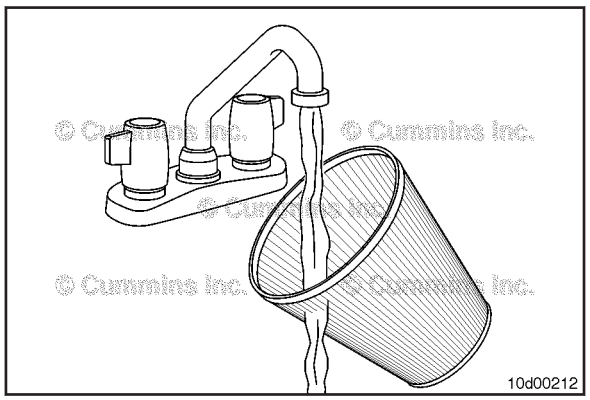


Clean

NOTE: It is possible a filter which is damaged or clogged with soot due to an exhaust leak will not be able to be cleaned to maximum efficiency. Replacement of the element will be necessary.

Tap the filter element to dislodge any large embedded particles or dirt.

Gently brush the filter element with a soft bristle brush.



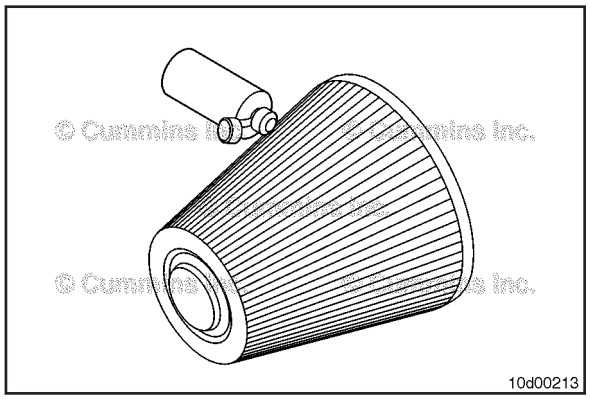
⚠CAUTION⚠
To avoid damage to the components, do not use gasoline, high-pressure water or air, caustic cleaning solutions, or parts-cleaning solvents to clean the air filter.

⚠CAUTION⚠
To avoid damage to the components, do not use compressed air, an open flame or heat dryers to dry the air filter.

NOTE: Always flush from the clean side to the dirty side. This will remove the particles and dirt, and **not** drive it into the air filter.

Rinse the air filter element with low pressure water. Tap water is okay.

After rinsing the air filter, shake off all the excess water and let the filter element air dry.



NOTE: Do **not** use automatic transmission fluid, motor oil, diesel fuel, WD-40® lubricant, or any other light weight oil. Use approved filter oil.

After cleaning the air filter, **always** re-oil the filter element with oil before using. The effectiveness of the air filter is greatly reduced if it is used without oiling. Sparingly squeeze small amounts of oil out of a bottle across the top of each pleat.

Let the oil wick into the filter element for twenty minutes. Then re-oil any dry area that are showing.

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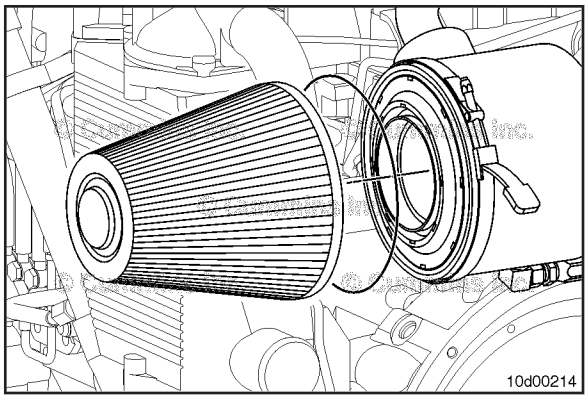
Install

Install the turbocharger silencer cone.

Install the o-ring around the outside of the filter base.

Install the filter onto the engine and secure with the clamp.



Air Crossover (010-019)

Remove

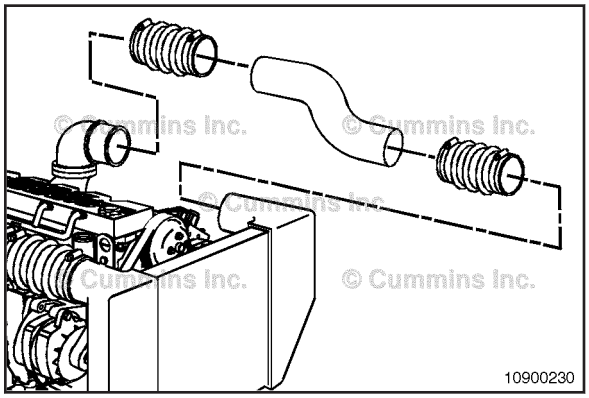
All Applications Except Marine

NOTE: Brush away all loose dirt from around the area of the air handling connections to avoid contamination of the interior of the engine.

Loosen the hose clamps and position the crossover tube so it can be removed.

Remove the crossover tube.

Install the protective caps from the Air Handling Clean Care Kit, Part Number 4919508, on all open connection points, including inlet to the engine, charge-air cooler, and ends of the crossover tube.



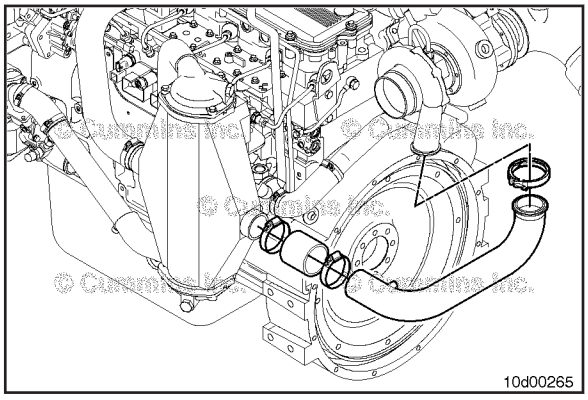
Marine Applications

NOTE: The graphics used in this procedure are of the QSL9 engine; however, the procedure is the same for the QSC8.3 engine.

Remove the flange clamp from the turbocharger outlet.

Loosen the hose clamps and pull the air crossover from the aftercooler housing air inlet.

Discard the turbocharger flange o-ring.



Clean and Inspect for Reuse

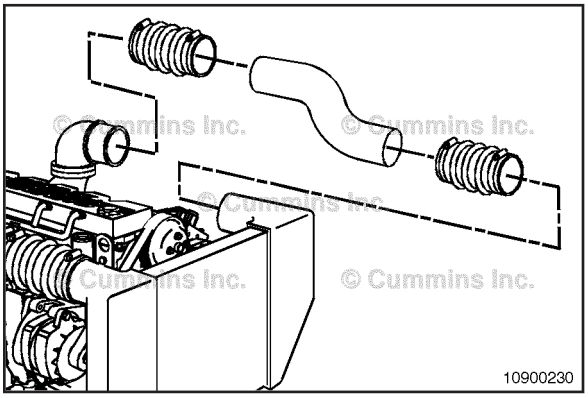
All Applications Except Marine

Check the crossover tube for cracks, holes, and worn sections.

Also check for poor sealing between the hose and tube.

Inspect the clamps for wear.

Replace damaged components with a new hose and clamps if necessary.



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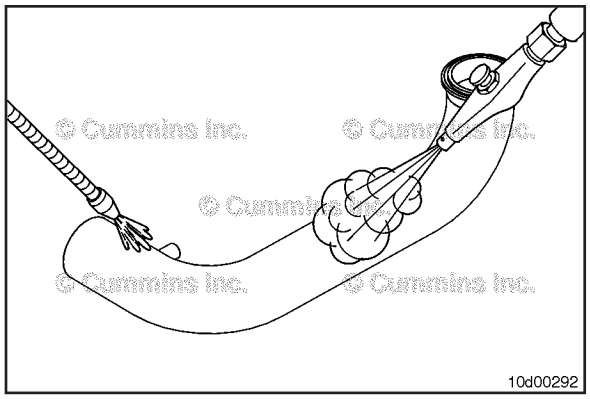


Marine Applications

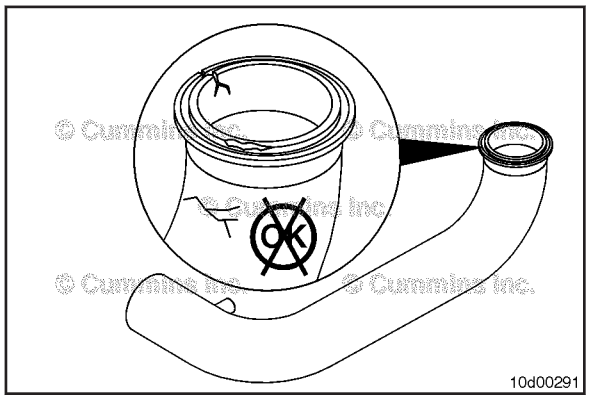
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use solvent to clean the air crossover tube.

Dry with compressed air.

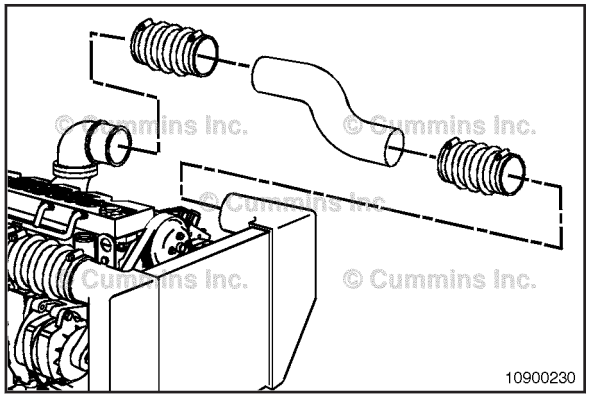


Inspect the tube for damage to the sealing flange or cracks in the tube.

Replace the tube if excessive damage is found.

Replace any hose that has extruded or cracked.

Replace any cracked or damaged clamps.



Install

All Applications Except Marine

Remove all protective caps from the components.

Install the crossover tube and clamps in the reverse order of removal.

Tighten the clamps. Refer to the OEM service manual for the torque specification.

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Marine Applications

Install a new o-ring seal on the turbocharger flange.

Install the hose and clamps.

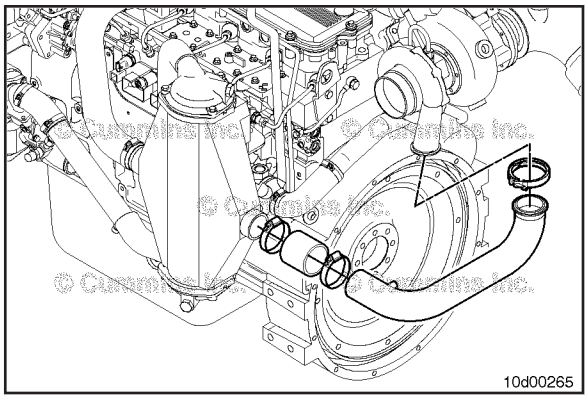
Install the air crossover tube and the flange clamp.

Tighten the flange clamp.

Torque Value: 8 N•m [71 in-lb]

Tighten the hose clamps.

Torque Value: 8 N•m [71 in-lb]

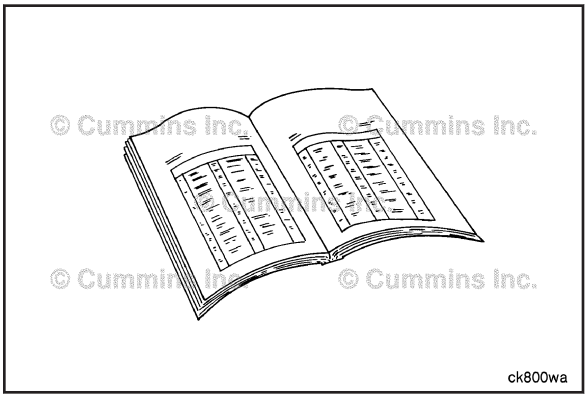


Air Inlet Connection (010-022)

Preparatory Steps

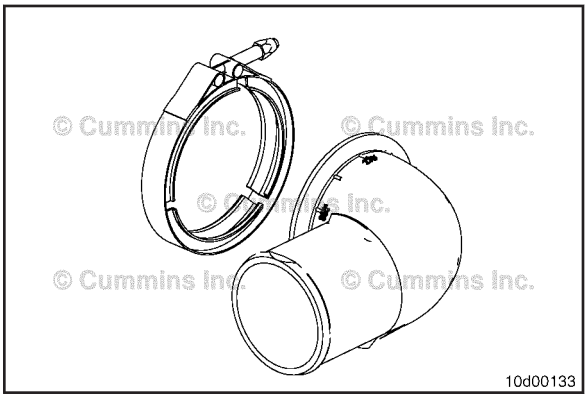
NOTE: Brush away all loose dirt from around the area of the air handling connections to avoid contamination of the interior of the engine.

- Remove the air crossover pipe that is attached to the intake connection. Refer to Procedure 010-019 in Section 10.



Remove

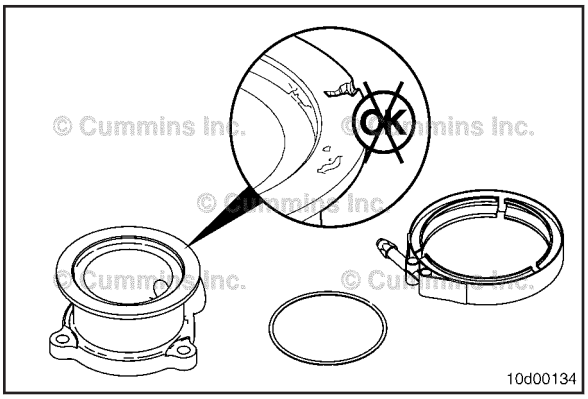
Remove the v-band clamp, air inlet connection and seat.

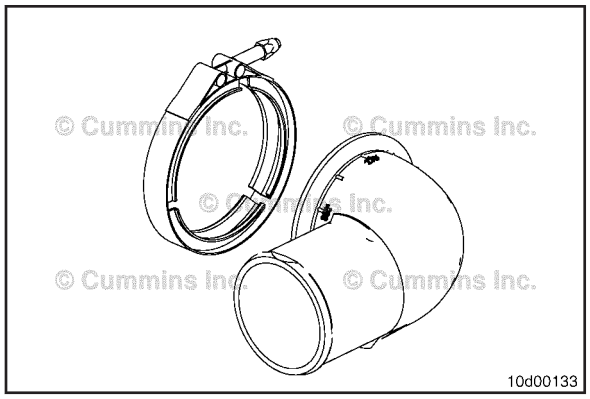


Clean and Inspect for Reuse

Inspect the air inlet connection and seal for cuts, cracks, holes, or worn sections.

Replace if necessary.



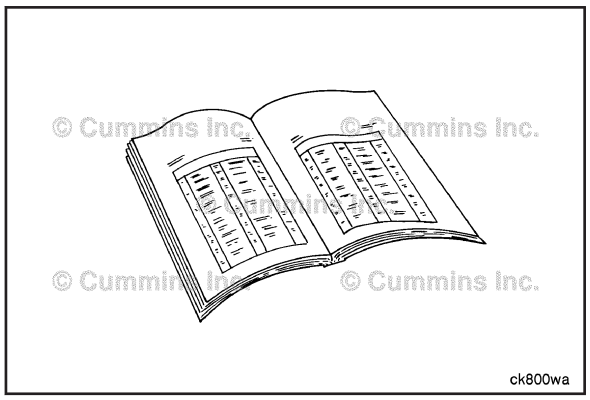


Install

Install the seal, air inlet connection and v-band clamp.

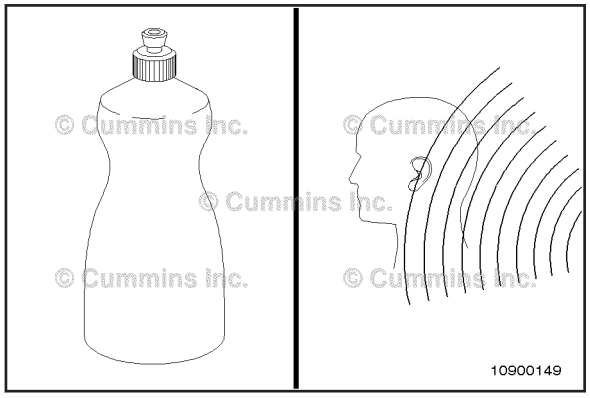
Tighten v-band clamp.

Torque Value: 8 N•m [71 in-lb]



Finishing Steps

- Install the air crossover pipe that is attached to the connection. Refer to Procedure 010-019 in Section 10.
- Operate the engine and check for leaks.



Air Leaks, Air Intake and Exhaust Systems (010-024)

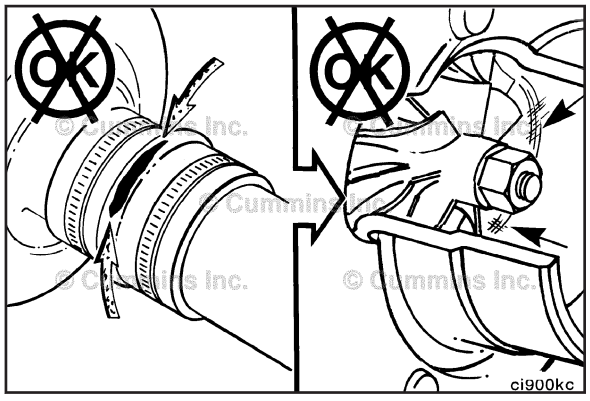
Initial Check

Leaks in the intake air system are most commonly identified by:

1 Inspection of piping for cracked or loose clamps.

2 Applying a solution of soapy water in the suspected area and inspecting for bubbles.

3 Listening for a high-pitched whining or sucking noise in the suspected area.

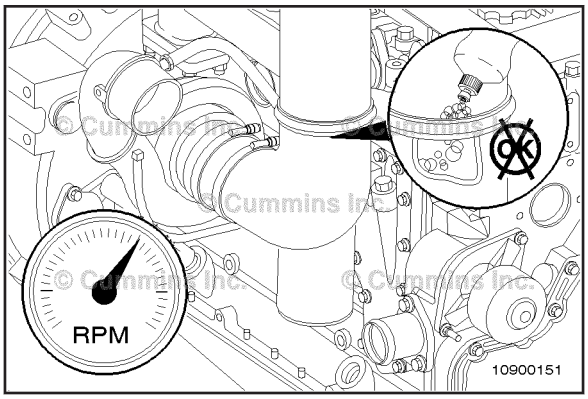


⚠CAUTION⚠
Engine intake air must be filtered to prevent dirt and debris from entering the engine. If intake air piping is damaged or loose, unfiltered air will enter the engine and cause premature wear.

Inspect the inlet air piping for cracked hoses and damaged or loose clamps.

Operate the engine at high idle, and use a solution of soapy water to spot intake air leaks.

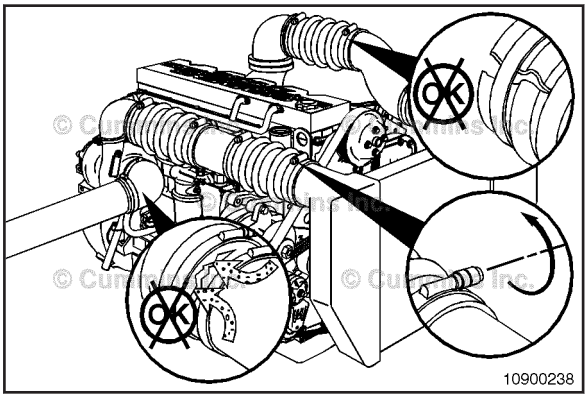
If an air leak exists, the soap bubbles will be drawn in with the air.



Replace damaged pipes and tighten loose clamps to make sure the air inlet system does **not** leak.

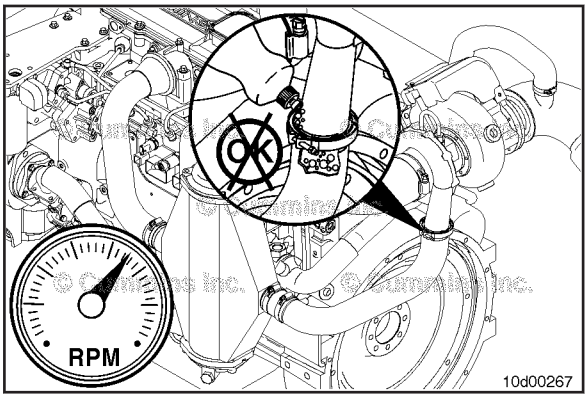
Check for corrosion of the inlet system piping under the clamps and hoses. Corrosion can allow corrosive products and dirt to enter the intake system.

Disassemble and clean as required.



Pressure Side Intake System:

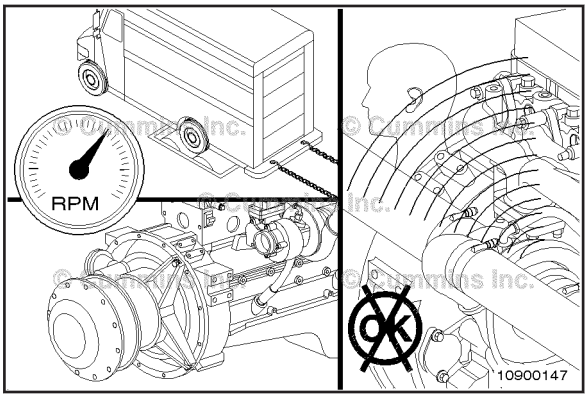
Leaks in the intake system will reduce the amount of air to the cylinders during engine operation and decrease engine performance.

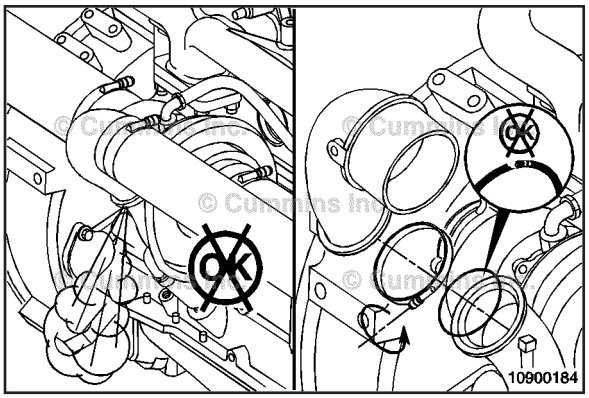


Operate the engine at full throttle and rated rpm with maximum load.

Listen for a high-pitched whistling sound from the turbocharger, nearby piping, and connections.

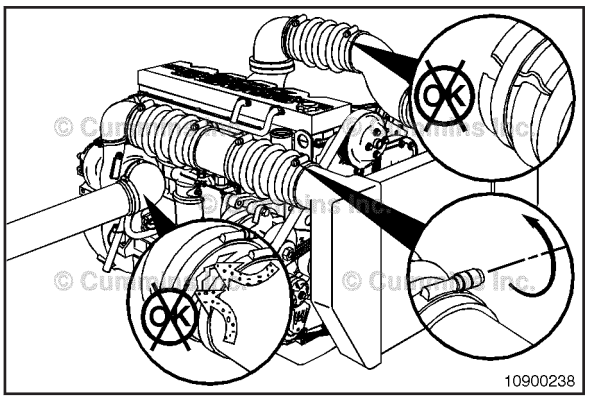
Apply a soapy water solution to sealing surfaces and inspect for bubbles. Bubbles can be easily detected.





Leaks can also be found at the turbocharger compressor outlet connection.

Inspect for damage, replace sealing o-ring, and tighten loose clamps. Refer to Procedure 010-033 in Section 10.

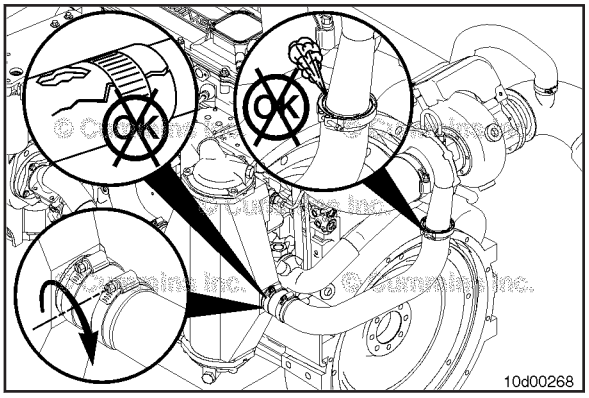


Charge Air Cooler Tubing or Connecting Hoses:

Inspect the hose and tubing for damage. Refer to Procedure 010-019 in Section 10.

Tighten loose clamps.

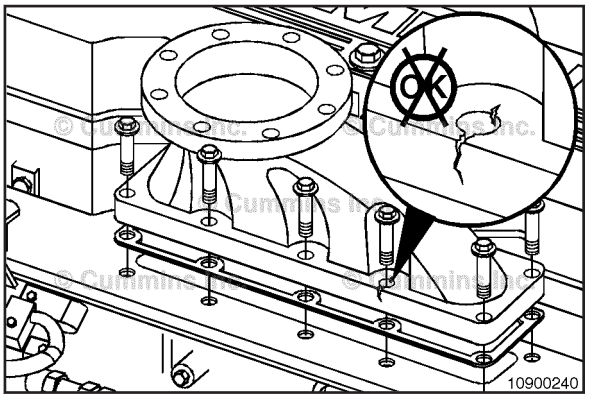
See the equipment manufacturer's specifications for the correct torque value.



Aftercooler or Aftercooler Hose Connections:

Inspect the aftercooler housing end caps, zinc anode plugs, and condensation valve for leaks. Refer to Procedure 010-005 in Section 10.

Inspect the air connection hoses and tubes for leaks. Refer to Procedure 010-019 in Section 10.



Air Intake Connection:

Inspect for damage.

If necessary, replace the gasket or tighten loose clamps. Refer to Procedure 010-080 in Section 10.

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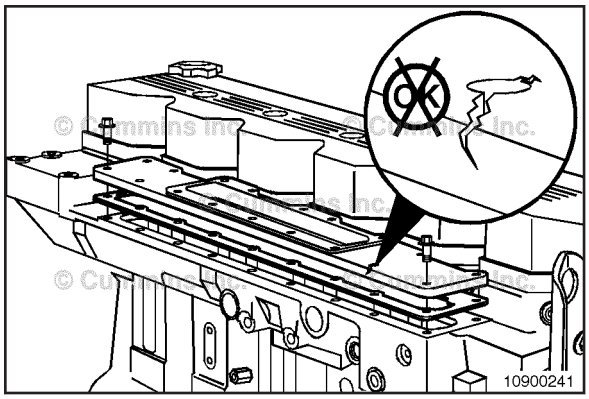
Intake Manifold:

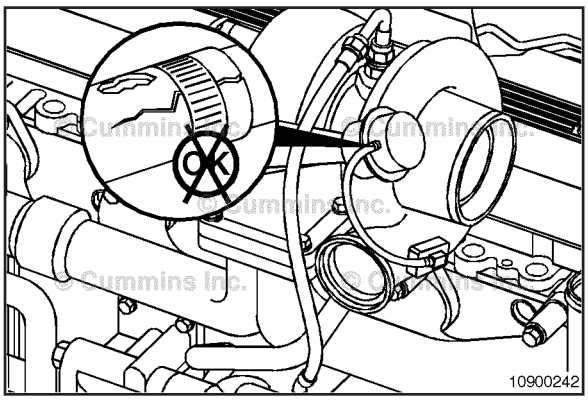
Inspect for damage.

Replace the gasket, if necessary. Refer to Procedure 010-108 in Section 10.



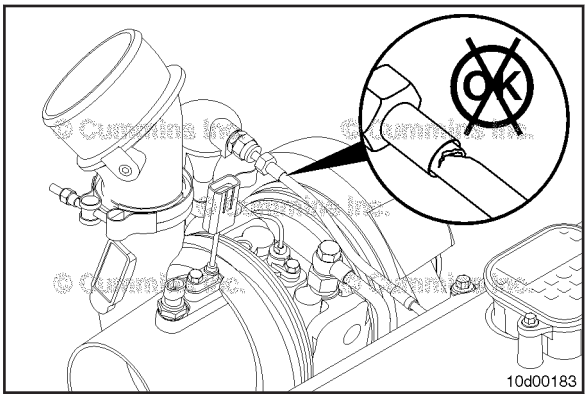
Wastegate Capsule/Plumbing:

Inspect for damage. Refer to Procedure 010-033 in Section 10.



Variable Geometry Turbocharger Actuator Plumbing:

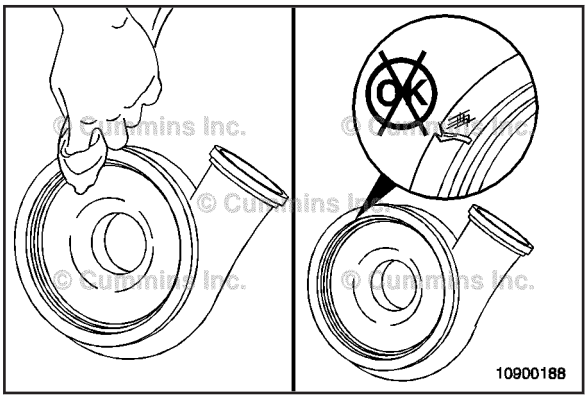
Inspect for cracks and/or air leaks. Refer to Procedure 010-033 in Section 10.

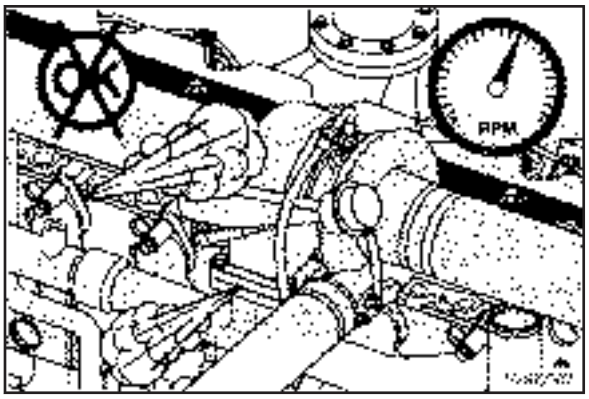


Compressor Housing Sealing Surface:

Inspect for damage. Refer to Procedure 010-033 in Section 10.

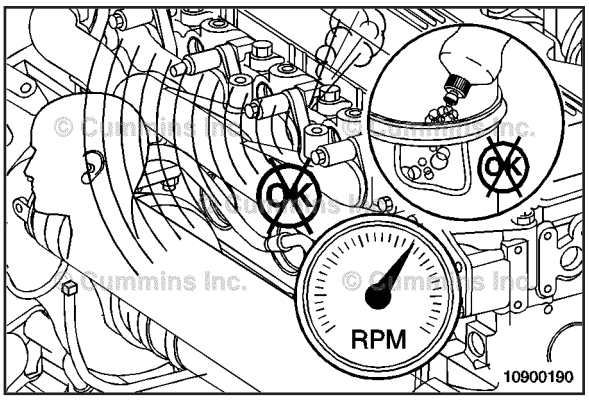
Clean surface with a clean cloth.





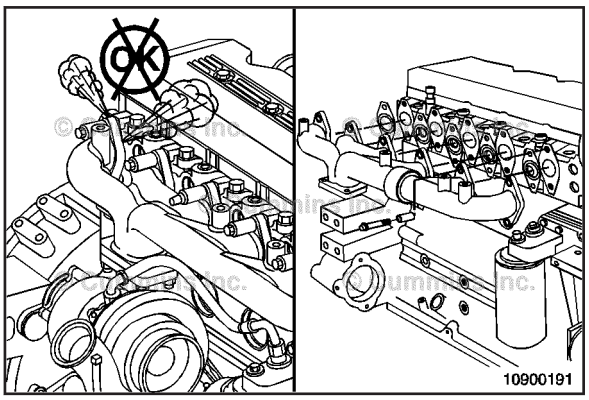
Exhaust System:

Leaks in the exhaust system will cause the turbocharger to operate at a lower speed, reducing the amount of air going to the cylinders during engine operation.



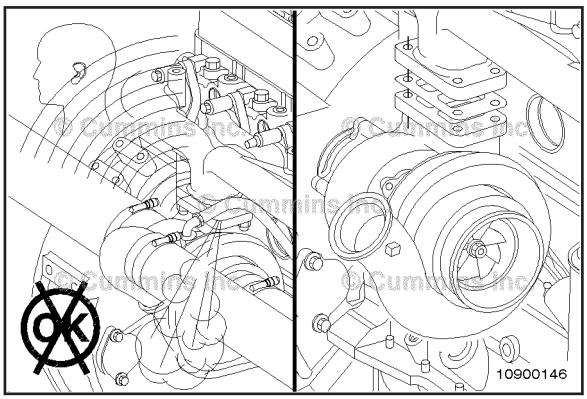
Operate the engine at full throttle and rated rpm with maximum load.

Leaks can be identified by noise, soapy water, or discoloration caused by the escaping hot gases.



Inspect the exhaust manifold gaskets for leaks. Refer to Procedure 011-007 in Section 11.

Refer to Procedure 011-008 in Section 11.



Inspect the turbocharger mounting gaskets for leaks. Refer to Procedure 010-033 in Section 10.

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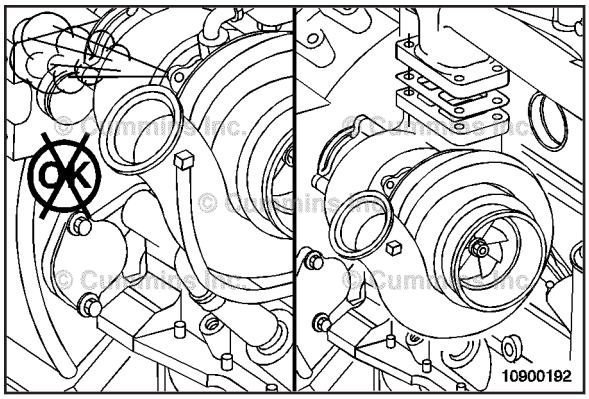
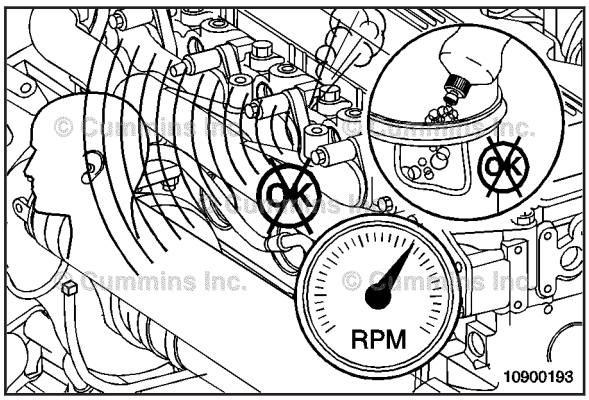
Inspect the turbine housing sealing surface for leaks. Refer to Procedure 010-033 in Section 10.



Operate the engine at full throttle and rated rpm with maximum load.

Listen and inspect again for leaks.



Charge-Air Cooler (010-027)

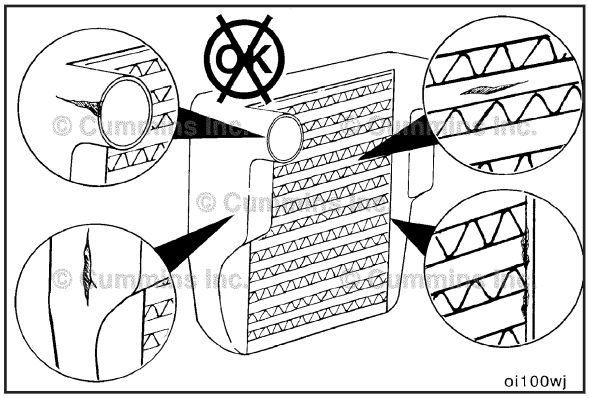
Initial Check

Inspect the charge-air cooler for cracks, holes, and other damage.

Inspect the tubes, fins, and welds for tears, breaks, or other damage.

If any damage causes the charge-air cooler to fail the air leak check, the charge air cooler **must** be replaced.

Inspect the charge air cooler plumbing for cracks and other damage.

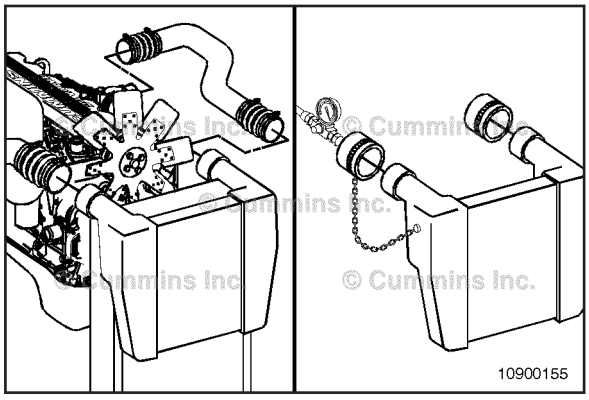


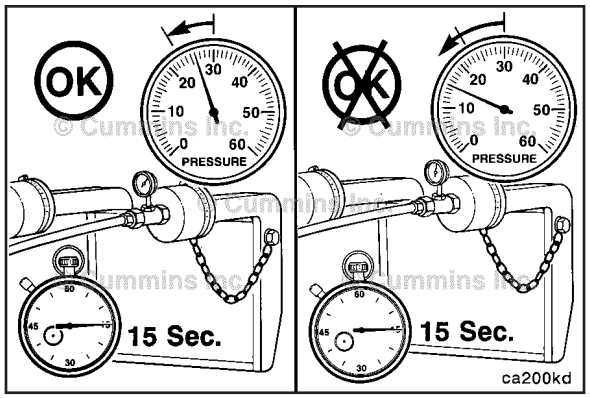
Leak Test

⚠WARNING⚠
To reduce the possibility of injury if either plug blows off during the test, secure safety chains on the test plugs to any convenient capscrew on the radiator assembly. This test must be performed with securely fastened safety chains.

To check the charge-air cooler for cracked tubes or header, remove the inlet and outlet hoses from the cooler. The charge-air cooler does **not** have to be removed from the chassis.

Use protective caps from the Air Handling Clean Care Kit, Part Number 4919508, to cover open points on the plumbing, engine, and charge-air cooler.



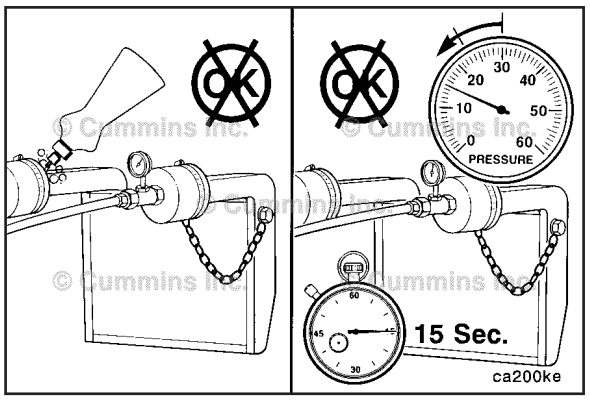


Apply air pressure to the cooler until the pressure gauge reads a steady 207 kPa [30 psi] of air pressure.

Shut off the air flow to the cooler, and start a stopwatch at the same time. Record the leakage at 15 seconds.

If the pressure drop is 48 kPa [7 psi] or less in 15 seconds, the cooler is operational.

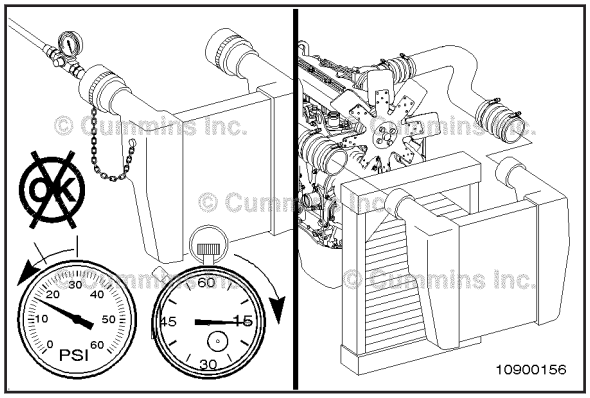
If the pressure drop is greater than 48 kPa [7 psi] in 15 seconds, check all connections again.



Determine if the pressure drop is caused by a leak in the charge-air cooler or by a leaky connection. Use a spray bottle filled with soapy water, applied to all hose connections. Watch for bubbles to appear at the location of the leak.

If the pressure drop is caused by a leaky connection, repair the connection, and repeat the test. If the leak is within the charge-air cooler, repeat the test to verify the accuracy of the pressure drop measurement. Similar pressure drop readings **must** be obtained at least three consecutive tests before the reading can be considered accurate.

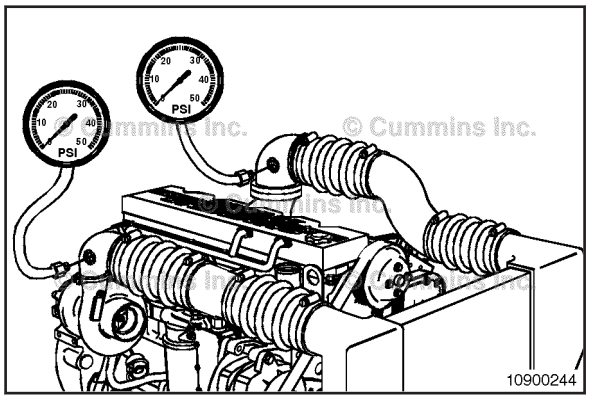
NOTE: If a charge-air cooler leak causes a pressure drop of more than 48 kPa [7 psi] in 15 seconds, it will appear as a major leak in a leak tank.



If the pressure drop is greater than 48 kPa [7 psi] in 15 seconds, the charge air cooler **must** be replaced.

Refer to the OEM service manual for replacement instructions.

NOTE: Charge-air coolers are **not** designed to be 100-percent leak-free. If the pressure drop is less than 48 kPa [7 psi] in 15 seconds, the charge-air cooler does **not** need to be replaced.



Pressure Test

Obtain two pressure gauges, Part Number 3823205. Check both gauges on the same pressure source at 206 kPa [30 psi] to verify consistency.

Install one pressure gauge in the 1/8-inch fitting in the turbocharger compressor outlet elbow. Install the other pressure gauge in the intake manifold.

Another alternative to measure the intake manifold pressure is to use the monitor mode on INSITE™ electronic service tool.

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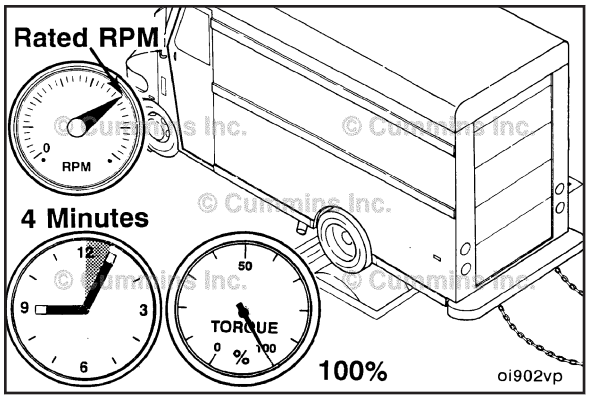
Operate the engine at rated rpm and load. Record the readings on the two gauges.

If the differential pressure is greater than 20.6 kPa [3 psi], check the charge air cooler and associated piping for plugging, restrictions, or damage.

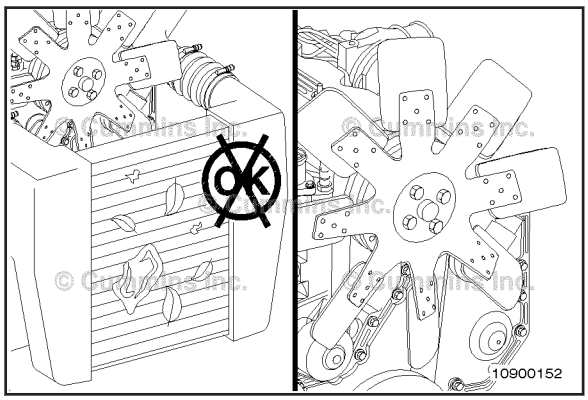
Clean or replace, if necessary.



Temperature Differential Test

Inspect the charge-air cooler fins for obstructions to air flow. Remove obstructions such as a winterfront or debris. Manually lock the shutters in the OPEN position, if equipped.

Lock the fan drive in the ON mode to prevent erratic test results. This can be done by installing a jumper wire across the temperature switch.



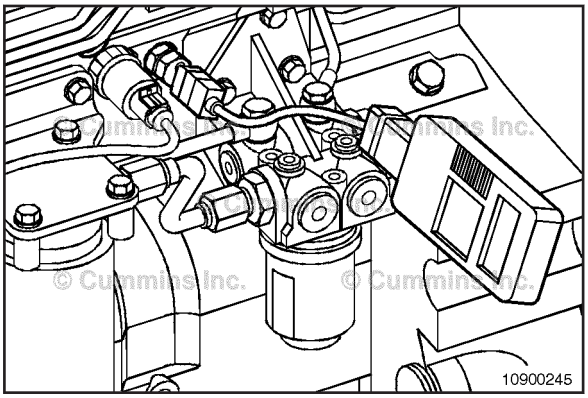
Install fluke digital thermometer, Part Number 3822666, into the intake manifold at the 1/8-inch NPT tap near the air horn connection with the intake manifold.

Install the thermocouple bead probe, Part Number 3164498.

Connect the digital multimeter, Part Number 3164488, and the temperature adaptor, Part Number 3164499, to the thermocouple bead probe to read intake air temperature.

Another alternative is to use the monitor mode on the INSITE™ electronic service tool.

Install another thermocouple at the air cleaner inlet to measure ambient air temperature.

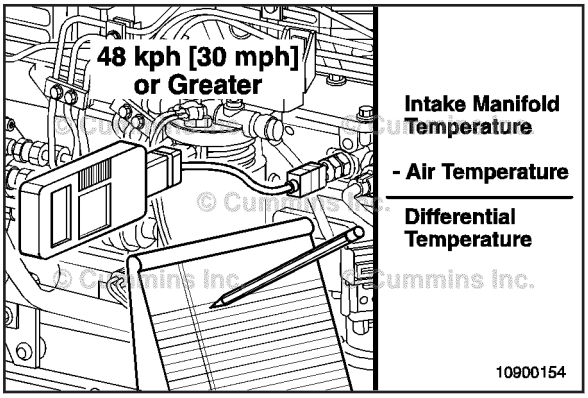


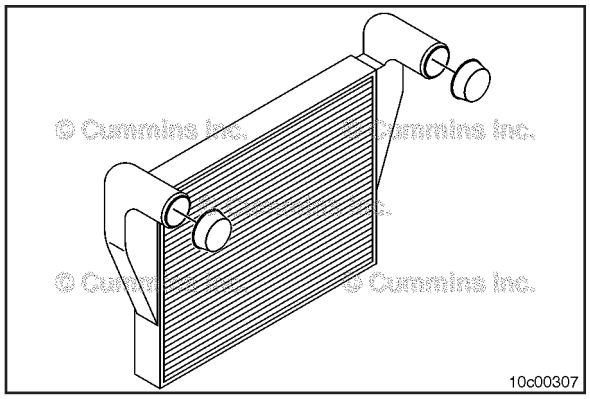
Perform a road test with the engine at peak power and a vehicle speed of 48 kph [30 mph] or greater.

Record the intake manifold temperature and the ambient air temperature.

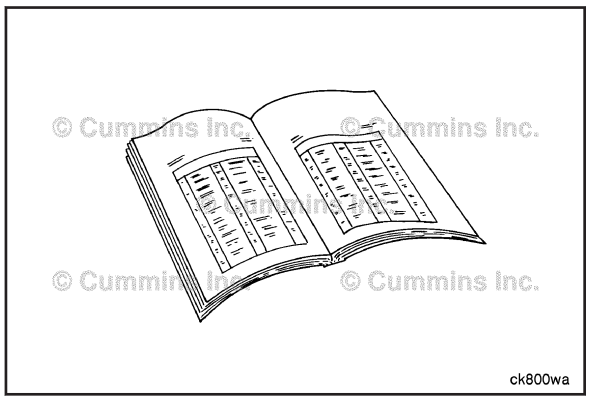
Calculate the differential temperature:

- Intake manifold temperature - ambient air temperature = differential temperature
- Maximum Differential Temperature: 21°C [38°F].





If the temperature differential is greater than the specifications, check the charge-air cooler for dirt and debris on the fins and clean as necessary. If the problem still exists, check the charge-air cooler for debris in the fins or between the charge-air cooler and radiator. Confirm full fan engagement.

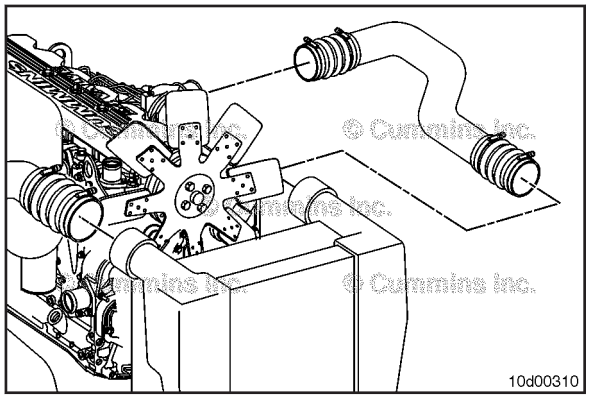


Preparatory Steps

⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

- Use compressed air to clean debris from the outside of the charge-air cooler.
- Remove the charge-air cooler piping. Refer to Procedure 010-019 in Section 10.



Remove

Remove the charge-air cooler. Refer to the OEM service manual.

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Clean

⚠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.

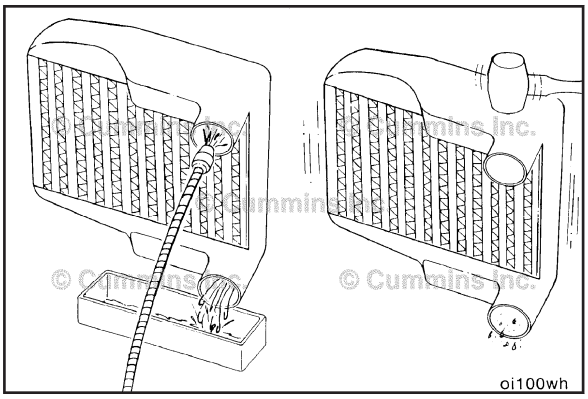
△CAUTION△
Do not use caustic cleaners to clean the charge-air cooler. Damage to the charge-air cooler will result.

NOTE: If the engine experiences a turbocharger failure or any other occasion where oil or debris is put into the charge-air cooler, the charge-air cooler **must** be cleaned.

Flush the charge-air cooler internally with solvent in the opposite direction of normal airflow. Shake the charge-air cooler, and lightly tap on the end tanks with a rubber mallet to dislodge trapped debris. Continue flushing until all debris or oil is removed (i.e., the water runs clear).

NOTE: Make sure that the tubes are in the upright position when flushing.

If the debris can **not** be totally removed from the charge-air cooler, the charge air cooler **must** be replaced.

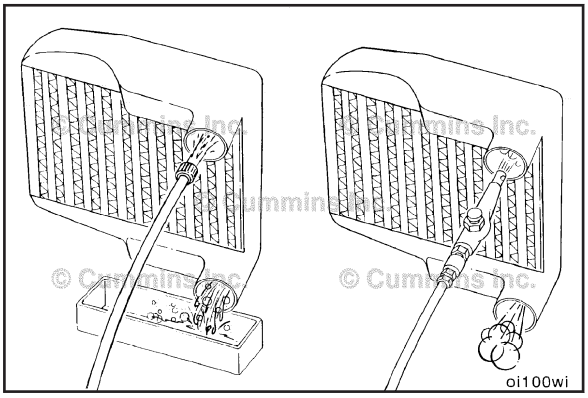


⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△
The charge-air cooler must be rinsed, dried, and free of solvent, oil, and debris, or engine damage will result.

After the charge-air cooler has been thoroughly cleaned of all oil and debris with solvent, wash the charge-air cooler internally with hot soapy water to remove the remaining solvent. Rinse thoroughly with clean water.

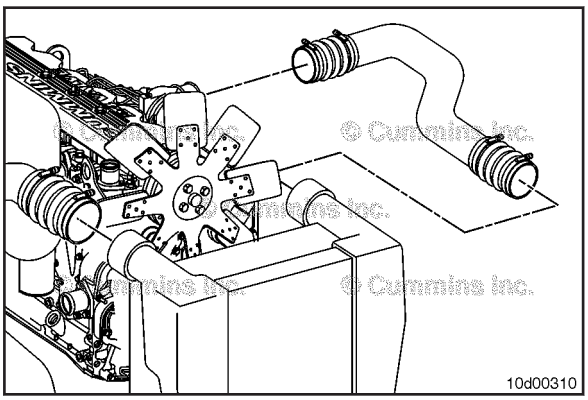
Blow compressed air through the inside of the charge-air cooler in the opposite direction of normal air flow until the charge-air cooler is dry internally.

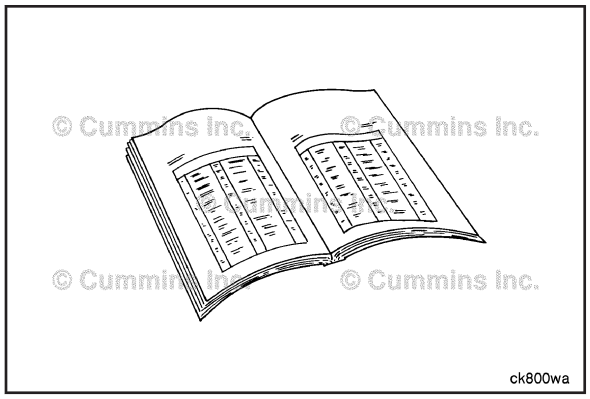


Install

Install the charge-air cooler.

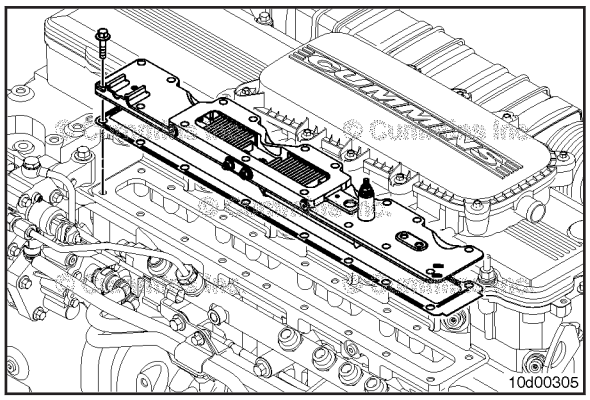
Refer to the OEM service manual for instructions.





Finishing Steps

- Install the charge-air cooler piping. Refer to Procedure 010-019 in Section 10.
- Operate the engine and check for leaks.



Cold Starting Aid (010-029)

General Information

The cold starting aid is **not** a serviceable part.

If the cold starting aid has cracked, broken, or melted elements, the entire air intake manifold **must** be replaced. Refer to Procedure 010-023 in Section 10.

ISC, ISL CM554 preheat/post-heat cycle information:

The intake air heaters are used in B and C engines to aid starting in cold ambient conditions. There are two phases of intake air heater operation:

- Preheat (after key on and before cranking)
- Post-heat (just after a successful engine start).

The intake air heater is used in starting during cold temperatures and to reduce white smoke after such a start.

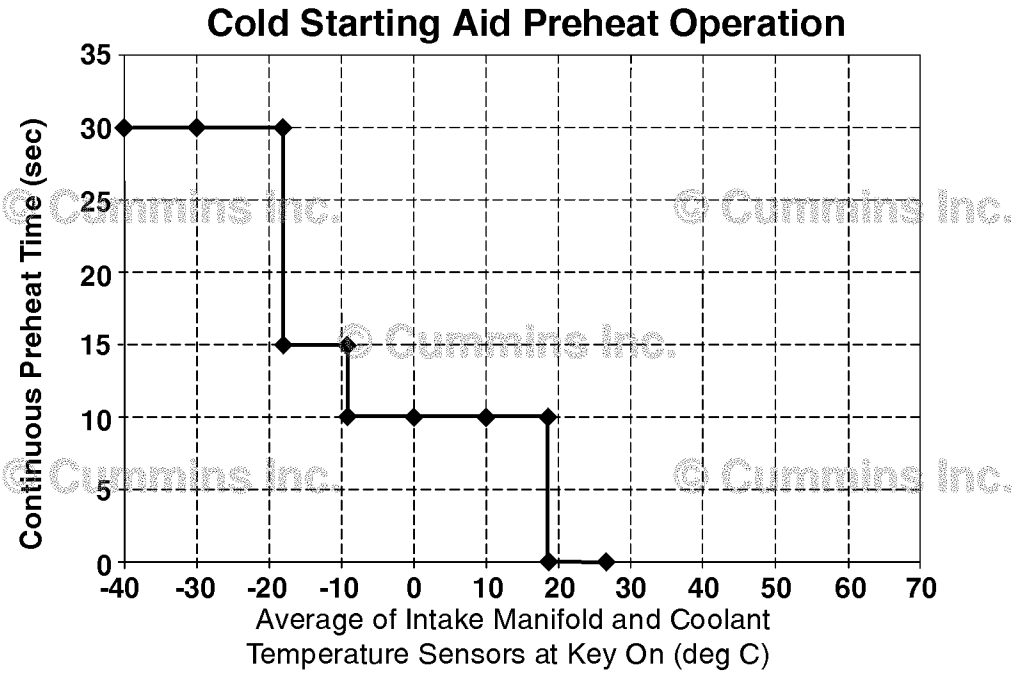
The intake air heaters or grid heaters are energized or de-energized from two relays controlled by the ECM. The amount of time the intake air heaters stay on in the preheat phase is a function of the intake manifold temperature at key on; preheat time increases with colder intake manifold temperatures. The maximum duration of preheat is 45 seconds and no engine preheat is needed for coolant or intake air temperatures exceeding 4.4°C [40 °F] for ISC/ISL engines.

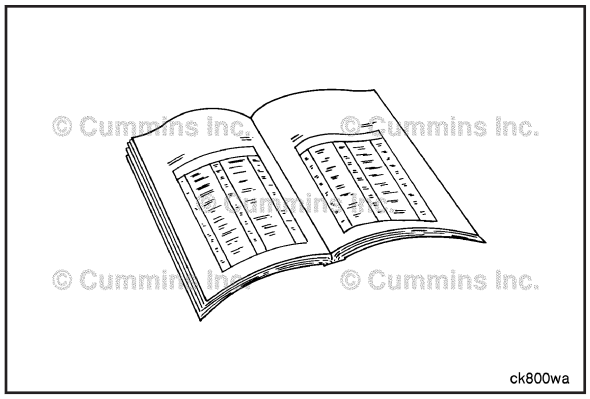
A “Wait-to-Start” lamp is also controlled by the ECM and is illuminated (to indicate that the driver **must not** crank the engine) while the intake air heaters are activated just after key on, during the preheat phase.

During cranking, the intake air heater is turned off to allow maximum current to be used by the starter. The post-heat cycle can operate for several minutes on very cold days before the intake air heaters are de-energized.

QSC, QSL CM554 preheat cycle information:

The preheat cycle of the electric intake heater varies by ambient temperature and is controlled by the ECM. During the preheat cycle, the ECM sends power to the OEM-supplied “Wait-to-Start” lamp. The operator **must not** crank the engine until the “Wait-to-Start” lamp is deactivated. Consult the Operation and Maintenance Manual for further details on start procedures. Figure 1 illustrates the intake heater preheat cycle.



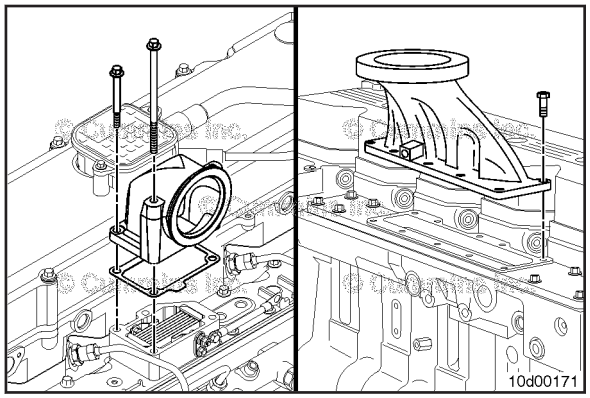


Preparatory Steps

⚠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.
- Disconnect the grid heater wiring.
- Disconnect the air intake heater wiring. Refer to the OEM service manual.
- Remove the charge-air piping from the air intake connection adapter. Refer to Procedure 010-019 in Section 10.
- Remove the air inlet connection, if equipped. Refer to Procedure 010-022 in Section 10.
- Remove the turbocharger control valve, if equipped. Refer to Procedure 019-388 In Section 19.
- Disconnect the battery. Refer to Procedure 013-009 in Section 13.

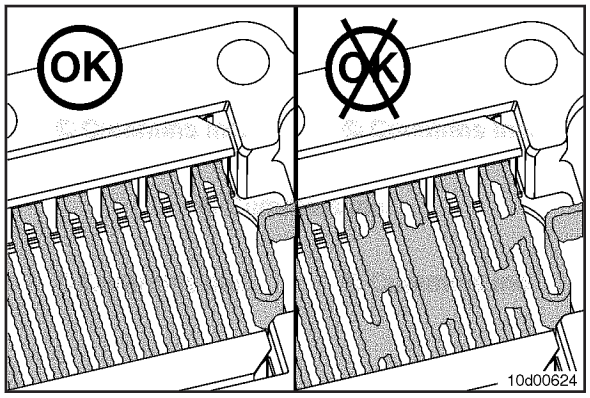


Remove

NOTE: If the grid heater is to be removed for any length of time, apply tape over the hole to keep debris out of the air intake manifold.

Remove the intake air heater.

The intake heater is installed under the intake manifold cover on some engines. Use the following procedure if removing the intake manifold cover is required. Refer to Procedure 010-108 in Section 10.



Clean and Inspect for Reuse

Inspect the air intake manifold heater for plugging or soot build up. If plugged, check for the source; turbocharger, air compressor, temperature/pressure sensor, relay, and wiring harness.

Soot **only** covering individual elements is acceptable. Soot bridging the heating elements is **not** acceptable.

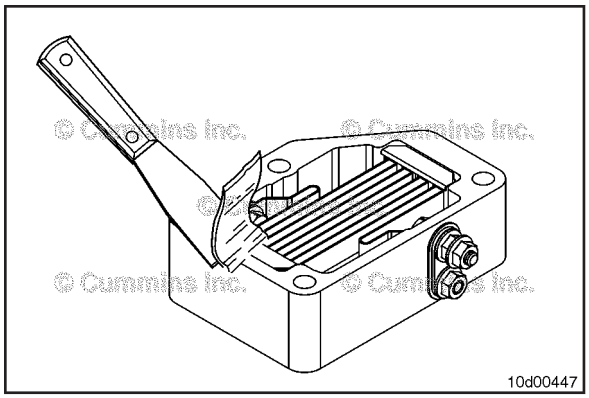
Replace the air intake manifold heater if necessary.

Keep the gasket material and any other material out of the cylinder head intake manifold.

Clean the intake air heater sealing surfaces.

Clean the air intake manifold cover sealing surface.

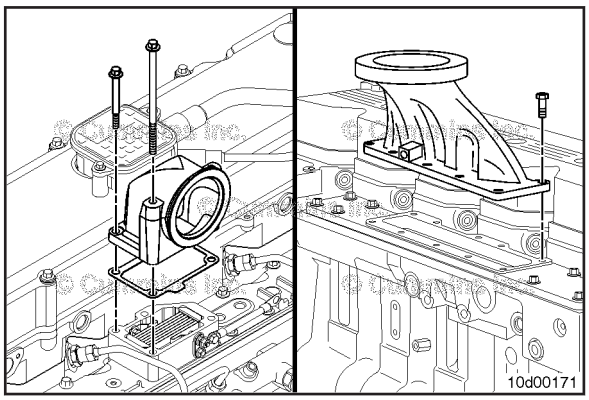
Clean the air intake connection sealing surface.



Install

Install the grid heater.

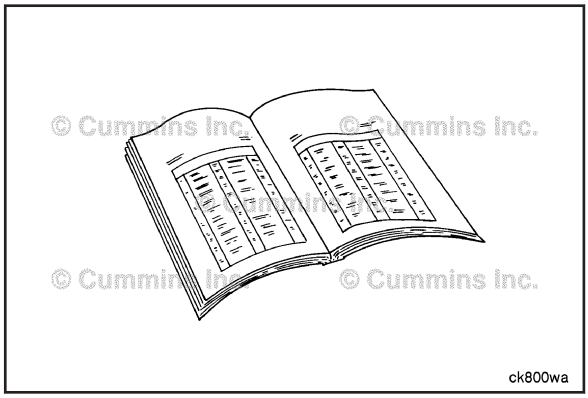
- Use the following procedure if the grid heater is located under the intake manifold cover. Refer to Procedure 010-108 in Section 10.

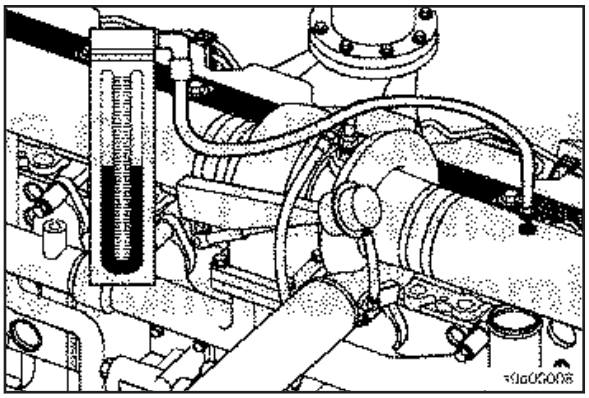


Finishing Steps

⚠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 injector supply lines. Refer to Procedure 006-051 in Section 6.
- Install the air intake connection. Refer to Procedure 010-080 in Section 10.
- Install the air inlet connection, if equipped. Refer to Procedure 010-022 in Section 10.
- Install the turbocharger control valve, if equipped. Refer to Procedure 019-388 In Section 19.
- Connect the grid heater wiring.
- Connect the air intake heater wiring. Refer to the OEM service manual.
- Install the charge- air piping to the air intake connection adapter. Refer to Procedure 010-019 (Air Crossover) in Section 10.
- Connect the battery. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.





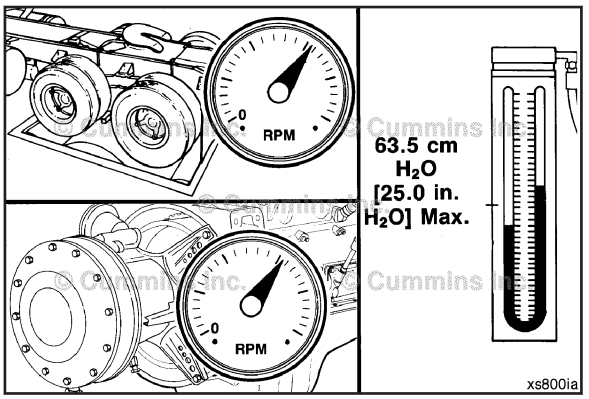
Air Intake Restriction (010-031)

Measure

Install a vacuum gauge or water manometer in the intake air piping.

The gauge adapter **must** be installed at a 90-degree angle to the airflow in a straight section of pipe, one pipe diameter before the turbocharger.

NOTE: On marine applications, remove the pop-up flag restriction gauge from the base of the air filter and install the vacuum gauge or water manometer.

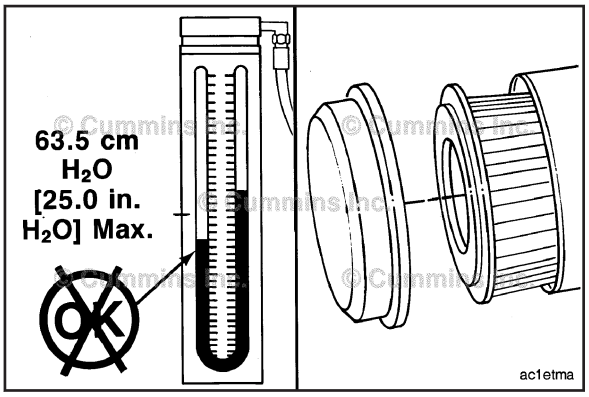


Operate the engine at full throttle and rated rpm with maximum load.

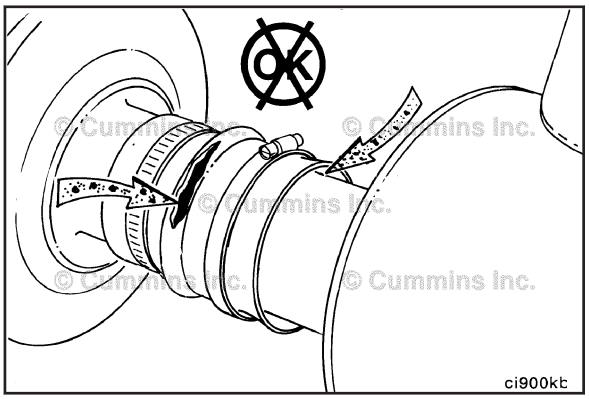
Record the data on the gauge or manometer.

Inlet Air Restriction (All Applications Except Marine)		
cm H_2O		in H_2O
63.5	MAX	25.0

Intake Air Restriction (Marine Applications)			
	cm H_2O		in H_2O
Dirty Filter	63.5	MAX	25.0
Clean Filter	38.1	MAX	15.0



If restriction exceeds specifications, replace or clean the air filter element. Refer to the OEM service manual.



Inspect the intake piping for damage. Refer to the OEM service manual.

Remove the test equipment.

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Turbocharger (010-033)

Initial Check

Remove the intake pipe from the turbocharger. See the Remove section in this procedure.

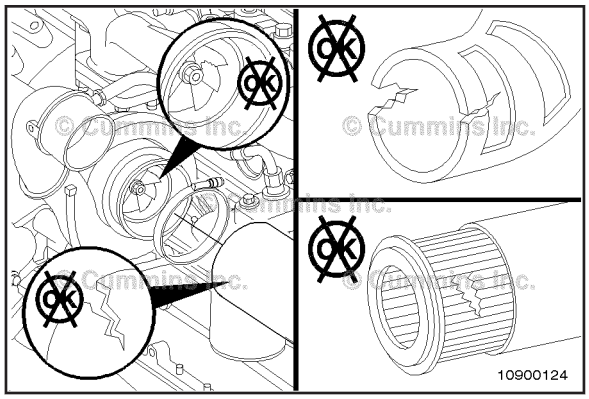
Use the following procedure if equipped with an engine mounted air cleaner. Refer to Procedure 010-013 in Section 10.

Inspect the turbocharger compressor impeller blades for damage.

Replace the turbocharger if damage is found. See the Remove and Install sections in this procedure.

If the compressor impeller is damaged, inspect the intake piping and filter element for damage.

Repair any damage before operating the engine.



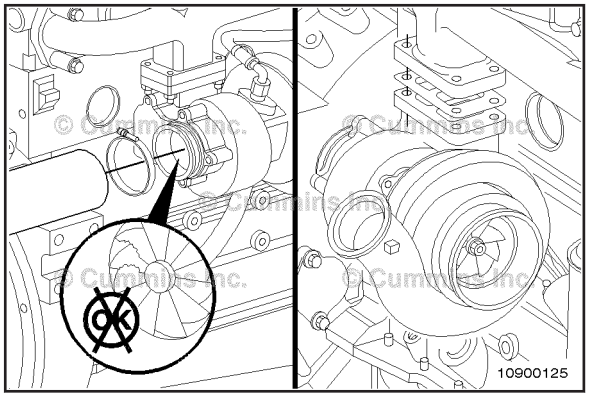
⚠CAUTION⚠
Be sure to tie the exhaust piping up above the water line to prevent water from feeding back into the vessel while the exhaust piping is removed. Failure to do so can result in the vessel sinking.

Remove the exhaust pipe from the turbocharger. See the Remove section in this procedure.

Use the following procedure if equipped with sea water cooled exhaust outlet. Refer to Procedure 011-017 in Section 11.

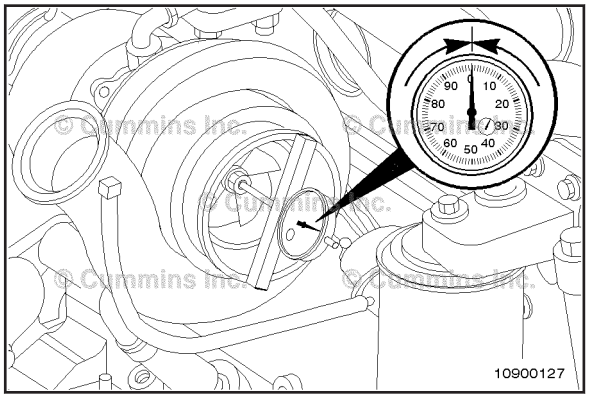
Inspect the turbine wheel for damage.

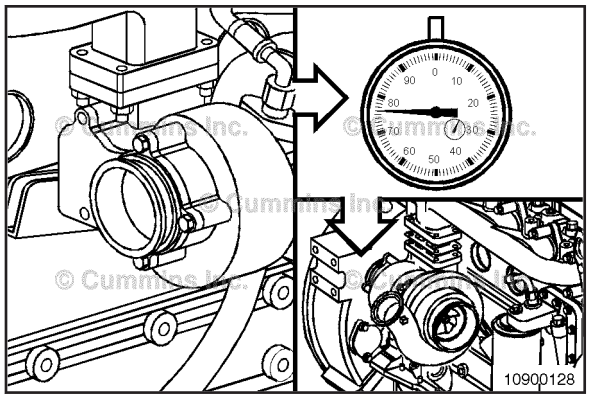
Replace the turbocharger if damage is found. See the Remove and Install sections in this procedure.



Axial Clearance Check:

- Use dial depth gauge, Part Number ST-537.
- Push the rotor assembly away from the gauge.
- Set the gauge on zero.





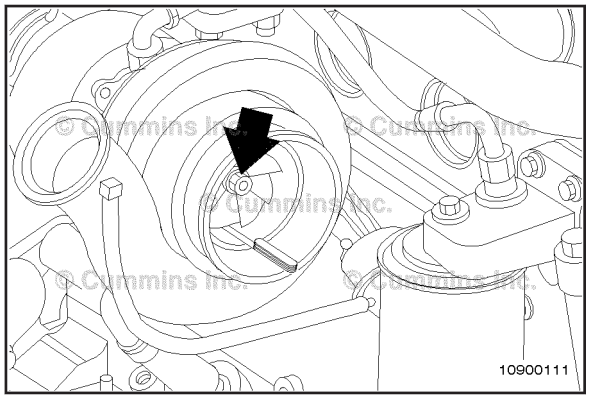
Push the rotor assembly toward the gauge and record the reading.

Axial Clearance (HX40WG - Wastegate)		
mm		in
0.025	MIN	0.001
0.127	MAX	0.005

Axial Clearance (HY40V - Variable Geometry)		
mm		in
0.025	MIN	0.001
0.127	MAX	0.005

Axial Clearance (HX55 - Wastegate, Water Cooled)		
mm		in
0.038	MIN	0.0015
0.093	MAX	0.0037

Replace the turbocharger if the clearance does **not** meet the specifications. See the Remove and Install sections in this procedure.



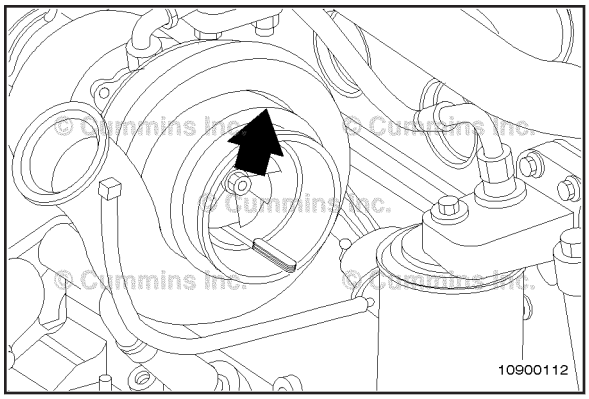
Radial Clearance Check:

Use a wire-type feeler gauge to measure the clearance between the turbocharger compressor wheel and the turbocharger compressor housing.

Gently push the compressor wheel toward the compressor housing and gauge.

Record the clearance.

With the feeler gauge in the same location, gently push the turbocharger compressor wheel away from the turbocharger compressor housing and measure the clearance between the compressor wheel and the housing.



Subtract the smaller clearance from the larger clearance. This is the radial bearing clearance.

Wastegate Radial Bearing Clearance (HX40WG - Wastegate)

mm		in
0.330	MIN	0.013
0.508	MAX	0.020

Radial Bearing Clearance (HX55 - Wastegate, Water Cooled)

mm		in
0.044	MIN	0.0172
0.608	MAX	0.0239

For variable geometry turbochargers, check the radial movement of the rotor system by pushing the turbocharger compressor wheel toward the wall of the compressor cover with light finger pressure. The turbocharger passes inspection if the wheel does **not** contact the compressor cover wall.

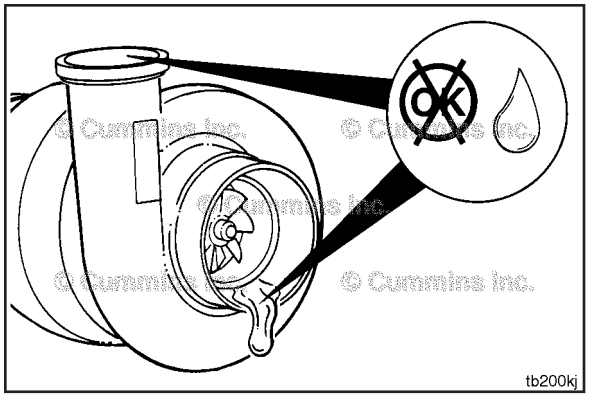
Repeat the procedure on the turbocharger turbine wheel.

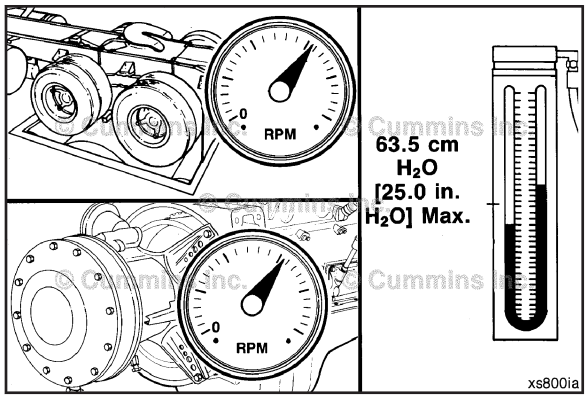
Replace the turbocharger if the radial bearing clearance does **not** meet specifications. See the Remove and Install sections in this procedure.

Leak Check

- Inspect the turbocharger compressor intake and discharge for oil.
- If oil is present in the compressor intake as well as in the discharge, check upstream in the turbocharger for the source of the oil.

NOTE: Some marine engines have a closed crankcase breather system which is connected to the engine mounted air cleaner assembly. Check the closed crankcase breather system. Refer to Procedure 010-013 in Section 10.



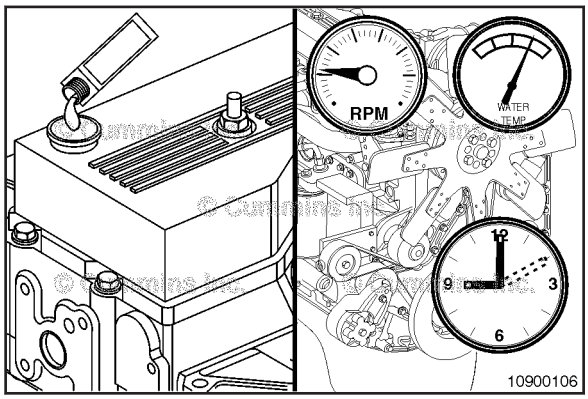


If oil is present **only** in the discharge side, install the air intake and charge-air cooler piping. Refer to the original equipment manufacturer (OEM) service manual.

Check for intake restriction. Refer to Procedure 010-031 in Section 10.

NOTE: If the engine experiences a turbocharger malfunction or any other occasion where oil is put into the charge-air system, the charge-air system **must** be inspected and cleaned. Refer to Procedure 010-027 in Section 10. Use the following procedure if the engine is equipped with an aftercooler. Refer to Procedure 010-005 in Section 10.

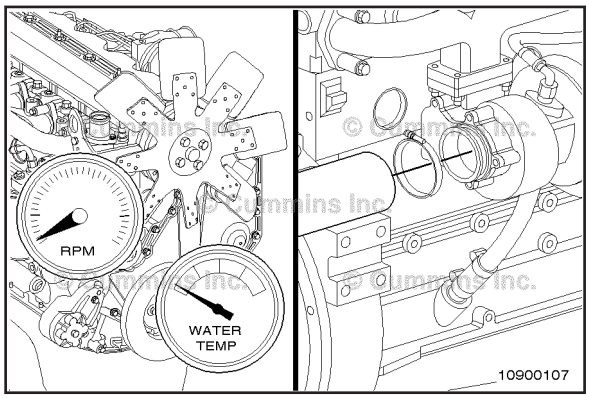
NOTE: If the engine experiences a turbocharger malfunction that results in coolant or oil entering the intake, the charge-air cooler system as well as the fuel control housing **must** be inspected and cleaned. Use the following procedure for the charge-air cooler. Refer to Procedure 010-027 in Section 10. Use the following procedure for the fuel control housing. Refer to Procedure 005-009 in Section 5.



Add one unit of fluorescent tracer, Part Number 3376891, to each 38 liters [10 gal] of engine lubricating oil.

Operate the engine at low idle for 10 minutes.

NOTE: Do **not** operate the engine with the charge-air piping removed. The lack of boost pressure on the outlet side of the compressor can cause progressive damage to the turbocharger.



Shut the engine OFF.

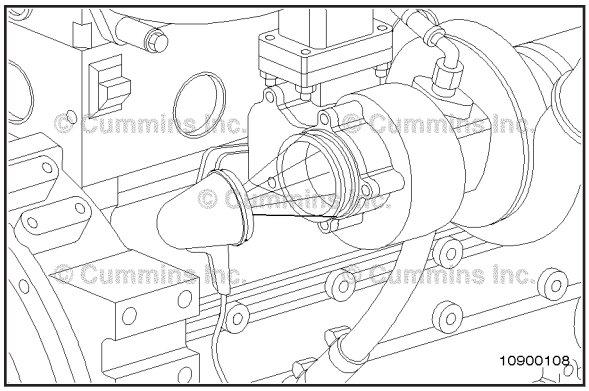
Allow the turbocharger to cool.

Remove the exhaust pipe from the turbine housing. See the Remove section in this procedure.

Use the following procedure if equipped with a sea water cooled exhaust outlet. Refer to Procedure 011-017 in Section 11.

Use a high-intensity black light, Part Number 3163339, to inspect the turbine outlet for leaks.

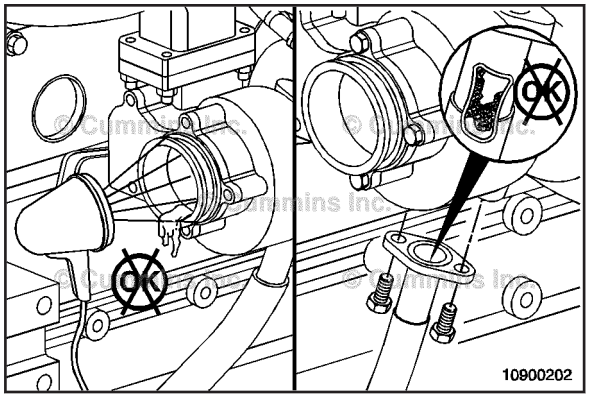
A yellow glow indicates an oil leak. A dark blue glow indicates fuel in the oil.



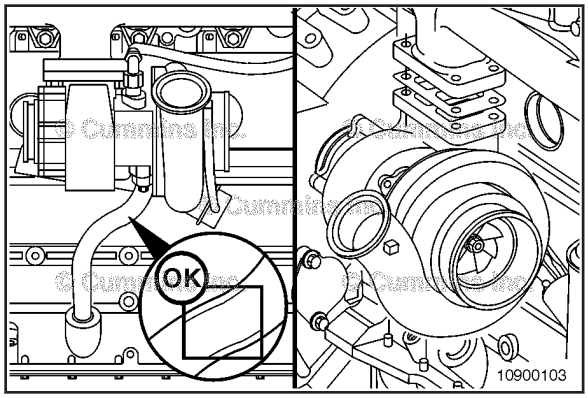
If oil is found in the turbine housing, remove the oil drain line and check for restrictions. Refer to Procedure 010-045 in Section 10.

Clear any restrictions found.

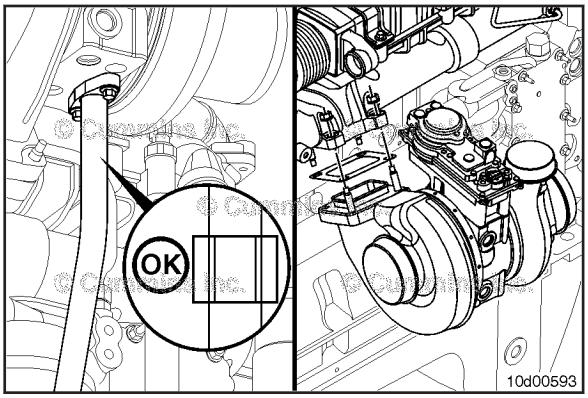
Install the turbocharger drain line. Refer to Procedure 010-045 in Section 10.

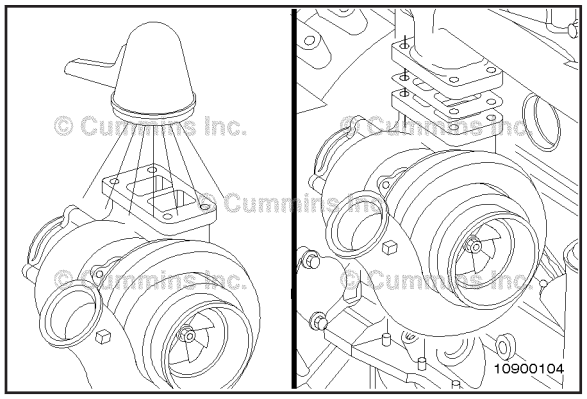


If the oil drain line was **not** restricted, remove the turbocharger. See the Remove and Install sections in this procedure.



If these checks do **not** reveal the problem, remove the turbocharger. See the Remove and Install sections in this procedure.

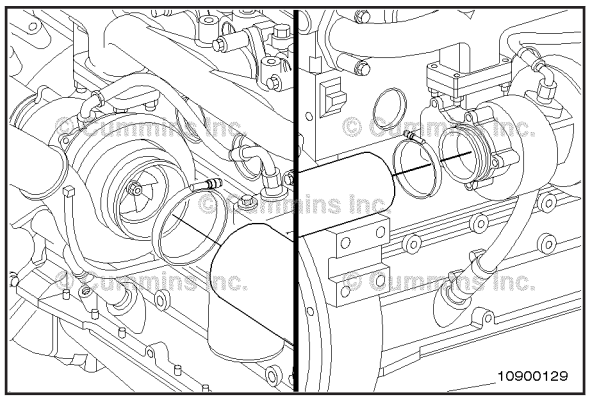




Use a high-intensity black light, Part Number 3163339, to inspect the turbine inlet for leaks.

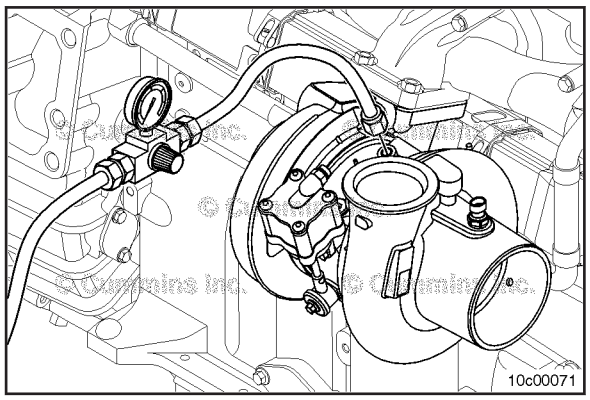
A yellow glow indicates an oil leak from the engine.

If a yellow glow is **not** seen in the turbine inlet, replace the turbocharger. See the Remove and Install sections in this procedure.



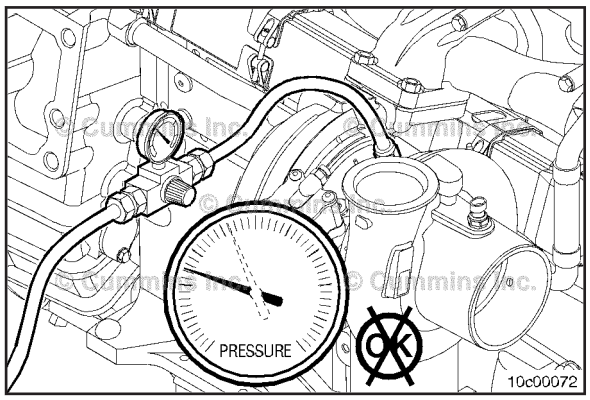
Install the exhaust pipe to the turbocharger turbine outlet and tighten the clamp. Use the following procedure if the exhaust outlet is sea water cooled. Refer to Procedure 011-017 in Section 11.

Install the intake pipe to the turbocharger compressor inlet and tighten the clamp. Use the following procedure if equipped with an engine mounted air cleaner. Refer to Procedure 010-013 in Section 10.



Locally manufacture a turbocharger coolant leak test kit to connect to the coolant inlet and outlet.

- An air pressure regulator is required to control shop air pressure during the test.
- A M14x1.5 male plug is required to block the water outlet.
- A hose with an appropriate fitting to connect to the air pressure regulator and a 13/16”-16 female flat face o-ring fitting is required to connect to the water inlet.



Apply shop air supply to pressurize the turbocharger coolant passage to 276 kPa [40 psi].

Close the air pressure regulator.

Check the gauge for a pressure decrease. The pressure **must not** decrease more than 34 kPa [5 psi] in 1 minute.

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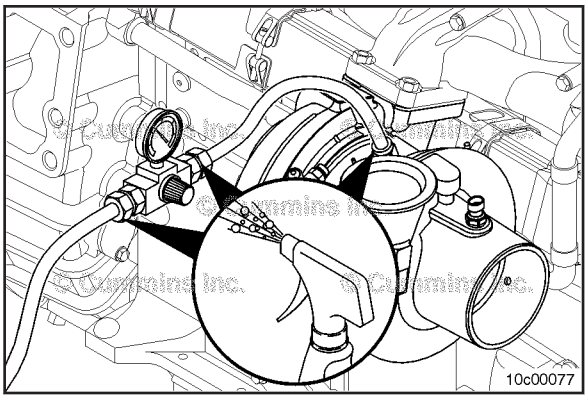
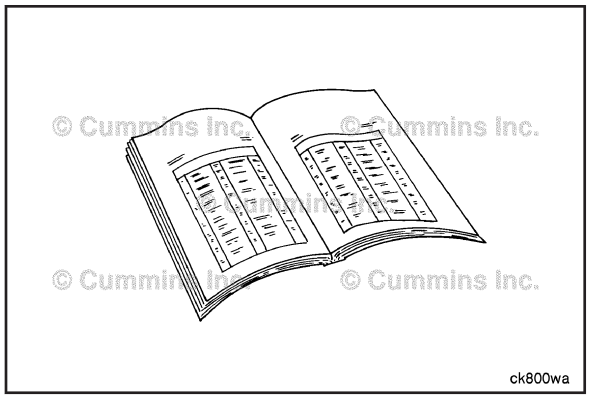
If the pressure decrease is more than 34 kPa [5 psi] in 1 minute, use a spray bottle of soapy water to wet all hose connections. Bubbles will appear if the connections are leaking.

If the pressure decreases and the hose connections are **not** leaking, replace the turbocharger.





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 ⚠
Some state and federal agencies have determined that used engine oilcan 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 regul

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the cooling system, variable geometry turbocharger **only**. Refer to Procedure 008-018 in Section 8.
- Remove the oil supply line from the turbocharger. Refer to Procedure 010-046 in Section 10.
- Remove the oil drain line from the turbocharger. Refer to Procedure 010-045 in Section 10.
- Remove the turbocharger coolant lines, variable geometry turbocharger **only**. Refer to Procedure 010-041 in Section 10.
- Disconnect the turbocharger actuator air supply line, variable geometry turbocharger **only**. Refer to Procedure 010-118 in Section 10.
- This procedure is for engines equipped with CM850 fuel system. Disconnect the turbocharger speed sensor, variable geometry turbocharger **only**. See the following procedure in the Troubleshooting and Repair Manual, ISB, ISBe2, ISB3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9, CM850, Electronic Control System, Bulletin 4021416. Refer to Procedure 019-390 in Section 19.
- This procedure is for engines equipped with CM850 fuel system. Disconnect the turbocharger compressor air inlet temperature sensor, if equipped. See the following procedure in the Troubleshooting and Repair Manual, ISB, ISBe2, ISB3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9, CM850, Electronic Control System, Bulletin 4021416.Refer to Procedure 019-395 in Section 19.
- This procedure is for engines equipped with CAPS fuel system. Disconnect the turbocharger compressor air inlet temperature sensor, if equipped. See the following procedure in the Troubleshooting and Repair Manual, ISC, QSC8.3, and ISL Engines, Bulletin 3666271. Refer to Procedure 019-395 in Section 19.

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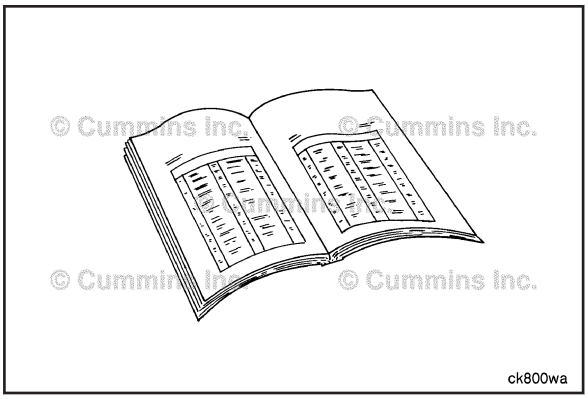
Marine Applications



⚠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 draining oil or replacing filters that oil is not spilled or drained into the bilge area. The oil and oil filters must be discarded in accordance with local environmental regulations.

△CAUTION△
Use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

△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.

- Shut off the sea water supply valve(s). Refer to the original equipment manufacturer (OEM) service manual.
- Disconnect the battery. Refer to the OEM service manual.
- Drain the cooling system. Refer to Procedure 008-018 in Section 8.
- Remove the wastegate actuator heat shield. Refer to Procedure 011-032 in Section 11.
- Remove the oil supply line from the turbocharger. Refer to Procedure 010-046 in Section 10.
- Remove the oil drain line from the turbocharger. Refer to Procedure 010-045 in Section 10.
- Remove the turbocharger coolant lines. Refer to Procedure 010-041 in Section 10.
- Remove the engine mounted air cleaner. Refer to Procedure 010-013 in Section 10.
- Disconnect the sea water cooled exhaust outlet. Refer to Procedure 011-017 in Section 11.
- Disconnect the air crossover pipe. Refer to Procedure 010-019 in Section 10.

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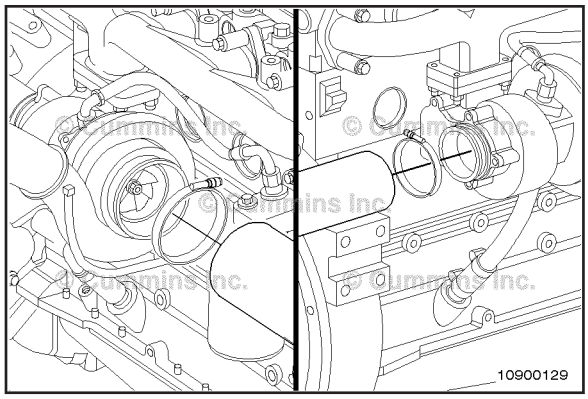
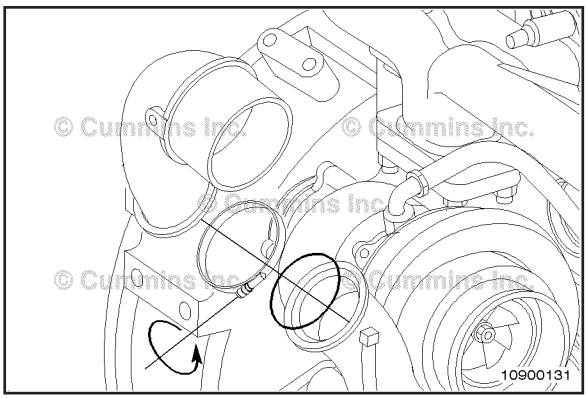


Remove

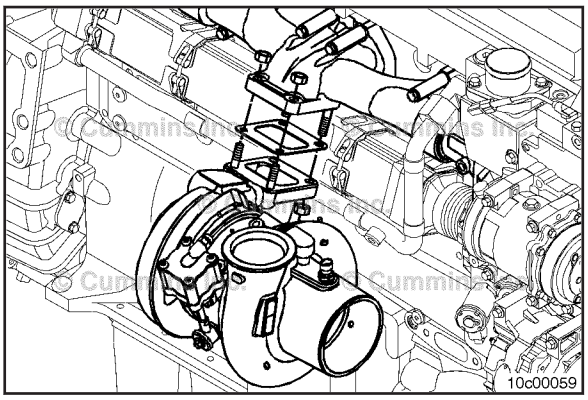
All Applications Except Marine

Remove the exhaust piping.

Remove the turbocharger compressor air inlet pipe.



Remove the turbocharger compressor outlet elbow, V-band clamp, and o-ring from the turbocharger compressor outlet.



⚠WARNING⚠
This component or assembly weights greater than 25 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift the component or assembly.

Remove the four turbocharger mounting nuts.

Remove the turbocharger and gasket.

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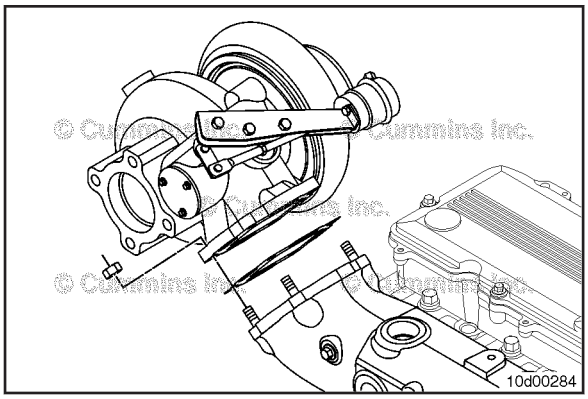
Marine Applications

⚠WARNING⚠
This component or assembly weights greater than 25 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift the component or assembly.

⚠CAUTION⚠
The gasket water ports are larger on the top and bottom passages. The gasket is also marked "Turbocharger" on the side facing the turbocharger. The gasket must be installed with the port size matching the ports of the exhaust manifold and turbocharger, and with the "Turbocharger" marking facing the turbocharger to prevent damage to the turbocharger from overheating.

Remove the turbocharger mounting nuts and turbocharger.

Remove the gasket.

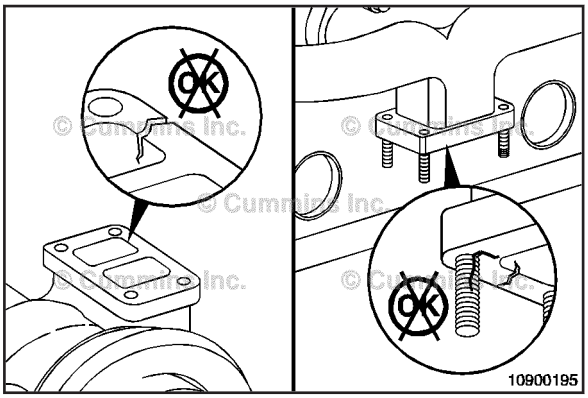


Clean and Inspect for Reuse

Clean the turbocharger and exhaust manifold gasket surfaces.

Inspect the turbocharger and exhaust manifold gasket surfaces, and the mounting studs for cracks or other damage.

For wet manifolds, use the following procedure. Refer to Procedure 011-008 in Section 11.



Cracking of the turbine housing inlet flange may require turbocharger replacement.

Acceptance and rejection guidelines are shown in this illustration.

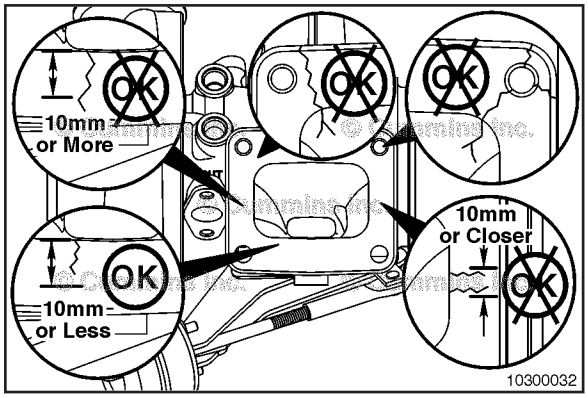
If the exhaust gasket is available, **always** make sure that any cracks lie within its sealing area.

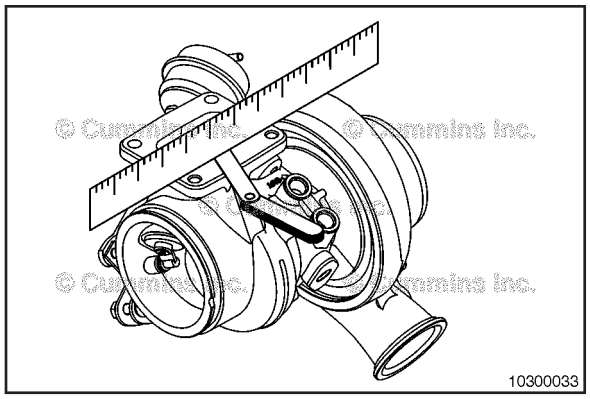
Acceptable cracks **must**:

- be 10 mm [0.39 in] or less in length.
- be separated from each other by no less than 10 mm [0.39 in].
- **not** extend to the edge of the flange.

Replace the exhaust manifold if any cracks or other damage is found in the mounting flange surfaces. Refer to Procedure 011-007 in Section 11.

For wet manifolds, use the following procedure. Refer to Procedure 011-008 in Section 11.



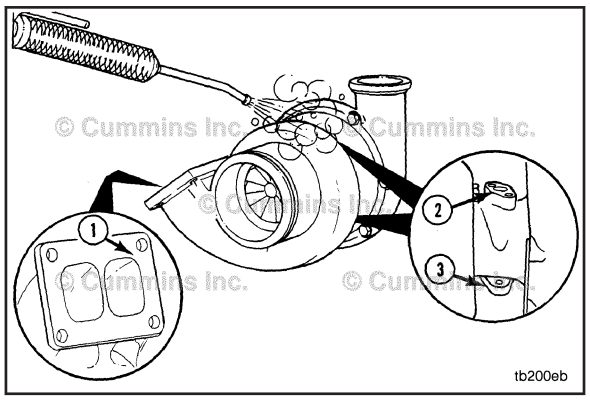


Turbocharger Flatness Check

- Place a straightedge over the turbocharger manifold mounting surface.
- Measure the gap between the port surface and the ruler with a feeler gauge.

Mounting Surface Flatness Specification		
mm		in
0.1	MAX	0.004

If the mounting surface is out of specification, the turbocharger **must** be replaced.



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

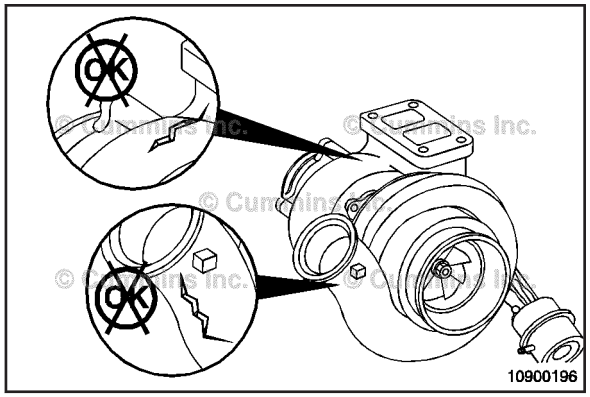
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Remove all carbon deposits and gasket material from surfaces.

Use solvent or steam to clean the exterior of the turbocharger.

Dry with compressed air.



Inspect the turbine and compressor housings.

If cracks that go all the way through the outer walls are found, the turbocharger **must** be replaced.

NOTE: A charge-air cooler malfunction can cause progressive damage to the turbine housing. If the turbine housing is damaged, check the charge-air cooler. Refer to Procedure 010-027 in Section 10.

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Install

All Applications Except Marine

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

Apply a film of high-temperature anti-seize compound to the turbocharger mounting studs.

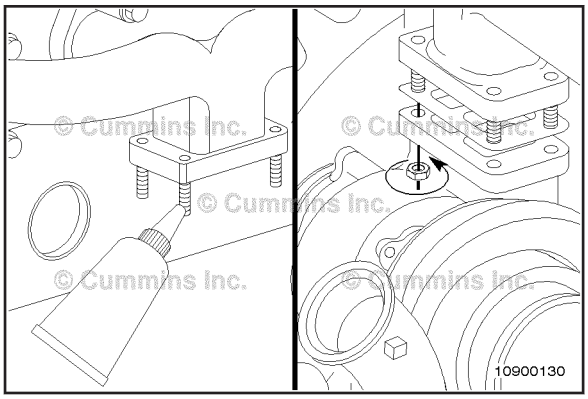
Install a new gasket and install the turbocharger.

Install and tighten the four mounting nuts.

NOTE: The torque values have been established with anti-seize compound as a lubricant.

Torque Value:
Variable Geometry Turbocharger 60 N•m [44 ft-lb]

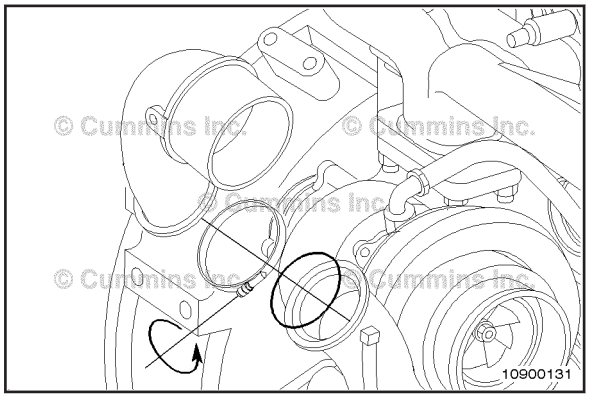
Torque Value:
Wastegate Turbocharger 45 N•m [33 ft-lb]



Install the turbocharger compressor outlet elbow, V-band clamp, and new o-ring seal on the turbocharger compressor discharge outlet.

Tighten the clamp.

Torque Value: 8 N•m [71 in-lb]

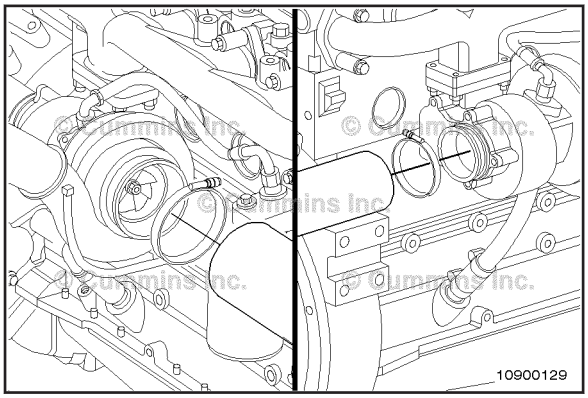


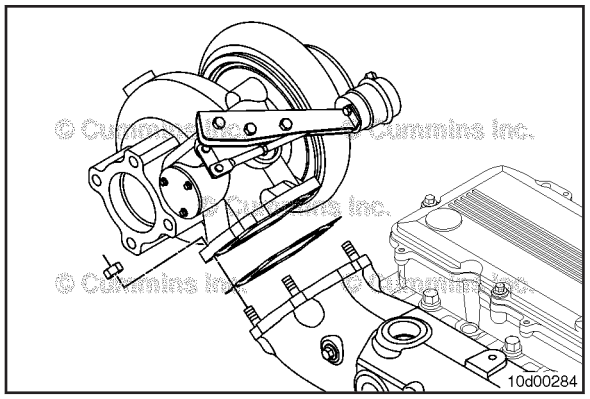
Install the intake pipe to the turbocharger compressor inlet and tighten the clamp.

Torque Value: 8 N•m [71 in-lb]

Install the exhaust pipe to the turbocharger turbine outlet and tighten the clamp.

Torque Value: 8 N•m [71 in-lb]





Marine Applications

⚠WARNING⚠

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

△CAUTION△

The gasket water ports are larger on the top and bottom passages. The gasket is also marked "Turbocharger" on the side facing the turbocharger. The gasket must be installed with the port size matching the port size of the exhaust manifold and turbocharger, and with the "Turbocharger" marking facing the turbocharger to prevent damage to the turbocharger from overheating.

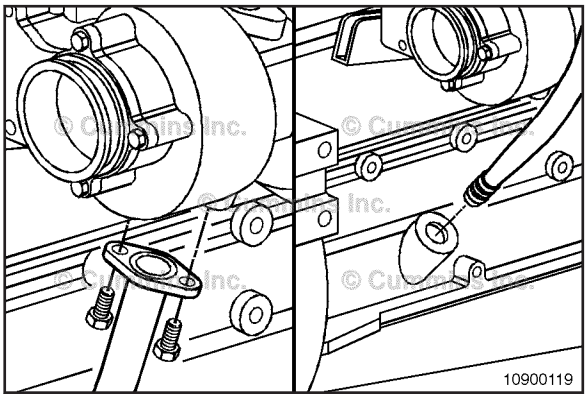
Apply a film of high-temperature anti-seize compound to the turbocharger mounting studs.

Use a new gasket and install the turbocharger.

Install and tighten the four mounting nuts.

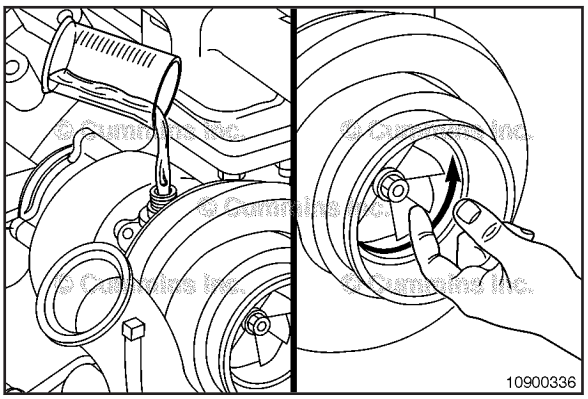
NOTE: The torque values given have been established using anti-seize compound as a lubricant.

Torque Value: 43 N•m [32 ft-lb]



Prime

Install the turbocharger oil drain line. Refer to Procedure 010-045 in Section 10.



Lubricate the bearings by pouring 59 to 89 ml [2 to 3 oz] of clean 15W-40 engine oil into the turbocharger oil supply line fitting. Rotate the turbine wheel to allow oil to enter the bearing housing.

Finishing Steps

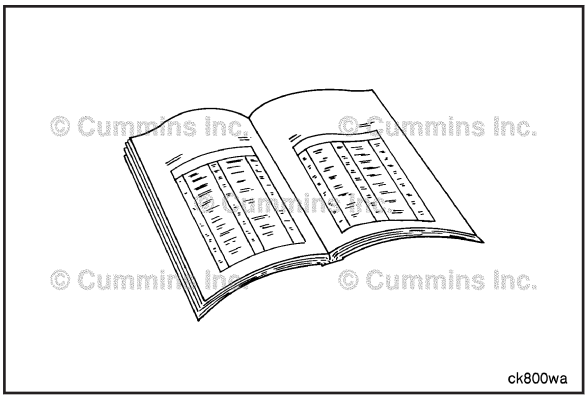
All Applications Except Marine

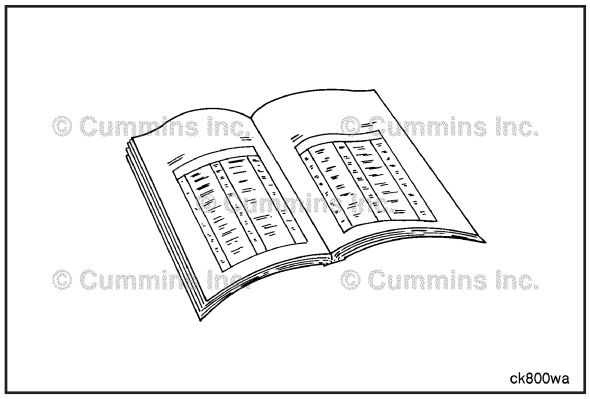
⚠WARNING⚠

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.

NOTE: If a stationary aftertreatment regeneration is needed to complete repair, make sure that the engine is brought up to operating temperature before the regeneration is started.

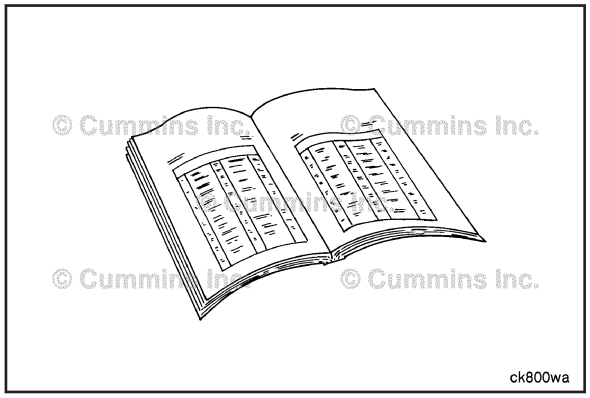
- Install the turbocharger oil supply line. Refer to Procedure 010-046 in Section 10.
- Connect the turbocharger coolant lines, variable geometry turbocharger **only**. Refer to Procedure 010-041 in Section 10.
- Connect the turbocharger speed sensor, variable geometry turbocharger **only**. See the following procedure in the Troubleshooting and Repair Manual, ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB8.3, ISL, ISLe3, ISLe4, and QSL9, CM850 Electronic Control System, Bulletin 4021416. Refer to Procedure 019-390 in Section 19.
- Connect the turbocharger speed sensor. See the following procedure in the Troubleshooting and Repair Manual, ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB8.3, ISL, ISLe3, ISLe4, and QSL9, CM850 Electronic Control System, Bulletin 4021416. Refer to Procedure 019-390 in Section 19.
- Connect the turbocharger compressor air inlet temperature sensor, if equipped. See the following procedure in the Troubleshooting and Repair Manual, ISC, QSC8.3, and ISL Engines, Bulletin 3666271. Refer to Procedure 019-395 in Section 19.
- Fill the cooling system.Refer to Procedure 008-018 in Section 8.
- Connect the turbocharger compressor air inlet temperature sensor. See the following procedure in the Troubleshooting and Repair Manual, ISC, QSC8.3, and ISL Engines, Bulletin 3666271. Refer to Procedure 019-395 in Section 19.
- Fill the cooling system, variable geometry turbocharger **only**. Refer to Procedure 008-018 in Section 8.
- Connect the battery. Refer to the OEM service manual.
- Operate the engine and check for leaks.





Marine Applications

- Connect the turbocharger coolant lines. Refer to Procedure 010-041 in Section 10.
- Install the engine mounted air cleaner. Refer to Procedure 010-013 in Section 10.
- Install the sea water cooled exhaust outlet. Refer to Procedure 011-017 in Section 11.
- Connect the air crossover pipe. Refer to Procedure 010-019 in Section 10.
- Install the heat shield. Refer to Procedure 011-032 in Section 10.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the battery. Refer to the OEM service manual.
- Open the sea water valve(s). Refer to the OEM service manual.
- Operate the engine and check for leaks.



Turbocharger Coolant Hoses (010-041)

Preparatory Steps

Variable Geometry

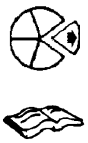
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

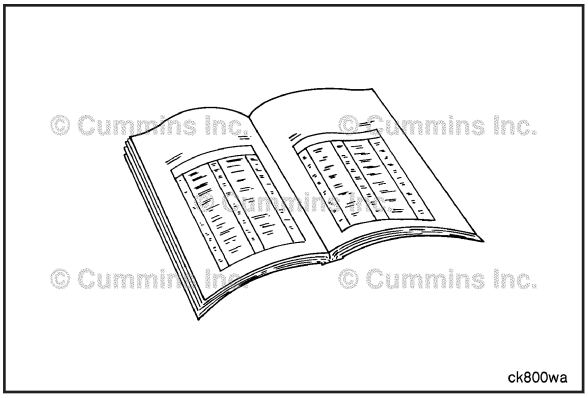
⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the batteries. Reference the equipment manufacturer service information.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.

Marine Applications





⚠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.

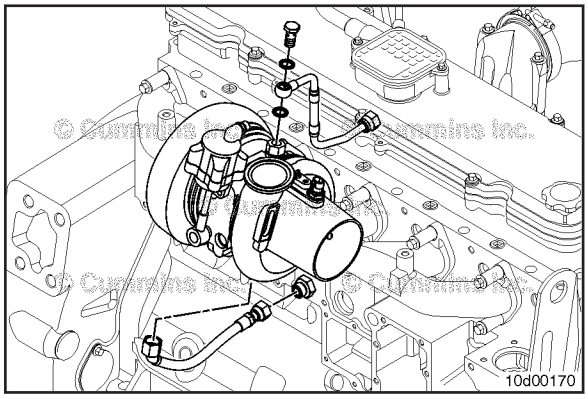
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

△CAUTION△
Use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the heat shield. Refer to Procedure 011-032 in Section 11.

Remove

Variable Geometry

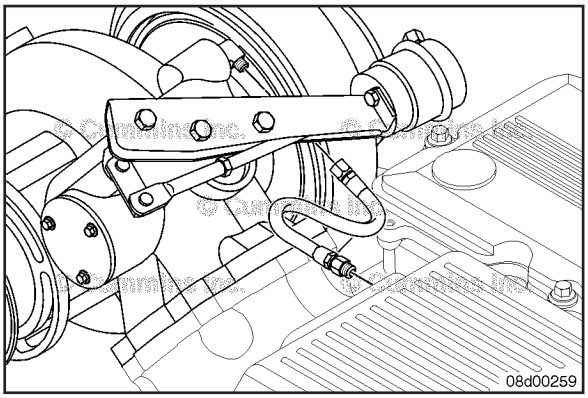


NOTE: Use a second wrench to hold the coolant line coupling while loosening the line.

Remove the turbocharger coolant supply line from the turbocharger and cylinder block.

Remove the turbocharger coolant return line from the turbocharger and the cylinder block.

Marine Applications



NOTE: The graphic shown here is of the QSC8.3 marine engine. The QSL marine engine is different **only** in that the expansion tank is located on the front of the engine and the vent line has P-clips securing the line.

Remove the coolant vent line from the side of the turbocharger turbine housing and the coolant expansion tank.

On QSL9 engines, remove the p-clips which secure the line to the rocker lever housing.

Remove the coolant vent line.

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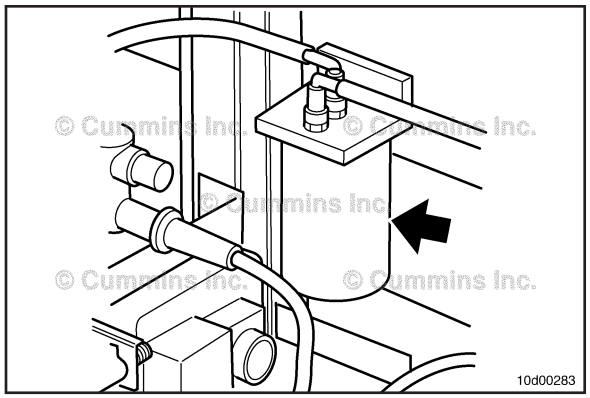
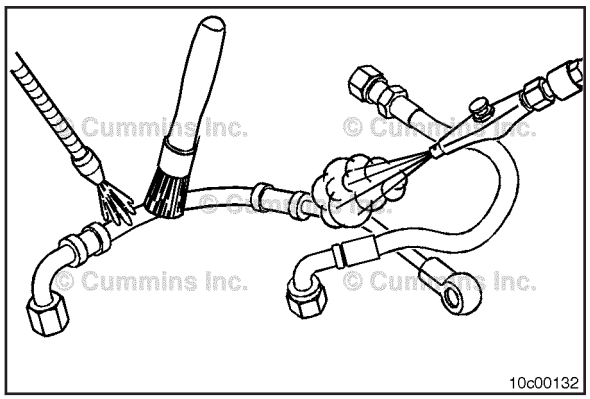


Remove the coolant inlet hose clamps from the turbocharger turbine housing connection and the rear of the cylinder block. Remove the coolant inlet hose.

Remove the hose pipe fittings from the turbocharger turbine housing and the rear of the cylinder block.



Clean and Inspect for Reuse

All Applications

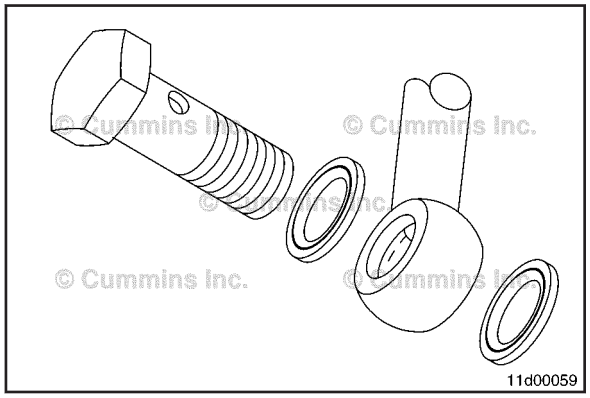
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠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 turbocharger coolant hoses with solvent.

Dry with compressed air.



Inspect for burrs or debris around the banjo fittings.

Inspect for cracks in the lines and connectors. Replace as necessary.

Inspect the hose fittings and clamps for cracks or other damage.

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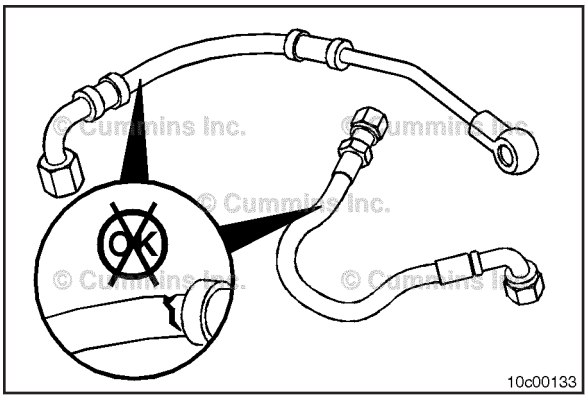
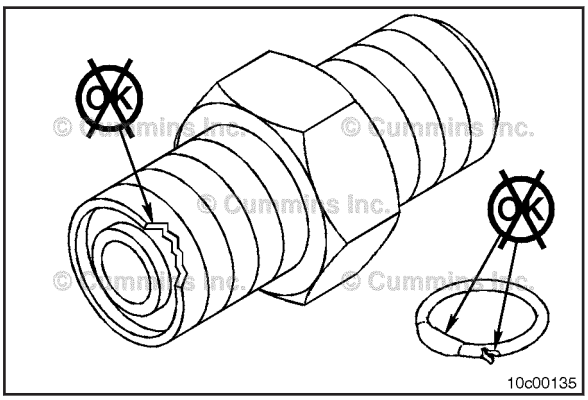
Check the o-rings for cuts or deformation. Replace as necessary.

Check the turbocharger coolant lines for cracks or other damage. Replace if damage is found.



Check the face of the coolant fittings on the engine and on the turbocharger to make sure the o-ring is in place and is **not** damaged. A damaged or missing o-ring will result in a coolant leak.



Install

Variable Geometry

Install the turbocharger coolant return line to the top of the turbocharger and the block.

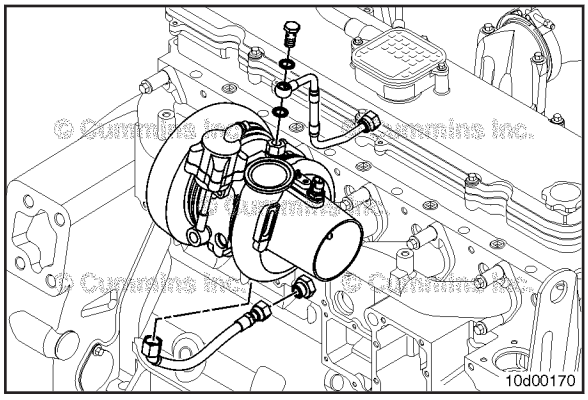
Install the turbocharger coolant supply line to the bottom of the turbocharger and the block.

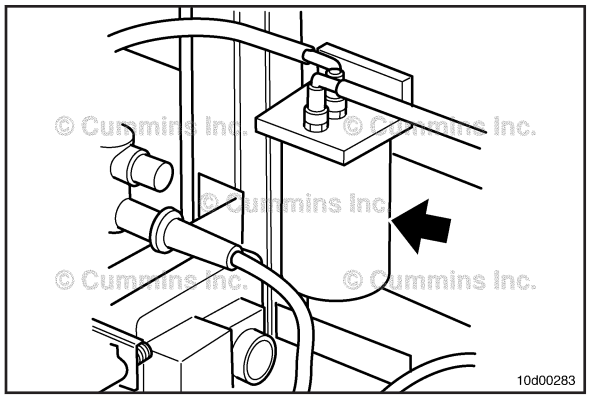
Check the face of the coolant fittings on the engine and on the turbocharger to make sure the o-ring is in place and is **not** damaged. A damaged or missing o-ring will result in a coolant leak.

NOTE: Use a second wrench to hold the coolant line coupling while tightening the line.

Tighten the fittings.

Torque Value: 46 N•m [34 ft-lb]





Marine Applications

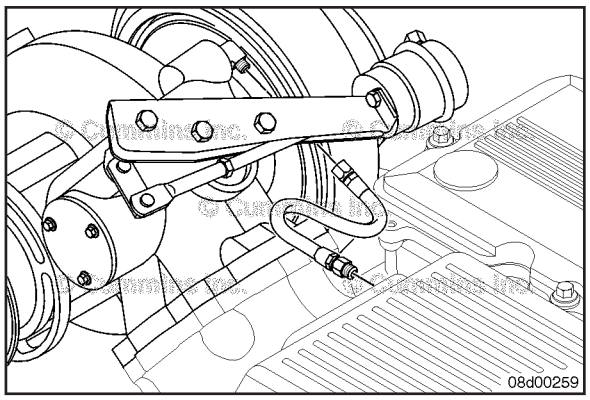
Install the pipe nipple at the rear of the cylinder block and the elbow at the bottom of the turbocharger turbine housing.

Align the elbow and tighten the banjo capscrew.

Torque Value: 160 N•m [118 ft-lb]

Install the molded coolant supply hose to the rear of the cylinder block and the bottom of the turbocharger turbine housing. Install the hose clamps and tighten.

Torque Value: 8 N•m [71 in-lb]



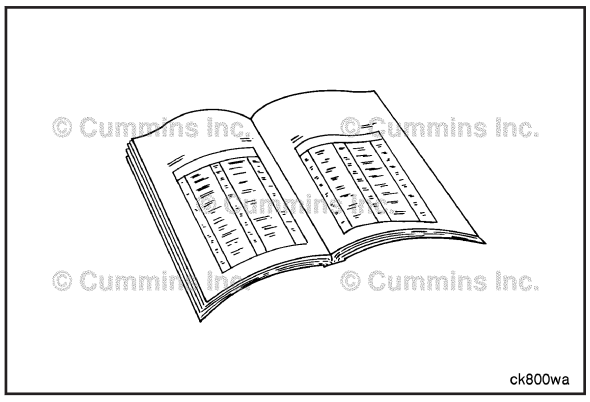
Install the coolant vent line to the side of the turbocharger turbine housing.

Torque Value: 15 N•m [133 in-lb]

Install the coolant vent line to the rear of the coolant expansion tank and tighten.

Torque Value: 15 N•m [133 in-lb]

On QSL9 engines, install the p-clips to 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.

- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- Install the heat shield. Refer to Procedure 011-032 in Section 11, if installed.
- Connect the battery. Reference the equipment manufacturer service information.
- Operate the engine and check for leaks.

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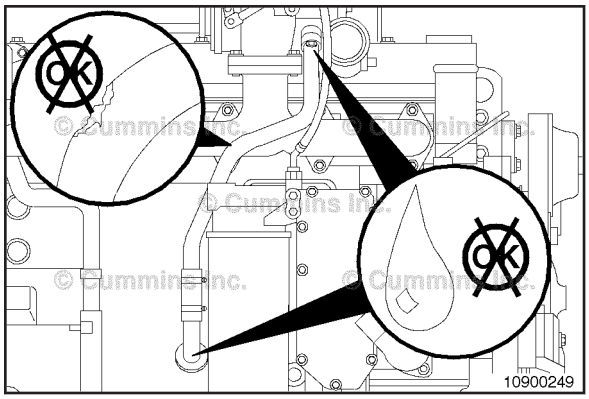
Turbocharger Oil Drain Line (010-045)

Initial Check

Inspect the turbocharger oil drain line for oil leaks or damage.

Repair as necessary.



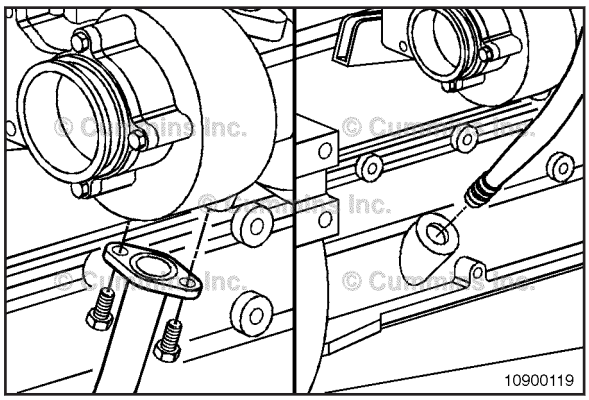
Remove

⚠CAUTION⚠
Use caution when draining oil or replacing filters that oil is not spilled or drained into the bilge area. The oil and oil filters must be discarded in accordance with local environmental regulations.

Remove the capscrews from the oil drain tube.

Loosen the hose clamps on the connecting hoses, if equipped.

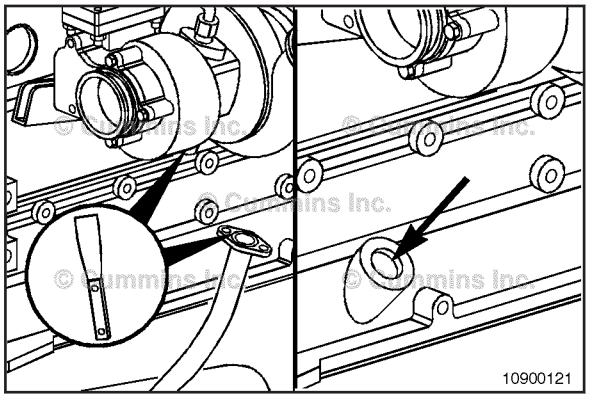
Pull the drain line out of the drain line boss.



Clean and Inspect for Reuse

Clean the gasket sealing surfaces.

Clean the o-ring seating bore and make sure it is free of dirt and debris.

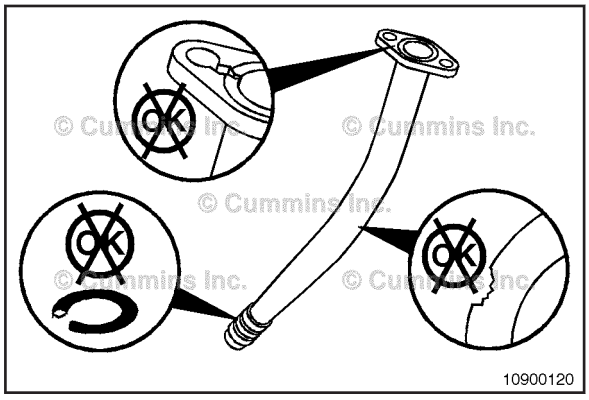


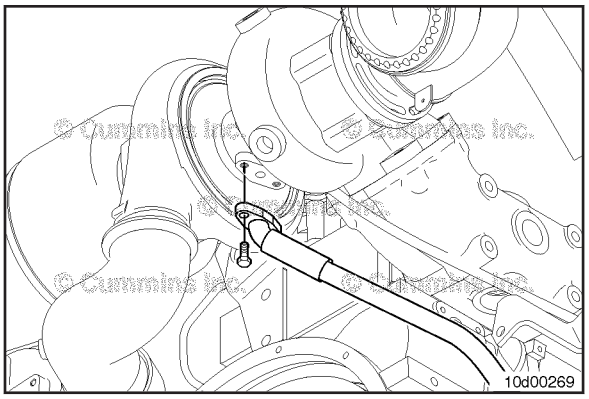
Inspect the line for cracks, wear, and damage.

Inspect the o-ring for fretting and cracking. Replace if necessary.

Check the rubber section of the drain line for deterioration.

Inspect the connector hoses and clamps for cracks or wear. Replace if necessary.





Install

Apply a thin film of clean engine oil to the drain line o-rings.

Push the oil drain line into the drain line boss. Make sure both o-rings are completely seated in the bore.

Install a new gasket to the oil drain line.

Install the turbocharger oil drain line mounting capscrews.

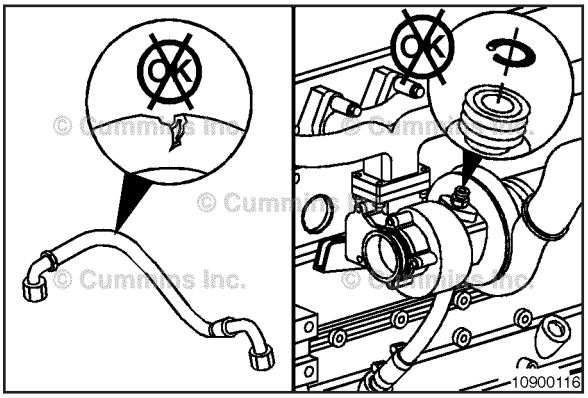
Install the hose and hose clamps, if equipped. Tighten the hose clamps.

Torque Value: 5.6 N•m [50 in-lb]

Tighten the mounting capscrews.

Torque Value: 27 N•m [239 in-lb]

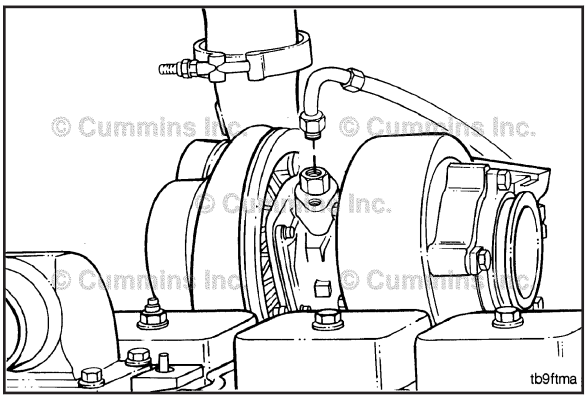
Operate the engine and check for leaks.



Turbocharger Oil Supply Line (010-046)

Initial Check

Inspect the line for oil leaks or damage. Replace as necessary.



Remove

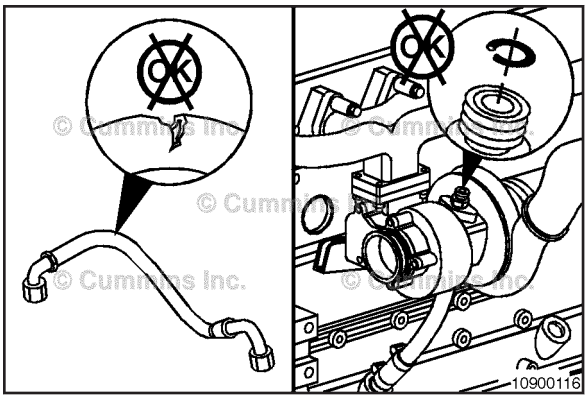
Remove the oil supply line from the oil filter head (1).

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

Inspect for Reuse

Inspect the line for cracks, wear, and damage.

Inspect o-rings for cracking and fretting. Replace as necessary.



Install

⚠CAUTION⚠
Maintain a minimum distance of 10 mm [0.39 in] between the oil supply line and the turbine housing or exhaust manifold, and 5 mm [0.20 in] between the oil supply line and other components to prevent oil line high temperature damage and chafing.

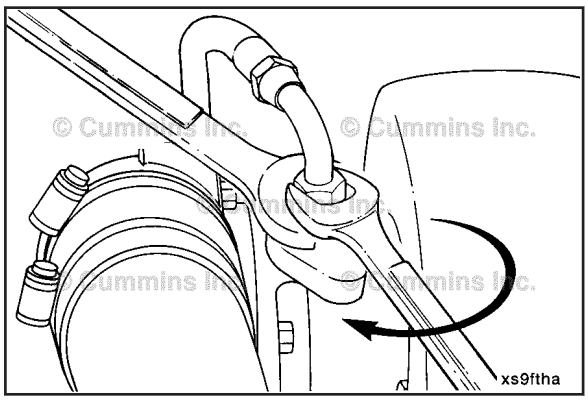
Apply a thin film of oil to the o-ring seals.

Fill the turbocharger oil inlet with clean oil.

Install the oil supply line at both the filter head and the turbo bearing housing.

Tighten the oil supply line to final torque.

Torque Value: 24 N•m [212 in-lb]

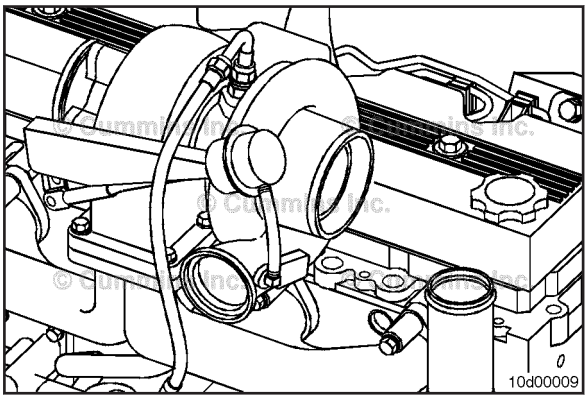


Turbocharger Wastegate Actuator (010-050)

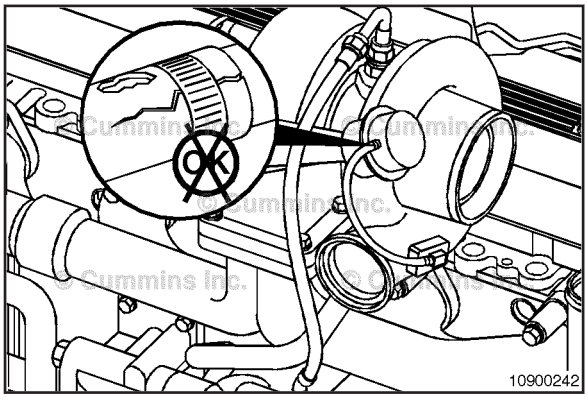
Initial Check

⚠CAUTION⚠
All wastegates come precalibrated and can not be adjusted in the field. Attempts to adjust the wastegate can result in engine damage.

The integral wastegate line takes boost from the turbocharger compressor outlet to the wastegate capsule.



Inspect the integral wastegate actuator hose for cracks or holes. Replace the hose if damaged.



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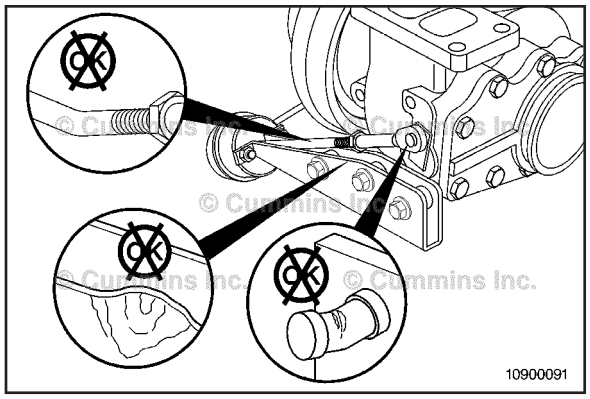
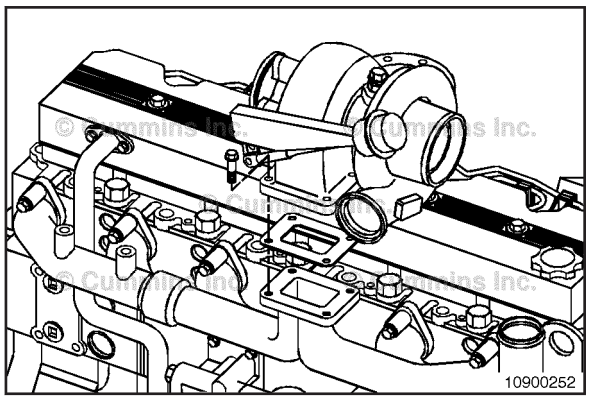


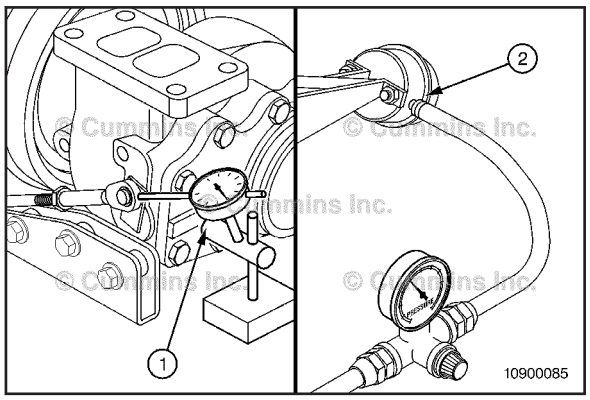
Inspect the wastegate mounting bracket, actuator rod, and lever for damage. A bent wastegate mounting bracket, actuator rod, or lever can cause improper operation.

If the wastegate mounting bracket, actuator rod, or lever is bent, it **must** be replaced.



Test

In some applications the turbocharger **must** be removed to test the wastegate actuator. Refer to Procedure .



Disconnect the integral boost line from the wastegate capsule.

Attach a dial indicator (1) as shown, so that its shaft is in line with the wastegate actuator rod. Set the indicator to zero.

Connect clean, regulated air pressure and a pressure gauge to the capsule. Apply 200 kPa [29 psi] to make sure the wastegate is functioning properly.

The rod **must** move approximately 5 mm [0.200 in] without any sticking or air leakage.

Air **must not** be heard, such as air leaking through a functional wastegate capsule.

A small amount of travel when air pressure is first applied is normal. The tolerance is being removed from the system.

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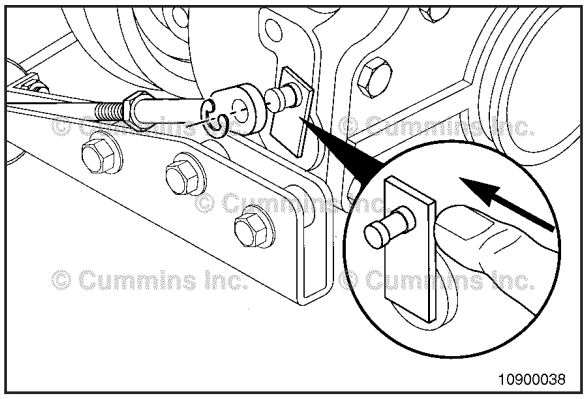
If no movement of the actuator rod is detected, detach the actuator control rod from the wastegate lever pin.

Actuate the lever by hand to be sure that the shaft rotates freely and is **not** seized.

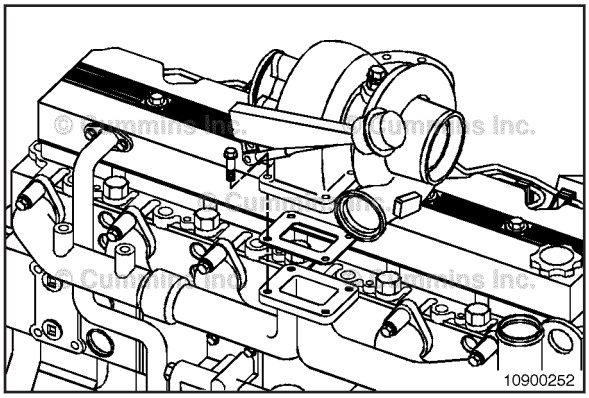
If the wastegate lever can **not** be moved by hand, replace the turbocharger. Refer to Procedure .

If the wastegate lever moves freely by hand, replace the turbocharger wastegate actuator.

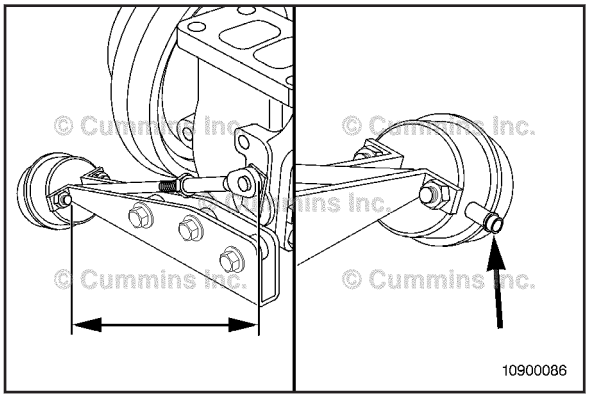


Remove

In some applications the turbocharger **must** be removed in order to remove the wastegate actuator. Refer to Procedure .

