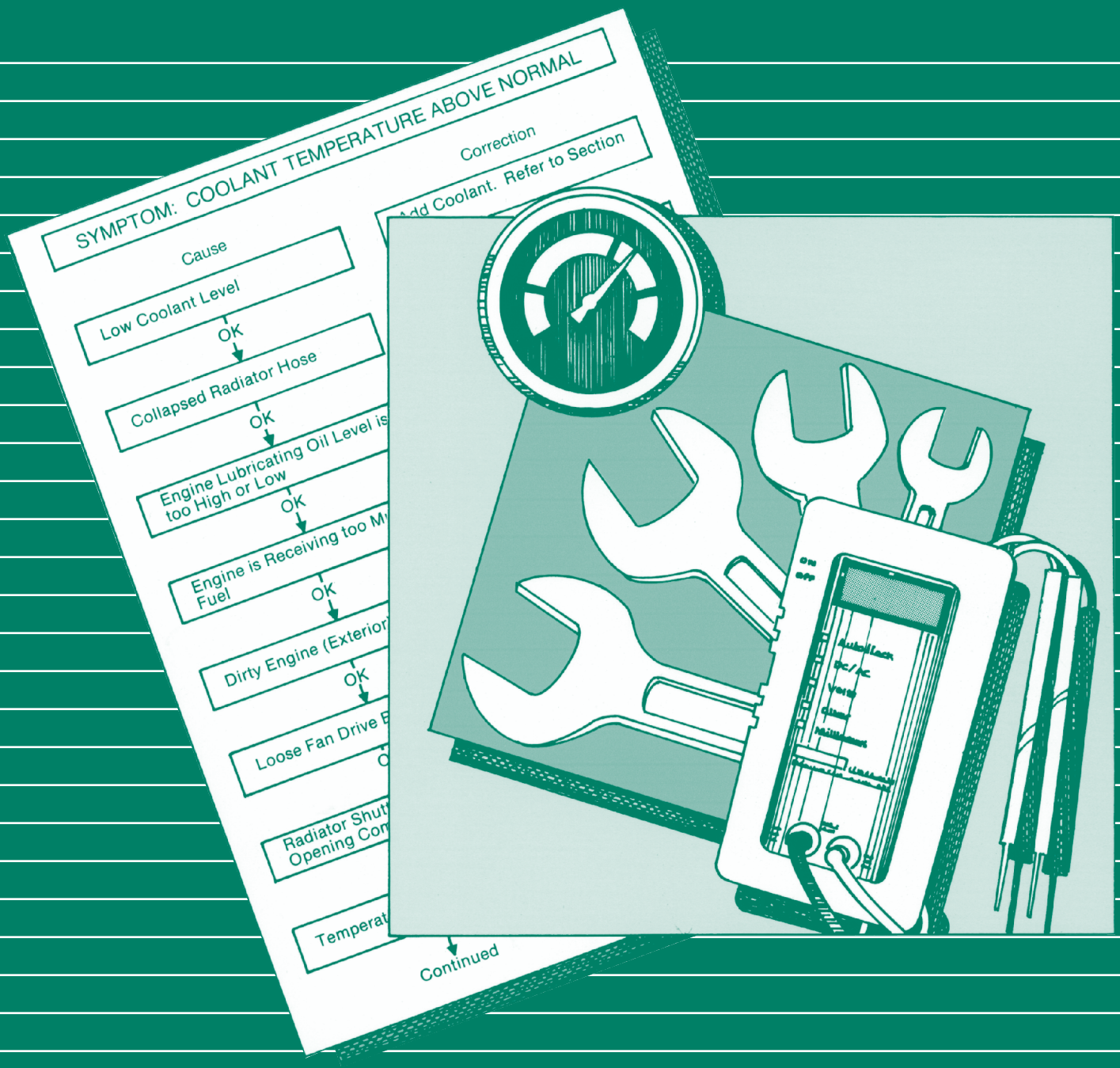
Service Manual
ISB^{e}, ISB, and QSB (Common Rail Fuel System)
Volume 2



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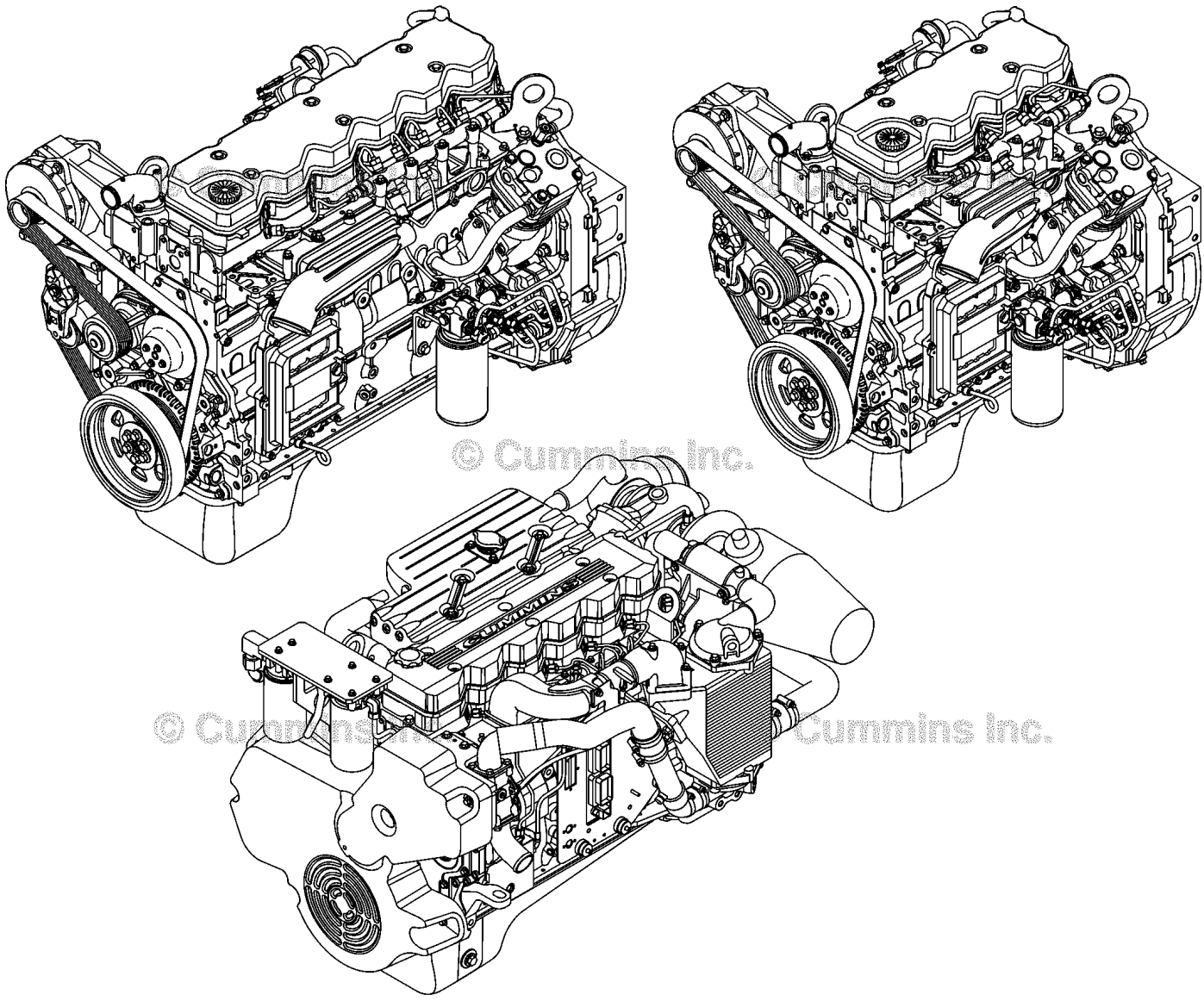

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Foreword

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

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

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

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

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

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

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

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

Table of Contents

Section i - Introduction

Section Contents

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About the Manual

General Information

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

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

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

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

How to Use the Manual

General Information

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

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

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

Each section contains the following in sequence:

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

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

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

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

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

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

Symbols

General Information

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

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

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

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

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

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

INSPECTION is required.

CLEAN the part or assembly.

PERFORM a mechanical or time **MEASUREMENT**.

LUBRICATE the part or assembly.

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

TIGHTEN to a specific torque.

PERFORM an electrical **MEASUREMENT**.

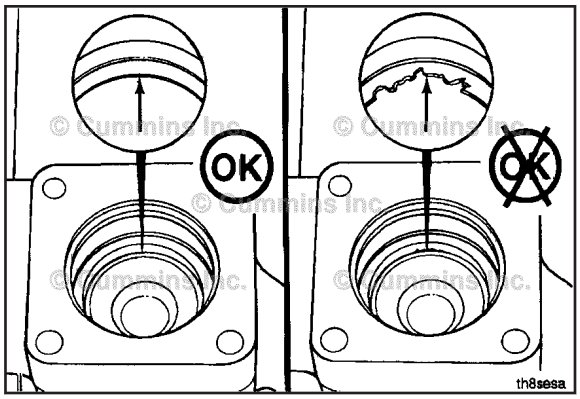
Refer to another location in this manual or another publication for additional information.

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

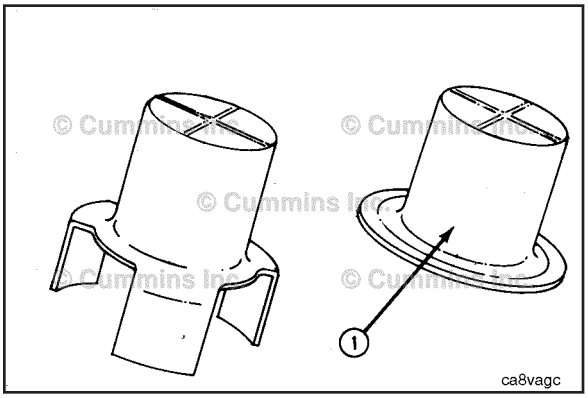
Illustrations

General Information

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



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



General Safety Instructions

Important Safety Notice

⚠ WARNING ⚠

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

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

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

- Some state and federal agencies in the United States of America have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.
- Do **not** connect the jumper starting or battery charging cables to any ignition or governor control wiring. This can cause electrical damage to the ignition or governor.
- **Always** torque fasteners and fuel connections to the required specifications. Overtightening or undertightening can allow leakage. This is critical to the natural gas and liquefied petroleum gas fuel and air systems.
- **Always** test for fuel leaks as instructed, as odorant can fade.
- Close the manual fuel valves prior to performing maintenance and repairs, and when storing the vehicle inside.
- Coolant is toxic. If **not** reused, dispose of in accordance with local environmental regulations.
- The catalyst reagent contains urea. Do **not** get the substance in your eyes. In case of contact, immediately flood eyes with large amounts of water for a minimum of 15 minutes. Avoid prolonged contact with skin. In case of contact, immediately wash skin with soap and water. Do **not** swallow internally. In the event the catalyst reagent is ingested, contact a physician immediately.
- The catalyst substrate contains Vanadium Pentoxide. Vanadium Pentoxide has been determined by the State of California to cause cancer. Always wear protective gloves and eye protection when handling the catalyst assembly. Do not get the catalyst material in your eyes. In Case of contact, immediately flood eyes with large amounts of water for a minimum of 15 minutes. Avoid prolonged contact with skin. In case of contact, immediately wash skin with soap and water.
- The Catalyst substrate contains Vanadium Pentoxide. Vanadium Pentoxide has been determined by the State of California to cause cancer. In the event the catalyst is being replaced, dispose of in accordance with local regulations.
- California Proposition 65 Warning - Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

General Repair Instructions

General Information

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

⚠WARNING⚠

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

1 Air Compressor
2 Air Controls
3 Air Shutoff Assemblies
4 Balance Weights
5 Cooling Fan
6 Fan Hub Assembly
7 Fan Mounting Bracket(s)
8 Fan Mounting Capscrews
9 Fan Hub Spindle
10 Flywheel
11 Flywheel Crankshaft Adapter
12 Flywheel Mounting Capscrews
13 Fuel Shutoff Assemblies
14 Fuel Supply Tubes
15 Lifting Brackets
16 Throttle Controls
17 Turbocharger Compressor Casing
18 Turbocharger Oil Drain Line(s)
19 Turbocharger Oil Supply Line(s)
20 Turbocharger Turbine Casing
21 Vibration Damper Mounting Capscrews
22 Manual Service Disconnect
23 High Voltage Interlock Loop
24 High Voltage Connectors/Connections and Harnesses
25 High Voltage Battery System
26 Power Inverter
27 Generator Motor
28 Clutch Pressure Plate

- Follow all safety instructions noted in the procedures
- Follow the manufacturer's recommendations for cleaning solvents and other substances used during repairs. Some solvents have been identified by government agencies as toxic or carcinogenic. Avoid excessive breathing, ingestion and contact with such substances. **Always** use good safety practices with tools and equipment
- Provide a clean environment and follow the cleaning instructions specified in the procedures
- All components **must** be kept clean during any repair. Contamination of the components will cause premature wear.
- Perform the inspections specified in the procedures
- Replace all components or assemblies which are damaged or worn beyond the specifications

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

Welding on a Vehicle with an Electronic Controlled Fuel System

⚠CAUTION⚠

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

General Cleaning Instructions

Definition of Clean

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

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

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

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

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

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

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

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

Abrasive Pads and Abrasive Paper

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

⚠WARNING⚠

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

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

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

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

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

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

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

⚠ WARNING ⚠

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

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

Gasket Surfaces

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

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

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

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

Solvent and Acid Cleaning

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

⚠ WARNING ⚠

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

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

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

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

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

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

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

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

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

Steam Cleaning

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

⚠WARNING⚠

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

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

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

Plastic Bead Cleaning

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

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

△CAUTION△

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

△CAUTION△

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

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

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

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

2 Operating Pressure — 270 kPa (40 psi) for piston cleaning. Pressure should not cause beads to break.

3 Steam clean or wash the parts with solvent to remove all of the foreign material and plastic beads after cleaning. Rinse with hot water. Dry with compressed air.

⚠CAUTION⚠

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

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

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

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

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

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

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

Fuel System

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

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

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

Choose lint free towels for fuel system work.

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

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

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

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

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

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

Acronyms and Abbreviations

General Information

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

ANSI	American National Standards Institute
API	American Petroleum Institute
ASTM	American Society of Testing and Materials
ATDC	After Top Dead Center
BTU	British Thermal Unit
BTDC	Before Top Dead Center
°C	Celsius
CAN	Controller Area Network
CO	Carbon Monoxide
CCA	Cold Cranking Amperes
CARB	California Air Resources Board
C.I.B.	Customer Interface Box
C.I.D.	Cubic Inch Displacement
CNG	Compressed Natural Gas
CPL	Control Parts List
cSt	Centistokes
DEF	Diesel Exhaust Fluid
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
ECM	Engine Control Module
EFC	Electronic Fuel Control
EGR	Exhaust Gas Recirculation
EPA	Environmental Protection Agency
°F	Fahrenheit
ft-lb	Foot-Pound Force
FMI	Failure Mode Indentifier
GVW	Gross Vehicle Weight
Hg	Mercury
hp	Horsepower
H_2O	Water
inHg	Inches of Mercury
in H_20	Inches of Water
ICM	Ignition Control Module
IEC	International Electrotechnical Commission
km/l	Kilometers per Liter
kPa	Kilopascal
LNG	Liquid Natural Gas
LPG	Liquified Petroleum Gas
LTA	Low Temperature Aftercooling
MCRS	Modular Common Rail System
MIL	Malfunction Indicator Lamp
MPa	Megapascal
mph	Miles Per Hour
mpq	Miles Per Quart
N•m	Newton-meter

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

Section 5 - Fuel System - Group 05

Section Contents

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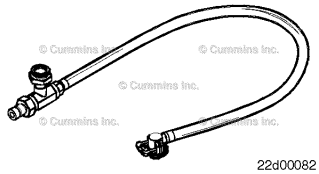
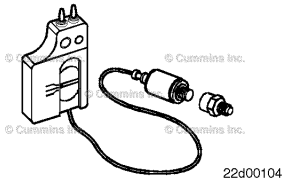
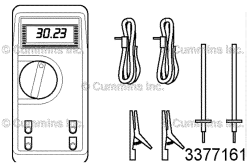
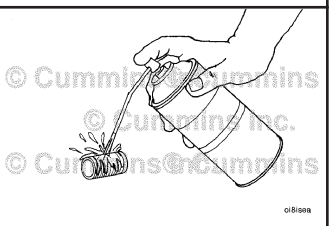
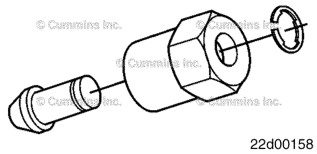
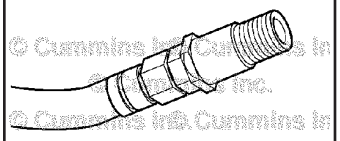
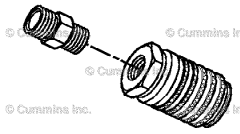
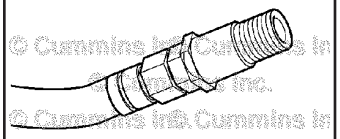
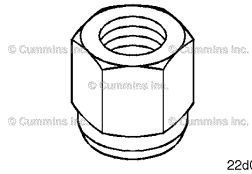
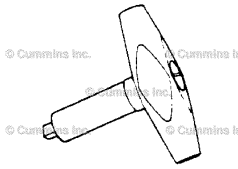
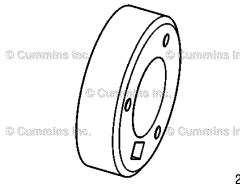
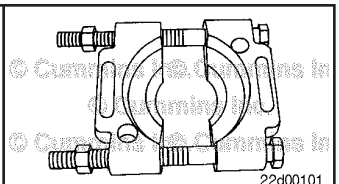
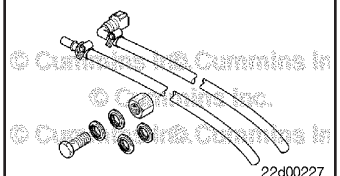
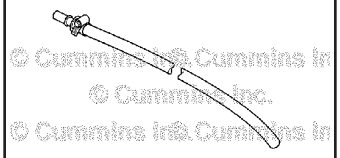
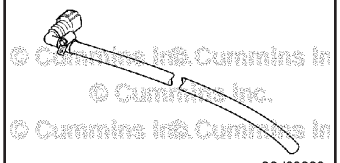
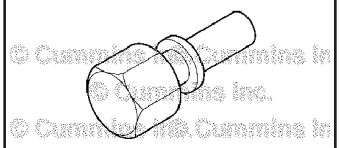
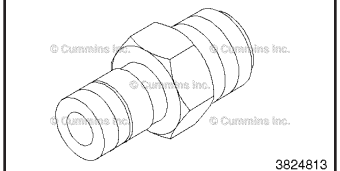
Service Tools

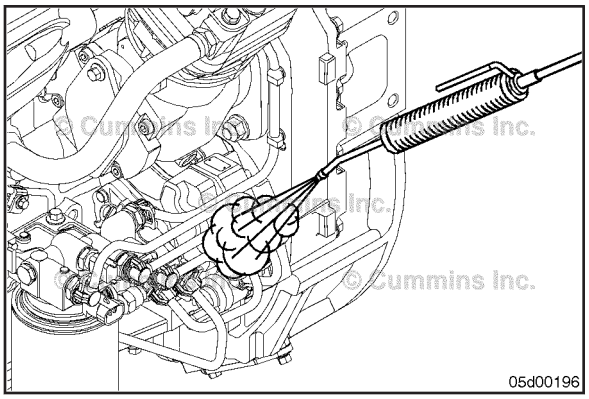
Fuel System

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
3164044	**Fuel Pressure Gauge Adapter** Used to measure fuel pressure and detect air in the fuel system. Use with Pressure/Vacuum Module, Part Number 3164491 (engines **without** EGR **only**)	
3164491	**Pressure/Vacuum Module** Used to measure fuel pressure and restriction.	
3164488 or 3164489	**Digital 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.	
3824510	**Quick Dry (QD) Cleaner** Used to clean parts and tools safely.	
3164325	**Fuel System Leak Tester** Used to cut off the fuel supply to the injector to diagnose it for leakage and malfunction. Used on fuel rails with 14 mm threads.	
3823705	**Graduated Beaker** Used to measure fuel return flows.	

Tool No.	Tool Description	Tool Illustration
3164618	**Fuel Return Flow Hose (injector and fuel pump)** The tool uses a special fitting to connect to the fuel return circuits to measure return flow from the injectors and fuel pump (EGR engines **only**).	 22d00217
3164621	**Lift Pump Performance Test Orifice** This tool connects to the diagnostic fitting on the inlet to the fuel filter. It is used to measure flow from the lift pump through an orifice **without** the engine running. The tool consists of a 0.043-inch orifice, Part Number 3045018, and a Compuchek® coupling, Part Number 3376859 (EGR engines **only**).	 3164621
3376859	**Compuchek® Quick-Connect Coupling** This tool connects to the diagnostic fitting on the inlet to the fuel filter. It is used when measuring inlet restriction when running the lift pump and does **not** contain an orifice (EGR engines **only**).	 3376859
3164583	**Fuel Line Cap** This tool is used to cap a quick-connect fuel line that has been disconnected from the engine. This prevents back-flow out of the line (engines **without** EGR **only**).	 3164583
3164617	**Fuel Return Flow Hose (fuel rail pressure relief valve)** The tool uses a special banjo fitting to connect to the fuel return circuit to measure return flow from the rail pressure relief valve.	 22d00217
3164025	**Fuel Connector Remover** Used to remove the high-pressure fuel connector from the cylinder head.	 22d00081
3823208	**Torque Wrench (injector terminal nuts)** This 13 in-lb torque wrench is used to tighten the injector solenoid terminal nuts.	 3823208
3164707	**Fuel Pump Drive Gear Retention Tool** Use to secure fuel pump gear drive while removing or installing drive gear retaining nut.	 22d00147

Tool No.	Tool Description	Tool Illustration
3375326	**Bearing Separator Tool** Use to remove the fuel pump gear.	 22d00101
4918354	**Fuel Return Flow Tester Kit** Used to check injector and HPCR pump drain flow.	 22d00227
4918433	**Fuel Drain Hose** Used with 5/16 quick disconnect fittings male connector (hose included in kit Part Number 4918354).	 22d00228
4918434	**Fuel Drain Hose** Used with 5/16 quick disconnect fittings female connector (hose included in kit Part Number 4918354).	 22d00229
4918464	**Fuel Tube Plug** Used to plug low pressure fuel lines.	 22d00232
3824842	**Compucheck® Fitting** Used to check fuel pressure/restriction. 10 mm O-ring connection.	 3824813



EFC Actuator Valve (005-007)

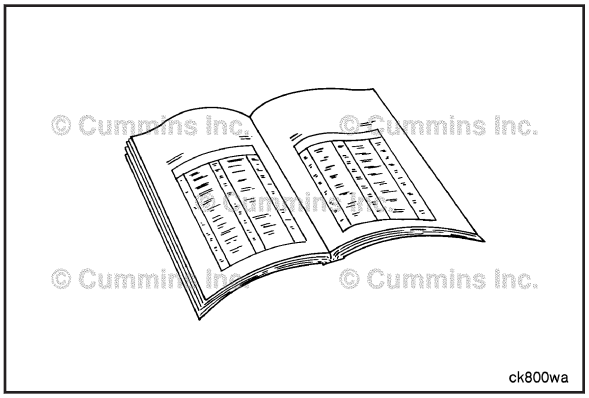
Preparatory Steps

⚠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.

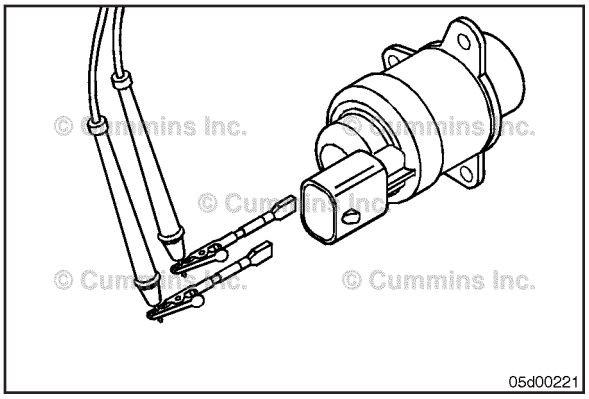
Steam clean the fuel pump and the area around the fuel pump.

Dry with compressed air.



Initial Check

Confirm that the lift pump is functional. Refer to Procedure 005-045 in Section 5.



Measure

Measure the resistance of the electronic fuel control actuator valve.

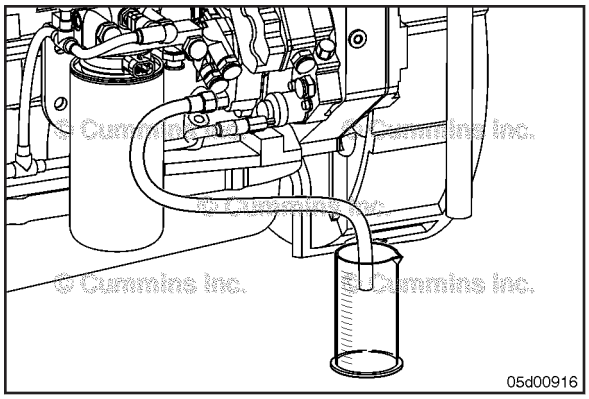
- Minimum Resistance: 0.1 ohms
- Maximum Resistance: 5 ohms

Install the electrical connection after measurement.

With the keyswitch ON and the engine cranking, check the high pressure injection pump.

Check the high pressure injection pump fuel flow as follows:

- Disconnect the high pressure fuel line to the fuel rail from the high pressure injection pump.
- Connect a clear hose to the outlet of the high pressure injection pump.
- Place the high pressure fuel clear hose into an empty bucket.
- Crank the engine for 30 seconds and measure the fuel pump flow.



Minimum fuel pump flow is 75 ml [2.5 oz] in 30 seconds at 125 rpm or 90 ml [3.04 oz] in 30 seconds at 150 rpm for 4-cylinder and 6-cylinder engines.

If the minimum fuel flow is **not** achieved, the high-pressure injection pump is defective. Refer to Procedure 005-016 in Section 5.

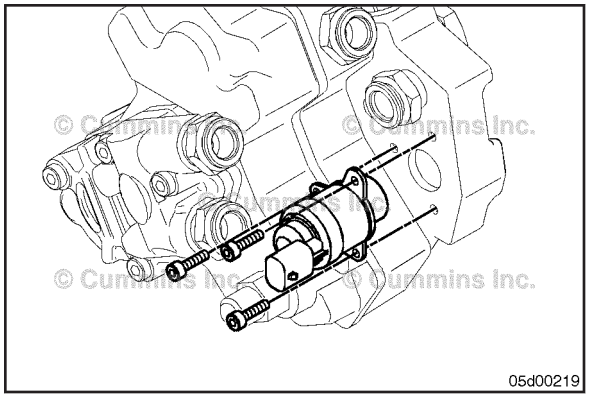
If the minimum fuel flow is achieved, the electronic fuel control (EFC) actuator is defective.

Remove

Remove the electrical connector

Remove the three capscrews.

Remove the EFC actuator by twisting and pulling outward.



Install

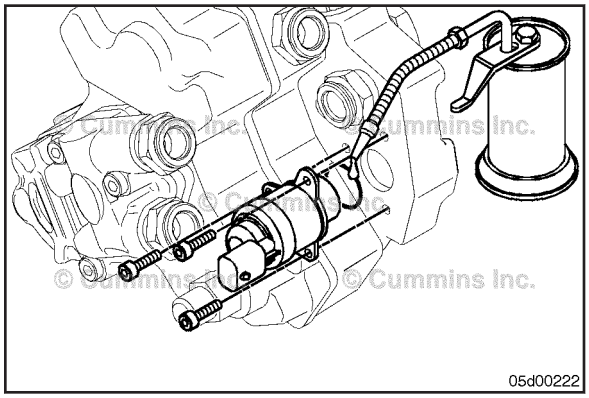
⚠CAUTION⚠
Do not pause more than 2 minutes between torque steps 1 and 2. This can cause the capscrews not to maintain their torque value. Leakage or engine damage can result.

NOTE: Lubricate the new o-ring with clean oil before installation.

Install a new o-ring on the electronic fuel control actuator.

Install the electronic fuel control actuator by twisting and pushing inward until flush with the mounting surface.

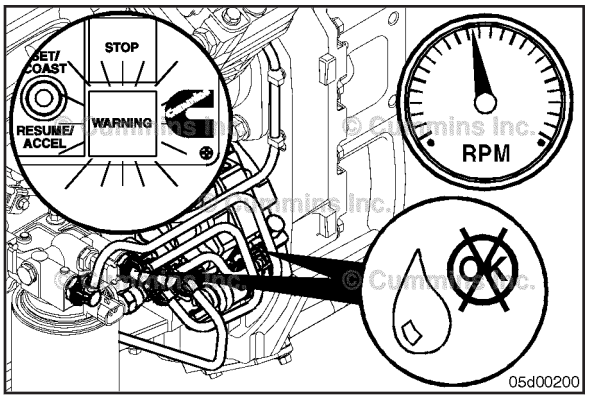
NOTE: Be sure the electronic fuel control actuator flange is flush with the mounting surface on the fuel pump before tightening the capscrews.



Torque Value:

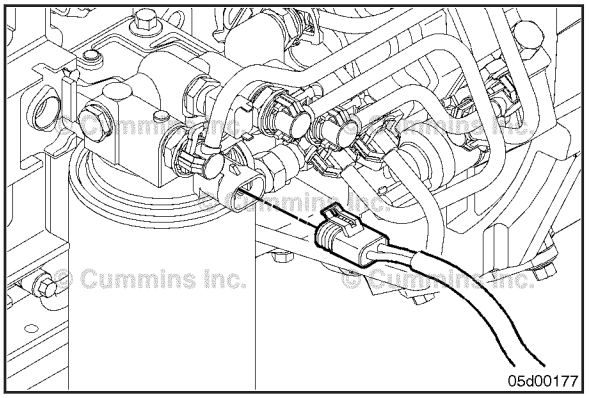
Step 1	3 N•m	[27 in-lb]
Step 2	7 N•m	[62 in-lb]

Install the electrical connector.



Finishing Steps

Operate the engine and check for leaks or fault codes.

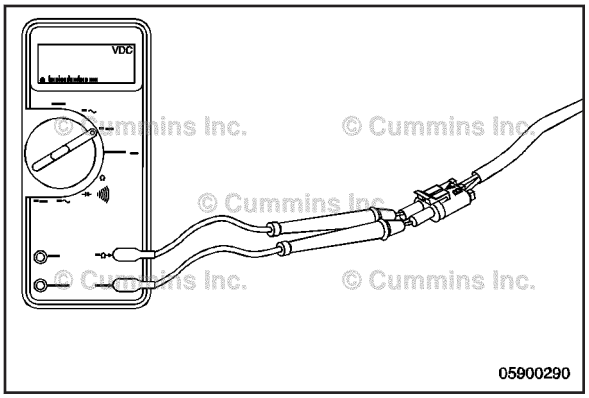


Engine Fuel Heater, Electric (005-008)

Initial Check

NOTE: The fuel heater is **not** controlled by the electronic control module (ECM). A bimetallic strip acts as a thermostat. The fuel heater will turn on below approximately 4°C [39°F] and turn off above approximately 27°C [81°F].

Remove the 2-pin connector from the fuel heater.



Check for proper voltage to the fuel heater thermostat control.

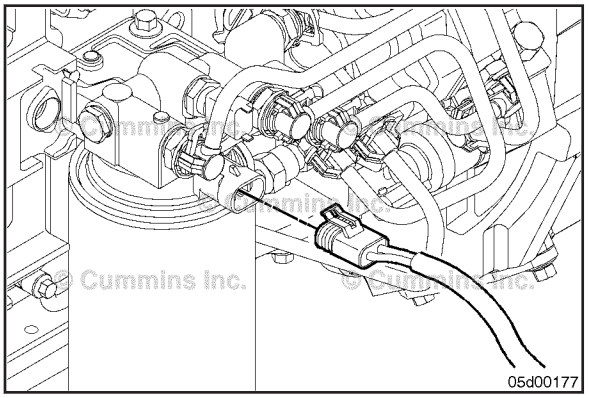
Fuel Heater Voltage
12-volt system - 12 VDC
24-volt system - 24 VDC

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

Check the wiring between the thermostat control and the fuel heater

Check voltage at the OEM harness connectors.

NOTE: Voltage out of the thermostat will be zero if the temperature is above the range needed to turn on the thermostat.



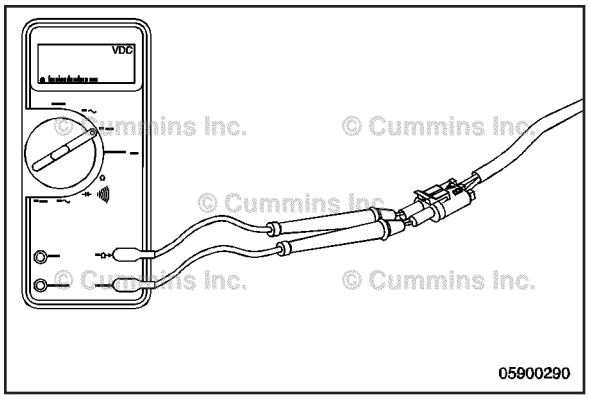
NOTE: The fuel heater on engines **without** EGR **is** controlled by the electronic control module (ECM). The CM800 ECM contains a relay that turns the fuel heater on and off based on the fuel temperature sensor reading.

NOTE: To test the voltage to the fuel heater, use the Fuel Heater Override test in INSITE™. Refer to INSITE™ documentation or Section 14 for more information.

Check for proper voltage to the fuel heater during the Fuel Heater Override test.

Fuel Heater Voltage
12-volt system - 12 VDC
24-volt system - 24 VDC

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



Remove

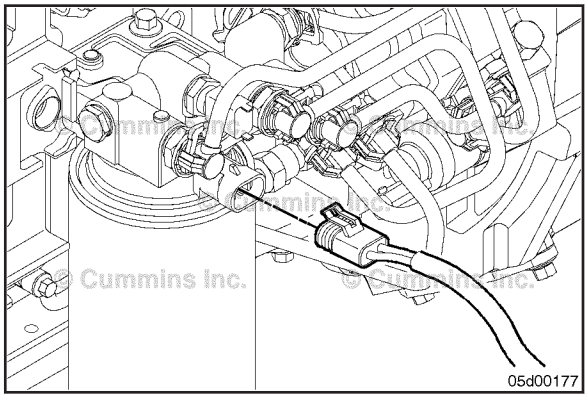
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠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.

Steam-clean the fuel heater and the area around the heater and fuel pump.

Dry with compressed air.

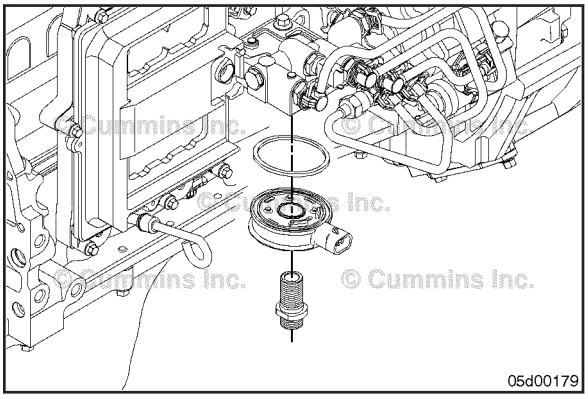
Disconnect the connector from the fuel heater.



Remove the fuel filter.

Remove the fuel filter spud.

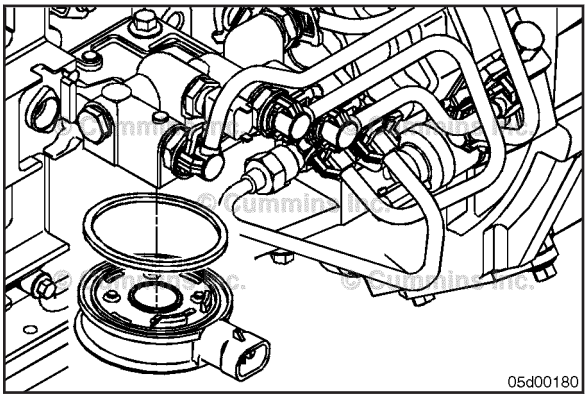
Remove the fuel heater from the filter head. The heater should be able to be pulled off the filter head.

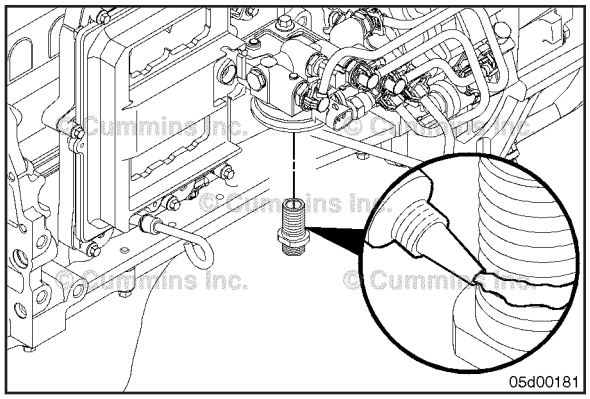


Install

△CAUTION△
Make sure that no dirt or debris enters the fuel heater to prevent the passing of contaminants to the high-pressure fuel pump and injectors. Small amounts of dirt and debris can cause a malfunction of these components.

Place the fuel heater, gasket side facing up, against the filter head.



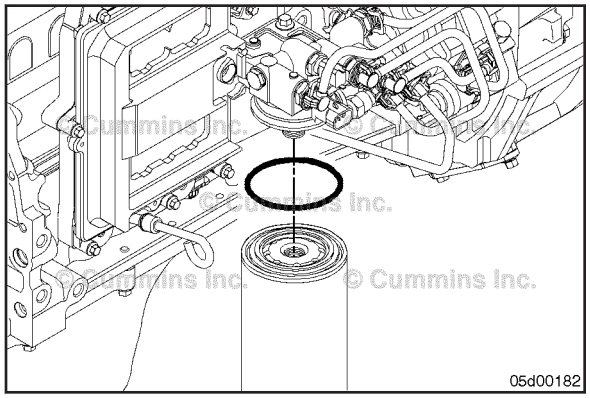


NOTE: Do **not** apply an excessive amount of Loctite due to its being passed into the fuel pump after installation.

Apply Loctite 648, or equivalent, to the filter spud.

Install the fuel filter spud.

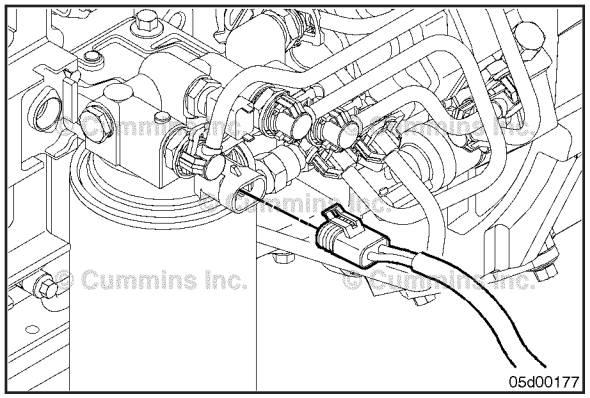
Torque Value: 30 N•m [22 ft-lb]



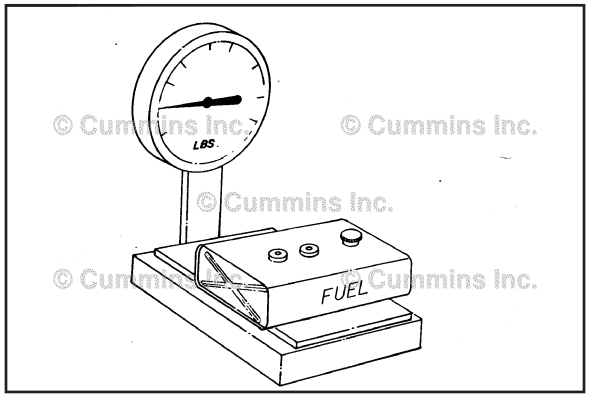
Install an o-ring between the fuel heater and the filter canister.

Install the fuel filter.

Torque Value: 34 N•m [25 ft-lb]



Connect the connector to the fuel heater.



Fuel Consumption (005-010)

Measure

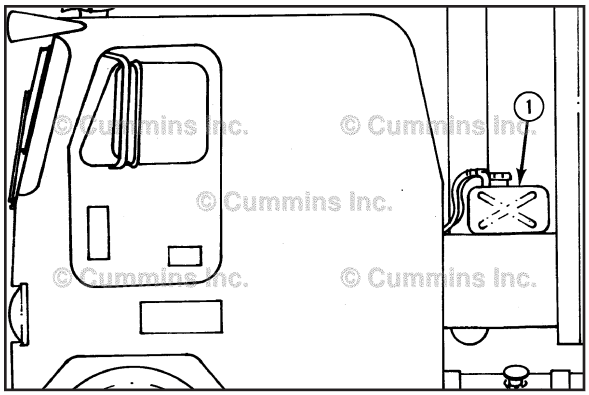
Refer to the fuel consumption checklist sheets in Section TS.

NOTE: The most accurate method of checking 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 remotely mounted tank with enough capacity to run 80 km [50 mi].

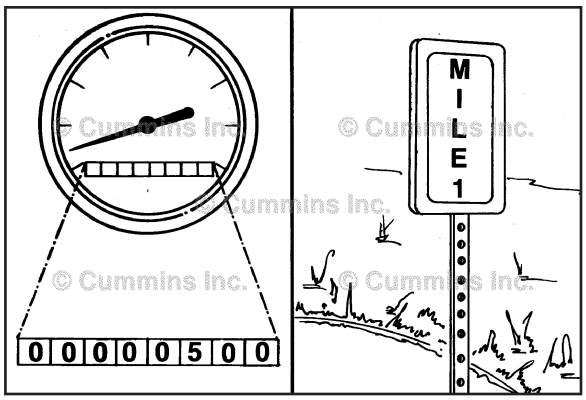
Fill the fuel tank. Weigh the tank with the fuel. The weight of Number 2 diesel fuel is nominally 0.844 kg per liter [7.04 lb per gal].

Install the remote tank (1).

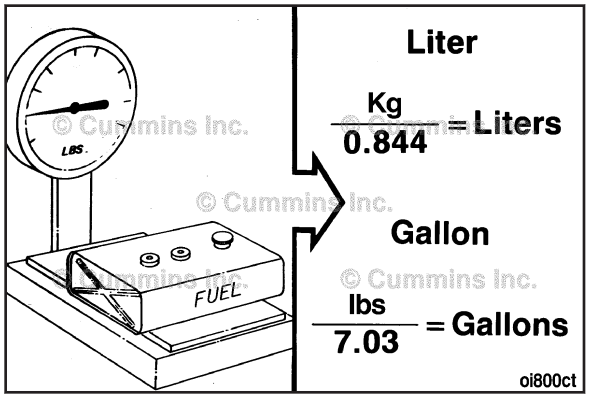
Install the return fuel line to the test tank, or the results will **not** be accurate.



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



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

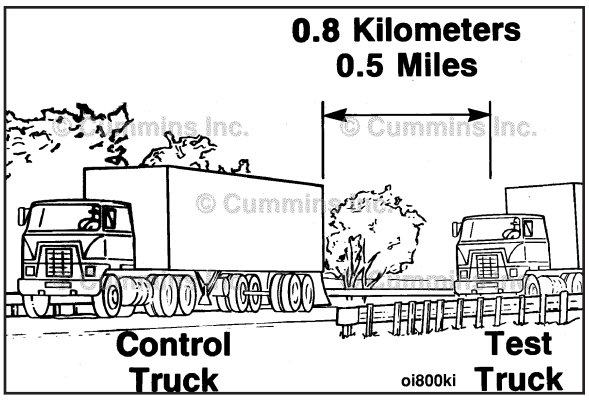


Compute the kilometers per liter or miles per gallon.

- Miles ÷ gallons = Miles per gallon
- Kilometers ÷ liters = Kilometers per liter

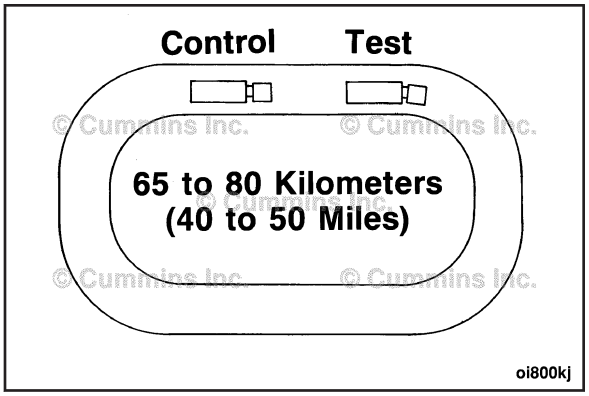
In addition to the measurement of the fuel used, the following factors provide points for running a test similar to the recognized Type II Society of Automotive Engineers Fuel Test.

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

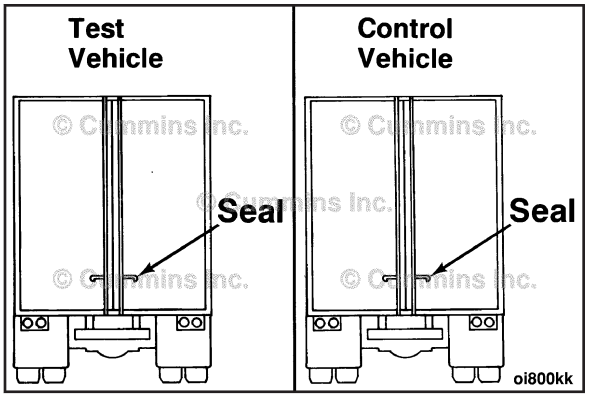


Perform the test with the test vehicle and a control vehicle. The control vehicle compensates for changes in traffic conditions.

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

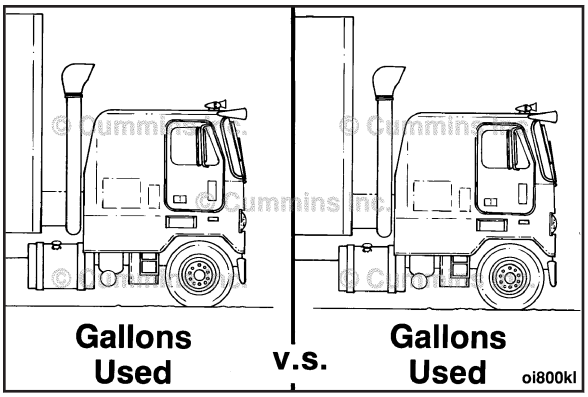


The test course **must** be 65 to 80 km [40 to 50 mi] long.



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

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



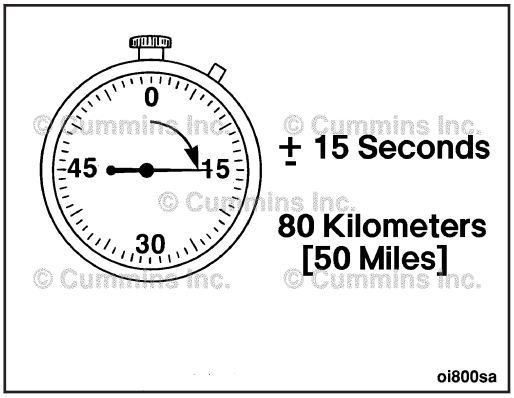
Drive the truck on a warm-up test run. Drive enough tests to achieve the following:

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

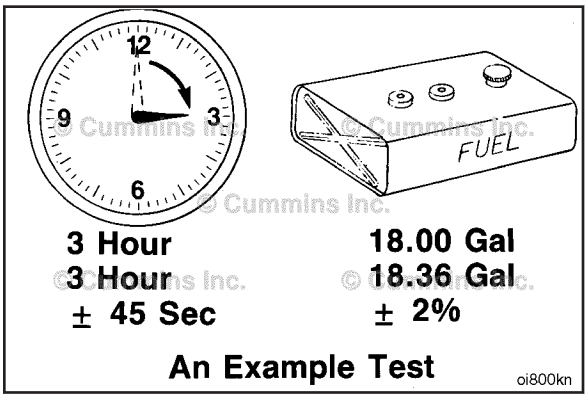
The fuel usage of the test truck between test drives **must** fall within a 2-percent range (e.g., 2.55 versus 2.60 km/ liters [6.00 versus 6.12 mpg]).

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

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

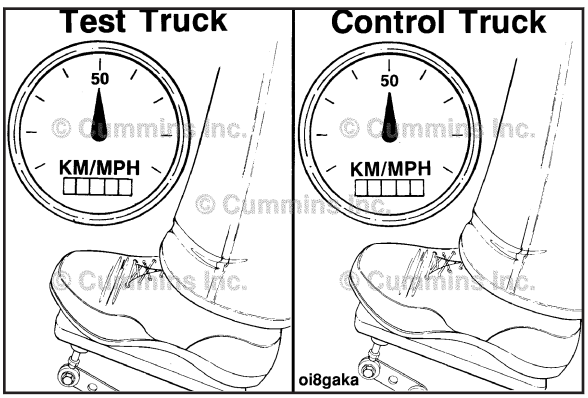


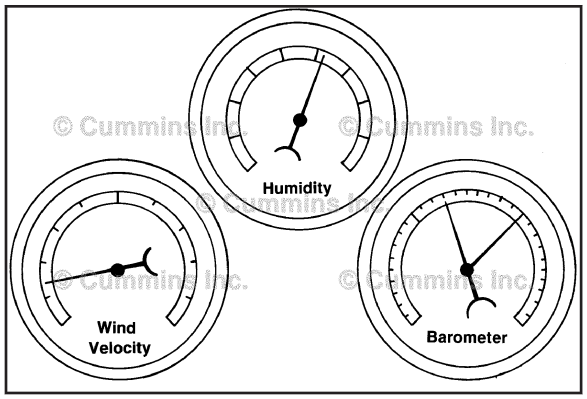
A minimum of three test drives that meet these conditions make a valid test. A single test drive is unreliable.



Use the same experienced drivers for all of the tests.

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

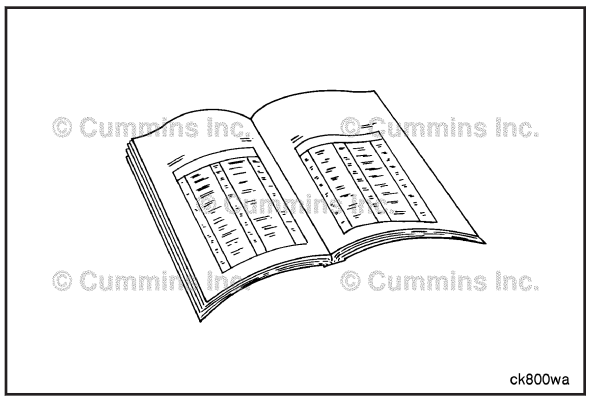




During the test, record the following:

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

NOTE: Avoid testing under any extreme conditions.



Fuel Pump (005-016)

General Information

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

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

△CAUTION△
Be sure that the fuel inlet and return valves are returned to the open position before cranking the engine. Engine damage can result if the valves are in the wrong position when the engine is cranked or started. Environmental damage can also occur.

There are four different mounting locations available for high-pressure fuel pumps. The pump can be mounted in a high or low position in either a front or rear gear train engine. Due to the number of different fuel pump mounting locations, the steps in this procedure have been written to be generic. Some of the illustrations do **not** represent the parts being removed or installed.

Refer to Procedure 005-999 in Section F.

Test

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

If the engine will **not** start, disconnect the high-pressure fuel outlet line from the high-pressure injection pump. Refer to Procedure 006-060 in Section 6.

Disconnect the fuel pump actuator connector.

Insert a clear hose to the outlet of the high-pressure injection pump, and run the other end into an empty bucket.

Crank the engine and measure the amount of fuel exiting the fuel pump.

NOTE: Do **not** crank the engine for 30 seconds continuously. Crank the engine in 10 second intervals with a 30 second break between cranking. This reduces the possibility of overheating the starter motor.

Fluid Measure	Time	Engine Speed	
4-cylinder	75 ml [2.5 oz]	30 seconds	125 rpm
6-cylinder	90 ml [3.04 oz]	30 seconds	150 rpm

If the high-pressure injection pump does **not** meet the flow specifications:

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

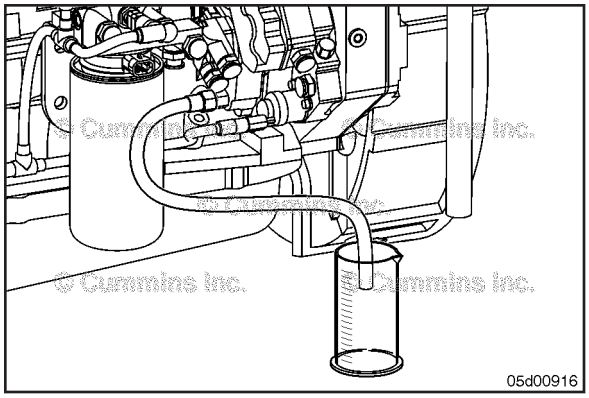
Check for inlet restriction. Refer to Procedure 006-020 in Section 6.

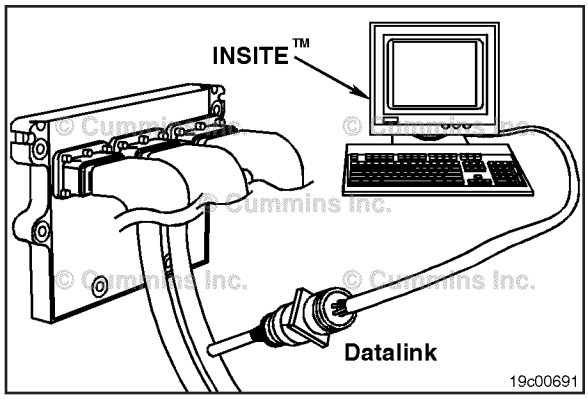
Check the fuel filter restriction. Refer to Procedure 006-015 in Section 6.

If these checks are acceptable, replace the fuel pump actuator. Refer to Procedure 005-007 in Section 5.

After replacing the fuel pump actuator, measure the fuel pump flow again. If the flow is **not** within specification, replace the fuel pump.

Connect the high-pressure fuel line and the fuel pump actuator electrical connection.





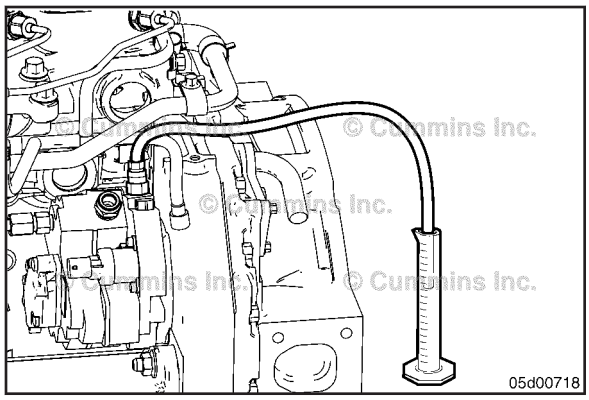
⚠WARNING⚠

The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

If the engine **can** be started, a measurement of the fuel return flow can diagnose a high-pressure fuel pump problem. The following steps describe how to test the high-pressure fuel pump return flow.

A malfunctioning fuel return overflow valve or fuel pump can result in high return from the fuel pump.

The return fuel flow from the pump **must** be measured at idle conditions. The Fuel System Leakage Test in INSITE™ electronic service tool can be used to increase system pressure and therefore increase the ability to detect high leakage.



Without Electric Lift Pump

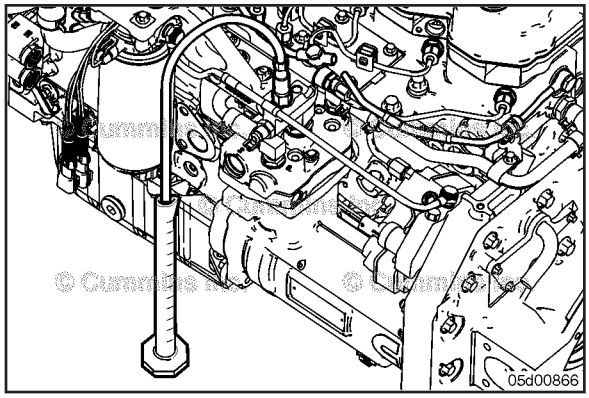
Disconnect the fuel pump return line.

3.9L and 5.9L Engines

- Attach the fuel pressure gauge adapter, Part Number 3164044, to the fuel pump return fitting. Install a quick-disconnect block-off fitting, Part Number 3164583, on the disconnected drain line.

4.5L and 6.7L Engines

- Attach the female quick-disconnect fuel drain hose, Part Number 4918434, onto the fuel pump drain connection. Install a quick-disconnect block-off fitting, Part Number 4918464, on the disconnected drain line.



With Electric Lift Pump

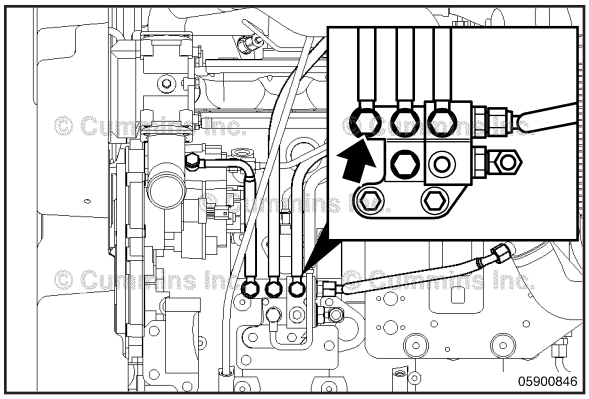
△CAUTION△

If tool Part Number 3164618 is installed at the fuel pump, it will block return flow and cause possible damage to the fuel pump. Install tool Part Number 3164618 only at the fuel return manifold.

Follow the fuel return line from the fuel pump to the fuel return manifold. At the fuel return manifold, remove the banjo bolt for fuel pump return line and install test fitting, Part Number 3164618.

For automotive and industrial applications, the return manifold is located near the top of the engine, beside the fuel rail.

For marine engines, the return manifold is located on the side of the engine block, next to the ECM.



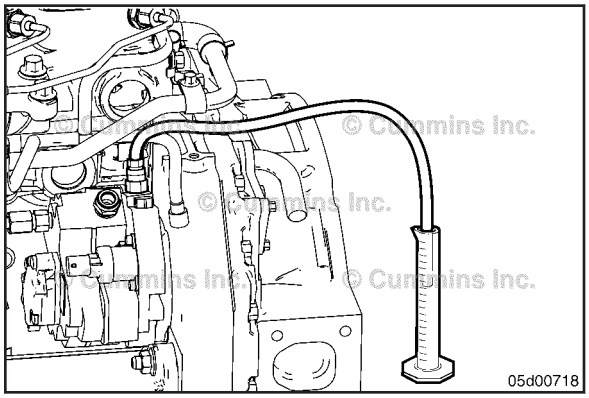
⚠WARNING⚠
Fuel can be returned at highly elevated temperatures. Wear safety glasses and protective gloves and clothing when performing this test. Avoid contact with returned fuel.

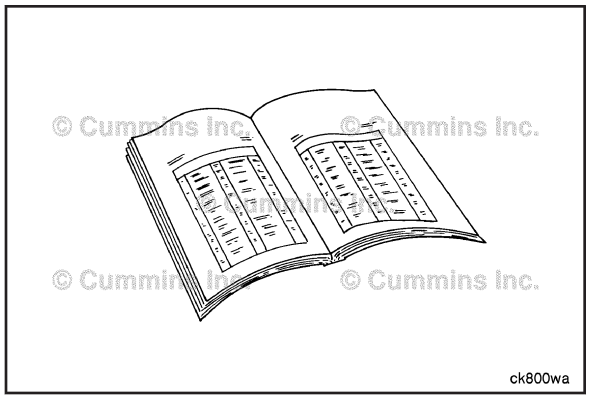
Place the end of the fuel pressure gauge adapter tool or fuel drain hose into a 500 ml graduated beaker, Part Number 3823705.

Start the engine.

Measure the flow rate by recording the amount of time required to fill the beaker to the 400 ml lever. Flow Specification: Standard Idle Conditions (750 rpm) 4- and 6-cylinder 400 ml (maximum) in 25 seconds

Maximum Flow: Standard Idle Conditions (750 rpm)	
4- and 6-cylinder	400 ml in 25 seconds





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.

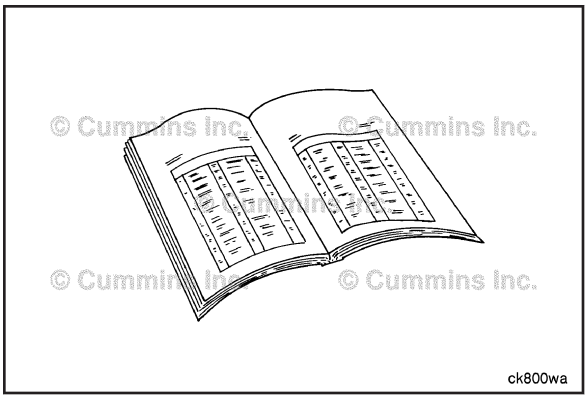
△CAUTION△
Do not vent the fuel system on a hot engine; this can cause fuel to spill onto a hot exhaust manifold, which can cause a fire.

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

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

- Disconnect the batteries. Refer to the OEM service manual.
- Disconnect the low-pressure fuel supply and drain lines. Refer to Procedure 006-024 in Section 6.
- Remove the low-pressure fuel supply and drain lines. Refer to Procedure 006-013 in Section 6.
- For engines with a low mount fuel filter, the fuel filter head **must** be removed to remove the fuel pump. Refer to Procedure 006-017 in Section 6.

Marine Applications



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

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

⚠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 draining the fuel system , so that fuel is not spilled or drained into the bilge area. The fuel must be disposed of in accordance with local environmental regulations.

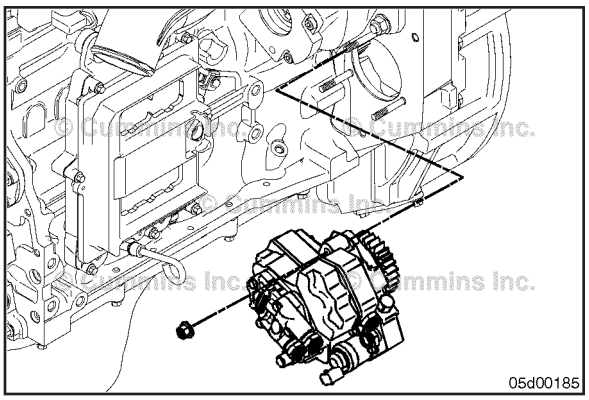
- Disconnect the batteries. Refer to the OEM service manual.
- Remove the low-pressure fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Remove the low-pressure fuel drain lines. Refer to Procedure 006-013 in Section 6.
- Apply a counter-torque to the fitting on the high-pressure pump to reduce the possibility of a leak or a loose fitting. Remove the high-pressure supply line from the fuel pump to the fuel rail (flared connection).
- Disconnect the fuel control actuator electrical connector.
- Remove the dipstick mounting capscrew and position the dipstick out of the way for pump removal.
- Remove the valve cover lubrication vent flex hose connector at the engine block mounted adapter. Refer to Procedure 003-002
- Remove the belt guard section located in front of the sea water pump. Refer to Procedure 008-001 in Section 8.

Remove

NOTE: A counter-torque **must** be applied to the fitting on the high-pressure pump. This is to prevent the fitting from being loosened and to prevent the possibility of a leak.

Disconnect the high-pressure supply line from THE high-pressure fuel pump to the fuel rail and loosen the holding brackets.

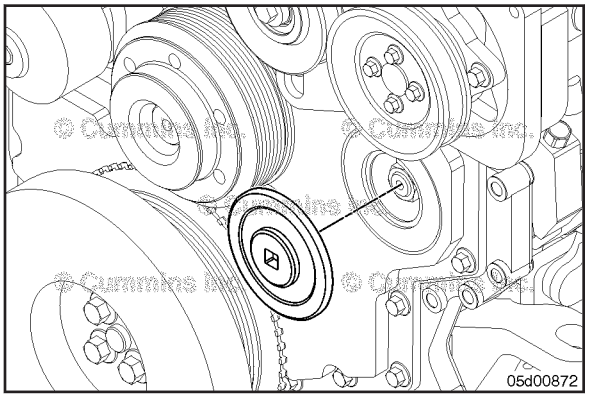
Disconnect the EFC actuator valve wire harness connector.



Rear Gear Train

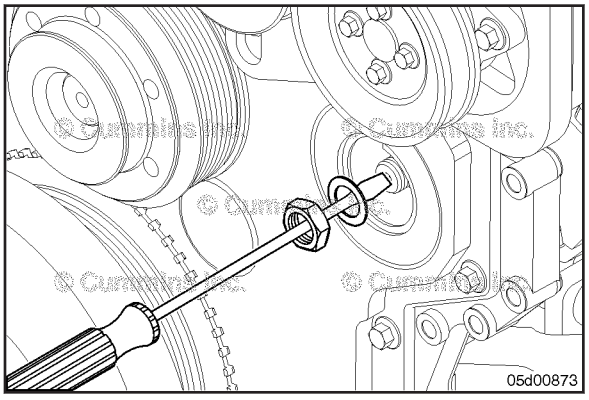
Remove the three flanged fuel pump mounting nuts.

Remove the fuel pump from the gear housing.



Front Gear Train

Remove the fuel pump drive access cover with a 3/8-inch drive ratchet.



⚠CAUTION⚠
Place a clean cloth in the air-gap between the fuel pump drive gear and the gear cover, or use a screwdriver to prevent the mounting nut and lock washer from being dropped into the front gear train.

⚠CAUTION⚠
The fuel pump drive gear is captive between the gear housing and the gear cover. Do not rotate the engine while the gear is not supported by the fuel pump drive shaft. The gear, gear housin, or gear cover can be damaged.

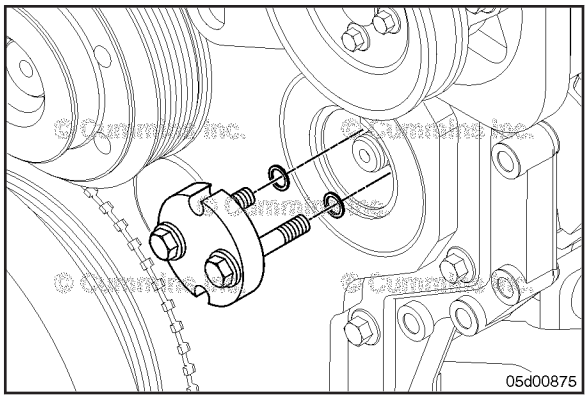
Remove the fuel pump drive gear retaining nut and lock washer.

⚠CAUTION⚠

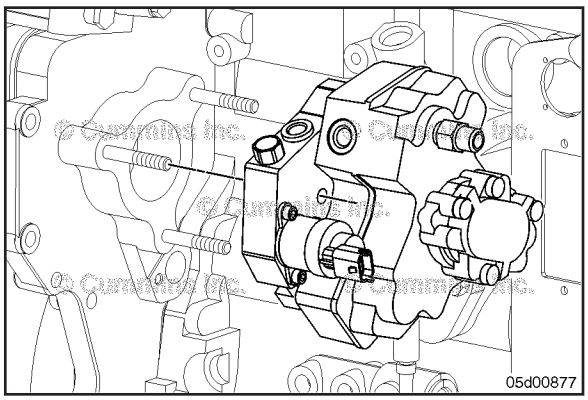
Protect the fuel pump drive shaft threads from damage during gear removal.

Install the fuel pump drive gear puller onto the drive shaft and gear.

Hold the gear puller while removing the fuel pump drive gear.

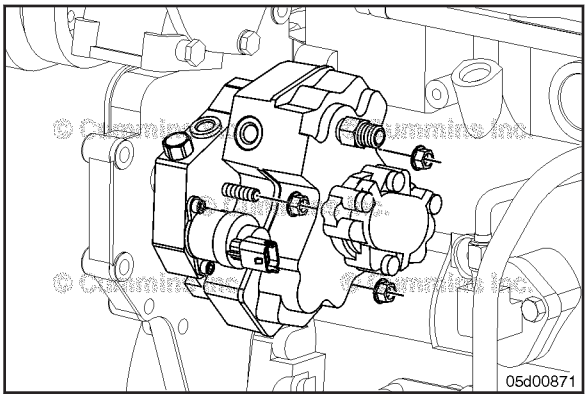


Remove the fuel pump assembly.

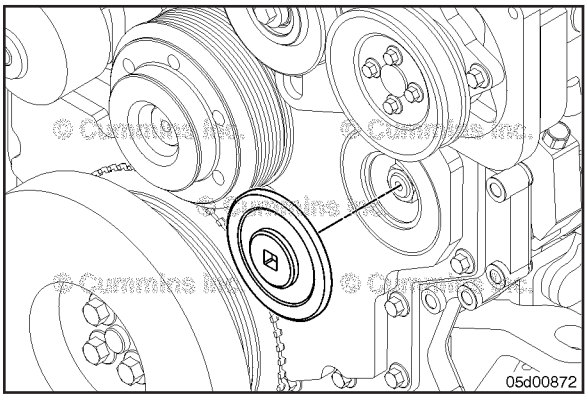


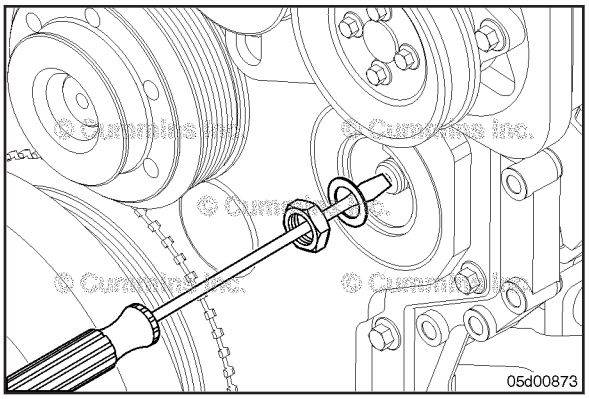
Marine Applications

Remove the three fuel pump flanged mounting nuts.



Remove the fuel pump drive access cover with a 3/8-inch drive ratchet.

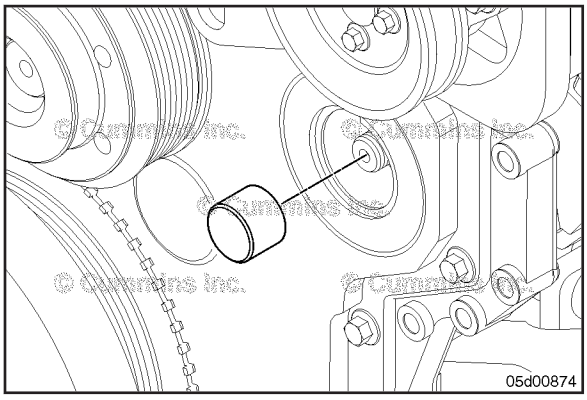




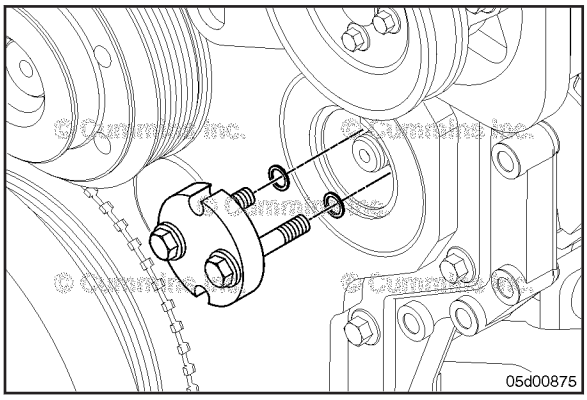
⚠CAUTION⚠
Place a clean cloth in the air gap between the fuel pump drive gear and the gear cover, or use a screw driver to prevent the mounting nut and lock washer from being dropped into the front gear train.

⚠CAUTION⚠
The fuel pump drive gear is captive between the gear housing and the gear cover. Do not rotate the crankshaft while the gear is not supported by the fuel pump drive shaft. The gear, gear housing, or gear cover can be damaged.

Remove the fuel pump drive gear retaining nut and lock washer.

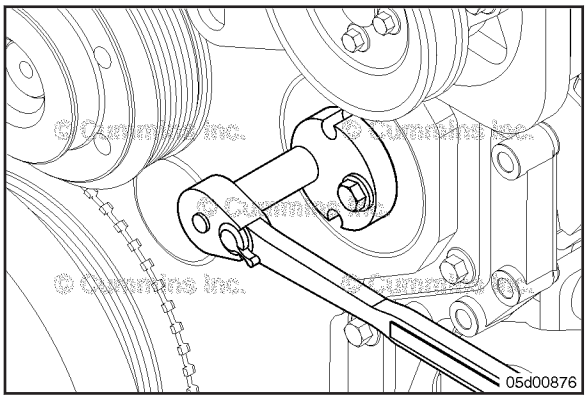


Install the spacer, Part Number 4918317, from service tool, Part Number 3163381, onto the fuel pump drive shaft.



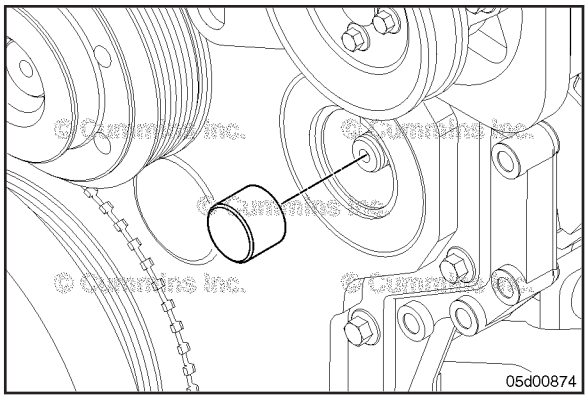
⚠CAUTION⚠
Protect the fuel pump drive shaft threads from damage while removing the fuel pump gear.

Install the fuel pump drive gear puller, Part Number 3163381, onto the fuel pump drive shaft and gear.

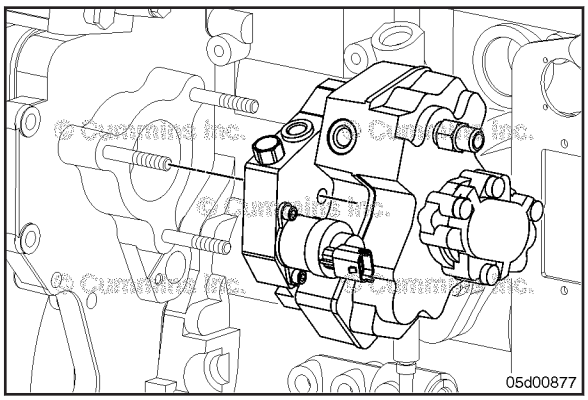


Use a ratchet and remove the fuel pump drive gear from the fuel pump drive shaft.

Remove the spacer, Part Number 4918317, from the fuel pump drive shaft.



Remove the fuel pump assembly.

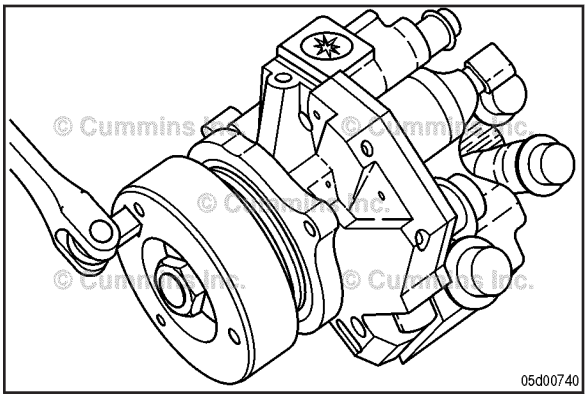


Disassemble

Rear Gear Train

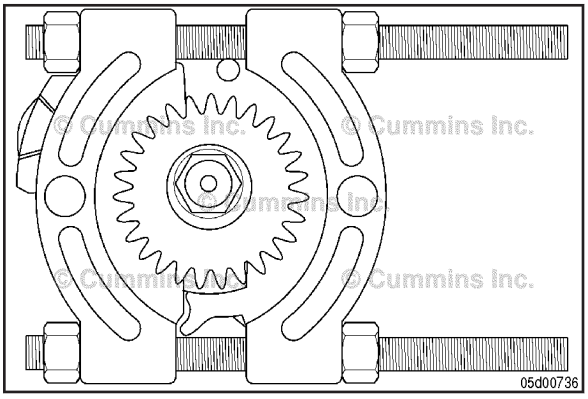
Use a fuel pump retention tool, Part Number 3164707, and a ½-inch breaker bar to retain the fuel pump drive gear.

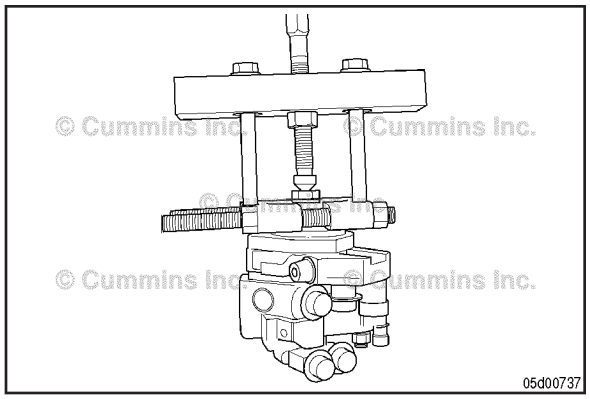
Loosen the clamp load of the fuel pump drive gear retaining nut by rotating it **counterclockwise**. Do **not** remove it from the shaft.



Install a bearing separator, Part Number 3375326, or equivalent, between the fuel pump mounting flange and the drive gear.

Secure the bearing separator.

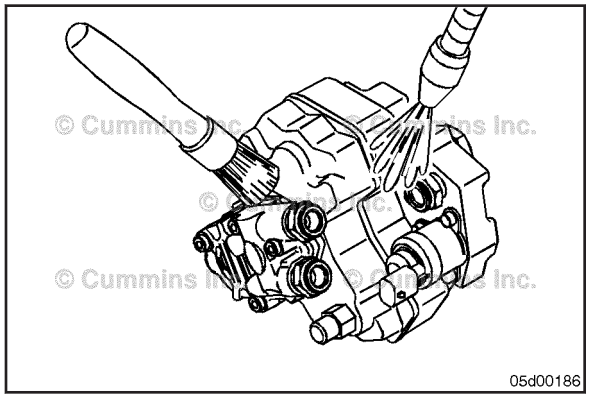




Install a Snap-On™ puller, Part Number CG150-02, or equivalent onto the bearing separator, Part Number 3375326, and the fuel pump driveshaft.

Rotate the puller screw until the drive gear is separated from the driveshaft.

Remove the drive gear retaining nut, lock washer, and drive gear from the fuel pump driveshaft.



Clean and Inspect for Reuse

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

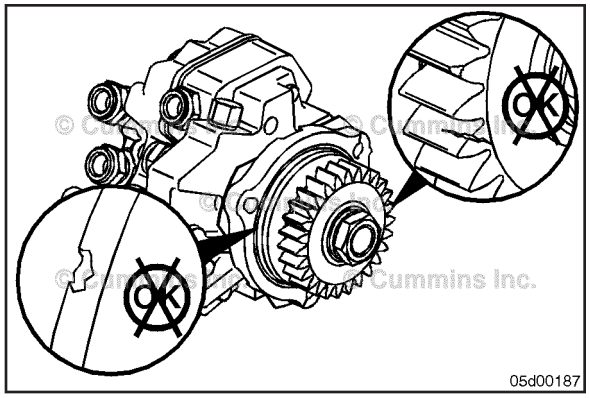
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△
Use solvent or cleaner that will not harm aluminum.

△CAUTION△
Do not allow the cleaner to enter the fuel fittings. Dirt and debris can damage the fuel system.

Clean the fuel pump with solvent.

Dry with compressed air.



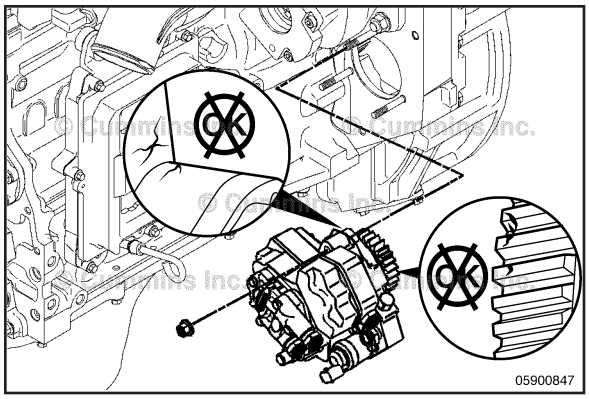
Inspect the driveshaft and gear for damage. Replace if damage is found.

Inspect the o-ring seal for damage. Replace if damage is found.

Inspect the o-ring seal area for damage. Clean and repair any burred surfaces.

Inspect the gear housing, high-pressure pump mounting bore, and mounting studs for cracks.

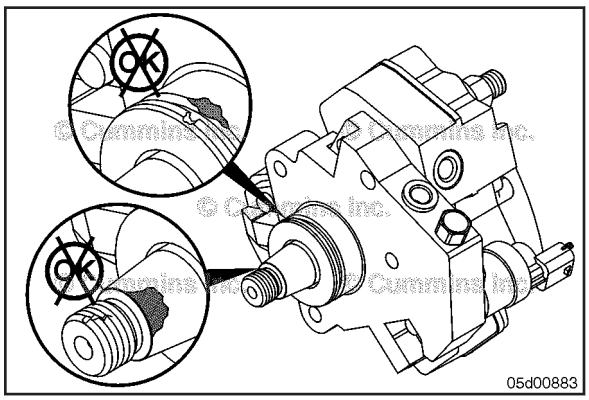
Replace if damage is found.



Marine Applications

Inspect the driveshaft for damage. Replace the fuel pump if damage is found.

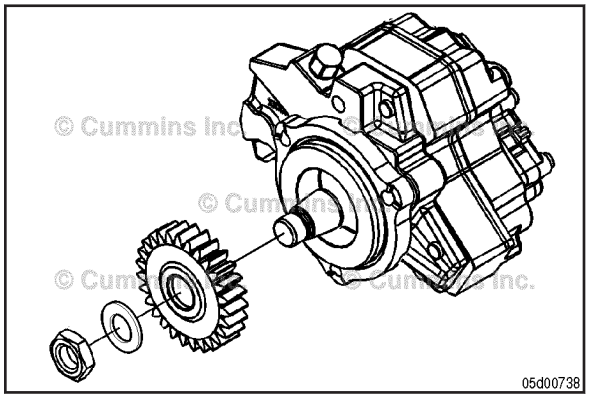
Inspect the o-ring seal area for damage. Clean and repair any burred surfaces.



Assemble

The pump driveshaft nose and drive gear shaft mating surface **must** be clean and dry prior to assembly.

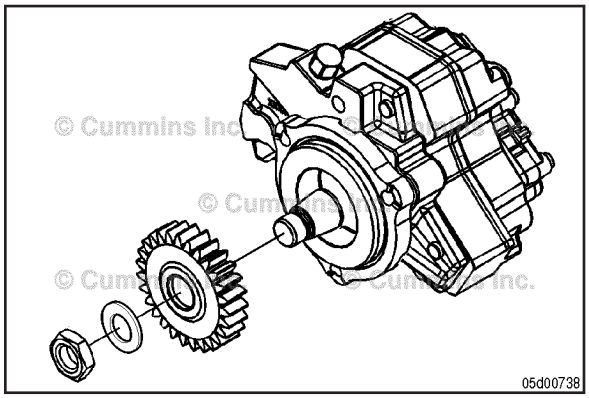
Wipe off the driveshaft and gear with solvent and a lint-free cloth. Do **not** touch the mating surfaces after wiping.

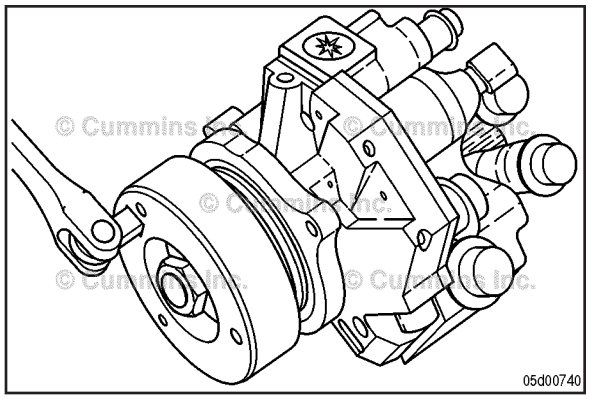


Rear Gear Train

Install the drive gear onto the driveshaft.

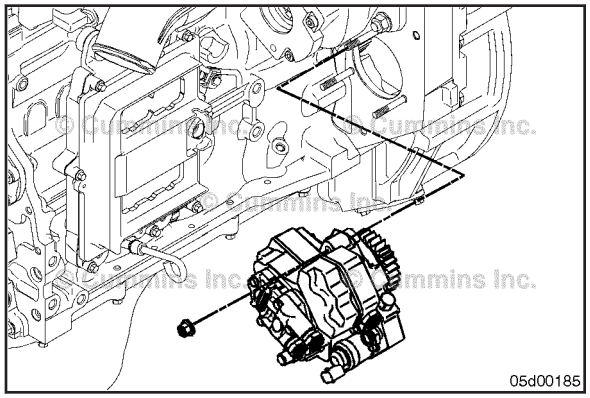
Install the driveshaft lockwasher and retaining nut and finger tighten.





Use the fuel pump gear retention tool, Part Number 3164707, and a 1/2 inch breaker bar to hold the drive gear in place while tightening the drive gear retaining nut.

Torque Value: 105 N•m [77 ft-lb]

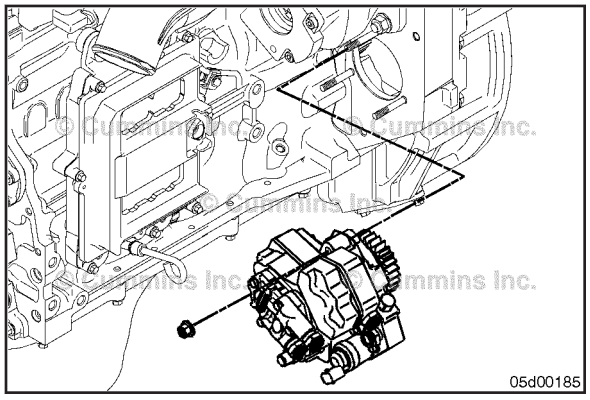


Install

Automotive and Industrial

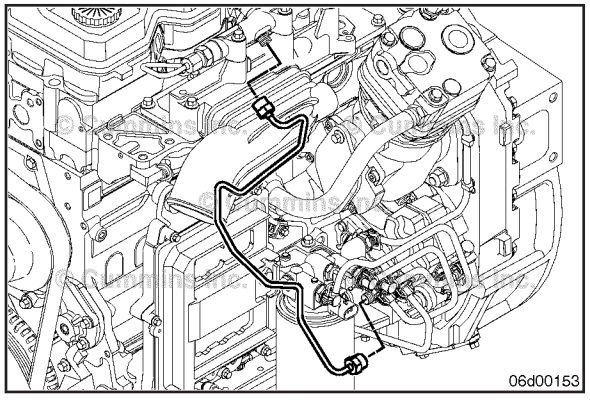
Install the fuel pump on the gear housing.

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



Install the fuel pump mounting nuts and tighten.

Torque Value: 25 N•m [221 in-lb]



Install the high-pressure supply line from the high-pressure pump to the fuel rail and tighten the holding brackets.

NOTE: Apply a counter-torque on the high-pressure pump outlet port to prevent over-tightening.

Torque Value:
3.9L and 5.9L High-Pressure Supply Line

Step 1	30 N•m	[22 ft-lb]

Torque Value:
4.5L and 6.7L High-Pressure Supply Line

Step 1	30 N•m	[22 ft-lb]

Connect the EFC actuator valve wire harness connector.

Front Gear Train

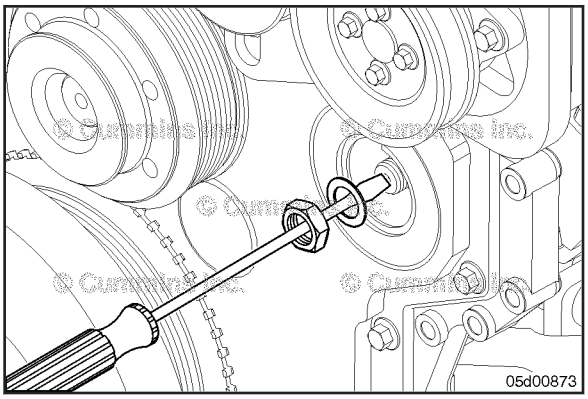
⚠CAUTION⚠
Place a clean cloth in the air-gap between the fuel pump drive gear and the gear cover, or use a screw driver to prevent the mounting nut and lock washer from being dropped into the front gear train.

⚠CAUTION⚠
The fuel pump drive gear is captive between the gear housing and the gear cover. Do not rotate the engine while the gear is not supported by the fuel pump drive shaft. The gear, gear housing, or gear cover can be damaged.

NOTE: The engine barring tool, Part Number 3824591, can be used to prevent the crankshaft from rotating while tightening the retaining nut.

Install the drive gear retaining nut and lock washer onto the drive shaft. Tighten the gear retaining nut.

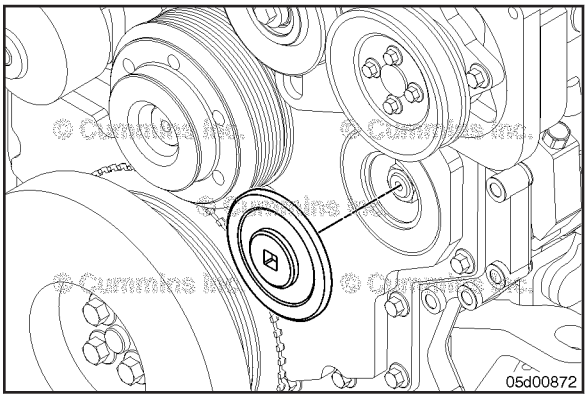
Torque Value: 105 N•m [77 ft-lb]



Install a new square cut o-ring onto the fuel pump drive access cover.

Install the fuel pump drive access cover with a 3/8-inch drive ratchet. The plate is threaded into the gear cover.

Torque Value: 8 N•m [71 in-lb]



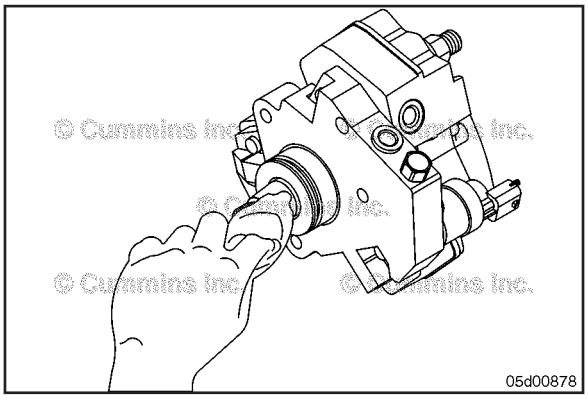
Marine Applications

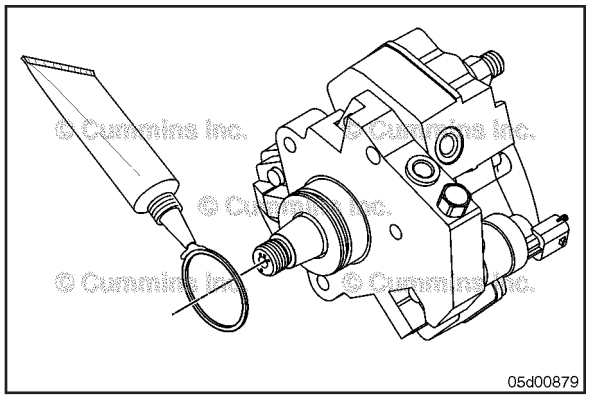
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

The fuel pump driveshaft nose and drive gear shaft mating surface **must** be clean and dry prior to installation.

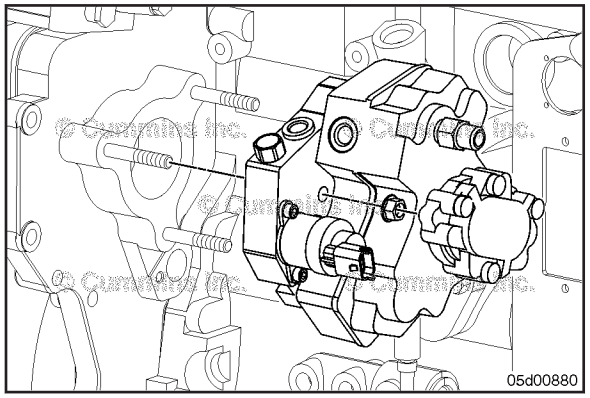
Wipe off the driveshaft and gear with solvent and a lint-free cloth. Do **not** touch the mating surfaces after wiping.





Install a new seal ring on the front of the fuel pump assembly. Be sure the seal ring is **not** twisted.

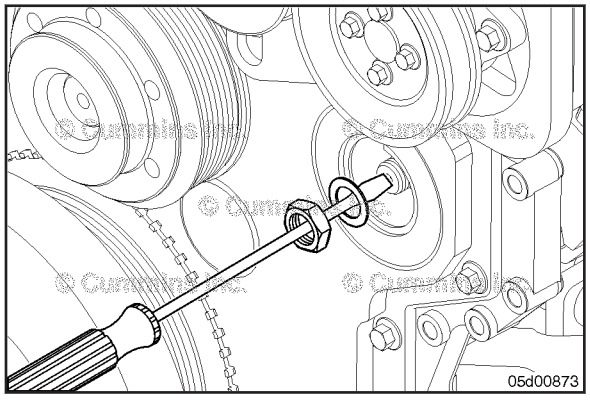
Lubricate the seal ring and the mounting bore of the gear housing with P-80 rubber lubricant emulsion, Part Number 3824878.



Install the fuel pump onto the gear housing.

Install the three fuel pump to gear housing mounting nuts and tighten.

Torque Value: 25 N•m [221 in-lb]



△CAUTION△
Place a clean cloth in the air gap between the fuel pump drive gear and the gear cover, or use a screw driver to prevent the mounting nut and lockwasher from being dropped into the front gear train.

△CAUTION△
The fuel pump drive gear is captive between the gear housing and the gear cover. Do not rotate the crankshaft while the gear is not supported by the fuel pump drive shaft. The gear, gear housing, or gear cover can be damaged.

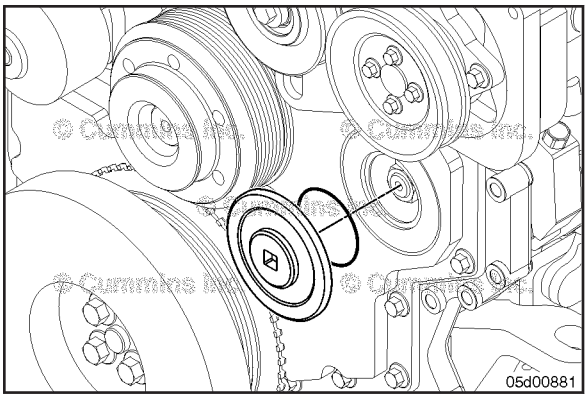
NOTE: The engine barring tool, Part Number 3824591, can be used to prevent the crankshaft from rotating while tightening the retaining nut.

Install the drive gear retaining nut and lock washer onto the drive shaft. Tighten the retaining nut.

Torque Value: 105 N•m [77 ft-lb]

Install a new square cut o-ring onto the fuel pump drive access cover.

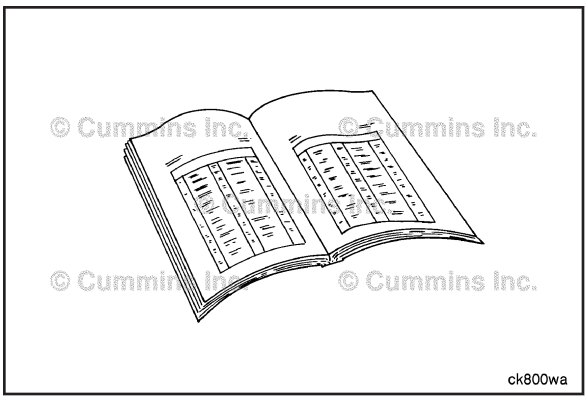
Install the fuel pump drive access cover with a 3/8-inch drive ratchet. The plate is threaded into the gear cover.



Finishing Steps

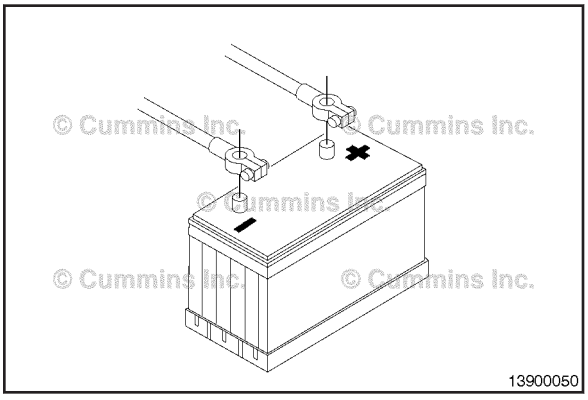
With Electric Lift Pump

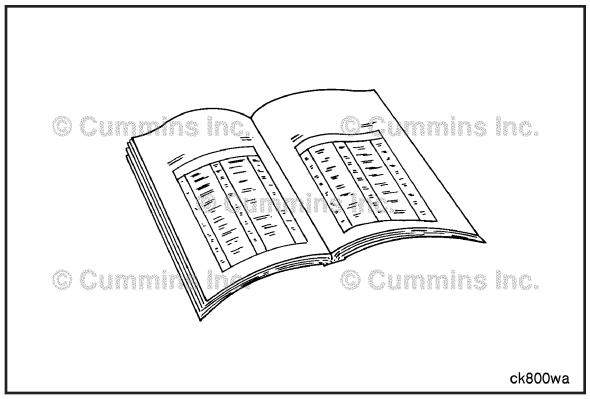
- For engines with a low mount fuel filter, install the fuel filter head. Refer to Procedure 006-017 in Section 6.
- Install the low-pressure fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Install the low-pressure fuel drain lines. Refer to Procedure 006-013 in Section 6.



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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.
- Prime the fuel system. See the Prime section in this procedure.
- If the fuel pump was replaced due to a fuel leak from the weep hole or a fuel in oil complaint, then it is necessary to measure the fuel inlet restriction and fuel drain line restriction. A fuel line restriction can result in a fuel pump leak. Use the following procedures to check fuel inlet restriction and drain line restriction. Refer to Procedure 006-020 in Section 6. Refer to Procedure 006-012 in section 6.





Marine Applications

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

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

- Install the valve cover lubrication vent flex hose connection at the block mounted adapter. Refer to Procedure 003-018 in Section 3.
- Apply a counter-torque to the fitting on the high-pressure pump to reduce the possibility of a leak or a loose fitting. Install the high-pressure fuel supply line from the fuel pump to the fuel rail (flared connection).
- Install the low-pressure fuel supply lines. Refer to Procedure 006-024 in Section 6.
- Install the low-pressure fuel drain lines. Refer to Procedure 006-013 in Section 6.
- Connect the fuel control actuator electrical connector.
- Install the belt guard section located in front of the sea water pump. Refer to Procedure 008-001 in Section 8.
- Connect the batteries. Refer to the OEM service manual.
- Prime the fuel system. See the Prime step in this procedure.
- If the fuel pump was replaced due to a fuel leak from the weep hole or a fuel in oil complaint, then it is necessary to measure the fuel inlet restriction and fuel drain line restriction. A fuel line restriction can result in a fuel pump leak. Use the following procedures to check fuel inlet restriction and drain line restriction. Refer to Procedure 006-020 in Section 6. Refer to Procedure 006-012 in section 6.

Operate the engine and check for leaks.

Prime

Automotive and Industrial

⚠WARNING⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

⚠CAUTION⚠
Be sure that the fuel inlet and return valves are returned to the open position before cranking the engine. Engine damage can result if the valves are in the wrong position when the engine is cranked or started. Environmental damage can also occur.

⚠CAUTION⚠
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system, so that fuel is not spilled or drained. The fuel and fuel filters must be discarded in accordance with local environmental regulations.

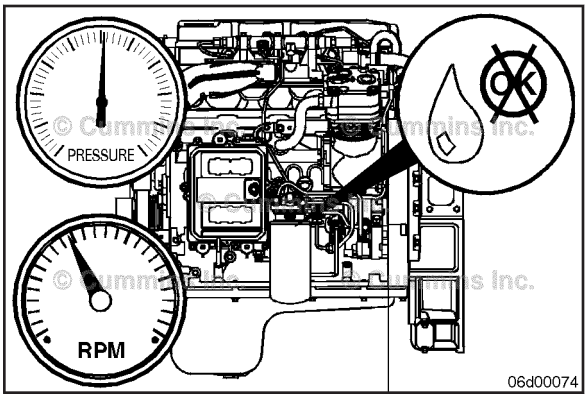
Refer to Procedure 005-999 in the Familiarization section for further information.

With Electric Lift Pump

Allow the lift pump to run by turning the ke switch ON and waiting 30 seconds before starting.

NOTE: It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will prime the fuel system.

Operate the engine and check for leaks.



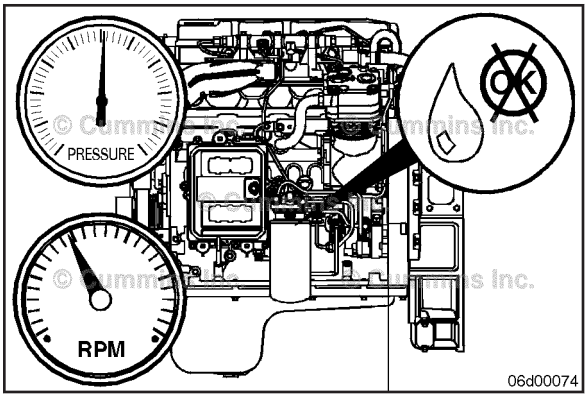
With Hand Priming Pump

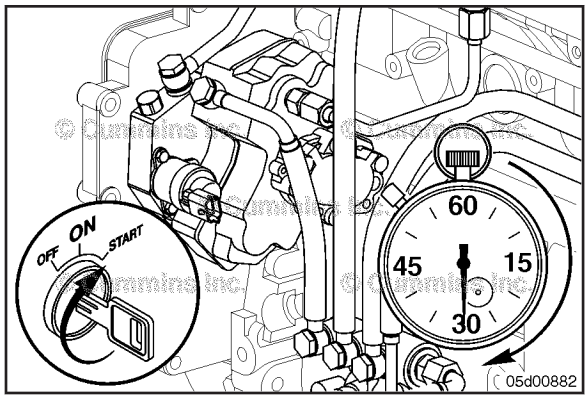
Dry Fuel Filter and Fuel Tubes: this condition occurs if the engine has come from the manufacturing plant without being tested before shipping, if the fuel filters have been changed. Before starting the engine, pump the hand priming pump 120 times.

Full Fuel Filter and Fuel Tubes: This condition occurs if the engine is being installed for the first time after being built, but was tested at the manufacturing plant or is being installed again. Before starting the engine, pump the hand priming pump 40 times.

NOTE: It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will prime the fuel system.

Operate the engine and check for leaks.





Marine Applications

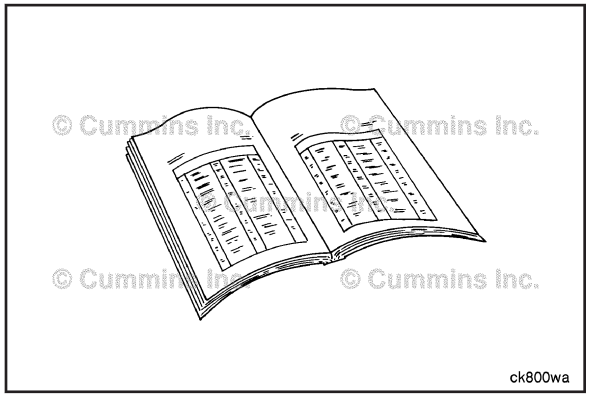
⚠WARNING⚠
Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

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

NOTE: It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will prime the engine.

The fuel transfer pump is initiated by turning the keyswitch to the ON position. The pump will run for 50 to 60 seconds, then shut off. Priming the fuel system requires cycling the keyswitch several (five or more) times to make sure the fuel filter is primed properly and that all the air is out of the fuel system, downstream through the fuel cooler.



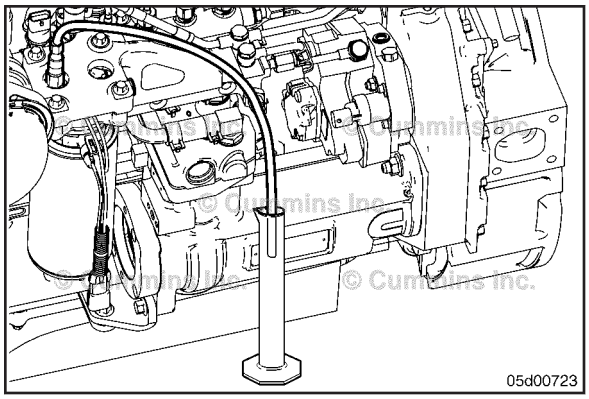
Fuel Lift Pump (005-045)

Initial Check

This procedure applies to some 5.9L automotive applications and all 5.9L marine applications.

High fuel inlet restriction can result in poor lift pump performance or lift pump damage. Before replacing the lift pump, measure the fuel inlet restriction. Refer to Procedure 006-020 in Section 6.

Measure



⚠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 an M10 male Compuchek™ fitting, Part Number 3824842, on the diagnostic port on the inlet side of the fuel filter.

NOTE: Fuel filter may be remote mounted off-engine.

Connect the service tool containing a 1.09-mm [0.043-in] orifice, Part Number 3164621, to the diagnostic port.

Allow the other end of the hose to drain into a 500-ml graduated beaker, Part Number 3823705.

NOTE: This test is performed with the engine **not** running.

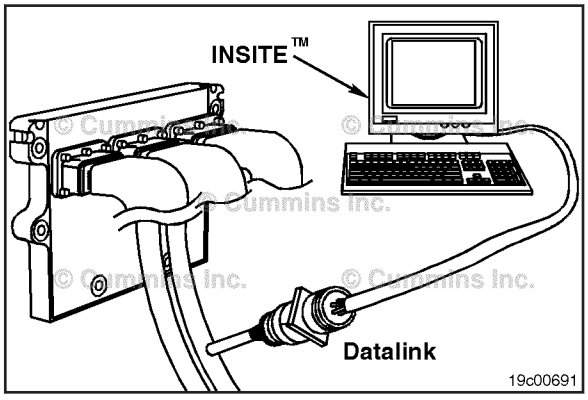
Start the lift pump by using the INSITE™ electronic service tool lift pump override test. Use the following procedure for INSITE™ electronic service tool test instructions. Refer to Procedure 014-008 in Section 14.

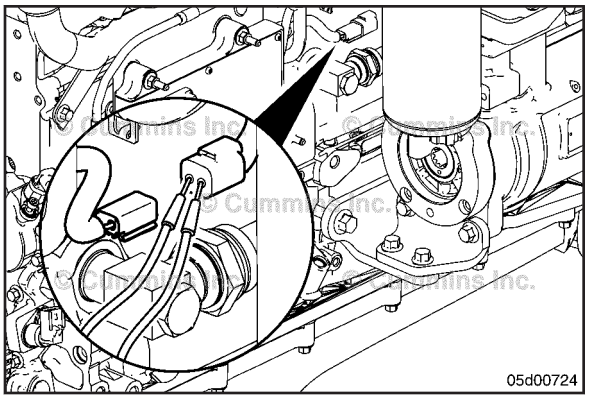
Alternatively, the lift pump can be temporarily activated by turning the keyswitch ON or by “bumping” the starter without starting the engine.

Measure the amount of fuel flowed by the lift pump in a 30-second interval:

- Fuel flow rate for lift pump (engine **not** running) - greater than 300 ml in 30 seconds.

NOTE: The lift pump may run longer than 30 seconds at key ON. A separate bucket is recommended to catch excess fuel pumped after the 30 second test interval.



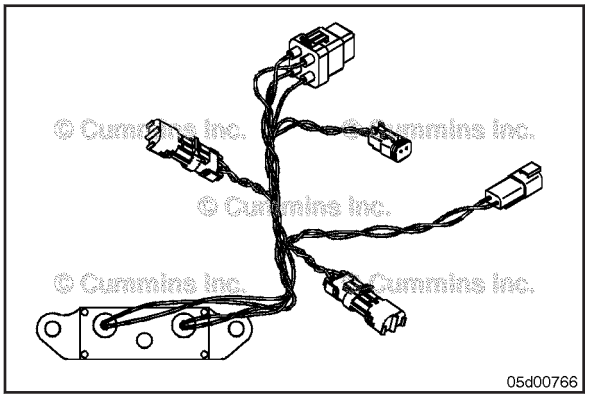


Voltage will **only** be present when the lift pump is commanded ON and when the lift pump is connected to the harness. To measure lift pump voltage, use the INSITE™ electronic service tool lift pump override test and a breakout connector between the lift pump and the engine harness

Check the voltage and resistance at the lift pump.

If the voltage does **not** meet the specifications, check the power supply.

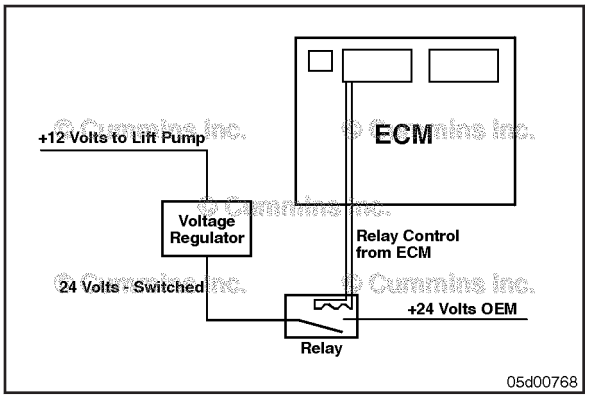
System	Voltage
12-VDC	9-VDC (minimum)
24-VDC	21-VDC (minimum)



Two additional components that could possibly be included on 24-volt systems are a relay and a voltage regulator.

The 2-pin Deutsch™ connector for fuel lift pump signal and return that attaches to the lift pump on 12-volt systems instead connects to a 24-volt relay. The relay, when switched ON by the ECM, delivers 24 volts from an OEM-connected source to the voltage regulator. The voltage regulator converts the 24-volt input to a 12-volt output. The lift pump used is a 12-volt lift pump and grounds through an OEM connection.

NOTE: On some 24-volt systems, the harness may have been replaced by a service harness without a voltage regulator. This service harness still uses the relay switched by the ECM, but uses an alternate, un-switched, 12-volt source instead of the OEM supplied 24-volt source.



Specifications

- The relay is located in the harness between the voltage regulator and the OEM power supply on the bottom edge of the ECM. The relay is switched ON for 60 seconds after the keyswitch is turned ON. It is also switched ON anytime the engine is cranking or running. The relay **must** provide 24 volts of power output to the voltage regulator.
- The voltage regulator is located just below the ECM. It receives 24 volts from the relay when the relay is switched ON. The regulator provides 12 volts of power output to the lift pump.
- A 12-volt lift pump is used in vehicles with a 24-volt power system. It should run any time the relay is switched ON, as described above.

If the output voltage of the voltage regulator is 24 volts, the regulator has failed and **must** be replaced.

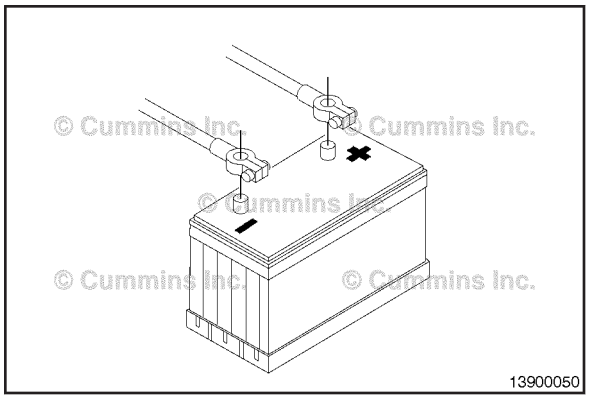
Preparatory Steps

⚠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 batteries.

Shut off the fuel supply and return lines. Refer to the OEM service manual.

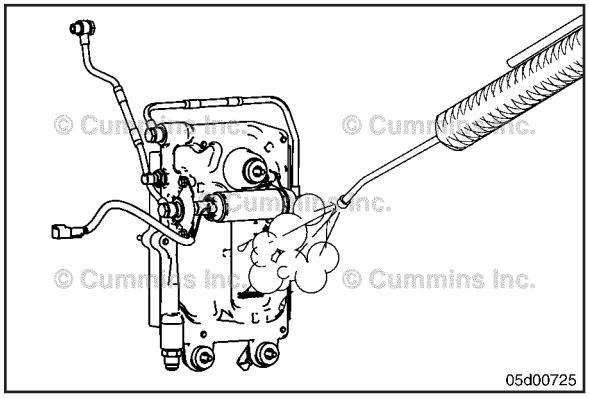
For marine applications, remove the ECM cooling plate. Refer to Procedure Procedure 006-006 in Section 6.



Remove

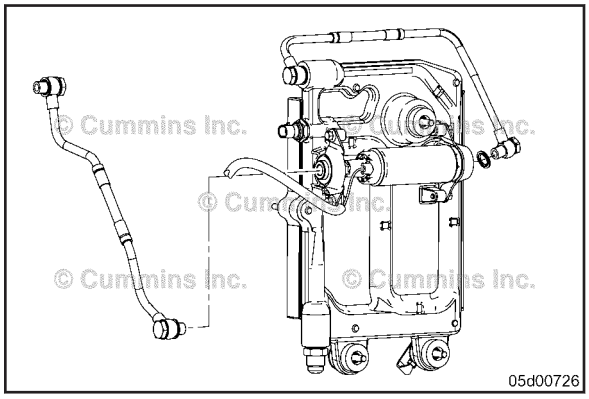
Thoroughly clean the fittings and components before removal.

NOTE: Make sure that debris, water, steam, or cleaning solution does **not** reach inside the fuel system.



Remove the fuel lift pump inlet and outlet fuel lines.

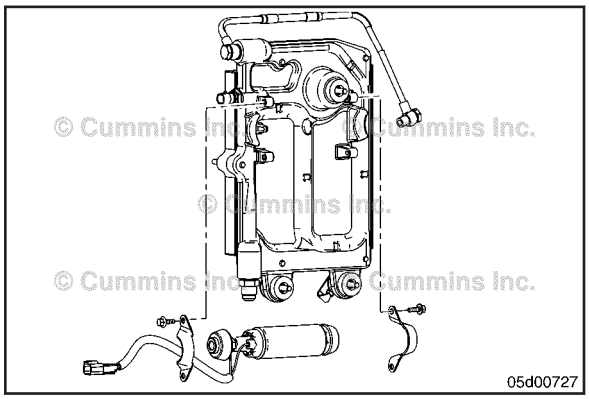
Disconnect the fuel lift pump wiring harness connector.

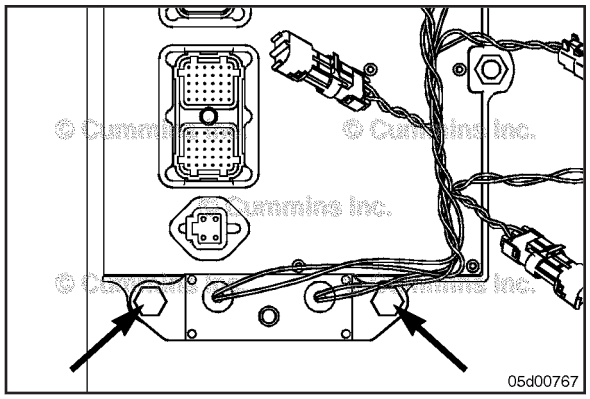


Remove the fasteners holding the lift pump to the back of the ECM cooler plate.

Remove the fuel lift pump.

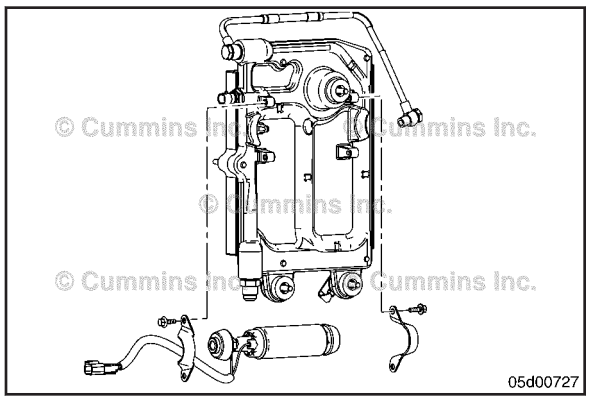
NOTE: For most automotive applications, the lift pump can be removed without having to remove the ECM and ECM mounting plate.





For 24-volt systems with voltage regulators, remove the voltage regulator from the bottom edge of the ECM by removing the lower two ECM mounting capscrews. The relay is fastened to the wiring harness near the ECM connectors.

Disconnect the voltage regulator wiring harness connectors and remove the voltage regulator assembly.

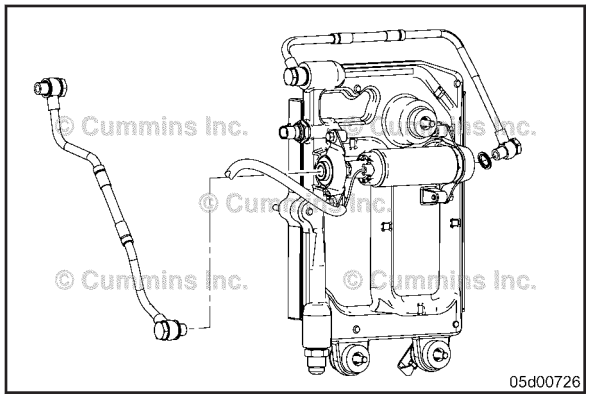


Install

NOTE: Make sure the inlet and outlet are properly oriented with the thin brass outlet section pointing toward the rear of the engine. Check the lift pump for labeling of inlet and outlet ports. Verify that the correct pump (12-VDC or 24-VDC) is installed.

Install the lift pump on the mounting bracket behind the ECM cooling plate.

Torque Value: 7 N•m [62 in-lb]



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

Install the fuel lift pump inlet and outlet fuel lines.

Torque Value: 24 N•m [212 in-lb]

For 24-volt systems with voltage regulators, install the voltage regulator at the bottom edge of the ECM and install the lower two ECM mounting capscrews.

Torque Value: 25 N•m [221 in-lb]

Connect the fuel lift pump and, if equipped, the 24-volt voltage regulator connector(s) to the wiring harness.

Finishing Steps

For marine applications, install the ECM cooling plate. Refer to Procedure Procedure 006-006

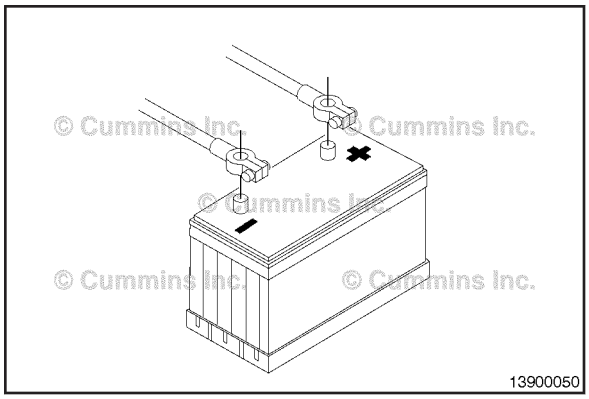
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Open the fuel supply and return valves. Refer to OEM service manual.

Connect the batteries.

Prime the system. See the Prime step at the end of this procedure.

Operate engine and check for leaks.



Prime

⚠WARNING⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

⚠WARNING⚠
Be sure that the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when ignition is cranked or started. Environmental damage can also occur. Refer to Procedure Procedure 005-999 (Fuel System Overview) in Familiarization section for further information.

It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will prime the fuel system.

Allow the lift pump to run by turning the keyswitch ON and waiting 30 seconds before starting.

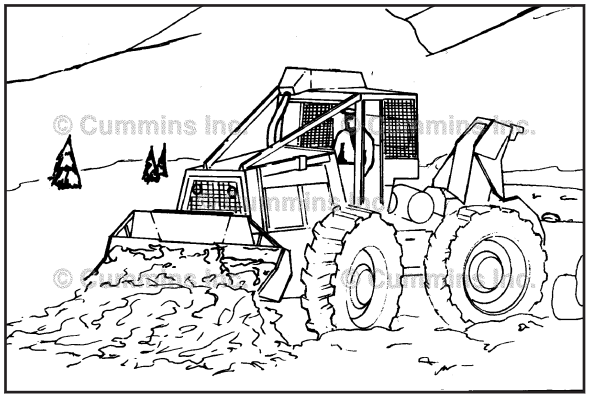
Stall Speed Test (005-054)

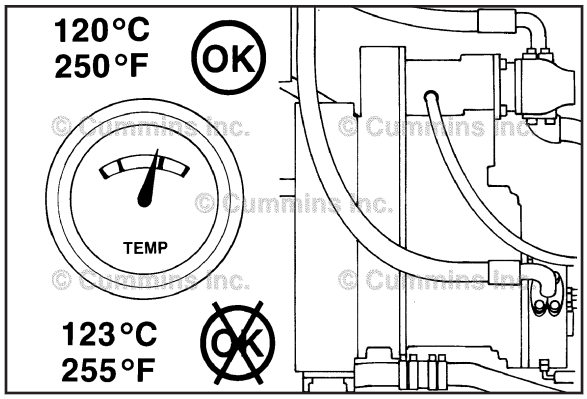
Stall Speed Check

Converter Transmission's Stall Speed

The stall speed is the engine speed (rpm) obtained at full throttle when the converter output shaft is locked.

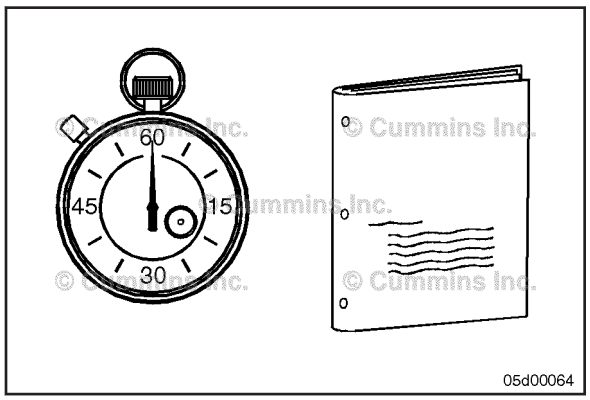
NOTE: It is possible that the vehicle brakes will **not** hold an electronically controlled transmission.





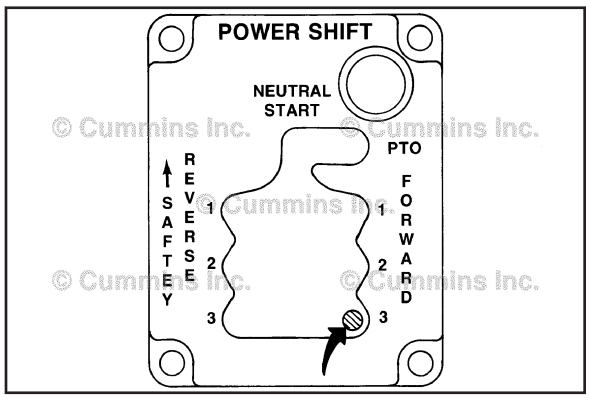
⚠CAUTION⚠

Do not exceed 120°C [248°F] converter oil temperature. Overheating can result and converter damage can occur. If the oil temperature exceeds 120±C [248°F], put the transmission in neutral, and operate the engine until the oil temperature is below 120°C[248°F]. Check the converter oil level.

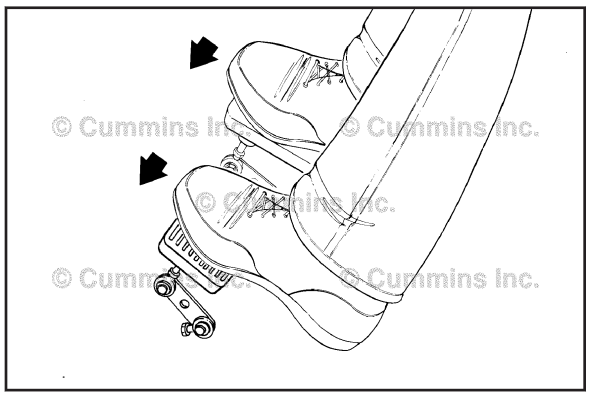


The following equipment is needed for this check:

- Stopwatch
- Equipment manufacturer's stall speed and time-to-stall specifications.



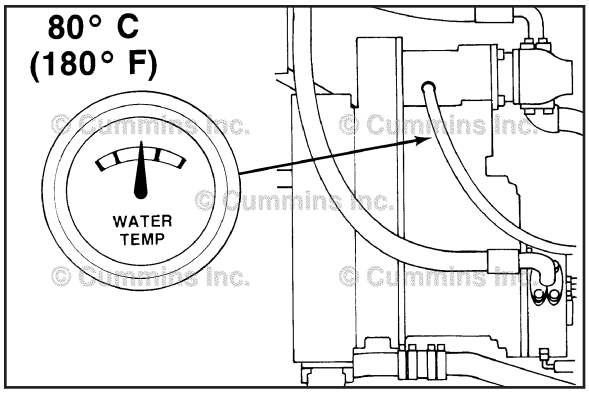
Place the gear selector in the highest gear or full forward.



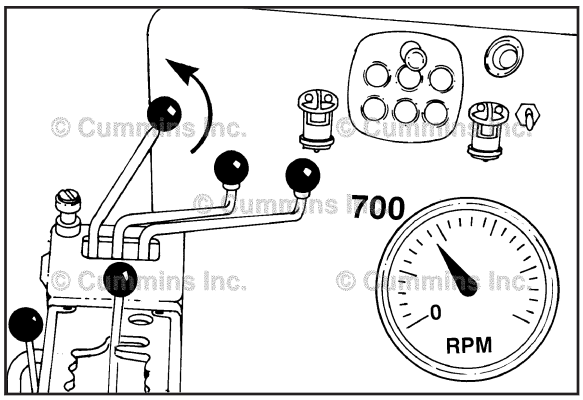
Make sure the vehicle has good brakes and air pressure in the brake system.

NOTE: The brakes **must** prevent the vehicle from moving when the engine is at full throttle. Engage the vehicle brakes to keep the vehicle from moving.

Operate the engine until the converter temperature is 80°C [176°F] or above.

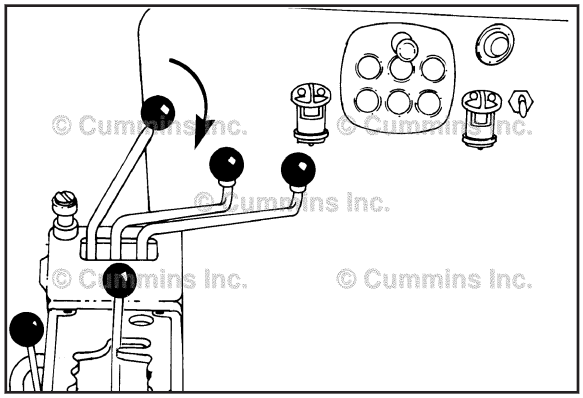


Bring the engine speed back to low idle.



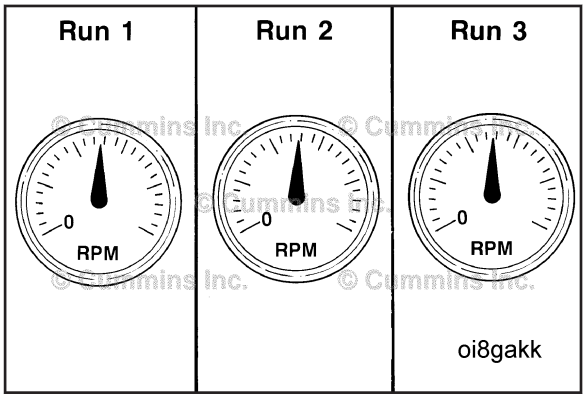
⚠CAUTION⚠
Do not exceed 120°C [248°F] converter oil temperature. Overheating and damage to the converter can occur.

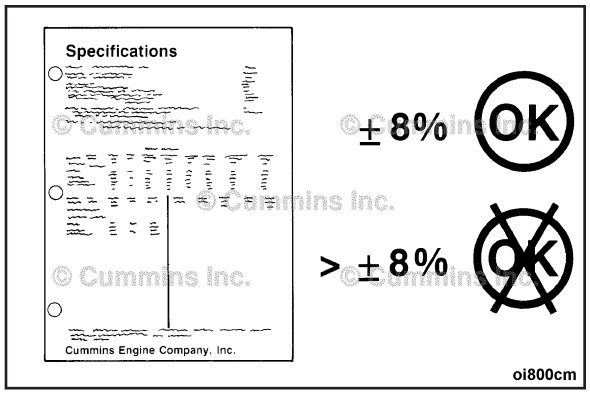
Quickly move the throttle to the full-open position with the vehicle brakes applied.



Check the engine speed (rpm) at the point of stall:

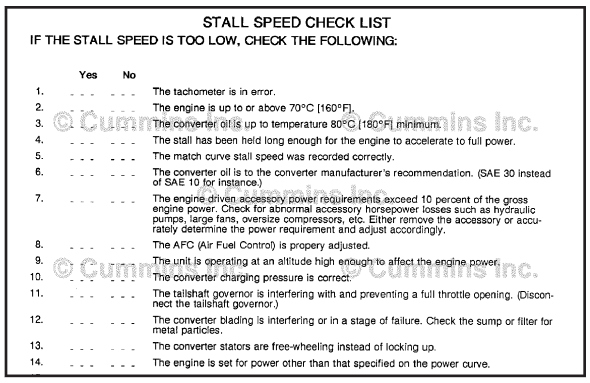
- **Always** hold the speed until it is stable.
- Take several readings.
- Make sure the readings are accurate.





Check the speed (rpm) against the specifications for the equipment, converter, or automatic transmission.

NOTE: The stall speed for the engine and converter/ transmission can vary ±8 percent from the manufacturer's specifications.



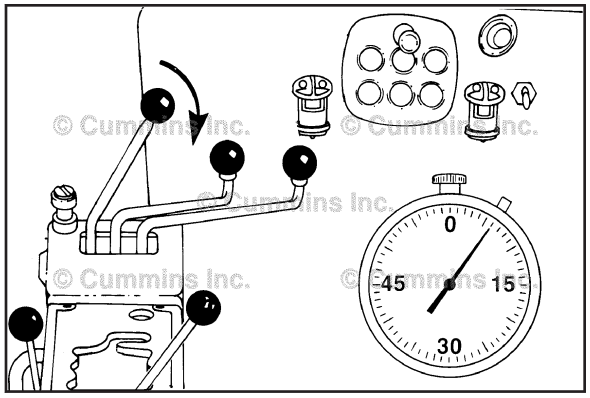
STALL SPEED CHECK LIST

IF THE STALL SPEED IS TOO LOW, CHECK THE FOLLOWING:

	Yes	No	
1.	- - -	- - -	The tachometer is in error.
2.	- - -	- - -	The engine is up to or above 70°C [160°F].
3.	- - -	- - -	The converter oil is up to temperature 80°C [180°F] minimum.
4.	- - -	- - -	The stall has been held long enough for the engine to accelerate to full power.
5.	- - -	- - -	The match curve stall speed was recorded correctly.
6.	- - -	- - -	The converter oil is to the converter manufacturer's recommendation. (SAE 30 instead of SAE 10 for instance.)
7.	- - -	- - -	The engine driven accessory power requirements exceed 10 percent of the gross engine power. Check for abnormal accessory horsepower losses such as hydraulic pumps, large fans, oversize compressors, etc. Either remove the accessory or accurately determine the power requirement and adjust accordingly.
8.	- - -	- - -	The AFC (Air Fuel Control) is propery adjusted.
9.	- - -	- - -	The unit is operating at an altitude high enough to affect the engine power.
10.	- - -	- - -	The converter charging pressure is correct.
11.	- - -	- - -	The tailshaft governor is interfering with and preventing a full throttle opening. (Disconnect the tailshaft governor.)
12.	- - -	- - -	The converter blading is interfering or in a stage of failure. Check the sump or filter for metal particles.
13.	- - -	- - -	The converter stators are free-wheeling instead of locking up.
14.	- - -	- - -	The engine is set for power other than that specified on the power curve.

If the stall speed is **not** within the specifications, refer to the Stall Speed Checklist at the end of this section.

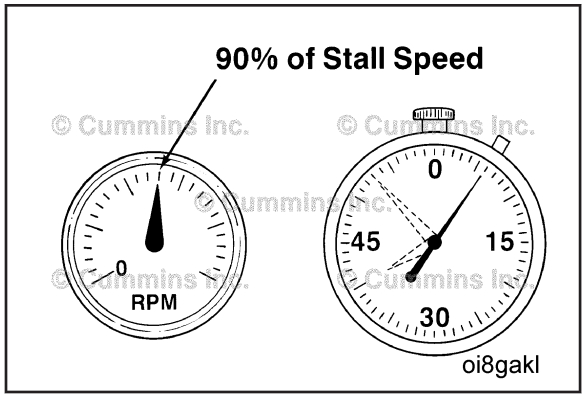
Check the equipment manufacturer's troubleshooting procedures for other reasons for stall speed problems.



Time Speed Check

Perform the previous Stall Speed Check procedure through the “Bring the engine speed back to low idle” step; then:

- Quickly move the throttle to the full-open position, and start the stopwatch at the same time.

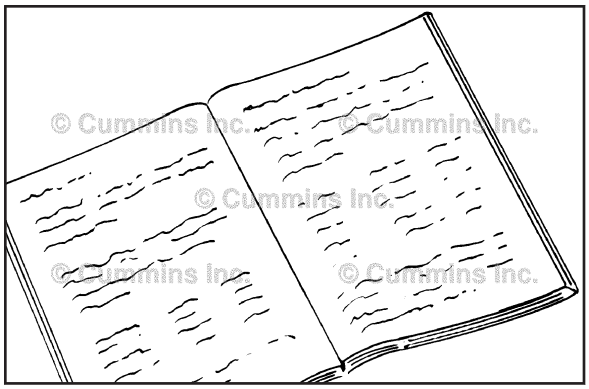


- When the engine speed is 90 percent of the stall speed rpm, stop the stopwatch.
- **Example:** Stall speed 2089 [2089 x 0.90 = 1880 rpm]

NOTE: The type of unit and the stall speed rpm can make the stall speed time a maximum of 10 seconds.

Check the equipment manufacturer's specifications for the time to stall or the acceleration time.

If the time is excessive, refer to the Stall Speed Checklist at the end of this procedure.



Stall Speed Checklist

	Yes	No	
1.			The tachometer is in error.
2.			Engine temperature is up to or above 70°C [160°F].
3.			The converter oil is up to temperature 80°C [180°F].
4.			The stall has been held long enough for the engine to accelerate to full-power.
5.			The match curve stall speed was recorded correctly.
6.			The converter oil is to the converter manufacturer's recommendation (SAE 30 instead of SAE 10, for instance).
7.			The engine-driven accessory power requirements exceed 10 percent of the gross engine power. Check for abnormal accessory horsepower losses such as hydraulic pumps, large fans, oversized compressors, and so on. Either remove the accessory or accurately determine the power requirement and adjust accordingly.
8.			The unit is operating at an altitude high enough to affect the engine's power.
9.			The converter charging pressure is correct.
10.			The tailshaft governor is interfering with and preventing a full-throttle opening. Disconnect the tailshaft governor. Do **not** exceed the manufacturer's maximum output speed.

11.			The converter blading is interfering or in a stage of failure. Check the sump or filter for particles.
12.			The converter stators are free-wheeling instead of locking up.
13.			The engine is set for power other than that specified on the power curve.
14.			The converter is wrong due to improper build or rebuild of unit.
15.			The converter is performing to the published absorption curve.
16.			The engine and converter match is correct. Check the engine and converter models for the proper match.
17.			The engine is matched to too large of a converter. If this condition is believed to exist, please report the engine-converter-accessory information to the factory.
18.			The engine power is down. The engine torque rise could be less than shown on the standard engine curve. See the fuel setting adjustments and the turbocharger air manifold pressure check.

	Yes	No	
1.			The engine is high in power.
2.			The tachometer is in error.
3.			The accessory power requirements are less than 10 percent of the gross engine power.
4.			The converter oil is aerating or foaming. Check for low oil level, air leaks in suction line, lack of foam inhibitor in the oil, or suction screen or filter. It would be accompanied by a noticeable loss of machine performance.
5.			The converter is being held at full-stall. Check for slipping front disconnect clutch or a rotating output shaft. On the converter-transmission package, this can be impossible to check.

6.			The converter turbine element is beginning to fail and lose blades, or the converter was originally built with the wrong size element.
7.			The engine and converter match is correct due to a revision in the engine rating or the converter performance.
8.			If the oil level is too high on the transmission-converter units with the oil sump in the transmission, it can cause severe aeration due to parts dipping into the oil.
9.			The converter is performing to the published absorption curve.
10.			The converter charging pressure is correct.

The reasons for abnormal stall speeds listed above are some that have been encountered by Cummins representatives and probably do **not** include all possible causes. The correction of the problem is either covered in the vehicle service manual, the converter service manual, or is self-explanatory.

Notes

Section 6 - Injectors and Fuel Lines - Group 06

Section Contents

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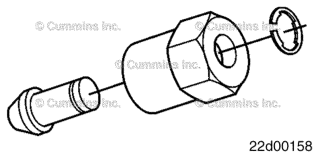
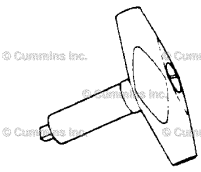
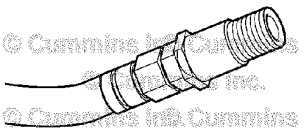
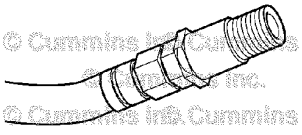
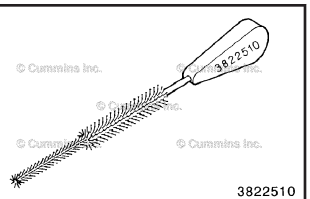
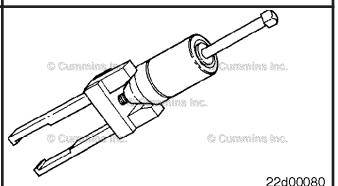
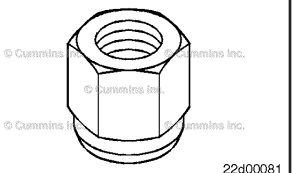
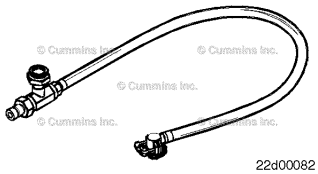
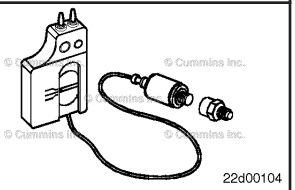
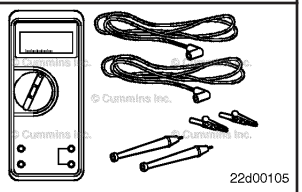
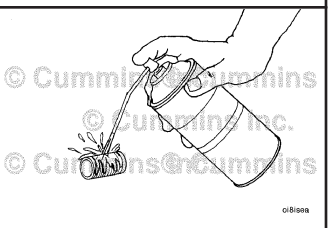
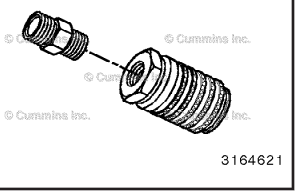
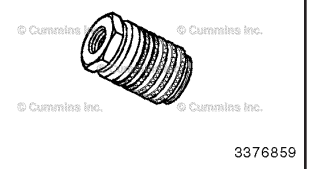
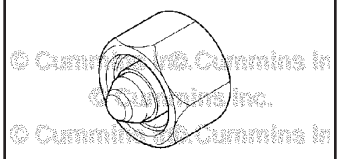
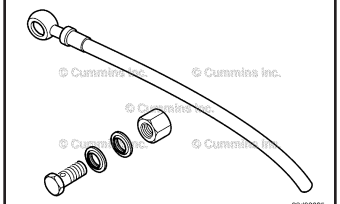
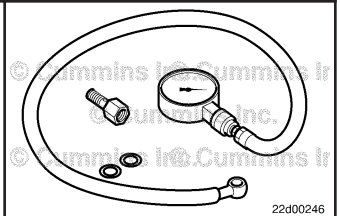
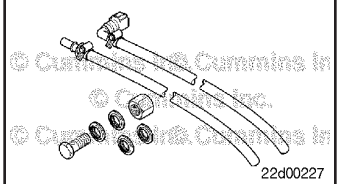
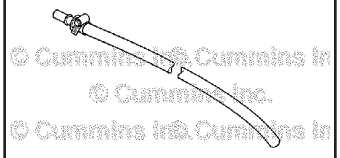
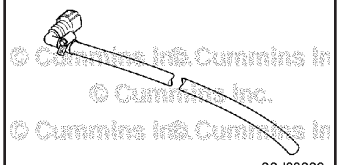
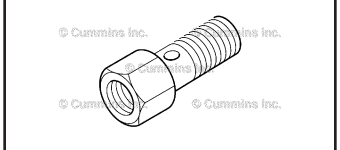
Service Tools

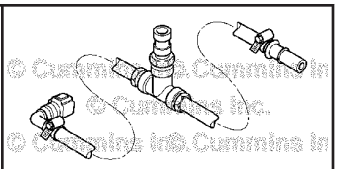
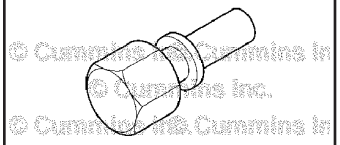
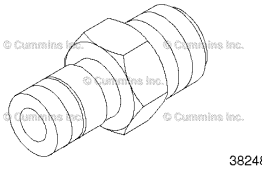
Injectors and Fuel Lines

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
3164325	**Fuel System Leak Tester** Used to cut off the fuel supply to the injector to diagnose it for leakage or other malfunction. Used on fuel rails with 14 mm threads.	 22d00158
3823208	**Torque Wrench - Injector Terminal Nuts** This 13 in-lb torque wrench is used to tighten the injector terminal nuts.	 3823208
3823705	**Graduated Beaker** Used to measure fuel return flows.	 22d00140
3164617	**Fuel Return Flow Hose (fuel rail pressure relief valve)** This tool uses a special fitting to measure return flow from the pressure relief valve on the fuel rail (engines **with** EGR **only**).	 22d00217
3164618	**Fuel Return Flow Hose (injector and fuel pump)** This tool uses a special fitting to connect to the fuel return circuits to measure return flow from the injectors and fuel pump (engines **with** EGR **only**).	 22d00217
3164583	**Fuel Line Cap** This tool is used to cap a quick-connect fuel line that has been disconnected from the engine. This prevents back-flow out of the line.	 3164583

Tool No.	Tool Description	Tool Illustration
3822510	**Injector Bore Brush** Used to clean the injector bore.	
3823024	**Injector Puller** Used to pull the injector.	
3164025	**Fuel Connector Remover** Used to pull the fuel connector.	
3164044	**Fuel Pressure Gauge Adapter** Used to measure fuel pressure and detect air in the fuel system. Use with tool, Part Number 3164491.	
3164491	**Pressure/Vacuum Module** Used to measure fuel pressure and restriction. Use with digital multimeter, Part Number 3164488 or 3164489.	
3164488 or 3164489	**Digital 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.	
3824510	**Quick Dry (QD) Cleaner** Used to clean parts and tools safely.	
3164621	**Lift Pump Performance Test Orifice** This tool connects to the diagnostic fitting on the inlet to the fuel filter. It is used to measure flow from the lift pump through an orifice **without** the engine running. The tool consists of a 0.043-inch orifice, Part Number 3045018, and a Compuchek® coupling, Part Number 3376859 (EGR engines **only**).	

Tool No.	Tool Description	Tool Illustration
3376859	**Compuchek® Quick-Connect Coupling** This tool connects to the diagnostic fitting on the inlet to the fuel filter. It is used when measuring inlet restriction when running the lift pump and does **not** contain an orifice (EGR engines **only**).	 3376859
4918298	**Fuel System Leak Tester** Used to cut off injector fuel supply when diagnosing injector leakage or malfunction. (Used on fuel rails with 18 mm threads).	 22d00224
4918295	**Fuel Return Flow Hose Kit** Used to check fuel return flow from 12 mm banjo fitting connections.	 22d00225
4918324	**Fuel Pressure Gauge Adapter Kit** Used to check fuel pressure/restriction at connections with 12 mm banjo fittings. (Gauge **must** be purchased separately).	 22d00246
4918354	**Fuel Return Flow Tester Kit** Used to check injector and HPCR pump drain flow.	 22d00227
4918433	**Fuel Drain Hose** Used with 5/16 quick disconnect fittings male connector (hose included in kit Part Number 4918354).	 22d00228
4918434	**Fuel Drain Hose** Used with 5/16 quick disconnect fittings female connector (hose included in kit Part Number 4918354).	 22d00229
4918413	**12 mm Banjo Screw** 12 mm banjo screw with 1/8 NPT pipe tap used to check fuel pressure/restriction.	 22d00230

Tool No.	Tool Description	Tool Illustration
4918462	**Fuel Pressure Gauge Adapter Kit** Used to check fuel pressure/restriction.	 22d00231
4918464	**Fuel Tube Plug** Used to plug low pressure fuel lines.	 22d00232
3824842	**Compucheck® Fitting** Used to check fuel pressure/restriction. 10 mm O-ring connection.	 3824813

Air in Fuel (006-003)

General Information

A replacement of fuel supply lines, fuel filters, fuel injection pump, high-pressure fuel lines, and injectors will let air enter the fuel system. Air in the system can make the engine hard to start, run rough, misfire, produce low power, or can cause excessive smoke and a fuel knock.

A few bubbles exiting the line during the test is expected. A foamy appearance is indication of a leak that allows air to enter, a severe inlet restriction that causes cavitation, or a system that is **not** yet primed. If fuel inlet restriction (Refer to Procedure Procedure 006-020) is **not** excessive, the source of air entry should be isolated to one of the following:

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

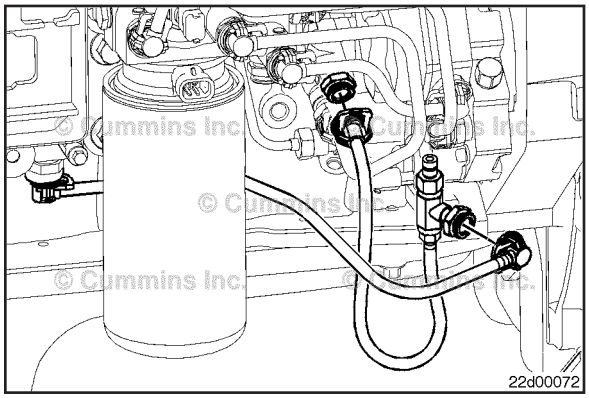
⚠WARNING⚠
Be sure that the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when engine is cranked or started. Environmental damage can also occur. Refer to Procedure Procedure 005-999 (Fuel System Overview) in Familiarization section for further information.

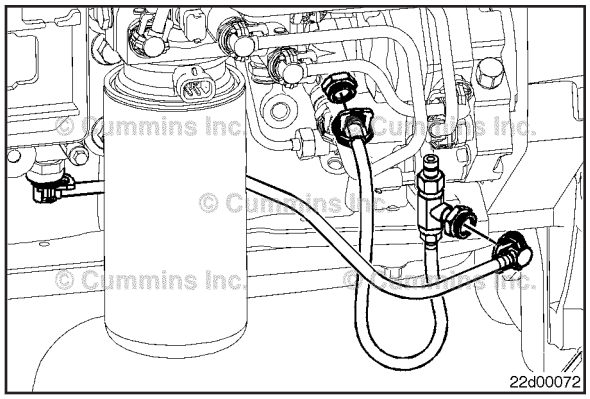
Test

NOTE: On quick-disconnect fittings with a white tang; push in the white tang to release the fuel line.

Install the fuel pressure gauge adapter service tool, Part Number 3164044, between the ECM cooling plate and the gear pump.

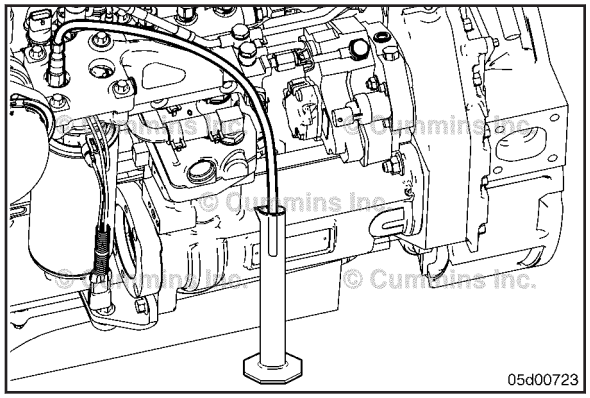
Operate the engine at idle and check for air bubbles in the clear line.





If air continues to bubble through the clear hose for several minutes, then an air leak is present.

This test checks for air leaks in the fuel supply lines. If all components are functioning properly, the fuel lines after the lift pump will **always** have a positive pressure. Any poor connections in lines will result in an external leak and **not** air in the fuel.



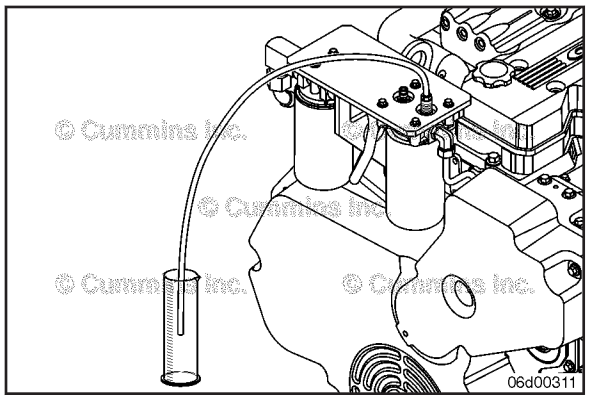
NOTE: This tool does **not** contain an orifice and will result in maximum flow from the lift pump. This will cause maximum fuel inlet vacuum and will make air leaks and inlet restriction easier to identify.

Install the M10 male Compucheck™ quick-connect fitting, Part Number 3824842, on the diagnostic port of the inlet side of the fuel filter head.

Connect the Compucheck™ quick-connect coupling, Part Number 3376859, to the Compucheck™ quick-connect fitting.

Attach a hose to the outlet of the tool.

Collect fuel flow from the hose in a bucket or similar container.



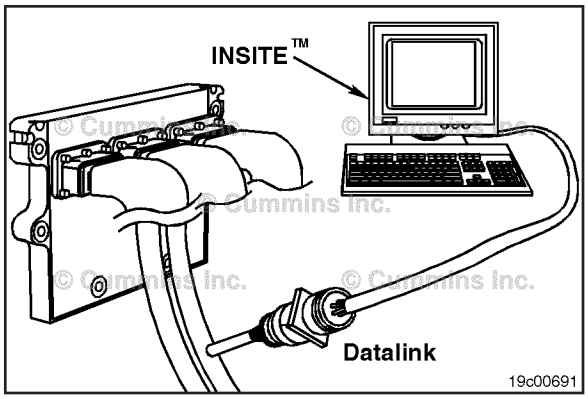
⚠CAUTION⚠
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system, that fuel is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The fuel and fuel filters must be discarded in accordance with local environmental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

NOTE: On Marine applications the fuel filter head bracket is located on the front of the cylinder head. Refer to Procedure Procedure 100-002 for component location.

NOTE: This test is performed with the engine **not** running.

Start the lift pump by turning on the key switch. (The lift pump will operate for 30-60 seconds and then stop. Turning the key off and back on could be necessary to verify if air is still present.)

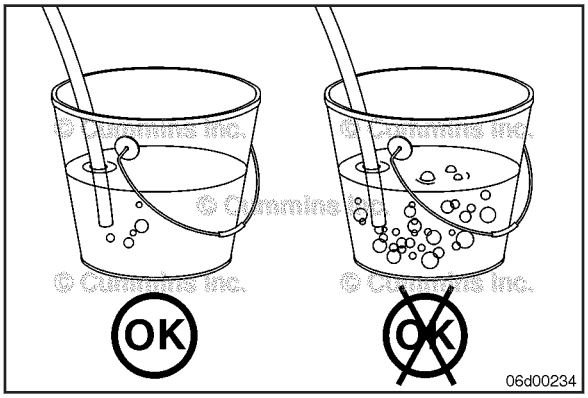
This can also be done by using the INSITE™ electronic service tool lift pump override test. See the INSITE™ user's manual.



Collect fuel in a bucket or similar device.

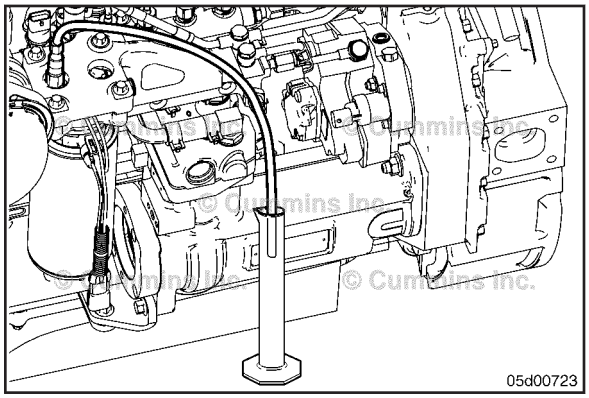
Look for air bubbles in the fuel as it fills the bucket or similar container.

If air continues to bubble through the clear hose for several minutes, then an air leak is present.



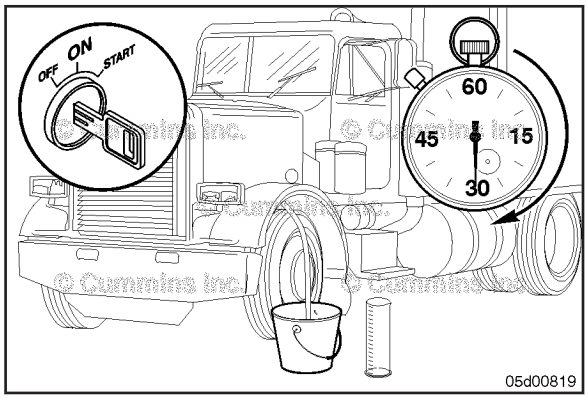
Obtain a 1.09 mm [0.043 in] orificed diagnostic fuel line, Part Number 3164621.

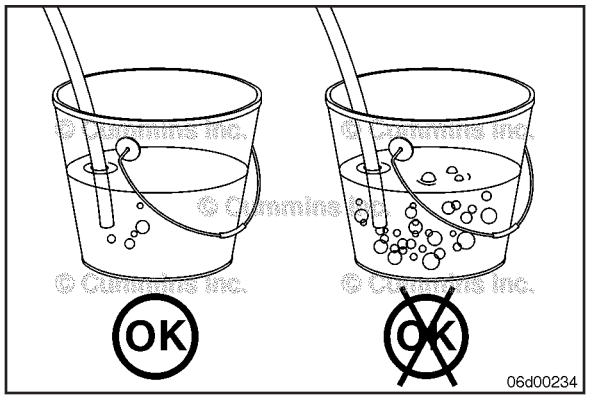
Install an M10 Compuchek™ fitting, Part Number 3824842, at the inlet to the on engine fuel filter and attach the 1.09 mm [0.043 in] diagnostic fuel line.



Route the outlet of the 0.043-inch diagnostic fuel line into a collection device of suitable size (a 5-gallon bucket is recommended)

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





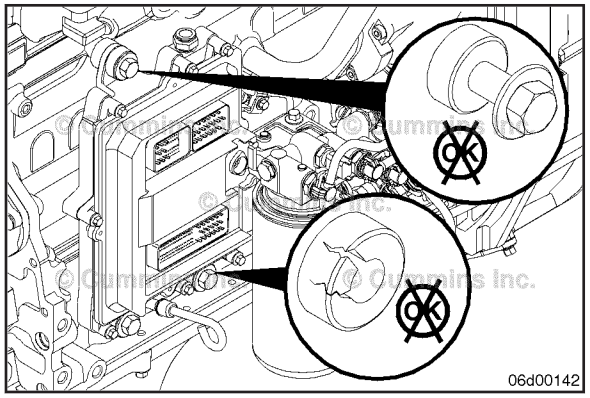
Observe the fuel flow exiting the diagnostic fuel line while the engine runs at idle.

If air continues to bubble through the clear hose for several minutes, then an air leak is present.

ECM Cooling Plate, Fuel Cooled (006-006)

General Information

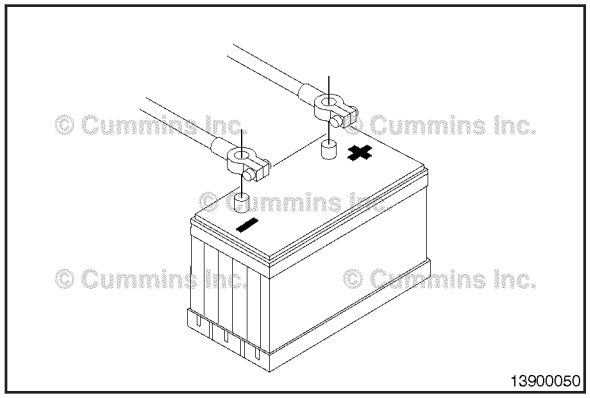
NOTE: Engines with electric lift pumps use passages within the ECM cooling plate to cool the ECM; the fuel is **not** in direct contact with the backside of the ECM. On engines without an electric lift pump, the fuel entering the ECM cooling plate directly contacts the rear side of the ECM. For this reason, a gasket is required between the ECM and the cooling plate for engines without an electric lift pump. For engines with an air cooled ECM cooling plate, Refer to Procedure Procedure 019-002



Initial Check

Check the electronic control module (ECM) cooling plate for leaks, damaged isolators, or loose capscrews.

NOTE: Clean around ECM cooling plate fuel line connections. Dirt or contaminants can damage the 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.

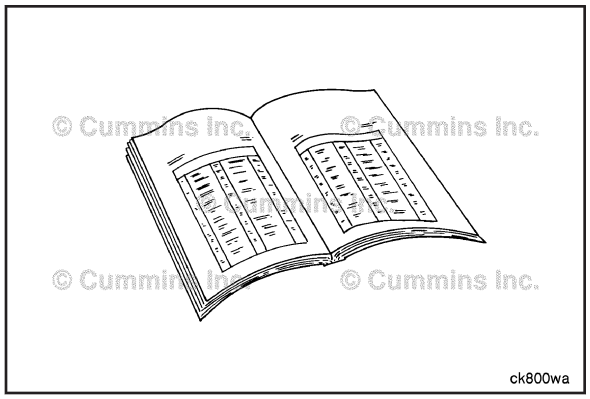
Disconnect the batteries.

Remove the ECM and cooling plate from the engine as an assembly. Refer to Procedure Procedure 019-031 in ISB (4 cylinder) and ISB^{e} (4 and 6 Cylinder) Controls Troubleshooting and Repair Manual Bulletin 3666477.

Disconnect the fuel lines from the inlet and outlet of the ECM cooling plate.

Remove the ECM from the cooling plate. Refer to Procedure Procedure 019-031 in the CM850 Electronic Control System, ISB Engine Troubleshooting and Repair Manual Bulletin 4021377.

Disconnect the fuel lines from the inlet and outlet of the ECM cooling plate.



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

NOTE: Label or note the locations of all p-clips for the wiring harness and harness connection locations before they are removed, so they can be re-installed in their correct location.

Disconnect the batteries.

Disconnect the battery supply cables from the ECM bracket.

Shut off the sea water supply valve(s). Refer to the OEM service manual.

Shut off the fuel supply and return, and remove the fuel cooler. Refer to Procedure Procedure 006-062

Remove the sea water aftercooler assembly. Refer to Procedure Procedure 010-005

Disconnect the engine harness, OEM harness and ECM power harness connectors from the ECM.

Disconnect the SIM module connector.

Disconnect the fuel supply line from the combined fuel manifold to the fuel lift pump at the combined fuel manifold. Refer to Procedure Procedure 006-024

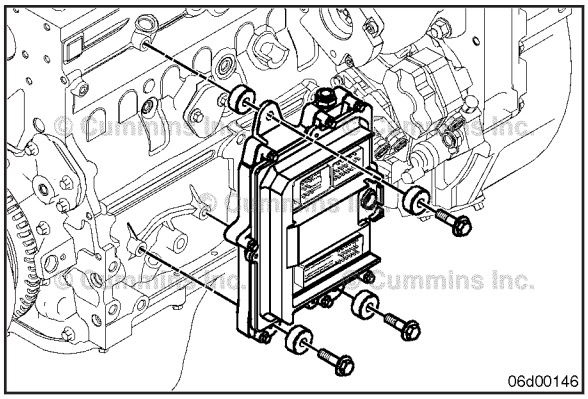
Disconnect the fuel supply line from the ECM cooling plate to the fuel filter at the ECM cooling plate. Refer to Procedure Procedure 006-024

Remove

Remove the ECM and cooling plate mounting capscrews.

Do **not** lose any of the heat-resistant grommets.

Remove the ECM and cooling plate from the engine. Drain any remaining fuel into the fuel can.

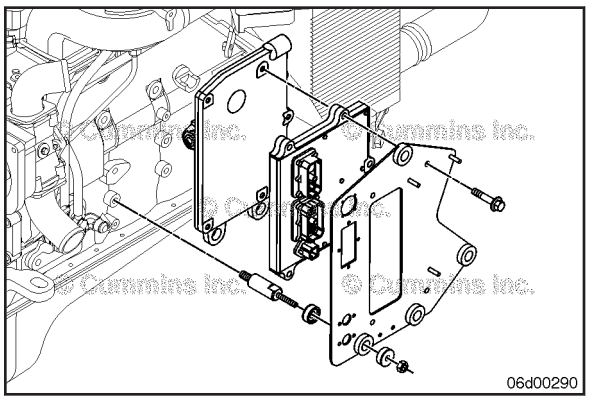


NOTE: The ECM cooling plate, ECM, and ECM mounting bracket are removed and installed as an assembly.

NOTE: The ECM mounting bracket has three mounting studs at the bottom of the bracket and one capscrew at the top. Remove the top mounting capscrew last.

Remove the three bottom ECM bracket mounting nuts and grommets.

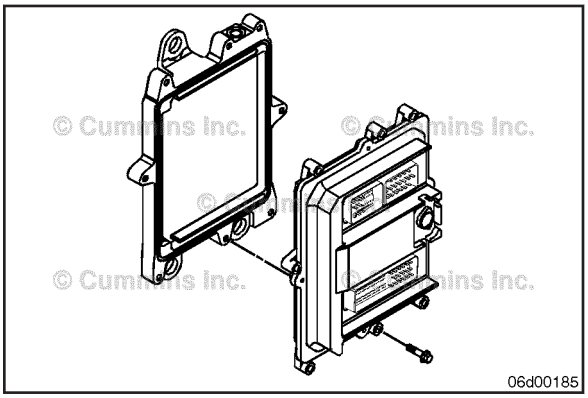
Remove the top capscrew and the ECM mounting bracket, ECM, and fuel cooled ECM cooling plate.



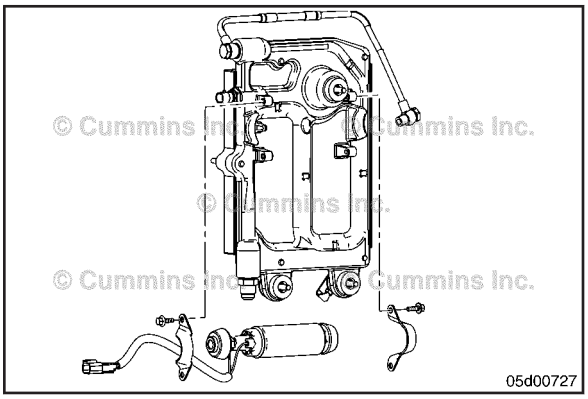
Disassemble

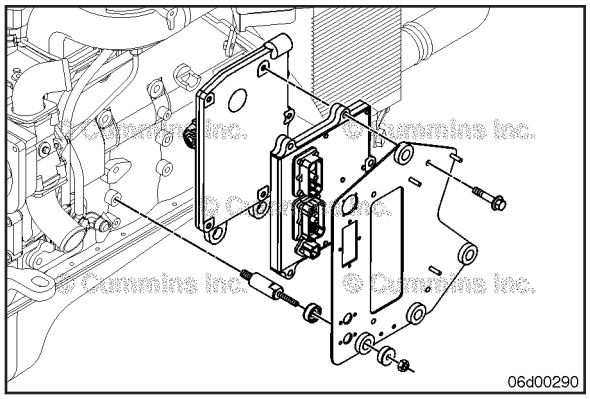
For engines without a lift pump remove the cooling plate from the back of the ECM.

Remove and discard the gasket.



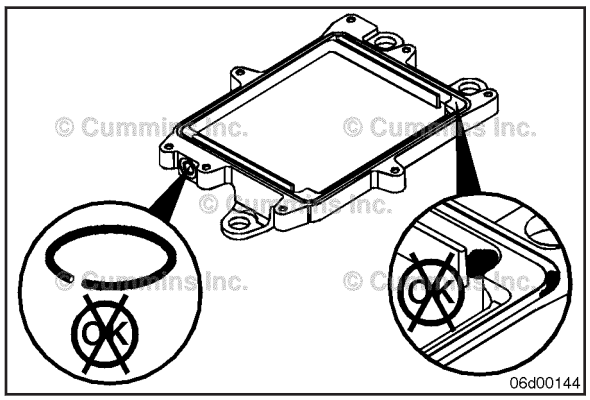
Remove the fuel lines and lift pump from the ECM cooling plate. Refer to Procedure Procedure 005-045





Remove the four capscrews holding the ECM and fuel cooled ECM cooling plate to the mounting bracket.

Remove the fuel lift pump. Refer to Procedure Procedure 005-045



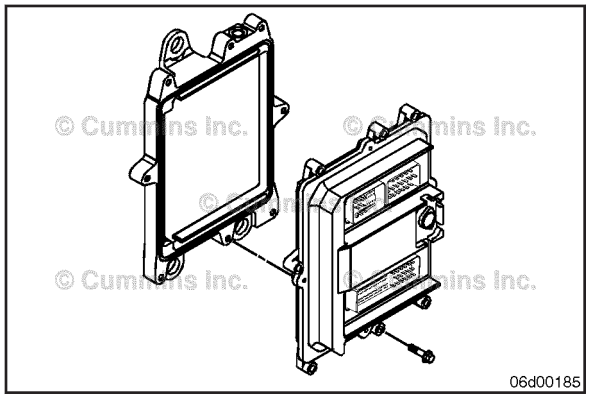
Clean and Inspect for Reuse

⚠CAUTION⚠
To reduce the possibility of engine damage, do not paint the cooling plate. Make sure there is no grease or dirt between the ECM and the cooling plate. This can prevent effective cooling of the ECM.

Be sure the ECM is clean.

Check the ECM cooling plate and o-ring for damage.

For engines with an electric lift pump, be sure internal ECM cooling plate passages are free of debris.



Assemble

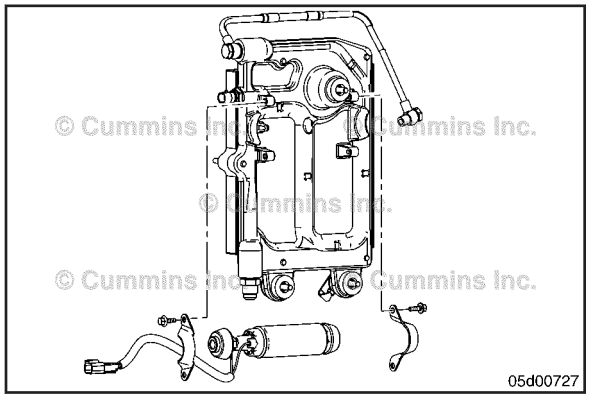
The ECM and ECM cooling plate will be installed as an assembly.

Use a new gasket between the ECM and cooling plate. If the new gasket contacts diesel fuel, it may swell and be difficult to install. Engines with an electric lift pump do **not** use a gasket.

Install the heat-resistant star washer grommets on the cooling plate where necessary.

Tighten the capscrews.

Torque Value: 10 N•m [89 in-lb]

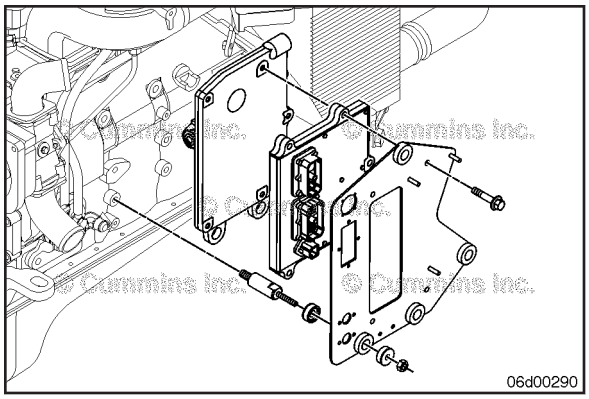


Install the fuel lift pump to the ECM cooling plate. Refer to Procedure Procedure 005-045

Install the fuel lift pump to the ECM plate. Refer to Procedure Procedure 005-045

Install the ECM and ECM cooling plate to the mounting bracket with four capscrews.

Torque Value: 24 N•m [212 in-lb]



Install

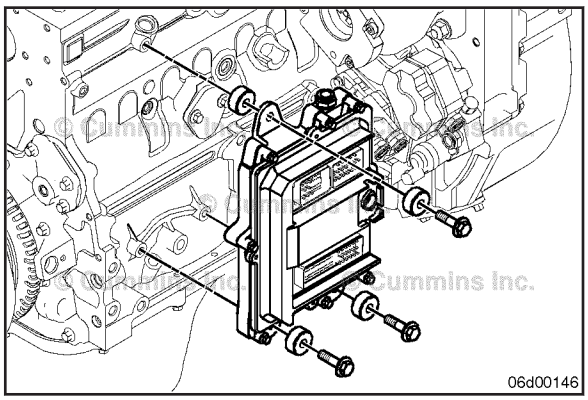
NOTE: For engines without an electric lift pump, the ECM and ECM cooling plate are installed as an assembly.

Install the ECM cooling plate on the engine.

Install heat-resistant grommets in proper locations.

Install the ECM cooling plate mounting capscrews.

Torque Value: 24 N•m [212 in-lb]



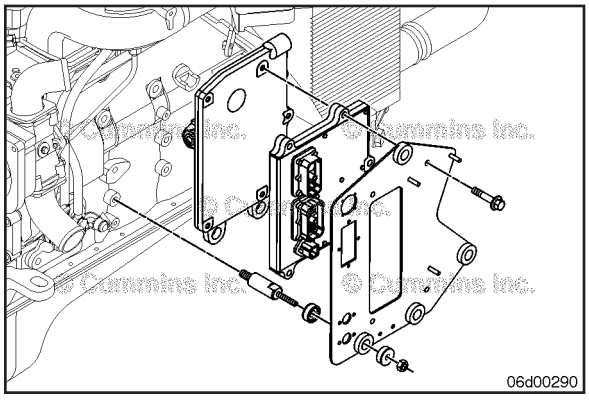
Align the mounting bracket over the three lower studs using new grommets. Loosely install the capscrew at the top of the bracket.

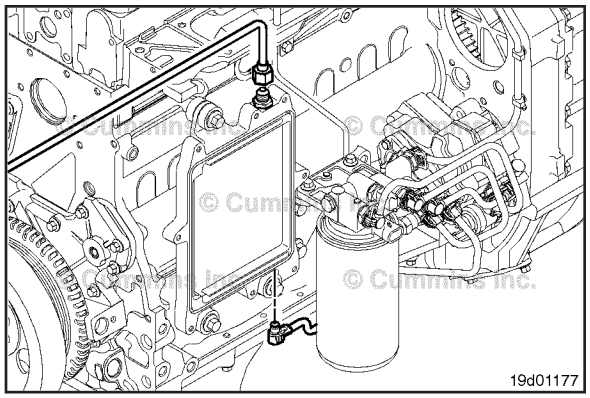
NOTE: Make sure all fuel lines and wiring harnesses are routed correctly and **not** pinched.

Install the three outer grommets and nuts.

Tighten the capscrew and nuts evenly.

Torque Value: 24 N•m [212 in-lb]





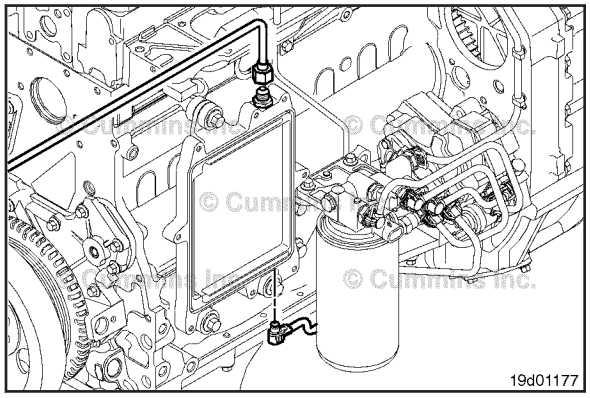
Finishing Steps

Install the ECM and cooling plate to the engine as an assembly. Refer to Procedure 019-031 in the ISB (4 cylinder) and ISB^{e} (4 and 6 cylinder) Controls Troubleshooting and Repair Manual Bulletin 3666477.

Connect the fuel lines to the inlet and outlet of the ECM cooling plate.

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

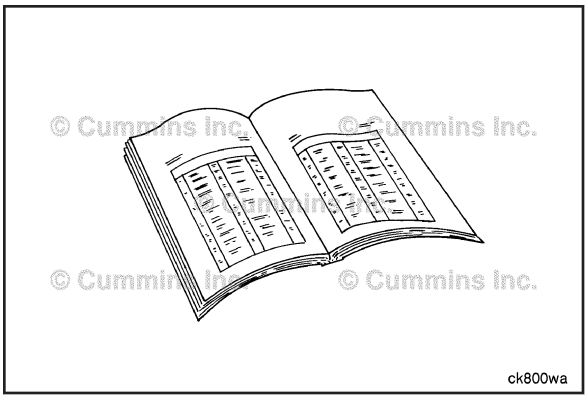


Install the ECM to the cooling plate. Refer to Procedure Procedure 019-031 in the CM850 Electronic Control System, ISB Engine Troubleshooting and Repair Manual Bulletin 4021377.

Connect the fuel lines to the inlet and outlet of the ECM cooling plate.

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



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

Connect the fuel supply line from the ECM cooling plate to the fuel filter. Refer to Procedure Procedure 006-024

Connect the fuel supply line from the combined fuel manifold to the fuel lift pump at the combined fuel manifold. Refer to Procedure Procedure 006-024

Connect the battery supply cables to the ECM mounting bracket. Refer to Procedure Procedure 013-009

Connect the SIM module, engine harness, OEM harness, SIM and ECM power harness connectors to the ECM. Refer to Procedure Procedure 019-043 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISB Engines, Bulletin 4021337. Attach all p-clips to their original locations.

Install the sea water aftercooler assembly. Refer to Procedure Procedure 010-005

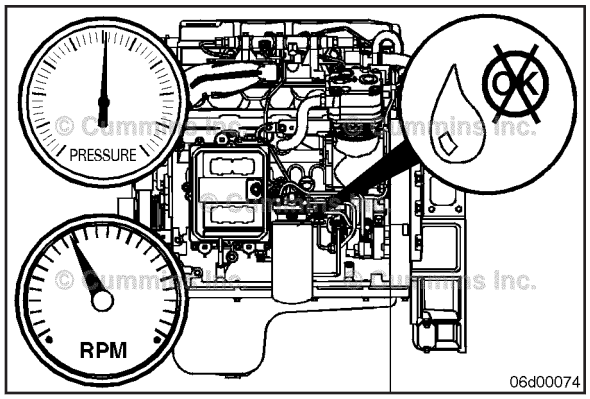
Install the fuel cooler. Refer to Procedure Procedure 006-062

Connect the batteries.

Open the sea water supply valve(s). Refer to the OEM service manual.

Open the fuel supply and return lines. Prime the fuel system. Refer to Procedure Procedure 005-016

Operate the engine and check for leaks.



Prime

⚠WARNING⚠
The fuel pump high-pressure lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

△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.

⚠WARNING⚠
Be sure that the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when engine is cranked or started. Environmental damage can also occur. Refer to Procedure Procedure 005-999 (Fuel System Overview) in Familiarization section for further information.

NOTE: On marine applications engines, cycle the key switch at least five times allowing the lift pump to run thirty seconds on each cycle to properly prime the fuel system.

Allow the lift pump to run by turning the key switch ON and waiting thirty seconds before starting.

Operate the engine and check for leaks or fault codes.

⚠WARNING⚠
The fuel pump high-pressure lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

⚠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.

After Filter Change:

Primary Method:

Unlock the manual priming pump handle by turning counter-clockwise. Pump the primer handle until resistance is felt (approximately 140-150 strokes). Lock the manual priming pump handle and crank the engine. Start should occur within 5 seconds.

NOTE: Do **not** fill new filters with fuel prior to assembly as this will allow unfiltered fuel to enter the system and may cause damage to the fuel system components.

Alternative Method:

Unlock the manual priming pump handle by turning counter-clockwise. Pump the primer handle 60 times. Lock manual priming pump handle and crank the engine. Start should occur within approximately 20 seconds.

NOTE: Do **not** exceed starter cranking limitations.

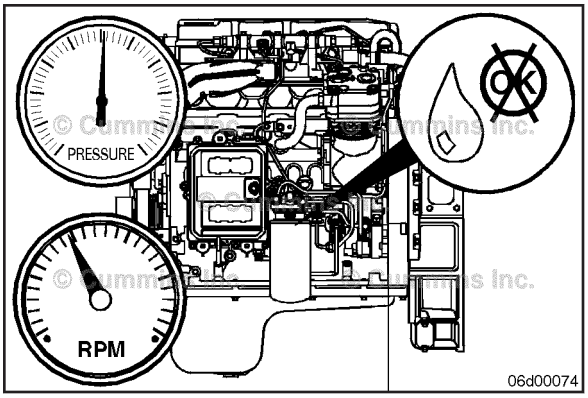
After Running the Vehicle Tank Dry:

Ensure there is fuel in the vehicle fuel tank. Unlock the manual priming pump handle by turning it counter-clockwise. Pump the primer until resistance is felt (50-60) strokes. Lock manual priming pump handle and crank the engine. Start should occur within 5 seconds.

NOTE: Do **not** remove and fill filters with fuel prior to priming the system in an attempt to reduce priming time as this will allow unfiltered fuel to enter the system and may cause damage to fuel system components.

It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will prime the fuel system.

Operate the engine and check for leaks or fault codes.



Fuel Drain Line Restriction (006-012)

General Information

The fuel drain line restriction is measured at a fuel return manifold located near the point at which the OEM connects the vehicle fuel drain line. To locate this manifold, follow the fuel drain lines from their source, (rail pressure relief valve, injector return, or high pressure injector pump return) to their termination point. The termination point will occur at the fuel return manifold.

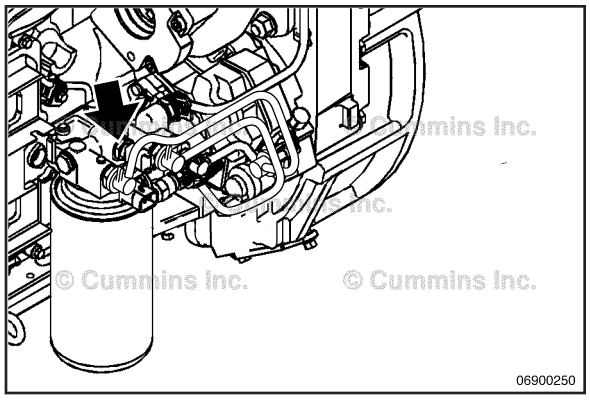
⚠CAUTION⚠
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system that fuel is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The fuel and fuel filters must be discarded in accordance with local environmental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

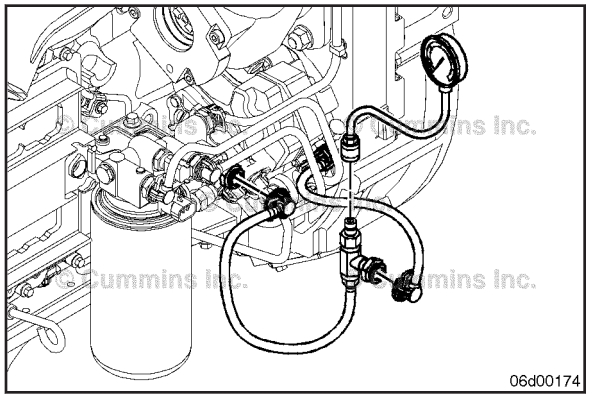
⚠WARNING⚠
Be sure that the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when ignition is cranked or started. Environmental damage can also occur. Refer to Procedure 005-999 in Section F for further information.

Setup

Low Mount Fuel Return Manifold

The integral fuel filter head return manifold is located on the fuel filter head.





Disconnect the fuel drain line connecting the fuel pump drain to the fuel return manifold.

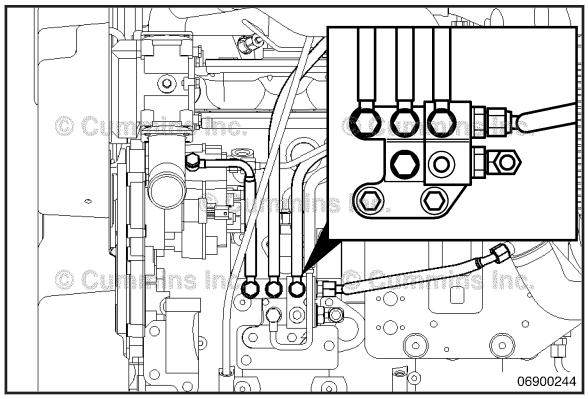
Insert a fuel pressure gauge adapter tool, Part Number 3164044, between the fuel return manifold and the fuel drain line.

Attach a pressure gauge to the Compuchek™ fitting on the fuel pressure gauge adapter.

Marine Applications Without Fuel Cooler

For Marine applications, the fuel return manifold is located on the engine block beside the ECM. This manifold contains both the inlet and outlet fuel.

NOTE: If the engine has a fuel cooler, it will be located between the fuel return manifold and the OEM fuel drain line connection. The fuel drain restriction is tested at the fuel manifold on engines without a fuel cooler.

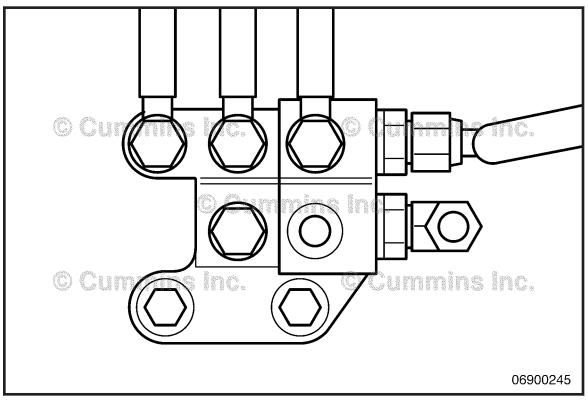


Remove either banjo bolt from the fuel drain side of the fuel manifold.

NOTE: Arrows on the fuel return manifold illustrate the direction of fuel flow through the manifold.

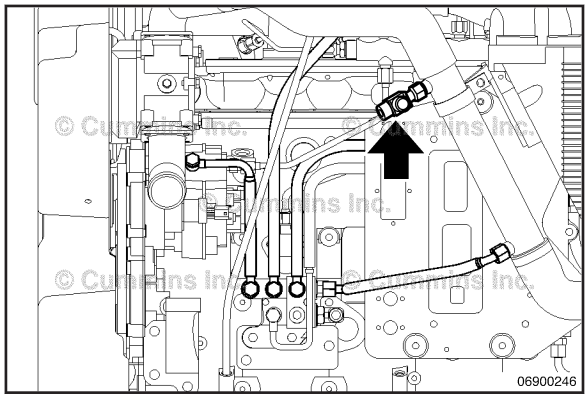
Install the M12 x 1/8” NPT banjo screw, Part Number 4918413, in place of the banjo bolt.

Insert a pressure gauge into the back of the banjo screw.



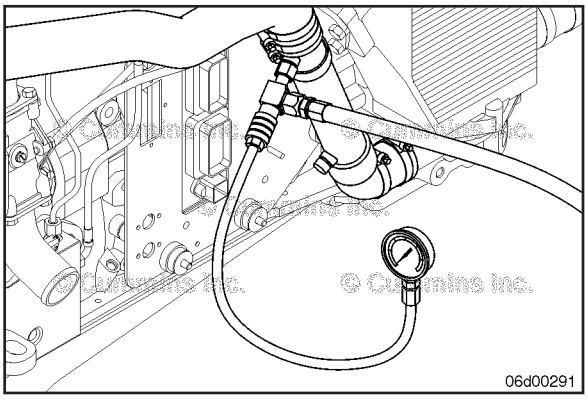
Marine Applications With Fuel Cooler

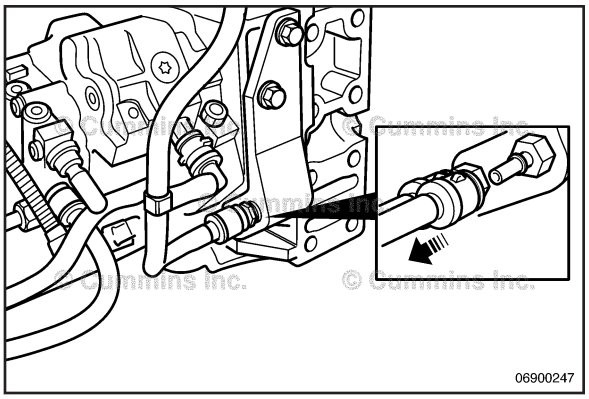
NOTE: If the engine has a fuel cooler, it will be located between the fuel return manifold and the OEM fuel drain line connection. For engines with a fuel cooler, the fuel drain restriction will be tested at the diagnostic test port at the outlet of the fuel cooler.



Remove the pipe plug from the diagnostic test port at the outlet of the fuel cooler. Refer to Procedure 006-062 in Section 6 for fuel cooler cautions and specifications.

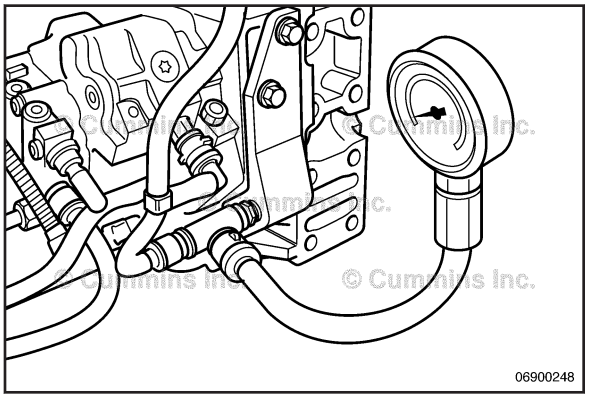
Install a pressure gauge into the diagnostic test port.





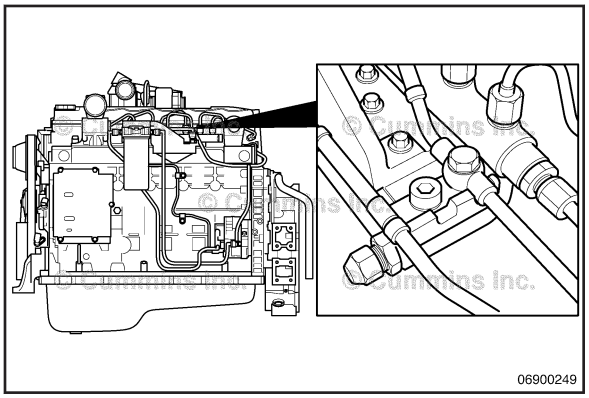
Gear Housing Fuel Return Manifold

Disconnect the quick-disconnect fitting on the fuel drain line closest to the connection to the OEM fuel drain line.



Insert a pressure gauge adapter, Part Number 4918462, between the disconnected fuel drain line and the OEM fuel drain line connection.

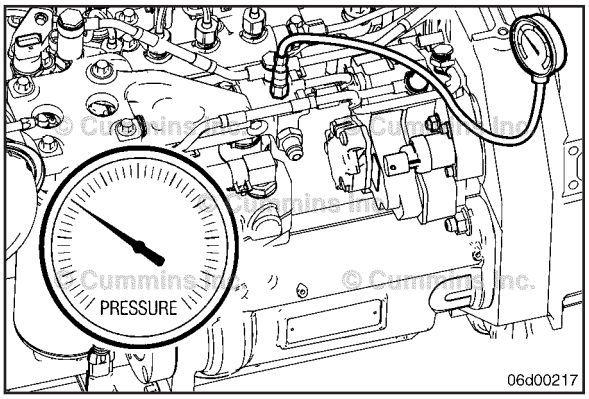
Attach a pressure gauge to the fitting on the fuel pressure gauge adapter.



High Mount Fuel Return Manifold

The fuel return manifold is located beside the fuel rail near the top of the engine.

NOTE: The fuel filter could be remote mounted off the engine.



Remove the banjo bolt from the fuel return manifold. (This is an inline banjo fitting).

Install the M12 x 1/8” NPT banjo screw, Part Number 4918413, in place of the banjo bolt.

Insert a pressure gauge into the back of the banjo screw.

NOTE: If two banjo fittings are present on the fuel return manifold, the M12 x 1/8” NPT banjo screw can be used in either location.

Marine Applications

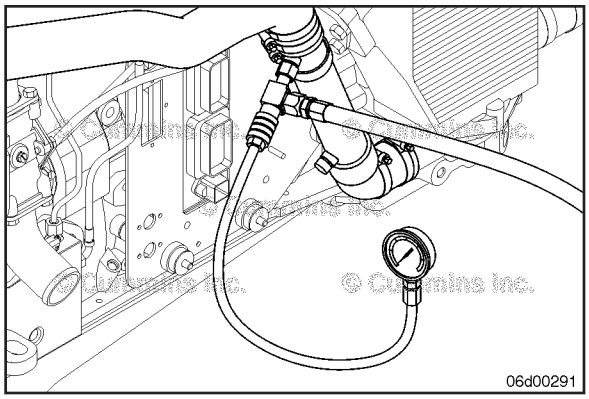
⚠CAUTION⚠

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.

Remove the pipe plug from the fuel drain connection.

Install a Compuchek™ fitting.

Attach a pressure gauge to the Compuchek™ fitting.



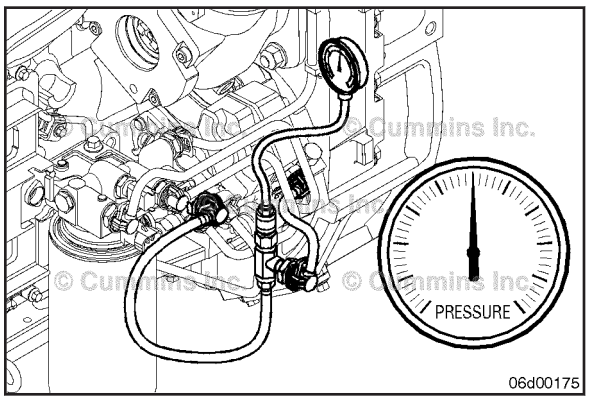
Initial Check

Automotive and Industrial

Operate the engine at cranking or low idle and measure the fuel pressure.

Observe the reading on the gauge.

Allowable Drain Line Restriction		
kPa		psi
20.0	MAX	2.9

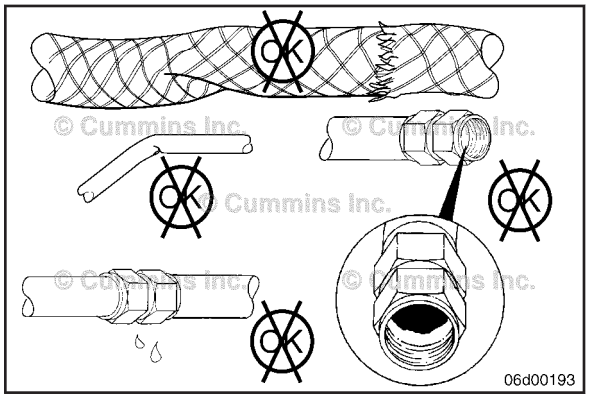


If the fuel drain line restriction is too high, check:

1 O.E.M fuel lines to the tank for proper size, leaks, bends, or clogs

2 Fuel drain valves for restrictions or plugging (marine applications only)

3 Fuel tank vents for plugging.

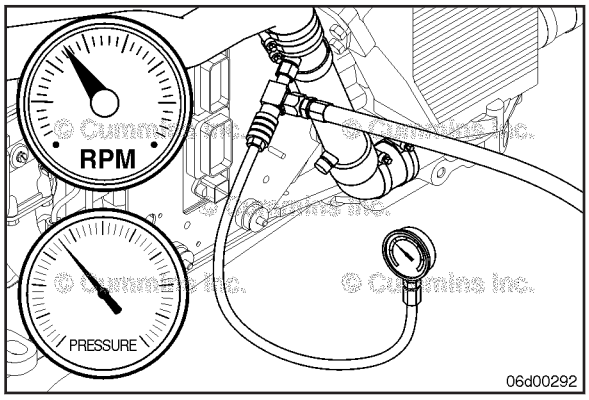


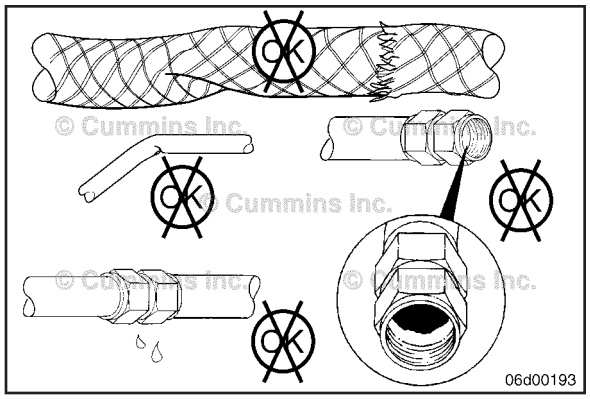
Marine Applications

Operate the engine at rated no-load rpm and measure the fuel pressure.

Observe the reading on the gauge.

Allowable Fuel Drain Line Restriction (Marine Engines)		
kPa		in Hg
14.0	MAX	4





If the fuel drain line restriction is too high, check the original equipment manufacturer's fuel lines to the tank for proper size, leaks, bends, or clogs.

Check the fuel drain valves for restrictions for plugging. Check for possible plugged fuel tank vents.

Fuel Drain Lines (006-013)

General Information

Due to the number of different fuel line routing and connector styles, the steps in this procedure have been written to be generic. Some of the illustrations may **not** represent the parts being removed or installed.

The fuel drain line restriction is measured at a fuel return manifold located near the point at which the OEM connects the vehicle fuel drain line. To locate this manifold, follow the fuel drain lines from their source, (rail pressure relief valve, injector return, or high pressure injector pump return) to their termination point. The termination point will occur at the fuel return manifold.

NOTE: All engines have three fuel drain lines as follows: (1) from the injector return port in the cylinder head to the combined fuel manifold, (2) from the high-pressure fuel pump to the combined fuel manifold, and (3) from the fuel pressure relief valve to the combined fuel manifold.

NOTE: For marine applications, there is a fourth fuel drain line: (4) from the combined fuel manifold to the fuel cooler.

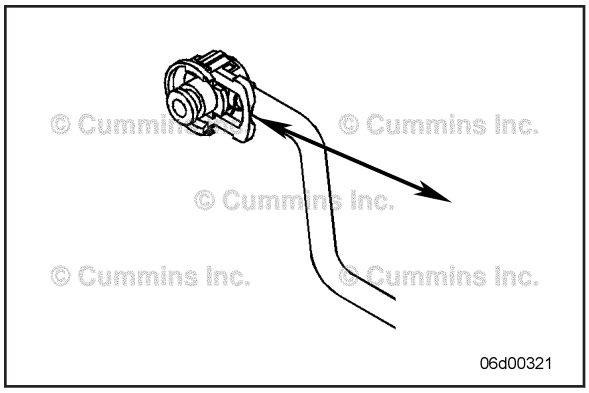
CAUTION
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system, that fuel is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The fuel and fuel filters must be discarded in accordance with local environmental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

WARNING
Be sure that the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when engine is cranked or started. Environmental damage can also occur. Refer to Procedure Procedure 005-999 (Fuel System Overview) in Familiarization section for further information.

Directions for service of a white tang quick-disconnect fitting:

Push in white tang to release fuel line.

Pull to lock fuel line.

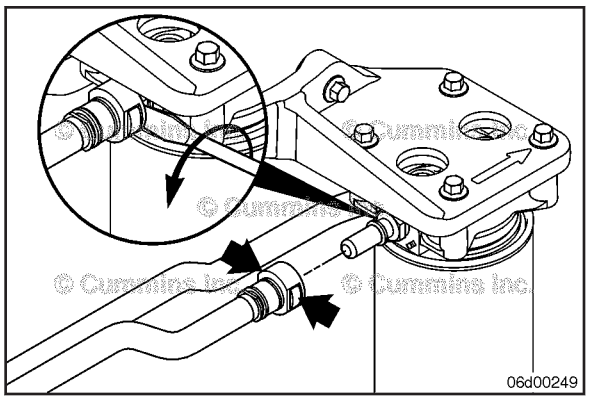


Directions for service of a two-button quick-disconnect fitting:

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

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

Install the quick-disconnect style fuel lines by pushing quick-disconnect fitting onto male union until it clicks.



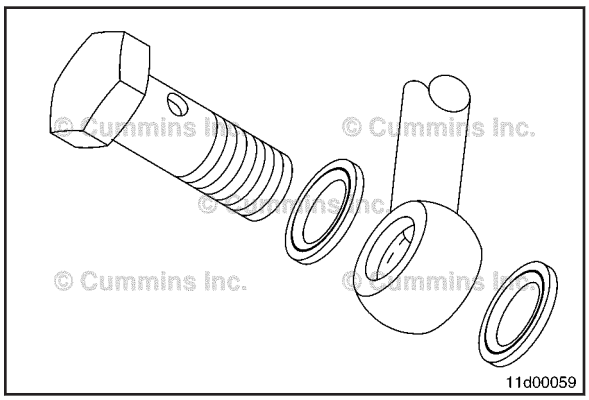
Directions for service of a banjo bolt fitting:

A sealing washer is used on both sides of a banjo fitting.

NOTE: New sealing washers **must** be used when installing the banjo bolt fitting.

Installation:

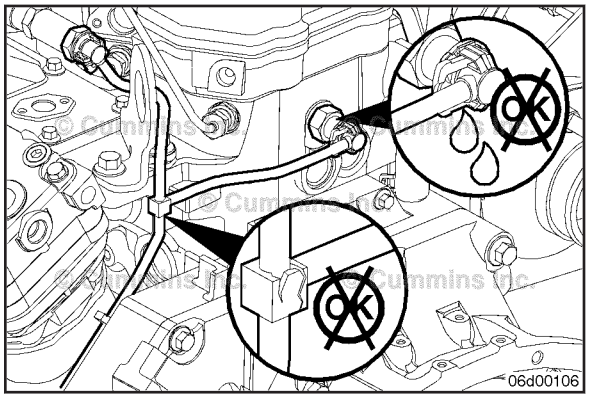
Torque Value: 24 N•m [212 in-lb]

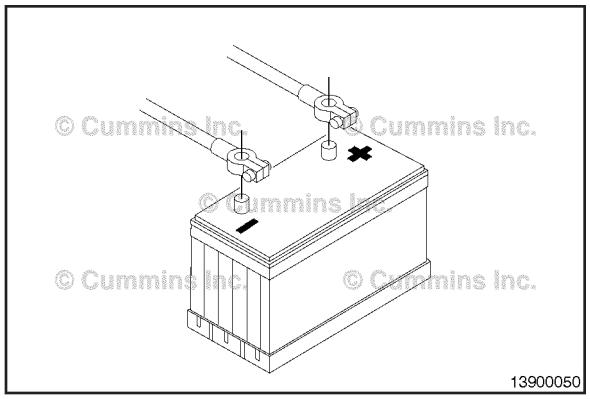


Initial Check

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

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

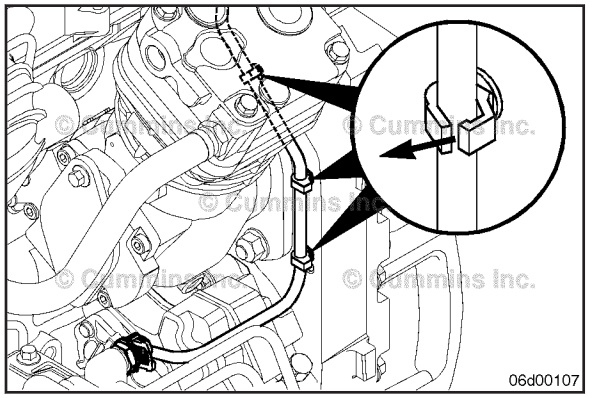




Preparatory Steps

⚠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.

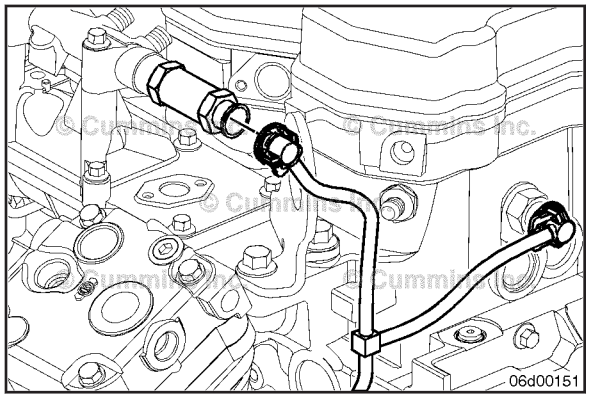
Disconnect the batteries.



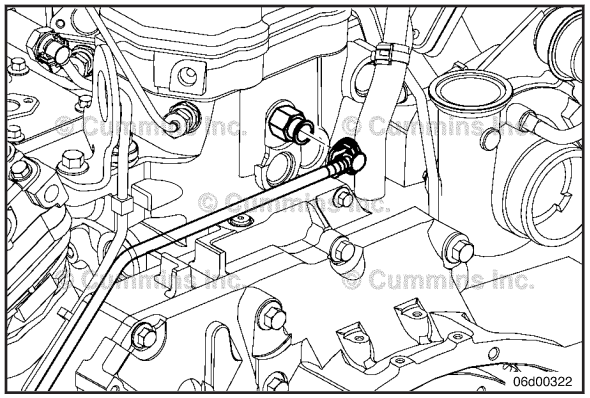
Remove

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

Remove all capscrews from the fuel drainline.

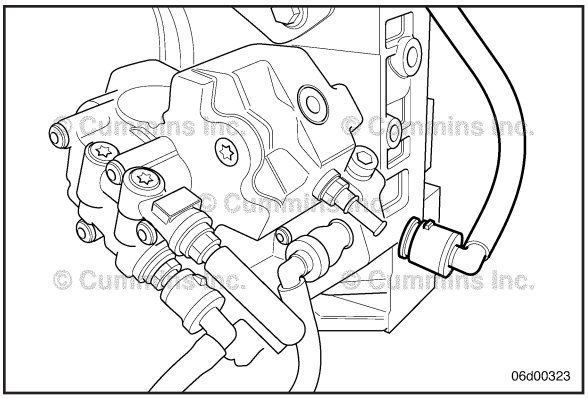


Remove the fuel drain line from the fuel rail pressure relief valve.



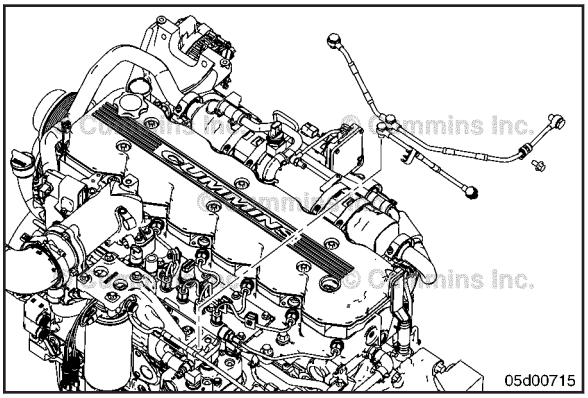
Remove the fuel drain line from the injector drain port at the back of the cylinder head.

Remove the fuel drain line from the fuel injector pump.



Remove the fuel drain line from the fuel return manifold.

NOTE: For marine applications, each of the drain lines individually connect to the fuel return manifold.



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

Marine applications have four fuel drain lines as follows:

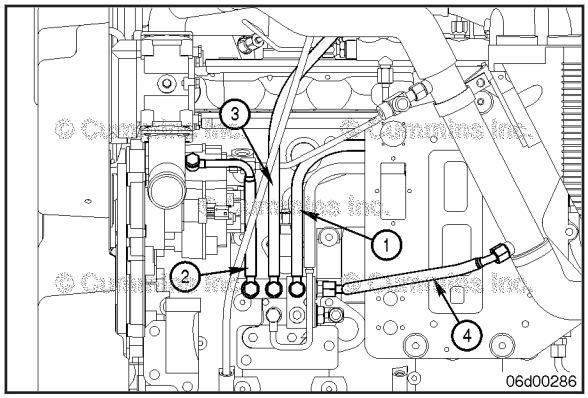
1 From the injector return port in the cylinder head to the combined fuel manifold

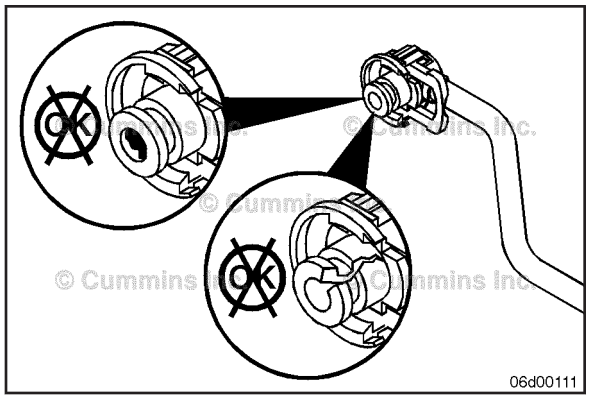
2 From the high-pressure fuel pump to the combined fuel manifold

3 From the fuel pressure relief valve to the combined fuel manifold

4 From the combined fuel manifold to the fuel cooler.

Shut off the fuel supply and return valves. Remove the banjo bolts, fittings, clips, and fuel drain lines.



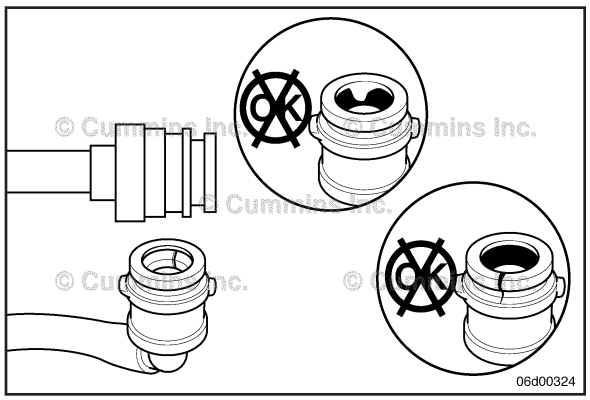


Inspect for Reuse

Inspect the fuel drain lines for clogging and pinched areas.

Check the connector and o-ring for damage.

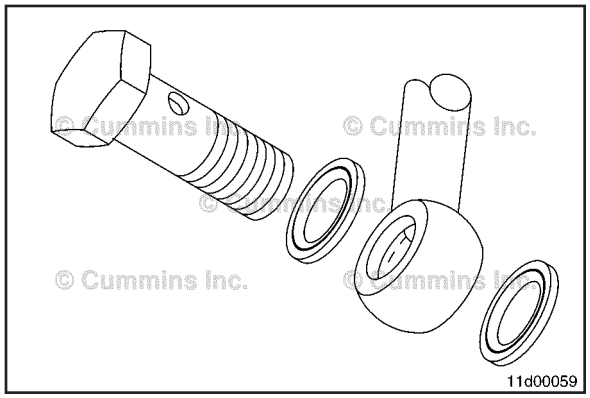
Replace fuel line if damaged.



Inspect the fuel drain lines for clogging, and pinched areas.

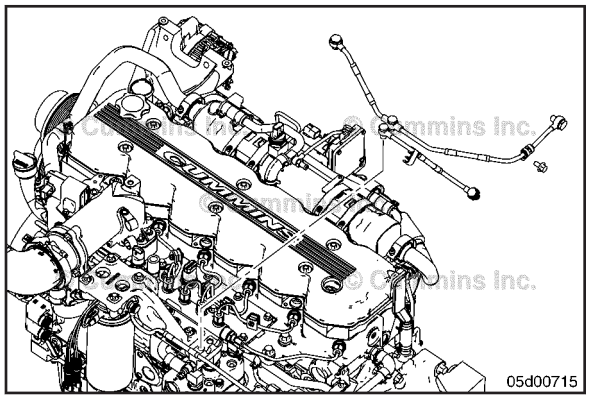
Check the connector and o-ring for damage.

Replace fuel line if damaged



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

Replace fuel line if damaged.



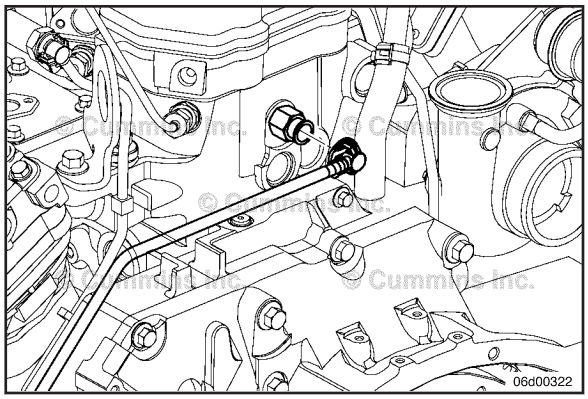
Install

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

NOTE: The fitting for the injector return flow on the back of the cylinder head contains a check valve to maintain proper back-pressure. Fuel exiting the check valve returns to the tank.

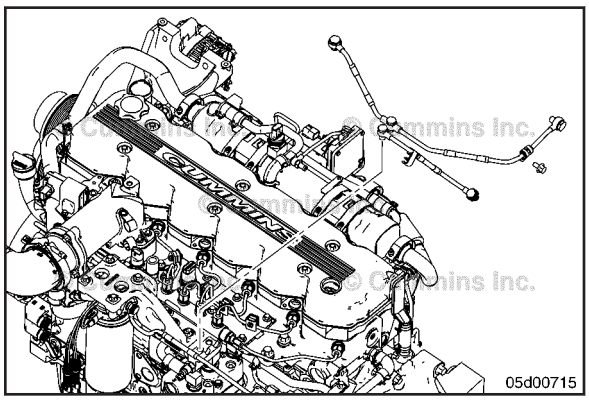
Install the injector return flow fitting into the back of the cylinder head.

NOTE: For engines with quick-disconnect fittings; attach the fuel drain line to the injector return flow drain fitting. Securely lock the connector.

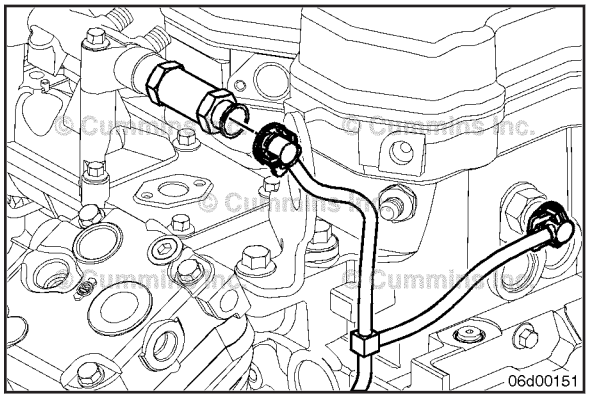


Install the fuel drain line(s) on the fuel return manifold.

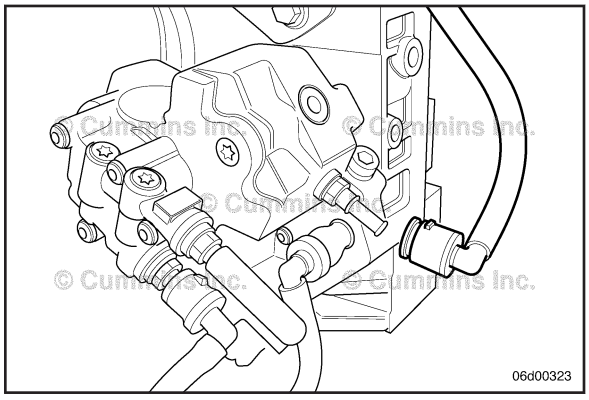
NOTE: For marine applications each of the fuel drain lines individually connect to the fuel return manifold.

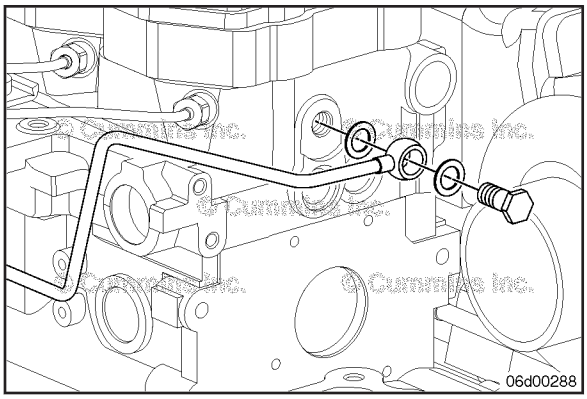


Install the fuel drain line on the fuel rail pressure relief valve.



Install the fuel drain line on the fuel injector pump.





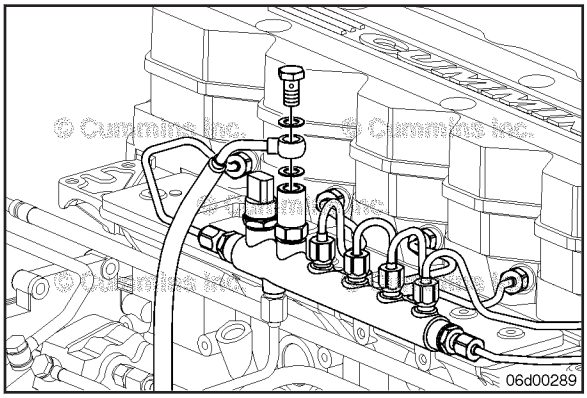
NOTE: The fitting for the injector return flow on the back of the cylinder head contains a check valve to maintain proper back pressure. Fuel exiting the check valve returns to the combined fuel manifold then to the fuel cooler and fuel tank.

Install the fitting using new sealing washers.

Torque Value: 24 N•m [212 in-lb]

Install the other end of the fuel line to the combined manifold using a banjo bolt and new sealing washers.

Torque Value: 24 N•m [212 in-lb]

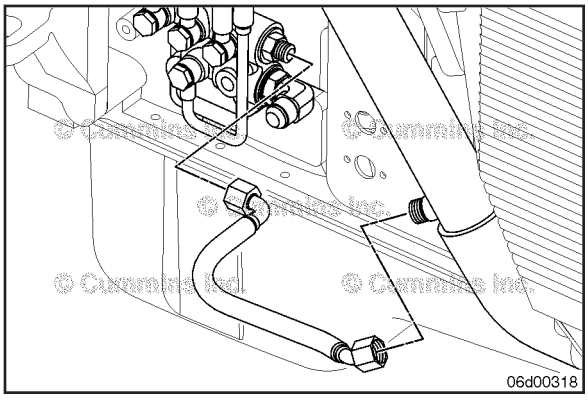


Install the fuel line from the fuel pressure relief valve to the combined fuel manifold using new sealing washers and banjo bolt.

Torque Value: 24 N•m [212 in-lb]

Install the fuel line from the high-pressure fuel pump to the combined fuel manifold using new sealing washers and two banjo bolts.

Torque Value: 24 N•m [212 in-lb]



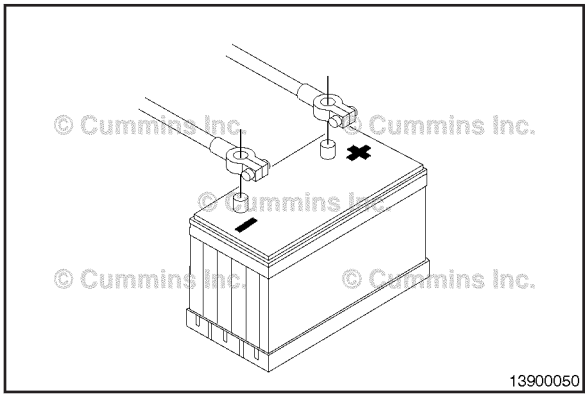
Install the fuel line from the combined fuel manifold to the fuel cooler. Use a second wrench at the fuel cooler to prevent damaging the cooler when tightening the fitting.

Torque Value: 24 N•m [212 in-lb]

Open the fuel supply and return valves.

Prime the fuel system. Refer to Procedure Procedure 005-016

Operate the engine and check for leaks.



Finishing Steps

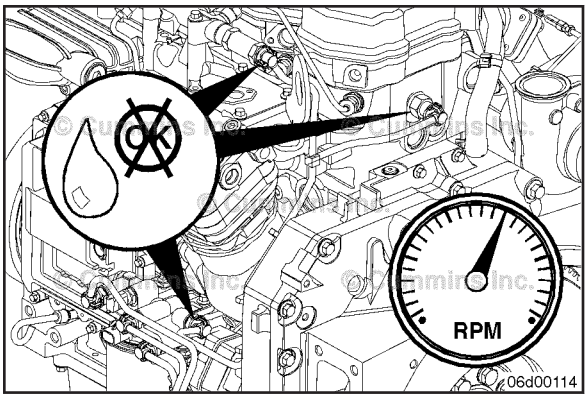
Attach all p-clip mounting capscrews.

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

For marine applications, **Open** the fuel inlet and return valves.

Operate the engines and check for leaks.



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

General Information

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

⚠WARNING⚠
Drain the fuel into a container, and dispose of contents in accordance with local environmental regulations.

⚠WARNING⚠
Be sure that the fuel inlet and return valves are returned to the open position before cranking the engine. Engine damage can result if valves are in the wrong position when the engine is cranked or started. Environmental damage can also occur.Use the following procedure for further information. Refer to Procedure 006-999 in Section F.

Setup

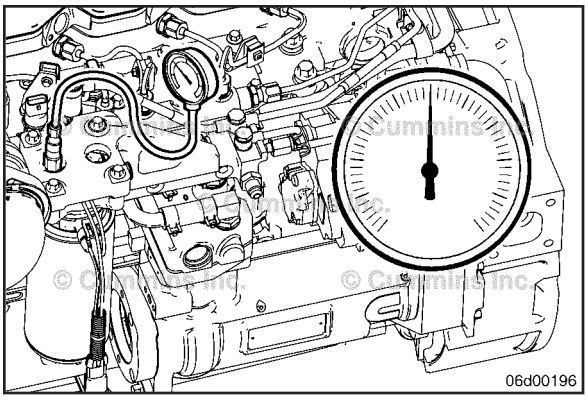
With Fuel Filter Diagnostic Test Ports

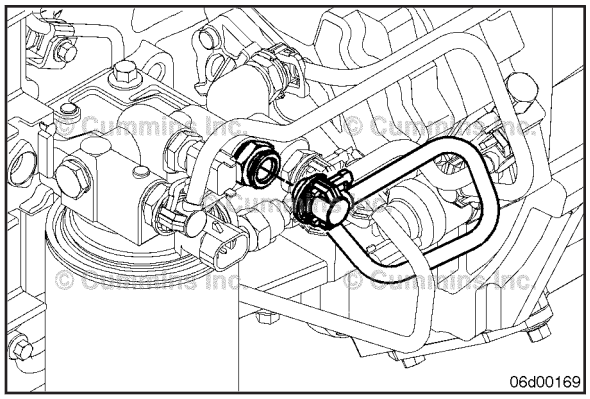
Use the following steps to check the fuel filter restriction to measure the pressure drop across the fuel filter.

NOTE: The fuel inlet and outlet are labeled on fuel filter head using text or arrows. Figures do **not** necessarily display the true orientation of the inlet or outlet of the fuel filter.

Install an M10 male Compuchek™ fitting, Part Number 3824842, on the diagnostic port on the inlet side of the fuel filter.

Connect a fuel pressure gauge to the Compuchek™ fitting.

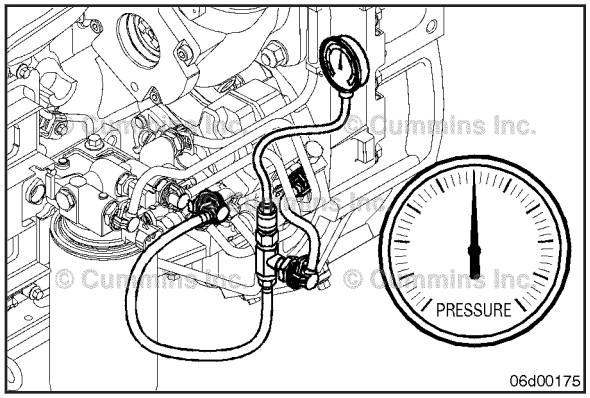




Without Fuel Filter Diagnostic Ports

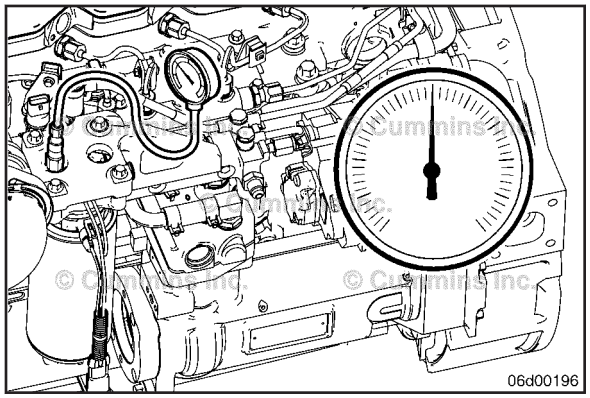
Use the following steps to check the fuel filter restriction to measure the pressure drop across the fuel filter.

Disconnect the gear pump supply line from the fuel filter inlet.



Insert the fuel pressure gauge adapter, Part Number 3164044, between the gear pump supply line and the fuel filter head inlet.

Attach a pressure gauge to the Compuchek™ fitting on the fuel pressure gauge adapter.



Initial Check

With Electric Lift Pump(s)

Measure the fuel pressure at the fuel filter inlet.

NOTE: For marine applications, **open** the fuel inlet and return valves.

Measure the pressure at **high** idle:

Fuel Pressure Range At Fuel Filter Inlet with Electric Lift Pump (Engine Running)		
kPa		**psi**
0	MIN	0
79.9	MAX	11.6

If the engine will **not** start, measure the fuel pressure while cranking the engine:

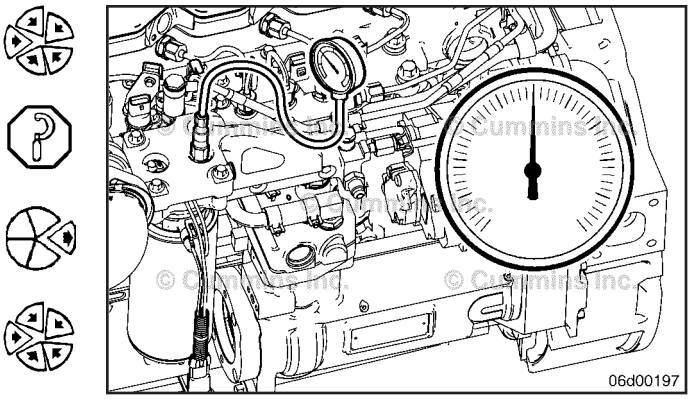
Fuel Pressure Range At Fuel Filter Inlet with Electric Lift Pump (Engine Cranking)		
kPa		**psi**
0	MIN	0
79.9	MAX	11.6

Record the fuel filter inlet pressure.

Install a M10 male Compuchek™ fitting, Part Number 3824842, on the diagnostic port on the outlet side of the fuel filter.

Connect a fuel pressure gauge to the Compuchek™ fitting.

Measure the pressure at **low** idle:



Fuel Pressure Range At Fuel Filter Outlet with Electric Lift Pump (Engine Running)		
kPa		**psi**
0	MIN	0
79.9	MAX	11.6

If the engine will **not** start, measure the fuel pressure while cranking the engine:

Fuel Pressure Range At Fuel Filter Outlet with Electric Lift Pump (Engine Cranking)		
kPa		**psi**
0	MIN	0
79.9	MAX	11.6

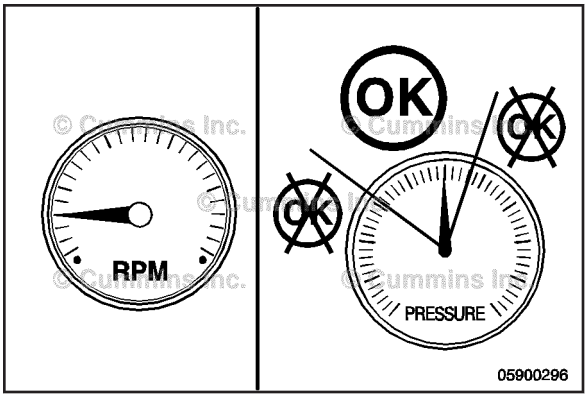
Record the fuel filter outlet pressure value and subtract it from the previously measured fuel filter inlet pressure.

Maximum Pressure Drop Across Fuel Filter		
kPa		**psi**
34	MAX	5

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

Without Electric Lift Pump

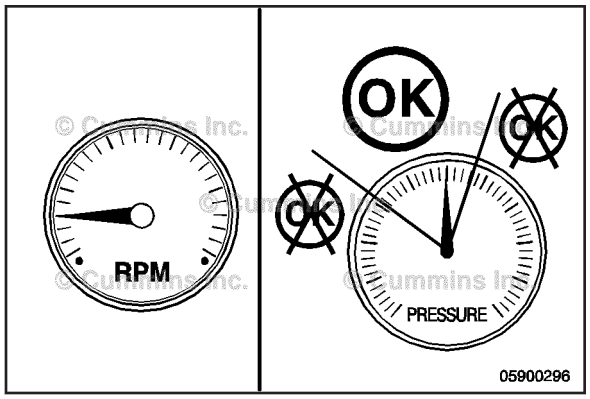
Measure the fuel pressure at **low** idle:



Fuel Pressure Range At Fuel Filter Inlet without Electric Lift Pump (Engine Running)		
kPa		**psi**
503	MIN	73
1303	MAX	189

If the engine will **not** start, measure the fuel pressure at the fuel filter inlet (engine cranking).

Fuel Pressure Range At Fuel Filter Inlet without Electric Lift Pump (Engine Cranking)		
kPa		**psi**
303	MIN	44
1103	MAX	160



If the fuel pressure is below the minimum at the inlet side of the filter:

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

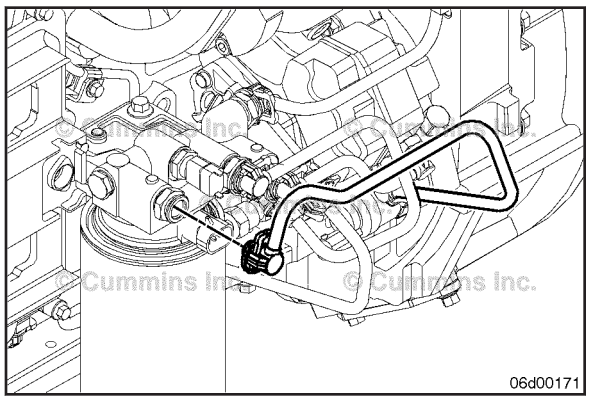
2 For engines with an electric lift pump, check for a malfunctioning electric lift pump. Refer to Procedure 005-045 in Section 5.

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

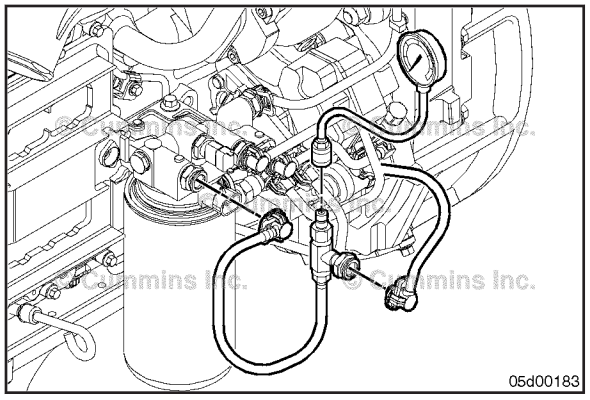
4 For engines without an electric lift pump, check for a damaged gear pump. Refer to Procedure 005-016 in Section 5.

Reconnect the fuel lines.

Record the fuel filter inlet pressure measured.

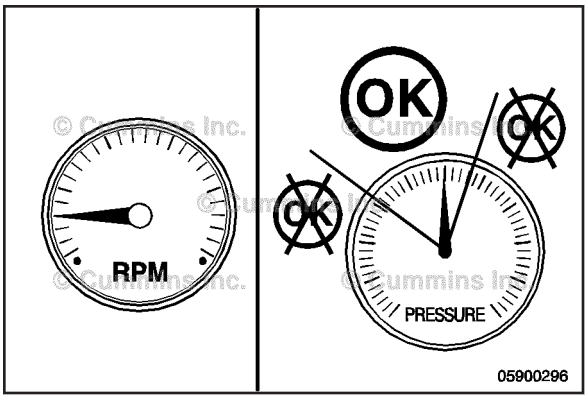


Disconnect the high pressure pump inlet from the fuel filter exit.



Insert the fuel pressure gauge adapter, Part Number 3164044, between the high pressure pump inlet line and the fuel filter outlet.

Measure the fuel outlet pressure at **low** idle.

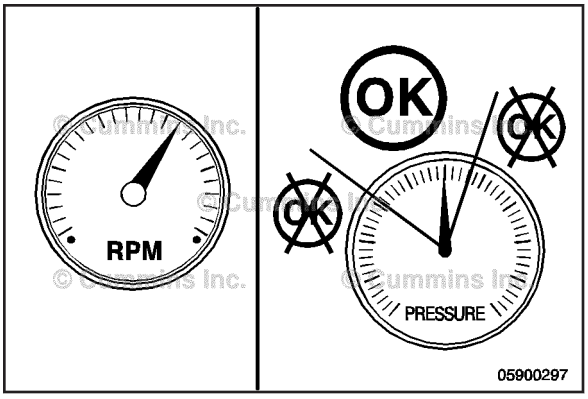


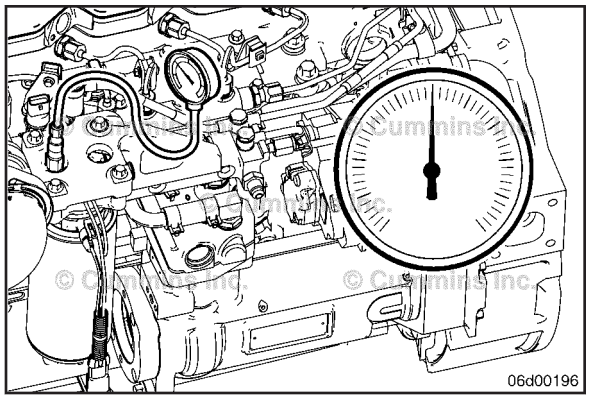
Fuel Pressure Range At Fuel Filter Outlet without Electric Lift Pump (Engine Running)		
kPa		**psi**
503	MIN	73
1303	MAX	189

Record the fuel filter outlet pressure and subtract it from the fuel filter inlet pressure.

Maximum Pressure Drop Across Fuel Filter		
kPa		**psi**
200	MAX	29

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





Marine Applications

NOTE: For marine application engines, the lift pump outlet pressure to the filter is measured at the diagnostic port on the inlet side of the fuel filter head. Refer to Procedure 005-045 in Section 5.

To check the fuel filter restriction, measure the pressure drop across the fuel filter using the following steps.

Install an M10 male Compuchek™ fitting, Part Number 3824842, on the diagnostic port on the inlet side of the fuel filter.

Connect a fuel pressure gauge to the Compuchek™ fitting.

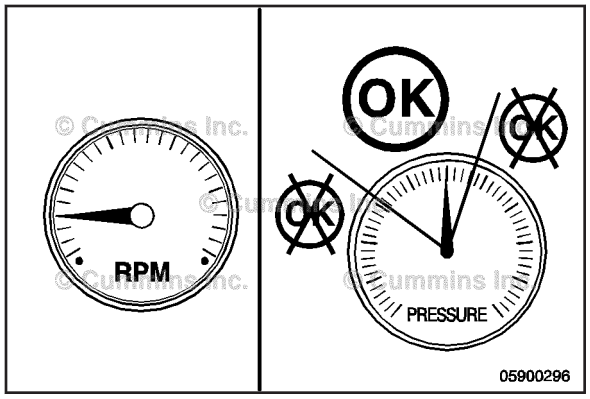
Measure the pressure at high idle:

Fuel Pressure Range At Fuel Filter Inlet (Engine Running)		
kPa		**psi**
0	MIN	0
79.9	MAX	11.6

If the engine will **not** start, measure the fuel pressure while cranking the engine:

Fuel Pressure Range At Fuel Filter Inlet (Engine Cranking)		
kPa		**psi**
0	MIN	0
79.9	MAX	11.6

Record the fuel filter inlet pressure measured.

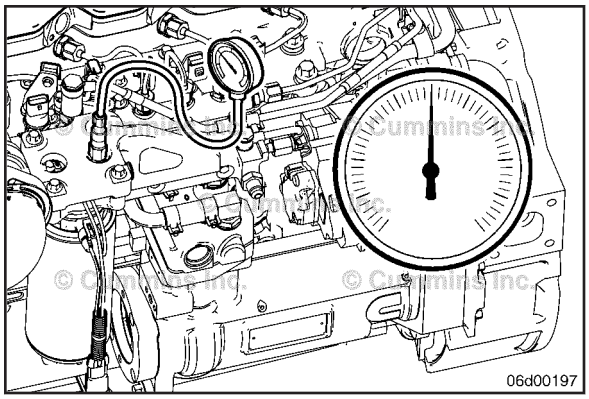


If the fuel pressure is below the minimum at the inlet side of the filter, the electric lift pump can be damaged or inlet restriction can be too high. Refer to Procedure 005-045 in Section 5. Refer to Procedure 006-020 in Section 6.

Install an M10 Compuchek™ fitting, Part Number 3824842, on the diagnostic port on the outlet side of the fuel filter.

Connect a fuel pressure gauge to the quick-disconnect fitting.

Measure the pressure at low idle:



Fuel Pressure Range At Fuel Filter Inlet (Engine Running)		
kPa		**psi**
0	MIN	0
79.9	MAX	11.6

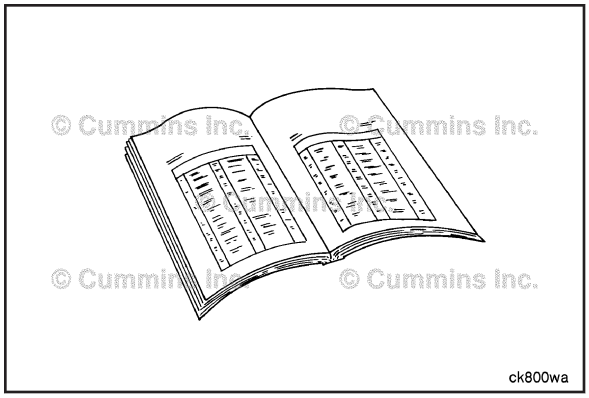
Record the fuel filter outlet pressure value and subtract it from the previously measured fuel filter inlet pressure.

Fuel Pressure Drop Across Fuel Filter		
kPa		**psi**
34	MAX	5

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

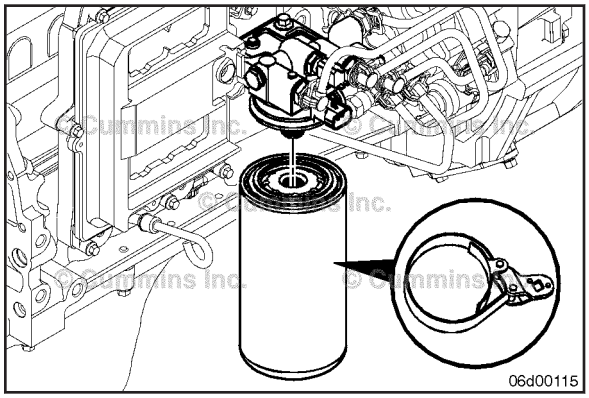
Remove

NOTE: For marine applications, shut off fuel supply to engine.



⚠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.

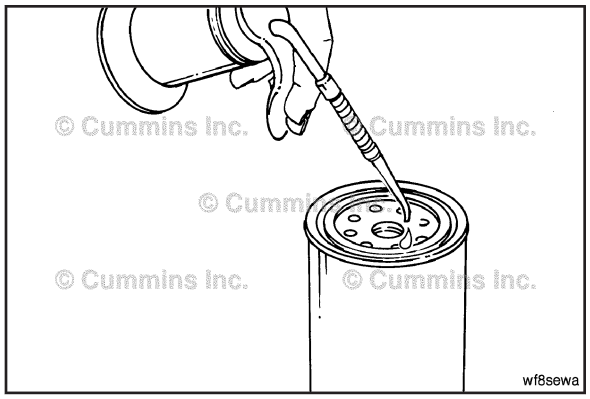
△CAUTION△
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system, so that fuel is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The fuel and fuel filters must be discarded in accordance with local environmental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



Loosen and remove the fuel filter.

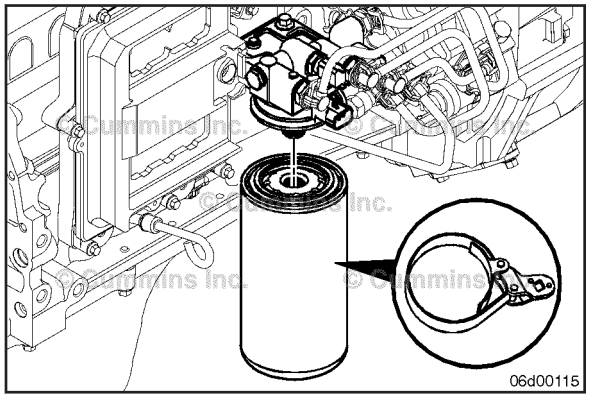
Make sure the seal ring does **not** stick to the fuel filter head.

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



Install

Lubricate the o-ring seal with clean lubricating oil.



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

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

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

Use the following procedure for the correct fuel filter part number. Refer to Procedure 018-024 in Section V.

Install the filter on the filter head. Tighten the filter until the gasket contacts the filter head surface.

Tighten the fuel filter an additional ¾ turn after contact or follow filter manufacturer instructions.

Torque Value: 23 N•m [17 ft-lb]

NOTE: For marine applications, **open** the fuel inlet and return valves.

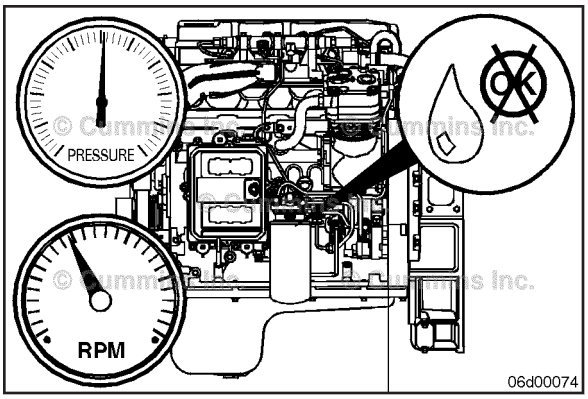
Prime

With Electric Lift Pump(s)

⚠WARNING⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

⚠WARNING⚠
Be sure that the fuel inlet and return valves are returned to the open position before cranking the engine. Engine damage can result if valves are in the wrong position when the engine is cranked or started. Environmental damage can also occur. Use the following procedure for further information. Refer to Procedure 006-999 in Section F.

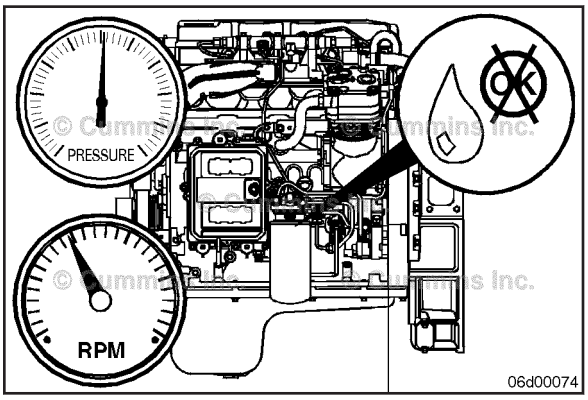
⚠CAUTION⚠
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system that fuel is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The fuel and fuel filters must be discarded in accordance with local environmental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

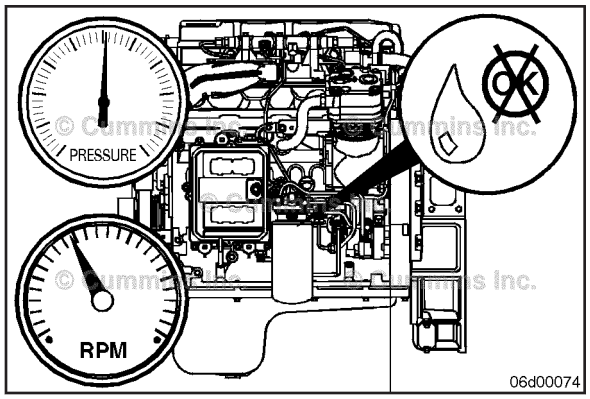


Allow the lift pump to run by turning the keyswitch ON and waiting 30 seconds before starting.

NOTE: It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will prime the fuel system.

Operate the engine and check for leaks.



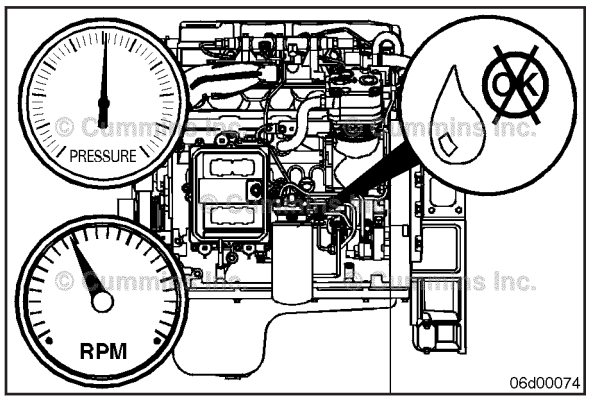


Without Electric Lift Pump

⚠WARNING⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

⚠WARNING⚠
Be sure that the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when the engine is cranked or started. Environmental damage can also occur.Use the following procedure for further information. Refer to Procedure 006-999 in Section F.

△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.



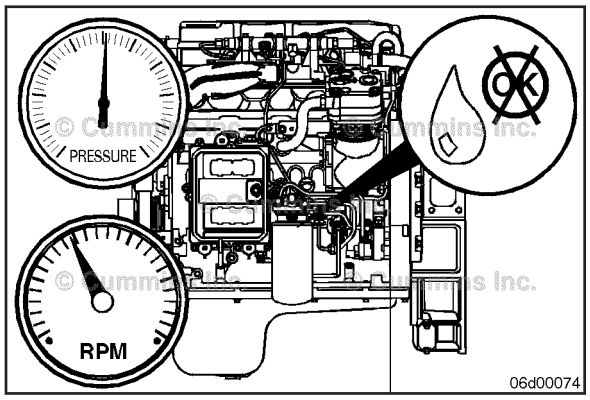
NOTE: To prevent damage to the hand pump priming seals, clean the fuel pump head and priming pump with Quick Dry Spray Cleaner, Part Number 3824510 or equivalent, and compressed air prior to priming the fuel system.

After Filter Change:

Primary Method:

Unlock the manual priming pump handle by turning it counterclockwise. Pump the primer handle until resistance is felt (approximately 140-150 strokes for dry filters, or 20 to 60 strokes for pre-filled filters).

Lock the manual priming pump handle and crank the engine.



Alternative method:

Unlock the manual priming pump handle by turning it counterclockwise. Pump the primer handle 60 times. Lock the manual priming pump handle and crank the engine. Start should occur within approximately 20 seconds.

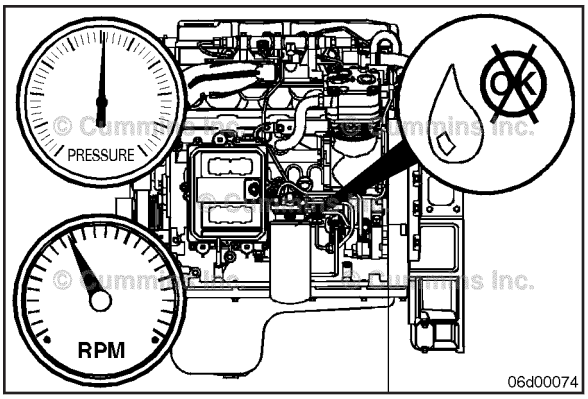
NOTE: Do **not** exceed starter cranking limitations.

After Running the Vehicle Tank Dry:

Be sure there is fuel in the vehicle fuel tank. Unlock the manual priming pump handle by turning it **counterclockwise**. Pump the primer until resistance is felt (50-60) strokes. Lock the manual priming pump handle and crank the engine. Start should occur within 5 seconds.

NOTE: It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will prime the fuel system.

Operate the engine and check for leaks.



Marine Applications

⚠WARNING⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

△CAUTION△
Failure to open the fuel return valve will result in damage to the fuel cooler. Be sure that both the fuel supply and return valves are open. Be sure that there is an unrestricted flow of fuel back to the fuel tank prior to cycling the keyswitch to prime the fuel system.

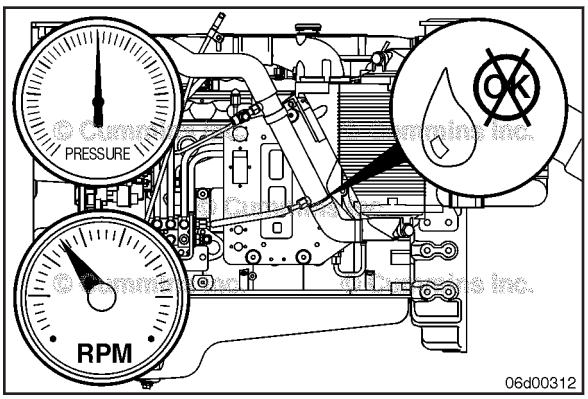
△CAUTION△
To avoid damage to the fuel system, do not vent air from the high-pressure fuel system before starting the engine. It is not necessary to pre-fill the on-engine fuel filter before installation. Cycling the keyswitch several times and cranking the engine will fill the fuel filter and prime the fuel system.

Open the fuel supply and return valves to the engine. Refer to the OEM service manual.

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

Priming the fuel system requires cycling the keyswitch several (5 or more) times to make sure the fuel filter is primed properly and that all the air is out of the fuel system down stream through the fuel cooler.

Operate the engine and check for leaks.



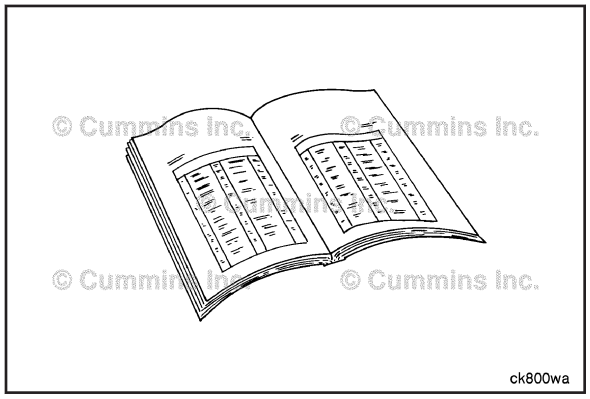
Fuel Filter Head (006-017)

General Information

Due to the number of different fuel filter head designs and mounting locations, the steps in this procedure have been written to be generic. Some of the illustrations may **not** represent the parts being removed or installed.

NOTE: Fuel filter may be remotely mounted off of the engine.

⚠WARNING⚠
Be sure that the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when the engine is cranked or started. Environmental damage can also occur. Refer to Procedure 006-999 (Familiarization section) for further information.



Preparatory Steps

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

⚠WARNING⚠
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: On marine applications, 90 degree STOR connectors are used to connect the fuel lines to the fuel filter head.

NOTE: Fuel filter may be remotely mounted off of the engine.

Disconnect the fuel filter head supply and drain line connectors.

Refer to Procedure 006-024 and Procedure 006-013.

NOTE: On Marine applications it will be necessary to remove the oil filter outlet line in order to remove the fuel filter outlet line and fitting. Refer to Procedure 007-092.

Remove the fuel filter. Refer to Procedure 006-015.

Disconnect the fuel heater connector, if applicable.

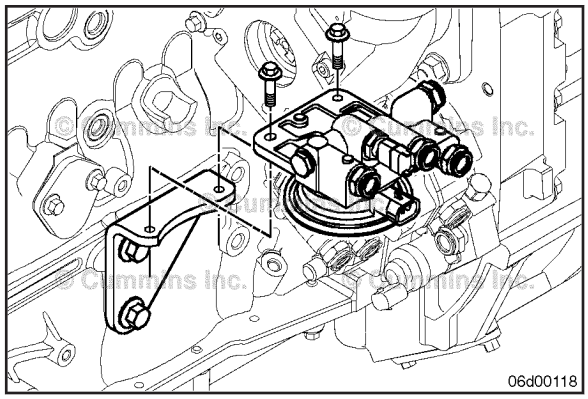
Remove

Low Mount Fuel Filter

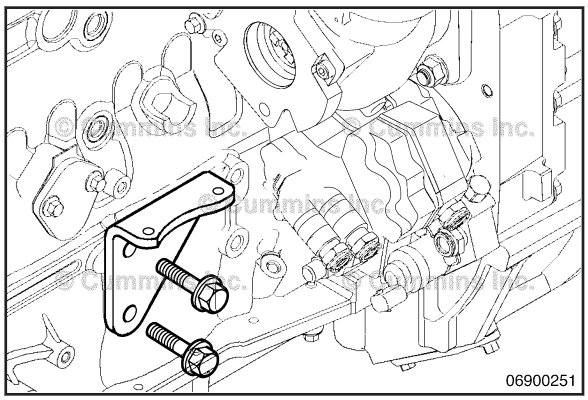
NOTE: The fuel filter head and fuel filter head bracket may be one piece.

Remove the fuel filter head bracket capscrews.

Remove the fuel filter head.



Remove the capscrews holding the fuel filter head bracket in place.

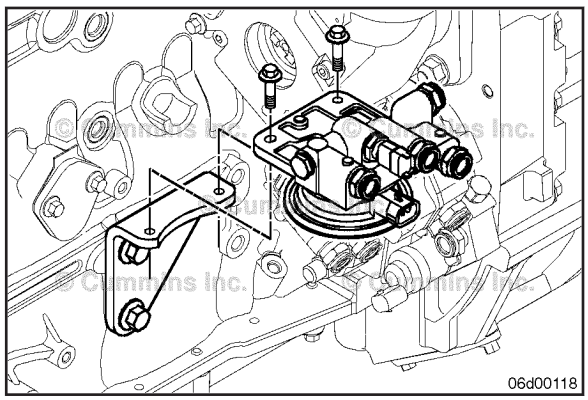


High Mount Fuel Filter

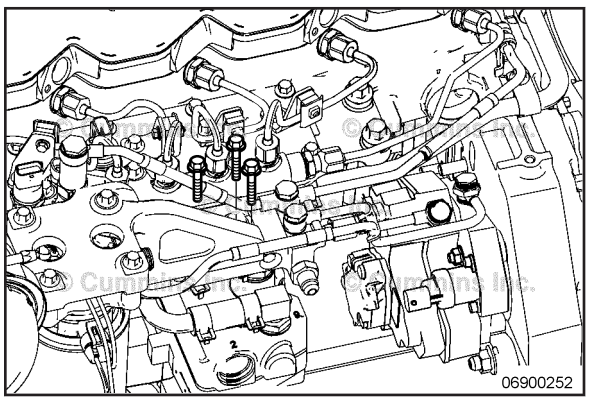
NOTE: The fuel filter head and fuel filter head bracket may be one piece.

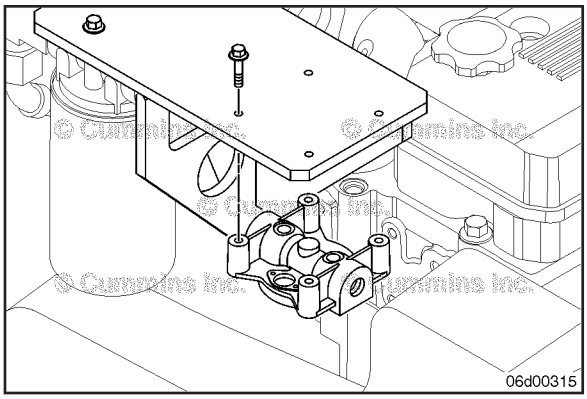
Remove the fuel filter head bracket capscrews.

Remove the fuel filter head.



Remove the capscrews holding the fuel filter head bracket in place.

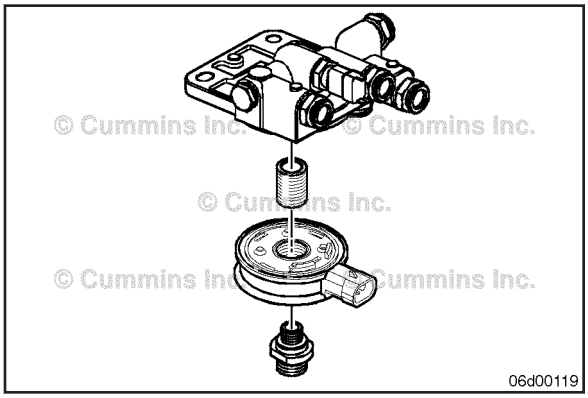




Marine Applications

NOTE: The filter head is marked with an IN and OUT for the line connections. Be sure to note the direction of the markings as the filter head is removed to be sure the filter head is **not** installed backwards and the lines are not connected in reverse during installation.

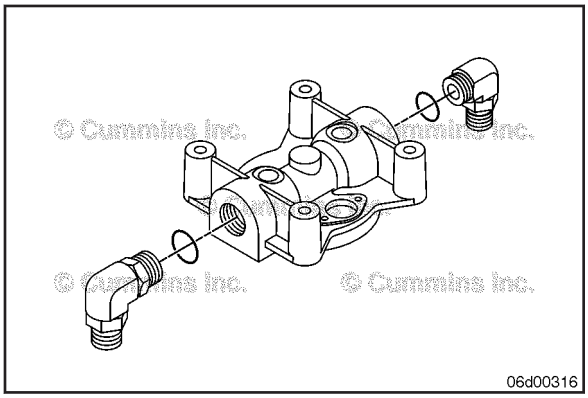
Remove the four mounting capscrews and the fuel filter head.



Disassemble

Automotive and Industrial

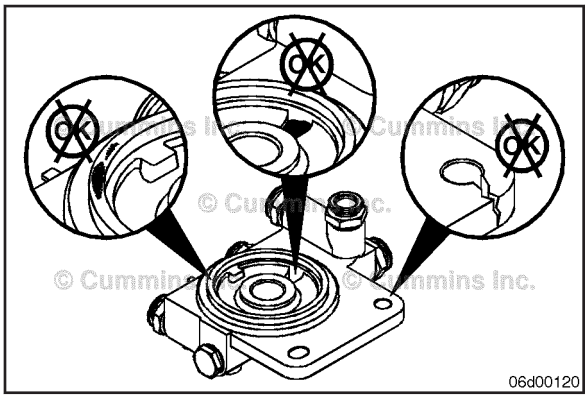
Remove the fuel heater, if equipped. Refer to Procedure 005-008.



Marine Applications

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

Remove the 90-degree straight thread o-ring connector.



Clean and Inspect for Reuse

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

Assemble

Automotive and Industrial

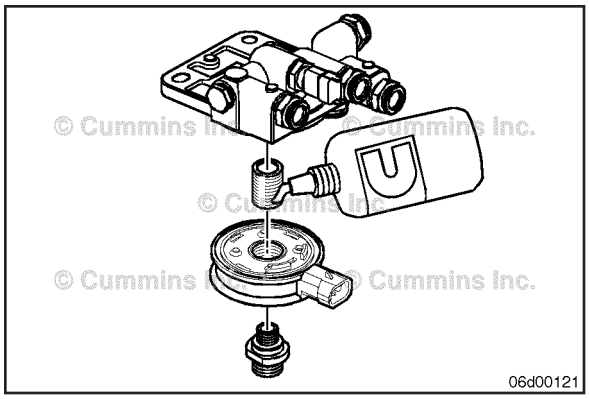
Apply Loctite™ 648 sealant, or equivalent, to the filter adapter threads that are engaging the fuel filter head **only**.

Assemble the filter head.

Install the fuel filter adapter and fuel heater.

Torque Value: 30 N•m [22 ft-lb]

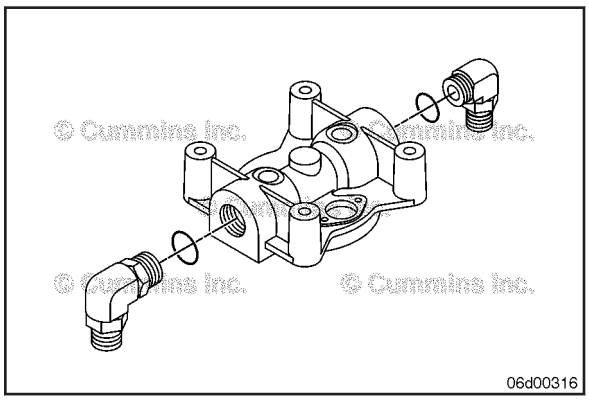
NOTE: Make sure there is an o-ring between the fuel filter head and heater.



Marine Applications

Use new compression seal rings and install the 90-degree straight thread o-ring elbow in the inlet port of the fuel filter head.

Use new compression seal rings and install the 90-degree straight thread o-ring elbow in the outlet port of the fuel filter head.



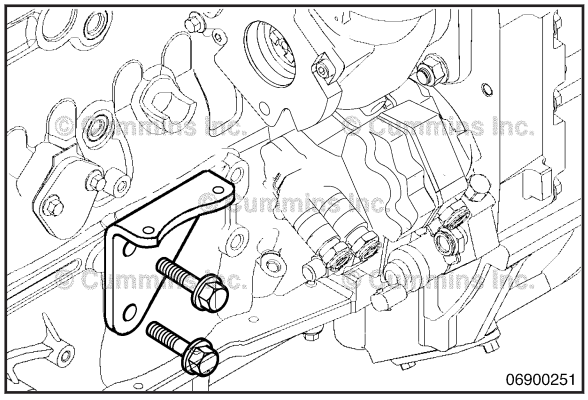
Install

Low Mount Fuel Filter

Install the fuel filter head bracket.

Install the fuel filter head bracket capscrews.

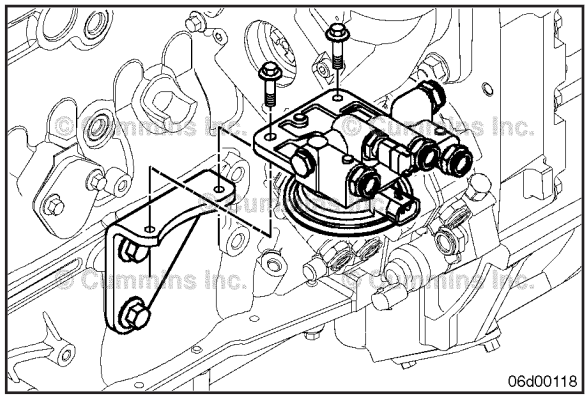
Torque Value: 24 N•m [212 in-lb]

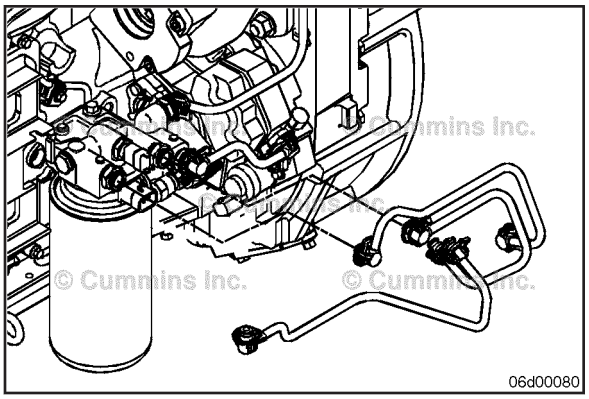


Install the fuel filter head.

Install the fuel filter head capscrews.

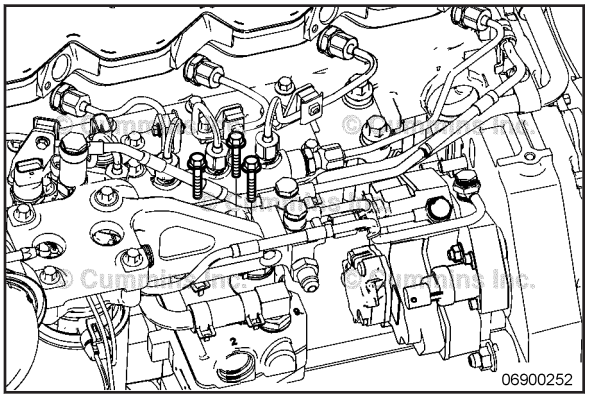
Torque Value: 24 N•m [212 in-lb]





Install the fuel filter. Refer to Procedure 006-015.

Install fuel supply and drain lines. Refer to Procedure 006-024.

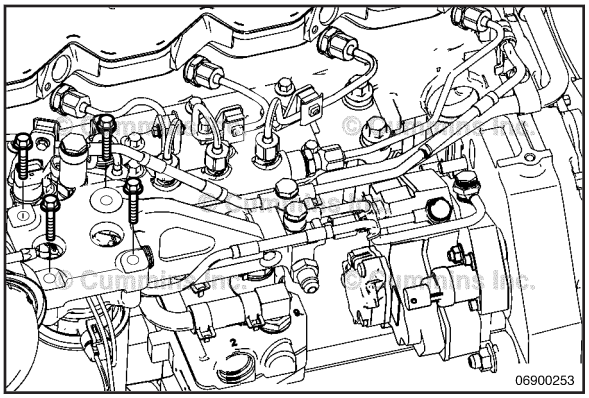


High Mount Fuel Filter

Install the fuel filter head bracket.

Install the fuel filter head bracket capscrews.

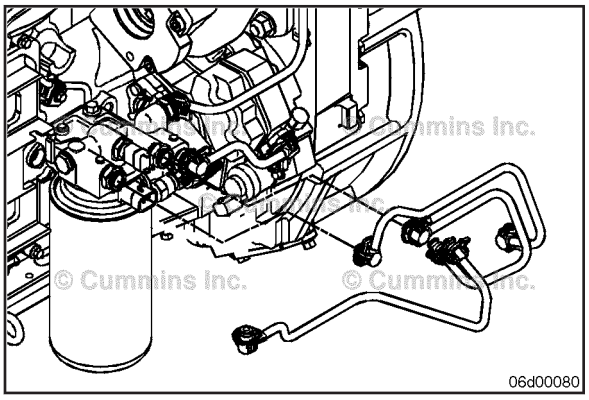
Torque Value: 24 N•m [212 in-lb]



Install the fuel filter head.

Install the fuel filter head capscrews.

Torque Value: 24 N•m [212 in-lb]



Install the fuel filter. Refer to Procedure 006-015.

Install fuel supply and drain lines. Refer to Procedure 006-024.

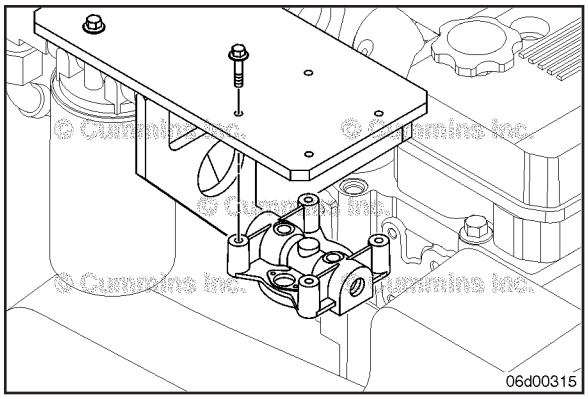
Marine Applications

NOTE: The filter head is marked with an IN and OUT for the line connections. Be sure the filter head is installed in the same direction as it was removed.

Install the fuel filter head.

Tighten the retaining capscrews.

Torque Value: 30 N•m [25 ft-lb]



Prime

With Electric Lift Pump

⚠WARNING⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

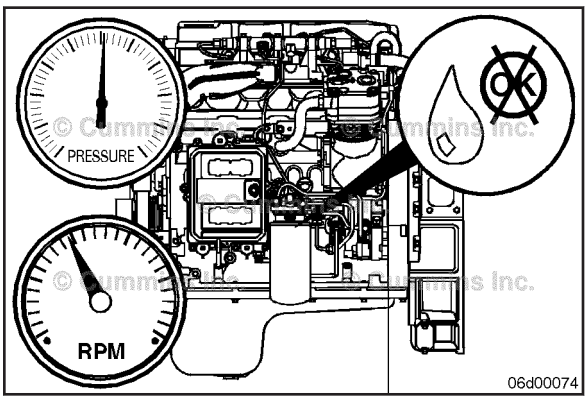
⚠WARNING⚠
Be sure that the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when the engine is cranked or started. Environmental damage can also occur. Refer to Procedure 006-999 in Familiarization section for further information.

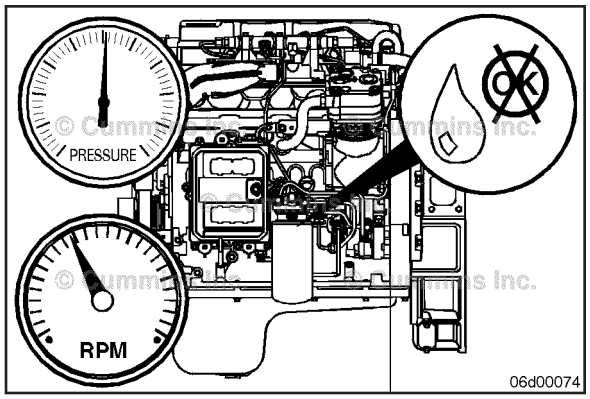
⚠CAUTION⚠
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system that fuel is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The fuel and fuel filters must be discarded in accordance with local environmental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

Allow the lift pump to run by turning the keyswitch ON and waiting 30 seconds before starting.

NOTE: It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will prime the fuel system.

Operate the engine and check for leaks.





Without Electric Lift Pump

⚠WARNING⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

⚠WARNING⚠
Be sure that the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when the engine is cranked or started. Environmental damage can also occur. Refer to Procedure 006-999 in Familiarization section for further information.

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

After Filter Change:

Primary Method:

Unlock the manual priming pump handle by turning counterclockwise. Pump the primer handle until resistance is felt (approximately 140-150 strokes). Lock the manual priming pump handle and crank the engine. Start should occur within 5 seconds.

NOTE: Do **not** fill new filters with fuel prior to assembly as this will allow unfiltered fuel to enter the system and may cause damage to fuel system components.

Alternative method:

Unlock the manual priming pump handle by turning counterclockwise. Pump the primer handle 60 times. Lock manual priming pump handle and crank the engine. Start should occur within approximately 20 seconds.

NOTE: Do **not** exceed starter cranking limitations.

After Running the Vehicle Tank Dry:

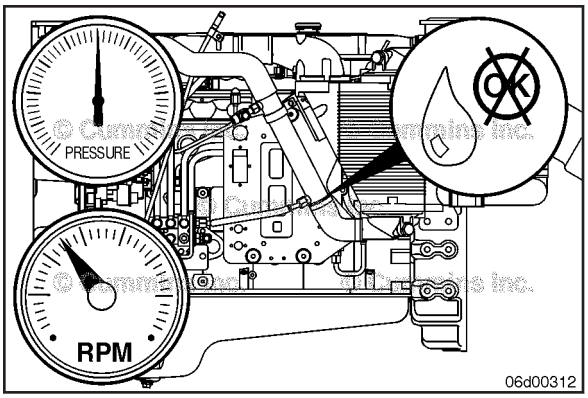
Ensure there is fuel in the vehicle fuel tank. Unlock the manual priming pump handle by turning it counter-clockwise. Pump the primer until resistance is felt (50-60) strokes. Lock manual priming pump handle and crank the engine. Start should occur within 5 seconds.

NOTE: Do **not** remove and fill filters with fuel prior to priming the system in an attempt to reduce priming time as this will allow unfiltered fuel to enter the system and may cause damage to fuel system components.

NOTE: It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will prime the fuel system.

Operate the engine and check for leaks.

Marine Applications



⚠WARNING⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

⚠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.

NOTE: It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cycling the keyswitch several times and cranking the engine will prime the fuel system.

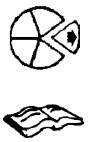
NOTE: It is **not** necessary to pre-fill the on-engine fuel filter.

Priming the fuel system requires cycling the keyswitch several (5 or more) times to make sure the fuel filter is primed properly and that all the air is out of the fuel system down stream through the fuel cooler.

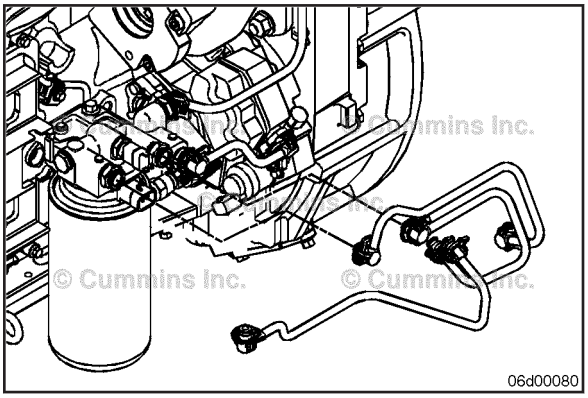
Operate the engine and check for leaks.

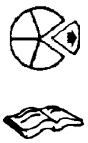
Fuel Filter Head Bracket (006-018)

Remove



Remove the fuel supply and return line connectors. Refer to Procedure 006-024

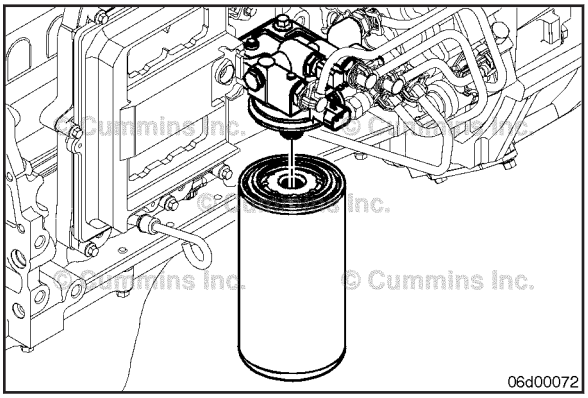


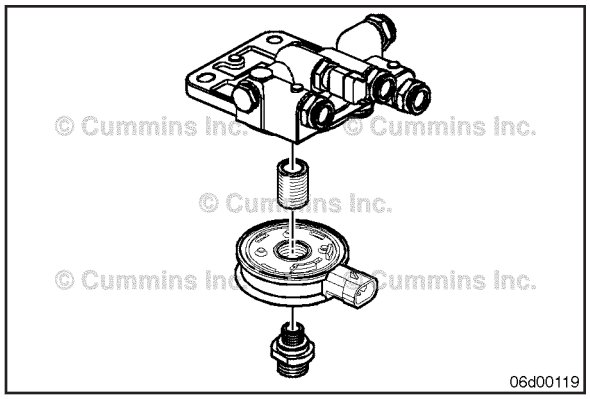


Remove the fuel filter. Refer to Procedure 006-015

Disconnect the fuel heater connector, if applicable.

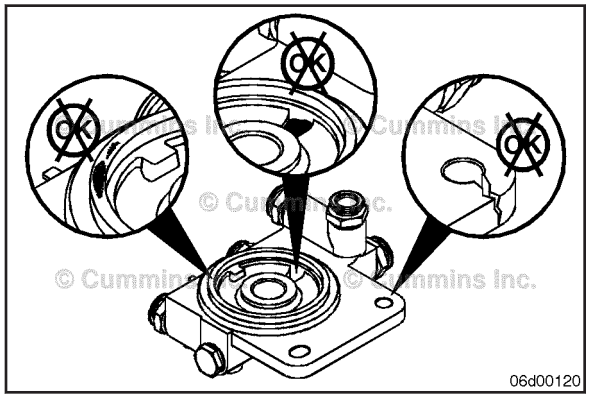
Remove the fuel filter bracket capscrews.