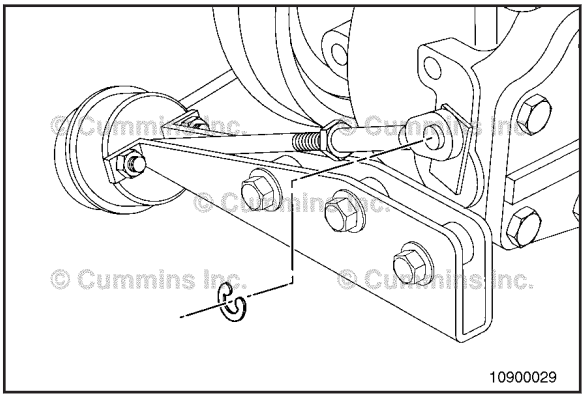


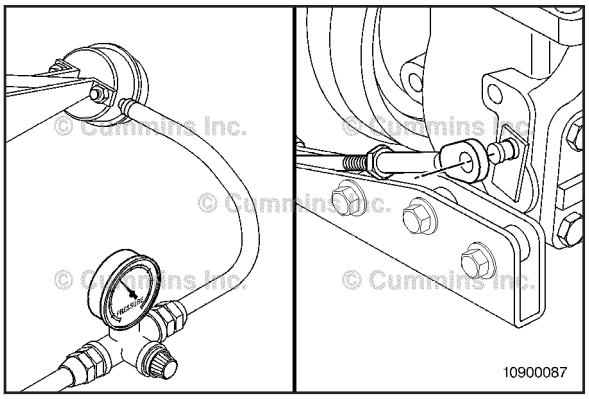
Prior to removal, note position length of the control rod from the boost capsule housing and orientation of the boost capsule hose connector in relation to the mounting bracket.



Remove the retaining clip from the control lever.

Remove the integral boost line from the wastegate capsule.



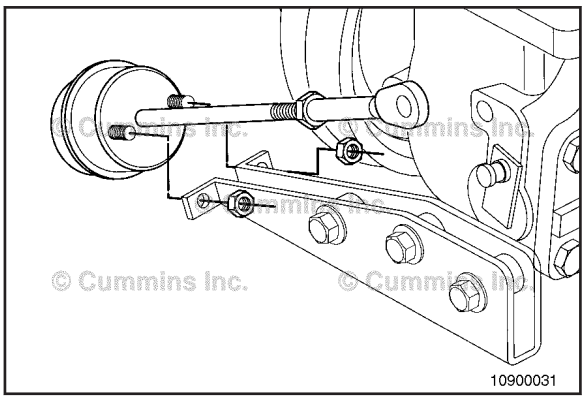


CAUTION

Be careful not to bend the control lever. Engine damage can result.

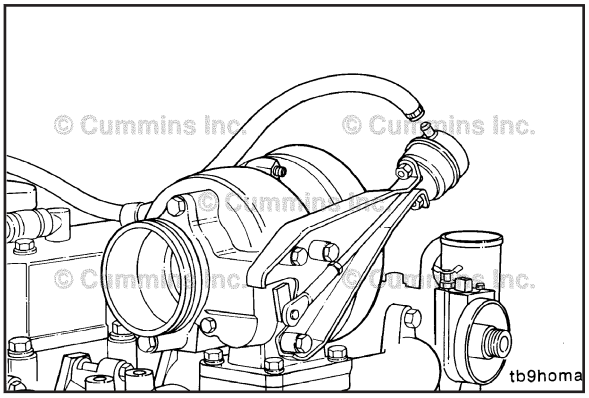
Remove the boost capsule actuator rod end from the turbocharger wastegate lever. This can be accomplished by slowly applying regulated air pressure to the boost capsule until the control rod is activated.

Remove the control rod from the turbocharger wastegate lever pin.



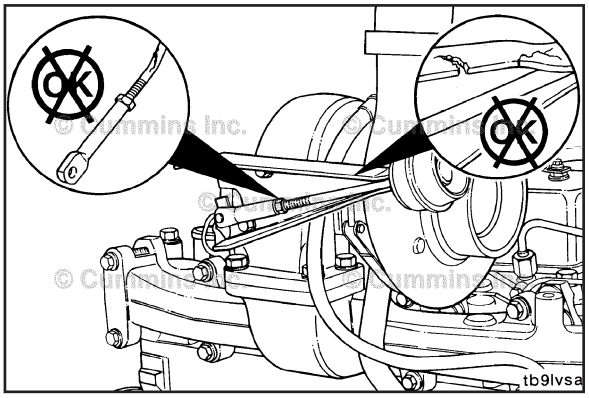
If the boost capsule diaphragm material is ruptured and will **not** hold air pressure, manually pull the control rod outward in order to overcome boost capsule spring tension for removal of the control rod from the turbocharger wastegate lever pin.

Loosen the boost capsule mounting capscrews, disconnect the air supply hose, and remove the assembly from the mounting bracket.



Clean and Inspect for Reuse

Inspect the wastegate actuator hose for cracks or holes. Replace the hose if damaged.



Inspect the wastegate mounting bracket, actuator rod, and lever for damage. A bent wastegate mounting bracket, actuator rod, or lever can cause improper operation.

If the wastegate mounting bracket, actuator rod, or lever is bent, it must be replaced.

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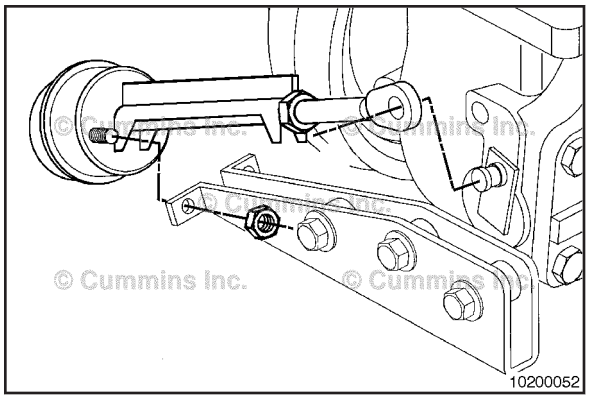
Install

Fit the actuator mounting studs into the holes in the bracket, and fit both actuator mounting capscrews.

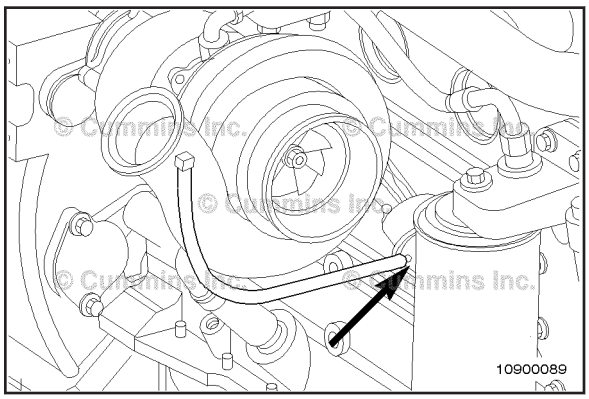
Refit the end-link onto the crank-pin. Install the control rod retaining clip.

Torque Value: 8 N•m [71 in-lb]

Cut the tie wrap and remove the tie wrap and spacer piece.



Refit the air supply hose to the actuator, use the new hose clamp provided.



Turbocharger Wastegate Valve Body (010-055)

Preparatory Steps

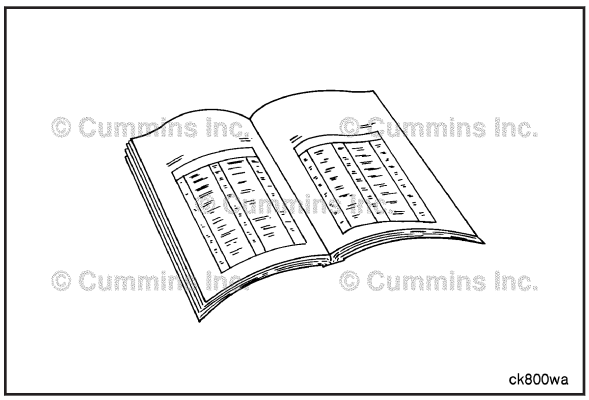
Marine Applications

NOTE: This step applies to marine engines **only**.

Remove the actuator heat shield. Refer to Procedure 011-032.

Remove the exhaust connection from the turbocharger. Refer to Procedure 011-017.

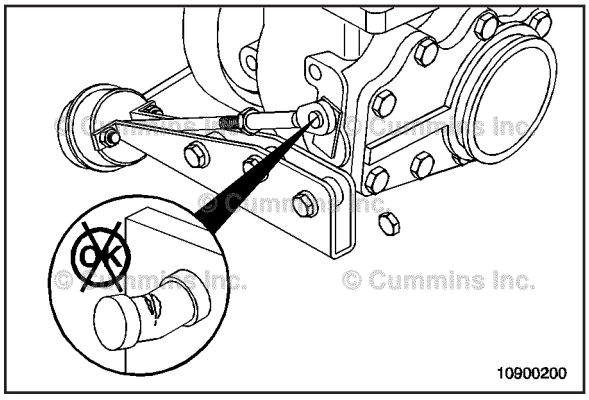
Remove the round inspection plate from the turbocharger.

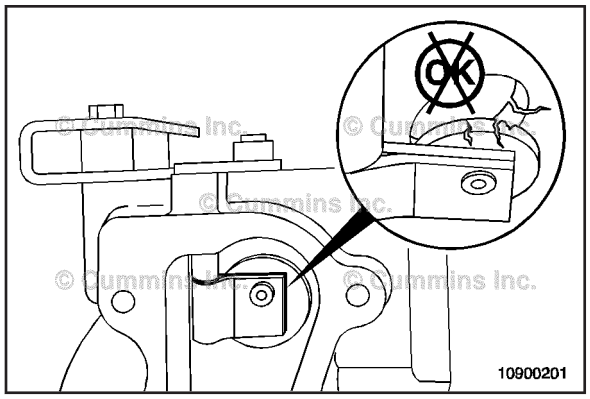


Maintenance Check

Inspect the lever pin.

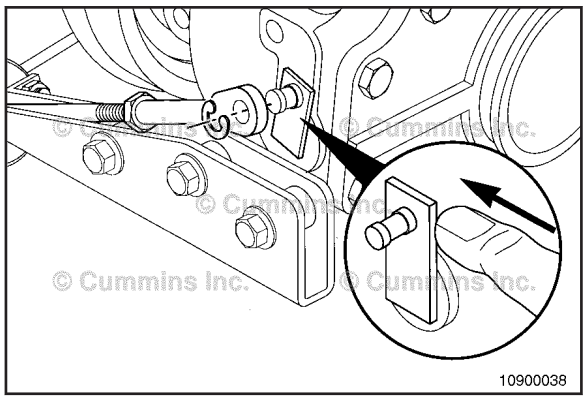
Replace the turbocharger if worn excessively, Refer to Procedure 010-033.





Inspect the valve and valve seat for cracks or erosion.

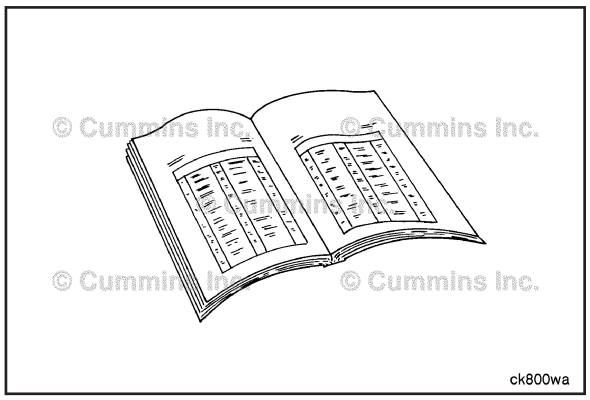
Replace the turbocharger if damage is found. Refer to Procedure 010-033.



Actuate the lever by hand to verify that the shaft rotates freely and is **not** seized.

Check for excessive movement between the shaft and bushing.

Replace the turbine housing if the shaft and bushing are damaged or seized.



Finishing Steps

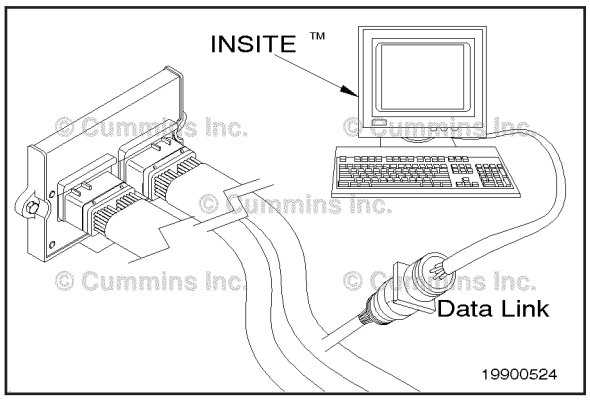
Marine Applications

NOTE: This step applies to marine engines **only**.

Install the inspection plate.

Install the exhaust connection. Refer to Procedure 011-017.

Install the actuator heat shield. Refer to Procedure 011-032.



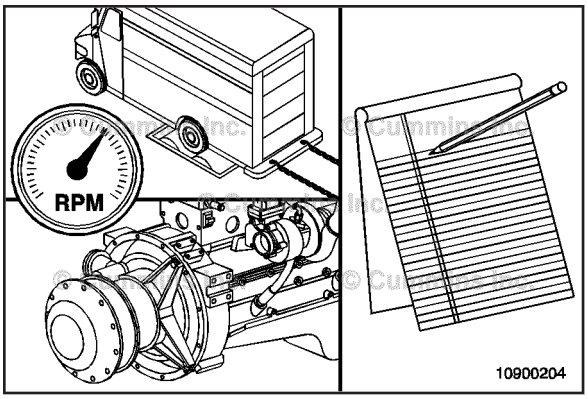
Intake Manifold Pressure (010-057)

Measure

Measure the boost pressure at the intake manifold. Use INSITE™ electronic service tool for hookup and monitoring procedures.

Operate the engine at rated rpm and full load. Record the boost reading.

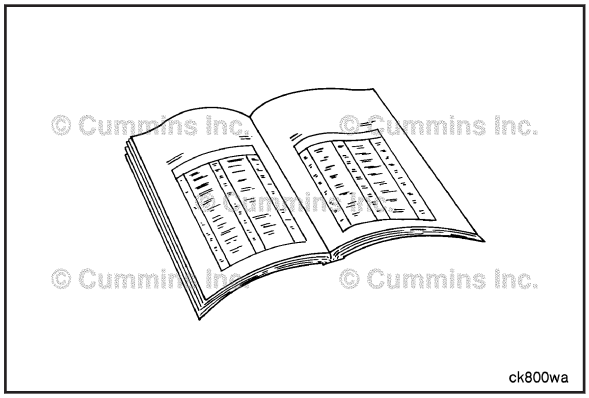
NOTE: Reference the Sales Performance Curve and the Data Sheet for specifications.



Air Intake Connection (010-080)

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.
- Disconnect the grid heater wiring.
- Remove the air inlet crossover tube. Refer to Procedure 010-019 in Section 10.
- Remove the air inlet connection, if equipped. Refer to Procedure 010-022 in Section 10.
- Remove the injector supply lines, if required. Refer to Procedure 006-051 in Section 6.
- Disconnect the injector pass-through for the number 3 and 4 cylinders.
- Disconnect the air compressor air supply tube from the bottom of the air intake connection.

Remove

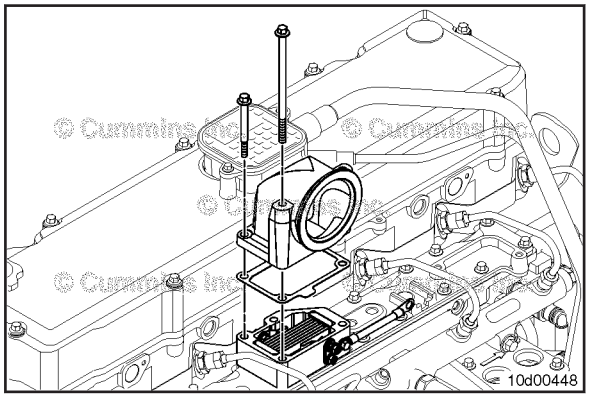
Remove the mounting capscrews.

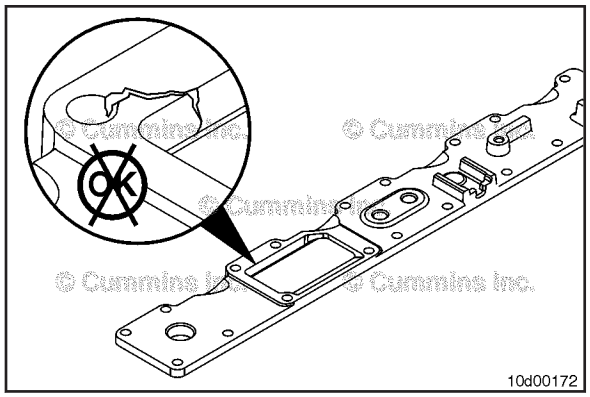
Remove the air intake connection.

Tape off the intake manifold opening to prevent debris from entering the intake system.

NOTE: Be sure **not** to tape over the entire manifold edges so that the surface can be cleaned.

NOTE: On engines with the grid heater mounted on top of the intake manifold cover, the grid heater will now be loose.



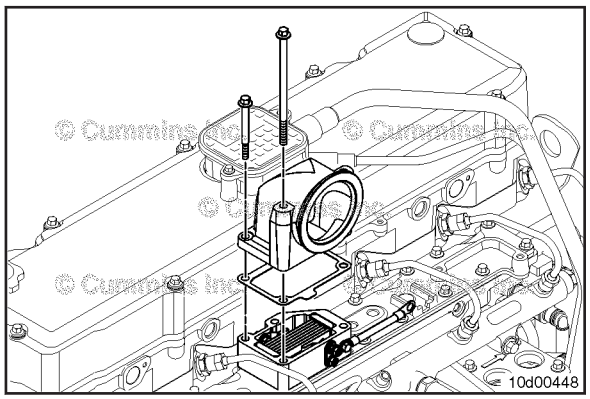


Clean and Inspect for Reuse

Clean the sealing surfaces.

NOTE: Keep gasket material and any other material out of the air intake.

Inspect the air intake connection for cracks or other damage.



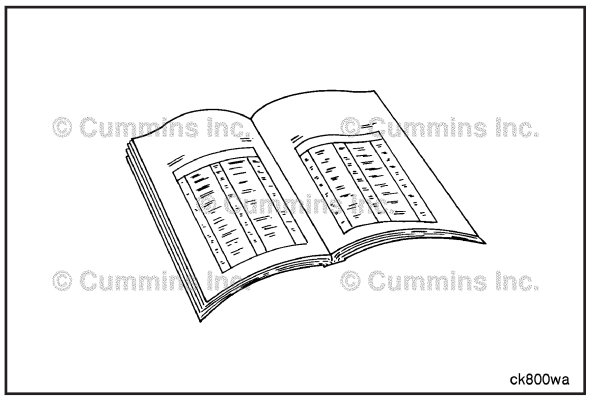
Install

Install the air intake connection. Use a new gasket.

Torque Value: 24 N•m [212 in-lb]

NOTE: Some capscrews are shared with fuel line braces on some engines.

NOTE: On some engines, the air intake connection mounts on top of the grid heater and shares capscrews.



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 electrical connections to the injector pass-through for the number 3 and 4 cylinders.
- Install the injector supply lines, if removed. Refer to Procedure 006-051 in Section 6.
- Connect the air inlet connection, if equipped. Refer to Procedure 010-022 in Section 10.
- Install the air crossover tube. Refer to Procedure 010-019 in Section 10.
- Connect the cold starting aid.
- Connect the air compressor air supply tube to the bottom of the air intake connection using a new o-ring seal.
- Connect the battery. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

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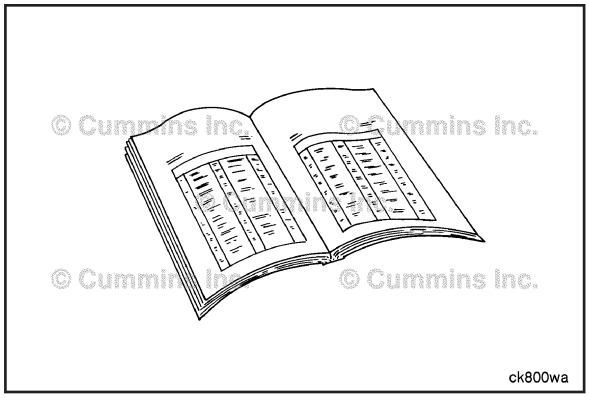
Air Intake Manifold Cover (010-108)

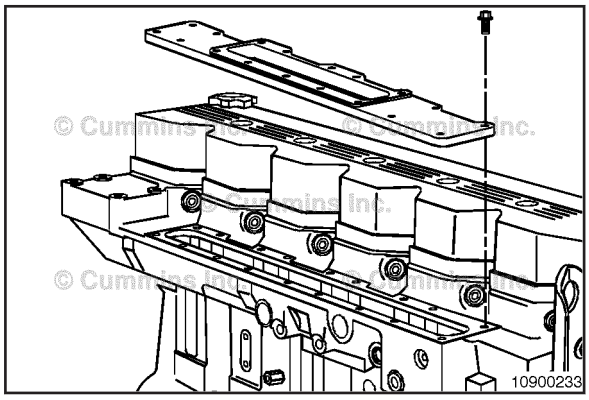
Preparatory Steps



⚠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.
- Disconnect the cold starting aid.
- Remove the air crossover tube. Refer to Procedure 010-019 in Section 10.
- Disconnect the air inlet connection, if equipped. Refer to Procedure 010-022 in Section 10.
- Remove the air intake connection. Refer to Procedure 010-080 in Section 10.
- Remove the injector supply lines, if required. Refer to Procedure 006-051 in Section 6.
- Remove the turbocharger control valve, if equipped. Refer to Procedure 019-388 in Section 19. It can be found in the Troubleshooting and Repair Manual, CM870 Electronic Control System, ISC and ISL Engines, Bulletin 4021416.

Remove



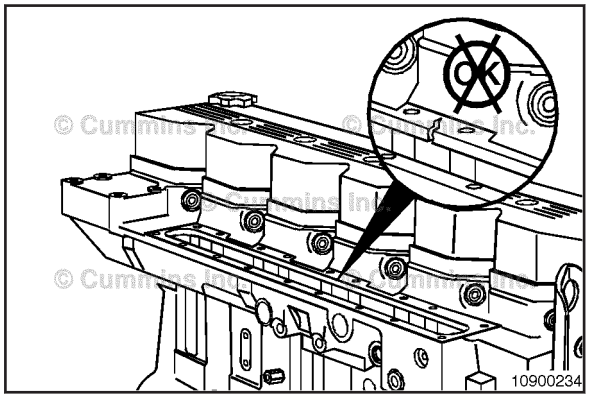
Some engines have a grid heater mounted on top of the intake manifold cover. Remove the grid heater, if equipped. Refer to Procedure 010-029 in Section 10.

Remove the mounting capscrews and the air intake manifold cover.

Tape off the intake manifold opening to prevent debris from entering the intake system.

NOTE: Be sure **not** to tape over the entire manifold edges, so the surface can be cleaned.

Clean and Inspect for Reuse



Clean the sealing surfaces.

NOTE: Keep the gasket material and any other material out of the air intake.

Remove the tape.

Inspect the intake manifold for cracks or other damage.

NOTE: When inspecting the intake manifold for oil or debris from an air system failure, also inspect the cylinder head for oil and debris.

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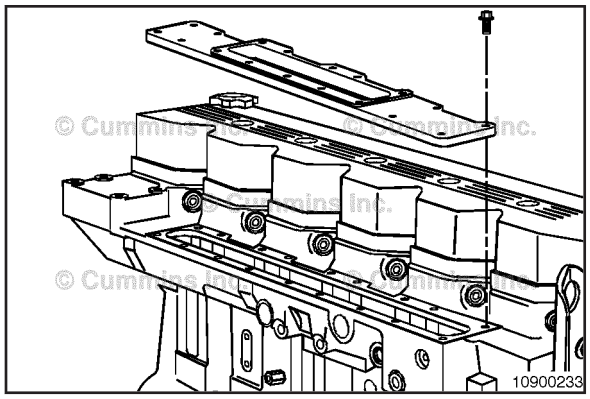


Install

Install the air intake manifold cover with intake air heater (if equipped) and a new gasket.

Install the air intake manifold cover and a new gasket.

Torque Value: 24 N•m [212 in-lb]

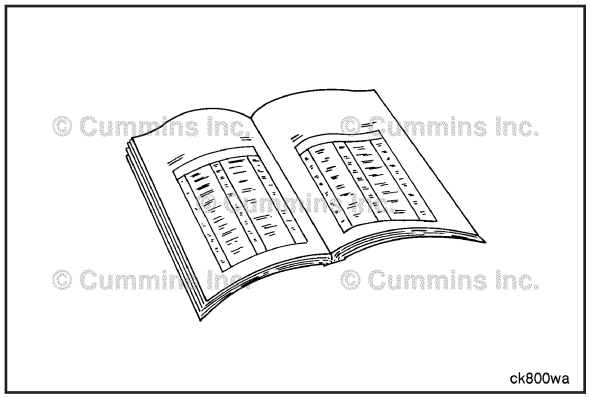
FIPG gasket manifold cover to head joint

- Apply FIPG to mating face side of intake manifold cover.
- Assemble grid heater /spacer, air intake connection and gasket to cylinder head.
- Tighten the capscrews within 15 minutes of RTV application

Standard gasket manifold cover to head joint

- Assemble the intake manifold cover and gasket to the cylinder head
- Tighten the capscrews.

NOTE: Some capscrews are shared with fuel line braces on some engines.



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 grid heater, if equipped. Refer to Procedure 010-029 in Section 10.
- Install the injector supply lines, if removed. Refer to Procedure 006-051 in Section 6.
- Install the air intake connection. Refer to Procedure 010-080 in Section 6.
- Install the air inlet connection, if used. Refer to Procedure 010-022 in Section 10.
- Install the turbocharger control valve, if equipped. Refer to Procedure 019-388 in Section 19. It can be found in the Troubleshooting and Repair Manual, CM870 Electronic Control System, ISC and ISL Engines, Bulletin 4021416.
- Install the air crossover tube. Refer to Procedure 010-019 in Section 10.
- Connect the cold starting aid.
- Connect the battery. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

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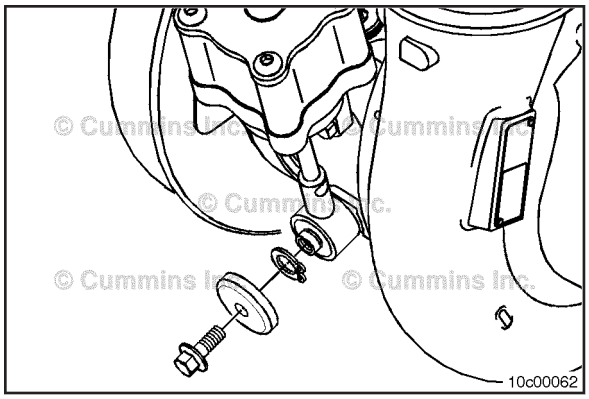
Variable Geometry Turbocharger Actuator, Pneumatic (010-113)

Remove

Remove the air line from the actuator.

Remove the capscrew holding the actuator rod to the turbocharger cross-shaft.

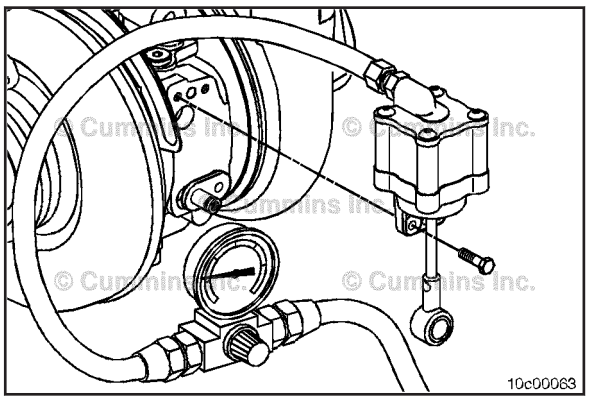
Remove the snap ring from the cross-shaft.



Loosen the two capscrews holding the actuator to the turbocharger bearing housing.

Use coupling, Part Number 3824843, to apply 414 kPa [60 psi] regulated air pressure to the actuator air inlet to reduce spring load at the linkage.

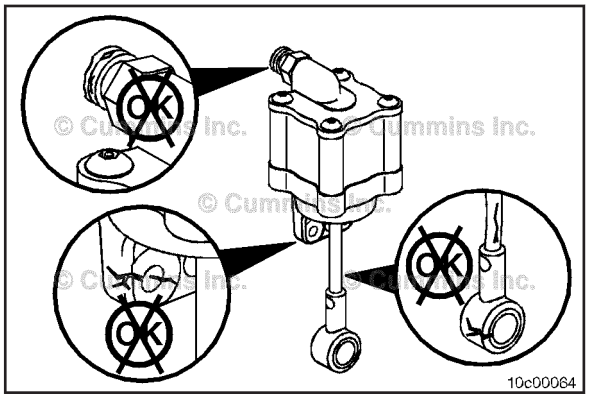
Remove the two loosened capscrews and actuator.



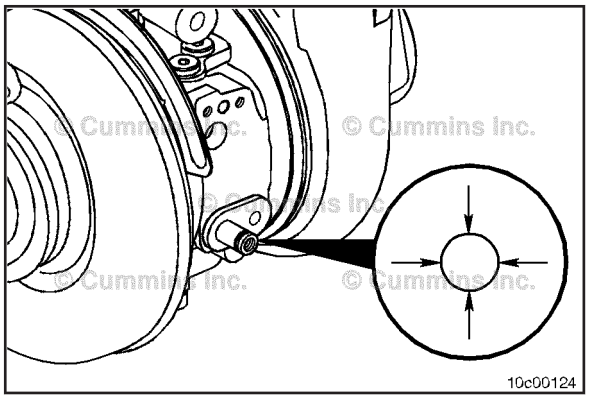
Clean and Inspect for Reuse

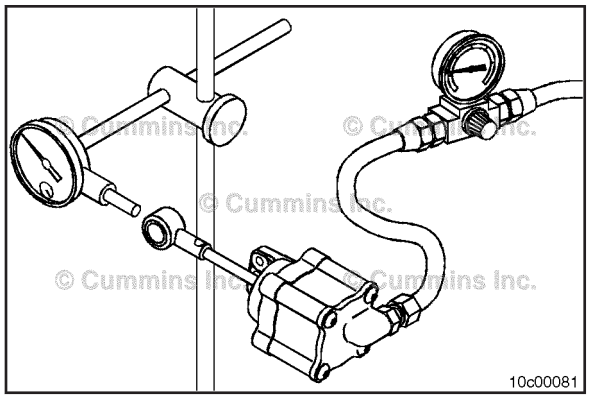
Inspect the actuator mounting bracket, rod and body. If the actuator is bent or cracked, it **must** be replaced.

Inspect the bushing in the actuator rod end that attaches to the turbocharger cross-shaft for wear, scoring, or damage. Replace the actuator, if damage is found.



Inspect the outside diameter of the turbocharger cross-shaft pin. Replace the turbocharger if wear is found.





Test

Attach a dial indicator as shown, so the shaft is in line with the actuator rod. Set the dial indicator to zero with no air pressure applied to the actuator.

Connect a clean, regulated air pressure supply and a pressure gauge to the actuator. Apply a minimum of 414 kPa [60 psi] air pressure to make sure the actuator is functioning properly.

The rod **must** move without any sticking.

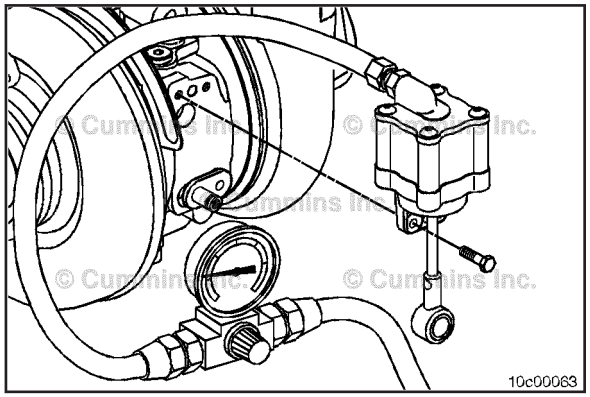
Actuator Movement Range 10.8 mm [0.425 in]

NOTE: No air **must** be heard leaking through a functional actuator.

Spray soapy water on the actuator housing to check for air leaks. Replace the actuator housing if leaks are found.

Replace the actuator if no movement of the actuator rod is detected, the actuator is sticking, or an air leak is found.

NOTE: This test can be performed with the actuator removed or installed on the turbocharger.



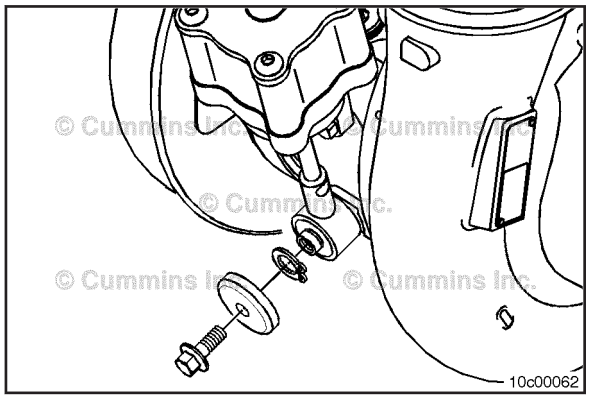
Install

Use coupling, Part Number 3824843, to apply 414 kPa [60 psi] regulated air pressure to the actuator.

Install the actuator on the turbocharger bearing housing.

Install and tighten the two capscrews.

Torque Value: 17 N•m [150 in-lb]



Install the actuator rod to the turbocharger cross-shaft.

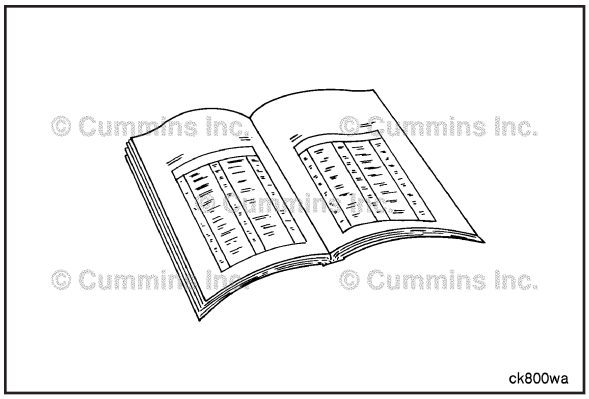
Install the snap ring.

Install and tighten the capscrew.

Torque Value: 23 N•m [17 ft-lb]

Finishing Steps

- Install the turbocharger actuator air supply line to the actuator. Refer to Procedure 010-118.
- Operate the engine and check for leaks.



Turbocharger Actuator Air Line (010-118)

Preparatory Steps

Remove the turbocharger control valve, if necessary. Refer to Procedure 019-388 (Turbocharger Control Valve) in Section 19, in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISC and ISL Engines, Bulletin 4021416.

Remove

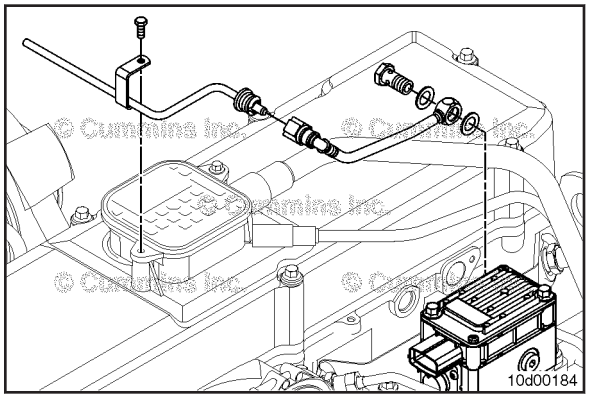
Disconnect the air line from the turbocharger actuator.

Disconnect the air line from the quick-connect fitting on the intake side of the engine.

Remove the mounting capscrew from the crankcase breather.

Disconnect the banjo fitting from the turbocharger control valve.

Use masking tape to tape the end of the air line and turbocharger control valve to prevent contamination.

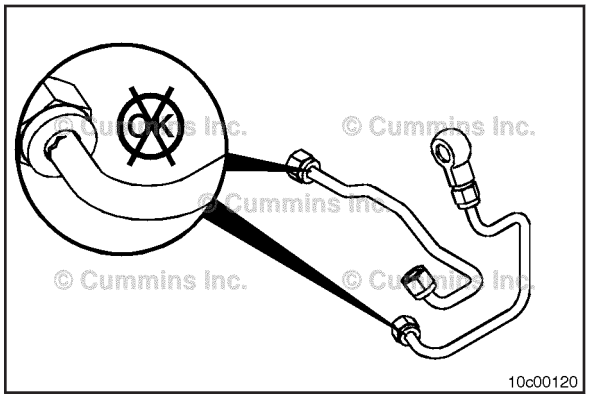


Clean and Inspect for Reuse

Inspect the air line for wear or damage.

Inspect the o-rings for signs of damage or distortion.

Replace as necessary.



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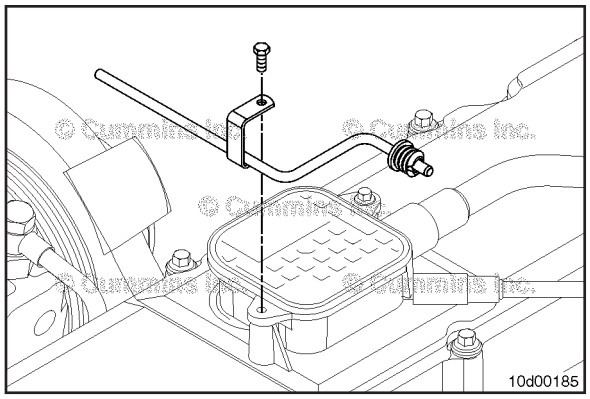
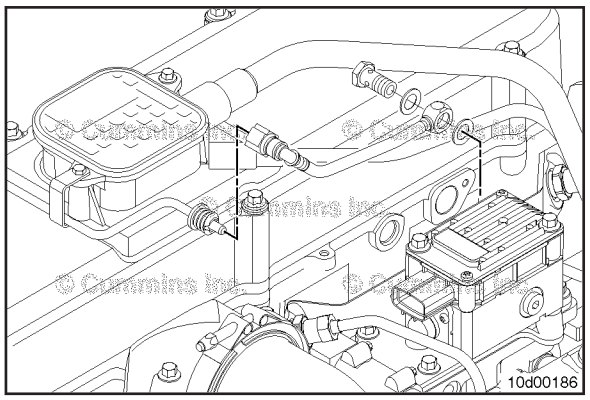


Install

Remove the masking tape from the ends of the turbocharger actuator supply line before installing the line.

Install the air line and the mounting capscrew to the crankcase breather.

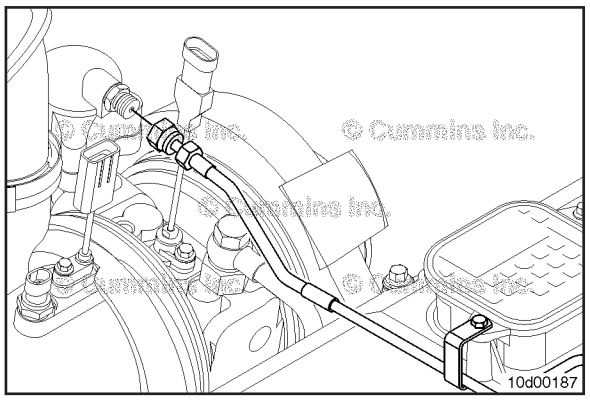
Torque Value: 5 N•m [44 in-lb]



Connect the flexible elbow to the turbocharger control valve, use new sealing washers.

Torque Value: 8 N•m [71 in-lb]

Install the quick connect fitting to the air line.



Connect the air supply line to the turbocharger actuator.

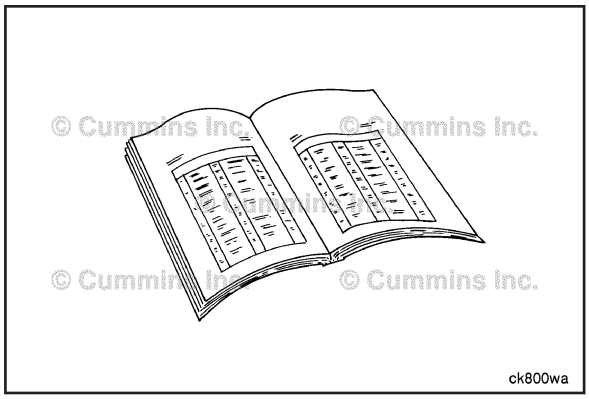
Torque Value: 24 N•m [18 ft-lb]

Finishing Steps

Operate the engine and check for proper operation. Check for air leaks.

Air Intake Connection Adapter (010-131)

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

QSC Engines

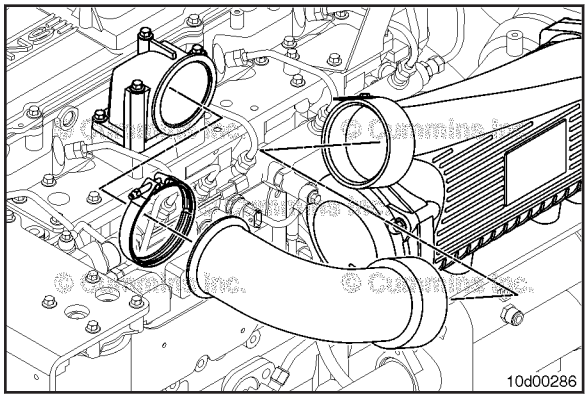
This step applies to the QSC8.3 marine engine.

Loosen the clamp at the air intake connection.

Remove the two capscrews and the retaining brace from the aftercooler.

Remove the air intake connection adapter.

Discard the o-ring.



QSL Engines

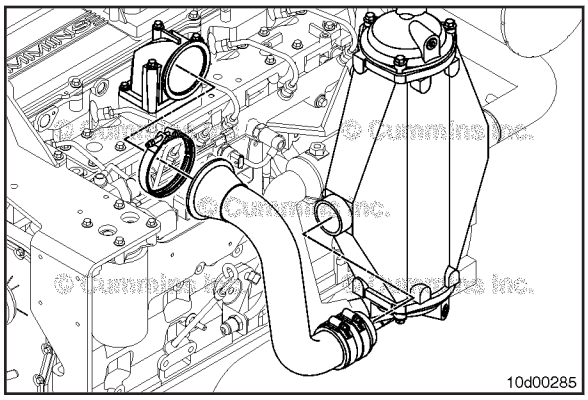
This step applies to the QSL9 marine engine.

Loosen the hose clamps at the aftercooler outlet connection.

Loosen the clamp at the air intake connection.

Remove the air intake connection adapter.

Discard the o-ring.



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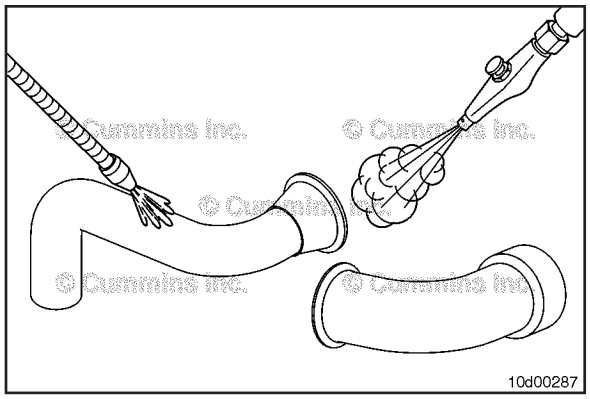


Clean and Inspect for Reuse

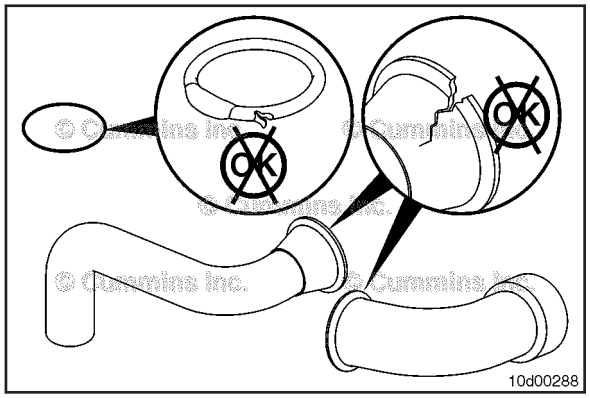
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the parts with solvent.

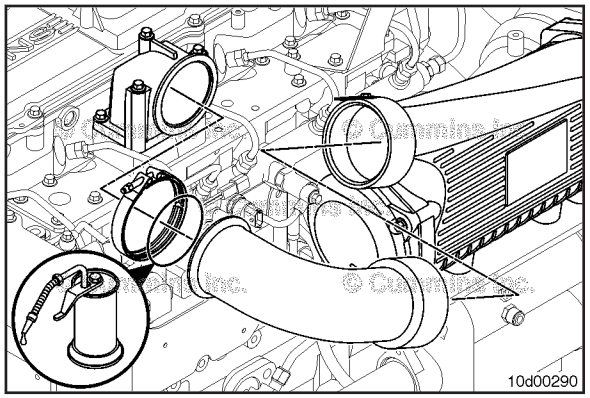
Dry with compressed air.



Inspect the parts for cracks or other damage.

Inspect the o-rings for damage.

Replace the parts if damaged.



Install

QSC Engines

This step applies to the QSC8.3 marine engine.

Install a new o-ring on the air intake connection adapter. Lubricate the o-ring with clean engine oil.

Install the adapter to the aftercooler and the air intake connection.

Install the retaining clip at the aftercooler.

Install the clamp at the air intake connection. Tighten the clamp.

Torque Value: 8 N•m [71 in-lb]

Tighten the retaining clip at the aftercooler.

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QSL Engines

This step applies to the QSL9 marine engine.

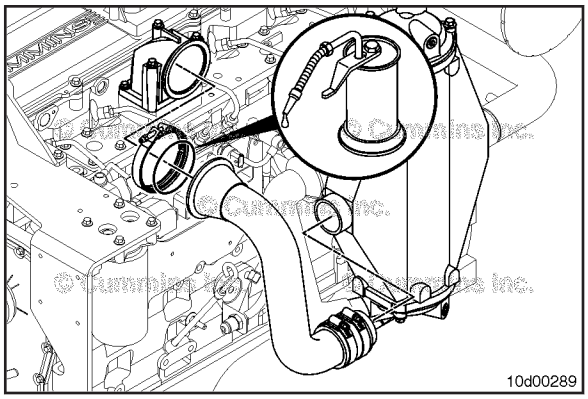
Install a new o-ring on the air intake connection adapter. Lubricate the o-ring with clean engine oil.

Install the adapter to the aftercooler outlet and the air intake connection. Tighten the clamp.

Torque Value: 8 N•m [71 in-lb]

Tighten the hose clamps at the aftercooler.

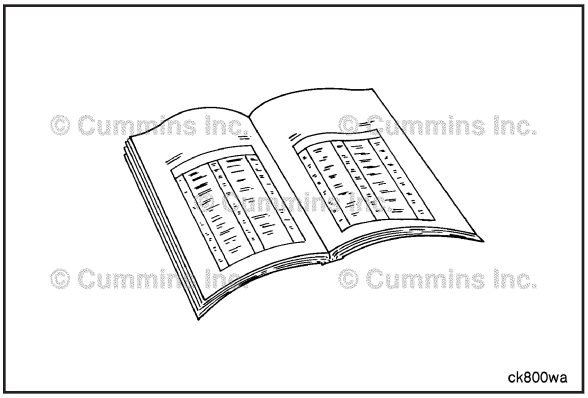
Torque Value: 8 N•m [71 in-lb]



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.

- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for boost leaks.



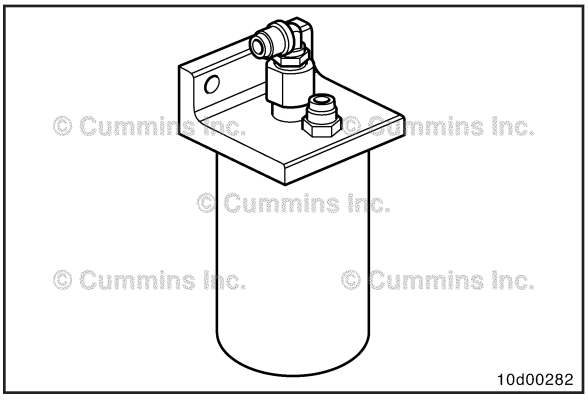
Inline Air Filter (010-133)

General Information

The inline air filter is in the line that feeds the dosing control unit. It is in the system to protect the dosing control unit from excessive oil carryover.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

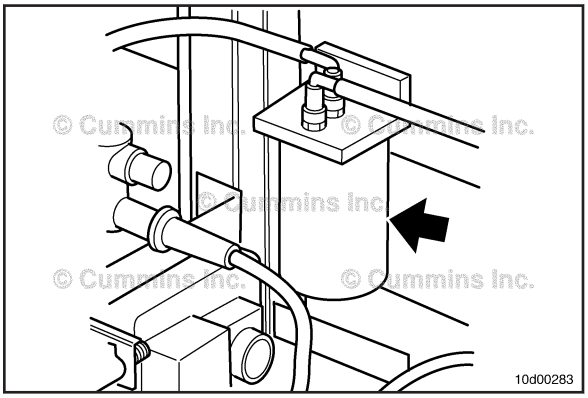
Drain down the vehicle air system before removing this filter. Refer to OEM service manual.

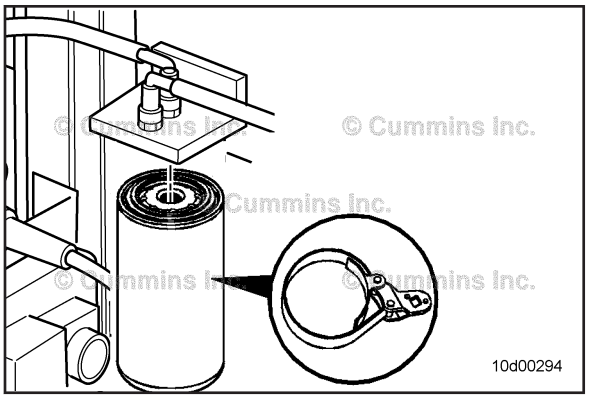


Preparatory Steps

Locate the inline air filter. Refer to the OEM service manual.

Drain down the vehicle air system. Refer to OEM service manual.



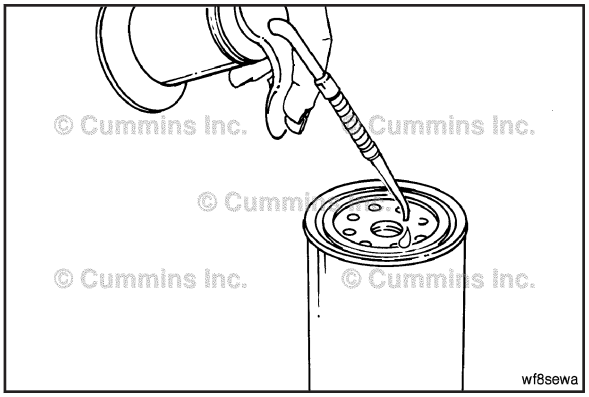


Remove

Clean the area around the inline air filter head.

Use the oil filter wrench, Part Number 3400158, to remove the filter.

Clean the sealing surface of the filter head.



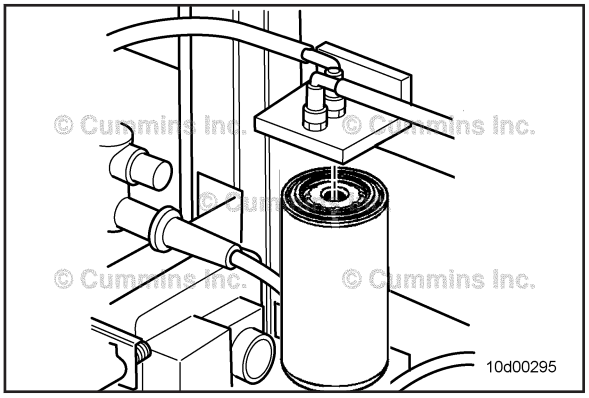
Install

Use the correct inline air filter.

See Cummins/Fleetguard®/Nelson filter specifications for the correct inline air filter part number.

NOTE: Be careful that **nothing** enters into the filter. Be careful to peel the seal back. Puncturing the seal with a knife or sharp object can create debris in the inline air filter container.

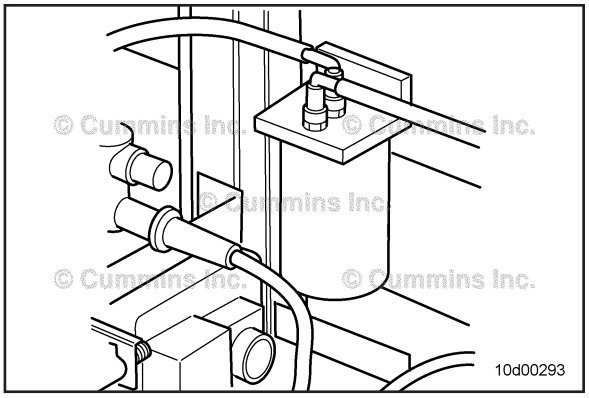
Use clean 15W-40 oil to coat the gasket surface of the filter.



△CAUTION△
Mechanical overtightening of filter can distort the threads or damage the filter element seal.

Install the filter on the inline air filter head. Tighten the filter until the gasket contacts the filter head surface.

Tighten 3/4 to 1 turn after gasket makes contact with the filter head.

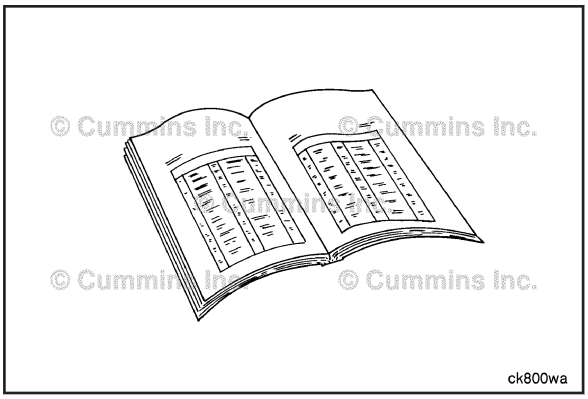


Finishing Steps

Start engine and check for leaks.

Turbocharger Exhaust Connection Adapter (010-141)

Preparatory Steps

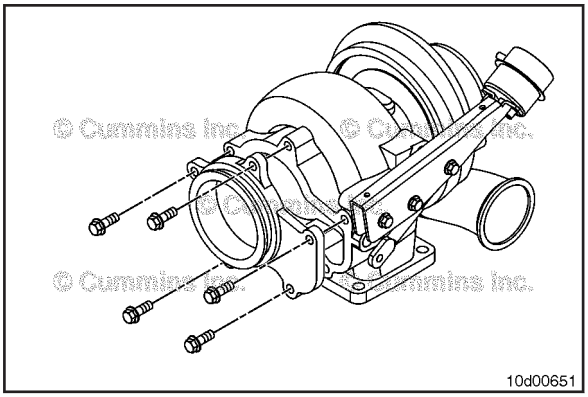


⚠WARNING⚠
The exhaust and exhaust components can remain hot after the engine has been shut down or secured. To avoid the risk of fire, property damage, burns or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they might come in contact with hot exhaust or exhaust components.

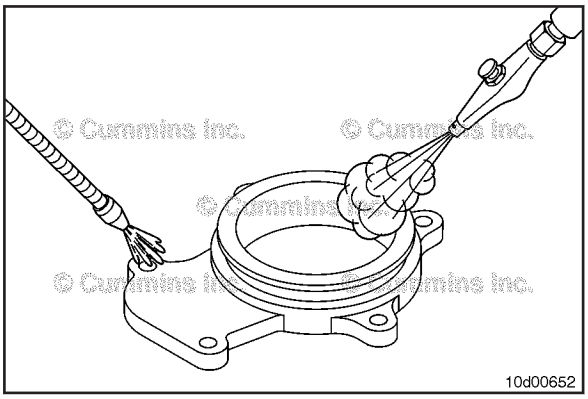
- Remove the exhaust piping from the exhaust outlet connection adapter. Refer to the OEM service manual.

Remove

Remove the five mounting capscrews and the exhaust connection adapter from the turbocharger.



Clean and Inspect for Reuse



⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠WARNING⚠
When using 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 exhaust outlet connection adapter with solvent.

Dry with compressed air.

Inspect all of the sealing surfaces for damage or other signs of leakage.

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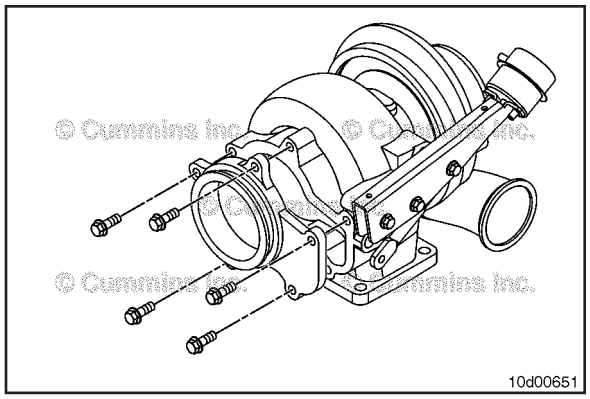
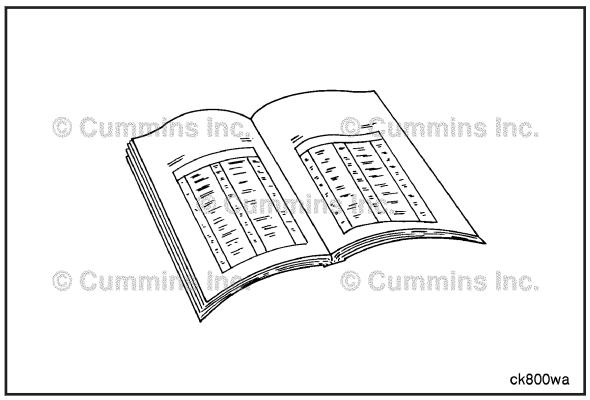


Install

Install a new gasket and the exhaust outlet connection adapter to the turbocharger.

Torque Value: 25 N•m [221 in-lb]



Finishing Steps

- Install the exhaust piping to the exhaust outlet connection adapter. Refer to the OEM service manual.
- Operate the engine and check for leaks.

Section 11 - Exhaust System - Group 11

Section Contents

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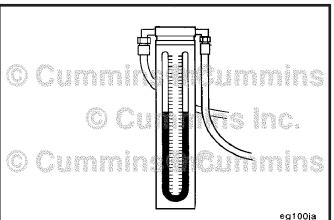
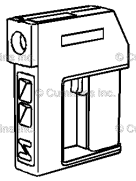
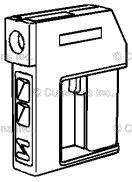
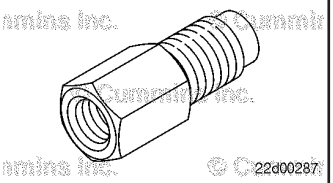
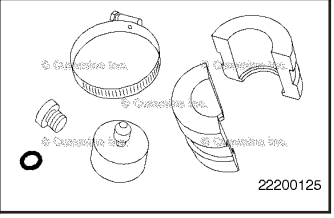
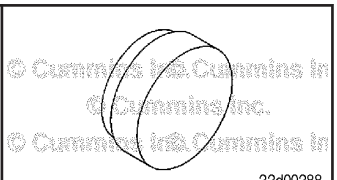
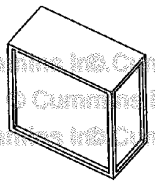
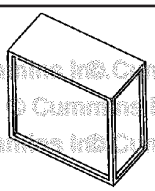
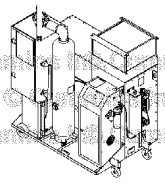
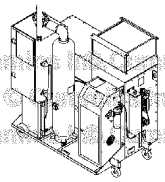
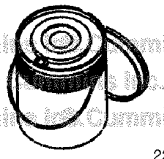
Service Tools

Exhaust System

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
ST-1111-3	**Manometer** Used to measure exhaust restriction.	
3824941	**Infrared Thermometer** Used to measure the surface temperature of exhaust components.	
3164487	**Infrared Thermometer** Used to measure the surface temperature of exhaust components.	
ST-1273	**Pressure Gauge** Used to measure inches of mercury (in Hg) pressure.	
4918576	**Exhaust Restriction/Pressure Adapter** Used to convert aftertreatment temperature sensor ports to 1/8" NPT pipe thread so that service tool ST-1273 can be used to measure exhaust pressure.	
4918625	**EGR Cooler Leak Check Kit** Used to pressure test the EGR cooler.	

Tool No.	Tool Description	Tool Illustration
4918709	**Exhaust Manifold Seal Installer** Used to install the exhaust manifold seal.	 22d00288
4918839	**Diesel Particulate Filter Cleaner HEPA Filter** Used to replace the HEPA filter on diesel particulate filter cleaner, Part Number 4918840.	 22c00333
4919054	**Diesel Particulate Filter Cleaner HEPA Filter** Used to replace the HEPA filter on diesel particulate filter cleaner, Part Number 4919052.	 22c00333
4918840	**Diesel Particulate Filter Cleaner** This machine is used with diesel particulate filter cleaner adapter kit, Part Number 4918893 or 4919182, to clean the diesel particulate filter once it is removed from the vehicle. (U.S.A. **only**. **Not** intended for use in Canada.)	 22c00331
4919052	**Diesel Particulate Filter Cleaner** This machine is used with diesel particulate filter cleaner adapter kit, Part Number 4918893 or 4919182, to clean the diesel particulate filter once it is removed from the vehicle. (For use in the U.S.A. and Canada.)	 22c00331
4918841	**Diesel Particulate Filter Cleaner Vacuum Filter** Used to replace the vacuum filter on diesel particulate filter cleaner, Part Number 4918840.	 22c00334
4918842	**Diesel Particulate Filter Cleaner Canister Filter** Used to replace the canister filters on diesel particulate filter cleaner, Part Number 4918840. Two are required per machine.	 22c00335
4919053	**Diesel Particulate Filter Cleaner Canister Filter** Used to replace the canister filters on diesel particulate filter cleaner, Part Number 4919052. Two are required per machine.	 22c00335

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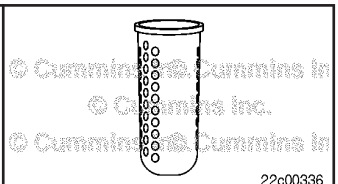
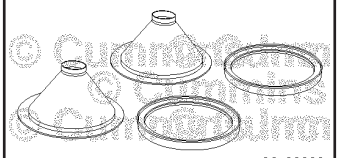
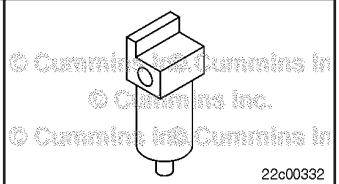
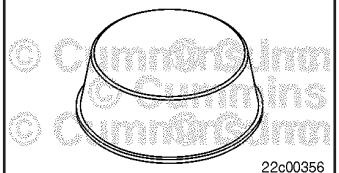
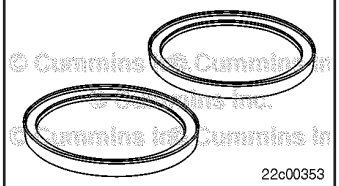
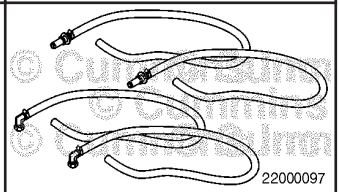
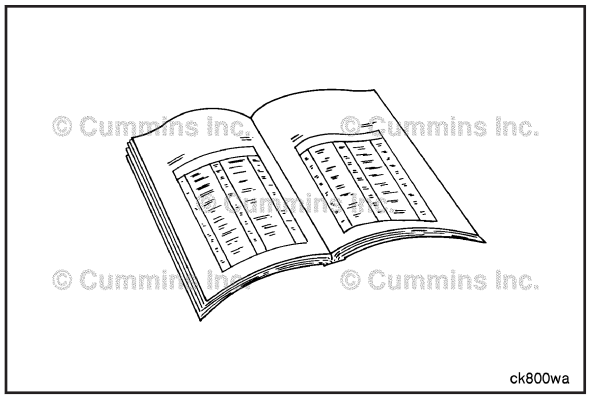
Tool No.	Tool Description	Tool Illustration
4918851	**Diesel Particulate Filter Cleaner Water Separator** Used to replace the water separator on diesel particulate filter cleaner, Part Number 4918840.	 22c00336
4919172	**Diesel Particulate Filter Cleaner Adapter Kit** Used with Part Number 4919052 to adapt the diesel particulate filter to the cleaner. Software unlock card, Part Number 4919055, is included in this adapter kit to upload the required cleaning parameters.	 22c00329
4918896	**Diesel Particulate Filter Cleaner Oil Separator Filter** Used to replace the oil separator filter on diesel particulate filter cleaner, Part Number 4918840.	 22c00332
4919508	**Air Handling Clean Care Kit** Contains a variety of caps to prevent contamination of vehicle air handling plumbing during service procedures.	 22c00356
4919182	**Diesel Particulate Filter Cleaner Adapter Kit** Used with Part Number 4919052 or 4918840, to adapt an aftermarket or reto-fit diesel particulate filter to the cleaner.	 22c00353
5298701	**Diesel Exhaust Fluid Leak Test Kit** Used with vacuum pump, Part Number 3162422, to identify leaks, restrictions and malfunctioning connectors in diesel exhaust fluid lines.	 22000097



Exhaust Manifold, Dry (011-007)

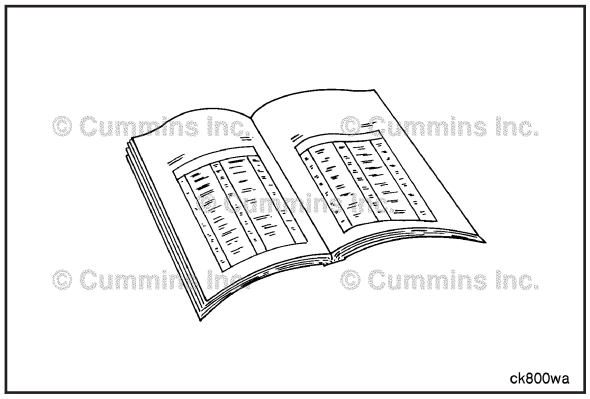
Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

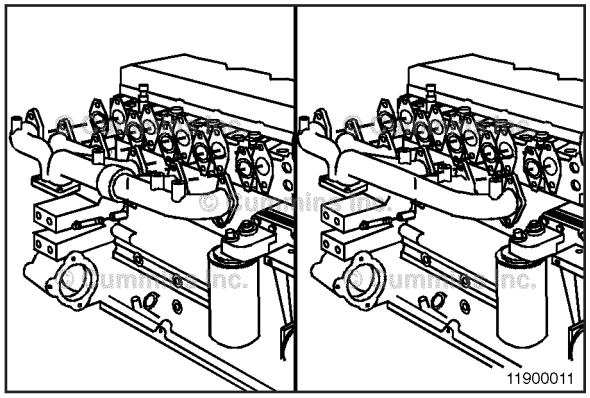
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

NOTE: Brush away all dirt from around the area of the air handling connections to avoid contamination of the interior of the engine.



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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 air crossover tube and charge-air cooler hose. Refer to Procedure 010-019 in Section 10.
- Disconnect the air intake and exhaust piping. Refer to Procedure 010-022 in Section 10.
- Remove the turbocharger. Refer to Procedure 010-033 in Section 10.



Remove

NOTE: Apply a thin coating of nickel-based, high-temperature compound grease to the coarse threads of the manifold capscrews, after removal.

Remove the capscrews, exhaust manifold, and gaskets.

Use heavy tape to cover open points in the exhaust manifold and cylinder head.

Disassemble

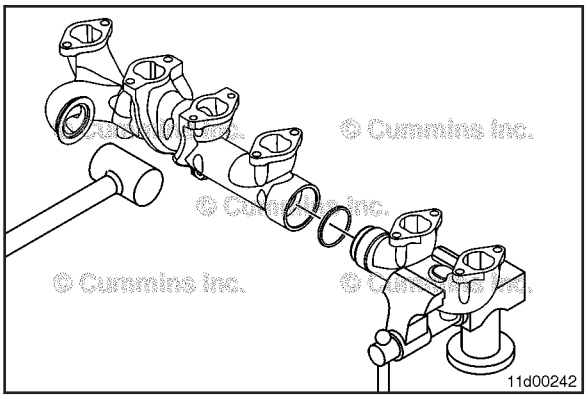
Use a vise to clamp on one section of the exhaust manifold.

Do **not** allow the jaws of the vise to contact the exhaust manifold sealing surfaces.

Use a soft-faced mallet to lightly tap on the other section of the exhaust manifold to separate it from the section held in the vise.

Use heavy tape to cover open points in the exhaust manifold and cylinder head.

NOTE: If the exhaust manifold will **not** separate, it may be necessary to heat the manifold in the slip joint area to allow for separation of the manifold.

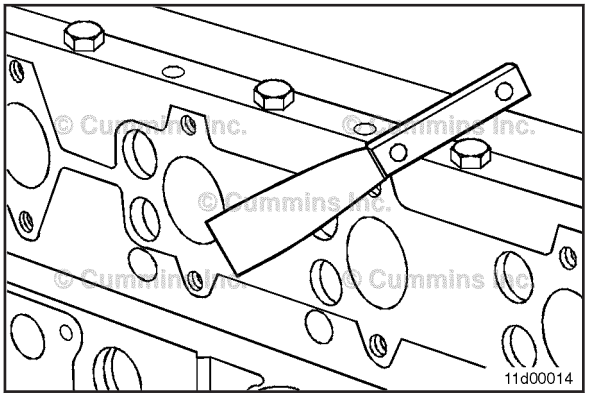


Clean and Inspect for Reuse

Clean the sealing surfaces of the head and exhaust manifold.

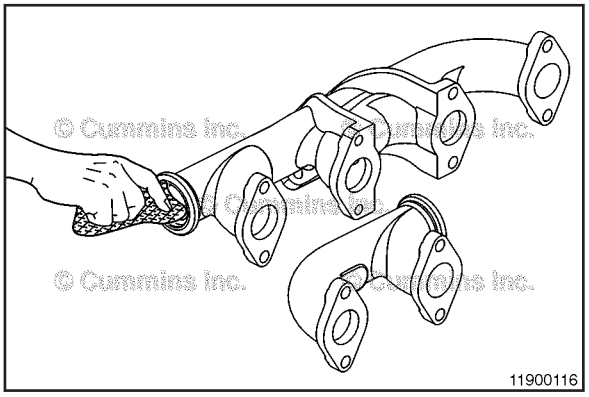
Use 240-grit emery cloth to remove carbon deposits from the sealing surfaces.

Take caution to keep debris out of the cylinder head.



Multi-piece **Only**:

Clean the multi-piece sealing joint.

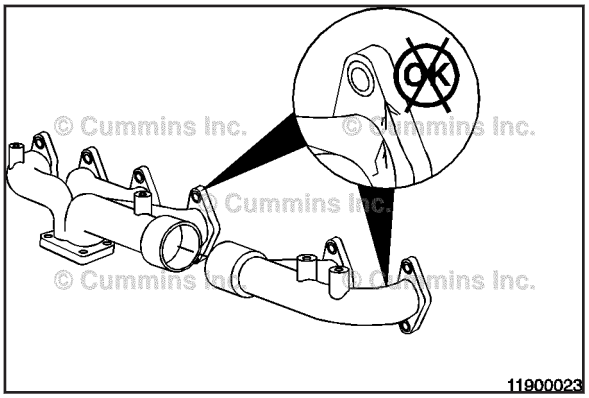


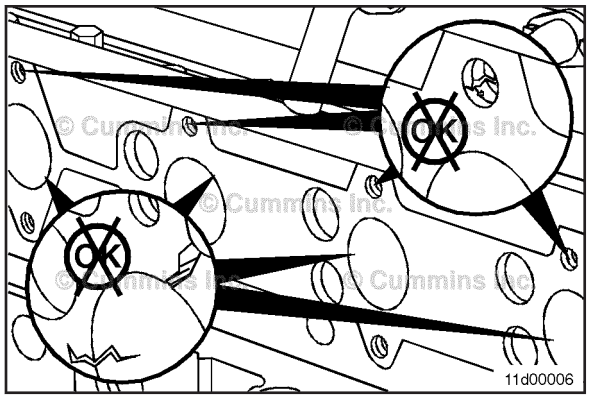
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

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

Use steam to clean the exhaust manifold.

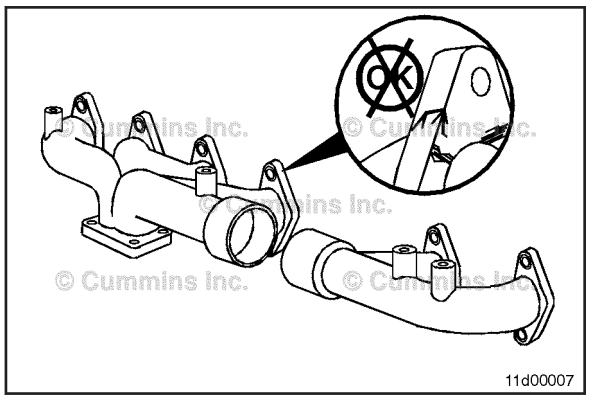
Dry with compressed air.





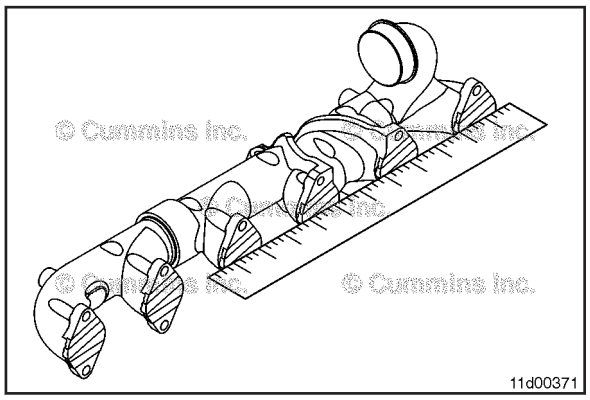
Inspect the cylinder head bosses and turbocharger mounting studs for damage. Repair or replace as necessary.

NOTE: If the exhaust manifold is damaged, check the charge-air cooler. A damaged charge-air cooler can cause progressive damage to the exhaust manifold. Refer to Procedure 010-027 in Section 10.



Inspect the gasket surfaces for gouges, scratches, or burnout.

Inspect the exhaust manifold for cracks, soot streaking, leaks, and burnout.



Measure the manifold surface for flatness. Place a ruler over all exhaust ports in the manifold section . Measure, with a feeler gauge, the gap between the port surface and the ruler.

Exhaust Manifold Flatness		
mm		**in**
0.30	MAX	0.012

If any port measures out of specification, replace the manifold.

NOTE: For multi-piece manifolds, each section **must** be verified to be flat independently.

The assembled two-piece or three-piece manifold are **not** required to meet the flatness specification of an one piece manifold, as some misalignment is allowed for in the design of the manifold. Some misalignment will be eliminated when the manifold capscrews are tightened to specification during installation.

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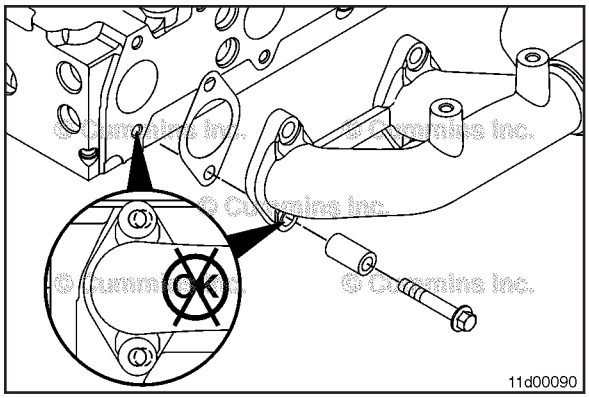
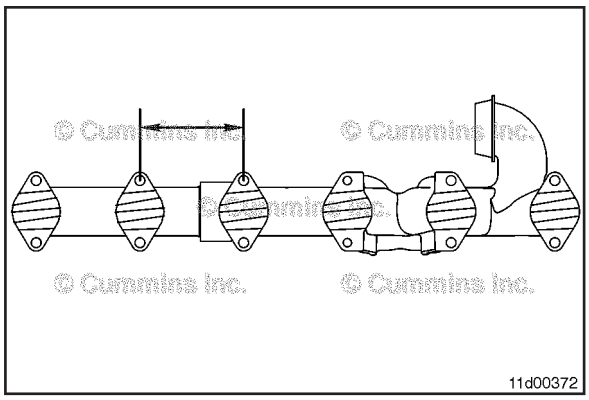
Check the manifold-to-cylinder head fit. If the manifold mounting capscrew holes do **not** line up with the tapped holes in the cylinder head, replace the exhaust manifold.



Install

Measure the distance between the center of the mounting holes of the ports with a slip joint between them.

If the distance is **not** within specification, put the manifold on a flat surface with the ports face down and lightly tap the manifold with a soft-faced mallet until the measurements are within specification.



Manifold Section Distance		
mm		**in**
136	MIN	5.35
138	MAX	5.43

Install the manifold assembly on the engine by first inserting the capscrews through the top of the port. Use new gaskets on all cylinders.

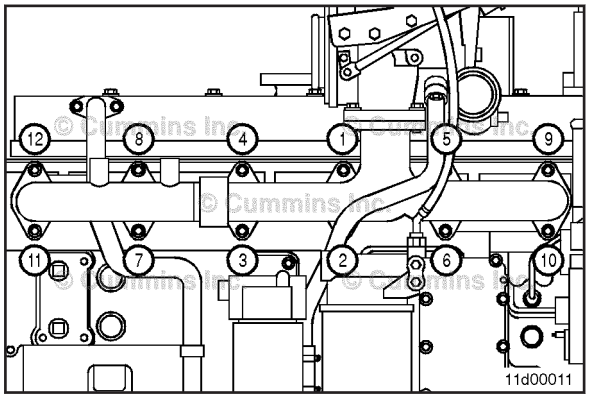
Lubricate the capscrews prior to installation.

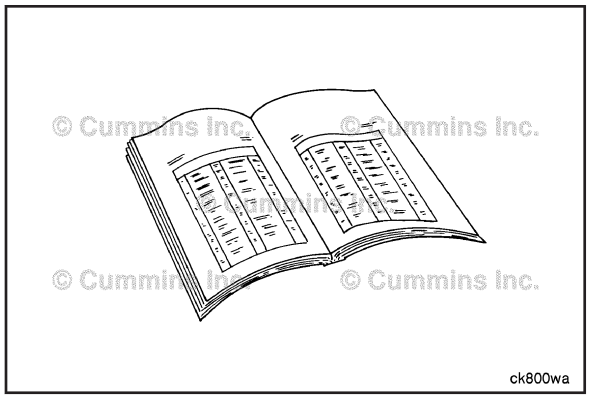
Insert the capscrews into the bottom of the exhaust ports and gaskets.

Tighten the exhaust manifold mounting capscrews.

Torque Value:
Exhaust Manifold Mounting Capscrews 53 N•m [39 ft-lb]

Follow the tightening sequence as shown in the illustration.





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 turbocharger. Refer to Procedure 010-033 in Section 10.
- Connect the air intake and exhaust pipe. Refer to Procedure 010-022 in Section 10.
- Connect the charge-air cooler hose and crossover tube. Refer to Procedure 010-019 in Section 10.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

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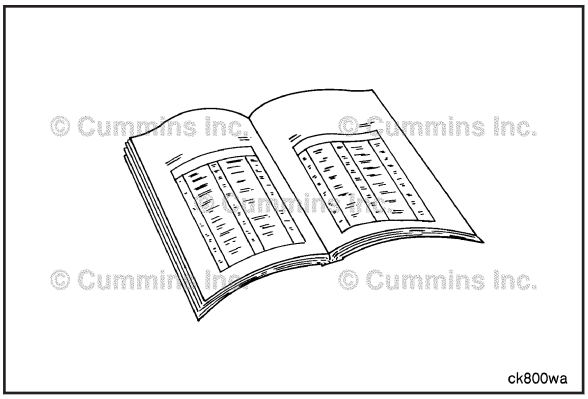
Exhaust Manifold, Wet (011-008)

Preparatory Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

△CAUTION△
Use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

△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 heat exchanger to prevent damage to components downstream in the sea water system.

NOTE: This procedure applies to marine engines **only**.

NOTE: If a check for a turbocharger gasket leak is being performed, do **not** break the seal between the turbocharger and the exhaust manifold. Remove the two components as one assembly.

- Disconnect the batteries. Refer to Procedure 013-009.
- Close the sea water supply valve(s). Refer to the OEM service manual.
- Drain the sea water from the heat exchanger by removing the zinc plug from the bottom of the heat exchanger. Refer to Procedure 008-052 or 008-053.
- Drain the engine coolant. Refer to Procedure 008-018.
- Remove the exhaust outlet connection. Refer to Procedure 011-017.
- Remove the turbocharger heat shield. Refer to Procedure 011-032.
- Remove the coolant expansion tank, if equipped. Refer to Procedure 008-052.
- Remove the coolant heat exchanger. Refer to Procedure 008-053.

NOTE: If the turbocharger and exhaust manifold are to be removed as an assembly, then continue on with the following steps. If **not**, refer to Procedure 010-033.

- Disconnect the closed crankcase system from the rocker lever cover, if equipped. Refer to Procedure 003-020.
- Remove the air crossover from the turbocharger. Refer to Procedure 010-019.
- Remove the turbocharger coolant hoses from the turbocharger. Refer to Procedure 010-041.
- Remove the turbocharger oil drain line from the turbocharger. Refer to Procedure 010-045.
- Remove the turbocharger oil supply line from the turbocharger. Refer to procedure 010-046.
- Remove the coolant vent line. Refer to Procedure 008-017.

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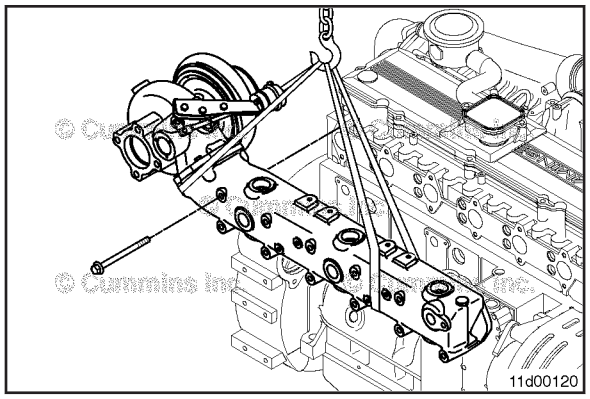


Remove

⚠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.

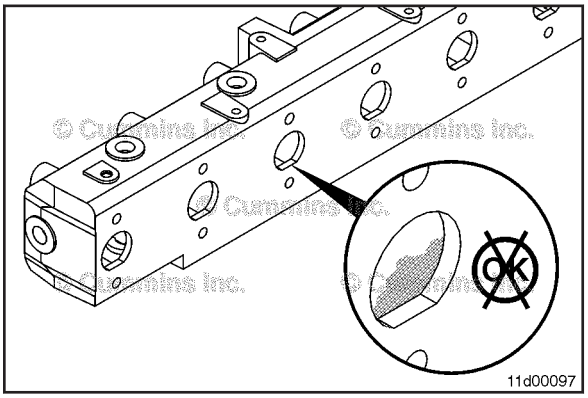
Remove the coolant supply line.

Loosen two capscrews and leave them in place to hold the weight of the exhaust manifold.

Remove the remaining 10 exhaust manifold mounting capscrews.

Attach a lifting device to support the weight of the exhaust manifold.

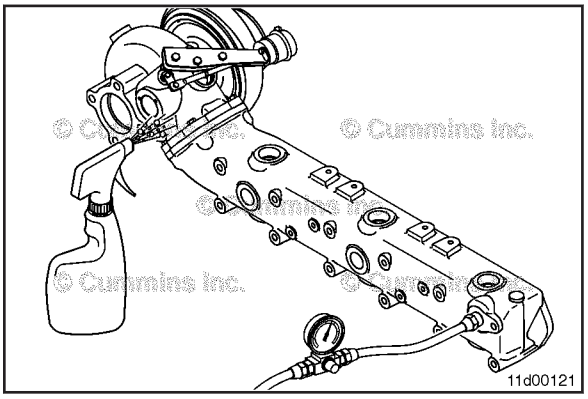
Remove the two remaining mounting capscrews and the exhaust manifold.



Clean and Inspect for Reuse

Inspect all the sealing surfaces.

Inspect the inside of the exhaust manifold for possible signs of leakage (rust marks, antifreeze stains, carbon washed away).



△CAUTION△
If the turbocharger was not removed from the exhaust manifold, do not place the turbocharger into water. Damage to the turbocharger will occur if water enters any of the turbocharger openings.

Plug all open coolant passages.

If the turbocharger was **not** removed from the exhaust manifold, pressure test the exhaust manifold and turbocharger as a unit.

Check all sealing surfaces with soapy water for possible leaks.

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⚠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.

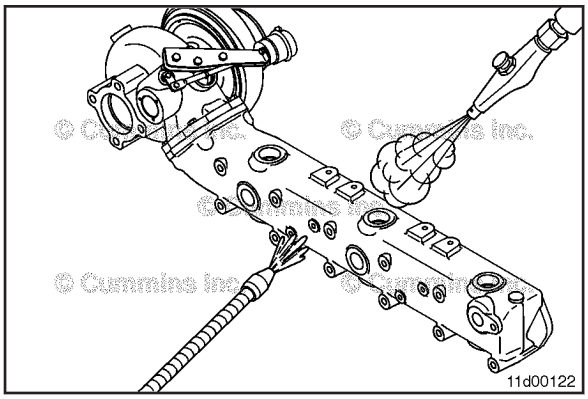
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△
Cover all openings of the turbocharger before cleaning or repainting the exhaust manifold. Damage will result if paint enters the turbocharger.

If no leaks are found, clean and repaint the exterior surfaces of the exhaust manifold.

Use solvent to clean the turbocharger and exhaust manifold assembly.

Dry with compressed air.



Install

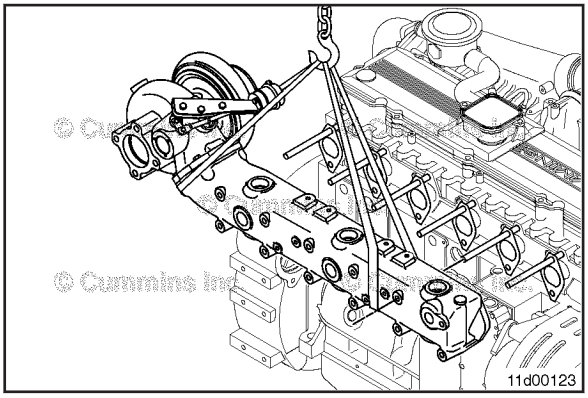
⚠WARNING⚠
This assembly weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this assembly.

NOTE: The exhaust manifold gaskets are bi-directional and can be installed in either direction.

Install six guide pins into the cylinder head to aid in installing the exhaust manifold assembly.

Install new exhaust manifold gaskets over the studs.

Use a hoist to install the exhaust manifold over the guide studs.



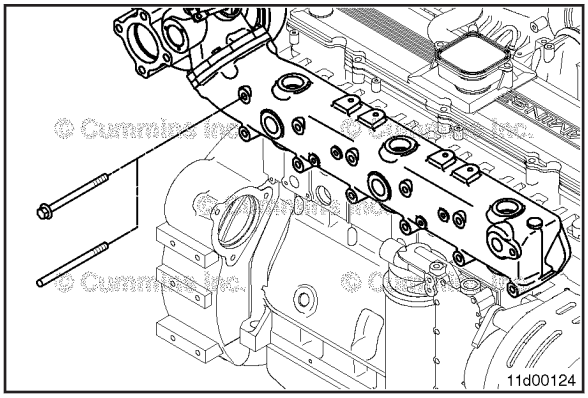
Install the upper six capscrews, but do **not** tighten at this time.

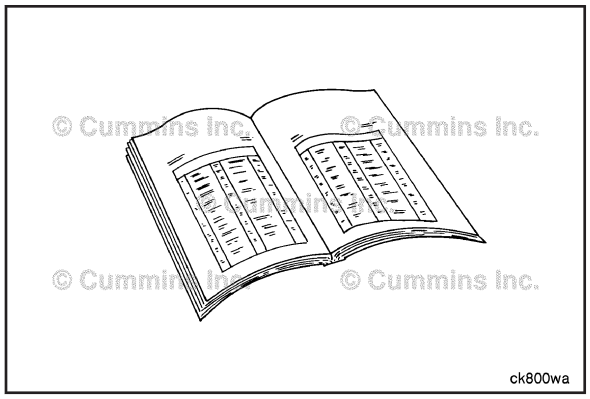
Remove the guide pins one at a time and install the mounting capscrew. Make sure the gaskets stay in place during this process.

Tighten the capscrews in a crisscross pattern from the center out.

Torque Value: 43 N•m [32 ft-lb]

Install the exhaust manifold coolant supply line.





Finishing Steps

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

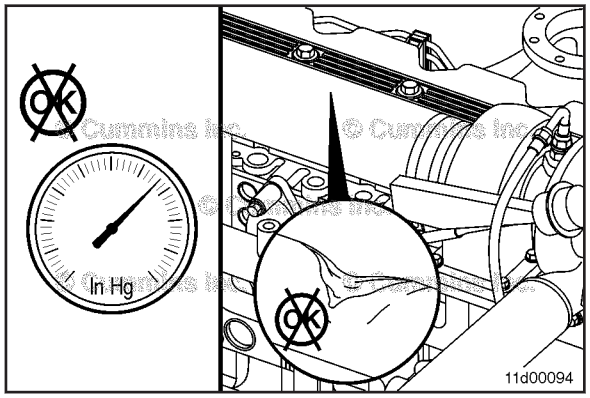
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the coolant vent lines. Refer to Procedure 008-017.

NOTE: If the turbocharger and exhaust manifold were removed as an assembly, then continue on with the following steps. If **not**, refer to Procedure 010-033 to install the turbocharger.

- Install the turbocharger oil supply line to the turbocharger. Refer to Procedure 010-046.
- Install the turbocharger oil drain line to the turbocharger. Refer to Procedure 010-045.
- Install the turbocharger coolant hoses. Refer to Procedure 010-041.
- Install the air crossover to the turbocharger. Refer to Procedure 010-019.
- Connect the closed crankcase system, if equipped. Refer to Procedure 003-020.
- Install the coolant heat exchanger. Refer to Procedure 008-053.
- Install the coolant expansion tank, if equipped. Refer to Procedure 008-052.
- Install the turbocharger heat shield. Refer to Procedure 011-032.
- Install the exhaust outlet connection. Refer to Procedure 011-017.
- Fill the engine with coolant. Refer to Procedure 008-018.
- Open the sea water supply valve(s).
- Connect the batteries. Refer to Procedure 013-009.

Operate the engine and check for leaks.



Exhaust Restriction (011-009)

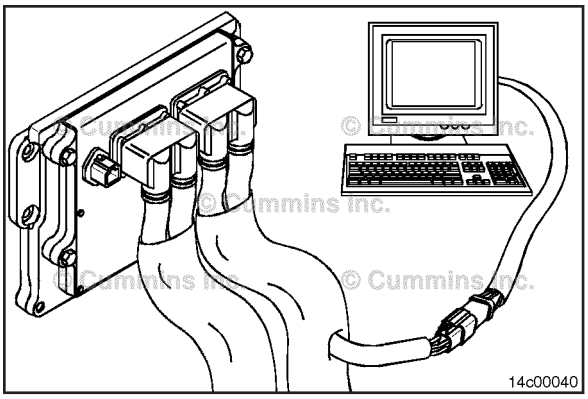
General Information

When measuring exhaust restriction, it is preferred that the measurement point be within one pipe diameter of the turbocharger outlet.

If this requirement can **not** be met, make sure to inspect the exhaust outlet tubing between the turbocharger outlet and the exhaust pressure tap location for damage to the exhaust piping.

Initial Check

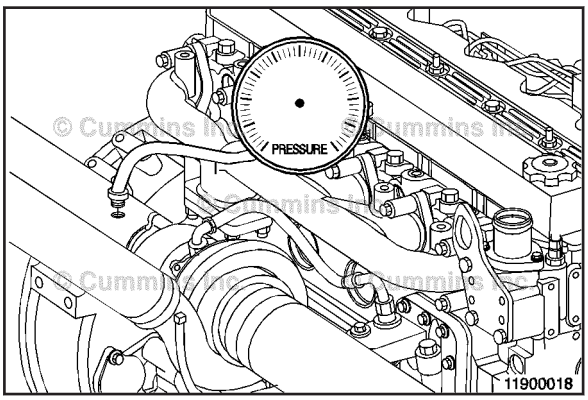
Use INSITE™ electronic service tool to check for fault codes. If any are present, follow the troubleshooting steps as outlined in the corresponding fault code troubleshooting procedure.



Measure

Connect pressure gauge, Part Number ST-1273, to the pressure tap in the exhaust head pipe or at the inlet of the muffler, diesel oxidation catalyst, or exhaust gas filter.

Operate the engine at rated speed and load. Record the exhaust restriction. Compare the measured restriction to the exhaust system specifications in the following procedure. Refer to Procedure 018-020 in Section V.

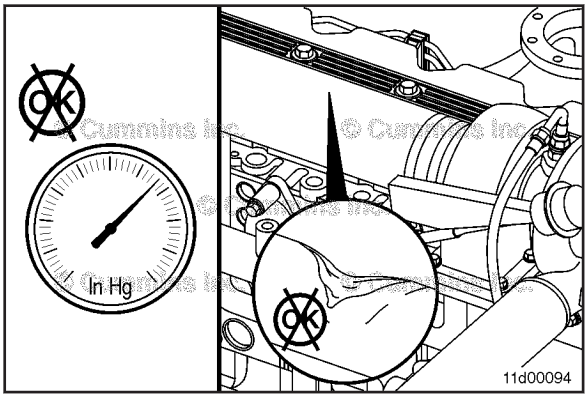


If the exhaust restriction exceeds the specifications inspect:

1 The exhaust piping for damage. Refer to the original equipment manufacturer (OEM) service manual.

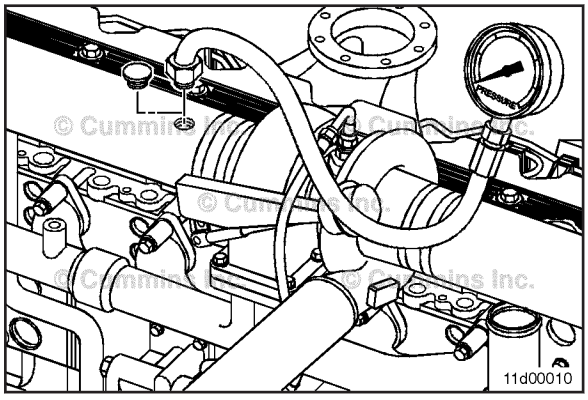
2 The diesel oxidation catalyst and/or muffler. Refer to the OEM service manual.

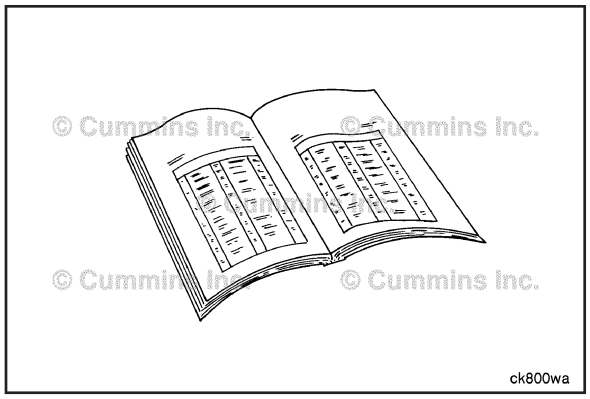
3 The exhaust gas filter (if equipped). Refer to the OEM service manual.



Remove the test equipment.

Install and tighten the pipe plug.





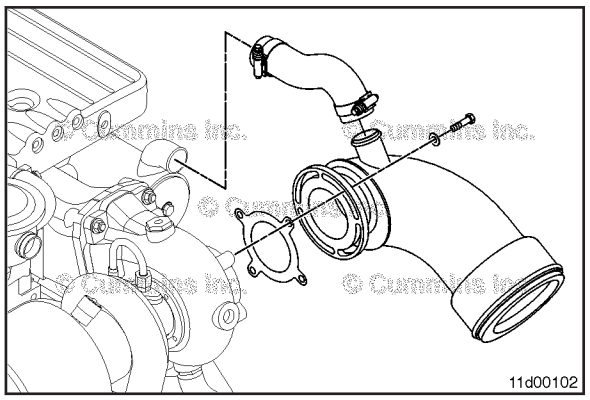
Exhaust Outlet Connection (011-017)

Preparatory Steps

⚠CAUTION⚠

Before disconnecting the exhaust outlet piping, be sure to fasten the piping above the water level to prevent the vessel from taking on water and possibly sinking.

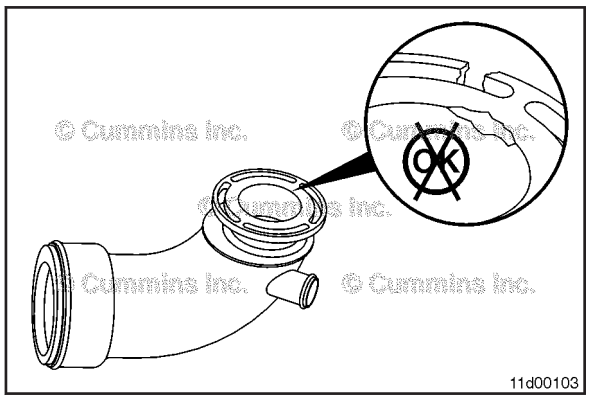
- Close the sea water supply valve(s). Refer to the OEM service manual.
- Remove the exhaust piping from the exhaust outlet connection. Refer to the OEM service manual.



Remove

Loosen the hose clamps and remove the hose from the heat exchanger and the exhaust outlet connection.

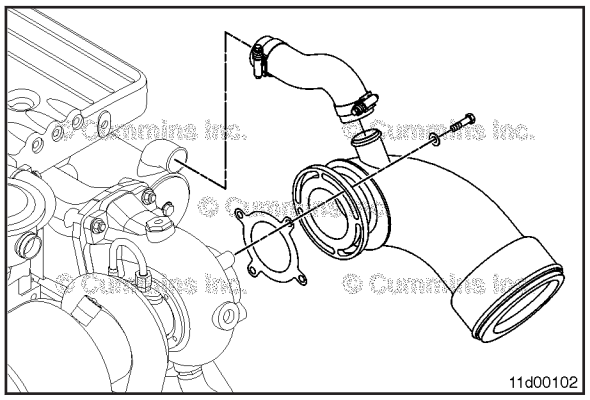
Remove the mounting capscrews and the exhaust outlet connection from the turbocharger.



Clean and Inspect for Reuse

Inspect all the sealing surfaces and gasket for damage or other signs of leakage.

Inspect the inside of the connection to make sure no water passages are blocked.



Install

Install a new gasket and the exhaust outlet connection to the turbocharger.

Tighten the mounting capscrews.

Torque Value: 24 N•m [18 ft-lb]

Install the hose on the heat exchanger and the exhaust outlet connection. Tighten the hose clamps.

Torque Value: 8 N•m [71 in-lb]

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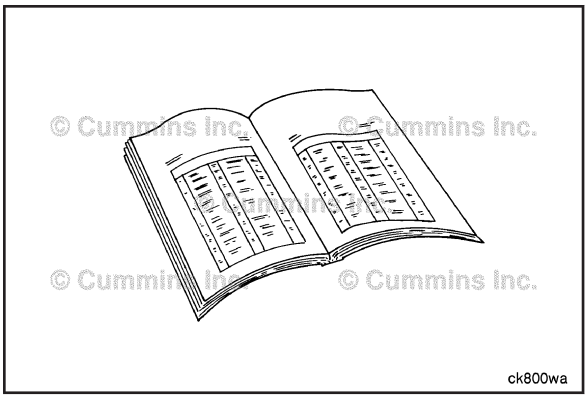
Finishing Steps

- Install the exhaust piping to the exhaust outlet connection. Refer to the OEM service manual.
- Open the sea water supply valve(s). Refer to the OEM service manual.

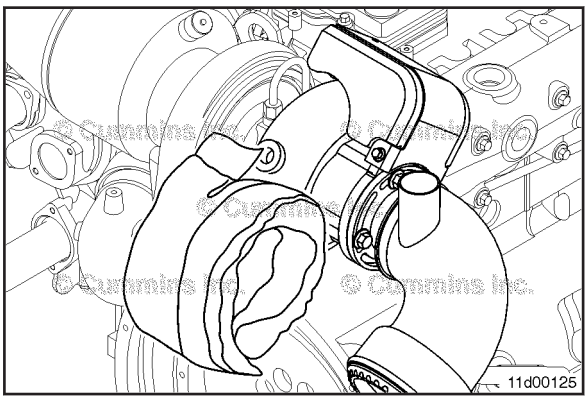
Operate the engine and check for leaks.



Heat Shield (011-032)

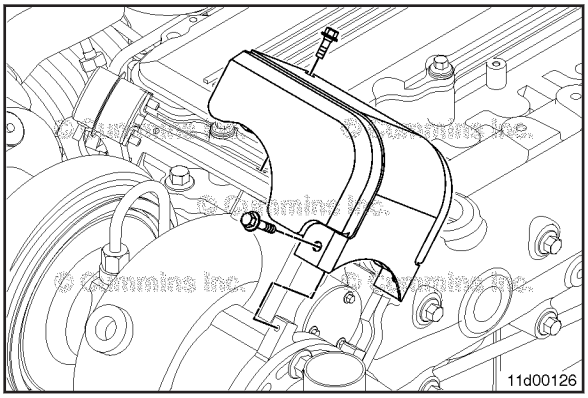
Remove

Remove the heat shield insulation wrapping from the turbine housing.



Remove the wastegate actuator heat shield mounting capscrews.

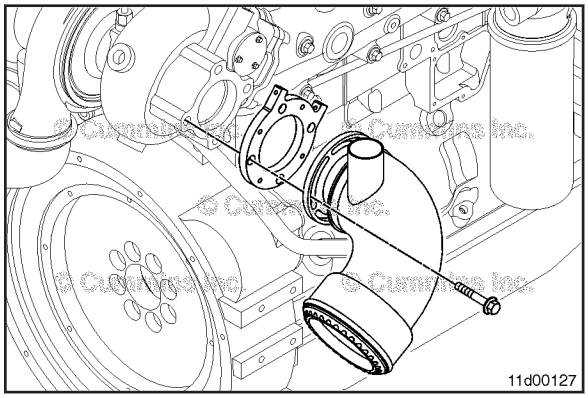
Remove the insulation and heat shield.

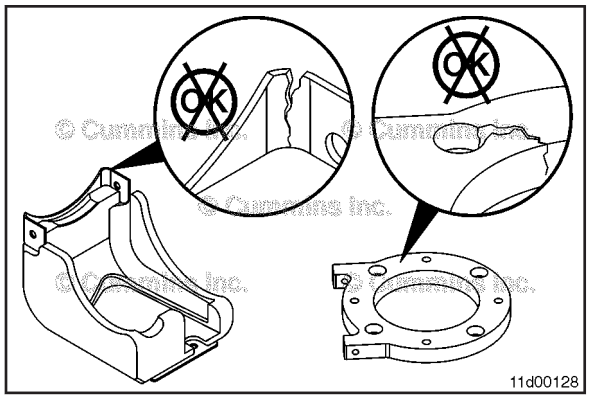


⚠CAUTION⚠
Be sure to tie the exhaust piping up above the water line to prevent water from feeding back into the vessel while the exhaust piping is removed. Failure to do so can result in the vessel sinking.

Remove the exhaust outlet connection. Refer to Procedure 011-017.

Tap the heat shield mounting bracket and remove the bracket from the exhaust flange.



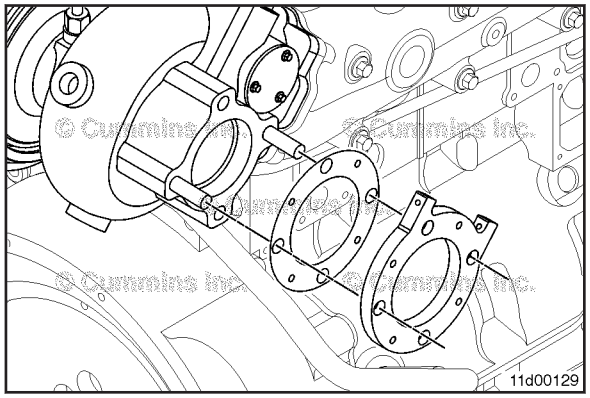


Clean and Inspect for Reuse

Clean the gasket sealing surfaces.

Inspect the mounting area and the sheet metal for cracks.

Replace the heat shield if damage or cracks are found.



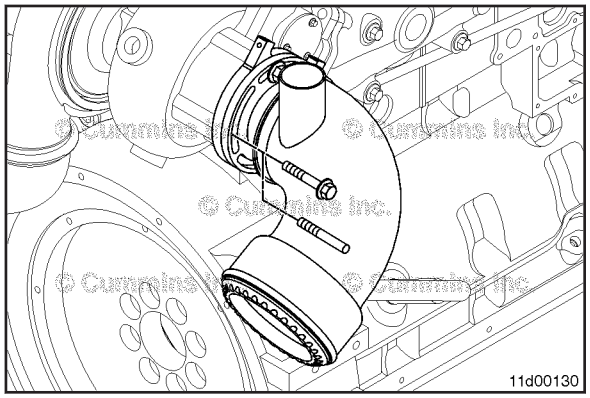
Install

Install two guide pins in the turbine outlet to hold the gasket and heat shield mount.

Install a new gasket.

Place the heat shield mount on the guide pins.

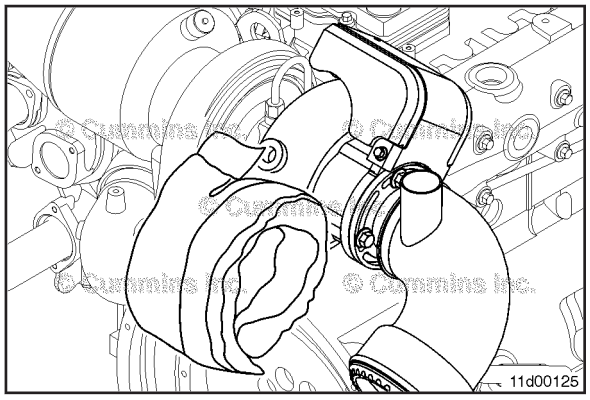
Install a new exhaust outlet gasket.



Install the exhaust outlet connection and the lower mounting capscrews.

Remove the guide pins.

Refer to Procedure 011-017.



Install the wastegate actuator heat shield mounting capscrews.

Install the insulating wrap.

Operate the engine and check for leaks.

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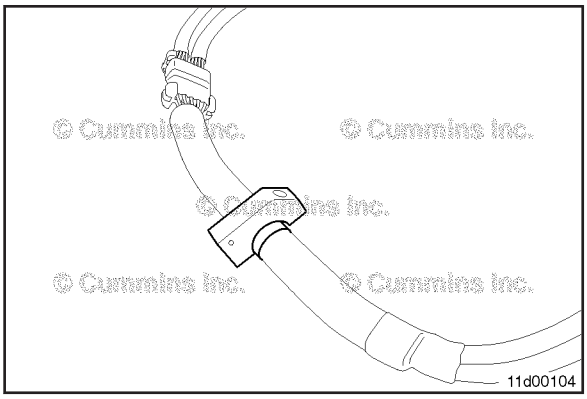
Exhaust Gas Treatment Monitor Unit (011-035)

General Information

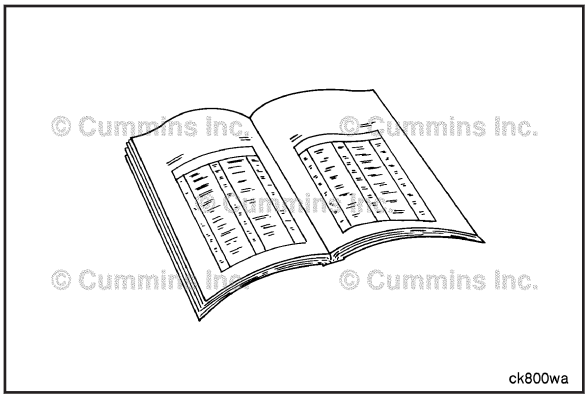


The exhaust gas treatment monitor unit needs to be reset after removal and installation of the following components:

- exhaust gas pressure sensor
- exhaust gas temperature sensor
- exhaust gas treatment monitor harness.

To reset, pass a magnet over the white strip in the center of the exhaust gas treatment monitor unit. The exhaust gas treatment fault code and maintenance lamps on the vehicle dashboard will flash twice to signify that the exhaust gas treatment monitor unit has been reset.

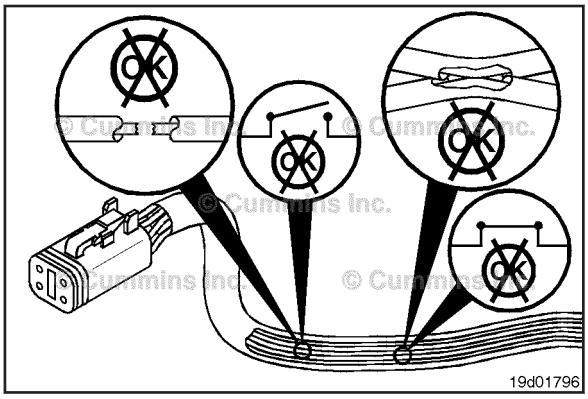
Remove



Disconnect the power leads. Refer to the vehicle manufacturer's service manual.

Disconnect the exhaust gas treatment monitor harness. Refer to Procedure 011-038.

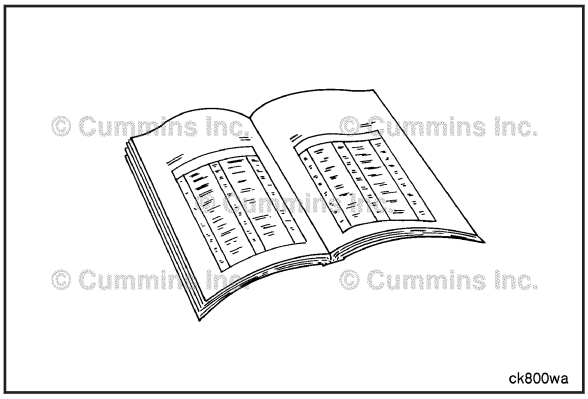
Inspect for Reuse



Inspect the connectors for any damage, or bent or broken pins. Repair or replace, if necessary.

Inspect for damaged or exposed wires. Repair or replace, if necessary.

Install



Connect the exhaust gas treatment monitor harness. Refer to Procedure 011-038.

Connect the power leads. Refer to the vehicle manufacturer's service manual.

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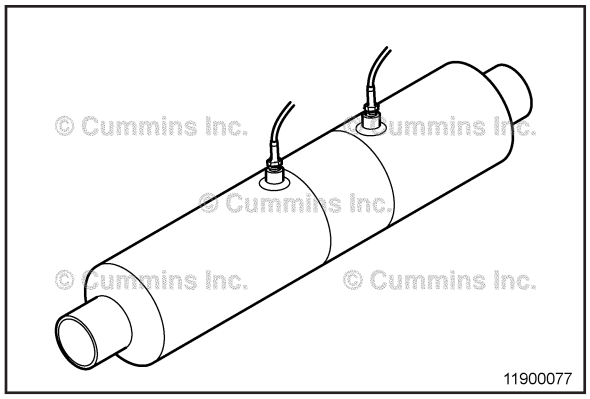

Aftertreatment Selective Catalytic Reduction (SCR) Catalyst (011-036)

General Information

ISLe4 Engines

⚠WARNING⚠
The exhaust and exhaust components can remain hot after the vehicle stopped moving. To reduce the risk of fire, property damage, burns or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they are likely to come in contact with hot exhaust or exhaust components.

⚠WARNING⚠
The catalyst substrate contains Vanadium Pentoxide. Vanadium Pentoxide has been determined by the State of California to cause cancer. Always wear protective gloves, dust mask 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. Refer to the Materials Safety Data Sheet (MSDS) for additional information.

⚠WARNING⚠
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. Do not cut open the exhaust catalyst assembly.

⚠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.

Due to the number of various exhaust aftertreatment applications, this procedure has been written to be generic. **Not** all illustrations within this procedure will represent the application being serviced.

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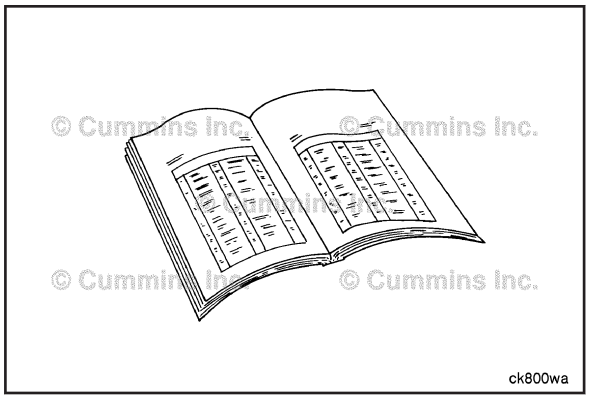
Preparatory Steps

ISL Engines

⚠WARNING⚠
The exhaust and exhaust components can remain hot after the vehicle stopped moving. To reduce the risk of fire, property damage, burns or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they are likely to come in contact with hot exhaust or exhaust components.

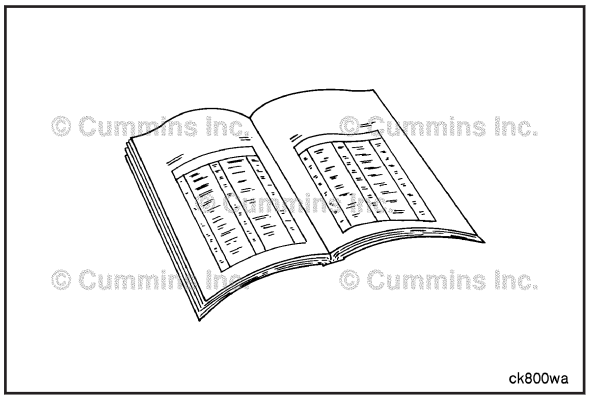
- Disconnect the exhaust gas temperature sensor, if necessary. Refer to Procedure 011-037 in Section 11.
- Disconnect the exhaust gas pressure sensor, if necessary. Refer to Procedure 011-039 in Section 11.



ISLe4 Engines

⚠WARNING⚠
The exhaust and exhaust components can remain hot after the vehicle stopped moving. To reduce the risk of fire, property damage, burns or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they are likely to come in contact with hot exhaust or exhaust components.

- Disconnect the exhaust gas temperature sensor, if necessary. Refer to Procedure 011-037 in Section 11.



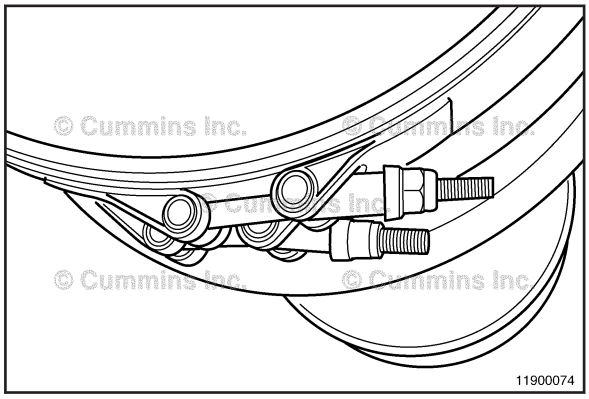
Remove

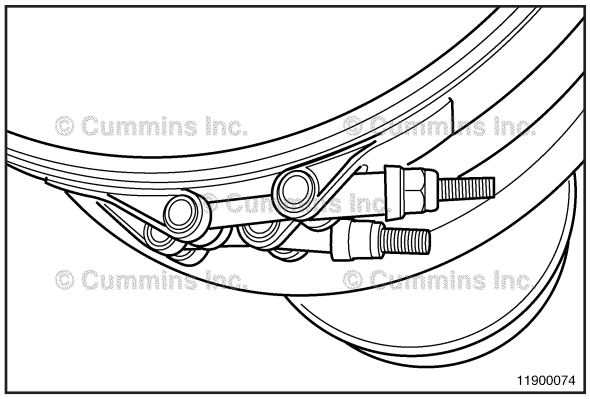
ISL Engines

⚠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 exhaust gas filter assembly from the vehicle. Refer to the vehicle manufacturer's service manual.

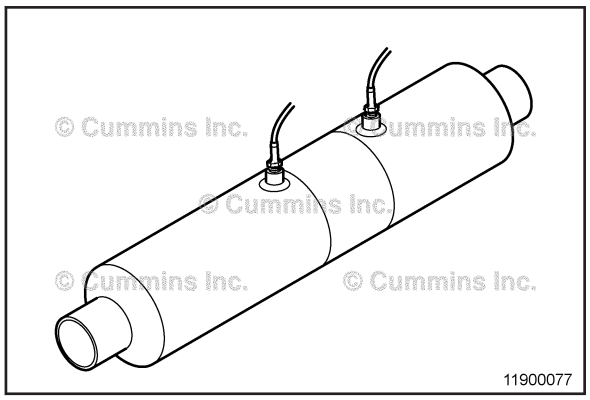
NOTE: It may be possible to remove the V-band clamps and separate the exhaust gas filter as listed in the Disassemble step with the exhaust gas filter assembly still installed in the vehicle.





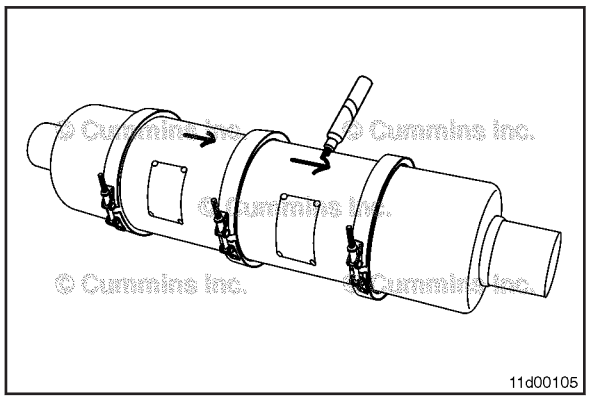
ISLe4 Engines

Disconnect the OEM exhaust connections. Refer to the OEM service manual.



⚠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.

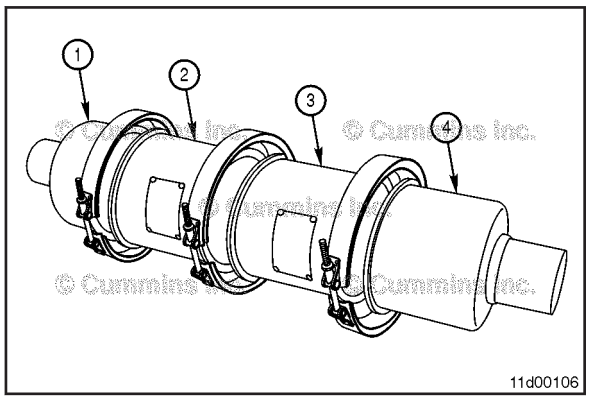
Lower the exhaust catalyst from the underside of the vehicle/application.



Disassemble

ISL Engines

Mark the direction of exhaust flow on both the exhaust gas filter catalyst section and the exhaust gas filter section to aid in assembly.



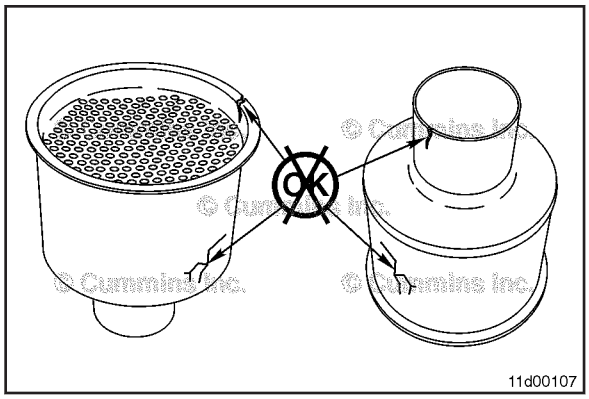
Remove the V-band clamps holding the sections together. Separate the mating sections by approximately 13 mm [0.5 in] to allow removal over the gasket retainer rings.

Discard the gaskets.

Clean and Inspect for Reuse

ISL Engines

Check the inlet and outlet sections for any cracks or damage. Replace if necessary.

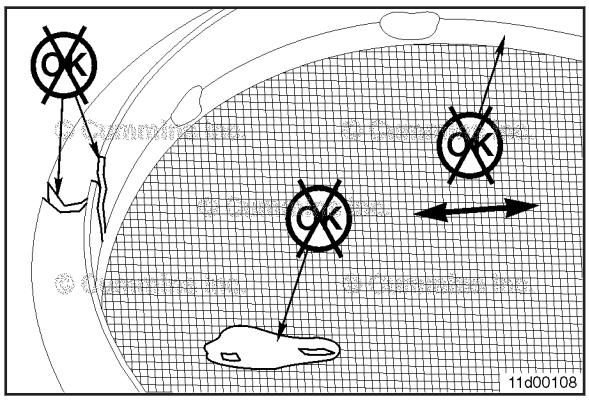


Check the inlet and outlet face of the catalyst section for:

Fuel, oil, or coolant buildup. A fluid soaked exhaust gas catalyst will have a glossy sheen and a strong fuel or oil odor. Replace the exhaust gas filter catalyst section if any damage is found.

Cracks or gouges deeper than 4 mm [0.156 in]. Replace the exhaust gas filter catalyst section if any damage is found.

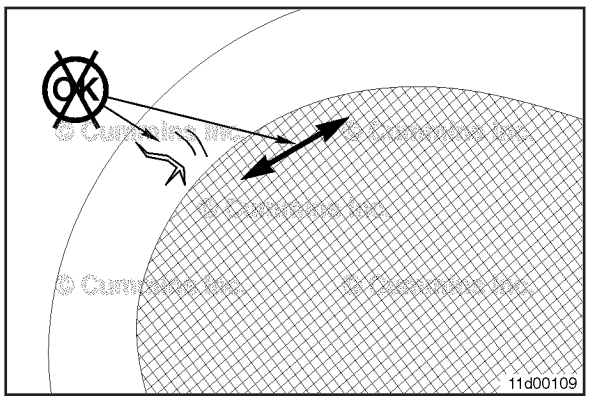
If the exhaust gas filter catalyst section has shifted, moved or is loose inside the canister, replace the exhaust gas filter catalyst.



Inspect the exhaust gas filter for any cracks or gouges. Replace the exhaust gas filter section if any damage is found.

Inspect the outlet face of the exhaust gas filter for any black areas. Replace the exhaust gas filter section if there are more than 20 damaged cells.

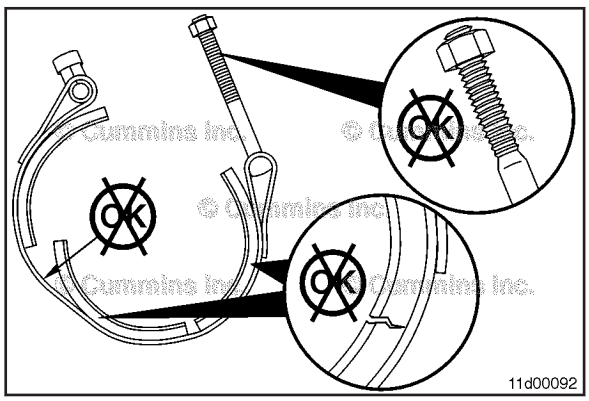
Return the exhaust gas filter section to the nearest Cummins® Authorized Repair Location for cleaning.

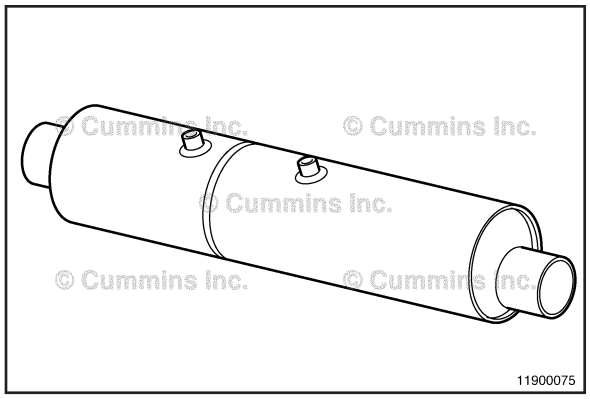


Inspect the V-band clamps for signs of over-extension. The band **must not** be bent or damaged.

Inspect the V-band clamp threads for damage.

Replace the V-band clamp if damage is found.





ISLe4 Engines

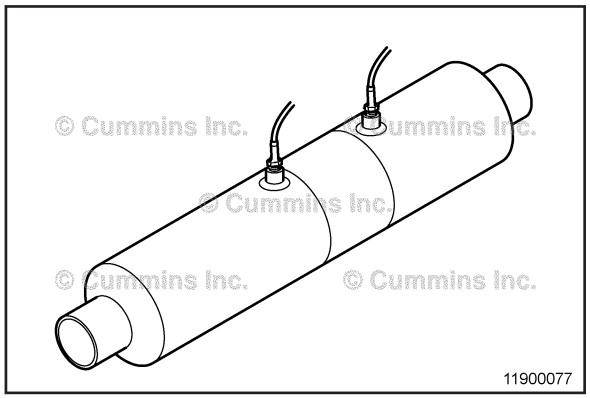
⚠WARNING⚠

The catalyst substrate contains Vanadium Pentoxide. Vanadium Pentoxide has been determined by the State of California to cause cancer. Always wear protective gloves, dust mask 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. Refer to the Materials Safety Data Sheet (MSDS) for additional information.

Remove any loose paint, corrosion, from exhaust catalyst sealing surfaces with a wire brush.

Excessive fuel or oil buildup will damage the exhaust catalyst. If oil from an upstream engine failure is visible in the exhaust plumbing, replace the catalyst. If evidence of fuel in the exhaust stream is apparent and Fault Code 1687 occurs, replace the catalyst.

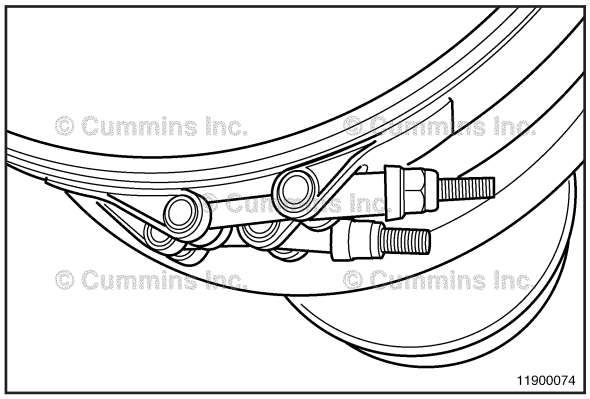
NOTE: Prior to the replacement of the exhaust catalyst, the source of the upstream failure **must** be identified and corrected. If the exhaust catalyst is replaced due to progressive damage from engine oil or fuel contamination, clean the tailpipe from the turbocharger outlet to the exhaust catalyst.



Inspect exhaust catalyst for:

- Loose paint
- Excess Corrosion
- Damage to the body of exhaust catalyst, i.e. splits or cracks to the body of the exhaust catalyst or connecting pipe work.

Inspect exhaust catalyst for signs of catalyst solution leaks.



Check/inspect all fittings and supports brackets before reuse.

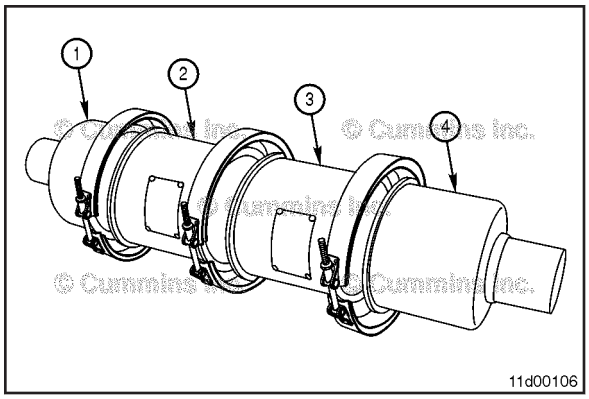
Assemble

ISL Engines

Assemble the sections of the exhaust gas filter. Use the V-band clamps and new gaskets. Make sure marks on the exhaust side of the catalyst and filter sections are aligned with the outlet.

Tighten the V-band clamp.

Torque Value: 20 N•m [177 in-lb]

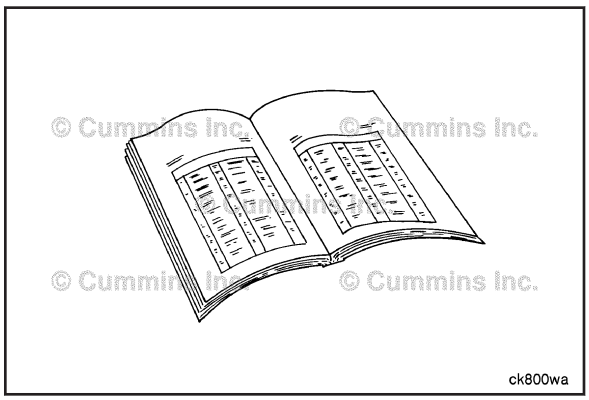


Install

ISL Engines

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

Install the exhaust gas filter assembly into the vehicle. Refer to the OEM service manual.



ISLe4 Engines

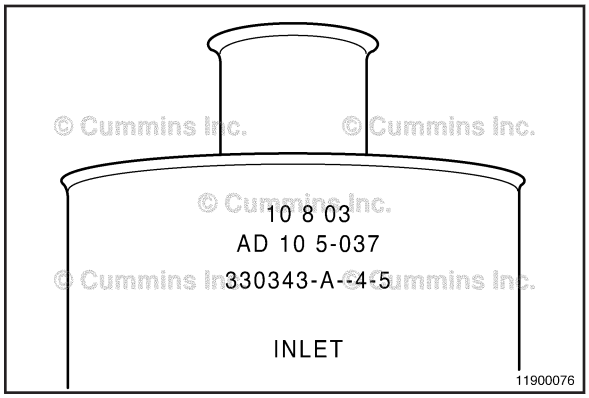
NOTE: Check the correct catalyst part number is selected.

The exhaust catalyst is marked with “INLET” for assembly, (INLET to engine).

Lift catalyst into position.

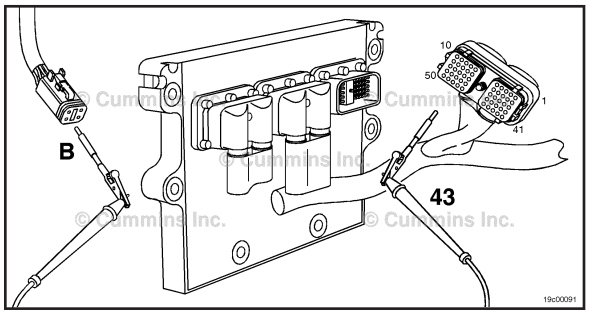
Connect OEM holding clamps.

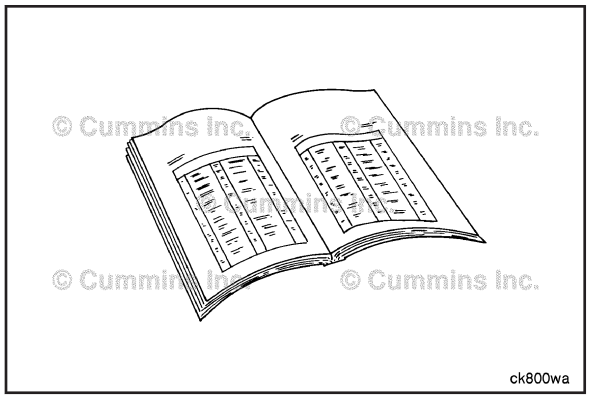
Connect each end of exhaust catalyst to the vehicle exhaust pipe work.



Test

Use INSITE™ electronic service tool to initiate a aftertreatment SCR catalyst efficiency test.

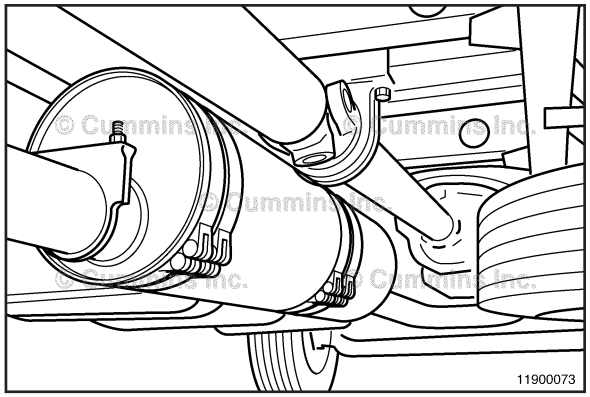




Finishing Steps

ISL Engines

- Connect the exhaust gas temperature sensor, if necessary. Refer to Procedure 011-037 in Section 11.
- Connect the exhaust gas pressure sensor, if necessary. Refer to Procedure 011-039 in Section 11.
- Operate the vehicle and check for leaks.

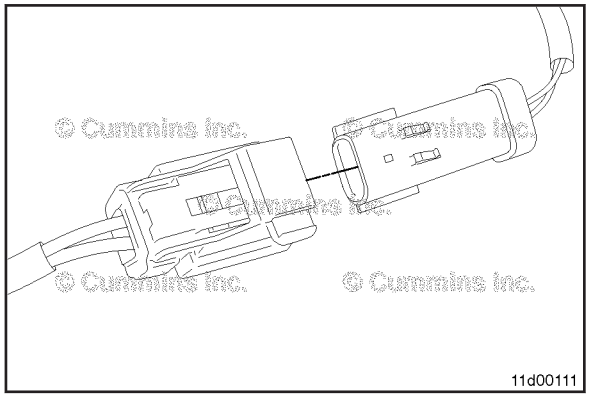


ISLe4 Engines

⚠WARNING⚠

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. Do not cut open the exhaust catalyst assembly.

- Connect the exhaust gas temperature sensor, if necessary. Refer to Procedure 011-037 in Section 11.
- Operate the vehicle and check for leaks.



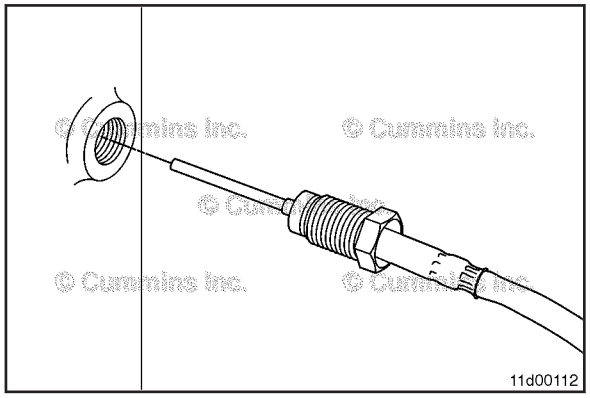
Exhaust Gas Temperature Sensor (011-037)

Remove

Slide the locking tab on the top side of the connector to the unlock position.

Press down on the tab near the end of the harness connector where the harness wires lead into the connector.

Pull outward on the connector away from the sensor to disconnect.



Remove the sensor from the mounting boss in the exhaust piping.

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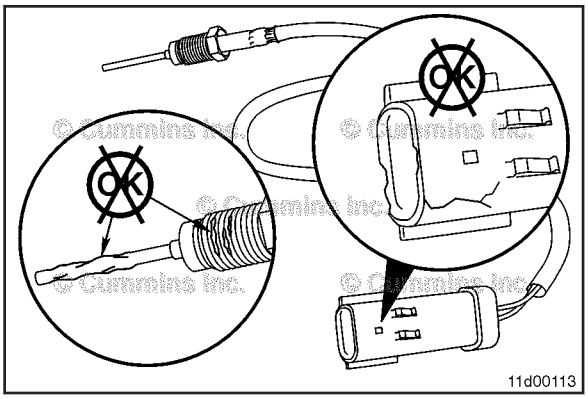
Clean and Inspect for Reuse

Inspect for damaged or exposed wires, bent or broken pins, damaged connectors, or damaged threads.

Replace if any damage is found.



Install

Put a light coating of anti-seize on the exhaust gas temperature sensor mounting threads.

Install the sensor into the mounting boss in the exhaust piping.

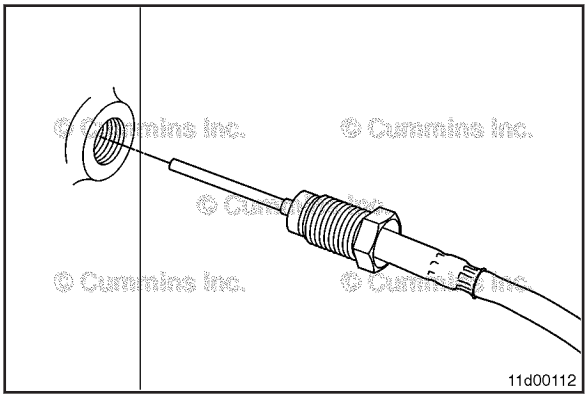
Tighten the sensor.

Torque Value: 30 N•m [22 ft-lb]

Push the connectors together until they lock.

Slide the locking tab to the lock position.

Reset the exhaust gas treatment monitor unit. Refer to Procedure 011-035.



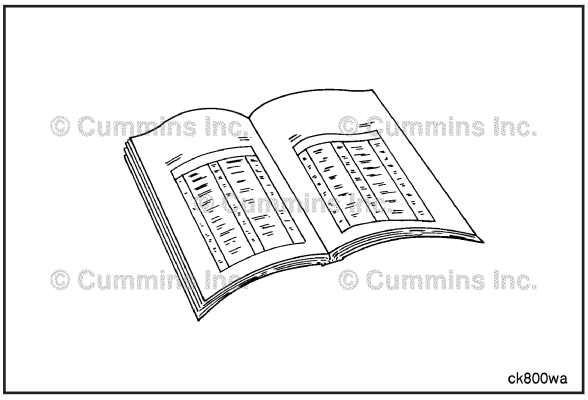
Exhaust Gas Treatment Monitor Harness (011-038)

Preparatory Steps

Disconnect the exhaust gas treatment monitor diagnostic lamps and the OEM harness connector to the exhaust gas treatment monitor harness. Refer to the vehicle manufacturer's service manual.

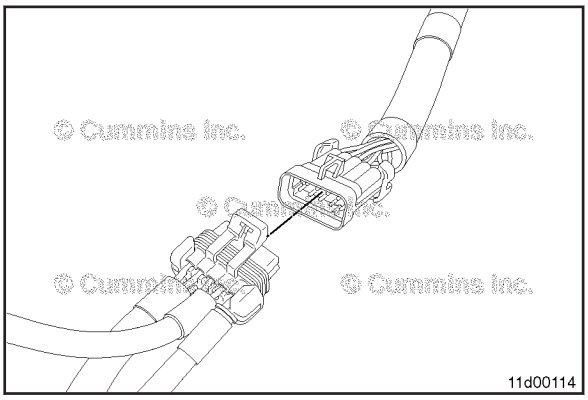
Disconnect the exhaust gas temperature sensor. Refer to Procedure 011-037.

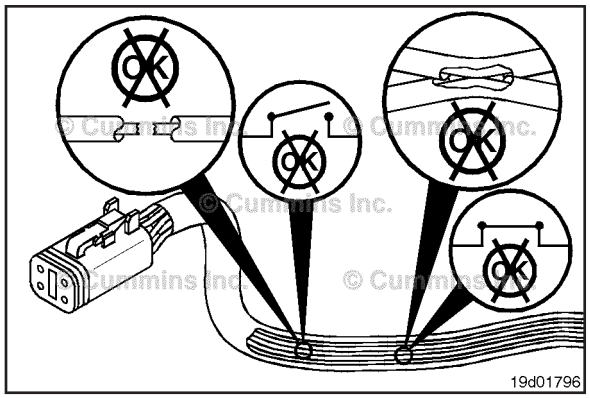
Disconnect the exhaust gas pressure sensor. Refer to Procedure 011-039.



Remove

Disconnect the exhaust gas treatment monitor harness from the exhaust gas treatment monitor unit by pulling up on the tab and releasing the connector.

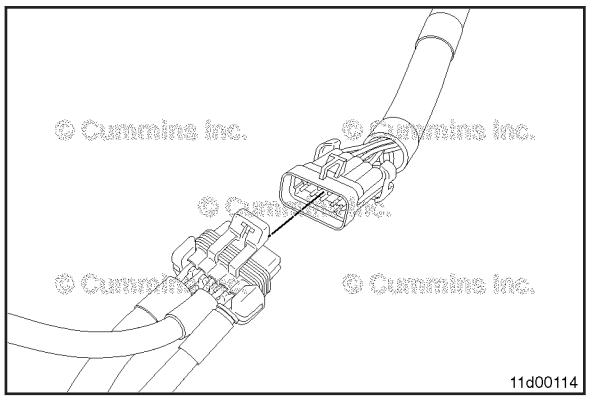




Inspect for Reuse

Inspect the connectors for any damage or bent or broken pins. Repair or replace if necessary.

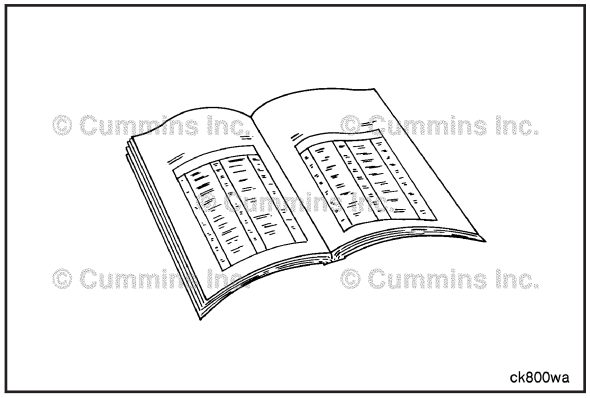
Inspect for damaged or exposed wires. Repair or replace if necessary.



Install

Connect the exhaust gas treatment monitor harness to the exhaust gas treatment monitor unit.

Push the connectors together until they lock.



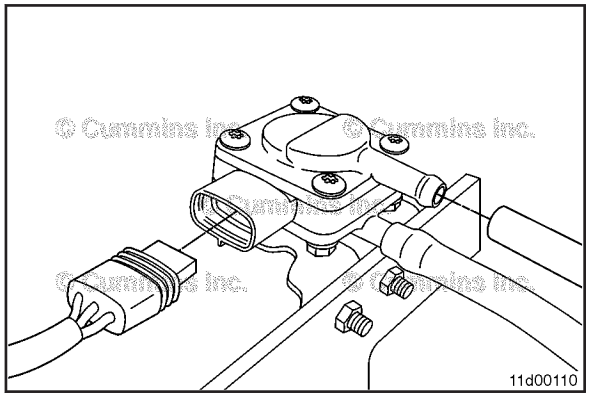
Finishing Steps

Connect the exhaust gas pressure sensor. Refer to Procedure 011-039.

Connect the exhaust gas temperature sensor. Refer to Procedure 011-037.

Connect the exhaust gas treatment monitor diagnostic lamps and the OEM harness. Refer to the vehicle manufacturer's service manual.

Reset the exhaust gas treatment monitor unit. Refer to Procedure 011-035.



Exhaust Gas Pressure Sensor (011-039)

Remove

Push down on the locking tab and pull the connector apart.

Disconnect the hose from the inlet fitting.

Remove the sensor from the mounting location. Refer to the vehicle manufacturer's service manual.

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Install

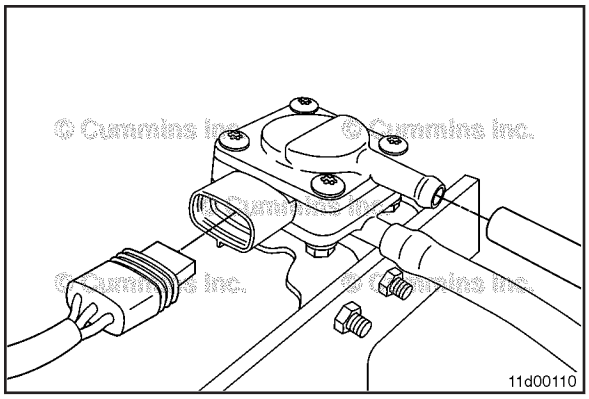
Push the connectors together until they lock.

Connect the hose to the inlet fitting.

Connect the sensor to the exhaust gas treatment monitor unit harness.

Attach the sensor to the mounting location. Refer to the vehicle manufacturer's service manual.