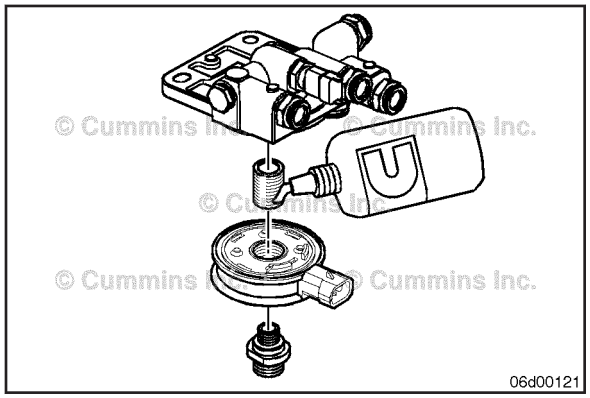
Disassemble

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



Inspect for Reuse

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



Assemble

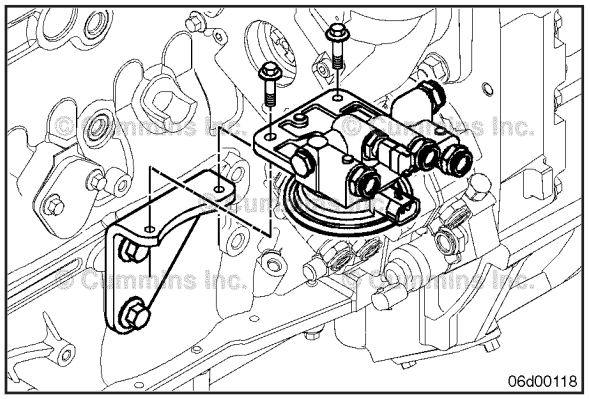
Apply Loctite 648, or equivalent, to the filter adapter threads that are engaging the filter head **only**

Assemble the filter head.

Install the filter adapter and fuel heater.

Torque Value: 30 N•m [22 ft-lb]

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



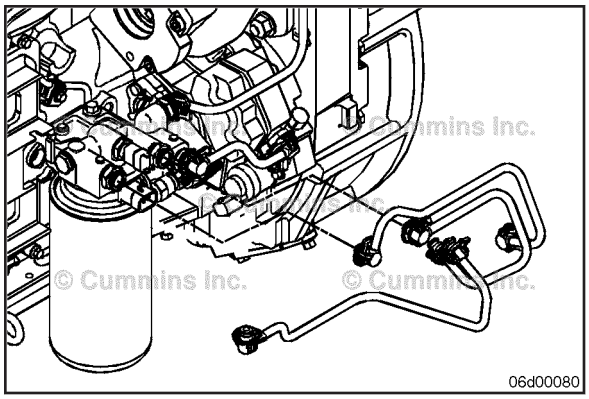
Install

Install the filter head bracket. Tighten the retaining capscrews.

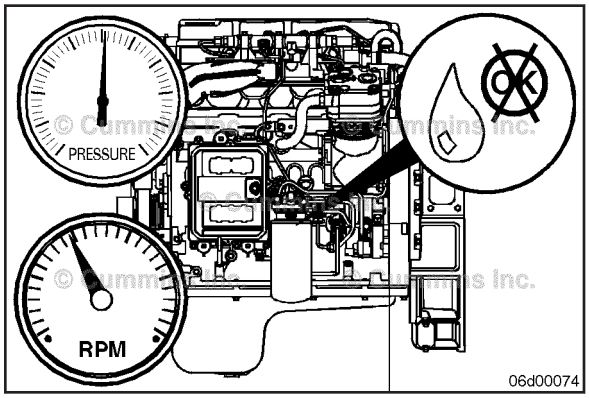
Torque Value: 24 N•m [212 in-lb]

Install the fuel filter. Refer to Procedure 006-015

Install fuel return and supply lines. Refer to Procedure 006-024



Run the engine and check for leaks.



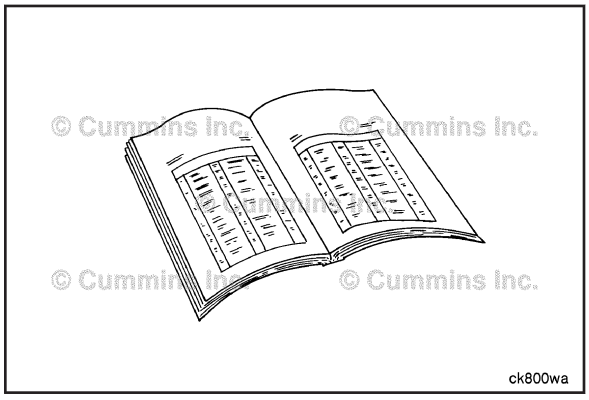
Fuel Manifold (Combined) (006-019)

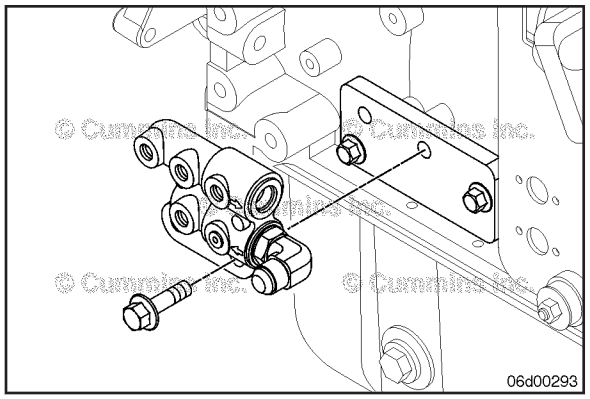
Preparatory Steps

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

⚠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.

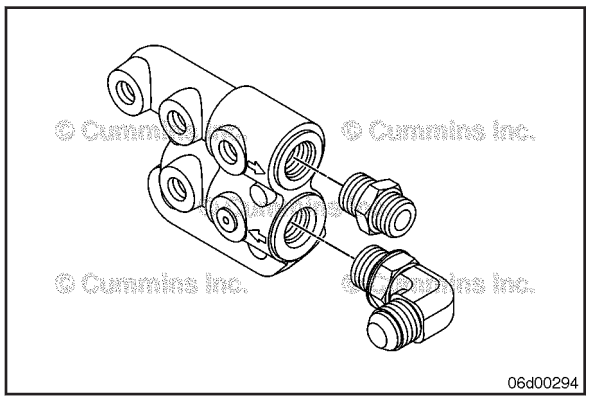
- Shut off the fuel supply and return lines.
- Disconnect the fuel drain lines at the combined fuel manifold. Refer to Procedure 006-013
- Disconnect the fuel supply lines at the combined fuel manifold. Refer to Procedure 006-024





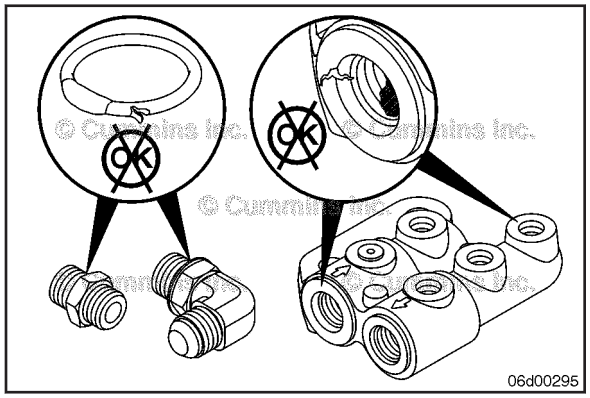
Remove

Remove the two mounting capscrews and the combined fuel manifold.



Disassemble

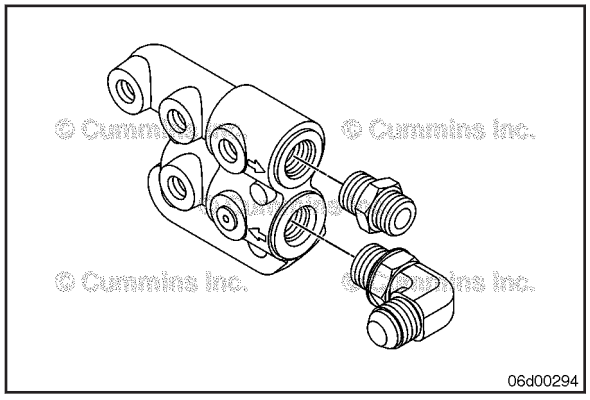
Remove the fittings from the combined fuel manifold.



Inspect for Reuse

Inspect the manifold for cracks, passage blockage, and material or debris on the sealing surfaces.

Inspect the o-rings on the fittings for cuts or damage.



Assembly

NOTE: Arrows mark the inlet and outlet of the combined fuel manifold.

Use new seal rings and install the 90-degree elbow in the inlet port of the manifold. Align the elbow and tighten the locknut.

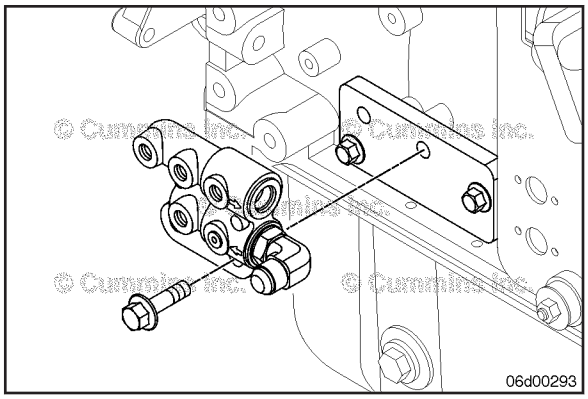
Use new seal rings and install the straight thread o-ring fitting in the outlet port of the fitting.

Install

Use two capscrews and install the combined fuel manifold to the engine.

Tighten the capscrews.

Torque Value: 77 N•m [57 ft-lb]

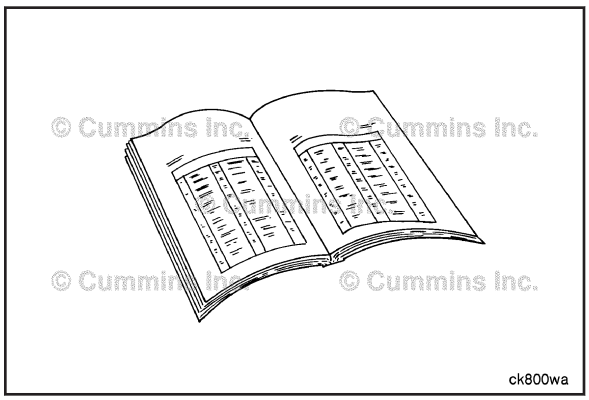


Finishing Steps

⚠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 lines at the combined fuel manifold. Refer to Procedure 006-013
- Connect the fuel supply lines at the combined fuel manifold. Refer to Procedure 006-024
- Open the fuel supply and return lines.
- Prime the fuel system. Refer to Procedure 005-016

Operate the engine and check for leaks.



Fuel Inlet Restriction (006-020)

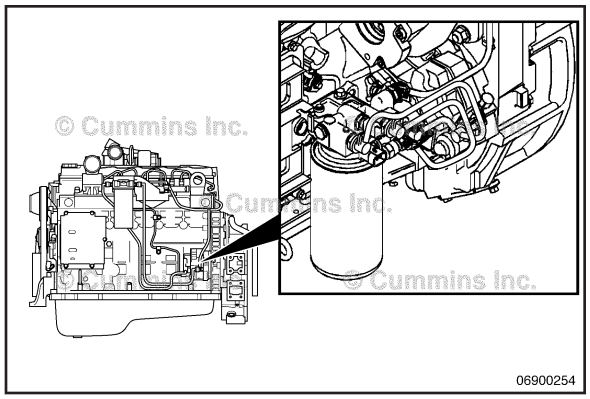
General Information

⚠WARNING⚠
Depending on the circumstances, 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⚠
Drain the fuel into a container, and dispose of contents in accordance with local environmental regulations.

⚠CAUTION⚠
Be sure that the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when engine is cranked or started. Environmental damage can also occur.

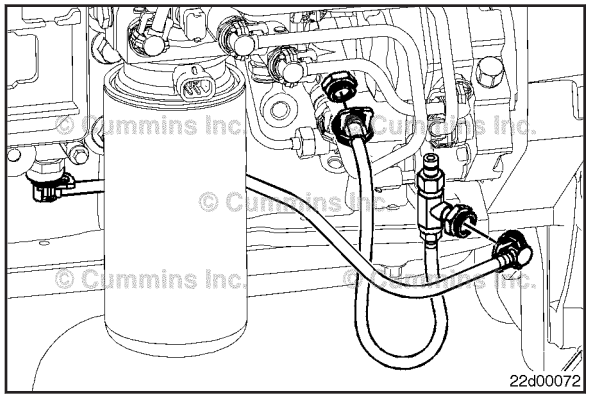
Drain the fuel into a container. Refer to Procedure 006-999 in the Familiarization section for further information.



Setup

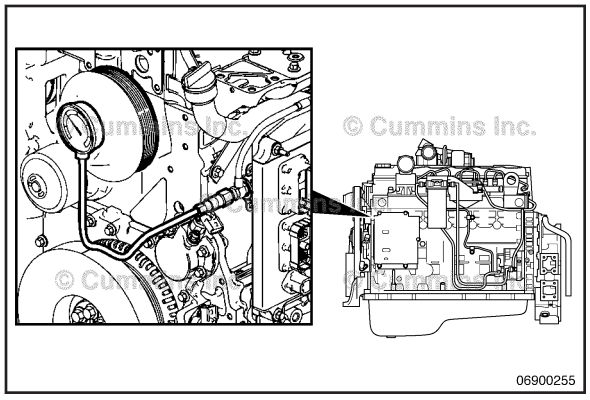
NOTE: If quick-disconnect fittings have a white tang, push the white tang in to release the line.

Disconnect the fuel line from the electronic control module (ECM) cooler exit port.

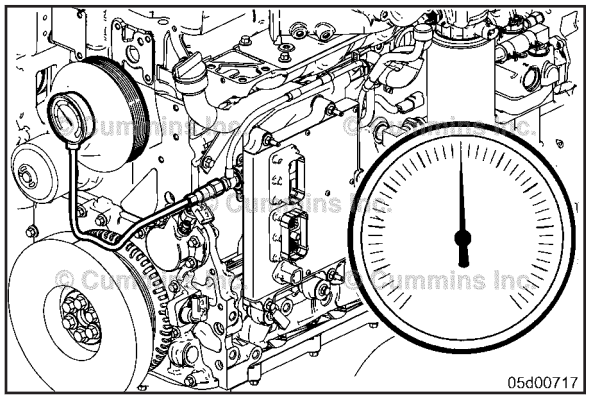


Install a fuel pressure gauge adapter, Part Number 3164044, between the cooling plate and the inlet to the gear pump.

Install a vacuum gauge that has a range of at least 0 to 508.0 mm-Hg [0 to 20 in-Hg].



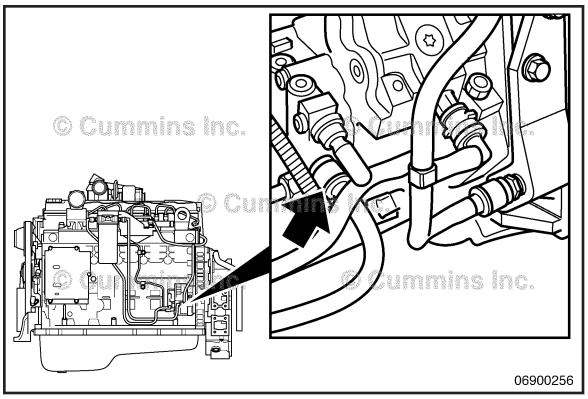
Remove the banjo bolt on the inlet to the lift pump.



Install an M12 x 1/8 inch NPT banjo bolt, Part Number 4918413.

Install a vacuum gauge into the back of this banjo bolt.

Remove the banjo bolt from the inlet to the gear pump.

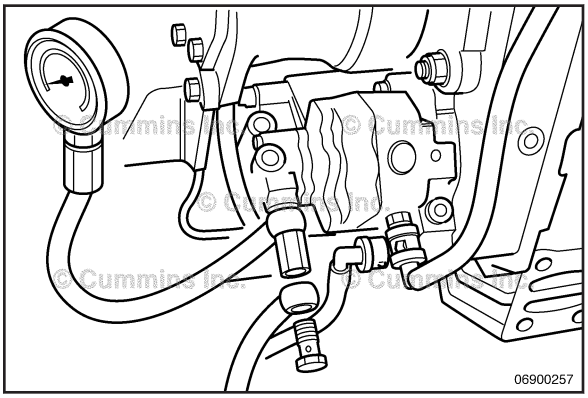


Measurement of the fuel inlet restriction requires the use of a pressure gauge adapter kit, Part Number 4918324.

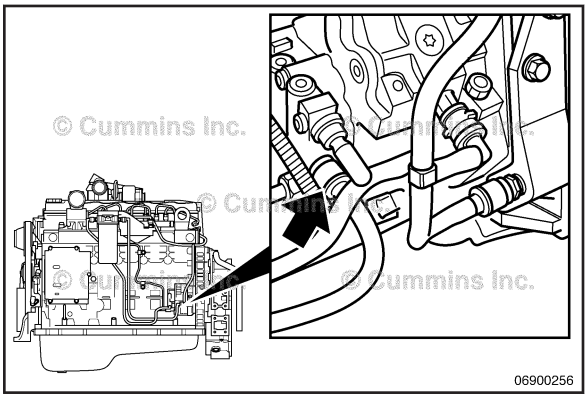
Install the M12 male x M12 female adapter, contained in the pressure gauge adapter kit, through the banjo fitting on the inlet to the gear pump.

Install the original banjo bolt contained in the pressure gauge adapter kit, through the banjo fitting on the pressure gauge hose, and into the M12 male x M12 female adapter.

Install a vacuum gauge that has a range of at least 0 to 508.0 mm-Hg [0 to 20 in-Hg] onto the pressure gauge adapter.

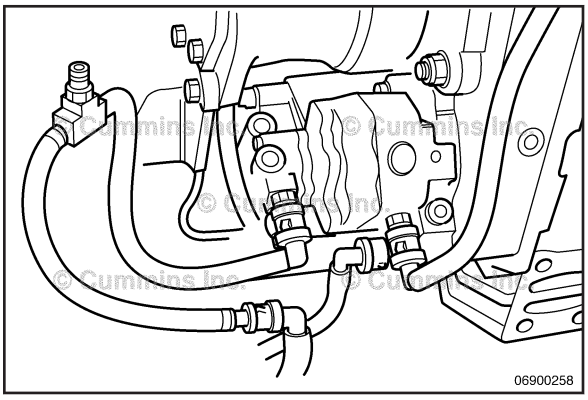


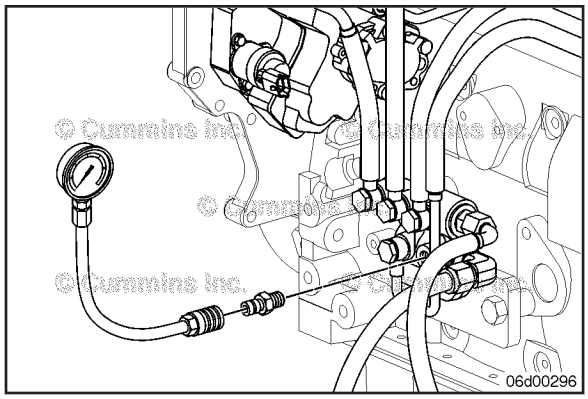
Disconnect the fuel supply line from the inlet to the gear pump.



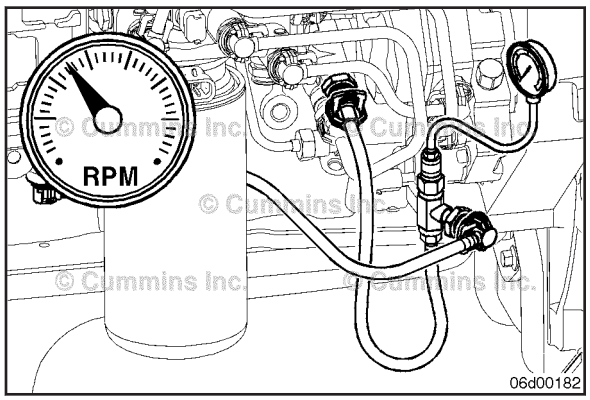
Install a pressure gauge adapter, Part Number 4918462, between the fuel supply line and the inlet to the gear pump.

Install a vacuum gauge that has a range of at least 0 to 508.0 mm-Hg [0 to 20 in-Hg] onto the pressure gauge adapter.





Remove a plug in the portion of the combined fuel manifold and install a Compucheck® vacuum gauge fitting, Part Number 3824842, with a range of at least 0 to 508 mm-Hg [0 to 20 in-Hg].



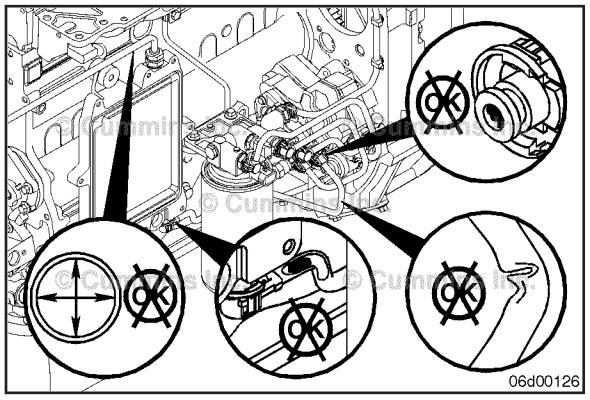
Initial Check

NOTE: For marine applications, open the fuel supply and return valves.

Operate the engine to **high** idle and measure the fuel inlet restriction.

Allowable Fuel Inlet Restriction at High Idle

	kPa		in Hg
Without Electric Lift Pump	50.8	MAX	15.0
With Electric Lift Pump	20.3	MAX	6.0
Marine Applications	13.5	MAX	4.0

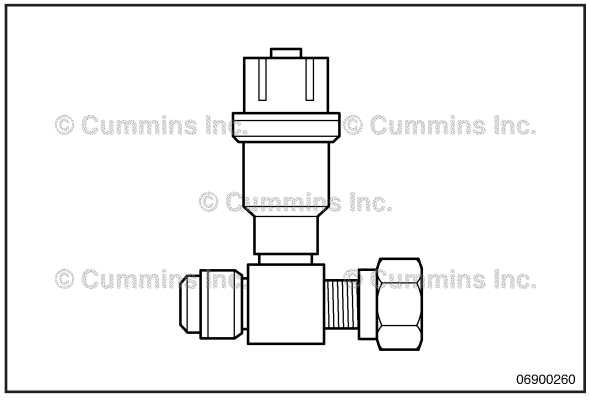


If the fuel inlet restriction is too high, check the original equipment manufacturer (OEM) fuel lines from the tank for proper size; and make certain there are no kinks or bends in the fuel lines and that the fuel lines are **not** clogged.

Make sure there are no clogged fuel strainers, filters, or malfunctioning check valves.

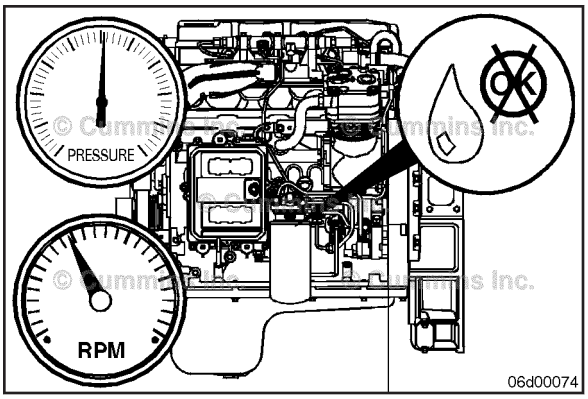
Check the OEM fuel tanks for debris plastic wrappers, paper, etc.) that could intermittently block fuel pickup tubes.

Check the OEM fuel lines for internal damage, such as damaged wall linings, that could intermittently block fuel flow.



If the issue is intermittent and no issues can be found while the engine is being serviced, install a fuel filter minder, Fleetguard® Part Number 3892576s, at the connection between the OEM fuel supply lines and the engine. A fuel filter minder will capture the peak restriction in millimeters and inches of mercury. If the issue occurs again, the fuel filter minder can be checked to see if there is something on the OEM side causing the high restriction.

Prime



⚠WARNING⚠
Depending on the circumstances, 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.

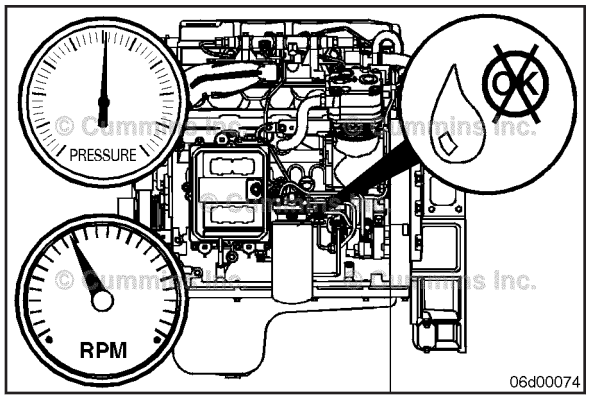
⚠WARNING⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

△CAUTION△
Be sure that the fuel inlet and return valves are returned to the open position before cranking the engine. Engine damage can result if valves are in the wrong position when the engine is cranked or started. Environmental damage can also occur.

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

Allow the lift pump to run by turning the key switch ON and waiting 30 seconds before starting.

Refer to Procedure 006-999 in the Familiarization section for further information.



⚠WARNING⚠
Depending on the circumstances, 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⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

⚠CAUTION⚠
Be sure that the fuel inlet and return valves are returned to the open position before cranking the engine. Engine damage can result if valves are in the wrong position when the engine is cranked or started. Environmental damage can also occur.

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

Refer to Procedure 006-999 in the Familiarization section for further information.

After Filter Change:

Primary Method: Unlock the manual priming pump handle by turning **counter-clockwise**

Pump the primer handle until resistance is felt (approximately 140-150 strokes).

Lock the manual priming pump handle by turning clockwise and crank the engine.

Start should occur within 5 seconds.

NOTE: Do **not** fill new filters with fuel prior to assembly, as this will allow unfiltered fuel to enter the system and may cause damage to fuel system components.

Alternative method:

Unlock the manual priming pump handle by turning counter-clockwise.

Pump the primer handle 60 times.

Lock manual priming pump handle by turning clockwise and crank the engine.

Start should occur within approximately 20 seconds.

NOTE: Do **not** exceed starter cranking limitations.

If the vehicle tank has run dry:

- Add fuel to the fuel tank.
- Unlock the manual priming pump handle by turning it **counterclockwise**
- Pump the primer until resistance is felt (50-60) strokes.
- Lock manual priming pump handle by turning clockwise and crank the engine.
- Start should occur within 5 seconds.

NOTE: Do **not** remove and fill filters with fuel prior to priming the system in an attempt to reduce priming time, as this will allow unfiltered fuel to enter the system and cause damage to fuel system components.

Fuel Supply Lines (006-024)

General Information

Due to the number of different fuel supply line routings and connector styles, the steps in this procedure have been written to be generic. Some of the illustrations may **not** represent the parts being removed or installed.

⚠WARNING⚠
Be sure that the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when engine is cranked or started. Environmental damage can also occur. Refer to Procedure Procedure 005-999 (Fuel System Overview) in Familiarization section for further information.

⚠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.

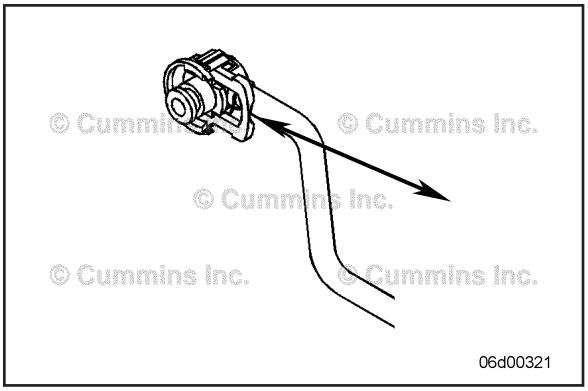
⚠WARNING⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high pressure fuel. To avoid the possibility of personal injury, never loosen any fittings while the engine is running.

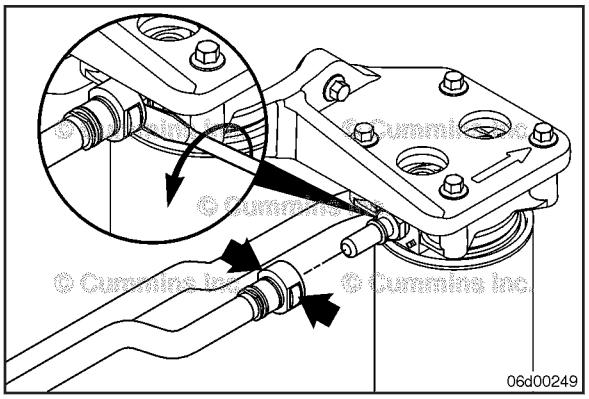
⚠WARNING⚠
Fuel can be returned at highly elevated temperatures. Wear safety glasses, protective gloves, and clothing when performing this test. Avoid any contact with returned fuel.

Directions for service of a white tang quick-disconnect fitting:

Push in white tang to release fuel line.

Pull to lock fuel line.



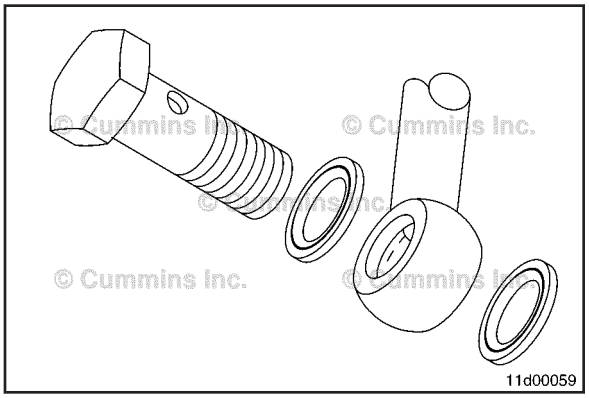


Directions for service of a two-button quick-disconnect fitting:

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

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

Install the quick-disconnect style fuel lines by pushing quick-disconnect fitting onto male union until it clicks.



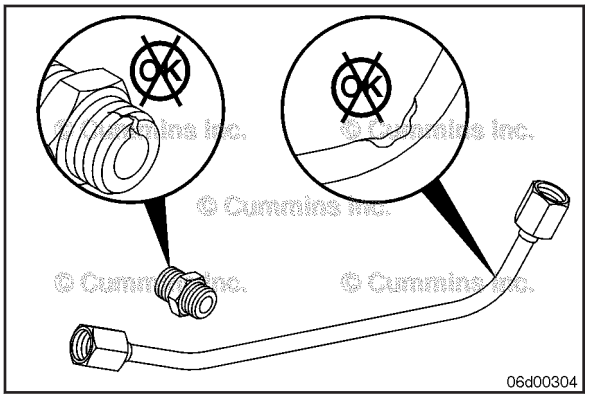
Directions for service of a banjo bolt fitting:

A sealing washer is used on both sides of a banjo fitting.

NOTE: New sealing washers **must** be used when installing the banjo bolt fitting.

Installation:

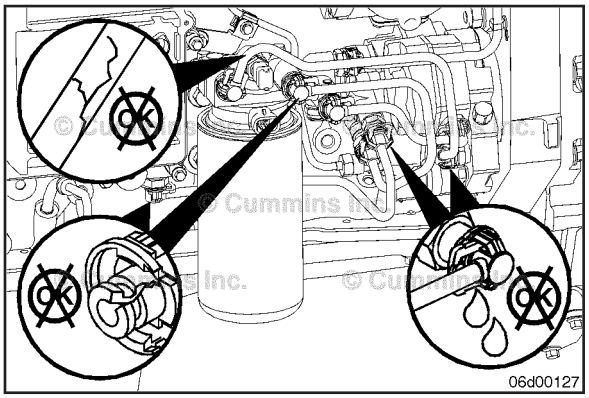
Torque Value: 24 N•m [212 in-lb]



Directions for service of a Straight Thread O-ring fitting:

A sealing o-ring is used to seal the connection.

Torque Value: 37 N•m [27 ft-lb]



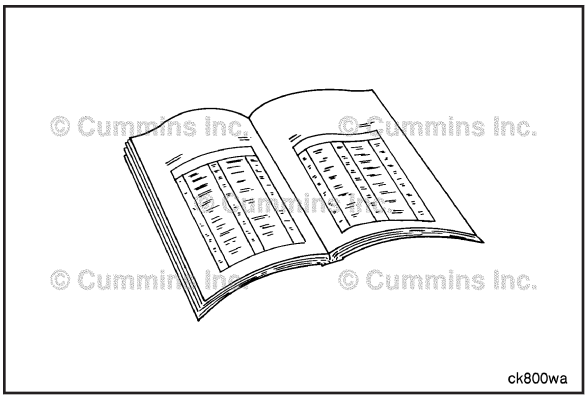
Initial Check

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

Check for loose or broken brackets.

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

Preparatory Steps

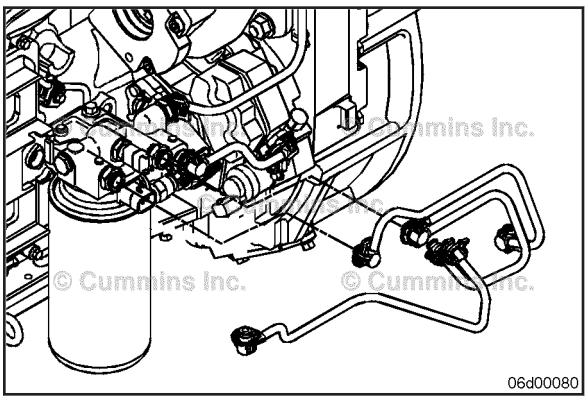


⚠CAUTION⚠
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system that fuel is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The fuel and fuel filters must be discarded in accordance with local environmental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

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

Shut off the fuel supply to the engine.

Remove



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

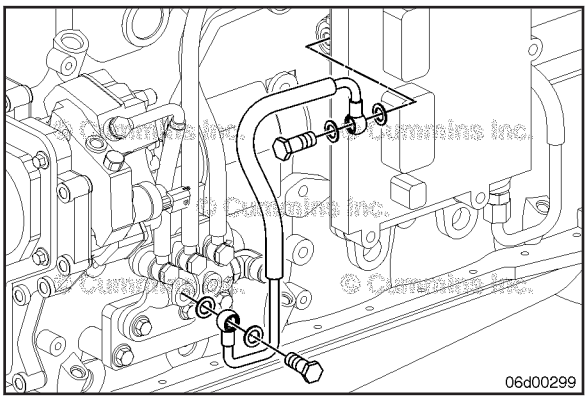
NOTE: Engines with a fuel cooled ECM cooling plate will have a fuel supply line connecting the ECM cooling plate to the inlet of the gear pump.

Remove the fuel supply line connecting the ECM cooling plate to the inlet of the gear pump, if applicable.

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

NOTE: Fuel filter may be remote mounted off of the engine.

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

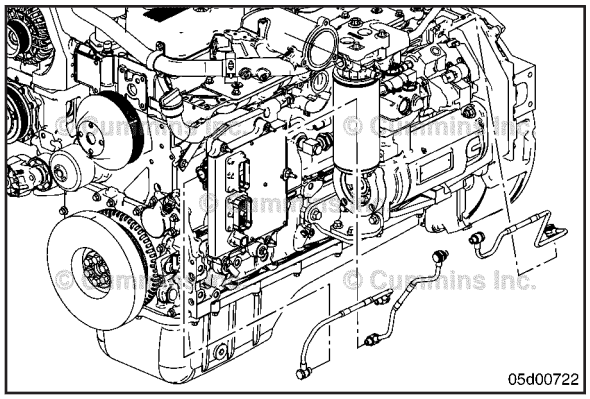


NOTE: Mark the location of all p-clips and routing of fuel supply lines to ensure that they are replaced in the correct location during reassembly.

For marine applications, **shut off** fuel supply and return valves.

NOTE: For marine applications, a fuel supply line connects the fuel supply manifold to the inlet of the electric lift pump.

Remove the fuel supply line connecting the fuel supply manifold to the inlet of the electric lift pump, if applicable.



NOTE: For engines equipped with a fuel cooled ECM cooling plate, there is a fuel supply line connecting the ECM cooling plate to the electric fuel lift pump.

Remove the fuel supply line connecting the ECM cooling plate to the electric fuel lift pump, if applicable.

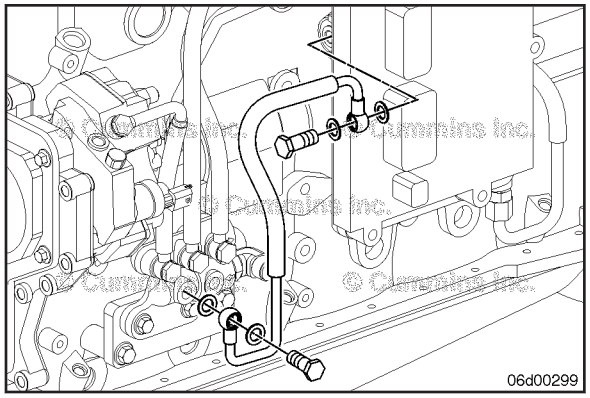
Remove the fuel supply line connecting the electric fuel lift pump, to the fuel filter inlet, if applicable.

NOTE: For marine applications, a fuel supply line connects the fuel cooled ECM cooling plate to the inlet of the fuel filter head.

Remove the fuel supply line connecting the fuel cooled ECM cooling plate to the inlet of the fuel filter head, if applicable.

NOTE: The fuel filter may be remote mounted off of the engine.

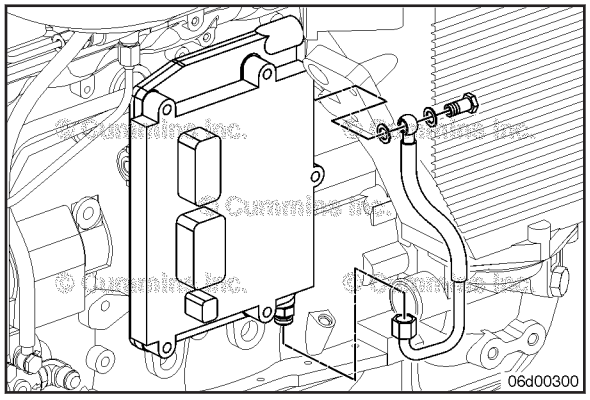
Remove the fuel supply line connecting the fuel filter outlet to the gear pump inlet.



⚠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.

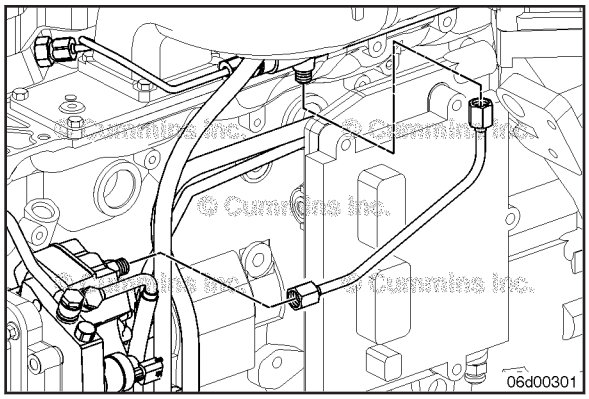
⚠CAUTION⚠
Use caution when disconnecting or removing fuel lines, replacing filters and priming the fuel system that fuel is not spilled or drained into the bilge area. Do not drop or throw filter elements into the bilge area. The fuel and fuel filters must be discarded in accordance with local environmental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

Disconnect the fuel line from the combined fuel manifold and the fuel lift pump.

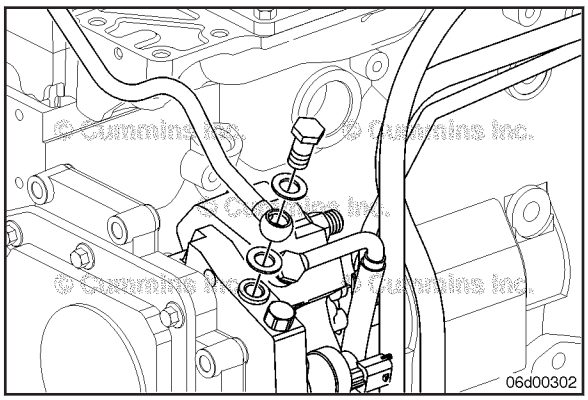


Disconnect the fuel line from the fuel lift pump to the ECM cooling plate.

Disconnect the fuel line from the high pressure fuel pump to the fuel rail.

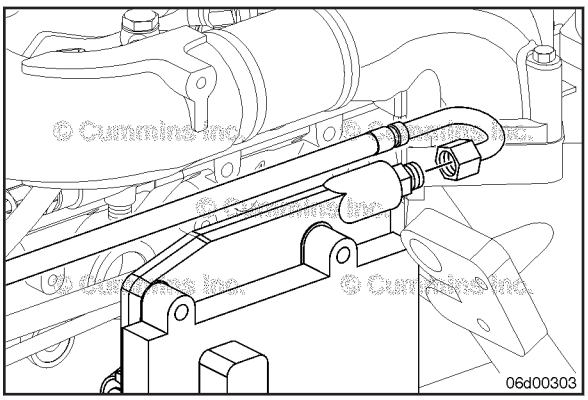


Disconnect the fuel line from the fuel filter to the high pressure fuel pump.



NOTE: Identify the location(s) where the p-clip(s) are located on the fuel line for correct installation of the fuel line.

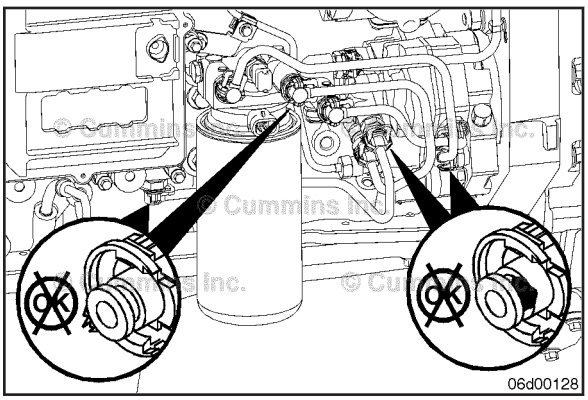
Disconnect the fuel line from the ECM cooling plate to the fuel filter.

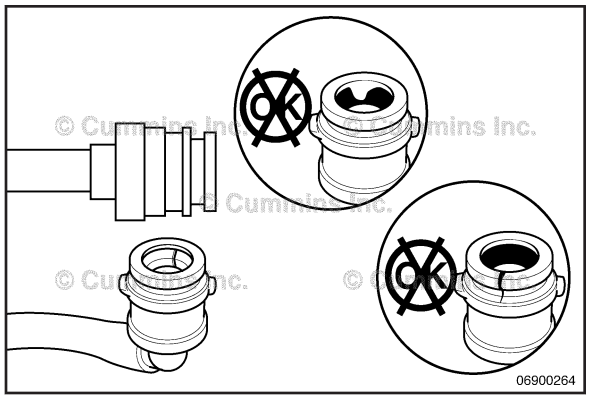


Clean and Inspect for Reuse

Inspect for cracks, wear, or pinched areas.

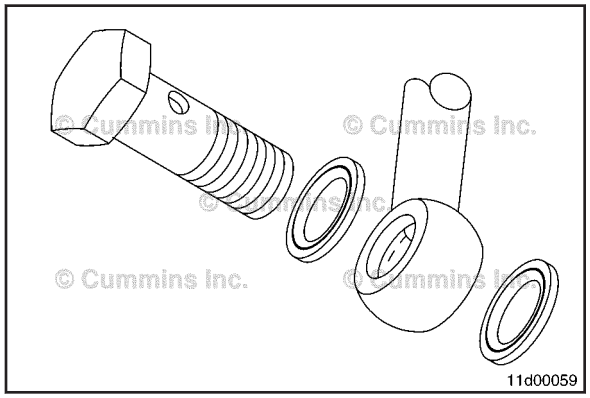
Check the tips for damage, rounding, or cracking; replace if necessary.





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

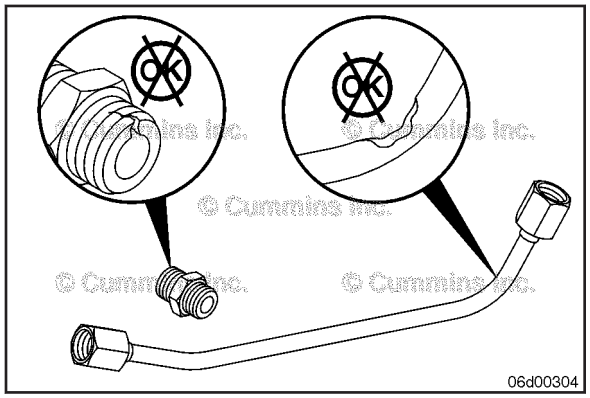
On quick-disconnect fittings, be certain that the o-rings are not frayed or cut, and that the lock tangs are **not** damaged.



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

Use new sealing washers during installation.

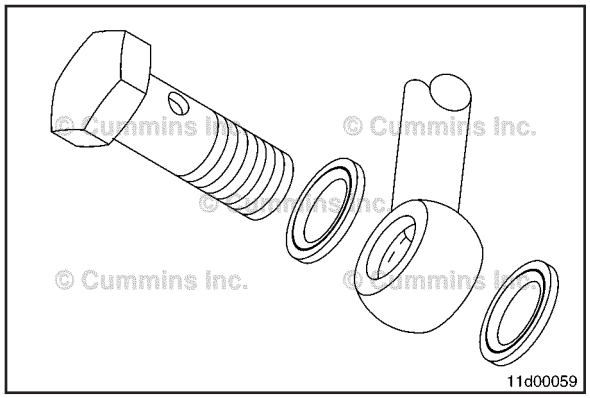
Replace the fuel lines if damaged.



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

Inspect and replace o-rings if damaged.

Replace the fuel lines as necessary.

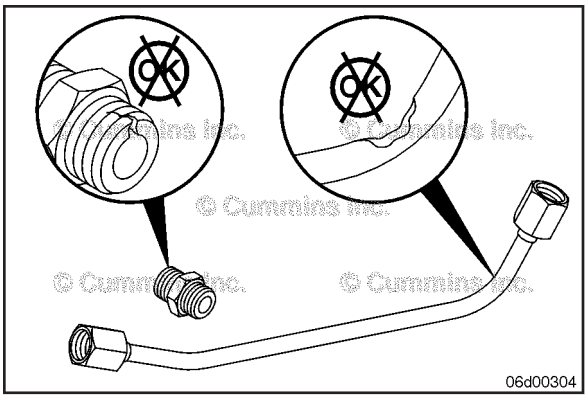


Inspect the face of the banjo connector for sealing surface damage.

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

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

Replace the fuel lines as necessary.



Install

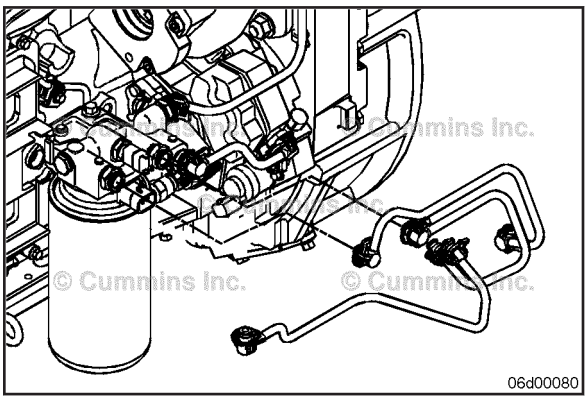
NOTE: Engines with a fuel cooled ECM cooling plate will have a fuel supply line connecting the ECM cooling plate to the inlet to the gear pump.

Install the fuel supply line connecting the ECM cooling plate to the inlet to the gear pump, if applicable.

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

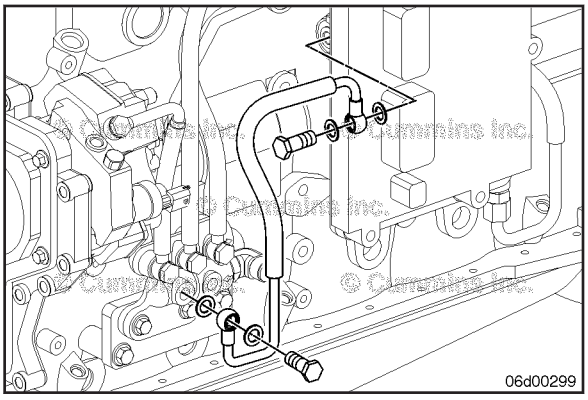
Install the fuel supply line connecting the fuel filter head to the inlet to the high pressure pump.

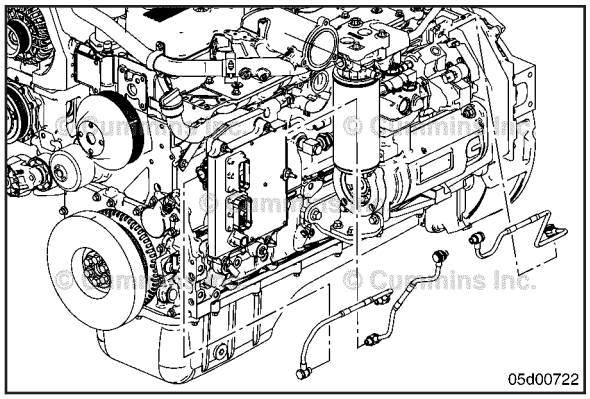
Install p-clips and p-clip mounting cap screws in locations noted during removal.



NOTE: For marine applications, a fuel supply line connects the fuel supply manifold to the inlet of the electric lift pump.

Install the fuel supply line connecting the fuel supply manifold to the inlet of the electric lift pump, if applicable.





NOTE: For engines equipped with a fuel cooled ECM cooling plate, there is a fuel supply line connecting the ECM cooling plate to the electric fuel lift pump.

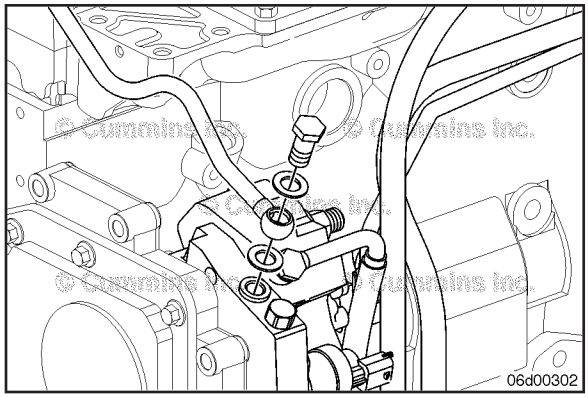
Install the fuel supply line connecting the ECM cooling plate to the electric fuel lift pump, if applicable.

Install the fuel supply line connecting the electric fuel lift pump to the inlet of the fuel filter head.

NOTE: For marine applications, a fuel supply line connects the fuel cooled ECM cooling plate to the inlet of the fuel filter head.

Install the fuel supply line connecting the fuel cooled ECM cooling plate to the inlet of the fuel filter head, if applicable. Install the fuel supply line connecting the fuel filter outlet to the gear pump inlet.

Install p-clips and p-clip mounting cap screws in locations noted during removal.



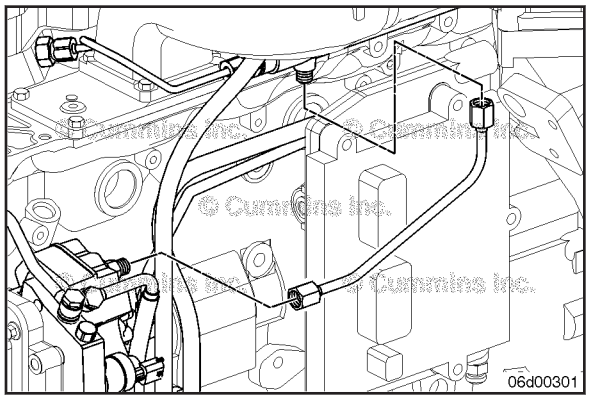
Connect the fuel line from the fuel filter to the high pressure fuel pump.

Torque Value:
Fuel Filter Connection

Step 1	37 N•m	[27 ft-lb]

Torque Value:
Banjo Bolt Connection

Step 1	24 N•m	[221 in-lb]



Connect the fuel line from the high pressure fuel pump to the fuel rail.

Torque Value:
Fuel Rail Fitting

Step 1	37 N•m	[27 ft-lb]

Torque Value:
Fuel Pump Banjo Bolt

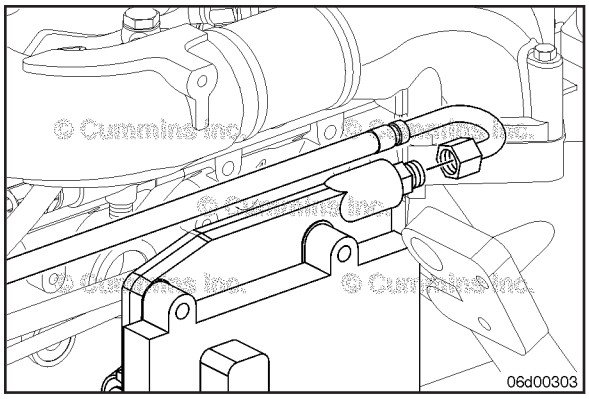
Step 1	24 N•m	[221 in-lb]

Connect the fuel line from the ECM cooling plate to the fuel filter.

Install the p-clip(s) in their original location(s)

Torque Value:
Fuel Line Straight Thread Connections
Step 1 37 N•m [27 ft-lb]

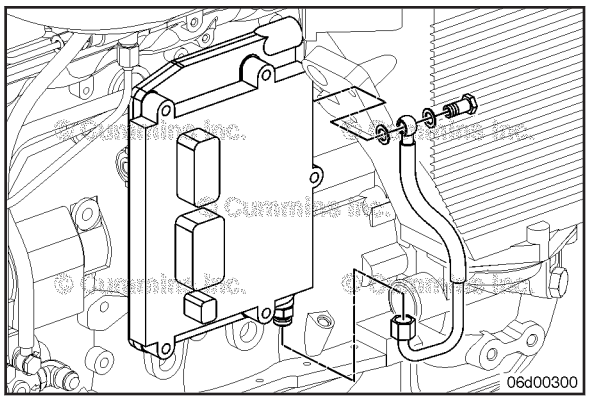
Torque Value:
P-Clips
Step 1 24 N•m [221 in-lb]



Connect the fuel line from the fuel lift pump to the ECM cooling plate.

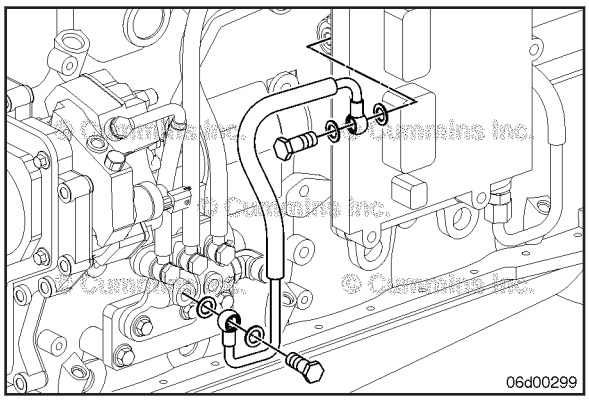
Torque Value:
Straight Thread Connection
Step 1 37 N•m [27 ft-lb]

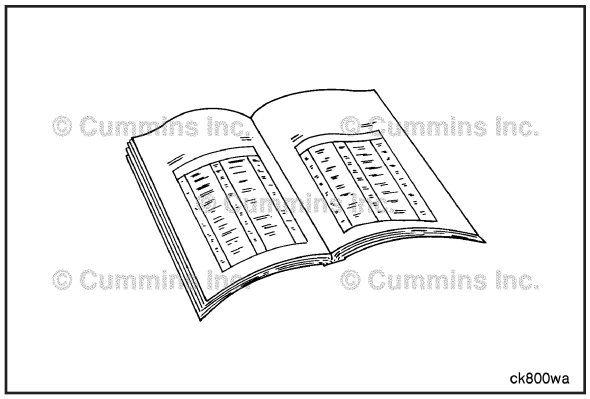
Torque Value:
Banjo Bolt Connection
Step 1 24 N•m [221 in-lb]



Connect the fuel line from the combined fuel manifold and the fuel lift pump.

Torque Value:
Banjo Bolt Connections
Step 1 24 N•m [221 in-lb]





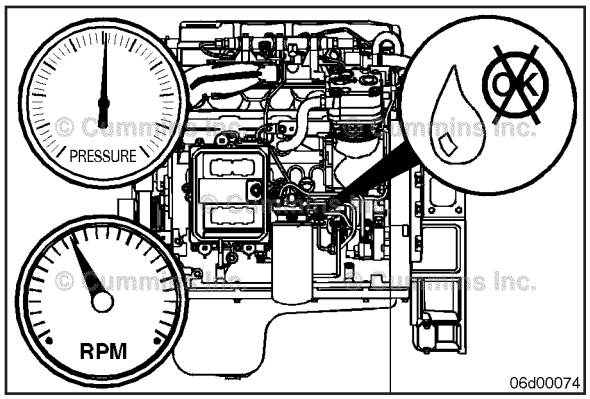
Finishing Steps

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

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

- Open the fuel supply valve.
- Prime the fuel system. Refer to Procedure 005-016

Operate the engine and check for leaks.



Prime

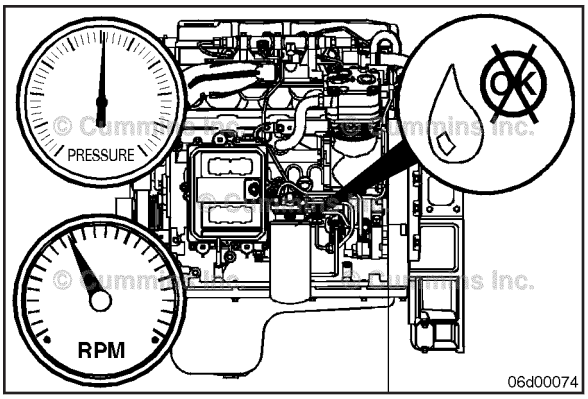
⚠WARNING⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

On marine application engines, **open** fuel supply and return valves.

⚠WARNING⚠
Be sure that the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when engine is cranked or started. Environmental damage can also occur. Refer to Procedure Procedure 005-999 (Fuel System Overview) in Familiarization section for further information.

NOTE: Cycle the key switch at least five times allowing the lift pump to run 30 seconds on each cycle to properly prime the fuel system. Refer to Procedure Procedure 005-016 for correct priming procedure.

NOTE: It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will prime the fuel system.



⚠WARNING⚠

The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

After Filter Change:

Primary Method:

Unlock the manual priming pump handle by turning counterclockwise. Pump the primer handle until resistance is felt (approximately 140-150 strokes). Lock the manual priming pump handle and crank the engine. Start should occur within 5 seconds.

NOTE: Do **not** fill new filters with fuel prior to assembly as this will allow unfiltered fuel to enter the system and may cause damage to fuel system components.

Alternative method:

Unlock the manual priming pump handle by turning counterclockwise. Pump the primer handle 60 times. Lock manual priming pump handle and crank the engine. Start should occur within approximately 20 seconds.

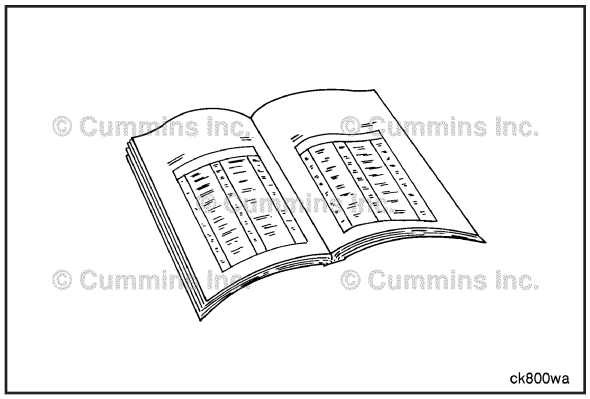
NOTE: Do **not** exceed starter cranking limitations.

After Running the Vehicle Tank Dry:

Ensure there is fuel in the vehicle fuel tank. Unlock the manual priming pump handle by turning it counterclockwise. Pump the primer until resistance is felt (50-60) strokes. Lock manual priming pump handle and crank the engine. Start should occur within 5 seconds.

NOTE: Do **not** remove and fill filters with fuel prior to priming the system in an attempt to reduce priming time as this will allow unfiltered fuel to enter the system and may cause damage to fuel system components.

NOTE: It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will prime the fuel system.



Injector (006-026)

General Information

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

⚠WARNING⚠
Fuel may be returned at highly elevated temperatures. Wear safety glasses and protective gloves and clothing when performing this test. Avoid any contact with returned fuel.

⚠WARNING⚠
The pressure within the fuel rail is extremely high. A high-pressure leak can penetrate the skin. Stand clear of the engine while it is running.

△CAUTION△
Be sure the fuel inlet and return valves are returned to the open position before cranking the engine. Engine damage can result if valves are in the wrong position when the engine is cranked or started. Environmental damage can also occur.

The fuel return manifold is located near the point at which the OEM connects the vehicle fuel drain line. To locate this manifold, follow the fuel drain lines from their source, (rail pressure relief valve, injector return, or high pressure injector pump return) to their termination point. The termination point will occur at the fuel return manifold. Refer to Procedure 006-999 in Section 6.

An internal leak from either the high-pressure connector or the fuel injector will result in increased fuel return flow from the cylinder head. The single cylinder cut-out test will **not** be able to isolate this leak because it occurs before it reaches the control needle inside the injector. Because all injectors share the same pressurized fuel supply from the rail, all cylinders will share the loss of fuel equally.

Due to the varying engine configurations, the following steps have been established to cover a majority of engine configurations. The purpose of the following steps are to isolate and measure the injector return fuel drain flow. In some configurations this requires isolating the high-pressure fuel pump and/or fuel rail pressure relief valve fuel drain flows.

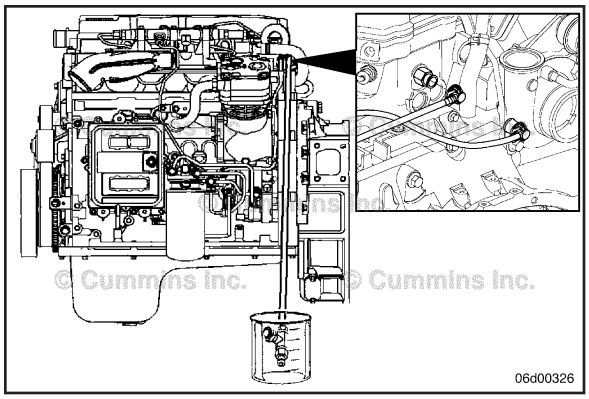
Setup

Low Mount Fuel Drain Manifold

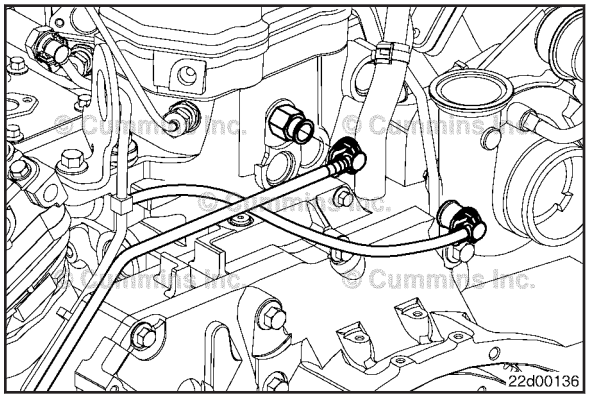
3.9L and 5.9L Engines Without EGR

These engines have a quick-disconnect fitting, with a white tang in the fuel return port at the back of the cylinder head.

Check for excessive flow in the injector return circuit due to leakage.

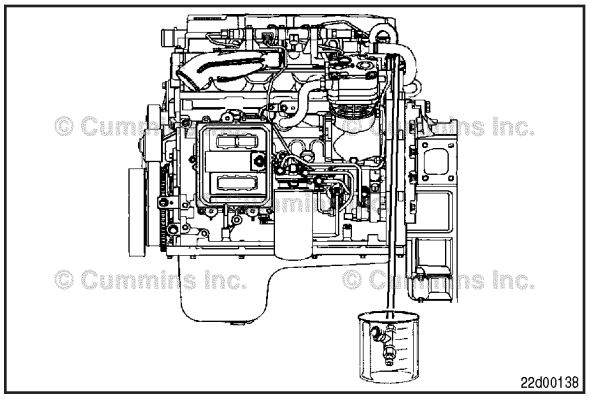


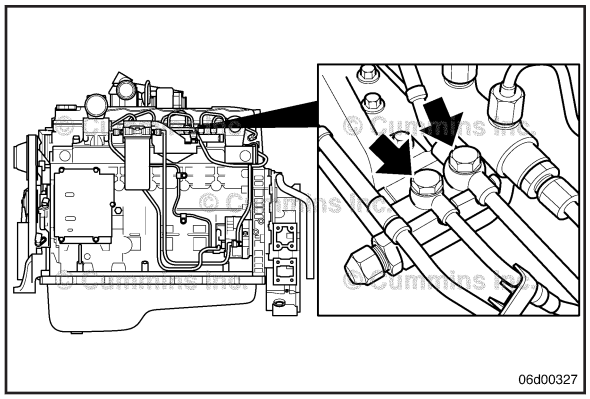
Remove the quick-disconnect fuel line from the back of the cylinder head and attach the fuel pressure gauge adapter, Part Number 3164044.



Install the quick-disconnect block-off fitting, Part Number 3164583, on the drain line removed from the cylinder head to prevent the back flow of fuel from the drain line.

Place the loose end of the fuel pressure gauge adapter tool into a graduated cylinder, Part Number 3823705.



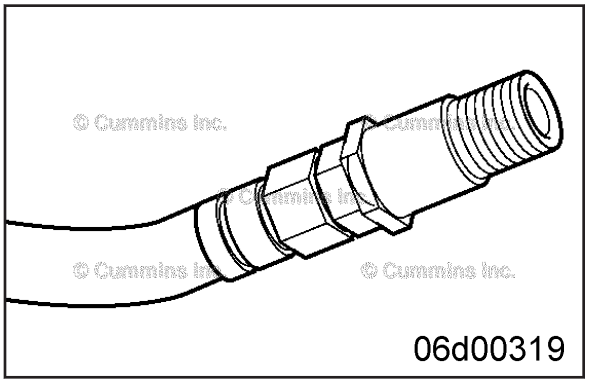


High Mount Fuel Drain Manifold with Two Banjo Fittings

5.9L Engines with EGR

These engines have a banjo fitting in the fuel return port at the back of the cylinder head.

If the pressure relief valve fuel return flow measures zero, proceed with this procedure. If the pressure relief valve fuel return flow is **not** zero, use the following procedure for reseating or replacement instructions. Refer to Procedure 006-061 in Section 6.

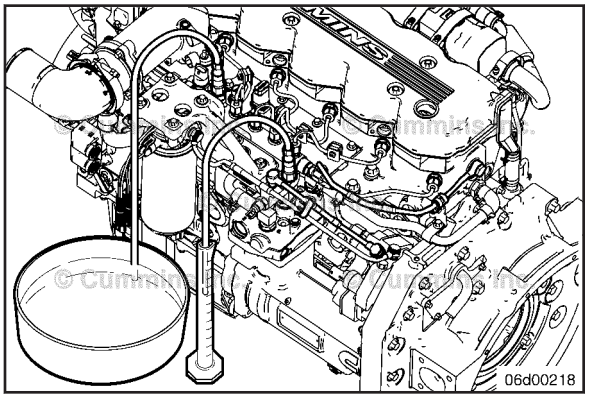


The injector and the fuel rail pressure relief valve share the same return line. Therefore, it is necessary to isolate the fuel rail pressure relief valve flow from the fuel injector return flow.

Remove the banjo bolt from the fuel rail pressure relief valve.

Install the pressure relief valve return flow hose, Part Number 3164617, in place of the banjo bolt.

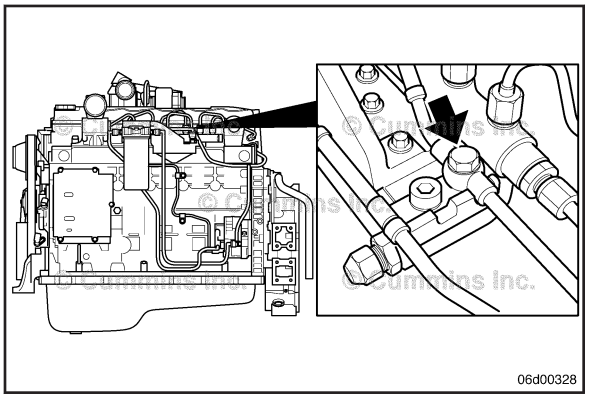
Drain any fuel into a drain pan.



Follow the fuel drain line from the back of the cylinder head to the fuel return manifold.

Remove the banjo bolt from the fuel injector drain line at the fuel return manifold. Install the fuel drain hose, Part Number 3164618, in place of the banjo bolt.

Place the end of the fuel injector drain line fuel return flow hose in a graduated cylinder, Part Number 3823705, and collect return flow.



High Mount Fuel Drain Manifold with One Banjo Fitting

6.7 L Engines in Industrial Applications

These engines have a banjo fitting in the fuel return port at the back of the cylinder head.

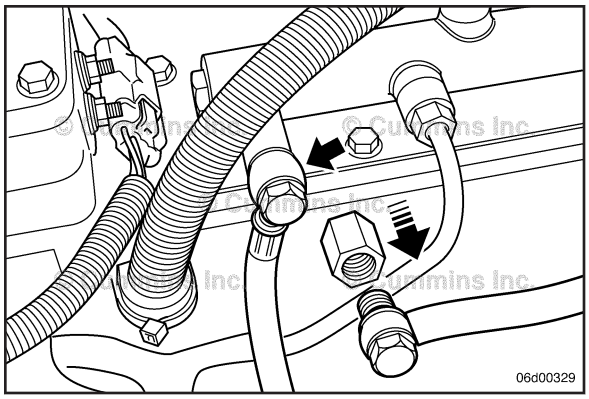
If the pressure relief valve fuel return flow measures zero, proceed with this procedure. If the pressure relief valve fuel return flow is **not** zero, use the following procedure for reseating or replacement instructions. Refer to Procedure 006-061 in Section 6.

Isolation of the fuel rail pressure relief valve flow from the injector return flow requires the use of the fuel rail pressure relief valve flow tester kit, Part Number 4918295.

Remove the banjo bolt from the fuel rail pressure relief valve.

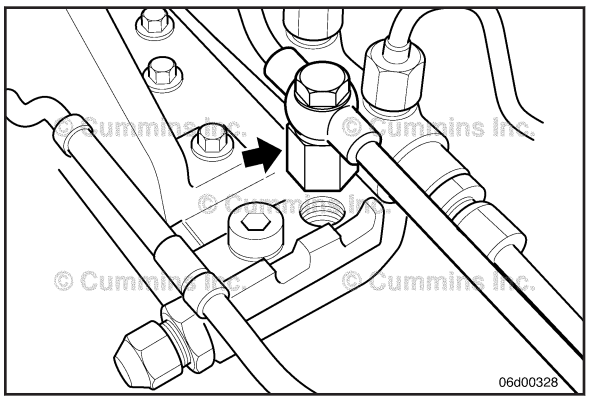
Install the fuel rail pressure relief valve fuel drain hose onto the pressure relief valve using the banjo bolt supplied in the tester kit.

Install the cap supplied in the pressure relief valve tester kit onto the existing banjo, to cap off the pressure relief valve fuel drain line.



Measurement of injector return flow requires the use of a fuel system leak tester, Part Number 4918354. The fuel system leak tester contains Part Numbers: 4918297, 4918433, and 4918434.

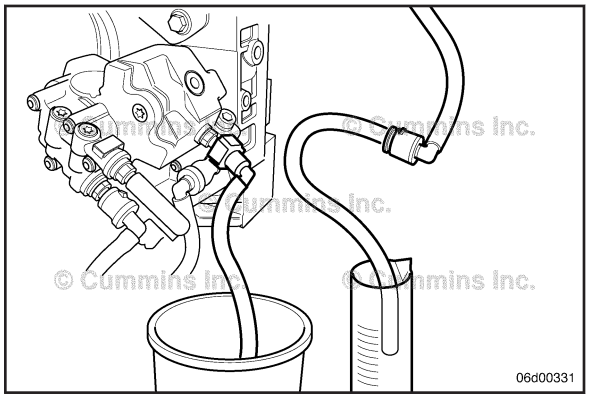
Remove the banjo bolt from the fuel drain line at the fuel return manifold. (This is the inline banjo fitting). Install a cap, Part Number 4918297, onto the banjo bolt to prevent fuel flow to the return manifold.



To prevent high pressure fuel pump return flow from entering the injector return flow, remove the fuel return line quick-disconnect on the injector pump.

Install a fuel drain hose with a female quick-disconnect, Part Number 4918434, onto the high pressure fuel pump and drain into a bucket.

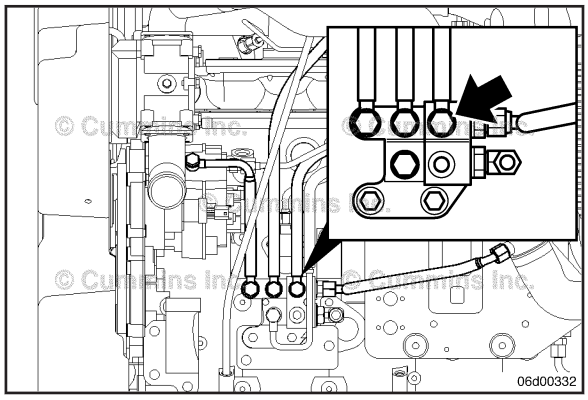
Insert a fuel drain hose with male quick-disconnect, Part Number 4918433, into the removed fuel drain line. Place the end of the fuel drain hose into a graduated cylinder, Part Number 3823705.

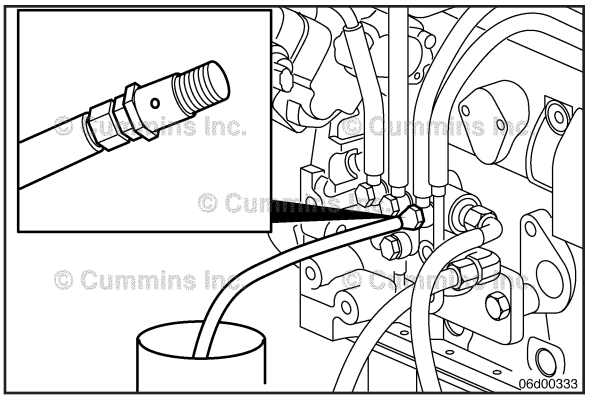


Marine Applications

NOTE: The fuel return manifold on marine engines is located on the side of the engine block, in front of the ECM.

Follow the fuel drain line from the injector return port at the back of the cylinder head to the fuel return manifold.

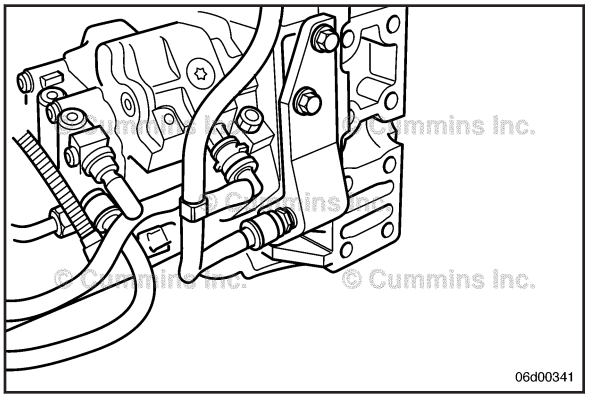




Remove the banjo bolt from the injector drain line at the fuel return manifold.

Insert a fuel drain hose, Part Number 3164618, in place of the banjo bolt.

Insert the end of the fuel drain hose into a graduated cylinder, Part Number 3823705, to measure injector return flow.



Gear Housing Fuel Drain

4.5L Industrial and Automotive Applications

It also applies to 6.7L automotive applications and some 6.7L industrial applications. These engines have a banjo fitting in the fuel return manifold at the back of the cylinder head and a combined fuel return manifold

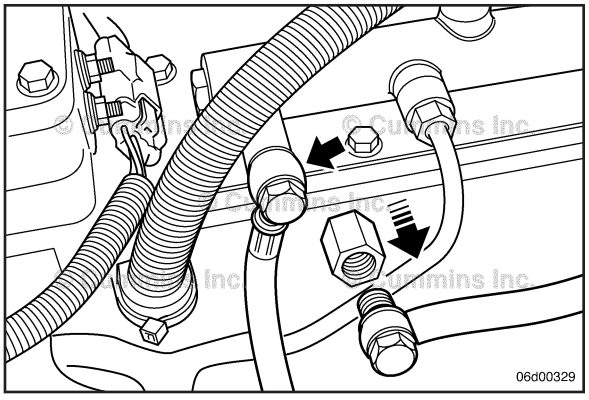
6.7L Engines in Industrial Applications

These engines have a banjo bolt fitting at the back of cylinder head and one banjo bolt in the fuel return manifold

If the pressure relief valve fuel return flow measures zero, proceed with this procedure. If the pressure relief valve fuel return flow is **not** zero, use the following procedure for reseating and replacement instructions. Refer to Procedure 006-061 in Section 6.

To measure the fuel injector return flow, it is necessary to isolate the fuel rail pressure relief valve flow.

NOTE: A banjo bolt or a quick-disconnect fitting can be present on the fuel rail pressure relief valve.



For engines with a banjo fitting on the fuel rail pressure relief valve, use the fuel rail pressure relief valve flow tester kit, Part Number 4918295.

Remove the banjo bolt from the fuel rail pressure relief valve.

Install the fuel rail pressure relief valve fuel drain hose onto the pressure relief valve using the banjo bolt supplied in the tester kit.

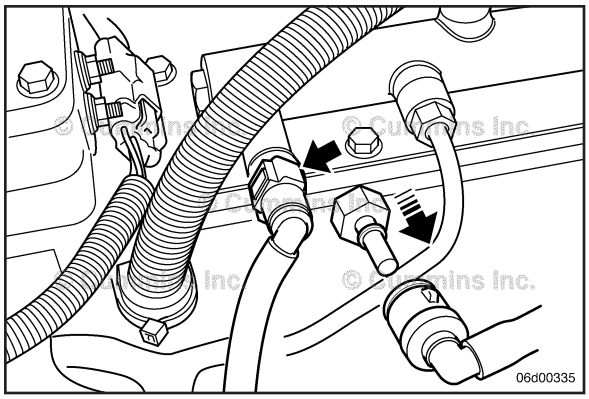
Install the cap supplied in the pressure relief valve tester kit onto the existing banjo to cap off the fuel drain line.

For engines with a quick-disconnect fitting on the fuel rail pressure relief valve, use a female quick-disconnect drain hose and a block-off fitting to isolate the fuel pressure relief valve flow.

Remove the quick-disconnect fitting from the pressure relief valve.

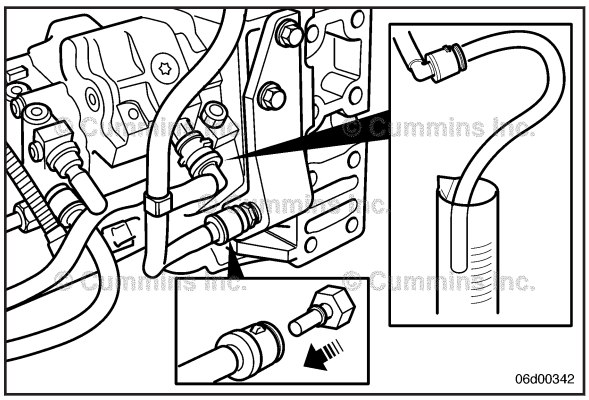
Install a pressure gauge adapter, Part Number 4918462, on the fuel rail pressure relief valve and drain into a bucket.

Install a quick-disconnect block-off fitting, Part Number 4918464, into the fuel drain line removed from the fuel rail pressure relief valve.



Remove the quick-disconnect fitting on the fuel drain line from the fuel return manifold.

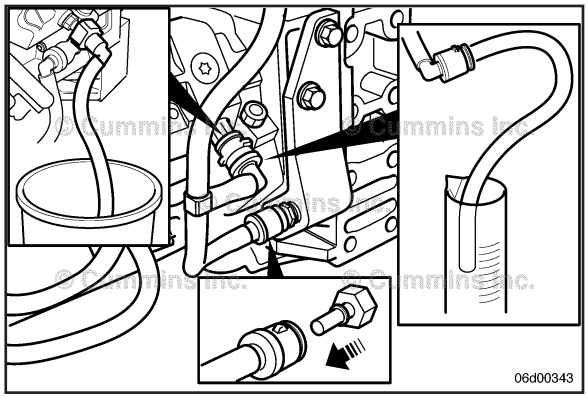
Install a quick-disconnect block-off fitting, Part Number 4918464, into the fuel drain line to prevent fuel flow into the fuel return manifold.

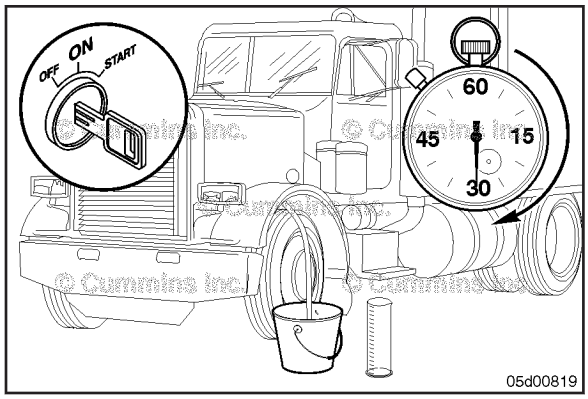


To prevent high pressure fuel pump drain flow from entering the injector return flow, remove the fuel drain line from the high pressure fuel pump.

Install a fuel drain hose with female quick-disconnect, Part Number 4918434, onto the high pressure fuel pump and drain into a bucket.

Install a fuel drain hose with a male quick-disconnect fitting, Part Number 4918433, into the fuel drain line removed from the injector pump. This hose will be placed into a graduated cylinder, Part Number 3823705, to measure injector fuel return flow.





Initial Check

⚠WARNING⚠
Fuel can be returned at highly elevated temperatures. Wear safety glasses and protective gloves and clothing when performing this test. To reduce the possibility of personal injury, avoid contact with returned fuel.

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

For Marine applications, open fuel supply and return valves.

Start the engine. Start INSITE™ electronic service tool Fuel Leakage Test and allow the injectors to get up to operating temperature for at least 1 minute. By allowing the injectors to get up to operating temperature, more accurate fuel flow measurements can be made.

This test elevates the fuel rail pressure.

With the fuel drain hose, Part Number 3164618 in a graduated cylinder, measure the injector drain flow for 1 minute.

Flow Specification: INSITE™ Fuel Leakage Test active	
4-cylinder	200 ml per minute [6.8 fl-oz per minute] maximum
6-cylinder	300 ml per minute [10.1 fl-oz per minute] maximum

Flow Specification: Standard Idle Conditions (leak may not be detected)	
4-cylinder	120 ml per minute [4 fl-oz per minute] maximum
6-cylinder	180 ml per minute [6 fl-oz per minute] maximum

If the engine will **not** start, crank the engine and measure the amount of fuel returned from the injectors.

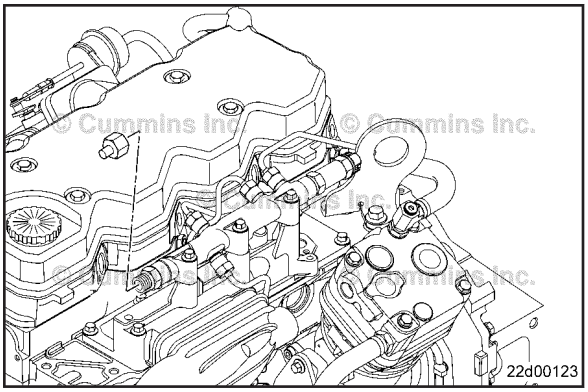
Flow Specification: Engine Cranking	
4- and 6- cylinder	90 ml per minute [3 fl-oz per minute maximum]
NOTE: Be sure **not** to overheat the starter.	

If fuel flow is greater than specification, it is necessary to perform the injector isolation test described below.

Test

Before attempting to isolate the leak, make sure that all the high pressure fuel connectors are tightened to the correct torque. Refer to Procedure 006-052 in Section 6.. If a connector is **not** tightened to the proper torque, tighten the connector and perform the previous test again. If the injector return flow is greater than the specified flow rate, it is necessary to block off the fuel to one injector at a time to determine the location of the leak.

With the engine **not** running, remove the fuel injector supply line connecting the rail to cylinder number 1.



3.9L and 5.9L Engines

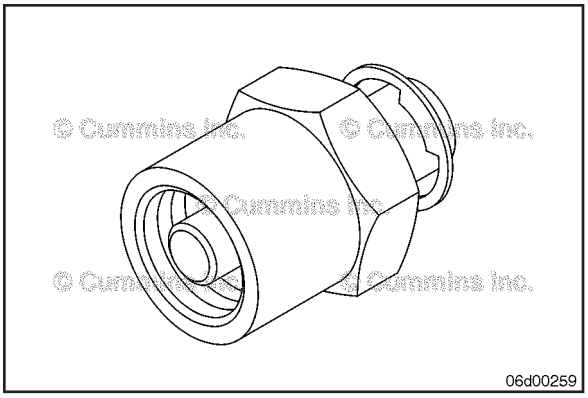
Install the injector leakage isolation tool, Part Number 3164325, on the rail where the number 1 cylinder fuel line connects.

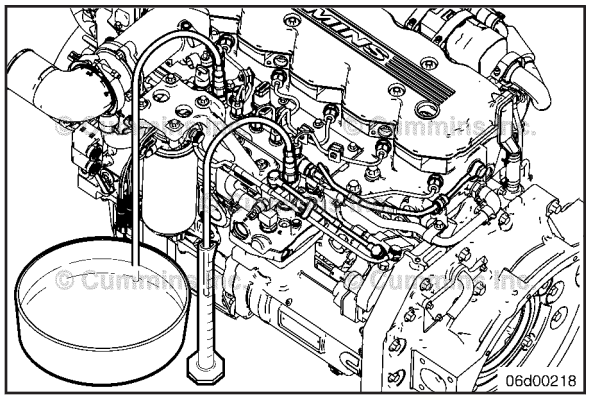
Torque Value: 30 N•m [22 ft-lb]

4.5L and 6.7L Engines

Install the injector leakage isolation tool, Part Number 4918298, on the rail where the number 1 cylinder fuel line connects.

Torque Value: 35 N•m [26 ft-lb]





Repeat the leakage flow test with cylinder one blocked off and record the flow rate.

Install the fuel injector supply line. Refer to Procedure 006-051 in Section 6.

Repeat the leakage test with each cylinder blocked off.

Record the flow rate for each test.

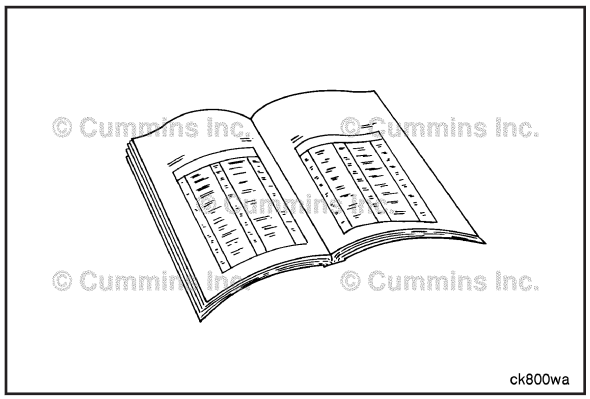
The flow rate will decrease below the maximum specified flow when the cylinder with the leak is blocked.

The table represents the results from a leakage test with a leak present in cylinder number 5 injector or high pressure connector.

Leak Test Results						
Cylinder blocked	1	2	3	4	5	6
ml/minute [fl-oz/minute]	210 [7]	220 [7]	215 [7]	210 [7]	91 [3]	220 [7]

If this test is performed and there is **not** a significant change in fuel return flow while cutting out one injector, there may be a problem with more than one injector. Compare the fuel flow difference across all injectors. If there is more than one injector that caused a noticeable decrease in flow, those could be the injectors with the problems.

Another cause of this problem could be the customer is operating on fuels with lower viscosity than specified. Fuels with low viscosity will result in higher injector leakage and greater drain flow rates.



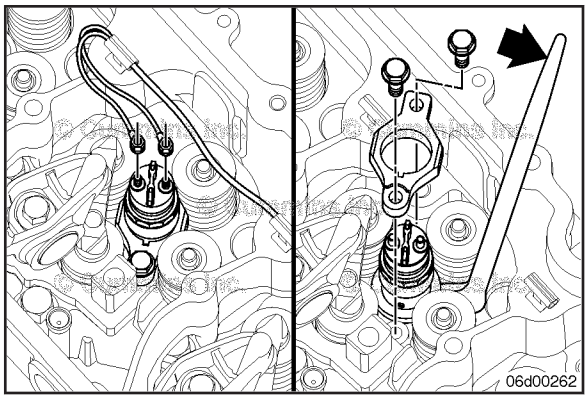
Preparatory Steps

CAUTION

The fuel connector must be removed before removing the injector or damage to the connector will result.

- Remove the high-pressure fuel line from the fuel rail and high-pressure connector. Refer to Procedure 006-051 in Section 6.
- Remove the high-pressure connector. Refer to Procedure 006-052 in Section 6.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the exhaust rocker lever. Refer to Procedure 003-008 in Section 3.

Remove



Disconnect the solenoid wires.

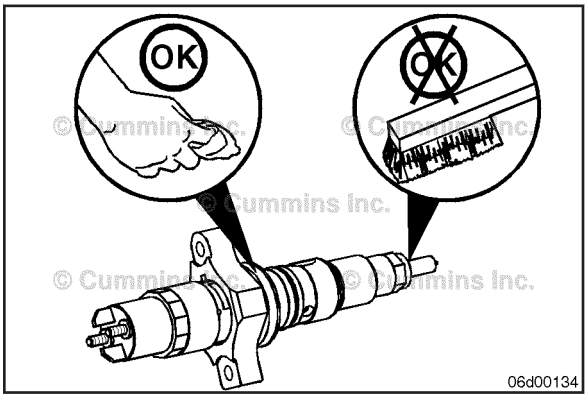
Remove the two injector hold-down capscrews and remove the injector hold-down clamp.

NOTE: The injector hold-down clamp is **not** removable on all engines.

Use the injector remover, Part Number 3823024, to remove the injector from the cylinder head.

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

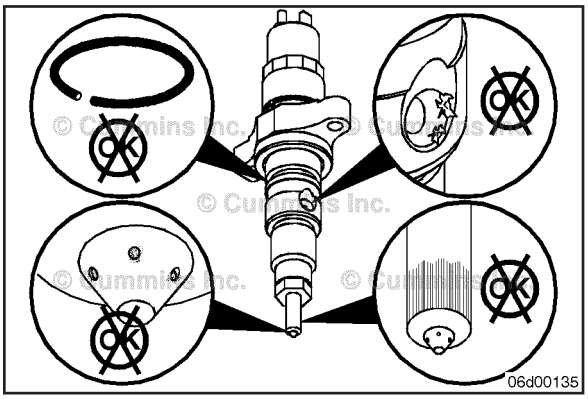
Clean and Inspect for Reuse



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

△CAUTION△
Do not use 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 injector tip and body with safety solvent and a soft, clean rag.



Inspect the injector tip for carbonization or corrosion.

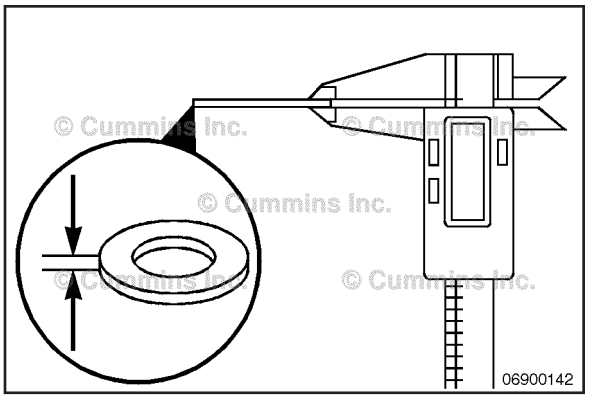
Check for terminal damage to the solenoid.

Inspect the injector inlet and high-pressure connector tip for damage.

Overheating will cause the nozzle to turn a dark yellow/tan or blue color, depending on the degree of overheating.

Inspect the injector o-rings for damage and replace if necessary.

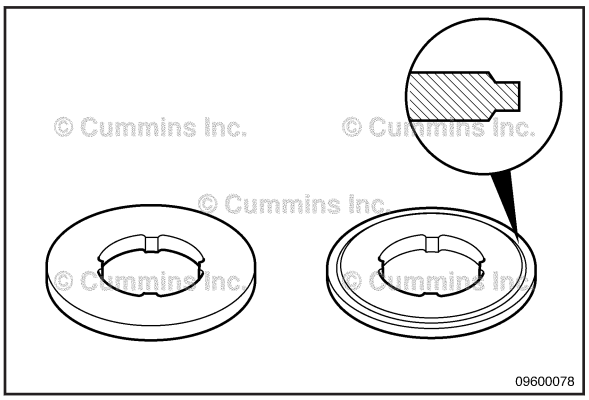
Resistance between terminals **must** be less than 3.0 ohms.



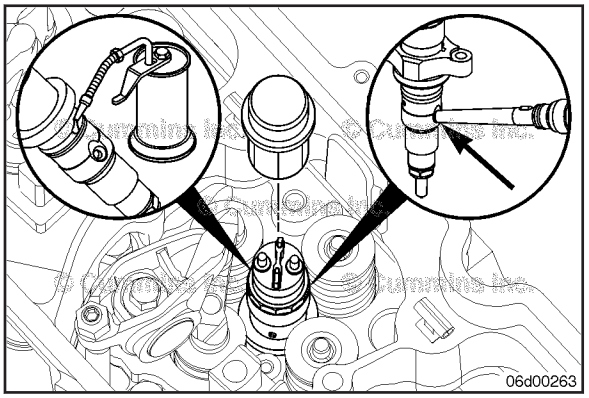
CAUTION

The incorrect sealing washer can cause high-pressure fuel leaks and/or performance problems because of incorrect injector protrusion.

Verify the injector sealing washer is the correct thickness.



Sealing washers 1.5 mm [0.06 in] come in a flat and saucer shape.



Install

Make sure the injector bore is clean and that **only** one (1) sealing washer is installed on the injector nozzle.

The rounded edge of the injector hold-down clamp is positioned toward the rocker levers. The fuel inlet hole on the injector faces the intake side of the engine.

NOTE: The injector hold-down is removable on some injectors.

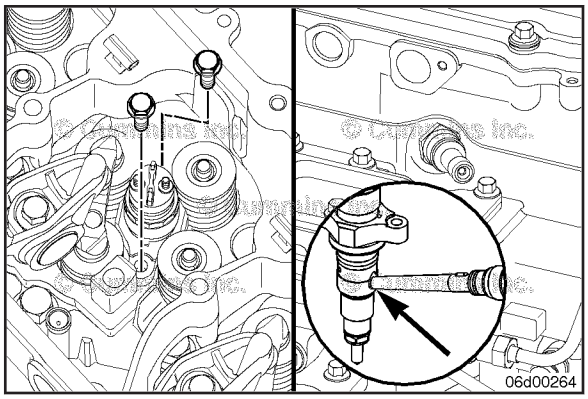
Lubricate the injector o-ring with clean engine oil.

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

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

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

Install the injector hold-down and injector hold-down capscrews, but do **not** tighten.

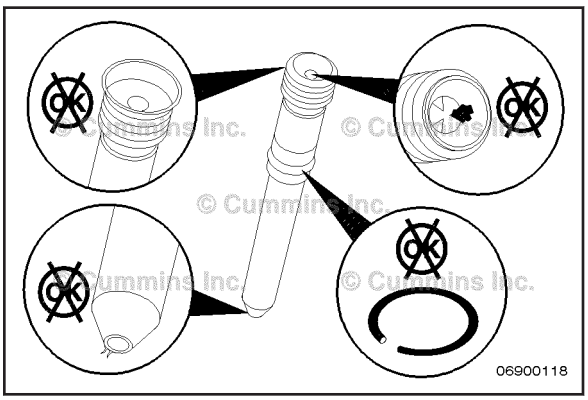


Inspect the fuel connector. Look for burrs or deformation around the inlet and outlet sides of the connector.

Check the edge filters for signs of plugging or material contamination.

Do **not** reuse a high-pressure fuel connector if debris is present.

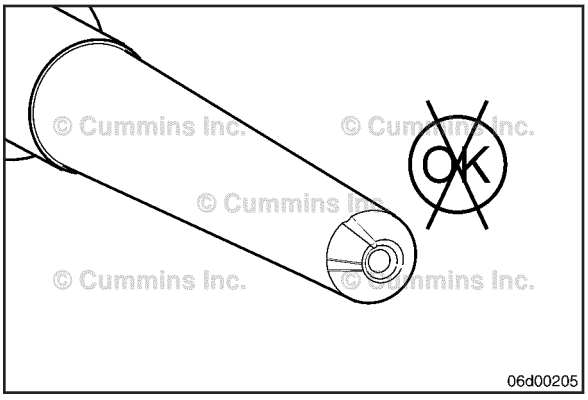
Check for o-ring tearing or deterioration.



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 the condition is observed.

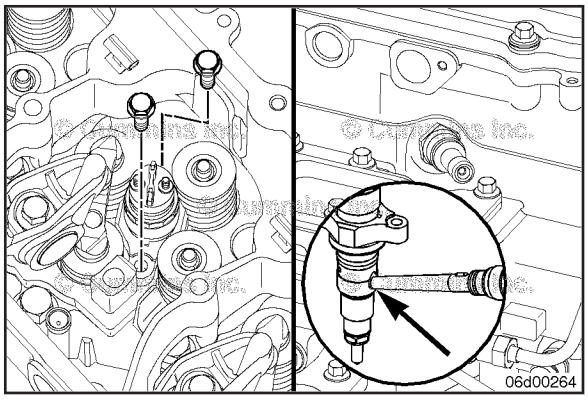


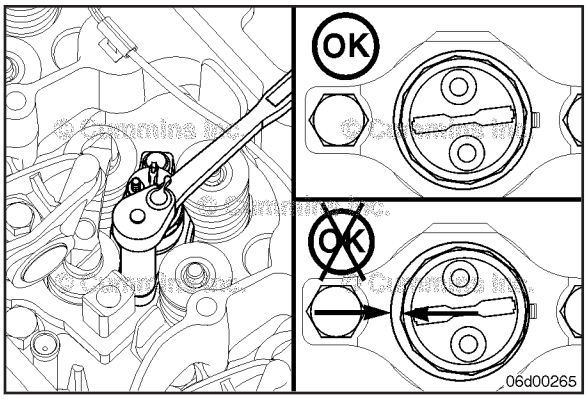
Install the high-pressure fuel connector making sure the end of the high-pressure fuel connector is in the injector inlet port.

Start the high-pressure fuel connector retaining nut and tighten partially.

Torque Value: 15 N•m [133 in-lb]

This is **not** the final torque for the high-pressure fuel connector retaining nut.





Tighten the injector hold-down capscrews.

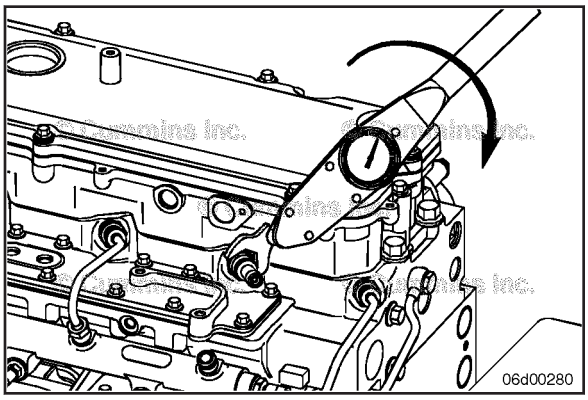
Make sure to tighten the hold-down capscrews evenly. Check to make sure the gap between the hold-down clamp and the injector is equally spaced around the injector body.

Tighten finger-tight and alternate between capscrews, turning 90 degrees per turn until reaching the following torque value.

Torque Value:
(3.9L and 5.9L): 10 N•m [89 in-lb]

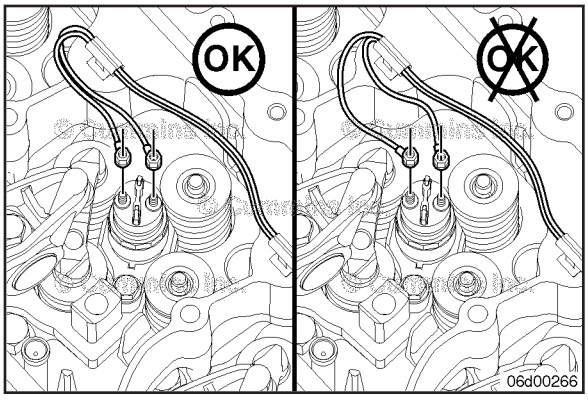
Tighten finger-tight and alternate between capscrews turning 90 degrees per turn until reaching the following torque value.

Torque Value:
(4.5L and 6.7L): 8 N•m [71 in-lb]



△CAUTION△
The injector solenoid terminals will yield and may malfunction if too much torque is applied. Do not over tighten.

Tighten the high-pressure fuel connector retaining nut. Refer to Procedure 006-052 in Section 6.



Connect and tighten the solenoid wires.

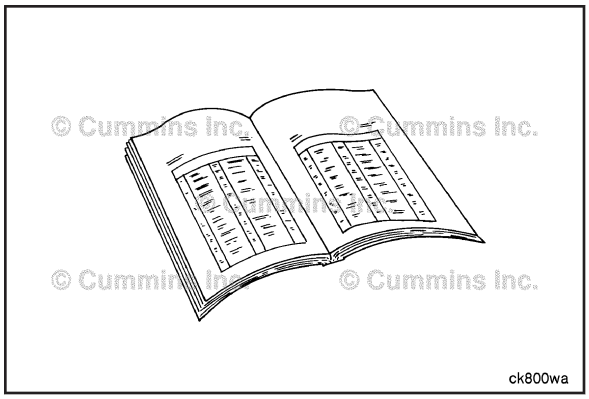
Torque Value: 1.5 N•m [13 in-lb]

Use service tool, Part Number 3823208, or a torque wrench.

Be sure the solenoid wires can **not** make contact with the rocker levers when installed.

Finishing Steps

- Install the exhaust rocker and adjust the exhaust valve lash. Refer to Procedure 003-008 in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the high-pressure fuel line from the fuel rail to the high-pressure connector. Refer to Procedure 006-051 in Section 6.
- For Marine applications, **open** fuel supply and return valves.
- Operate the engine and check for leaks.

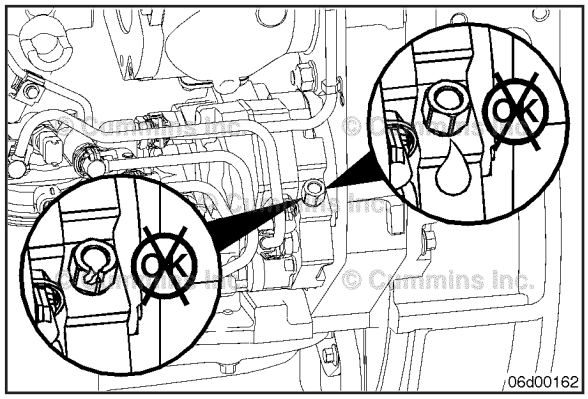


Fuel Return Overflow Valve (006-044)

Initial Check

Check the fuel return overflow valve for external leaks or other damage.

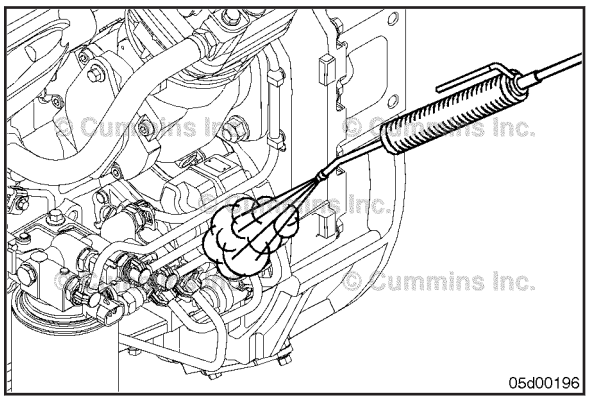
To test fuel pump return flow, Refer to Procedure 005-016



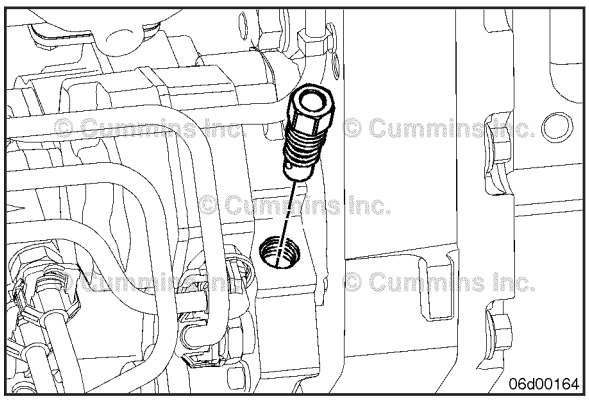
Remove

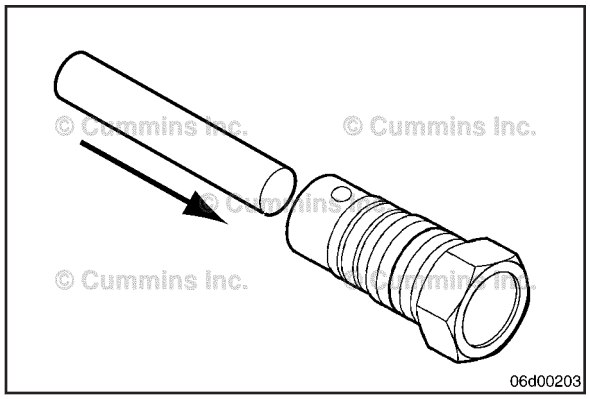
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

Steam-clean the fuel pump.



Remove the fuel return overflow valve.

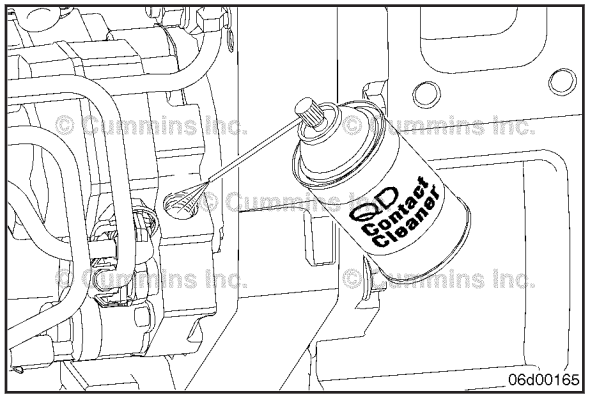




Inspect for Reuse

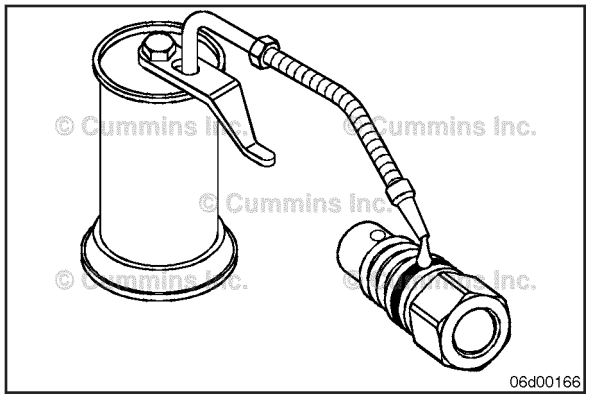
Make sure all holes and internal passages are clear and free of debris.

Depress the center of the valve at the end of the overflow valve with a soft plastic or wooden object. The valve should depress easily and return fully.



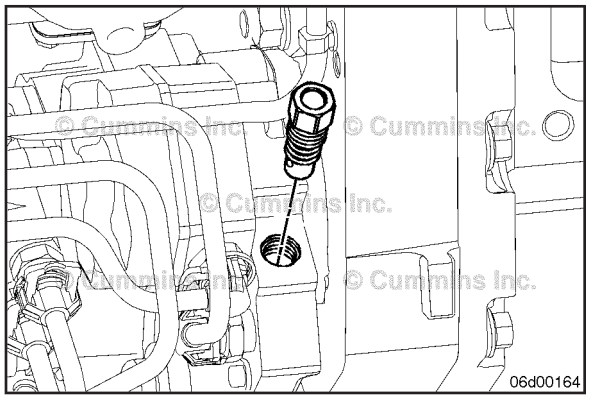
Clean

Clean the mounting hole with quick-dry contact cleaner.



Install

Lubricate the new o-ring, thread, and bite edge with clean lubricating oil.



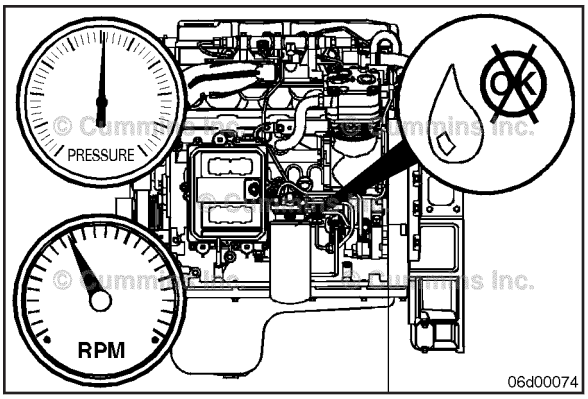
Install and hand-tighten the fuel return overflow valve.

Tighten to the following specification.

Torque Value:

Fuel Return Overflow Valve		
Step 1	20 N•m	[177 in-lb]

Operate the engine and check for leaks.

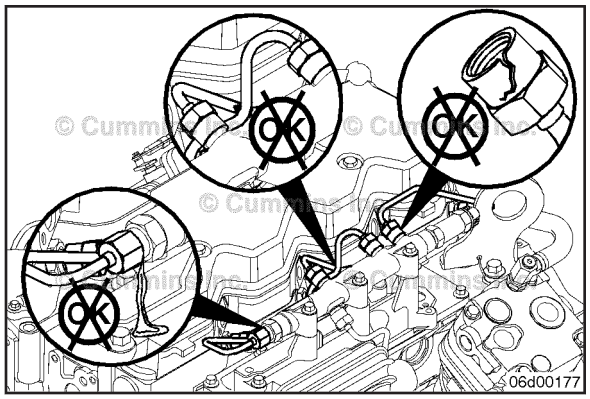


Injector Supply Lines (High Pressure) (006-051)

General Information

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

⚠WARNING⚠
Make sure that the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when engine is cranked or started. Environmental damage can also occur. Refer to Procedure Procedure 005-999 (Fuel System Overview) in Familiarization section for further information.



Initial Check

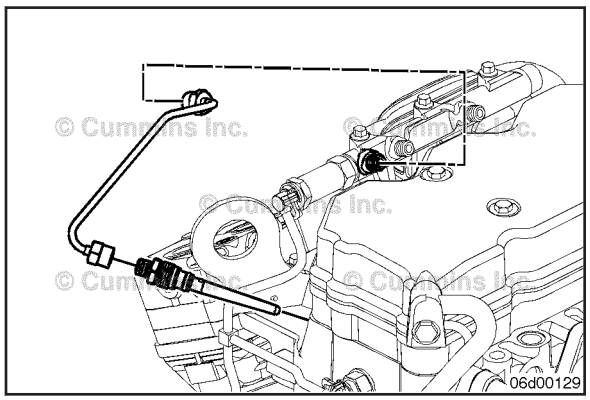
⚠WARNING⚠
While testing the injectors, keep hands and body parts away from the injector nozzle. Fuel coming from the injector is under extreme pressure and can cause serious injury by penetrating the skin.

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

⚠WARNING⚠
Drain the fuel into a container, and dispose of contents in accordance with local environmental regulations.

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

Inspect the injector high-pressure supply lines for cracks, chafe, leaks, and loose or broken brackets.



Remove

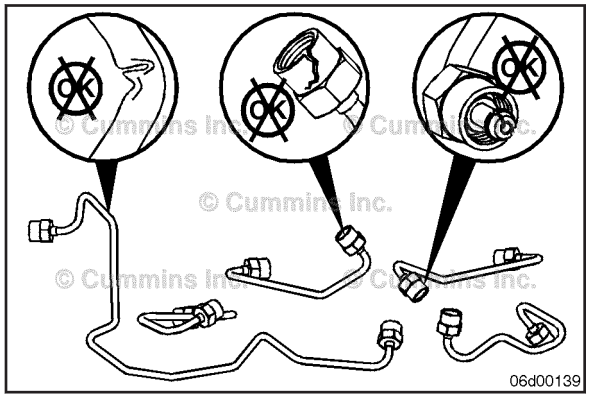
NOTE: For removal and installation of the fuel pump to rail high-pressure line. Refer to Procedure Procedure 005-016 in Section 5.

Remove the injector supply line brace cap screws. Do **not** remove braces and isolators from fuel line.

NOTE: It may be necessary to remove the air intake connection to remove all of the injector supply lines. Refer to Procedure Procedure 010-080 in Section 10.

Disconnect the injector supply lines from the high-pressure fuel connectors and from the fuel rail.

Remove the injector supply lines.



Inspect for Reuse

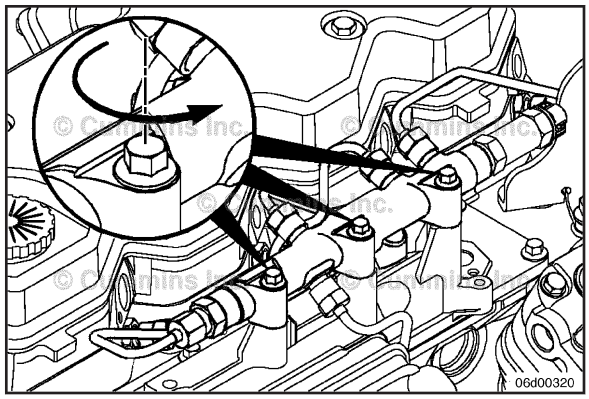
Inspect the high-pressure fuel supply line ferrules for any signs of burrs or foreign material rounding or cracking; replace if necessary.

Check for cracks, wear, or pinched areas; replace if necessary.

Inspect the ends of the high-pressure lines for damaged sealing surfaces.

Install

Loosen the capscrews for the fuel rail. Do **not** remove the fuel rail. The capscrews are loosened to allow proper alignment of the fuel rail after installing the new fuel line.



Install and hand-tighten all of the fuel lines.

Tighten the Injector High Pressure Supply Lines:

3.9L and 5.9L **without** electric lift pump.

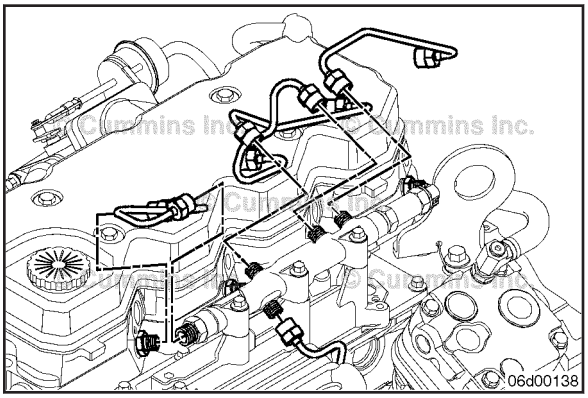
Torque Value: 22 N•m [195 in-lb]

5.9L **with** electric lift pump.

Torque Value: 30 N•m [22 ft-lb]

4.5L and 6.7L engines.

Torque Value: 35 N•m [26 ft-lb]

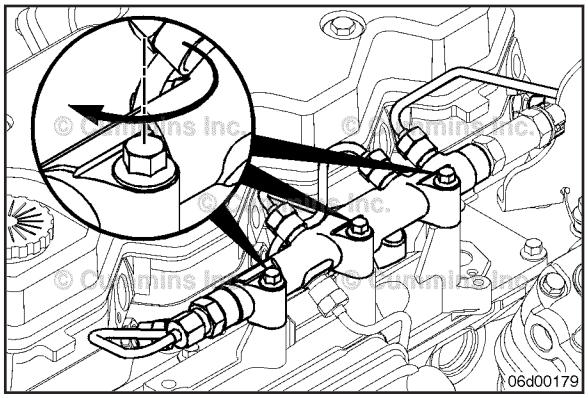


Tighten the injector supply line brace cap screws.

Torque Value: 24 N•m [212 in-lb]

Tighten the capscrews for the fuel rail.

Torque Value: 24 N•m [212 in-lb]



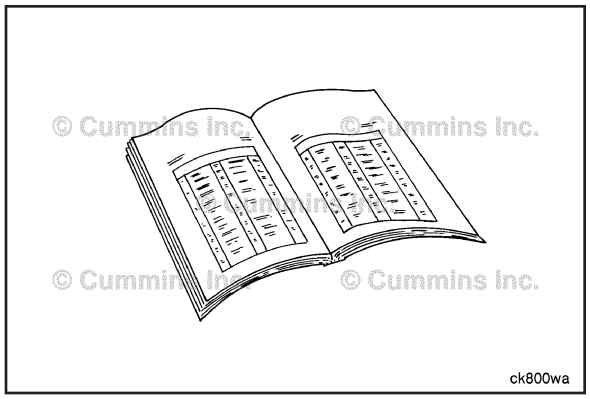
Finishing Steps

⚠WARNING⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

For marine applications, **open** the fuel supply and return valves.

It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will prime the fuel system.

Operate engine and check for leaks.



Fuel Connector (Head Mounted) (006-052)

General Information

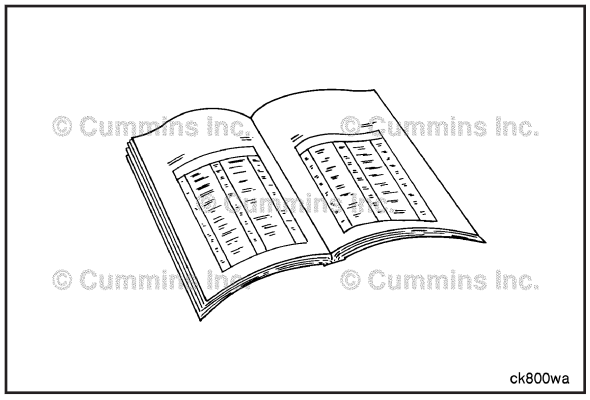
⚠WARNING⚠
The fuel pump, high-pressure fuel lines, and fuel rail contain very high-pressure fuel. Do not loosen any fittings while the engine is running. Wait at least 10 minutes after shutting down the engine before loosening any fittings in the high-pressure fuel system to allow pressure to decrease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

⚠WARNING⚠
Make sure that the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when engine is cranked or started. Environmental damage can also occur. Refer to Procedure 006-999 in Section F.

The fuel return manifold is located near the point at which the OEM connects the vehicle fuel drain line. To locate this manifold, follow the fuel drain lines from their source, (rail pressure relief valve, injector return, or high pressure injector pump return) to their termination point. The termination point will occur at the fuel return manifold.

An internal leak from either the high-pressure connector or the fuel injector will result in increased fuel return flow from the cylinder head. Single cylinder cut-outs will **not** be able to isolate this leak because it occurs before it reaches the control needle inside the injector. Because all injectors share the same pressurized fuel supply from the rail, all cylinders will share the loss of fuel equally.

Use the following procedure to check for a leak at the fuel connector. Refer to Procedure 006-026 in Section 6.



Preparatory Steps

- Remove the high-pressure injector supply line from the fuel rail to the cylinder head. Refer to Procedure 006-051 in Section 6.

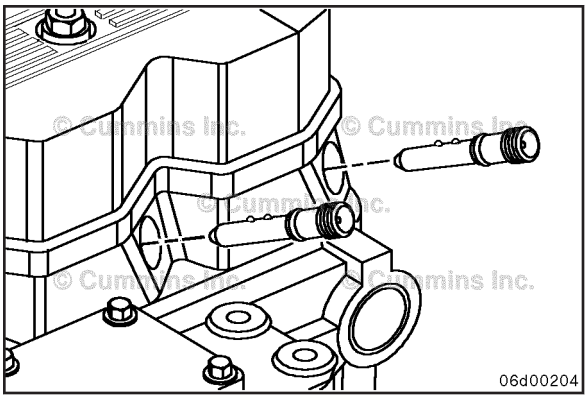
Remove

Remove the fuel connector retaining nut.

Install the fuel connector remover, Part Number 3164025.

NOTE: When removing the fuel connector from the cylinder head, care **must** be taken to make sure the connector o-ring is **not** damaged.

Remove the fuel connector from the cylinder head.

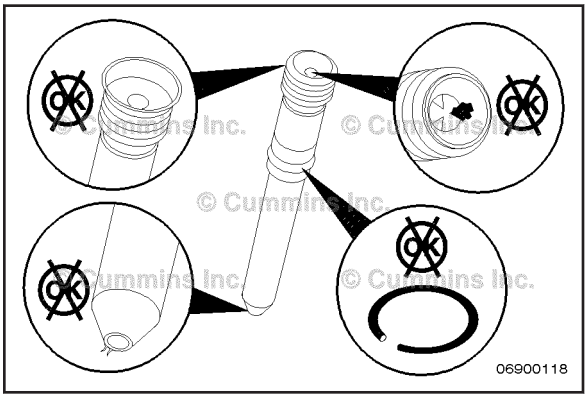


Clean and Inspect for Reuse

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.

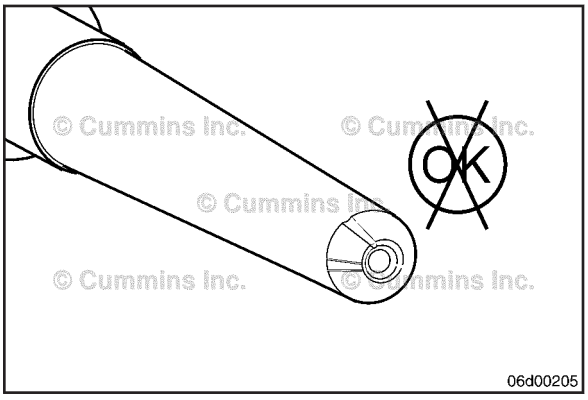
Check the o-ring for tearing or deterioration.

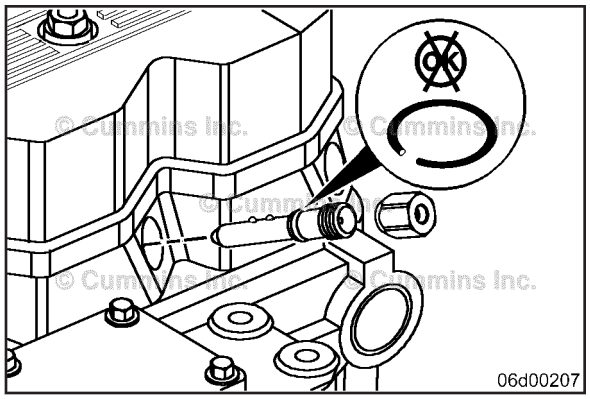


Inspect the outlet sealing surface of the high-pressure connector for wear, an uneven seating surface, or signs of leakage.

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

Lubricate the fuel connector o-ring and the threads on the fuel connector retaining nut.

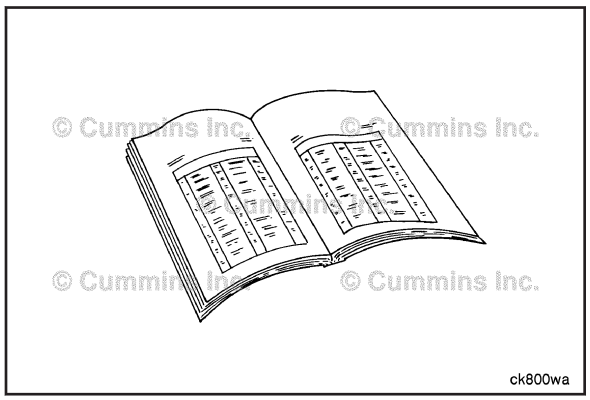
Carefully insert the fuel connector, aligning the guide ball with the slot in the cylinder head at the 12-o'clock position.

NOTE: Use even axial force when installing to prevent the possibility of damage. Make sure **not** to tear the o-ring as the connector is being installed.

NOTE: If the injector was removed along with the high-pressure connector, the installation steps **must** be followed. Refer to Procedure 006-026 in Section 6.

Tighten the fuel connector retaining nut.

Torque Value:
Fuel Connector (cylinder head-mounted)
Step 1 55 N•m [41 ft-lb]



Finishing Steps

⚠WARNING⚠
Make sure the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when engine is cranked or started. Environmental damage can also occur. Refer to Procedure 006-999 in Section F.

- Install the high-pressure injector supply line. Refer to Procedure 006-051 in Section 6.
- For marine applications, **open** the fuel supply and return valves.
- Operate the engine and check for leaks.

Fuel Rail (006-060)

General Information

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

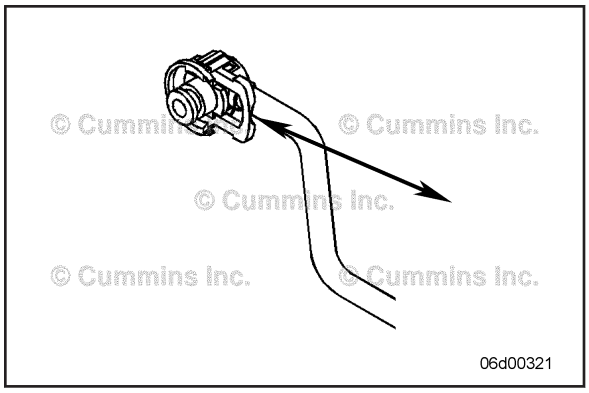
△CAUTION△
Make sure the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when engine is cranked or started. Environmental damage could also occur. Refer to Procedure 005-999 in Section F for further information.

Due to the number of different fuel rail configurations, the steps in this procedure have been written to be generic. Some of the illustrations are **not** representative of the parts being removed or installed.

Directions for service of a white tang quick-disconnect fitting:

Push in the white tang to release the fuel line.

Pull to lock the fuel line.

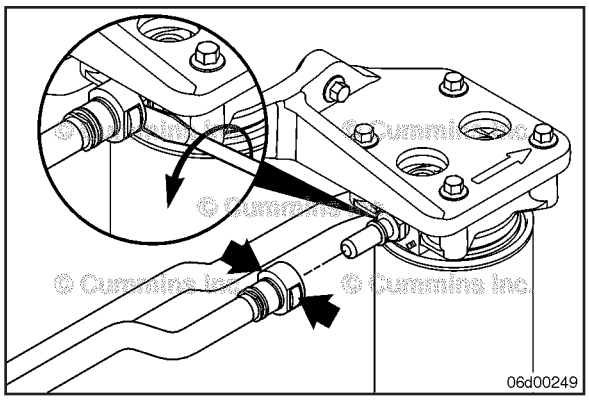


Directions for service of a two-button, quick-disconnect fitting:

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

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

Install the quick-disconnect style fuel lines by pushing the quick-disconnect fitting onto the male union until it clicks.



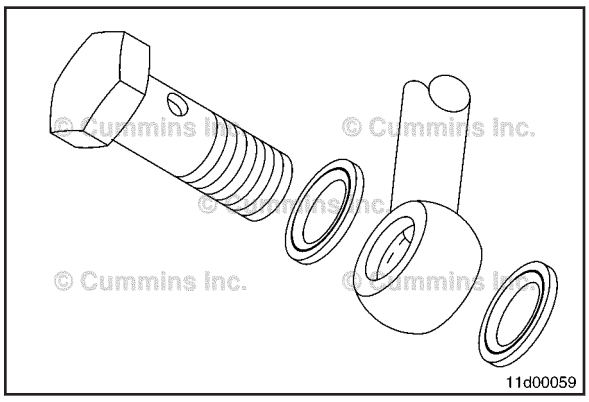
NOTE: New sealing washers **must** be installed when installing the banjo bolt fitting.

Directions for service of a banjo bolt fitting:

A sealing washer is used on both sides of a banjo fitting.

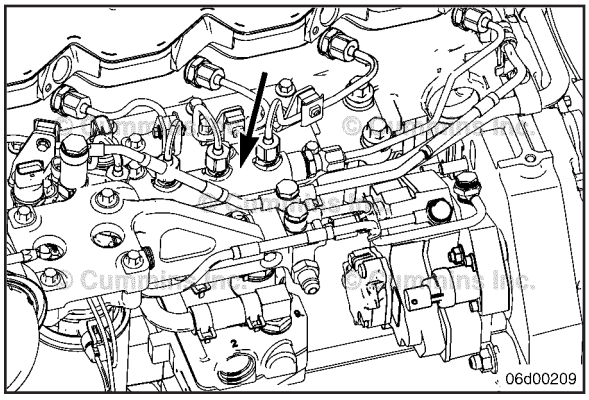
Installation:

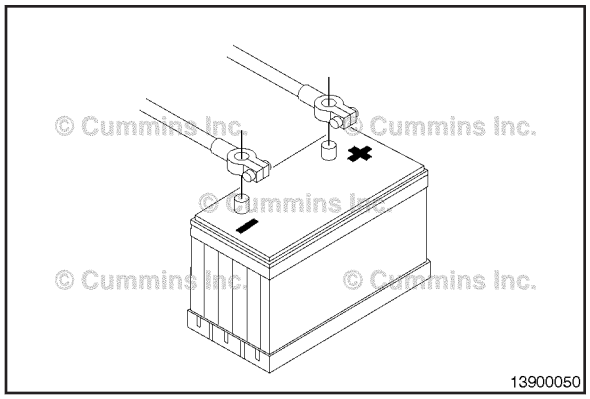
Torque Value: 24 N•m [212 in-lb]



Initial Check

Check the fuel rail for leaks, loose capscrews, or other damage.





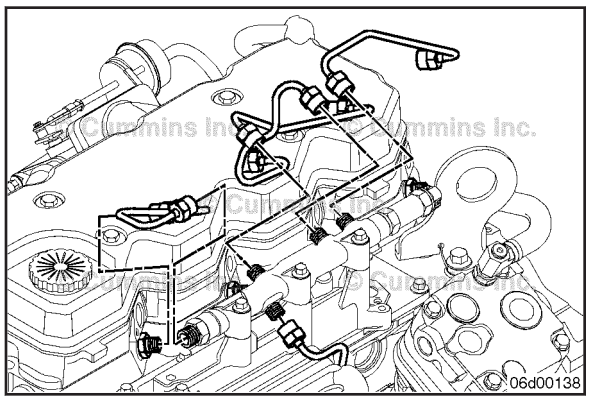
Preparatory Steps

Automotive and Industrial

⚠WARNING⚠

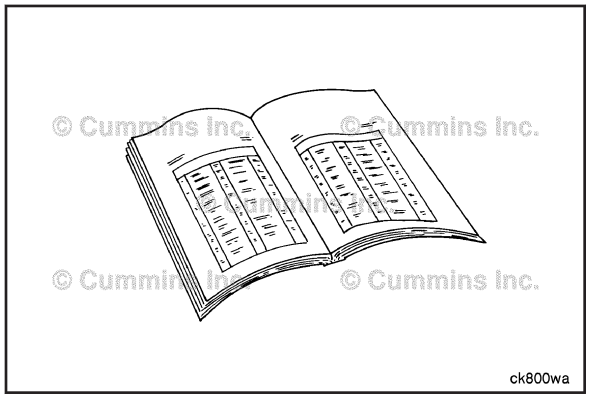
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.



NOTE: Note the location of the high-pressure supply lines so they are replaced in the same location during assembly.

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



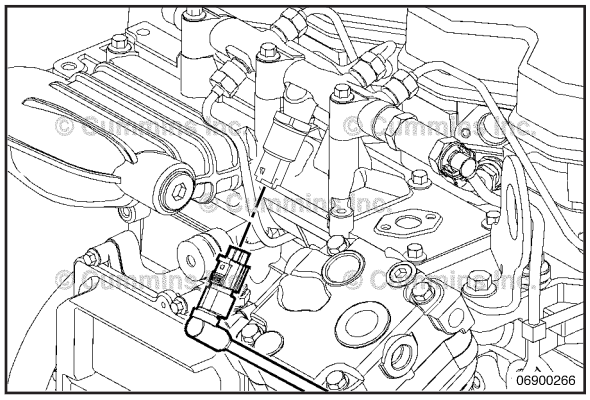
Marine Applications

△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.

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

Close the fuel supply and return valves to the engine.



Remove

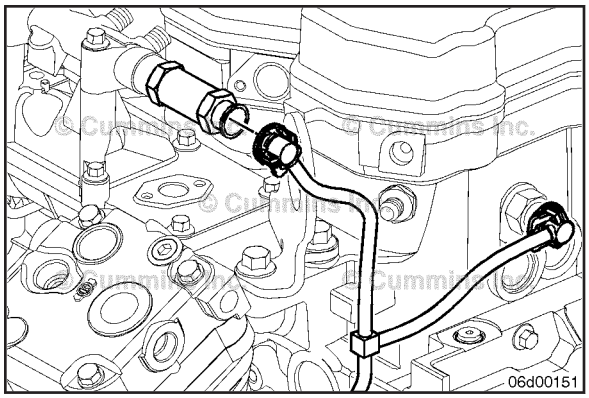
NOTE: Do **not** remove the fuel rail pressure sensor unless it is being replaced. The fuel pressure sensor **must** be replaced if it is removed from the fuel rail.

Disconnect the fuel pressure wiring harness sensor connector.

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

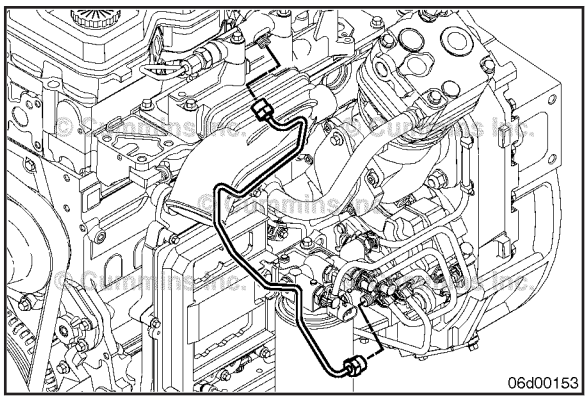
NOTE: The fuel rail pressure relief valve drain line can have either a banjo fitting or a quick-disconnect fitting.

Disconnect the fuel pressure relief valve drain line.



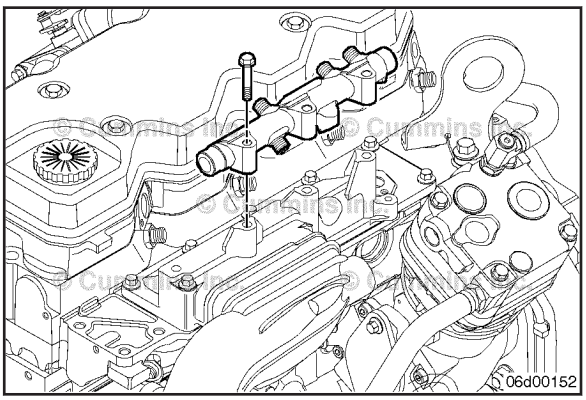
NOTE: It is **not** necessary to remove the high-pressure supply line from the engine.

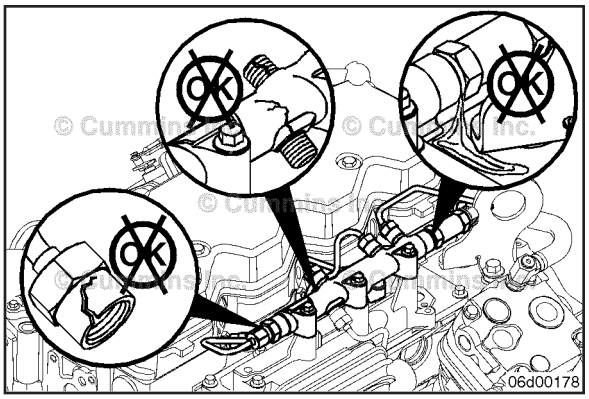
Disconnect the high-pressure supply line that connects the fuel pump to the fuel rail.



NOTE: For some engines, it could be necessary to loosen the three cap screws holding the fuel filter bracket in place. This will provide adequate clearance to separate the high-pressure supply line from the fuel rail.

Remove the capscrews and the fuel rail.





Clean and Inspect for Reuse

⚠CAUTION⚠
Internal passages of the fuel rail can only be cleaned with contact cleaner, Part Number 3824510 or equivalent. Do not use a parts washer to clean the fuel rail. Dirt or Contaminants can damage the fuel system.

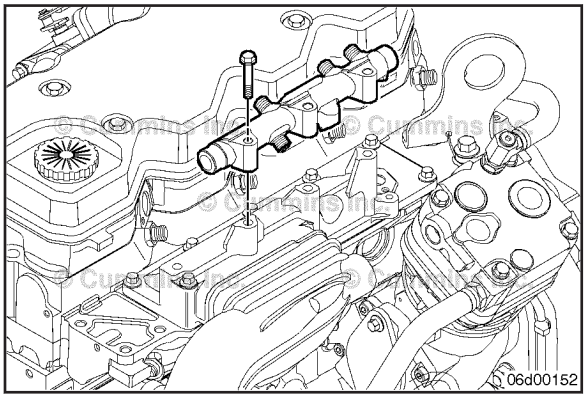
Inspect the fuel line connections at the fuel rail for cracks or scratches.

Inspect the inlets of the high-pressure lines for damaged sealing surfaces.

Check for loose or damaged pressure sensors and pressure relief valve.

Replace the fuel rail pressure sensor if damaged. Use the following procedure in the ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9, CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416. Refer to Procedure 019-115 in Section 19.

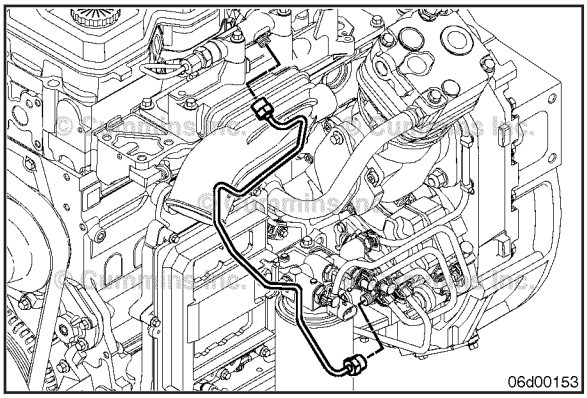
Replace the pressure relief valve if it is damaged or leaking. Refer to Procedure 006-061 in Section 6. When replacing a fuel rail, the new fuel rail will come with the pressure sensor and relief valve installed.



Install

Install the fuel rail on the engine.

Hand-tighten the fuel rail capscrews.



Hand-tighten the holding bracket capscrews to loosely fit the high-pressure pump to fuel rail line to the cylinder block.

Connect the high-pressure supply line to the high-pressure fuel pump and high-pressure fuel rail.

NOTE: Apply a counter-torque on the high-pressure pump outlet port to prevent overtightening.

Torque Value:
3.9L and 5.9L High-Pressure Supply Line
Step 1 30 N•m [22 ft-lb]

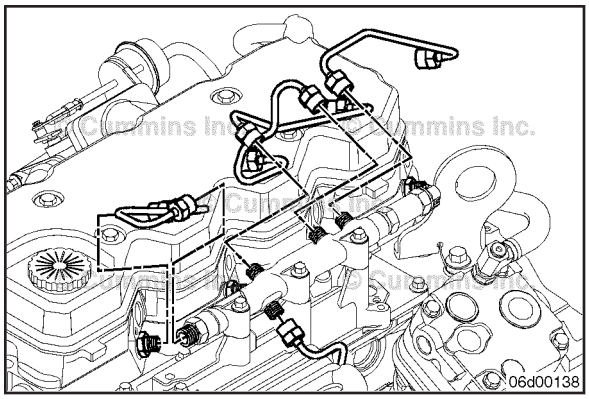
Torque Value:
4.5L and 6.7L High-Pressure Supply Line
Step 1 36 N•m [27 ft-lb]

Tighten the high-pressure fuel line holding bracket capscrews

Torque Value: 24 N•m [212 in-lb]

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

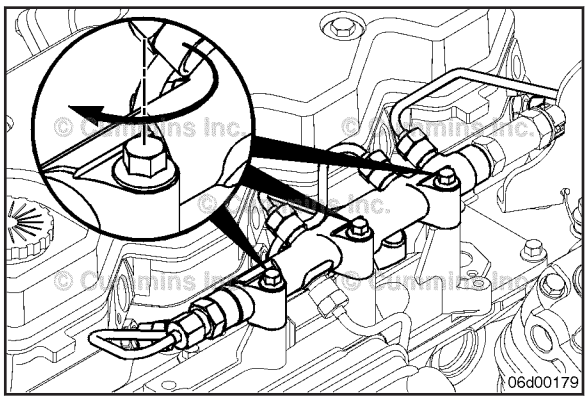
Install the injector supply line(s) that connect the fuel rail to the fuel injectors. Refer to Procedure 006-051 in Section 6.



NOTE: If the fuel filter head bracket capscrews were loosened during removal of the fuel rail, tighten the fuel filter head bracket capscrews. Be sure that the fuel filter head bracket is **not** in contact with the high-pressure supply line connecting the high-pressure fuel pump to the fuel rail. Refer to Procedure 006-017 in Section 6, for the fuel filter head bracket.

Tighten the fuel rail capscrews.

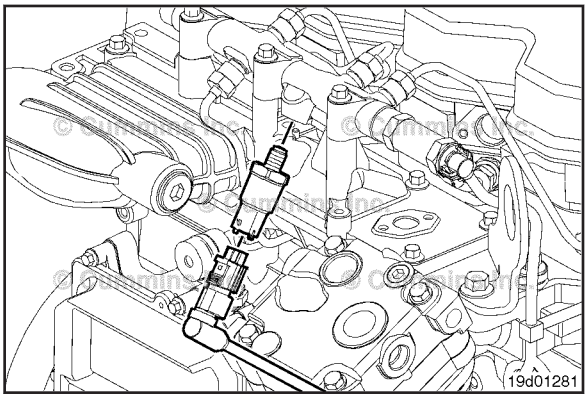
Torque Value: 24 N•m [212 in-lb]



Install the fuel rail pressure sensor, if applicable.

Torque Value: 70 N•m [52 ft-lb]

Connect the fuel pressure sensor connector.



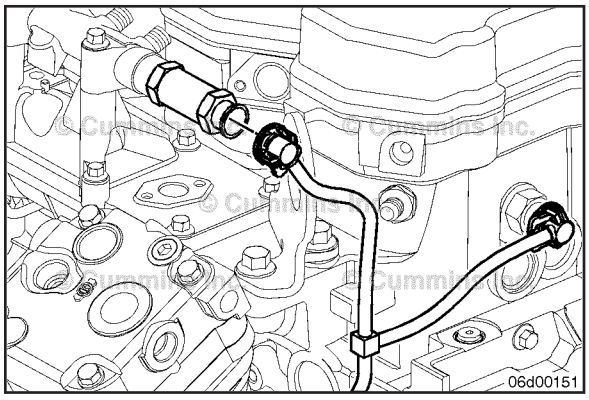
NOTE: The fuel rail pressure relief valve drain line has either a banjo fitting or a quick-disconnect fitting. Be sure that the quick disconnect is locked in place, if applicable.

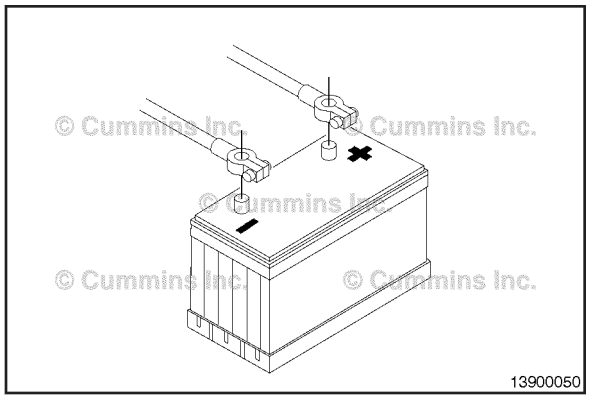
NOTE: Overtightening the fuel pressure relief valve can result in a leak.

Install the fuel pressure relief valve and tighten, if applicable.

Torque Value: 100 N•m [74 ft-lb]

Connect the fuel rail pressure relief valve drain line. Refer to Procedure 006-013 in Section 6.

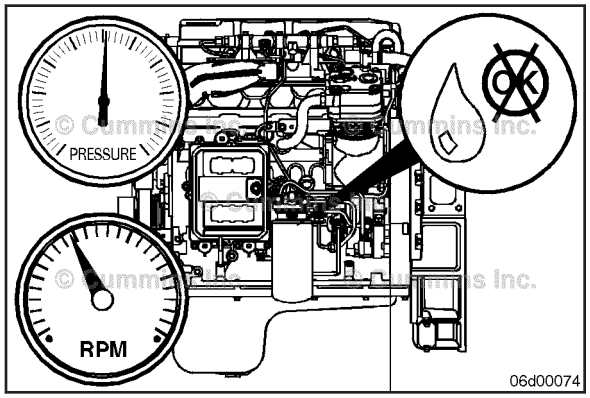




Finishing Steps

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

- Connect the batteries. Refer to Procedure 013-009 in Section 13.



- On marine applications, open the fuel supply and return valves.
- Operate the engine and check for leaks.

Fuel Pressure Relief Valve (006-061)

General Information

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

⚠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 avoid the possibility of personal injury, never loosen any fittings while the engine is running.

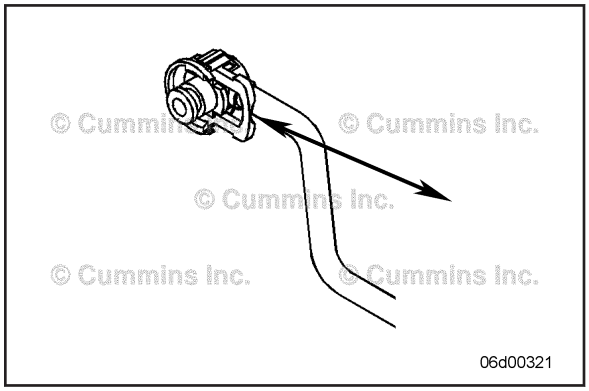
⚠WARNING⚠
Fuel can be returned at highly elevated temperatures. Wear safety glasses, protective gloves, and clothing when performing this test. Avoid any contact with returned fuel.

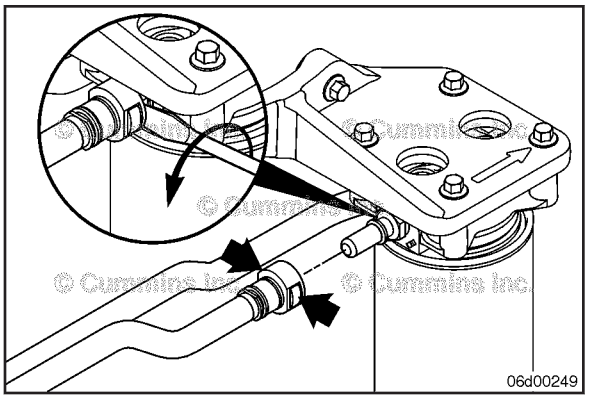
△CAUTION△
Make sure that the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when engine is cranked or started. Environmental damage can also occur. Refer to Procedure Procedure 005-999 (Fuel System Overview) in Familiarization section for further information.

Directions for service of a white tang quick-disconnect fitting:

Push in white tang to release fuel line.

Pull to lock fuel line.



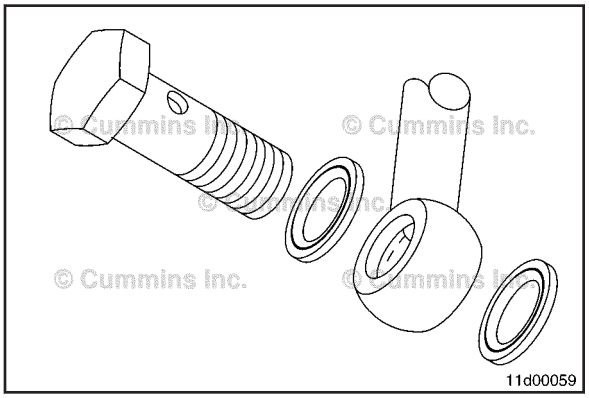


Directions for service of a two-button quick-disconnect fitting:

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

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

Install the quick-disconnect style fuel lines by pushing quick-disconnect fitting onto male union until it clicks.



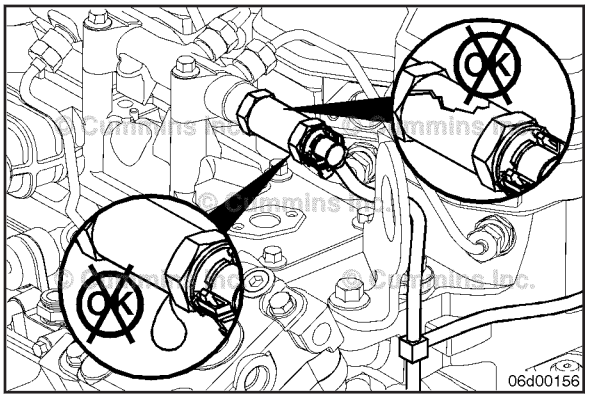
Directions for service of a banjo bolt fitting:

A sealing washer is used on both sides of a banjo fitting.

NOTE: New sealing washers **must** be used when installing the banjo bolt fitting.

Installation:

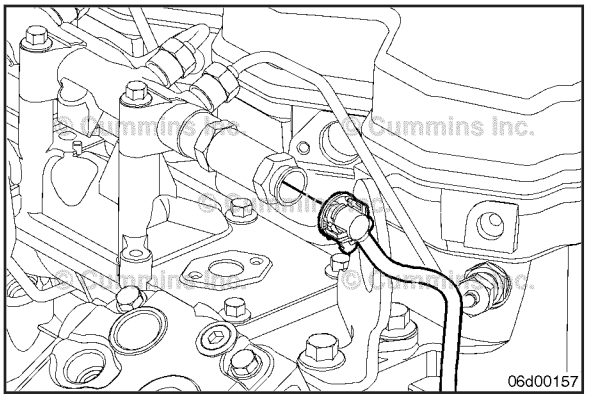
Torque Value: 24 N•m [212 in-lb]



Initial Check

△CAUTION△
Do not overtighten the component in an attempt to stop a leak. Overtightening can result in increased leakage. Always tighten fuel pressure relief valve again to specification.

Check the pressure relief valve for leaks or other damage.



Setup

White Tang Fitting on Pressure Relief Valve

The purpose of this test is to check for a fuel rail pressure relief valve that leaks excessive fuel to the fuel drain line.

Disconnect the fuel drain line from the fuel pressure relief valve.

Attach the fuel pressure gauge adapter tool, Part Number 3164044, to the fuel pressure relief valve.

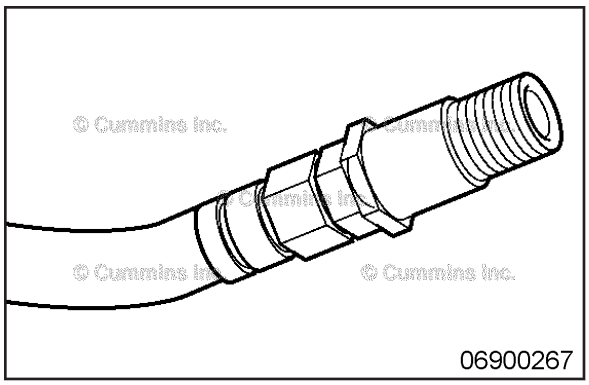
Install a quick-disconnect block-off fitting, Part Number 3164583 onto the drain line removed from the fuel pressure relief valve.

3.9L and 5.9L with Banjo Fitting on Pressure Relief Valve

The purpose of this test is to check for a fuel rail pressure relief valve that leaks excessive fuel to the fuel drain line.

Disconnect the fuel drain line from the fuel pressure relief valve.

Attach the fuel return flow hose, Part Number 3164617, to the fuel pressure relief valve.



4.5L and 6.7L with Banjo Fitting on Pressure Relief Valve

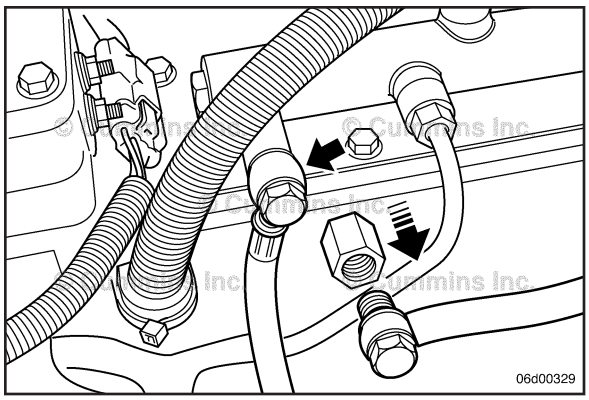
The purpose of this test is to check for a fuel rail pressure relief valve that leaks excessive fuel to the fuel drain line.

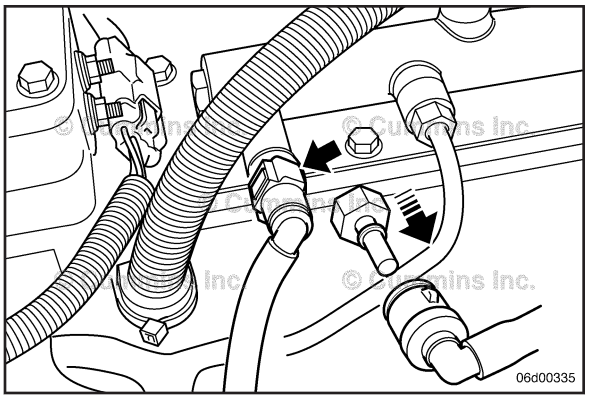
Disconnect the fuel drain line from the fuel pressure relief valve.

Measurement of fuel pressure relief valve flow leakage requires the use of a pressure relief valve flow tester, Part Number 4918295.

Install the fuel drain hose contained in the fuel pressure relief valve flow tester to the fuel pressure relief valve with a banjo bolt.

Cap off the drain line, disconnected from the fuel pressure relief valve, using the cap contained in the fuel pressure relief valve flow tester and a banjo bolt.





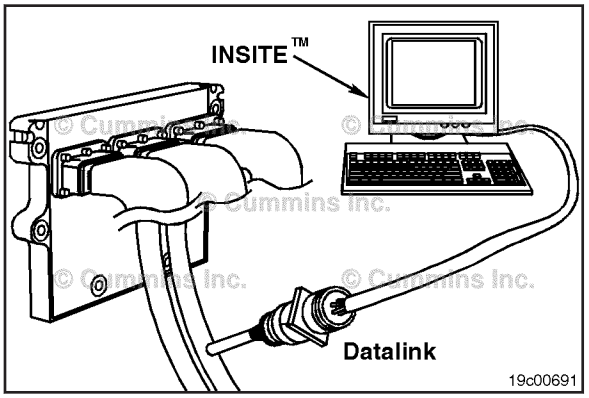
Two Button Fitting on Pressure Relief Valve

The purpose of this test is to check for a fuel rail pressure relief valve that leaks excessive fuel to the fuel drain line.

Disconnect the fuel drain line from the fuel pressure relief valve.

Attach a fuel drain hose with a female quick-disconnect, Part Number 4918434, to the fuel pressure relief valve.

Install a male quick-disconnect block off fitting, Part Number 4918464 into the drain line removed from the fuel pressure relief valve.



Test

If available, run the engine using INSITE™ fuel pressure override test. Otherwise, run at idle. Place the end of the fuel drain hose, or pressure gauge adapter, in a bucket and measure the flow.

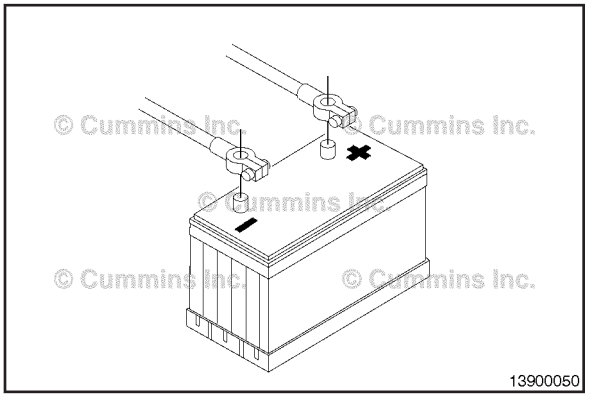
Specification At Idle: No flow.

INSITE™ Override: One drop per second (16 mL per minute or 0.5 ounce per minute).

NOTE: If return flow from rail pressure relief valve is greater than specification, restart engine and bring to high idle. The engine will attempt to reseat valve.

NOTE: If Fault Codes 449, 2311, 272, 553, or 2216 are active, do **not** replace the fuel rail pressure relief valve without first determining the cause of the fault condition. See to the appropriate troubleshooting tree(s).

If the valve does **not** reseat, replace valve.



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.

3.9L and 5.9L Engines

Disconnect the fuel pressure relief valve line.

4.5L and 6.7L Engines

If applicable, remove the cap screw holding the combination temperature and pressure sensor in place. Refer to Procedure Procedure 100-002 (Engine Views) for sensor location.

If applicable, remove the air intake combination temperature and pressure sensor.

If applicable, place tape over the sensor port to prevent debris from entering the air intake.

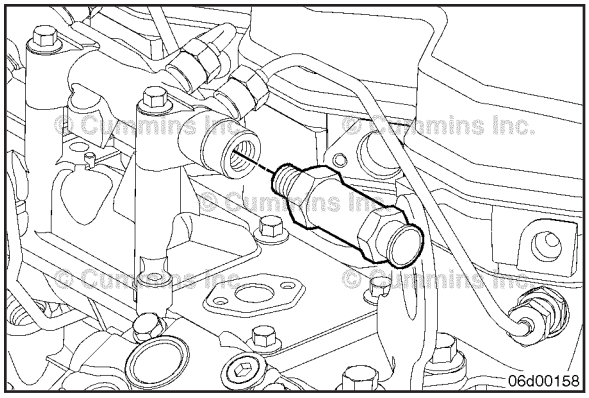
Remove

3.9L and 5.9L Engines

NOTE: The pressure relief valve is located between the fuel rail and the fuel pressure relief valve drain line.

⚠CAUTION⚠
Once the fuel pressure relief valve has been removed, it must be replaced. Reuse of pressure relief valve will cause a fuel leak.

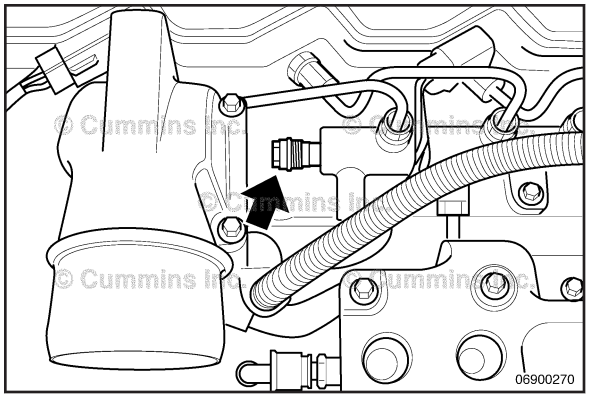
Remove the fuel rail pressure relief valve.

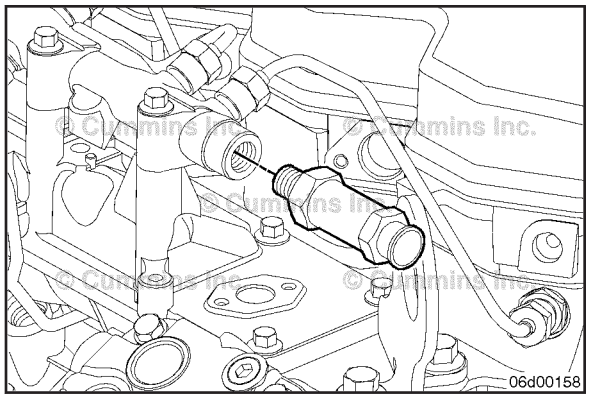


4.5L and 6.7L Engines

NOTE: The fuel pressure relief valve is a cartridge located at the front end of the fuel rail.

Remove the fuel pressure relief valve.





Install

Inspect and clean the sealing surface between the rail and the fuel pressure relief valve.

Install the fuel pressure relief valve and tighten.

NOTE: Overtightening the fuel pressure relief valve can result in a leak.

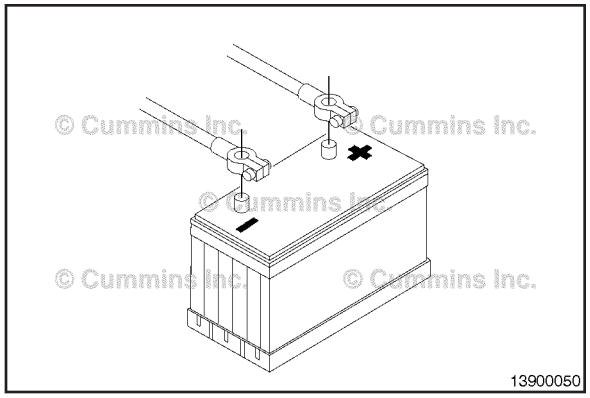
Torque Value: 100 N•m [74 ft-lb]

Finishing Steps

3.9L and 5.9L Engines

Connect the fuel pressure relief valve line.

NOTE: The fuel pressure relief valve drain line may either have a banjo fitting, or a quick-disconnect fitting. Be sure that the fuel drain line is securely locked, if a quick-disconnect fitting is used.



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

4.5L and 6.7L Engines

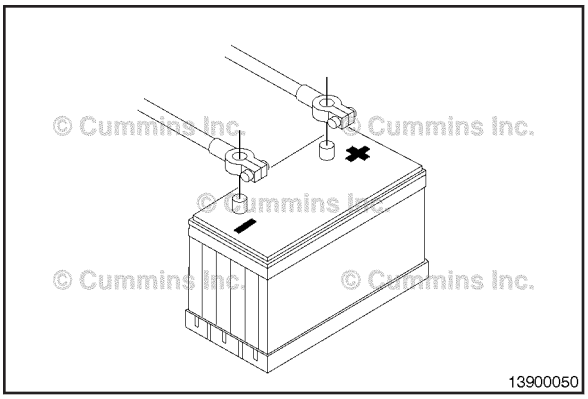
Remove any tape placed over the opening in the intake.

If applicable, Install the air intake combination temperature and pressure sensor.

If applicable, Install the cap screw holding the combination temperature and pressure sensor in place. Refer to Procedure Procedure 100-002 (Engine Views) for sensor location.

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



Prime

⚠WARNING⚠
The fuel pump high-pressure fuel lines and fuel rail contain very high-pressure fuel. Never loosen any fittings while the engine is running. Personal injury and property damage can result.

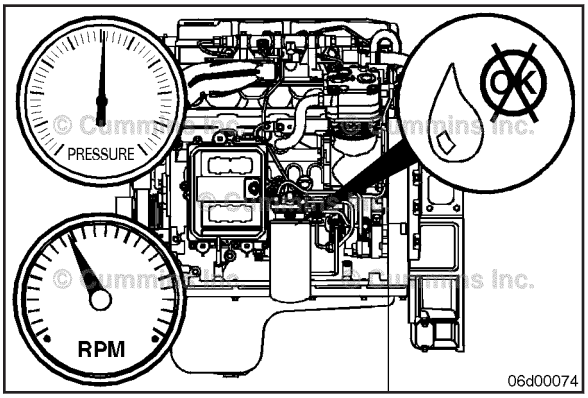
⚠WARNING⚠
Be sure that the fuel inlet and return valves are returned to the open position before cranking engine. Engine damage can result if valves are in the wrong position when engine is cranked or started. Environmental damage can also occur. Refer to Procedure Procedure 005-999 (Fuel System Overview) in Familiarization section for further information.

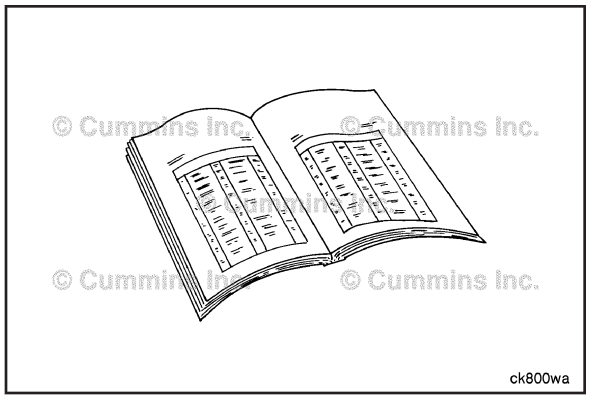
On marine application engines, **open** fuel supply and return valves.

NOTE: It is **not** necessary to vent air from the high-pressure fuel system before starting the engine. Cranking the engine will prime the fuel system.

For engines with an electric lift pump, allow the lift pump to run by turning the keyswitch ON and waiting 30 seconds before starting.

Operate the engine and check the pressure relief valve and fuel line for leaks.





Fuel Cooler (006-062)

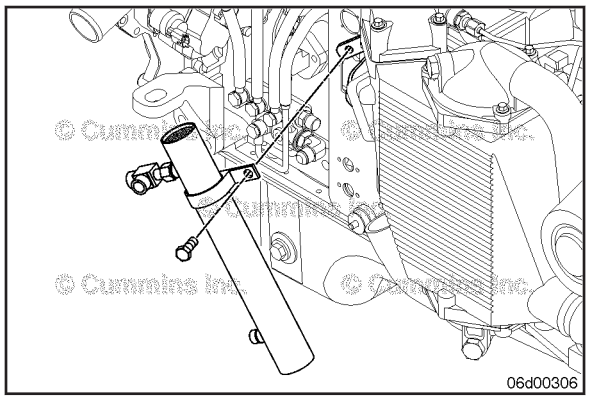
Preparatory Steps

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

⚠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 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.



Remove

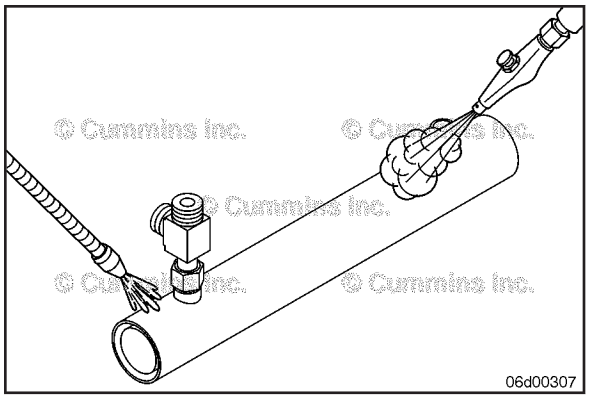
Remove the hose clamps at the top and bottom of the fuel cooler.

Remove the fuel cooler mounting clamp capscrew from the fuel cooler mounting bracket.

Remove the fuel cooler.

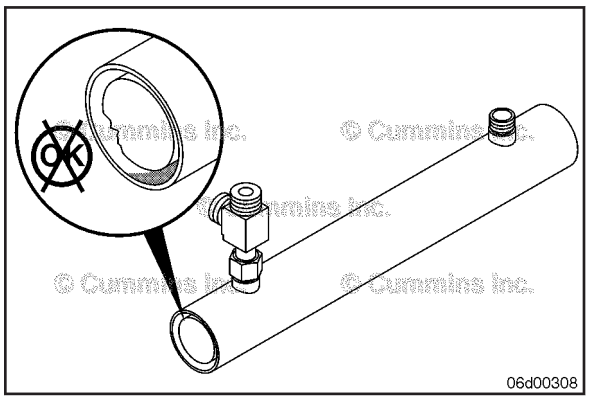
Clean and Inspect for Reuse

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.



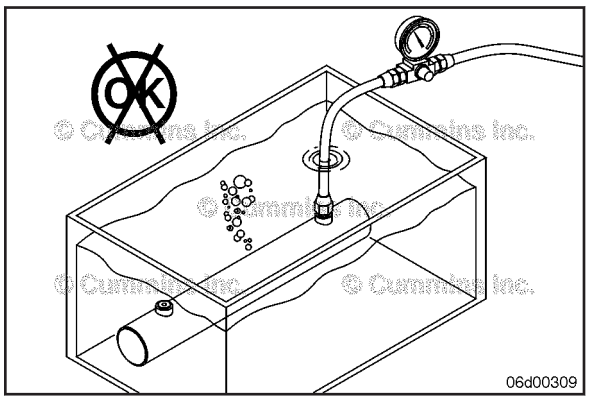
Pressure test the fuel side of the fuel cooler.

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.



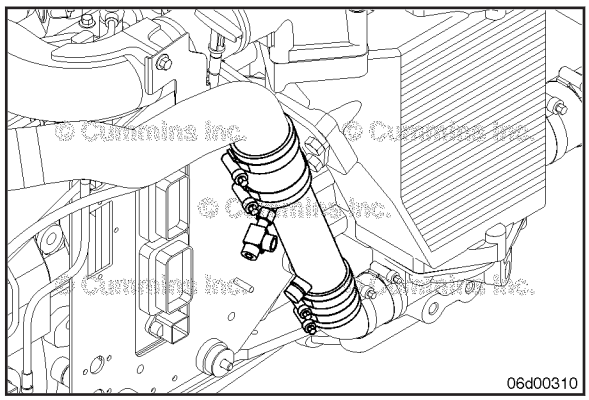
Install

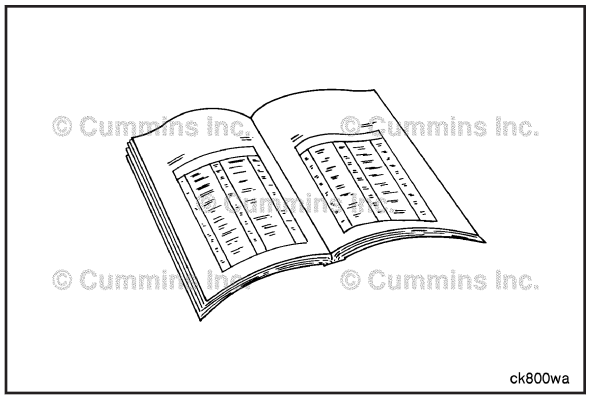
Install the fuel cooler to the fuel cooler mounting bracket using the mounting clamp and capscrew.

Torque Value: 24 N•m [18 ft-lb]

Install the fuel cooler sea water hoses. Tighten the hose clamps.

Torque Value: 3 N•m [30 in-lb]





Finishing Steps

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

△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

△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.

- 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.

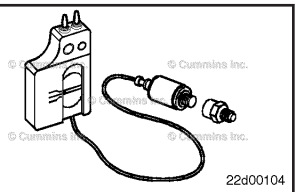
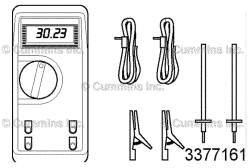
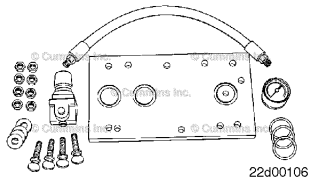
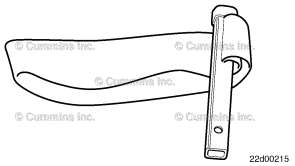
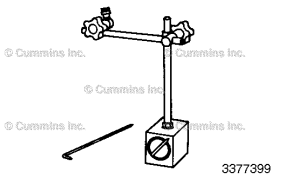
Section 7 - Lubricating Oil System - Group 07

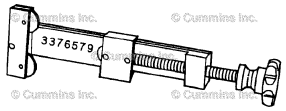
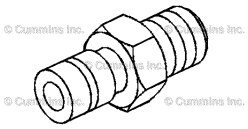
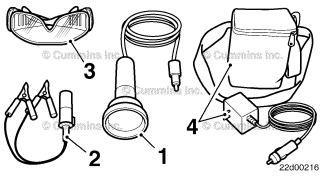
Section Contents

Service Tools

Lubricating Oil System

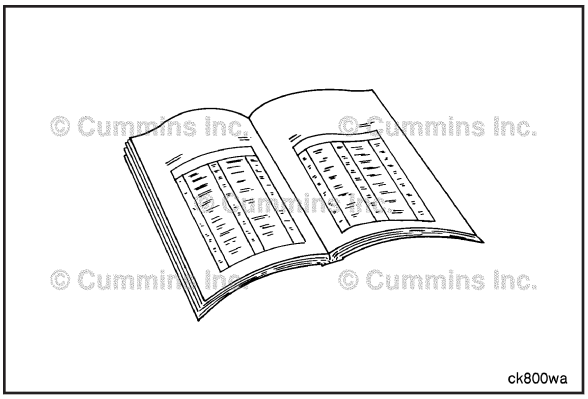
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3164491	**Pressure/Vacuum Module** Used to measure fuel pressure and restriction. Use with multimeter, Part Number 3164488 or 3164489.	
3164488	**Digital Multimeter** Used to measure electrical circuits: Voltage (volts), resistance (ohms), and current (amps).	
3823876	**Lubrication Oil Cooler Test Kit** Used to test the lubrication oil cooler for leaks.	
3823875	**Dipstick Install/Remove** Used to remove and install the lubrication oil dipstick.	
3400158	**Oil Filter Wrench** Used to remove oil filter.	
3377399	**Magnetic Base** Can be used with Metric Indicator Part Number 3824564 or SAE Indicator Part Number 4918289.	

Tool No.	Tool Description	Tool Illustration
3376579	**Tube (Filter) Cutter** Used to cut open the filter to permit inspection of the filter element.	 3376579
3824842	**Compucheck® Fitting** Used to measure fuel inlet restriction.	 22d00083
3163338	**Black Light Lamp (12VDC)** Black light with rechargeable battery and charger used with fluorescent tracer to locate oil and/or coolant leaks. Oil tracer Part Number 3376891, coolant tracer Part Number 3377438.	 22d00216

Engine Oil Heater (007-001)

Preparatory Steps



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

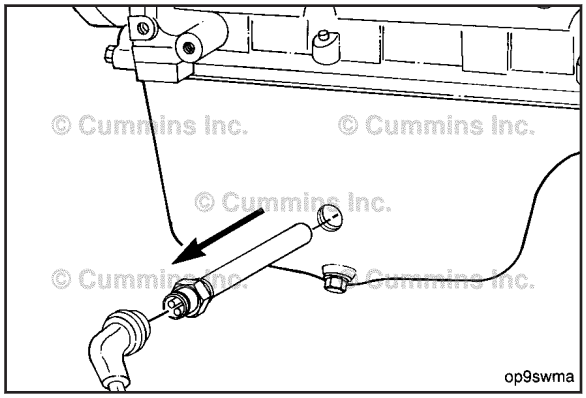
⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

Drain the lubricating oil. Refer to Procedure Procedure 007-037

Remove

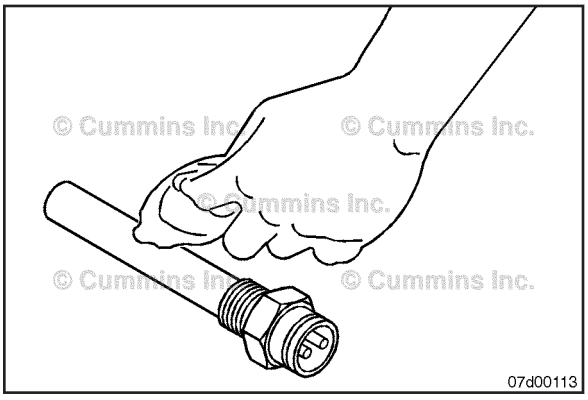
Disconnect the oil heater electrical cord.

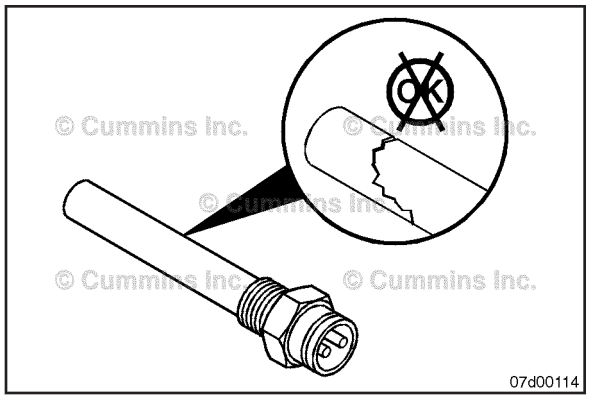
Remove the heater element.



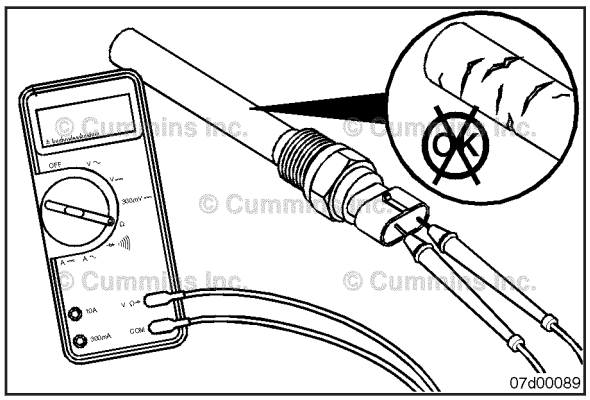
Clean and Inspect for Reuse

Clean the heater element with a dry, clean towel.





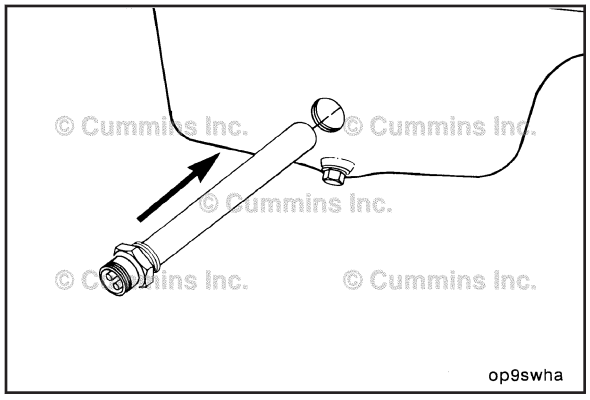
Check for cracks in the heating element.



Test

Perform a resistance test on the engine lubricating oil heater element.

The readings **must** be a minimum of 91 ohms to a maximum 101 ohms.

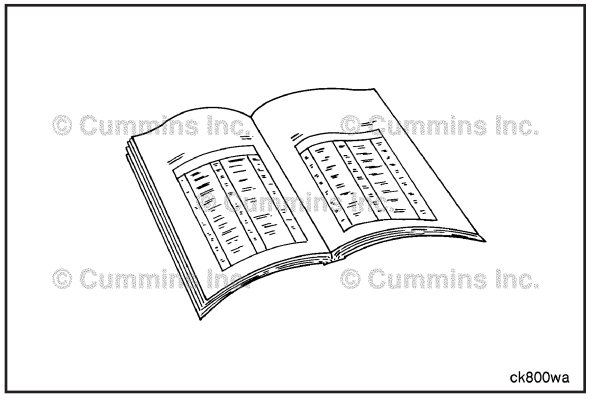


Install

Replace the heater element.

Torque Value: 80 N•m [59 ft-lb]

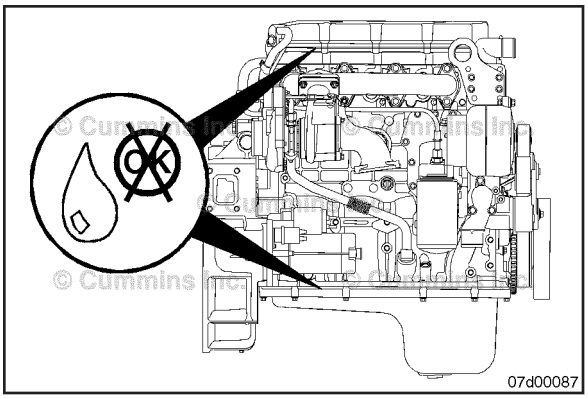
Connect oil heater electrical cord.



Finishing Steps

Refill the engine with clean oil to the correct level. Refer to Procedure Procedure 007-037

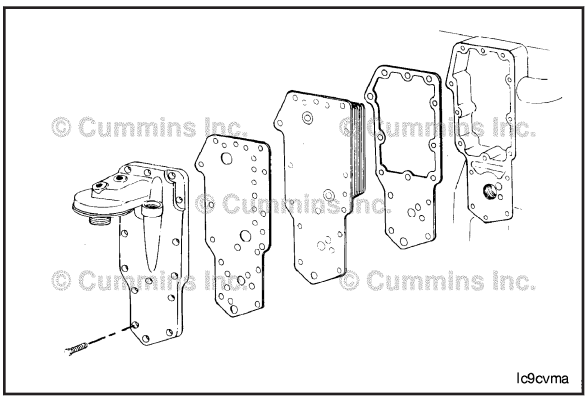
Operate the engine and check for leaks.



Lubricating Oil Cooler (007-003)

General Information

The lubricating oil cooler is mounted between the lubricating oil cooler cover and the cylinder block. Since neither the lubricating oil cooler or lubricating oil cooler cover can be removed without removing and installing the other, this procedure covers the removal and installation of both components.

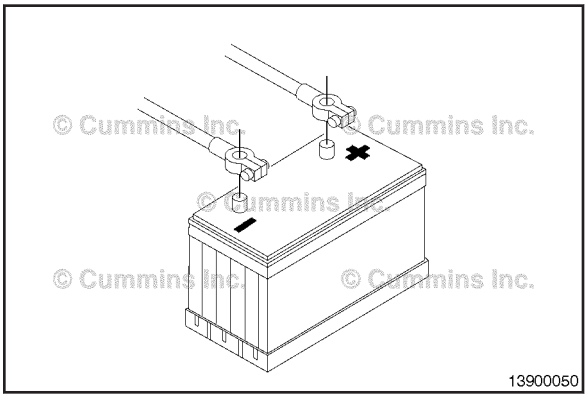


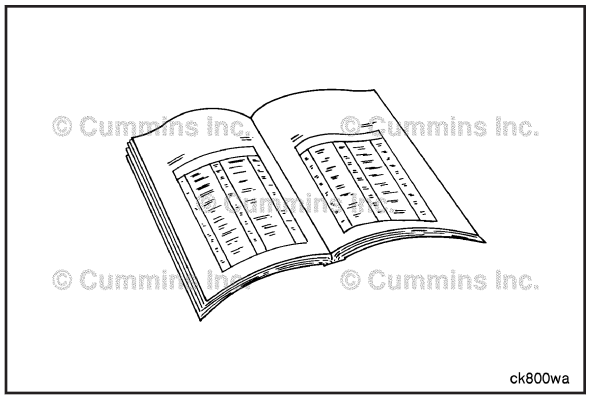
Preparatory Steps

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.

Disconnect the batteries.





⚠WARNING⚠
Coolant is toxic. Keep away from pets and children. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

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

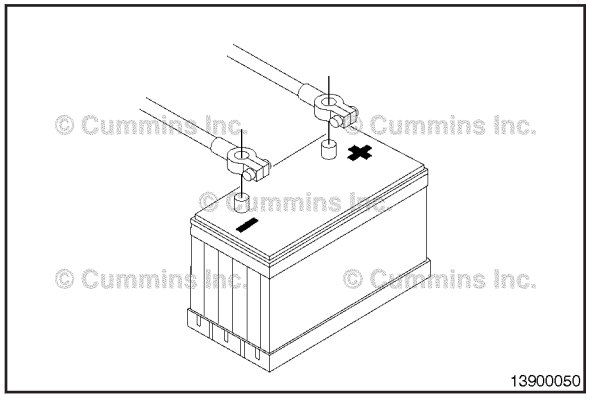
⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

Drain the coolant.Refer to Procedure 008-018.

Clean around the lubricating oil cooler cover.

Remove the lubricating oil filter.Refer to Procedure 007-013.

Disconnect the turbocharger supply line. Refer to Procedure 010-046.



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.

⚠WARNING⚠
Coolant is toxic. Keep away from pets and children. If not reused, dispose of in accordance with local environmental regulations.

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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.

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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.

Drain the engine coolant. Refer to Procedure 008-018.

Clean around the lubricating oil cooler cover.

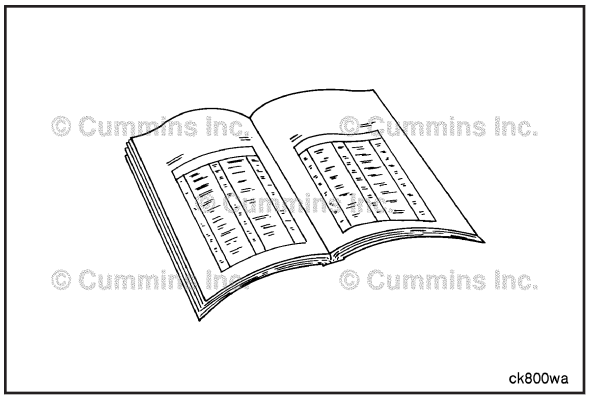
Disconnect the turbocharger supply line. Refer to Procedure 010-046.

Tag for location, and remove the lubricating oil lines for the oil filter. Refer to Procedure 007-092.

Remove the belt guard in front of the alternator. Refer to Procedure 008-001.

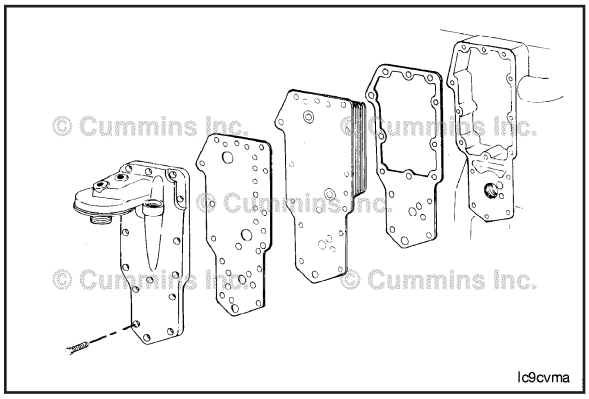
Release the belt tension on the alternator drive belt and remove the alternator belt from the alternator pulley. Refer to Procedure 008-002.

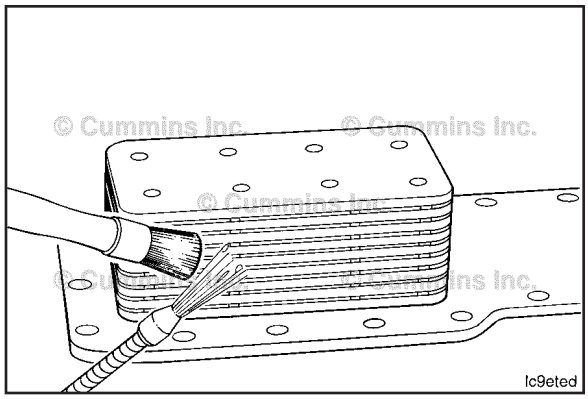
Remove the alternator. Refer to Procedure 013-001.



Remove

Remove the lubricating oil cooler housing capscrews, housing, gaskets, and cooler element.





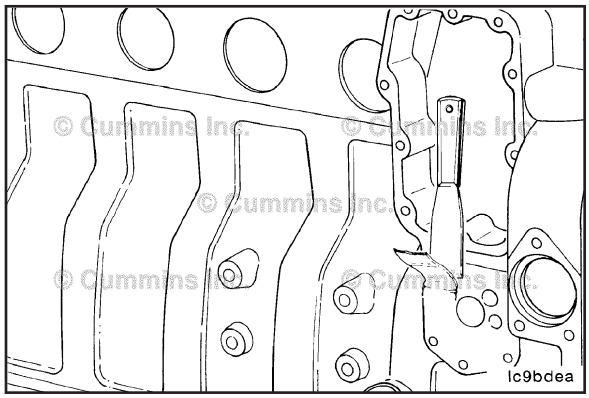
Clean and Inspect for Reuse

⚠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.

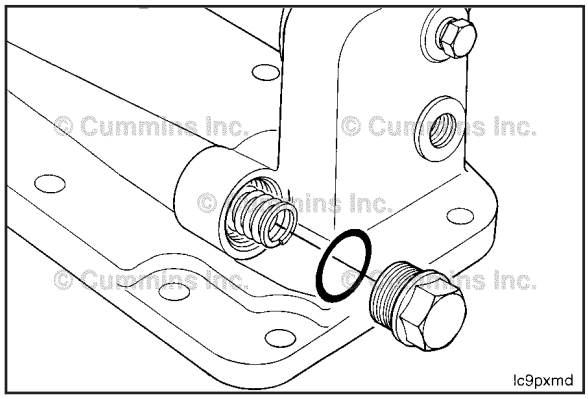
Use solvent to clean the oil cooler housing and cover.

NOTE: Replace the lubricating oil cooler if any debris is found or the engine has had a debris-causing failure.

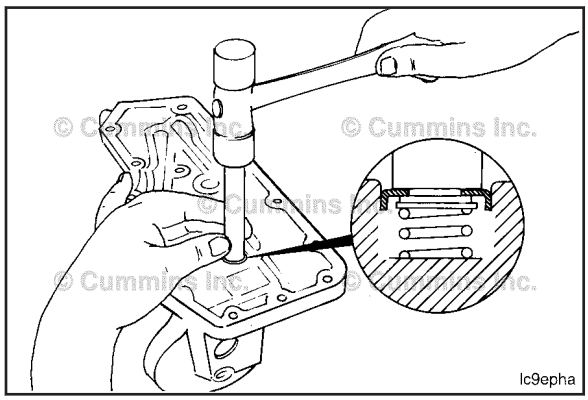


Clean the sealing surfaces.

When cleaning the oil cooler cover, be sure to clean the lubricating oil bypass valve.



If any debris is suspected to have gone through the engine or troubleshooting a lubricating oil pressure issue, remove and inspect the lubricating oil pressure regulator located in the lubricating oil cooler cover. Replace if necessary. Refer to Procedure 007-029.



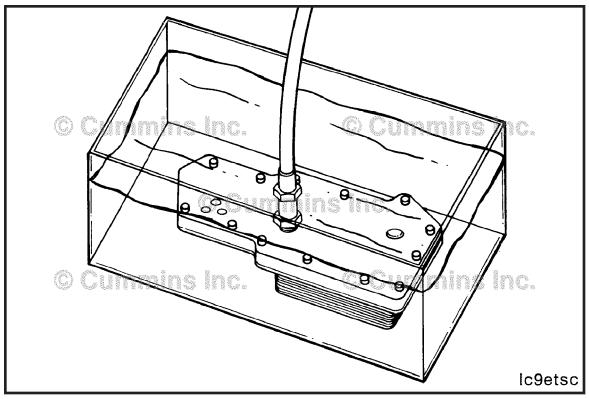
If any debris is suspected to have gone through the engine, inspect oil filter bypass valve located in the lubricating cooler cover. Make sure the valve is fully seated and opens and closes freely. Replace if necessary.

NOTE: The bypass valve requires a 345 kPa [50 psi] pressure differential to open.

Leak Test

Use the lubricating oil cooler pressure test kit, Part Number 3823876, to pressure-test the element to check for leaks. If leaks are detected, replace the element.

Air Pressure Test		
kPa		psi
449	MIN	65
518	MAX	75

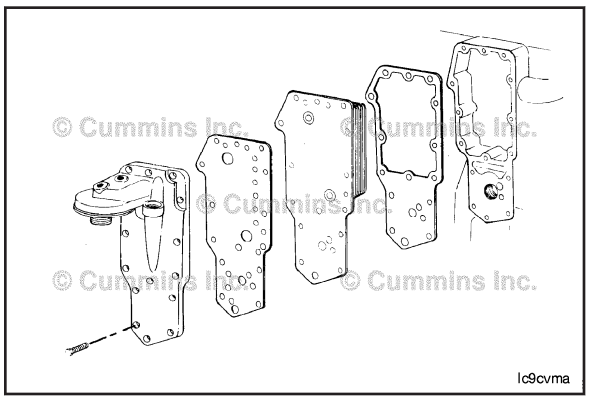


Install

NOTE: Be sure to remove the shipping plugs from the oil cooler element.

NOTE: When installing a new lubricating oil cooler be sure to use the correct part number. Replace with the same part number or use the engine serial number and QuickServe OnLine to ensure the use of the correct part.

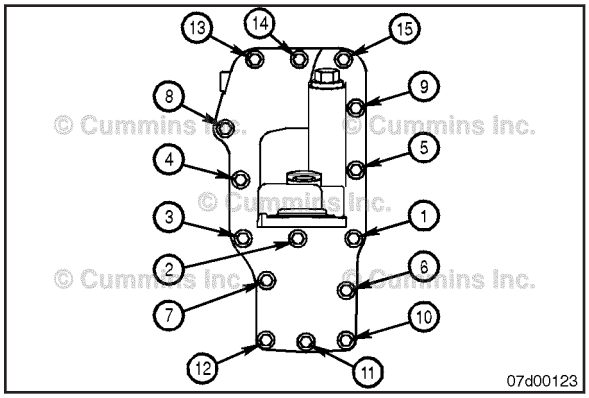
Assemble the lubricating oil cooler cover, capscrews, gaskets, and oil cooler.



If the engine uses a lubricating oil cooler cover in which the lubricating oil filter is mounted low, use the torque sequence shown.

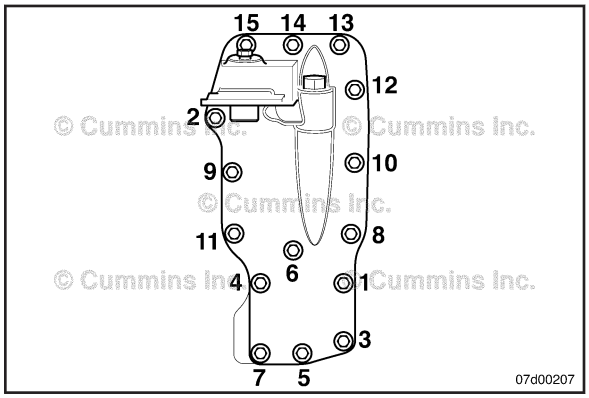
NOTE: Snug capscrew numbers six and eight, then tighten in the sequence shown.

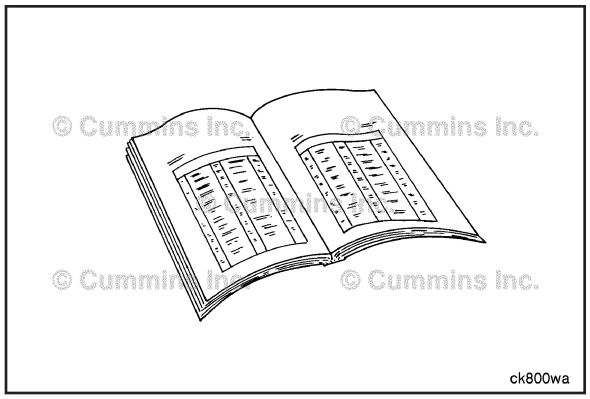
Torque Value: 24 N•m [212 in-lb]



If the engine uses a lubricating oil cooler cover in which the lubricating oil filter is mounted high, use the torque sequence shown.

Torque Value: 24 N•m [212 in-lb]





Finishing Steps

Automotive and Industrial

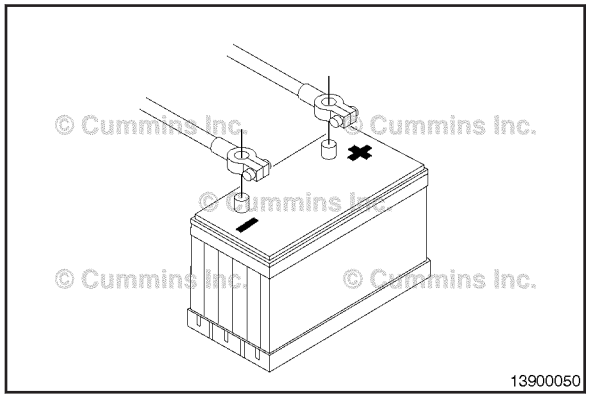
CAUTION
If the engine does not produce oil pressure in 15 seconds after starting the engine, shut off the engine to avoid component damage.

Connect the turbocharger lubricating oil supply line. Refer to Procedure 010-046.

Install the lubricating oil filter. Refer to Procedure 007-013.

Fill the engine with clean lubricating oil. Refer to Procedure 007-037.

Fill the cooling system. Refer to Procedure 008-018.

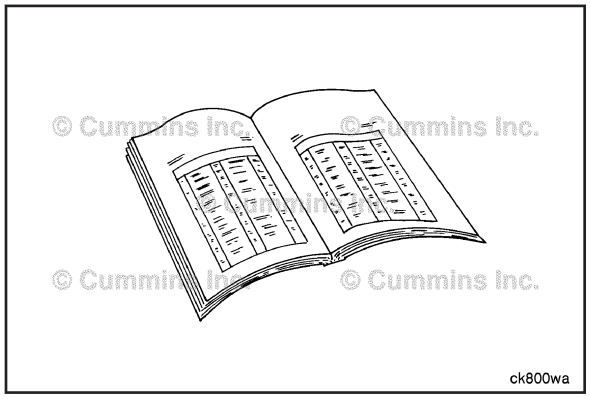


WARNING
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Connect the batteries.

Operate the engine and check for leaks.

Stop the engine, and check the coolant and lubricating oil level.



Marine Applications

CAUTION
If the engine does not produce oil pressure in 15 seconds after starting the engine, shut off the engine to avoid component damage.

Install the alternator. Refer to Procedure 013-001.

Install the alternator drive belt. Refer to Procedure 008-002.

Install the belt guard. Refer to Procedure 008-001.

Install the lubricating oil lines for the oil filter. Refer to Procedure 007-092.

Connect the turbocharger lubricating oil supply line. Refer to Procedure 010-046.

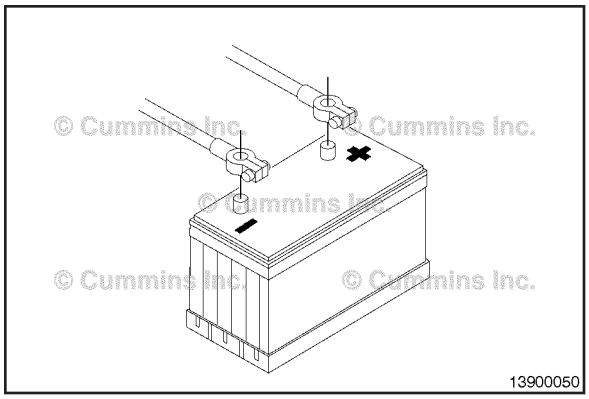
Fill the cooling system. Refer to Procedure 008-018.

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

Operate the engine and check for leaks.

Stop the engine, and check the coolant and lubricating oil level.



Lubricating Oil Dipstick (007-009)

Calibrate

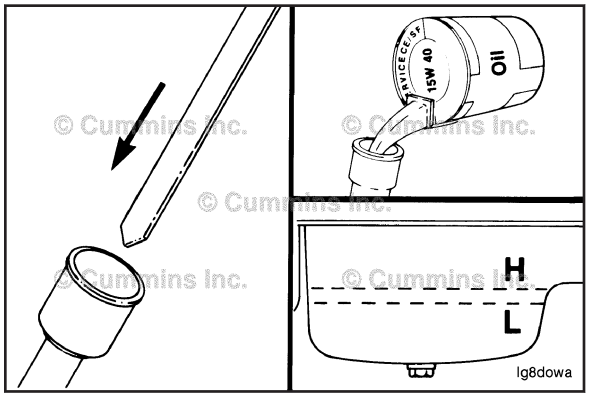
⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.

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

Drain the lubricating oil. Refer to Procedure 007-037

Wipe off the dipstick, and install it in the dipstick tube housing.

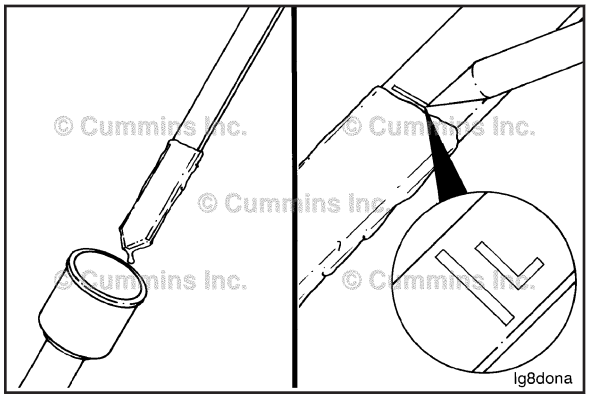
Use clean 15W-40 oil to fill the oil pan to the specified low oil level. The low oil level can be found by looking up the oil pan option for the engine serial number on QuickServe OnLine.

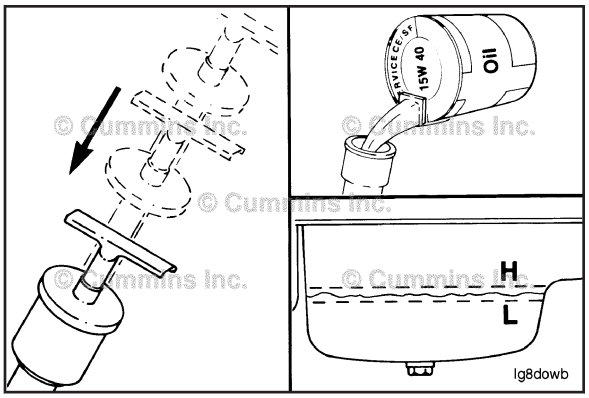


⚠CAUTION⚠
Use care when marking the dipstick, or the dipstick will break if the scribe mark is too deep.

Remove the dipstick, and scribe a mark across the stick at the oil level. Label the mark with an L to indicate the low oil level.

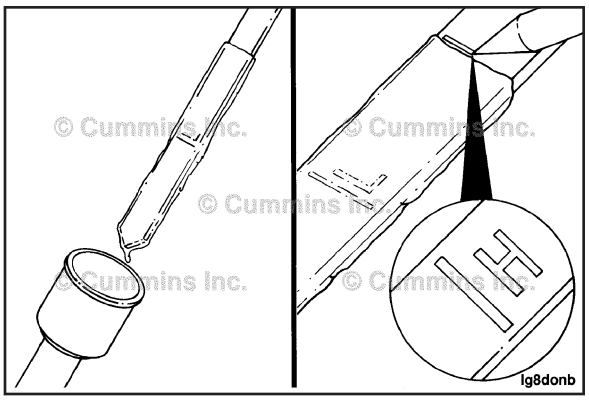
NOTE: If a new, blank dipstick is being used, cut the dipstick off approximately 38 mm [1.5 in] below the low oil level mark.



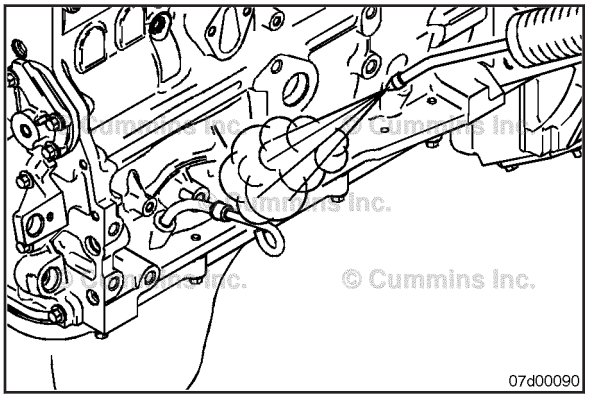


Wipe off the dipstick, and install it in the dipstick tube housing.

Fill the oil pan to the specified high oil level. The high oil level can be found by looking up the oil pan option for the engine serial number on QuickServe OnLine.



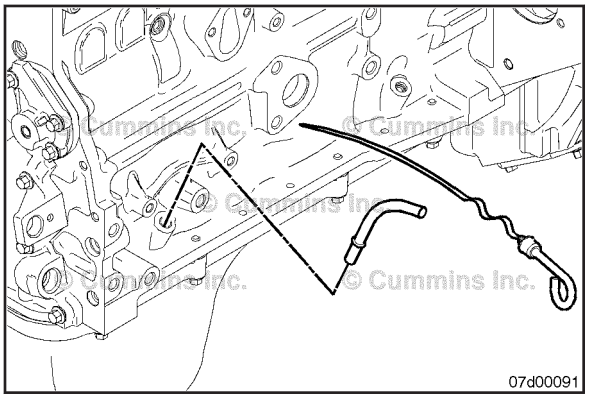
Remove the dipstick, and scribe an mark across the stick at the oil level. Label the mark with an H to indicate the high oil level.



Lubricating Oil Dipstick Tube (007-011)

Preparatory Steps

Clean the area around the dipstick tube before removing to prevent debris from entering the oil system.



Remove

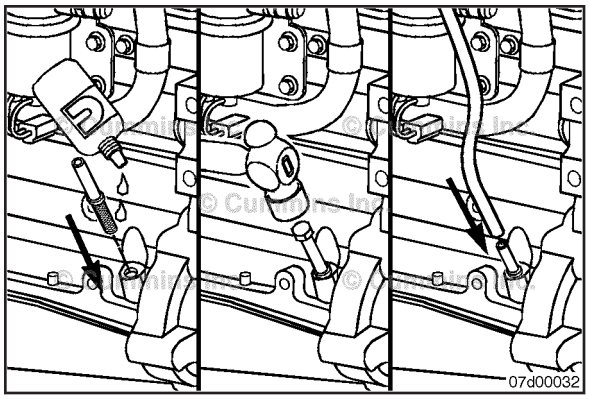
Remove dipstick from the dipstick tube.

Remove dipstick tube from the cylinder block.

Service Tip: Use a dent puller and 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 thread sealant around the bottom of the knurled end of the tube.

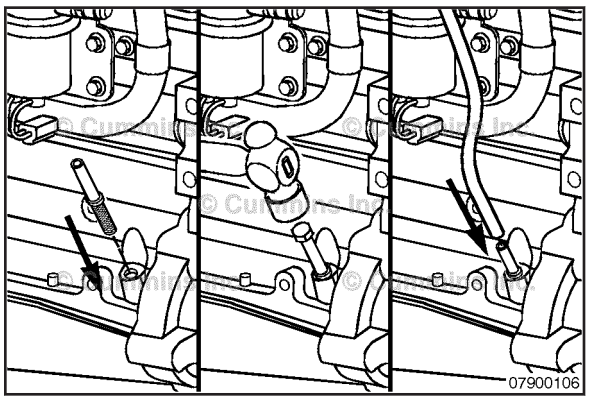


Place knurled end of tube into the dipstick tube bore in the cylinder block.

Use the dipstick tube installer tool, Part Number 3823875, to install the dipstick tube into the cylinder block.

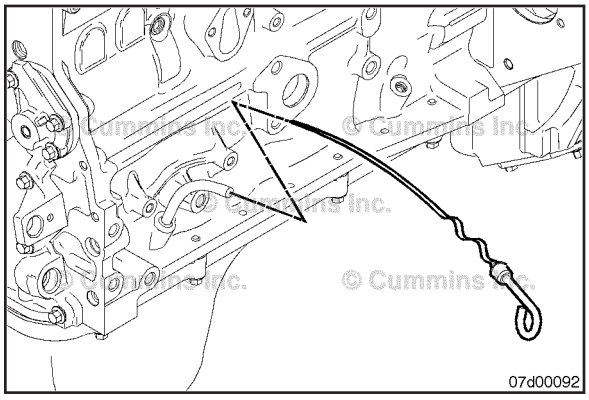
Lightly drive the dipstick tube until it seats against the block casting.

NOTE: If a flexible tube is to be used, soak the end of the nylon tube in hot water to help ease the installation.



Finishing Steps

Install dipstick into the dipstick tube.



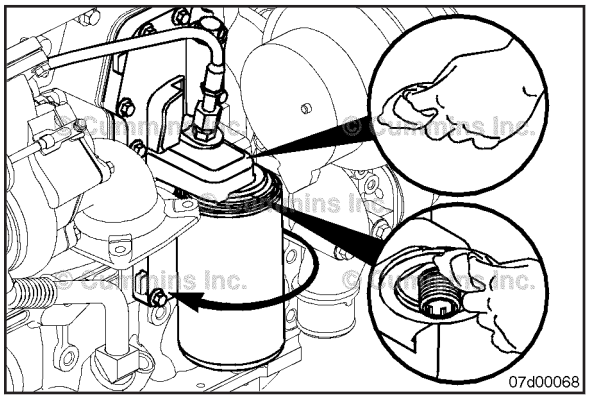
Lubricating Oil Filter (Spin-On) (007-013)

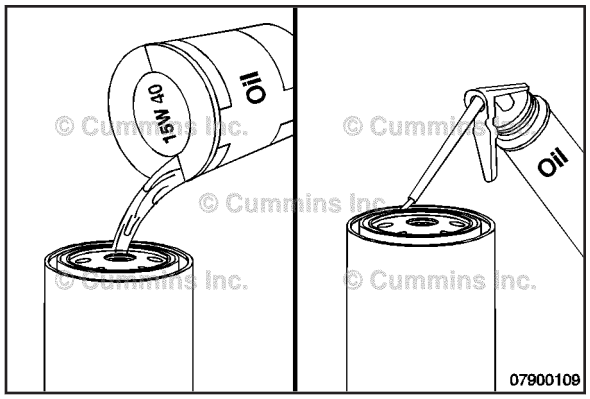
Remove

Clean the area around the lubricating oil filter head.

Use the oil filter wrench, Part Number 3400158, to remove the filter.

Clean the sealing surface of the filter head.





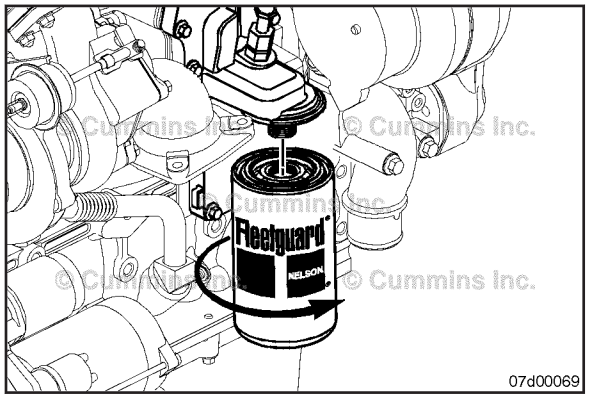
Install

⚠CAUTION⚠
The lack of lubrication during the delay until the filter is pumped full of oil at start-up can damage the engine.

Use clean 15W-40 oil to coat the gasket surface of the filter.

Fill the filter with clean 15W-40 oil.

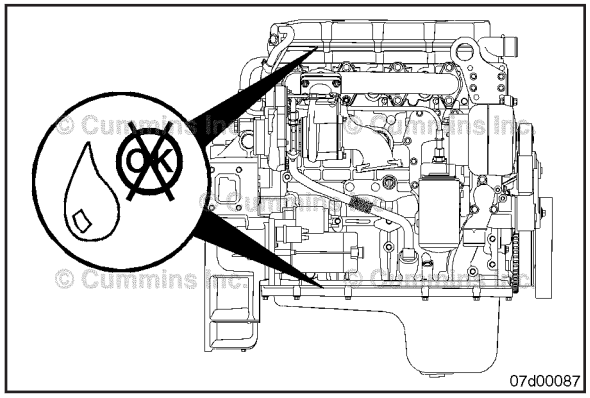
NOTE: Be careful that no debris is poured into the filter. If using an oil supply with a metallic or plastic seal under the cap, be careful to peel the seal back. Puncturing the seal with a knife or sharp object can create debris in the oil container.



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

Install the filter on the oil filter head. Tighten the filter until the gasket contacts the filter head surface.

Tighten 3/4 turn to 1 turn after gasket makes contact with the filter head.



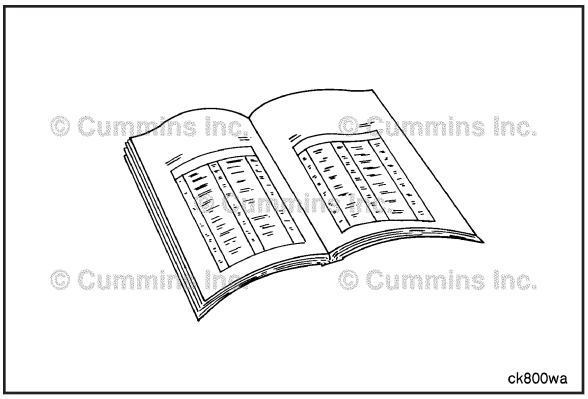
Finishing Steps

⚠CAUTION⚠
If the engine does not produce oil pressure in 15 seconds after starting the engine, shut off the engine to avoid component damage.

Operate the engine and check for leaks.

Shut down the engine and check the oil level. Refer to Procedure Procedure 007-037

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.

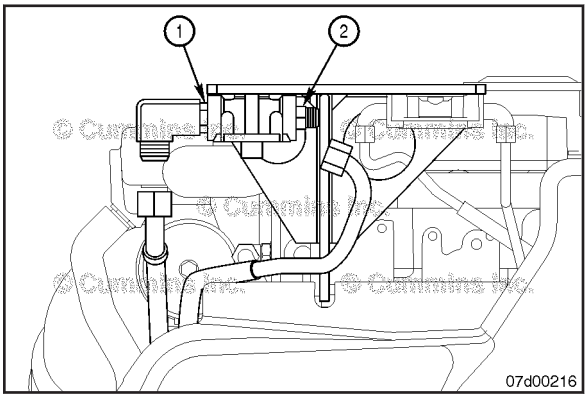
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

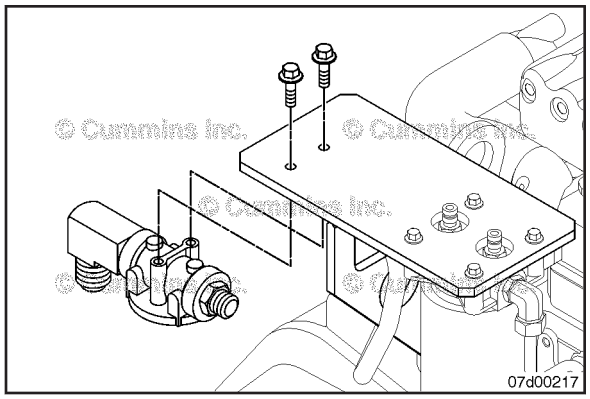
△CAUTION△
Use caution when draining oil or replacing filters that oil is not spilled or drained into the bilge area. The oil and oil filters must be discarded in accordance with local environmental regulations.

- 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
- Verify and mark the oil lubricating hoses and the adapter head for proper location.

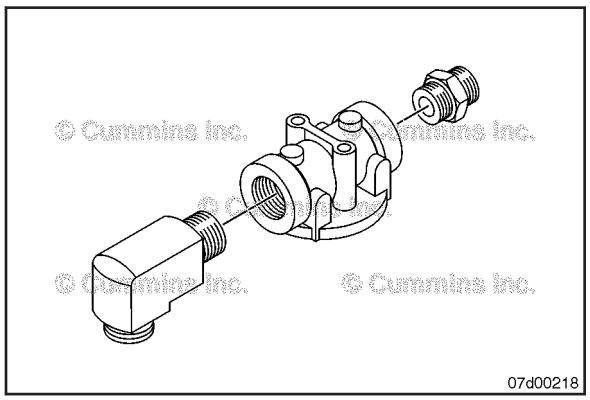
Remove

Loosen, but do not remove, the inlet (1) and outlet (2) lubricating oil filter head face seal connection locknuts.





Remove the two mounting capscrews and the lubricating oil filter head.

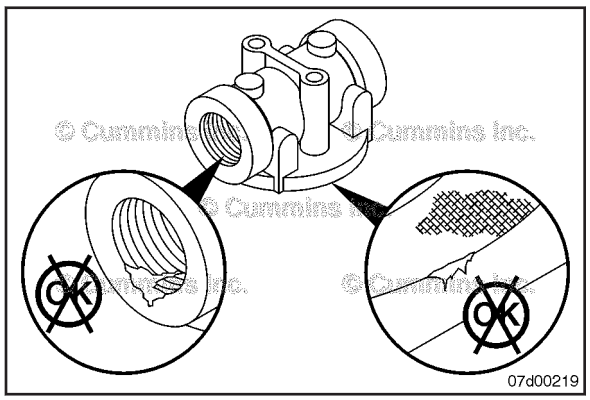


Disassemble

⚠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.

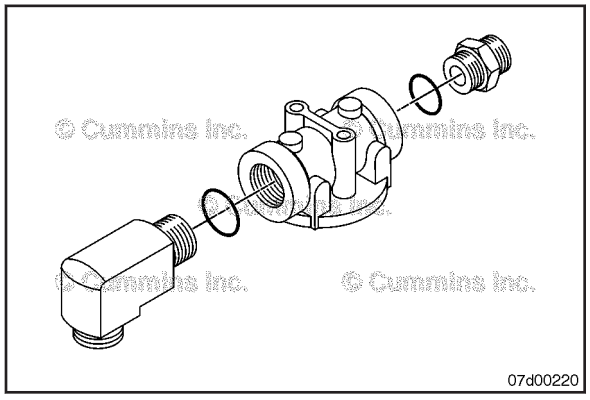
Label the filter head connectors to identify the lubricating oil connections and fitting orientation.

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 the o-rings 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.

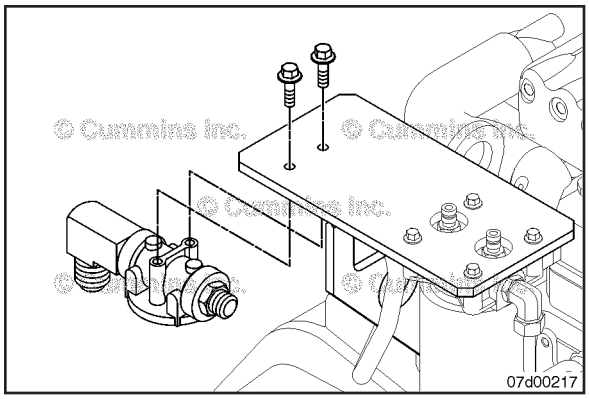
Do **not** torque or tighten the fitting locknuts at this time.

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: 18 N•m [13 ft-lb]

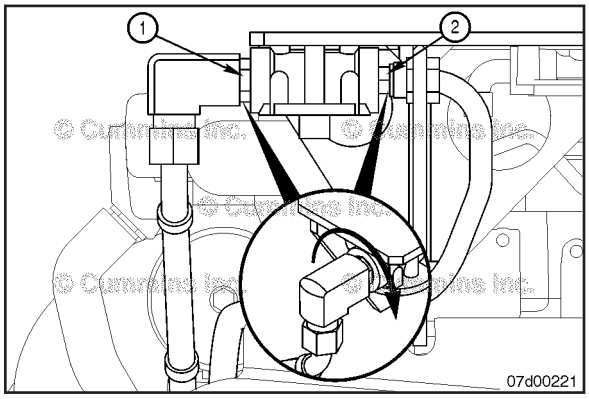


⚠CAUTION⚠
When installing the lubricating oil flex hoses, be sure there is proper clearance between the flex hoses and the alternator electrical connections.

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 filter inlet and outlet connection locking nuts.

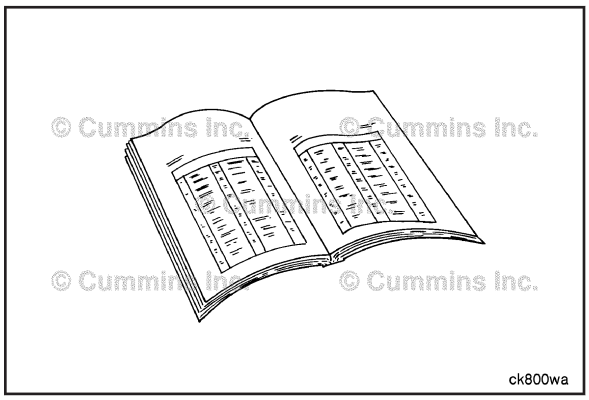
Torque Value: 76 N•m [56 ft-lb]

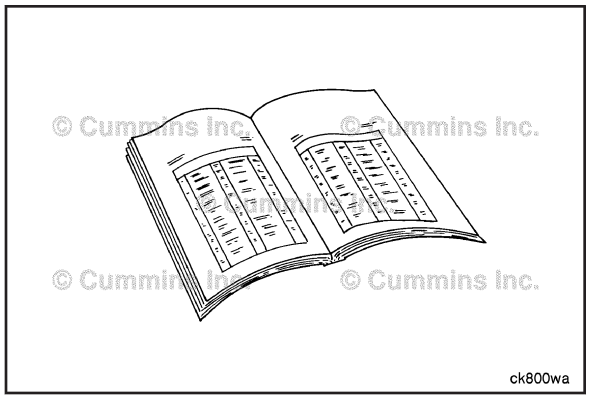


Finishing Steps

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

- 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.
- Shut down the engine and check the lubricating oil level. Add lubricating oil as necessary.





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.

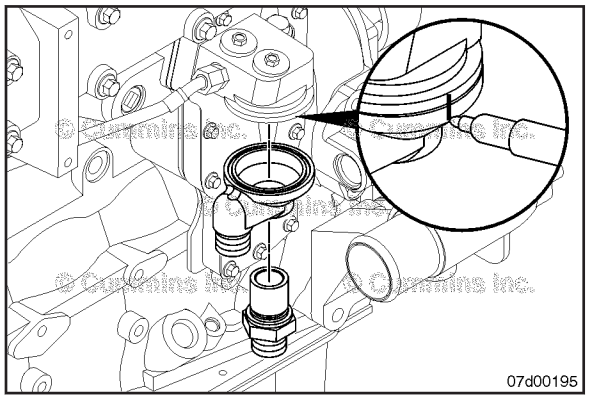
⚠WARNING⚠
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

⚠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.

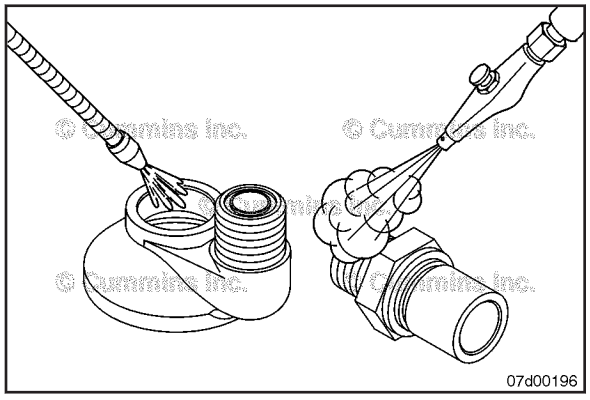
Tag for location and remove the lubricating oil lines for the oil filter. Refer to Procedure 007-092



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.

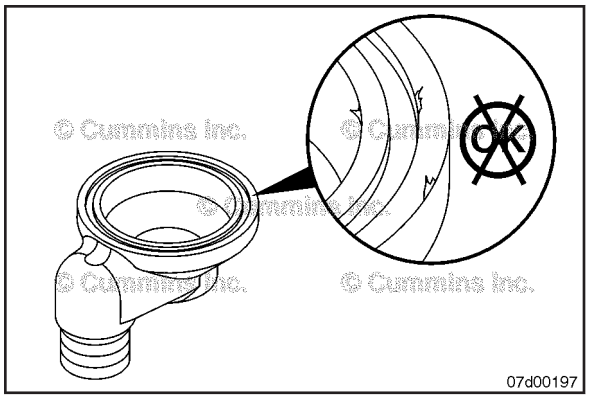
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

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.



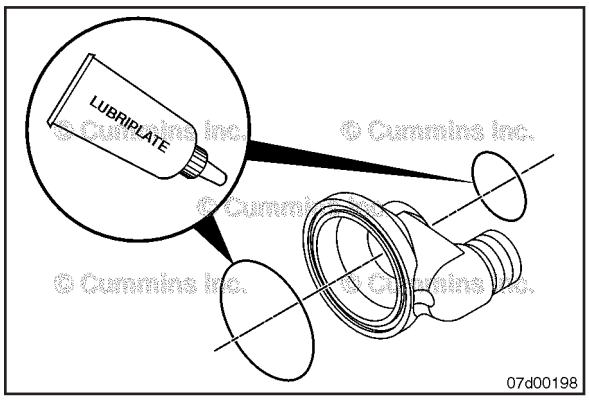
Install

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.

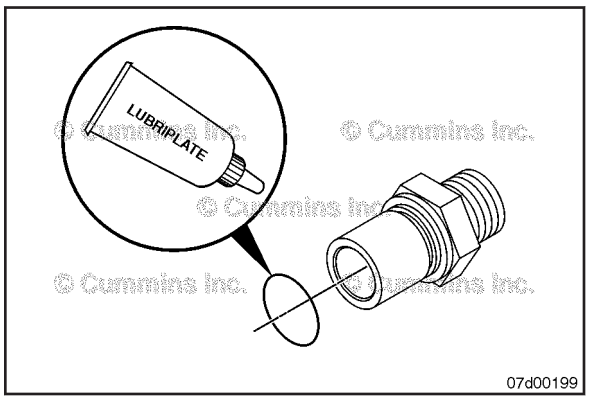
Install a small o-ring in the groove on the other side of the filter head cover.

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.

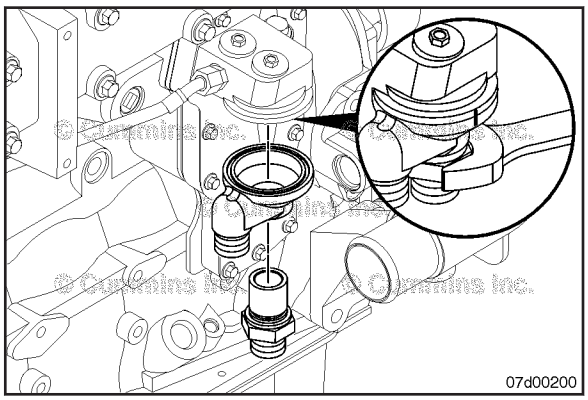


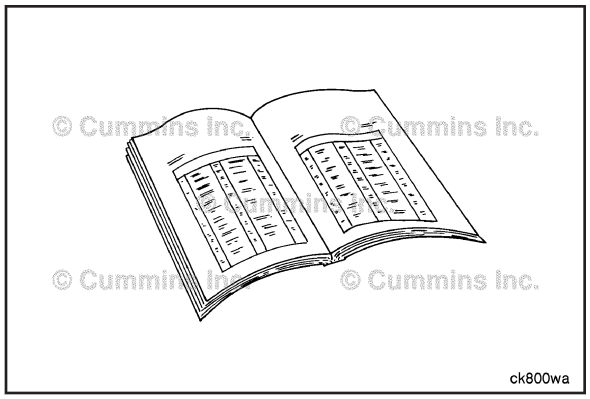
Install the outer hose connector, on the oil filter adapter, to the rear of the engine and align the marks made before removal.

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]

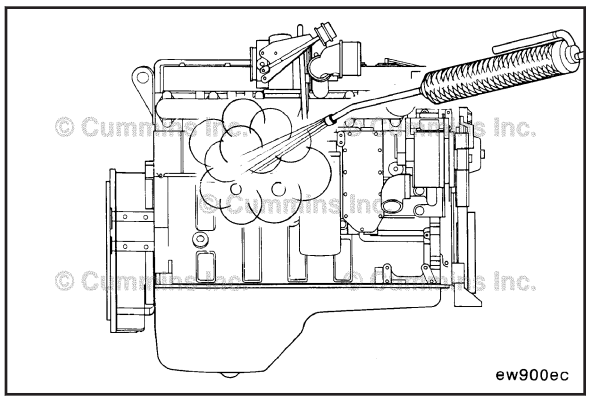




Finishing Steps

Install the lubricating oil lines for the oil filter. Refer to Procedure 007-092

Operate the engine and check for leaks.

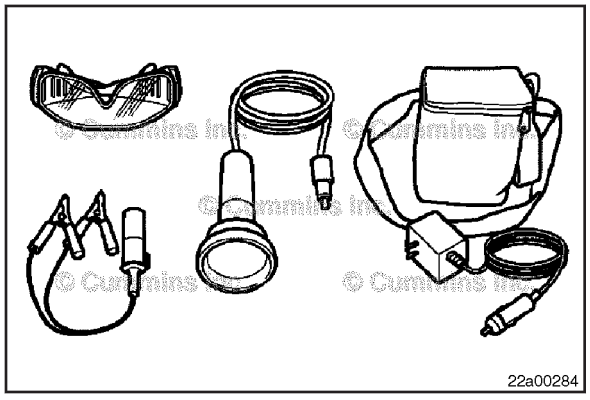


Lubricating Oil Leaks (007-024)

Initial Check

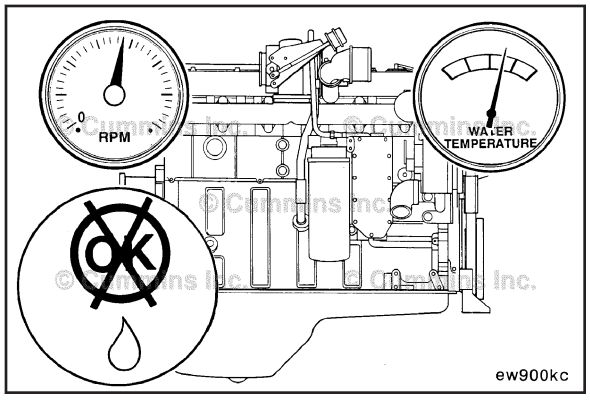
⚠WARNING⚠
Wear safety glasses or a face shield, as well as protective clothing, to prevent personal injury when using a steam cleaner or high-pressure water.

Use a steam cleaner or high-pressure washer to clean the engine.



A black light kit, Part Number 3163338, can be very helpful when locating the source of an oil leak.

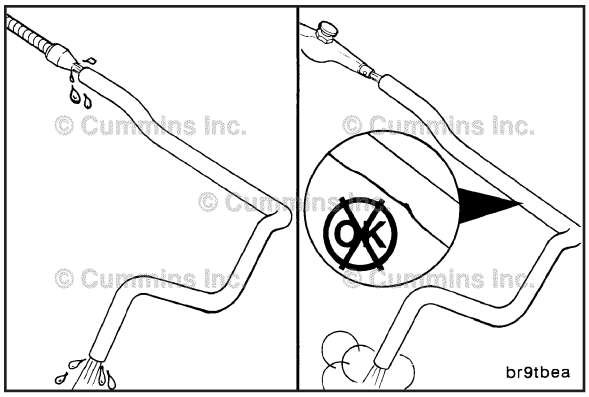
Add the fluorescent tracer, Part Number 3376891, before running the engine. The tracer will be highlighted by the black light to help identify the source of the leak.



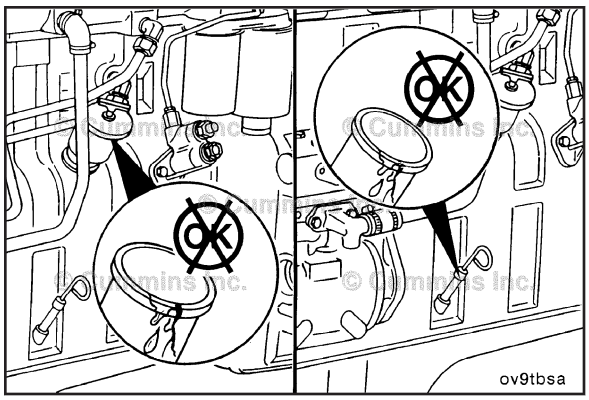
Operate the engine until the coolant temperature reaches 82°C [180°F]. Inspect the exterior of the engine for leaking gaskets, seals, o-rings, pipe plugs, or fittings.

NOTE: Before replacing any gaskets, check the capscrews to make sure they are tightened to the correct torque values. Refer to Procedure 018-009 in Section V for capscrew torque specifications.

Inspect the engine crankcase breather tube and hose for restriction or leaks. Refer to Procedure 003-018 in Section 3.

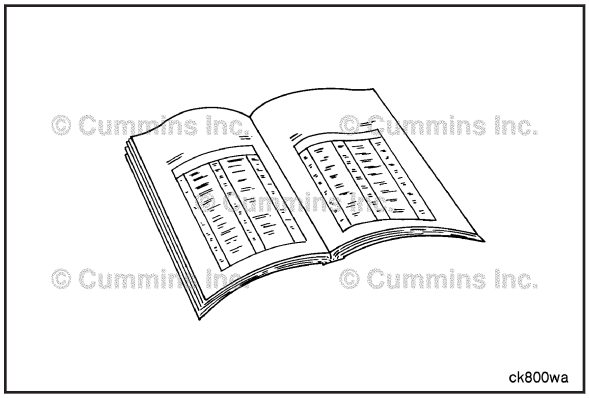


Check for a loose or missing oil dipstick tube, dipstick, or oil fill cap.



Lubricating Oil Pan (007-025)

Preparatory Steps

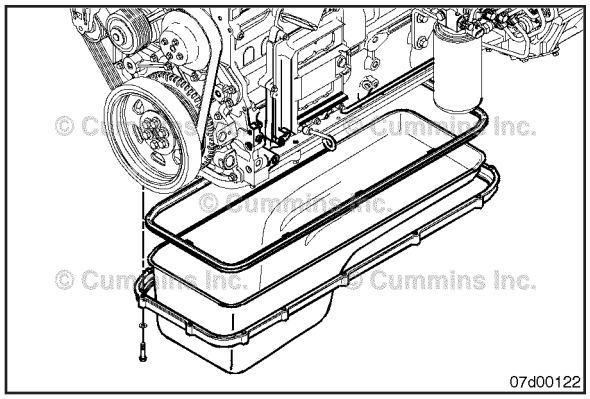


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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

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

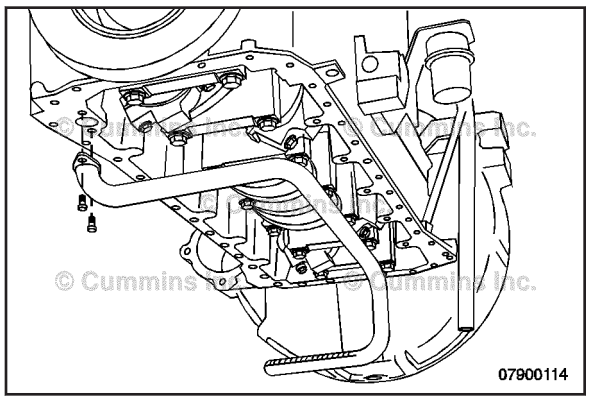
- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.



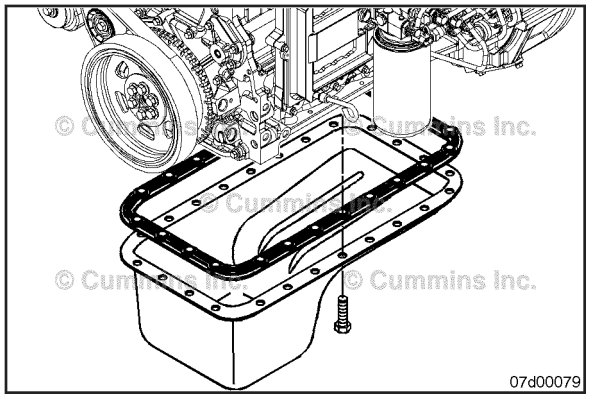
Remove

Oil Pan, Suspended

Remove the lubricating oil pan support mounting flange and gasket.



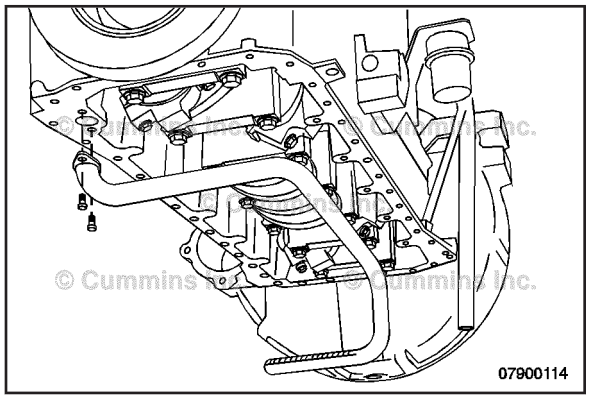
Remove the suction tube, if necessary. Refer to Procedure 007-035 in Section 7.



Oil Pan, Standard

Remove the lubricating oil pan and gasket.

Discard the gasket.

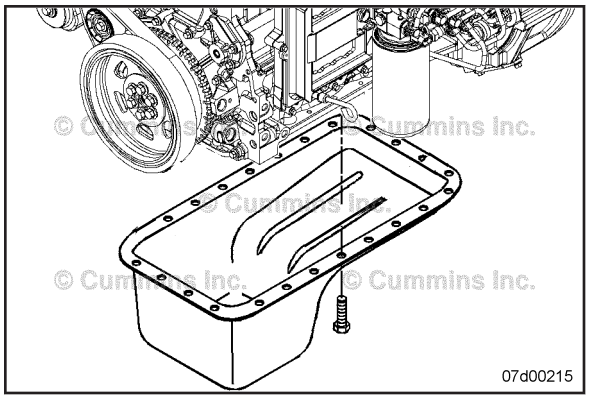


Remove the suction tube, if necessary. Refer to Procedure 007-035 in Section 7.

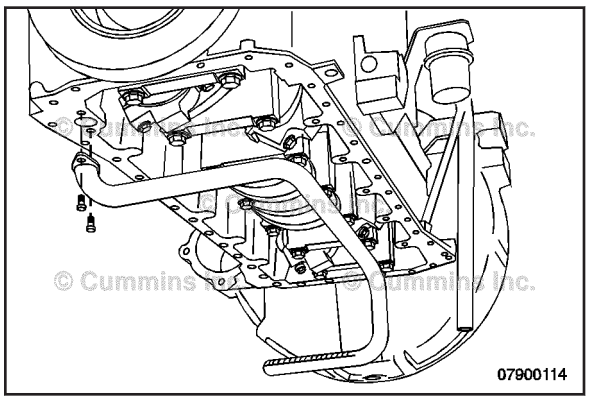
Oil Pan, Formed-in-Place Gasket

Remove the lubricating oil pan.

NOTE: You can damage the lubricating oil pan flange by using a pry bar or screwdriver to break the formed-in-place gasket seal. Use a utility knife to cut the seal and loosen the pan.



Remove the suction tube, if necessary. Refer to Procedure 007-035 in Section 7.



Clean and Inspect for Reuse

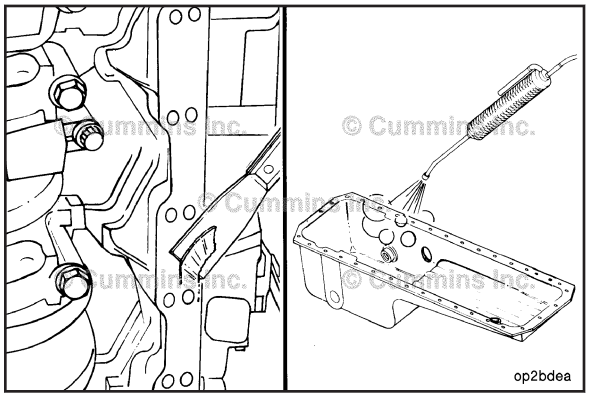
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

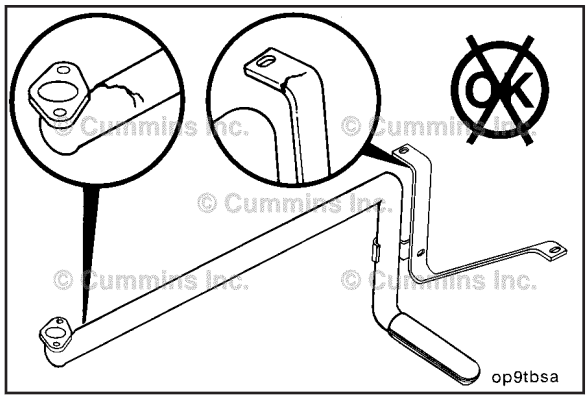
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Scrape all remaining gasket material from the oil pan and the block.

NOTE: The use of air or power tools, such as a high speed sander with an abrasive pad, to clean the gasket material can overheat the oil pan and cause damage to the sealing flange.

Steam clean the oil pan. Dry the oil pan with compressed air.

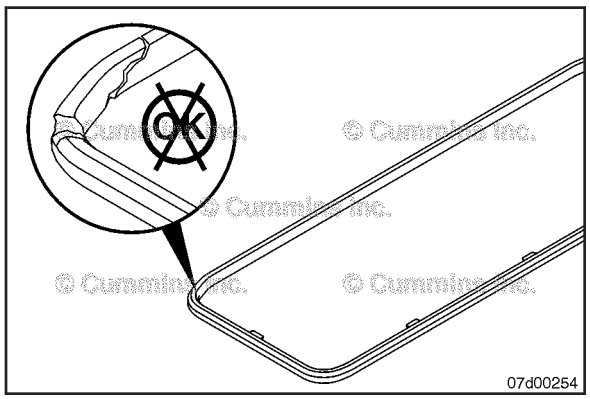




Inspect the oil pan support flange, suction tube, and tube braces for cracks or other damage.

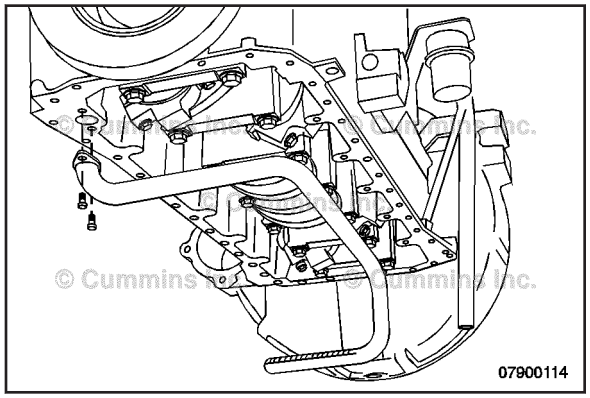
NOTE: If cracks or other damage is found, replace the damaged part. Do **not** attempt to repair the oil pan by welding.

If the suction tube **must** be replaced, Refer to Procedure 007-035 in Section 7.



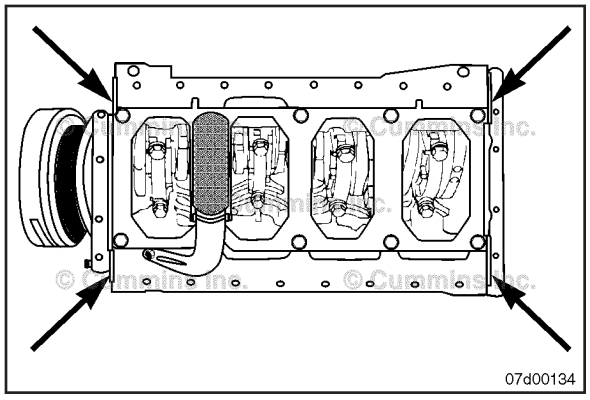
For suspended oil pans, inspect the flexible mounting gasket for cracking, brittleness, and any other damage.

Replace the gasket if damage is found.



Install

If the suction tube has been removed, install the suction tube. Refer to Procedure 007-035 in Section 7.



For rear gear train engines apply a 2-mm [1/16-inch] bead of sealant, Part Number 3164070, to the oil pan mounting surfaces at the cylinder block to front gear cover joints and the cylinder block to rear gear housing joints.

For front gear train engines, apply a 2-mm [1/16-inch] bead of sealant, Part Number 3164070, to the oil pan mounting surfaces at the cylinder block to front gear housing joint and the cylinder block to rear seal housing joint.

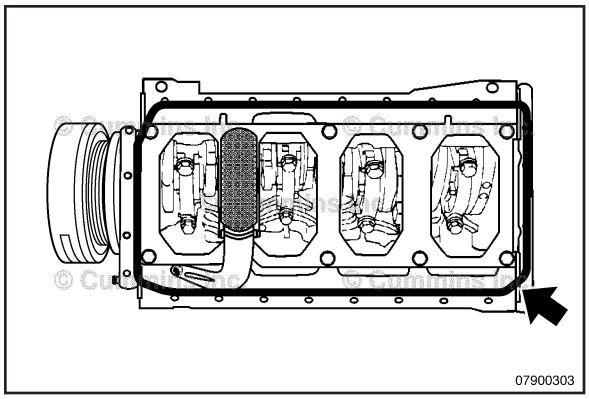
Oil Pan, Formed-in-Place Gasket

If installing a formed-in-place gasket pan, apply a 4-mm [1/8-inch] bead of sealant, Part Number 3164070, to the oil pan mounting surfaces at the cylinder block to front gear housing joints and the cylinder block to rear gear housing joints.

Make sure there is a continuous sealing path.

NOTE: Install three guide pins, Part Number 3164977, to improve alignment of the oil pan sealing components to the cylinder block.

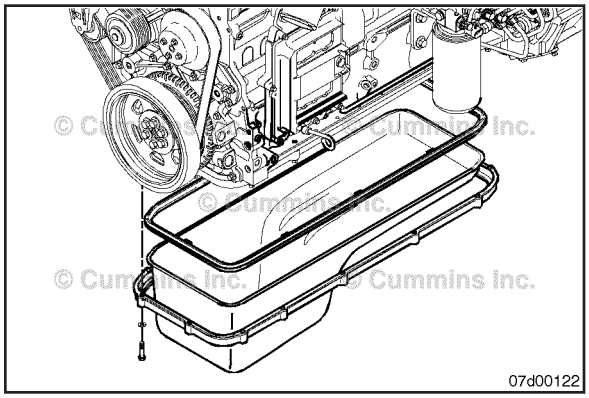
NOTE: Install the oil pan housing within 10 minutes of applying the sealant, or it will **not** seal correctly. Once installed, allow the sealant to dry for 30 minutes before running the engine.



Oil Pan, Suspended

Assemble the gasket onto the oil pan.

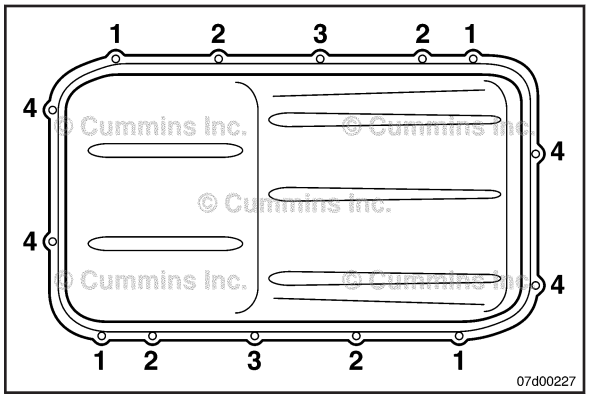
Install the support mounting flange to the oil pan and gasket assembly.



Oil Pan, Suspended (four-cylinder)

Tighten all capscrews in the sequence shown in the illustration.

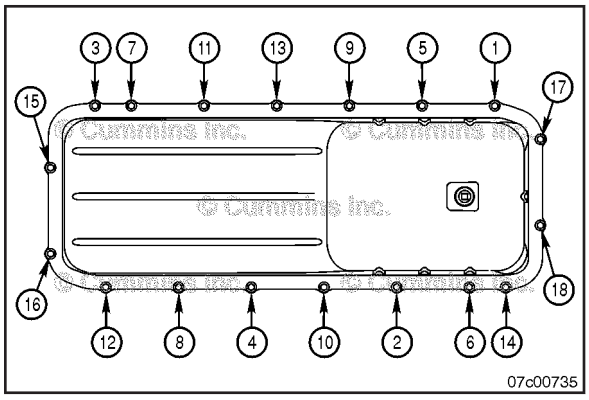
Torque Value: 26 N•m [230 in-lb]

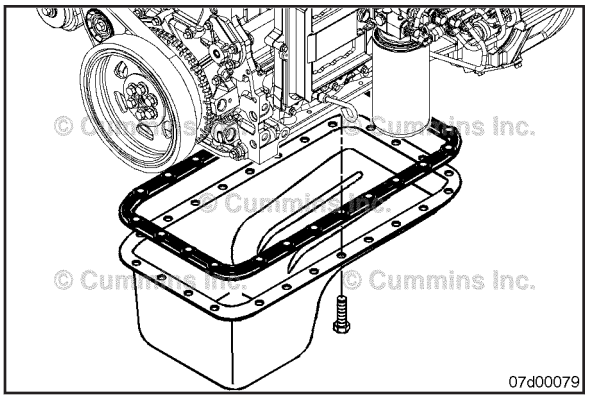


Oil Pan, Suspended (six-cylinder)

Tighten all capscrews in the sequence shown in the illustration.

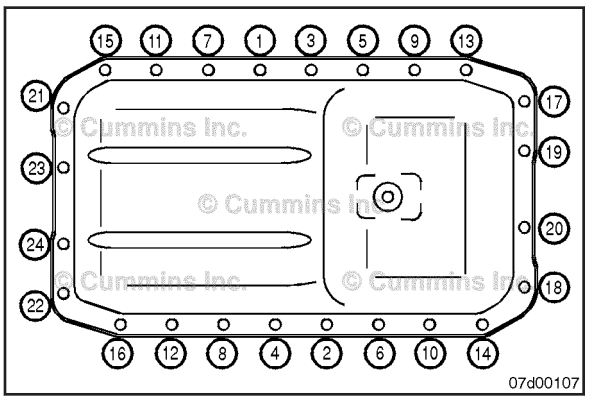
Torque Value: 26 N•m [230 in-lb]





Oil Pan, Standard

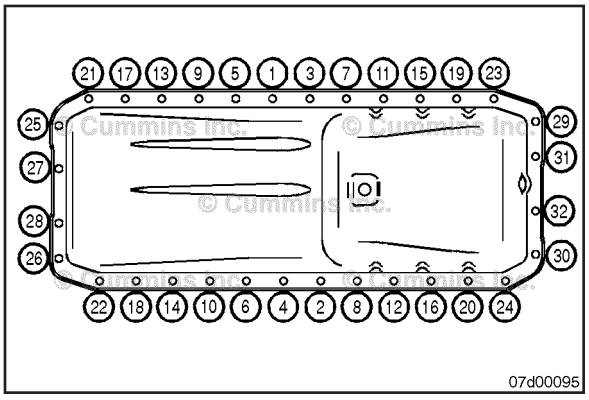
Assemble a new gasket onto the oil pan.



Four-Cylinder

Tighten all capscrews in the sequence shown in the illustration.

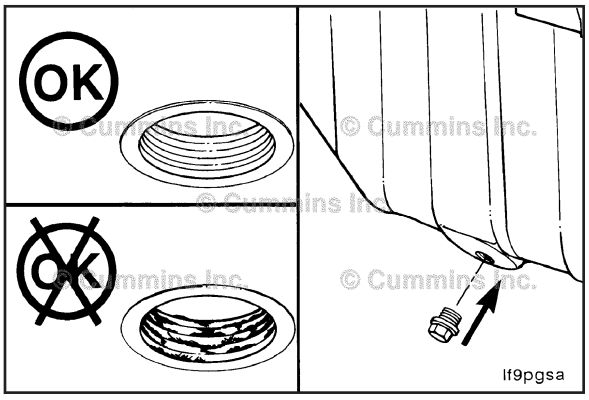
Torque Value: 28 N•m [249 in-lb]



Six-Cylinder

Tighten all capscrews in the sequence shown in the illustration.

Torque Value: 28 N•m [249 in-lb]



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

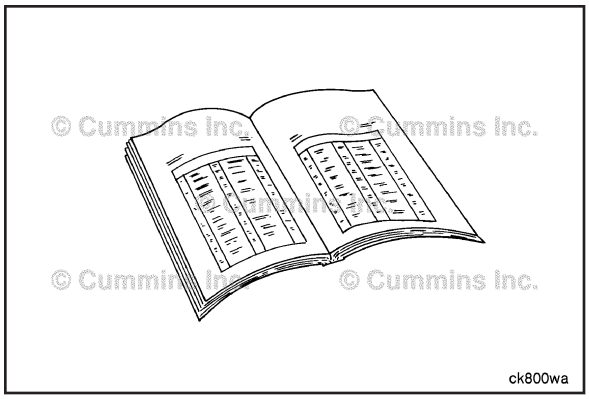
Install and tighten the oil pan drain plug.

Torque Value: 60 N•m [44 ft-lb]

Finishing Steps

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

- Fill the engine with clean lubricating oil. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. Refer to the OEM service manual.
- Start and operate the engine to check for leaks.

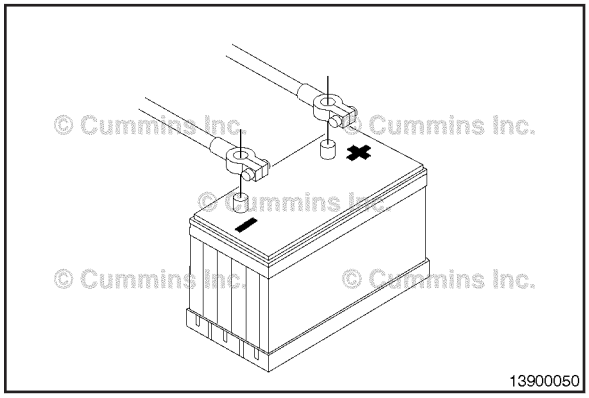


Lubricating Oil Pressure Regulator (Main Rifle) (007-029)

Preparatory Steps

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

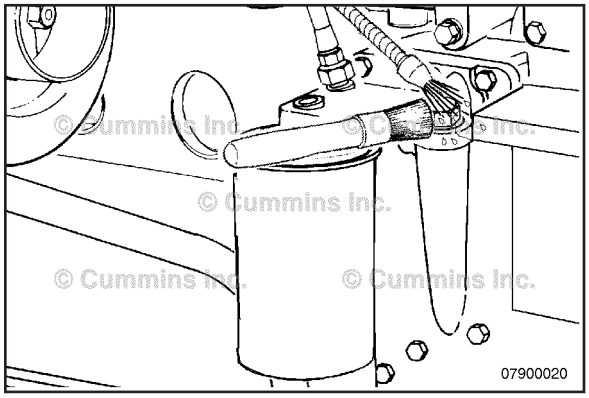
Disconnect the batteries.



Remove

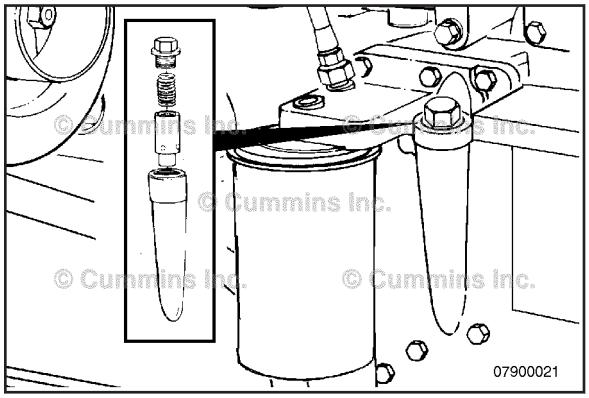
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

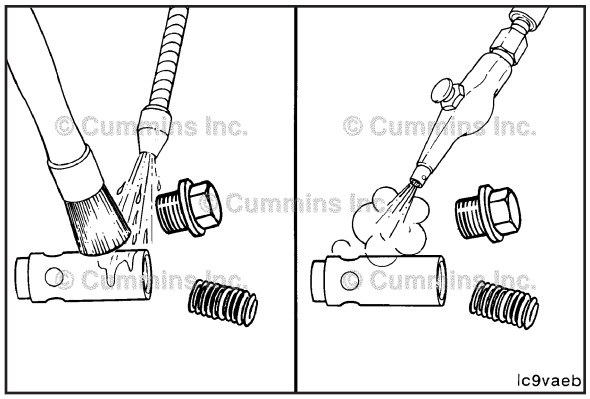
Thoroughly clean the area around the pressure regulator plug with clean solvent to prevent debris from falling into the plunger bore when the plug is removed.



Remove the pressure regulator, nut, valve plug, spring, and plunger.

Service Tip: The plunger normally can be removed by inserting a finger into the plunger bore until snug and pulling up. If the plunger can **not** be removed in this manner, the plunger is probably stuck and will require removal of the housing.





Clean

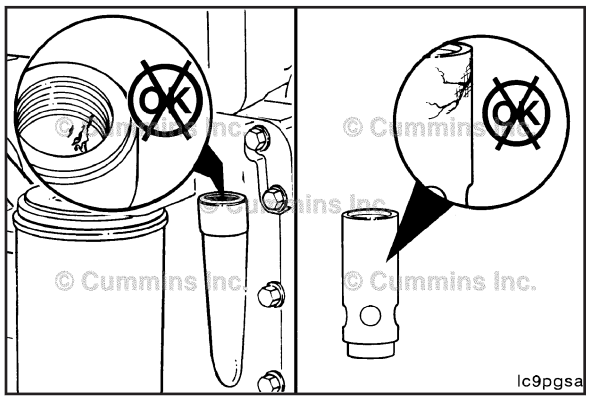
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

Use solvent to clean the spring, plunger, plug, washer, and pressure regulator valve housing.

Dry the parts with compressed air.

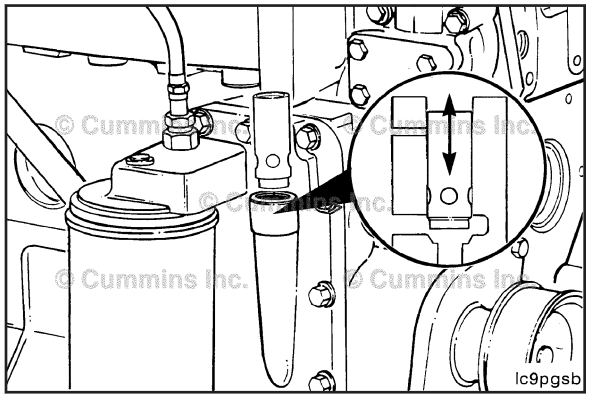
NOTE: If the plunger bore requires cleaning, remove the housing so as **not** to flush debris into the engine.



Inspect for Reuse

Inspect the plunger and plunger bore for nicks or scratches.

NOTE: Polished areas on the plunger and bore are acceptable.

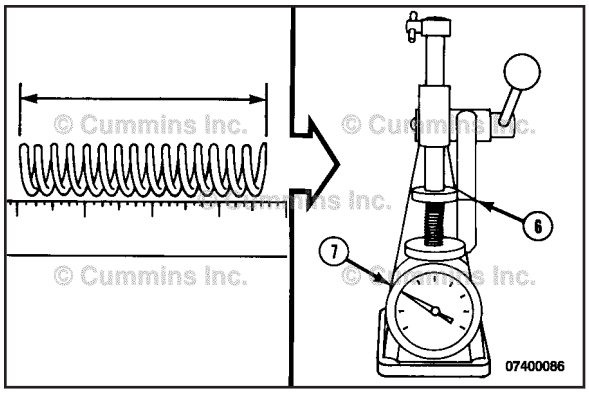


Verify that the plunger moves freely in the bore.

Measure the pressure regulator spring at the following heights.

Pressure Regulator Spring Pressure			
	N		lb
@41.25 mm [1.624 in]	127	MIN	29
@44.50 mm [1.752 in]	109	MIN	25

NOTE: When the load is 105 N [24 lb], the regulator valve opens. When the load is 142 N [32 lb], the regulator valve is seated.



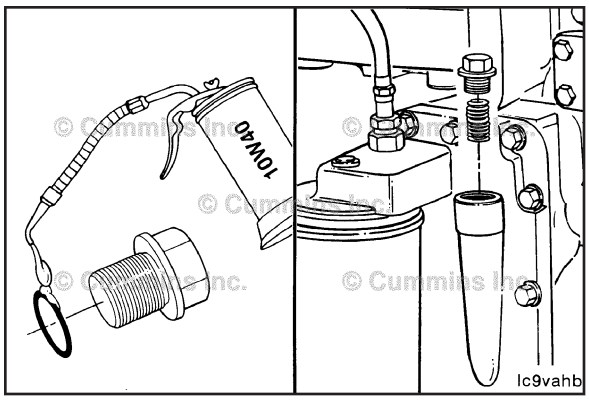
Install

Install a new sealing o-ring on the valve plug and lubricate with clean 15W-40 engine oil.

Assemble the plunger, spring, and valve plug.

Install the pressure regulator assembly and tighten.

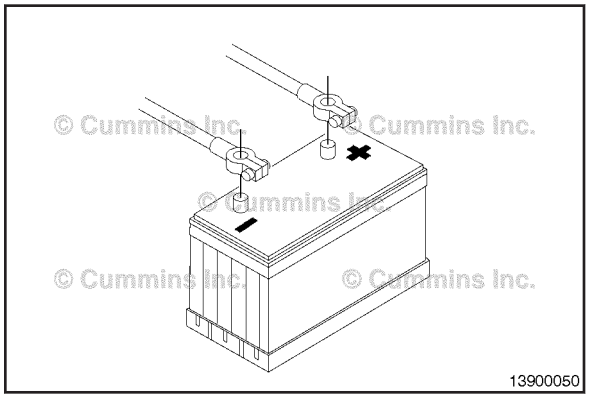
Torque Value: 80 N•m [59 ft-lb]



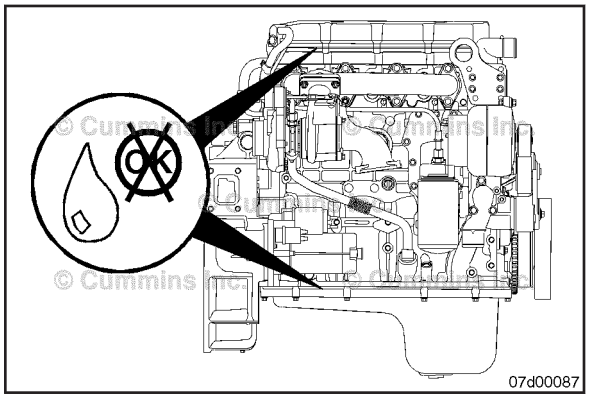
Finishing Steps

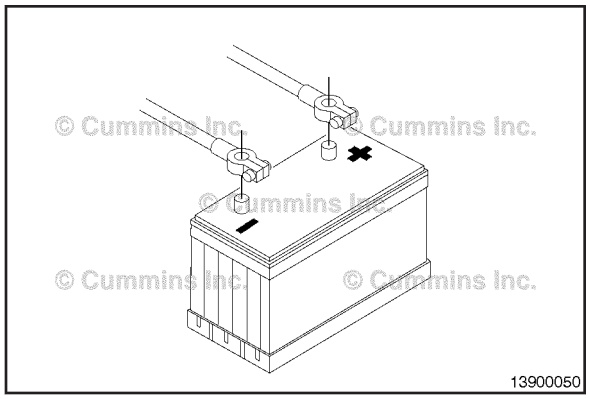
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Connect the batteries.



Operate the engine and check for leaks.



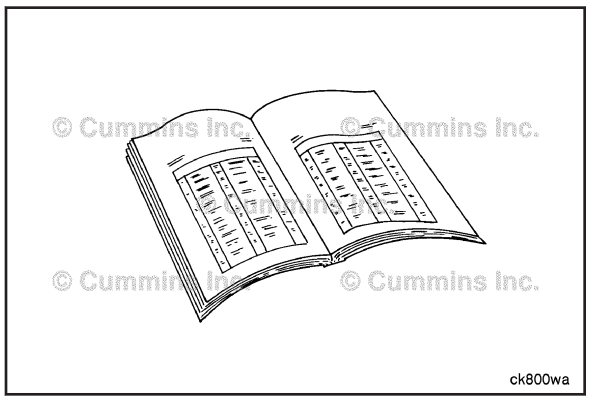


Lubricating Oil Pump (007-031)

Preparatory Steps

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

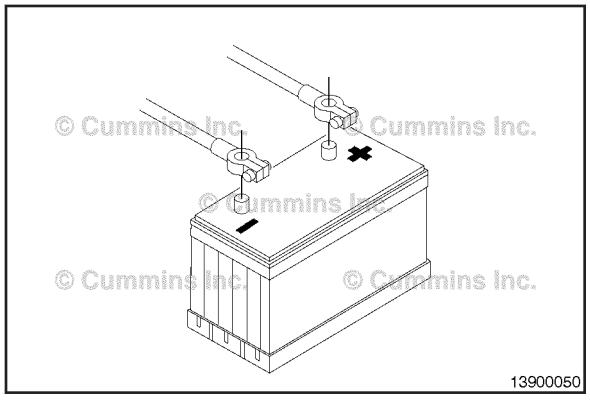
Disconnect the batteries.



Remove the drive belt. Refer to Procedure Procedure 008-002

Remove the vibration damper/crankshaft speed indicator ring. If equipped with a viscous damper Refer to Procedure Procedure 001-052. If equipped with a rubber damper Refer to Procedure Procedure 001-051. If equipped with crankshaft speed indicator ring only, Refer to Procedure Procedure 001-071

Remove the front gear cover. Refer to Procedure Procedure 001-031



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

Remove the belt guards. Refer to Procedure Procedure 008-001

Remove the seawater pump drive belt. Refer to Procedure Procedure 008-126

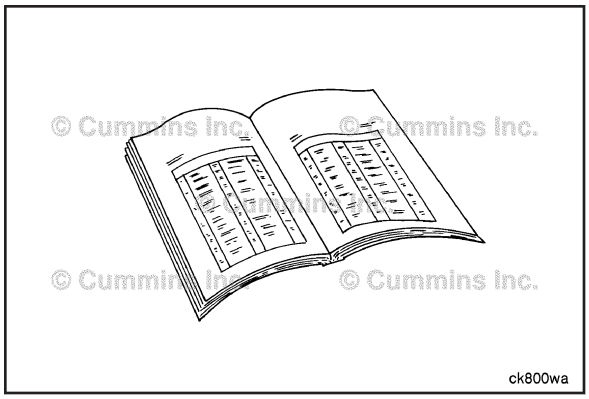
Remove the water pump drive belt. Refer to Procedure Procedure 008-002

Remove the fan hub. Refer to Procedure Procedure 008-039

Remove the crankshaft position sensor. Refer to Procedure Procedure 019-365 in Troubleshooting and Repair Manual, CM850 Electronic Control System, Bulletin 4021337.

Remove the vibration damper and tone wheel. Refer to Procedure Procedure 001-051 or Refer to Procedure Procedure 001-052

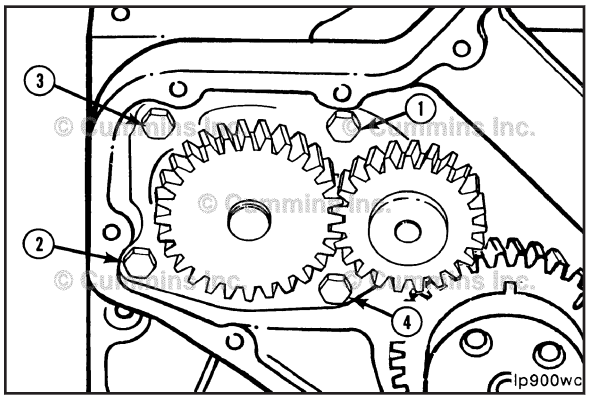
Remove the front gear cover. Refer to Procedure Procedure 001-031



Remove

Remove the four mounting capscrews (1, 2, 3, and 4).

Remove the lubricating oil pump from the bore in the cylinder block.

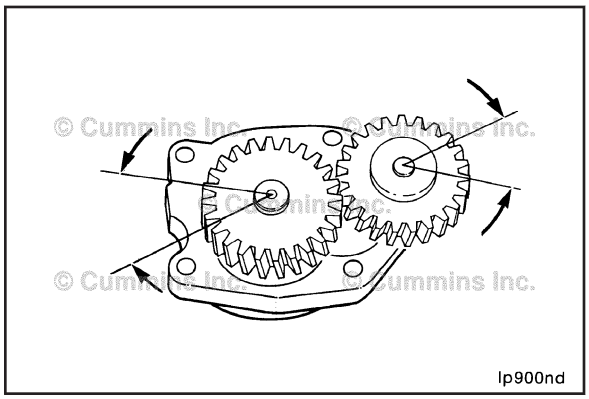


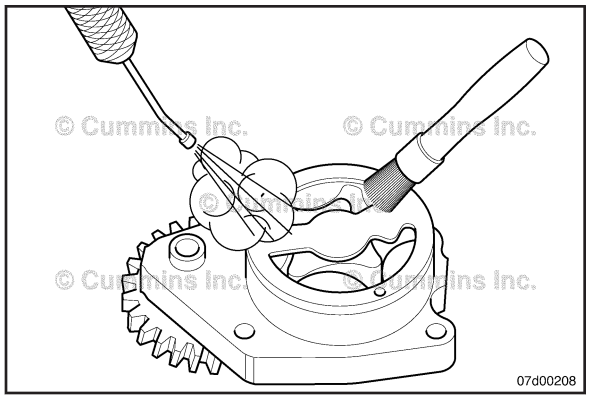
Initial Check

Measure the gear backlash.

Lubricating Oil Pump Gear Backlash Limits		
mm		**in**
0.170	MIN	0.007
0.300	MAX	0.012

If the backlash is out of specification, the lubricating oil pump **must** be replaced.





Clean and Inspect for Reuse

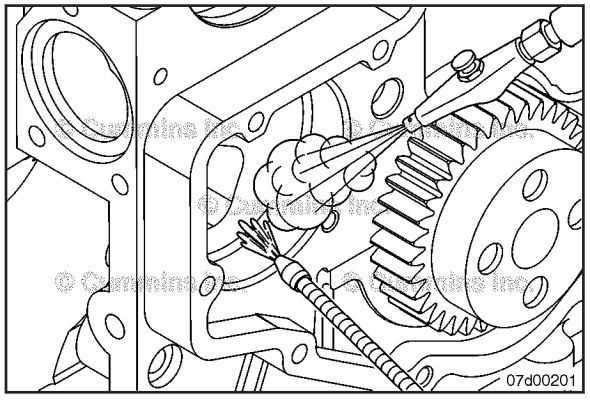
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠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 lubricating oil pump with solvent.

Dry with compressed air.



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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.

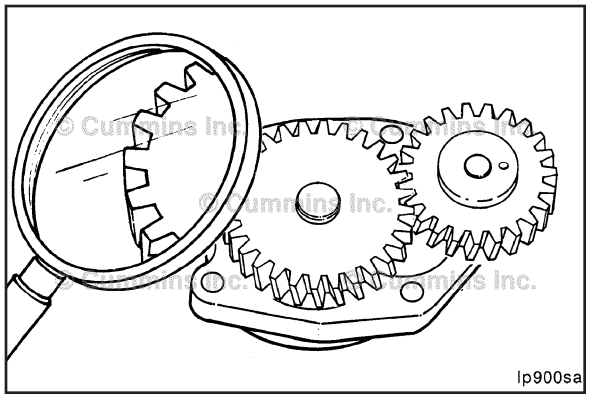
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

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

With the pump removed use solvents to clean the cylinder block cavity.

Dry with compressed air.

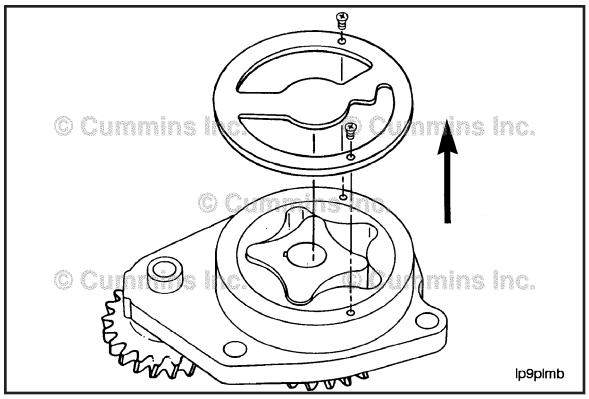
NOTE: Do **not** allow solvents to enter the lubricating oil system when cleaning the cylinder block cavity.



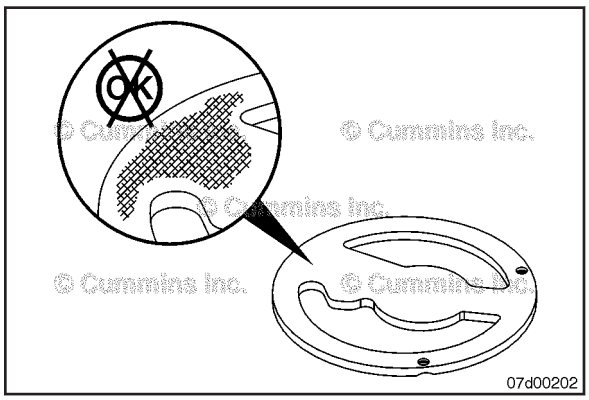
Inspect the lubricating oil pump gears for chips, cracks, or excessive wear.

If debris has been expected to have gone through the lubricating oil pump, the rear cover plate can be removed to inspect for internal damage.

NOTE: The lubricating oil pump is serviced/replaced as an assembly. No internal parts are available for rebuild/ replacement.

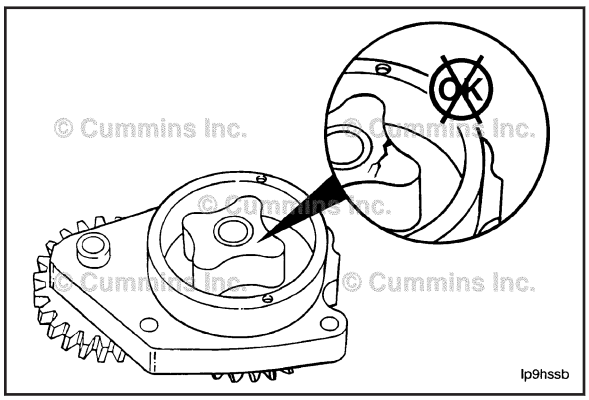


Inspect the rear cover plate for scoring or grooves. If the cover is scored or grooved too badly, the lubricating oil pump **must** be replaced.



Inspect the lubricating oil pump housing and gerotor drive for damage and excessive wear.

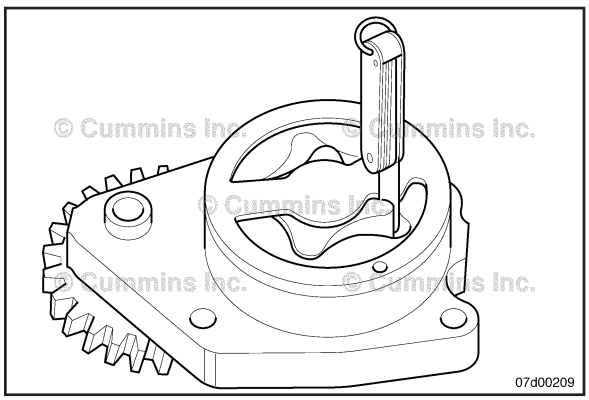
If the lubricating oil pump is damaged, the lubricating oil pump **must** be replaced.