Reset the exhaust gas treatment monitor unit. Refer to Procedure 011-035.



Aftertreatment Nozzle (011-040)

General Information

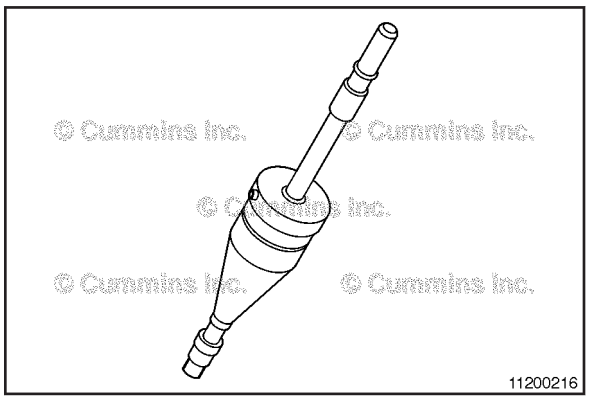
⚠WARNING⚠
The aftertreatment diesel exhaust fluid (DEF) contains urea. Do not get the substance in your eyes. In case of contact, immediately flood eyes with large amounts of water for a minimum of 15 minutes. Avoid prolonged contact with skin. In case of contact, immediately wash skin with soap and water. Do not swallow internally. In the event the catalyst reagent is ingested, contact a physician immediately.

⚠WARNING⚠
The exhaust system may remain hot for an extended length of time.

The aftertreatment nozzle is used to spray DEF into the exhaust system.

It is made from stainless steel.

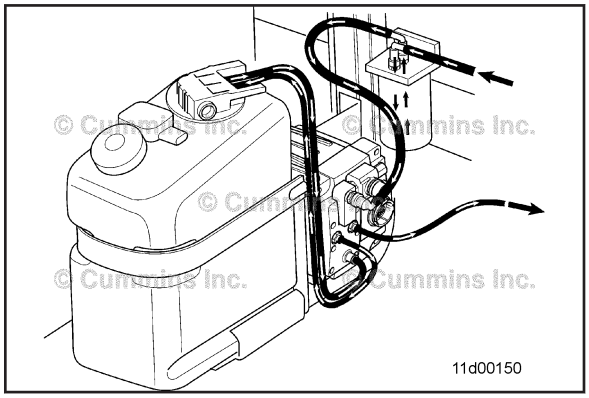
Care should be taken when handling the aftertreatment nozzle, to prevent damage or bending of the nozzle locating pin or DEF intake connector.



Initial Check

Check the pipework going to and coming from the aftertreatment DEF dosing control unit for any signs of a leak.

DEF leaks will leave a white deposit around the fittings.



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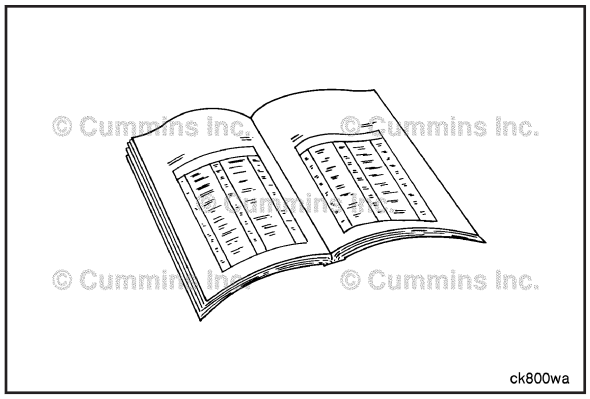
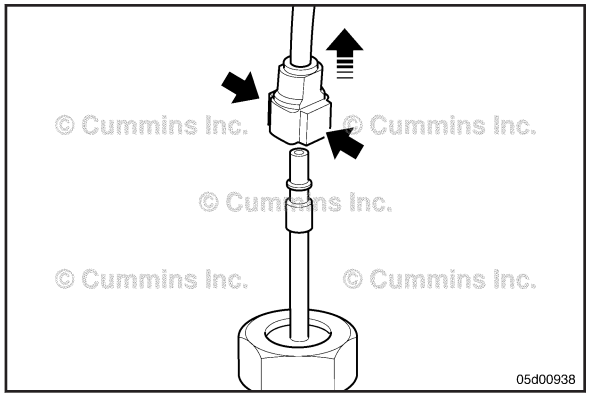


Preparatory Steps

⚠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.

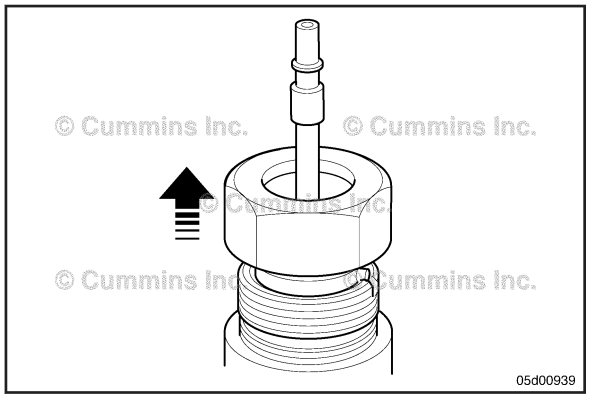
- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.



Remove

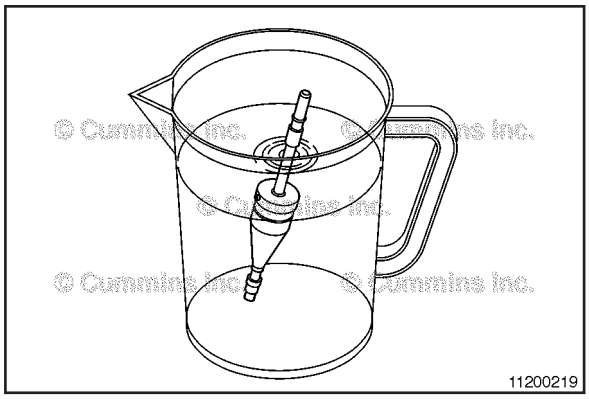
Disconnect the aftertreatment DEF supply pipework from the aftertreatment nozzle and drain any excess aftertreatment DEF into a suitable container. The fitting is a quick release fitting; to release, press both sides of the fitting.

Remove the aftertreatment nozzle retaining nut.



The aftertreatment nozzle will then lift out of the exhaust system locating boss.

Clean and Inspect for Reuse



⚠WARNING⚠
The aftertreatment DEF 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.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

NOTE: It may be necessary to warm the aftertreatment nozzle in the exhaust system prior to testing for blockage. This helps to soften the normal buildup that can form in the nozzle holes while cold.

To clean the nozzle, use **only** clean, very warm water (+ 40°C (104°F]).

Immerse the aftertreatment nozzle in a suitable container of clean, warm, and demineralized water.

Connect an air line with a pressure of no more than 69 kPa [10 psi], and blow through the injector. When immersed in water, the different spray angles from each hole will be clearly visible.

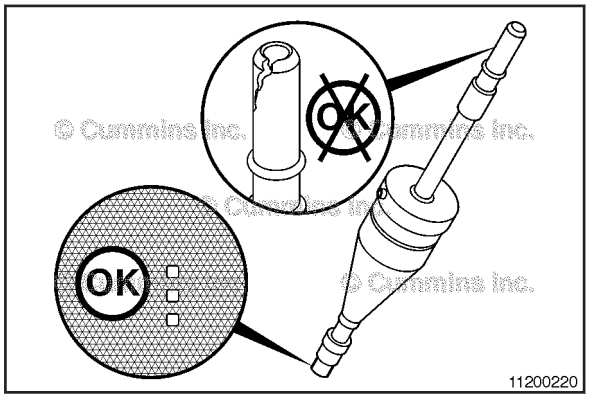
Dry with compressed air.

Inspect the tip of the aftertreatment nozzle.

All spray holes should be clearly visible.

Check the body of the injector for damage.

NOTE: If shaken, there may be a slight noise from the aftertreatment nozzle. This is normal.



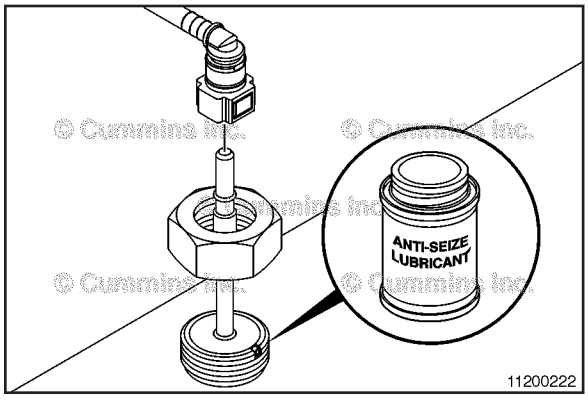
Install

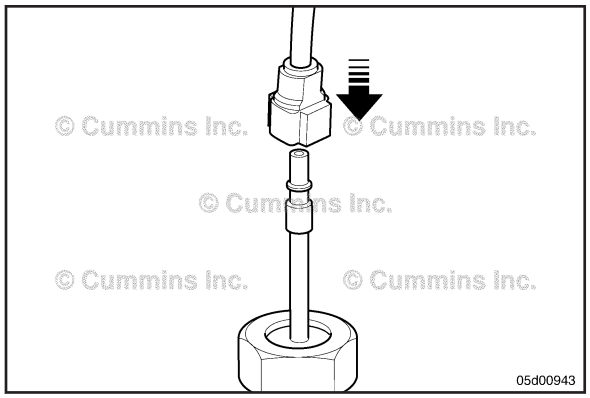
Install the aftertreatment nozzle into the exhaust system locating boss. Make sure the aftertreatment nozzle locating pin is located correctly in the exhaust system locating boss. Care **must** be taken **not** to damage the locating pin.

Apply high temperature anti-seize compound to the threads of the locating boss.

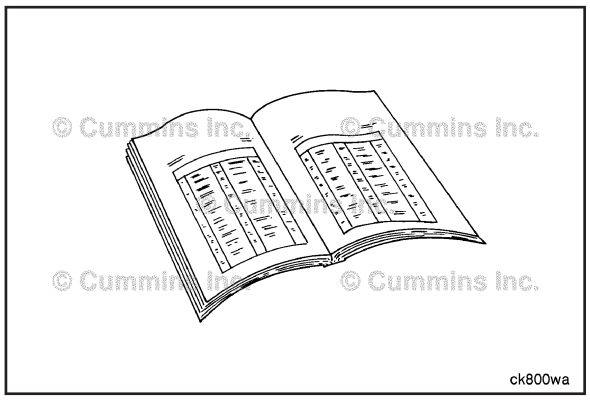
Install the aftertreatment nozzle retaining nut.

Torque Value: 60 N•m [44 ft-lb]





Connect the aftertreatment DEF supply to the aftertreatment nozzle.



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 proper operation.

Aftertreatment Diesel Exhaust Fluid Dosing Unit Air Side Flushing (011-082)

General Information

⚠WARNING⚠

Diesel exhaust fluid (DEF) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety data sheet (MSDS) for additional information.

⚠WARNING⚠

The aftertreatment system will stay hot to touch for long periods of time after the engine has been shut down. To reduce the possibility of personal injury, avoid direct contact of hot components with your skin

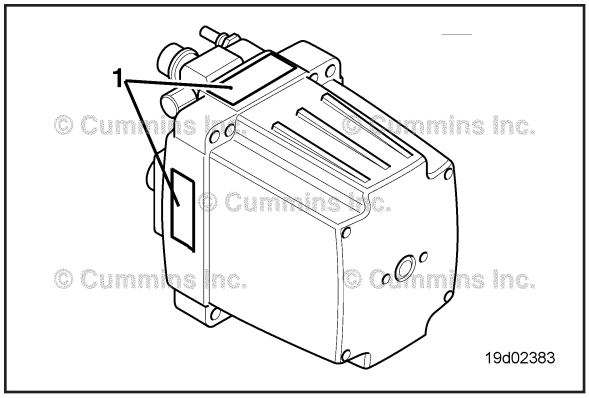
⚠WARNING⚠

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. Refer to the Materials Safety Data Sheet (MSDS) for additional information.

NOTE: The DEF dosing unit is **not** serviceable. Do **not** open the case.

This procedure is used to flush the DEF dosing unit if DEF crystals have built up in the air circuit of the pump. A blockage in the DEF injector circuit can result in DEF entering the air system. Over time, urea crystal growth in the air circuit leads to a reduction or total loss of air flow and failure of the component.

Initial Check



Locate the DEF dosing unit on the vehicle.

The DEF dosing unit dataplate is located either on the top or the side of the unit, as shown in the illustration (1).

Check the pipework going to and returning from the DEF dosing unit for any signs of a leak.

DEF leaks will leave a white deposit around the fittings.

Remove the aftertreatment nozzle and make sure that it is completely clear of blockage. Refer to Procedure 011-040 in Section 11.

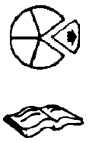
Connect the air flow meter from service tool kit, Part Number 5296510, to the aftertreatment nozzle DEF supply line.

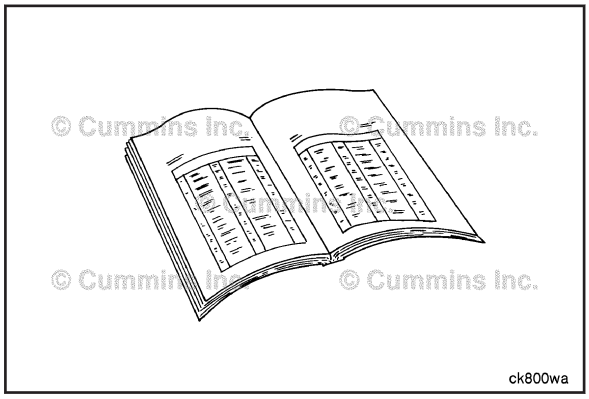
Start and operate the engine. The DEF dosing unit will go through its priming cycle. After a maximum of 140 seconds, air should pass through the dosing line and through the air flow meter.

Specification: Air flow greater than 25 liters [6.6 gal] per minute.

Perform the DEF flushing procedure, regardless of the initial air flow measurement.

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⚠
Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

- Disconnect the batteries. Refer to the OEM service manual.
- Release the pressure in all vehicle air tanks. Refer to the OEM service manual.

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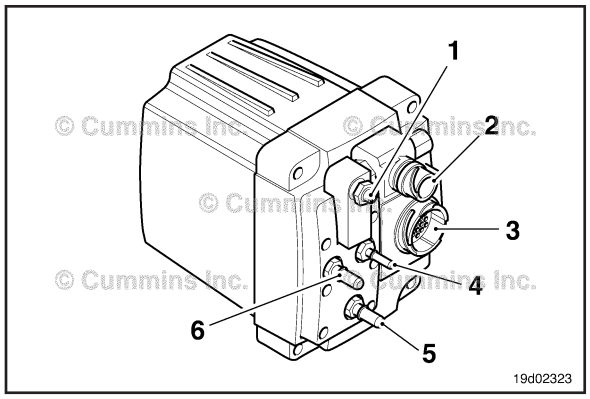


Flush

CAUTION

Fluid can attempt to force through the solenoid exhaust port on the doser. Damage to the selective catalytic reduction (SCR) dosing unit can occur.

The DEF dosing unit **must** be wiped with a clean damp cloth and/or a wash bottle with mild detergent. This will remove any contamination and reduce the risk of debris entering the DEF dosing unit.

The dosing control unit connections are listed below:

1 Compressed air supply

2 Air solenoid connector (2-pin)

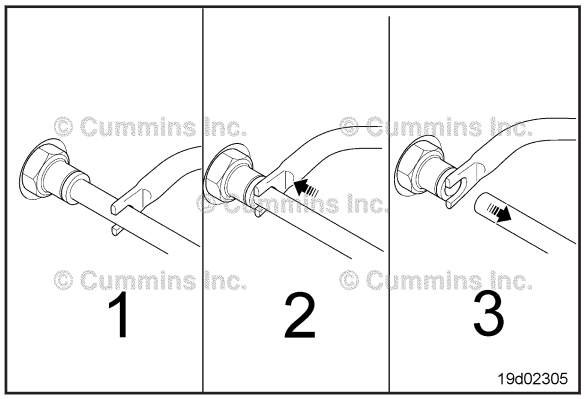
3 ITT Cannon™ on connector (37-pin)

4 DEF supply to aftertreatment nozzle (PTFE line)

5 DEF supply to pump

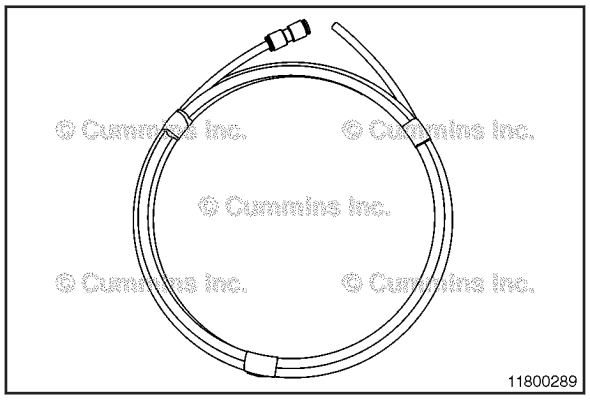
6 DEF return.

Lines 4, 5, and 6 have quick-fit connections. A quick release fitting is also used for the air connection at the top of the diesel exhaust fluid dosing unit. To release the fitting, apply equal pressure to both sides of the release collar, and pull the pipe from the fitting.



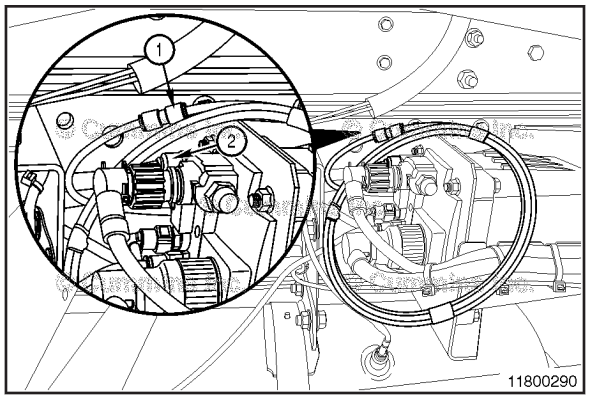
NOTE: Make sure the vehicle air supply to the DEF dosing unit is either drained down or isolated before removing the air supply line.

- Disconnet the air supply line to the dosing unit.



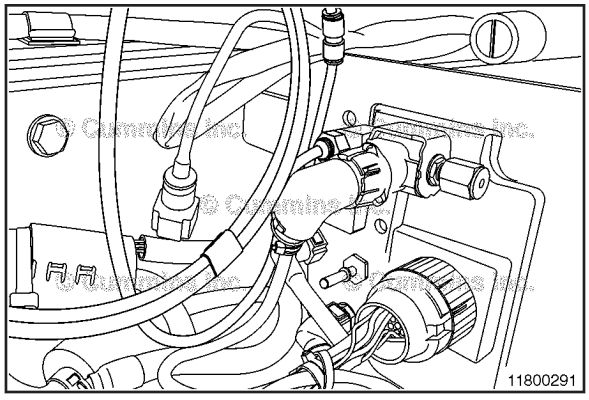
- Coil the polytetrafluoroethylene (PTFE) pipe and fasten using tape. Fill the piping with clean water.

- Connect one end of the coiled PTFE pipe to the dosing pump air supply port (1), and the opposite end to the regulated vehicle air supply (2), using the barrel connector from service tool kit, Part Number 5296510.
- Remove the air flow meter from the aftertreatment nozzle DEF supply line and direct the line into a suitable container away from electrical components.
- Start and operate the engine. The DEF dosing unit will go through its priming cycle After a maximum of 140 seconds, the water will attempt to force through the aftertreatment nozzle DEF supply line.
- Collect the fluid in a container.
- If INSITE™ electronic service tool is available, the Diesel Exhaust Fluid Doser Pump Air Solenoid Click Test can be used during the flush to toggle the solenoid valve. This will improve the effectiveness of the procedure.
- If **all** the water has been forced out of the air solenoid exhaust port, the flush procedure should be repeated (no more than three attempts should be necessary).
- Once all the water is delivered from the injector line, wait for 30 seconds for clear air flow.



NOTE: Make sure the vehicle air supply to the DEF dosing unit is either drained down or isolated before removing the air supply line.

- Remove the coiled PTFE pipe and barrel connector from the DEF dosing unit air supply line.
- Connect the OEM air supply line to the dosing unit.



Test

⚠ WARNING ⚠

Diesel exhaust fluid (DEF) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety data sheet (MSDS) for additional information.

⚠ WARNING ⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Connect the air flow meter from service tool kit, Part Number 5296510, to the aftertreatment nozzle DEF supply line.

Start and operate the engine. The DEF dosing unit will go through its priming cycle. After a maximum of 140 seconds, air should pass through the dosing line and through the air flow meter.

Specification: Air flow greater than 25 liters [6.6 gal] per minute.

If the air flow is less than the specification, or if air leaks from the air regulating unit, the dosing unit will require replacement. Refer to the OEM service manual or contact a Cummins® Authorized Repair Location.

Remove the air flow meter from the aftertreatment nozzle DEF supply line and connect the diesel exhaust fluid supply to the aftertreatment nozzle. Refer to Procedure 011-040 in Section 11.

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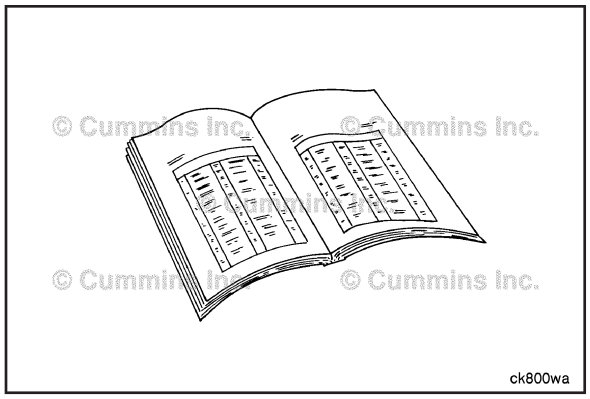
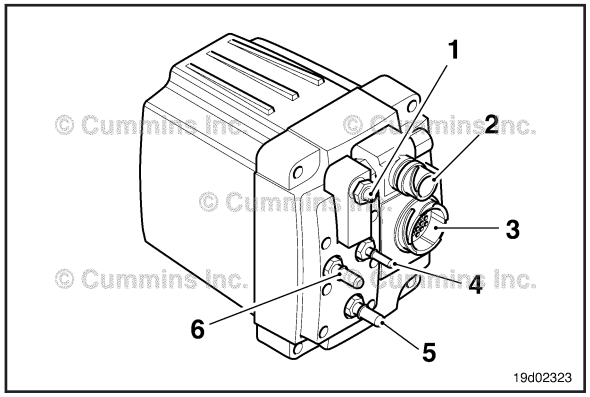


Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the batteries. Refer to the OEM service manual.
- Start and operate the engine to build up air pressure.
- Check for air or DEF leaks.
- Check for active fault codes.



Aftertreatment Diesel Exhaust Fluid Dosing Unit (011-058)

General Information

⚠WARNING⚠

DEF contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety data sheet (MSDS) for additional information.

⚠WARNING⚠

The exhaust and exhaust components can remain hot after the engine has been shut down or secured. To avoid the risk of fire, property damage, burns or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they might come in contact with hot exhaust or exhaust components

The diesel exhaust fluid (DEF) dosing unit connections are illustrated:

1 Compressed air supply

2 Air solenoid connector (2-pin)

3 37-pin ITT Cannon™ connector

4 DEF supply to aftertreatment nozzle polytetrafluoroethylene (PTFE) line.

5 DEF supply to pump

6 DEF return

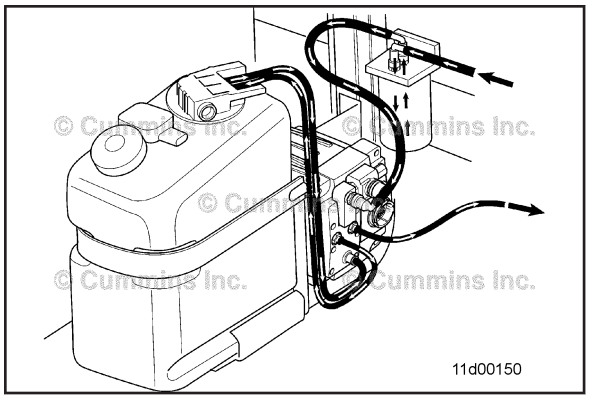
Lines 4, 5, and 6 have quick-fit connections.

This procedure describes a method for testing the air flow from the aftertreatment nozzle line.

Initial Check

©heck the DEF nozzle supply line for signs of damage or leaks.

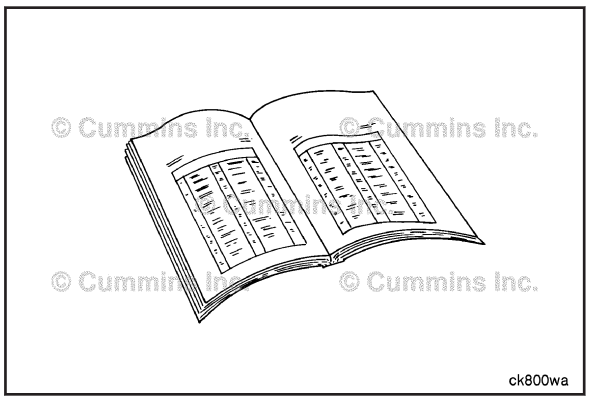
DEF will leave white deposits if a leak exists.



Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

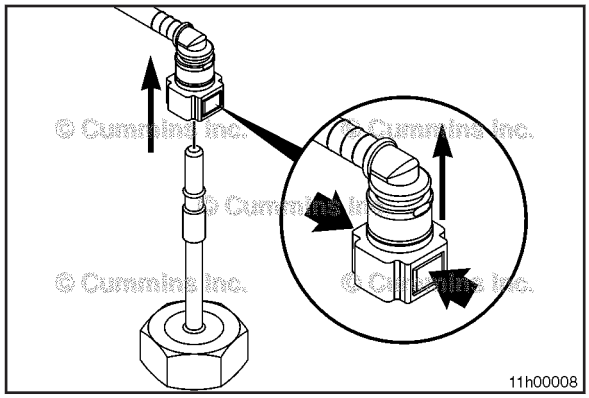
- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.



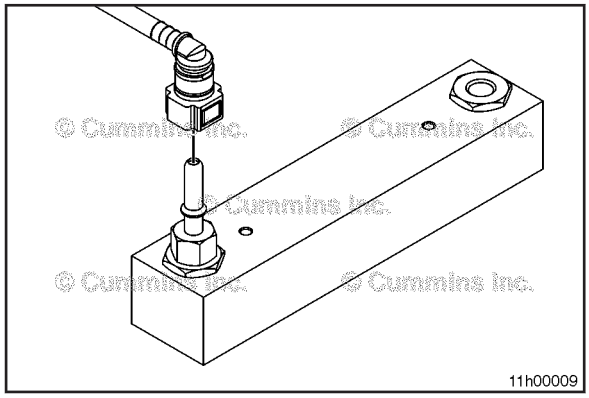
Remove

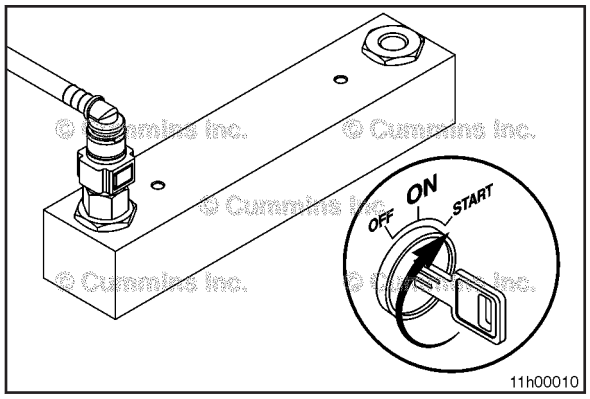
⚠WARNING⚠
DEF contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety data sheet (MSDS) for additional information.

Disconnect the DEF pipework from the aftertreatment nozzle and drain any excess DEF into a suitable container. The fitting is a quick release fitting. To release, press both sides of the fitting.



Connect the aftertreatment nozzle line to the air flow meter, Part Number 5296510.





Test

⚠WARNING⚠
DEF contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety data sheet (MSDS) for additional information.

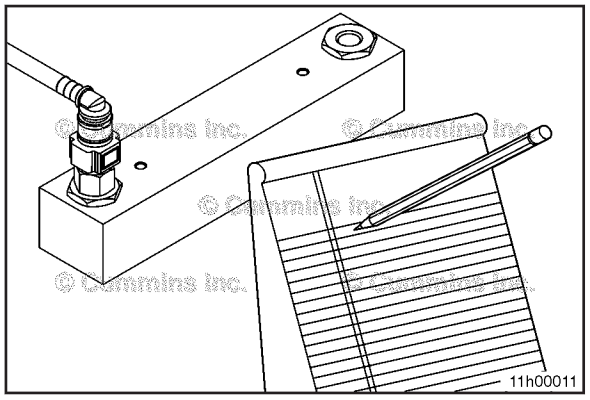
Start the vehicle and wait 140 seconds for the pump to begin the prime cycle.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

NOTE: Some early calibrations do **not** have the 140 second delay, and the pump will begin the prime cycle when the vehicle is started.

Thirty seconds after the prime cycle is completed, the dosing unit will exhaust air down the aftertreatment injection line.

NOTE: The DEF dosing unit could take up to 20 attempts to prime. Each prime attempt will last 30 seconds.



⚠WARNING⚠
The exhaust and exhaust components can remain hot after the engine has been shut down or secured. To avoid the risk of fire, property damage, burns, or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they might come in contact with hot exhaust or exhaust components

NOTE: Make sure that the airflow meter flow adjustment is set to allow maximum airflow, in order to prevent a false reading.

Record the reading from the airflow meter.

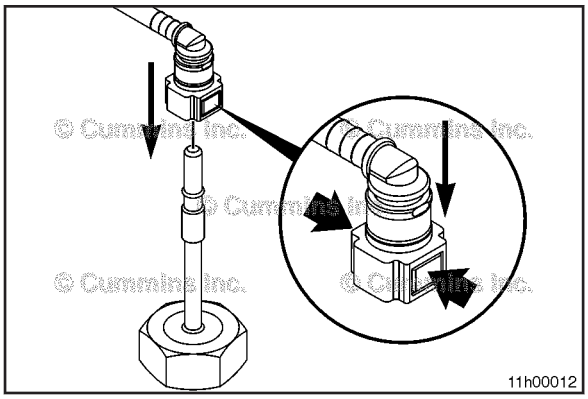
The airflow should be a minimum of 25 liters per minute [6.6 gallons per minute].

Install

⚠WARNING⚠
DEF contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety data sheet (MSDS) for additional information.

Remove the airflow meter from the aftertreatment nozzle line.

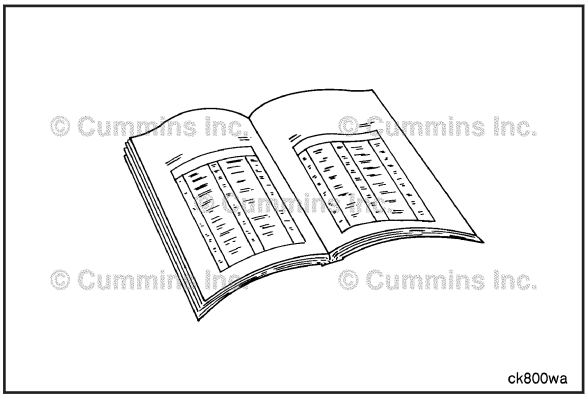
Connect the aftertreatment nozzle line to the aftertreatment nozzle.

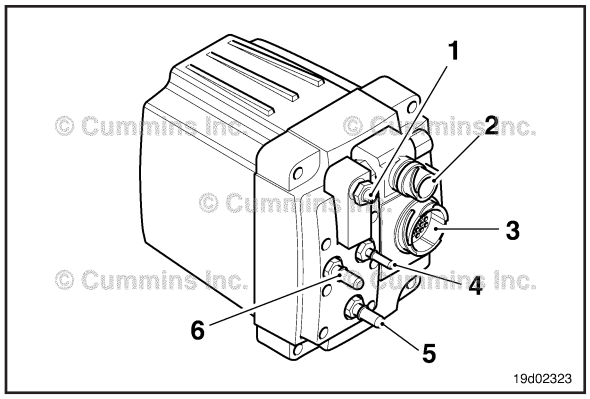


Finishing Steps

⚠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 OEM service manual.
- Operate the engine and check for leaks.





Aftertreatment Diesel Exhaust Fluid Dosing Unit Filter (011-060)

General Information

⚠WARNING⚠
Diesel exhaust fluid (DEF) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety data sheet (MSDS) for additional information.

⚠WARNING⚠
The exhaust and exhaust components can remain hot after the engine has been shut down or secured. To avoid the risk of fire, property damage, burns or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they might come in contact with hot exhaust or exhaust components.

The diesel exhaust fluid (DEF) dosing unit connections are as illustrated:

1 Compressed air supply

2 Air solenoid connector (2 pin)

3 37-pin ITT Cannon™ connector

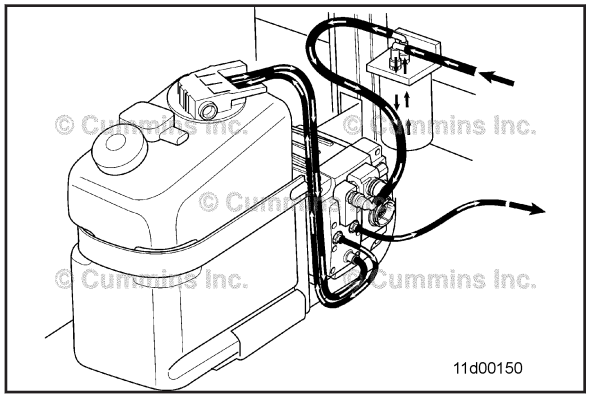
4 DEF supply to aftertreatment nozzle (PTFE line)

5 DEF supply to pump

6 DEF return

Lines 4, 5, and 6 have quick-fit connections.

The DEF supply line contains a screen filter.



Initial Check

Visually check the DEF supply and return lines and fittings for signs of damage, leaks, or faulty connectors.

If accessible, make sure that the primary filter fitted to the DEF tank is a 35 micron filter. (Previously, this was a 70 micron filter).

Make sure that any contaminants found prior to carrying out this check have been removed and that the DEF lines have been cleared.

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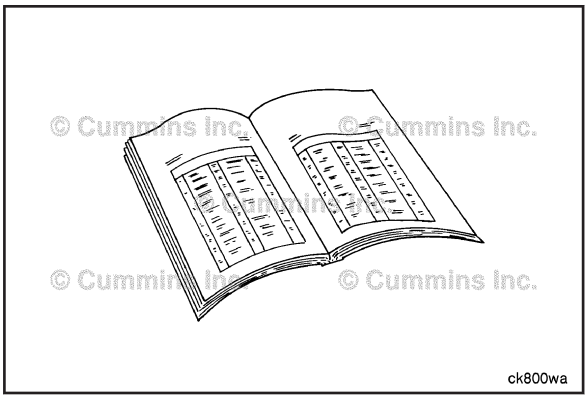
Preparatory Steps

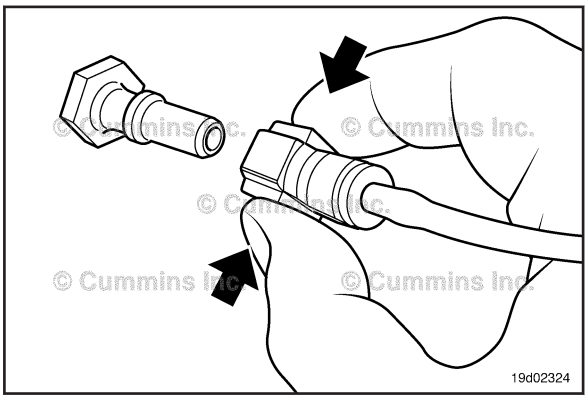


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

NOTE: Do **not** power wash or steam clean this unit. Use compressed air to remove any loose debris.

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.

Remove



⚠WARNING⚠
Diesel exhaust fluid (diesel exhaust fluid) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the diesel exhaust fluid is ingested, contact a physician immediately. Reference the Materials Safety Data Sheet (MSDS) for additional information.

The DEF dosing unit **must** be wiped with a clean damp cloth and/or a spray bottle with mild detergent. This will remove any contamination and reduce the risk of debris entering the DEF dosing unit.

NOTE: Do **not** power wash or steam clean this unit.

Disconnect the DEF supply pipework from the DEF dosing unit and drain any excess catalyst solution into a suitable container. The fitting is a quick release fitting; to release, press both sides of the fitting.

NOTE: The inline screen filter is **not** a serviceable part. Therefore, it can **not** be cleaned. If it is found to be blocked or damaged, it **must** be replaced.

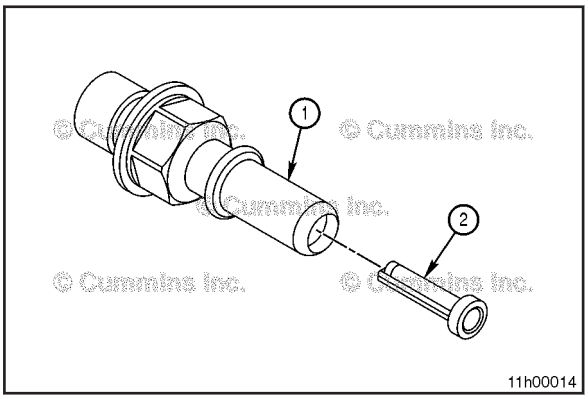
Remove the DEF supply line fitting.

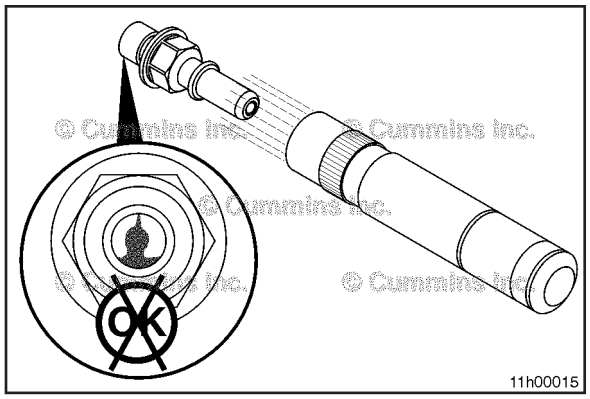
The inlet fitting and screen filter as illustrated:

1 Inlet fitting and screen filter housing

2 100 micron screen filter

NOTE: The screen filter is **not** removable from the connector. This is for illustration purposes **only**.

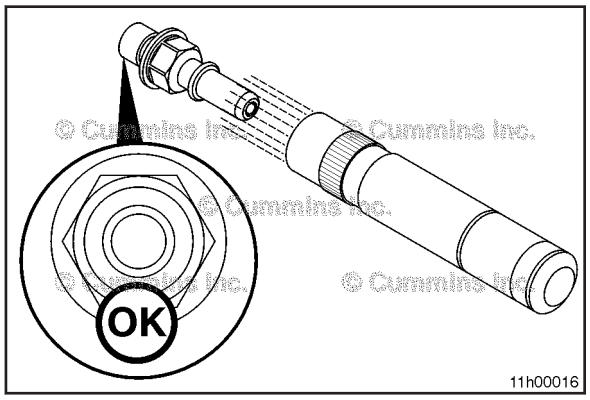




Inspect for Reuse

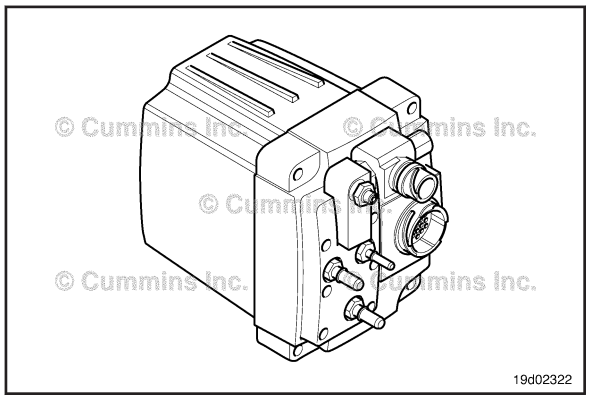
⚠WARNING⚠
Diesel exhaust fluid (diesel exhaust fluid) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the diesel exhaust fluid is ingested, contact a physician immediately. Reference the Materials Safety Data Sheet (MSDS) for additional information.

To inspect the screen filter, shine a light through one end of the screen filter to determine whether or **not** it is blocked.



If the filter is blocked or restricted, it should **not** be reused. It **must** be replaced.

NOTE: A white bead of adhesive may be visible in the inlet fitting. This adhesive is used to bond the screen filter to the inlet fitting, and is normal.

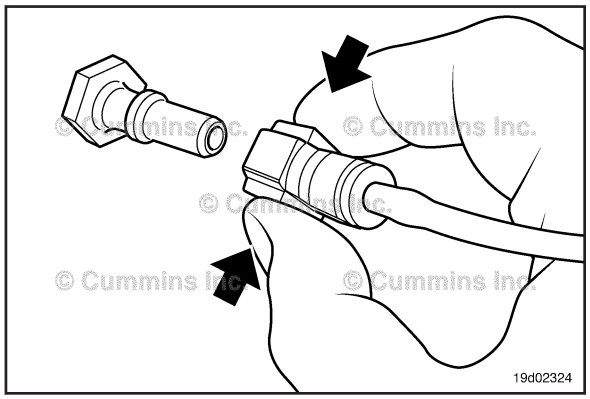


Install

⚠WARNING⚠
Diesel exhaust fluid (diesel exhaust fluid) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the diesel exhaust fluid is ingested, contact a physician immediately. Reference the Materials Safety Data Sheet (MSDS) for additional information.

Install the inline screen filter assembly into the diesel exhaust fluid dosing unit.

Torque Value: 15 N•m [133 in-lb]

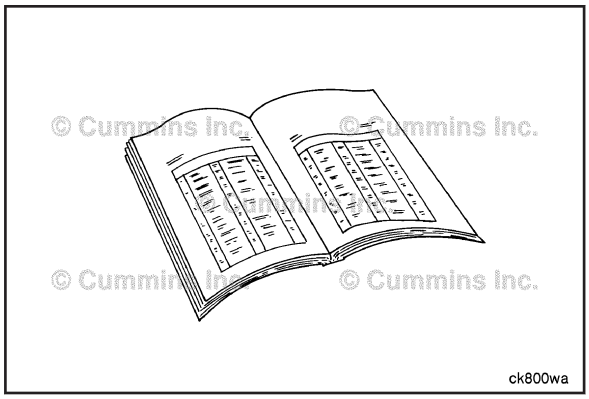


Connect the DEF supply line to the DEF dosing unit.

Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.

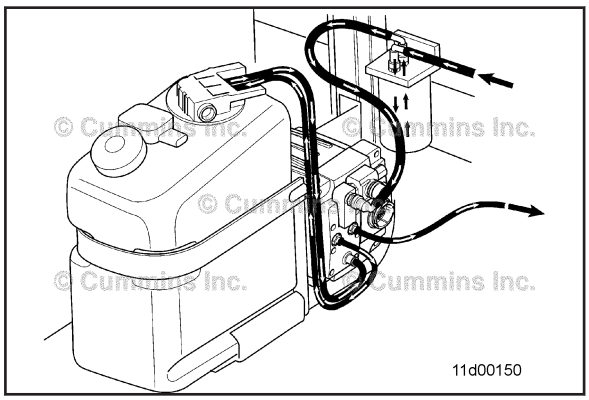


Aftertreatment Diesel Exhaust Fluid Tank Filter (011-083)

General Information

⚠WARNING⚠
Diesel exhaust fluid (DEF) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety data sheet (MSDS) for additional information.

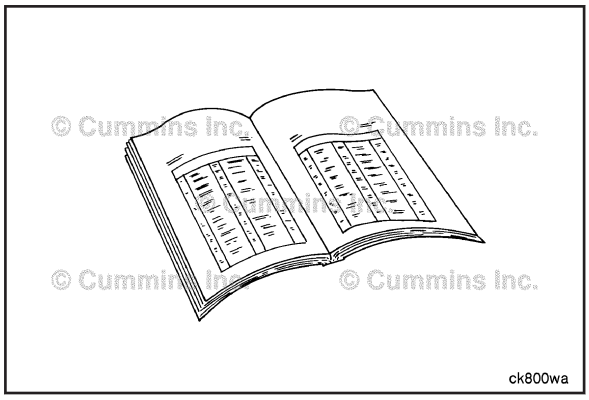
⚠WARNING⚠
To reduce the possibility of personal injury, wear goggles and protective clothing.

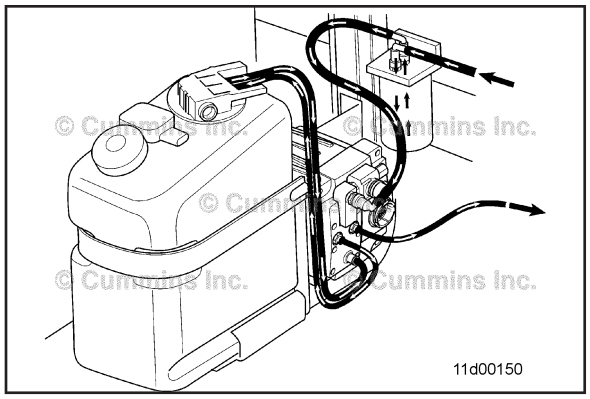


Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.





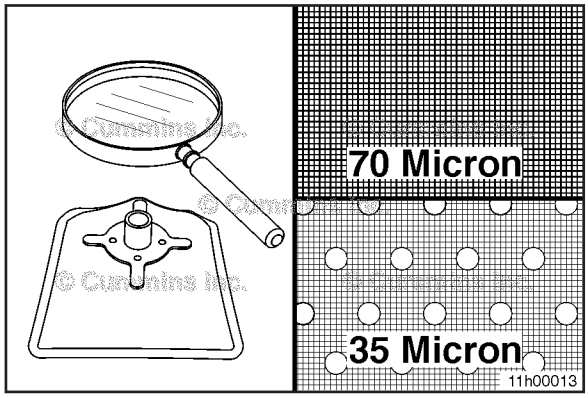
Remove

⚠WARNING⚠
Diesel exhaust fluid (DEF) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety data sheet (MSDS) for additional information.

Disconnect the electrical connections and pipework from the DEF tank level sensor assembly.

Remove the DEF tank level sensor assembly from the DEF tank. Refer to the OEM service manual.

NOTE: In some cases, the DEF tank is bonded to the vehicle chassis, leaving no access to the DEF tank level sensor assembly. If this is the case, contact the OEM to arrange for the tank to be removed and inspected.



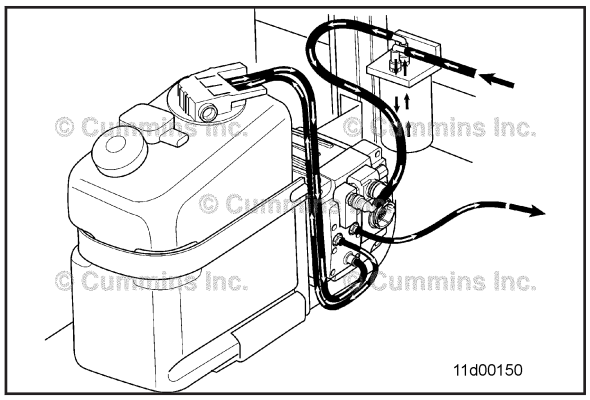
Inspect for Reuse

⚠WARNING⚠
Diesel exhaust fluid (DEF) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety data sheet (MSDS) for additional information.

Inspect the inlet filter attached to the DEF tank level sensor assembly. Confirm that the filter is a 35 micron filter, per the illustration.

Inspect the DEF tank level sensor assembly inlet filter for dirt or contamination. If signs of dirt or contamination are found, replace the inlet filter.

NOTE: If the inlet filter is **not** a 35 micron filter, then replace the inlet filter with a 35 micron filter.



Install

⚠WARNING⚠
Diesel exhaust fluid (DEF) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety data sheet (MSDS) for additional information.

NOTE: Make sure that the DEF tank level sensor assembly is kept free from any contamination during installation to the vehicle.

Install the electrical connections and pipework that is attached to the DEF tank level sensor assembly.

Refer to the OEM service manual for instructions.

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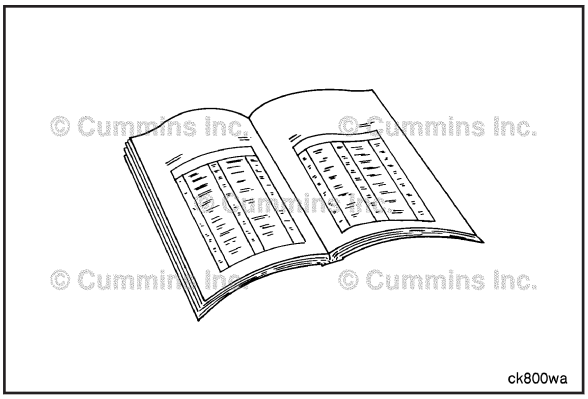
Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the batteries. Refer to the OEM service manual.



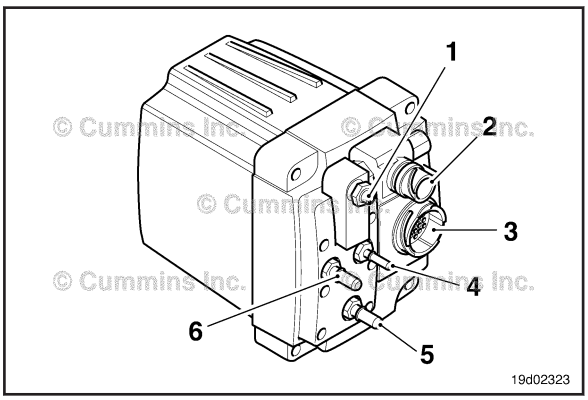
Aftertreatment Diesel Exhaust Fluid Line Restriction Test (011-086)

General Information

⚠WARNING⚠
The diesel exhaust fluid 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 diesel exhaust fluid is ingested, contact a physician immediately.

⚠WARNING⚠
The exhaust and exhaust components can remain hot after the engine has been shut down or secured. To avoid the risk of fire, property damage, burns or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they might come in contact with hot exhaust or exhaust components.

The diesel exhaust fluid (DEF) dosing unit connections are illustrated:



1 Compressed air supply

2 Air solenoid connector (2 pin)

3 37-pin ITT Cannon™ connector

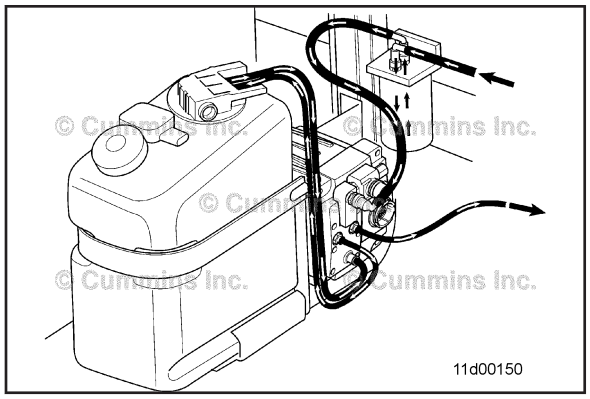
4 DEF supply to aftertreatment nozzle (PTFE line)

5 DEF supply to pump

6 DEF return

Lines 4, 5, and 6 have quick-fit connections.

This procedure describes a method for testing the diesel exhaust fluid supply and return lines for leaks and/or restrictions.



Initial Check

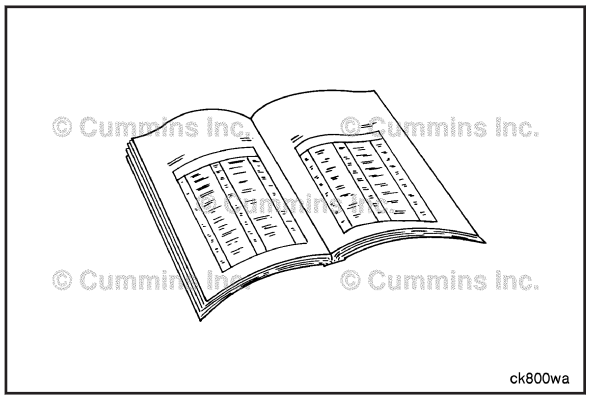
Visually check the DEF supply and return lines and fittings for signs of damage, leaks, or faulty connectors.

DEF leaks will leave a white deposit around the fittings.

A hand vacuum pump is required for this procedure. Check the performance of the hand vacuum pump prior to carrying out this test.

This can be done by blocking the pump nozzle and pumping until a vacuum of 15 kPa [2 psi] is generated. The vacuum pump gauge should show no noticeable change to the vacuum over the next 60 seconds.

NOTE: Always use the collection cup with the vacuum pump during testing to make sure that no diesel exhaust fluid reaches the vacuum pump, as this could potentially result in corrosion or damage to the vacuum pump's internal components.

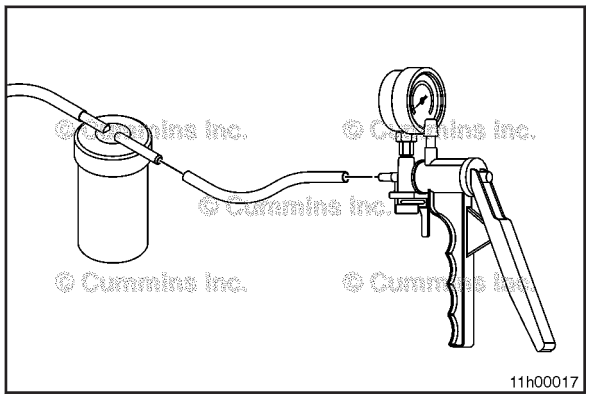


Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.



Remove

Make sure that the dosing unit and diesel exhaust fluid lines are free from dirt and debris.

Connect the vacuum pump to the collection cup using the tube supplied in the kit.

Test

⚠WARNING⚠
DEF contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety data sheet (MSDS) for additional information.

The DEF dosing unit must be wiped with a clean damp cloth and/or a spray bottle with mild detergent. This will remove any contamination and reduce the risk of debris entering the DEF dosing unit.

NOTE: Do **not** power wash or steam clean this unit.

Leak Test

1 Disconnect the DEF supply pipework from the DEF dosing unit and drain any excess DEF into a suitable container, then remove the DEF supply line connection from the DEF tank.

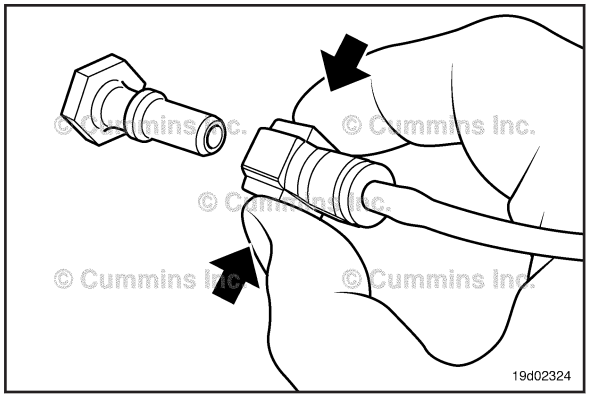
2 Block one end of the DEF supply line and attach the male J2044 line from the vacuum test kit to the opposite end.

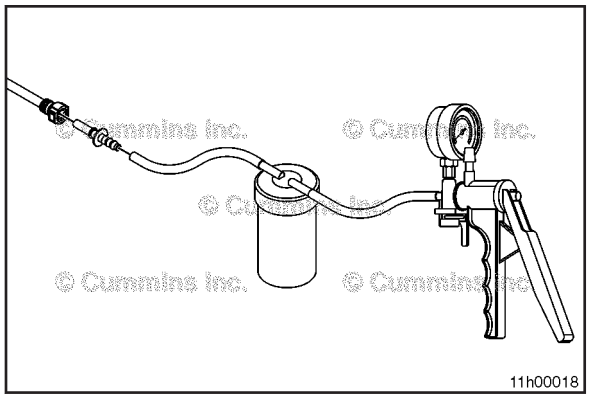
3 Slowly operate the vacuum pump until a vacuum of 15 kPa [2 psi] is achieved, then hold for 60 seconds. Observe the gauge to confirm that the pump holds the vacuum, with no noticeable change to gauge reading. If the gauge value changes in this time, a leak exists in the system. Disconnect the vacuum pump and investigate / repair the source of the leak.

4 Connect the DEF supply line to the DEF tank.

5 Repeat these steps with the DEF return line.

NOTE: Consult the OEM service manual for information regarding DEF line routing and repair/replacement procedures.





Supply Line Restriction

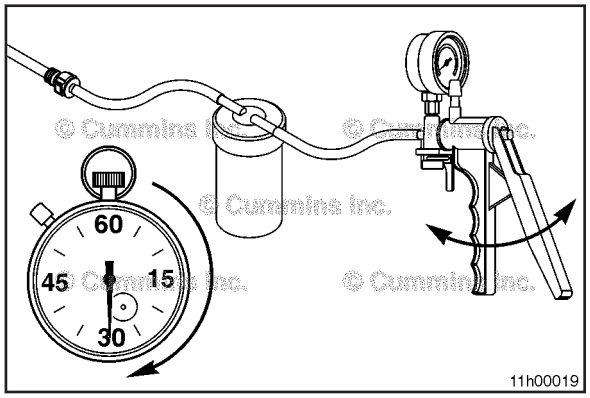
1 Connect the male J2044 line from the vacuum test kit to the DEF supply line to dosing unit connector.

2 Gradually operate the vacuum pump while observing the clear pipe lines that leads to the collection cup. At the moment when fluid reaches the collection cup and is static in the line, record the pressure displayed by the vacuum gauge.

3 If the vacuum gauge reads 20 kPa [3 psi] or less, the restriction in the line is acceptable and fluid can be drained back to the tank. However, if the pressure exceeds 20 kPa [3 psi] at any time, a restriction or blockage has been detected. Disconnect the vacuum pump and look for the routing of the DEF line that could result in restriction. If no routing issues are found, replace the line.

4 Connect the DEF supply line to the DEF dosing unit.

NOTE: Consult the OEM service manual for information regarding DEF line routing and repair/replacement procedures.



Return Line Restriction

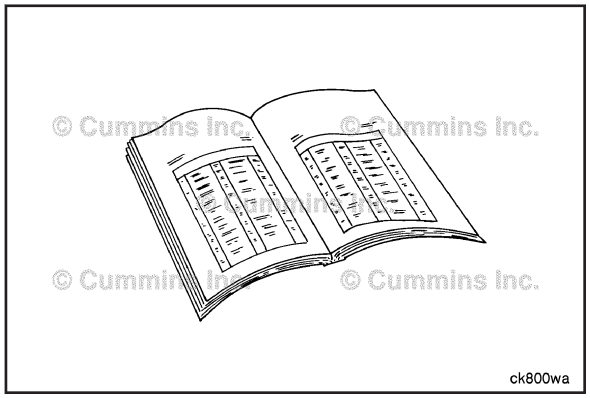
1 Connect the male J2044 line from the vacuum test kit to the DEF return line to dosing unit connector.

2 Operate the vacuum pump continuously for 30 seconds while observing the clear pipe lines that lead to the collection cup. The vacuum pump should **not** draw DEF from the tank, although some DEF may still remain in the lines.

3 The vacuum pump gauge should **not** read above 0 kPa [0 psi] during this test. If the vacuum gauge reads above 0 kPa [0 psi] during this test, a line restriction or blockage has been detected. Disconnect the vacuum pump and look for the routing of the DEF line that could result in restriction. If no routing issues are found, replace the line.

4 Connect all DEF lines.

NOTE: Consult the OEM service manual for information regarding DEF line routing and repair / replacement procedures.



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 OEM service manual.
- Operate the engine and check for leaks.

Section 12 - Compressed Air System - Group 12

Section Contents

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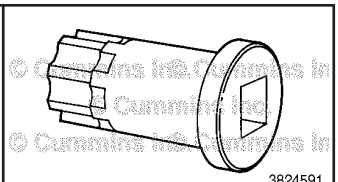
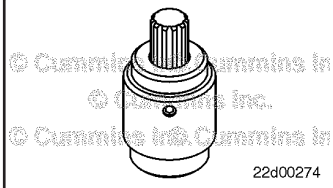
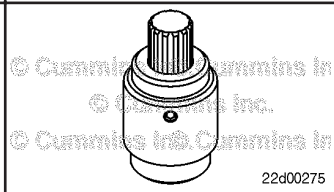
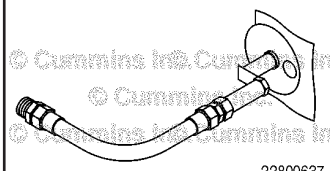
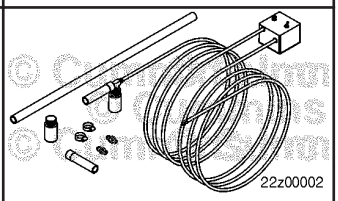
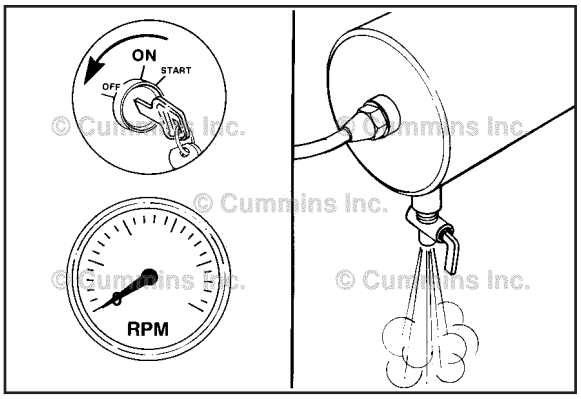
Service Tools

Compressed Air System

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3824591	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	 3824591
3165101	**Air Compressor Adapter Replacer (11-tooth Spline)** Used to address wear problems on the air compressor spline adapter.	 22d00274
3165102	**Air Compressor Adapter Replacer (13-tooth Spline)** Used to address wear problems on the air compressor spline adapter.	 22d00275
4918883	**Air Compressor Discharge Tool** Used to measure acceptable oil carryover on Knorr-Bremse™ air compressors.	 22800637
2892280	**Air Compressor Cleaning Kit** Used to clean and remove internal carbon deposits and other foreign material from WABCO™ air compressor cylinder heads.	 22z00002



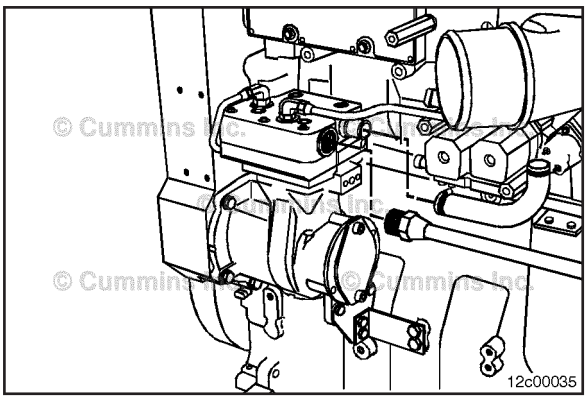
Air Compressor Carbon Buildup (012-003)

Initial Check

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

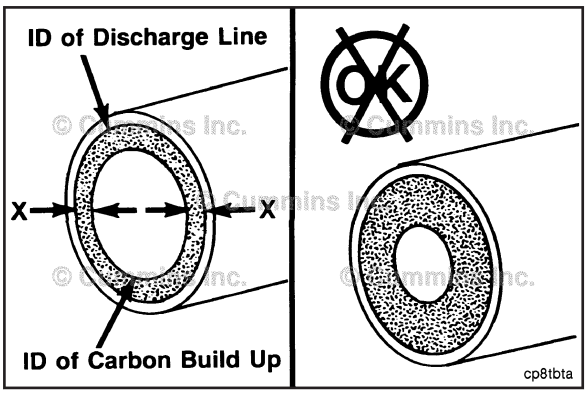
Shut the engine OFF.

Open the petcock on the wet tank to release the compressed air from the system.



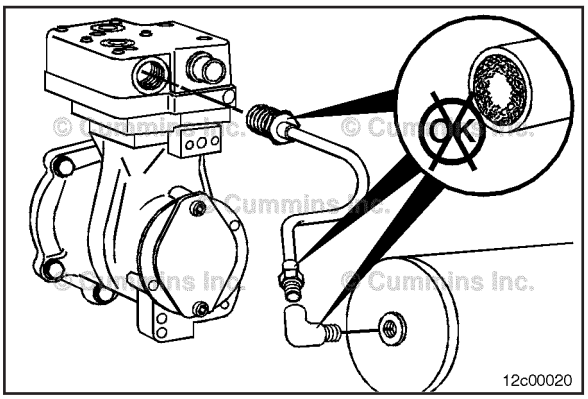
⚠WARNING⚠
Air discharge lines can be very hot. Be sure the lines are cool before handling to reduce the possibility of personal injury.

Remove the air inlet and outlet connections from the air compressor.



Measure the total carbon buildup thickness inside the air discharge line as shown.

NOTE: The carbon buildup thickness **must not** exceed 1.6 mm [0.06 in].



⚠WARNING⚠
The air discharge line must be capable of withstanding extreme heat and pressure to prevent the possibility of personal injury and property damage. Refer to the orginal equipment manufacturer (OEM) service manual.

NOTE: If the total carbon deposit thickness exceeds specification, remove and clean, or replace the air discharge line. Refer to the OEM service manual for specifications.

Continue to check for carbon buildup in the air discharge line connections up to the first connection or wet tank.

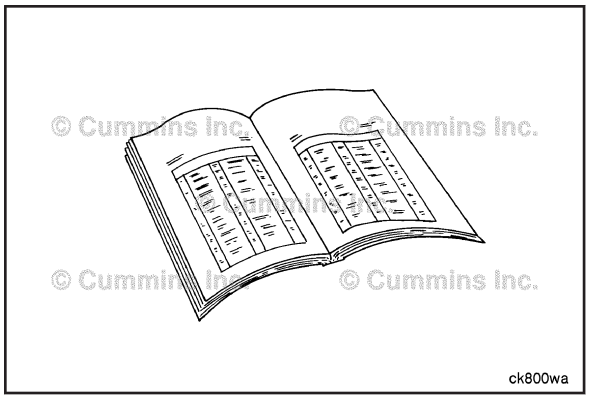
Clean or replace any lines and fittings with carbon buildup thicker than 1.6 mm [0.06 in]. Refer to the OEM service manual for cleaning or replacement instructions.

Clean

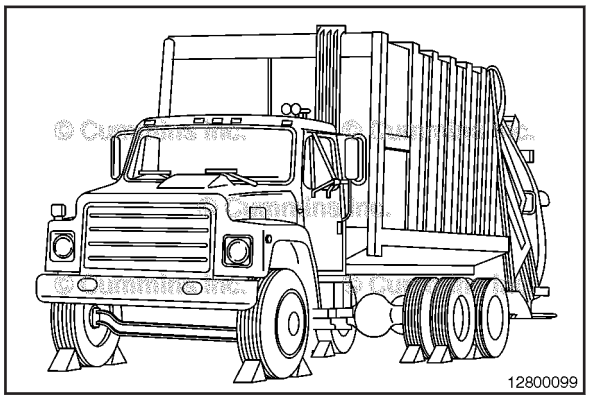
Use the Air Compressor Cleaning Kit, Part Number 2892280, to clean and remove internal carbon deposits and other foreign material from the air compressor cylinder head.

The items below are **not** included in the air compressor cleaning kit, Part Number 2892280, but are required to perform the repair.

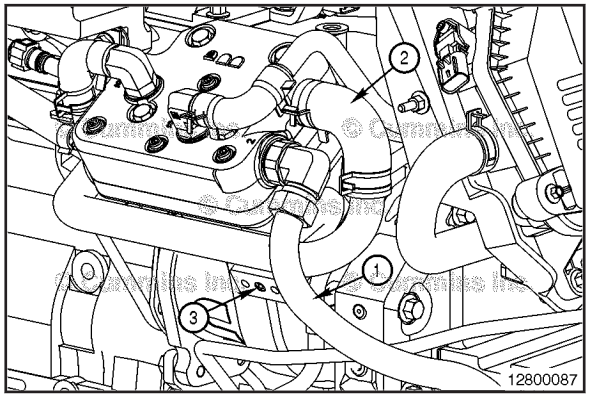
- Regulated shop air 621 kPa [90 psi]
- Automatic transmission fluid (ATF)
- Shop rags, and a 19 liter [5 gallon] bucket
- INSITE™ electronic service tool.



Park the vehicle on a level surface and in an area where it is safe to idle for an extended period of time. Chock the vehicle wheels, and completely drain the vehicle air system.



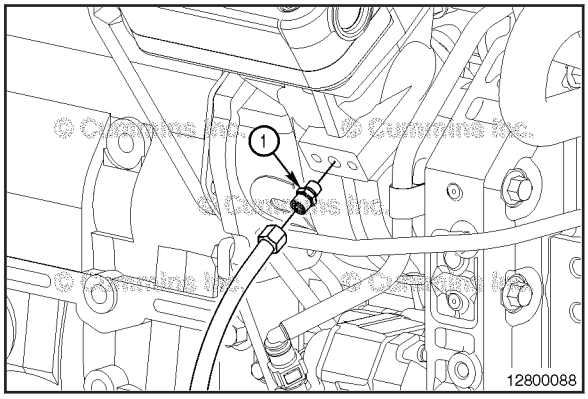
Remove the air compressor discharge line (1), air compressor intake line (2), and air governor signal line (3) at the air compressor.

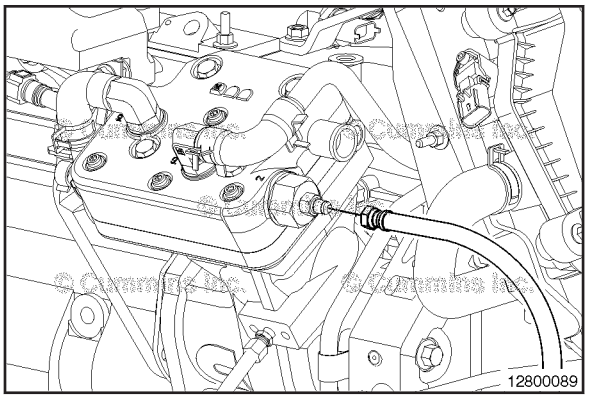


Install and tighten the M10 connector (1) into the unloader port of the air compressor housing.

Install and tighten the unloader control valve hose to the M10 connector installed into the air compressor housing.

NOTE: Some air compressors have two unloader ports in the air compressor housing. Make sure that one of the ports is plugged with an appropriate pipe plug.

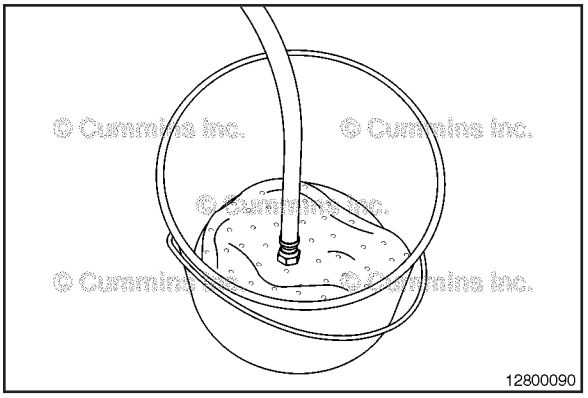




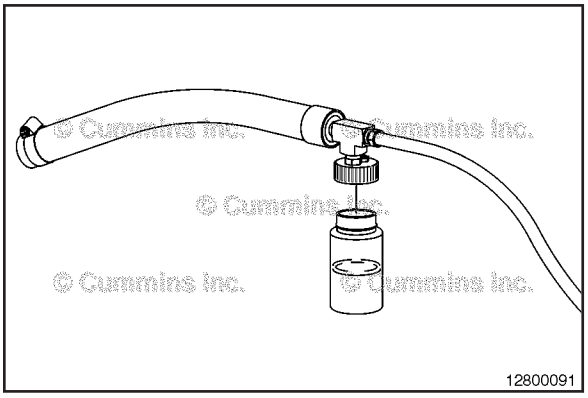
⚠CAUTION⚠

While cleaning the air compressor cylinder head, do NOT install the original intake or discharge plumbing. Only use the intake and discharge lines and fitting supplied with the air compressor cleaning kit during this procedure.

Install the discharge line and clamp from kit, Part Number 2892280, onto the discharge port fitting on the air compressor cylinder head.



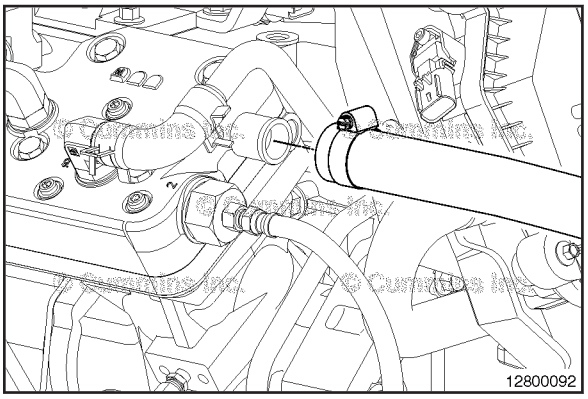
Place the discharge line into a 19 liter [5 gallon] bucket and cover with several oil absorption pads.



Pour 89 ml [3 fluid ounces] of automatic transmission fluid into the dispensing bottle.

Install the dispensing bottle onto the dispensing hose assembly.

NOTE: For best results, use Dexron III automatic transmission fluid or equivalent.



Install and tighten the dispensing hose assembly and clamp to the intake port of the air compressor cylinder head.

Connect the regulated shop air at 621 kPa [90 psi] to the air compressor cleaner.

NOTE: The next three steps will happen quickly. For best results, read the remaining instructions prior to continuing with the cleaning procedure. Do **not** cycle the unloader until all 89 ml [3 fluid ounces] of ATF have been applied.

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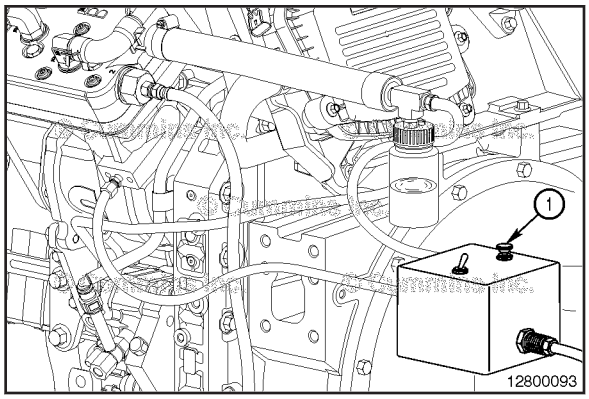
Start the engine, and let it idle for 1 minute.

The air compressor may draw in the automatic transmission fluid naturally (no forced air applied). If the fluid is **not** pulled from the dispensing bottle, press and hold the 'Clean' button (1) on the air compressor cleaner until all 89 ml [3 fluid ounces] of automatic transmission fluid have been dispensed.

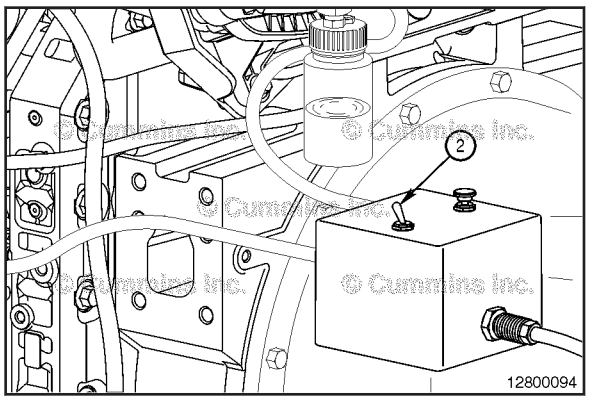
Shut the engine OFF.



Pour 89 ml [3 fluid ounces] of automatic transmission fluid into the dispensing bottle, and install back onto the dispensing hose assembly.

Toggle the 'Unloader' switch (2) on to apply air pressure to the unloader signal port.

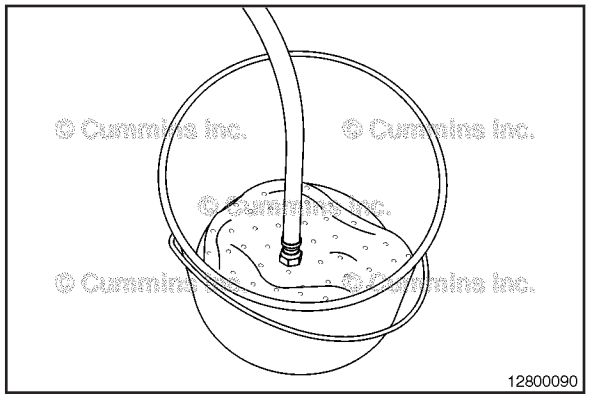
Do **not** relieve pressure at the unloader valve at this time.



Start the engine.

Immediately depress and hold the 'Clean' button on the air compressor cleaner until all 89 ml [3 fluid ounces] of automatic transmission fluid have been dispensed. Continue to hold the 'Clean' button down for an additional 10 to 20 seconds.

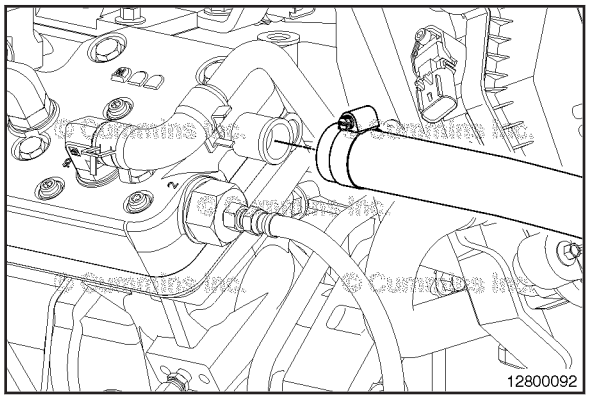
NOTE: A heavy mist of automatic transmission fluid should be coming from the discharge hose.

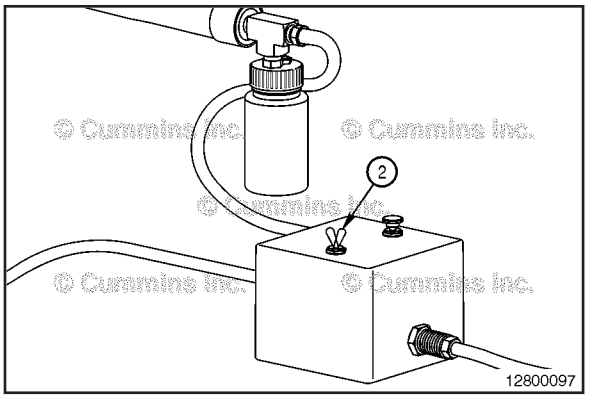


Shut the engine OFF.

Remove the discharge hose assembly from the air compressor cylinder head intake port.

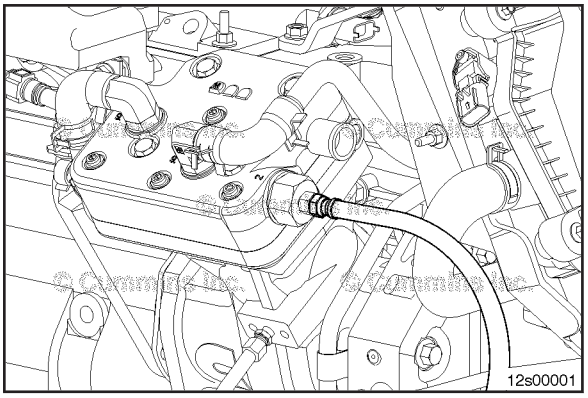
Start the engine.



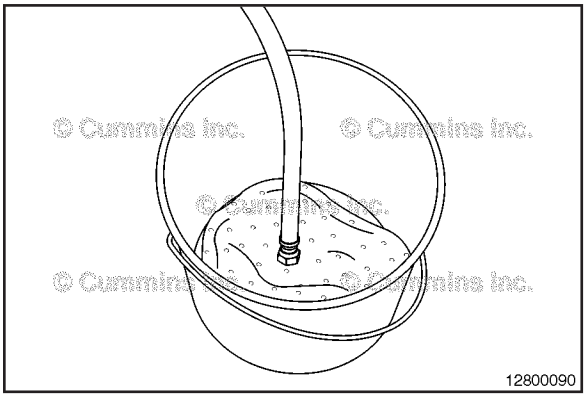


Continuously cycle the 'Unloader' switch on the air compressor cleaner for up to 25 cycles.

NOTE: When the air compressor cylinder head has been adequately cleaned, there should be an audible difference between loaded and unloaded states of the air compressor. Installation of a 1.5 m [5 ft] length of rubber hose over the intake port may help to audibly identify when the unloader is functioning properly.

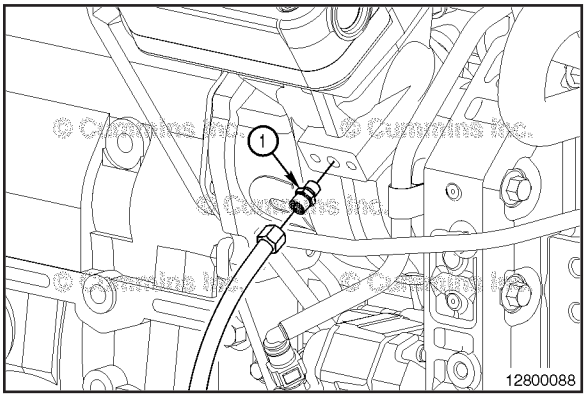


Verify constant suction at the air compressor cylinder head intake port when the air compressor is loaded (unloader switch OFF), and fluctuating air flow when unloaded (unloader switch ON). If constant suction is **not** present in a loaded state, repeat the cleaning process one additional time.



⚠CAUTION⚠
Operating the air compressor with no filter in place at the intake port may allow dust or debris to enter the air compressor. A rubber hose should be placed over the intake port and routed to an area free of air born dust and debris.

With the discharge hose still installed, relieve the pressure at the unloader port (switch OFF), and operate the engine at high idle for 3 - 5 minutes to remove any excess automatic transmission fluid.

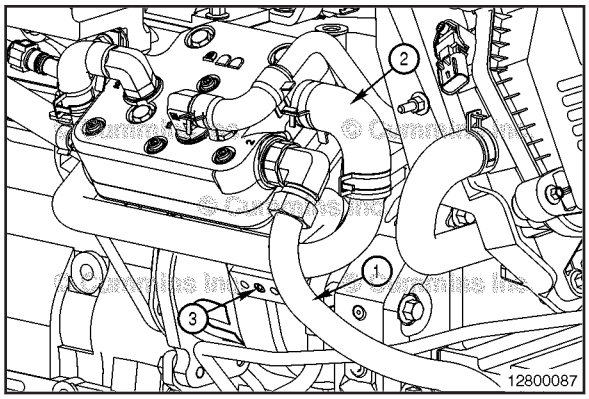


Allow engine to return to low idle. Shut the engine OFF.

Remove the unloader control valve hose and M10 connector (1).

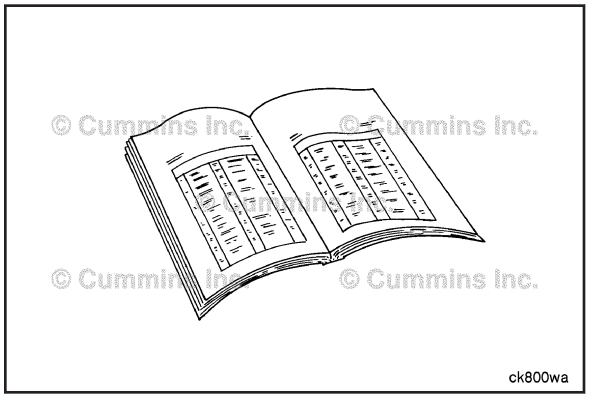
Install the vehicle air governor and/or signal line (3) and air inlet (2) and outlet (1) connections on the air compressor.

Operate the engine and verify the air compressor is functioning properly.



Air Compressor Coolant Lines (012-004)

Preparatory Steps



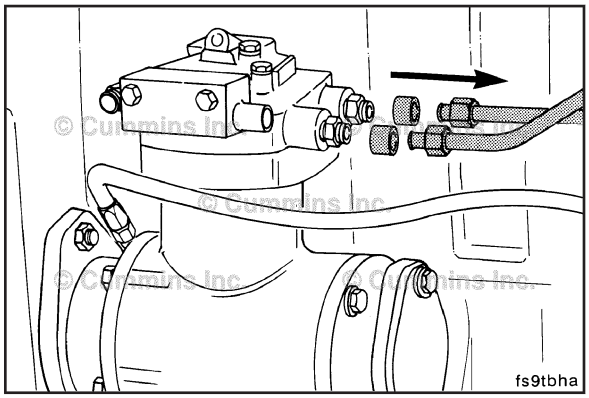
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Drain the cooling system. Refer to Procedure 008-018 in Section 8.

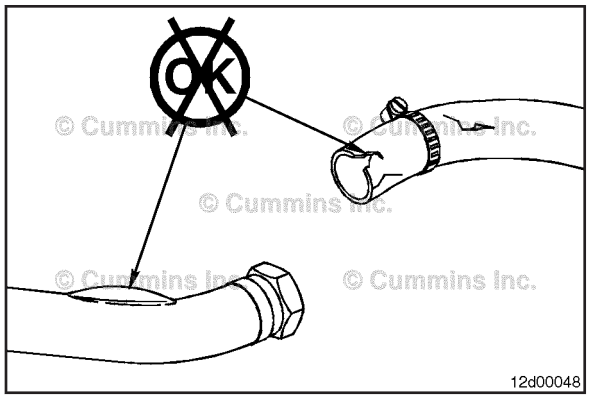
Remove



NOTE: The air compressor cooling lines illustrated can differ depending on the compressor installed. Although different, the procedure remains the same.

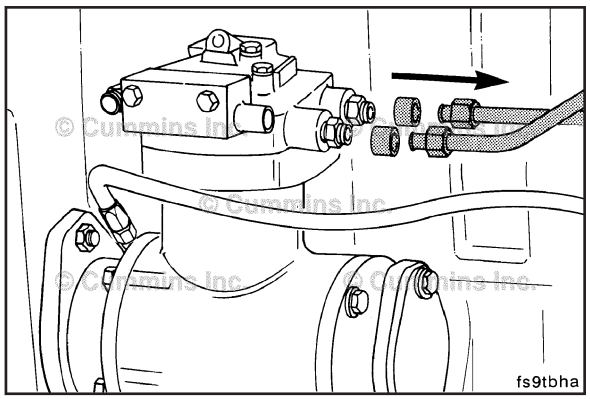
Remove the coolant lines from the air compressor.

Remove the coolant lines from the air compressor cylinder head and cylinder block.



Inspect for Reuse

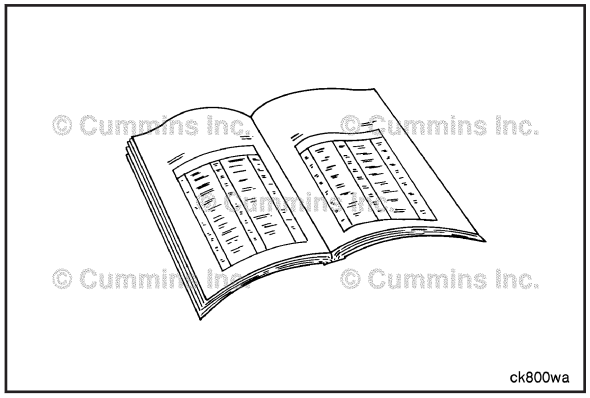
Inspect the coolant hoses and coolant lines for restriction of coolant flow.



Install

NOTE: The air compressor cooling lines illustrated can differ depending on compressor installed. Although different, the procedure remains the same.

Install the coolant lines.

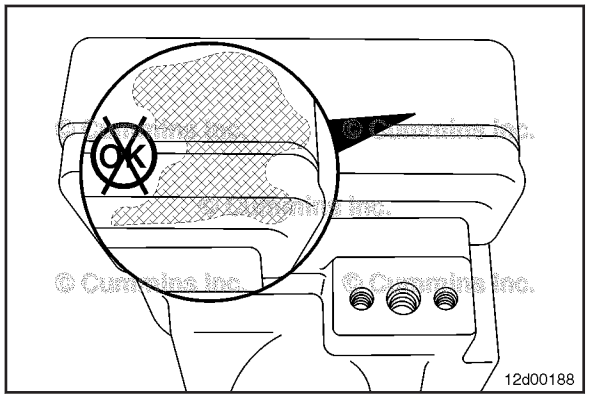


Finishing Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the battery. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

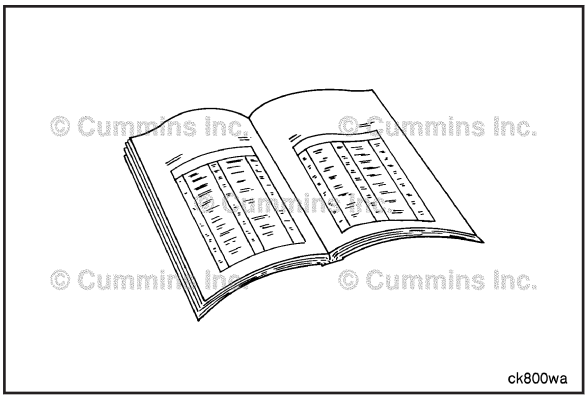


Air Compressor Cylinder Head, Single Cylinder (012-007)

Initial Check

Inspect the cylinder head for signs of a coolant leak. A coolant leak will be identified by an area of engine paint appearing to have been washed away. White crystalline clusters of material are **not** a sign of a coolant leak. If a leak is found, rebuild the air compressor head using a gasket kit. Go to the Disassemble section below.

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.

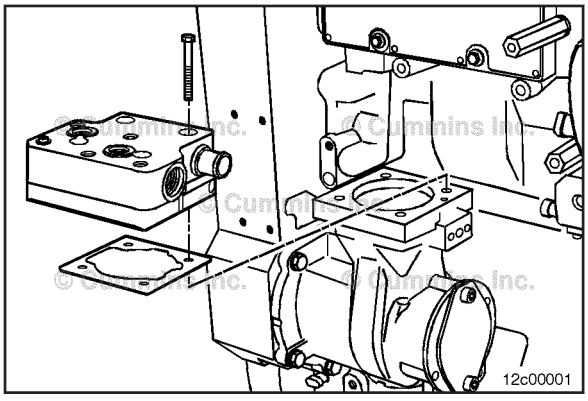
⚠ WARNING ⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ WARNING ⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠ WARNING ⚠
Air pressure must be released from the system before removing the air governor. The governor can be under pressure and cause personal injury.

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the air compressor coolant lines. Refer to Procedure 012-004 in Section 12.
- Remove the air governor or air governor signal line, if necessary. Refer to the OEM service manual.

Remove



Remove the four 8-mm capscrews.

Do **not** remove the three M6 internal hex capscrews at this time.

Remove the head and gasket.

NOTE: Due to an interference with the fuel pump on some applications, it can be difficult to remove all four mounting capscrews completely from the air compressor cylinder head while the air compressor is still mounted to the engine. To remove the cylinder head, completely remove the front two capscrews and completely loosen the rear two capscrews. Simultaneously lift the left rear capscrew and cylinder head to unseat the locating dowel from the air compressor housing. Slowly rotate the head **counterclockwise**, using the right rear locating dowel as a pivot point until enough clearance is available to lift the cylinder head off the air compressor.

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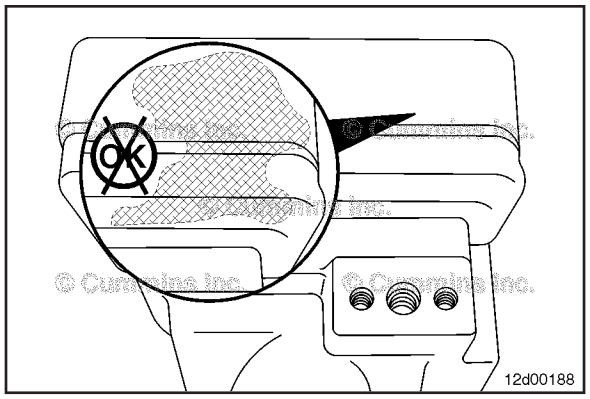
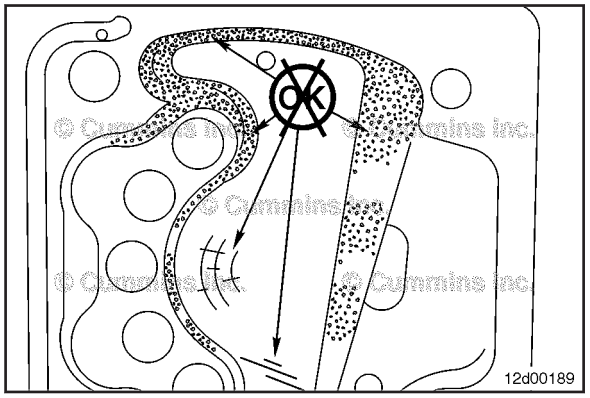


Clean and Inspect for Reuse

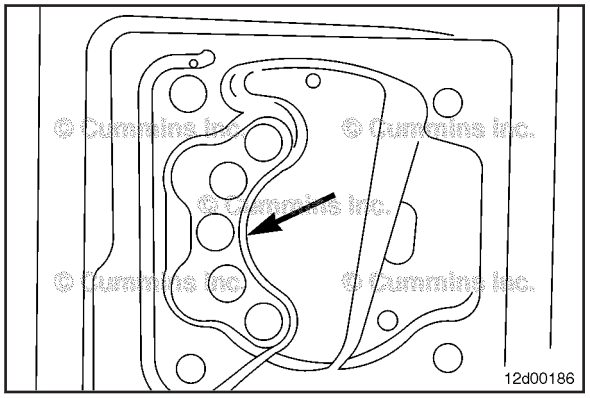
NOTE: The below clean and inspect steps are **only** to be completed if the air compressor cylinder head was removed as part of another repair.The air compressor cylinder head does **not** need to be removed if the unloader and valve assembly are determined to be stuck/ seized. Refer to Procedure 012-003 in Section 12.

Inspect the cylinder head for signs of an external coolant leak. A large coolant leak from the air compressor cylinder head will have blistered/removed paint and/or have a white deposit build up.

If a large coolant leak is observed, the head **must** be rebuilt with a gasket kit. Refer to the Cylinder Head Gasket Kit in the Install section.



Inspect the unloader valve plate and cylinder head for deep scratching or scoring. If the cylinder head is scratched or scored deeply, it **must** be replaced.



Verify that the unloader piston is in the proper orientation and operates properly. If, upon inspection, the unloader piston and plate are stuck open, exposing any area of the relief chamber, carefully remove the unloader plate from the unloader piston pinions.

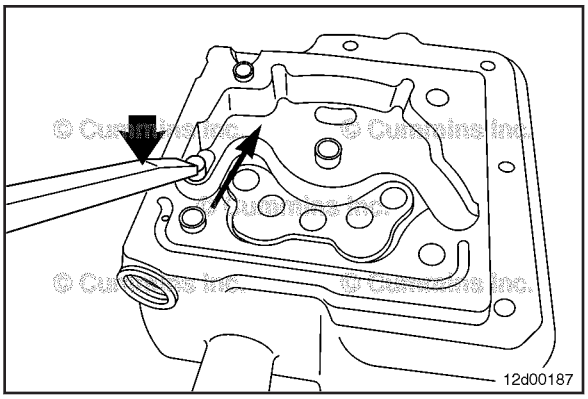
NOTE: The unloader piston and plate **must always** default to the fully closed position.

Place a few drops of automatic transmission fluid into the unloader piston bore. Coat the front and back side of the piston with fluid.

Use a stiff wooden handle to apply pressure to the unloader valve against the spring. Slide the unloader piston through the full range of rearward travel. When the spring is fully compressed, quickly let the pressure off, allowing the spring to drive the piston back to its closed state. Repeat cycling the unloader piston in this manner 5 to 10 times.

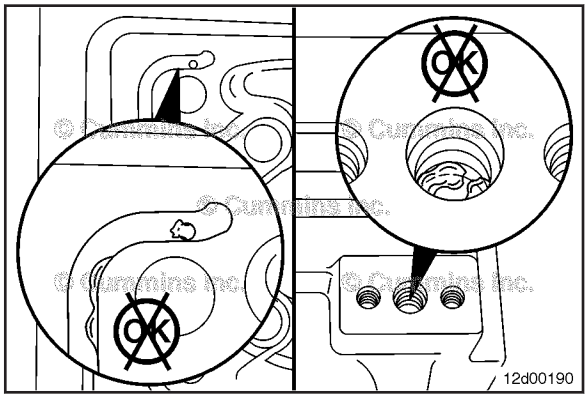
If the unloader piston continues to demonstrate any resistance to movement, or slow response while returning to the default closed position, the cylinder head **must** be replaced.

NOTE: The above steps can be completed without removing the air compressor cylinder head from the air compressor by using the Air Compressor Cleaning Kit, Part Number 2882280. Refer to Procedure 012-003 in Section 12.

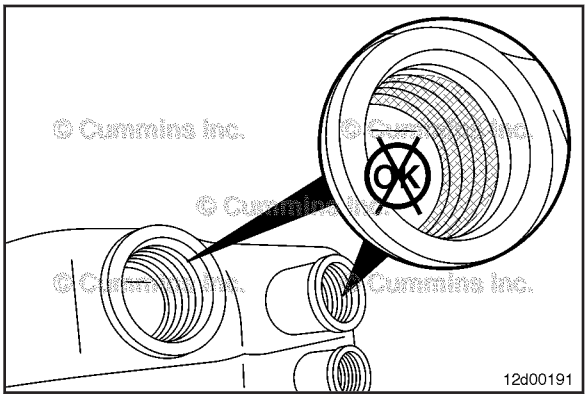


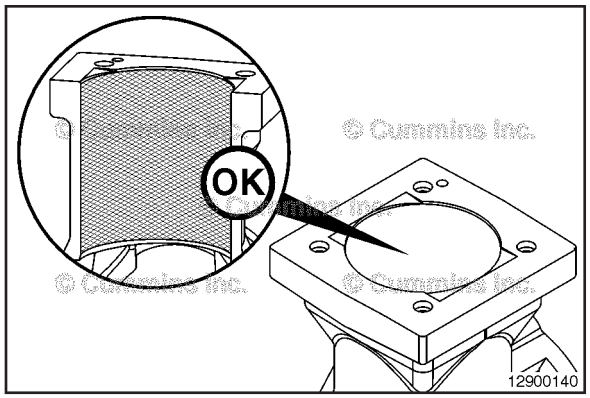
Inspect the unloader channel and governor supply port, as well as the unloader piston, for signs of rust.

NOTE: Rust present in the unloader channel and/or governor feed port indicates that either the air dryer has malfunctioned, or improper draining of the vehicle air tanks. Use the following procedure to check the air governor for proper operation. Refer to Procedure 012-016 in Section 12. Refer to the OEM service manual for troubleshooting the air dryer, as well as proper maintenance intervals for the vehicle compressed air tanks.

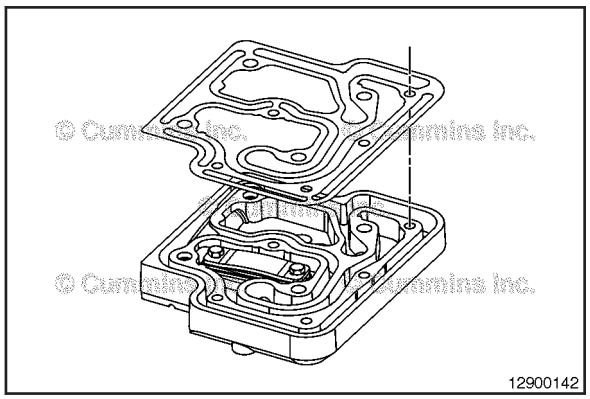


Inspect the intake and discharge ports for heavy carbon buildup. Use the following procedure for proper reuse guidelines. Refer to Procedure 012-003 in Section 12.





While the air compressor cylinder head is removed, inspect the rotating components and the cylinder bore of the air compressor for damage. Refer to Procedure 012-014 in Section 12.



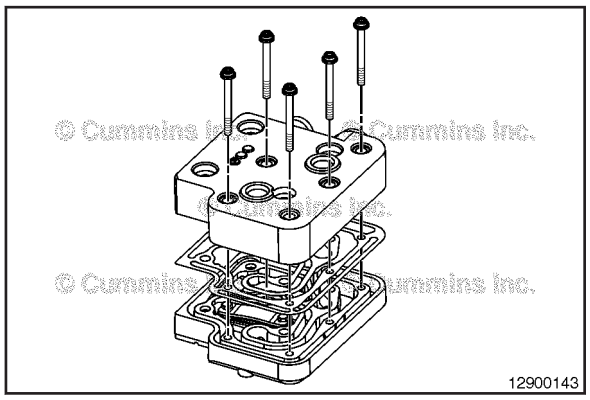
Disassemble

Air compressor cylinder heads can be rebuilt with new gaskets if air or coolant leaks are detected.

Disassemble the cylinder head by removing the five internal hex capscrews.

Separate the cylinder head.

Remove and discard the old gasket.

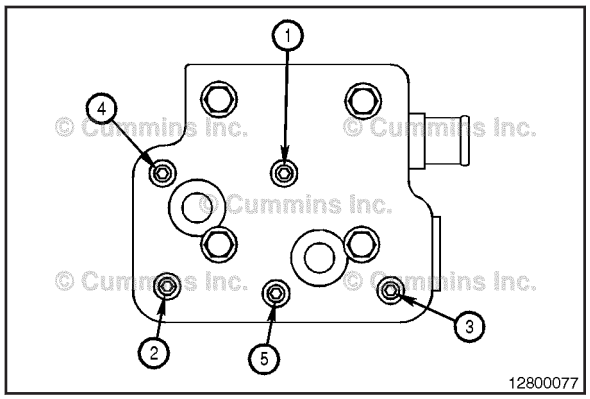


Inspect the sealing surface on both the upper and lower sections of the cylinder head for damage.

Replace the exhaust valve if there was a coolant related failure, or it is suspected that it is **not** sealing.

Do **not** reuse the exhaust valve capscrews.

Clean and inspect sealing surface.



Assemble

Place the new exhaust valve with the flat surface down.

Torque Value:

Step 1	5 N•m	[44 in-lb]
Step 2	10 N•m	[89 in-lb]

Carefully place a new gasket on the lower section of the cylinder head.

Place the upper section of the cylinder head and insert five internal hex capscrews, and finger tighten.

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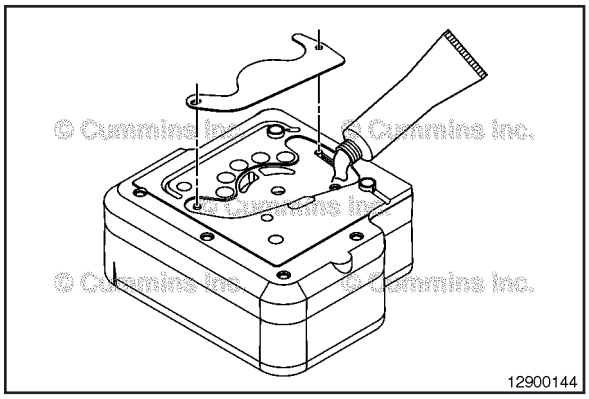
NOTE: If installing a new air compressor cylinder head assembly, the following steps should **not** be performed. New cylinder head assemblies are already assembled per the instructions below. Skip to placement of the cylinder head assembly onto the air compressor housing.

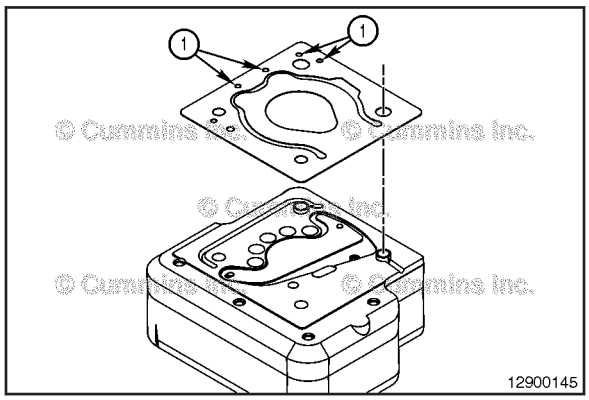
Apply a light coating of assembly lubricant, Part Number 3163087 or equivalent, to the unloader plate recess of the cylinder head.

Place the unloader plate onto the unloader piston pinion, as well as the stationary pinion, and press the unloader plate into the assembly lubricant.



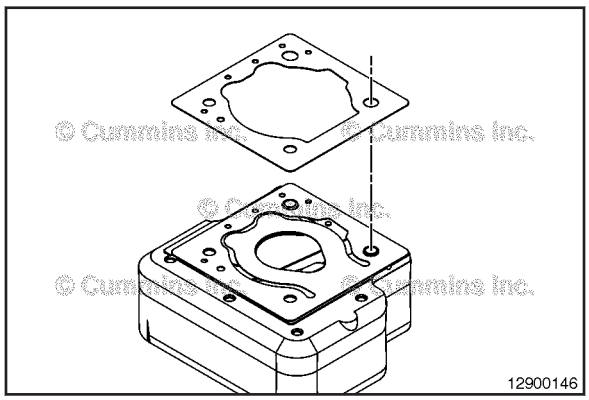
Install the air compressor intake valve.

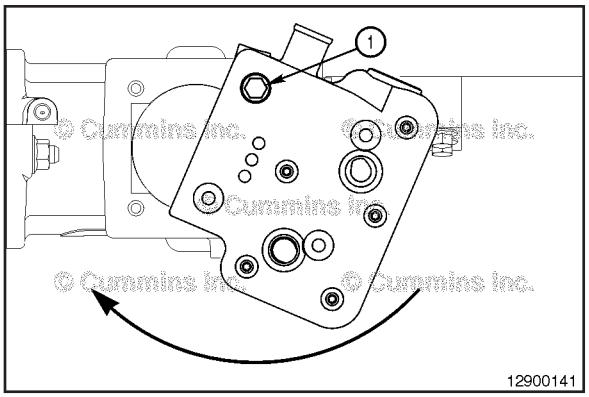
Make sure the intake valve is oriented so the unloader channel of the cylinder head is exposed by four holes (1).



Install the sealing gasket in a similar manner.

Make sure to orient the gasket so the four holes are **not** blocked by the sealing gasket.





Install

NOTE: A new gasket kit **must** be used each time the air compressor cylinder head is removed and installed. Do **not** reuse the cylinder head mounting capscrews.

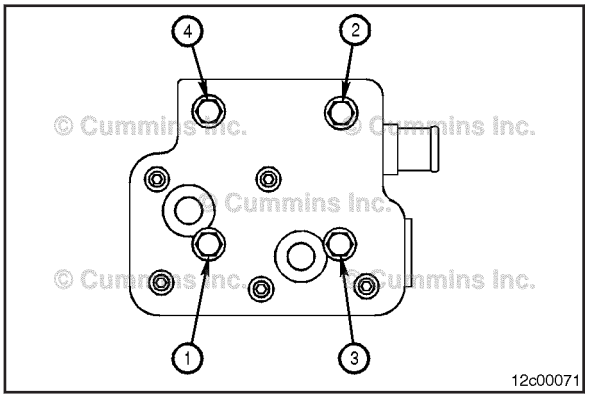
NOTE: Due to an interference with the fuel pump on some applications, following a specific installation sequence of the air compressor cylinder head and mounting capscrews will make installation possible with the air compressor still installed on the engine.

Before placing the cylinder head on the air compressor housing, insert the rear right capscrew (1) through the mounting hole. Place the cylinder head on the air compressor housing such that the right rear locating dowel and mounting capscrew engage the mounting hole in the air compressor housing.

Insert the rear left capscrew through the cylinder head mounting hole. Rotate the cylinder head clockwise into position, using the rear right capscrew and locating dowel as a pivot. Once the cylinder head has been properly set onto the air compressor housing, insert the front two capscrews.

Install the cylinder head and gasket.

Install the four 8-mm capscrews.

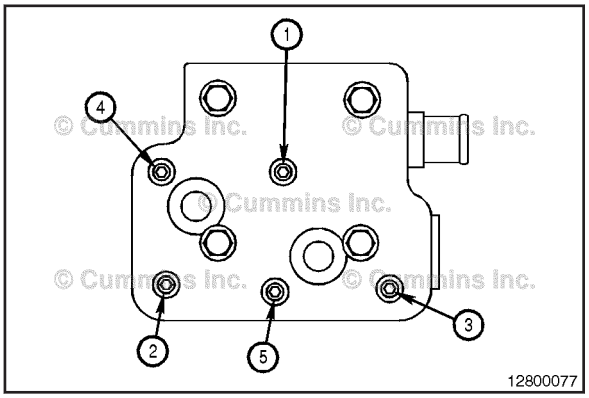


Tighten the capscrews in the sequence shown. Use the torque plus angle method.

Torque Value:

Step 1	25 N•m	[221 in-lb]
Step 2	Rotate capscrews 90 degrees.	

NOTE: If a new head assembly is being installed, the five small head cover bolts **MUST** be tightened.



If a new head assembly is being installed, tighten the five small head cover capscrews in the sequence shown.

Torque Value:

Step 1	6 N•m	[53 in-lb]
Step 2	Rotate 90 degrees.	

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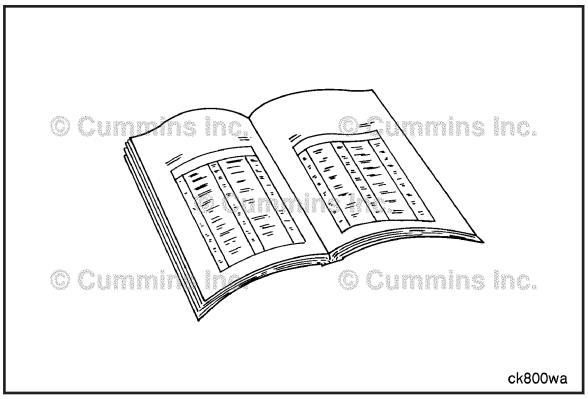
Finishing Steps

⚠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 air compressor coolant lines. Refer to Procedure 012-004 in Section 12.
- Install the air inlet and outlet connections from the air compressor. Refer to Procedure 012-004 in Section 12.
- Install the air governor or air governor signal line, if necessary. Refer to the OEM service manual.
- 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.



Air Compressor Unloader and Valve Assembly (012-013)

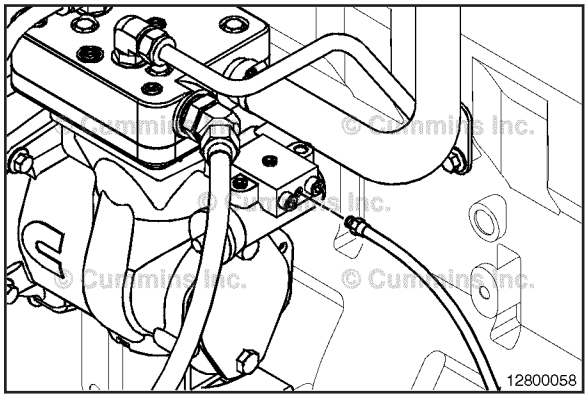
Preparatory Steps

⚠WARNING⚠
Air pressure must be released from the system before removing the air governor. The governor can be under pressure and cause personal injury.

Remove the air governor or air governor signal line from the air compressor. Install the pipe plugs into all of the air governor unloader ports on the air compressor.

Operate the engine to activate the air compressor.

If the air system pressure does **not** rise, the unloader valve assembly is malfunctioning. Clean the air compressor cylinder head. Refer to Procedure 012-003 in Section 12.

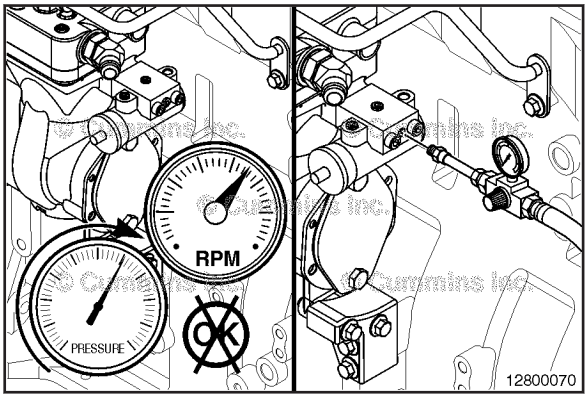


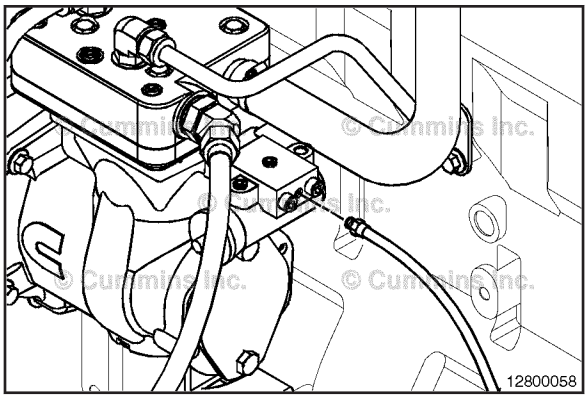
If the air compressor has multiple air governor unloader ports, install a pipe plug into one of the ports, and a shop air fitting into the other unloader port.

Connect a regulated shop air hose to the fitting in the unloader port.

Operate the engine to activate the air compressor.

When the air system pressure has reached 586 kPa [85 PSI], apply 698 kPa [100 psig] of shop air pressure to the unloader port. If the vehicle air system pressure continues rising, the unloader valve assembly is malfunctioning. Clean the air compressor cylinder head. Refer to Procedure 012-003 in Section 12.





Connect the OEM air governor signal line to the air compressor unloader port.

Operate the engine to activate the air compressor. Verify that the system still builds pressure properly.

If the air system pressure continues to build beyond the governed point, the air governor is malfunctioning. Refer to Procedure 012-016 in Section 12.

Air Compressor (012-014)

Pressure Test

⚠WARNING⚠

The external pressure tank used must meet Society of Automotive Engineers (SAE) J10 and FMVSS121 standards, and have a safety pressure relief valve which opens between 1034 to 1207 kPa [150 to 175 psi]. Failure to use the proper pressure vessel and plumbing can result in property damage and serious personal injury.

Start the engine and operate at idle engine speed.

NOTE: Once the external pressure tank pressure reaches 862 kPa [125 psi], shut the engine OFF. Depending on the size of the external tank and the diameter/length of the discharge hose being used, the buildup time will vary.

For example, a single cylinder (318 cc) compressor filled an 42 liters [11 gal] tank to 862 kPa [125 psi] with a (#10 x 6ft length) discharge hose in 90 seconds. This was considered to be the specification for this setup.

Verify that the air compressor will build pressure in the external tank. If air pressure successfully builds to 862 kPa [125 psi], the air compressor functions properly. Remove the external air discharge hose from the air compressor and install the vehicle air discharge hose and air governor signal hose to the compressor. Reference the symptom tree being utilized to inspect the rest of the air system components for leaks and proper operation.

If the air compressor fails to build to 862 kPa [125 psi], the air compressor is malfunctioning and the cylinder head needs to be repaired based on the marking scribed on the head. Refer to Procedure 012-003 in Section 12.

Air Compressor Diagnostic Test

1 Park the vehicle. Use wheel chocks or an appropriate anti-roll device to stabilize the vehicle.

- Drain the vehicle air system.
- Remove the air discharge hose and air govenor signal hose from the air compressor. Install pipe plugs into the air compressor unloader signal ports.
- Plumb the air compressor discharge hose into an external pressure tank. The external pressure tank **must** be equipped with a pressure gauge and pressure relief valve. Make sure that the fittings are installed with appropriate thread sealant and do **not** leak.

Start the engine and operate at rated engine speed.

Verify that the air compressor will build pressure in the external tank. If air pressure fails to build in the pressure tank, the air compressor has malfunctioned. Refer to Procedure 012-013 in Section 12.

NOTE: Once the external pressure tank pressure reaches 689 kPa [100 psi], shut the engine OFF.

Monitor the pressure gauge on the external tank for rapid leak down of the air pressure. If the air tank loses more than 138 kPa [20 psi] in a 5 minute period, the pressure relief valve, intake valve, or exhaust valve has malfunctioned. The air compressor cylinder head intake and exhaust valve are **not** serviceable. Replace the air compressor cylinder head. Refer to Procedure 012-007 in Section 12.

NOTE: Do **not** cycle air accessories such as seats, doors, wipers, air bags, etc.

1 If there is any noticeable decrease of the air gauge readings, or if the air dryer cycled during the 10 minute test, repair the leaks.

NOTE: Leaks in systems that hold pressure for 5 to 10 minutes may be hard to find.

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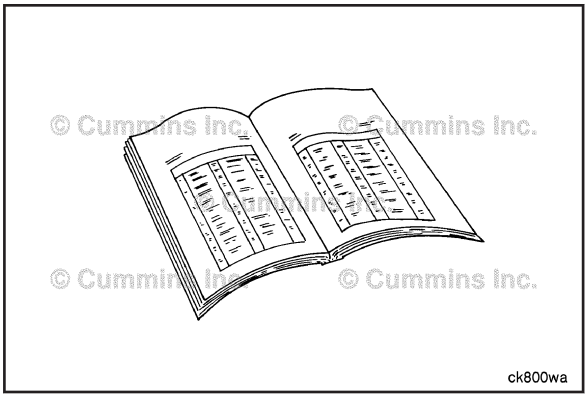
Preparatory Steps



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

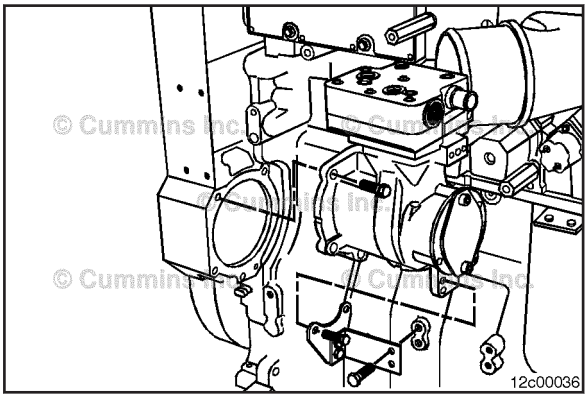
⚠WARNING⚠
Wear safety glasses or a face shield, as well as protective clothing, to prevent personal injury when using a steam cleaner or high-pressure water.

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Remove

Remove the air compressor support brackets and capscrews.

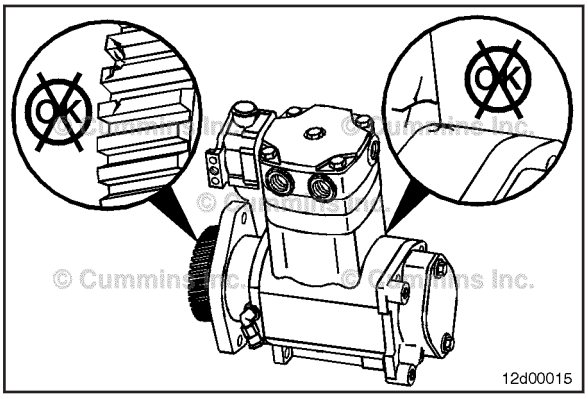
Remove the two capscrews and the air compressor.



Clean and Inspect for Reuse

Inspect the compressor housing for cracks or other damage.

Inspect the drive gear for cracks or other damage.



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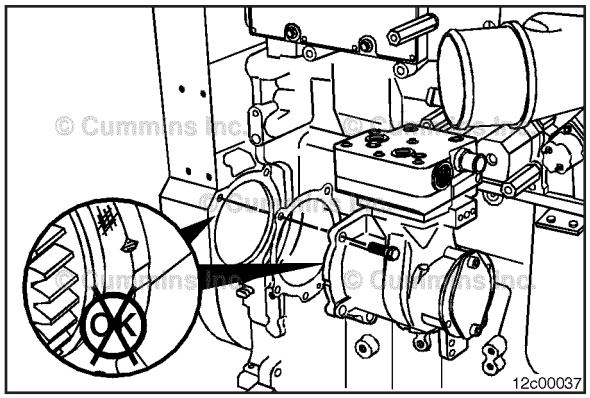
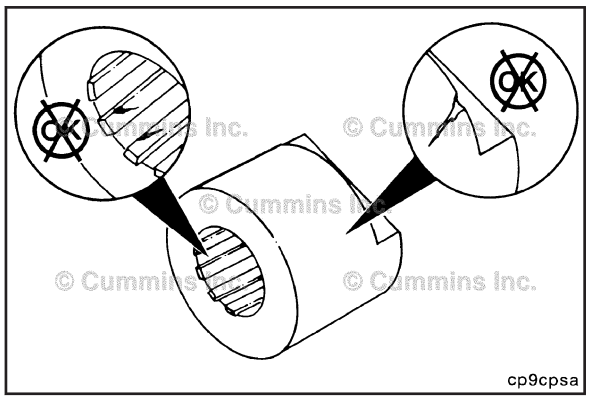


Make sure the gasket surfaces of the front gear housing and the air compressor are clean and **not** damaged.



Power Steering Coupling (if applicable)

Inspect the power steering coupling for wear or cracks.

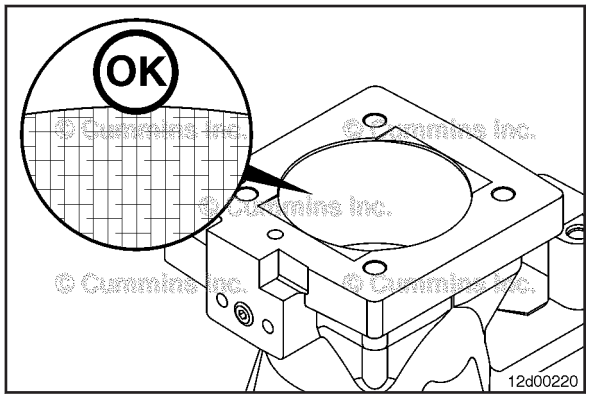
Replace the coupling, if damaged. Refer to the OEM service manual.

Remove the air compressor cylinder head if it is **not** already removed. Refer to Procedure 012-007 in Section 12.

Inspect the inside circumference for vertical scratches deep enough to be felt with a fingernail.

If a fingernail catches in the scratch, the air compressor must be replaced.

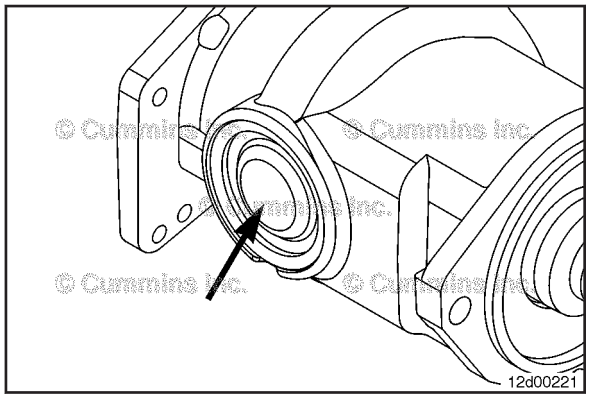
Inspect the inside circumference for scuffing, scoring, or polishing.



If the cylinder head is removed, inspect the bore and rotating components within the air compressor.

Inspect the air compressor bore for signs of scoring and polishing.

NOTE: A cross hatch honing pattern **must** be visible within the bore. If any part of the bore is scored or polished, the air compressor **must** be replaced.



If internal damage to the rotating assembly (crankshaft, piston, and connecting rod) is suspected, the plug on the bottom of the air compressor **must** be removed to inpect the rotating assembly.

NOTE: A replacement plug and gasket kit is available for assembling the air compressor.

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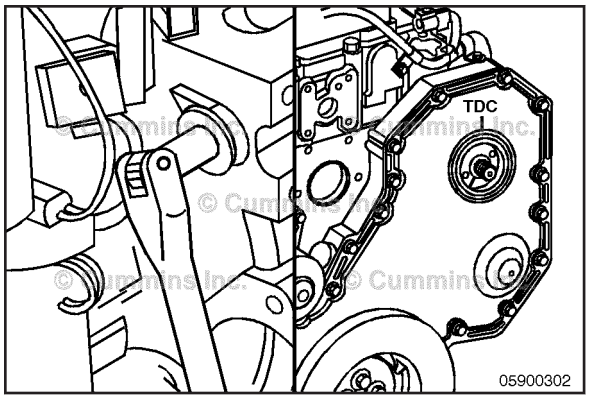
Install

Air Compressor Timing (for Single-Cylinder Air Compressor **Only**)

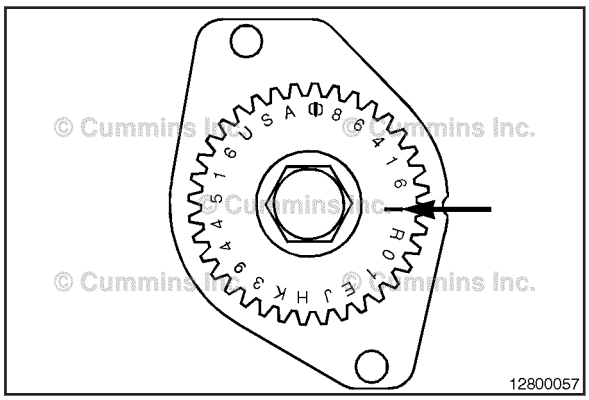
Rotate the engine so that the number 1 cylinder is at top dead center (TDC). This is done by aligning the timing mark on the fuel pump gear with the TDC mark.



NOTE: There are two similar marks on the air compressor gear that look like “[I]” and “I”. The timing mark to be used when timing the air compressor to the engine is “I”.

Cummins® Single-Cylinder Air Compressors

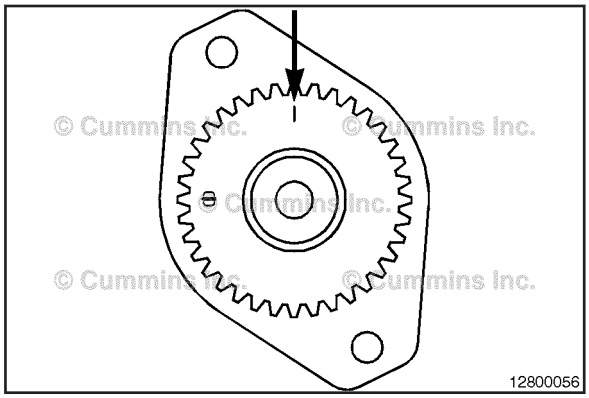
Viewing the compressor from the gear end (with the compressor in a vertical position), rotate the gear so the “I” timing mark is at the 3-o'clock position. The Cummins® single-cylinder air compressor will have a divot on the housing at the 3-o'clock position to aid in timing the compressor. Once the timing mark is at the 3-o'clock position, this will set the compressor at 60-degrees before TDC of the compressor's compression stroke.



Holset® Air Compressors

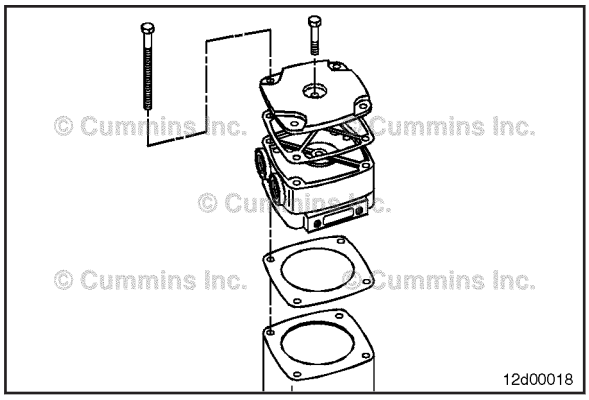
Viewing the compressor from the gear end (with the compressor in a vertical position), rotate the gear so the “I” timing mark is at the 12-o'clock position. This will set the compressor at 60-degrees before TDC of the compressor's compression stroke.

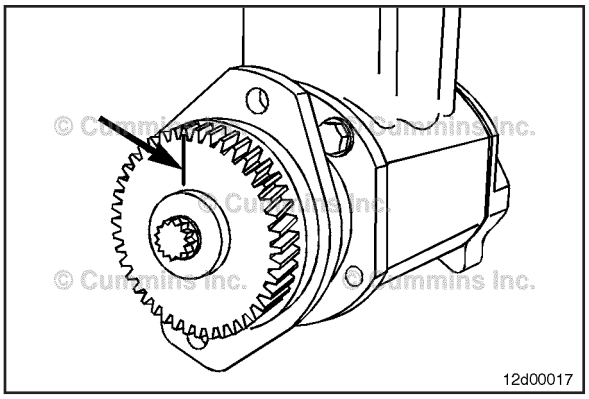
NOTE: Some Holset® compressors have a divot or drilling on the housing at the 10-o'clock position; IGNORE this mark.



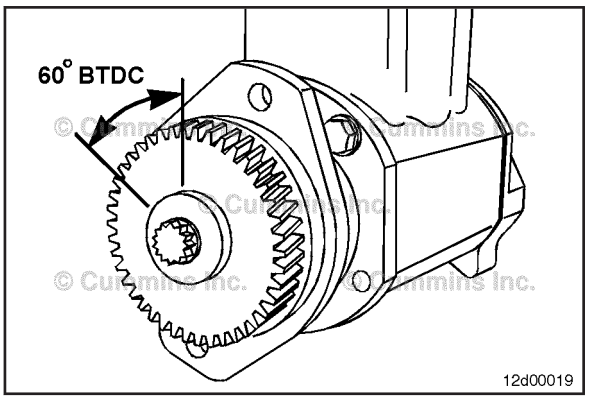
Air Compressor Timing (for Single-Cylinder Air Compressor **Only**, Other than Holset® or Cummins®)

Locate TDC on the compressor crankshaft by removing the unloader valve or head. See the respective air compressor manual. TDC does **not** have to be exact. The system is tolerant of some misalignment.

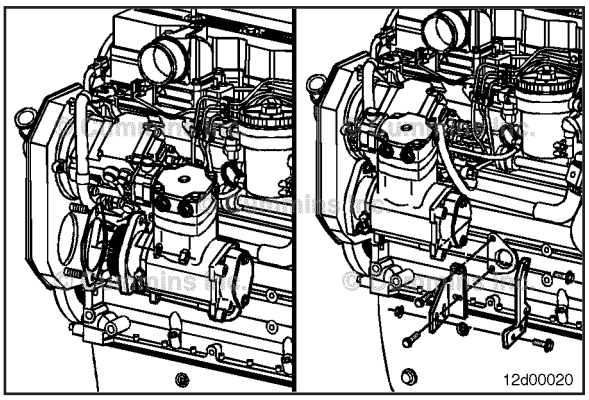




Use ink or a Dykem® marking pen to mark the air compressor gear face at TDC (12-o'clock position when viewed from the front).

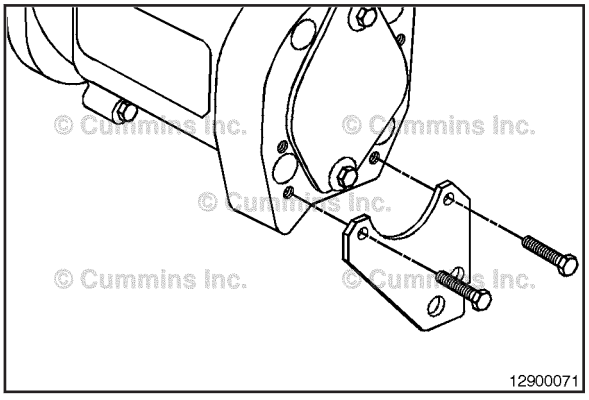


Rotate the compressor TDC mark to 60-degrees, or six teeth on a 36-tooth gear, before TDC. This is approximately 10-o'clock when viewed from the front of the air compressor.



Install the air compressor and new gasket to the gear housing.

Torque Value: 77 N•m [57 ft-lb]



Install the brace to the air compressor.

Tighten the capscrews.

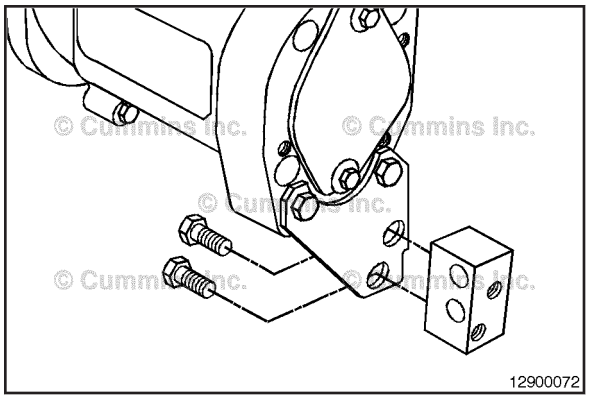
Torque Value: 43 N•m [32 ft-lb]

Install the spacer to brace capscrews and hand-tighten.

Make sure there are no gaps between the spacer and the brace, and no gaps between the spacer and the cylinder block.

Tighten the capscrews.

Torque Value: 43 N•m [32 ft-lb]

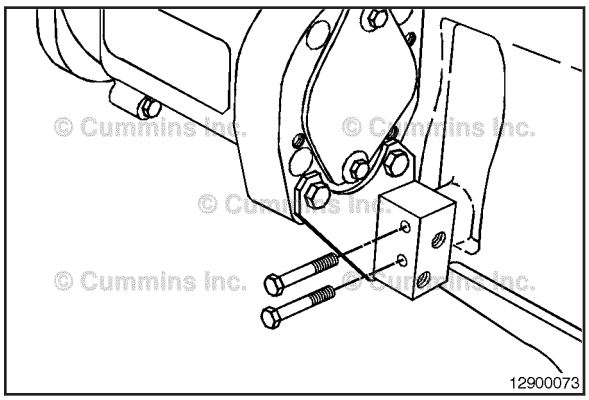


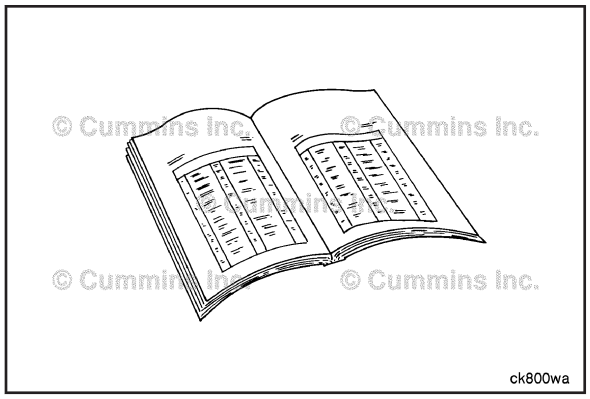
Install the capscrews that connect the spacer to the cylinder block and hand-tighten.

Make sure there are no gaps between the spacer and the brace, and no gaps between the spacer and the cylinder block.

Tighten the capscrews.

Torque Value: 43 N•m [32 ft-lb]



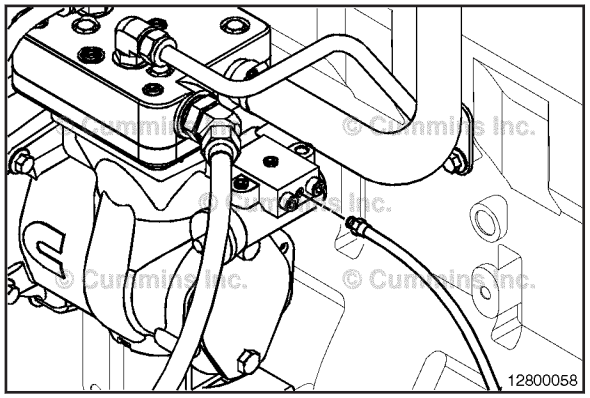


Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Install the oil supply line. Refer to Procedure 012-110 in Section 12.
- Install the air inlet and air outlet connections to the air compressor.
- Install the air governor or air governor signal line, if necessary. Refer to the OEM service manual.
- Install the air compressor coolant lines. Refer to Procedure 012-004 in Section 12.
- Install the air lines.
- Install any attachments to the rear of the air compressor. Refer to the OEM service manual.
- Fill the engine cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine to activate the air compressor and check for leaks.



Air Governor (012-016)

Pressure Test

The air compressor governor location can vary. The air governor can be air compressor mounted or chassis mounted.

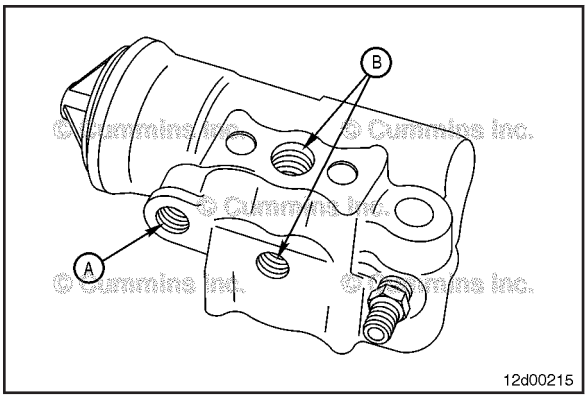
If the air pressure is being governed at either a higher or lower pressure than the equipment manufacturer's specification, connect a regulated shop air pressure line to the air compressor governor air signal port.

NOTE: Be positive the gauge is accurate and the supply lines and fittings are in good condition before performing any air pressure checks. Use a master gauge of known accuracy to check the air pressure gauge.

NOTE: When performing the test, be sure the air system pressure does **not** exceed the manufacturer's maximum allowable pressure.

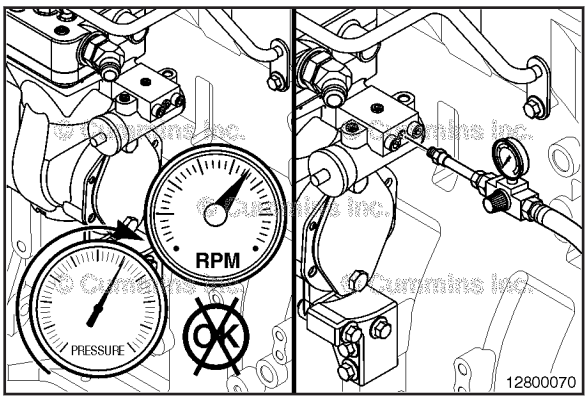
NOTE: Make sure the governor vent port (A) is open to the atmosphere. If this port is plugged, the air governor will malfunction.

- Inspect the governor control lines for restrictions.
- Drain the air system and install a gauge of known accuracy onto the unloader port (B) of the air governor. If the governor has two unloader ports, make sure one is plugged.



- Start the engine and apply the brakes to initiate air compressor pumping. Note the governor cut-out pressure (pressure at which the compressor stops pumping).
- Apply the brakes until the compressor starts to pump. Note the cut-in pressure.

  NOTE: Zero pressure in the governor unloader line will allow the compressor to start pumping.
- Allow the system to build pressure until the air compressor unloads.
- Apply the brakes until the compressor starts to pump. Note the time it takes for the governor unloader port to go from system pressure to 0 kPa [0 psi]. The cycle should take less than 2 seconds.
- Repeat steps three through six for a total of three runs.



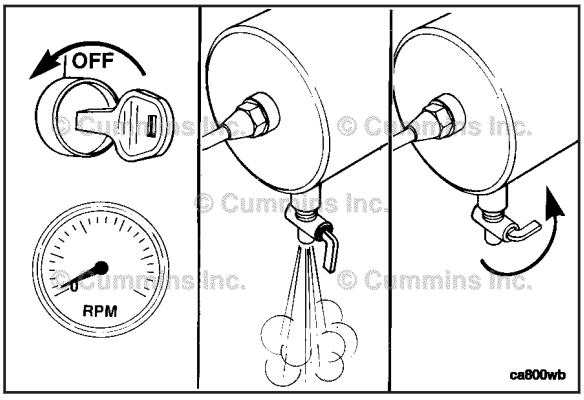
Air Leaks, Compressed Air System (012-019)

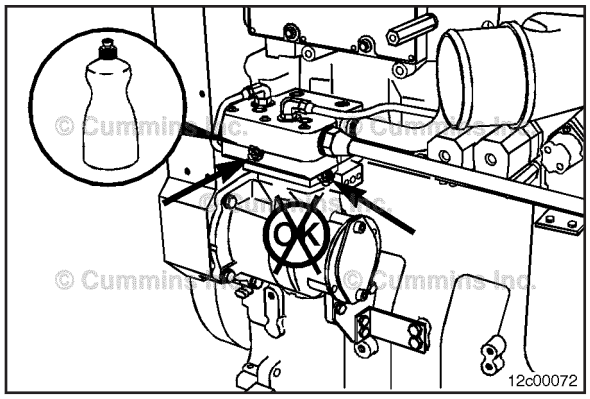
Initial Check

⚠WARNING⚠
Wear appropriate eye and face protection when releasing air pressure from the compressed air system. Flying debris and dirt can cause personal injury.

Shut off the engine.

Open the drain cock on the wet tank to release air from the system. Close the draincock after the pressure is released.



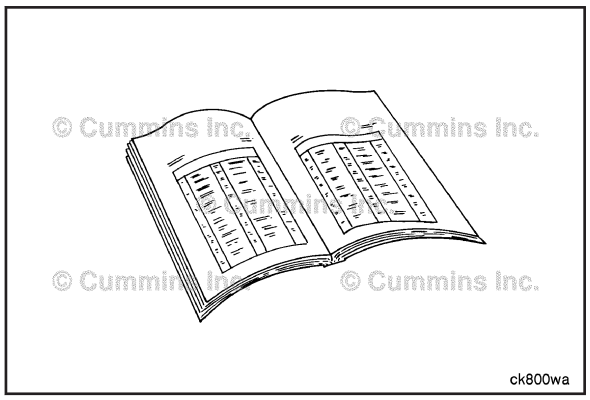


Operate the engine to activate the air compressor.

With the air compressor pumping between 550 to 690 kPa [80 to 100 psi], use a solution of soapy water to check for air leaks in the following areas:

- Air compressor head gasket
- Air compressor cover gasket
- Hose and fitting leaks.

If air leaks are found, verify that the air compressor head and cover bolts are torqued properly. Make sure hoses and fittings are tight. Replace if necessary.

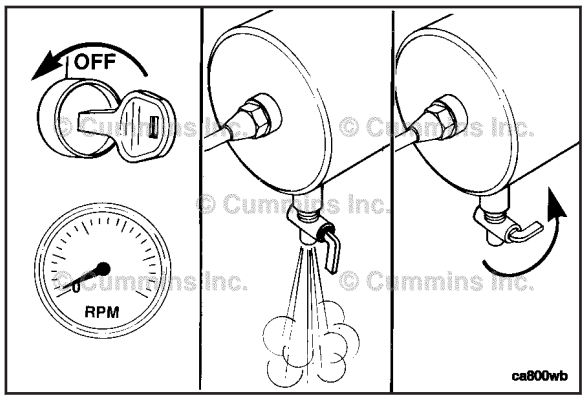


Air Compressor (Oil Carryover) (012-020)

Inspect for Reuse

Perform this test in conjunction with troubleshooting the air compressor pumping oil into the air system.

NOTE: Small oil deposits at the air dryer purge valve are normal. The air compressor is lubricated with engine oil, and small amounts of carryover are to be expected. Oil carryover is more common on naturally aspirated air compressors. Oil or moisture can be expected at any purge or drain valves up to and including the air dryer, which will include ping tanks and/or cooling or condesation tanks. If there is no oil or condensation found at the tanks after the air dryer, then the air dryer is working correctly and sized adequately.



⚠WARNING⚠
The air discharge line and other equipment will become hot during the course of the test. To prevent burns, use protective gloves when touching heated surfaces.

Operate the engine until the coolant temperature reaches normal operating temperature. Once the coolant has reached operating temperature, shut the engine down and completely drain the vehicle air system.

NOTE: Failure to warm the engine adequately can result in false test results.

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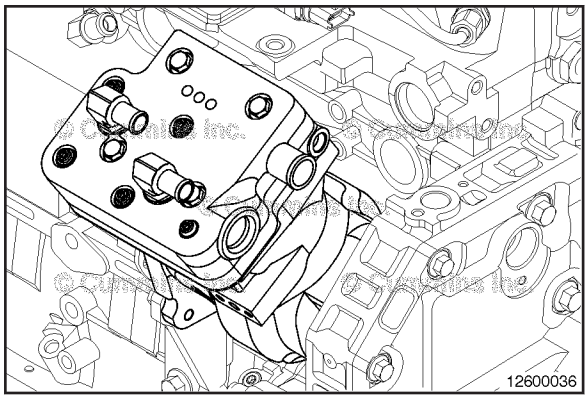
⚠WARNING⚠
The discharge from the air compressor will be hot, possibly contain oil vapors, and will be noisy. Make sure there is adequate ventilation and hearing protection is worn, particularly if the type of vehicle requires the test be conducted in an enclosed environment.

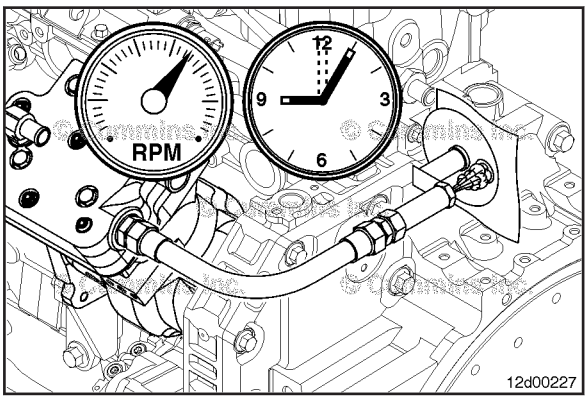
Disconnect the discharge pipe from the air compressor cylinder head.

Disconnect the air inlet plumbing at the air compressor cylinder head.



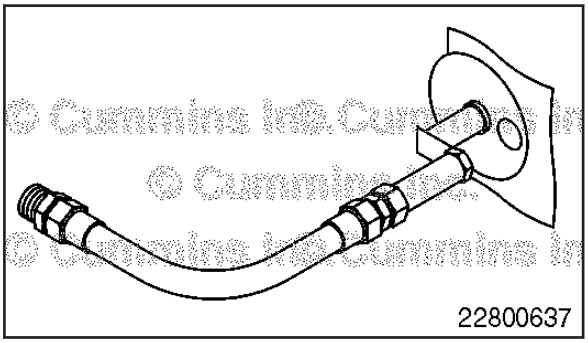
Connect the oil carryover test tool, Part Number 4918883, to the air compressor cylinder head discharge port.

NOTE: If the application presents restricted access to the air compressor, a high temperature flexible hose (minimum 15 mm [0.6 in] inside diameter) can be connected directly to the discharge port of the compressor in order to carry out the test outside the engine compartment. Be sure to have a 90 degree bend near the end of the flexible hose during testing.

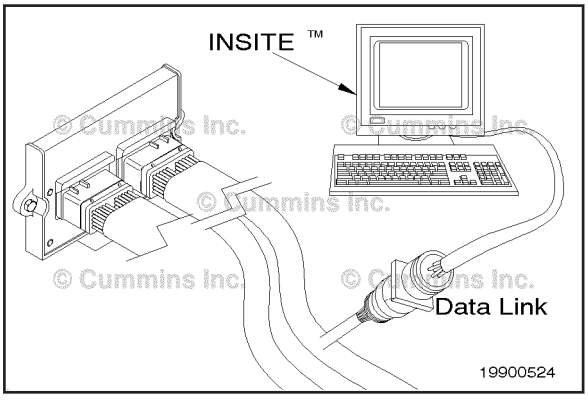


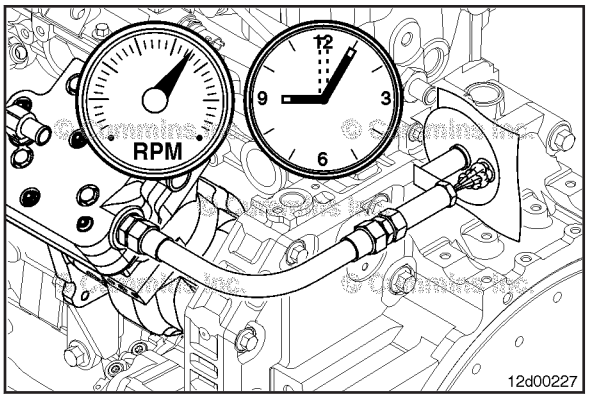
Install the test paper into the service tool, Part Number 4918883. Make sure it is held at a right angle to and in line with the flow of compressed air, at a distance **not** to exceed 100 mm [3.9 in] from the end of the compressor discharge pipe or flexible hose, if fitted.

The test paper can be standard clean copier paper, typically 80 grams/sq meter. It **must** be mounted in the air compressor discharge line tool, leaving a 70 mm [2.76 in] diameter circle of the paper exposed. The outline of the circle in the mask **must** be drawn onto the test paper to later aid in comparison.



NOTE: It may be necessary to use INSITE™ electronic service tool to increase the maximum engine speed, without vehicle speed sensor (VSS), to 2100 rpm.



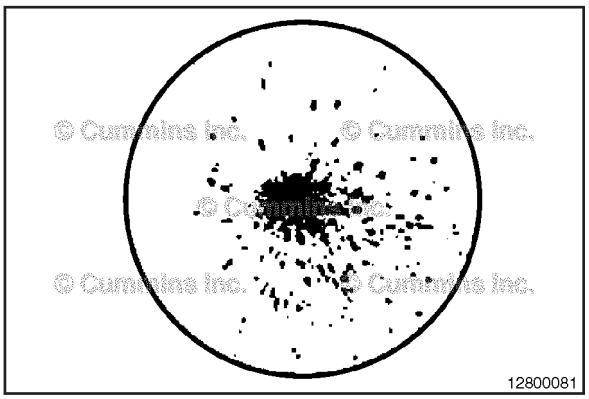


To perform the test, start the engine and run at high idle. Leave the test paper in the airflow for exactly 5 minutes. Remove the test paper, or rotate the tool mask exposing a new circular test area.

Repeat this test until three comparable circular test areas are generated.

Shut the engine down.

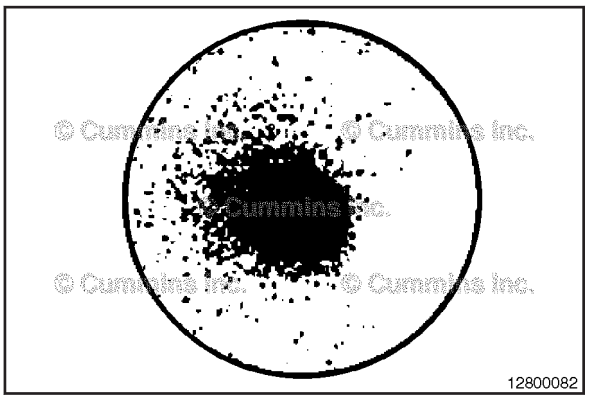
NOTE: If the maximum engine speed, without VSS, was adjusted in the previous step, change it back to the original value upon completion of the test.



NOTE: Compare the test results with the reference results shown below.

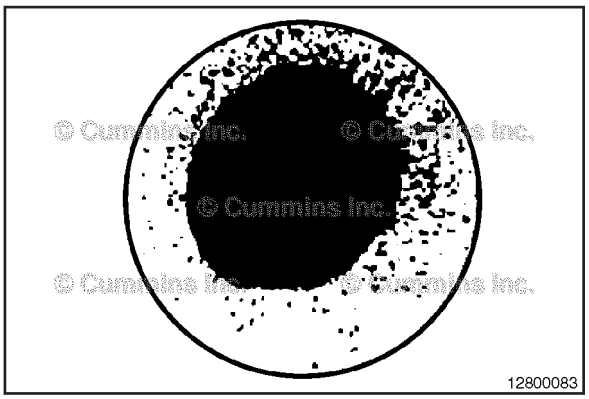
Time Air Compressor Has Been In Service (Months/ Years):

- Less Than 6 Months - Compressor in good condition
- 6 Months to 2 Years - Compressor in good condition
- Greater Than 2 Years - Compressor in good condition.



Time Air Compressor Has Been In Service (Months/ Years):

- Less Than 6 Months - Compressor needs to be replaced
- 6 Months to 2 Years - Compressor in acceptable condition
- Greater Than 2 Years - Compressor in good condition.



Time Air Compressor Has Been In Service (Months/ Years):

- Less Than 6 Months - Compressor needs to be replaced
- 6 Months to 2 Years - Compressor needs to be replaced
- Greater Than 2 Years - Compressor needs to be replaced.

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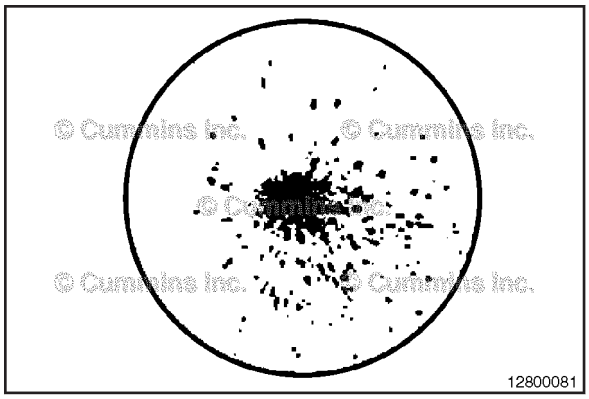
NOTE: This step **must** be completed if the compressor assembly is replaced as a result of this test and is requested to be returned via the CORE, or enhanced parts return (EPR) return process.

If the compressor is deemed failed and needs to be replaced, please place the test paper, with results of Oil Carryover Test, in a sealable plastic bag, seal to prevent oil contamination, and include with the failed compressor.

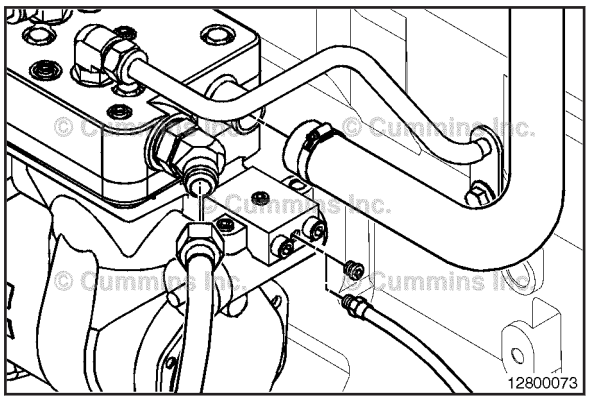


Air Pressure Relief Valve (012-024)

Test

Remove the air governor or air governor line from the air compressor.

Remove the air intake line from the air compressor cylinder head.



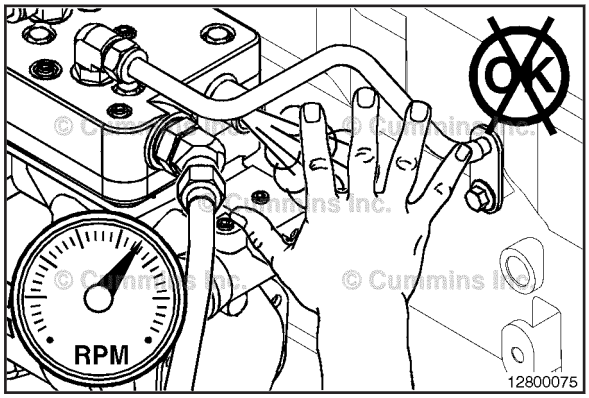
Operate the engine to activate the air compressor.

Under normal operating conditions, the air compressor intake port will create a vacuum.

To check for the presence of a vacuum, hold a piece of paper or cardstock 5 cm [2 in] in front of the air compressor intake port.

Observe the response of the paper.

Shut the engine off.

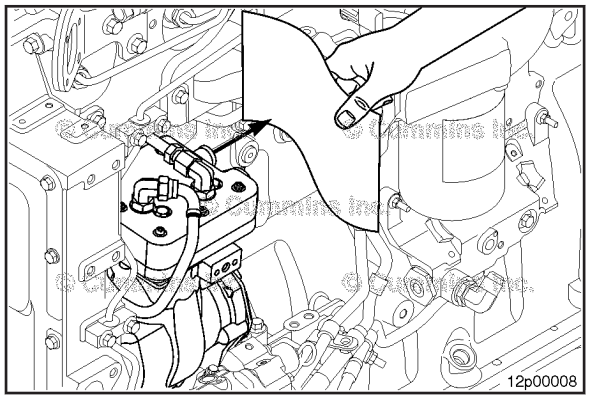


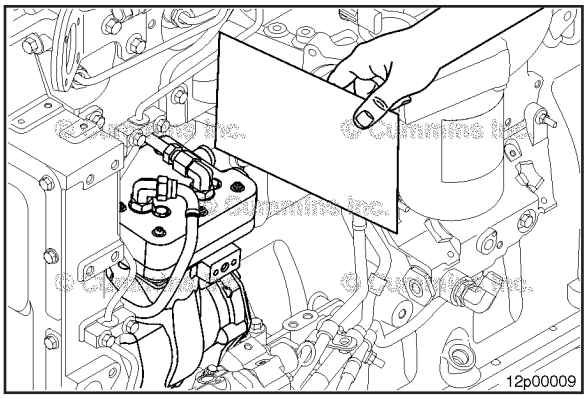
If the paper is blown away from the air compressor intake port, replace these components:

- Air pressure relief valve. See equipment manufacturer service information.

NOTE: For engines equipped with Wabco™ air compressors, the air pressure relief valve is an integral part of the air compressor cylinder head.

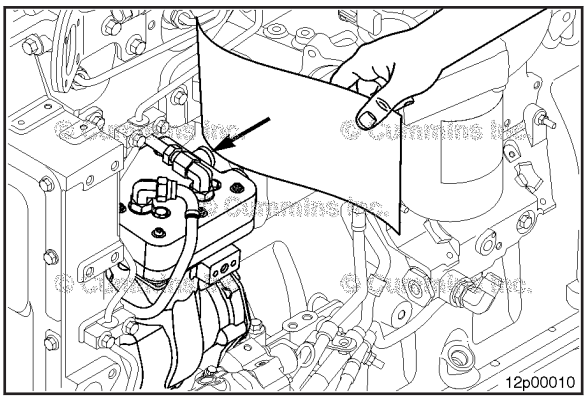
- Air compressor cylinder head. Refer to Procedure 012-007 in Section 12.



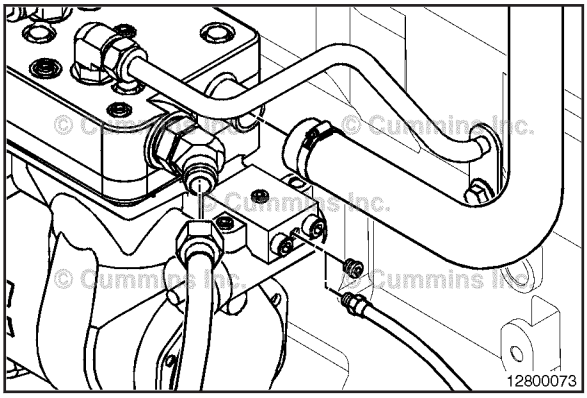


If the paper does **not** move:

- Check the downstream air system components for damage or restrictions.
- Make sure the intake and exhaust valves are functioning properly. Refer to Procedure 012-014 in Section 12.

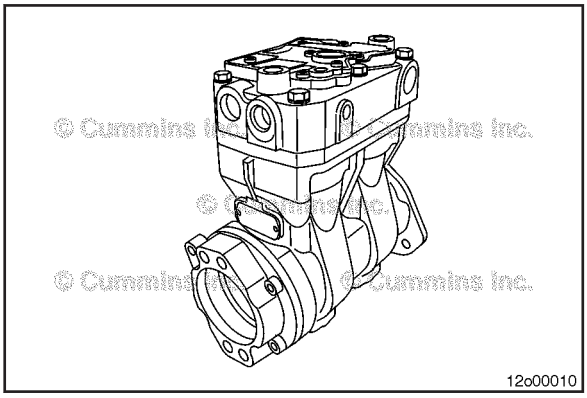


If the paper is pulled toward the air compressor intake, the air compressor relief valve is working properly.



Install the air intake line to the cylinder head.

Install the air governor or air governor line to the air compressor.



Air Compressor Rear Bearing Housing, Two Cylinder (012-112)

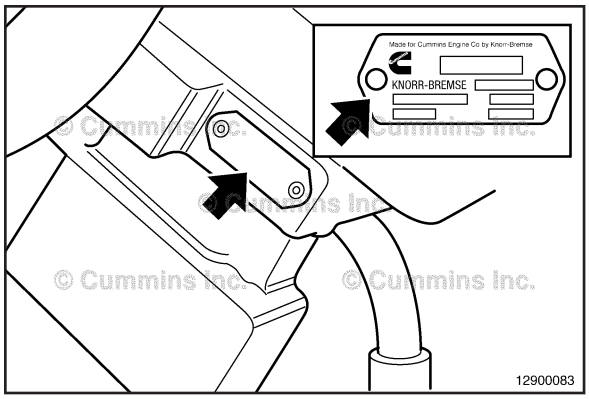
General Information

Before removing the rear bearing housing of the air compressor, **always** check to make sure parts are available for the type of air compressor being serviced. If parts are **not** available, it will be necessary to replace the entire air compressor.

NOTE: The following procedure has been specifically designed to cover Knorr-Bremse™ air compressor configurations.

Cummins® engines are equipped with a variety of air compressors. This procedure will cover the removal, cleaning, inspection, and installation of rear bearing housing of the Knorr-Bremse™ brand of air compressors with two cylinders.

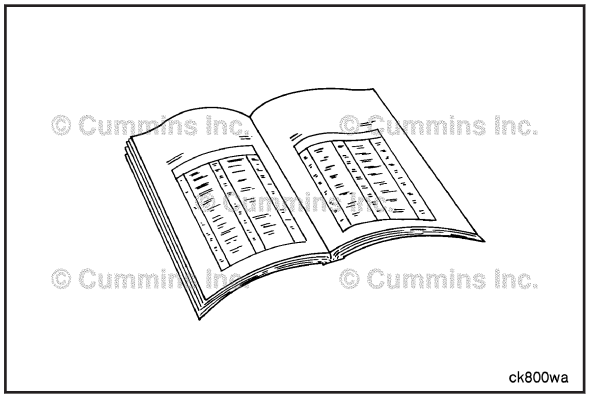
To determine what brand air compressor your specific engine has, look on the air compressor dataplate, usually located on the side of the air compressor.



Preparatory Steps

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

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

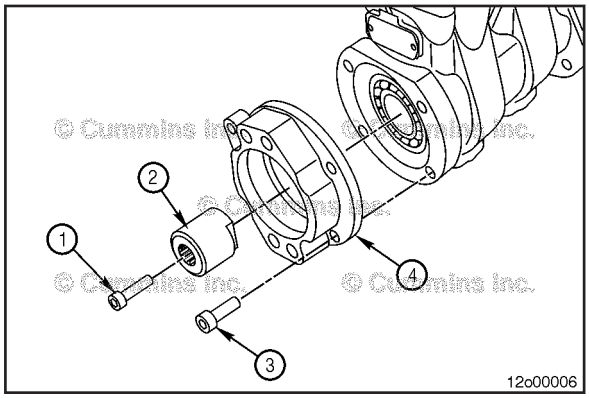


Remove

Remove the drive adapter capscrew (1) and drive adapter (2).

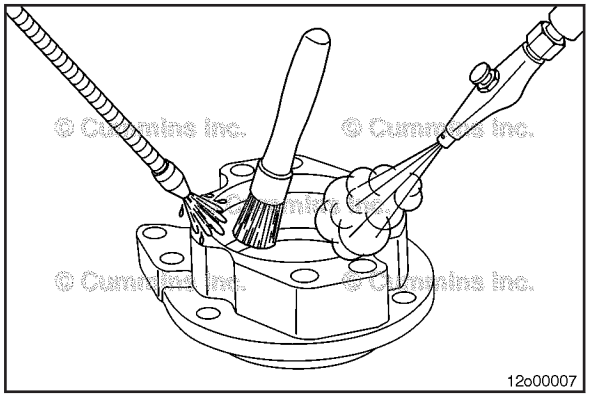
Remove the rear bearing housing mounting capscrews (3).

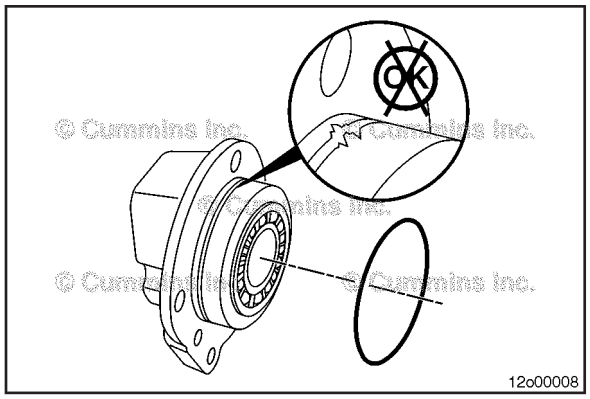
Remove the rear bearing housing (4).



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.



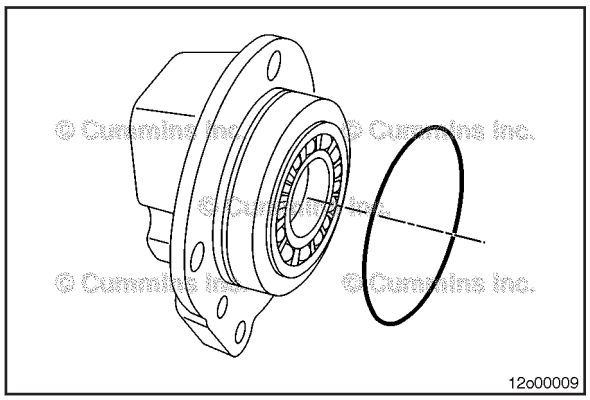


Remove the o-ring seal.

Gasket sealing surfaces **must** be clean and free of all old gasket material, carbon, rust, and other buildup. Surfaces **must** be free of scratches, gouges, burrs, and other deformities.

Inspect the air compressor rear bearing.

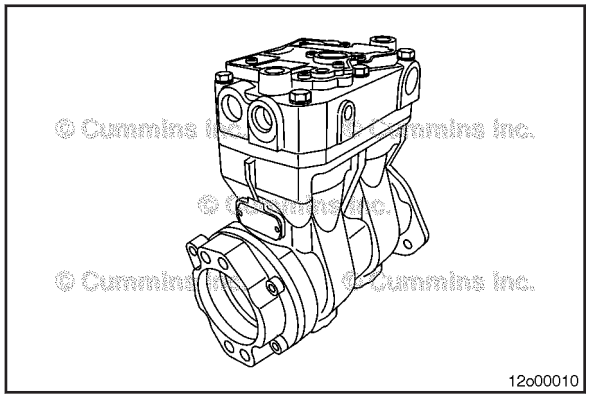
Replace the complete air compressor assembly, if any damage is found.



Install

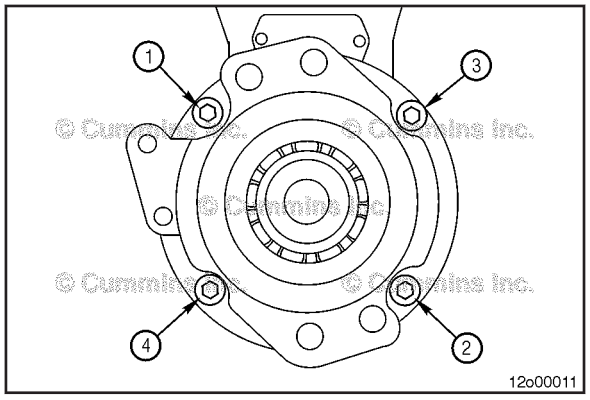
Knorr-Bremse™ Air Compressors

Install a new o-ring seal in the compressor rear bearing housing.



Install the rear bearing housing.

Install the mounting capscrews.



Tighten the capscrews in the sequence shown.

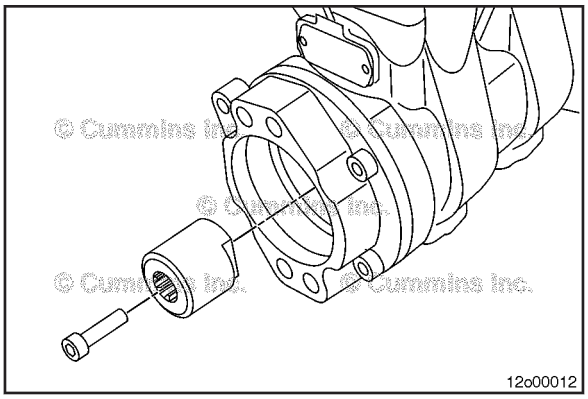
Torque Value: 22 N•m [195 in-lb]

Install the drive adapter and mounting capscrew.

NOTE: Loctite™ 638, or equivalent **must** be applied to the capscrew during installation.

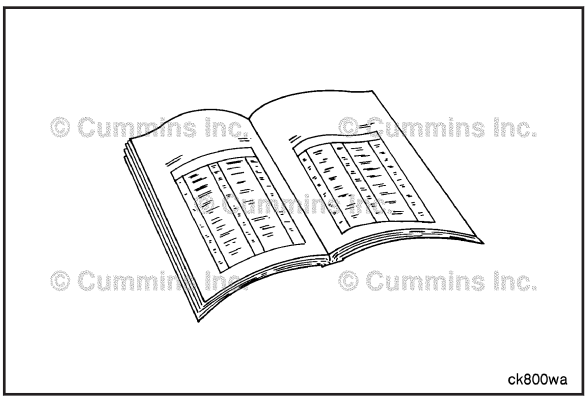
Tighten the capscrew.

Torque Value: 25 N•m [221 in-lb]



Finishing Steps

- Install the air compressor. Refer to Procedure 012-014 in Section 12.
- Operate the engine and check for leaks.



Notes

Section 13 - Electrical Equipment - Group 13

Section Contents

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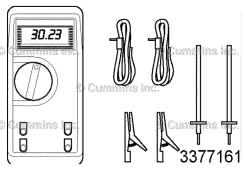
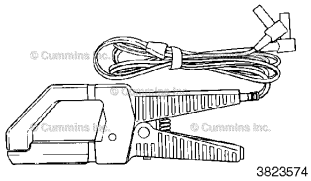
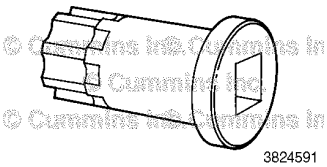
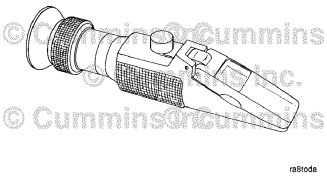
Service Tools

Electrical Equipment

The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3164488 or 3164489	**Digital Multimeter** Used to measure electrical circuits: voltage (volts), resistance (ohms), and current (amperes). Standard meter, Part Number 3164488, Automotive meter, Part Number 3164489, with built-in temperature adapter and tachometer.	
3164490	**Clamp-on Current Probe** Used to measure DC current from 0 to 1000 amperes or AC current from 0 to 1000 amperes.	
3824591	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	
CC-2800	**Refractometer** The Fleetguard® refractometer is used to check the charge condition of a conventional battery.	

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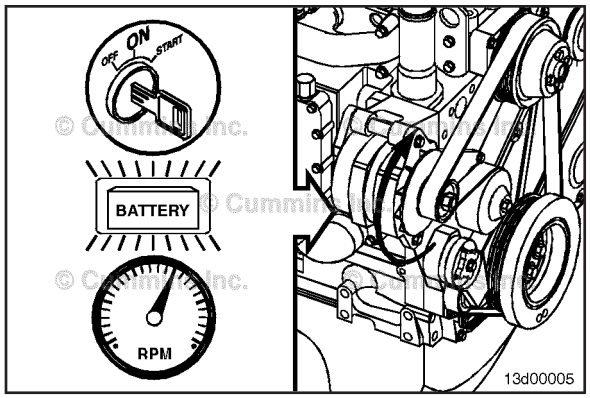
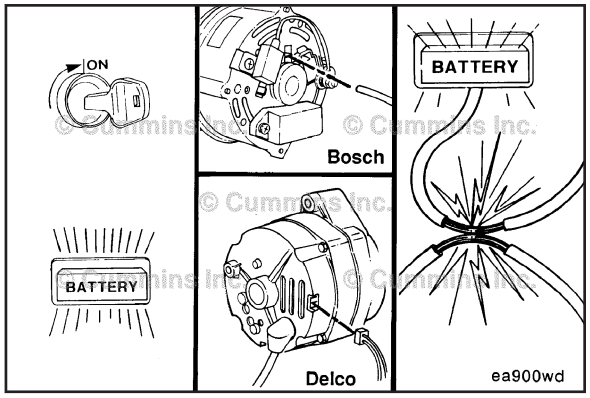


Alternator (013-001)

Initial Check

Check the drive belt and alternator pulley to be sure the alternator is rotating.



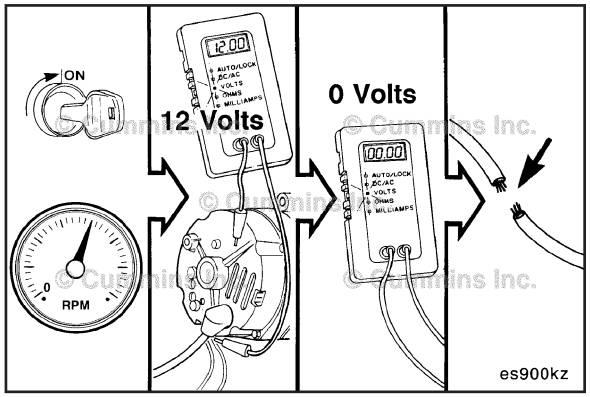
⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Check the battery and all wiring connections.

Inspect the wiring for defects.

Check all connections for tightness and cleanliness, including the slip connectors at the alternator and engine compartment bulkhead, and connections at the battery.



Test

NOTE: This test applies to Bosch® alternators.

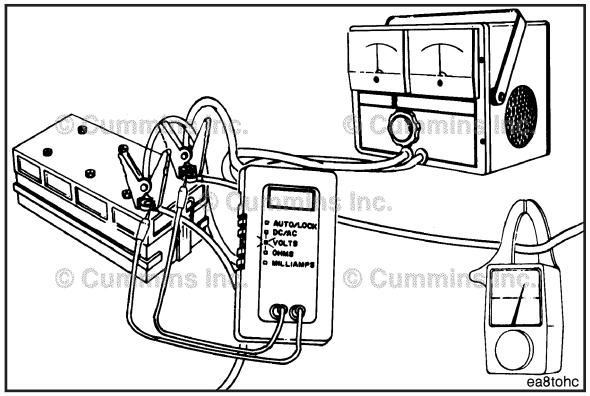
With the ignition switch "ON" and all wiring harness leads connected, connect a voltmeter from:

Bosch®

- Alternator "BAT" "B+" terminal to ground
- Alternator Number 1 to ground
- Alternator Number 2 to ground
- Alternator D+ K1 to ground.

A zero reading indicates an open circuit between the alternator connections and the battery.

Locate and repair the open circuit.



Digital Multimeter, Part Number 3164488; Clamp-on Current Probe, Part Number 3823574:

Connect a carbon pile load (battery tester) across the battery posts of the battery boxes.

Clamp an induction pickup type amp meter around the battery cable, or use the digital multimeter, Cummins® Part Number 3164488, with the clamp-on current probe, Cummins® Part Number 3823574.

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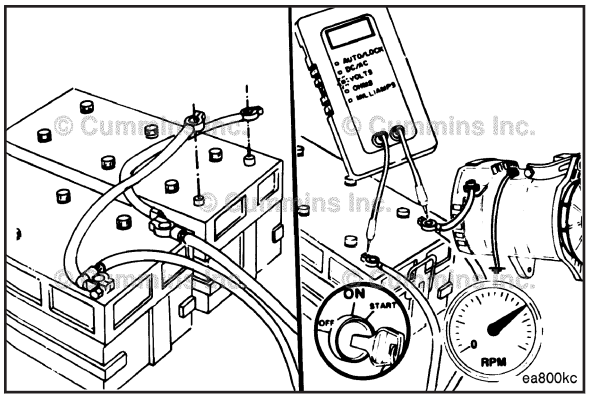
Digital Multimeter, Part Number 3164488:

Disconnect any cables that lead to any other battery boxes in the circuit, negative (-) cables first.

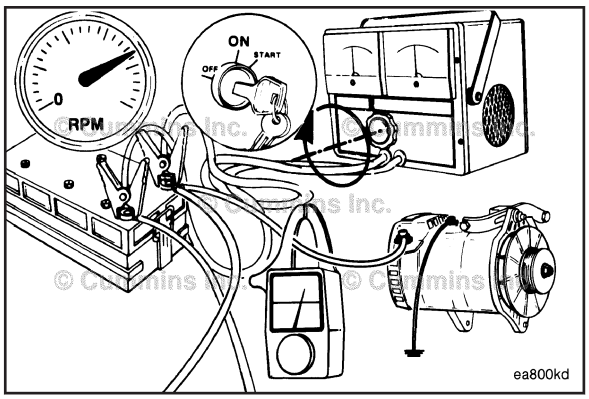
Operate the engine at high idle and measure the alternator voltage output to the batteries with digital multimeter, Part Number 3164488. See the alternator manufacturer's specifications.



Operate the engine at high idle and adjust the systems analyzer/battery tester to apply the maximum rated amperage load to the alternator. See the alternator manufacturer's specifications.

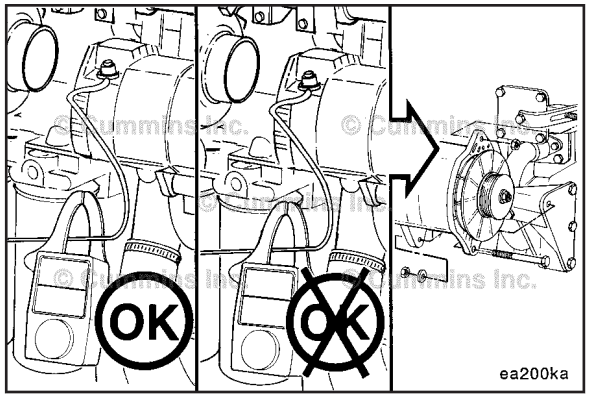
NOTE: The alternator maximum rated amperage output is normally stamped or labeled on the alternator.

Measure the alternator amperage output. See the alternator manufacturer's specifications.



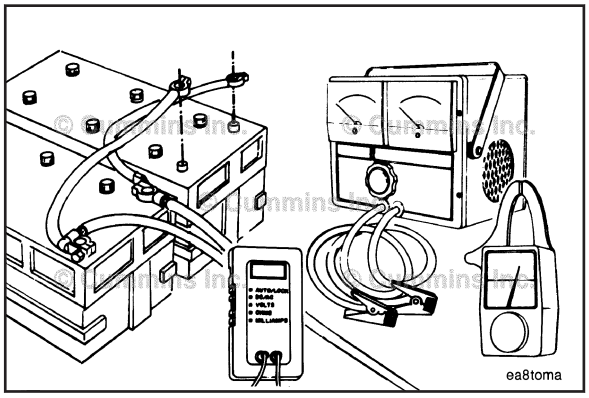
If the gauge on the carbon pile load testing equipment does **not** indicate approximately the same output as the induction-type ampmeter, determine which is defective and replace it. See the alternator manufacturer's specifications.

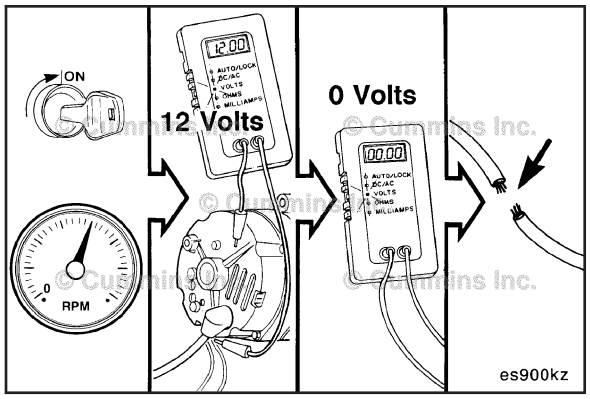
If the alternator output (amps) is **not** within 10 percent of rated output, repair or replace the alternator. See the alternator manufacturer's instructions for repair procedures.



Shut off the engine and remove the test equipment.

Connect all battery cables, negative (-) cable last.





NOTE: This test applies to Delco alternators.

NOTE: Any multimeter reading of zero voltage indicates an open circuit.

Check for open circuits.

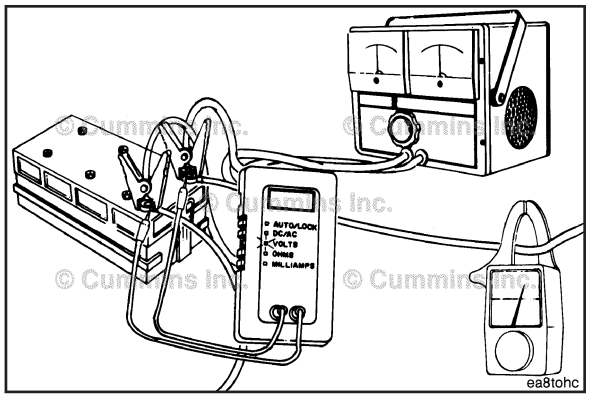
Turn the keyswitch to the ON position.

Connect a multimeter, Cummins® Part Number 3164488 or 3164489, to the following locations:

Delco Alternators

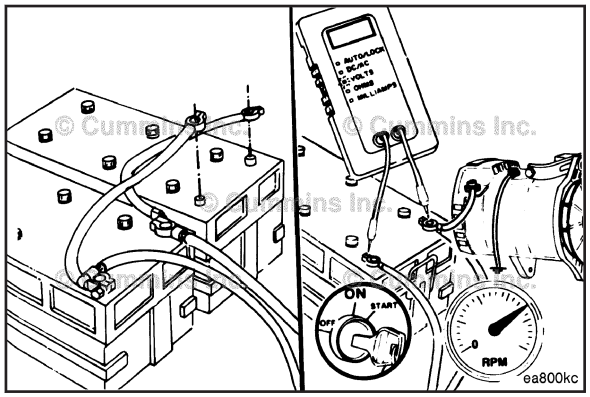
- Alternator "BAT" terminal to ground
- Alternator blade terminal "Number 1" to ground
- Alternator blade terminal "Number 2" to ground

Locate and repair the open circuit.



Connect a carbon-pile load (battery/alternator tester) across the battery posts of the battery boxes.

Clamp an induction pickup-type ampere-hour meter around the battery cable; or use the digital multimeter, Part Number 3164488 or 3164489, with the clamp-on current probe, Part Number 3164490.



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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⚠
Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.

Disconnect any cables that lead to any other battery boxes in the circuit, negative (-) cables first.

Operate the engine at high idle; and measure the alternator voltage output to the batteries with digital multimeter, Part Number 3164488 or 3164489. Refer to the OEM specifications.

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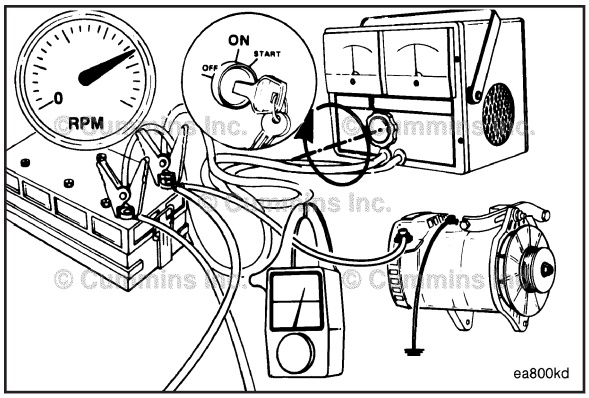
Operate the engine at high idle and adjust the carbon-pile load-testing equipment to apply the maximum rated amperage load to the alternator. Refer to the OEM specifications.

NOTE: The alternator maximum rated amperage output is normally stamped or labeled on the alternator.

Measure the alternator amperage output. Refer to the OEM specifications.

If the alternator output (amps) is **not** within 10 percent of rated output, repair or replace the alternator. Refer to the OEM service manual for repair procedures.

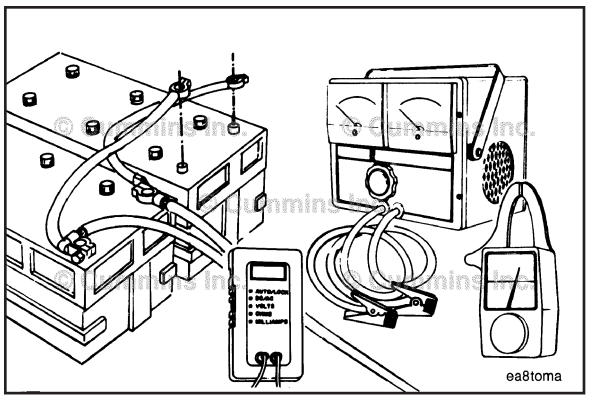


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.

Shut off the engine and remove the test equipment.

Connect all battery cables, negative (-) cable last.

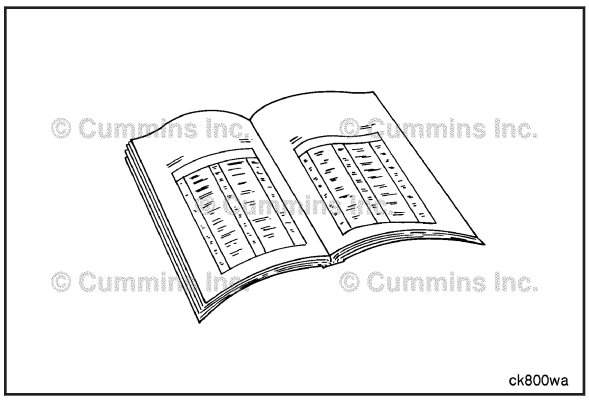


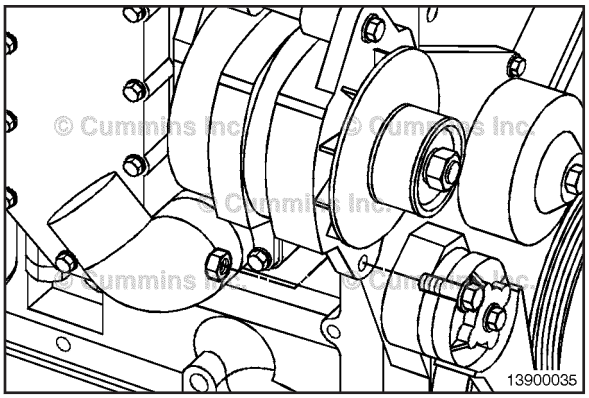
Preparatory Steps

⚠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 and tag all wires and complete the following steps:

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Disconnect the battery ground cable.
- Remove the belt guard, if equipped. Refer to Procedure 008-001 in Section 1.
- Remove the drive belt from the alternator pulley. Refer to Procedure 008-002 in Section 8.
- Tag and label wires attached to the alternator.
- Remove the wires attached to the alternator.

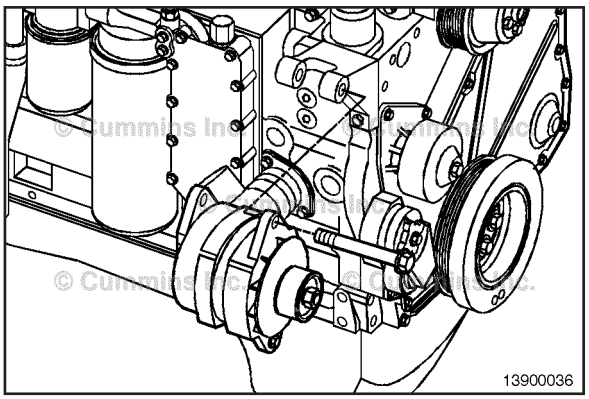




Remove

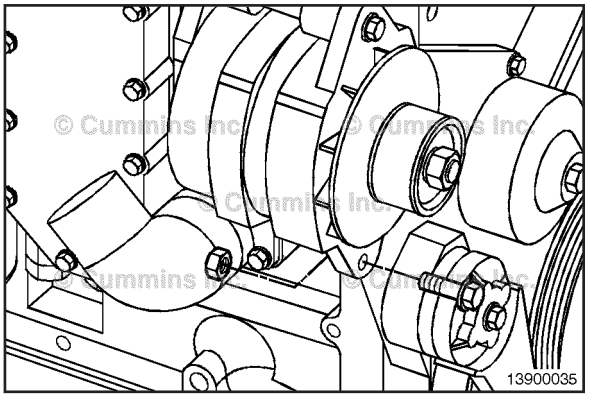
All Applications Except Marine

Remove the alternator link capscrew.



Remove the alternator mounting capscrew.

Remove the alternator.



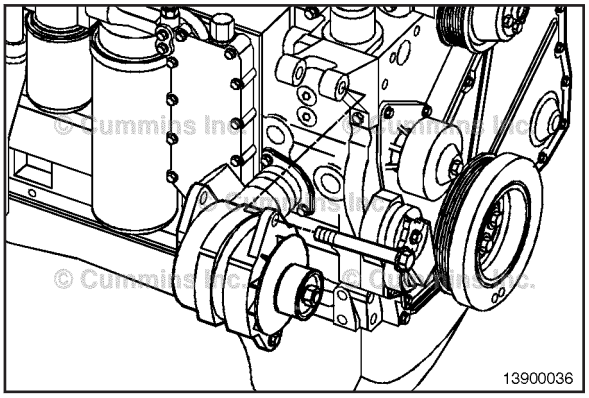
Marine Applications

Loosen the alternator link capscrew at the engine mounting location.

Loosen the alternator link capscrew at the alternator.

Loosen the alternator mounting capscrew.

Remove the alternator link capscrew at the alternator.



Remove the alternator mounting capscrew.

Remove the alternator.

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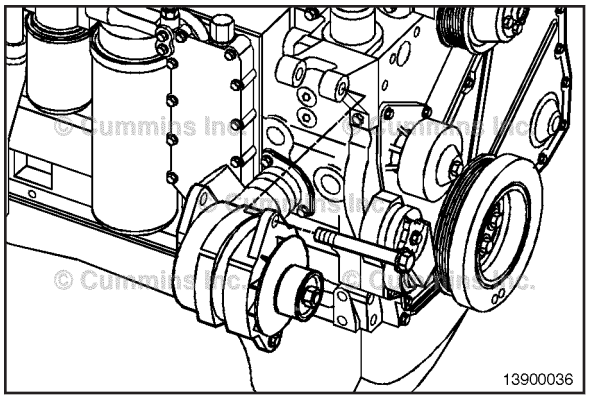
Install

All Applications Except Marine

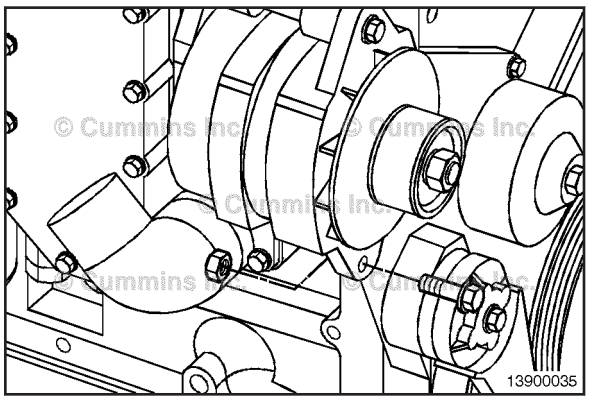
Install the alternator and alternator capscrews in the reverse order of removal.

Torque Value: 43 N•m [32 ft-lb]



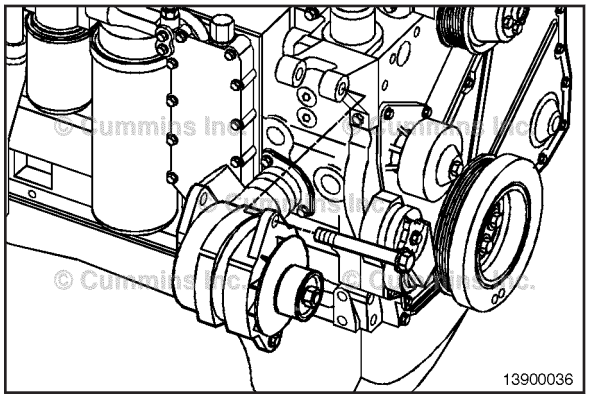
Install the alternator link capscrew.

Torque Value: 24 N•m [18 ft-lb]



Marine Applications

Install the alternator upper mounting bracket capscrew. Do **not** tighten at this time.



Install the alternator link capscrew at the alternator.

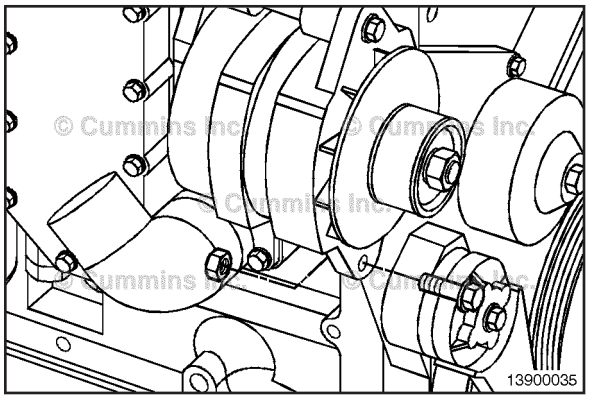
Tighten the upper mounting bracket capscrew.

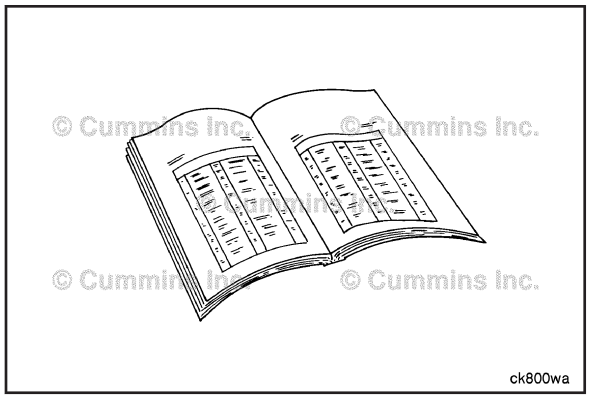
Torque Value:
Upper Mounting Capscrew
Step 1 77 N•m [57 ft-lb]

Tighten the lower mounting link at the alternator and engine mounting location.

Torque Value:
Alternator Link at Alternator
Step 1 44 N•m [32 ft-lb]

Torque Value:
Alternator Link at Engine Mounting Location
Step 1 24 N•m [18 ft-lb]



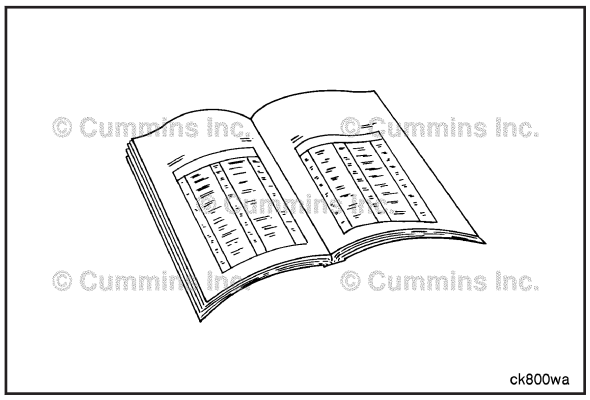


Finishing Steps

⚠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 belt guard, if equipped. Refer to Procedure 008-001 in Section 8.
- Operate the engine and verify proper alternator operation.



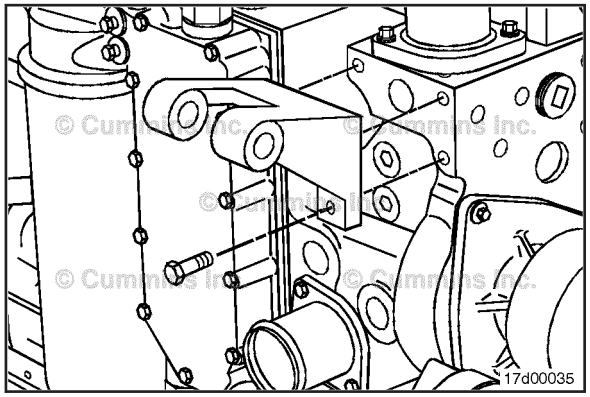
Alternator Bracket (013-003)

Preparatory Steps

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to the OEM service manual.
- Remove the alternator. Refer to Procedure 013-001 in Section 13.



Remove

Side Mounted Bracket

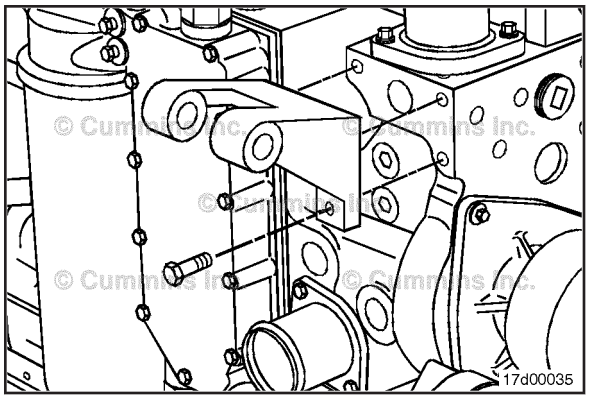
Remove the bracket mounting capscrews and the side mounted bracket.

Install

Side Mounted Bracket

Install the side mounted bracket and bracket mounting capscrews.

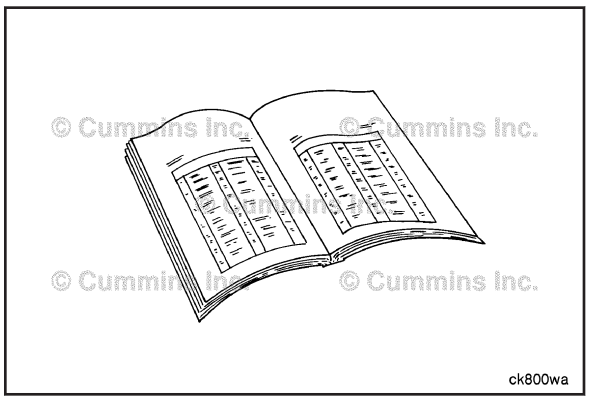
Torque Value: 24 N•m [212 in-lb]



Finishing Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the alternator. Refer to Procedure 013-001 in Section 13.
- Connect the batteries. Refer to the OEM service manual.
- Start the engine and check for proper operation.



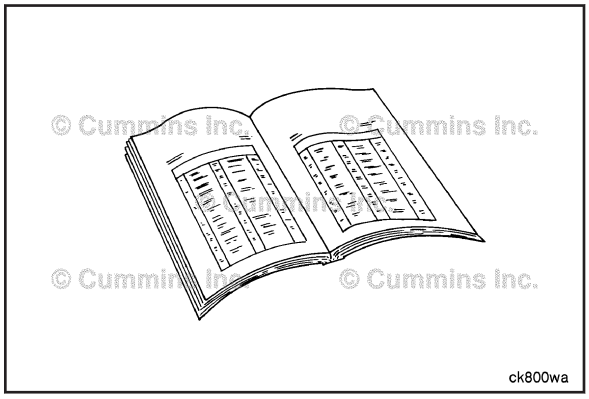
Drive Belt, Alternator (013-005)

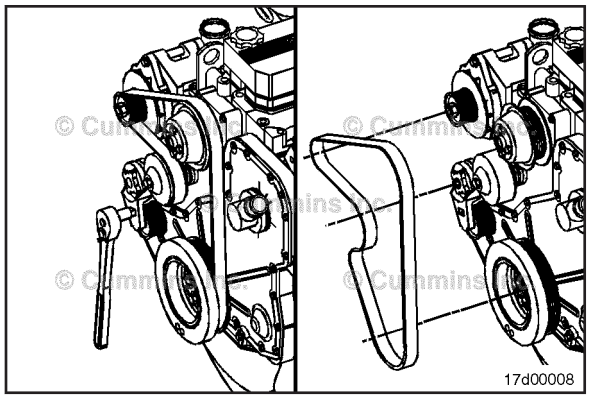
Preparatory Steps

⚠CAUTION⚠
Make sure that the engine is shut off and any starting mechanisms are isolated before any maintenance is performed.

⚠CAUTION⚠
The removal and replacement of any guards covering rotating components, drives and/or belts, must only be accomplished by a trained and certified technician. All fasteners removed must be replaced when installing the guards. If fastener replacement is required, verify the correct part number (or equivalent) is used. Do not substitute a fastener of lesser quality. Possible equipment damage or serious personal injury can occur.

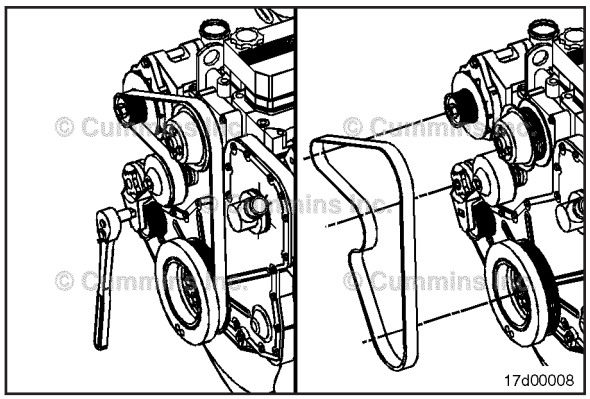
- Remove the belt guard, if equipped. Refer to Procedure 008-001 in Section 8.





Remove

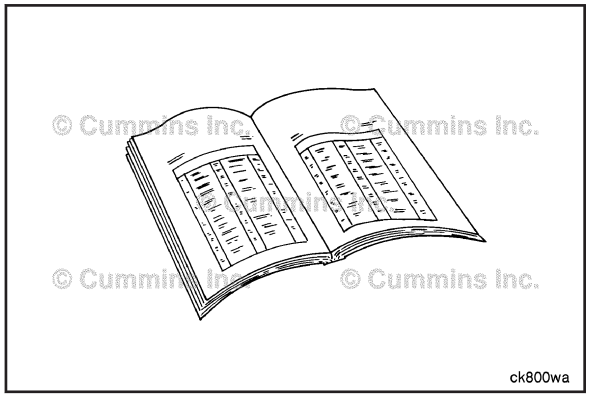
Lift the belt tensioner to relieve tension on the belt and remove the drive belt.



Install

NOTE: If difficulty is experienced installing the drive belt (i.e., the belt seems too short), position the belt over the grooved pulleys first and then, while holding the tensioner up, slide the belt over the water pump pulley.

- Lift and hold the belt tensioner. Install the drive belt and release the tensioner.
- Refer to Procedure 008-002 in Section 8.



Finishing Steps

⚠CAUTION⚠

The removal and replacement of any guards covering rotating components, drives and/or belts, must only be accomplished by a trained and certified technician. All fasteners removed must be replaced when installing the guards. If fastener replacement is required, verify the correct part number (or equivalent) is used. Do not substitute a fastener of lesser quality. Possible equipment damage or serious personal injury can occur.

- Install the belt guard, if equipped. Refer to Procedure 008-001 in Section 8.

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Batteries (013-007)

Initial Check

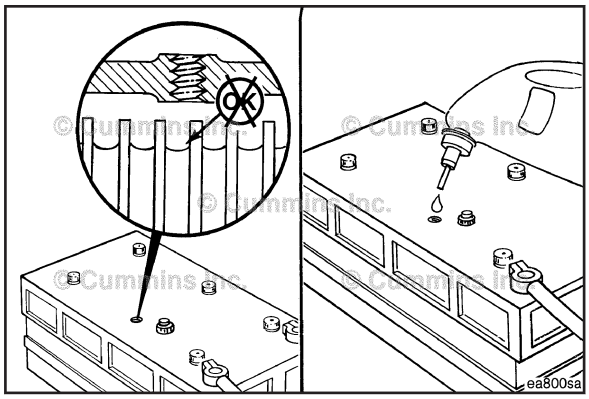
⚠WARNING⚠

Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.

If conventional batteries are used, remove the cell caps or covers and check the electrolyte level.

NOTE: Maintenance-free batteries are sealed and do **not** require the addition of water.

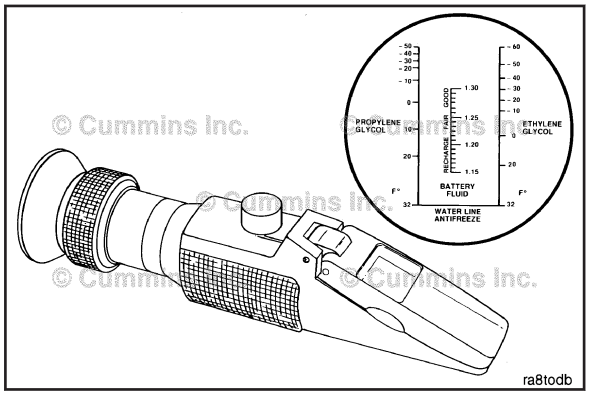
Fill each battery cell with distilled water. Refer to the battery manufacturer's specifications.



Use the Fleetguard® Refractometer, Part Number CC-2800, to check the specific gravity of the battery electrolyte.

Refer to the battery fluid column in the refractometer to determine the state-of-charge of each battery cell.

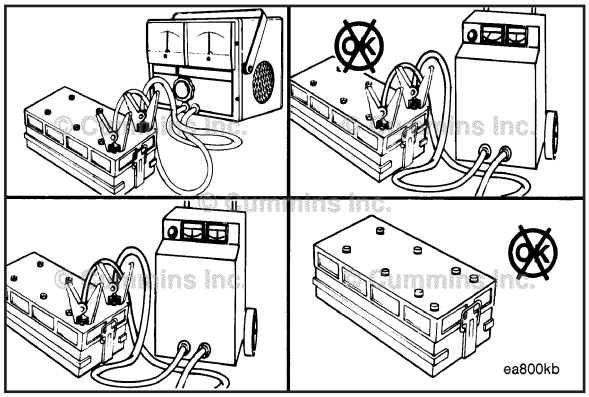
If water has been added to a dry cell, recharge the battery to mix the added water with the existing battery electrolyte to prevent inaccurate readings.

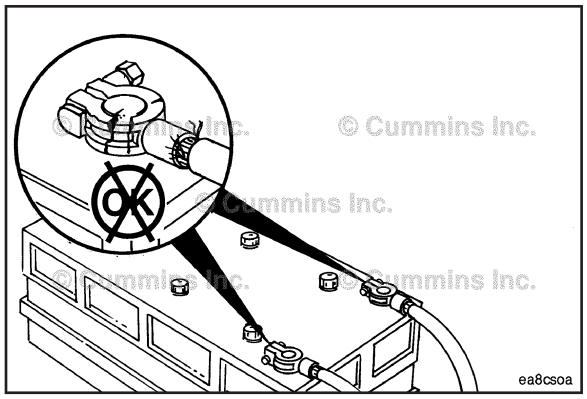


Use a battery tester to test the output amperage of maintenance-free or conventional vent cap batteries.

If the output amperage is low, use a battery charger to charge the battery. Refer to the manufacturer's instructions.

Replace the battery if it will **not** charge to the manufacturer's specifications, or will **not** maintain a charge.





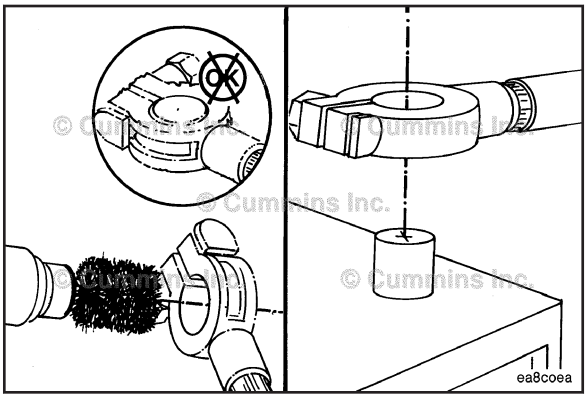
Battery Cables and Connections (013-009)

Initial Check

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Inspect the battery terminals for loose, broken, or corroded connections.

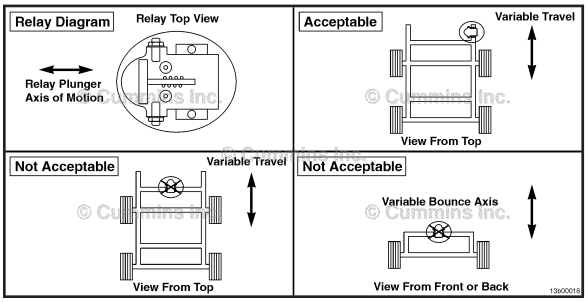
Repair or replace broken cables or terminals.



If the connections are corroded, remove the cables and use a battery brush to clean the cable and battery terminals.

Install and tighten the battery cables.

Use grease to coat the battery terminals to prevent corrosion.



Starter Magnetic Switch (013-017)

Initial Check

⚠CAUTION⚠
Improper installation of the starter magnetic switch can result in starter over-run damage.

To make sure that the magnetic switch is **not** activated by vehicle movement, the axis of the plunger **must** be horizontal to the ground and perpendicular to vehicle travel.

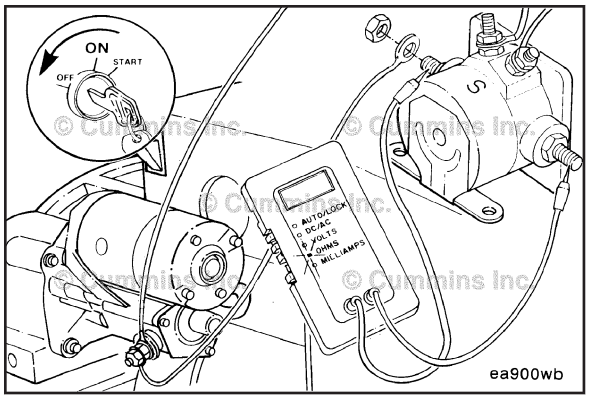
Do **not** mount an external magnetic switch on the engine or on any metal that can possibly resonate as the result of road or engine vibration.

- Refer to the OEM service manual for proper magnetic switch installation.

Resistance Check

Remove the cable connecting the magnetic switch to the starting motor solenoid from the magnetic switch terminal.

Set the digital multimeter, Cummins® Part Number 3164488, to measure resistance (ohms).

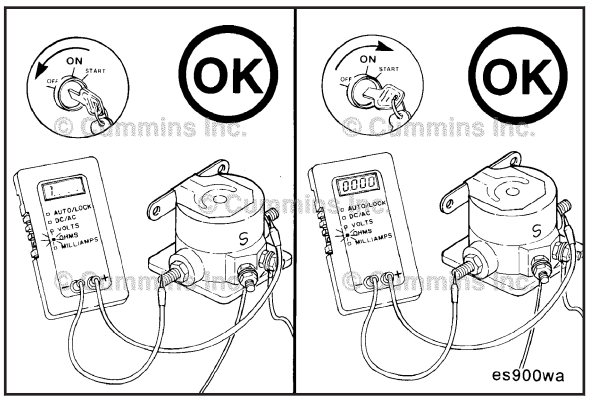


Connect the leads to the two large switch terminals.

With the starting motor switch in the OFF position, the multimeter **must** indicate resistance greater than 100k ohms.

Turn the starting motor switch to the START position.

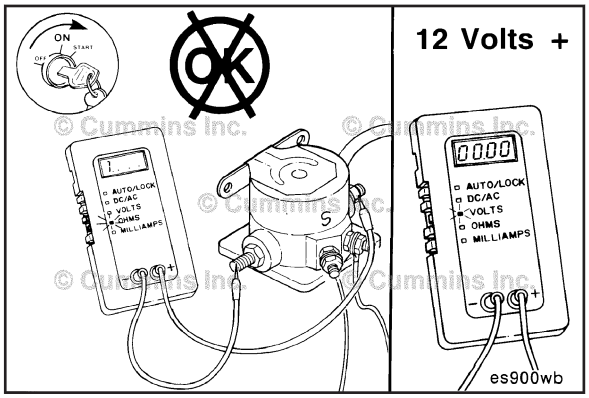
The multimeter **must** indicate less than 10 ohms. If **not** within specifications, replace the starter magnetic switch according to the manufacturer's instructions.



Voltage Check

If the multimeter indicates resistance at greater than 100k ohms with the starting motor switch in the "START" position, turn the starting motor switch to the "OFF" position.

Set the multimeter scale to read DC voltage.

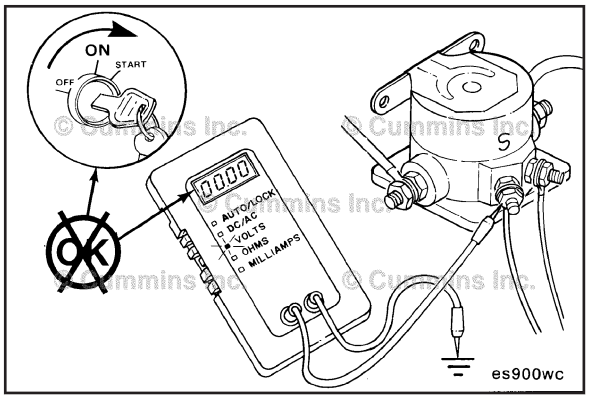


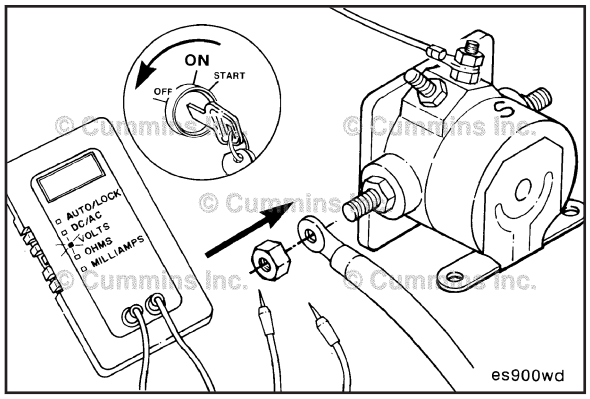
Connect one multimeter lead to the magnetic switch terminal marked "S" and the other lead to ground.

Turn the starting motor switch to the "START" position.

If the multimeter indicates no voltage, the magnetic switch is **not** the cause of the complaint. Refer to Procedure 013-018 in Section 13.

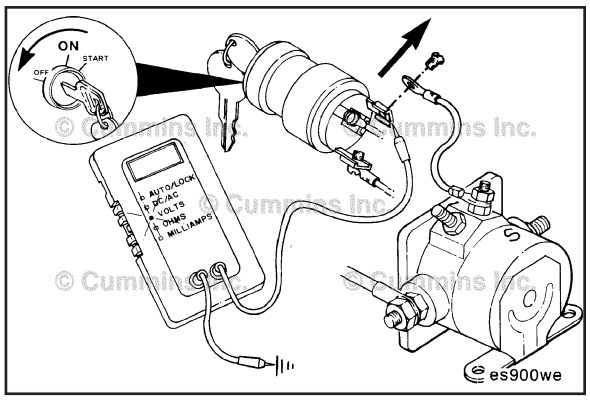
If the starter magnetic switch is **not** within specification, replace the switch according to the manufacturer's instructions.





Turn the starting motor switch to the "OFF" position.

Remove the multimeter leads and connect the magnetic switch to the starting motor solenoid wire.



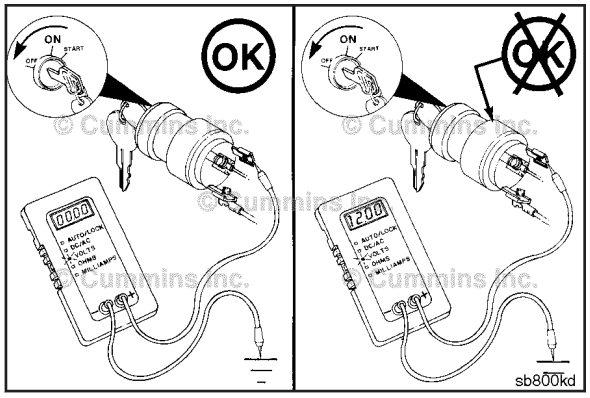
Starter Switch (013-018)

Voltage Check

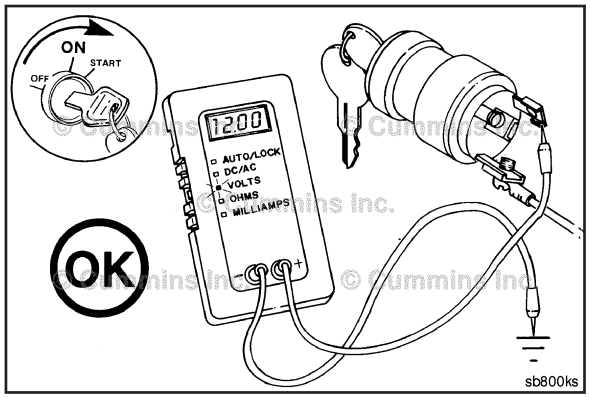
⚠WARNING⚠
Be sure the starting motor switch is in the "OFF" position to prevent electrical shock and personal injury.

Remove the wire connecting the starting motor switch to the magnetic switch (marked “S” or “START”) from the starter switch terminal.

Connect the positive (+) lead of the digital multimeter, Cummins Part Number 3164488, or equivalent to the starter switch terminal and the negative (-) lead to a chassis or engine ground location.



NOTE: Set the multimeter to indicate DC volts with the starting motor switch in the "OFF" position, there must **not** be voltage at the starter switch terminal. If the meter indicates voltage, the starter switch is malfunctioning and **must** be replaced.

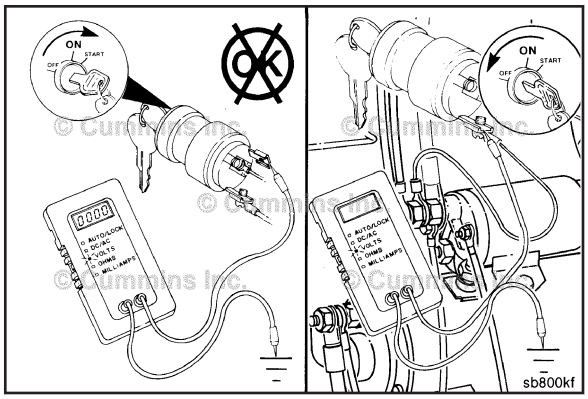


Turn the starting motor switch to the “START” position.

The multimeter **must** indicate system voltage.

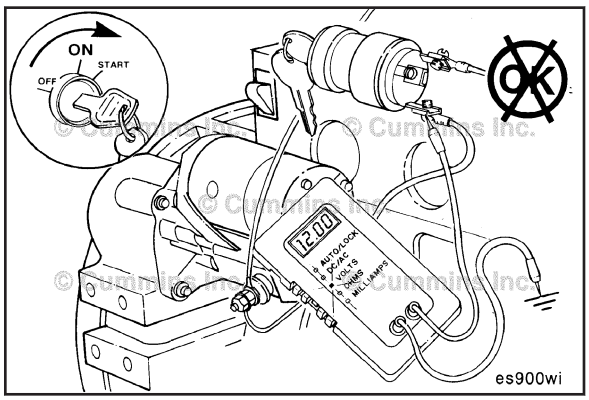
If there is **no** voltage, turn the starting motor switch to the “OFF” position.

Connect the multimeter positive (+) lead to the starter switch terminal having a wire connecting the starter switch to the starting motor solenoid B terminal.



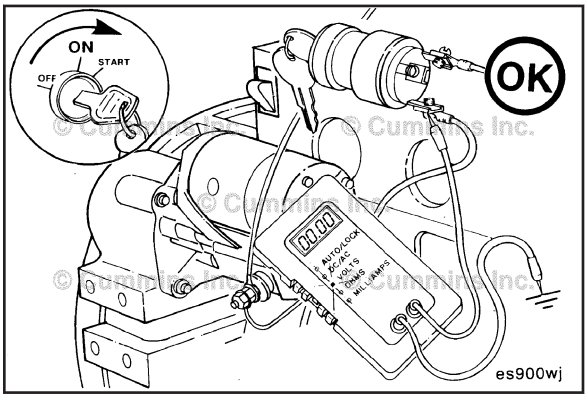
Turn the starting motor switch to the “START” position.

If the meter indicates system voltage at the starter switch input terminal, the starter switch is defective and **must** be replaced. Refer to the manufacturer's procedure for replacement.



If the meter indicates no voltage, the switch is **not** the cause of the complaint.

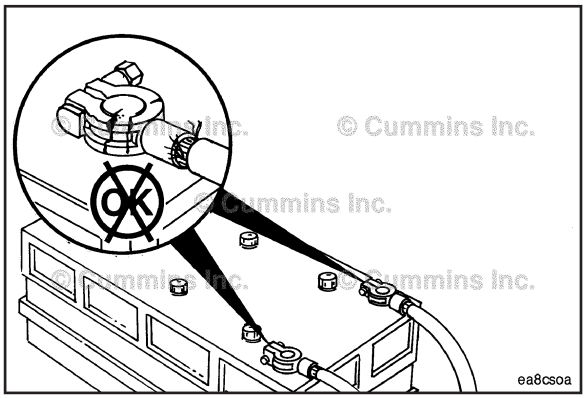
Check the wiring from the starter switch to the starting motor solenoid B terminal and from the starting motor solenoid to the battery for broken or damaged wires.



Starter Solenoid (013-019)

Initial Check

Before troubleshooting the starting motor, make sure the battery terminals are **not** loose or corroded. Refer to Procedure 013-009 in Section 13.



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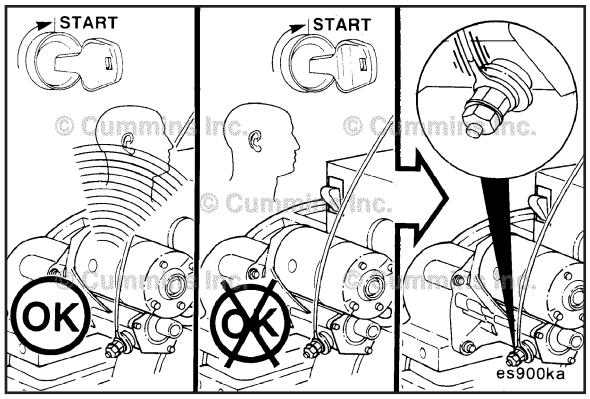
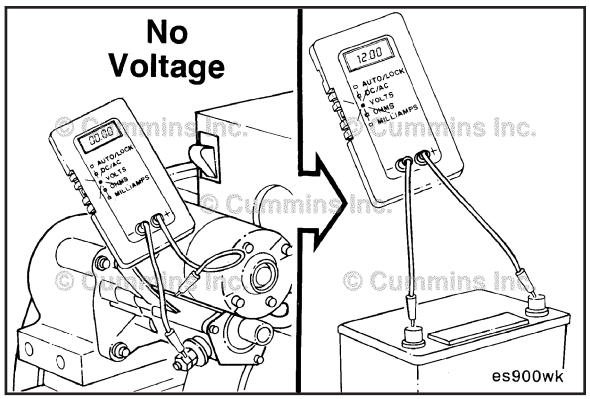
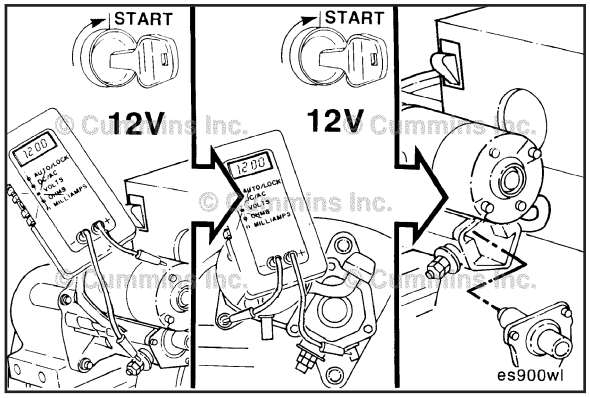


If the starting motor solenoid does **not** make an audible sound, check for loose wiring connections.



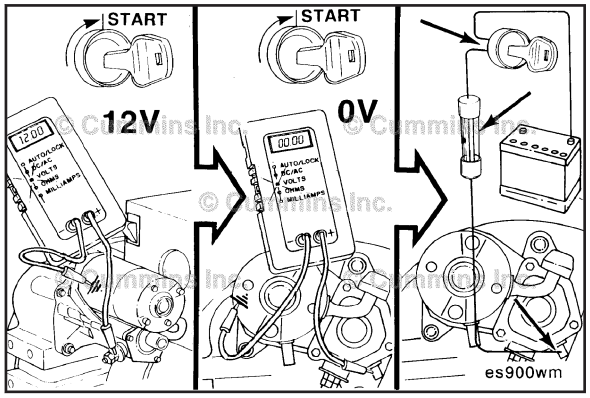
Use a digital multimeter, Cummins® Part Number 3164488, or equivalent, to set the voltage scale.

Check for system voltage at the starting motor solenoid battery terminal.



If the multimeter indicates system voltage at the starting motor battery terminal, check the voltage at the starting motor solenoid S terminal, when the starting switch is energized.

If the multimeter indicates system voltage at the S terminal, but the starter does **not** engage, the starting motor solenoid is malfunctioning and the starter **must** be replaced. Refer to Procedure 013-020 in Section 13.



If the multimeter does **not** indicate system voltage at the S terminal, check:

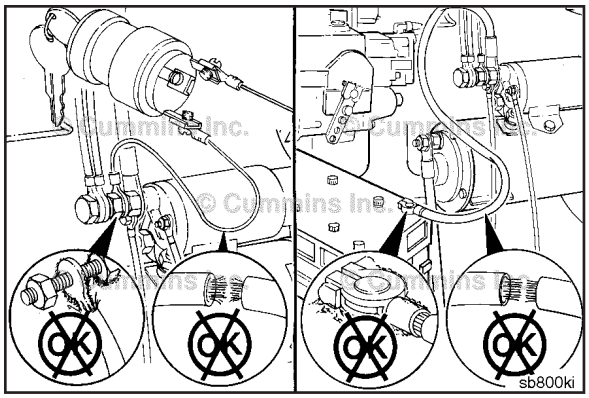
- Fuses
- Voltage to the ignition switch and magnetic switch. Refer to Procedure 013-018 in Section 13. Refer to Procedure 013-017 in Section 13.
- Application safety shutoff systems

Voltage Check

Set the digital multimeter, Part Number 3164488, to measure DC voltage.

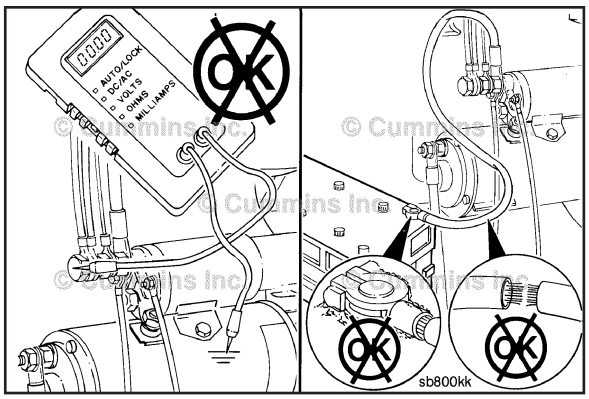
Connect the multimeter positive (+) lead to the starter solenoid positive cable terminal and the negative (-) lead to a chassis or engine ground location.

The multimeter **must** show a voltage with the starter switch “OFF” to be normal.



If the multimeter does **not** indicate a voltage, check the cable connecting the starter solenoid and battery for breaks.

Also check for loose or corroded connections.

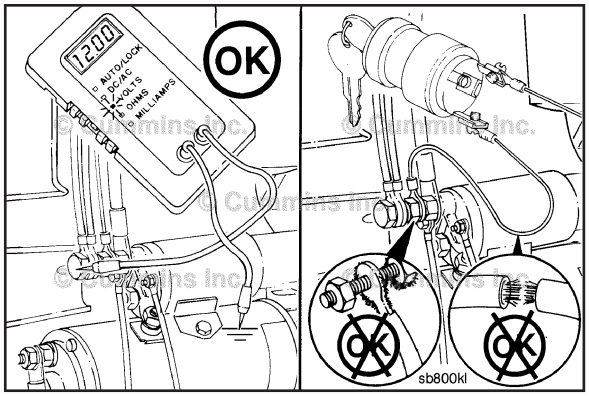


If the multimeter indicates a voltage, but the starter will **not** operate, check the wire connecting the starter solenoid to the starter switch for breaks.

Also check for loose or corroded connections.

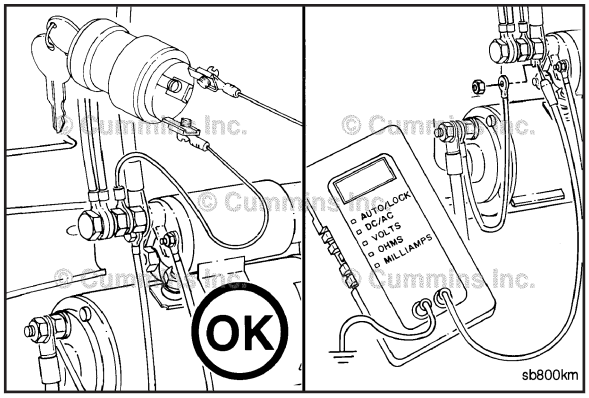
Be sure to check for:

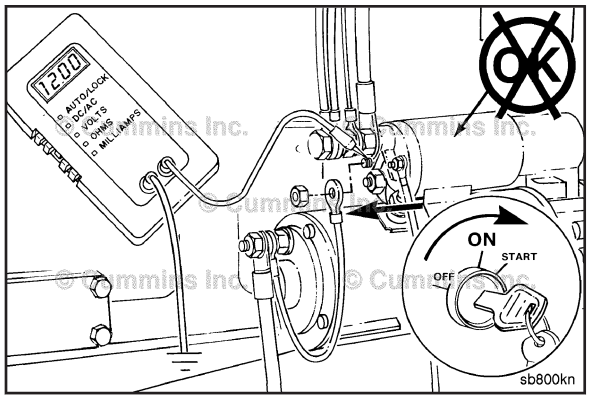
- Fuses
- Application engine shutoff systems.



If the wire connecting the starter solenoid and starter switch is **not** loose or damaged, and the starter will **not** operate, remove the cable connecting the starter and starter solenoid from the solenoid terminal.

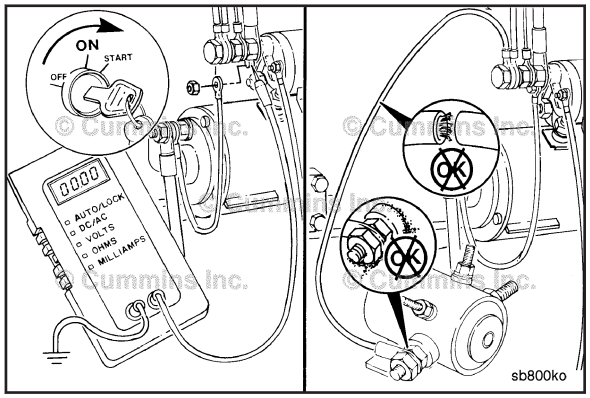
Connect the multimeter positive (+) lead to the solenoid positive (+) terminal and the negative (-) lead to the chassis or an engine ground location.



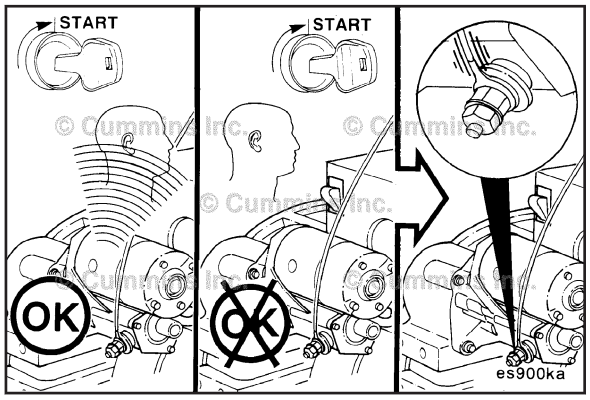


Turn the starter switch to the ”START” position.

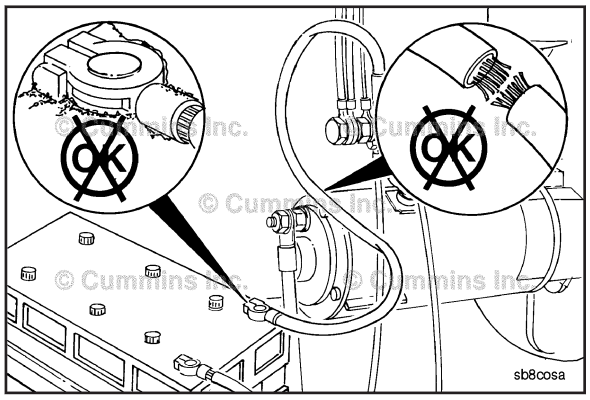
If the multimeter indicates a voltage, the starter solenoid is malfunctioning and **must** be replaced. Refer to Procedure 013-020 in Section 13.



If the multimeter does **not** indicate a voltage, check the wire connecting the starter solenoid to the magnetic switch for breaks, and for loose or corroded connections.



If the wire connecting the starter solenoid to the magnetic switch is **not** loose or damaged and the starter will **not** operate, check the cable connecting the starter solenoid to the starting motor for breaks, and for loose or corroded connections.



Check the cable connecting the starting motor to the battery for breaks, and for loose or corroded connections.

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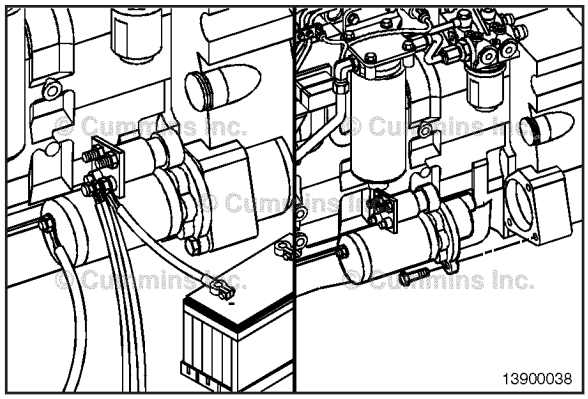
If the cables are **not** loose or damaged, the starting motor is defective and **must** be replaced. Refer to Procedure 013-020 in Section 13.



Starting Motor (013-020)

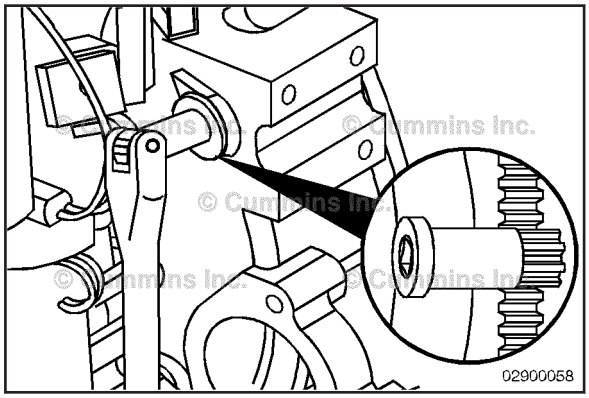
Rotation Check

If the starting motor solenoid is making a sound but the engine is **not** rotating, turn the keyswitch to the OFF position, and attempt to bar the crankshaft in both directions.

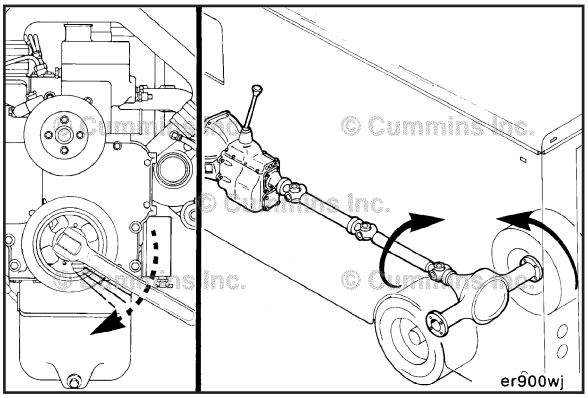
Bar the engine with the barring tool, Part Number 3824591.

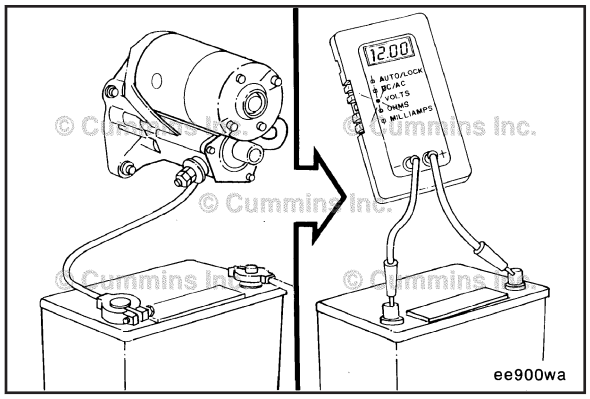
If the crankshaft will bar over, attempt to start the engine. If the starting motor cranks the engine, check the starting motor pinion gear and flywheel ring gear for damage.

If damage to the starting motor pinion gear and/or flywheel ring gear is found when replacing the components, make sure to measure the distance from the starting motor mounting flange to the forward face of the front side of the flywheel ring gear. Follow the measure step of this procedure .



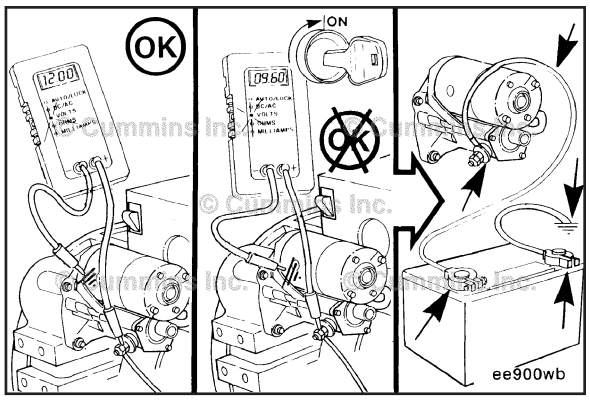
If the crankshaft does **not** rotate or requires more than the normal effort to bar, check for an internal malfunction or a problem with the drive unit and/or accessories.





If the engine cranking speed is too slow or will **not** crank at all, and the engine rotates freely:

- Make sure the wiring connections are clean, tight, and **not** damaged
- Check the battery voltage. Refer to Procedure 013-007 in Section 13.



Check the voltage at the starting motor during cranking. If the voltage drops more than 2.4 VDC on a 12 volt system, or 4.8 VDC on a 24 volt system, check that all connections are clean and tight.

If the cables are correct and the voltage drop exceeds the limit, replace the starting motor.

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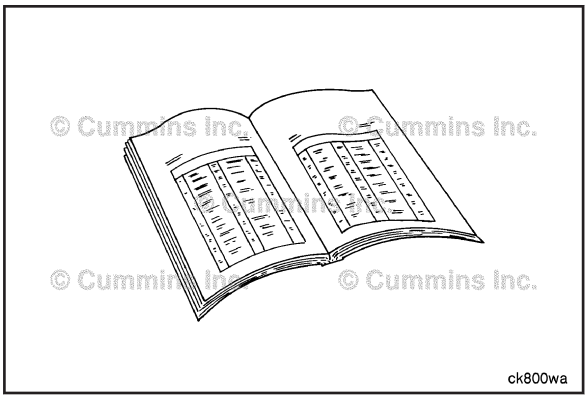
Preparatory Steps



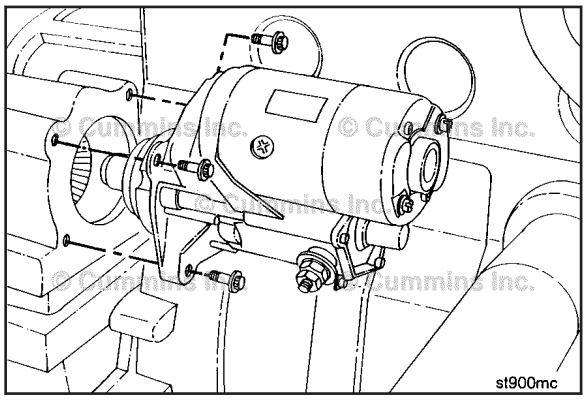
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

- Disconnect the battery cables from the battery terminals. 013-009 in Section 13.
- If equipped with a jump start protection cover, remove the jump start protection cover nut (M5) and jump start protection cover to gain access to the electrical connections.
- Identify each wire with a tag indicating its location on the starting motor.
- Remove the electrical connections from the starting motor.
- Prior to removing the starter, use steam to clean the area around the starting motor, to prevent debris from entering the flywheel housing.
- Dry with compressed air.

Remove



Remove the three capscrews and the starting motor.

If equipped with a System Integration Module relay, remove the relay support bracket from the starting motor mounting capscrew.

If equipped with a starting motor spacer, remove the spacer and clean all surfaces between the starting motor, starting motor spacer, and flywheel housing with a wire brush.

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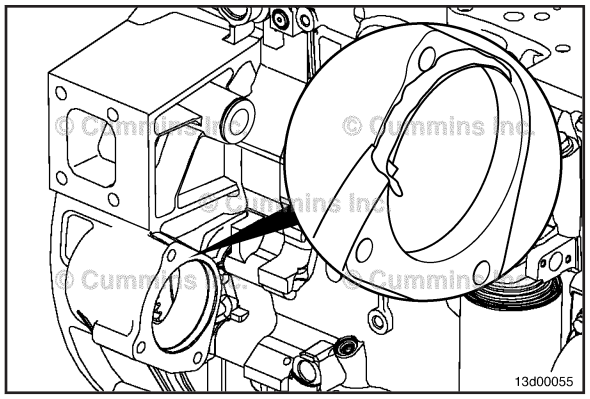
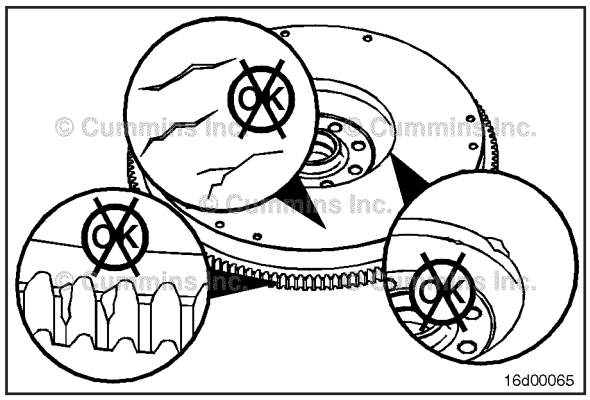


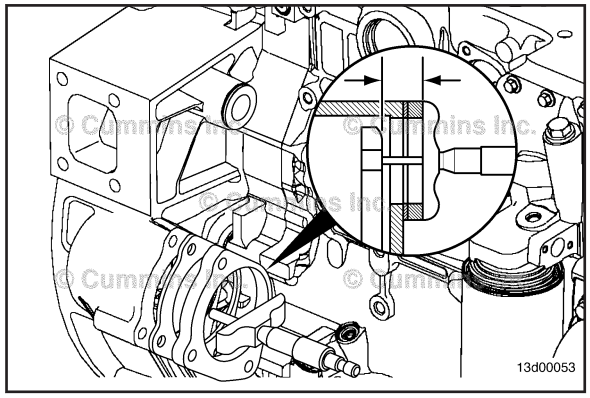
Clean and Inspect for Reuse

For engines that use wet flywheel housing, clean any left over sealant from the starting motor mounting flange on both the flywheel housing and starting motor. Make sure these surfaces are clean of oil and debris.



Inspect the starting motor pinion gear and/or flywheel/ flexplate ring gear for chipping or uneven wear.

If the start motor pinion gear and/or flywheel ring gear teeth are damaged, they **must** be replaced. Refer to Procedure 016-005 in Section A.



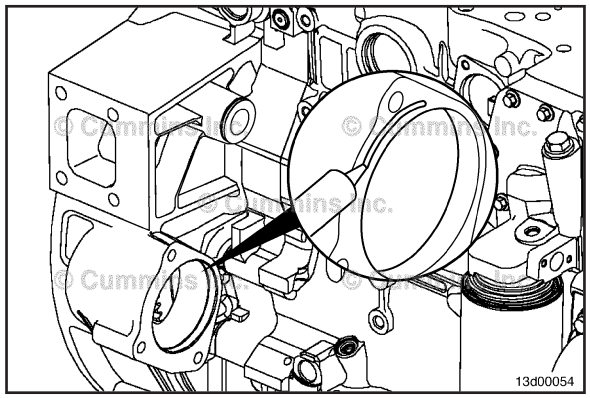
Measure

Use a depth micrometer or vernier caliper to measure the distance from the starting motor mounting flange to the forward face of the front side of the flywheel ring gear.

NOTE: Include any spacers previously removed when completing the measurement.

Starting Motor Spacing		
mm		**in**
49.28	MIN	1.94
52.32	MAX	2.06

Add or remove spacers as necessary to achieve the correct starting motor spacing.



Install

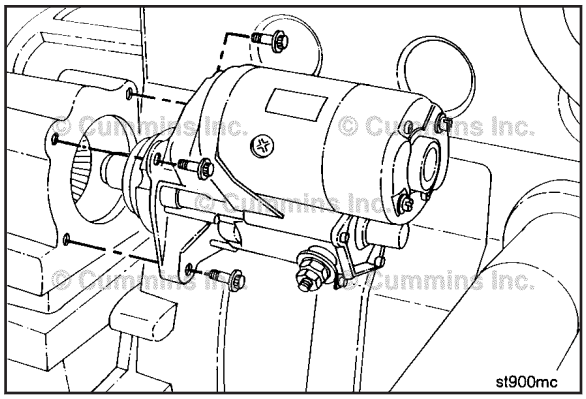
For engines with wet flywheel housings, apply a 1.5 to 2.0 mm [0.06 to 0.09 in] wide bead of sealant, Part Number 3164067, to the flywheel housing starting motor mounting flange.

NOTE: If a starting motor spacer is required, make sure to apply sealant to the side of the spacer that contacts the starting motor.

If equipped, install the system integration module relay support bracket mounting capscrews.

Install the three capscrews, the starting motor, and starting motor spacer, if required.

Torque Value: 43 N•m [32 ft-lb]



Cummins® Branded Starters

⚠CAUTION⚠
Do not overtighten the electrical connections. Starting motor damage can result.

NOTE: Use the location tags to help identify where each wire connection goes.

Connect the electrical connections to the starting motor.

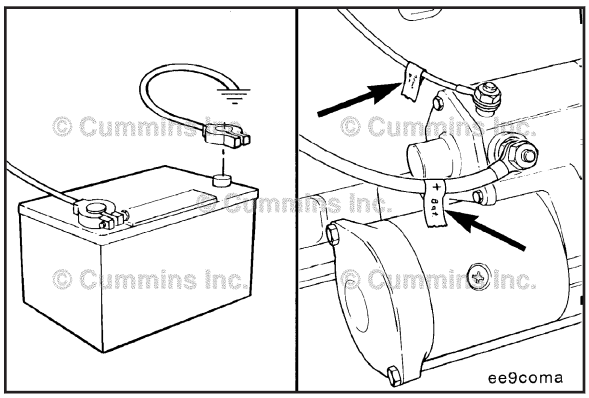
Torque Value:
M5 4 N•m [35 in-lb]

Torque Value:
M10 21 N•m [186 in-lb]

If starter came installed with the the jump start protection cover, install the jump start protection and jump start protection cover nut on the M terminal post.

Torque Value:
M5 4 N•m [35 in-lb]

NOTE: The jump start protection cover nut is the third nut on the M terminal, M5 terminal size. Failure to observe the proper torque specification can result in loss of conductivity to the M lead and result in a no crank condition for the starter and engine.



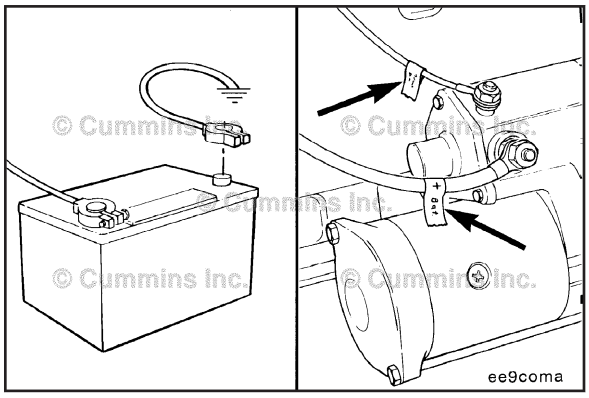
Non-Cummins® Branded Starters

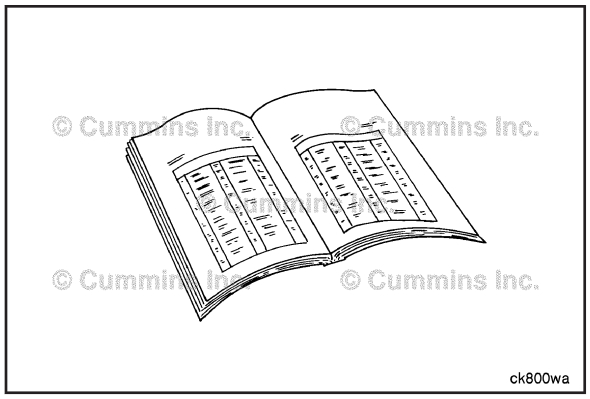
⚠CAUTION⚠
Do not overtighten the electrical connections. Starting motor damage can result.

NOTE: Use the location tags to help identify where each wire connection goes.

Connect the electrical connections to the starting motor.

For Non-Cummins® branded starters, refer to the equipment manufacturer service information for torque specifications.





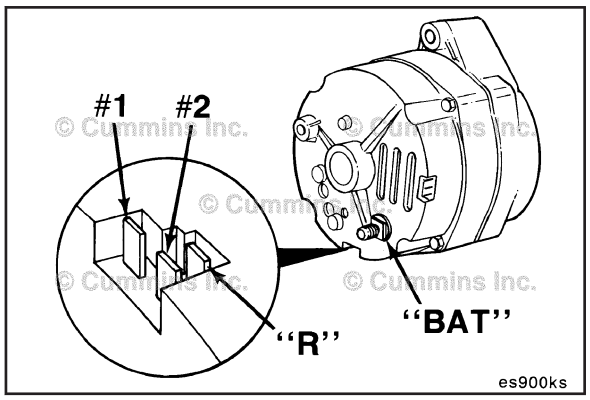
Finishing Steps

Cummins® Branded Starters

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

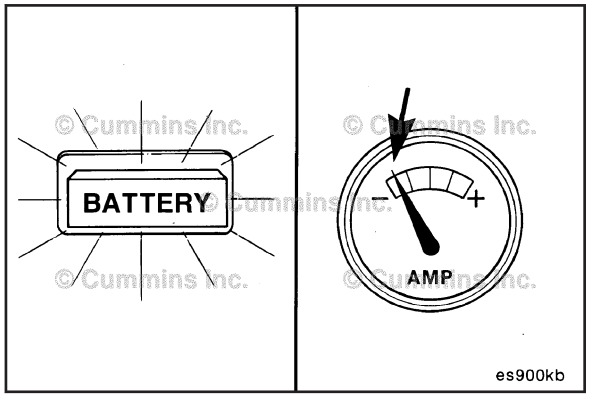
- Connect the battery cables to the battery terminals. Refer to Procedure 013-009 in Section 13.



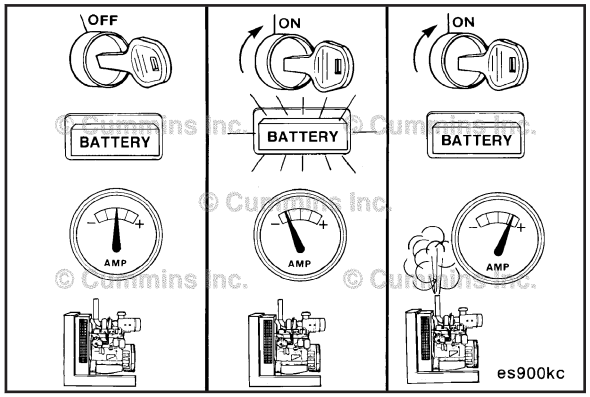
Charging System Indicator (013-023)

Initial Check

Be sure the correct terminals are being used on the alternator. The R terminal (Delco®) or W terminal (Bosch® K1) provide half of the system voltage and is used to operate accessories such as the tachometer on generator sets.



Trouble with the starting system can be indicated by the indicator lamp or ampmeter.

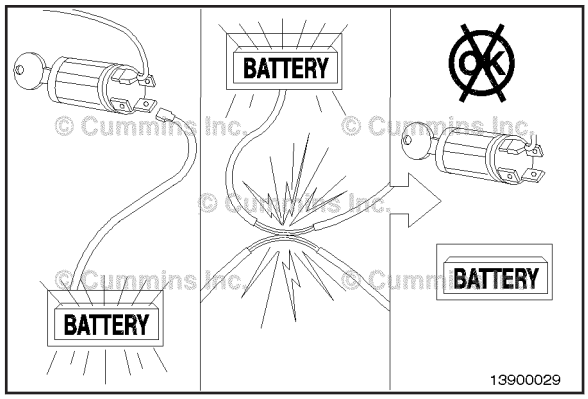


Check the indicator lamp for normal operation as shown below:

Engine	Switch	Lamp	Ampmeter
Stopped	OFF	OFF	0
Stopped	ON	ON	-
Running	ON	OFF	+

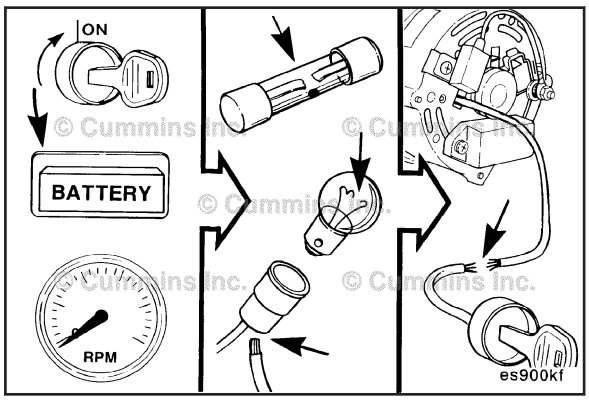
If the lamp is on when the switch is OFF and the engine is **not** running, disconnect the lamp lead at the ignition switch.

- If the lamp stays on, there is a short to a positive wire.
- If the lamp goes out, there is a short in the switch.



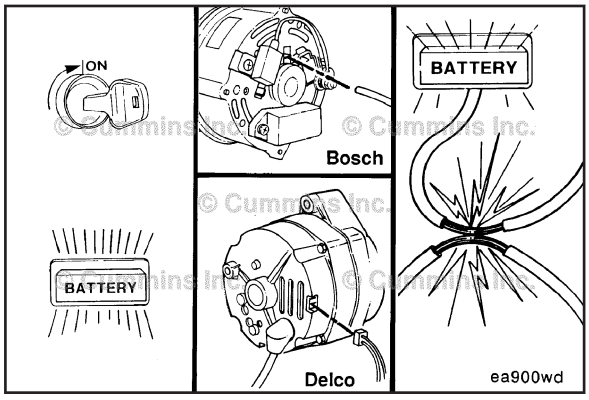
If the lamp goes off when the switch is ON and the engine is **not** running, there can be an open in the circuit.

Check for a blown fuse, a burned out bulb, defective bulb socket, or an open in the No. 1 or D (+) lead circuit between alternator and ignition switch.



If the lamp is on when the switch is ON and the engine is running, disconnect the lead to the alternator.

- If the lamp stays on, there is a short to the ground in the lamp circuit.
- If the lamp goes out, inspect the alternator.

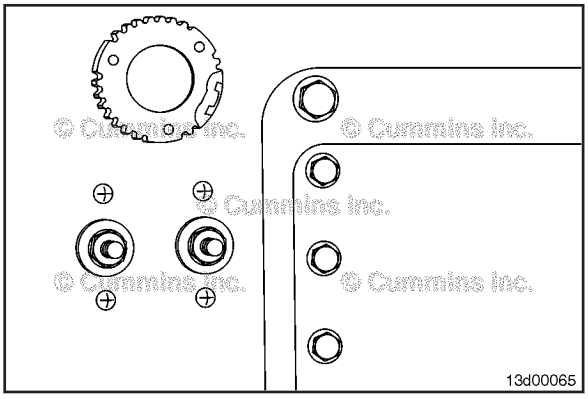


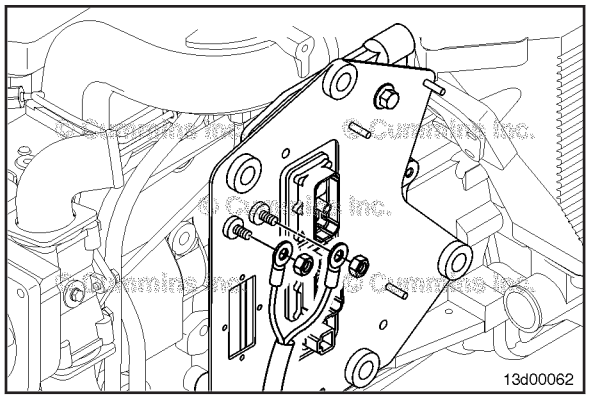
ECM Unswitched Power Terminal Blocks (013-047)

General Information

In addition to the heavy duty battery connections used for the starter, marine engines equipped with an Electronic Control Module (ECM) and the SmartCraft system use an additional unswitched power supply. The connection is installed directly from the battery to lug style connectors mounted on the side of the engine.

These terminal lug blocks are located on the left side of the engine near the OEM interface connector and the service tool datalink connection. The positive terminal block is red and the negative terminal block is black.

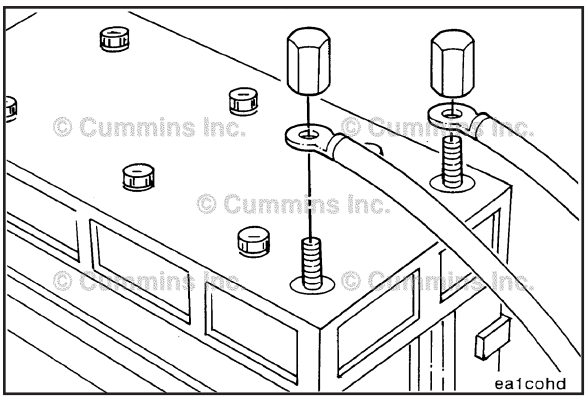




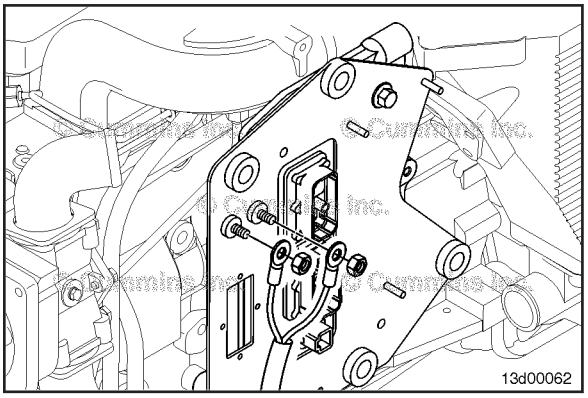
Initial Check

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

The unswitched power supply wires connect from the battery to the positive and negative terminal blocks. These wires are supplied by the OEM.



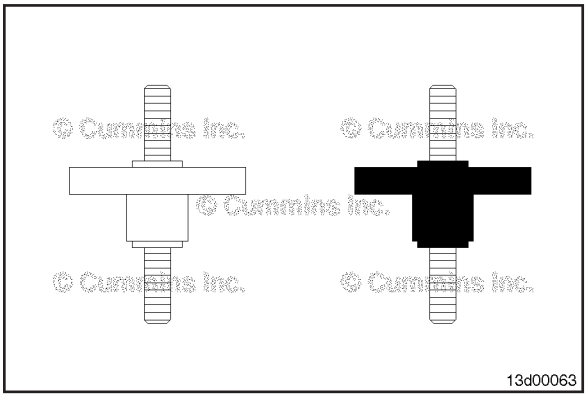
Before removing the unswitched power supply wires from the engine, be sure the positive and negative wires are disconnected from the battery. Refer to procedure 013-009.



Always install the unswitched positive and negative wire connectors to the terminal blocks before installing the connections to the battery.

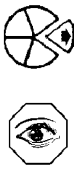
Torque the connections to the terminal blocks to the specified value.

Torque Value: 5 N•m [45 in-lb]



If for some reason the terminal blocks are damaged, new terminal blocks can be obtained and installed.

Preparatory Steps



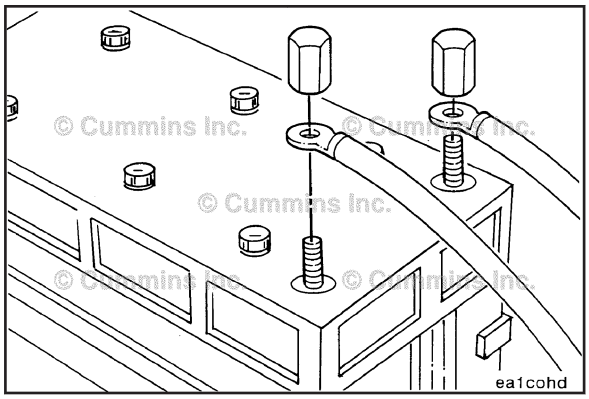
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Before removing the unswitched power supply wires from the engine, be sure the positive and negative wires are disconnected from the battery. Refer to Procedure 013-009.

If a battery switch is being used on the vessel, be sure to disconnect all batteries.

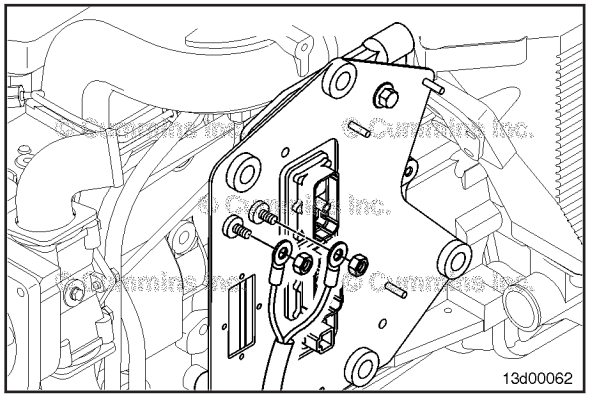
Remove the external unswitched power supply battery connection from the battery.

Remove the unswitched wire connectors from the positive and negative terminal blocks.



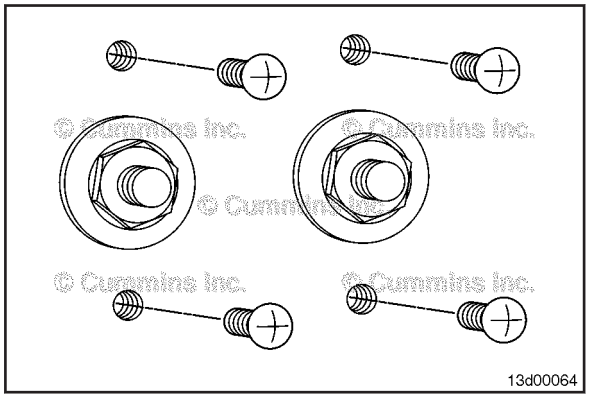
Remove

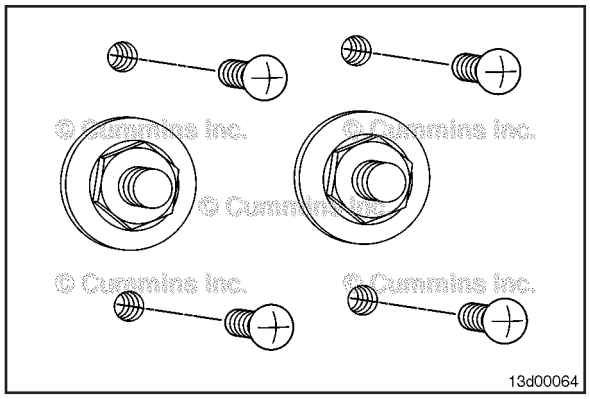
Remove the engine wiring harness connectors from the back of the positive or negative terminals. Some plates may have to be removed to complete this operation.



Remove the upper and lower mounting capscrews from the positive or negative terminal blocks. Slide the terminal blocks out the back of the mounting plate.

Some plates may have to be removed to complete this operation.



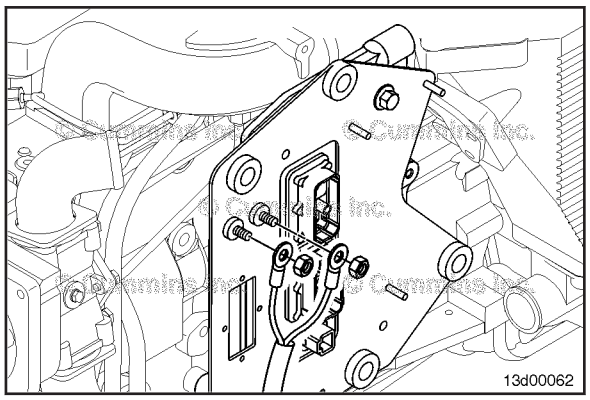


Install

Install the new positive or negative terminal block through the rear of the mounting plate. On some models the plate will have to be removed to complete this operation.

Install the mounting capscrews and torque to the specified value.

Torque Value: 3.5 N•m [30 in-lb]

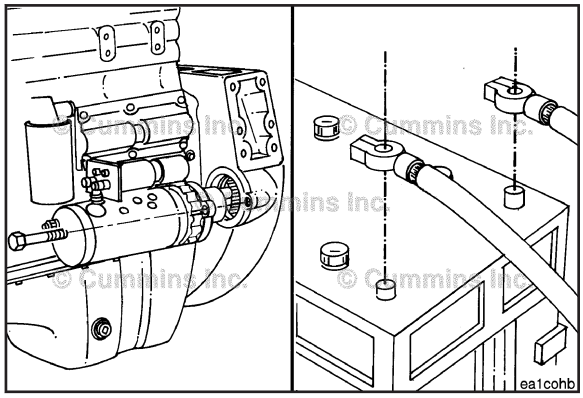


Install the engine wiring harness positive or negative wire connectors to the correct positive and negative terminal blocks located on the back of the mounting plate.

Some plates may have to be removed to complete this operation.

Torques to the specified value.

Torque Value: 5 N•m [45 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 unswitched power supply connectors to the positive and negative terminal blocks.

Install the unswitched power supply connectors to the battery and tighten the battery connection.

Ensure the positive and negative wires are connected to the proper battery terminals. Refer to Procedure 013-009.

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Section 14 - Engine Testing - Group 14

Section Contents

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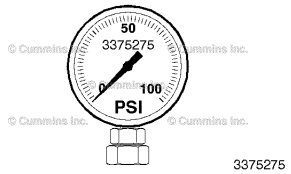
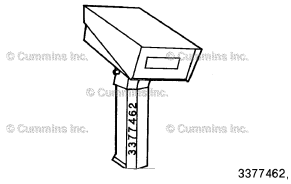
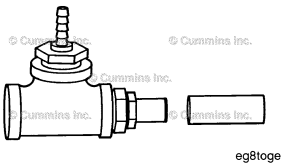
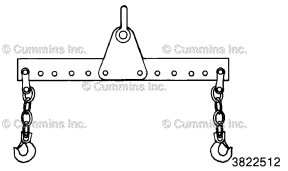
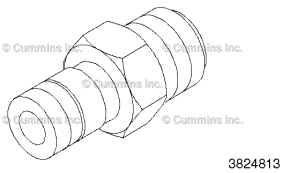
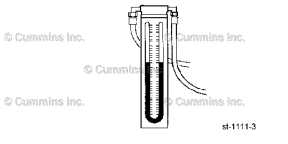
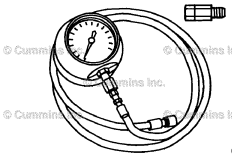
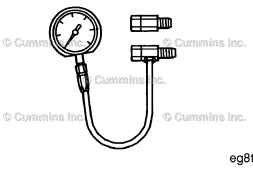
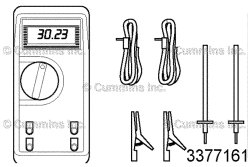
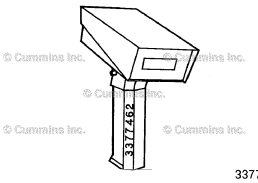
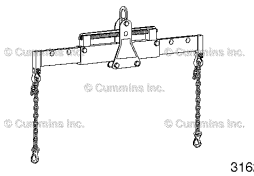
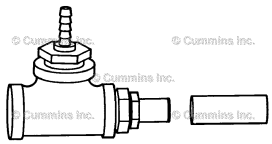
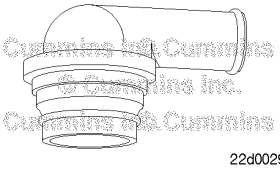
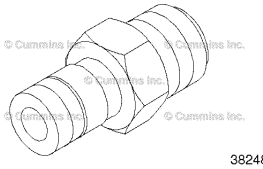
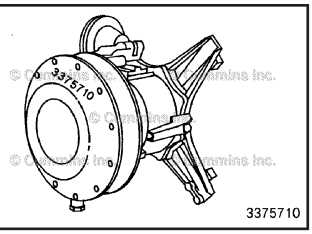
Service Tools

Engine Testing

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
3375275	**Pressure Gauge (0 to 1103 kPa [0 to 160 psi])** Used to measure lubricating oil pressure.	
3377462	**Digital Optical Tachometer** Used to measure engine speed (rpm)	
3822566	**Blowby Checking Tool** Used to check engine crankcase blowby.	
3162871	**Engine Lifting Fixture** Used to remove and install the engine.	
3824843	**Compuchek™ Fitting** Used for connection to diagnostics machine.	
ST-1111-3	**Manometer** Used with the blowby check tool to measure engine crankcase pressure.	

Tool No.	Tool Description	Tool Illustration
ST-1273	**Pressure Gauge** Used to measure engine intake manifold pressure, exhaust restriction, lift pump output pressure, and pressure drop across fuel filter.	
ST-434	**Vacuum gauge** Used to measure lift pump inlet restriction. Hose adapter, Cummins® Part Number ST-434-2, and Vacuum Gauge, ST-434-12, are used to perform the test.	
3164488 or 3164489	**Multimeter** Used to measure electrical circuits: Voltage (volts), resistance (ohms), and current (amps). 3164488 - Standard meter. 3164489 - Automotive meter with built in temperature adapter and tachometer.	
3377462	**Digital Optical Tachometer** Used to measure engine speed (rpm).	
3162871	**Engine Lifting Fixture** Used to remove and install the engine.	
3822566	**Blowby Tool** Used to check engine crankcase blowby.	
3990099	**Oil Fill Adapter** Used to measure blowby from the oil fill port in the rocker lever cover. NOTE: Will **not** work with all rocker lever cover oil fill ports. Thread type and size can be different.	
3377244	**Compuchek™ Fitting** Used to connect to the diagnostics machine. With 1/8 NPT connection.	

Tool No.	Tool Description	Tool Illustration
3375710	**Drivetrain Dynomometer** Used to measure engine horsepower.	

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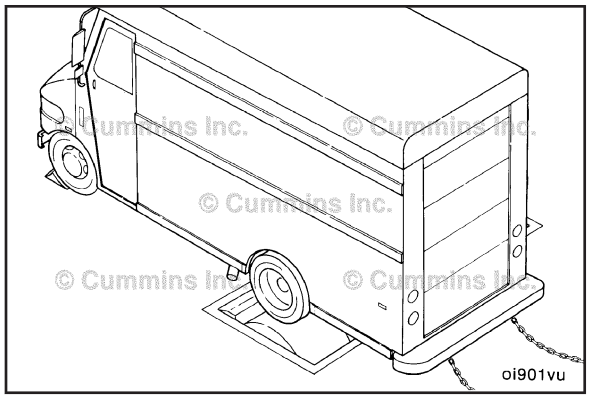


Engine Testing (Chassis Dynamometer) (014-002)

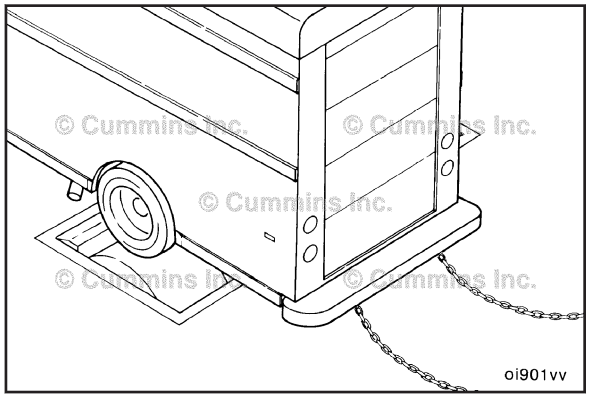
Setup

The performance of an engine installed in on-highway vehicles can be tested on a chassis dynamometer.

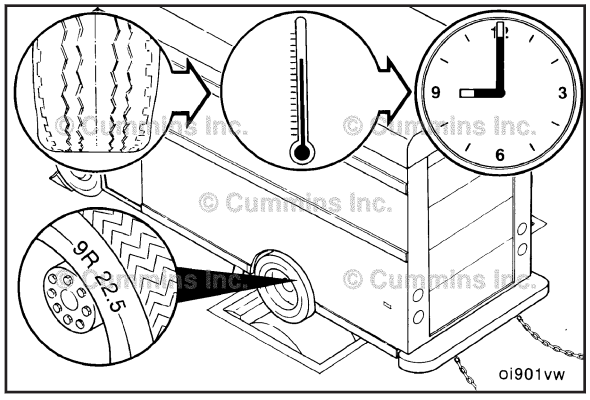
NOTE: Because of driveline efficiency and engine-driven accessories, the engine horsepower when measured at the rear wheels will be reduced by approximately:

- 20 percent for single-axle vehicles
- 25 percent for tandem-axle vehicles
- 35 percent for recreational vehicles.

NOTE: These percentages are used for engine run-in **only** and are **not** to be used as absolute figures.



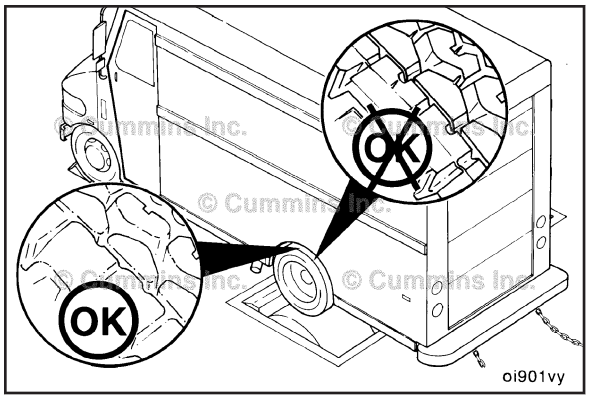
⚠WARNING⚠
Follow all of the vehicle manufacturer's safety precautions before installing or operating a vehicle on a chassis dynamometer. Failure to do so can cause damage to the vehicle and/or harm personnel.



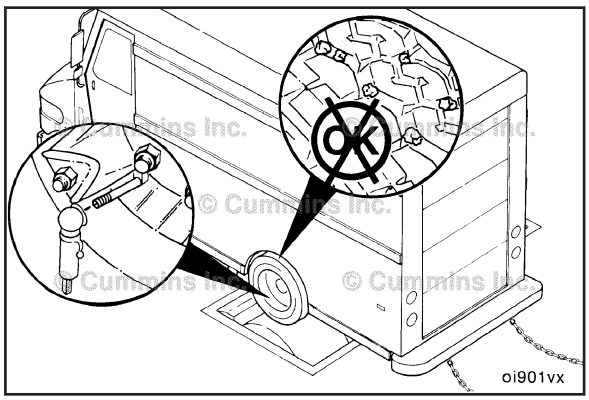
⚠CAUTION⚠
Low-profile tires are more sensitive to heat than bias ply tires. Excessive operating time at full load can damage the tires due to overheating. Check the tire manufacturer's recommendations for the maximum allowable chassis dynamometer operating time.

While operating the chassis dynamometer, follow the general safety precautions listed below:

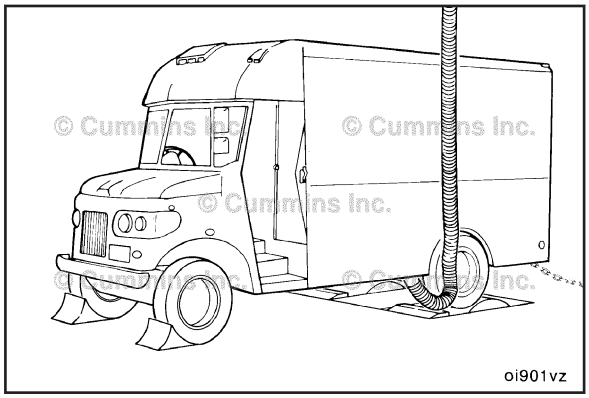
- Use tires that have more than 160 km [100 mi] of use. Do **not** use new tires.
- Do **not** use recapped tires or tires of different sizes or designs.



- Make sure the tires are inflated to the manufacturer's specifications.
- Remove all rocks or other materials from the treads of the tires that will be rotating on the dynamometer rollers.



- Make sure there is correct overhead clearance for exhaust stacks, air deflectors, or other attachments above the cab.

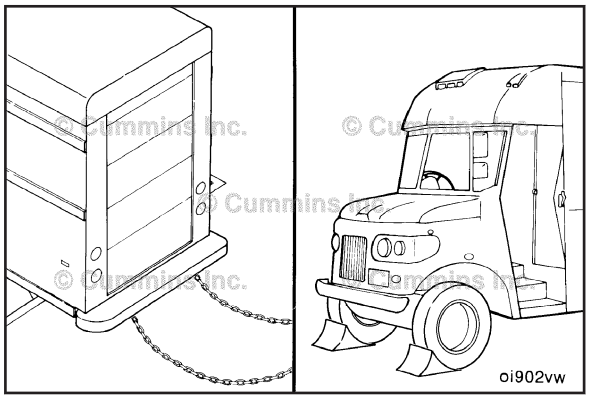


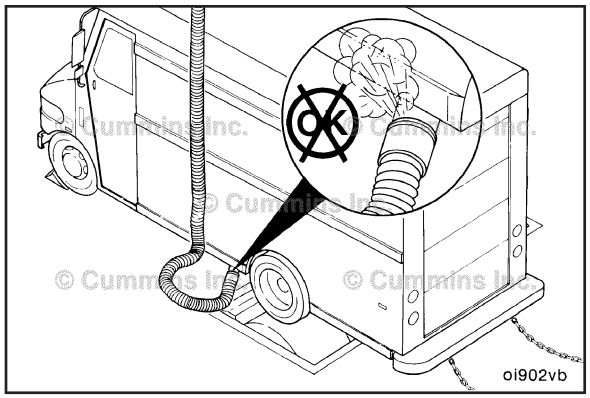
⚠CAUTION⚠
To prevent damage to the chassis dynamometer, make sure there is enough slack in the tie-down chains.

Carefully position the vehicle on the rollers.

Attach the tie-down chains to the rear of the vehicle.

Place wheel chocks in front of the front tires.





⚠WARNING⚠

Some exhaust gas constituents may be toxic and/or carcinogenic. Make sure the ventilation hose does not leak.

Adjust the vehicle and dynamometer room exhaust system to make sure all the exhaust gases are removed from the room.

Read the chassis dynamometer and vehicle manufacturer's recommendations and specifications for testing procedures.

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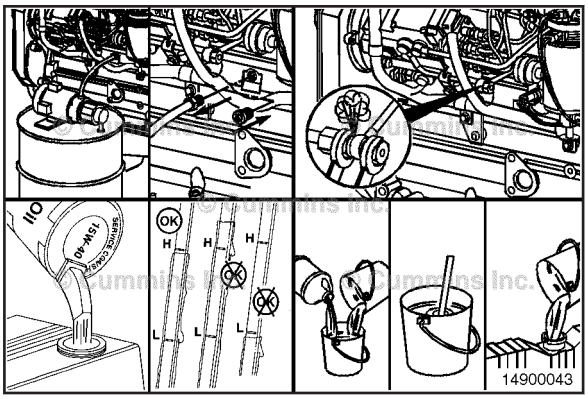
Test



⚠WARNING⚠
Check the coolant level only when the engine is stopped. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Failure to do so can cause personal injury from heated coolant spray.

The following procedure assumes that the lubricating oil and fuel systems were correctly primed, the dipstick calibrated, and the engine filled to the correct levels with lubricating oil and coolant during installation of the engine into the chassis. If these systems were **not** serviced during installation of the engine.

Use the following procedures for instructions on priming the lubricating oil and the fuel system and calibrating the dipstick.

- Use the following procedure in the Service Manual, ISF2.8 CM2220 F101. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the Service Manual, ISF2.8 CM2220 E and ISF2.8 CM2220 AN Bulletin 4022178. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the Service Manual, ISF2.8 CM2220 E and ISF2.8 CM2220 AN Bulletin 4022178. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the Service Manual, ISF3.8 CM2220 Bulletin 4021704. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the Troubleshooting and Repair Manual, ISC, ISCe, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB, ISBe 4 and 6 Cylinder, Bulletin 4021271. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 014-006 in Section 14.

Reference the Operation and Maintenance Manual for instructions on filling the lubricating oil and the cooling systems.

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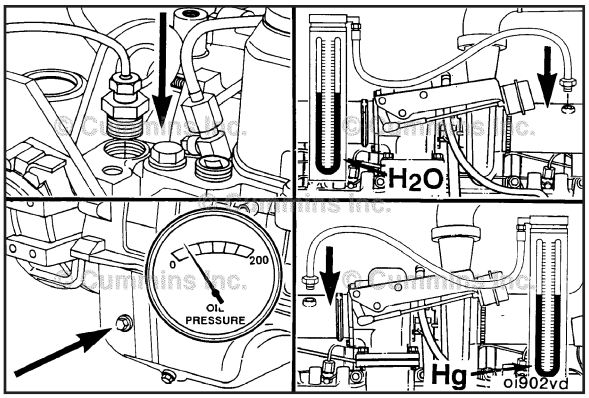

The number of instruments and gauges required to perform a chassis dynamometer test will vary according to type and the capability of the test equipment used.

See the service tools listed at the beginning of this section.

To correctly monitor an engine's performance, record the following parameters:

- Lubricating oil pressure (vehicle instrument panel)
- Engine speed (rpm) (vehicle instrument panel)
- Wheel horsepower (whp) (dynamometer controls)
- Blowby: Refer to Procedure 014-010 in Section 14.
- Exhaust back pressure:
- Use the following procedure in the Service Manual, ISF2.8 CM2220 F101, Bulletin 4310846. Refer to Procedure 011-009 in Section 14.
- Use the following procedure in the Service Manual, ISF2.8 CM2220 E and ISF2.8 CM2220 AN Bulletin 4022178. Refer to Procedure 011-009 in Section 11.
- Use the following procedure in the Service Manual, ISF3.8 CM2220 Bulletin 4021704. Refer to Procedure 011-009 in Section 11.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193. Refer to Procedure 011-009 in Section 11.
- Use the following procedure in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087. Refer to Procedure 011-009 in Section 11.
- Use the following procedure in the Troubleshooting and Repair Manual, ISC, ISCe, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418. Refer to Procedure 011-009 in Section 11.
- Use the following procedure in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003. Refer to Procedure 011-009 in Section 11.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB, ISBe 4 and 6 Cylinder, Bulletin 4021271. Refer to Procedure 011-009 in Section 11.
- Use the following procedure in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207. Refer to Procedure 011-009 in Section 11.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 011-009 in Section 11.
- Coolant temperature (vehicle instrument panel):
- Use the following procedure in the Service Manual, ISF2.8 CM2220 F101, Bulletin 4310846. Refer to Procedure 008-018 in Section 18.
- Use the following procedure in the Service Manual, ISF2.8 CM2220 E and ISF2.8 CM2220 AN Bulletin 4022178. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Service Manual, ISF3.8 CM2220 Bulletin 4021704. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, ISC, ISCe, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB, ISBe 4 and 6 Cylinder, Bulletin 4021271. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 008-018 in Section 8.
- Coolant pressure:
- Use the following procedure in the Service Manual, ISF2.8 CM2220 F101, Bulletin 4310846. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Service Manual, ISF2.8 CM2220 E and ISF2.8 CM2220 AN Bulletin 4022178. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, ISC, ISCe, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB, ISBe 4 and 6 Cylinder, Bulletin 4021271. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 008-018 in Section 8.
- Intake manifold pressure:
- Use the following procedure in the Service Manual, ISF2.8 CM2220 F101, Bulletin 4310846. Refer to Procedure 019-159 in Section 19.
- Use the following procedure in the Service Manual, ISF2.8 CM2220 E and ISF2.8 CM2220 AN Bulletin 4022178. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the Service Manual, ISF3.8 CM2220 Bulletin 4021704. Refer to Procedure 010-057 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193. Refer to Procedure 010-057 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087. Refer to Procedure 010-057 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, ISC, ISCe, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418. Refer to Procedure 010-057 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003. Refer to Procedure 010-057 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB, ISBe 4 and 6 Cylinder, Bulletin 4021271. Refer to Procedure 010-057 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207. Refer to Procedure 010-057 in Section 10.
- Inlet air restriction:
- Use the following procedure in the Service Manual, ISF2.8 CM2220 F101, Bulletin 4310846. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the Service Manual, ISF2.8 CM2220 E and ISF2.8 CM2220 AN Bulletin 4022178. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the Service Manual, ISF3.8 CM2220 Bulletin 4021704. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, ISC, ISCe, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB, ISBe 4 and 6 Cylinder, Bulletin 4021271. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 010-031 in Section 10.
- Fuel supply pressure:
- Use the following procedure in the Service Manual, ISF2.8 CM2220 F101, Bulletin 4310846. Refer to Procedure 006-051 in Section 6.
- Use the following procedure in the Service Manual, ISF2.8 CM2220 E and ISF2.8 CM2220 AN Bulletin 4022178. Refer to Procedure 005-016 in Section 5.
- Use the following procedure in the Service Manual, ISF3.8 CM2220 Bulletin 4021704. Refer to Procedure 006-024 in Section 6.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193. Refer to Procedure 006-024 in Section 6.
- Use the following procedure in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087. Refer to Procedure 006-024 in Section 6.
- Use the following procedure in the Troubleshooting and Repair Manual, ISC, ISCe, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418. Refer to Procedure 006-024 in Section 6.
- Use the following procedure in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003. Refer to Procedure 006-024 in Section 6.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB, ISBe 4 and 6 Cylinder, Bulletin 4021271. Refer to Procedure 006-024 in Section 6.
- Use the following procedure in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207. Refer to Procedure 006-024 in Section 6.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 006-024 in Section 6.

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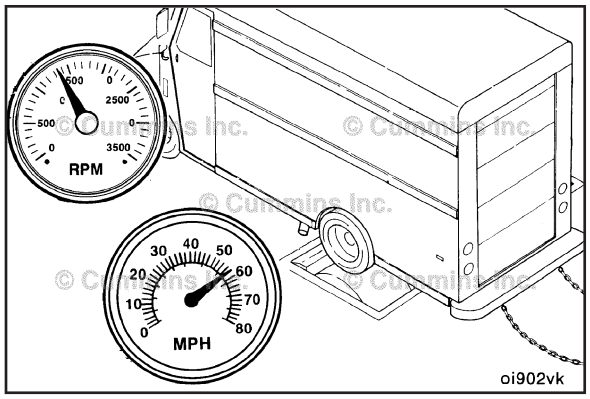


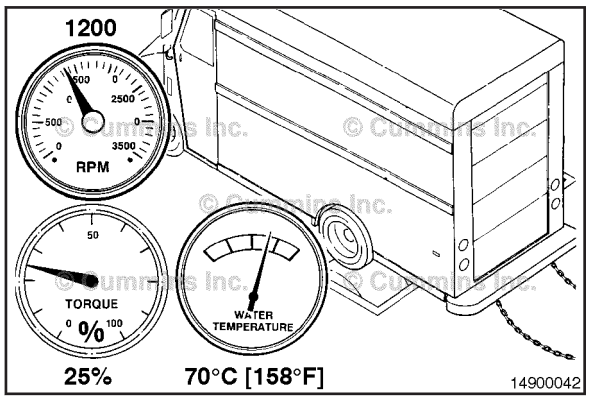
Engine Run-in (Chassis Dynamometer) (014-003)

Test

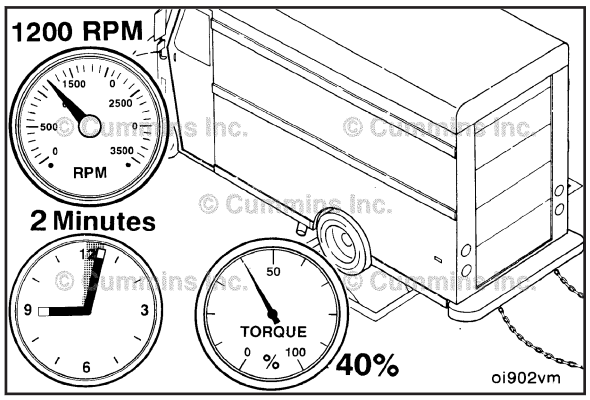
⚠CAUTION⚠
Prior to operating the engine and to reduce the possibility of internal component damage. Refer to Procedure 014-002 in Section 14.

NOTE: For general operating procedures and safety precautions. Refer to Procedure 014-005 in Section 14.

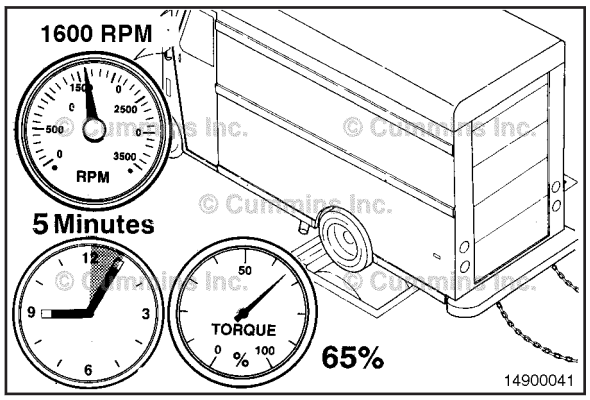
NOTE: Operate the vehicle in a gear that produces a road speed of 90 to 95 kph [55 to 60 mph].



Operate the engine at 1200 rpm and 25 percent of torque peak load until the water temperature reaches 70°C [160°F].