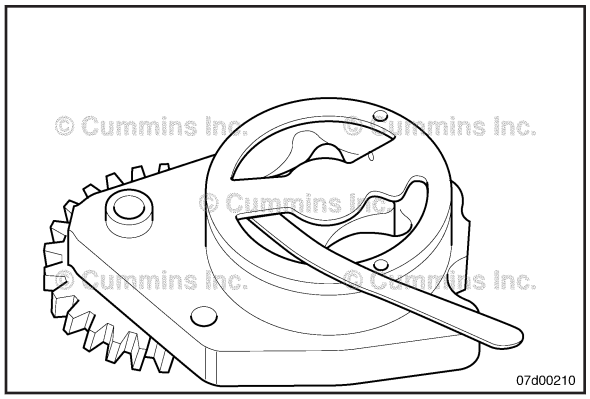


Measure

Measure the tip clearance.

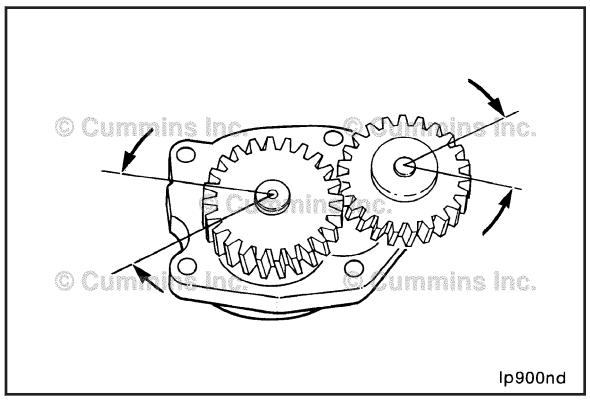
Tip Limit		
mm		**in**
0.178	MAX	0.007





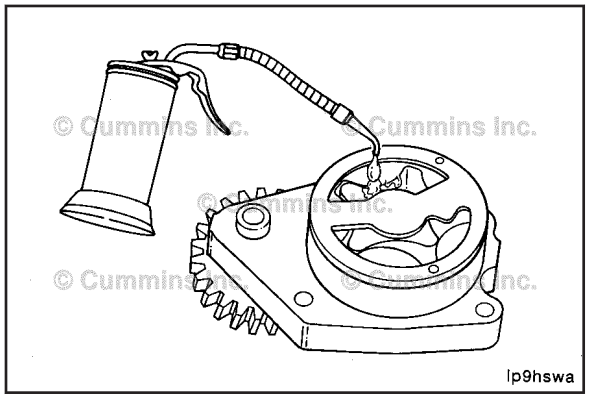
Measure the clearance of the gerotor drive/gerotor planetary to port plate.

Gerotor Drive/Planetary to Port Plate Limit		
mm		in
0.127	MAX	0.005



Measure the gear backlash.

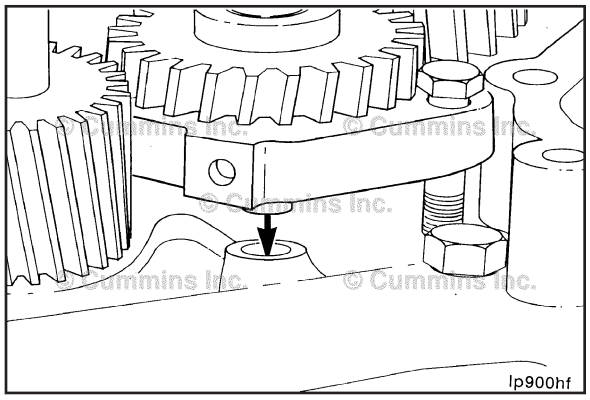
Backlash Limits (used pump)		
mm		in
0.170	MIN	0.007
0.300	MAX	0.012



Install

CAUTION
Failure to fill the pump with oil during installation can result in a slow prime at initial engine start-up, resulting in severe engine damage.

Lubricate the lubricating oil pump with clean 15W-40 engine oil.



CAUTION
To reduce the possibility of engine damage, make sure the idler gear pin is installed in the locating bore in the cylinder block.

Install the lubricating oil pump.

NOTE: If installing a new lubricating oil pump ensure that the pump is correct for your engine. For example, lubricating oil pumps for 4 and 6 cylinder engines are physically interchangeable, but have different flow characteristics.

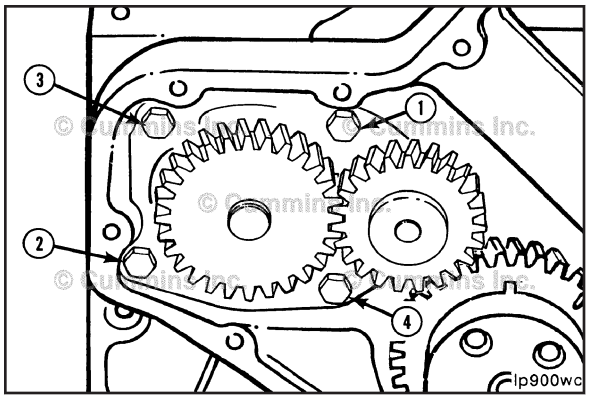
Using the sequence shown, torque the capscrews in the following sequence:

Initial Torque

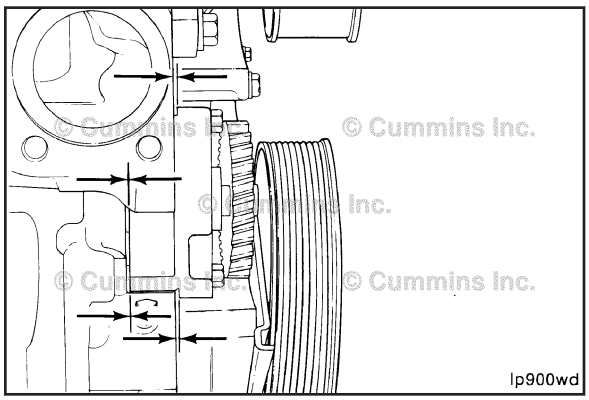
Torque Value: 8 N•m [70 in-lb]

Final Torque

Torque Value: 24 N•m [212 in-lb]



NOTE: The back plate on the pump seats against the bottom of the bore in the cylinder block. When the lubricating oil pump is correctly installed, the flange on the lubricating oil pump will **not** touch the cylinder block.



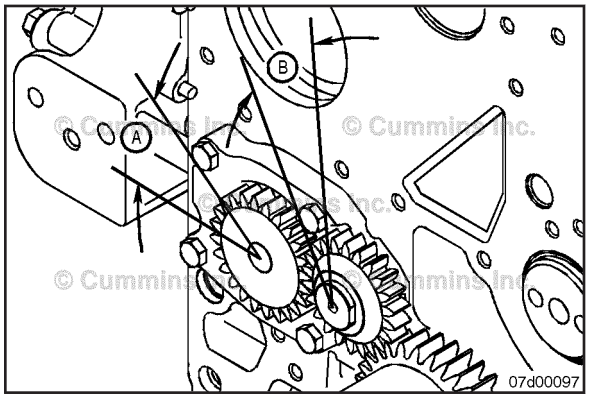
NOTE: Be sure the gear backlash is correct if installing a new lubricating oil pump.

Measure the gear backlash.

Backlash Limits (new pump)

	mm		in
A	0.300	MIN	0.011
	0.500	MAX	0.019
B	0.150	MIN	0.005
	0.250	MAX	0.009

NOTE: If you are reinstalling a used pump and have already measured the backlash you do **not** need to complete this step.

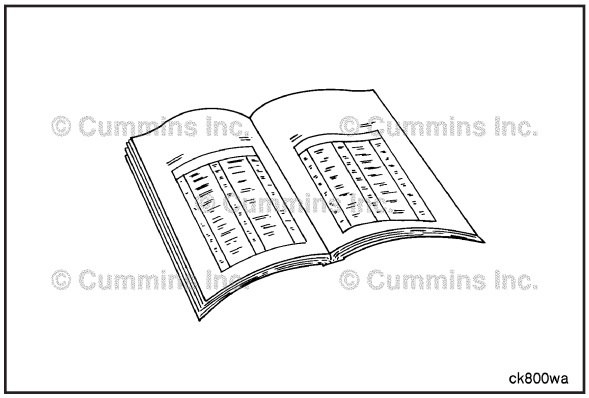


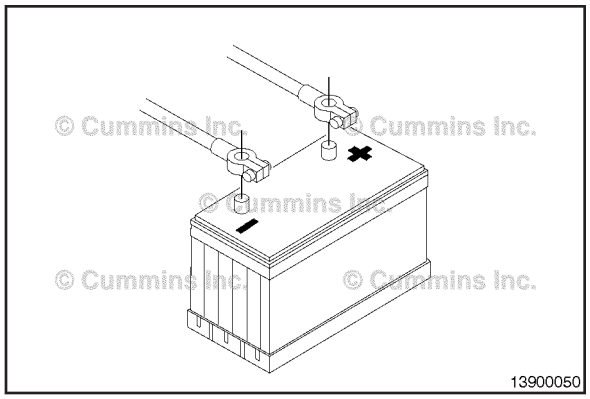
Finishing Steps

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

Install the vibration damper/crankshaft speed indicator ring. If equipped with a viscous damper, Refer to Procedure Procedure 001-052. If equipped with a rubber damper, Refer to Procedure Procedure 001-051. If equipped with a crankshaft speed indicator ring only, Refer to Procedure Procedure 001-071

Install the belt. Refer to Procedure Procedure 008-002

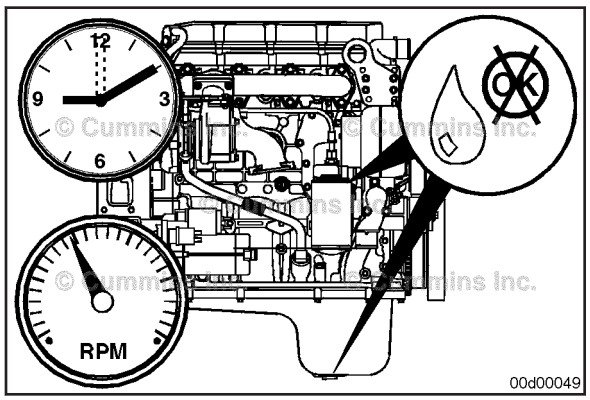




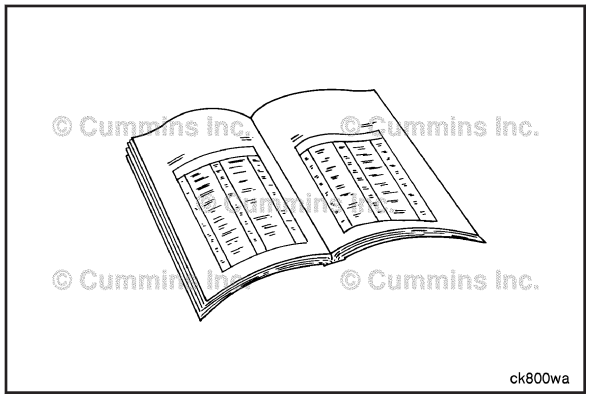
⚠WARNING⚠

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



Operate the engine and check for leaks.



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

Install the crankshaft speed indicator ring. Refer to Procedure Procedure 001-071

Install the vibration damper. Refer to Procedure Procedure 001-051 or Refer to Procedure Procedure 001-052

Install the crankshaft position sensor. Refer to Procedure Procedure 019-365 in Troubleshooting and Repair Manual, CM850 Electronic Control System, ISB Engines, Bulletin 4021337.

Install the fan hub. Refer to Procedure Procedure 008-039

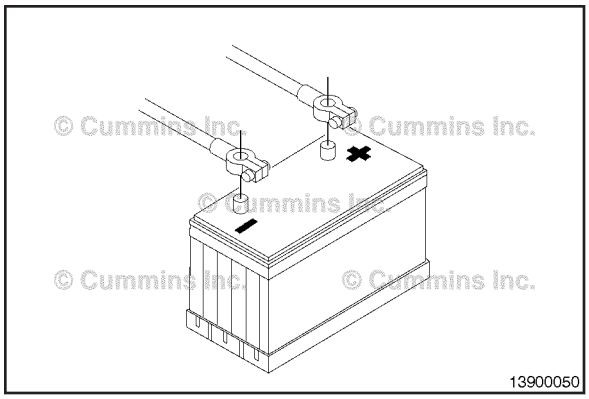
Install the water pump drive belt. Refer to Procedure Procedure 008-002

Install the seawater pump drive belt. Refer to Procedure Procedure 008-126

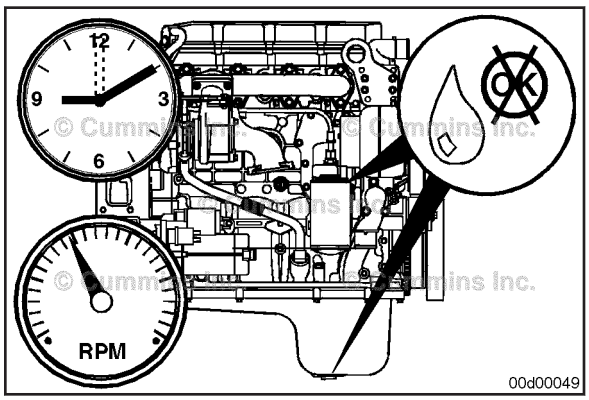
Install the belt guards. Refer to Procedure Procedure 008-001

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



Operate the engine at idle for 5 to 10 minutes and check for leaks and loose parts.

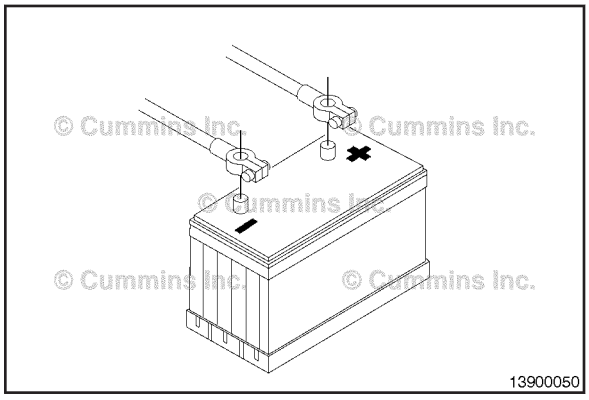


Lubricating Oil Suction Tube (Block-Mounted) (007-035)

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.

Disconnect the batteries.

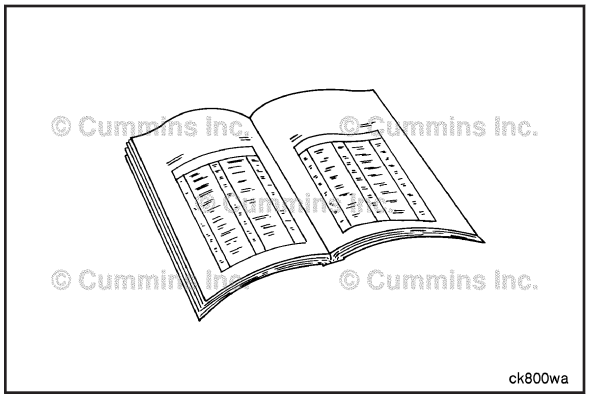


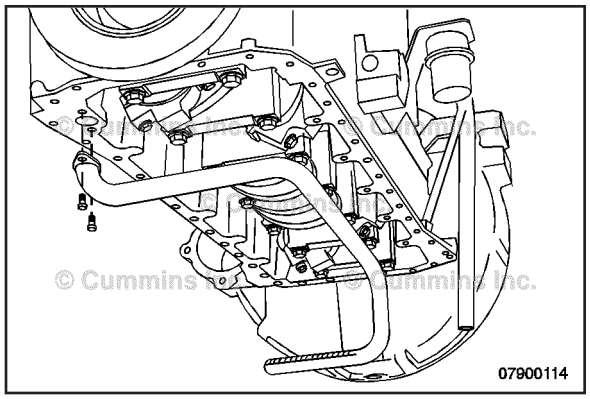
⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

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

Drain the lubricating oil. Refer to Procedure Procedure 007-037

Remove the lubricating oil pan and gasket. Refer to Procedure Procedure 007-025

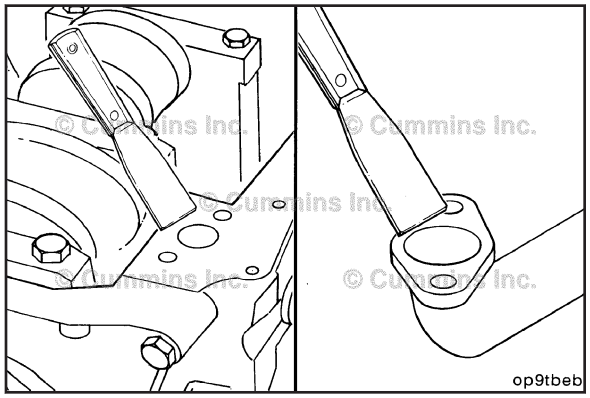




Remove

Remove the suction tube mounting capscrews.

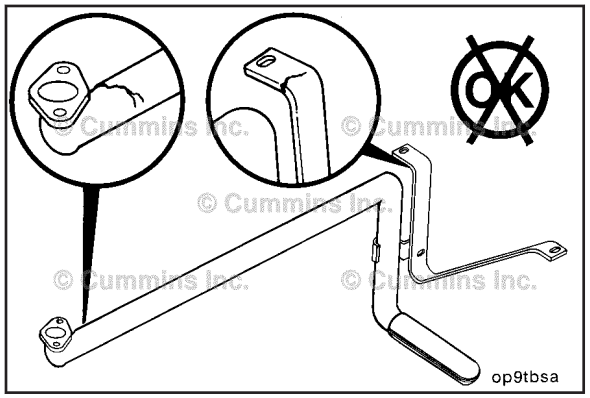
Remove the suction tube.



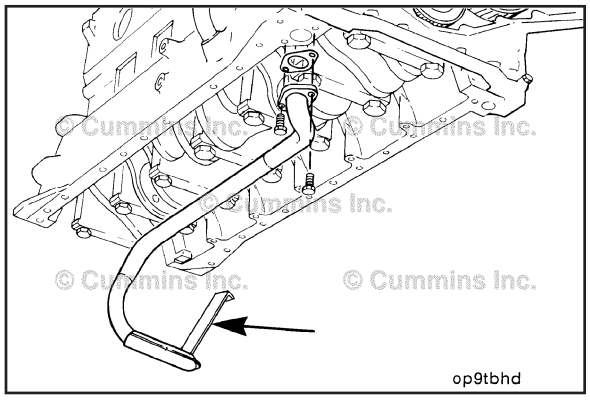
Clean and Inspect for Reuse

Using a putty knife, clean the gasket surfaces.

Clean the suction tube surface with hot, soapy water.



Inspect the suction tube for cracks.



Install

⚠CAUTION⚠

The suction tube gasket is not symmetrical. Failure to install it properly can result in low oil pressure and engine damage.

Install the lubricating oil suction tube gasket and suction tube.

Install and tighten the suction tube mounting capscrews.

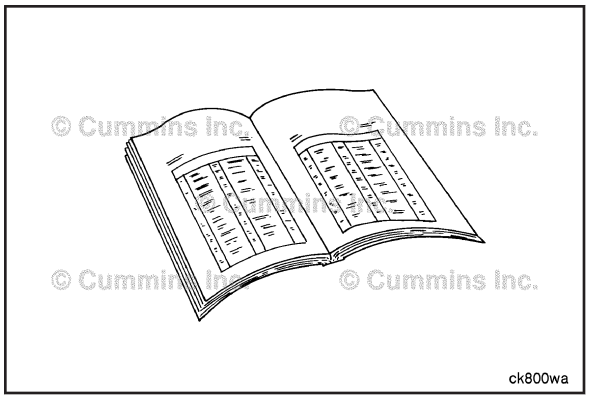
Torque Value: 24 N•m [212 in-lb]

NOTE: Take care to ensure the oil suction tube gasket openings align with both the oil suction tube and the block.

Finishing Steps

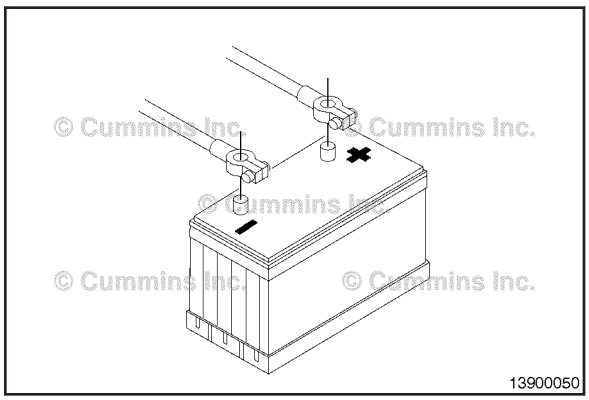
Install oil pan and gasket. Refer to Procedure Procedure 007-025

Fill the engine with lubricating oil. Refer to Procedure Procedure 007-037



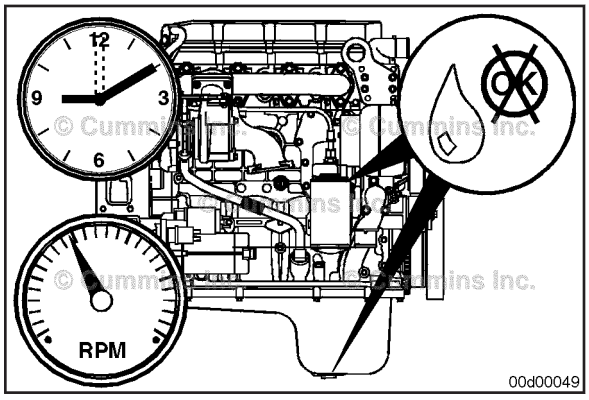
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

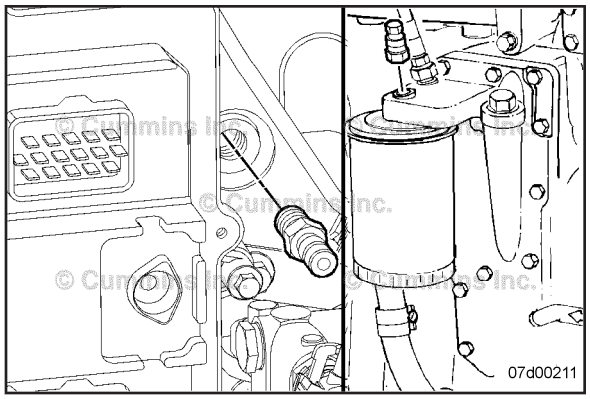
Connect the batteries.



Operate the engine and check for leaks.

Stop the engine, and check the lubricating oil level with the dipstick.





Lubricating Oil System (007-037)

Measure

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

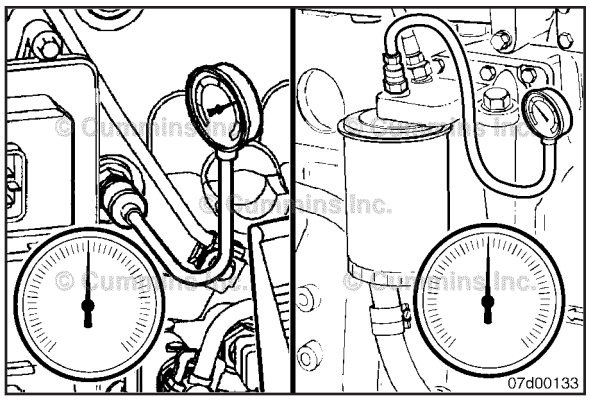
⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

Locate the appropriate port for measuring oil pressure. On most engines a port can be found adjacent to the ECM along the main oil gallery. If this port is **not** accessible, another port can be located on the top of the oil filter head.

Remove the plug.

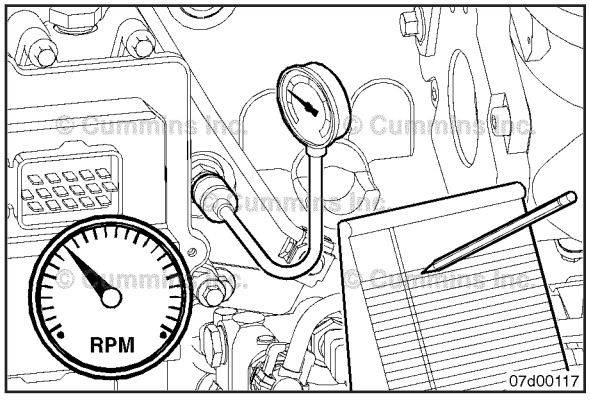
NOTE: It is preferred that oil pressure be checked at the main oil gallery, if accessible.

Install a Compuchek® fitting.



△CAUTION△
If the lubricating oil pressure does not develop within 15 seconds, shut down the engine to reduce the possibility of internal damage.

Connect a pressure gauge. Start the engine.



Allow the engine to run and achieve operating temperature. Check for leaks.

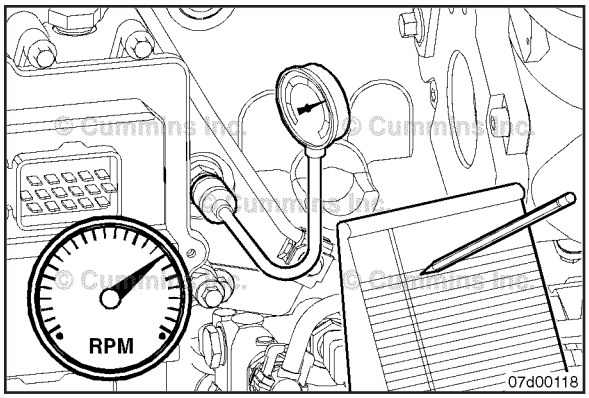
Record the lubricating oil pressure readings at idle.

Oil Pressure at Low Idle		
kPa		psi
69	MIN	10

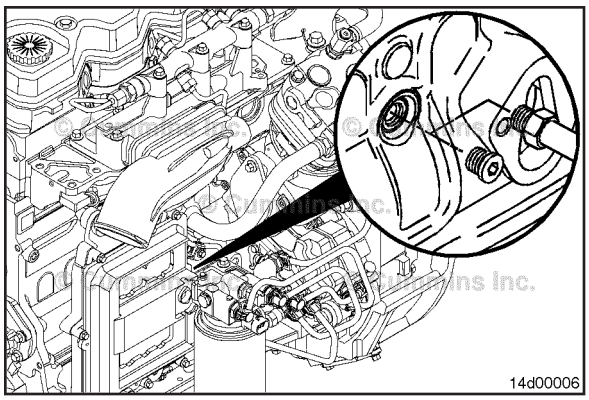
Increase engine speed to rated speed and hold for 30 seconds.

Record the lubricating oil pressure readings at rated engine speed.

Oil Pressure at Rated Engine Speed		
kPa		psi
207	MIN	30



Remove the oil pressure gauge/Compuchek® fitting and install the previously removed plug. For pipe plugs, Refer to Procedure Procedure 017-007. For straight thread plugs, Refer to Procedure Procedure 017-011



Drain

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

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

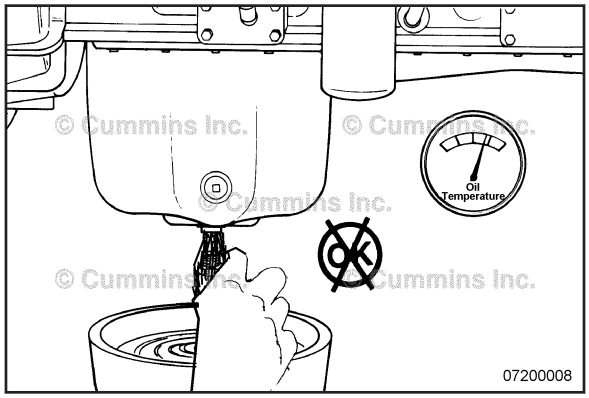
NOTE: For most engines use a container that can hold at least 20 liters [21 qt] of lubricating oil. Some engines may be equipped with an increased capacity oil pan requiring a container that can hold 28 liters [30 qt] of lubricating oil.

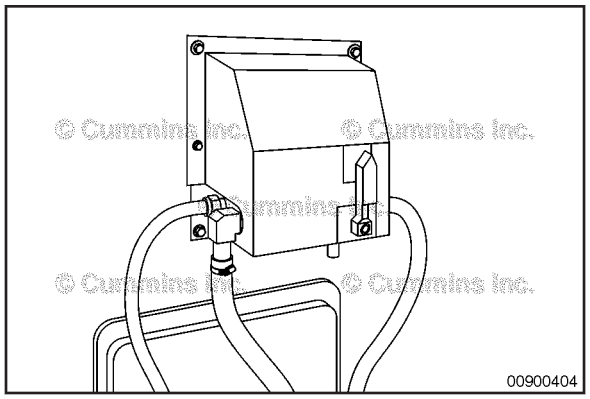
Operate the engine until the coolant temperature reaches 60°C [140°F].

Shut off the engine.

Remove the oil drain plug. Drain the oil immediately to be sure all the oil and suspended contaminants are removed from the engine.

If performing an oil drain as part of a service maintenance interval, remove and replace the oil filter. Refer to Procedure Procedure 007-013





⚠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.

△CAUTION△
Use caution when draining oil or 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: Use a container that can hold at least 20 liters [21 qt] of lubricating oil.

Operate the engine until the coolant temperature reaches 60°C [140°F].

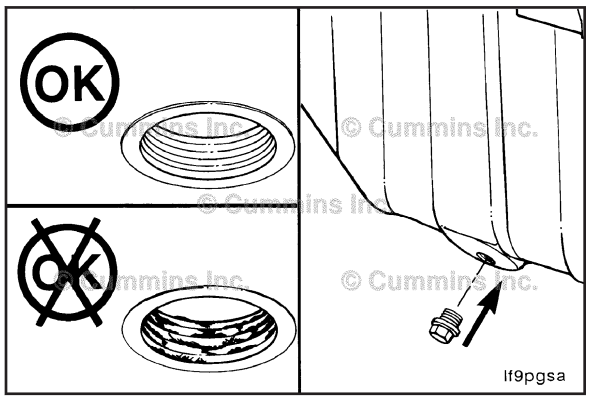
Shut off the engine.

Place the lubricating oil pump-out device outlet hose, if equipped, into a suitable container used to discard the used engine oil.

Open the inlet valve to the oil pump-out device.

Start the pump-out device and drain the lubricating oil from the engine immediately to be sure all the oil and suspended contaminants are removed from the engine.

If performing an oil drain as part of a service maintenance interval, remove and replace the oil filter. Refer to Procedure Procedure 007-013



Fill

Clean and check the lubricating oil drain plug threads and sealing surface. Use new sealing washer, if damaged.

Install the lubricating oil pan drain plug.

Automotive and Industrial Applications:

Steel Oil Pan Drain Plug Torque			
	N•m		ft-lb
M18	60	MIN	44
M22	80	MIN	59

Cast Aluminum Oil Pan Drain Plug Torque			
	N•m		ft-lb
M22	60	MIN	44

Marine Applications:

Marine Oil Pan Drain Plug Torque		
N•m		ft-lb
50	MIN	37

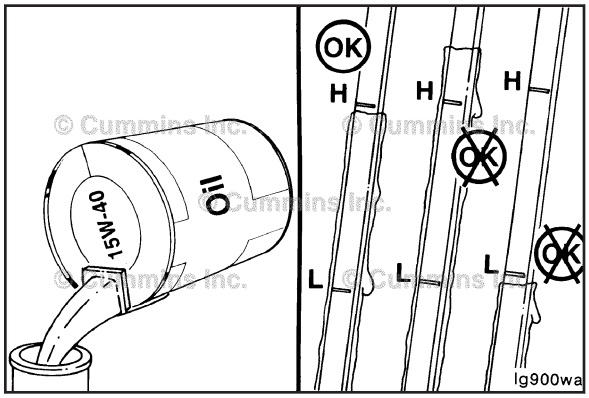
NOTE: Use a high-quality 15W-40 multiviscosity oil, such as Cummins Premium Blue®, or its equivalent, in Cummins® engines. Choose the correct oil for your operating climate. Refer to Cummins Engine Oil Recommendations, Bulletin 3810340

Fill the lubricating oil pan with clean 15W-40 lubricating oil to the low level. Refer to Procedure Procedure 018-017 (Lubricating Oil System in Section V) for common lubricating oil pan capacities, or by looking up the oil pan option for the engine serial number on QuickServe OnLine.

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.

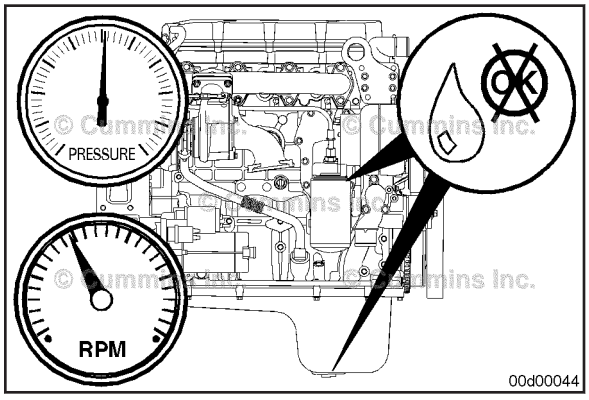
NOTE: If the engine is **not** equipped with a side-fill, wait at least 5 minutes before measuring the oil level with the dipstick to allow the oil to drain to the pan.

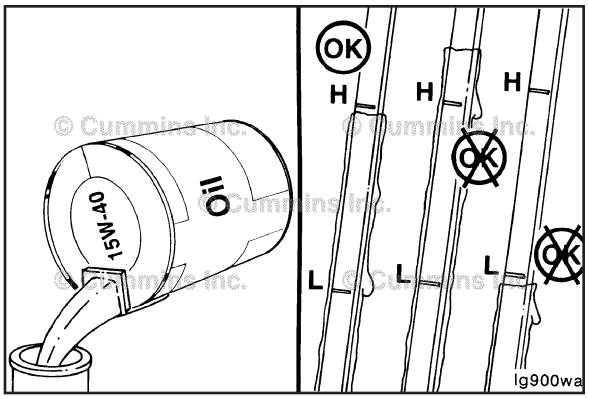
Service Tip: If the oil capacity of the oil pan is **not** known, fill the lubricating oil pan to the smallest oil pan capacity listed in Refer to Procedure Procedure 018-017 (Lubricating Oil System in Section V) for the engine being worked on. Then add 1 quart of oil at a time until it reaches the high mark on the dipstick. Record the number of quarts added so that capacity is known the next time the oil is drained.



Idle the engine to inspect for leaks at the drain plug and, if replaced, the oil filter seal.

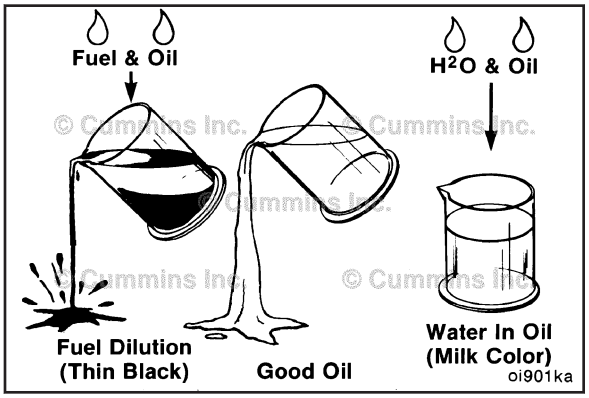
NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm that the correct oil level is in the oil pan.





Shut off the engine. Wait approximately 5 minutes to let the oil drain from the upper parts of the engine. Check the level again.

Add oil as necessary to bring the oil level to the H (high) mark on the dipstick.



Lubricating Oil Contamination (007-044)

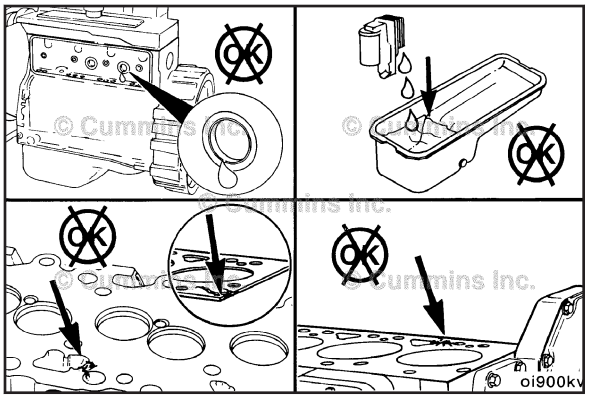
General Information

Lubricating Oil Dilution

⚠CAUTION⚠
Diluted oil can cause severe engine damage.

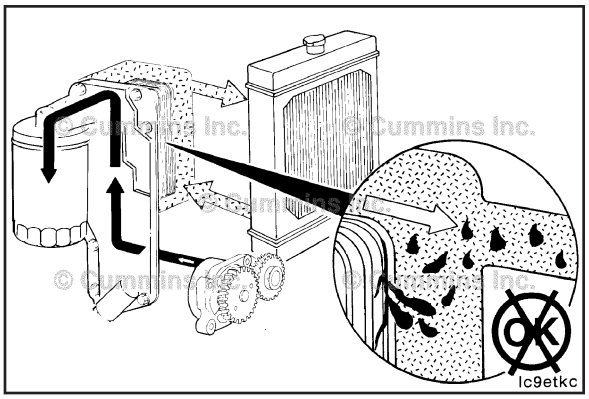
Check the condition of the lubricating oil.

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



Coolant in the oil can be caused by:

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

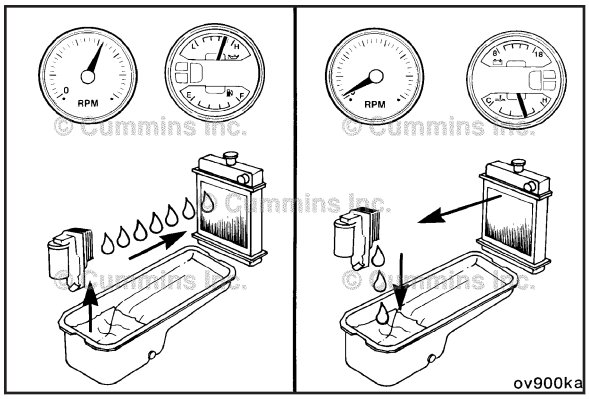


Coolant-Diluted Lubricating Oil

Since the lubricating oil cooler design does **not** require gaskets or seals to maintain the separation of oil and coolant, the element itself **must** leak to allow mixing of the fluids.Refer to Procedure 007-003 in Section 7.

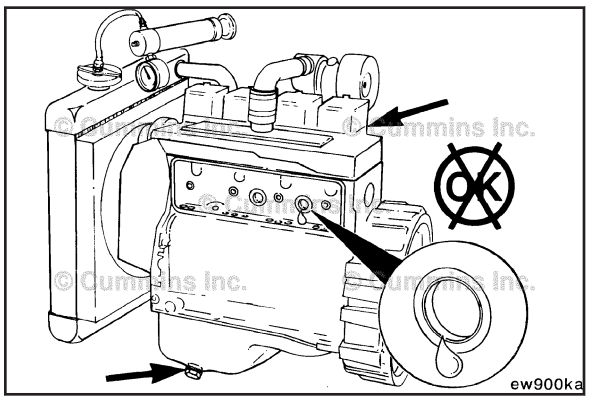
During operation, the lubricating oil pressure will be higher than coolant pressure. A leak in the lubricating oil cooler will show as lubricating oil in the coolant.

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



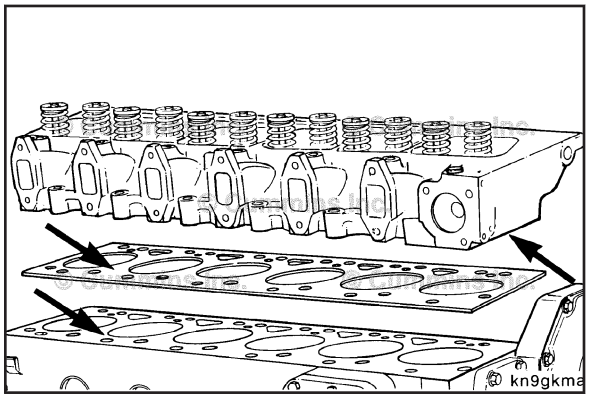
To check for leaks, pressurize the cooling system to 140 kPa [20 psi]. With the system pressurized, remove the following components, and inspect for leaks.

- Valve covers (leaks indicate cracked head)
- Lubricating oil drain plug (leaks indicate defective lubricating oil cooler, head gasket, cracked head or block)
- Tappet cover (expansion plug leak).



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

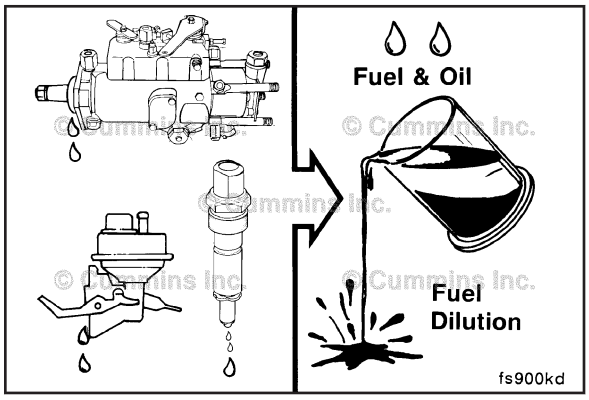
Remove the cylinder head and gasket, and inspect for cracks or damage.

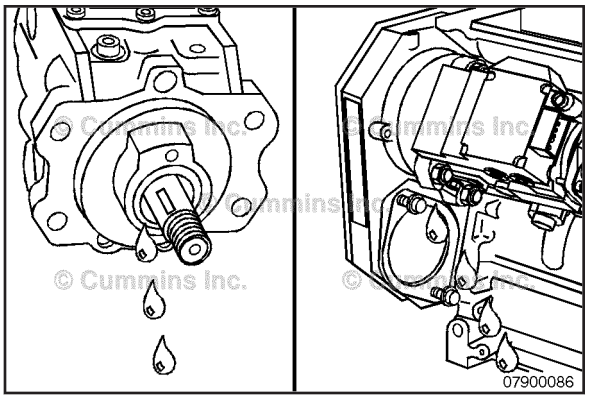


Fuel-Diluted Lubricating Oil

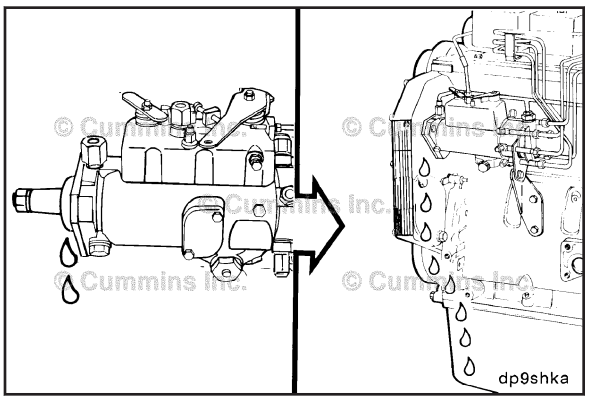
Fuel dilution is limited to five sources:

1 Injection pump shaft seal
2 Fuel leaking by the rings
3 Fuel transfer pump
4 A crack in the cylinder head from the fuel filter location to the air intake
5 Injector leakage.

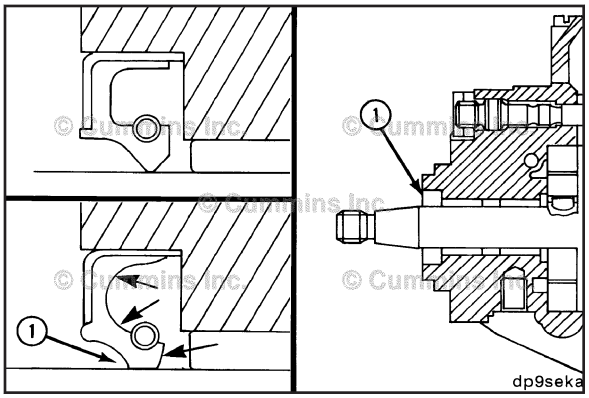




Use the following logic to determine the source of the oil dilution with fuel:

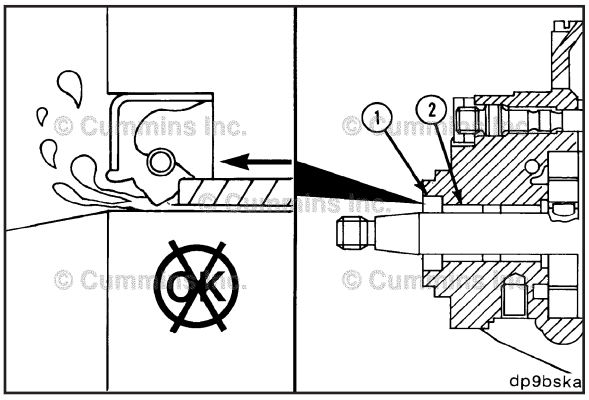


A worn or damaged fuel injection pump shaft seal will allow fuel to leak into the gear housing and then into the lubricating oil pan.



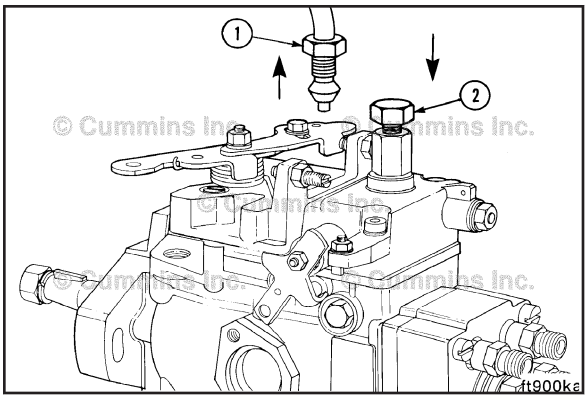
The seal is designed to provide increased sealing as the pump case pressure increases. Pressure forces the lip (1) tighter around the shaft.

A worn seal could leak during start-up and shutdown when case pressure is low. A worn seal can **not** easily be detected by pressurizing the pump.

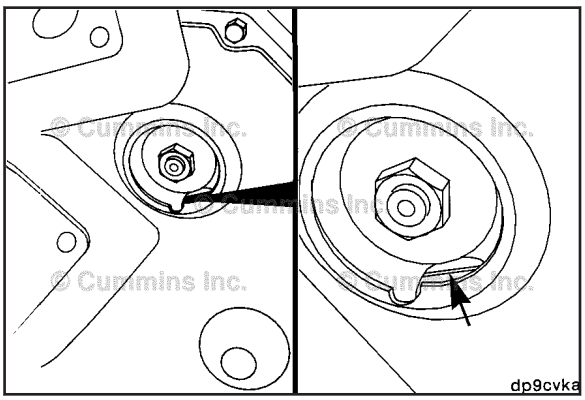


The bushing (2) in the Bosch® VE fuel injection pump can cause a seal leak. If the bushing is loose in the housing, it will move toward the seal raising the lip (1) and providing a leak path for fuel.

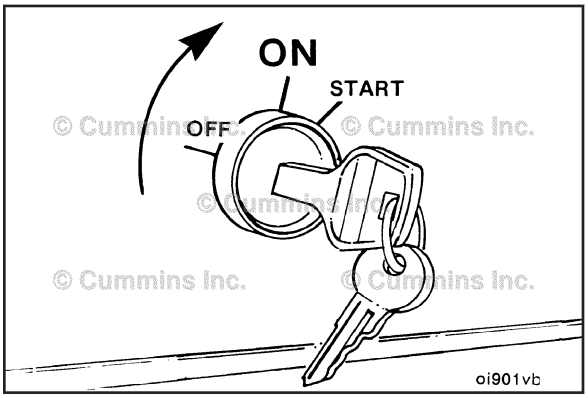
To check for such a leak, or a damaged seal (Bosch® VE **only**) , remove the fuel drain manifold connection (1) at the pump, and install a plug (2).



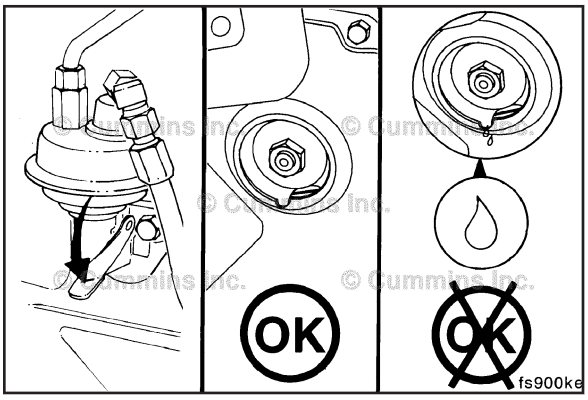
Remove the access cover, and rotate the engine so one of the holes in the fuel injection pump gear exposes the back gear housing.

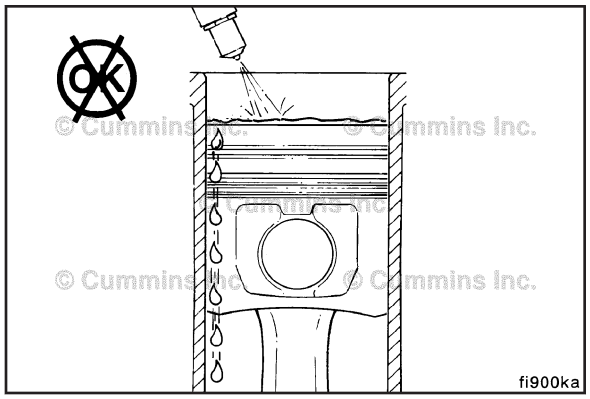


Activate the fuel shutdown valve by turning the switch to the ON position.



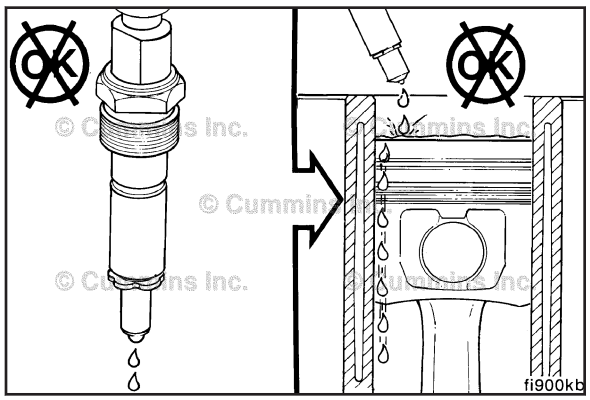
Use a small mirror to check for leaks while pumping the priming lever on the lift pump. If a leak is found, replace the injection pump. The seal can be replaced by a Cummins Authorized Service Center.





Incomplete combustion in the cylinders can result in unburned fuel draining into the oil pan.

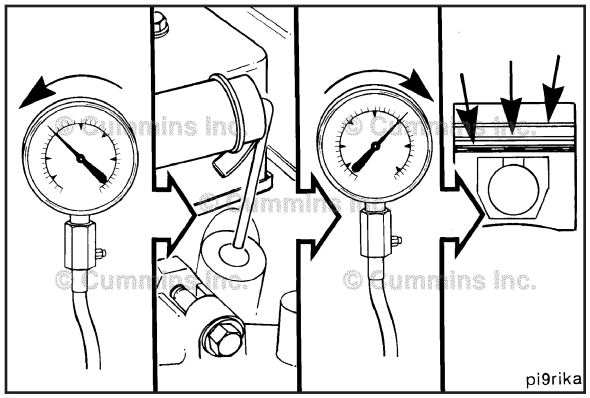
This condition can be caused by a leaking injector or reduced compression caused by inadequate piston ring sealing.



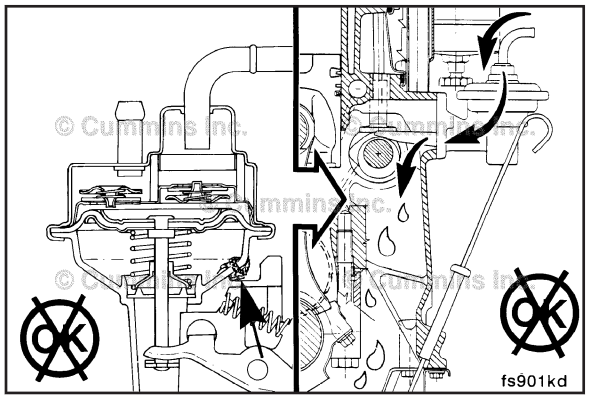
An increase in white exhaust smoke during the first start of the day is a symptom that an injector is leaking.

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

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



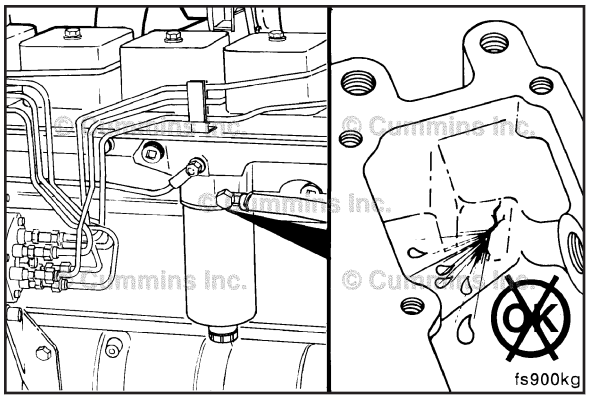
Perform a compression check to verify piston ring sealing. Refer to Procedure 014-008 in Section 14.



There is a remote possibility for fuel to drain into the oil from the diaphragm-type fuel transfer pump.

For this to happen, the diaphragm in the pump will break and the drain hole will need to be plugged.

Another remote possibility, is that a crack or porosity in the head casting will allow fuel to leak to the air intake and onto the cylinders.



Lubricating Oil Pressure Sensor, OEM (007-052)

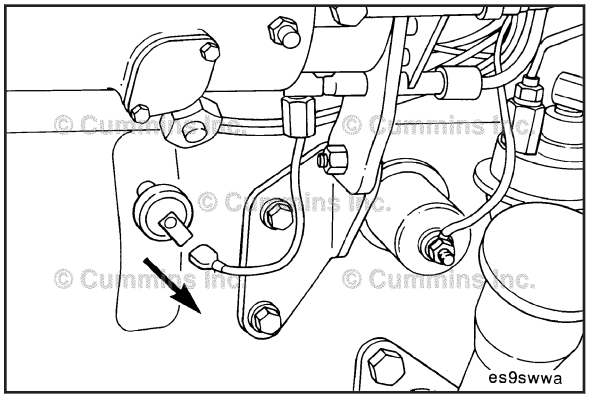
Remove

Disconnect the wire from the sending unit.

Remove the pressure sensor.

NOTE: The sending units illustrated can differ from those installed by the original equipment manufacturer (OEM).

NOTE: The locations of OEM-installed Oil Pressure Sensors can vary. Refer to OEM's documentation if necessary.



Install

Install the sending unit.

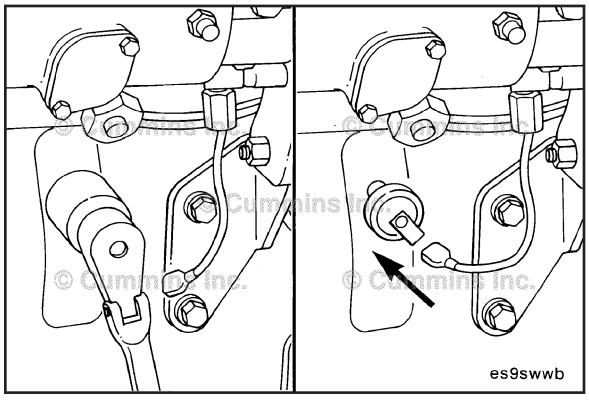
Connect the wire to the sending unit.

Torque Value:
Installed into Cast Iron

Step 1	16 N•m	[142 in-lb]

Torque Value:
Installed into Aluminum

Step 1	10 N•m	[89 in-lb]

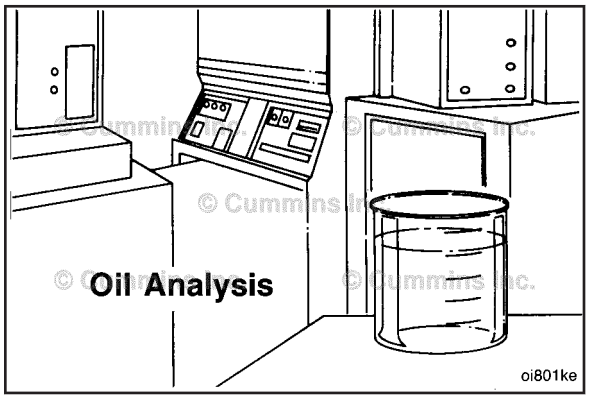


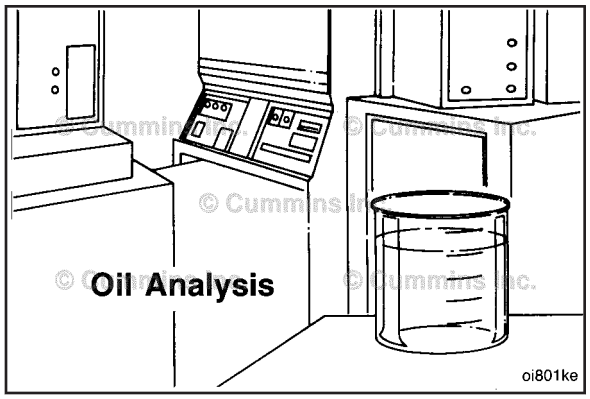
Lubricating Oil and Filter Analysis (007-083)

Inspect

An analysis of used oil can help diagnose internal engine damage and determine if it was caused by one of the following:

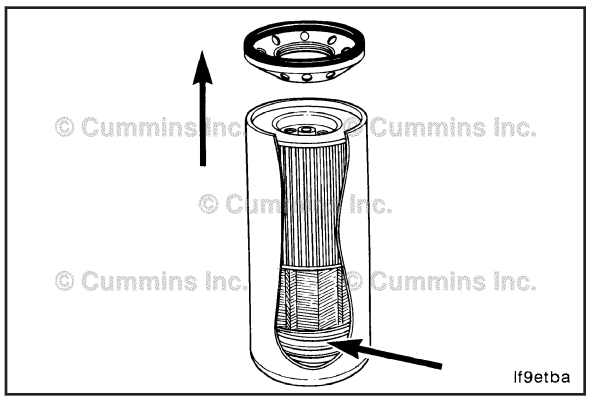
- Intake air filter malfunction
- Coolant leaks
- Oil diluted with fuel
- Metal particles causing wear.



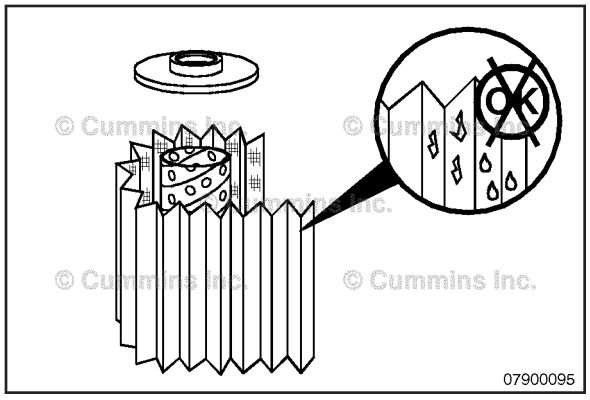


For additional oil analysis information, refer to Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340.

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.

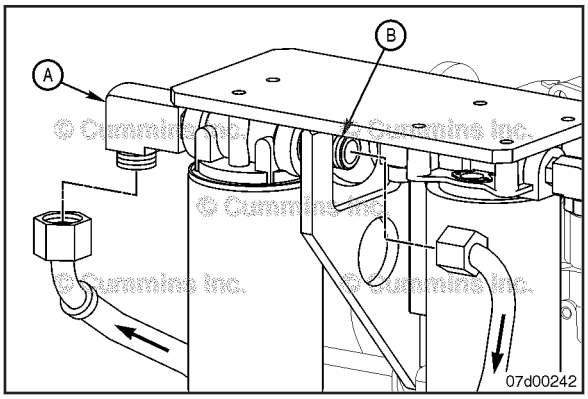
△CAUTION△
Use caution when draining oil that oil is not spilled or drained into the bilge area. The oil must be disposed in accordance with local environmental regulations.

△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 oil hoses and oil filter head for correct location.

- Oil inlet
- Oil outlet.

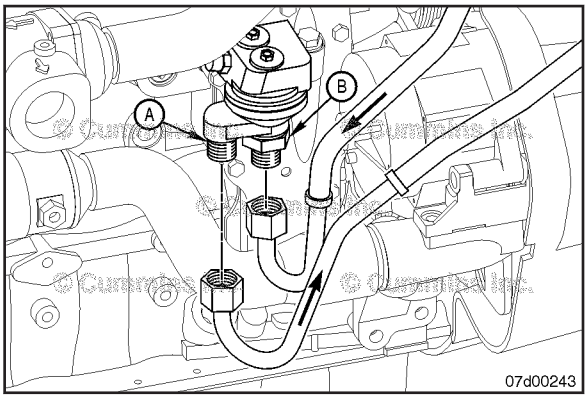
Disconnect the oil lines from the lubricating oil filter head.



Verify and mark the oil hoses and adapter head for correct location.

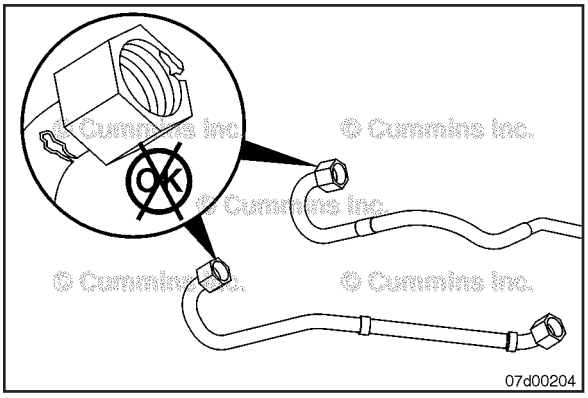
- Oil outlet
- Oil inlet.

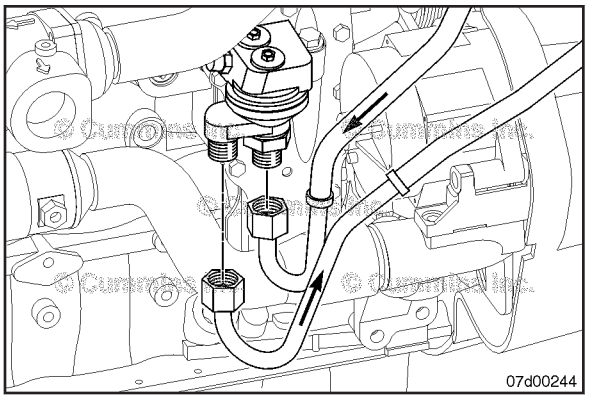
Disconnect the oil lines from the adapter head.



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.

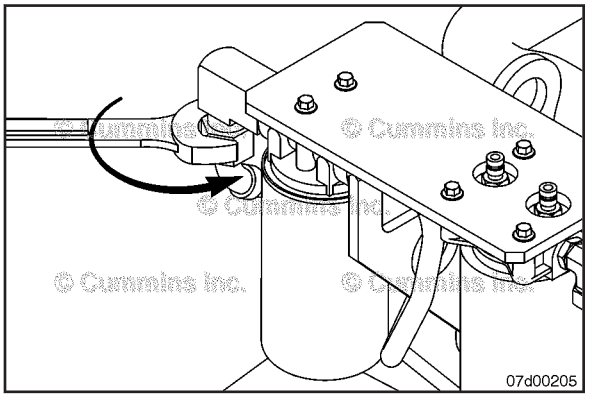
Install the hoses to the lubricating oil filter connectors and tighten finger tight.

Install the hose to the center (return) connection of the lubricating oil cooler housing filter adapter and tighten.

Torque Value: 76 N•m [56 ft-lb]

Install the hose to the lubricating oil cooler housing filter adapter outer (supply) connection and tighten.

Torque Value: 76 N•m [56 ft-lb]



Tighten the hoses on the filter head.

Torque Value: 76 N•m [56 ft-lb]

Operate the engine and check for leaks and proper oil pressure.

Check the lubricating oil level.

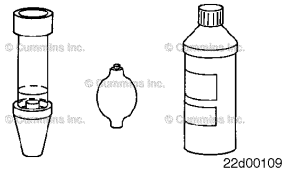
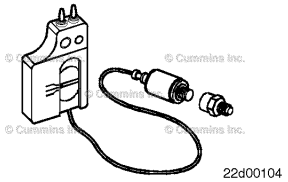
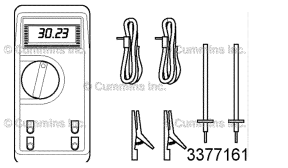
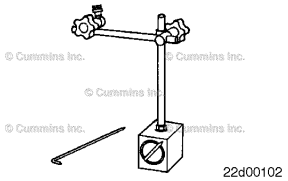
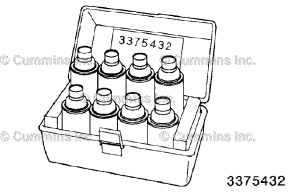
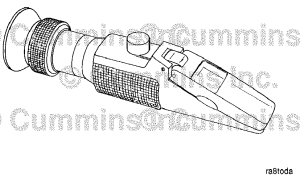
Section 8 - Cooling System - Group 08

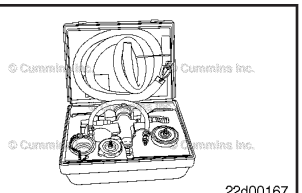
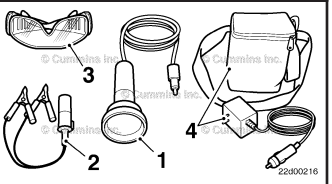
Section Contents

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 Tester** Used to test for combustion gasses in the cooling system.	
3164491	**Pressure/Vacuum Module** Used to measure fuel pressure and restriction. Use with multimeter, Part Number 3164488 or 3164489.	
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.	
3377399	**Magnetic Base Indicator Holder** Used in conjunction with Dial Indicator. Metric — Part Number 3824564. SAE — Part Number 4918289.	
3375432	**Crack Detection Kit** Used to detect cracks in engine components.	
CC-2800	**Refractometer** The Fleetguard® refractometer is used to check the charge condition of a conventional battery.	

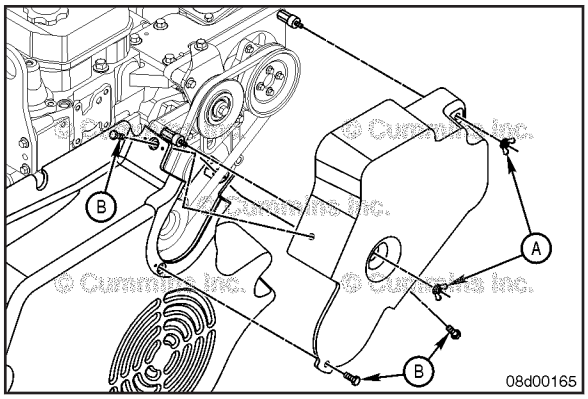
Tool No.	Tool Description	Tool Illustration
3824319	**Coolant Dam/Pressure Tester** Using shop air pressure the coolant dam creates a vacuum, holding the coolant in with little or no coolant loss.	 22d00167
3163338	**Black Light Lamp (12VDC)** Used with fluorescent tracer to locate coolant and/or oil leaks. Lamp operates off vehicle battery or portable rechargeable battery included in kit. Oil tracer Part Number 3376891, coolant tracer Part Number 3377438.	 22d00216

Belt Guard (008-001)

Remove

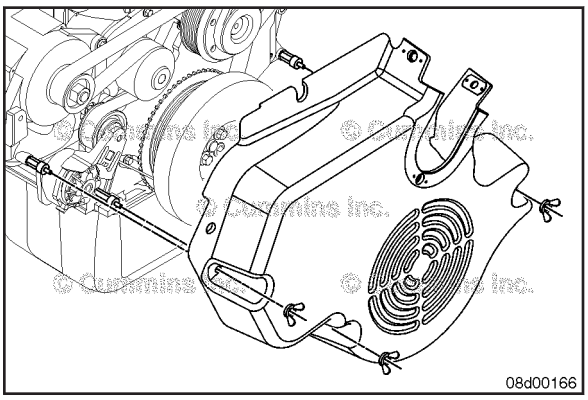
Remove the two wing nuts (A) and three capscrews (B) on the sea water pump belt guard.

Remove the upper belt guard.

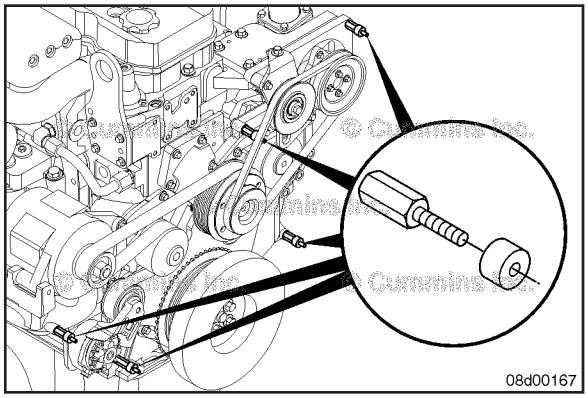


Remove the three wing nuts on the alternator/engine water pump belt guard.

Remove the lower belt guard.



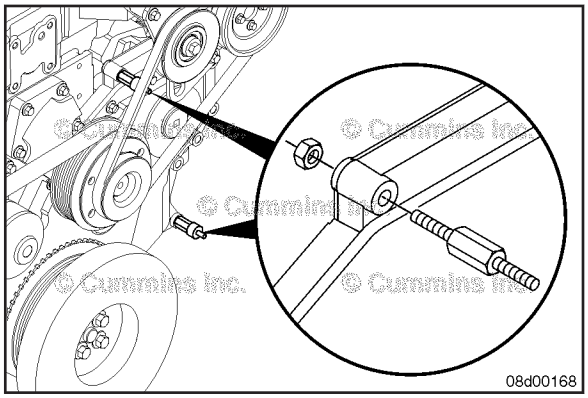
Remove the five rubber isolators from the upper and lower belt guard mounting studs.

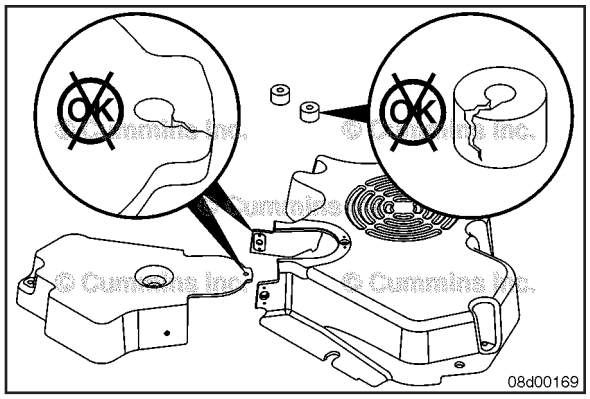


NOTE: Two of the studs are attached with nuts from the rear side of the gear housing.

Remove the locknut, if applicable.

Remove the stud.



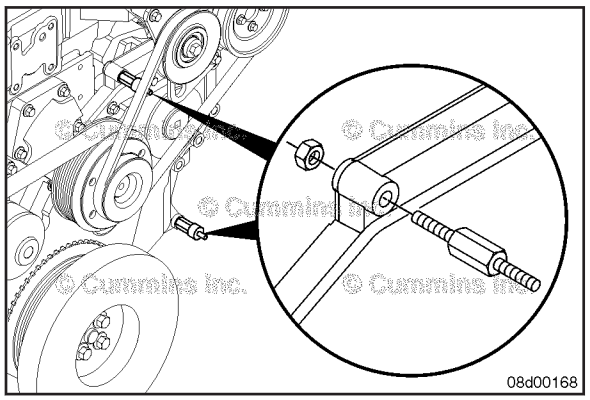


Inspect for Reuse

Inspect the belt guards 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.

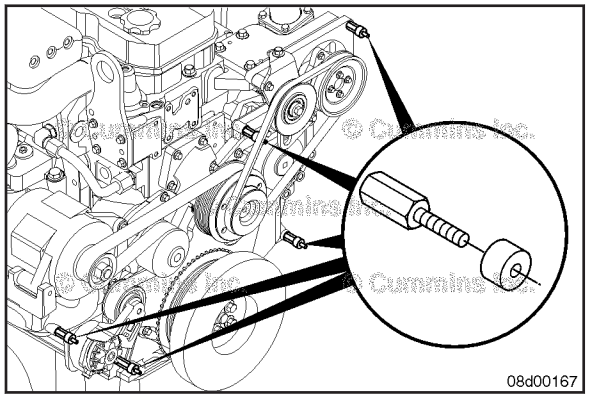


Install

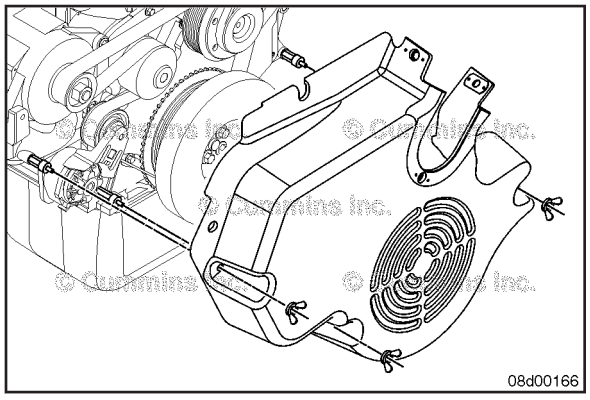
NOTE: Two of the studs are attached with nuts from the rear side of the gear housing.

Install and tighten the five studs and nuts as shown.

Torque Value: 15 N•m [133 in-lb]



Install the five rubber isolator onto the five studs.



NOTE: Install the lower portion of the belt guard first, then install the upper portion of the belt guard.

Align the lower belt guard attachment holes with the three mounting studs.

Install the lower belt guard over the mounting studs.

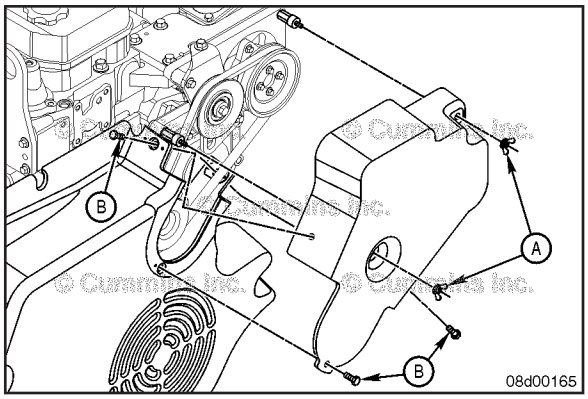
Install and tighten the three wing nuts finger tight.

Align and install the upper belt guard to the engine.

Tighten the wing nuts (A) finger tight.

Attach the top belt guard to the lower belt guard and engine; use the three mounting capscrews (B).

Torque Value: 5 N•m [44 in-lb]



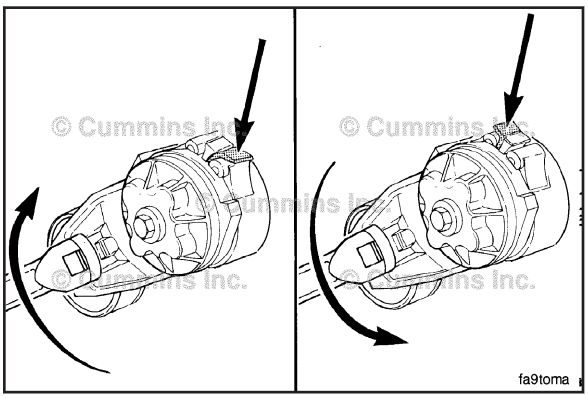
Drive Belt, Cooling Fan (008-002)

Remove

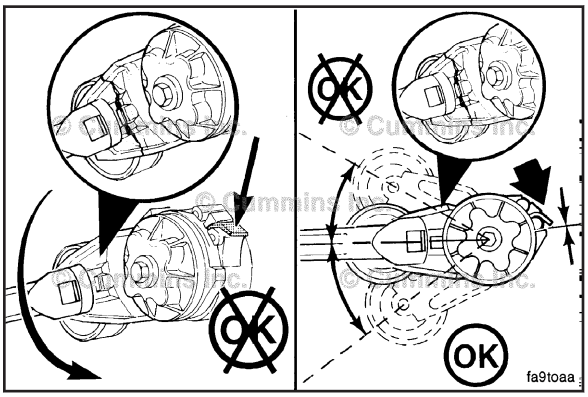
⚠CAUTION⚠
The belt tensioner is spring-loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

Pivot the tensioner to relieve tension in the belt, and remove the belt.

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



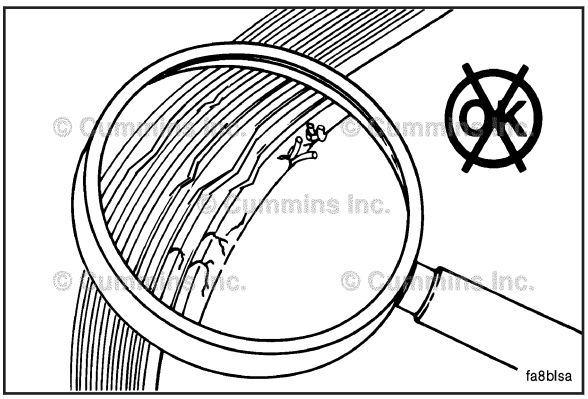
⚠CAUTION⚠
Applying excessive force in the opposite direction of windup or after the tensioner has been wound up to the positive stop can cause the tensioner arm to crack or break.

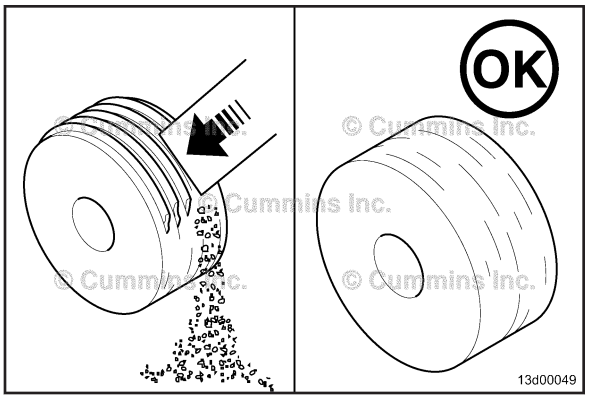


Inspect for Reuse

Inspect the drive belt for:

- Cracks
- Glazing
- Tears or cuts
- Hardening
- Excessive wear.





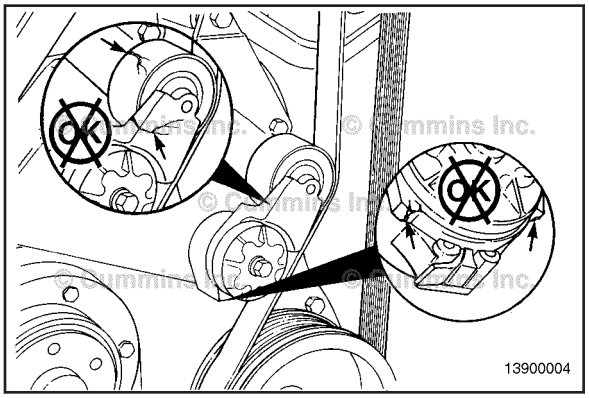
Inspect the idler pulleys for wear or cracks.

Plastic pulleys often have a build-up of road dirt and belt material that is **not** to be confused with wear.

The dirt can be removed with a suitable tool to check for wear.

Clean, check and reuse idlers with a build up of dirt, rather than replacing.

Replace the belt tensioner idler. Refer to Procedure 008-087

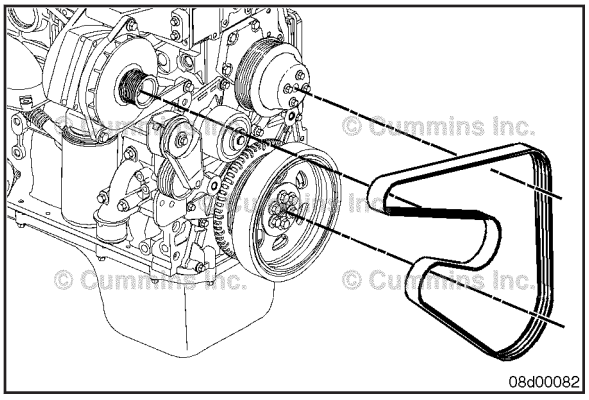


Inspect the drive belt pulleys and idlers for cracks or broken grooves.

To replace the fan pulley, the alternator drive belt, the water pump tensioner. Refer to Procedure 008-039

To replace the cooling fan belt tensioner. Refer to Procedure 008-087

To replace the crankshaft pulley, contact an Authorized Cummins Repair Location.



Install

CAUTION
The belt tensioner is spring-loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

Route the drive belt on the engine, except for the water pump pulley.

Pivot the tensioner and install the drive belt, slipping the belt over the water pump pulley last.

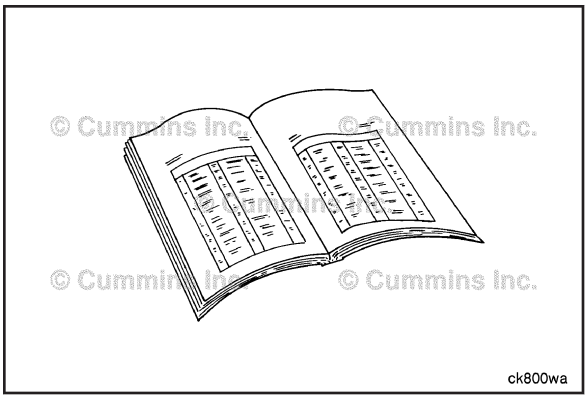
Release the tensioner to apply tension to the drive belt.

Check the alignment of the belt with the tensioner and the rest of the front end auxiliary drive.

Operate the engine and check for belt squeal. Excessive belt squeal indicates belt slippage.

Coolant Heater (008-011)

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 the coolant system that coolant is not spilled or drained into the bilge area. The coolant must be discarded in accordance with local environmental regulations.

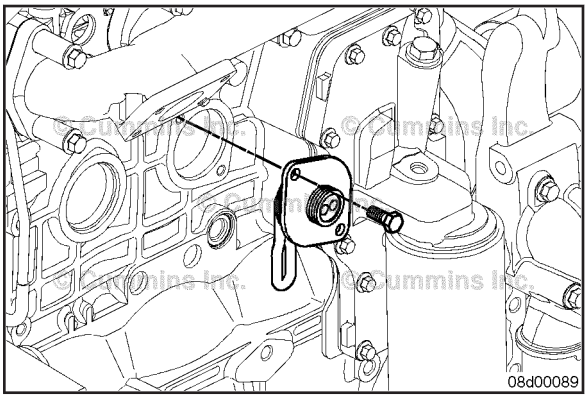
- Drain the engine cooling system. Refer to Procedure 008-018.
- Disconnect the block heater electrical cord.

Remove

Flange Mounted

Remove the two block heater retaining capscrews.

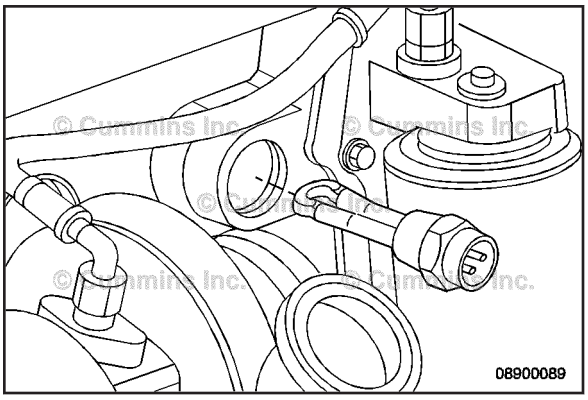
Remove the block heater from the block.

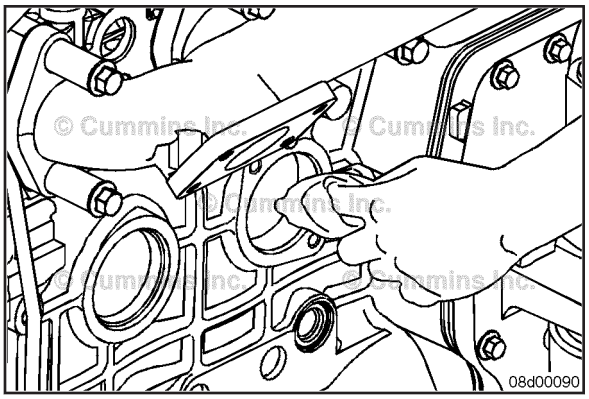


Threaded

Remove the block heater retaining nut.

Remove the block heater from the block.

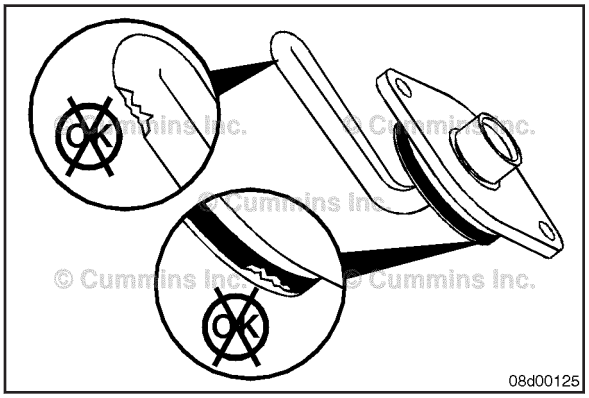




Clean and Inspect for Reuse

Clean the cup plug bore (or hole) thoroughly with a clean rag.

Make sure there are no burrs, metal shavings, or sharp edges that can possibly cut the o-ring.

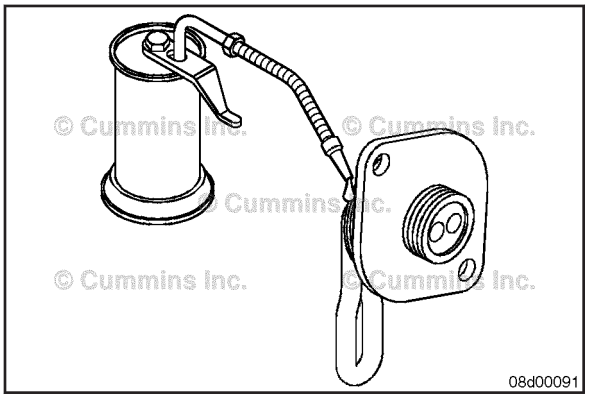


⚠WARNING⚠
To reduce the possibility of personal injury, do not touch the electrical supply wires or component while the testing procedure is in action.

Check the coolant heater for cracks on the element.

Check the o-ring for cracks.

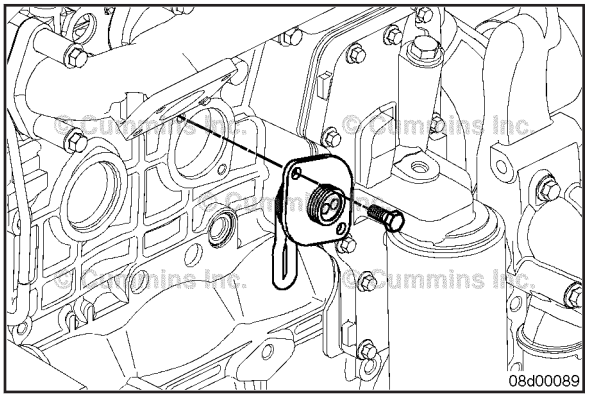
Test the coolant heater resistance. The resistance **must** read between minimum 18.2 to maximum 21.1 ohms.



Install

Flange Mounted

Lubricate the new heater o-ring with clean 15W-40 engine oil.



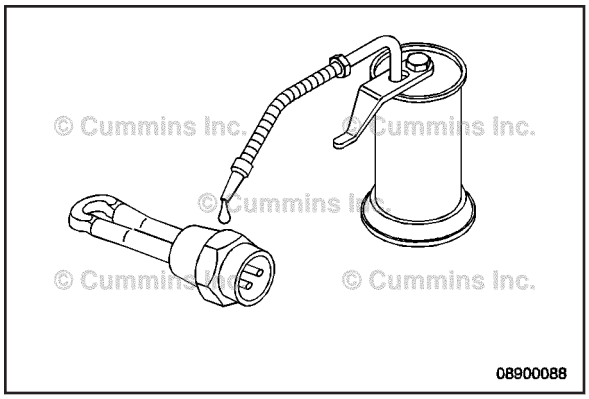
Install the heater.

Tighten the two retaining capscrews.

Torque Value: 24 N•m [212 in-lb]

Threaded

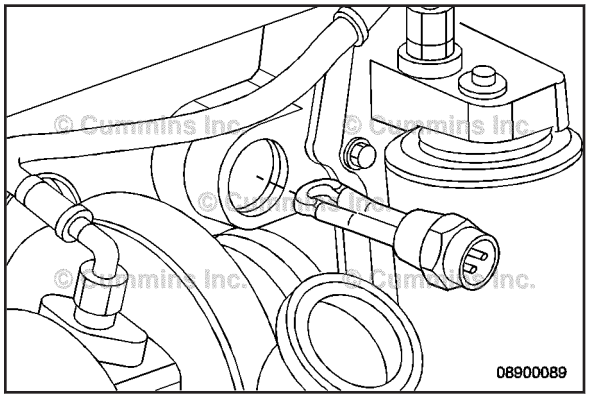
Lubricate the new heater o-ring with clean engine oil.



Install the heater.

Tighten the retaining nut.

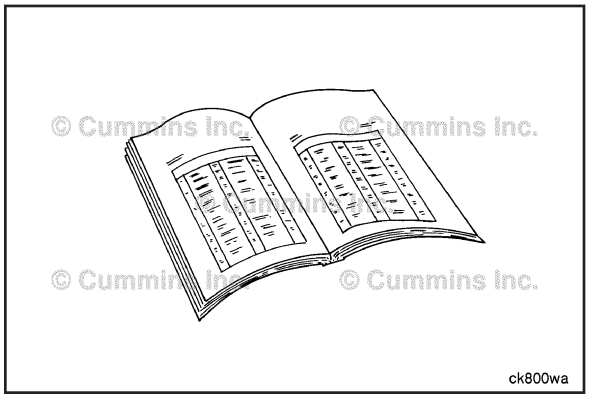
Torque Value: 55 N•m [41 ft-lb]



Finishing Steps

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

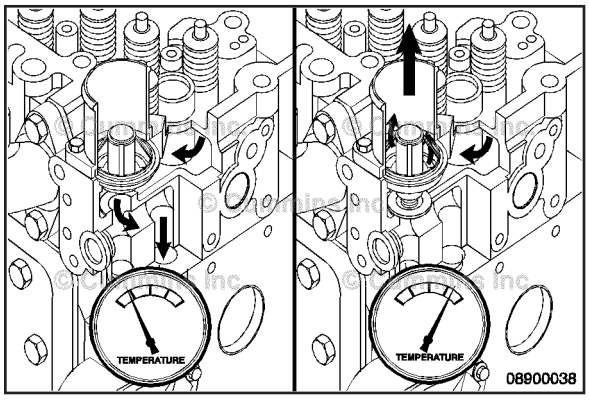
- Attach the heater electrical cord.
- Fill the engine cooling system. Refer to Procedure 008-018.

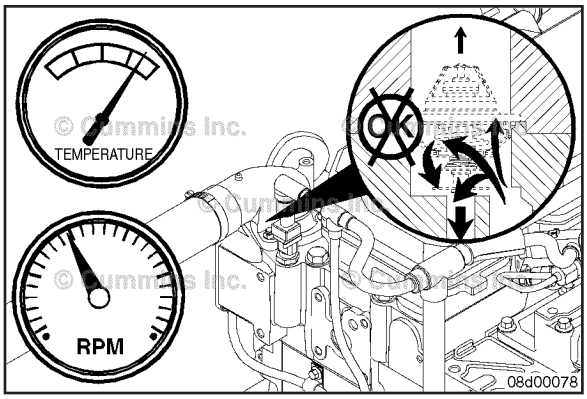


Coolant Thermostat (008-013)

General Information

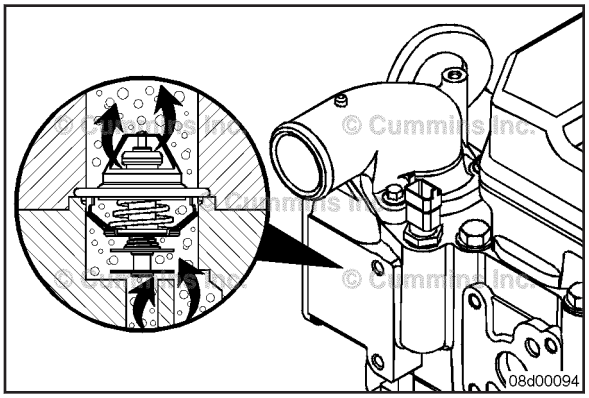
The thermostat controls the engine coolant temperature. When the coolant temperature is below the operating range, engine coolant is bypassed back to the inlet of the water pump. When the engine coolant temperature reaches the operating range, the thermostat opens, sealing off the bypass, allowing engine coolant to flow to the radiator on automotive or industrial engines, or to the heat exchanger or keel cooler on QSB5.9 marine engines. The thermostat begins opening at 68°C [155°F]





⚠CAUTION⚠
Never operate the engine without a thermostat. Without a thermostat, the path of least resistance for the coolant is through the bypass to the water pump inlet. This can cause the engine to overheat.

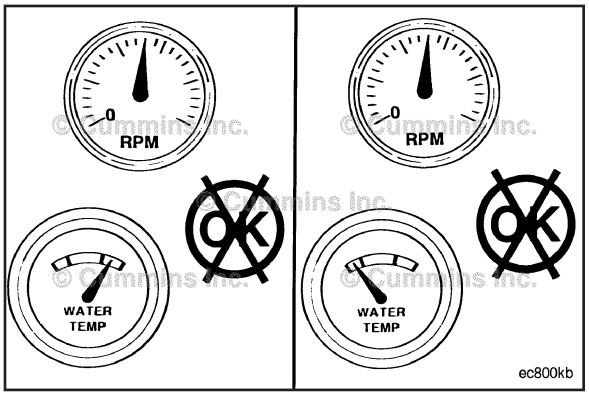
An incorrect or malfunctioning thermostat can cause the engine to run too hot or too cold.



⚠CAUTION⚠
A missing check ball can cause the engine to run cold, resulting in engine damage.

The thermostat contains two check balls to vent air past the thermostat when it is closed. This is needed for the cooling system to fill.

NOTE: Some off-highway applications use a thermostat with one check ball. When servicing a thermostat always be sure to replace it with the same part number. Though an incorrect thermostat will physically fit, it will lead to improper engine operation.



Leak Test

NOTE: The leak test portion of this procedure does **not** apply to QSB5.9 keel cooled marine engines.Refer to Procedure 008-014 for testing QSB5.9 keel cooled engines.

⚠CAUTION⚠
The engine thermostat must operate properly for the engine to operate in the most efficient heat range. Overheating or overcooling will shorten engine life.

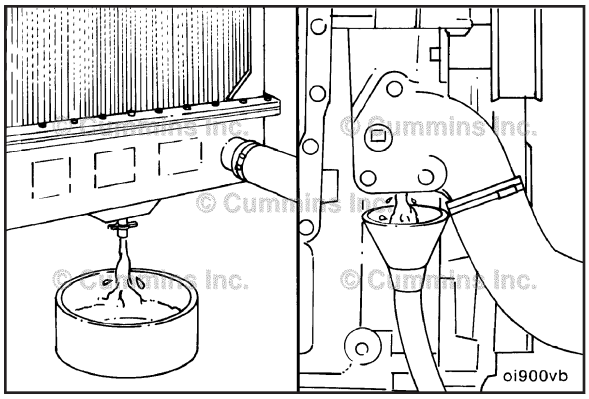
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠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 so that it 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 below the level of the thermostat.Refer to Procedure 008-018.

On QSB5.9 engines with keel cooling, remove the coolant hose from the inlet side of the keel cooler thermostat housing.

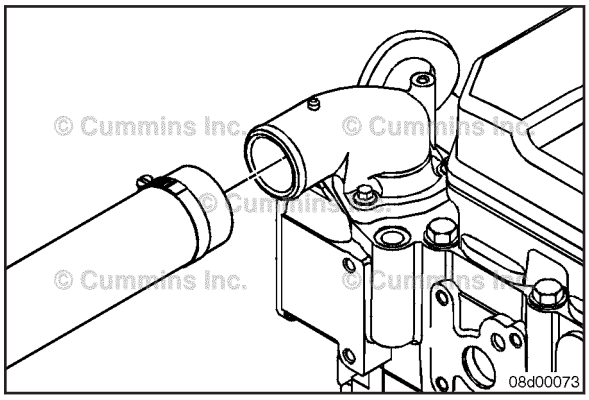


⚠WARNING⚠
Complete this test with the engine coolant temperature below 50°C [122°F]. Hot steam can cause serious personal injury.

Loosen radiator hose clamp.

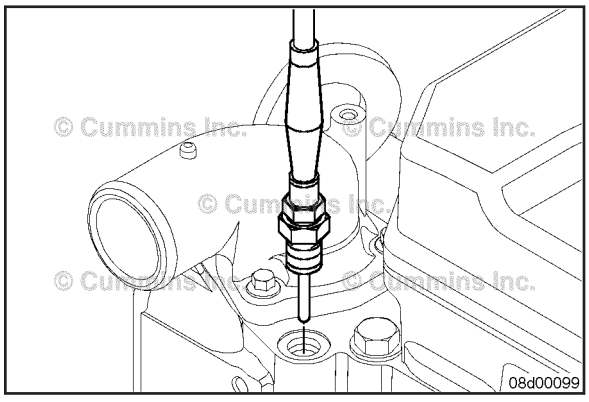
Remove the radiator hose from the water outlet connection.Refer to Procedure 008-045.

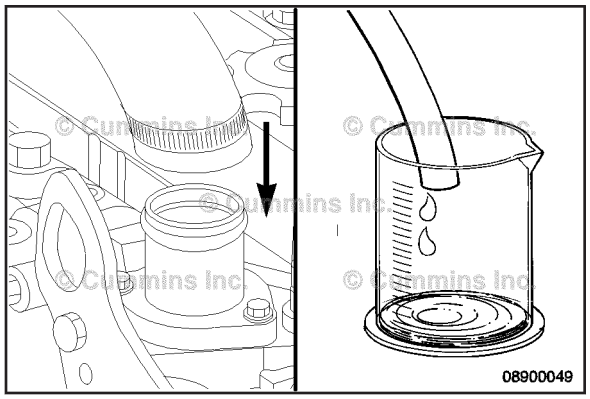
Marine applications, remove the heat exchanger hose from the water outlet connection and plug the heat exchanger engine coolant inlet connection.Refer to Procedure 008-053.



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 water header plate on the engine side of the water outlet connection.

Marine applications, use the service tool to monitor engine temperature.

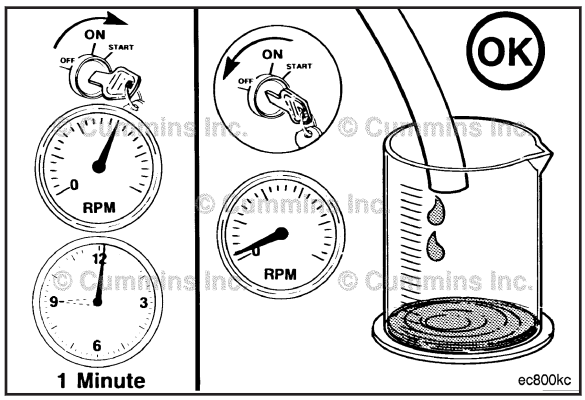




Install a hose of the same size on the water outlet connection long enough to reach a remote, dry container used to collect coolant.

Install and tighten a hose clamp on the water outlet connection.

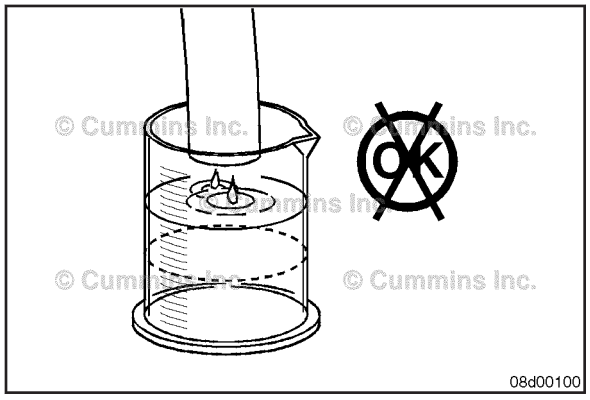
Place the other end of the hose in a dry container.



Operate the engine at rated rpm for 1 minute.

Shut off the engine and measure the amount of coolant collected in the container.

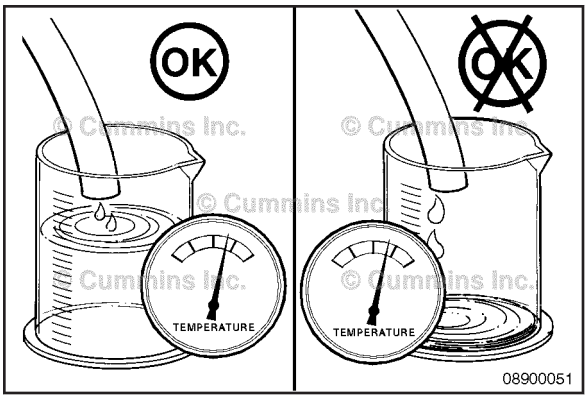
The amount of coolant collected **must not** be more than 100 cc [3.3 fl oz].



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 test the thermostat opening temperature.

Start the engine and monitor the water temperature with an electronic service tool or a gauge.



Thermostat Initial Opening Temperature - Automotive Applications without EGR		
°C		°F
81	MIN	178
83	MAX	182

Thermostat Initial Opening Temperature - Automotive Applications with EGR		
°C		°F
86	MIN	186
89	MAX	193

Thermostat Initial Opening Temperature - Marine Applications		
°C		°F
70	MIN	158
72	MAX	162

Thermostat Initial Opening Temperature - Industrial Applications		
°C		°F
87	MIN	188
89	MAX	192

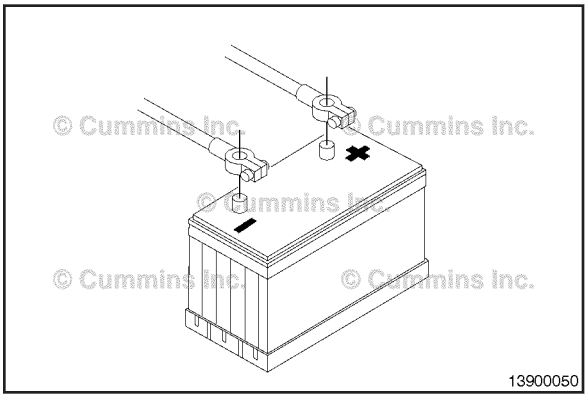
Shut off the engine when the coolant starts to flow.

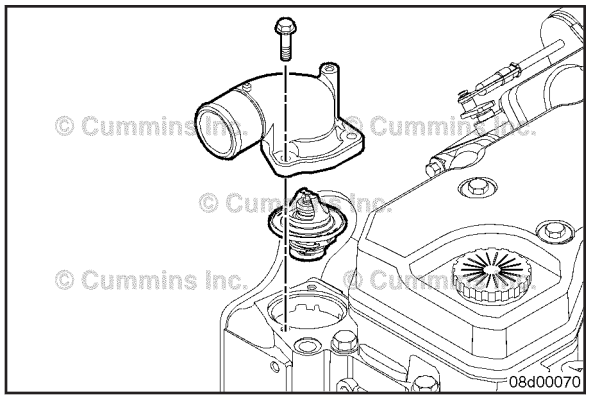
If coolant does **not** start flowing into the container during the initial opening temperature range, the thermostat **must** be replaced.

Preparatory Steps

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

Disconnect the batteries.Refer to Procedure 013-009.





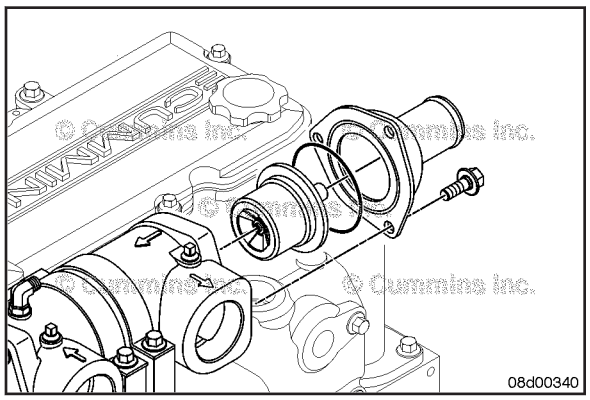
Remove

NOTE: This stepblock does **not** apply to QSB5.9 marine engines with keel cooling.

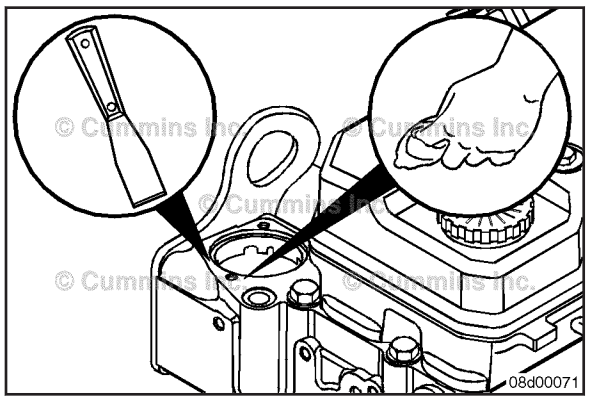
Remove the water outlet connection capscrews.

Remove the water outlet connection.

Remove the thermostat.



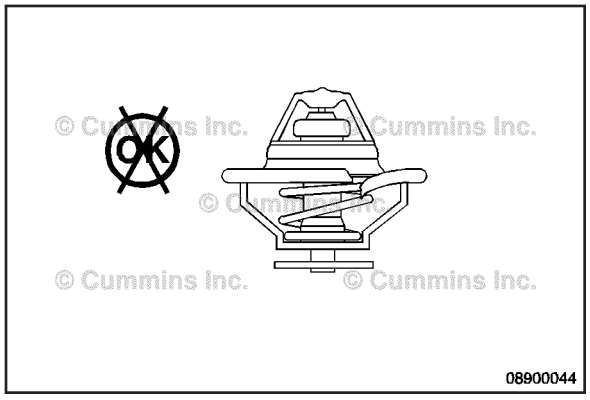
On QSB5.9 marine engines with keel cooling, remove the water inlet connection capscrews and the water inlet connection from the thermostat housing used with keel cooling.



Clean and Inspect for Reuse

CAUTION
Do not let any debris fall into the thermostat cavity when cleaning the gasket surfaces. Damage to the cooling system and engine can occur.

Clean the mating surfaces with a gasket scraper and a clean cloth.

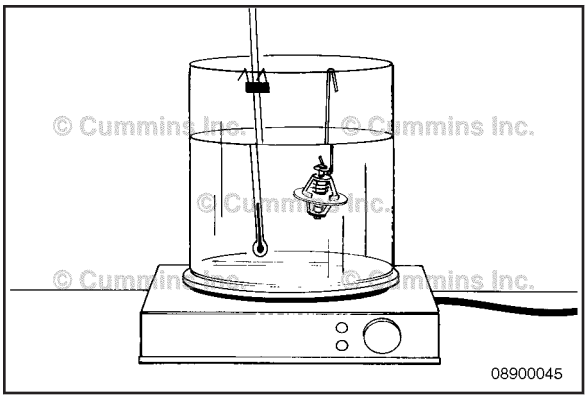


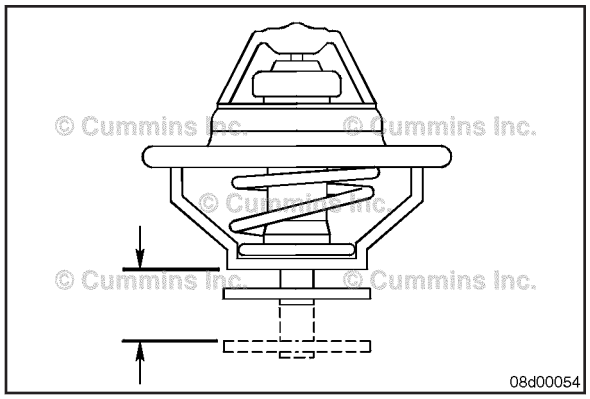
Inspect the thermostat for cracks, tears, damage, missing soft seat.

Remove and discard the gasket.

NOTE: Do **not** allow the thermostat or thermometer to touch the container.

Suspend the thermostat and a 100°C [212°F] thermometer in a container of water.





Heat the water and check the thermostat as follows:

The nominal operating temperature is stamped on the thermostat. The thermostat **must** meet the following criteria:

- It **must** begin to open within 1°C [2°F] of nominal temperature.
- It **must** be fully open within 12°C [22°F] of nominal temperature.

Thermostat Opening Temperatures - Automotive Applications without EGR

	°C		°F
Initial Opening Temperature	81	MIN	178
	83	MAX	182
Fully Opened Temperature	94	MAX	202

Thermostat Opening Temperatures - Automotive Applications with EGR

	°C		°F
Initial Opening Temperature	86	MIN	186
	89	MAX	193
Fully Opened Temperature	97	MAX	207

Thermostat Opening Temperatures - Industrial Engines

	°C		°F
Initial Opening Temperature	87	MIN	188
	89	MAX	192
Fully Opened Temperature	96	MAX	205

The nominal operating temperature for Marine application engines **must** meet the following criteria:

- It **must** begin to open with 1°C [2°F] of nominal temperature.
- It **must** be fully open within 14°C [15°F] of nominal temperature.

Thermostat Opening Temperature - Marine Applications

	°C		°F
Initial Opening Temperature	71	MIN	158
	72	MAX	162
Fully Opened Temperature	85	MAX	185

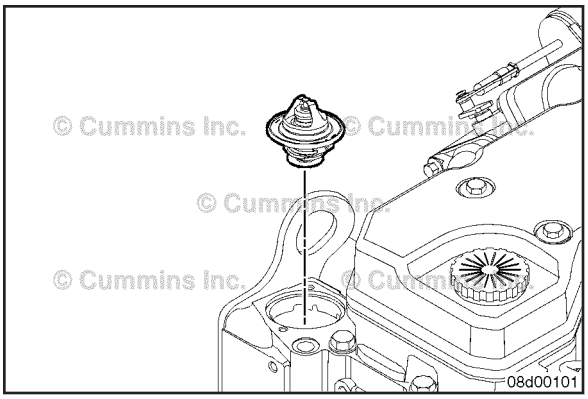
NOTE: The fully open distance between the thermostat flange and housing is 14.3 mm [0.563 in] minimum.

Install

⚠CAUTION⚠
Always use the correct thermostat and do not operate the engine without a thermostat installed. The engine can overheat if operated without a thermostat because the path of least resistance for the coolant is through the bypass to the pump inlet. An incorrect thermostat can cause the engine to overheat or run too cold.

Install the thermostat into the thermostat housing.

NOTE: Make sure a new thermostat seal is installed on the outer lip of the thermostat flange every time the thermostat is installed.

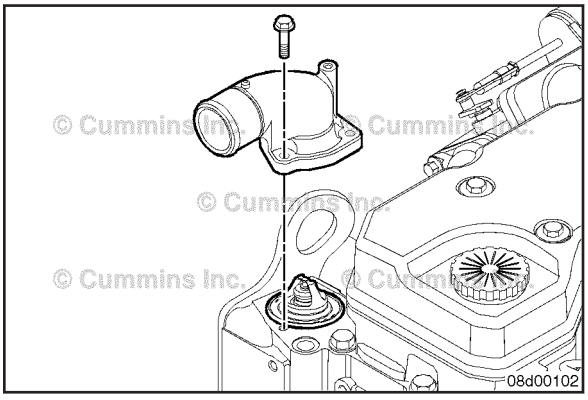


NOTE: This stepblock does **not** apply to QSB5.9 engines with keel cooling.

Install the water outlet connection and mounting capscrews.

Tighten the capscrews.

Torque Value: 10 N•m [89 in-lb]



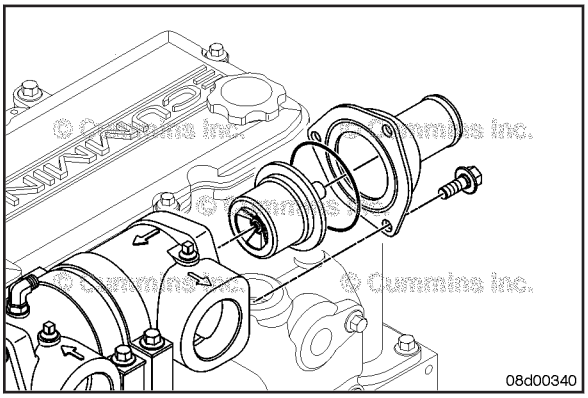
⚠CAUTION⚠
Always use the correct thermostat and do not operate the engine without a thermostat installed. The engine can overheat if operated without a thermostat because the path of least resistance for the coolant is through the bypass to the pump inlet. An incorrect thermostat can cause the engine to overheat or run too cold.

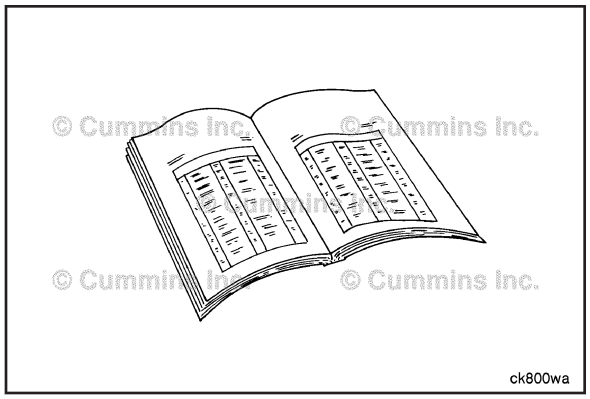
NOTE: Make sure a new thermostat seal is installed on the outer lip of the thermostat flange every time the thermostat is installed.

On QSB5.9 marine engines with keel cooling, install the thermostat into the water inlet connection of the thermostat housing used with keel cooling.

Install the water outlet connection and tighten the capscrews.

Torque Value: 24 N•m [18 ft-lb]





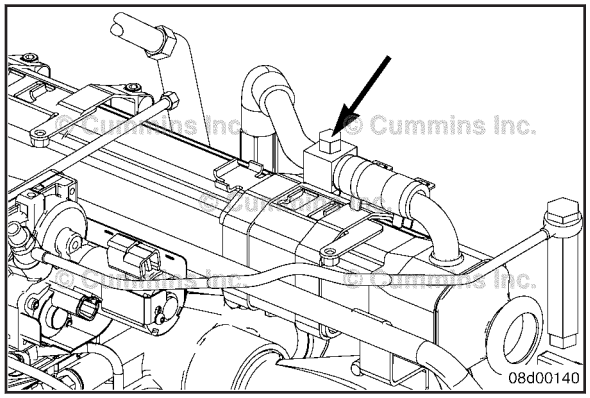
Finishing Steps

⚠CAUTION⚠

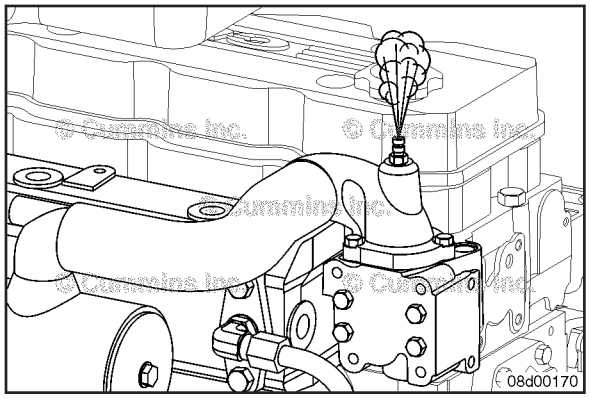
Always vent the engine during filling to remove air from the coolant system, or overheating can result.

On marine applications with heat exchangers, install the heat exchanger coolant hose.Refer to Procedure 008-053.

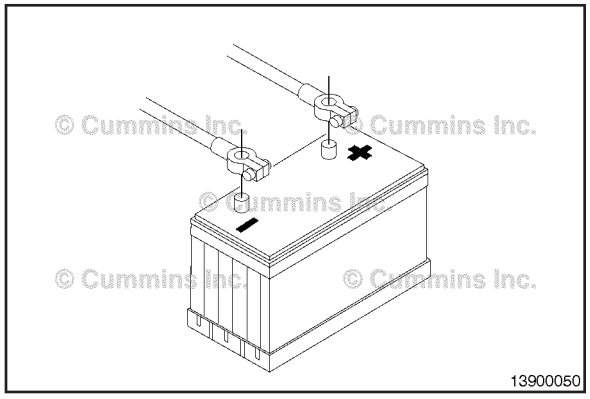
Fill the cooling system.Refer to Procedure 008-018.



NOTE: On engines with EGR, the pipe plug in the EGR coolant line **must** be removed during filling.



NOTE: Marine applications vent air from the vent on top of the engine coolant outlet connection.

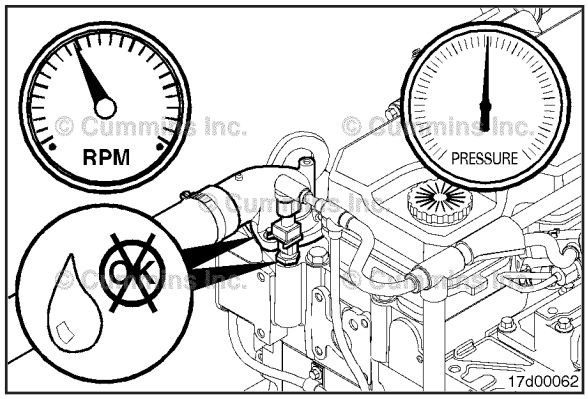


⚠WARNING⚠

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

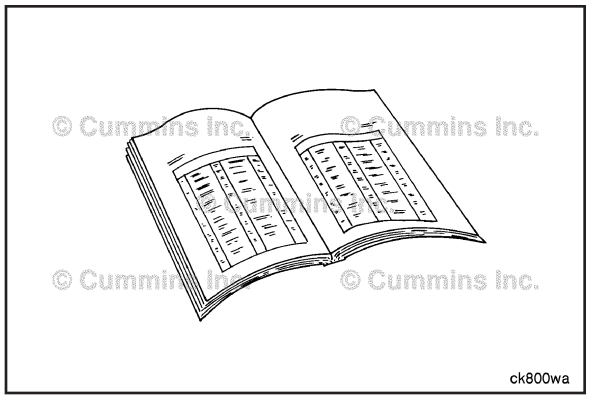
Operate the engine and check for leaks.



Coolant Thermostat Housing (008-014)

General Information

This procedure applies to QSB5.9 keel cooled engines **only**



Preparatory Steps

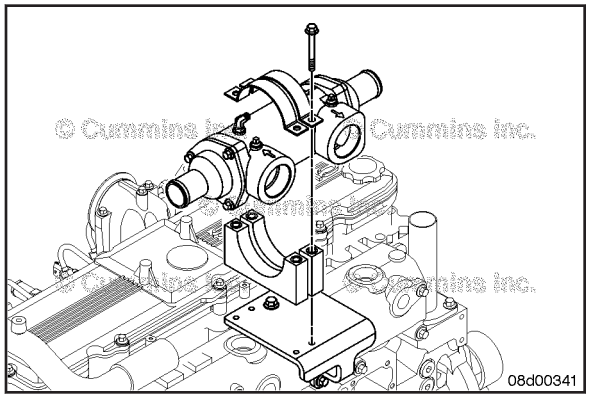
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠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 so that it 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 from the thermostat housing. Refer to the OEM troubleshooting and repair manual.
- Disconnect the coolant vent line from the thermostat housing. Refer to Procedure 008-017
- Disconnect the coolant inlet and outlet hoses from the thermostat housing.



Remove

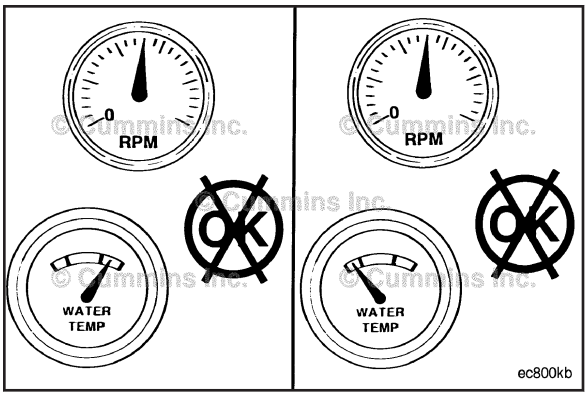
Remove the four thermostat housing mounting capscrews.

Remove the two clamps and the thermostat housing.

Remove the two vibration isolators.

Leak Test

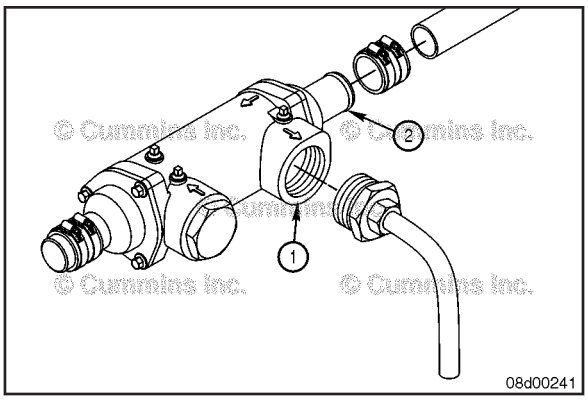
The engine thermostat and thermostat seal **must** operate properly in order for the engine to operate in the most efficient heat range. Overheating or overcooling will shorten engine life.



Fabricate a test fixture to seal all of the water connections except the outlet port to the keel cooler and the inlet port of the thermostat housing.

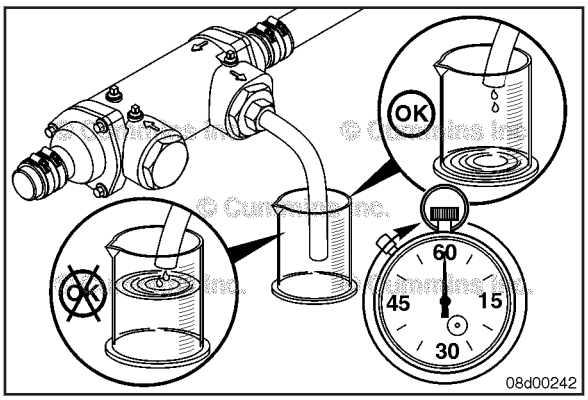
On the outlet port to the keel cooler (1), install a hose long enough to reach a remote, dry container to collect any water. Place the open end of the hose in the dry container.

Connect a filtered tap water hose to the inlet port (2) of the thermostat housing with the pressure regulated to 152 kPa [22 psi] of filtered tap water.

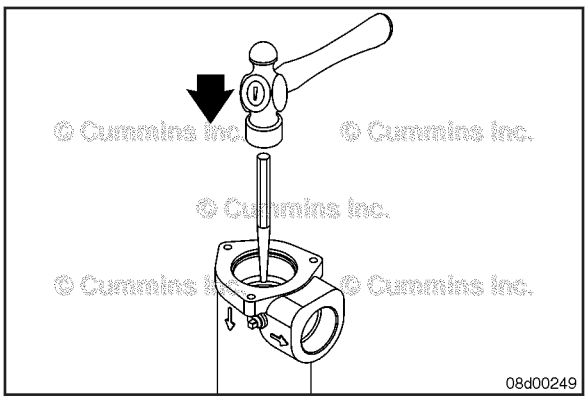


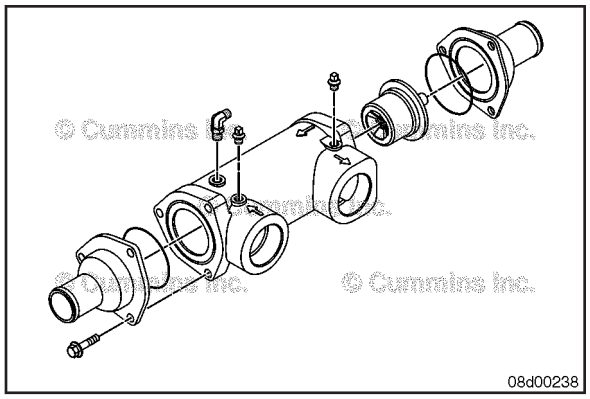
Apply 152 kPa [22 psi] of water pressure to the thermostat housing for 1 minute.

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





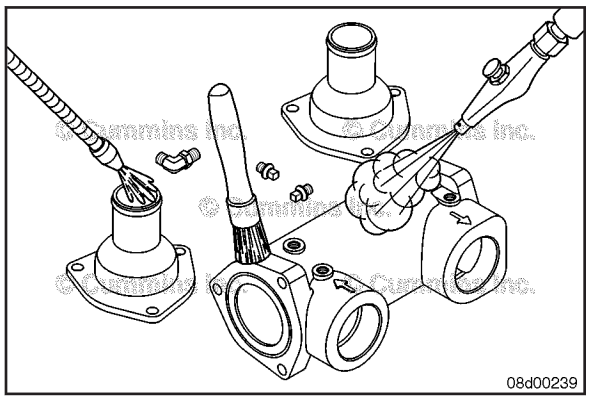
Disassemble

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.

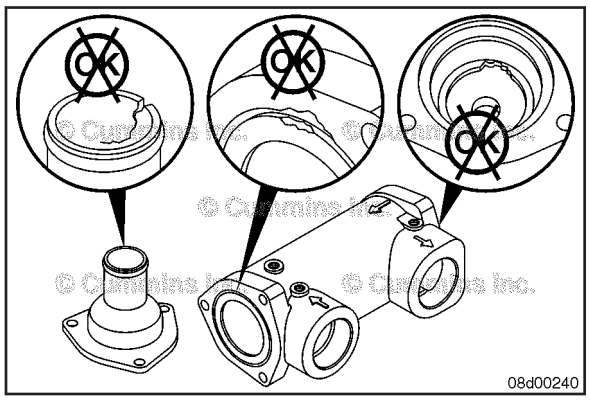


Clean and Inspect for Reuse

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

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

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.

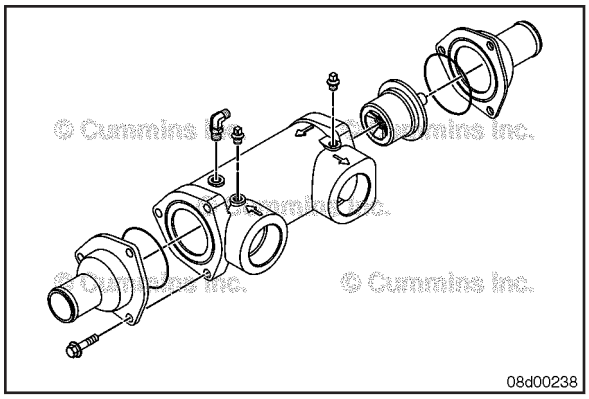
Torque Value: 44 N•m [32 ft-lb]

Install the two pipe plugs and tighten.

Torque Value: 15 N•m [133 in-lb]

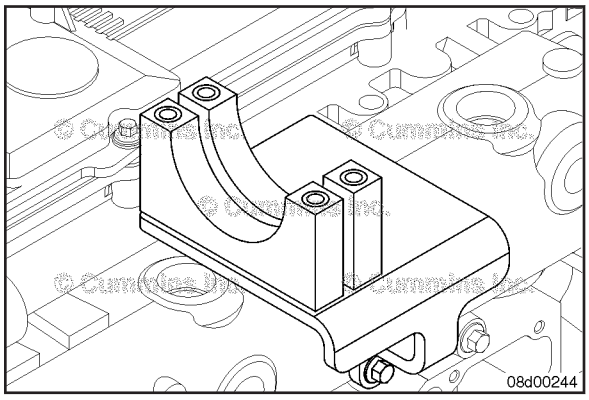
Install the coolant vent line fitting. Tighten the fitting so it faces the thermostat housing inlet end.

Install the keel cooler inlet and outlet fittings. Refer to the OEM troubleshooting and repair manual.



Install

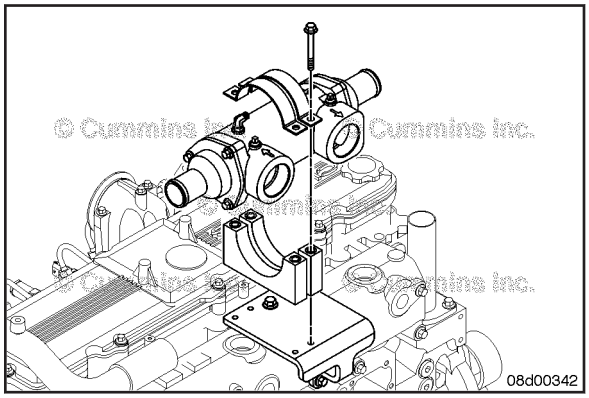
Place the vibration isolators on top of the thermostat housing support bracket.

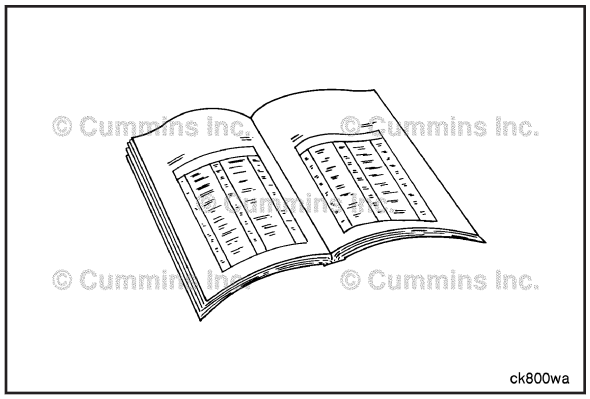


Install the thermostat housing onto the isolators using clamps and capscrews as shown.

Tighten the capscrews.

Torque Value: 44 N•m [32 ft-lb]





Finishing Steps

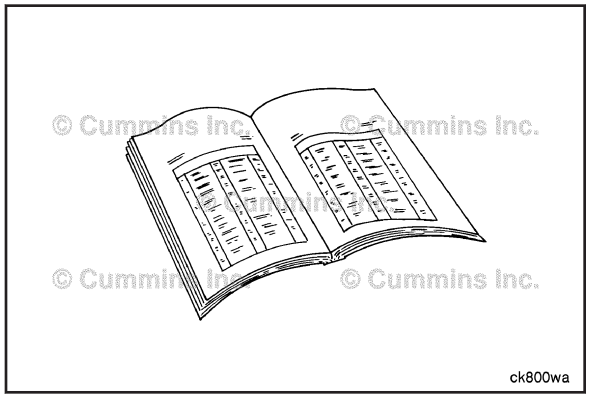
- Install the coolant inlet and outlet hoses.
- Install the coolant vent line. Refer to Procedure 008-017
- Install the keel cooler inlet and outlet hoses. Refer to the OEM troubleshooting and repair manual.
- Fill the engine with coolant. Refer to Procedure 008-018
- Connect the batteries. Refer to Procedure 013-009

Operate the engine and check for leaks.

Coolant Thermostat Housing Support (008-015)

General Information

This procedure applies to QSB5.9 marine keel cooled 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.

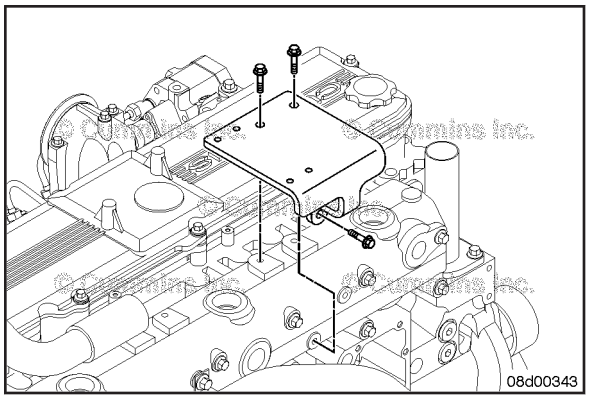
⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

△CAUTION△
Use caution when draining coolant so that it 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

Remove the three thermostat housing support mounting capscrews and the thermostat housing support.



Clean and Inspect for Reuse

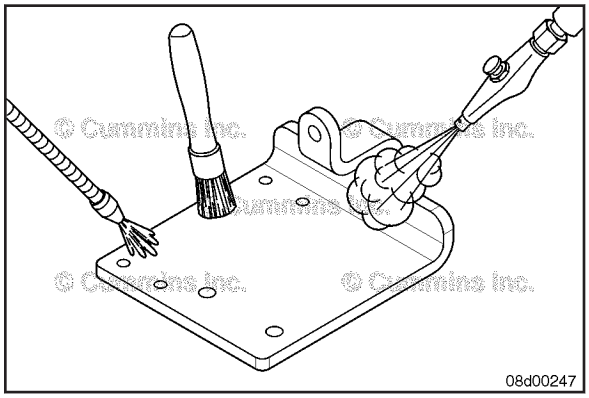
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

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

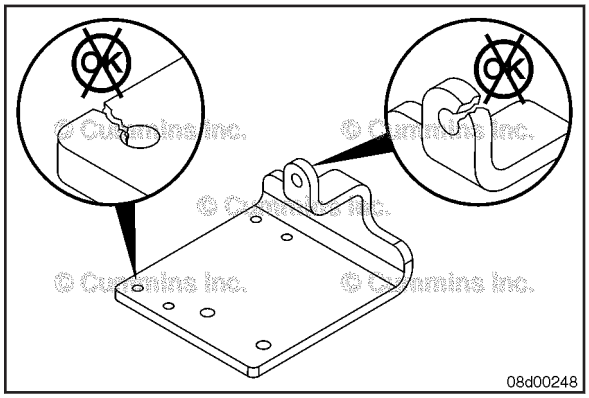
Use solvent to clean the bracket.

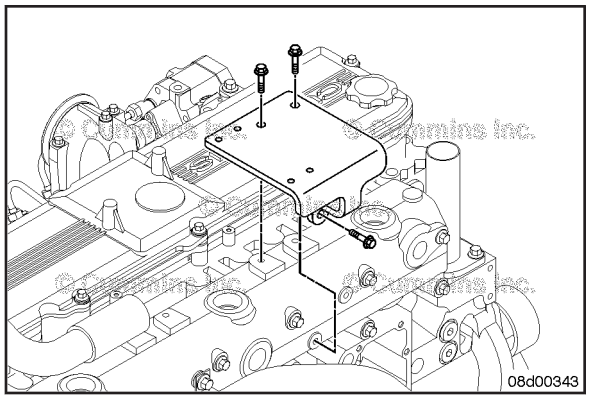
Dry with compressed air.



Inspect the bracket for cracks or other damage.

Repair or replace the bracket if damaged.



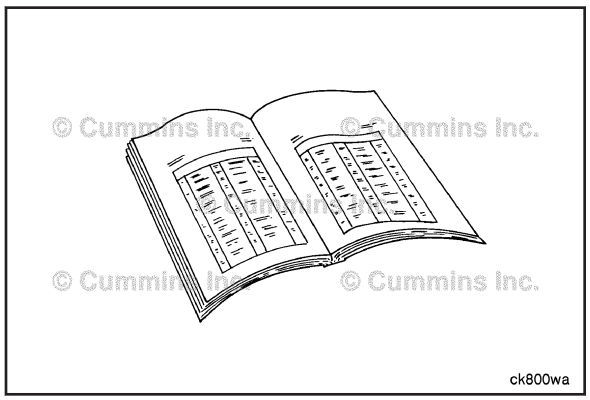


Install

Install the thermostat housing bracket and mounting 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

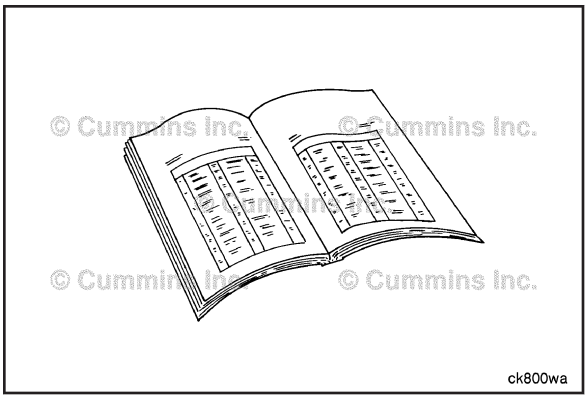
Operate the engine and check for leaks.

Coolant Vent Lines (008-017)

General Information

This procedure applies to the QSB5.9 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.

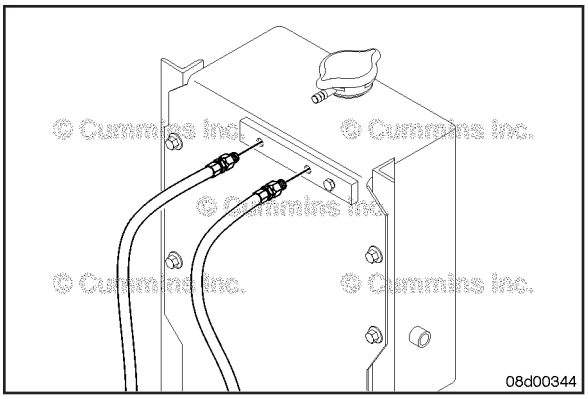
△CAUTION△
Use caution when draining coolant so that it is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

- Drain the engine coolant. Refer to Procedure 008-018

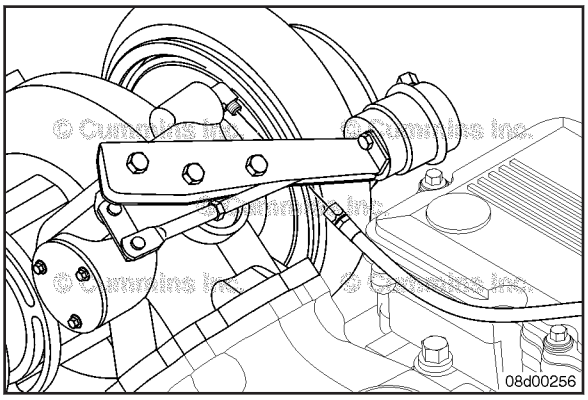
Remove

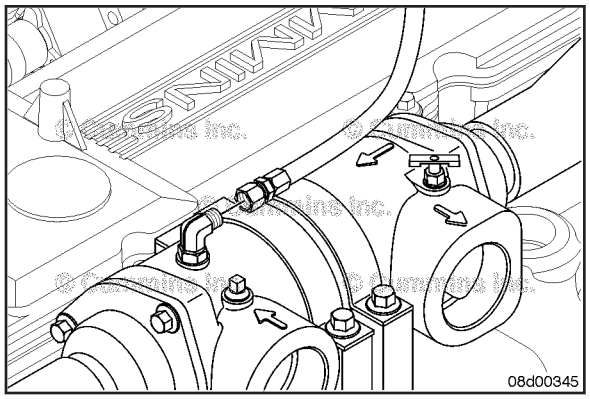
Disconnect the exhaust manifold coolant vent line from the expansion tank and the top of the exhaust manifold.

Disconnect the turbocharger coolant vent line from the top of the expansion tank.

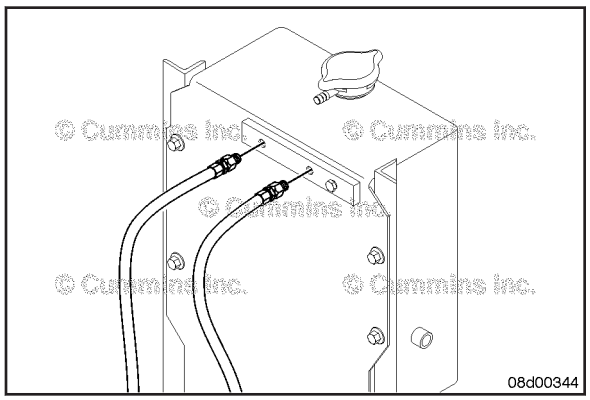


Disconnect the turbocharger coolant vent line from the top of the turbocharger.





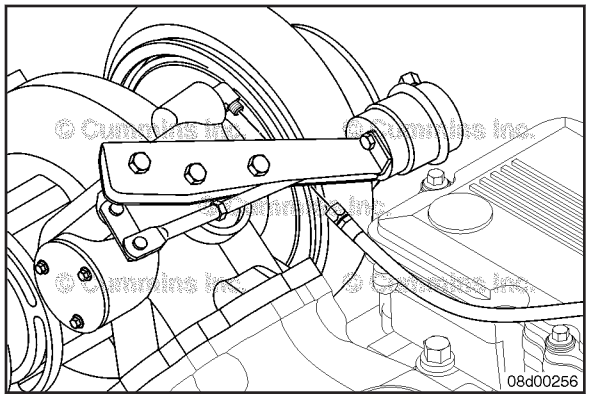
Disconnect the coolant vent line from the top of the expansion tank and the top of the thermostat housing.



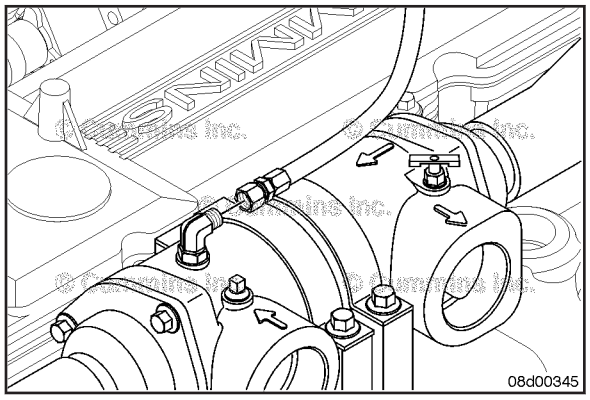
Install

Connect the coolant vent line at the top of the expansion tank and the top of the exhaust manifold.

Connect the coolant vent line for the turbocharger at the top of the expansion tank.



Connect the coolant vent line to the top of the turbocharger.

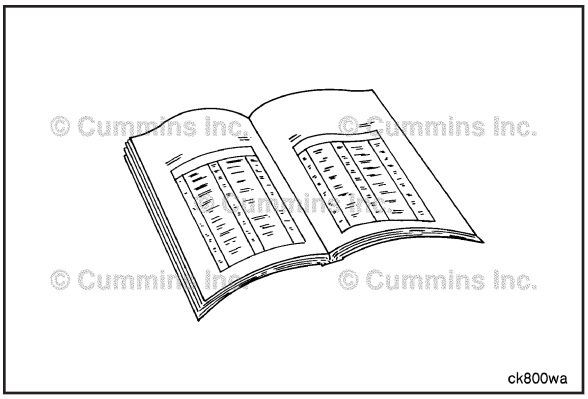


Connect the coolant vent line from the top of the expansion tank and to the top of the thermostat housing.

Finishing Steps

- Fill the cooling system. Refer to Procedure 008-018

Operate the engine and check for leaks.



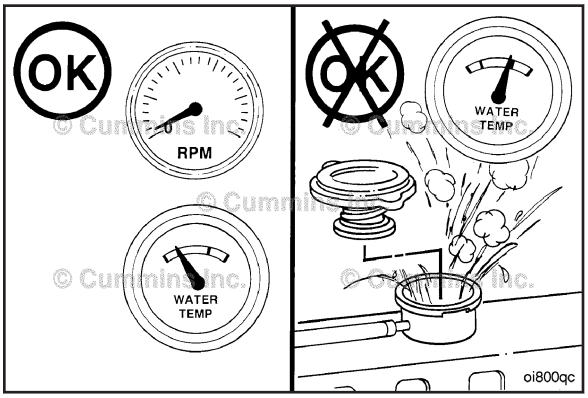
Cooling System (008-018)

General Information

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

NOTE: Never use a sealing additive to stop leaks in the coolant system. This can result in coolant system plugging and inadequate coolant flow, causing the engine to overheat.

The engine coolant level **must** be checked daily.



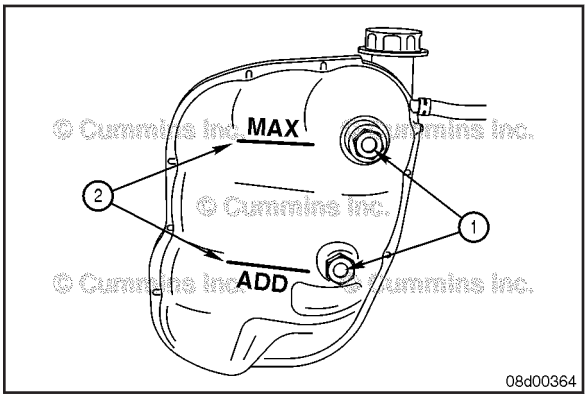
△CAUTION△
Do not add cold coolant to a hot engine. Engine castings can be damaged. Allow the engine to cool below 50°C [120°F] before adding coolant.

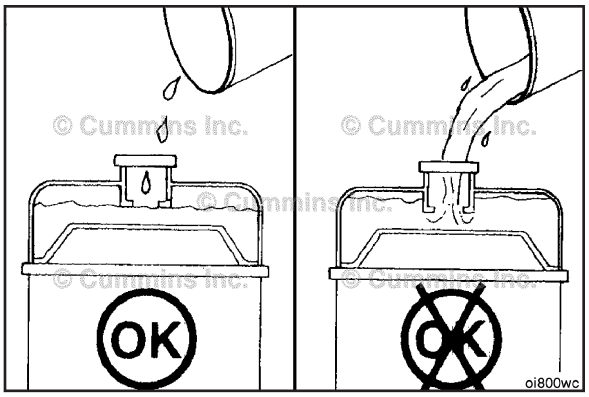
NOTE: In the event of a water pump or EGR cooler malfunction, it is recommended that coolant level switches be checked for operation. Consult the OEM service manual for operational checks and repairs.

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 "top tanks", have sight glasses (1) or are made of a clear material (**not** shown) to aid in checking the coolant level (2) without removing the radiator cap.

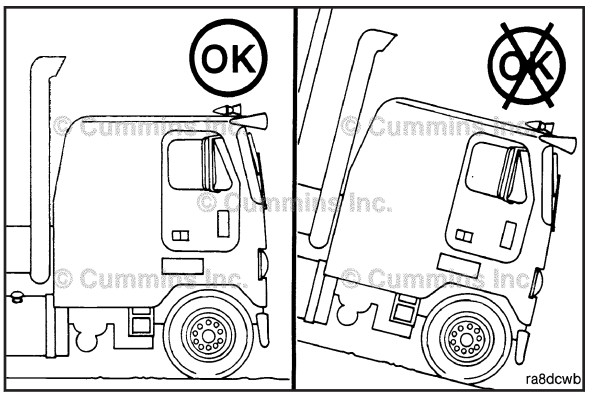
It is important to understand the impact of temperature on the expansion of the coolant. Most "top tanks" do **not** have a provision for a "FULL HOT" coolant level. Filling the "top tank" while hot will result in a low operating level once the system has cooled.





Fill the cooling system with coolant to the bottom of the fill neck in the radiator fill or recovery/expansion tank.

NOTE: Some radiators have two fill necks, both of which **must** be filled when the cooling system is drained.



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.

⚠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.

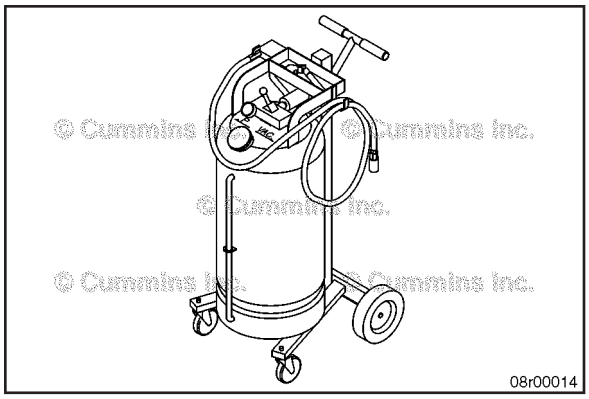
△CAUTION△
Do not use the coolant replacement tool to evacuate contaminated coolant or a system that is suspected of contamination. This could result in cross contamination of coolant. The coolant drain method should be used for removing contaminated coolant. Reference the manufacturer's manual for specific instructions on cleaning the tool of contaminants.

NOTE: Refer to the OEM service manual 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.

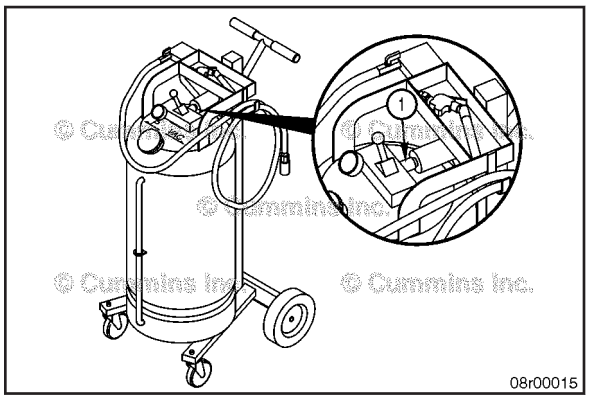
Remove the radiator cap.



⚠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 liter [18 gal] is adequate for most applications. An additional storage tank can be used for cooling system packages with more than 68 liter [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.

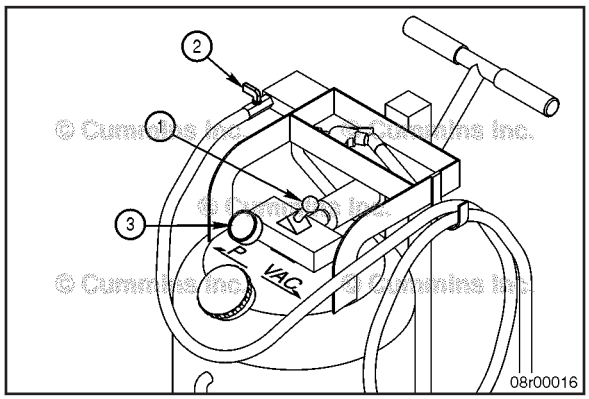


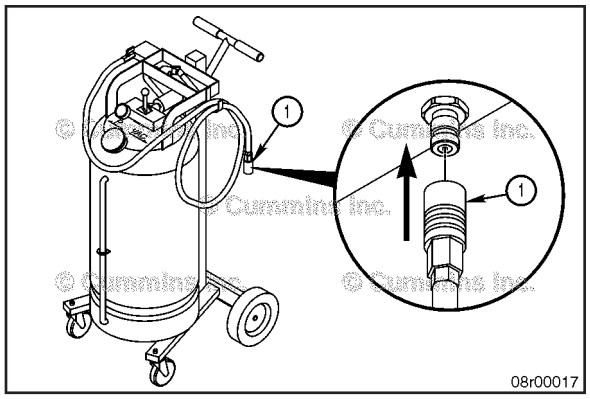
Connect the coolant replacement tool to a shop air supply regulated at 621 kPa [90 psi].

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.

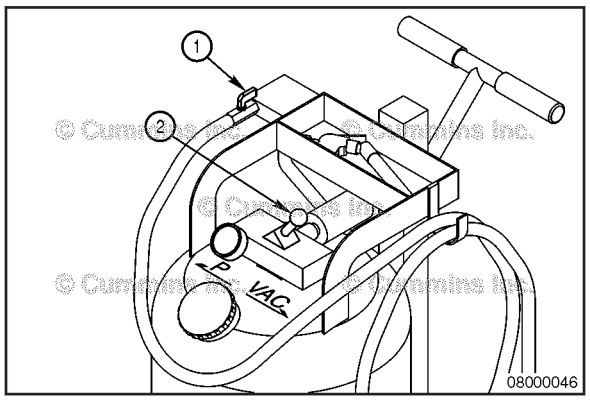
Maintain approximately a 508 mm-Hg [20 in-Hg] vacuum to achieve a faster drain.





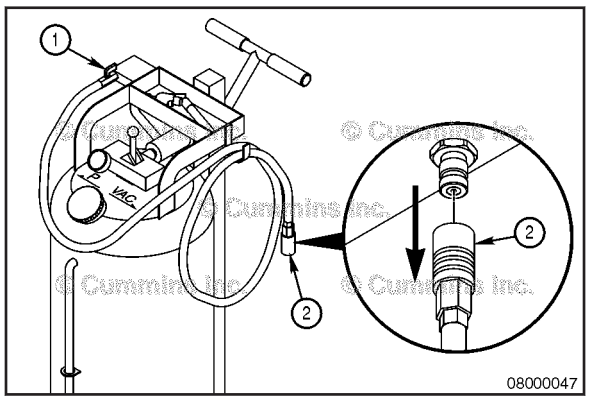
Attach the fill hose quick disconnect coupling (1) of the coolant replacement tool to the quick disconnect fitting. Location of the fitting may vary between OEMs, but the fitting is generally located in the lowest point of the vehicle/equipment cooling system package.

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.



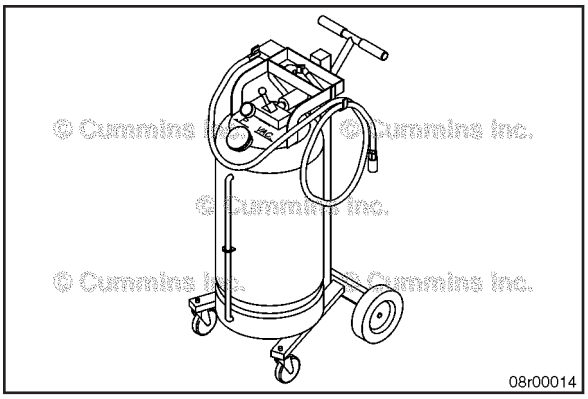
When the cooling system has been evacuated, a coolant and air mixture will be visible in the clear section of the coolant replacement tool fill hose.

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.

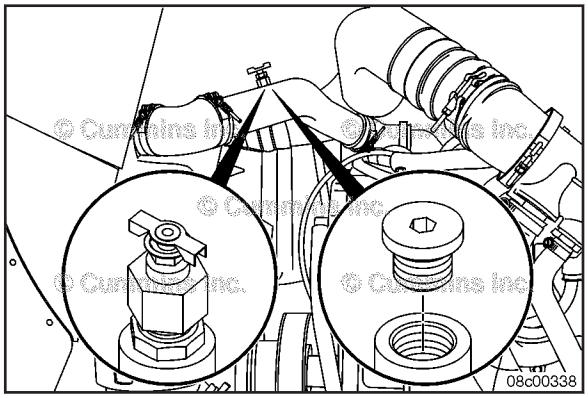
Cummins Inc. recommends the use of either a 50/50 mixture of good quality water and fully-formulated antifreeze, or fully-formulated coolant when filling the cooling system. The fully-formulated antifreeze or coolant **must** meet TMC RP329 or TMC RP330 specifications.

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.

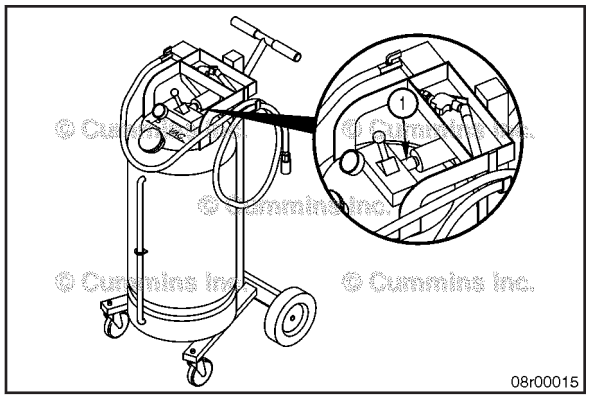
Reference the Cummins® Coolant Requirement and Maintenance, Bulletin 3666132, for more engine coolant specifications.



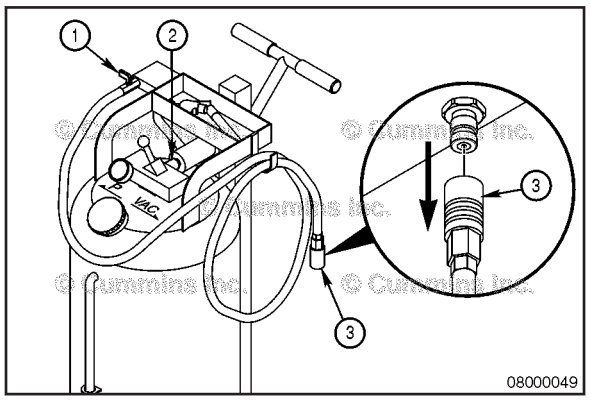
⚠CAUTION⚠
Opening the manual bleed valve or removing the pipe plug on applicable installations is critical. Failure to do so can result in engine damage.

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.



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.



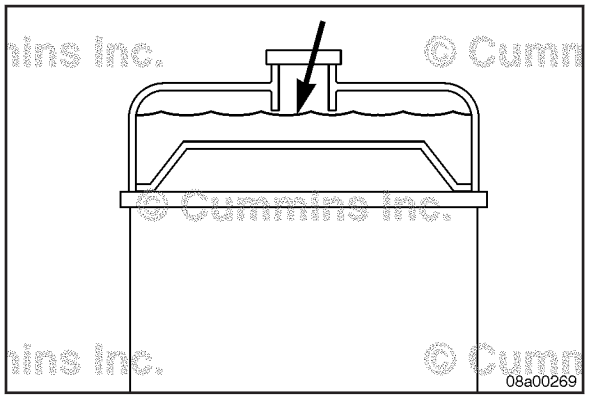
Connect the coolant replacement tool to a shop air supply regulated at 621 kPa [90 psi].

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 "top 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 "top tanks" do **not** have a provision for a "FULL HOT" coolant level. Filling the "top tank" while hot will result in a low operating level once the system has cooled.

⚠CAUTION⚠

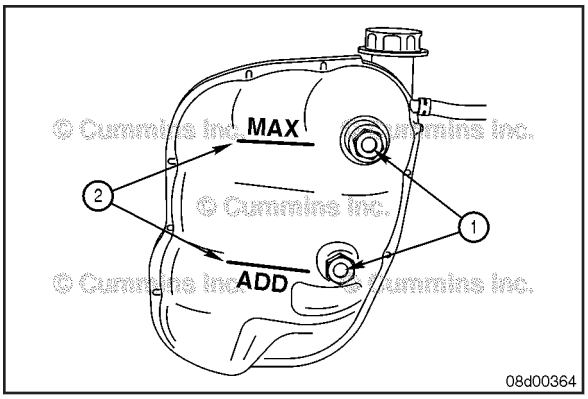
The cooling system must be filled properly to prevent air locks or serious engine damage can result.

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.

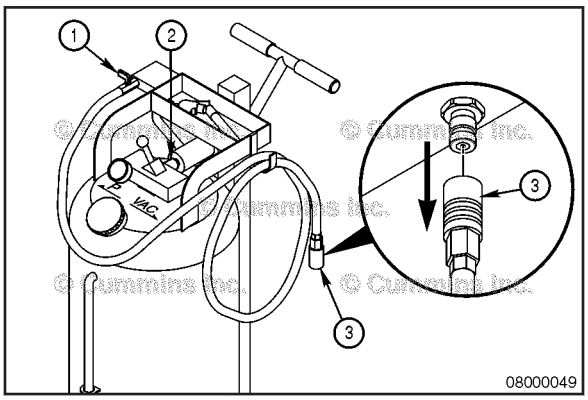
To remove an air pocket from the cooling system, the coolant replacement tool can be used. Refer to the vacuum section of this procedure.



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.

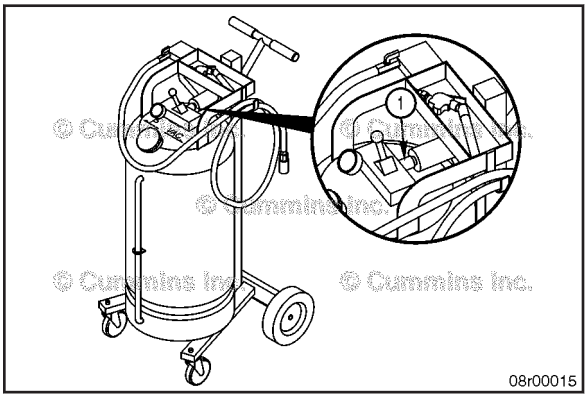


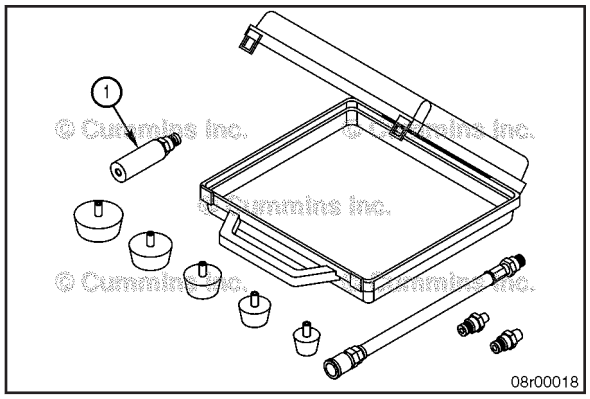
Vacuum

The following steps are used to place a vacuum on the cooling system using the coolant replacer tool, Part Number 2892459.

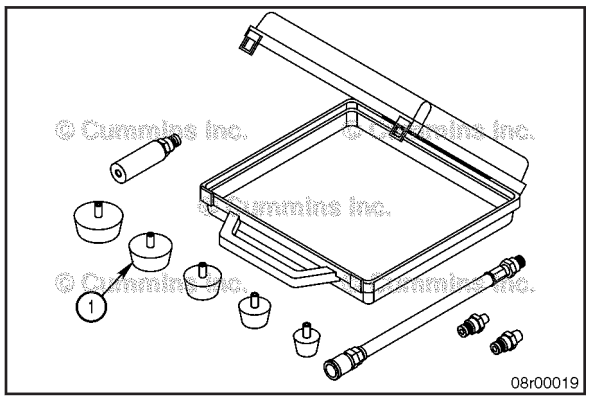
Be sure there is no air pressure in the coolant replacement tool tank by opening the pressure relief valve (1) located on the control block of the coolant replacement tool.

Clamp off any vent hoses/connections or overflow to the cooling system.





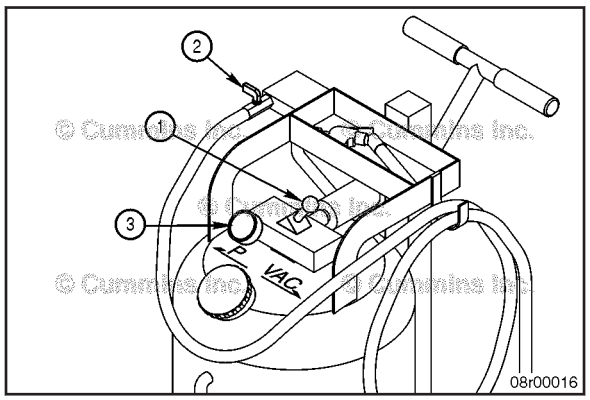
Attach the coolant dam handle (1) to the fill hose of the coolant replacement tool.



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.

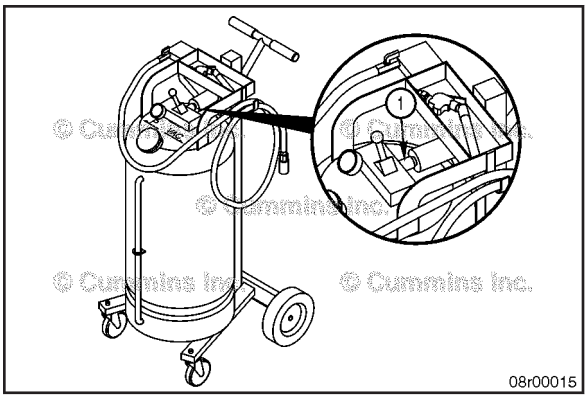
Once the cooling system is put into a vacuum, any air trapped in the cooling system will be evacuated through the top of the system. This is noticed as air bubbles through the overflow tank or top of the radiator.

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

Automotive and Industrial

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [122°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

Isolate the engine from the vehicle cooling system by closing coolant flow valves to the equipment heating systems before initiating repair. This will prevent the heater circuit from draining, minimizing the chance for air pockets to be present during the fill process.

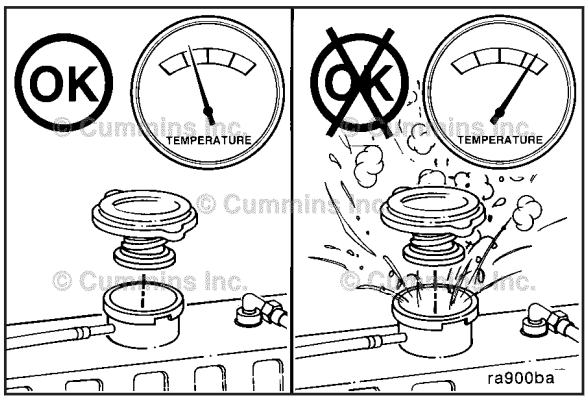
This air can be very difficult to purge in some applications that have several feet of plumbing and multiple heater cores.

NOTE: If the coolant is being changed, or if the cooling system is being flushed, it is desirable to leave the coolant flow valves to the equipment heating systems open, in order to completely drain the system.

Use the OEM service manual for any special coolant drain and fill requirements.

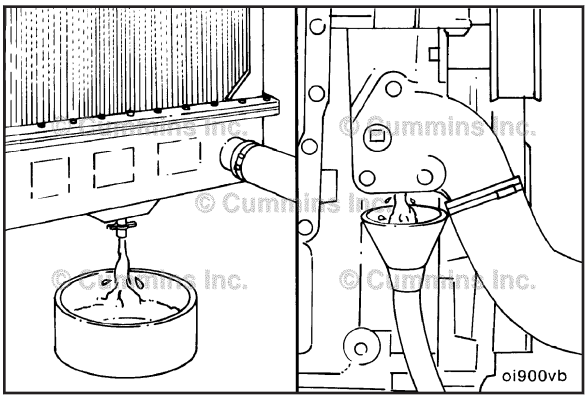
These special instructions can also be located near the cooling system access or fill door on the vehicle.

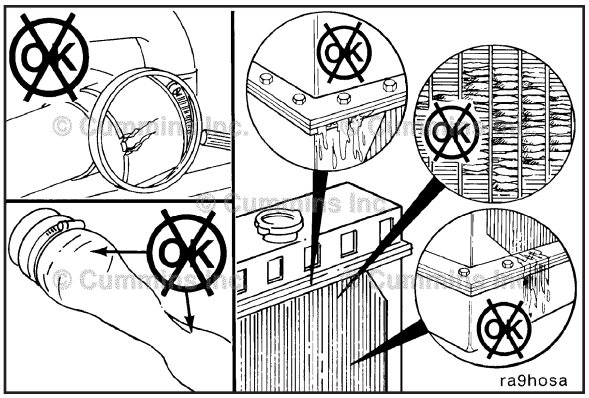
Remove the radiator/expansion tank cap to allow the coolant to drain completely.



⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

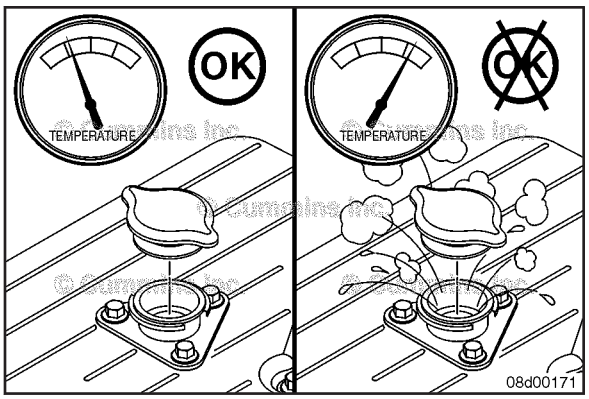
Drain the cooling system by opening the drain valve on the radiator and removing the plug in the bottom of the water inlet. A drain pan with a capacity of 19 liters [5 gal] will be adequate for most applications.





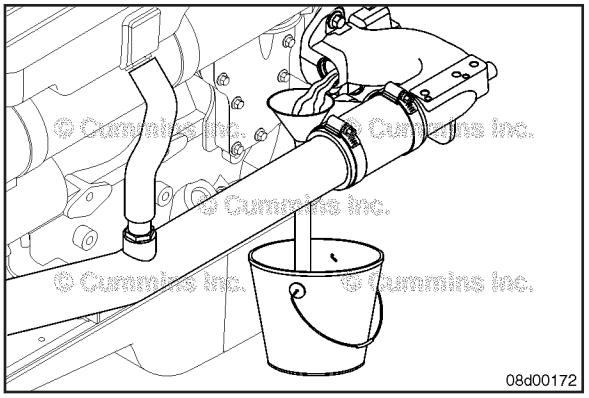
Check for damaged hoses and loose or damaged hose clamps. Replace as required. Check the radiator for leaks, damage, and buildup of dirt. Clean and replace as required.

After the cooling system is completely drained, close the drain valves. Reference the OEM service manual for complete cooling system drain information.



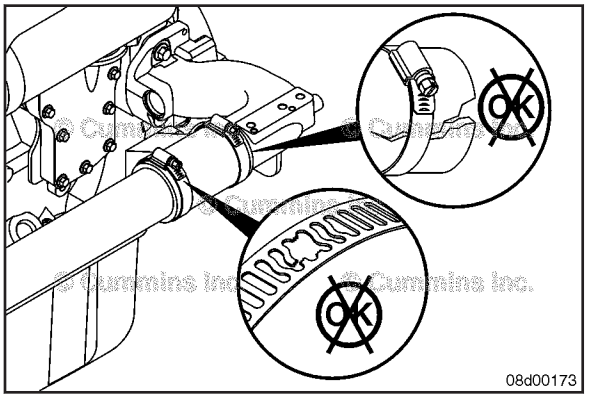
Marine Applications

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [122°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.



⚠WARNING⚠
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 removing the plug in the rear of the water pump inlet. A drain pan with a capacity of 19 liters [5 gal] will be adequate in most applications.



Check for damaged hoses and loose or damaged hose clamps. Replace as required. Check for leaks, damage, and buildup of dirt. Clean and replace as required.

Fill

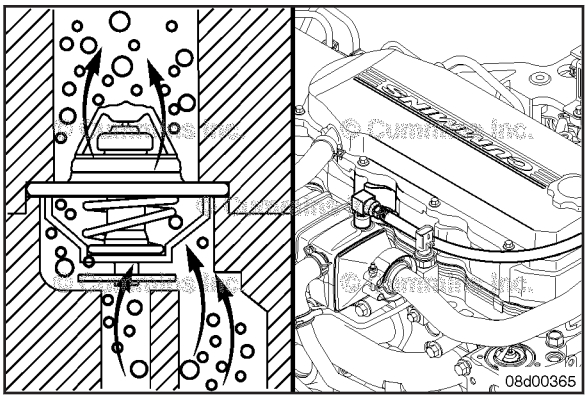
Automotive and Industrial

⚠CAUTION⚠
The system must be filled properly to prevent air locks or serious engine damage can result. During filling, air must be vented from the engine coolant passages. Wait 2 to 3 minutes to allow air to be vented; then add mixture to bring the level to the top.

To be sure air is vented during the fill process:

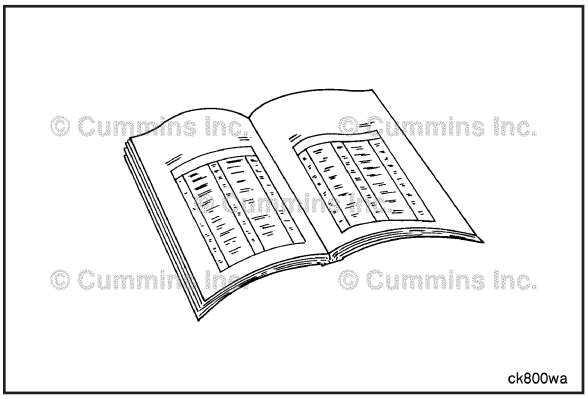
- Some thermostats have check balls that allow air to vent through the thermostat when the thermostat is closed.
- An air vent port connection, which connects to the top tank/coolant recovery tank of the cooling system, is located next to the water outlet.

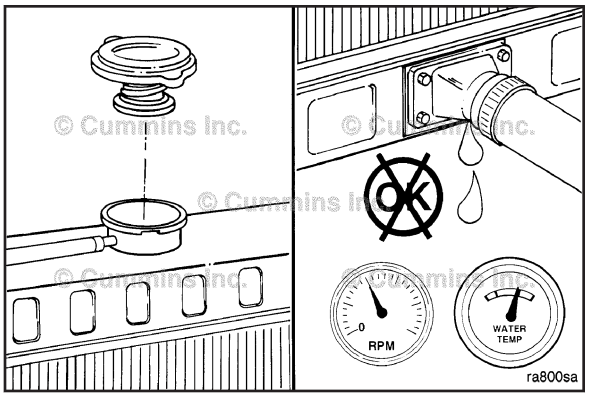
The system has a designed fill rate of 19 liters [5 gal] per minute.



⚠CAUTION⚠
Never use water alone for coolant. Damage from corrosion can be the result of using water alone for coolant.

Reference the Cummins® Coolant Requirement and Maintenance, Bulletin 3666132, for more engine coolant specifications.





⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [122°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Do not stand near the surge tank or radiator while operating the engine with the pressure cap off. If the vehicle is equipped with a fill door on side of the surge tank, keep it closed due to coolant expansion.

△CAUTION△
Do not operate the engine with the pressure cap off at temperatures above 93°C [200°F]. This can result in potential engine damage by cavitation of the water pump and localized boiling.

△CAUTION△
Topping off the system while hot is not recommended when using the fill door on transit bus applications equipped with surge tanks. Bringing the level to the bottom of the door while the system is hot will not provide adequate volume of coolant for lower operating temperatures. This can result in cavitation of the water pump and greatly increase the potential for engine damage.

△CAUTION△
Before topping off coolant, allow the system temperature to cool to ambient. This will ensure that an adequate amount of coolant is available to the water pump during all periods of operation.

△CAUTION△
Do not relieve the system pressure while hot in order to "top off" immediately before returning the vehicle to service. The system will not be able to generate the pressure through the expansion of the coolant necessary for operation. This can result in potential engine damage by cavitation of the water pump and localized boiling.

Remove the radiator or fill cap.

Fill the cooling system to the capacity or level stated in the OEM service manual, using a mixture of 50 percent water and 50 percent ethylene glycol or propylene glycol antifreeze.

Sequence of Events for Coolant Fill and Deaeration

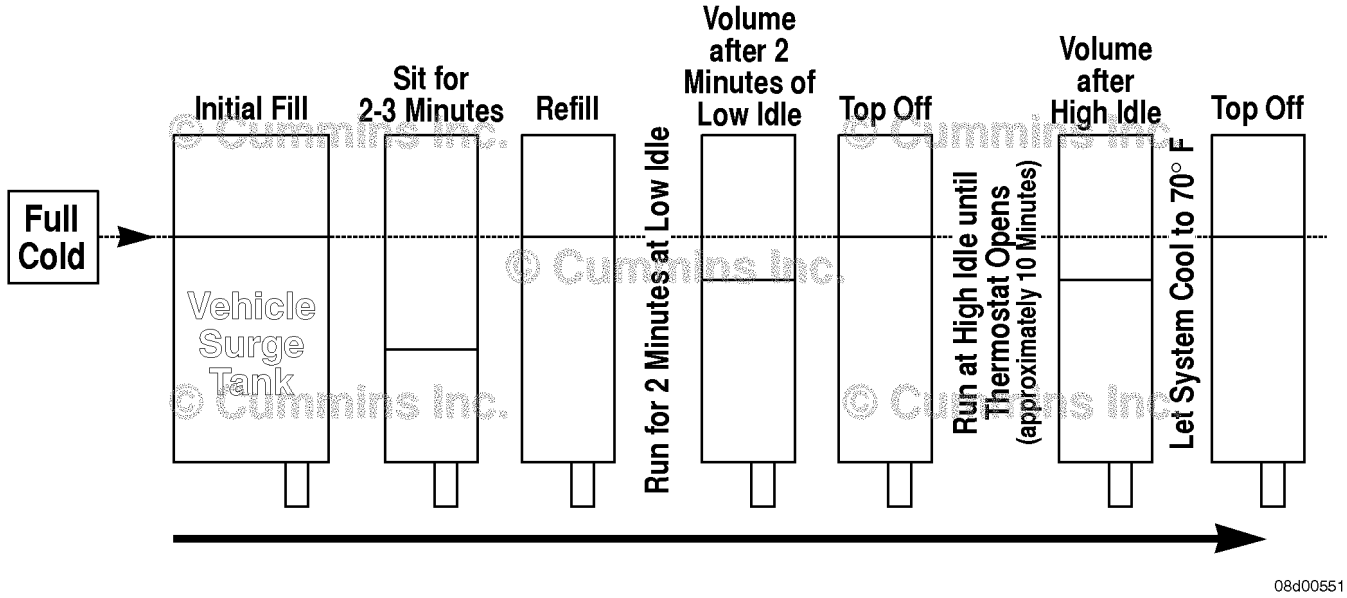


Figure 1: Sequence of Events for Coolant Fill and Deaeration.

NOTE: If all coolant drained from the system was collected, the same volume or more **must** go back into the system. If any drained coolant remains after filling, this is an indication of an air pocket which **must** be purged before returning the vehicle to service.

Unless indicated otherwise by OEM instructions, it is critical that all shutoff valves be returned to their open positions once the system has been refilled and the deaeration process is about to begin. This will help to make sure as much air as possible will be purged from the heating circuit. See the OEM service manual for valve locations.

Wait 2 to 3 minutes, without starting the engine, to allow the system to naturally purge entrained air and coolant level to stabilize.

Add 50/50 mixture to bring the coolant level back to FULL.

Turn all cab heater switches to HIGH in order to allow maximum coolant flow through heater core(s).

With the radiator pressure cap off:

- Operate the engine at LOW IDLE for 2 minutes.
- Turn off the engine and add coolant to bring the level back to FULL, using 50/50 mixture.

With the radiator pressure cap off:

NOTE: After starting a cold engine, increase the engine speed (rpm) slowly to provide adequate lubrication to the bearings and to allow the oil pressure to stabilize.

- Start the engine.
- Operate the engine at HIGH idle until the thermostats open.

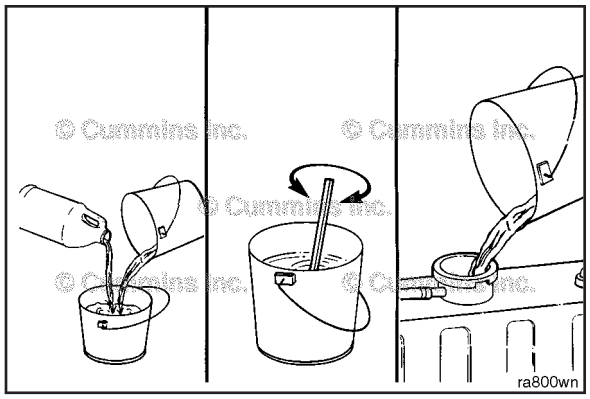
Allow the engine to idle 2 minutes before shutting it down. This allows adequate cool down of pistons, cylinders, bearings, and turbocharger components.

Turn off the engine and check the coolant level according to the OEM service manual recommendations and add, if necessary, to bring it back to the FULL level.

Install the pressure cap. Operate the engine until it reaches a temperature of 80°C [176°F] and check for coolant leaks.

Check the coolant level again to make certain the system is full of coolant or that the coolant level has risen to the hot level in the recovery/expansion tank in the system, if equipped.

Go to Figure 1 for a graphic explanation of the fill process.



Marine Applications

QSB5.9 with Heat Exchanger

⚠CAUTION⚠
To avoid engine damage, the system must be filled properly to reduce the possibility of air locks. During filling, air must be vented from the engine coolant passages. Wait 2 to 3 minutes to allow air to be vented; then add mixture to bring the level to the top.

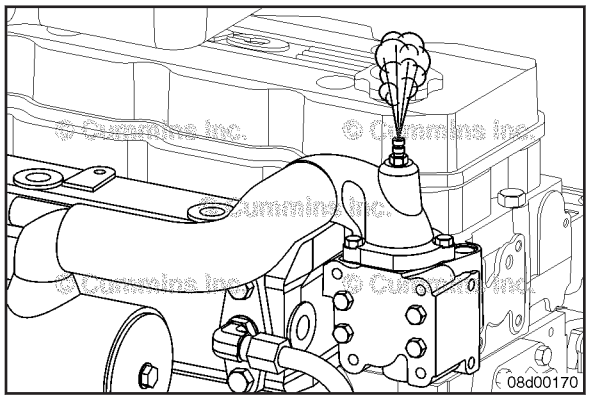
⚠CAUTION⚠
Never use water alone for coolant. Damage from corrosion can be the result of using water alone for coolant.

The system has a design fill rate of 19 liters per minute [5 gal per minute].

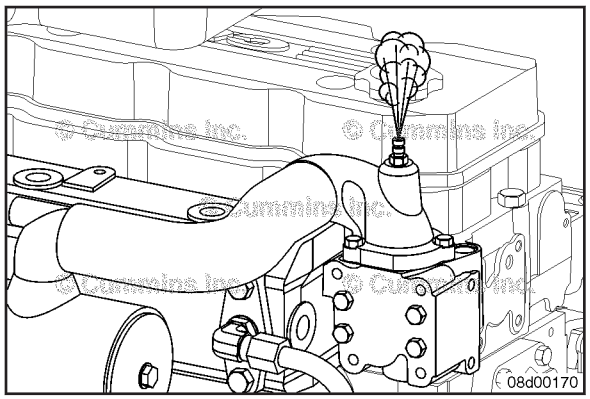
Use a mixture of 50-percent water and 50-percent ethylene glycol or propylene glycol antifreeze to fill the cooling system.

Marine Engine Coolant Capacity

	liters		U.S.gal
Engine only	10	MAX	2.6
Engine and heat exchanger	25	MAX	6.6



Marine engines **must** be vented at the coolant outlet housing and at the rear of the expansion tank during filling.



QSB5.9 with Keel Cooling

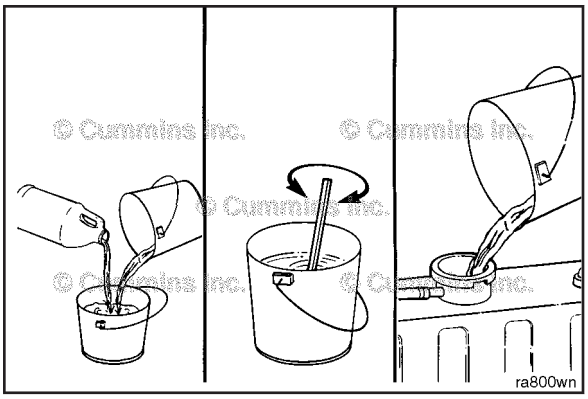
⚠CAUTION⚠
To avoid engine damage, the system must be filled properly to reduce the possibility of air locks. During filling, air must be vented from the engine coolant passages. Wait 2 to 3 minutes to allow air to be vented; then add coolant mixture to bring the level to the top.

⚠CAUTION⚠
Never use water alone for coolant. Damage from corrosion can be the result of using water alone for coolant.

Open all engine mounted and remote heater petcocks.

Fill the engine with the correct coolant.

Use a mixture of 50-percent water and 50-percent ethylene glycol or propylene glycol antifreeze to fill the cooling system. Reference the Cummins® Coolant Requirements and Maintenance, Bulletin 3666132.



Fill the engine until coolant is visible from the keel-cooled thermostat housing.

Close the aftercooler and remote mounted heater petcocks.

NOTE: The timing of this action will depend on the height of the petcocks in the cooling system.

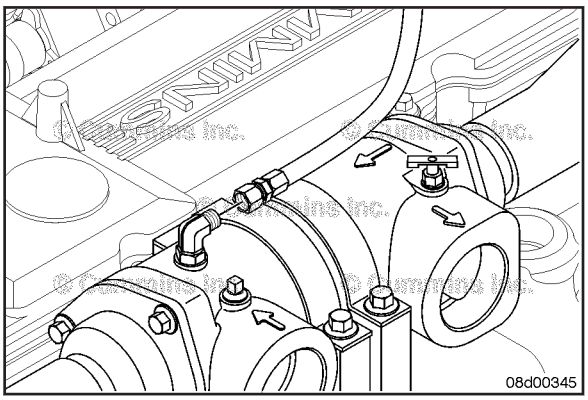
Continue to fill the system until the coolant expansion tank is filled to the proper level and the low coolant level sensor is covered.

Start the engine and monitor the coolant level and the low coolant alarm until all air is purged from the cooling system. Operate the engine for 5 minutes with the pressure cap removed; do **not** exceed 50°C [122°F].

Check the coolant level again after the engine is shutdown. Fill if needed.

Install the pressure cap.

Start the engine and monitor the low coolant alarm during initial startup.



Flush

Automotive and Industrial

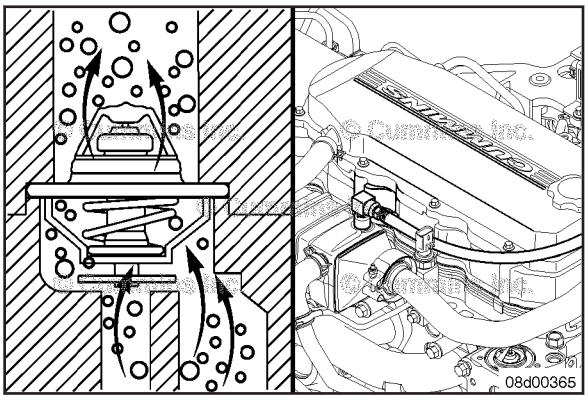
⚠CAUTION⚠

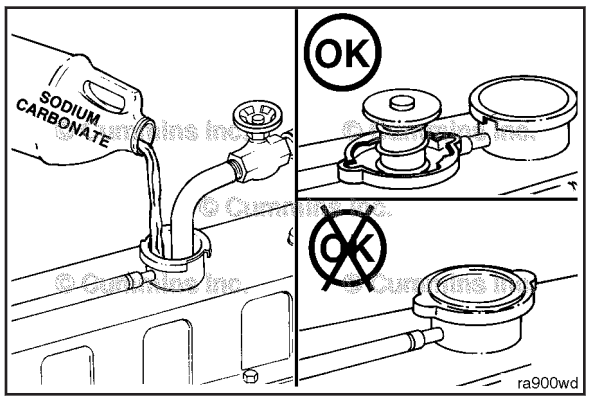
The system must be filled properly to prevent air locks or serious engine damage can result. During filling, air must be vented from the engine coolant passages. Wait 2 to 3 minutes to allow air to be vented; then add mixture to bring the level to the top.

To vent air during the fill process:

- Some thermostats have check balls that allow air to vent through the thermostat when closed.
- An air vent port connection, which connects to the top tank/coolant recovery tank of the cooling system, is located next to the water outlet.

This provides adequate venting for a fill rate of 19 liters [5 gal] per minute.

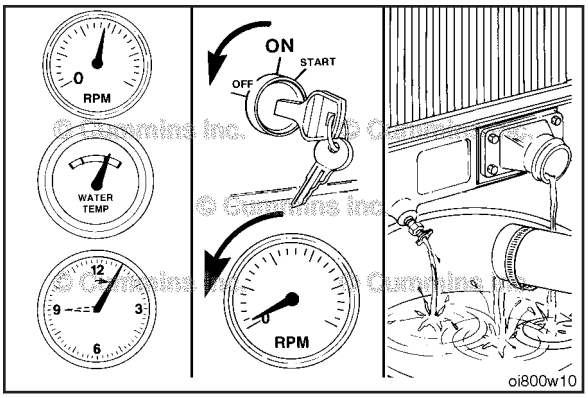




NOTE: An alternate to using sodium carbonate, as outlined in this procedure, is to use Restore™.

Restore™ is a heavy-duty cooling system cleaner that removes corrosion products, silica gel, and other deposits. The performance of Restore™ is dependent on time, temperature, and concentration levels. An extremely scaled or flow-restricted system, for example, can require higher concentrations of cleaners, higher temperatures, longer cleaning time, or the use of Restore Plus™. Up to twice the recommended concentration levels of Restore™ can be used safely. Restore Plus™ **must** be used **only** at its recommended concentration level. Extremely scaled or fouled systems can require more than one cleaning.

△CAUTION△
Do not install the radiator cap. The engine is to be operated without the cap for this process.



⚠ WARNING ⚠
Coolant is toxic. Keep away from children and pets. Dispose of in accordance with local environmental regulations.

⚠ WARNING ⚠
Do not stand near the surge tank or radiator while operating the engine with the pressure cap off. If the vehicle is equipped with a fill door on side of the surge tank, keep it closed due to coolant expansion.

⚠ CAUTION ⚠
Do not operate the engine with the pressure cap off at temperatures above 200 degrees F. This can result in potential engine damage by cavitation of the water pump and localized boiling.

⚠ CAUTION ⚠
Before topping off coolant, allow the system temperature to cool to ambient. This will ensure that an adequate amount of coolant is available to the water pump during all periods of operation.

⚠ CAUTION ⚠
Do not relieve the system pressure while hot in order to "top off" immediately before returning the vehicle to service. The system will not be able to generate the pressure through the expansion of the coolant necessary for operation. This can result in potential engine damage by cavitation of the water pump and localized boiling.

Fill the cooling system with a mixture of sodium carbonate and water (or a commercially available equivalent) to the capacity or level stated in the OEM service manual.

NOTE: Adequate venting is provided for a fill rate of 19 liters [5 gal] per minute.

Unless indicated otherwise by the OEM instructions, it is critical that all shutoff valves be returned to their open positions once the system has been refilled and the deaeration process is about to begin. This will help to make sure as much air as possible will be purged from the cooling system. See the OEM service manual for valve locations.

Wait 2 to 3 minutes without starting the engine, to allow the system to naturally purge entrained air and the coolant level to stabilize.

Add plain water to bring the level back to FULL.

Turn all cab heater switches to HIGH in order to allow maximum coolant flow through heater core(s). The blower does **not** have to be on.

With the radiator or 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 radiator or pressure cap off:

- Start the engine.

NOTE: After starting a cold engine, increase the engine speed (rpm) slowly to provide adequate lubrication to the bearings and to allow the oil pressure to stabilize.

Allow the engine to idle 2 minutes before shutting it down. This allows adequate cool down of pistons, cylinders, bearings, and turbocharger components.

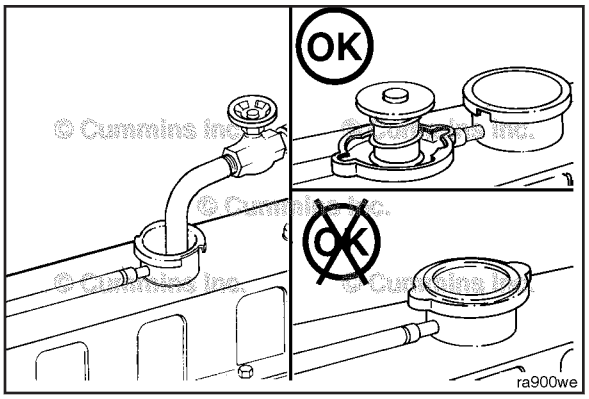
Shut the engine OFF and check the coolant level according to the OEM service manual recommendations and add, if necessary, to bring it back to the FULL level.

Install the radiator or pressure cap.

Operate the engine for 1 to 1½ hours with the coolant temperature above 80°C [176°F].

Shut the engine OFF. Allow the coolant temperature to drop to 50° C [122° F] before draining the cooling system.

Drain the cooling system.



⚠WARNING⚠
Do not stand near the surge tank or radiator while operating the engine with the pressure cap off. If the vehicle is equipped with a fill door on side of the surge tank, keep it closed due to coolant expansion.

△CAUTION△
Do not operate the engine with the pressure cap off at temperatures above 93°C [200°F]. This can result in potential engine damage by cavitation of the water pump and localized boiling.

NOTE: Do **not** install the radiator cap.

Fill the cooling system with good quality water to the capacity or level stated in the OEM service manual.

Unless indicated otherwise by OEM instructions, it is critical that all shutoff valves be returned to their open positions once the system has been refilled and the deaeration process is about to begin. This will help to make sure as much air as possible will be purged from the cooling system. See the OEM service manual for valve locations.

Wait 2 to 3 minutes, without starting the engine, to allow the system to naturally purge entrained air and the coolant level to stabilize.

Add plain water to bring the level back to FULL.

Turn all cab heater switches to HIGH in order to allow maximum coolant flow through heater core(s).

With the radiator or pressure cap off:

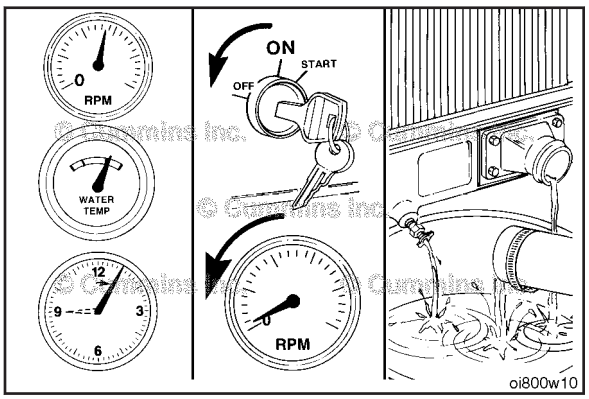
- Operate the engine at LOW IDLE for 2 minutes.
- Shut the engine OFF and add plain water to bring the level back to FULL.

With the radiator or pressure cap off:

NOTE: After starting a cold engine, increase the engine speed (rpm) slowly to provide adequate lubrication to the bearings and to allow the oil pressure to stabilize.

- Start the engine.

Allow the engine to idle 2 minutes before shutting it down. This allows adequate cool down of pistons, cylinders, bearings, and turbocharger components.



Shut the engine OFF, allow the cooling system to to cool to 50°C [122°F].

Drain the cooling system.

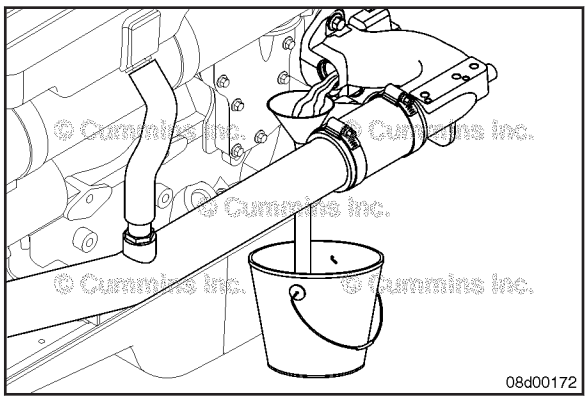
NOTE: If the water being drained is still dirty, the system **must** be flushed again until the water is clean.

Marine Applications

RESTORE™ is a heavy-duty cooling system cleaner that removes corrosion products, silica gel, and other deposits. The performance of RESTORE™ is dependent on time, temperature, and concentration levels. An extremely scaled or flow-restricted system, for example, can require higher concentrations of cleaners, higher temperatures, longer cleaning time,s or the use of RESTORE Plus™. Up to twice the recommended concentration levels of RESTORE™ can be used safely. RESTORE Plus™ **must** be used **only** at its recommended concentration level. Extremely scaled or fouled systems can require more than one cleaning.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

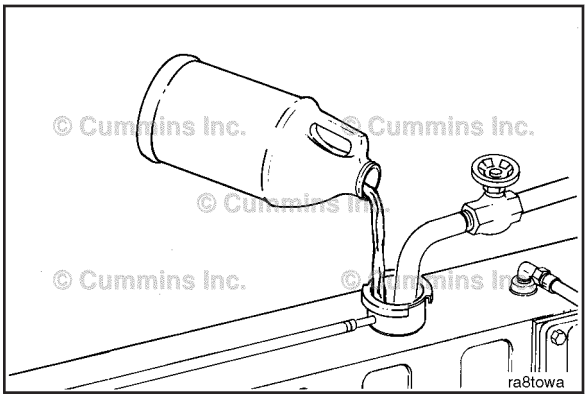
If **not** previously done, drain the cooling system. See the Drain section in this procedure. Do **not** allow the cooling system to dry out.



⚠CAUTION⚠
Fleetguard® RESTORE™ contains no antifreeze. Do not allow the cooling system to freeze during the cleaning operations.

⚠CAUTION⚠
The system must be filled properly to prevent air locks. 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 air to be vented; then add mixture to bring the level to the top.

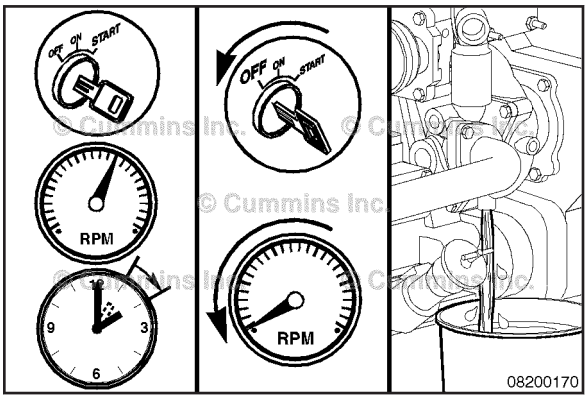
Immediately add 3.8 liters [1 gal] of Fleetguard® RESTORE™, RESTORE Plus™, or equivalent, for each 38 to 57 liters [10 to 15 gal] of cooling system capacity. Fill the system with clean water.

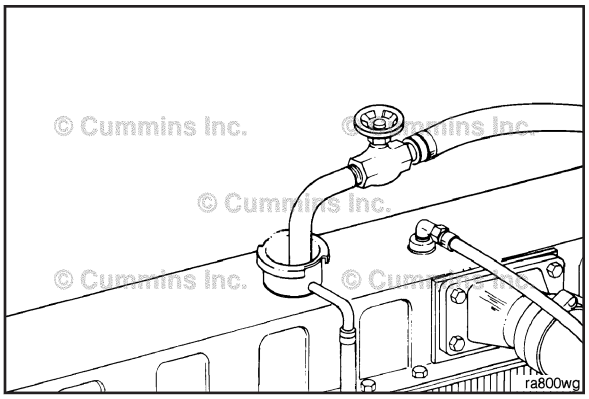


⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [122°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

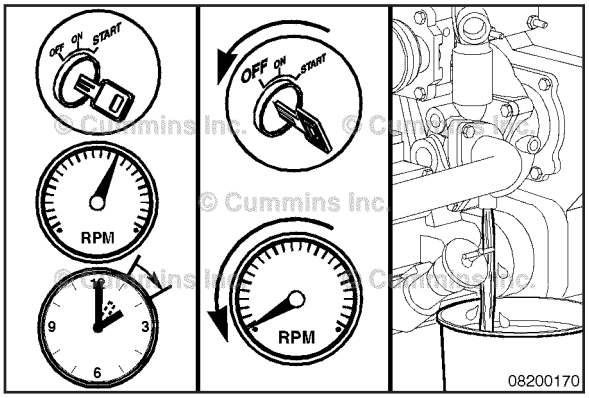
Operate the engine at normal operating temperatures, at least 85°C [185°F], for 1 to 1½ hours.

Shut the engine OFF, allow to cool to 50°C [122°F], and drain the cooling system.





Fill the cooling system with clean water.



⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [122°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

Operate the engine for 5 minutes with the coolant temperature above 85°C [185°F].

Shut the engine OFF, allow 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 water is clean.

Cooling System Diagnostics (008-020)

General Information

The following procedure covers common troubleshooting steps to help identify:

- Engine overheat causes. See the Initial Check step 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.

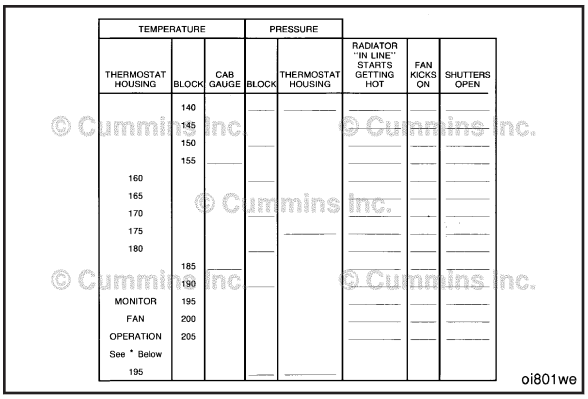
- External and internal coolant leaks/loss. See the Pressure Test step of this procedure.
- Combustion gas leaks into the cooling system. See the Test step of this procedure.

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 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 with a new switch. Be certain **not** to over tighten 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.

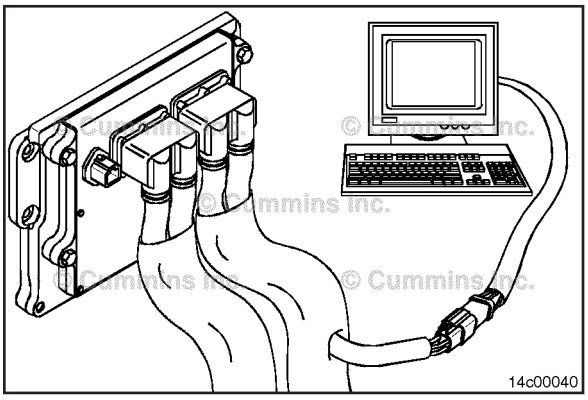


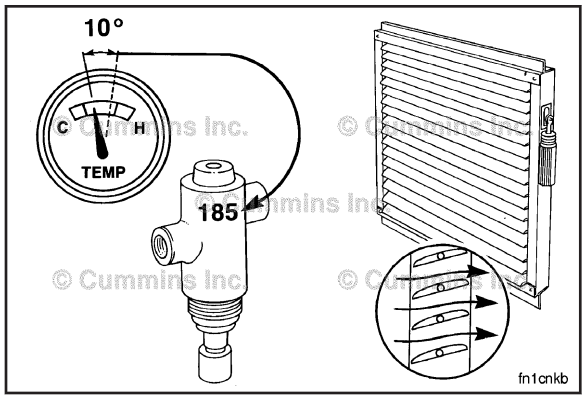
Initial Check

Connect an electronic service tool to the vehicle's data link.

Turn the keyswitch to the ON position.

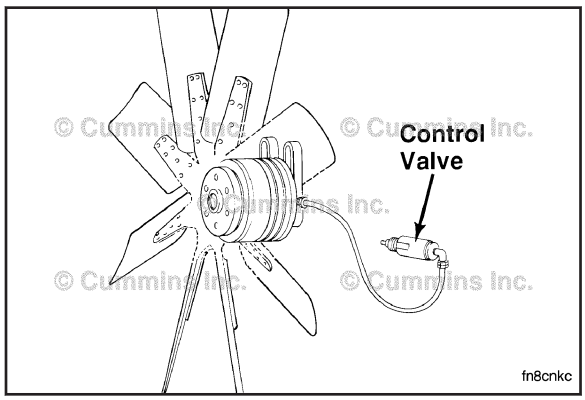
Monitor the coolant temperature with the electronic service tool.





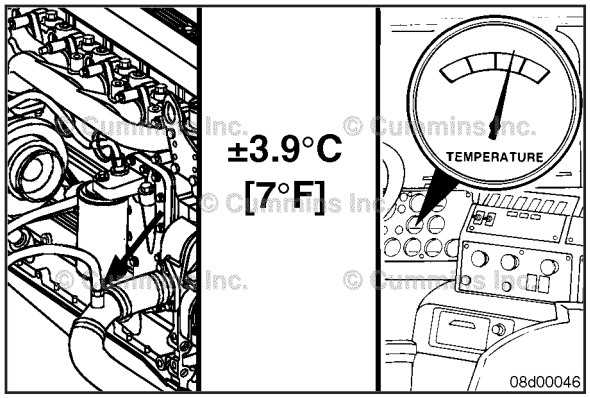
Check the coolant temperature when the shutters are opened. Compare this value to what is stamped on the shutter control.

Cummins Inc. recommends that the shutters open at 85°C [185°F].



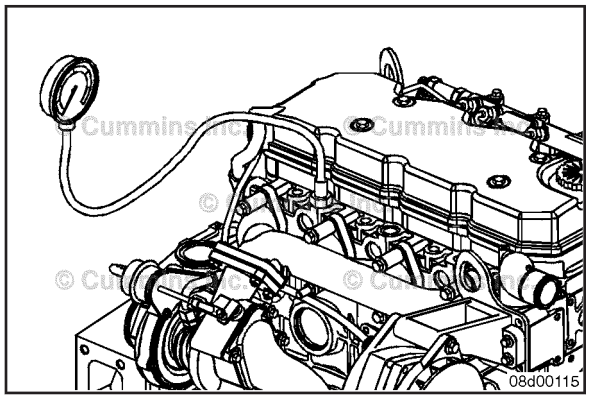
Check the coolant temperature when the fan is engaged. Compare this value to what is stamped on the fan control.

Cummins Inc. recommends that the fan engage at 96°C [205°F].



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.

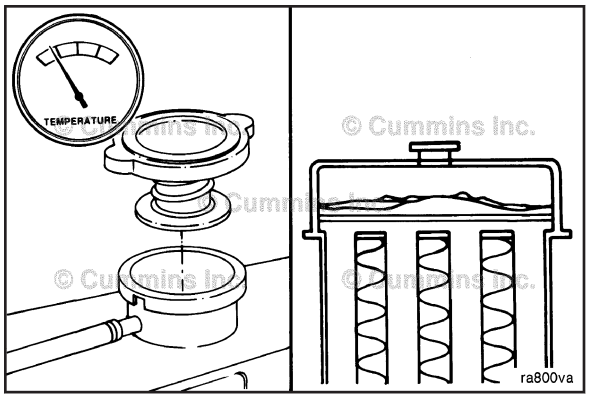
If no manufacturer's specifications are available, replace the gauge if it is **not** within ±3.9°C or 7°F of the correct reading.



Measure the coolant pressure at a coolant tap on the exhaust side of the cylinder head. Use the plug at the rear of the cylinder head on the exhaust side of the engine on Marine applications. Refer to Procedure 008-062 in Section 8.

Pressure Test

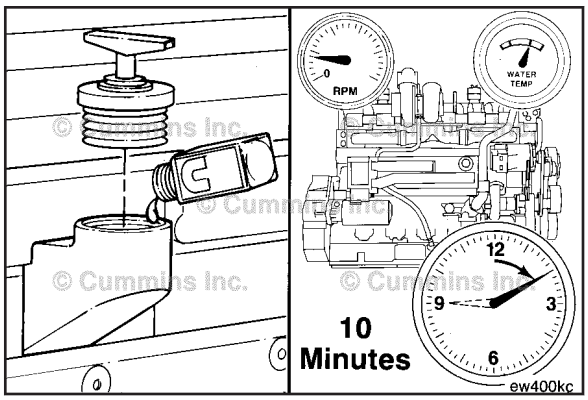
Check the coolant level and fill if necessary. Refer to Procedure 008-018 in Section 8.



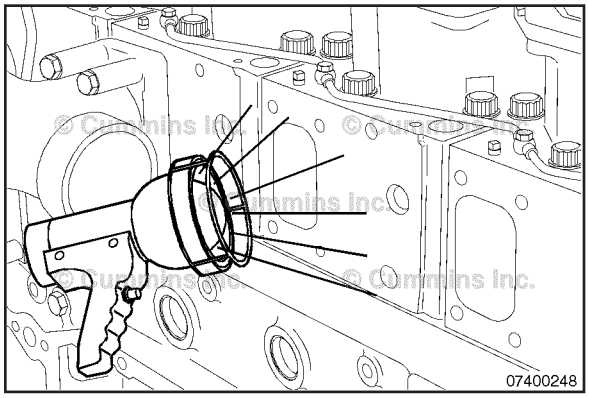
To aid in determining the location of the coolant leak, it may be necessary to add fluorescent tracer, Part Number 3377438, to the coolant.

Add one unit of fluorescent tracer to each 38 liters [10 U.S. gallons] 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.

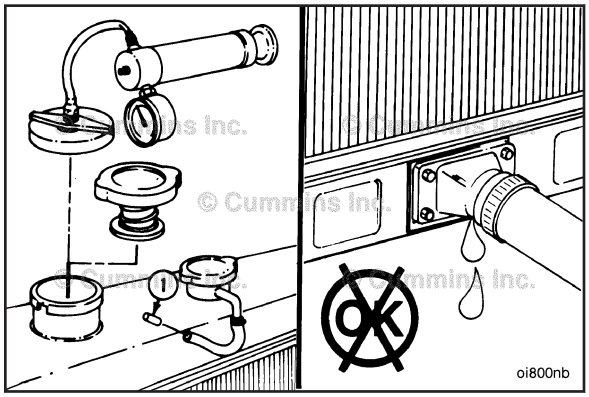


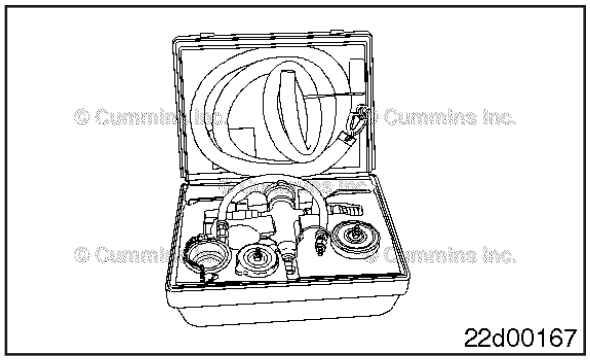
⚠CAUTION⚠
Do not apply more than 138 kPa [20 psi] air pressure to the cooling system. The water pump seal can be damaged.

If the radiator is equipped with a pressure relief valve, plug the overflow line (1).

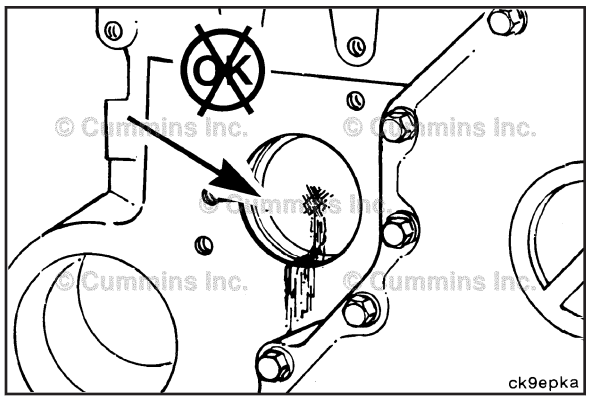
Install the pressure tester on the radiator fill neck or surge tank, if equipped, and apply air pressure.

Measurements		
	kPa	psi
Air Pressure	138	20





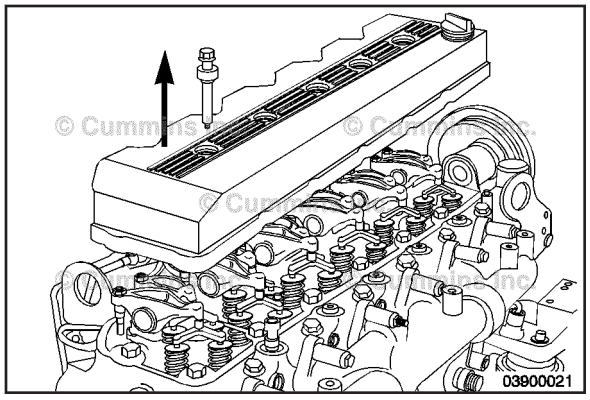
The Coolant Dam™/Pressure Tester service tool, Part Number 3824319, can also be used to pressurize the cooling system. The Coolant Dam™/Pressure Tester uses shop air rather than a hand air pump.



For external coolant leaks, inspect the exterior of the engine for coolant leaks 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 lines. Refer to Procedure 011-031 in Section 11.
- EGR valve. Refer to Procedure 011-022 in Section 11.
- EGR cooler coolant lines, if equipped, and coolant cooled. Refer to Procedure 011-031 in Section 11.
- Variable geometry turbocharger and coolant lines, if equipped. Refer to Procedure 010-033 in Section 10.
- Turbocharger coolant hoses. Refer to Procedure 010-041 in Section 10.

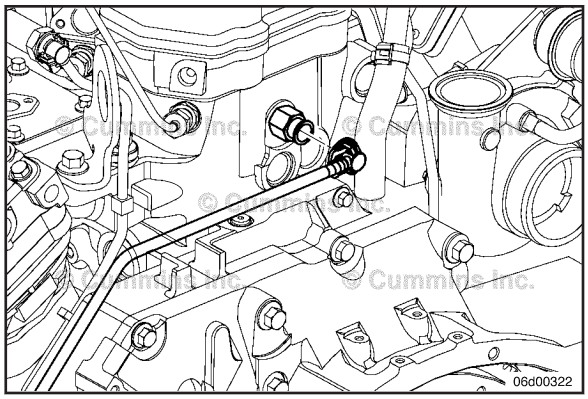


For internal coolant leaks, inspect the interior of the engine. It may be necessary to remove the following components to looks for signs of a coolant leak.

- Rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- If equipped with a variable geometry turbo, remove the turbo oil drain line. Refer to Procedure 010-045 in Section 10.

For suspected fuel in the coolant/coolant in the fuel, disconnect the fuel drain connection at the rear of the cylinder head. Refer to Procedure 006-013 in Section 6.

NOTE: For engines with quick-disconnect fittings, it may be necessary to remove the check valve installed in the fuel drain port in the cylinder head to gain access to the fuel drain port.

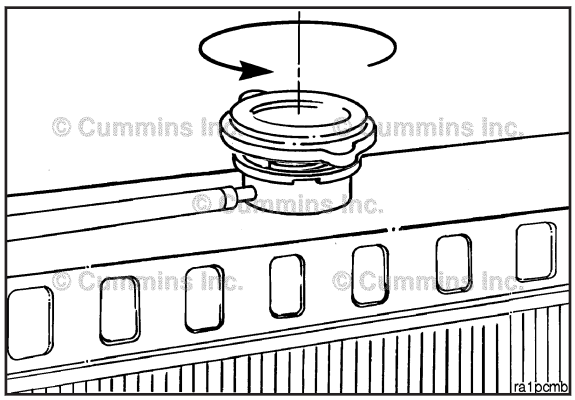


Test

NOTE: All cab heaters and air conditioners **must** be turned off, and the engine fan control **must** be turned to the AUTOMATIC position, if applicable.

NOTE: Install the test equipment at the expansion tank filler neck on Marine applications.

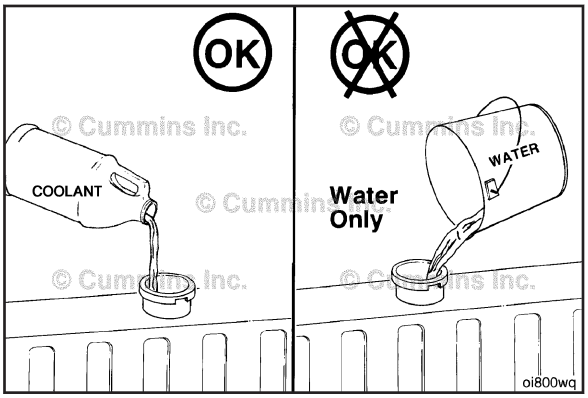
Remove the radiator cap, and leave it off for the following test.



Combustion Gas Leak

Use combustion gas tester, Part Number 3822985, or its equivalent, to test for combustion gases in the cooling system.

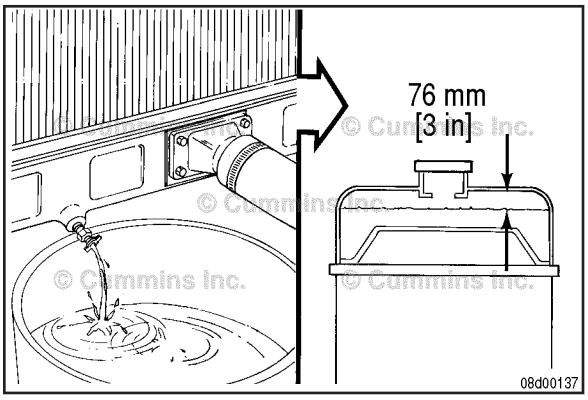
It is recommended that the cooling system contain a mixture of 50-percent antifreeze and 50-percent water during the combustion gas leak test. The use of water **only** can result in a color change in the test fluid from blue to turquoise or light green during the test. This is **not** an indication of a combustion gas leak.

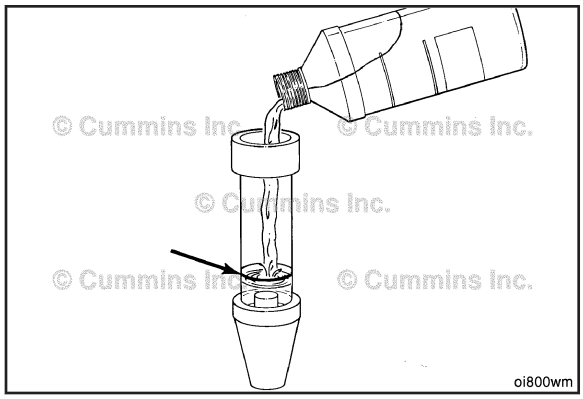


⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

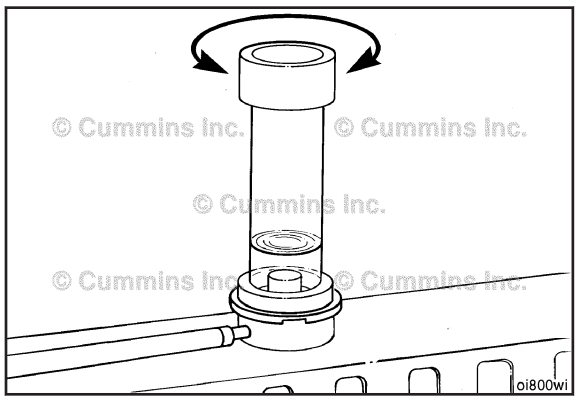
Drain the coolant level down approximately 76 mm [3 in] below the radiator cap seal ledge in the radiator fill neck.

If the coolant is above this point, the coolant can contaminate the test fluid, causing the test to be ineffective.



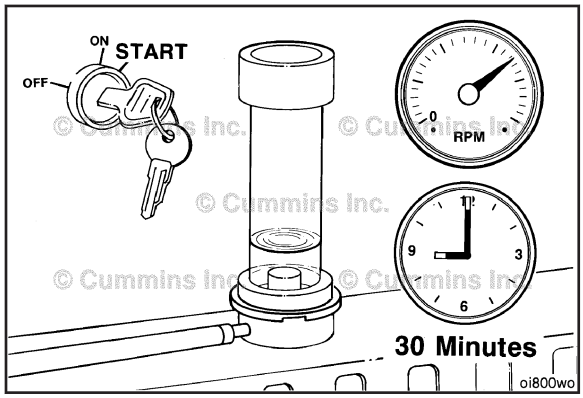


Pour the test fluid into the combustion gas leak test instrument until it is up to the yellow fill line on the instrument.

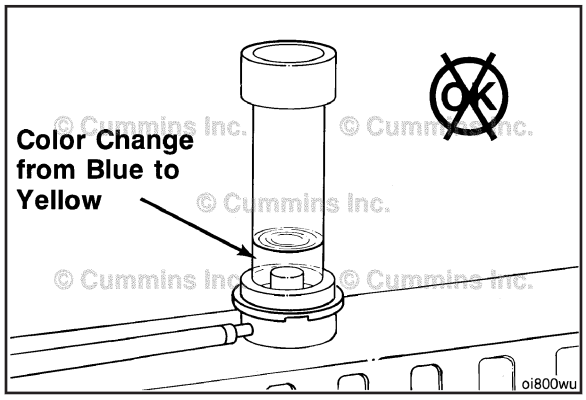


Insert the rubber tip of the combustion gas leak test instrument into the radiator fill neck. Hold the instrument down firmly and turn back and forth to make certain that an airtight seal is formed between the tester and the radiator fill neck.

NOTE: Install the test equipment at the expansion tank filler neck on Marine applications.

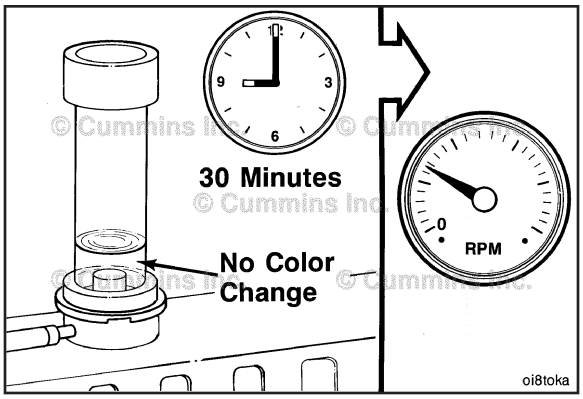


Start the engine and run at high idle for approximately 30 minutes. Monitor the engine temperature and color of the test fluid during engine operation. Do **not** allow the engine temperature to exceed 100°C [212°F] during the test.

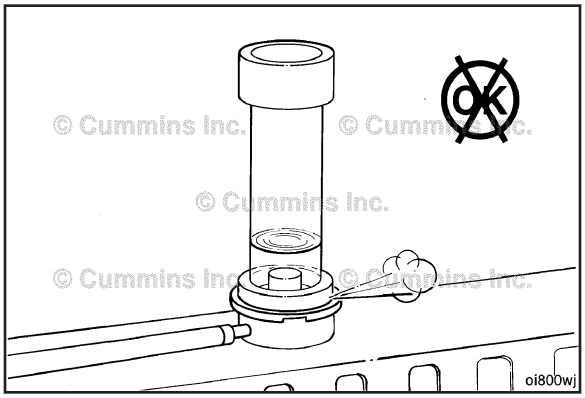


If the color of the test fluid changes from blue to yellow or green anytime during the test, combustion gases are leaking into the cooling system. Discontinue the test if the color of test fluid changes from blue to yellow or green.

If the color of the test fluid does **not** change from blue to yellow or green during the 30-minute test period, return the engine to low idle.

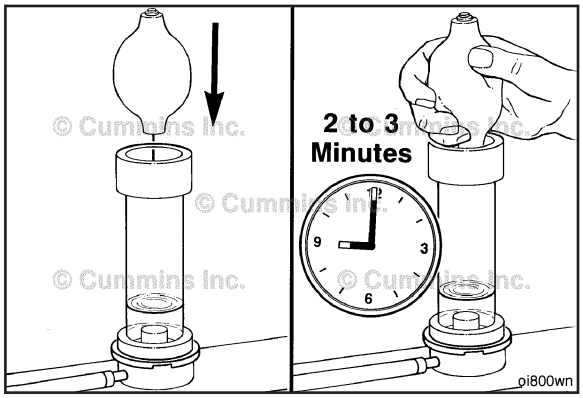


Check the test instrument to make sure it is firmly sealed in the radiator fill neck.

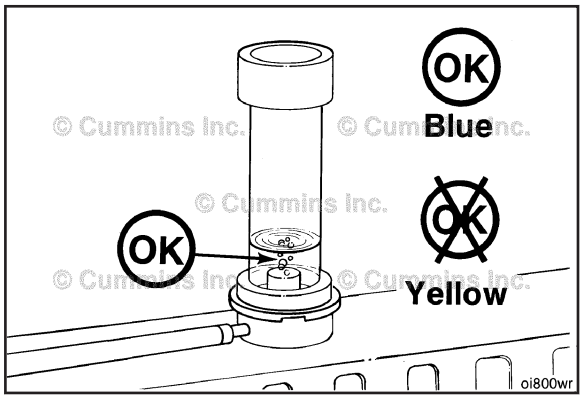


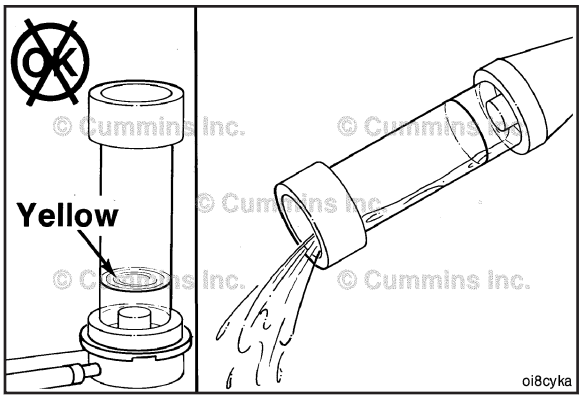
Insert the tip of the rubber ball into the hole in the top of the test instrument. Squeeze the rubber ball 2 to 3 minutes to draw air from the radiator through the test fluid.

If the color of the test fluid remains blue, combustion gases are **not** entering the cooling system. If the color of the test fluid changes from blue to yellow or green, combustion gases are entering the cooling system and further investigation is required to determine the source of the combustion leak.



As the cooling system warms up to operating temperature, air will be expelled through the combustion gas tester in the form of bubbles in the test fluid. This is due to normal expansion of the coolant. Do **not** mistake the presence of air bubbles in the tester as combustion gases or air leaks into the cooling system. A change in the color of the test fluid from blue to yellow or green is the **only** indication of combustion gas in the cooling system.

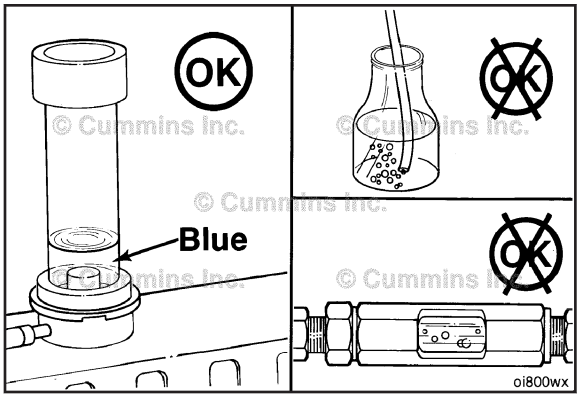




A positive result from the combustion gas leak tester indicates the following:

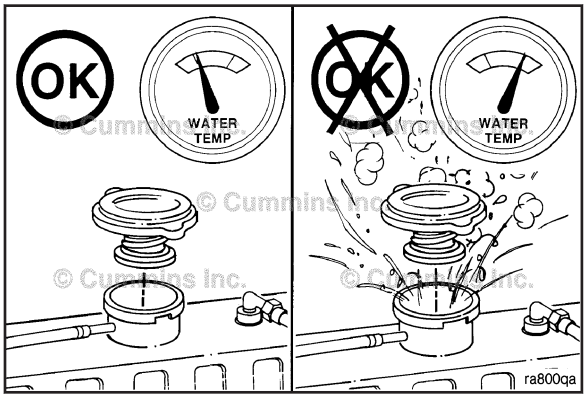
- Cylinder head gasket or cylinder head casting leakage. Refer to Procedure 002-004 in Section 2.
- On marine engines, the wet exhaust manifold can be cracked. Refer to Procedure 011-008 in Section 11. The turbocharger wet exhaust housing can be cracked, or the turbocharger to exhaust manifold gasket can be damaged or installed improperly by 90 degrees, causing the exhaust gases to leak into the cooling system. Refer to Procedure 010-033 in Section 10.

NOTE: Discard the tester fluid if it has indicated positive.



A negative result from the combustion gas leak tester, coupled with a continuous flow of air bubbles from the previous test, indicates the following:

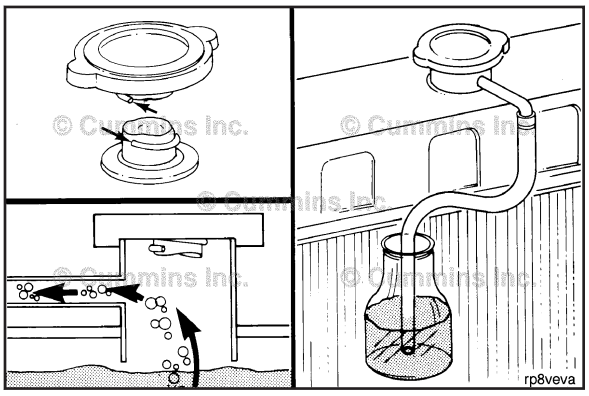
- Defective fan, shutter, or heater air control valve
- Air compressor head or head gasket leakage
- Air entrained due to a bad radiator check valve or incorrect fill.



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.

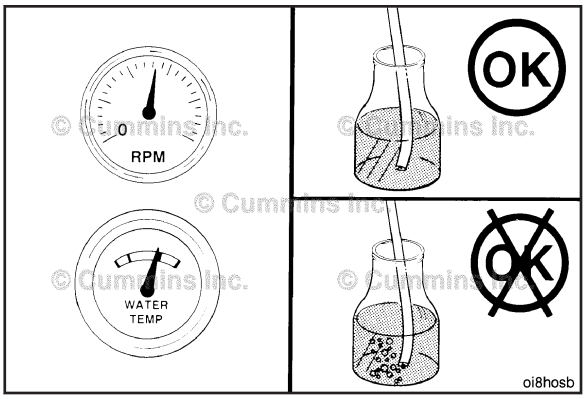
Put the free end of the hose below the water level in a container of water.

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.

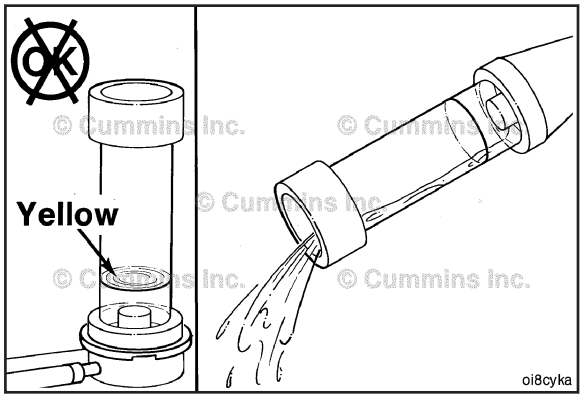


Analyzing the Data

Check the color of fluid in the combustion gas leak tester. A yellow or green color will indicate a combustion leak. A blue color will indicate there is no leak. This information will help isolate the source of air in the cooling system, if any.

NOTE: The test kit is **not** sensitive enough to detect very small combustion gas leaks.

Do **not** rule out combustion gas leaks if the combustion gas leak test does **not** indicate a combustion gas leak.



Worksheet

Fill in the blanks with the test data as the test is being run. Record the cylinder head coolant pressure and cab gauge coolant temperature reading at each of the thermostat housing temperature points listed on the left side of the matrix below. Mark when the radiator line gets hot, when the fan starts operating, and when the shutters open.

Coolant Temperature	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						
155						Start monitoring radiator “in” line
160						
165						
170						
175						
180						
185						
190						
195						

200						
205						Cool engine down

Fan Clutch, On-Off (008-027)

General Information

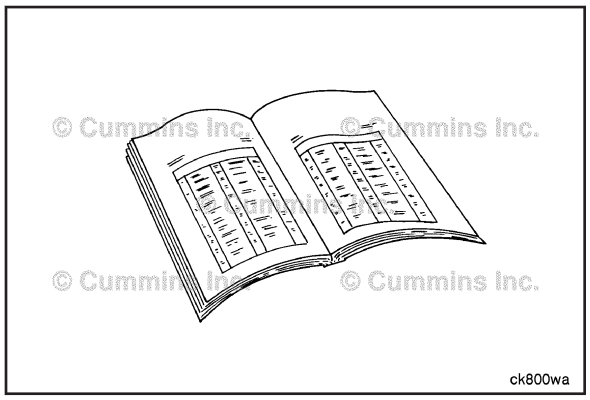
All fan clutches can be controlled by the engine electronic control module (ECM). The ECM monitors coolant temperature and intake manifold termperature to determine when to engage the cooling fan. Some applications have additional sensors monitored by the ECM for fan control (for example, air conditioner pressure and transmission temperature). These are various fan clutch types such as:

- Air engaged
- Air disengaged
- Electric
- Viscous
- On-off.

Refer to the manufacturer's service manual to determine fan clutch type.

The ECM is capable of using either a zero (“0”) VDC or 12/24 VDC signal to engage the fan clutch. The exact enable logic can be selected in the Features and Parameters section of INSITE™.

Refer to the equipment manufacturer's service manual for fan clutch troubleshooting and repair information.

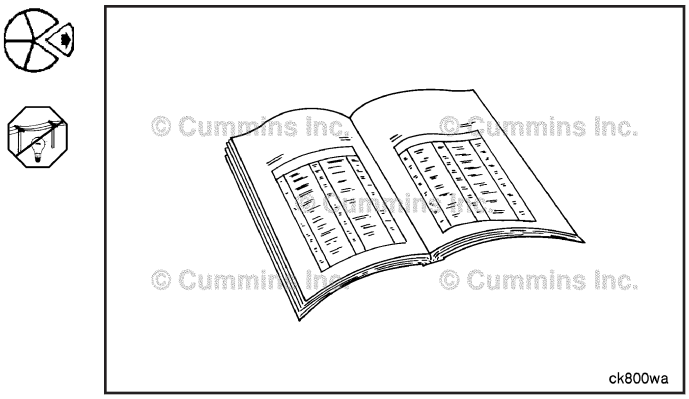


Fan Hub, Belt Driven (008-036)

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 (Battery Cables and Connections) in Section 13.
- Remove the cooling fan drive belt. Refer to Procedure 008-002 (Drive Belt, Cooling Fan) in Section 8.
- Remove the fan spacer and pulley. Refer to Procedure 008-039 (Fan Spacer and Pulley) in Section 8.



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

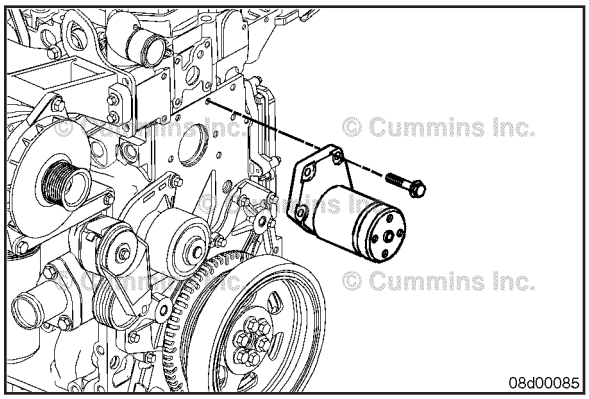
- Disconnect the batteries. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13.
- Remove the belt guards. Refer to Procedure 008-001 (Belt Guard) in Section 8.
- Remove the drive belt, seawater pump. Refer to Procedure 008-126 (Drive Belt, Seawater Pump) in Section 8.
- Remove the drive belt, cooling fan. Refer to Procedure 008-002 (Drive Belt, Cooling Fan) in Section 8.

Remove

Remove the four fan hub mounting capscrews.

Remove the fan hub.

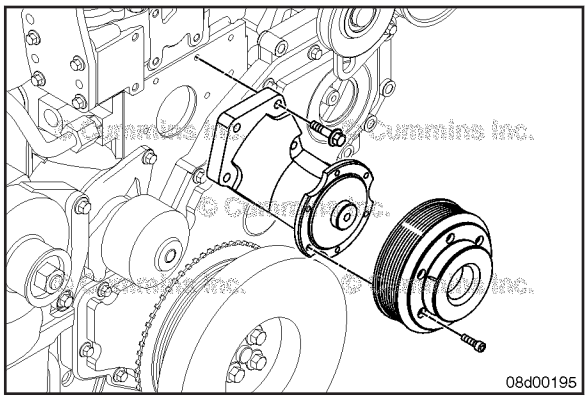
NOTE: There are many available fan hub configurations. Be sure to note the location, orientation, and mounting pattern of the hub prior to removal from the engine.

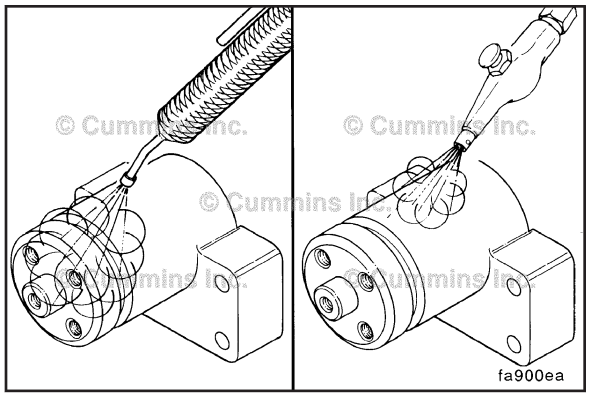


Remove the fan hub pulley from the fan hub.

Remove the four hub mounting capscrews.

Remove the fan hub.





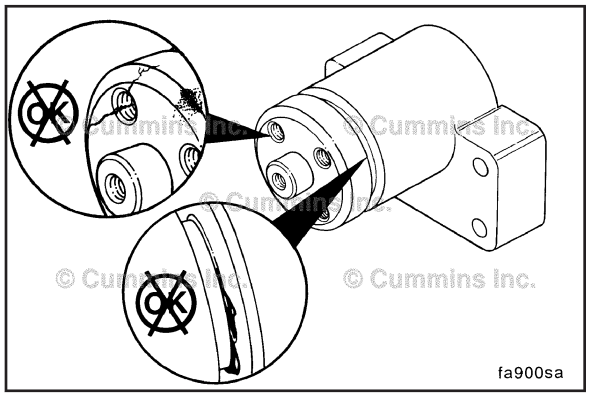
Clean and Inspect for Reuse

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

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

Steam clean the exterior of the fan hub.

Dry with compressed air.

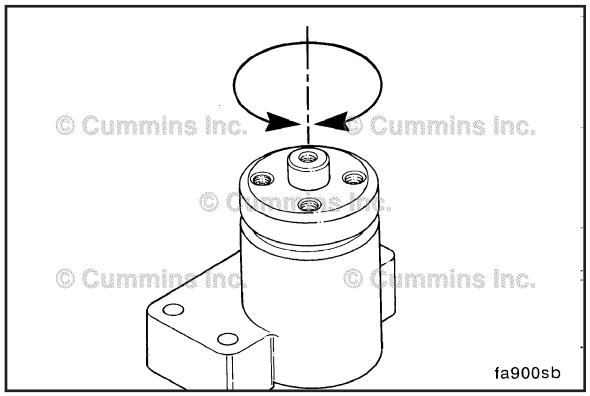


Inspect the fan hub for indications of oil seal leakage.

Inspect the fan hub for cracks or other damage.

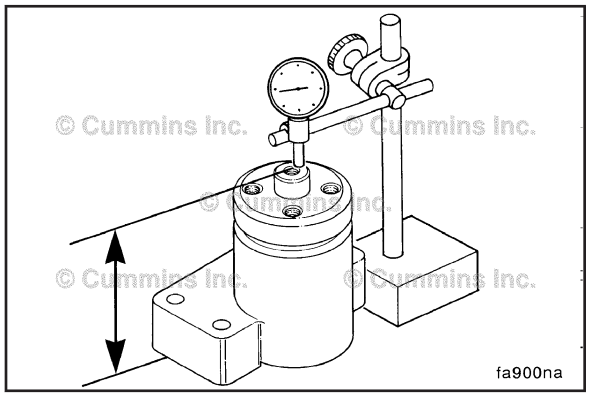
Inspect the fan hub chamfer and fan pulley mating surface for damage.

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.



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.

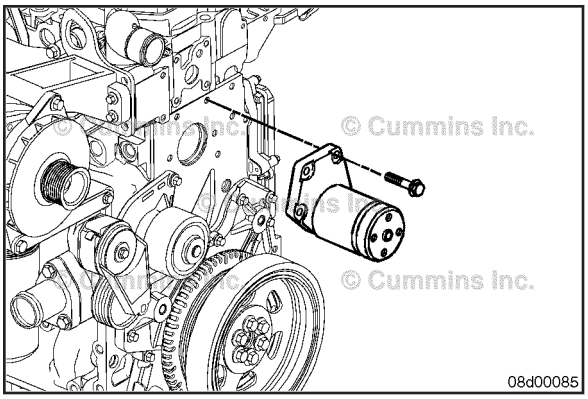
Fan Hub End Play		
mm		**in**
0.15	MAX	0.006

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 hub.

Torque Value: 33 N•m [24 ft-lb]

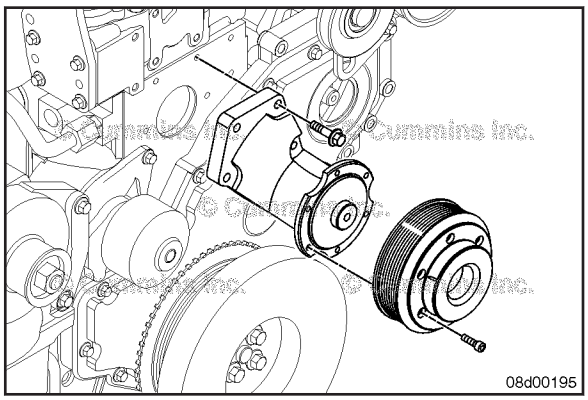


Install the hub with four mounting capscrews.

Torque Value: 33 N•m [24 ft-lb]

Install the fan hub pulley with the six mounting capscrews.

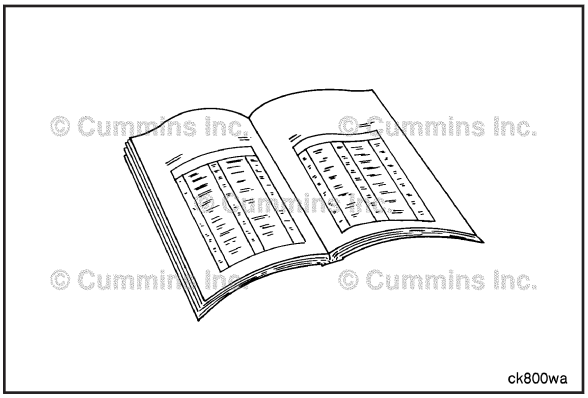
Torque Value: 12 N•m [106 in-lb]

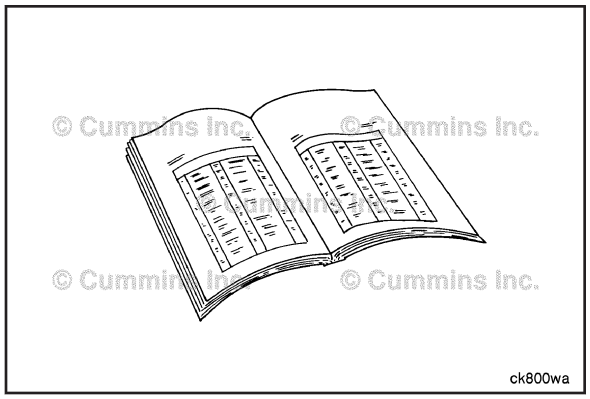


Finishing Steps

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

- Install the fan spacer and pulley. Refer to Procedure 008-039 (Fan Spacer and Pulley) in Section 8.
- Install the cooling fan drive belt. Refer to Procedure 008-002 (Drive Belt, Cooling Fan) in Section 8.
- Connect the batteries. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13.
- Operate the engine and check for proper operation.

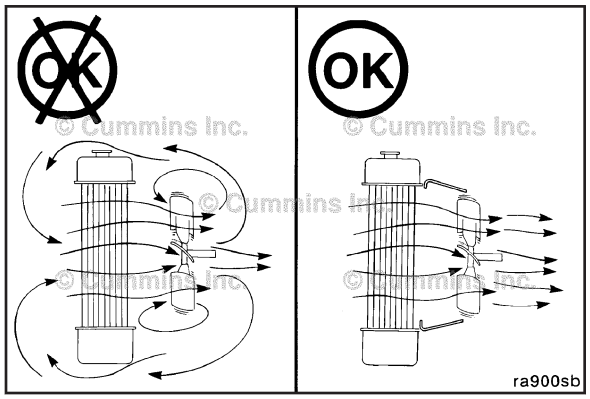




⚠WARNING⚠

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

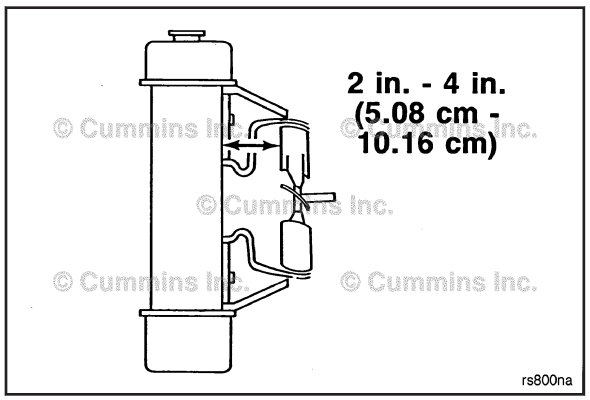
- Install the drive belt, cooling fan. Refer to Procedure 008-002 (Drive Belt, Cooling Fan) in Section 8.
- Install the drive belt, seawater pump. Refer to Procedure 008-126 (Drive Belt, Seawater Pump) in Section 8.
- Install the belt guards. Refer to Procedure 008-001 (Belt Guard) in Section 8.
- Connect the batteries. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13.
- Operate the engine and check for proper operation.



Fan Shroud Assembly (008-038)

Remove

To remove the fan shroud, refer to the original equipment manufacturer's manual.



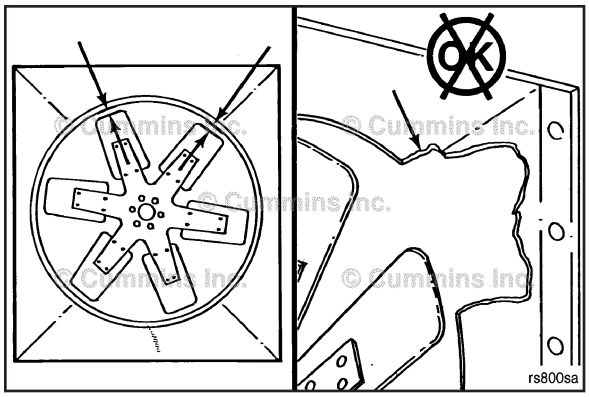
Inspect for Reuse

Inspect the fan shroud for proper fan clearance.

Check the fan shroud for cracks, air leaks, or damage.

Install

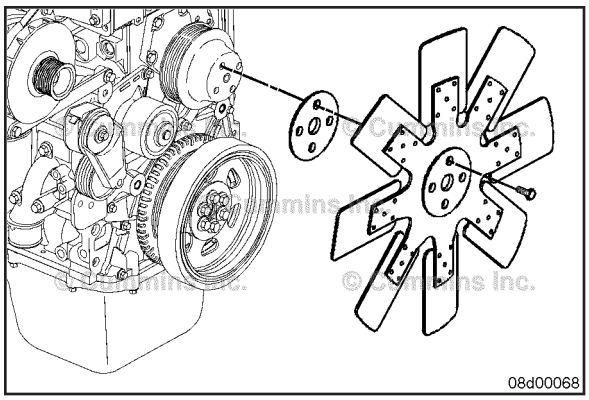
To install the fan shroud, refer to the original equipment manufacturer's manual.



Fan Spacer and Pulley (008-039)

Preparatory Steps

Remove the cooling fan drive belt. Refer to Procedure 008-002 (Drive Belt, Cooling Fan) in Section 8.

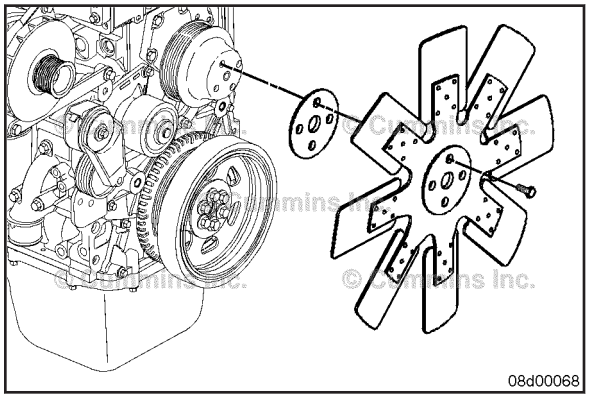


Remove

Remove the four fan capscrews, fan, and spacer.

Remove the cooling fan drive belt. Refer to Procedure 008-002 (Drive Belt, Cooling Fan) in Section 8.

Remove the fan pulley.

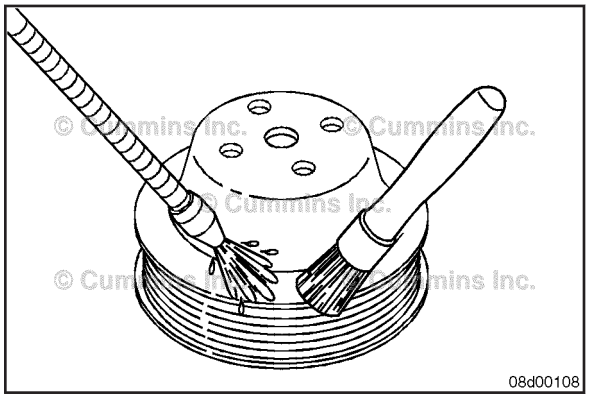


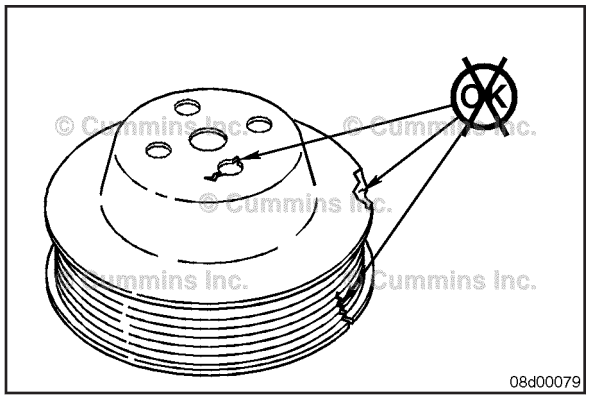
Clean and Inspect for Reuse

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

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

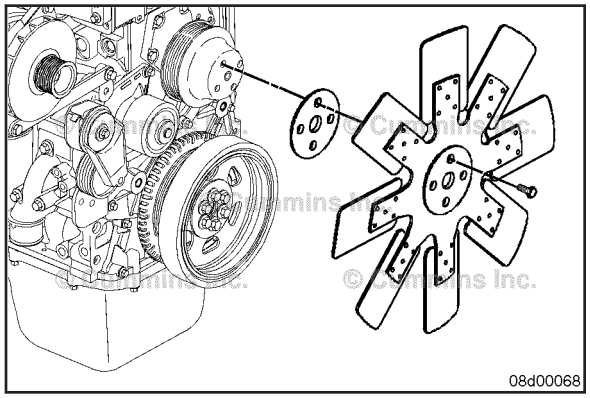
Clean the fan pulley and spacer with solvent and dry with compressed air.





Inspect the fan pulley for cracks near the bolt holes and for damage at the drive belt contact surface.

If damage is found on the fan pulley, the fan hub **must** also be inspected. Refer to Procedure 008-036 (Fan Hub, Belt Driven) in Section 8.



Install

Install the fan pulley.

Install the cooling fan and drive belt. Refer to Procedure 008-002 (Drive Belt, Cooling Fan) in Section 8.

Install the spacer, fan, and fan capscrews.

Torque Value:
M6

Step 1	10 N•m	[89 in-lb]

Torque Value:
M10

Step 1	43 N•m	[32 ft-lb]

Torque Value:
M12

Step 1	77 N•m	[57 ft-lb]

NOTE: Use the tension of the drive belt to hold the cooling fan in place when tightening the mounting capscrews. Do **not** hold the fan blades to keep the cooling fan from rotating.

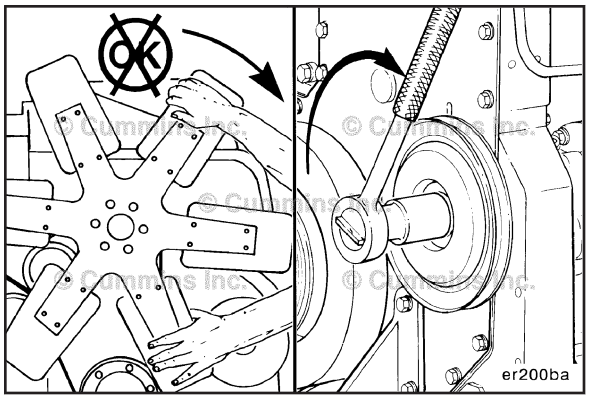
Finishing Steps

Operate the engine and check for proper operation.

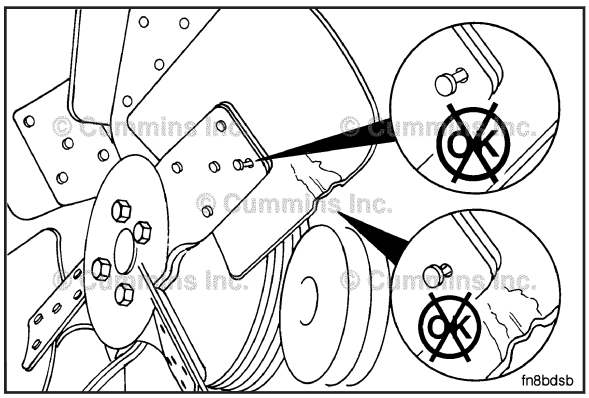
Fan, Cooling (008-040)

Inspect for Reuse

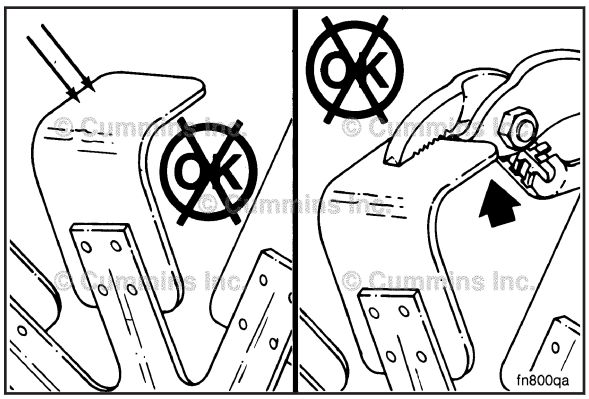
⚠WARNING⚠
Do not rotate the engine by pulling or prying on the fan. The fan blade(s) can be damaged and cause the fan to fail and cause personal injury or property damage. Use the accessory drive shaft or the crankshaft barring tool to rotate the crankshaft.



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.

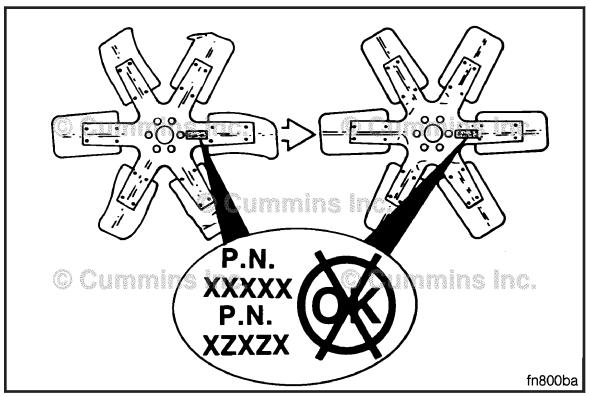


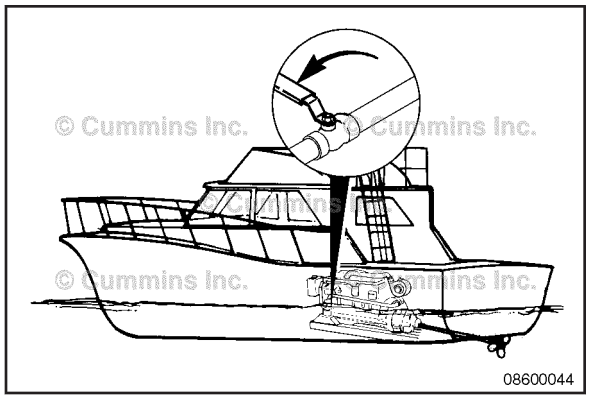
⚠WARNING⚠
Do not straighten a bent fan blade or continue to use a damaged fan. A bent or damaged fan blade can fail during operation and cause personal injury or property damage.



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.

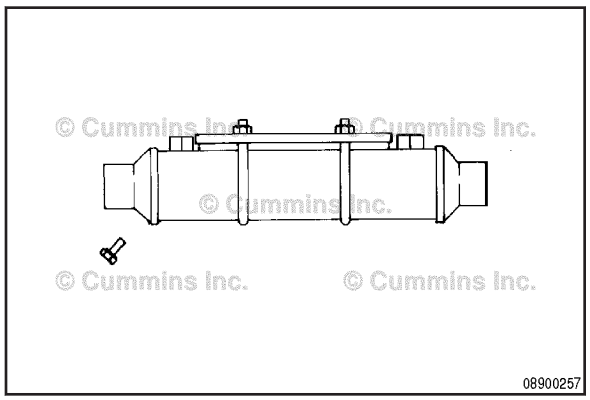




Marine Gear Oil Cooler (008-041)

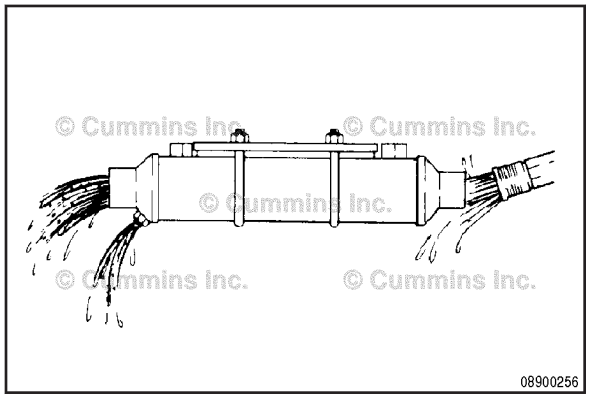
Flush

Shut off the sea water inlet valve on the vessel hull, if so equipped.



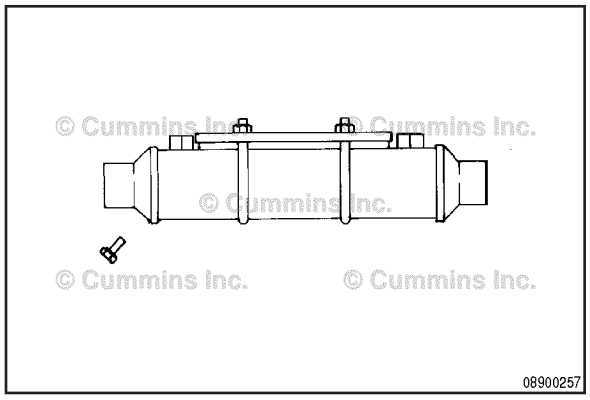
Remove the marine gear oil cooler drain plug and drain the sea water from the gear oil cooler.

Disconnect the sea water inlet and outlet connections.



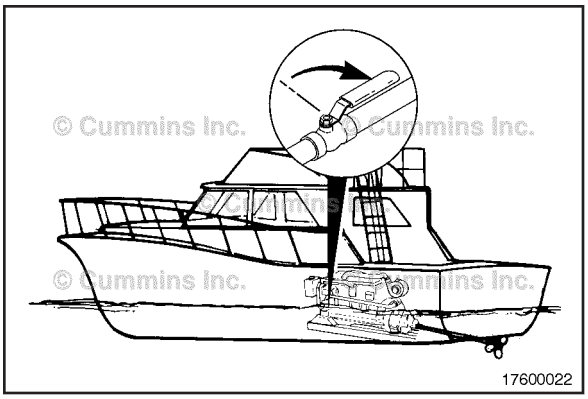
Use clean water to back flush all the debris from the cooler.

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.

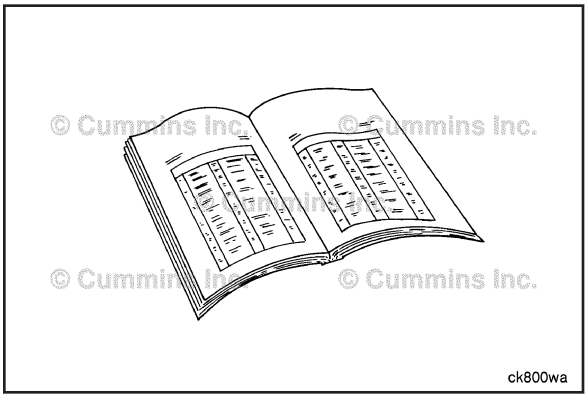


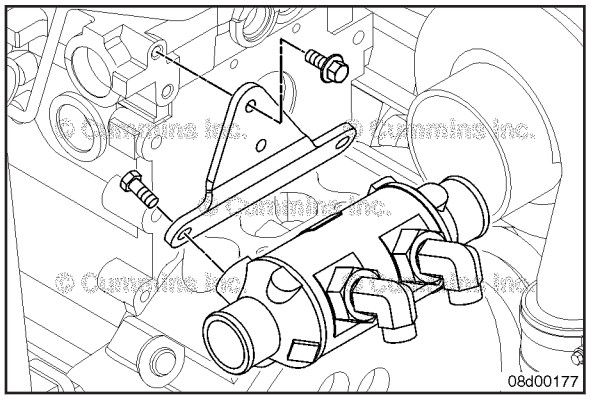
Preparatory Steps

⚠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 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.

- Shut off the sea water inlet valve(s) on the vessel hull, if equipped. Refer to the OEM troubleshooting and repair manual.
- Disconnect the battery power to the engine. Refer to Procedure 013-009
- Drain the sea water system. Refer to Procedure 010-005
- Remove the air cleaner element. Refer to Procedure 010-013





Remove

⚠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.

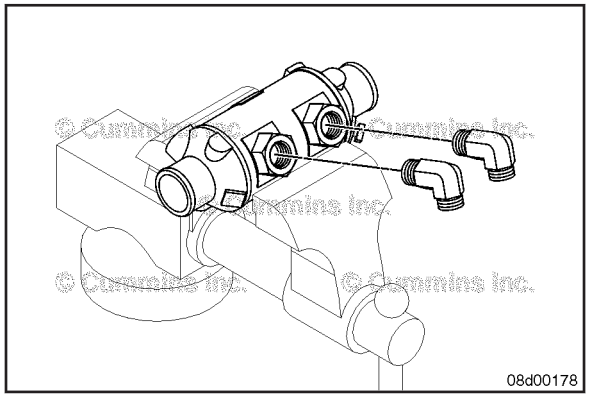
Remove and plug the sea water supply line for the shaft log seal from the gear oil cooler (if equipped).

Remove the transmission oil supply and return lines; mark their locations.

Disconnect the marine gear oil pressure/temperature sensor (if equipped).

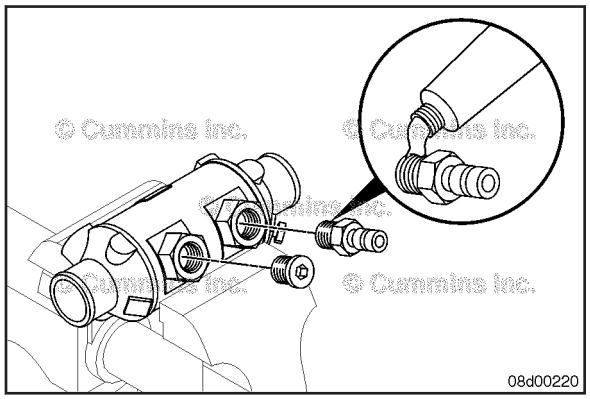
Remove the two cooler bracket to cylinder head mounting capscrews and the marine gear oil cooler.

Remove the two bracket to cooler mounting capscrews.



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.

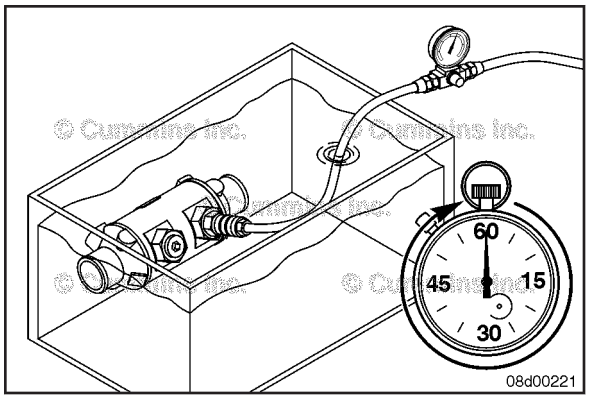
⚠WARNING⚠
Troubleshooting with high pressure air presents the risk of equipment damage, personal injury, or death. Troubleshooting must be performed by trained, experienced technicians.

⚠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.



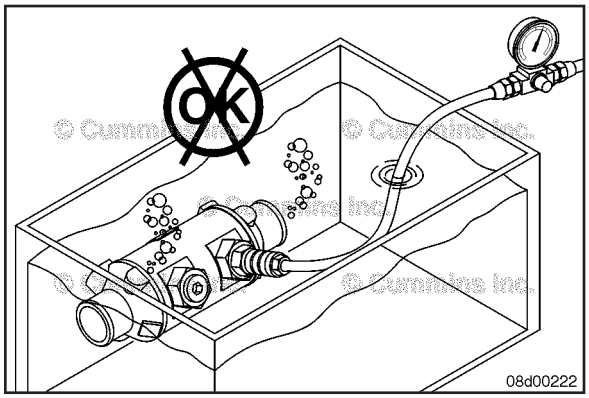
Inspect for air bubbles at the fitting braze joints.

Inspect for air bubbles at the opening at each end of the cooler.

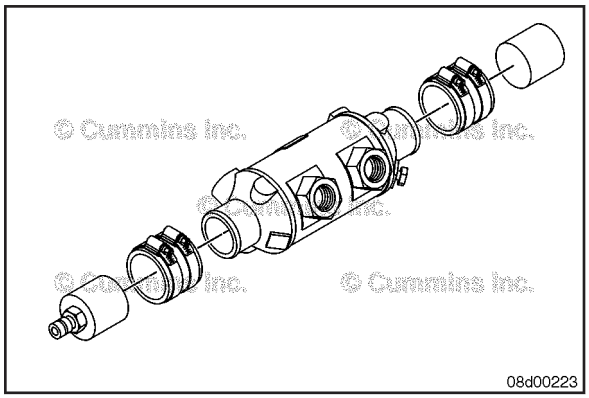
If leaks are detected, replace the gear oil cooler.

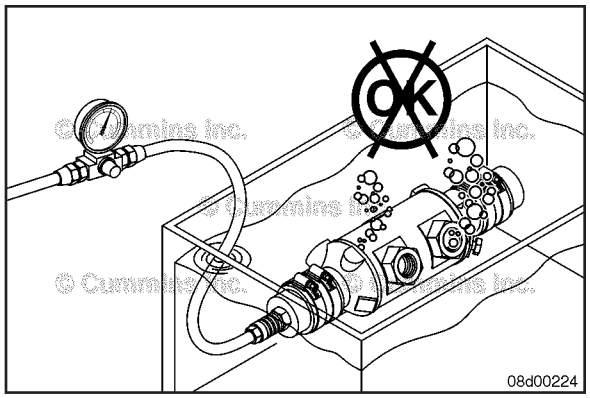
Remove the cooler from the tank. Shut off the air supply and disconnect the air supply.

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.





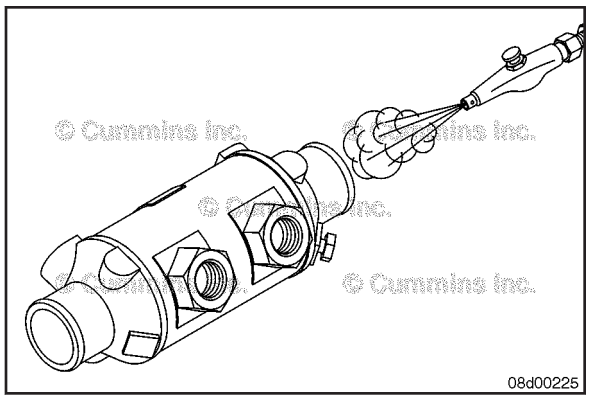
Submerge the cooler into a tank of water for one minute.

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.

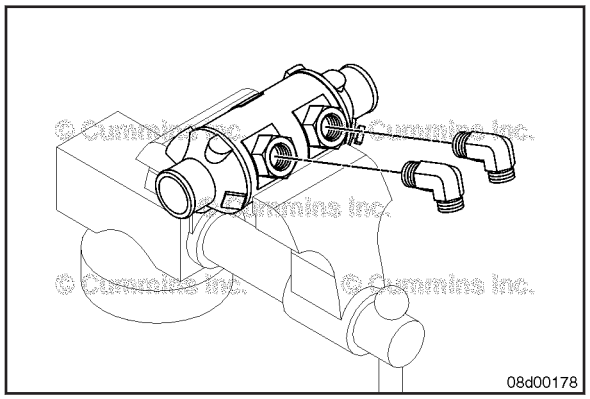
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠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 side 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.

Tighten the two locknuts.

Torque Value: 24 N•m [18 ft-lb]

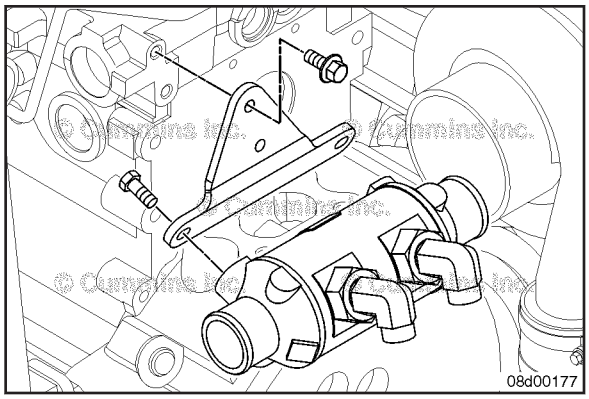
Install

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]

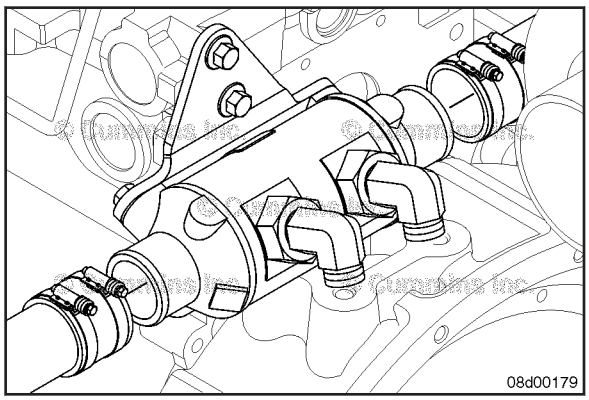


Install the marine gear oil cooler sea water discharge hose and tighten the hose clamp.

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]

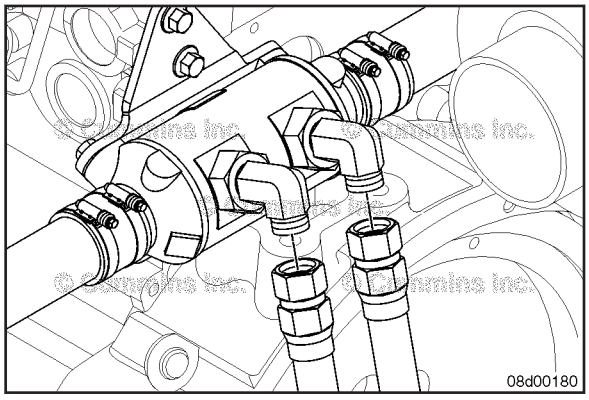


Install the transmission oil supply and return hoses to the gear cooler.

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).

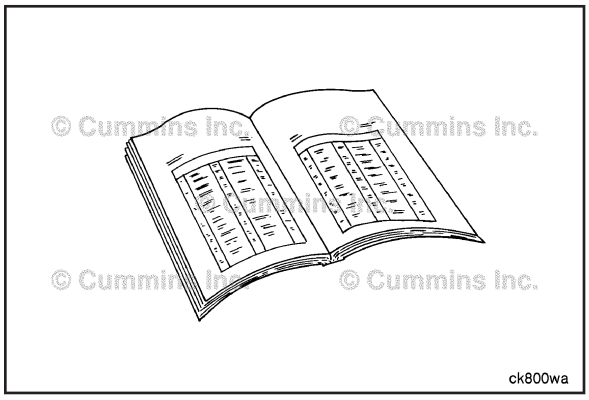


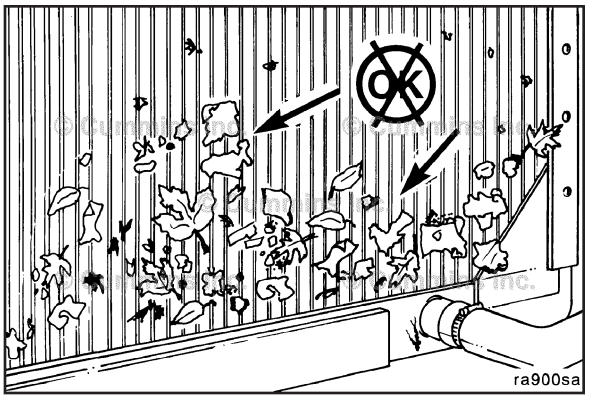
Finishing Steps

⚠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 cleaner. Refer to Procedure 010-013
- Connect the batteries. Refer to Procedure 013-009
- Open the sea water inlet valve(s).

Operate the engine and check for leaks.

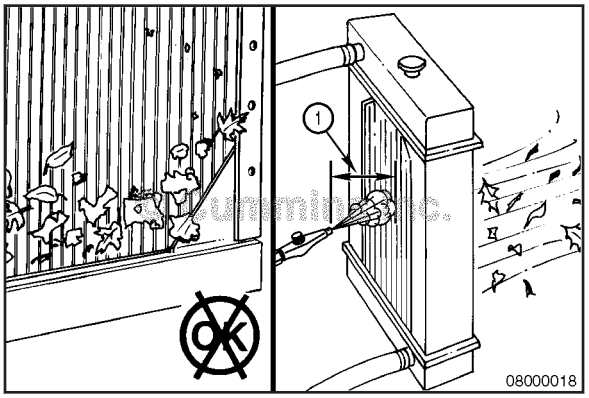




Radiator (008-042)

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

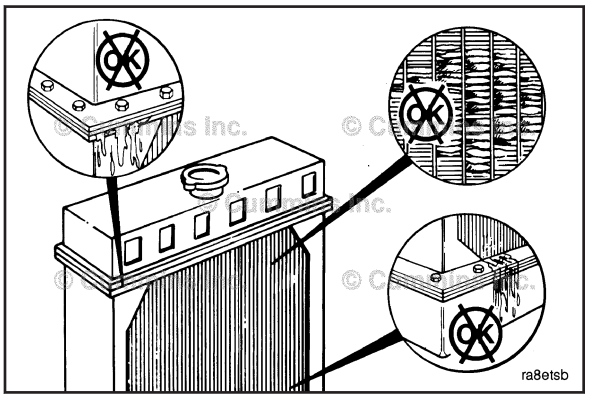
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△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.