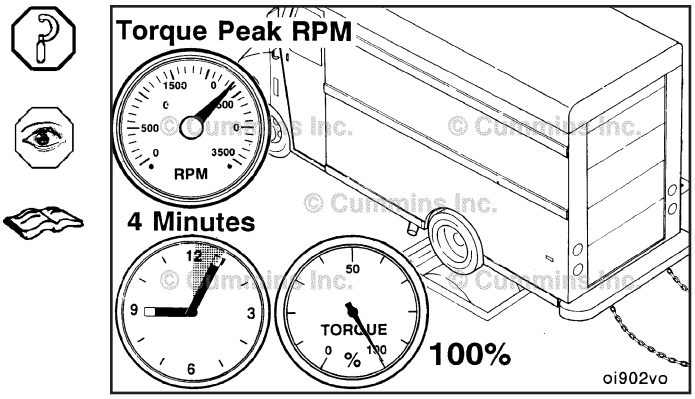
Operate the engine at 1200 rpm and 40 percent of torque peak load for 2 minutes. Check the gauges and record the readings.



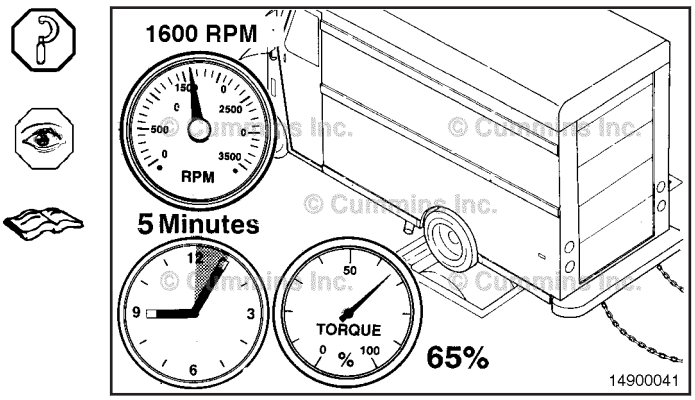
Operate the engine at 1600 rpm and 65 percent of torque peak load for 5 minutes. Check the gauges and record the readings.

Operate the engine at torque peak rpm and full load for 4 minutes. Check the gauges and record the readings.

NOTE: See the engine data sheet for the torque peak rpm of the engine model being tested.

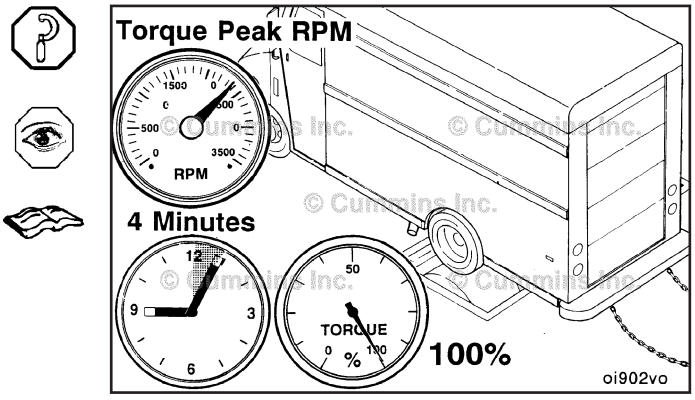


Operate the engine at 1600 rpm and 65 percent of torque full load for 5 minutes. Check the gauges and record the readings. Compare the readings to those published in the appropriate engine data sheet.



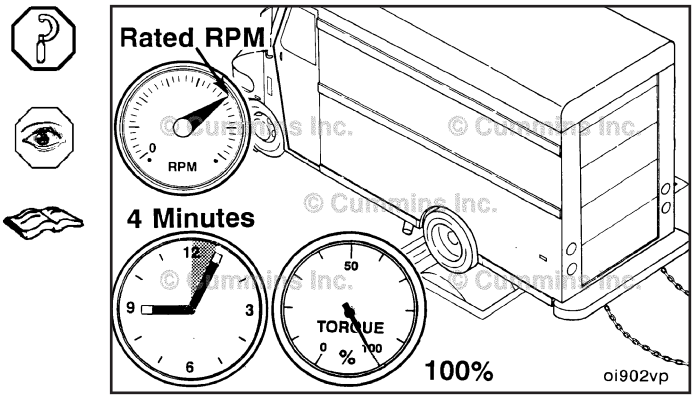
Operate the engine at torque peak rpm and full load for 4 minutes. Check the gauges and record the readings.

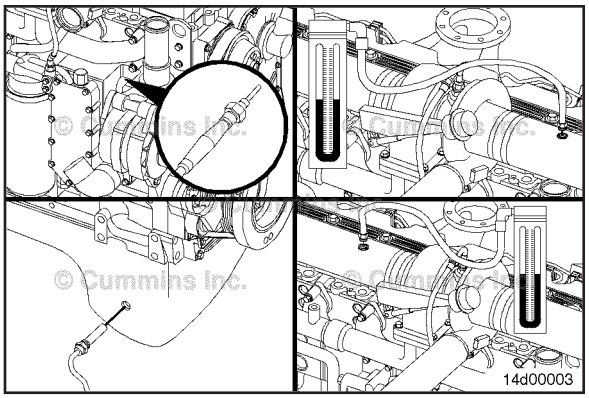
NOTE: See the engine data sheet for the torque peak rpm of the engine model being tested.



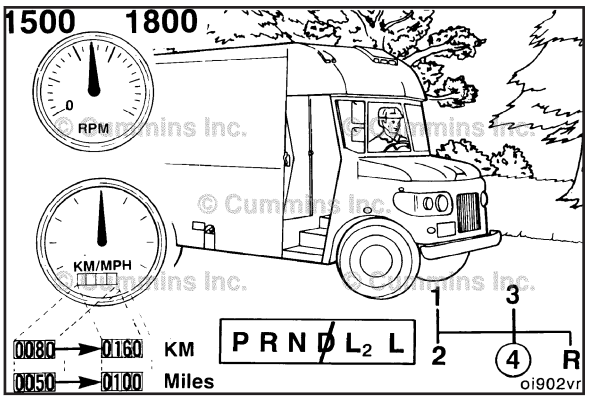
⚠CAUTION⚠
Do not shut off the engine immediately after the run-in is complete. Allow the engine to cool by operating it at low idle for a minimum of 3 minutes to avoid internal component damage.

Operate the engine at rated speed (rpm) and full load for 4 minutes. Check the gauges and record the readings. Compare the readings to those published in the appropriate engine data sheet.





Make sure to remove all dynamometer instrumentation from the vehicle.

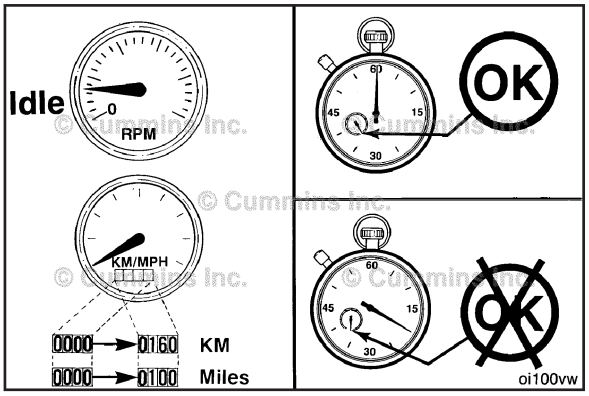


Engine Run-in (Without Dynamometer) (014-004)

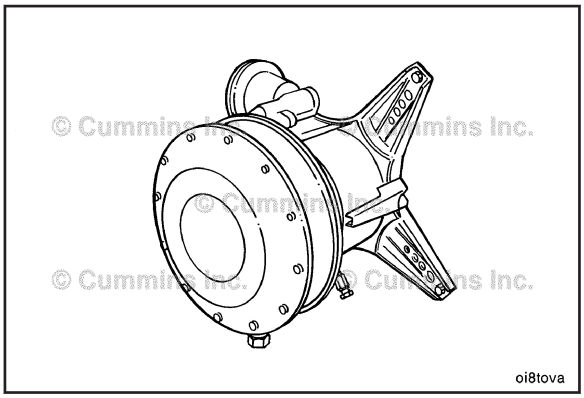
Test

⚠CAUTION⚠
Refer to Engine Test (Engine Dynamometer) (014-005) before operating the engine to avoid internal component damage.

Operate the engine at 1500 to 1800 rpm in high gear for the first 80 to 160 km [50 to 100 mi] after rebuild.



NOTE: Do **not** idle the engine for more than 5 minutes at any one time during the first 160 km [100 mi] of operation.



Engine Testing (Engine Dynamometer) (014-005)

Setup

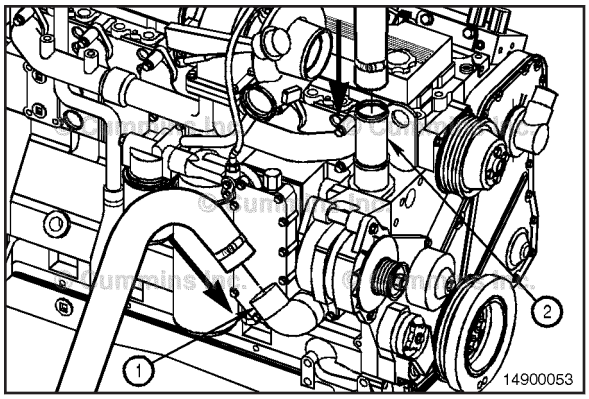
Use engine lifting fixture, Part Number 3162871, to install the engine to the test stand. Align and connect the dynamometer. Refer to the manufacturer's instructions for aligning and testing the engine.

NOTE: Make sure the dynamometer capacity is sufficient to permit testing at 100 percent of the engines rated horsepower. If the capacity is **not** enough, the testing procedure **must** be modified to the restrictions of the dynamometer.

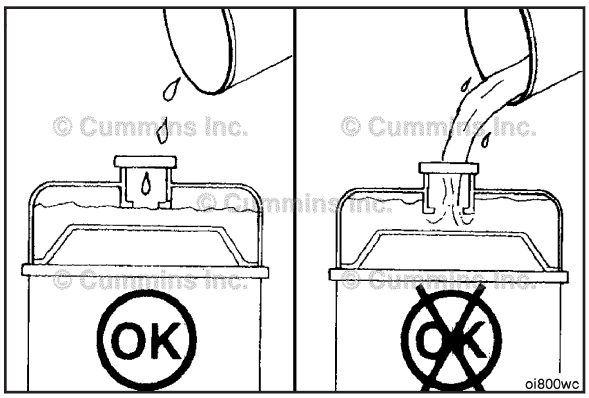
Connect the coolant supply to the water inlet connection (1).

Connect the coolant return to the water outlet connection (2).

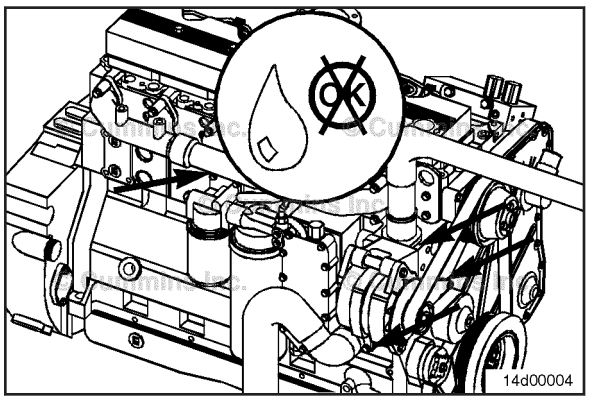
Install the drain plugs, close all the water drain cocks, and make sure all the clamps and fittings are tight.



Fill the cooling system with coolant to the bottom of the fill neck in the radiator fill (or expansion) tank.



Inspect the engine for coolant leaks at connections, fittings, plates, and plugs. Repair if necessary.



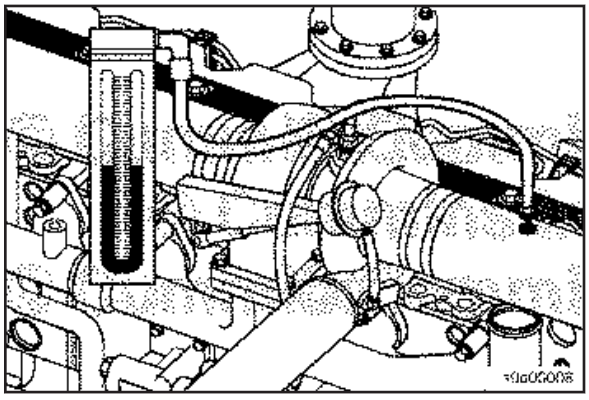
Air Inlet Restriction

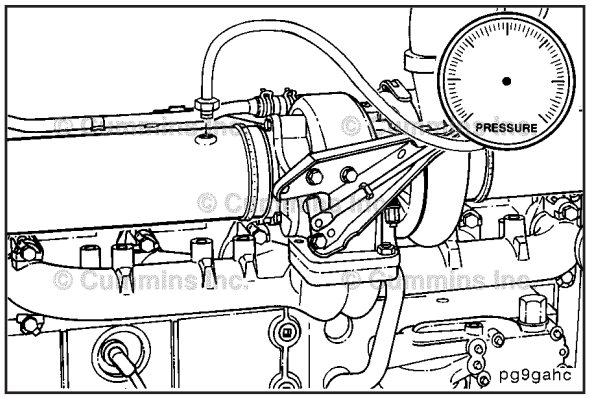
Connect a water manometer, Part Number ST-1111-3, to the turbocharger air inlet pipe to test air restriction.

NOTE: The manometer connection **must** be installed at a 90-degree angle to the airflow in a straight section of pipe, one pipe diameter before the turbocharger.

NOTE: A vacuum gauge, Part Number ST-434, can be used in place of the water manometer.

Minimum Gauge Capacity 760 mm H_2O [30 in H_2O]





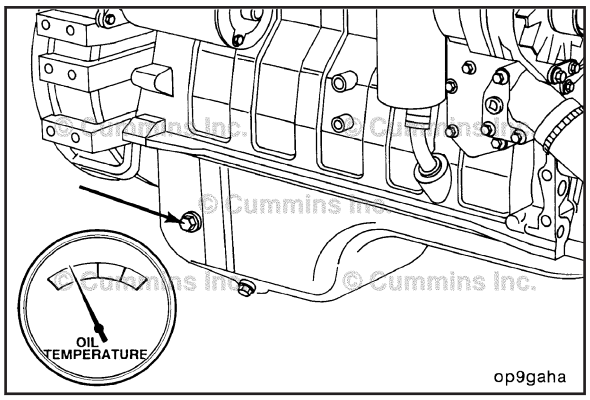
Exhaust Restriction

Connect a mercury manometer to a straight section of the exhaust piping near the turbocharger outlet to check exhaust restriction.

NOTE: A pressure gauge, Cummins Part Number ST-1273, can be used in place of the mercury manometer.

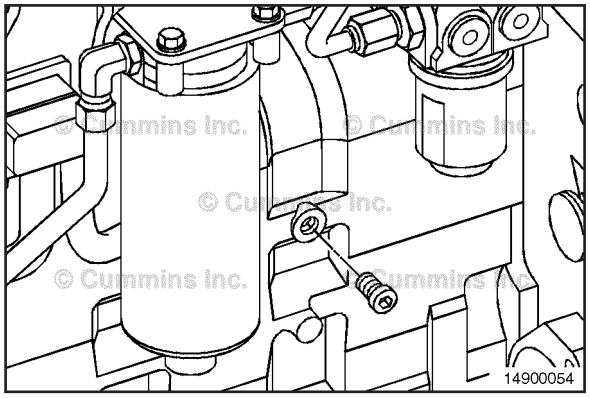
NOTE: For automotive applications, a tapped hole is provided on the inlet side of the catalyst for checking exhaust restrictions.

Minimum Gauge Capacity 254 mm Hg [10 in Hg]



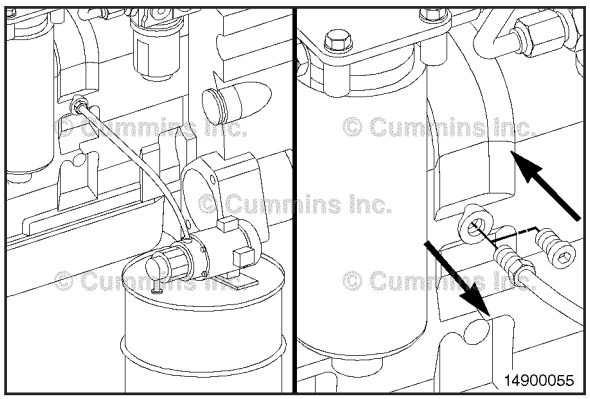
Attach the lubricating oil temperature sensor in the location shown.

Minimum Gauge Capacity 150 °C [300 °F]



⚠CAUTION⚠
The lubricating oil system must be primed before operating the engine after if has been rebuilt to avoid internal damage.

To prime the lubricating oil system using external pressure, connect the supply to a tapped hole in the main lubricating oil rifle.



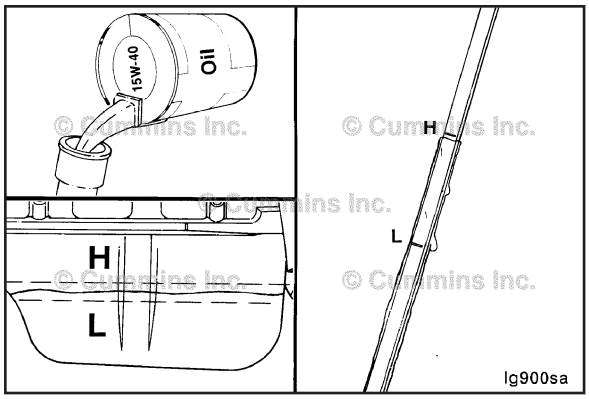
Use a pump capable of supplying 210 kPa [30 psi] of continuous pressure. Connect the pump to the port on the main lubricating oil rifle as shown.

Use clean lubricating oil to prime the system until the oil pressure registers on the gauge.

Remove the lubricating oil supply tube and install the plug.

Make sure the lubricating oil has had time to drain to the lubricating oil pan and fill the engine to the high mark as measured on the dipstick.

Use the correct lubricating oil as specified in the Operation and Maintenance Manual.



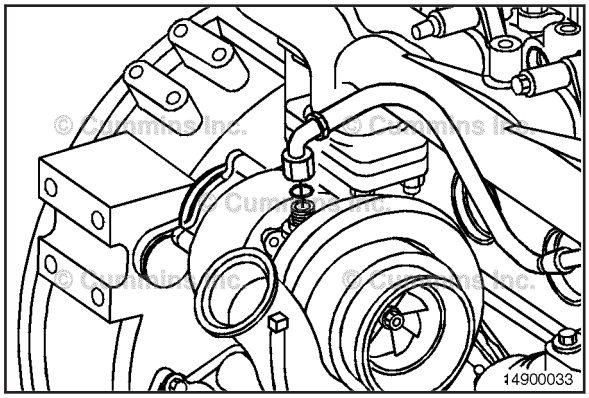
If an external pressure pump is **not** available, prime the lubricating system according to the following procedure.

Fill the engine with lubricating oil to the high-level mark on the dipstick.

Disconnect the turbocharger lubricating oil supply tube.

Pour 50 to 60 cc [2.0 to 3.0 fl oz] of clean 15W-40 lubricating oil into the turbocharger lubricating oil supply hole.

Connect the lubricating oil supply tube to the turbocharger.

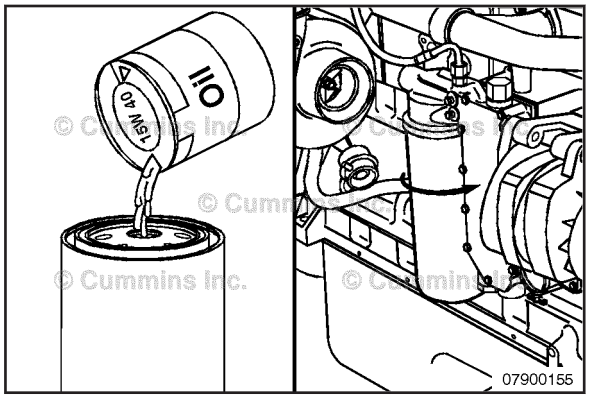


⚠CAUTION⚠
Mechanical overtightening can distort the threads or damage the filter element seal.

Fill the lubricating oil filters with clean 15W-40 lubricating oil.

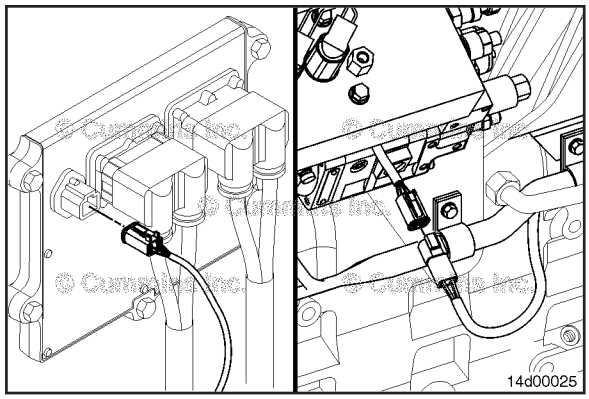
Screw the filters onto the filter head fitting until the gasket contacts the filter head surface.

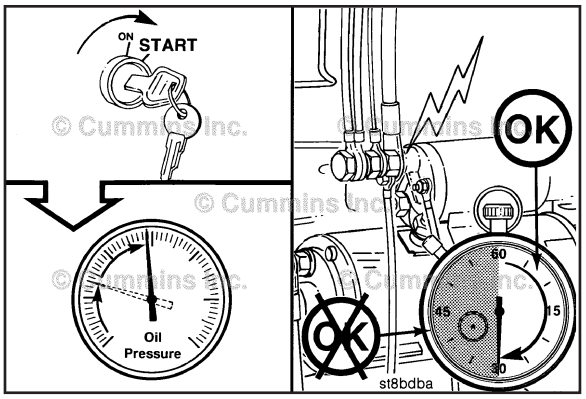
Tighten the filter as specified by the manufacturer.



CM850 Control Module - Disconnect the 4-pin power connector from the ECM to prevent the engine from starting.

CM554 Control Module -Disconnect the CAPS injection control valve connector so that the engine does **not** start.





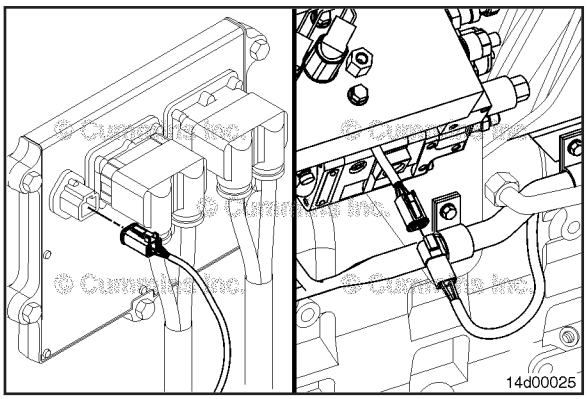
CAUTION

Do not crank the starting motor for periods longer than 30 seconds. Excessive heat will damage the starting motor.

Crank the engine until the lubricating oil pressure gauge indicates system pressure.

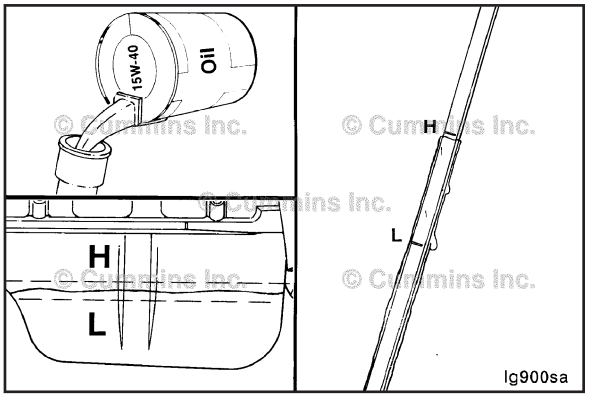
NOTE: Allow two minutes between the 30-second cranking periods so the starter motor can cool.

NOTE: If pressure is **not** indicated, find and correct the problem before continuing.



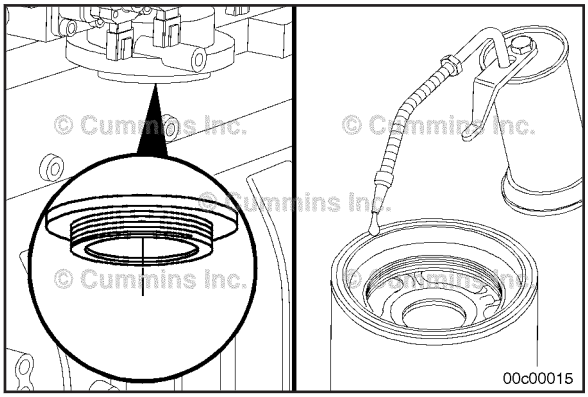
CM850 Control Module - Connect the 4-pin power connector to the ECM.

CM554 Control Module - Connect the injection control valve connector.



Allow the lubricating oil to drain into the lubricating oil pan and measure the lubricating oil level with the dipstick.

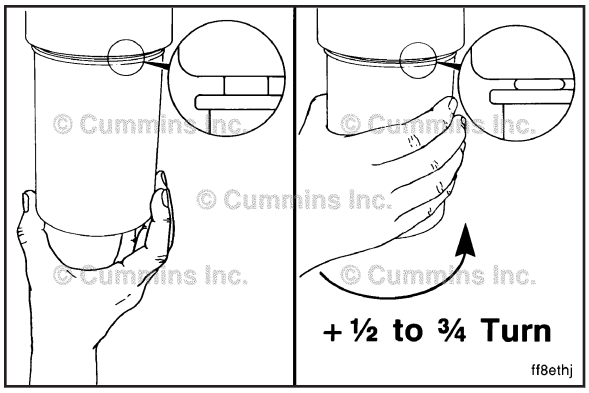
Add lubricating oil as necessary to bring the level to the high-level mark.



Lubricate the gasket on the oil filter with clean 15W-40 lubricating oil.

Screw the oil filter onto the filter head until the gasket contacts the filter head surface.

Tighten the filter as specified by the manufacturer.

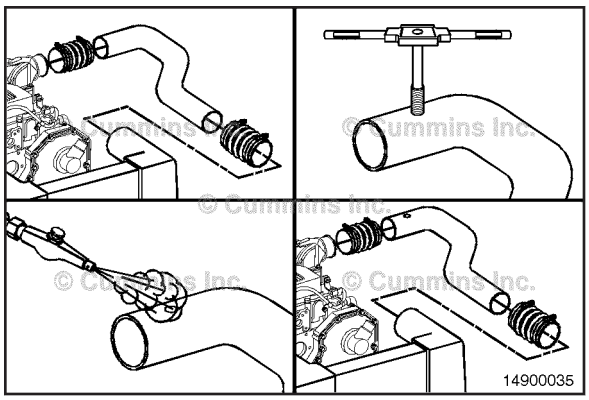


⚠CAUTION⚠
Do not attempt to install pipe thread fittings in plastic or rubber intake piping.

If INSITE™ electronic service tool is available, use it to monitor intake manifold pressure during the test. This eliminates the need to install a gauge as shown below.

If the air crossover tube does **not** have a pipe plug and tapped hole, perform the following procedure:

- Remove the charge air cooler air crossover tube from the engine.
- Drill and tap a 1/8-inch pipe thread hole in the tube four to six inches from intake opening.
- Clean all metal shavings from the air crossover tube.
- Install the crossover tube.



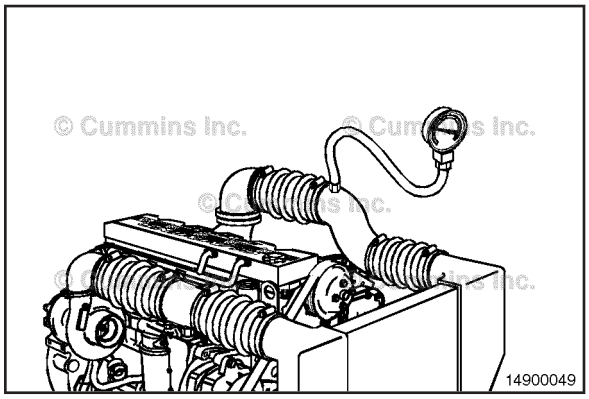
To determine the amount of turbocharger boost, remove the pipe plug in the air crossover tube and install the intake manifold pressure sensor or pressure gauge, Part Number ST-1273.

Minimum Gauge Capacity 1905 mm Hg [75 in Hg]

For an accurate engine crankcase blowby measurement, insert a blowby checking tool in the crankcase breather vent.

Connect a water manometer to the blowby tool. A pressure gauge can be used in place of the manometer.

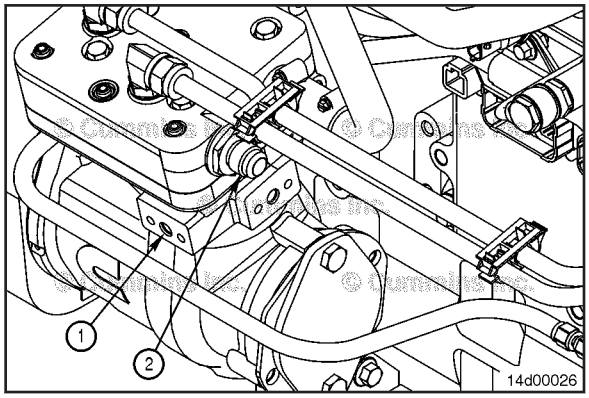
Minimum Gauge Capacity 1270 mm H_2O [50 in H_2O]

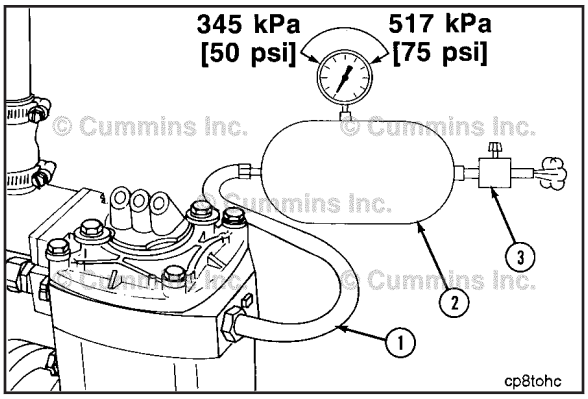


To be able to unload the compressor, connect a source of compressed air to the unloader (1). This air line **must** contain a valve between the source and the unloader.

NOTE: All air compressors manufactured by Cummins Inc. **must** be loaded during engine run-in. All air compressors **must** be unloaded during the engine performance check.

NOTE: The compressed air load in the accompanying illustration **must** be attached to the air compressor outlet (2).



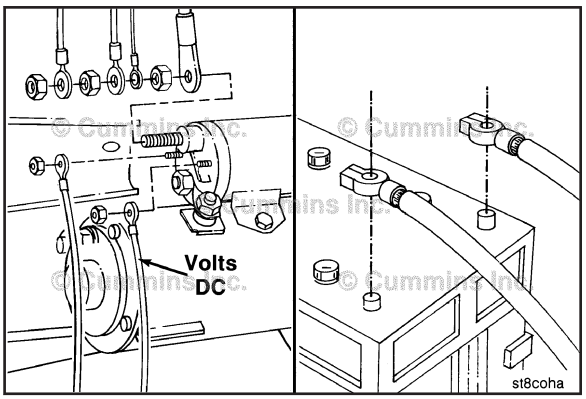


To provide a load on the air compressor, connect an air tank (2) to the compressor outlet, use steel tubing or a high-temperature hose (1).

Install an air regulator (3) that can maintain tank air pressure of 345 to 517 kPa [50 to 75 psi] at both the minimum and the maximum engine rpm.

Hose Temperature (Minimum) 260 °C [500 °F]

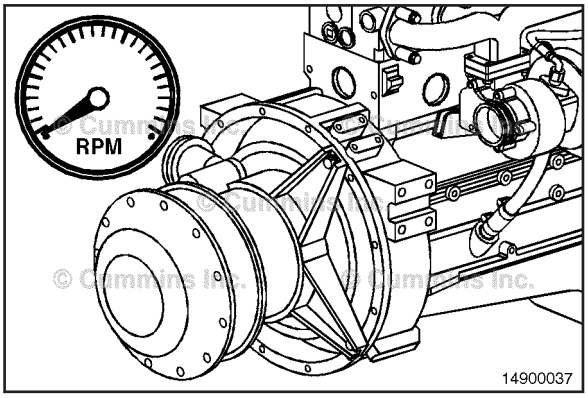
NOTE: If the engine is equipped with a variable geometry turbocharger, the turbocharger control valve will require a continous air supply of at least 621 kPa [90 psi].



Inspect the voltage rating on the starter motor before installing the electrical wiring.

Attach electrical wires to the starter motor and the batteries, if used.

NOTE: If another method of starting the engine is used, follow the manufacturer's instructions to make the necessary connections.

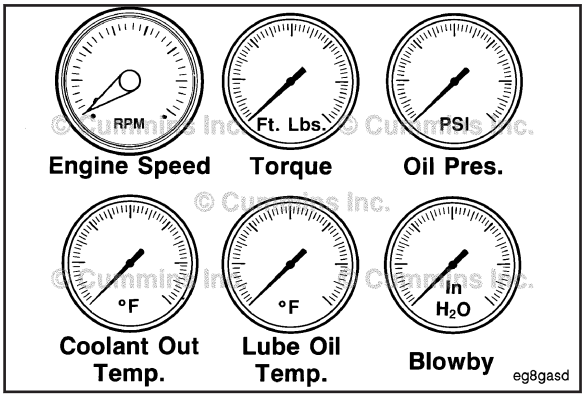


Engine Run-in (Engine Dynamometer) (014-006)

Run-In Instructions

The engine run-in period allows the tester to detect assembly errors and to make final adjustments needed for performance that meets specifications.

NOTE: The amount of time specified for the following engine run-in phases are minimums. Additional time can be used, if desired, at each phase except engine idle periods.

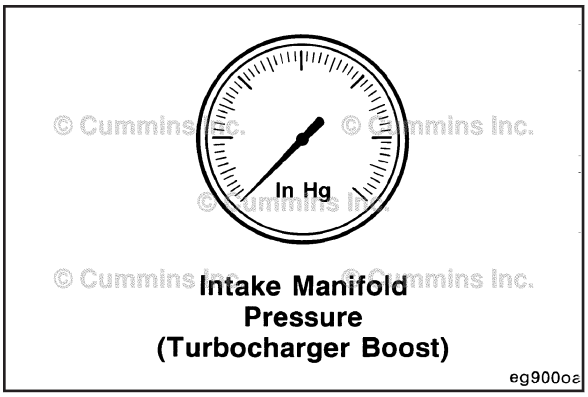


Measurements from these indicators and gauges **must** be observed closely during all phases of the engine run-in period.

- Engine speed
- Torque
- Oil pressure
- Coolant outlet temperature
- Lube oil temperature
- Blowby.

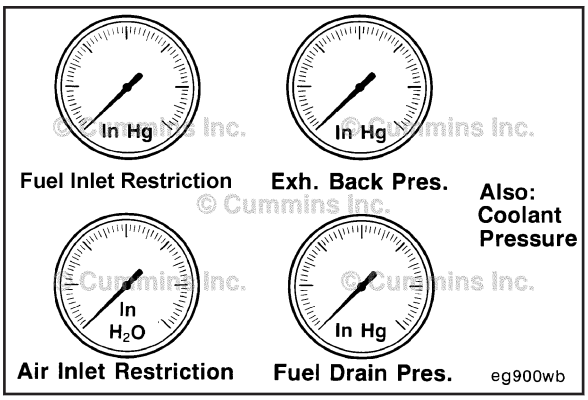
To evaluate the engine performance correctly, this additional measurement **must** be observed during engine run-in phases:

- Intake manifold pressure.



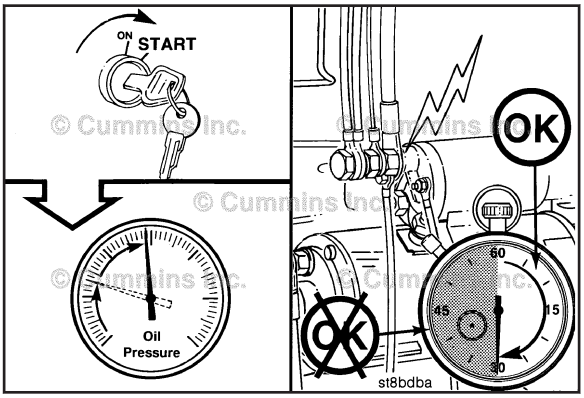
It is good practice to observe these measurements even if engine performance meets specifications. If engine performance does **not** meet specifications, these measurements can indicate possible reasons for under performance.

- Fuel inlet restriction
- Exhaust back pressure
- Air inlet restriction
- Fuel drain pressure
- Coolant pressure.



⚠CAUTION⚠
Do not crank the engine for more than 30 seconds. Excessive heat will damage the starting motor.

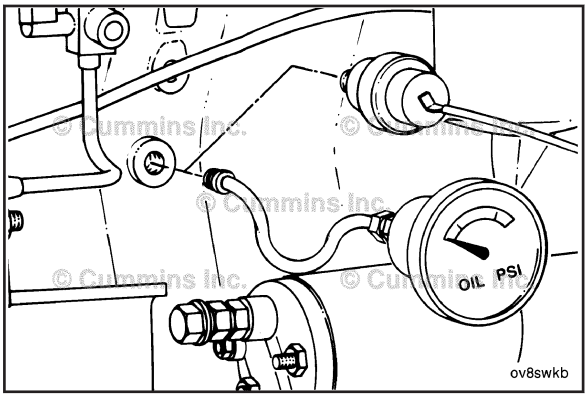
Crank the engine and observe the lubricating oil pressure when the engine starts. If the engine fails to start within 30 seconds, allow the starting motor to cool for 2 minutes before cranking the engine again.

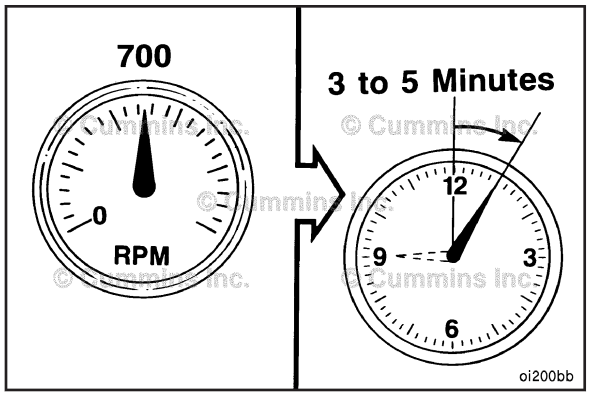


⚠CAUTION⚠
If the lubricating oil pressure is not within specifications, shut off the engine immediately. Low lubricating oil pressure will cause engine damage.

Engine lubricating oil pressure **must** be at least 70 kPa [10 psi] at 700 rpm.

Correct the problem if the lubricating oil pressure is **not** within specifications.

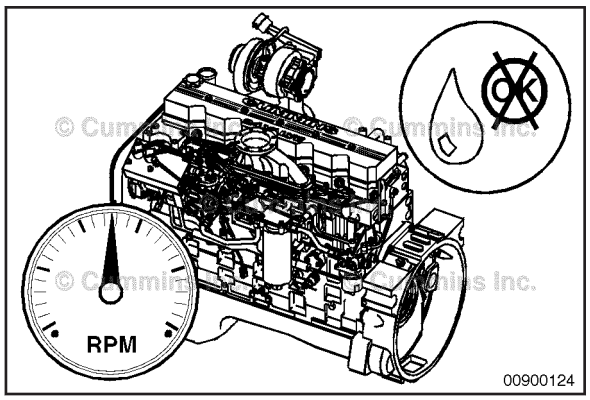




⚠CAUTION⚠

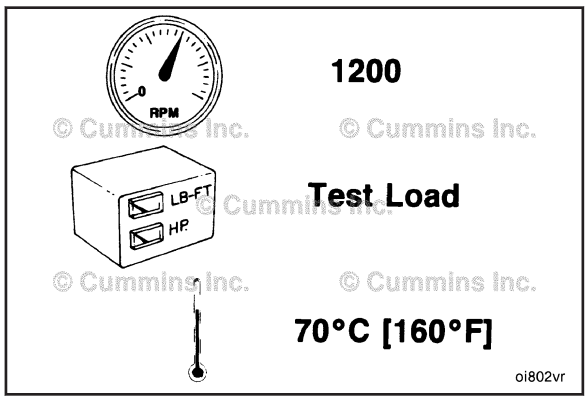
Do not operate the engine at idle speed longer than specified during engine run-in. Excessive carbon formation will cause damage to the engine.

Operate the engine at approximately 700 rpm for 3 to 5 minutes.



Listen for unusual noises and watch for coolant, fuel, lubricating oil leaks. Check for correct engine operation in general.

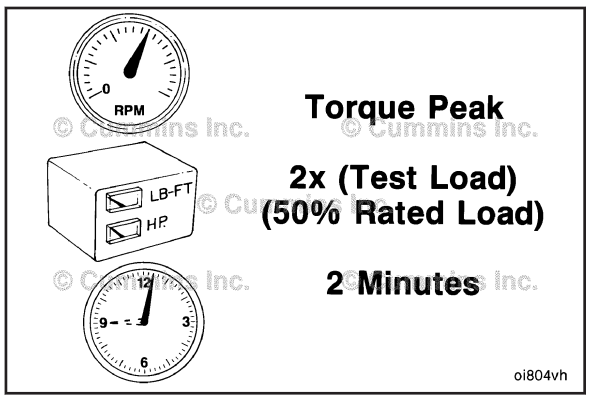
NOTE: Repair all leaks or component problems before continuing the engine run-in.



Move the throttle to obtain 1200-rpm engine speed, and set the test load to 25 percent of the rated load.

Operate the engine at this speed and load level until the coolant temperature is 70°C [160°F]. Check all gauges and record the data.

NOTE: Do **not** proceed to the next step until a steady blowby reading is obtained.



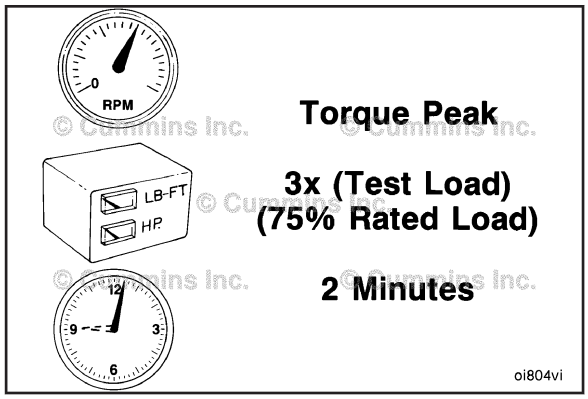
Open the throttle to the speed that peak torque occurs, and adjust the dynamometer load to 50 percent of torque peak load. Operate the engine at this speed and load level for 2 minutes.

Check all gauges and record the data.

NOTE: Do **not** proceed to the next step until blowby is stable within specifications.

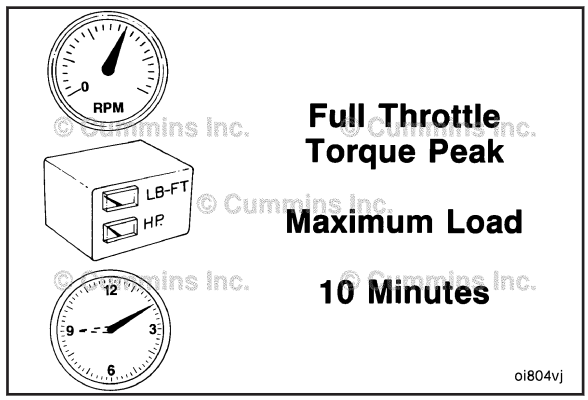
With the engine speed remaining at torque peak rpm, increase the dynamometer load to 75 percent of torque peak load. Operate the engine at this speed and load level for 2 minutes. Check all gauges and record the data.

NOTE: Do **not** proceed to the next step until blowby is stable within specifications.



Move the throttle lever to its fully opened position, and increase the dynamometer load until the engine speed is at torque peak rpm. Operate the engine at this speed and load level for 10 minutes or until the blowby becomes stable within specifications.

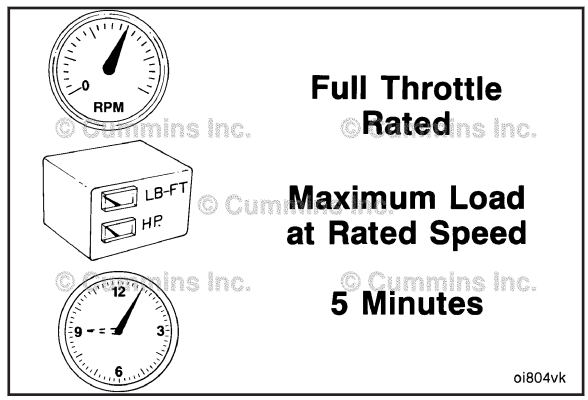
Check all gauges and record the data.



Reduce the dynamometer load until the engine speed increases to the engine's rated rpm.

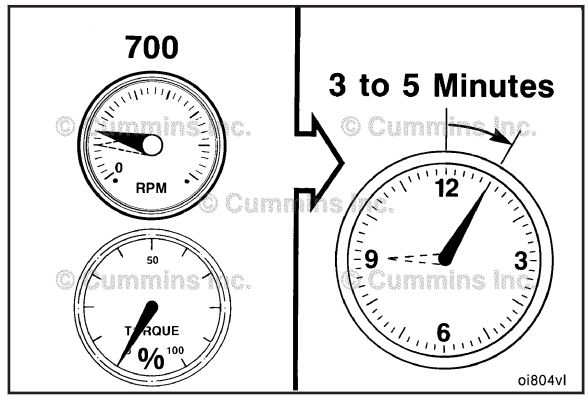
Operate the engine at rated rpm for 5 minutes.

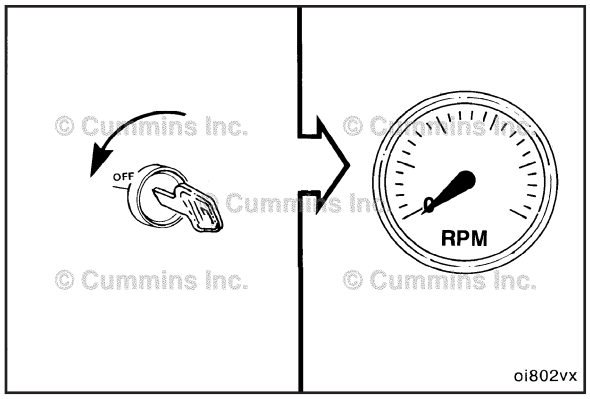
Check all gauges and record the data.



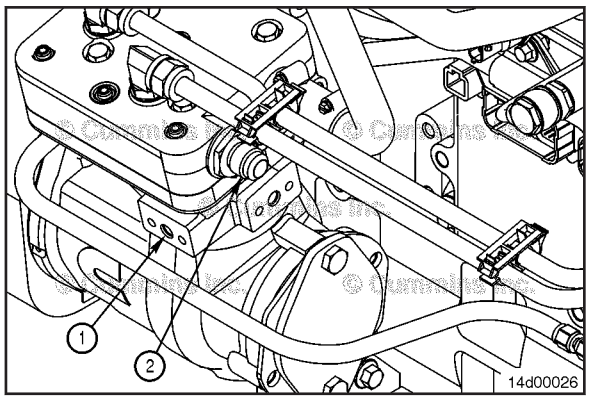
⚠CAUTION⚠
Shutting off the engine immediately after operating at full load will damage the turbocharger and internal components. Always allow the engine to cool before shutting it off.

Remove the dynamometer load completely, and operate the engine at 700 rpm for 3 to 5 minutes. This period will allow the turbocharger and other components to cool.





Shut off the engine.

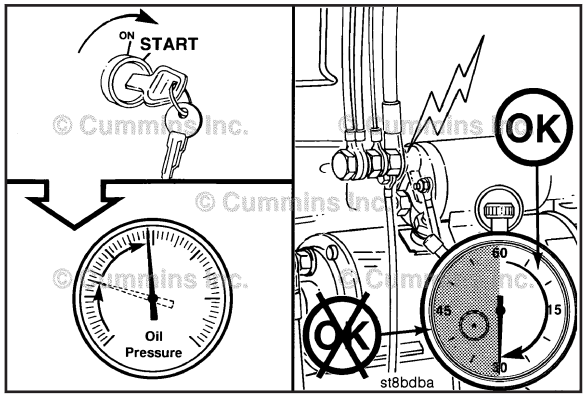


Engine Dynamometer Test - Performance Checking

Make sure the air compressor is unloaded during the performance check.

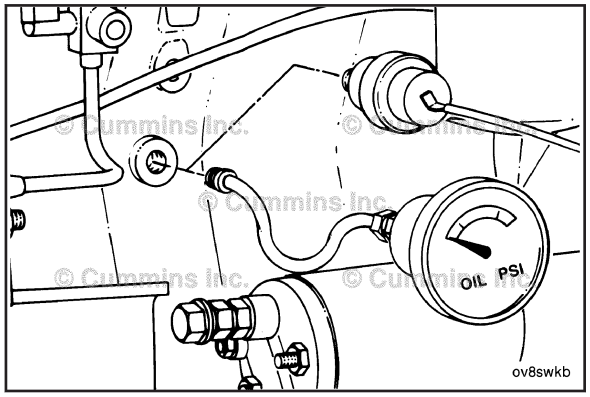
Apply regulated air pressure of 655 kPa [95 psi] to the air compressor unloader (1).

NOTE: If the engine is equipped with a variable geometry turbocharger, the turbocharger control valve will require a continuous air supply of at least 621 kPa [90 psi].



⚠CAUTION⚠
Do not crank the engine for more than 30 seconds. Excessive heat will damage the starter motor.

Crank the engine and observe the oil pressure when the engine starts. If the engine fails to start within 30 seconds, allow the starter motor to cool for 2 minutes before cranking the engine again.



⚠CAUTION⚠
If the lubricating oil pressure is not within specifications, shut off the engine immediately. Low lubricating oil pressure will cause engine damage. Correct the problem if lubricating oil pressure is not within specifications.

Engine lubricating oil pressure **must** be at least 69 kPa [10 psi] at approximately 700 rpm.

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Make sure the engine is at operating temperature.

Move the throttle to the fully depressed position. Adjust the dynamometer load until the engine maintains the rated rpm.

Allow the readings to stabilize. Read the horsepower.

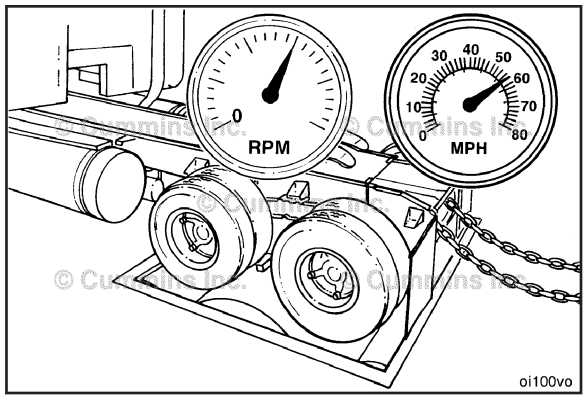
Check all the gauges and record the readings.

NOTE: The horsepower reading will **not** be accurate if the lubricating oil temperature and fuel temperature are **not** within specifications.

Lubricating Oil Temperature		
°C		**°F**
90	MAX	194

Fuel Temperature		
°C		**°F**
65	MAX	149

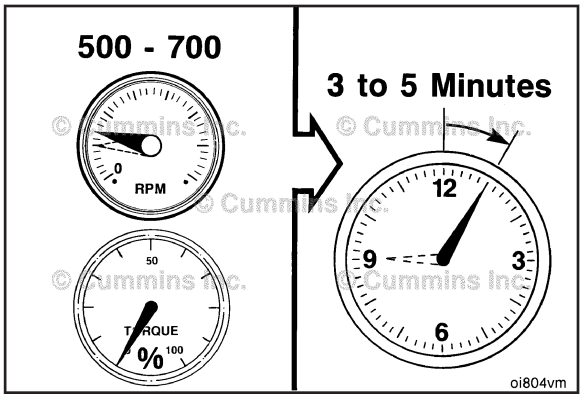
Check all gauges and record the data.



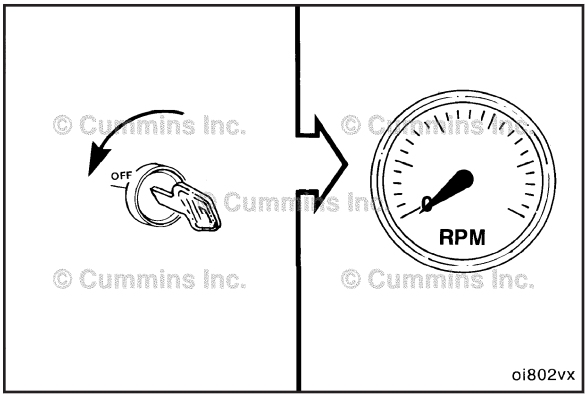
⚠CAUTION⚠
Do not shut off the engine immediately after it has been loaded. It must be allowed to sufficiently cool.

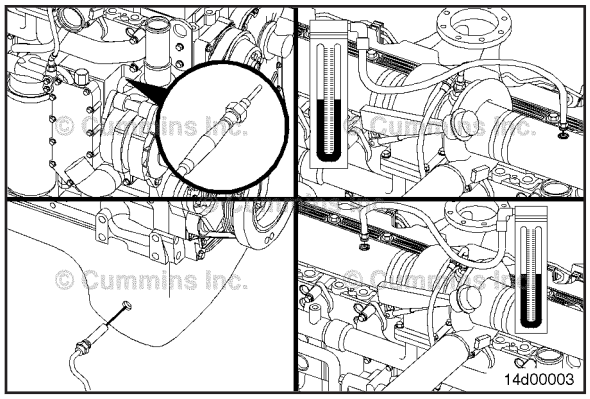
Remove the dynamometer load completely, and operate the engine at idle speed for 3 to 5 minutes. This will allow the turbocharger and other components to cool.

NOTE: Idle periods longer than 5 minutes are to be avoided.



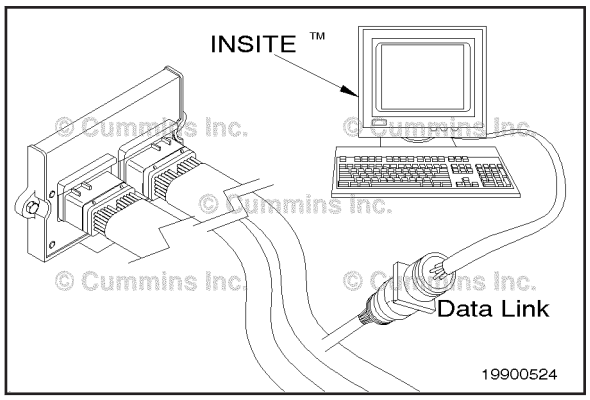
Shut off the engine after the cool down period.





Remove all test instrumentation. Remove the engine from the dynamometer.

NOTE: If the engine is to be stored temporarily and does **not** have permanent-type antifreeze, it is necessary to drain all coolant. Drain locations are identified on the engine side views. Refer to Procedure 008-018 in Section 8.



Engine Testing (In Chassis) (014-008)

Setup

The Setup for Dynamometer function is used to prepare the attached electronic control module (ECM) for advanced diagnostic tests run on the dynamometer. For purposes of this test, the Maximum Engine Speed without a vehicle speed sensor (VSS), the Maximum Vehicle Speed in Top Gear, and the Maximum Vehicle Speed in Lower Gear are set to their maximum values. The idle shutdown feature is disabled. All of these values are automatically reset to their previous values when the engine keyswitch is turned off.

Settings

Maximum Engine Speed without VSS: For testing purposes, this speed is temporarily set to the maximum value allowed (3000 rpm).

Maximum Vehicle Speed in Top Gear: For testing purposes, this speed is temporarily set to the maximum value allowed (120 mph).

Maximum Vehicle Speed in Lower Gear: For testing purposes, this speed is temporarily set to the maximum value allowed (120).

Idle Shutdown: This feature is temporarily disabled for testing purposes (Disable).

Some J1939 electronic subsystems **must** be disabled. The user has the ability to enable or disable the J1939 datalink with the service tool.

Refer to the INSITE™ user's manual for detailed setup for Dynamometer Instructions.

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Automated Cylinder Performance Test

The automated cylinder performance test is the most thorough test of cylinder performance (versus the single-cylinder cutout test, which tests the performance of individual cylinders **only**). The service tool **must** be attached to an electronic control module (ECM) to perform this test. Follow the steps outlined in Preparing to Run the Automated Cylinder Performance Test, to make sure the best possible outcome is achieved.

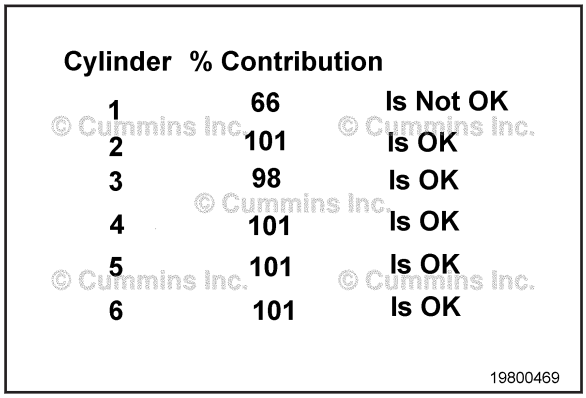
This test is automated in the sense that, once the test is started, the service tool controls what cylinders are disabled or enabled, what ECM values are recorded, and what information displays as a result of the test. Once the test is finished, follow the steps outlined in After Running the Automated Cylinder Performance Test to make sure the engine returns to its original state.

This test will produce a Pass or Fail message for each cylinder. Its percent contribution value is also displayed.

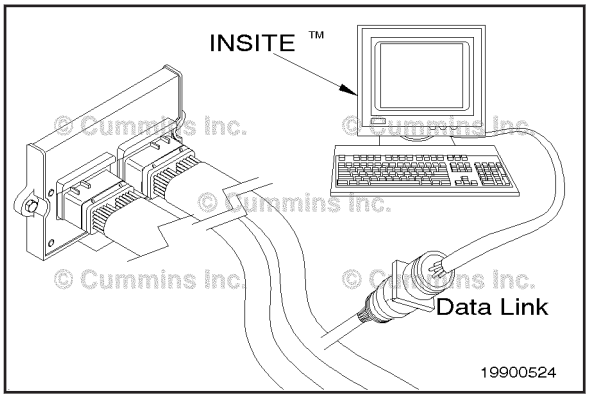
Preparing to Run the Automated Cylinder Performance Test

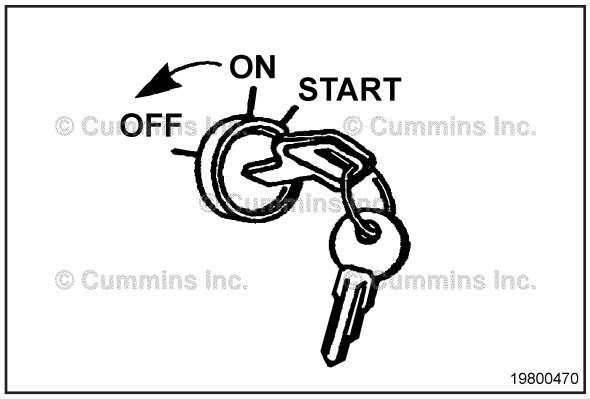
Before performing this test, make sure you:

1. Clear the areas around the engine and the fan, and make sure the exhaust is vented correctly.
2. Operate the engine until the coolant temperature is a minimum of 76.7°C [170°F].
3. Shut off the engine.
4. Lock the fan clutch in the ON position for continuous operation.
5. Shut off the air conditioning.
6. Disengage any devices that can cause the load on the engine to vary.
7. With the vehicle stationary, start the engine and let it idle.
8. Start the test using INSITE™.



Refer to the INSITE™ user's manual for detailed automated cylinder performance test instructions.



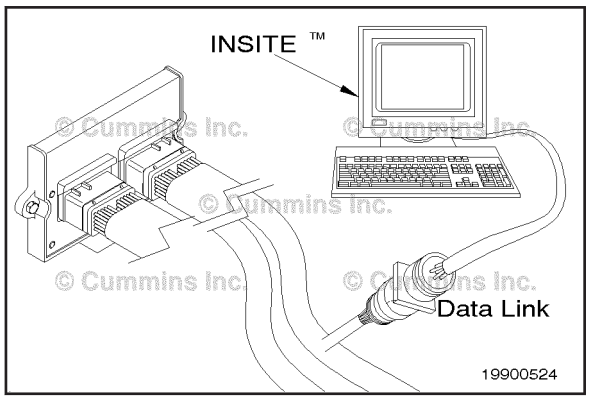


After Running the Automated Cylinder Performance Test

It is normal for the engine rpm to vary during the test, but if the engine rpm goes to high idle for more than 5 seconds at a time, shut off the engine.

Once the test is complete, make sure to:

1. Shut off engine.
2. Return the fan to normal operation, if necessary.
3. Perform the suggested repairs that resulted from the test.
4. Return any disengaged devices to their normal mode of operation.



Cylinder Cutout Test

Use the single-cylinder cutout test to remove individual cylinders from the engine firing cycle and to monitor a running engine while the selected cylinder is disabled. The system displays the percent load and rpm values while the cylinder is disabled.

The service tool **must** be attached to a running engine in a nonmoving vehicle to perform this test.

Refer to the INSITE™ user's manual for detailed cylinder cutout test instructions.

Cylinder to be Cut Out

None: Select this option to run all cylinders.

1 through 6: Select one of these options to shut off cylinder Nos. 1 through 6, respectively. **Only** one cylinder can be shut off at a time.

Monitor

Percent Load: The percent of load that the engine is carrying.

rpm: The engine's revolutions per minute.

Turbocharger Actuator Test

Use the turbocharger actuator test to verify the correct functioning of the variable geometry turbocharger actuator. During the test, air pressure is applied to the actuator and rod travel is measured.

The service tool **must** be attached to an ECM to perform this test.

Refer to INSITE™ user's manual for detailed turbocharger actuator test instructions.

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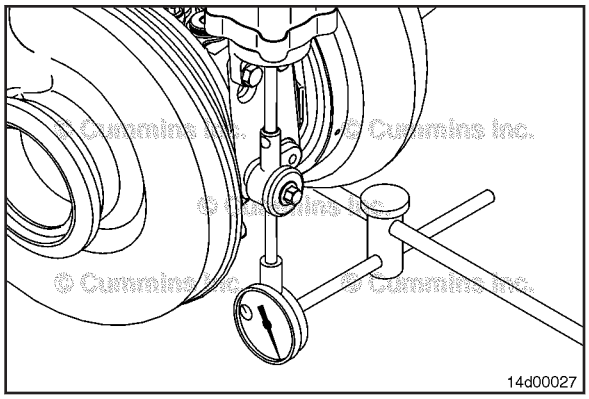
Use INSITE™ to extend and retract the turbocharger actuator rod several times.

Measure the distance the actuator rod travels when extended.

Turbocharger Actuator Rod Travel		
mm		in
10.8	MIN	0.40
11.8	MAX	0.46



Crankcase Blowby, Measure (014-010)

General Information

Excessive crankcase blowby can indicate an engine or engine-related component malfunction that allows combustion gases or air to enter the crankcase. This results in the buildup of higher than normal crankcase pressure, which results in increased levels of blowby.

This procedure describes how to measure crankcase blowby and how to determine what component is malfunctioning.

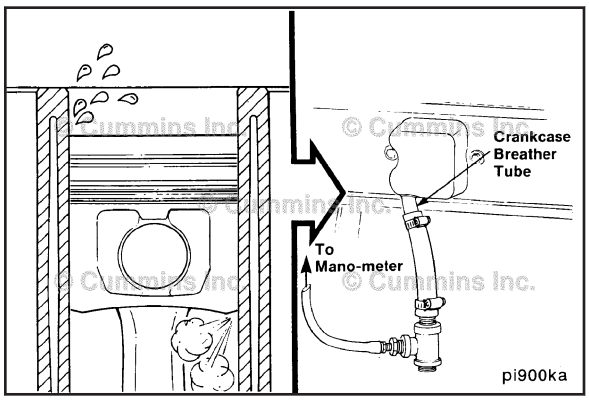
Blowby is typically measured for the following situations:

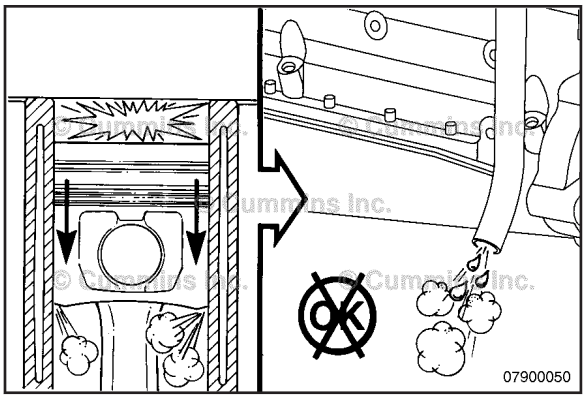
- Verifying engine break-in after an engine rebuild
- Troubleshooting for excessive lubricating oil out of the crankcase breather tube, commonly referred to as oil carryover (for open crankcase ventilation systems)
- Troubleshooting oil in the air intake system (for closed crankcase ventilation systems)
- Troubleshooting high crankcase pressure (for engines equipped with a crankcase pressure sensor)
- Troubleshooting possible internal engine damage (worn piston rings, valve stem seals, or guides, turbocharger, air compressor, etc.).

NOTE: For specific crankcase gases (blowby) symptom information and direction, reference the Crankcase Gases (Blowby) Excessive troubleshooting symptom tree in Section TS of the appropriate engine service manual.

The following measure step will give general guidelines for measuring blowby relative to the above situations.

NOTE: Some illustrations in this procedure do **not** show actual engine configurations. However, the procedure is the same.





It is important to note that the terms blowby and carryover (oil out of the breather tube) are commonly used interchangeably.

When measuring blowby, and there is an excessive amount of oil coming out of the breather tube, the quantity of oil can affect the blowby measurement.

The blowby measurement is affected by the oil collecting on the orifice of the blowby measurement service tool. This reduces the size of the orifice, which results in higher than actual blowby measurements.

If this occurs, it will be necessary to:

- Find a different location on the engine to measure blowby (oil fill, oil fill cap, unused turbocharger drain location, etc.)
- Clean any oil residue from the breather and dry thoroughly before measuring blowby
- Determine if there is an issue causing the breather to be flooded with oil, for example:
- Incorrect oil level
- Vehicle operation (excessive angularity, excessive engine side-to-side movement)
- Internal engine components deflecting oil toward the breather cavity (piston cooling nozzles, accessory oil drains, etc.)
- Determine if another breather option is available for the engine being serviced.

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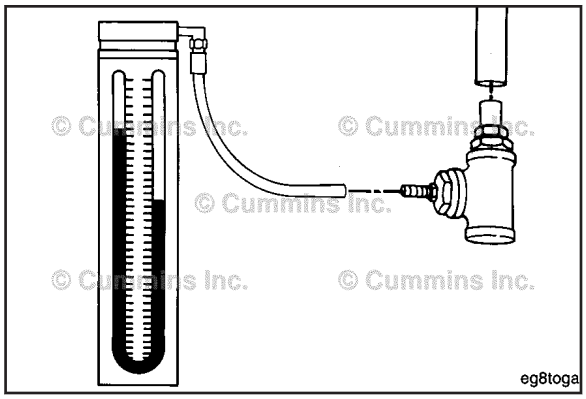

The tools used to measure blowby are similar in design. The difference between the tools is in the size of the orifice. Different size orifices are available to more accurately measure blowby by accommodating the wide variety of engine configurations and ratings. This is due to the fact that engine blowby is dependent on the volume of intake airflow.

For example:

If measuring blowby on two identically configured and sized engines, but the horsepower ratings and rated speed are different, the maximum blowby values measured will be different.

The engine with the higher horsepower rating and rated speed will have a higher volume of intake airflow, which will result in higher blowby. This means that if the smaller orifice blowby tool was used on the engine with a higher horsepower rating and rated speed, the measurement can exceed the limits of the pressure measuring tool.

Blowby Tool Part Number	Orifice Size mm [in]
3822476	5.61 mm [0.221 in]
3822566	7.67 mm [0.302 in]

To measure the crankcase blowby pressure, connect a Cummins® water manometer, Part Number ST1111-3, or equivalent, pressure gauge, or transducer to the blowby tool.

NOTE: Cummins® water manometer, Part Number ST1111-3, can measure a maximum of 944 mm [36 in] of water.

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The following charts show the relationship of measured pressure to flow rate, depending on the blowby tool used.

Blowby Conversion Table (5.61-mm [0.221-in] orifice, Blowby Tool, Part Number 3822476)	
mm [in] of H_2O	**Liter [cfm] per Minute**
25.4 [1]	27 [0.953]
50.8 [2]	40 [1.413]
76.2 [3]	48 [1.695]
101.6 [4]	58 [2.048]
127 [5]	64 [2.260]
152.4 [6]	71 [2.507]
177.8 [7]	76 [2.684]
203.2 [8]	81 [2.860]
228.6 [9]	86 [3.037]
254 [10]	90 [3.178]
279.4 [11]	94 [3.320]
304.8 [12]	98 [3.461]
330.2 [13]	102 [3.602]
355.6 [14]	105 [3.708]
381 [15]	109 [3.849]
406.4 [16]	112 [3.955]
431.8 [17]	115 [4.061]
457.2 [18]	118 [4.167]
482.6 [19]	121 [4.723]
508 [20]	124 [4.379]
533.4 [21]	128 [4.520]
558.2 [22]	131 [4.626]
584.2 [23]	135 [4.767]
609.6 [24]	137 [4.838]
635 [25]	140 [4.944]
660.4 [26]	144 [5.085]
685.8 [27]	147 [5.191]
711.2 [28]	150 [5.297]
736.6 [29]	154 [5.438]
762 [30]	157 [5.544]
787.4 [31]	160 [5.650]
812.8 [32]	163 [5.756]
838.2 [33]	166 [5.862]
863.6 [34]	169 [5.968]
889 [35]	172 [6.074]

Blowby Conversion Table (7.67-mm [0.302-in] orifice, Blowby Tool, Part Number 3822566)	
mm [in] of H_2O	**Liter [cfm] per Minute**
25.4 [1]	50 [1.766]
50.8 [2]	84 [2.966]
76.2 [3]	103 [3.637]
101.6 [4]	119 [4.202]
127 [5]	133 [4.697]
152.4 [6]	145 [5.121]
177.8 [7]	155 [5.474]
203.2 [8]	164 [5.792]

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Blowby Conversion Table (7.67-mm [0.302-in] orifice, Blowby Tool, Part Number 3822566)	
mm [in] of H_2O	Liter [cfm] per Minute
228.6 [9]	172 [6.074]
254 [10]	180 [6.357]
279.4 [11]	187 [6.604]
304.8 [12]	193 [6.816]
330.2 [13]	200 [7.063]
355.6 [14]	206 [7.275]
381 [15]	211 [7.451]
406.4 [16]	217 [7.663]
431.8 [17]	222 [7.840]
457.2 [18]	226 [7.981]
482.6 [19]	229 [8.087]
508 [20]	235 [8.299]
533.4 [21]	239 [8.440]
558.8 [22]	242 [8.546]
584.2 [23]	246 [8.687]
609.6 [24]	248 [8.758]

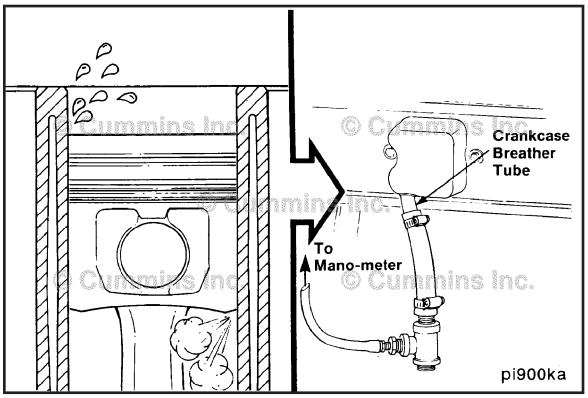
The following chart contains general blowby specifications for MidRange engines. Due to the wide variety of engine types, configurations, and ratings, these specifications are intended to **only** be used as a guide to help identify if a problem exists. These specifications are **not** intended to be used as engine condemnation limits.

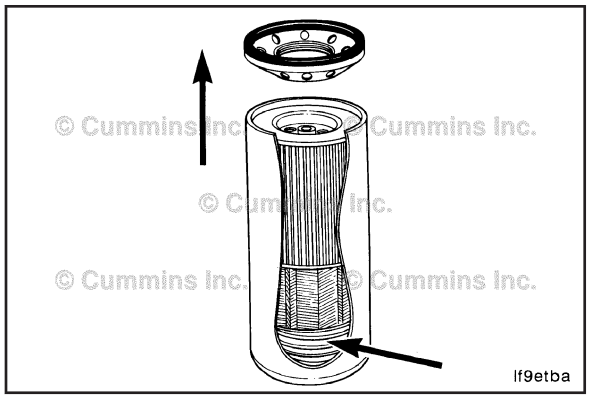
NOTE: If internal engine damage is suspected to be the cause of the excessive blowby condition, other steps can be taken to confirm this.

Measuring blowby **must only** be considered when confirming engine break-in after a rebuild or if another symptom is present. These symptoms can include:

- Excessive carryover (oil out of the crankcase breather tube)
- High crankcase pressure (for engines equipped with a crankcase pressure sensor)
- Low power
- Oil consumption
- Exhaust smoke.

If no other symptom is present, blowby measurements need **not** be taken.





If internal engine damage is suspected to be the cause of the excessive blowby condition, other steps can be taken to confirm this. The steps include:

- Confirm engine maintenance practices
- Cut the oil filter open and check for debris
- Take an oil sample and inspect for contamination.

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MidRange Blowby Specifications Chart				
	Blowby Specification For New or Rebuild - mm [in] H_2O		Blowby Specification For Troubleshooting - mm [in] H_2O	
Engine Model	Blowby Tool 3822476-5.61 mm [0.221 in] Orifice	Blowby Tool 3822566-7.67 mm [0.302 in] Orifice	Blowby Tool 3822476-5.61 mm [0.221 in] Orifice	Blowby Tool 3822566-7.67 mm [0.302 in] Orifice
A1400 and A1700 (Naturally Aspirated)	25.4 [1]		25.4 [1]	
A2000 and A2300 (Naturally Aspirated)	25.4 [1]		38.1 [1.5]	
A2000 and A2300 (Turbocharged)	38.1 [1.5]		50.8 [2]	
ISF2.8	147.3 [5.8]		711.2 [28]	
ISF3.8		71.1 [2.8]		254 [10]
B3.3 Tier 1, 2		50.8 [2]		101.6 [4]
B3.3, QSB3.3 Tier 3		101.6 [4]		152.04 [6]
B3.3, QSB3.3 Tier 4 Interim (Less than 74 HP)		50.8 [2]		101.6 [4]
B3.9, QSB3.9-30, B4.5, QSB4.5-30, and B4.5^{s} (Naturally Aspirated) (Less than 250 hp)	25.4 [1]		76.2 [3]	
B3.9, QSB3.9-30, B4.5, QSB4.5-30, and B4.5^{s} (Turbocharged) (Less than 250 hp)	101.6 [4]		431.8 [17]	
B3.9, QSB3.9-30, B4.5, QSB4.5-30, and B4.5^{s} (Turbocharged) (Greater than 250 hp)		25.4 [1]		127 [5]
B5.9 (Naturally Aspirated)	50.8 [2]			
B5.9, and QSB5.9-30, (Less than 250 hp)	228 .6 [9]		863.6 [34]	
B5.9, and QSB5.9-30, (Greater than 250 hp)		50.8 [2]		228.6 [9]
ISB, ISB^{e}, QSB^{e}, ISD^{e}, QSB5.9-44, ISB6.7, and QSB6.7		101.6 [4]		254 [10]
C8.3		203 [8]		457 [18]
ISC, ISC^{e}, QSC8.3, ISL, ISL^{e}, and QSL9		203.2 [8]		304.8 [12]
B Gas International, B Gas Plus, B LPG Plus, B5.9G, B5.9 LPG	228.6 [9]		889 [35]	
C8.3G, C Gas Plus, ISL G, L Gas Plus		203 [8]		457 [18]
ISB4.5 CM2350 B104	152.4		330.2	

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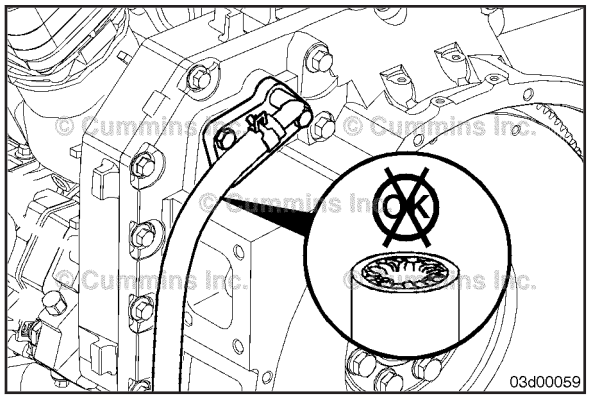

Initial Check

NOTE: The location and type of crankcase breathers vary by engine configuration (Front Gear Train or Rear Gear Train) and/or engine application (Marine, Industrial, and Automotive).

Prior to measuring blowby pressure, check the crankcase breather tube for obstructions.

- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the B3.3 and QSB3.3 CM2150 Service Manual, Bulletin 4021540. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 003-018 in Section 3.
- Reference the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704.
- Use the following procedure for Open Crankcase Ventilation systems. Refer to Procedure 003-018 in Section 3.
- Use the following procedure for Closed Crankcase Ventilation systems. Refer to Procedure 003-024 in Section 3.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the B4.5s and B6.7s Series Engines Troubleshooting and Repair Manual, Bulletin 4095243. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220E, ISF2.8 CM2220 AN and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178. Refer to Procedure 003-024 in Section 3. Refer to Procedure 003-026 in Section 3.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 003-024 in Section 3.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 003-024 in Section 3.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISF3.8 CM2220 L110 Service Manual, Bulletin 4358480. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the ISL9 CM2350 L101 Service Manual, Bulletin 4310787. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the QSL9 M CM2250 L106 Service Manual, Bulletin 4358343. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the QSB6.7 CM2350 B112 Service Manual, Bulletin 4358498. Refer to Procedure 003-018 in Section 3.

If troubleshooting a complaint of excessive oil out of the breather tube, it can be necessary to remove the breather components to clean and remove any lubricating oil buildup before performing any blowby measurements.

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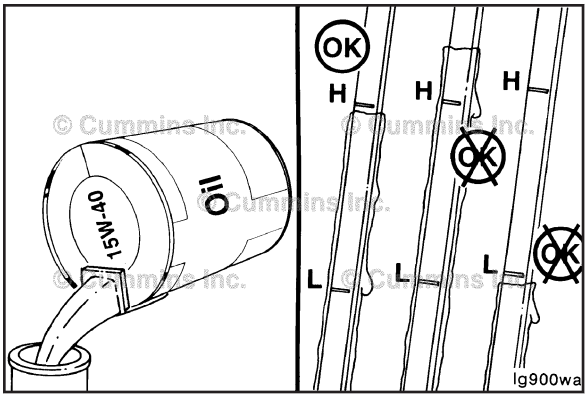
Check the engine oil level and, if necessary, proper calibration of the dipstick. If the level is too high, it can cause a higher than normal blowby pressure and/or excessive carryover.



- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the B3.3 and QSB3.3 CM2150 Service Manual, Bulletin 4021540. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISFF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220E, ISF2.8 CM2220 AN, and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 007-043 in Section 7.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 007-043 in Section 7.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISF3.8 CM2220 F110 Service Manual, Bulletin 4358480. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the ISL9 CM2350 L101 Service Manual, Bulletin 4310787. Refer to Procedure 007-037 in Section 7.
- Use the following procedure in the QSL9 M CM2250 L106 Service Manual, Bulletin 4358343. Refer to Procedure 007-037 in Section 7.
- Use the following procedure in the QSB6.7 CM2350 B112 Service Manual, Bulletin 4358498. Refer to Procedure 007-011 in Section 7.
- Use the following procedure in the QSB6.7 CM2350 B112 Service Manual, Bulletin 4358498. Refer to Procedure 007-037 in Section 7.

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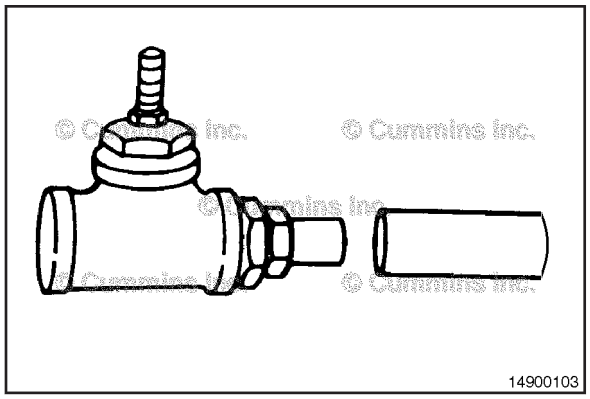
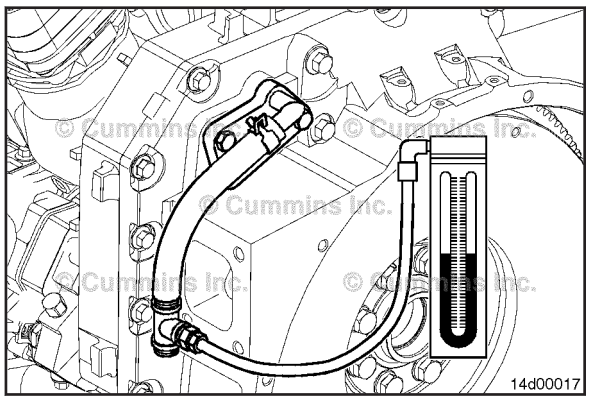


Measure

Choose the appropriate blowby measurement service tool to use for the engine being serviced. Reference the MidRange Blowby Specifications Chart in this procedure and determine the appropriate blowby measurement service tool to use, based on engine type and/or horsepower.

Blowby Tool Part Number	Orifice Size mm [in]
3822476	5.61 mm [0.221 in]
3822566	7.67 mm [0.302 in]

NOTE: Either service tool can be used to measure blowby, as long as the blowby measurement is correctly matched to the correct flow rate. Reference the flow rate conversion tables in this procedure for the correct orifice.



To measure the crankcase blowby pressure, connect a water manometer, Part Number ST1111-3, pressure gauge, or transducer to the blowby measurement service tool.

NOTE: The location of the crankcase breather tube can vary by engine configuration (front gear train or rear gear train) and/or application (Marine, Industrial, and Automotive). See Section E for crankcase breather tube locations.

Install the appropriate blowby service tool(s):

- For typical open crankcase breather/ventilation systems, connect the appropriate blowby service tool to the end of the crankcase breather tube. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.
- For engines with closed crankcase ventilation systems (without a crankcase ventilation filter), disconnect the breather tube and plug the intake manifold or turbocharger compressor housing port. Connect the appropriate blowby service tool to the end of the crankcase breather tube. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.
- For crankcase breather/ventilation systems with crankcase ventilation filters, follow the proceeding steps on connecting the blowby measurement equipment.

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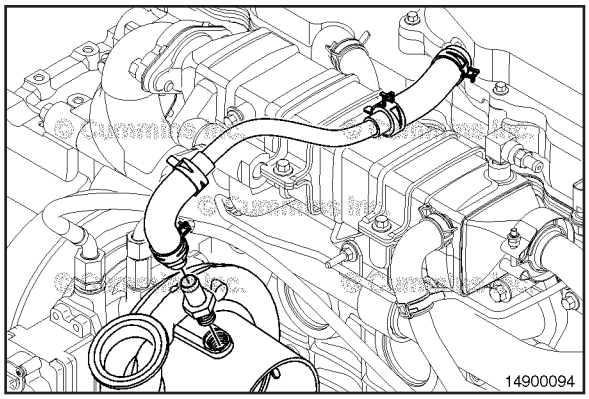
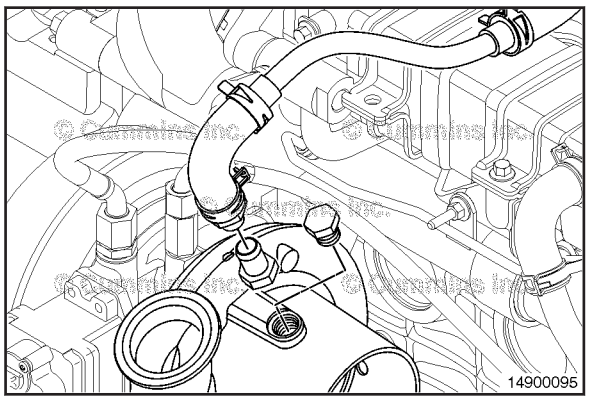
For ISB CM2150 engines that have the crankcase ventilation filter located on top of the rocker lever cover, use the following steps to connect the blowby measurement tools.

- Disconnect the crankcase ventilation line from the turbocharger/original equipment manufacturer (OEM) intake plumbing. If the crankcase ventilation line is connected to the turbocharger housing, remove the inlet fitting.

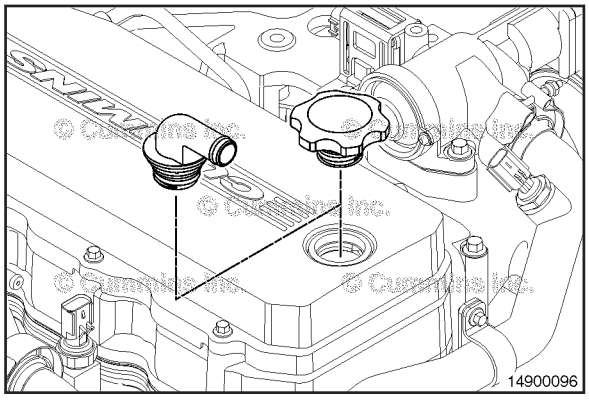


- If the crankcase ventilation line is connected to the turbocharger housing, install a straight thread plug, Part Number 3089567. Plug the crankcase ventilation line with a suitable fitting.

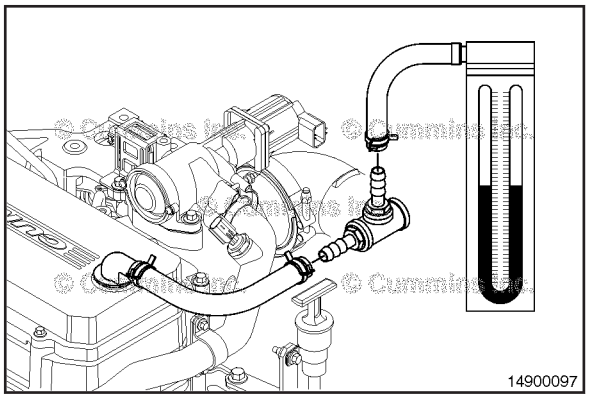
NOTE: If the crankcase ventilation line is connected to the OEM intake plumbing (**not** shown), use a suitable fitting to plug the port in the intake plumbing. Also plug the crankcase ventilation line coming from the engine with a suitable fitting.

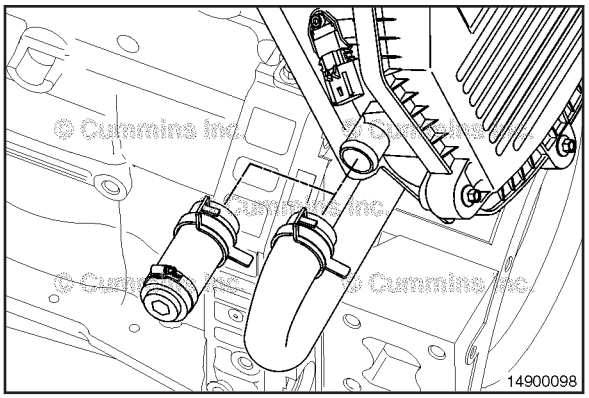


- Remove the oil fill cap from the rocker lever cover. Install an oil fill adapter, Part Number 3990099.



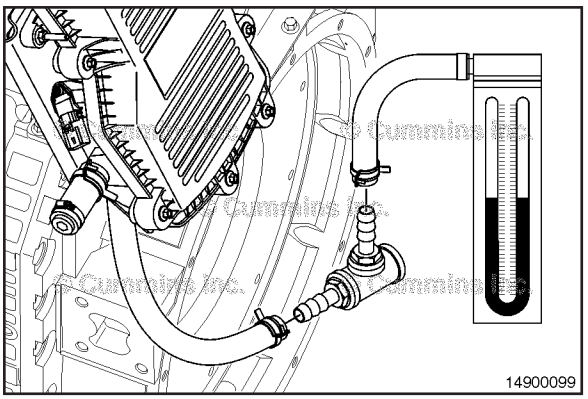
- Connect the appropriate blowby service tool to the outlet of the oil fill adapter. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.



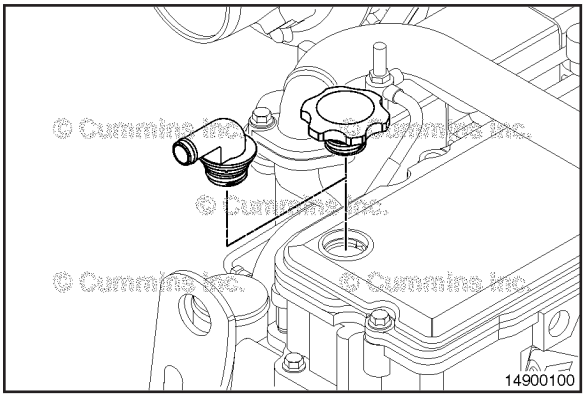


For ISB CM2150 engines that have the crankcase ventilation filter located at the rear of the engine, use the following steps to connect the blowby measurement tools.

- Disconnect the crankcase ventilation line from the crankcase ventilation filter housing. Plug or cap the crankcase ventilation filter housing.

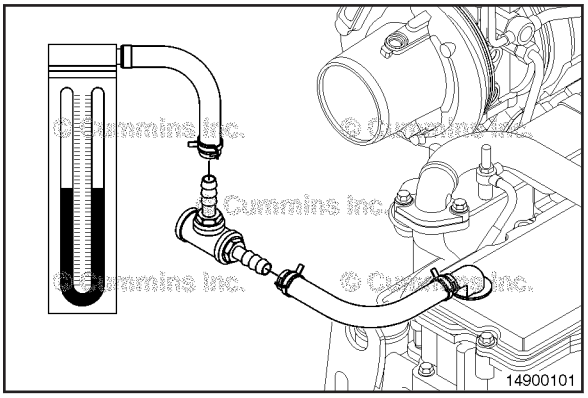


- Connect the appropriate blowby service tool to the crankcase ventilation line exiting the flywheel housing. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.



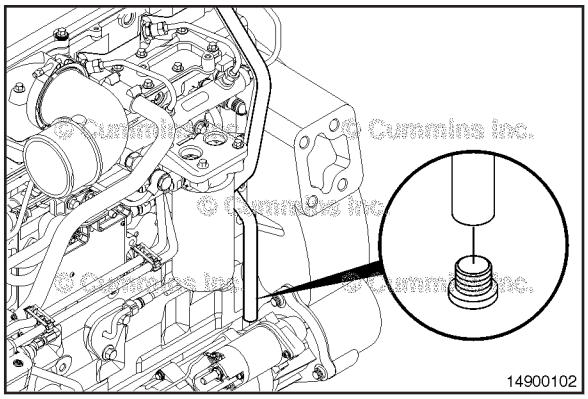
For ISC and ISL CM2150 and QSL CM2250 engines, use the following steps to connect the blowby measurement tools.

- Remove the oil fill cap from the rocker lever cover. Install an oil fill adapter, Part Number 3990099.



- Connect the appropriate blowby service tool to the outlet of the oil fill adapter. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.

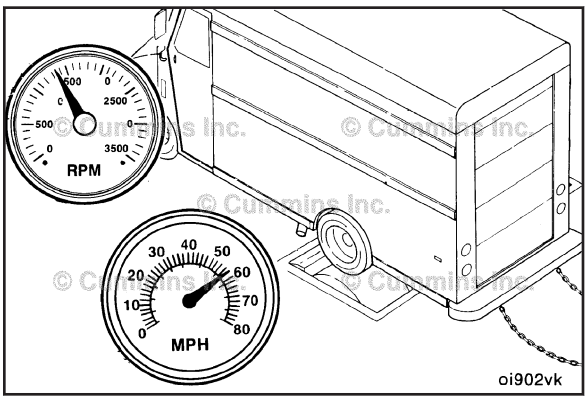
- Use a suitable fitting to plug the crankcase breather tube.



Engine Blowby Contribution:

Operate the engine at rated speed and under load by:

- For engine run-in, a chassis dynamometer or engine dynamometer.
- For engine testing, a chassis dynamometer or engine dynamometer.
- A stall speed test (for engines equipped with automatic transmissions **only**).



⚠CAUTION⚠
When measuring blowby and there is an excessive amount of oil coming out of the breather tube, the quantity of oil can affect the blowby measurement.

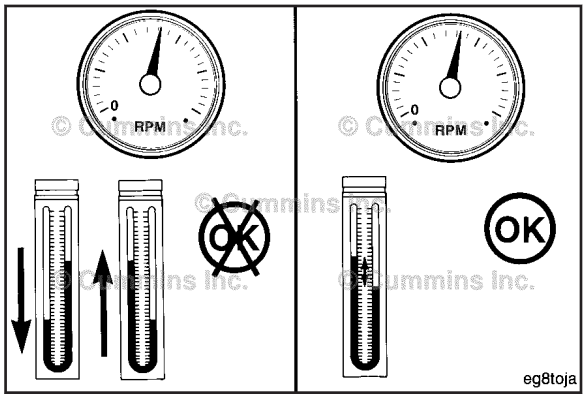
Operate the engine at rated rpm and full load until a steady reading is obtained.

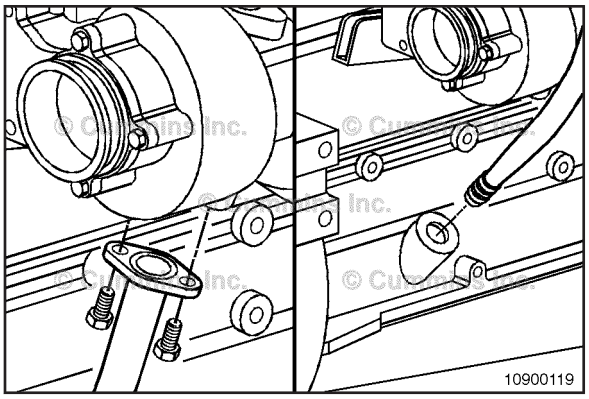
NOTE: When measuring blowby, the value can “spike” initially as the engine reaches peak power and rated speed. Wait for the blowby measurement to stabilize before taking a reading.

NOTE: For engine run-in, if a sudden increase in blowby occurs, or if blowby exceeds the maximum allowable limit during any run-in step, return to the previous step and continue the run-in. If blowby does **not** reach an acceptable level, discontinue the run-in and determine the cause.

Record the steady blowby measurement.

Remove the engine blowby service tool and the water manometer, pressure gauge, or transducer, if the blowby is within specification.





Turbocharger Blowby Contribution:

NOTE: For engines equipped with dual turbochargers, the Turbocharger Oil Drain Line Isolation Test may need to be conducted twice to determine which turbocharger is contributing high blowby. The first test should be conducted with both turbocharger drain lines isolated. If the blowby contribution is above specifications, conduct a second test with **only** the low pressure turbocharger oil drain line isolated. If the blowby contribution is within specification, inspect the compressor and turbine areas of the low pressure turbocharger for signs of an oil leak. Replace the low pressure turbocharger, if necessary. If the blowby contribution is out of specification, replace the high pressure turbocharger.

With the engine blowby service tool and water manometer or pressure gauge still installed:

- Isolate the turbocharger, if equipped, to determine if the high blowby pressure is due to turbocharger seal leakage.
- To measure the turbocharger blowby contribution, disconnect the turbocharger oil drain line.
- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the B3.3 and QSB3.3 CM2150 Service Manual, Bulletin 4021540. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the B4.5s and B6.7s Series Engines Troubleshooting and Repair Manual, Bulletin 4095243. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220E, ISF2.8 CM2220 AN and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISF3.8 CM2220 F110 Service Manual, Bulletin 4358480. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISL9 CM2350 L101 Service Manual, Bulletin 4310787. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the QSL9 M CM2250 L106 Service Manual, Bulletin 4358343. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the QSB6.7 CM2350 B112 Service Manual, Bulletin 4358498. Refer to Procedure 010-045 in Section 10.

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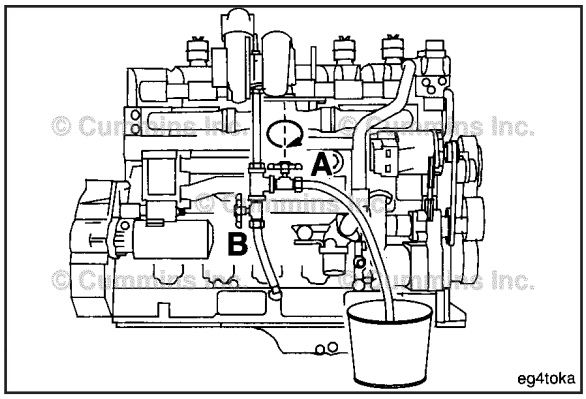
Preferred Turbocharger Isolation Method:

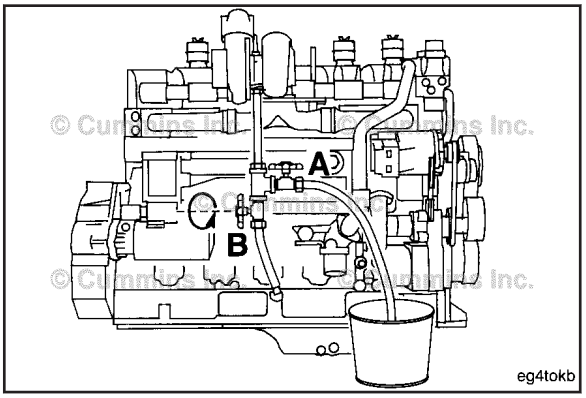
Install a hose assembly with two shutoff valves (A and B), as shown in the illustration, between the turbocharger and turbocharger drain line location in the cylinder block. The valves **must** have a minimum inside diameter of 19 mm [0.75 in]. Place the other hose in a 8 to 9 liter [2 to 3 gal] container.

NOTE: Some turbocharger oil drain tubes are a single one piece tube. It can be necessary to create a turbocharger isolation tool. Use a new or used turbocharger drain line and cut a middle section out of the turbocharger drain line to fit the check valves and hoses.

Close the valve (A) that allows oil to drain into the bucket.



Open the valve (B) that allows oil to drain into the engine.

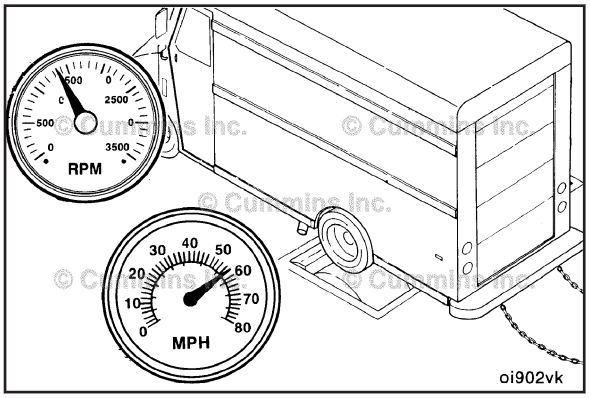


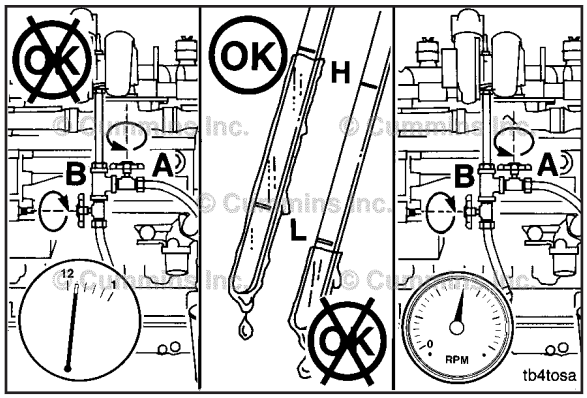
Operate the engine at rated speed and under load by either:

- For engine testing, a chassis dynamometer or engine dynamometer
- A stall speed test (for engines equipped with automatic transmissions **only**).

Operate the engine at rated rpm and full load until a steady reading is obtained.

NOTE: When measuring blowby, the value can “spike” initially as the engine reaches peak power and rated speed. Wait for the blowby measurement to stabilize before taking a reading.





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

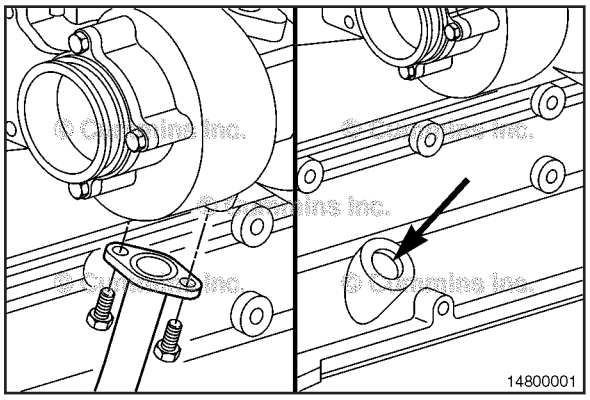
⚠WARNING⚠
Troubleshooting presents the risk of equipment damage, personal injury, or death. Troubleshooting must be performed by trained, experienced technicians.

△CAUTION△
Do not operate the engine with valve (A) open and valve (B) closed for more than 1 minute. Monitor the amount of oil accumulating in the bucket. The engine can run out of lubricating engine oil and severe engine damage will occur.

Continue operating at rated speed and load.

Open valve (A) and close valve (B).

Record the blowby pressure reading.



△CAUTION△
Do not operate the engine for more than 1 minute. Monitor the amount of oil accumulating in the container. The engine can be run out of lubricating engine oil and severe engine damage will result.

Alternate Turbocharger Isolation Method:

With the turbocharger oil drain line disconnected from the cylinder block, run the turbocharger drain line into a large container.

Plug the turbocharger oil drain port in the cylinder block.

Operate the engine at rated speed and under load by either:

- For engine testing, a chassis dynamometer or engine dynamometer
- A stall speed test (for engines equipped with automatic transmissions **only**).

Record the peak blowby pressure measurement.

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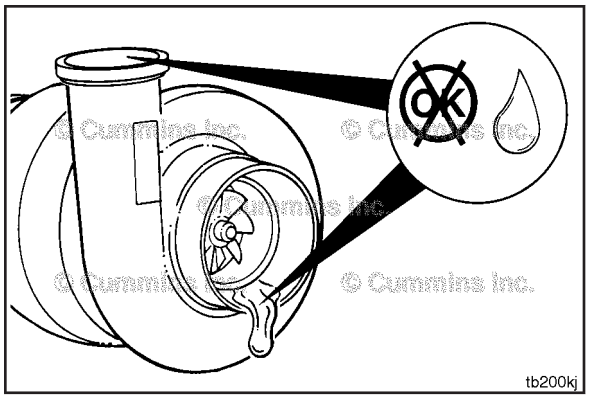
Determine the turbocharger blowby pressure contribution by determining the difference in the blowby pressure measurement with the turbocharger drain isolated, valve (A) open, and turbocharger drain **not** isolated, valve (A) closed.

Blowby Pressure Differential	
Turbocharger Blowby Contribution	Maximum: 30 percent

If the turbocharger blowby contribution is out of specification, inspect the compressor and turbine areas of the turbocharger for signs of an oil leak. Replace the turbocharger, if necessary.

- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the B3.3 and QSB3.3 CM2150 Service Manual, Bulletin 4021540. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 010-033 in Section 10 (single turbocharger). Refer to Procedure 010-034 in Section 10 (dual turbocharger). Refer to Procedure 010-035 in Section 10 (dual turbocharger).
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and (dual turbocharger applications) ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the B4.5s and B6.7s Series Engines Troubleshooting and Repair Manual, Bulletin 4095243. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220E, ISF2.8 CM2220 AN and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178 for single turbocharger applications. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISF3.8 CM2220 F110 Service Manual, Bulletin 4358480. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the ISL9 CM2350 L101 Service Manual, Bulletin 4310787. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the QSL9 M CM2250 L106 Service Manual, Bulletin 4358343. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the QSB6.7 CM2350 B112 Service Manual, Bulletin 4358498. Refer to Procedure 010-033 in Section 10.



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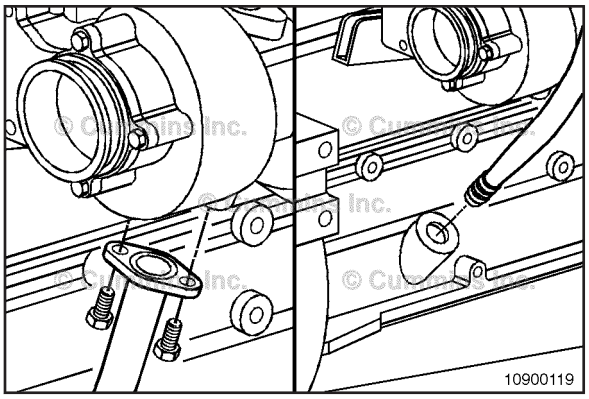

If installed, remove the turbocharger oil drain line assembly and shutoff valves.

- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the B3.3 and QSB3.3 CM2150 Service Manual, Bulletin 4021540. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the B4.5s and B6.7s Series Engines Troubleshooting and Repair Manual, Bulletin 4095243. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220 E, ISF2.8 CM2220 AN and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISF3.8 CM2220 F110 Service Manual, Bulletin 4358480. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the ISL9 CM2350 L101 Service Manual, Bulletin 4310787. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the QSL9 M CM2250 L106 Service Manual, Bulletin 4358343. Refer to Procedure 010-045 in Section 10.
- Use the following procedure in the QSB6.7 CM2350 B112 Service Manual, Bulletin 4358498. Refer to Procedure 010-045 in Section 10.

Check the engine oil level and add oil, if necessary.

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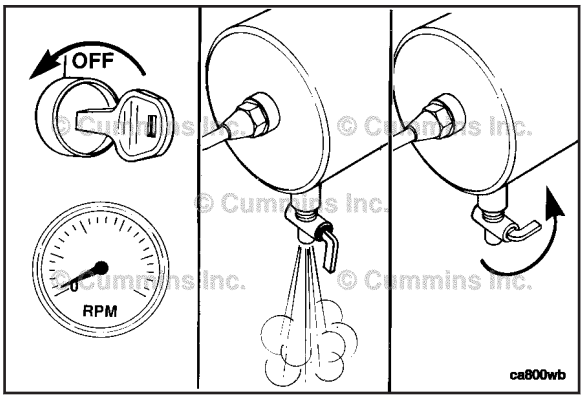
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

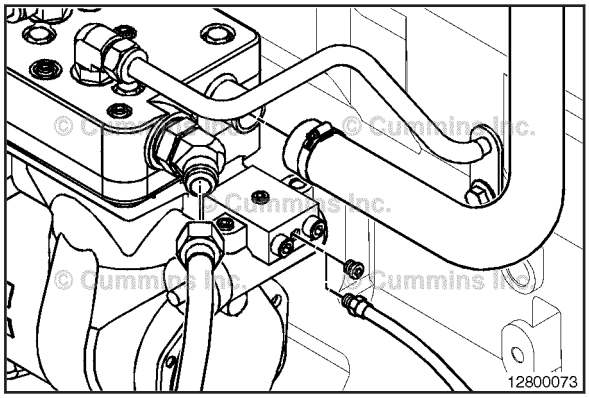


Air Compressor Blowby Contribution:

With the engine blowby service tool and the water manometer, pressure gauge, or transducer still installed, isolate the air compressor, if equipped, to determine if there is internal damage to the air compressor contributing to high engine crankcase pressure. The air compressor can be isolated by unloading the air compressor.

With the engine shut off, bleed the vehicle's air system down by opening the drain cock on the wet tank to release compressed air from the system.

NOTE: The air compressor governor/unloader location can vary on each engine application. The air governor/ unloader can be air compressor mounted or chassis mounted.

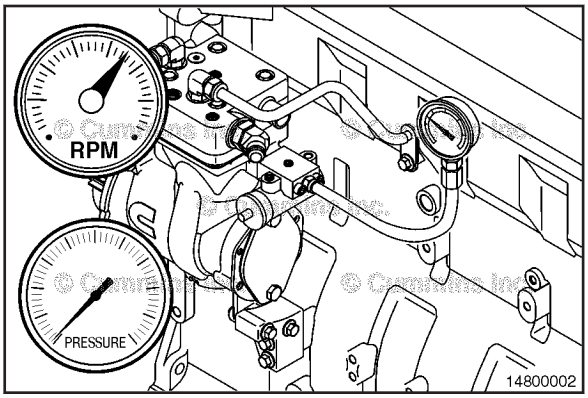


Disconnect the air signal line from the air compressor governor/unloader air signal port.

Disconnect the air compressor discharge line and air intake hose from the air compressor.

NOTE: On turbocharged air compressors, make sure to plug the air intake hose connected to the engine intake manifold or the engine will **not** reach full power during test.

To unload the air compressor, determine the pressure needed at the governor/unloader air signal port to start and stop the air compressor from pumping.



NOTE: Typical 621 kPa [90 psi] of air pressure is the set point between starting and stopping of the air compressor pumping. Refer to the OEM service manual.

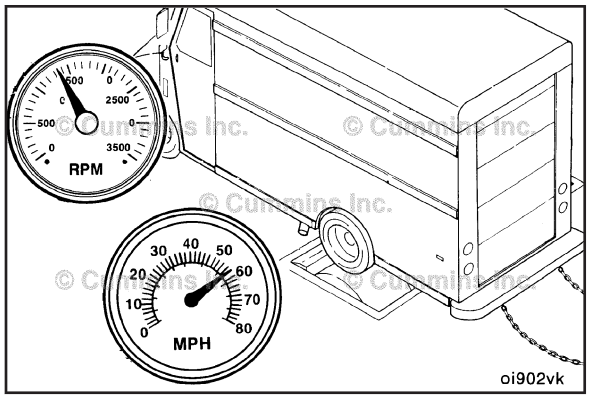
Connect a regulated shop air pressure line, with pressure gauge, to the air compressor governor/unloader air signal port.

NOTE: When performing the test, make sure that the air system pressure does **not** exceed the manufacturer's maximum allowable pressure.

Run the engine and increase the signal pressure to the air governor/unloader to determine when the air compressor will stop pumping (system pressure stops rising at this point). Record the signal line pressure.

Reduce the signal pressure to determine when system pressure starts the air compressor pumping again (system pressure will begin to rise again at this point). Record the signal line pressure.

NOTE: Allow the air compressor to pump long enough to build enough pressure in the system to release and operate the air brakes.



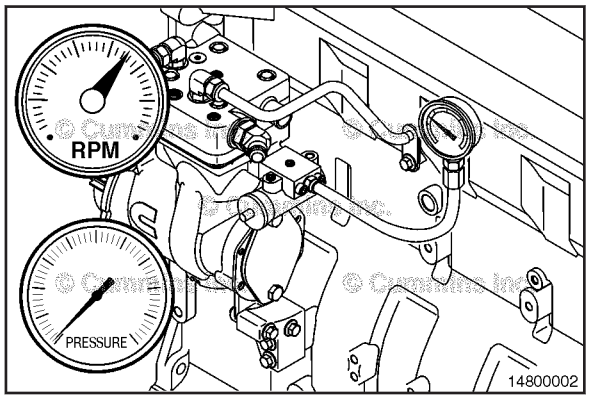
With the regulated shop air pressure line still connected to the air compressor governor/unloader air signal port, regulate the signal pressure so that the air compressor starts pumping (system pressure will begin to rise again at this point). Use the pressure value recorded previously as a set point.

Operate the engine at rated speed and under load by either:

- For engine testing, a chassis dynamometer or engine dynamometer.
- A stall speed test (for engines equipped with automatic transmissions **only**).

Operate the engine at rated rpm and full load until a steady reading is obtained.

NOTE: When measuring blowby, the value can “spike” initially as the engine reaches peak power and rated speed. Wait for the blowby measurement to stabilize before taking a reading.



Continue operating the engine at rated speed and load.

Increase the signal pressure (system pressure stops rising at this point). Use the pressure value recorded previously as a set point.

Operate the engine at rated rpm and full load until a steady reading is obtained.

NOTE: When measuring blowby, the value can “spike” initially as the engine reaches peak power and rated speed. Wait for the blowby measurement to stabilize before taking a reading.

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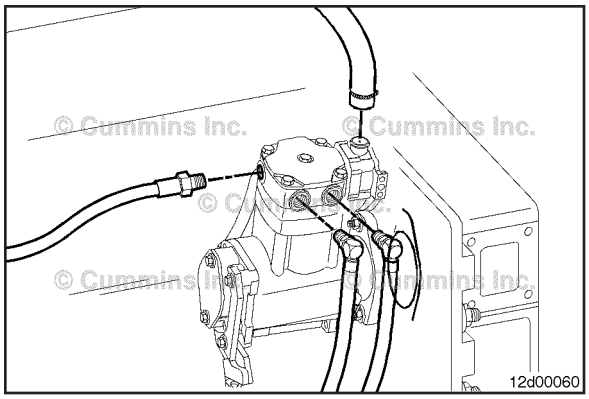
Determine the air compressor blowby pressure contribution by determining the difference in the blowby pressure measurement with the air compressor pumping and the air compressor **not** pumping.

Blowby Pressure Differential	
Air Compressor Contribution	Maximum: 30 percent

If the air compressor blowby contribution is out of specification, replace the air compressor.



- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISF3.8 CM2220 F110 Service Manual, Bulletin 4358480. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISL9 CM2350 L101 Service Manual, Bulletin 4310787. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the QSB6.7 CM2350 B112 Service Manual, Bulletin 4358498. Refer to Procedure 012-014 in Section 12.

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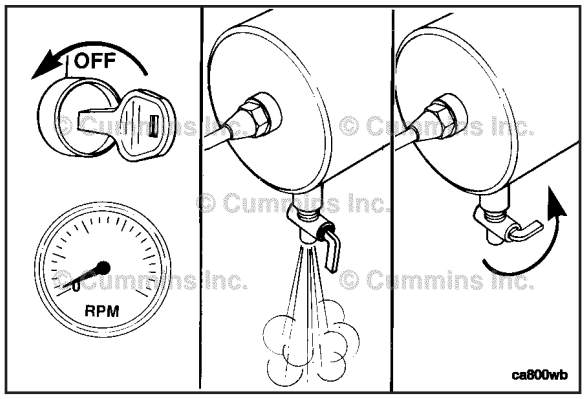
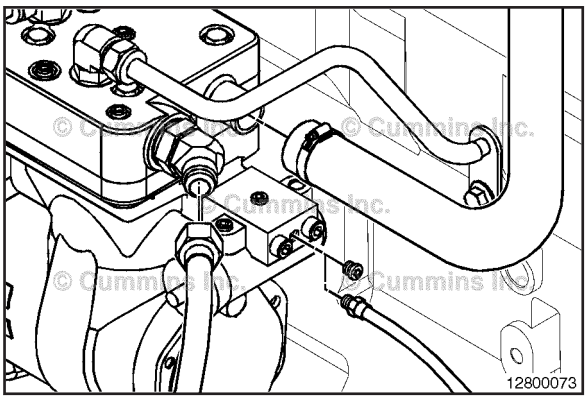


⚠WARNING⚠

Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

With the engine shut off, bleed the vehicle's air system down by opening the drain cock on the wet tank to release compressed air from the system.



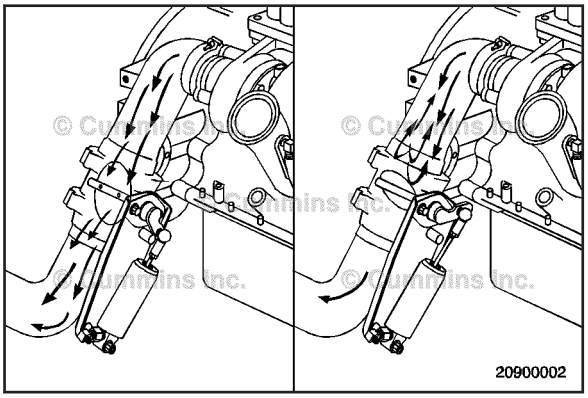
Disconnect the regulated shop air pressure line, with pressure gauge, from the air compressor governor/ unloader air signal port.

Connect the air signal line. Refer to the OEM service manual.

Remove the engine blowby service tool and water manometer or pressure gauge if the blowby is within specification.

NOTE: On turbocharged air compressors, make sure to remove the plug previously installed in the air intake hose connected to the engine intake manifold.

Connect the air compressor discharge line and air intake hose from the air compressor.



Exhaust Brake Blowby Contribution:

NOTE: Not all vehicles are equipped with an exhaust brake.

With the engine blowby service tool and the water manometer, pressure gauge, or transducer still installed, measure blowby pressure during exhaust brake operation, if equipped.

Operate the vehicle going down a long inclined road such as a highway or interstate off ramp. Begin exhaust brake operation at rated engine speed while measuring blowby pressure during exhaust brake operation.

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Also, measure exhaust back pressure during exhaust brake operation.

Operate the engine until a steady reading is obtained.

NOTE: When measuring blowby, the value can “spike” initially as the engine reaches peak power and rated speed. Wait for the blowby measurement to stabilize before taking a reading.

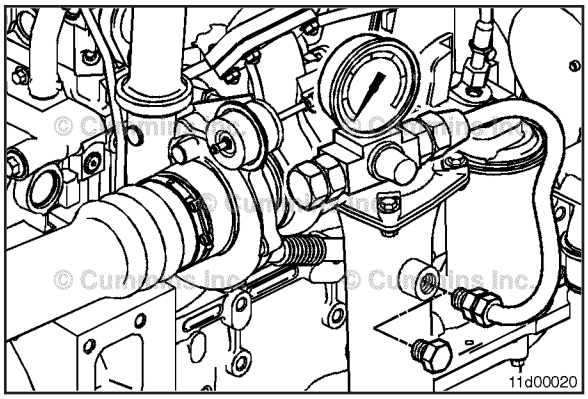
If blowby pressure is above specification during exhaust brake operation and exhaust back pressure is above specification, repair or replace the exhaust brake. See the manufacturer's instructions.

If the blowby pressure is above specification during exhaust brake operation and the exhaust back pressure is within specification, check the turbocharger blowby contribution. Reference the turbocharger oil drain isolation step previously in this procedure.

Remove the engine blowby service tool and the water manometer, pressure gauge, or transducer.

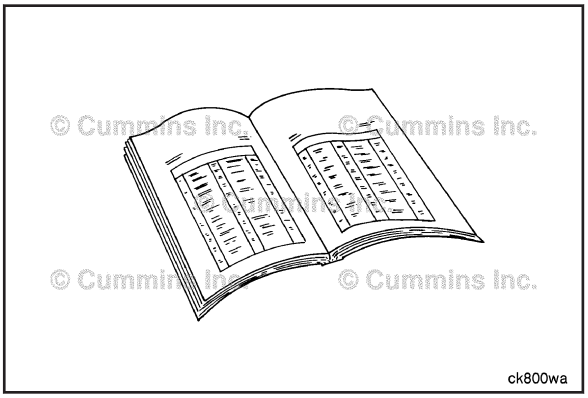
Remove the pressure gauge used to measure exhaust back pressure during exhaust brake operation.

Install a plug in the test port.



Base Engine Component Blowby Contribution:

Base engine components can also be contributing factors of increased crankcase blowby and higher than normal crankcase pressure. Reference the Crankcase Gases (Blowby) Excessive troubleshooting symptom tree in Section TS of the appropriate engine service manual to evaluate the remaining possible causes for increased blowby and higher than normal crankcase pressure. The following are listed as possible base engine component causes:



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

- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220 E, ISF2.8 CM2220 AN and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISF3.8 CM2220 F110 Service Manual, Bulletin 4358480. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISL9 CM2350 L101 Service Manual, Bulletin 4310787. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the QSL9 M CM2250 L106 Service Manual, Bulletin 4358343. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the QSB6.7 CM2350 B112 Service Manual, Bulletin 4358498. Refer to Procedure 002-004 in Section 12.

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Cylinder head valve guides are excessively worn.

- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220E, ISF2.8 CM2220AN and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISF3.8 CM2220 F110 Service Manual, Bulletin 4358480. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the ISL9 CM2350 L101 Service Manual, Bulletin 4310787. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the QSL9 M CM2250 L106 Service Manual, Bulletin 4358343. Refer to Procedure 002-004 in Section 2.
- Use the following procedure in the QSB6.7 CM2350 B112 Service Manual, Bulletin 4358498. Refer to Procedure 002-004 in Section 12.

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Air compressor is malfunctioning.

- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 012-014 in Section 2.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISF3.8 CM2220 Service Manual, Bulletin 4021704. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISF3.8 CM2220 F110 Service Manual, Bulletin 4358480. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISL9 CM2350 L101 Service Manual, Bulletin 4310787. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the QSB6.7 CM2350 B112 Service Manual, Bulletin 4358498. Refer to Procedure 012-014 in Section 12.

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Piston or piston rings are worn or damaged.

- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220 E, ISF2.8 CM2220 AN and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178. Refer to Procedure 001-043 in Section 1.Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISF3.8 CM2220 F110 Service Manual, Bulletin 4358480. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISL9 CM2350 L101 Service Manual, Bulletin 4310787. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the QSL9 M CM2250 L106 Service Manual, Bulletin 4358343. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the QSB6.7 CM2350 B112 Service Manual, Bulletin 4358498. Refer to Procedure 001-043 in Section 1.

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Aftertreatment Testing (014-013)

Regeneration

CAUTION

Engine systems equipped with exhaust aftertreatment must operate on low sulphur diesel with a maximum sulfur content of 50 parts per million. The use of high sulfur fuel will shorten the life of certain components in the exhaust system, including the diesel oxidation catalyst. This damage could cause the engine to become inoperable and affect the warranty coverage on the engine system. Refer to Fuels for Cummins Engines, Bulletin 3379001.

Under some operating conditions, such as low speed, low load, or stop and go duty cycles, the engine aftertreatment catalyst may **not** be operating at very high temperatures, and if non-approved high sulfur content fuel is used, there is a probability that ammonium sulphate will accumulate on the catalyst, which will consequently reduce the effectiveness of NOx conversion in the SCR system.

To rectify this problem, a Cummins® Authorized Repair Location will need to perform a Stationary (Parked) De-Sulfur Regeneration of the aftertreatment catalyst. This **must** be performed at a Cummins® Authorized Repair Location.

A stationary regeneration can **only** be performed with the use of the INSITE™ electronic service tool, which is initiated by selecting the feature option "De-Sulfur Regeneration Test". INSITE™ electronic service tool will then perform a timed engine warm-up and will then raise the engine speed to between 2380 to 2450 RPM for a defined period. A stationary (parked) regeneration will typically take approximately 2 hours to complete, and the vehicle **must not** be left unattended during this period.

WARNING

During regeneration, exhaust gas temperature can reach 800 °C [1500°F], and exhaust system surface temperature can exceed 700 °C [1300°F], which is hot enough to ignite or melt common materials, and to burn people. The exhaust and exhaust components can remain hot after the vehicle has stopped moving. To avoid the risk of fire, property damage, burns or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they are likely to come in contact with hot exhaust or exhaust components.

NOTE: When the stationary regeneration process has been completed and before the vehicle is returned to service, the lubricating oil and filter **must** be changed.

To perform a stationary (parked) regeneration, follow the steps listed:

1 Prepare the vehicle.

- Make sure that the fuel tank is full and that the oil quantity is sufficient.
- Inspect the exhaust piping and components for leaks, cracks, and loose connections. Reference Procedure 010-024 in Section 10 of the appropriate Service Manual. Tighten exhaust clamps, if necessary. Refer to the OEM service manual.

2 Select an appropriate external location to park the vehicle.

- Preferably on a surface that will **not** burn or melt under high exhaust temperatures (such as clean concrete or gravel, **not** grass or asphalt). Any Items that can burn, melt or explode (such as gasoline, paper, plastics, fabrics, compressed gas containers, hydraulic lines) **must** be placed at least 3 m [10 ft] from the exhaust outlet.

3 Park the vehicle securely and make sure that the parking brake is applied.

- Set the transmission in Park, if provided; otherwise in Neutral.
- Place heavy duty wheel chocks at the front and rear of at least two tires.

4 Set up a safe area around the vehicle exhaust, and use barriers to prevent any bystanders from entering within 1.5 m [5 ft] of the exhaust outlet.

- Make sure that a serviceable fire extinguisher is nearby.
- Check the exhaust system components, and confirm that there is nothing on or near the exhaust system surfaces (such as tools, shop cloths, grease, debris or organic material).

5 Connect the INSITE™ electronic service tool and make sure that it is placed on a stable surface. Check that any additional fault codes have been resolved and cleared. Initiate the stationary regeneration by selecting the "De-Sulfur Regeneration Test" and follow the on-screen instructions to perform the process.

- Once the regeneration commences, the engine speed will initially remain at idle to allow the engine to warm-up. This will be followed by a slow controlled acceleration to attain the appropriate elevated speed for regeneration. At

this point, the fuel injection sequencing is adjusted and it will be noted that the engine running tone will change. This is normal during the regeneration process. At the end of this elevated speed period, the engine will decelerate to idle for a short cooling phase, whereby the regeneration process will be completed.

- Select the stop button on the INSITE™ electronic service tool monitor screen
- Depress the clutch (if equipped)
- Depress the brake
- Depress the acceleration pedal
- Switch the engine OFF.

6 Monitor the area.

- Make sure that the vehicle and surrounding area is monitored during regeneration. If any unsafe condition occurs, shut down the engine immediately.

When the stationary regeneration process is completed, the temperature of the exhaust aftertreatment components will remain elevated for at least 5 minutes.

⚠ WARNING ⚠

The exhaust and exhaust components can remain hot after the engine has been shut down or secured. To avoid the risk of fire, property damage, burns or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they might come in contact with hot exhaust or exhaust components.

Take the vehicle for a short test drive, and operate the vehicle as instructed by INSITE™ electronic service tool, so that the Aftertreatment High NOx fault code can be reset. Reference the Fault Code Troubleshooting Manual, Bulletin 4021677.

Change the lubricating oil and filter **before** the vehicle is returned to service. Reference Procedure 007-002 in the appropriate Operation and Maintenance Manual.

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Notes

Section 16 - Mounting Adaptations - Group 16

Section Contents

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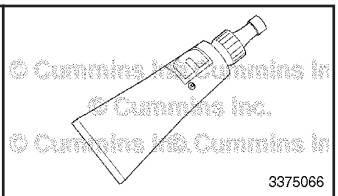
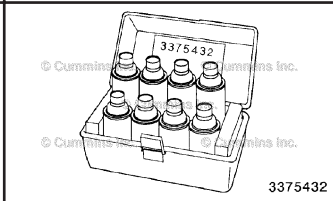
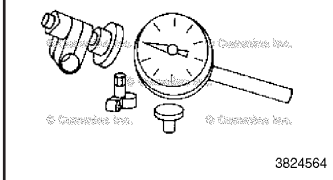
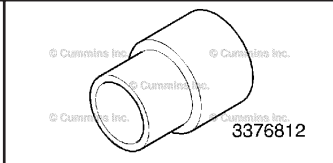
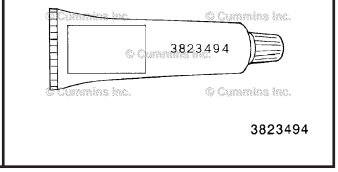
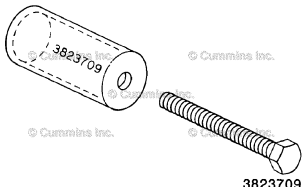
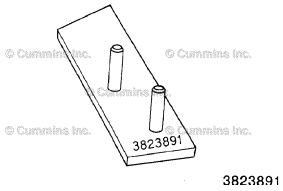
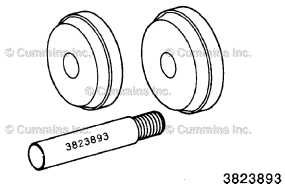
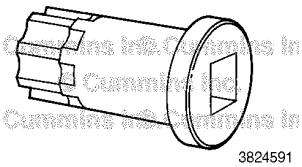
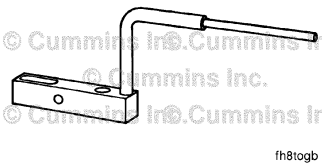
Service Tools

Mounting Adaptations

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
3375066	**Pipe Sealant** Used on capscrew threads and pipe plugs.	
3375068	**Cup Plug Sealant** Used when installing cup plugs.	
3375432	**Crack Detection Kit** Used to detect cracks.	
3376050	**Dial Indicator and Sleeve Assembly** Used with dial gauge attachment, Part Number ST-1325, to measure flywheel and flywheel housing run-out.	
3376812	**Cup Plug Driver** Used to install cup plug in flywheel housing.	
3823494	**Three-bond Sealant** Heavy duty silicone-type cup plug sealant.	

Tool No.	Tool Description	Tool Illustration
3823709	**Idler Shaft Puller and Capscrew** Used to remove idler shaft from idler gear and flywheel housing.	
3823891	**Gear Locking Tool** Used to prevent rotation of the power take-off (PTO) output shaft while tightening the output flange capscrew.	
3823893	**Bearing Race Driver** Used to install output shaft bearing races.	
3824591	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	
3824928	**Offset Wrench (C-Series Engine)** Used to tighten the hidden capscrews in the rear engine power take-off (REPTO) flywheel housing.	
ST-1325	**Dial Indicator Attachment** Attaches to crankshaft flange to provide measuring of flywheel and flywheel housing runout with dial bore gauge.	

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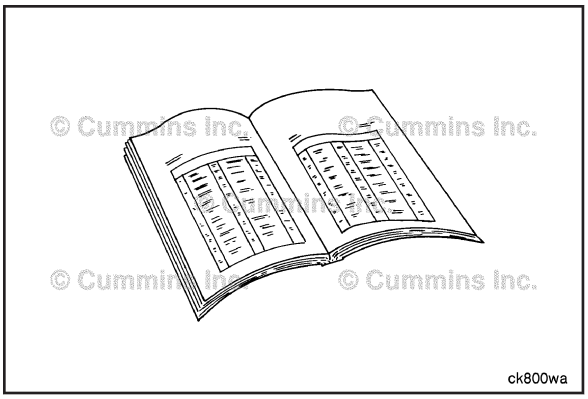
Engine Support Bracket, Front (016-002)

Preparatory Steps

Marine Applications

- Remove the belt guard. Refer to Procedure 008-001 in Section 8.



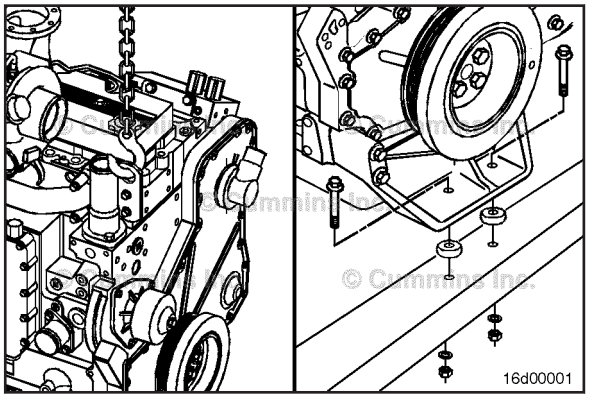
Remove

All Applications Except Marine

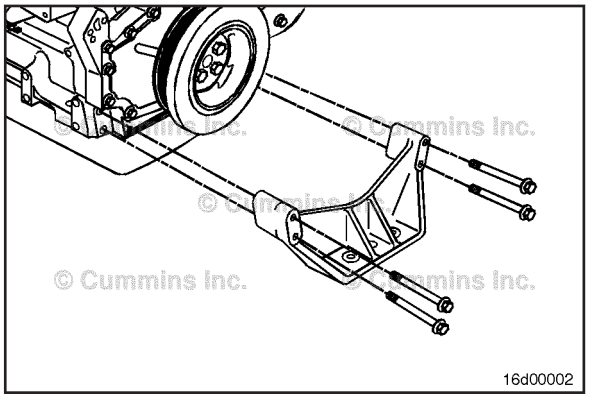
Use a hoist or lifting fixture to support the front of the engine.

Remove the capscrews from the front engine mount.

NOTE: Make sure to save any shims or spacers removed and record their location.



Remove the four mounting capscrews and the front engine support.

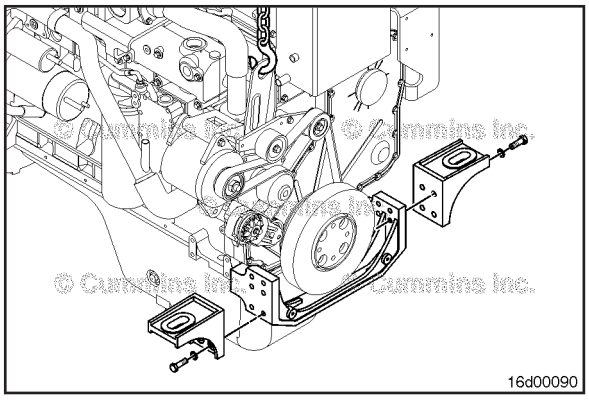


Marine Applications

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

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

Remove the brackets and spacer (if equipped) from the mounting frame and front engine support.



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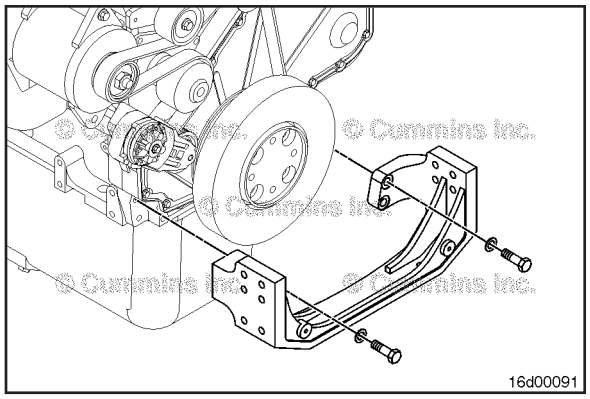
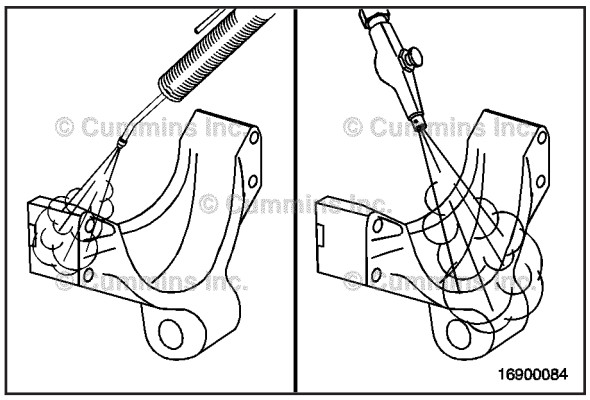


Remove the mounting capscrews and the front engine support.



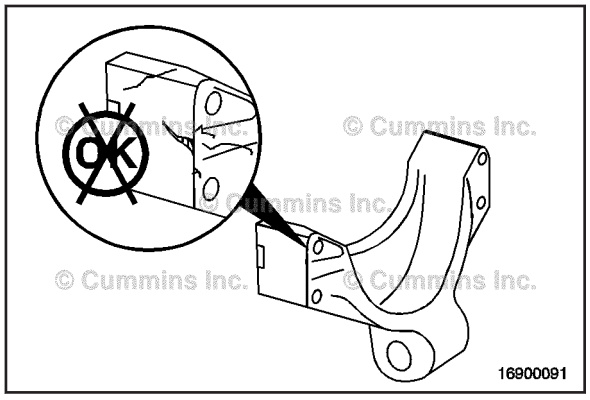
Clean and Inspect for Reuse

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

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

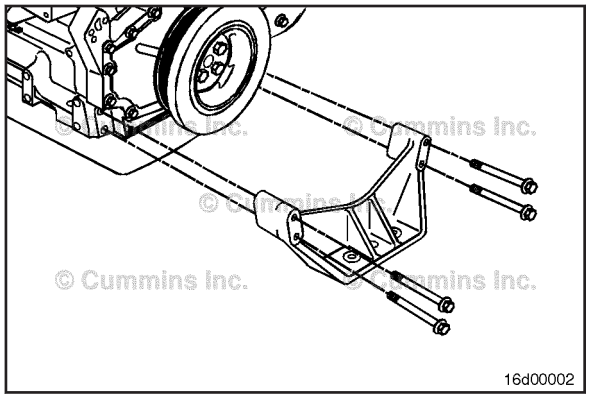
Use steam or solvent to clean the front engine support.

Dry with compressed air.



Inspect the support for cracks or other damage.

If the support is cracked or otherwise damaged, it **must** be replaced.



Install

All Applications Except Marine

Install the front support and mounting capscrews.

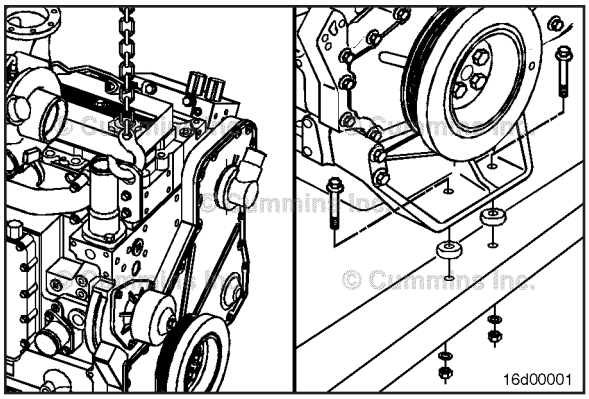
Torque Value: 112 N•m [83 ft-lb]

Lower the front of the engine.

Install the front engine mount capscrews.

Tighten the capscrews to the manufacturer's specifications.

Remove the lifting fixture or hoist from the front of the engine.



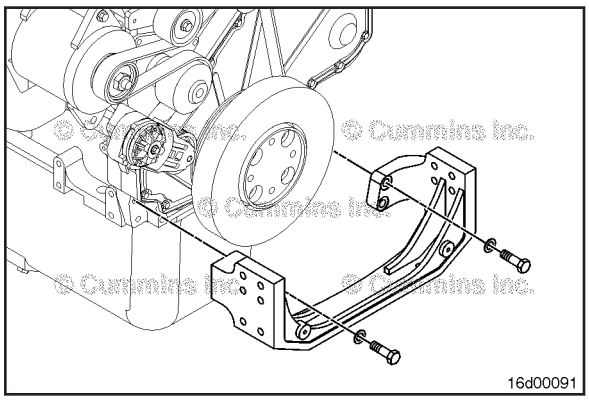
Marine Applications

Install the front engine mount and mounting capscrews.

Lightly coat the threads with Loctite™ 277, or equivalent.

Tighten the capscrews.

Torque Value: 126 N•m [93 ft-lb]

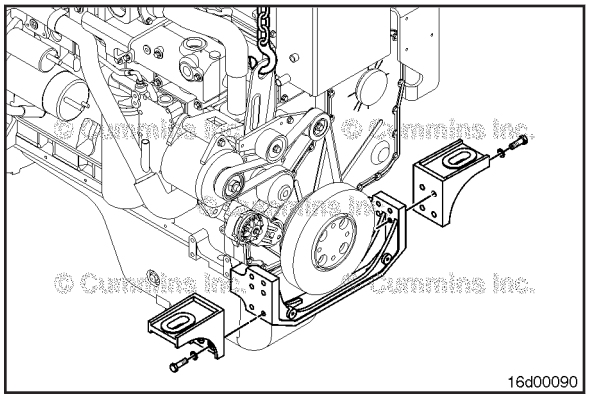


Install the support brackets and spacers (if required) to the engine mounting frame and front engine support.

Tighten the capscrews.

Torque Value: 112 N•m [83 ft-lb]

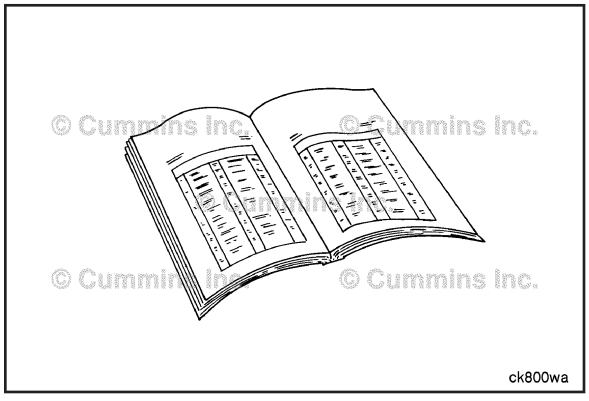
Remove the lifting fixture or hoist from the front engine lifting bracket.

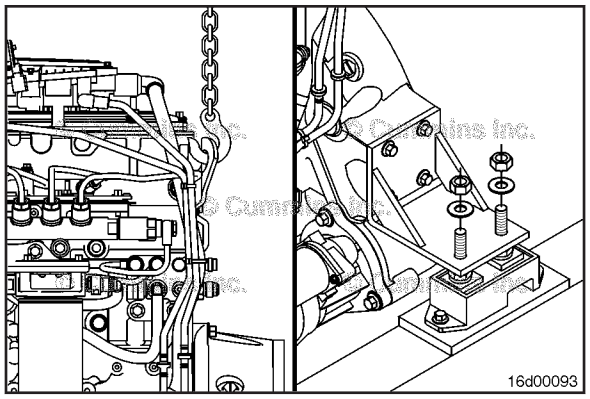


Finishing Steps

Marine Applications

- Install the belt guard. Refer to Procedure 008-001 in Section 8.





Engine Support Bracket, Rear (016-003)

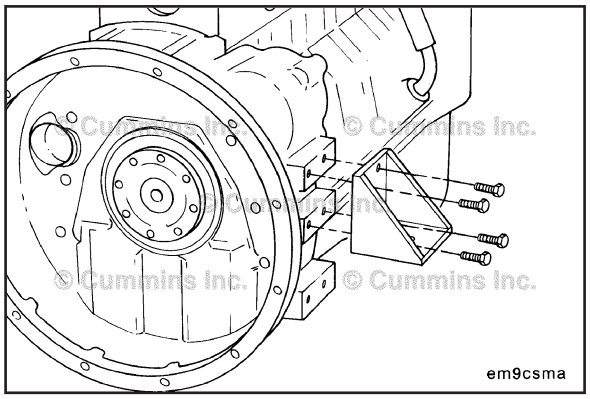
Remove

All Applications Except Marine

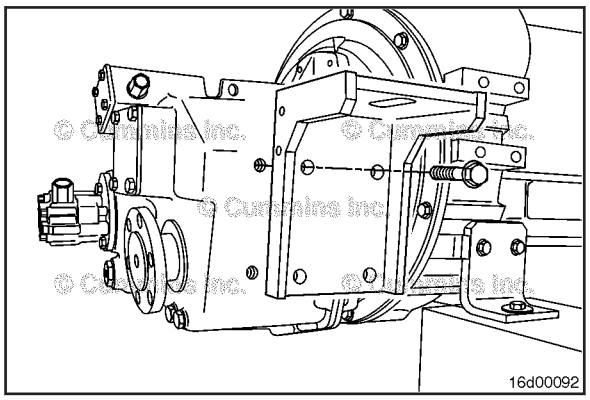
⚠WARNING⚠
The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

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

Remove the capscrew from the rear engine mount.



Remove the four capscrews and rear support bracket.

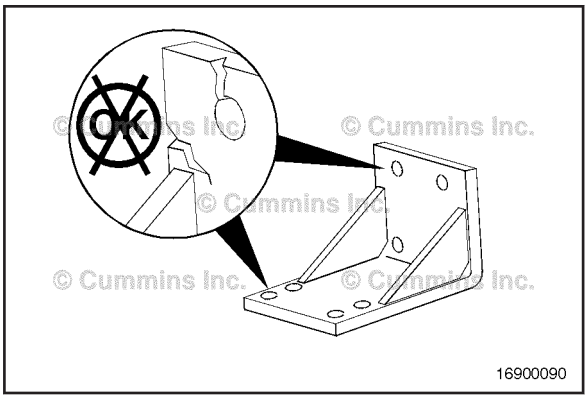


Marine Applications

Remove the rear mounting supports.

Refer to the marine gear OEM service manual or the Marine Recreational B and C Installation Directions, Bulletin 3884649.

Clean and Inspect for Reuse



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

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

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

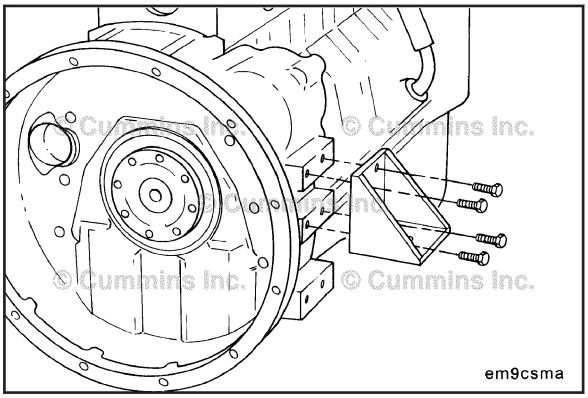
Use steam or solvent to clean the rear engine support.

Dry with compressed air.

Inspect the support bracket for cracks or damage. If the support bracket is cracked, it **must** be replaced.

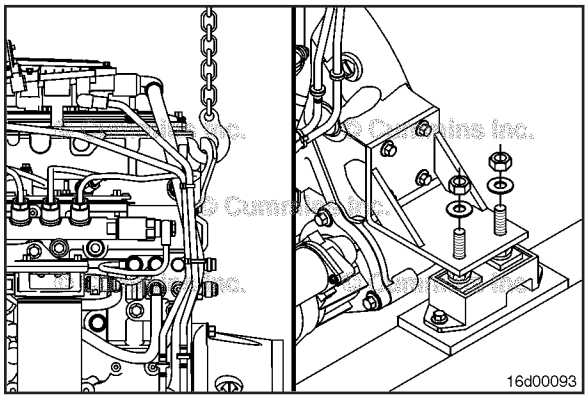
Install

All Applications Except Marine



Install the support bracket and mounting capscrews.

Torque Value: 71 N•m [52 ft-lb]

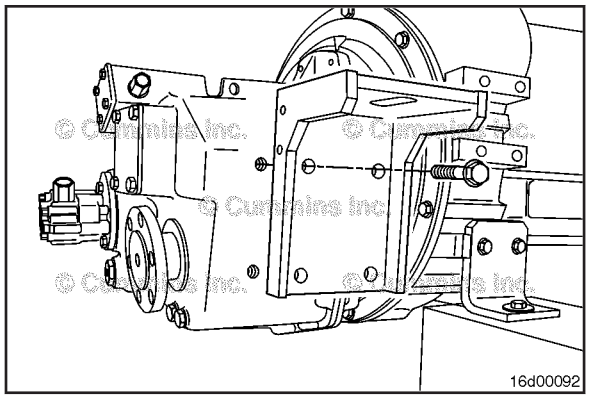


Lower the rear of the engine.

Install the rear engine mount capscrews.

Tighten to the manufacturer's specifications.

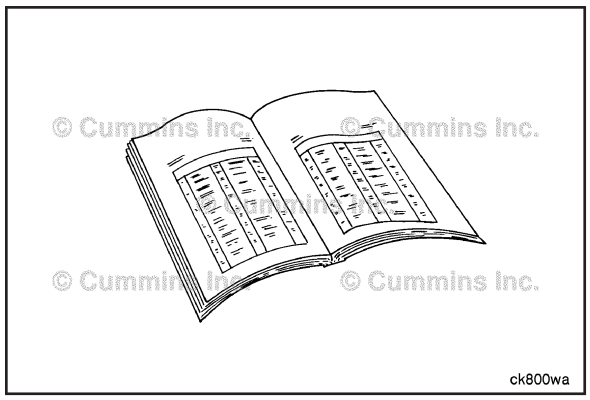
Remove the lifting fixture or hoist from the rear of the engine.



Marine Applications

Install the rear mounting bracket. Refer to the marine gear OEM service manual for bracket torque specifications.

Refer to the vessel OEM service manual for engine isolator torque specifications or the Marine Recreational B and C Installation Directions, Bulletin 3884649.



Flexplate (016-004)

Preparatory Steps

Automotive and Industrial

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

- Disconnect the battery. Refer to Procedure 013-009 in Section 13.
- Remove the transmission and related components. Refer to the OEM service manual.

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.

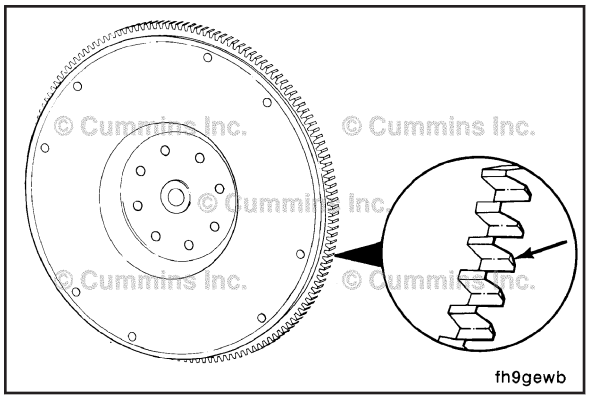
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the drive gear. Refer to OEM service manual.

Initial Check

For automotive and industrial applications, inspect the flexplate ring gear teeth for damage.

If the flexplate ring gear is damaged, make sure to evaluate the following possible causes prior to replacing the flexplate.



Mechanical

A mechanical issue can typically be identified by seeing damage to the ring gear of the flexplate in 3 distinct locations for 6 cylinder engines (commonly called 120 degree milling), and 2 locations for 4 cylinder engines (commonly called 180 degree milling). The following can be causes for mechanical issues:

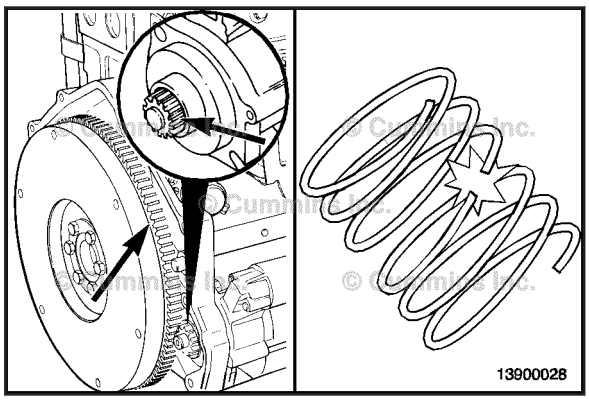
1 The possibility of improper starter motor spacing. Refer to Procedure 013-020 in Section 13.

2 The interference between the ring gear land area and the starting motor pinion. The wrong starting motor might be installed, refer to the original equipment manufacturer's specifications.

3 The possibility of a damaged starter motor pinion. Inspect the pinion for nicks and burrs. If replacement of the starting motor is necessary. Refer to Procedure 013-020 in Section 13.

4 The torque converter/transmission is damaged or incorrectly mounted. Refer to the OEM service manual.

5 Incorrect starting motor pinion to flexplate ring gear pitch and teeth match. Refer to the OEM service manual.



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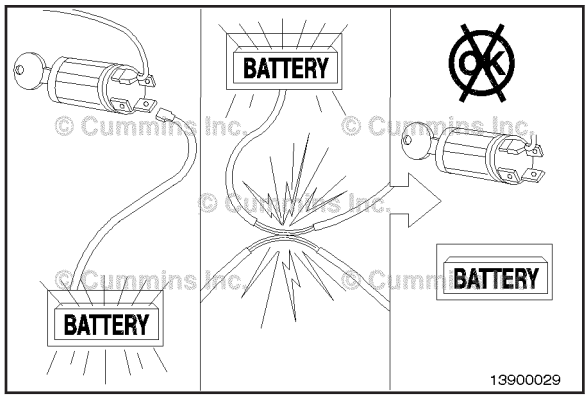


Electrical

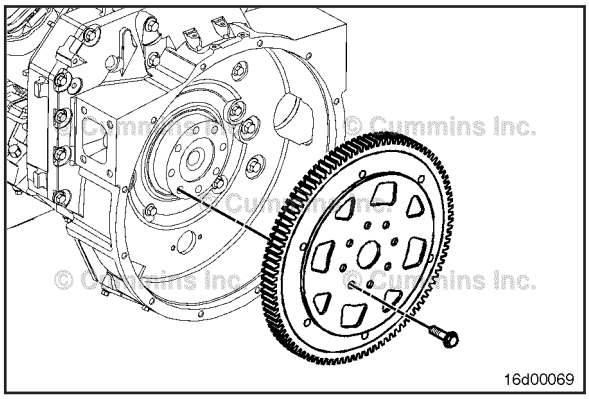
An electrical issue can typically be identified by seeing damage to the ring gear of the flexplate 360 degrees around the circumference of the ring gear (commonly called 360 degree milling). The following can be causes for electrical issues:

1 The operator is attempting to start engine while engine is already running. Check if a starter lockout feature is available through the OEM (activated with INSITE™ electronic service tool) or the starting motor manufacturer.

2 The key switch is causing intermittent starting motor engagement when the engine is running. Inspect the key switch. Refer to Procedure 013-020 in Section 13.

3 The orientation of the starter relay, where in the direction of the pull contact is in the direction of the vehicle's travel. This results in intermittent starter motor engagement when the engine is running. Relocate the starter relay. Refer to the OEM service manual.

4 Intermittent starter motor wiring issues. Refer to the OEM service manual.

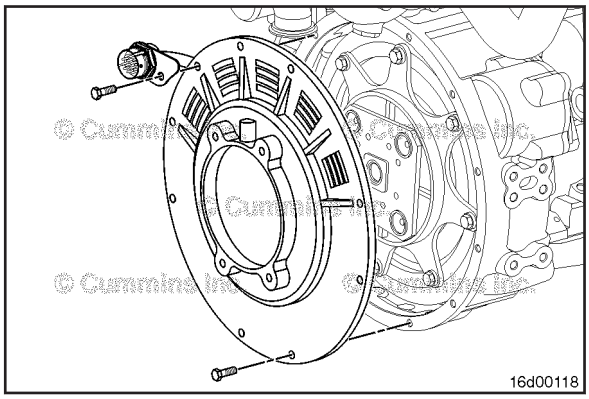


Remove

Automotive and Industrial

Remove the flexplate capscrews and flexplate.

NOTE: Some flexplates require mounting plates and/or adapters. It may be necessary to remove any mounting plates and/or adapters prior to or with the flexplate. Make sure to note the location of any mounting plates and/or adapters for later installation.

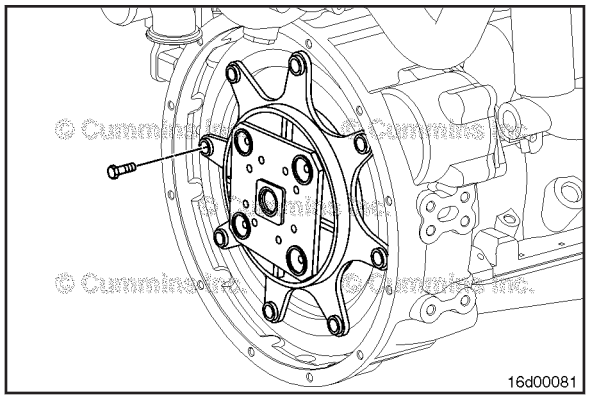


Marine Applications

Remove the nine flex-coupling guard capscrews, harness connector, and the flex-coupling guard (if equipped).

Remove the flexplate mounting capscrews.

Remove the flexplate from the flywheel.



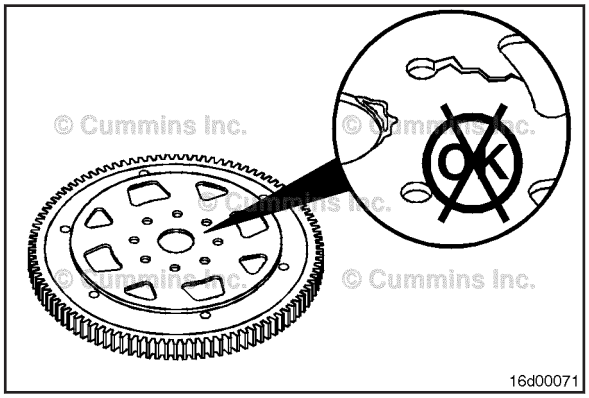
Inspect for Reuse

Automotive and Industrial

Inspect the teeth of the ring gear for chips or uneven wear.

Check the flexplate for cracks.

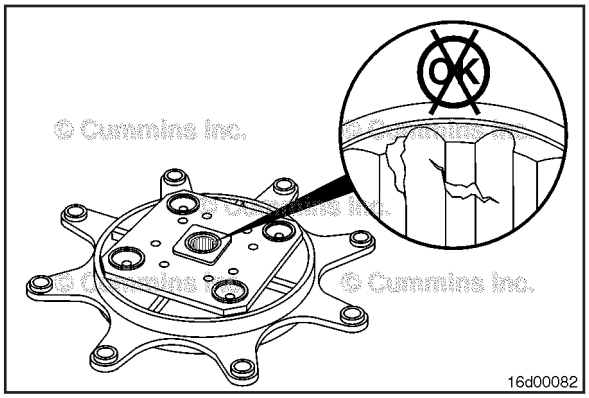
Replace the flexplate if any damage is found.



Marine Applications

Check the flexplate for cracks at the mounting holes, drive splines, and the inner drive plate.

Replace the flexplate if any damage is found.



Install

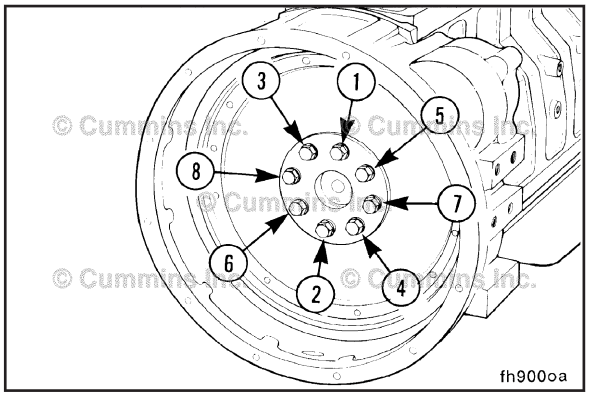
Automotive and Industrial

NOTE: Some flexplates require mounting plates and/or clamp rings. It may be necessary to install any mounting plates and/or clamp rings prior to or with the flexplate as noted during removal.

Install the flexplate, the flexplate capscrews, and tighten.

Torque Value:

Flexplate Capscrews		
Step 1	30 N•m	[22 ft-lb]
Step 2	Plus 60-degree turn	



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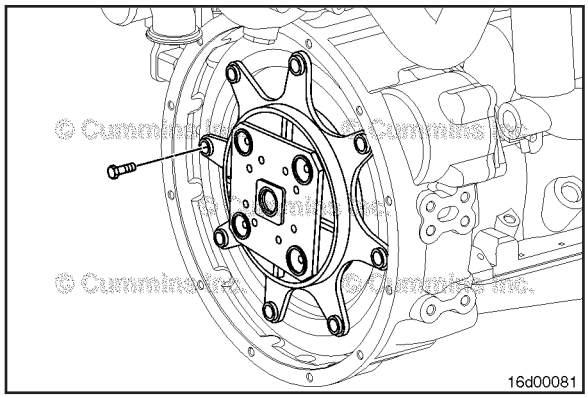
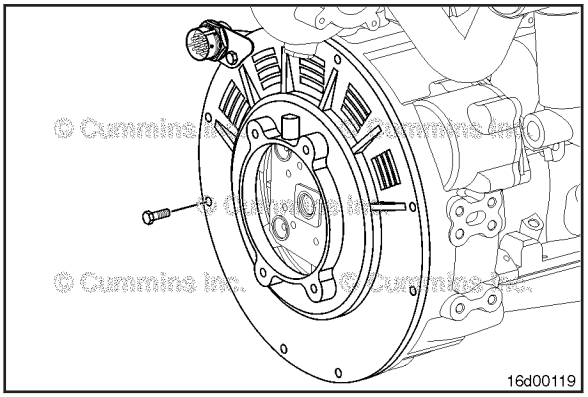


Marine Applications

Install the flexplate and flexplate mounting capscrews.

Tighten the capscrews.

Torque Value: 44 N•m [32 ft-lb]

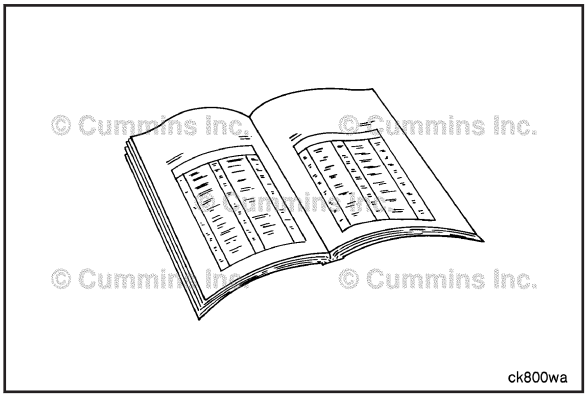


If the engine is equipped with a flex-coupling guard plate, install the flex-coupling guard plate onto the flywheel housing. Position the wiring harness connector at the 11 o'clock position, as shown in the illustration. Install a capscrew to hold it in place.

Install the remaining eight capscrews.

Tighten the capscrews.

Torque Value: 36 N•m [27 ft-lb]



Finishing Steps

Automotive and Industrial

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠

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

- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Install the transmission and related components. Refer to the OEM service manual.
- Operate the engine and check for noise or vibration.

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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⚠
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 the batteries. Refer to Procedure 013-009 in Section 13.
- Install the drive gear. Refer to OEM service manual.
- Check the crankcase end play.Refer to Procedure 001-016 in Section 1.
- Operate the engine and check for noise or vibration.

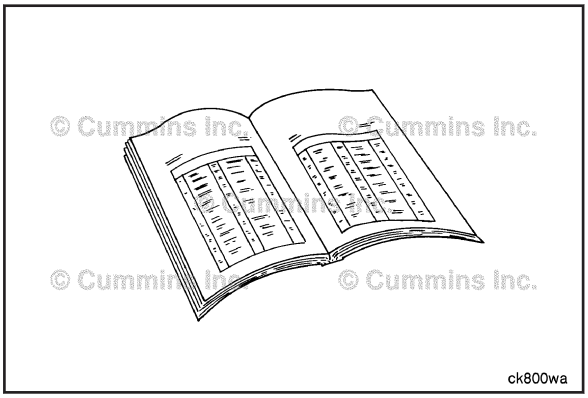
Flywheel (016-005)

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.

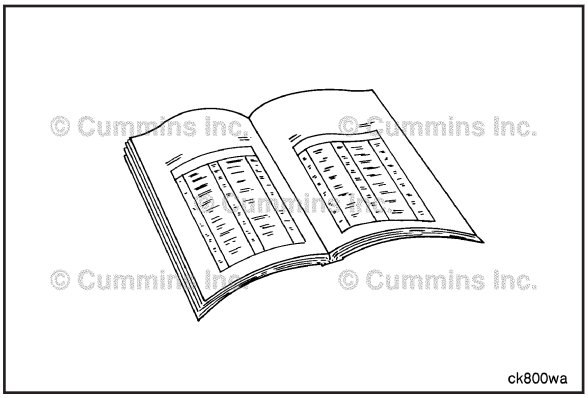
- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the vehicle driveline and transmission. See the manufacturer's service manual.
- Remove the clutch discs and the pressure plate.

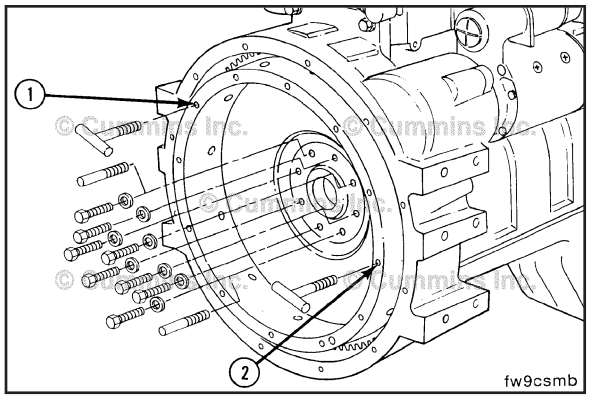


Marine Applications

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

- Use a hoist or suitable lifting device to support the rear of the engine if the engine supports are mounted to the marine gear.
- Remove the propeller shaft, marine gear and drive plate. Refer to the vessel OEM or marine gear OEM service manual.
- Remove the marine gear housing adapter, if used. Refer to the marine gear OEM service manual.





Remove

NOTE: Use the barring tool, Part Number 3824591, to hold the flywheel to prevent rotation.

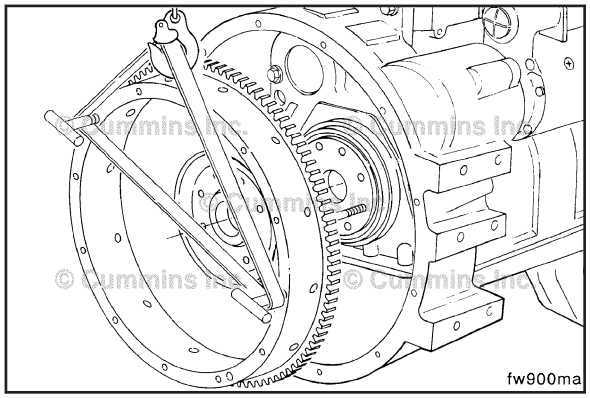
Remove two capscrews 180 degrees apart.

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

NOTE: If a clutch is used in the equipment, the threads in the clutch pressure plate mounting capscrew holes can be metric or standard. Be sure to use the correct capscrews.

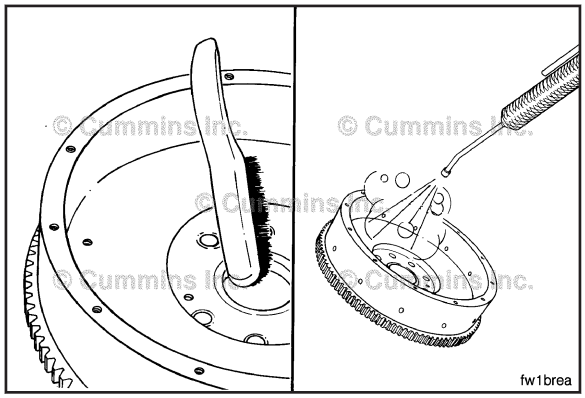
Determine the capscrew thread design and size, and install two T-handles in the flywheel at points (1) and (2).

Remove the remaining six flywheel mounting capscrews.



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

Remove the flywheel from the guide pins.



Clean and Inspect for Reuse

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

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠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.

If the pilot bearing was removed, use a wire brush to clean the crankshaft pilot bore.

Use steam or solvent to clean the flywheel.

Dry with compressed air.

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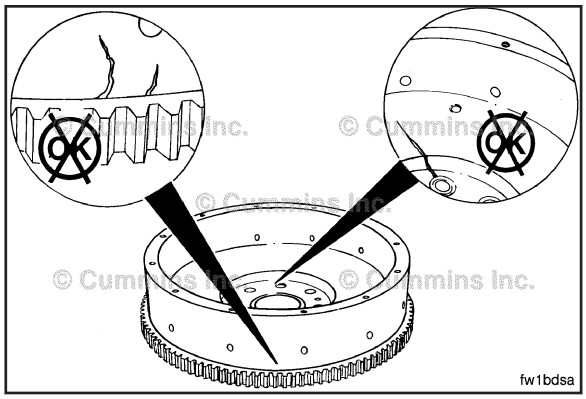
⚠WARNING⚠

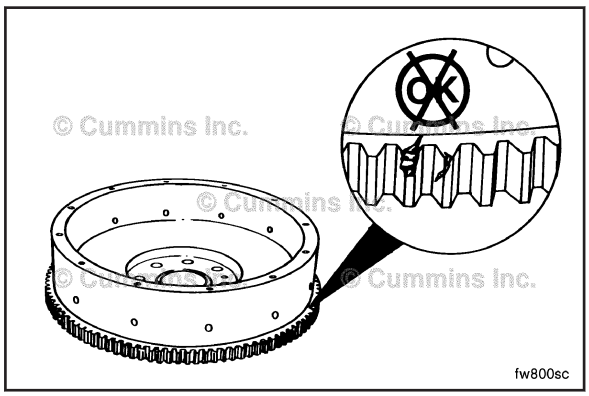
Do not use a cracked or resurfaced flywheel. These can break, causing serious personal injury or property damage.

Use the crack detection kit, Part Number 3375432, to check for cracks in the flywheel. Follow the instructions provided with the kit.



Inspect the flywheel ring gear teeth for cracks and chips.

NOTE: If the ring gear teeth are cracked or broken, the ring gear **must** be replaced. Refer to Procedure 016-008 in Section 16.

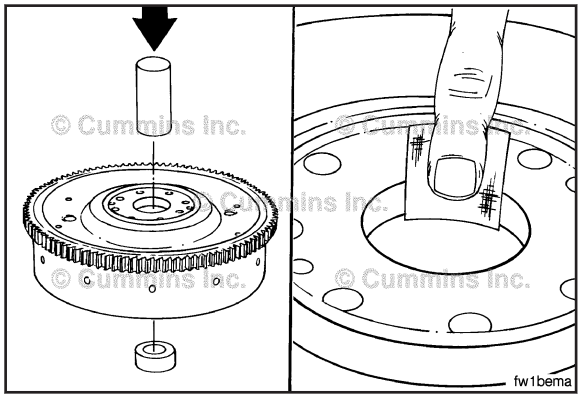


Install

NOTE: Use a new pilot bearing when installing a new or rebuilt clutch.

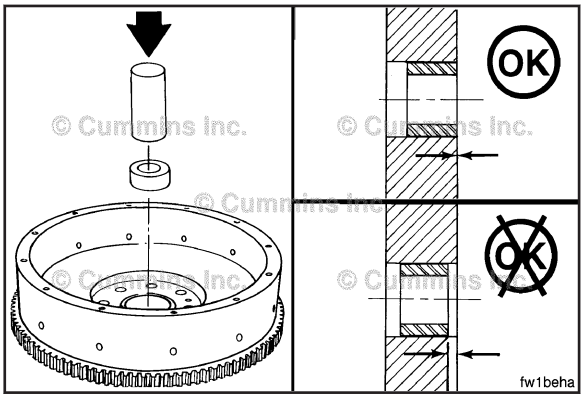
Use a mandrel and a hammer to remove the pilot bearing.

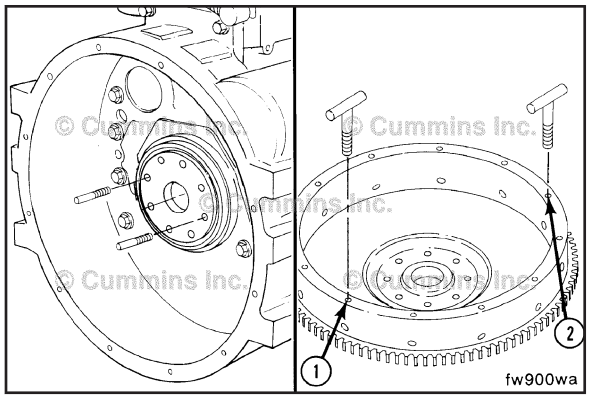
Use Scotch-Brite™ 7448 or equivalent to clean the pilot bore.



Use a mandrel and hammer to install the pilot bearing.

NOTE: The pilot bearing **must** be installed even with the pilot bore surface.

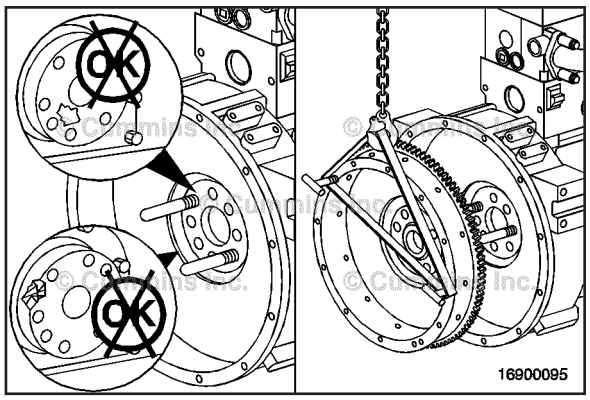




Install two M12 x 1.25 x 90-mm guide pins into the crankshaft flange 180 degrees apart.

NOTE: If a clutch is used in the equipment, the threads in the clutch pressure plate mounting capscrew holes can be metric or standard. Be sure to use the correct capscrews.

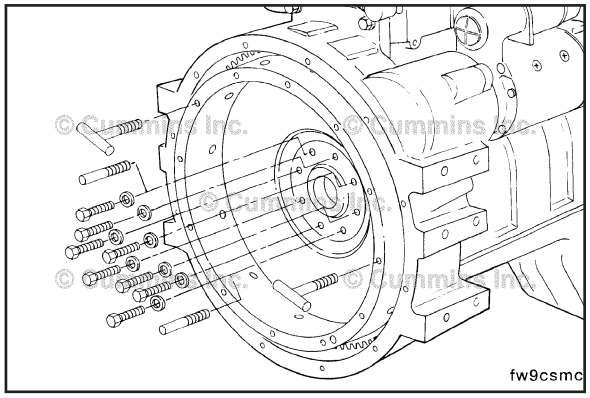
Determine the capscrew thread design and size, and install two T-handles into the flywheel at points (1) and (2).



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

Inspect the rear face of crankshaft and flywheel mounting flange for cleanliness and nicks or burrs.

Install the flywheel on the guide pins.

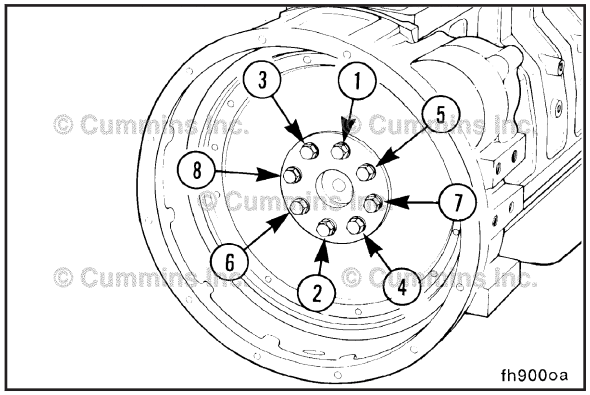


Lubricate the threads of the capscrews and the surface of the washers with clean lubricating engine oil.

Install the six capscrews.

Remove the T-handle and guide pins.

Install the remaining capscrews into the holes from where the guide pins were removed.



Hold the crankshaft when tightening the flywheel capscrews, use the barring tool, Part Number 3824591.

Tighten the capscrews in a star pattern.

Torque Value: 137 N•m [101 ft-lb]

Measure

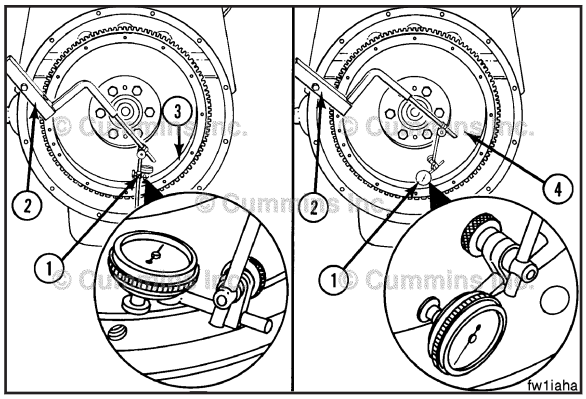
Bore Runout

Use the dial indicator gauge (1), Part Number 3376050, or its equivalent and dial gauge attachment (2), Part Number ST-1325, to inspect the flywheel bore (3) and the surface (4) runout.

Install the attachment to the flywheel housing.

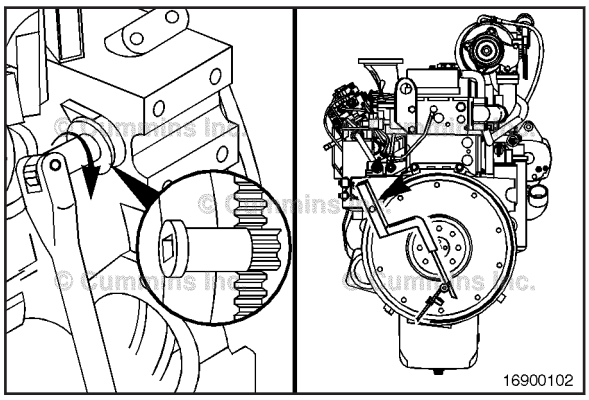
Install the gauge on the attachment.

Install the contact tip of the indicator against the inside diameter of the flywheel bore, and set the dial indicator at zero.



Use the barring tool, Cummins Part Number 3374591, to rotate the crankshaft one complete revolution.

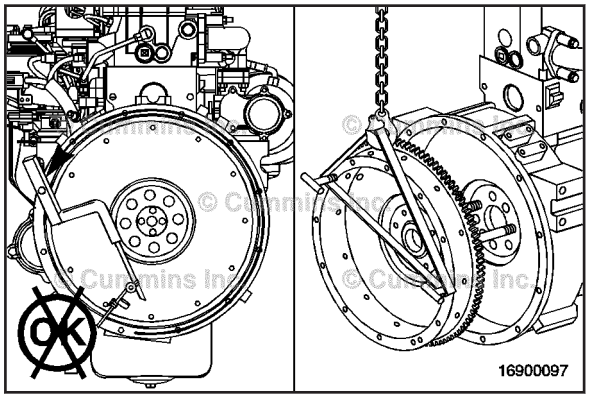
Flywheel Total Indicator Reading		
mm		in
0.127	MAX	0.0050



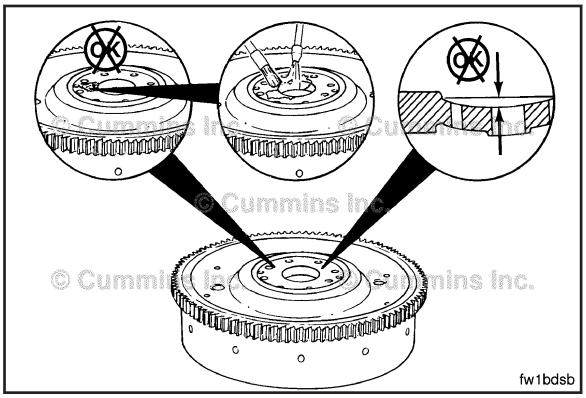
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

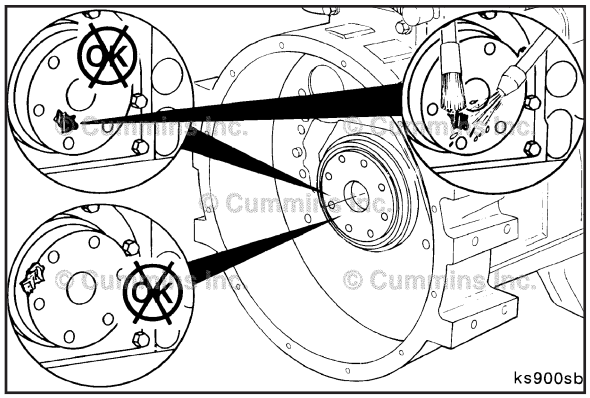
NOTE: If the total indicator reading (TIR) is greater than the specification, do the following:

Remove the flywheel.

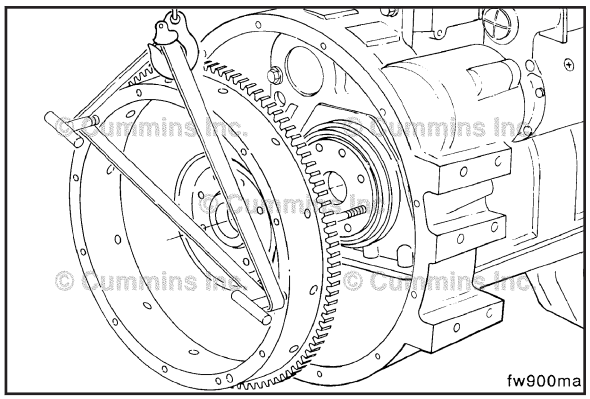


Inspect the flywheel mounting surface for dirt or damage.





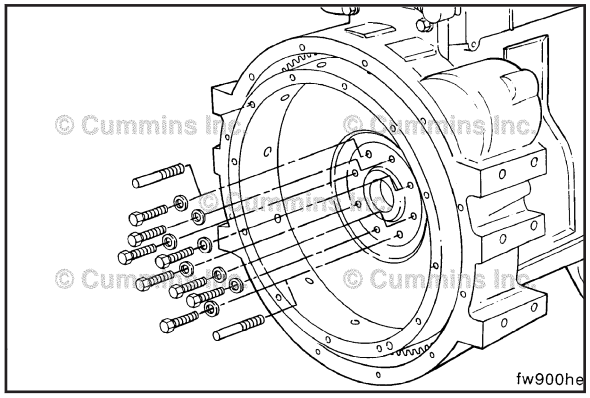
Inspect the crankshaft for dirt or damage.



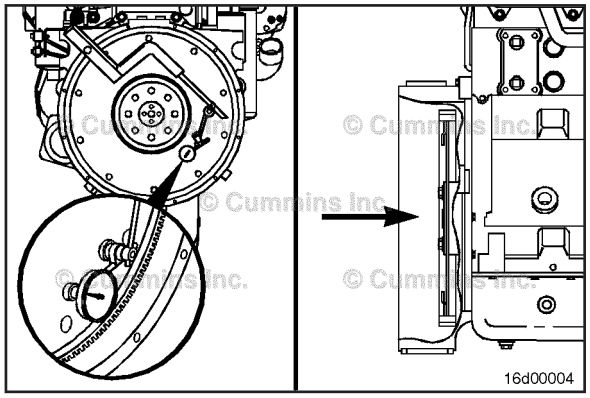
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Install the flywheel.

Inspect the bore runout.



Replace the flywheel if the runout does **not** meet specifications.



Face Runout

Install the contact tip of the indicator against the flywheel face.

When locating the contact tip, see the Flywheel Face Runout Total Indicator Reading Table later in this procedure. Locate the contact tip so that it corresponds with a radius listed in the table, but is still as close to the outside diameter of the flywheel as possible, to inspect the flywheel face (1) runout.

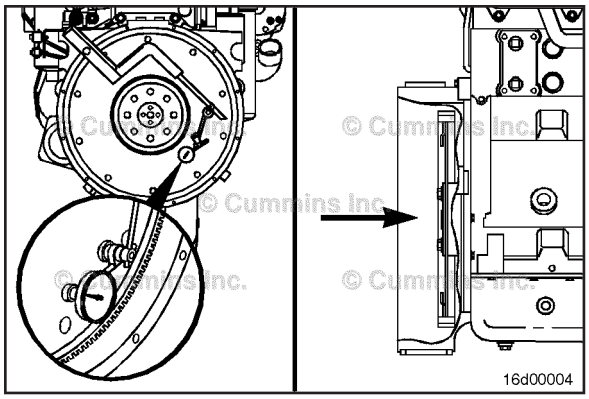
Push the flywheel forward to remove the crankshaft end clearance. Adjust the dial on the indicator until the needle points to zero.

Use the barring tool, Part Number 3824591, to rotate the crankshaft one complete revolution. Measure and record the flywheel runout at four equal points on the flywheel.

The flywheel **must** be pushed toward the front of the engine to remove the crankshaft end clearance each time a point is measured.

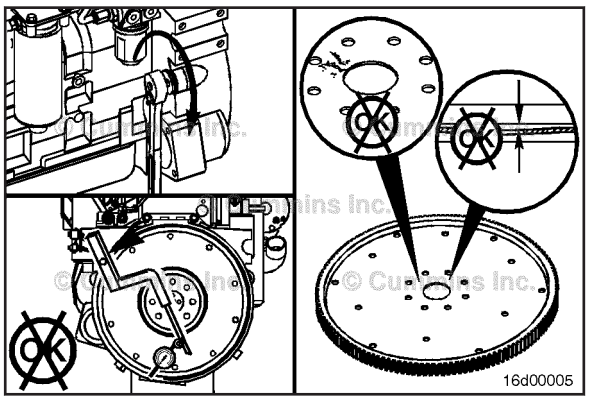
Determine the total indicator reading (TIR).

TIR is determined by calculating the difference between the highest and lowest measurement from the four locations measured.



If the flywheel face runout is **not** within specifications, remove the flywheel. Check for nicks, burrs, or foreign material between the flywheel mounting surface and the crankshaft flange.

Replace the flywheel if the runout is **not** within specification.



Finishing Steps

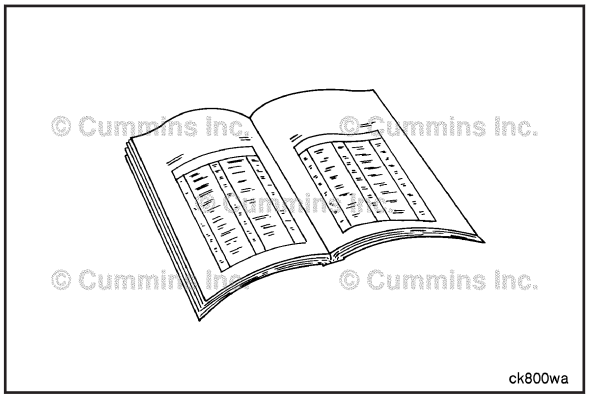
All Applications Except Marine

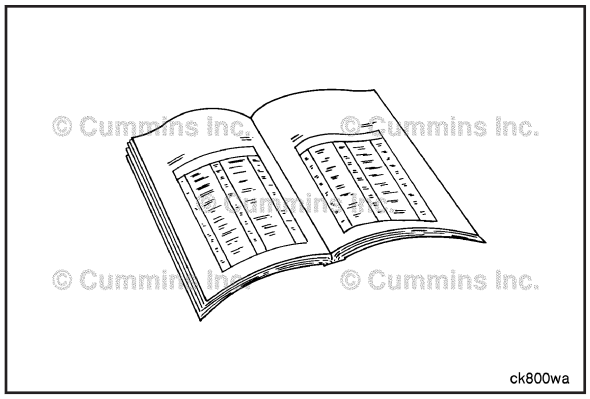
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the clutch discs and the pressure plate.

NOTE: Use the barring tool, Part Number 3824591, to hold the flywheel to prevent rotation.

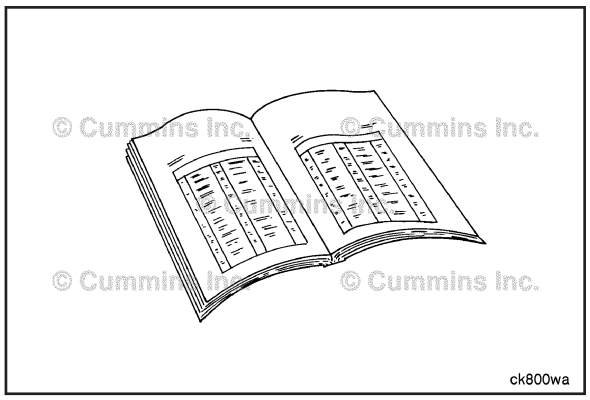
- Install the vehicle driveline and transmission. See the manufacturer's service manual.
- Connect the battery. Refer to Procedure 013-009.
- Operate the engine and check for noise or vibration.





Marine Applications

- Install the drive plate, marine gear drive adapter and the marine drive gear. Refer to the marine drive OEM service manual.
- Install the engine supports, if removed. Refer to the vessel OEM service manual.
- Install the propeller drive. Refer to the vessel OEM service manual.
- Operate the engine and check for leaks.



Flywheel Housing (016-006)

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

⚠WARNING⚠
Support the rear of the engine using the rear support attached to the cylinder head. Failure to support the engine can cause personal injury.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- If equipped with a wet flywheel housing, drain the oil from the flywheel housing by removing the plug in the bottom of the flywheel housing. Use a container that can hold at least 28 liters [30 qt] of lubricating oil.
- Remove the starting motor. Refer to Procedure 013-020 in Section 13.
- Remove the transmission, clutch, and all related components, if equipped. See equipment manufacturer service information.
- Remove the flywheel/ring gear assembly. Refer to Procedure 016-005 in Section 16.
- Remove the rear engine mounts. Refer to Procedure 016-003 in Section 16.
- Remove any original equipment manufacturer (OEM) attached components (mufflers, shift mechanisms, air filters, etc.) to the flywheel housing. See equipment manufacturer service information.

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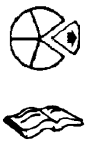
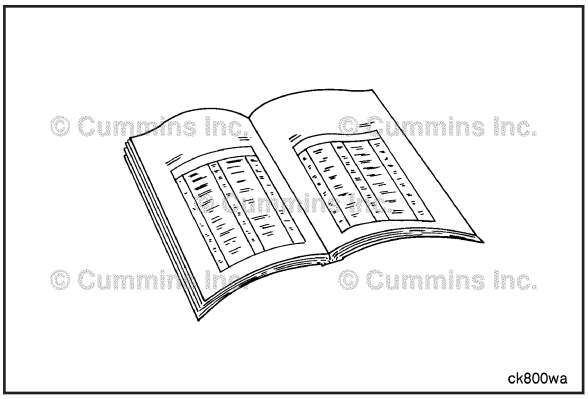
Marine Applications





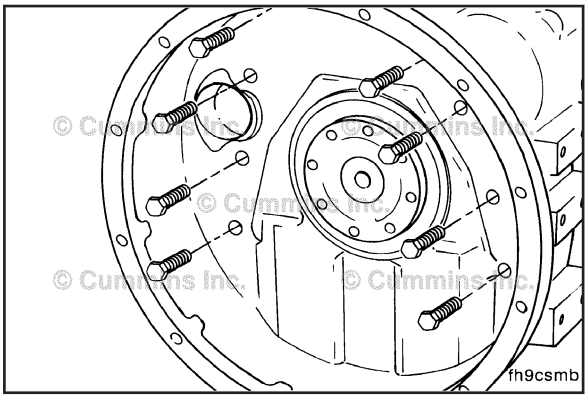
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

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

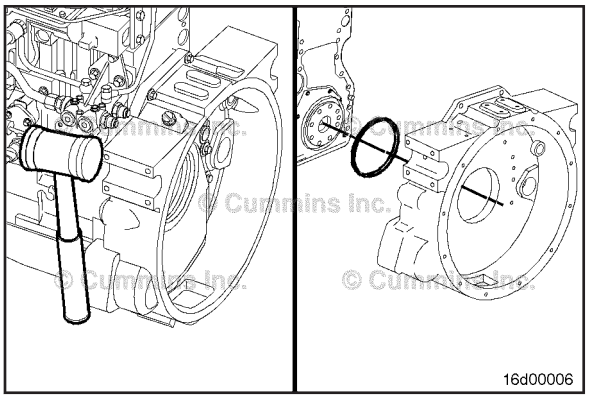
- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the propeller shaft. Refer to the vessel OEM service manual.
- Remove the marine drive gear, drive gear adapter, if equipped, and the drive plate.
- Use a hoist or suitable lifting device to lift the rear of the engine. Remove the rear engine mounts. Refer to Procedure 016-003 in Section 16.
- Remove the flywheel. Refer to Procedure 016-005 in Section 16.
- Remove the starting motor. Refer to Procedure 013-020 in Section 13.
- Remove the aftercooler mounting capscrews. Refer to Procedure 010-005 in Section 10.

Remove



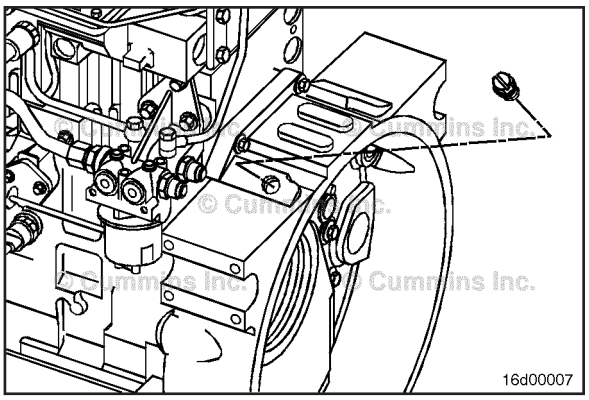
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

While supporting the flywheel housing, remove the mounting capscrews.



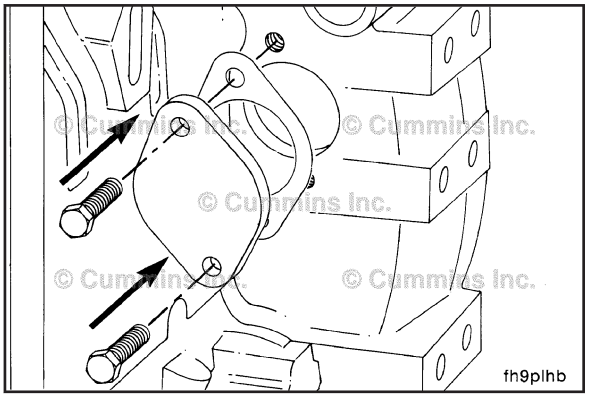
Use a rubber hammer to loosen the flywheel housing.

Remove the flywheel housing and rectangular seal.

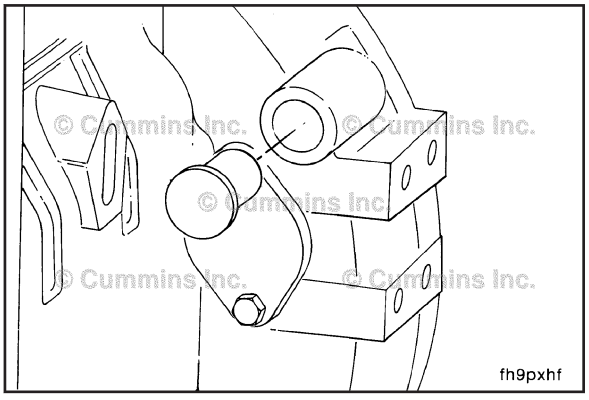


Disassemble

Remove and note the location of any threaded plugs in the flywheel housing.



Remove the access plate and, if equipped, the gasket.



Remove the plug from the barring gear hole.

Clean and Inspect for Reuse

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

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

⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

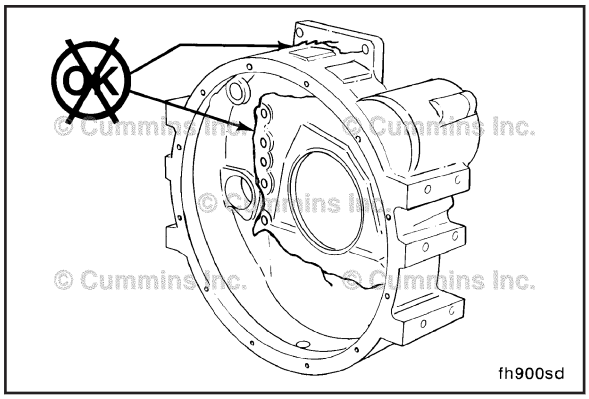
Use steam or solvent to clean the flywheel housing.

Dry with compressed air.

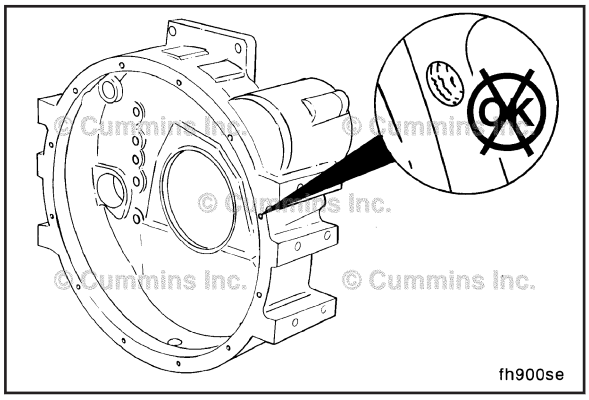
Inspect the flywheel housing for cracks, especially in the bolt pattern area.

Inspect all surfaces for nicks, burrs, or cracks.

Use a fine crocus cloth to remove small nicks and burrs.



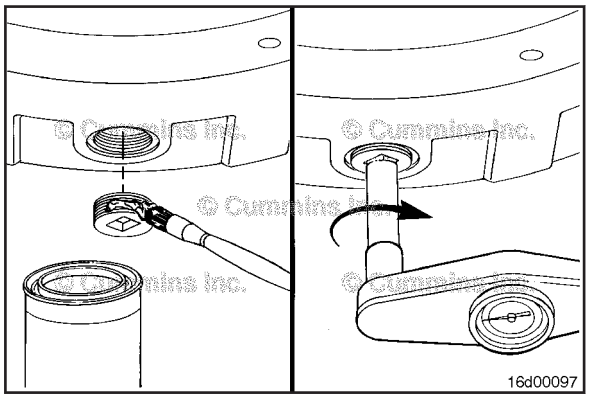
Inspect for damaged threads commonly caused by cross threaded capscrews or installing an incorrect capscrew. Heli-coils are available to repair damaged threads.

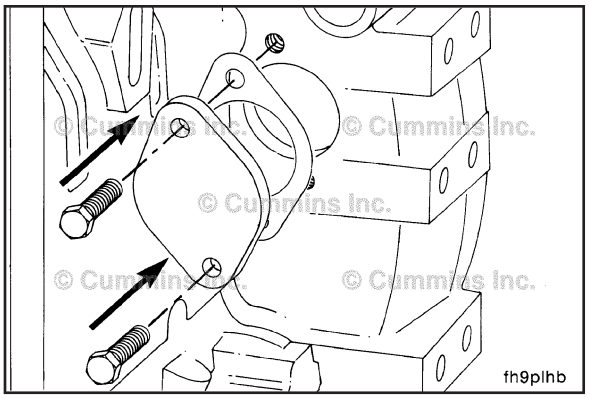


Assemble

For wet flywheel housings, apply pipe sealant, Part Number 3375066, to any threaded plugs previously removed.

Install and tighten the plugs. Refer to Procedure 017-007 in Section 17.



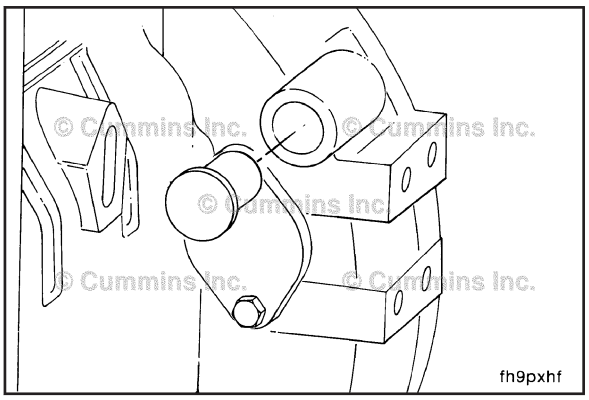


Install the access plate and new gasket.

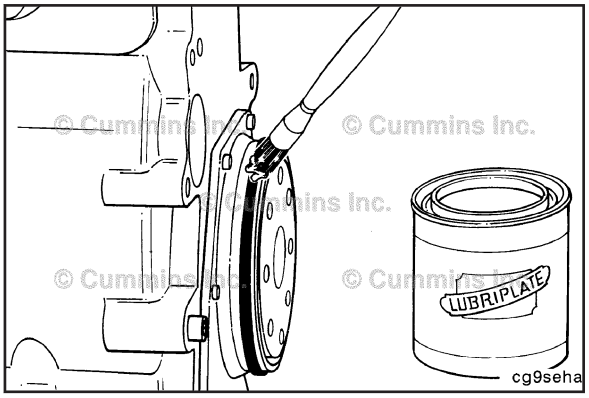
Install the capscrews and tighten.

Torque Value: 24 N•m [212 in-lb]

NOTE: If a gasket was **not** previously installed, apply sealant, Part Number 3164067, to the perimeter of the access plate.

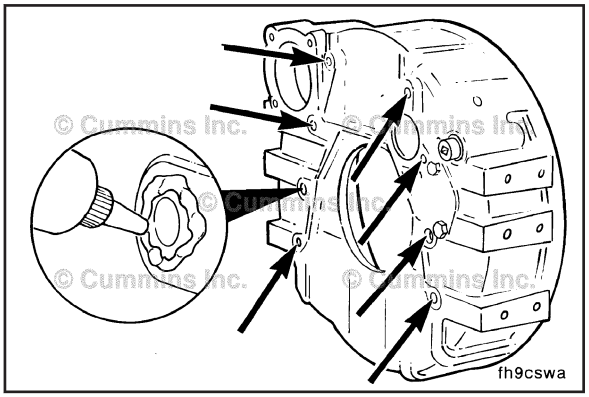


Install a new o-ring. Install the barring gear hole plug.



Install

Install rectangular seal and lubricate with Lubriplate™ 105 multi-purpose lubricant, or equivalent.



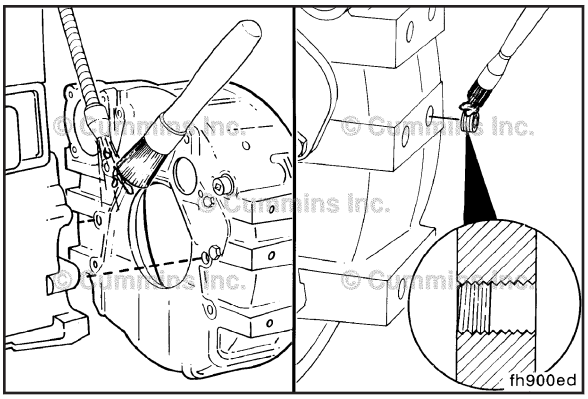
Wet Flywheel Applications

Apply a continuous bead of Three-Bond™, or equivalent, around all capscrew holes on the mounting surface of the flywheel housing.

Wet Flywheel Applications

NOTE: The capscrew holes on the mounting pads are drilled through. Coat set screws with Loctite™ 277, or equivalent, and install into holes.

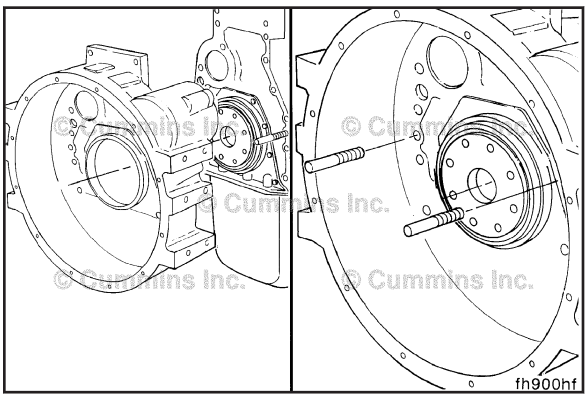
Set Screw Installation Depth (Flywheel Housing)		
mm		**in**
3.00	MAX	0.118



Inspect the rear face of the cylinder block and flywheel housing mounting surface for cleanliness and nicks or burrs.

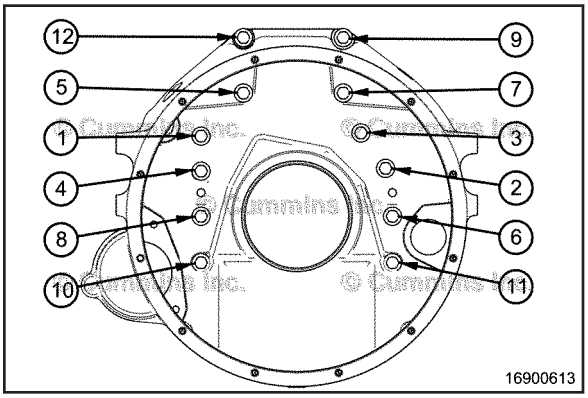
Install the flywheel housing over the two ring dowels.

NOTE: Be sure the sealing ring is **not** damaged during installation.

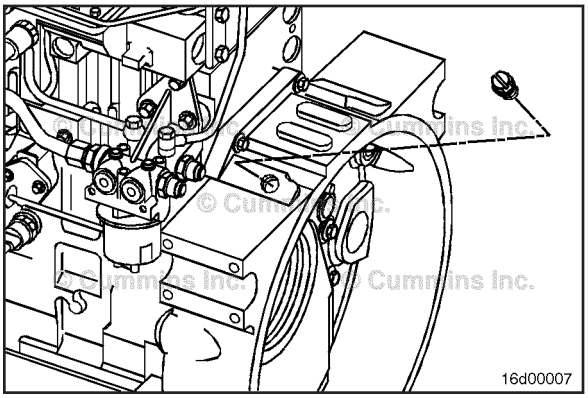


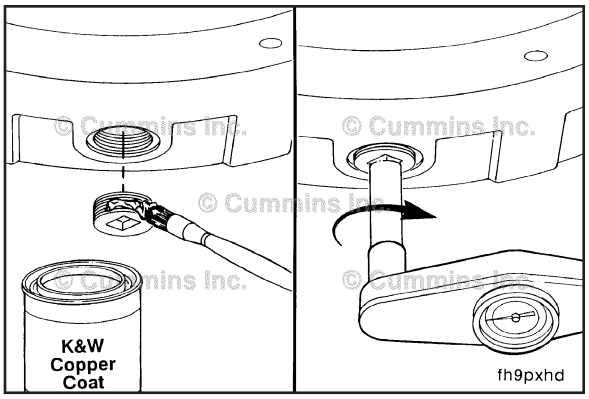
Tighten the flywheel housing capscrews in sequence shownn.

Torque Value: 77 N•m [57 ft-lb]

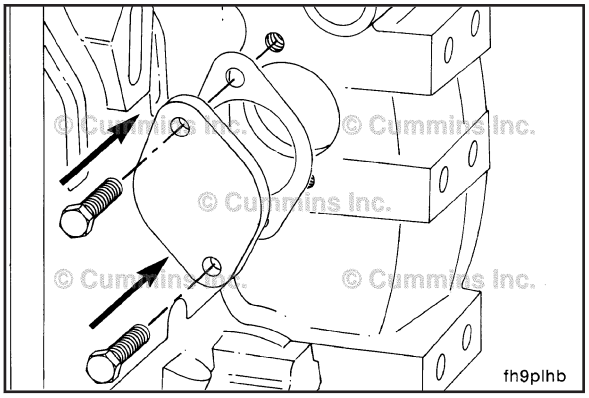


Install the plastic plug in the tachometer drive access hole.





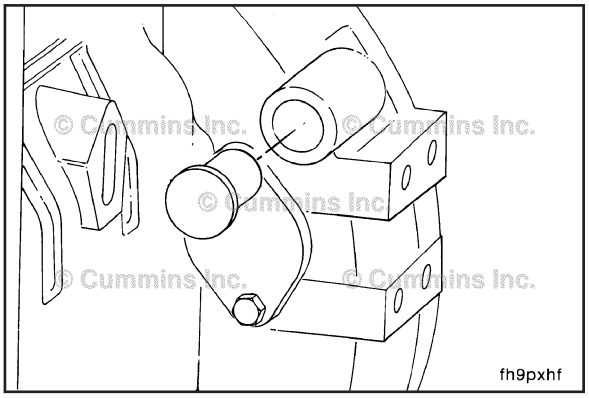
- Coat the flywheel housing drain plug with pipe sealant and install in the hole in the bottom of the flywheel housing.
- Tighten the plug.
- Refer to Procedure 018-012 in Section V.



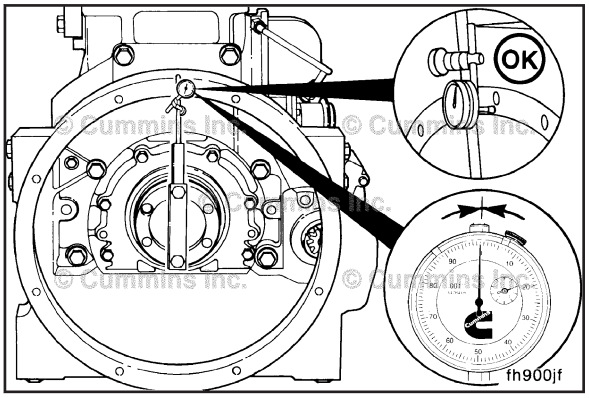
Install the access plate and new gasket.

Install the capscrews and tighten.

Torque Value: 24 N•m [212 in-lb]



Install the plug into the barring gear hole.



Measure

Face Alignment

⚠CAUTION⚠

The dial indicator tip must not enter the capscrew holes or the gauge will be damaged.

Install a dial indicator as illustrated.

NOTE: The extension bar for the indicator **must** be rigid for an accurate reading. It **must not** sag. Position the indicator at the 12 o'clock position. Adjust the dial until the needle points to zero.

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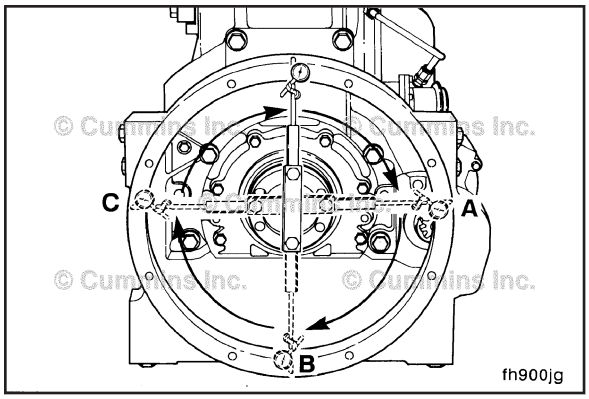
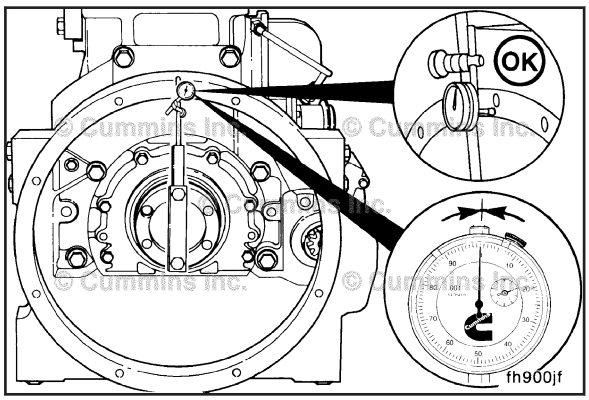
Slowly rotate the crankshaft. Record the readings at the 3 o'clock, 6 o'clock, and 9 o'clock positions.

NOTE: The crankshaft **must** be pushed toward the front of the engine to remove the crankshaft end clearance each time a position is measured.

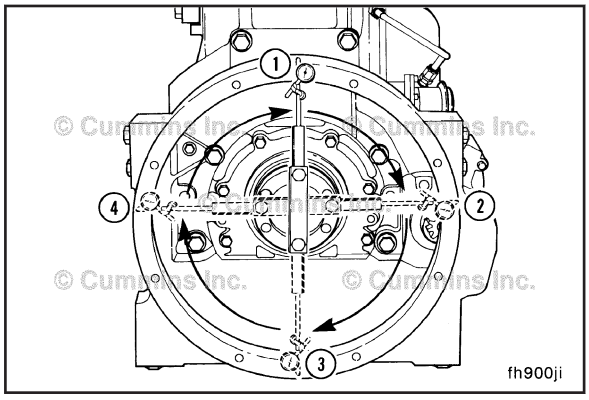


Continue to rotate the crankshaft until the indicator is at the 12 o'clock position. Check the indicator to make sure the needle points to zero. If it does **not**, the readings will be incorrect.



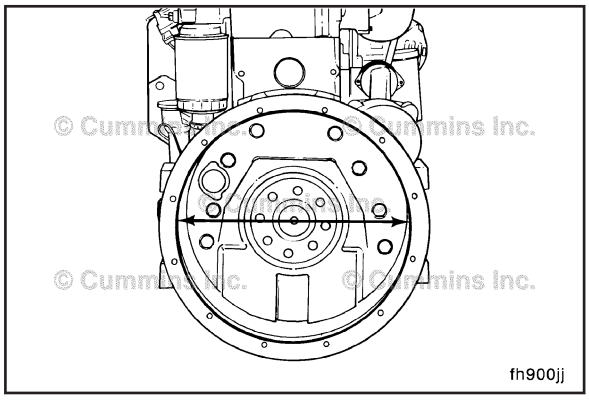
Determine the Total Indicator Reading (TIR).

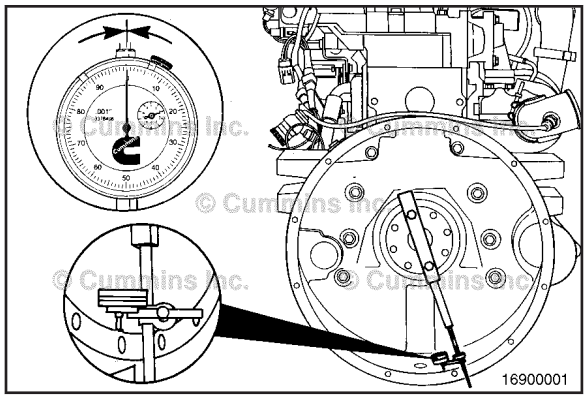
Example:	mm	in
12 o'clock	0.00	0.000
3 o'clock	+0.08	+0.003
6 o'clock	- 0.05	- 0.002
9 o'clock	+0.08	+0.003
Equals TIR	0.13	0.005



The maximum allowable TIR is determined by the diameter of the housing bore. If out of specifications, replace the housing.

Flywheel Housing Bore Size/TIR				
SAE No.	Bore Diameter	TIR Max		
-	mm	in	mm	in
2	447.68 to 447.80	17.625 to 17.30	0.20	0.008
3	409.58 to 409.70	16.125 to 16.130	0.20	0.008

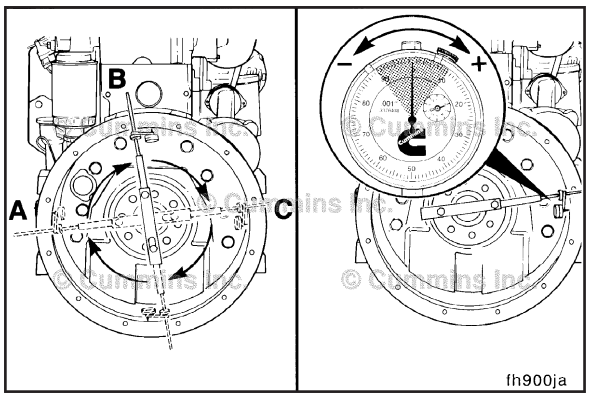




Bore Alignment

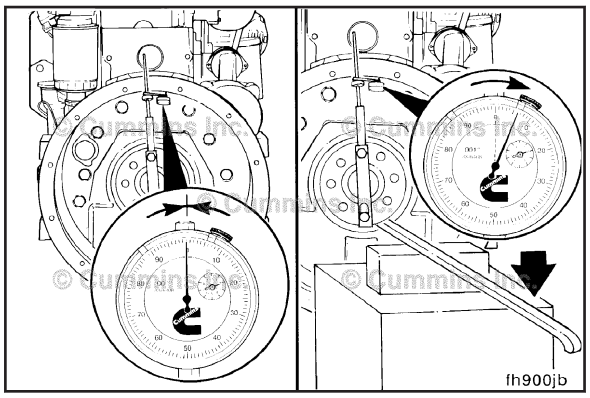
Attach a dial indicator gauge, Part Number 3376050, to the crankshaft. The dial indicator can be mounted by any method that holds the extension bar of the indicator rigid so it does **not** sag. If the bar sags or the indicator slips, the readings obtained will be inaccurate.

Position the indicator in the 6 o'clock position and the gauge at zero.



Slowly rotate the crankshaft. Record the readings obtained at the 9 o'clock, 12 o'clock, and 3 o'clock positions as (a), (b), and (c) in the concentricity work sheet. Recheck 0 at the 6 o'clock position.

The values for (a), (b), and (c) can be positive or negative. See the accompanying figure to determine the correct sign when recording these values.



⚠CAUTION⚠

Do not force the crankshaft beyond the point where the bearing clearance has been removed. Do not pry against the flywheel housing. These actions could cause false bearing clearance readings.

Rotate the crankshaft until the dial indicator is at the 12 o'clock position and 0 the gauge.

Use a pry bar to raise the rear of the crankshaft to its upper limit. Record the value as (d) in the concentricity work sheet. This is the vertical bearing clearance adjustment and will **always** be positive.

Be careful **not** to damage the sealing surface when using a pry bar on the crankshaft.

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Use the concentricity work sheet to determine the values for the total vertical, and total horizontal values.

The total horizontal is equal to the 9-o'clock reading, (a), minus the 3-o'clock reading, (c).

The total vertical is equal to the 12-o'clock reading, (b), plus the bearing clearance, (d).

Example:

6 o'clock = ref = 0

9 o'clock = [a] = 0.004

12 o'clock = [b] = 0.003

3 o'clock = [c] = -0.002

Using the work sheet and the numbers from the example, the total horizontal value equals 0.006 and the total vertical value equals 0.005.

Concentricity Worksheet

9 o'clock	a = 0.004
3 o'clock	c = -0.002
Total Horizontal	a – c = .006
12 o'clock	b = .003
Bearing Clearance	d = .002
Total Vertical	b + d = .005

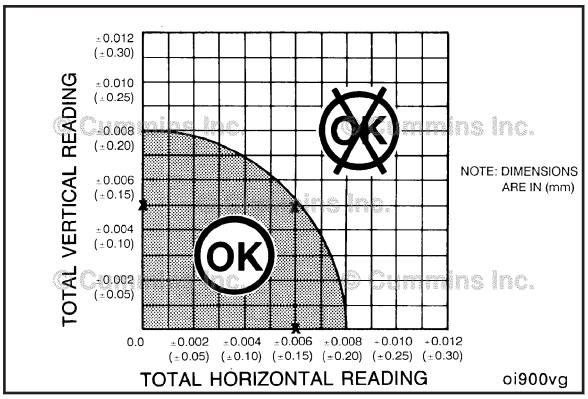
oi900vf

Mark the total horizontal value on the horizontal side of the chart and the total vertical on the vertical side of the chart.

Use a straight edge to find the intersection point of the total horizontal and total vertical values. The intersection point **must** fall within the shaded area for the flywheel housing concentricity to be within specification.

Use the total horizontal and total vertical values from the previous example to the intersection point falls within the shaded area. Therefore, the flywheel housing concentricity is within specification.

Use the accompanying chart for (Society of Automotive Engineers) SAE 1, 2, and 3 flywheel housings.



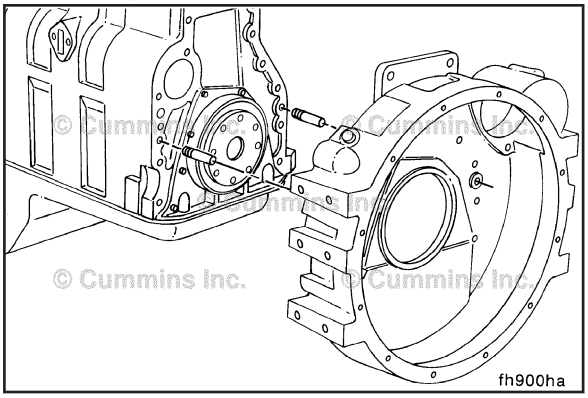
If the intersection point falls outside the shaded area, the ring dowels **must** be removed and the housing repositioned.

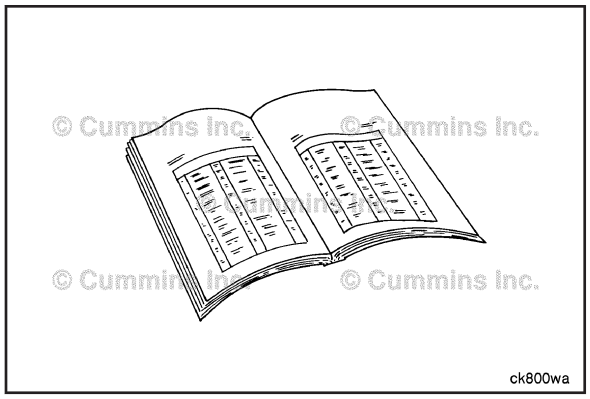
NOTE: The ring dowels are **not** required to maintain concentricity of the housing; the clamping force of the capscrews holds the housing in place.

After the ring dowels are discarded, install the flywheel housing on the engine.

To position the housing, tighten the capscrews enough to hold the flywheel housing in place, but loose enough to enable small movement when struck lightly with a mallet.

Recheck the concentricity. When concentricity is within specification, torque the capscrews to the specified value.





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 both rear engine mounts. Refer to Procedure 016-003 in Section 16.
- Install the flywheel/ring gear assembly. Refer to Procedure 016-005 in Section 16.
- Install the starting motor. Refer to Procedure 013-020 in Section 13.
- Install the clutch, transmission, and all related components, if equipped. See the OEM service manual.
- Install the transmission and related components, if equipped. See equipment manufacturer service information.
- If equipped with a wet flywheel housing, fill the flywheel housing with oil. See equipment manufacturer service information.
- If previously removed, attach any OEM components (mufflers, shift mechanisms, air filters, etc.) to the flywheel housing. See equipment manufacturer service information.
- Connect the battery. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks or vibration.

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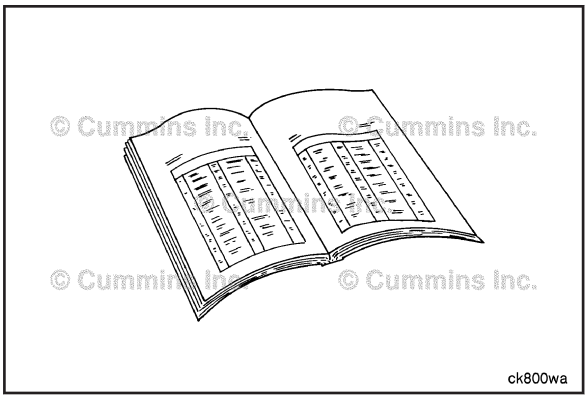
Marine Applications

⚠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 two aftercooler mounting capscrews into the flywheel housing. Refer to Procedure 010-005 in Section 10.
- 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, marine drive adapter, if equipped, and the marine drive gear. Refer to the marine drive gear OEM service manual.
- Install the rear engine mounts. Refer to Procedure 016-003 in Section 16.
- Install the propeller drive. Refer to the vessel OEM service manual.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks or vibration.



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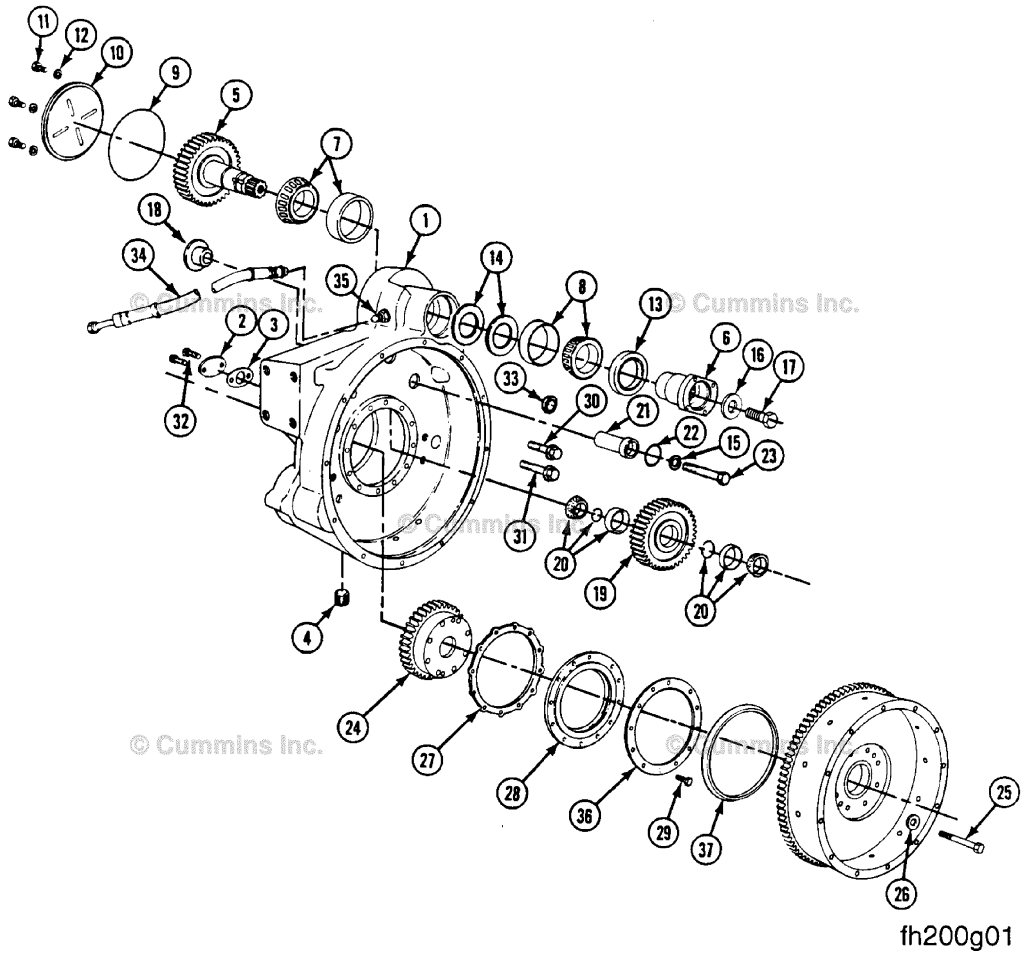
Flywheel Housing, REPTO (016-007)

Exploded View



Rear Engine Power Takeoff

1 Housing, flywheel - 1
2 Cover, access hole - 1
3 Gasket, cover plate - 1
4 Plug, threaded drain - 1
5 Shaft, accessory drive output - 1
6 Flange, power takeoff - 1
7 Bearing, roller (large) - 1
8 Bearing, roller (medium) - 1
9 Seal, rectangular ring (tetra) - 1
10 Plate, cover (ribbed) - 1
11 Capscrew - 4
12 Washer, plain - 4
13 Seal, oil (output shaft) - 1
14 Shims (see next page)

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15 Washer, plain - 1
16 Washer, plain (PTO flange) - 1
17 Screw, hexagon head cap - 1
18 Retainer, shaft - 1
19 Gear, idler - 1
20 Assembly, bearing and race - 2
21 Shaft, idler - 1
22 Seal, o-ring - 2
23 Screw, hexagon head cap - 1
24 Gear, crankshaft - 1
25 Screw, hexagon head cap - 8
26 Washer, plain - 8
27 Gasket, carrier - 1
28 Kit, seal - 1
29 Screw, captive washer cap - 12
30 Screw, hexagon head cap - 5
31 Screw, hexagon head cap - 7
32 Screw, hexagon head cap - 2
33 Plug, expansion - 1
34 Hose, flexible oil supply - 1
35 Connection, mate oil supply - 1
36 Ring, clamping - 1
37 Seal, dust - 1.

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Flywheel Housing, REPTO (016-007)

Exploded View

NOTE: There are seven shims available. A given REPTO can have any combination of these shims.

Reference Number	Description	mm	in
14	Shim	0.127	0.005
14	Shim	0.254	0.010
14	Shim	0.381	0.015
14	Shim	0.051	0.002
14	Shim	0.076	0.003
14	Shim	0.508	0.020
14	Shim	1.016	0.040

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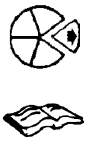
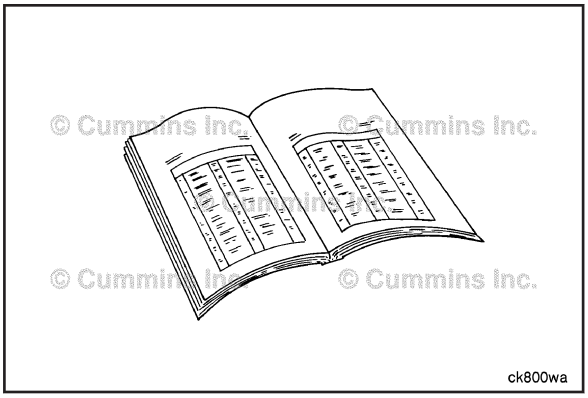
Preparatory Steps



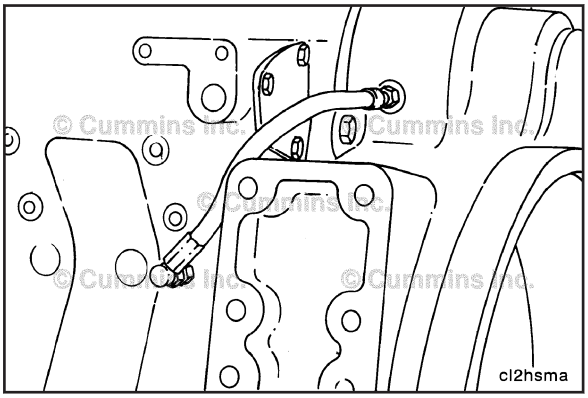


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

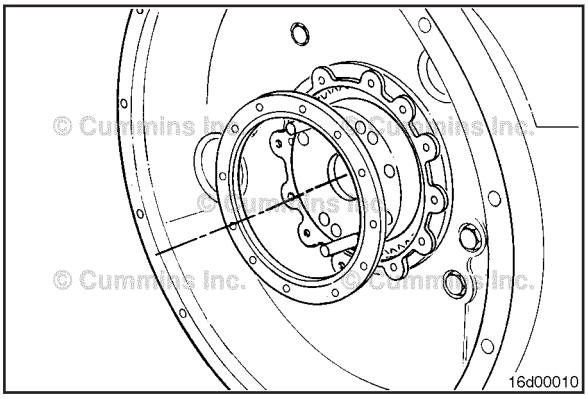
- Disconnect the battery. Refer to the OEM service manual.
- Remove the transmission, clutch, and all related components, if equipped. Refer to the OEM service manual.
- Remove the flywheel/ring gear assembly. Refer to Procedure 016-005 in Section 16.
- Adequately support the engine to prevent damage.
- Remove the starting motor. Refer to Procedure 013-020 in Section 13.
- Remove both rear engine mounts. Refer to Procedure 016-003 in Section 16.

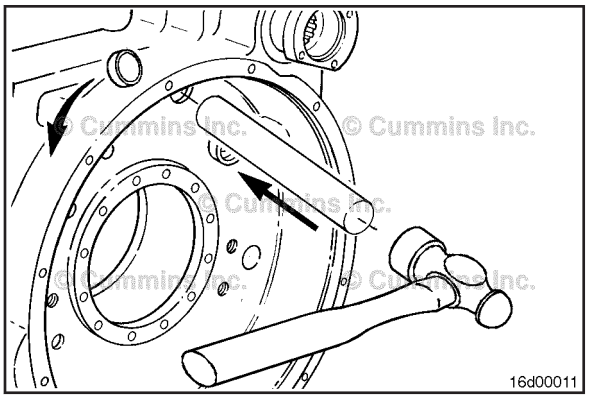
Remove

Remove the REPTO oil supply line.



Remove the oil seal capscrews, oil seal, and gasket.

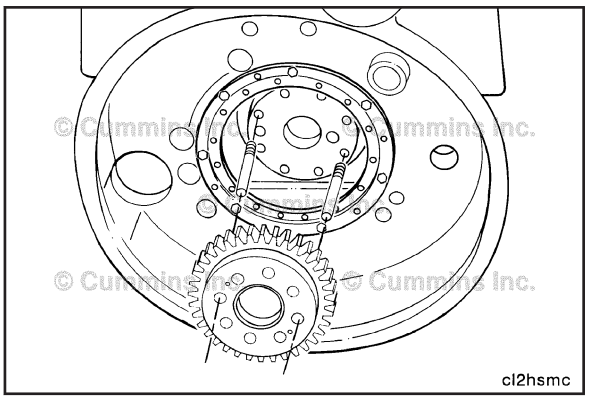




To gain access to the housing capscrews, use a drift to drive the cup plugs straight through into the housing.

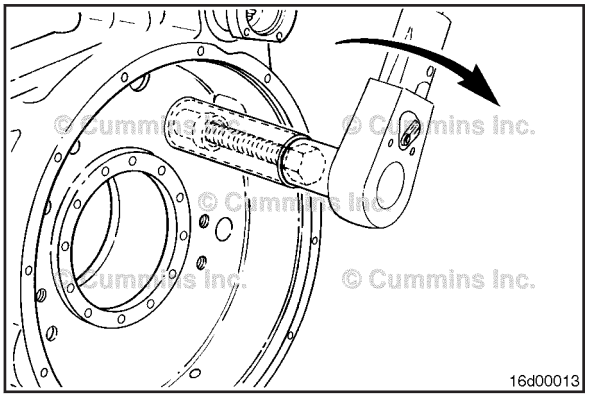
Retrieve the plugs from inside the housing.

Do **not** attempt to back the plugs out or rotate the plugs out of the housing. The cup plug bore will be damaged and oil leakage will occur.



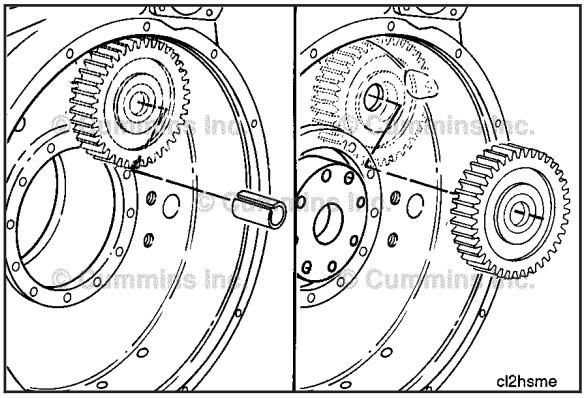
Install two crankshaft locator studs, Part Number 3822784, into the crankshaft flywheel mounting flange, 180 degrees apart.

Remove the crankshaft drive gear.



△CAUTION△
The idler gear will fall when the shaft is removed.

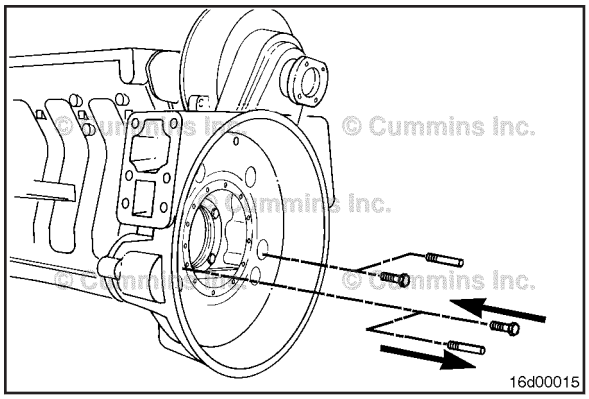
Use the idler shaft puller, Part Number 3823709, to remove the idler shaft.



Remove the idler gear to gain access to the rest of the housing capscrews.

Remove two of the capscrews and install two guide pins, Part Number 3376638, to support the housing during removal.

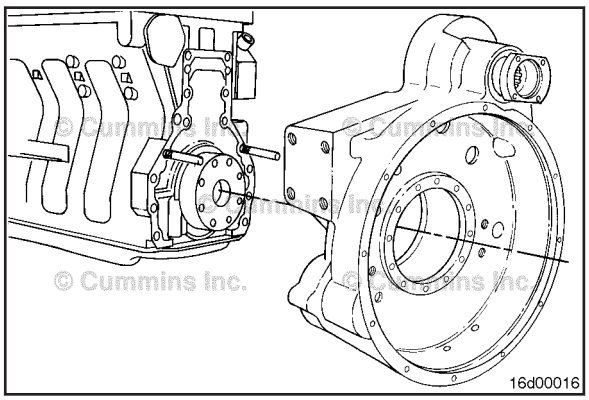
Use an offset wrench, Part Number 3823892, to remove the capscrews that are **not** visible.



⚠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 remaining capscrews. Use a rubber hammer to loosen the housing.

Remove the housing.

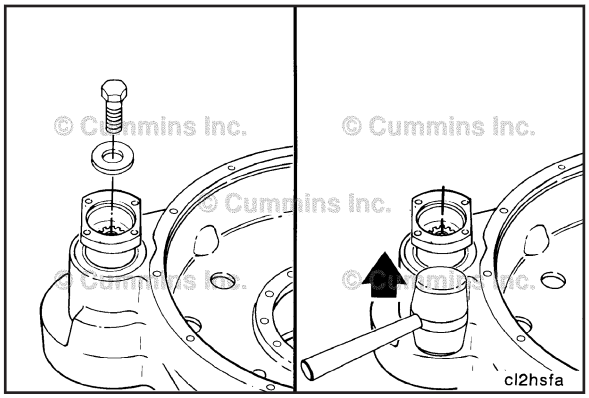


Disassemble

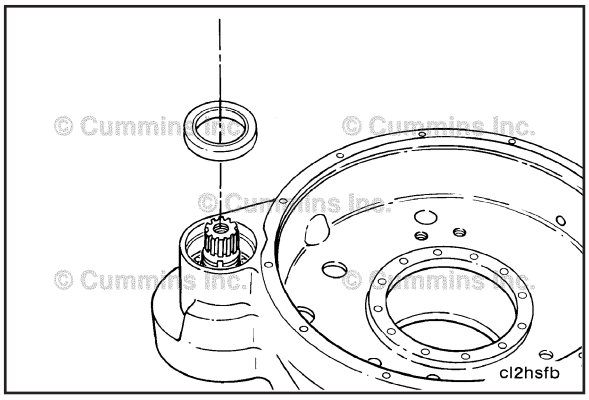
Use gear locking tool, Part Number 3823891, to prevent the output shaft from turning when removing the retainer capscrew.

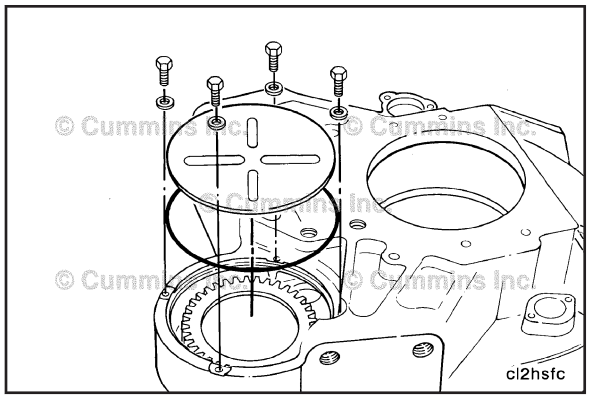
Remove the capscrew and washer that secures the output flange to the output shaft.

Use a rawhide hammer to remove the output flange and flat washer from the output shaft.



Use a dent puller to remove the seal. Do **not** damage the surface of the housing or seal bore.



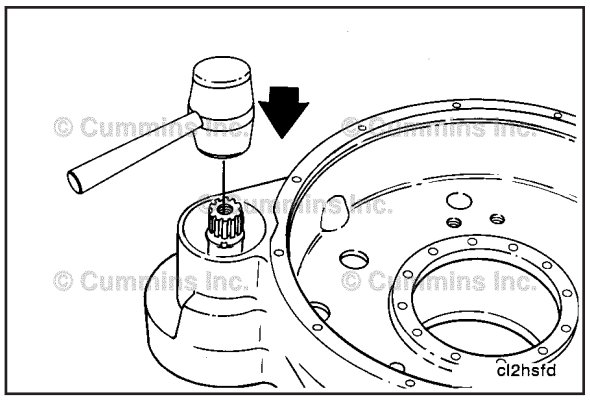


When the housing is turned over, the bearing will fall out. Do **not** allow the bearing to be damaged.

Turn the housing over so the four cover plate capscrews are accessible. Be careful **not** to damage the output shaft.

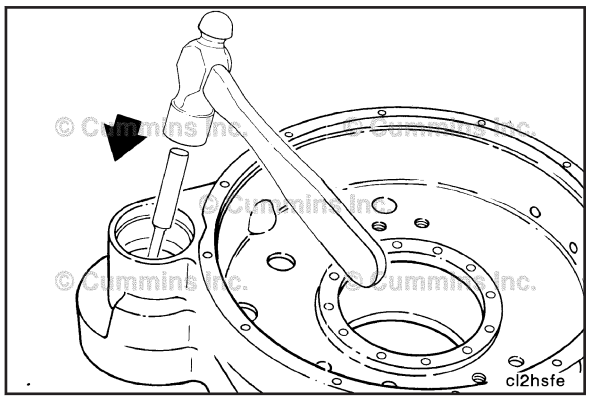
Remove the capscrews and ribbed cover plate from the output gear housing.

Remove and discard the square cut o-ring.

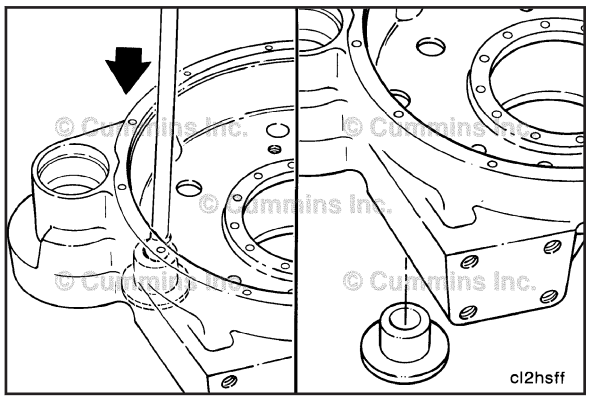


Save the original shims for rebuild purposes. They will be used to set the proper end clearance on the output shaft and bearing assembly.

Turn the housing over and use a rawhide hammer to hit the end of the output shaft to remove the output shaft sub-assembly from the REPTO housing.



With the housing positioned so the cylinder block mating surface is down, use a hammer and brass punch to drive the bearing outer races out of the output shaft housing bore.



Support the housing in a press with the cylinder block mating surface down.

With a long mandrel, press out the idler shaft bushing.

Remove and discard the o-ring.

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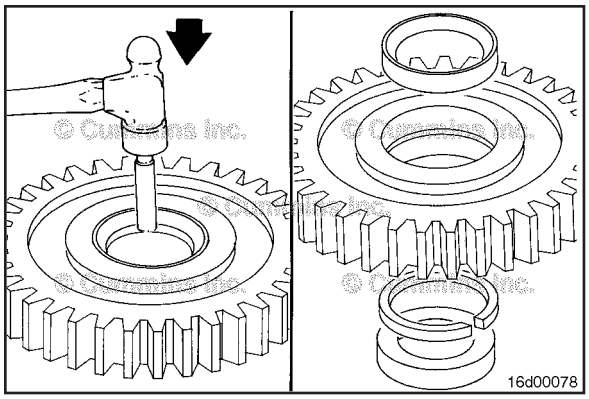
Use a hammer and brass drift to remove the two bearing outer races from the bore of the idler gear. Discard the outer races.

Remove the large spacer ring from the center groove of the gear. Discard the spacer ring.



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.

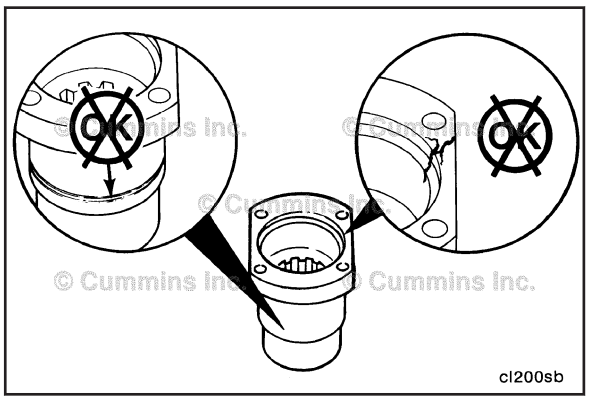
Use a steam cleaner to clean all areas of the idler gear.

Inspect the output shaft and bearings for wear.

Inspect the output gear for damage.

Inspect the output flange for damage or wear grooves from the oil seal.

Replace if necessary.

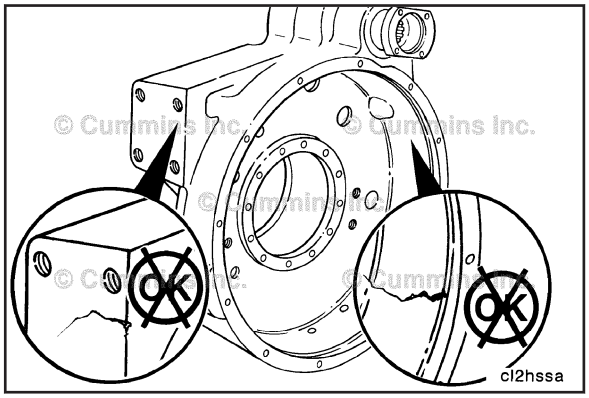


Inspect the REPTO housing for cracks at the rear engine mounting surfaces and the flywheel bore.

Replace the housing if cracked.

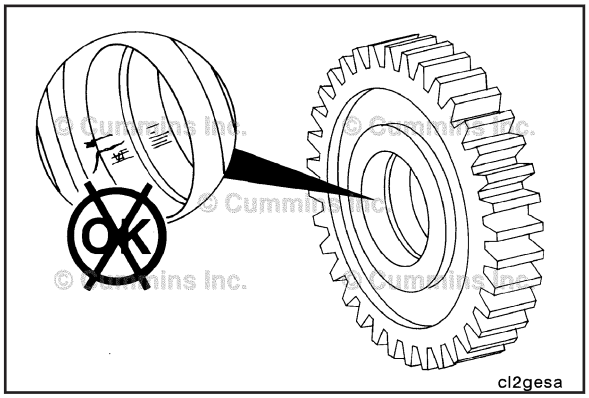
Inspect the idler shaft bushing for wear.

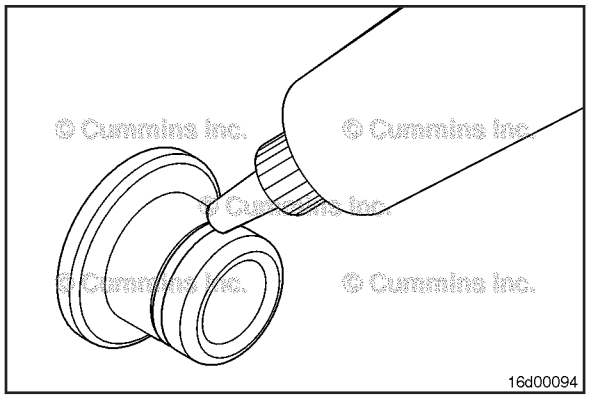
Replace the bushing if worn.



Inspect the bore, side faces, and teeth of the idler gear.

Replace the gear if there are cracks or discoloration from heat damage, or any other damage.

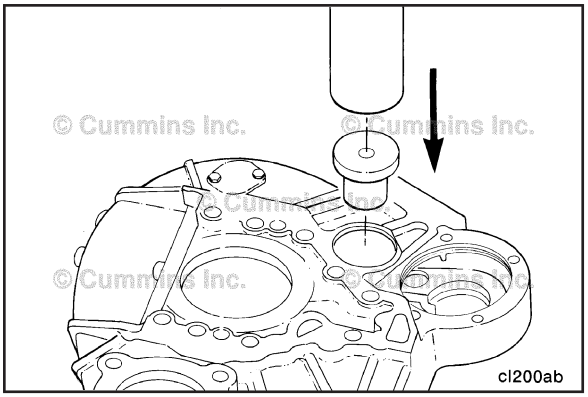




Assemble

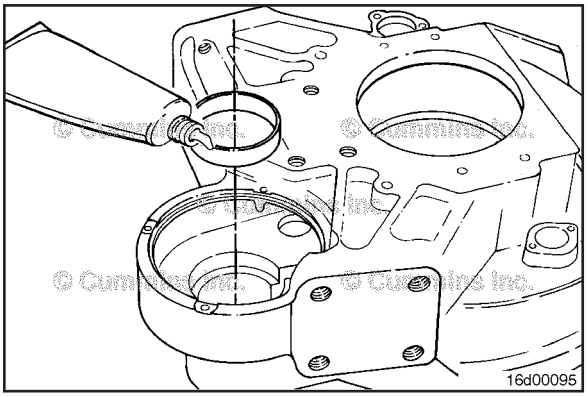
Install a new o-ring on the idler shaft bushing.

Use assembly lubricant, Part Number 3163087, or equivalent, to lubricate the o-ring.



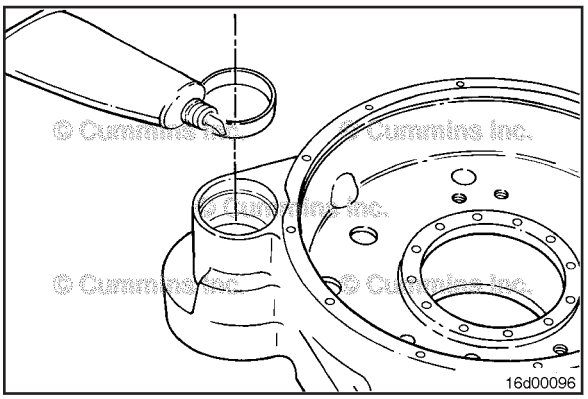
Support the housing evenly with the engine mating surface up.

Press the new bushing into the housing until it is below the surface of the cylinder block mating surface.



Use assembly lubricant, Part Number 3163087, or equivalent, to lubricate the larger bearing race.

Use the larger end of the driver, Part Number 3823893, to press the bearing race to the shoulder in the housing.



Turn the housing over and support it evenly in the press.

Use assembly lubricant, Part Number 3163087, or equivalent, to lubricate the smaller bearing race.

Use the smaller end of the driver, Part Number 3893893, to press the bearing race to the shoulder in the housing.

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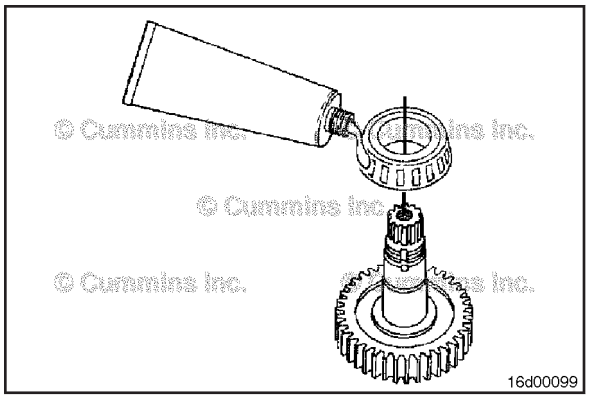
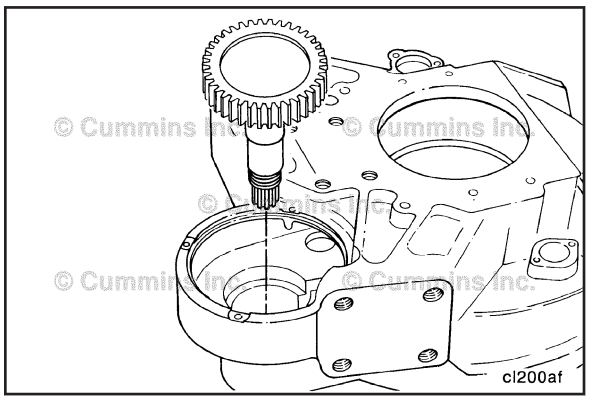
Use assembly lubricant, Part Number 3163087, or equivalent, to lubricate the output shaft and larger bearing.

Install the larger bearing onto the output shaft.



Position the housing on the table so the cylinder block mating surface is up.

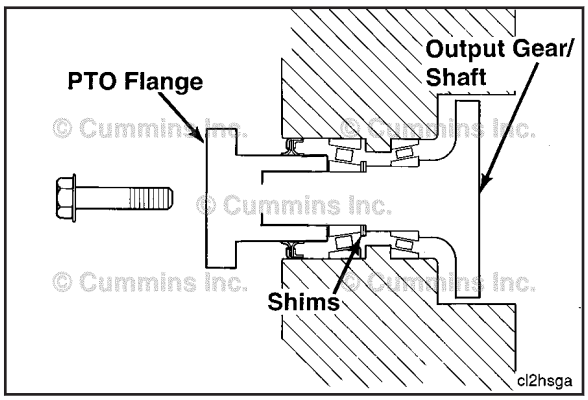
Install the output shaft assembly into the housing.



The correct end clearance (rolling resistance) is determined by the number and thickness of shims used between the two bearings.

When the shim thickness is increased, there is more shaft end clearance and less rolling resistance.

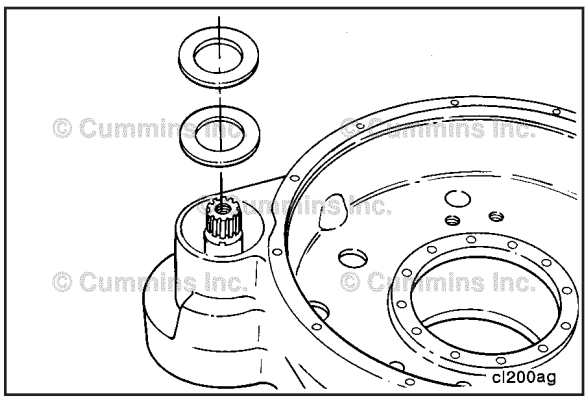
When the shim thickness is decreased, there is less shaft end clearance and more rolling resistance.



Turn the housing over with the engine mating surface down, while holding the output shaft and gear in place.

If the original thickness of shims is **not** available for reuse, a beginning thickness of 1.47 mm [0.058 in] can be used as a starting point.

Install the original thickness of shims.



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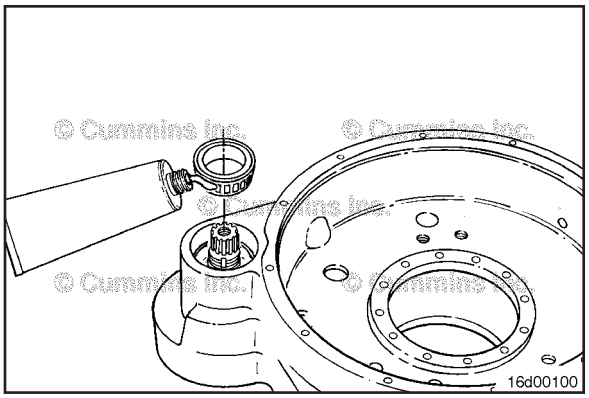
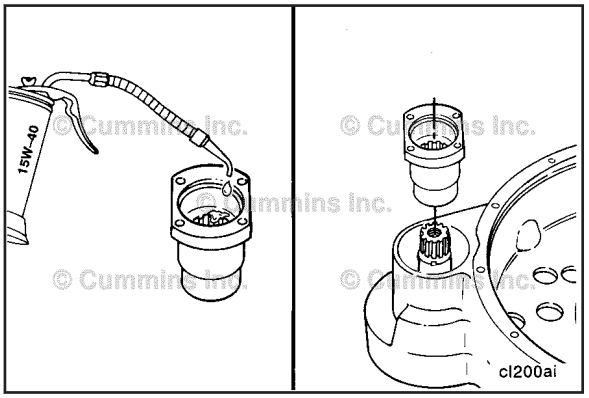


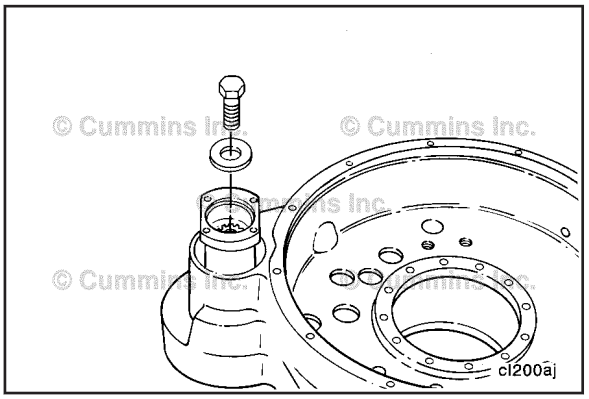
Use assembly lubricant, Part Number 3163087, or equivalent, to lubricate the smaller bearing.

Install the smaller bearing onto the shaft.



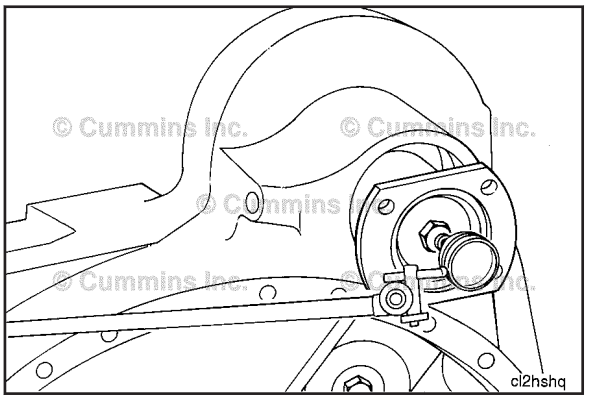
Temporarily install the output flange before installing the oil seal.

Use clean 15W-40 engine oil to lubricate the splines.



Install the flat washer and capscrew. Use the gear locking tool, Part Number 3823891, to hold the output shaft while tightening the capscrew.

Torque Value: 205 N•m [151 ft-lb]



Measure the shaft end play.

Shaft End Play		
mm		**in**
0.0	MIN	0.0
0.03	MAX	0.001

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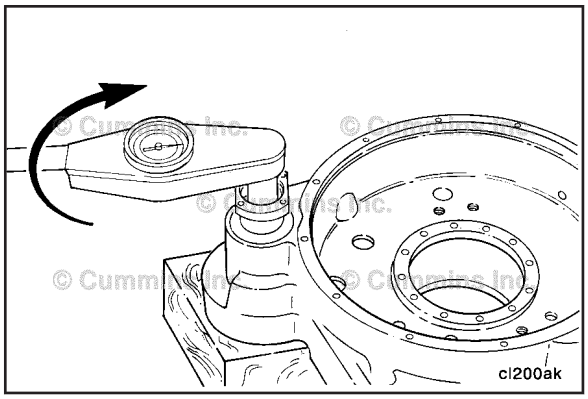
Check the output shaft rolling resistance with a torque wrench.

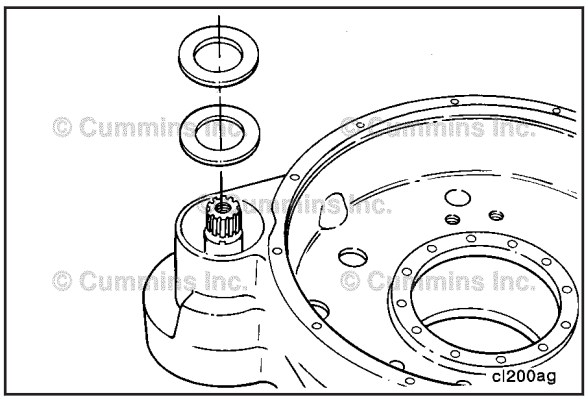
Rolling Resistance 0.6 to 1.1 N•m [5 to 10 in-lb]



If the rolling resistance is **not** within specification, remove the output flange and smaller bearing.

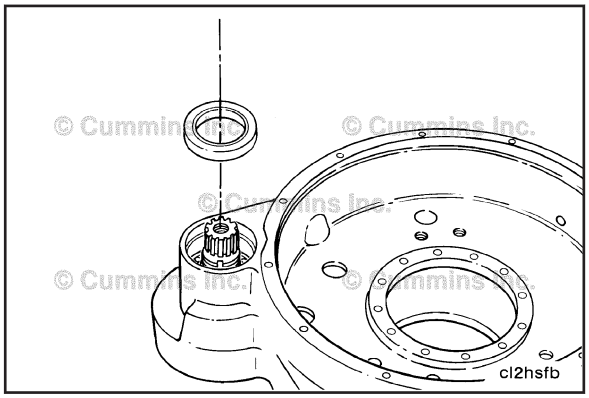
Add or subtract shims to obtain the correct rolling resistance.

Adding more shims will decrease the resistance and removing shims will increase resistance. Any combination of shims can be used.



Once the correct rolling resistance is obtained, remove the output flange and install a new oil seal.

Press the oil seal flush with the housing surface.

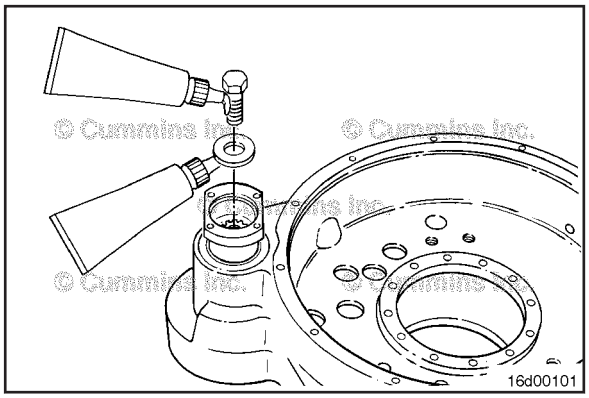


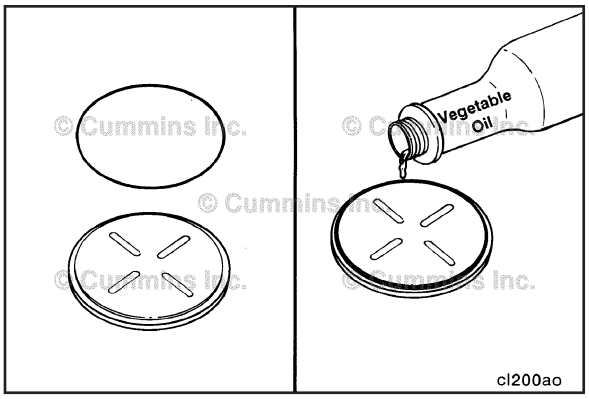
Apply pipe sealant, Part Number 3375066, to the output flange capscrew and under the washer.

Install the output flange flat washer and capscrew.

Tighten the capscrew.

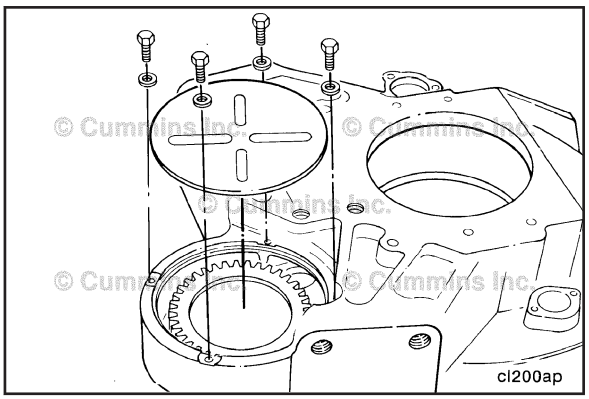
Torque Value: 205 N•m [151 ft-lb]





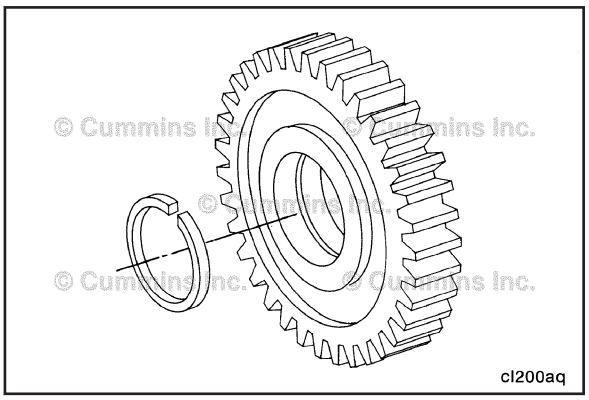
Install a new o-ring on the bearing housing cover.

Use clean vegetable oil to lubricate the o-ring.



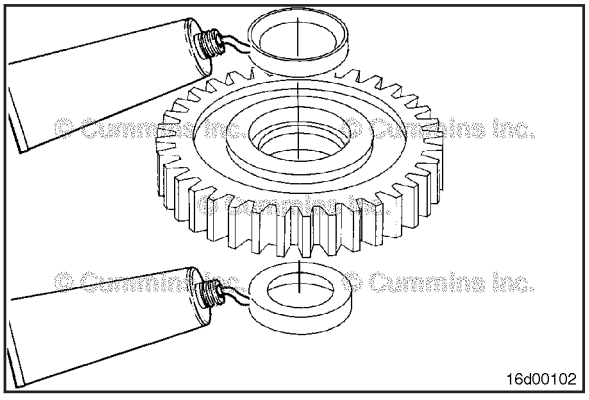
Install and tighten the cover and four capscrews.

Torque Value: 18 N•m [159 in-lb]



Insert a new spacer ring into the bore of the idler gear.

Push until it snaps into place in the center groove.



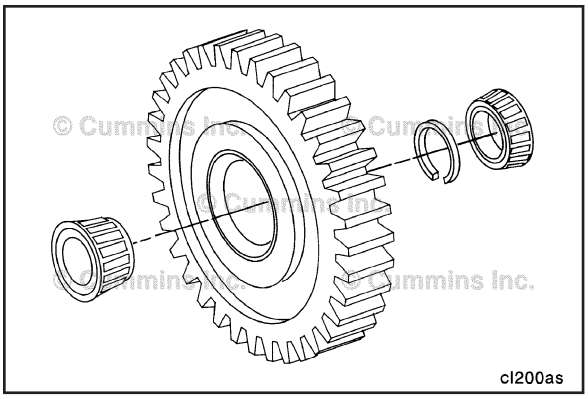
Use assembly lubricant, Part Number 3163087, or equivalent, to lubricate the bearing outer races.

Press the two new bearing outer races into the bore of the idler gear.

The larger side of the taper **must** face toward the outside of the gear.

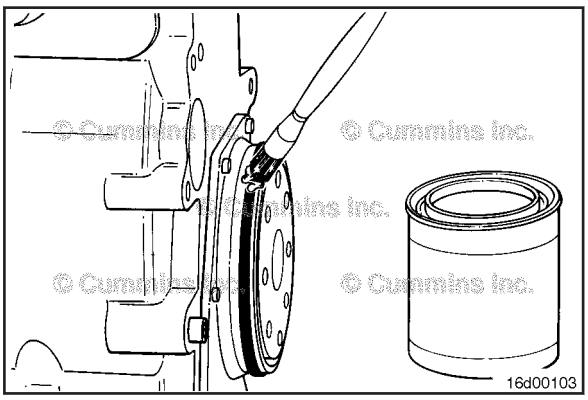
Do **not** interchange individual parts that make up the idler gear bearing assembly. Rebuild the idler gear with bearings that are packaged together.

Keep the two roller bearing assemblies and the spacer ring with the idler gear.

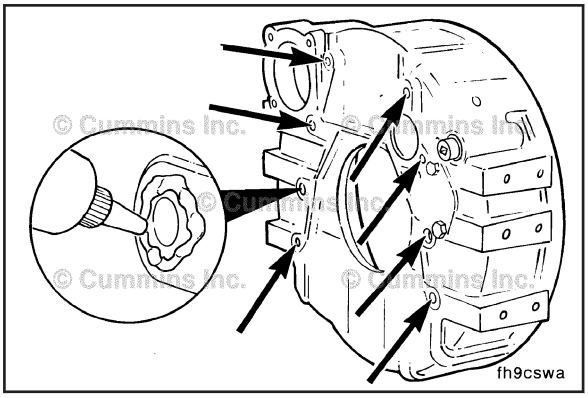


Install

Install the rectangular seal on the rear seal carrier and lubricate with assembly lubricant, Part Number 3163087, or equivalent.



Apply a continuous bead of RTV sealant, Part Number 3164067, or equivalent, around all capscrew holes on the mounting surface of the flywheel housing.

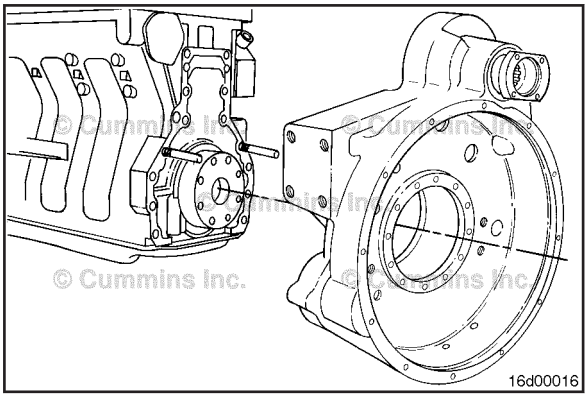


⚠WARNING⚠
This component or assembly weighs greater than 23 kg {50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Inspect the rear face of the cylinder block and flywheel housing mounting surface for cleanliness and nicks or burrs.

Install the flywheel housing over the two ring dowels.

Be sure the sealing ring is **not** damaged during installation.



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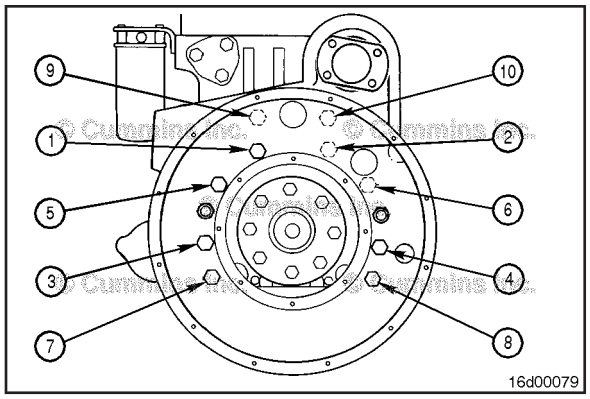
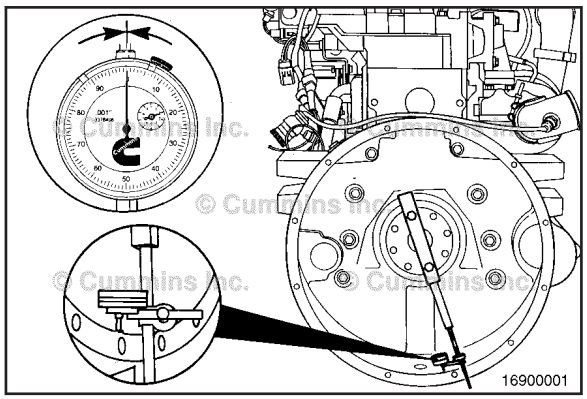
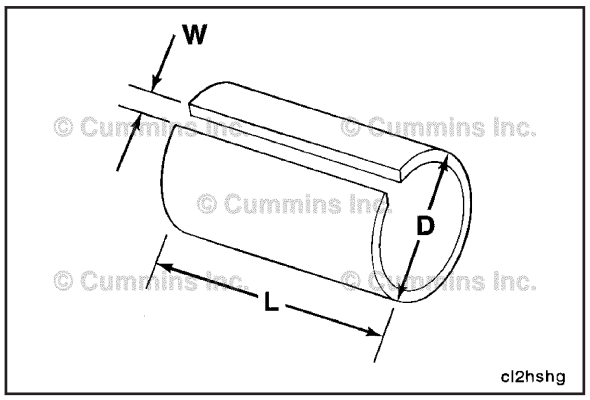


Install the capscrews and tighten in the sequence shown. Use an offset wrench, Part Number 3823892, for capscrews hidden from view.

Torque Value: 77 N•m [57 ft-lb]



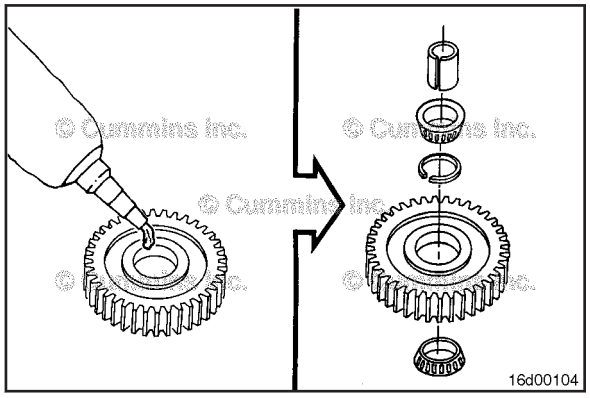
Before installing the idler gear, measure the flywheel housing bore and face alignment. Refer to Procedure 016-006 in Section 16.



Fabricate a sleeve from 38.10 mm [1.50 in] PVC (or equivalent) to the following dimensions:

Length: 25.4 mm [1.0 in]

Slot: 12.70 mm [0.50 in]



The outer bearing races of new replacement gears are already pressed into the gear.

Apply a thin film of assembly lubricant, Part Number 3163087, or equivalent, on the outer races and bearings.

Install the bearing and spacer into the idler gear. Use the babricated PVC (or equivalent) sleeve to hold the bearing assembly together when installing the idler gear assembly.

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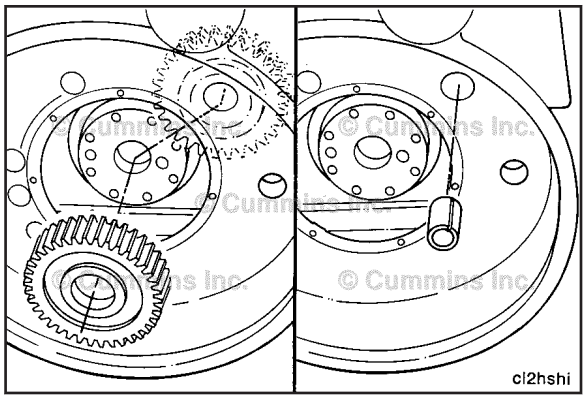
Apply a thin film of assembly lubricant, Part Number 3163087, or equivalent, into the idler shaft bore of the housing and on the idler shaft.

NOTE: For idler scissor gears, loosen the screws in the scissor gear by turning **counterclockwise** until they will no longer turn. The screws will **not** come out of the gear

Install the idler gear assembly with snap ring facing out into the flywheel housing.

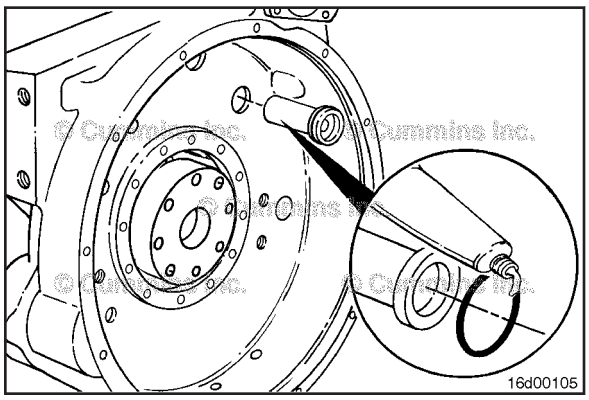
Hold the idler gear and bearing in place and remove the plastic sleeve.



Use clean assembly lubricant, Part Number 3163087, or equivalent, to lubricate the idle shaft o-ring and install the o-ring into the shaft.

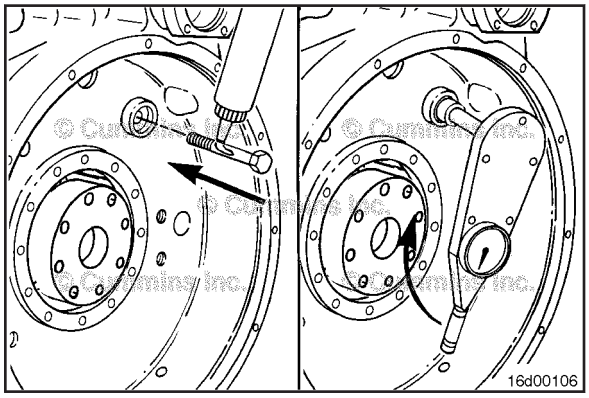
Hold the gear assembly in place and insert the idler shaft through the housing and idler gear bearings.

Do **not** use a hammer when installing the idler shaft and capscrew or the part can be damaged.



Apply assembly lubricant, Part Number 3163087, or equivalent, under the head of the idler shaft capscrew. Insert the capscrew through the idler shaft. Tighten the installation capscrew with a torque wrench.

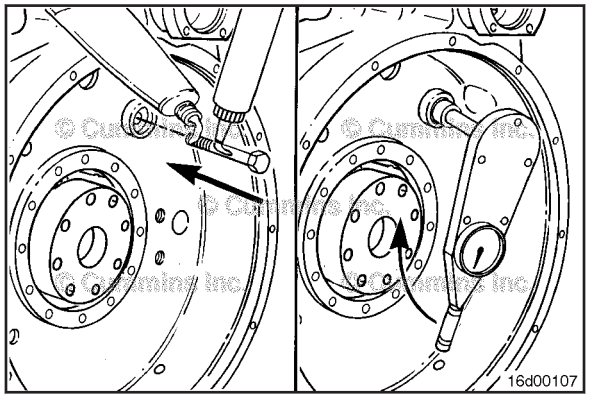
The torque needed to draw the idler shaft in place **must not** exceed 88 N•m [65 ft-lb]. If installation torque exceeds this amount, it is an indication of misalignment between the bore and the shaft. Remove the idler shaft and install it again.

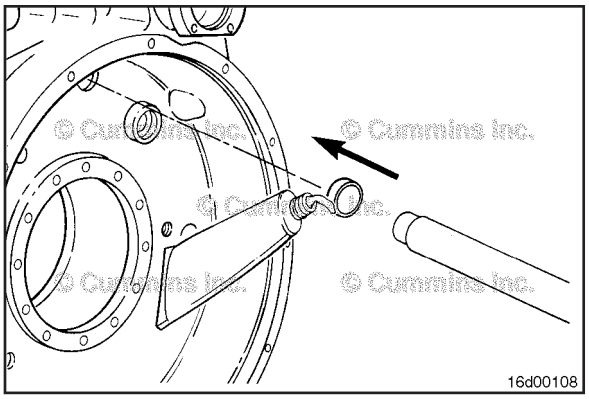


When the idler shaft has been seated, remove the capscrew.

Apply pipe sealant, Part Number 3375066, to the threads of the idler shaft capscrew. Apply assembly lubricant, Part Number 3163087, or equivalent, under the head of the capscrew and tighten to the final torque value.

Torque Value: 105 N•m [77 ft-lb]

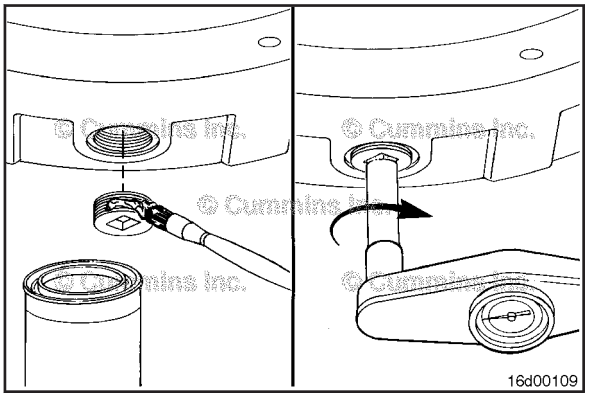




Apply a film of cup plug sealant, Part Number 3375068, to the outside diameter of the cup plugs.

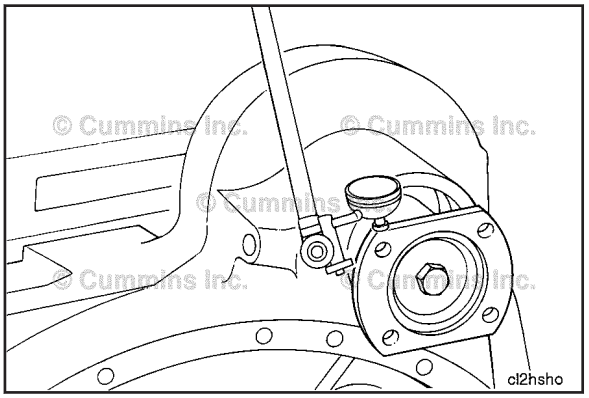
Use a driver, Part Number 3823710, to install the cup plugs into the housing, as illustrated.

When installing cup plugs, make sure they are flush with the spot face on the flywheel housing and are **not** cocked.

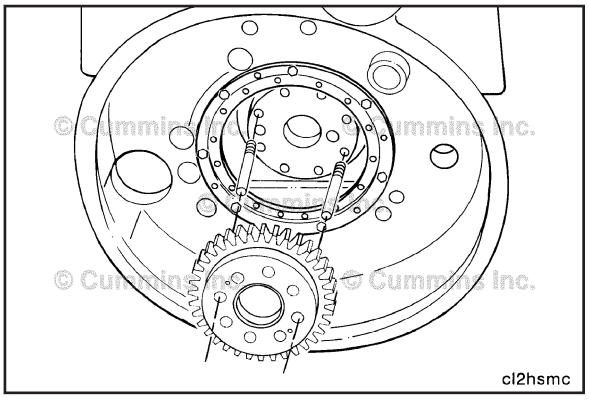


Coat the flywheel housing drain plug with pipe sealant and install it in the hole in the bottom of the flywheel housing.

Tighten the plug. Refer to Procedure 017-007 in Section 17.



Turn the output flange so that the flat sides are on the top and bottom. This prevents any interference when the transmission is installed onto the housing.



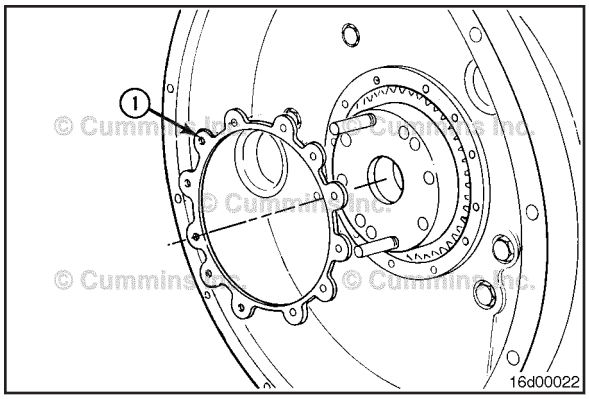
Install two crankshaft locator studs, Part Number 3822784, into the crankshaft flywheel mounting flange 180 degrees apart.

Make sure the crankshaft and the crankshaft gear are clean.

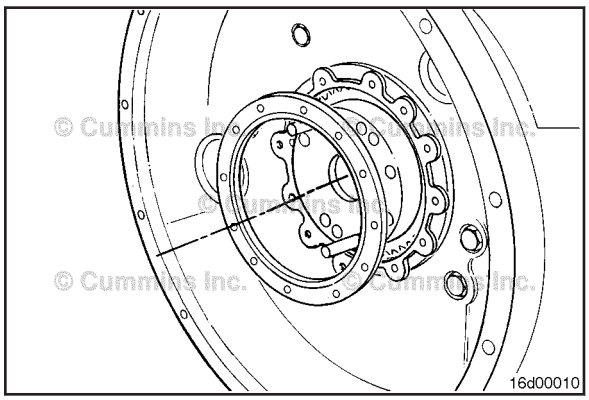
Install the crankshaft gear in the locator studs.

Do **not** use any lubricant to install the seal. The oil seal **must** be installed with the crankshaft gear seal contact surface and the lip of the seal clean and dry to provide a proper oil sealing surface.

Install a new gasket (1) in the flywheel housing.



Install a new seal over the crankshaft gear seal contact surface.

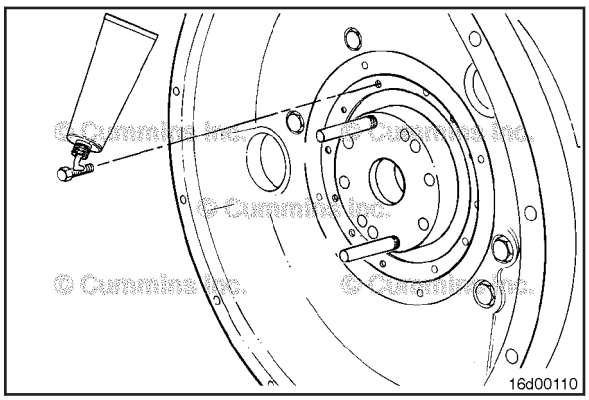


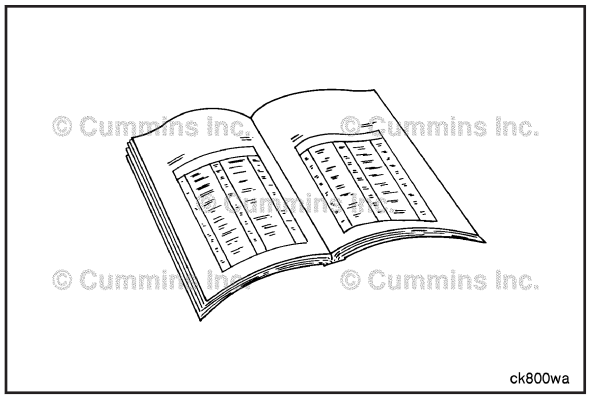
Apply sealant, Part Number 3375066, to seal the retainer capscrews.

Install the capscrews and tighten in a star pattern.

Torque Value:

Step 1	7 N•m	[62 in-lb]
Step 2	19 N•m	[168 in-lb]



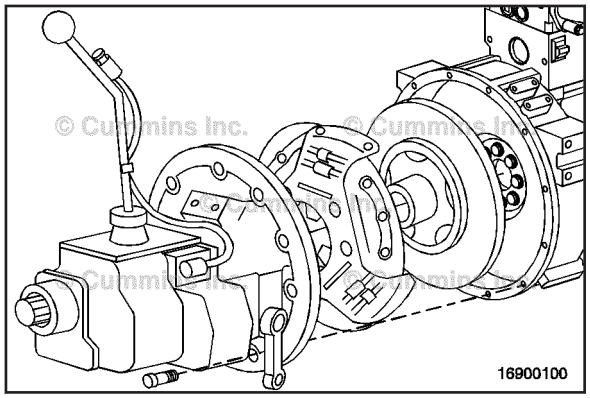


Finishing Steps

⚠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 starting motor. Refer to Procedure 013-020 in Section 13.
- Install the rear engine mounts. Refer to Procedure 016-003 in Section 16.
- Install the flywheel/ring gear assembly. Refer to Procedure 016-005 in Section 16.
- Install the flexplate, if installed. Refer to Procedure 016-004 in Section 16.
- Install the flywheel, if installed. Refer to Procedure 016-005 in Section 16.
- Install the transmission, clutch, and all related components, if equipped. Refer to the OEM service manual.
- Connect the battery. Refer to the OEM service manual.
- Operate the engine and check for leaks.

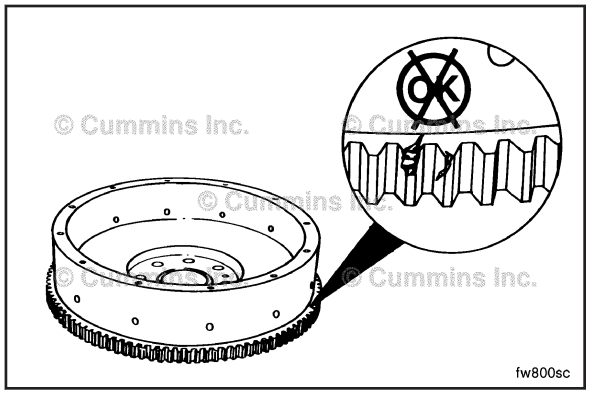


Flywheel Ring Gear (016-008)

Initial Check

Remove the transmission. See the equipment manufacturer's instructions.

Remove the flywheel/ring gear assembly. Refer to Procedure 016-005 in Section 16.

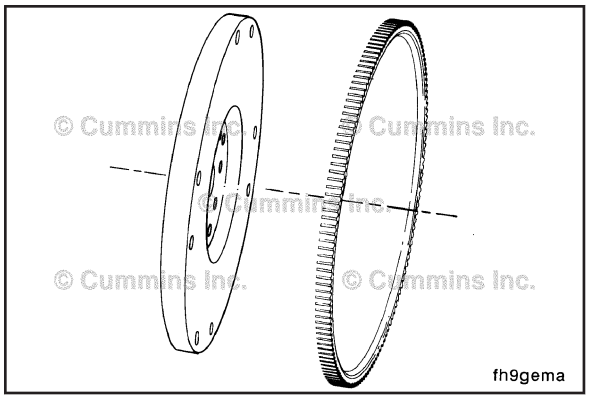


Inspect the ring gear teeth for cracks and chips.

NOTE: If the ring gear teeth are damaged, the ring gear **must** be replaced.

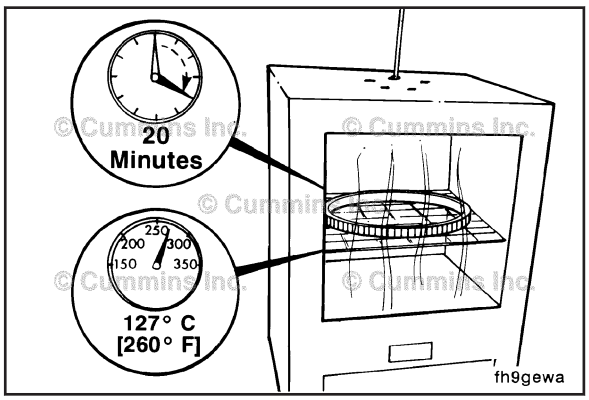
Remove

Use the drift pin to drive the ring gear from the flywheel.

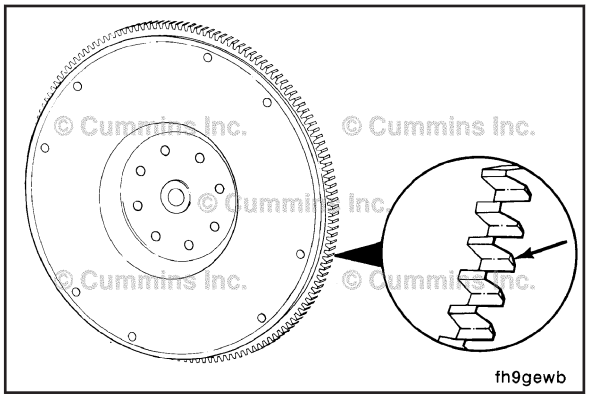


Install

Heat the ring gear for 20 minutes in an oven pre-heated to 127°C [260°F].

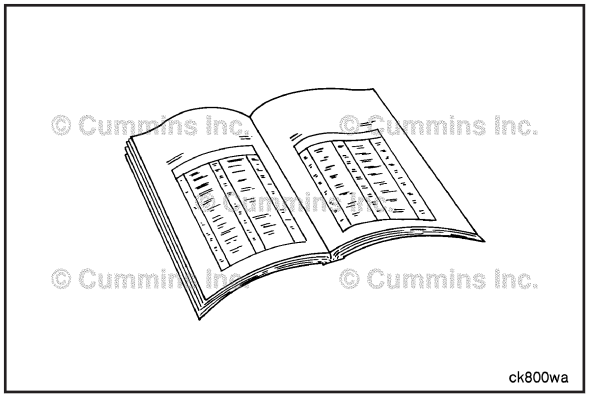


Install the ring gear. The ring gear **must** be installed so the bevel on the teeth is toward the crankshaft side of the flywheel.