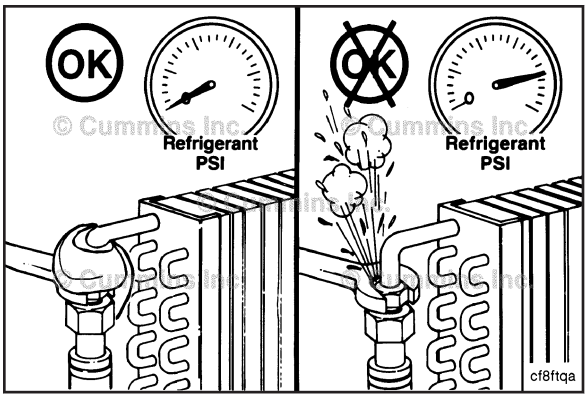
Inspect the radiator core and gasket for leaks.

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.

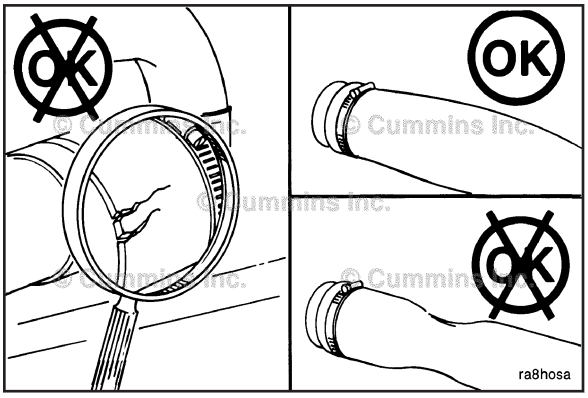


Radiator Hoses (008-045)

Inspect for Reuse

Inspect all hoses for cracks, cuts, or collapsing.

NOTE: The silicone engine coolant hose will exhibit swelling because of the elasticity of the hose.

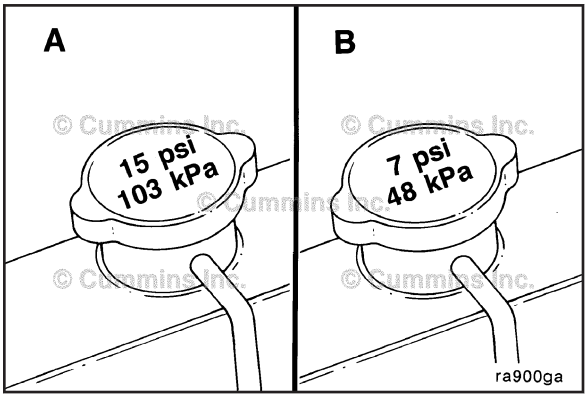


Radiator Pressure Cap (008-047)

General Information

The cooling system is designed to use a pressure cap to prevent boiling of the coolant. Refer to the OEM's cooling system specifications for the correct radiator pressure cap for your application.

An incorrect or malfunctioning cap can result in the loss of coolant and the engine running hot.



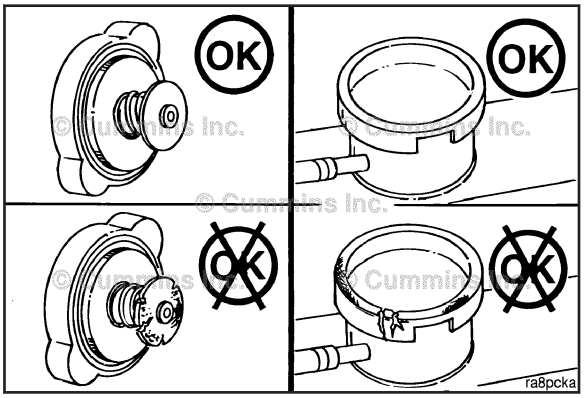
Inspect for Reuse

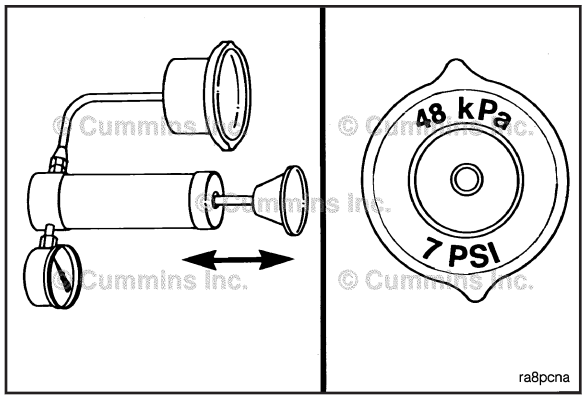
Be sure the correct radiator pressure cap is being used.

Inspect the rubber seal of the pressure cap for damage.

Inspect the radiator fill neck for cracks or other damage.

Refer to the OEM service manual for instructions if the fill neck is damaged.

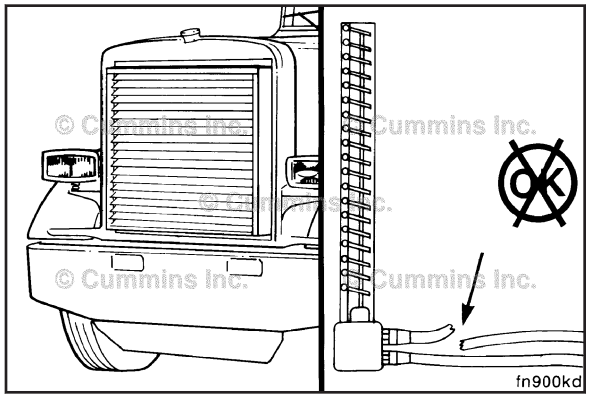




Pressure-test the radiator cap. Refer to the OEM service manual for radiator cap test procedures.

The pressure cap **must** seal within 14 kPa [2 psi] of the value stated on the cap, or it **must** be replaced.

An incorrect or malfunctioning cap can result in the loss of coolant and the engine running hot.

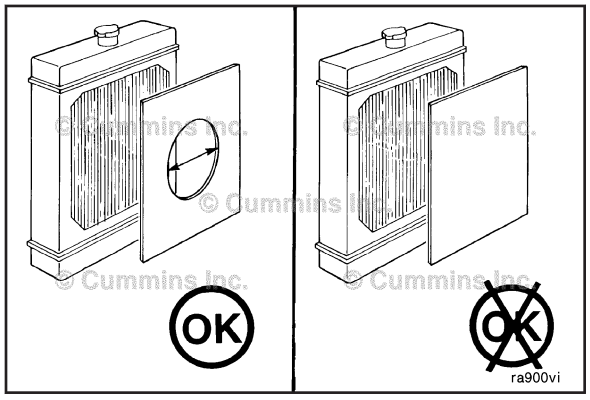


Radiator Shutter Assembly (008-049)

General Information

Shutters are designed to control airflow 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 airflow and the engine running cold.

NOTE: Make sure the air temperature sensor is functioning correctly. Check the air-operated shutter controls. Check for air leaks. Refer to the equipment manufacturer's 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 charge air cooled frontal area **must** be left open to airflow.

Winterfronts: 387 cm^2 [60 in^2].

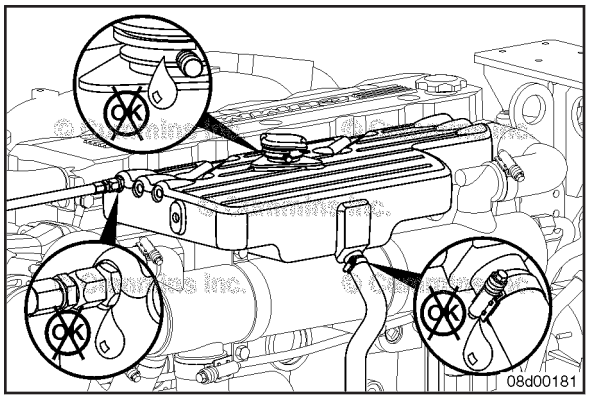
Expansion Tank (008-052)

General Information

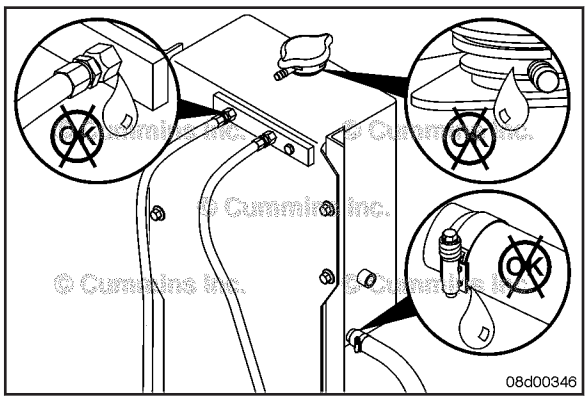
This procedure applies to QSB5.9 marine engines **only**

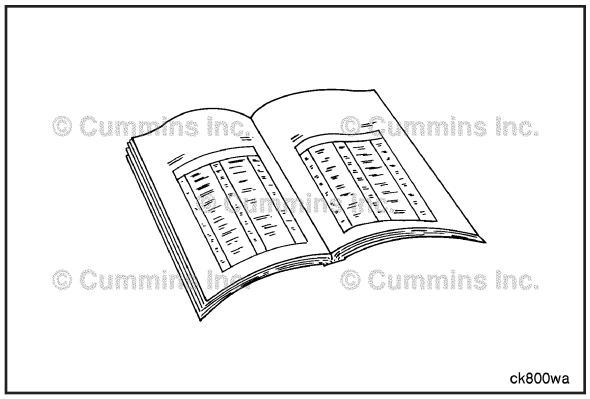
Initial Check

Check the expansion tank, hoses and vent line connections for signs of leaks.



Check the expansion tank, hoses, and vent line connections for signs of leaks.





Preparatory Steps

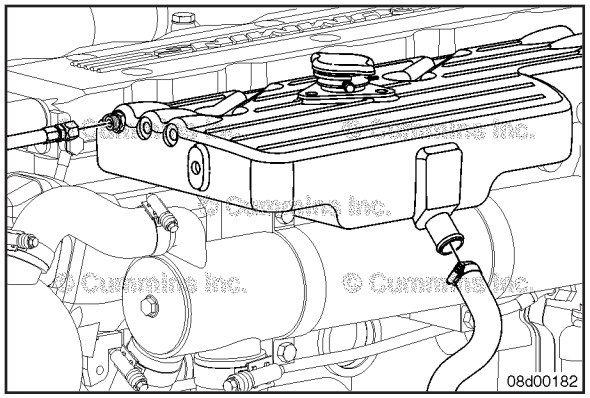
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
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 so that it 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, CM850 Electronic Control System, Bulletin 4021416.

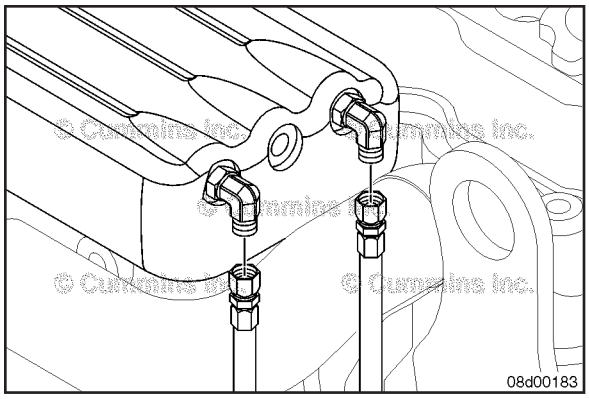


Remove

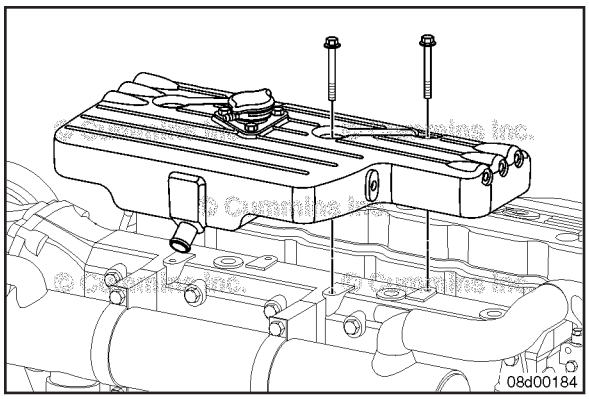
Disconnect the coolant make-up hose from the expansion tank and the coolant transfer tube.

Disconnect the turbocharger coolant vent line.

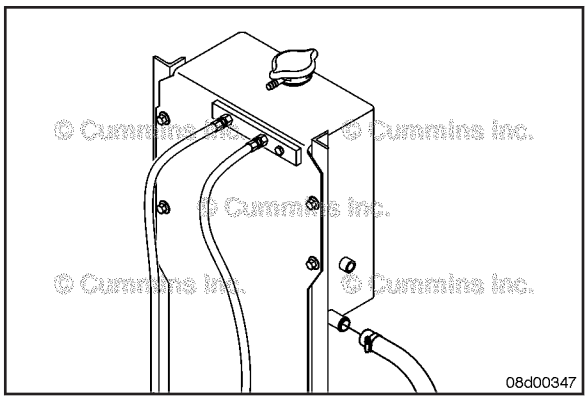
Remove the coolant vent lines at the front of the expansion tank.



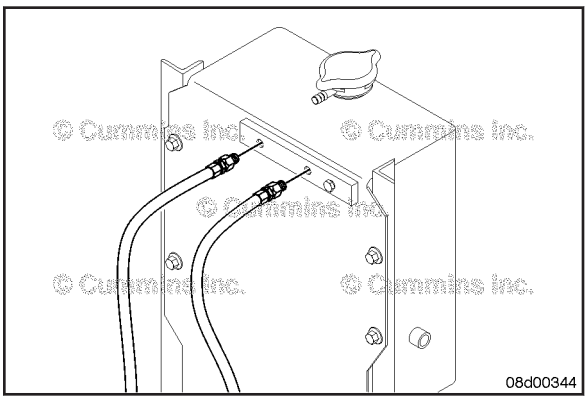
Remove the four mounting capscrews and lift the expansion tank from the engine.

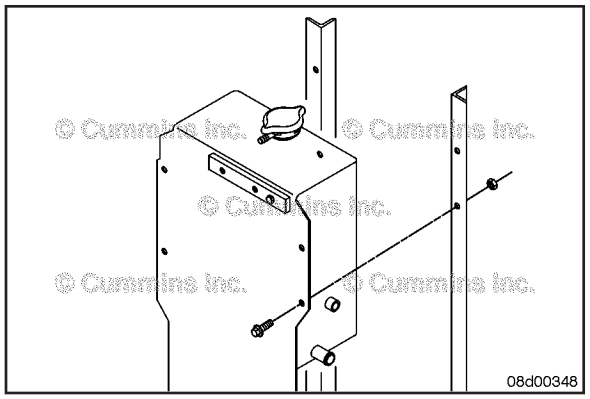


Disconnect the coolant make-up hose from the expansion tank and the coolant transfer tube.

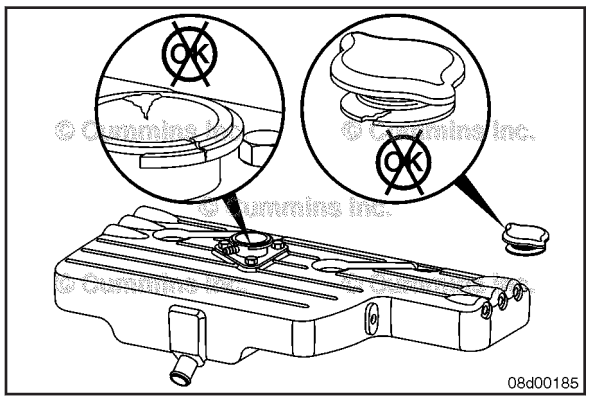


Remove the coolant vent lines from the rear of the expansion tank.





Remove the mounting capscrews and the expansion tank. Refer to the OEM troubleshooting and repair manual.

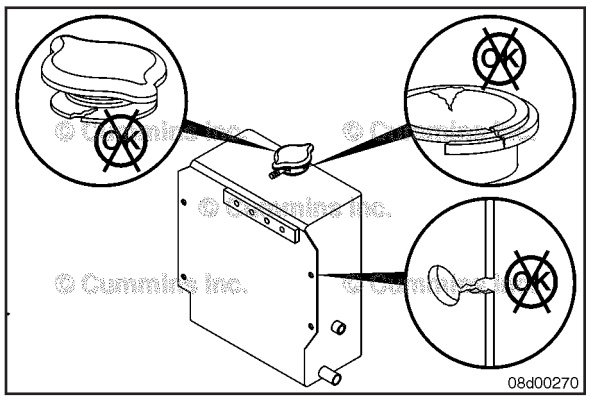


Inspect for Reuse

Inspect the mounting areas for cracks.

Inspect all connection points for cracks or signs of leakage.

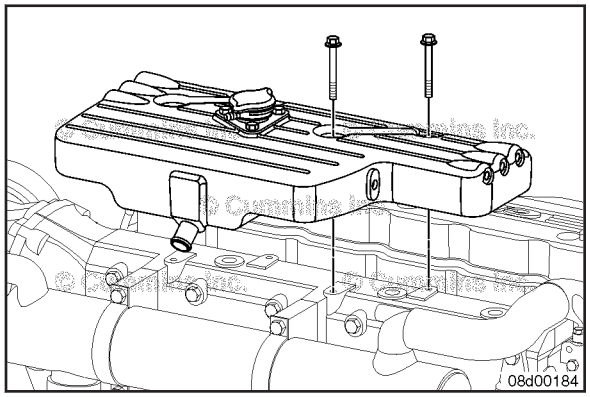
Inspect the fill neck and pressure cap for leakage or cracks.



Inspect the 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.



Install

Install the expansion tank onto the exhaust manifold.

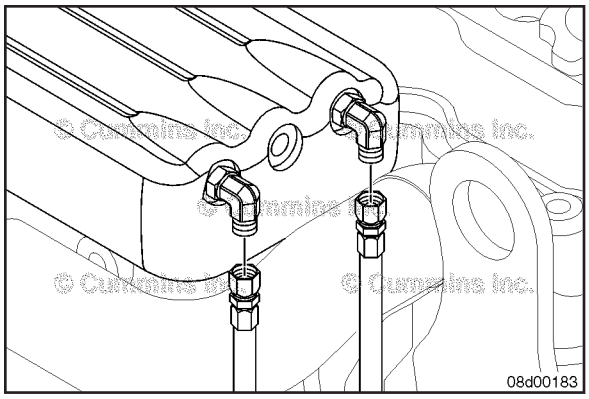
Install and tighten the four mounting capscrews.

Torque Value: 43 N•m [32 ft-lb]

Install the vent line connections at the front of the expansion tank.

Torque Value: 14 N•m [124 in-lb]

Install the fill neck (if removed)

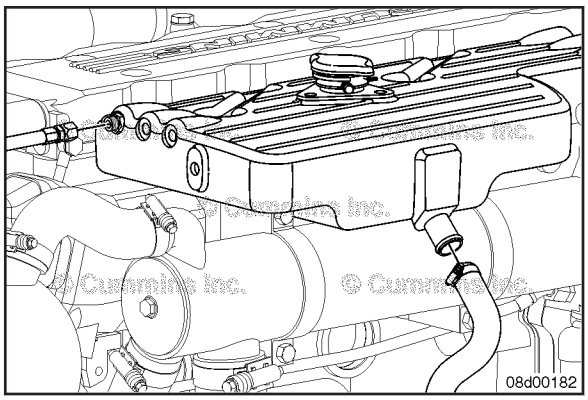


Install the turbocharger vent tube to the expansion tank.

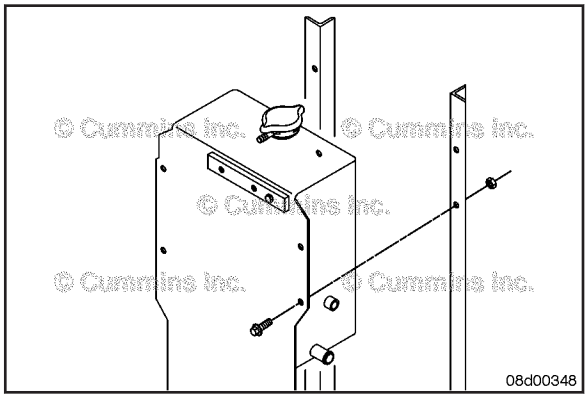
Torque Value: 14 N•m [124 in-lb]

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]

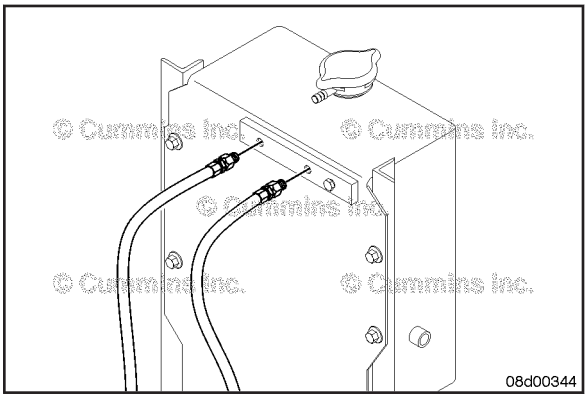


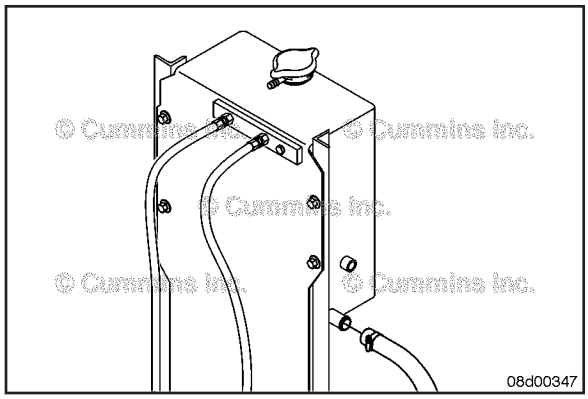
Install the expansion tank. Refer to the OEM troubleshooting and repair manual.



Install the coolant 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]

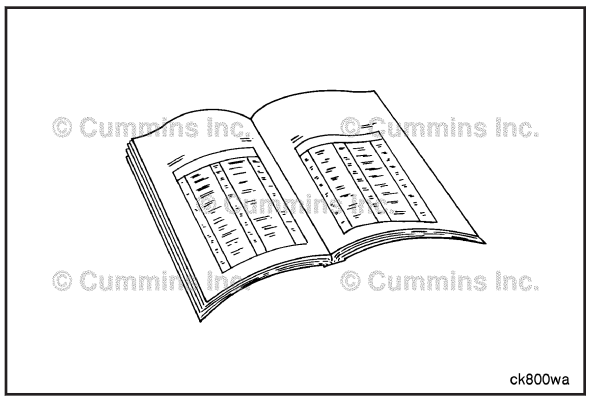




Install the coolant make-up hose and clamps to the expansion tank and coolant transfer tube.

Tighten the hose clamps.

Torque Value: 8 N•m [70 in-lb]



Finishing Steps

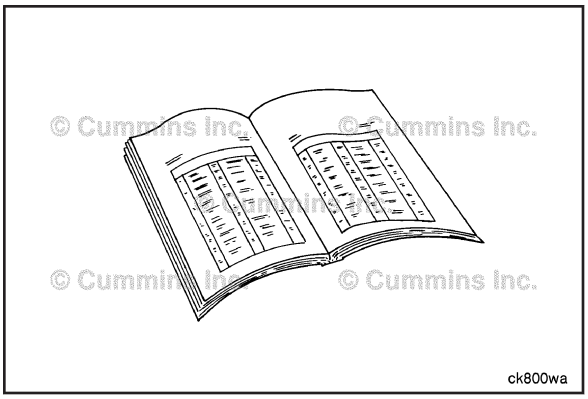
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Connect the engine coolant level sensor connector. Refer to Procedure 019-017 in Troubleshooting and Repair Manual, CM850 Electronic Control System, Bulletin 4021416.
- 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)

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. 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 battery power supply from the engine. Refer to Procedure 013-009 in Section 13.
- 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.

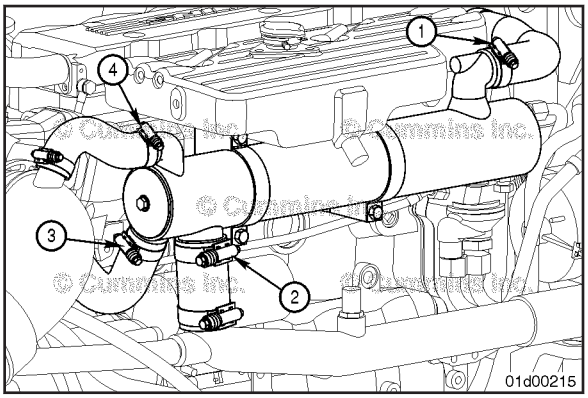
Remove

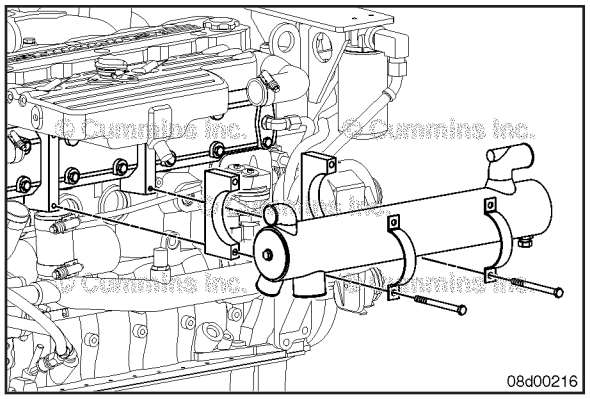
Loosen the hose clamp(s) on the engine coolant heat exchanger inlet hose (1). Disconnect the hose from the heat exchanger.

Loosen the hose clamp(s) on the engine coolant heat exchanger outlet hose (2). Disconnect the hose from the heat exchanger.

Loosen the hose clamp(s) to the sea water coolant heat exchanger inlet hose (3). Disconnect the hose from the heat exchanger.

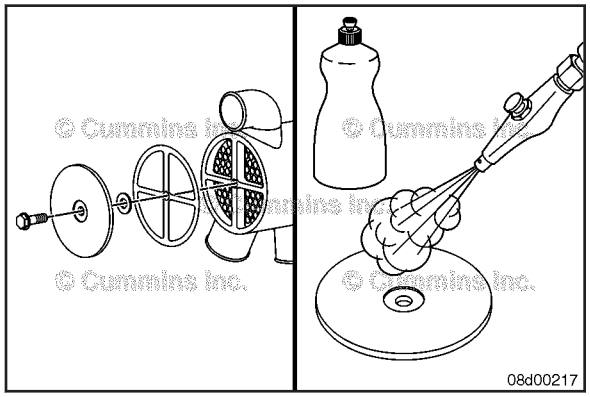
Loosen the hose clamp(s) on the sea water coolant heat exchanger outlet hose (4). Disconnect the hose from the heat exchanger.





NOTE: The rear mounting capscrew has a retaining clip.

Remove the four mounting capscrews, retaining clamps and isolators, and 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.

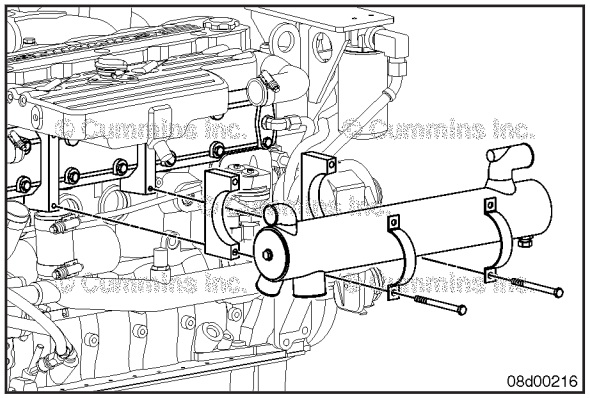
Remove the end caps and clean with soap and water.

Dry the end caps with compressed air.

Install a new gasket, seal, spacer and washer.

Install and tighten the end cap mounting capscrews.

Torque Value: 8 N•m [71 in-lb]



Install

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).

Connect the sea water coolant heat exchanger inlet hose (3).

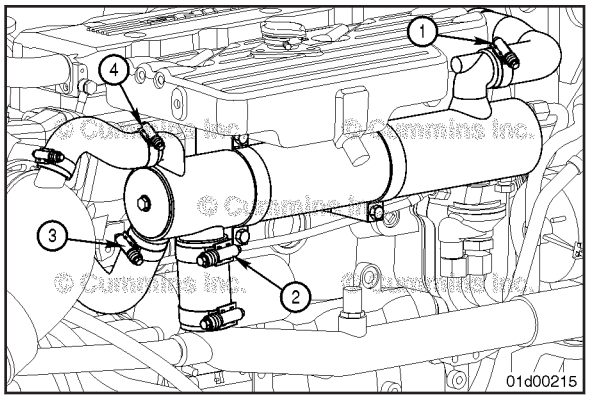
Connect the sea water coolant heat exchanger outlet hose (4).

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]



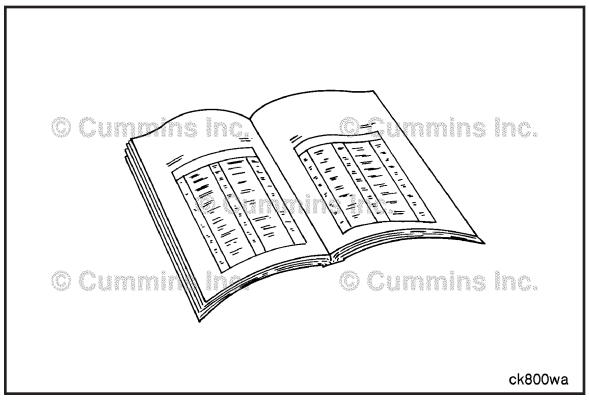
Finishing Steps

⚠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.

⚠CAUTION⚠
Use caution when filling 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.

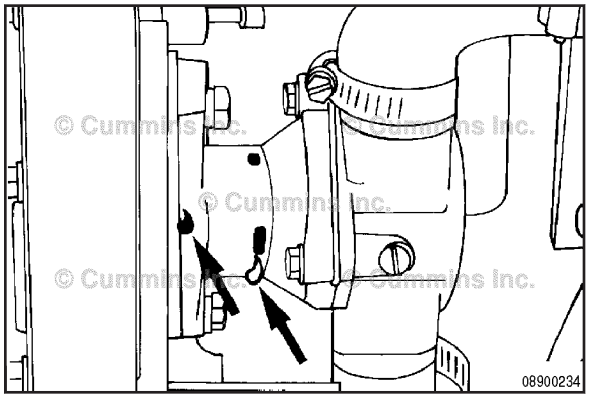
- Connect the coolant make-up hose from the expansion tank to the coolant transfer tube. Refer to Procedure 008-052 in Section 8.
- Fill the engine cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.

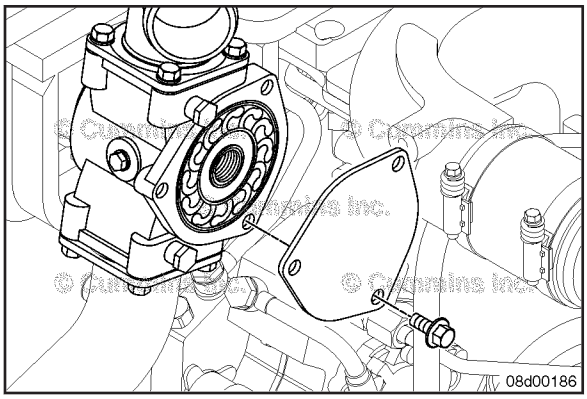


Sea Water Pump (008-057)

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.



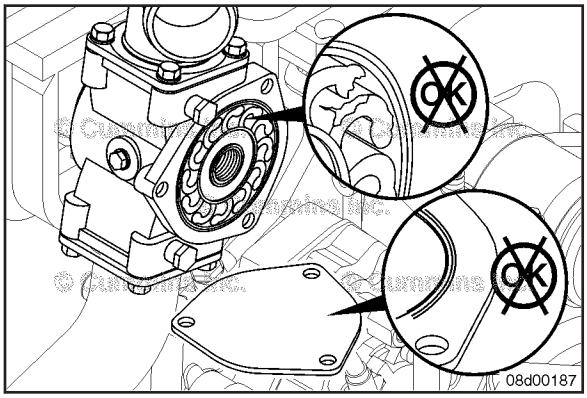


⚠CAUTION⚠
Zinc plugs expand and can break off during removal. Inspect the zinc plug to make sure it is in one piece. Refer to Procedure 008-059. If not, it must be replaced with a new zinc plug, and the broken pieces must be retrieved from the aftercooler to prevent damage to components downstream in the sea water system.

Shut off the sea water supply.

Drain the sea water pump by removing the zinc plug from the aftercooler. Refer to Procedure 010-005.

Remove the cover from the back of the sea water pump.



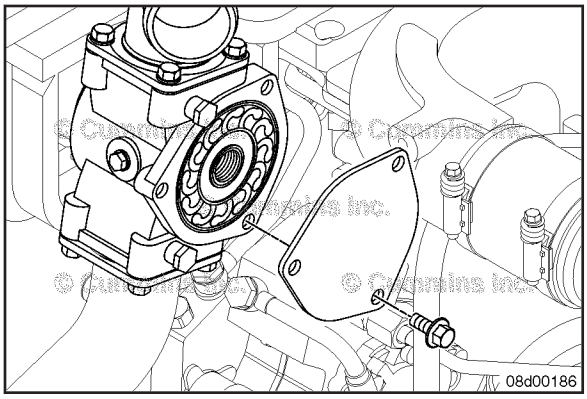
Inspect the cover for signs of grooves worn into the cover surface.

Inspect the impeller for missing, badly worn blades, or chunks of blades 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.

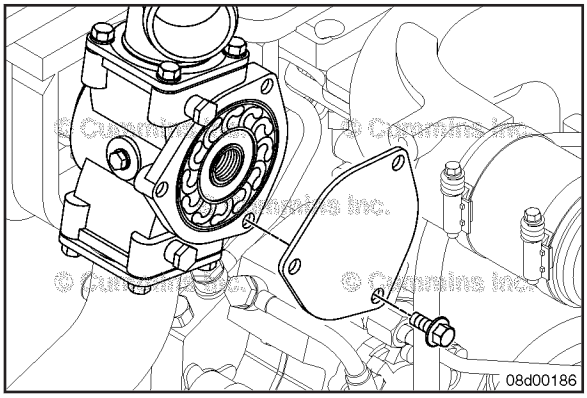
If the impeller is damaged, the sea water circuit down stream (fuel cooler and aftercooler and aftercooler element) of the pump **must** be checked and cleaned.

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⚠
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.

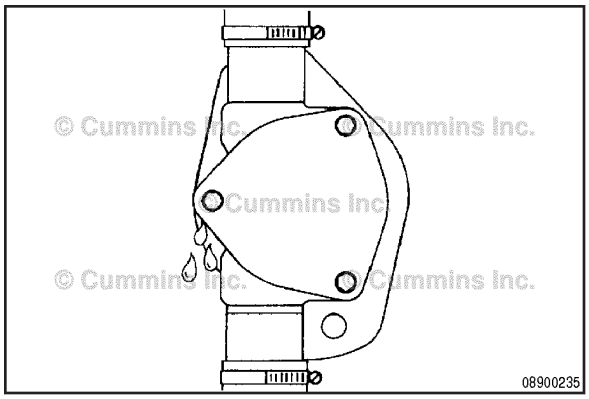
Shut off the sea water supply.

Drain the sea water pump by removing the zinc plug from the aftercooler. Refer to Procedure 010-005.

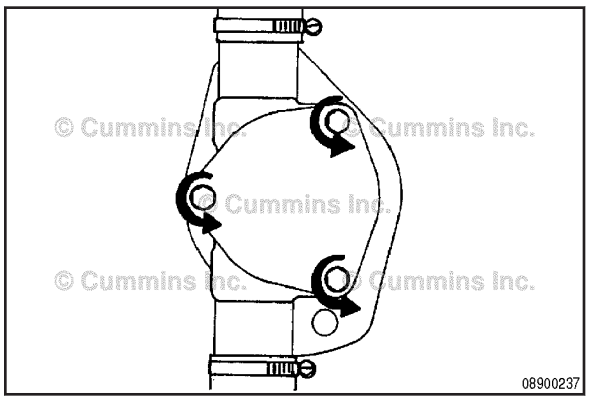
Remove the cover from the back of the sea water pump.

⚠CAUTION⚠
If the impeller has failed and pieces are missing, all pieces must be retrieved. The engine heat exchanger, gear oil cooler, and sea water aftercooler must be flushed. Refer to procedures 008-053, 008-041, 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.



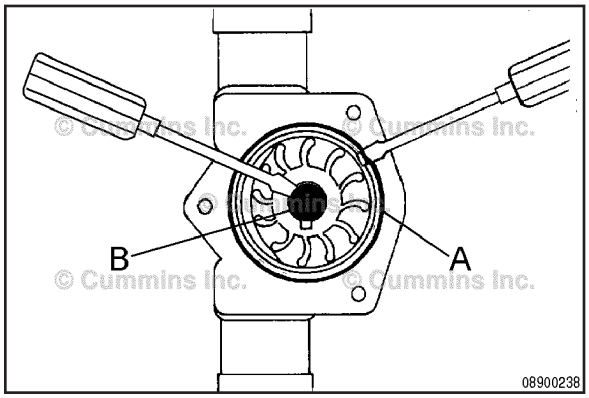
Remove the capscrews. Lift off the cover.



Use a small screwdriver to remove the o-ring (A).

Use a small screwdriver to remove the inner cap (B).

Clean the o-ring groove.

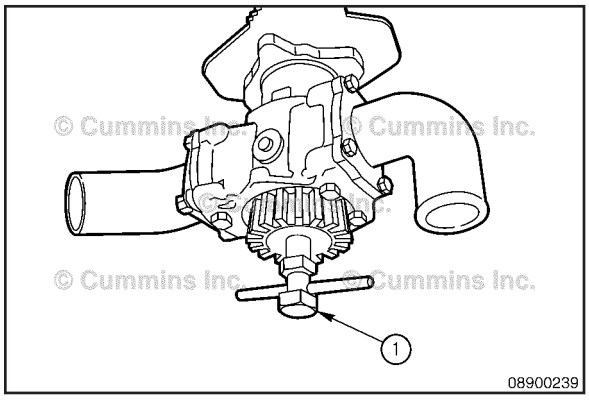


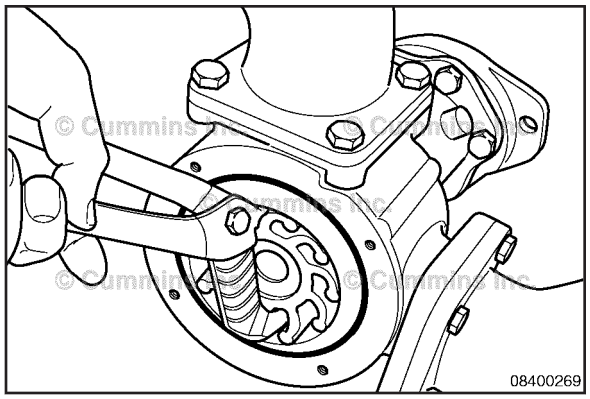
⚠CAUTION⚠
Do not pry against the pump housing to remove the impeller as this can cause damage to the liner.

Be sure to note the direction of impeller fins for proper re-installation. Mark the outer surface.

An impeller removal tool is available from Sherwood Pumps, Part Number 23631.

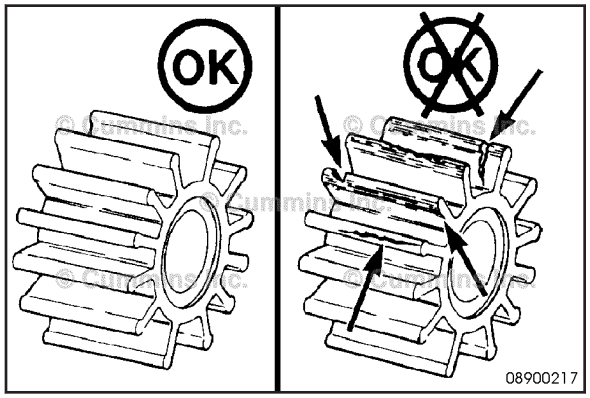
If the impeller is equipped with a threaded insert, use the special tool or a ¾-NFT bolt (1) to insert in the impeller to pull the impeller out.





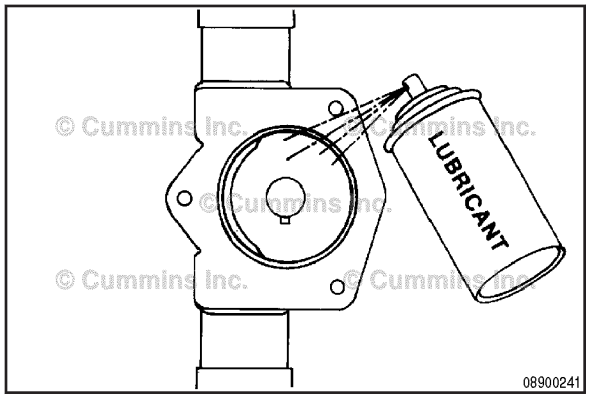
Be sure to note the direction of impeller fins for proper re-installation. Mark the outer surface.

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 blades.

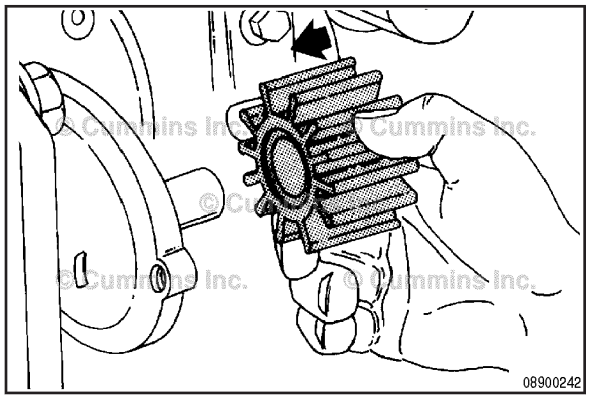
Replace as necessary.



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.

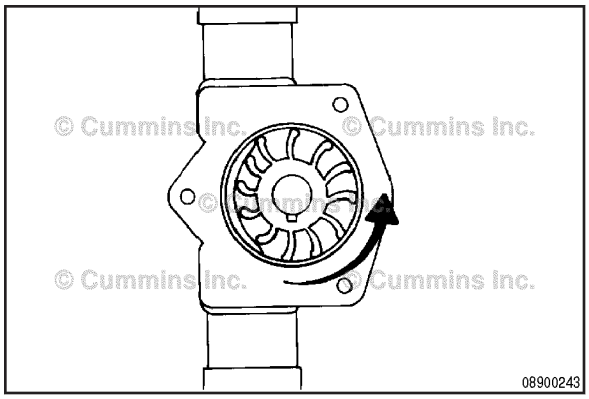


If the impeller is in good shape and will be reused, install it in the same direction from which it was removed. See the mark you made during removal.

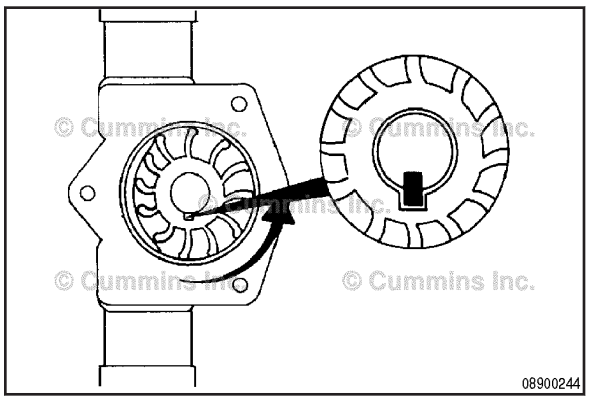
If the impeller was **not** marked and the original rotation or direction can **not** be determined, replace the impeller with a new one.

An oil filter strap wrench or even plastic wire straps can be used as an installation aid to hold the vanes.

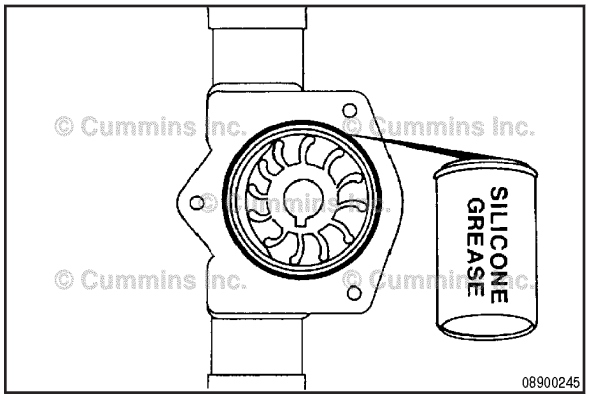
Guide the impeller into the housing, twisting it **counterclockwise** as it is advanced so that the vanes will be deflected in the proper direction.



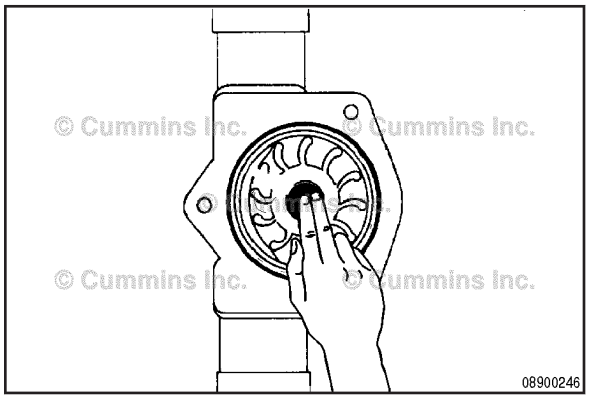
Continue to turn the impeller while pushing it into the housing. It will slide all the way in when the keyway lines up with the key.

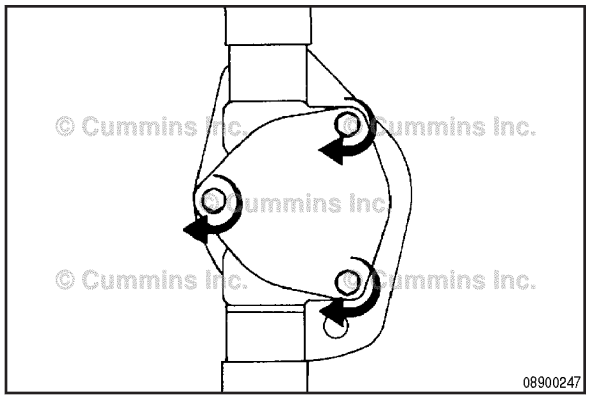


Insert the new o-ring into the impeller housing. Use a little silicone grease to hold it in place.



Install the rubber impeller cap into the center hub of the impeller.

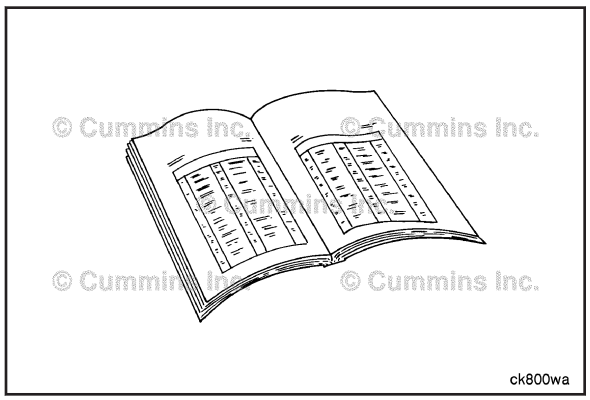




Install a new gasket, cover plate, and capscrews.

Tighten the capscrews.

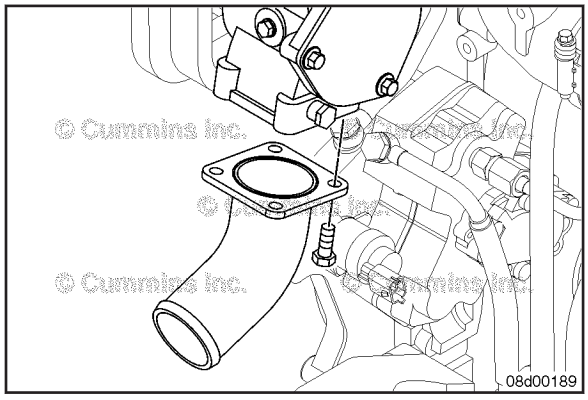
Torque Value: 24 N•m [212 in-lb]



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. Refer to Procedure 010-005.
- Remove the sea water pump inlet and outlet hoses. Refer to Procedure 008-104.
- Remove the belt guard. Refer to Procedure 008-001.
- Remove the sea water pump drive belt. Refer to Procedure 008-126.
- Remove the sea water pump drive pulley. Refer to Procedure 008-127.

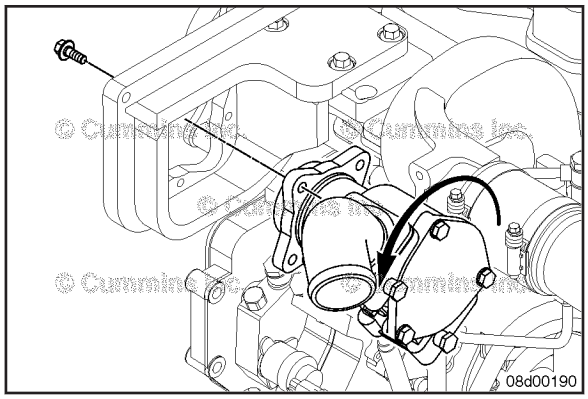


Remove

Remove the lower hose connection from the sea water pump.

Remove the four sea water pump mounting capscrews.

Rotate the sea water pump top hose connection away from the engine (**clockwise** when facing the front of the engine) until the mounting flange of the sea water pump aligns with the cutouts on the sea water pump mounting bracket, and remove the sea water pump.

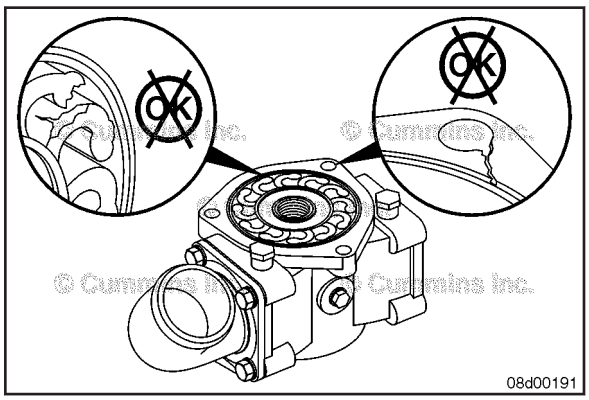


Inspect for Reuse

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.



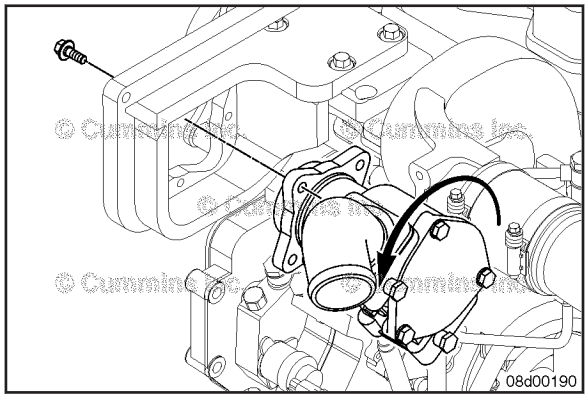
Install

NOTE: If a new sea water pump is being installed, the sea water pump **must** be painted before installation.

Install the sea water pump through the mounting bracket by twisting the top hose connection away from the engine so the sea water pump mounting flange will align with the cutouts on the sea water pump mounting bracket.

Insert the sea water pump through the mounting bracket and rotate the top hose connection toward the engine until the sea water pump mounting holes align with the mounting holes in the mounting bracket. Install the four mounting capscrews and tighten.

Torque Value: 24 N•m [18 ft-lb]

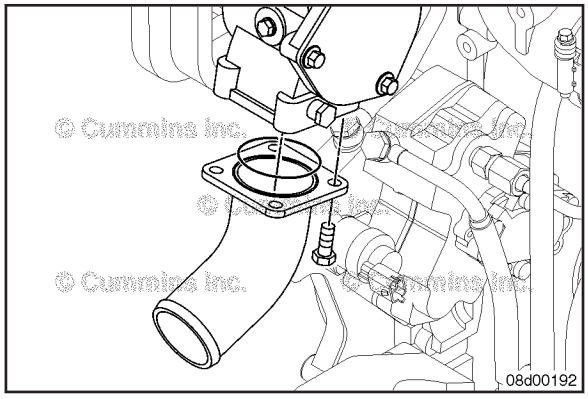


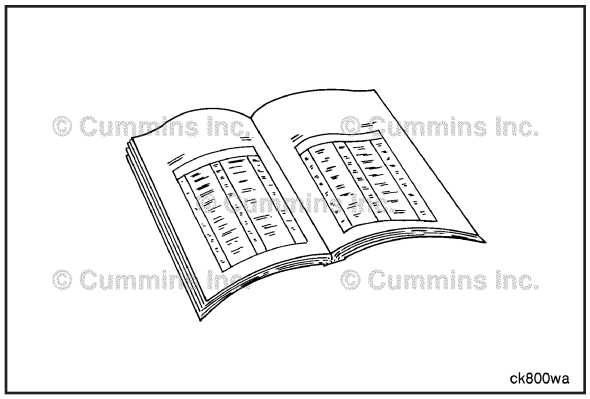
Install a new o-ring on the lower hose connection of the sea water pump.

Install the lower hose connection so it is oriented away from the engine at 45 to 50 degrees.

Install the four mounting capscrews and tighten the capscrews evenly using a crisscross pattern.

Torque Value: 24 N•m [18 ft-lb]

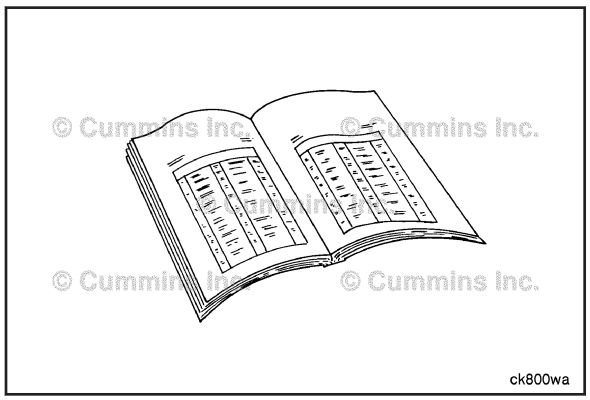




Finishing Steps

- Install the sea water pump inlet and outlet hoses. Refer to Procedure 008-104.
- Install the zinc plug in the aftercooler. Refer to Procedure 010-005.
- Install the sea water pump drive pulley. Refer to Procedure 008-127.
- Install the sea water pump drive belt. Refer to Procedure 008-126.
- Open the sea water supply.
- Install the belt guard. Refer to Procedure 008-001.

Operate the engine and check for leaks.

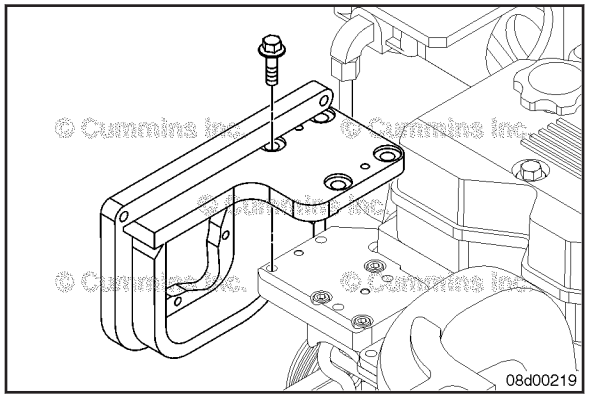


Sea Water Pump Support (008-058)

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.

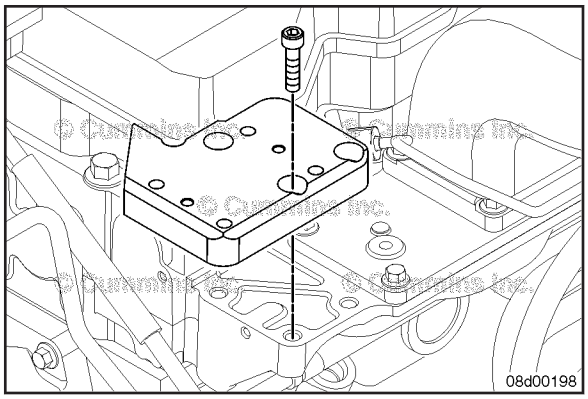
- Shut off the sea water supply valve(s).
- Drain the sea water pump by removing the zinc plug from the aftercooler. Refer to Procedure 010-005
- Remove the sea water pump inlet and outlet hoses. Refer to Procedure 008-104
- Remove the belt guard. Refer to Procedure 008-001
- Remove the sea water pump drive belt. Refer to Procedure 008-126
- Remove the sea water pump drive pulley. Refer to Procedure 008-127
- Remove the sea water pump drive belt tensioner. Refer to Procedure 009-058
- Remove the sea water pump. Refer to Procedure 008-057



Remove

Remove the four sea water pump mounting bracket capscrews and the sea water pump mounting bracket.

Remove the sea water pump mounting bracket support.



Clean and Inspect for Reuse

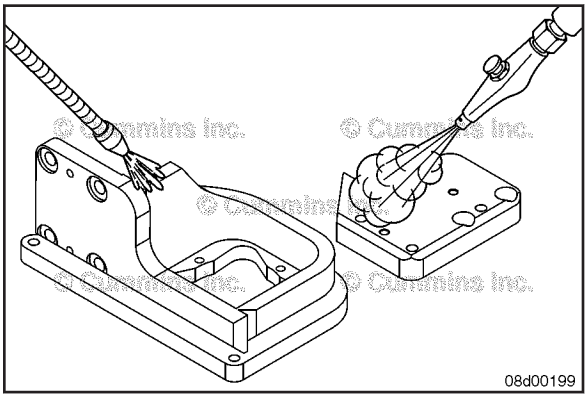
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

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

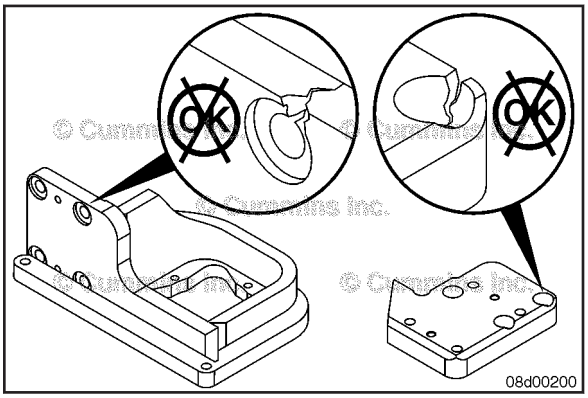
Use solvent to clean the support and mounting bracket.

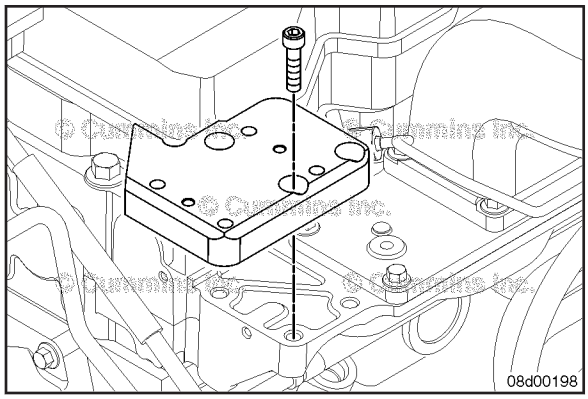
Dry with compressed air.



Inspect the support and mounting bracket for cracks or other damage.

If the parts are cracked, they **must** be replaced.

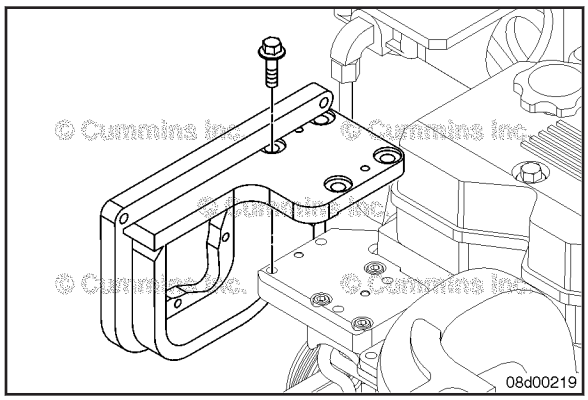




Install

Install the sea water pump mounting bracket support. Push the mounting bracket support against the front of the cylinder head and hold in place while the capscrews are being tightened to maintain belt alignment.

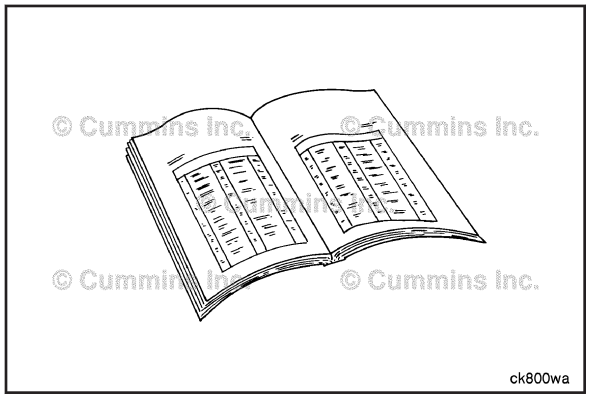
Torque Value: 44 N•m [32 ft-lb]



Install the sea water pump mounting bracket and mounting capscrews.

Tighten the capscrews.

Torque Value: 44 N•m [32 ft-lb]



Finishing Steps

- Install the sea water pump. Refer to Procedure 008-057
- Install the sea water pump drive belt tensioner. Refer to Procedure 009-058
- Install the sea water pump drive pulley. Refer to Procedure 008-127
- Install the sea water pump drive belt. Refer to Procedure 008-126
- Install the belt guard. Refer to Procedure 008-001
- Install the sea water pump inlet and outlet hoses. Refer to Procedure 008-104
- Install the zinc plug into the aftercooler. Refer to Procedure 010-005
- Open the sea water supply valve(s).

Operate the engine and check for leaks.

Zinc Anode (008-059)

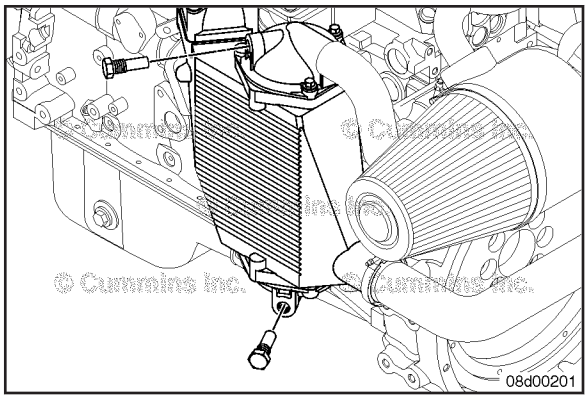
Remove

⚠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.

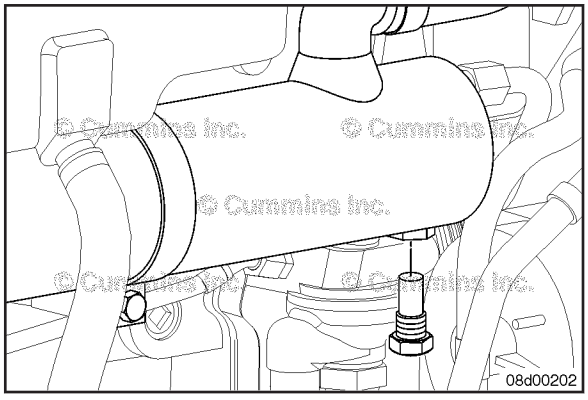
⚠CAUTION⚠
In some cases, it will be necessary to hold the welded fitting on the heat exchanger with an additional wrench to prevent damage to the heat exchanger.

QSB5.9 marine engines have three zinc plugs, two in the aftercooler assembly and one in the heat exchanger assembly.

Shut off the sea water supply valve(s) and remove the zinc anode plugs from the bottom and top of the aftercooler assembly.



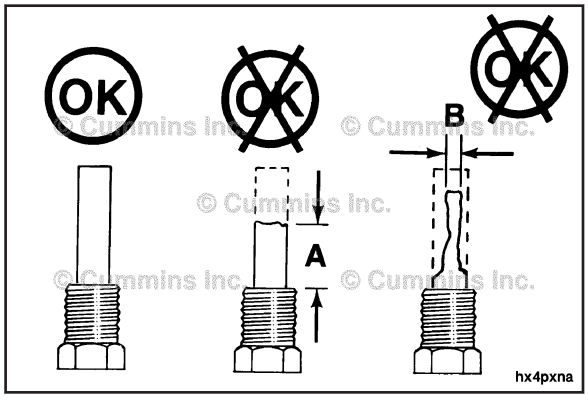
Remove the zinc anode plug from the bottom of the heat exchanger.



Inspect the sacrificial zinc 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.

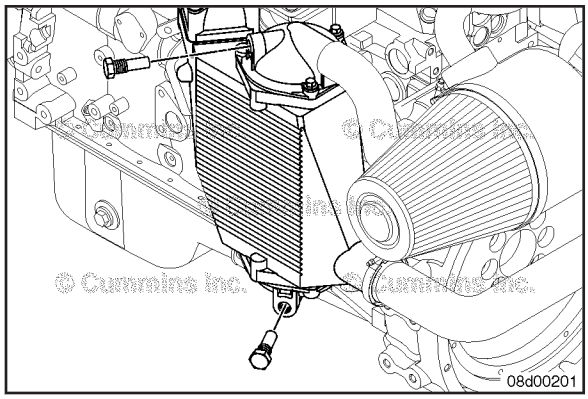
Check the length of all the zinc plugs in the heat exchanger and aftercooler, and replace them if they are 50 percent eroded. Frequency of replacement depends upon the chemical reaction of raw water circulated through the heat exchanger and aftercooler.



Zinc 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 plug does **not** meet specification, replace it with a new zinc plug.



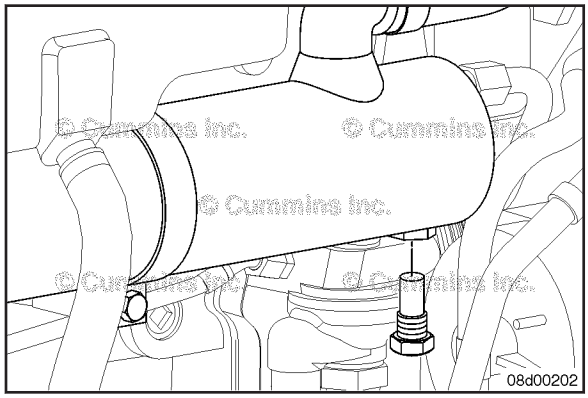
Install

⚠CAUTION⚠

Do not use thread sealant or Teflon™ tape on the zinc anodes. 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]

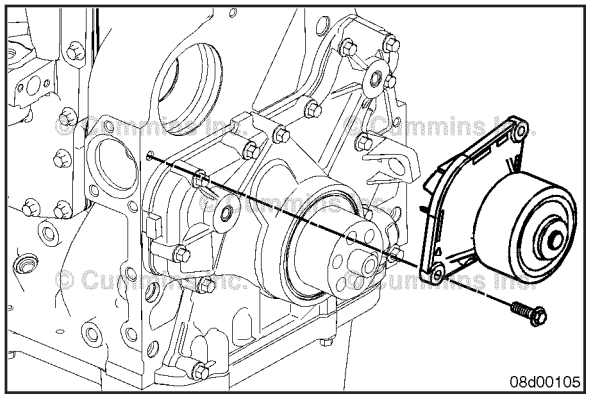


Install the zinc anode plug in the bottom of the heat exchanger.

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

The water pump is a belt-driven, centrifugal-type pump with the inlet and bypass as integral parts of the cylinder block.

NOTE: It is **not** practical to replace the components of the water pump; the water pump is serviced as an assembly.

Initial Check

Inspect the water pump housing for cracks and/or damage.

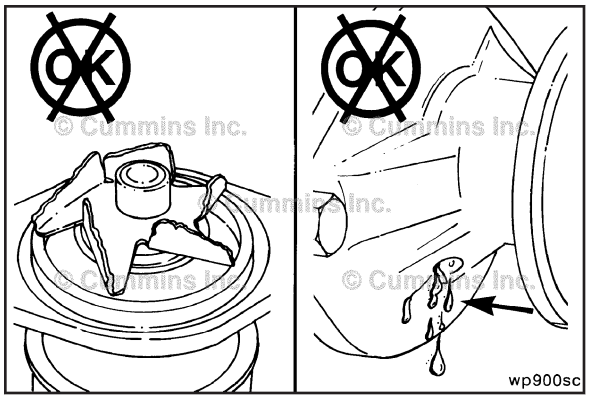
Check the water pump seal weep hole. The water pump seal design requires a coolant film for lubrication and cooling. Therefore, it is normal to observe a minor chemical buildup or streaking at the weep hole.

Use the following guidelines to determine if water pump replacement is necessary:

Make sure the weep hole is open.

NOTE: A small screwdriver or a similar tool can be used to remove any debris.

If no leakage is observed from the weep hole under operating conditions, do **not** replace the water pump.



Preparatory Steps

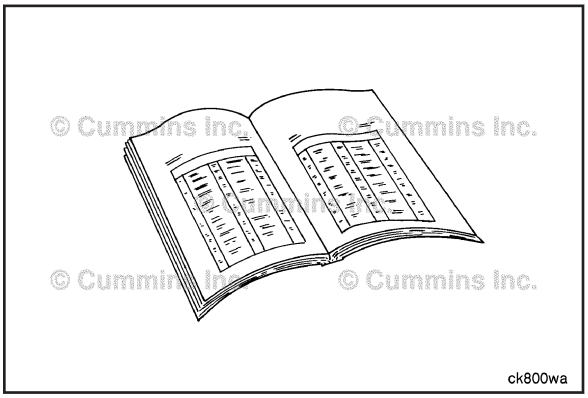
Automotive and Industrial

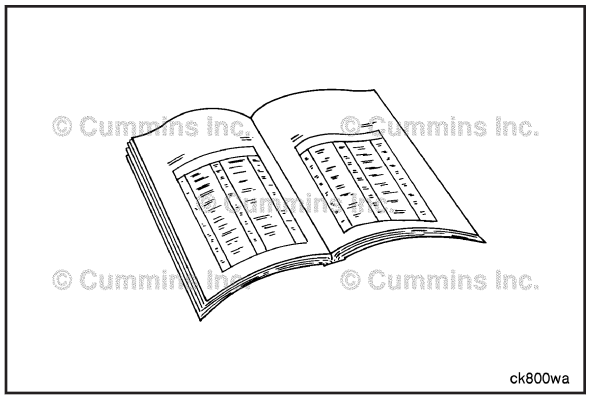
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the batteries. Refer to the OEM service manual.
- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.
- Remove the cooling fan drive belt. Refer to Procedure 008-002 in Section 8.





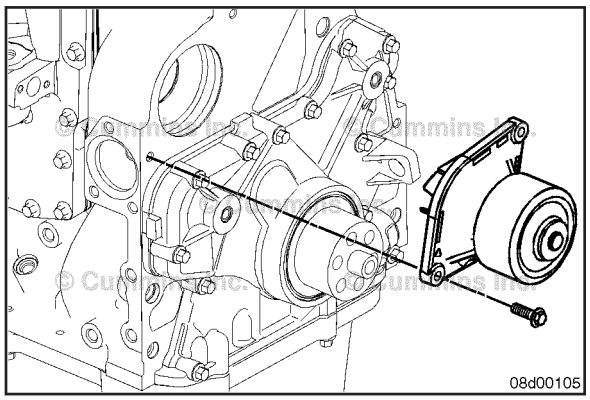
Marine Applications

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

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the batteries. Refer to the OEM service manual.
- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.
- Remove the upper and lower belt guards. Refer to Procedure 008-001 in Section 8.
- Remove the water pump drive belt from the alternator and water pump pulleys. This can be done without removing the sea water pump drive belt. Refer to Procedure 008-002 in Section 8.



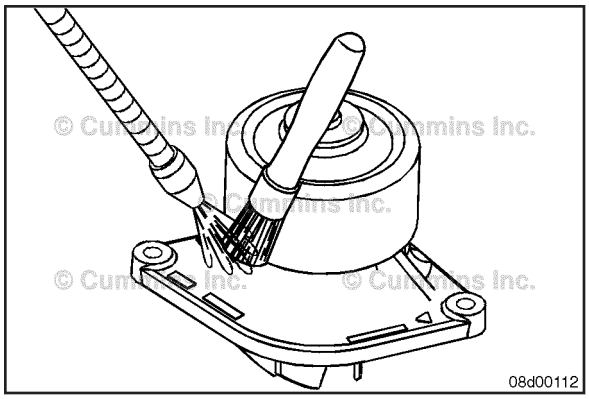
Remove

Remove the water pump mounting capscrews.

Remove the water pump.

Remove and discard the o-ring seal.

Clean and Inspect for Reuse



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

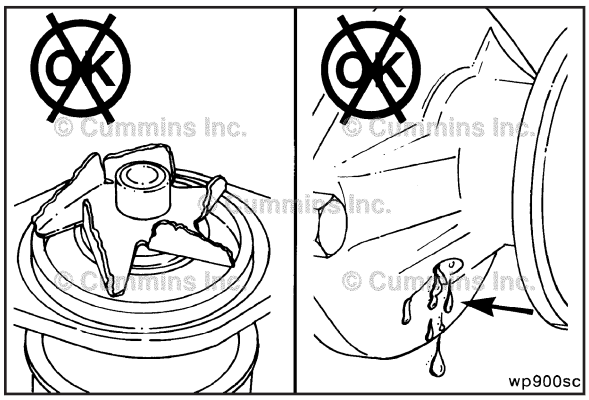
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

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

Clean the water pump with solvent. Dry with compressed air.

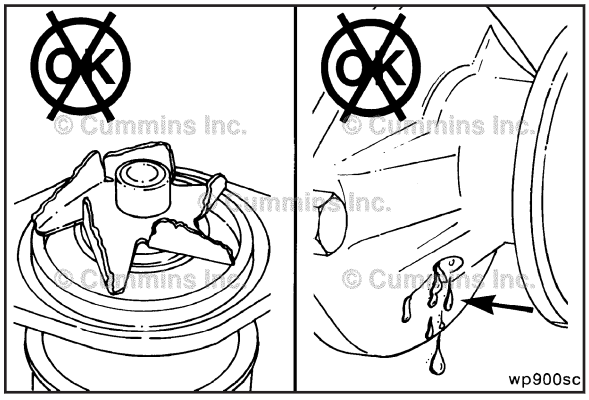
Inspect the impeller for cracks, missing blades, slippage on the shaft, and other types of damage.

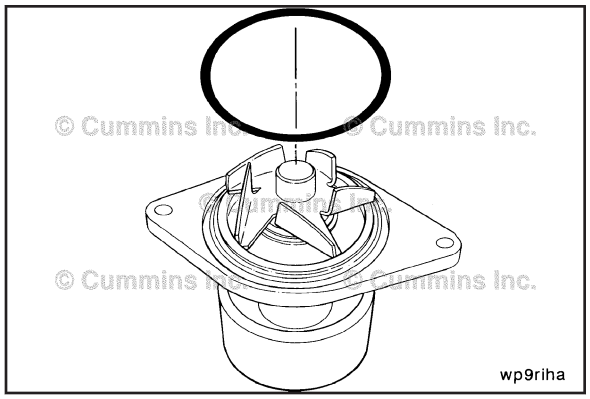
Replace the water pump if any damage is found.



Inspect the water pump housing for damage and cracks.

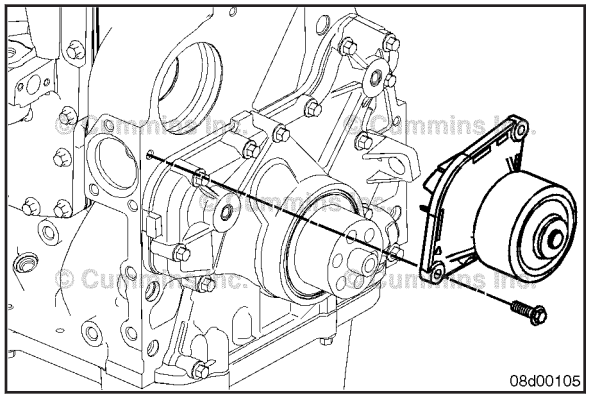
Replace the water pump if any damage is found.





Install

Install a new sealing ring into the water pump groove.

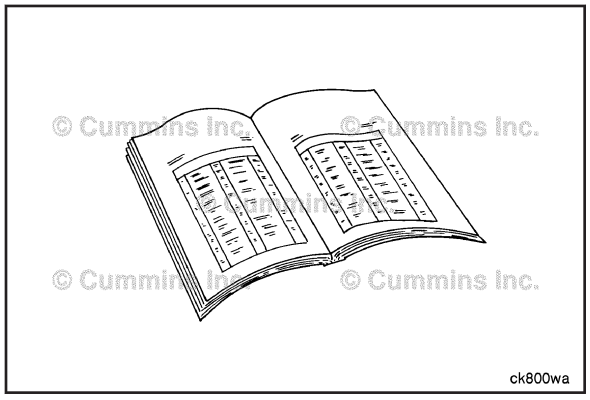


Install the water pump and mounting capscrews.

Tighten the capscrews.

Torque Value:
9.8 Grade 24 N•m [212 in-lb]

Torque Value:
10.9 Grade 30 N•m [22 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⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

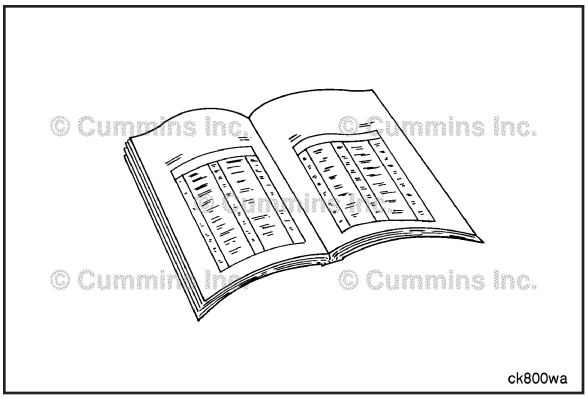
- Install the cooling fan drive belt. Refer to Procedure 008-002 in Section 8.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine until it reaches a temperature of 88°C [190°F].
- Check for coolant leaks.

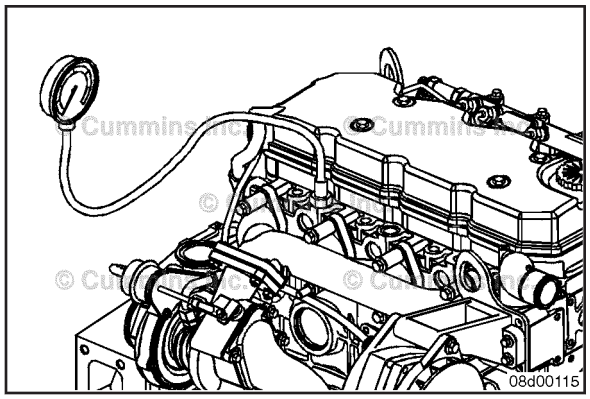
Marine Applications

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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 water pump drive belt. Refer to Procedure 008-002 in Section 8.
- Install the belt guards. Refer to Procedure 008-001 in Section 8.
- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine until it reaches a temperature of 88°C [190°F].
- Check for coolant leaks.





Measure

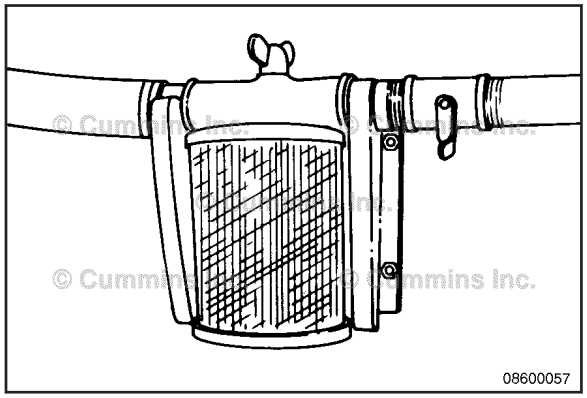
Measure the coolant pressure at a coolant tap on the exhaust side of the cylinder head. Marine applications, use the 3/4-inch NPT plug at the rear of the cylinder head.

NOTE: Marine applications use the 3/4-inch NPT plug at the rear of the cylinder head.

Minimum Pressure Gauge Capacity		
kPa		psi
207	MIN	30

Cooling System Pressure - Open Thermostat - Marine and without EGR - without Pressure Cap			
	kPa		psi
Water Outlet at 2000 rpm	17.2	MIN	2.5
½-NPT Head Port at 2000 rpm	68.9	MIN	10.0
¾-NPT Head Port at 2000 rpm	82.7	MIN	12.0
Water Outlet at 2500 rpm	24.1	MIN	3.5
½-NPT Head Port at 2500 rpm	99.9	MIN	14.5
¾-NPT Head Port at 2500 rpm	117.2	MIN	17.0

Cooling System Pressure - Open Thermostat - with EGR - without Pressure Cap			
	kPa		psi
Water Outlet at 2000 rpm	20.7	MIN	3.0
½-NPT Head Port at 2000 rpm	56.5	MIN	8.2
¾-NPT Head Port at 2000 rpm	64.8	MIN	9.4
Water Outlet at 2500 rpm	29.0	MIN	4.2
½-NPT Head Port at 2500 rpm	81.4	MIN	11.8
¾-NPT Head Port at 2500 rpm	93.1	MIN	13.5



Sea Water Strainer (008-067)

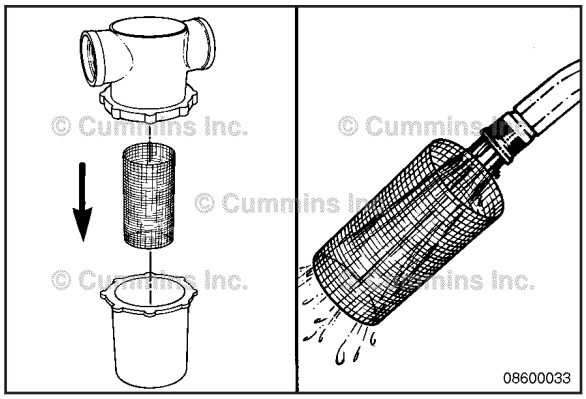
General Information

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.

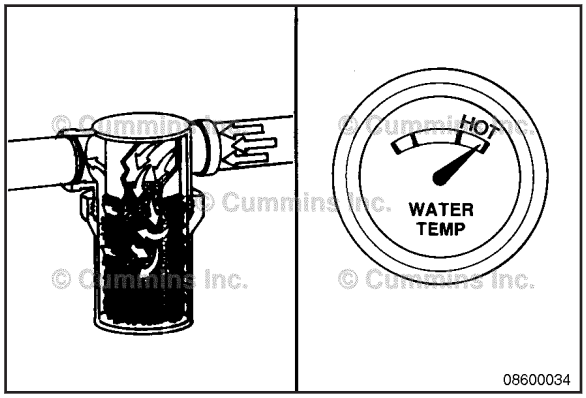
Inspect the sea water strainer daily for any foreign objects that could restrict water flow.



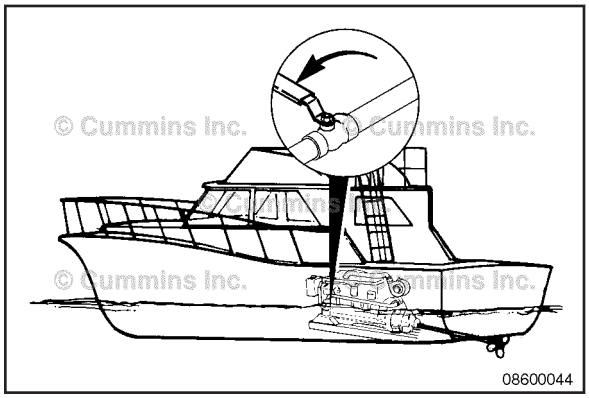
⚠CAUTION⚠

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.



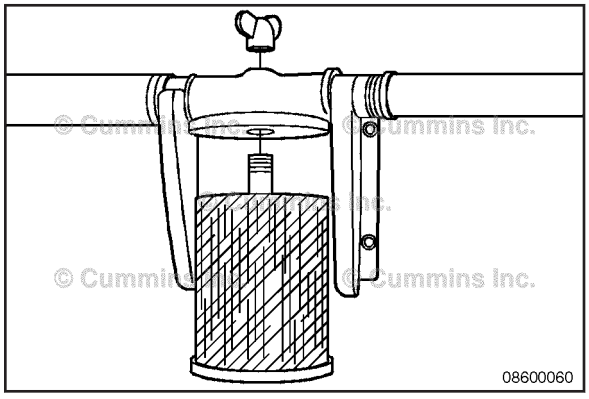
NOTE: If the sea water strainer is below the water level, close the sea water inlet valves before servicing the sea water strainer.

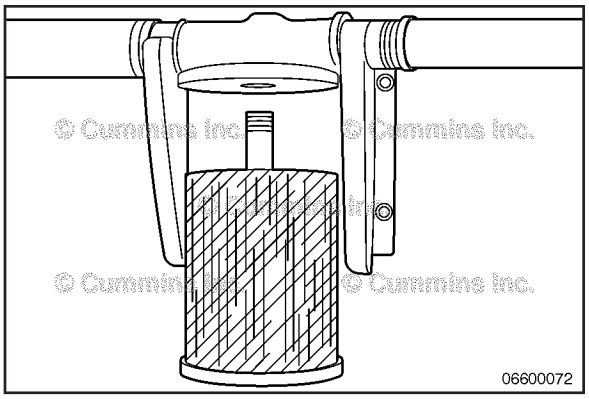


Disassemble

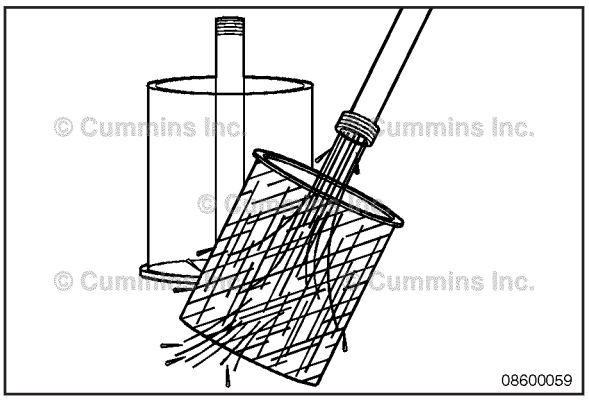
Marine Applications

Loosen and remove the sea water strainer wing nut(s) as required.

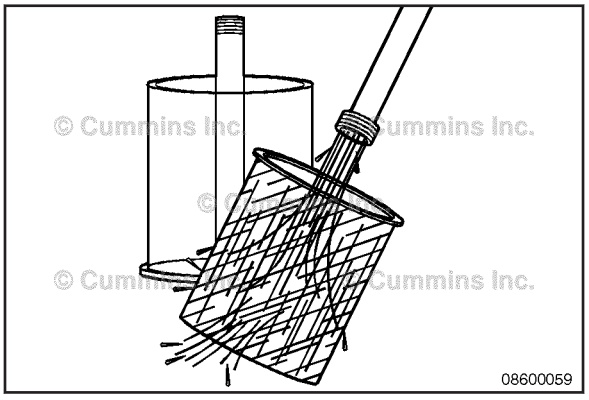




Remove the sea water strainer assembly. Be careful **not** to damage o-ring. Retain and inspect for damage.



Remove the sea water strainer basket.

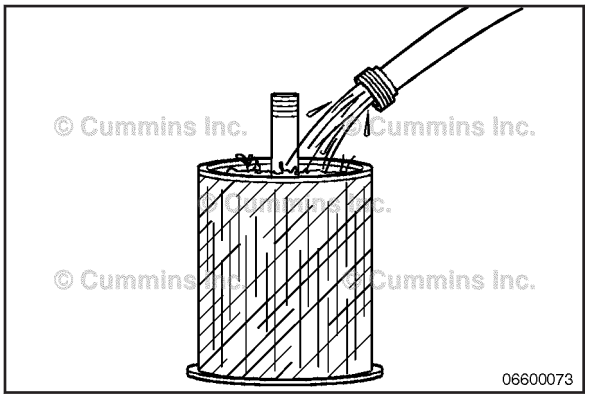


Clean

Marine Applications

Empty all debris from the sea water strainer basket.

Clean the sea water strainer.



Prime

Marine Applications

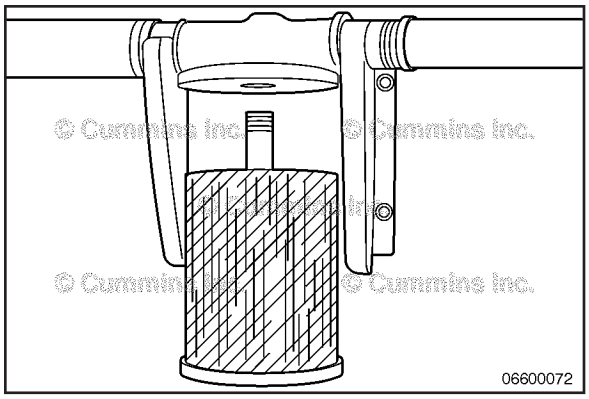
Prime the sea water strainer with clean water.

Assemble

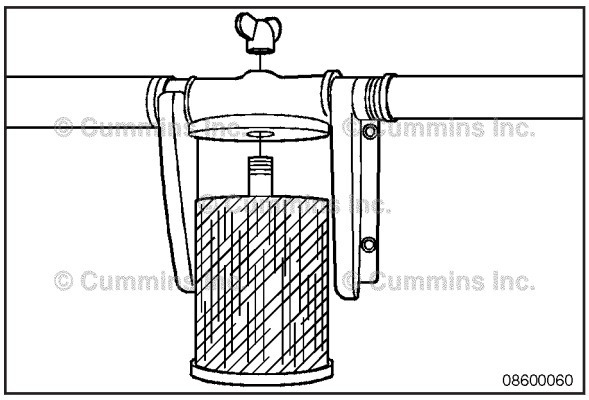
Marine Applications

Install the sea water strainer.

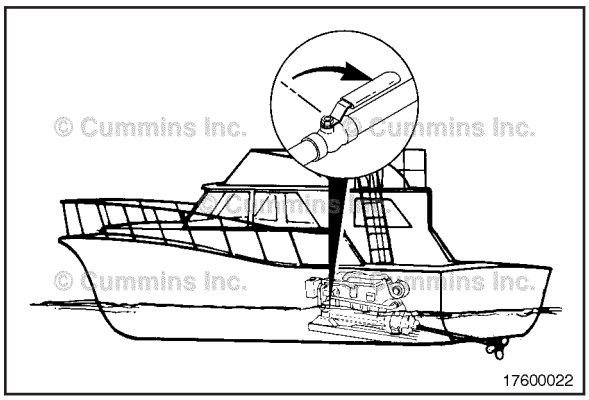
Inspect o-ring seal for tears or damage. Replace if necessary. Be sure o-ring is seated properly.



Install and tighten the wing nut(s).



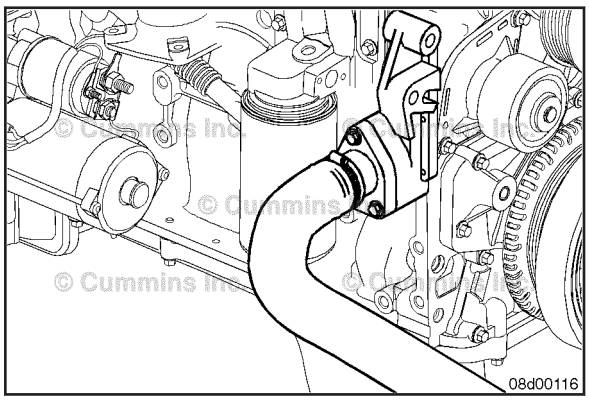
Open the sea water inlet valves.

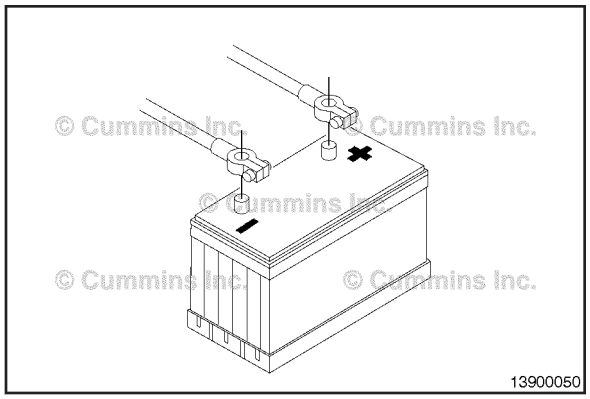


Water Inlet Connection (008-082)

Initial Check

Check the alignment of the fan belt and for evidence of leaks.

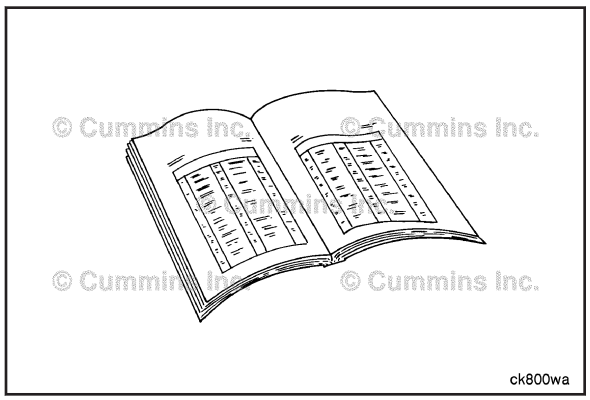




Preparatory Steps

⚠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.

Disconnect the batteries.



⚠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.

Drain the cooling system. Refer to Procedure 008-018

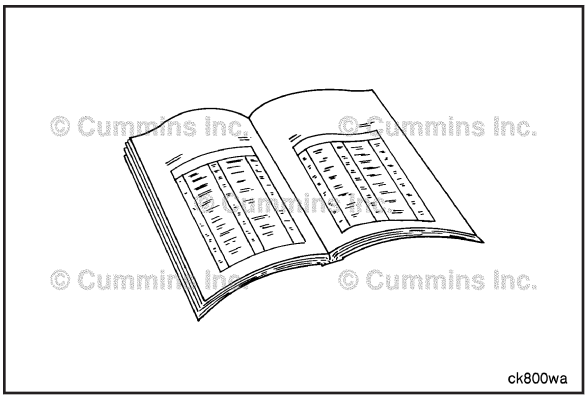
Remove the cooling fan drive belt. Refer to Procedure 008-002

Remove the fan belt tensioner. Refer to Procedure 008-087

Remove the lower radiator hose. Refer to Procedure Procedure 008-045

If necessary, remove the alternator. Refer to Procedure Procedure 013-001

If necessary, remove the alternator mounting brackets. Refer to Procedure Procedure 013-003



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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 the belt guards. Refer to Procedure 008-001

Remove the water pump drive belt from the alternator pulley and the belt tensioner. This can be done without removing the sea water pump drive belt. Refer to Procedure 008-002

Remove the fan belt tensioner. Refer to Procedure 008-087

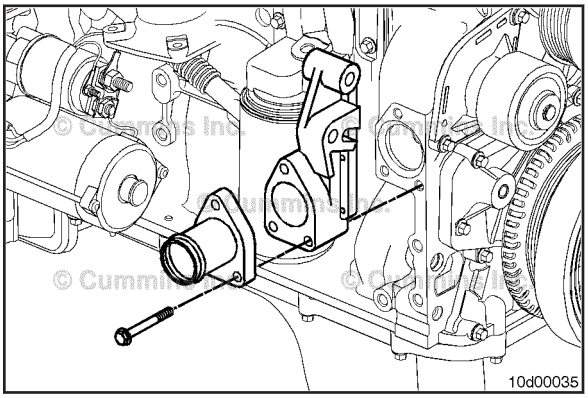
Remove the alternator. Refer to Procedure 013-001

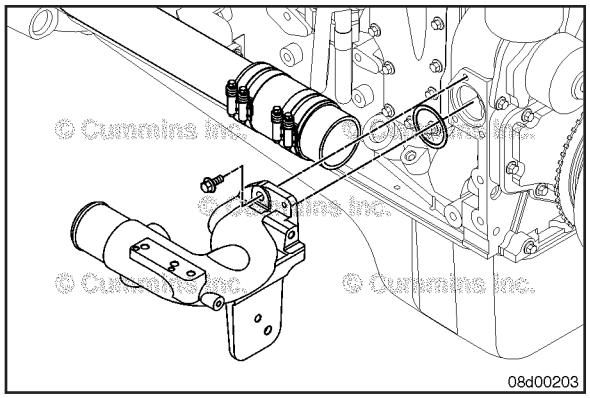
Remove the alternator mounting bracket. Refer to Procedure 013-003

Remove

Remove the coolant hoses.

Remove the capscrews, water inlet connection, gasket, and rectangular sealing ring.

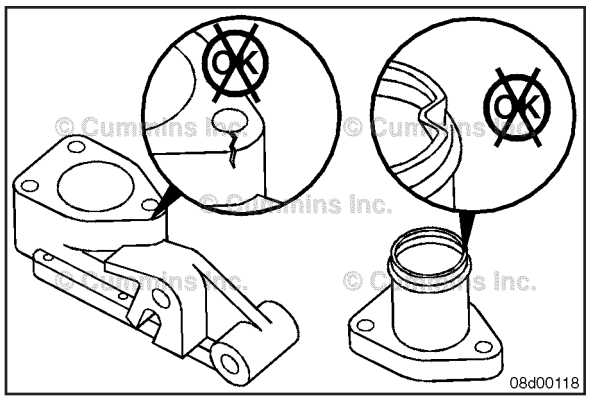




Loosen and slide the two hose clamps on the coolant return junction connection hose back on the coolant return junction.

Remove the three mounting capscrews from the water inlet connection.

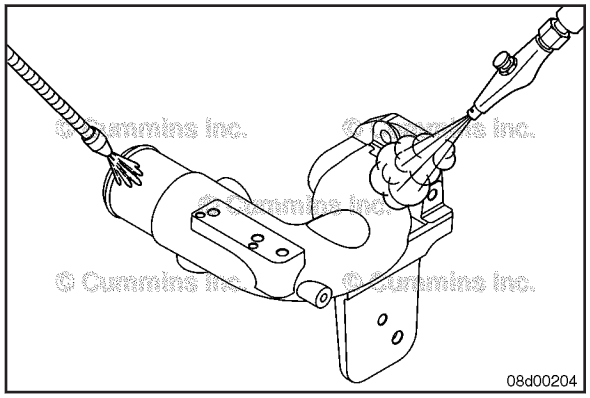
Slide the water inlet connection from the coolant return junction and remove the water pump inlet and sealing ring. Discard the sealing ring.



Clean and Inspect for Reuse

Inspect the rectangular sealing ring for cracks.

If evidence of leaking exists, replace rectangular sealing ring.



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

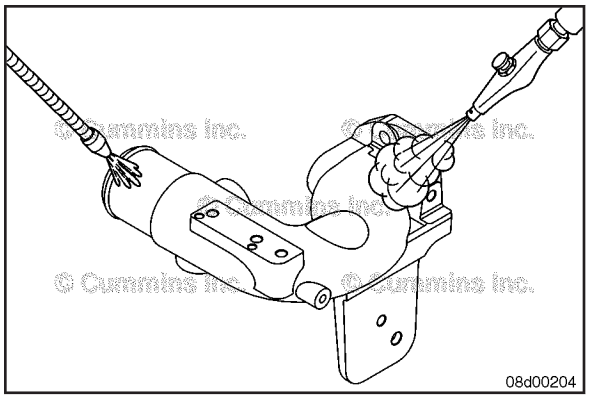
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

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

Clean the inlet connection with solvent.

Dry with compressed air.

Inspect the sealing surface for cracks or other damage.



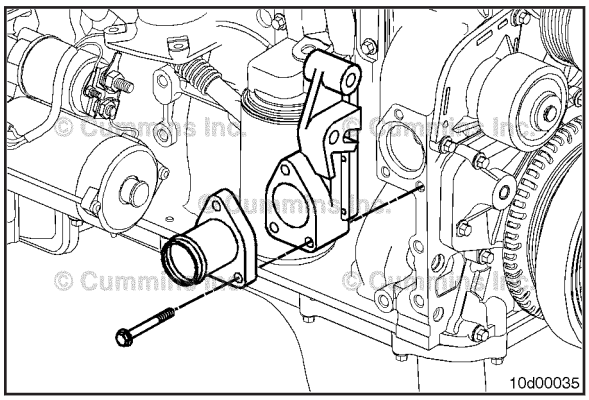
Install

Install the capscrews, water inlet connection, gasket, and rectangular sealing ring.

Align the roll pins against the front face of the cylinder block and tighten the capscrews.

Torque Value:
M10
Step 1 43 N•m [32 ft-lb]

Torque Value:
M12
Step 1 80 N•m [59 ft-lb]



Install the coolant hoses.

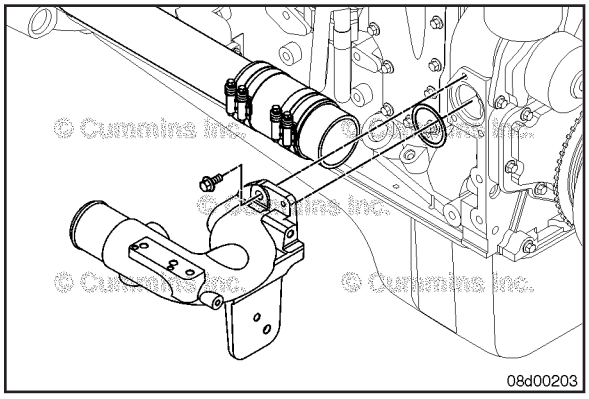
NOTE: The upper water inlet connection mounting capscrew is shorter than the two lower capscrews. Install the shorter capscrew in the upper mounting hole.

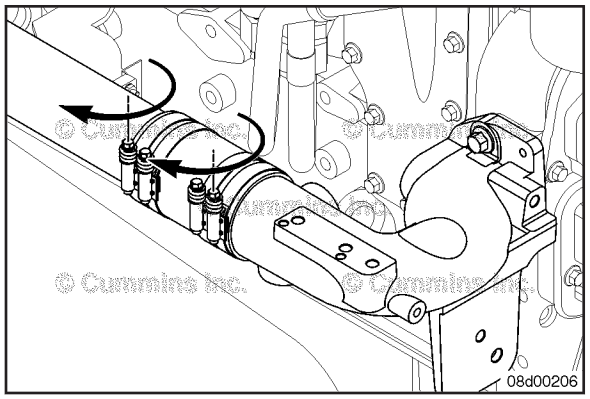
Install a new rectangular seal ring onto the engine block. A small amount of Lubriplate™ multi-purpose lubricant can be used to hold the ring in place.

Slide the water inlet connection into the hose connection of the coolant return junction until the mounting capscrew holes line up with the holes in the cylinder block and the dowel pins contact the front of the machined block surface. The dowel pins are for making sure of correct belt alignment.

Install the three mounting capscrews in the connection. Tighten the capscrews.

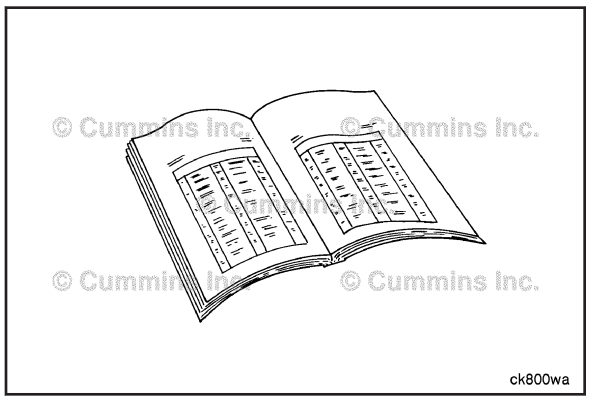
Torque Value: 43 N•m [32 ft-lb]





Slide the two hose clamps into place on the coolant return junction connection and tighten.

Torque Value: 8 N•m [71 in-lb]



Finishing Steps

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

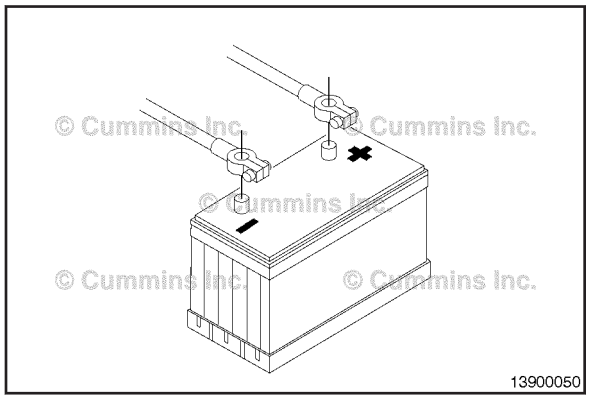
Install the fan belt tensioner. Refer to Procedure 008-087

Install the cooling fan drive belt. Refer to Procedure 008-002

Install the lower radiator hose. Refer to Procedure Procedure 008-045

If necessary, install the alternator and alternator mounting brackets. Refer to Procedure Procedure 013-001 and Refer to Procedure Procedure 013-003

Fill the cooling system. Refer to Procedure 008-018



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

Operate the engine and check for leaks, alignment, and tension on the drive belt.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Fill the engine with coolant. Refer to Procedure 008-018

Install the fan belt tensioner. Refer to Procedure 008-087

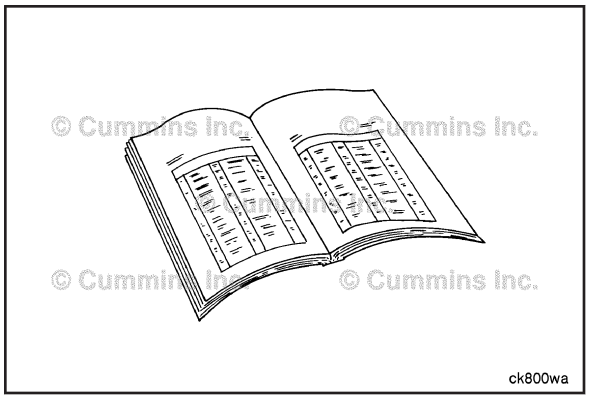
Install the alternator mounting bracket. Refer to Procedure 013-003

Install the alternator. Refer to Procedure 013-001

Connect the batteries. Refer to Procedure 013-009

Install the water pump drive belt onto the alternator pulley and the belt tensioner. This can be done without removing the sea water pump drive belt. Refer to Procedure 008-002

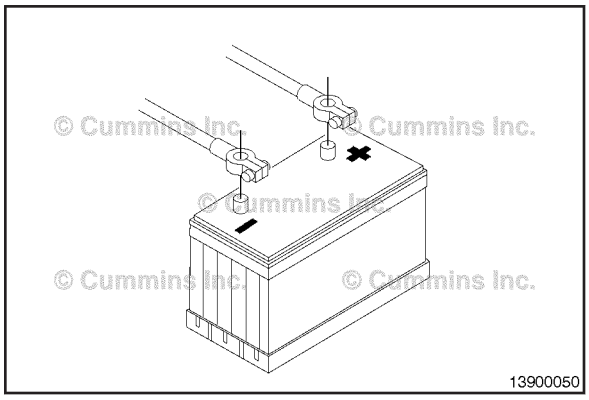
Install the belt guard. Refer to Procedure 008-001



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

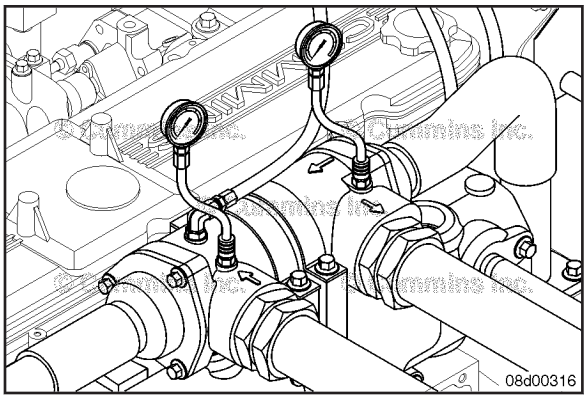
Operate the engine and check for leaks.



Keel Cooler (008-083)

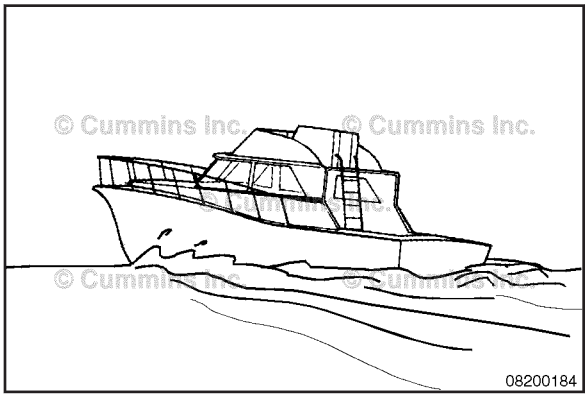
General Information

The temperature and pressure differential tests can be conducted at the same time if the temperature probe enters the coolant flow completely.



Temperature Differential Test

Install temperature probes into the inlet and outlet test ports of the keel cooler thermostat housing.



Run the engine under rated rpm and load until the engine temperature reaches its maximum. Record the inlet and outlet coolant temperatures.

A temperature differential of 25°C [77°F] or greater is required for adequate system cooling. If the temperature differential meets this specification, test the coolant pressure difference.

If the temperature difference is less than 25°C [77°F], inspect the vessel's keel coolers. Some problems that can cause a high coolant temperature differential include:

1 keel cooler size is too small

2 seawater temperature is too hot

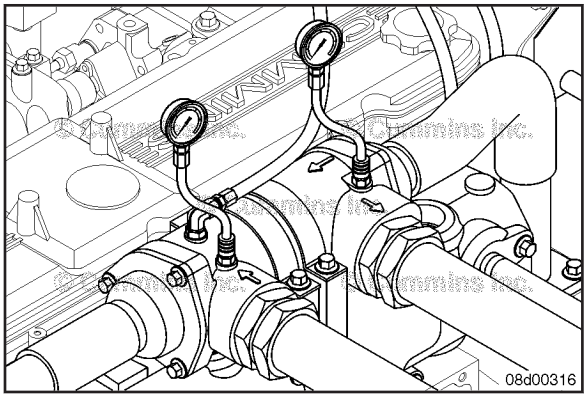
3 marine growth on the keel cooler

4 fouling on 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 troubleshooting and repair manual.



Pressure Differential Test

Install test fittings and gauges into the inlet and outlet of the keel cooler thermostat housing.

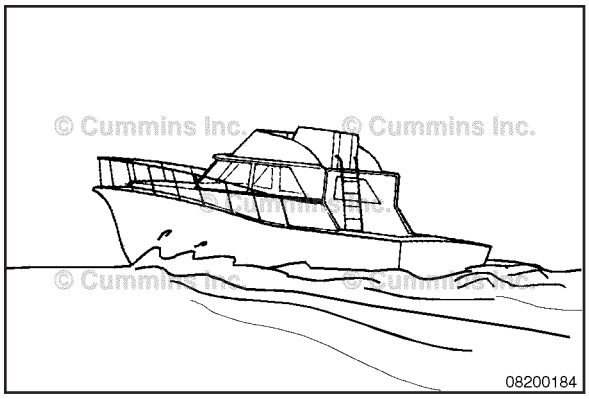
Run the engine under rated rpm and load until the engine temperature reaches its maximum. Record the inlet and outlet coolant pressures. If the pressure difference is less than 34 kPa [5 psi], remove and test the keel cooler thermostat. Refer to Procedure 008-014

If the pressure difference is greater than 34 kPa [5 psi], inspect the vessel's keel coolers. Some problems that can cause high differential pressure are:

1 blockage in the keel cooling system

2 internal damage to the keel cooler.

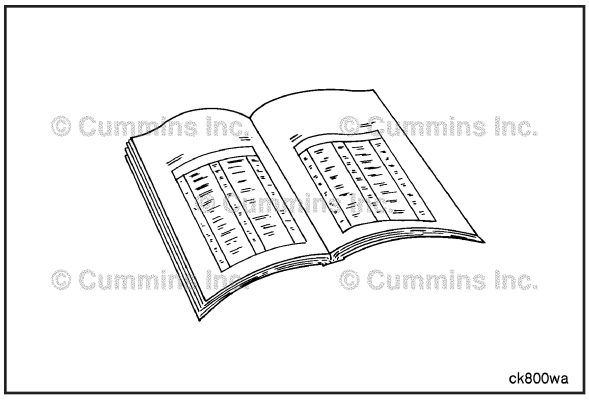
Refer to the keel cooler OEM troubleshooting and repair manual.



Cooling Fan Belt Tensioner (008-087)

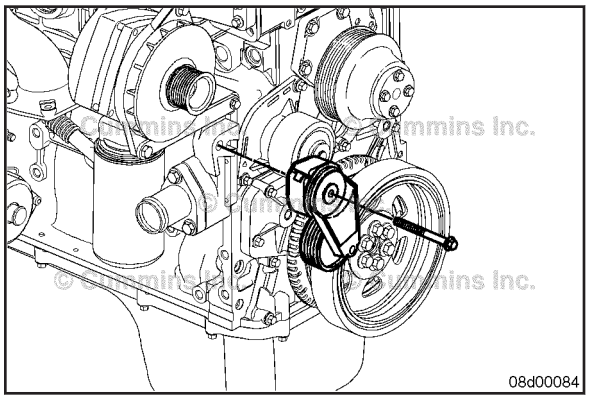
Preparatory Steps

- Remove cooling fan drive belt. Refer to Procedure 008-002.



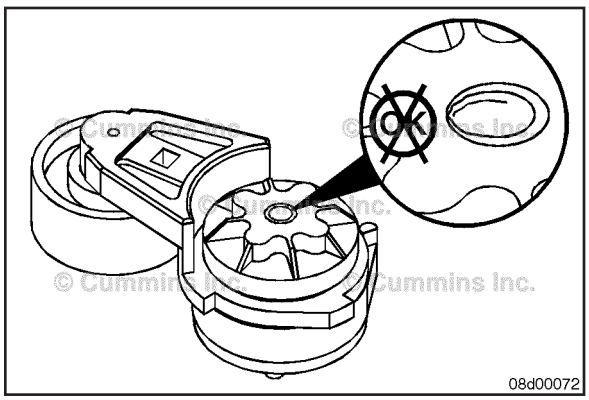
Remove

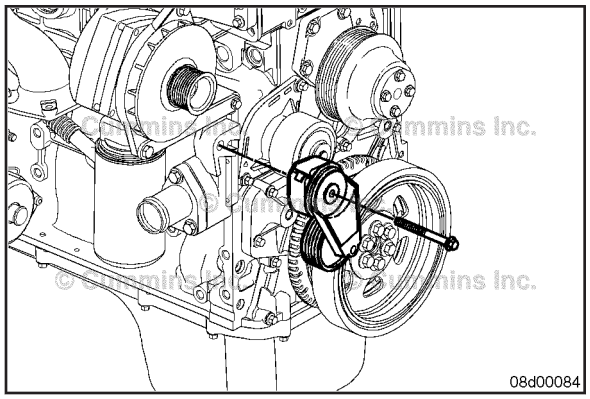
Remove the belt tensioner mounting capscrew and belt tensioner.



Inspect for Reuse

Inspect the tensioner bushing between the arm and the spring case.



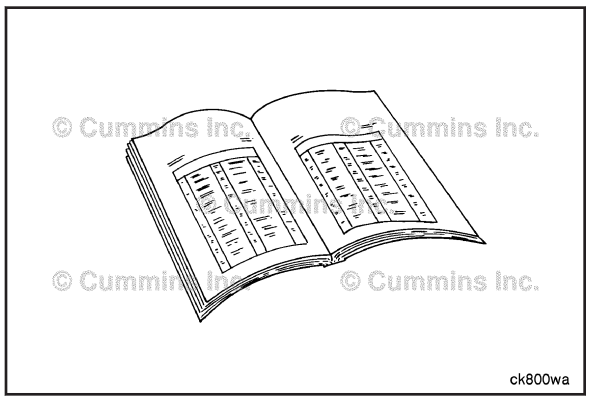


Install

Install the belt tensioner.

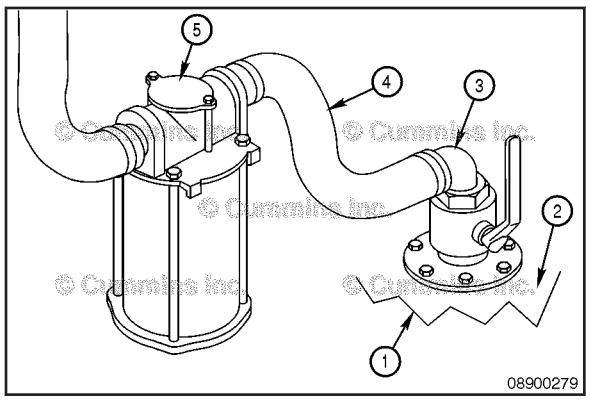
Install and tighten the belt tensioner capscrew.

Torque Value: 43 N•m [32 ft-lb]



Finishing Steps

- Install cooling fan drive belt. Refer to Procedure 008-002.



Sea Water System Diagnostics (008-103)

General Information

Typical sea water cooling system

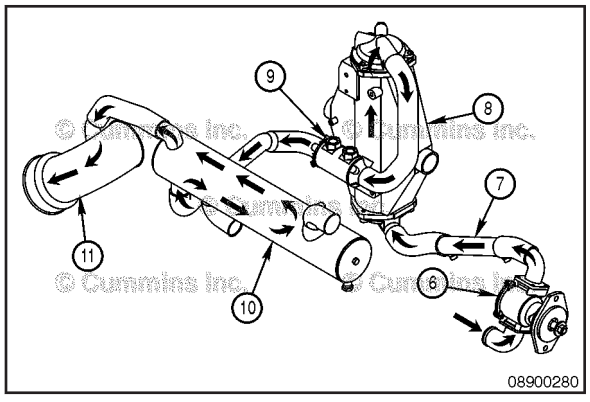
1 Grate-type strainer located on the bottom of the boat hull

2 Vessel bottom/hull

3 Sea water inlet valve

4 Hose

5 Sea water strainer



6. Sea water pump

7. Fuel cooler

8. Aftercooler

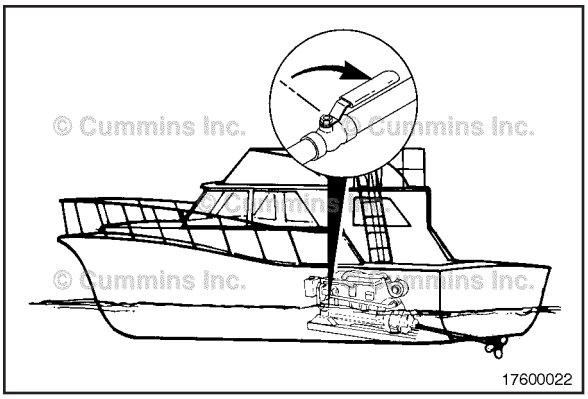
9. Transmission oil cooler

10. Heat exchanger

11. Sea water outlet.

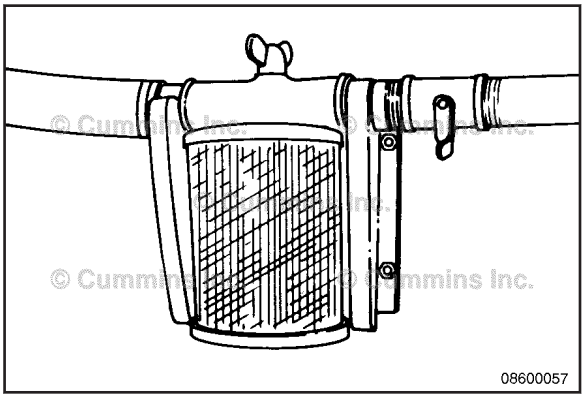
Initial Check

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.



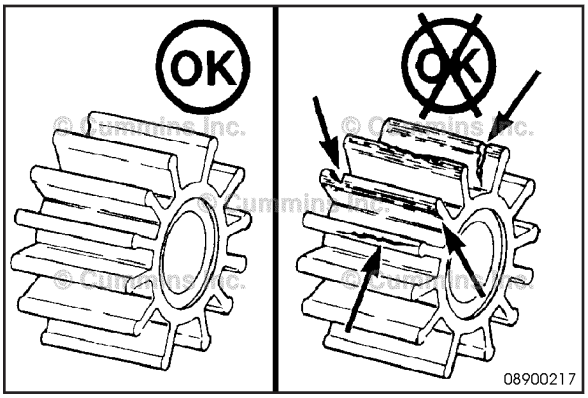
Inspect the sea water strainer for foreign objects that could restrict the water flow.

Some strainers have clear covers for easy inspection. If the strainer has to be opened for inspection, Refer to Procedure 008-067

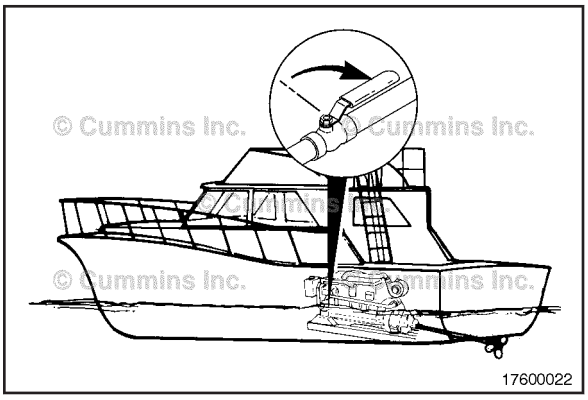


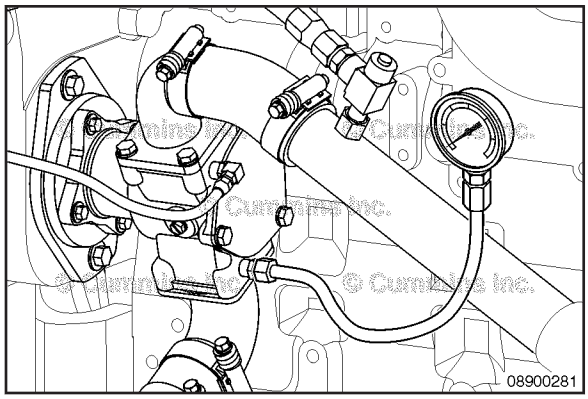
If the engine was in operation with the sea water system highly restricted due to a closed sea water inlet valve or a clogged sea water strainer, the sea water impeller **must** be inspected for damage.

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



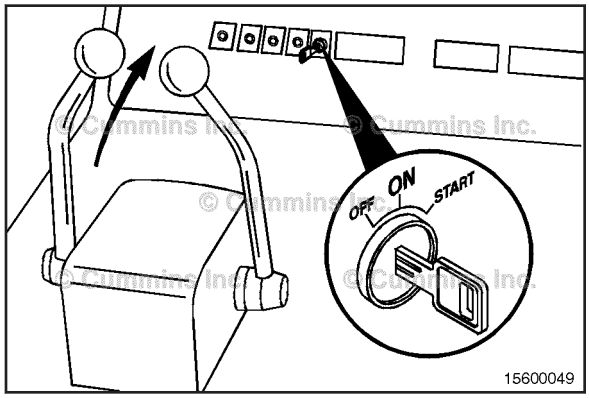
If the engine continues to overheat, perform the following procedures. If the engine does **not** overheat at the dock, perform a sea trial and check for overheating under way.



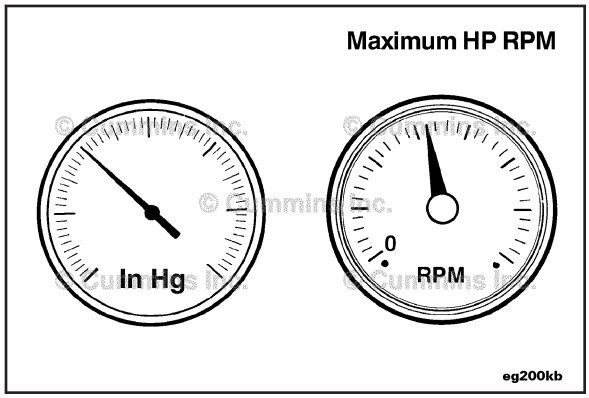


Test

Attach a vacuum gauge to the inlet side of the sea water pump.

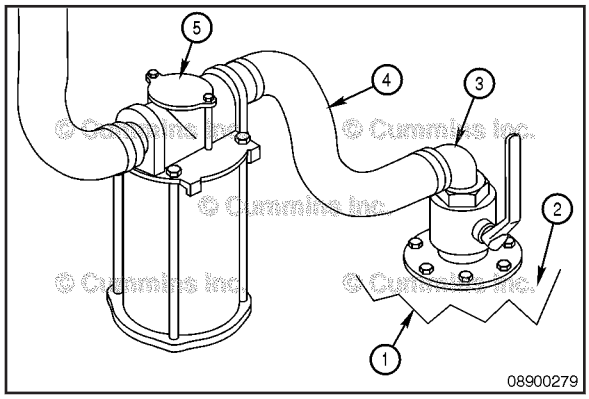


Start the engine.



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.

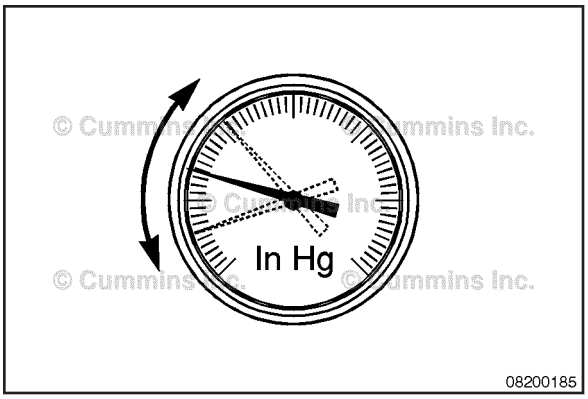


If the sea water inlet restriction is above specification, the source of the restriction **must** be found. Troubleshooting and repair of excessive sea water restriction is a boat manufacturer or boat owner responsibility. Refer to the vessel's OEM service manual. If the inlet restriction is within the 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.

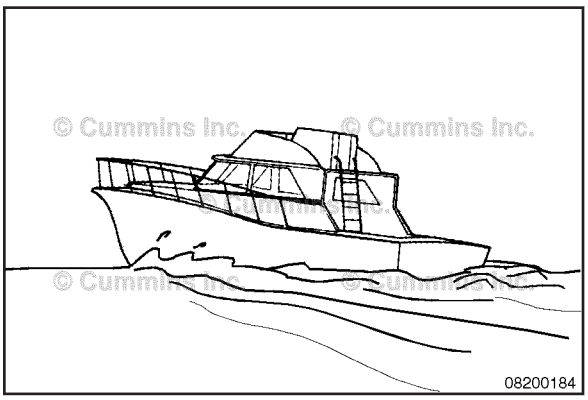
If the sea water inlet restriction readings fluctuate during the test, inspect the sea water supply for leaks or air intrusion. Troubleshooting and repair of excessive sea water restriction is a boat manufacturer or boat owner responsibility. Refer to the vessel's OEM service manual. Troubleshooting 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.



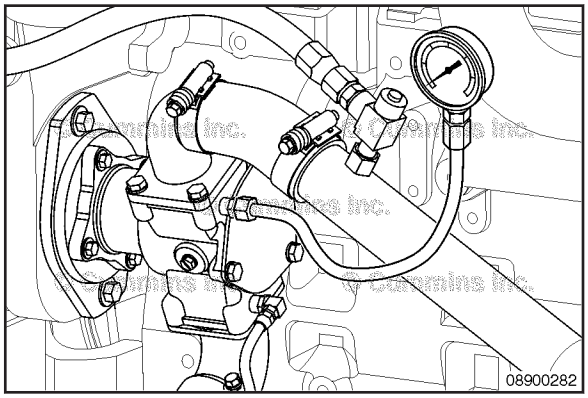
It is possible that aeration (gauge fluctuation) will **only** occur while the vessel is underway due to the introduction of air. Refer to the vessel's OEM service manual.

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

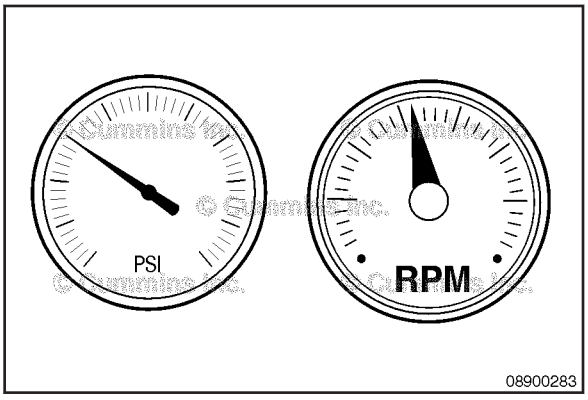
Attach a pressure gauge to the outlet side of the sea water pump to check pump outlet pressure.

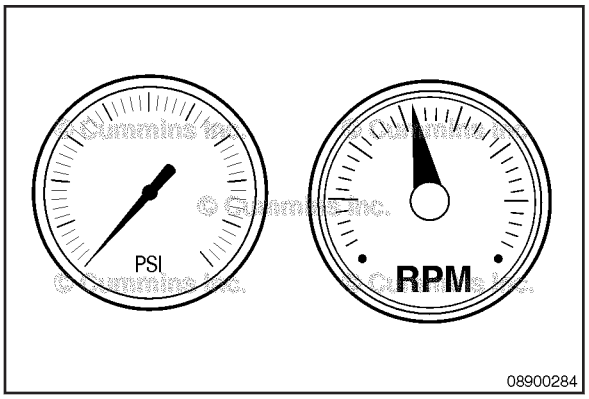


Start the engine and record the sea water outlet pressure from low idle to rated speed at 500 rpm increments. This test can be conducted while the vessel is at dock and **not** in gear or underway.

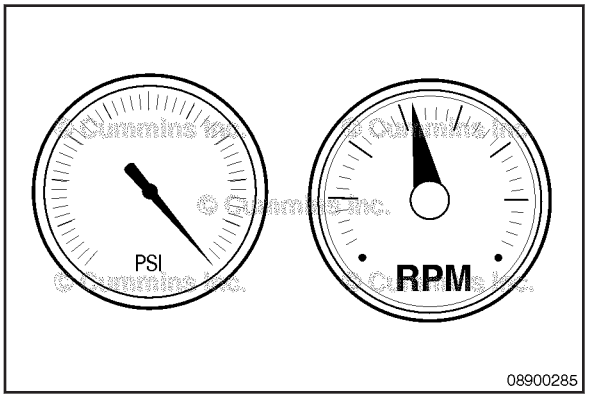
Refer to Procedure 018-018 for Marine engine specifications.

If the sea water pump outlet pressure is within specifications, see the Temperature Differential Test step in this procedure.



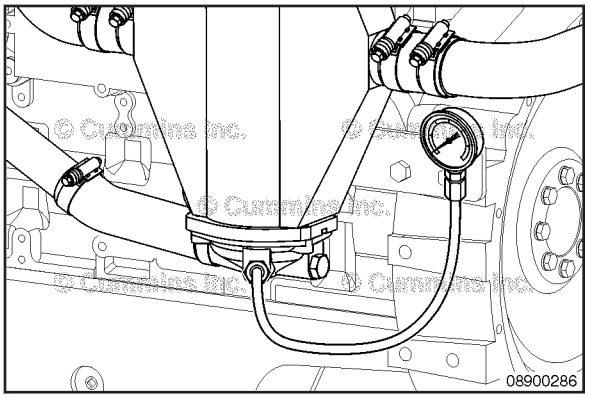


If sea water pressure is **not** present, check the pump for damage. Refer to Procedure 008-057



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.

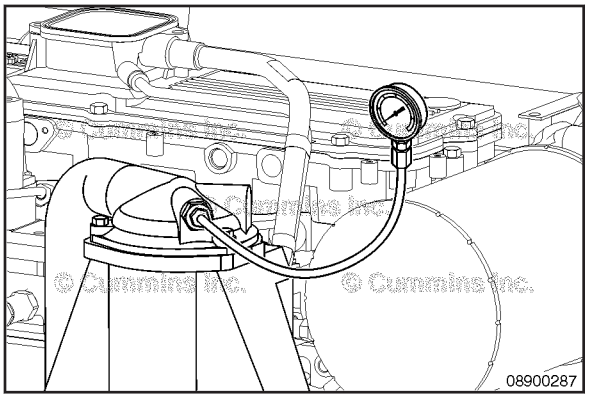
Refer to Procedure 018-018 for Marine engine specifications.



Pressure Differential Test

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.



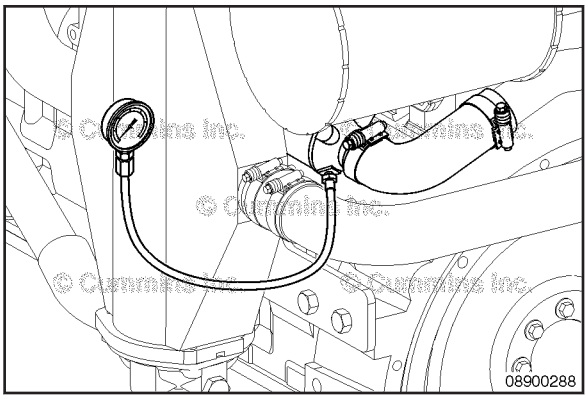
If the pressure drop is within specification, check the sea water pressure at the discharge side of the aftercooler outlet. Record the reading.

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.

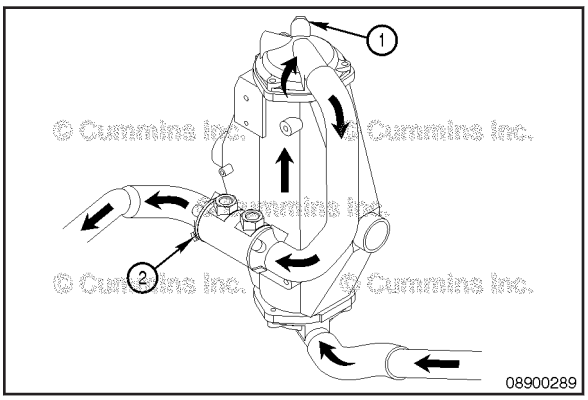
Refer to Procedure 018-018 for Marine engine specifications.

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.



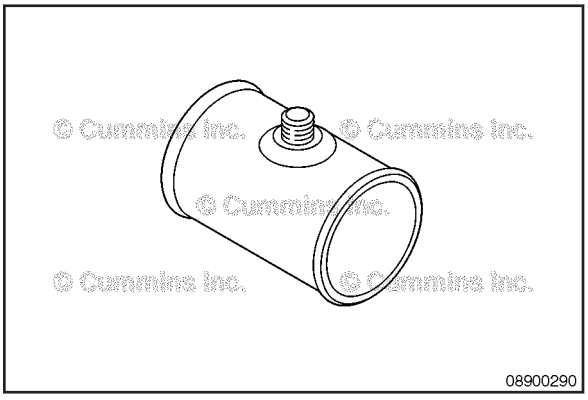
If the pressure drop between the inlet side (1) and the outlet side (2) of the gear cooler is greater than the maximum specification, check for blockage in the gear cooler. Clean or replace if necessary. Refer to Procedure 008-041

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.

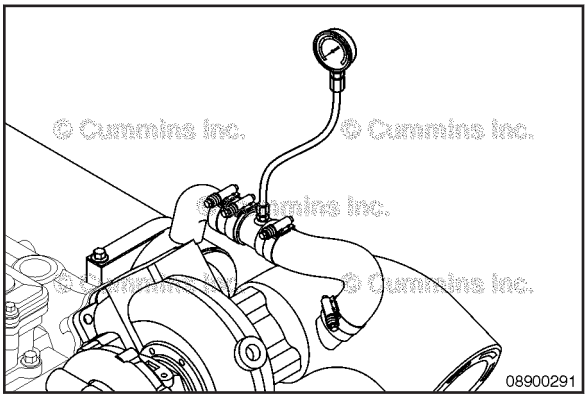
Fabricate a sea water test tool by using a 38 mm [1-1/2 in] pipe with a fitting in the center to connect a pressure gauge.

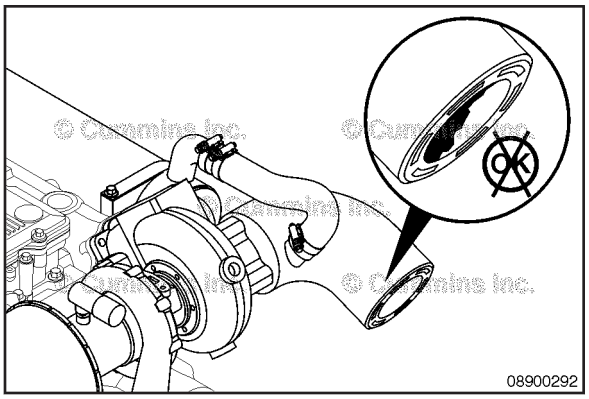


Install the fabricated test tool between the outlet side of the heat exchanger and the exhaust elbow. Check the pressure drop across the heat exchanger.

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.

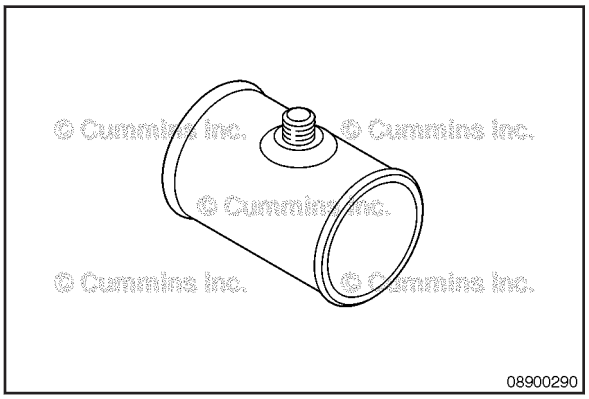




If the pressure drop across the heat exchanger is within specification, determine the pressure drop across the exhaust elbow (diffuser). This is done by subtracting the heat exchanger outlet pressure form the sea water pump outlet pressure. If this pressure exceeds the maximum specification, check for blockage in the exhaust elbow (diffuser) and exhaust system of the vessel. Clean or replace if necessary.

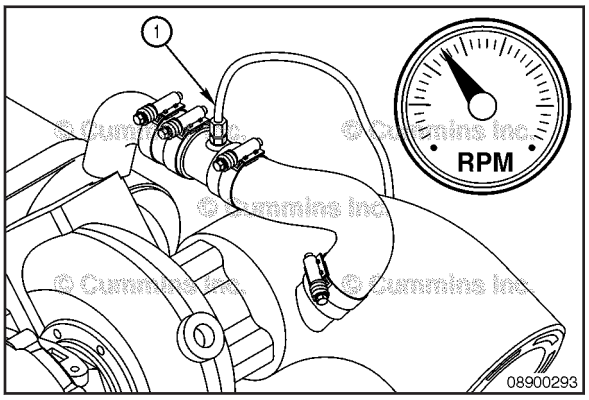
Refer to Procedure 018-018 for Marine engine specifications.

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.

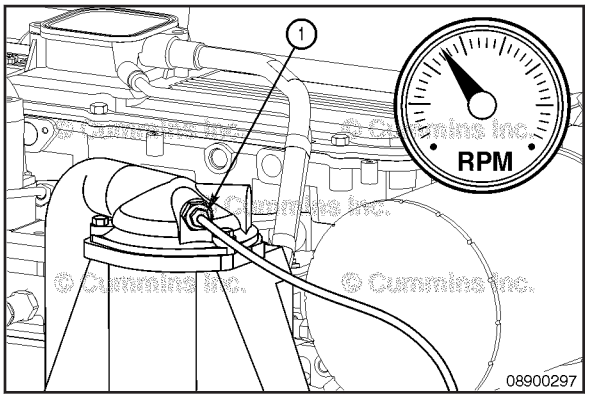


Temperature Differential Test

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.

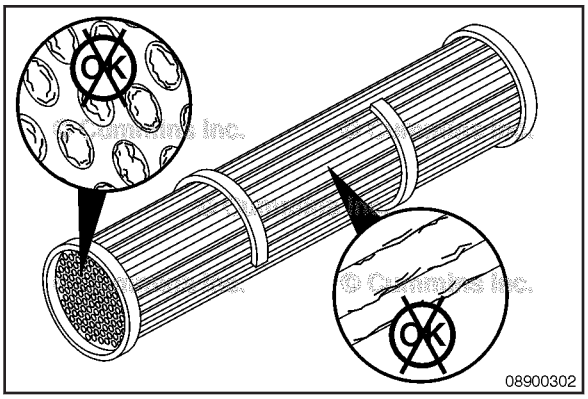


Install the sea water test tool with a temperature probe between the outlet side of the heat exchanger and the exhaust elbow (1). Operate the engine at rated rpm and load and record the temperature.



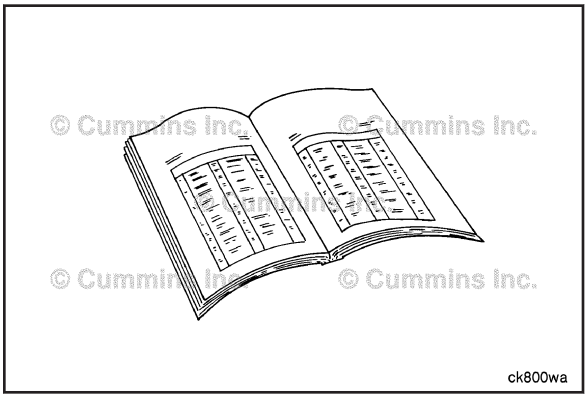
Install the temperature probe in the outlet side of the aftercooler (1). Operate the engine at the rated rpm and load and record the temperature. If the temperature difference between the aftercooler outlet and the engine heat exchanger outlet is greater than 20°C [40°F], check the sea water pump for 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



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.

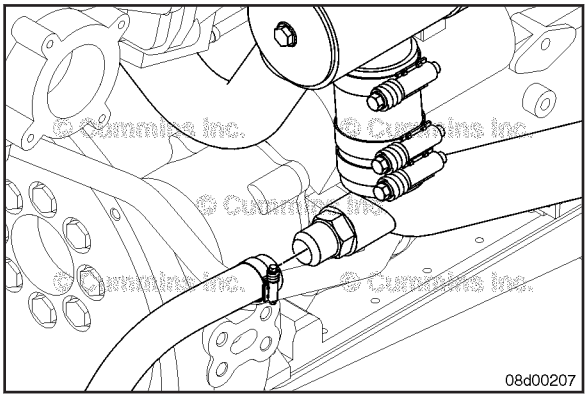
⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

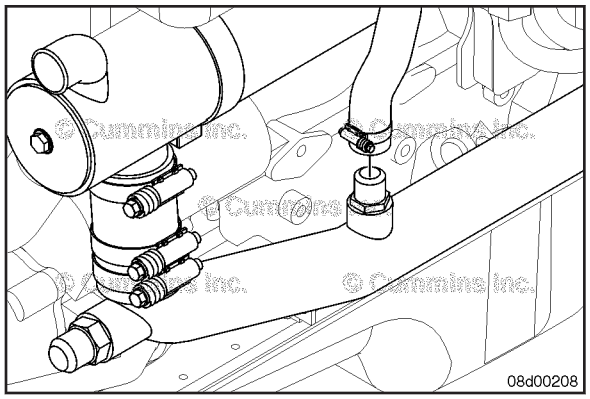
△CAUTION△
Use caution when draining the coolant system that coolant is not spilled or drained into the bilge area. The coolant must be disposed of in accordance with local environmental regulations.

- Disconnect the batteries. Refer to Procedure 013-009
- Drain the engine coolant. Refer to Procedure 008-018

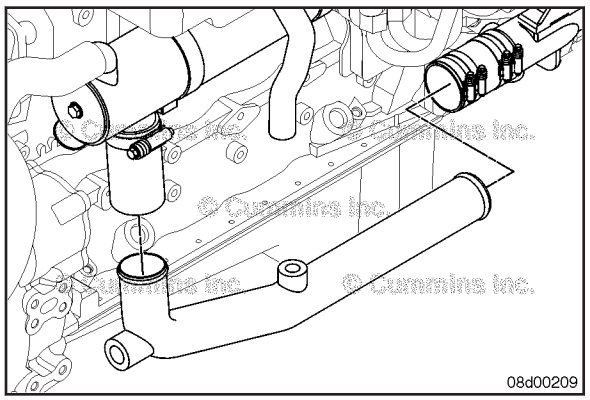
Remove

Remove the turbocharger water drain line from the coolant return junction.

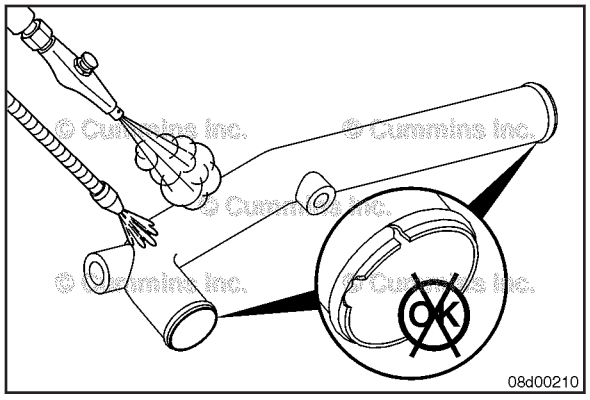




Remove the expansion tank coolant fill tube from the coolant return junction.



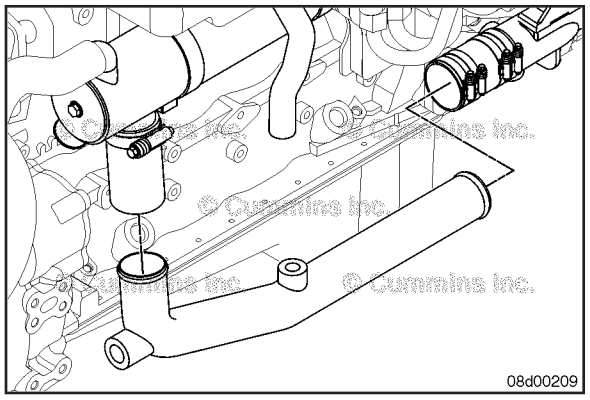
Loosen the hose clamps on both ends of the coolant return junction and remove the tube.



Clean and Inspect for Reuse

Clean the inlet connection of the coolant return junction.

Inspect the connection ends for cracks or other damage.



Install

Install the four hose clamps over the hose connections of the coolant return junction.

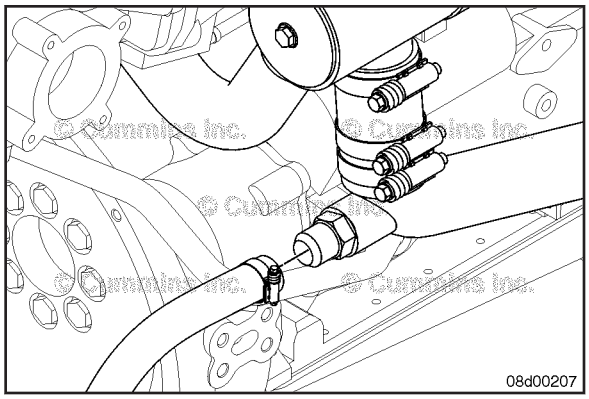
Install the coolant return junction onto the hose connection at the water inlet connection and the rear end of the heat exchanger.

Position the hose clamps and tighten.

Torque Value: 8 N•m [71 in-lb]

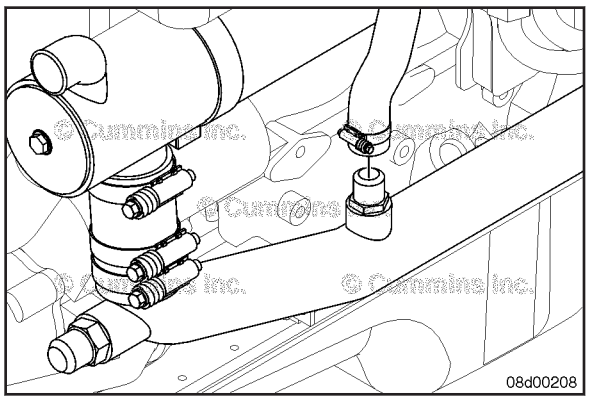
Install turbocharger water drain hose and tighten the hose clamps.

Torque Value: 8 N•m [71 in-lb]



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]



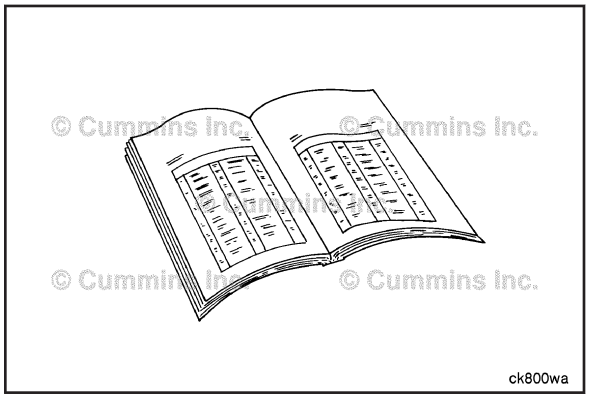
Finishing Steps

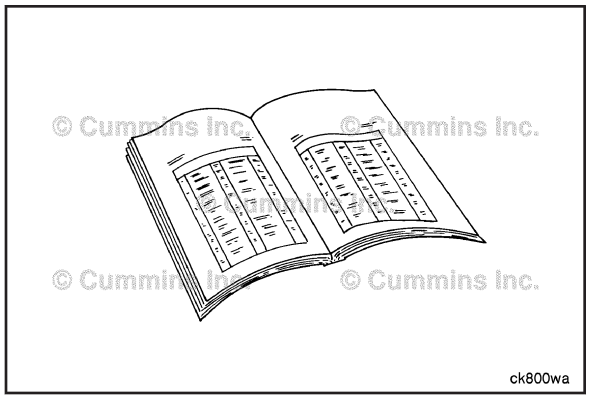
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- 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.

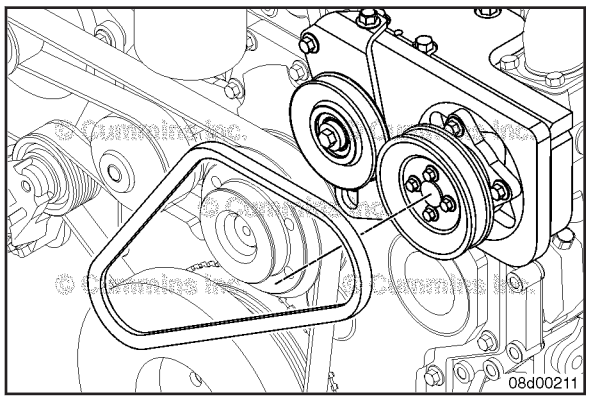




Drive Belt, Sea Water Pump (008-126)

Preparatory Steps

- Remove the belt guard. Refer to Procedure 008-001 (Belt Guard) in Section 8.
- Remove the belt guard. Refer to Procedure 008-001 (Belt Guard) in Section A.
- Remove the belt guard. Refer to Procedure 008-002 (Drive Belt, Cooling Fan) in Section 8.



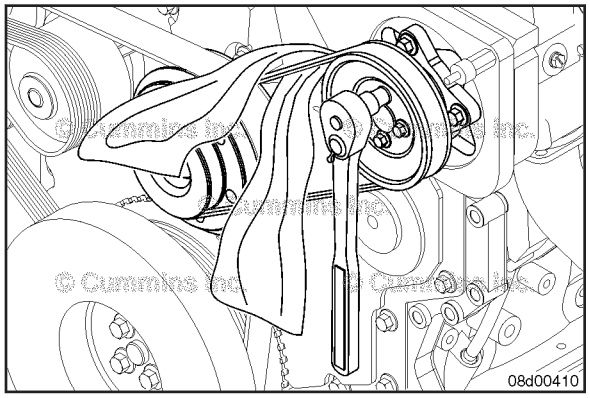
Remove

Belt removal with adjustment tensioner:

Loosen the locking capscrew on the seawater pump idler pulley.

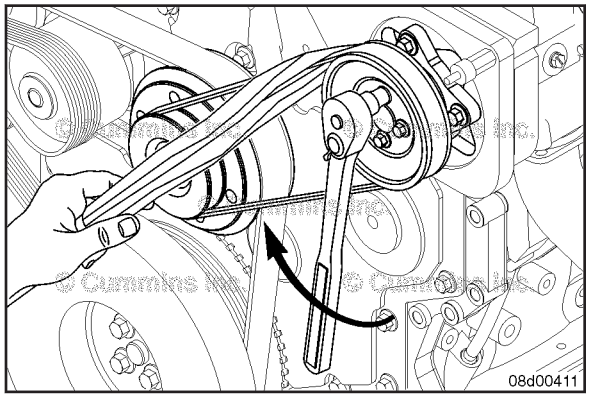
Turn the adjusting screw **counterclockwise** to loosen the drive belt.

Loosen and remove the drive belt from the seawater pump pulley.



Belt removal without adjustment tensioner:

- Place the shop towel around the belt in front of the seawater pump idler pulley.
- Install the ratchet with an 8 mm [.31 in] socket on one of the seawater pump idler pulley capscrews.

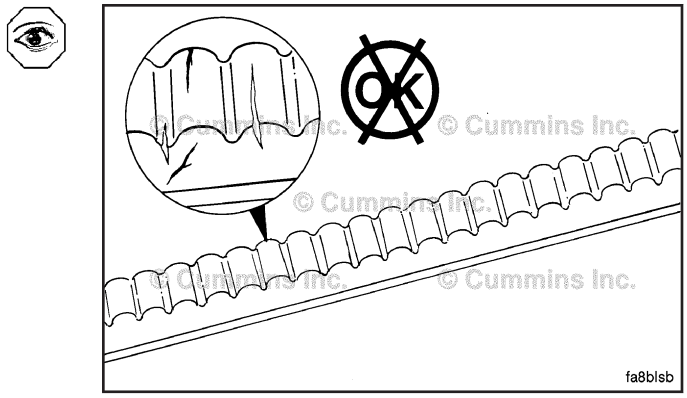


△CAUTION△
Turning the water pump pulley in the counterclockwise direction will result in impeller damage and will loosen the water pump pulley capscrew.

NOTE: Do **not** use the ratchet to rotate the pulley in the **counterclockwise** direction under any circumstance.

- Use the shop towel and pull outward on the belt while rotating the ratchet in the **clockwise** direction.

Inspect for Reuse

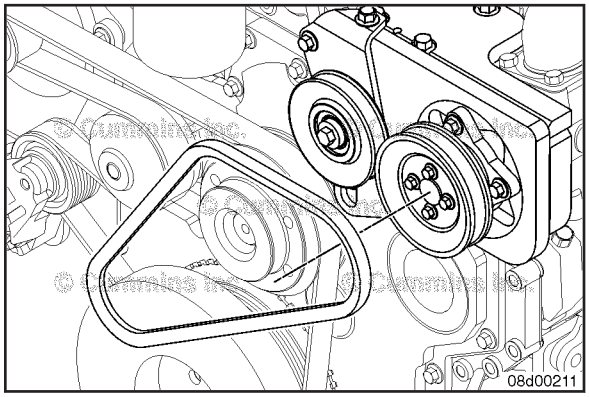


Inspect the belts daily. Replace the belts if they are cracked, frayed, or have chunks of material missing. Small cracks are acceptable.

Adjust belts that have a glazed or shiny surface, which indicates belt slippage. Correctly installed and tensioned belts will show even pulley and belt wear. Belt damage can be caused by:

- Incorrect tension
- Incorrect size or length
- Pulley misalignment
- Incorrect installation
- Severe operating environment
- Oil or grease on the belts.

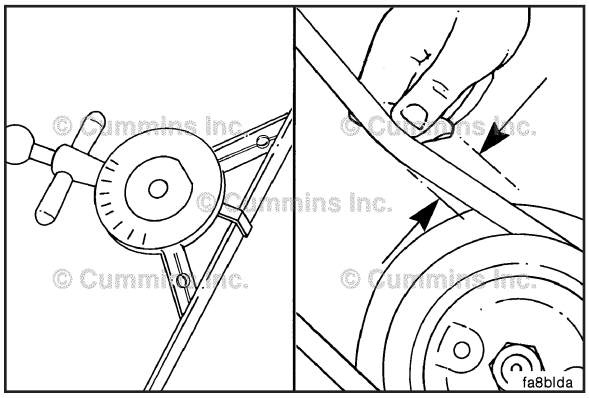
Install



Belt installation with adjustment tensioner:

Install the belt over the pulleys.

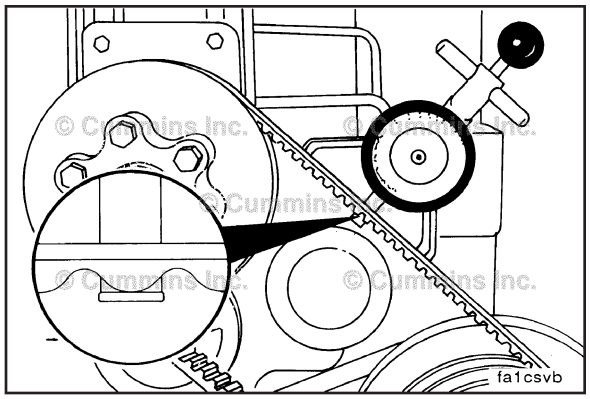
Tighten the belt by turning the adjusting screw **clockwise**



Measure the belt tension in the center span of the pulleys.

Refer to Procedure 018-005 (Belt Tension) in Section V for the correct gauge and tension value for the belt width used.

An alternate method (deflection method) can be used to check belt tension by applying 110 N [25 lbf] of force between the pulleys on v-belts. If the deflection is more than one belt thickness per foot of pulley center distance, the belt tension **must** be adjusted.



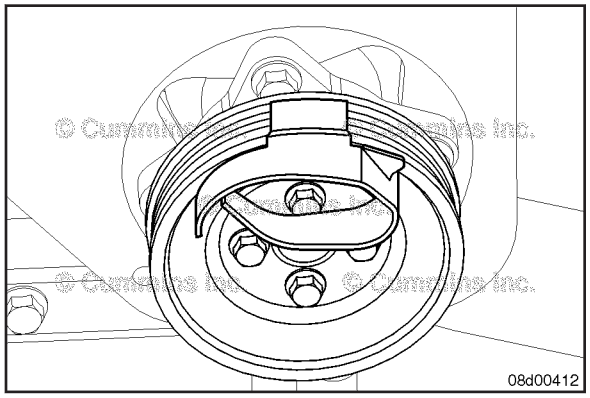
For cogged belts, make sure that the belt tension gauge is positioned so that the center tensioning leg is placed directly over the high point (hump) of a cog. Other positioning will result in incorrect measurement.

Refer to Procedure 018-005 (Belt Tension) in Section V for the correct gauge and tension value for the belt width used.

Tighten the locking capscrew in the center of the idler pulley.

Torque Value: 45 N•m [33 ft-lb]

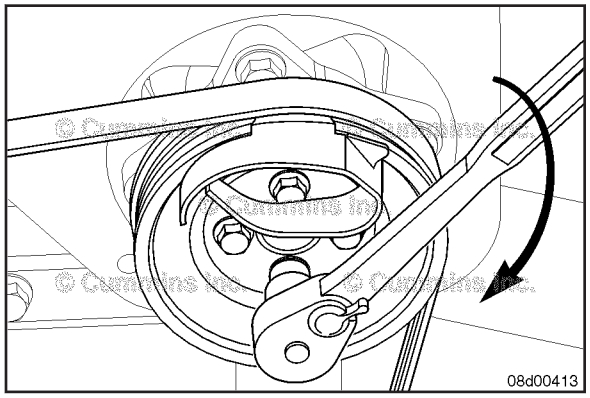
Check the final belt tension.



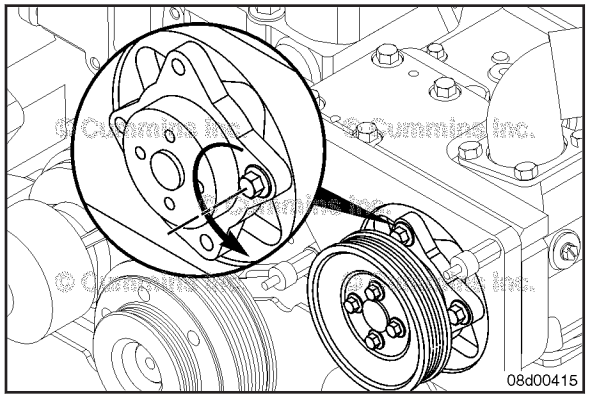
Belt installation without adjustment tensioner, installed with tool:

NOTE: No lubricants or soaps can be used to install belts. The tool is supplied with the new replacement belt.

- Insert the special tool (provided) over the grooves of the seawater pump idler pulley.



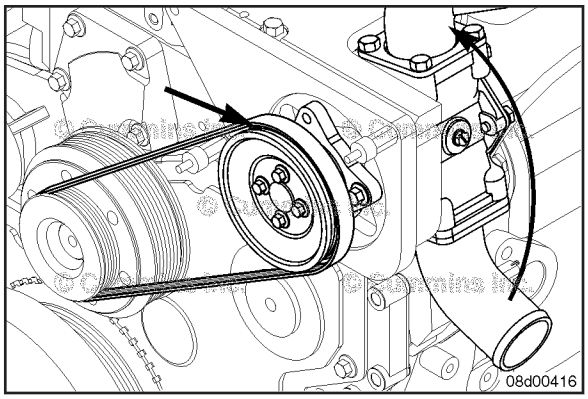
- Place the belt over the tool.
- Rotate the pulley 360 degrees in the **clockwise** direction, use a ratchet and an 8 mm [.31 in] socket until the belt is fully installed.
- Make sure the belt is correctly aligned in the grooves of the pulleys. If the belt is not correctly installed after first revolution, continue to rotate the pulley until the belt is properly aligned.



Optional installation:

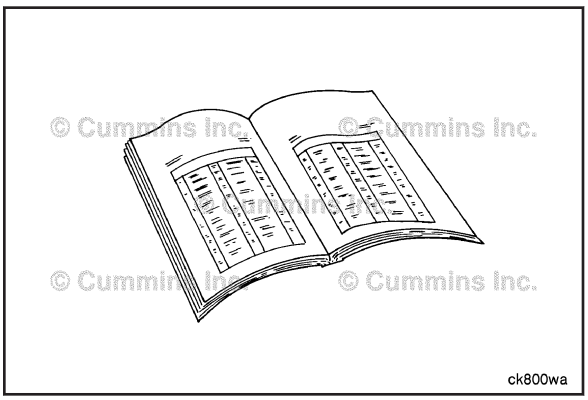
- Remove three mounting capscrews from the seawater pump.
- Loosen the remaining capscrew.

- Push the pump in, use a pry bar so that the belt can be rolled onto the pulley by hand.
- Align the seawater pump.
- Place the capscrews back in the pump.
- Torque capscrews to specifications. Refer to Procedure 008-057 (Sea Water Pump) in Section 8.
- Rotate the pulley **clockwise** to make sure that the belt is properly aligned.



Finishing Steps

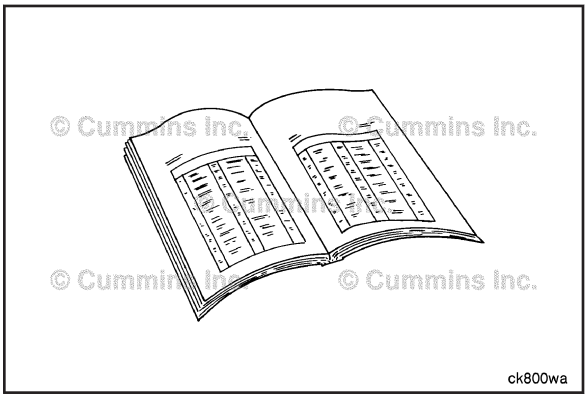
- Install the belt guard. Refer to Procedure 008-001 (Belt Guard) in Section 8.
- Install the belt guard. Refer to Procedure 008-001 (Belt Guard) in Section A.
- Refer to Procedure Install the belt guard. 008-002 (Drive Belt, Cooling Fan) in Section 8.
- Operate the engine and check for proper operation.



Sea Water Pump Pulley (008-127)

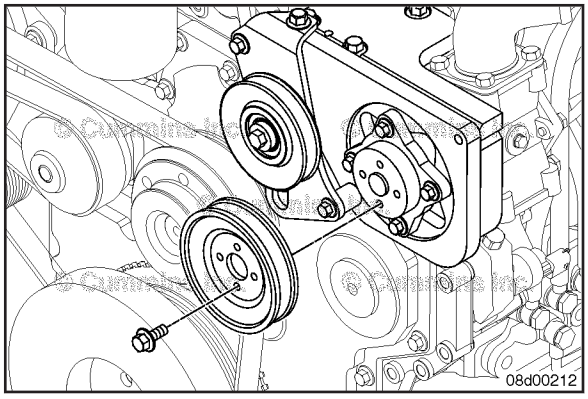
Preparatory Steps

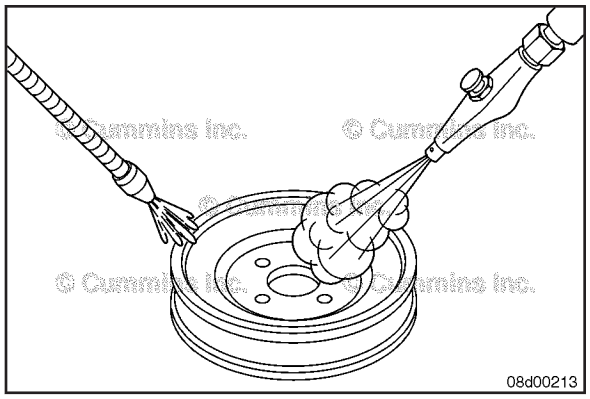
- Remove the belt guard. Refer to Procedure 008-001
- Remove the sea water pump drive belt. Refer to Procedure 008-126



Remove

Remove the four mounting capscrews and the sea water pump pulley.





Clean and Inspect for Reuse

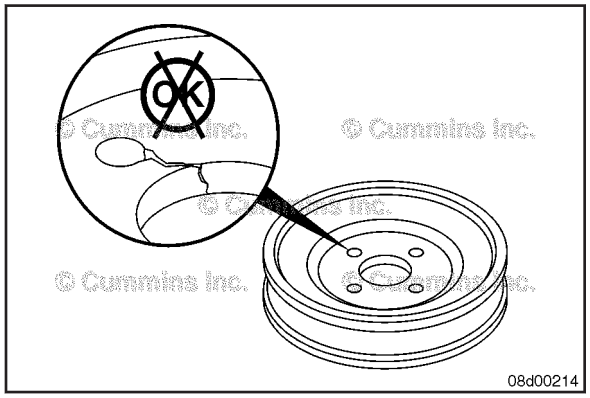
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
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.

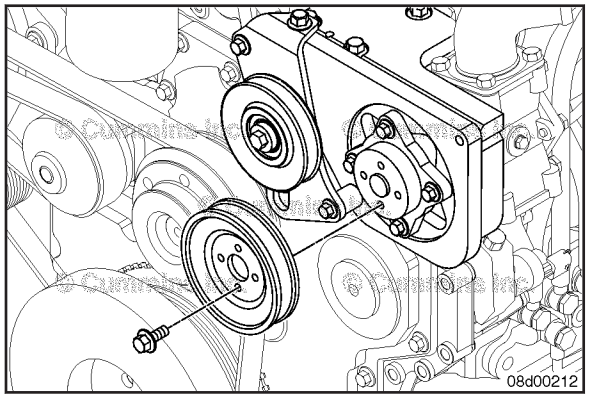
Use solvent to clean the pulley.

Dry with compressed air.



Inspect the pulley for cracks or other damage.

If the pulley is cracked or damaged, it **must** be replaced.



Install

Install the sea water pump pulley using four mounting capscrews.

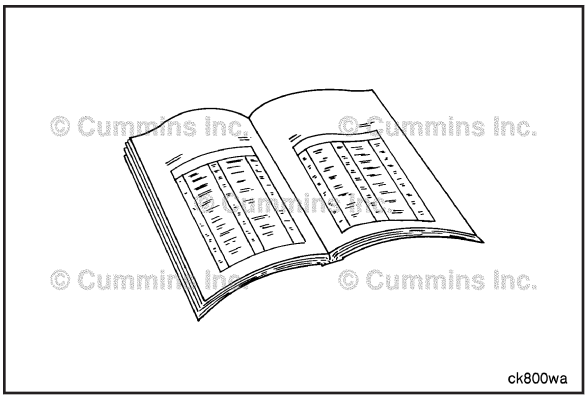
Tighten the capscrews.

Torque Value: 10 N•m [89 in-lb]

Finishing Steps

- Install the sea water pump drive belt. Refer to Procedure 008-126
- Install the belt guard. Refer to Procedure 008-001

Operate the engine and check for leaks.



Notes

Section 9 - Drive Units - Group 09

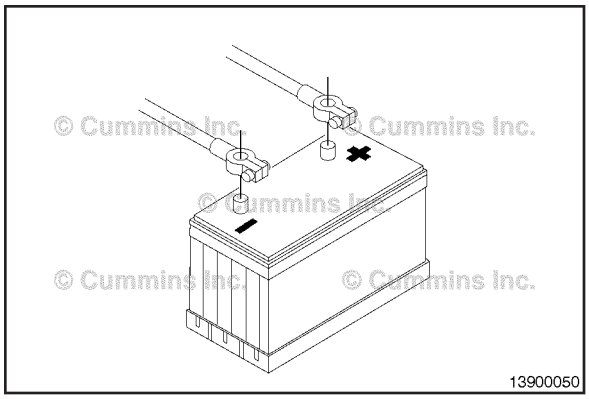
Section Contents

Accessory Drive (009-001)

Preparatory Steps

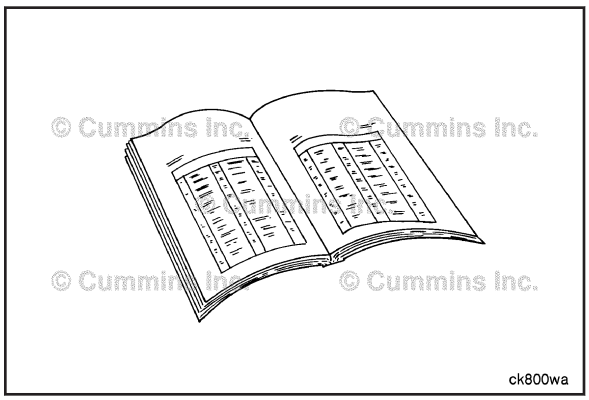
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Disconnect the batteries.



Remove the driven accessory. Refer to the OEM instructions.

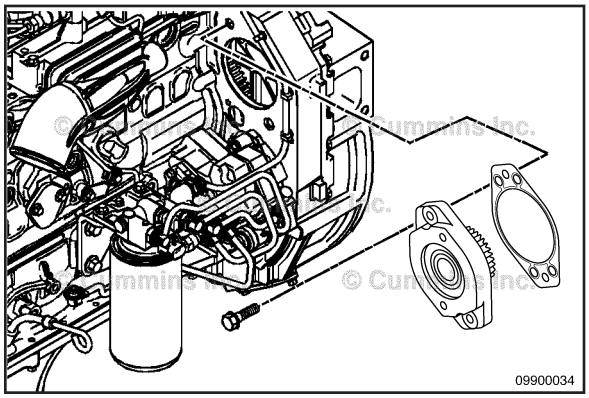
NOTE: Typically the driven accessory is a hydraulic pump. Refer to Procedure Procedure 009-016 for general removal instructions.



Remove

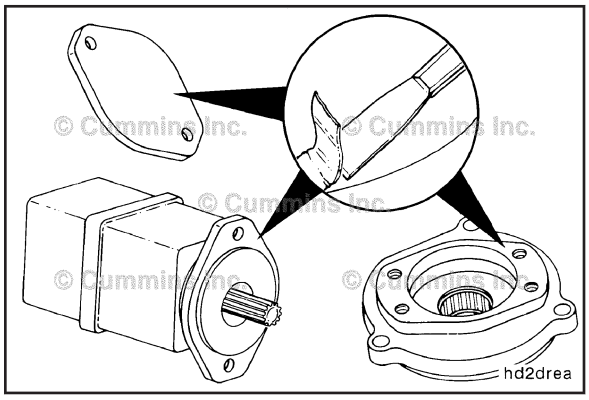
Remove the two capscrews securing the accessory drive to the rear gear housing.

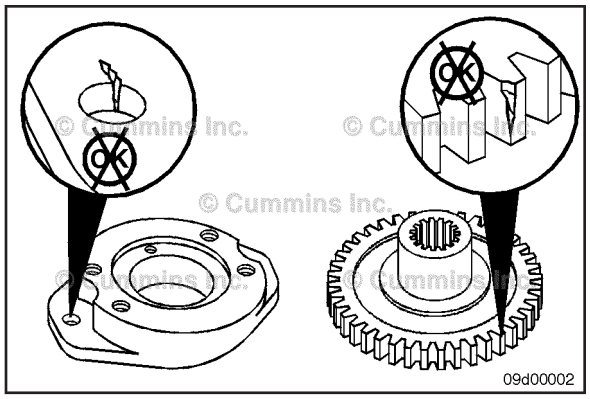
Remove the accessory drive and gasket.



Clean and Inspect for Reuse

Remove any residual gasket material from the mounting surfaces of the accessory drive, driven accessory/ hydraulic pump, and, if equipped, the cover plate surface.





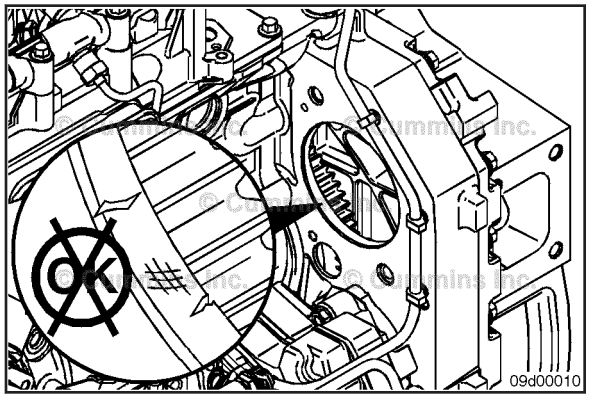
NOTE: Make sure the oil supply hole in the accessory drive housing is open and free of debris.

Inspect the accessory drive housing for cracks.

Inspect the accessory drive gear and shaft splines for cracks, broken teeth, and other damage.

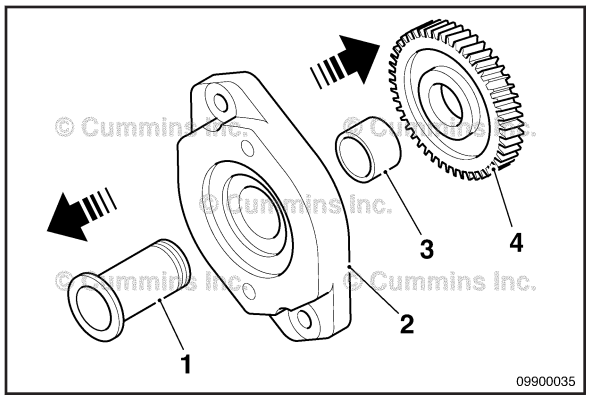
NOTE: If there is damage to the accessory drive gear teeth or there are signs of excessive heat, make sure to inspect the associated camshaft and fuel pump gears for damage. Measure camshaft gear backlash upon installation.

Replace any damaged components. See the Disassemble step of this procedure.



NOTE: Make sure the oil supply hole in the gear housing is open and free of debris.

Inspect the inside diameter of the drive gear bore for excessive wear or damage; replace if necessary.



Disassemble

If damage was found to a component of the accessory drive during the Clean and Inspect for Reuse step, the following components of the accessory drive, if damaged, may be replaced by disassembling the accessory drive.

1 Accessory Drive Shaft

2 Accessory Drive Housing

3 Accessory Drive Bearing

4 Accessory Drive Gear

NOTE: Before disassembling the accessory drive, check to make sure the parts for the specific accessory drive being serviced are available. If **not**, replace the accessory drive as an assembly.

Use a hydraulic press and proper support to disassemble the accessory drive in the following order.

1 Press the drive shaft from the drive gear and housing

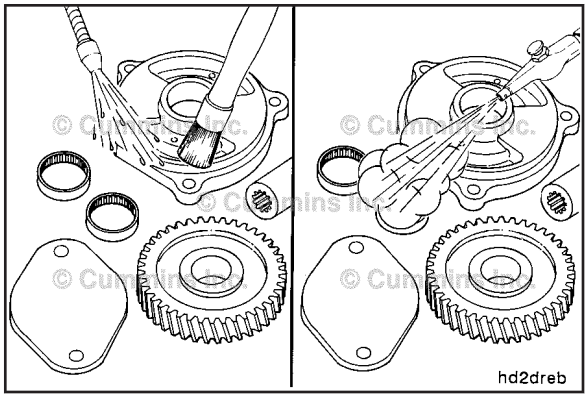
2 Press the bearing from the housing.

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

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

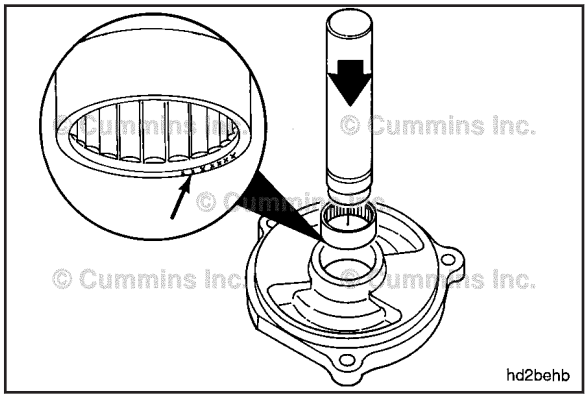
Clean the accessory drive components with solvent.

Dry with compressed air.



Inspect the bearing for binding, seizing, and excessive noise when spun.

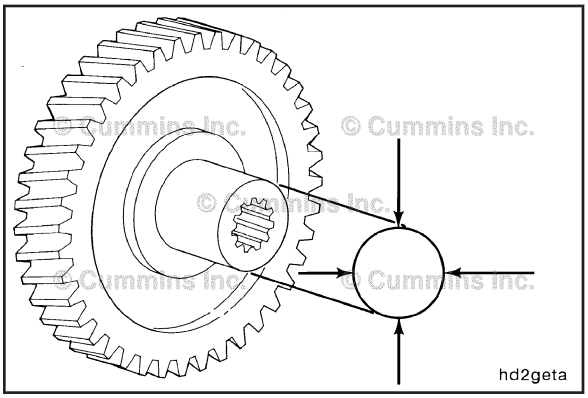
Replace if any damage is found.



Measure the inside diameter of the accessory drive gear bore.

Accessory Drive Gear Bore Inside Diameter (Accessory Drive Adapter)		
mm		**in**
38.920	MIN	1.5323
38.945	MAX	1.5333

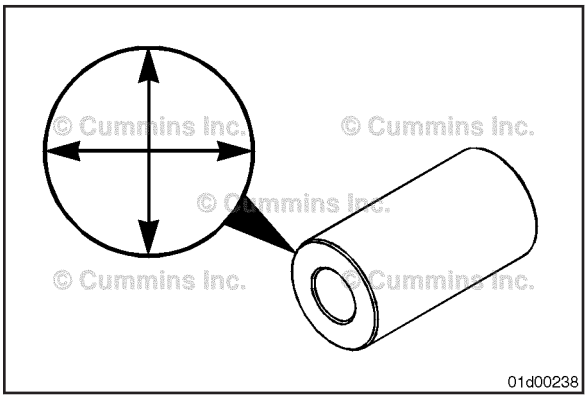
If out of specification, replace the accessory drive gear.

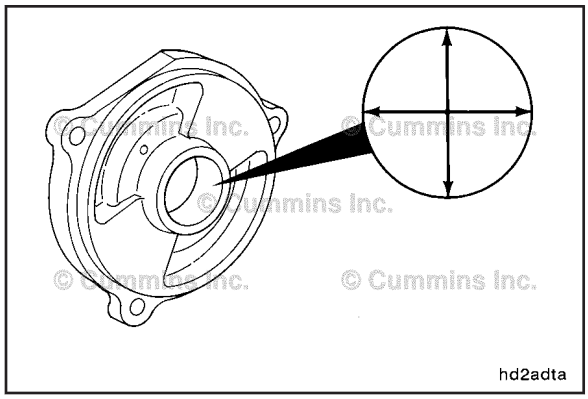


Measure the outside diameter of the accessory drive shaft at multiple locations along the shaft.

Accessory Drive Shaft Outside Diameter (Accessory Drive Adapter)		
mm		**in**
39.008	MIN	1.5357
39.020	MAX	1.5362

If out of specification, replace the accessory drive shaft.

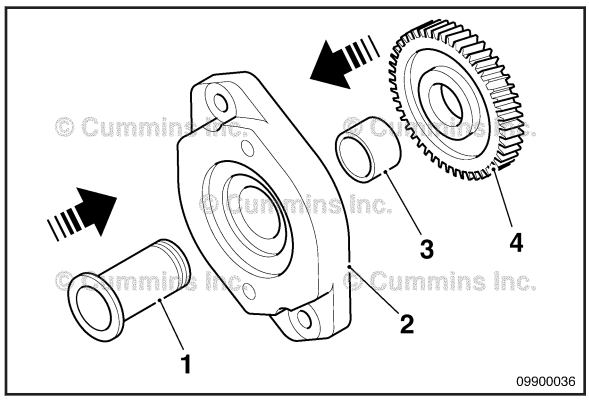




Measure the inside diameter of the bearing bore in the accessory drive adapter housing.

Bearing Bore Inside Diameter (Accessory Drive Adapter)		
mm		in
67.759	MIN	2.6755
67.983	MAX	2.6765

If out of specification, replace the housing.



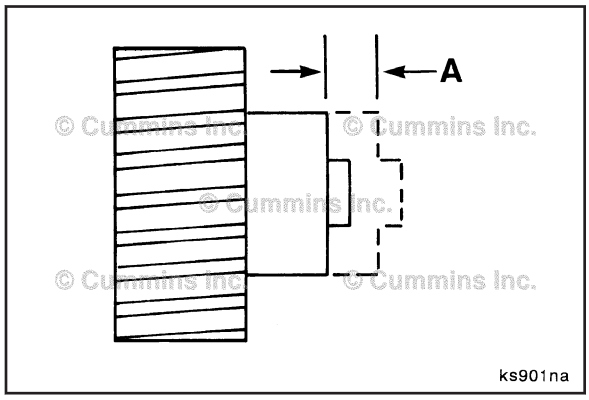
Assemble

Use a hydraulic press and proper support to assemble the accessory drive in the following order:

1 Press the accessory drive shaft into the bearing, while supporting the bearing inner race, until the drive shaft bottoms on the inner race

2 Press the outer race of the bearing, with drive shaft, into the accessory drive housing, until the outer race bottoms in the housing

3 Press the accessory drive gear onto the shaft while supporting the bottom of the drive shaft. Press until gear bottoms against inner bearing race.



Measure

Using gauge, Part Number 3824564, and magnetic base, Part Number 3377399, check the accessory drive gear end play.

Accessory Drive Gear End Play		
mm		in
0.5	MIN	0.020

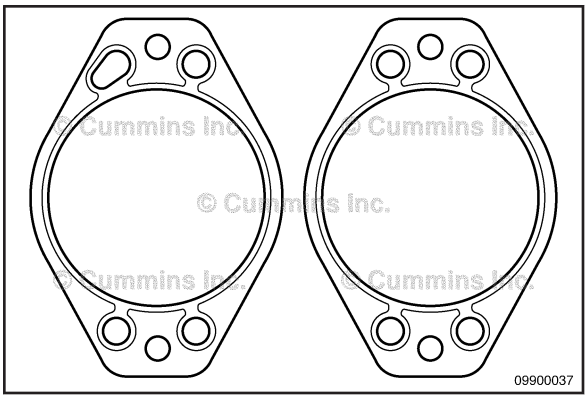
If the end plays is out of specification:

1 If just assembled, check if the drive gear and bearing were completely pressed onto the drive shaft

2 If **not** previously disassembled, disassemble the accessory drive and inspect for damage. Replace as necessary

3 Replace the accessory drive assembly.

Initial Check



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

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

There are two types of accessory drive gasket:

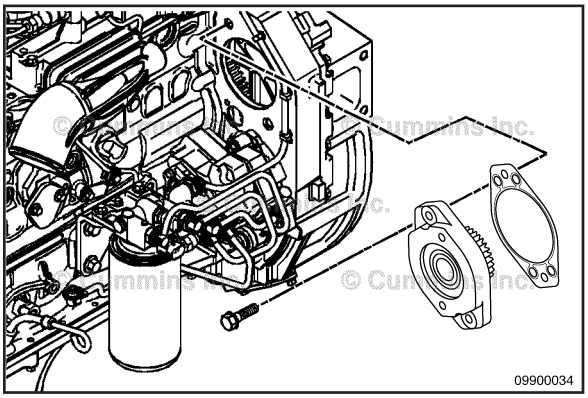
1 Three round oil supply passages and one elongated oil supply passage

2 Four round oil supply passages.

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

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

Install



CAUTION
Failure to line up the oil supply hole to the accessory drive properly will result in accessory drive damage.

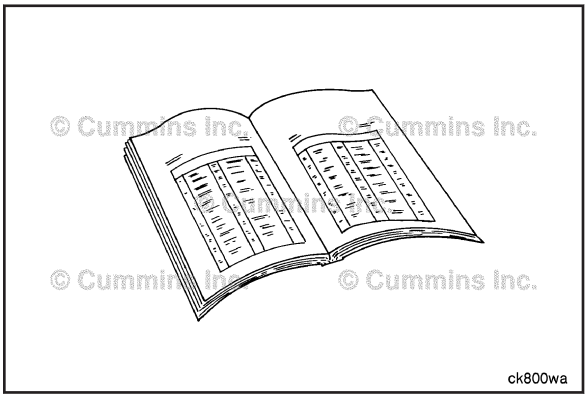
Install the accessory drive and new gasket.

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

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

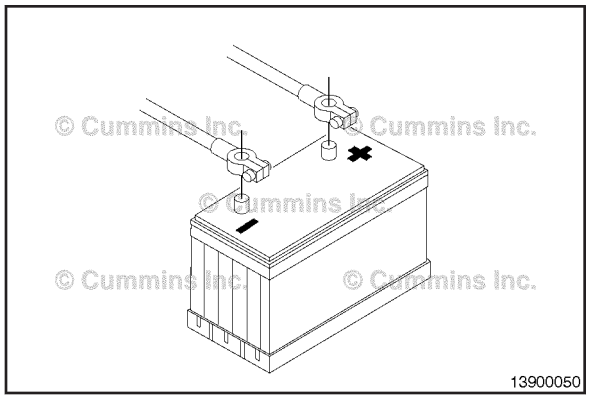
Torque Value: 62 N•m [46 ft-lb]

Finishing Steps



Install the driven accessory. Refer to the OEM instructions.

NOTE: Typically the driven accessory is a hydraulic pump. Refer to Procedure Procedure 009-016 for general installation instructions.

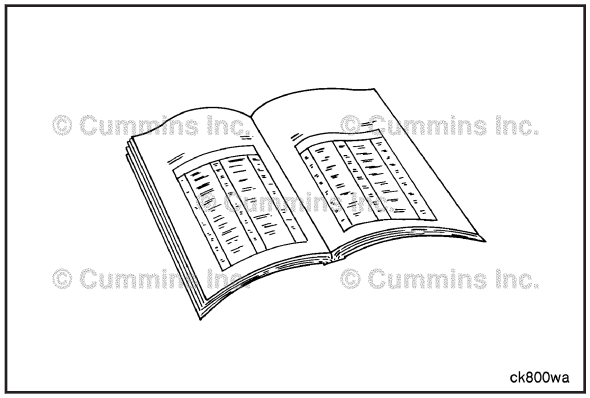


⚠WARNING⚠

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

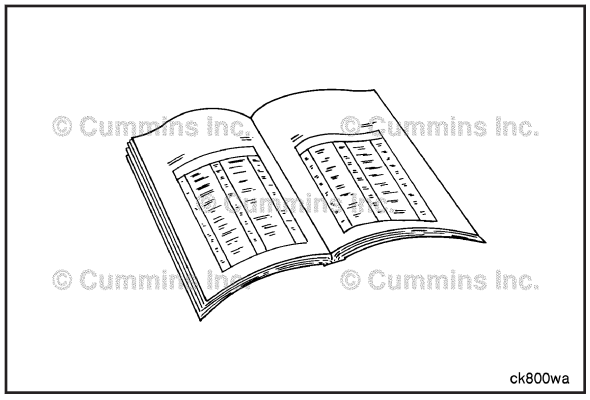
Operate the engine and check for leaks.



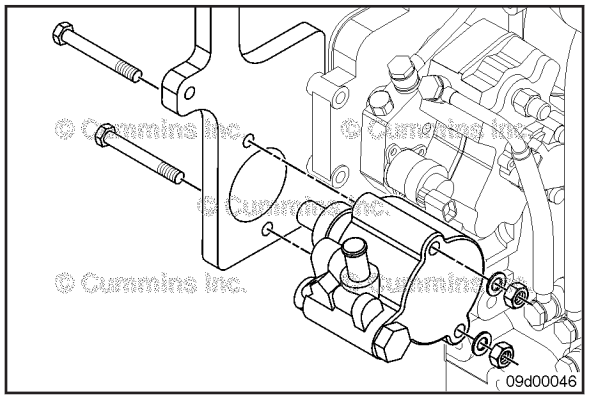
Hydraulic Pump Drive (009-016)

Preparatory Steps

- Disconnect the hydraulic line and hose from the pump.
- Cover the hose connections to protect from contamination.
- Remove the drive belt. Refer to Procedure 008-126 in Section 8.
- Remove the retaining capscrews and pulley from the hydraulic pump shaft.



- Disconnect all hydraulic lines from the pump.
- Cover the hose connections to protect from contamination.



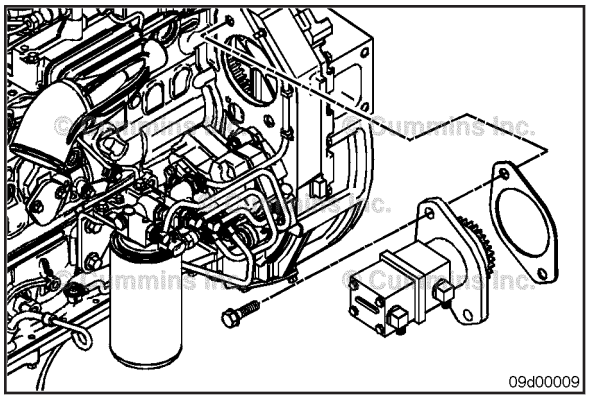
Remove

Remove the nuts and bolts supporting the pump.

Remove the pump.

NOTE: Refer to the OEM service manual for removal procedures.

Remove the hydraulic pump and gear assembly.



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.

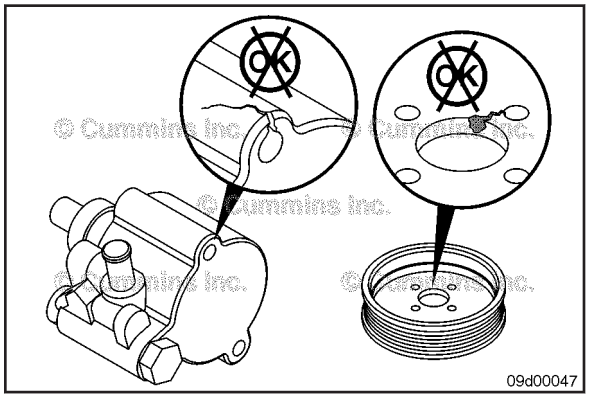
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

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

Clean the outside of the pump.

Inspect the pump for any damage or cracks.

Inspect the pulley for any cracks, damage, or wear.



⚠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.

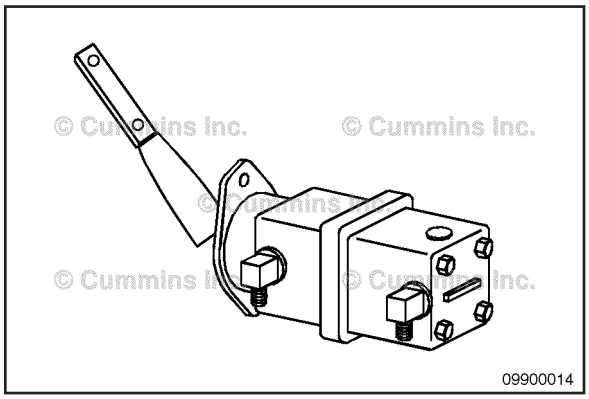
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

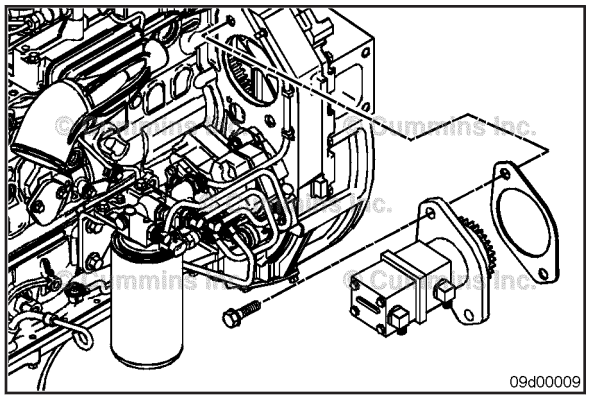
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the gasket material from the hydraulic pump with a putty knife and a clean rag.

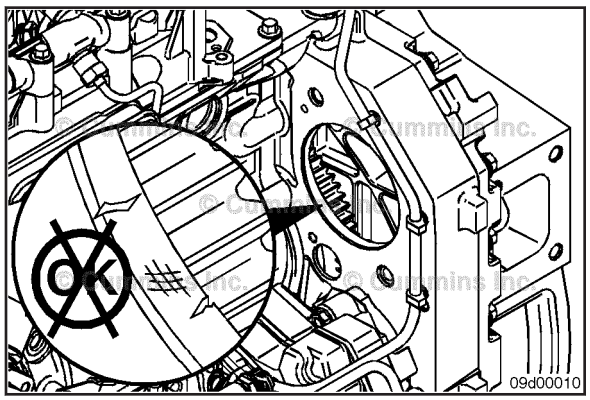
Clean the hydraulic pump gear with solvent.

Dry with compressed air.

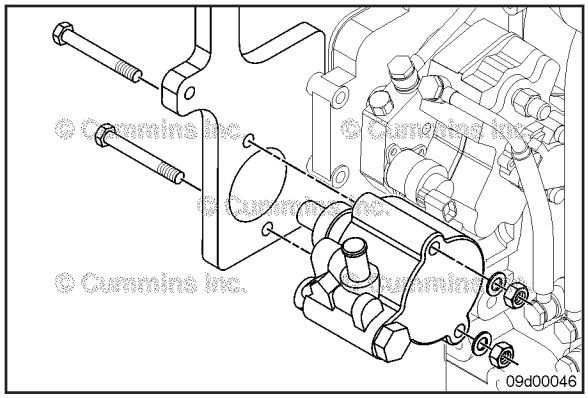




Inspect the hydraulic pump drive for cracks, broken teeth, and other damage.



Inspect the inside diameter of the drive gear bore for excessive wear or damage; replace if necessary.



Install

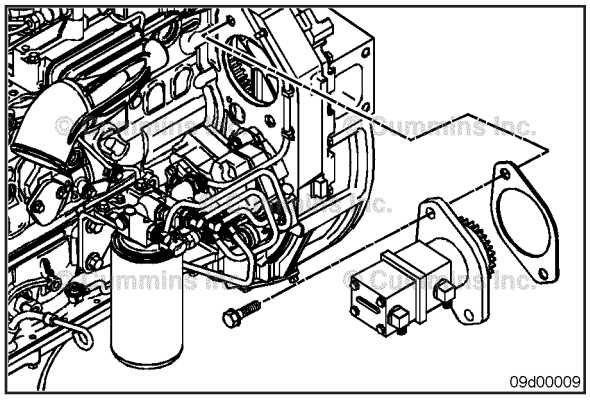
Support the pump in place on the bracket.

Insert the bolts through the bracket and the pump.

Install the nuts on the end of the bolts.

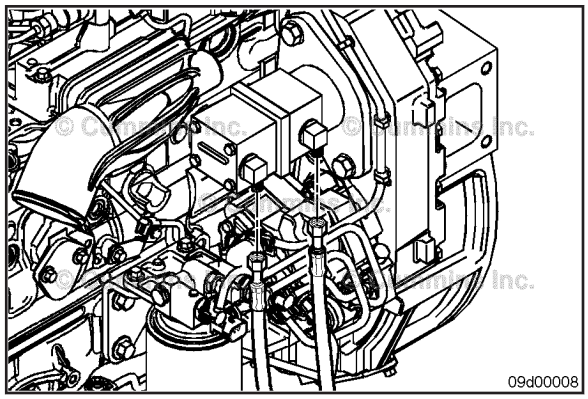
Alternately tighten the bolts.

Torque Value: 41 N•m [30 ft-lb]



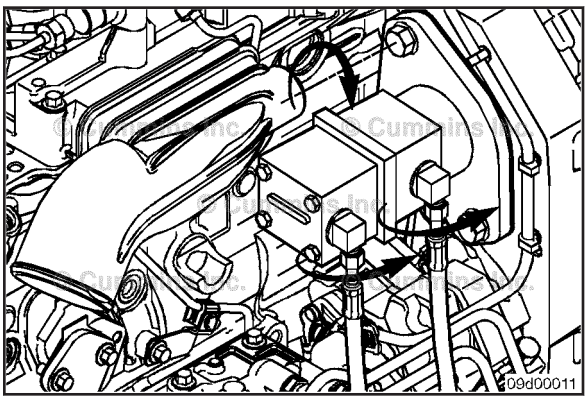
Use a new gasket and install the hydraulic pump.

Connect all hydraulic lines to the pump.



Tighten mounting capscrews.

Torque Value: 62 N•m [46 ft-lb]

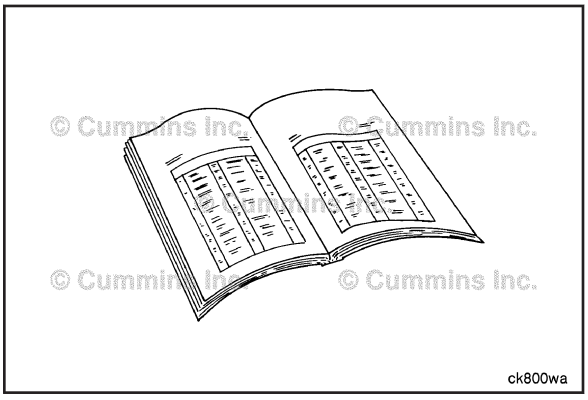


Finishing Steps

- Install the pulley onto the hydraulic pump shaft and retaining capscrews.

Torque Value: 33 N•m [288 in-lb]

- Install the drive belt. Refer to Procedure 008-126 in Section 8.
- Remove the hydraulic line connection covers.
- Connect the hydraulic line (1) and hose (2) to the pump.



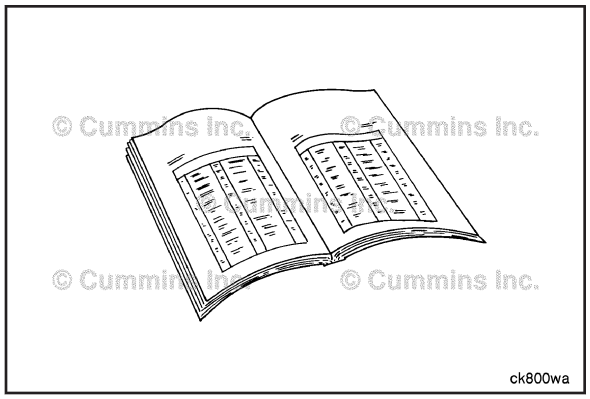
Torque Value:

Hose Sleeve Nut		
Step 1	27 N•m	[239 in-lb]

Torque Value:

Hose Clamp		
Step 1	6 N•m	[50 in-lb]

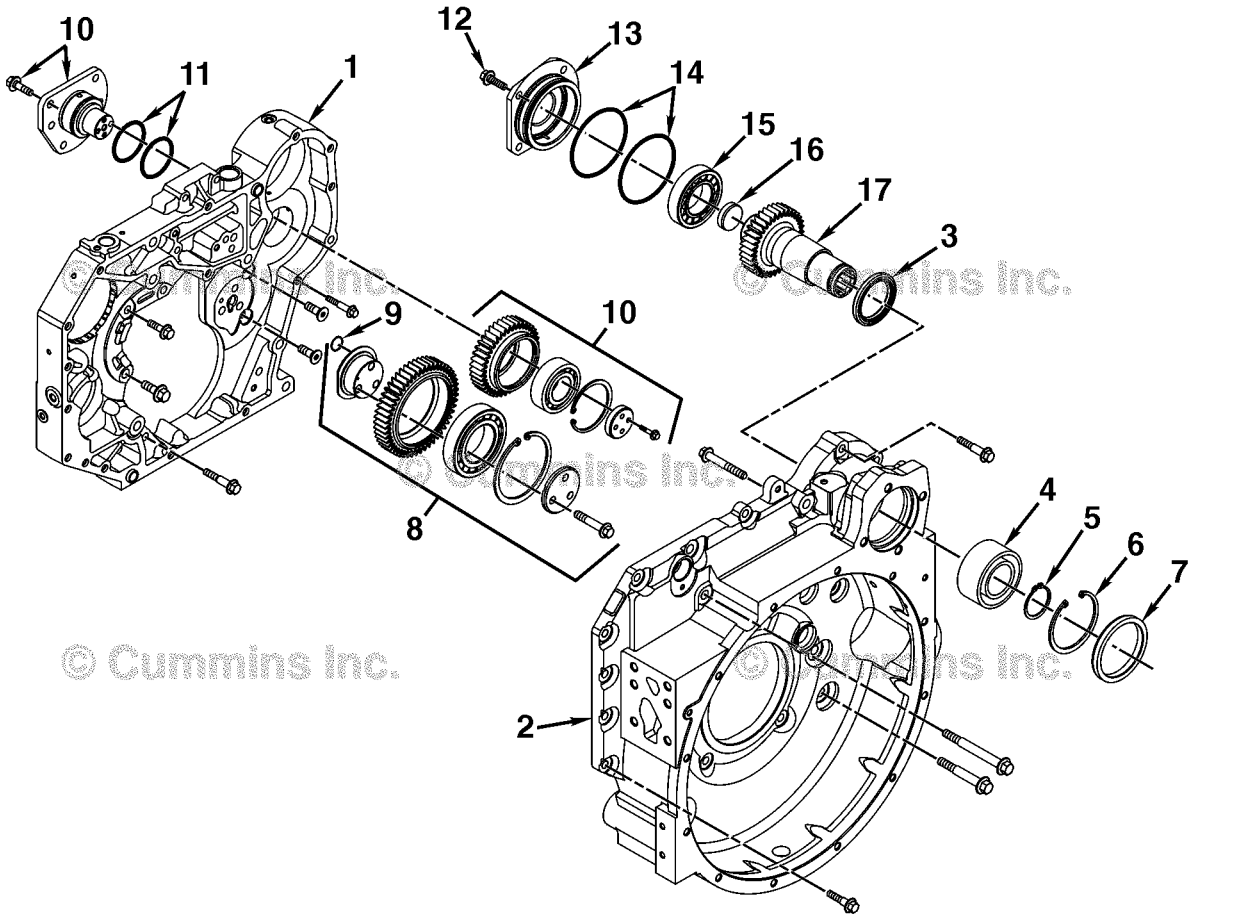
- Operate the engine and check for leaks.



- Remove the hydraulic line connection covers.
- Connect all hydraulic lines to the hydraulic pump.
- Operate the engine and check for leaks.

REPTO (009-022)

Exploded View



1 Gear housing
2 Flywheel housing
3 PTO shaft oil seal
4 PTO shaft ball bearing
5 PTO shaft retainer clip
6 PTO shaft bearing retainer clip
7 Adaptor ring
8 Gear, idler 1 assembly (service assembly)

9 Seal, o-ring, idler 1

10 Gear, idler 2 assembly (service assembly)

11 X2 housing oil seal o-rings

12 PTO shaft housing screws

13 PTO shaft housing

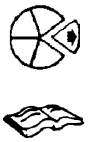
14 X2 PTO shaft support housing oil seal o-rings

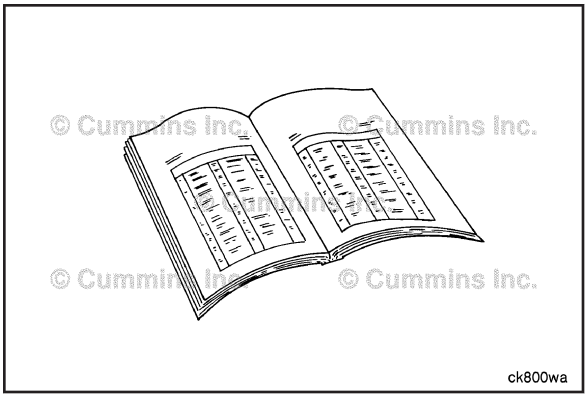
15 PTO shaft housing bearing

16 PTO shaft plug

17 PTO shaft.

Preparatory Steps

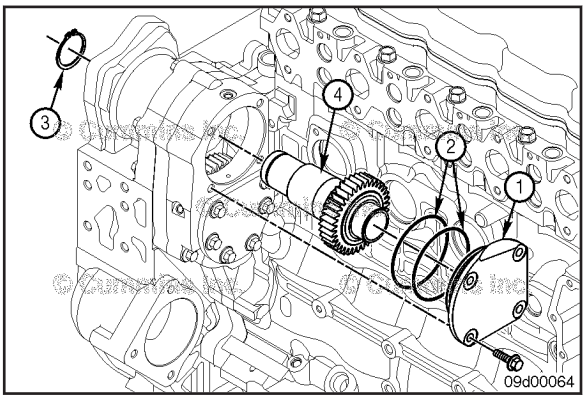




⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the battery. Refer to Procedure 013-009 in Section 13.
- Remove the 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 reduce the possibility of 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 four retaining bolts and remove the PTO shaft support housing (1).

The PTO shaft bearing in the support housing will separate, leaving the inner race fixed on the PTO shaft.

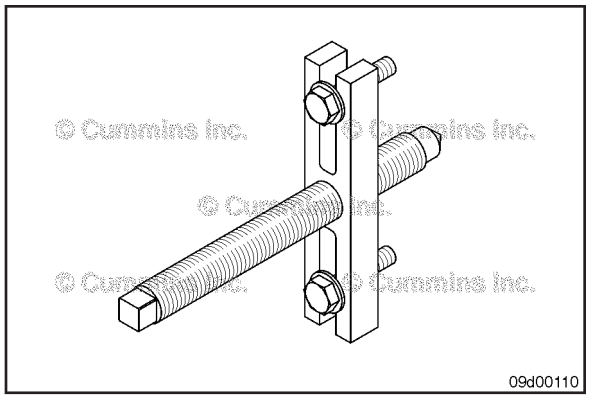
The outer race and caged rolling elements remain fixed in the support housing.

Do **not** damage the bearing during this process.

Keep the bearing assembly clean and free from contamination.

Remove and discard the two sealing o-rings (2) from the PTO shaft housing.

Remove the external retainer clip (3) from the PTO shaft.

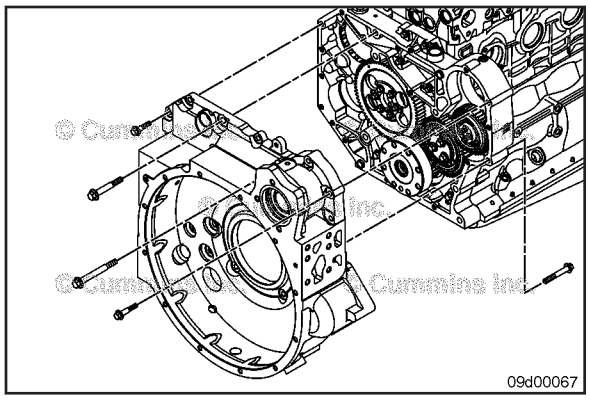


Remove the PTO shaft (4) using an installer/puller tool similar to that shown in the illustration. The tool used **must** be 5 inches in length and be able to accept the 12mm bolts on the pump mounting face of the flywheel housing. Press the PTO shaft out of the bearing using a large washer or similar to blank the hole in the center of the shaft and by screwing the threaded portion of the tool.

NOTE: Some early versions of the REPTO system use Loctite™ to bond the inner race of the flywheel housing bearing onto the PTO shaft. Later versions use an interference fit.

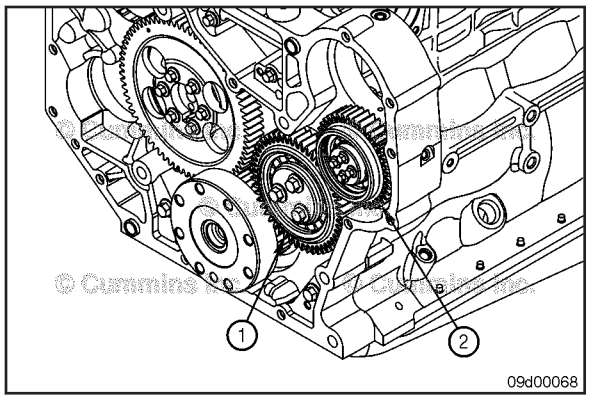
The PTO shaft bearing in the flywheel housing remains complete and fixed in place.

Do **not** damage the PTO shaft.

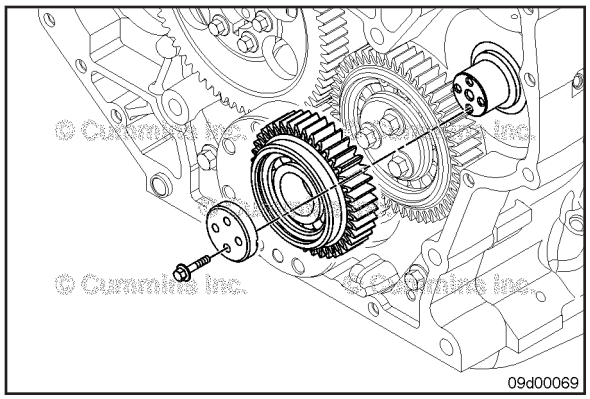


⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

Remove the REPTO flywheel housing. Refer to Procedure 016-006 in Section 16.



Identify the position of idler assemblies 1 and 2.



Remove the four bolts and retainer washer from idler 2.

Remove idler assembly 2 from the support shaft.

The bearing has a split inner race and part of this remains fixed on the support shaft.

The retaining edge part of the inner race is removed in this process.

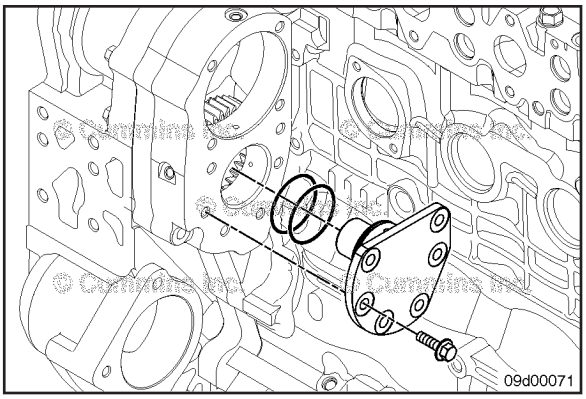
The outer bearing race and caged rolling elements remain fixed inside idler assembly 2.

Do **not** damage the bearing during this procedure.

Keep the bearing clean and free from contamination.

Remove the six retaining bolts and idler 2 support housing.

Remove and discard the two oil seal o-rings from the support housing.



Remove the three bolts and retainer washer from idler assembly 1.

Remove idler assembly 1 and the support shaft.

The bearing has a split inner race and part of this remains fixed on the support shaft.

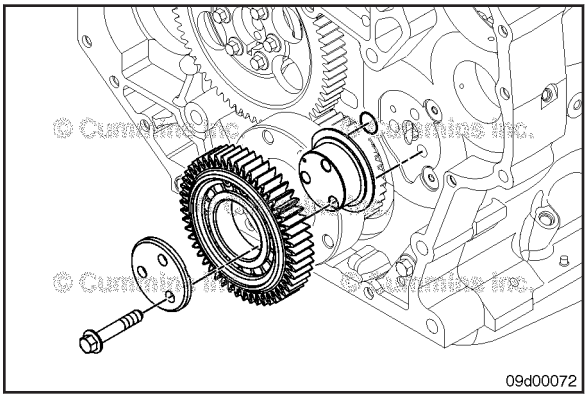
The retaining edge part of the inner race is removed in this process.

Remove and discard the oil supply seal o-ring.

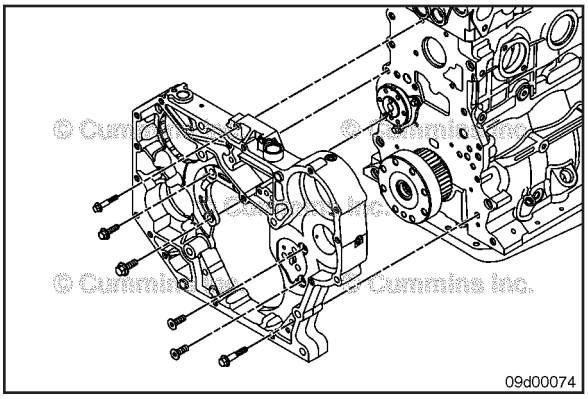
The outer bearing race and caged rolling elements remain fixed inside idler assembly 1.

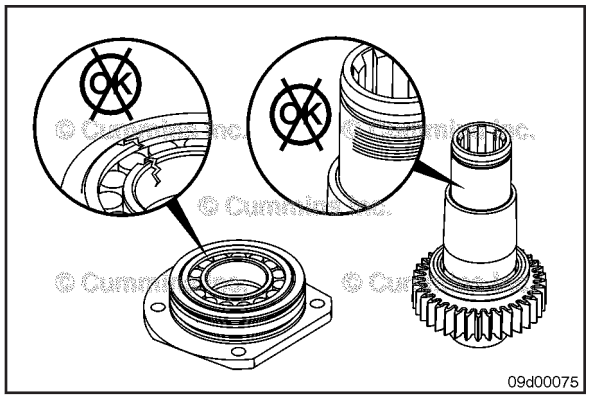
Do **not** damage the bearing during this procedure.

Keep the bearing assembly clean and free from contamination.



Remove the REPTO rear gear cover. Refer to Procedure 001-034 in Section 1.





Clean and Inspect for Reuse

⚠WARNING⚠

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

Use a steam cleaner to clean all areas of the REPTO assembly.

Inspect the PTO shaft bearings for wear or damage.

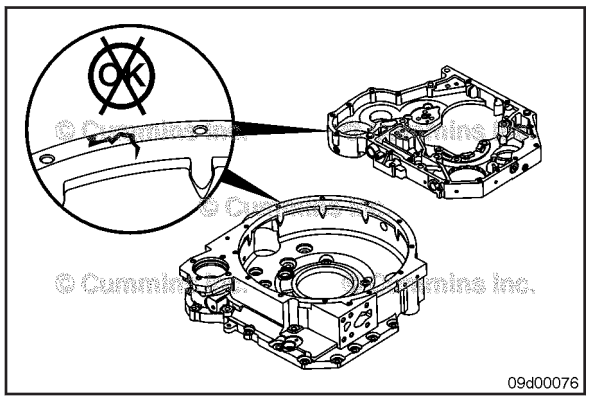
Replace the PTO shaft bearings if they are worn or damaged.

Inspect the PTO shaft for damage and/or wear grooves from the oil seal.

Inspect the PTO shaft gear for damage.

Replace the PTO shaft bearing if it is worn or damaged.

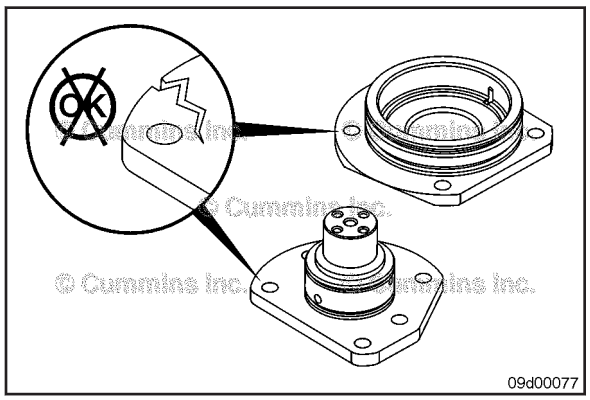
The PTO shaft housing bearing **must** be replaced every time the PTO shaft is removed.



Inspect the REPTO flywheel housing for cracks at the rear engine mounting surfaces and flywheel bore.

Inspect the REPTO gear cover for cracks.

Replace the complete REPTO housing and/or gear cover assembly, if cracked or damaged.



Inspect the idler 2 and PTO shaft support housing assemblies for cracks or damage.

Replace the complete idler assembly 2 if there are cracks or damage.

Replace the PTO shaft support housing if there are cracks or damage.

Inspect the teeth, side faces, and bore of idler gear 1.

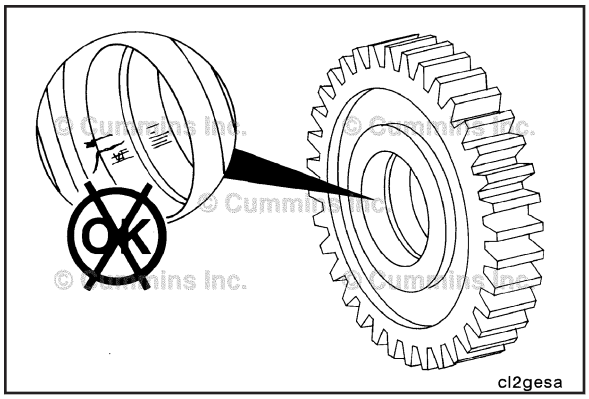
Inspect the teeth, side faces, and bore of idler gear 2.

Replace the complete idler assembly if there are cracks or discoloration from heat damage, or any other damage.

Inspect the bearing of idler 1.

Inspect the bearing of idler 2.

Replace the complete idler assembly if there is any damage or wear present in the bearing.

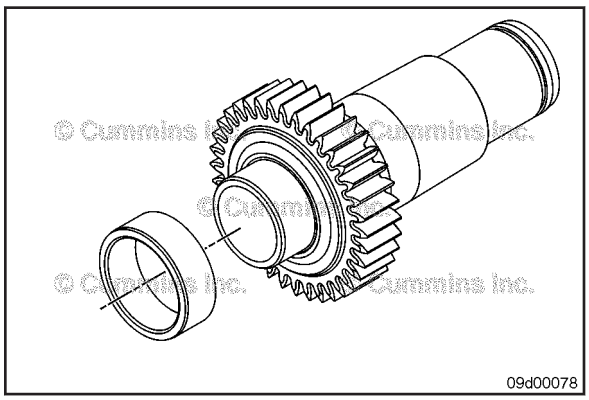


Disassemble

Use a bearing puller to remove the inner bearing race from the PTO shaft.

Discard the inner race.

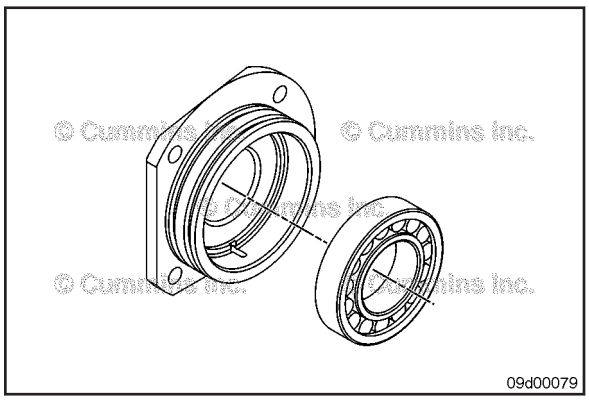
Do **not** damage the PTO shaft in this process.



Use a bearing puller to remove the bearing outer race and caged rolling elements from the PTO shaft support housing.

Discard the outer race and caged rolling elements.

Do **not** damage the PTO shaft support housing in this process.



Use a seal puller to remove the PTO shaft oil seal (1) from the flywheel housing.

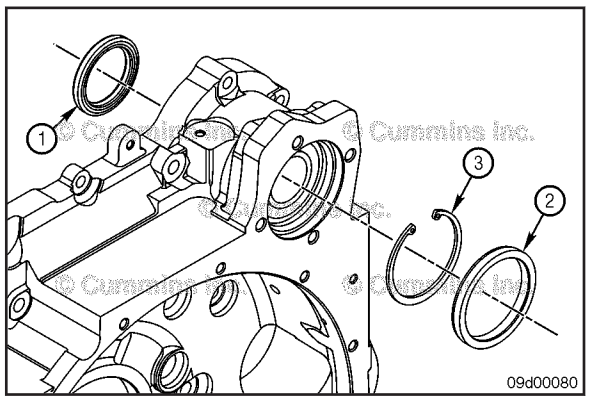
Discard the oil seal.

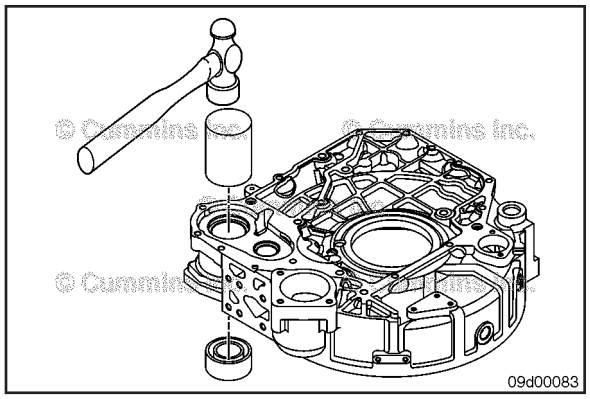
Use a standard puller tool to remove the accessory mounting adaptor ring (2).

Discard the adaptor ring, if damaged.

Do **not** damage the flywheel housing.

Remove the bearing retainer clip (3) from the flywheel housing.





Position the flywheel housing with the transmission mating face downward.

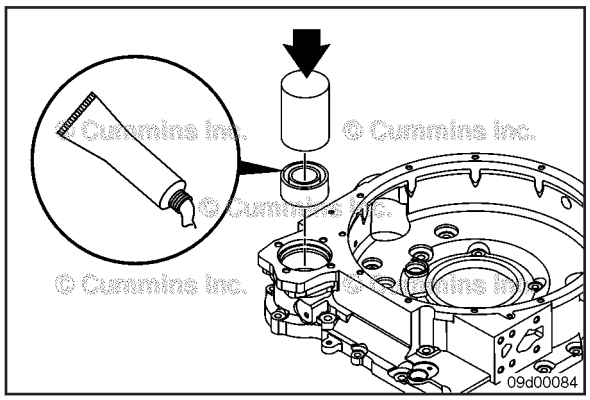
Leave a path for the bearing to exit.

Support on a flat surface so the load is evenly distributed.

Use a hammer and suitable bearing drift to push out the bearing.

Do **not** damage the flywheel housing.

Discard the bearing.



Preparatory Steps

Use assembly lubricant, Part Number 3163087 or equivalent, to lubricate the new flywheel housing bearing outer race and rolling elements.

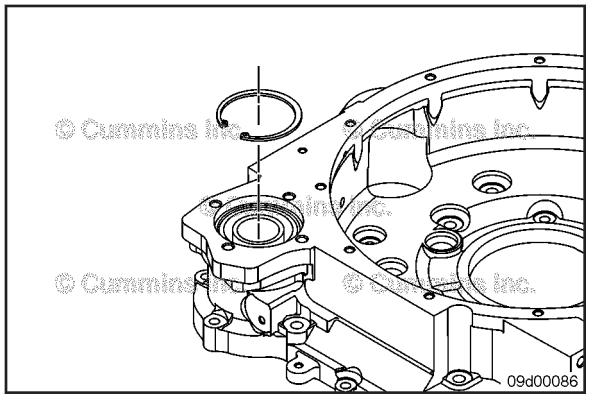
Position the flywheel housing with the engine mating face downward.

Support on a flat surface so the load is evenly distributed.

Press the new bearing fully into the housing.

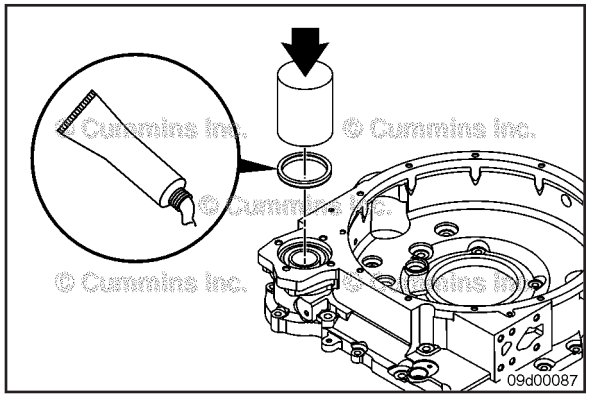
Apply the load **only** to the outer bearing race. Applying load to the inner bearing race will result in damage.

Make sure the outer bearing race is fully seated in the housing recess.



Replace the bearing retainer clip in the flywheel housing.

Make sure the clip is fully located in the groove.



Use assembly lubricant, Part Number 3163087 or equivalent, to lubricate the flywheel housing accessory mounting adaptor ring.

Position the flywheel housing with the engine mating face down.

Support on a flat surface so the load is evenly distributed.

Press the new accessory mounting adaptor ring into the housing.

Make sure the ring is fully seated in the housing recess.

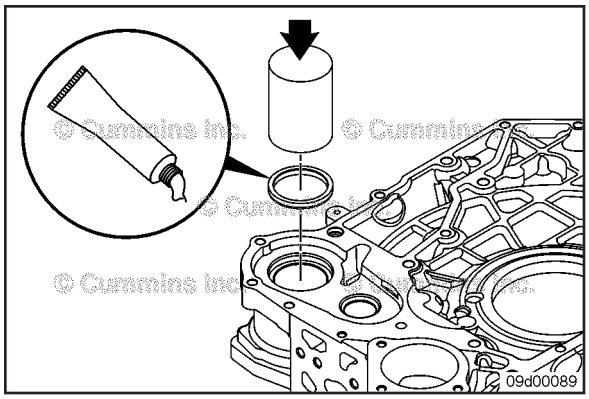
Use assembly lubricant, Part Number 3163087 or equivalent, to lubricate the new PTO shaft oil seal.

Position the flywheel housing with the transmission mating face downward.

Support on a flat surface so the load is evenly distributed.

Press the new PTO shaft oil seal fully into the flywheel housing recess.

Make sure the new seal is fully seated on the shoulder and is aligned correctly.



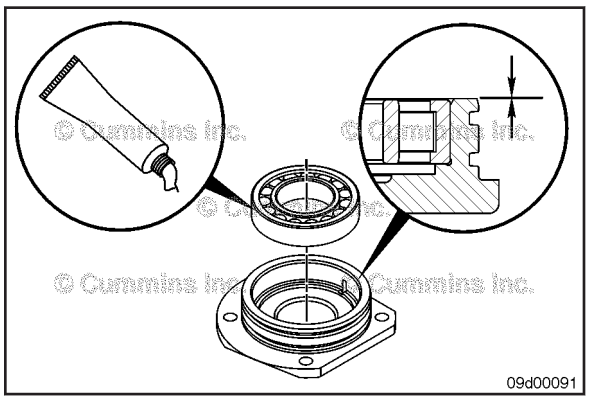
Use assembly lubricant, Part Number 3163087 or equivalent, to lubricate the new PTO shaft support housing bearing outer race and rolling elements.

Position the PTO shaft support housing on a flat surface with the bearing entrance facing upward.

Press the new lubricated bearing outer race into the PTO shaft support housing until it is exactly flush with the top of the housing entrance.

The outer race **must** be located to within a maximum tolerance of +/- 0.2 mm [0.008 in] from the top of the housing entrance.

Do **not** damage or load the exposed rolling elements in this process. Apply the press load to the outer race **only**.

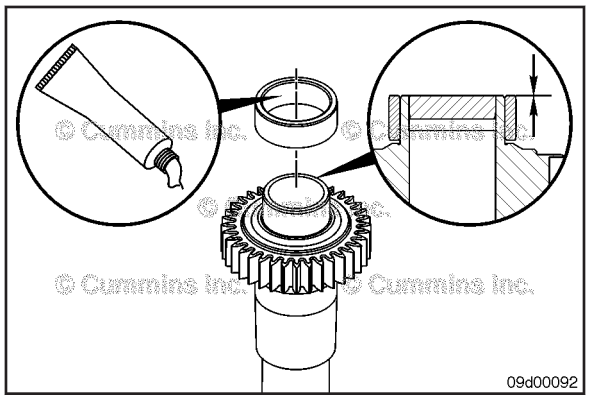


Use assembly lubricant, Part Number 3163087 or equivalent, to lubricate the new PTO shaft support housing bearing inner race.

Position the PTO shaft on a flat surface with the accessory drive end facing downward.

Press the new lubricated bearing inner race into the PTO shaft until it is exactly flush with the top end of the PTO shaft.

The inner race **must** be located to within a maximum tolerance of +/- 0.2 mm [0.008 in] from the end of the shaft.

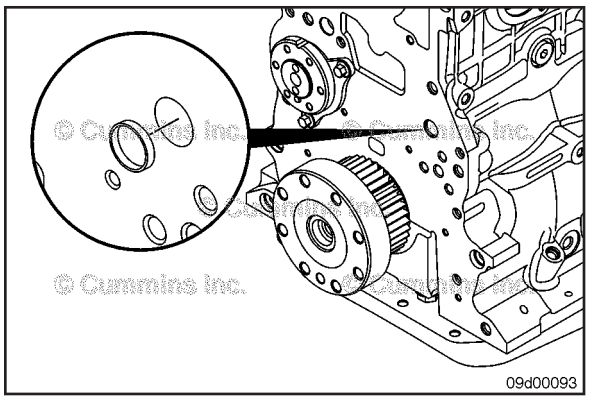


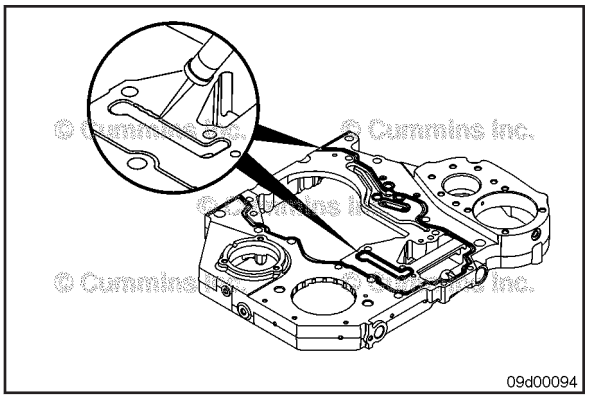
Install

Make sure the rear engine block face is clean and free from previous sealant or any other contamination.

Inspect the rear face of the cylinder block for nicks and burrs or any other damage.

NOTE: Make sure the oil cup plug from the piston cooler nozzle rifle is removed prior to installation. Be sure any sealant present behind this cup plug is removed. This passage is used to feed the REPTO system with lubrication oil.



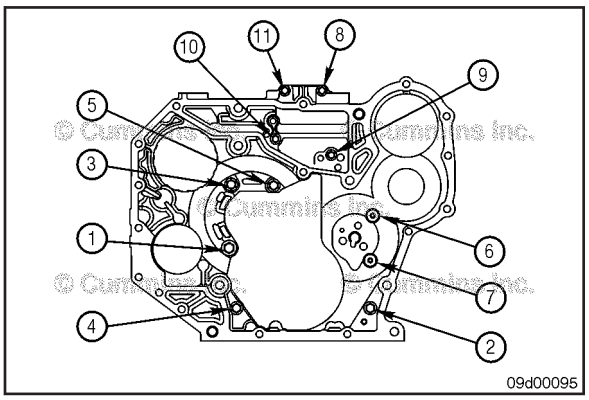


Inspect the rear gear cover mating surfaces and make sure they are clean and free from any form of contamination or damage.

Apply a continuous bead of RTV sealant, Part Number 3164067 or equivalent, around the specific path on the REPTO gear cover shown. Refer to Procedure 001-034 in Section 1.

NOTE: The sealant **must** be applied with care around the auxiliary oil port cavity. Do **not** allow excessive sealant to overflow into the oil port cavity.

NOTE: The REPTO system requires a special REPTO crankshaft with increased gear torque capacity.



Inspect the REPTO rear gear cover on the cylinder block.

Tighten the screws in the sequence shown.

Torque Value:
M12: 77 N•m [57 ft-lb]

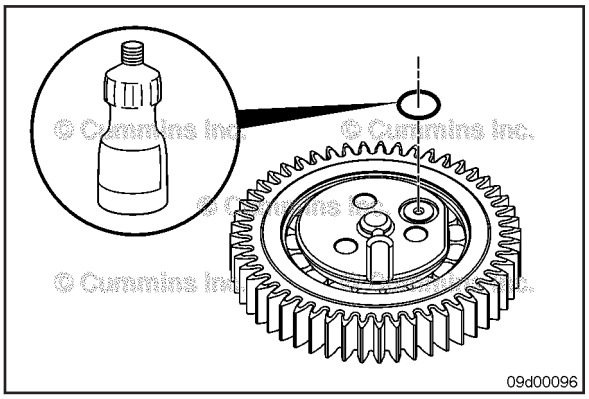
Torque Value:
M10: 47 N•m [35 ft-lb]

Torque Value:
M8: 24 N•m [212 in-lb]

Install the two flat hex screws at positions 6 and 7 then tighten.

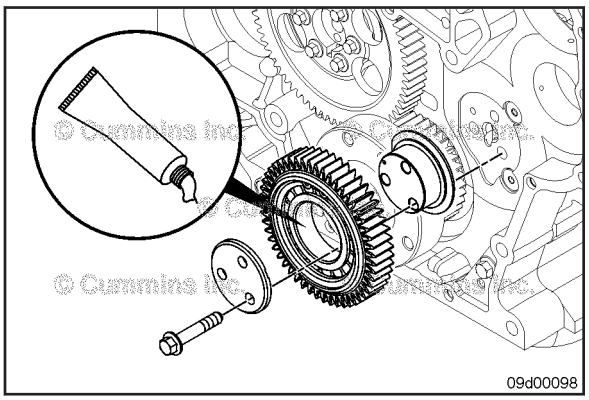
Torque Value: 47 N•m [35 ft-lb]

Refer to Procedure 001-034 in Section 1.



Use clean vegetable oil to lubricate the new oil seal o-ring to be installed with idler assembly 1.

Install the new oil supply seal o-ring on the rear of idler assembly 2.



Lubricate the bearing of idler assembly 1 with assembly lubricant, Part Number 3163087.

Install idler assembly 1 on the cylinder block rear face engaging in mesh with the crankshaft gear.

Make sure the retaining edge part of the split inner bearing race is in position and the oil seal o-ring is in place.

Tighten the three retaining bolts with retaining washer.

Torque Value: 43 N•m [32 ft-lb]

Check that the backlash between idler assembly 1 gear and the crankshaft gear is no more than 0.28 mm [0.011] and no less than 0.08 mm [0.003].

Install two new o-rings on idler assembly 2 shaft support housing.

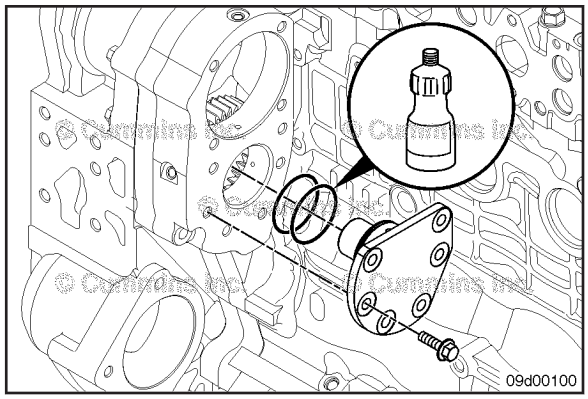
Use clean vegetable oil to lubricate the o-rings.

Install idler assembly 2 shaft support housing complete with the correctly positioned inner bearing race into the REPTO gear cover.

Do **not** damage the two new o-rings during this process.

Tighten the six retaining bolts in a crisscross diagonal pattern.

Torque Value: 35 N•m [26 ft-lb]



Lubricate the bearing rolling elements of idler assembly 2 with assembly lubricant, Part Number 3163087.

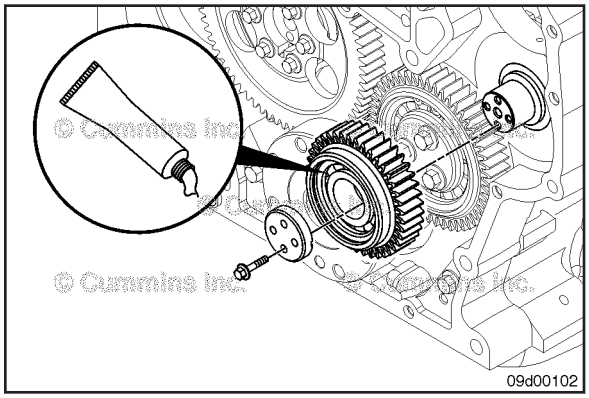
Install idler assembly 2 on the shaft engaging in mesh with idler assembly 1

Make sure the retaining edge part of the split inner bearing race is in position.

Tighten the four retaining bolts in an opposite pattern with the retaining washer.

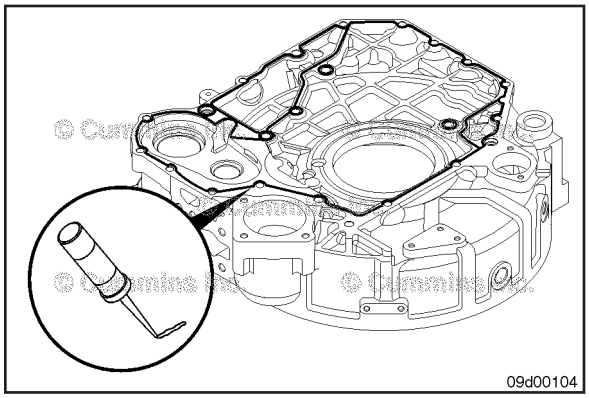
Torque Value: 12 N•m [106 in-lb]

Check that the backlash between the idler assembly 2 gear and idler assembly 1 gear is no more than 0.28 mm [0.011] and no less than 0.08 mm [0.003].



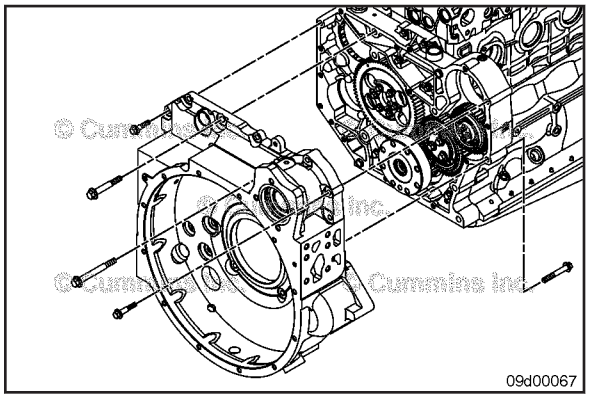
Clean the mating face of the REPTO flywheel housing and make sure it is free from damage.

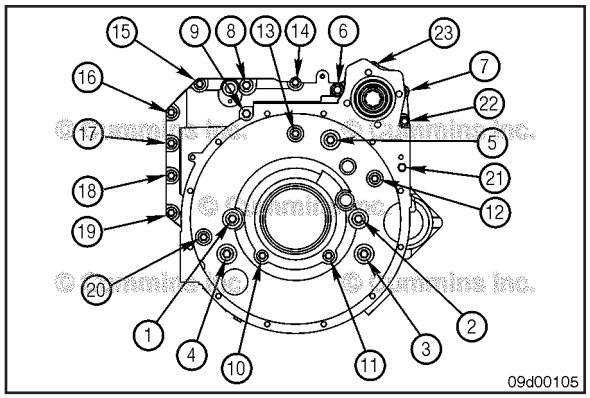
Apply a continuous bead of RTV sealant, Part Number 3164067 or equivalent, around the indicated REPTO path and all capscrew holes on the mating face of the flywheel housing. Refer to Procedure 016-006 in Section 16.



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

Install the flywheel housing over the locating ring dowels.



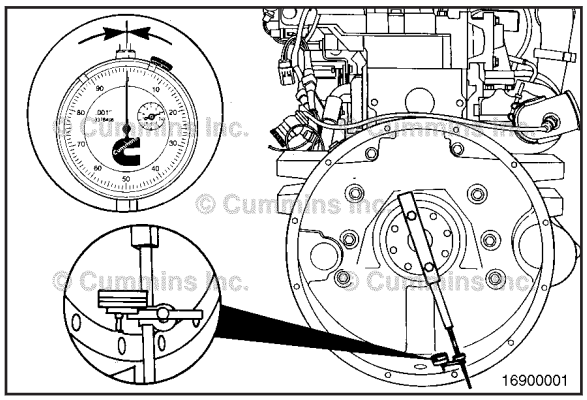


Install the capscrews and tighten in the sequence shown.

Torque Value:
M12: 85 N•m [63 ft-lb]

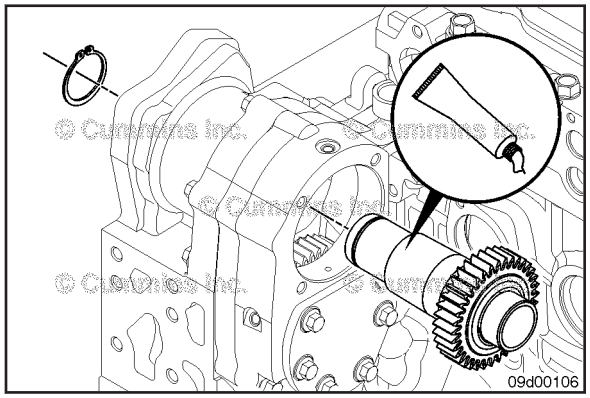
Torque Value:
M10: 49 N•m [36 ft-lb]

NOTE: Capscrew number 21 is inserted from the engine side of the flywheel housing. Refer to Procedure 016-006 in Section 16.



Measure the flywheel housing bore face alignment.

Make sure the runout is within the required specification. Refer to Procedure 016-006 in Section 16.



Lubricate the taper section of the PTO shaft generously with assembly lubricant, Part Number 3163087.

Use an installer tool similar to that shown in the illustration to install the PTO shaft complete with the inner bearing race pre installed in the correct position. The installer tool **must** be 5 inches in length and be able to accept the 10 mm diameter bolts used on this PTO bearing housing mating face.

Use the installer tool to press the PTO shaft through the seal and into the flywheel housing bearing inner race. This is an interference fit. It can possibly be necessary to use long bolts and a supporting thick washer. The flywheel housing bearing inner race **must** be axially supported during this process to prevent the press loads from damaging the bearing.

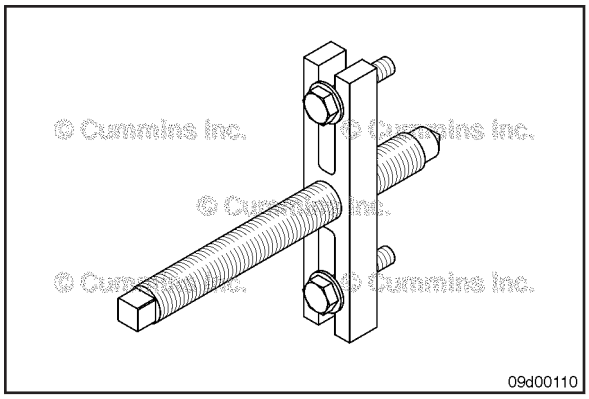
NOTE: Some early versions of the REPTO system used Loctite™ in place of this interference fit. If the service parts allow the PTO shaft to float in the flywheel housing inner race, then a small quantity of Loctite™ **must** be applied to the inner bearing race.

The PTO shaft **must** be inserted as straight and central as possible so the oil seal remains intact and in the correct position.

Small rotations of the shaft will aid insertion through the seal.

NOTE: Make sure the PTO shaft oil seal is **not** damaged during this process. Make sure the lip on the PTO shaft oil seal does **not** become folded over or misaligned.

Install the retainer clip on the end of the PTO shaft.



Install two new o-rings on the PTO shaft support housing.

Lubricate the o-rings with clean vegetable oil.

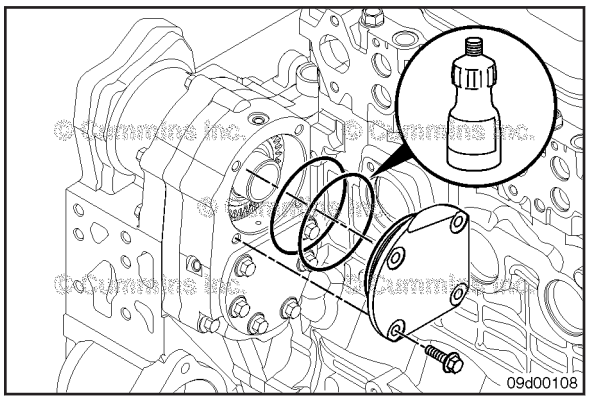
Install the PTO shaft support housing complete with the correctly installed bearing outer race and caged rolling elements.

Tighten the four retaining bolts in a crisscross diagonal pattern.

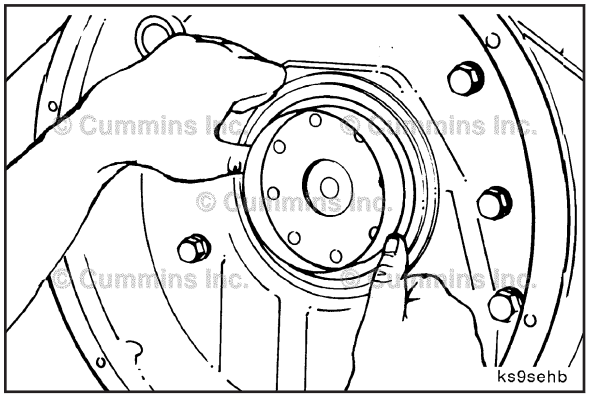
Torque Value: 35 N•m [26 ft-lb]

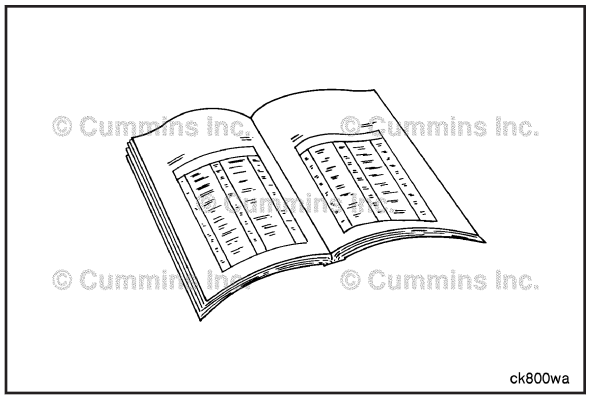
Do **not** damage the bearing rolling elements during this process.

Make sure the complete REPTO gear train backlash, with the crankshaft gear locked, is no more than 0.71 mm [0.028 in] and no less than 0.10 mm [0.004 in].



Install a new rear crank seal. Refer to Procedure 001-024 in Section 1.



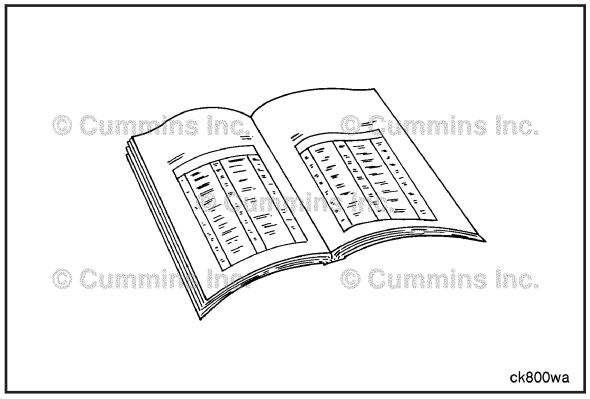


Finishing Steps

⚠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 both rear engine mounts. Refer to Procedure 016-003 in Section 16.
- Install the starting motor. Refer to Procedure 013-020 in Section 13.
- Adequately support the engine to reduce the possibility of damage.
- Install the flywheel/ring gear assembly. 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 Procedure 013-009 in Section 13.
- Operate the engine and check for leaks



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.

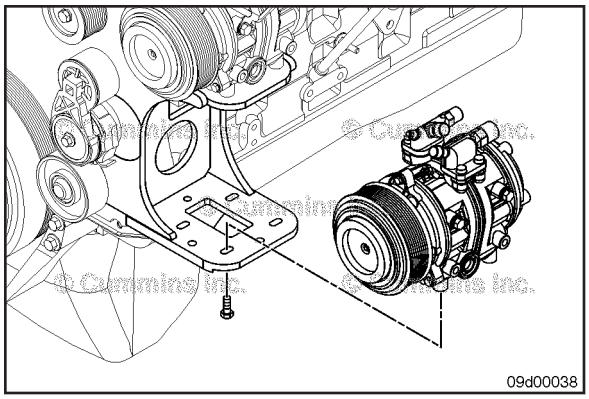
- Disconnect the battery. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and 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.

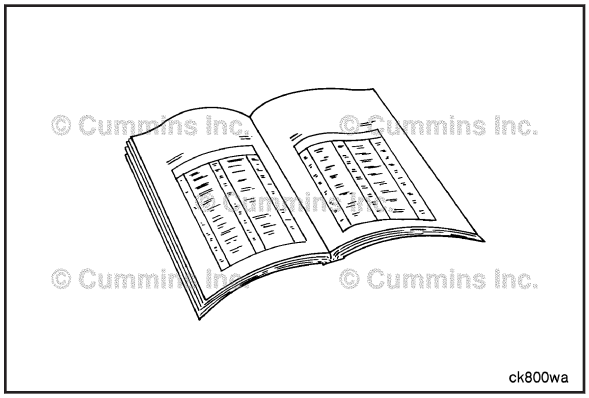
Remove the refrigerant compressor.

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.

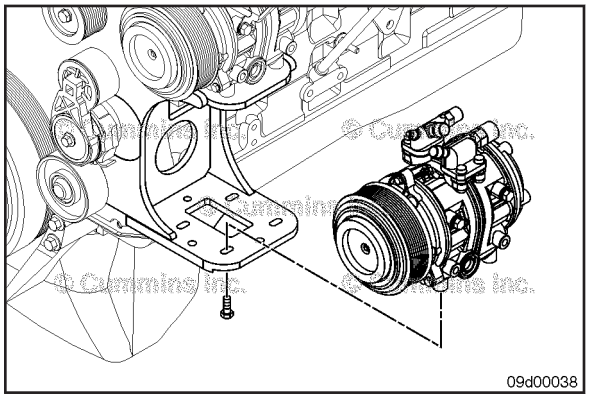


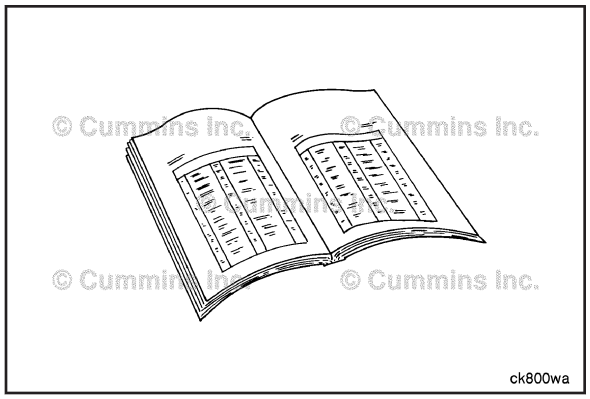
Install

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.



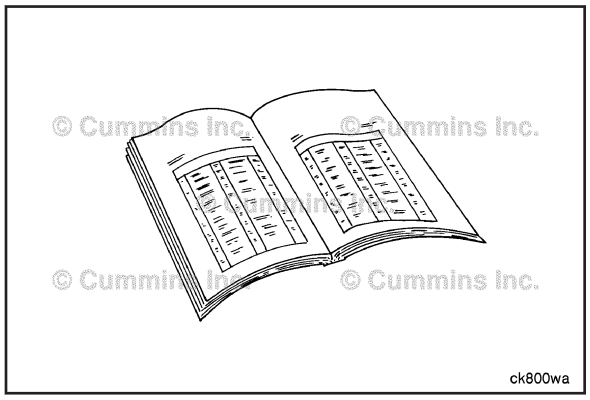


Finishing Steps

⚠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)

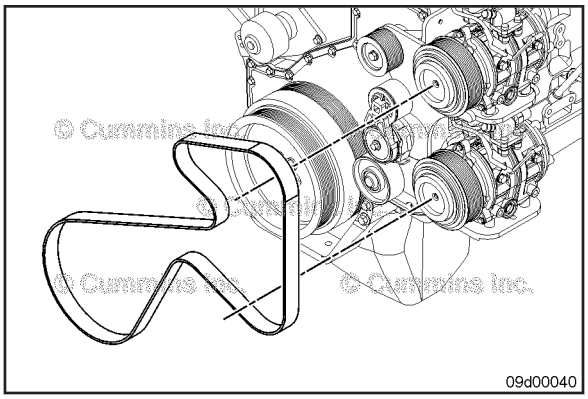
Preparatory Steps

⚠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.

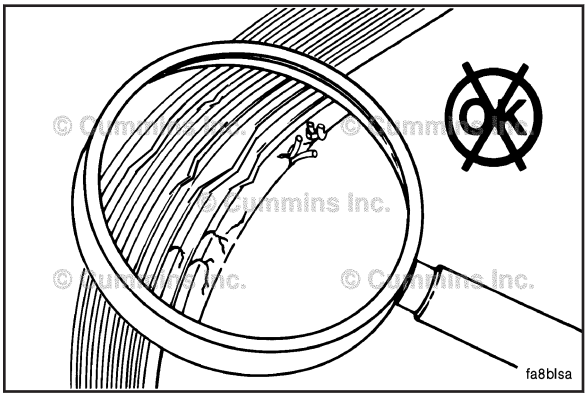
⚠CAUTION⚠
Applying excessive force in the opposite direction of windup or after the tensioner has been wound to the positive stop can cause the tensioner arm to crack or break.

⚠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.

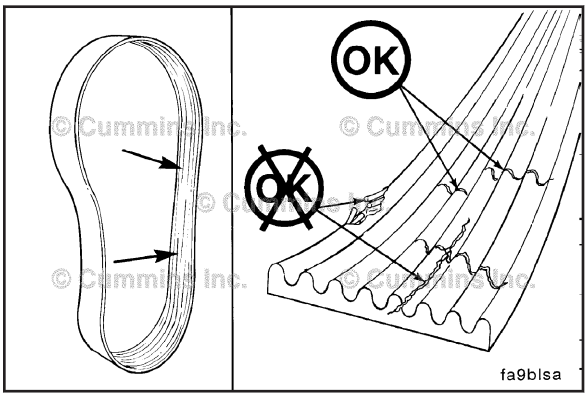
NOTE: If a socket extension is necessary, support the head of the ratchet with one hand to prevent the belt tensioner arm from unintended loading.

Inspect for Reuse



Inspect the belt for:

- Cracks
- Glazing
- Tears or cuts
- Hardening
- Excessive wear.

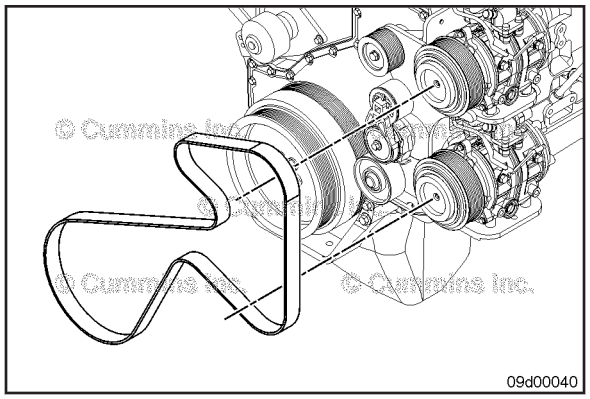


Check the belt for damage.

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

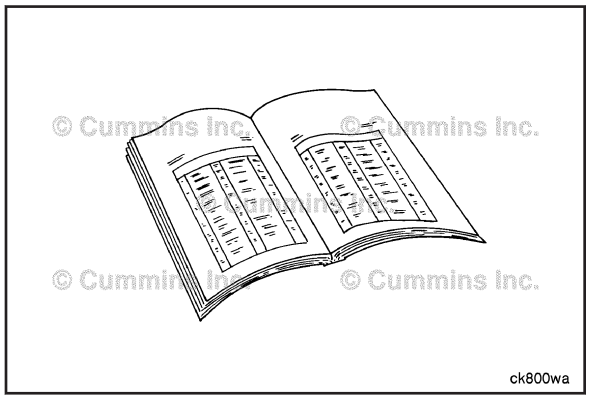
CAUTION

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.

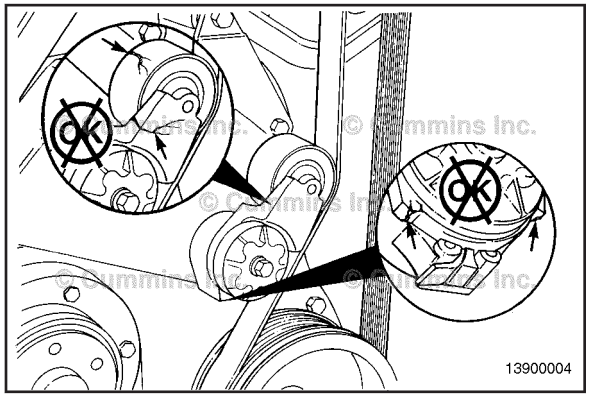


Finishing Steps

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

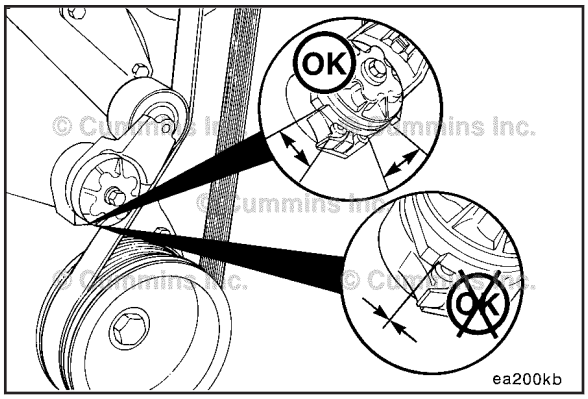
Check the tensioner arm, pulley, and stops for cracks.

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.

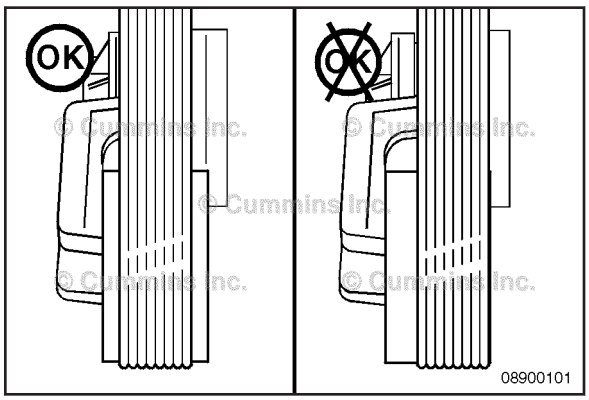
If either stop is touching, the drive belt **must** be replaced.

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.

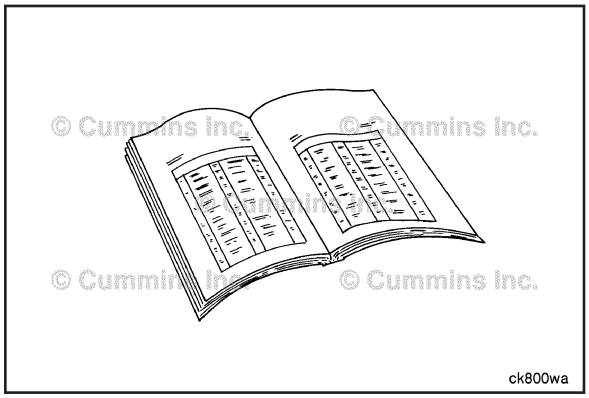
Misaligned belts, either too far forward or backward, can cause belt wear, belt roll-off failures, or increase uneven tensioner bushing wear.

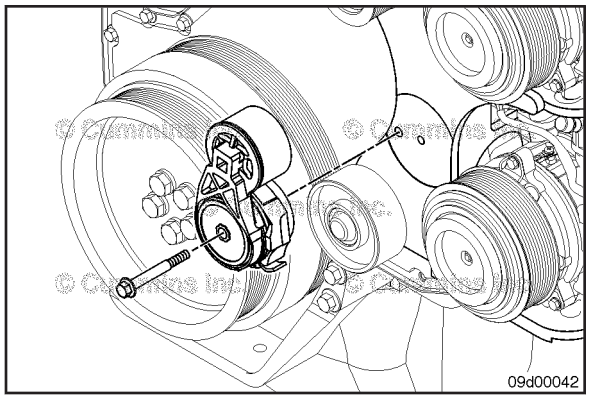


Preparatory Steps

⚠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.

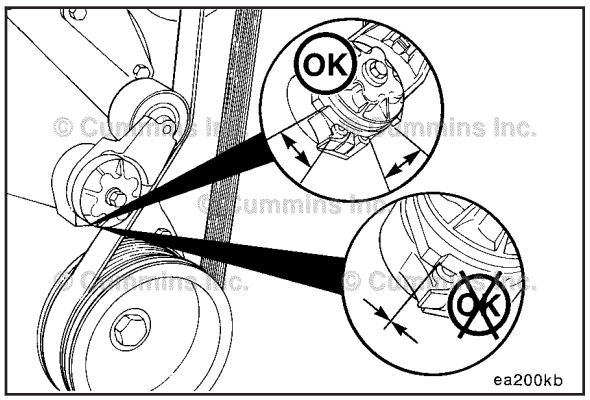
- Disconnect the battery. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and 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

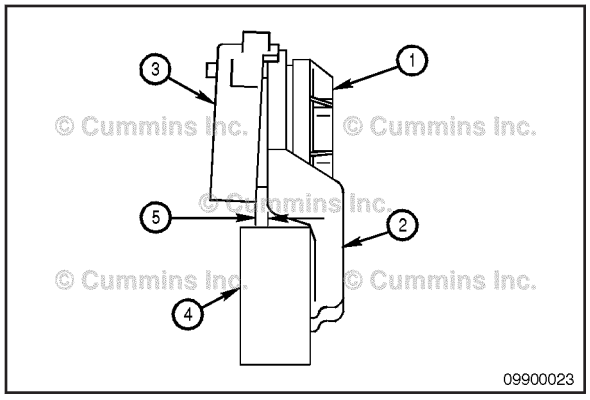
Remove the capscrew and belt tensioner from the mounting location.



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.

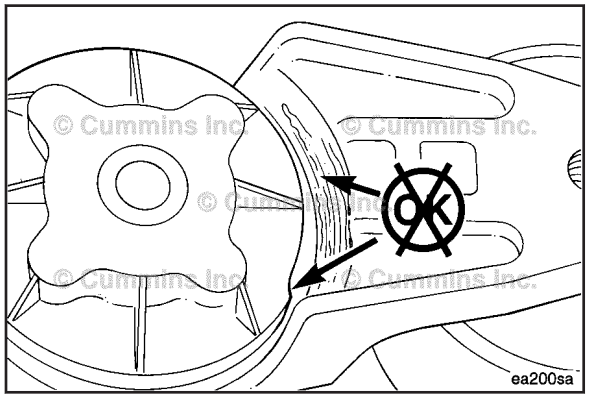


Measure the clearance between the tensioner spring casing and the tensioner arm to verify tensioner wear-out and uneven bearing wear.

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.

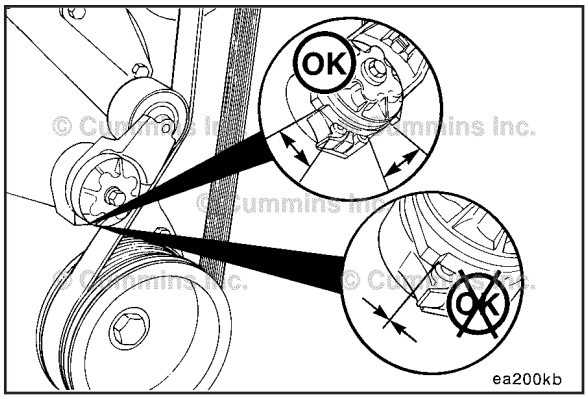
1. Tensioner cap
2. Tensioner arm
3. Spring case
4. Tensioner pulley
5. Clearance gap.



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.

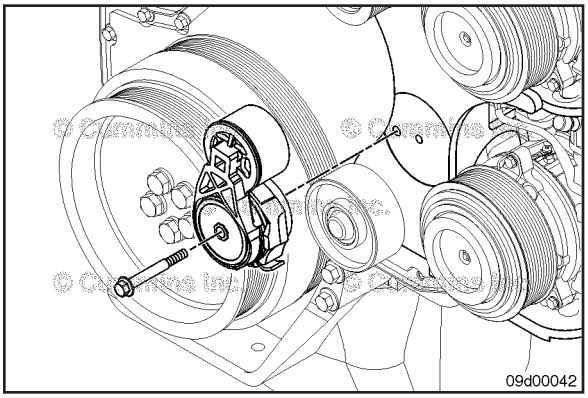
Inspect the mating surface for debris. The tensioner can become misaligned if particles are trapped between the mating surfaces.



Install

Install the belt tensioner and capscrew.

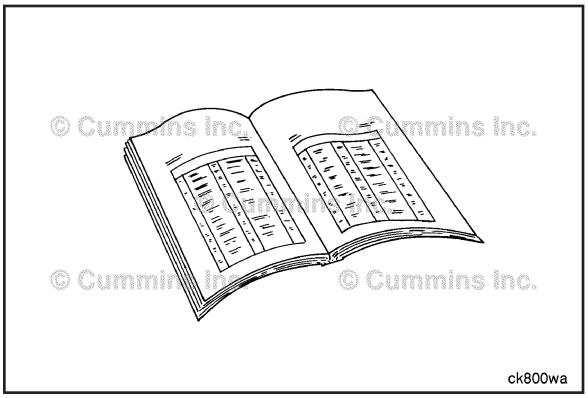
Torque Value: 43 N•m [32 ft-lb]

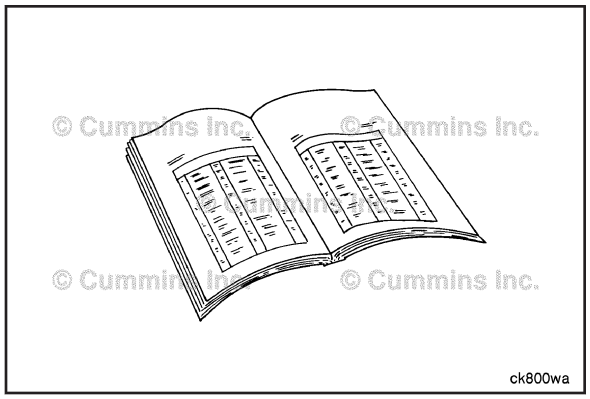


Finishing Steps

⚠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.



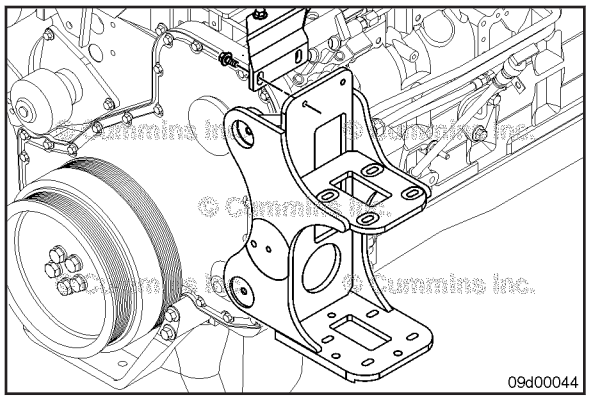


Refrigerant Compressor Mounting Bracket (009-055)

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.

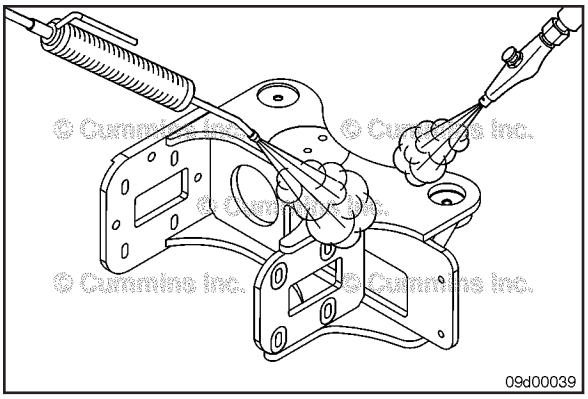
- Disconnect the battery. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271, or Procedure 013-009 (Battery Cables and Connections) in Section 13 of the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and 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.

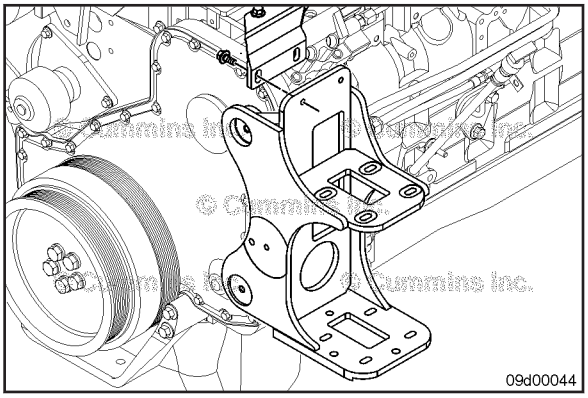
Use steam or solvent to clean the refrigerant compressor mounting brackets.

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.

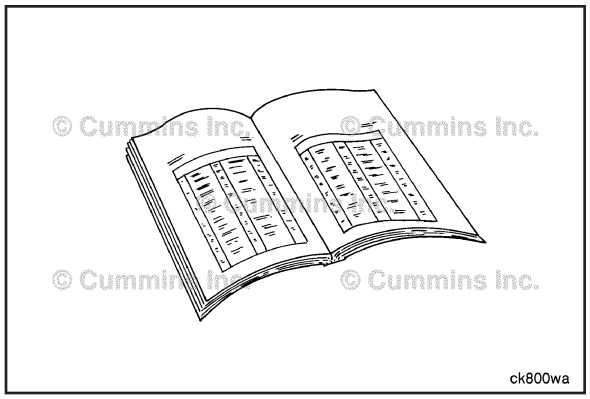
Install



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.

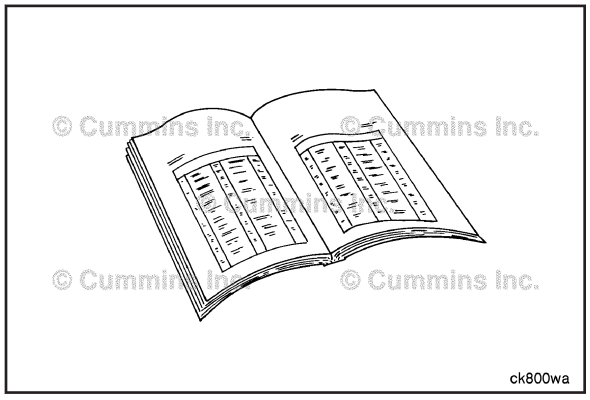


Finishing Steps

⚠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.



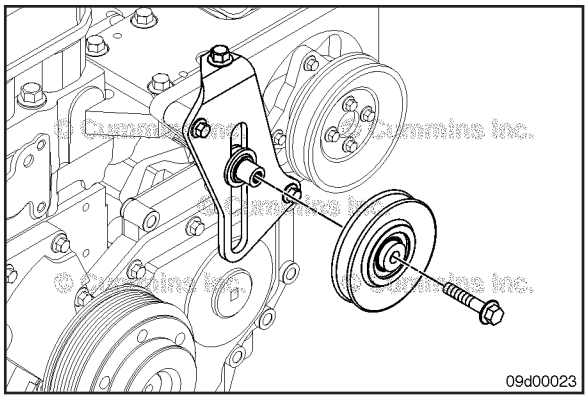
Idler Pulley Sea Water Pump (009-057)

Preparatory Steps

- Remove the belt guard. Refer to Procedure 008-001
- Remove the sea water pump drive belt. Refer to Procedure 008-126

Remove

Remove the sea water pump idler pulley mounting capscrew and the idler pulley.



Clean and Inspect for Reuse

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

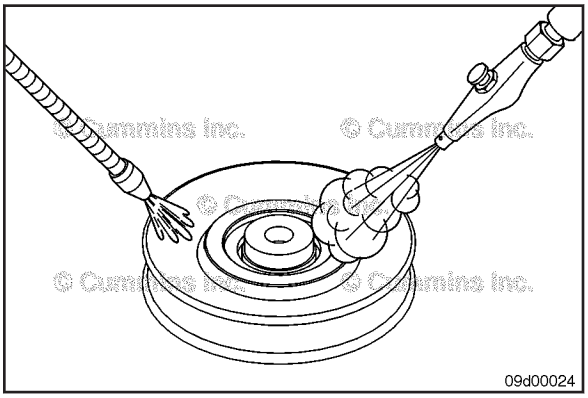
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufactuerer's instructions before using.

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

△CAUTION△
To avoid damage and possible failure of the bearing, do not spray solvent or compressed air directly on the sealed bearing.