Finishing Steps

- Install the flywheel/ring gear assembly. Refer to Procedure 016-005 in Section 16.
- Install the transmission, clutch, and all related components (if equipped). See the manufacturer's instructions.



Engine Mounts (016-010)

General Information

Some vibration exists in all piston type engines, due to the pulsating power inputs and reciprocating components. Some of these vibrations are internal to the engine and are compensated, or balanced, by opposing forces within the engine structure. These are generally **not** of interest to vibration isolation designs. The vibrations that are offset or balanced internally will cause shaking moments and forces that **must** be reacted to by the engine mounts. If these moments and forces are **not** adequately reduced by the engine mounting and isolation systems, they can cause customer dissatisfaction and/or damage, due to component fatigue.

The effectiveness of an engine mounting system in isolating the vehicle structure from engine vibration depends on the relationship between the frequency of the vibration coming from the engine and the natural frequency of the engine mounting system. The mounting system effectiveness is commonly measured with the term “transmissibility”. Transmissibility is the amount of engine vibration which is transmitted through the mounting system to the vehicle structure.

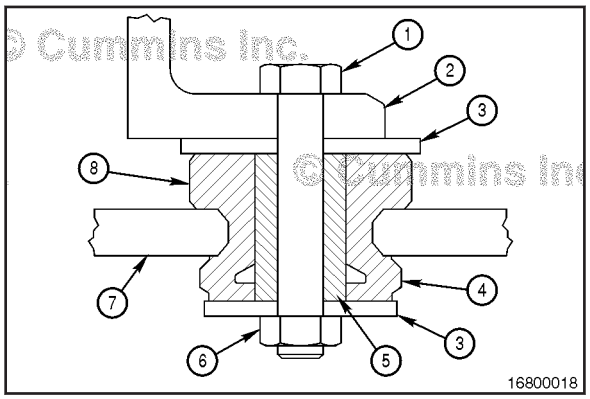
Transmissibility values greater than one indicate the engine mounting system is actually transmitting more vibration into the vehicle structure than is coming from the engine. This is possible if the natural frequency of the mounting system is close to the frequency of the engine vibration. This can result in the mounting system operating at or near resonance, with a resulting magnification of the input vibration. This is obviously an undesirable situation.

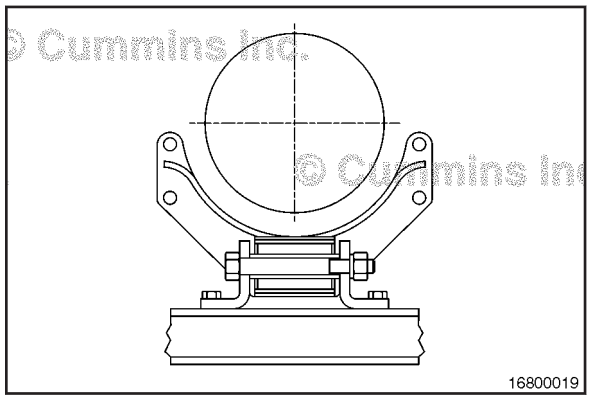
Transmissibility values of less than one indicate the mounting system is transmitting **only** a fraction of the vibration input from the engine, thus isolating the vehicle from engine vibration. Good engine mounts will reduce the amount of engine vibration transmitted to the chassis frame by at least 50 percent at idle.

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 may **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. Hard engine mounts will give little or no isolation, and can actually magnify the vibration transmitted to the chassis.

The following are illustrations of typical FRONT engine mounts.

1 Bolt
2 Supported member
3 Snubbing washer (or flat bracket surface of equal diameter
4 Rebound tail
5 Bonded metal center
6 Locknut
7 Supporting member
8 Rubber mount.





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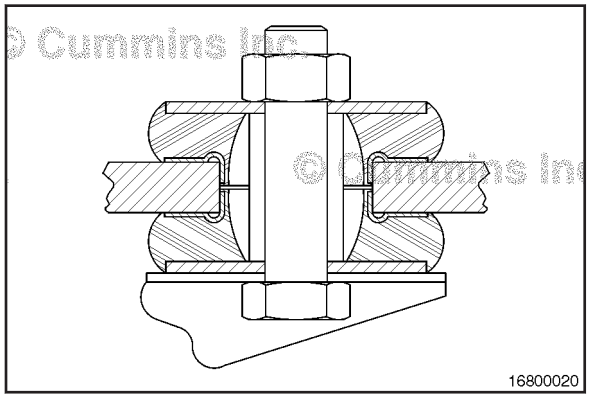
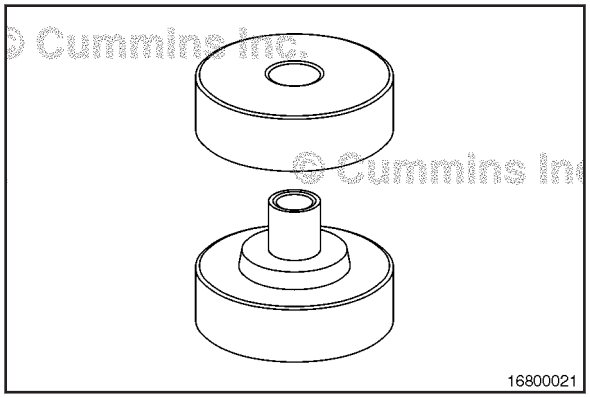
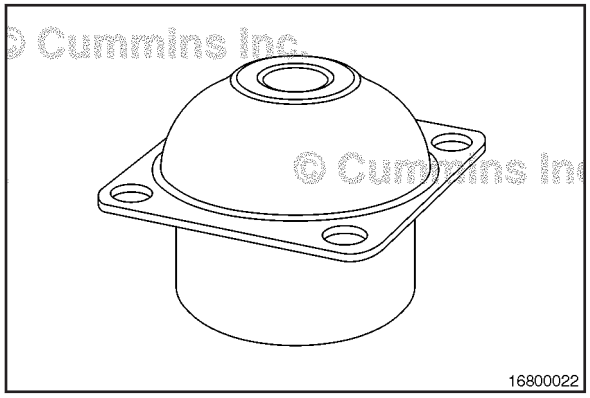
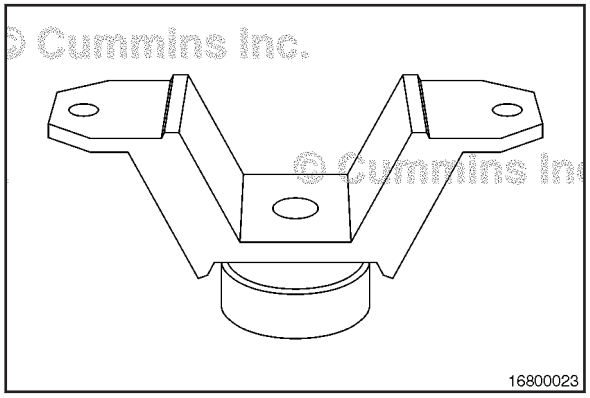
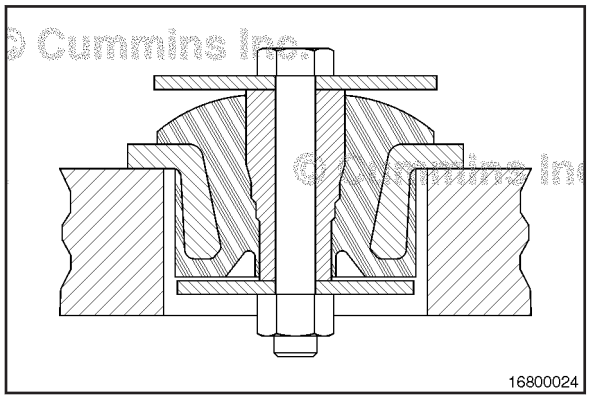


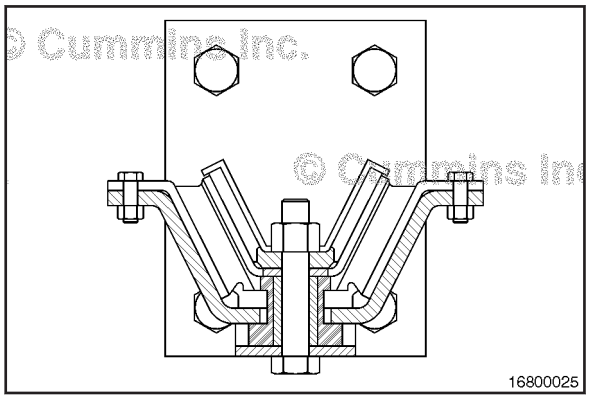


The following are illustrations of typical REAR engine mounts.









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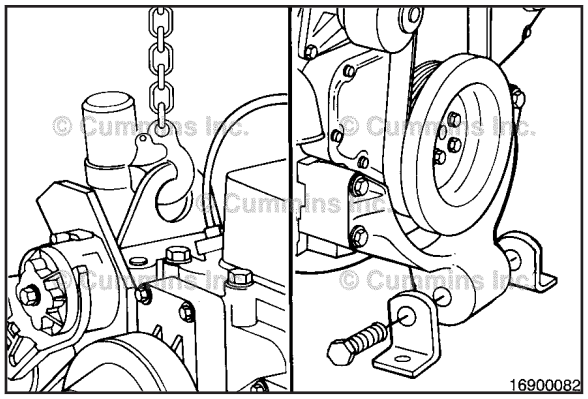


Remove

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

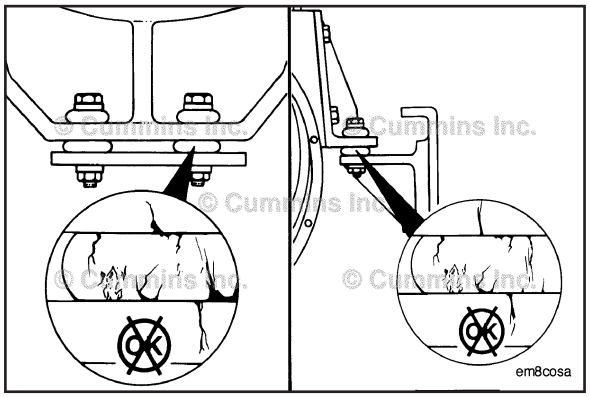
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Use a hoist or lifting fixture to support the engine.

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

Remove the capscrews from the engine mounts.

NOTE: Certain applications will require loosening of the rear engine mount fasteners to allow removal of the front engine support bracket.



Inspect for Reuse

△CAUTION△
Damaged engine mounts and brackets can cause engine misalignment. Drivetrain component damage can result in excessive vibration complaints.

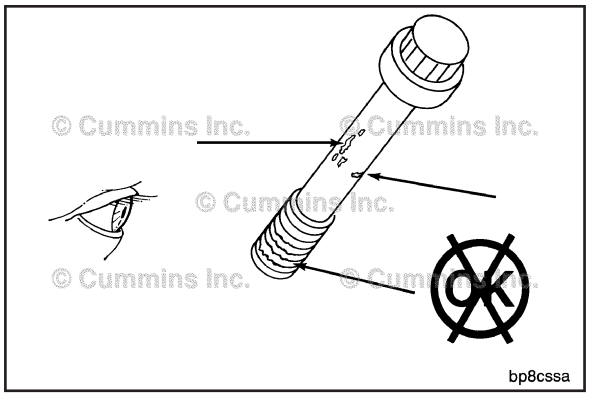
Inspect all rubber-cushioned mounts for cracks and other damage. Look for interference or contact between metal components.

Inspect all mounting brackets for cracks and damaged bolt holes.

Inspect the mounting capscrew to make sure it is **not** too long, which will **not** provide enough preload on the mount.

Replace any damaged parts as necessary.

NOTE: Damaged engine mounts, brackets, and mounting hardware can cause the engine to move out of alignment and damage the driveline components in the equipment. This can result in vibration complaints.



Inspect the capscrew for the following:

- Damaged threads
- Rust or corrosion-caused pitting
- Nicked, bent, stretched, or galled.

The capscrew **must** be replaced if it has any of the listed damages.

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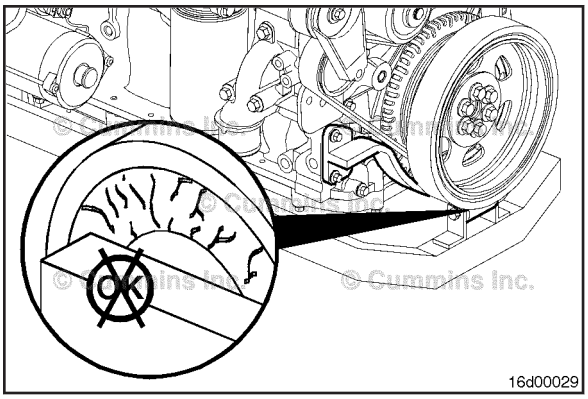
For barrel mounts, inspect for signs of contact between the side brackets and the front engine support bracket.

Contact between the engine mount and side brackets can cause vibration complaints. If contact is found, replace the front engine support bracket.



Install

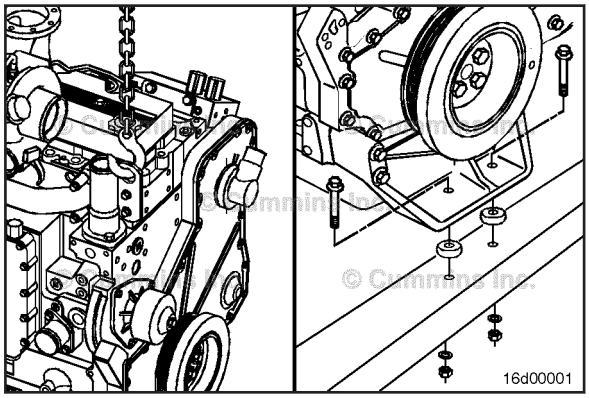
NOTE: Make sure to install any shims or spacers in the same location as removed.

Align the engine in the chassis.

Install the engine mount fasteners and tighten. Refer to the OEM service manual for torque specifications.

Remove the lifting fixture or hoist from the engine lifting brackets.

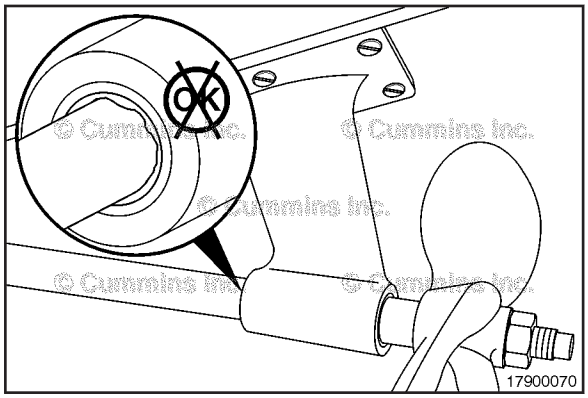
Connect all engine and chassis mounted accessories that were removed.



Propeller Shaft (016-025)

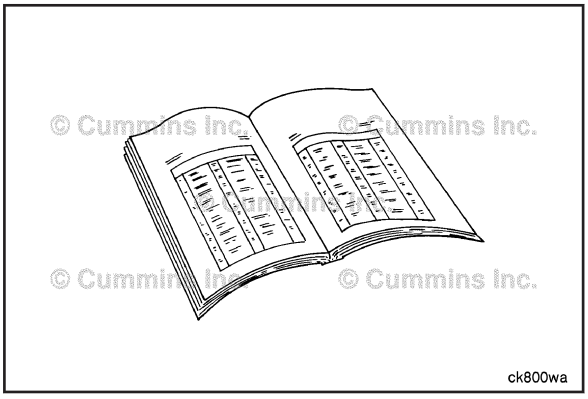
General Information

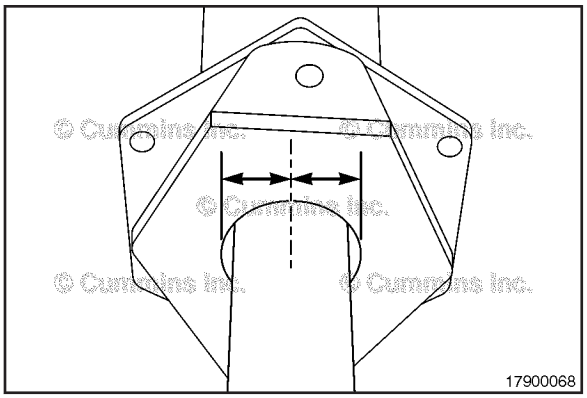
Improper alignment of the propeller shaft can result in many problems. Vibration is usually the first indicator. Failure of the shaft seal or stuffing box can also occur. If damaged shaft seals, stuffing box, strut, cutlass bearing, or propeller are found, refer to an authorized OEM repair location.



Preparatory Steps

Shaft alignment is checked when isolators are replaced, adjusted, or any time excessive vibration has been noticed. Also, any time the vessel has been taken out of the water and stored or blocked minor changes can take place in the shape of the hull. The shaft is checked and realigned as necessary after the vessel has been placed back in the water.

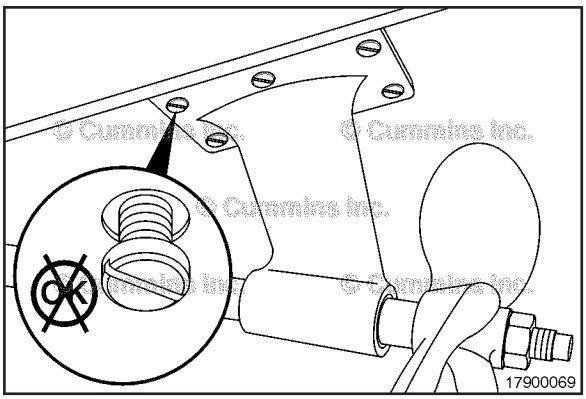




Out of Water

Inspect the propeller shaft for debris and burrs. Clean the propeller shaft.

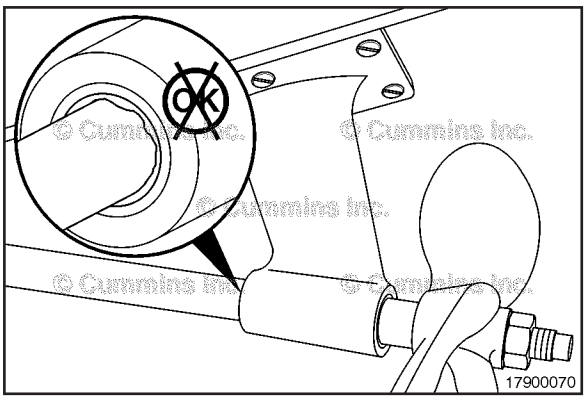
Check that the shaft is centered in the opening of the stuffing box flange. The specifications will vary by manufacturer. If any problems are noted, refer to an authorized OEM service location.



Inspect the strut. Make sure the strut is mounted solidly to the hull.

Check that the shaft is aligned with the cutlass bearing, and that the bearing is **not** worn.

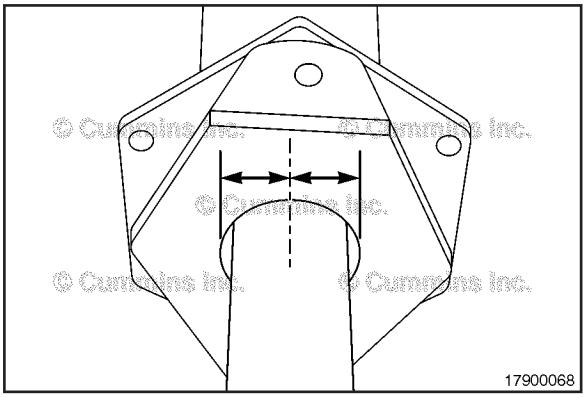
If any problems are noted, refer to an authorized OEM service location.



A misaligned shaft will cause uneven wear of the cutlass bearing.

If the strut or cutlass bearing needs to be repaired or replaced, refer to an authorized OEM service location.

NOTE: Initially align the shaft out of the water using the following instructions, then perform a final alignment after the vessel is in the water.

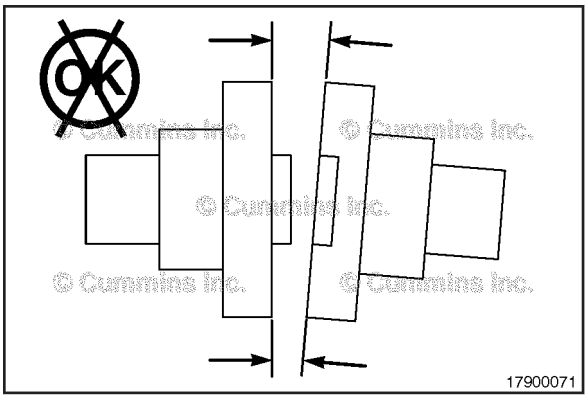


Alignment

Check that the shaft is centered in the opening of the stuffing box flange.

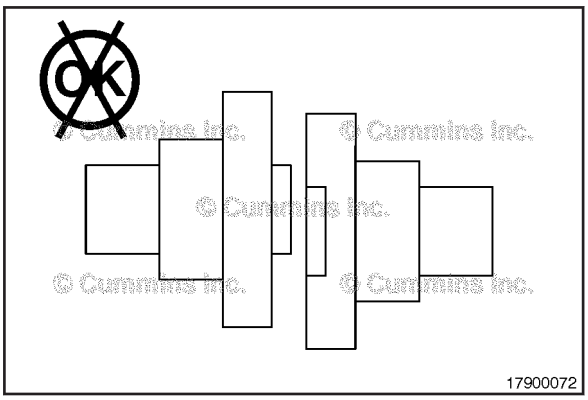
Unbolt the propeller shaft coupling from the marine gear coupling.

The faces of the marine gear (1) couplings and propeller (2) **must** be parallel.



The couplings **must** be aligned.

A straight edge can be used to help align the couplings

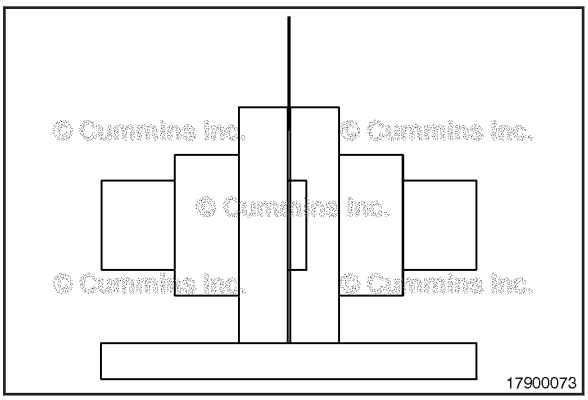


Use a feeler gauge (3) to check the alignment of the coupling in four different places, 90 degrees apart. The variation is to be within 0.051 to 0.102 mm [0.002 to 0.004 in].

If the flange is out of alignment the engine mounting will need to be adjusted until the alignment is correct. Refer to Engine Mounting/Drive Systems section in the Marine Recreational Installation Directions, Bulletin 3884649.

Make sure all mounting bolts and nuts are torqued to the proper specifications. Refer to Procedure 016-026, or the OEM literature.

Bolt the coupling in place and torque to the specifications for the capscrew and bolt size.



Specifications

Capscrews, Bolts and Nuts Torque for Fine and Coarse Threads				
	SAE Grade 5		SAE Grade 8	
	(1) As Received	(2) Lubricated	(1) As Received	(2) Lubricated
	N•m [ft-lb]	N•m [ft-lb]	N•m [ft-lb]	N•m [ft-lb]
1/4	12 ± 1 [9 ± 1]	9 ± 1 [7 ± 1]	19 ± 1 [14 ± 1]	15 ± 1 [11 ± 1]
5/16	26 ± 3 [19 ± 2]	20 ± 3 [15 ± 2]	37 ± 3 [27 ± 2]	30 ± 3 [22 ± 2]
3/8	45 ± 4 [33 ± 3]	37 ± 3 [27 ± 2]	62 ± 5 [46 ± 4]	52 ± 4 [38 ± 3]
7/16	71 ± 5 [52 ± 4]	54 ± 4 [40 ± 3]	99 ± 8 [73 ± 6]	81 ± 7 [60 ± 5]
1/2	108 ± 8 [80 ± 6]	88 ± 7 [65 ± 5]	152 ± 11 [112 ± 8]	122 ± 9 [90 ± 7]
9/16	152 ± 11 [112 ± 8]	112 ± 11 [90 ± 8]	214 ± 16 [158 ± 12]	176 ± 14 [130 ± 10]
5/8	214 ± 16 [158 ± 12]	176 ± 14 [130 ± 10]	304 ± 22 [224 ± 16]	244 ± 20 [180 ± 15]

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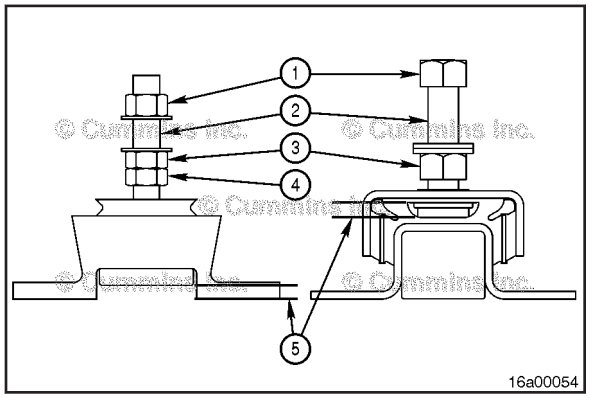
Capscrews, Bolts and Nuts Torque for Fine and Coarse Threads				
	SAE Grade 5		SAE Grade 8	
3/4	380 ± 27 [280 ± 20]	305 ± 27 [225 ± 20]	529 ± 41 [390 ± 30]	434 ± 34 [320 ± 25]
7/8	607 ± 43 [448 ± 32]	488 ± 41 [360 ± 30]	854 ± 68 [630 ± 50]	691 ± 54 [510 ± 40]
1	922 ± 68 [680 ± 50]	732 ± 61 [540 ± 45]	1302 ± 95 [960 ± 70]	1051 ± 81 [775 ± 60]
1 1/8	1152 ± 81 [850 ± 60]	915 ± 81 [675 ± 60]	1844 ± 136 [1360 ± 100]	1491 ± 115 [1100 ± 85]
1 1/4	1593 ± 115 [1175 ± 85]	1254 ± 102 [925 ± 75]	2508 ± 203 [1850 ± 150]	2034 ± 169 [1500 ± 125]

1. Use for all capscrews, bolts, and nuts coated only with the fastener manufacturer's rust preventive oil and use for parts wiped or washed nearly free of oil. Do **not** use for plated parts.
2. Use for all capscrews and nuts whose threads and washer faces are lubricated.



Marine Vibration Isolator (016-026)

General Information

This illustration shows the different types of marine isolators, and the location of the snubber and corresponding gap used to determine loading of the isolator.

1 Top nut

2 Leveling stud

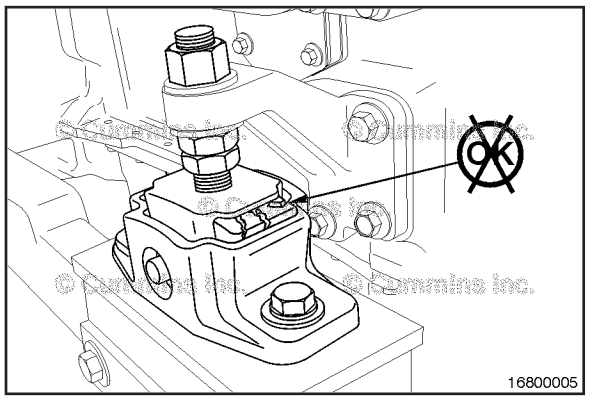
3 Adjusting nut

4 Jam nut

5 Snubber gap.

Generally, it is recommended to replace isolators as a set, but the age of the isolators and the conditions that caused the damage need to be reviewed.

Isolators of different designs should **not** be mixed in the same installation.



Initial Check

Check that the rubber portion of the isolator is **not** cracked, damaged, or pushed out from the isolator housing.

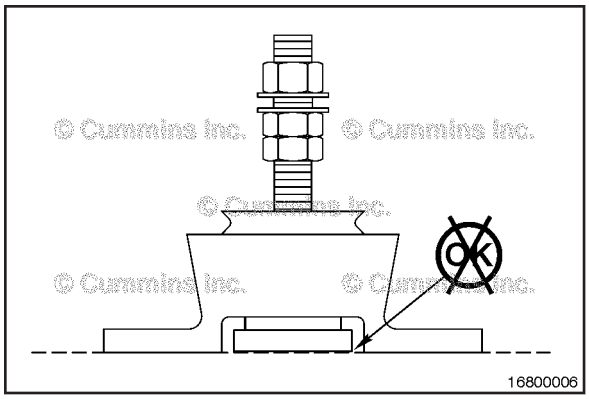
If the rubber is damaged, the isolator will need to be replaced.

Check that the isolator is **not** fully compressed. If an isolator is in the fully compressed condition, there will be no clearance in the snubber gap.

If **only** one isolator is compressed, then the loading of the isolators may be unbalanced. Reference the Install Section of this procedure for steps to balance the load. If the isolator is still compressed after adjusting the load, then the isolator will need to be replaced.

If two isolators that are diagonally across from each other are significantly more compressed or fully compressed, then the loading on the isolators is unbalanced. Reference the Install Section of this procedure for steps to balance the load.

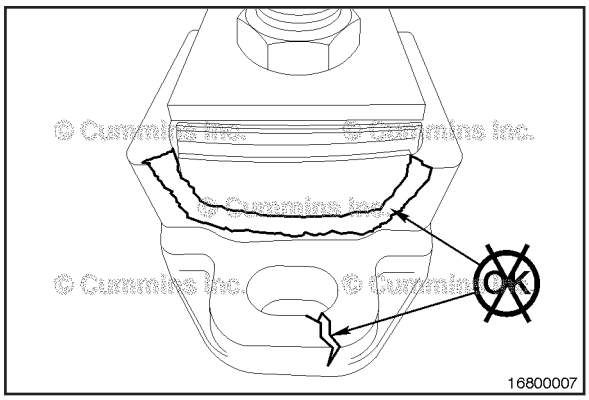
If two isolators that are both on one side of the engine or both at the front or rear of the engine are fully compressed, then the isolators will need to be replaced.



Check that the metal parts of the isolator are **not** damaged, cracked, bent, or warped. If they are, the isolator will need to be replaced.

Check for excessive corrosion. If corrosion is enough to weaken the structure or impede the function of the isolator, it will need to be replaced.

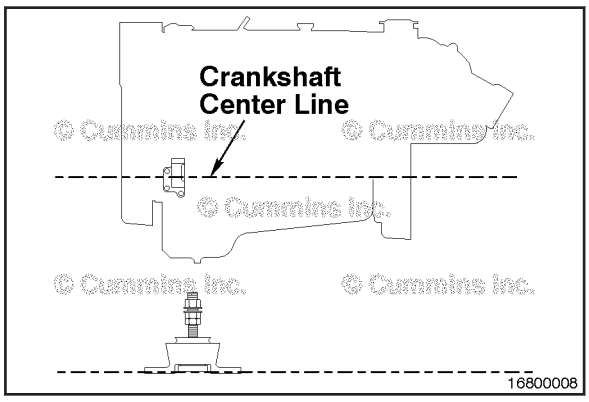
If an isolator is damaged or worn and less than one year old, check that the isolator part number is correct for the engine.

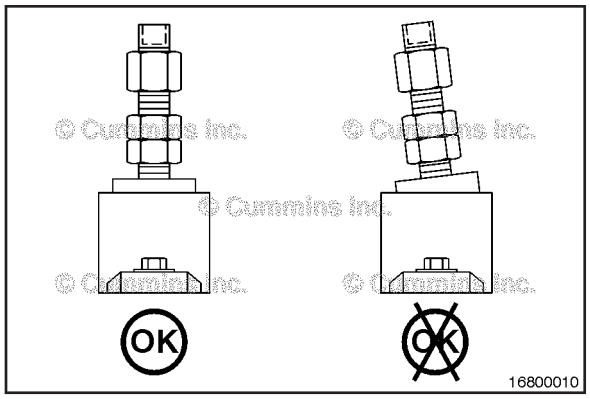


Check that the isolator mounting base is parallel with the engine crankshaft centerline and that the stud is perpendicular to the base, when looking from the side of the engine. The oil pan flange can be used as a visual reference. The engine support brackets **must** also be parallel.

The alignment of the isolator base to the crank centerline should be within four degrees of parallel.

The alignment of the isolator stud to the base should be within four degrees of perpendicular.

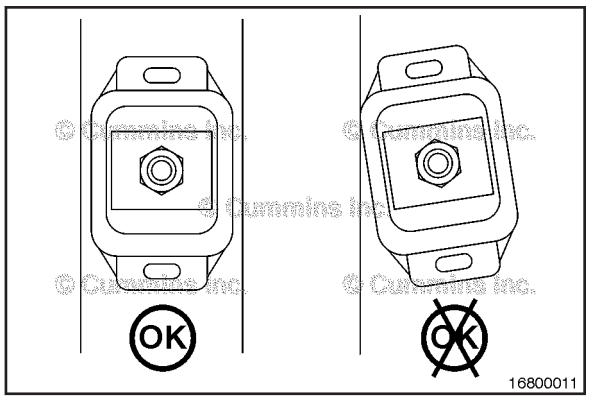




Check that the isolator mounting base is parallel to the transverse crankshaft centerline and that the stud is perpendicular to the base when looking from the front or back of the engine. The engine support brackets **must** also be parallel.

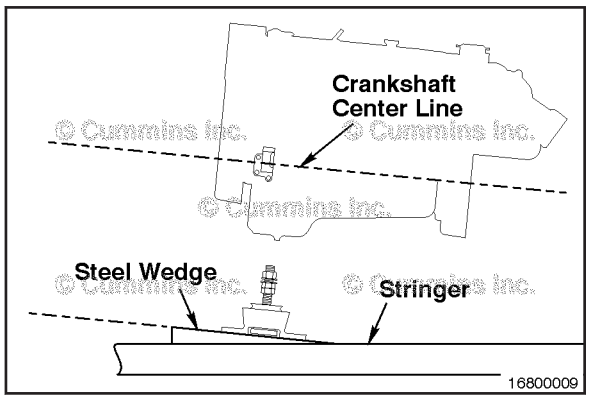
The alignment of the isolator base to the transverse crankshaft centerline should be within two degrees of parallel.

The alignment of the isolator stud to the base should be within two degrees of perpendicular.

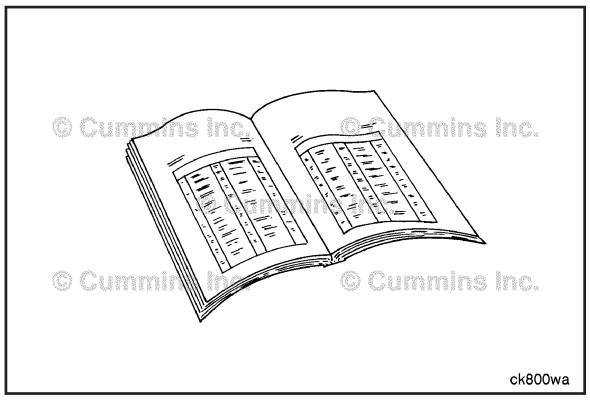


Check that the isolator mounting base is parallel to the crankshaft centerline when looking from the top of the engine.

The alignment of the isolator base to the crankshaft centerline should be within two degrees of parallel.



If the isolator is out of alignment, the mounting will need to be adjusted. Wedges can be used to shim the base to achieve proper alignment. Shims **must** be made of a solid material that will **not** compress under the weight of the 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.

- Disconnect the battery. Refer to the original equipment manufacturer (OEM) service manual.
- Disconnect the propeller shaft. Disengage the flange. Refer to Procedure 016-025 in Section 16.

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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.

The engine needs to be supported before removing the isolators. The amount of space available will determine the best method for this support.

Remove the top nut from the isolator's adjusting stud. Remove the bolts or capscrews retaining the isolator base.

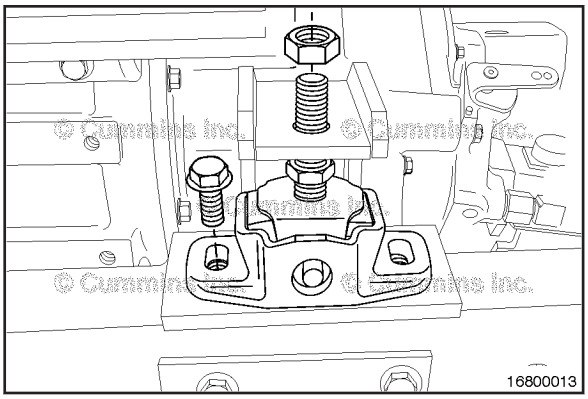
Raise the engine if necessary to facilitate the removal of the isolator.

Make sure that any equipment used for hoisting of jacking the engine is capable of handling the weight of the engine and marine gear. Any engine component used for attaching or support such as the lifting brackets or engine supports **must** be correct for the engine. Reference the appropriate manual for General Engine information in Section V for the engine weight.

Remove the isolator.

If reusing the isolator, mark the position of the isolator relative to the engine to make sure of installation in the same location.

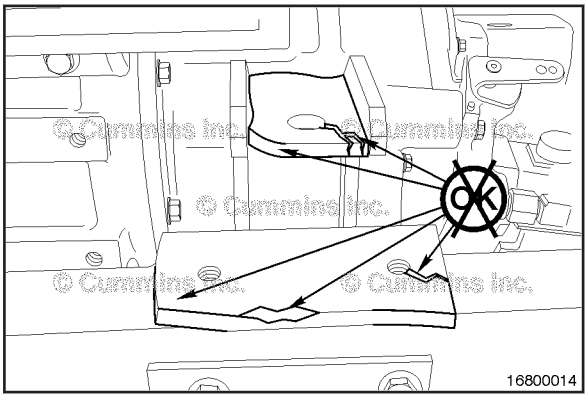
If replacing the worn or damaged isolator with a new isolator, measure the height of the adjusting nut on the stud to assist in setting the new isolator adjusting nut height.

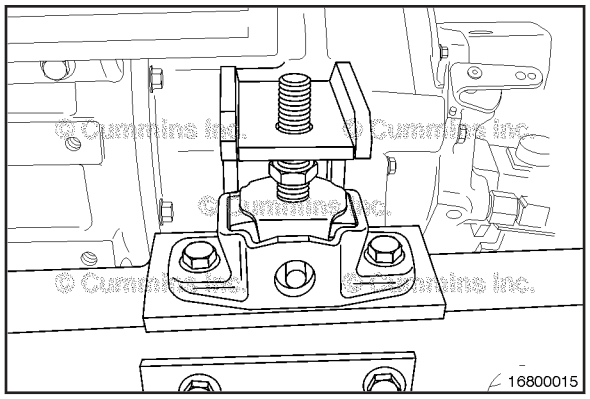


Inspect for Reuse

Inspect the vessel stringers or engine bed to make sure they have **not** been damaged and that they can continue to support the weight of the engine. This is especially true of stringers constructed of wood, wood core, or hollow fiberglass.

Inspect the mounting holes in the stringers or the engine bed for damage. If the stringers, engine bed, or mounting holes need to be repaired, contact an OEM qualified repair location.





Install

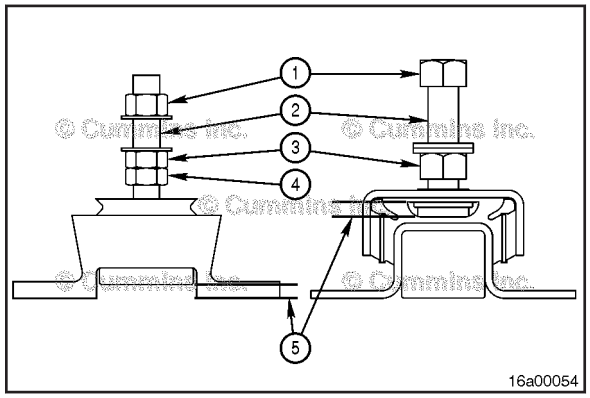
Set the new isolator in place. Check that the isolator is properly aligned. Reference the Initial Check section in this procedure for alignment information.

Set the adjusting nut at the approximate height of the isolator removed.

Replace other isolators that need to be changed using the same technique.

Install the washer and top nut.

Lower the engine so that its weight is fully supported by the isolators.



Verify that the isolators are loaded evenly. Depending on the configuration of the engine, the weight may **not** be evenly distributed on all four corners.

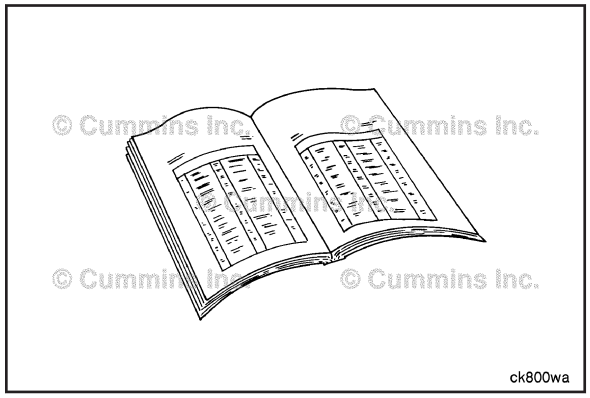
The engine will be heavier at either the front or back, depending the on configuration. Therefore, the isolators on the heavier end will be compressed more.

Check the snubber gap on all isolators.

If **only** one isolator or two isolators that are diagonally across from each other are significantly more compressed, the loading on the isolators is unbalanced.

Adjust the loading on the isolators by raising or lowering the adjusting nut on the stud. Raising the adjusting nut will increase the load. Lowering the adjusting nut will decrease the load.

The engine should be lifted and the load removed from the isolator before moving the adjusting nut, to prevent damage to the threads.



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.

- Align the propeller shaft. Refer to Procedure 016-025 in Section 16.
- Connect the battery cables. Refer to the OEM service manual.
- Start the engine and check for proper operation.

Engine Drive Shaft (016-027)

General Information

Marine Applications

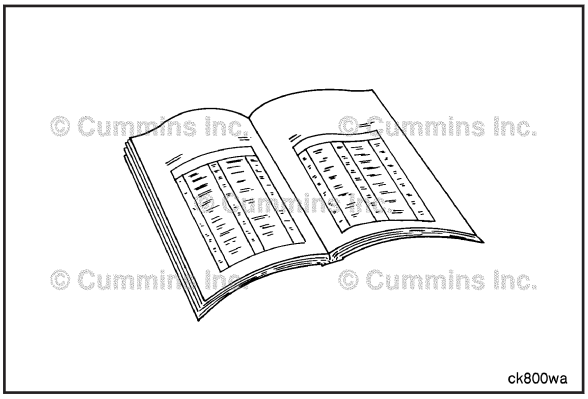
These instructions are for a single unit drive shaft, which attaches to the engine and transmission with flange mount U-joints. Some marine engines are equipped with drive shafts that are various lengths, depending on the boat builder design. This allows the engine to be mounted some distance from the propulsion system drives. The drive system discussed in this procedure is the Pod drive shaft. This procedure will cover removal, alignment, and installation.

Preparatory Steps

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.



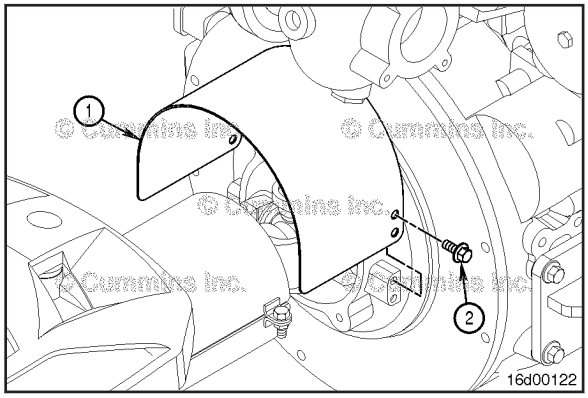
Remove

Marine Applications

Back out the capscrews (2) supporting the engine end shield (1).

Support the shield while removing the last capscrew.

Remove the shield.



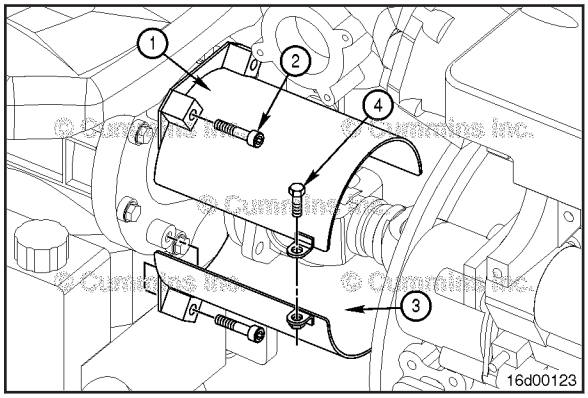
Back out the bolts (4) that are holding the two halves of the transmission end shield together.

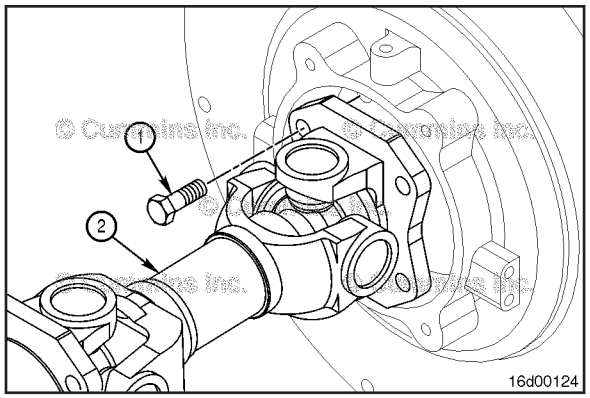
Back out the capscrews (2) that are supporting the upper half of the drive shaft shield (1).

Remove the upper half of the shield.

Back out the capscrews, that are supporting the lower half of the shield (3).

Remove the shield.

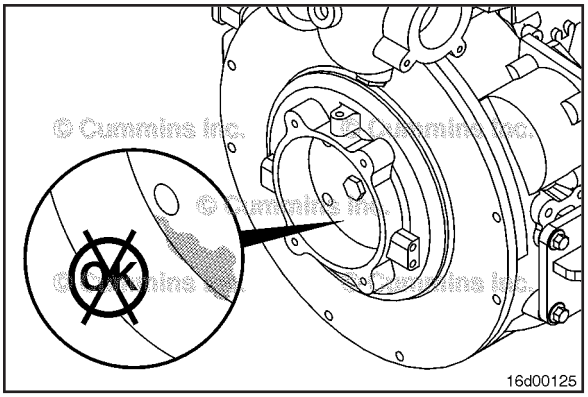




⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

NOTE: The longer drive shafts can be very heavy. The technician should consider whether two technicians are needed for the procedure.

Back out the capscrews (1) from each end of the drive shaft (2). Support the shaft while removing the last capscrew from each end. Set the drive shaft to one side.

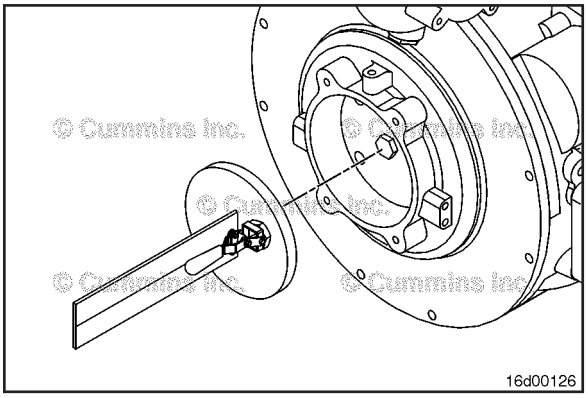


Setup

Marine Applications

Alignment Kit, Part Number 2892196

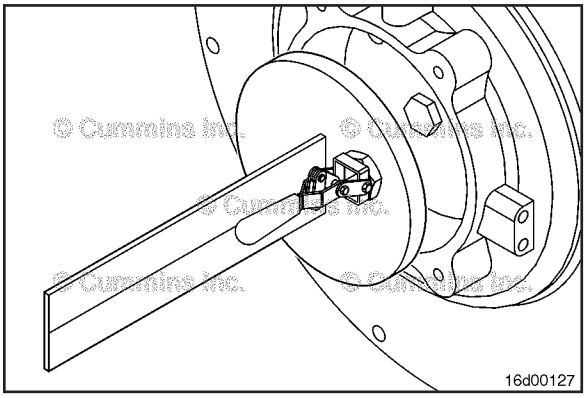
- Check the engine side coupler flange for proper seating prior to alignment tool installation.
- Check all mating surfaces and magnets for debris which could interfere with the alignment tool seating.



Install the alignment tool marked “ENGINE” to the engine drive coupling flange with the blade parallel to the ground.

Install the alignment tool marked “GEAR” to the transmission input flange with the blade parallel to the ground.

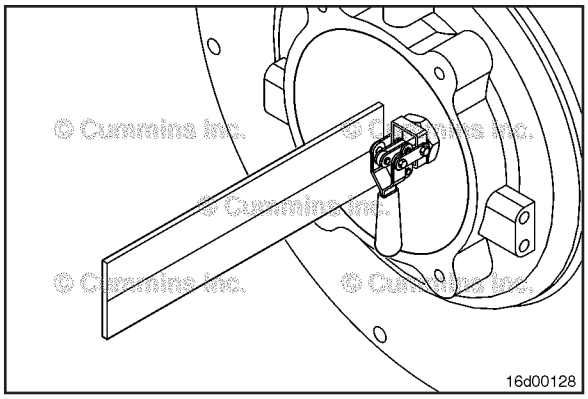
Confirm that the tools are firmly attached with no movement of any kind.



Pull out on the release lever to release the tools for changing position or removal.

Do **not** pry the alignment tools off with a pry bar, screwdriver, or similar tool, because damage can occur.

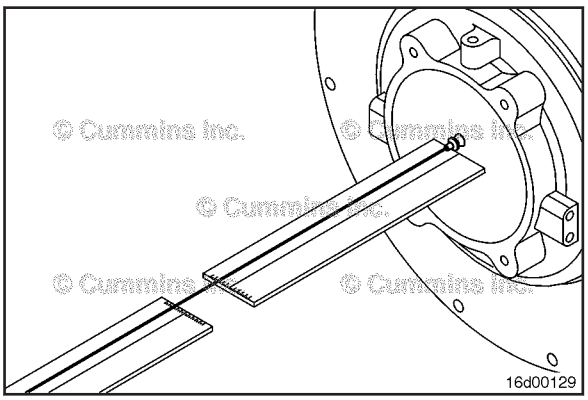
Make sure the release lever is disengaged when measuring.



For drive shafts longer than 254 mm [10 in]:

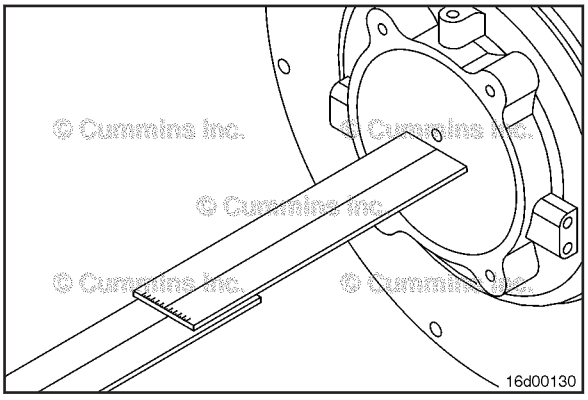
- Insert the indicator line into the holes in the tool blades using the pegs to hold the line tight.
- Install the line in the tool so **not** to interfere with free movement of the line.

Make sure the line is tight and does **not** sag.



The alignment tool blades overlap with the 254 mm [10 in] drive shaft installation and no indicator line is necessary.

When installing the alignment tools, confirm that the blades are **not** against each other, and that the blades are parallel to the ground.



Measure

Marine Applications

Drive shafts longer than 254 mm [10 in]:

- Check the horizontal alignment of the engine and pod.

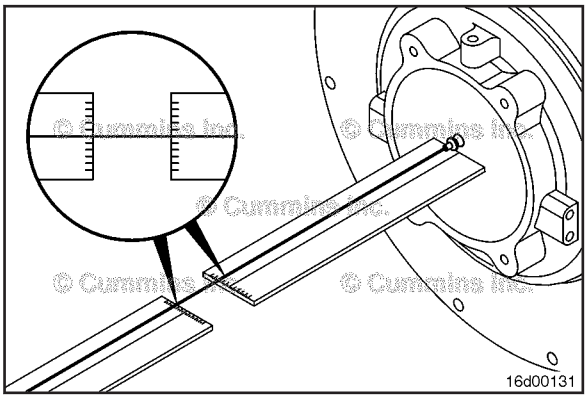
Read the end of the tool where the line crosses the degree scale.

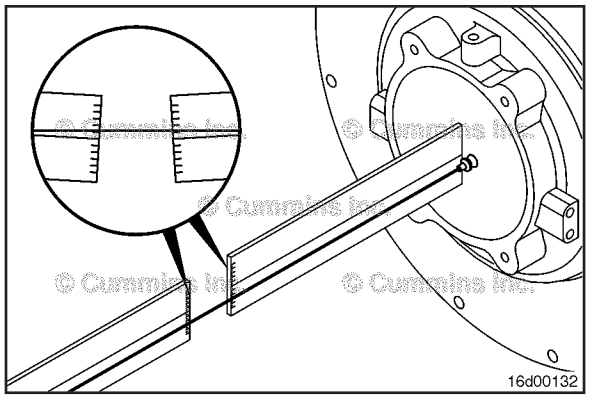
Move the engine side to side to get as close to “0” as possible.

Rotate both tools 180 degrees.

Confirm that the readings in this position are the same as the previous test. If **not**, check the tool fit-up to the flanges again.

Horizontal Alignment: 0 degrees ± 1/2 degree.



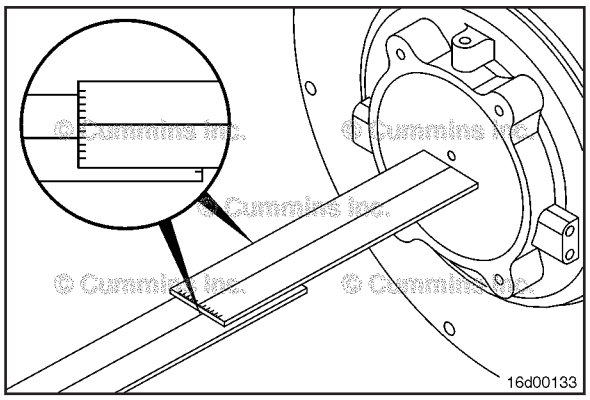


Check the vertical alignment:

- Rotate both tools 90 degrees so they are perpendicular to the ground.

Read the angles of the pod and engine where the lines cross the scales at the free end of the blades. This gives the operator the vertical angles of the engine and pod. The readings on both scales should be very close to the same.

Vertical Alignment: 2 degrees ± 1 degree.

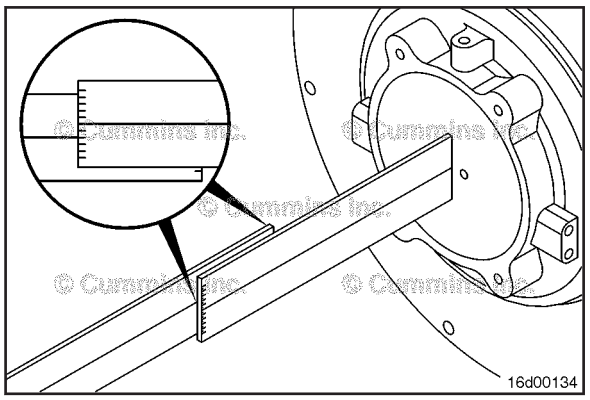


Drive shafts 254 mm [10 in]:

- Check the horizontal alignment of the pod and engine read the angle where the tool center lines cross the scale at the free end of the blades.

Move the engine side to side to get as close to “0” degrees as possible on the pod and engine ends.

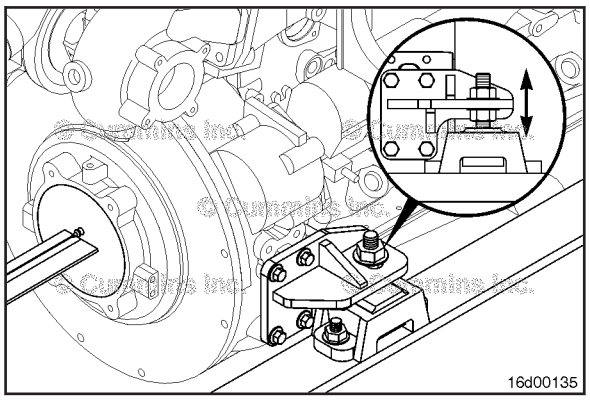
Horizontal Alignment: 0 degrees ± 1/2 degree.



Rotate both tools 90 degrees so they are perpendicular to the ground.

Check the vertical alignment of the engine and pod:

- Read the angle where the tool center lines cross the scales at the free ends of the blades.



Adjust

Marine Applications

Adjust the engine mounts to get as close to 2 degrees as possible on both the engine and pod ends.

The readings on both scales should be very close to the same.

Vertical alignment: 2 degrees ± 1 degree.

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Install

Marine Applications

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

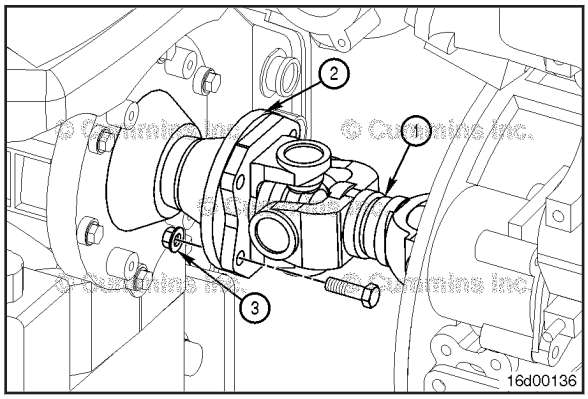
NOTE: The longer drive shafts can be very heavy. The technician should consider whether two technicians are needed for this procedure.

Fully collapse (push) the splined portion of the drive shaft (1) together.

Attach the drive shaft to the transmission input shaft flange (2).

Tighten the four locknuts (3) on the four (1/2-20 x 1.12 in long) transmission input shaft flange bolts.

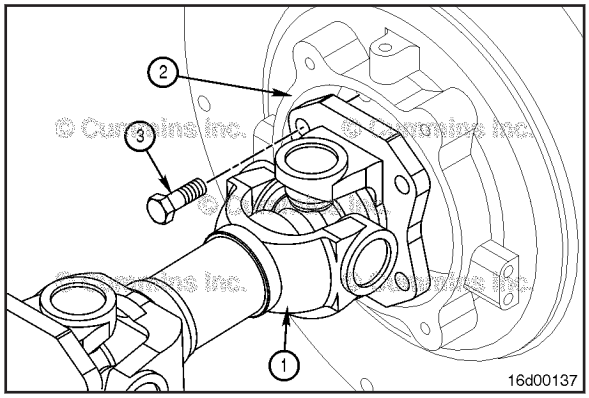
Torque Value: 149 N•m [110 ft-lb]



Attach the drive shaft (1) to the engine coupler (2).

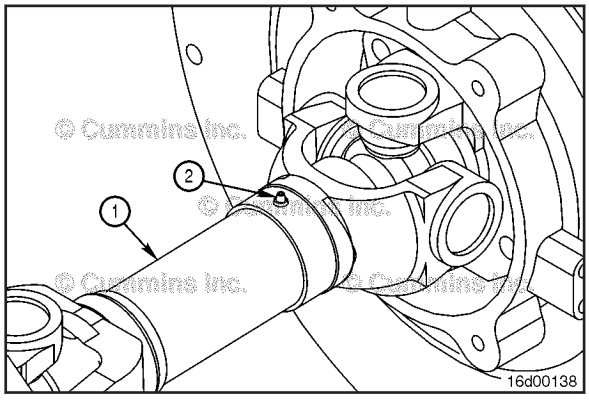
Tighten the four capscrews (3) (1/2-20 x 2-1/ 2 in long) on the engine coupler (2).

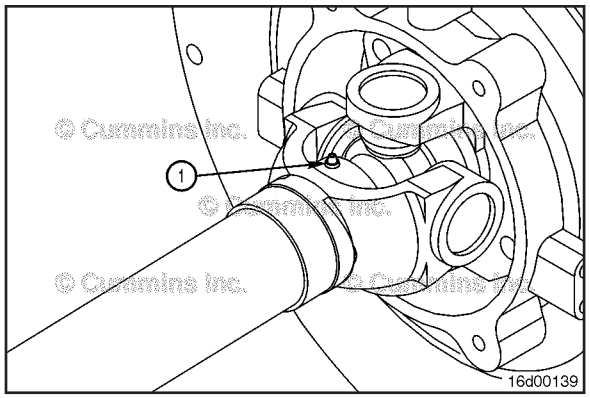
Torque Value: 149 N•m [110 ft-lb]



Lubricate the drive shaft slip-joint (1) through the grease fitting (2) by applying approximately 3 to 6 pumps of the specified grease from a typical hand-operated grease gun.

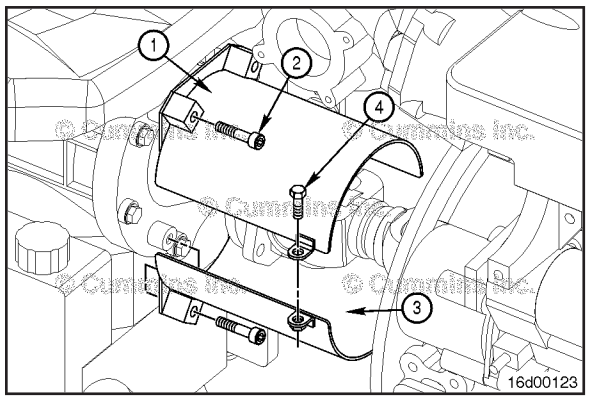
Use Mercury™ Engine Coupler Spline Grease, Part Number 92-802869A1, or equivalent.





Drive shafts over 254 mm [10 in] have a grease fitting in the cross member of the U joints (1). These should be lubricated with the specified grease.

Use Mercury™ U-joint and Gimbal Bearing Grease, Part Number 92-802870A1, or equivalent.



Install the top (1) and bottom (3) drive shaft shields on the transmission end as shown.

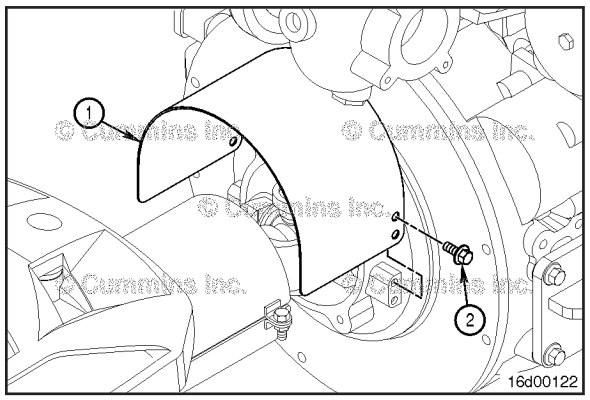
Coat the capscrew threads with Loctite™ 277, or equivalent.

Install the bolts (4) which are securing the two halves of the drive shaft shield.

Tighten the drive shaft shield retaining capscrews (2), capscrews (4) and nuts on the transmission end.

Torque Value:
Socket Head Capscrew (2) 36 N•m [27 ft-lb]

Torque Value:
Capscrew and Nut (4) 23 N•m [204 in-lb]

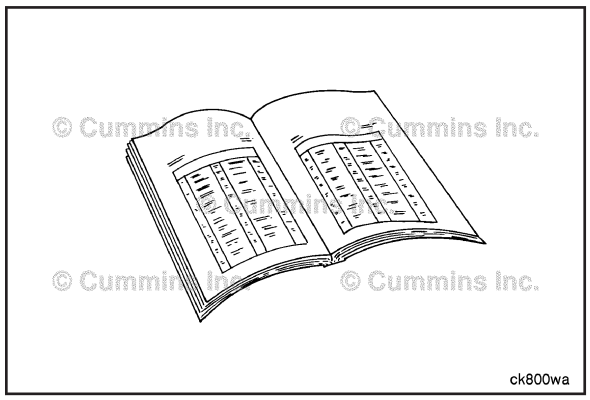


Install the engine end drive shaft shield (1) in the flywheel housing cover.

Coat the capscrew threads with Loctite™ 277, or equivalent.

Tighten the drive shaft shield retaining capscrews (2).

Torque Value: 36 N•m [27 ft-lb]



Finishing Steps

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.

- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the equipment and check for operation and loose components.

Section 17 - Miscellaneous - Group 17

Section Contents

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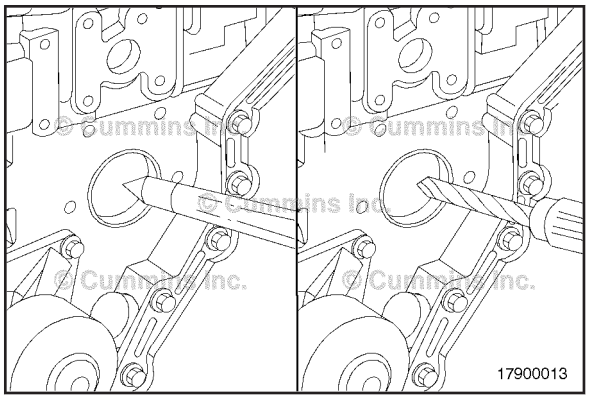
Cup Plug (017-002)

Remove

⚠CAUTION⚠
Do not allow metal shavings to fall in the engine when drilling a hole in the cup plug. Damage to engine components can occur.

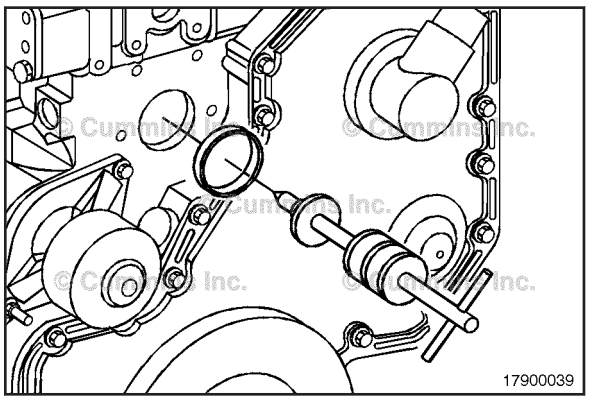
Use a center punch to mark the cup plug for drilling.

Drill an 1/8-inch hole into the cup plug.



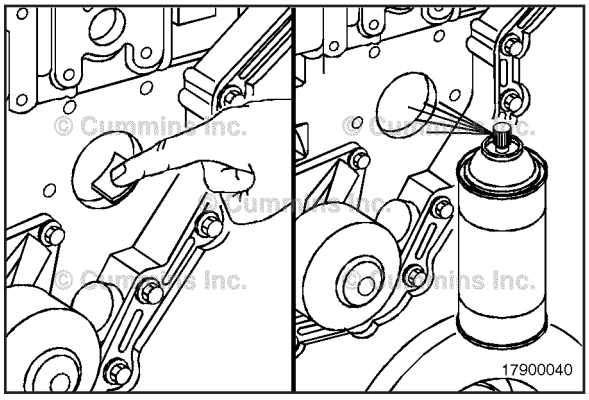
Use a dent puller to remove the plug.

Discard all used cup plugs. Do **not** use them again.

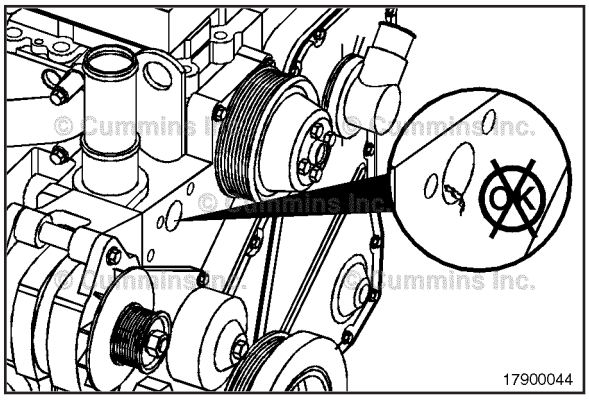


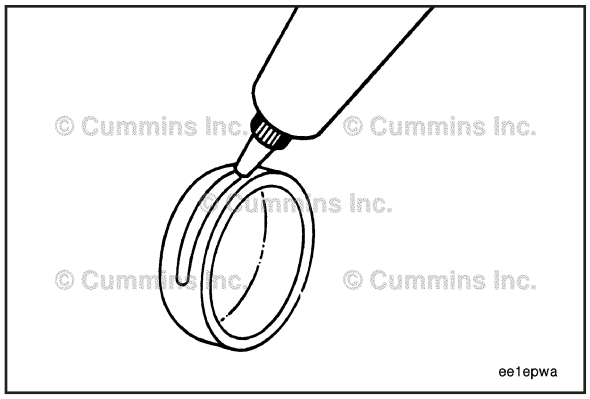
Clean and Inspect for Reuse

Thoroughly clean the cup plug hole using Scotch-Brite™, or equivalent. Use spray cleaner, Cummins Part Number 3375433, or equivalent, to perform a final clean of the bore.



Inspect the cup plug bores for damage.



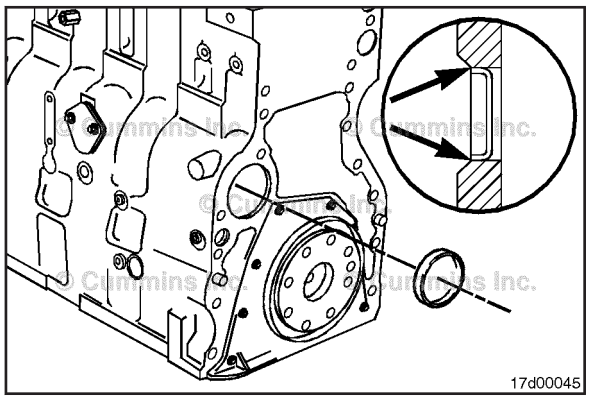


Install

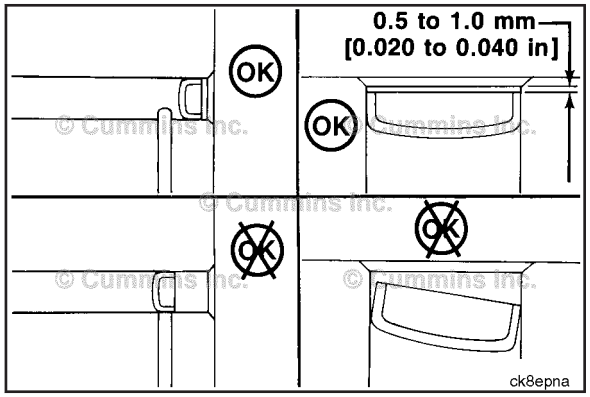
⚠CAUTION⚠
Excessive sealant can run back into the engine and cause damage to other components. Allow the sealant to dry for a minimum of 2 hours before operating the engine. The plug can come out of the bore if the sealant is not dry.

Apply a 2 mm [1/16 in] bead of cup plug sealant, Part Number 3375068, or equivalent to the outside circumference of the cup plug and the inside diameter of cup plug bore.

NOTE: Do **not** install a used cup plug. Discard all plugs after removal.

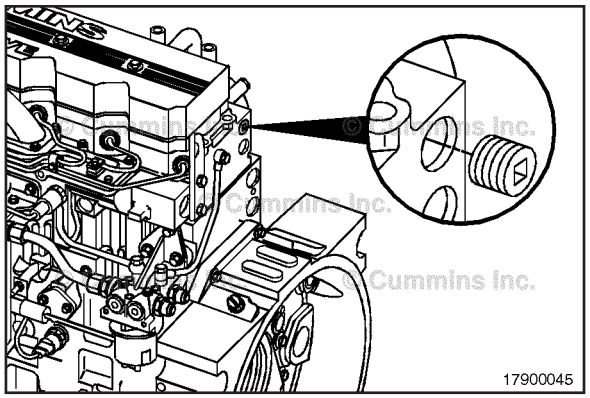


Install the cup plug with the appropriate cup plug driver. See the Service Tools Catalog, Bulletin Number 3377710.



⚠CAUTION⚠
Do not install the cup plug too deeply. If the cup plug is not installed straight and flat, it must be replaced with a new cup plug.

The cup plug **must** be installed with the edge of the cup plug 0.5 to 1.0 mm [0.020 to 0.040 in] deeper than the leading chamber of the bore.



Pipe Plug (017-007)

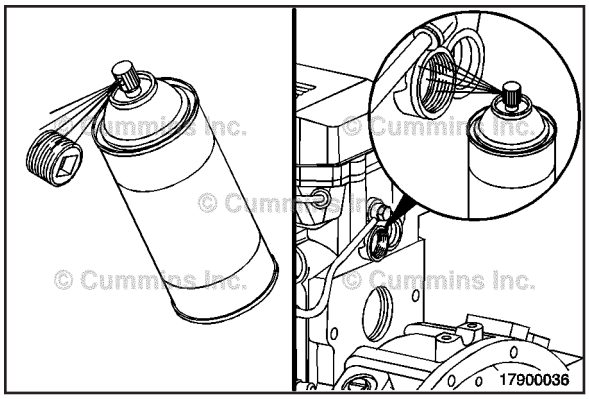
Remove

Remove the pipe plug.

Clean and Inspect for Reuse

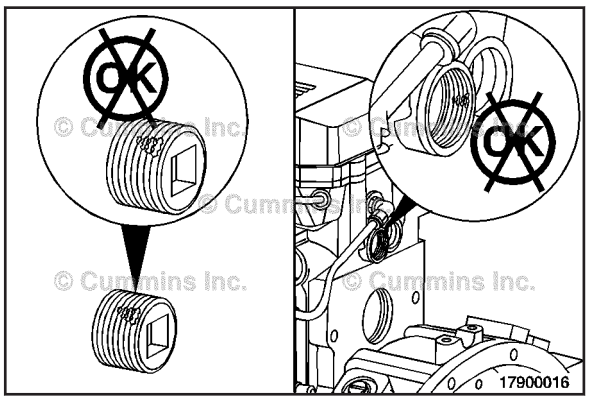
Center Sump Pan

Use spray cleaner, Part Number 3375433, or equivalent to clean the threads of the pipe plugs and threaded bores.



Inspect the threads of the pipe plugs for mutilation or damage.

Inspect the threaded bores for damage.

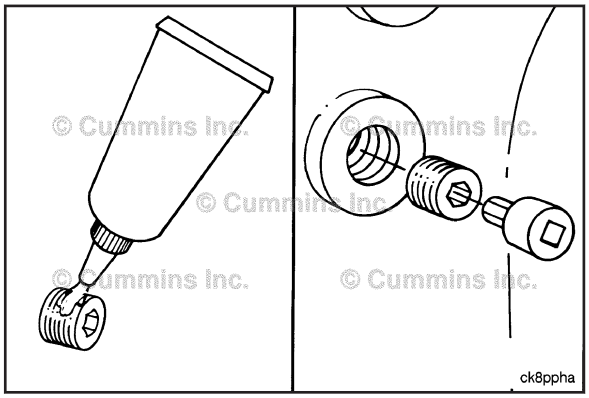


Install

Apply a film of pipe plug sealant, Part Number 3375066, or equivalent to the threads.

Install and tighten the pipe plugs.

Refer to the following illustration for torque values.

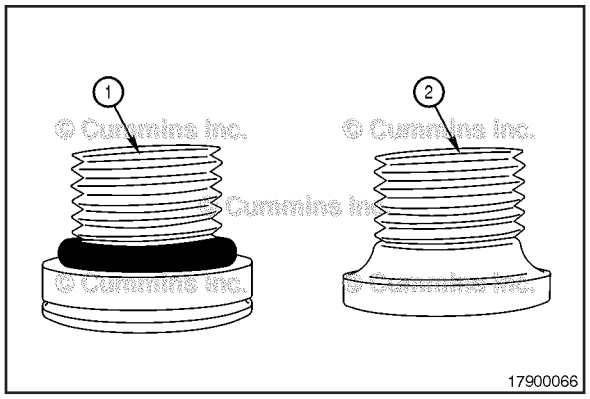


Tighten pipe plugs to the appropriate torque values.

Pipe Plug Torque Values

Size			Torque		Torque	
Thread	Actual Thread O.D.		In Aluminum Components		In Cast Iron or Steel Components	
in.	mm	[in]	N•m	[ft-lbs]	N•m	[ft-lbs]
1/16	8.1	[0.32]	5	[45 in-lb]	15	[10]
1/8	10.4	[0.41]	15	[10]	20	[15]
1/4	13.7	[0.54]	20	[15]	25	[20]
3/8	17.3	[0.68]	25	[20]	35	[25]
1/2	21.6	[0.85]	35	[25]	55	[40]
3/4	26.7	[1.05]	45	[35]	75	[55]
1	33.5	[1.32]	60	[45]	95	[70]
1¼	42.2	[1.66]	75	[55]	115	[85]
1½	48.3	[1.90]	85	[65]	135	[100]

ck8ppoa



Straight Thread Plug (017-011)

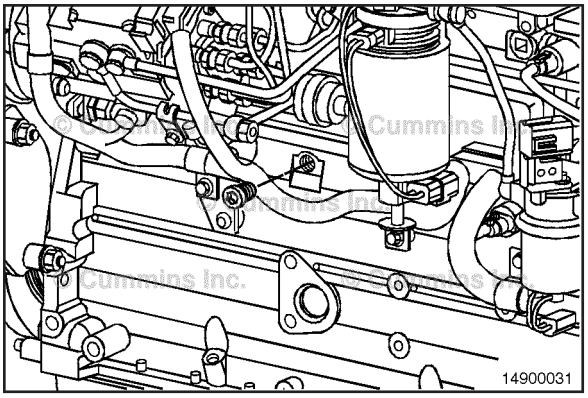
General Information

Two types of straight thread plugs are used:

1 Straight thread plug with o-ring

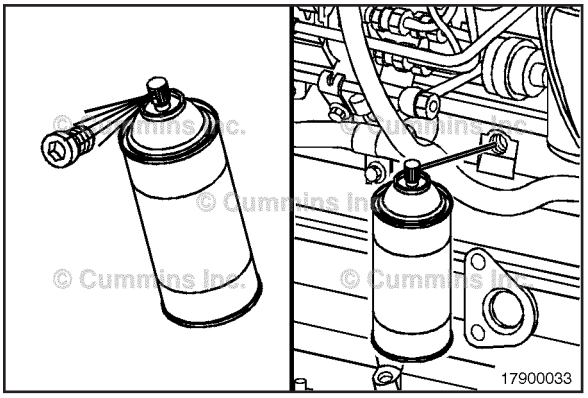
2 Straight thread plug with formed in-place sealant.

The two plugs are interchangeable and reusable. The **only** difference between the two plugs is the installation torque value. See the install step of this procedure.



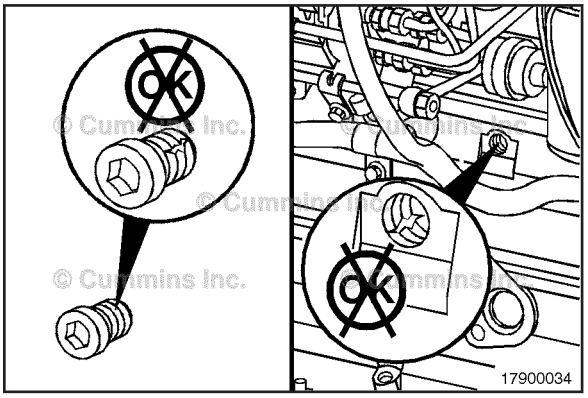
Remove

Select the appropriate size Allen wrench or socket, and remove the plug.



Clean and Inspect for Reuse

Use spray cleaner, Part Number 3375433, or equivalent, to clean the threads of the straight-thread plugs and threaded bores.



Inspect the threads of the pipe plugs for mutilation or damage.

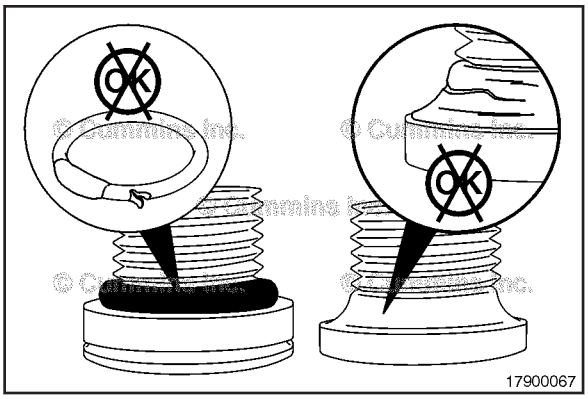
Replace the plugs, if damaged.

Inspect the threaded bores for damage.

Repair the bores, if necessary.

For straight thread plugs with an o-ring, inspect the o-ring for cuts, tears, or deformation. Replace the o-ring if necessary.

For straight thread plugs with formed in-place sealant, inspect the sealant for damage. If damaged, replace the entire plug.



Install

If equipped with a straight thread plug with o-ring, install a new o-ring on the straight-thread plug, if required.

Lubricate the o-ring with clean 15W-40 oil.

Install and tighten the plug.

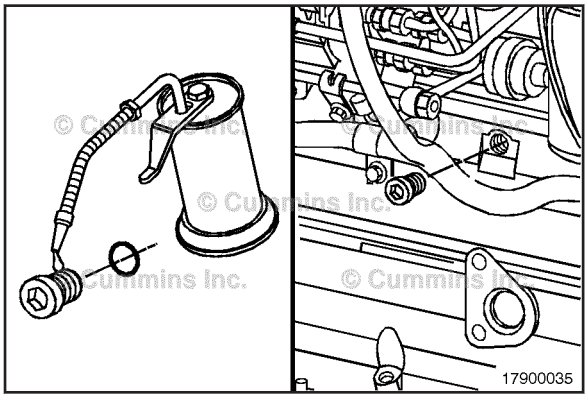
Torque Value:
M10 10 N•m [89 in-lb]

Torque Value:
M12 20 N•m [177 in-lb]

Torque Value:
M14 25 N•m [221 in-lb]

Torque Value:
M16 35 N•m [25 ft-lb]

Torque Value:
M18 45 N•m [33 ft-lb]



If equipped with a straight thread plug with formed in-place sealant, install and tighten the plug.

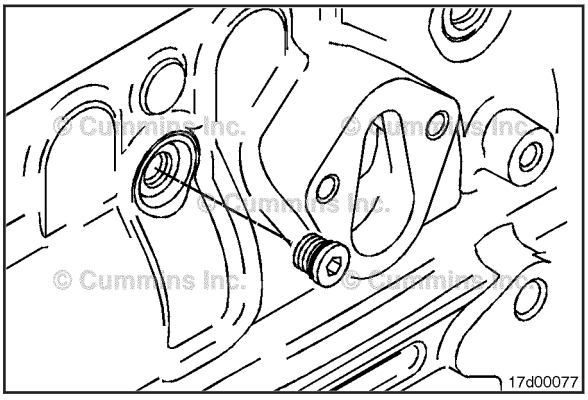
Torque Value:
M10 18 N•m [160 in-lb]

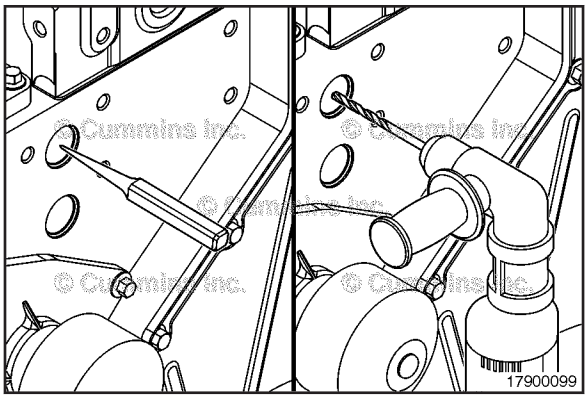
Torque Value:
M12 25 N•m [221 in-lb]

Torque Value:
M14 30 N•m [22 ft-lb]

Torque Value:
M16 40 N•m [30 ft-lb]

Torque Value:
M18 50 N•m [37 ft-lb]





Expansion Plug (017-015)

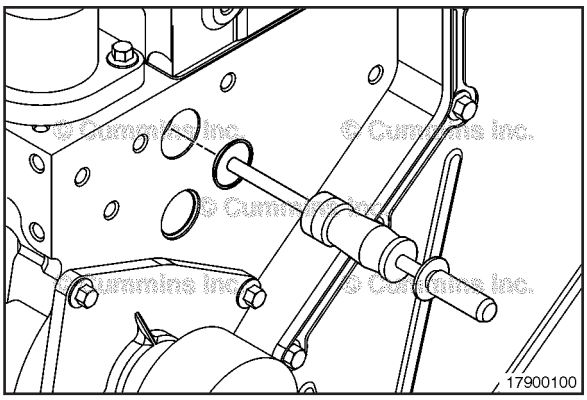
Remove

CAUTION

Do not allow metal shavings to fall in the engine when drilling a hole in the expansion plug. Damage to engine components can occur.

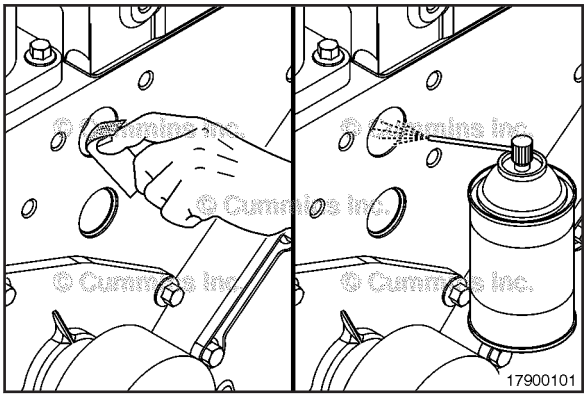
Use a center punch to mark the expansion plug for drilling.

Drill an 1/8-inch hole into the expansion plug.



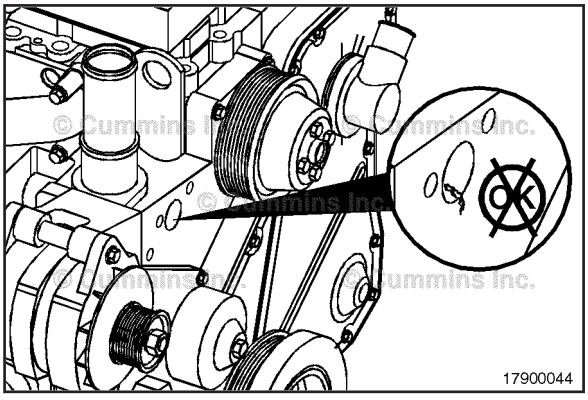
Use a dent puller to remove the plug.

Discard all used expansion plugs and expansion plug o-rings. Do **not** use them again.



Clean and Inspect for Reuse

Thoroughly clean the expansion plug hole using Scotch-Brite™ or equivalent. Use spray cleaner, Cummins® Part Number 3375433 or equivalent, to perform a final cleaning of the bore.

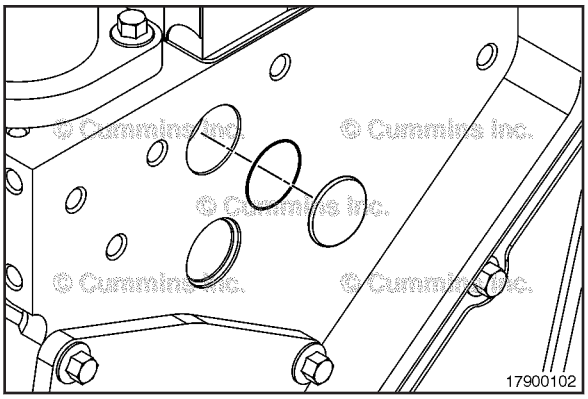


Inspect the expansion plug bores for damage.

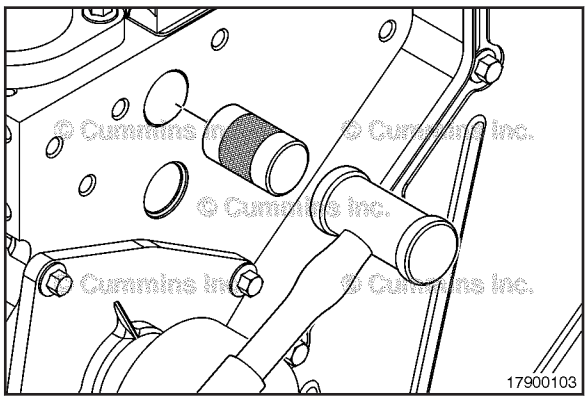
Install

Install the expansion plug o-ring into the bore.

Install the expansion plug with the convex side facing out.

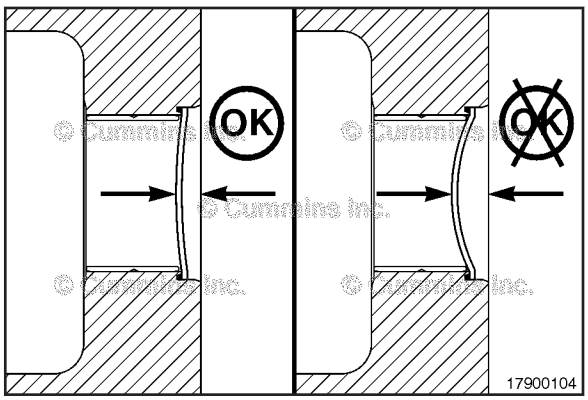


Use a hammer and a flat driver to strike the expansion plug twice to flatten the plug against the o-ring.



Check the plug for proper installation.

- The installed plug **must not** protrude above the edge of the bore.
- The installed plug **must not** be more than 1 to 3.5 mm [0.04 to 0.14 in] below the edge of the bore.



Notes

Section 20 - Vehicle Braking - Group 20

Section Contents

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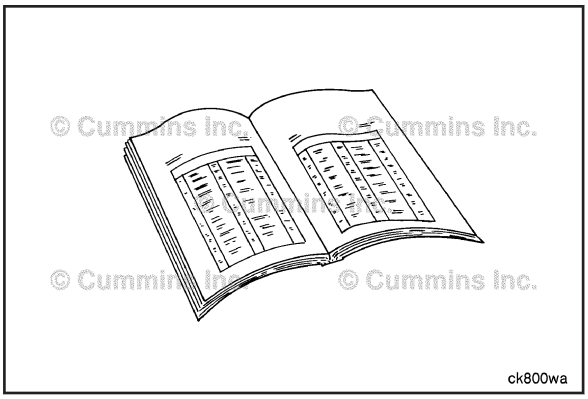
Engine Brake Assembly (020-004)

Preparatory Steps

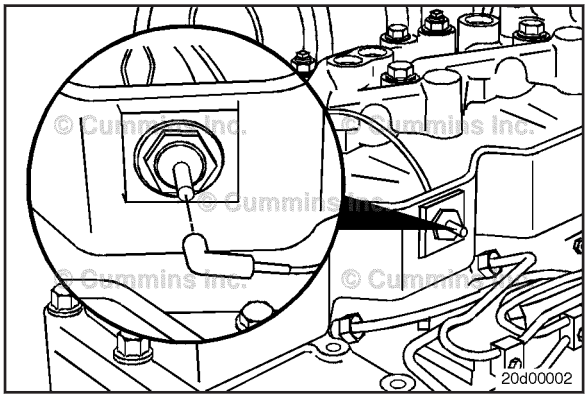
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.



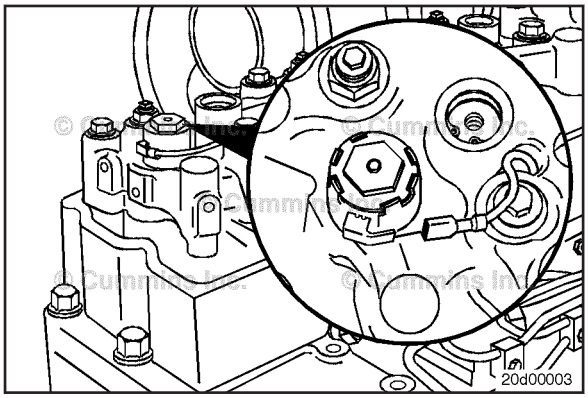
Remove

Disconnect the wiring harness from the electrical connectors in the rocker lever housing.



NOTE: It is easier to remove the wire from the rocker lever housing after the brake is removed.

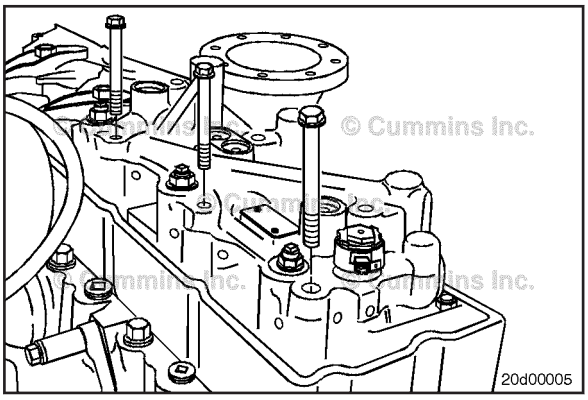
Unplug the wires from the brake solenoid.

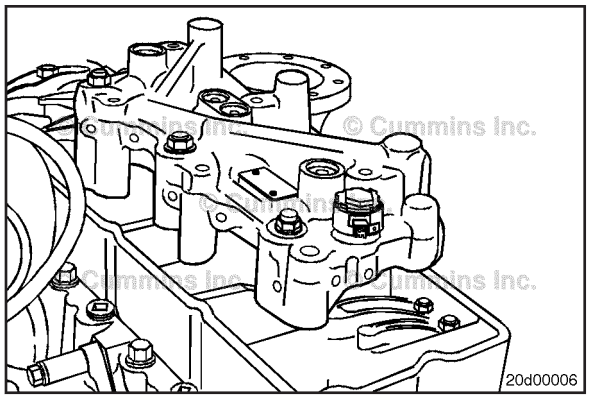


NOTE: Use **only** grade 12.9 mounting capscrews for engine brake assemblies. Verify all mounting capscrews are grade 12.9. If any capscrews are found that are **not** grade 12.9, replace the capscrews.

Remove the six mounting capscrews and flat washers from one or both of the engine brake assemblies, as required.

NOTE: Engines with an engine serial number (ESN) of 73001424 and higher use a bracket underneath the mounting capscrews above cylinders 1 and 4 in place of a hardened washer. This bracket is used to route the solenoid wire away from moving parts and prevent wire chaffing.

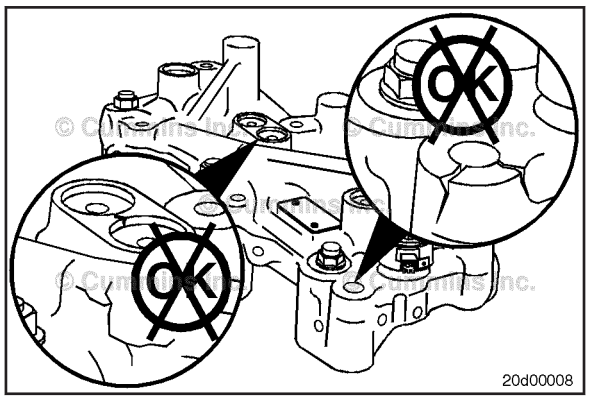




Remove the brake assembly or assemblies, as required.

Remove the adjusting cap from the exhaust rocker arms.

Remove the rocker lever housing, if necessary. Refer to Procedure 003-013 in Section 3.



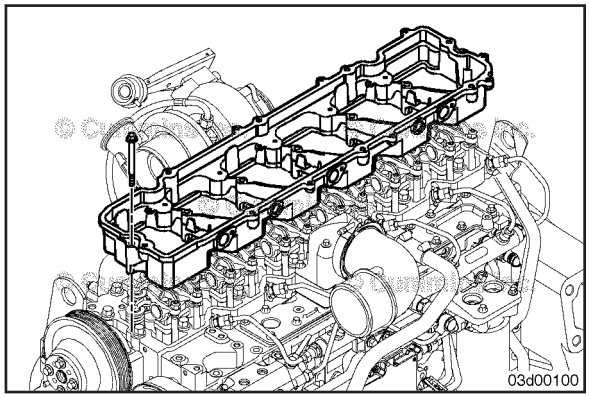
Clean and Inspect for Reuse

⚠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 the engine brake assembly with solvent and a brush.

Inspect the engine brake assembly for cracks or any other damage.

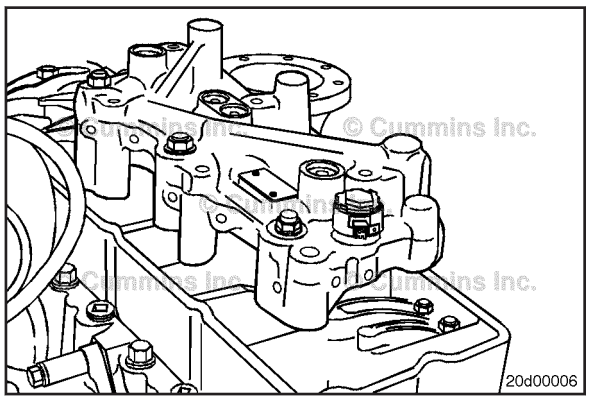


Install

If necessary, check and set the valve lash prior to installing the engine brake. Refer to Procedure 003-004 in Section 3.

To install the engine brake specific crossheads and rocker lever hold-downs. Refer to Procedure 003-008 in Section 3.

If necessary, install the rocker lever housing and mounting bolts. Refer to Procedure 003-013 in Section 3.



At the intake mounting stud (cylinder 1 and/or cylinder 4) lubricate the oil adapter and o-ring with lubricating oil.

Install the engine brake overhead assembly.

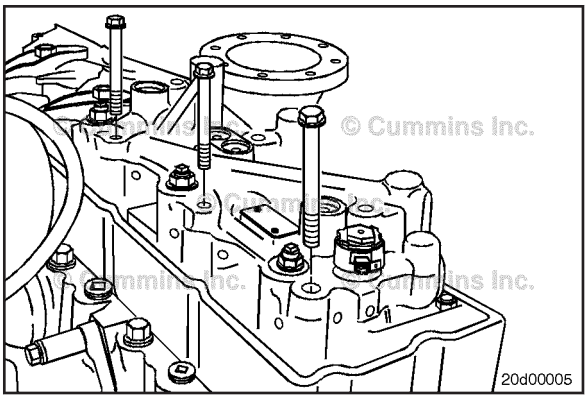
NOTE: Make sure the oil supply adapter at the intake manifold stud is fitted into the oil supply hole in the brake assembly.

⚠CAUTION⚠
Use only grade 12.9 mounting capscrews for engine brake assemblies. Verify all mounting capscrews are grade 12.9. If any capscrews are found that are not grade 12.9, replace the capscrews.

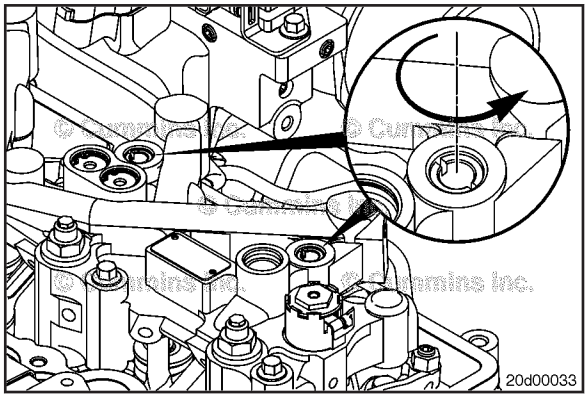
Install the six 10-mm mounting capscrews (three for the front brake assembly, three for the rear brake assembly) with flat washers at the brake mounting spacers (exhaust side of engine) and hand-tighten.

NOTE: Engines with an engine serial number (ESN) of 73001424 and higher use a bracket underneath the mounting capscrews above cylinders numbers 1 and 4 in place of a hardened washer. This bracket is used to route the solenoid wire away from moving parts and prevent wire chaffing.

NOTE: Do **not** tighten the capscrews to their final torque specification at this time.



Turn the adjusting sleeves in the engine brake housing until they make contact with the rocker arm pedestals. No preload **must** be imparted on the housing.



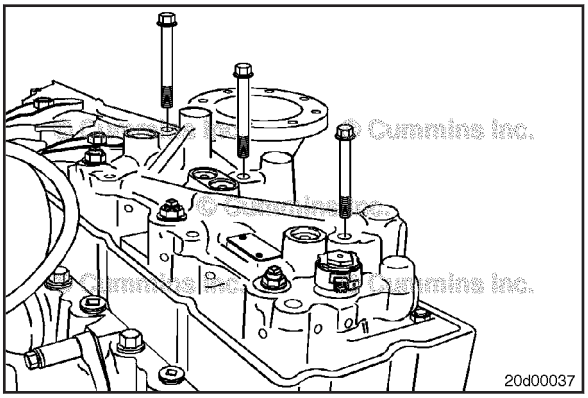
Install the six 10-mm mounting capscrews (three for the front brake assembly, three for the rear brake assembly) with flat washers (intake side of the engine).

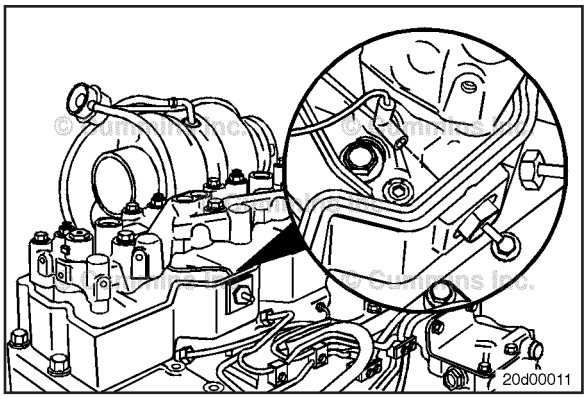
NOTE: Engines with an engine serial number (ESN) of 73001424 and higher use a bracket underneath the mounting capscrews above cylinders 1 and 4 in place of a hardened washer. This bracket is used to route the solenoid wire away from moving parts and prevent wire chaffing.

Tighten the six 10-mm mounting capscrews for the front brake assembly and the six 10-mm mounting capscrews for the rear brake assembly.

NOTE: No tightening sequence is required but the capscrews can be tightened in a crossing sequence.

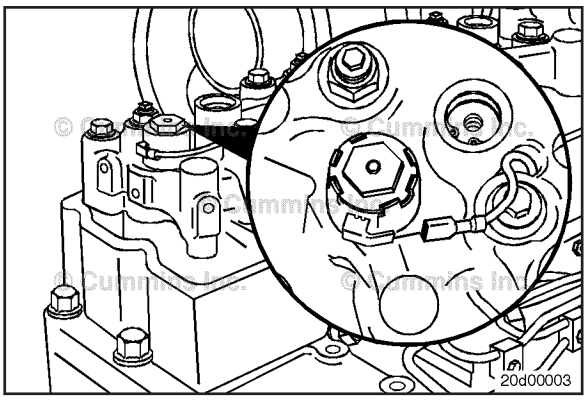
Torque Value: 32 N•m [24 ft-lb]





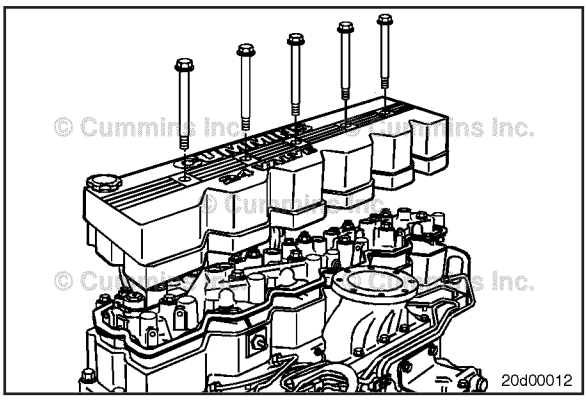
Install the wires to the terminals on the inside of the spacer.

NOTE: The longer wire **must** be connected to the front engine brake solenoid. It is possible to install the wires in the incorrect orientation, which will result in an interference with the rocker levers.



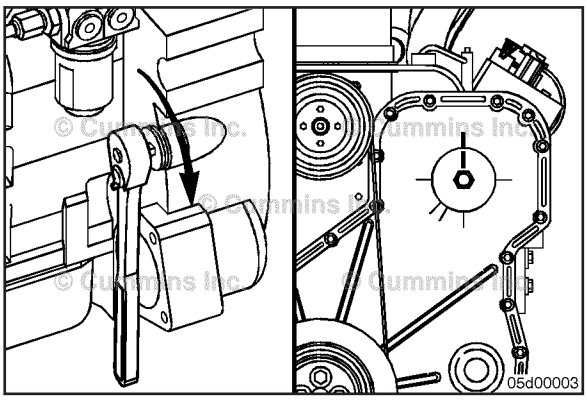
NOTE: On engines equipped with a bracket to prevent the wire from chaffing, secure the wire to the bracket, Part Number 4890404.

Connect the wires from the terminals on the inside of the spacer to the solenoid.



Adjust

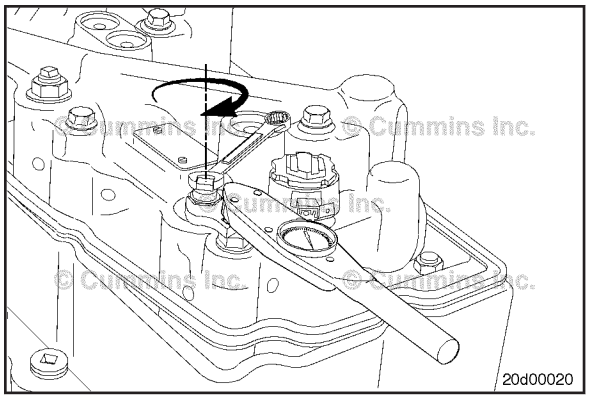
Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.



Use barring tool, Part Number 3824591, to rotate the crankshaft to align the mark on the fuel pump gear with the top dead center mark on the gear cover.

When the engine is in the top dead center position, brake lash can be set on cylinders 1, 3, and 5.

Use two wrenches to hold the adjusting nut and loosen the lock nuts on the brake at cylinders 1, 3, and 5.

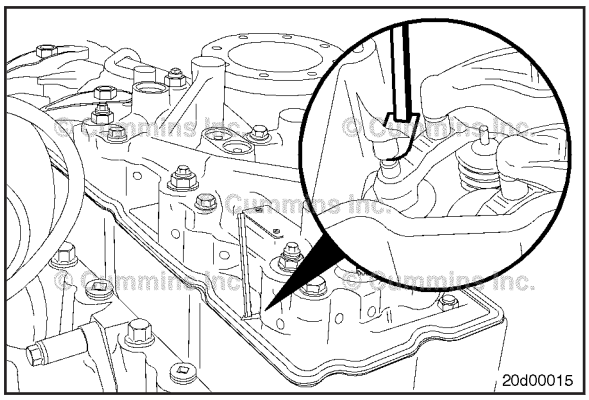


Brake Lash - Feeler Gauge Method

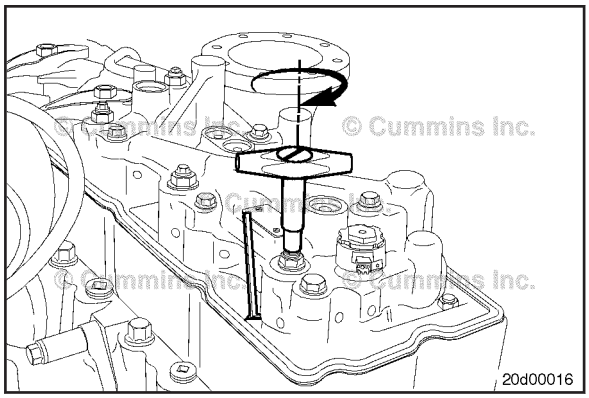
Insert the appropriate brake lash feeler gauge between the brake slave piston and exhaust crosshead pin on cylinder 1.

Brake Lash - Feeler Gauge	
Tool Part Number	**Lash Specification**
3163681	2.286 mm [0.090 in]

NOTE: If the correct size feeler gauge is **not** available there is an alternate dial indicator method for setting the brake lash following in this procedure.



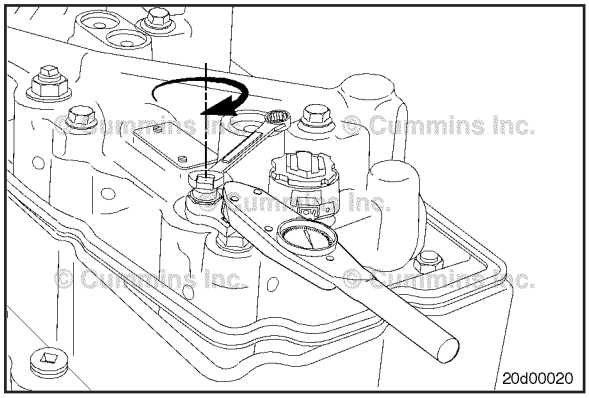
Use the 0.68 N•m [6 in-lb] torque wrench, Part Number 3376592, to tighten the adjusting nut until the torque wrench "clicks" or until drag is felt on the feeler gauge.



Remove the feeler gauge. Use two wrenches to hold the adjusting nut and tighten the locknut.

Torque Value: 35 N•m [26 ft-lb]

Repeat for cylinders 3 and 5.



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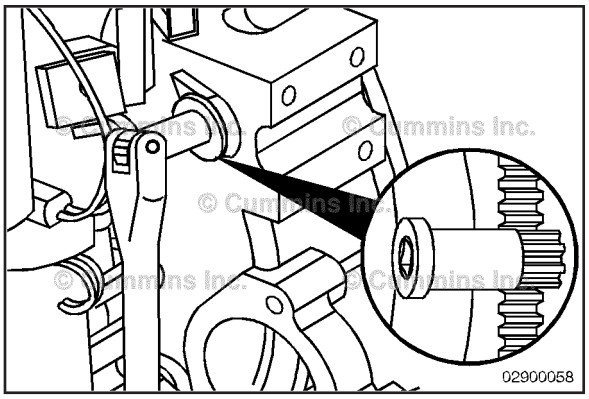
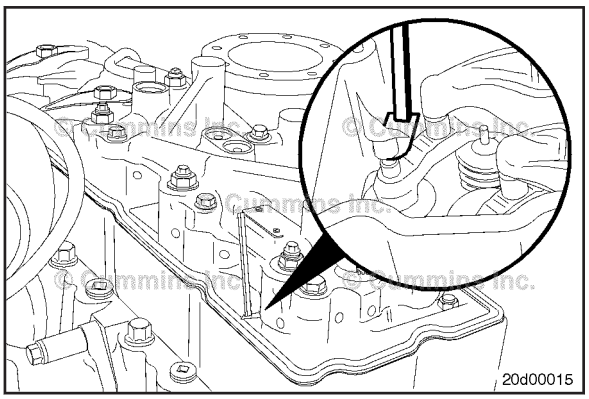


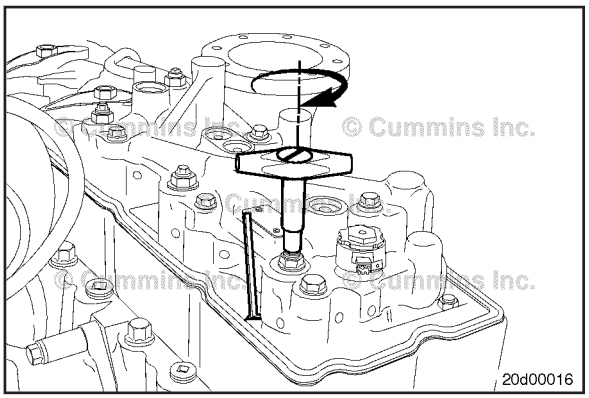
Use the engine barring tool, Part Number 3824591, to rotate the crankshaft 360 degrees to align the mark on the fuel pump gear with the mark on the gear cover that is 180 degrees away from top dead center.

When the engine is in position, brake lash can be set on cylinders 2, 4, and 6.

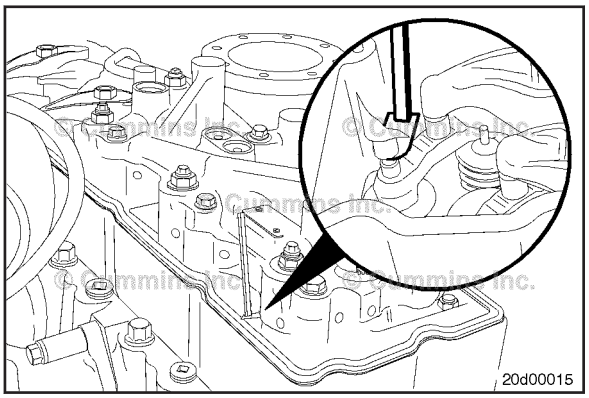


Insert the appropriate brake lash feeler gauge between the brake sleeve piston and the exhaust crosshead pin on cylinder 2.

Brake Lash - Feeler Gauge	
Tool Part Number	**Lash Specification**
3163681	2.286 mm [0.090 in]



Use a 6 in-lb torque wrench, Part Number 3376592, to tighten the adjusting nut until the torque wrench "clicks" or until drag is felt on the feeler gauge.



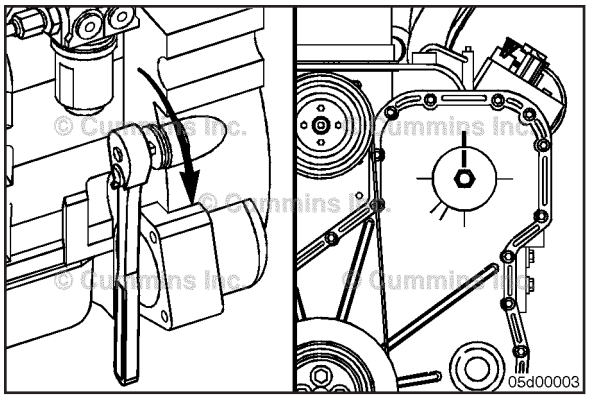
Remove the feeler gauge. Use two wrenches to hold the adjusting nut and tighten the locknut.

Torque Value: 35 N•m [26 ft-lb]

Repeat for cylinders 4 and 6.

The following method can be used instead of the feeler gauge method if a feeler gauge of the proper size is **not** available.

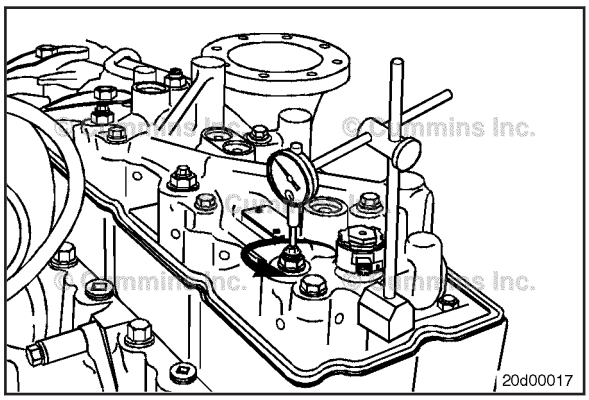
Use barring tool, Part Number 3824591, to rotate the crankshaft to align the mark on the fuel pump gear with the top dead center mark on the gear cover.



Brake Lash - Dial Indicator

Tighten the backlash adjusting nut on cylinder 1 until resistance is felt. Place the dial indicator tip on the adjusting nut and zero the dial indicator. Turn the lash adjusting nut in a **counterclockwise** direction until the appropriate lash is reached.

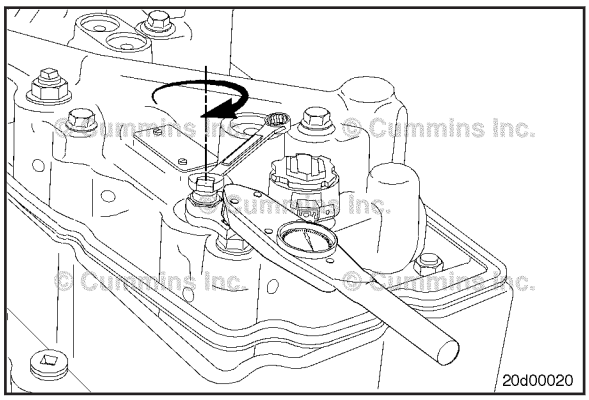
Brake Lash Specification 2.286 mm [0.090 in]



Use two wrenches to hold the adjusting nut and tighten the locknut.

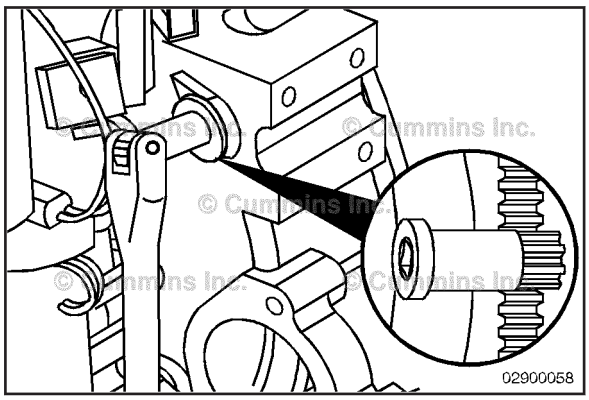
Torque Value: 35 N•m [26 ft-lb]

Repeat for cylinders 3 and 5.



Use engine barring tool, Part Number 3824591, to rotate the crankshaft 360 degrees to align the mark on the fuel pump gear with the mark on the gear cover that is 180 degrees away from top dead center.

When the engine is in position, brake lash can be set on cylinders 2, 4, and 6.



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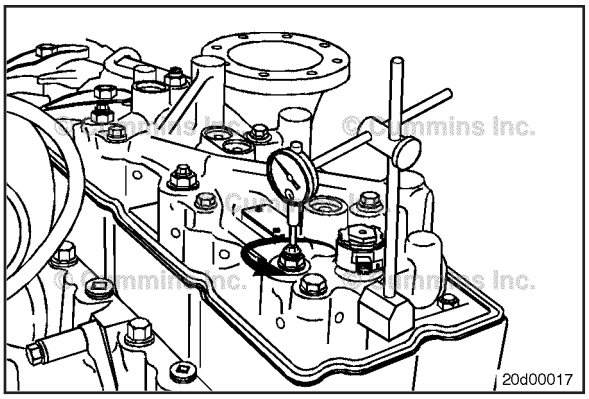
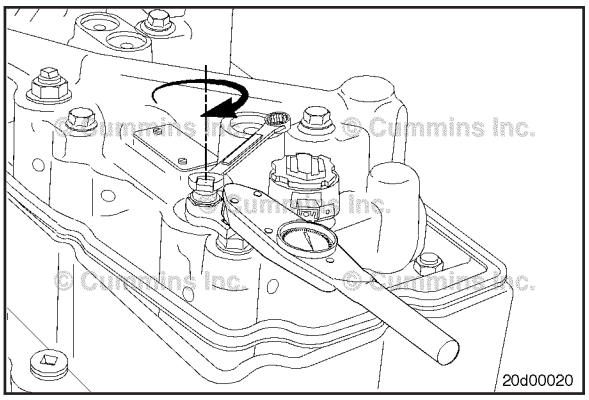


Tighten the backlash adjusting nut on cylinder number 2 until resistance is felt. Place the dial indicator tip on the adjusting nut and zero the dial indicator. Turn the lash adjusting nut in a **counterclockwise** direction until the appropriate lash is reached.

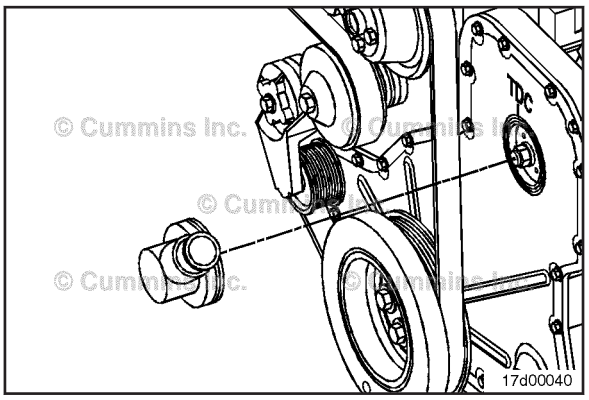
Brake Lash Specification 2.286 mm [0.090 in]



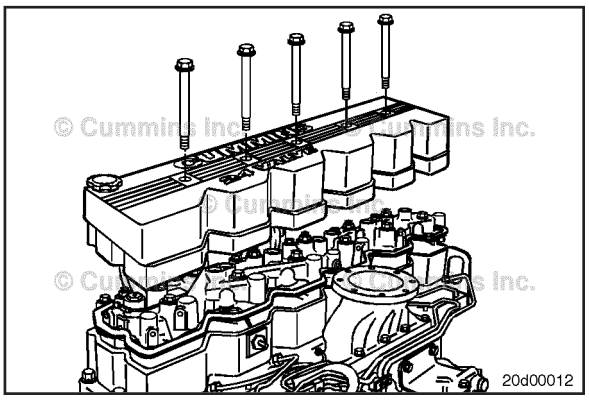
Use two wrenches, hold the adjusting nut and tighten the locknut.

Torque Value: 35 N•m [26 ft-lb]

Repeat for cylinders 4 and 6.



Install the plastic fuel pump drive cover located on the front of the engine.



Install the rocker lever cover.

Refer to Procedure 003-011 in Section 3.

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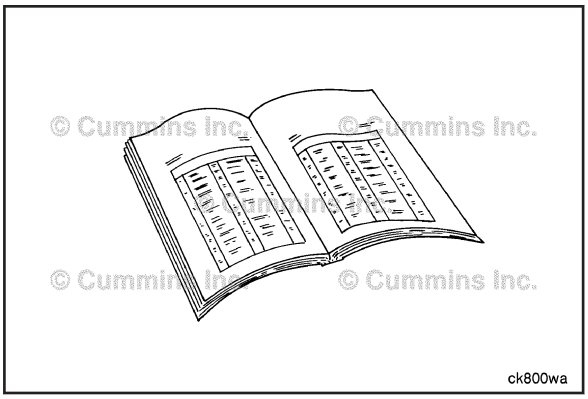
Finishing Steps



⚠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.

- Operate the engine and verify proper engine brake operation.

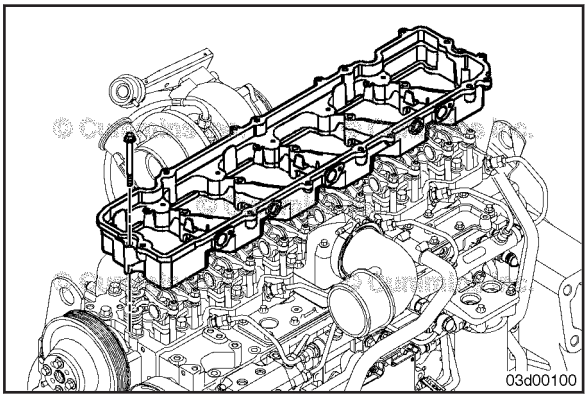
Engine Brake Housing Spacer (020-007)

Preparatory Steps

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

Remove the engine brake assemblies. Refer to Procedure 020-004.

Remove

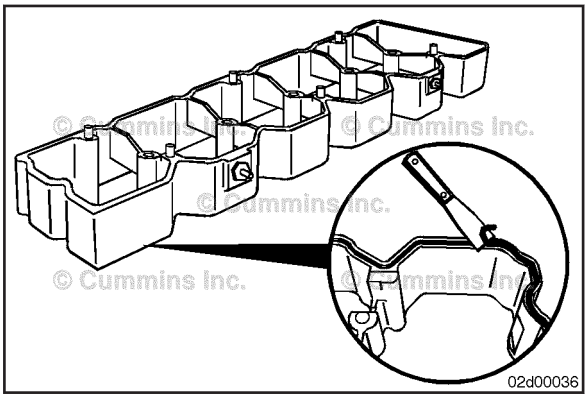


⚠CAUTION⚠
Do not damage the mounting surface of the spacer when removing it from the cylinder head, or oil leaks can result when the spacer is installed.

Remove the engine brake spacer 5 mounting capscrews.

Carefully remove the engine brake spacer from the cylinder head.

Clean and Inspect for Reuse



⚠CAUTION⚠
Be sure to remove all RTV from the groove in the mounting surface spacer, or oil leaks can result after installation.

Carefully clean the RTV from the mounting surface of the spacer.

Clean all RTV from the top of cylinder head where the spacer is mounted.

Inspect the engine brake spacer for cracks or any other damage, especially on the cylinder head mounting surface.

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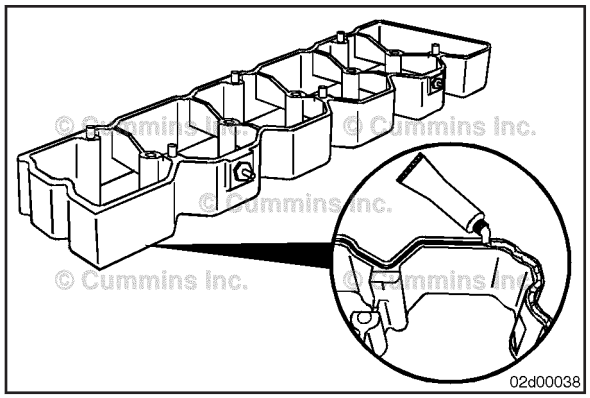
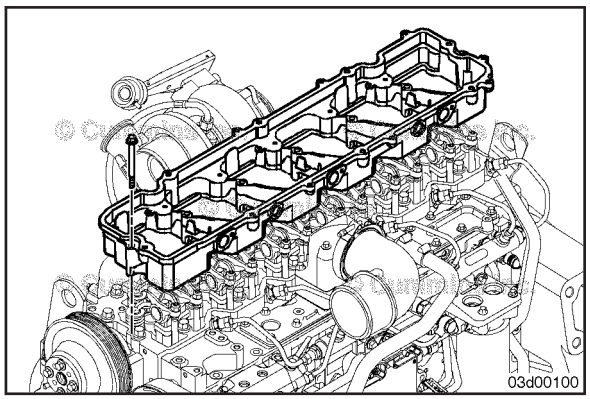


Install

⚠CAUTION⚠
To minimize the possibility of oil leaks, allow the RTV to cure for at minimum 1 hour prior operating the engine.

NOTE: Once the RTV has been applied, make sure to install the spacer within 15 minutes.

Apply a continuous bead of RTV in the groove around the brake spacer.



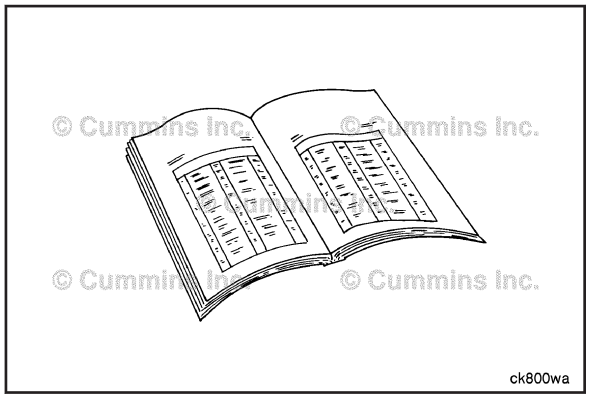
Install the engine brake spacer and the 5 mounting capscrews.

Torque Value: 32 N•m [23 ft-lb]

Finishing Steps

Install the engine brake assemblies. Refer to Procedure 020-004.

Install the rocker lever cover. Refer to Procedure 003-011.



Engine Brake Solenoid Valve (020-012)

Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.

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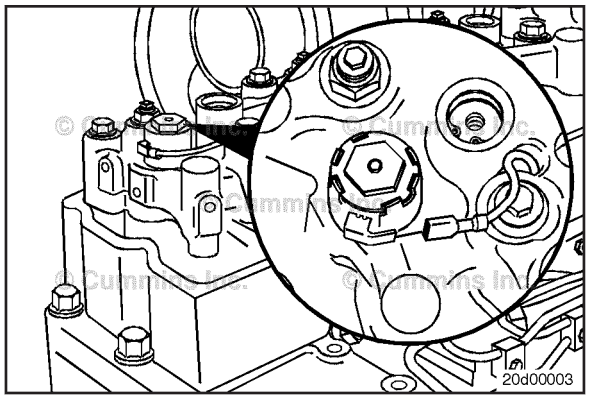
Remove

Disconnect the engine brake wiring harness from the solenoid.

Remove the solenoid and discard the o-rings.



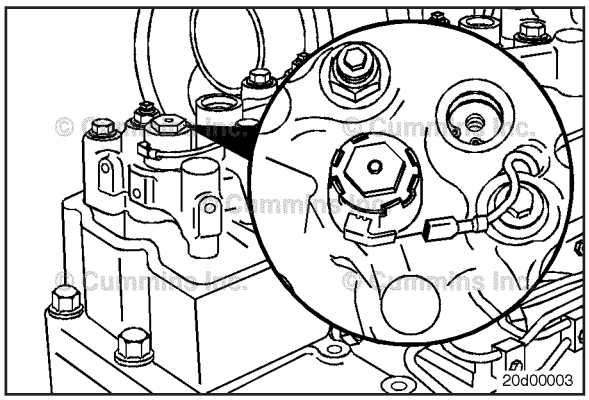
Install

Install new o-rings and the solenoid.

Tighten the solenoid.

Torque Value: 20 N•m [177 in-lb]

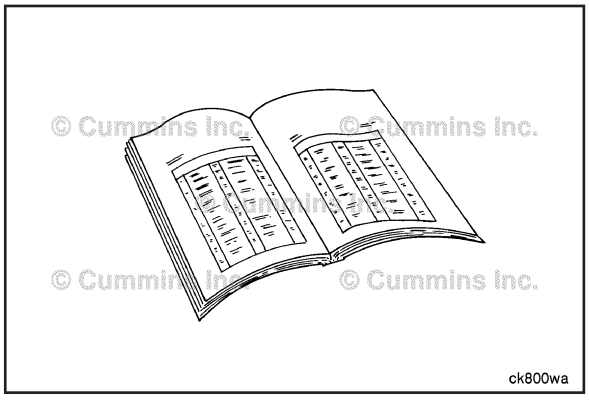
Connect the engine brake wiring harness to the solenoid.

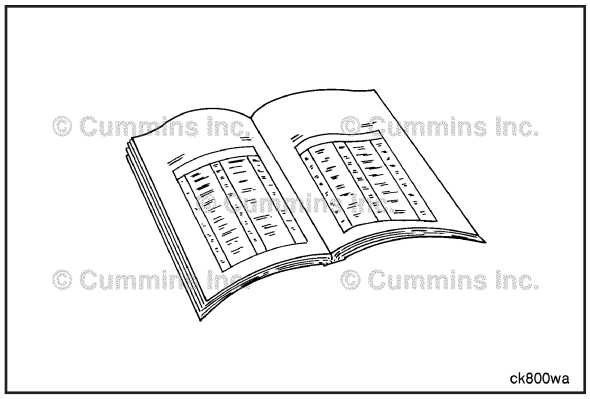


Finishing Steps

⚠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 cover. Refer to Procedure 003-011 in Section 3.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine, check for leaks, and verify proper engine brake operation.



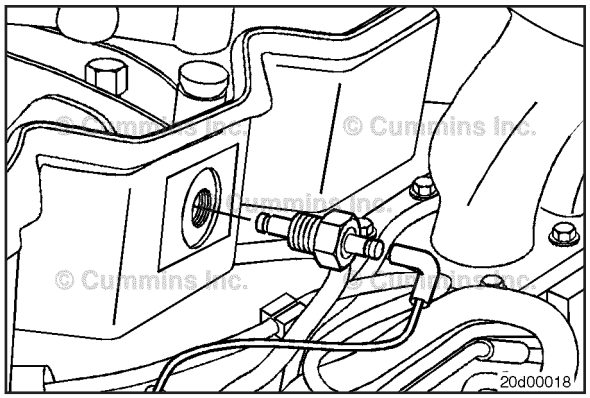


Engine Brake Wiring Harness (020-015)

Preparatory Steps

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.

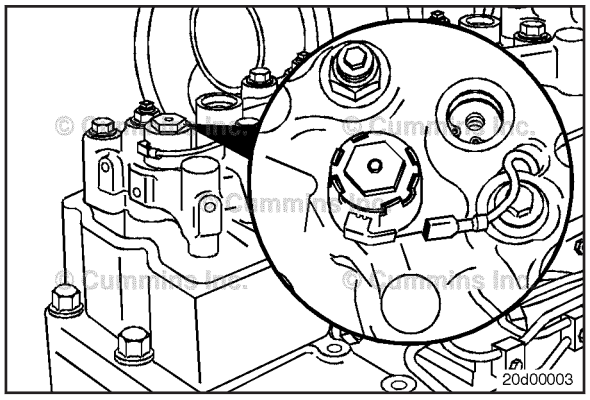


Remove

Remove the engine plug connector at the engine brake spacer.

Remove the engine receptacle connector retaining nut and o-ring.

Remove the engine receptacle from the engine brake spacer.



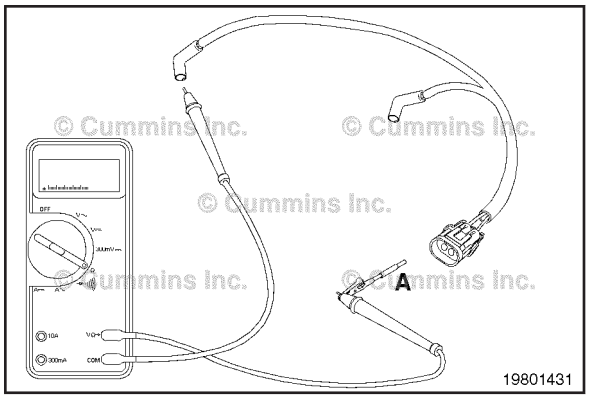
Disconnect the solenoid wires.

Resistance Check

Insert a test lead into pin A in the brake harness.

Insert the other test lead into the corresponding engine pass-through terminal connector in the brake harness.

Measure the resistance. The multimeter **must** read a closed circuit (10 ohms or less).

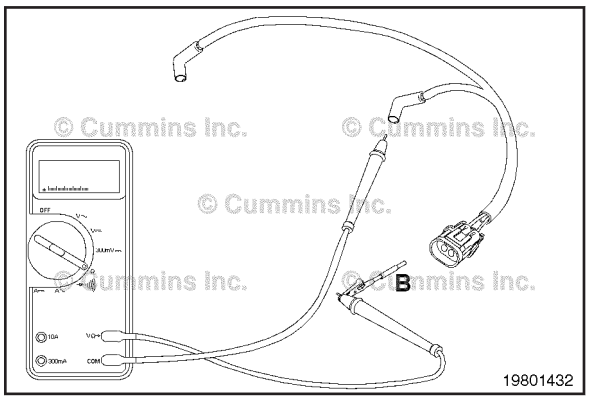


Remove the test lead from pin A and insert it into pin B.

Insert the other test lead into the corresponding engine pass-through terminal connector.

Measure the resistance. The multimeter **must** read a closed circuit (10 ohms or less).

If the resistance values are **not** correct, inspect the wires for an open circuit.

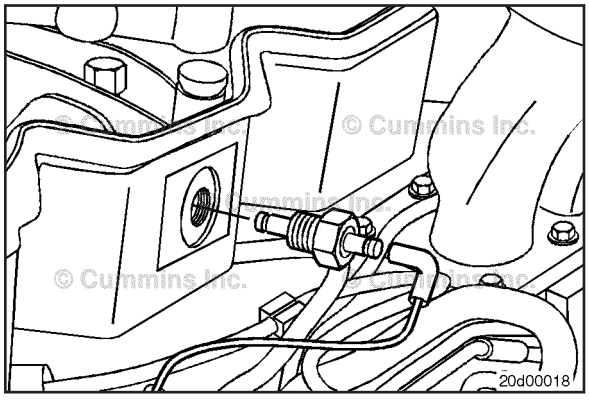


Install

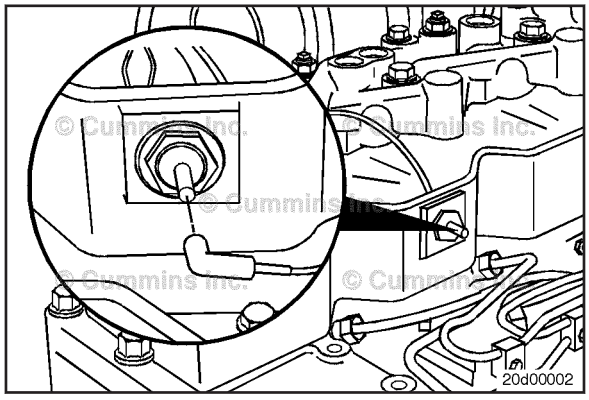
Install the engine receptacle into the engine brake spacer.

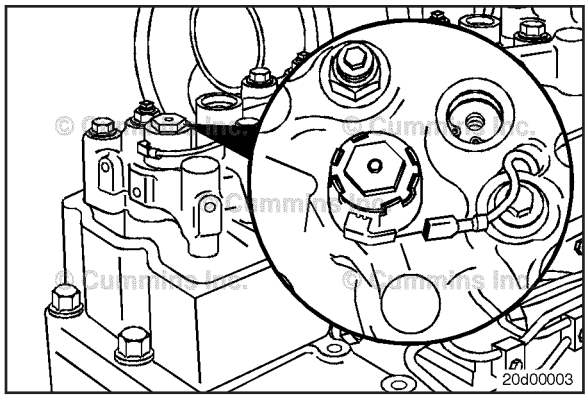
Install the engine receptacle connector retaining o-ring and tighten the nut.

Torque Value: 11 N•m [97 in-lb]

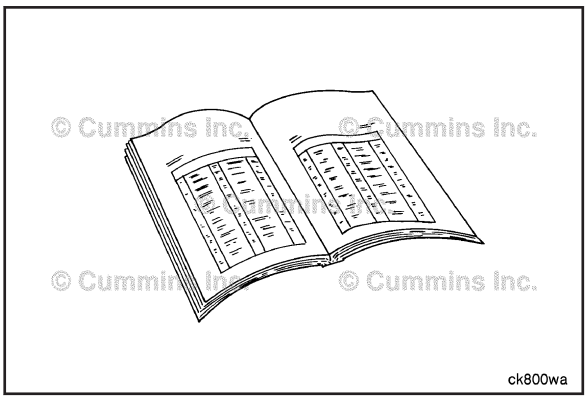


Install the engine plug connector at the rocker lever housing.





Connect the solenoid wires.



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 cover. Refer to Procedure 003-011 in Section 3.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and verify proper engine brake operation.

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Section L - Service Literature

Section Contents

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Additional Service Literature

General Information

The following publications can be purchased.

Bulletin Number	Title of Publication
3666271	ISC, QSC8.3, and ISL Electronic Control System Troubleshooting and Repair Manual
4021416	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
4021418	ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Troubleshooting and Repair Manual
3666121	Holset® Air Compressors Master Repair Manual
4022281	SmartCraft™ Marine Control System
3666267	ISC CM554 Wiring Diagram
3666395	QSC CM554 Wiring Diagram
3666416	ISL CM554 Wiring Diagram
3666478	QSL9 CM554 Wiring Diagram
4021421	ISC and ISL CM850 Electronic Control Module Wiring Diagram
4021524	QSB4.5, QSB6.7, QSC8.3 and QSL9 CM850 Electronic Control System Wiring Diagram
4021598	ISLe4 CM850 Wiring Diagram
4081885	QSL9 and QSC8.3 Marine CM850 Electronic Control Module with SmartCraft™ 1.0 Wiring Diagram
4082045	SmartCraft™ 2.2 Zeus™ Wiring Diagram
4082050	SmartCraft™ 2.2 Digital Throttle and Shift (DTS) Wiring Diagram
4082051	SmartCraft™ 2.2 Non-Digital Throttle and Shift (Non-DTS) Wiring Diagram
4082052	Asius System Wiring Diagram
4021428	OISC, ISCe, and ISL Operation and Maintenance Manual
4021518	QSC8.3 and QSL9 Operation and Maintenance Manual
4021557	ISLe3 and ISLe4 (Common Rail Fuel System) Operation and Maintenance Manual
4021571	ISLe3 and ISLe4 (Common Rail Fuel System) Operation and Maintenance Manual
4081893	CMD Smartcraft™ Diesel View Configuration and Operation Manual
4081961	CMD System Speedometer and Tachometer Operation Manual
4021481	QSC8.3 and QSL9 Marine Owners Manual
4915536	QSC8.3 and QSL9 Owners Manual
3379000	Air for Your Engine
3379001	Fuel for Cummins® Engines
3379009	Operation of Diesel Engines in Cold Climates
3666132	Cummins® Coolant Requirements and Maintenance
3810303	Parts Reuse Guidelines
3810340	Cummins® Engine Oil and Oil Analysis Recommendations
3884649	Marine Recreational B and C Installation Directions
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Contact Information

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Cummins Customized Parts Catalog

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The catalog cover, as well as the content, is customized with you in mind. You can use it in your shop, at your worksite, or as a coffee table book in your RV or boat. The cover contains your name, company name, address, and telephone number.

This new catalog was designed to provide you with the exact information you need to order parts for your engine. This will be valuable for customers that do not have easy access to Cummins QuickServe Online.

Additional Features of the Customized Catalog include:

- Engine Configuration Data
- Table of Contents
- Separate Option and Parts Indexes
- Service Kits (when applicable)
- ReCon Part Numbers (when applicable)

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- International Distributors and Original Equipment Manufacturers order the CPC from their regional Cummins Parts Distribution Centers (PDC).
- International PDC orders are called into Iron Mountain at (++) 630-283-2420.
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- Find the Customized Parts Catalog button located on the left of the homepage
- Select format. Your Price is also shown here
- Finalize Shopping Cart and Check Process as described on the website

North America call Iron Mountain Fulfillment Services (IMFS) at 800-646-5609, International customers call (++) 630-283-2420. Provide IMFS the catalog detail as described on the website. This step is required until we have our On Line form available.

Required information needed for your Customized Parts Catalog Order.

- Customer Name
- Street Address
- Company Name (optional)
- Telephone no.
- Credit Card No.
- Cummins Engine Serial Number (located on the engine data plate)

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Notes

Section V - Specifications

Section Contents

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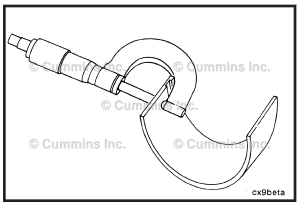
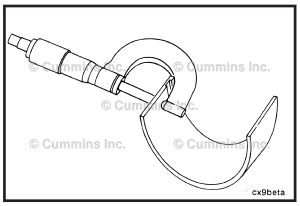
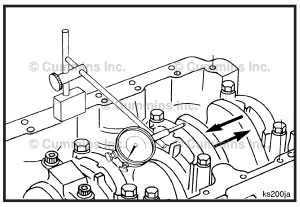
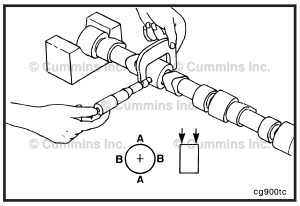
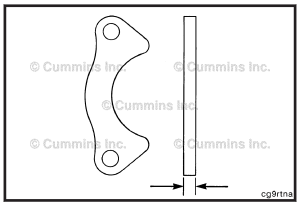
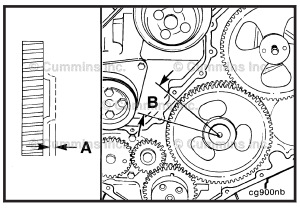
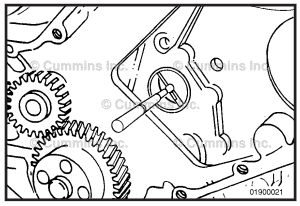
Cylinder Block - Group 01 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Bearings, Connecting Rod (001-005)					
Standard		2.457 2.469	MIN MAX	0.0968 0.0972	
Bearings, Main (001-006)					
Standard		3.446 3.454	MIN MAX	0.1357 0.1360	
Crankshaft End Play Limits		0.085 mm 0.385 mm	MIN MAX	0.003 in 0.015 in	
Camshaft (001-008)					
Camshaft Bearing Journal Diameter		59.962 mm 60.013 mm	MIN MAX	2.3607 in 2.3627 in	
Camshaft Thrust Plate		9.40 mm 9.60 mm	MIN MAX	0.370 in 0.378 in	
Camshaft End Play (A)		0.12 mm 0.50 mm	MIN MAX	0.005 in 0.020 in	
Camshaft Gear Backlash Limits (B)		0.08 mm 0.33 mm	MIN MAX	0.003 in 0.013 in	
Camshaft Bushings (001-010)					
Without bushing		64.013	MAX	2.5202	
With bushing		60.120	MAX	2.3669	

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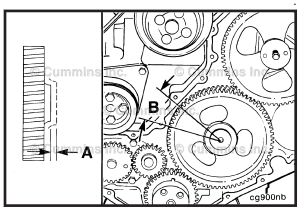
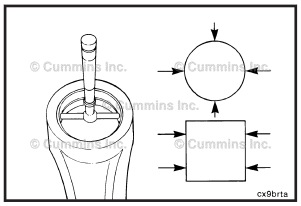
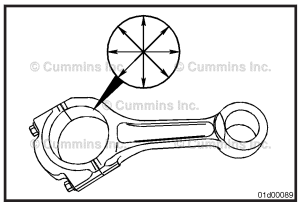
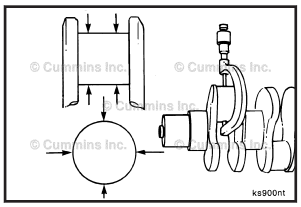
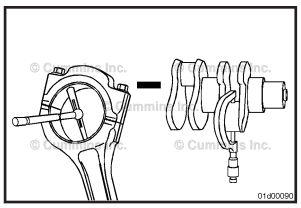
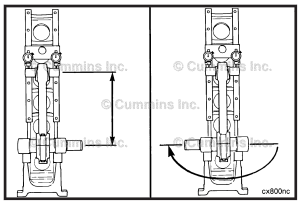
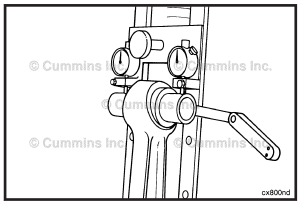
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Camshaft Gear (Camshaft Installed) (001-012)					
Camshaft End Play (A)		0.12 mm 0.50 mm	MIN MAX	0.005 in 0.020 in	
Camshaft Gear Backlash Limits (B)		0.08 mm 0.33 mm	MIN MAX	0.003 in 0.013 in	
Connecting Rod (001-014)					
Connecting Rod Piston Pin Bushing Diameter		45.023 mm 45.035 mm	MIN MAX	1.7726 in 1.7730 in	
Connecting Rod Crank Bore Diameter (Bearings Removed)		80.987 mm 81.013 mm	MIN MAX	3.1885 in 3.1895 in	
Out-of-Roundness		0.050 mm	MAX	0.002 in	
Taper		0.013 mm	MAX	0.0005 in	
Bearing Clearance		0.038 mm 0.116 mm	MIN MAX	0.0015 in 0.0045 in	
Straight Split Connecting Rod Length		215.975 mm 216.025 mm	MIN MAX	8.5029 in 8.5049 in	
Angle Split Connecting Rod Length		215.950 mm 216.050 mm	MIN MAX	8.5020 in 8.5059 in	
Bushing removed Bushing installed		0.20 0.30	MAX MAX	0.008 0.012	

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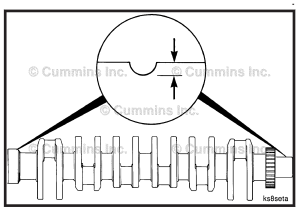
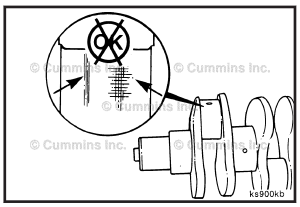
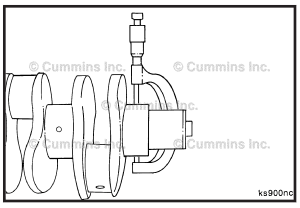
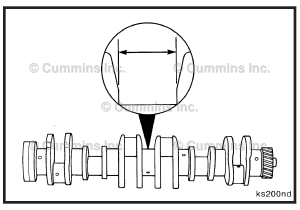
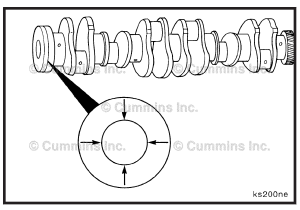
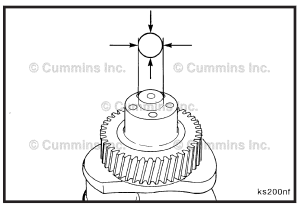
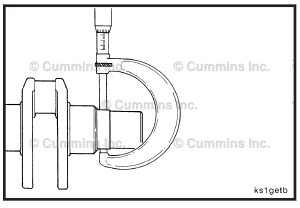
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Crankshaft (001-016)					
Crankshaft Front and Rear Oil Seal Wear Groove		0.25 mm	MAX	0.010 in	
Crankshaft Connecting Rod Journal Diameter		76.000 mm	MIN	2.9921 in	
		76.026 mm	MAX	2.9931 in	
Crankshaft Connecting Rod Out of Roundness		0.050 mm	MAX	0.002 in	
Crankshaft Connecting Rod Journal Taper		0.013 mm	MAX	0.0005 in	
Crankshaft Main Bearing Journal Diameter		98.006 mm	MIN	3.8585 in	
		98.032 mm	MAX	3.8595 in	
Crankshaft Main Bearing Journal Out of Roundness		0.050 mm	MAX	0.002 in	
Crankshaft Main Bearing Journal Taper		0.013 mm	MAX	0.0005 in	
Crankshaft Thrust Face Width (Standard)		42.98 mm	MIN	1.692 in	
		43.08 mm	MAX	1.696 in	
Crankshaft Rear Oil Seal Flange Outside Diameter		129.98 mm	MIN	5.117 in	
		130.03 mm	MAX	5.119 in	
Crankshaft Damper Pilot Outside Diameter		23.92 mm	MIN	0.942 in	
		24.00 mm	MAX	0.945 in	
Crankshaft Gear Journal Outside Diameter		75.987 mm	MIN	2.9916 in	
		76.006 mm	MAX	2.9924 in	

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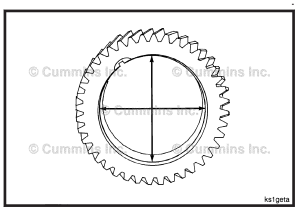
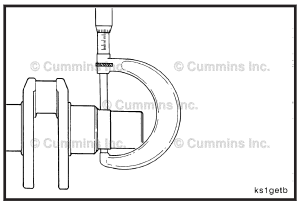
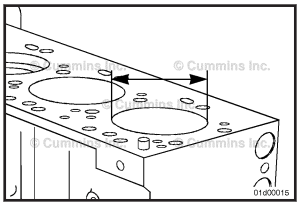
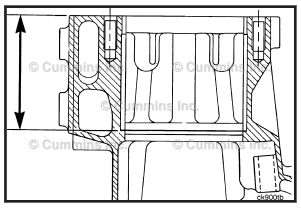
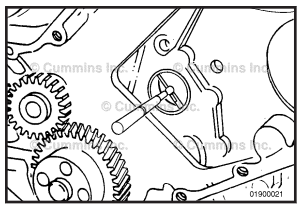
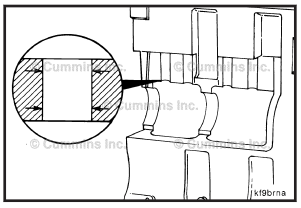
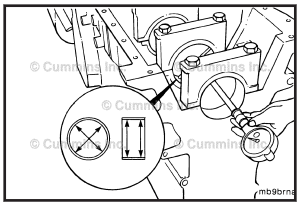
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Crankshaft Gear, Front (Crankshaft Removed) (001-019)					
Crankshaft Gear Bore Inside Diameter		75.898 mm	MIN	2.9881 in	
		75.923 mm	MAX	2.9891 in	
Crankshaft Gear Journal Outside Diameter		75.987 mm	MIN	2.9916 in	
		76.006 mm	MAX	2.9924 in	
Cylinder Block (001-026)					
Cylinder Liner Bore in Block (Press Fit Bore)		130.900 mm	MIN	5.1535 in	
		130.950 mm	MAX	5.1555 in	
Cylinder Block Counterbore Depth from Cylinder Block Head Deck		122.930 mm	MIN	4.8397 in	
		123.000 mm	MAX	4.8425 in	
Camshaft Bore Diameter (Without Bushing)		64.01 mm	MAX	2.520 in	
Tappet Bore Diameter		31.295 mm	MIN	1.2321 in	
		31.325 mm	MAX	1.2333 in	
Main Bearing Bore Diameter		104.982 mm	MIN	4.1331 in	
		105.018 mm	MAX	4.1346 in	

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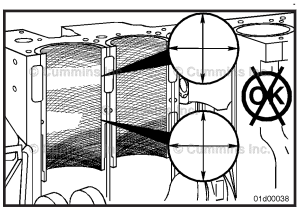
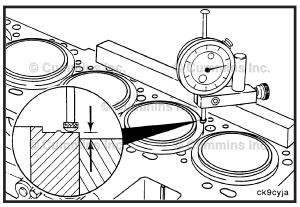
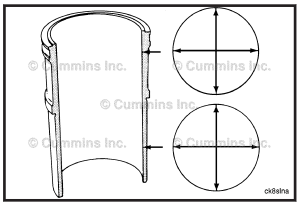
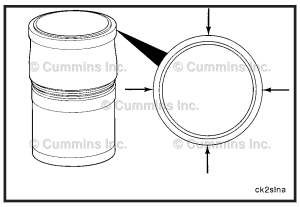
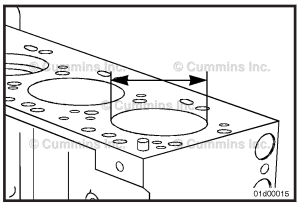
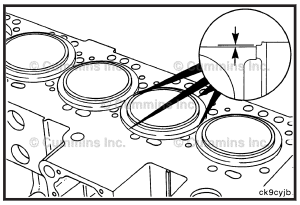
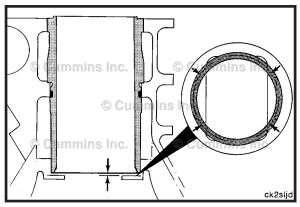
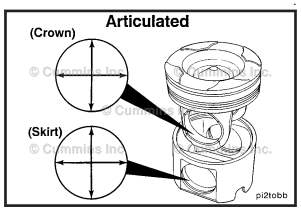
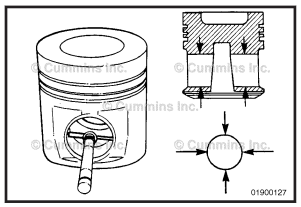
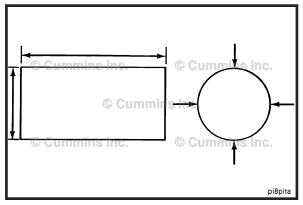
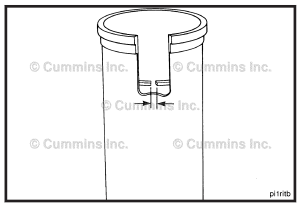
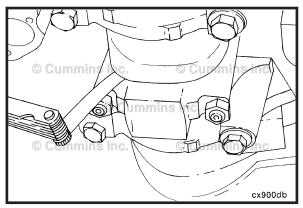
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Cylinder Liner (001-028)					
Taper		0.04	MAX	0.0016	
Out Of Round		0.04	MAX	0.0016	
Bore Diameter		114.04	MAX	4.4898	
Cylinder Liner Protrusion		0.026 mm 0.122 mm	MIN MAX	0.0010 in 0.0048 in	
Cylinder Liner Inside Diameter		114.000 mm 114.040 mm	MIN MAX	4.4882 in 4.4898 in	
Cylinder Liner Out Diameter (Top Press Fit)		130.938 mm 130.958 mm	MIN MAX	5.1550 in 5.1558 in	
Cylinder Liner Bore in Block (Press Fit Bore)		130.900 mm 130.950 mm	MIN MAX	5.1535 in 5.1555 in	
Cylinder Liner Protrusion		0.026 mm 0.122 mm	MIN MAX	0.0010 in 0.0048 in	
Cylinder Liner to Block Clearance		0.229 mm	MIN	0.009 in	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Piston (001-043)					
Crown		45.016	MIN	1.7723	
		45.036	MAX	1.7731	
Skirt		45.012	MIN	1.7721	
		45.026	MAX	1.7727	
Piston Pin Bore Diameter		45.006 mm	MIN	1.7719 in	
		45.012 mm	MAX	1.7721 in	
Piston Pin Diameter		44.997 mm	MIN	1.7715 in	
		45.003 mm	MAX	1.7718 in	
Piston Rings (001-047)					
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	
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	
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	
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	
Piston and Connecting Rod Assembly (001-054)					
Connecting Rod and Crankshaft Side Clearance		0.10 mm	MIN	0.004 in	
		0.30 mm	MAX	0.012 in	

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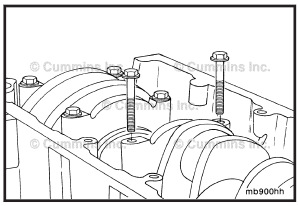
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	

Cylinder Block - Group 01 - Torque Values

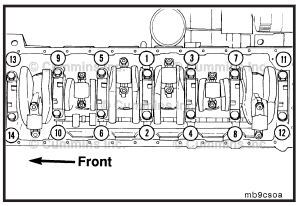
Bearings, Main (001-006)

Main Bearing Cap Initial Torque			50 N•m	[37 ft-lb]



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	

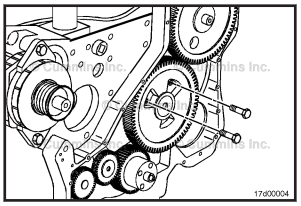


Torque Value:
135 mm [5.3 in] Capscrew

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	

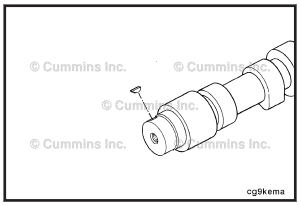
Camshaft (001-008)

Camshaft Thrust Plate Capscrews		24 N•m	[212 in-lb]



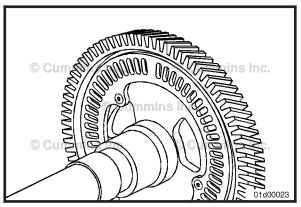
Camshaft Gear (Camshaft Installed) (001-012)

Camshaft Thrust Plate Capscrews		24 N•m	[212 in-lb]



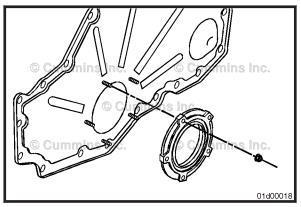
Camshaft Gear (Camshaft Removed) (001-013)

Camshaft Gear Timing Plate Capscrews		7 N•m	[62 in-lb]



Crankshaft Seal, Front (001-023)

Front Seal Carrier Mounting Nuts		8 N•m	[71 in-lb]



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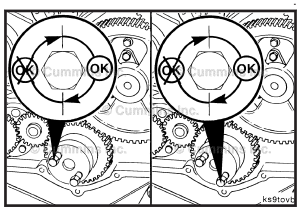
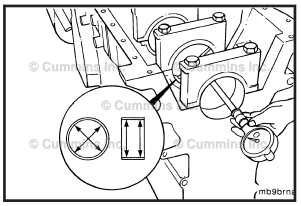
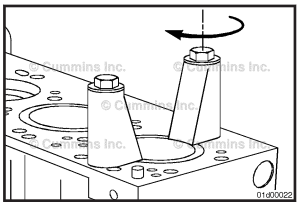
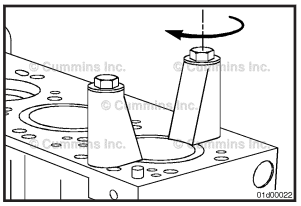
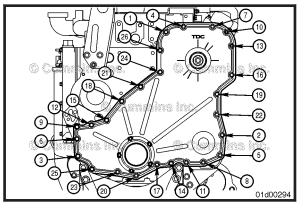
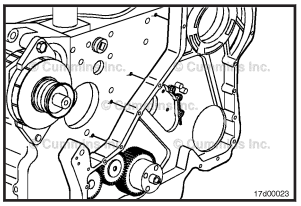
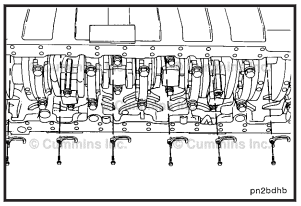
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Crankshaft Wear Sleeve, Front (001-025)				
Wear Sleeve Installation Capscrews		20 N•m	[180 in-lb]	
Cylinder Block (001-026)				
Main Bearing Cap Capscrews		176 N•m	[130 ft-lb]	
Cylinder Liner (001-028)				
		68 N•m	[50 ft-lb]	
		68 N•m	[50 ft-lb]	
Gear Cover, Front (001-031)				
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]		
Gear Housing, Front (001-033)				
Gear Housing Mounting Capscrews		40 N•m	[30 ft-lb]	
Piston Cooling Nozzle (001-046)				
Banjo Mounted Piston Cooling Nozzle		25 N•m	[221 in-lb]	

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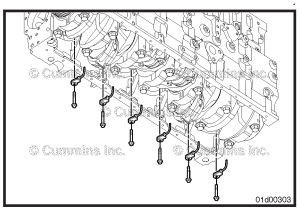
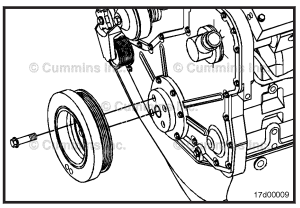
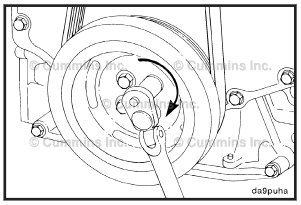
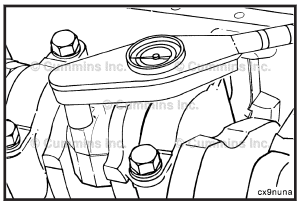
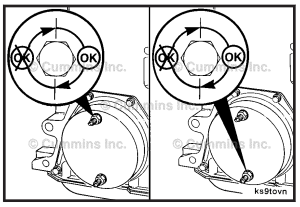
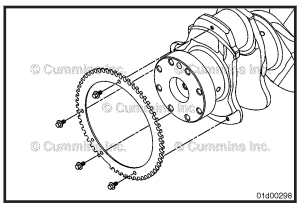
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Flange Head Capscrew Mounted Piston Cooling Nozzles		33 N•m	[24 ft-lb]	
Vibration Damper, Rubber (001-051)				
Vibration Damper, Rubber		200 N•m	[148 ft-lb]	
Vibration Damper, Viscous (001-052)				
Vibration Damper, Viscous		200 N•m	[148 ft-lb]	
Connecting Rod Nuts 60 44 Loosen capscrews 70 52 Advance 90 degrees				
Piston and Connecting Rod Assembly (001-054)				
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			
				
Crankshaft Wear Sleeve, Rear (001-067)				
Rear Seal Installation Tool		20 N•m	[180 in-lb]	
Crankshaft Speed Indicator Ring (001-071)				
Crankshaft Speed Indicator Ring Capscrews		8 N•m	[71 in-lb]	

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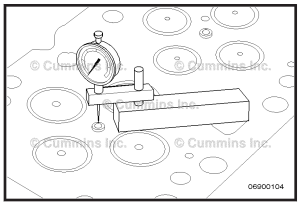
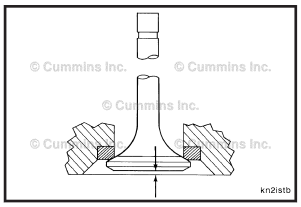
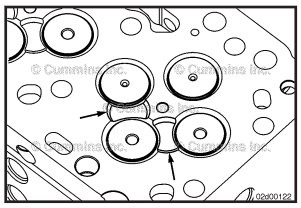
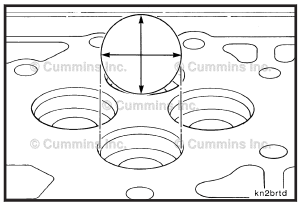
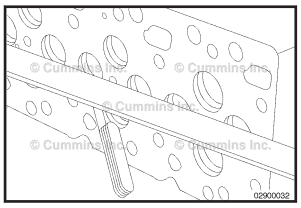
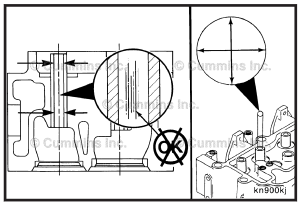
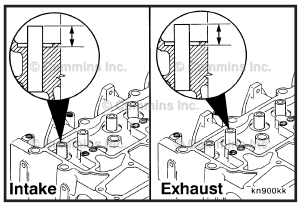
Cylinder Head - Group 02 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Cylinder Head (002-004)					
Injector Protrusion (CAPS Fuel System)		2.60 mm	MIN	0.102 in	
		3.40 mm	MAX	0.134 in	
Injector Protrusion (Cummins® Common Rail Fuel System)		2.25 mm	MIN	0.088 in	
		2.80 mm	MAX	0.110 in	
Standard Head Valve Recess in Cylinder Head		0.84 mm	MIN	0.033 in	
		1.32 mm	MAX	0.052 in	
Scallop Head Valve Recess in Cylinder Head		0.69 mm	MIN	0.027 in	
		1.17 mm	MAX	0.046 in	
Cylinder Head Insert Bore Inside Diameter		39.371 mm	MIN	1.550 in	
		39.401 mm	MAX	1.551 in	
Cylinder Head Insert Bore Inside Diameter for Oversized Seats		39.625 mm	MIN	1.560 in	
		39.655 mm	MAX	1.561 in	
End to End		0.203	MAX	0.008	
Side to Side		0.075	MAX	0.003	
Valve Guide Inside Diameter		8.019 mm	MIN	0.316 in	
		8.081 mm	MAX	0.318 in	
Valve Guide Height (Installed)		13.15 mm	MIN	0.518 in	
		13.65 mm	MAX	0.537 in	

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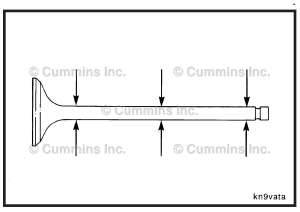
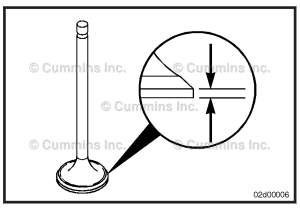
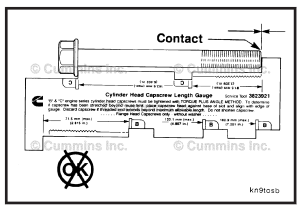
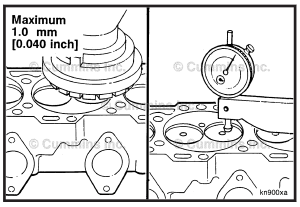
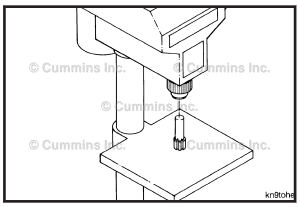
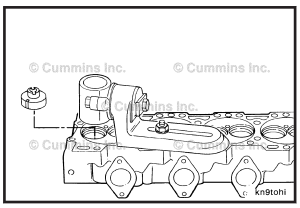
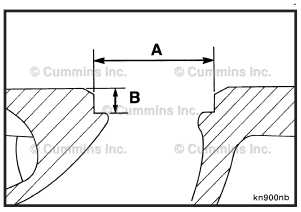
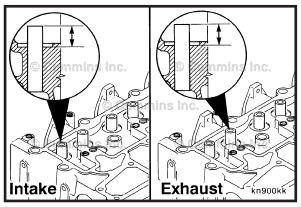
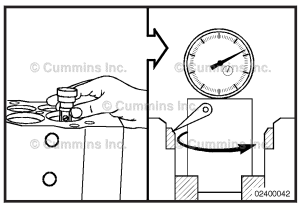
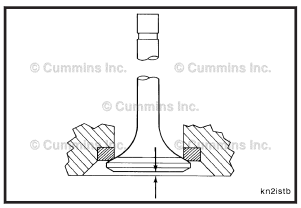
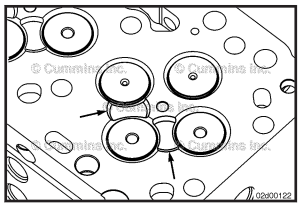
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Valve Stem Diameter		7.96 mm 7.98 mm	MIN MAX	0.313 in 0.314 in	
Exhaust Intake		1.83 2.20	MIN MIN	0.072 0.087	
Cylinder Head Capscrew Free Length		162.6 mm	MAX	6.4 in	
Amount of Material Removed		0.5	MAX	0.02	
Surface Finish		3.2 µM	MAX	125 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	
Exhaust Intake		1.09 1.62 0.59 1.12	MIN MAX MIN MAX	0.0430 0.064 0.023 0.044	
Oversize Valve Guide Bore Dimensions		16.441 mm 16.481 mm	MIN MAX	0.6473 in 0.6489 in	
Intake - 3824058 Exhaust - 3824060 Intake - 3824059 Exhaust - 3824061		54.151 54.181 47.251 47.281 54.405 54.435 47.505 47.535	MIN MAX MIN MAX MIN MAX MIN MAX	2.1319 2.1331 1.8603 1.8615 2.1419 2.1431 1.8703 1.8715	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
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	
Intake		3.68	MIN	0.145	
		4.14	MAX	0.163	
Exhaust		3.17	MIN	0.125	
		3.63	MAX	0.143	
Valve Guide Height (Installed)		13.15 mm	MIN	0.518 in	
		13.65 mm	MAX	0.537 in	
Valve Seat-to-Valve Guide Runout		0.2 mm	MAX	0.008 in	
Standard Head Valve Recess in Cylinder Head		0.84 mm	MIN	0.033 in	
		1.32 mm	MAX	0.052 in	
Scallop Head Valve Recess in Cylinder Head		0.69 mm	MIN	0.027 in	
		1.17 mm	MAX	0.046 in	

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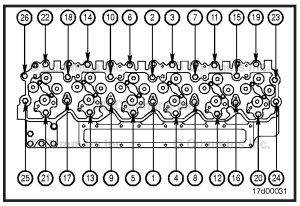
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	

Cylinder Head - Group 02 - Torque Values

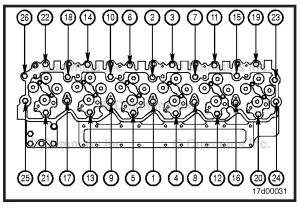
Cylinder Head (002-004)

80 N•m [59 ft-lb]



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.	

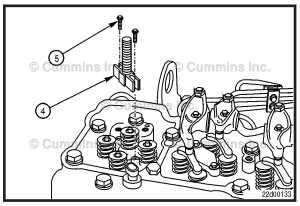


Torque Value:
Cummins® Common Rail Fuel System

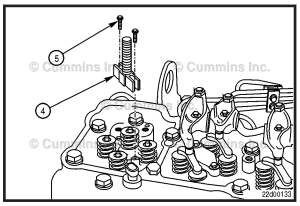
Step 1	50 N•m	[37 ft-lb]
Step 2	150 N•m	[111 ft-lb]
Step 3	Loosen all capscrews	
Step 4	115 N•m	[85 ft-lb]
Step 5	115 N•m	[85 ft-lb]
Step 6	Advance 120 degrees.	

Valve Guide Seal, Cylinder Head (002-016)

Cylinder Head Valve Guide Seal Capscrews — 5 N•m [44 in-lb]



Cylinder Head Valve Guide Seal Capscrews — 5 N•m [44 in-lb]



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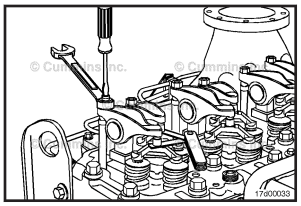
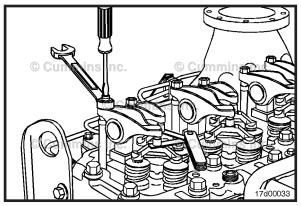
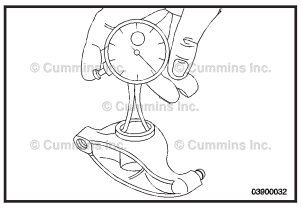
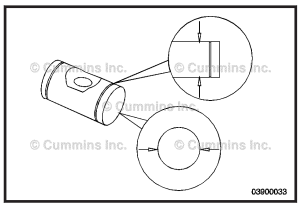
Rocker Levers - Group 03 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Overhead Set (003-004)					
Intake		0.152	MIN	0.006	
		0.559	MAX	0.022	
Exhaust		0.381	MIN	0.015	
		0.813	MAX	0.032	
Intake		0.305	NOM	0.012	
Exhaust		0.559	NOM	0.022	
Rocker Lever (003-008)					
Rocker Lever Bore		24.987 mm	MIN	0.984 in	
		25.013 mm	MAX	0.985 in	
Rocker Lever Shaft		24.950 mm	MIN	0.982 in	
		24.962 mm	MAX	0.983 in	

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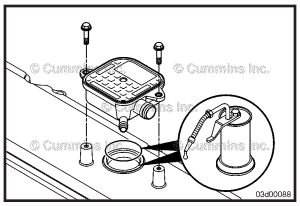
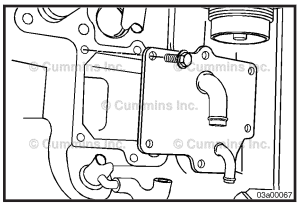
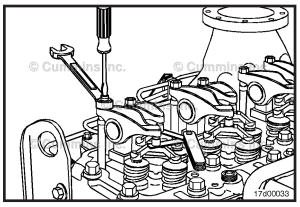
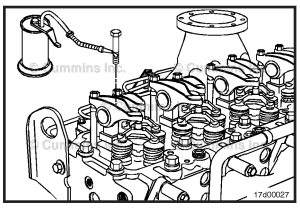
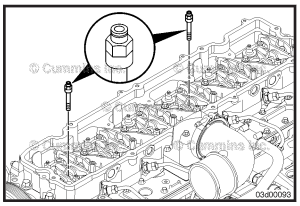
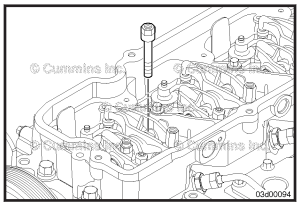
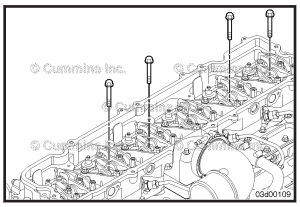
Rocker Levers - Group 03 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Crankcase Breather (External) (003-001)				
Crankcase Breather (External)		7 N•m	[62 in-lb]	
Crankcase Breather (Internal) (003-002)				
Crankcase Breather (Internal)		10 N•m	[89 in-lb]	
Overhead Set (003-004)				
Valve Adjusting Screw Locknut		24 N•m	[212 in-lb]	
Rocker Lever (003-008)				
Pedestal Capscrews		65 N•m	[48 ft-lb]	
Engine Brake Oil Supply Studs		65 N•m	[48 ft-lb]	
Exhaust Rocker Lever Mounting Studs		65 N•m	[48 ft-lb]	
Intake Pedestal Capscrews		65 N•m	[48 ft-lb]	

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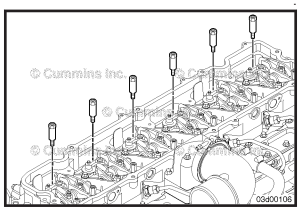
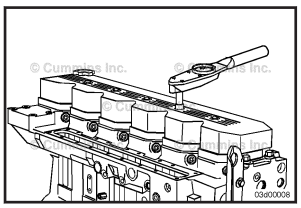
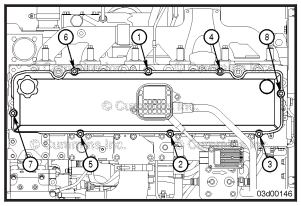
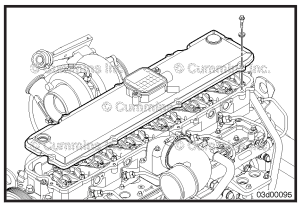
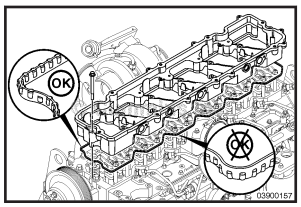
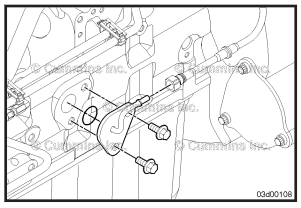
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
		24 N•m	[212 in-lb]	
Rocker Lever Cover (003-011) Center Bolted Rocker Lever Cover Mounting Capscrews		12 N•m	[106 in-lb]	
Perimeter Rocker Lever Cover Mounting Capscrews		12 N•m	[106 in-lb]	
		12 N•m	[106 in-lb]	
Rocker Lever Housing (003-013) Perimeter Bolted Rocker Lever Housing Mounting Capscrews		24 N•m	[212 in-lb]	
Crankcase Breather Tube (003-018) Crankcase Breather Drain Line Cover		45 N•m	[33 ft-lb]	

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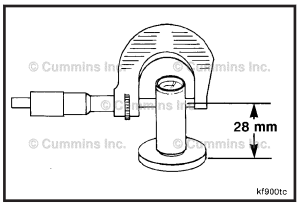
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.

Cam Followers/Tappets - Group 04 - Specifications

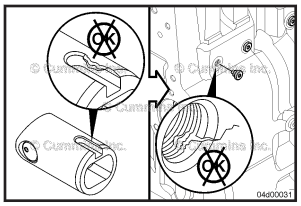
Tappet (004-015)

Valve Tappet Stem Diameter	15.936 mm	MIN	0.627 in
	15.977 mm	MAX	0.629 in



Cam Followers/Tappets - Group 04 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
Tappet (004-015)			
Tappet Guide Screw		10 N•m	[89 in-lb]



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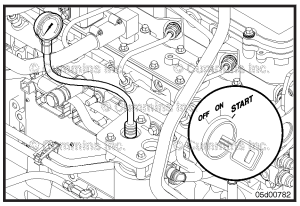
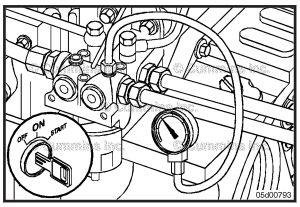
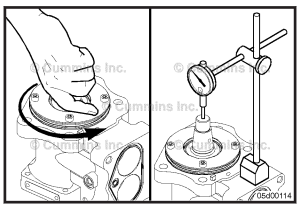
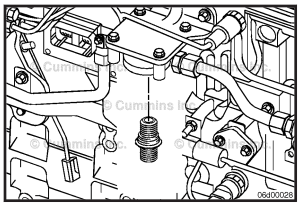
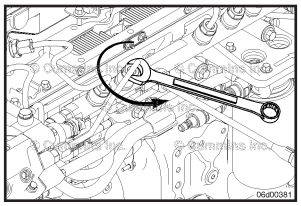
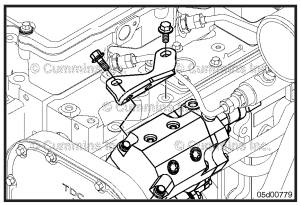
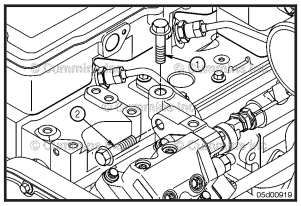
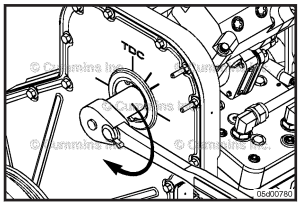
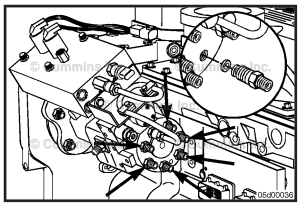
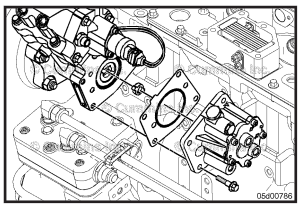
Fuel System - Group 05 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Fuel Pump Gear Pump (005-025)					
Minimum Gear Pump Pressure at Cranking		105 kPa	MIN	15 psi	
Fuel Lift Pump Output Pressure		35 kPa	MIN	5 psi	
Fuel Lift Pump (005-045)					
Fuel Lift Pump Inlet Restriction		102 mm Hg	MAX	4 in Hg	
Fuel Pump Cam Housing Module (005-088)					
Camshaft End Clearance		0.05 mm	MAX	0.002 in	

Fuel System - Group 05 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Engine Fuel Heater, Electric (005-008)				
Fuel Filter Spud		30 N•m	[22 ft-lb]	
Fuel Pump (005-016)				
Fuel Rail Nut		65 N•m	[48 ft-lb]	
Fuel Pump Mounting Nuts		44 N•m 65 N•m	[32 ft-lb] [48 ft-lb]	
		44 N•m 65 N•m 80 N•m	[32 ft-lb] [48 ft-lb] [59 ft-lb]	
Fuel Injection Pump Gear Nut		180 N•m	[133 ft-lb]	
Fuel Pump Delivery Valve (005-020)				
Fuel Delivery Valve Outlet Fitting Assemblies		81 N•m	[60 ft-lb]	
Fuel Pump Gear Pump (005-025)				
Fuel Pump Gear Pump Mounting Bolts		34 N•m	[25 ft-lb]	

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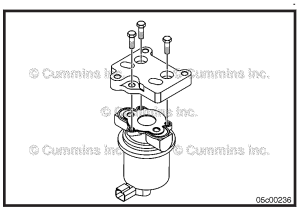
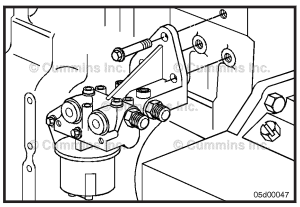
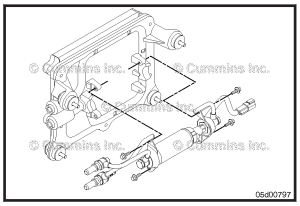
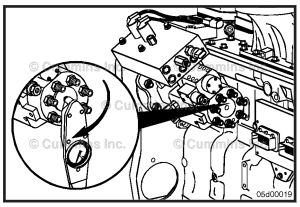
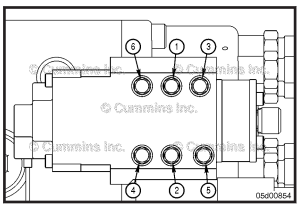
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Fuel Lift Pump (005-045)				
Adapter And Lift Pump Assembly Bolts		12.4 N•m	[110 in-lb]	
Block Mounted Lift Pump		43 N•m	[32 ft-lb]	
Ecm Cooling Plate Mounted Lift Pump		10 N•m	[89 in-lb]	
Rotor, CAPS Fuel Injection Pump (005-072)		14 N•m	[10 ft-lb]	

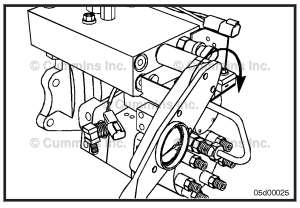
Injection Control Valve (005-078)



Torque Value:

Step 1	1.8 N•m	[16 in-lb]
Step 2	3.6 N•m	[32 in-lb]
Step 3	5.6 N•m	[50 in-lb]
Step 4	Torque to 5.6 N•m [50 in-lb] three more times following the torque sequence	

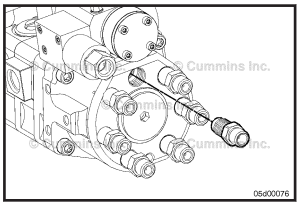
Snubber, Rate Shape (005-081)



Torque Value:

Step 1	14 N•m	[124 in-lb]
Step 2	Rotate 80 degrees	

Fuel Pump Distributor Inlet Fitting (005-084)



Torque Value:

Step 1	5.7 N•m	[50 in-lb]
Step 2	Rotate 120 degrees clockwise	

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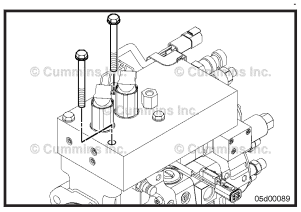
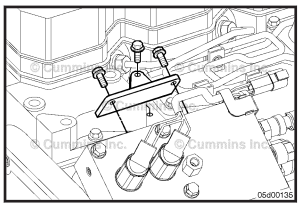
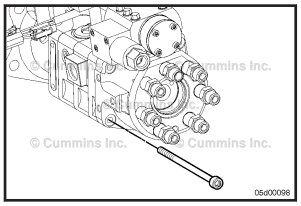
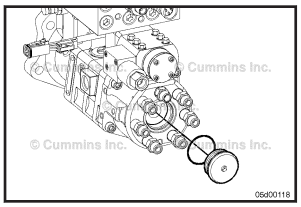
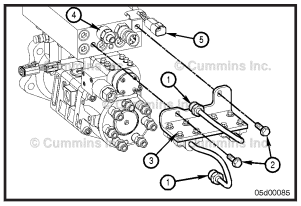
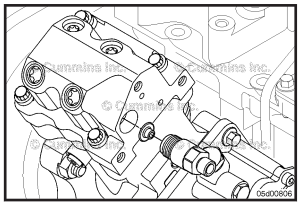
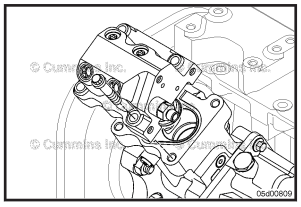
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Fuel Pump Accumulator Module (005-085)		68 N•m	[50 ft-lb]	
		44 N•m	[32 ft-lb]	
Fuel Pump Distributor and Injection Control Valve Module (005-086)				
Distributor Capscrews		48 N•m	[35 ft-lb]	
Distributor Plug		14 N•m	[120 in-lb]	
Fuel Pump Rate Shape Tube (005-090)				
Fuel Pump Rate Shape Tube Nuts		46 N•m	[34 ft-lb]	
		Capscrew 41 30 Thermistor Adapter 34 25		
Fuel Pump Head Outlet Fitting (005-226)				
Torque Value:				
Step 1	13.6 N•m	[120 in-lb]		
Step 2	Rotate 90 degrees			
Fuel Pump Head (005-227)		68 N•m	[50 ft-lb]	

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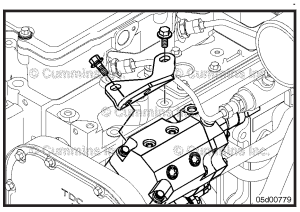
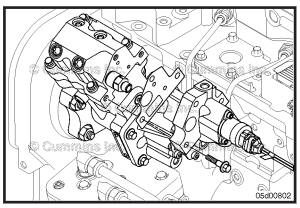
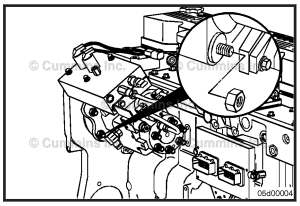
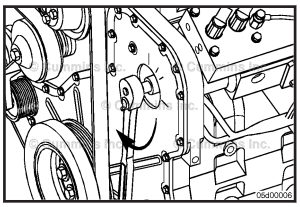
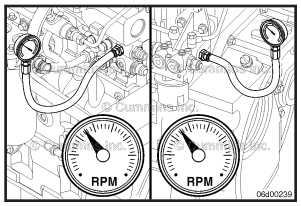
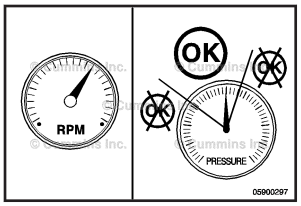
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
		43 N•m 43 N•m	[32 ft-lb] [32 ft-lb]	
Fuel Pump Actuator Housing (005-228)				
Fuel Pump Actuator Housing		34 N•m	[25 ft-lb]	
Fuel Injection Pump (005-229)				
Fuel Pump Mounting Nut		44 N•m 44 N•m 68 N•m	[32 ft-lb] [32 ft-lb] [48 ft-lb]	
Fuel Injection Pump		180 N•m	[132 ft-lb]	

Injectors and Fuel Lines - Group 06 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Fuel Drain Line Restriction (006-012)				
All Applications Except Marine		254.0	MAX	10.0
Marine Applications		101.6	MAX	4.0
Fuel Filter (Spin-On Type) (006-015)				
Maximum Allowable Pressure Drop Across Fuel Filter		80 kPa	MAX	11.7 psi

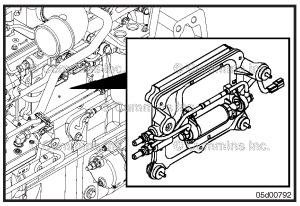




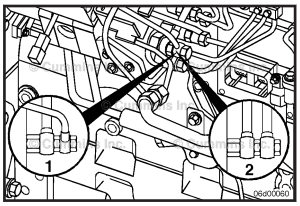
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	

Injectors and Fuel Lines - Group 06 - Torque Values

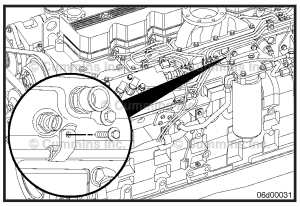
Engine Control Module Cooling Plate, Fuel Cooled (006-006)

Ecm Cooling Plate Mounting Capscrews		24 N•m	[212 in-lb]	

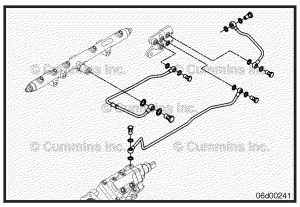
Fuel Drain Lines (006-013)



Torque Value:			
Style One (1)			
Step 1	24 N•m	[212 in-lb]	
Torque Value:			
Style Two (2)			
Step 1	24 N•m	[212 in-lb]	

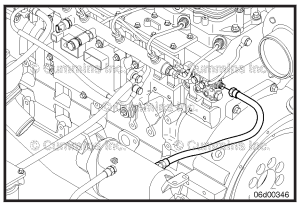


Torque Value:			
M12 banjo bolts			
Step 1	24 N•m	[212 in-lb]	
Torque Value:			
P-clip capscrew			
Step 1	24 N•m	[212 in-lb]	



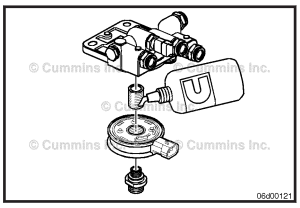
Torque Value:			
M12 banjo bolts			
Step 1	24 N•m	[212 in-lb]	
Torque Value:			
M16 banjo bolts			
Step 1	43 N•m	[32 ft-lb]	
Torque Value:			
P-clip capscrew			
Step 1	24 N•m	[212 in-lb]	

Marine Fuel Line		37 N•m	[27 ft-lb]

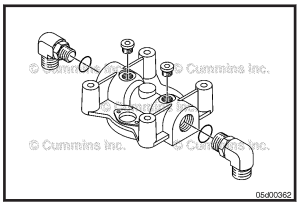


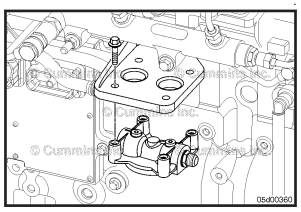
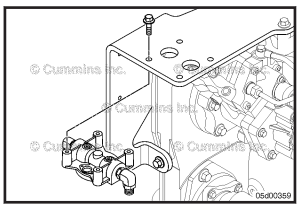
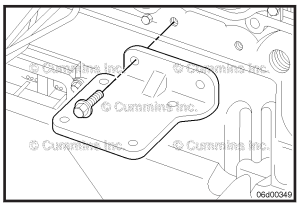
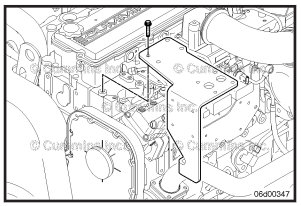
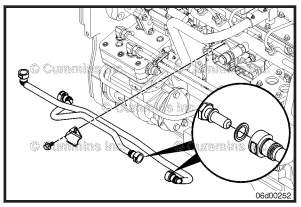
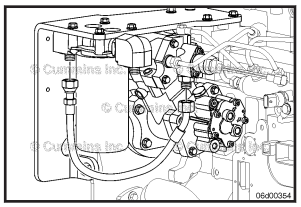
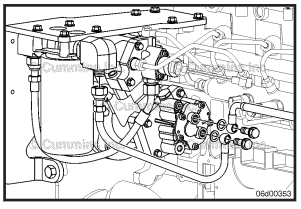
Fuel Filter Head (006-017)

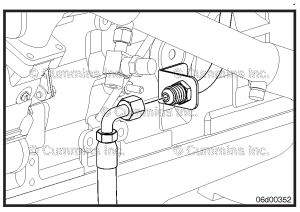
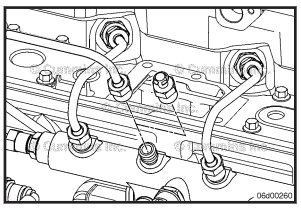
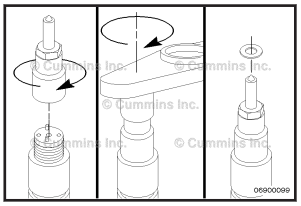
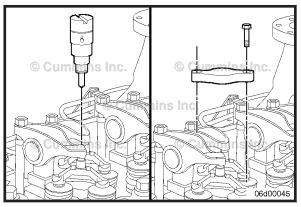
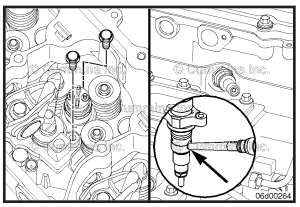
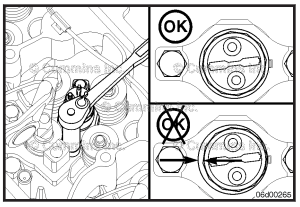
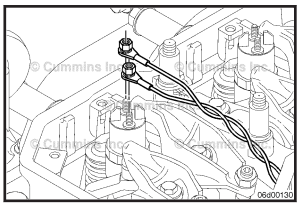
Fuel Filter Adapter		30 N•m	[22 ft-lb]



Fuel Filter Head Test Port Plugs		27 N•m	[239 in-lb]
		14 N•m	[124 in-lb]



Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
		24 N•m	[212 in-lb]	
Fuel Filter Head Mounting Capscrews		30 N•m	[22 ft-lb]	
Fuel Filter Head Bracket (006-018)				
Fuel Filter Head Bracket Capscrews		43 N•m	[32 ft-lb]	
		43 N•m	[32 ft-lb]	
37 N•m	[27 ft-lb]			
24 N•m	[212 in-lb]			
Fuel Supply Lines (006-024)				
		24 N•m 24 N•m 24 N•m	[212 in-lb] [212 in-lb] [212 in-lb]	
		37 N•m	[27 ft-lb]	
		37 N•m 37 N•m 24 N•m	[27 ft-lb] [27 ft-lb] [212 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
		24 N•m 37 N•m	[212 in-lb] [27 ft-lb]	
Injector (006-026) Isolation Tool, Part Number 3164325		38 N•m	[28 ft-lb]	
Mechanical Injector Retaining Nut		47 N•m	[35 ft-lb]	
Injector Hold-Down Clamp		10 N•m	[89 in-lb]	
		15 N•m	[133 in-lb]	
Injector Hold-Down Capscrews		10 N•m	[89 in-lb]	
Injector Wiring Harness		1.25 N•m	[11 in-lb]	

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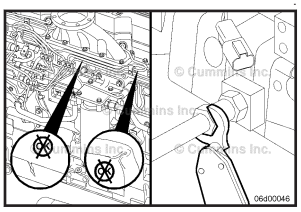
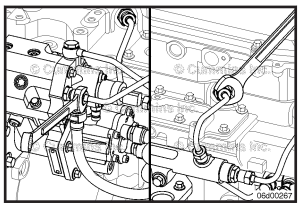
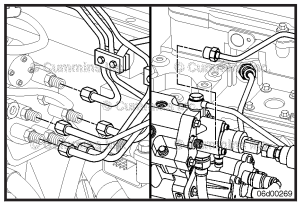
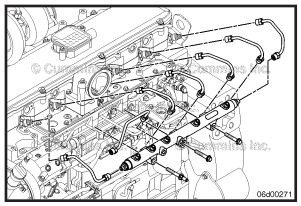
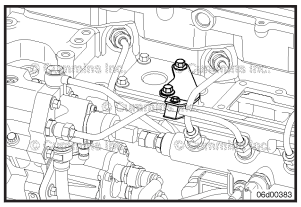
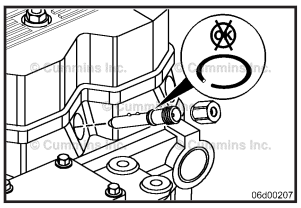
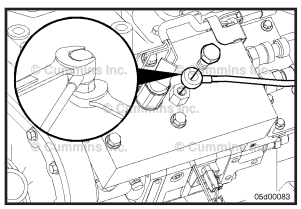
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Injector Supply Lines (High Pressure) (006-051)		24 N•m 38 N•m 3 N•m	[212 in-lb] [28 ft-lb] [27 in-lb]	
		38 N•m 38 N•m 38 N•m	[28 ft-lb] [28 ft-lb] [28 ft-lb]	
24 N•m 9 N•m	[212 in-lb] [80 in-lb]			
		24 N•m 38 N•m 3 N•m	[212 in-lb] [28 ft-lb] [27 in-lb]	
		38 N•m 38 N•m	[28 ft-lb] [28 ft-lb]	
38 N•m 38 N•m	[28 ft-lb] [28 ft-lb]			
		24 N•m 9 N•m	[212 in-lb] [80 in-lb]	
Fuel Connector (Head Mounted) (006-052)		55 N•m	[41 ft-lb]	
Fuel Pump Air Bleed Line (006-056) Banjo Capscrew At Air Bleed Fitting		8 N•m	[70 in-lb]	

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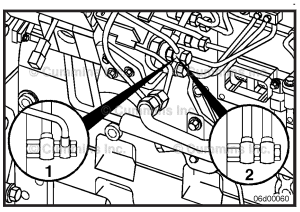
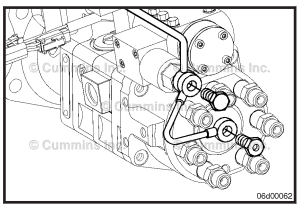
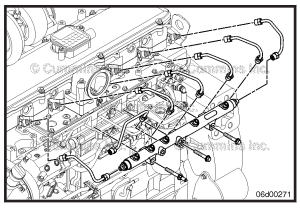
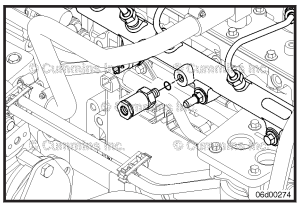
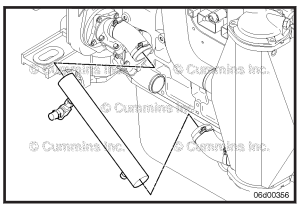
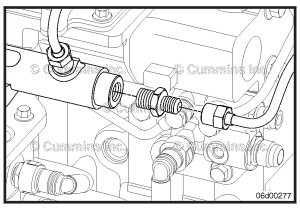
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Banjo Capscrew Drain Fitting		8 N•m 24 N•m 24 N•m	[70 in-lb] [18 ft-lb] [18 ft-lb]	
Banjo Capscrew Distributor Plug		8 N•m	[70 in-lb]	
Fuel Rail (006-060) Fuel Rail Assembly Capscrews		43 N•m	[32 ft-lb]	
Fuel Pressure Relief Valve (006-061) Fuel Pressure Relief Valve		100 N•m 37 N•m	[74 ft-lb] [27 ft-lb]	
Fuel Cooler (006-062) Fuel Cooler Sea Water Hose Clamps		8 N•m	[71 in-lb]	
Fuel Rail High Pressure Fitting (006-067) Fuel Pressure Relief Valve		100 N•m	[74 ft-lb]	

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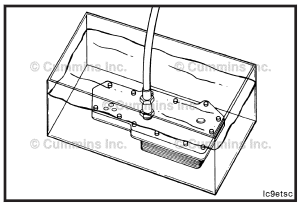
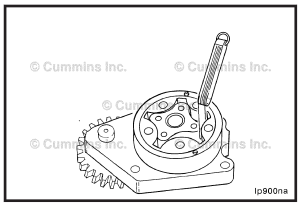
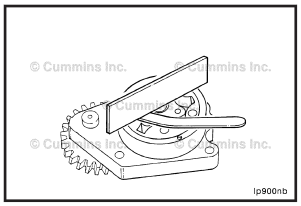
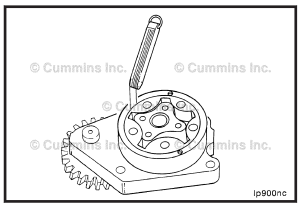
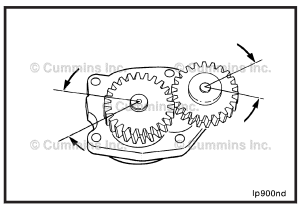
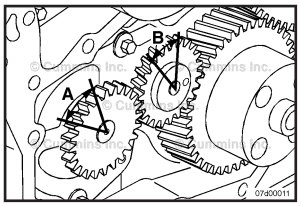
Lubricating Oil System - Group 07 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Lubricating Oil Cooler (007-003)					
Air Pressure Test		449 kPa	MIN	65 psi	
		518 kPa	MAX	75 psi	
Lubricating Oil Pump (007-031)					
Tip Clearance		0.0254 mm	MIN	0.001 in	
		0.1778 mm	MAX	0.007 in	
Gerotor Drive/Gerotor Planetary to Port Plate Clearance		0.0254 mm	MIN	0.001 in	
		0.1270 mm	MAX	0.005 in	
Gerotor Planetary to Body Bore Clearance		0.1778 mm	MIN	0.007 in	
		0.3810 mm	MAX	0.015 in	
Lubricating Oil Pump Gears Backlash Limits (Used Pump)		0.0762 mm	MIN	0.003 in	
		0.3302 mm	MAX	0.013 in	
A		0.0762	MIN	0.003	
		0.3302	MAX	0.013	
B		0.0762	MIN	0.003	
		0.3302	MAX	0.013	

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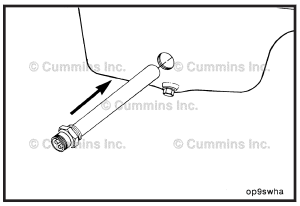
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	

Lubricating Oil System - Group 07 - Torque Values

Engine Oil Heater (007-001)

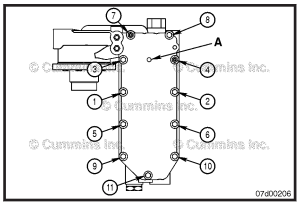
Engine Oil Heater Element		120 N•m	[89 ft-lb]
		24 N•m	[212 in-lb]



Lubricating Oil Cooler (007-003)

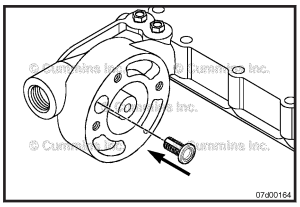
Torque Value:

Step 1	24 N•m	[212 in-lb]
Step 2	32 N•m	[24 ft-lb]



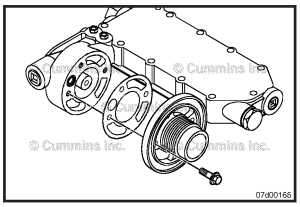
Lubricating Oil Filter Bypass Valve (007-014)

Lubricating Oil Bypass Valve Pipe Plug		45 N•m	[33 ft-lb]



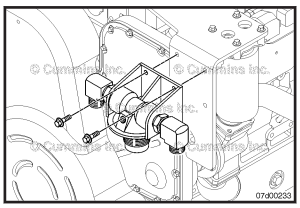
Lubricating Oil Filter Head (007-015)

Lubricating Oil Filter Head Mounting Capscrews		24 N•m	[212 in-lb]

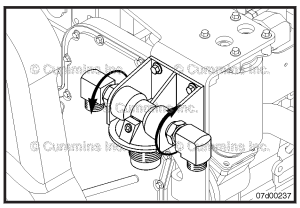


Lubricating Oil Filter Head (Remote-Mounted) (007-017)

Lubricating Oil Filter Head Assembly		24 N•m	[18 ft-lb]



Lubricating Oil Filter Tube Locking Nut		100 N•m	[74 ft-lb]



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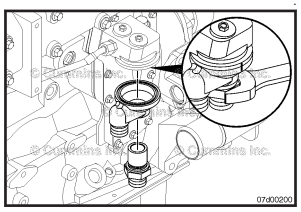
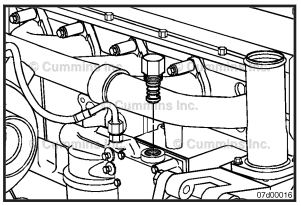
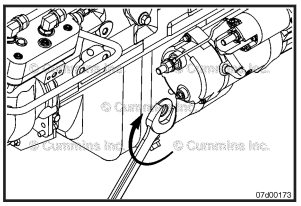
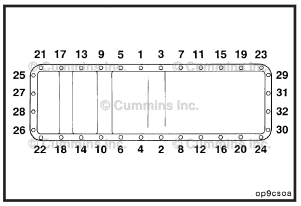
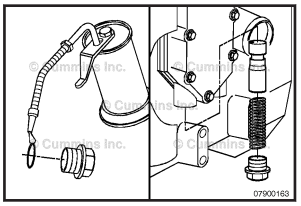
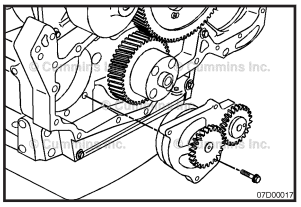
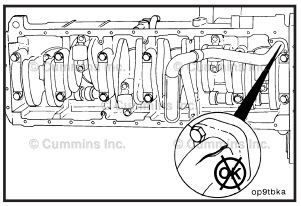
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Lubricating Oil Filter Head Adapter (007-018)				
Lubricating Oil Filter Head Adapter		100 N•m	[74 ft-lb]	
Lubricating Oil High Pressure Relief Valve (007-021)				
Lubricating Oil High Pressure Relief Valve		50 N•m	[37 ft-lb]	
Lubricating Oil Pan (007-025)				
Composite Oil Pan Bulkhead Fitting		24 N•m	[212 in-lb]	
Lubricating Oil Pan Mounting Capscrews		28 N•m	[248 in-lb]	
Lubricating Oil Pressure Regulator (Main Rifle) (007-029)				
Lubricating Oil Pressure Regulator (Main Rifle)		80 N•m	[59 ft-lb]	
		36 N•m	[27 ft-lb]	
Lubricating Oil Pump (007-031)				
Lubricating Oil Pump Mounting Capscrews		24 N•m	[212 in-lb]	
Lubricating Oil Suction Tube (Block-Mounted) (007-035)				
Lubricating Oil Suction Tube To Block		10 N•m 10 N•m 10 N•m	[89 in-lb] [89 in-lb] [89 in-lb]	

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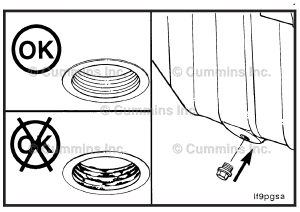
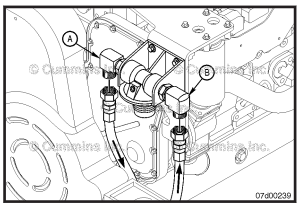
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Lubricating Oil System (007-037)				
Lubricating Oil Drain Plug		80 N•m 60 N•m 60 N•m	[59 ft-lb] [44 ft-lb] [44 ft-lb]	
Lubricating Oil Lines (007-092)				
Adapter Plate And Remote Oil Filter Head Hoses		100 N•m	[74 ft-lb]	

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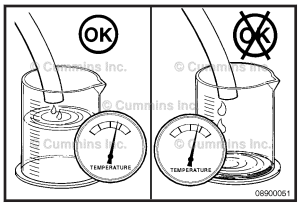
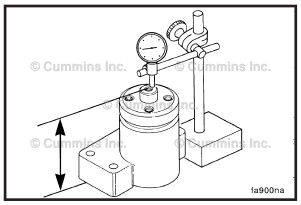
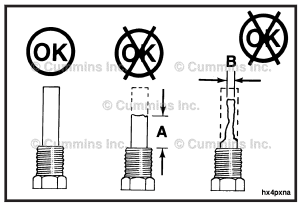
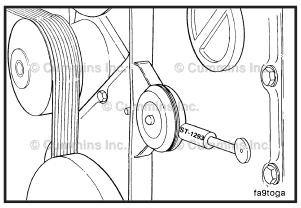
Cooling System - Group 08 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Coolant Thermostat (008-013)				
Thermostat Initial Opening Temperature		81 °C	MIN	178 °F
		83 °C	MAX	182 °F
Fan Spacer and Pulley (008-039)				
Fan Hub End Play		0.15 mm	MAX	0.006 in
Zinc Anode (008-059)				
Zinc anode Plug Erosion Limits				
A		19.0	MIN	0.750
New		51.0	MAX	2.000
B		6.4	MIN	0.250
New		16.0	MAX	0.630
Belt Tensioner, Automatic (Water Pump) (008-080)				
Belt Tension		356 N	MIN	80 lbf
		534 N	MAX	120 lbf

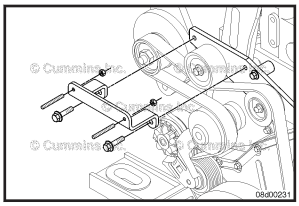
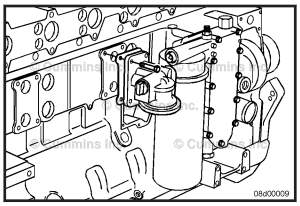
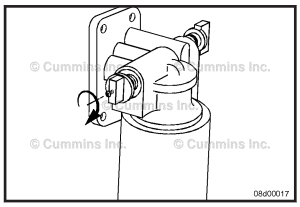
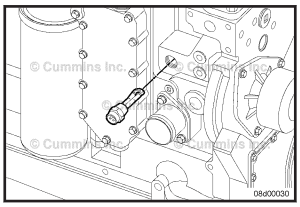
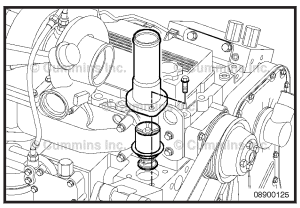
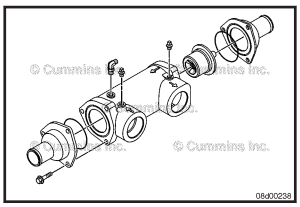


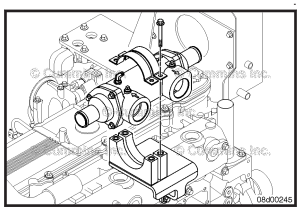
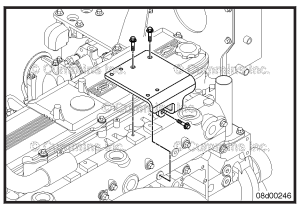
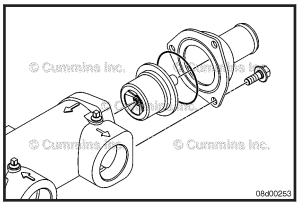
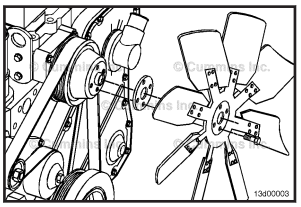
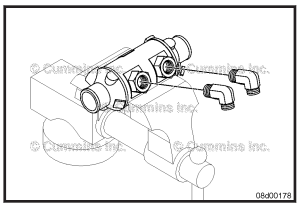
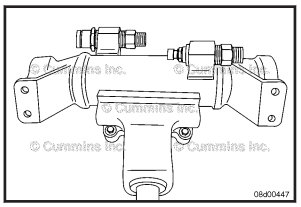
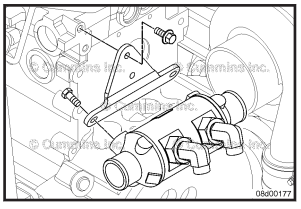


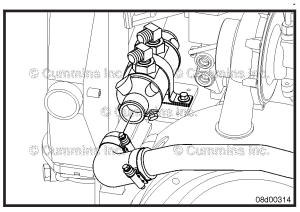
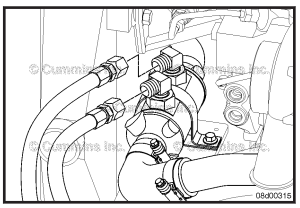
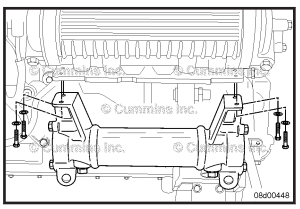
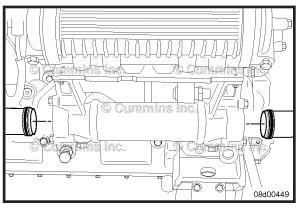
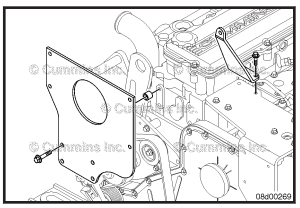
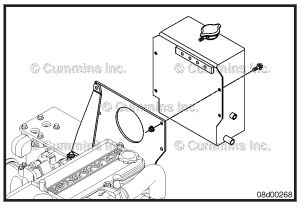
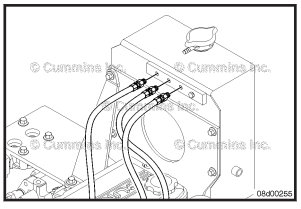


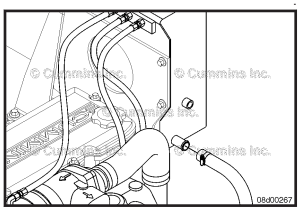
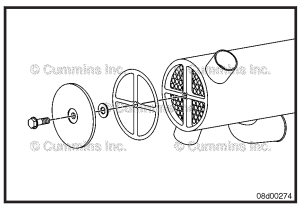
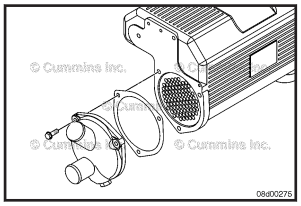
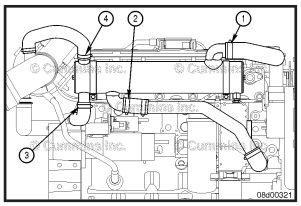
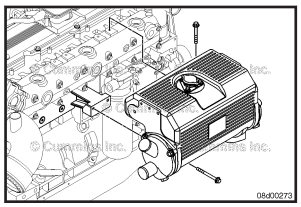
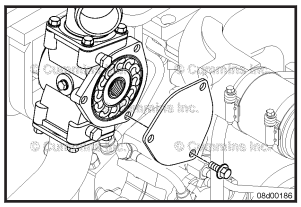
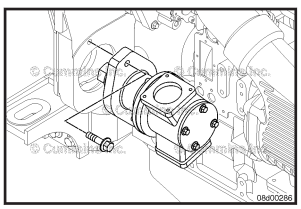


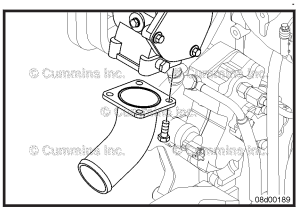
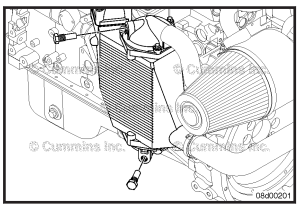
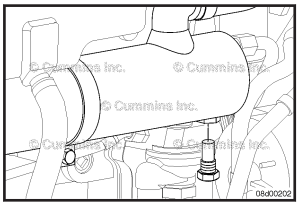
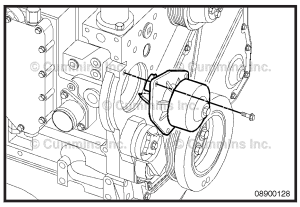
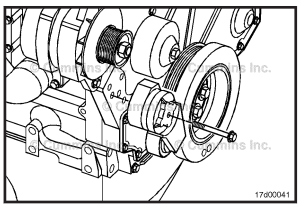
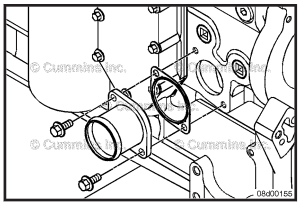
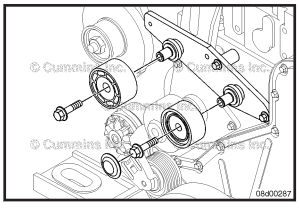
Cooling System - Group 08 - Torque Values

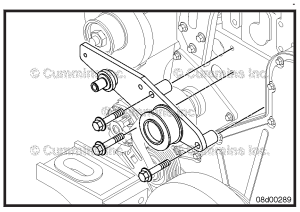
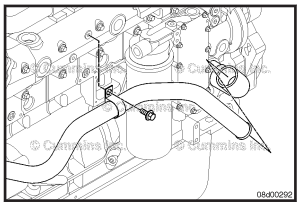
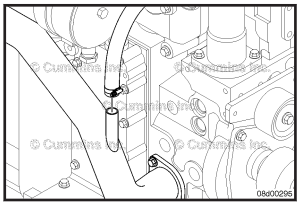
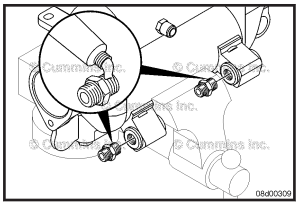
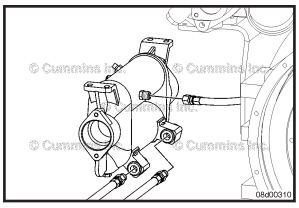
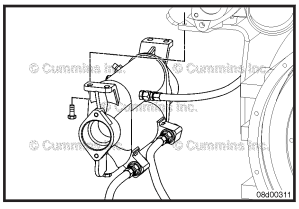
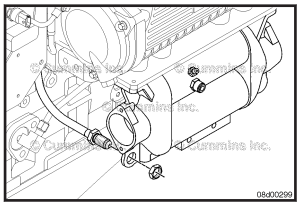
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Belt Guard (008-001)				
Belt Guard Mounting Bracket		20 N•m 15 N•m	[15 ft-lb] [133 in-lb]	
Coolant Filter Head (008-007)				
Coolant Filter Head Mounting Capscrews		24 N•m	[212 in-lb]	
		24 N•m	[212 in-lb]	
Coolant Filter Valve (008-009)				
Coolant Filter Valve Shutoff Screw		1.5 N•m	[12 in-lb]	
Coolant Heater (008-011)				
Coolant Heater		75 N•m	[55 ft-lb]	
Coolant Thermostat (008-013)				
Water Outlet Connection Mounting Capscrews		24 N•m	[212 in-lb]	
		24 N•m	[212 in-lb]	
		24 N•m	[212 in-lb]	
Coolant Thermostat Housing (008-014)				
Keel Cooled Thermostat Housing Inlet Port		44 N•m 44 N•m 15 N•m	[32 ft-lb] [32 ft-lb] [133 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Thermostat Housing Mounting Capscrews		44 N•m	[32 ft-lb]	
Coolant Thermostat Housing Support (008-015) Thermostat Housing Support Bracket		44 N•m	[32 ft-lb]	
Coolant Thermostat Seal (008-016) Thermostat Housing Hose Connection		44 N•m	[32 ft-lb]	
Fan, Cooling (008-040) Cooling Fan Mounting Capscrews		43 N•m	[32 ft-lb]	
Marine Gear Oil Cooler (008-041) Marine Gear Oil Cooler Fitting Locknuts		24 N•m	[212 in-lb]	
Marine Gear Cooler Oil Temperature Sensor		30 N•m 15 N•m	[22 ft-lb] [133 in-lb]	
Marine Gear Oil Cooler		18 N•m 44 N•m	[159 in-lb] [32 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Marine Gear Cooler Sea Water Discharge Hose Clamp		8 N•m 8 N•m	[71 in-lb] [71 in-lb]	
Transmission Oil Supply And Return Hoses		30 N•m	[22 ft-lb]	
Marine Gear Oil Cooler Capscrews		30 N•m	[22 ft-lb]	
Sea Water Inlet And Outlet Pipe		24 N•m	[212 in-lb]	
Expansion Tank (008-052) Expansion Tank Mounting Bracket Capscrews		43 N•m	[32 ft-lb]	
Expansion Tank Mounting Capscrews		43 N•m	[32 ft-lb]	
Expansion Tank Vent Lines		14 N•m	[124 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Expansion Tank Make-Up Hoses Clamps		8 N•m	[70 in-lb]	
Heat Exchanger (008-053)				
Qsl Heat Exchanger End Caps		8 N•m	[71 in-lb]	
Qsc Heat Exchanger End Caps		44 N•m 55 N•m	[32 ft-lb] [41 ft-lb]	
Heat Exchanger Hose Clamps		8 N•m 44 N•m	[71 in-lb] [32 ft-lb]	
Qsc Lower Heat Exchanger Mounting Capscrews		44 N•m 44 N•m	[32 ft-lb] [32 ft-lb]	
24 N•m [212 in-lb] 8 N•m [71 in-lb] 24 N•m [212 in-lb]				
Sea Water Pump (008-057)				
Sea Water Pump Cover Capscrews		24 N•m	[212 in-lb]	
24 N•m [212 in-lb]				
Sea Water Pump Mounting Capscrews		24 N•m	[18 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Sea Water Pump Inlet And Outlet Connections		133 N•m	[15 in-lb]	
Zinc Anode (008-059) Aftercooler Zinc Anodes		45 N•m	[35 ft-lb]	
Heat Exchanger Zinc Anode		45 N•m	[35 ft-lb]	
Water Pump (008-062) Water Pump Mounting Capscrews		24 N•m	[212 in-lb]	
Belt Tensioner, Automatic (Water Pump) (008-080) Tensioner Mounting Capscrews		24 N•m 43 N•m	[212 in-lb] [32 ft-lb]	
Water Inlet Connection (008-082) Water Inlet Mounting Capscrews		24 N•m	[212 in-lb]	
Pulley, Fan Idler (008-111) Fan Idler Pulley Mounting Capscrew		52 N•m	[38 ft-lb]	

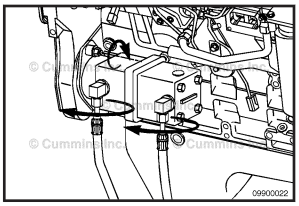
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Bracket, Fan Idler Pulley (008-112)				
Fan Idler Pulley Bracket Capscrews		52 N•m	[38 ft-lb]	
Coolant Return Junction Block (008-113)				
Junction Block Hose Clamps		8 N•m	[71 in-lb]	
8 N•m [71 in-lb]				
Expansion Tank Fill Line Tube		8 N•m	[71 in-lb]	
24 N•m [18 ft-lb]				
Marine Gear Oil and Fuel Cooler Assembly (008-129)				
Marine Gear Oil Cooler Fittings		30 N•m 15 N•m	[22 ft-lb] [133 in-lb]	
Transmission Oil Lines To Cooler		30 N•m 24 N•m	[22 ft-lb] [18 ft-lb]	
Marine Gear Oil Cooler Mounting Capscrews		30 N•m	[22 ft-lb]	
Fuel Supply Hose Jam Nuts		30 N•m	[22 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	

Drive Units - Group 09 - Torque Values

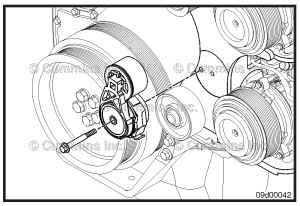
Hydraulic Pump Drive (009-016)

Hydraulic Pump Mounting Bolts		43 N•m	[32 ft-lb]



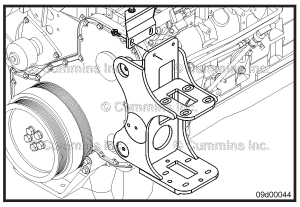
Belt Tensioner, Refrigerant Compressor, Automatic (009-053)

Belt Tensioner Capscrew		43 N•m	[32 ft-lb]



Refrigerant Compressor Mounting Bracket (009-055)

Refrigerant Compressor Mounting Bracket		46 N•m	[34 ft-lb]



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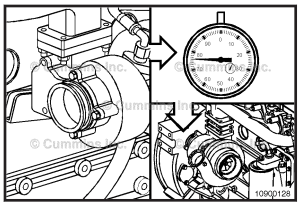
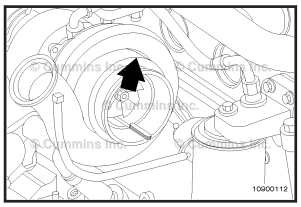
Air Intake System - Group 10 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Turbocharger (010-033)				
Axial Clearance (HX40WG - Wastegate)		0.025 mm	MIN	0.001 in
		0.127 mm	MAX	0.005 in
Axial Clearance (HY40V - Variable Geometry)		0.025 mm	MIN	0.001 in
		0.127 mm	MAX	0.005 in
Axial Clearance (HX55 - Wastegate, Water Cooled)		0.038 mm	MIN	0.0015 in
		0.093 mm	MAX	0.0037 in
Wastegate Radial Bearing Clearance (HX40WG - Wastegate)		0.330 mm	MIN	0.013 in
		0.508 mm	MAX	0.020 in
Radial Bearing Clearance (HX55 - Wastegate, Water Cooled)		0.044 mm	MIN	0.0172 in
		0.608 mm	MAX	0.0239 in
Mounting Surface Flatness Specification		0.1 mm	MAX	0.004 in





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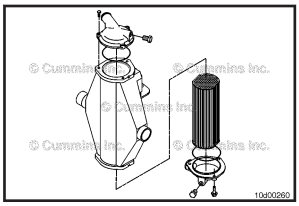
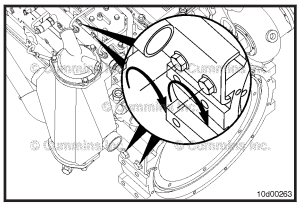
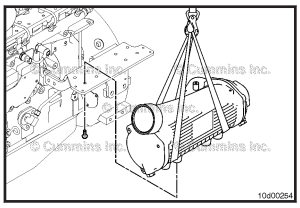
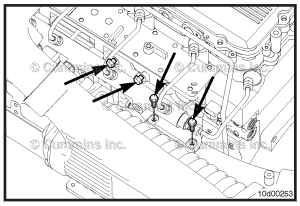
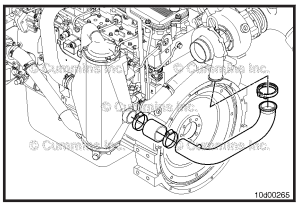
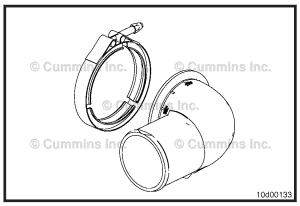
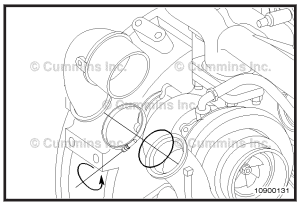
Air Intake System - Group 10 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Aftercooler Assembly (Sea Water) (010-005)				
Aftercooler Assembly End Cap		43 N•m 43 N•m 55 N•m	[32 ft-lb] [32 ft-lb] [41 ft-lb]	
Aftercooler Assembly Mounting Capscrews Bracket To Flywheel Housing Aftercooler Assembly Mounting Capscrews Bracket To Cylinder Head Aftercooler Assembly Mounting Capscrews Aftercooler To Bracket		100 N•m 44 N•m 35 N•m	[74 ft-lb] [32 ft-lb] [26 ft-lb]	
Qsc Aftercooler Lower Mounting Capscrews		35 N•m	[26 ft-lb]	
Qsc Aftercooler To Cylinder Block		44 N•m 35 N•m	[32 ft-lb] [26 ft-lb]	
Air Crossover (010-019)				
Air Crossover Flange Clamp		8 N•m 8 N•m	[71 in-lb] [71 in-lb]	
Air Inlet Connection (010-022)				
Air Inlet Connection V-Band Clamp		8 N•m	[71 in-lb]	
		60 N•m 45 N•m	[44 ft-lb] [33 ft-lb]	
Turbocharger (010-033)				
Turbocharger Compressor Outlet V-Band		8 N•m	[71 in-lb]	

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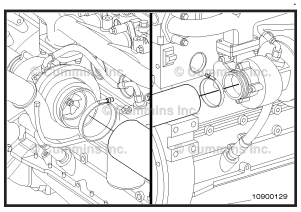
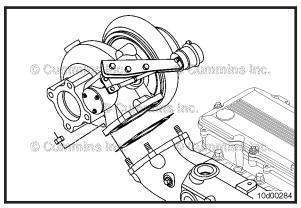
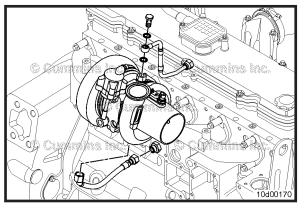
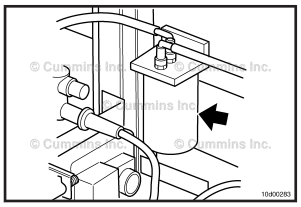
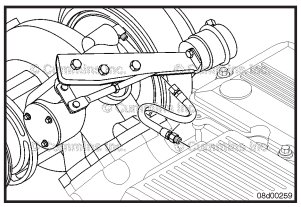
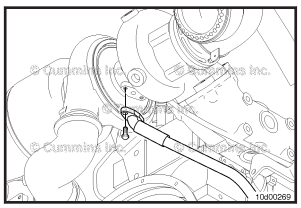
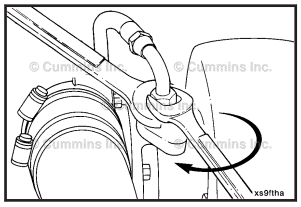
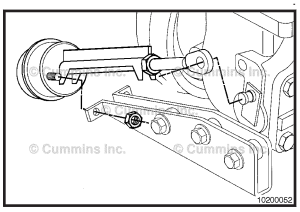
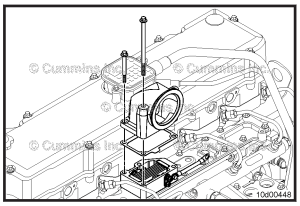
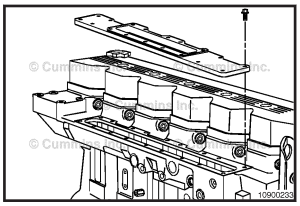
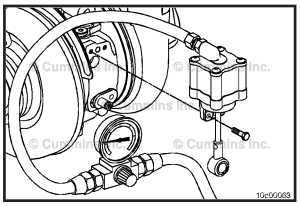
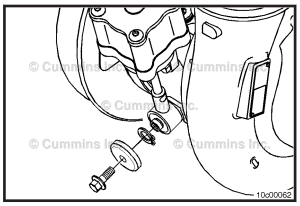
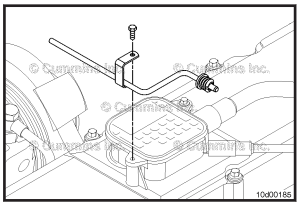
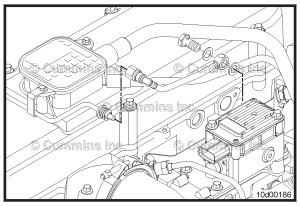
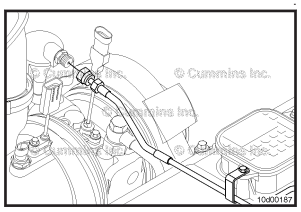
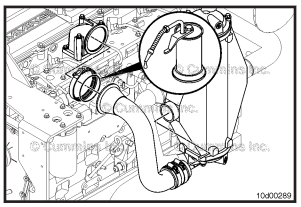
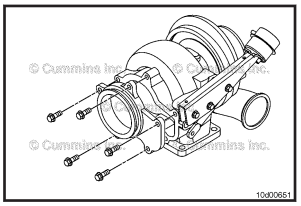
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Turbocharger Compressor Inlet		8 N•m 8 N•m	[71 in-lb] [71 in-lb]	
Turbocharger Mounting Nuts (Marine Applications)		43 N•m	[32 ft-lb]	
Turbocharger Coolant Hoses (010-041) Turbocharger Coolant Lines		46 N•m	[34 ft-lb]	
Turbocharger Coolant Line Banjo Capscrew		160 N•m 8 N•m	[118 ft-lb] [71 in-lb]	
Coolant Vent Line At Turbocharger		15 N•m 15 N•m	[133 in-lb] [133 in-lb]	
Turbocharger Oil Drain Line (010-045) Turbocharger Oil Drain Line Hose Clamps		5.6 N•m 27 N•m	[50 in-lb] [239 in-lb]	
Turbocharger Oil Supply Line (010-046) Turbocharger Oil Supply Line Torque		24 N•m	[212 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Turbocharger Wastegate Actuator (010-050)				
Actuator Mounting Capscrews		8 N•m	[71 in-lb]	
Air Intake Connection (010-080)				
Air Intake Connection		24 N•m	[212 in-lb]	
Air Intake Manifold Cover (010-108)				
Intake Manifold		24 N•m	[212 in-lb]	
Variable Geometry Turbocharger Actuator, Pneumatic (010-113)				
Actuator Housing Capscrews		17 N•m	[150 in-lb]	
Actuator Rod Capscrew		23 N•m	[17 ft-lb]	
Turbocharger Actuator Air Line (010-118)				
Turbocharger Actuator Air Line Mounting		5 N•m	[44 in-lb]	
Flexible Elbow Mounting		8 N•m	[71 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Actuator Air Supply Line		24 N•m	[18 ft-lb]	
8 N•m [71 in-lb]				
Air Intake Connection Adapter (010-131)				
Air Intake Connection Clamp		8 N•m 8 N•m	[71 in-lb] [71 in-lb]	
Turbocharger Exhaust Connection Adapter (010-141)				
Turbocharger Exhaust Connection Adapter		25 N•m	[221 in-lb]	

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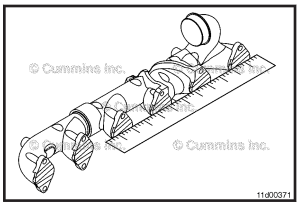
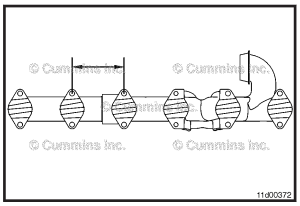
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Exhaust Manifold, Dry (011-007)					
Exhaust Manifold Flatness		0.30 mm	MAX	0.012 in	
Manifold Section Distance		136 mm 138 mm	MIN MAX	5.35 in 5.43 in	

Exhaust System - Group 11 - Specifications

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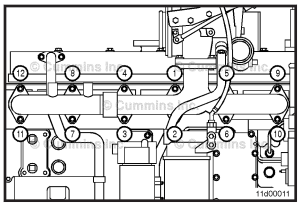
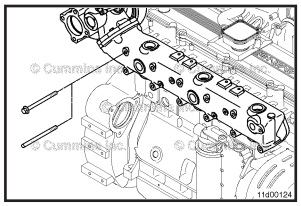
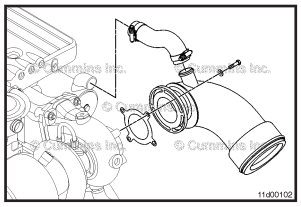
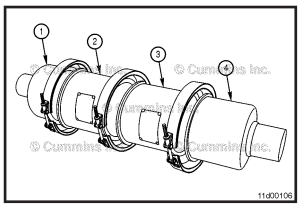
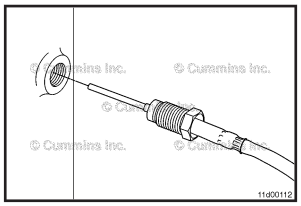
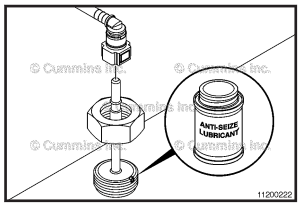
Exhaust System - Group 11 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Exhaust Manifold, Dry (011-007)				
Exhaust Manifold Mounting Capscrews		53 N•m	[39 ft-lb]	
Exhaust Manifold, Wet (011-008)				
Exhaust Manifold Mounting Capscrews		43 N•m	[32 ft-lb]	
Exhaust Outlet Connection (011-017)				
Exhaust Outlet Connection		24 N•m 8 N•m	[18 ft-lb] [71 in-lb]	
Aftertreatment Selective Catalytic Reduction (SCR) Catalyst (011-036)				
V-Band Clamp Torque		20 N•m	[177 in-lb]	
Exhaust Gas Temperature Sensor (011-037)				
Exhaust Gas Temperature Sensor		30 N•m	[22 ft-lb]	
Aftertreatment Nozzle (011-040)				
Aftertreatment Nozzle Retaining Nut.		60 N•m	[44 ft-lb]	

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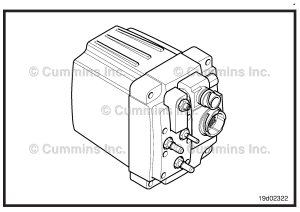
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Aftertreatment Diesel Exhaust Fluid Dosing Unit Filter (011-060)				
Aftertreatment Diesel Exhaust Fluid Dosing Unit Filter Equalizing Element Cap		15 N•m	[133 in-lb]	

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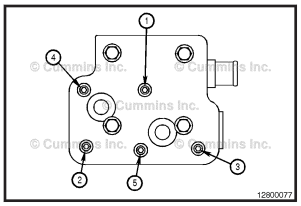
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.

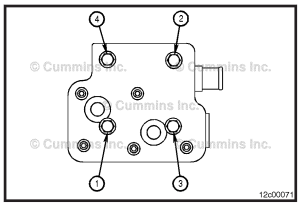
Compressed Air System - Group 12 - Torque Values

Air Compressor Cylinder Head, Single Cylinder (012-007)



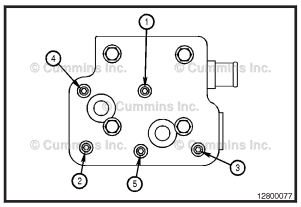
Torque Value:

Step 1	5 N•m	[44 in-lb]
Step 2	10 N•m	[89 in-lb]



Torque Value:

Step 1	25 N•m	[221 in-lb]
Step 2	Rotate capscrews 90 degrees.	

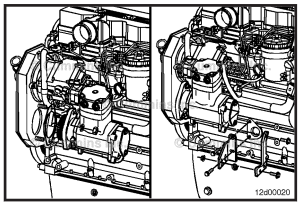


Torque Value:

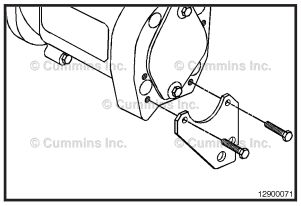
Step 1	6 N•m	[53 in-lb]
Step 2	Rotate 90 degrees.	

Air Compressor (012-014)

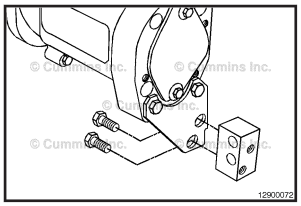
Air Compressor Mounting Nuts	77 N•m	[57 ft-lb]



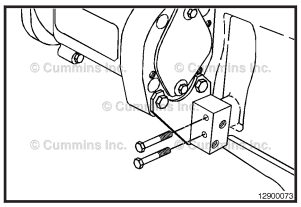
Air Compressor Support Brace Capscrews	43 N•m	[32 ft-lb]



Air Compressor Support Brace Capscrews	43 N•m	[32 ft-lb]



Support Brace To Cylinder Block Capscrews	43 N•m	[32 ft-lb]



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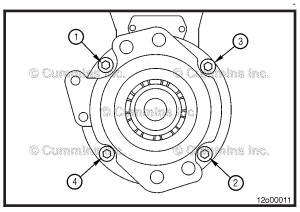
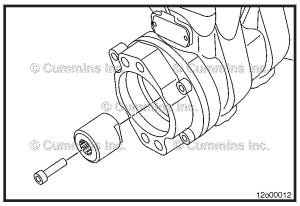
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Air Compressor Rear Bearing Housing, Two Cylinder (012-112)				
		22 N•m	[195 in-lb]	
		25 N•m	[221 in-lb]	

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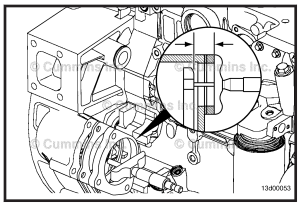
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.

Electrical Equipment - Group 13 - Specifications

Starting Motor (013-020)

Starting Motor Spacing	49.28 mm	MIN	1.94 in
	52.32 mm	MAX	2.06 in



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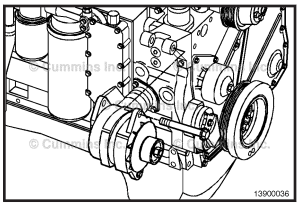
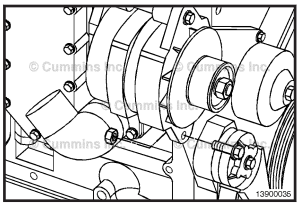
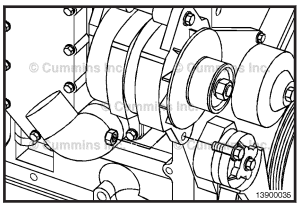
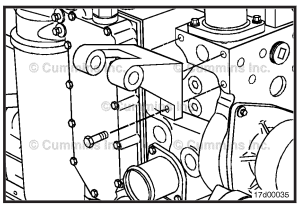
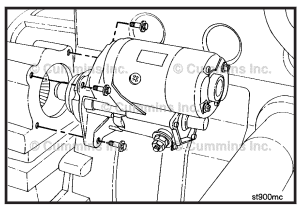
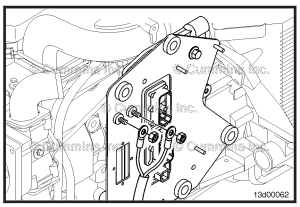
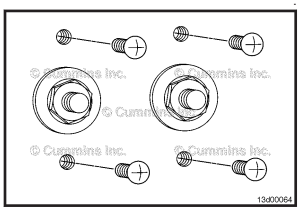
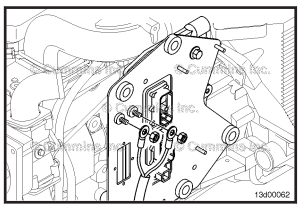
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	

Electrical Equipment - Group 13 - Torque Values

Alternator (013-001)

Alternator Mounting (All Except Marine)		43 N•m	[32 ft-lb]	
Alternator Link (All Except Marine)		24 N•m	[18 ft-lb]	
Torque Value:				
Upper Mounting Capscrew				
Step 1	77 N•m	[57 ft-lb]		
Torque Value:				
Alternator Link at Alternator				
Step 1	44 N•m	[32 ft-lb]		
Torque Value:				
Alternator Link at Engine Mounting Location				
Step 1	24 N•m	[18 ft-lb]		
Alternator Bracket (013-003)				
Alternator Mounting Bracket Capscrews		24 N•m	[212 in-lb]	
Starting Motor (013-020)				
Starter Motor Mounting Capscrews		43 N•m	[32 ft-lb]	
	4 N•m	[35 in-lb]		
	21 N•m	[186 in-lb]		
	4 N•m	[35 in-lb]		
ECM Unswitched Power Terminal Blocks (013-047)		5 N•m	[45 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
		3.5 N•m	[30 in-lb]	
		5 N•m	[45 in-lb]	

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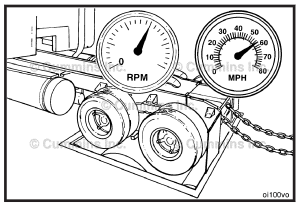
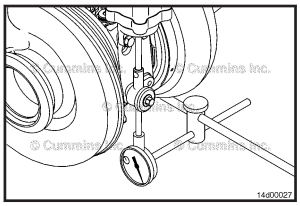
Engine Testing - Group 14 - Specifications

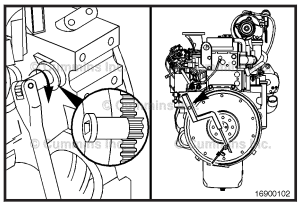
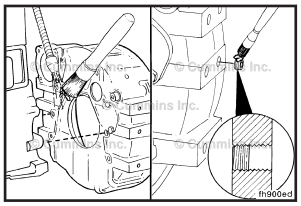
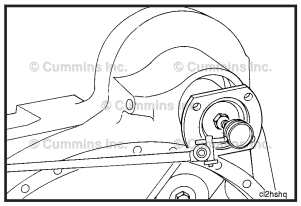
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Engine Run-in (Engine Dynamometer) (014-006)				
Lubricating Oil Temperature		90 °C	MAX	194 °F
Fuel Temperature		65 °C	MAX	149 °F



Engine Testing (In Chassis) (014-008)				
Turbocharger Actuator Rod Travel		10.8 mm	MIN	0.40 in
		11.8 mm	MAX	0.46 in



Mounting Adaptations - Group 16 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Flywheel (016-005)					
Flywheel Total Indicator Reading		0.127 mm	MAX	0.0050 in	
Flywheel Housing (016-006)					
Set Screw Installation Depth (Flywheel Housing)		3.00 mm	MAX	0.118 in	
Flywheel Housing, REPTO (016-007)					
Shaft End Play		0.0 mm 0.03 mm	MIN MAX	0.0 in 0.001 in	

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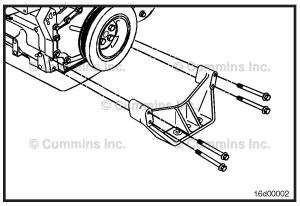
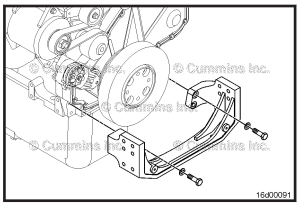
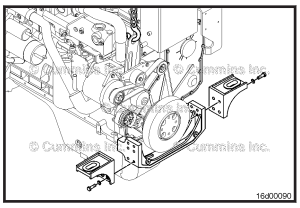
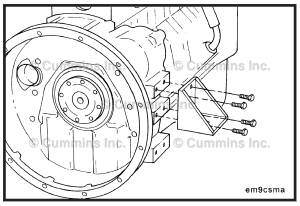
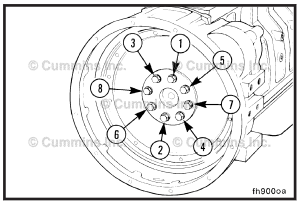
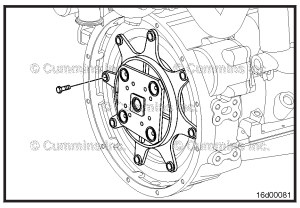
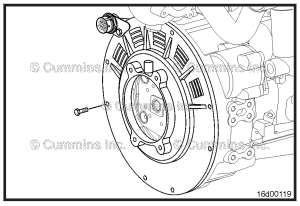
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Mounting Adaptations - Group 16 - Torque Values				
Engine Support Bracket, Front (016-002)				
Front Engine Support Bracket Mounting Capscrews		112 N•m	[83 ft-lb]	
Front Engine Mount Capscrews		126 N•m	[93 ft-lb]	
Front Engine Support Brackets		112 N•m	[83 ft-lb]	
Engine Support Bracket, Rear (016-003)				
Rear Engine Support Bracket Mounting Capscrews		71 N•m	[52 ft-lb]	
Flexplate (016-004)				
Torque Value:				
Flexplate Capscrews				
Step 1	30 N•m		[22 ft-lb]	
Step 2	Plus 60-degree turn			
Flexplate Mounting Capscrews		44 N•m	[32 ft-lb]	
Flex-Coupling Guard Plate Mounting Capscrews		36 N•m	[27 ft-lb]	

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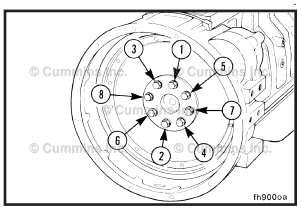
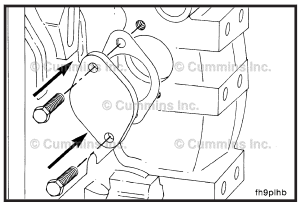
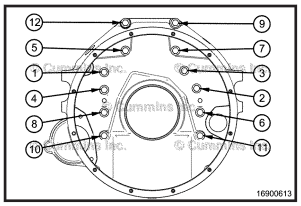
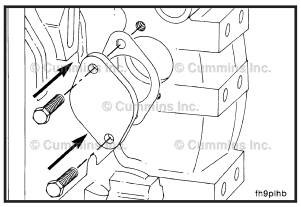
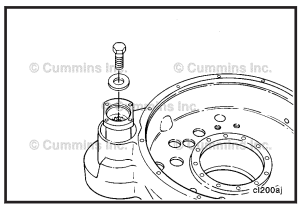
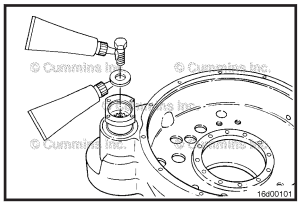
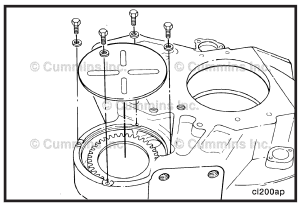
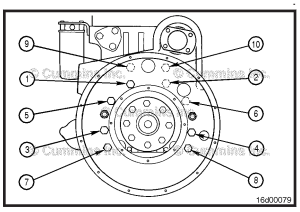
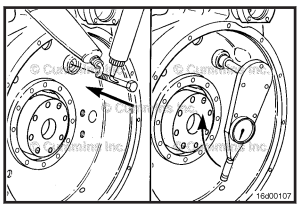
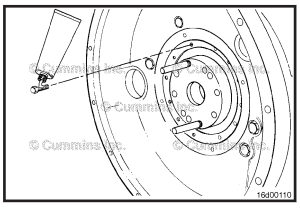
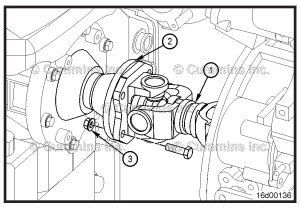
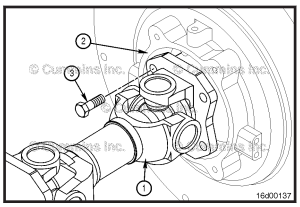
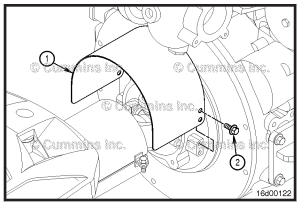
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Flywheel (016-005)				
Flywheel Capscrews		137 N•m	[101 ft-lb]	
Flywheel Housing (016-006)				
Access Cover Capscrews		24 N•m	[212 in-lb]	
Flywheel Housing Mounting Capscrews		77 N•m	[57 ft-lb]	
Flywheel Housing Access Plate Capscrew		24 N•m	[212 in-lb]	
Flywheel Housing, REPTO (016-007)				
Flywheel Housing Flat Washer And Capscrew		205 N•m	[151 ft-lb]	
Output Flange Flat Washer And Capscrew		205 N•m	[151 ft-lb]	
Housing Cover Capscrews		18 N•m	[159 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Flywheel Housing Capscrews		77 N•m	[57 ft-lb]	
Idler Shaft Capscrew		105 N•m	[77 ft-lb]	
Torque Value: Step 1 7 N•m [62 in-lb] Step 2 19 N•m [168 in-lb]				
Engine Drive Shaft (016-027)		149 N•m	[110 ft-lb]	
		149 N•m	[110 ft-lb]	
36 N•m [27 ft-lb] 23 N•m [204 in-lb]		36 N•m	[27 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.

Miscellaneous - Group 17 - Torque Values

10 N•m	[89 in-lb]
20 N•m	[177 in-lb]
25 N•m	[221 in-lb]
35 N•m	[25 ft-lb]
45 N•m	[33 ft-lb]
18 N•m	[160 in-lb]
25 N•m	[221 in-lb]
30 N•m	[22 ft-lb]
40 N•m	[30 ft-lb]
50 N•m	[37 ft-lb]

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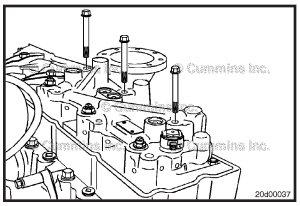
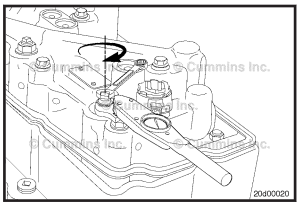
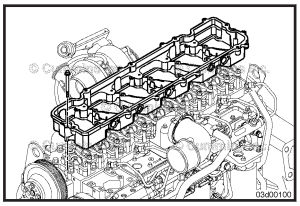
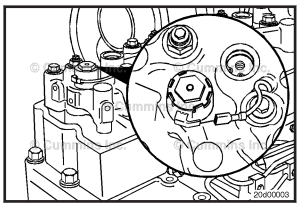
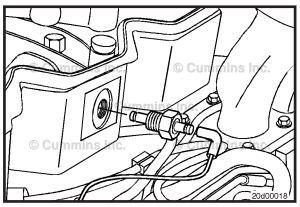
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Vehicle Braking - Group 20 - Torque Values				
Engine Brake Assembly (020-004)				
Engine Brake Mounting Capscrews		32 N•m	[24 ft-lb]	
Engine Brake Adjusting Locknut		35 N•m	[26 ft-lb]	
	35 N•m	[26 ft-lb]		
	35 N•m	[26 ft-lb]		
	35 N•m	[26 ft-lb]		
Engine Brake Housing Spacer (020-007)				
Engine Brake Spacer Mounting Capscrews		32 N•m	[23 ft-lb]	
Engine Brake Solenoid Valve (020-012)				
Engine Brake Solenoid		20 N•m	[177 in-lb]	
Engine Brake Wiring Harness (020-015)				
Engine Brake Wiring Harness Receptacle Connector		11 N•m	[97 in-lb]	

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General Engine

Specifications

All Applications Except Marine

Listed below are the general specifications for this engine.

Horsepower.....See engine dataplate
Firing Order.....1-5-3-6-2-4
Crankshaft Rotation (viewed from front of engine)..... **Clockwise**
Bore and Stroke
8.3 liters.....114 mm [4.49 in] x 135 mm [5.32 in]
8.9 liters.....114 mm [4.49 in] x 144.5 mm [5.69 in]
Dry Weight
8.3 liters.....694 kg [1530 lb]
8.9 liters.....706 kg [1555 lb]
Wet Weight
8.3 liters.....723 kg [1595 lb]
8.9 liters.....738 kg [1625 lb]
Overhead Adjustment
Intake Valve Adjustment.....0.305 mm [0.012 in]
Exhaust Valve Adjustment.....0.559 mm [0.022 in]
Engine Brake Adjustment.....2.286 mm [0.090 in]

Marine Applications

Listed below are the general specifications for this engine.

Horsepower.....See engine dataplate
Firing Order.....1-5-3-6-2-4
Crankshaft Rotation (viewed from front of engine)..... **Clockwise**
Displacement
QSC8.3.....8.3 liters [505 in^3]
QSL9.....8.9 liters [540 in^3]
Bore and Stroke
8.3 liters (QSC8.3 Engine).....114 mm [4.49 in] x 135 mm [5.31 in]
8.9 liters (QSL9 Engine).....114 mm [4.49 in] x 145 mm [5.71 in]
Dry Weight
8.3 liters (QSC8.3 Engine).....880 kg [1940 lb]
8.9 liters (QSL9 Engine).....891 kg [1965 lb]
Dry Weight - Engine with Heat Exchanger System - Average
8.3 liters (QSC8.3 Engine).....896 kg [1975 lb]
8.9 liters (QSL9 Engine).....907 kg [2000 lb]
Overhead Adjustment
Intake Valve Adjustment.....0.305 mm [0.012 in]
Exhaust Valve Adjustment.....0.559 mm [0.022 in]

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Fuel System

Specifications

Cummins® Common Rail Fuel System

Maximum Fuel Return Line Pressure
- All Applications Except Marine....254 mm-Hg [10 in-Hg]
- Marine Applications....102 mm-Hg [4 in-Hg]

Maximum Fuel Inlet Restriction (gear pump inlet)
- All Applications Except Marine....254 mm-Hg [10 in-Hg]

Maximum Fuel Inlet Restriction - at original equipment manufacturer (OEM) Connection (Dirty Filter) Loaded Condition
- All Application Except Marine....203.2 mm-Hg [8 in-Hg]
- Marine Applications....102 mm-Hg [4 in-Hg]

Maximum Fuel Inlet Restriction - at OEM Connection (Clean Filter) Loaded Condition
- Marine Applications....63.5 mm-Hg [2.5 in-Hg]

Minimum Gear Pump Pressure (during cranking)
- During Cranking Condition....105 kPa [15 psi]
- During Rated Condition....483 kPa [70 psi]

Maximum Filter Pressure Drop....138 kPa [20 psi]
Minimum Lift Pump Pressure (gear pump inlet during cranking)....35 kPa [5 psi]
Minimum Engine Cranking Speed....150 rpm
Primary Off engine fuel filter element....10 Micron
Secondary On engine fuel filter element....3 Micron

CAPS Fuel System

Maximum Fuel Inlet Restriction at Rated (measured at lift pump inlet)....102 mm-Hg [4 in-Hg]
Maximum Fuel Inlet Restriction at Rated (measured at CAPS pump inlet)....254 mm-Hg [10 in-Hg]
Minimum Lift Pump Pressure....35 kPa [5 psi]
Maximum Filter Pressure Drop at Rated....102 mm-Hg [4 in-Hg]
Minimum Gear Pump Pressure (during cranking)....69 kPa [10 psi]
Minimum Engine Cranking Speed....150 rpm

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Lubricating Oil System

Specifications

All Applications Except Marine

Oil Pressure
- At Low Idle (minimum allowable)....69 kPa [10 psi]
- At Rated Speed (minimum allowable)....207 kPa [30 psi]

Regulated Oil Pressure....517 kPa [75 psi]
Lubricating Oil Filter Capacity....3.78 liters [4 qt]

Oil Pan Capacity, Low to High (8.3 liter engines)
- Standard Oil Pan....15.1 to 18.9 liters [16 to 20 qt]
- Standard Oil Pan with Cylinder Block Stiffener Plate....16.1 to 19.9 liters [17 to 21 qt]

Total System Capacity (Oil Pan and New Oil Filter) (8.3 liter engines)
- Standard Oil Pan....22.7 liters [24 qt]
- Standard Oil Pan with Cylinder Block Stiffener Plate....23.7 liters [25 qt]

Oil Pan Capacity, Low to High (8.9 liter engines)
- Standard Oil Pan....18.9 to 22.7 liters [20 to 24 qt]
- Standard Oil Pan with Cylinder Block Stiffener Plate....19.9 to 23.7 liters [21 to 25 qt]
- Large Oil Pan "Power Generation" with Cylinder Block Stiffener Plate....20.5 to 29.9 liters [21.1 to 31.7 qt]

Total System Capacity (Oil Pan and New Oil Filter) (8.9 liter engines)
- Standard Oil Pan....26.5 liters [28 qt]
- Standard Oil Pan With Cylinder Block Stiffener Plate....27.4 liters [29 qt]
- Large Oil Pan "Power Generation" with Cylinder Block Stiffener Plate....33.7 liters [35.7 qt]

Oil Pressure at Normal Operating Temperature

QSC8.3 Engines
- Idle Speed - Minimum in Filter Head Upstream of Filter....N/A
- Idle Speed - Minimum in Main Oil Gallery....138 kPa [20 psi]
- Rated Speed - Measured in Filter Head Upstream of Filter (Low)....N/A
- Rated Speed - Measured in Filter Head Upstream of Filter (High)....N/A
- Rated Speed - Measured in Main Oil Gallery (Low)....276 kPa [40 psi]
- Rated Speed - Measured in Main Oil Gallery (High)....483 kPa [70 psi]

Oil Pressure at Normal Operating Temperature

QSL9 Engines
- Idle Speed - Minimum in Filter Head Upstream of Filter....N/A
- Idle Speed - Minimum in Main Oil Gallery....179 kPa [26 psi]
- Rated Speed - Measured in Filter Head Upstream of Filter (Low)....N/A
- Rated Speed - Measured in Filter Head Upstream of Filter (High)....N/A
- Rated Speed - Measured in Main Oil Gallery (Low)....386 kPa [56 psi]
- Rated Speed - Measured in Main Oil Gallery (High)....490 kPa [71 psi]

Oil Pan Capacity - Shallow (Option 9351)

QSC8.3 Engines
- Low....15.1 liter [4.0 gal]
- High....18.9 liter [5.0 gal]
- Total System Capacity (Maximum Sump and Filter)....21.6 liter [5.7 gal]
- By-Pass Oil Filter Capacity....2.6 liter [0.7 gal]

Oil Pan Capacity - Shallow (Option 9467)

QSL9 Engines
- Low....17.0 liter [4.5 gal]
- High....20.8 liter [5.5 gal]
- Total System Capacity (Maximum Sump and Filter)....25.4 liter [6.7 gal]
- By-Pass Oil Filter Capacity....2.6 liter [0.7 gal]

Oil Pan Capacity - Deep (Option 9397)

QSL9 Engines
- Low....18.9 liter [5.0 gal]
- High....22.7 liter [6.0 gal]
- Total System Capacity (Maximum Sump and Filter)....25.4 liter [6.7 gal]
- By-Pass Oil Filter Capacity....2.6 liter [0.7 gal]

Oil Temperature

QSC8.3 and QSL9 Engines
- Maximum Allowable Oil Temperature (Sump)....121°C [250°F]

Oil Consumption Rate

QSC8.3 and QSL9 Engines

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Volume Percent of Fuel Consumption Rate.....0.08 percent

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Cooling System

Specifications

All Applications Except Marine

Coolant Capacity (engine **only**).....11.1 liters [11.7 qt]
Standard Modulating Thermostat Range.....82 to 93°C [180 to 200°F]
Recommended Pressure Cap.....103 kPa [15 psi]
Minimum Fill Rate (without low-level alarm).....19 liters/min [5 gpm]
Maximum Deaeration Time.....25 minutes
Maximum Top Tank Coolant Temperature With CAPS Fuel System.....100°C [212°F]
Maximum Top Tank Coolant Temperature With Cummins Common Rail Fuel System.....107°C [225°F]

Winterfronts - Automotive Only

Air Passage Area.....774 cm^2 [120 in^2]

Marine Applications

Coolant Capacity

Engine **Only** .....25 liter [6.5 gal]
Engine Including Heat Exchanger and Integral.....29 liter [7.75 gal]
Minimum Coolant Makeup Capacity.....1.4 liter [0.38 gal]
Maximum Pressure Drop Across Any External Cooling System Circuit.....34 kPa [5 psi]
Maximum Allowable Block Coolant System Pressure.....483 kPa [70 psi]
Maximum Coolant Head From Crankshaft Centerline With 15 psi Pressure Cap.....34 m [112 ft]
Maximum Coolant Temperature at Engine Outlet.....96°C [205°F]
Minimum Allowable Coolant Expansion Space.....6 percent system capacity
Maximum Sea Water Pressure.....103 kPa [15 psi]
Maximum Sea Water Pressure Drop Across Heat Exchanger.....34 kPa [5 psi]
Maximum Sea Water Inlet Restriction.....-17 kPa [-5 in Hg]

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Air Intake System

Specifications

All Applications Except Marine

⚠CAUTION⚠

Engine intake air must be filtered to prevent dirt and debris from entering the engine. If the air intake piping is damaged or loose, unfiltered air will enter the engine and cause premature wear.

Maximum Intake Restriction

Clean Air Filter Element.....254 mm H_2O [10 in H_2O]

Dirty Air Filter Element.....635 mm H_2O [25 in H_2O]

Charge-Air Cooler Restriction (maximum).....152 mm Hg [6.0 in Hg]

Marine Applications

Maximum Allowable Intake Restriction QSL and QSC 540 metric horse power and below

Clean Filter .....381 mm H_2O [15 in H_2O]

Dirty Filter.....635 mm H_2O [25 in H_2O]

Maximum Air Cleaner Inlet Temperature Rise Over Ambient.....17°C [30°F]

Maximum Allowable Intake Restriction QSC 550 metric horse power and above

Clean Filter.....254 mm H_2O [10 in H_2O]

Dirty Filter.....381 mm H_2O [15 in H_2O]

Maximum Air Cleaner Inlet Temperature Rise Over Ambient.....17°C [30°F]

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Exhaust System

Specifications

Maximum Exhaust Restriction - Muffler

Hg.....76 mm-Hg [3 in-Hg]
H_2O.....1016 mm-H_2O [40 in-H_2O]
Exhaust Restriction - Diesel Oxidation Catalyst.....114 mm-Hg [4.5 in-Hg]
Exhaust Restriction - Exhaust Gas Filter.....140 mm-Hg [5.5 in-Hg]
Exhaust Restriction - Selective Catalytic Reduction.....15 kPa [2.2 psi]

Marine Applications

Exhaust Restriction QSL9 Engines.....10 kPa [3 in-Hg]
Exhaust Restriction QSC8.3 Engines built before July 1, 2008.....10 kPa [3 in-Hg]
Exhaust Restriction QSC8.3 Engines built on or after July 1, 2008.....17 kPa [5 in-Hg]

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Electrical System

Batteries (Specific Gravity)

Specific Gravity at 27°C [80°F]	State of Charge
1.260 to 1.280	100 percent
1.230 to 1.250	75 percent
1.200 to 1.220	50 percent
1.170 to 1.190	25 percent
1.110 to 1.130	Discharged

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Compressed Air System

Specifications

Cummins 18.7 CFM Model

Cylinders....1
Compressor Swept Volume at 1250 RPM....6.6 l/sec. [14.0 cfm]
Piston Displacement....31 cc [19.405 C.I.D.]
Bore....85 mm [3.346 in]
Stroke....56 mm [2.204 in]
Speed....Engine speed
Cooling....Engine coolant
Lubrication....Engine lubricating oil

Plumbing Line Sizes

- Coolant Inlet and Outlet....3/4 x 116 STOR
- Air Inlet....25.4 mm [1 in] Nominal
- Air Outlet....M27 x 2 STOR
- Unloader Port....M10 x 1 STOR
- Governor Mounting Direct....M8 x 1.25

Height, Overall (Approximate)....217.4 mm [8.56 in]
Width, Overall (Approximate)....142 mm [5.59 in]
Length, Overall (Approximate)....216 mm [8.50 in]
Weight (Approximate)....15 kg [35.0 lb]

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Engine Testing

Specifications

Engine Blowby Specifications..... 30.5 cm H_2O [12.0 in H_2O]

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Cummins®/Fleetguard® Filter Specifications

General Information

Cummins Filtration™ is a subsidiary of Cummins Inc. Cummins Filtration™ filters are developed through joint testing at Cummins Inc. and Cummins Filtration™. Cummins Filtration™ filters are standard on new Cummins® engines. Cummins Inc. recommends their use.

Cummins Filtration™ products meet all Cummins® Source Approval Test standards to provide the quality filtration necessary to achieve the engine's design life. If other brands are substituted, the purchaser should insist on products that the supplier has tested to meet Cummins® quality standards.

Cummins Inc. can **not** be responsible for problems caused by non-genuine filters that do **not** meet Cummins Inc. performance or durability requirements.

Filter Part Numbers (All Applications Except Marine)				
-	**Water-separating Filter**	**Fuel Filter**	**Lubricating Oil Filter**	**Inline Air Filter (ISLe4 only)**
Without CM850	-	-	-	-
Cummins® Part Number	3944269	N/A	3401544	N/A
Cummins Filtration™ Part Number	FS1022	N/A	LF9009	N/A
With CM850	-	-	-	-
Cummins® Part Number	4070801	3959612	3401544	N/A
Cummins Filtration™ Part Number	FS1003	FF5488	LF9009	AS0247400

Filter Part Numbers (Marine Applications)			
-	**Water-separating Filter**	**Fuel Filter**	**Lubricating Oil Filter**
Cummins® Part Number	3971757	3959612	3401544
Racor® Part Number	1000MA	-	-
Cummins Filtration™ Part Number	-	FF5488	LF9009

NOTE: LF9009 **must** be used. A venturi type filter **must** be used in order to benefit from the bypass filtration section of the oil filter. Do **not** use LF3000. Engine durability will be reduced by the use of the wrong lubricating oil filter.

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Drive Belt Tension

Tension Chart

SAE Belt Size	Belt Tension Gauge Part No.		Belt Tension New		Belt Tension Range Used*	
	Click-type	Burroughs	N	lbf	N	lbf
0.380 in	3822524		620	140	270 to 490	60 to 110
0.440 in	3822524		620	140	270 to 490	60 to 110
1/2 in	3822524	ST-1138	620	140	270 to 490	60 to 110
11/16 in	3822524	ST-1138	620	140	270 to 490	60 to 110
3/4 in	3822524	ST-1138	620	140	270 to 490	60 to 110
7/8 in	3822524	ST-1138	620	140	270 to 490	60 to 110
4 rib	3822524	ST-1138	620	140	270 to 490	60 to 110
5 rib	3822524	ST-1138	670	150	270 to 530	60 to 120
6 rib	3822525	ST-1293	710	160	290 to 580	65 to 130
8 rib	3822525	ST-1293	890	200	360 to 710	80 to 160
10 rib	3822525	3823138	1110	250	440 to 890	100 to 200
12 rib	3822525	3823138	1330	300	530 to 1070	120 to 240
12 rib K section	3822525	3823138	1330	300	890 to 1070	200 to 240
31 rib	-	3164750	1668	375	1330 to 1560	300 to 350

NOTE: This chart does not apply to automatic belt tensioners.

* A belt is considered used if it has been in service for ten minutes or longer.

* If used belt tension is less than the minimum value, tighten the belt to the maximum used belt value.

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Capscrew Markings and Torque Values

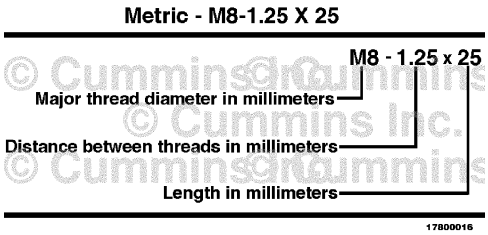
General Information

⚠CAUTION⚠

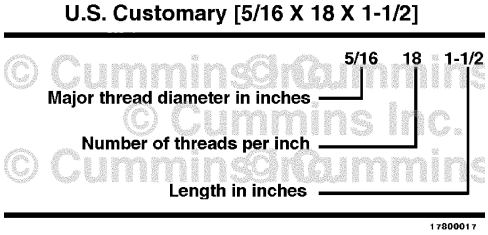
When replacing capscrews, always use a capscrew of the same measurement and strength as the capscrew being replaced. Using the wrong capscrews can result in engine damage.

Metric capscrews and nuts are identified by the grade number stamped on the head of the capscrew or on the surface of the nuts. U.S. Customary capscrews are identified by radial lines stamped on the head of the capscrew.

The following examples indicate how capscrews are identified:

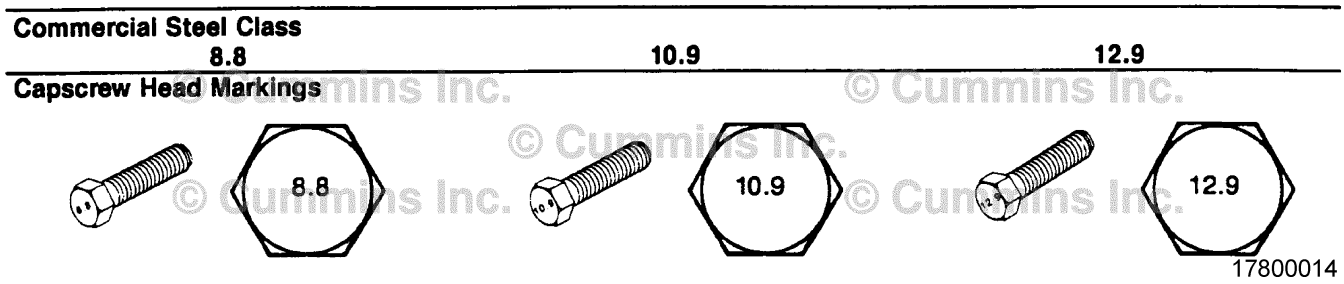


- **Always** use the torque values listed in the following tables when specific torque values are **not** available.
- Do **not** use the torque values in place of those specified in other sections of this manual.
- The torque values in the table are based on the use of lubricated threads.
- When the ft-lb value is less than 10, convert the ft-lb value to in-lb to obtain a better torque with an in-lb torque wrench. Example: 6 ft-lb equals 72 in-lb.



- **Always** use the torque values listed in the following tables when specific torque values are **not** available.
- Do **not** use the torque values in place of those specified in other sections of this manual.
- The torque values in the table are based on the use of lubricated threads.
- When the ft-lb value is less than 10, convert the ft-lb value to in-lb to obtain a better torque with an in-lb torque wrench. Example: 6 ft-lb equals 72 in-lb.

Capscrew Markings and Torque Values - Metric



Body Size	Torque				Torque				Torque			
Diameter	Cast Iron		Aluminium		Cast Iron		Aluminium		Cast Iron		Aluminium	
mm	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
6	9	5	7	4	13	10	7	4	14	9	7	4
7	14	9	11	7	18	14	11	7	23	18	11	7

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Body Size	Torque				Torque				Torque			
Diameter	Cast Iron		Aluminium		Cast Iron		Aluminium		Cast Iron		Aluminium	
mm	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
8	23	17	18	14	33	25	18	14	40	29	18	14
10	45	33	30	25	65	50	30	25	70	50	30	25
12	80	60	55	40	115	85	55	40	125	95	55	40
14	125	90	90	65	180	133	90	65	195	145	90	65
16	195	140	140	100	280	200	140	100	290	210	140	100
18	280	200	180	135	390	285	180	135	400	290	180	135
20	400	290	—	—	550	400	—	—	—	—	—	—

Capscrew Markings and Torque Values - U.S. Customary

SAE Grade Number	5	8
Capscrew Head Markings These are all SAE Grade 5 (3 line)		
	Capscrew Torque - Grade 5 Capscrew	Capscrew Torque - Grade 8 Capscrew

17800015

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Capscrew Body Size	Cast Iron		Aluminium		Cast Iron		Aluminium	
	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
1/4 - 20	9	7	8	6	15	11	8	6
1/4 - 28	12	9	9	7	18	13	9	7
5/16 - 18	20	15	16	12	30	22	16	12
5/16 - 24	23	17	19	14	33	24	19	14
3/8 - 16	40	30	25	20	55	40	25	20
3/8 - 24	40	30	35	25	60	45	35	25
7/16 - 14	60	45	45	35	90	65	45	35
7/16 - 20	65	50	55	40	95	70	55	40
1/2 - 13	95	70	75	55	130	95	75	55
1/2 - 20	100	75	80	60	150	110	80	60
9/16 - 12	135	100	110	80	190	140	110	80
9/16 - 18	150	110	115	85	210	155	115	85
5/8 - 11	180	135	150	110	255	190	150	110
5/8 - 18	210	155	160	120	290	215	160	120
3/4 - 10	325	240	255	190	460	340	255	190
3/4 - 16	365	270	285	210	515	380	285	210
7/8 - 9	490	360	380	280	745	550	380	280
7/8 - 14	530	390	420	310	825	610	420	310
1 - 8	720	530	570	420	1100	820	570	420
1 - 14	800	590	650	480	1200	890	650	480

Fraction, Decimal, Millimeter Conversions

Conversion Chart

Fraction	inch	mm	Fraction	inch	mm
1/64	0.0156	0.397	33/64	0.5156	13.097
1/32	0.0313	0.794	17/32	0.5313	13.494
3/64	0.0469	1.191	35/64	0.5469	13.891
1/16	0.0625	1.588	9/16	0.5625	14.288
5/64	0.0781	1.984	37/64	0.5781	14.684
3/32	0.0938	2.381	19/32	0.5938	15.081
7/64	0.1094	2.778	39/64	0.6094	15.478
1/8	0.1250	3.175	5/8	0.6250	15.875
9/64	0.1406	3.572	41/64	0.6406	16.272
5/32	0.1563	3.969	21/32	0.6563	16.669
11/64	0.1719	4.366	43/64	0.6719	17.066
3/16	0.1875	4.763	11/16	0.6875	17.463
13/64	0.2031	5.159	45/64	0.7031	17.859
7/32	0.2188	5.556	23/32	0.7188	18.256
15/64	0.2344	5.953	47/64	0.7344	18.653
1/4	0.2500	6.350	3/4	0.7500	19.050
17/64	0.2656	6.747	49/64	0.7656	19.447
9/32	0.2813	7.144	25/32	0.7813	19.844
19/64	0.2969	7.541	51/64	0.7969	20.241
5/16	0.3125	7.938	13/16	0.8125	20.638
21/64	0.3281	8.334	53/64	0.8281	21.034
11/32	0.3438	8.731	27/32	0.8438	21.431
23/64	0.3594	9.128	55/64	0.8594	21.828
3/8	0.3750	9.525	7/8	0.8750	22.225
25/64	0.3906	9.922	57/64	0.8906	22.622
13/32	0.4063	10.319	29/32	0.9063	23.019
27/64	0.4219	10.716	59/64	0.9219	23.416
7/16	0.4375	11.113	15/16	0.9375	23.813
29/64	0.4531	11.509	61/64	0.9531	24.209
15/32	0.4688	11.906	31/32	0.9688	24.606
31/64	0.4844	12.303	63/64	0.9844	25.003
1/2	0.5000	12.700	1	1.0000	25.400

Conversion Factor: 1 inch = 25.4 mm

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Newton-Meter to Foot-Pound Conversions

Conversion Chart

N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
1	9 in-lb	55	41	155	114
5	44 in-lb	60	44	160	118
6	53 in-lb	65	48	165	122
7	62 in-lb	70	52	170	125
8	71 in-lb	75	55	175	129
9	80 in-lb	80	59	180	133
10	89 in-lb	85	63	185	136
11	97 in-lb	90	66	190	140
12	106 in-lb	95	70	195	144
14	124 in-lb	100	74	200	148
15	133 in-lb	105	77	205	151
16	142 in-lb	110	81	210	155
18	159 in-lb	115	85	215	159
20	15 ft-lb	120	89	220	162
25	18	125	92	225	165
30	22	130	96	230	170
35	26	135	100	235	173
40	30	140	103	240	177
45	33	145	107	245	180
50	37	150	111	250	184
NOTE: To convert from Newton-Meters to Kilogram-Meters divide Newton-Meters by 9.803.					

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Pipe Plug Torque Values

Torque Table

Size		Torque		Torque	
Thread	Actual Thread O.D.	In Aluminum Components		In Cast Iron or Steel Components	
in	**in**	**N•m**	**ft-lb**	**N•m**	**ft-lb**
1/16	0.32	5	45 in-lb	15	10
1/8	0.41	15	10	20	15
1/4	0.54	20	15	25	20
3/8	0.68	25	20	35	25
1/2	0.85	35	25	55	40
3/4	1.05	45	35	75	55
1	1.32	60	45	95	70
1-1/4	1.66	75	55	115	85
1-1/2	1.90	85	65	135	100

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Tap-Drill Chart - U.S. Customary and Metric

General Information

NOTE ON SELECTING TAP-DRILL SIZES: The tap drill sizes shown on this card give the theoretical tap drill size for approximately 60% and 75% of full thread depth. Generally, it is recommended that drill sizes be selected in the 60% range as these sizes will provide about 90% of the potential holding power. Drill sizes in the 75% range are recommended for shallow hole tapping (less than 1 1/2 times the hole diameter) in soft metals and mild steel.

Tap Size		Drill
60%	75%	Size
		48
		1.95mm
		5/64
	3-48	47
		2.00mm
	M2.5x.45	2.05mm
		46
3-48	3056	45
		2.10mm
M2.5x.45	M2.6x.45	2.15mm
3-56	4-36	44
		2.20mm
M2.6x.45		2.25mm
4-36	4-40	43
		2.30mm
		2.35mm
4-40	4-48	42
		3/32
	M3x.6	2.40mm
4-48		41
		2.45mm
		40
M3x.6	M3x.5	2.50mm
		39
	5-40	38
M3x.5		2.60mm
5-40	5-44	37
		2.70mm
5-44	6-32	36
		2.75mm
		7/64
		35
		2.80mm
		34
6-32	6-40	33
	M3.5x6	2.90mm
		32
M3.5x6		3.00mm
6-40		31
		3.10mm
		1/8
		3.20mm
	M4x.75	3.25mm
		30
	M4x.7	3.30mm
M4x.75		3.40mm
M4x.7	8-32	29
		3.50mm
	8-36	28
8-32		9/64
		3.60mm
8-36		27
		3.70mm
		26
	M4.5x.75	3.75mm
	10-24	25
		3.80mm
		24
M4.5x.75		3.90mm
		23
		5/32
10-24		22
	M5x1	4.00mm
	10-32	21
		20
	M5x.9	4.10mm
M5x1	M5x.8	4.20mm
10-32		19
M5x.9		4.25mm
M5x.8		4.30mm
		18
		11/64
		17

Tap Size		Drill
60%	75%	Size
		4.40mm
	12-24	16
		4.50mm
		15
	M5.5x.9	4.60mm
12-24	12-28	14
		13
		4.70mm
M5.5x.9		4.75mm
12-28		3/16
		12
		4.80mm
		11
		4.90mm
		10
		9
	M6x1	5.00mm
		8
		5.10mm
	1/4-20	7
		13/64
		6
M6x1		5.20mm
		5
	M6x.75	5.25mm
		5.30mm
1/4-20		4
M6x.75		5.40mm
	1/4-28	3
		5.50mm
		7/32
		5.60mm
1/4-28		2
		5.70mm
		5.75mm
		1
		5.80mm
		5.90mm
		A
		15/64
	M7x1	6.00mm
		B
		6.10mm
		C
M7x1		6.20mm
		D
	M7x.75	6.25mm
		6.30mm
		E
		1/4
M7x.75		6.40mm
		6.50mm
	5/16-18	F
		6.60mm
		G
		6.70mm
		17/64
	M8x1.25	6.75mm
5/16-18		H
		6.80mm
		6.90mm
	5.16-24	I
M8x1.25	M8x1	7.00mm
		J
		7.10mm
5/16-24		K
		9/32
M8x1		7.20mm
		7.25mm
		7.30mm
		L
		7.40mm
		M

Tap Size		Drill
60%	75%	Size
		7.50mm
		19/64
		7.60mm
		N
		7.70mm
	M9x1.25	7.75mm
		7.80mm
		7.90mm
	3/8-16	5/16
M9x1.25	M9x1	8.00mm
		O
		8.10mm
M9x1		8.20mm
		P
		8.25mm
		8.30mm
3/8-16	1/8-27NPT	21/64
		8.40mm
	3/8-24	Q
	M10x1.5	8.50mm
		8.60mm
		R
3/8-24		8.70mm
1/8-27NPT		11/32
	M10x1.25	8.75mm
M10x1.5		8.80mm
		S
		8.90mm
M10x1.25	M10x1	9.00mm
		T
		9.10mm
		23/64
M10x1		9.20mm
		9.30mm
	7/16-14	U
		9.40mm
	M11x1.5	9.50mm
		3/8
		V
		9.60mm
		9.70mm
		9.75mm
M11x1.5		9.80mm
7/16-14		W
		9.90mm
	7/16-20	25/64
		10.00mm
7/16-20		X
	M12x1.75	10.20mm
		Y
		13/32
		Z
M12x1.75	M12x1.5	10.50mm
	1/2-13	27/64
M12x1.5	M12x1.25	10.75mm
M12x1.25		11.00mm
1/2-13		7/16
1/4-18NPT		
		11.25mm
		11.50mm
		29/64
		11.75mm
		11.50mm
	1/2-20	29/64
	9/16-12	15/32
	M14x2	12.00m
		12.25mm
9/16-12		31/64
M14x2	M14x1.5	12.50mm
	9/16-18	1/2
M14x1.5	M14x1.25	12.75mm
M14x1.25		13.00mm
9/16-18		33/64

Tap Size		Drill
60%	75%	Size
		13.25mm
	5/8-11	17/32
	M15x1.5	13.50mm
M15x1.5		13.75mm
5/8-11		35/64
	M16x2	14.00mm
		14.25mm
	5/8-18	9/16
M16x2	M16x1.5	14.50mm
5/8-18		37/64
		14.75mm
M16x1.5		15.00mm
		19.32
		15.25mm
		39/64
	M17x1.5	15.50mm
M17x1.5	M18x2.5	15.75mm
		5/8
M18x2.5	M18x2	16.00mm
M18x2		16.25mm
	3/4-10	41/64
	M18x1.5	16.50mm
3/4-10	M19x2.5	21/32
M18x1.5		16.75mm
M19x2.5		17.00mm
		43/64
		17.25mm
3/4-16	3/4-16	11/16
	M20x2.5	17.50mm
		17.75mm
		45/64
M20x2.5	M20x2	18.00mm
M20x2		18.25mm
		23/32
	M20x1.5	18.50mm
		47/64
M20x1.5		18.75mm
		19.00mm
		3/4
		19.25mm
	7/8-9	49/64
	M22x2.5	19.50mm
7/8-9		25/32
		19.75mm
M22x2.5	M22x2	20.00mm
	7/8-14	51/64
M22x2		20.25mm
	M22x1.5	20.50mm
7/8-14		13/16
		20.75mm
M22x1.5	M24x3	21.00mm
		53/64
		21/25mm
		27/32
M24x3		21.50mm
		21.75mm
		55/64
	M24x2	22.00mm
	1"-8	7/8
M24x2		22.25mm
	M24x1.5	22.50mm
1"-8		57/64
M24x1.5		22.75mm
	M25x2	23.00mm
	1"-12	29/32
M25x2		23.25mm
1"x12	1"-14	59/64
	M25x1.5	23.50mm
M20x1.5		23.75mm
1"-14		15/16

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Weights and Measures - Conversion Factors

Conversion Chart

Quantity	U.S. Customary		Metric		From U.S. Customary To Metric Multiply By	From Metric To U.S. Customary Multiply By
	Unit Name	Abbreviation	Unit Name	Abbreviation		
Area	sq. inch	in^2	sq. millimeters	mm^2	645.16	0.001550
			sq. centimeters	cm^2	6.452	0.155
	sq. foot	ft^2	sq. meter	m^2	0.0929	10.764
Fuel Consumption	pounds per horsepower hour	lb/hp-hr	grams per kilowatt hour	g/kW-hr	608.277	0.001645
Fuel Performance	miles per gallon	mpg	kilometers per liter	km/l	0.4251	2.352
	gallons per mile	gpm	liters per kilometer	l/km	2.352	0.4251
Force	pounds force	lbf	Newton	N	4.4482	0.224809
Length	inch	in	millimeters	mm	25.40	0.039370
	foot	ft	millimeters	mm	304.801	0.00328
Power	horsepower	hp	kilowatt	kW	0.746	1.341
Pressure	pounds force per sq. inch	psi	kilopascal	kPa	6.8948	0.145037
	inches of mercury	in Hg	kilopascal	kPa	3.3769	0.29613
	inches of water	in H_2O	kilopascal	kPa	0.2488	4.019299
	inches of mercury	in Hg	millimeters of mercury	mm Hg	25.40	0.039370
	inches of water	in H_2O	millimeters of water	mm H_2O	25.40	0.039370
	bars	bars	kilopascals	kPa	100.001	0.00999
	bars	bars	millimeters of mercury	mm Hg	750.06	0.001333
Temperature	fahrenheit	°F	centigrade	°C	(°F-32) ÷1.8	(1.8 x °C) +32
Torque	pound force per foot	ft-lb	Newton-meter	N•m	1.35582	0.737562
	pound force per inch	in-lb	Newton-meter	N•m	0.113	8.850756
Velocity	miles/hour	mph	kilometers/hour	kph	1.6093	0.6214
Volume: liquid displacement	gallon (U.S.)	gal.	liter	l	3.7853	0.264179
	gallon (Imp*)	gal.	liter	l	4.546	0.219976
	cubic inch	in^3	liter	l	0.01639	61.02545
	cubic inch	in^3	cubic centimeter	cm^3	16.387	0.06102
Weight (mass)	pounds (avoir.)	lb	kilograms	kg	0.4536	2.204623
Work	British Thermal Unit	BTU	joules	J	1054.5	0.000948
	British Thermal Unit	BTU	kilowatt-hour	kW-hr	0.000293	3414
	horsepower hours	hp-hr	kilowatt-hour	kW-hr	0.746	1.341

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Barometric Pressure at Altitude

Specifications

Barometric Pressure at Altitude					
Pressure				Altitude	
kPa	PSI	mm Hg	in Hg	m	ft.
103.2	14.96	773.9	30.47	-152	-500
101.3	14.69	760.0	29.92	0	0
99.5	14.43	746.3	29.38	152	500
97.7	14.17	733.0	28.86	305	1000
96.0	13.92	719.8	28.34	458	1500
94.2	13.66	706.6	27.82	610	2000
92.5	13.42	693.9	27.32	762	2500
90.8	13.17	681.2	26.82	914	3000
89.2	12.93	668.8	26.33	1067	3500
87.5	12.69	656.3	25.84	1219	4000
85.9	12.46	644.3	25.37	1372	4500
84.3	12.23	632.2	24.89	1524	5000
82.8	12.01	620.7	24.44	1677	5500
81.2	11.78	609.1	23.98	1829	6000
79.7	11.56	597.8	23.54	1982	6500
78.2	11.34	586.5	23.09	2134	7000
76.7	11.13	575.5	22.66	2286	7500
75.2	10.91	564.4	22.22	2438	8000
73.8	10.71	553.8	21.80	2591	8500
72.4	10.50	543.1	21.38	2743	9000
71.1	10.31	532.8	20.98	2896	9500
69.7	10.11	522.5	20.57	3048	10,000
67.1	9.73	502.8	19.80	3353	11,000
64.4	9.34	483.1	19.02	3658	12,000
62.0	8.99	464.7	18.30	3963	13,000
59.5	8.63	446.3	17.57	4267	14,000
57.2	8.30	429.0	16.89	4572	15,000
54.9	7.96	411.7	16.21	4877	16,000

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Notes

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Bulletin 4021418
Printed in U.S.A. 23-JULY-2014