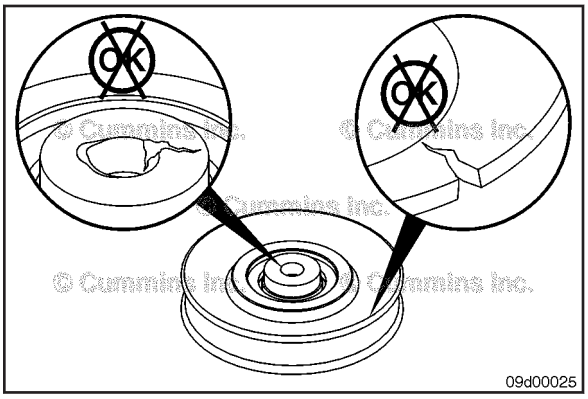
Use solvent to clean the idler pulley.

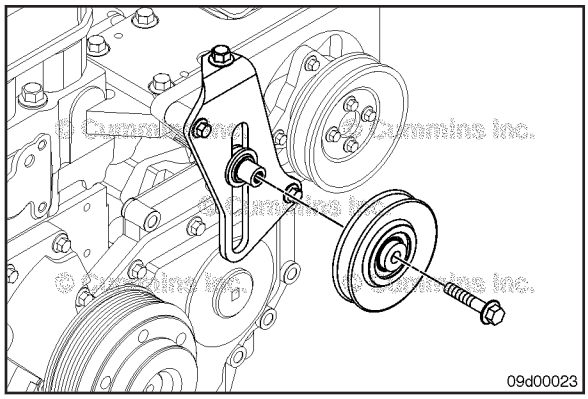
Dry with compressed air.



Inspect the pulley for cracks or other damage.

Inspect the center bearing for damage and that it rotates freely.



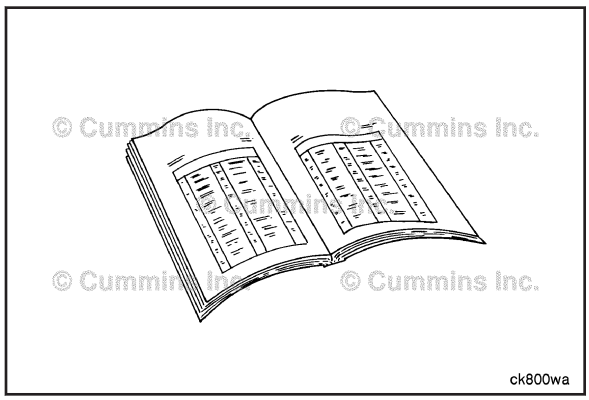


Install

Install the idler pulley, mounting capscrew and outer flat washer.

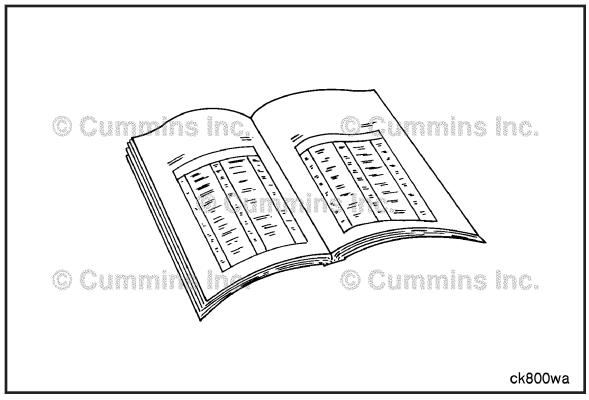
Tighten the capscrew.

Torque Value: 44 N•m [32 ft-lb]



Finishing Steps

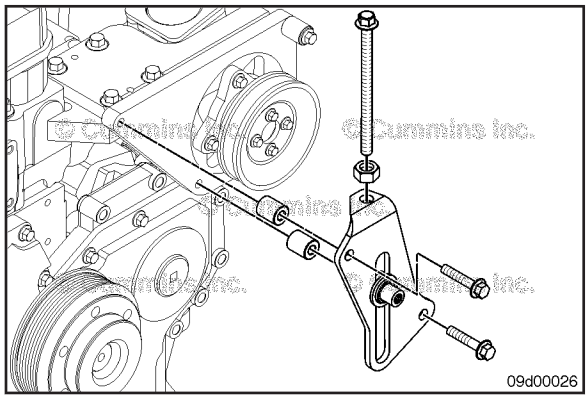
- Install the sea water pump drive belt. Refer to Procedure 008-126
- Install the belt guard. Refer to Procedure 008-001



Idler Pulley Mounting Bracket (009-058)

Preparatory Steps

- Remove the belt guard. Refer to Procedure 008-001
- Remove the sea water pump drive belt. Refer to Procedure 008-126
- Remove the sea water pump idler pulley. Refer to Procedure 009-057



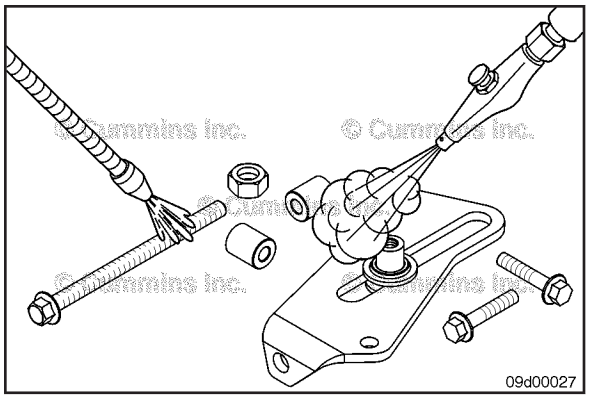
Remove

Remove the two mounting capscrews and the idler pulley mounting bracket.

Remove the adjusting screw and locking nut from the bracket.

Remove the stepped washer and sliding collar.

Clean and Inspect for Reuse



⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufactuerer'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 manufactuerer's instructions before using.

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

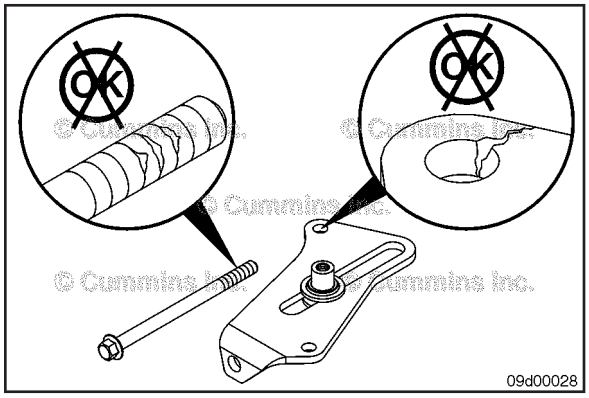
Use solvent to clean the idler pulley mounting bracket, adjusting screw, and related parts.

Dry with compressed air.

Inspect the bracket for cracks or other damage.

Inspect the idler pulley adjusting capscrew for thread damage.

Replace the component if damage is found.



Install

Install the idler pulley adjusting screw and locking nut.

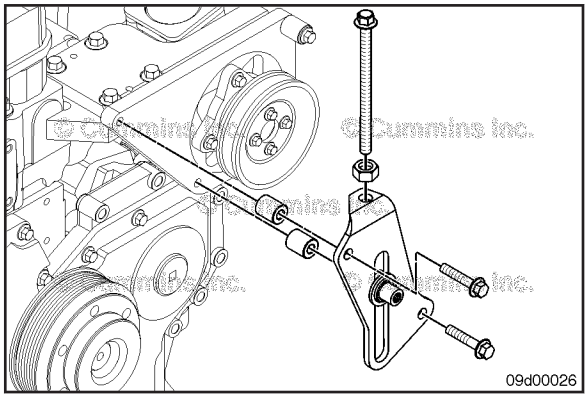
Install the sliding collar.

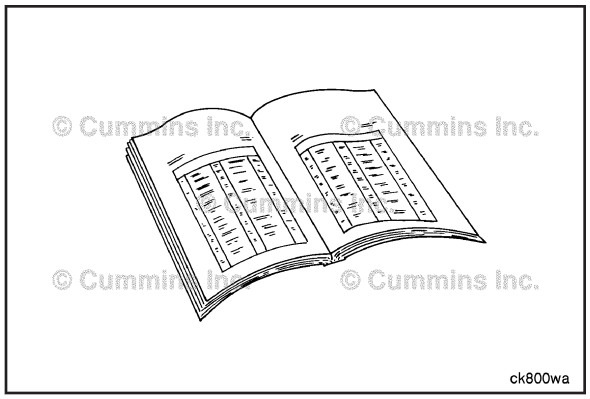
Install the stepped washer with the smaller diameter facing out.

Install the sea water pump idler pulley mounting bracket to the sea water pump support with two mounting capscrews.

Tighten the capscrews.

Torque Value: 44 N•m [32 ft-lb]





Finishing Steps

- Install the sea water pump idler pulley. Refer to Procedure 009-057
- Install the sea water pump drive belt. Refer to Procedure 008-126
- Install the belt guard. Refer to Procedure 008-001

Operate the engine and check for leaks.

Section 10 - Air Intake System - Group 10

Section Contents

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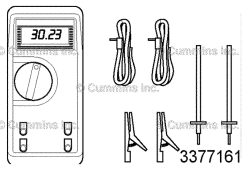
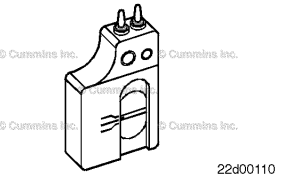
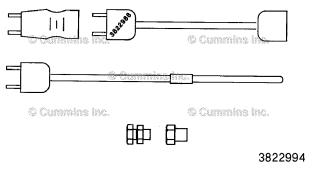
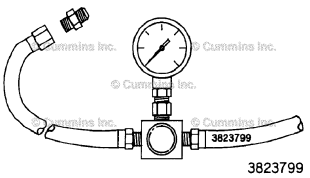
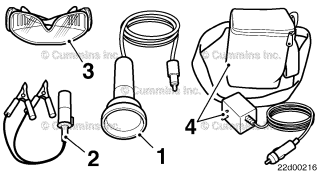
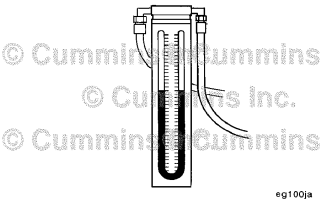
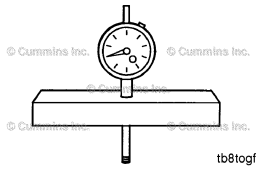
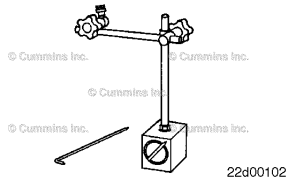
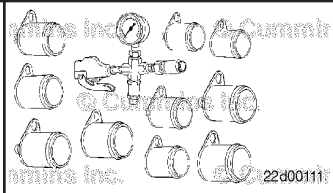
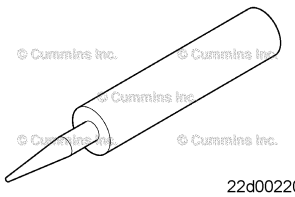
Service Tools

Air Intake System

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

Tool No.	Tool Description	Tool Illustration
3164488, 3164489	**Digital 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.	
3164499	**Digital Thermometer** Used to measure ambient air temperature. Use with digital multimeter, Part Number 3164488.	
3164498	**Bead Probe** Used with digital thermometer, Part Number 3164499.	
3823799	**Turbocharger Wastegate Pressure-Setting Kit** Used to apply regulated pressure to wastegate actuator during troubleshooting and calibrating procedures.	
3163338	**Black Light Lamp (12VDC)** Used with fluorescent tracer to locate coolant and/or oil leaks. Lamp operates off vehicle battery or portable rechargeable battery included in kit. Oil tracer Part Number 3376891, coolant tracer Part Number 3377438.	
ST-1111-3	**Manometer** Used to measure pressure and restriction 0 to 2.5 kPa [0 to 36 in H_2O] pressure differential with more accuracy.	

Tool No.	Tool Description	Tool Illustration
ST-537	**Dial Depth Gauge** Measure turbocharger axial motion.	
3377399	**Magnetic Base Indicator Holder** Used in conjunction with dial indicator, Metric — Part Number 3824564. SAE — Part Number 4918289.	
3824556	**Charge Air Cooler Tester** Used to pressure test charge air coolers.	
3164070	**RTV Sealant** Used to seal rear gear housing to block, front cover to block, and intake manifold to cylinder head joints.	

Aftercooler Assembly (010-005)

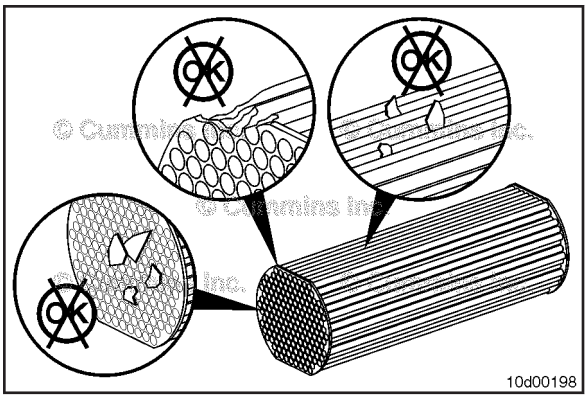
Initial Check

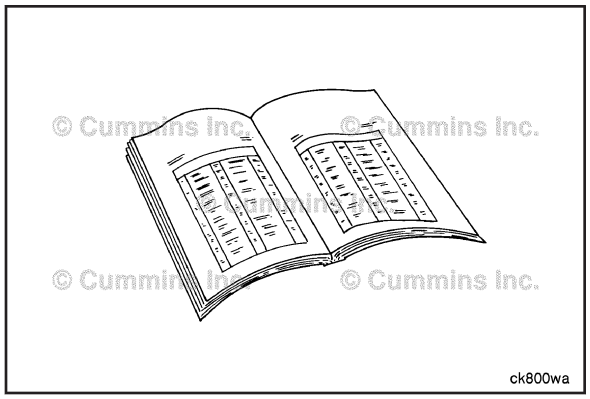
A turbocharger or sea water pump failure can cause damage to the aftercooler assembly.

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.





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 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.

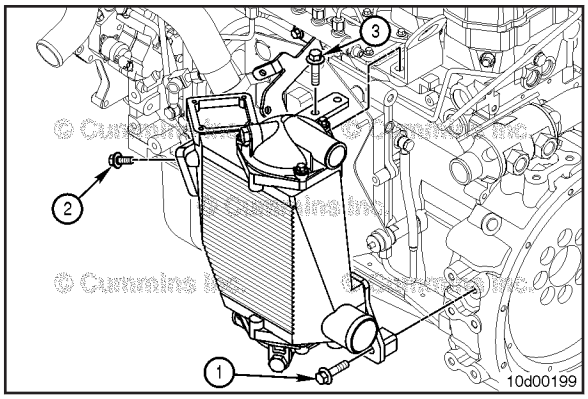
- Shut off the sea water supply and return line(s). Refer to the OEM troubleshooting and repair manual.
- Shut off the fuel supply and return lines. Refer to the OEM troubleshooting and repair manual.
- Disconnect the battery power from the engine. Refer to Procedure 013-009
- Drain the sea water by removing the zinc plug at the bottom of the aftercooler assembly.
- Remove the aftercooler air box drain plug and drain the condensation from the aftercooler housing core.
- Loosen the aftercooler top and bottom air connection hose clamps.
- If necessary, remove the four capscrews and the aftercooler air discharge connection.
- Disconnect the aftercooler air inlet connection.
- 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.

Remove

NOTE: The rear engine lifting bracket is secured to the engine with the aftercooler mounting capscrews.

Loosen the aftercooler mounting capscrews at the flywheel housing (1), the cylinder block (2), and the cylinder head (3).

Remove the aftercooler assembly.

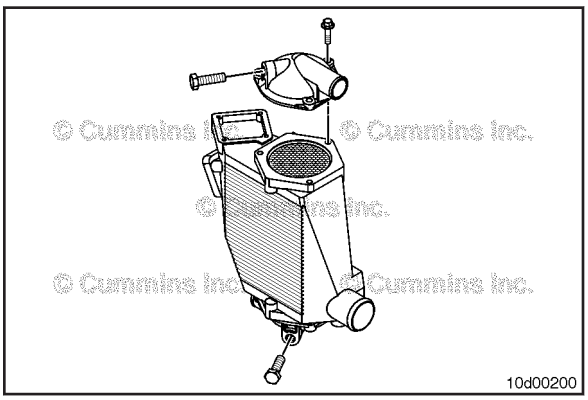


Disassemble

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.



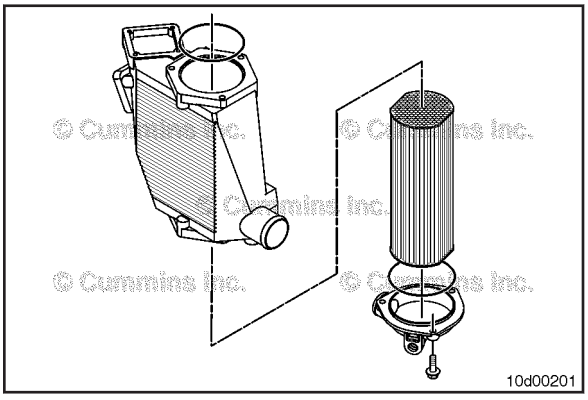
CAUTION
The aftercooler core assembly will slide out of the cooler housing when removing the lower aftercooler water connection. To reduce the possibility of damaging the core, lay the aftercooler assembly on its side to remove the connection and the core.

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.



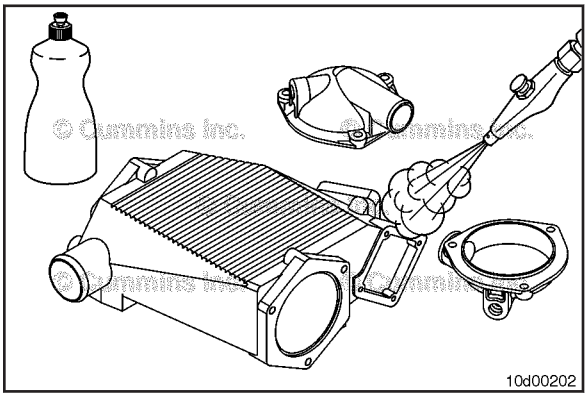
Clean and Inspect for Reuse

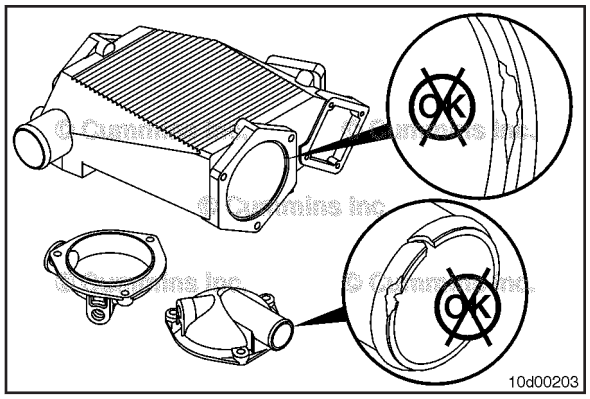
WARNING
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

NOTE: The aftercooler core can be cleaned and tested by a radiator cleaning facility. Ultrasonic cleaning is the preferred method of cleaning.

Use soap and water to clean the aftercooler and end caps.

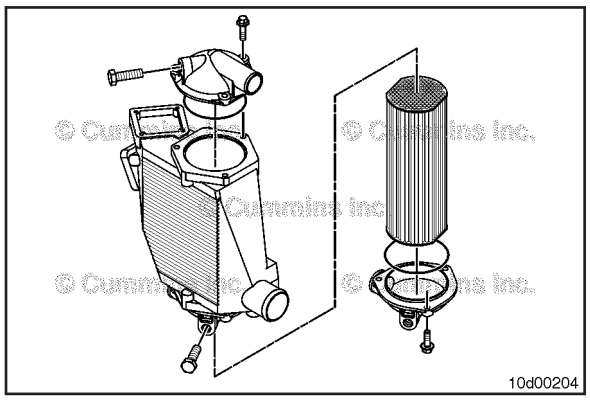
Dry with compressed air.





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.

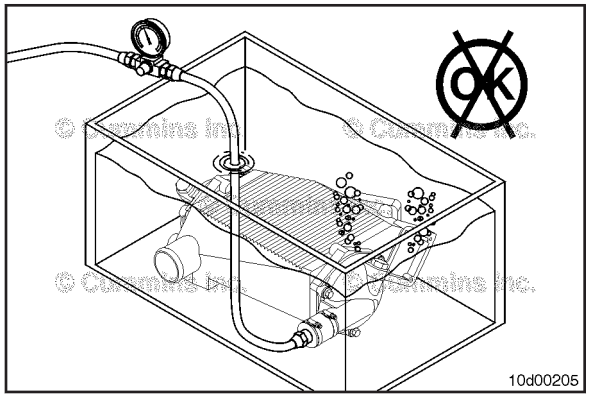
Install a new o-ring around the lower core O.D. Install the water end cap and tighten the capscrews.

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. Refer to Procedure 008-059



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.

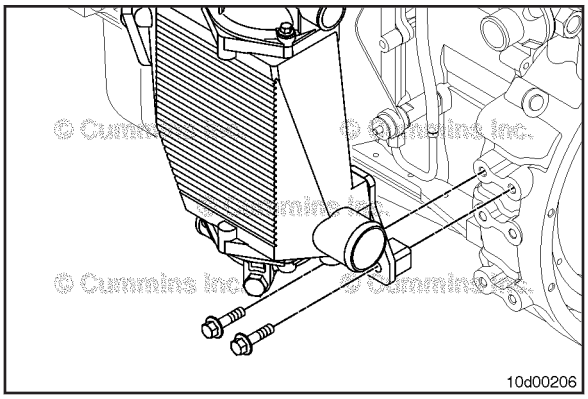
Apply 276 kPa [40 psi] air pressure.

Lower the assembly into a tank of water and check for leaks.

Completely dry the aftercooler with compressed air.

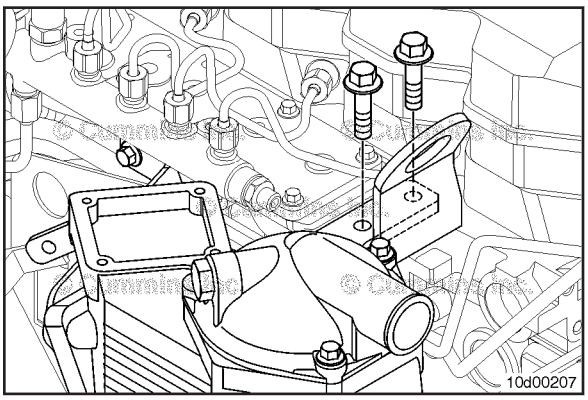
Install

Loosely install the aftercooler assembly to the flywheel housing first using two mounting capscrews.



NOTE: The rear engine lifting bracket is secured by the aftercooler to cylinder head mounting capscrews. The aftercooler bracket **must** be installed on top of the lifting bracket.

Install the upper capscrews first. Be sure the aftercooler bracket is installed on top of the lifting bracket.



Install the aftercooler to bracket mounting capscrews.

Tighten all capscrews.

Torque Value:
Aftercooler to Flywheel Housing

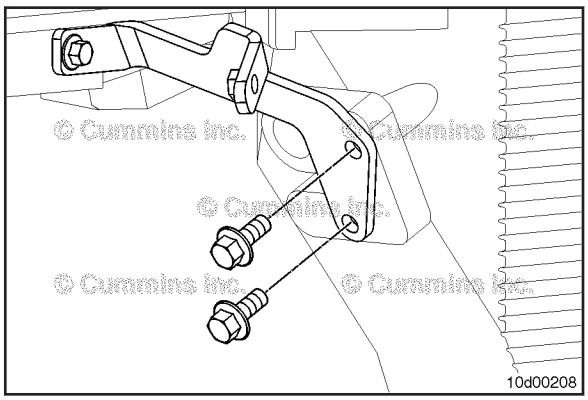
Step 1	60 N•m	[44 ft-lb]

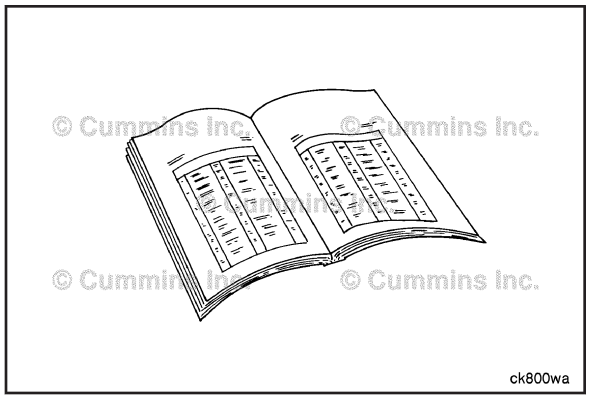
Torque Value:
Aftercooler to Cylinder Head

Step 1	77 N•m	[57 ft-lb]

Torque Value:
Aftercooler to Bracket

Step 1	35 N•m	[26 ft-lb]





Finishing Steps

- 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 four capscrews and the aftercooler air discharge to the intake air connection.
- 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 troubleshooting and repair manual.
- Open the fuel supply and return lines. Refer to the OEM troubleshooting and repair manual.

Operate the engine and check for leaks.

Air Cleaner Assembly (Engine Mounted) (010-013)

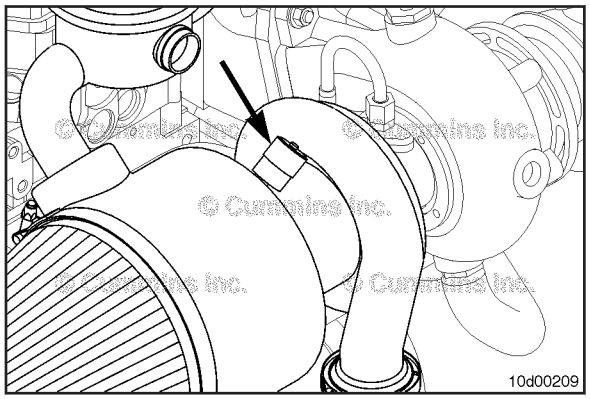
General Information

The closed crankcase system has three major parts.

1 The air cleaner assembly; this filters the incoming air and an 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.

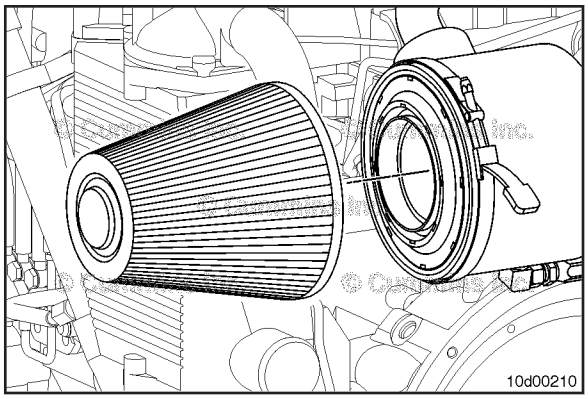
3 Closed crankcase drain plumbing; this includes the drain hoses and check valve. The check valve prevents crankcase pressure from flowing backwards in the air cleaner.



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

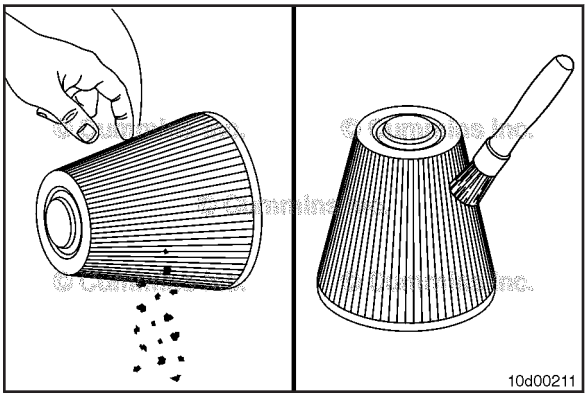


⚠CAUTION⚠
Use caution when disconnecting or removing oil lines, or replacing filters, so that oil is not drained into the bilge area. Do not drop or throw filter elements into the bilge area. The oil and filters must be discarded in accordance with local environmental regulations.

Release the clamp and remove the air cleaner element.

Remove the turbocharger silencer cone from inside the filter element.

Clean

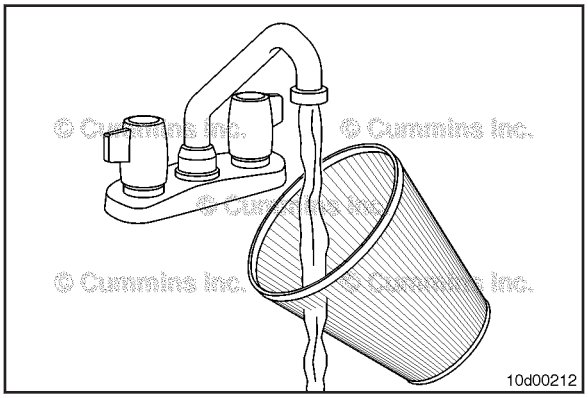


NOTE: It is possible that a filter which is damaged or clogged with soot due to an exhaust leak will not be able to be cleaned to maximum efficiency. Replace the element if necessary.

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.

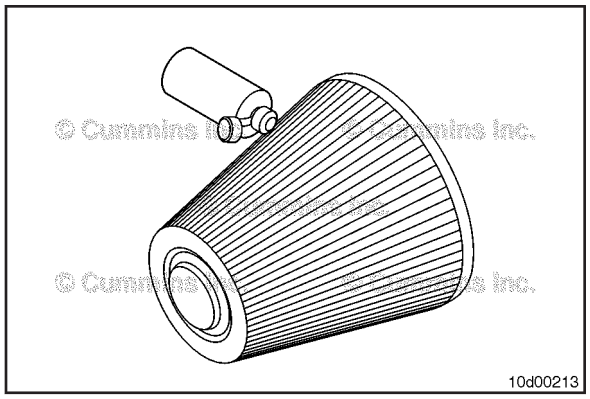


⚠CAUTION⚠
To avoid damage to the components, do not use compressed air, an open flame or heat dryers to dry the air filter.

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.

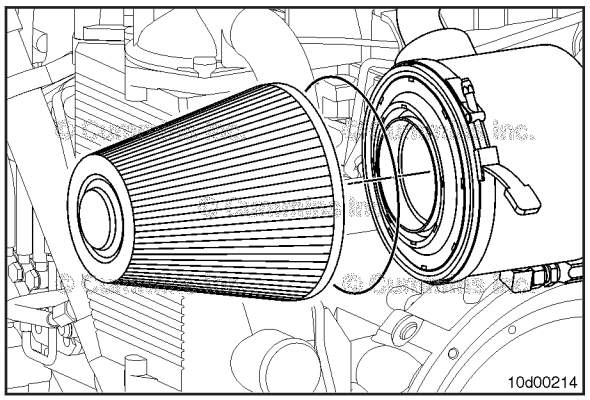
After rinsing the air filter, shake off all the excess water and let the filter element air dry.



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 20 minutes. Then re-oil any dry areas that are showing.



Install

Install the turbocharger silencer cone.

Install the o-ring around the outside of the filter base.

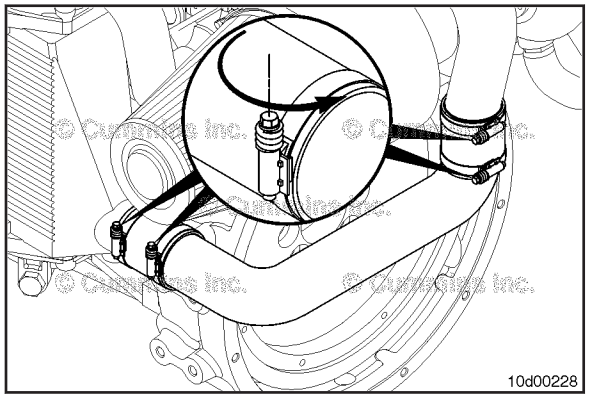
Install the filter onto the engine and secure with the clamp.

Air Crossover (010-019)

General Information

On automotive and industrial applications, the air crossover refers to the piping connecting to the charge air cooler.

On marine applications, the air crossover refers to the pipe from the outlet of the seawater cooled aftercooler to the air intake connection.

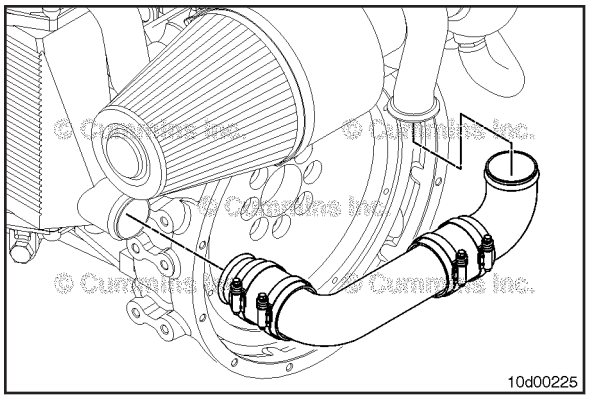


Remove

Loosen the four hose clamps at the turbocharger and aftercooler assembly.

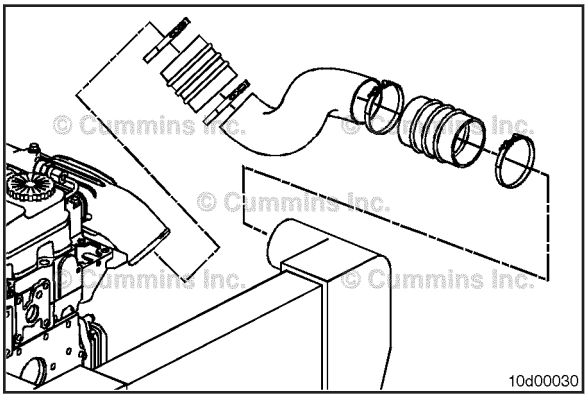
Slide the hose clamps to the middle of the air crossover.

Remove the air crossover.



Loosen the air crossover hose clamps.

Remove the air crossover tube.



Clean and Inspect for Reuse

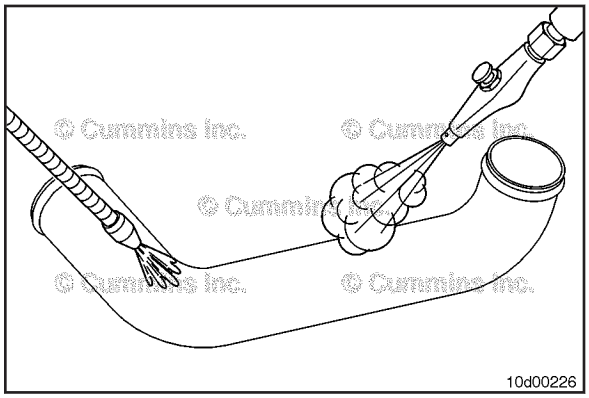
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

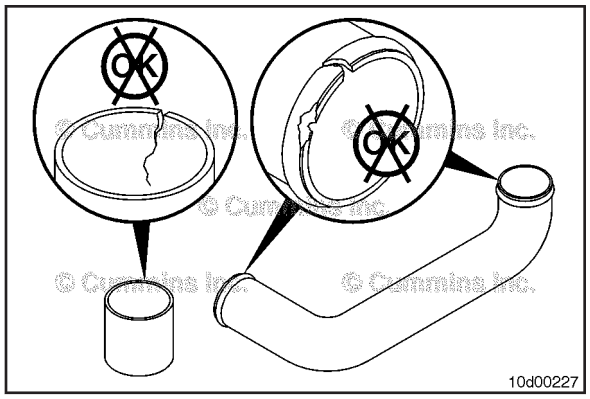
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

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

Clean the connections with solvent.

Dry with compressed air.

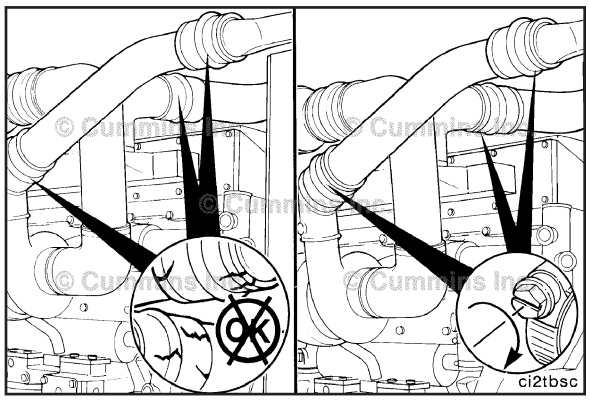




Inspect the air connection ends for nicks, burrs or other damage.

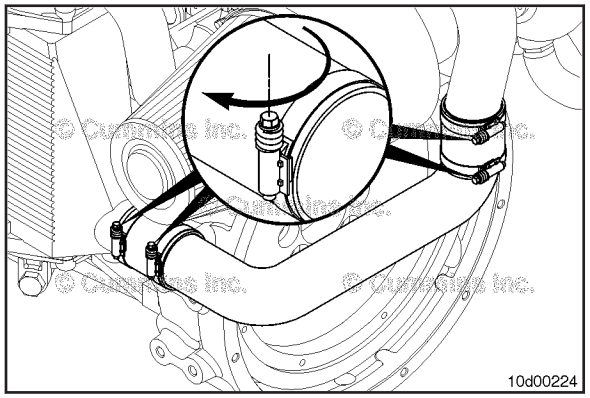
Inspect the hose connections for damage or cuts.

Replace if necessary.



Check the crossover tube for cracks, holes, and worn sections.

If any damage is found, replace the air crossover and mounting components.



Install

⚠CAUTION⚠

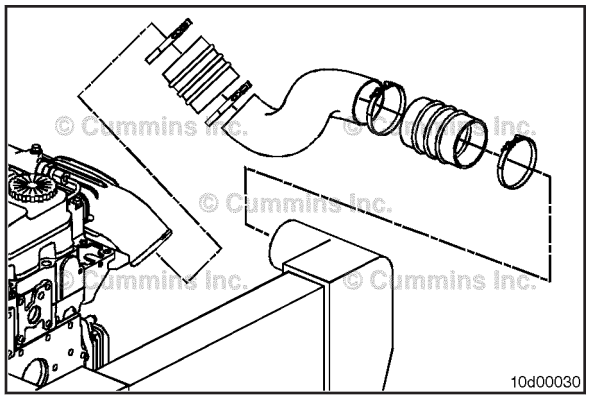
Be sure the stainless steel air crossover does not contact the aluminum connections of the turbocharger or aftercooler assembly. Contact with these components will cause erosion and damage the aluminum components.

Install the hose connections over the end of the air crossover pipe.

Install the air crossover over the ends at the aftercooler assembly and the turbocharger.

Center the hoses and tighten the hose clamps.

Torque Value: 8 N•m [71 in-lb]

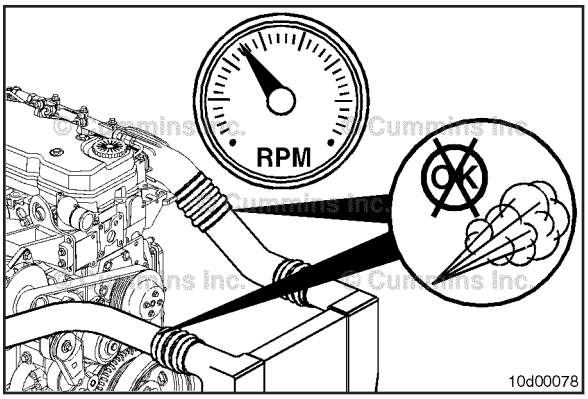


Install the air crossover tube and clamps.

Tighten the clamps. Refer to the OEM specifications.

Finishing Steps

Operate the engine and check for leaks.



Air Inlet Connection (010-022)

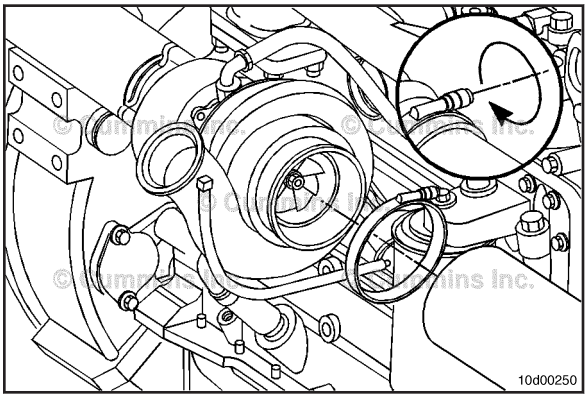
General Information

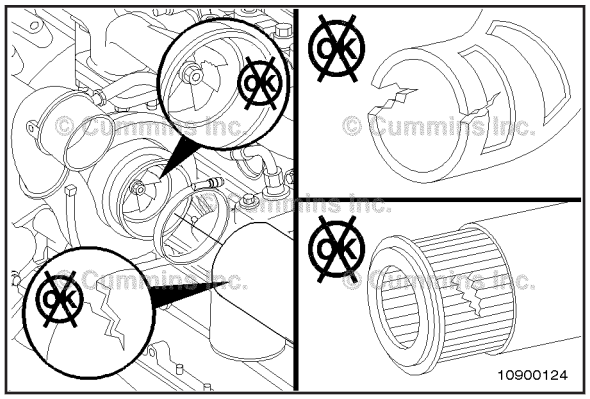
The air inlet connection connects the turbocharger air inlet to the OEM air inlet piping.

Remove

Loosen the clamps which hold the air inlet connection to the turbocharger air inlet and the OEM air inlet piping.

Remove the air inlet connection.





Clean and Inspect for Reuse

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

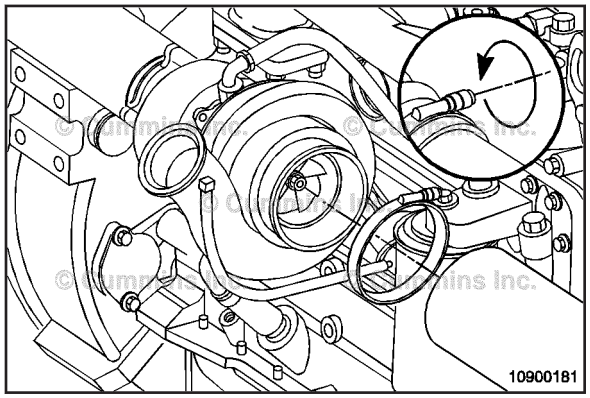
⚠WARNING⚠
Use skin and eye protection when handling caustic solutions to reduce the possibility of personal injury.

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

Clean the piping and connections with solvent or hot soapy water and dry with compressed air.

Check the piping and connections for cracks, holes, and worn sections.

If any damage found, replace the damaged components.



Install

Install the air inlet piping and connections.

Tighten the attaching clamps. Refer to OEM specifications.

Finishing Steps

Operate the engine and check for leaks.

Air Intake Manifold (010-023)

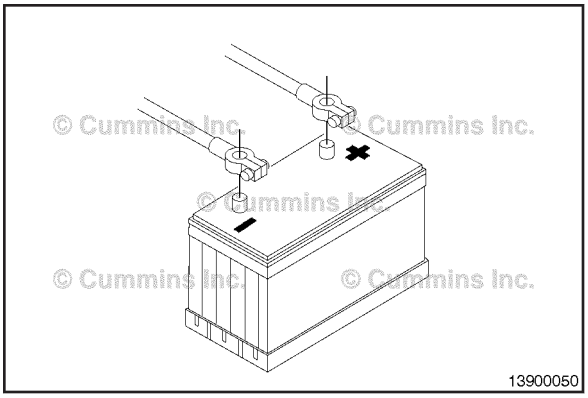
General Information

The air intake manifold is the part(s) that connect to the cylinder head intake downstream of the cold starting aid. Some engines use a one-piece air intake manifold while other engines use a two-piece air intake manifold.

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 batteries.



Remove the charge air piping. Refer to Procedure Procedure 010-019

Remove the injector supply lines. Refer to Procedure Procedure 006-051

Remove the fuel supply lines. Refer to Procedure Procedure 006-024

Remove the high pressure fuel rail. Refer to Procedure Procedure 006-060

Remove the air intake connection adaptor (if applicable). Refer to Procedure Procedure (010-131)

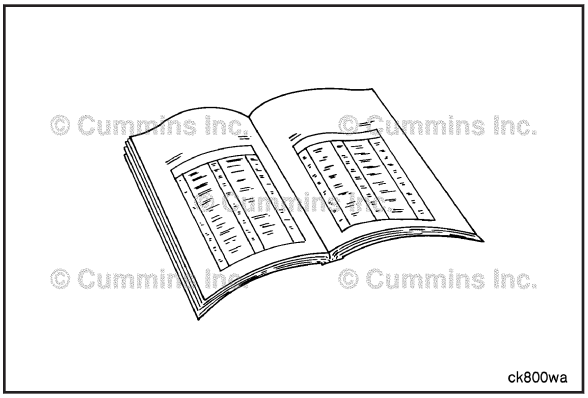
Remove the air intake connection. Refer to Procedure Procedure 010-080

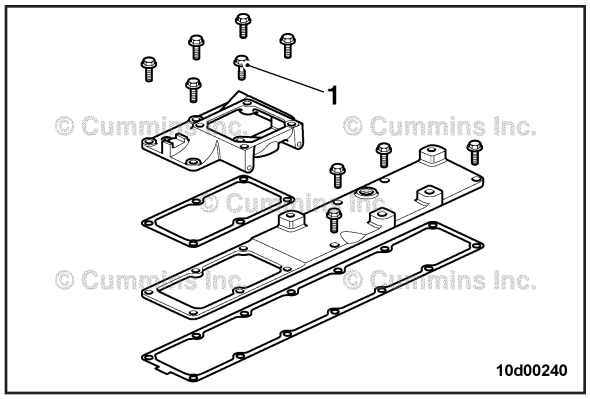
NOTE: On some engines, the intake connection is an integral (non-removable) part of the intake manifold.

NOTE: This step may also require removal of the EGR connection tube, as well as disconnection of the EGR pressure differential sensor and EGR temperature sensor. Refer to Procedure Procedure 011-025 for the EGR connection tube. Refer to Procedure Procedure 100-002 (Engine Views) for sensor locations.

Remove the cold starting aid on engines equipped with either a cylindrical or a “brick” style cold starting aid. Refer to Procedure Procedure 010-029

Remove the intake manifold temperature/pressure sensor. Refer to Procedure Procedure 100-002 (Engine Views) for sensor location.





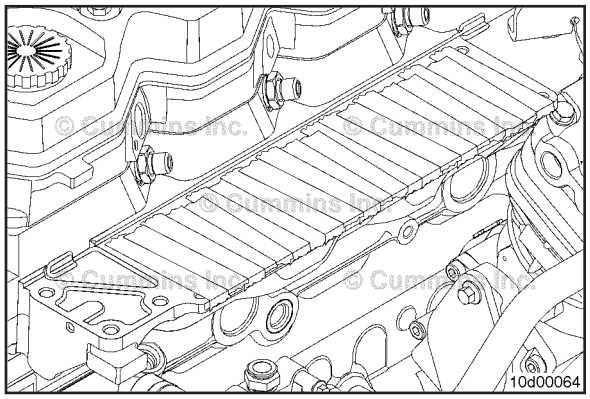
Remove

NOTE: Keep the gasket material, and any other material out of the air intake.

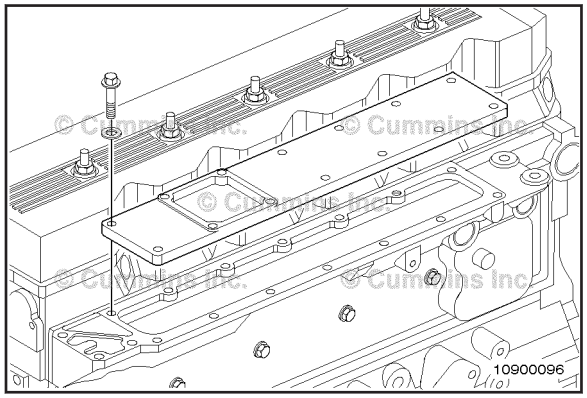
Remove the six capscrews that hold the upper part of the intake manifold to the lower part.

⚠CAUTION⚠
There is a captive capscrew (1) in this manifold, the captive capscrew must be removed after the other five capscrews have been removed, to prevent damage to the intake manifold.

Remove the lower part of the intake manifold.

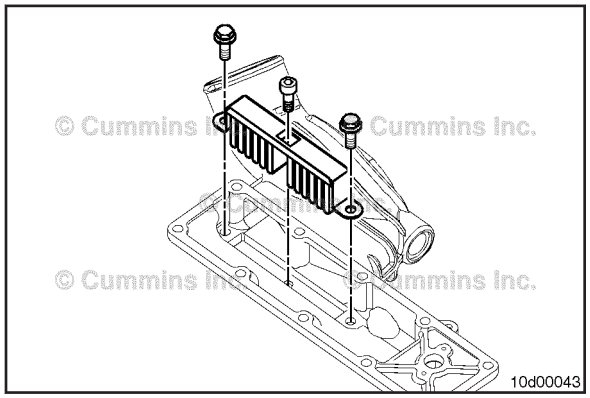


If the air intake manifold will be off for a prolonged period of time, tape off the intake manifold opening to prevent debris from entering the intake system.



NOTE: Keep the gasket material, and any other material out of the air intake.

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

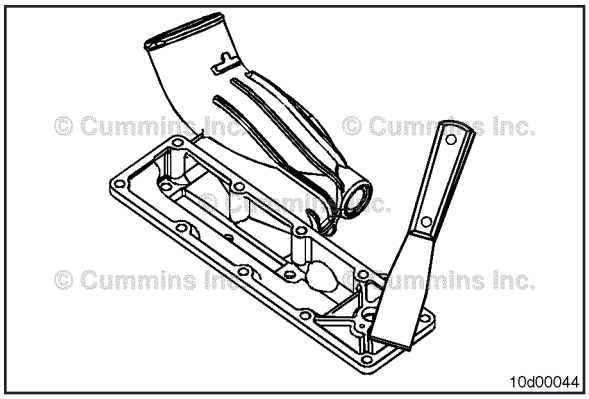


If the engine has an integral cold-starting aid, remove it. Refer to Procedure Procedure 010-029

Clean and Inspect for Reuse

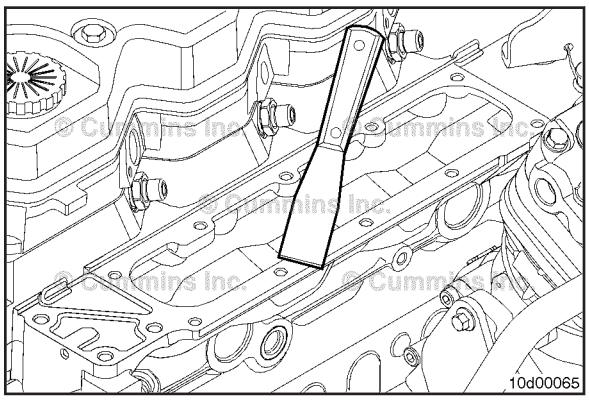
NOTE: Keep the gasket material and any other material out of the air intake.

Clean all air intake manifold sealing surfaces with a gasket scraper and a clean rag.



Clean the cylinder head sealing surfaces where the intake manifold seals.

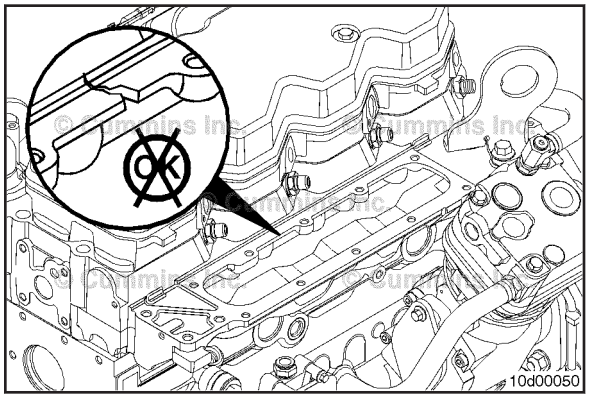
NOTE: Engines equipped with EGR have a corrosion resistant green Teflon™ coating on the inside surfaces of the intake manifold. Soot buildup is common on these surfaces, and does **not** need to be cleaned off.

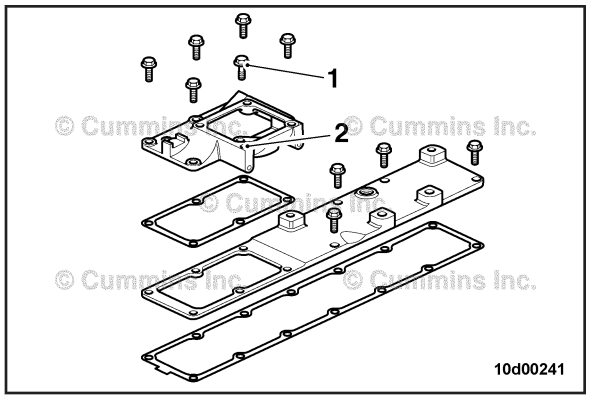


Inspect the intake manifold for cracks or other damage.

NOTE: When inspecting the intake manifold for oil or debris from an air system failure, also inspect the cylinder head for oil and debris.

NOTE: On engines equipped with EGR, soot buildup on the cylinder head intake surfaces is common and does **not** need to be cleaned off.





Install

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

Install the lower part of the intake manifold with a new gasket. Apply a light coating of thread sealant, Part Number 3824041, to the capscrews before installation. Only install the capscrews finger tight at this time.

Install the upper part of the intake manifold with a new gasket.

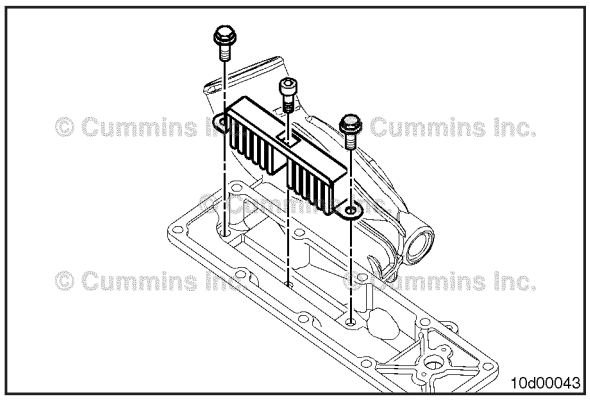
NOTE: There is a captive capscrew (1) in the manifold. Install the captive capscrew first, but only install it finger tight. Apply a light coating of thread sealant, Part Number, 3824041 to the capscrew before installation.

Install the rest of the capscrews in the upper part of the intake manifold. Apply a light coating of thread sealant, Part Number 3824041, to the capscrews before installation.

Tighten ALL of the intake manifold capscrews to the proper torque value.

Torque Value:
Air Intake Manifold Cover
Step 1 24 N•m [18 ft-lb]

Service Tip: If the captive capscrew is lost or broken, the threads in the captive capscrew hole (2) of the upper part of the intake manifold may be drilled or filed out to 9.5 mm (3/8 in.) diameter. This allows a standard M8 x 1.25 x 30 mm capscrew to be used in place of the captive capscrew. Apply a light coating of thread sealant part number 3824041 to the capscrew before installation and use caution to prevent dropping it into the intake manifold.



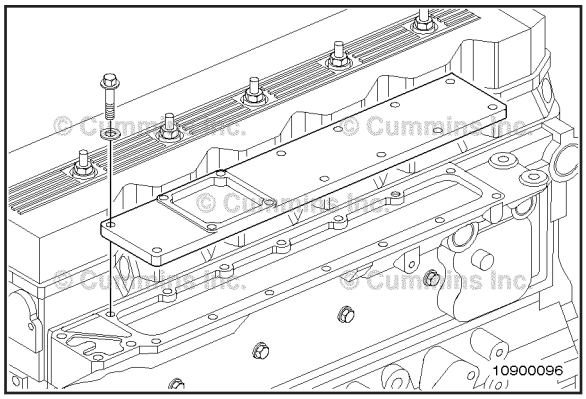
NOTE: Remove the tape from the intake manifold opening before continuing with the installation process.

If the engine was equipped with an integral cold starting aid, install the cold starting aid. Refer to Procedure Procedure 010-029

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

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

Torque Value:
Air Intake Manifold Cover
Step 1 24 N•m [18 ft-lb]



Finishing Steps

Install the intake manifold temperature/pressure sensor. Refer to Procedure Procedure 100-002 (Engine Views) for sensor location.

Install the cold starting aid on engines equipped with either a cylindrical or a “brick” style cold starting aid. Refer to Procedure Procedure 010-029

Install the air intake connection. Refer to Procedure Procedure 010-080

NOTE: On some engines, the intake connection is an integral (non-removable) part of the intake manifold.

NOTE: This step may also require installation of the EGR connection tube, as well as connection of the EGR pressure differential sensor and EGR temperature sensor. Refer to Procedure Procedure 011-025 for the EGR connection tube. Refer to Procedure Procedure 100-002 (Engine Views) for sensor locations.

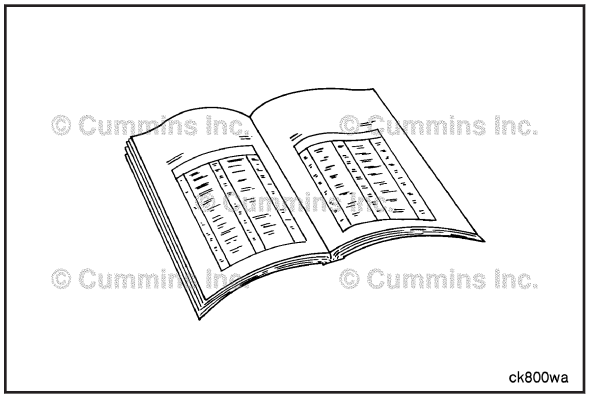
Install the air intake connection adaptor (if applicable). Refer to Procedure Procedure (010-131)

Install the high pressure fuel rail. Refer to Procedure Procedure 006-060

Install the fuel supply lines. Refer to Procedure Procedure 006-024

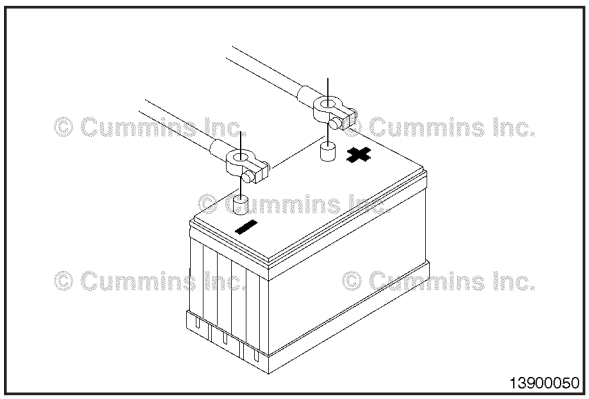
Install the injector supply lines. Refer to Procedure Procedure 006-051

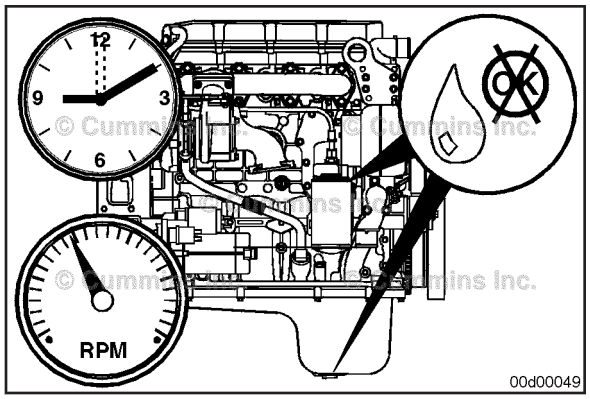
Install the charge air piping. Refer to Procedure Procedure 010-019



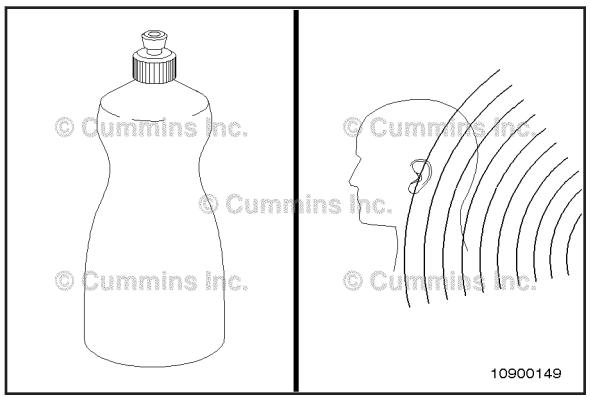
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Remove the batteries.





Operate the engine and check for leaks.



Air Leaks, Air Intake and Exhaust Systems (010-024)

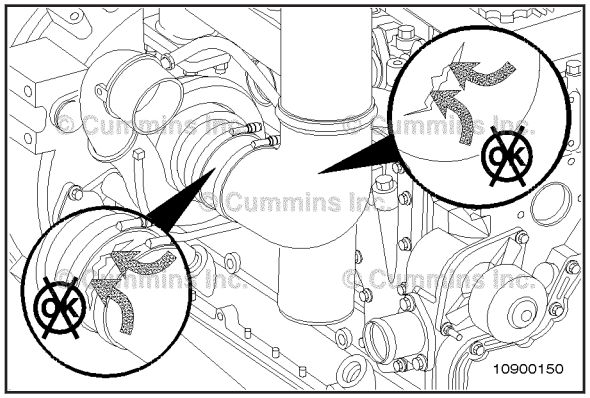
Initial Check

Leaks in the intake air system are most commonly identified by:

1 Inspection of piping for cracked or loose clamps

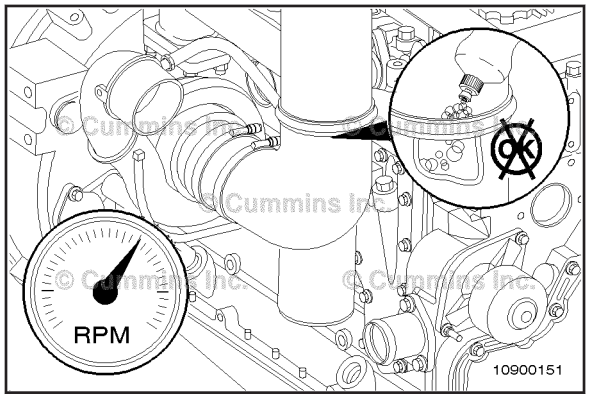
2 Applying a solution of soapy water in the suspected area and inspecting for bubbles

3 Listening for high-pitched whining or sucking noise in the suspected area.



CAUTION

Engine intake air must be filtered to keep 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 inlet air leaks.

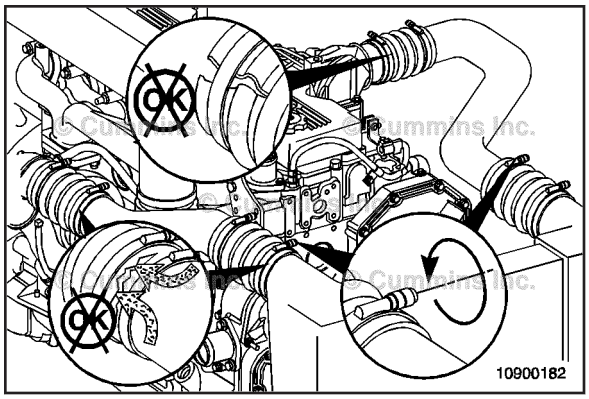
If an air leak exists at the turbocharger fresh air inlet, the soap bubbles will be drawn in with the air.

Replace damaged pipes and tighten loose clamps, if necessary, to make sure the air inlet system does **not** leak.

Torque Value: 10 N•m [89 in-lb]

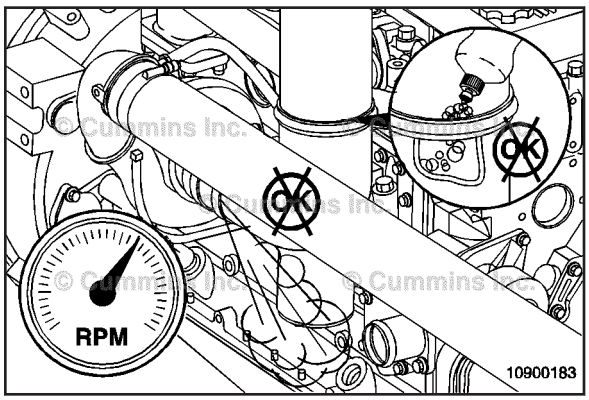
Check for corrosion of the inlet system piping under the clamps and hoses. Corrosion can allow corrosive products and dirt to enter the intake system.

Disassemble and clean as required.



Pressure-Side Intake System

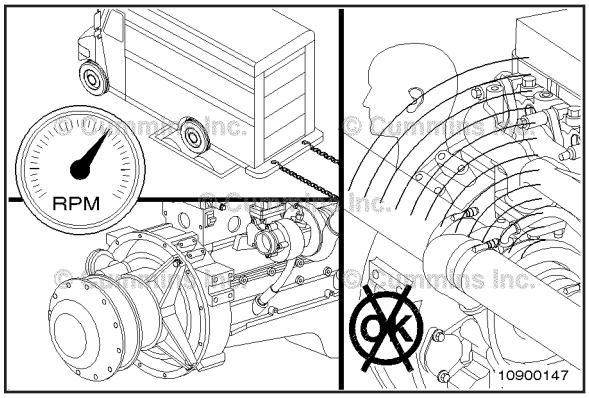
Leaks in the intake system will reduce the amount of air to the cylinders during engine operation and decrease engine performance.



Operate the engine at full throttle and rated rpm with maximum load.

Listen for a high-pitched whistling noise from the turbocharger, nearby piping, and connections.

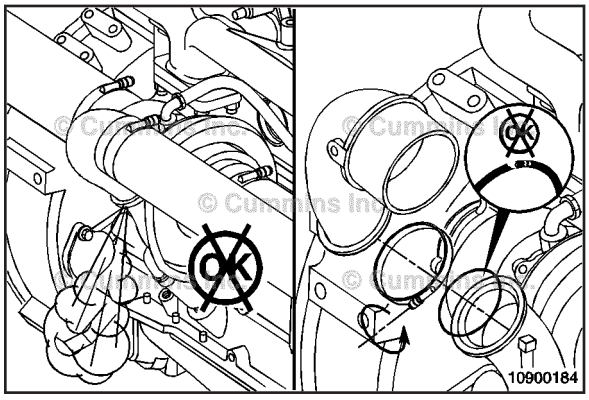
Apply a soapy water solution to sealing surfaces and inspect for bubbles.

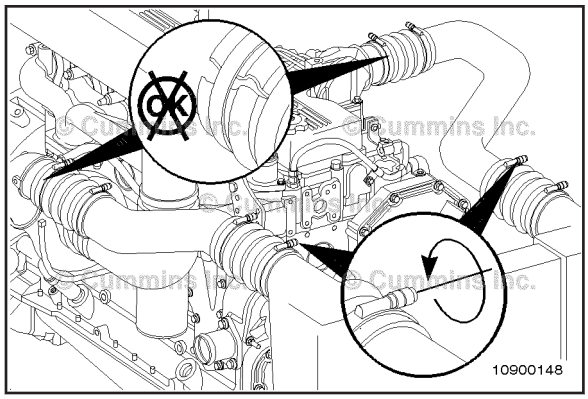


Leaks can also be found at the turbocharger outlet connection.

Inspect for damage, replace sealing o-ring, and tighten loose clamps.

Torque Value: 10 N•m [89 in-lb]



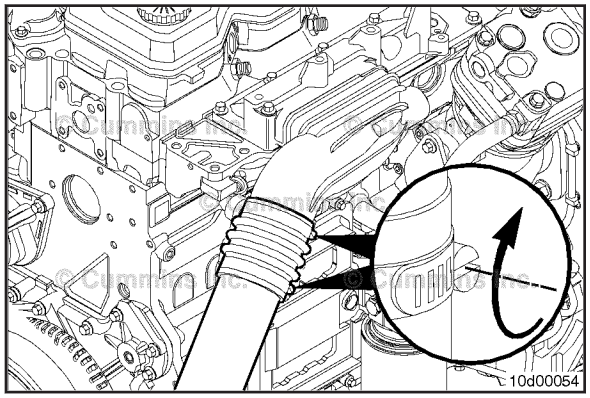


Charge Air Cooler Tubing or Connection Hoses

Inspect the hose and tubing for damage. Refer to Procedure Procedure 010-019

Tighten loose clamps.

Refer to the equipment manufacturer's specifications for the correct torque value.

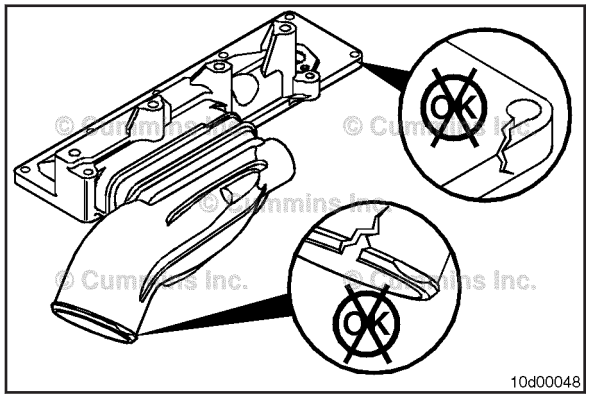


Intake Manifold Connection

Inspect for damage.

Tighten loose clamps.

Replace the connection clamp, if necessary. Refer to Procedure 010-023

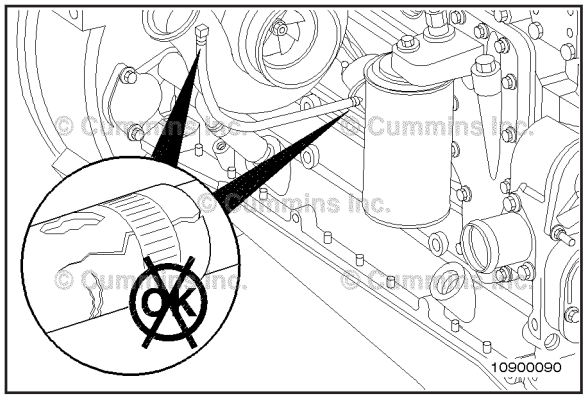


Intake Manifold

Inspect for damage.

If damage is found, replace the gasket if the engine was originally equipped with a gasket.

If the engine was originally equipped with sealant, replace with RTV sealant, Cummins Part Number 3164070 or equivalent. Refer to Procedure Procedure 010-023



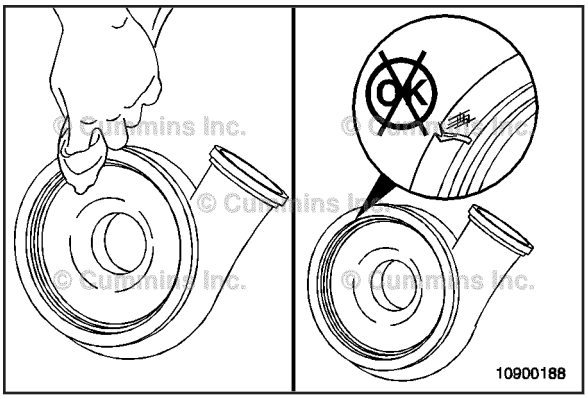
Wastegate Actuator/Plumbing

Inspect for damage. Refer to Procedure Procedure 010-050

Compressor Housing Sealing Surface

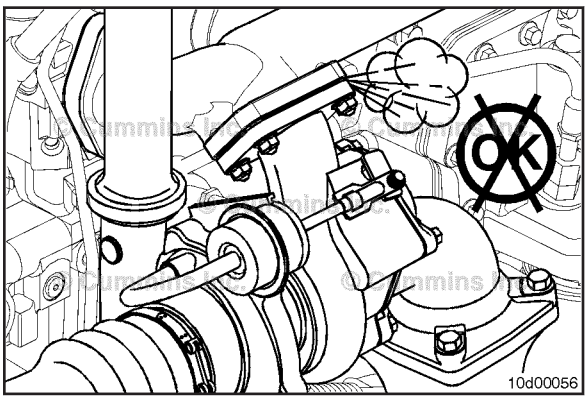
Inspect for damage.

Clean surface with a clean cloth.



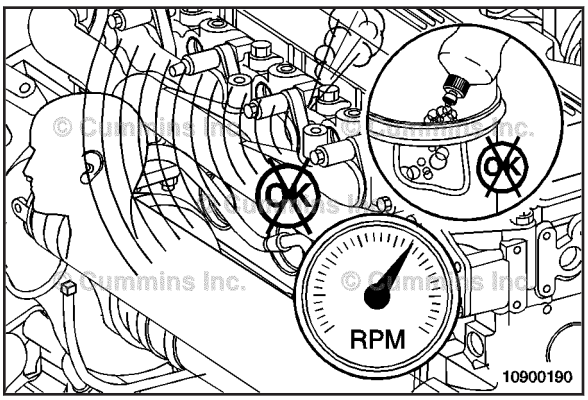
Exhaust System

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.



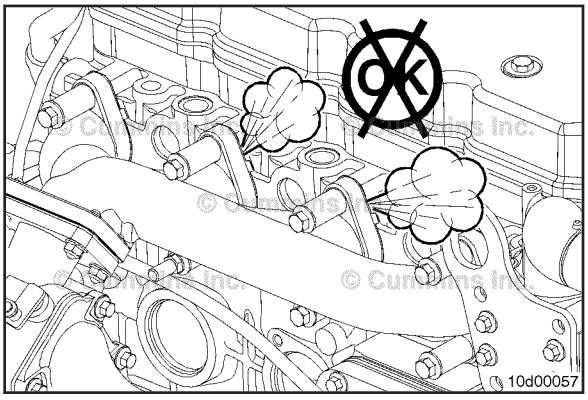
Operate the engine at full throttle and rated rpm with maximum load.

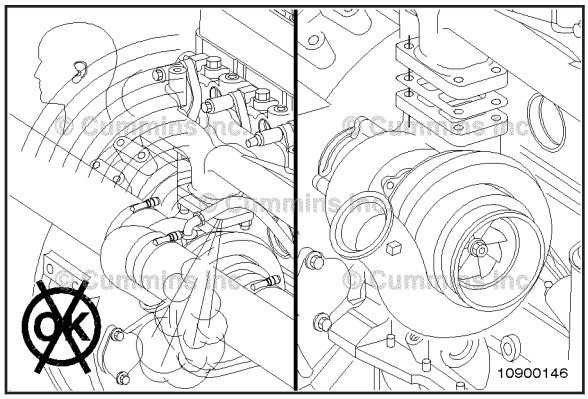
Leaks can be identified by noise, soapy water, or discoloration caused by the escaping hot gases.



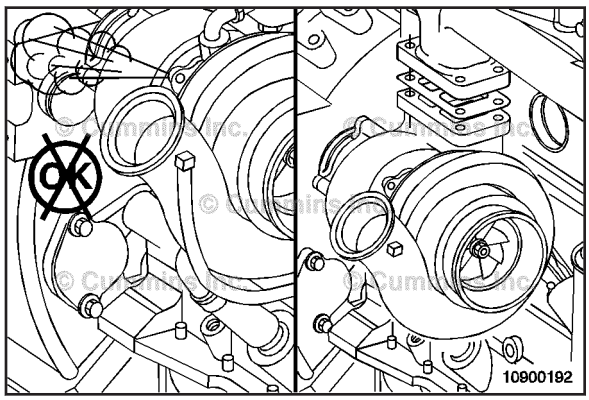
Leaks can be found at:

- Exhaust manifold gaskets

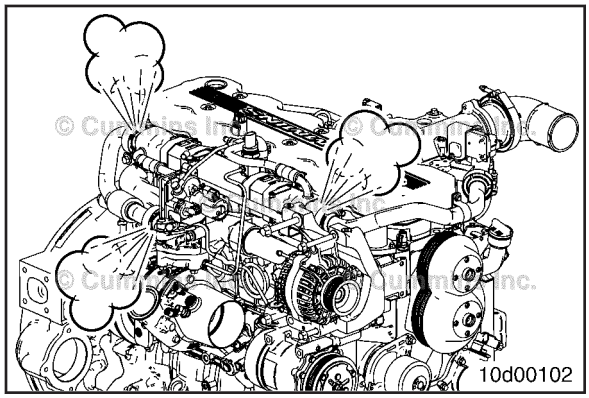




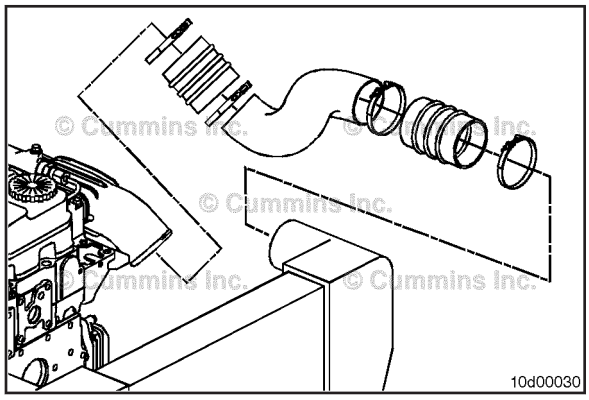
- Turbocharger mounting gaskets



- Turbine housing sealing surface.



- EGR component gaskets (if equipped).



Charge-Air Cooler (CAC) (010-027)

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 Procedure 010-019, (Air Crossover).

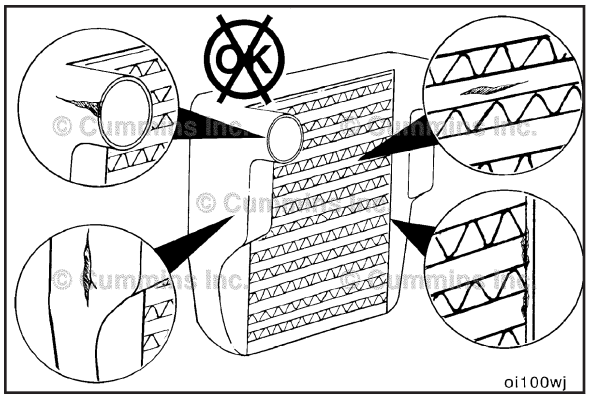
Initial Check

Inspect the charge air cooler for cracks, holes, and damage.

Inspect the tubes, fins, and welds for tears, breaks, or other damage.

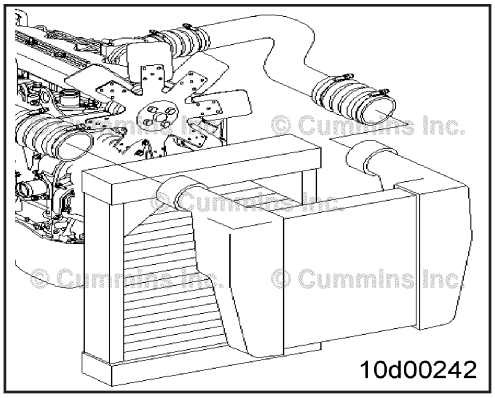
If any damage causes the charge air cooler to fail the air leak check, the charge air cooler **must** be replaced.

Inspect the charge air cooler plumbing for cracks and damage.



Remove

Remove the charge air cooler. Refer to the OEM service manual.



Clean

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.

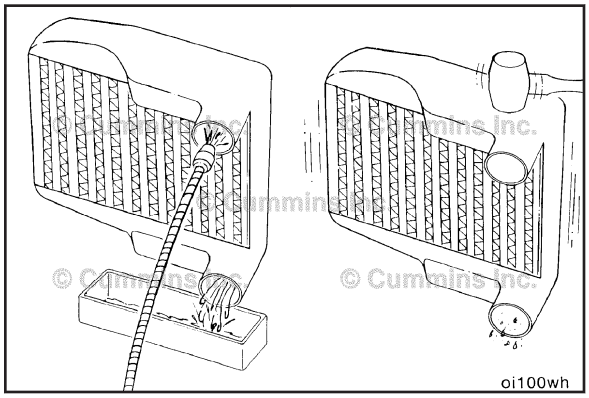
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

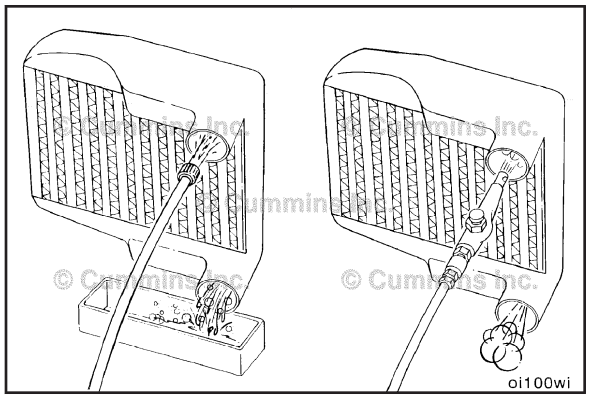
△CAUTION△
Do not use caustic cleaners to clean the charge air cooler. Damage to the charge air cooler will result.

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 vertical direction when flushing.

If the debris can **not** be totally removed from the charge air cooler, the charge air cooler **must** be replaced.



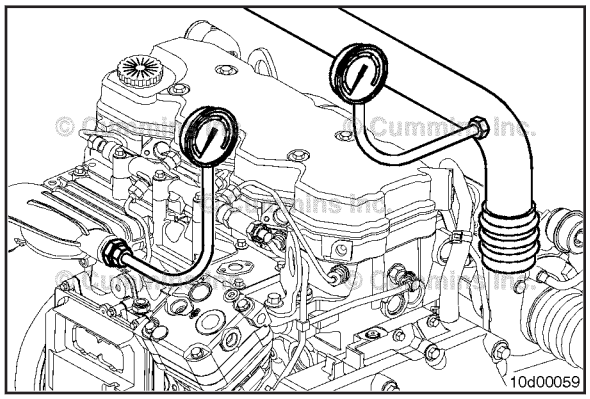


⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△CAUTION△
The charge air cooler must be rinsed, dried, and cleaned 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 airflow until the charge air cooler is dry internally.

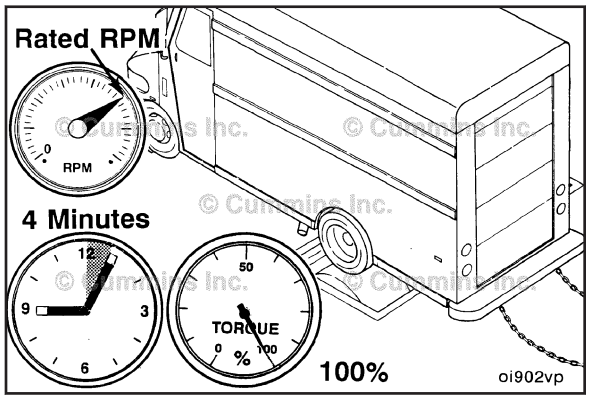


Pressure Test

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 would be to use the monitor mode on the INSITE™ service tool.



Operate the engine at rated rpm and load. Record the readings on the two gauges.

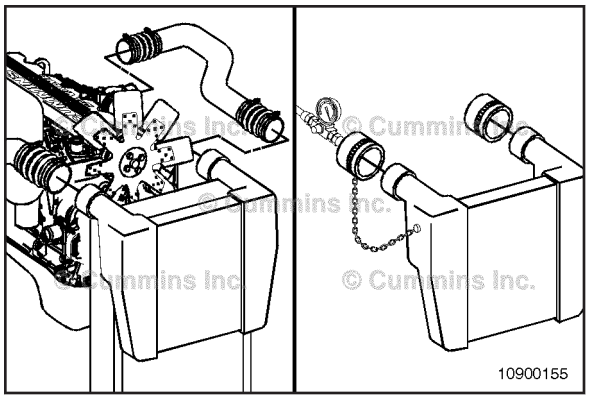
If the differential pressure is greater than 20.6 kPa [3 psi], check the charge air cooler and associated piping for plugging, restrictions, or damage.

Clean or replace, if necessary.

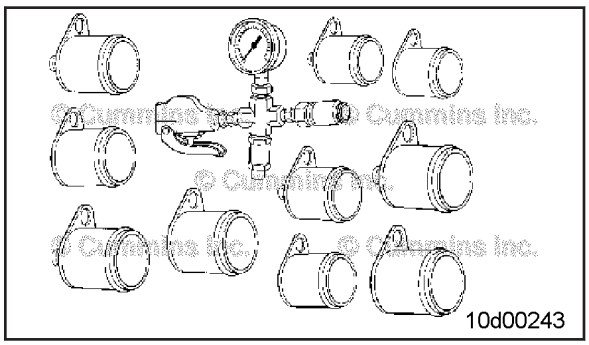
Leak Test

⚠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 not be performed without 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.



To perform the leak test, use tool 3824556. Install the cap over the outlet side of the cooler. Install the gauge end of the tool with a regulated shop air supply line and a shutoff valve to the inlet side of the cooler.

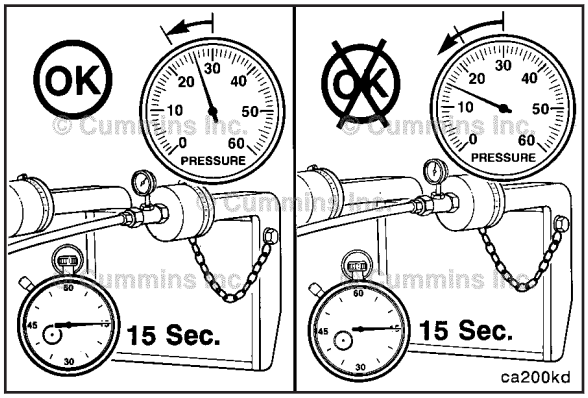


Apply air pressure to the cooler until the pressure gauge reads a steady 207 kPa [30 psi] of air pressure.

Shut off the airflow 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.

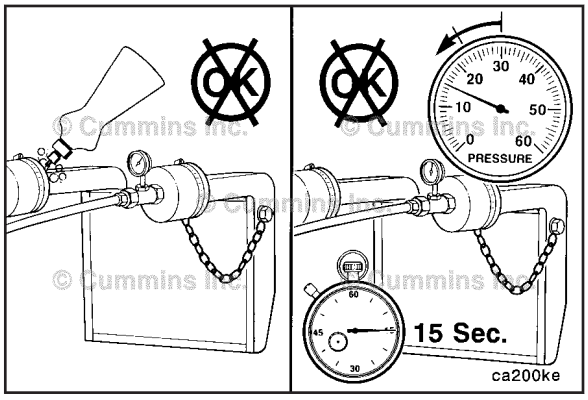
If the pressure drop is greater than 48 kPa [7 psi] in 15 seconds, check all connections again.

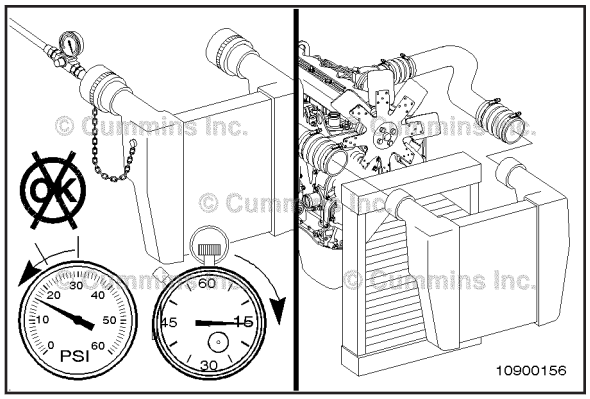


Determine if the pressure drop is caused by a leak in the charge air cooler or from a leaky connection. Use a spray bottle filled with soapy water applied to all hose connections, and watch for bubbles to appear at the location of the leak.

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 in at least three consecutive tests before the reading can be considered accurate.

NOTE: If a charge air cooler leaks more than 48 kPa [7 psi] in 15 seconds, it will appear as a major leak in a leak tank.

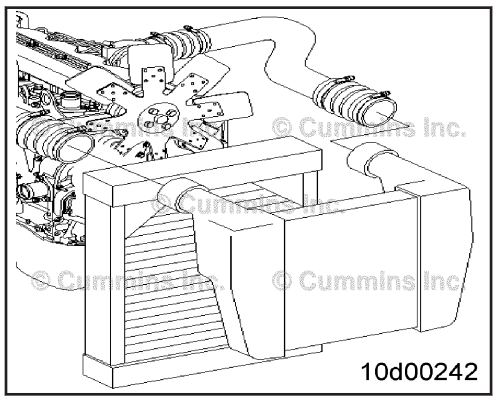




If the pressure drop is greater than 48 kPa [7 psi] in 15 seconds, the charge air cooler **must** be replaced.

Refer to the OEM service manual for replacement instructions.

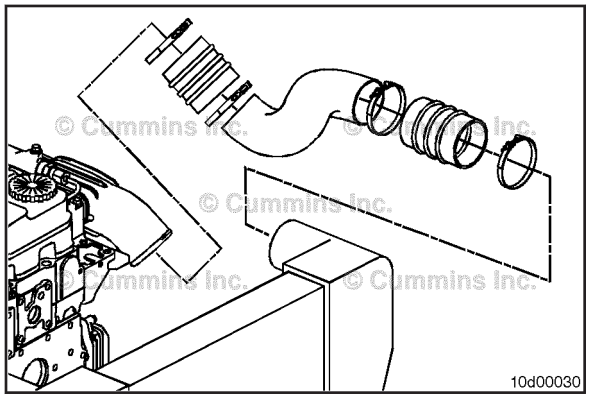
NOTE: Charge air coolers are **not** designed to be 100-percent leak free. If the pressure drop is less than 48 kPa [7 psi] in 15 seconds, then the charge air cooler does **not** need to be replaced.



Install

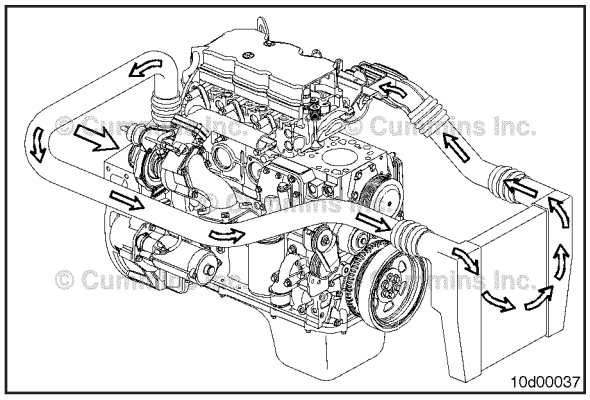
Install the charge air cooler.

Refer to the OEM service manual for instructions.



Finishing Steps

Install the charge air cooler piping. Refer to Procedure Procedure 010-019 (Air Crossover)

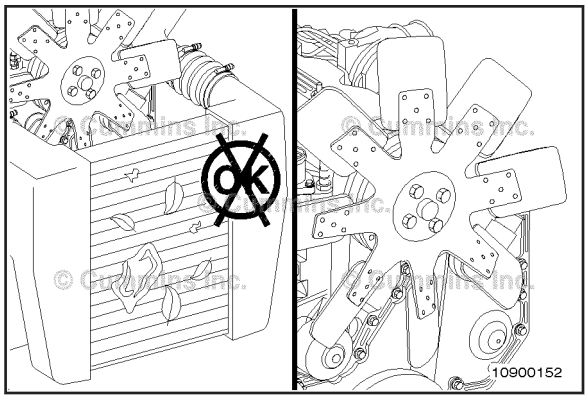


Operate the engine and check for leaks.

Temperature Differential Test

Inspect the charge air cooler fins for obstructions to airflow. Remove obstructions such as a winterfront or debris. Manually lock 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.

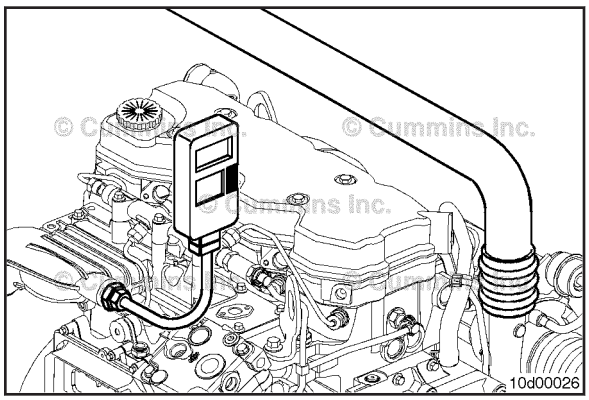


Install the thermocouple bead probe Part Number 3154498.

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 would be to use the monitor mode on the INSITE™ service tool.

Install another thermocouple at the air cleaner inlet to measure ambient air temperature.



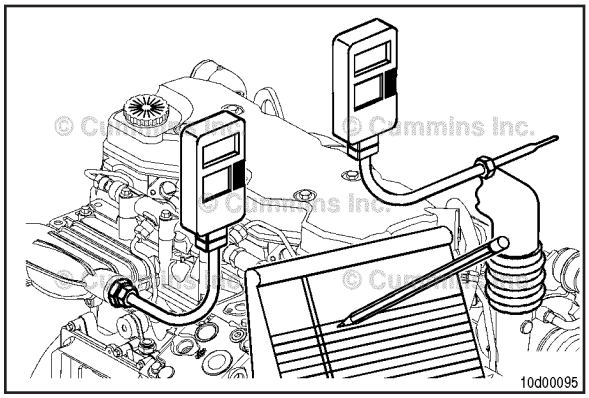
Perform a road test with the engine at peak power and a vehicle speed of 48 km/h [30 mph] or greater.

Record the intake manifold temperature and the ambient air temperature.

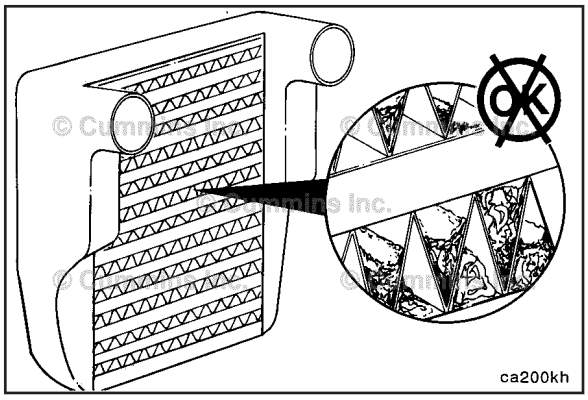
Calculate the differential temperature:

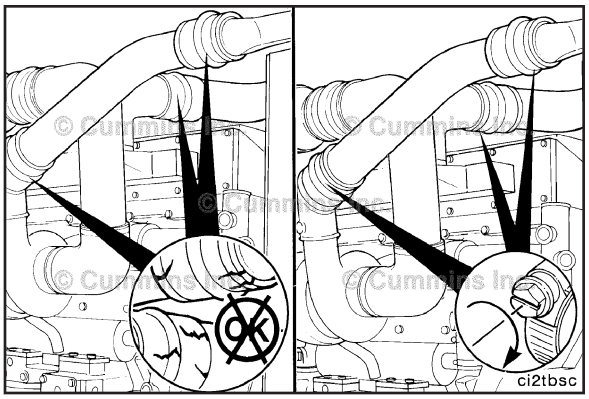
Intake manifold temperature - ambient air temperature = differential temperature.

- Differential temperature, delta T = 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.





Charge-Air Piping (010-028)

Maintenance Check

Inspect the charge-air piping and hoses for leaks, holes, cracks, or loose connections. Tighten the hose clamps if necessary. Refer to the vehicle or equipment manufacturer's specifications for the correct torque value.

Cold Starting Aid (010-029)

General Information

There are three types of cold starting aids used on ISB, ISB^{e}, and QSB engines. They are cylindrical, brick, and integral style. To gain access to the integral cold starting aid, the air intake manifold **must** be removed.

ISB CM850 preheat cycle information:

The intake air heater system is used to aid starting during cold temperatures. It energizes and de-energizes a heater driver (which controls a high current relay) and the “Wait-To-Start” lamp. Use of this system prior to cold start is termed as “preheat”. The amount of time necessary to turn on the intake air heater drivers during preheat is a function of the intake manifold temperature at key on, as shown in Figure 1.

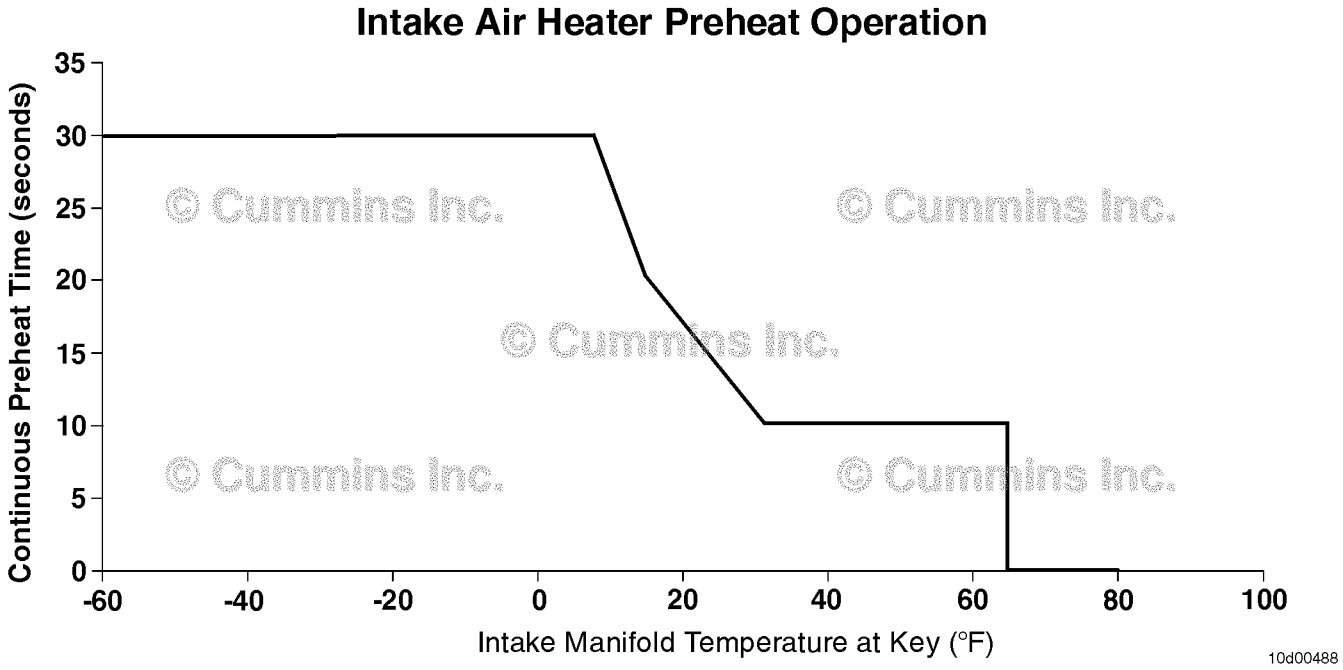


Figure 1: ISB CM850 and QSB CM850 Preheat Time in Seconds

ISB CM850 post-heat cycle information:

After a cold start, the grid heater can be activated during warm-up, which is termed “post-heat”. The post-heat schedule is determined by the average of the intake manifold temperature at key on. Post-heat is deactivated at vehicle speeds greater than 19 mph (30.5 kph). Post-heat operation parameters are listed in the Table 1.

Table 1: ISB CM850 Post-heat Operation Parameters			
Intake Manifold Temperature at Key On	**Heater**	**Duration (Seconds)**	**Dutycycle**
< -40°C [-40°F]	Both	20	Continuous
One	10	Continuous	
One	120	25/75	
-40 to -26°C [-40 to -15°F]	Both	20	Continuous
One	10	Continuous	
One	120	25/75	
-26 to -17°C [-15 to 1°F]	Both	20	Continuous
One	10	Continuous	
One	120	25/75	
-17 to -9°C [1° to 15°F], rpm < 1076	Both	10	Continuous
One	130	25/75	
-17 to -9°C [1 to 15°F], rpm > 1076	Both	10	Continuous
One	90	Continuous	
One	40	50/50	
-9 to -1°C [15 to 30°F], rpm < 1076	Both	10	Continuous
One	130	25/75	
-9 to -1°C [15 to 30°F], rpm > 1076	Both	10	Continuous
One	90	Continuous	
One	40	50/50	
-1 to 19°C [30 to 66°F], rpm < 1076	Both	10	Continuous
One	130	25/75	
-1 to 19°C [30 to 66°F], rpm > 1076	Both	10	Continuous
One	90	Continuous	
One	40	50/50	
> 19°C [66°F]	OFF		

QSB CM850 preheat cycle information:

The preheat cycle of the electric intake heater varies by ambient temperature, and is controlled through 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. There is no post-heat cycle for the QSB CM850 engine.

ISBe CM800 preheat cycle information (intake manifold heater optional):

The intake air heater system is used to aid starting in cold temperatures. It energizes and de-energizes two heater drivers (which control two high current relays) and the “Wait-To-Start” lamp. Use of this system prior to cold start is termed as “preheat”. The amount of time necessary to turn on the intake air heater drivers during preheat is a function of intake manifold temperature at key on, as shown in Figure 2.

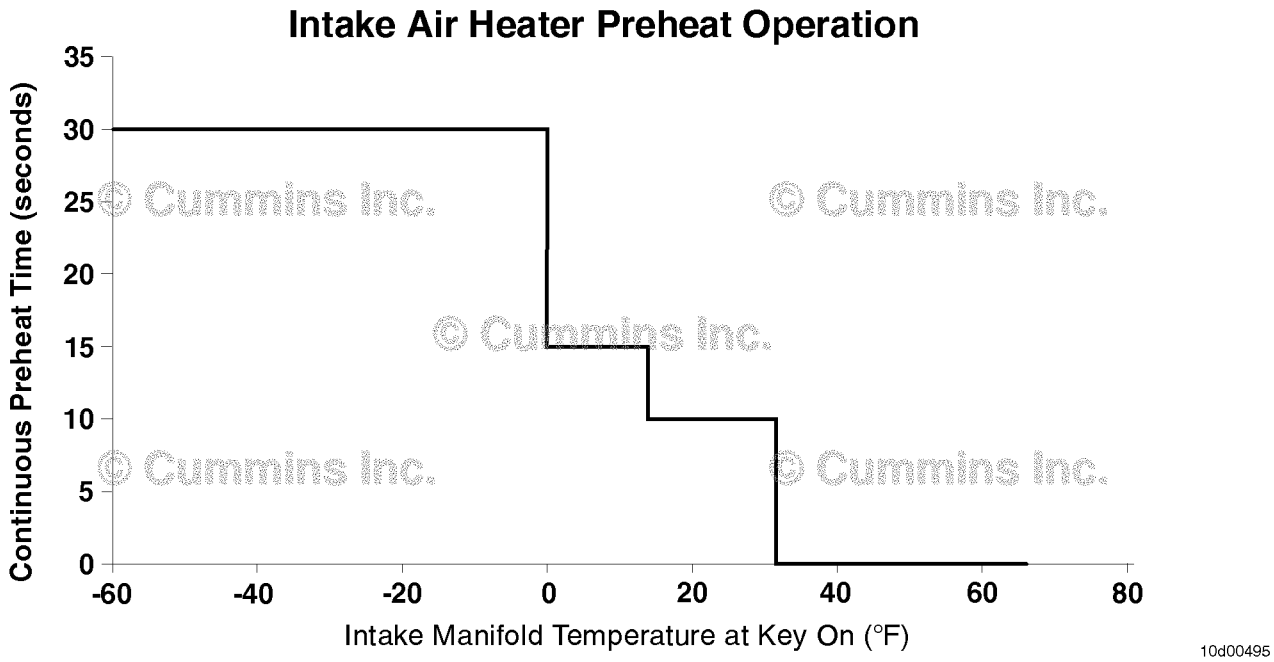


Figure 2: ISBe CM800 Preheat Time in Seconds

ISBe CM800 post-heat cycle information (intake manifold heater optional):

After a cold start, the grid heater could be activated during warm-up, which is termed “post-heat”. The post-heat schedule is determined by the average of the intake manifold temperature at key on. Post-heat is deactivate at vehicle speeds greater than 16.1 kph [10 mph]. Post-heat operation is listed in Table 2.

Table 2: ISBe CM800 Post-heat Operation Parameters

Intake Manifold Temperature at Key On	Heater	Duration (seconds)	Dutycycle
< -40°C [-40°F]	Both	20	Continuous
One	10	Continuous	
One	180	25/75	
-40 to -26°C [-40 to -15°F]	Both	20	Continuous
One	10	Continuous	
One	180	25/75	
-26 to -18°C [-15 to 1°F]	Both	20	Continuous
One	10	Continuous	
One	180	25/75	
-17 to -9°C [1 to 15°F], rpm < 1076	Both	15	Continuous
One	195	25/75	
-17 to -9°C [1 to 15°F], rpm > 1076	Both	15	Continuous
One	135	Continuous	
One	60	50/50	
-9 to -1°C [15 to 30°F], rpm < 1076	Both	15	Continuous
One	195	25/75	
-9 to -1°C [15 to 30°F], rpm > 1076	Both	15	Continuous
One	135	Continuous	
One	60	50/50	

Table 2: ISBe CM800 Post-heat Operation Parameters			
Intake Manifold Temperature at Key On	**Heater**	**Duration (seconds)**	**Dutycycle**
-1 to 19°C [30 to 66°F], rpm < 1076	Both	15	Continuous
One	195	25/75	
-1 to 19°C [30 to 66°F], rpm > 1076	Both	15	Continuous
One	135	Continuous	
One	60	50/50	
> 19°C [66°F]	OFF		

ISBe CM850 preheat cycle information (intake manifold heater optional):

The intake air heater system is used to aid in starting in cold temperatures. It energizes and de-energizes two heater drivers (which control two high-current relays) and the “Wait-To-Start” lamp. Use of this system prior to cold start is termed as “preheat”. The amount of time necessary to turn on the intake air heater drivers during preheat is a function of intake manifold temperature at key on, as shown in Figure 3.

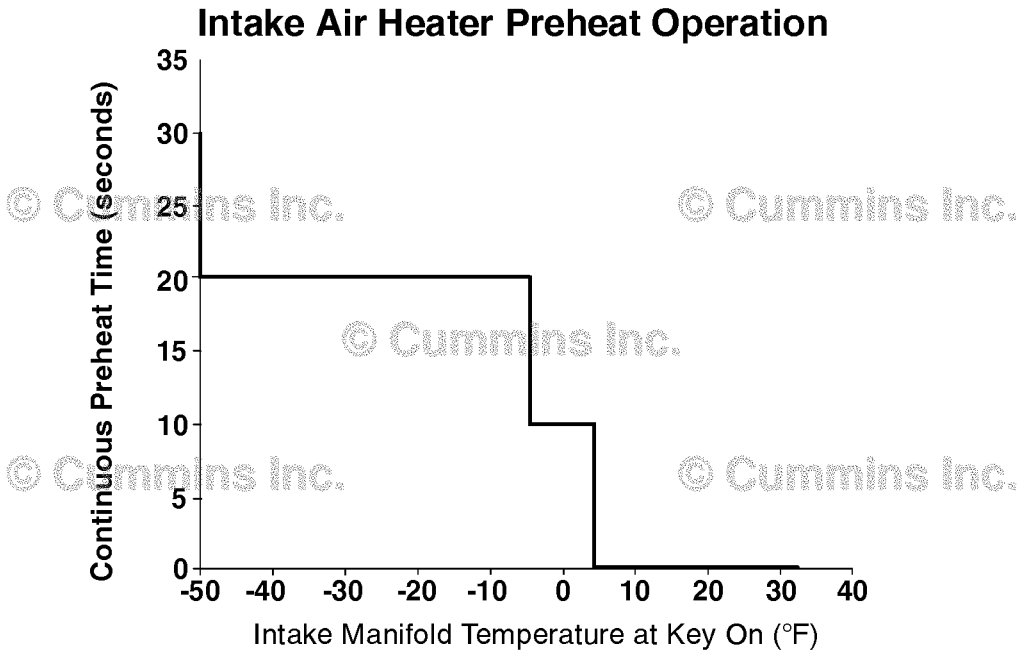


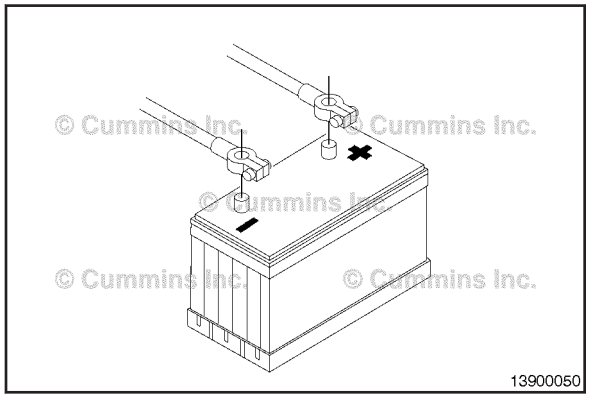
Figure 3: ISBe CM850 Preheat Time in Seconds

ISBe CM850 post-heat cycle information (intake manifold heater optional):

After a cold start, the grid heater could be activated during warm-up, which is termed “post-heat”. The post-heat schedule is determined by the average of the intake manifold temperature at key on. Post-heat is deactivated at vehicle speeds greater than 30.5 kph [19 mph]. Post-heat operation is listed in Table 3.

Table 3: ISBe CM850 Post-heat Operation Parameters			
Intake Manifold Temperature at Key On	**Heater**	**Duration (Seconds)**	**Dutycycle**
< -40°C [-40°F]	Both	30	Continuous
One	30	Continuous	
One	180	50/50	
-40 to -20°C [-40 to -4°F]	Both	30	Continuous
One	15	Continuous	

Table 3: ISBe CM850 Post-heat Operation Parameters			
Intake Manifold Temperature at Key On	**Heater**	**Duration (Seconds)**	**Dutycycle**
One	150	50/50	
-20 to -16°C [-4 to 3°F]	Both	30	Continuous
One	120	50/50	
-16 to -11°C [3 to 13°F], rpm < 1076	Both	15	Continuous
One	90	50/50	
-16 to -11°C [3 to 13°F], rpm > 1076	Both	15	Continuous
One	60	50/50	
-10 to -6°C [14 to 22°F], rpm < 1076	Both	10	Continuous
One	60	50/50	
-10 to -6°C [14 to 22°F], rpm > 1076	Both	10	Continuous
One	40	50/50	
-5 to -0.6°C [23 to 31°F], rpm < 1076	Both	5	Continuous
One	30	50/50	
-5 to -0.6°C [23 to 31°F], rpm > 1076	Both	5	Continuous
One	20	50/50	
> 0°C [32°F]	OFF		

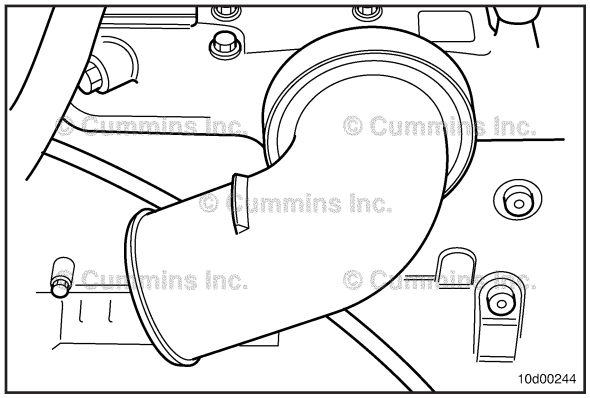


Preparatory Steps

⚠WARNING⚠

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

- Disconnect the batteries. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13.
- Remove the charge air piping. Refer to Procedure 010-019 (Air Crossover) in Section 10.



Remove

Cylindrical Type

Remove the air intake connection adaptor v-band clamp and air intake connection adapter.

- Refer to Procedure 010-131 (Air Intake Connection Adapter) in Section 10.

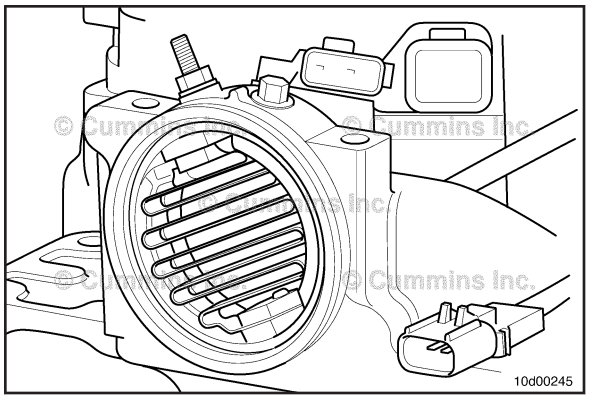
Remove the electrical supply terminal.

Remove the nylon isolating spacer from the electrical supply terminal.

Disconnect the cold starting aid wiring.

Remove the ground strap capscrew from the air intake manifold and remove the ground strap.

Remove the cylindrical cold starting aid assembly from the air intake manifold.

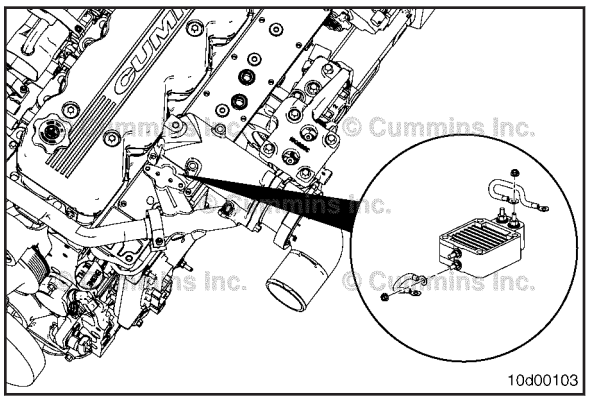


Brick Type

Disconnect the cold starting aid wiring.

If the cold starting aid is equipped with a ground wire, make sure to remove it.

Remove the air intake connection.

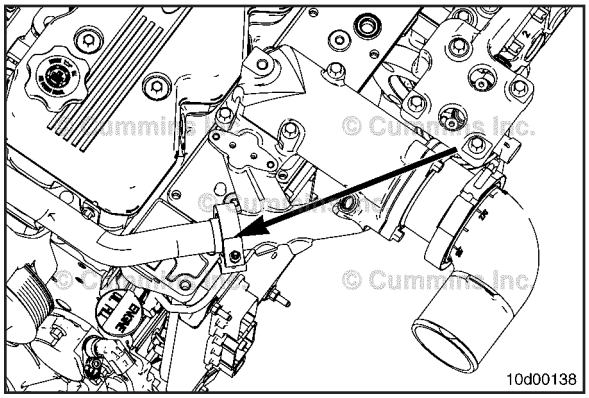


Some engines may have EGR. On these engines, disconnect the EGR pressure differential sensor and EGR temperature sensor.

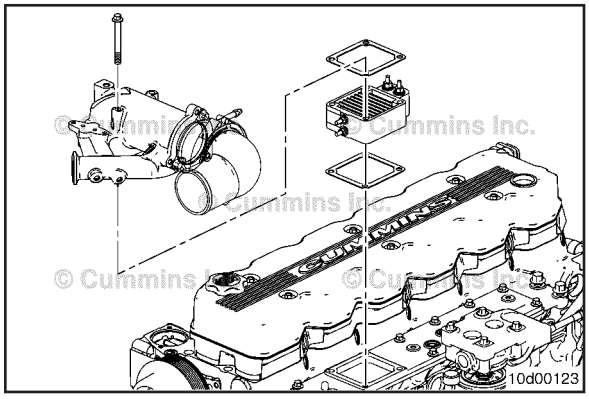
- Refer to Procedure 100-002 (Engine Diagrams) in Section E for sensor locations.

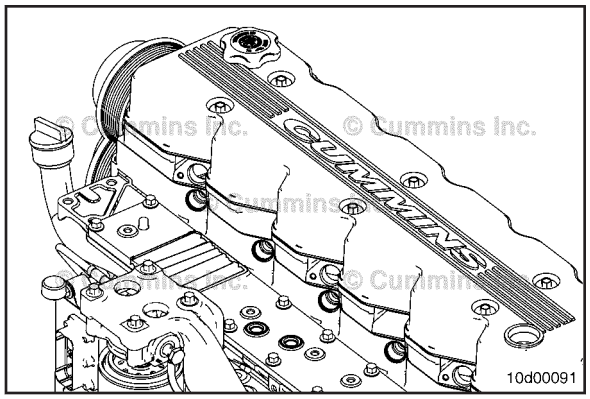
Remove the EGR connection tube V-band clamp from the air intake connection.

- Refer to Procedure 011-025 (EGR Connection Tubes) in Section 11.

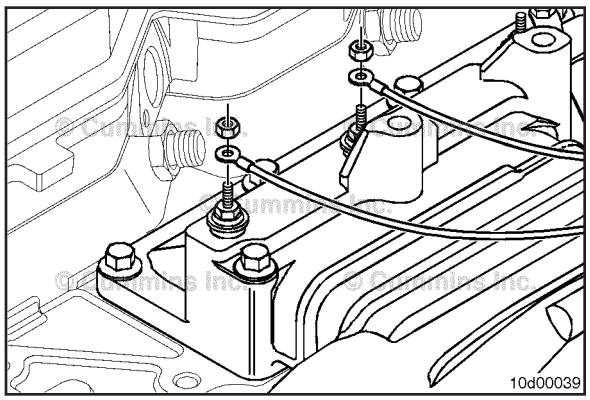


Remove the cold starting aid.



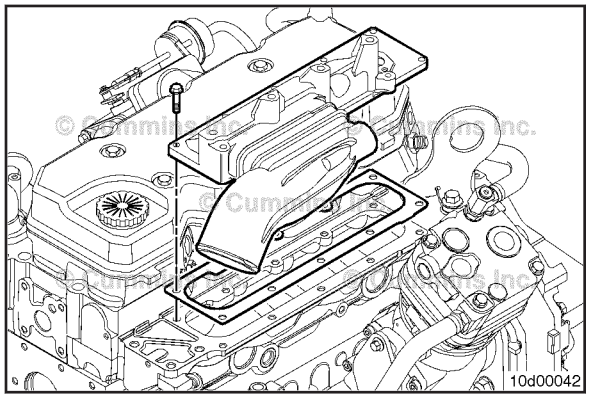


If the cold starting aid is to be removed for any length of time, apply tape over the hole to keep debris out of the air intake.



Integral Type

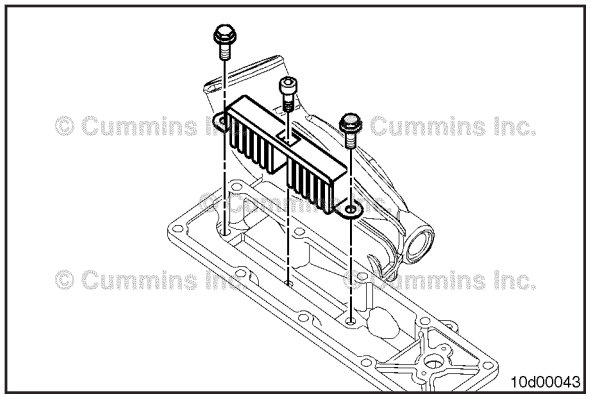
Disconnect the cold starting aid wiring.



Removal of the intake manifold temperature/pressure sensor is **not** necessary.

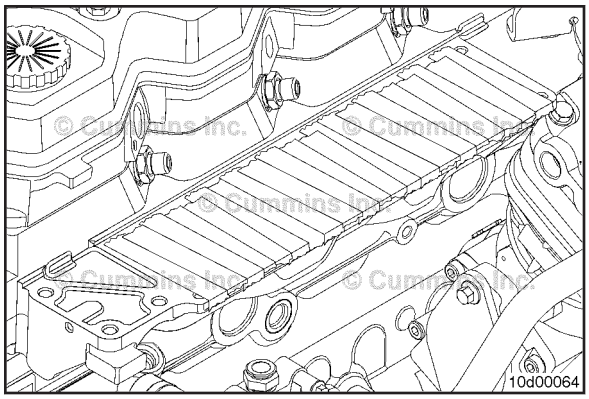
Remove the air intake manifold.

- Refer to Procedure 010-023 (Air Intake Manifold) in Section 10.



Remove the cold starting aid from the intake manifold.

If the intake cover will be off for a prolonged period of time, apply tape over the hole to keep debris out of the air intake.



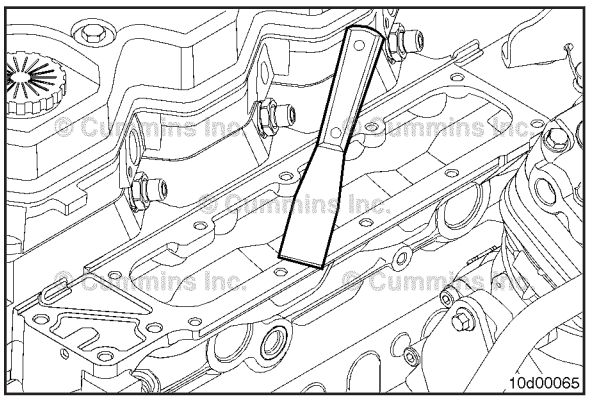
Clean and Inspect for Reuse

Keep the gasket material and any other materials out of the air intake manifold.

On engines equipped with EGR, it is **not** uncommon to see evidence of soot buildup on the cold starting aid heating elements.

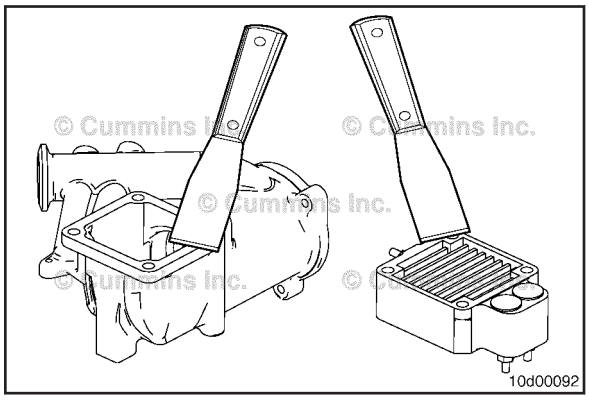
Check the air filter and connections for evidence of dust buildup in the cold starting aid. Dirt or leaking may be found.

Clean the air intake, cold starting aid, and intake connection sealing surfaces with a gasket scraper and a clean rag.



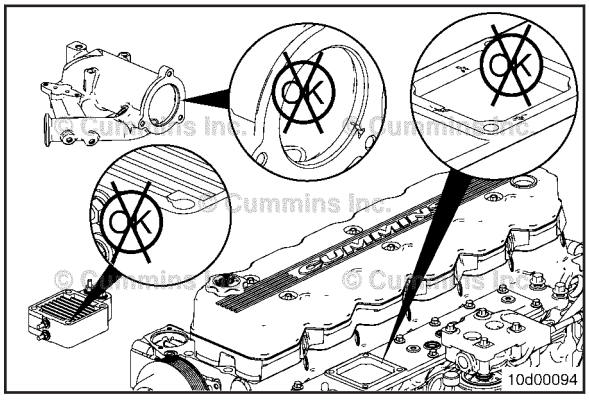
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

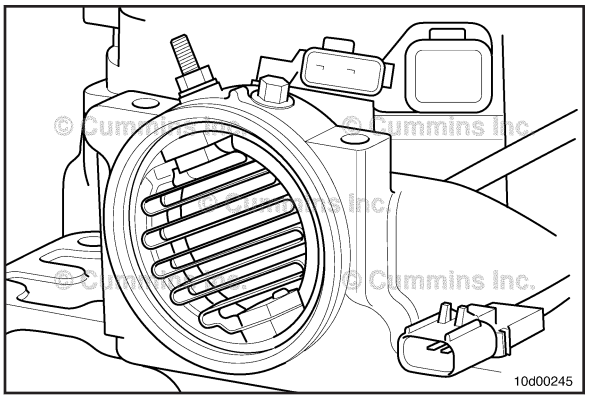
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.



Remove the tape or rag from the intake manifold.

Inspect the intake manifold cover, cold starting aid, and air intake connection sealing surfaces for cracks or other damage.





Install

Cylindrical Type

Fit the cold starting aid into the intake manifold.

Rotate the cold starting aid to align the electrical supply terminal with the machined hole in the top of the air intake manifold.

Insert the electrical supply terminal through the air intake manifold hole.

Install the nylon isolating spacer onto the electrical supply terminal.

Thread the terminal into the cold starting aid and torque to specification.

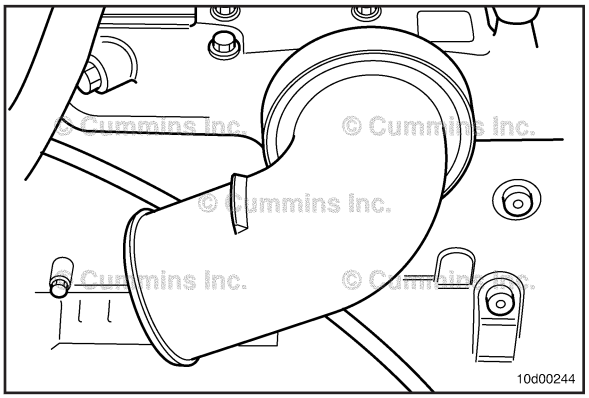
Torque Value: 8 N•m [71 in-lb]

Connect the cold starting aid wiring.

Install the ground strap and ground strap attaching capscrew to the intake manifol.

Tighten to specification.

Torque Value: 8 N•m [71 in-lb]

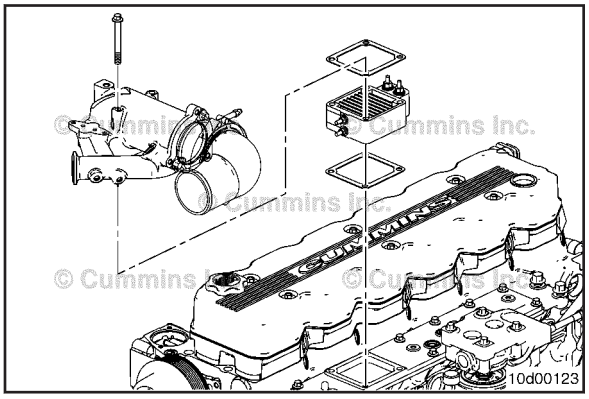


Install the air intake connection adaptor v-band clamp and air intake connection adapter.

- Refer to Procedure 010-131 (Air Intake Connection Adapter) in Section 10.

Torque the clamp to specification.

Torque Value: 10 N•m [89 in-lb]



Brick Type

Remove the tape, if applied over the air intake manifold.

Install the following components with the four mounting capscrews finger tight.

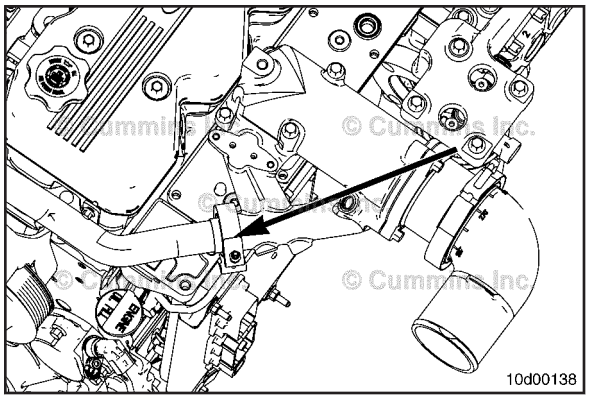
Install the cold starting aid, air intake connection, and air inlet adapter.

NOTE: Some engines have EGR. Connect the EGR pressure differential sensor and the EGR temperature sensor. Refer to Procedure 100-002 (Engine Diagrams) In Section E for sensor location.

Install the EGR connection tube v-band clamp.

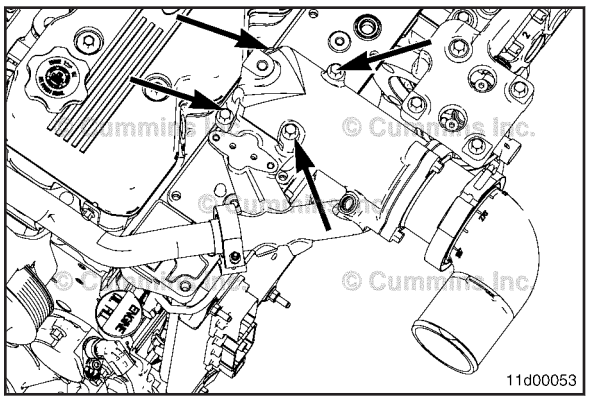
- Refer to Procedure 011-025 (EGR Connection Tubes) in Section 11.

Torque Value: 11 N•m [97 in-lb]



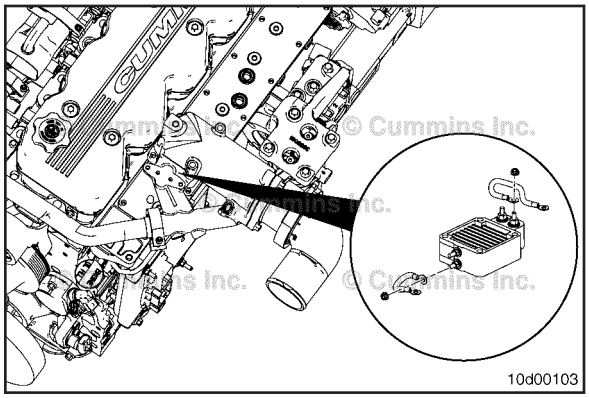
Tighten the four mounting capscrews.

Torque Value: 24 N•m [212 in-lb]



Connect the cold starting aid wiring.

If the cold starting aid is equipped with a ground wire, make sure to install it.

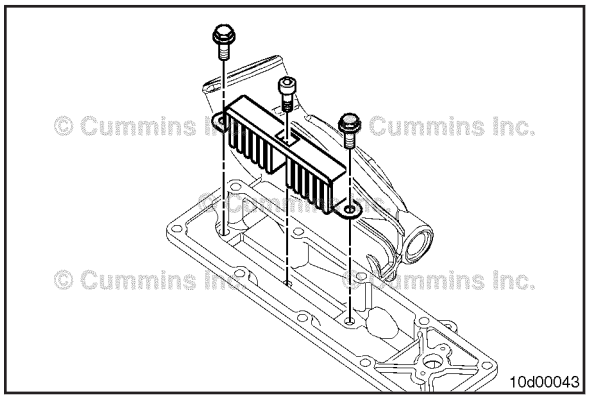


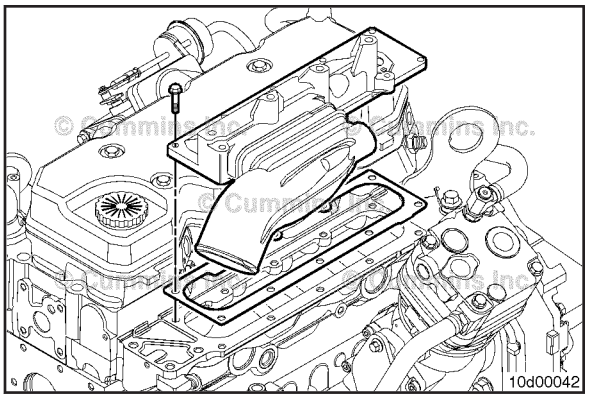
Integral Type

Install the cold starting aid into the air intake manifold and tighten the capscrews.

Torque Value: 14 N•m [124 in-lb]

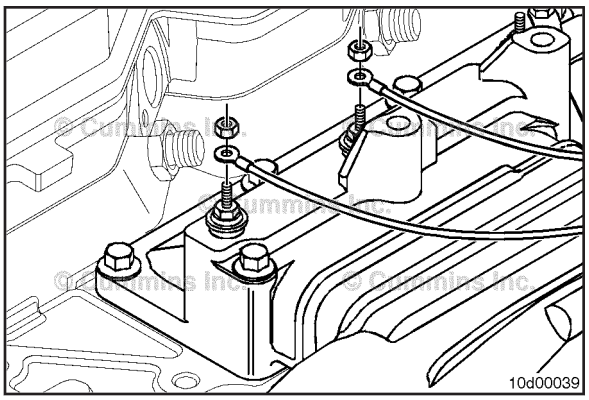
Remove the tape, if applied over the air intake manifold.



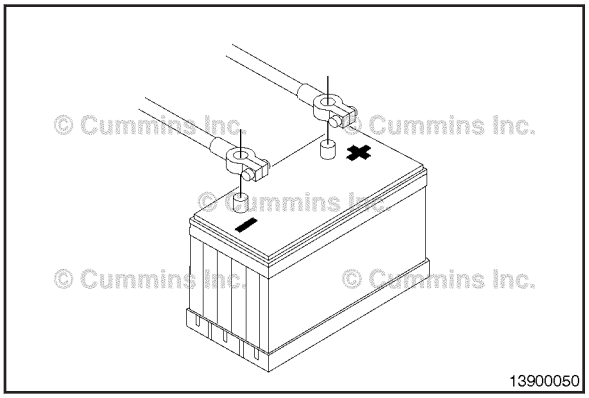


Install the air intake manifold.

- Refer to Procedure 010-023 (Air Intake Manifold) in Section 10.



Connect the cold starting aid wiring.



Finishing Steps

⚠WARNING⚠

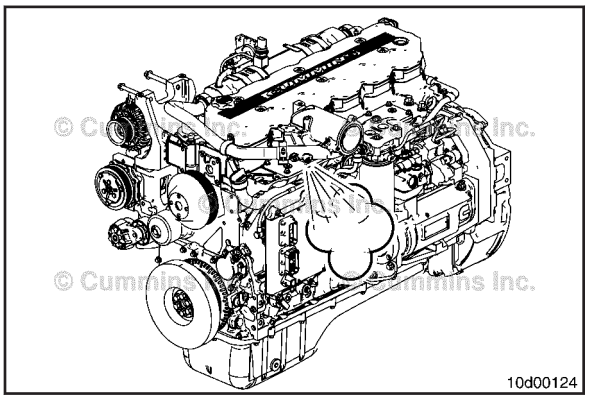
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Install the charge air piping.

- Refer to Procedure 010-019 (Air Crossover) in Section 10.

Connect the batteries.

- Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13.



Operate engine and check for leaks.

- Refer to Procedure 010-024 (Air Leaks, Air Intake and Exhaust Systems) in Section 10.

Test

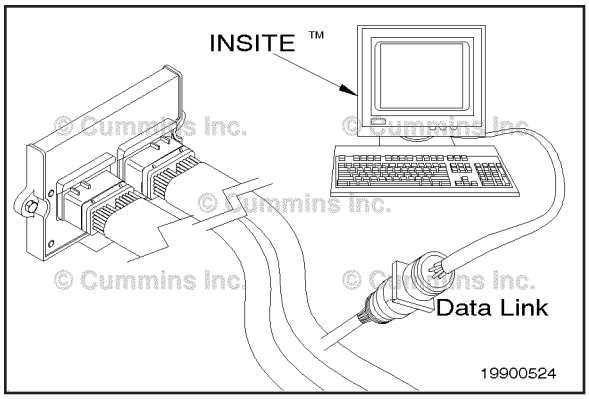
⚠WARNING⚠
Avoid touching the cold starting aid with your hands while the cold starting aid is operating.

Connect INSITE™ electronic service tool.

From the list of ECM diagnostic tests, select “Intake Air Heater Override”.

Follow the on-screen instructions to determine if the cold starting aid and cold starting aid circuitry are functioning properly.

To check if the cold starting aid is heating, use an infrared non-contact thermometer, Part Number 3164487.



Air Intake Restriction (010-031)

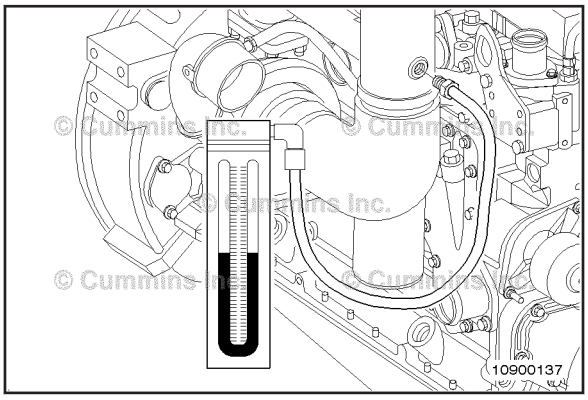
Measure

Manometer, Part Number ST-1111-3

Install a vacuum gauge or water manometer, Part Number ST-1111-3, in the inlet 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.

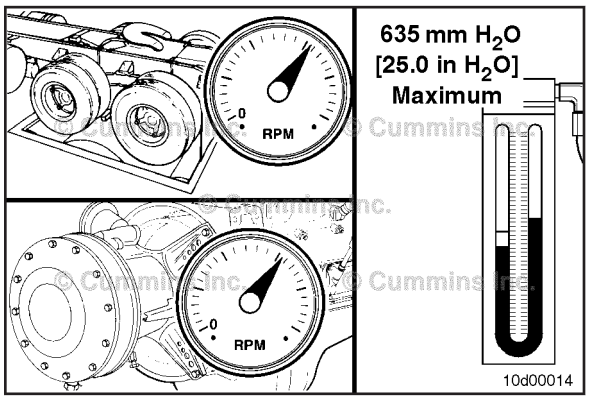
NOTE: On many automotive, industrial and marine applications, the air intake restriction can be measured by removing the pop-up flag restriction gauge and installing a vacuum gauge of water manometer.



Operate the engine at full throttle and rated rpm with maximum load.

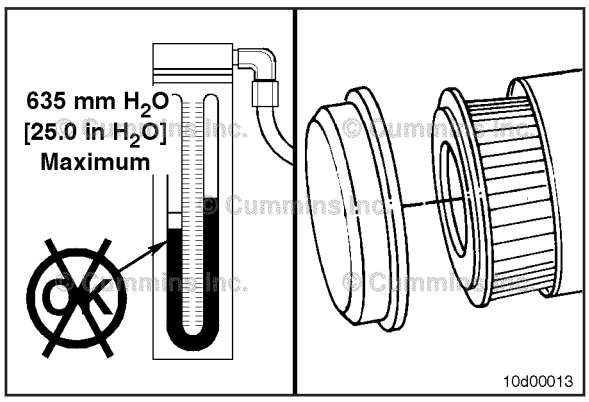
Record the data on the gauge or manometer.

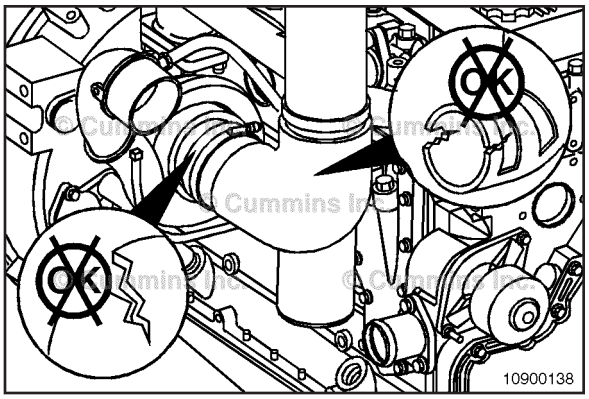
Air Intake Restriction		
mm H_2O		in H_2O
635	MAX	25



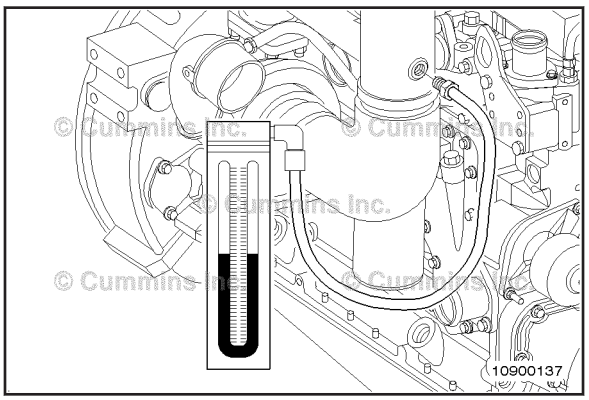
If restriction exceeds specifications:

- Replace or clean the air filter element. Refer to the equipment manufacturer's instructions.

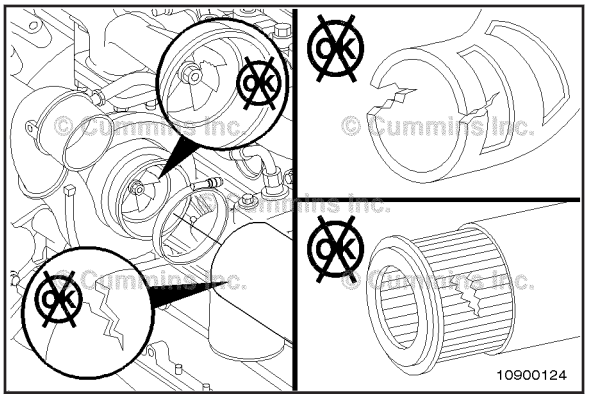




- Inspect the air inlet piping for damage. Refer to the equipment manufacturer's repair instructions.



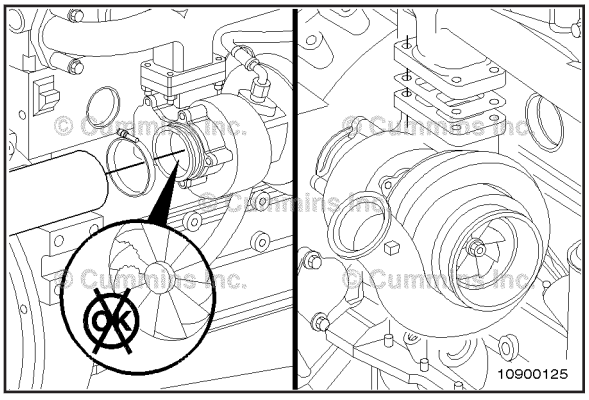
Remove the test equipment.



Turbocharger (010-033)

Initial Check

- Remove the inlet pipe and air inlet connection from the turbocharger. Refer to Procedure 010-022 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 inlet piping and filter element for damage.
- Repair any damage before operating the engine.

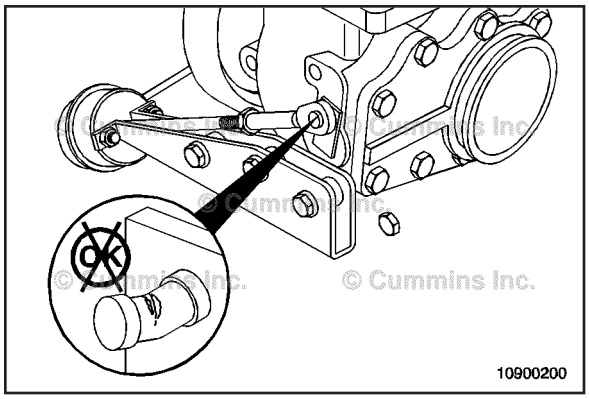


△CAUTION△
On Marine applications, before disconnecting the exhaust outlet piping, be sure to fasten the piping above the water level to prevent the vessel from taking on water and possibly sinking.

- Remove the exhaust pipe from the turbocharger.
- Inspect the turbine wheel for damage.
- Replace the turbocharger if damage is found. See the Remove and Install sections in this procedure.

Wastegate Check

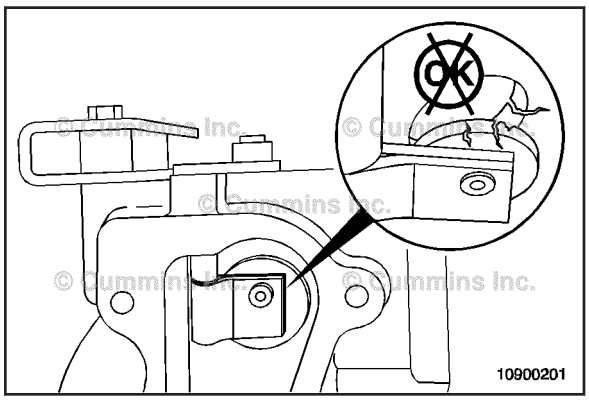
- Inspect the lever pin.
- Replace the turbocharger if the lever pin is bent or worn excessively. See the Remove and Install sections in this procedure.



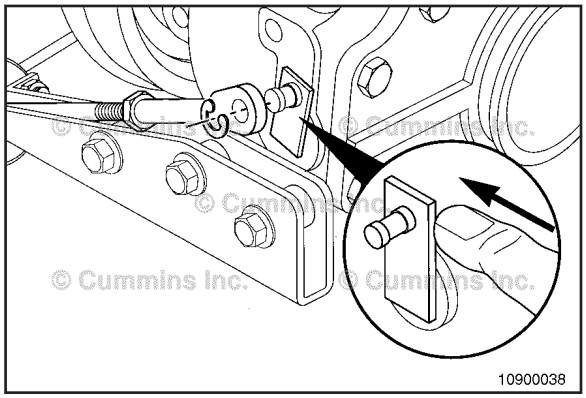
- Inspect the valve and valve seat for cracks or erosion.

NOTE: On some turbochargers, removal of the turbine exhaust outlet cover may be necessary to inspect the valve and valve seat. If the turbine exhaust outlet cover is removed, replace the gasket before installing the cover.

- Replace the turbocharger if the valve or valve seat are excessively cracked or eroded. See the Remove and Install sections in this procedure.

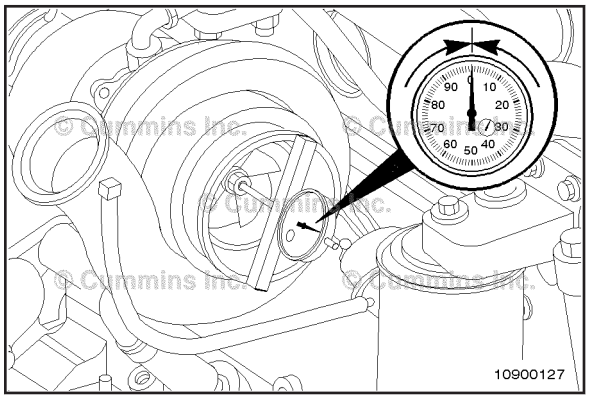


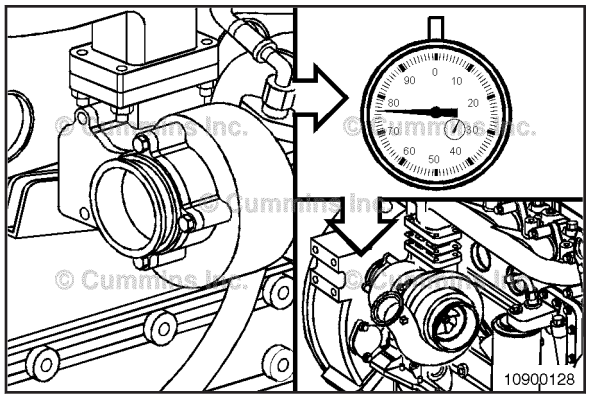
- Actuate the lever by hand to verify that the shaft rotates freely and is **not** seized.
- Check for excessive movement between the shaft and bushing.
- Replace the turbocharger if the shaft is seized or if there is excessive movement between the shaft and bushing. See the Remove and Install sections 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 to zero.





- Push the rotor assembly toward the gauge and record the reading.

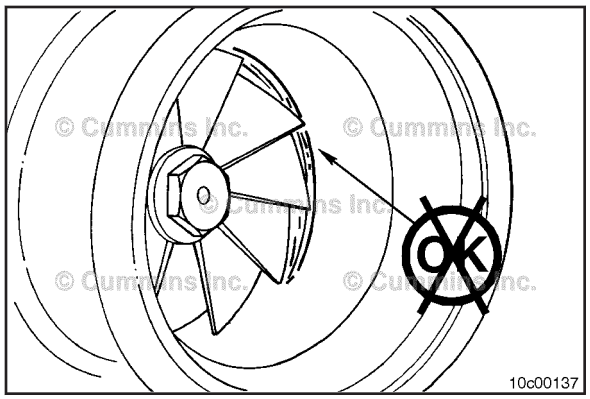
HE221W, HE211W, and HE201W - Axial Clearance		
mm		**in**
0.010	MIN	0.0004
0.076	MAX	0.0030

HX40, H1E, HY30W, HX35W, and HY35W - Axial Clearance		
mm		**in**
0.038	MIN	0.0015
0.093	MAX	0.0037

HX27/25W - Axial Clearance		
mm		**in**
0.057	MIN	0.0022
0.103	MAX	0.0040

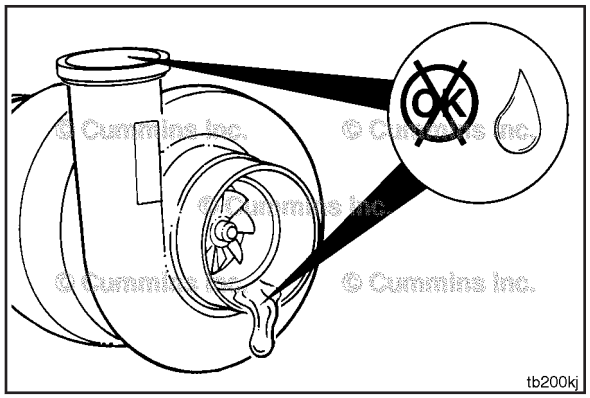
Variable Geometry, HY35V - Axial Clearance		
mm		**in**
0.038	MIN	0.0015
0.093	MAX	0.0037

- Replace the turbocharger if the clearance does **not** meet specifications. See the Remove and Install sections in this procedure.



Radial Clearance Check:

- Inspect compressor wheel for signs of contact with compressor housing. Replace turbocharger if evidence of contact is present.

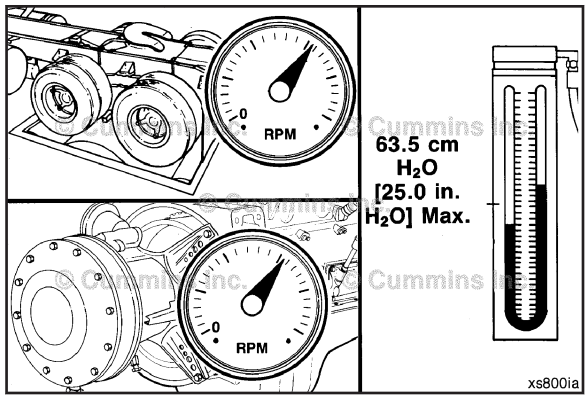


- Inspect the turbocharger compressor intake and discharge for oil.
- If oil is present in the compressor intake as well as in the discharge, check upstream of the turbocharger for the source of the oil.

NOTE: Light oil and/or misting of the compressor intake is acceptable on engines equipped with a closed crankcase ventilation system, in which the crankcase in vented into the air inlet piping.

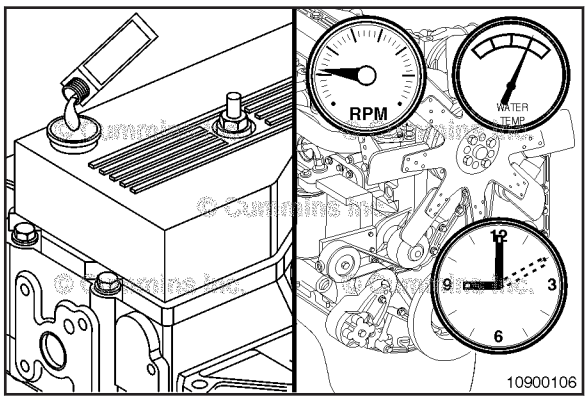
NOTE: If the engine experiences a turbocharger failure or any other occasion where oil is put into the charge-air system, the charge-air system **must** be inspected and cleaned. This includes the aftercooler assembly in Marine engines. Refer to Procedure 010-027 in Section 10. Refer to Procedure 010-005 in Section 10.

- If heavy deposits and/or streaks of oil are present **only** in the discharge side, install the air inlet and charge-air cooler piping to check the air restriction indicator. Reference the equipment manufacturer service information.
- Check for air intake restriction. Refer to Procedure 010-031 in Section 10.
- If **no** intake restriction is found, replace the turbocharger. See the Remove and Install sections in this procedure.



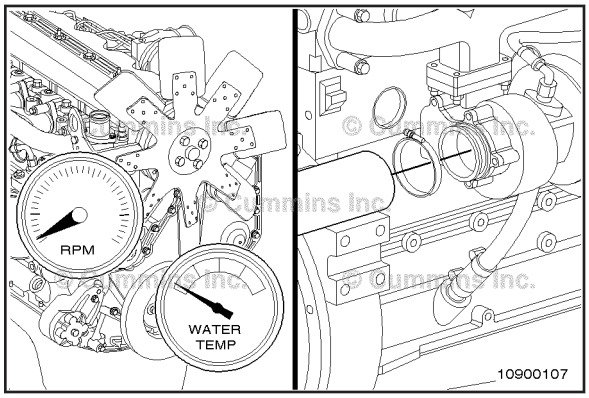
Leak Test

- 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.



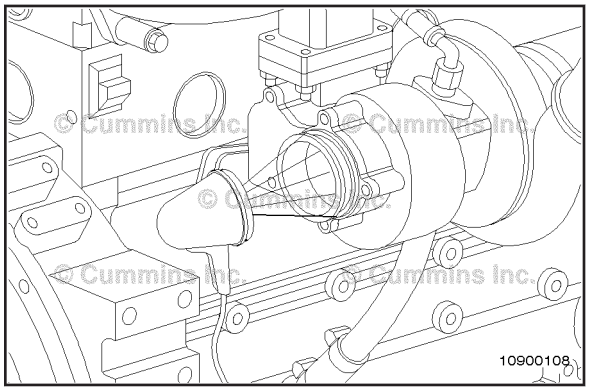
⚠CAUTION⚠
On Marine applications, before disconnecting the exhaust outlet piping, be sure to fasten the piping above the water level to prevent the vessel from taking on water and possibly sinking.

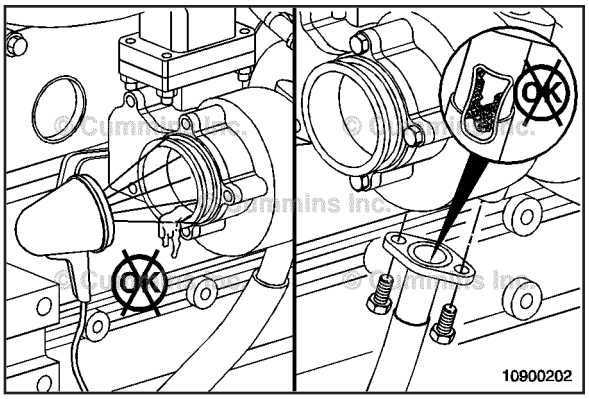
- Turn engine OFF.
- Allow the turbocharger to cool.
- Remove the exhaust pipe from the turbine housing.



Use a high-intensity black light, Part Number 3163338, to inspect the turbine outlet for leaks.

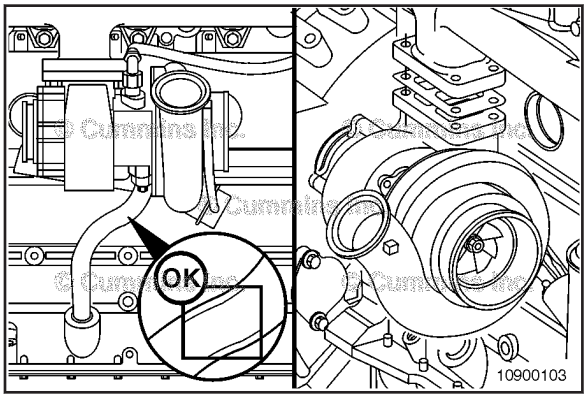
- A yellow glow indicates an oil leak.
- A dark blue glow indicates fuel in the oil.



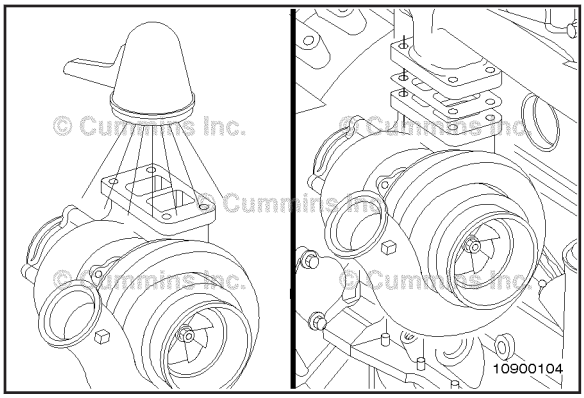


- If oil is found on the turbine housing, remove the oil drain line, and check for restrictions. Refer to Procedure 010-045 in Section 10.
- Clear any restrictions found.
- Install the drain line and new o-ring seals into the engine block. Refer to Procedure 010-045 in Section 10.

NOTE: On automotive engines the exhaust catalyst **must** be inspected. Refer to Procedure 011-056 in Section 11.



- If the oil drain line was **not** restricted, remove the turbocharger. See the Remove section in this procedure.

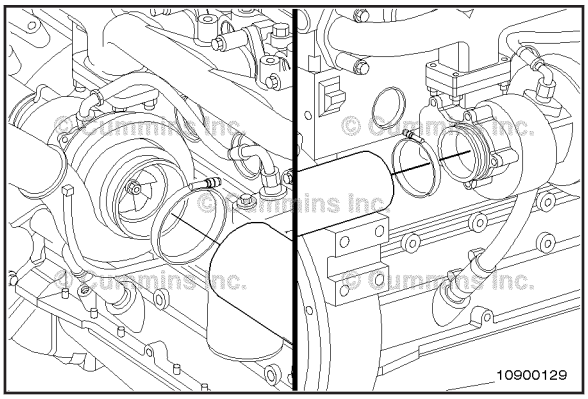


- Use a high-intensity black light, Part Number 3163338, to inspect the turbine inlet for leaks.
- A yellow glow indicates an oil leak from the engine.
- If a yellow glow is seen, the turbocharger can be reinstalled and returned to service. A light coating of oil in the turbine housing and on the turbine does **not** need to be cleaned as it will be burned off during engine operation. Any puddles of oil in the turbine housing **must** be removed with a clean rag prior to installation.

NOTE: On automotive engines the exhaust catalyst **must** be inspected. Refer to Procedure 011-056 in Section 11.

- 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.
- Install the intake pipe to the turbocharger compressor inlet.



Preparatory Steps

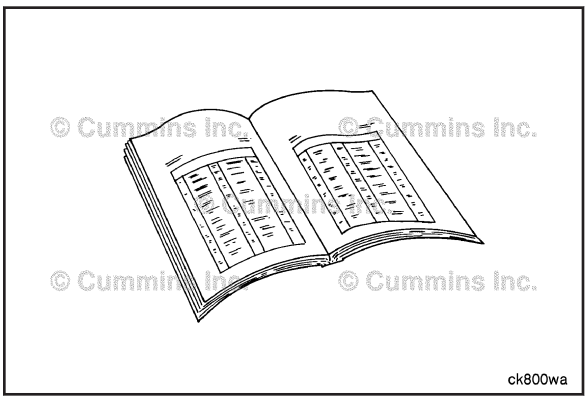
Automotive and Industrial

⚠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.

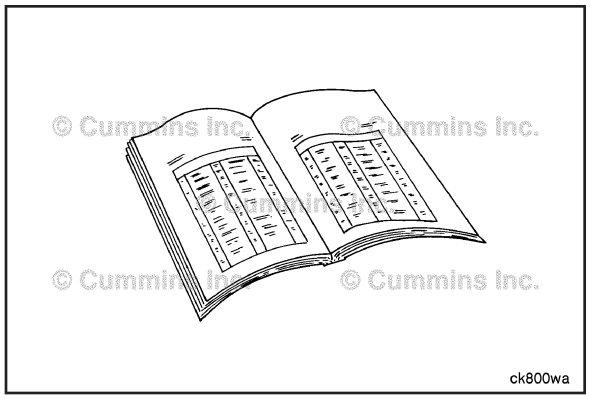
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

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

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



- Disconnect vehicle batteries. Reference the equipment manufacturer service information.
- Drain the coolant, variable geometry turbochargers **only**. Refer to Procedure 008-018 in Section 8.
- Disconnect the charge-air cooler piping. Refer to Procedure 010-019 in Section 10.
- 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 electrical connections from the turbocharger, variable geometry turbocharger **only**.



Marine Applications

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

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

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

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

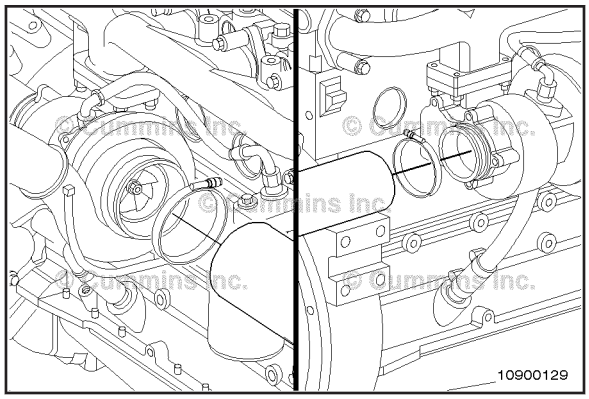
⚠CAUTION⚠
Be sure to tie the exhaust piping up above the water line to prevent water from feeding back into the vessel while the exhaust piping is removed. Failure to do so can result in the vessel sinking.

- Disconnect the vehicle batteries. Reference the equipment manufacturer service information.
- Shut off the sea water inlet valve(s). Reference the equipment manufacturer service information.
- Drain the engine coolant. Refer to Procedure 008-018 in Section 8.
- Remove the air cleaner assembly. Refer to Procedure 010-013 in Section 10.
- Remove the air crossover from the turbocharger. Refer to Procedure 010-019 in Section 10.
- Remove the exhaust outlet connection. Refer to Procedure 011-017 in Section 11.
- Disconnect the coolant lines from the turbocharger. Refer to Procedure 010-041 in Section 10.
- Disconnect the turbocharger oil supply line. Refer to Procedure 010-046 in Section 10.
- Disconnect the turbocharger oil drain line. Refer to Procedure 010-045 in Section 10.

Remove

Automotive and Industrial

- Remove the exhaust piping.
- Remove the turbocharger compressor air inlet connection. Refer to Procedure 010-022 in Section 10.



⚠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⚠

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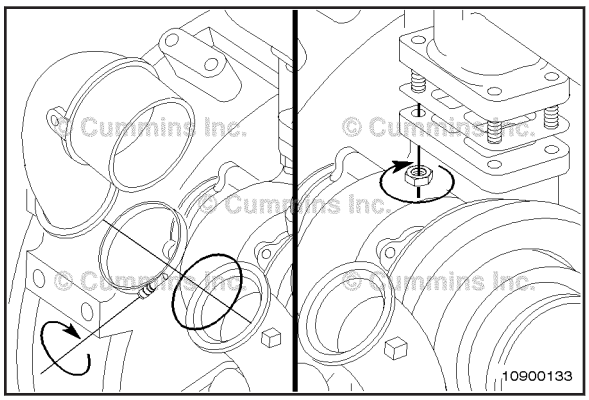
- Remove the turbocharger compressor outlet elbow, V-band clamp, and o-ring from the turbocharger compressor outlet.



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

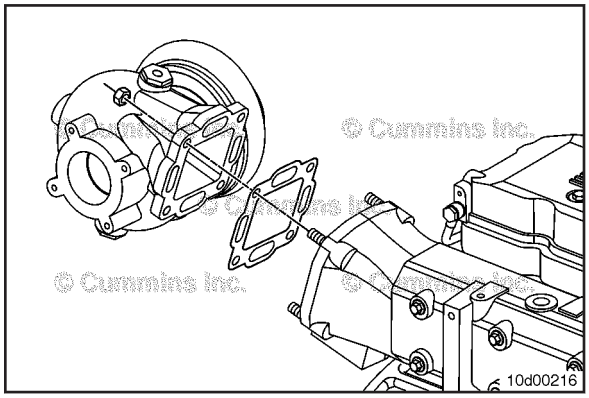
- Remove the four turbocharger mounting nuts.
- Remove the turbocharger and gasket.
- Never reuse a turbocharger mounting gasket.

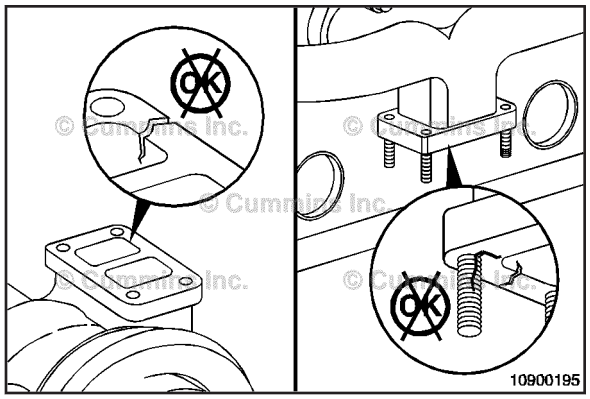
Marine Applications

⚠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.

△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.

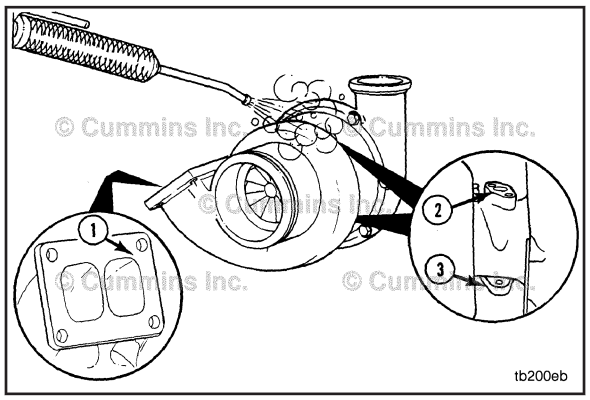
- Remove the turbocharger mounting nuts and turbocharger.
- Remove the gasket.





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.
- Replace the turbocharger if any cracks are found in the mounting flange surfaces. See the Remove and Install sections in this procedure.
- Replace the exhaust manifold if any cracks or other damage is found in the mounting flange surfaces. Use the following procedure for automotive and industrial applications. Refer to Procedure 011-007 in Section 11. Use the following procedure for marine applications. Refer to Procedure 011-036 in Section 11

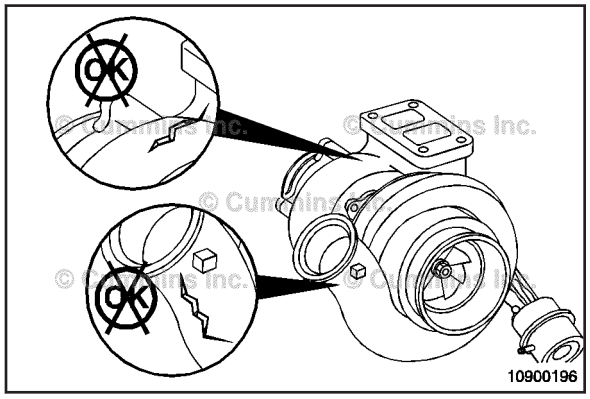


⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠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.

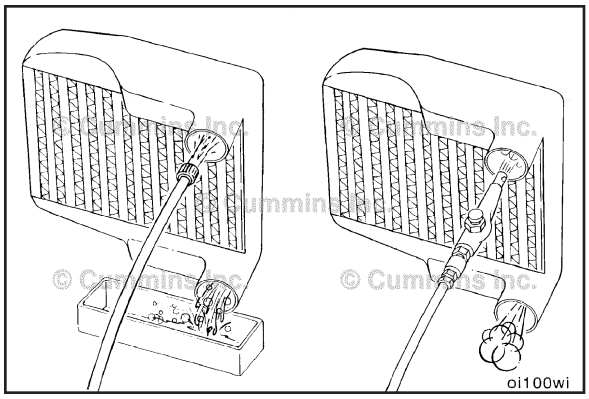
- Remove all carbon deposits and gasket material from surfaces (1, 2, and 3).
- Use solvent or steam to clean the exterior of the turbocharger.
- Dry with compressed air.



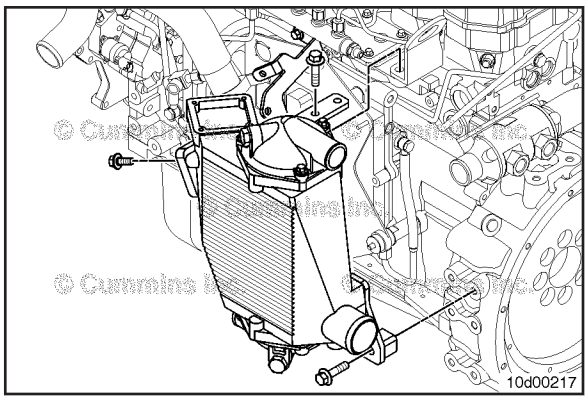
- Inspect the turbine and compressor housings.
- If cracks are found which go all the way through the outer walls, the turbocharger **must** be replaced.

NOTE: On automotive and industrial engines, a charge-air cooler damage 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.

NOTE: On automotive and industrial engines, if the engine experiences a turbocharger damage or any other event in which oil or debris is introduced into the charge air system, the charge air system **must** be inspected and cleaned. Refer to Procedure 010-027 in Section 10.



NOTE: On Marine engines, if the engine experiences turbocharger damage or any other event in which oil or debris is introduced into the intake air system, the aftercooler assembly **must** be inspected and cleaned. Refer to Procedure 010-005 in Section 10.



Install

Automotive and Industrial

⚠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.

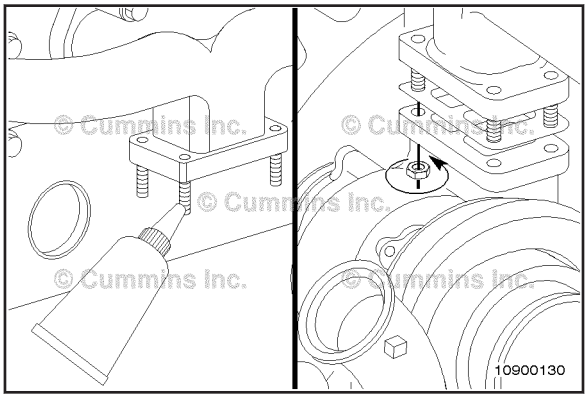
- Apply a film of high-temperature anti-seize compound to the turbocharger mounting studs.

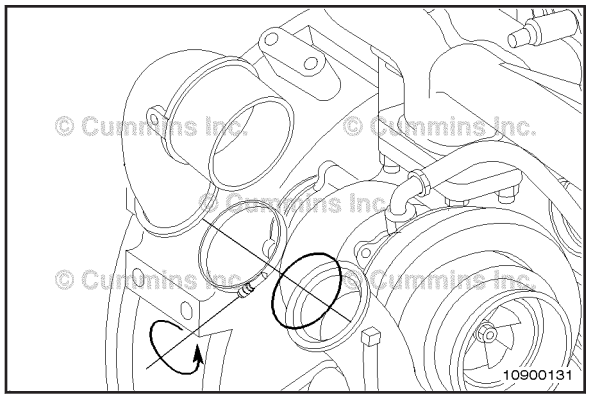
△CAUTION△
The new gasket must match the one that was removed. Use of the incorrect gasket will result in turbocharger damage. Never reuse a turbocharger mounting gasket.

- 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.

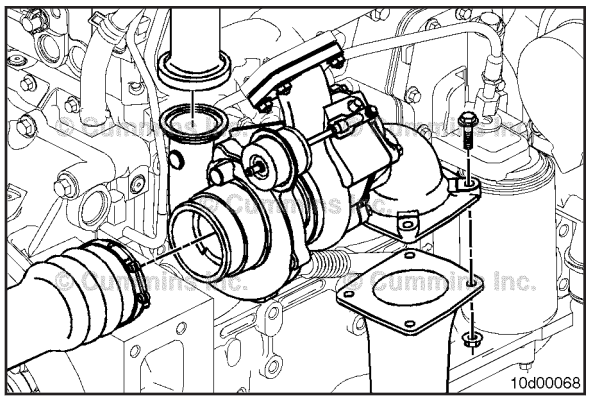
Torque Value: 43 N•m [32 ft-lb]





- Install the turbocharger compressor outlet elbow, V-band clamp, and a new o-ring seal on the turbocharger compressor discharge outlet, if applicable.
- Tighten the clamp.

Torque Value: 8 N•m [71 in-lb]



- Rotate the compressor housing to fit the intake pipes, if necessary.

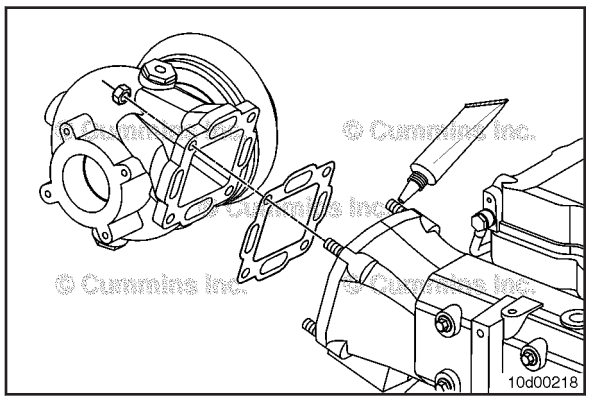
NOTE: Use the snap ring or loosen the V-band clamp to make necessary adjustments. Make sure the snap ring is seated and/or the V-band clamp is tight when finished with adjustment.

- Install the inlet pipe and air inlet connection and tighten the clamp.

Torque Value: 8 N•m [71 in-lb]

- Install the exhaust pipe and tighten the clamp.

Torque Value: 8 N•m [71 in-lb]



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.

△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.

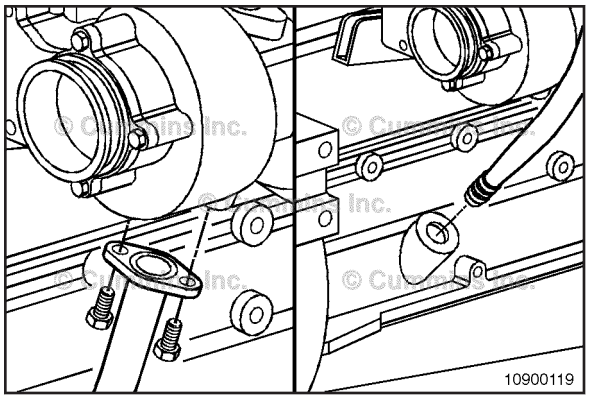
- Apply a film of high-temperature anti-seize compound to the turbocharger mounting studs.
- Use a new gasket and install the turbocharger.
- Install and tighten the four mounting nuts.

NOTE: The torque values given have been established using anti-seize compound as a lubricant.

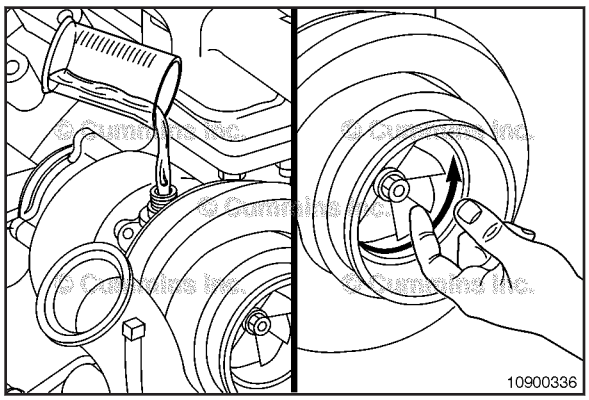
Torque Value: 43 N•m [32 ft-lb]

Prime

- Install and tighten the turbocharger oil drain line. Refer to Procedure 010-045 in Section 10.



- Lubricate the bearings by pouring 60 to 90 cc's [2 to 3 oz] of clean 15W-40 engine oil in the turbocharger oil supply line fitting.
- Rotate the turbine wheel to allow oil to enter the bearing housing.

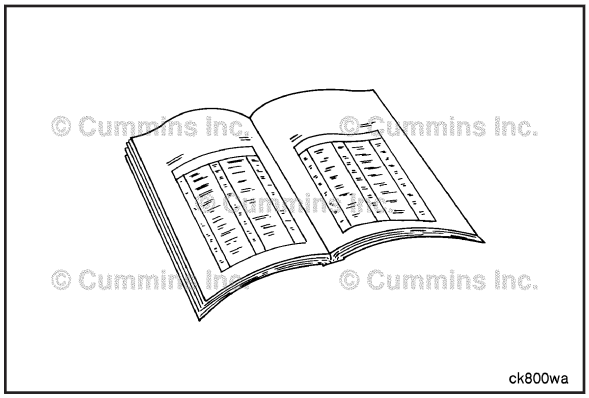


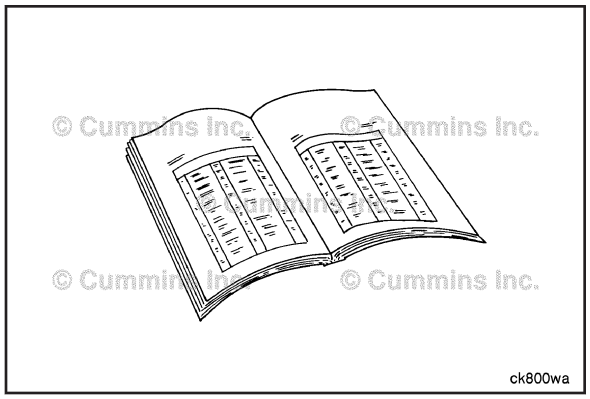
Finishing Steps

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.

- Install the charge-air cooler piping. Refer to Procedure 010-019 in Section 10.
- Install and tighten the turbocharger oil supply line. Refer to Procedure 010-046 in Section 10.
- Install the turbocharger coolant lines, variable geometry turbocharger **only**. Refer to Procedure 010-041 in Section 10.
- Connect the electrical connections to the turbocharger, variable geometry turbocharger **only**
- Fill the cooling system, variable geometry turbocharger **only**. Refer to Procedure 008-018 in Section 8.
- Connect the vehicle batteries. Reference the equipment manufacturer service information.
- Operate the engine and check for leaks.



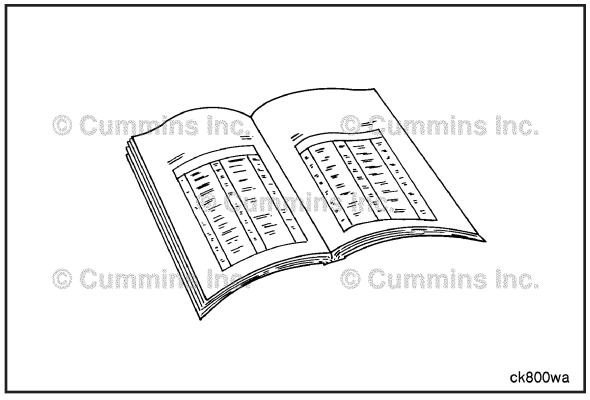


Marine Applications

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

- Install the oil supply line. Refer to Procedure 010-046 in Section 10.
- Install the coolant lines. Refer to Procedure 010-041 in Section 10.
- Install the air crossover to the turbocharger. Refer to Procedure 010-019 in Section 10.
- Install the air cleaner assembly. Refer to Procedure 010-013 in Section 10.
- Install the outlet connection. Refer to Procedure 011-017 in Section 11.
- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- Open the sea water supply valve(s). Reference the equipment manufacturer service information.
- Connect the vehicle batteries. Reference the equipment manufacturer service information.

Operate the engine and check for leaks.



Turbocharger Coolant Hoses (010-041)

Preparatory Steps

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

△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.

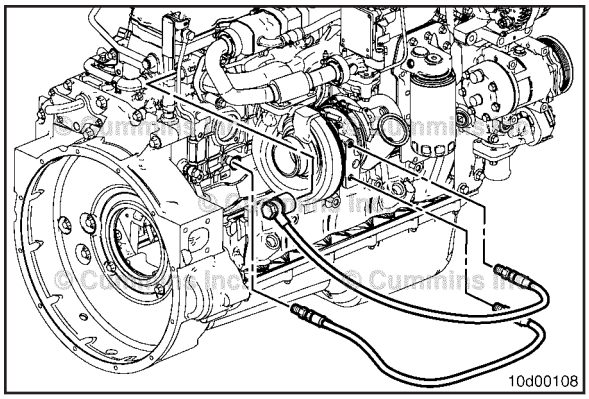
Drain the coolant. Refer to Procedure 008-018

Remove

NOTE: All lines and banjo screws used in the coolant plumbing have increased annulus ports. **Always** use the correct Cummins part number and do **not** use standard lines or banjo screws as a substitute.

Remove the supply and return coolant lines that attach to the variable geometry turbine bearing housing.

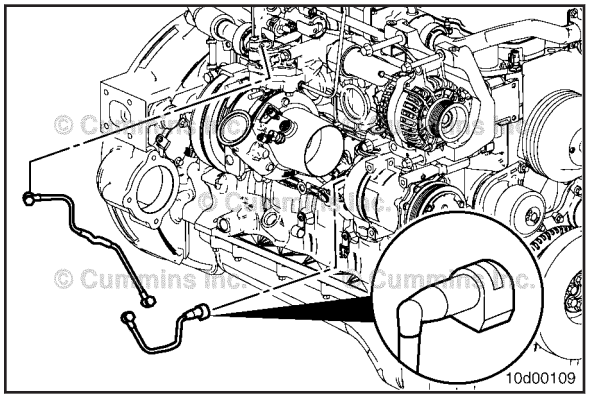
Discard the seals.



Disconnect the variable geometry actuator supply and return coolant lines from the actuator.

NOTE: Three of the connections are banjo fittings. The connection from the block to the turbocharger at the block location is a quick-disconnect fitting. Pinch the quick-disconnect fitting to remove it from the block fitting.

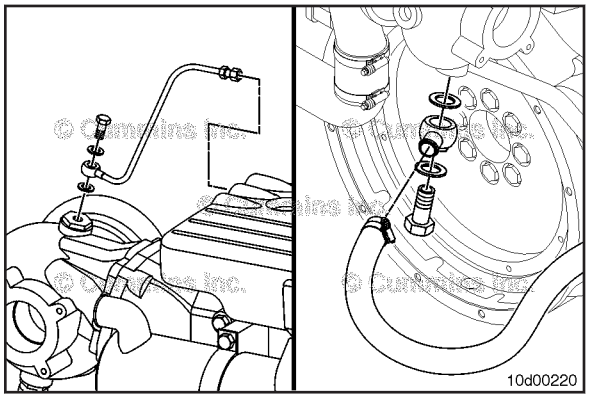
Discard the seals.



Remove the coolant vent line from the top of the turbocharger turbine housing and the coolant expansion tank.

Remove the coolant outlet line hose clamps from the turbocharger turbine housing connection and the coolant transfer tube. Remove the coolant outlet line.

Remove the hose pipe fittings from the turbocharger turbine housing and the coolant transfer tube.

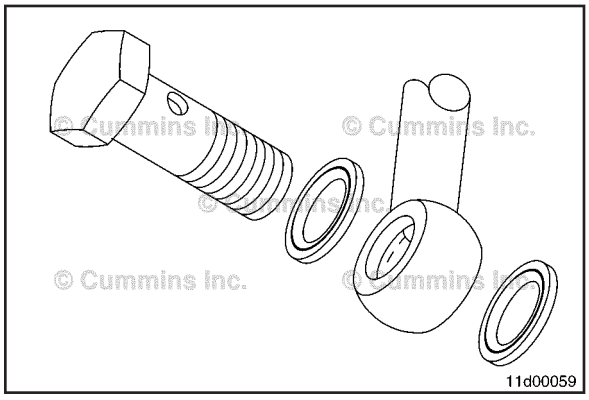


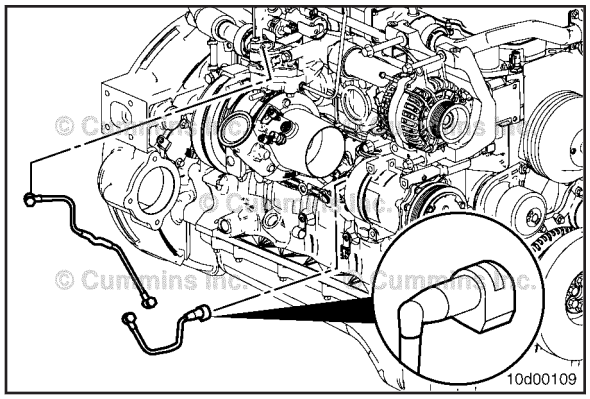
Inspect

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.





Install

NOTE: All lines and banjo screws used in the coolant plumbing have increased annulus ports. Do **not** use standard lines or banjo screws as a substitute.

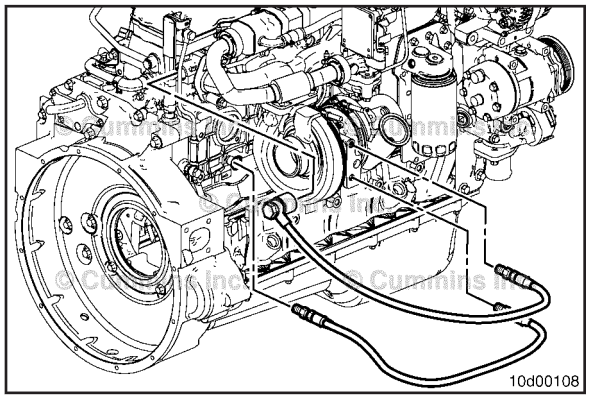
NOTE: Three of the connections are banjo fittings. The connection from the block to the turbocharger at the block location is a quick-disconnect fitting. Push the quick-disconnect fitting to install it onto the block fitting.

Attach the variable geometry actuator supply line using new seals on the banjo connection.

Install the variable geometry actuator return line using new seals on both banjo connections.

Torque Value:
10-mm banjo fittings

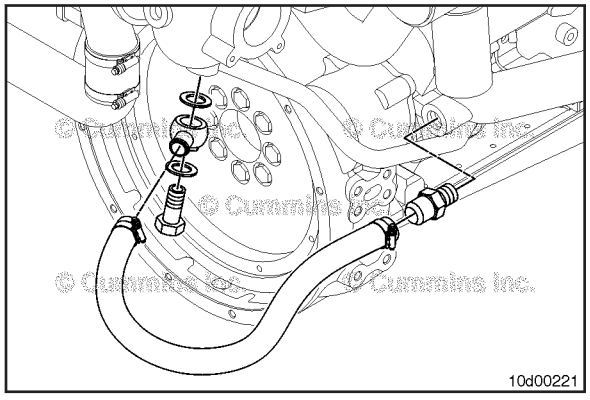
Step 1	15 N•m	[133 in-lb]



Install the supply and return lines for the variable geometry turbine housing using new seals on the banjo connections.

Torque Value:
14-mm banjo fittings

Step 1	24 N•m	[212 in-lb]



Install the pipe nipple at the end of the coolant transfer tube and the elbow at the bottom of the turbocharger turbine housing.

Torque Value: 24 N•m [212 in-lb]

Install the molded coolant drain hose to the coolant transfer tube and the bottom of the turbocharger turbine housing. Install the hose clamps and tighten.

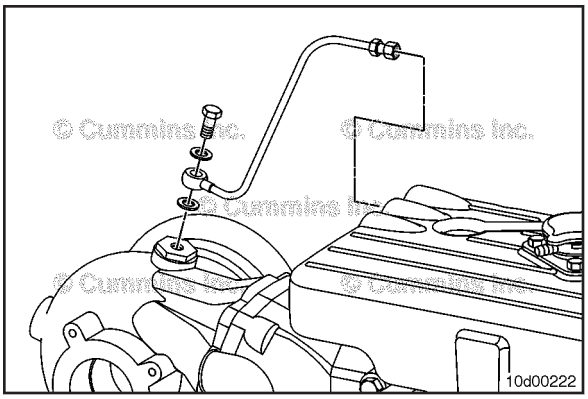
Torque Value: 8 N•m [71 in-lb]

Install the coolant vent line to the top of the turbocharger turbine housing with the banjo bolt.

Torque Value: 24 N•m [212 in-lb]

Install the coolant vent line to the rear of the coolant expansion tank and tighten.

Torque Value: 24 N•m [212 in-lb]

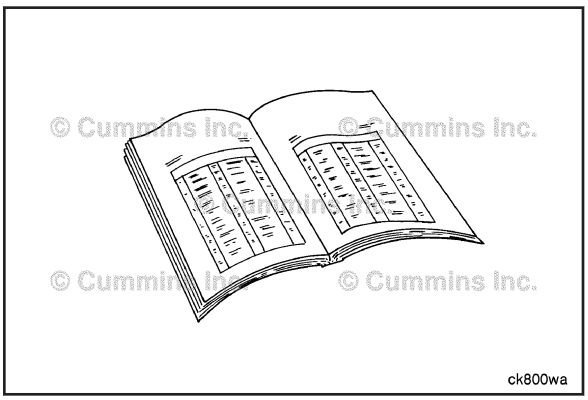


Finishing Steps

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Fill the cooling system. Refer to Procedure 008-018

Operate the engine and check for leaks.

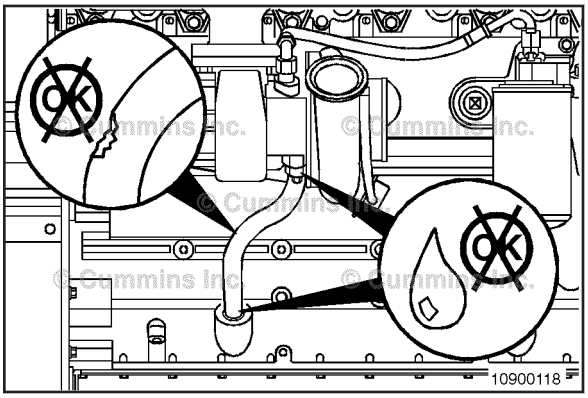


Turbocharger Oil Drain Line (010-045)

Initial Check

Inspect the line for oil leaks or damage.

Repair or replace as necessary.



Remove

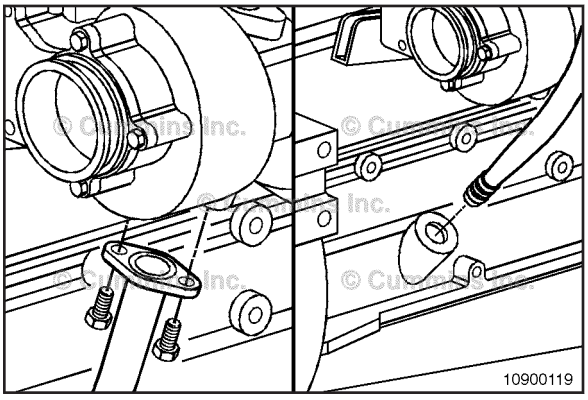
NOTE: Marine applications use a hose connection at the cylinder block end of the drain tube. An additional oil drain fitting is mounted in the cylinder block and seals with an o-ring.

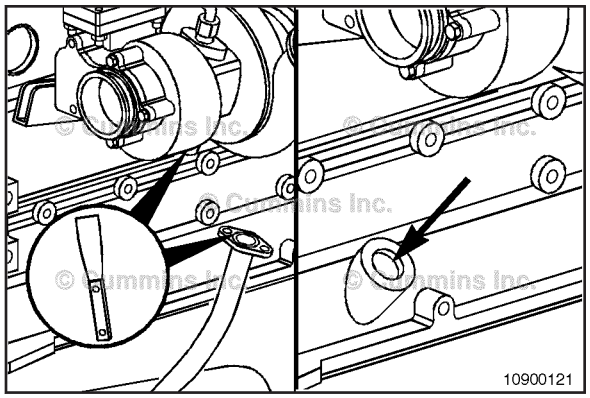
Remove the capscrews from the turbocharger oil drain tube.

Remove the hose clamps from the drain boss, if applicable.

Pull the drain line out of the drain line boss.

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

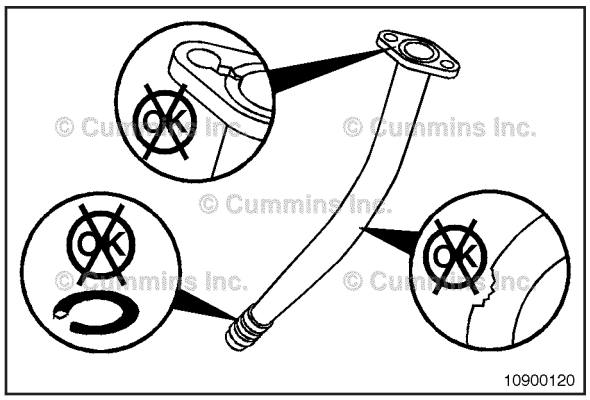




Clean and Inspect for Reuse

Clean the gasket sealing surfaces.

Clean the o-ring seating bore, and make sure it is free of dirt and debris.

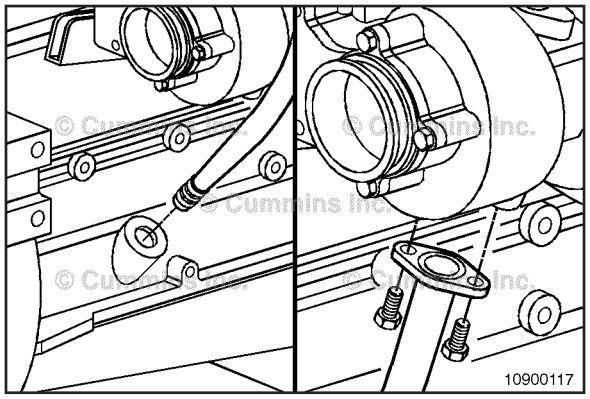


⚠CAUTION⚠
A restricted oil drain line can cause the turbocharger bearing housing to be pressurized, causing oil to leak past the seal rings, which can cause component damage.

Inspect the line for cracks, wear, and damage.

Inspect the o-ring for fretting and cracking and replace as necessary.

NOTE: An adequate supply of good filtered oil is very important to the life of the turbocharger. Be positive that high-quality oil is used and that it and the oil filter are changed according to the maintenance recommendations. See the proper Operation and Maintenance Manual for maintenance recommendations.



Install

Automotive and Industrial

Apply a thin film of oil to the drain line o-rings.

Push the drain line into the drain line boss. Make sure both o-rings are completely seated in the bore.

Install the drain line capscrews with a new gasket.

M6

Torque Value: 10 N•m [89 in-lb]

M8

Torque Value: 23 N•m [204 in-lb]

Operate the engine and check for leaks.

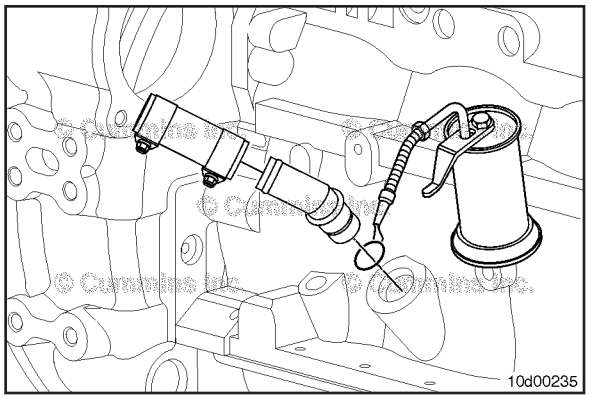
Marine Applications

Install a new o-ring on the turbocharger oil drain line connection (cylinder block end), if applicable. Apply a light film of lubricating oil to the o-ring.

Push the connection into the cylinder block until the o-ring is completely seated.

Install the hose connection over the end of the drain line connection.

Install two hose clamps over the oil drain hose.



Install the drain line into the drain line hose connection at the cylinder block.

Install the drain line and a new gasket to the bottom of the turbocharger.

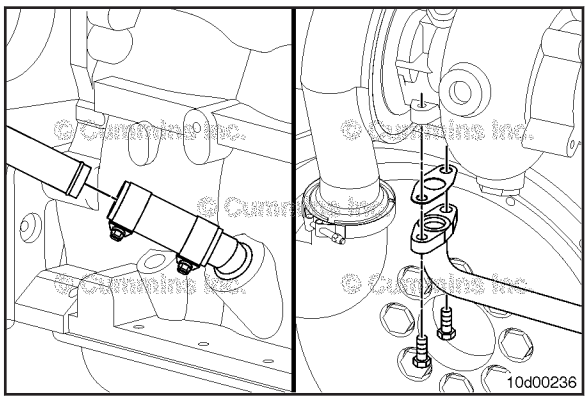
Tighten the capscrews at the bottom of the turbocharger.

Torque Value: 23 N•m [204 in-lb]

Tighten the hose clamps.

Torque Value: 8 N•m [71 in-lb]

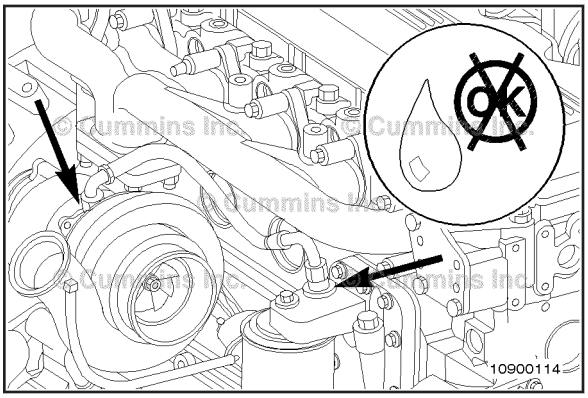
Operate the engine and check for leaks.



Turbocharger Oil Supply Line (010-046)

Initial Check

Inspect the line for oil leaks or damage. Replace as necessary.

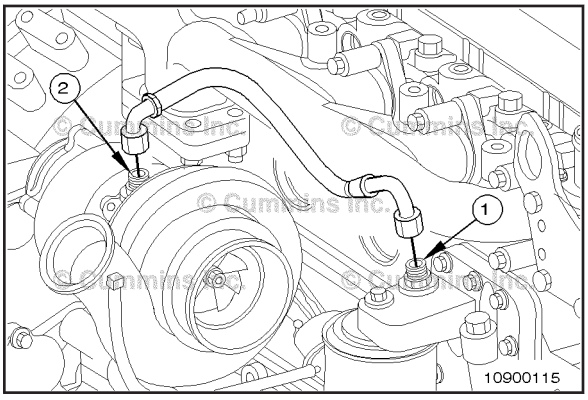


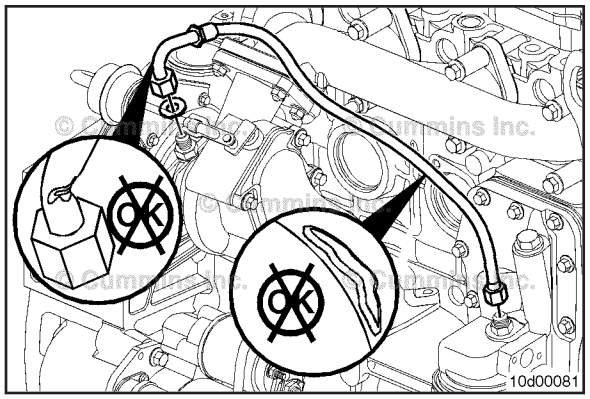
Remove

Remove the oil supply line from the oil filter head (1).

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

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



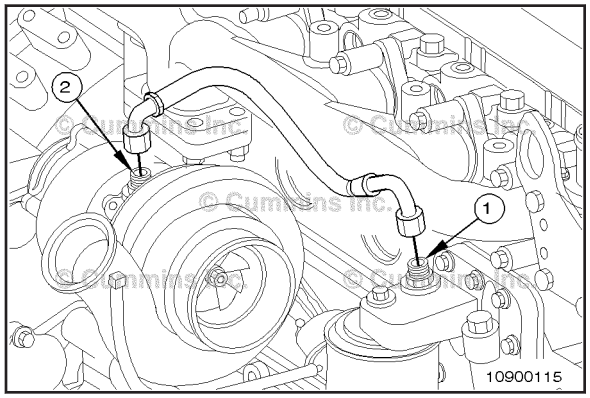


Inspect for Reuse

Inspect the line for cracks, wear, and damage.

NOTE: Some turbocharger oil supply line fittings may seal with copper sealing washers, others may seal with o-ring seals.

Discard the old copper seal washers or o-ring seals.



Install

⚠CAUTION⚠

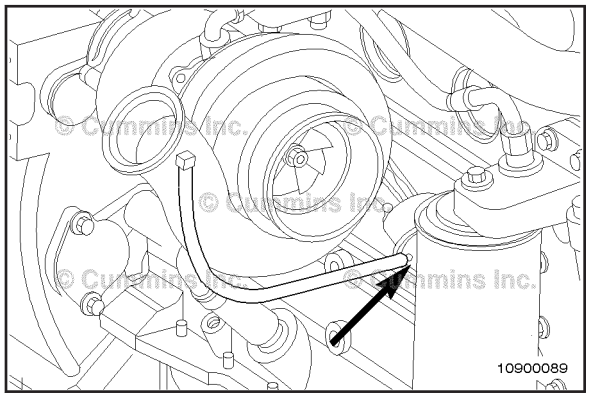
Maintain a minimum distance of 10 mm [0.39 in] between the oil supply line and the turbine housing or exhaust manifold, and 5 mm [0.20 in] between the oil supply line and other components to prevent oil line high temperature damage and chafing.

Fill the turbocharger oil inlet with clean oil.

Install the oil supply line at both the filter head and the turbocharger bearing housing. Use new copper seal washers or o-ring seals.

Tighten the oil supply line to final torque.

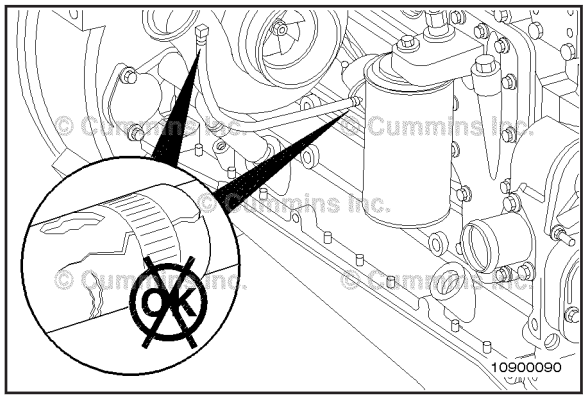
Torque Value: 28 N•m [21 ft-lb]



Turbocharger Wastegate Actuator (010-050)

Initial Check

The integral wastegate line takes boost from the turbocharger compressor outlet to the wastegate capsule.



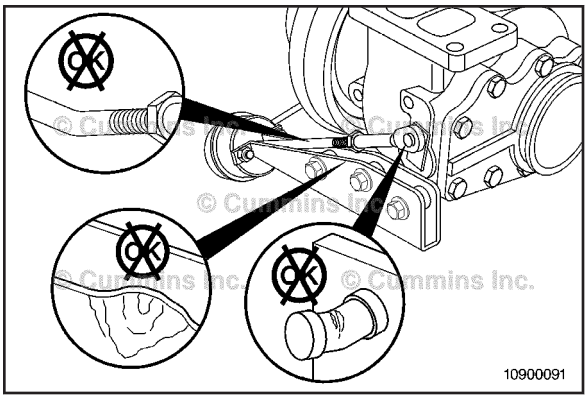
Inspect the integral wastegate actuator hose for cracks or holes.

Replace the hose if damaged.

⚠CAUTION⚠
A bent wastegate mounting bracket, actuator rod, or lever can cause improper operation.

Inspect the wastegate mounting bracket, actuator rod, and lever for damage.

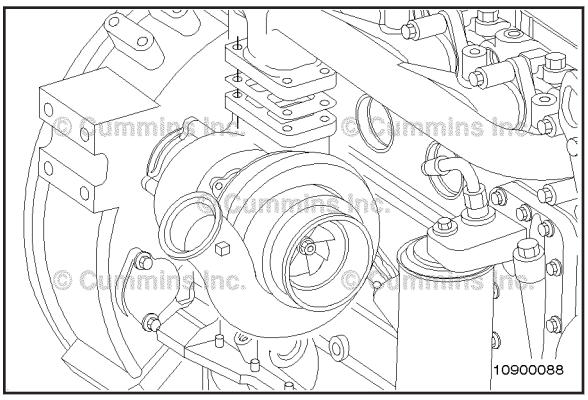
If the wastegate mounting bracket, actuator rod, or lever is bent, it **must** be replaced.



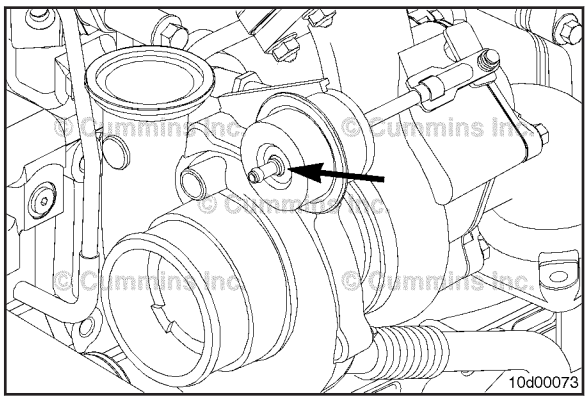
Remove

NOTE: In some applications, the turbocharger **must** be removed in order to remove the wastegate actuator. Refer to Procedure Procedure 010-033

NOTE: If a wastegate actuator leak test is to be performed, do the leak test before removal of the wastegate actuator.

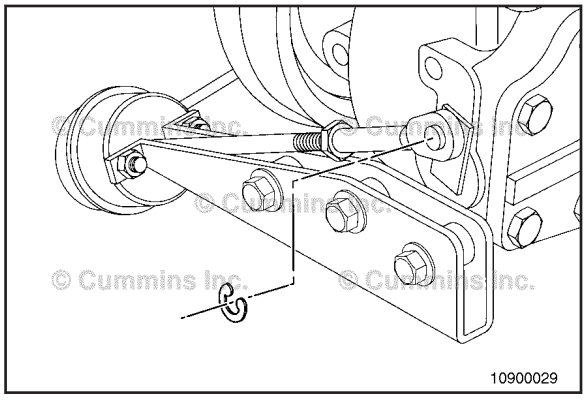


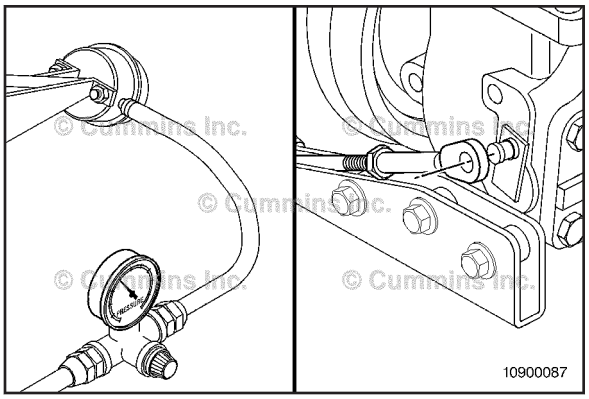
NOTE: Prior to removal, note the orientation of the boost capsule hose connector in relation to the mounting bracket.



Remove the retaining clip from the control lever.

Disconnect the integral boost line from the wastegate capsule.



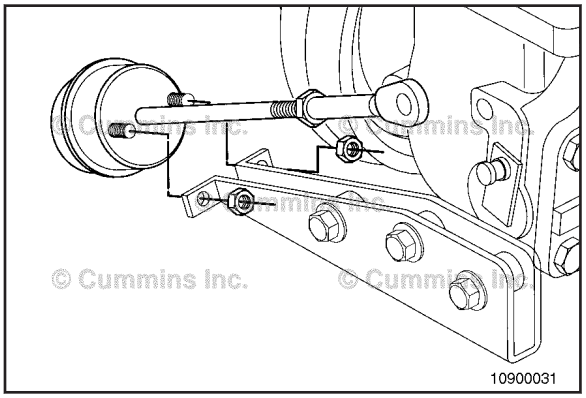


CAUTION
Be careful not to bend the control lever.

Air Regulator with Pressure Gauge Part Number 3823799

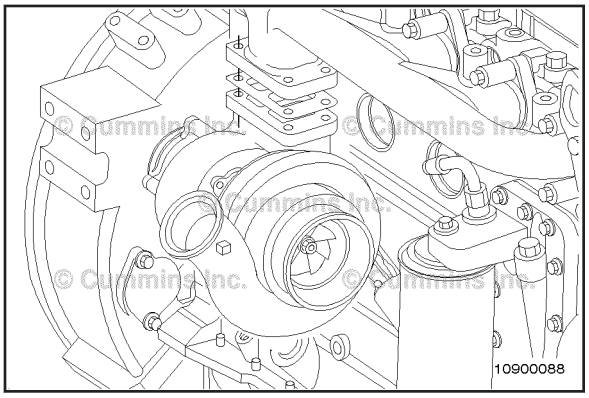
Disconnect the boost capsule actuator rod end from the turbocharger wastegate lever. This can be accomplished by slowly applying regulated air pressure to the boost capsule until the control rod is activated.

Disconnect the control rod from the turbocharger wastegate lever pin.



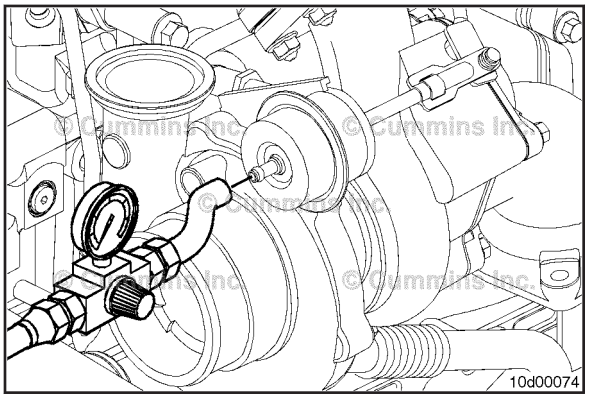
NOTE: If the boost capsule diaphragm material is ruptured and will **not** hold air pressure, manually pull the control rod outward in order to overcome boost capsule spring tension for removal of the control rod from the turbocharger wastegate lever pin.

Loosen the boost capsule mounting capscrews, disconnect the air supply hose, and remove assembly from the mounting bracket.



Leak Test

NOTE: In some applications, the turbocharger **must** be removed in order to test the wastegate actuator. Refer to Procedure Procedure 010-033



Disconnect the integral boost line from the wastegate capsule.

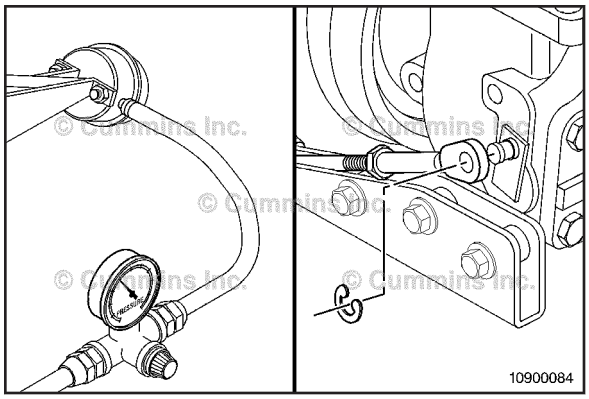
Connect clean, regulated air pressure and a pressure gauge to the capsule. Apply 200 kPa [29 psi] and check for actuator rod movement.

NOTE: No air should be heard (i.e., leaking noise) through a functional wastegate capsule.

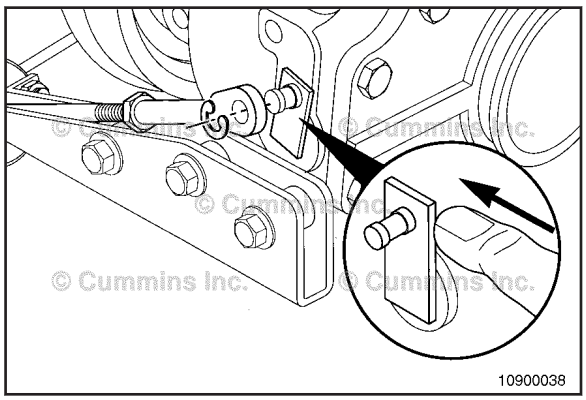
If the actuator rod shows no sign of movement, remove the actuator rod retaining clip and disconnect the actuator rod from the turbocharger wastegate pin.

Reapply air pressure to the wastegate capsule and check for actuator rod movement. If there is no movement, replace the wastegate actuator.

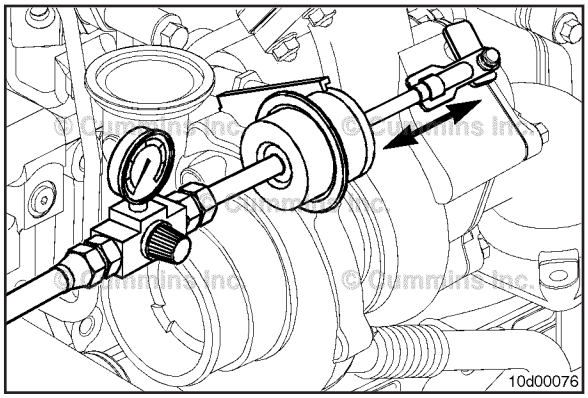
If the wastegate actuator does move, then move the wastegate lever back and forth and feel for smooth and proper operation.



If the wastegate lever does **not** move freely or binds, spray a penetrating oil on the wastegate lever joint and try to free the wastegate lever by working the lever back and forth. If the lever does **not** become free, then replace the turbocharger. Refer to Procedure Procedure 010-033

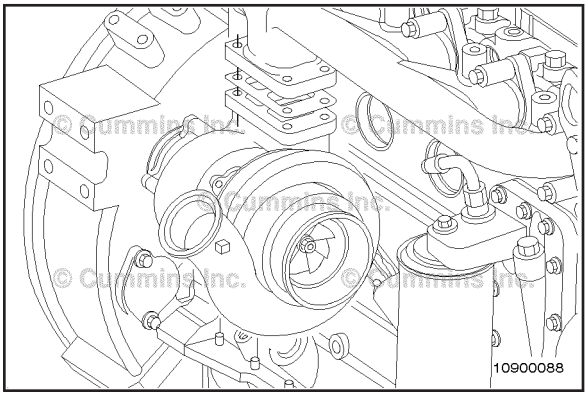


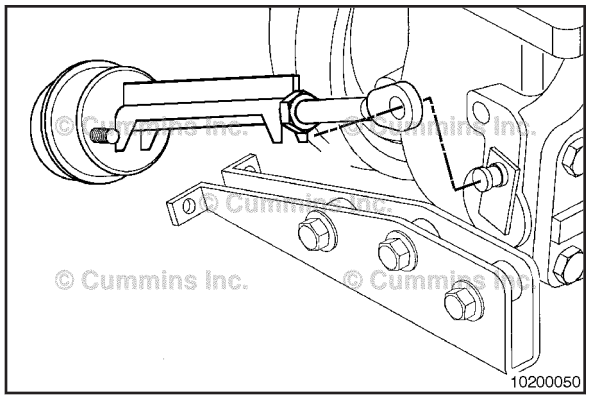
If the lever does become free and operate smoothly, then reconnect the actuator rod and recheck for movement with air pressure.



Install

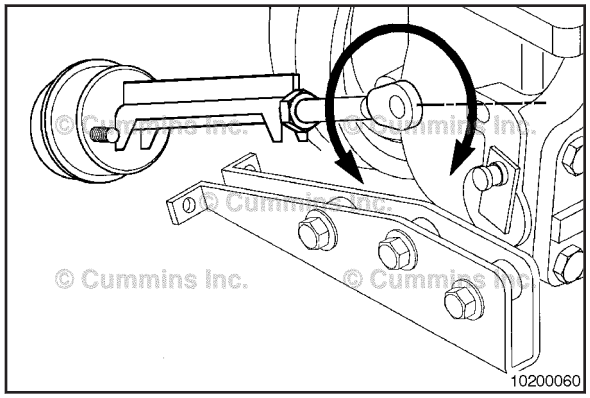
NOTE: In some applications, the turbocharger **must** be removed in order to install a new wastegate actuator. Refer to Procedure Procedure 010-033



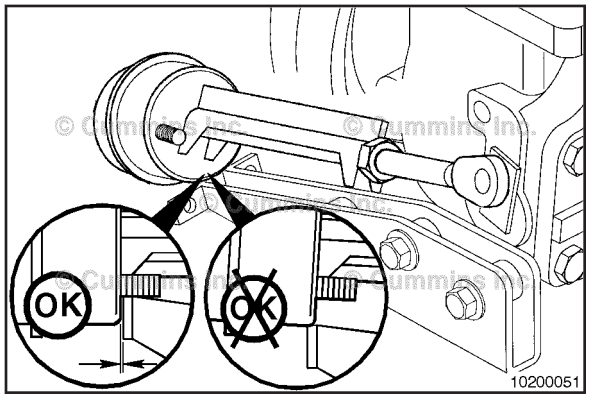


Fit the end-link over the turbocharger wastegate lever pin. With the spine of the spacer visible and the turbocharger wastegate lever pushed toward the rod, lay the actuator alongside the mounting bracket.

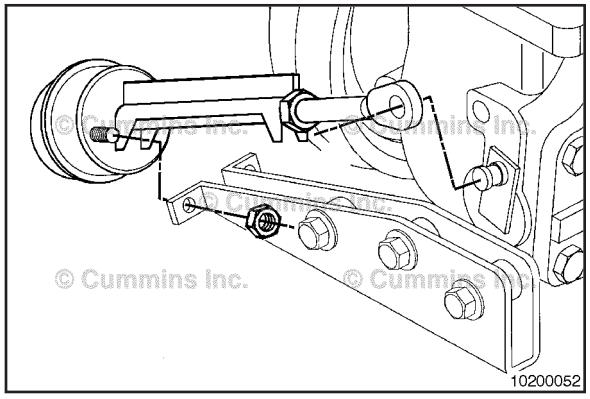
NOTE: Do **not** fit the two studs into the mounting holes at this time.



Adjust the length of the actuator assembly by removing from the turbocharger, rotating the end-link, and refitting the actuator until the underside of the actuator will just fit over the bracket mounting studs with less than 0.5-mm [0.020-in] gap.



The setting is correct when the underside of the actuator will just fit over the bracket with less than 0.5-mm [0.020-in] gap.



Fit the actuator mounting studs into the holes in the bracket.

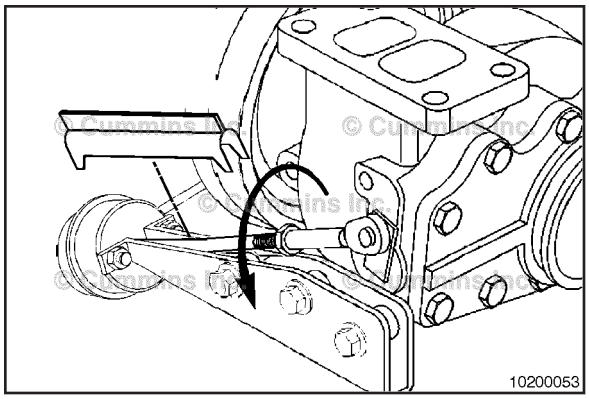
Refit the end-link onto the crank pin. Install the control rod retaining clip.

Tighten the mounting nuts to proper torque specification.

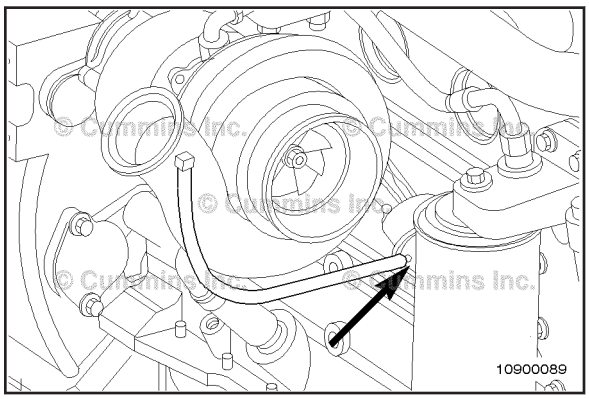
Torque Value: 8 N•m [71 in-lb]

Tighten the control rod jam nut against the end-link. Cut the tie wrap and remove tie wrap and spacer piece. Discard tie wrap. Continue turning jam nut in the same direction, and tighten against end-link.

Torque Value: 8 N•m [71 in-lb]



Refit the air supply hose to the actuator using the new hose clamp provided.

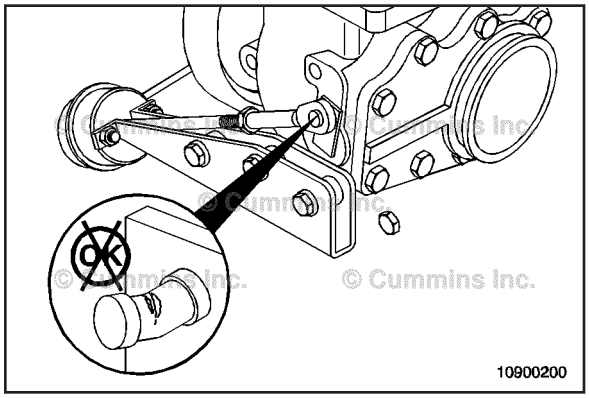


Turbocharger Wastegate Valve Body (010-055)

Maintenance Check

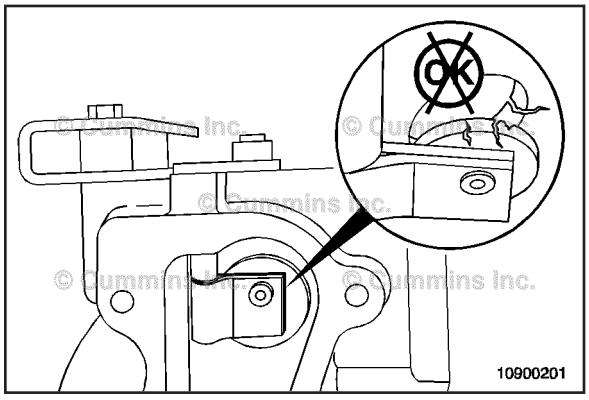
Inspect the lever pin.

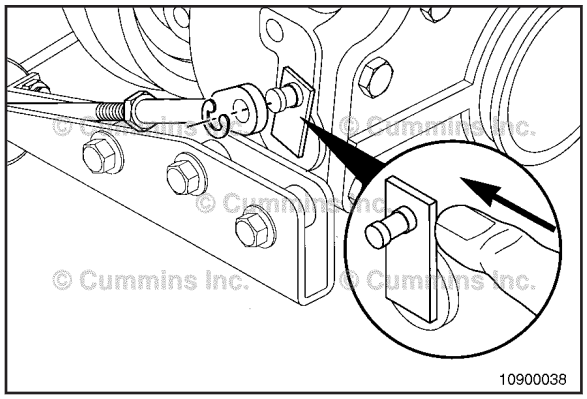
Replace the turbine housing assembly if worn excessively. Refer to the Turbocharger Master Repair Manual, Bulletin 3380555.



Inspect the valve and valve seat for cracks or erosion.

Replace the turbine housing assembly if worn excessively. Refer to the Turbocharger Master Repair Manual, Bulletin 3380555.

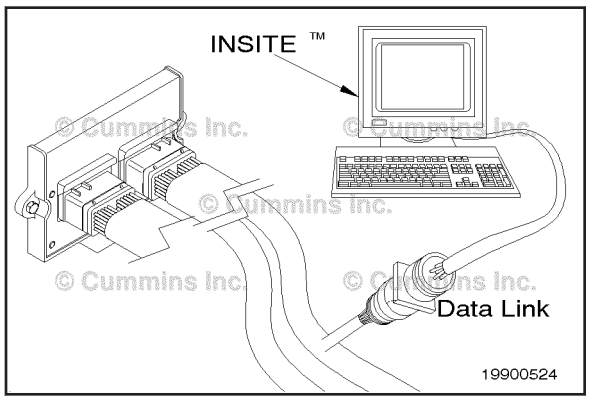




Actuate the lever by hand to verify that the shaft rotates freely and is **not** seized.

Check for excessive movement between the shaft and bushing.

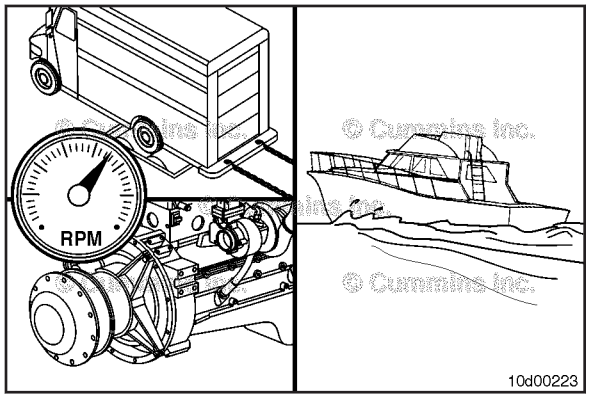
Replace the turbine housing if the shaft and bushing are damaged or seized. Refer to the Turbocharger Master Repair Manual, Bulletin 3380555.



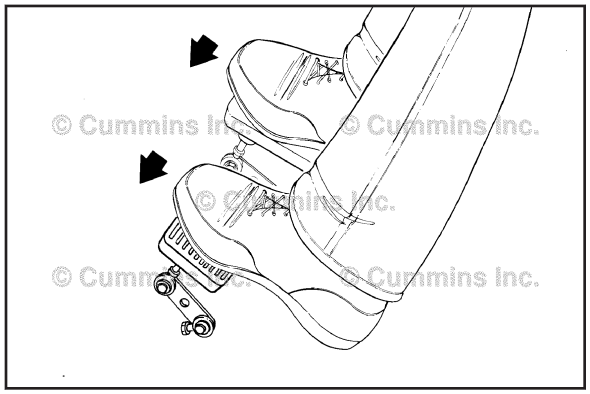
Boost Pressure (010-057)

Measure

Use INSITE™ electronic service tool to measure the boost pressure at the intake manifold.



Operate the engine at rated rpm and full load. Record the boost reading.



Alternate Loading Method (if equipped with an automatic transmission)

If a chassis dynamometer is **not** available, an alternate method of engine loading can be used. Stalling the engine, using the vehicle torque converter, can produce a full-load condition.

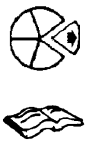
Stall the vehicle until the engine speed is steady at full-throttle condition.

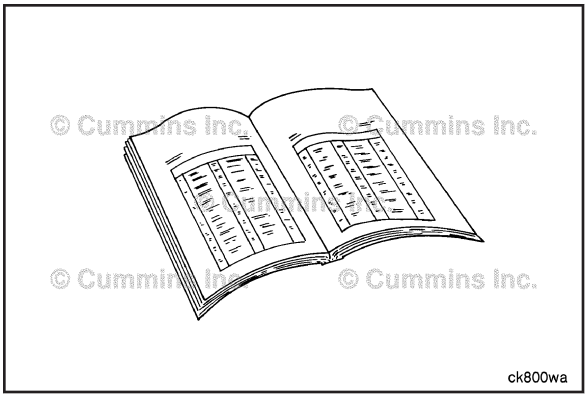
Record the stall speed and boost reading.

Air Intake Connection (010-080)

Preparatory Steps

Without EGR

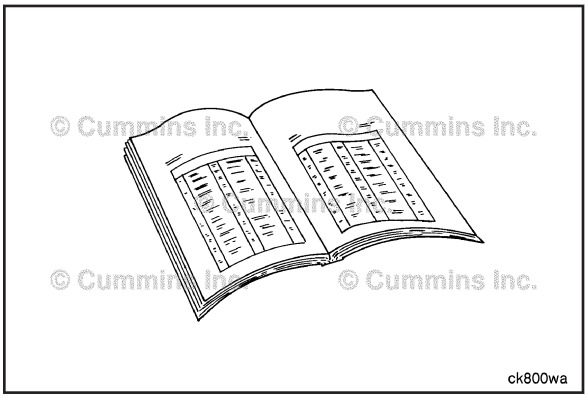




⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

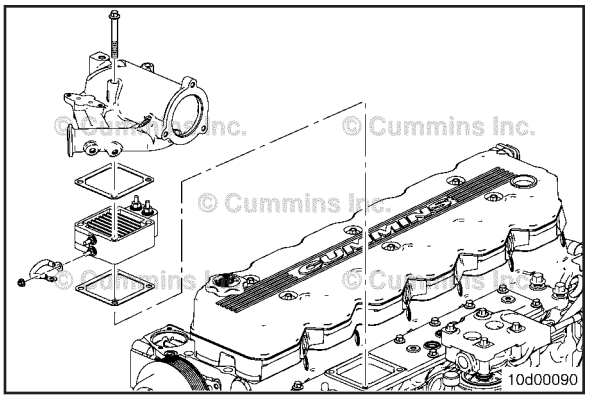
- Disconnect the batteries. Refer to OEM service manual.
- Disconnect the cold starting aid (if equipped). Refer to Procedure 010-029 in Section 10.
- Remove the charge-air piping. Refer to Procedure 010-019 in Section 10.
- Remove the air intake connection adapter (if applicable). Refer to Procedure 010-131 in Section 10.

With EGR



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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.
- Disconnect the cold starting aid (if equipped). Refer to Procedure 010-029 in Section 10.
- Remove the charge-air piping. Refer to Procedure 010-019 in Section 10.
- Remove the air intake connection adapter (if applicable). Refer to Procedure 010-131 in Section 10.
- Use the following procedure in the ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416, to remove the EGR temperature sensor. Refer to Procedure 019-378 in Section 19.
- Use the following procedure in the ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416, to remove the EGR differential pressure sensor. Refer to Procedure 019-370 in Section 19.
- Remove the EGR connection tube. Refer to Procedure 011-025 in Section 11.
- Remove the EGR mixer. Refer to Procedure 011-021 in Section 11.

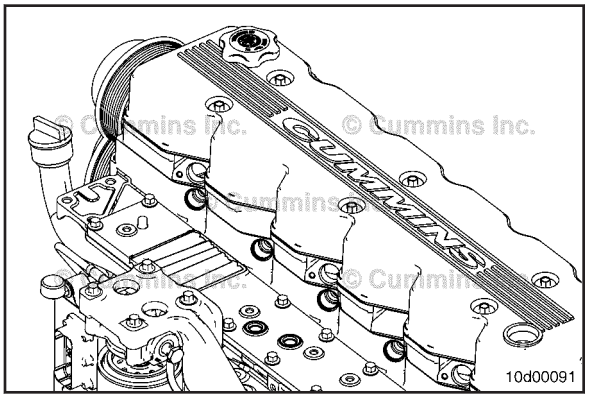


Remove

Automotive and Industrial

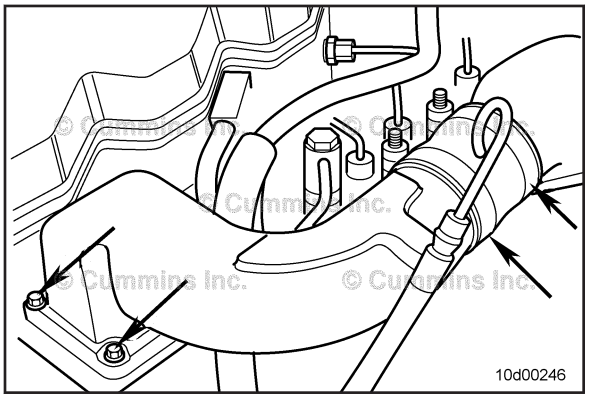
Remove the mounting capscrews, air intake connection, top gasket, cold starting aid, and bottom gasket.

NOTE: Some air intake connections may **not** have an EGR connection as shown.



NOTE: Be sure **not** to tape over all manifold edges so the mounting surfaces can be properly cleaned.

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

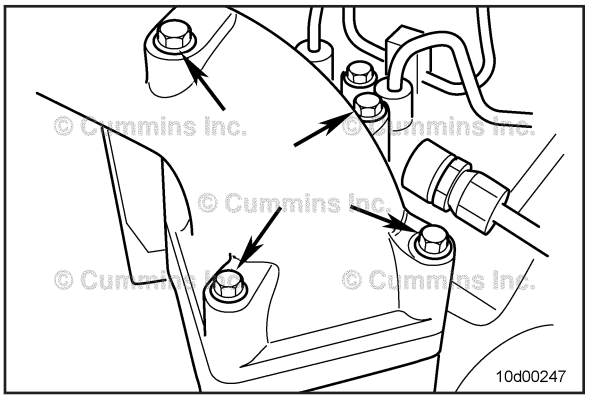


Marine Applications

Remove the four mounting capscrews at the intake manifold.

Loosen the hose clamps.

Remove the front portion of the connection.



Remove the four mounting capscrews at the aftercooler assembly.

Remove the rear portion of the connection.

Clean and Inspect for Reuse

Automotive and Industrial

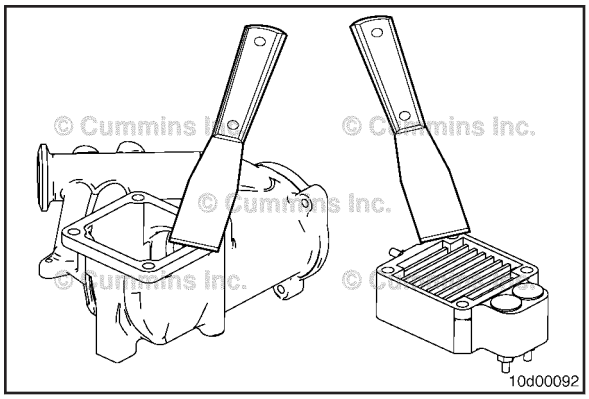
NOTE: Keep the gasket material and any other debris out of the air intake.

Remove old gasket material from the air intake connection, cold starting aid (if equipped), and intake manifold cover sealing surface.

Remove the pipe plugs from the cross-drillings.

NOTE: On engines equipped with EGR:

- The inside of the air intake connection may have a protective coating. When cleaning the intake connection, do **not** damage this coating. It protects the air intake connection from corrosion.
- A nylon brush is advised when cleaning the cross drillings and the EGR orifice. Avoid using hard wire brushes, as the EGR orifice is a very sensitive measurement device.

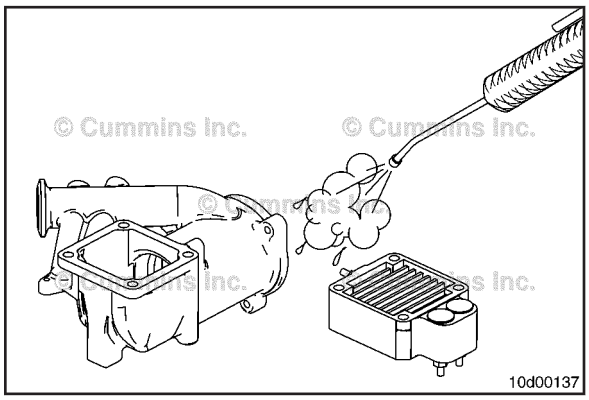


⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠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.

Saturate the inside of the air intake connection, the EGR differential pressure sensor flow ports, and cross drillings with safety solvent.

NOTE: Cleaning solvent needs to be safe for cleaning aluminum. Mineral based solvents can be used if expected results with the safety solvent are not acceptable.



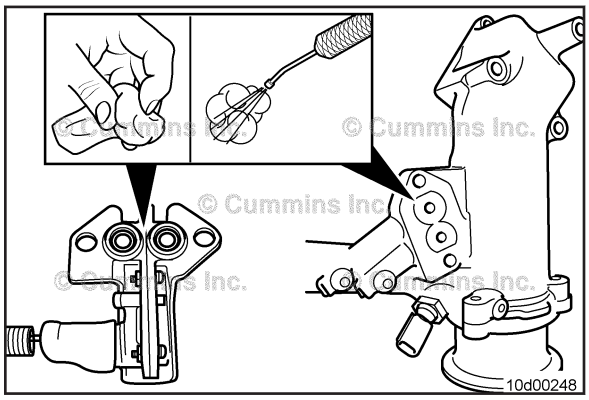
Clean out the debris in the air intake connector with a non-abrasive brush.

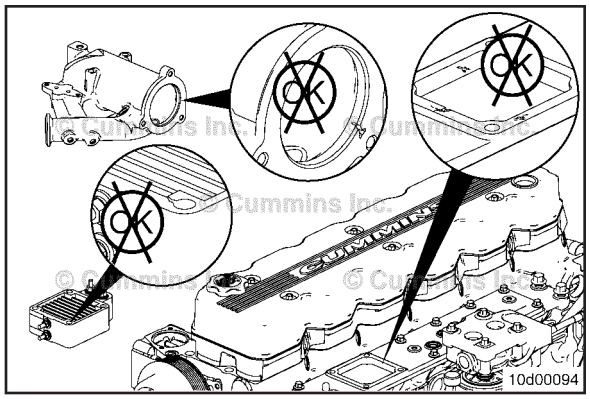
Clean the EGR differential pressure sensor flow ports and cross drillings with a pipe cleaner or similar device. Be sure to clean the ports completely prior to installing the air intake connection.

Dry the air intake connection, EGR differential pressure sensor flow port, and cross drillings with compressed air.

Install the pipe plugs in cross drillings. Use thread sealant to prevent any leaks.

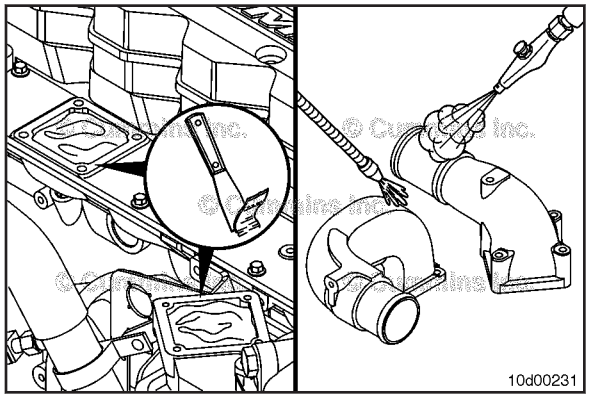
NOTE: On engines equipped with EGR, it is **not** uncommon to have a layer of soot and carbon buildup on the intake connection inner surfaces.





Remove the tape or rag from the intake manifold. Inspect the intake manifold cover, cold starting aid, and air intake connection sealing surfaces for cracks or other damage.

NOTE: Some air intake connections may **not** have an EGR connection as shown.



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.

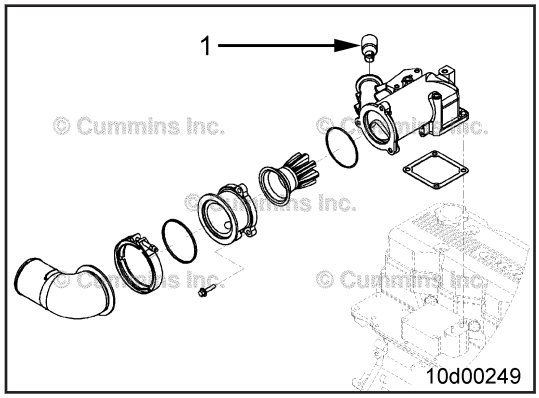
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

NOTE: Use a rag inside the intake manifold and the aftercooler assembly to prevent gasket material from entering the engine while scraping off the gasket material.

Clean the gasket surfaces of the aftercooler and intake manifold.

Clean the connections with solvent. Dry with compressed air. Inspect the two air inlet connections for nicks, burrs, or other damage.

Inspect the hose connection for damage or cuts. Replace if necessary.



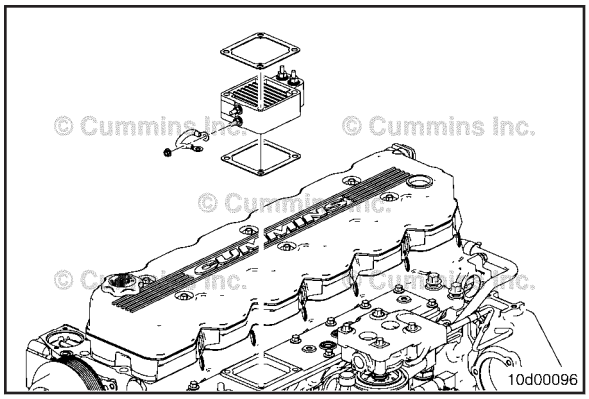
Install

Automotive and Industrial

INITIAL CHECK: If replacing the air intake connection on engines equipped with EGR, check to make sure the EGR measurement venturi (1) is properly installed.

NOTE: The EGR measurement venturi (1) is a non-serviceable part. The air intake connection **must** be purchased with the EGR measurement venturi pre-installed.

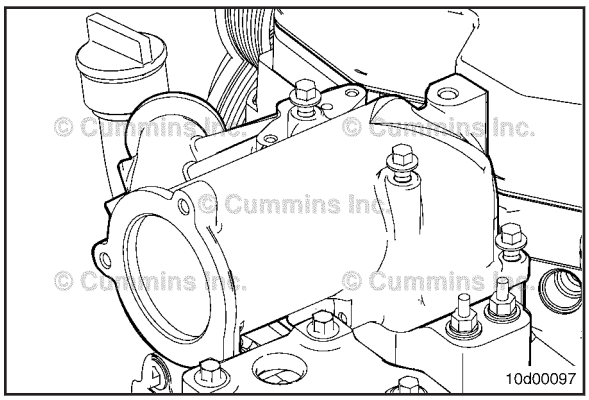
Position the cold starting aid (if equipped) using new gaskets. Refer to Procedure 010-029 in Section 10.



Install the air intake connection and four mounting screws.

If the engine is equipped with EGR, leave the four capscrews loose at this point. This will help minimize assembly stress on the attaching EGR connection tube to be installed next.

If the engine is **not** equipped with EGR, go to the step referencing tightening the four capscrews.

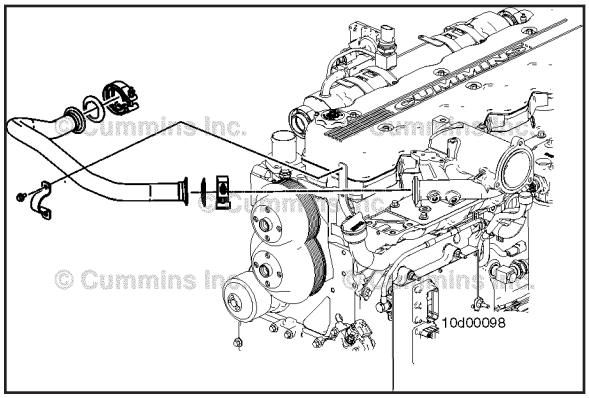


If the engine is equipped with EGR, position the air intake connection so that the Marmon™ flange meets the tube flare connection correctly.

Install the EGR connection tube. Refer to Procedure 011-025 in Section 11.

Tighten the V-band clamps.

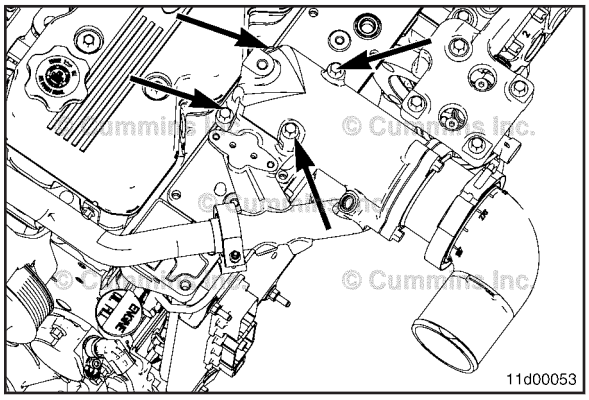
Torque Value: 11 N•m [97 in-lb]

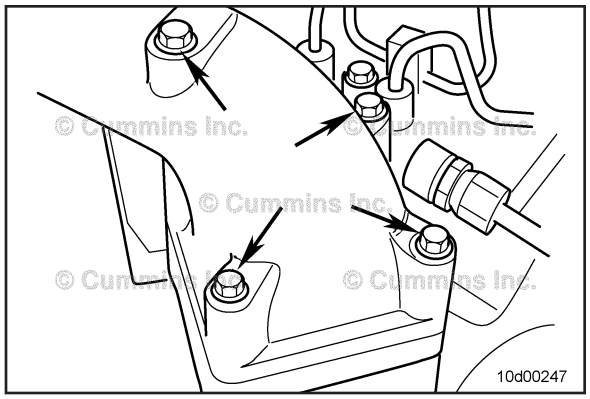


Tighten the four capscrews on the air intake connection.

Torque Value: 24 N•m [212 in-lb]

NOTE: Some air intake connections may **not** have an EGR connection as shown.



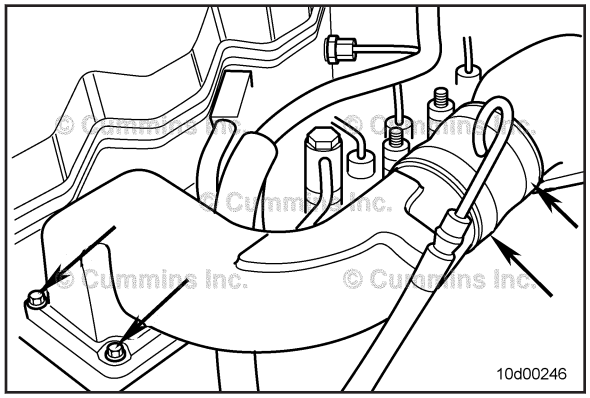


Marine Applications

Install the rear connection on the aftercooler assembly with a new gasket and the four mounting capscrews.

Tighten the capscrews.

Torque Value: 15 N•m [133 in-lb]



Install the front portion of the air intake connection and the four capscrews.

Tighten the capscrews.

Torque Value: 15 N•m [133 in-lb]

Tighten the hose clamps.

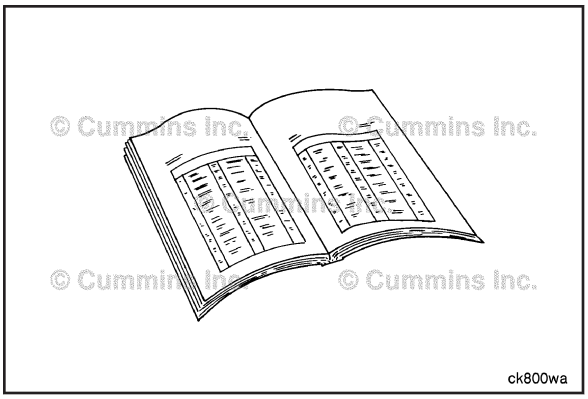
Torque Value: 8 N•m [71 in-lb]

Finishing Steps

With EGR

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

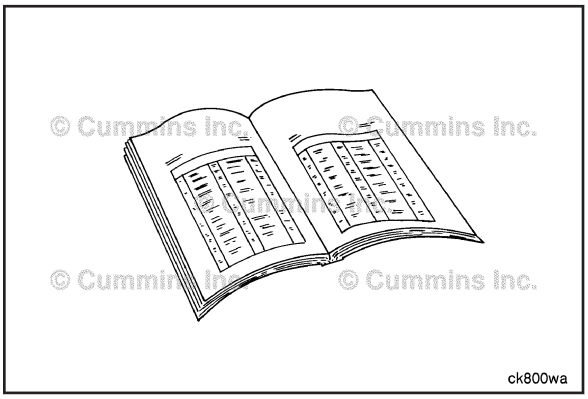
- Install the EGR mixer. Refer to Procedure 011-021 in Section 11.
- Install the EGR connection tube. Refer to Procedure 011-025 in Section 11.
- Use the following procedure in the ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416, to install the EGR differential pressure sensor. Refer to Procedure 019-370 in Section 19.
- Use the following procedure in the ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416, to install the EGR temperature sensor. Refer to Procedure 019-378 in Section 19.
- Install the air intake connection adapter (if applicable). Refer to Procedure 010-131 in Section 10.
- Install the charge-air piping. Refer to Procedure 010-019 in Section 10.
- Connect the cold starting aid (if equipped). Refer to Procedure 010-029 in Section 10.
- Connect the batteries. Refer to the OEM service manual
- Operate the engine and check for leaks.



Without EGR

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

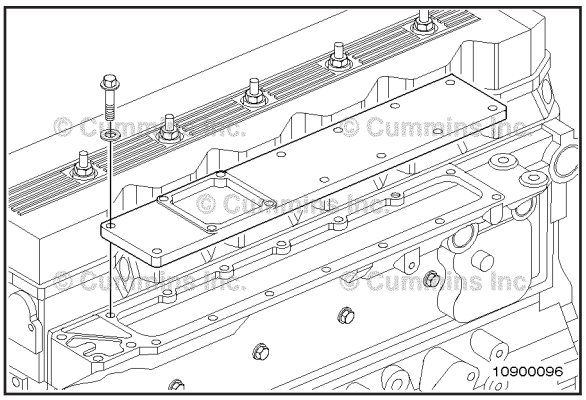
- Install the air intake connection adapter (if applicable). Refer to Procedure 010-131 in Section 10.
- Install the charge-air piping. Refer to Procedure 010-019 in Section 10.
- Connect the cold starting aid (if equipped). Refer to Procedure 010-029 in Section 10.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Air Intake Manifold Cover (010-108)

Preparatory Steps

- Remove the air intake connection. Refer to Procedure 010-080
- Remove the injector supply lines. Refer to Procedure 006-051
- Remove the fuel rail. Refer to Procedure 006-060

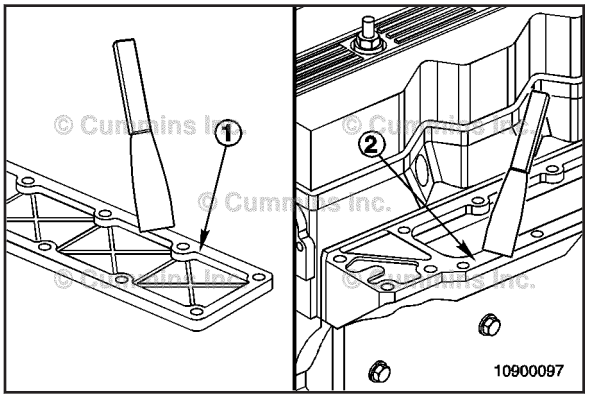


Remove

Remove the mounting capscrews and the intake cover.

Tape off the intake manifold opening to prevent debris from entering the intake system.

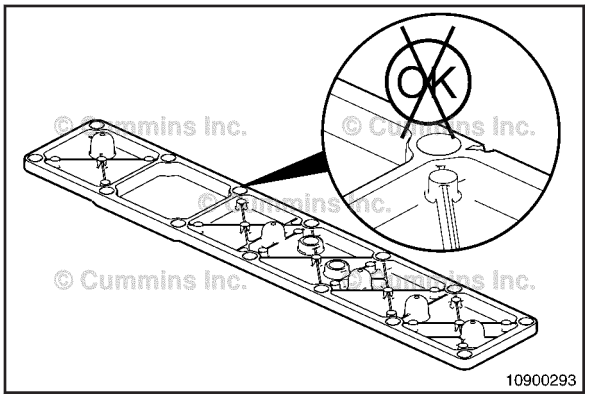
NOTE: Be sure **not** to tape over all manifold edges so that the surface can be cleaned.



Clean and Inspect for Reuse

NOTE: Keep the gasket material and any other material out of the air intake.

Clean the sealing surfaces (1 and 2) with a putty knife and a clean rag.

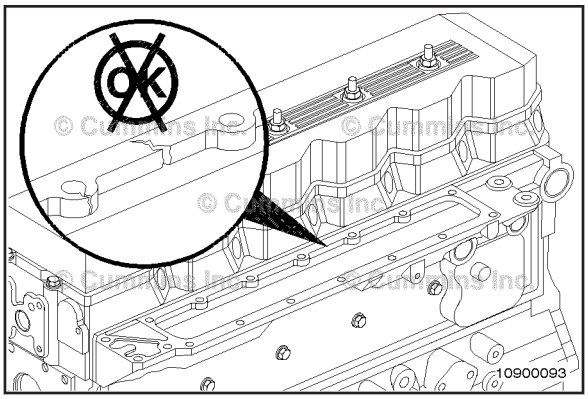


Inspect the intake manifold cover for cracks or other damage.

Remove the tape.

Inspect the intake manifold for cracks or other damage.

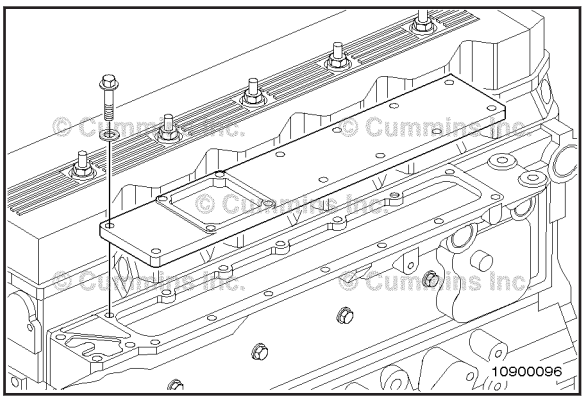
NOTE: When inspecting the intake manifold for oil or debris from an air system failure, also inspect the cylinder head for oil and debris.



Install

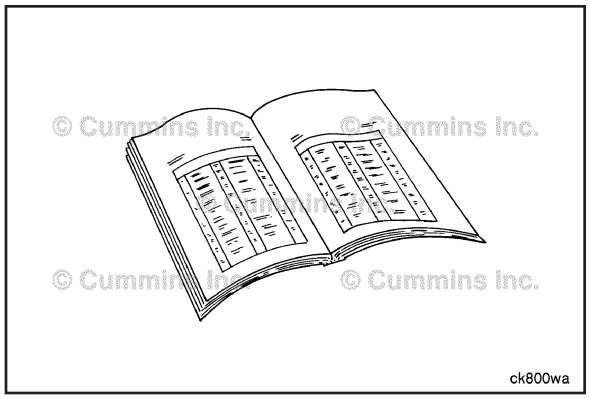
Install the cover and new gasket.

Torque Value: 24 N•m [212 in-lb]



Finishing Steps

- Install the air intake connection. Refer to Procedure 010-080
- Install the injector supply lines. Refer to Procedure 006-051
- Install the fuel rail. Refer to Procedure 006-060



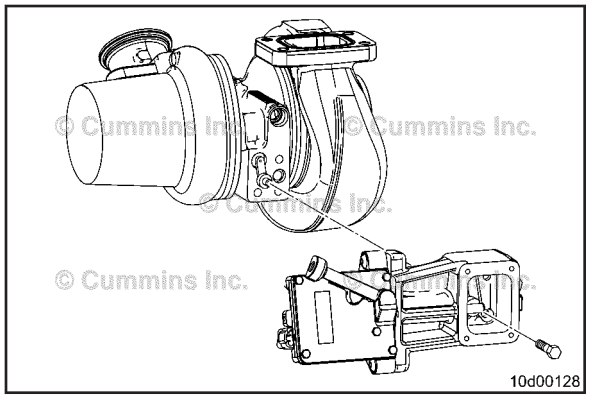
Variable Geometry Turbo Actuator (010-113)

Preparatory Steps

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Remove, drain, or disconnect the following:

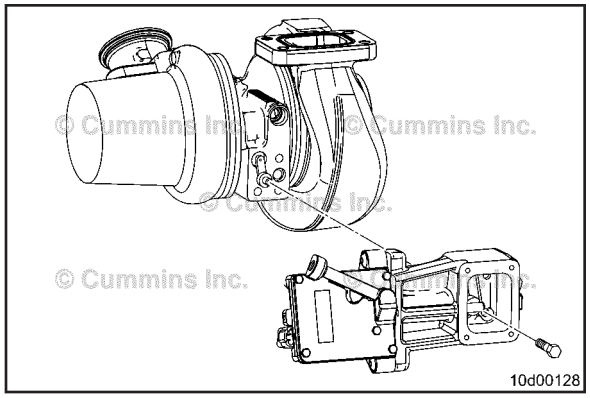
- Variable geometry turbocharger if necessary to access and service the actuator. Refer to Procedure 010-033
- Coolant. Refer to Procedure 008-018
- Electrical connections from actuator.
- Actuator coolant lines.
- Four capscrews from the dust cover plate, and the cover gasket.
- Three capscrews, actuator assembly, and pivot block.



Remove

Remove the three capscrews that attach the actuator housing to the turbocharger.

Remove the actuator assembly and pivot block.



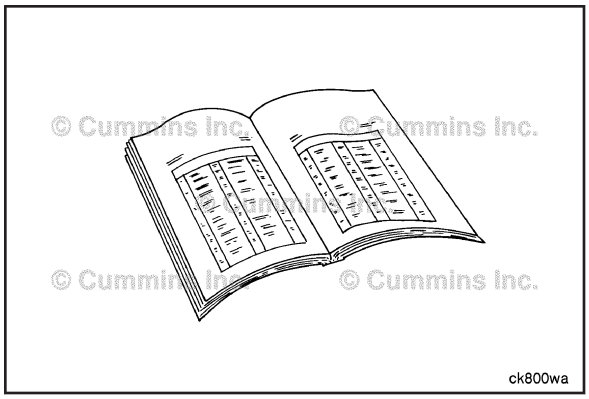
Install

Install a new pivot block and position the actuator on the turbocharger.

Install the three mounting capscrews.

Torque Value: 17 N•m [150 in-lb]

Finishing Steps



⚠CAUTION⚠
The position sensor pins can be bent if the engine harness connector is mated to the sensor connector at an angle. Therefore, the engine harness connector must be inserted straight into the position sensor connector to avoid damaging the pins. Bent pins will result in poor engine performance and intermittent fault codes.

Install, connect, and fill the following.

- Four new capscrews, the dust cover plate, and a new gasket.
- Transfer the turbocharger dataplate information to new datatag.
- Actuator coolant lines.
- Electrical connections to the actuator.
- Cooling system. Refer to Procedure 008-018
- Clear any fault codes.

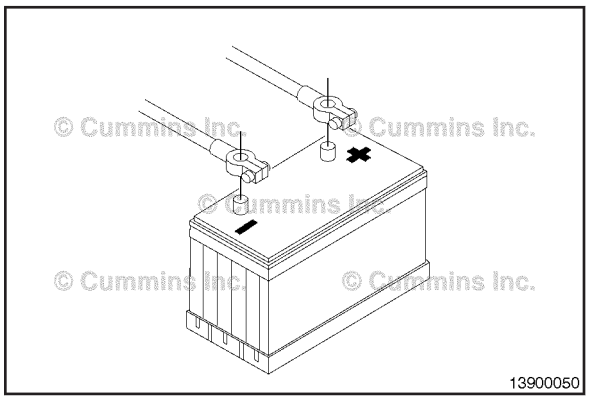
Air Intake Connection Adapter (010-131)

General Information

The air intake connection adapter refers to the part of the air intake system upstream of the air intake connection. This procedure does **not** apply to all engines because some engines do **not** have an air intake connection adapter which is serviceable.

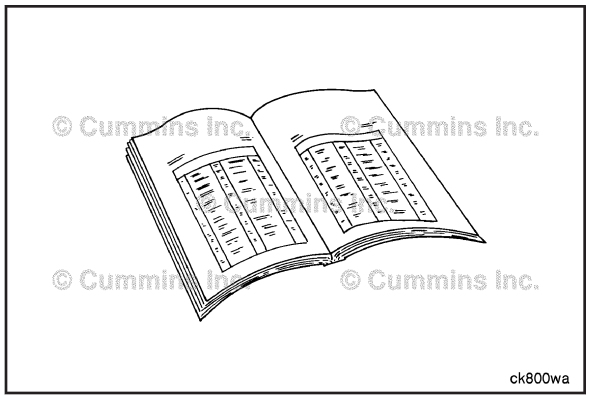
There are two styles of air intake connection adapters used on ISB engines. One style uses a single piece air intake connection adapter, the other style uses a two piece air intake connection adapter.

Preparatory Steps

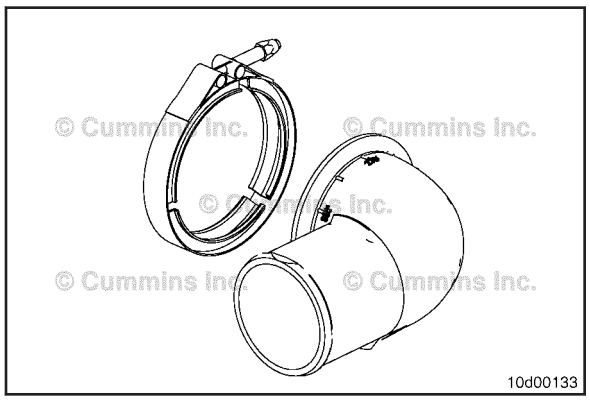


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Disconnect the batteries.

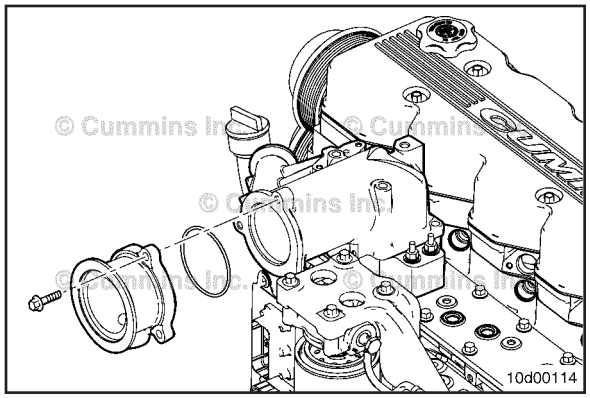


Remove the charge air piping between the air intake connection adapter and the outlet of the charge air cooler. Refer to Procedure Procedure 010-019



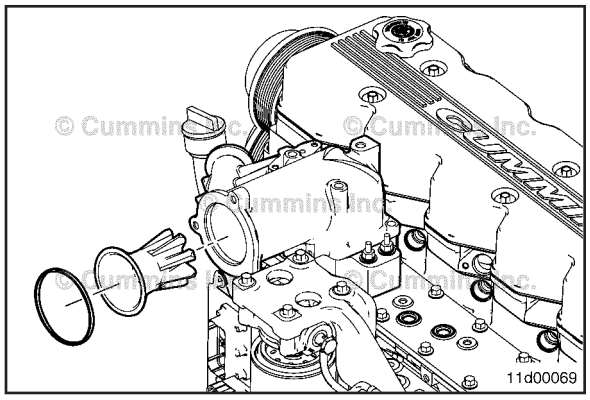
Remove

Remove the v-band clamp, the elbow piece of the air intake connection adapter, and the seal.



Remove the three capscrews that hold the straight piece of the air intake connection adapter to the air intake connection, and remove the seal.

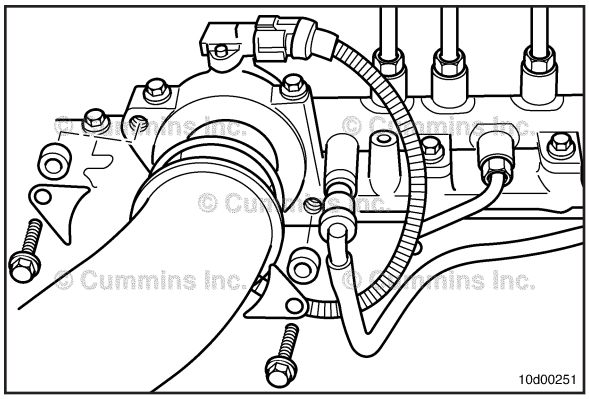
NOTE: On engines equipped with air compressors, remove the air compressor intake line from the adapter.



Service Tip: On engines equipped with EGR, the air intake connection adapter holds the EGR mixer in place.

Remove the v-band clamp, seal, and air intake connection adapter.

Remove the air compressor intake line from the adapter (if applicable).



Clean and Inspect for Reuse

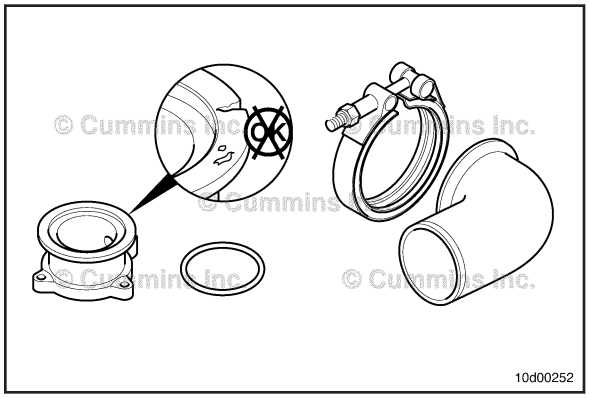
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

Clean the air intake connection adapter with solvent and dry with compressed air.

Inspect the air intake connection adapter, seal, and clamps for damage, cuts, cracks, holes, or worn sections.

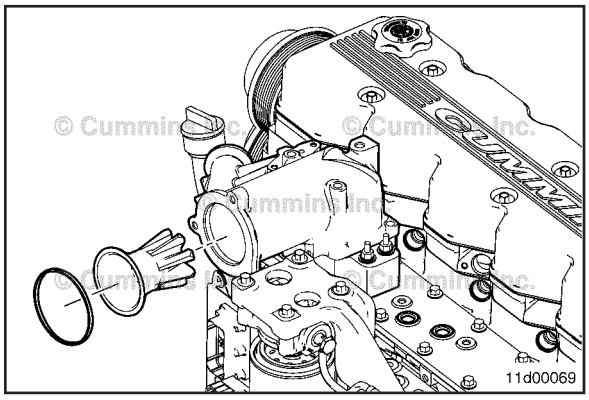
Replace components if necessary.

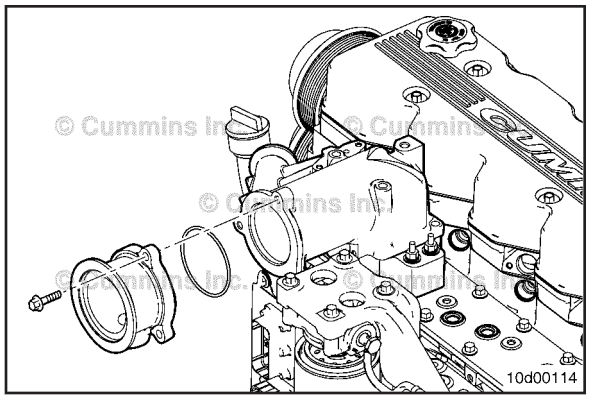


Install

Install the air intake connection adapter straight piece and seal to the air intake connection.

Service Tip: If the EGR mixer was removed, make sure it is installed before tightening the capscrews.



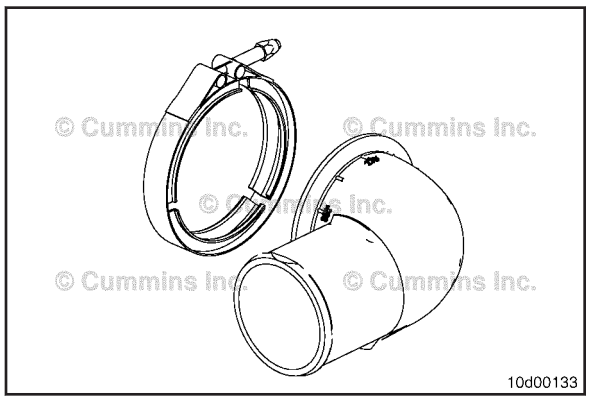


Tighten the three capscrews.

Torque Value: 24 N•m [212 in-lb]

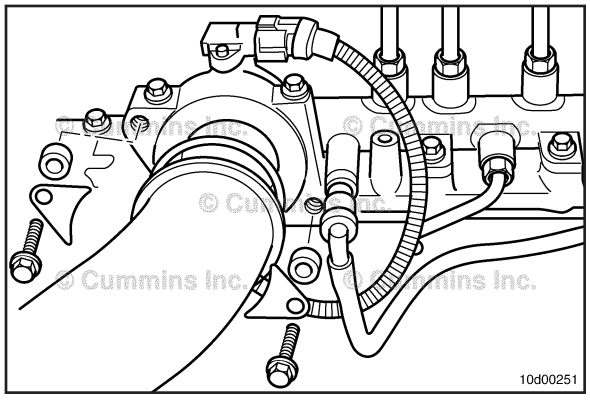
Install the air compressor intake line from the adapter (if applicable).

Install the seal, air intake connection adapter elbow, and V-band clamp.



Tighten the V-band clamp.

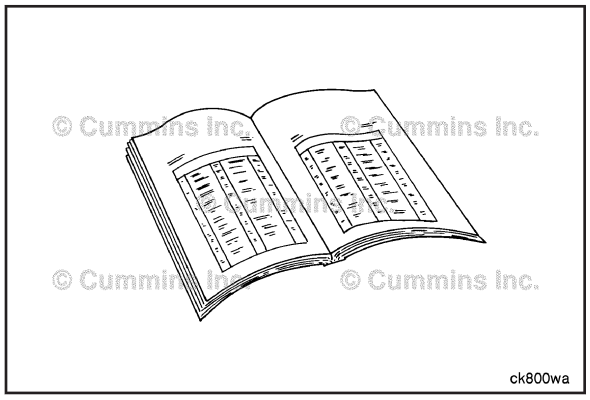
Torque Value: 8 N•m [71 in-lb]



Install the seal, air intake connection adapter, and v-band clamp.

Tighten the v-band clamp.

Torque Value: 10 N•m [89 in-lb]



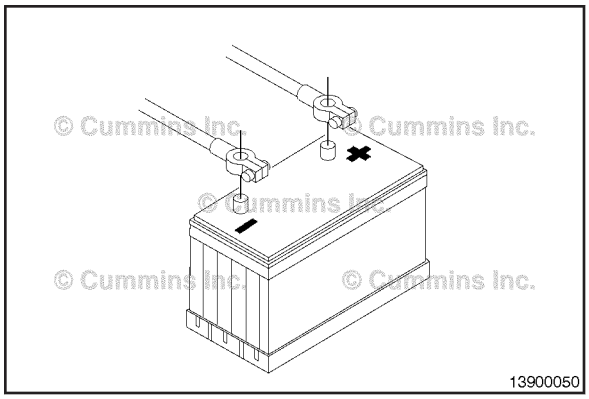
Finishing Steps

Install the charge air piping between the air intake connection adapter and the outlet of the charge air cooler. Refer to Procedure Procedure 010-019

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

Operate engine and check for leaks.



Turbocharger Compressor Outlet Connection (010-132)

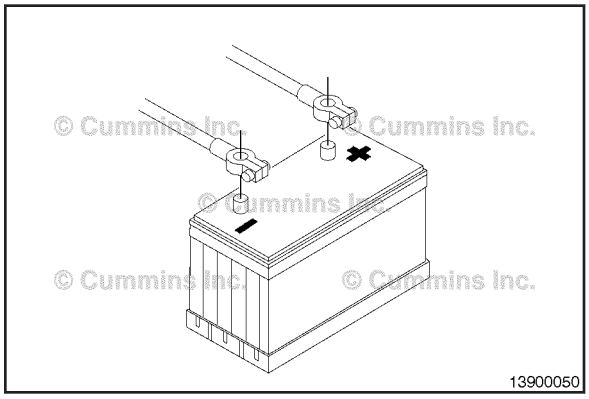
General Information

This procedure includes instructions on removal, cleaning/inspection, and installation of the turbocharger compressor outlet connection. There are many different styles of outlet connection on the ISB/QSB/ISB^{e} series engines, and the pictures contained in this procedure may **not** exactly represent the actual hardware on the engine being serviced. However, the procedures for removal, cleaning/inspection, and installation of each different turbocharger compressor outlet connection are identical.

Preparatory Steps

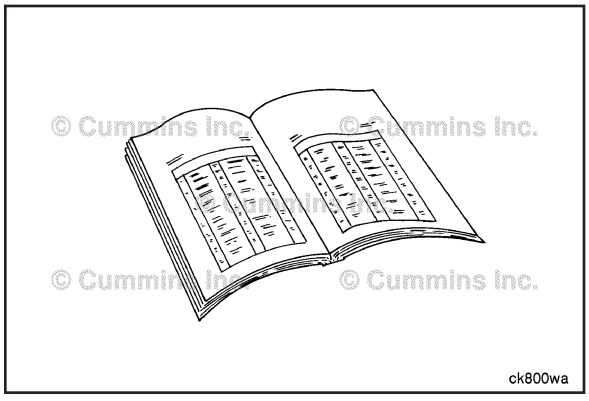
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

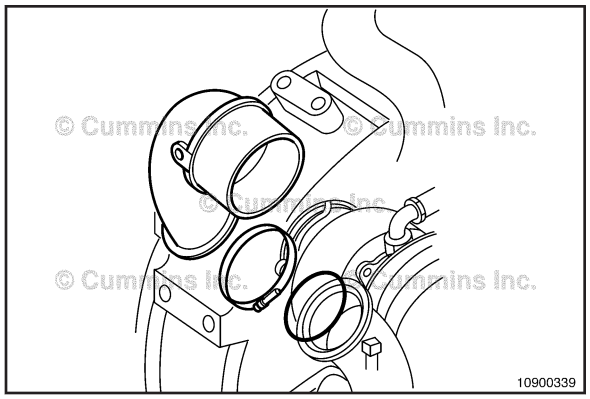
Disconnect the batteries.



Clean the outside of the turbocharger compressor outlet connection with a clean cloth, making sure to remove any dirt which could fall into the intake when the charge air piping is removed.

Disconnect the charge air piping and connections from the turbocharger compressor outlet connection. Refer to Procedure Procedure 010-019

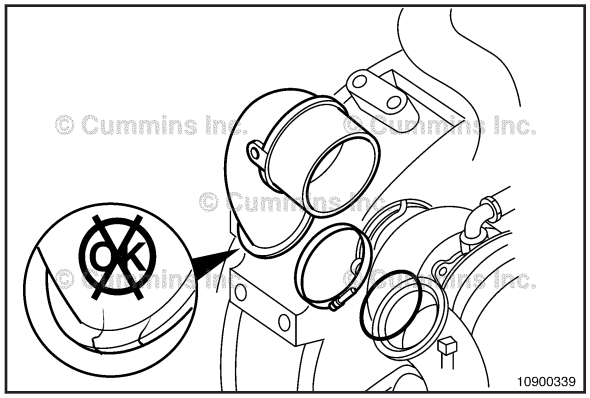




Remove

Loosen the clamp holding the turbocharger compressor outlet connection to the turbocharger.

Remove the turbocharger compressor outlet connection and seal, taking care **not** to drop the seal or any foreign matter into the turbocharger.



Clean and Inspect for Reuse

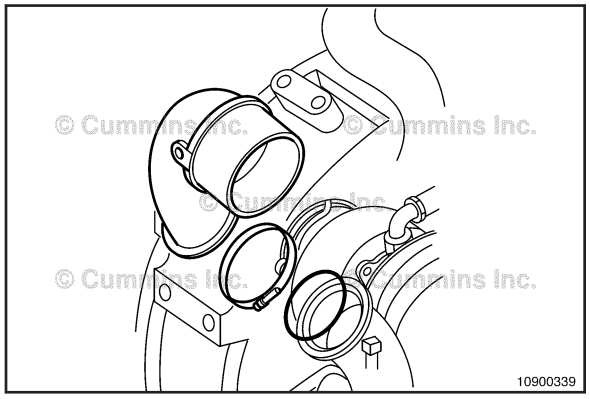
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠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.

Clean the turbocharger compressor outlet connection with solvent and dry with compressed air.

Inspect the turbocharger compressor outlet connection for cracks, damage, or abnormal wear. Replace as necessary.

Discard the o-ring seal, it is **not** re-useable.



Install

Install the turbocharger compressor outlet connection and o-ring seal.

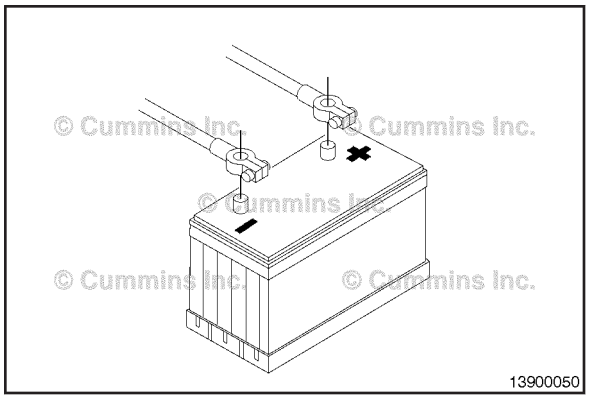
Use a new o-ring seal.

Install the clamp and tighten to specification:

Torque Value: 10 N•m [89 in-lb]

Finishing Steps

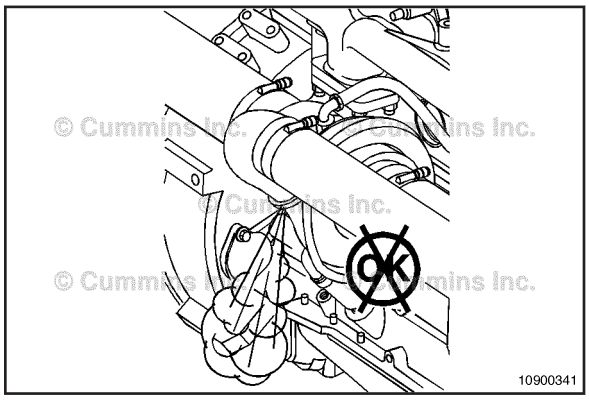
Reconnect the charge air piping to the turbocharger compressor outlet connection. Refer to Procedure Procedure 010-019. Refer to the OEM manual for the torque specification on the clamp.



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

Reconnect the batteries.

Operate the engine at rated speed, using soapy water to check for leaks at the turbocharger compressor outlet connection joints.



Notes

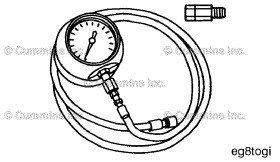
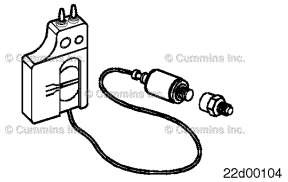
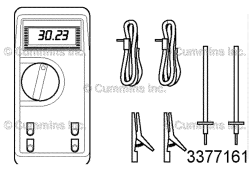
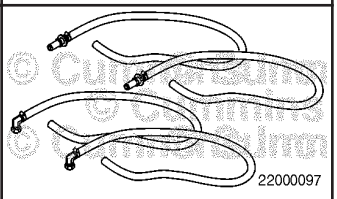
Section 11 - Exhaust System - Group 11

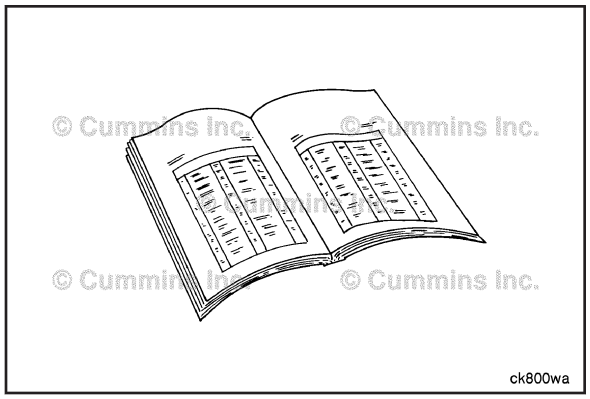
Section Contents

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-1273	**Pressure Gauge** Used to measure exhaust restriction.	
3164491	**Pressure/Vacuum Module** Used to measure pressure and vacuum. Use with digital multimeter, Part Number 3164488 or 3164489.	
3164488 or 3164489	**Digital Multimeter** Used to measure electrical circuits: Voltage (volts), resistance (ohms), and current (amps). Standard meter, Part Number 3164488, Automotive meter with built in temperature adapter and tachometer, Part Number 3164489.	
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.	



Exhaust Manifold, Dry (011-007)

Preparatory Steps

Without EGR

Disconnect the turbocharger air inlet and exhaust piping.

Disconnect the charge-air cooler piping. Refer to Procedure 010-019 in Section 10.

Remove the turbocharger. Refer to Procedure 010-033 in Section 10.

With EGR

Disconnect the turbocharger air inlet and exhaust piping.

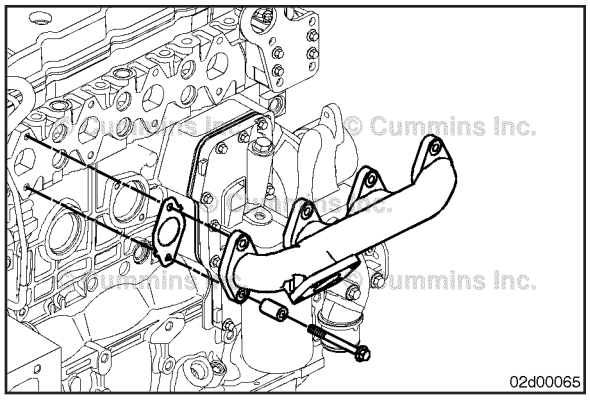
Disconnect the charge-air cooler piping. Refer to Procedure 010-019 in Section 10.

Remove the exhaust pressure sensor line. Refer to Procedure 011-027 in Section 11.

Remove the EGR valve. Refer to Procedure 011-022 in Section 11.

Remove the turbocharger. Refer to Procedure 010-033 in Section 10.

Remove the EGR cooler inlet tube. Refer to Procedure 011-024 in Section 11.

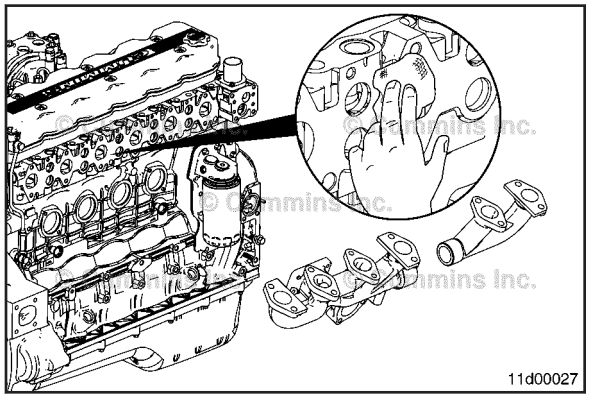


Remove

Remove the exhaust manifold mounting capscrews, lock plates, and spacers.

Remove the exhaust manifold and gaskets.

Discard the exhaust manifold gaskets. They are **not** reusable.



Clean and Inspect for Reuse

Clean the sealing surfaces of the head.

Clean the sealing surfaces of the exhaust manifold.

Use 240-grit inert cloth to remove carbon deposits from the sealing surface.

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

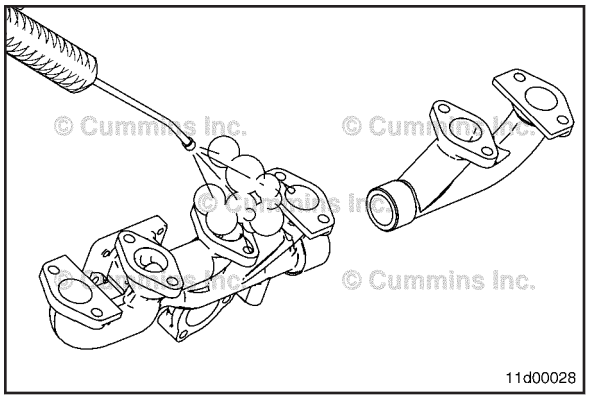
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use steam to clean the exhaust manifold. Dry with compressed air.

Clean the two-piece sealing joint.

NOTE: For two-piece exhaust manifolds, the sealing joint **must** come apart. If the joint does **not** come apart, replace the exhaust manifold.

Use 240-grit inert cloth to remove carbon deposits from the sealing surfaces.



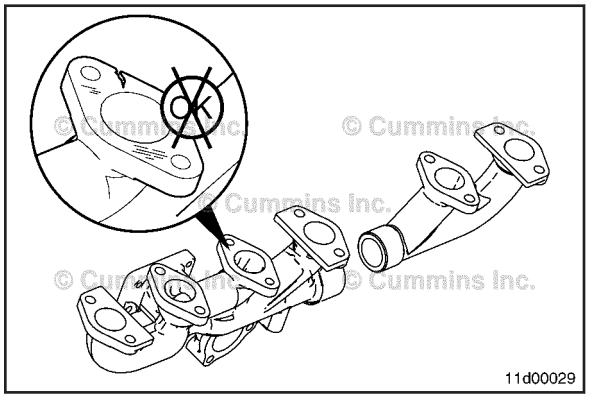
Inspect the parts for cracks and damage.

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.

Check for exhaust system-related fault codes. Use INSITE™ electronic service tool.

Inspect the gasket surfaces for gouges, scratches, or burnout.

Inspect the two-piece sealing joint for signs of exhaust leaks. If exhaust leaks are present at the joint, replace the manifold.



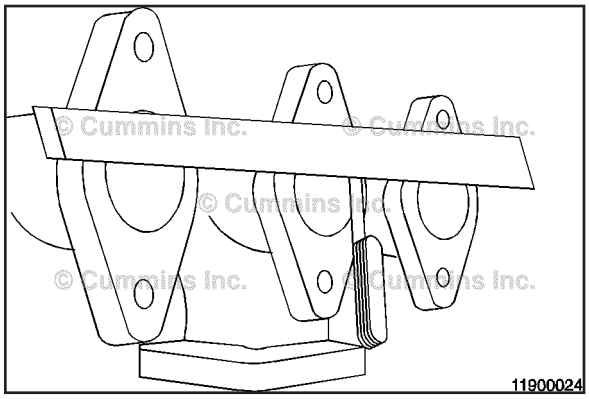
Use a precision straightedge, Part Number 4918219, to check the manifold mounting surfaces for flatness. Lay the straightedge on edge across all ports and measure the flatness with a feeler gauge.

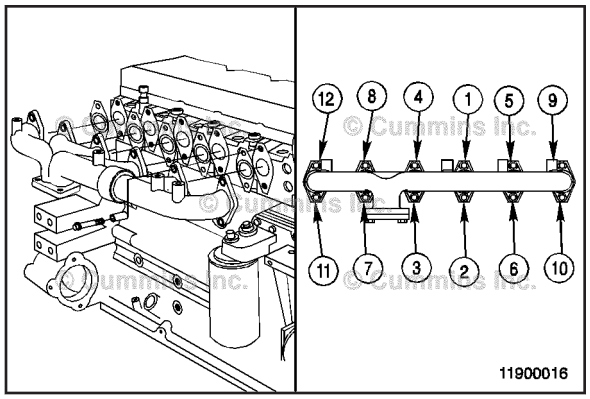
Exhaust Manifold Flatness		
mm		**in**
0.20	MAX	0.008

If any port measures out of specification, machine or replace the manifold.

NOTE: For multi-piece manifolds, each section **must** be verified to be flat, independently. If either section is found to be out of specification, replace both sections of the manifold.

The assembled two-piece manifold is **not** required to meet the flatness specification of the one piece manifold, as some misalignment is allowed in the design of the manifold. Some misalignment will be eliminated naturally when the manifold capscrews are tightened to specification during installation.





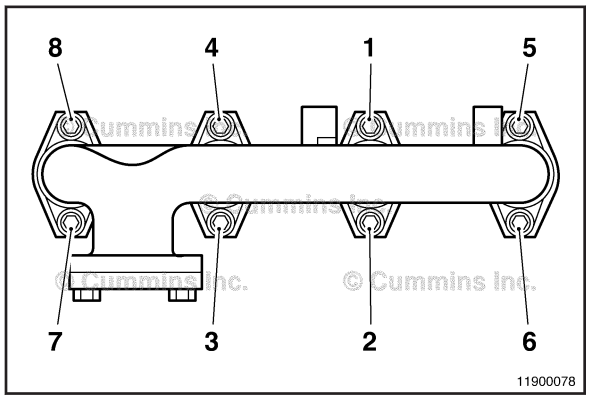
Install

Apply high-temperature anti-seize compound to the exhaust manifold capscrew threads.

Install the exhaust manifold, new gaskets, spacers, and lockplates.

Follow the tightening sequence shown in the illustration.

NOTE: To aid in alignment of the exhaust manifold, two capscrew passages have a smaller diameter than other passages. The location of these varies with manifold configuration. The capscrews in the smaller passages should be tightened first, with the remaining capscrews tightened in a sequence like the pattern shown in the illustration.



For QSB6.7 CM850 engines:

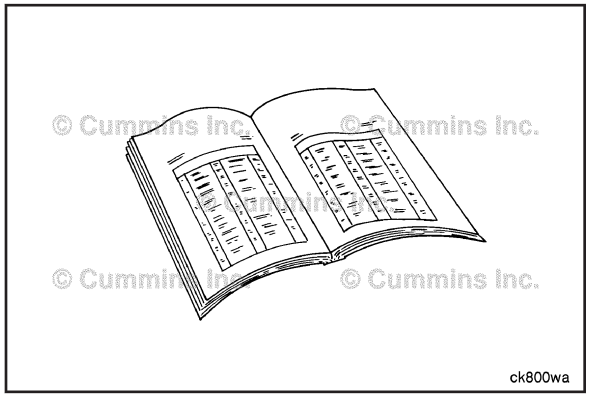
Tighten the exhaust manifold mounting capscrews.

Torque Value: 53 N•m [39 ft-lb]

For all other engines:

Tighten the exhaust manifold mounting capscrews.

Torque Value: 43 N•m [32 ft-lb]



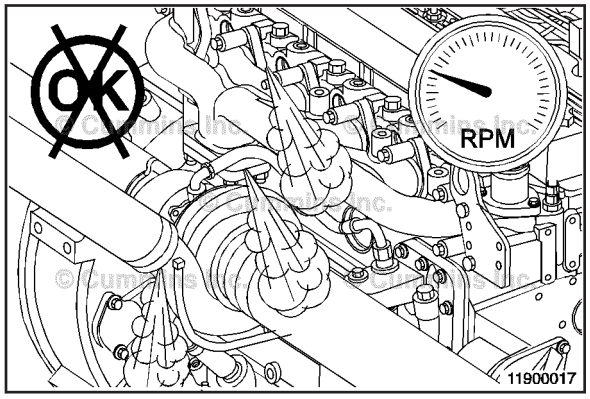
Finishing Steps

Without EGR

Install the turbocharger. Refer to Procedure 010-033 in Section 10.

Connect the turbocharger air inlet and exhaust piping.

Connect the charge air cooler piping. Refer to Procedure 010-019 in Section 10.



Operate the engine and check for leaks.

With EGR

Install the EGR cooler inlet tube. Refer to Procedure 011-024 in Section 11.

Install the turbocharger. Refer to Procedure 010-033 in Section 10.

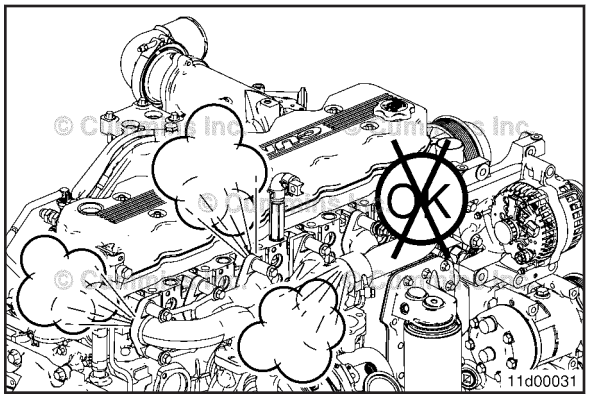
Install the EGR valve. Refer to Procedure 011-022 in Section 11.

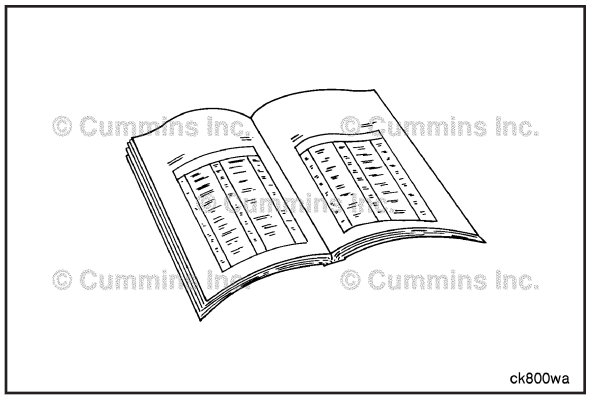
Install the exhaust pressure sensor line. Refer to Procedure 011-027 in Section 11.

Connect the turbocharger air inlet and exhaust piping.

Connect the charge air cooler piping. Refer to Procedure 010-019 in Section 10.

Operate the engine and check for leaks.





Exhaust Manifold, Wet (011-008)

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⚠
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.

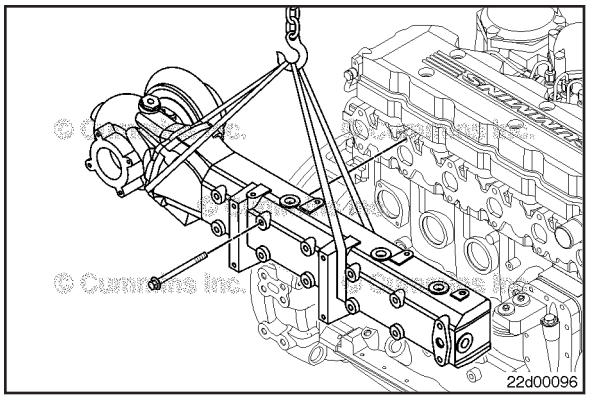
NOTE: If a check for a turbocharger gasket leak is being performed, do **not** break the seal between the turbocharger and the exhaust manifold. Remove the two components as one assembly.

- 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 008-053
- Drain the engine coolant. Refer to Procedure 008-018
- Remove the exhaust outlet connection. Refer to Procedure 011-017
- Remove the coolant expansion tank. 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

- Remove the closed crankcase system. 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

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.

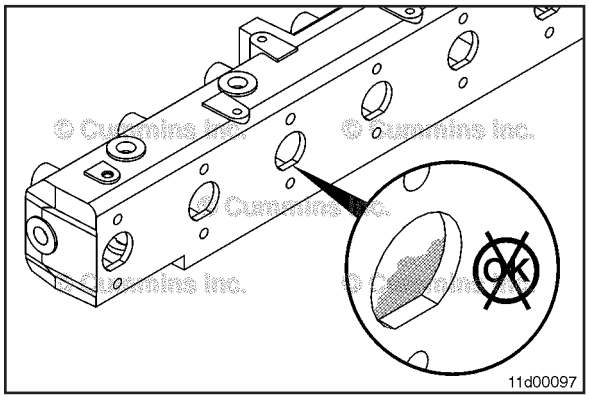
Loosen two capscrews and leave them in place to hold the weight of the exhaust manifold.

Remove the remaining 10 exhaust manifold mounting capscrews.

Attach a lifting device to support the weight of the exhaust manifold.

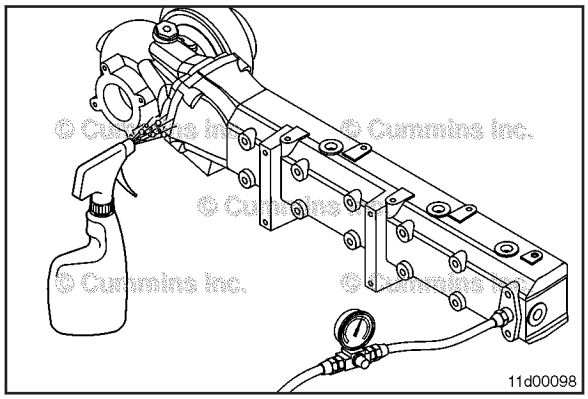
Remove the two remaining mounting capscrews and the exhaust manifold.

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).

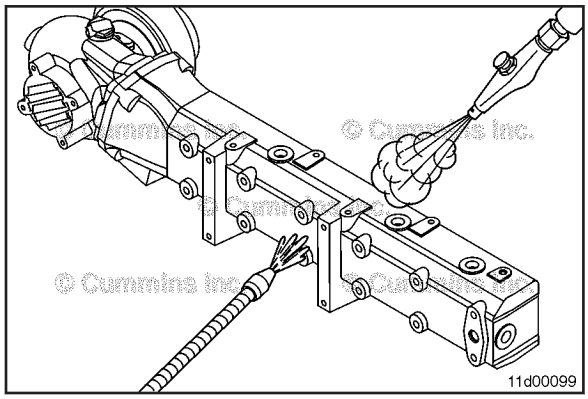


⚠CAUTION⚠
If the turbocharger was not removed from the exhaust manifold, do not place the turbocharger into water. Damage to the turbocharger will occur if water enters any of the turbocharger openings.

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.



⚠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.

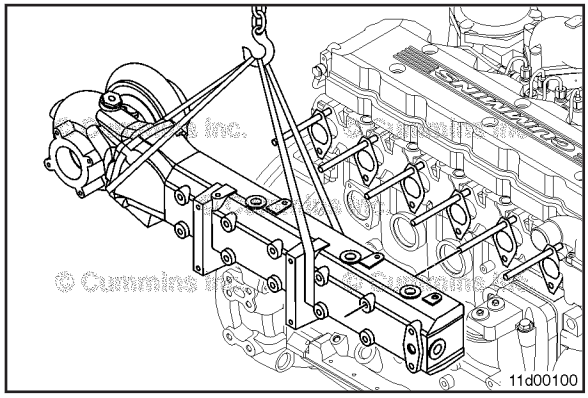
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△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

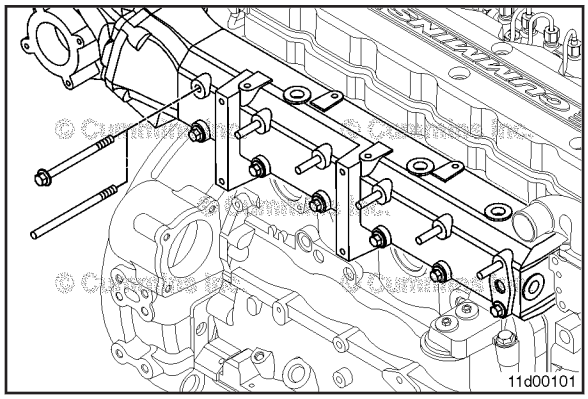
⚠WARNING⚠
This assembly weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this assembly.

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 lower six capscrews, but do **not** tighten at this time.

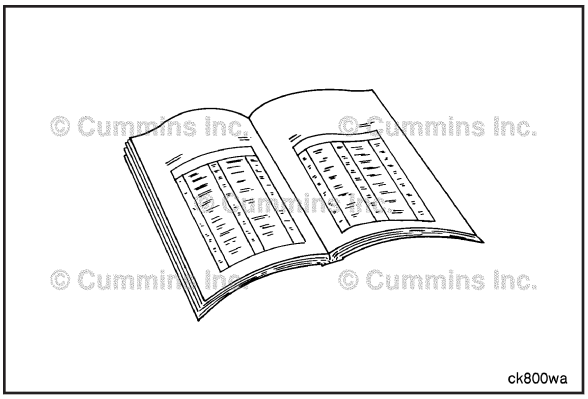
Remove the guide pins one at a time and install the mounting capscrew. Make sure the gaskets stay in place during this process.

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.

- 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 011-008 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
- Install the closed crankcase system. Refer to Procedure 003-020
- Install the coolant heat exchanger. Refer to Procedure 008-053
- Install the coolant expansion tank. Refer to Procedure 008-052
- 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).

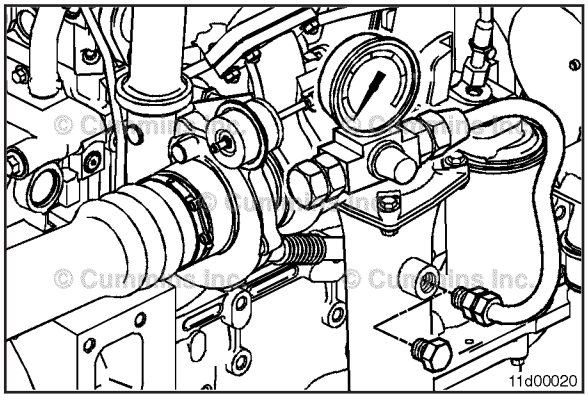
Operate the engine and check for leaks.

Exhaust Restriction (011-009)

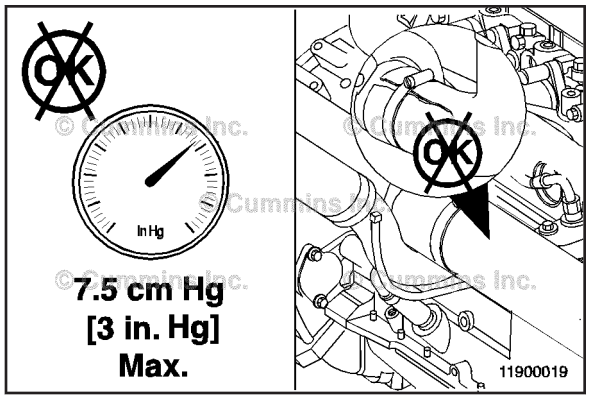
Measure

Install pressure gauge, Part Number ST-1273, to a pressure tap in the exhaust pipe. Install the gauge within 1 pipe diameter of the turbocharger outlet. Install the guage to the exhaust outlet connection test port on Marine applications.

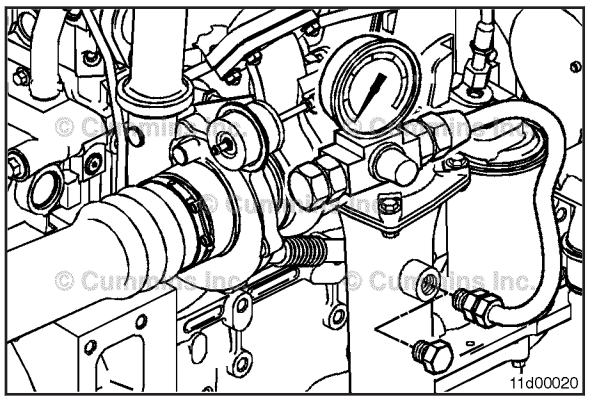
Operate the engine at rated speed and load. Record the exhaust back pressure.



Exhaust Restriction		
mm Hg		in H_2O
75	MAX	40



If exhaust pressure exceeds the specification, inspect the exhaust piping for damage. Refer to the equipment manufacturer's repair instructions.



Remove the test equipment.

Install a pipe plug into the pressure tap port, if applicable.

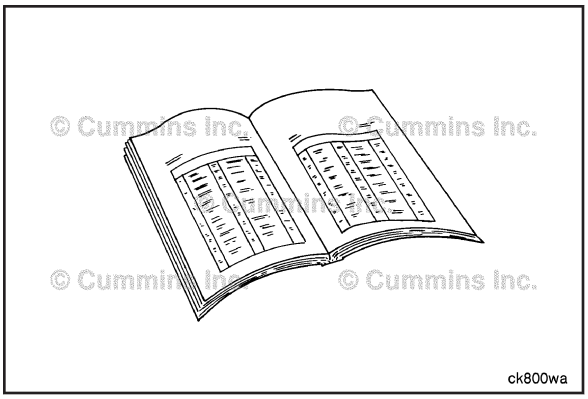
Exhaust Outlet Connection (011-017)

General Information

NOTE: This procedure applies to marine applications. The exhaust outlet connection to the turbocharger applies to all marine engines with wet exhaust systems. The instructions involving the integrated drive system do **not** apply to all marine applications.

The Zeus™ drive package uses an integrated exhaust system. An integrated exhaust system has a wet exhaust routed through the pod drive and exiting through the propeller hub. Because the exhaust discharges under water, an idle exhaust bypass circuit is required to reduce noise and vibration reduction at idle. The boat builder is expected to provide the hoses, waterlift muffler, and through-hull fittings for this circuit. There is a 50.8 to 76.2 mm [2 to 3 in] outlet port on the integrated exhaust system for QSB applications, which will be the customer interface point for the idle bypass system. The outlet port for QSC applications is 76.2 mm [3 in] wide. The main exhaust connection at the engine is available as a standard 90-degree elbow, or an exhaust riser, if needed.

Preparatory Steps

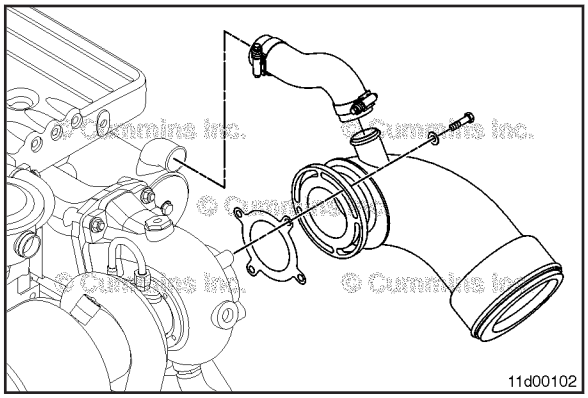


⚠CAUTION⚠
Before disconnecting the exhaust outlet piping, be sure to fasten the piping above the water level to prevent the vessel from taking on water and possibly sinking.

⚠CAUTION⚠
Vessels installed with integrated drive systems must be removed from the water to reduce the possibility of the vessel from taking on water and possibly sinking.

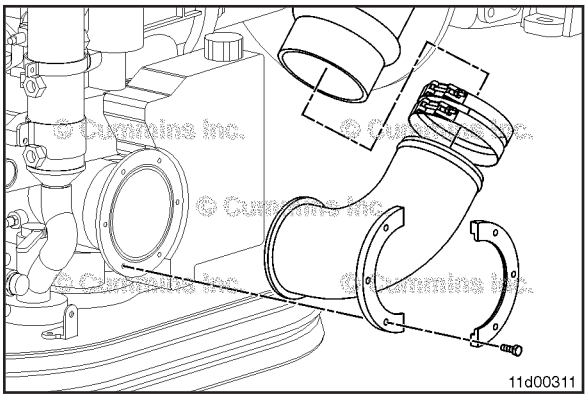
- Close the sea water supply valve(s). Refer to the OEM service manual.
- For integrated drive systems, the vessel **must** be removed from the water.
- Remove the exhaust piping from the exhaust outlet connection. Refer to the OEM service manual.

Remove



Loosen the hose clamps and remove the hose from the heat exchanger and the exhaust outlet connection.

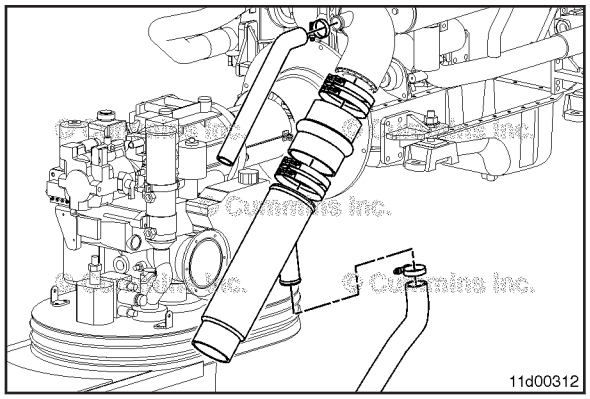
Remove the four mounting capscrews and the exhaust outlet connection from the turbocharger.



Remove the capscrews and retaining clamps from the lower exhaust elbow.

Loosen the hose clamps.

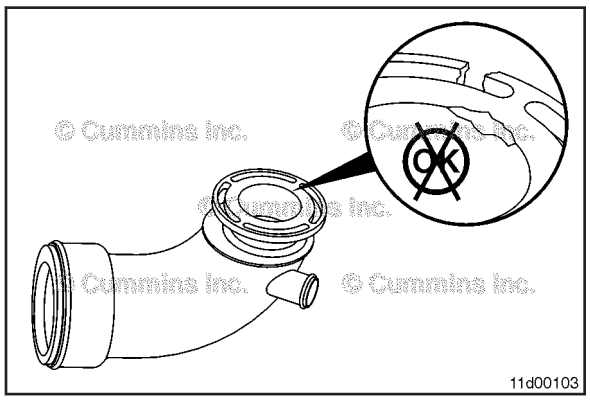
Remove the exhaust elbow connection.



Loosen the hose clamps.

Remove all hose connections.

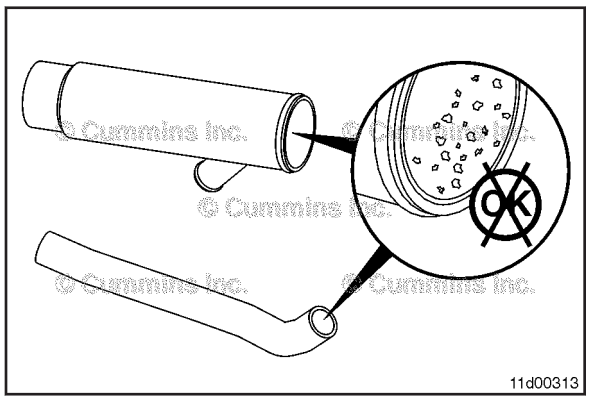
Remove the exhaust tube.



Clean and Inspect for Reuse

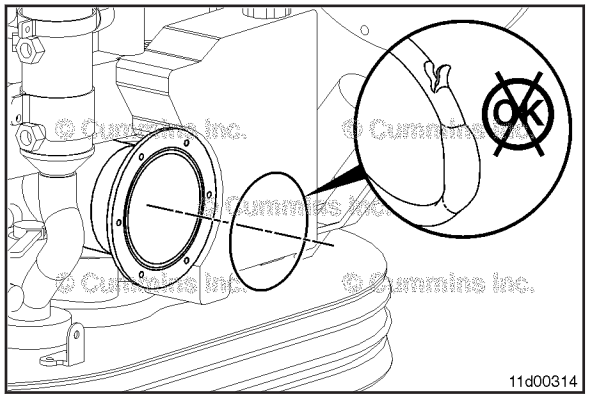
Inspect all the sealing surfaces and gasket for damage or other indications of leakage.

Inspect the inside of the connection to make sure the water passages are **not** blocked.



Inspect the inside of the exhaust tube passages for pitting.

Inspect the pod exhaust flange for damage.

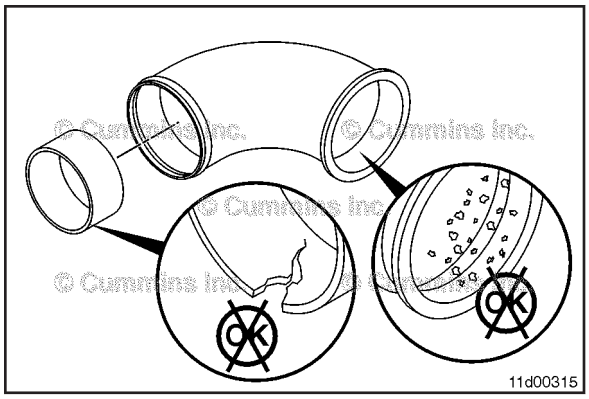


Remove and inspect the exhaust flange o-ring.

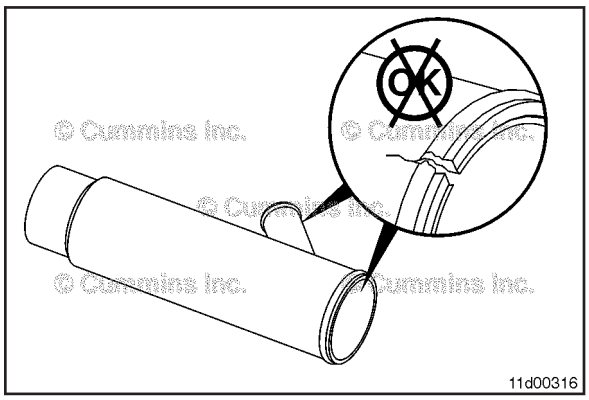
Remove the sealing grommet from the exhaust elbow and inspect for damage.

Replace the grommet if damaged.

Inspect the exhaust elbow for pitting or corrosion.



Inspect the exhaust tube for cracks and other damage to the lamination.



Install

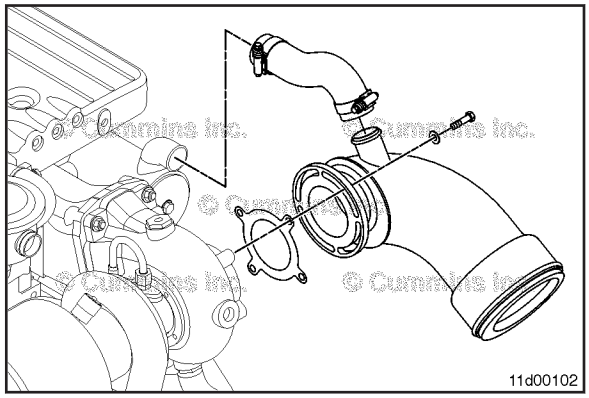
Install a new gasket and the exhaust outlet connection to the turbocharger.

Tighten the four mounting capscrews.

Torque Value: 24 N•m [212 in-lb]

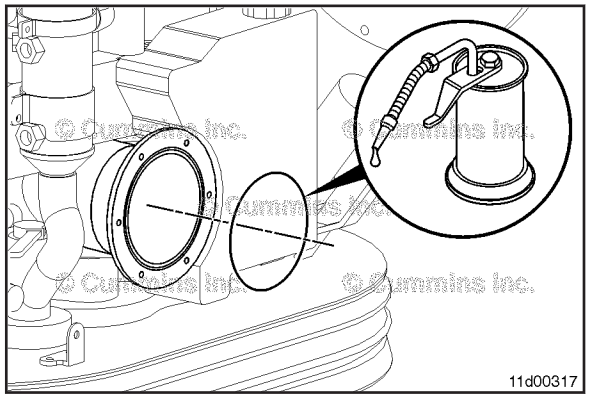
Install the hose on the heat exchanger and the exhaust outlet connection. Tighten the hose clamps.

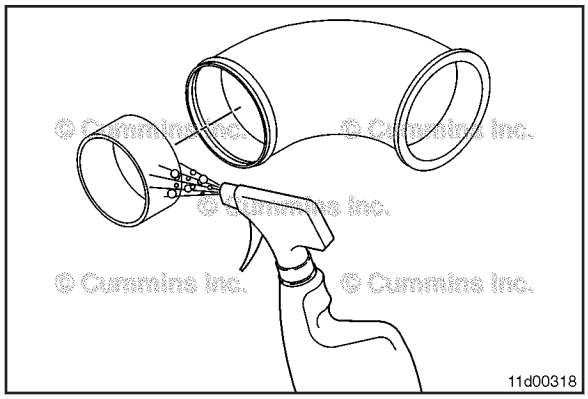
Torque Value: 24 N•m [212 in-lb]



Lightly coat the exhaust o-ring with grease or lubricant to reduce the possibility of o-ring damage.

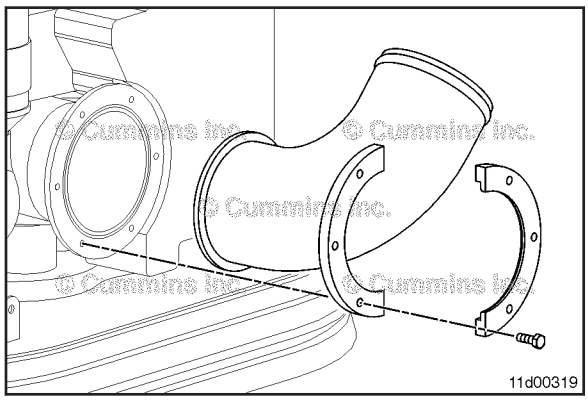
Install the exhaust o-ring into the groove of the pod exhaust flange.





Install the sealing grommet inside the exhaust elbow until the grommet is even with the edge of the exhaust elbow.

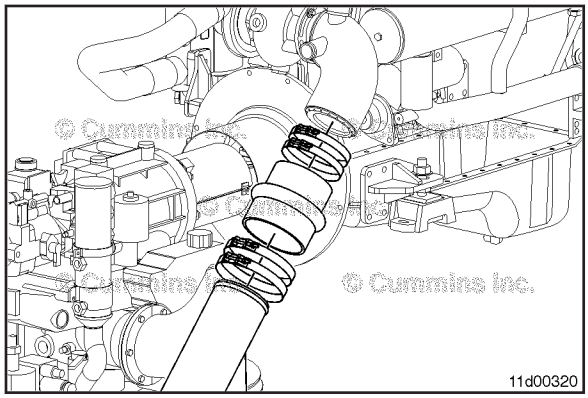
NOTE: Use soapy water on the outside of the grommet to aid in installation.



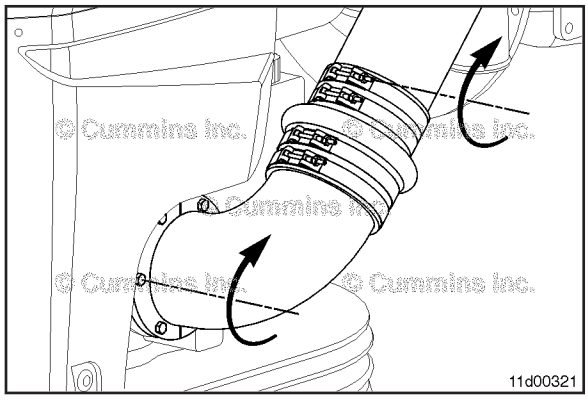
Use clamp rings to install the exhaust elbow.

Leave the clamp ring capscrews finger tight to allow the elbow pivots to align with the exhaust tube.

The o-ring **must** remain in place during this process or damage to the o-ring can occur.



Use a hump hose and hose clamps to connect the exhaust tube to the exhaust connection.



Align the lower elbow with the exhaust tube.

Tighten the hose clamps.

Torque Value: 6 N•m [53 in-lb]

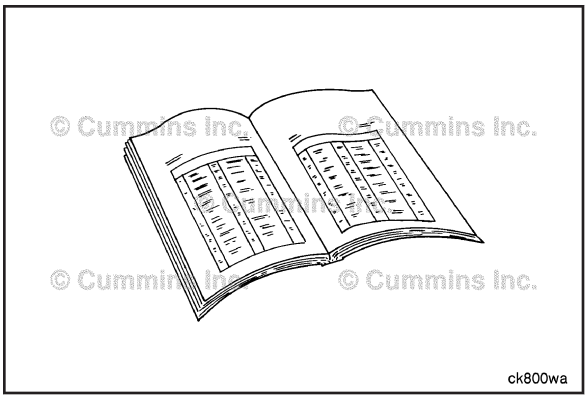
Tighten the clamp ring capscrews.

Torque Value: 23 N•m [204 in-lb]

NOTE: Use soapy water on the inside diameter of both connection points of the hump hose to aid in installation.

Finishing Steps

- Install the exhaust piping to the exhaust outlet connection. Refer to the OEM service manual.
- Place the vessel back into the water.
- Open the sea water supply valve(s). Refer to the OEM service manual.
- Operate the engine and check for leaks.

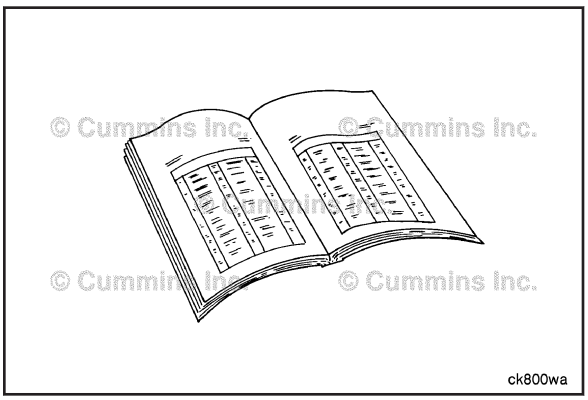


Exhaust Gas Recirculation Cooler (011-019)

Preparatory Steps

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Drain the engine coolant. Refer to Procedure 008-018 (Cooling System) in Section 8.
- Remove the exhaust pressure sensor tube. Refer to Procedure 011-027 (Exhaust Gas Pressure Sensor Tube) in Section 11.
- Remove the EGR cooler coolant lines. Refer to Procedure 011-031 (EGR Cooler Connection) in Section 11.
- Remove the EGR cooler connection. Refer to Procedure 011-024 (EGR Cooler Connection) in Section 11.
- Remove the EGR connection tube. Refer to Procedure 011-025 (EGR Connection Tubes) in Section 11.
- Remove the EGR valve coolant return line. Refer to Procedure 011-030 (EGR Valve Coolant Lines) in Section 11.

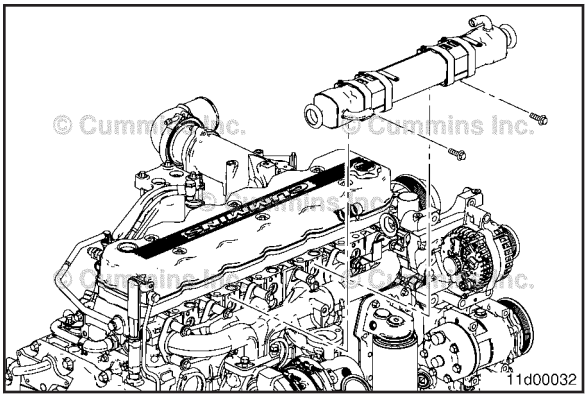


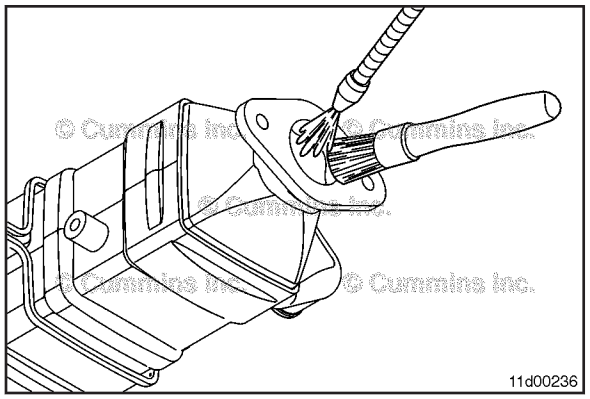
Remove

NOTE: When replacing the EGR cooler, it is **not** necessary to remove the brackets and clamping straps. New EGR coolers come as an assembly with all brackets and clamping straps already installed.

Remove the two capscrews that hold the EGR cooler and bracket assembly to the cylinder head.

Remove the EGR cooler as an assembly.





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.

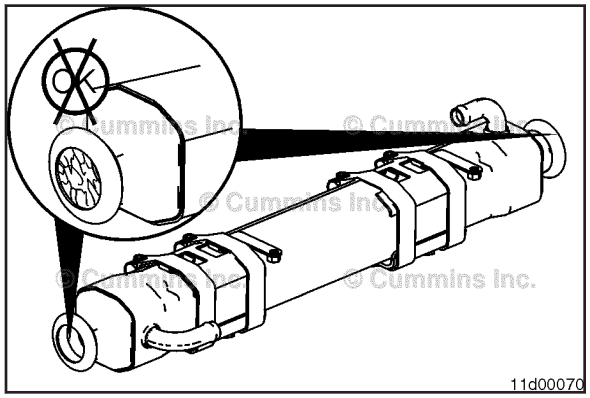
⚠WARNING⚠
Use skin and eye protection when handling caustic solutions to reduce the possibility of personal injury.

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

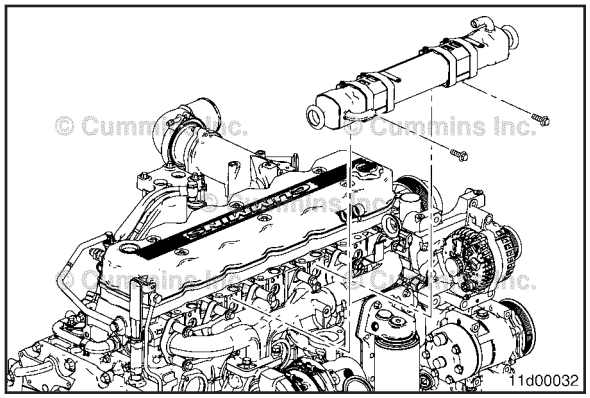
Use safety solvent to clean the soot from the inside of the EGR cooler.

Use compressed air to dry the inside of the EGR cooler.

If any solvents or cleaners entered the coolant side of the EGR cooler, use fresh water to flush the coolant side of the cooler to prevent solvents and cleaners entering the coolant.



Inspect the cooler for debris and plugging.



Install

Install the cooler and bracket assembly to the cylinder head, use two capscrews.

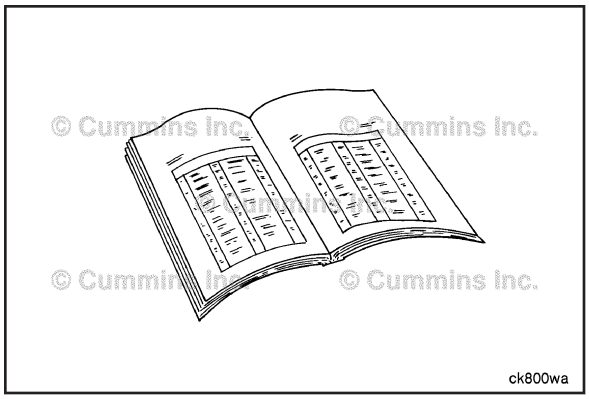
Tighten the capscrews.

Torque Value: 33 N•m [24 ft-lb]

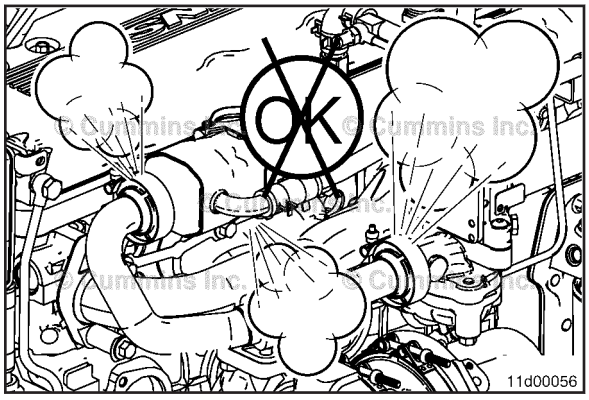
Finishing Steps

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Install the EGR valve coolant return line. Refer to Procedure 011-030 (EGR Valve Coolant Lines) in Section 11.
- Install the EGR cooler connection tube. Refer to Procedure 011-024 (EGR Cooler Connection) in Section 11.
- Install the EGR connection tube. Refer to Procedure 011-025 (EGR Connection Tubes) in Section 11.
- Install the EGR cooler coolant lines. Refer to Procedure 011-031 (EGR Cooler Connection) in Section 11.
- Install the exhaust pressure sensor tube. Refer to Procedure 011-027 (Exhaust Gas Pressure Sensor Tube) in Section 11.
- Fill the engine cooling system. Refer to Procedure 008-018 (Cooling System) in Section 8.

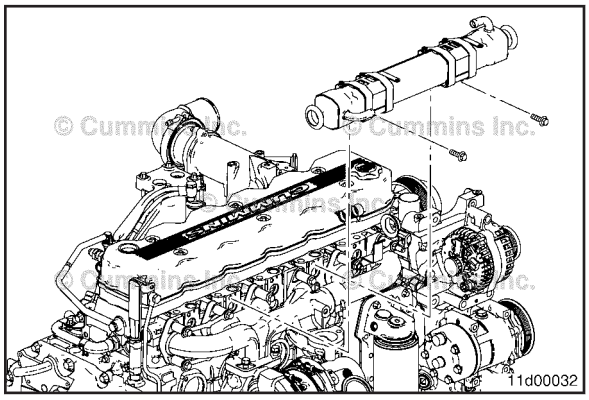


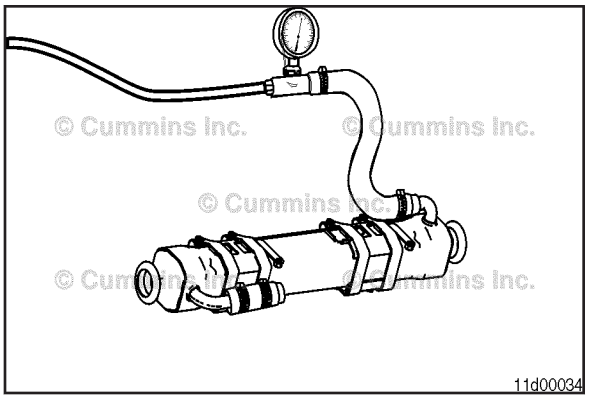
Operate the engine and check for boost/exhaust coolant leaks.



Test

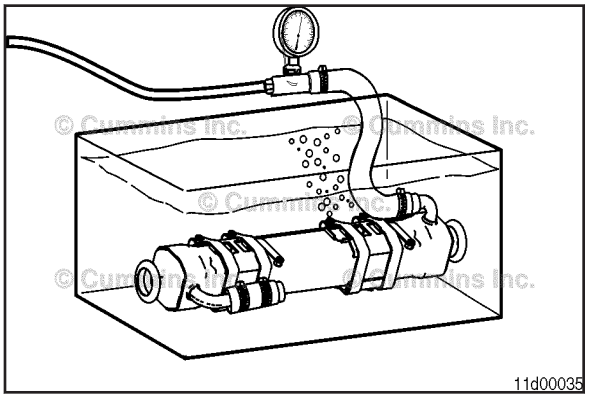
Remove the EGR cooler from the engine. Refer to the Remove section of this procedure.





Cap off one of the coolant connections and connect a regulated air supply hose to the other coolant connection.

Place the EGR cooler into a tank of heated water (60°C [140°F]).



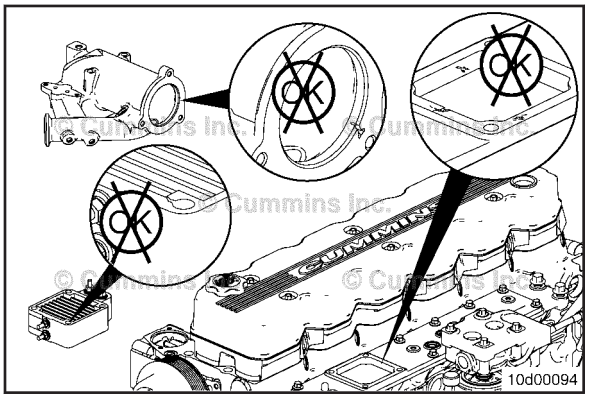
The EGR cooler **must** be completely submerged in the water.

Apply air pressure of 310 kPa [45 psi].

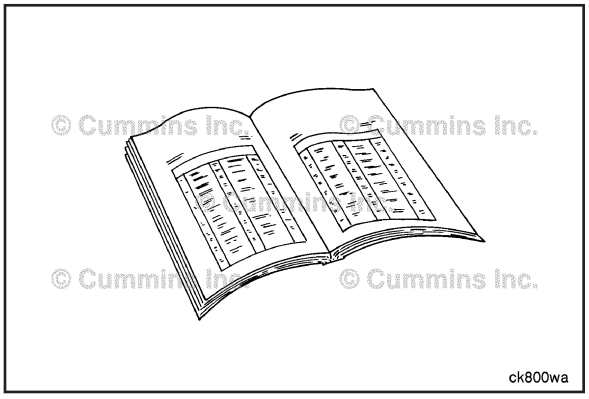
Inspect for air bubbles coming from the cooler. Observe the cooler for a minimum of 2 minutes under water.

Verify that any air bubbles are **not** a result of loose connections or trapped air.

If the EGR cooler leaks, it **must** be replaced.



Inspect the grid heater for deposits and plugging if the cooler was leaking internally.



EGR Mixer (011-021)

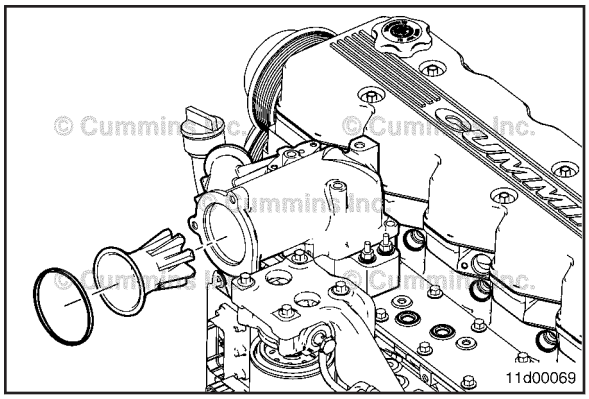
Preparatory Steps

Remove the charge air piping/hose. Refer to Procedure Procedure 010-019

Remove the two-piece air intake connection adapter. Refer to Procedure Procedure 010-131

Remove

Remove the mixer and o-ring seal from the air intake connection.



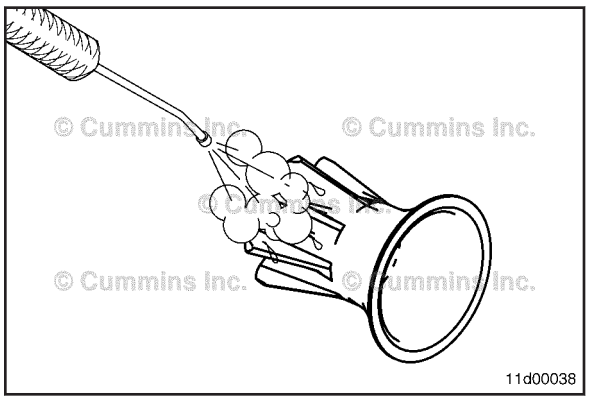
Clean and Inspect

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

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

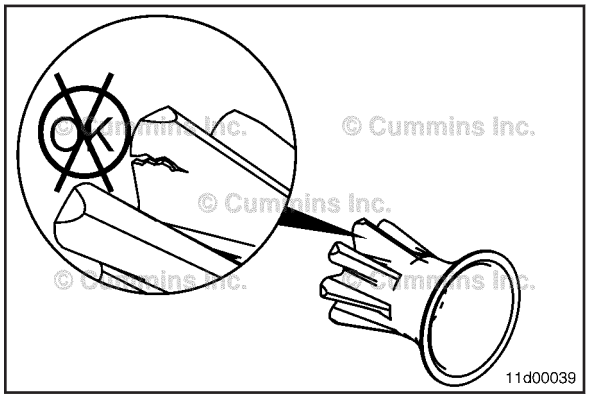
Clean the mixer in solvent.

Blow-dry with compressed air.



Inspect the mixer for erosion, plugging, trapped debris, and any damaged lobes that can affect airflow.

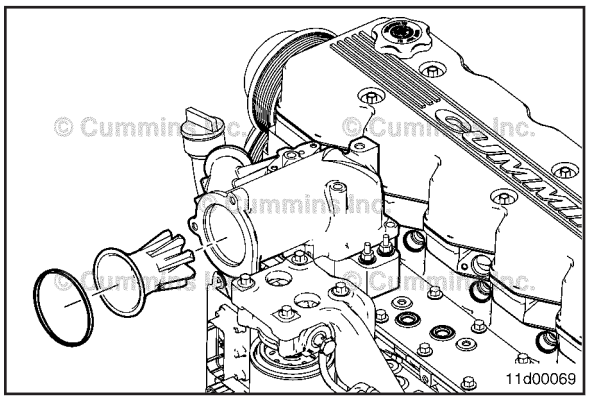
Inspect the o-ring seal for cuts or damage. Replace if damaged.

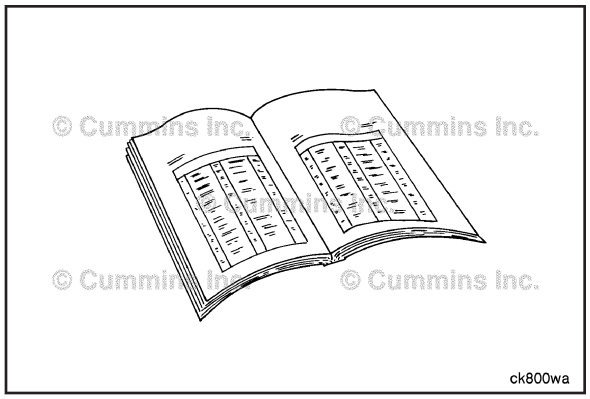


Install

Seat the mixer into the air intake connection.

Install the o-ring seal.

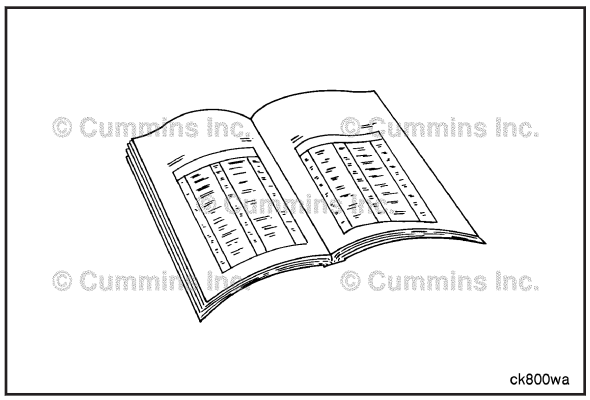




Finishing Steps

Install the two-piece air intake connection adapter. Refer to Procedure Procedure 010-131

Install the charge-air piping/hose. Refer to Procedure Procedure 010-019



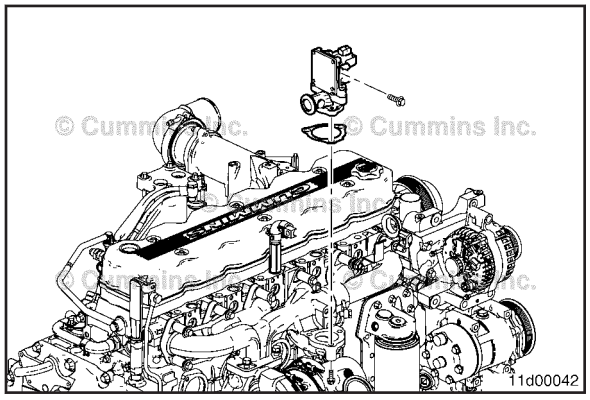
EGR Valve (011-022)

Preparatory Steps

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Disconnect and remove the following:

- Electrical connectors from the EGR valve.
- Drain the coolant. Refer to Procedure 008-018
- EGR valve coolant supply and return lines. Refer to Procedure 011-030
- Exhaust pressure sensor tube. Refer to Procedure 011-027



Remove

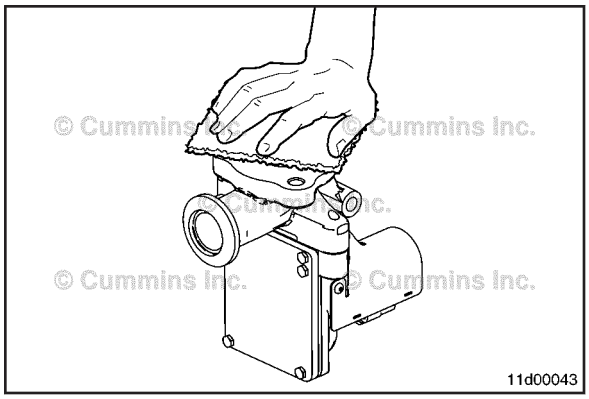
Remove the V-band clamp that connects the Exhaust Gas Recirculation (EGR) cooler connection tube to the EGR valve.

Remove the four capscrews, gasket, and EGR valve from the exhaust manifold.

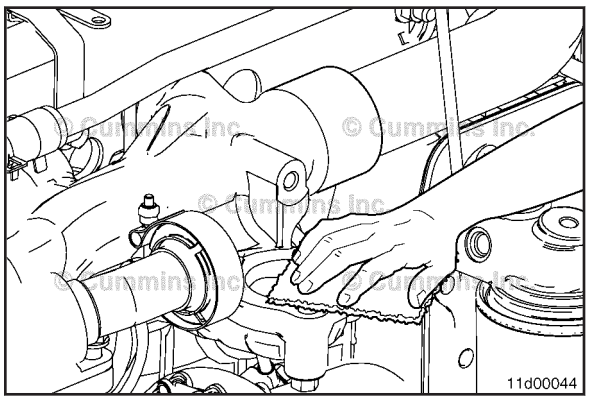
Discard the gasket.

Clean and Inspect for Reuse

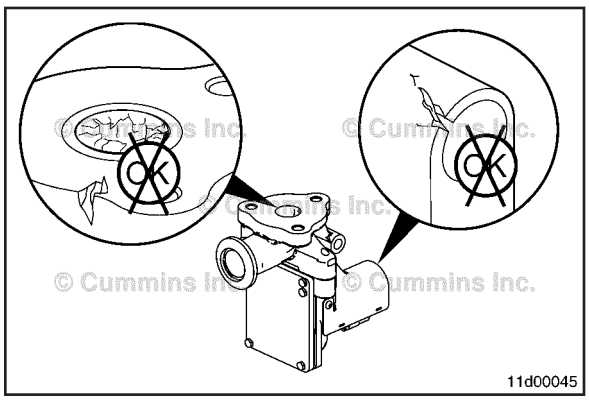
Clean the EGR valve marmon flange and the mounting surfaces of the EGR valve with a Scotch-Brite™ pad.



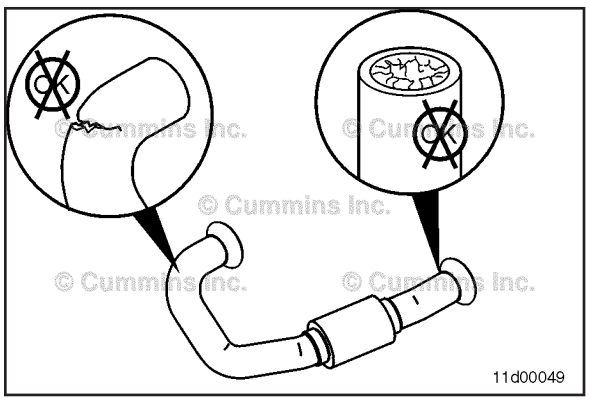
Clean the exhaust manifold with a Scotch-Brite™ pad.

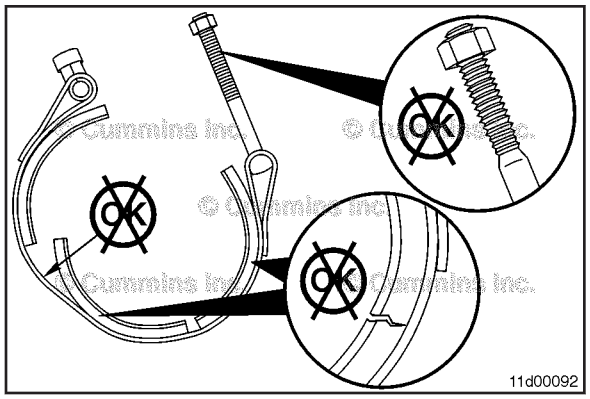


Inspect the EGR valve for cracks, leaks, corrosion, restriction, and debris.



Inspect the exhaust transfer tube for cracks, corrosion, and plugging.

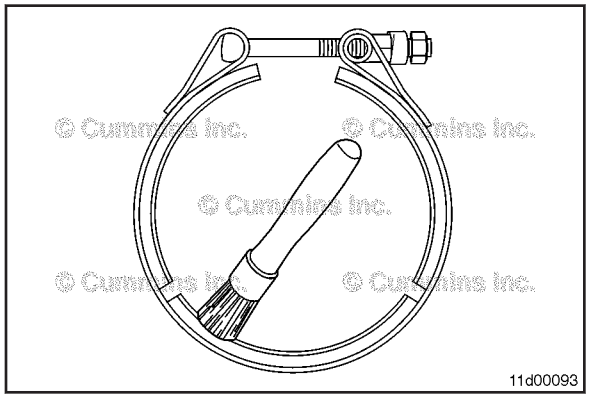




Inspect the V-band clamps for signs of overextension. The band **must not** be bent or damaged.

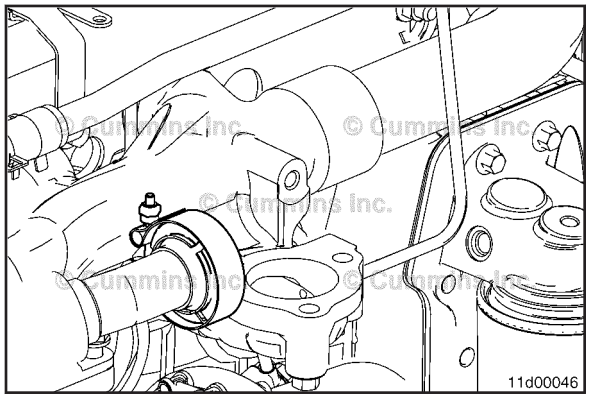
Inspect the V-band clamp threads for damage.

Replace the V-band clamp if damage is found.

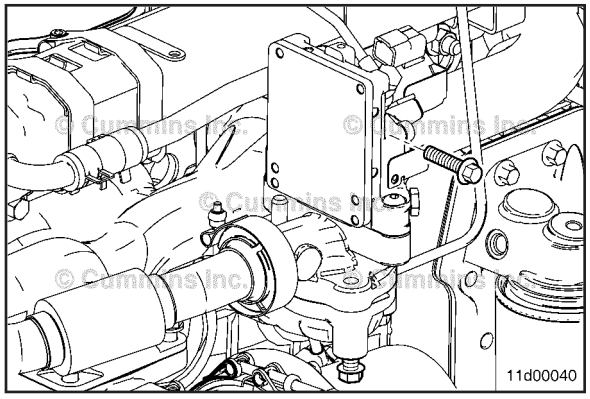


Install

Before installing the V-band clamp, coat the clamping surface with high temperature anti-seize compound.



Position the V-band clamp and new gasket onto the exhaust transfer tube.



Position the EGR valve and new mounting gasket.

Hold the EGR valve and gasket in place with the four mounting capscrews. Do **not** tighten the capscrews at this time.

Position the exhaust transfer tube V-band connection on the EGR valve.

Tighten the V-band clamp.

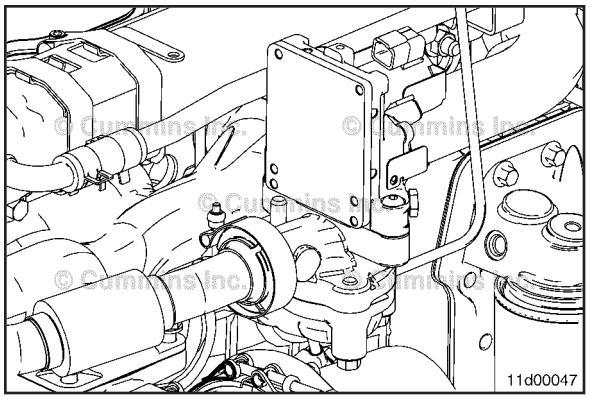
Torque Value: 11 N•m [100 in-lb]

Tighten the three upper vertical EGR mounting capscrews.

Torque Value: 43 N•m [32 ft-lb]

Tighten the upper horizontal EGR mounting capscrews.

Torque Value: 43 N•m [32 ft-lb]



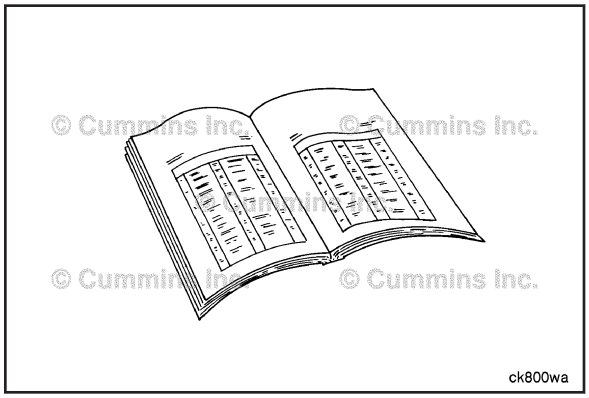
Finishing Steps

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

△CAUTION△
The position sensor pins can be bent if the engine harness connector is mated to the sensor connector at an angle. Therefore, the engine harness connector must be inserted straight into the position sensor connector to avoid damaging the pins. Bent pins will result in poor engine performance and intermittent fault codes.

Install and connect the following:

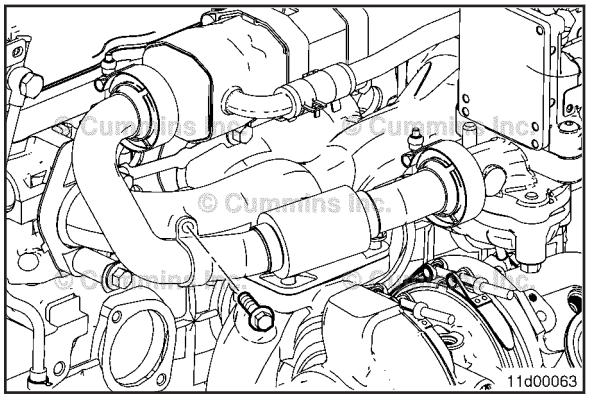
- Exhaust pressure sensor tube. Refer to Procedure 011-027
- EGR valve coolant supply and return lines. Refer to Procedure 011-030
- Electrical connectors to the EGR valve.
- Fill the engine cooling system. Refer to Procedure 008-018
- Operate the engine and check for exhaust leaks.

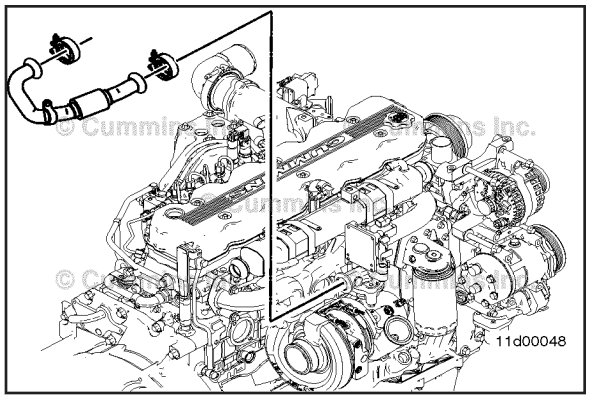


EGR Cooler Connection (011-024)

Remove

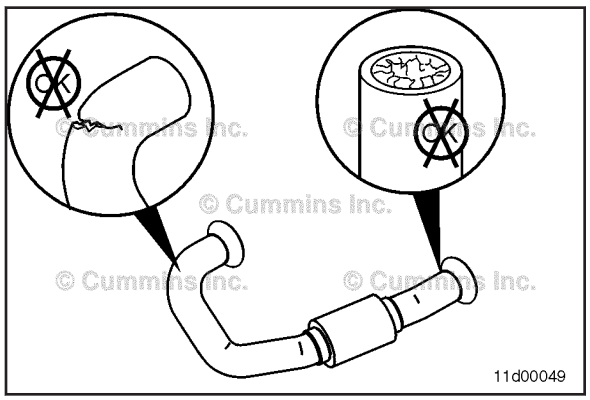
Remove the capscrews from the P-clip(s) that attach the tube to the exhaust manifold.





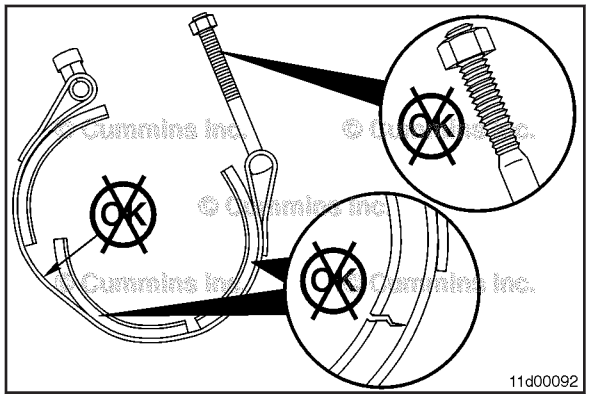
Remove the two V-band clamps, tube, and gaskets.

Discard the gaskets.



Inspect for Reuse

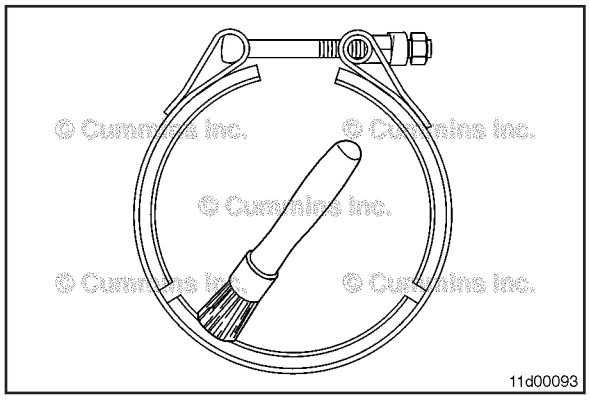
Inspect the tube for cracks, restrictions, plugging, and damage.



Inspect the V-band clamps for signs of overextension. 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.



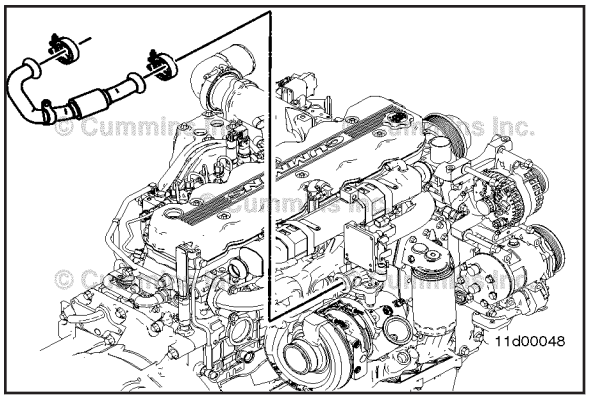
Install

Before installing the V-band clamp, coat the clamping surface with high temperature anti-seize compound.

Place new gaskets onto the tube.

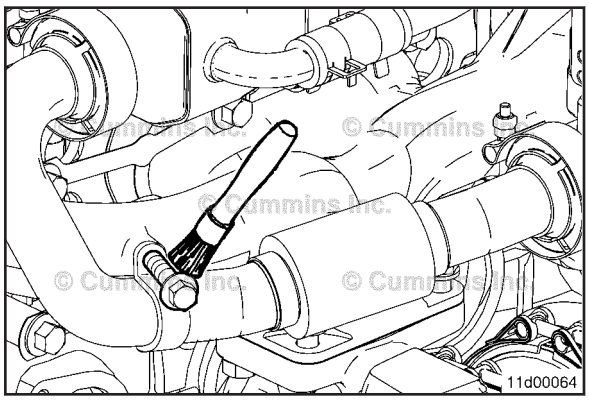
Install the tube.

Position the V-band clamps.



Coat the P-clip capscrew(s) with high-temperature anti-seize compound.

Loosely install the capscrew(s) for the P-clip(s).



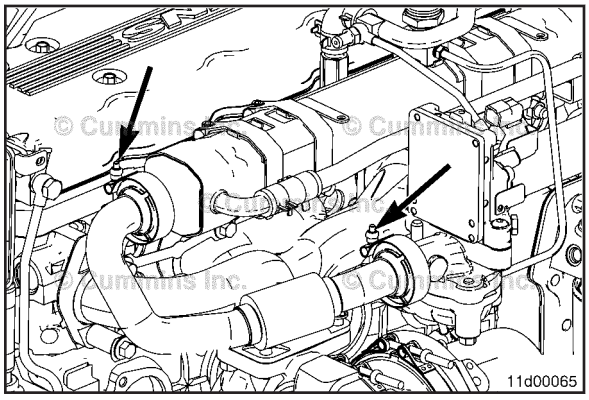
Tighten the V-band clamps.

Torque Value: 11 N•m [100 in-lb]

Tighten the P-clip capscrew(s).

Torque Value: 24 N•m [212 in-lb]

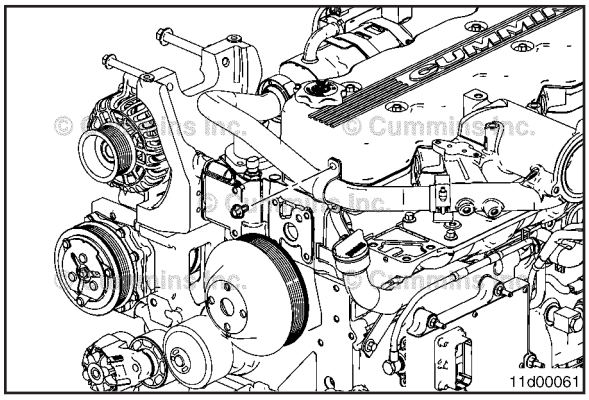
Operate the engine and check for boost and exhaust leaks.

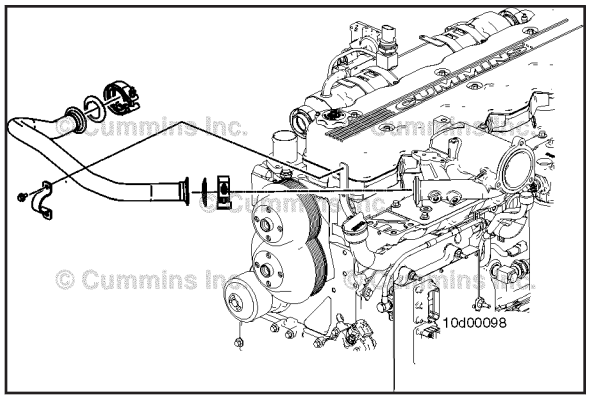


EGR Connection Tubes (011-025)

Remove

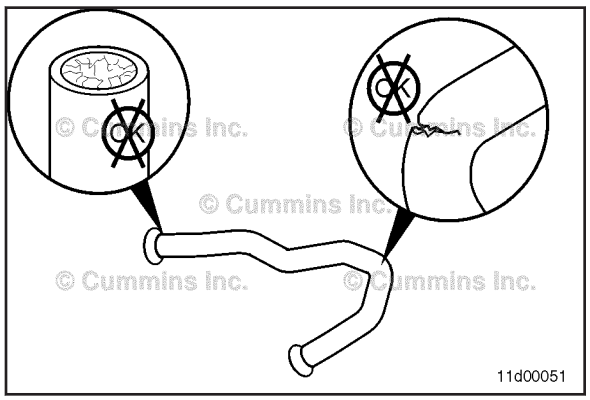
Remove the capscrews from the support brace that attaches the tube to the cylinder head, if applicable.





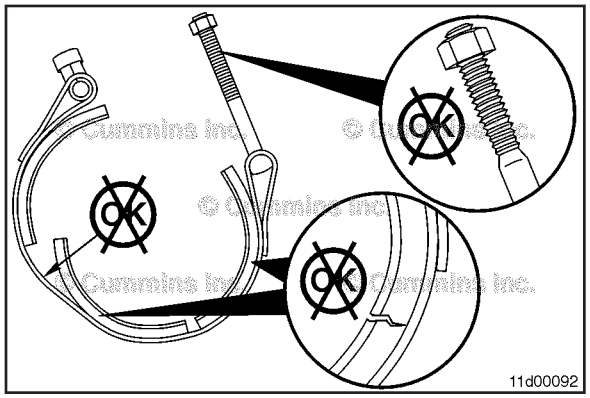
Remove the two V-band clamps, tube, and gaskets.

Discard the gaskets.



Inspect for Reuse

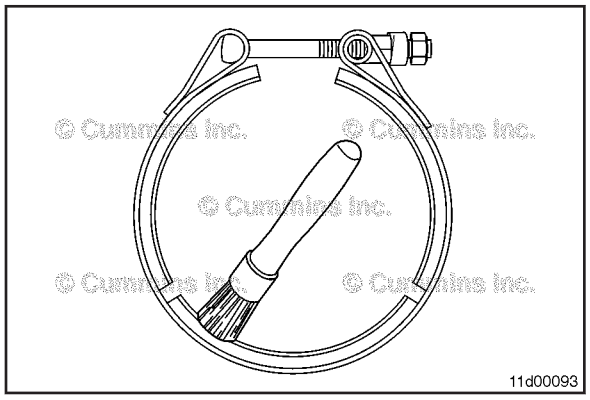
Inspect the tube for cracks, restrictions, plugging, and damage.



Inspect the V-band clamps for signs of overextension. 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.

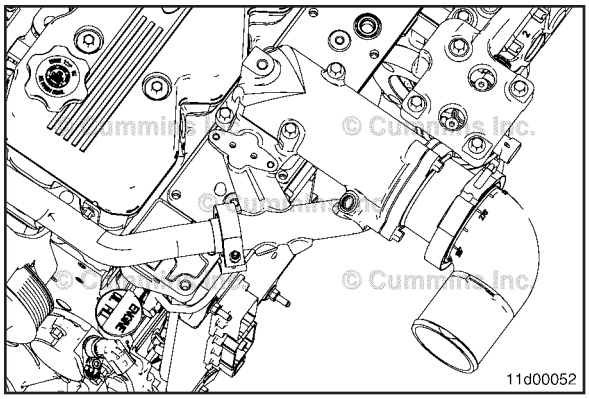


Install

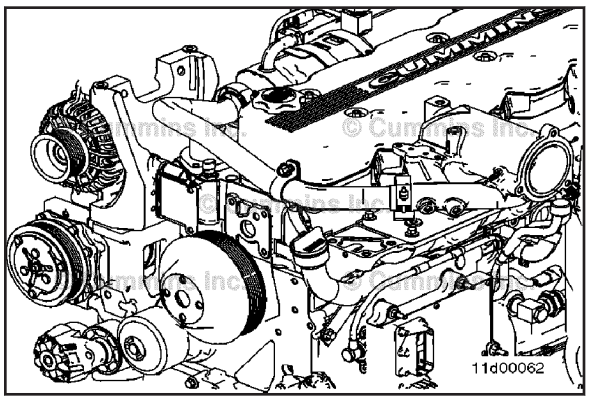
Before installing the V-band clamp, coat the clamping surface with high temperature anti-seize compound.

Place new gaskets onto the tube.

Position the tube, gasket, and V-band clamp on the cooler and intake cover marmon flange connections. Check for proper alignment.



Loosely install the capscrews for the tube support brace.



⚠CAUTION⚠
Do not force the tube to fit the intake cover or EGR cooler marmon flanges. Force fitting the tube will result in undesirable stress in the tube and possible tube failure.

If the tube does **not** align correctly, loosen the four air intake connection capscrews and reposition the air intake connection to allow for proper alignment.

Tighten the V-band clamp.

Torque Value: 11 N•m [100 in-lb]

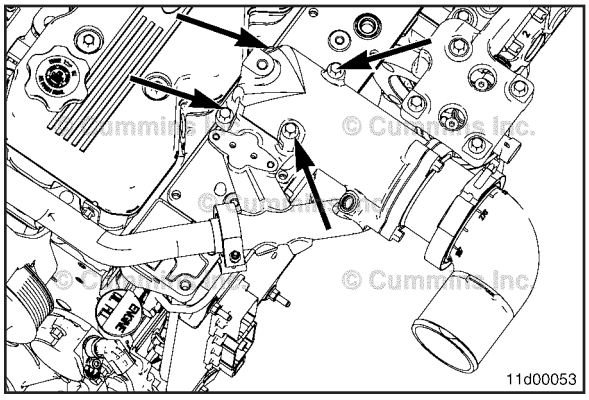
Tighten the support brace capscrews.

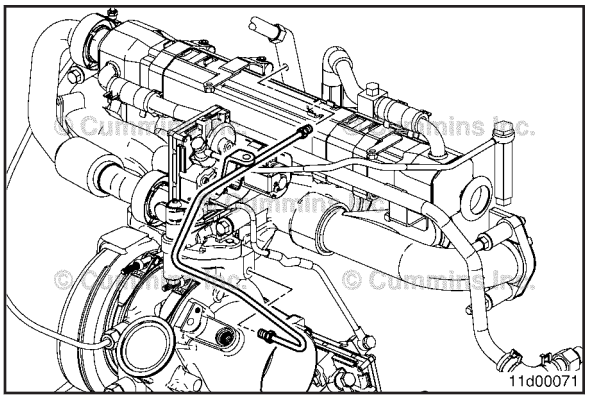
Torque Value: 24 N•m [212 in-lb]

Tighten the air intake connection capscrews, if loosened.

Torque Value: 24 N•m [212 in-lb]

Operate the engine and check for exhaust or boost leaks.





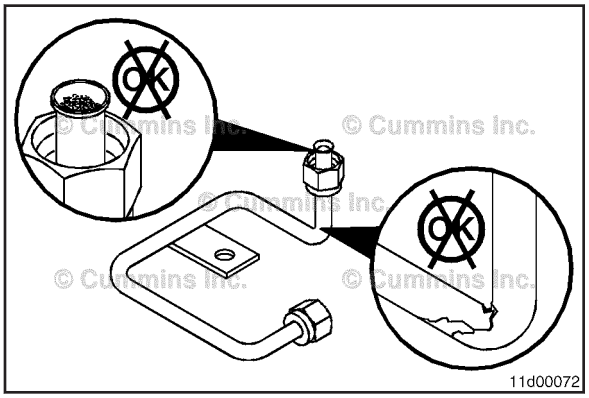
Exhaust Pressure Sensor Tube (011-027)

Remove

Remove the capscrew from the tube bracket.

Loosen the tube nuts at the exhaust manifold and the sensor adapter.

Remove the tube.



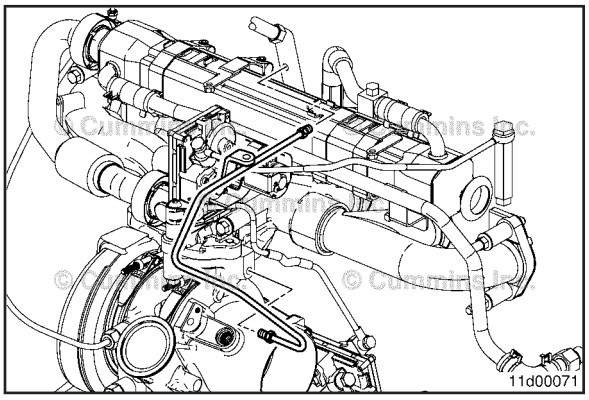
Clean and Inspect

⚠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.

Check the tube for cracks, chafing, pinched areas, and debris.

Clean the tube with solvent and dry with compressed air.



Install

Install the tube.

Connect and tighten the tube nuts.

Torque Value: 10 N•m [89 in-lb]

Start the engine and verify proper operation.

Check for fault codes.

EGR Valve Coolant Lines (011-030)

Preparatory Steps

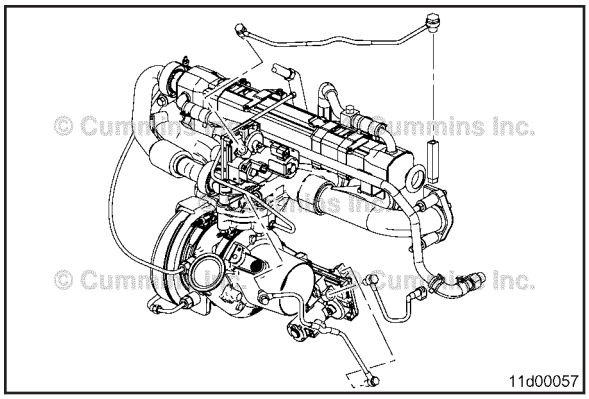
- Drain the coolant. Refer to Procedure 008-018

Remove

NOTE: All lines and banjo screws used in the water plumbing have increased annulus ports. Do **not** use standard lines or banjo screws as a substitute.

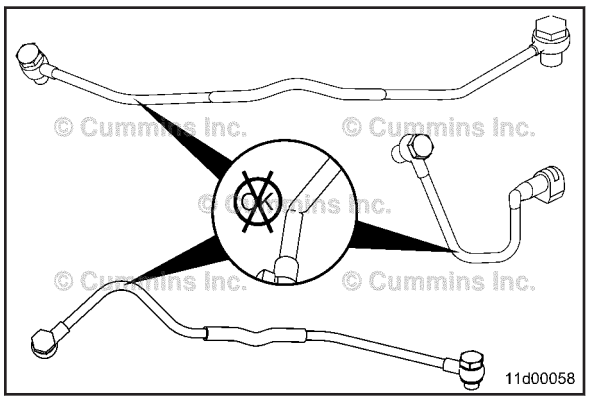
Remove the supply and return coolant lines for the EGR valve actuator.

Discard the banjo seals.

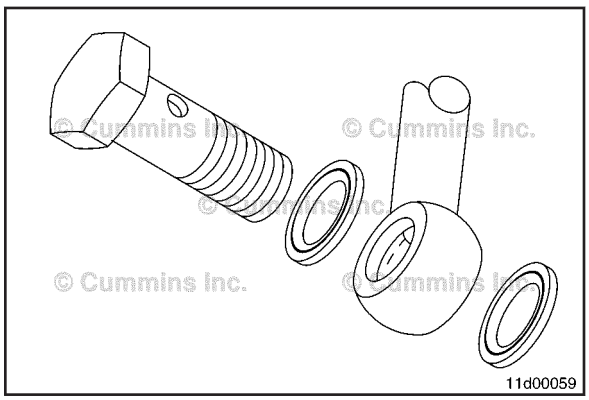


Inspect for Reuse

Inspect the lines for debris, clogging and pinched areas.



Inspect the banjo fittings for damage.



Install

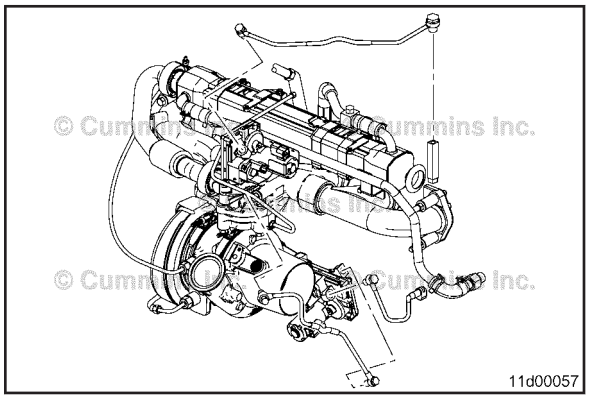
NOTE: All lines and banjo screws used in the water plumbing have increased annulus ports. Do **not** use standard lines or banjo screws as a substitute.

Install the supply and return lines using new banjo seals.

Tighten the fittings.

Torque Value:
10-mm Banjo
Step 1 15 N•m [133 in-lb]

Torque Value:
Vent Fitting Banjo
Step 1 15 N•m [133 in-lb]



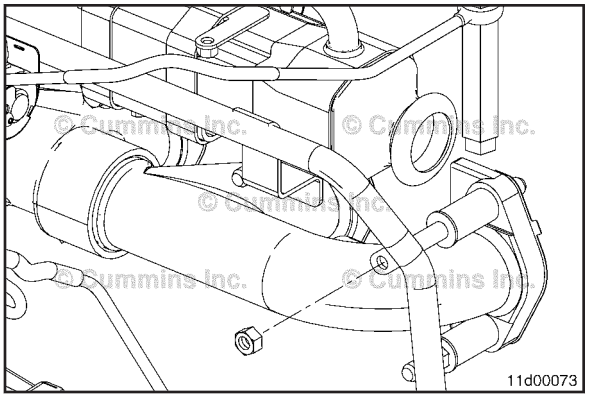
Finishing Steps

- Fill the engine cooling system. Refer to Procedure 008-018

EGR Cooler Coolant Lines (011-031)

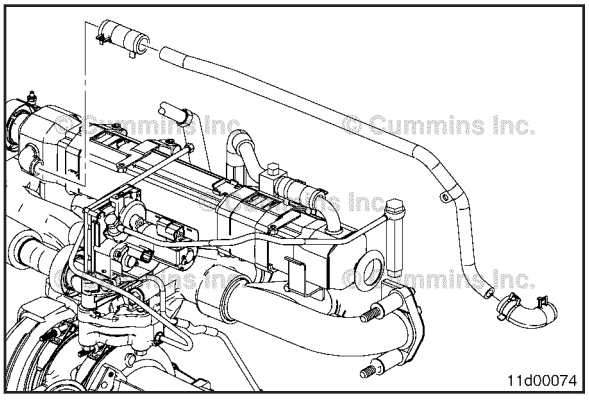
Preparatory Steps

Drain the coolant. Refer to Procedure 008-018



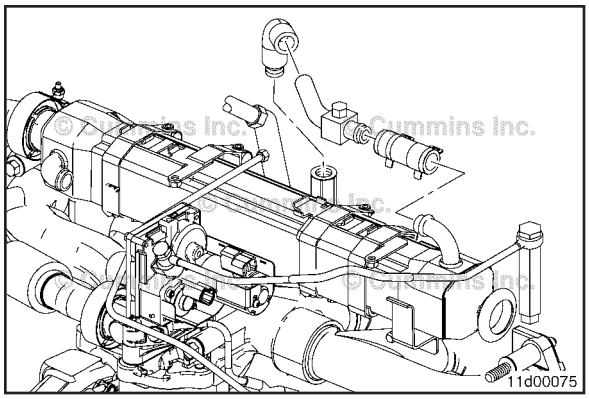
Remove

Remove the nut holding the steel coolant inlet tube bracket to the exhaust manifold.



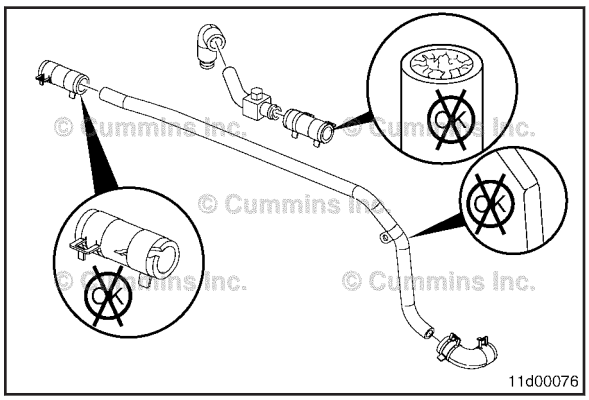
Remove the clamps and hoses from each end and remove the coolant inlet tube.

Remove the clamps and hoses from each end of the coolant return tube on top of the cooler and remove the tube.



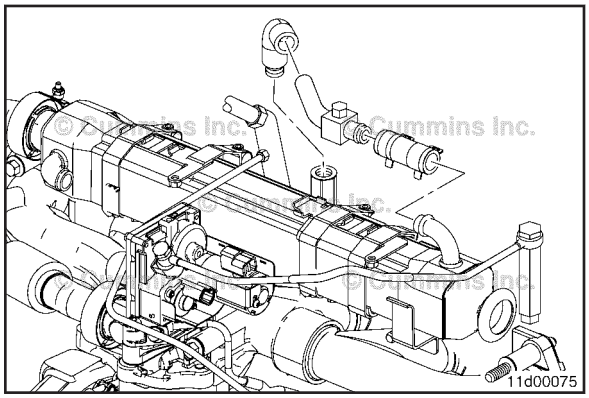
Clean and Inspect

Inspect the hoses and tubes for cracks, plugging, restrictions, and pinched areas.

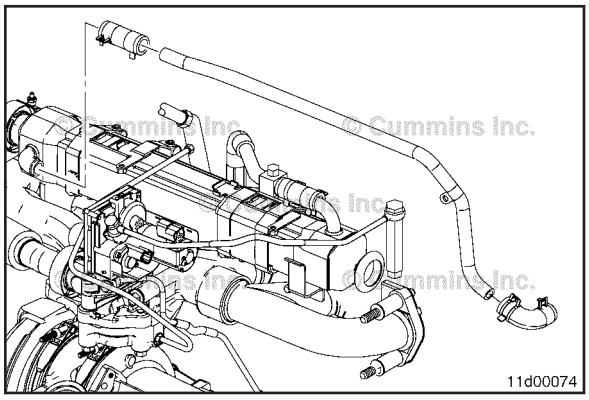


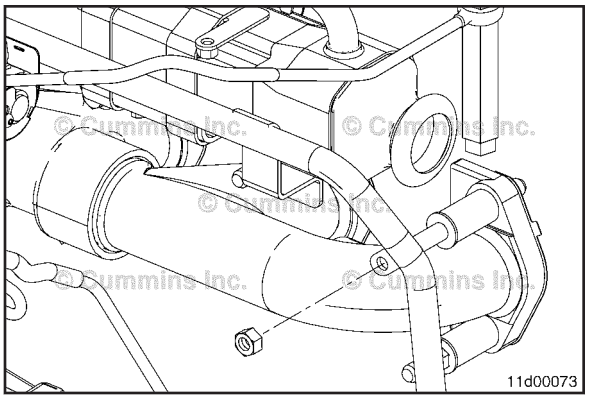
Install

Install the clamps and hoses to each end of the coolant return tube on top of the cooler and install the tube.



Install the clamps and hoses to each end and install the coolant inlet tube.





Install the nut holding the steel coolant inlet tube bracket to the exhaust manifold.

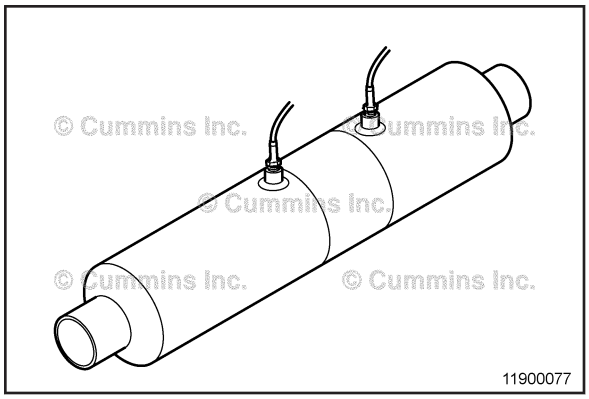
Torque Value: 45 N•m [33 ft-lb]

Finishing Steps

Fill the engine with coolant. Refer to Procedure 008-018

Aftertreatment Selective Catalytic Reduction (SCR) Catalyst (011-036)

General Information



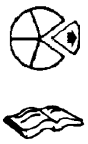
⚠WARNING⚠
The exhaust and exhaust components can remain hot after the vehicle stopped moving. To reduce the risk of fire, property damage, burns or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible materials are located where they are likely to come in contact with hot exhaust or exhaust components.

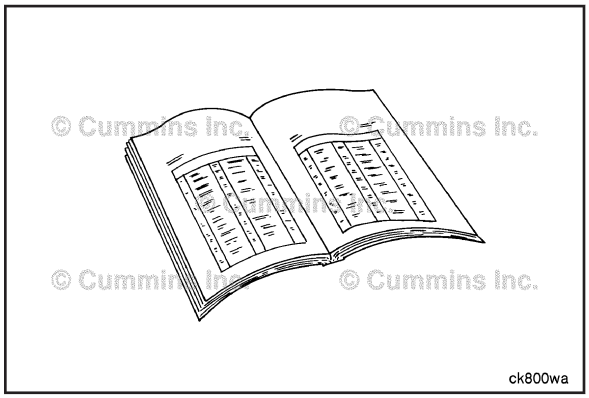
⚠WARNING⚠
The catalyst substrate contains Vanadium Pentoxide. Vanadium Pentoxide has been determined by the State of California to cause cancer. Always wear protective gloves, dust mask, and eye protection when handling the catalyst assembly. Do not get the catalyst material in your eyes. In case of 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.

⚠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 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.

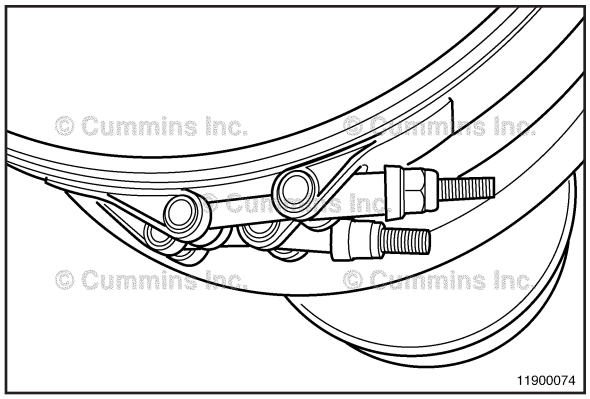
Preparatory Steps





⚠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.

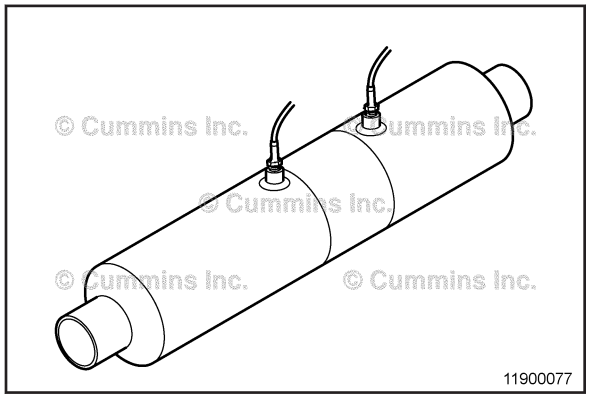
- Disconnect and remove the exhaust gas temperature sensors from the vehicle catalyst. Refer to Procedure 019-013 (Exhaust Gas Temperature Sensor) in Section 19 of the ISB, ISBe4, QSB4.5, QSB5.9, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 Engines, CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416.



Remove

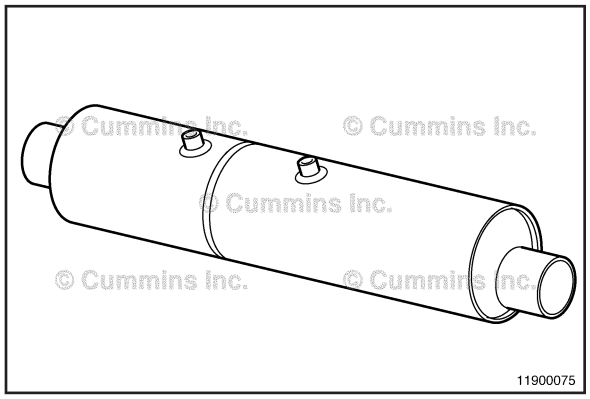
⚠WARNING⚠
The catalyst substrate contains Vanadium Pentoxide. Vanadium Pentoxide has been determined by the State of California to cause cancer. Always wear protective gloves, dust mask, and eye protection when handling the catalyst assembly. Do not get the catalyst material in your eyes. In case of 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.

Disconnect the OEM exhaust connections. Refer to the OEM specifications.



⚠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.



Clean and Inspect for Reuse

⚠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.

Remove any loose paint, corrosion, from exhaust catalyst sealing surfaces with a wire brush.

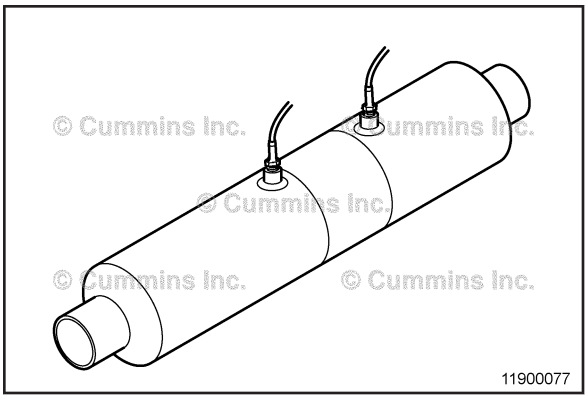
Excessive fuel or oil buildup will damage the exhaust catalyst. If oil from an upstream engine failure is visible in the exhaust plumbing, replace the catalyst. If evidence of fuel in the exhaust stream is apparent and Fault Code 1687 occurs, replace the catalyst.

NOTE: 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. Prior to the replacement of the exhaust catalyst, the source of the upstream failure **must** be identified and corrected.

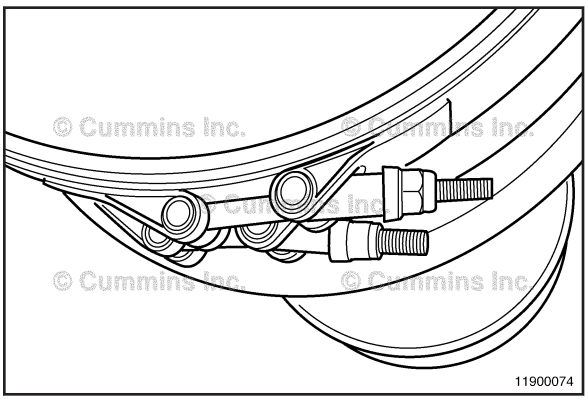
Inspect exhaust catalyst for:

- 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 pipework.

Inspect exhaust catalyst for signs of catalyst solution leaks.



Check/inspect all fittings and supports brackets before reuse.



Install

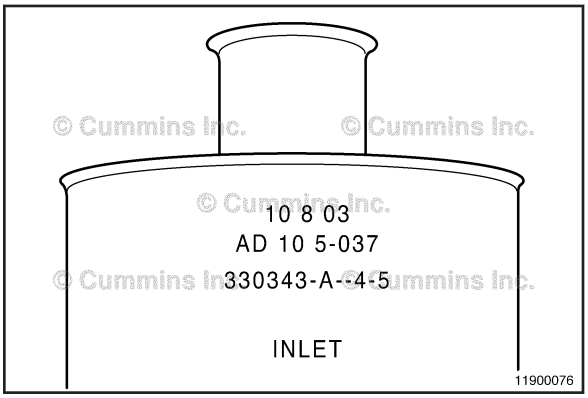
⚠WARNING⚠
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

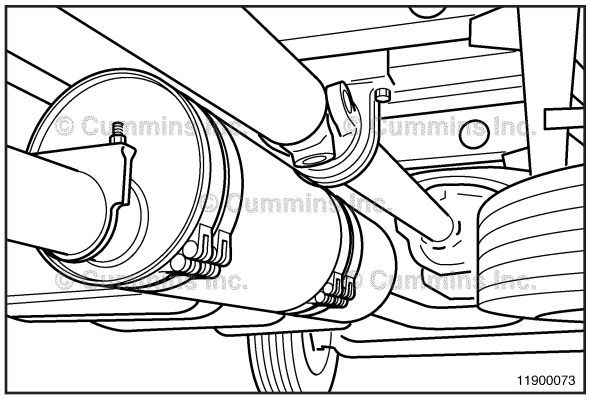
NOTE: Check the correct catalyst part number is selected.

The exhaust catalyst is marked with “INLET” for assembly, (INLET to engine).

Lift the catalyst into position.

Connect the OEM exhaust piping and holding clamps. Refer to the OEM instructions.

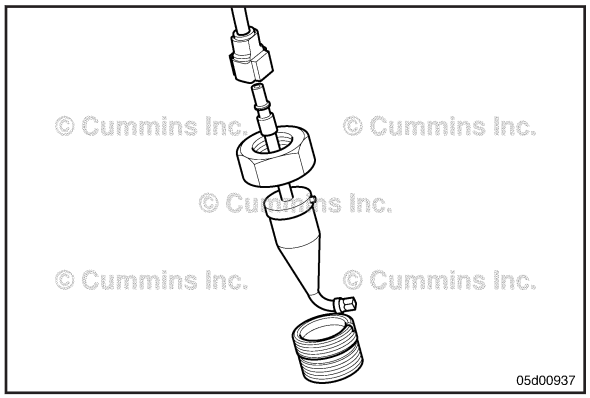




Finishing Steps

⚠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 catalyst assembly.

- Install and connect the exhaust gas temperature sensors. Refer to Procedure 019-013 (Exhaust Gas Temperature Sensor) in Section 19 of the ISB, ISBe4, QSB4.5, QSB5.9, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9 Engines, CM850 Electronic Control System Troubleshooting and Repair Manual, Bulletin 4021416.
- Check all the exhaust system clamps and fittings. Refer to OEM specifications.
- Start the engine and check the system for leaks.



Aftertreatment Nozzle (011-040)

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⚠
Exhaust system may remain hot for extended length of time.

The aftertreatment nozzle is used to spray diesel exhaust fluid into the exhaust system.

It is made from stainless steel.

Care should be taken when handling the aftertreatment nozzle, as there is ceramic insulation inside the nozzle. This is **not** replaceable and damage will **not** be evident if it is accidentally dropped.

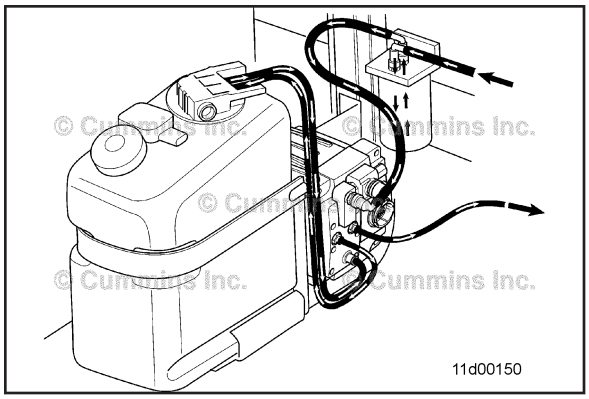
NOTE: Be sure the aftertreatment nozzle has been exposed to exhaust temperatures warmer than 120°C [248°F] for 3 minutes, to be sure the aftertreatment nozzle can be cleared. Failure to make this check can result in an incorrect nozzle repair.

If the aftertreatment nozzle is being removed for inspection, make certain it has been warmed in the exhaust prior to removal. If the engine was operated to normal operating temperature within 3 hours of the nozzle removal, operating the engine to warm the nozzle is **not** necessary.

Initial Check

Visually check the pipework going to and coming from the aftertreatment diesel exhaust fluid dosing unit for any signs of a leak.

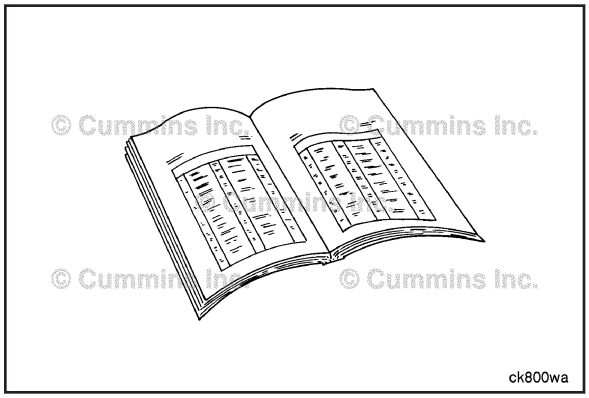
Diesel exhaust fluid leaks will leave a white deposit around the fittings.



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.

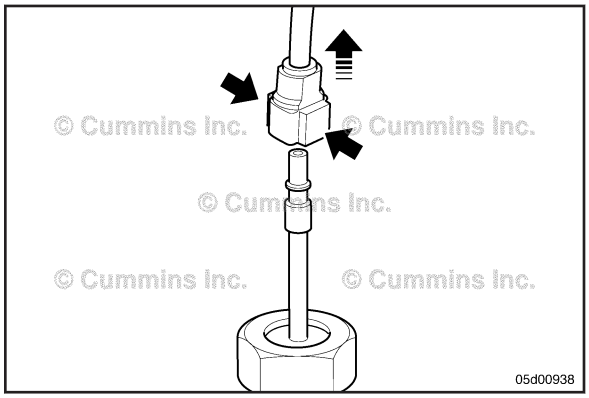
- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.



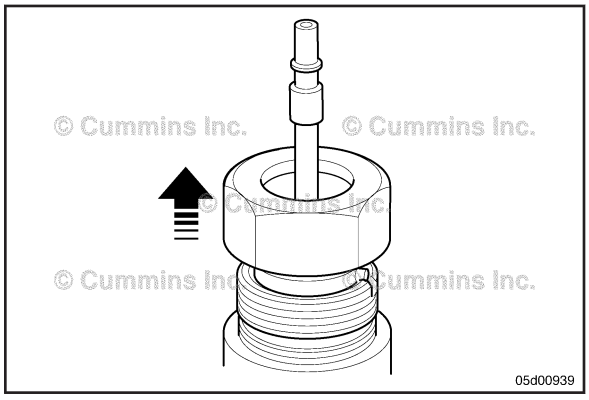
Remove

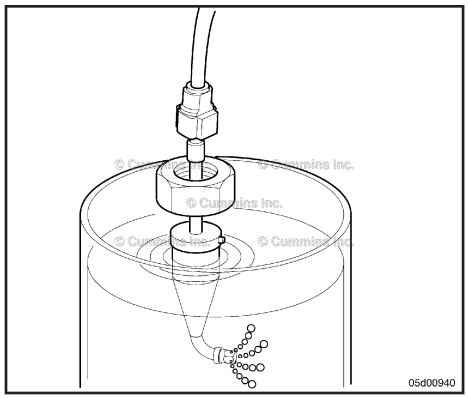
Disconnect the diesel exhaust fluid supply pipework from the aftertreatment nozzle and drain any excess catalyst solution into a suitable container. The fitting is a quick release fitting; to release, press both sides of the fitting.

Remove the aftertreatment nozzle retaining nut.



Lift the aftertreatment nozzle out of the exhaust system locating boss.





Clean and Inspect for Reuse

⚠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.

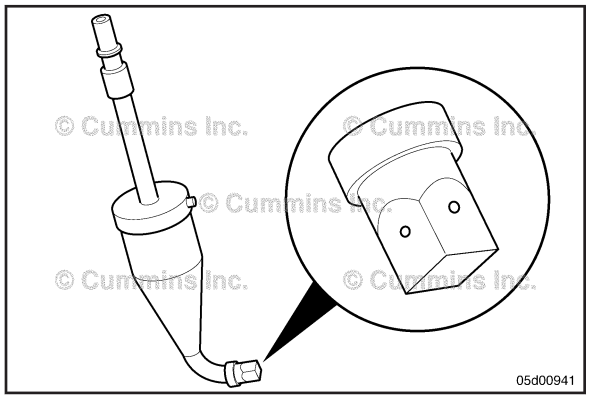
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

To clean the nozzle use hot water, warmer than 40°C [104°F], to make sure the crystals inside the nozzle can be removed.

Immerse the aftertreatment nozzle in a suitable container of clean, warm water.

Connect an air line with a pressure of no more than 69 kPa [10 psi], and blow through the aftertreatment nozzle. When immersed in water, the different spray angles from each hole will be clearly visible.

Dry with compressed air.

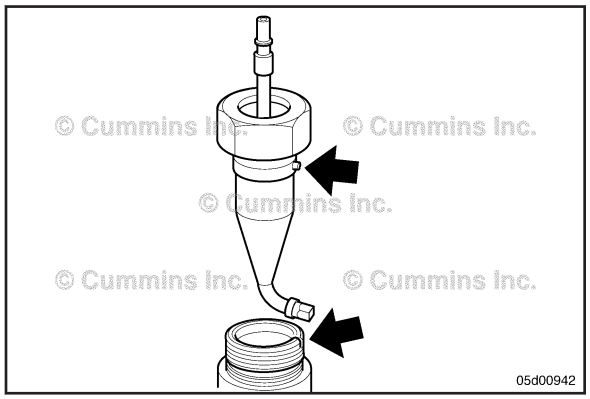


Visually inspect the tip of the aftertreatment nozzle.

All spray holes should be clearly visible.

Visually 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

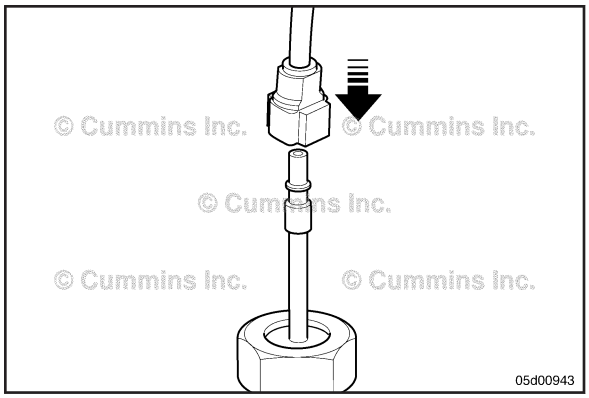
Install the aftertreatment nozzle into the exhaust system locating boss. A keyway in the exhaust system locating boss will orientate the aftertreatment nozzle correctly.

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]

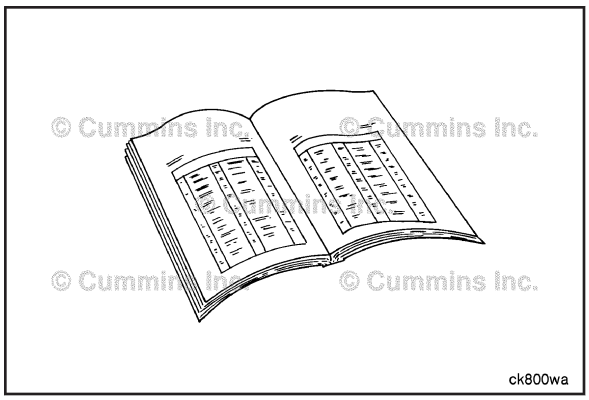
Connect the diesel exhaust fluid supply to the aftertreatment nozzle.

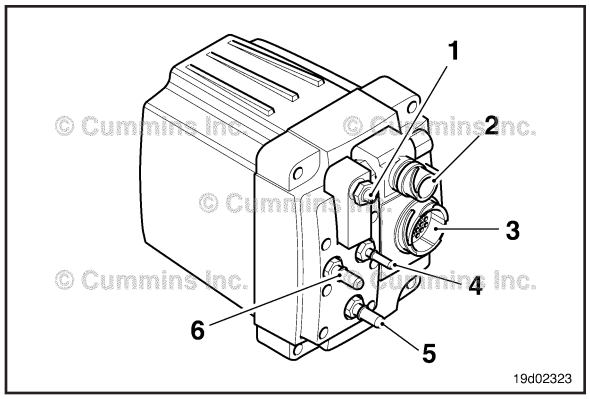


Finishing Steps

⚠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 (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

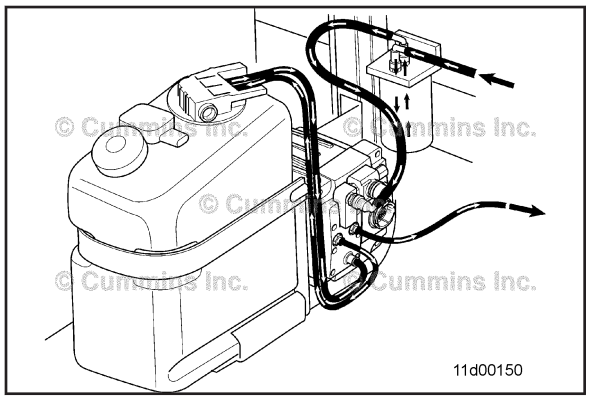
4 DEF supply to aftertreatment nozzle polytetrafluoroethylene (PTFE) line.

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

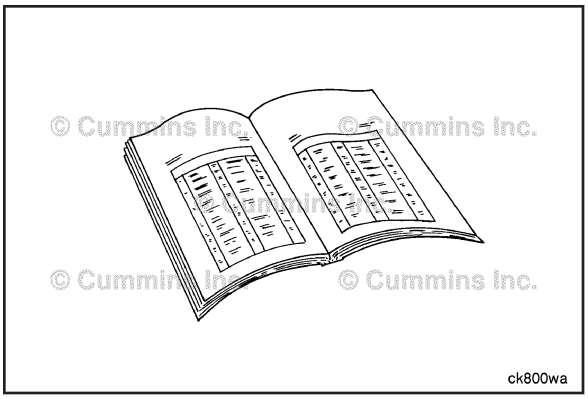
©heck the DEF nozzle supply line for signs of damage or leaks.

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.

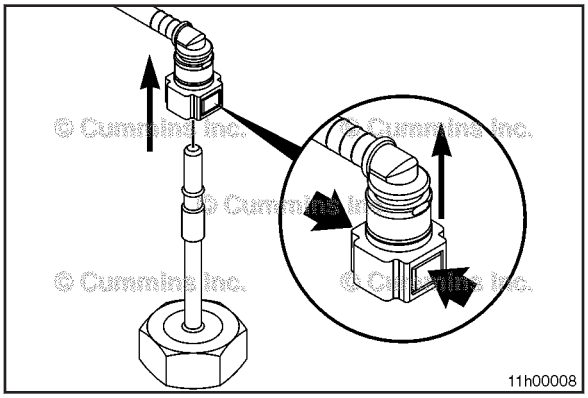
- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.



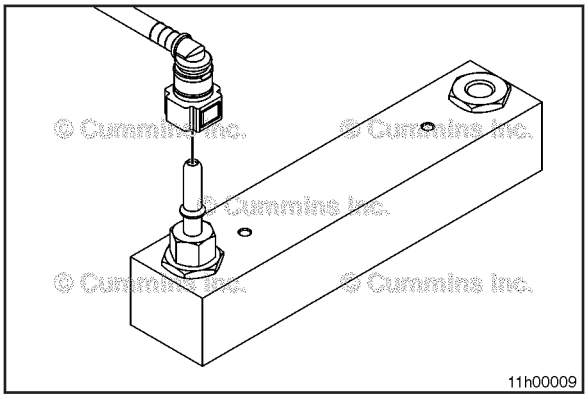
Remove

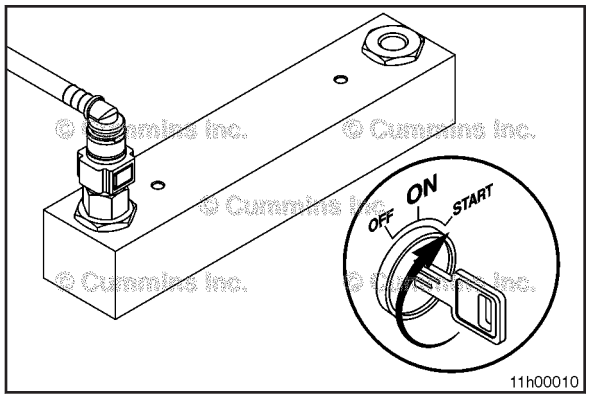
⚠WARNING⚠
DEF contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety data sheet (MSDS) for 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.

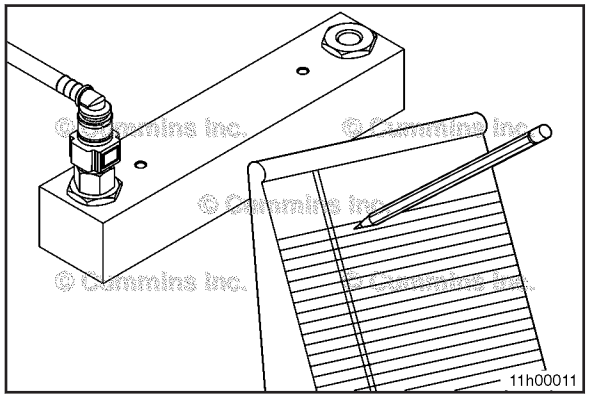
Start the vehicle and wait 140 seconds for the pump to begin the prime cycle.

⚠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.



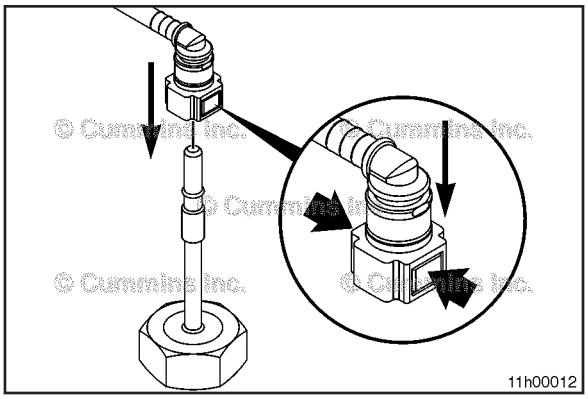
⚠WARNING⚠
The exhaust and exhaust components can remain hot after the engine has been shut down or secured. To avoid the risk of fire, property damage, burns, or other serious personal injury, allow the exhaust system to cool before beginning this procedure or repair and make sure that no combustible 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

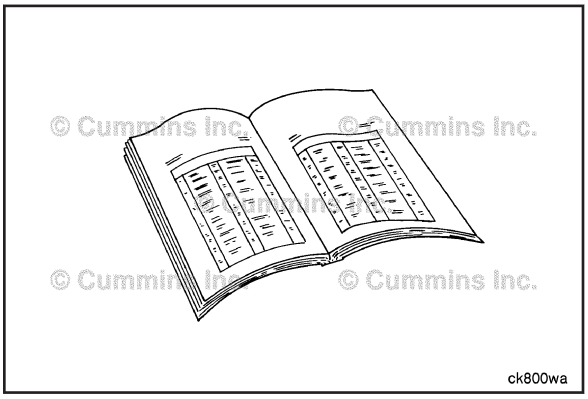


⚠WARNING⚠
DEF contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety data sheet (MSDS) for additional information.

Remove the airflow meter from the aftertreatment nozzle line.

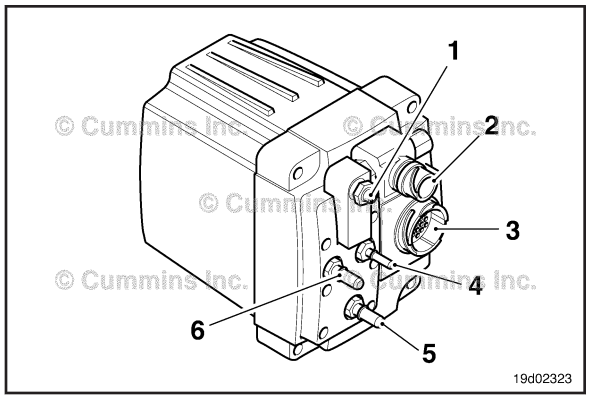
Connect the aftertreatment nozzle line to the aftertreatment nozzle.

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

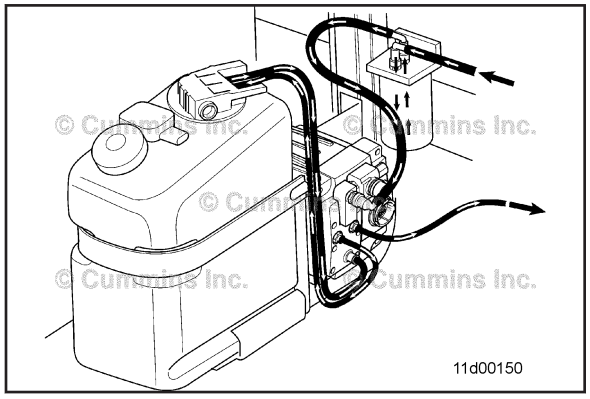
4 DEF supply to aftertreatment nozzle (PTFE line)

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.



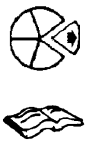
Initial Check

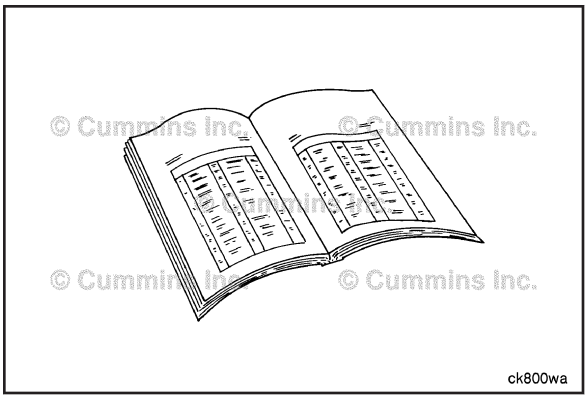
Visually check the DEF supply and return lines and fittings for signs of damage, leaks, or faulty connectors.

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.

Preparatory Steps



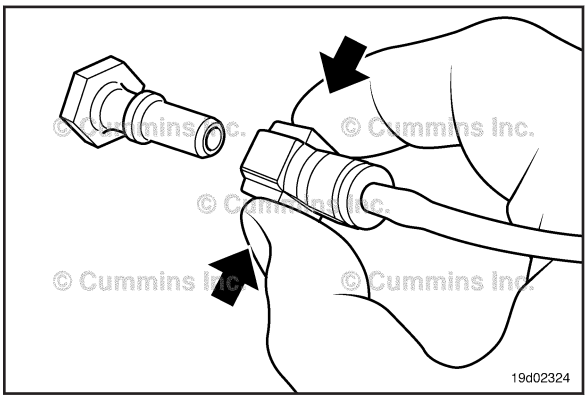


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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.

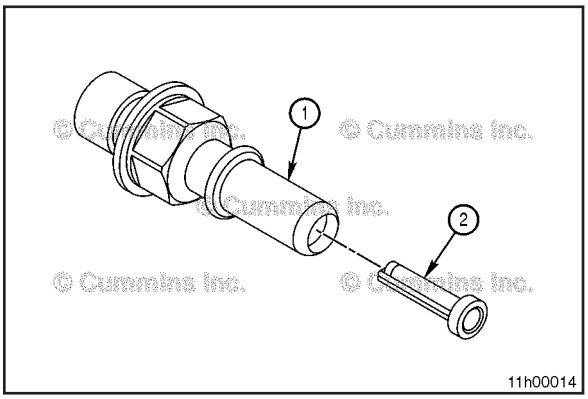
Remove the DEF supply line fitting.

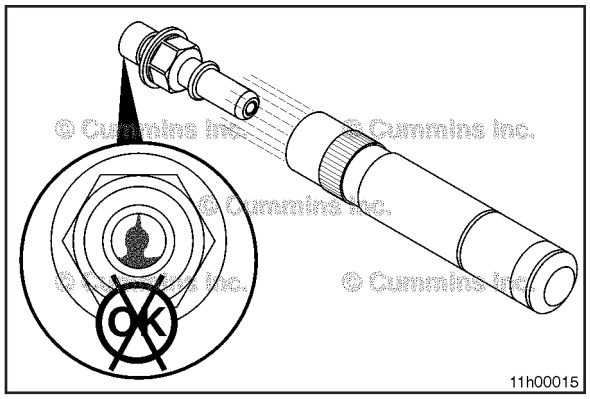
The inlet fitting and screen filter as illustrated:

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**.

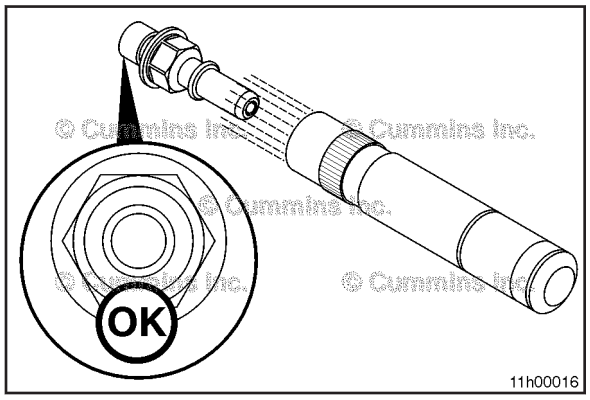




Inspect for Reuse

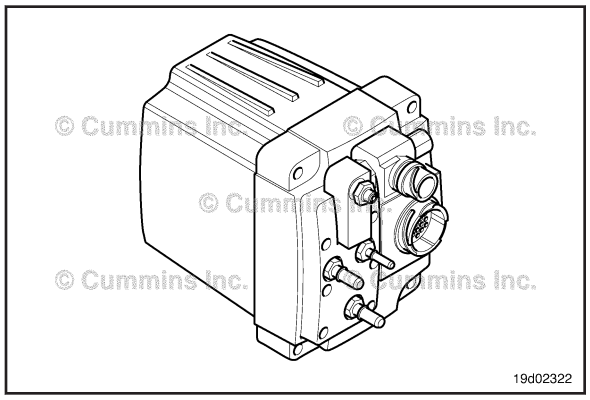
⚠WARNING⚠
Diesel exhaust fluid (diesel exhaust fluid) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the diesel exhaust fluid is ingested, contact a physician immediately. 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.

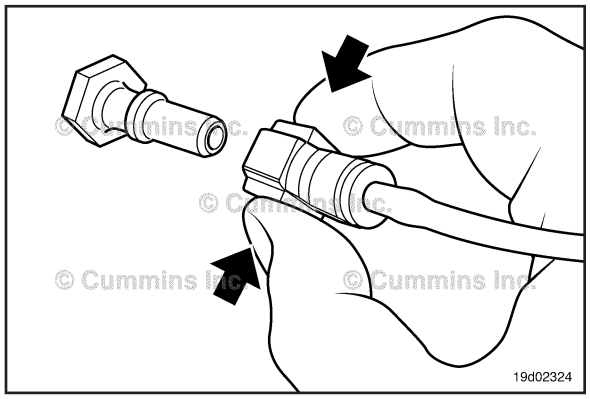


Install

⚠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]

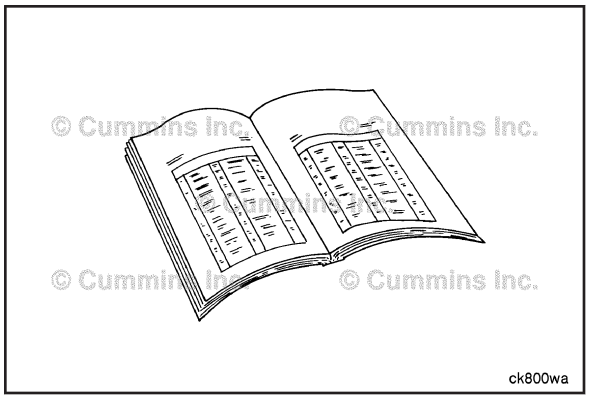


Connect the DEF supply line to the DEF dosing unit.

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 Dosing Unit Air Side Flushing (011-082)

General Information

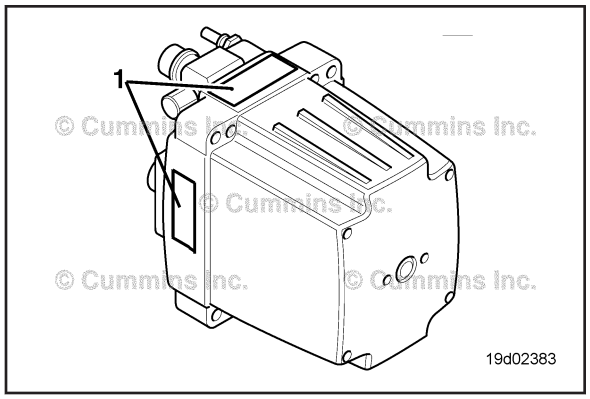
⚠WARNING⚠
Diesel exhaust fluid (DEF) contains urea. Do not get the substance in your eyes. In case of contact, immediately flush eyes with large amounts of water for a minimum of 15 minutes. Do not swallow. In the event the DEF is ingested, contact a physician immediately. Reference the materials safety 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.

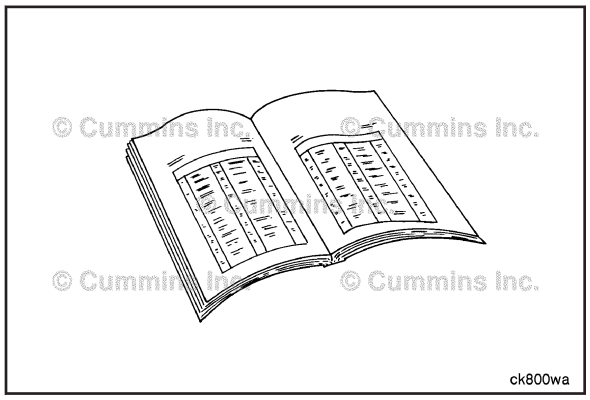
Remove the aftertreatment nozzle and make sure that it is completely clear of blockage. Refer to Procedure 011-040 in Section 11.

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.

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)

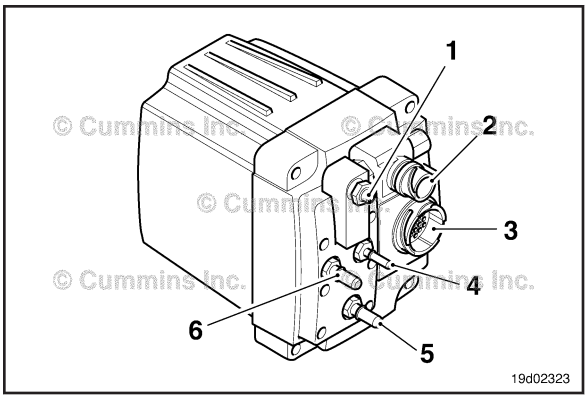
3 ITT Cannon™ on connector (37-pin)

4 DEF supply to aftertreatment nozzle (PTFE line)

5 DEF supply to pump

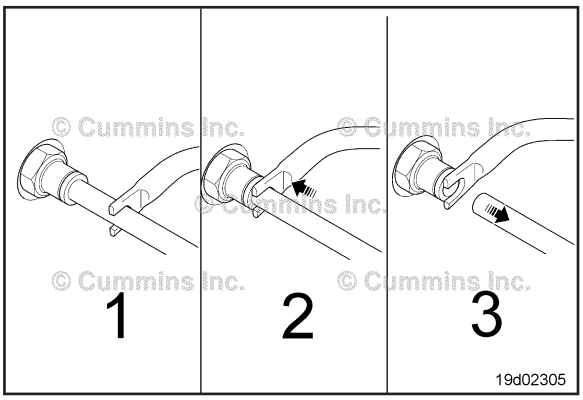
6 DEF return.

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 DEF dosing unit. To release the fitting, apply equal pressure to both sides of the release collar, and pull the pipe from the fitting.

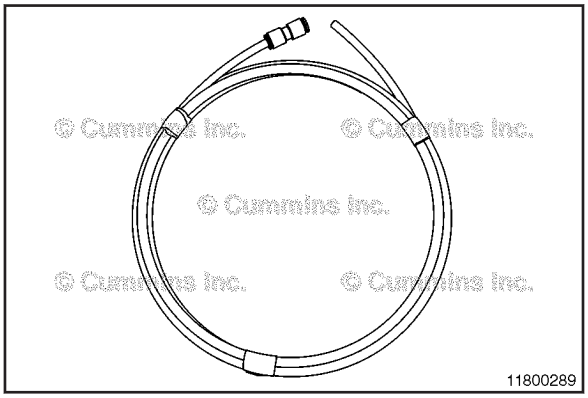


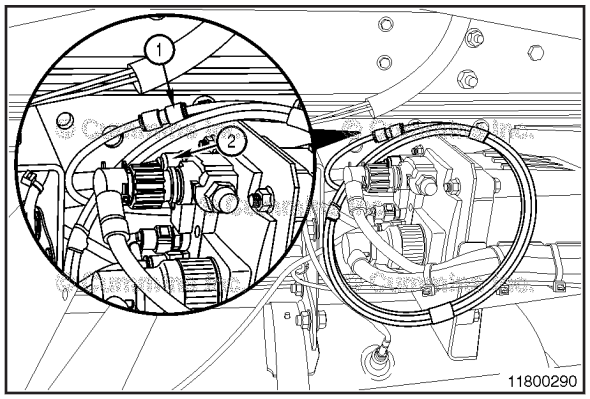
NOTE: Make sure the vehicle air supply to the DEF dosing unit is either drained down or isolated before removing the air supply line.

- Disconnet the air supply line to the dosing unit.

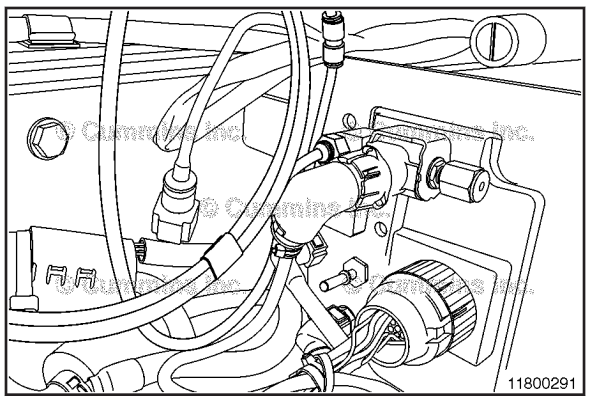


- Coil the polytetrafluoroethylene (PTFE) pipe and fasten using tape. Fill the piping with clean water.





- 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 DEF 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.

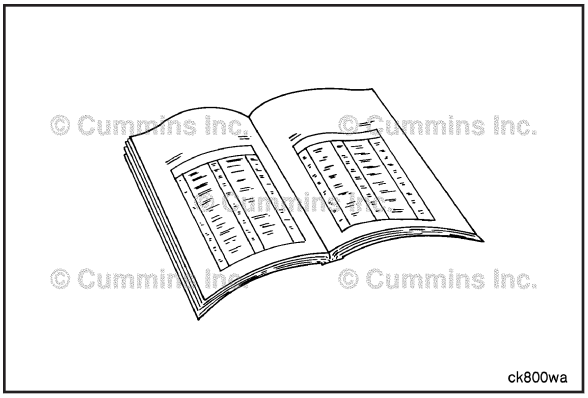
If the air flow is less than the specification or if air leaks from the air regulating unit, the dosing unit will require replacement. Refer to the OEM service manual or contact a Cummins® Authorized Repair Location.

Remove the air flow meter from the aftertreatment nozzle DEF supply line and connect the DEF supply to the aftertreatment nozzle. Refer to Procedure 011-040 in Section 11.

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.

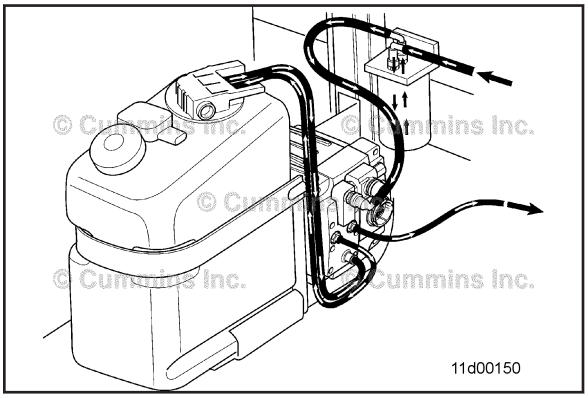


Aftertreatment Diesel Exhaust Fluid Tank Filter (011-083)

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.

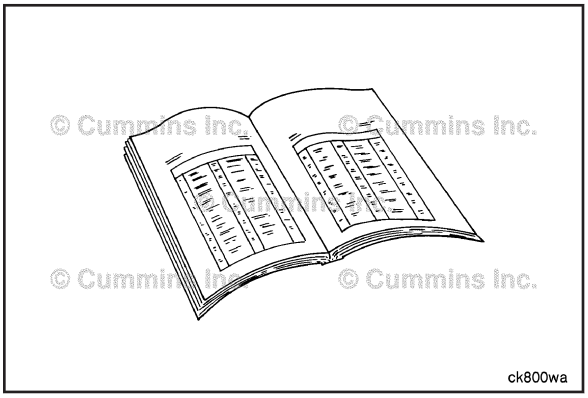
⚠WARNING⚠
To reduce the possibility of personal injury, wear goggles and protective clothing.

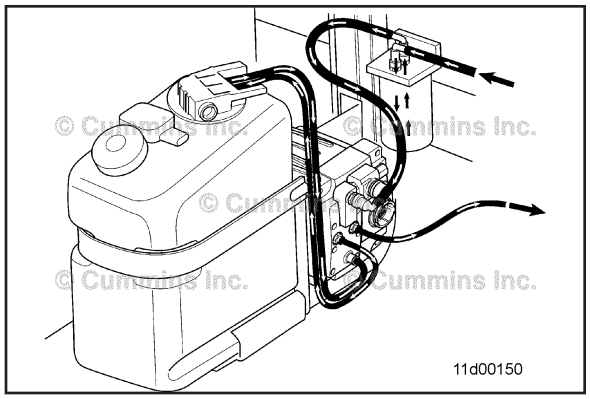


Preparatory Steps

⚠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.





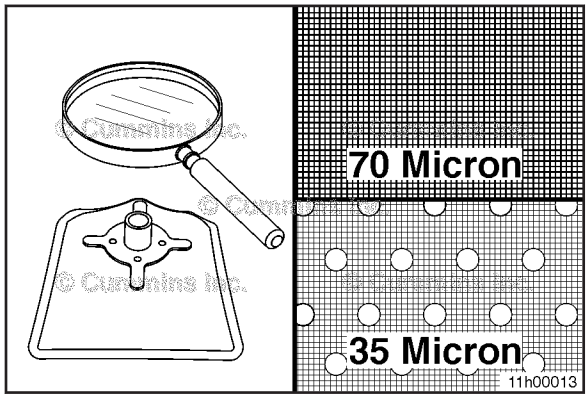
Remove

⚠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.



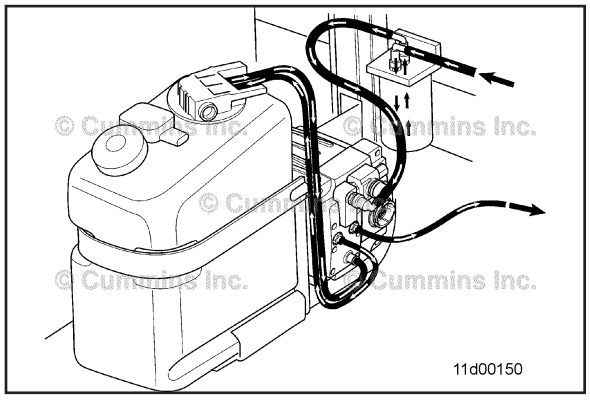
Inspect for Reuse

⚠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.

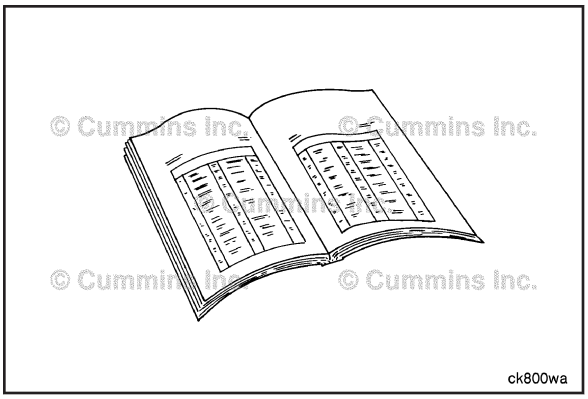
Install the electrical connections and pipework that is attached to the DEF tank level sensor assembly.

Refer to the OEM service manual for instructions.

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.



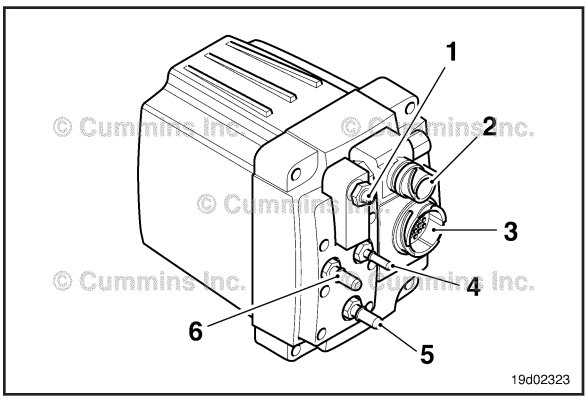
Aftertreatment Diesel Exhaust Fluid Line Restriction Test (011-086)

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.

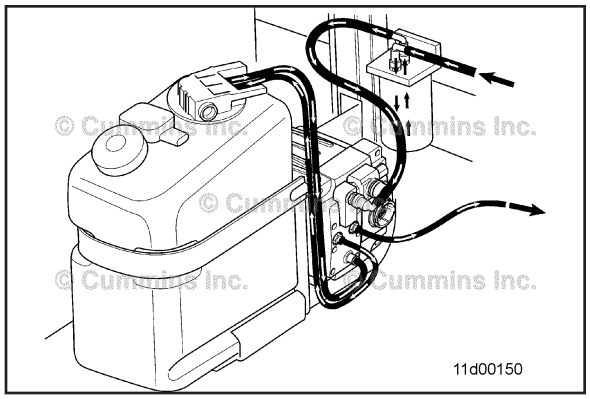
The diesel exhaust fluid (DEF) dosing unit connections are illustrated:



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

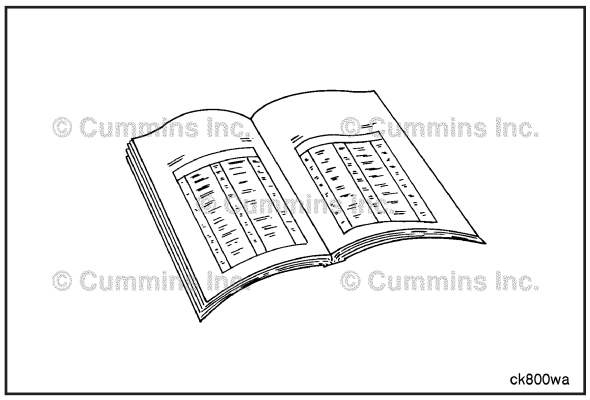
Visually check the DEF supply and return lines and fittings for signs of damage, leaks, or faulty connectors.

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.

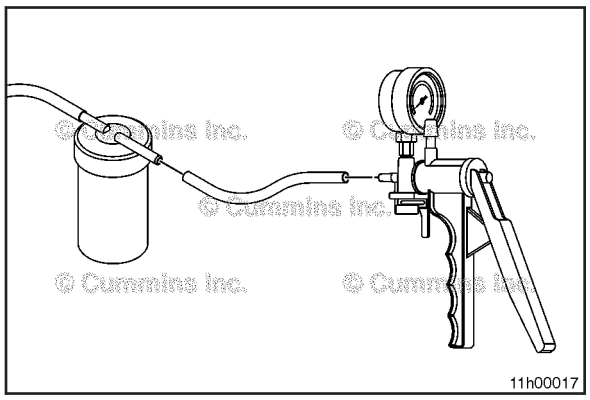


Preparatory Steps

⚠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.

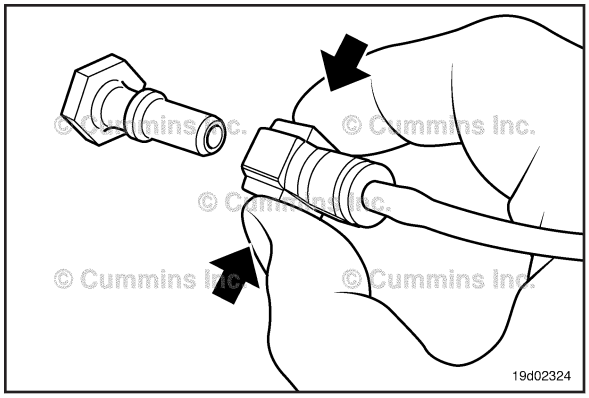
2 Block one end of the DEF supply line and attach the male J2044 line from the vacuum test kit to the opposite end.

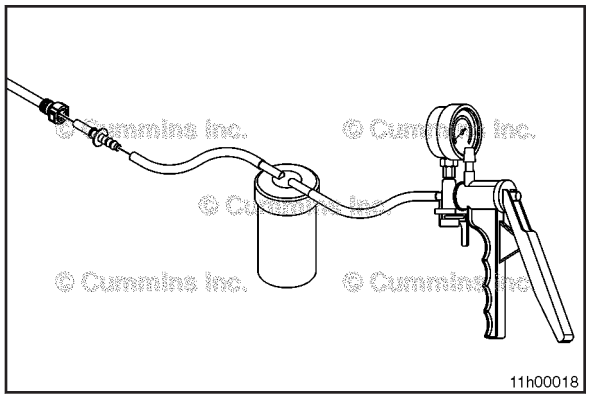
3 Slowly operate the vacuum pump until a vacuum of 15 kPa [2 psi] is achieved, then hold for 60 seconds. Observe the gauge to confirm that the pump holds the vacuum, with no noticeable change to gauge reading. If the gauge value changes in this time, a leak exists in the system. Disconnect the vacuum 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

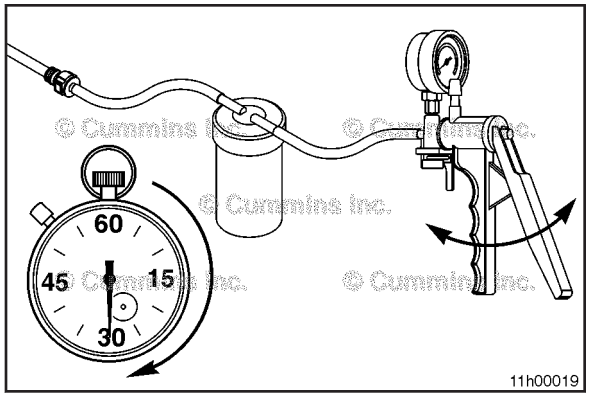
1 Connect the male J2044 line from the vacuum test kit to the DEF supply line to dosing unit connector.

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

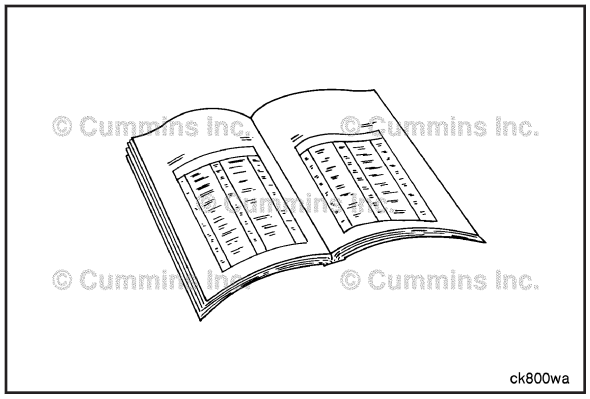
1 Connect the male J2044 line from the vacuum test kit to the DEF return line to dosing unit connector.

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.

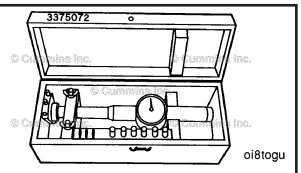
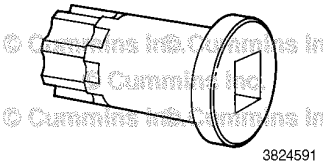
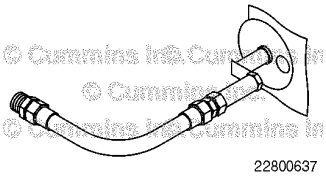
Section 12 - Compressed Air System - Group 12

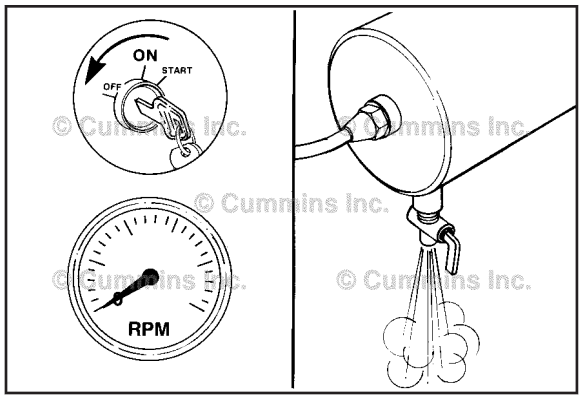
Section Contents

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
3376619	**Dial Bore Gauge** Used to measure the cylinder bores.	
3824591	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	
4918883	**Air Compressor Discharge Tool** Used to measure acceptable oil carryover on Knorr-Bremse™ air compressors.	



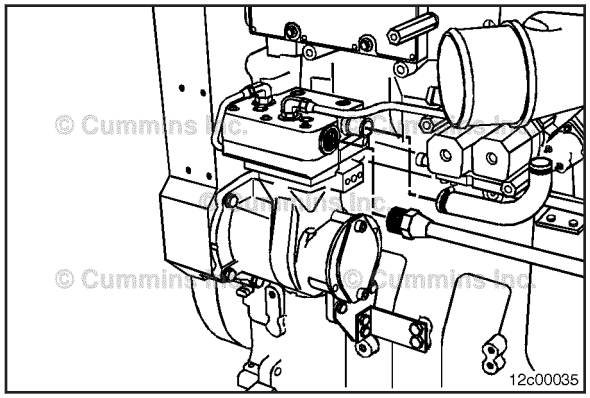
Air Compressor Carbon Buildup (012-003)

Initial Check

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

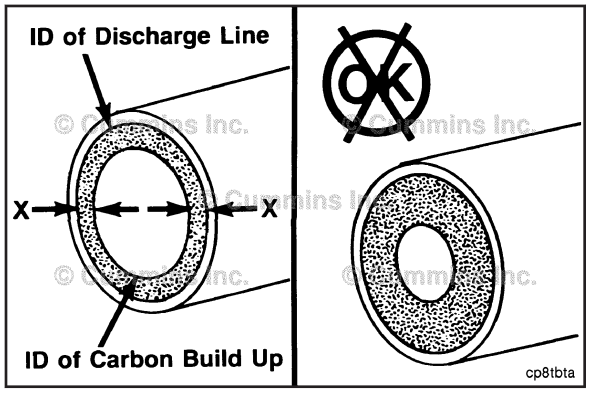
Shut the engine OFF.

Open the drain cock 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.

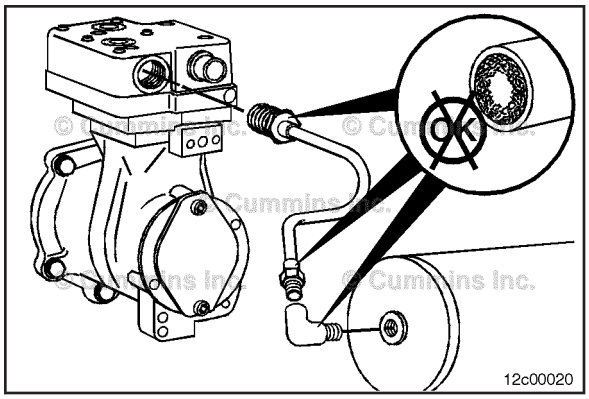
NOTE: The carbon buildup thickness **must not** exceed 1.6 mm [0.06 in].

⚠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 OEM service manual for specifications.

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 the manufacturer's 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 original equipment manufacturer (OEM) service manual for cleaning or replacement instructions.



Preparatory Steps

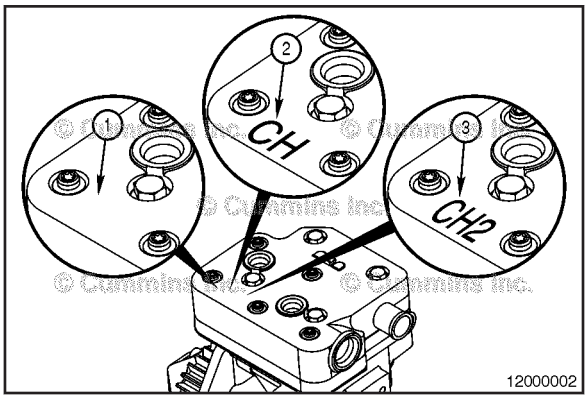
Check the marking on the air compressor head before cleaning or replacing the cylinder head.

Repair Direction:

1 No marking: Perform On-Engine Repair.

2 CH marking: Perform Off-Engine Repair.

3 CH2 marking: Replace the air compressor cylinder head. Refer to Procedure 012-007 in Section 12.



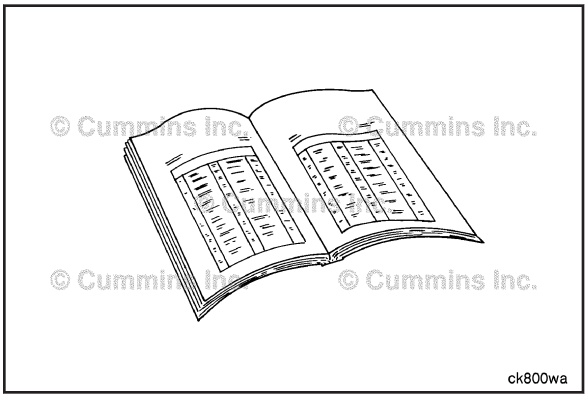
Clean

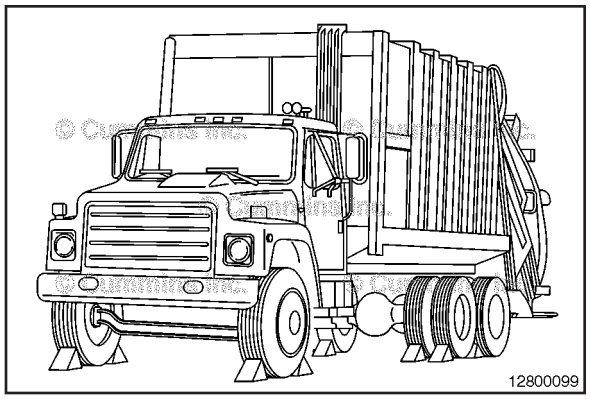
On-Engine Repair

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.

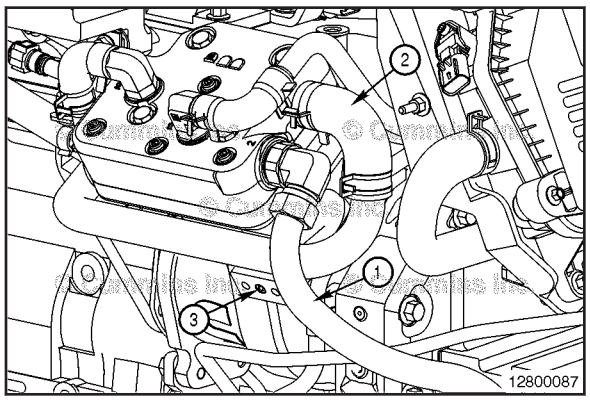
The items below are **not** included in the air compressor cleaning kit, Part Number 2892280, but are required to perform the repair.

- Regulated shop air 621 kPa [90 psi]
- Automatic transmission fliud (ATF)
- Shop rags, and a 19 liter [5 gal] bucket
- INSITE™ electronic service tool.

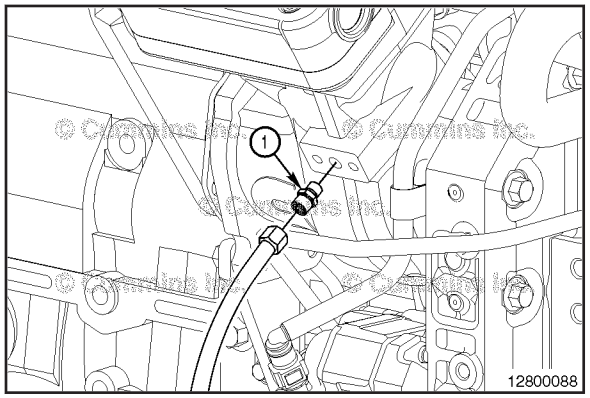




Park vehicle on a level surface and in an area where it is safe to idle for an extended period of time. Chock the vehicle wheels, and completely drain the vehicle air system.



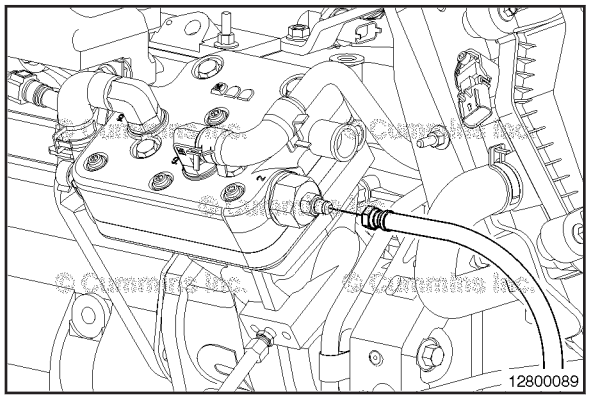
Remove the air compressor discharge line (1), air compressor intake line (2), and air governor signal line (3) at the air compressor.



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.

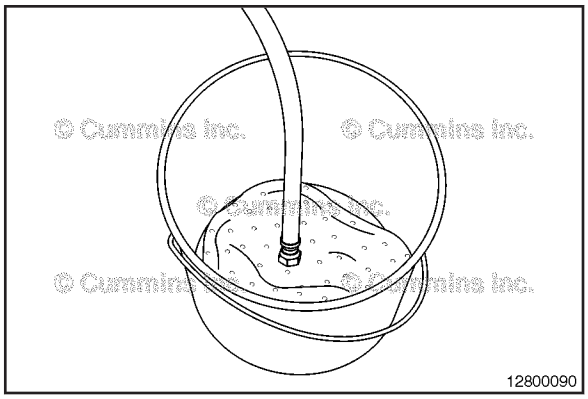
NOTE: Some air compressors have two unloader ports in the air compressor housing. Make sure that one of the ports is plugged with an appropriate pipe plug.



△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.

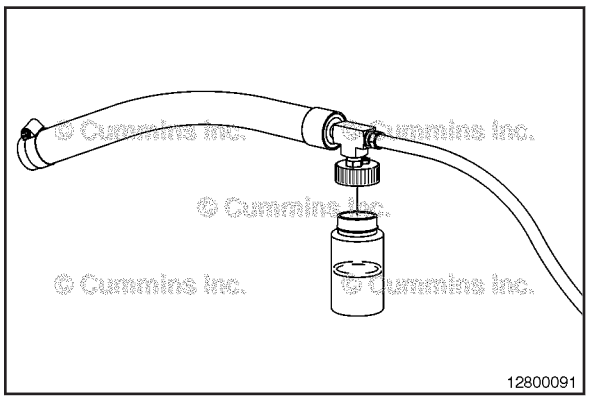
Place the discharge line into a 19 liter [5 gal] bucket and cover with several oil absorption pads.



Pour 89 ml [3 fluid ounces] of automatic transmission fluid into the dispensing bottle.

Install the dispensing bottle onto the dispensing hose assembly.

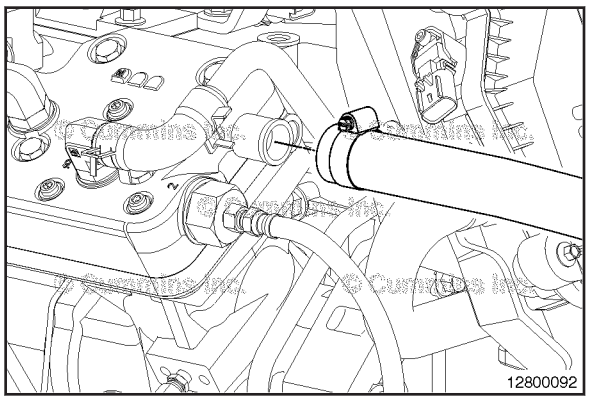
NOTE: For best results, use Dexron III automatic transmission fluid or equivalent.



Install and tighten the dispensing hose assembly and clamp to the intake port of the air compressor cylinder head.

Connect regulated shop air at 621 kPa [90 psi] to the air compressor cleaner.

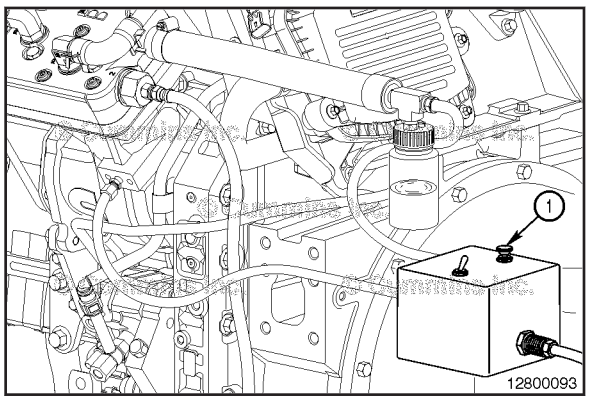
NOTE: The next three steps will happen quickly. For best results, read the remaining instructions prior to continuing with the cleaning procedure. Do **not** cycle the unloader until all 89 ml [3 fl oz] of ATF have been applied.

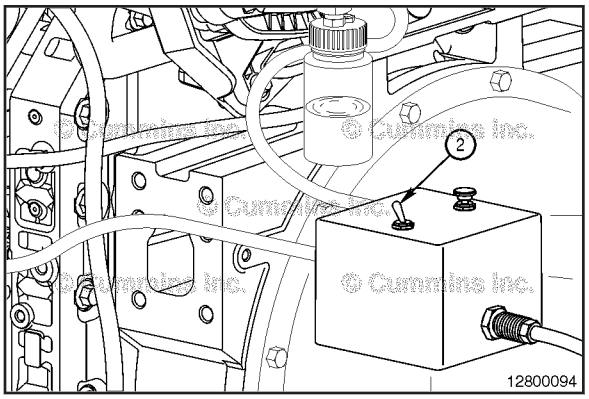


Start the engine, and let it idle for 1 minute.

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.

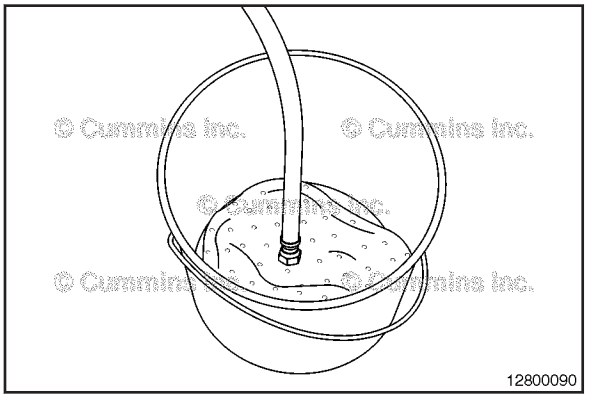




Pour 89 ml [3 fl oz] of automatic transmission fluid into the dispensing bottle, and install back onto the dispensing hose assembly.

Toggle the ‘Unloader’ switch (2) on to apply air pressure to the unloader signal port.

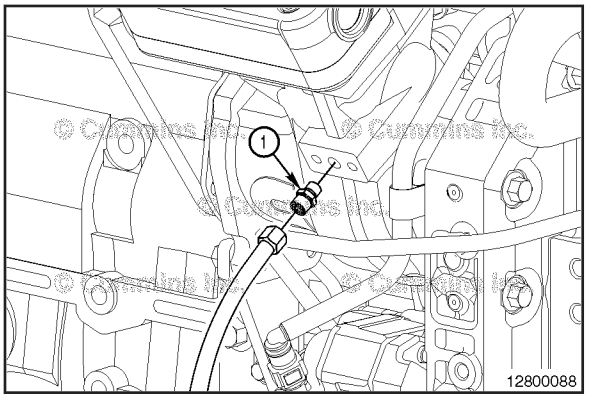
Do **not** relieve pressure at the unloader valve at this time.



Start the engine.

Immediately depress and hold the ‘Clean’ button on the air compressor cleaner until all 89 ml [3 fl oz] of automatic transmission fluid have been dispensed. Continue to hold the ‘Clean’ button down for an additional 10 to 20 seconds.

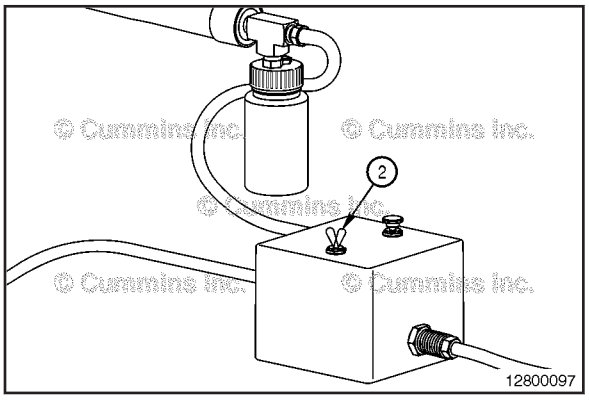
NOTE: A heavy mist of automatic transmission fluid will be coming from the discharge hose.



Shut the engine OFF.

Remove the discharge hose assembly from the air compressor cylinder head intake port.

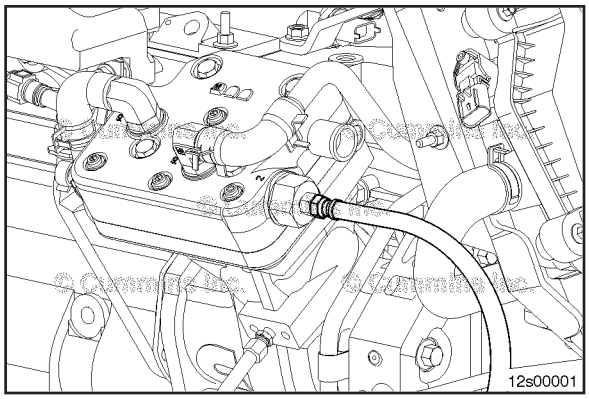
Start the engine.



Continuously cycle the ‘Unloader’ switch on the air compressor cleaner for up to 25 cycles.

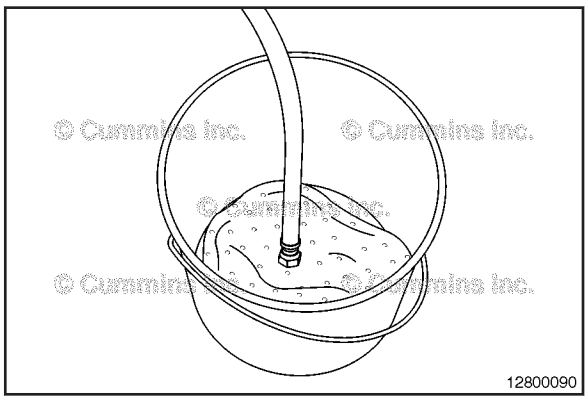
NOTE: When the air compressor cylinder head has been adequately cleaned, there should be an audible difference between loaded and unloaded states of the air compressor. Installation of a 1.5 meter [5 ft] length of rubber hose over the intake port may help to audibly identify when the unloader is functioning 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.



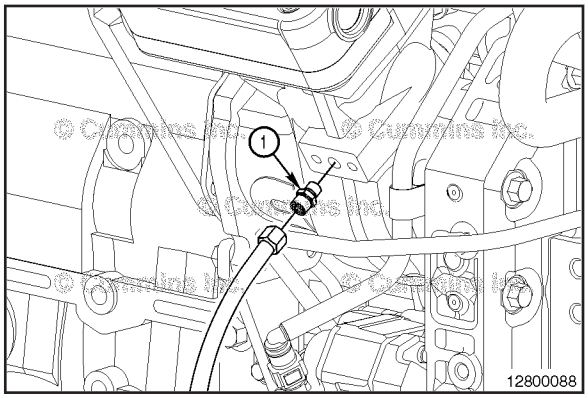
⚠CAUTION⚠
Operating the air compressor with no filter in place at the intake port may allow dust or debris to enter the air compressor. A rubber hose should be placed over the intake port and routed to an area free of airborne dust and debris.

With the discharge hose still installed, relieve the pressure at the unloader port (switch OFF), and operate the engine at high idle for 3 to 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).

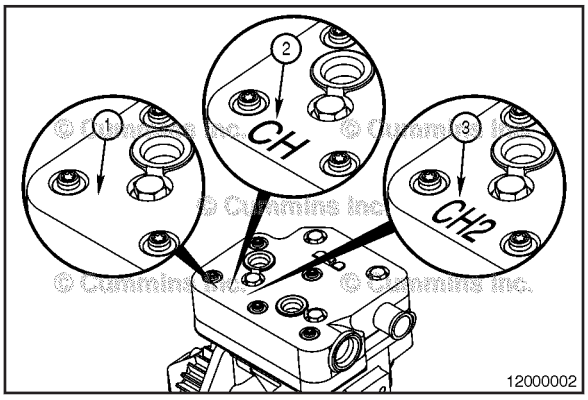


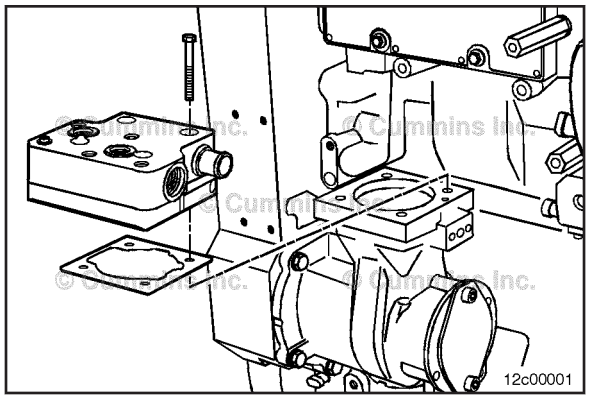
Use an engraving pen and mark the letters CH below the head bolt as shown.

Perform the Air Compressor Diagnostic Test to verify the air compressor is functioning properly.

- For ISBe, ISB, and QSB (Common Rail Fuel System) engine, use the following procedure. Refer to Procedure 012-014 in Section 12.
- For QSB4.5 CM2250 EC engine, use the following procedure. Refer to Procedure 012-014 in Section 12.

If the air compressor does **not** function properly, perform the Off-Engine Repair.





Off-Engine Repair

⚠WARNING⚠
Use skin and eye protection when handling caustic solutions to reduce the possibility of personal injury.

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

△CAUTION△
Do not use a sharp object to remove carbon. The sealing surfaces can be damaged.

△CAUTION△
Avoid getting debris and solvents into the clearance between the piston and bore.

△CAUTION△
Avoid the use of abrasive products similar to "Scotch Brite™" because any abrasive grit left after cleaning will shorten the life of the air compressor.

Remove the compressor head and valve assembly. Refer to Procedure 012-007 in Section 12.

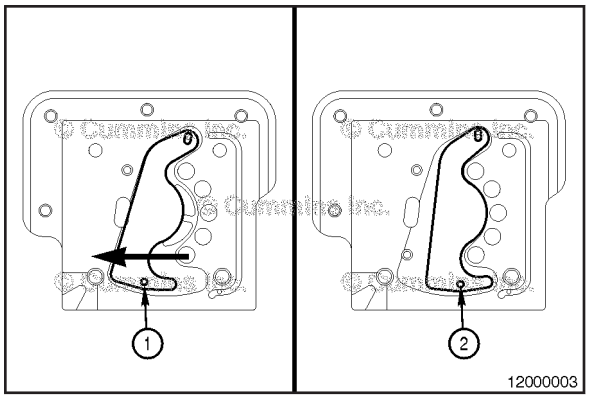
Remove carbon from the compressor head and valve assembly components with a non-abrasive solvent and a non-metallic brush.

NOTE: Using an abrasive solvent like carburetor cleaner can lead to further lubrication loss in the air compressor head.

Blow out passages with compressed air.

Verify the unloader slider plate is fully closed when at rest.

Remove the unloader slider plate and verify proper unloader piston travel. Use a stiff wood handle or equivalent non-abrasive device to move the unloader piston by pushing back on the unloader slider plate guide pin in the direction of arrow as indicated. Be careful **not** to damage the aluminum surface of the head or drop debris into the open slot in which the guide pin travels.



NOTE: When released, the unloader piston should return to the loaded position (closed) with a quick, smooth motion and audible snap.

If the unloader piston does **not** return completely to the loaded position with an audible snap; fill the open slot between the unloader slider plate guide pin and the closed position of the unloader position with automatic transmission fluid.

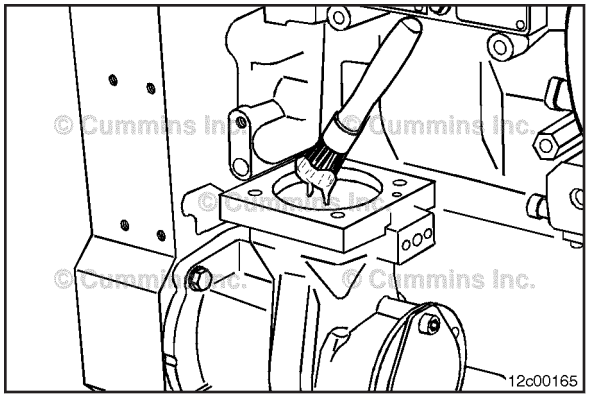
Actuate the unloader back and forth for three periods of 10 seconds. If the unloader is not free after 10 seconds, fill the open slot again with automatic transmission fluid each time until the piston is free and returns to the loaded position (closed) with a quick, smooth motion and audible snap.

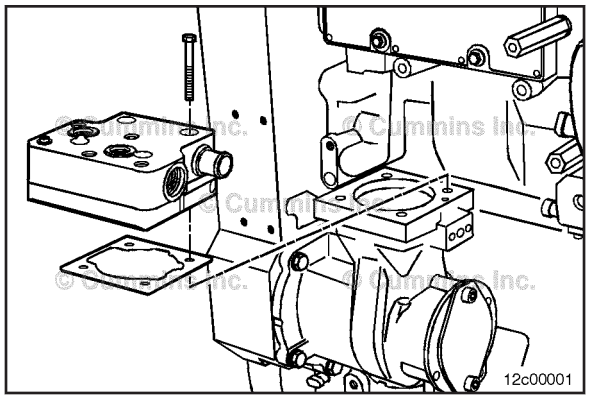
If the unloader piston does **not** return to the loaded position with a quick smooth motion and an audible snap when released after performing the steps above, replace the cylinder head.

Clean the compressor cylinder.

Rotate the crankshaft until the piston is at the top of the cylinder bore.

Remove any accumulated carbon and varnish by careful scraping and light application of solvents.

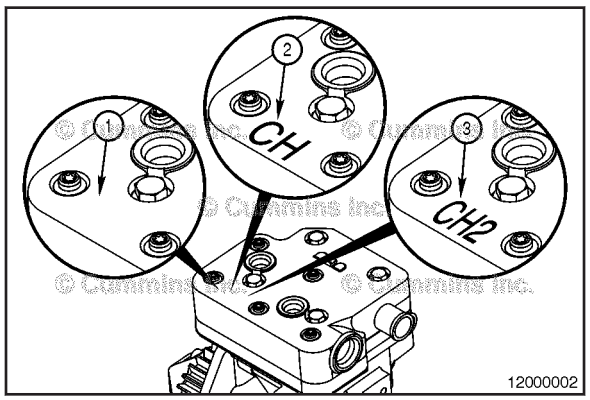




Using an engraving pen, mark the number 2 next to the CH marking already engraved on the cylinder head.

Install the compressor head and valve assembly.

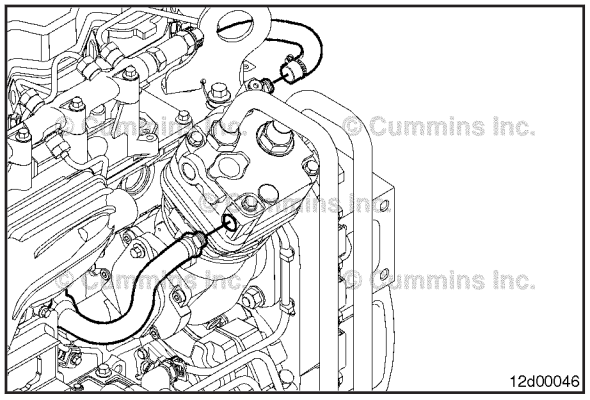
Install the compressor head and valve assembly. Refer to Procedure 012-007 in Section 12.



Perform the Air Compressor Diagnostic Test to verify the air compressor is functioning properly.

- For ISBe, ISB, and QSB (Common Rail Fuel System) engine, use the following procedure. Refer to Procedure 012-014 in Section 12.
- For QSB4.5 CM2250 EC engine, use the following procedure. Refer to Procedure 012-014 in Section 12.

If the air compressor does **not** function properly, replace the air compressor cylinder head. Refer to Procedure 012-007 in Section 12.

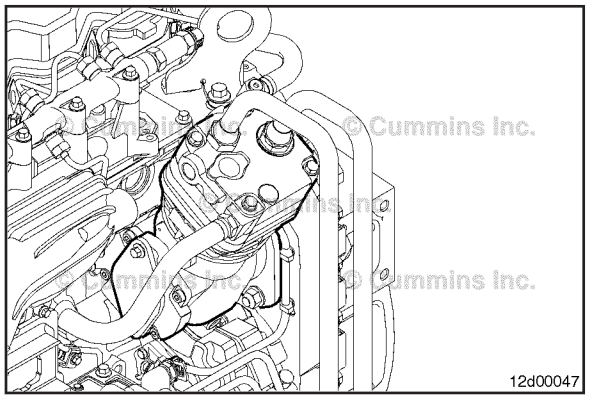


Air Compressor Coolant Lines (012-004)

Preparatory Steps

NOTE: Draining the cooling system is **not** required on air cooled air compressors.

Drain the cooling system. Refer to Procedure 008-018



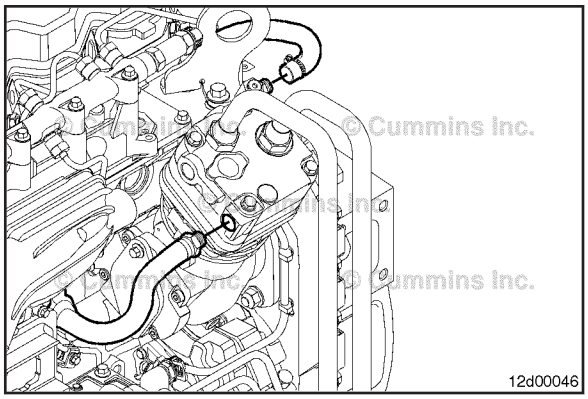
Initial Check

Inspect the coolant hoses for splits, cracks, hardening, or other damage.

Inspect metal coolant lines for kinks, corrosion, or cracks.

Remove

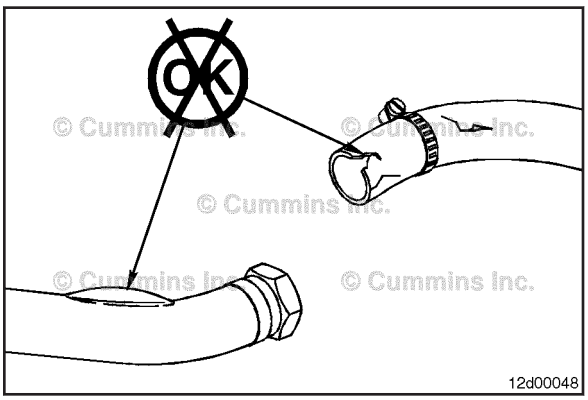
Remove the coolant lines from the air compressor (does **not** apply to air-cooled compressors).



Inspect for Reuse

Inspect the drive clips or connectors for damaged threads.

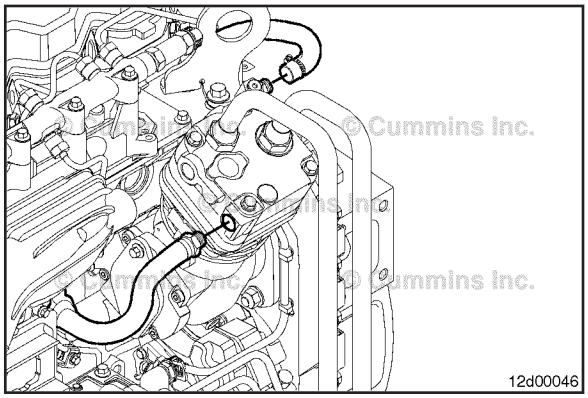
Inspect the coolant hoses and coolant lines for restriction of coolant flow.



Install

⚠CAUTION⚠
If rubber grommets are used on the coolant lines, be sure they are installed carefully to prevent cuts or tears to the grommets, which can cause leaks.

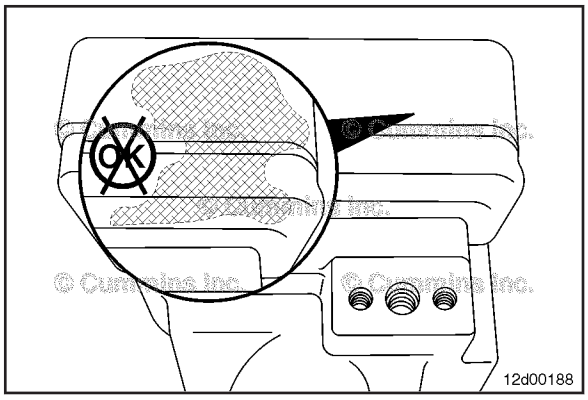
Install the coolant lines.

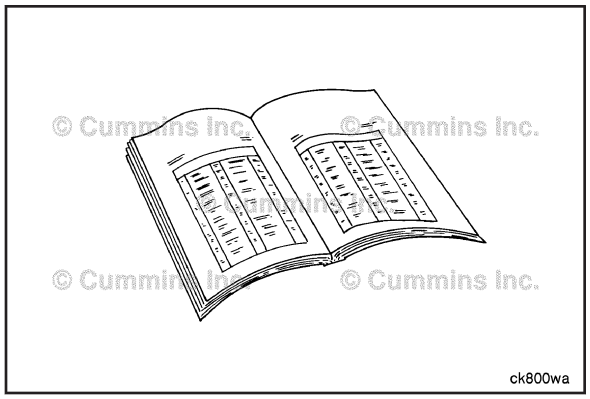


Air Compressor Cylinder Head, Single Cylinder (012-007)

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⚠
Wait until the temperature is below 50°C [120°F] to avoid personal injury from hot coolant.

Use this list for the ISB, ISBe, and QSB engines.

- Disconnect the batteries. See equipment manufacturer service information.
- Drain the cooling system. Refer to Procedure 008-018 in Section 8.
- Remove the air inlet and outlet connections from the air compressor. Refer to Procedure 012-014 in Section 12.
- Remove the air compressor coolant lines. Refer to Procedure 012-004 in Section 12.
- Remove the air governor or air governor signal line, if equipped. See equipment manufacturer service information.

Use this list for the QSB4.5 CM2250 EC engines.

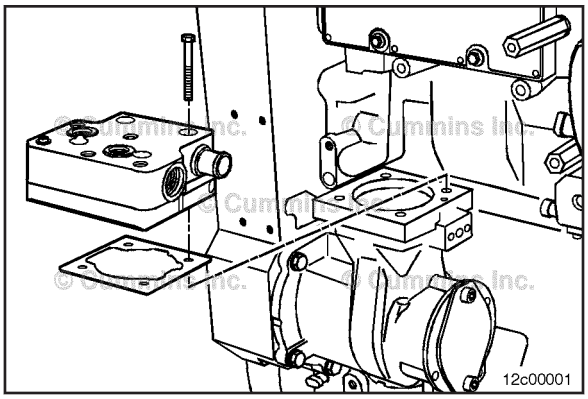
- Disconnect the batteries. See equipment manufacturer service information.
- Drain the cooling system. Refer to Procedure 008-018 in Section 8.
- Remove the air inlet and outlet connections from the air compressor. Refer to Procedure 012-014 in Section 12.
- Remove the air compressor coolant lines. Refer to Procedure 012-004 in Section 12.
- Remove the air governor or air governor signal line, if equipped. See equipment manufacturer service information.

Remove

Remove the four air compressor head mounting capscrews.

Remove the air compressor head and gasket.

Discard the gasket.

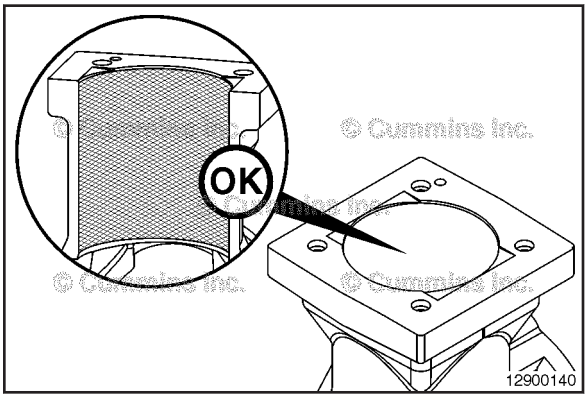


Clean and Inspect for Reuse

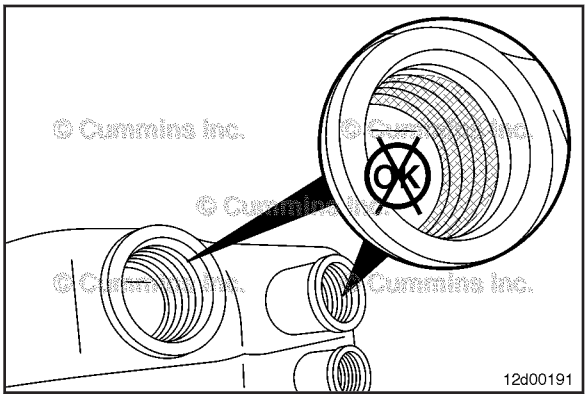
NOTE: Do **not** use an abrasive cleaning tool on any surface of the air compressor cylinder head or damage may occur.

Inspect the air compressor cylinder bore for damage.

- Use the following procedure for ISB, ISBe, and QSB engines. Refer to Procedure 012-014 in Section 12.
- Use the following procedure for QSB4.5 engines. Refer to Procedure 012-014 in Section 12.

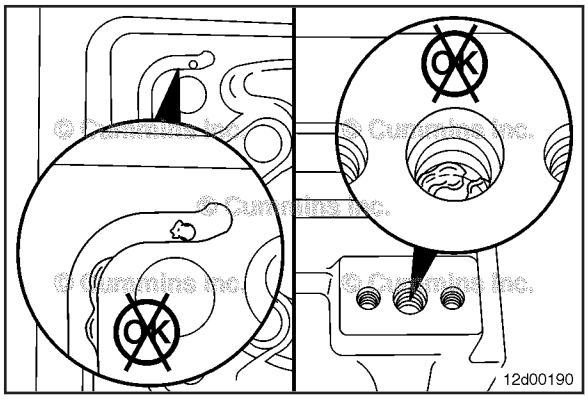


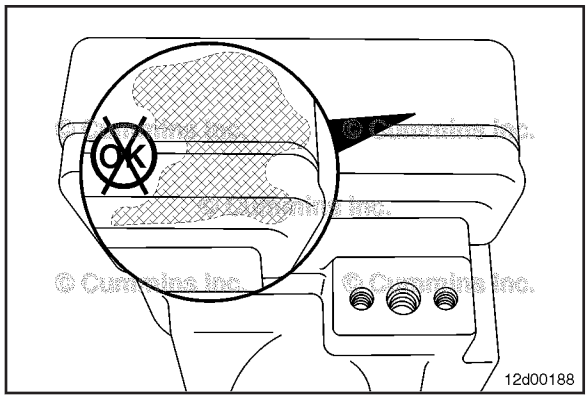
Inspect the intake and exhaust ports for excessive carbon build up. If excessive carbon build up is found, the head should be disassembled, cleaned, and reassembled using a new gasket kit. Refer to Procedure 012-003 in Section 12.



Inspect the air governor signal channel in the air compressor head. The channel should appear as a clean aluminum surface. If there is any sign of rust, dirt, or exhaust gas recirculation debris, the air compressor head **must** be replaced.

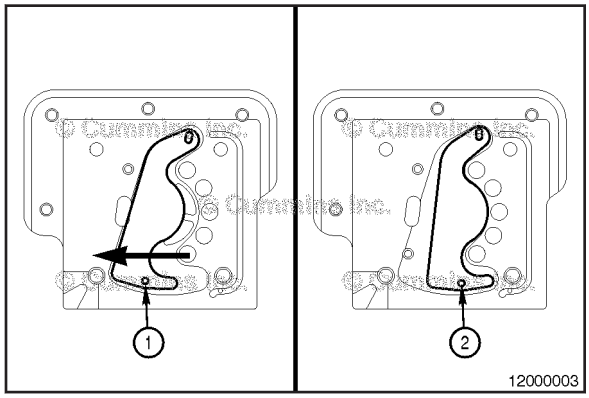
NOTE: If rust is found in the governor signal channel, it is the result of poor system maintenance. Check for proper operation of the air dryer and the wet tanks. See equipment manufacturer service procedures.





Inspect the cylinder head for signs of coolant leaks. A coolant leak can be recognized by looking for places where the engine paint on the compressor has been washed away. White crystalline clusters of material are **not** a sign of a coolant leak.

If a coolant leak is found, the cylinder head should be rebuilt using a gasket kit.



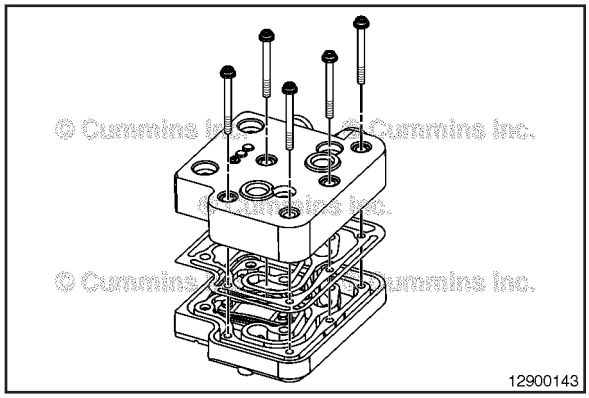
Verify the unloader slider plate is fully closed when at rest.

Remove the unloader slider plate and verify proper unloader piston travel. Use a stiff wood handle or equivalent non-abrasive device to move the unloader piston by pushing back on the unloader slider plate guide pin in the direction of arrow as indicated. Be careful **not** to damage the aluminum surface of the head or drop debris into the open slot in which the guide pin travels.

NOTE: When released, the unloader piston should return to the loaded position with a quick, smooth motion and audible snap.

If the unloader piston does **not** return to the loaded position with a quick, smooth motion and audible snap, use the below table for repair direction:

Guide Pin Action	Repair Direction
Guide pin can be moved to loaded (closed) position by hand.	Spring is broken or weak; replace cylinder head.
Guide pin does **not** return or slow to return to loaded position.	Refer to Procedure 012-003 in Section 12.



Disassemble

NOTE: Most repairs will **not** require disassembly of the air compressor head. Disassembly of the two halves of the air compressor head is **only** required in the case of coolant leaks or excessive carbon build up.

Disassemble the air compressor cylinder head by removing the five Torx™ head screws.

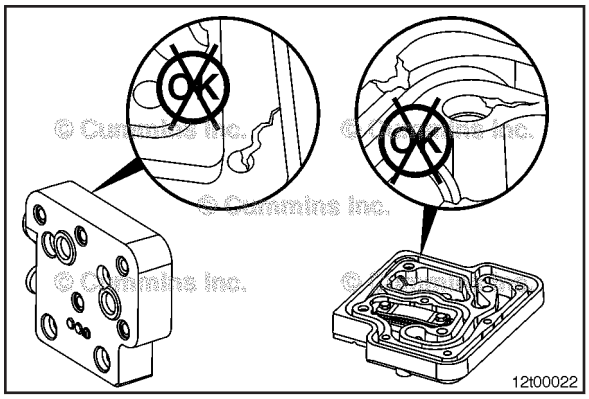
Discard these screws; they are **not** reusable and new screws will be provided in the gasket kit.

Separate the two halves of the cylinder head.

Remove and discard the old gasket.

NOTE: Do **not** remove the exhaust valve or exhaust valve capscrews. If the exhaust valve capscrews are removed, the cylinder head **must** be replaced.

Inspect the sealing surface on both halves of the cylinder head for damage. If damage is found, the cylinder head **must** be replaced.



Assemble

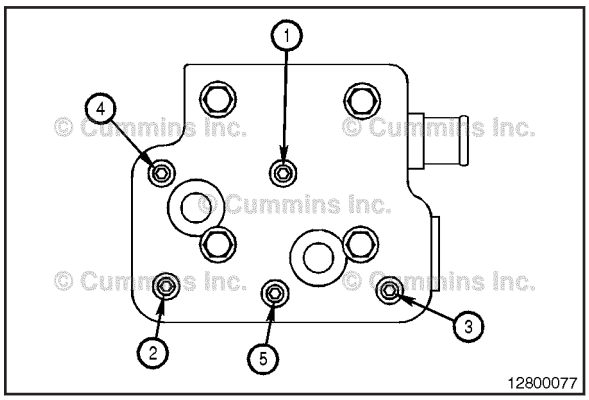
NOTE: The assembly process is **not** required for new air compressor cylinder head kits. These kits include a cylinder head with all of the gaskets assembled and ready for installation on the air compressor crankcase.

Place the new gasket on the lower section of the cylinder head.

Place the upper section of the cylinder head on the gasket.

Install the five Torx™ head capscrews finger-tight.

NOTE: Do **not** tighten these capscrews at this time. These will be tightened later during the installation procedure.

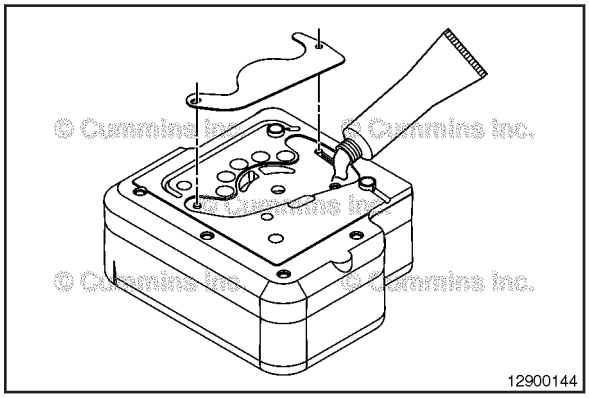


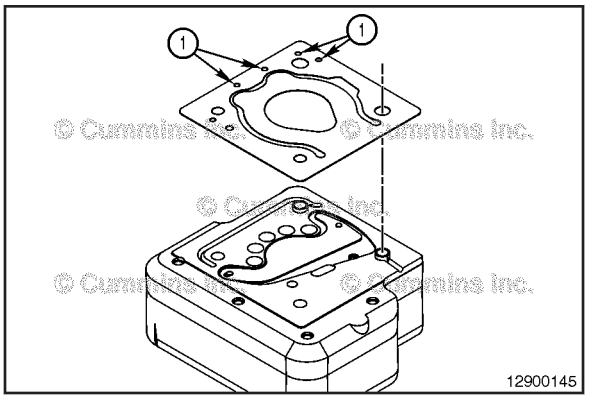
NOTE: Make sure the unloader slider plate, gasket surfaces, and valve plate are free of any debris before assembling the unloader slider plate.

Apply a spot of assembly lubricant, Part Number 3163087, or equivalent, to the back of the unloader slider plate and to the unloader slider plate guide pin.

Install the unloader slider plate onto the air compressor head by locating it on the unloader slider plate pivot pin and the unloader slider plate guide pin.

NOTE: Make sure the unloader slider plate is properly seated and that you have used enough assembly lubricant to securely hold it in position during the installation procedure or damage to the unloader slider plate may occur.

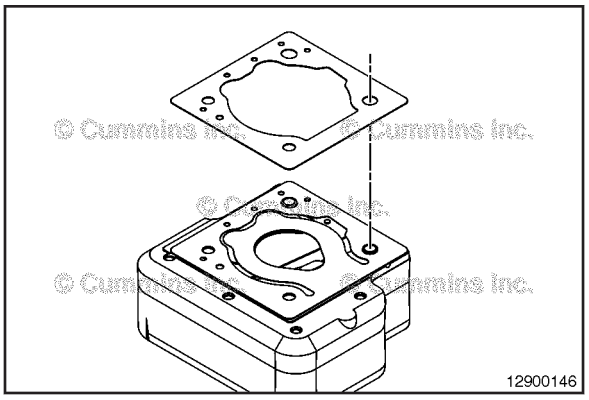




Make sure the intake valve is oriented so the governor signal channel of the cylinder head is exposed by four holes (1).

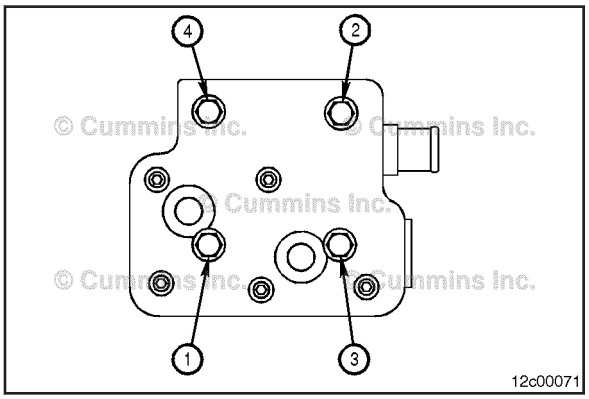
Install the air compressor intake reed valve. The intake reed valve has larger diameter holes on one side than the other to assist in proper orientation. The larger diameter hole is to be located on the spring pins protruding from the bottom of the air compressor cylinder head. When properly installed, the free end of the intake reed valve will cover the five circular intake holes in the bottom of the air compressor cylinder head.

NOTE: Air compressor heads may have one or two spring pins depending on part number.



Install the air compressor cylinder head gasket. The air compressor cylinder head gasket also has larger diameter holes on one side to assist in proper orientation and should be located on the spring pins protruding from the bottom of the air compressor cylinder head. When properly installed, the air compressor cylinder head gasket will allow free movement of the air compressor intake reed valve.

NOTE: If improperly installed, the air compressor cylinder head gasket will **not** allow proper movement of the intake reed valve and will prevent the air compressor from building air pressure properly.



Install

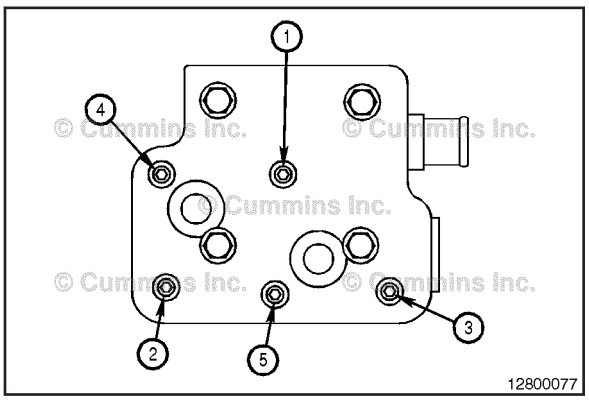
NOTE: When installing a used air compressor cylinder head, you **must** use new gaskets and capscrews. These components are **not** reusable and are available in the gaskets and seals kit. See the Assembly Section above for proper assembly of the necessary components.

Install the four air compressor head mounting 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 90 degrees	



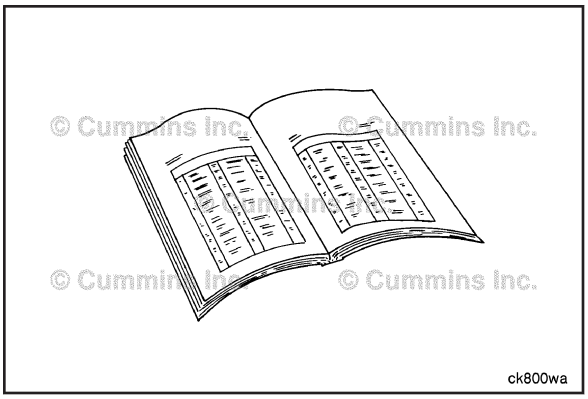
⚠CAUTION⚠
If the proper torque sequence is not followed as directed, a probable malfunction of the air compressor head may result.

Tighten the five Torx™ head capscrews in the sequence shown.

Torque Value:

Step 1	6 N•m	[53 in-lb]
Step 2	Rotate 90 degrees.	

Finishing Steps



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

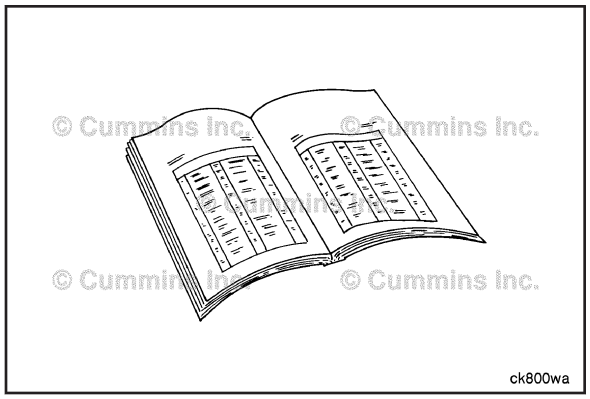
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Use this list for the ISB, ISBe, and QSB engines.

- 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 012-014 in Section 12.
- Install the air governor or air governor signal line, if equipped. See equipment manufacturer service information.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine to normal operating temperature and check for leaks.

Use this list for the QSB4.5 CM2250 EC engines.

- Install the air governor or air governor signal line, if equipped. See equipment manufacturer service information.
- 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 012-014 in Section 12.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine to normal operating temperature and check for leaks.



Air Compressor Cylinder Head, Two Cylinder (012-008)

Preparatory

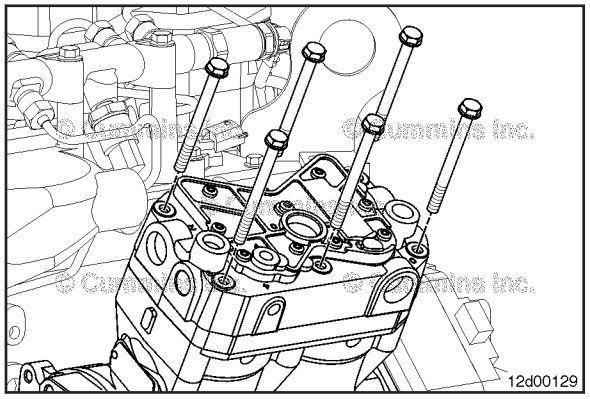
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠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⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°F [120°C] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the batteries. Refer to the OEM service manual.
- Steam clean the air compressor.
- Drain the engine cooling system. Refer to Procedure 008-018 in Section 8.
- Remove the coolant lines from the air compressor. Refer to the OEM service manual.
- Remove the air connections from the air compressor. Refer to the OEM service manual.



Remove

NOTE: Adhesive forces may have to be overcome during disassembly.

- Remove the six cylinder head capscrews.
- Remove the head, valve plate and gaskets.

Clean and Inspect for Reuse

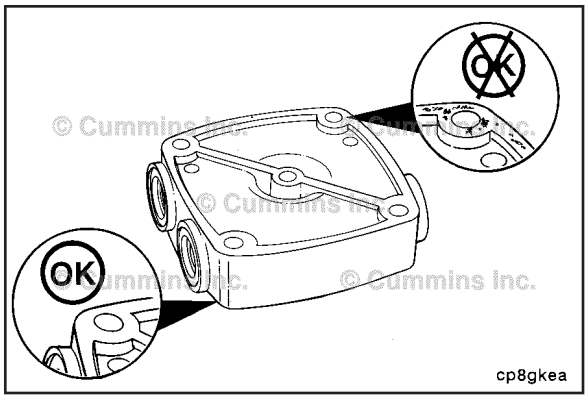


Inspect the compressor housing for cracks or other damage.

Clean the piston crown.

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.

The valve plate and cylinder head **must** be replaced if there are any signs of cavitation



Install



NOTE: New gaskets **must** be used.

Install the new cylinder head valve plate gasket.

Install the cylinder head valve plate.

Install the new cylinder head gasket.

Install the cylinder head.

Lubricate and install the six capscrews.

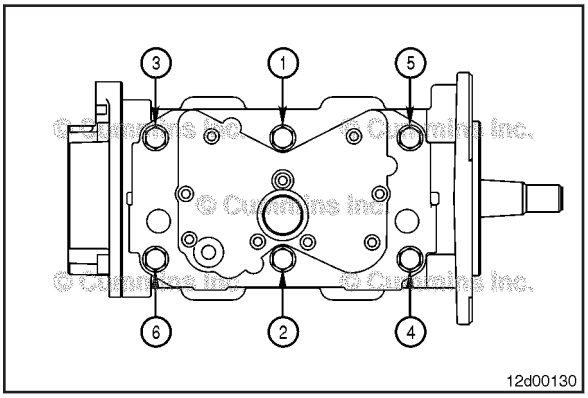
Tighten the capscrews in the sequence shown.

Torque Value:
Step 1 - All capscrews

Step 1	20 N•m	[177 in-lb]

Torque Value:
Step 2 - All capscrews

Step 1	33 N•m	[24 ft-lb]

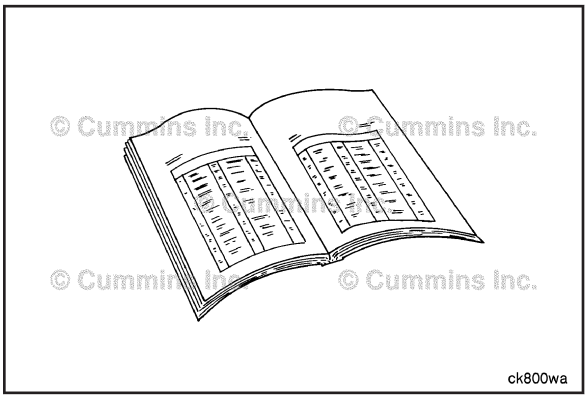


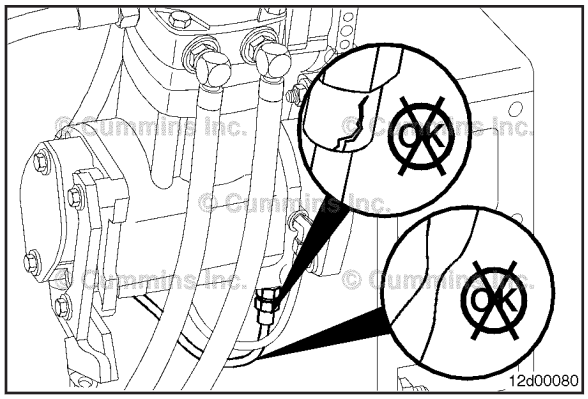
Finishing Steps



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

- Install the air compressor coolant lines. Refer to the OEM service manual.
- Install the air lines.
- Fill the engine cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the battery. Refer to the OEM service manual.
- Operate the engine and check for leaks.
- Operate the engine to activate the air compressor.

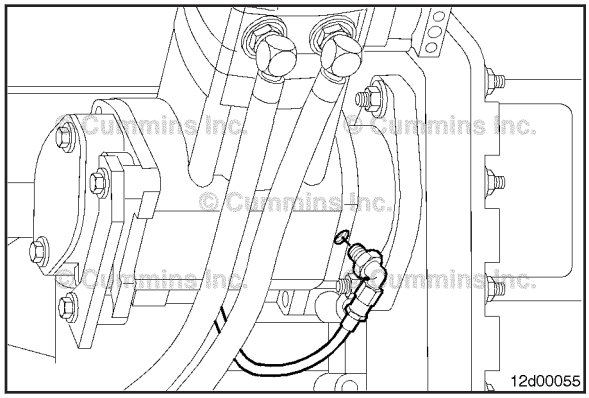




Air Compressor Oil Drain Line (012-009)

Initial Check

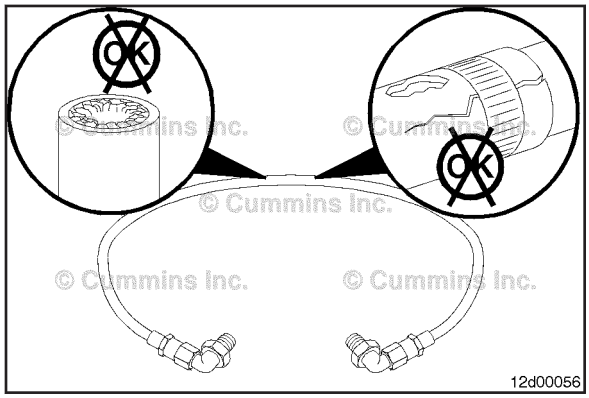
Inspect the air compressor oil drain line for cracks, cuts, or collapsing (if equipped).



Remove

If equipped, remove the air compressor oil drain line at the compressor.

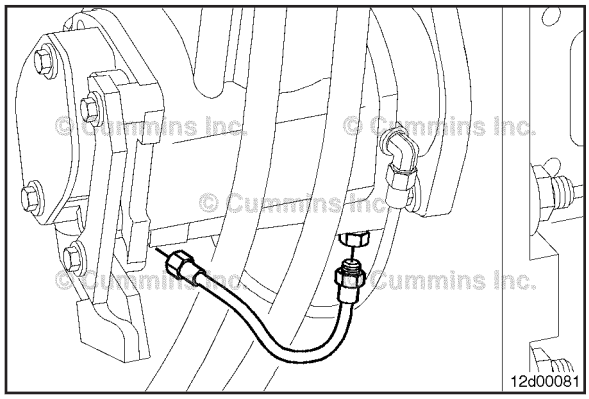
Remove the air compressor oil drain line on the side of the engine block.



Inspect for Reuse

Check the flexible lines for splits, cracks, or hardening.

Check the solid lines for kinks, cracks, or corrosion.



Install

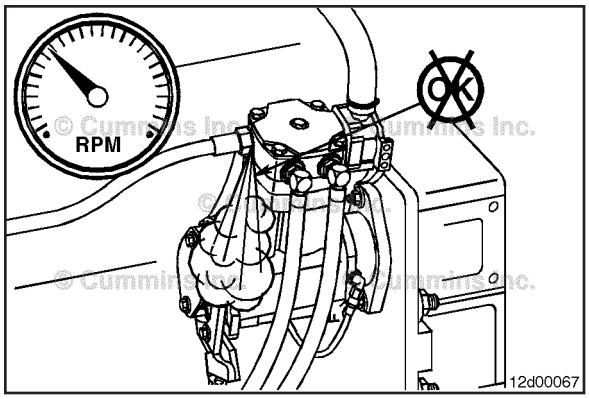
NOTE: Replace the air compressor oil drain line block connection o-ring or gasket.

Install the air compressor oil drain line onto the air compressor connection. Do **not** tighten completely.

Install the air compressor oil drain line onto the cylinder block connection and tighten.

Tighten the air compressor oil drain line connection to the air compressor.

Operate the engine and check for leaks and proper operation of the air compressor.

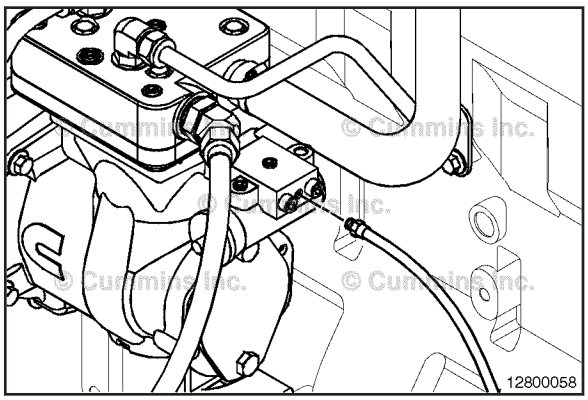


Air Compressor Unloader and Valve Assembly (012-013)

Initial Check

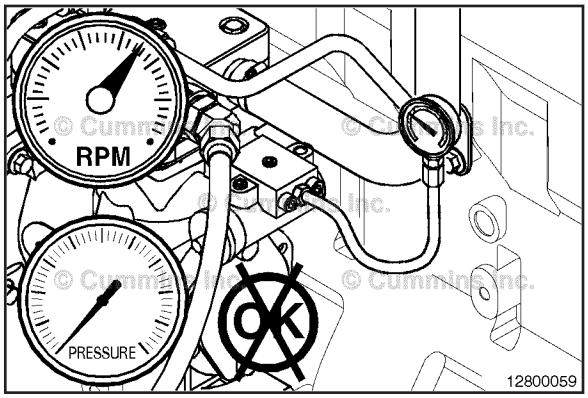
⚠WARNING⚠
Air pressure must be released from the system before removing the air governor. The governor can be under pressure and cause personal injury.

Disconnect the air governor or air governor signal line from 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. Refer to Procedure 012-003 in Section 12.

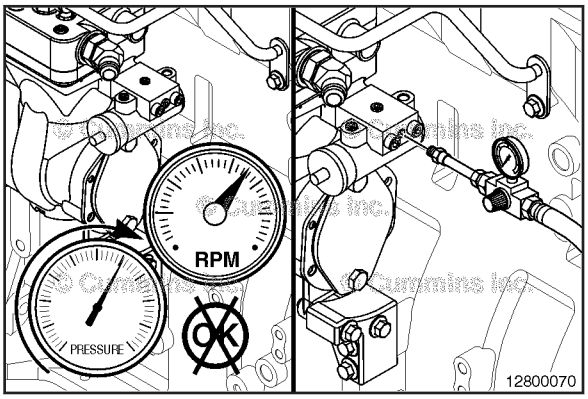


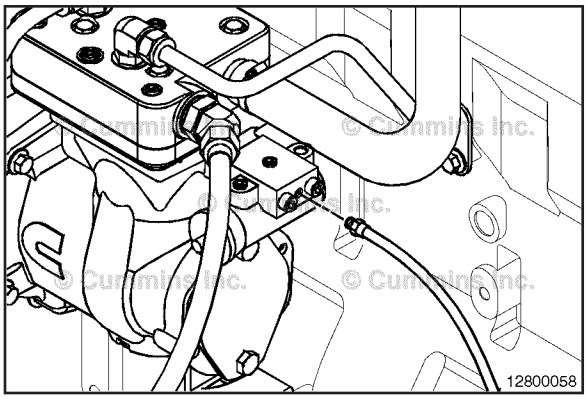
If the air compressor has multiple air governor unloader ports, install a pipe plug into one of the ports, and a shop air fitting into another unloader port.

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 system air pressure continues rising, the unloader valve assembly is malfunctioning. Refer to Procedure 012-003 in Section 12.





Connect the original equipment manufacturer (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 012-018 in Section 12.
- Refer to Procedure 012-017 in Section 12.

Air Compressor (012-014)

Pressure Test

⚠WARNING⚠

The external pressure tank used must meet SAE J10 and FMVSS121 standards, and have a safety pressure relief valve which opens between [150 to 175 psi]. Failure to use the proper pressure vessel and plumbing can result in property damage and serious personal injury.

Air Compressor Diagnostic Test

1 Park 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 or an appropriate anti-roll device to stabilize the vehicle.

2 Drain the vehicle air system.

3 Remove the air discharge hose and air governor signal hose from the air compressor.

4 Plumb an air discharge hose from the air compressor into an external pressure tank. The external pressure tank **must** be equipped with a 1034 kPa [150 psi] pressure gauge and 1034 kPa [150 psi] pressure relief valve. Make sure that the fittings are installed with appropriate thread sealant and do **not** leak.

5 Start the engine and operate at idle speed.

6 Record the amount of time required to fill the tank.

7 Divide the volume of the tank used (must be in in^3), by the time (sec). This is the pressure rate.

8 If the pressure rate is lower than the rate in the Pressure Rate Chart, the air compressor is malfunctioning and the air compressor cylinder head needs to be repaired, b ased on the marking scribed in the head. Refer to Procedure 012-003 in Section 12.

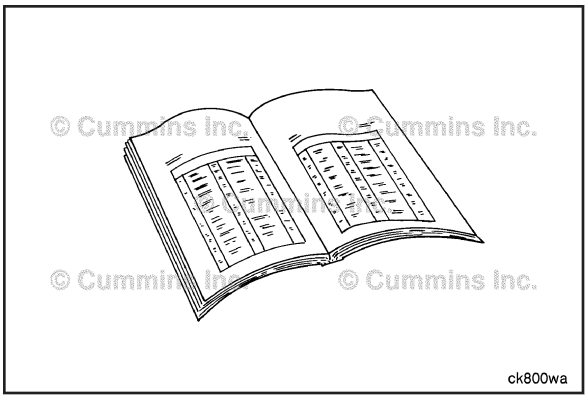
Pressure Rate Chart

Air Compressor Size	Minimum Time (sec)	Maximum Time (sec)	Tank Volume (in^3)	Rate Minimum (in^3/sec)
250cc	50	55	1000	18.18
318cc	40	45	1000	22.22
500cc	25	30	1000	33.33
636cc	20	25	1000	40

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 as shown in the Pressure Rate Chart.

Verify that the air compressor will build pressure and the pressure rate is higher than the rate in the Pressure Rate Chart. If air pressure successfully builds to 862 kPa [125 psi] and meets the pressure rate from the chart, the air compressor is functioning 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 to the symptom tree being utilized, to inspect the rest of the air system components for leaks and verify proper operation.

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.

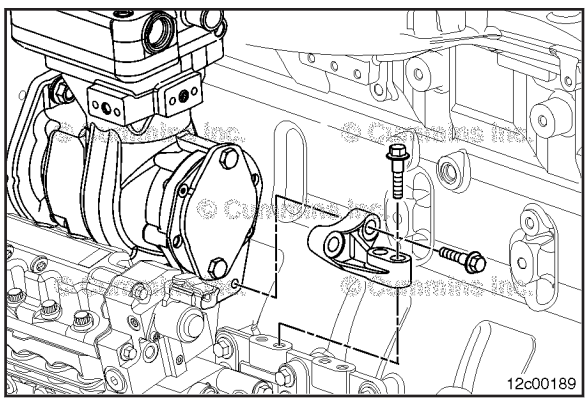
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

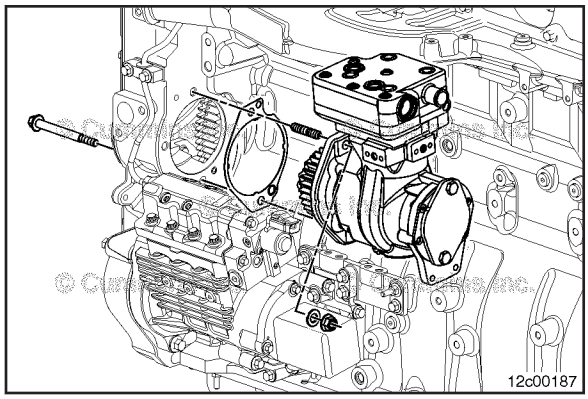
⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50° C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

- Disconnect the batteries. See equipment manufacturer service information.
- Drain the engine coolant. Refer to Procedure 008-018 (Cooling System) in Section 8.
- Use steam to clean the air compressor. Dry with compressed air.
- Remove the coolant lines from the air compressor. Refer to Procedure 012-004 in Section 12.
- Remove the air connections from the air compressor. Refer to Procedure 012-004 in Section 12.
- Remove or disconnect the air governor. See equipment manufacturer service information.
- Remove any driven equipment from the back of the air compressor, if equipped.

Remove

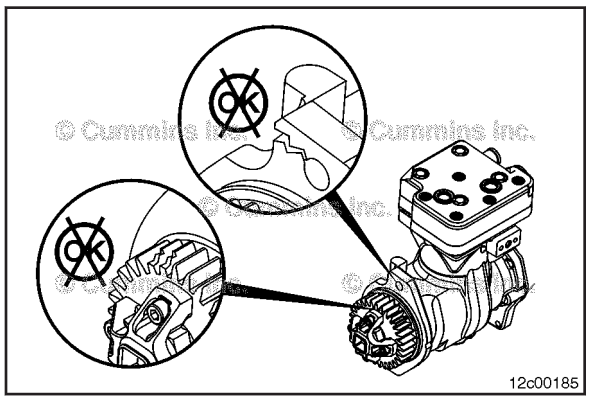
Remove the air compressor support bracket and capscrews from the rear of the compressor.





Remove the mounting nut, capscrew, and air compressor.

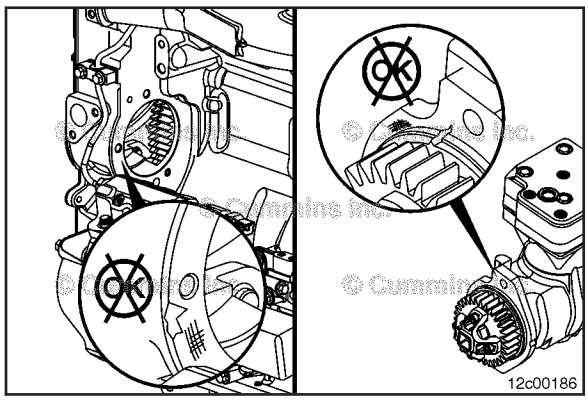
Discard the gasket.



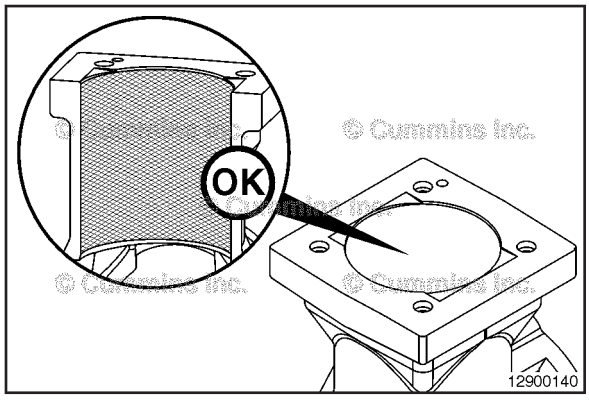
Clean and Inspect for Reuse

Inspect the air compressor housing for cracks or other damage.

Inspect the drive gear for cracks or other damage.



Make sure the gasket surfaces of the gear housing and air compressor are clean and **not** damaged.



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.

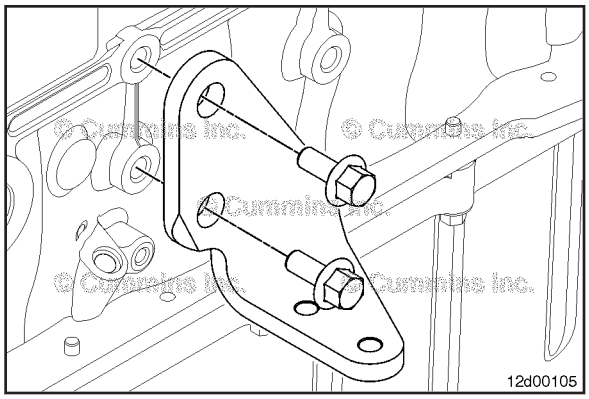
Inspect the inside circumference for scuffing, scoring, or polishing.

Assemble

Wabco™ Air Compressors

Install the cylinder block mounting bracket and mounting fasteners.

Tighten the mounting fasteners finger-tight.



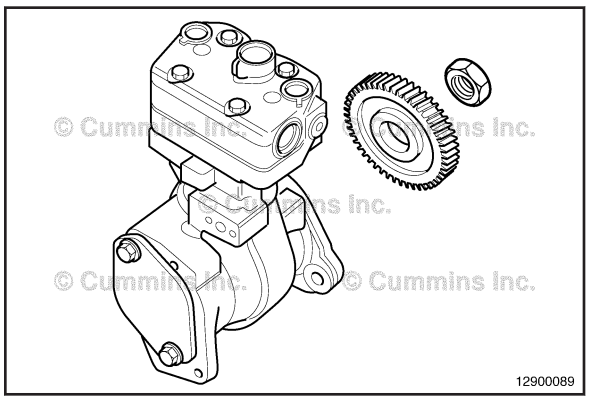
Knorr-Bremse™ Air Compressors

NOTE: Make sure the drive gear and air compressor drive shaft nose are clean and free of any oil before installing the gear on the air compressor driveshaft.

Install the drive gear onto the air compressor driveshaft.

Install the air compressor drive gear mounting fastener and tighten.

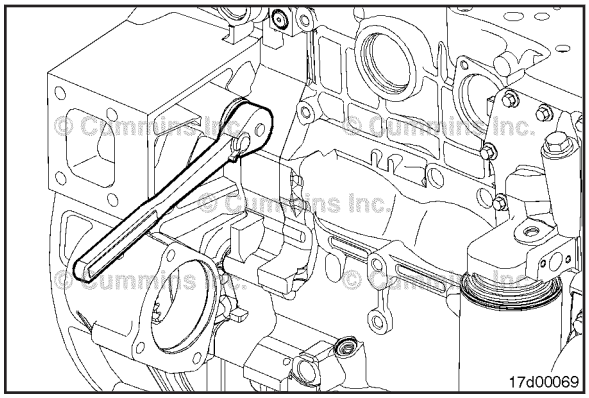
Torque Value: 160 N•m [118 ft-lb]



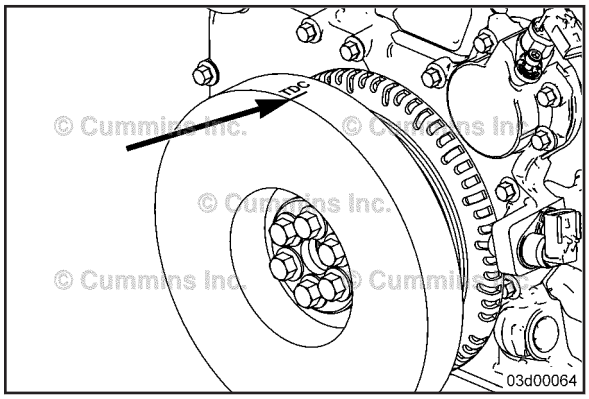
Time

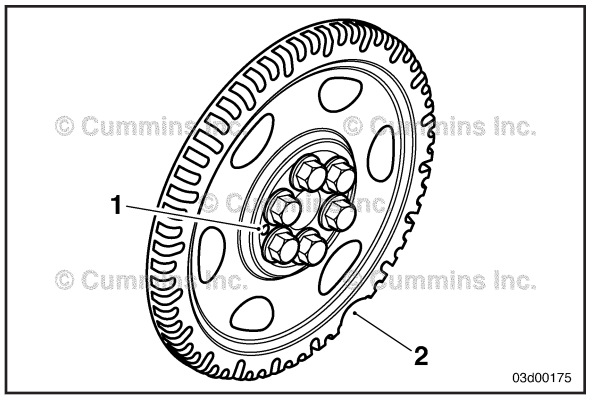
NOTE: To make sure the air compressor does not contribute to engine vibrations when installed, the air compressor must be properly timed to the engine.

Use the barring tool, Part Number 3824591, or equ

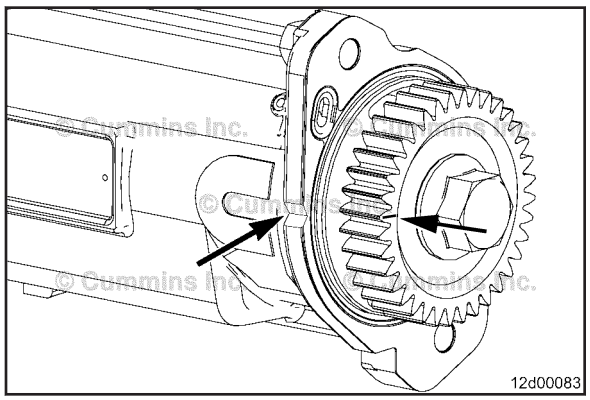


Align the vibration damper so that the TDC indicator on the vibration damper is at the 12-o'clock position.



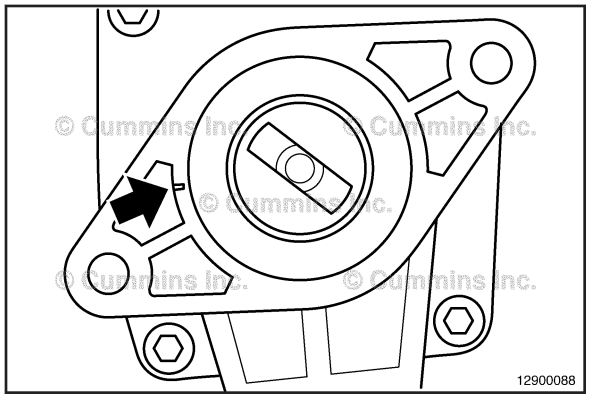


NOTE: If no TDC mark is present on either the vibration damper or the crankshaft speed indicator ring, align the large gap in the crankshaft speed indicator ring to the 5-o'clock position (2). The dowel pin can also be visible in the 9-o'clock position (1).



Wabco™ Air Compressors

Set the timing mark on the air compressor gear to the 9-o'clock position when looking at the gear. It **must** point at the casting depression on the side of the air compressor mounting flange.



Knorr-Bremse™ Air Compressors

Set the air compressor to TDC by aligning the two timing marks on the rear of the compressor and on the rear drive.

Install

Wabco™ Air Compressors

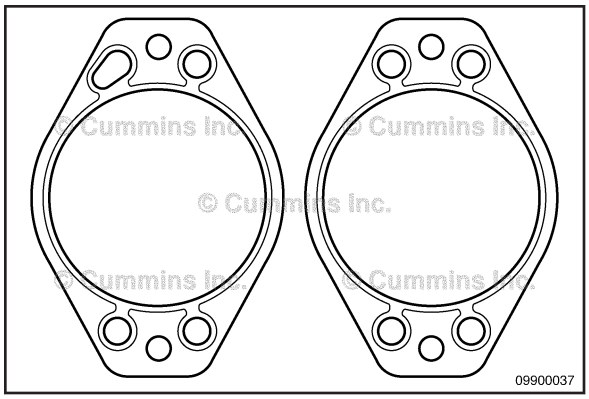
For Wabco™ air compressors, use the following procedure.

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

There are two types of accessory drive cover gaskets:

- Three round oil supply passages and one elongated oil supply passage
- Four round oil supply passages.

It is preferred that, when installing the air compressor, the gasket with the four round oil supply passages be used. The gasket can be installed in any orientation. If **only** the gasket with the one elongated oil supply passage is available, install the gasket so that the elongated oil supply passage is **not** over the oil supply port in the rear gear housing.



⚠CAUTION⚠
The air compressor gasket must sit flat against the gear housing without any interference to prevent air compressor failure.

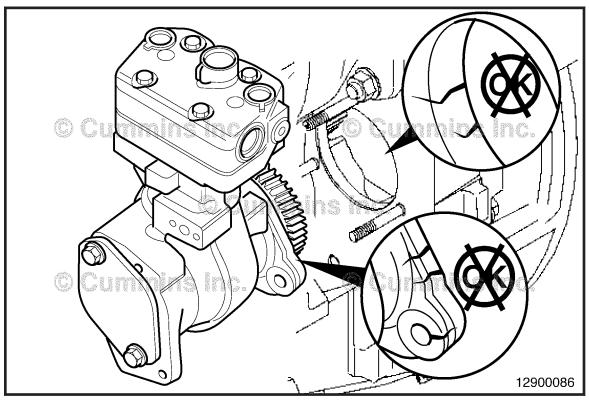
⚠CAUTION⚠
Air compressor failure can result if the oil feed hole is not aligned with the oil passage in the gear housing or if the wrong gasket is used.

NOTE: Rotate the engine slightly before or after top dead center (TDC), if necessary, to properly engage the compressor drive gear with the camshaft gear.

With the engine set at TDC, install the air compressor and a new gasket onto the rear gear housing engaging the air compressor drive gear with the camshaft gear.

Install the air compressor mounting fasteners and tighten.

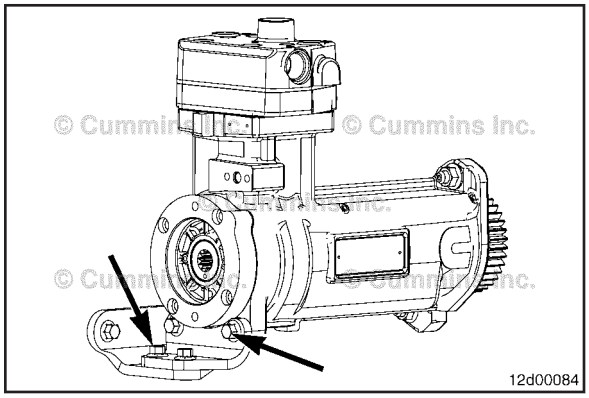
Install the air compressor mounting fasteners and finger-tighten the capscrews.

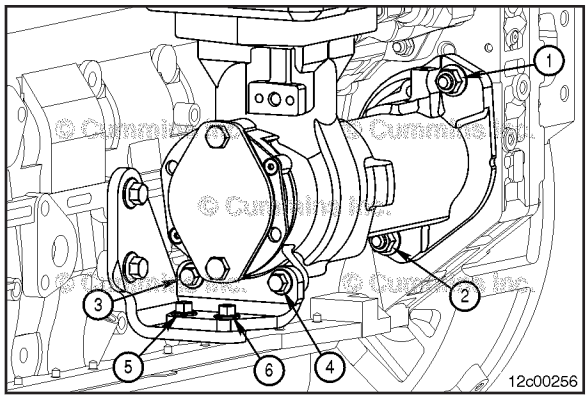


Install the air compressor support bracket.

Install the air compressor support bracket to the cylinder block mounting bracket mounting capscrews and finger-tighten.

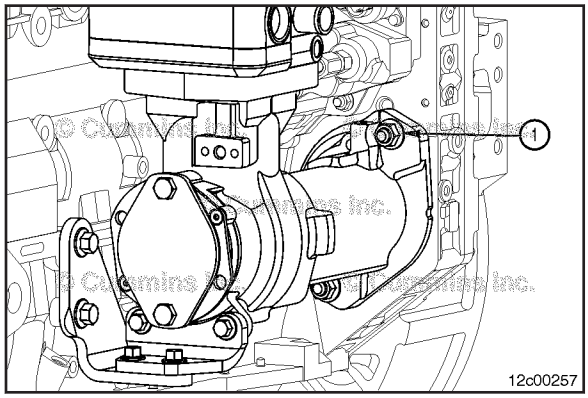
Install the air compressor support bracket mounting capscrews and finger-tighten.





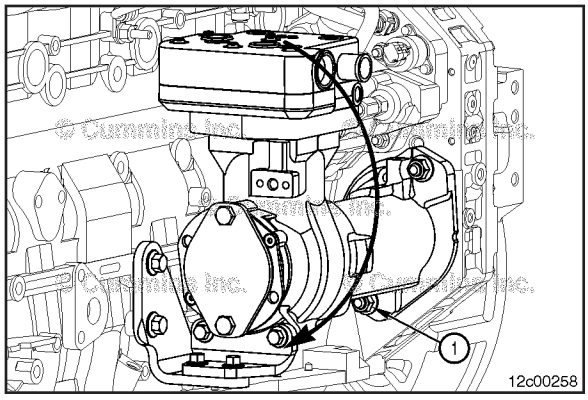
NOTE: For low mount designs, it is important to make sure of appropriate positioning of the air compressor relative to the engine block in order to minimize gear last. This will help minimize noise from the gear train during normal engine operation.

Loosen the six air compressor mounting capscrews.



Push the air compressor assembly as close to the engine block as possible and tighten the upper mounting capscrew (1).

Torque Value: 77 N•m [57 ft-lb]



Using the upper mounting capscrew as a pivot point, rotate the air compressor assembly in the **clockwise** direction when viewed from the front of the engine.

NOTE: This action should slightly move the bottom of the air compressor assembly towards the engine block.

Tighten the lower mounting capscrew (1).

Torque Value: 77 N•m [57 ft-lb]

⚠CAUTION⚠
Air compressor failure can result if any of the mating surfaces are not touching prior to tightening.

Verify the air compressor support bracket is contacting the cylinder block support bracket. Adjust the brackets as necessary. If necessary, loosen the cylinder block support bracket to align the components.

Tighten the air compressor support bracket mounting capscrews (1).

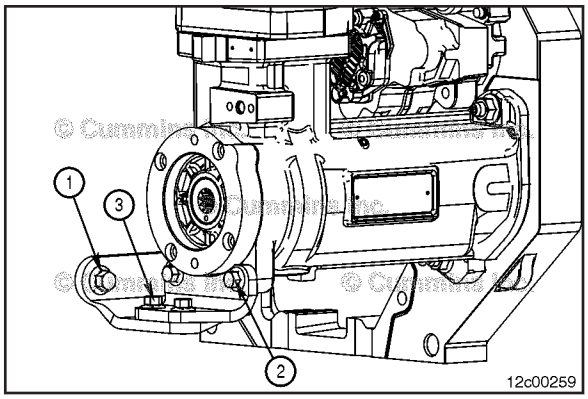
If loosened, tighten the cylinder block support bracket cylinder block mounting capscrews (2).

Tighten the compressor support bracket to the cylinder block support bracket mounting capscrews (3).

Torque Value:
M8 24 N•m [212 in-lb]

Torque Value:
M10 43 N•m [32 ft-lb]

Torque Value:
M12 77 N•m [57 ft-lb]



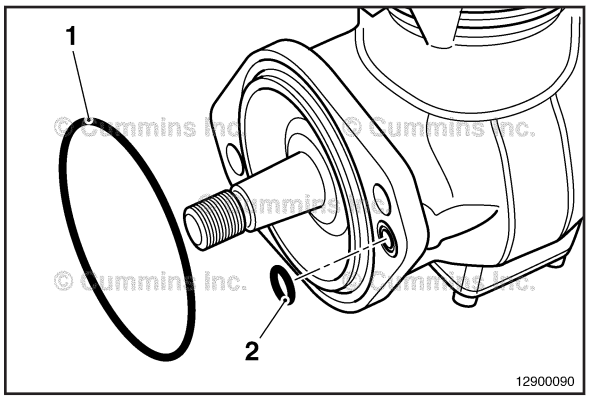
Knorr-Bremse™ Air Compressors

NOTE: Rotate the engine slightly before or after top dead center (TDC), if necessary, to properly engage the compressor drive gear with the camshaft gear.

Apply clean 15W-40 engine oil or assembly lubrication, Cummins® Part Number 3163087, or equivalent, to both o-ring recesses. This will help keep the o-rings in the correct location while installing the compressor.

Install new o-rings onto the air compressor.

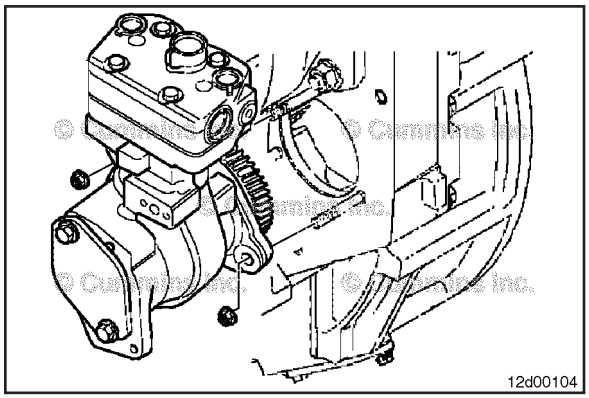
Locate both the large (1) and small (2) o-rings as shown in the illustration at right into the recesses; making sure they are both located correctly.

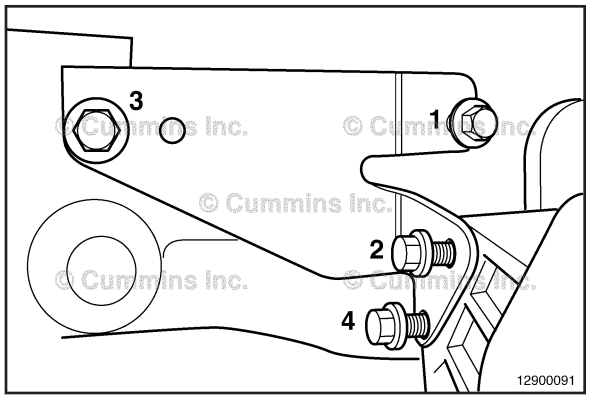


With the engine set at TDC, install the air compressor engaging the air compessor drive gear with the camshaft gear.

Install the air compressor mounting fasteners and tighten.

Torque Value: 77 N•m [57 ft-lb]

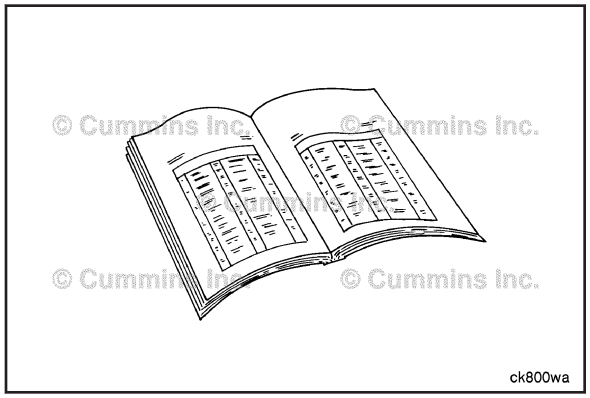




Install the four air compressor support bracket mounting capscrews and finger-tighten.

Tighten the air compressor support bracket mounting capscrews in the sequence shown.

Torque Value: 24 N•m [212 in-lb]

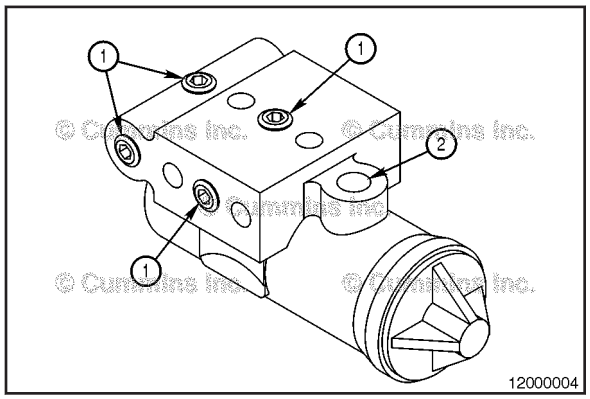


Finishing Steps

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

⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Install any driven equipment removed to the back of the air compressor, if equipped.
- Install or connect the air governor. See equipment manufacturer service information.
- Install the air connections to the air compressor. Refer to Procedure 012-004 in Section 12.
- Install the coolant lines. Refer to Procedure 012-004 in Section 12.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. See equipment manufacturer service information.
- Operate the engine and check for leaks.



Air Governor (Air Compressor Will Not Pump) (012-017)

Inspect for Reuse

Verify the air governor signal line is plumbed correctly to the unloader port on the air compressor.

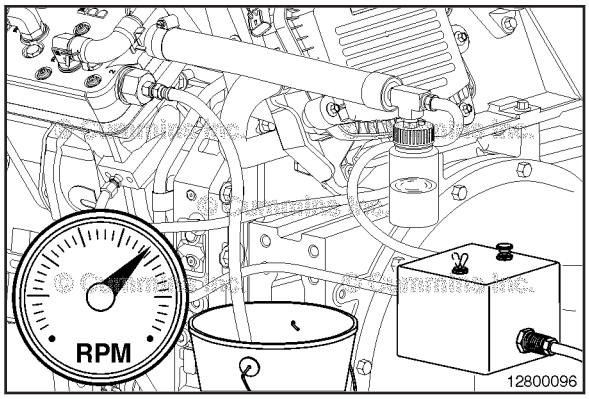
Disconnect and inspect the line for kinks, cuts, nicks or plugging inside the line.

Verify all unused ports (1) on the air governor are plugged except the exhaust port. The exhaust port (2) **must** be vented to the atmosphere at all times.

Activate the air compressor and allow the air pressure to buildup.

If pressure is reading below 125 psi according to the dash gauge, relieve 25 psi of pressure by applying the vehicle brakes to see if the air compressor starts to pump again.

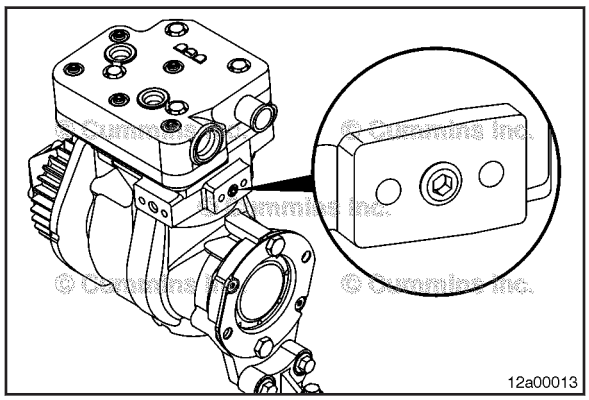
If the air compressor only pumps to the level it was before then the air governor needs to be inspected for proper operation. Refer to the original equipment manufacturer (OEM) service manual.



Air Governor (Air Compressor Pumps Continuously) (012-018)

Initial Check

Verify the unused unloader port, if applicable, on the air compressor has a pipe plug installed.

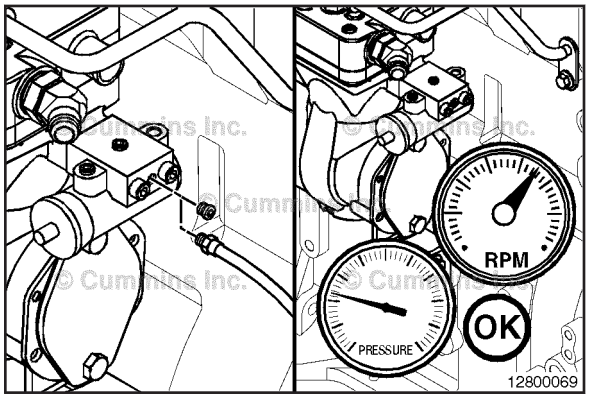


Remove and inspect the air governor signal line from the air compressor for kinks, cuts, nicks or plugging inside the line.

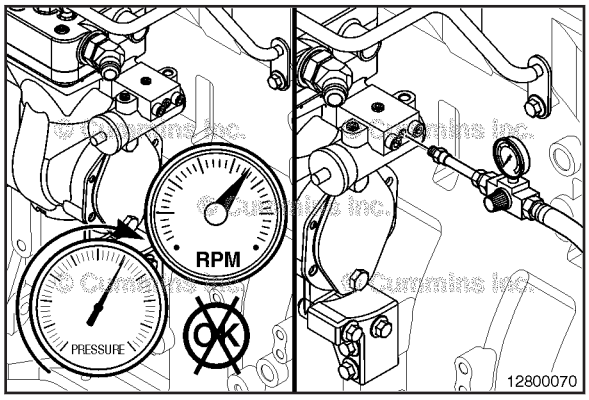
Install pipe plugs in the air governor unloader ports.

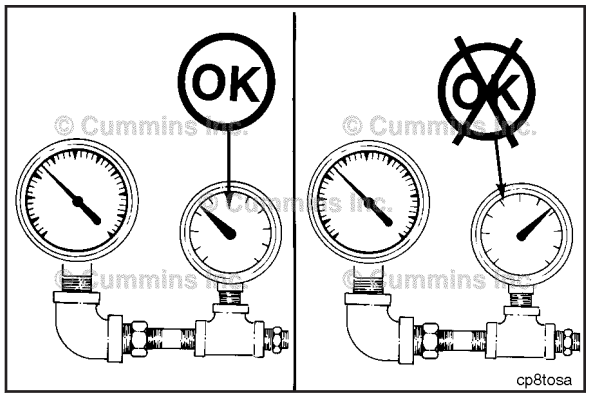
Operate the engine to activate the air compressor.

If air pressure stops rising, there is a leak in an accessory or an accessory air line. Refer to the original equipment manufacturer (OEM) service manual for troubleshooting and repair.



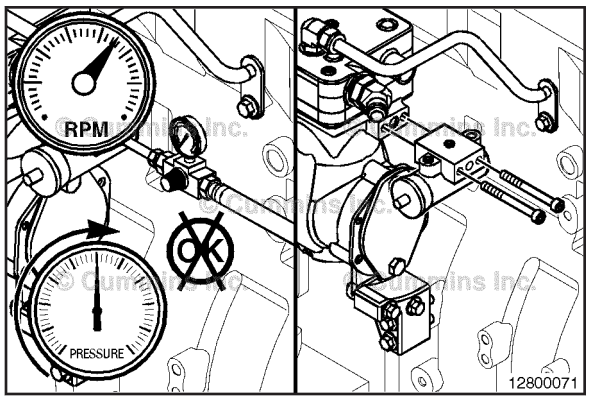
If the air compressor does **not** stop pumping (air pressure continues to rise) at the governed air pressure, connect a regulated shop air pressure line to the air compressor unloader valve port.





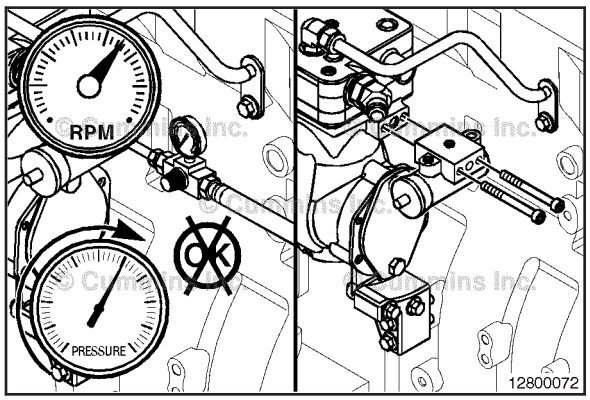
NOTE: Be sure the air pressure gauge is accurate and the supply lines and fittings are in good condition before performing any air pressure checks.

Use a master gauge of known accuracy to check the air pressure gauge.

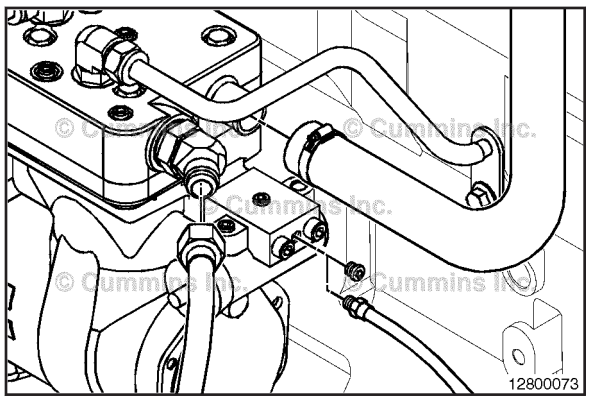


Apply 690-kPa [100-psi] air pressure to the unloader port.

If the air compressor stops pumping (air pressure stops rising), the air governor is malfunctioning and **must** be repaired or replaced. Refer to the equipment manufacturer's instructions.



If the air compressor continues to pump (air pressure continues to rise), the unloader valve is malfunctioning and **must** be replaced. Refer to Procedure 012-013 in Section 12.

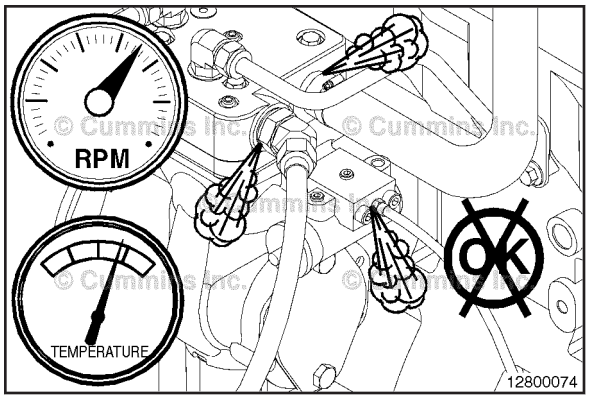


Remove the pipe plugs from the unloader ports used for accessory air lines.

Install and tighten the accessory air lines.

Connect the line to the unloader valve.

Operate the engine and check for air leaks.

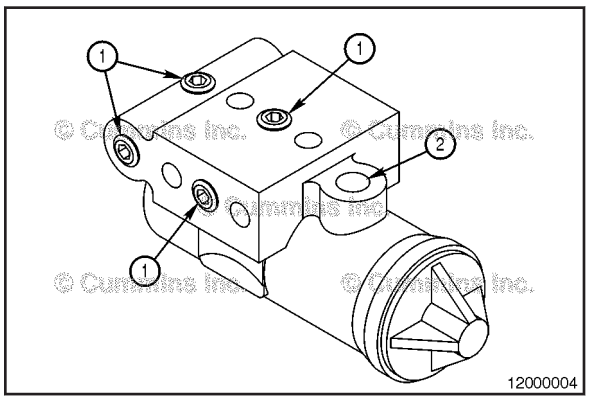


Air Leaks, Compressed Air System (012-019)

Initial Check

Verify the unused unloader port, if applicable, on the air compressor has a pipe plug installed.

Verify all unused ports are plugged with pipe plugs except for the exhaust port on the air governor. The air governor exhaust port **must always** be ventilated to the atmosphere.



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:

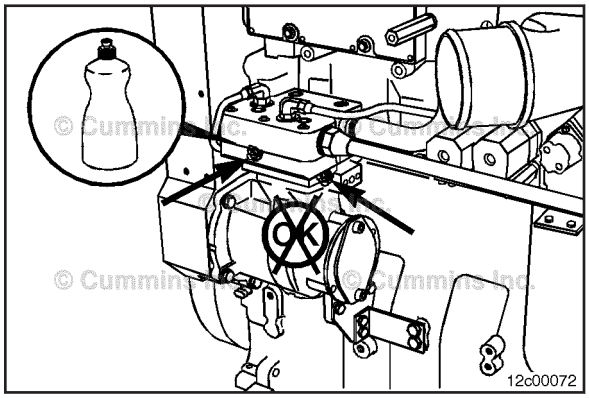
- Air compressor head gasket.
- Air compressor cover gasket.
- Fittings and hoses connected to the intake, discharge, and air governor signal line on the air compressor.
- Fittings and hoses connected at the air governor, wet tank, and the air dryer.

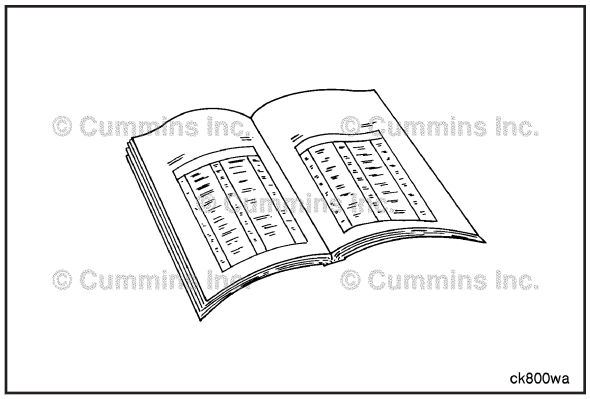
If air leaks are found at the air compressor head or cover gasket, verify that the air compressor head and cover bolts are tighten properly. Refer to Procedure 012-007 in Section 12.

Shut the engine OFF . Check for air leaks both at key-OFF and key-ON.

NOTE: Some components at key-ON can make the sound of an air leak.

Walk around the vehicle and listen for air leaks from the rest of the air system **not** already inspected.



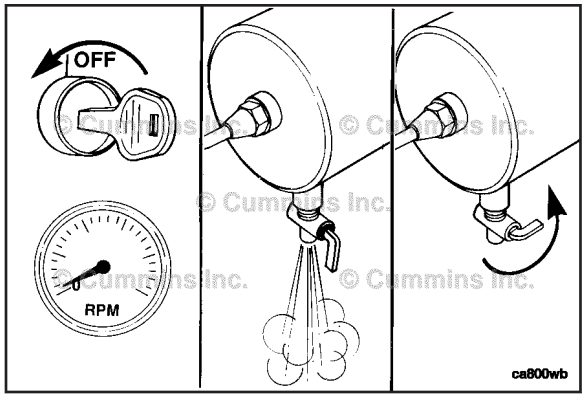


Air Compressor (Oil Carryover) (012-020)

Inspect for Reuse

Perform this test in conjunction with troubleshooting the air compressor pumping oil into the air system.

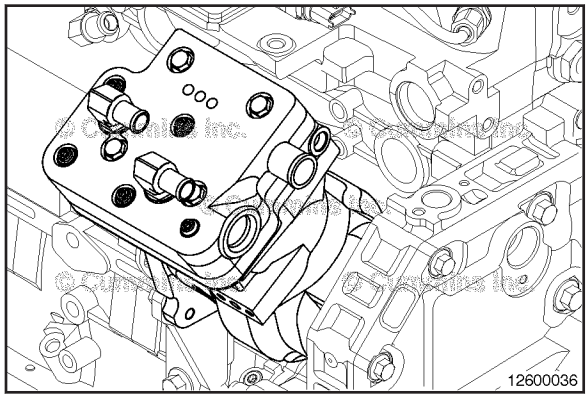
NOTE: Small oil deposits at the air dryer purge valve are normal. The air compressor is lubricated with engine oil, and small amounts of carryover are to be expected. Oil carryover is more common on naturally aspirated air compressors. Oil or moisture can be expected at any purge or drain valves up to 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.



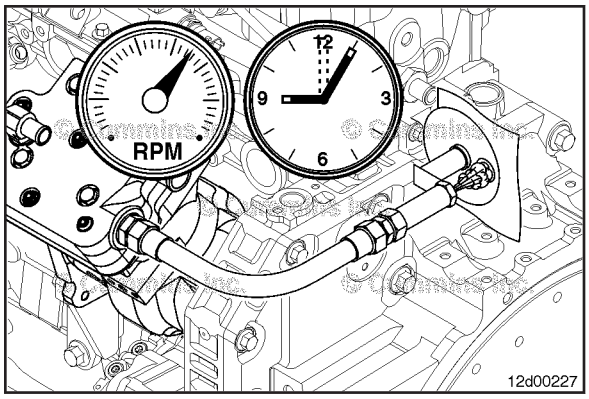
⚠WARNING⚠
The discharge from the air compressor will be hot, possibly contain oil vapors, and will be noisy. Make sure there is adequate ventilation and hearing protection is worn, particularly if the type of vehicle requires the test be conducted in an enclosed environment.

Disconnect the discharge pipe from the air compressor cylinder head.

Disconnect the air inlet plumbing at the air compressor cylinder head.

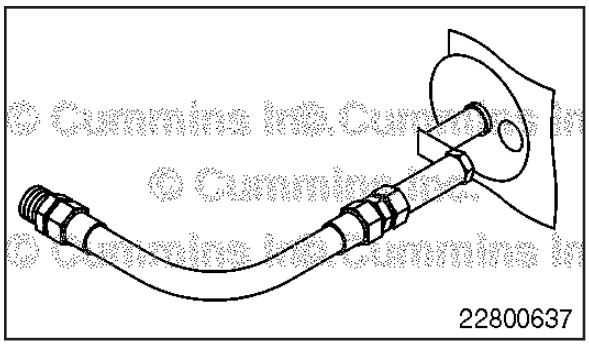
Connect the oil carryover test tool, Part Number 4918883, to the air compressor cylinder head discharge port.

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.

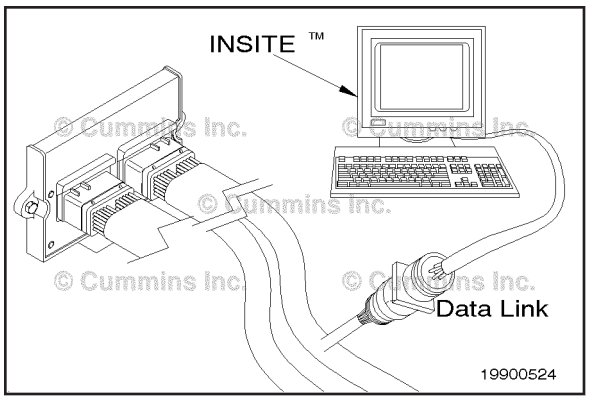


Install the test paper into the service tool, Part Number 4918883. Make sure it is held at a right angle to and in line with the flow of compressed air, at a distance **not** to exceed 100 mm [3.9 in] from the end of the compressor discharge pipe or flexible hose, if fitted.

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.

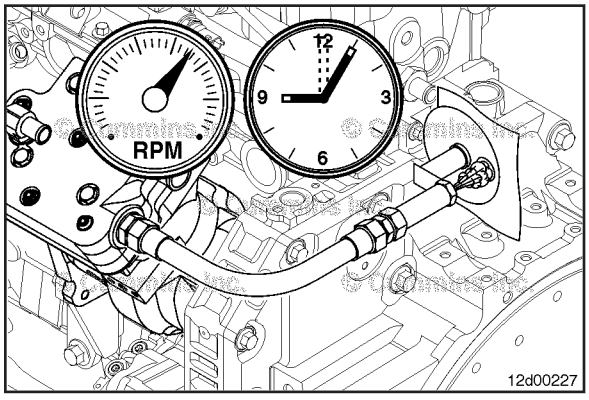


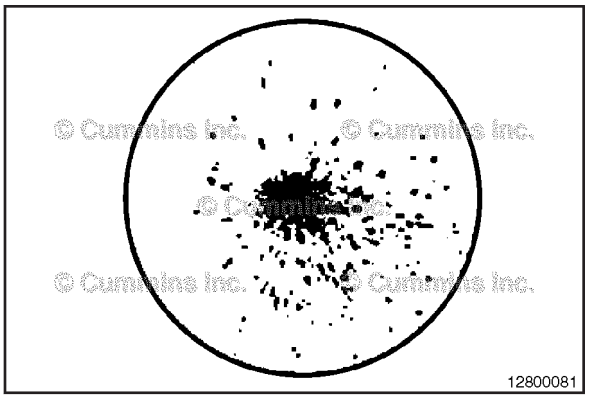
To perform the test, start the engine and run at high idle. Leave the test paper in the airflow for exactly 5 minutes. Remove the test paper, or rotate the tool mask exposing a new circular test area.

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.

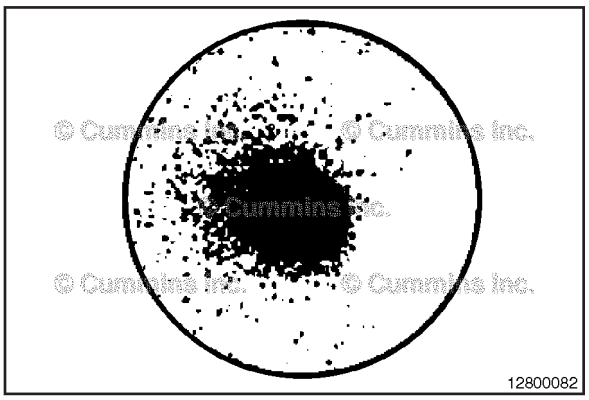




NOTE: Compare the test results with the reference results shown below.

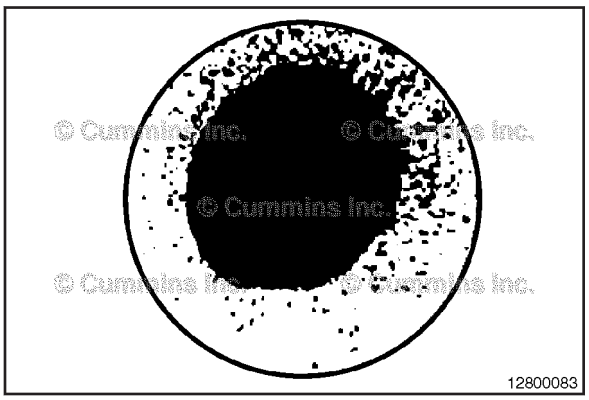
Time Air Compressor Has Been In Service (Months/ Years):

- 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.



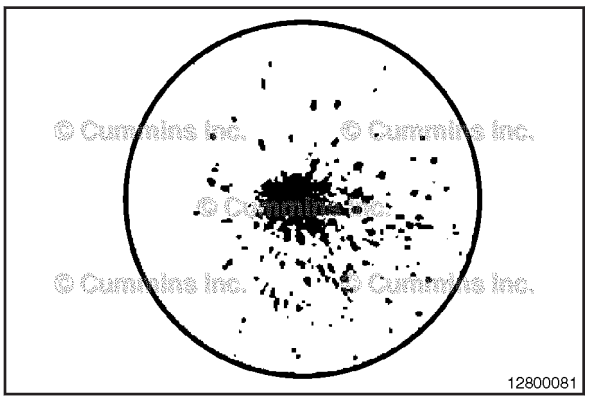
Time Air Compressor Has Been In Service (Months/ Years):

- 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.



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.

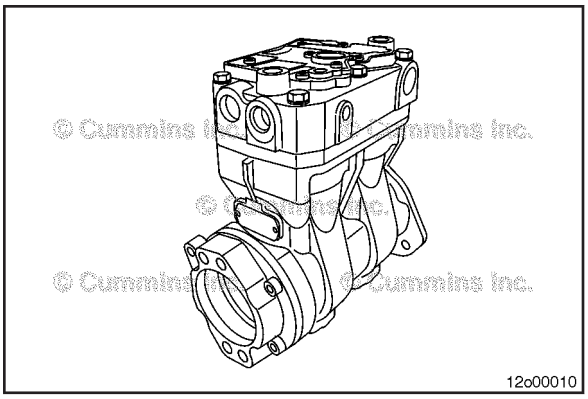
If the compressor is deemed failed and needs to be replaced, please place the test paper, with results of Oil Carryover Test, in a sealable plastic bag, seal to prevent oil contamination, and include with the failed compressor.

Air Compressor Rear Bearing Housing, Two Cylinder (012-112)

General Information

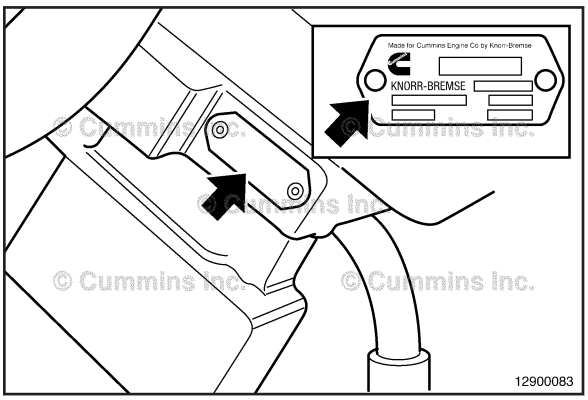
Before removing the rear bearing housing of the air compressor, **always** check to make sure parts are available for the type of air compressor being serviced. If parts are **not** available, it will be necessary to replace the entire air compressor.

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.

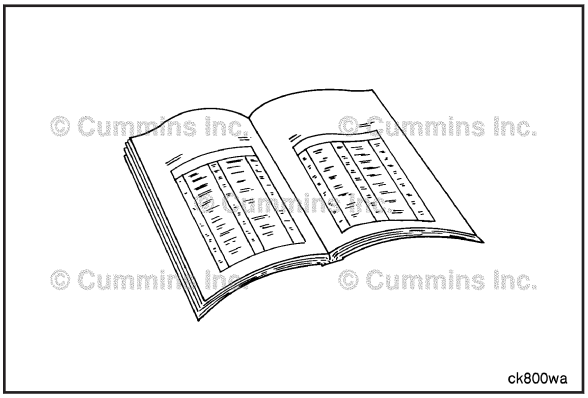
To determine what brand air compressor your specific engine has, look on the air compressor dataplate, usually located on the side of the air compressor.



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.

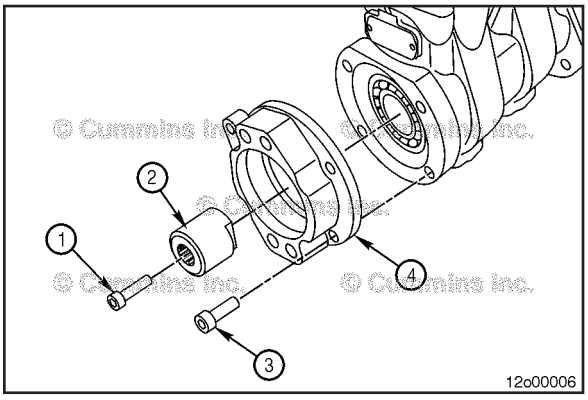


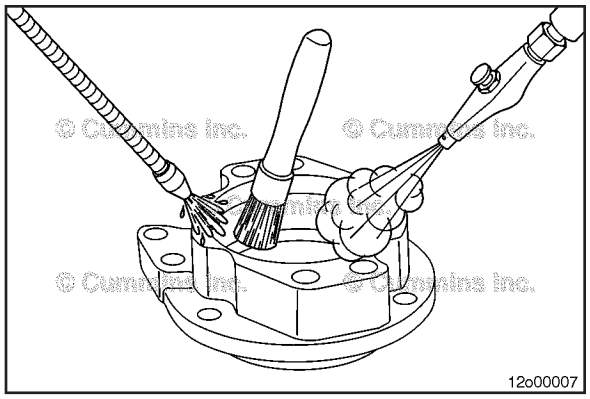
Remove

Remove the drive adapter capscrew (1) and drive adapter (2).

Remove the rear bearing housing mounting capscrews (3).

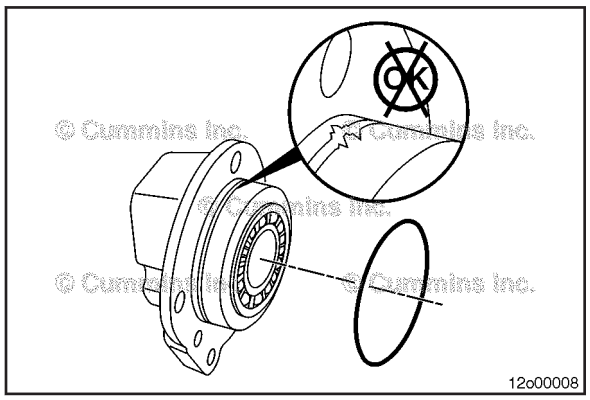
Remove the rear bearing housing(4).





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.

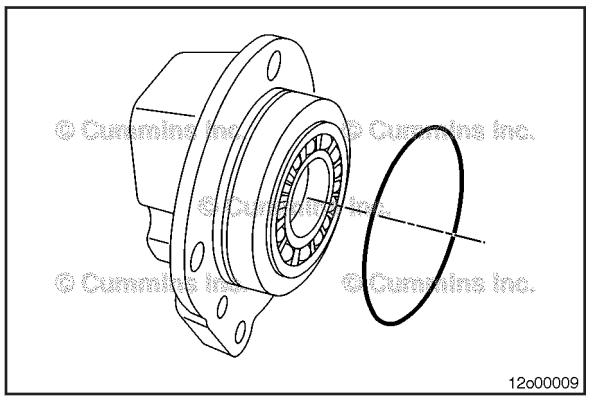


Remove the o-ring seal.

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.

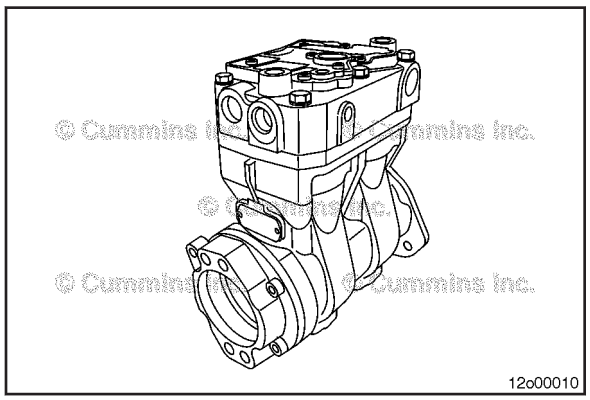
Replace the complete air compressor assembly, if any damage is found.



Install

Knorr-Bremse™ Air Compressors

Install a new o-ring seal in the compressor rear bearing housing.

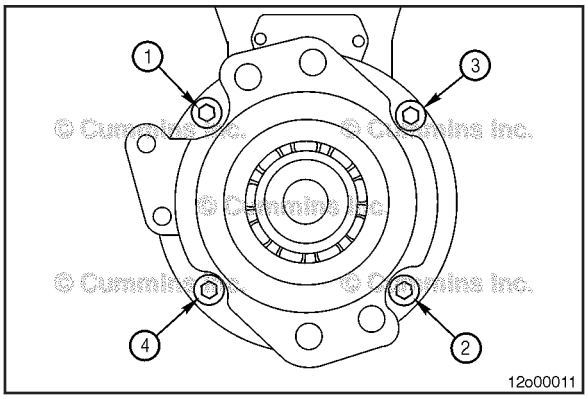


Install the rear bearing housing.

Install the mounting capscrews.

Tighten the capscrews in the sequence shown.

Torque Value: 22 N•m [195 in-lb]

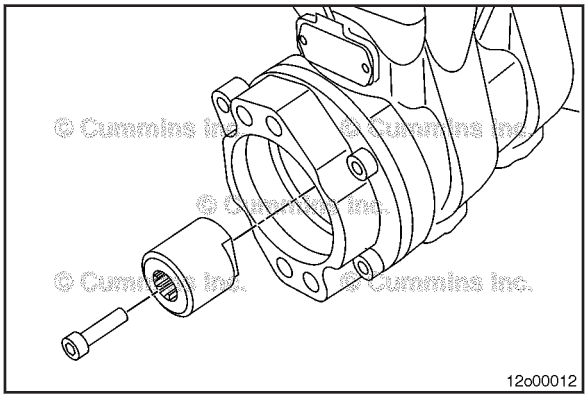


Install the drive adapter and mounting capscrew.

NOTE: Loctite™ 638, or equivalent **must** be applied to the capscrew during installation.

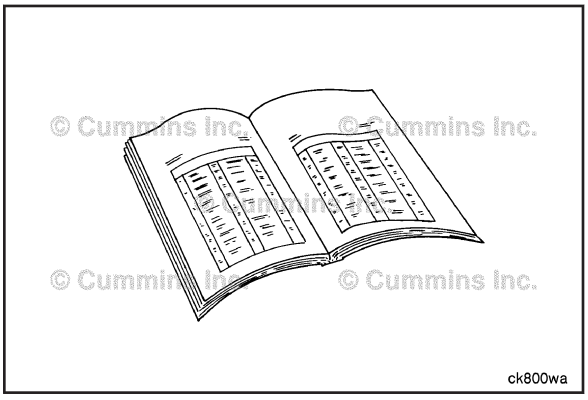
Tighten the capscrew.

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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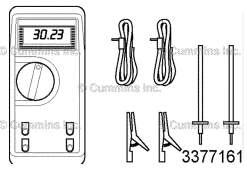
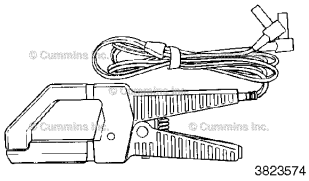
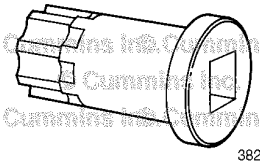
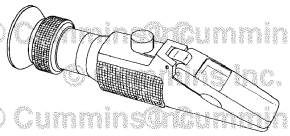
Service Tools

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 (VDC), resistance (ohms), and current (amps). 3164488 — Standard meter. 3164489 — Automotive meter with built in temperature adapter and tachometer.	
3164490	**Clamp-on Current Probe** Used to measure DC currents from 1 to 1000 amps or AC currents from 1 to 1000 amps.	
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.	

Alternator (013-001)

General Information

Due to the number of different alternator brands and configurations, the following procedure has been generalized to cover the most common configurations. Consult the alternator manufacturer for any information that is **not** covered in this procedure.

Typical Delco™ Alternator Wiring System

Indicator (I) Terminal

The main function of the indicator (I) terminal is to indicate if the alternator is working correctly. Typically, an indicator light is wired to this terminal. If the alternator is **not** charging properly, the light turns on. Another function of the indicator (I) terminal is that it can be used to supply up to 1 ampere of output at system voltage.

Lamp (L) Terminal

Similar to the I terminal, the L terminal is used to indicate if the alternator is working correctly. The difference between the L terminal and the I terminal is that the L terminal is a current sink **only** and can **not** be used to reduce turn on speed.

Relay (R) Terminal

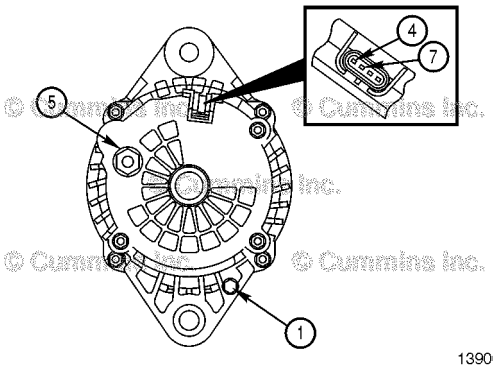
The function of the relay (R) terminal varies. It can supply up to 4 amperes of output at one-half nominal alternator voltage to power items such as a tachometer or an hour meter.

One-Wire System

This is the simplest of the wiring systems because the **only** wires connected to the alternator are at the battery (BAT) and ground terminals. (See Table 5.) Connecting to the R terminal, L terminal, and I terminal is optional.

Three-Wire System

This system requires more wiring because it has a battery (BAT) terminal, R terminal, two blade terminals identified as number 1 and number 2, and a ground terminal. Typically, in the three-wire system, the number 1 blade terminal serves as the I terminal. (See Table 5.) The advantage of the three-wire system is that it provides the same features as the one-wire system, plus remote sense. By connecting the number 2 blade terminal to the battery's positive (+) terminal, the voltage is both sensed and regulated at the battery, instead of at the alternator. This eliminates the potential for voltage losses in the wiring from the alternator to the battery.

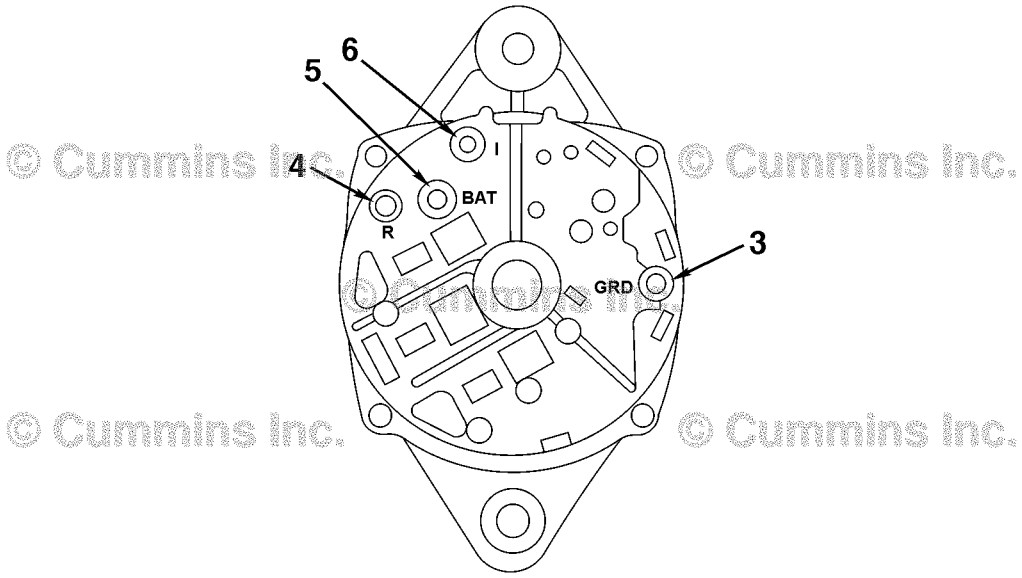


One Wire System, Typical Alternator (Delco-Remy™) with Combined Metri-Pack™ Connector

One Wire System, Typical Alternator (Delco-Remy™) with Combined Metri-Pack™ Connector		
1	**GRD***	**Ground**
4	**R***	**Charge indicator, automatic lockout system, tachometer****
5	**BAT**	**Battery**
7	L	Lamp Terminal

***Not** all alternators have this feature.

**Provides voltage pulses at about one-half system voltage at a frequency of one-tenth of generator rpm.



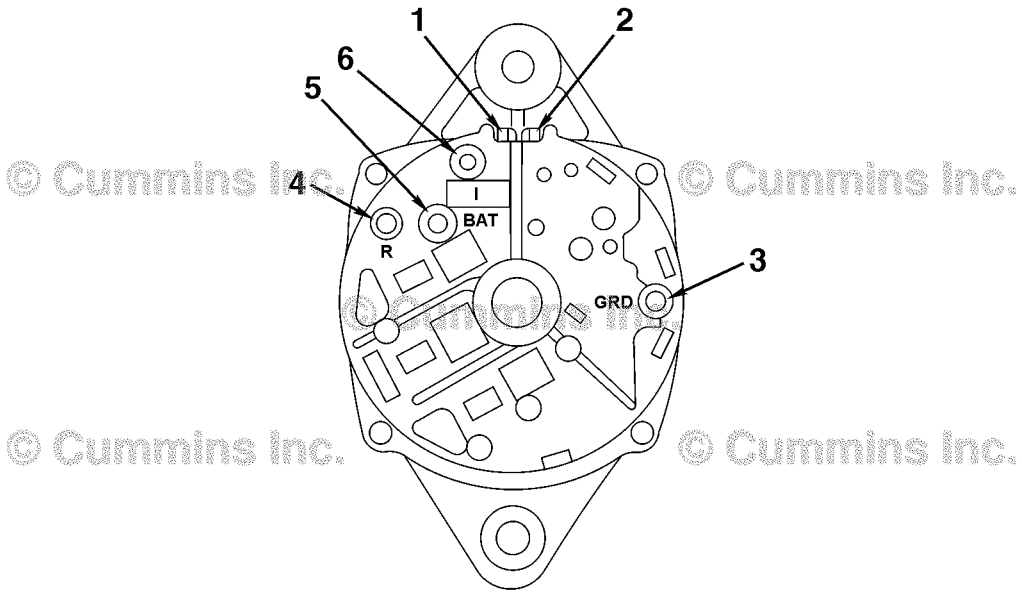
13900134

One Wire System, Typical Alternator (Delco-Remy™)

One Wire System, Typical Alternator (Delco-Remy™)		
3	**GRD***	**Ground**
4	**R***	**Charge indicator, automatic lockout system, tachometer****
5	**BAT**	**Battery**
6	I*	Indicator light

***Not** all alternators have this feature.

**Provides voltage pulses at about one-half system voltage at a frequency of one-tenth of generator rpm.



13900135

Three Wire System, Typical Alternator (Delco-Remy™)

Three Wire System, Typical Alternator (Delco-Remy™)		
Key	**Terminal**	**Connected To**
1	Blade number 1*	Indicator light
2	Blade number 2	Voltage sense
3	GRD*	Ground
4	R*	Charge indicator, automatic lockout system, tachometer**
5	BAT	Battery
6	I*	Indicator light

***Not** all alternators have this feature.

**Provides voltage pulses at about one-half system voltage at a frequency of one-tenth of alternator rpm.

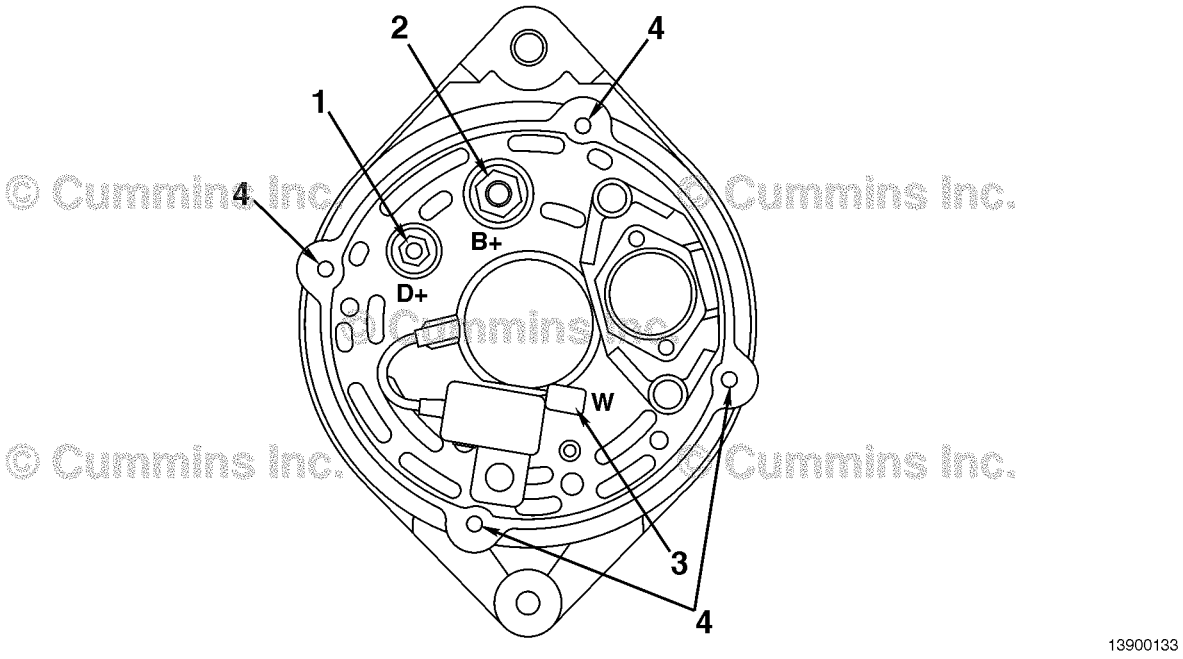
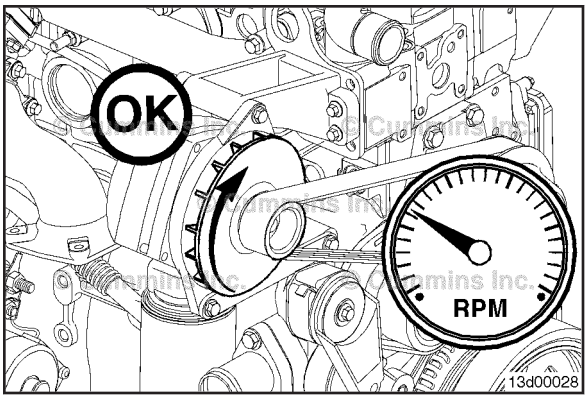


Table 6, Typical Alternator (Bosch™ K1)

Typical Bosch™ K1 Wiring System		
Key	**Terminal**	**Connected to**
1	D+	Electrical charging system status light
2	B+	Positive battery
3	W	Tachometer
4	—	Ground/assembly

Initial Check



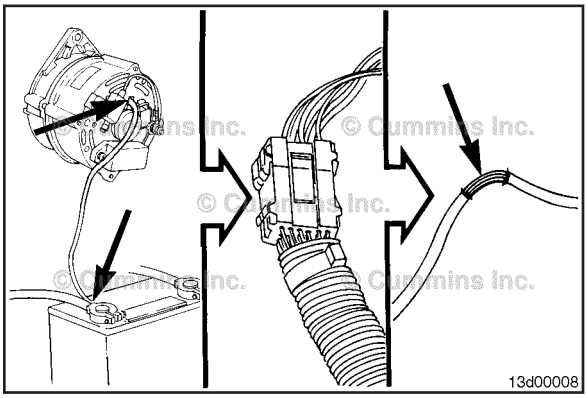
Check the drive belt and alternator pulley, to be sure the alternator is rotating properly.

If any problems exist, check the following:

1 If the drive belt is slipping on the alternator pulley, inspect the drive belt.Refer to Procedure 008-002 in Section 8. Refer to Procedure 008-087 in Section 8. Inspect the belt tensioner.

2 Remove the drive belt. Refer to Procedure 008-002 in Section 8. Check if the alternator pulley is loose on the shaft. If loose, remove the pulley and inspect for damage. Refer to the alternator manufacturer's and/or OEM service manual.

3 If the alternator will **not** rotate or does **not** rotate freely, the alternator **must** be replaced. See the Remove and Install steps of this procedure.



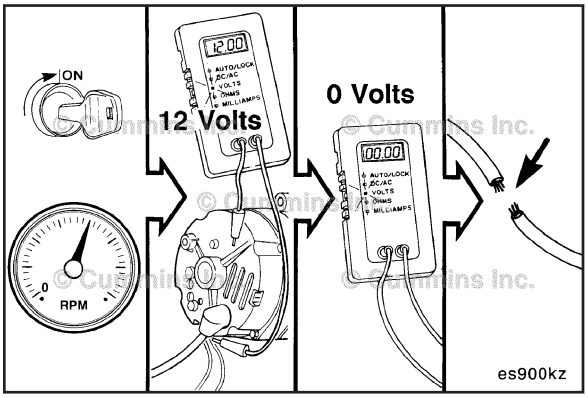
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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 the connections at the battery.

Test



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:

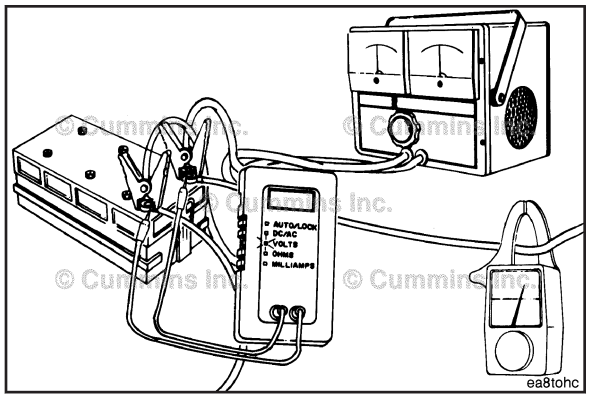
Delco™ Alternators

1 Alternator “BAT” terminal to ground

2 Alternator blade terminal “number 1” to ground

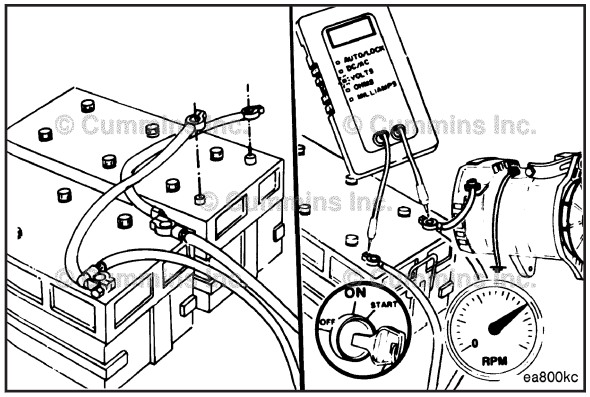
3 Alternator blade terminal “number 2” to ground.

Locate and repair the open circuit.



Connect a carbon-pile load (battery/alternator tester) across the batteries in one 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.

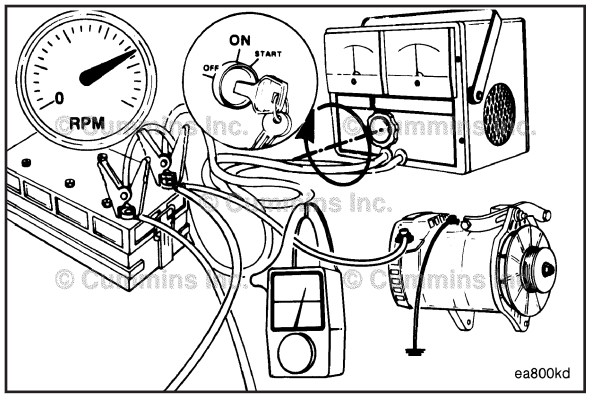


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠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 service manual.



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 service manual.

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.

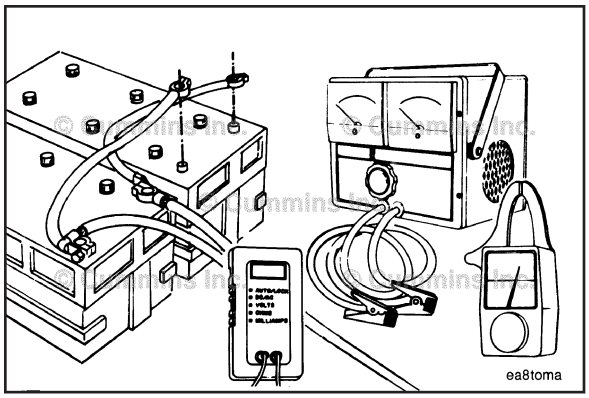
If the alternator output (amperes) are **not** within 10 percent of rated output, repair or replace the alternator. Refer to the OEM service manual for repair procedures.

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To avoid 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.



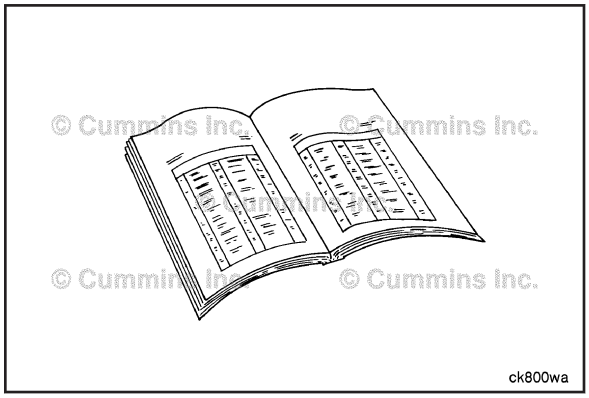
Preparatory Steps

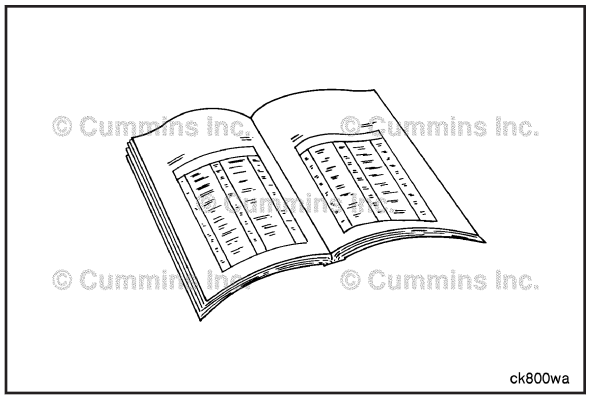
Automotive and Industrial

⚠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⚠
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 the ground cable from the battery terminal.
- Remove the drive belt from the alternator pulley.Refer to Procedure 008-002 in Section 8.
- Tag and label all wires on the alternator.
- Disconnect the wires.





Marine Applications

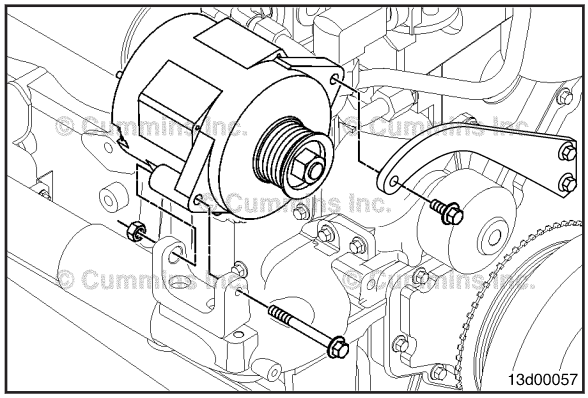
⚠WARNING⚠

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⚠

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 the ground cable from the battery. Refer to Procedure 013-009 in Section 13.
- Remove the belt guards. Refer to Procedure 008-001 in Section 8.
- Remove the water pump (cooling fan) drive belt from the alternator drive pulley. Refer to Procedure 008-002 in Section 8.
- Tag and label all wires on the alternator.
- Disconnect the wires.



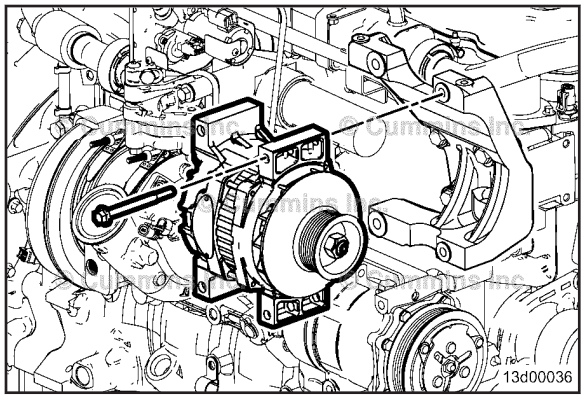
Remove

Spool Mount

Remove the upper alternator link capscrew.

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

Remove the alternator.



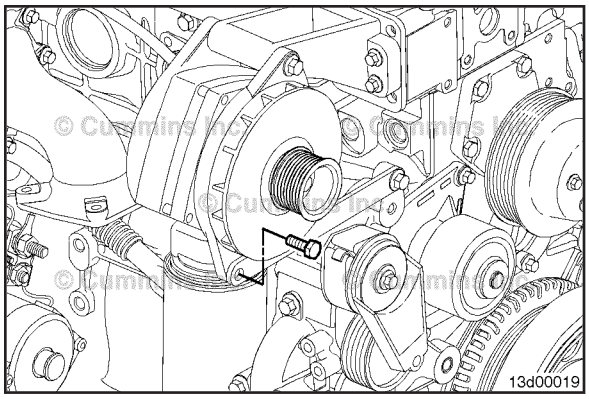
Pad Mount

Remove the alternator mounting capscrews.

Remove the alternator.

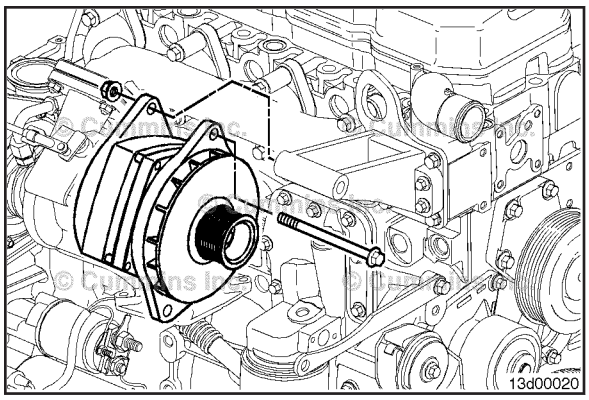
Hinge Mount

Remove the alternator link capscrew.



Remove the alternator mounting capscrew.

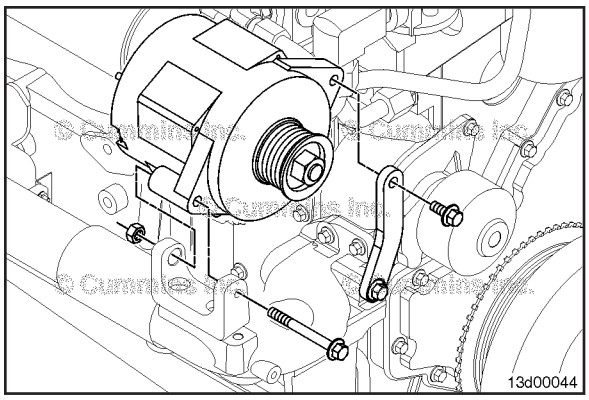
Remove the alternator.



Marine Applications

Remove the capscrew from the top of the alternator and alternator link.

Remove the mounting capscrew at the bottom of the alternator and alternator mounting bracket.



Typical Delco™ Alternator Wiring System

The main function of the indicator (I) terminal is to indicate if the alternator is working correctly. Typically, an indicator light is wired to this terminal. If the alternator is **not** charging properly, the light turns on. Another function of the indicator (I) terminal is that it can be used to supply up to 1 ampere of output at system voltage.

Relay (R) Terminal

The function of the relay (R) terminal varies. It can supply up to 4 amperes of output at one-half nominal alternator voltage to power items such as a tachometer or an hour meter.

One-Wire System

This is the simplest of the wiring systems because the **only** wires connected to the alternator are at the battery (BAT) and ground terminals. (See Table 5.) Connecting to the R terminal and I terminal is optional.

Three-Wire System

This system requires more wiring because it has a battery (BAT) terminal, R terminal, two blade terminals identified as number 1 and number 2, and a ground terminal. Typically, in the three-wire system, the number 1 blade terminal serves as the I terminal. (See Table 5.) The advantage of the three-wire system is that it provides the same features as the one-wire system, plus remote sense. By connecting the number 2 blade terminal to the battery's positive (+) terminal, the voltage is both sensed and regulated at the battery instead of the alternator. This eliminates the potential for voltage losses in the wiring from the alternator to the battery.

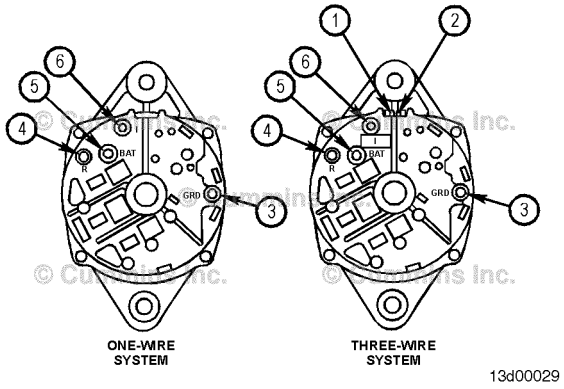


Table 5, Typical Alternator (Delco-Remy™)

Key	Terminal	Connected To
5	BAT	Battery
3	GRD*	Ground
4	R*	Charge indicator, automatic lockout system, tachometer**
1	Blade number 1*	Indicator light
2	Blade number 2	Voltage sense
6	I*	Indicator light

***Not** all alternators have this feature.

**Provides voltage pulses at about one-half system voltage at a frequency of one-tenth of the alternator rpm.

Install

Spool Mount

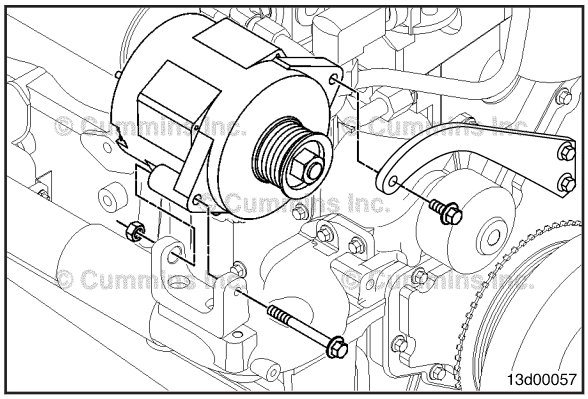
Install the alternator and the bottom alternator mounting capscrew and nut.

Install the upper alternator link mounting capscrew at the top of the alternator.

Tighten the capscrews.

Torque Value:
Lower Mounting Capscrew
Step 1 40 N•m [30 ft-lb]

Torque Value:
Upper Link Mounting Capscrew
Step 1 24 N•m [212 in-lb]



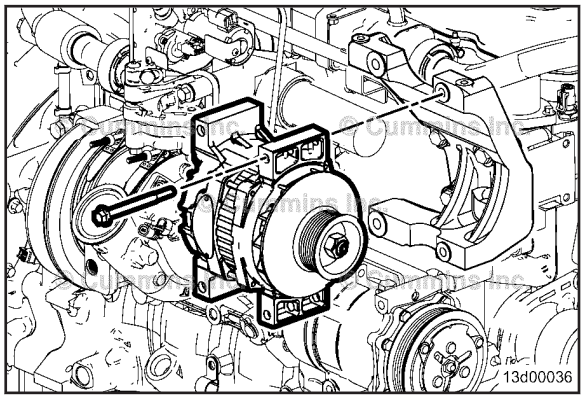
Pad Mount

Install the alternator.

Install and tighten the alternator mounting capscrews.

Torque Value:
M10 Capscrew
Step 1 36 N•m [27 ft-lb]

Torque Value:
M12 Capscrew
Step 1 64 N•m [47 ft-lb]

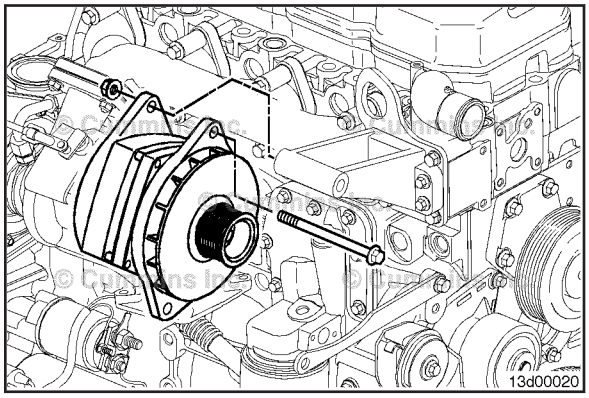


Hinge Mount

Install the alternator.

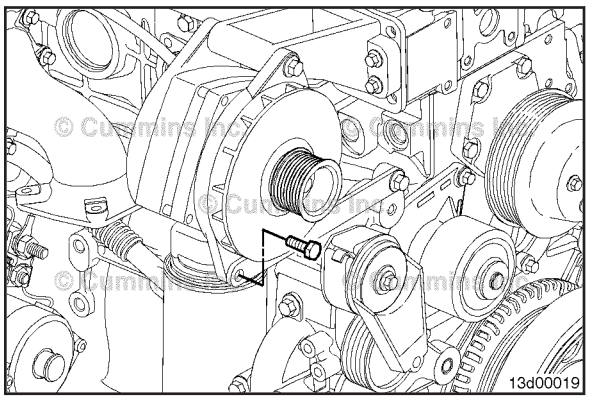
Install and tighten the alternator mounting capscrew.

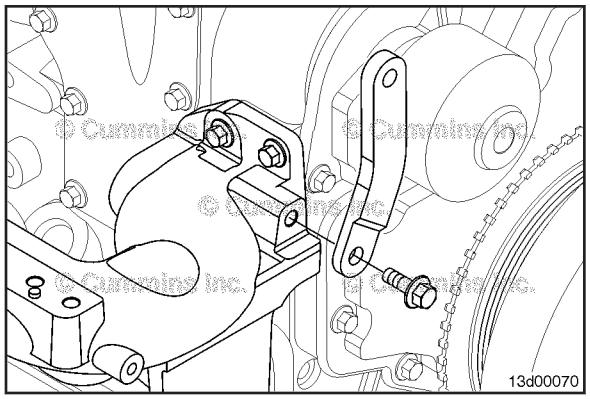
Torque Value: 40 N•m [30 ft-lb]



Install the alternator link capscrew.

Torque Value: 24 N•m [212 in-lb]



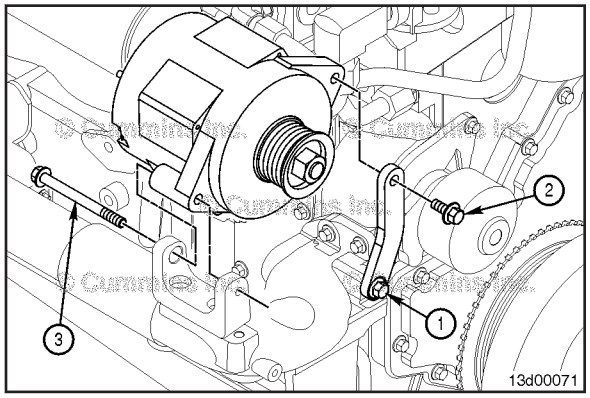


Marine Applications

Spool Mount or Saddle Mount

Inspect the water inlet connection. Test fit the alternator link to the water inlet. If the machined area is **not** sufficient for the link to sit flat as installed, the inlet will need to be replaced.

Refer to Procedure 008-082 in Section 8.



Install the alternator and alternator mounting capscrew.

Install the alternator link. Coat the lower capscrew threads (1) with a light coat of Loctite® 242, or equivalent, thread locking compound.

Install the capscrews.

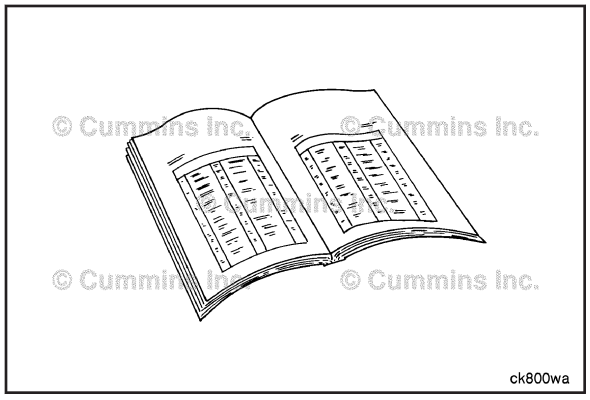
Tighten the capscrews.

Torque Value:
Capscrews (1,3)

Step 1	44 N•m	[33 ft-lb]

Torque Value:
Capscrew (2)

Step 1	35 N•m	[26 ft-lb]



Finishing Steps

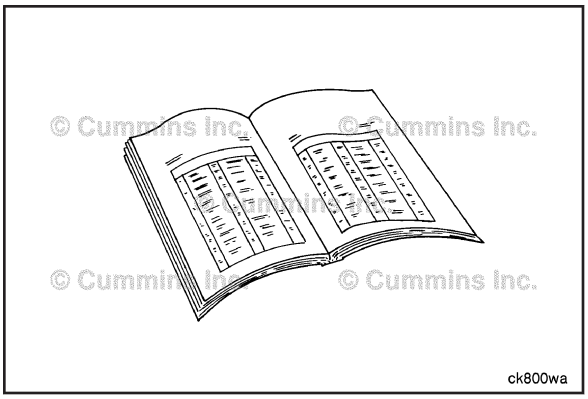
Automotive and Industrial

⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To avoid 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.

- Connect all wires to the alternator.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the battery ground cable. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for proper operation.

Marine Applications



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

⚠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.

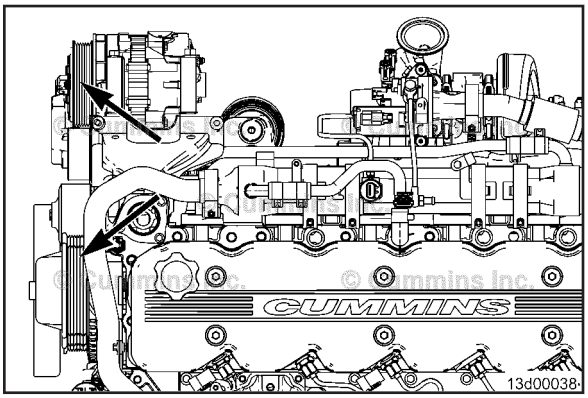
- Connect all wires to the alternator.
- Install the water pump (cooling fan) drive belt. Refer to Procedure 008-002 in Section 8.
- Install the belt guards. Refer to Procedure 008-001 in Section 8.
- Connect the battery ground cable. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for proper operation.

Alternator Bracket (013-003)

Initial Check

Check that the alternator pulley is in line with the other belt driven pulleys. Use Pulley Alignment Fixture, Part Number 3163524, to check the alignment.

If alternator pulley is out of alignment, verify that the correct alternator brackets have been used and/or have been installed correctly

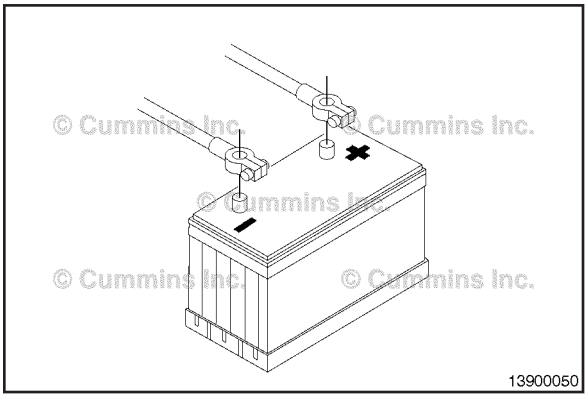


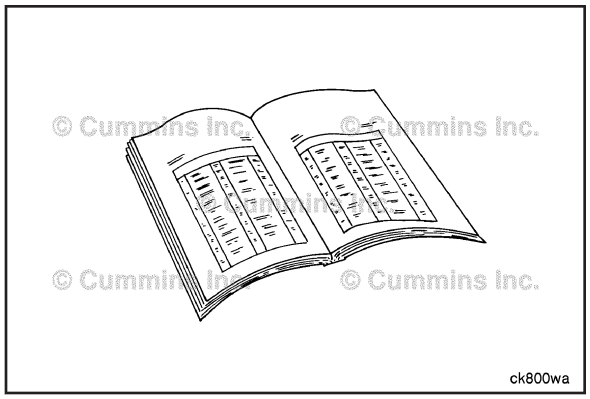
Preparatory Steps

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.

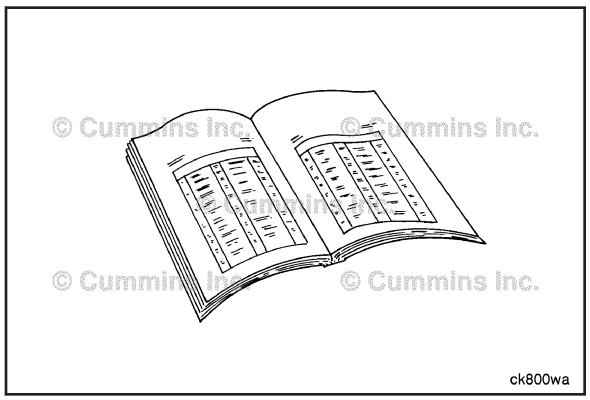
Disconnect the batteries.





Remove the drive belt. Refer to Procedure 008-002.

Remove the alternator. Refer to Procedure 013-001.



Marine Applications

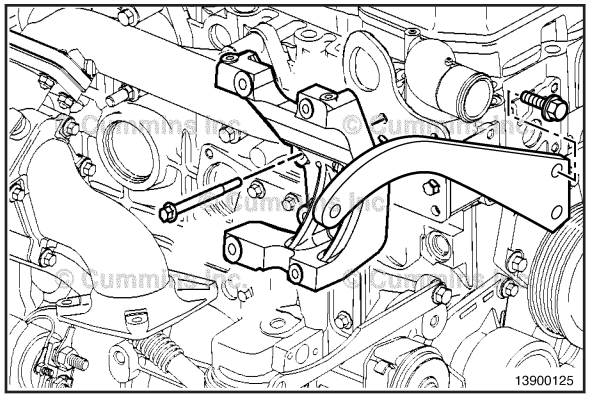
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Disconnect the battery. Refer to Procedure 013-009.

Remove the belt guards. Refer to Procedure 008-001.

Remove the water pump (cooling fan) drive belt from the alternator pulley. This can be done without removing the sea water pump drive belt. Refer to Procedure 008-002.

Remove the alternator. Refer to Procedure 013-001.



Remove

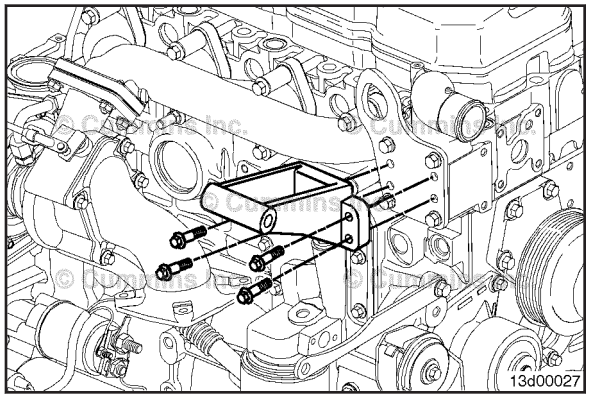
Spool Mount

NOTE: On some applications, the alternator bracket and water inlet are combined in the same bracket. Refer to Procedure 008-082, where applicable.

Remove the upper alternator bracket mounting capscrews.

Remove the lower alternator bracket mounting capscrews.

Remove the alternator bracket.



Hinge Mount:

Remove the upper alternator bracket mounting capscrews.

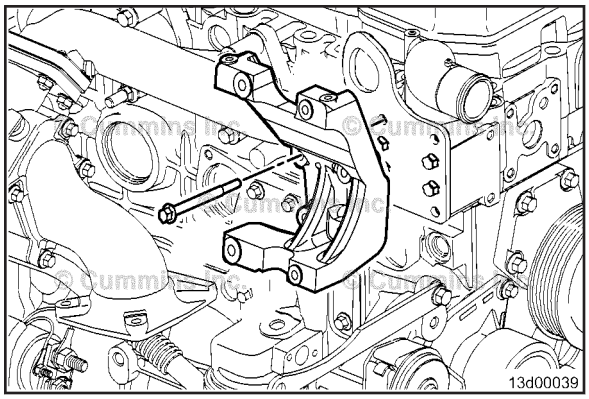
Remove the lower alternator bracket mounting capscrews.

Remove the alternator bracket.

Pad Mount

Remove the alternator bracket mounting capscrews.

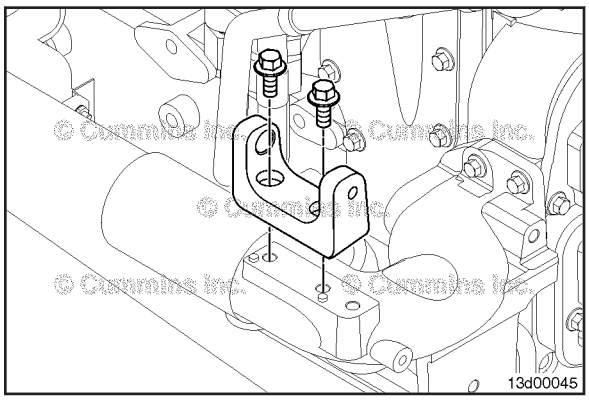
Remove the alternator bracket.



Marine Applications

Remove the two alternator mounting bracket capscrews.

Remove the alternator mounting bracket.



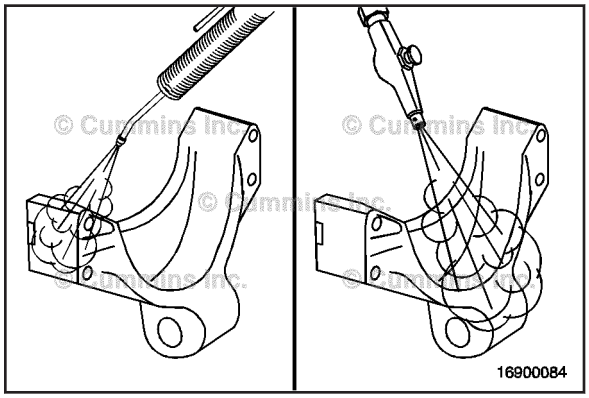
Clean and Inspect for Reuse

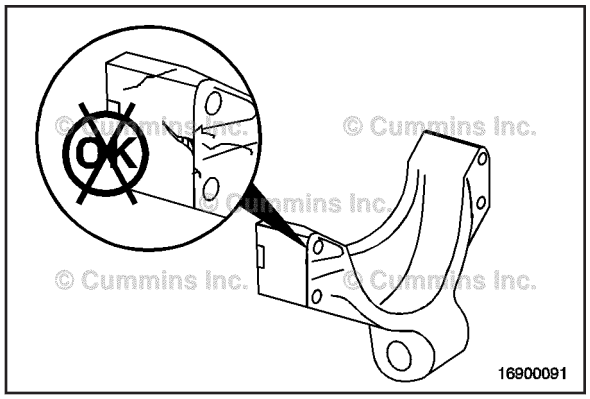
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠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.

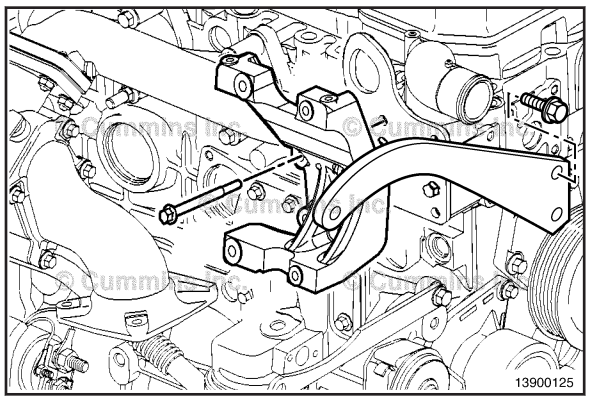
Use steam or solvent to clean the alternator brackets. Dry with compressed air.





Inspect the alternator brackets for cracks or damage.

If any cracks are found on the alternator brackets, they **must** be replaced.



Install

Spool Mount

NOTE: On some applications, the alternator bracket and water inlet are combined in the same bracket. Refer to Procedure 008-082, where applicable.

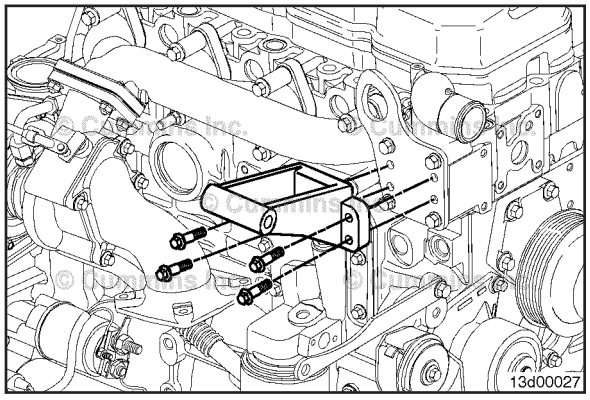
Install the upper alternator bracket and mounting capscrews.

Install the lower alternator bracket and mounting capscrew.

Tighten the upper and lower alternator bracket mounting capscrew.

Torque Value:

M8	24 N•m	[18 ft-lb]
M10	43 N•m	[32 ft-lb]



Hinge Mount.

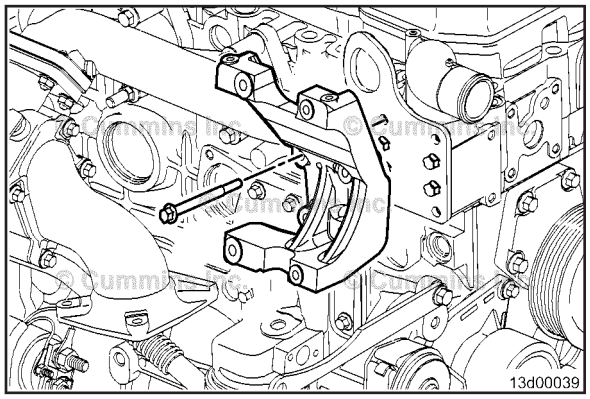
Install the upper alternator bracket and mounting capscrews.

Install the lower alternator bracket and mounting capscrew.

Tighten the upper and lower alternator bracket mounting capscrew.

Torque Value:

M8	24 N•m	[18 ft-lb]
M10	43 N•m	[32 ft-lb]



Pad Mount

△CAUTION△

If the alternator bracket has alignment roll pins, assure the pins are contacting the surface on cylinder head when the bracket is installed. Failure to do so will cause misalignment of the alternator pulley.

Install the alternator bracket.

Install and tighten the alternator bracket mounting capscrew.

Torque Value: 45 N•m [33 ft-lb]

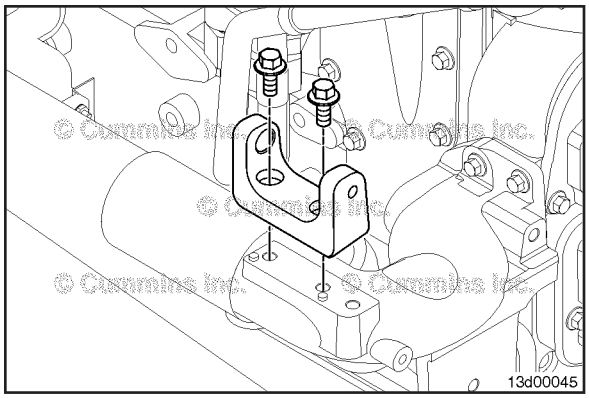
Marine Applications

NOTE: The coolant connection tube has two dowel pins used for correctly locating the alternator mounting bracket during installation.

Install the alternator mounting bracket over the two dowel pins.

Install the two alternator bracket mounting capscrews and tighten.

Torque Value: 54 N•m [40 ft-lb]

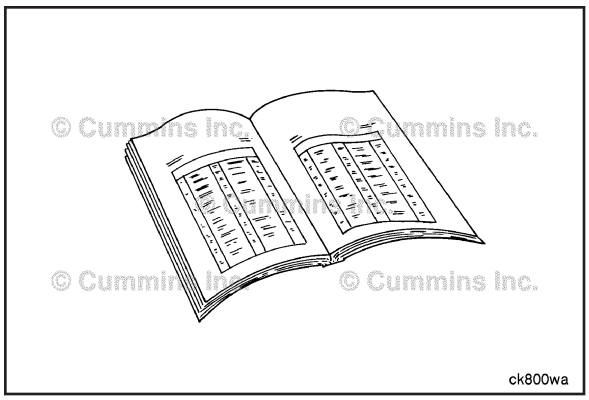


Finishing Steps

Automotive and Industrial

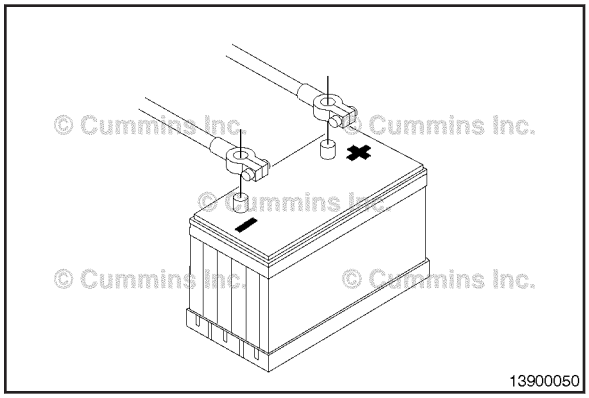
Install the alternator. Refer to Procedure 013-001.

Install the drive belt. Refer to Procedure 008-002.



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



Marine Applications

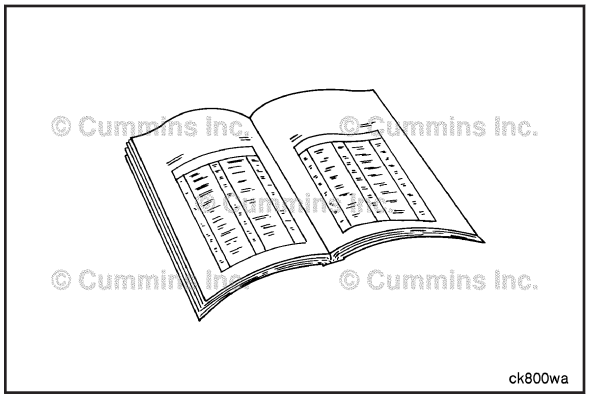
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

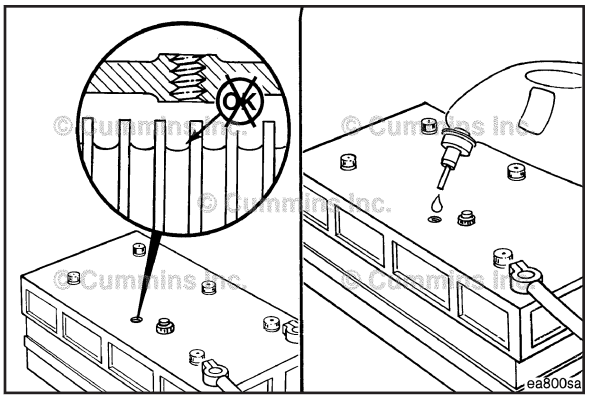
Install the alternator. Refer to Procedure 013-001.

Install the water pump (cooling fan) drive belt. Refer to Procedure 008-002

Install the belt guard. Refer to Procedure 008-001.

Connect the battery. Refer to Procedure 013-009.





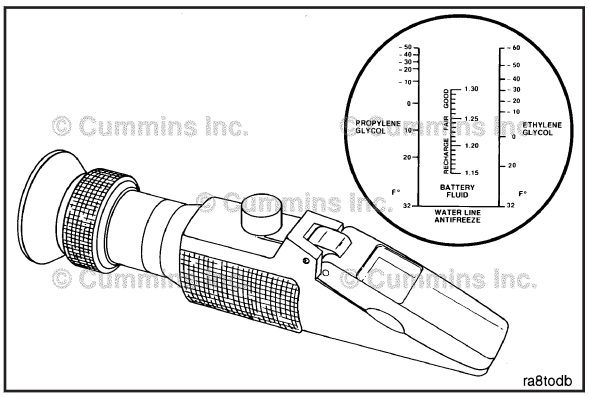
Batteries (013-007)

Initial Check

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.

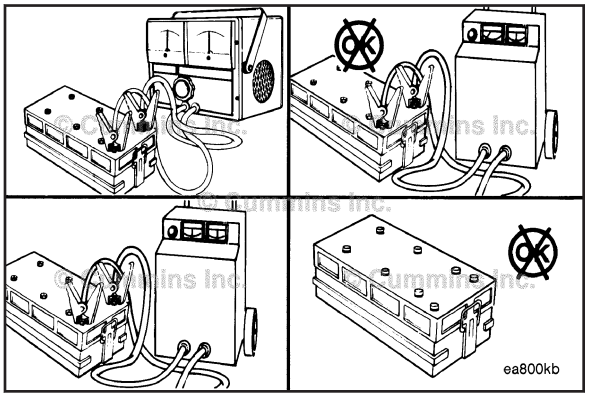
Fill each battery cell with distilled water. Refer to the battery manufacturer's specifications.



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 incorrect readings.



⚠CAUTION⚠
Do not connect battery charging cables to any electronic control system part. This can damage the electronic control system parts.

Using a carbon-pile load (battery/alternator tester), 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.

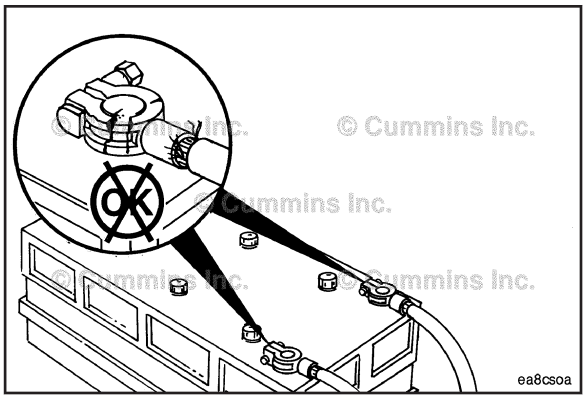
Battery Cables and Connections (013-009)

Initial Check

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

Inspect the battery terminals for loose, broken, or corroded connections.

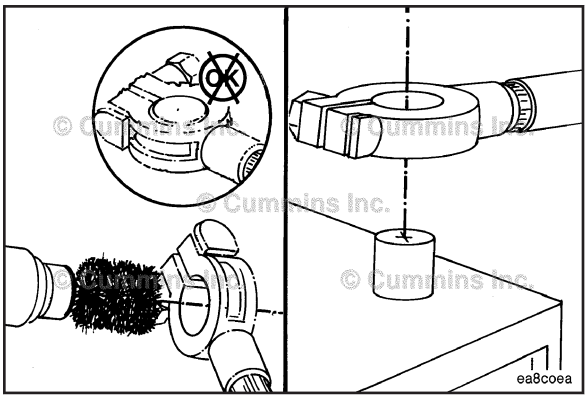
Repair or replace broken cables or terminals.



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)

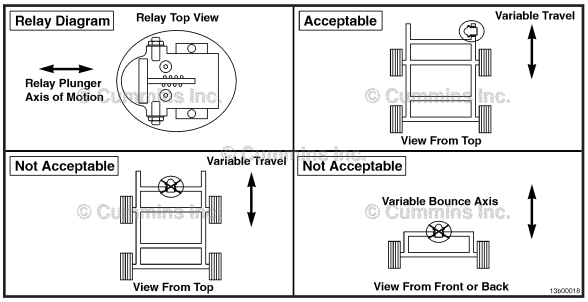
Initial Check

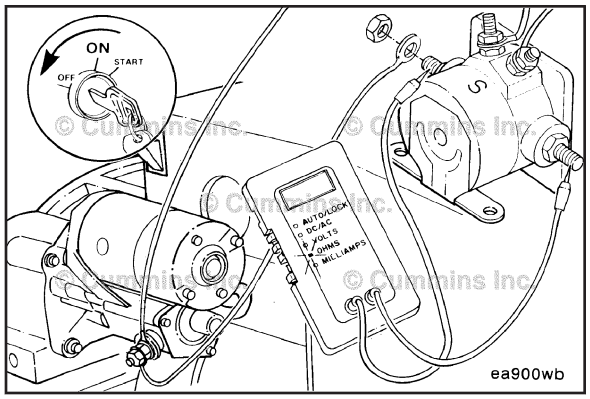
△CAUTION△
Improper installation of the starter magnetic switch can result in starter over-run damage.

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

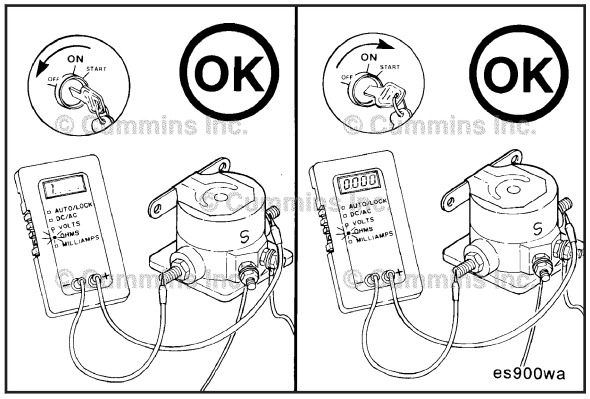
⚠WARNING⚠

Be sure the starter motor switch is in the OFF position to reduce the possibility of electrical shock and personal injury.

Remove the cable connecting the magnetic switch to the starter motor solenoid from the magnetic switch terminal.

Connect the leads of the digital multimeter, Part Number 3377161, or equivalent, to the two large switch terminals.

Set the digital multimeter, Part Number 3377161, to measure resistance (ohms).

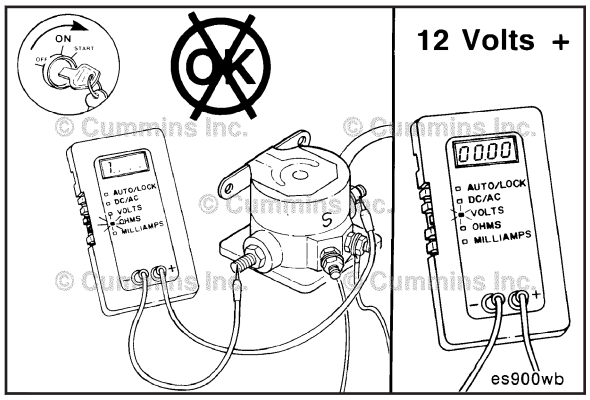


Connect the leads to the two large switch terminals.

With the keyswitch in the OFF position, the multimeter **must** indicate resistance greater than 100k ohms.

Turn the keyswitch to the START position.

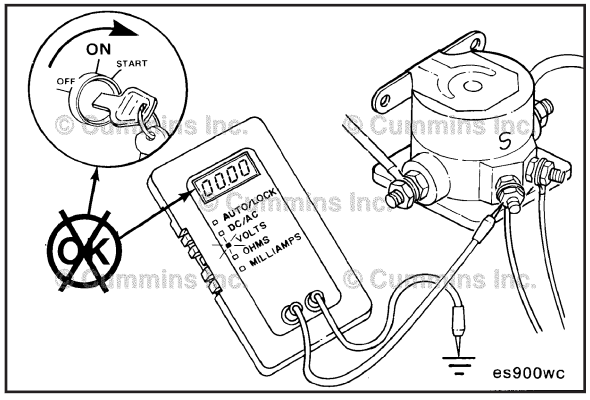
The multimeter **must** indicate less than 10 ohms. If **not** within specifications, replace the starter magnetic switch according to the manufacturer's instructions.



Voltage Check

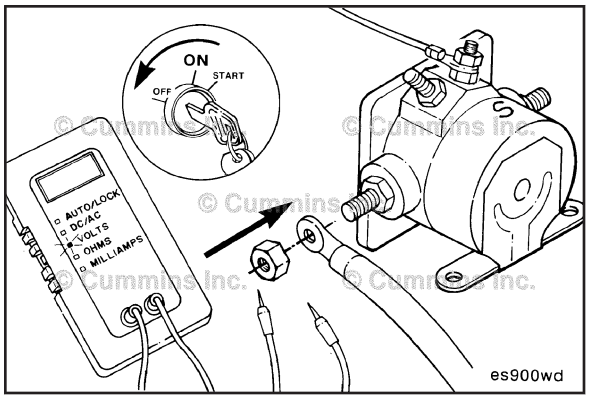
If the multimeter indicates resistance greater than 100k ohms with the keyswitch in the START position:

- Turn the keyswitch 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 keyswitch to the START position.
- If the multimeter indicates no voltage, the magnetic switch is **not** the cause of the complaint. If the starter magnetic switch is **not** within specification, replace the switch according to the manufacturer's instructions.

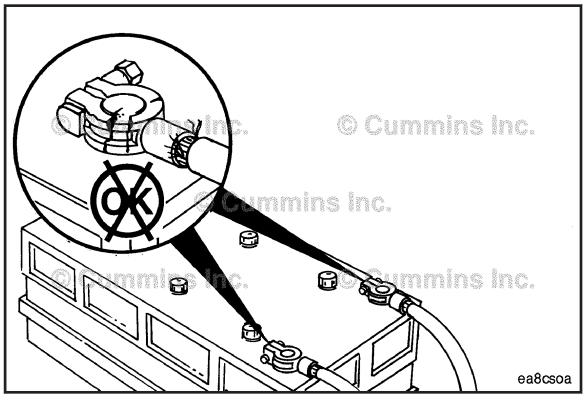
- Turn the keyswitch to the OFF position.
- Remove the multimeter leads, and connect the magnetic switch to the starter motor solenoid wire.



Starter Solenoid (013-019)

Initial Check

Before troubleshooting the starter motor, make sure the battery terminals are **not** loose or corroded. Refer to Procedure 013-007 and Refer to Procedure 013-009



Voltage Check

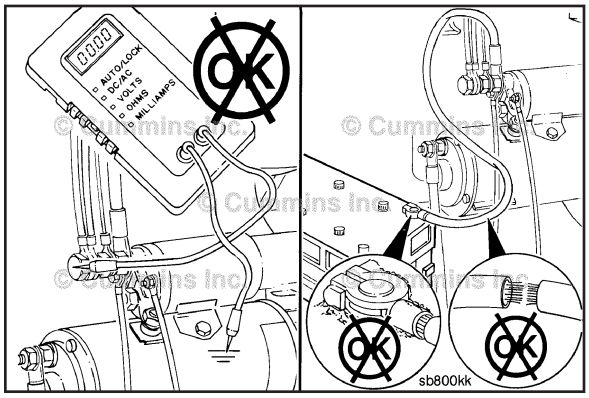
Digital Multimeter, Part Number 3377161

Set the digital multimeter, Part Number 3377161, to measure DC volts.

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 voltage with the keyswitch in the OFF position to be normal.

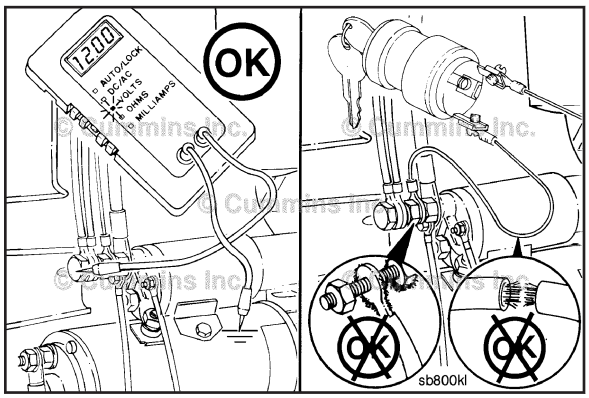
If the multimeter does **not** indicate voltage, check the cable connecting the starter solenoid and battery for breaks. Also, check for loose or corroded connections.

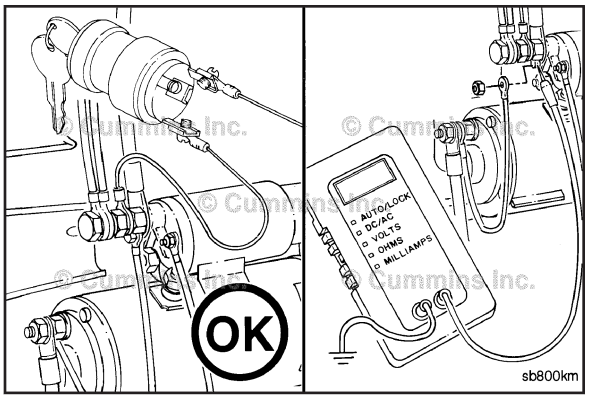


If the multimeter indicates voltage but the starter will **not** operate, check the wire connecting the starter solenoid to the keyswitch for breaks; and also check for loose or corroded connections.

In addition, be sure to check for:

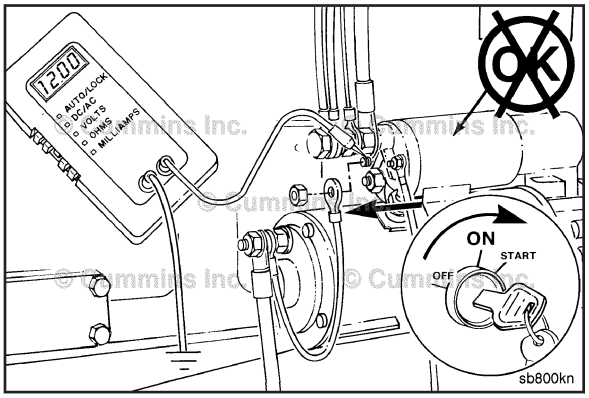
- Fuses
- Application engine shutoff systems.



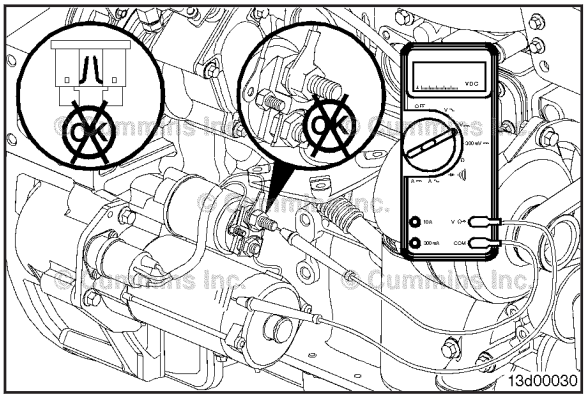


If the wire connecting the starter solenoid and keyswitch is **not** loose or damaged and the starter will **not** operate:

- Remove the cable connecting the starter and starter solenoid from the solenoid terminal.
- Connect the multimeter positive (+) lead to the solenoid "S" or switch terminal and the negative (-) lead to the chassis or an engine ground location.

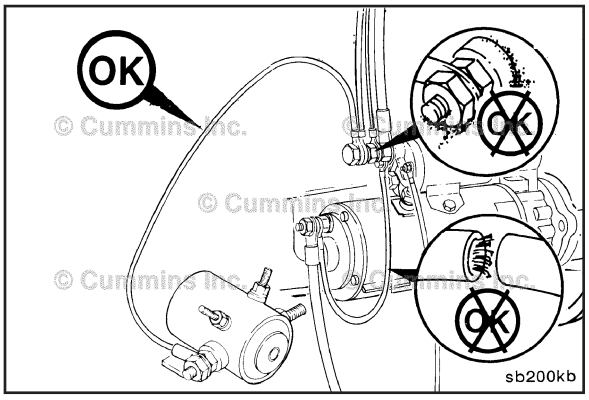


- Turn the keyswitch to the START position.
- If the multimeter indicates voltage and the starter will **not** operate, the starter solenoid is malfunctioning and **must** be replaced.
- Refer to Procedure 013-020



If the multimeter does **not** indicate system voltage:

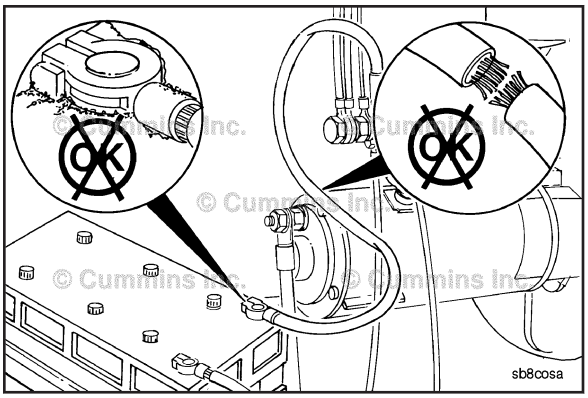
- Check the wire connecting the starter solenoid “S” or switch terminal to the magnetic switch for breaks, and for loose or corroded connections.
- Check that there are no blown fuses.
- Check voltage to the keyswitch and magnetic switch. Refer to Procedure 013-017 and Refer to Procedure 013-030
- Check application of the safety shut-off systems.



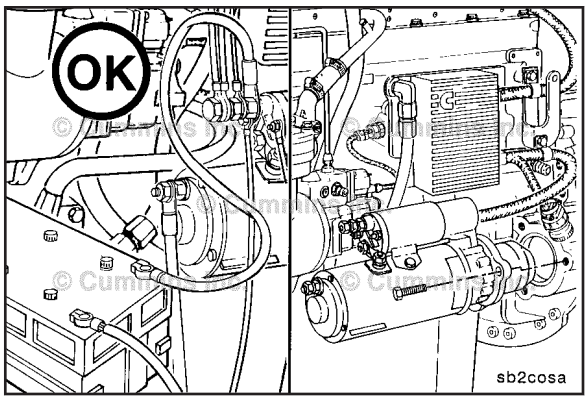
If the wire connecting the starter solenoid to the magnetic switch is **not** loose or damaged and the starter will **not** operate:

- Check the cable connecting the starter solenoid to the starter motor for breaks, and for loose or corroded connections.

- Check the cable connecting the starter motor to the battery for breaks, and for loose or corroded connections.



- If the cables are **not** loose or damaged, the starter motor is defective and **must** be replaced. Refer to Procedure 013-020



Starting Motor (013-020)

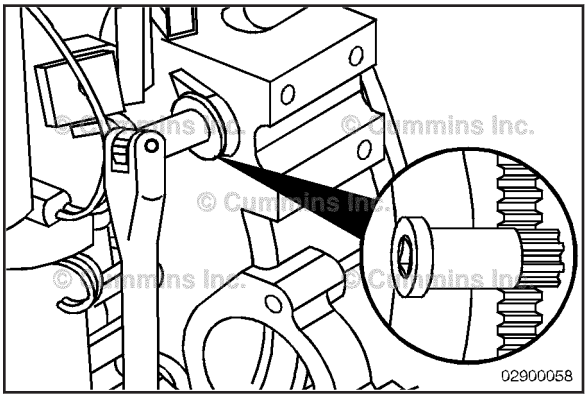
Rotation Check

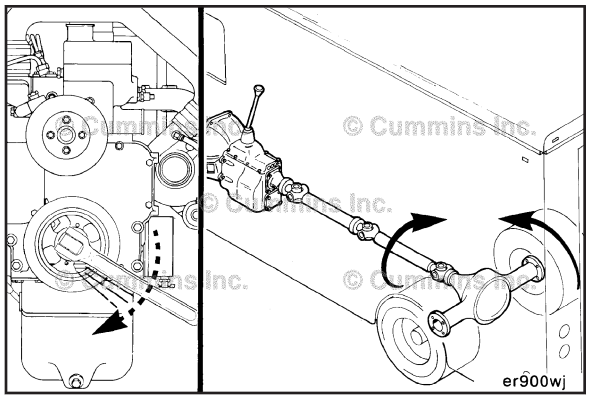
If the starter solenoid is making a sound but the engine is **not** rotating, turn the keyswitch to the OFF position, and attempt to bar the crankshaft in both directions.

Bar the engine with the barring tool, Part Number 3824591.

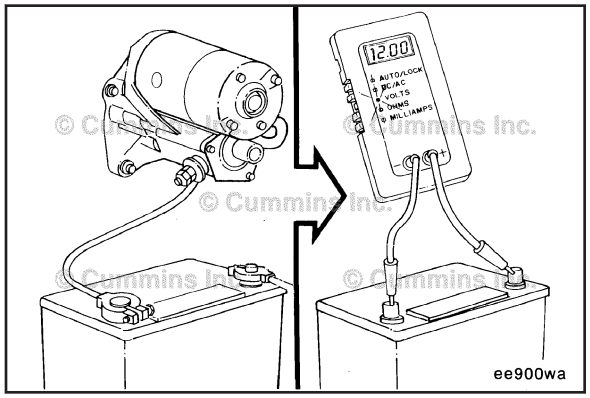
If the crankshaft will bar over, attempt to start the engine. If the starter motor cranks the engine, check the starter motor pinion gear and flywheel ring gear for damage.

If damage to the starter 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.





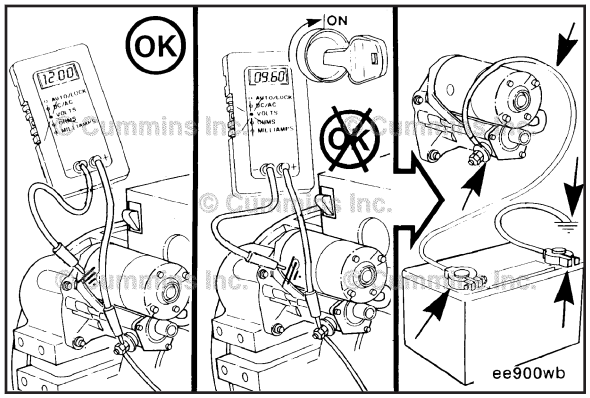
If the crankshaft does **not** rotate or requires more than the normal effort to bar, check for an internal malfunction or a problem with the drive unit and/or accessories.



If the engine cranking speed is too slow/will **not** crank at all, and the engine rotates freely:

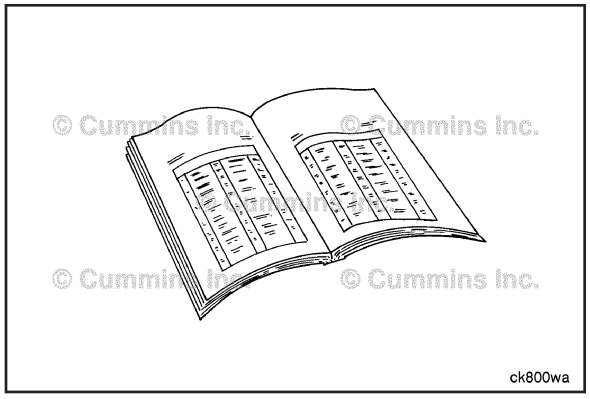
Make sure the wiring connections are clean, tight, and **not** damaged.

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 and 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.



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.

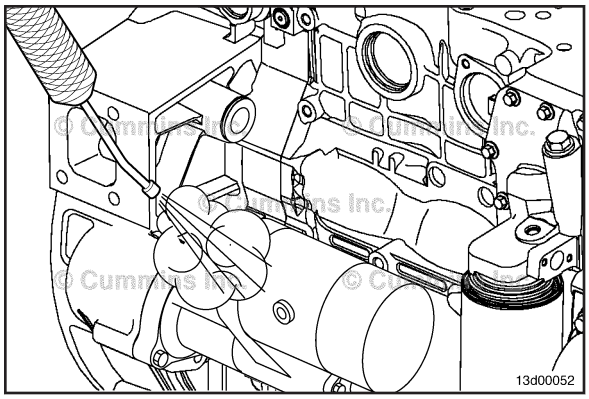
- Disconnect the ground cable from the battery terminal. Refer to the OEM service manual.
- Identify each wire with a tag indicating location on starting motor.
- Remove the electrical connections from the starting motor.

⚠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.

Prior to removing the starter, use steam to clean the area around the starting motor to prevent debris from entering the flywheel housing.

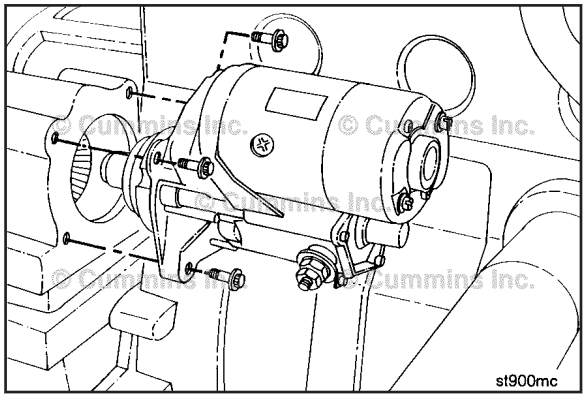
Dry with compressed air.



Remove

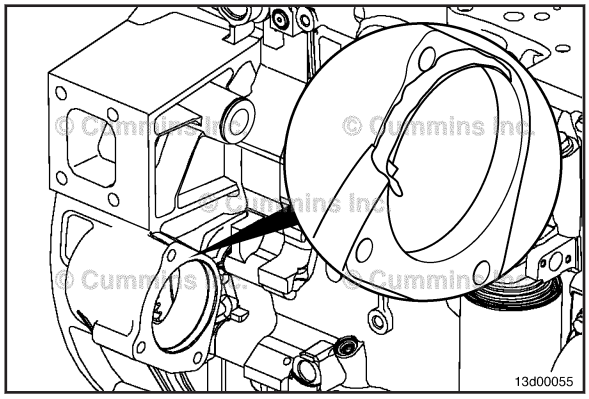
Remove the three capscrews and the starting motor.

NOTE: If equipped with a starting motor spacer, remove the spacer and clean all surfaces between the starting motor, starting motor spacer, and flywheel housing with a wire brush.



Clean and Inspect for Reuse

For engines that use wet flywheel housings, 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.

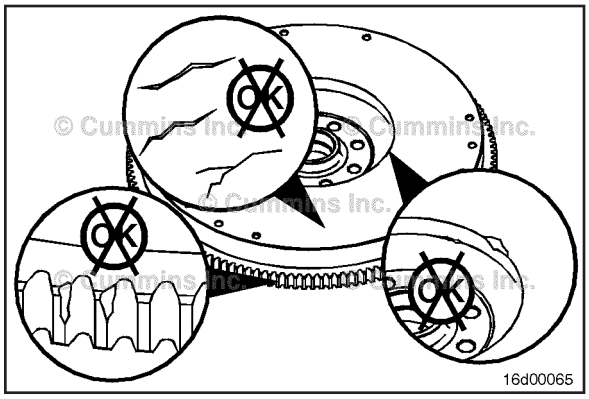


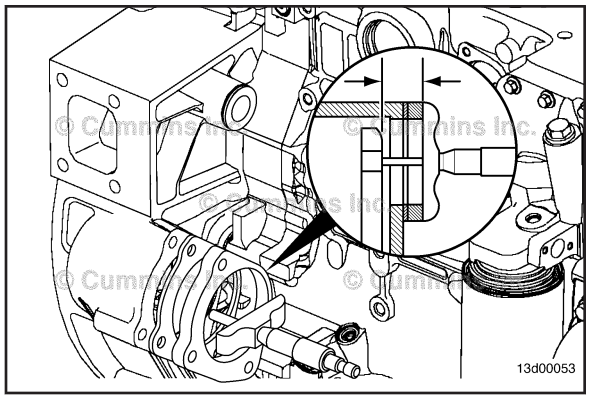
Inspect the starter motor pinion gear and/or flywheel ring gear for chipping or uneven wear.

NOTE: If the starter motor pinion gear and/or flywheel ring gear teeth are damaged, they **must** be replaced.

Use the following procedure if equipped, with a flywheel. Refer to Procedure 016-005 in Section 16.

Use the following procedure, if equipped with a flexplate. Refer to Procedure 016-004 in Section 16.





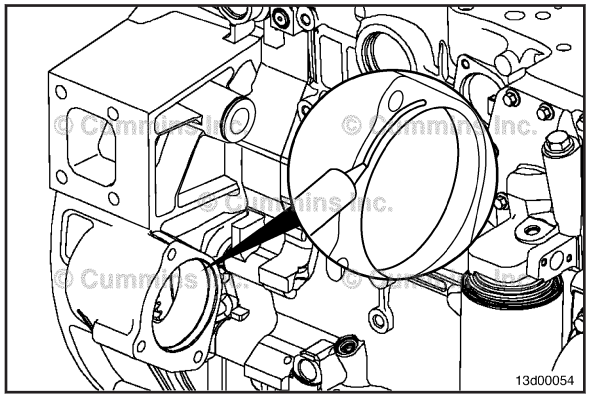
Measure

Using an inside micrometer or a vernier caliper, 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

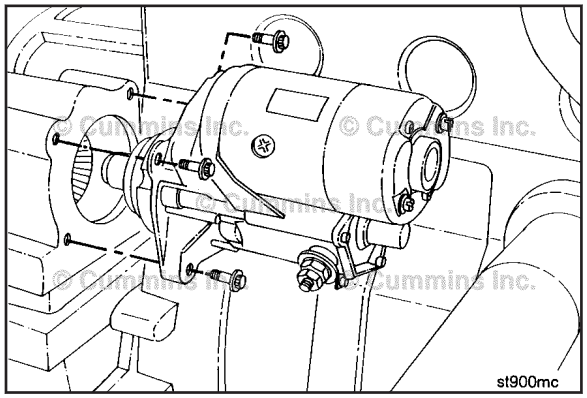
Add or remove spacers as necessary to achieve the correct starting motor spacing.



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.



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. Starter damage can result.

NOTE: Use the location tags to help identify where each wire connection goes.

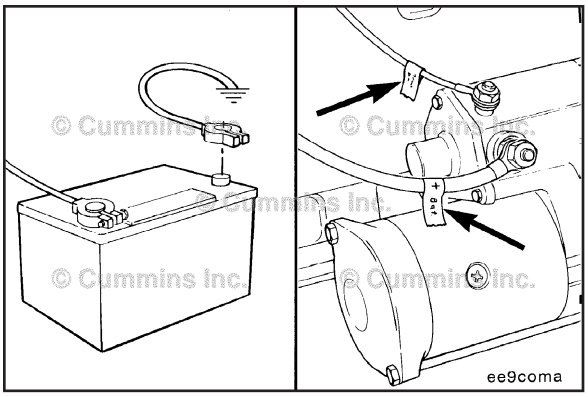
Connect the electrical connections to the starter motor.

Torque Value:
M5
Step 1 4 N•m [35 in-lb]

Torque Value:
M10
Step 1 21 N•m [185 in-lb]

Install the Jump Start Protection (JSP) cover and cover nut on the M-terminal post.

NOTE: The JSP cover nut is the third nut on the M-terminal, M5 terminal size. Failure to observe the proper torque specification can result in loss of conductivity to the M lead and result in a no crank condition for the starter and the engine.



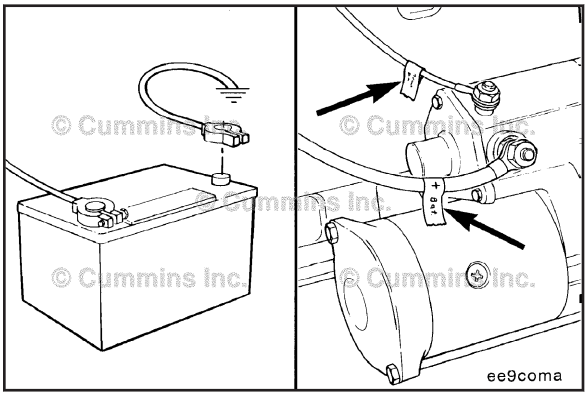
Non-Cummins® Branded Starters

⚠CAUTION⚠
Do not overtighten the electrical connections. Starter damage can result.

NOTE: Use the location tags to help identify where each wire connection goes.

Install the starter motor electrical connections.

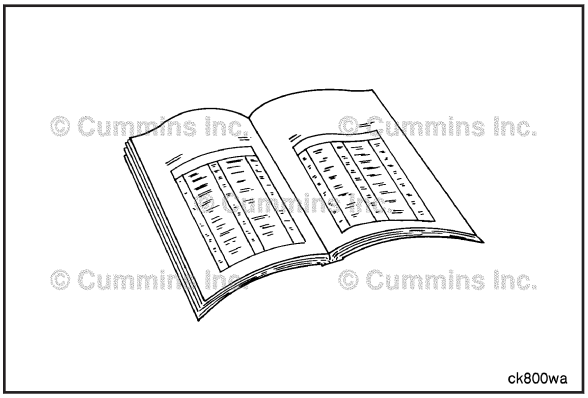
For Non-Cummins® branded starters, refer to the OEM service manual for torque specifications.

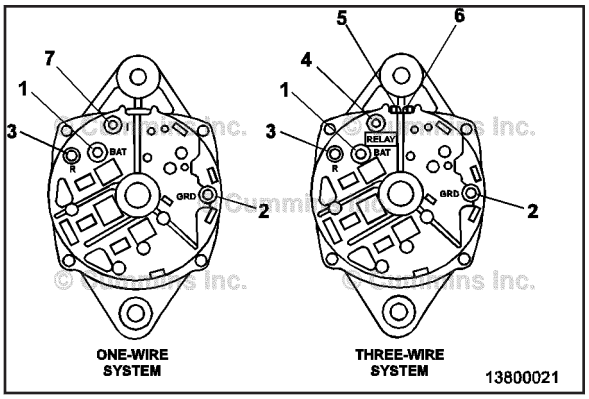


Finishing Steps

⚠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 ground cable to the battery terminal. Refer to the OEM service manual.



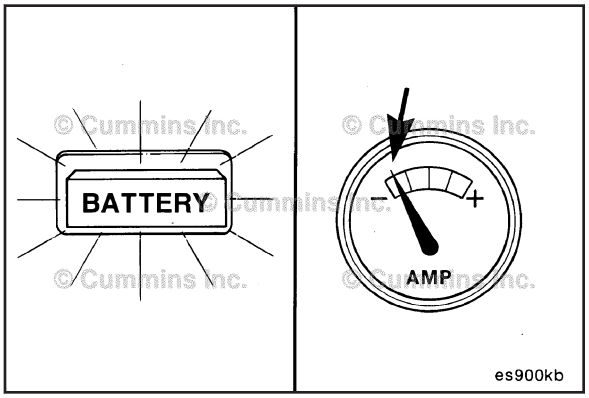


Charging System Indicator (013-023)

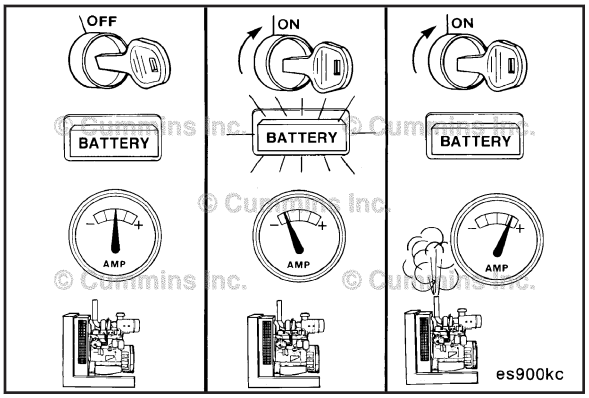
Initial Check

NOTE: Be positive that the correct terminals are used on the alternator.

Refer to the alternator manufacturer's instructions.

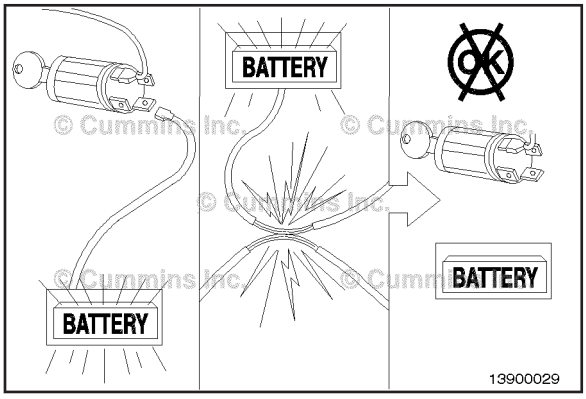


Trouble with the charging system can be indicated by the indicator lamp or ammeter.



Check the indicator lamp for normal operation as shown below.

Stopped	Off	Off	0
Stopped	On	On	(-)
Running	On	Off	(+)

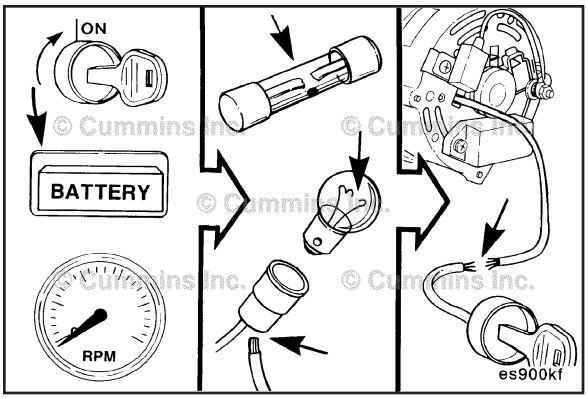


If the lamp is on when the switch is in the OFF position and the engine is **not** running, disconnect the lamp lead at the keyswitch.

- 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.

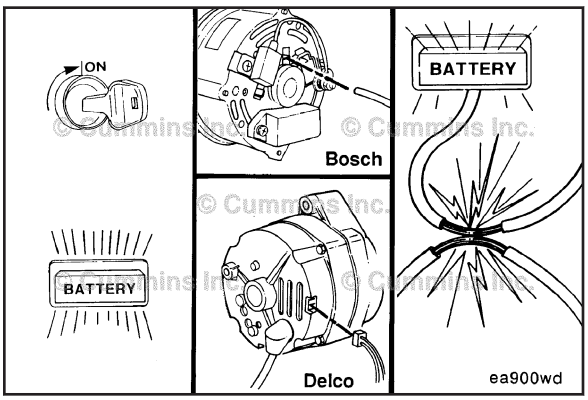
If the lamp is off when the switch is in the ON position and the engine is **not** running, there can be an open circuit.

Check for a blown fuse, a burned out bulb, defective bulb socket, or an open circuit in number 1 or "D+" lead between alternator and keyswitch.



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 ground in the lamp circuit. Refer to Procedure 013-001
- If the lamp goes out, inspect the alternator. Refer to Procedure 013-001



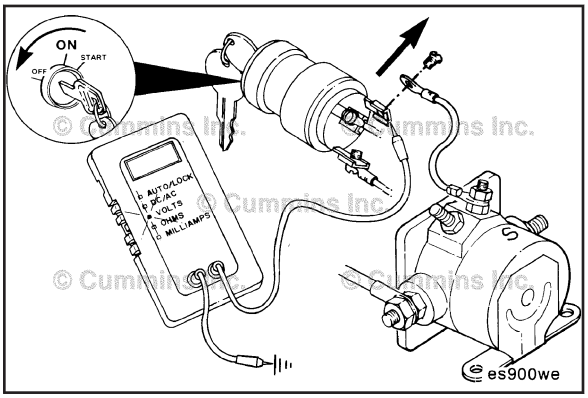
Key Switch (013-030)

Voltage Check

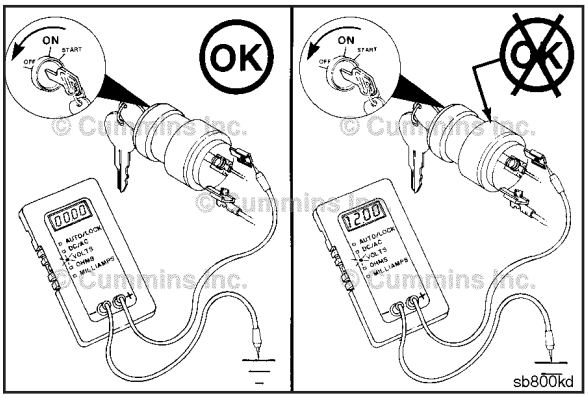
⚠WARNING⚠
Be sure the key switch is in the OFF position to reduce the possibility of electrical shock and personal injury.

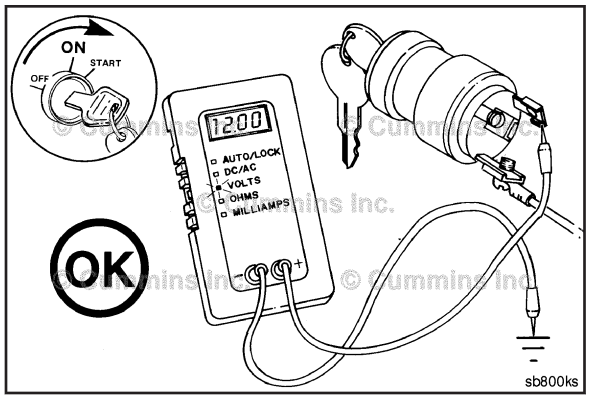
Remove the wire connecting the keyswitch to the magnetic switch (marked S or Start) from the keyswitch terminal.

Connect the positive (+) lead of digital multimeter, Part Number 3377163, or equivalent, to the keyswitch terminal and the negative (-) lead to a chassis or engine ground location.



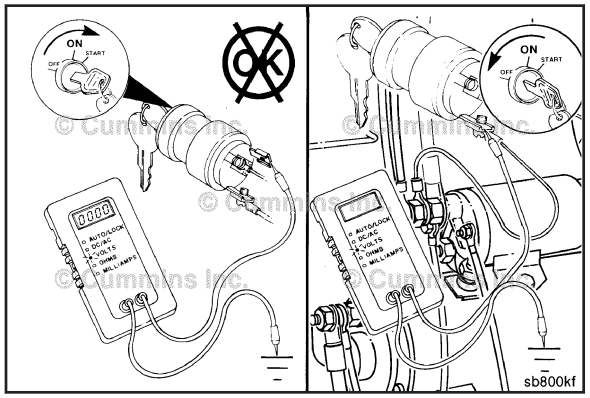
NOTE: Set the multimeter to indicate DC volts with the keyswitch in the OFF position. There **must** be no voltage at the keyswitch terminal. If the meter indicates voltage, the keyswitch is malfunctioning and **must** be replaced.





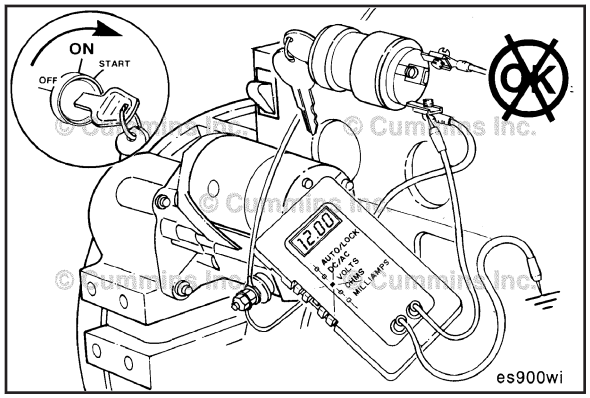
Turn the keyswitch to the START position.

The multimeter **must** indicate system voltage.



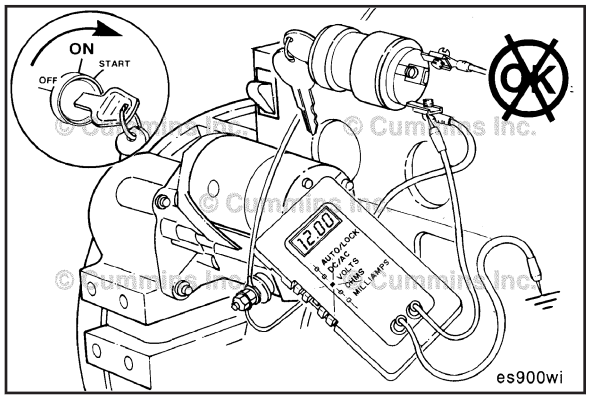
If there is no voltage:

- Turn the key switch to the OFF position.
- Check for supply voltage to the keyswitch by connecting the multimeter positive (+) lead to the key switch terminal having a wire connecting the keyswitch to the starter motor solenoid "B" terminal.



Turn the keyswitch to the START position.

If the meter indicates system voltage at the key switch input terminal, the key switch is defective and **must** be replaced. Refer to the original equipment manufacturer's manual for replacement.



If the meter indicates no voltage, the switch is **not** the cause of the complaint.

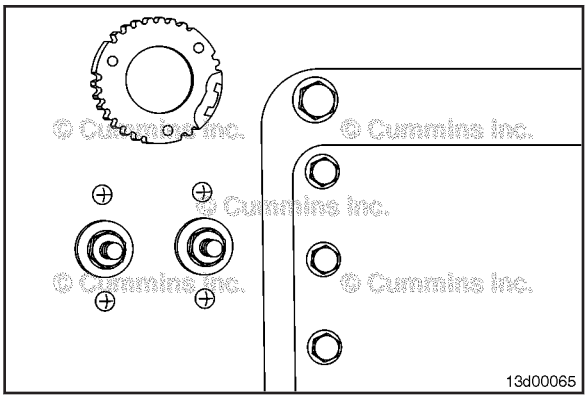
Check the wiring from the keyswitch to the starter motor solenoid "B" terminal, and from the starter motor solenoid to the battery, for broken or damaged wires.

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.

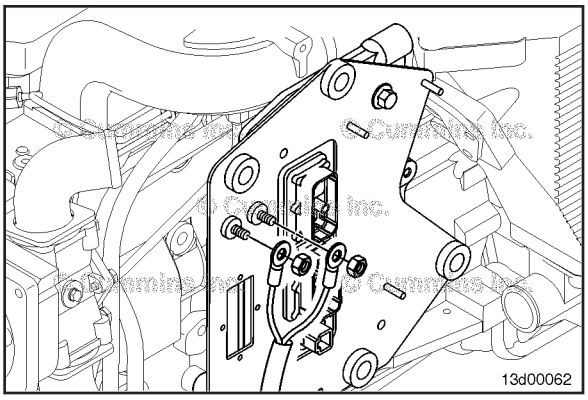
These terminal lug blocks are located on the left side of the engine near the OEM interface connector and the service tool datalink connection. The positive terminal block is red and the negative terminal block is black.



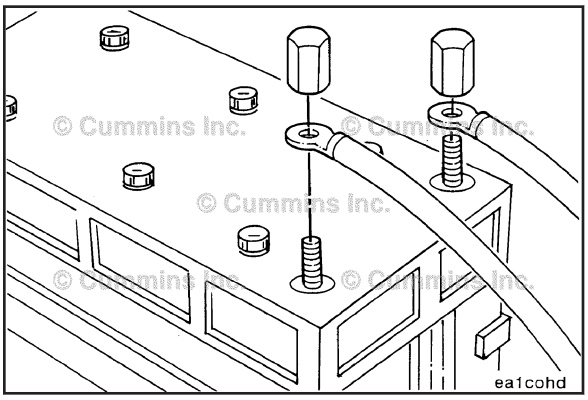
Initial Check

⚠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.



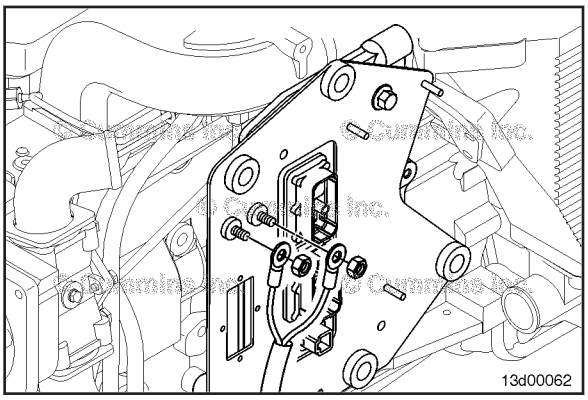
Before removing the unswitched power supply wires from the engine, be sure the positive and negative wires are disconnected from the battery. Refer to procedure 013-009.

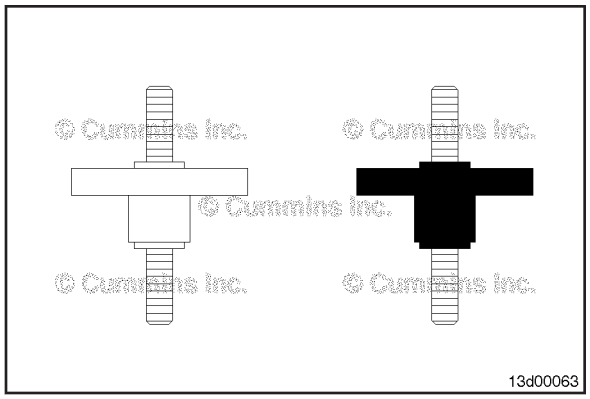


Always install the unswitched positive and negative wire connectors to the terminal blocks before installing the connections to the battery.

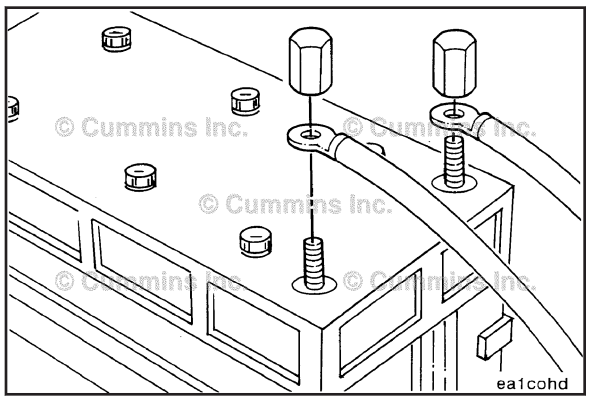
Torque the connections to the terminal blocks to the specified value.

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⚠

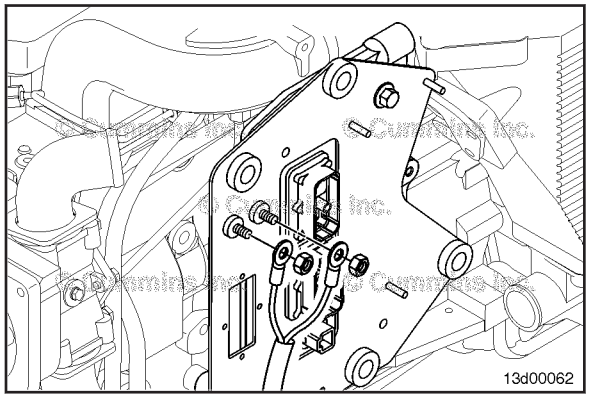
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

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.

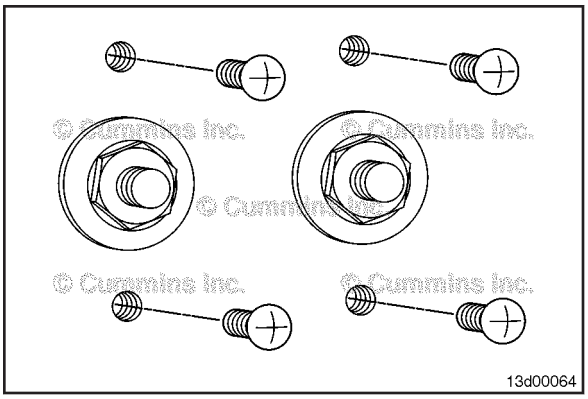


Remove

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.

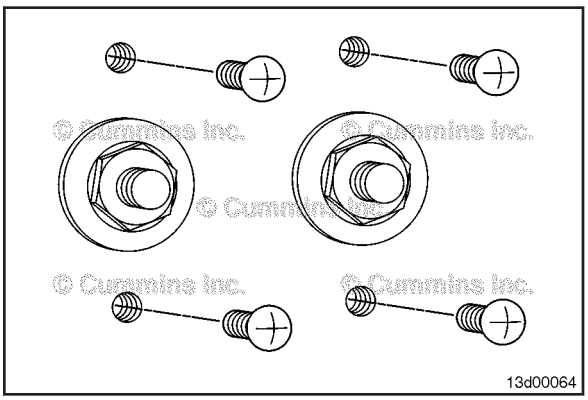


Install

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]

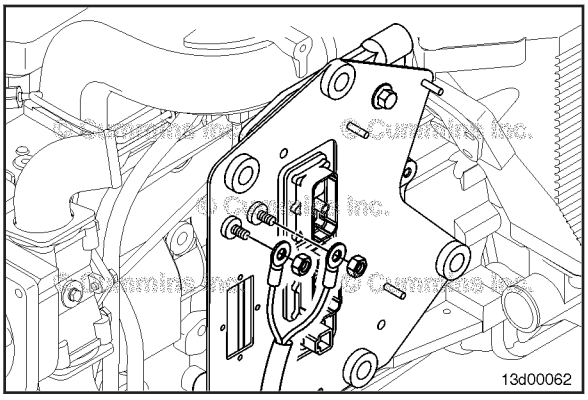


Install the engine wiring harness positive or negative wire connectors to the correct positive and negative terminal blocks located on the back of the mounting plate.

Some plates may have to be removed to complete this operation.

Torques to the specified value.

Torque Value: 5 N•m [45 in-lb]



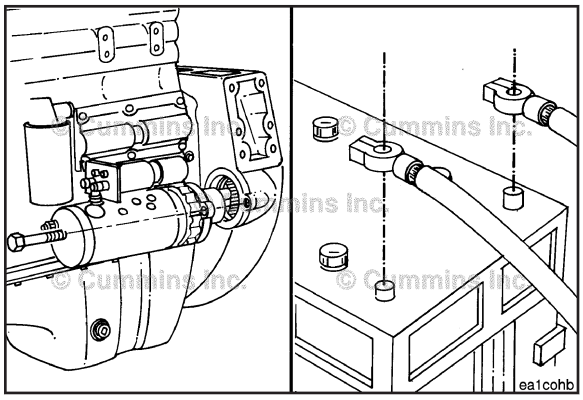
Finishing Steps

⚠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.



Notes

Section 14 - Engine Testing - Group 14

Section Contents

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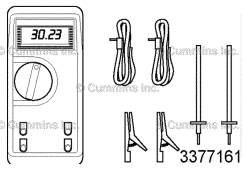
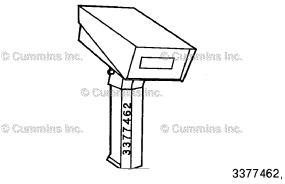
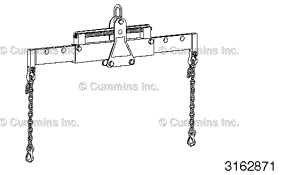
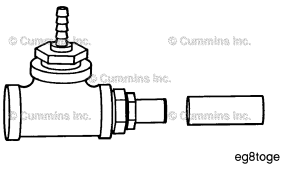
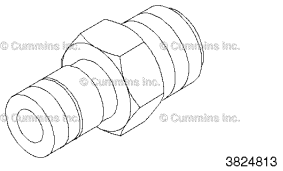
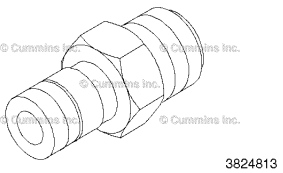
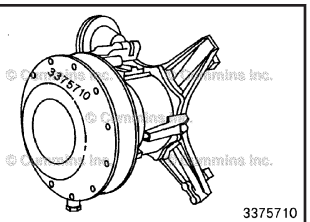
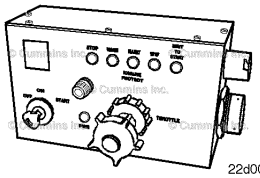
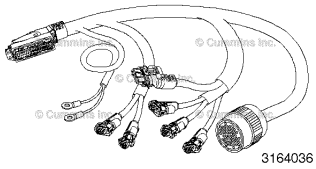
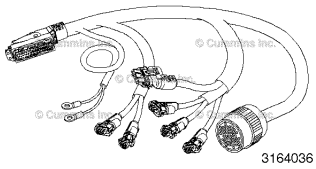
Service Tools

Engine Testing

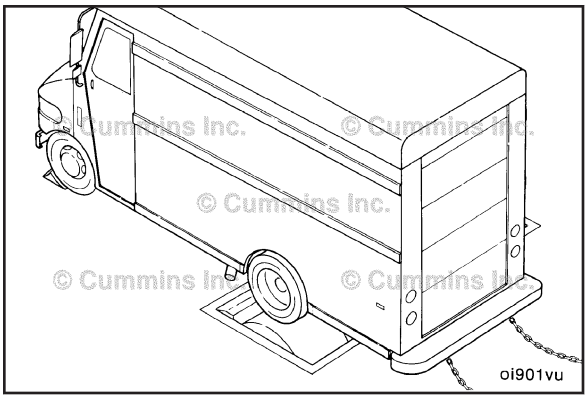
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
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.	
3377244	**Compuchek® Fitting** Used to connect diagnostics machine. With 1/8 NPT connection.	
3824842	**Compuchek® Fitting** Used to check fuel filter restriction. With 10 mm O-Ring connection.	

Tool No.	Tool Description	Tool Illustration
3375710	**Drivetrain Dynomometer** Used to measure engine horse power.	
3163890	**Engine Control** Used to start and control engine speed.	
3164036	**Harness** Used to in conjunction with engine control, Part Number 3163890, to connect unit to the ISB (4 cylinder) and ISB^{e} (4 and 6 cylinder) series engines.	
3164242	**Harness** Used to in conjunction with engine control, Part Number 3163890, to connect unit to the ISB (with common rail fuel system) series engines.	

Engine Testing (Chassis Dynamometer) (014-002)

Setup



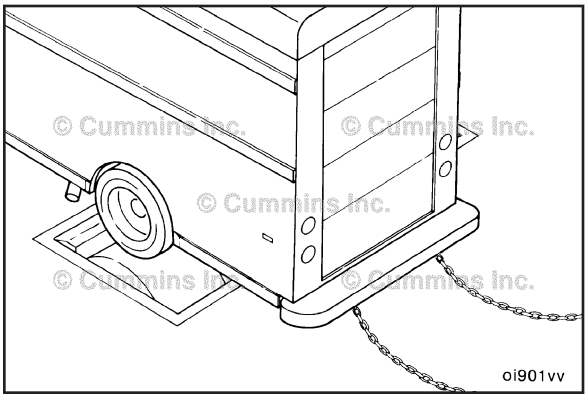
The performance of an engine installed in on-highway vehicles can be tested on a chassis dynamometer.

NOTE: Because of driveline efficiency and engine-driven accessories, the engine horsepower when measured at the rear wheels will be reduced by approximately:

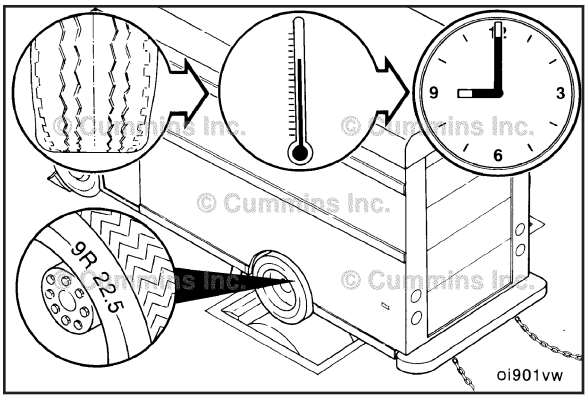
- 20 percent for single-axle vehicles
- 25 percent for tandem-axle vehicles
- 35 percent for recreational vehicles.

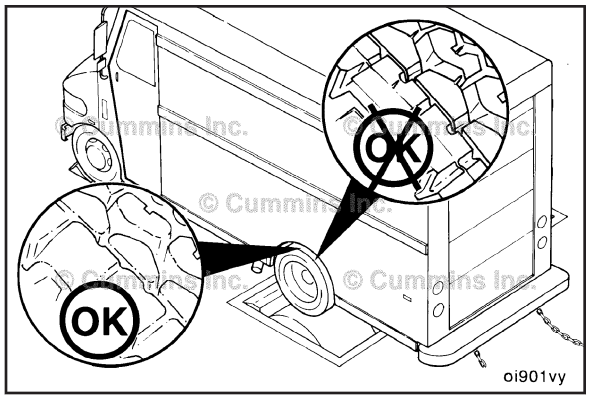
NOTE: These percentages are used for engine run-in **only** and are **not** to be used as absolute figures.

⚠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.



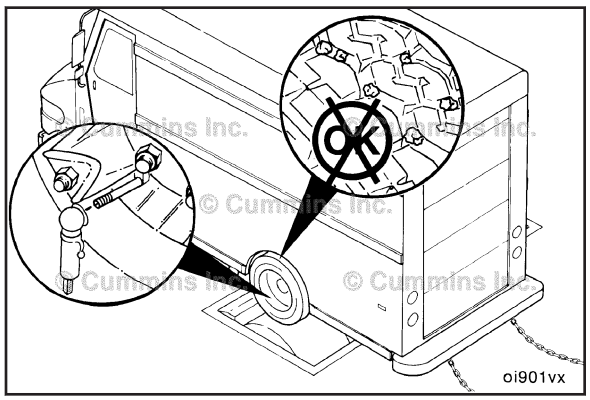
⚠CAUTION⚠
Low-profile tires are more sensitive to heat than bias ply tires. Excessive operating time at full load can damage the tires due to overheating. Check the tire manufacturer's recommendations for the maximum allowable chassis dynamometer operating time.



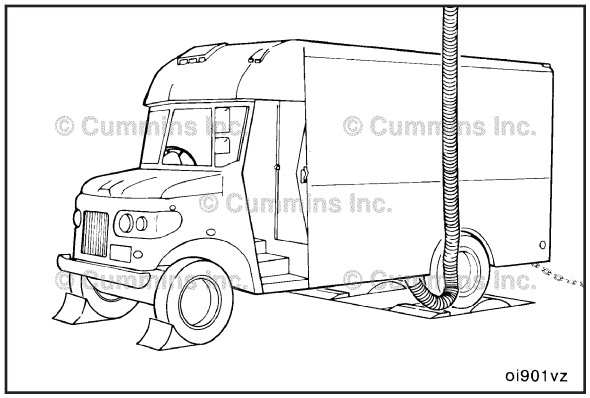


While operating the chassis dynamometer, follow the general safety precautions listed below:

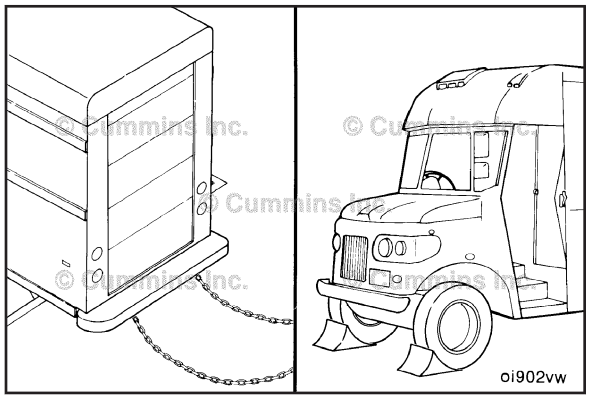
- Use tires that have more than 160 km [100 mi] of use. Do **not** use new tires.
- Do **not** use recapped tires or tires of different sizes or designs.



- 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.

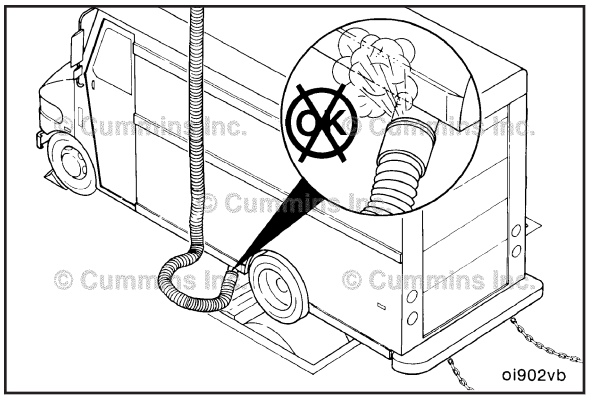
Place wheel chocks in front of the front tires.

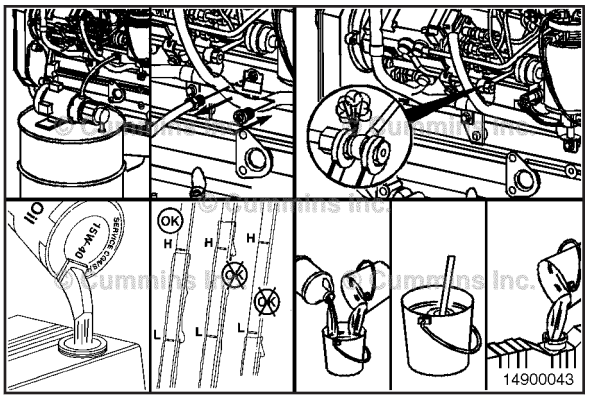
⚠WARNING⚠

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.





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.

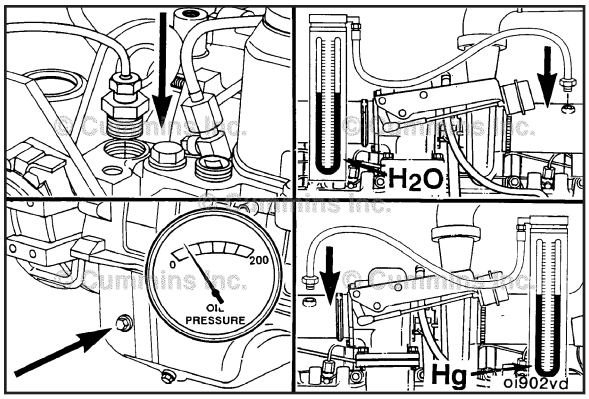
Use the following procedures for instructions on priming the lubricating oil and the fuel system and calibrating the dipstick.

- 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.

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.

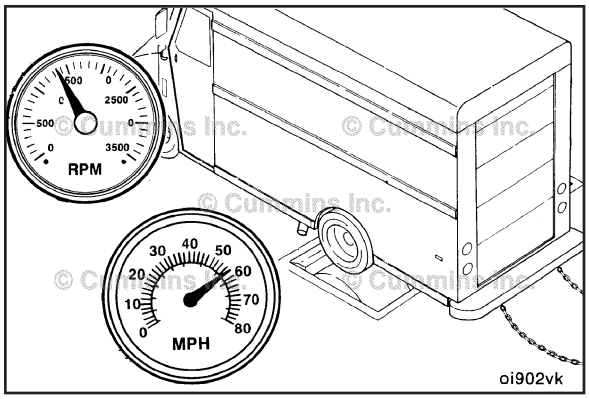
Engine Run-in (Chassis Dynamometer) (014-003)

Test

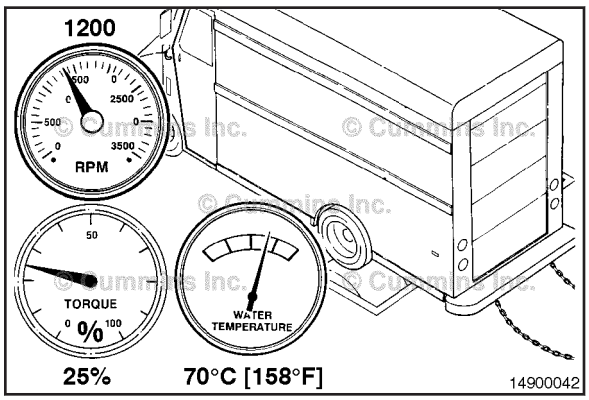
NOTE: Refer to Procedure 014-002 before operating the engine to avoid internal component damage.

NOTE: Refer to Procedure 014-005 for general operating procedures and safety precautions.

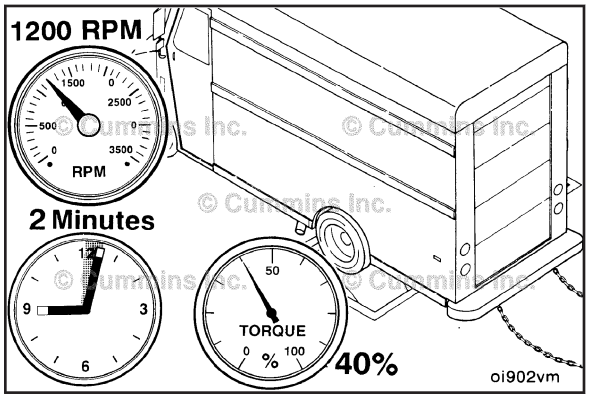
NOTE: Operate the vehicle in a gear that produces a road speed of 90 to 95 km/h [56 to 59 mph].



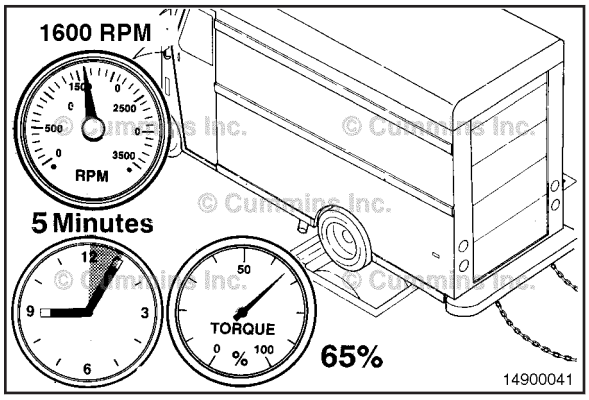
Operate the engine at 1200 rpm and 25 percent of torque peak load until the water temperature reaches 70°C [158°F].

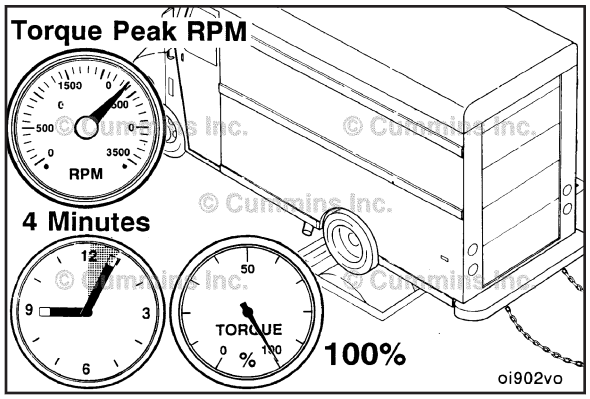


Operate the engine at 1200 rpm and 40 percent of torque peak load for 2 minutes. Check the gauges, and record the readings.



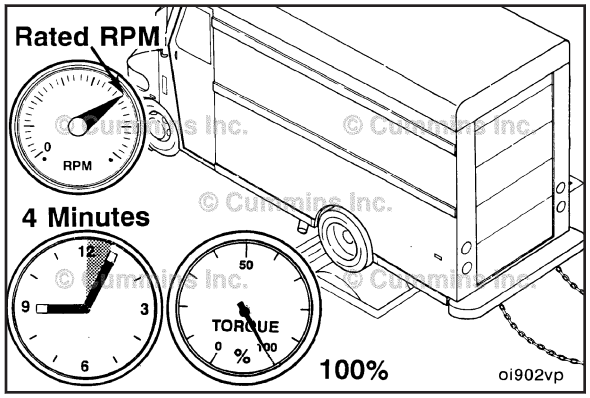
Operate the engine at 1600 rpm and 65 percent of torque peak load for 5 minutes. Check the gauges, and record the readings.





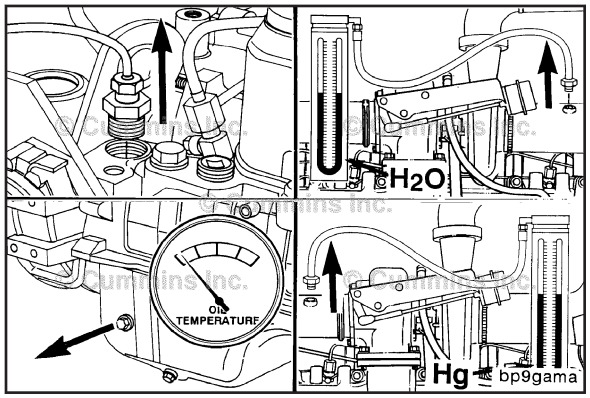
Operate the engine at torque peak rpm and full load for 4 minutes. Check the gauges and record the readings.

NOTE: Refer to the engine data sheet for the torque peak rpm of the engine model being tested.

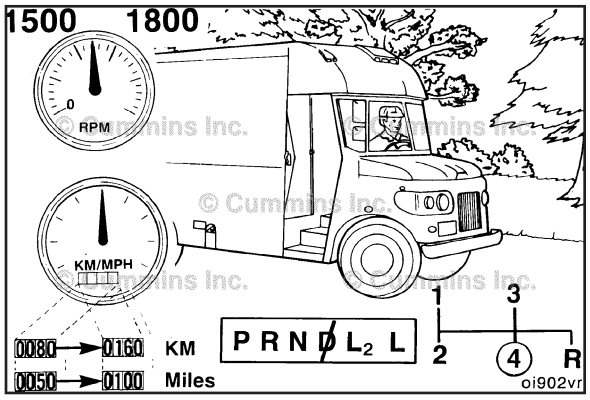


⚠CAUTION⚠
Do not shut off the engine immediately after the run-in is completed. Allow the engine to cool by operating it at low idle for a minimum of 3 minutes to avoid engine component damage.

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 on the appropriate engine data sheet.



Make sure all instrumentation is removed before removing the vehicle from the dynamometer.



Engine Run-in (Without Dynamometer) (014-004)

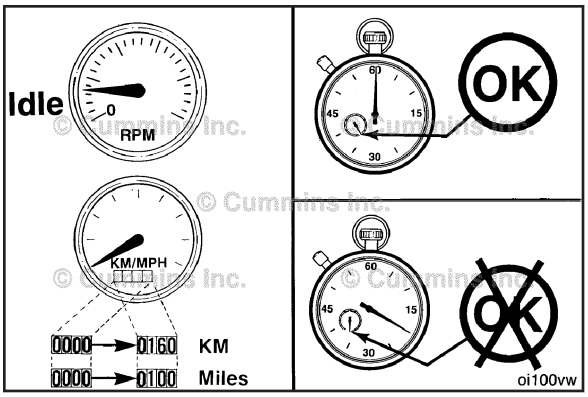
Test

On-Highway

⚠CAUTION⚠
Refer to Procedure 014-005 before operating the engine to avoid engine component damage.

Operate the engine at 1500 to 1800 rpm in high gear for the first 80 to 160 km [50 to 99 mi] after rebuild.

NOTE: Do **not** idle the engine for more than 5 minutes at any one time during the first 160 km [99 mi] of operation.



Engine Testing (Engine Dynamometer) (014-005)

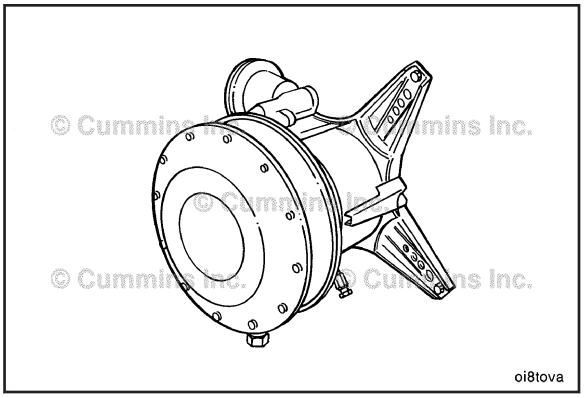
Setup

Use engine lifting fixture, Part Number 3822512, to remove the engine from the chassis. Refer to Procedure 000-001

Install the engine to the test stand.

Align and connect the dynamometer. Refer to the manufacturer's instructions for aligning and testing the engine.

Make sure the dynamometer capacity is sufficient to permit testing at 100 percent of the engine's rated horsepower. If the capacity is **not** enough, the testing procedure **must** be modified to the restrictions of the dynamometer.

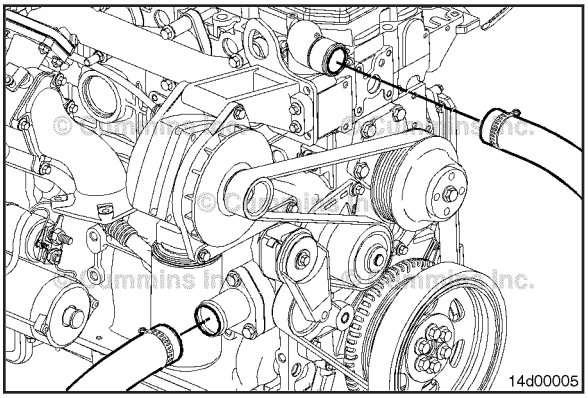


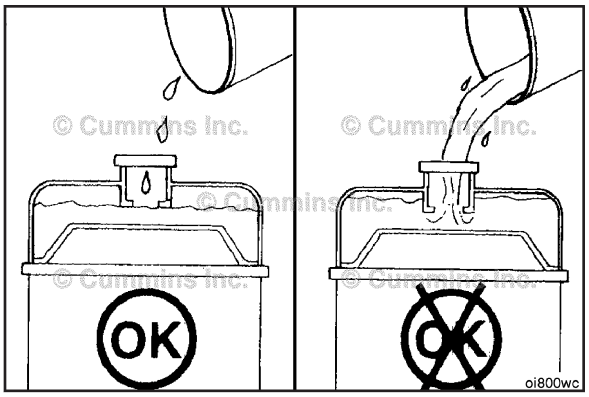
Connect the coolant supply to the coolant inlet connection (1).

Connect the coolant return to the coolant outlet connection (2).

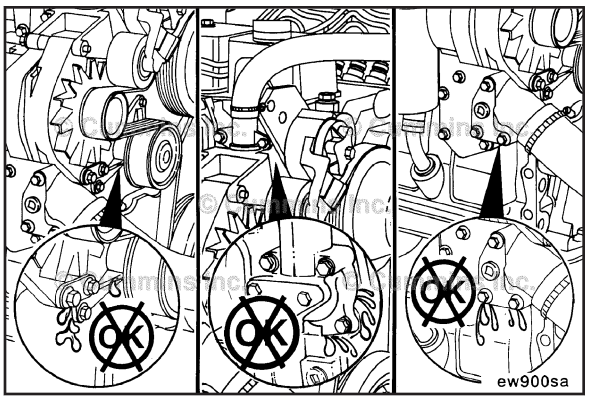
Install the drain plugs; close all the coolant draincocks.

Make sure all the clamps and fittings are tight.

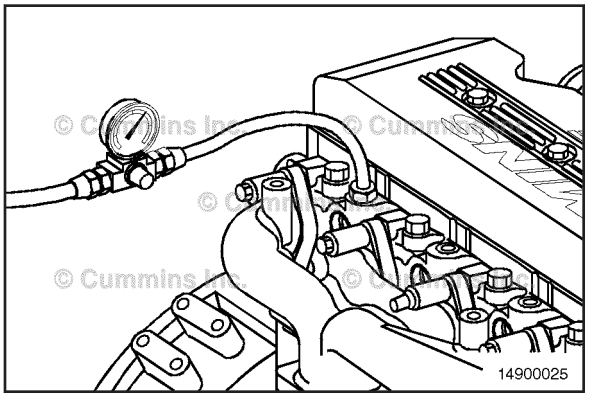




Fill the cooling system with coolant to the bottom of the fill neck in the radiator fill (or expansion) tank. Refer to Procedure 008-018



Inspect the engine for coolant leaks at connections, fittings, plates, and plugs. Repair as needed. Refer to Procedure 008-020 if any leaks are found.



Measure the coolant pressure at a coolant tap on the exhaust side of the cylinder head.

Minimum Gauge Capacity: 415 kPa [60 psi]

Open Thermostat		
rpm	**Location on Engine**	**Pressure**
2000	Water outlet	17.2 kPa [2.5 psi]
2000	1/2-NPT head port	68.9 kPa [10.0 psi]
2000	3/4-NPT head port	82.7 kPa [12.0 psi]
2500	Water outlet	24.1 kPa [3.5 psi]
2500	1/2-NPT head port	99.9 kPa [14.5 psi]
2500	3/4-NPT head port	117.2 kPa [17.0 psi]

⚠CAUTION⚠
Do not attempt to install pipe thread fittings in plastic or rubber intake piping. Damage to the components can occur.

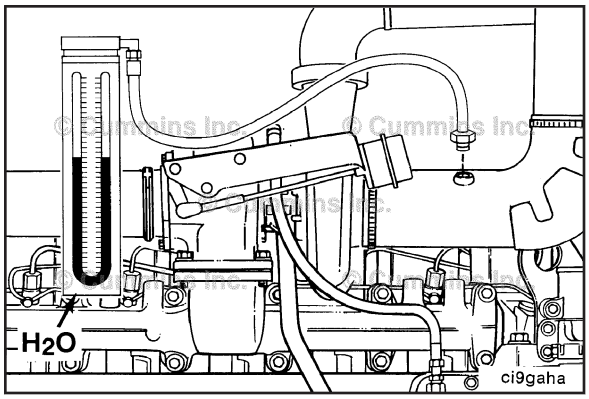
Air Inlet Restriction

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]

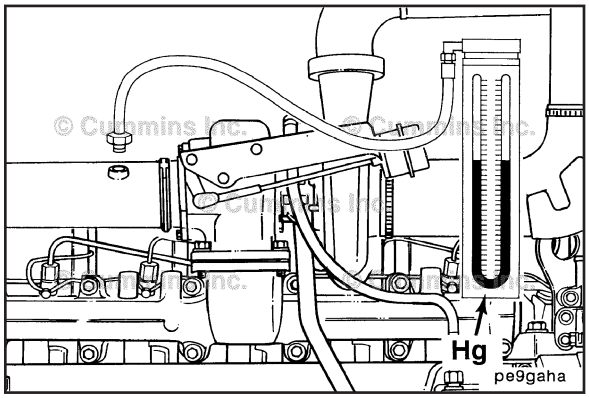


Exhaust Restriction

Connect a mercury manometer to a straight section of the exhaust piping near the turbocharger outlet to check the exhaust restriction.

NOTE: A pressure gauge, Part Number ST-1273, can be used in place of the mercury manometer.

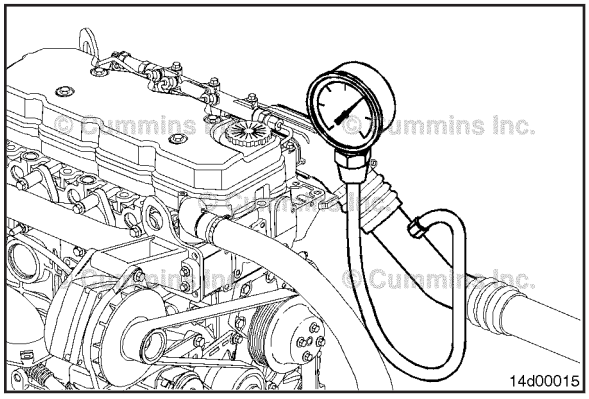
Minimum Gauge Capacity: 254 mm Hg [10 in Hg]



To determine the amount of turbocharger boost, remove the pipe plug in the charge air cooler tube.

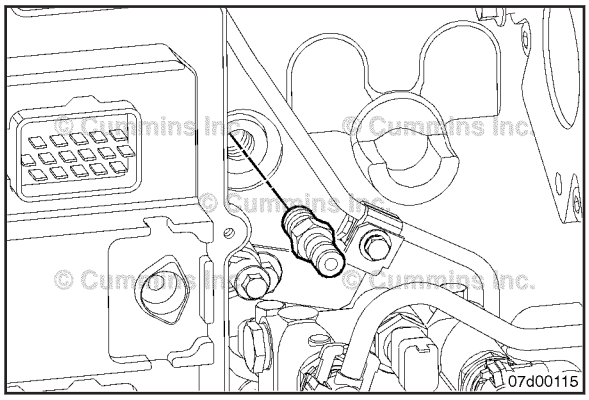
Install an intake manifold pressure sensor or pressure gauge, Part Number ST-1273.

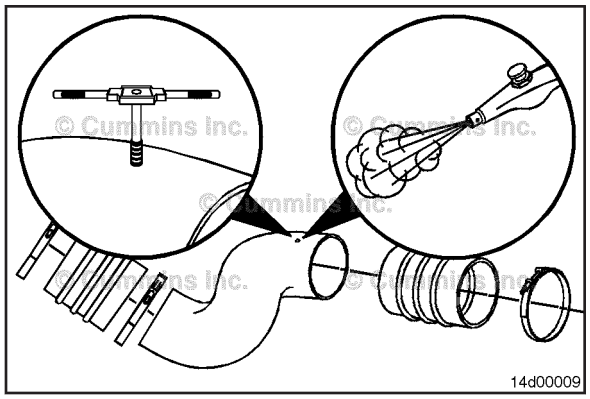
Pressure Gauge Capacity		
kPa		psi
276	MIN	40



Attach the lubricating oil temperature sensor in the location shown.

Minimum Gauge Capacity: 150°C [302°F]





⚠CAUTION⚠

Do not attempt to install pipe thread fittings in plastic or rubber intake piping. Damage to the piping can result.

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.

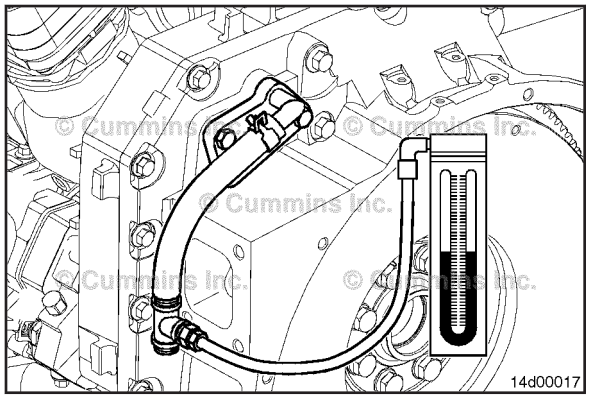
If the charge air cooler outlet tube does **not** have a pipe plug and tapped hole, perform the following procedure:

1 Remove the charge air cooler outlet tube from the engine. Refer to Procedure 010-019

2 Drill and tap a 1/8-inch pipe thread hole in the crossover tube in the location shown.

3 Clean all metal shavings from the air crossover tube.

4 Install the crossover tube. Refer to Procedure 010-019



Blowby

For accurate engine crankcase blowby measurement, insert a blowby checking tool, Part Number 3822566, in the crankcase breather vent.

Connect a water manometer, Part Number ST-1111-3, to the blowby tool. A pressure gauge can be used in place of the manometer.

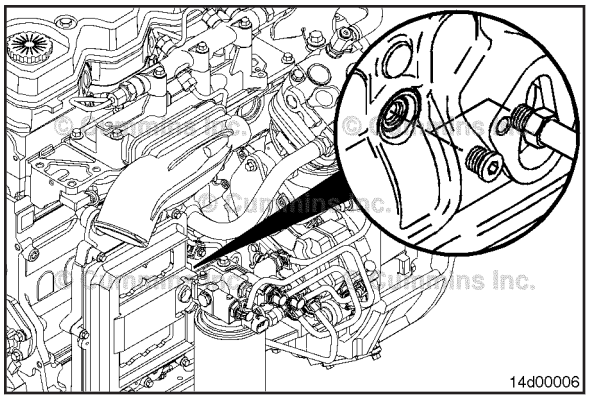
BLOWBY CONVERSION TABLE (7.67-mm [0.302-in] orifice)	
Inches of Water	**Liters per Minute**
1	50
2	84
3	103
4	119
5	133
6	145
7	155
8	164
9	172
10	180
11	187
12	193
13	200
14	206
15	211
16	217
17	222
18	226
19	229
20	232

⚠CAUTION⚠
The lubricating oil system must be primed before operating the engine after it has been rebuilt to avoid internal damage.

Priming the Lubricating System

Remove the plug.

To prime the system using external pressure, connect the supply to a tapped hole in the main oil rifle.



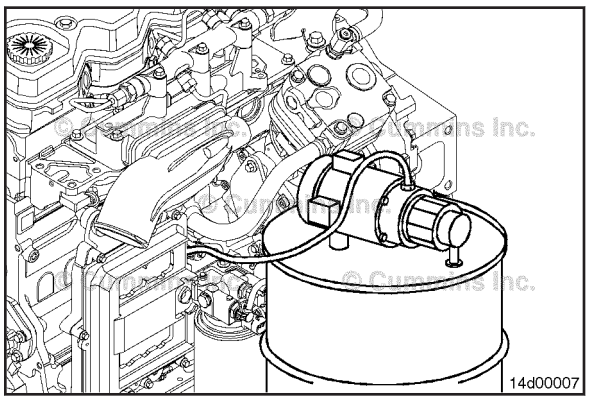
Use a pump capable of supplying 210 kPa [30 psi] of continuous pressure. Connect the pump to the port on the main oil rifle as shown.

Use clean 15W-40 oil to prime the system until the oil pressure registers on the gauge.

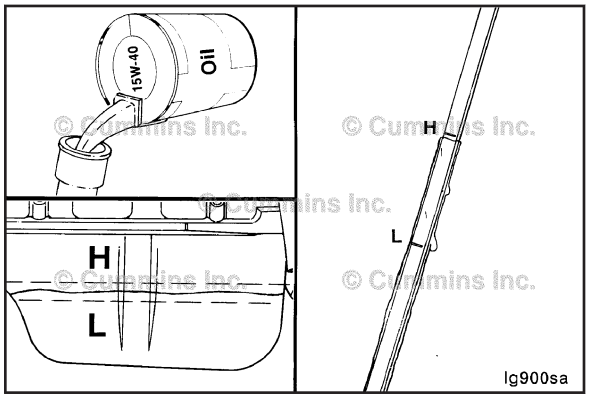
Remove the oil supply tube, and install the plug.

Tighten the plug.

Torque Value: 6 N•m [53 in-lb]

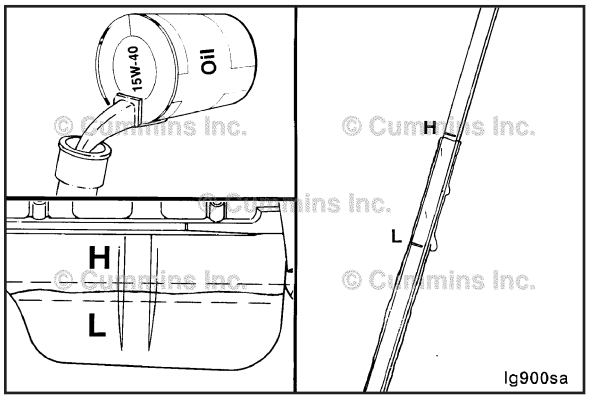


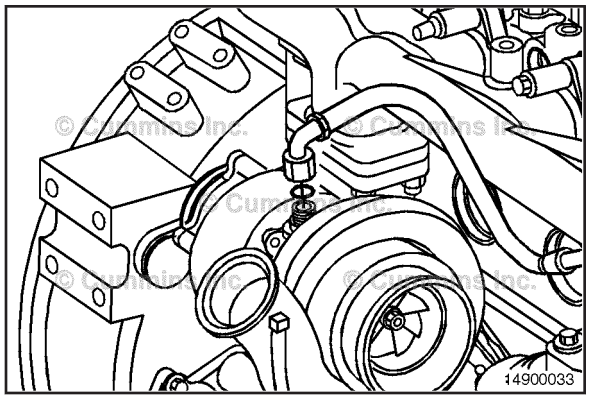
Make sure the lubricating oil has had time to drain to the oil pan and fill the engine to the high mark as measured on the dipstick.



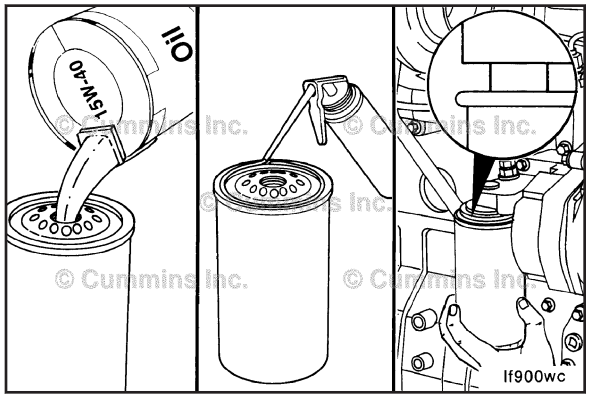
If an external pressure pump is **not** available, prime the lubricating system according to the following procedure:

- Fill the engine with clean 15W-40 oil to the high mark on the dipstick.



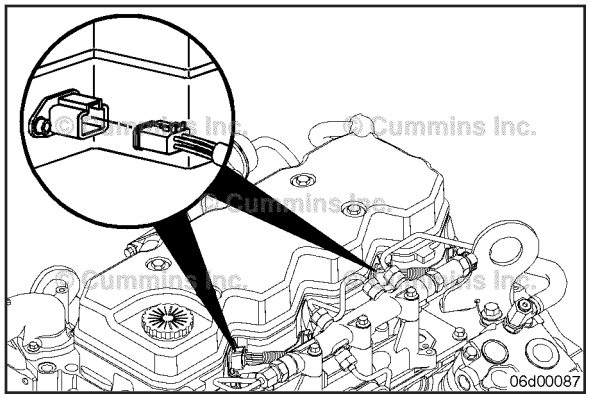


- Disconnect the turbocharger lubricating oil supply tube.
- Pour 50 to 60 cc [2 to 3 fl oz] of clean 15W-40 oil into the turbocharger oil supply hole.
- Connect the oil supply tube to the turbocharger.

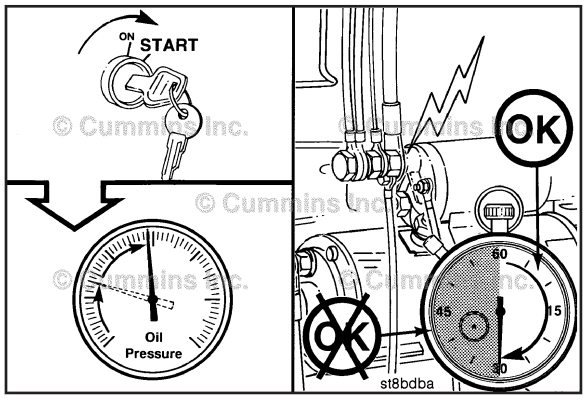


⚠CAUTION⚠
Mechanical overtightening can distort the threads or damage the filter element seal.

- Fill the lubricating oil filters with clean 15W-40 oil.
- Screw the filters onto the filter head until the gasket contacts the filter head surface.
- Tighten the filter as specified by the manufacturer.



To disable the engine for cranking, disconnect all of the injector pass-through connectors.



⚠CAUTION⚠
Do not crank the starter motor for periods longer than 30 seconds. Excessive heat will damage the starter motor.

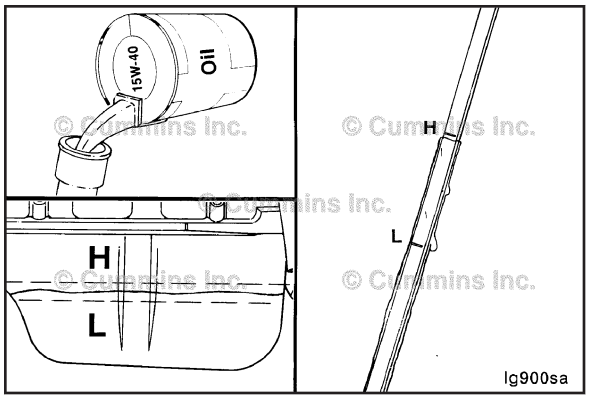
- Crank the engine until the oil pressure gauge indicates system pressure.

NOTE: Allow 2 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.

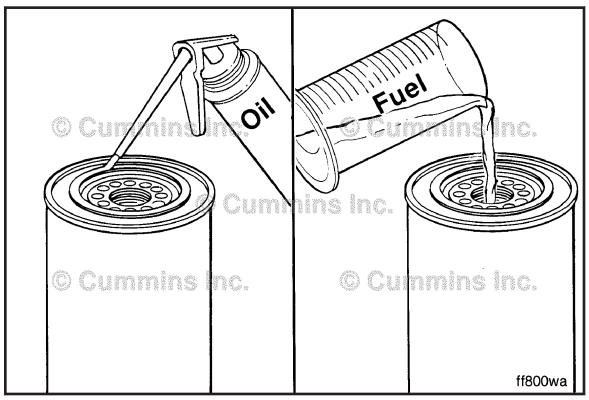
Allow the oil to drain into the oil pan, and measure the oil level with the dipstick.

Add oil, as necessary, to bring the level to the high level mark on the dipstick.



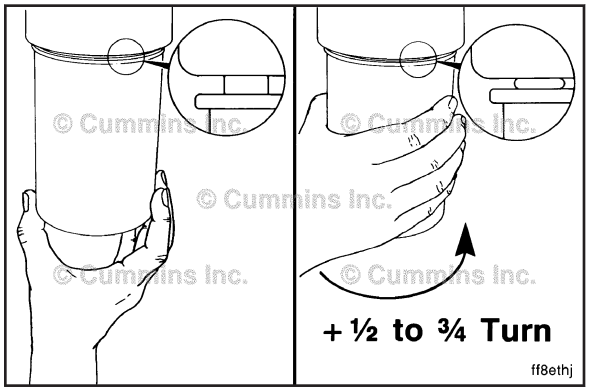
Lubricate the gasket on the fuel filter with clean 15W-40 oil.

Fill the fuel filter with clean fuel.



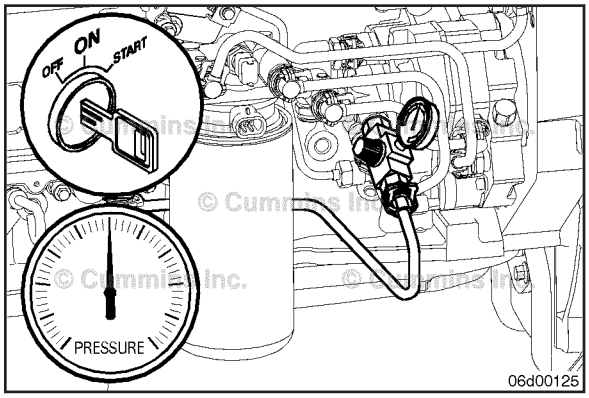
Screw the fuel filter onto the fuel filter head until the gasket contacts the fuel filter head surface.

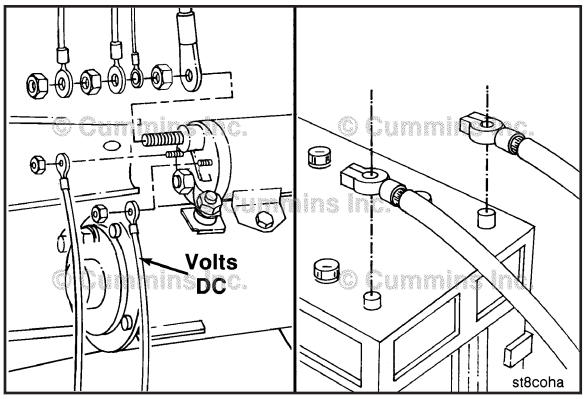
Tighten the filter as specified by the manufacturer.



To measure fuel filter restriction, Refer to Procedure 005-011

Fuel Filter Restriction Pressure Gauge Capacity		
kPa		psi
1379	MIN	200

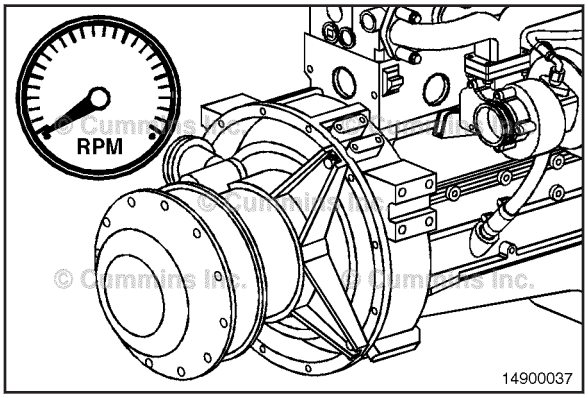




Inspect the voltage rating on the starter motor before installing the electrical wiring.

Attach electrical wires to the starter motor and the batteries, if used, negative (-) cable last.

NOTE: If another method of starting the engine is used, follow the manufacturer's instructions to make the necessary connections.

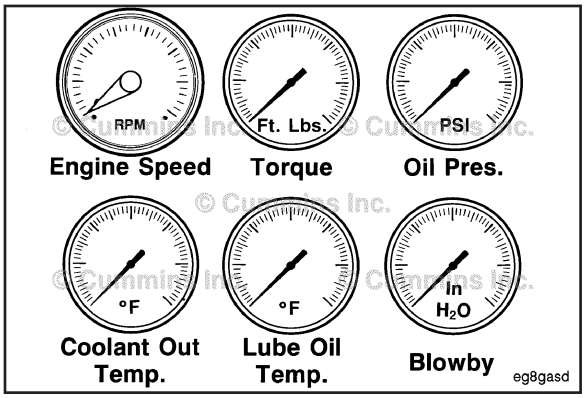


Engine Run-in (Engine Dynamometer) (014-006)

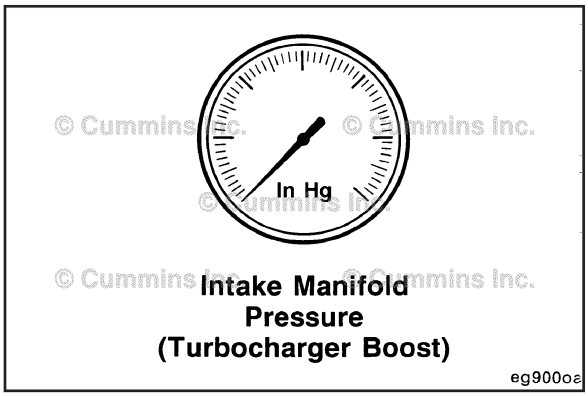
Run-In Instructions

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.

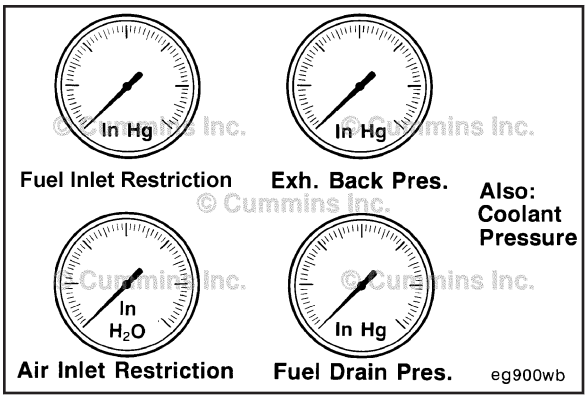


Measurements from these indicators and gauges **must** be observed closely during all phases of the engine run-in period. Refer to Procedure 014-005 for specifications and acceptable readings.



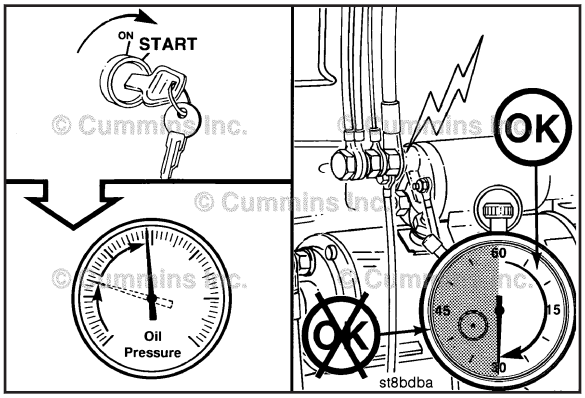
To evaluate the engine's performance correctly, this additional measurement **must** be observed during engine run-in phases.

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 underperformance.



⚠CAUTION⚠
Do not crank the engine for more than 30 seconds. Excessive heat will damage the starter motor.

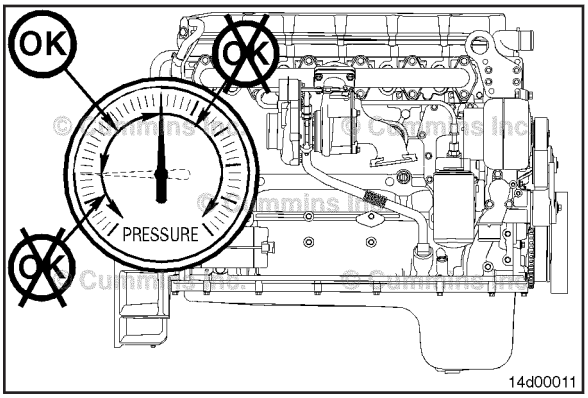
Crank the engine and observe the lubricating oil pressure when the engine starts. If the engine fails to start within 30 seconds, allow the starter motor to cool for 2 minutes before cranking the engine again.



⚠CAUTION⚠
If the lubricating oil pressure is not within specifications, shut off the engine immediately. Low lubricating oil pressure will cause engine damage.

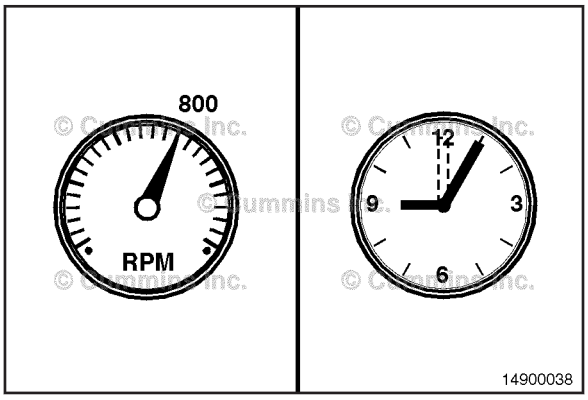
Engine lubricating oil pressure **must** be at least 69 kPa [10 psi] at 700 rpm.

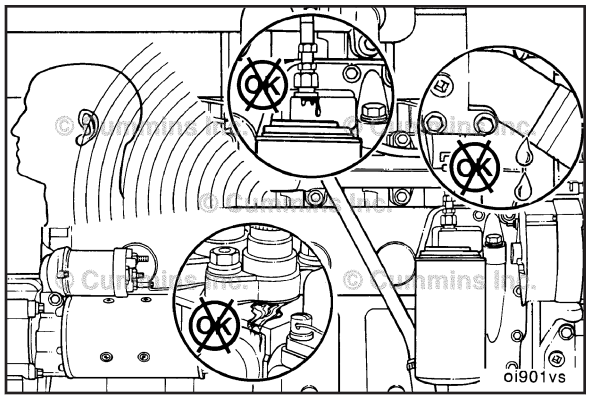
Correct the problem if the lubricating oil pressure is **not** within specifications.



⚠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 800 rpm for 3 to 5 minutes.



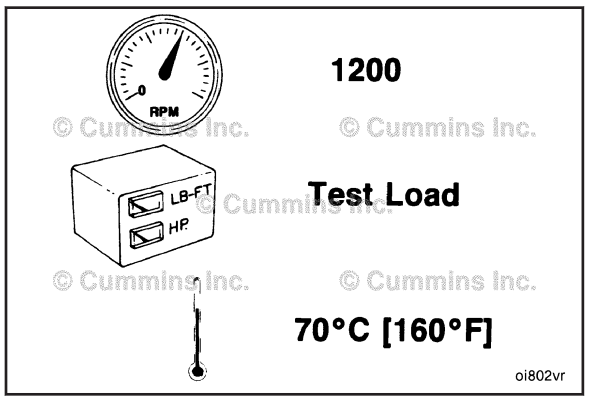


NOTE: Repair all leaks or component problems before continuing the engine run-in.

Listen for unusual noises.

Watch for coolant, fuel, and lubricating oil leaks.

Check for correct engine operation in general.

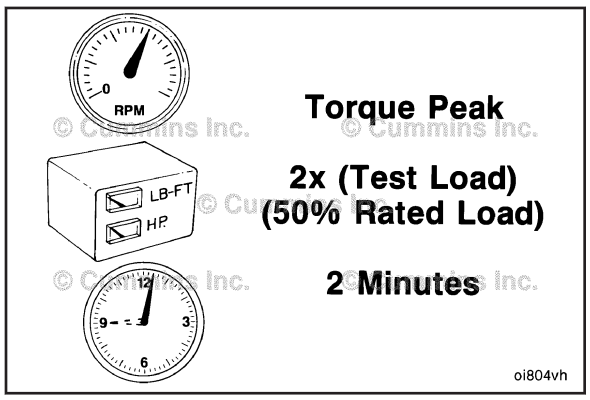


Move the throttle to obtain 1200 rpm engine speed, and set the test load to 25 percent of the rated load.

Operate the engine at this speed and load level until the coolant temperature is 70°C [158°F].

Check all gauges, and record the data.

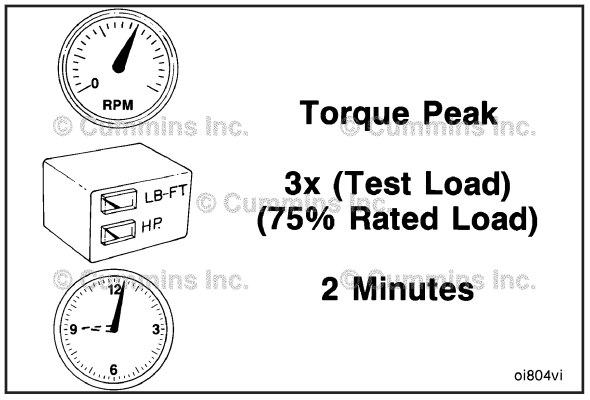
NOTE: Do **not** proceed to the next step until a steady blowby reading is obtained.



Adjust the throttle to obtain peak torque rpm, 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.



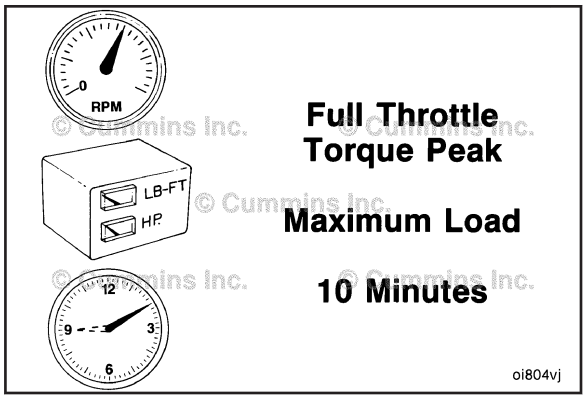
With the engine speed remaining at torque peak rpm, increase the dynamometer load to 75 percent of torque peak load. Operate the engine at this speed and load level for 2 minutes.

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.

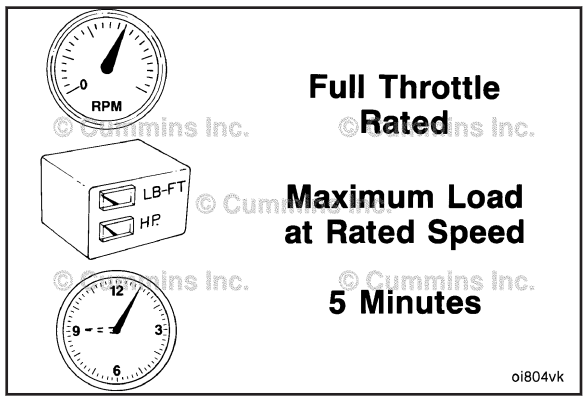
Check all gauges, and record the data.



Reduce the dynamometer load until the engine speed increases to the engine's rated rpm.

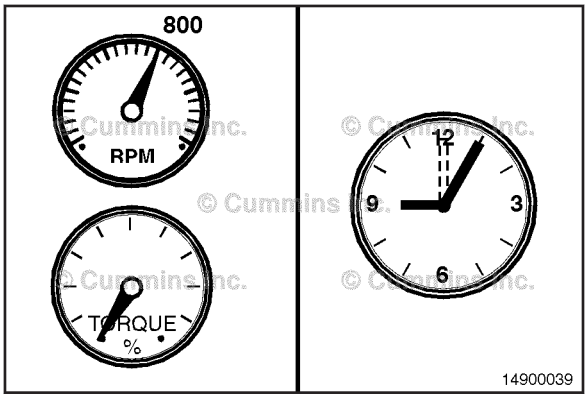
Operate the engine at rated rpm for 5 minutes.

Check all gauges, and record the data.

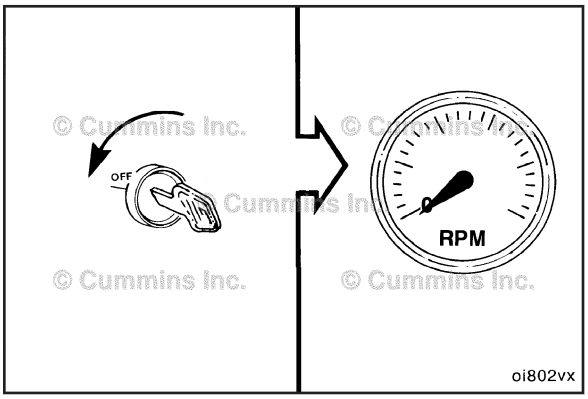


CAUTION
Shutting off the engine immediately after operating at full load will damage the turbocharger and internal components. Always allow the engine to cool before shutting it off.

Remove the dynamometer load completely, and operate the engine at 800 rpm for 3 to 5 minutes. This period will allow the turbocharger and other components to cool.

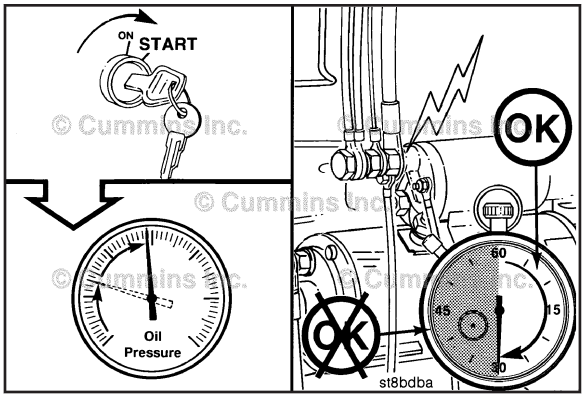


Shut off the engine.



Engine Dynamometer Test - Performance Check

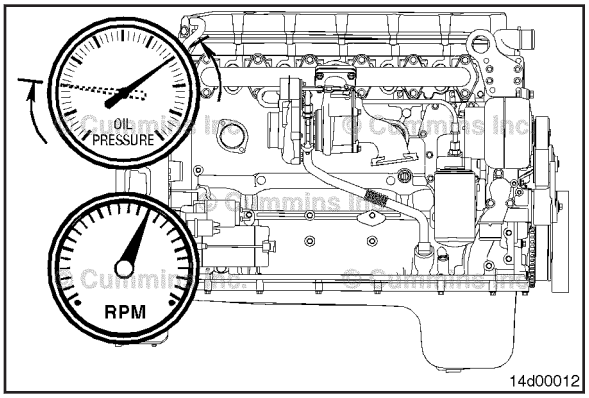
Make sure the air compressor will be unloaded during the performance check.



⚠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.

Make sure the engine is at operating temperature (71.1°C [160°F] minimum coolant temperature).

Move the throttle pedal to 100-percent throttle. Adjust the dynamometer load until the engine maintains the rated rpm.

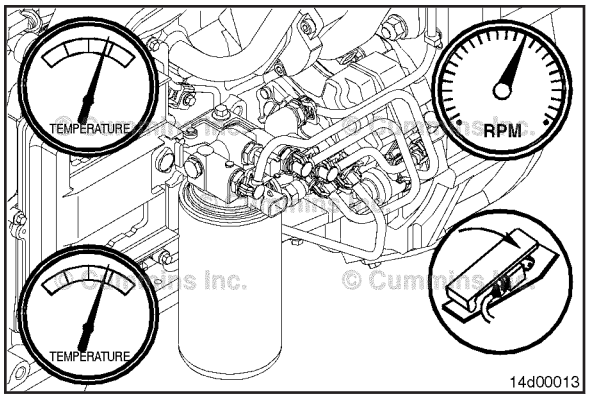
Allow the readings to stabilize. Read the horsepower.

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	MIN	194

Fuel Temperature		
°C		**°F**
32	MAX	90

Check all gauges, and record the data.



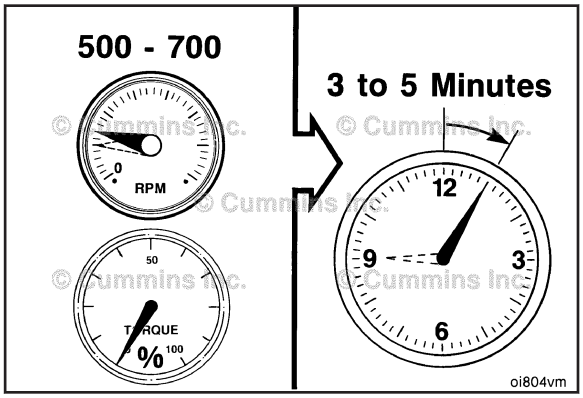
⚠CAUTION⚠
Do not shut off the engine immediately after it has been loaded. It must be allowed to cool sufficiently.

Move the throttle lever to its fully opened position, and increase the dynamometer load until the engine speed is at torque peak rpm. Allow the readings to stabilize. Read the torque. Check all of the gauges and record the readings.

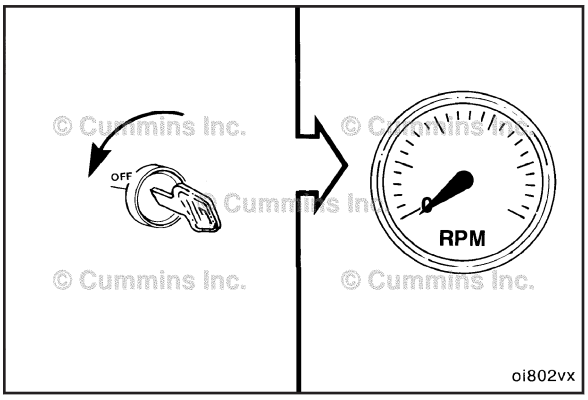
Remove the dynamometer load completely.

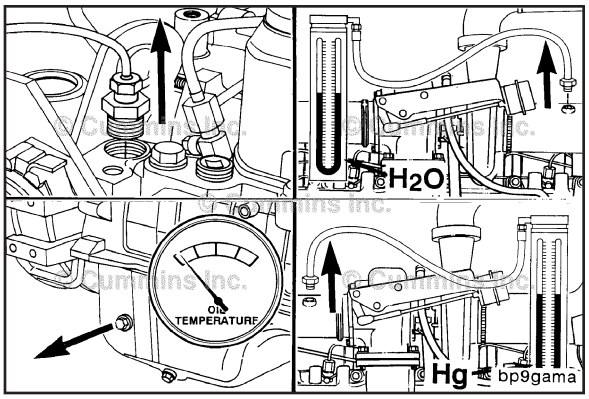
Operate the engine at idle speed for 3 to 5 minutes. This will allow the turbocharger and other components to cool.

NOTE: Idle periods longer than 5 minutes are to be avoided.



Shut off the engine after the cooldown 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. Refer to the Operation and Maintenance Manual, ISB (4 cylinder) and ISB^{e} (4 and 6 cylinder) Engines Bulletin .

Prepare the engine for engine painting. Refer to Procedure 000-007

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 that are run on the dynamometer. For purposes of this test, the maximum engine speed without 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 in the OFF position.

Settings

Maximum Engine Speed without VSS: For testing purposes, this speed is temporarily set to the maximum value allowed. **Maximum Engine Speed without VSS:** 3000 rpm

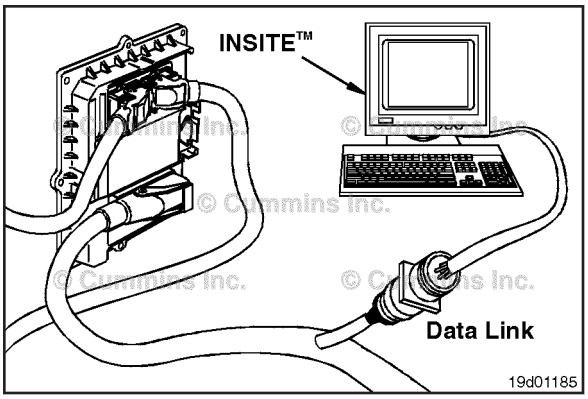
Maximum Vehicle Speed in Top Gear: For testing purposes, this speed is temporarily set to the maximum value allowed. **Maximum Vehicle Speed in Top Gear:** 120 mph

Maximum Vehicle Speed in Lower Gear: For testing purposes, this speed is temporarily set to the maximum value allowed. **Gear-down Protection (heavy engine load): 120**, **Gear-down Protection (light engine load): 120**

Idle Shutdown: This feature is temporarily disabled for testing purposes.

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™ service tool user's manual for detailed setup for dynamometer instructions.



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.

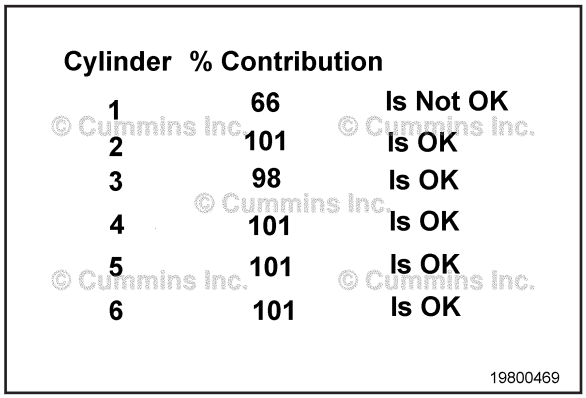
4 Lock the fan clutch in the ON position for continuous operation.

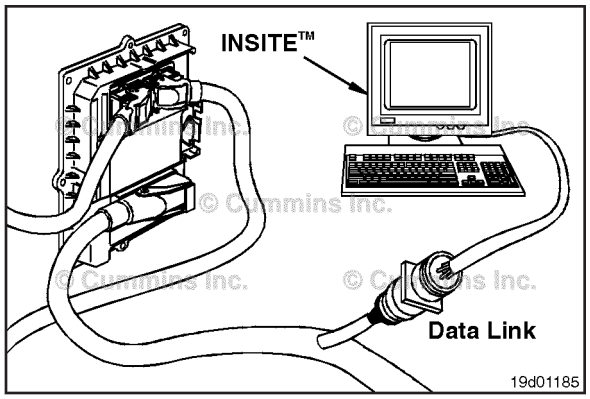
5 Shut off the air conditioning.

6 Disengage any devices that can cause the load on the engine to vary.

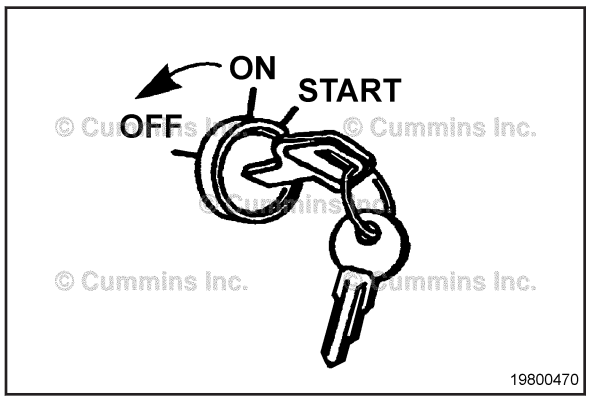
7 With the vehicle stationary, start the engine and let it idle.

8 Start the test using INSITE™ service tool.





Refer to the INSITE™ service tool 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.

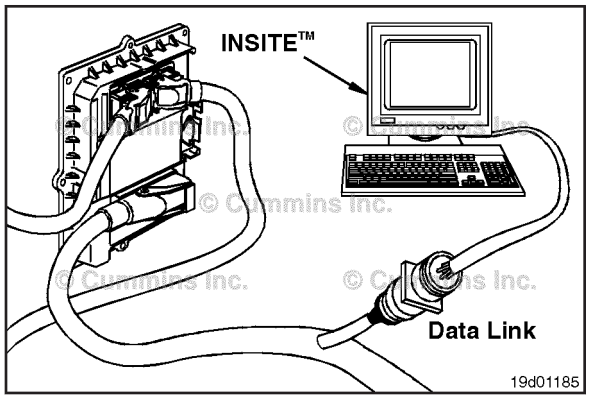
3 Perform the suggested repairs that resulted from the test.

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.



Cylinder to Be Cut Out

None: Select this option to run all cylinders.

1 to 6: Select one of these options to shut off cylinder number 1 through number 6, respectively. **Only** one cylinder can be shut off at a time.

Monitor

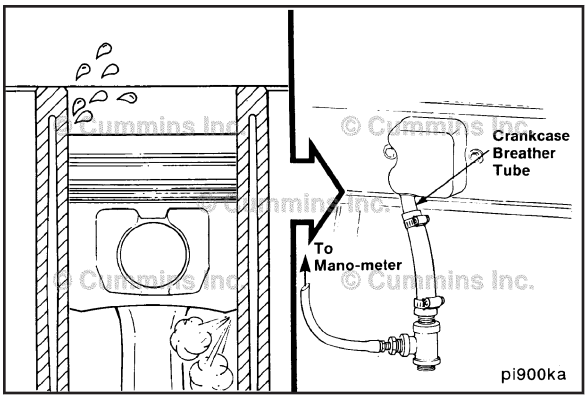
Percent Load: Is the percent of load that the engine is carrying.

rpm: Is the engine's revolutions per minute.

Refer to the INSITE™ service tool user's manual for detailed cylinder cutout test instructions.

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.

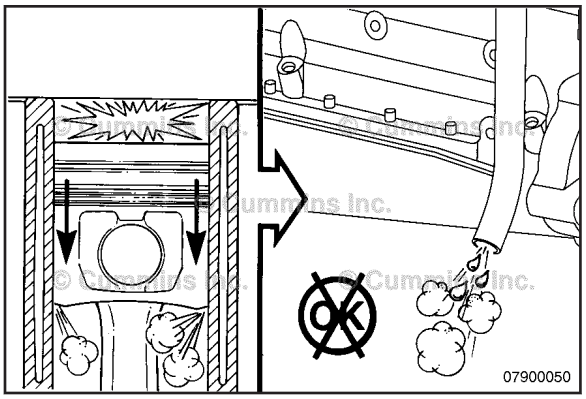
Blowby is typically measured for the following situations:

- 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.

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:

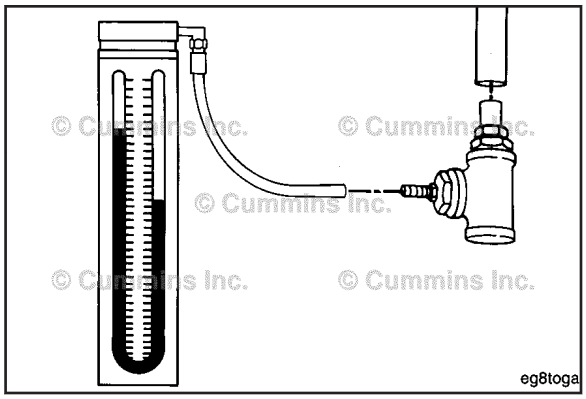
If measuring blowby on two identically configured and sized engines, but the horsepower ratings and rated speed are different, the maximum blowby values measured will be different.

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.



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]

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]

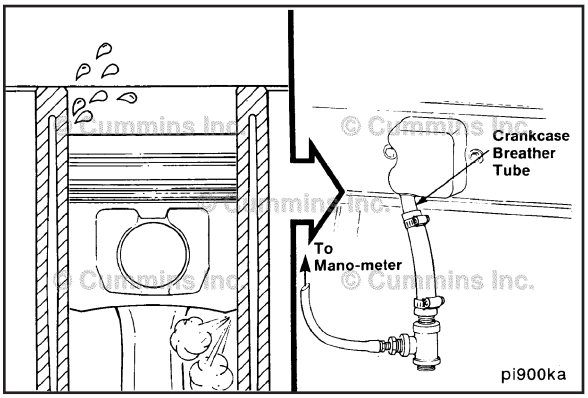
The following chart contains general blowby specifications for MidRange engines. Due to the wide variety of engine types, configurations, and ratings, these specifications are intended to **only** be used as a guide to help identify if a problem exists. These specifications are **not** intended to be used as engine condemnation limits.

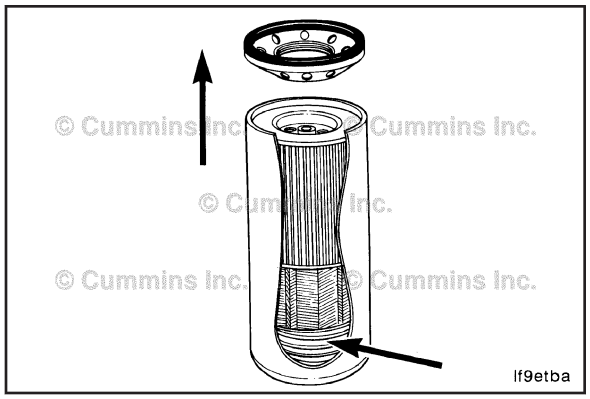
NOTE: If internal engine damage is suspected to be the cause of the excessive blowby condition, other steps can be taken to confirm this.

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.

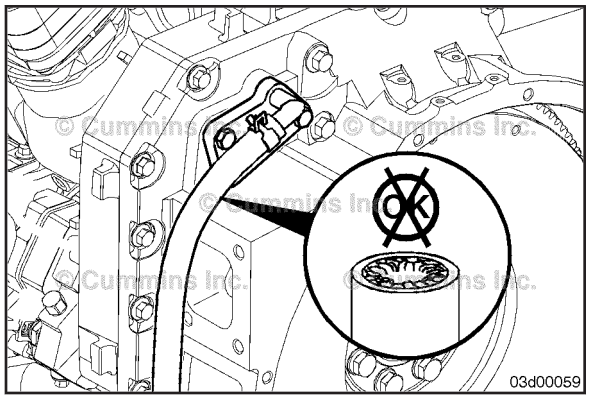




If internal engine damage is suspected to be the cause of the excessive blowby condition, other steps can be taken to confirm this. The steps include:

- Confirm engine maintenance practices
- Cut the oil filter open and check for debris
- Take an oil sample and inspect for contamination.

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	



Initial Check

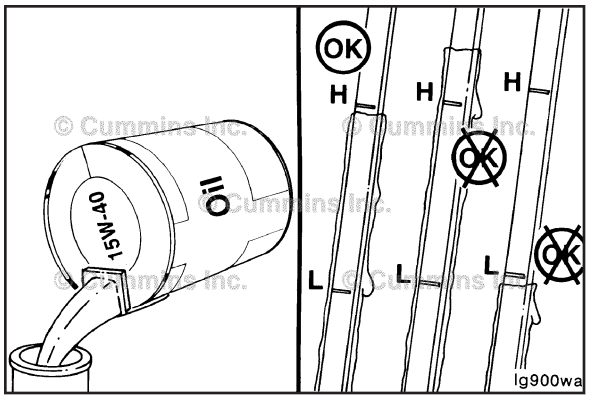
NOTE: The location and type of crankcase breathers vary by engine configuration (Front Gear Train or Rear Gear Train) and/or engine application (Marine, Industrial, and Automotive).

Prior to measuring blowby pressure, check the crankcase breather tube for obstructions.

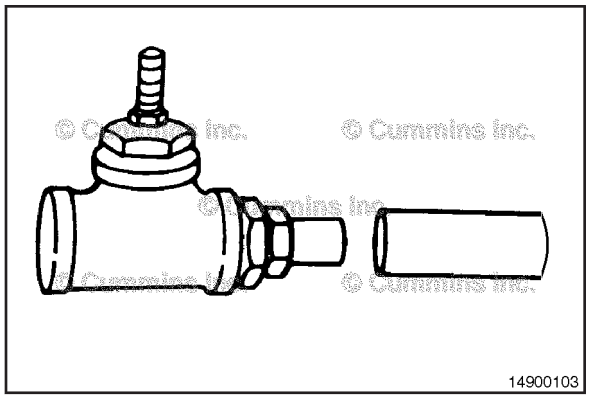
- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 003-018 in Section 3.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 003-018 in Section 3.
- Use the 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.

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.

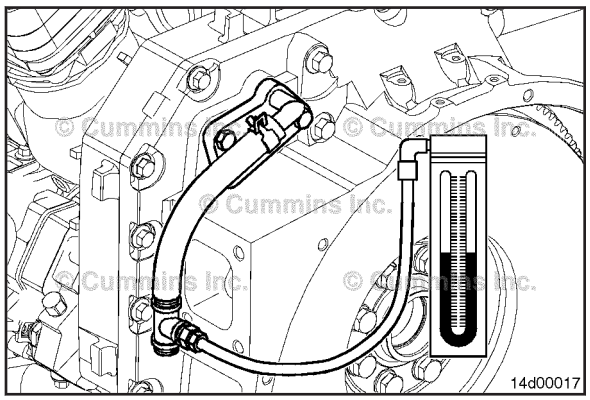


Measure

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.

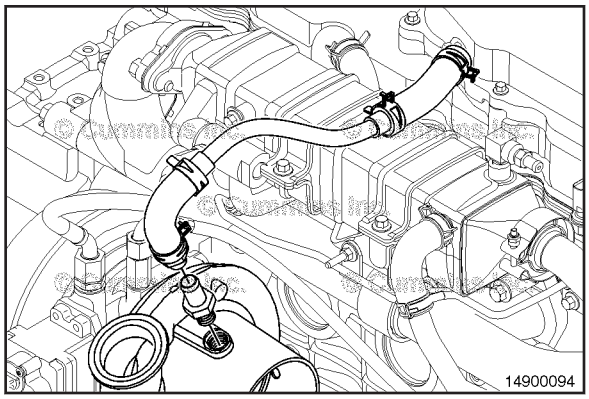
NOTE: The location of the crankcase breather tube can vary by engine configuration (front gear train or rear gear train) and/or application (Marine, Industrial, and Automotive). See Section E for crankcase breather tube locations.

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.

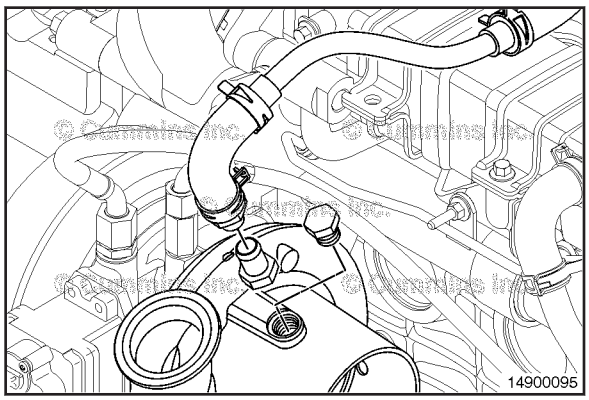
For ISB CM2150 engines that have the crankcase ventilation filter located on top of the rocker lever cover, use the following steps to connect the blowby measurement tools.

- 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.

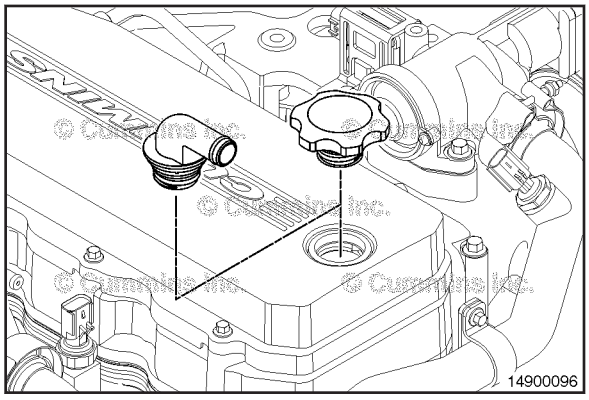


- If the crankcase ventilation line is connected to the turbocharger housing, install a straight thread plug, Part Number 3089567. Plug the crankcase ventilation line with a suitable fitting.

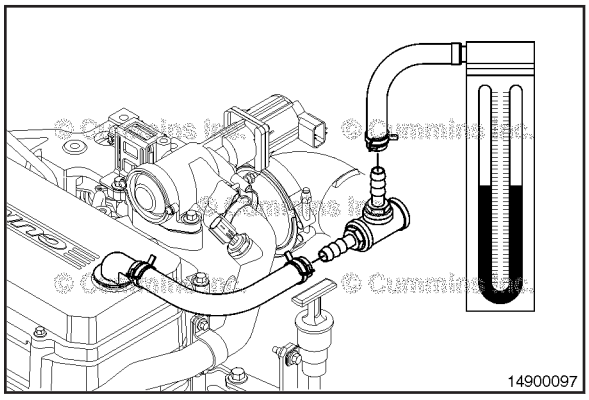
NOTE: If the crankcase ventilation line is connected to the OEM intake plumbing (**not** shown), use a suitable fitting to plug the port in the intake plumbing. Also plug the crankcase ventilation line coming from the engine with a suitable fitting.

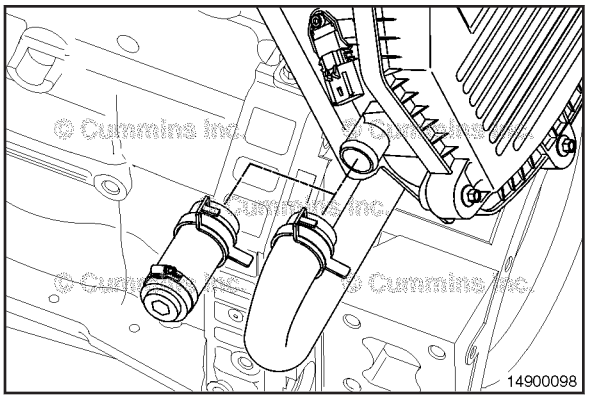


- Remove the oil fill cap from the rocker lever cover. Install an oil fill adapter, Part Number 3990099.



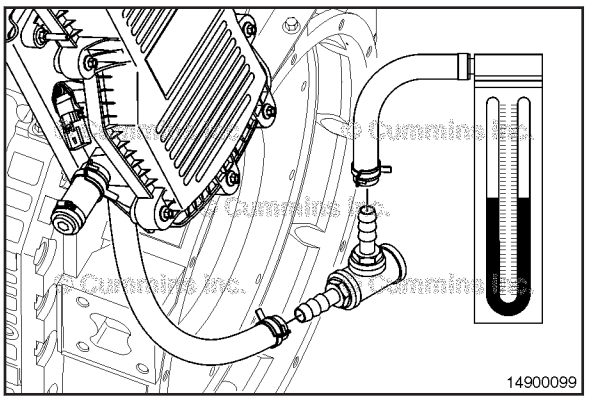
- Connect the appropriate blowby service tool to the outlet of the oil fill adapter. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.



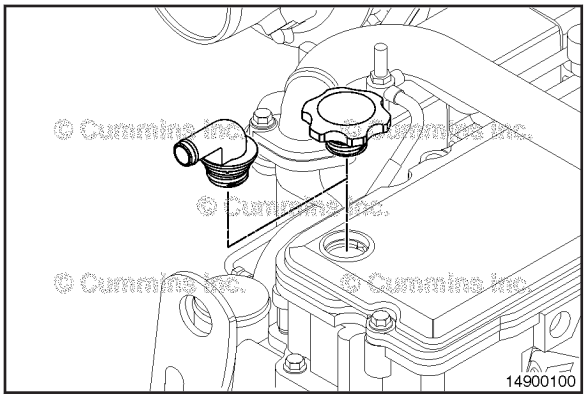


For ISB CM2150 engines that have the crankcase ventilation filter located at the rear of the engine, use the following steps to connect the blowby measurement tools.

- Disconnect the crankcase ventilation line from the crankcase ventilation filter housing. Plug or cap the crankcase ventilation filter housing.

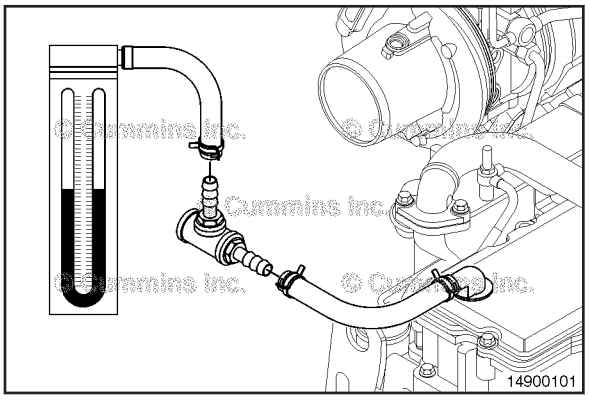


- Connect the appropriate blowby service tool to the crankcase ventilation line exiting the flywheel housing. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.



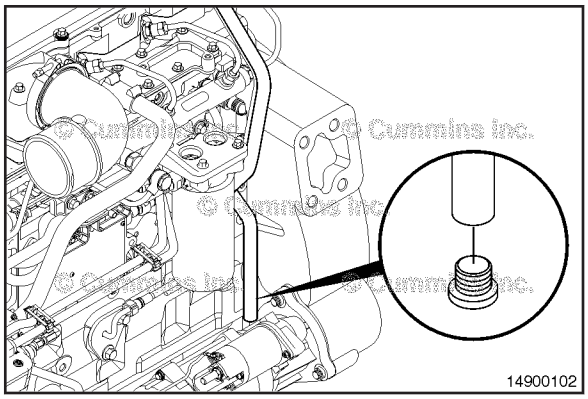
For ISC and ISL CM2150 and QSL CM2250 engines, use the following steps to connect the blowby measurement tools.

- 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.

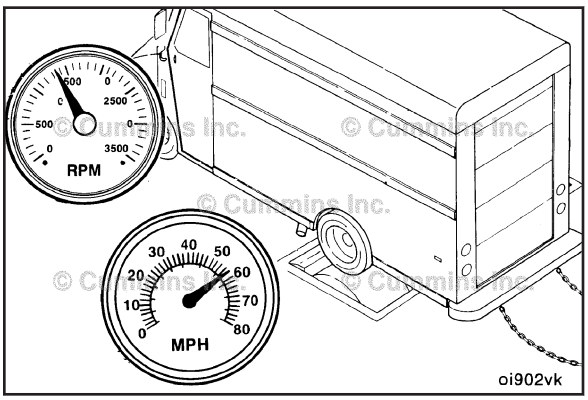
- Use a suitable fitting to plug the crankcase breather tube.



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.

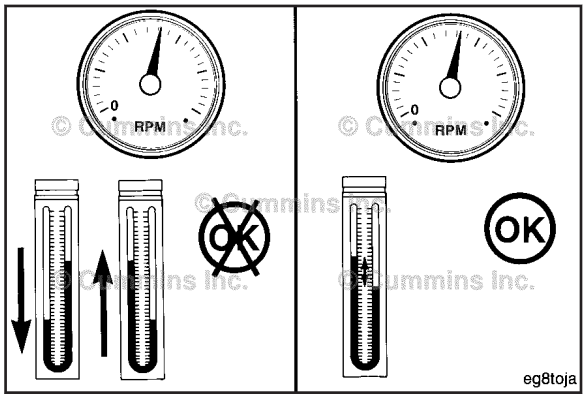
Operate the engine at rated rpm and full load until a steady reading is obtained.

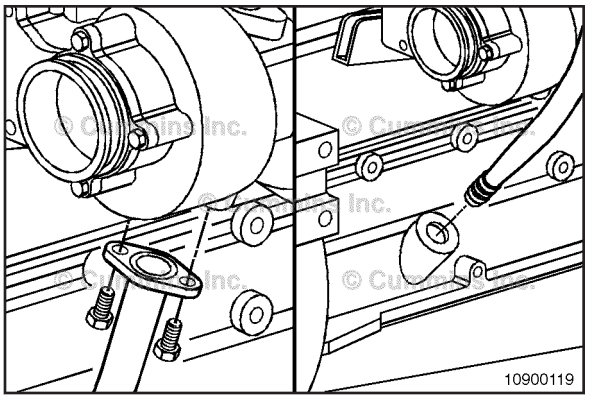
NOTE: When measuring blowby, the value can “spike” initially as the engine reaches peak power and rated speed. Wait for the blowby measurement to stabilize before taking a reading.

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:

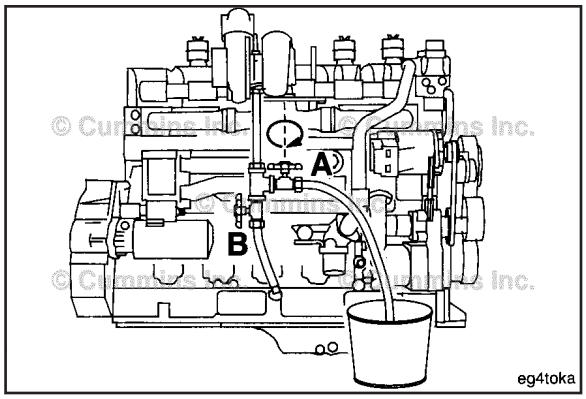
- Isolate the turbocharger, if equipped, to determine if the high blowby pressure is due to turbocharger seal leakage.
- To measure the turbocharger blowby contribution, disconnect the turbocharger oil drain line.
- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, 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.

Preferred Turbocharger Isolation Method:

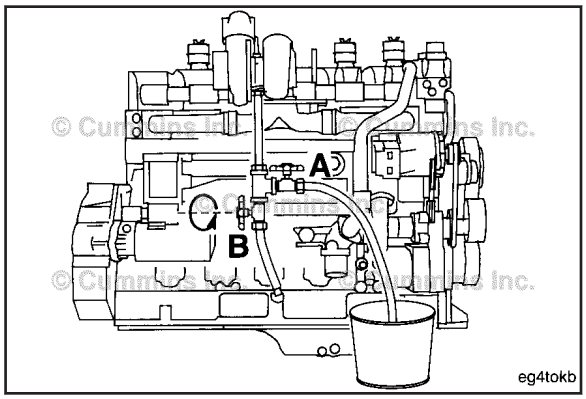
Install a hose assembly with two shutoff valves (A and B), as shown in the illustration, between the turbocharger and turbocharger drain line location in the cylinder block. The valves **must** have a minimum inside diameter of 19 mm [0.75 in]. Place the other hose in a 8 to 9 liter [2 to 3 gal] container.

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.

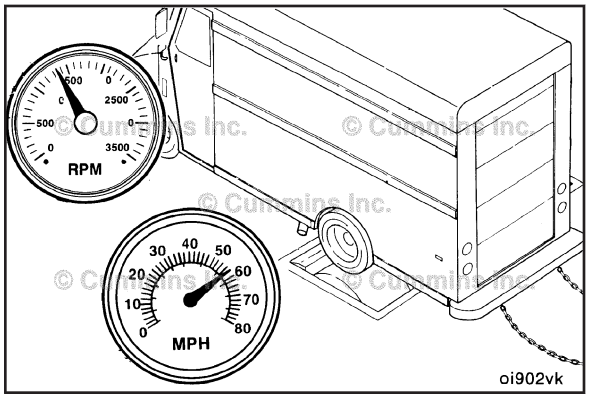


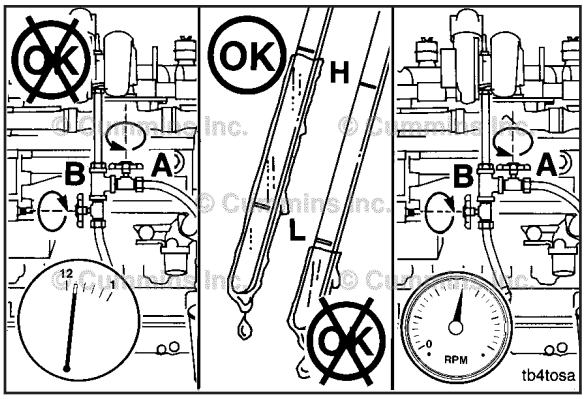
Operate the engine at rated speed and under load by either:

- 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.

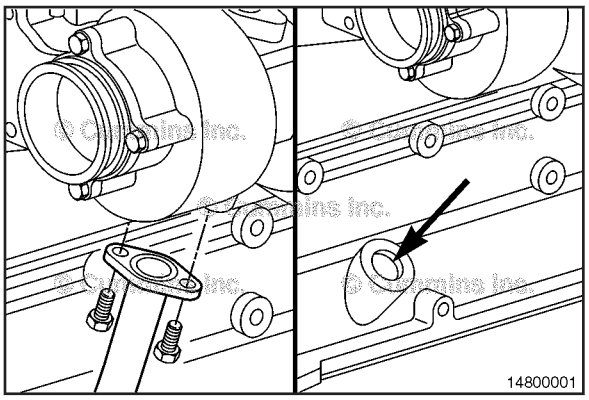
⚠WARNING⚠
Troubleshooting presents the risk of equipment damage, personal injury, or death. Troubleshooting must be performed by trained, experienced technicians.

△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**).

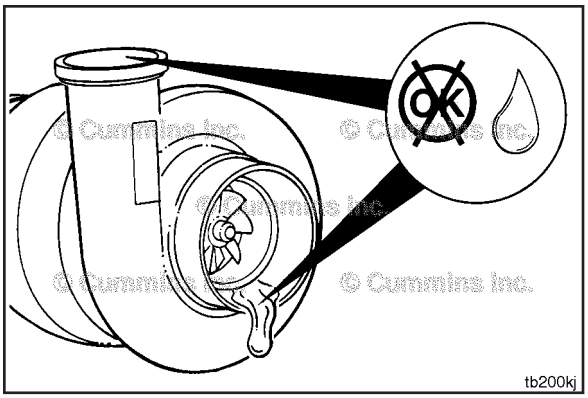
Record the peak blowby pressure measurement.

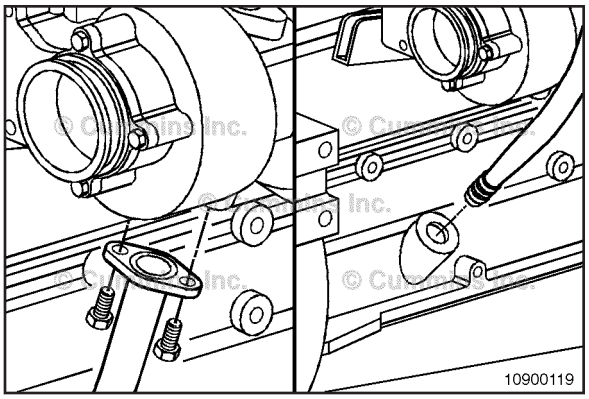
Determine the turbocharger blowby pressure contribution by determining the difference in the blowby pressure measurement with the turbocharger drain isolated, valve (A) open, and turbocharger drain **not** isolated, valve (A) closed.

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.





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.

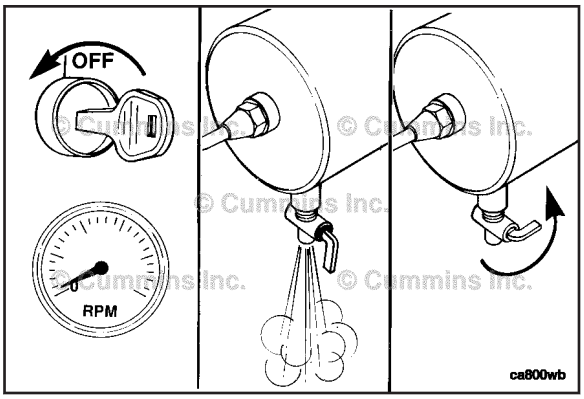
Check the engine oil level and add oil, if necessary.

⚠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.

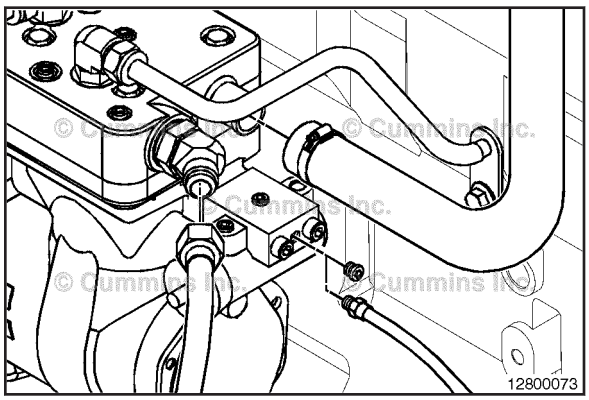


NOTE: The air compressor governor/unloader location can vary on each engine application. The air governor/ unloader can be air compressor mounted or chassis mounted.

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.

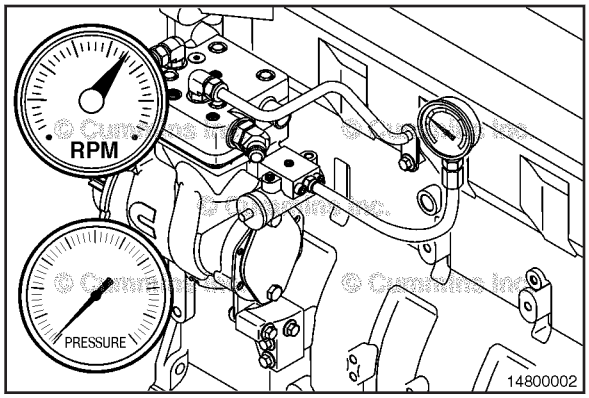
Connect a regulated shop air pressure line, with pressure gauge, to the air compressor governor/unloader air signal port.

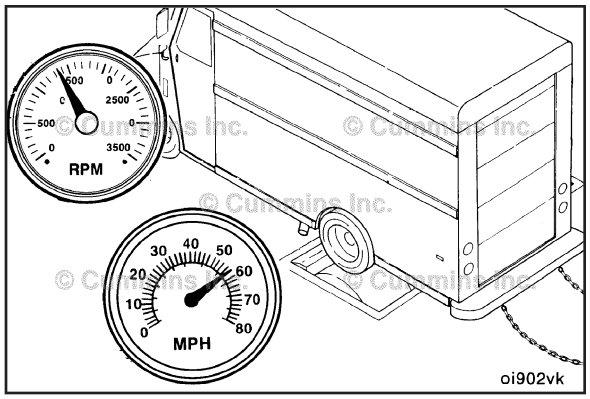
NOTE: When performing the test, make sure that the air system pressure does **not** exceed the manufacturer's maximum allowable pressure.

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.





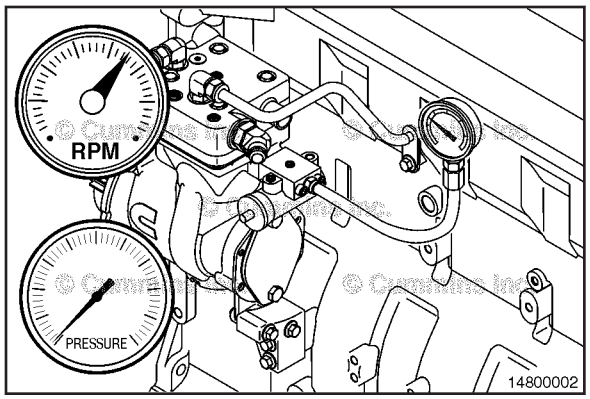
With the regulated shop air pressure line still connected to the air compressor governor/unloader air signal port, regulate the signal pressure so that the air compressor starts pumping (system pressure will begin to rise again at this point). Use the pressure value recorded previously as a set point.

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.

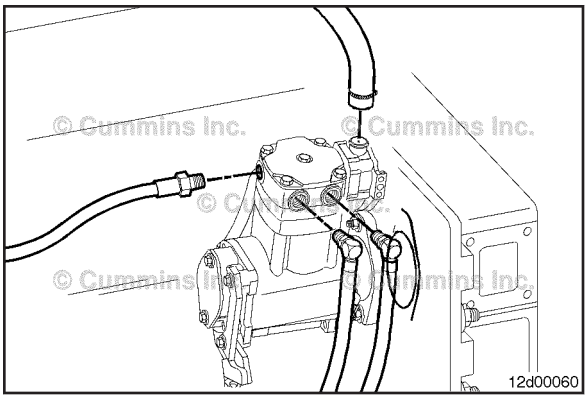
NOTE: When measuring blowby, the value can “spike” initially as the engine reaches peak power and rated speed. Wait for the blowby measurement to stabilize before taking a reading.

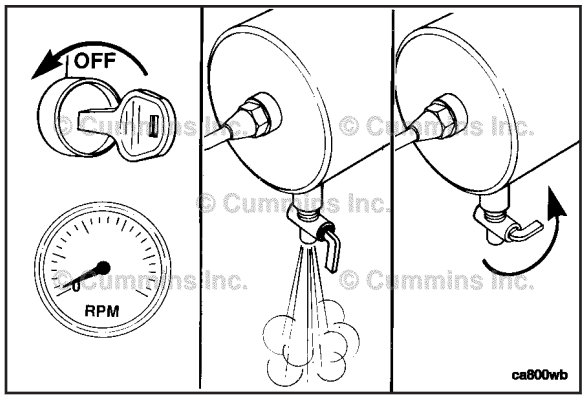
Determine the air compressor blowby pressure contribution by determining the difference in the blowby pressure measurement with the air compressor pumping and the air compressor **not** pumping.

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.

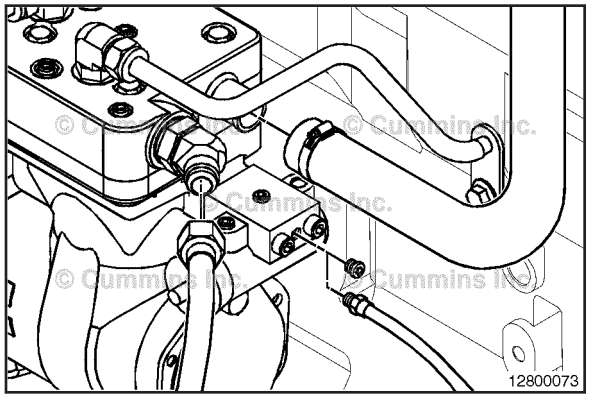




⚠WARNING⚠

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.



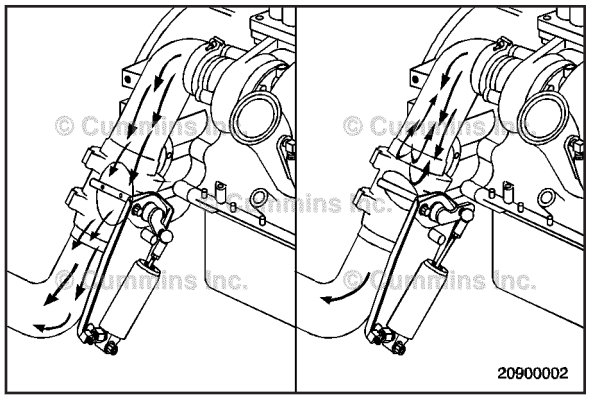
Disconnect the regulated shop air pressure line, with pressure gauge, from the air compressor governor/ unloader air signal port.

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.

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.

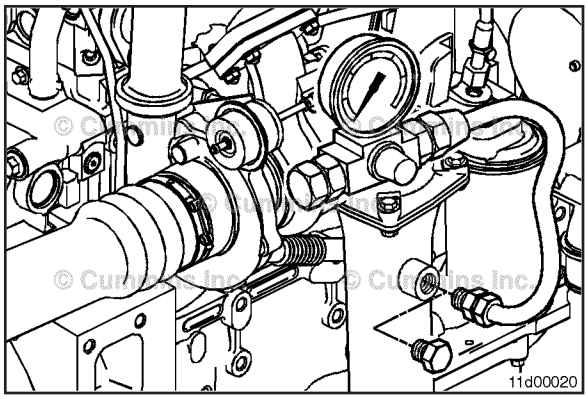
If blowby pressure is above specification during exhaust brake operation and exhaust back pressure is above specification, repair or replace the exhaust brake. See the manufacturer's instructions.

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.

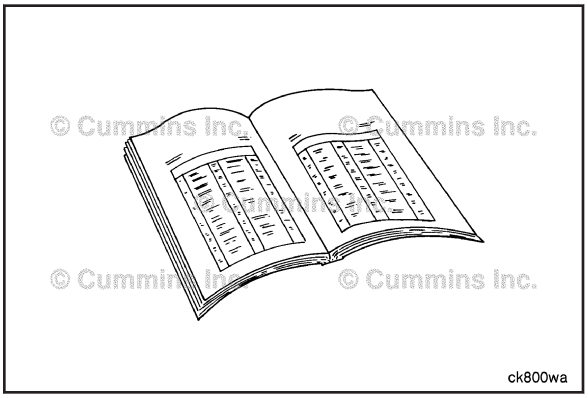
Remove the pressure gauge used to measure exhaust back pressure during exhaust brake operation.

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.

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.

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.

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.

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.

Notes

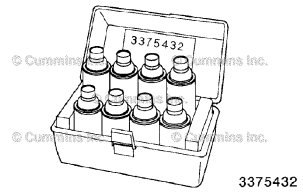
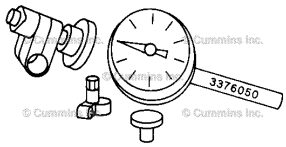
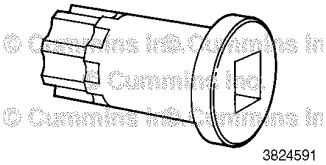
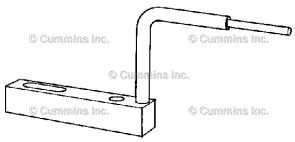
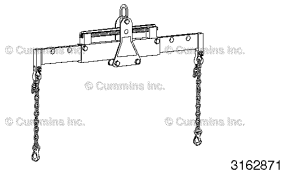
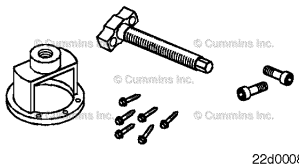
Section 16 - Mounting Adaptations - Group 16

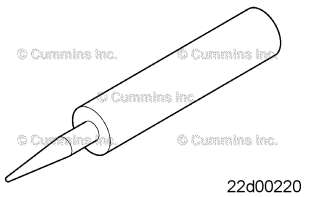
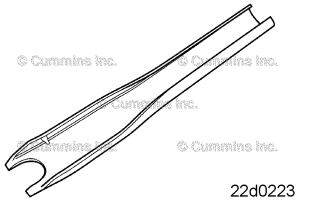
Section Contents

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
3375432	**Crack Detection Kit** Used to detect cracks in engine components.	
3376050	**Dial Indicator Gauge** Used with attachment Part Number ST-1325 for checking flywheel housing runout.	
3824591	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	
ST-1325	**Dial Gauge Attachment** Used with dial indicator Part Number 3376050 for checking flywheel housing runout.	
3162871	**Engine Lifting Fixture** Used to remove and install the engine.	
3164659	**Oil Seal Replacer (Front)** Used to remove/install the front crankshaft seal.	

Tool No.	Tool Description	Tool Illustration
3164660	**Oil Seal replacer (Rear)** Used remove/install rear crankshaft seal on engines equipped with unitized seal.	 22d00087
3376638	**Vibration Damper Guide Pin** Used to help align the vibration damper. M12 x 1.75	 22d00114
3376488	**Accessory Drive Support Guide Pin** Used to help align the accessory drive support. M10 x 1.5	 22d00115
3164070	**RTV Sealant** Used to seal flywheel housing to gear housing joint.	 22d00220
3165175	**Barring Plug Remover.** Removes flywheel housing plug. Removal of this plug is required prior to using Barring Tool, Part Number 3824591.	 22d0223

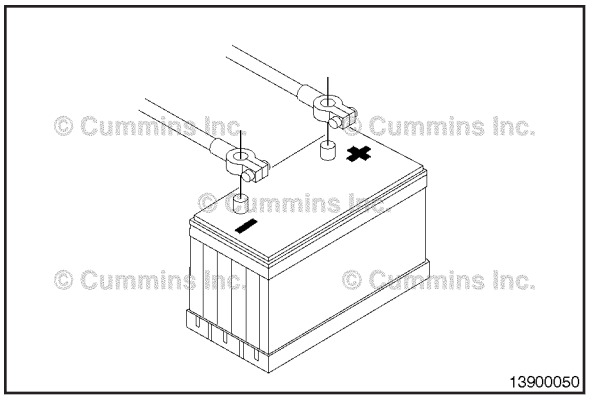
Engine Lifting Brackets (016-001)

Preparatory Steps

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

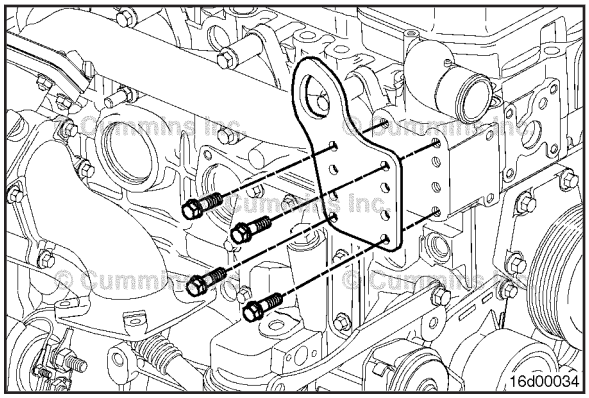
Disconnect the batteries.

For the front lifting bracket it may be necessary to remove the alternator and alternator bracket. Refer to Procedure Procedure 013-001and Refer to Procedure Procedure 013-003



Remove

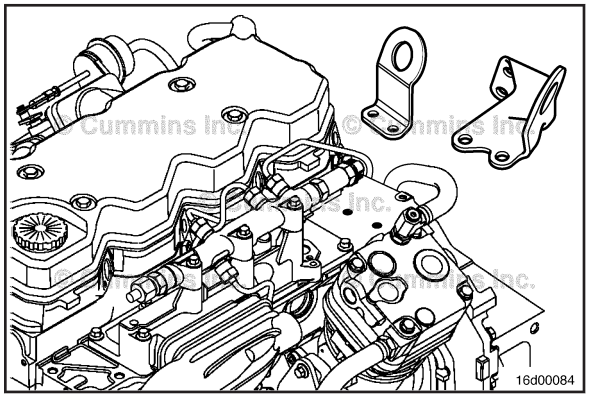
Remove the capscrews and the front lifting bracket.

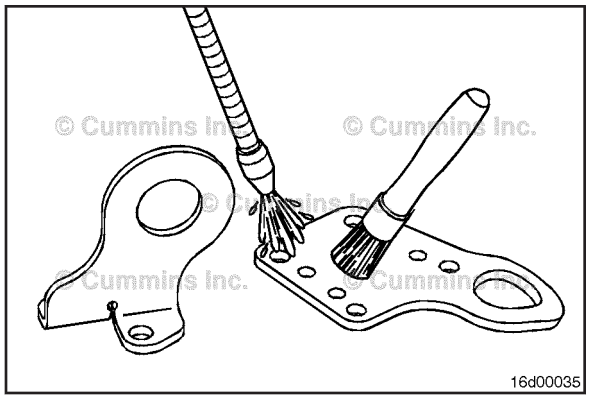


Remove the capscrews and the rear lifting bracket.

NOTE: Some engines use a two bolt rear lifting bracket and some engines use a four bolt rear lifting bracket.

⚠CAUTION⚠
On some engines, it may be necessary to remove the number 5 injector supply line and/or the number 6 injector supply line vibration isolator. Do not try to bend or pry the injector supply line, a fuel leak will result. Refer to Procedure Procedure 006-051





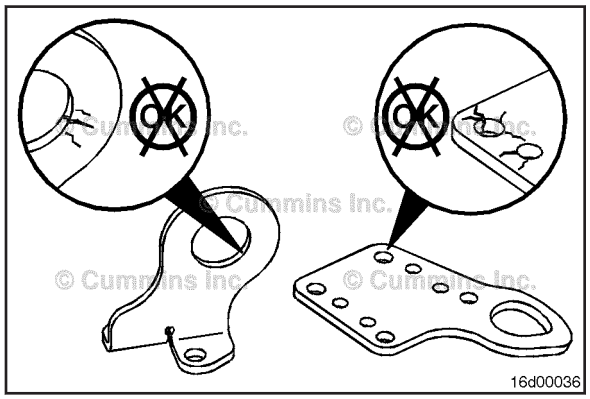
Clean and Inspect for Reuse

⚠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.

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

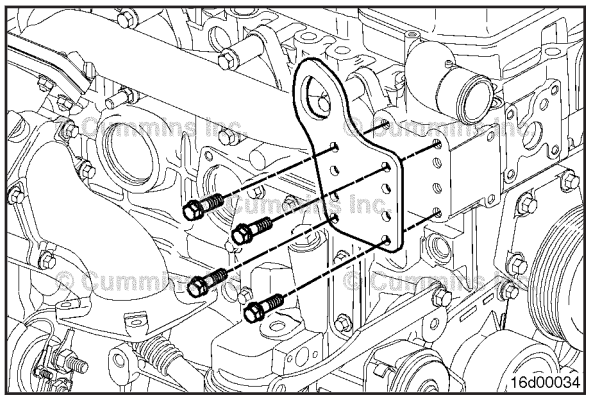
Use steam or solvent to clean the lifting brackets. Dry with compressed air.



⚠WARNING⚠
Do not use a cracked or damaged bracket. Do not weld a cracked bracket. Personal injury can result.

Inspect the brackets for cracks or damage.

Replace the bracket if it is cracked or damaged.



Install

For engines **not** equipped with pad mount alternators, install the capscrews and front bracket.

Tighten the capscrews.

Torque Value:
M8
Step 1 24 N•m [18 ft-lb]

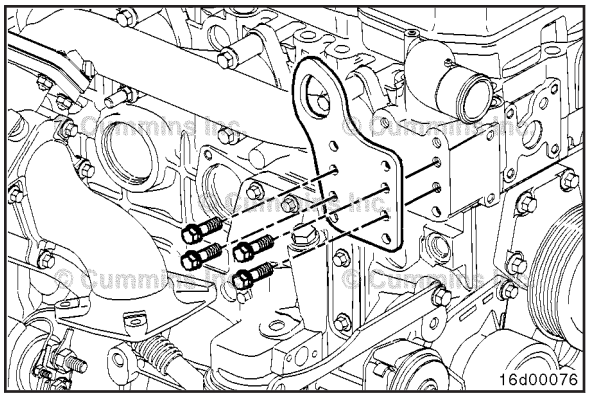
Torque Value:
M10
Step 1 43 N•m [32 ft-lb]

⚠WARNING⚠
Four 20 mm, grade 10.9, hex head capscrews must be used to install the front lifting bracket. If shorter capscrews or capscrews of a different grade are used, the engine can fall when lifting the engine. Personal injury and property damage can result.

For engines equipped with pad mount alternators, install the capscrews and front bracket.

Tighten the capscrews.

Torque Value: 32 N•m [24 ft-lb]

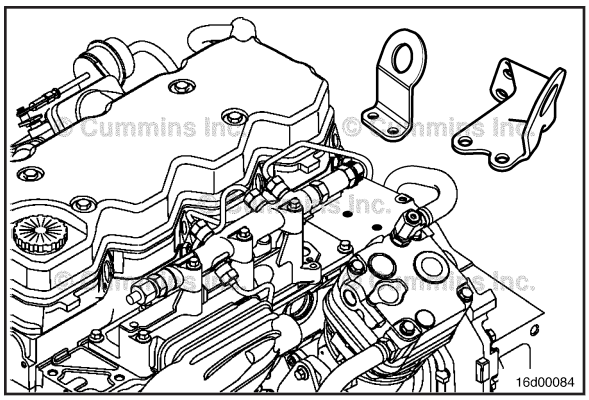


Install and tighten the rear bracket and capscrews.

NOTE: Some engines use a two bolt rear lifting bracket and some engines use a four bolt rear lifting bracket.

Torque Value:
M10
Step 1 43 N•m [32 ft-lb]

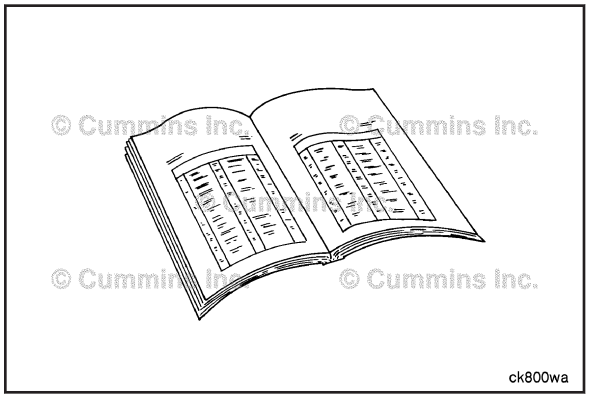
Torque Value:
M12
Step 1 77 N•m [57 ft-lb]



Finishing Steps

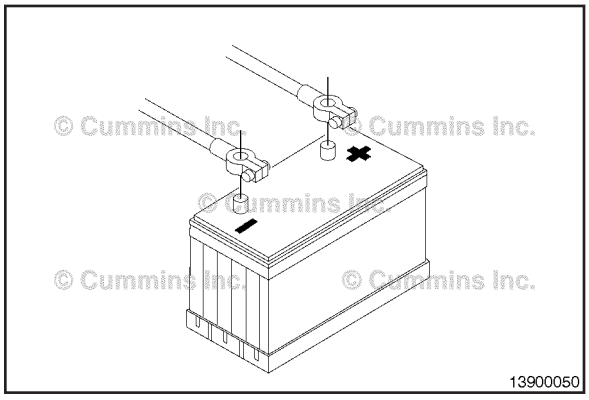
If removed, install the number 5 injector supply line and/or the number 6 injector supply line vibration isolator. Refer to Procedure Procedure 006-051

If previously removed install the alternator and alternator bracket. Refer to Procedure Procedure 013-001 and Refer to Procedure Procedure 013-003



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

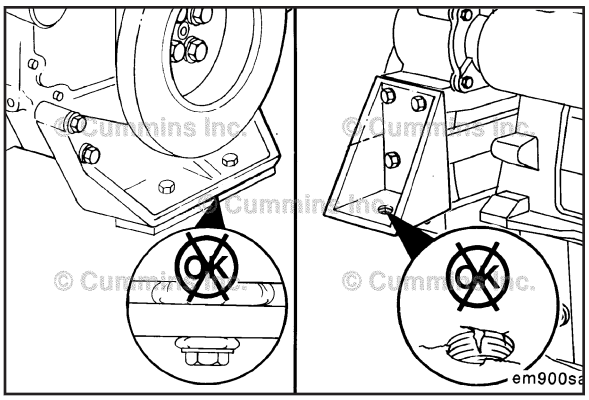
Connect the batteries.



Engine Support Bracket, Front (016-002)

General Information

Due to the number of different engine mounting configurations, the following procedure is written to be generic. Some of the illustrations may **not** represent the actual part being removed and installed.



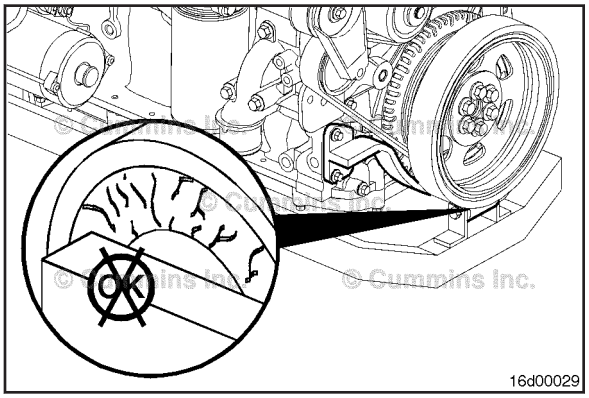
Initial Check

⚠CAUTION⚠
Damaged engine mounts and brackets can cause engine misalignment. Drivetrain component damage can result in excessive vibration complaints.

For All Engine Mounts, inspect all rubber-cushioned mounts for cracks or damage.

Inspect all mounting brackets for cracks or damaged bolt holes.

Replace any damage parts as necessary.



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 may cause vibration complaints. If contact is found, replace the front engine support bracket.

Remove

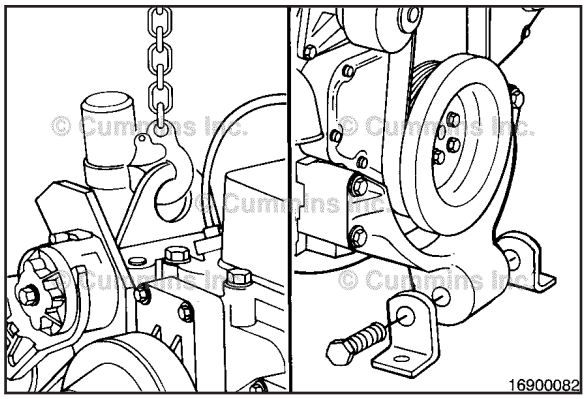
⚠WARNING⚠
The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

⚠WARNING⚠
The 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.

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

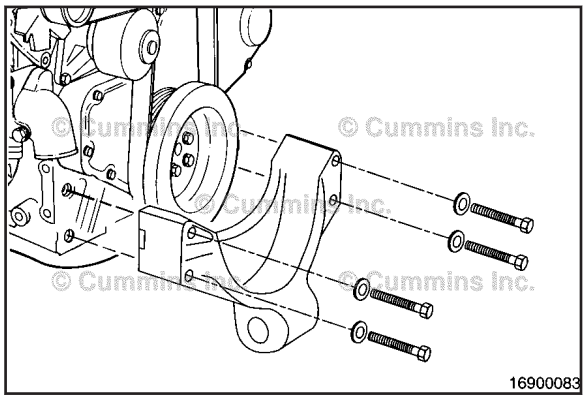
NOTE: When removing the front engine mount fasteners, keep track of the location of any shims or spacers used.

Remove the capscrews from the front engine mount.

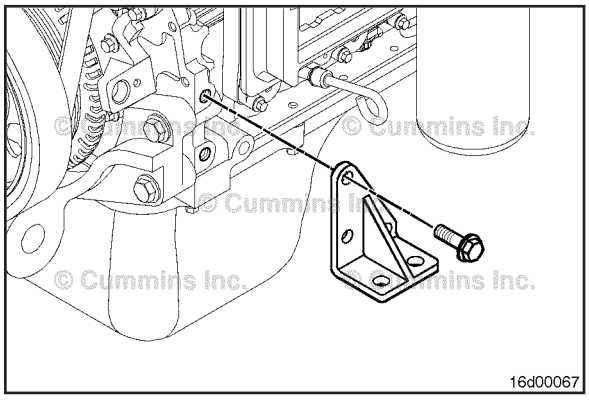


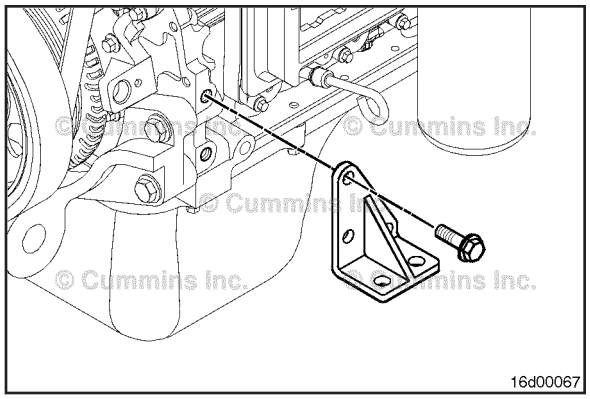
NOTE: Certain applications will require loosening of the rear engine mount fasteners to allow removal of the front engine support bracket.

For Front Mount, remove the front mount capscrews and bracket.



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





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

⚠WARNING⚠
The 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.

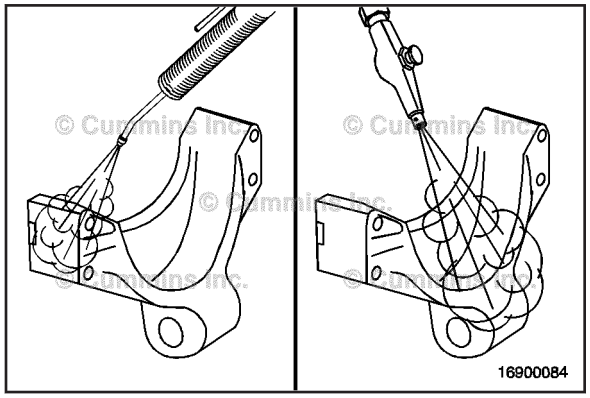
Certain applications will require loosening the rear mount capscrews to allow movement of the front mount bracket.

Use a suitable lifting fixture to support the front of the engine.

Remove the isolator mounting capscrews or nut from the base rails. Lift the engine.

Remove the side engine mount capscrews and the brackets.

Remove the vibration isolator.



Clean and Inspect for Reuse

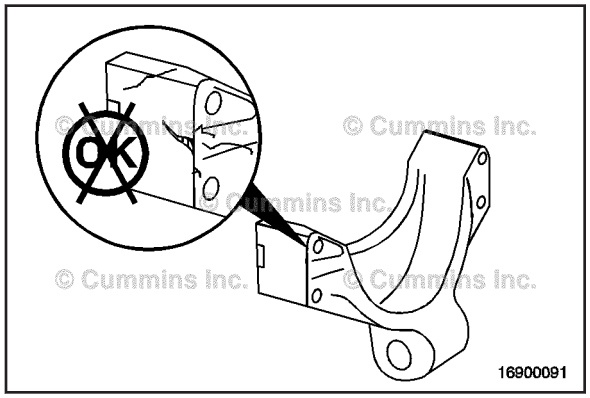
⚠WARNING⚠
When using a steam cleaner, wear protective clothing as well as safety glasses or a face shield. Hot steam can cause serious personal injury.

⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles as well as protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Compressed air used for cleaning should not exceed 207 kPa[30 psi]. Use only with protective clothing, as well as goggles/shield, and gloves to reduce the possibility of personal injury.

Use steam or solvent to clean the front engine support bracket(s).

Dry with compressed air.



Inspect the engine support bracket for cracks or damage.

If the engine support bracket is cracked, it **must** be replaced.

NOTE: Some front engine support brackets have rubber inserts. Make sure to inspect the inserts for separation, cracking and deterioration. If any damage is found, the front engine support bracket **must** be replaced.

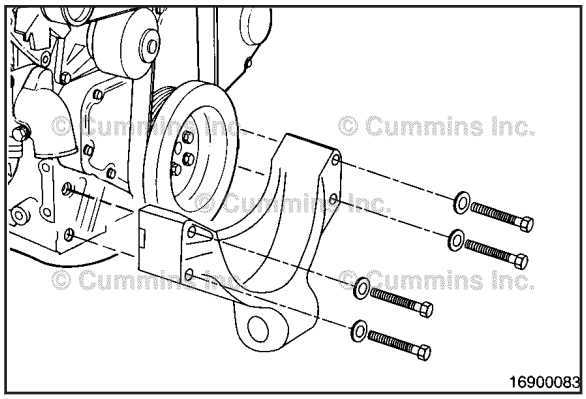
Install

For Front Mount, install the front mount bracket and capscrews.

Torque Value:
Grade 8.8
Step 1 80 N•m [60 ft-lb]

Torque Value:
Grade 10.9
Step 1 115 N•m [85 ft-lb]

Torque Value:
Grade 12.9
Step 1 125 N•m [95 ft-lb]

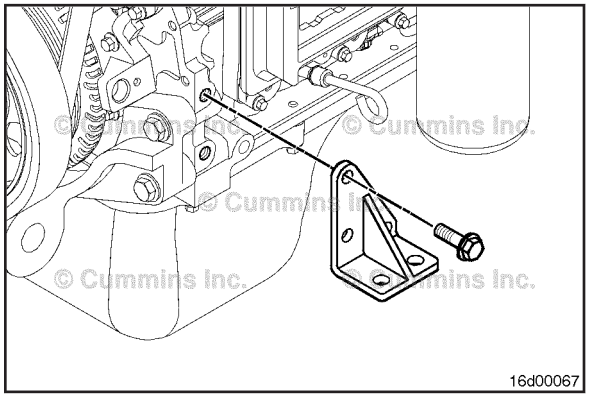


For Side Mount, install the side mount brackets and capscrews.

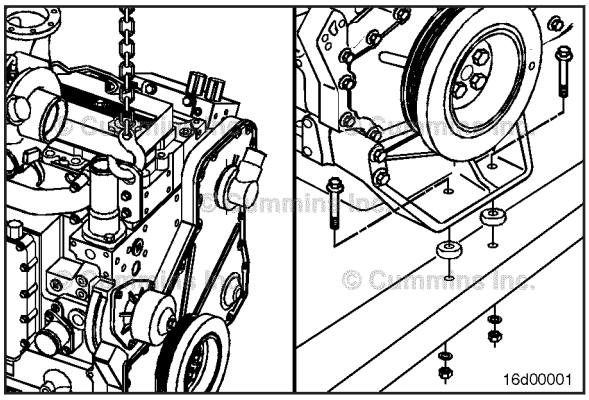
Torque Value:
Grade 8.8
Step 1 80 N•m [60 ft-lb]

Torque Value:
Grade 10.9
Step 1 115 N•m [85 ft-lb]

Torque Value:
Grade 12.9
Step 1 125 N•m [95 ft-lb]



Lower the front of the engine.

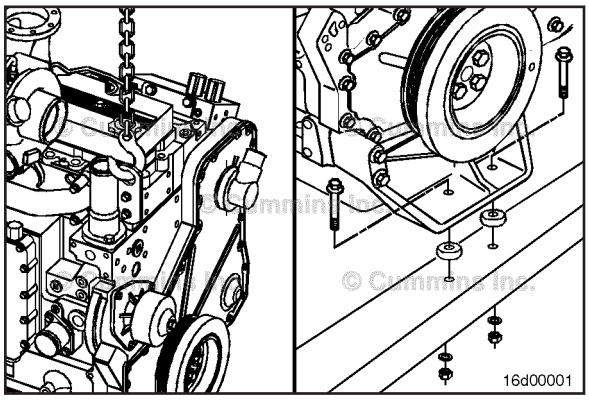


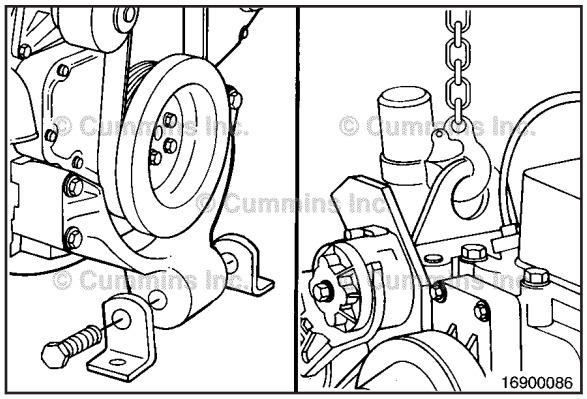
NOTE: Make sure to install any shims or spacers in the same location as removed.

Install the front engine mount fasteners and tighten. Refer to OEM specifications.

If previously loosened, tighten the rear engine mounting fasteners. Refer to OEM specifications.

Remove the lifting fixture or hoist from the front of the engine.





NOTE: Make sure to install any shims or spacers in the same location as removed.

Install the front engine mounting bolt.

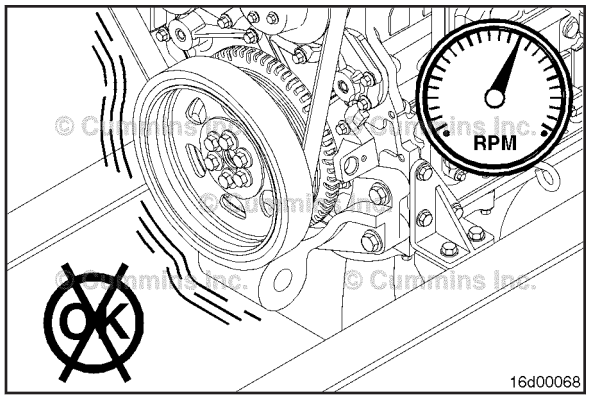
Install the hexagonal jam nut and tighten.

Torque Value: 350 N•m [258 ft-lb]

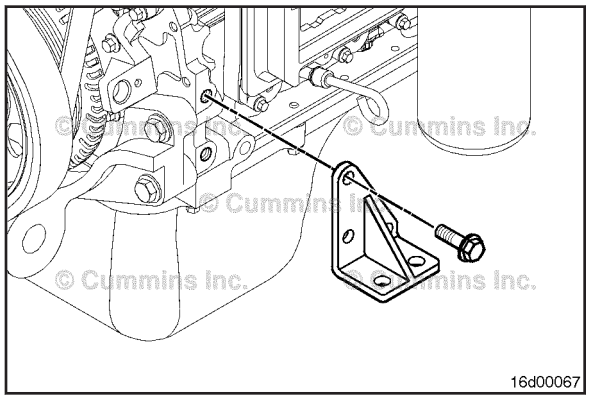
NOTE: After tightening the engine mounting bolt, inspect for signs of contact between the side brackets and the front engine support bracket. Contact between the engine mount and side brackets may cause vibration complaints. If contact is found, verify that all spacers and shims previously removed have been installed.

NOTE: If previously loosened, tighten the rear engine mount fasteners. Refer to OEM specifications.

NOTE: Remove the lifting fixture or hoist from the front of the engine.



Operate the engine and check for noise or vibration.



Install the vibration isolator onto the mounting bracket. Install the locking nut finger tight.

Install the side mount bracket and mounting capscrews.

Torque Value: 150 N•m [111 ft-lb]

Lower the front of the engine.

Install the front engine mount capscrews.

Tighten the isolator capscrews to the manufacturer's specifications.

Tighten the rear mounting brackets, if loosened.

Remove the lifting fixture or hoist from the front of the engine.

Engine Support Bracket, Rear (016-003)

General Information

Due to the number of different engine mounting configurations, the following procedure is written to be generic. Some of the illustrations may **not** represent the actual part being removed and installed.

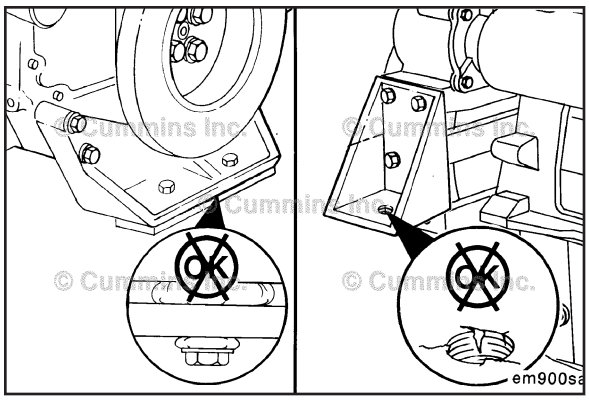
Initial Check

CAUTION
Damaged engine mounts and brackets can cause engine misalignment. Drivetrain component damage can result in excessive vibration complaints.

Inspect all rubber-cushioned mounts for cracks or damage.

Inspect all mounting brackets for cracks or damaged bolt holes.

Replace any damage parts as necessary.

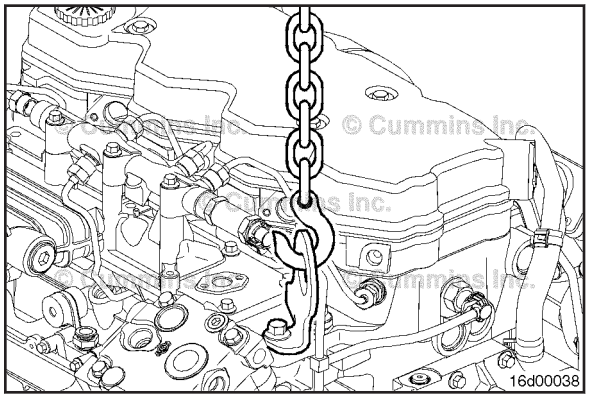


Remove

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

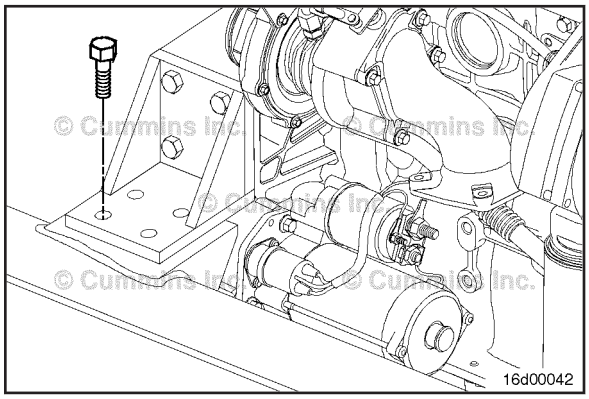
WARNING
This component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this component.

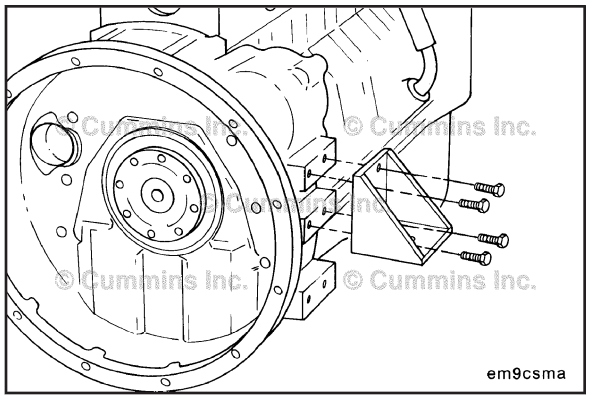
Use a hoist or lifting fixture to support the rear of the engine.



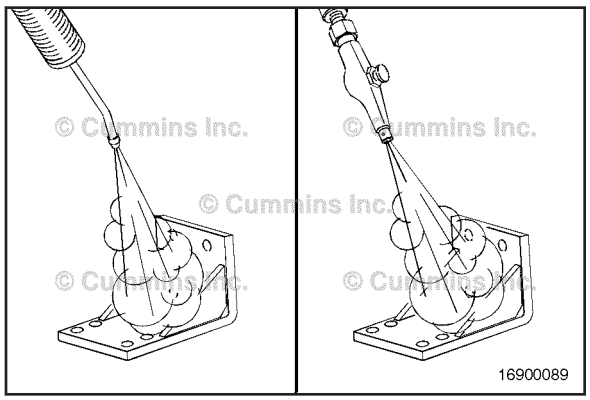
NOTE: When removing the rear engine mount fasteners, keep track of the location of any shims or spacers used.

Remove the engine mount fasteners.





Remove the rear support capscrews and bracket.



Clean and Inspect for Reuse

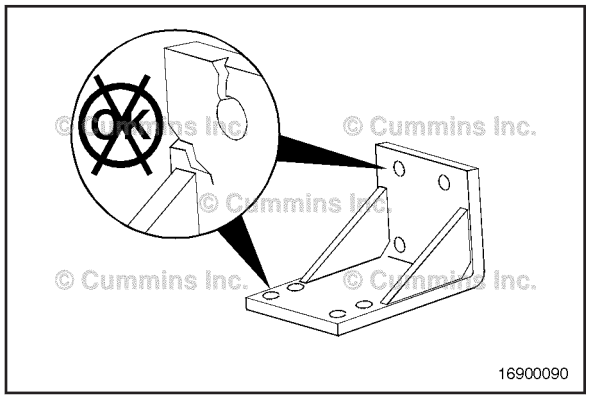
⚠WARNING⚠
When using a steam cleaner, wear protective clothing, as well as safety glasses or a face shield. Hot steam can cause serious personal injury.

⚠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⚠
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 bracket for cracks or damage.

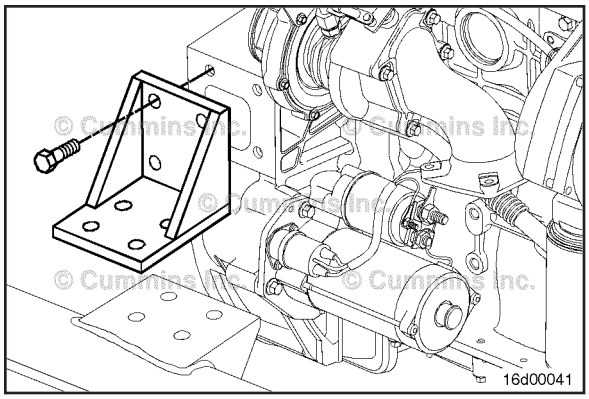
If the support bracket is cracked, it **must** be replaced.

NOTE: Some rear engine support brackets have rubber inserts. Make sure to inspect the inserts for separation, cracking and deterioration. If any damage is found, the rear engine support bracket **must** be replaced.

Install

Install the support bracket and mounting capscrews.

Torque Value: 77 N•m [57 ft-lb]



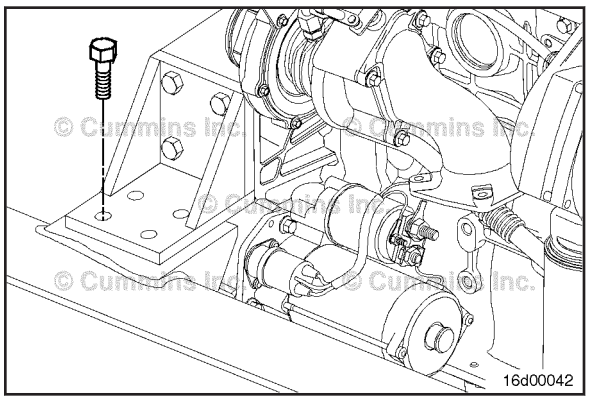
NOTE: Make sure to install any shims or spacers in the same location as removed.

Lower the rear of the engine.

Install the rear engine mount fasteners.

Tighten to the original equipment manufacturer's specifications.

Remove the lifting fixture or hoist from the rear of the engine.



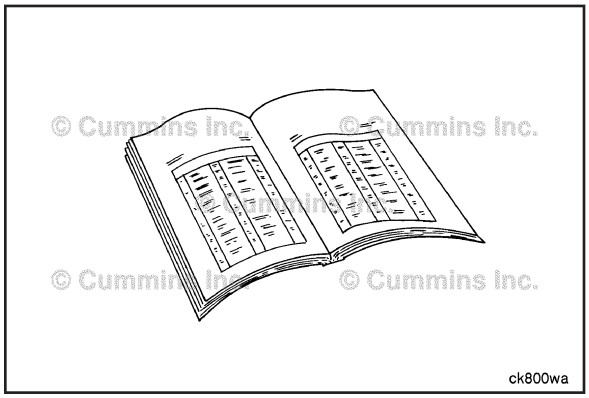
Flexplate (016-004)

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⚠
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.

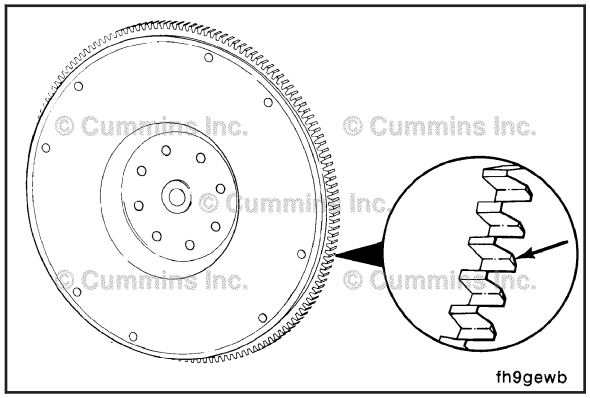
- Disconnect the batteries. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13.
- Remove the transmission and related components. Refer to the OEM service manual.



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

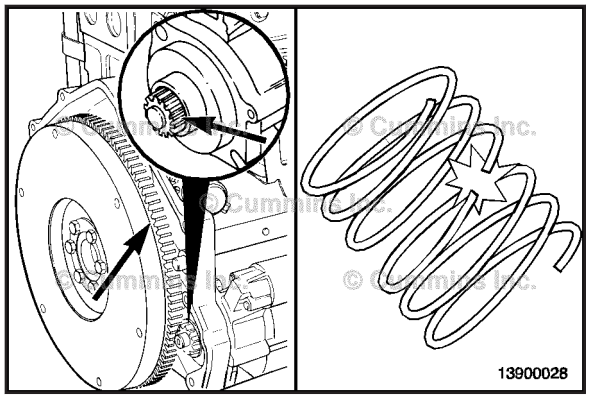
- Disconnect the batteries. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13.
- Remove the drive gear. Refer to OEM instructions.



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 (Starter Motor) 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 defect with the starter motor pinion. Inspect the pinion for nicks and burrs. If replacement of the starting motor is necessary, Refer to Procedure 013-020 (Starter Motor) in Section 13.

4 The torque converter/transmission is damaged or incorrectly mounted. Refer to the original equipment manufacturer's specifications

5 Incorrect starting motor pinion to flexplate ring gear pitch and teeth match. Refer to the original equipment manufacturer's specifications.

Electrical

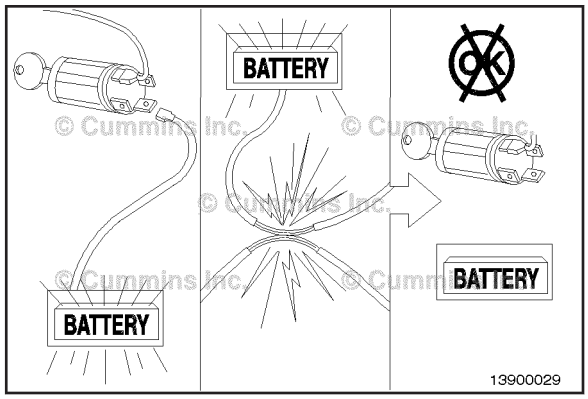
An electrical issue can typically be identified by seeing damage to the ring gear of the flywheel 360 degrees around the circumference of the ring gear (commonly called 360 degree milling). The following can be causes for electrical issues:

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 the 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 (Starter Motor) in Section 13.

3 The orientation of the starter relay, so that 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 original equipment manufacturer's specifications.

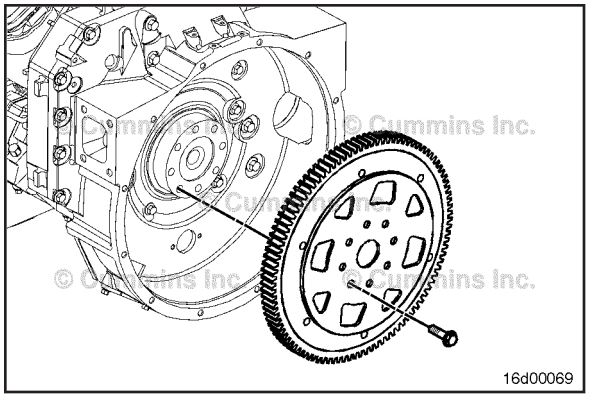
4 Intermittent starter motor wiring issues. Refer to the original equipment manufacturer's specifications.



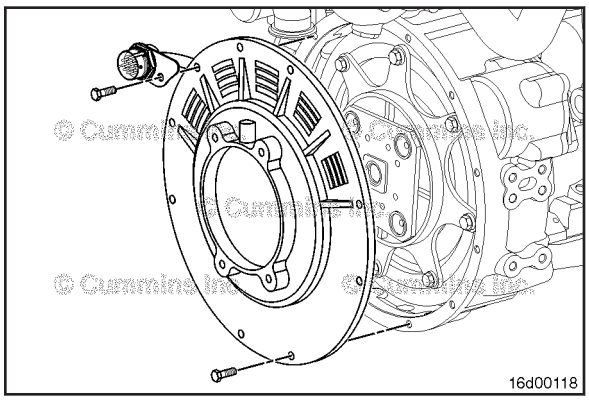
Remove

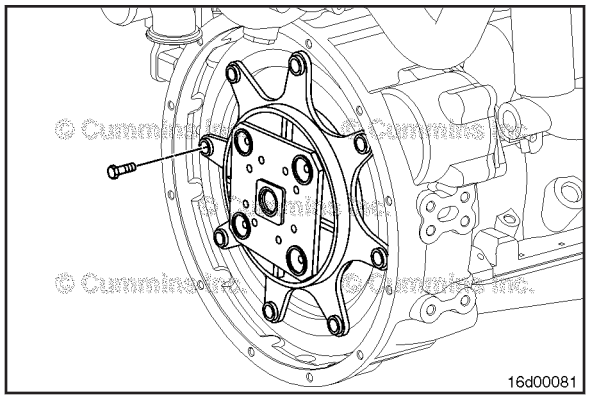
Remove the flexplate capscrews and flexplate.

NOTE: Some flexplates require mounting plates and/or adapters. It may be necessary to remove any mounting plates and/or adapters prior to or with the flexplate. Make sure to note the location of any mounting plates and/or adapters for later installation.



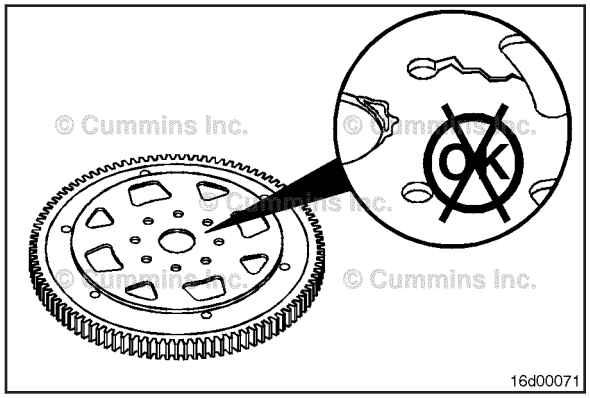
Remove the nine flex-coupling guard capscrews, harness connector, and the flex-coupling guard (if equipped).





Remove the flexplate mounting capscrews.

Remove the flexplate from the flywheel.

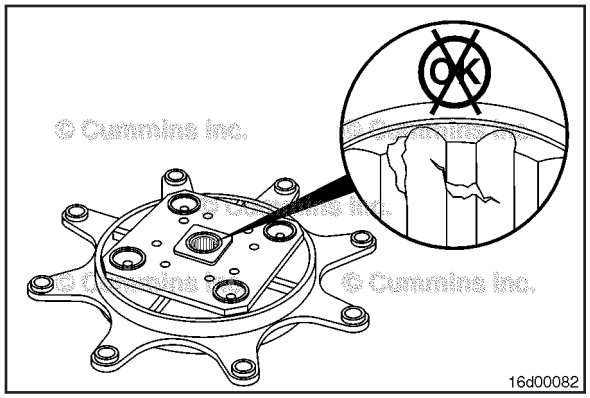


Inspect for Reuse

Inspect the teeth of the ring gear for chips or uneven wear.

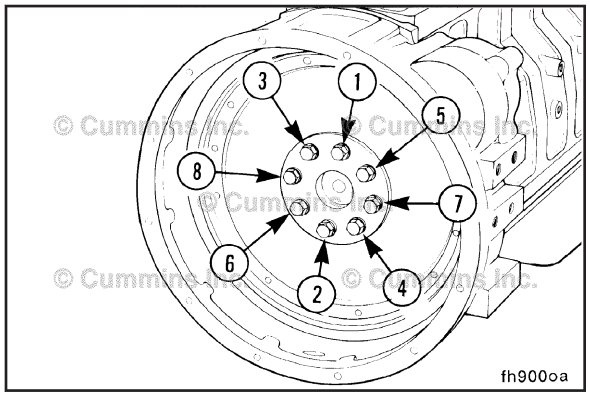
Check the flexplate for cracks.

Replace the flexplate if any damage is found.



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

NOTE: Some flexplates require mounting plates and/or clamp rings. It will be necessary to install any mounting plates and/or clamp rings prior to or with the flexplate as noted during removal.

Install the flexplate capscrews and flexplate, and tighten the capscrews.

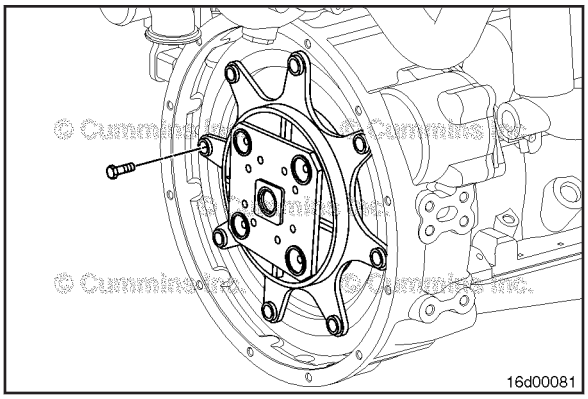
Torque Value:

Flexplate Capscrews		
Step 1	30 N•m	[22 ft-lb]
Step 2	Plus 60-degree turn	

Install the flexplate and flexplate mounting capscrews.

Tighten the capscrews.

Torque Value: 44 N•m [32 ft-lb]

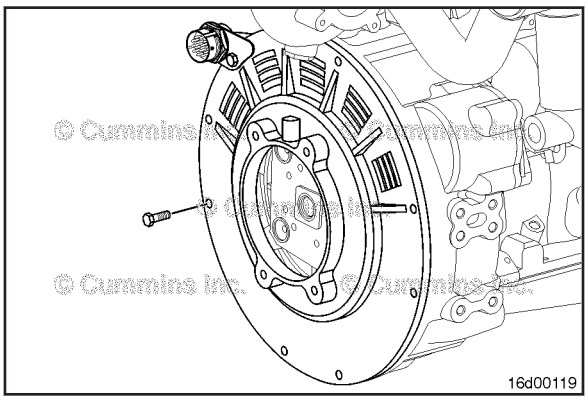


If the engine is equipped with a flex-coupling guard plate, install the flex-coupling guard plate onto the flywheel housing. Position the wiring harness connector at the 11 o'clock position, as shown in the illustration. Install a capscrew to hold it in place.

Install the remaining eight capscrews.

Tighten the capscrews.

Torque Value: 36 N•m [27 ft-lb]

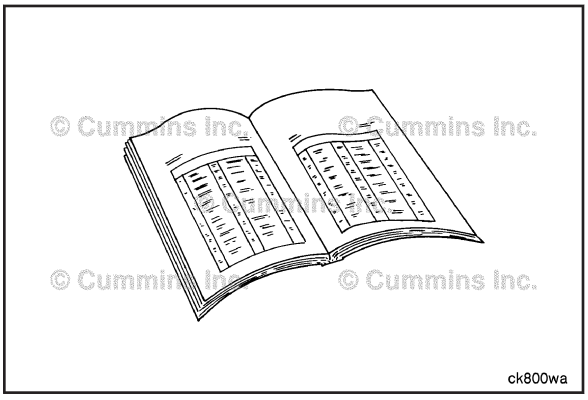


Finishing Steps

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

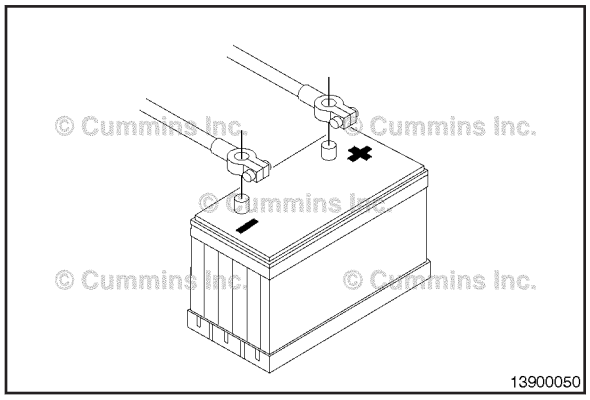
- Connect the batteries. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13.
- Install the transmission and related components. Refer to the OEM service manual.
- Operate engine and check for noise or vibration.



⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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 (Battery Cables and Connections) in Section 13.
- Install the drive gear. Refer to OEM instructions.
- Check the crankcase end play.Refer to Procedure 001-016 (Crankshaft) in Section 1.
- Operate the engine and check for noise or vibration.

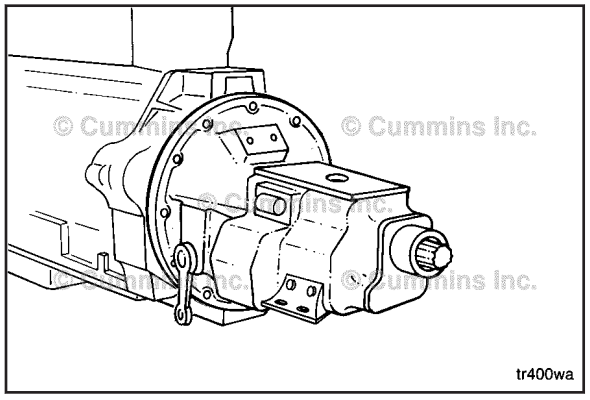


Flywheel (016-005)

Preparatory Steps

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

Disconnect the batteries.



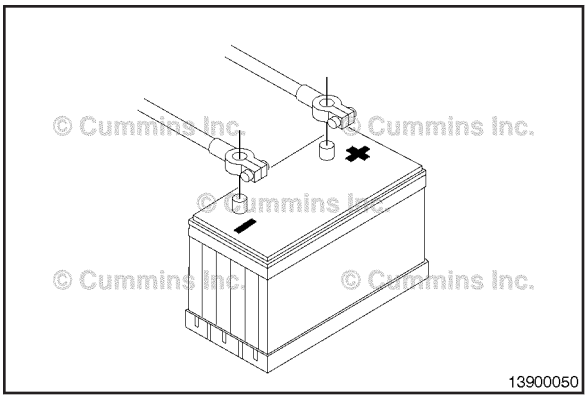
NOTE: Use a container that can hold at least 26 liters [27 US qt] of lubricating oil.

If equipped with a wet flywheel housing, drain the oil from the flywheel housing by removing the plug in the bottom of the flywheel housing.

Remove the transmission and all related components (if equipped). Refer to the OEM instructions.

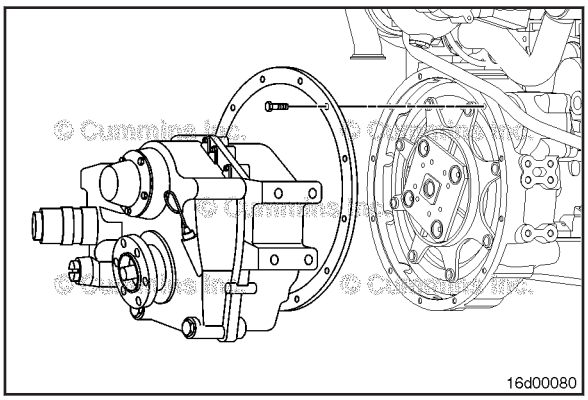
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Disconnect the batteries.



Remove the gear drive unit. Refer to the OEM instructions.

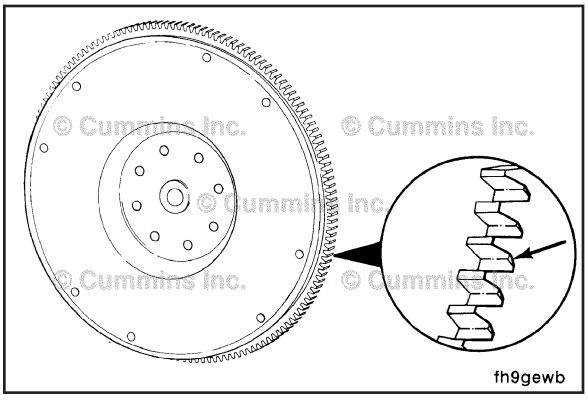
Remove the flexplate. Refer to Procedure 016-004

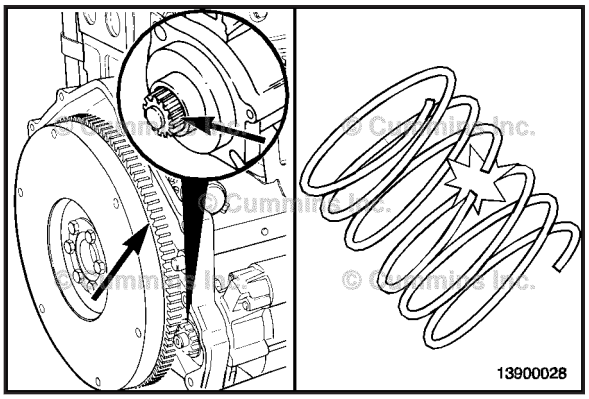


Initial Check

Inspect the flywheel ring gear teeth for damage.

If the flywheel ring gear is damaged make sure to inspect 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 flywheel 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 could be causes for mechanical issues:

1 Upon installation of the flywheel, make sure to check for proper starter motor spacing. Refer to Procedure Procedure 013-020

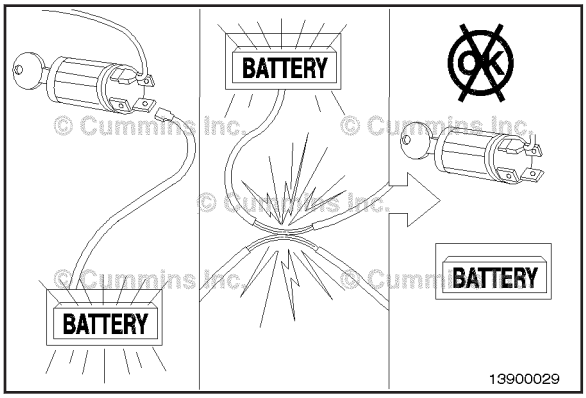
2 Interference between the ring gear land area and the starting motor pinion. The wrong starting motor may be installed. Refer to the original equipment manufacturer's specifications

3 There may be a defect with the starter motor pinion. Inspect the pinion for nicks and burrs. If replacement of the starting motor is necessary, Refer to Procedure Procedure 013-020

4 The ring gear may be improperly installed or damaged. Refer to Procedure Procedure 016-008

5 The flywheel face runout may be out of specification. See the Measure section of this procedure

6 Incorrect starting motor pinion to flywheel ring gear pitch/teeth match. Refer to the original equipment manufacturer's specifications.



Electrical

An electrical issue can typically be identified by seeing damage to the ring gear of the flywheel 360 degrees around the circumference of the ring gear (commonly called 360 degree milling). The following could be causes for electrical issues:

1 Operator is attempting to start engine while engine is already running. Check if a starter lockout feature is available through the OEM (activated with the INSITE™ Electronic Service Tool) or the starting motor manufacturer

2 Key switch causing intermittent starting motor engagement when the engine is running. Inspect the key switch. Refer to Procedure Procedure 013-030

3 Orientation of the starter relay so that 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 original equipment manufacturer's specifications

4 Intermittent starter motor wiring issues. Refer to the original equipment manufacturer's specifications.

Remove

NOTE: Use the barring tool, Part Number 3824591, to hold the flywheel to prevent rotation.

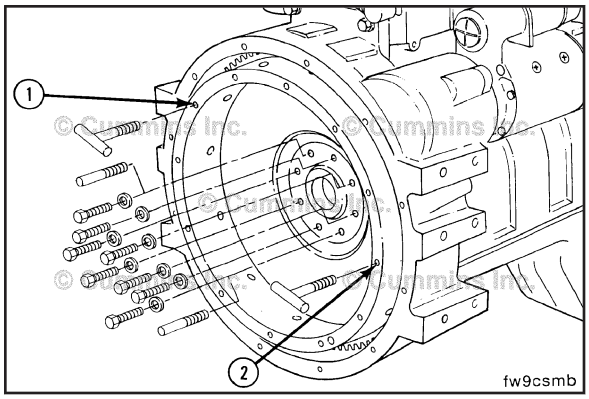
Remove two capscrews 180 degrees apart.

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.

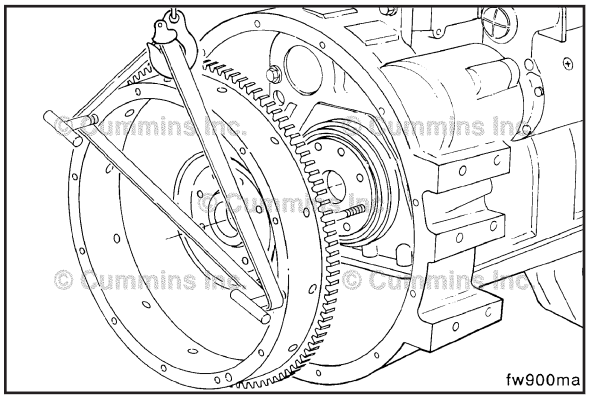
Determine the capscrew thread design and size, and install two T-handles in the flywheel at points (1 and 2).

Remove the remaining six flywheel mounting capscrews.



⚠WARNING⚠
This component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this component.

Remove the flywheel from the guide pins.



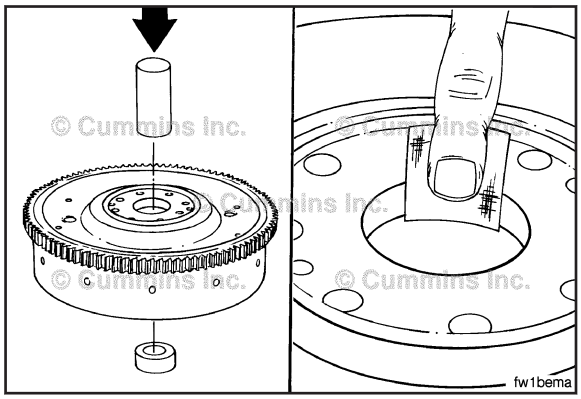
Disassemble

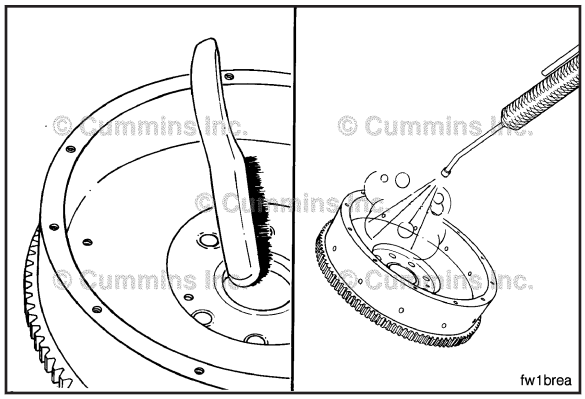
NOTE: Removal of the pilot bearing is only necessary if damaged or when installing a new or rebuilt clutch.

If equipped, remove the pilot bearing.

Use a mandrel and hammer to remove the pilot bearing.

Use an abrasive pad, Part Number 3823258, or equivalent, to clean the pilot bore





Clean and Inspect for Reuse

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

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

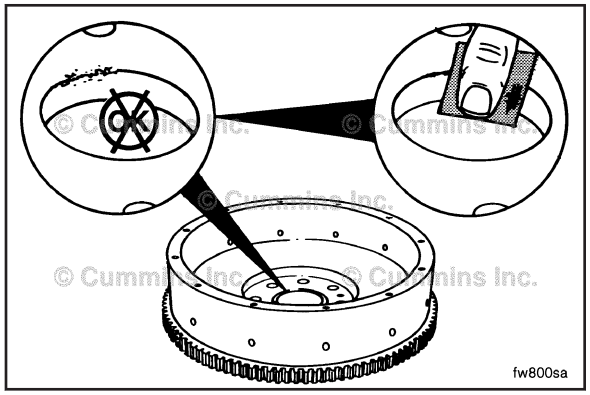
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Compressed air used for cleaning should not exceed 207 kPa[30 psi]. Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

If the pilot bearing was removed, use a wire brush to clean the crankshaft pilot bore.

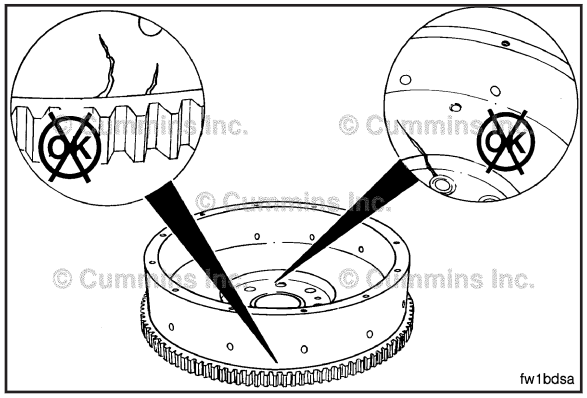
Use steam or solvent to clean the flywheel.

Dry with compressed air.



Inspect for nicks or burrs.

Use Scotch-Brite™ 7448 abrasive pad, or equivalent, to remove small nicks and burrs.

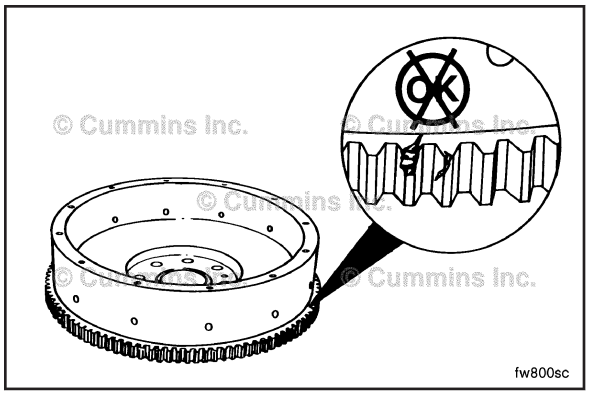


⚠WARNING⚠
Do not use a cracked or resurfaced flywheel. These can break, causing serious personal injury or property damage.

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.

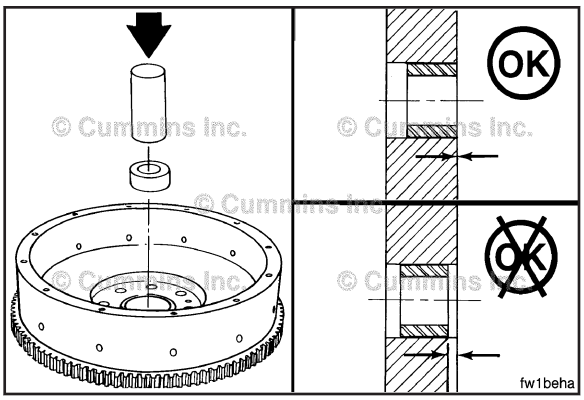
If the ring gear teeth are cracked or broken, the ring gear **must** be replaced. Refer to Procedure 016-008



Assemble

If removed, install a new pilot bearing.

Use a mandrel and hammer to install the pilot bearing. The pilot bearing **must** be installed evenly with the pilot bore surface.

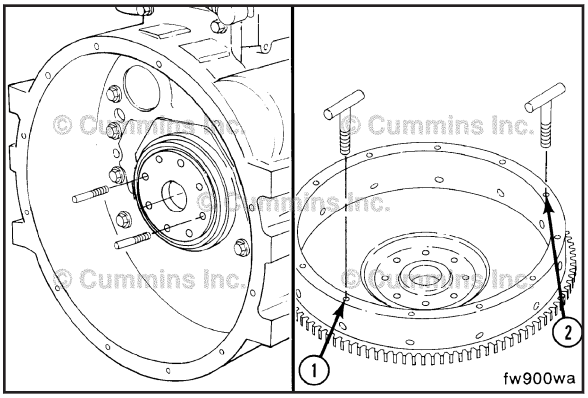


Install

Install two M12 x 1.25 x 90-mm guide pins into the crankshaft flange 180 degrees apart.

NOTE: If a clutch is used in the equipment, the threads in the clutch pressure plate mounting capscrew holes can be metric or standard. Be **sure** to use the correct capscrews.

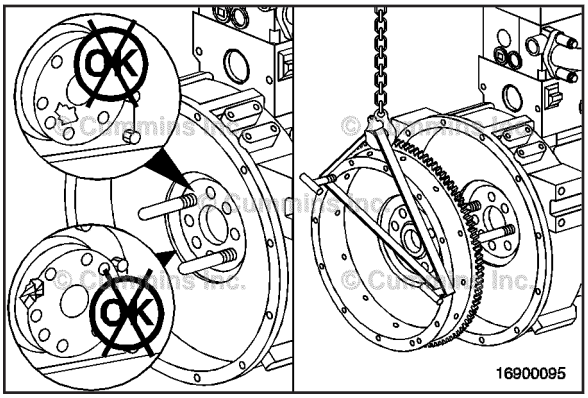
Determine the capscrew thread design and size, and install two T-handles into the flywheel (at points 1 and 2).

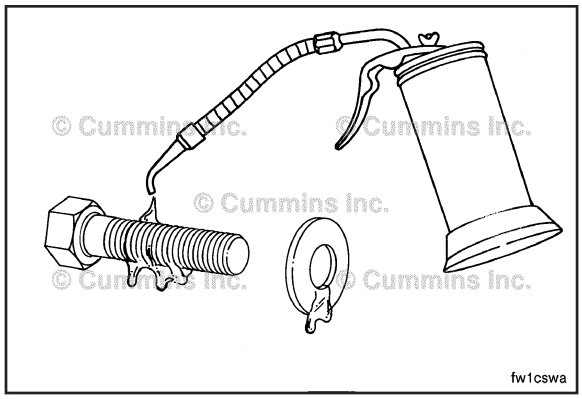


⚠WARNING⚠
The component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift the component.

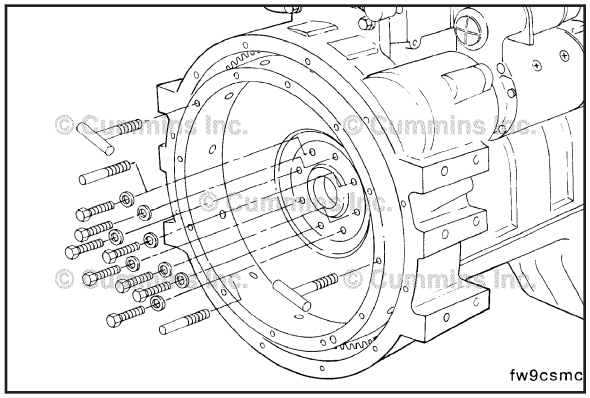
Inspect the rear face of crankshaft and flywheel mounting flange for cleanliness and raised nicks or burrs.

Install the flywheel on the guide pins.





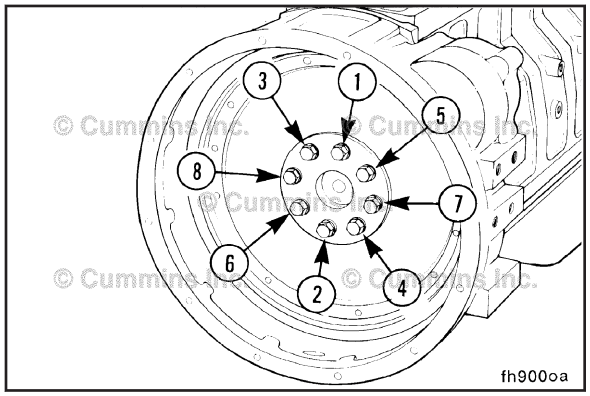
Lubricate the threads of the capscrews and the surface of the washers with clean lubricating engine oil.



Install the six capscrews.

Remove the T-handles and guide pins.

Install the remaining capscrews into the holes from which the guide pins were removed.

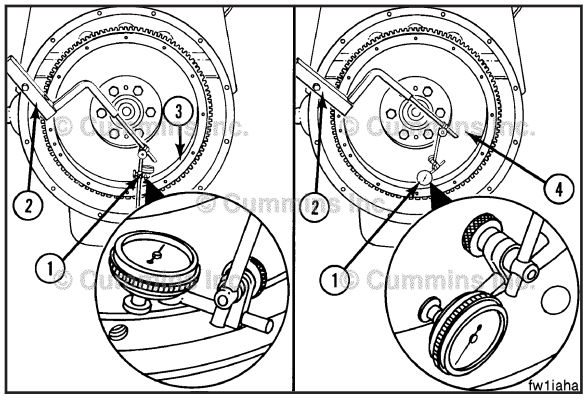


NOTE: Use the barring tool, Part Number 3824591, to hold the flywheel to prevent rotation.

Tighten the capscrews in a star pattern.

Torque Value:

Step 1	30 N•m	[22 ft-lb]
Step 2	Plus 60-degree turn	



Measure

Flywheel 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.

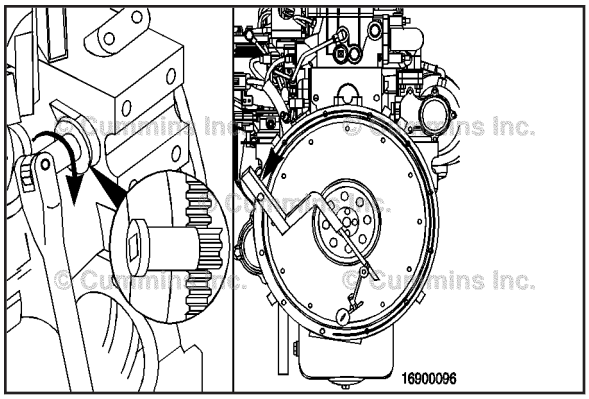
Install the attachment to the flywheel housing.

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, Part Number 3824591, to rotate the crankshaft one complete revolution.

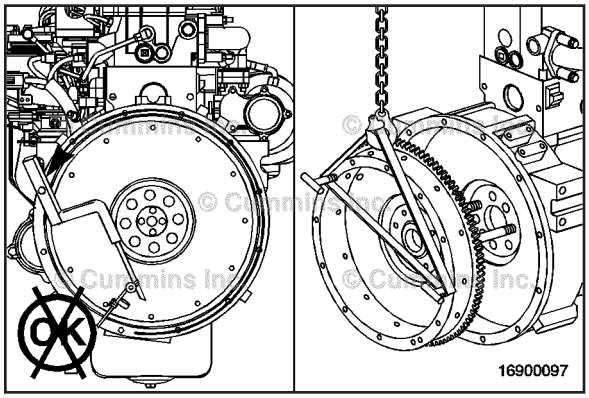
Flywheel Total Indicator Reading		
mm		in
0.127	MAX	0.0050



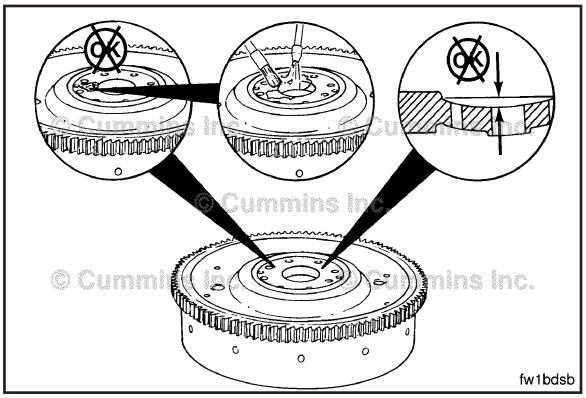
⚠WARNING⚠
The component weighs 23 kg [51 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift the component.

If the total indicator reading total indicator reading is greater than the specification, do the following:

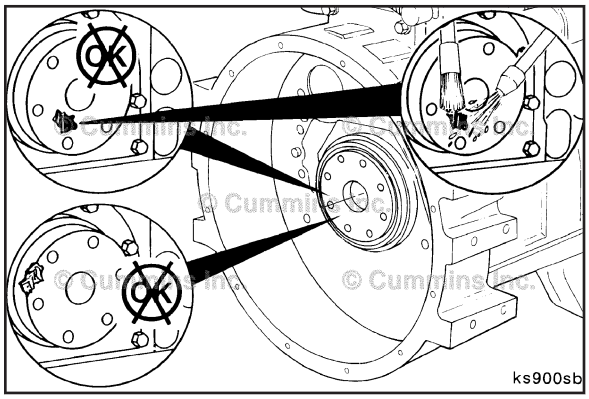
- Remove the flywheel.

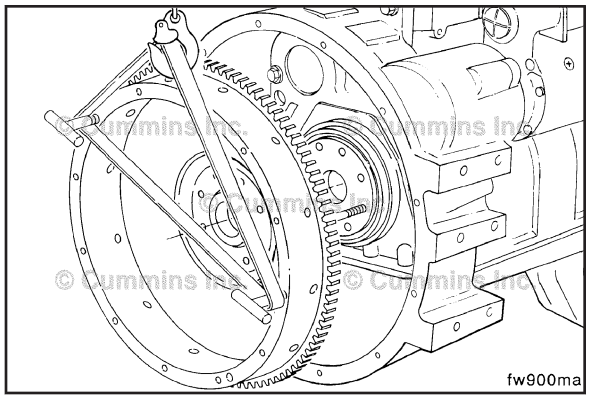


- Inspect the flywheel mounting surface for dirt or damage.



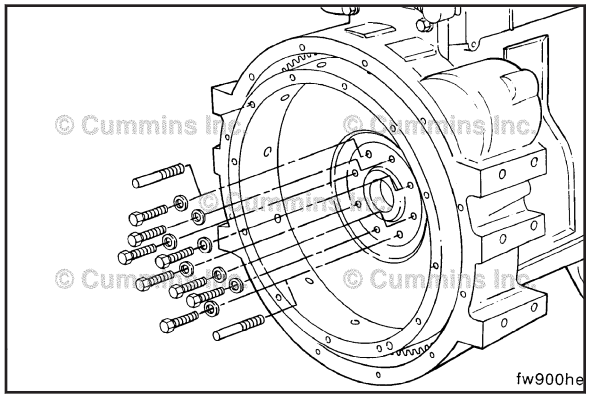
- Inspect the crankshaft for dirt or damage.





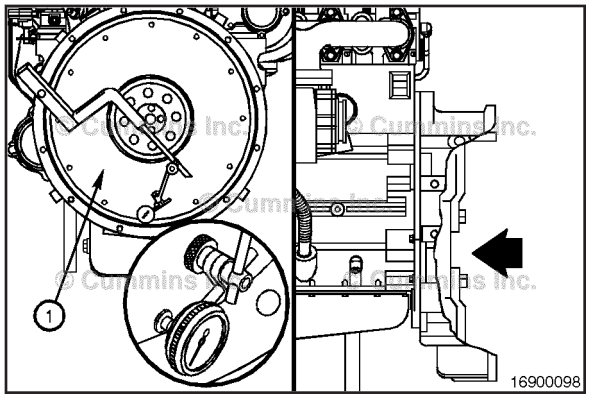
⚠WARNING⚠
The component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift the component.

- Install the flywheel.
- Inspect the bore runout again.



- Replace the flywheel if the runout does **not** meet specifications.

Flywheel Bore Runout		
mm		**in**
0.127	MAX	0.005

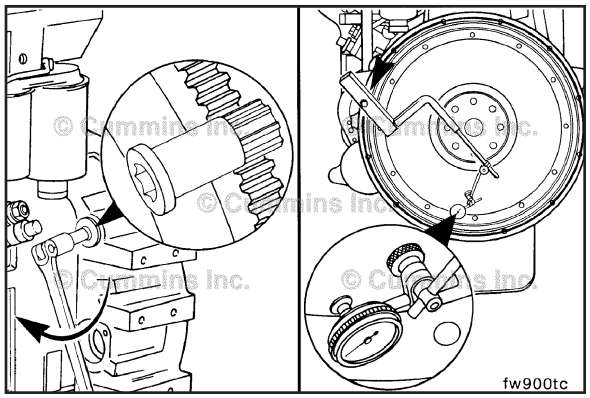


Flywheel Face Runout

Install the contact tip of the indicator against the flywheel face.

When locating the contact tip, see the Flywheel Face Runout Total Indicator Reading Table later in this procedure. Locate the contact tip so that it corresponds with a radius listed in the table, but is still as close to the outside diameter of the flywheel as possible, to inspect the flywheel face (1) runout.

Push the flywheel forward to remove the crankshaft end clearance. Adjust the dial on the indicator until the needle points to zero.



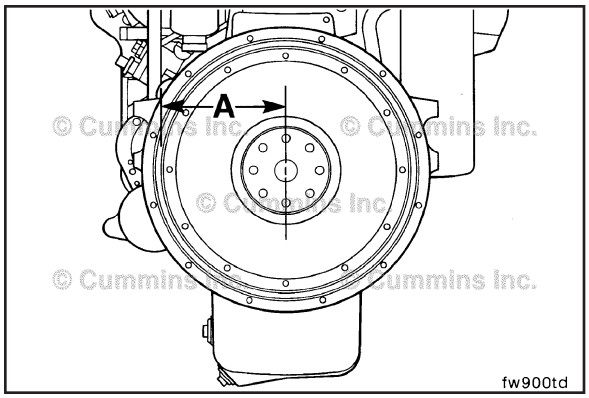
Use the barring tool, Part Number 3824591, to rotate the crankshaft one complete revolution. Measure and record the flywheel runout at four equal points on the flywheel.

The flywheel **must** be pushed toward the front of the engine to remove the crankshaft end clearance each time a point is measured.

Determine the total indicator reading (TIR).

TIR is determined by calculating the difference between the highest and lowest measurement from the four locations measured.

Measure the distance from the center of the flywheel to the contact tip of the indicator (A). Use this measurement to determine which specification to use from the table below.

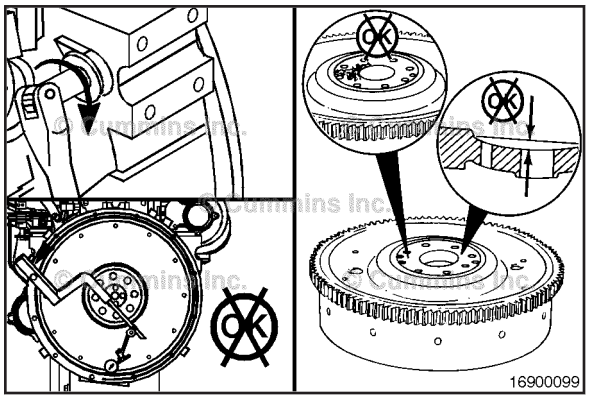


The total indicator reading **must not** exceed the following specifications:

Flywheel Radius (A)		Maximum Total Indicator Reading of Flywheel Face	
mm	**in**	**mm**	**in**
101.6	4	0.140	0.004
127	5	0.13	0.005
152.4	6	0.156	0.006
177.8	7	0.182	0.007
203.2	8	0.208	0.008
228.6	9	0.234	0.009
254	10	0.26	0.01

If the flywheel face runout is **not** within specifications, remove the flywheel. First check for nicks, burrs, or foreign material between the flywheel mounting surface and the crankshaft flange.

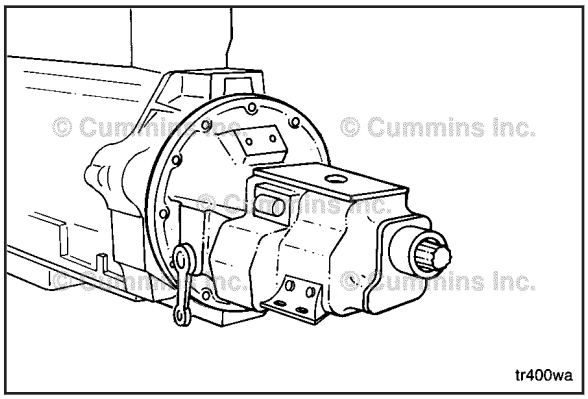
Replace the flywheel if the runout is **not** within specification.

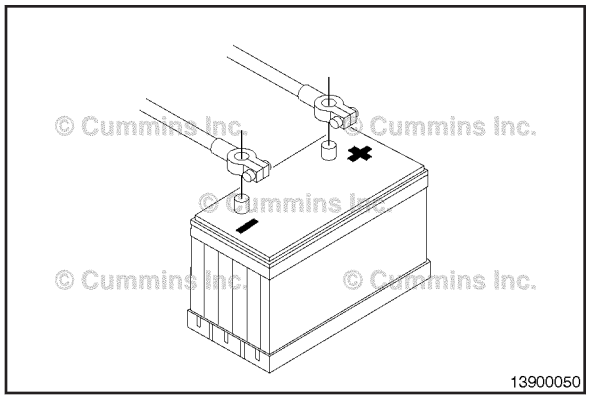


Finishing Steps

Install the transmission and all related components (if equipped). Refer to the OEM instructions.

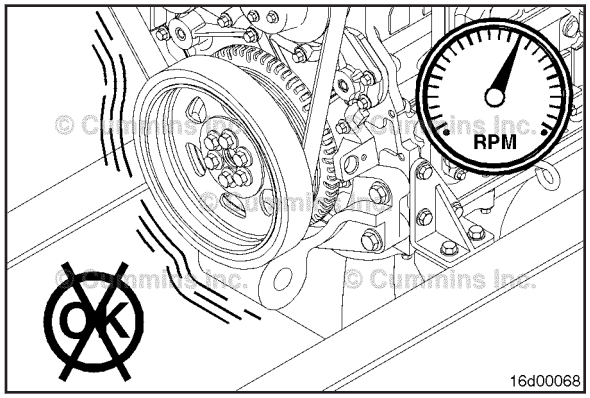
If equipped with a wet flywheel housing, fill the flywheel housing with oil. Refer to the OEM Instructions.



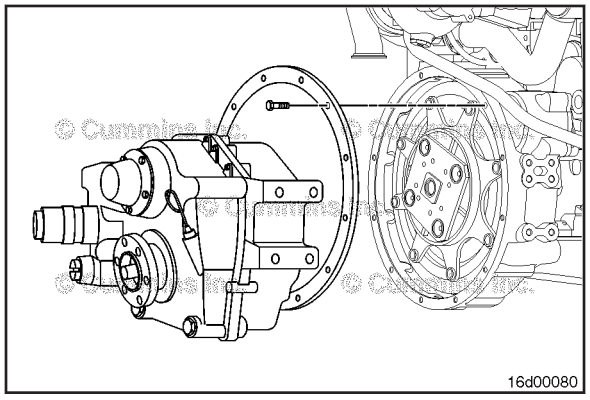


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Connect the batteries.

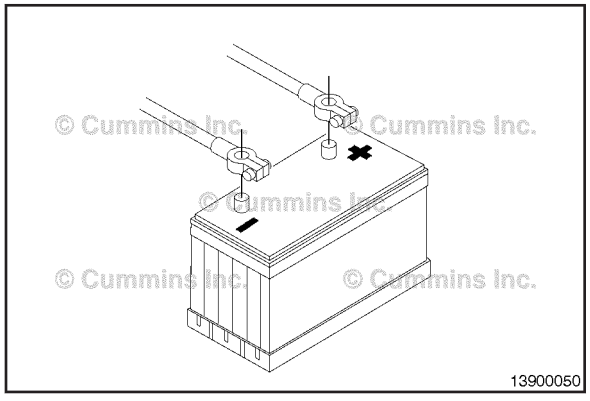


Operate the engine and check for noise or vibration.



Install the flexplate. Refer to Procedure 016-004

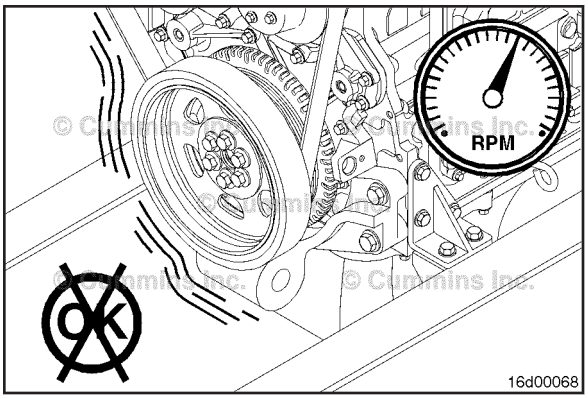
Install the drive unit. Refer to the OEM instructions.



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

Operate the engine and check for noise or vibration.

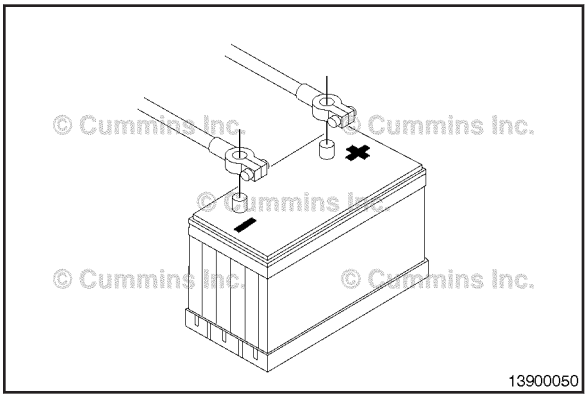


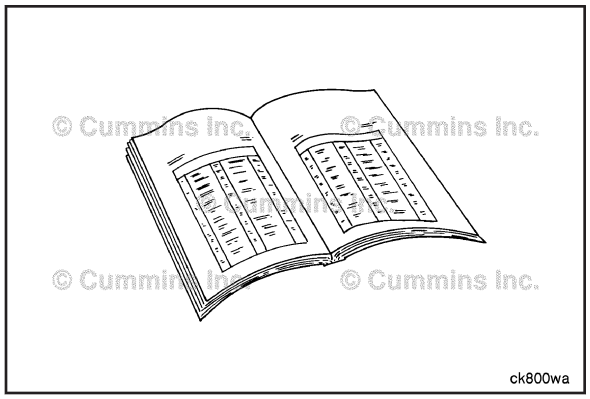
Flywheel Housing (016-006)

Preparatory Steps

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

Disconnect the batteries.





⚠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.

⚠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.

NOTE: Use a container that can hold at least 16 liters [27 US qt] of lubricating oil.

If equipped with a wet flywheel housing, drain the oil from the flywheel housing by removing the plug in the bottom of the flywheel housing.

Remove the starting motor. Refer to Procedure Procedure 013-020

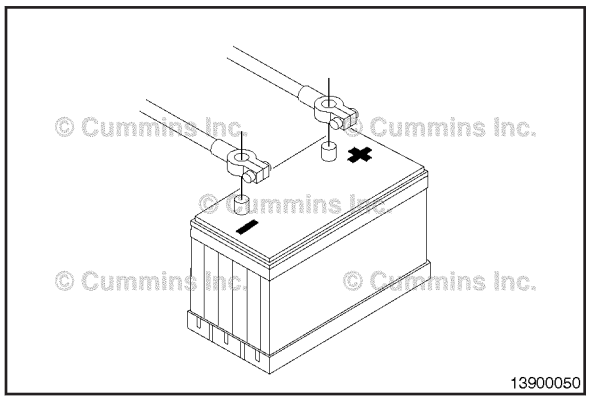
Remove the transmission, clutch, and all related components (if equipped). Refer to the OEM service manual.

Remove the flywheel/flexplate assembly. Refer to Procedure Procedure 016-005 or Refer to Procedure Procedure 016-004

For rear gear train engines, remove the rear crankshaft seal. Refer to Procedure Procedure 001-024

For some engines, it may be necessary to remove the crankcase breather tube. Refer to Procedure Procedure 003-018

Remove any OEM attached components (mufflers, shift mechanisms, air filters, etc.) to the flywheel housing. Refer to the OEM instructions.



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

⚠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.

⚠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.

Drain the coolant. Refer to Procedure Procedure 008-018

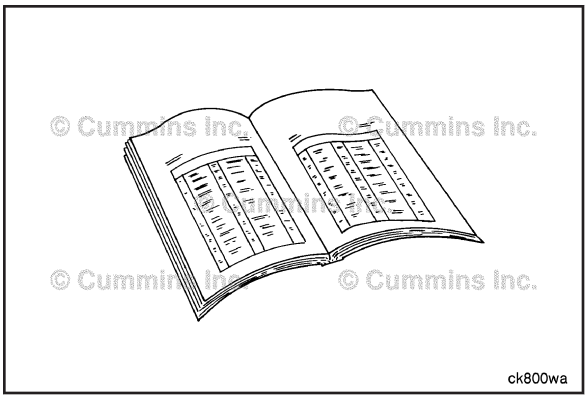
Remove the starter motor. Refer to Procedure Procedure 013-020

Remove the turbocharger. Refer to Procedure Procedure 010-033

Remove or loosen the aftercooler mounting capscrews and remove the aftercooler air inlet tube. Refer to Procedure Procedure 010-005

Remove the gear drive unit. Refer to the OEM instructions.

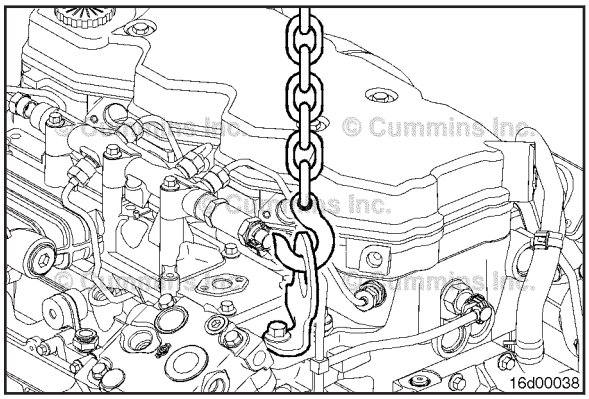
Remove the flexplate/flywheel. Refer to Procedure Procedure 016-005 or Refer to Procedure Procedure 016-004



Remove

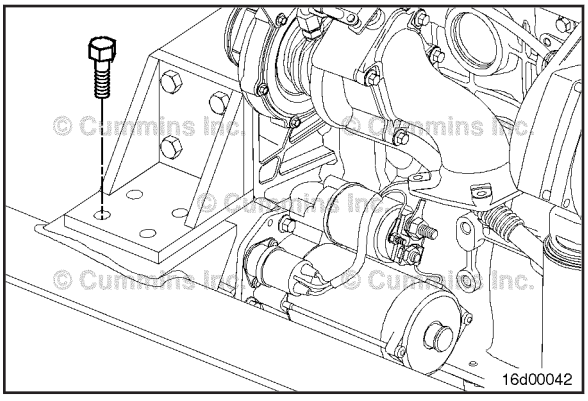
⚠WARNING⚠
The engine lifting equipment must be designed to lift the engine and transmission as an assembly without causing personal injury.

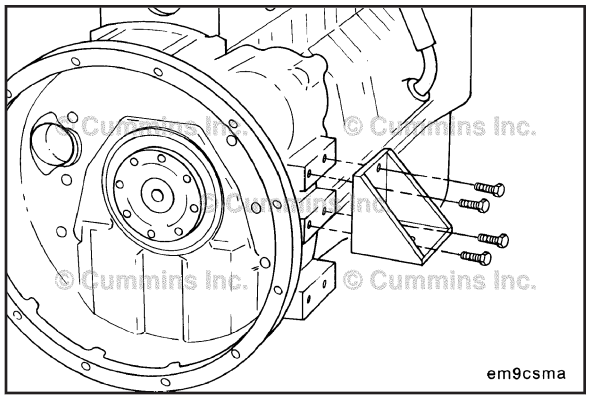
Use a hoist or lifting fixture to support the rear of the engine.



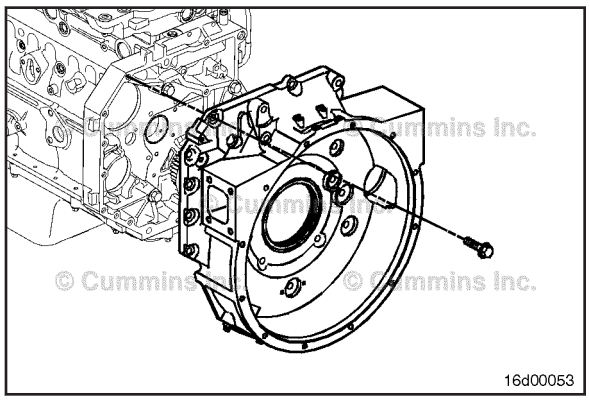
NOTE: When removing the rear engine mount fasteners, keep track of the location of any shims or spacers used.

Remove the engine mount fasteners.





Remove the rear support capscrews and bracket.



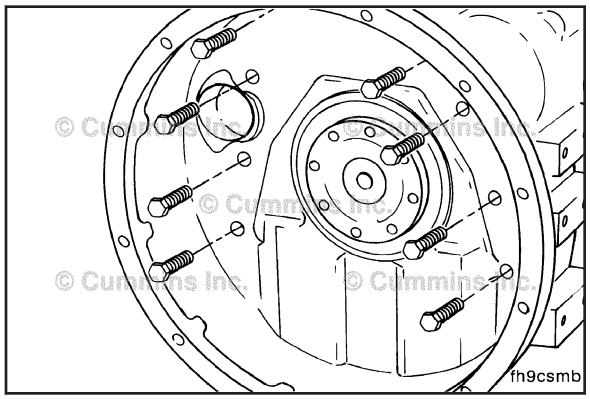
⚠WARNING⚠
This component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this component.

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

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

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

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



⚠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.

While supporting the flywheel housing, remove the mounting capscrews.

While supporting the flywheel housing, use a rubber hammer to loosen the flywheel housing.

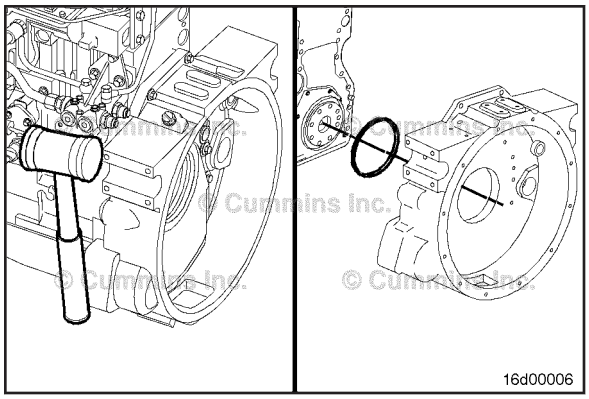
Remove the flywheel housing.

NOTE: Some engines may have an additional rectangular seal between:

1 The flywheel housing and the rear seal carrier

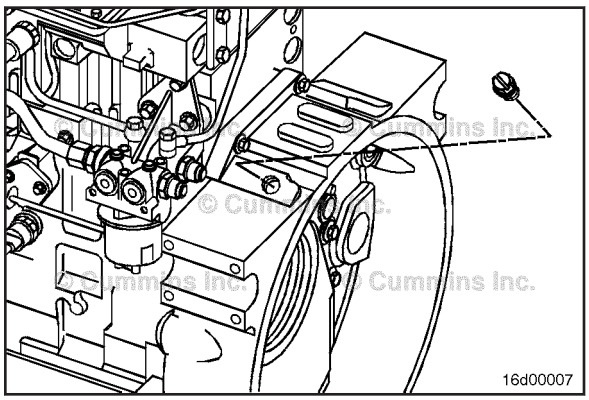
2 The flywheel housing and camshaft journal bore of the block.

NOTE: When removing the flywheel housing, note the location of any locating dowel rings.

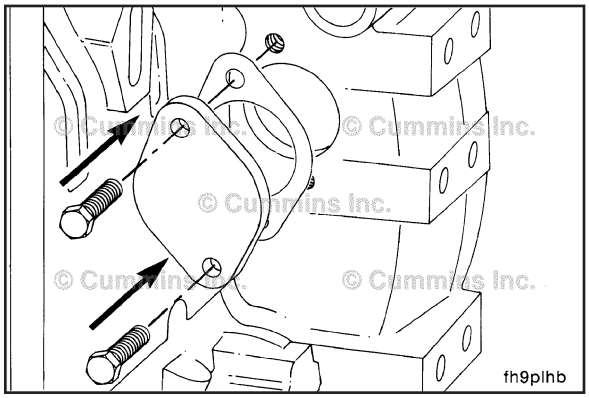


Disassemble

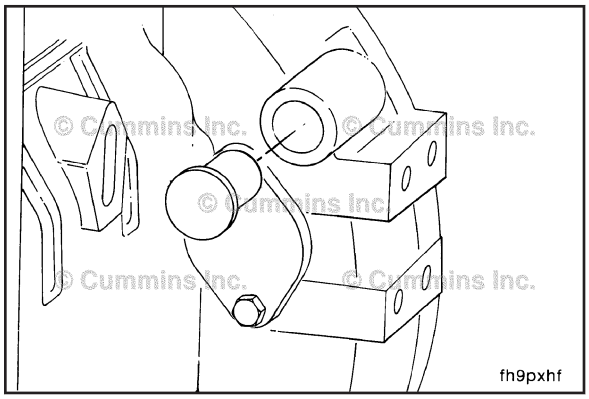
Remove and note the location of any threaded plugs in the flywheel housing.

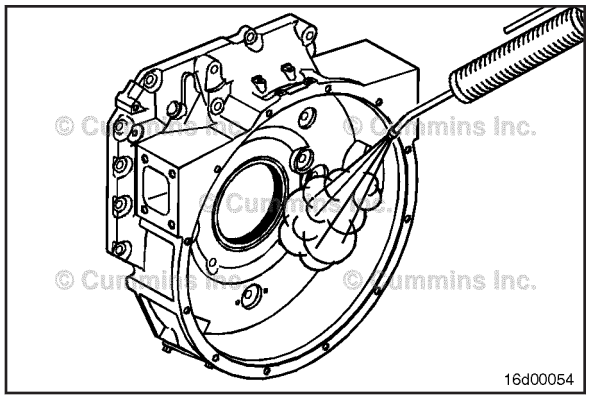


Remove the access plate and, if equipped, the gasket.



Remove the plug from the barring gear hole.





Clean and Inspect for Reuse

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

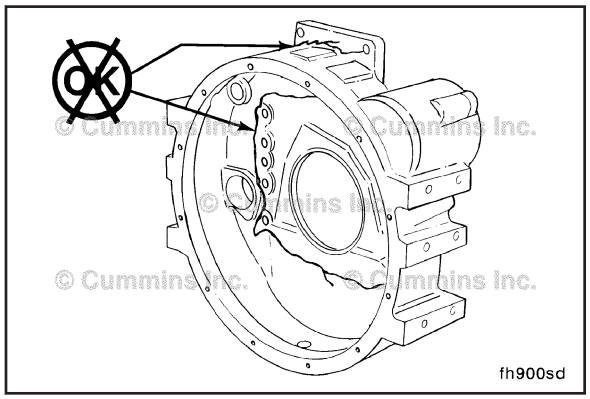
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Compressed air used for cleaning should not exceed 207 kPa[30 psi]. Use only with protective clothing, as well as goggles/shield, and gloves to reduce the possibility of personal injury.

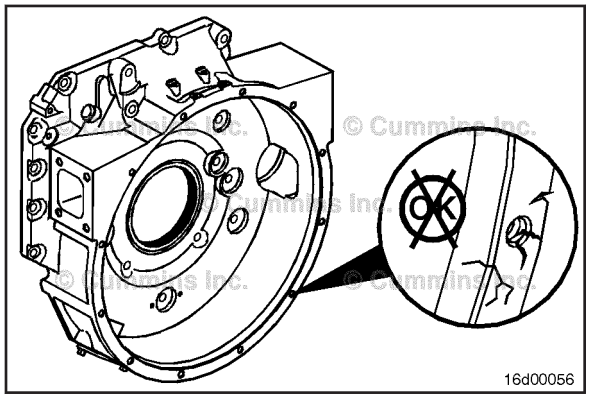
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use steam or solvent to clean the flywheel housing.

Dry with compressed air.



Inspect the flywheel housing for cracks, especially in the area of the flywheel housing that mounts to the cylinder block or rear gear housing.



Inspect the flywheel housing transmission/drive unit mounting surface for cracks.

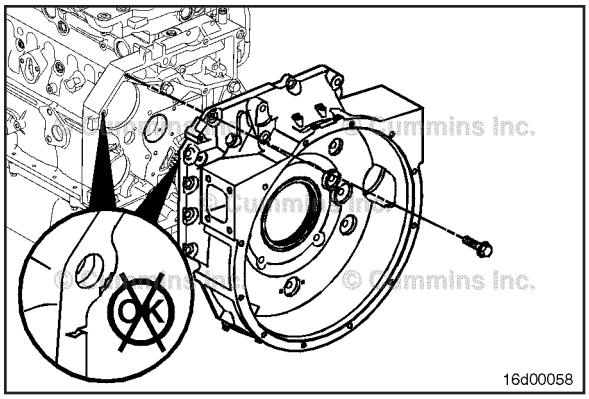
Also inspect for damaged threads commonly caused by cross-threaded capscrews or installing an incorrect capscrew.

NOTE: Helicoils are available to repair damaged threads.

Inspect the rear face of the gear housing and flywheel housing mounting surface for cleanliness and raised nicks or burrs.

Use fine crocus cloth to remove small nicks and burrs.

Thoroughly clean the flywheel housing and gear housing mating surfaces. These surfaces **must** be clean of oil and debris.

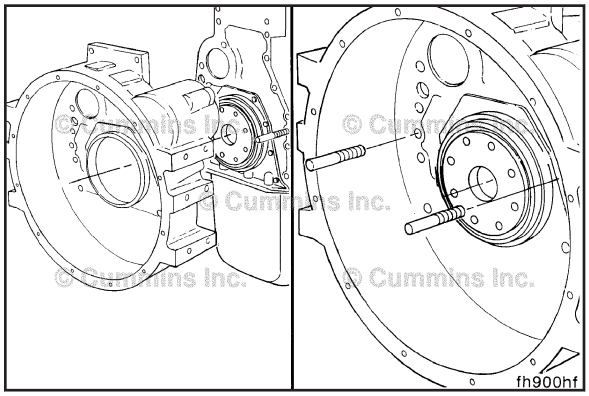


Measure

NOTE: Follow this step **only** if the flywheel housing (or rear gear housing for rear gear train engines) is being replaced or if troubleshooting a vibration/alignment issue. It is **not** necessary to measure bore alignment or face alignment when installing the original flywheel housing unless the dowel rings were removed during a previous repair.

Install the flywheel housing following the Install Step of this procedure, but do **not** torque the capscrews. Only tighten the capscrews enough to hold the flywheel wheel in place.

Service Tip: For rear gear train engines, when installing a new flywheel housing to check flywheel housing bore alignment and face alignment, do **not** apply sealant to the flywheel housing prior to installing for measurement.

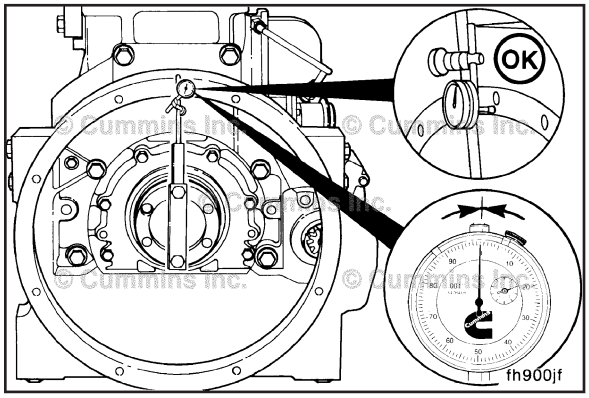


⚠CAUTION⚠
When barring the engine using service tool, Part Number 3824591, be careful to not apply excessive side loading to the flywheel housing. This may cause the flywheel housing to move and cause inaccurate measurement readings.

⚠CAUTION⚠
The dial indicator tip must not enter the capscrew holes, or the gauge will be damaged.

Face alignment is determined by calculating the total indicator reading (TIR).

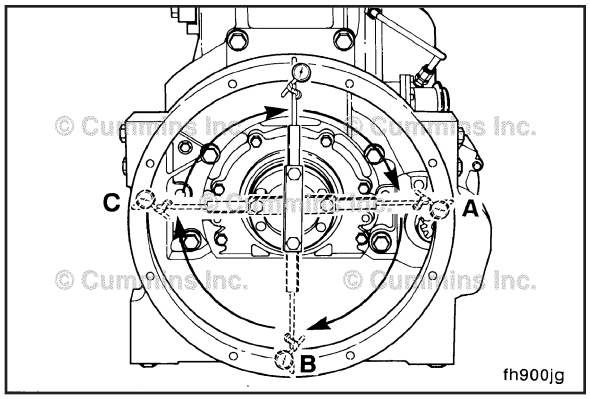
Attach the dial indicator gauge, Part Number 3376050, to the crankshaft. Use mounting tool, Part Number ST1325, to attach the dial indicator to the crankshaft as illustrated.



NOTE: 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 **not** be accurate.

Position the indicator at the 12-o'clock position, and zero the gauge.

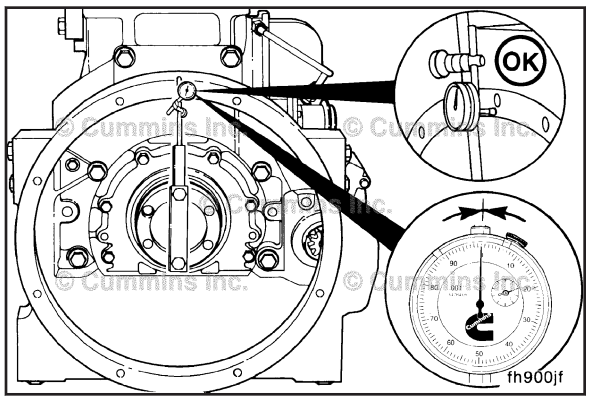
NOTE: The crankshaft **must** be pushed toward the front of the engine to remove the crankshaft end clearance each time a position is measured.



Using the barring tool, Part Number 3824591, slowly rotate the crankshaft.

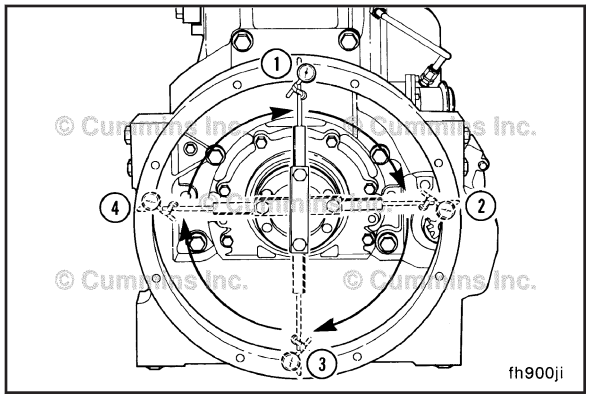
Record the readings at the 3-o'clock (A), 6-o'clock (B) , and 9-o'clock positions (C).

The values for A, B, and C could be positive or negative.



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 and the procedure will have to be redone.



Determine the total indicator reading (TIR).

TIR is determined by calculating the difference between the highest and lowest measurement from the four locations measured.

As the example below illustrates, the TIR would be:

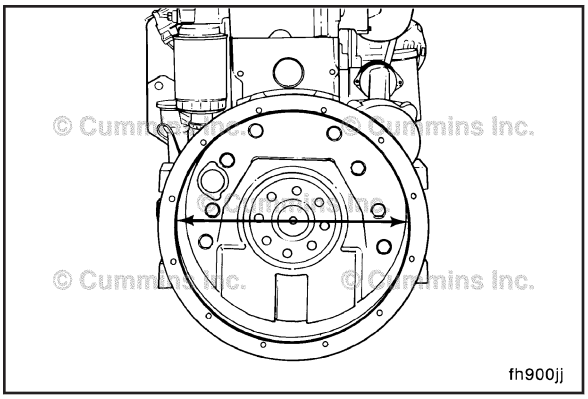
+ 0.08 mm — (-0.05 mm) = 0.13 mm

[+.003 in — (-0.002 in) = 0.005 in]

Example:		
12 o'clock	0.00 mm	[0.000 in]
3 o'clock	+0.08 mm	[+0.003 in]
6 o'clock	- 0.05 mm	[- 0.002 in]
9 o'clock	+0.08 mm	[+0.003 in]
Equals TIR	0.13 mm	[0.005 in]

The maximum allowable total indicator reading (TIR) is determined by the diameter of the housing bore. If out of specifications, replace the housing.

NOTE: For rear gear train engines, the rear gear housing may also be the cause of the TIR being out of specification.

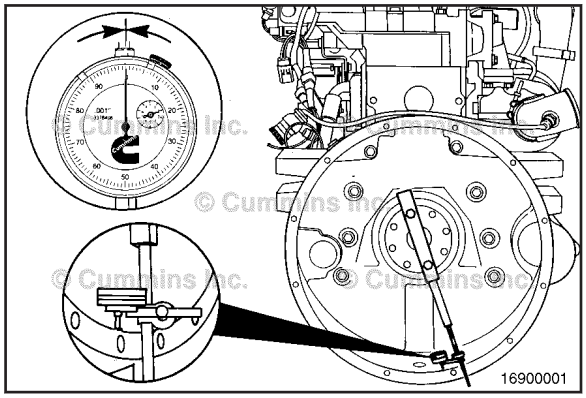


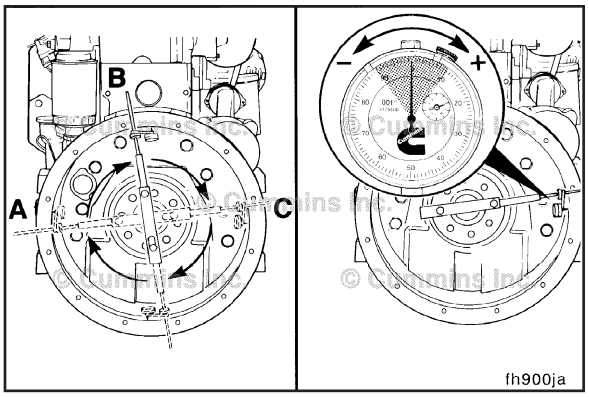
Flywheel Housing Bore and Face Runout				
SAE	Bore Diameter	Total Indicator Reading Maximum		
Number	mm	in	mm	in
00	784.15 to 784.65	30.990 to 31.010	0.25	0.01
0	657.45 to 647.95	25.490 to 25.510	0.28	0.011
1/2	584.00 to 584.40	22.992 to 23.008	0.30	0.012
1	510.98 to 511.38	20.117 to 20.133	0.36	0.014
2	447.55 to 447.81	17.620 to 17.630	0.41	0.016
3	409.45 to 409.71	16.120 to 16.130	0.48	0.019

Attach the dial indicator gauge, Part Number 3376050, to the crankshaft. Use mounting tool Part Number ST1325 to attach the dial indicator to the crankshaft as illustrated.

NOTE: 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 **not** be accurate.

Position the indicator in the 6-o'clock position, and zero the gauge.

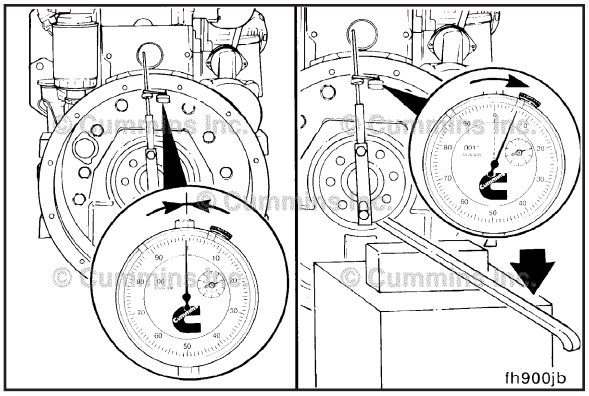




Slowly rotate the crankshaft. Record the readings obtained at the 9-o'clock, 12-o'clock, and 3-o'clock positions as A, B, and C in the concentricity work sheet.

Recheck zero at the 6-o'clock position. If it does **not**, the readings will be incorrect and the procedure will have to be redone.

The values for A, B, and C could 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 and result in engine damage.

Rotate the crankshaft until the dial indicator is at the 12-o'clock position and zero the gauge.

Using a pry bar, raise the rear of the crankshaft to its upper limit. Record the value as D on the concentricity work sheet. This is the vertical bearing clearance adjustment, which will **always** be positive.

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

Create a concentricity work sheet as illustrated to determine the values for the "total vertical" and "total horizontal" values.

NOTE: The values listed in the concentricity work sheet illustrated are for example only and are listed in inches. The actual numbers measured may differ.

Input the values recorded for A, B, C and D into the concentricity work sheet.

The total horizontal is the 9-o'clock reading, A, minus the 3-o'clock reading, C.

The total vertical is the 12-o'clock reading, B, plus the bearing clearance, D.

Example:

- Six o'clock = reference = 0
- Nine o'clock = (a) = 0.004
- Twelve o'clock = (b) = 0.003
- Three 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.

NOTE: Use the corresponding chart for the SAE 1, 2 or 3 flywheel housings being measured.

Using the illustration, mark the total horizontal value on the horizontal side of the chart and the total vertical on the vertical side of the chart.

Using a straightedge, 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.

Using the total horizontal and total vertical values from the previous example, the intersection point falls within the shaded area. Therefore, the flywheel housing concentricity is within specification.

NOTE: Make sure to use the correct total indicator reading (TIR) specifications for the flywheel housing being measured when comparing measurements.

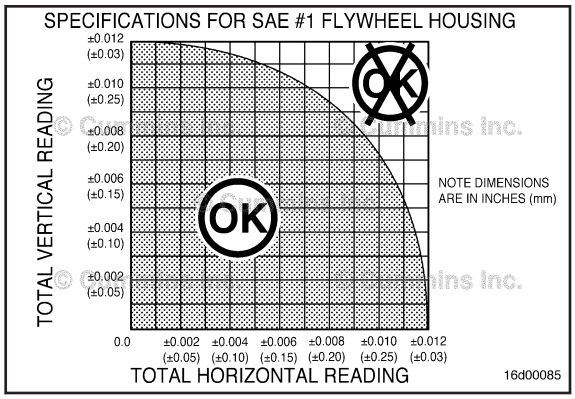


Chart for an SAE 2 flywheel housing.

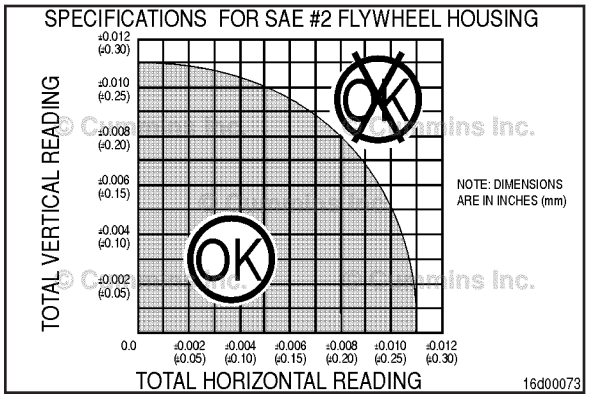
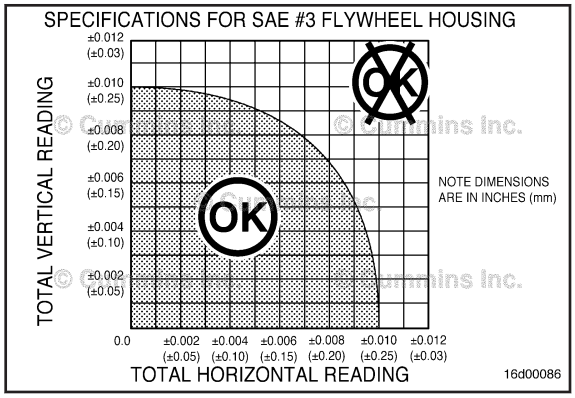
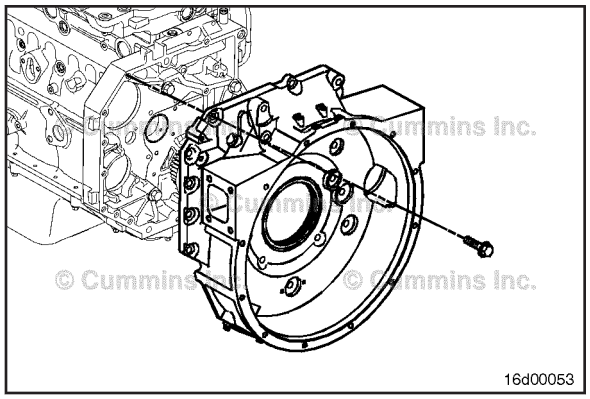


Chart for an SAE 3 flywheel housing.





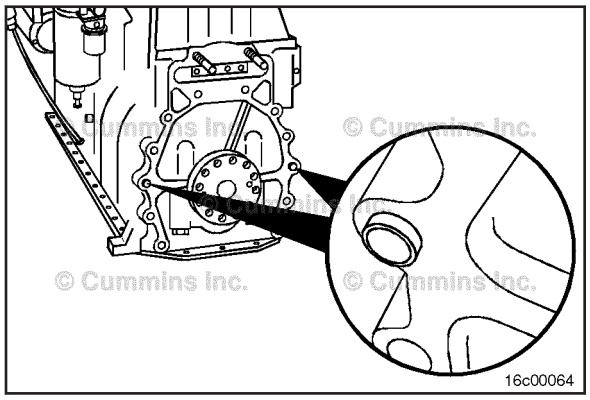
⚠CAUTION⚠

Do not remove the dowel rings located in the rear gear housing in an attempt to relocate the flywheel housing. The dowel rings are required to locate the rear gear housing to the cylinder block for proper gear alignment. Improper gear alignment will result in engine damage.

If the bore alignment is out of specification:

1 Determine if the flywheel housing, rear gear housing or cylinder block has recently been replaced. If any of these components have been replaced, remove and inspect/replace the component.

2 If the flywheel housing, rear gear housing or cylinder block have **not** been recently replaced. Remove the flywheel housing. Inspect the rear gear housing and flywheel housing mounting surfaces. If no damage is found, remove the rear gear housing and inspect the cylinder block and rear gear housing mounting surfaces.

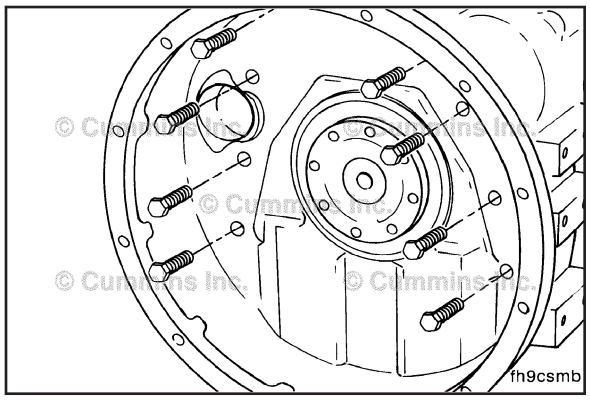


If the bore alignment is out of specification:

The ring dowels **must** be removed and the flywheel housing repositioned.

Use the dowel pin extractor service tool, Part Number 3163720, to remove the dowel pins from the block.

NOTE: The ring dowels are **not** required to maintain concentricity of the housing; the clamping force of the capscrews holds the housing in place.



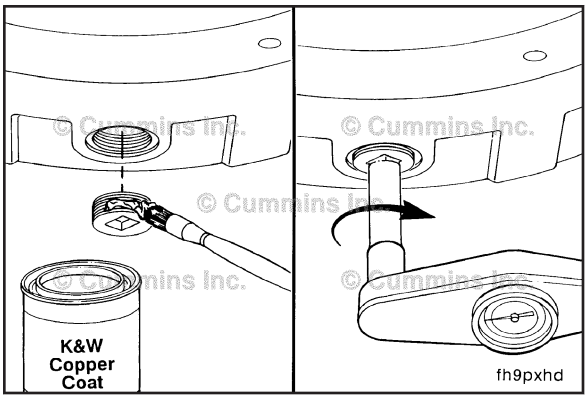
After the ring dowels are discarded, install the flywheel housing on the engine following the Install Step of this procedure, but do **not** torque the capscrews. Tighten the capscrews enough to hold the flywheel housing in place, but loose enough to allow small movement when struck lightly with a rubber mallet.

Recheck the bore alignment. When bore alignment is within specification, tighten the capscrews to the specified torque value outlined in the Install Step of this procedure.

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 Procedure 017-007 for pipe plug torque values for different plug sizes.

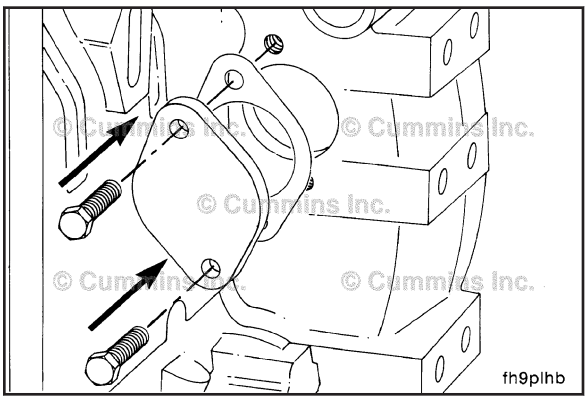


Install the access plate and new gasket.

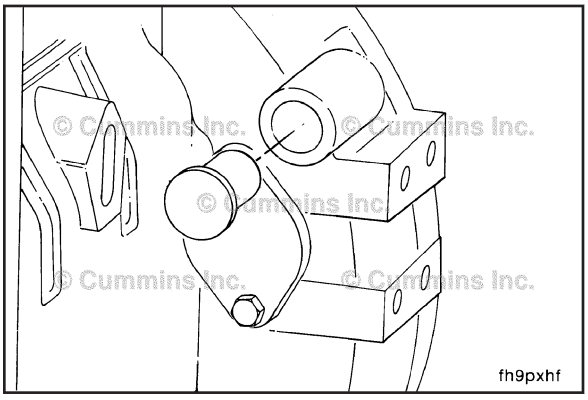
Install the capscrews and tighten.

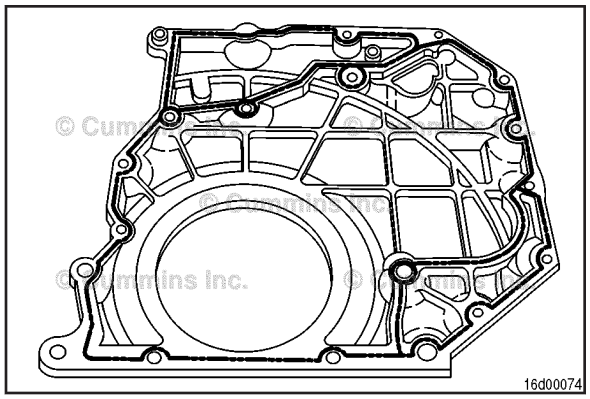
Torque Value: 24 N•m [18 ft-lb]

NOTE: If a gasket was **not** previously installed, apply sealant, Part Number 3164067, to the perimeter of the access plate.



With a new o-ring, install the barring gear hole plug.





Install

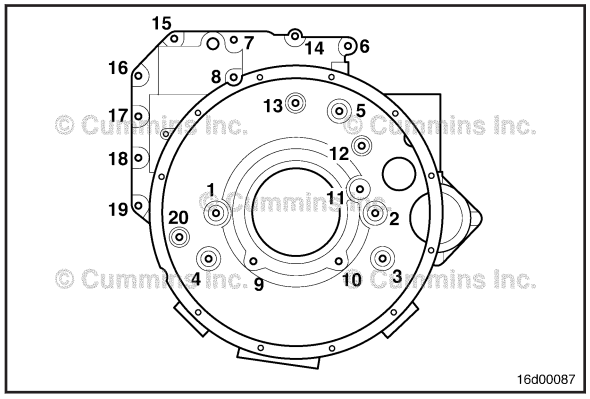
NOTE: Before installing the flywheel housing, make sure any locating dowel rings are in the same position as when the flywheel housing was removed.

NOTE: The sealant called for in the following step may appear different than what was originally used to build the engine.

Apply a 1.5 to 2.0 mm [0.06 to 0.08 in] wide bead of sealant, Part Number 3164070, to the back side of the flywheel housing in the path illustrated.

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

Install the flywheel housing and capscrews.



Tighten the flywheel housing capscrews in the sequence shown.

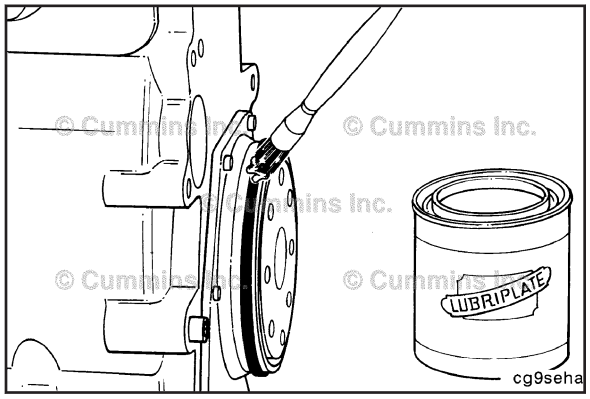
NOTE: Some engines are equipped with one additional capscrew **not** shown in the illustration. Tighten this capscrew last in the sequence.

Torque Value:
M10

Step 1	49 N•m	[36 ft-lb]

Torque Value:
M12

Step 1	85 N•m	[63 ft-lb]

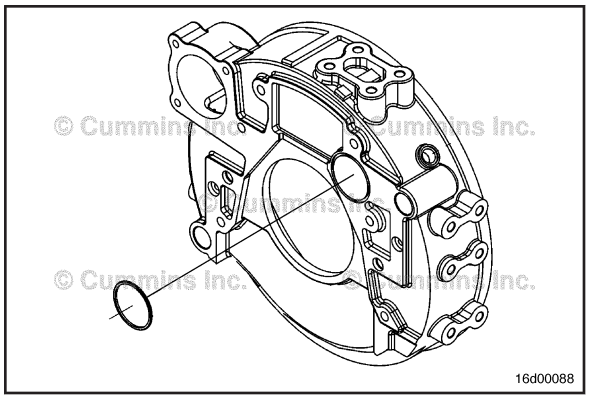


NOTE: Before installing the flywheel housing, make sure any locating dowel rings are in the same position as when the flywheel housing was removed.

If previously equipped, install a new rectangular seal on the rear seal carrier and apply assembly lube, Part Number 3163087.

If previously equipped, install a new rectangular seal for the camshaft journal bore to the back side of the flywheel housing.

Apply a small amount of sealant, Part Number 3164067, to hold the seal in place until the flywheel housing is installed.

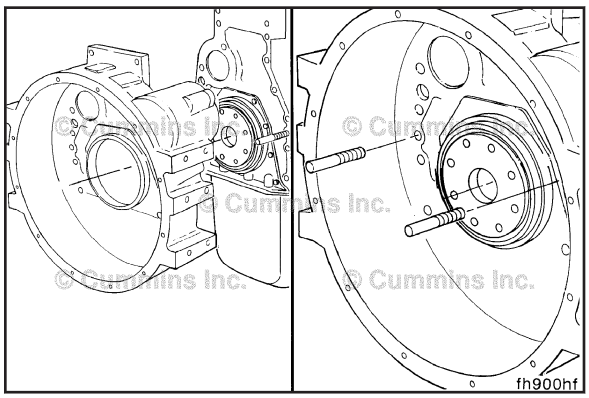


Inspect the rear face of the cylinder block and flywheel housing mounting surface for cleanliness and raised nicks or burrs.

Install two guide pins. Part Number 3163934.

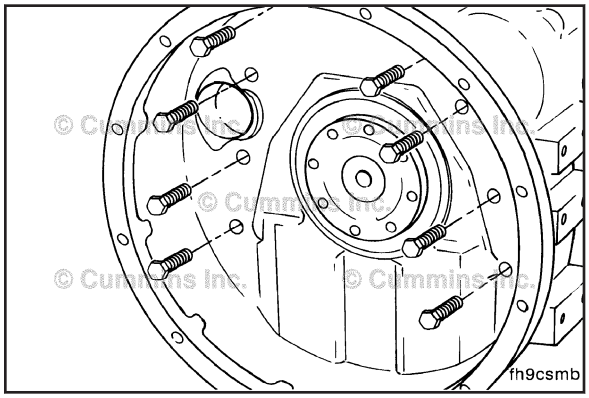
Install the flywheel housing over the guide pins, making sure the flywheel housing is located on the dowel rings.

NOTE: Be sure the sealing ring is **not** damaged during installation.



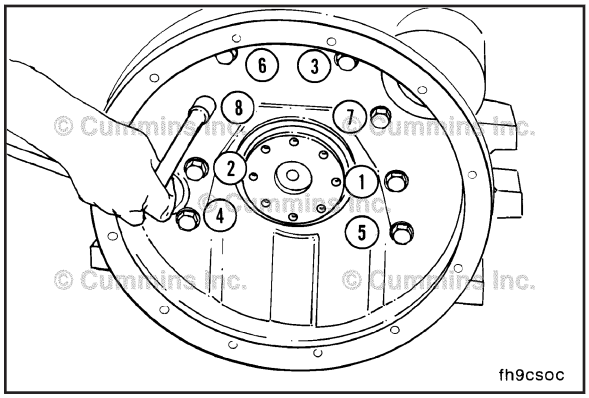
Remove the guide pins.

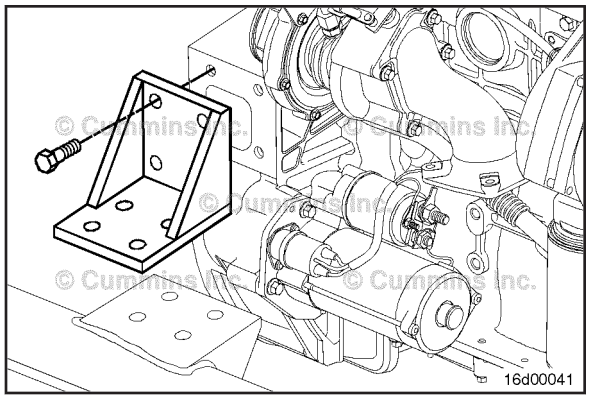
Install the mounting capscrews.



Tighten the flywheel housing capscrews in the sequence shown.

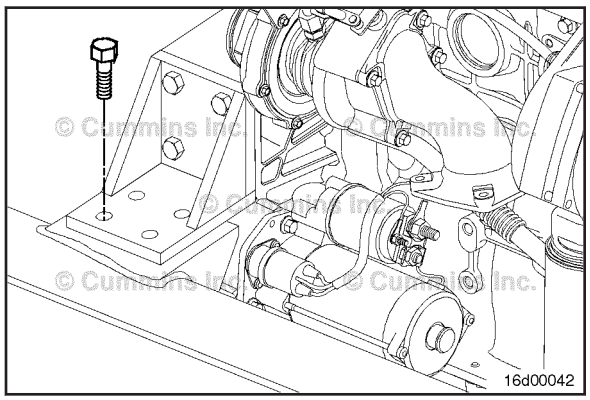
Torque Value: 77 N•m [57 ft-lb]





Install the rear engine support bracket and mounting capscrews.

Torque Value: 77 N•m [57 ft-lb]



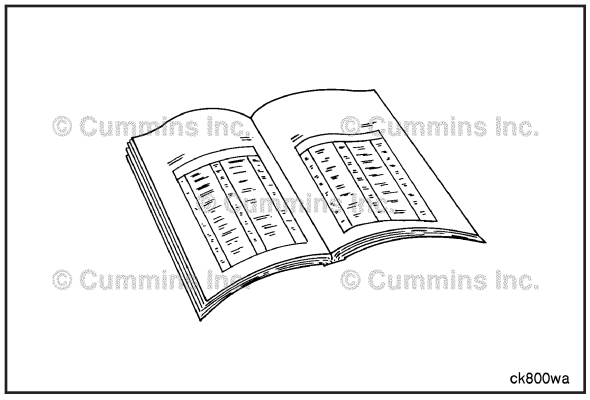
NOTE: Make sure to install any shims or spacers in the same location as removed.

Lower the rear of the engine.

Install the rear engine mount fasteners.

Tighten to the OEM specification.

Remove the lifting fixture or hoist from the rear of the engine.



Finishing Steps

If previously removed, install the crankcase breather tube. Refer to Procedure Procedure 003-018

For rear gear train engines, install the rear crankshaft seal. Refer to Procedure Procedure 001-024

Install the flywheel/flexplate assembly. Refer to Procedure Procedures 016-005 and Refer to Procedure Procedure 016-004

Install the starting motor. Refer to Procedure Procedure 013-020

Install the transmission and related components (if equipped). Refer to the OEM service manual.

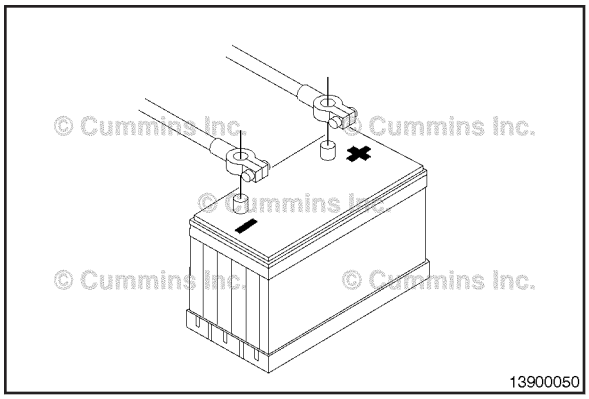
If equipped with a wet flywheel housing, fill the flywheel housing with oil. Refer to the OEM instructions.

If previously removed, attach any OEM components (mufflers, shift mechanisms, air filters, etc.) to the flywheel housing. Refer to the OEM instructions.

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

Operate the engine and check for leaks.



Install the flexplate/flywheel. Refer to Procedure Procedure 016-005 or Refer to Procedure Procedure 016-004

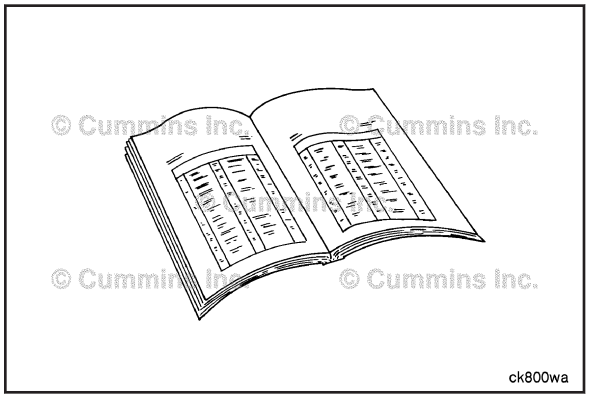
Install the gear drive unit. Refer to the OEM instructions.

Install the starting motor. Refer to Procedure Procedure 013-020

Install the aftercooler air inlet tube and tighten the aftercooler mounting capscrews. Refer to Procedure Procedure 010-005

Install the turbocharger. Refer to Procedure Procedure 010-033

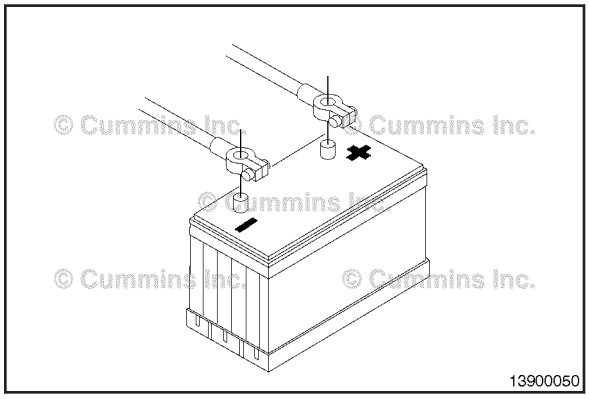
Fill the engine with coolant. Refer to Procedure Procedure 008-018



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

Operate the engine and check for leaks.



Flywheel Ring Gear (016-008)

General Information

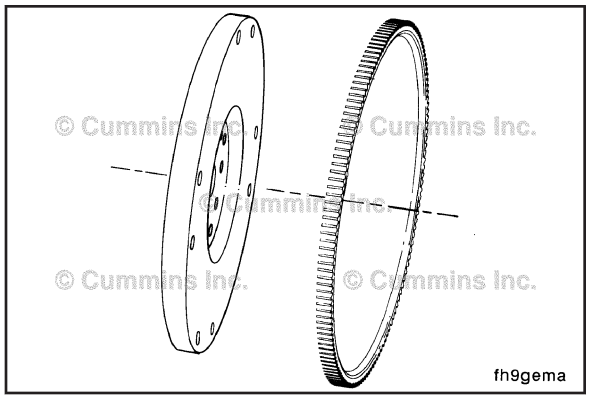
Prior to removing the damaged flywheel ring gear, first check if:

1 The ring gear is removable/replaceable

2 A replacement ring gear is available.

If may be necessary to replace the entire flywheel assembly.

NOTE: The ring gear on a flexplate is **not** replaceable. If the ring gear is damaged on a flexplate, the flexplate **must** be replaced as an assembly.

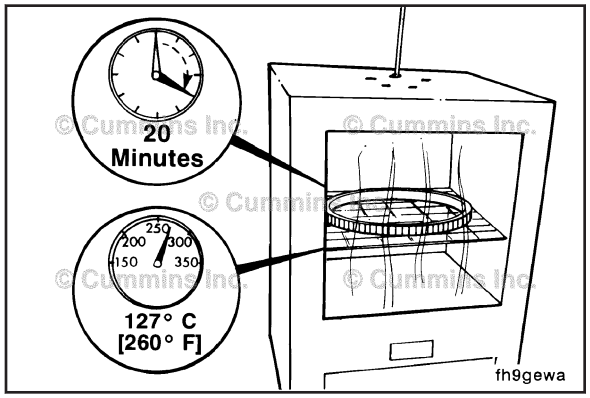


Disassemble

⚠WARNING⚠

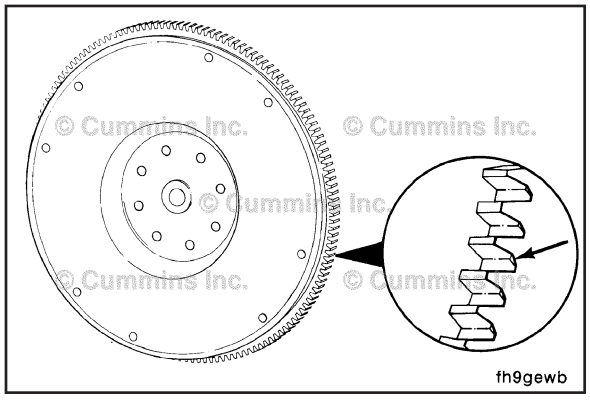
To reduce the possibility of severe eye damage, wear eye protection when you drive the gear from the flywheel. Do not use a steel drift pin or damage to the component can occur.

Use the brass drift pin to drive the ring gear from the flywheel.



Assemble

Heat the new ring gear for 20 minutes in an oven preheated to 127°C [261°F].



⚠WARNING⚠

To reduce the possibility of burns, wear protective gloves when installing the heated gear.

The ring gear **must** be installed so the bevel on the teeth is toward the crankshaft side of the flywheel.

Install the ring gear.

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

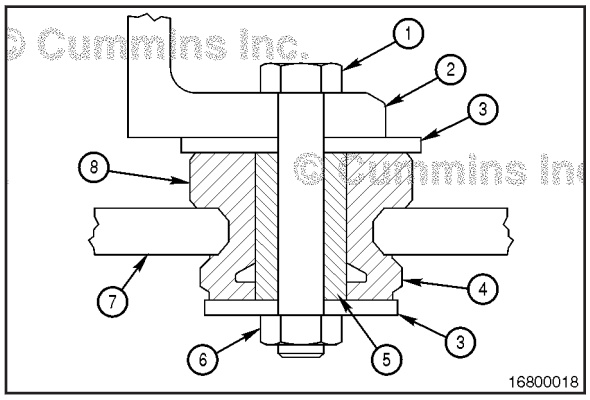
system is close to the frequency of the engine vibration. This can result in the mounting system operating at or near resonance, with a resulting magnification of the input vibration. This is obviously an undesirable situation.

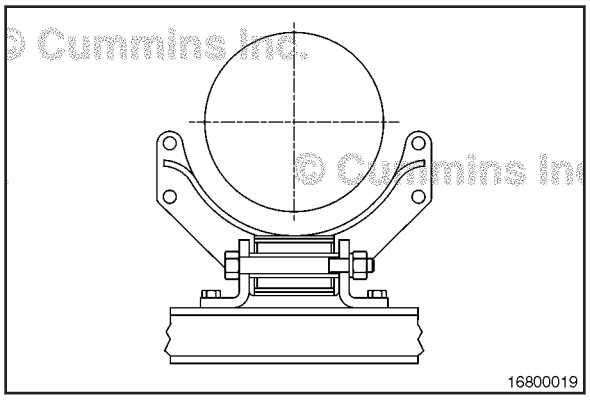
Transmissibility values of less than one indicate the mounting system is transmitting **only** a fraction of the vibration input from the engine, thus isolating the vehicle from engine vibration. Good engine mounts will reduce the amount of engine vibration transmitted to the chassis frame by at least 50 percent at idle.

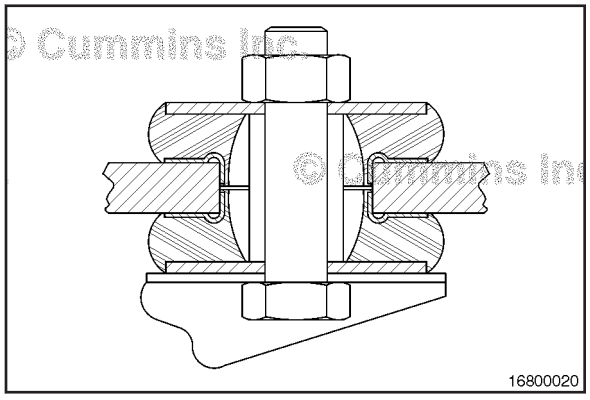
Stiffness (durometer) and size of the isolator, along with the weight of the engine or component applied, are the determining factors when designing a mounting system. An isolator that is correct for one engine may **not** be right for another. Likewise, because of weight differential, a particular isolator 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.

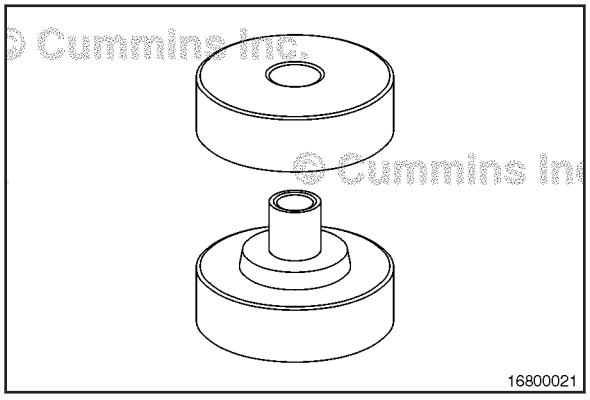
The following are illustrations of typical FRONT engine mounts.

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.

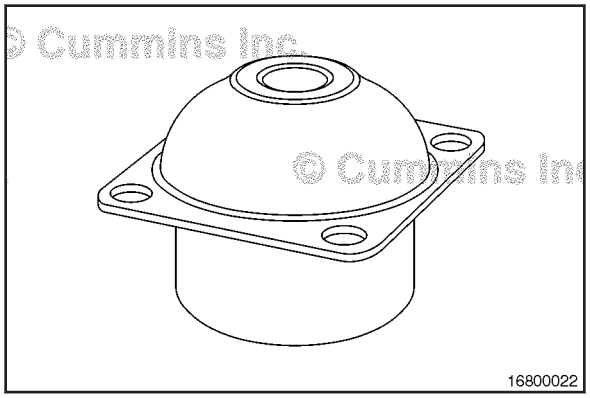


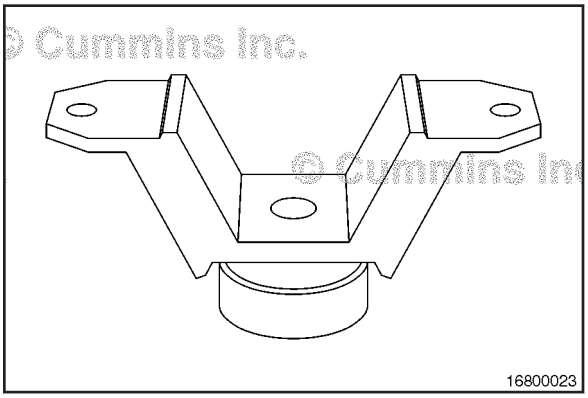


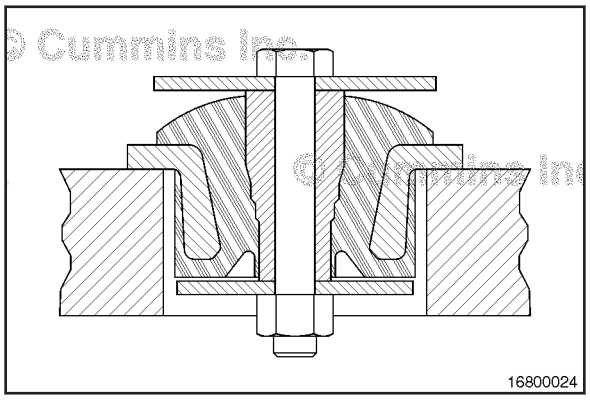


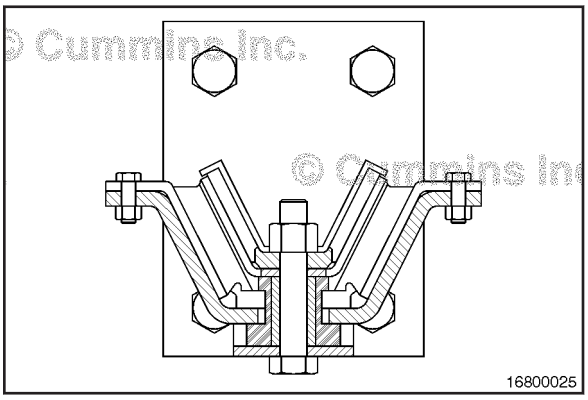


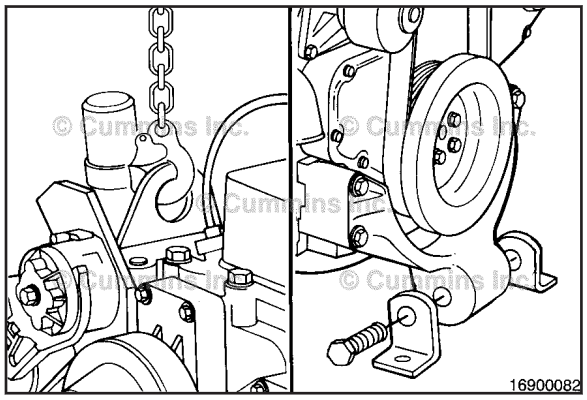
The following are illustrations of typical REAR engine mounts.











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.

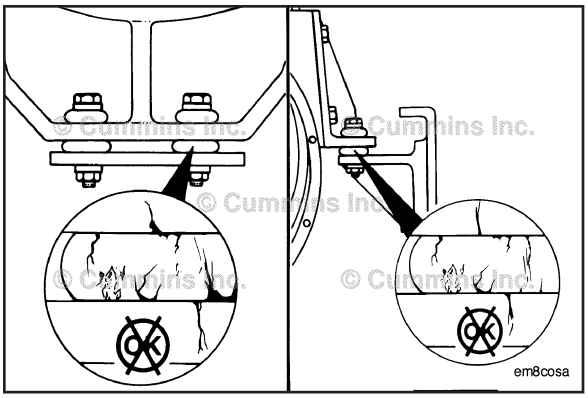
Use a hoist or lifting fixture to support the engine.

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.

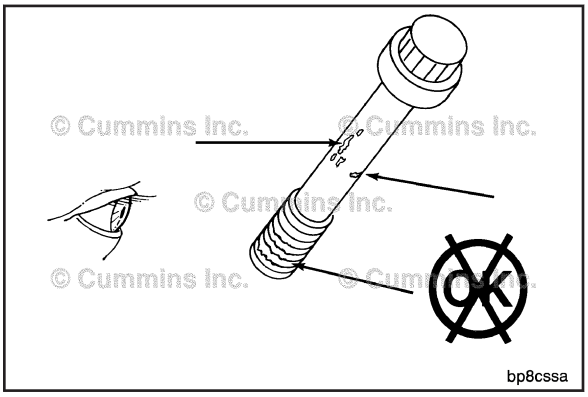
Inspect all rubber-cushioned mounts for cracks and other damage. Look for interference or contact between metal components.

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.

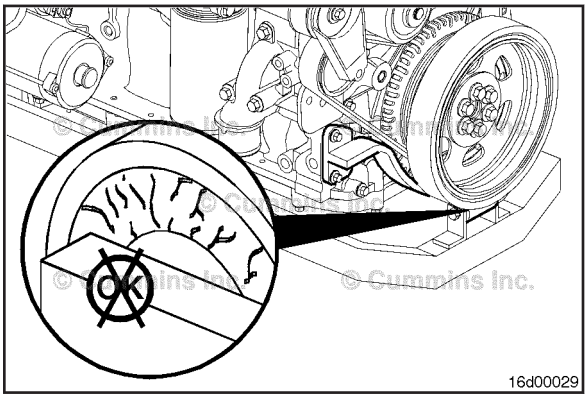
NOTE: Damaged engine mounts, brackets, and mounting hardware can cause the engine to move out of alignment and damage the driveline components in the equipment. This can result in vibration complaints.



Inspect the capscrew for the following:

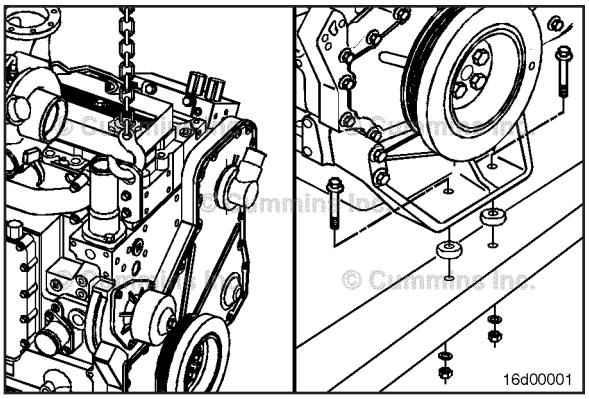
- Damaged threads
- Rust or corrosion-caused pitting
- Nicked, bent, stretched, or galled.

The capscrew **must** be replaced if it has any of the listed damages.



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

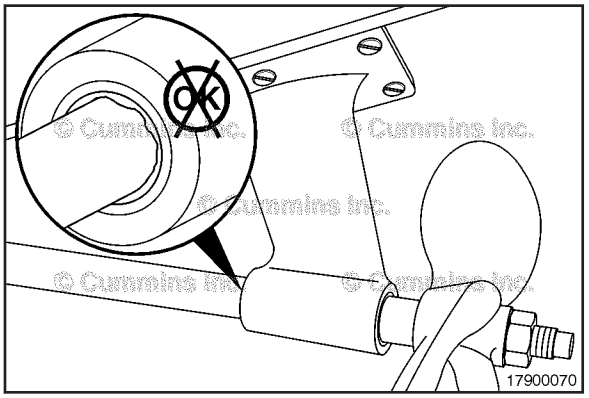
NOTE: Make sure to install any shims or spacers in the same location as removed.

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.

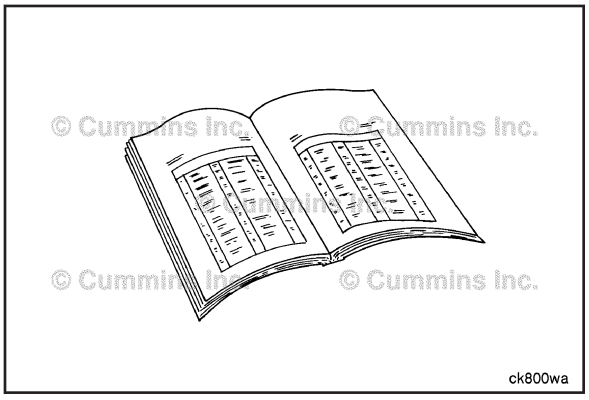
Connect all engine and chassis mounted accessories that were removed.



Propeller Shaft (016-025)

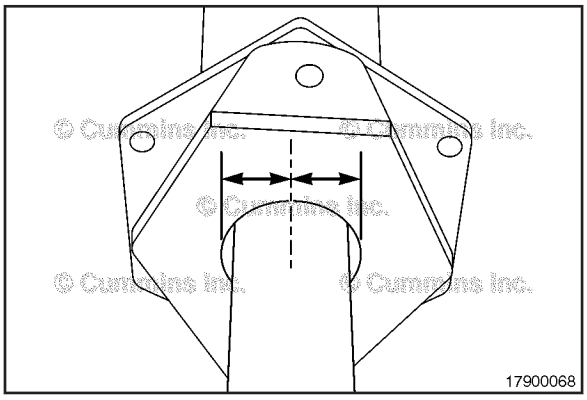
General Information

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

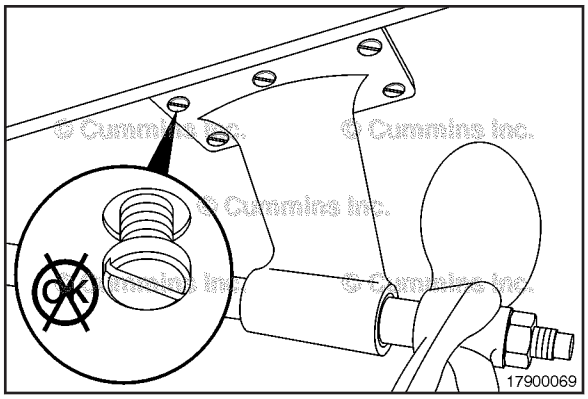
Inspect the propeller shaft for debris and burrs. Clean the propeller shaft.

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.

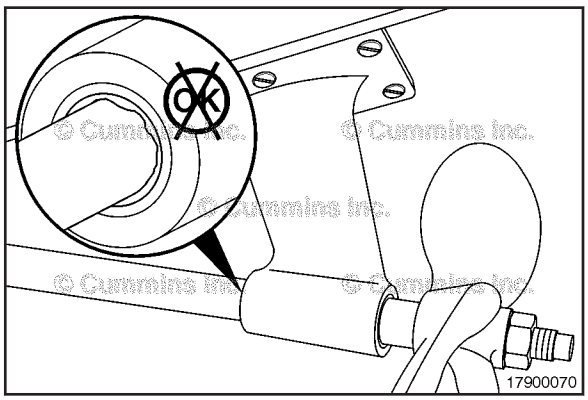
If any problems are noted, refer to an authorized OEM service location.



A misaligned shaft will cause uneven wear of the cutlass bearing.

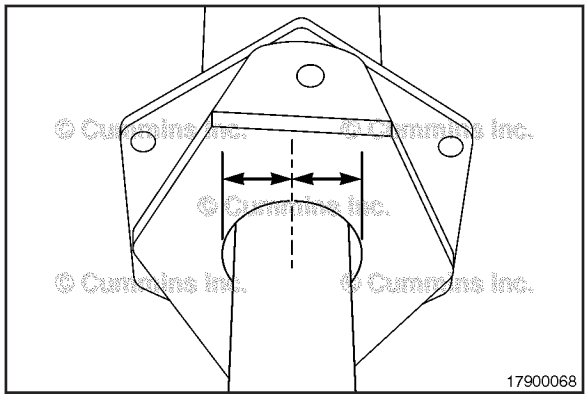
If the strut or cutlass bearing needs to be repaired or replaced, refer to an authorized OEM service location.

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.



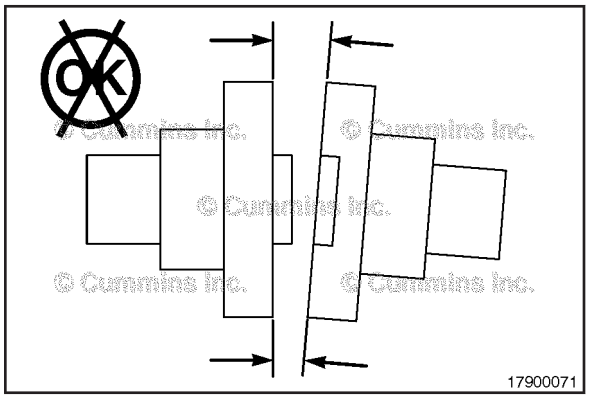
Alignment

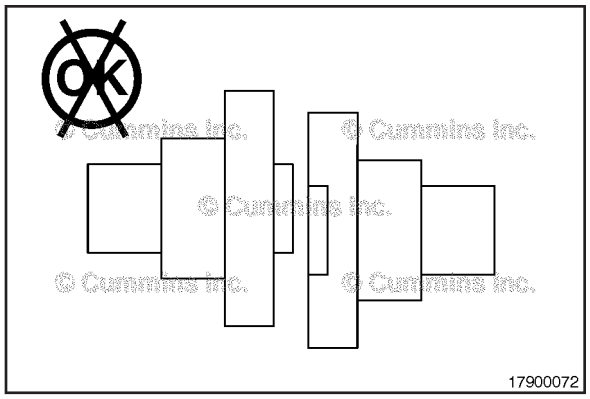
Check that the shaft is centered in the opening of the stuffing box flange.



Unbolt the propeller shaft coupling from the marine gear coupling.

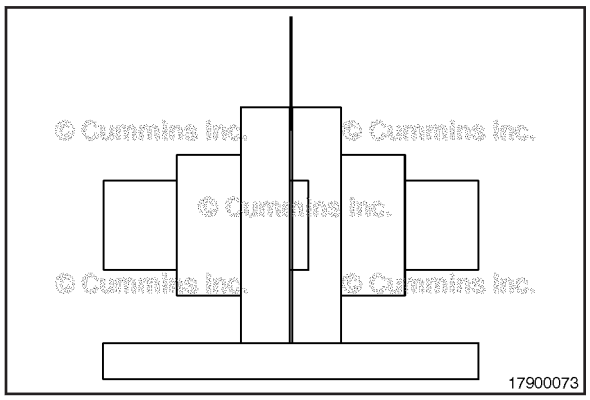
The faces of the marine gear (1) couplings and propeller (2) **must** be parallel.





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.

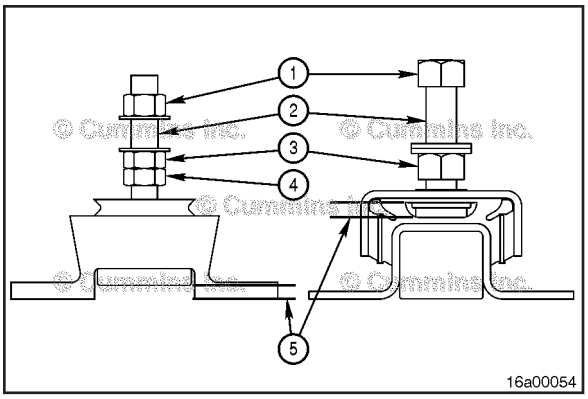
Specifications

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]
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

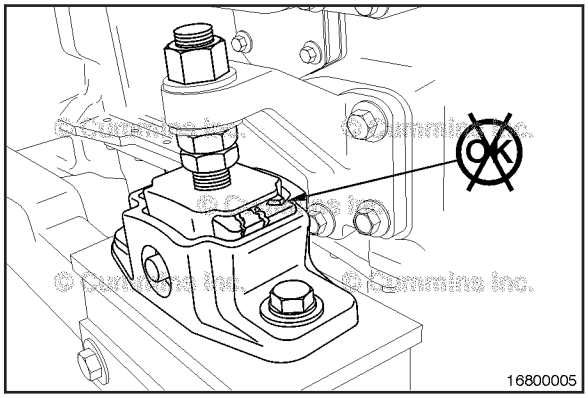
4 Jam nut

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.

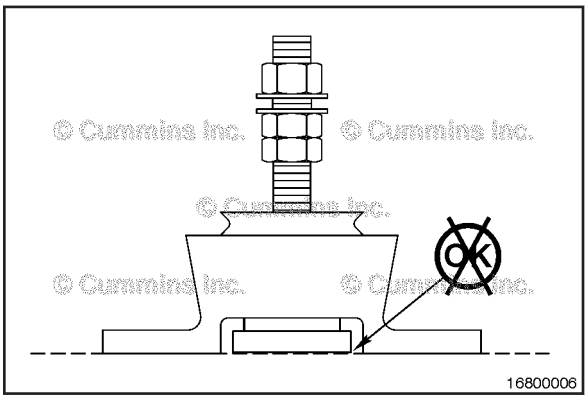
Isolators of different designs should **not** be mixed in the same installation.

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.

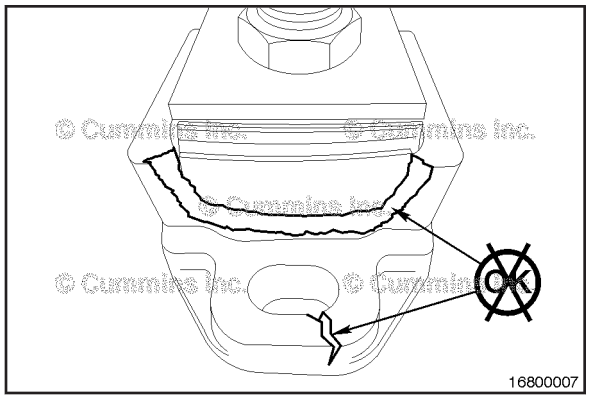


Check that the isolator is **not** fully compressed. If an isolator is in the fully compressed condition, there will be no clearance in the snubber gap.

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.

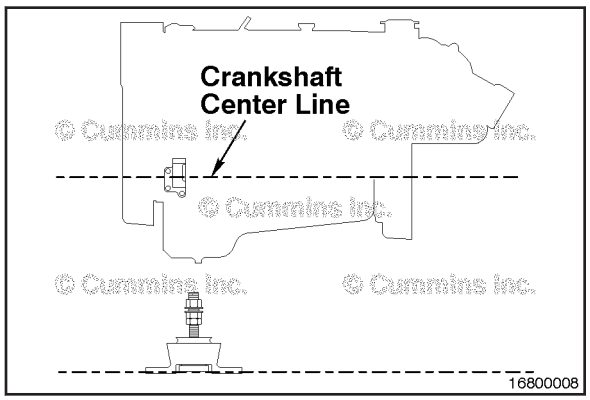
If two isolators that are both on one side of the engine or both at the front or rear of the engine are fully compressed, then the isolators will need to be replaced.



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.

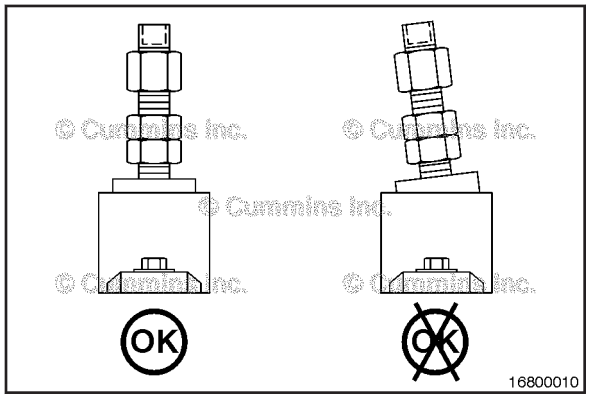
If an isolator is damaged or worn and less than one year old, check that the isolator part number is correct for the engine.



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.

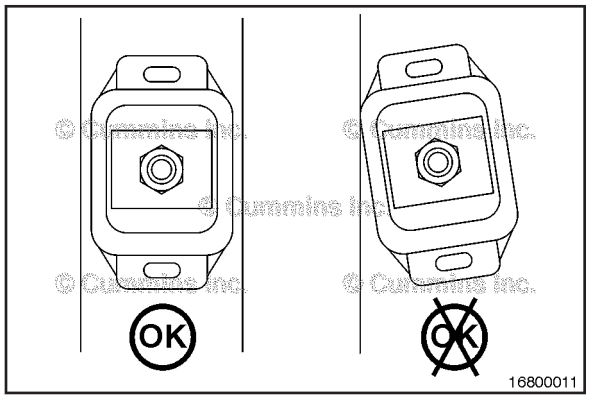
The alignment of the isolator stud to the base should be within four degrees of perpendicular.



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.

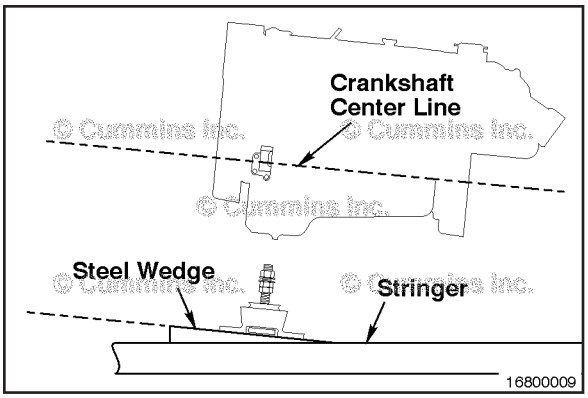
The alignment of the isolator stud to the base should be within two degrees of perpendicular.



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.

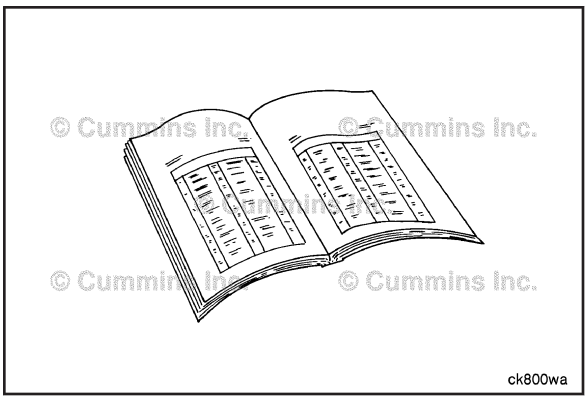
If the isolator is out of alignment, the mounting will need to be adjusted. Wedges can be used to shim the base to achieve proper alignment. Shims **must** be made of a solid material that will **not** compress under the weight of the engine.

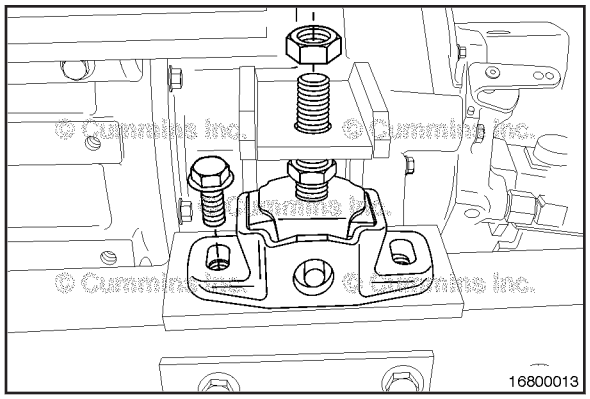


Preparatory Steps

⚠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.





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.

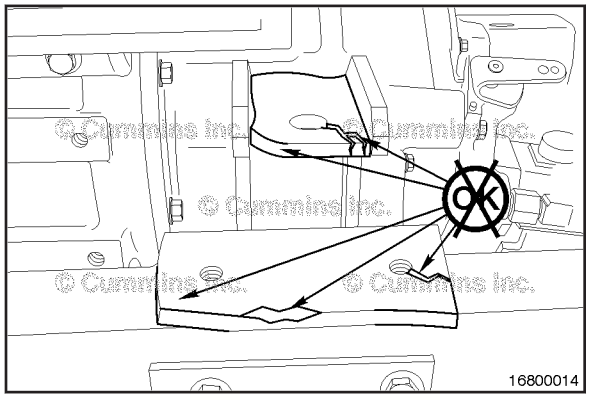
Raise the engine if necessary to facilitate the removal of the isolator.

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

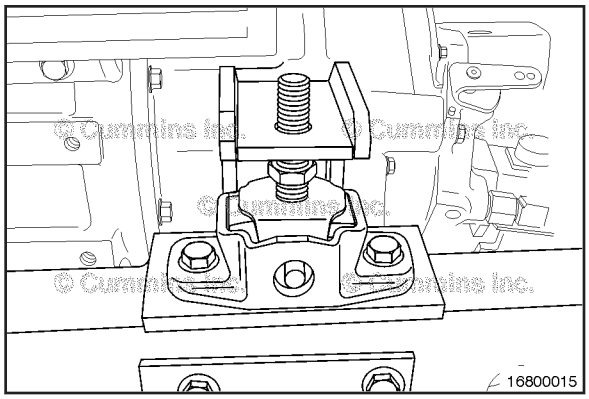
Set the new isolator in place. Check that the isolator is properly aligned. Reference the Initial Check section in this procedure for alignment information.

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.

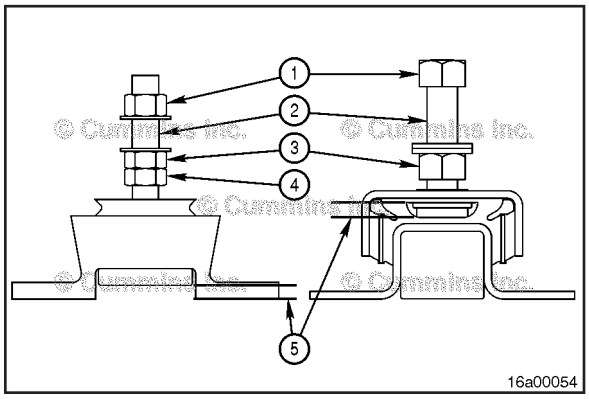
The engine will be heavier at either the front or back, depending the on configuration. Therefore, the isolators on the heavier end will be compressed more.

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.

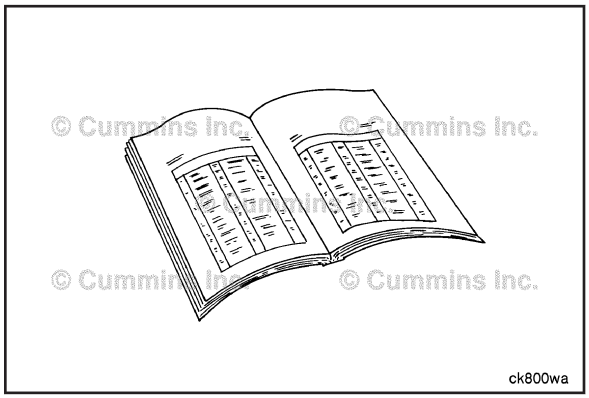
The engine should be lifted and the load removed from the isolator before moving the adjusting nut, to prevent damage to the threads.



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.

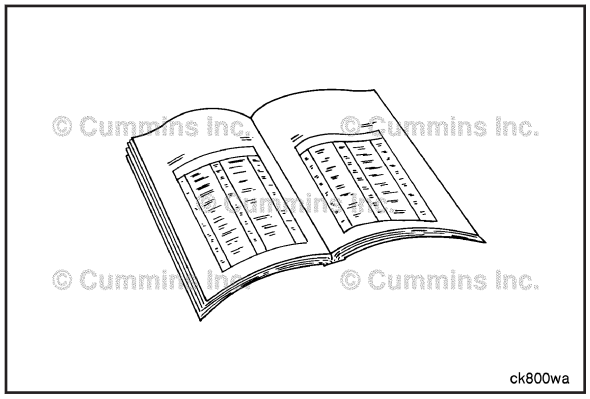


Engine Drive Shaft (016-027)

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.

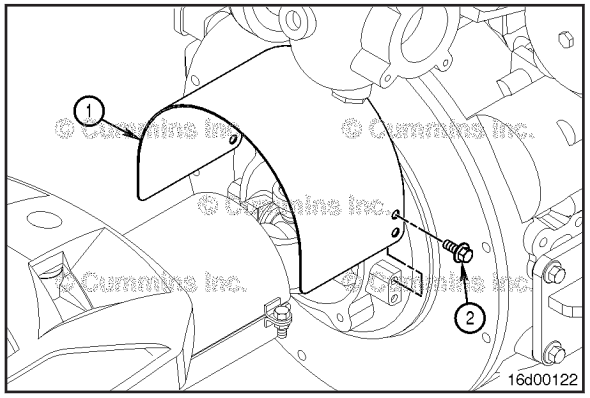


Preparatory Steps

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.



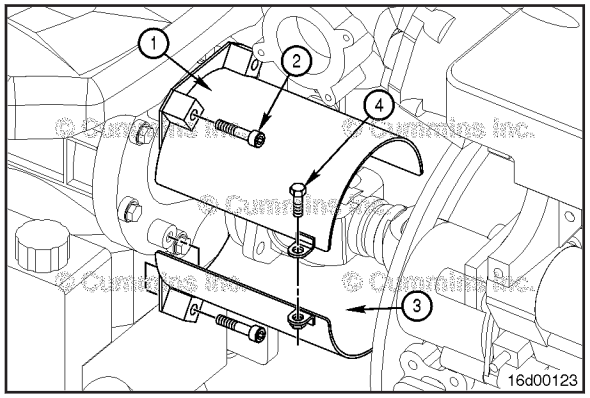
Remove

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 securing the two halves of the transmission end shield together.

Back out the capscrews (2) that are supporting the upper half of the shield (1).

Remove the upper half of the shield.

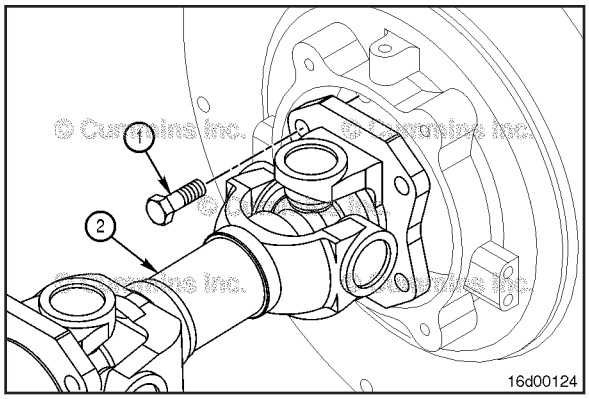
Back out the capscrews, that are supporting the lower half of the shield (3).

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.

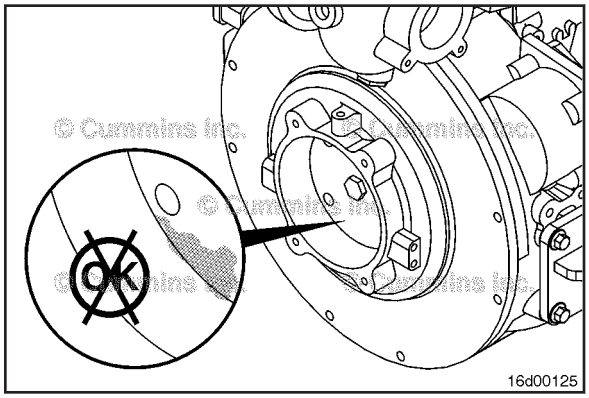
Back out the capscrews (1) from each end of the drive shaft (2). Support the shaft while removing the last capscrew from each end. Set the drive shaft to one side.



Setup

Marine Applications
Alignment Kit, Part Number 2892196

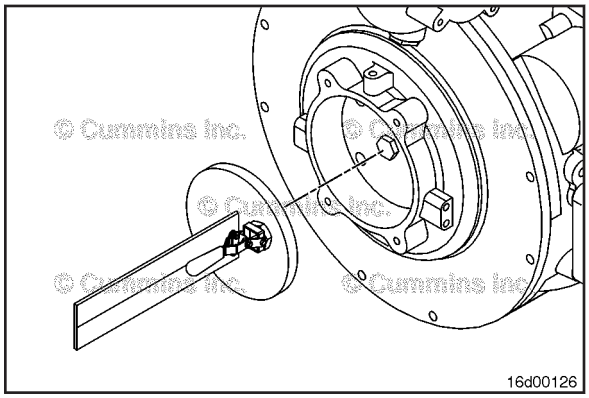
- Check the engine side coupler flange for proper seating prior to alignment tool installation.
- Check all mating surfaces and magnets for debris which could interfere with tool seating.



Install the alignment tool marked “ENGINE” to the engine drive coupling flange with blade parallel to the ground.

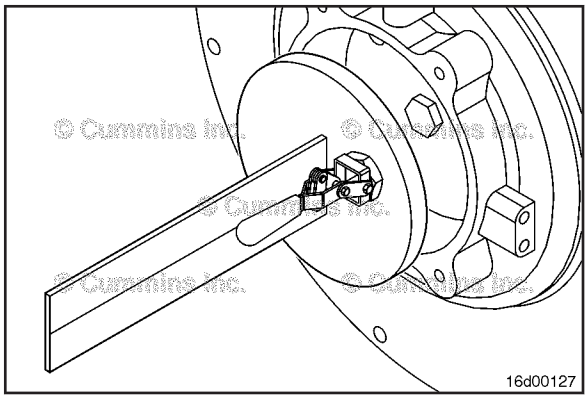
Install the alignment tool marked “GEAR” to the transmission input flange with the blade parallel to the ground.

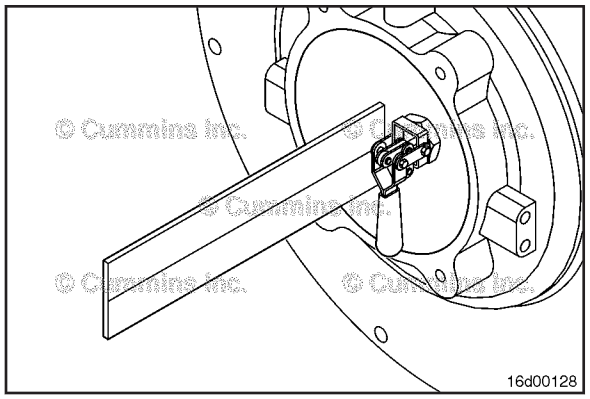
Confirm that the tools are firmly attached with no movement of any kind.



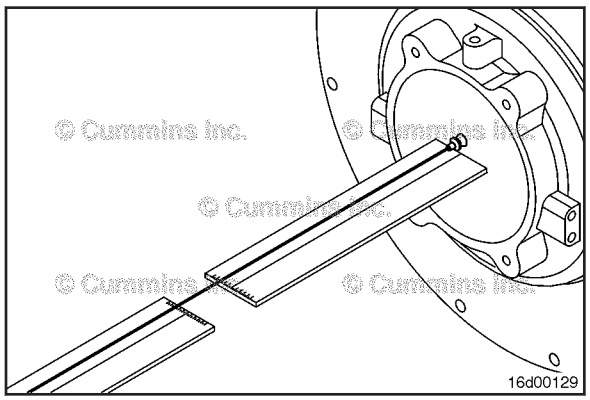
Pull out on the release lever to release the tools for changing position or removal.

Do **not** pry the alignment tools off with a pry bar, screwdriver, or similar tool, because damage can occur.





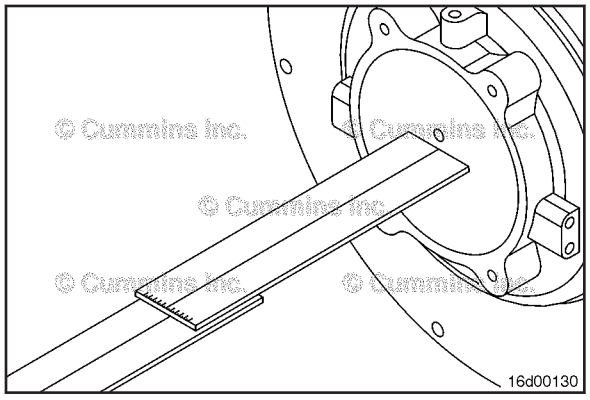
Make sure the release lever is disengaged when measuring.



For drive shafts longer than 254 mm [10 in]:

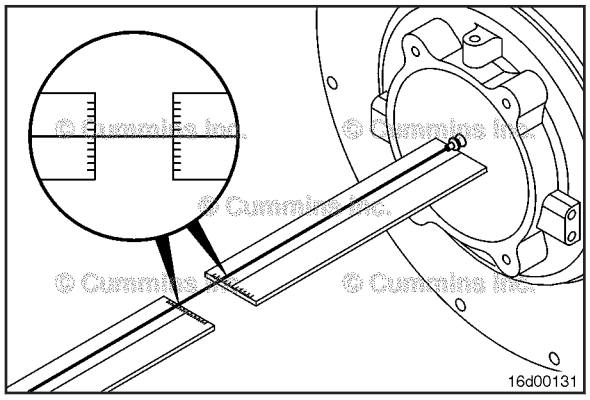
- Insert the indicator line into the holes in the tool blades using the pegs to hold the line tight.
- Install line in the tool so **not** to interfere with free movement of the line.

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 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.

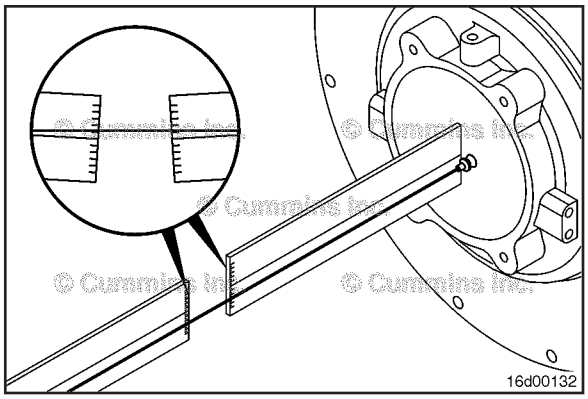
Horizontal Alignment: 0 degrees ± 1/2 degree.

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.

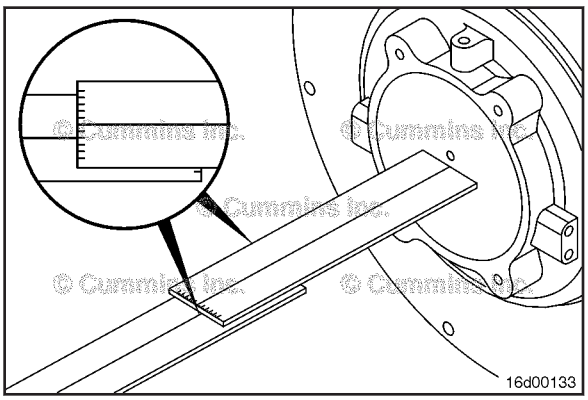


Drive shafts 254 mm [10 in]:

- 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.

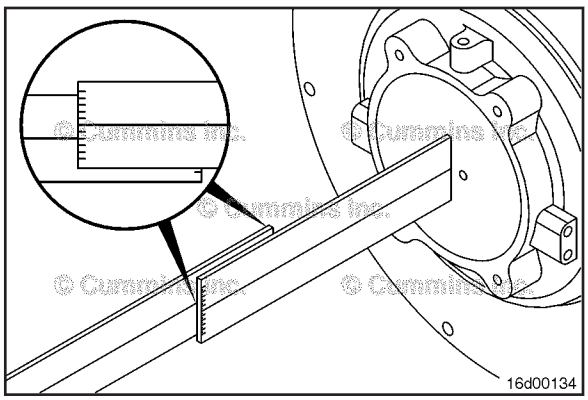
Horizontal Alignment: 0 degrees ± 1/2 degree.



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.



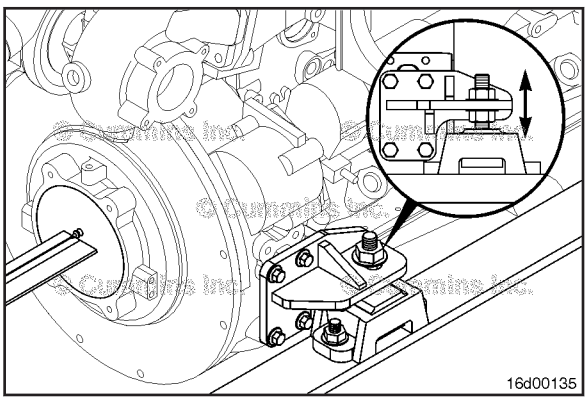
Adjust

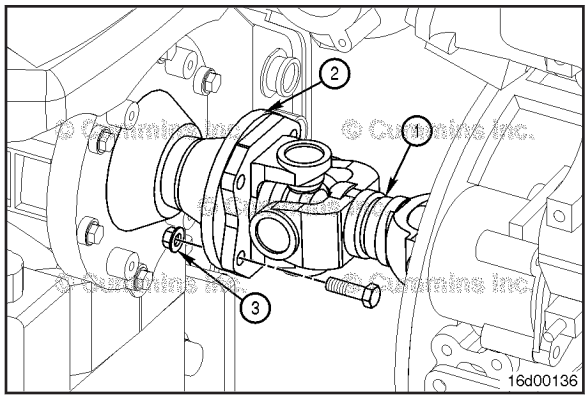
Marine Applications

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.





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.

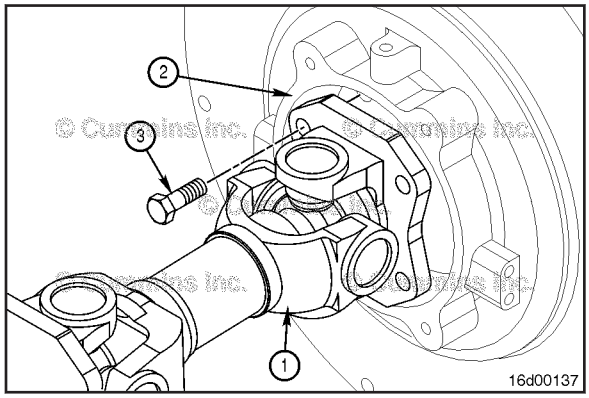
NOTE: The longer drive shafts can be very heavy. The technician should consider whether two technicians are needed for this procedure.

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 transmission input shaft flange bolts (1/2 - 20 x 1.12 in long).

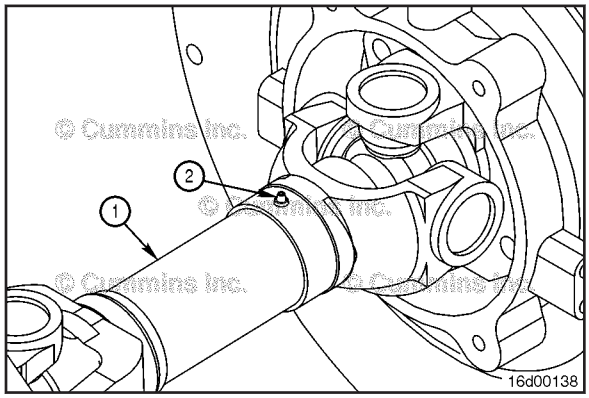
Torque Value: 149 N•m [110 ft-lb]



Attach the drive shaft (1) to the engine coupler (2).

Tighten the four capscrews (1/2 - 20 x 2.12 in long) (3) on the engine coupler (2) .

Torque Value: 149 N•m [110 ft-lb]

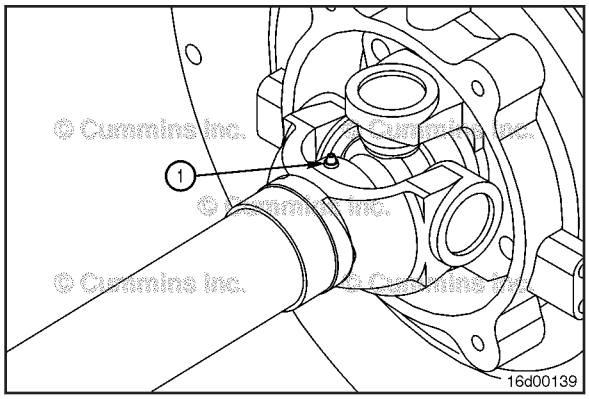


Lubricate the drive shaft slip-joint (1) through the grease fitting (2) by applying approximately 3 to 6 pumps of specified grease from a typical hand-operated grease gun.

Use Mercury™ Engine Coupler Spline Grease, Part Number 92-802869A1, or equivalent.

Driveshafts 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.



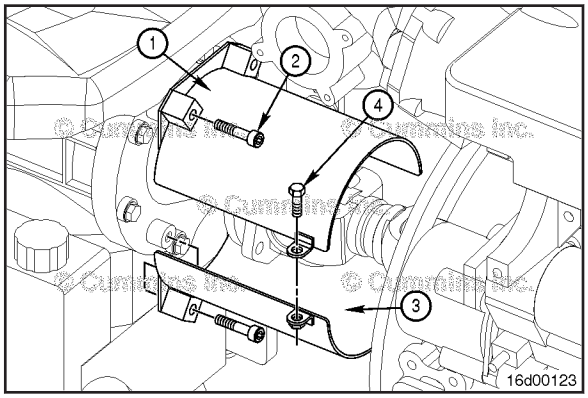
Install the top (1) and bottom (3) drive shaft shields on the transmission end as shown.

Coat the capscrew threads with Loctite™ 277, or equivalent.

Tighten the drive shaft shield retaining capscrews 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]

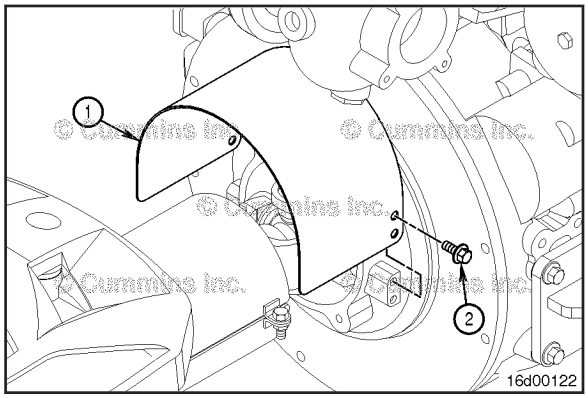


Install the engine end drive shaft shield (1) in the flywheel housing cover.

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]

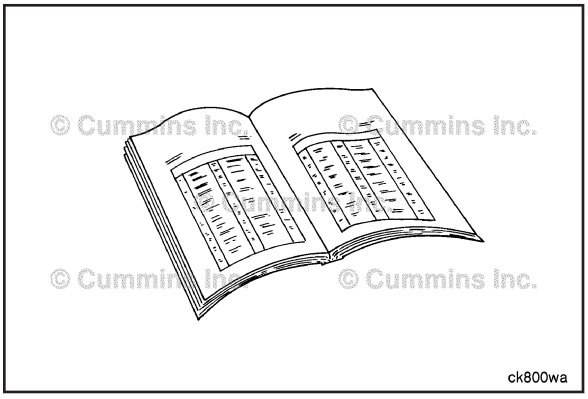


Finishing Steps

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.



Notes

Section 17 - Miscellaneous - Group 17

Section Contents

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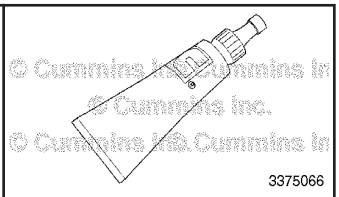
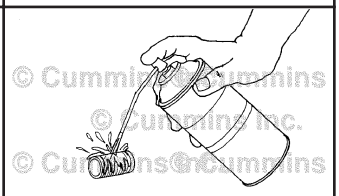
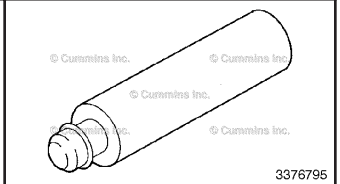
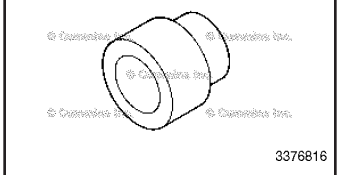
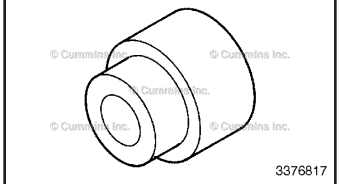
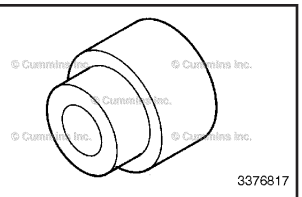
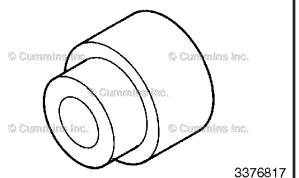
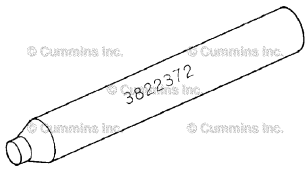
Service Tools

Miscellaneous

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 Plug Sealant** Used when installing pipe plugs to reduce the possibility of leaks.	
3375068	**Cup Plug Sealant** Used when installing cup plugs to reduce the possibility of leaks.	
3824510	**QD Spray Cleaner** Used to clean cup plug opening.	
3164085	**Cup Plug Driving Tools (universal handle)** Required use with driver heads to install new cup plugs to their proper depth, plus avoiding damage to the cup plug and the surrounding area.	
3376816	**Cup Plug Driving Tools (driver head, 1-inch nominal)** Required to install new cup plugs to their proper depth, plus avoiding damage to the cup plug and the surrounding area.	
3376817	**Cup Plug Driving Tools (driver head, 1-1/4-inch nominal)** Required to install new cup plugs to their proper depth, plus avoiding damage to the cup plug and the surrounding area.	

Tool No.	Tool Description	Tool Illustration
3823520	**Cup Plug Driving Tools (driver head, 11/16-inch nominal)** Required to install new cup plugs to their proper depth, plus avoiding damage to the cup plug and the surrounding area.	
3823524	**Cup Plug Driving Tools (driver head, 2-1/4-inch nominal)** Required to install new cup plugs to their proper depth, plus avoiding damage to the cup plug and the surrounding area.	
3822372	**Cup Plug Driving Tools** Required to install new cup plugs to their proper depth, plus avoiding damage to the cup plug and the surrounding area.	

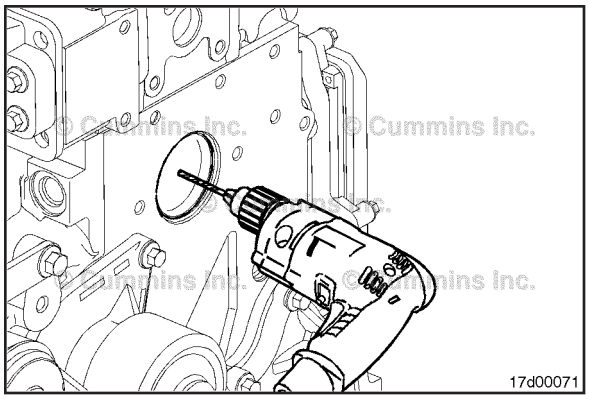
Cup Plug (017-002)

Remove

⚠CAUTION⚠
Do not allow metal shavings to fall inside the engine when drilling a hole in the cup plug. Damage to engine components can occur.

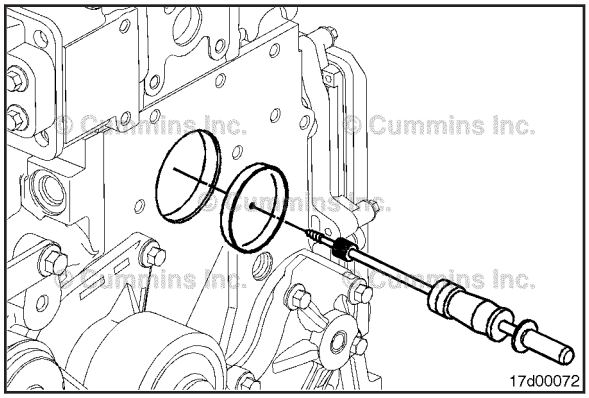
Use a center punch to mark the cup plugs for drilling.

Drill a 1/8-inch hole in the cup plug.



Use a dent puller to remove the plug.

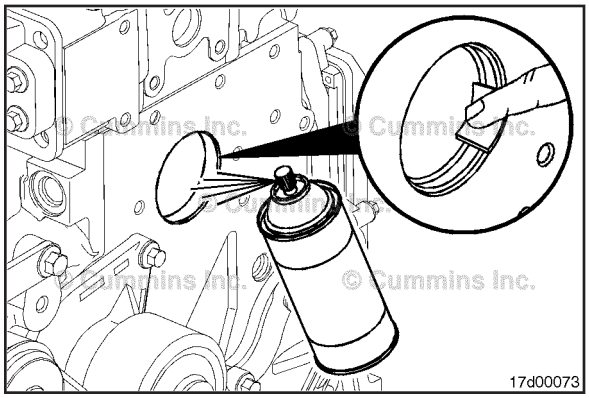
Discard all used cup plugs. Do **not** use them again.



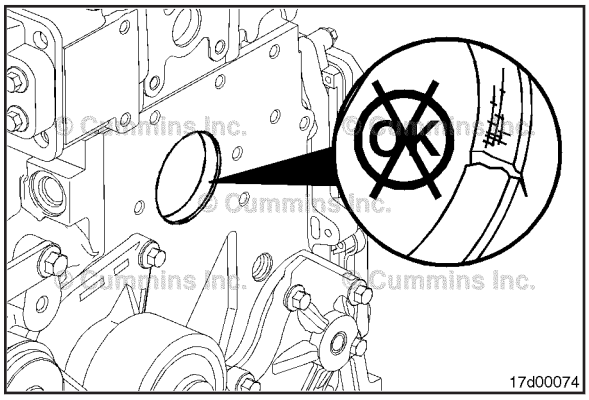
Clean and Inspect for Reuse

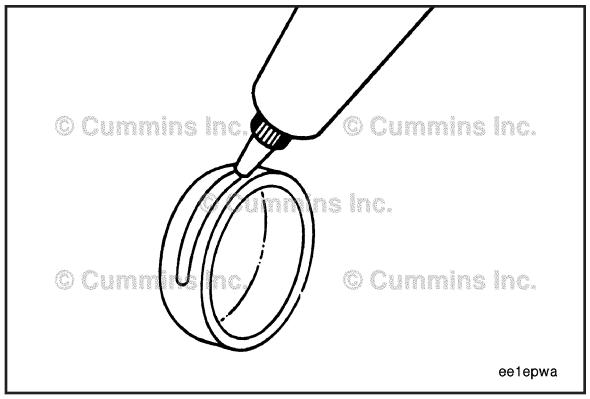
Thoroughly clean the cup plug hole using Scotch-Brite™ Pad, or equivalent.

Use spray cleaner, Part Number 3375433, or equivalent, to clean the bore for the final time.



Inspect the cup plug bores for damage.





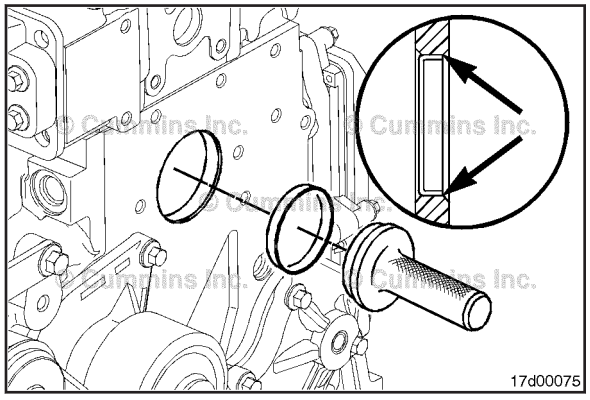
Install

⚠CAUTION⚠

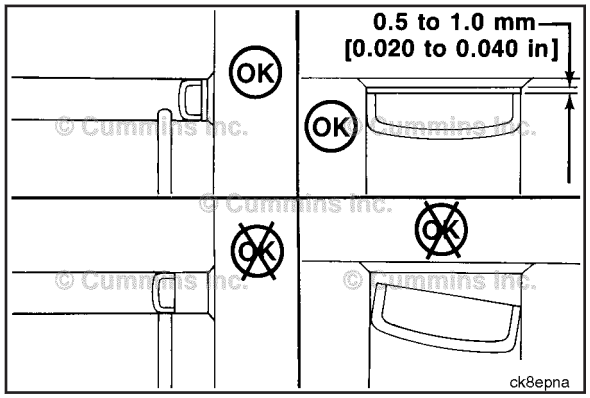
Excessive sealant can run back into the engine and cause damage to other components. Allow the sealant to dry for a minimum of 2 hours before operating the engine. The plug can come out of the bore if the sealant is not dry.

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 circumference of the cup plug bore.

NOTE: Do **not** install a used cup plug. Discard all plugs after removal.



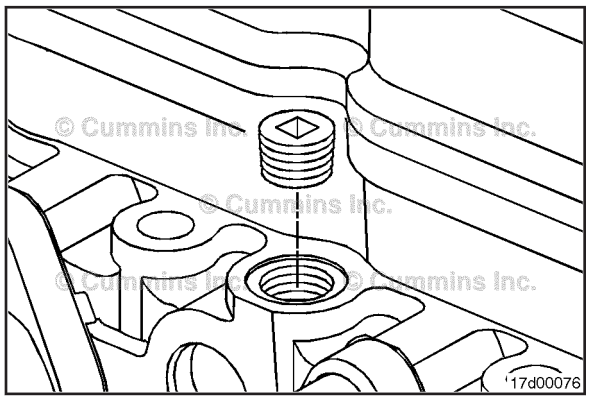
Install the cup plug with the appropriate cup plug driver. Reference the Service Products Catalog, Bulletin 3377710.



⚠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 or engine damage cab result.

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 chamfer of the bore.



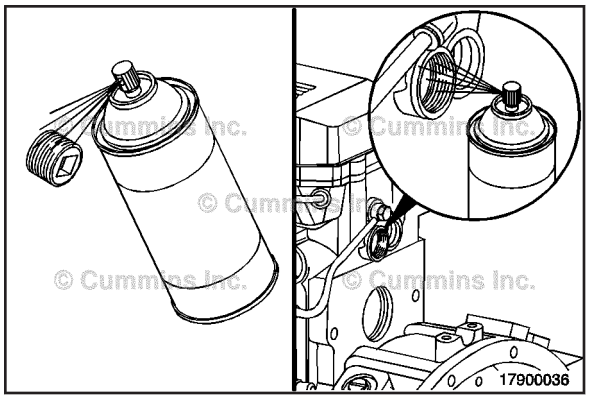
Pipe Plug (017-007)

Remove

Remove the pipe plug.

Clean

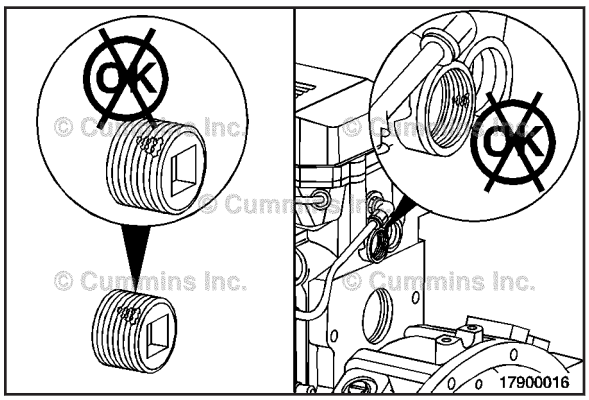
Use spray cleaner, Part Number 3375433, or equivalent, to clean the threads of the pipe plugs and threaded bores.



Inspect for Reuse

Inspect the threads of the pipe plugs for mutilation or damage.

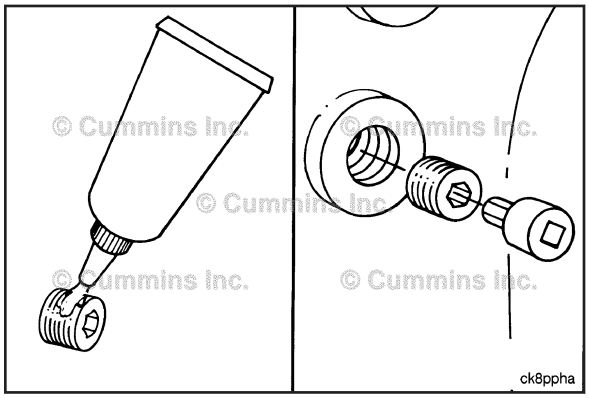
Inspect the threaded bores for damage.



Install

Apply a film of pipe plug sealant, Part Number 3375066, or equivalent, to the threads.

Install the pipe plugs.

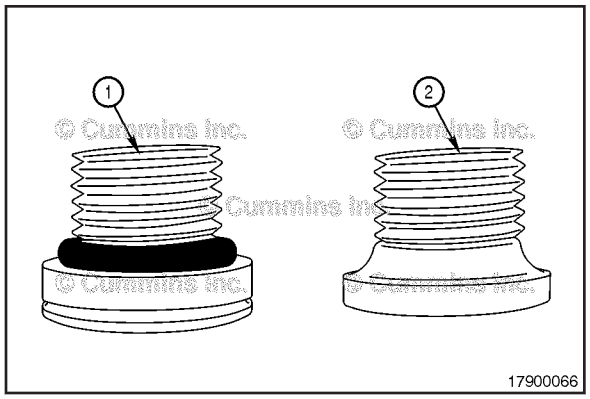


Tighten the pipe plugs. Refer to the adjoining chart for the appropriate torque values.

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)

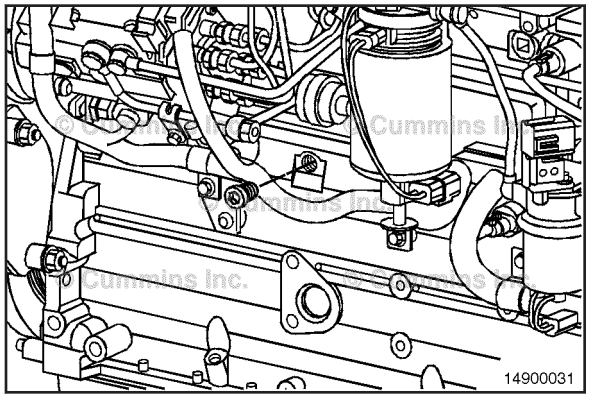
General Information

Two types of straight thread plugs are used:

1 Straight thread plug with o-ring

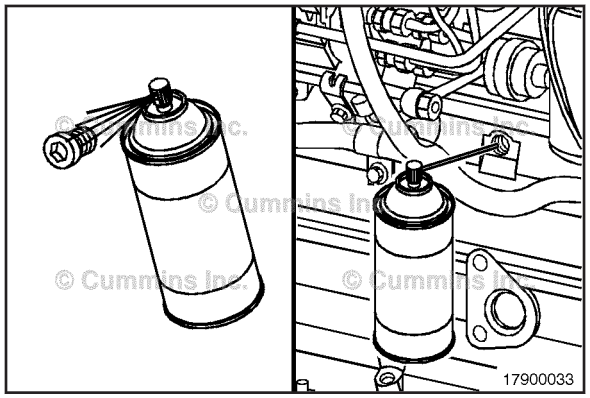
2 Straight thread plug with formed in-place sealant.

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.



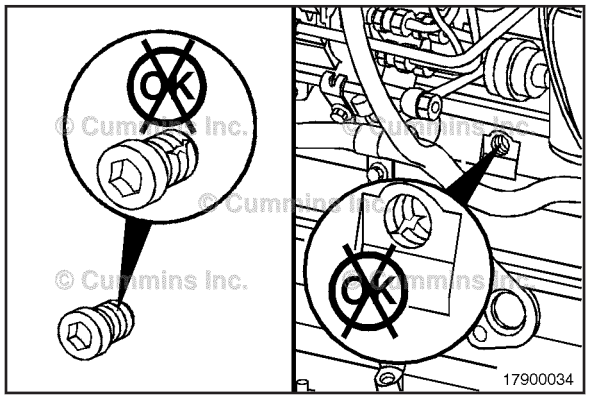
Remove

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.

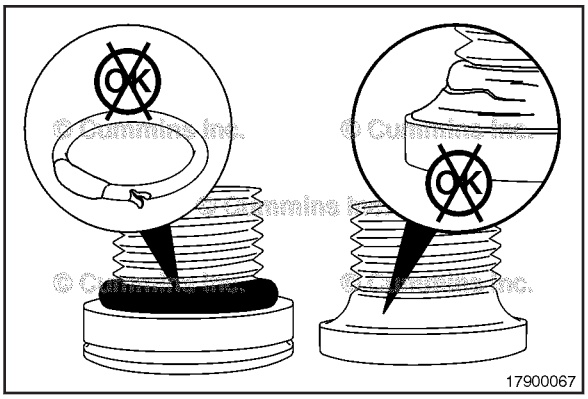
Replace the plugs, if damaged.

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.

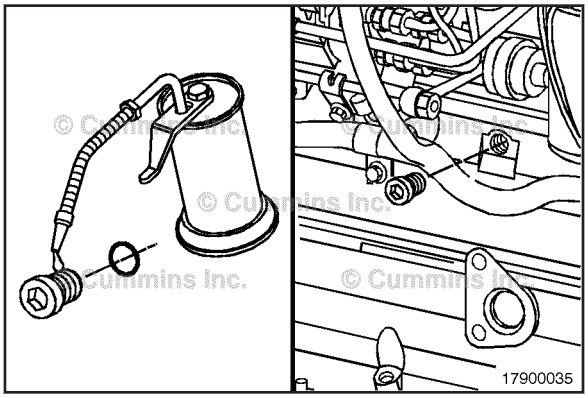
Torque Value:
M10 10 N•m [89 in-lb]

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.

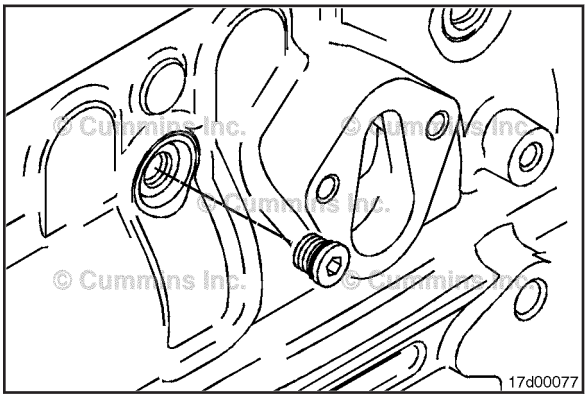
Torque Value:
M10 18 N•m [160 in-lb]

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]



Notes

Section 20 - Vehicle Braking - Group 20

Section Contents

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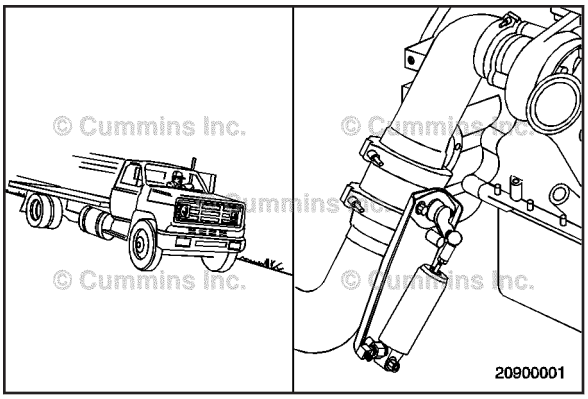
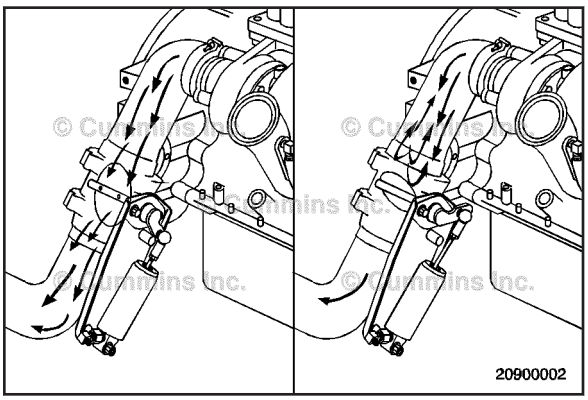
Engine Exhaust Brake (020-016)

General Information

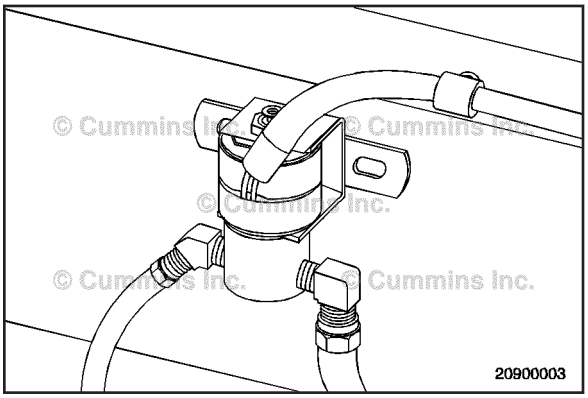
An engine exhaust brake retards the speed of the engine during motoring conditions to provide additional vehicle braking power and extend the life of the vehicle service brakes.



The exhaust brake retards engine speed by creating high exhaust back pressure. This back pressure is obtained by restricting airflow through the exhaust system. The exhaust brake can **only** be activated when the accelerator pedal is at its low idle position. With the throttle at low idle position, fueling commands to the cylinders will **not** detract from the braking power of the brake system.

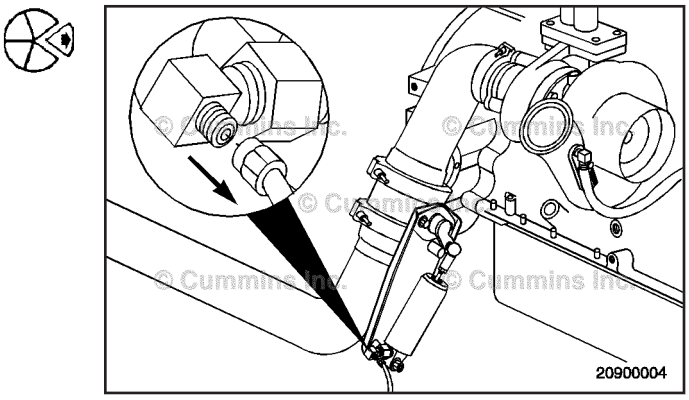


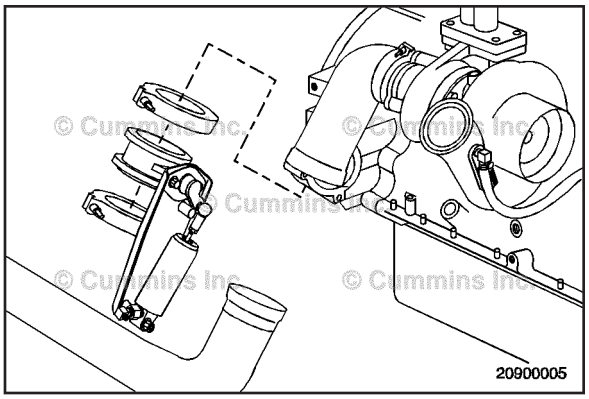
The exhaust brake is actuated by a solenoid. The solenoid can be controlled by the engine's electronic control module (ECM). The ECM monitors its sensors (such as accelerator pedal position and engine speed) and energizes the brake solenoid when the proper braking conditions are present.



Remove

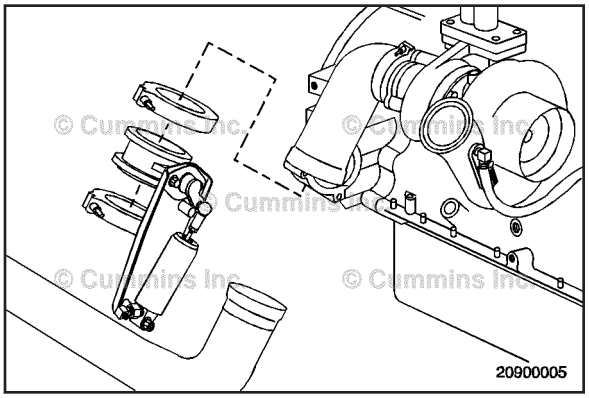
Disconnect the exhaust brake solenoid.





Loosen the exhaust clamps on the brake.

Remove the brake assembly from the exhaust system.

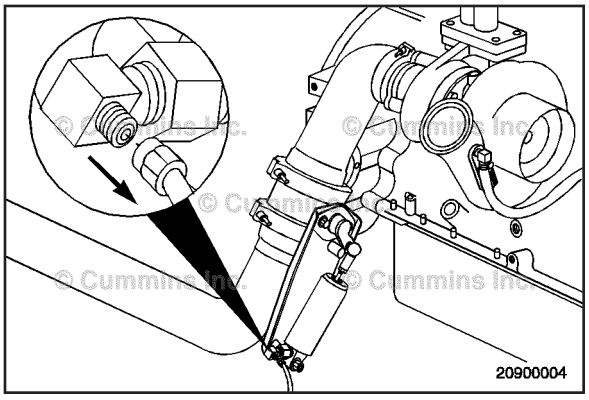


Install

Install the brake assembly into the exhaust system.

Tighten the exhaust clamps.

Torque Value: 9 N•m [80 in-lb]



Connect the exhaust brake solenoid.

Section L - Service Literature

Section Contents

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Additional Service Literature

General Information

The following publications can be purchased by contacting your Cummins distributor:

Bulletin	Title of Publication
3666477	Troubleshooting and Repair Manual, Electronic Control System, ISB (4 Cylinder) and ISB e (4 and 6 Cylinder) Series Engines
4021337	Troubleshooting and Repair Manual, CM850 Electronic Control System, ISB Series Engines
4021416	Troubleshooting and Repair Manual, ISB, ISBe2, ISBe3, ISBe4, QSB4.5, QSB5.9, QSB6.7, ISC, QSC8.3, ISL, ISLe3, ISLe4, and QSL9, CM850 Electronic Control System
3666483	ISB4 and ISB e Wiring Diagram
4021347	ISB CM850 Electronic Control Module Wiring Diagram
4021524	QSB4.5, QSB6.7, QSC8.3, and QSL9 CM850 Electronic Control Module Wiring Diagram
4021532	ISBe 4 CM850 Electronic Control Module Wiring Diagram
4081886	QSB Electronic Control System Wiring Diagram
3666496	Operation and Maintenance Manuals, ISB e and ISB (Common Rail Fuel System) Series Engines
4021531	Operation and Maintenance Manual, QSB4.5 and QSB6.7 (Common Rail Fuel System) Series Engines
4021355	Owners Manual, ISB e and ISB (Common Rail Fuel System) Series Engines
4021482	Owners Manual, QSB5.9 Engines
3379000	Air for Your Engine
3379001	Fuel for Cummins Engines
3379009	Operation of Diesel Engines in Cold Climates
3666132	Cummins Coolant Requirements and Maintenance
3810340	Cummins Engine Oil Recommendations
4021288	ISB (4 Cylinder) and ISB e (4 and 6 Cylinder) Series Engine Familiarization
4021324	ISB (4 Cylinder) and ISB e (4 and 6 Cylinder) Intake Air Heater System
4021385	ISB High Pressure Common Rail Fuel System Engine Familiarization

Service Literature Ordering Location

Contact Information

Region	Ordering Location
United States and Canada	Cummins Distributors or Credit Cards at https://store.cummins.com
All Other Countries	Cummins Distributors or Dealers

Cummins Customized Parts Catalog

General Information

Cummins is pleased to announce the availability of a parts catalog compiled specifically for you. Unlike the generic versions of parts catalogs that support general high volume parts content; Cummins Customized catalogs contain only the new factory parts that were used to build your engine.

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)

Ordering the Customized Parts Catalog

Ordering by Telephone

- North American Distributors, Original Equipment Manufacturers and Cummins Factory personnel order by calling Iron Mountain Fulfillment Services (IMFS) at 1-800-646-5609.
- 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.
- Retail Credit Card Orders require a 2 step ordering process.

Ordering On-Line

Access the Cummins QSOL store at https://store.cummins.com

- 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)

Unfortunately not all Cummins Engines can be supported by Customized Parts Catalogs. Engines older than 1984 or newer than 3 months may not have the necessary parts information to compile a catalog. We will contact you if this occurs and explain why we are unable to fill your order.

Customized Parts Catalogs are produced specifically for a single customer. This means they are not returnable for a refund. If we make an error and your catalog is not useable, we will correct that error by sending you a new catalog.

Notes

Section V - Specifications

Section Contents

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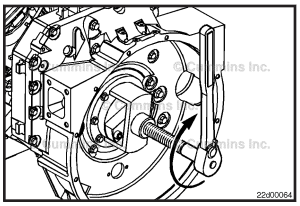
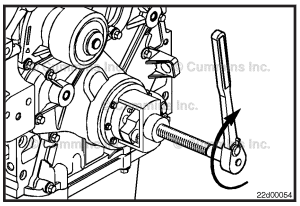
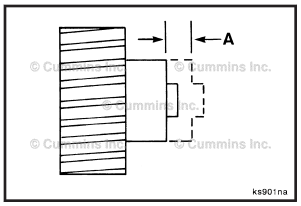
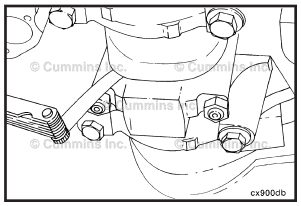
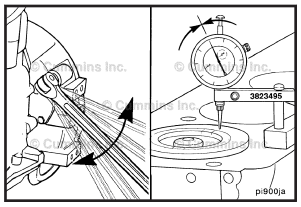
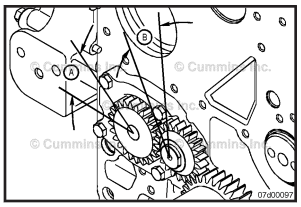
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Engine Disassembly - Group 00 - Torque Values				
Crankshaft Seal, Rear (001-024)				
Crankshaft Seal Replacer Capscrews		45 N•m	[33 ft-lb]	
Crankshaft Seal, Front (001-023)				
Crankshaft Seal Replacer Capscrews		33 N•m	[45 ft-lb]	

Engine Assembly - Group 00 - Specifications

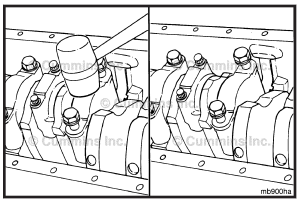
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Crankshaft (001-016)					
Crankshaft End Clearance		0.102 mm	MIN	0.004 in	
		0.432 mm	MAX	0.017 in	
Piston and Connecting Rod Assembly (001-054)					
Connecting Rod and Crankshaft Side Clearance		0.10 mm	MIN	0.004 in	
		0.33 mm	MAX	0.013 in	
Piston Protrusion		0.151 mm	MIN	0.006 in	
		0.485 mm	MAX	0.019 in	
Camshaft End Play (A)		0.12 mm	MIN	0.005 in	
		0.50 mm	MAX	0.020 in	
Camshaft Gear Backlash Limits (B)		0.08 mm	MIN	0.003 in	
		0.25 mm	MAX	0.010 in	
Lubricating Oil Pump (007-031)					
A		0.300	MIN	0.011	
		0.500	MAX	0.019	
B		0.150	MIN	0.005	
		0.250	MAX	0.009	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.

Engine Assembly - Group 00 - Torque Values

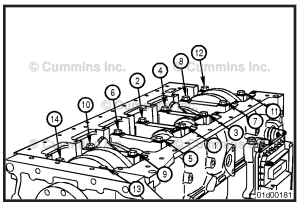
Crankshaft (001-016)

50 N•m [37 ft-lb]



Torque Value:

Step 1	50 N•m	[37 ft-lb]
Step 2	80 N•m	[59 ft-lb]
Step 3	Turn all capscrews through 90 degrees.	



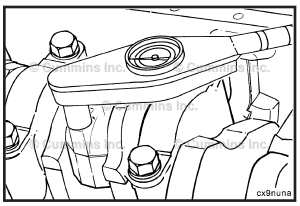
Torque Value:
Previously Installed Main Bearing Capscrews

Step 1	50 N•m	[37 ft-lb]
Step 2	60 N•m	[44 ft-lb]
Step 3	80 N•m	[59 ft-lb]
Step 4	Rotate 90 degrees.	

Torque Value:
New Main Bearing Capscrews

Step 1	120 N•m	[89 ft-lb]
Step 2	Loosen completely	
Step 3	60 N•m	[44 ft-lb]
Step 4	85 N•m	[63 ft-lb]
Step 5	Rotate 120 degrees.	

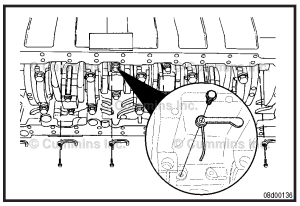
Piston and Connecting Rod Assembly (001-054)



Torque Value:

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

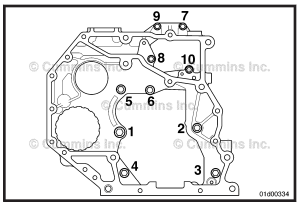
Piston Cooling Nozzle (001-046)



Torque Value:
J-Jet Capscrew

Step 1	15 N•m	[133 in-lb]

Gear Housing, Rear (001-034)



Torque Value:
M12

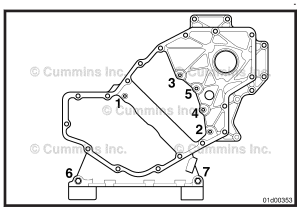
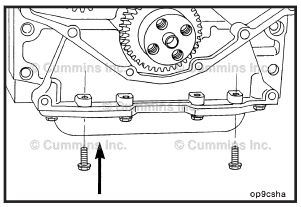
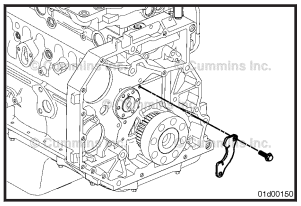
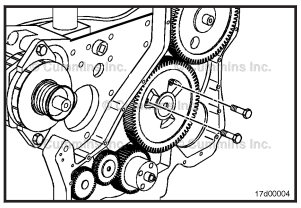
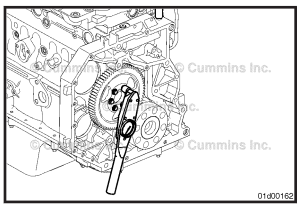
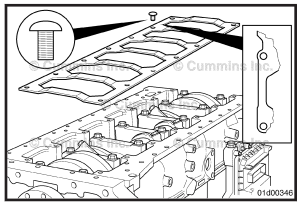
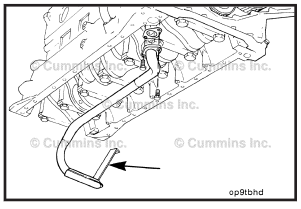
Step 1	50 N•m	[37 ft-lb]

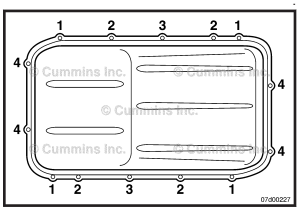
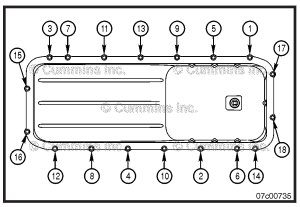
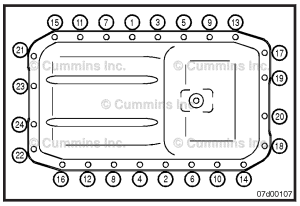
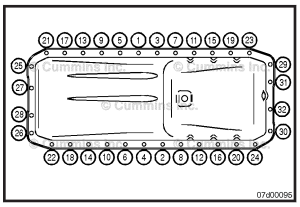
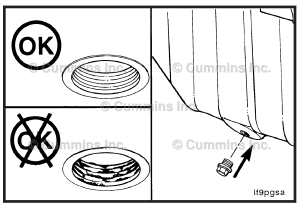
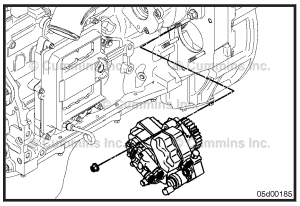
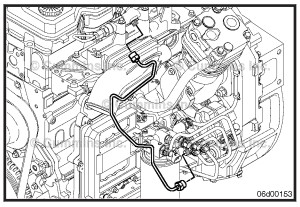
Torque Value:
M10

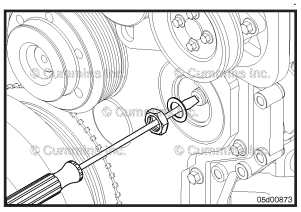
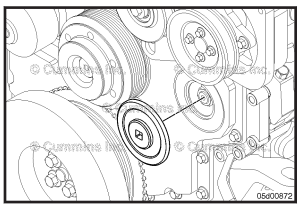
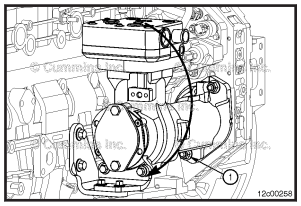
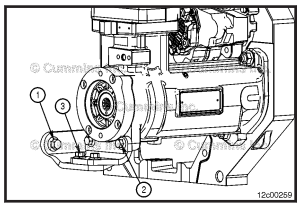
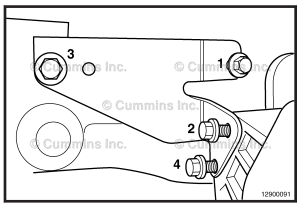
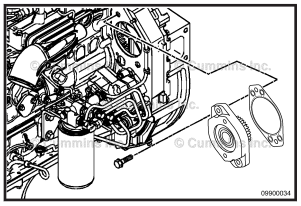
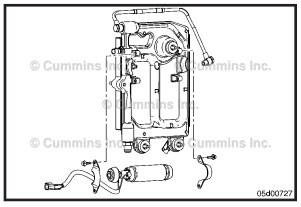
Step 1	47 N•m	[35 ft-lb]

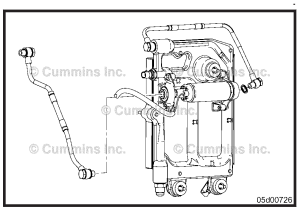
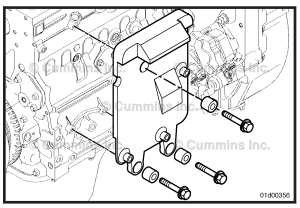
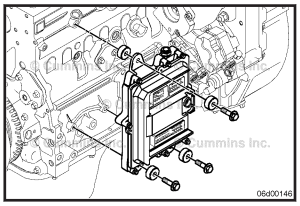
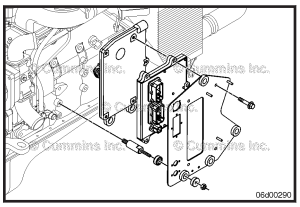
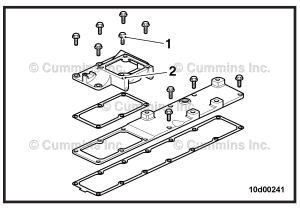
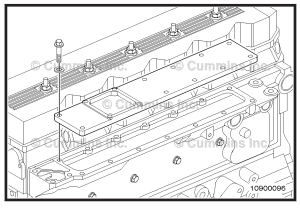
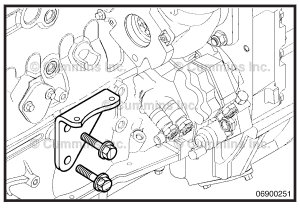
Torque Value:
M8

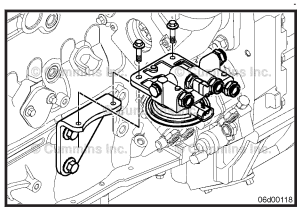
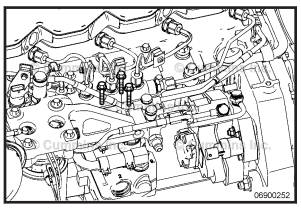
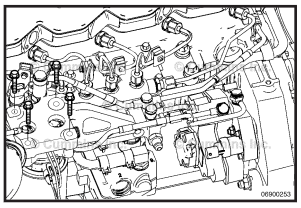
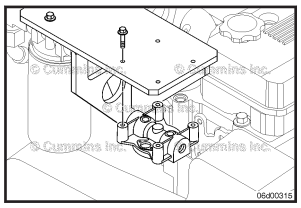
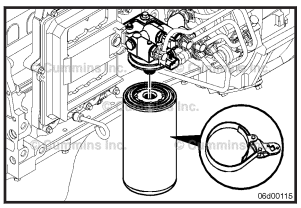
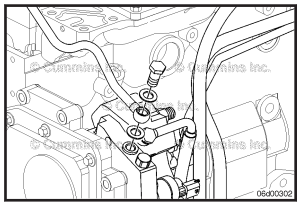
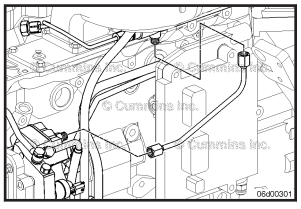
Step 1	24 N•m	[212 in-lb]

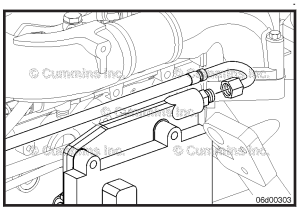
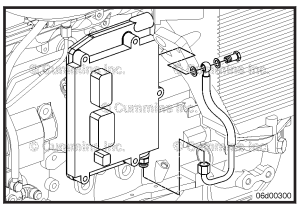
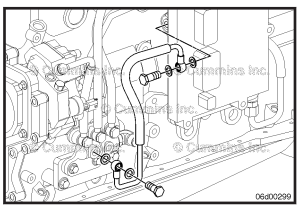
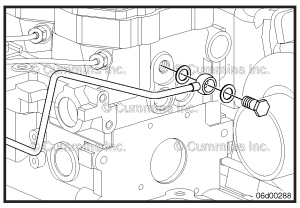
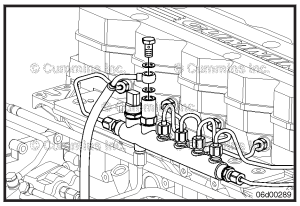
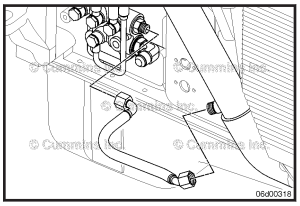
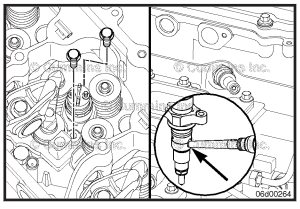
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Gear Housing, Front (001-033)				
Front Gear Housing Mounting Capscrews		24 N•m	[18 ft-lb]	
Oil Pan To Gear Housing Mounting Capscrews		24 N•m	[18 ft-lb]	
Camshaft (001-008)				
		24 N•m	[212 in-lb]	
		24 N•m	[212 in-lb]	
Camshaft Gear (Camshaft Installed) (001-012)				
Camshaft Gear Capscrews		36 N•m	[27 ft-lb]	
Block Stiffener Plate (001-089)				
Torque Value:				
Block Stiffener Plate Capscrews				
Step 1	43 N•m	[32 ft-lb]		
Lubricating Oil Suction Tube (Block-Mounted) (007-035)				
Suction Tube Capscrews		24 N•m	[212 in-lb]	

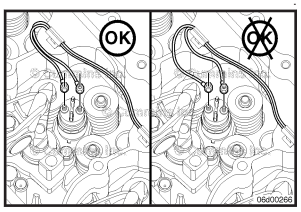
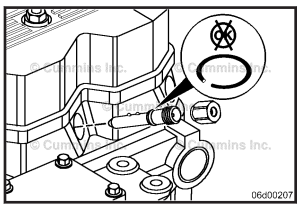
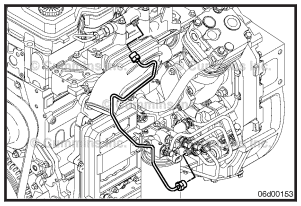
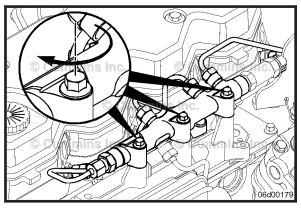
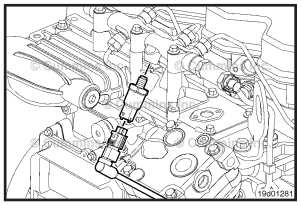
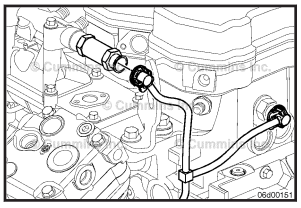
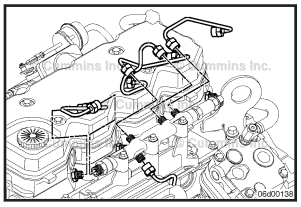
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Lubricating Oil Pan (007-025)				
Oil Pan Suspended - (Four Cylinder) Capscrew		26 N•m	[230 in-lb]	
Oil Pan, Suspended (Six-Cylinder) Capscrew		26 N•m	[230 in-lb]	
Four-Cylinder, Standard Capscrew		28 N•m	[249 in-lb]	
Six-Cylinder, Standard Capscrew		28 N•m	[249 in-lb]	
Lubricating Oil Pan Drain Plug		60 N•m	[44 ft-lb]	
Fuel Pump (005-016)				
Fuel Pump Mounting Nuts		25 N•m	[221 in-lb]	
Torque Value: 3.9L and 5.9L High-Pressure Supply Line				
Step 1		30 N•m	[22 ft-lb]	
Torque Value: 4.5L and 6.7L High-Pressure Supply Line				
Step 1		30 N•m	[22 ft-lb]	

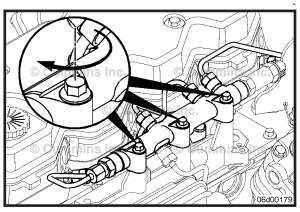
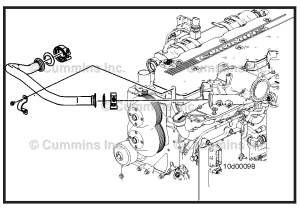
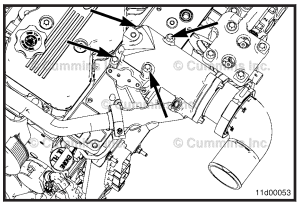
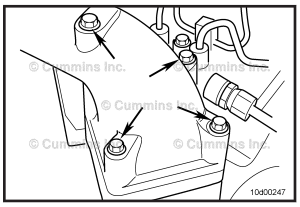
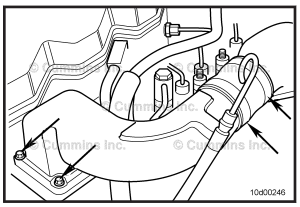
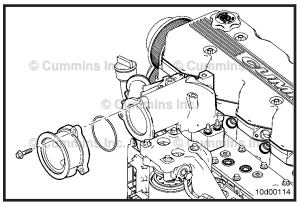
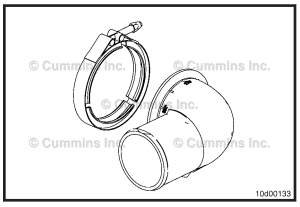
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Frnt Gear Train Gear Retaining Nut		105 N•m	[77 ft-lb]	
Front Gear Train Fuel Pump Drive Access Cover.		8 N•m	[71 in-lb]	
77 N•m [57 ft-lb]				
Air Compressor (012-014)		77 N•m	[57 ft-lb]	
		24 N•m 43 N•m 77 N•m	[212 in-lb] [32 ft-lb] [57 ft-lb]	
77 N•m [57 ft-lb]				
		24 N•m	[212 in-lb]	
Accessory Drive (009-001) Accessory Drive To Rear Gear Housing Capscrews		62 N•m	[46 ft-lb]	
Fuel Lift Pump (005-045) Fuel Lift Pump Mounting Capscrews		7 N•m	[62 in-lb]	

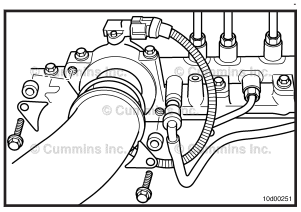
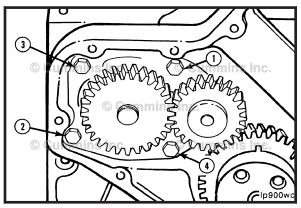
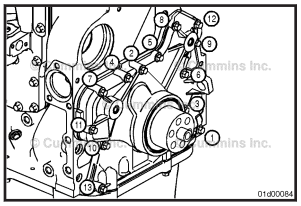
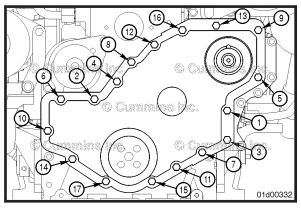
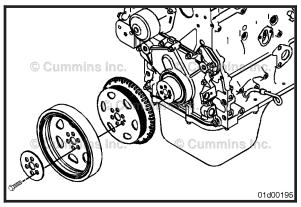
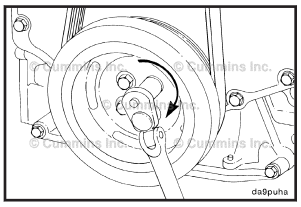
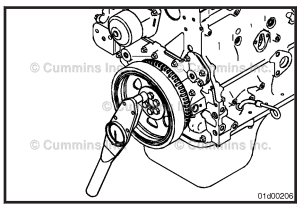
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Fuel Lift Pump Outlet Fuel Line Fittings		24 N•m 25 N•m	[212 in-lb] [221 in-lb]	
ECM Mounting Plate (001-103) Ecm Mounting Plate To Cylinder Block Mounting Capscrews.		24 N•m	[18 ft-lb]	
ECM Cooling Plate, Fuel Cooled (006-006) Ecm Cooling Plate Mounting Capscrews		24 N•m	[212 in-lb]	
Ecm Cooling Plate Assembly Mounting Capscrews		24 N•m	[212 in-lb]	
Air Intake Manifold (010-023) **Torque Value:** Air Intake Manifold Cover Step 1	24 N•m	[18 ft-lb]		
Torque Value: Air Intake Manifold Cover Step 1	24 N•m	[18 ft-lb]		
Fuel Filter Head (006-017) Fuel Filter Head Bracket Mounting Capscrews		24 N•m	[212 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Fuel Filter Head Mounting Capscrews		24 N•m	[212 in-lb]	
Fuel Filter Head Bracket Mounting Capscrews		24 N•m	[212 in-lb]	
Fuel Filter Head Mounting Capscrews		24 N•m	[212 in-lb]	
Fuel Filter Head Mounting Capscrews		30 N•m	[25 ft-lb]	
Fuel Filter (Spin-On Type) (006-015) Fuel Filter (Spin-On)		23 N•m	[17 ft-lb]	
Fuel Supply Lines (006-024)				
Torque Value: Fuel Filter Connection Step 1	37 N•m	[27 ft-lb]		
Torque Value: Banjo Bolt Connection Step 1	24 N•m	[221 in-lb]		
Torque Value: Fuel Rail Fitting Step 1	37 N•m	[27 ft-lb]		
Torque Value: Fuel Pump Banjo Bolt Step 1	24 N•m	[221 in-lb]		

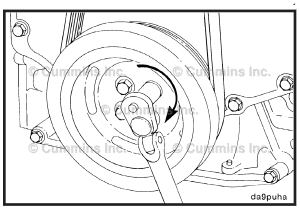
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Torque Value: Fuel Line Straight Thread Connections				
Step 1	37 N•m		[27 ft-lb]	
Torque Value: P-Clips				
Step 1	24 N•m		[221 in-lb]	
Torque Value: Straight Thread Connection				
Step 1	37 N•m		[27 ft-lb]	
Torque Value: Banjo Bolt Connection				
Step 1	24 N•m		[221 in-lb]	
Torque Value: Banjo Bolt Connections				
Step 1	24 N•m		[221 in-lb]	
Fuel Drain Lines (006-013)				
Cylinder Head Fuel Drain Line Fitting And Check Valve		24 N•m 24 N•m	[212 in-lb] [212 in-lb]	
Fuel Pressure Relief Valve Drain Line		24 N•m 24 N•m	[212 in-lb] [212 in-lb]	
Combined Fuel Manifold To Fuel Cooler Drain Line		24 N•m	[212 in-lb]	
Injector (006-026)		15 N•m	[133 in-lb]	
	10 N•m		[89 in-lb]	
	8 N•m		[71 in-lb]	

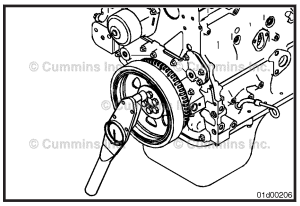
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Injector Solenoid Wires Nuts.		1.5 N•m	[13 in-lb]	
Fuel Connector (Head Mounted) (006-052)				
Torque Value:				
Fuel Connector (cylinder head-mounted)				
Step 1	55 N•m	[41 ft-lb]		
Fuel Rail (006-060)				
	3.9L and 5.9L High-Pressure Supply Line 30 22 4.5L and 6.7L High-Pressure Supply Line 36 27			
		24 N•m	[212 in-lb]	
Fuel Rail Capscrews		24 N•m	[212 in-lb]	
Fuel Pressure Sensor		70 N•m	[52 ft-lb]	
Pressure Relief Valve		100 N•m	[74 ft-lb]	
Injector Supply Lines (High Pressure) (006-051)				
Injector High-Pressure Supply Lines For		22 N•m	[195 in-lb]	
3.9L And 5.9L Engines Without Electric Lift		30 N•m	[22 ft-lb]	
Pump		35 N•m	[26 ft-lb]	

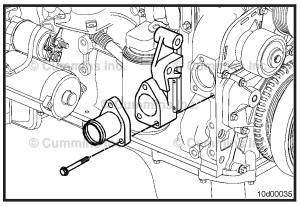
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Injector Supply Line Brace Capscrews		24 N•m 24 N•m	[212 in-lb] [212 in-lb]	
Air Intake Connection (010-080) Intake Manifold Cover Capscrews		11 N•m	[97 in-lb]	
Intake Manifold Cover Capscrews		24 N•m	[212 in-lb]	
Air Intake Connection Rear Portion Capscrews		15 N•m	[133 in-lb]	
Air Intake Connection Front Portion Capscrews		15 N•m 8 N•m	[133 in-lb] [71 in-lb]	
Air Intake Connection Adapter (010-131) Two Piece Air Intake Connection Adapter Capscrews.		24 N•m	[212 in-lb]	
Two Piece Air Intake Connection Adapter V Band Clamp		8 N•m	[71 in-lb]	

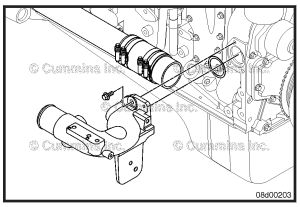
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Single Piece Air Intake Connection Adapter		10 N•m	[89 in-lb]	
Lubricating Oil Pump (007-031)				
Lubricating Oil Pump Capscrews Initial Torque		8 N•m 24 N•m	[70 in-lb] [212 in-lb]	
Gear Cover, Front (001-031)				
Front Cover Capscrew		24 N•m	[212 in-lb]	
Crankshaft Seal, Front (001-023)				
Front Cover Capscrews.		24 N•m	[18 ft-lb]	
Crankshaft Speed Indicator Ring (001-071)				
Torque Value:				
Step 1	50 N•m	[37 ft-lb]		
Step 2	Rotate 90 degrees			
Vibration Damper, Viscous (001-052)				
Torque Value:				
Step 1	40 N•m	[30 ft-lb]		
Step 2	Rotate 60 degrees			
Torque Value:				
Step 1	50 N•m	[37 ft-lb]		
Step 2	Rotate 90 degrees			

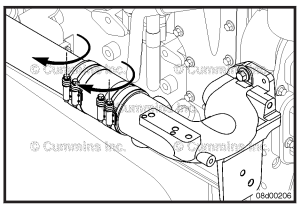
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Vibration Damper, Rubber (001-051)				
Torque Value:				
Step 1	40 N•m	[30 ft-lb]		
Step 2	Rotate 60 degrees			
Torque Value:				
Step 1	50 N•m	[37 ft-lb]		
Step 2	Rotate 90 degrees			
Water Inlet Connection (008-082)				
Torque Value:				
M10				
Step 1	43 N•m	[32 ft-lb]		
Torque Value:				
M12				
Step 1	80 N•m	[59 ft-lb]		
Water Inlet Mounting Capscrews		43 N•m	[32 ft-lb]	
Water Inlet Connection Hose Clamps		8 N•m	[71 in-lb]	
	24 N•m	[212 in-lb]		
	30 N•m	[22 ft-lb]		
Rocker Lever (003-008)				
Pedestal Mounting Capscrews		36 N•m	[27 ft-lb]	
Rocker Lever Housing (003-013)				
Rocker Lever Housing Capscrews		24 N•m	[212 in-lb]	

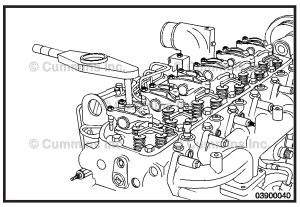


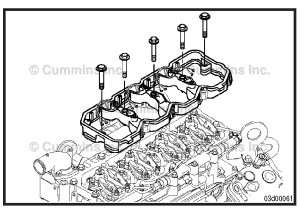


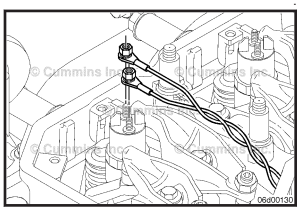
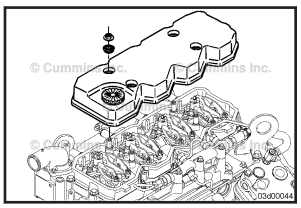
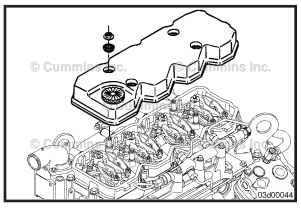
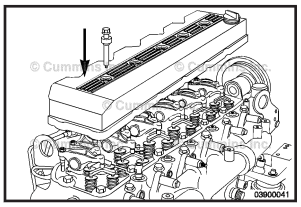
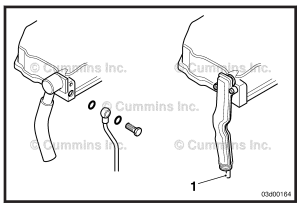
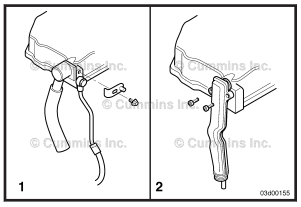
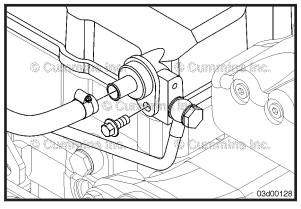


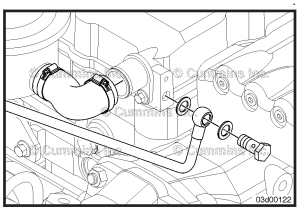
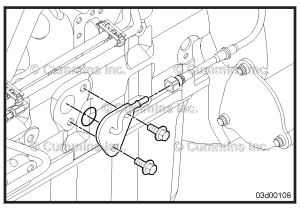
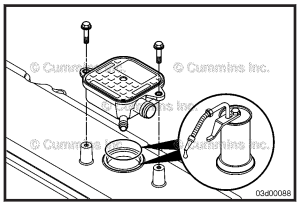
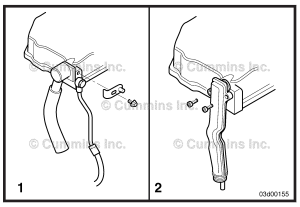
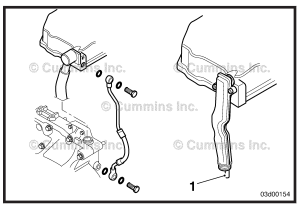
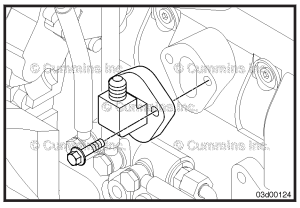
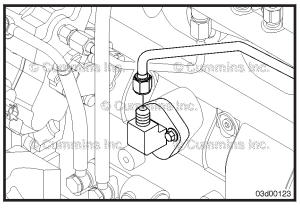


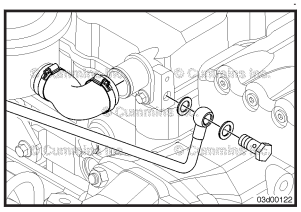
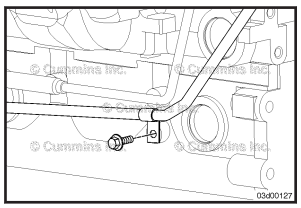
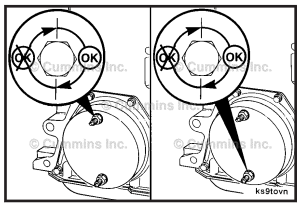
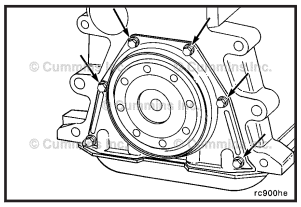
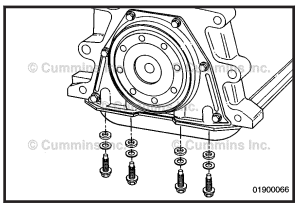
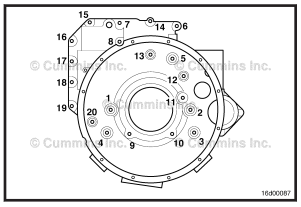
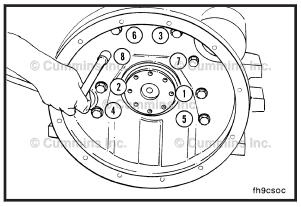


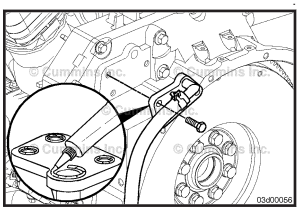
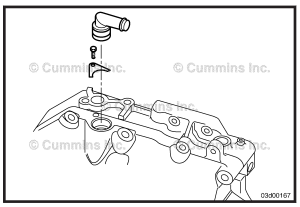
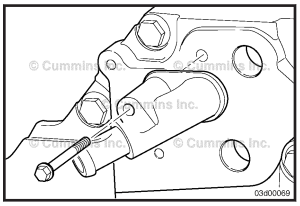
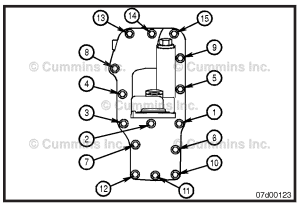
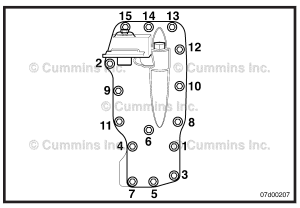
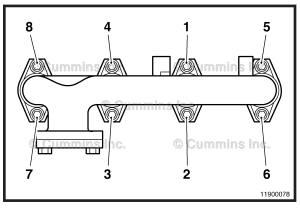
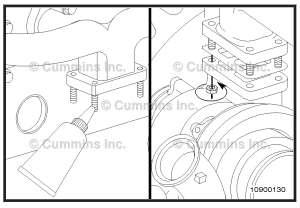


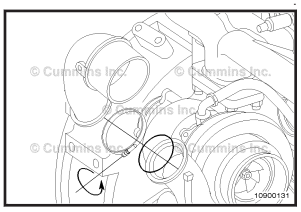
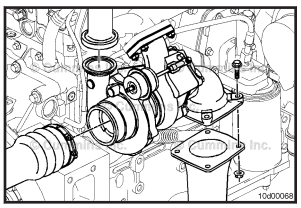
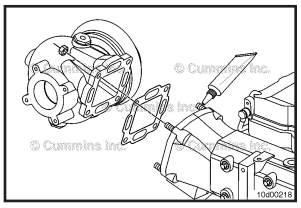
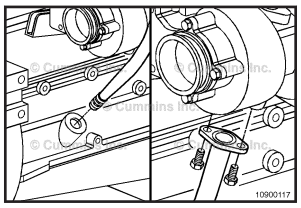
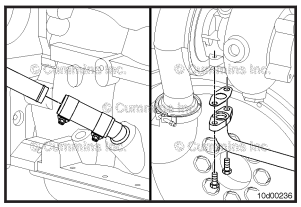
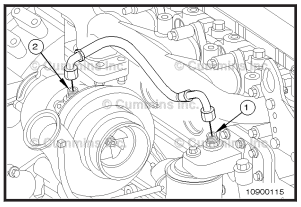
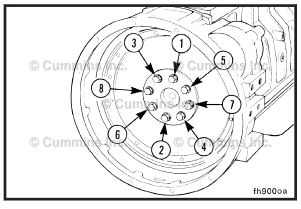


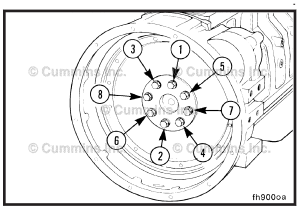
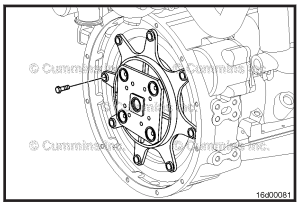
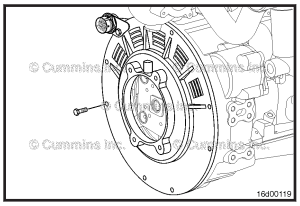
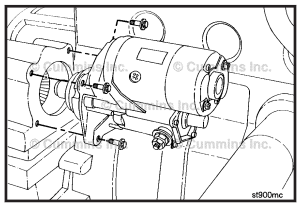
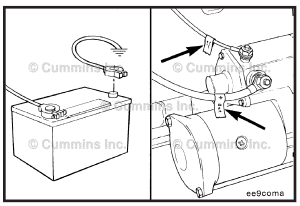
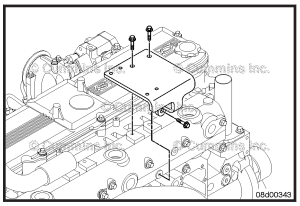
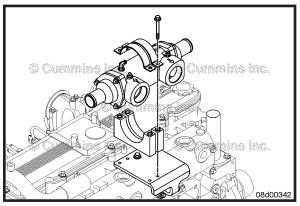
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Injector Wiring Nut		1.5 N•m	[13 in-lb]	
Rocker Lever Cover Capscrews		24 N•m	[212 in-lb]	
Rocker Lever Cover (003-011) Rocker Lever Cover Mounting Nuts.		24 N•m	[212 in-lb]	
Capscrew Mounted Rocker Lever Cover Capscrews.		24 N•m	[212 in-lb]	
Internal Mounted Crankcase Breather Banjo Bolt		12 N•m	[106 in-lb]	
Breather Tube Connections Capscrews		10 N•m	[89 in-lb]	
Open Draft Tube Type Cover Plate Capscrews		7 N•m 12 N•m	[62 in-lb] [106 in-lb]	

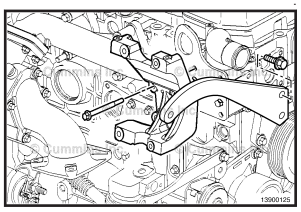
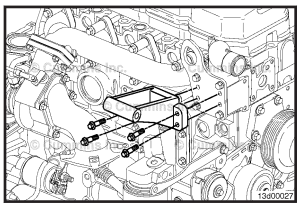
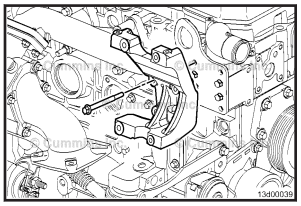
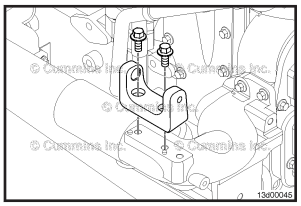
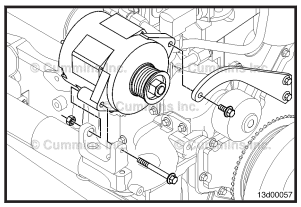
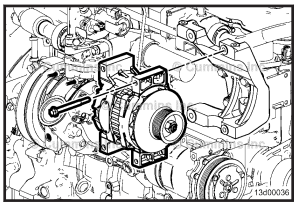
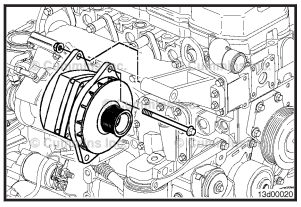
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Closed Crankcase Breather System Hose Clamps		6 N•m 12 N•m	[53 in-lb] [106 in-lb]	
Crankcase Breather (External) (003-001) Oil Drain Line Cover Plate Capscrews		24 N•m	[18 ft-lb]	
Crankcase Breather (External)		10 N•m	[89 in-lb]	
Crankcase Breather (Internal) (003-002) Breather Tube Connections Capscrews		10 N•m	[89 in-lb]	
Oil Drain Line Banjo Bolt		12 N•m 12 N•m	[106 in-lb] [106 in-lb]	
Breather Tube Check Valve Mounting Connector		24 N•m	[18 ft-lb]	
Breather Oil Drain Back Tube To Check Valve Fitting		30 N•m	[26 ft-lb]	

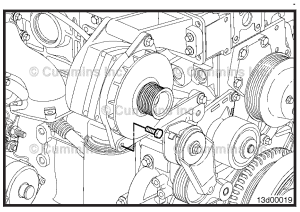
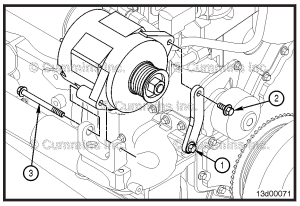
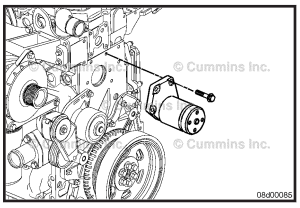
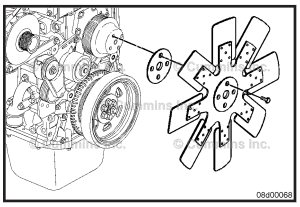
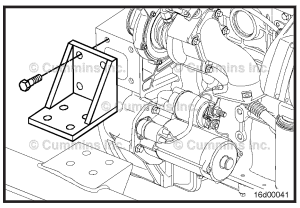
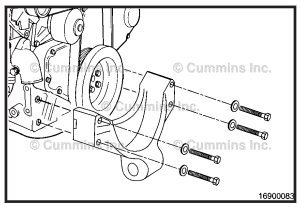
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Closed Crankcase Breather System Hose Clamps		6 N•m 12 N•m	[53 in-lb] [106 in-lb]	
P-Clip, Breather Oil Drain Back Tube		24 N•m	[18 ft-lb]	
Crankshaft Wear Sleeve, Rear (001-067)		20 N•m	[15 ft-lb]	
		10 N•m	[89 in-lb]	
		24 N•m	[18 ft-lb]	
Flywheel Housing (016-006) **Torque Value:** M10 Step 1	49 N•m	[36 ft-lb]		
Torque Value: M12 Step 1	85 N•m	[63 ft-lb]		
Marine Flywheel Housing Capscrews		77 N•m	[57 ft-lb]	

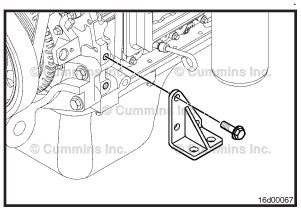
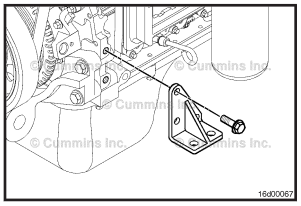
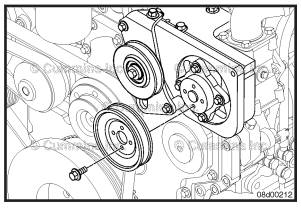
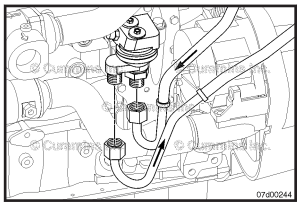
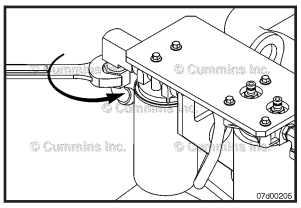
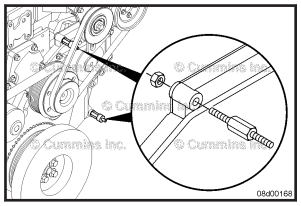
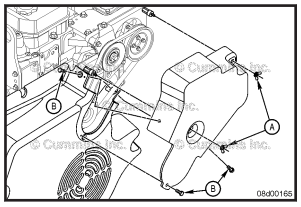
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Crankcase Breather Tube (003-018)				
Breather Tube Mounting Plate Adapter Capscrews		24 N•m	[18 ft-lb]	
Clamp Plate Breather Tube Adapter Capscrews		24 N•m	[18 ft-lb]	
Bearher Tube Adapter Capscrew		24 N•m	[18 ft-lb]	
Lubricating Oil Cooler (007-003)				
Lubricating Oil Cooler Capscrew		24 N•m	[212 in-lb]	
High Mount Lubricating Oil Cooler Capscrew		24 N•m	[212 in-lb]	
Exhaust Manifold, Dry (011-007)				
Exhaust Manifold Capscrews Torque		53 N•m 43 N•m	[39 ft-lb] [32 ft-lb]	
Turbocharger (010-033)				
Automotive Turbocharger Mounting Nuts		43 N•m	[32 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Turbocharger Compressor Discharge Outlet Clamp		8 N•m	[71 in-lb]	
Turbocharger Compressor Inlet Clamp		8 N•m 8 N•m	[71 in-lb] [71 in-lb]	
Marine Turbocharger Mounting Nuts		43 N•m	[32 ft-lb]	
Turbocharger Oil Drain Line (010-045) Turbocharger Oil Drain Line Capscrews		10 N•m 23 N•m	[89 in-lb] [204 in-lb]	
Turbocharger Oil Drain Line Connection		23 N•m 8 N•m	[204 in-lb] [71 in-lb]	
Turbocharger Oil Supply Line (010-046) Turbocharger Oil Supply Line		28 N•m	[21 ft-lb]	
Flywheel (016-005) **Torque Value:** Step 1 Step 2	 30 N•m Plus 60-degree turn	 [22 ft-lb]		

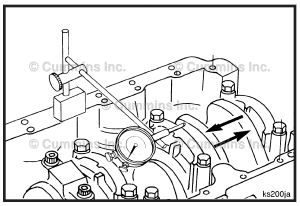
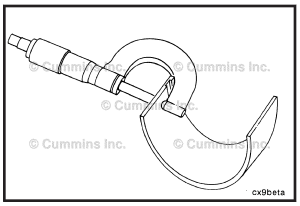
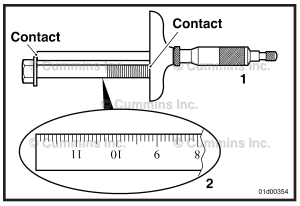
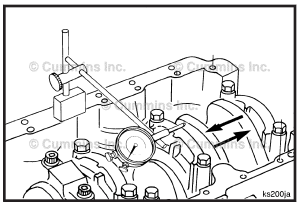
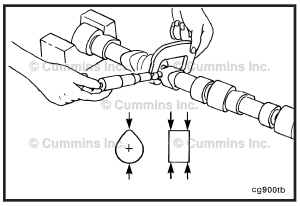
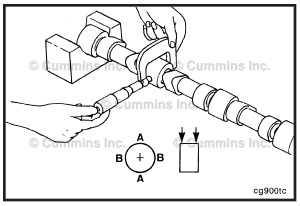
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Flexplate (016-004)				
Torque Value:				
Flexplate Capscrews				
Step 1	30 N•m	[22 ft-lb]		
Step 2	Plus 60-degree turn			
				
Flexplate Mounting Capscrews		44 N•m	[32 ft-lb]	
				
Flex-Coupling Guard Plate Mounting Capscrews		36 N•m	[27 ft-lb]	
				
Starting Motor (013-020)				
Starting Motor Mounting Capscrews		43 N•m	[32 ft-lb]	
				
Torque Value:				
M5				
Step 1	4 N•m	[35 in-lb]		
Torque Value:				
M10				
Step 1	21 N•m	[185 in-lb]		
				
Coolant Thermostat Housing Support (008-015)				
Thermostat Housing Support Bracket		44 N•m	[32 ft-lb]	
				
Coolant Thermostat Housing (008-014)				
Keel Cooled Thermostat Housing Clamps		44 N•m	[32 ft-lb]	
				

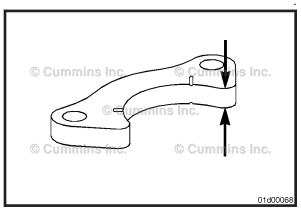
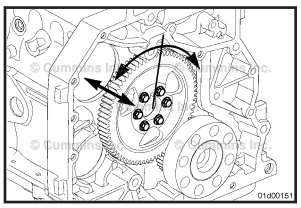
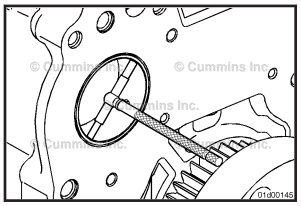
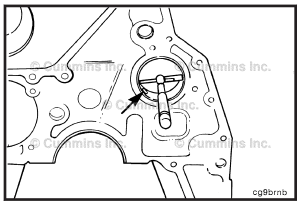
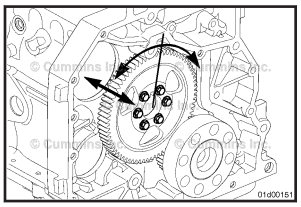
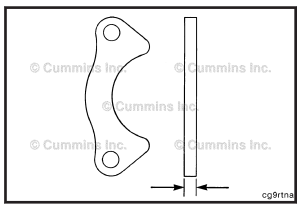
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Alternator Bracket (013-003)				
Spool Mount Upper And Lower Alternator Bracket Mounting Capscrews M8		24 N•m 43 N•m	[18 ft-lb] [32 ft-lb]	
Spool Mount Upper And Lower Alternator Bracket Mounting Capscrews M10				
Hinge Mount Upper And Lower Alternator Bracket Mounting Capscrews M8		24 N•m 43 N•m	[18 ft-lb] [32 ft-lb]	
Hinge Mount Upper And Lower Alternator Bracket Mounting Capscrews M10				
Alternator Bracket Mounting Capscrews		45 N•m	[33 ft-lb]	
Alternator Mounting Bracket Capscrews		54 N•m	[40 ft-lb]	
Alternator (013-001)				
Torque Value: Lower Mounting Capscrew Step 1	40 N•m	[30 ft-lb]		
Torque Value: Upper Link Mounting Capscrew Step 1	24 N•m	[212 in-lb]		
Torque Value: M10 Capscrew Step 1	36 N•m	[27 ft-lb]		
Torque Value: M12 Capscrew Step 1	64 N•m	[47 ft-lb]		
Alternator Capscrew		40 N•m	[30 ft-lb]	

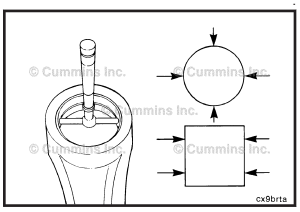
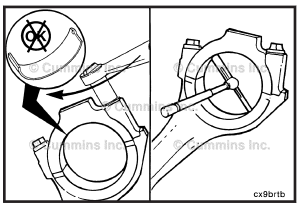
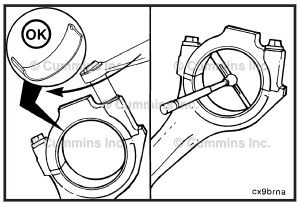
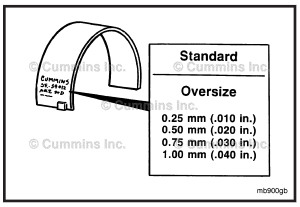
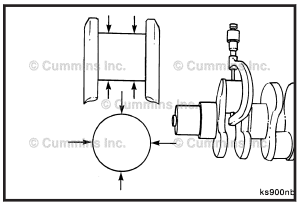
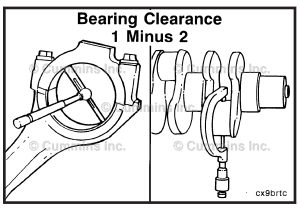
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Alternator Link Capscrew		24 N•m	[212 in-lb]	
Torque Value: Capscrews (1,3) Step 1	44 N•m	[33 ft-lb]		
Torque Value: Capscrew (2) Step 1	35 N•m	[26 ft-lb]		
Fan Hub, Belt Driven (008-036) Fan Hub Mounting Capscrews		33 N•m	[24 ft-lb]	
Fan Spacer and Pulley (008-039)				
Torque Value: M6 Step 1	10 N•m	[89 in-lb]		
Torque Value: M10 Step 1	43 N•m	[32 ft-lb]		
Torque Value: M12 Step 1	77 N•m	[57 ft-lb]		
Engine Support Bracket, Rear (016-003) Support Bracket Capscrew		77 N•m	[57 ft-lb]	
Engine Support Bracket, Front (016-002)				
Torque Value: Grade 8.8 Step 1	80 N•m	[60 ft-lb]		
Torque Value: Grade 10.9 Step 1	115 N•m	[85 ft-lb]		
Torque Value: Grade 12.9 Step 1	125 N•m	[95 ft-lb]		

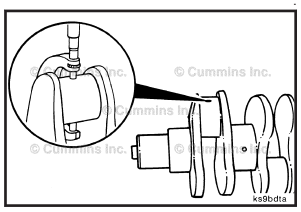
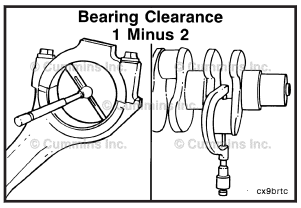
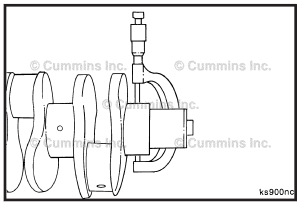
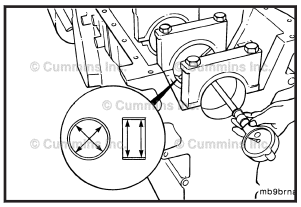
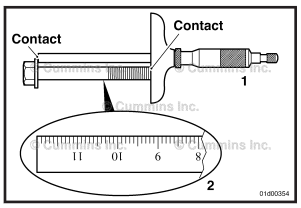
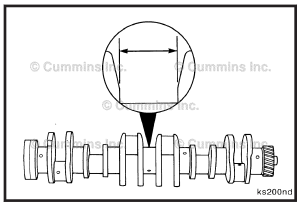
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Torque Value: Grade 8.8 Step 1	80 N•m	[60 ft-lb]		
Torque Value: Grade 10.9 Step 1	115 N•m	[85 ft-lb]		
Torque Value: Grade 12.9 Step 1	125 N•m	[95 ft-lb]		
Marine Front Engine Support Bracket Mounting Capscrews		150 N•m	[111 ft-lb]	
Sea Water Pump Pulley (008-127) Sea Water Pump Pulley Mounting Capscrews		10 N•m	[89 in-lb]	
Lubricating Oil Lines (007-092) Lubricating Oil Return Hose		76 N•m 76 N•m	[56 ft-lb] [56 ft-lb]	
Lubricating Oil Supply And Return Hoses At Filter Head		76 N•m	[56 ft-lb]	
Belt Guard (008-001) Belt Guard Mounting Studs		15 N•m	[133 in-lb]	
Upper Belt Guard Mounting Capscrews		5 N•m	[44 in-lb]	

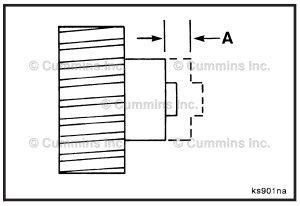
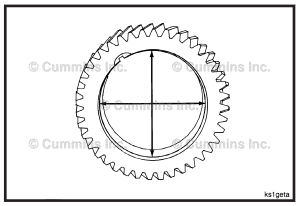
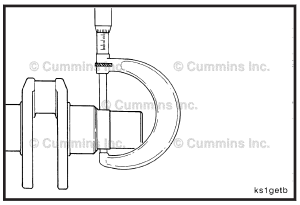
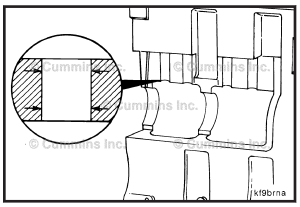
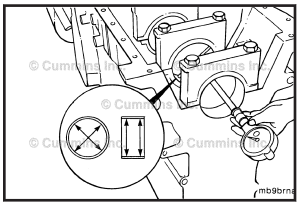
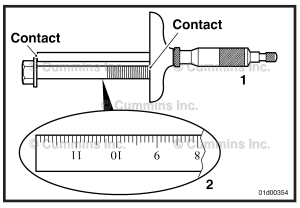
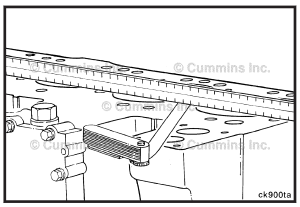
Cylinder Block - Group 01 - Specifications

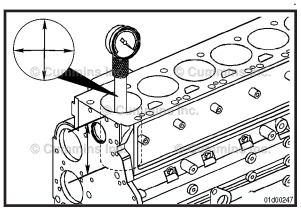
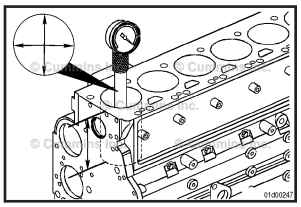
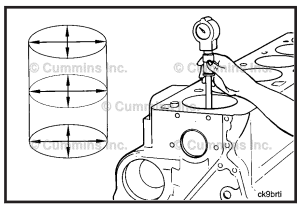
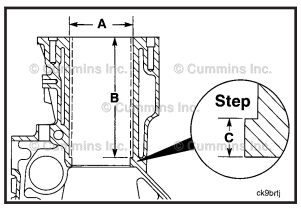
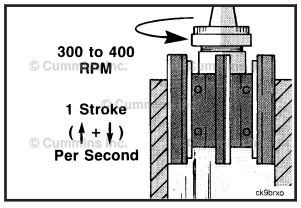
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Bearings, Main (001-006)					
Crankshaft End Play		0.102 mm	MIN	0.004 in	
		0.432 mm	MAX	0.017 in	
Standard		2.456	MIN	0.0967	
		2.464	MAX	0.097	
Oversize 0.25 mm [0.010 in]		2.706	MIN	0.1067	
		2.714	MAX	0.117	
Oversize 0.50 mm [0.020 in]		2.956	MIN	0.1167	
		2.964	MAX	0.117	
Oversize 0.75 mm [0.030 in]		3.206	MIN	0.1267	
		3.214	MAX	0.127	
Oversize 1.00 mm [0.040 in]		3.456	MIN	0.1367	
		3.464	MAX	0.137	
Main Bearing Underhead Capscrew Length		120.00 mm	MAX	4.724 in	
Crankshaft End Play		0.102 mm	MIN	0.004 in	
		0.432 mm	MAX	0.017 in	
Camshaft (001-008)					
Four Cylinder		609.6	MIN	24	
Six Cylinder		812.8	MIN	32	
Intake		47.175	MIN	1.857	
		47.855	MAX	1.884	
Exhaust		45.632	MIN	1.797	
		46.312	MAX	1.823	
Journal Diameter		53.995 mm	MIN	2.1258 in	
		54.045 mm	MAX	2.1278 in	

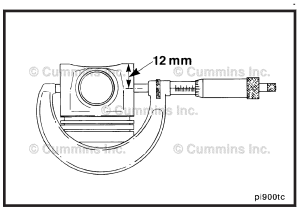
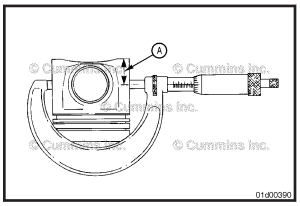
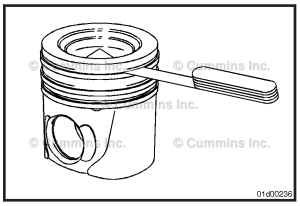
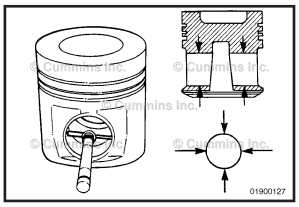
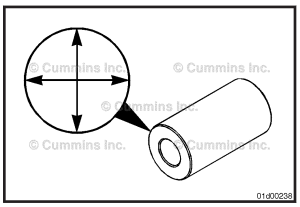
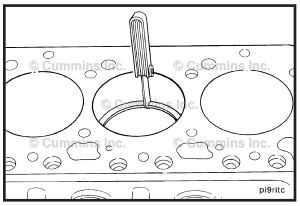
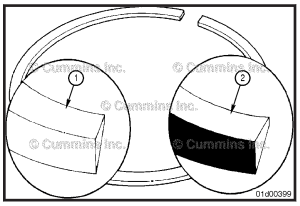
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Camshaft Thrust Plate Thickness (Front Gear Train Engines)		9.40 mm	MIN	0.370 in	
		9.60 mm	MAX	0.378 in	
Camshaft Thrust Plate Thickness (Rear Gear Train Engines)		5.25 mm	MIN	0.207 in	
		5.35 mm	MAX	0.211 in	
Camshaft End Play (A)		0.10 mm	MIN	0.004 in	
		0.36 mm	MAX	0.014 in	
Camshaft Gear Backlash Limits (B)		0.076 mm	MIN	0.003 in	
		0.280 mm	MAX	0.011 in	
Camshaft End Play (A)		0.12 mm	MIN	0.005 in	
		0.50 mm	MAX	0.020 in	
Camshaft Gear Backlash Limits (B)		0.08 mm	MIN	0.003 in	
		0.25 mm	MAX	0.010 in	
Camshaft Bushings (001-010)					
Camshaft Bore (Camshaft Bushing Previously Installed)		59.248	MAX	2.3326	
Camshaft Bore (Camshaft Bushing not Previously Installed)		54.164	MAX	2.1324	
Camshaft Bore (Bushing Installed)		54.083 mm	MIN	2.1293 in	
		54.147 mm	MAX	2.1318 in	
Camshaft Gear (Camshaft Installed) (001-012)					
Camshaft End Play		0.100 mm	MIN	0.004 in	
		0.360 mm	MAX	0.014 in	
Camshaft Backlash		0.076 mm	MIN	0.003 in	
		0.280 mm	MAX	0.011 in	
Camshaft Gear (Camshaft Removed) (001-013)					
Camshaft Thrust Plate		9.40 mm	MIN	0.370 in	
		9.60 mm	MAX	0.378 in	

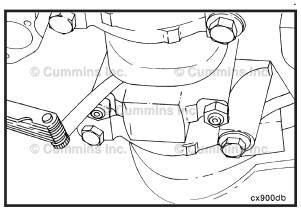
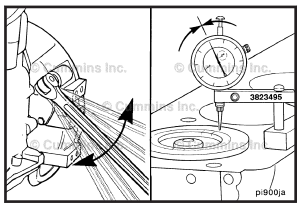
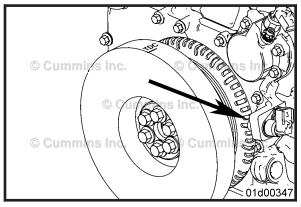
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Connecting Rod (001-014)					
Connecting Rod Piston Pin Bushing Diameter		40.019 mm	MIN	1.5756 in	
		40.042 mm	MAX	1.5765 in	
Connecting Rod Crankshaft Bore Diameter Bearings Removed		72.99 mm	MIN	2.873 in	
		73.01 mm	MAX	2.875 in	
Standard		69.05	MIN	2.719	
		69.10	MAX	2.720	
Oversize					
0.25 mm [0.010 in]		68.80	MIN	2.709	
		68.85	MAX	2.711	
0.50 mm [0.020 in]		68.55	MIN	2.699	
		68.60	MAX	2.701	
0.75 mm [0.030 in]		68.30	MIN	2.689	
		68.35	MAX	2.691	
1.00 mm [0.040 in]		68.05	MIN	2.680	
		68.10	MAX	2.681	
Standard		68.962	MIN	2.7150	
		69.013	MAX	2.7170	
Undersize					
0.25 mm [0.010 in]		68.712	MIN	2.7052	
		68.763	MAX	2.7072	
0.50 mm [0.020 in]		68.462	MIN	2.6954	
		68.513	MAX	2.6974	
0.75 mm [0.030 in]		68.212	MIN	2.6855	
		68.263	MAX	2.6875	
1.00 mm [0.040 in]		67.962	MIN	2.6767	
		68.013	MAX	2.6787	
Connecting Rod to Crankshaft Bearing Clearance		0.04 mm	MIN	0.002 in	
		0.12 mm	MAX	0.005 in	
Crankshaft Front and Rear Oil Seal Wear Groove		0.25 mm	MAX	0.010 in	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Crankshaft (001-016)					
Standard		68.987	MIN	2.7160	
		69.027	MAX	2.7176	
Undersize					
0.25 mm [0.010 in]		68.712	MIN	2.7052	
		68.774	MAX	2.7076	
0.50 mm [0.020 in]		68.462	MIN	2.6954	
		68.527	MAX	2.6979	
0.75 mm [0.030 in]		68.212	MIN	2.6855	
		68.274	MAX	2.6879	
1.00 mm [0.040 in]		67.962	MIN	2.6767	
		68.027	MAX	2.6782	
Connecting Rod to Crankshaft Bearing Clearance		0.04 mm	MIN	0.002 in	
		0.12 mm	MAX	0.005 in	
Standard		82.962	MIN	3.2662	
		83.013	MAX	3.2682	
Undersize					
0.25 mm [0.010 in]		82.712	MIN	3.2564	
		82.763	MAX	3.2584	
0.50 mm [0.020 in]		82.462	MIN	3.2465	
		82.513	MAX	3.2485	
0.75 mm [0.030 in]		82.212	MIN	3.2367	
		82.263	MAX	3.2387	
1.0 mm [0.040 in]		81.962	MIN	3.2268	
		82.013	MAX	3.2289	
Main Bearing Bore to Crankshaft Bearing Clearance		0.04 mm	MIN	0.002 in	
		0.12 mm	MAX	0.005 in	
Main Bearing Underhead Capscrew Length		120.00 mm	MAX	4.724 in	
Crankshaft Thrust Face Width (Standard)		37.48 mm	MIN	1.475 in	
		37.55 mm	MAX	1.478 in	
Crankshaft Damper Pilot Outside Diameter		24.92 mm	MIN	0.981 in	
		25.00 mm	MAX	0.984 in	
Crankshaft Gear Journal Outside Diameter		70.59 mm	MIN	2.779 in	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
		70.61 mm	MAX	2.780 in	
Crankshaft End Clearance		0.102 mm 0.432 mm	MIN MAX	0.004 in 0.017 in	
Crankshaft Gear, Front (Crankshaft Removed) (001-019)					
Crankshaft Gear Bore Inside Diameter		70.51 mm 70.55 mm	MIN MAX	2.776 in 2.779 in	
Crankshaft Gear Journal Outside Diameter		70.59 mm 70.61 mm	MIN MAX	2.779 in 2.780 in	
Cylinder Block (001-026)					
Tappet Bore Diameter		16.000 mm 16.055 mm	MIN MAX	0.630 in 0.632 in	
Main Bearing Bore Diameter with Bearings Removed		87.983 mm 88.019 mm	MIN MAX	3.4639 in 3.4653 in	
Main Bearing Underhead Capscrew Length		120.00 mm	MAX	4.724 in	
End-to-End Side-to-Side		0.076 0.051	MAX MAX	0.003 0.002	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Cylinder Bore Diameter - 3.9L and 5.9L Engines Only (New Cylinder Block)		102.010 mm	MIN	4.0161 in	
		102.030 mm	MAX	4.0169 in	
Cylinder Bore Diameter - 3.9L and 5.9L Engines Only (Used Cylinder Block)		102.010 mm	MIN	4.0161 in	
		102.050 mm	MAX	4.0177 in	
Out-of-Roundness		0.038 mm	MAX	0.0015 in	
Taper		0.076 mm	MAX	0.003 in	
Cylinder Bore Diameter - 4.5L and 6.7L Engines Only (New Cylinder Block)		106.990 mm	MIN	4.2122 in	
		107.010 mm	MAX	4.2130 in	
Cylinder Bore Diameter - 4.5L and 6.7L Engines (Used Cylinder Block)		106.990 mm	MIN	4.2122 in	
		107.030 mm	MAX	4.2138 in	
Out-of-Roundness		0.038 mm	MAX	0.0015 in	
Taper		0.076 mm	MAX	0.003 in	
First Rebore		102.469	NOM	4.0342	
Second Rebore		102.969	NOM	4.0539	
Rebore		107.45	NOM	4.2303	
3.9L and 5.9L Machined Bore Diameter (A)		104.500 mm	MIN	4.1140 in	
		104.515 mm	MAX	4.1146 in	
4.5L and 6.7L Machined Bore Diameter (A)		109.700 mm	MIN	4.3189 in	
		109.715 mm	MAX	4.3195 in	
Cylinder Bore Depth (B)		192.65 mm	MAX	7.5846 in	
Standard Bore/Repair Sleeve		102.000	MIN	4.0157	
		102.040	MAX	4.0173	
First Rebore		102.500	MIN	4.0354	
		102.540	MAX	4.0370	
Second Rebore		103.000	MIN	4.0551	
		103.040	MAX	4.0567	
Standard Bore/Repair Sleeve		106.990	MIN	4.2122	
		107.010	MAX	4.2130	
Rebore		107.490	MIN	4.2319	
		107.510	MAX	4.2327	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Piston (001-043)					
3.9L and 5.9L Standard Piston Skirt Diameter		101.864 mm	MIN	4.0104 in	
		101.887 mm	MAX	4.0113 in	
4.5L and 6.7L Standard Piston Skirt Diameter		106.878 mm	MIN	4.2078 in	
		106.892 mm	MAX	4.2083 in	
Intermediate		0.040	MIN	0.0016	
		0.110	MAX	0.0043	
Oil control		0.040	MIN	0.0016	
		0.085	MAX	0.0033	
Piston Pin Bore		40.006 mm	MIN	1.5750 in	
		40.012 mm	MAX	1.5753 in	
Piston Pin Diameter		39.997 mm	MIN	1.5747 in	
		40.003 mm	MAX	1.5749 in	
Piston Rings (001-047)					
Top		0.29	MIN	0.011	
		0.58	MAX	0.023	
Intermediate		0.88	MIN	0.035	
		1.37	MAX	0.054	
Oil		0.28	MIN	0.011	
		0.77	MAX	0.030	
Top		0.30	MIN	0.012	
		0.46	MAX	0.018	
Phosphate Coated Intermediate		0.82	MIN	0.032	
		1.18	MAX	0.047	
Chrome Faced Intermediate		0.52	MIN	0.021	
		0.88	MAX	0.034	
Oil		0.22	MIN	0.010	
		0.58	MAX	0.023	

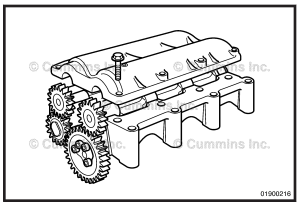
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Piston and Connecting Rod Assembly (001-054)					
Connecting Rod and Crankshaft Side Clearance		0.10 mm	MIN	0.004 in	
		0.33 mm	MAX	0.013 in	
Piston Protrusion		0.151 mm	MIN	0.006 in	
		0.485 mm	MAX	0.019 in	
Crankshaft Speed Indicator Ring (001-071)					
Crankshaft Speed/Position Sensor Air Gap		0.8 mm	MIN	0.032 in	
		1.5 mm	MAX	0.060 in	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	

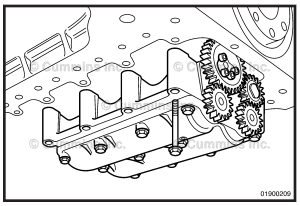
Cylinder Block - Group 01 - Torque Values

Balancer (001-004)

Balancer Assembly Cover Capscrews		32 N•m	[24 ft-lb]



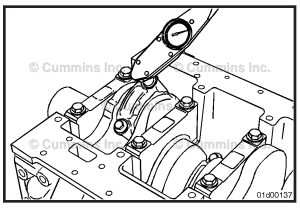
Balancer Installation Torque		48 N•m	[35 ft-lb]



Bearings, Connecting Rod (001-005)

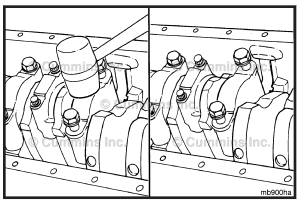
Torque Value:

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



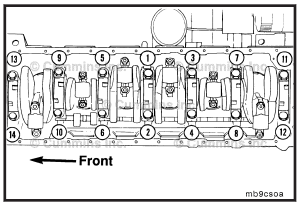
Bearings, Main (001-006)

Main Bearing Capscrews.		50 N•m	[37 ft-lb]



Torque Value:

Step 1	50 N•m	[37 ft-lb]
Step 2	80 N•m	[59 ft-lb]
Step 3	Rotate 90 degrees.	



Torque Value:
Previously Installed Main Bearing Capscrews

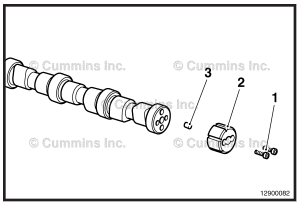
Step 1	60 N•m	[44 ft-lb]
Step 2	80 N•m	[59 ft-lb]
Step 3	Rotate 90 degrees.	

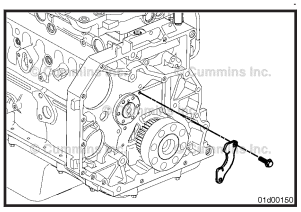
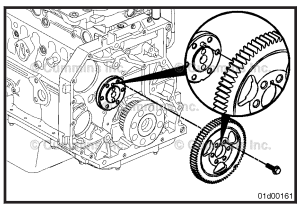
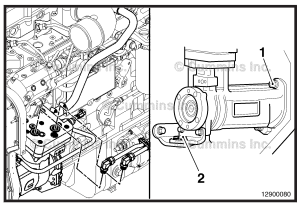
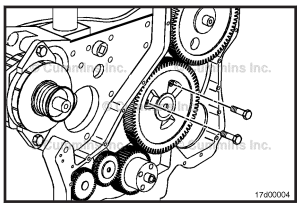
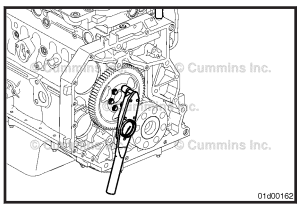
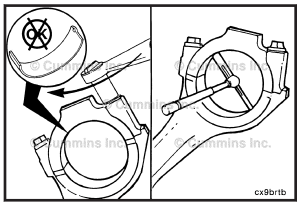
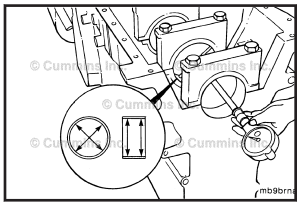
Torque Value:
New Main Bearing Capscrews

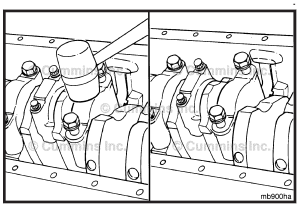
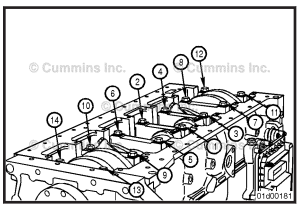
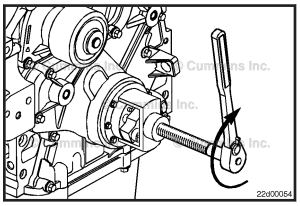
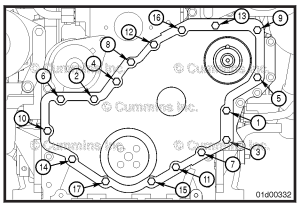
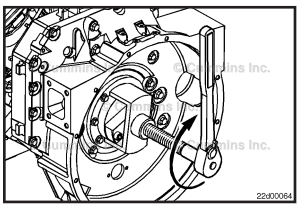
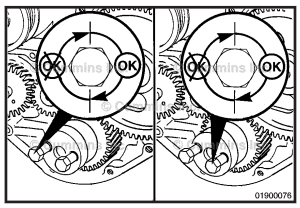
Step 1	120 N•m	[89 ft-lb]
Step 2	Loosen completely	
Step 3	60 N•m	[44 ft-lb]
Step 4	85 N•m	[63 ft-lb]
Step 5	Rotate 120 degrees.	

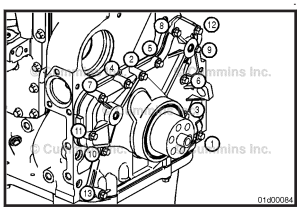
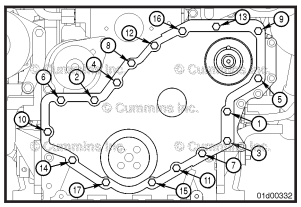
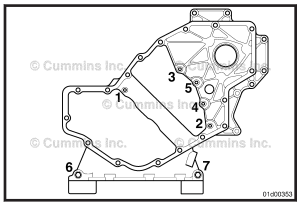
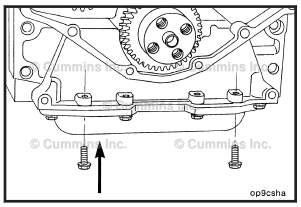
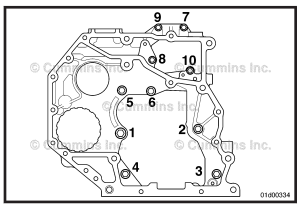
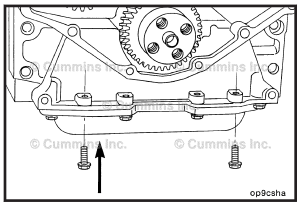
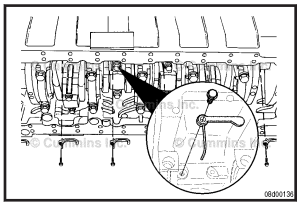
Camshaft (001-008)

	10 N•m	[89 in-lb]

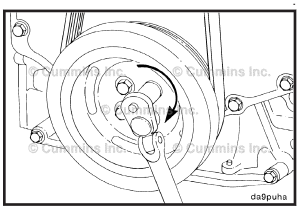


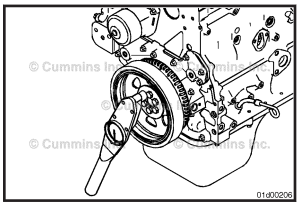
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
		24 N•m	[212 in-lb]	
		36 N•m	[27 ft-lb]	
		77 N•m 24 N•m 43 N•m 77 N•m	[57 ft-lb] [212 in-lb] [32 ft-lb] [57 ft-lb]	
		24 N•m	[212 in-lb]	
Camshaft Gear (Camshaft Installed) (001-012) Camshaft Gear Capscrews		36 N•m	[27 ft-lb]	
Connecting Rod (001-014) Connecting Rod Capscrews		100 N•m	[74 ft-lb]	
Crankshaft (001-016) Main Bearing Capscrews		176 N•m	[130 ft-lb]	

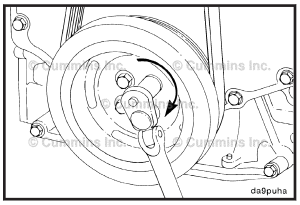
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
		50 N•m	[37 ft-lb]	
Torque Value:				
Step 1	50 N•m	[37 ft-lb]		
Step 2	80 N•m	[59 ft-lb]		
Step 3	Turn all capscrews through 90 degrees.			
Torque Value:				
Previously Installed Main Bearing Capscrews				
Step 1	50 N•m	[37 ft-lb]		
Step 2	60 N•m	[44 ft-lb]		
Step 3	80 N•m	[59 ft-lb]		
Step 4	Rotate 90 degrees.			
Torque Value:				
New Main Bearing Capscrews				
Step 1	120 N•m	[89 ft-lb]		
Step 2	Loosen completely			
Step 3	60 N•m	[44 ft-lb]		
Step 4	85 N•m	[63 ft-lb]		
Step 5	Rotate 120 degrees.			
Crankshaft Seal, Front (001-023)				
Crankshaft Seal Replacer Capscrews		33 N•m	[45 ft-lb]	
Front Cover Capscrews.		24 N•m	[18 ft-lb]	
Crankshaft Seal, Rear (001-024)				
Crankshaft Seal Replacer Capscrews		45 N•m	[33 ft-lb]	
Crankshaft Wear Sleeve, Front (001-025)				
Wear Sleeve Capscrew		20 N•m	[15 ft-lb]	
		176 N•m	[130 ft-lb]	

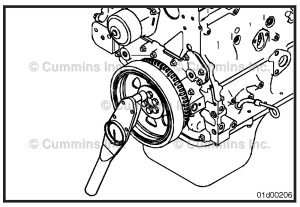
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Gear Cover, Front (001-031)				
Front Cover Capscrew		24 N•m	[212 in-lb]	
Front Gear Cover Capscrews.		24 N•m	[212 in-lb]	
Gear Housing, Front (001-033)				
Front Gear Housing Mounting Capscrews		24 N•m	[18 ft-lb]	
Oil Pan To Gear Housing Mounting Capscrews		24 N•m	[18 ft-lb]	
Gear Housing, Rear (001-034)				
Torque Value:				
M12				
Step 1	50 N•m	[37 ft-lb]		
Torque Value:				
M10				
Step 1	47 N•m	[35 ft-lb]		
Torque Value:				
M8				
Step 1	24 N•m	[212 in-lb]		
		28 N•m	[248 in-lb]	
Piston Cooling Nozzle (001-046)				
Torque Value:				
J-Jet Capscrew				
Step 1	15 N•m	[133 in-lb]		

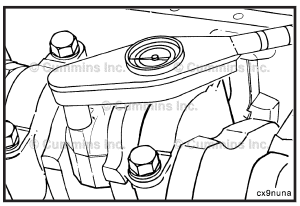
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Vibration Damper, Rubber (001-051)				
Torque Value:				
Step 1	40 N•m	[30 ft-lb]		
Step 2	Rotate 60 degrees			
Torque Value:				
Step 1	50 N•m	[37 ft-lb]		
Step 2	Rotate 90 degrees			
Vibration Damper, Viscous (001-052)				
Torque Value:				
Step 1	40 N•m	[30 ft-lb]		
Step 2	Rotate 60 degrees			
Torque Value:				
Step 1	50 N•m	[37 ft-lb]		
Step 2	Rotate 90 degrees			
Piston and Connecting Rod Assembly (001-054)				
Torque Value:				
Step 1	30 N•m	[22 ft-lb]		
Step 2	60 N•m	[44 ft-lb]		
Step 3	Rotate 60 degrees clockwise			
Crankshaft Wear Sleeve, Rear (001-067)			20 N•m	[15 ft-lb]
			10 N•m	[89 in-lb]

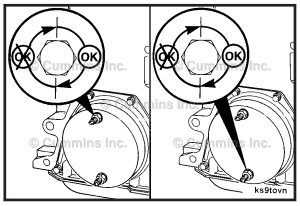


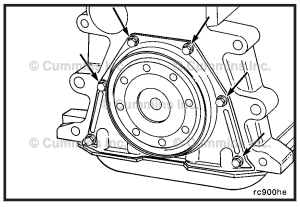


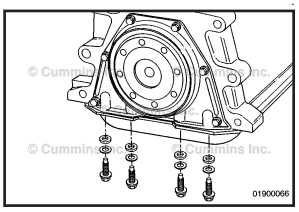
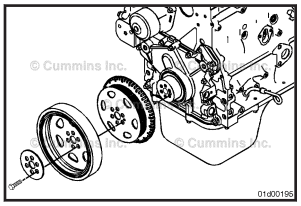
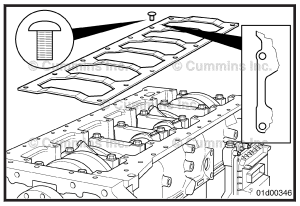
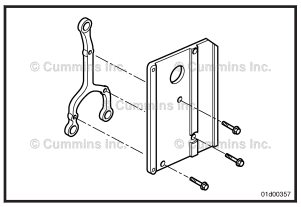
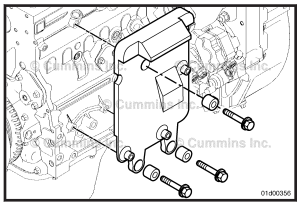
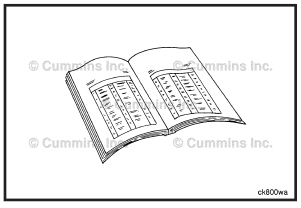




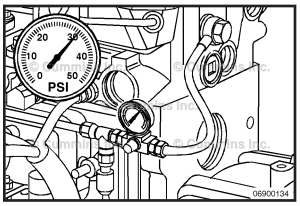
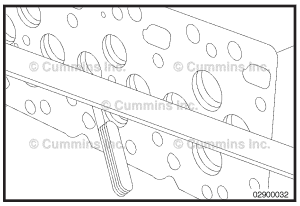
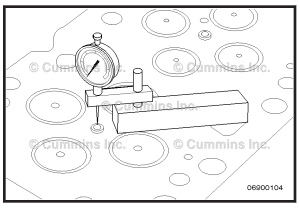
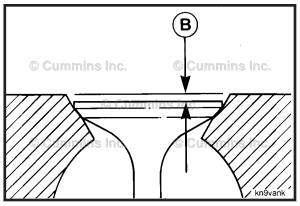
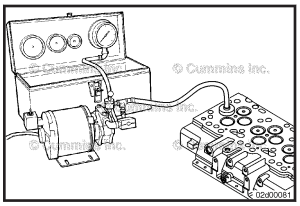
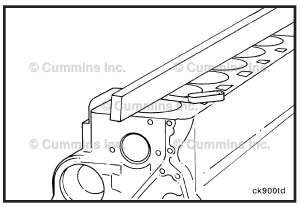
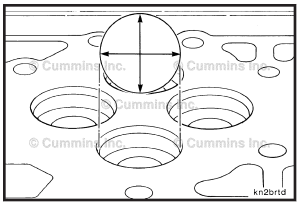


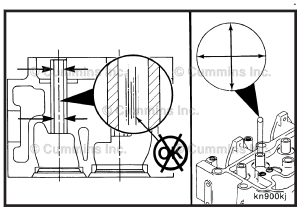
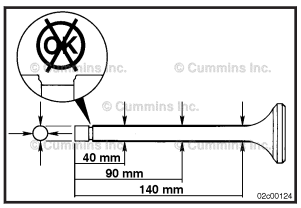
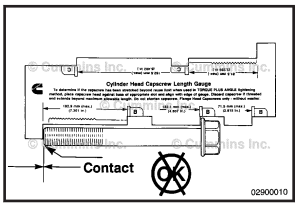
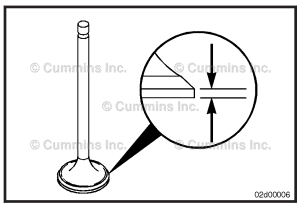
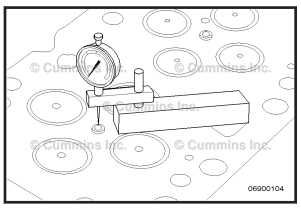
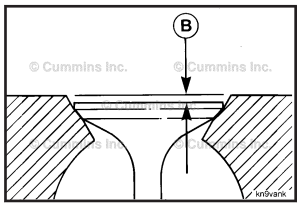




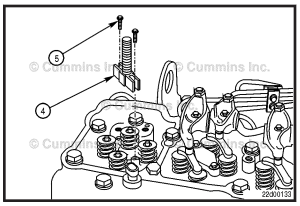
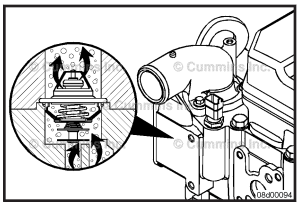
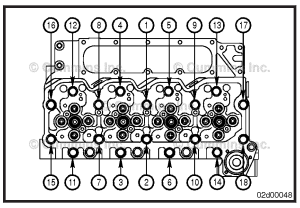
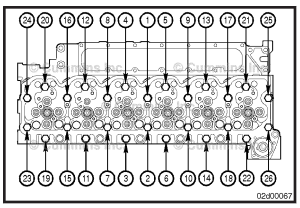
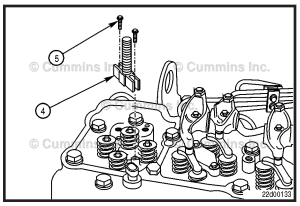
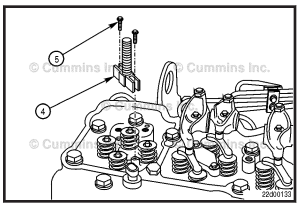
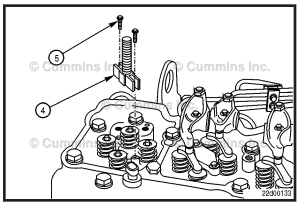
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
		24 N•m	[18 ft-lb]	
Crankshaft Speed Indicator Ring (001-071)				
Torque Value:				
Step 1	50 N•m	[37 ft-lb]		
Step 2	Rotate 90 degrees			
Block Stiffener Plate (001-089)				
Torque Value:				
Block Stiffener Plate Capscrews				
Step 1	43 N•m	[32 ft-lb]		
ECM Mounting Plate (001-103)				
Aluminum Ecm Mounting Plate To Steel Yoke Mounting Capscrews.		24 N•m	[18 ft-lb]	
Ecm Mounting Plate To Cylinder Block Mounting Capscrews.		24 N•m	[18 ft-lb]	
Torque Value:				
For Engine Side of Ground Strap				
Step 1	24 N•m	[18 ft-lb]		

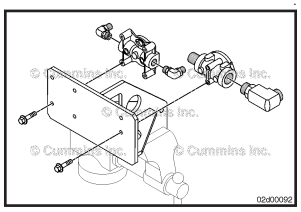
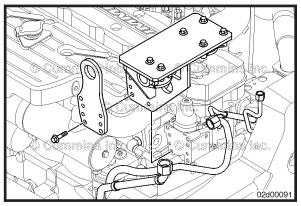
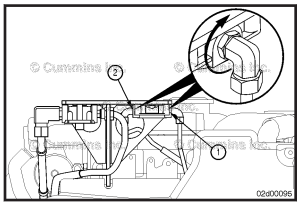
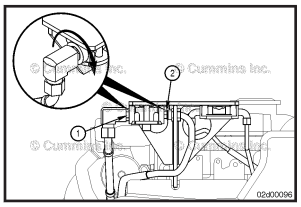
Cylinder Head - Group 02 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Cylinder Head (002-004)					
End-to-End		0.305	MAX	0.012	
Side-to-Side		0.076	MAX	0.003	
Injector Protrusion		2.45 mm	MIN	0.096 in	
		3.15 mm	MAX	0.124 in	
Intake Valve Depth (Installed)		0.584 mm	MIN	0.023 in	
		1.092 mm	MAX	0.043 in	
Exhaust Valve Depth (Installed)		0.965 mm	MIN	0.038 in	
		1.473 mm	MAX	0.058 in	
Used		51	NOM	15	
New		69	NOM	20	
End-To-End		0.075	MAX	0.003	
Side-To-Side		0.075	MAX	0.003	
Cylinder Head Insert Bore Inside Diameter (I.D.)		34.847 mm	MIN	1.3719 in	
		34.863 mm	MAX	1.3726 in	

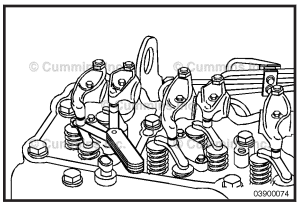
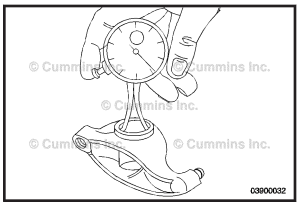
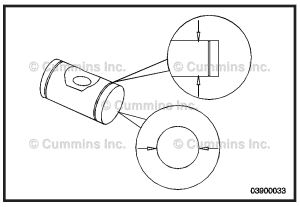
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Valve Guide Bore Diameter		7.027 mm 7.077 mm	MIN MAX	0.2767 in 0.2786 in	
Valve Stem Diameter		6.96 mm 7.01 mm	MIN MAX	0.2740 in 0.2760 in	
Short Capscrew Long Capscrew		132.1 152.1	MAX MAX	5.20 5.99	
Valve Rim Thickness Limit		0.79 mm	MIN	0.031 in	
Injector Protrusion		2.45 mm 3.15 mm	MIN MAX	0.096 in 0.124 in	
Intake Valve Depth (Installed)		0.584 mm 1.092 mm	MIN MAX	0.023 in 0.043 in	
Exhaust Valve Depth (Installed)		0.965 mm 1.473 mm	MIN MAX	0.038 in 0.058 in	

Cylinder Head - Group 02 - Torque Values

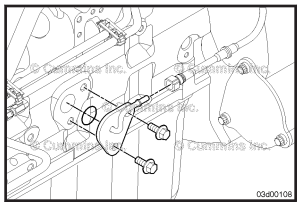
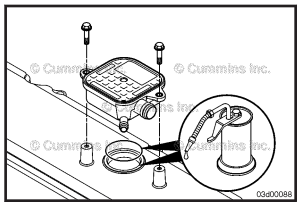
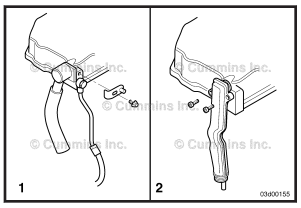
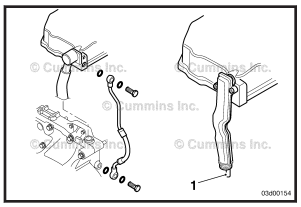
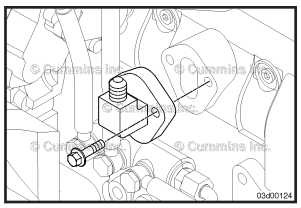
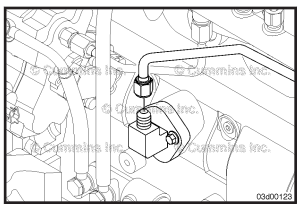
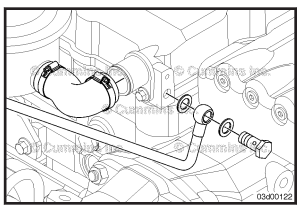
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Cylinder Head (002-004)				
Valve Spring Compressor Capscrews.		5 N•m	[44 in-lb]	
Thermostat And Water Outlet Connection Capscrews		10 N•m 18 N•m	[89 in-lb] [159 in-lb]	
Pressure Test Fixture Nuts		80 N•m	[59 ft-lb]	
Pressure Test Fixture Nuts		80 N•m	[59 ft-lb]	
		5 N•m	[44 in-lb]	
Valve Guide Seal, Cylinder Head (002-016)		5 N•m	[44 in-lb]	
		5 N•m	[44 in-lb]	

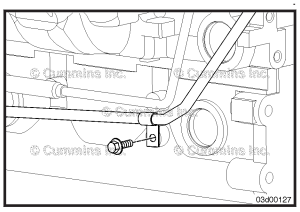
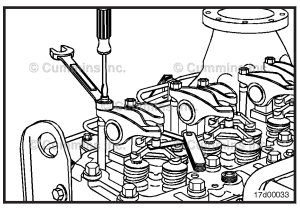
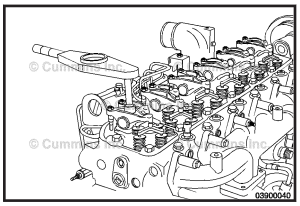
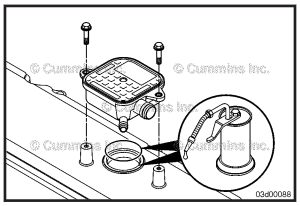
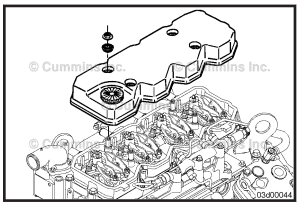
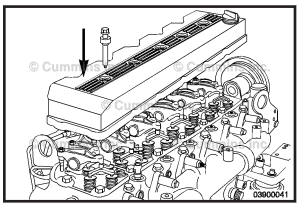
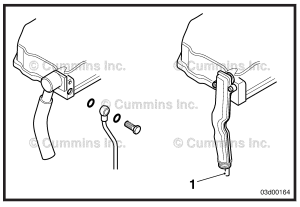
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Mounting Bracket, Lubricating Oil and Fuel Filter (002-033)				
Torque Value: Fuel Filter Head				
Step 1	30 N•m	[25 ft-lb]		
Torque Value: Lubricating Oil Filter Head				
Step 1	18 N•m	[160 in-lb]		
Lubricating Oil And Fuel Filter Mounting Bracket		24 N•m	[18 ft-lb]	
Fuel Filter Head Connection Locking Nuts		37 N•m 37 N•m	[27 ft-lb] [27 ft-lb]	
Lubricating Oil Filter Tube Locking Nut		76 N•m 76 N•m	[56 ft-lb] [56 ft-lb]	

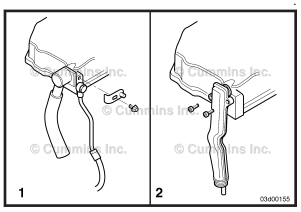
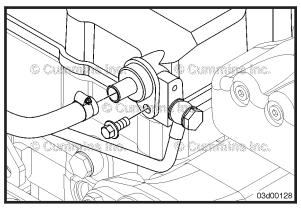
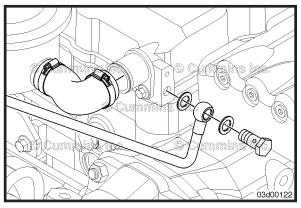
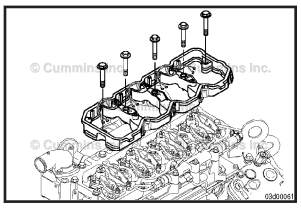
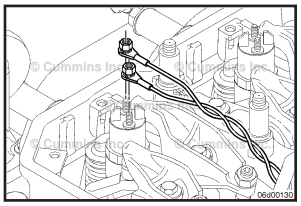
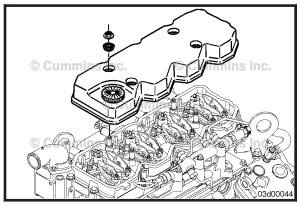
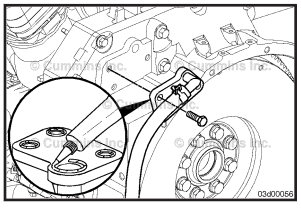
Rocker Levers - Group 03 - Specifications

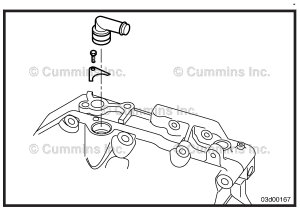
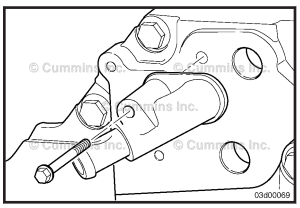
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Overhead Set (003-004)					
Intake		0.152	MIN	0.006	
		0.381	MAX	0.015	
Exhaust		0.381	MIN	0.015	
		0.762	MAX	0.030	
Rocker Lever (003-008)					
Rocker Lever Bore		22.027 mm	MAX	0.867 in	
Rocker Lever Shaft		21.965 mm	MIN	0.865 in	

Rocker Levers - Group 03 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Crankcase Breather (External) (003-001)				
Oil Drain Line Cover Plate Capscrews		24 N•m	[18 ft-lb]	
Crankcase Breather (External)		10 N•m	[89 in-lb]	
Crankcase Breather (Internal) (003-002)				
Breather Tube Connections Capscrews		10 N•m	[89 in-lb]	
Oil Drain Line Banjo Bolt		12 N•m 12 N•m	[106 in-lb] [106 in-lb]	
Breather Tube Check Valve Mounting Connector		24 N•m	[18 ft-lb]	
Breather Oil Drain Back Tube To Check Valve Fitting		30 N•m	[26 ft-lb]	
Closed Crankcase Breather System Hose Clamps		6 N•m 12 N•m	[53 in-lb] [106 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
P-Clip, Breather Oil Drain Back Tube		24 N•m	[18 ft-lb]	
Overhead Set (003-004) Locknut		24 N•m	[212 in-lb]	
24 N•m [212 in-lb] **Rocker Lever (003-008)** Pedestal Mounting Capscrews		36 N•m	[27 ft-lb]	
Rocker Lever Cover (003-011) External Mounted Crankcase Breather Assembly Capscrews		10 N•m	[89 in-lb]	
Rocker Lever Cover Mounting Nuts.		24 N•m	[212 in-lb]	
Capscrew Mounted Rocker Lever Cover Capscrews.		24 N•m	[212 in-lb]	
Internal Mounted Crankcase Breather Banjo Bolt		12 N•m	[106 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Breather Tube Connections Capscrews		10 N•m	[89 in-lb]	
Open Draft Tube Type Cover Plate Capscrews		7 N•m 12 N•m	[62 in-lb] [106 in-lb]	
Closed Crankcase Breather System Hose Clamps		6 N•m 12 N•m	[53 in-lb] [106 in-lb]	
Rocker Lever Housing (003-013) Rocker Lever Housing Capscrews		24 N•m	[212 in-lb]	
Injector Wiring Nut		1.5 N•m	[13 in-lb]	
Rocker Lever Cover Capscrews		24 N•m	[212 in-lb]	
Crankcase Breather Tube (003-018) Breather Tube Mounting Plate Adapter Capscrews		24 N•m	[18 ft-lb]	

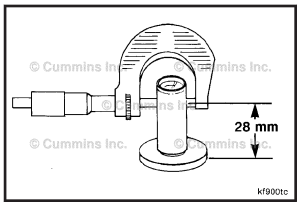
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Clamp Plate Breather Tube Adapter Capscrews		24 N•m	[18 ft-lb]	
Bearher Tube Adapter Capscrew		24 N•m	[18 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.

Cam Followers/Tappets - Group 04 - Specifications

Tappet (004-015)

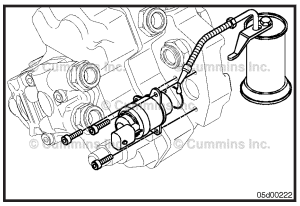
Valve Tappet Stem Diameter	15.936 mm	MIN	0.627 in
	15.977 mm	MAX	0.629 in



Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	

Fuel System - Group 05 - Torque Values

EFC Actuator Valve (005-007)

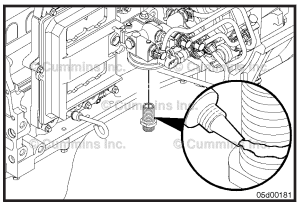


Torque Value:

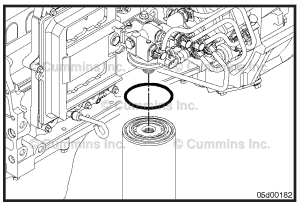
Step 1	3 N•m	[27 in-lb]
Step 2	7 N•m	[62 in-lb]

Engine Fuel Heater, Electric (005-008)

Fuel Filter Spud Without A Fuel Heater		30 N•m	[22 ft-lb]

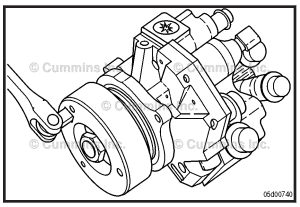


	34 N•m	[25 ft-lb]

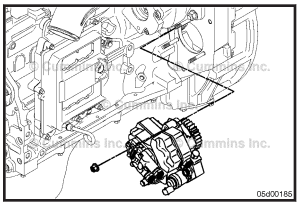


Fuel Pump (005-016)

Fuel Pump Drive Gear Retaining Nut	105 N•m	[77 ft-lb]



Fuel Pump Mounting Nuts	25 N•m	[221 in-lb]

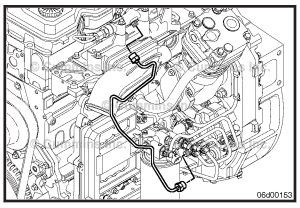


Torque Value:
3.9L and 5.9L High-Pressure Supply Line

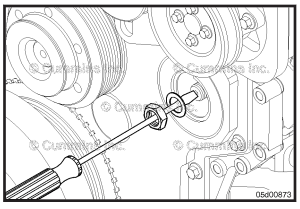
Step 1	30 N•m	[22 ft-lb]

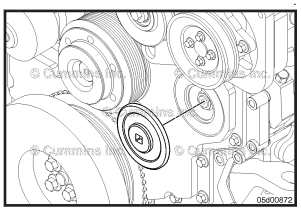
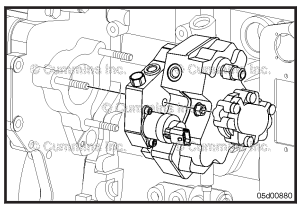
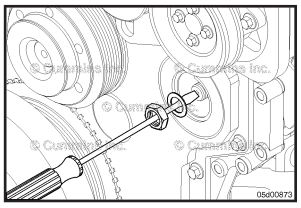
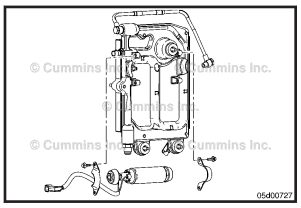
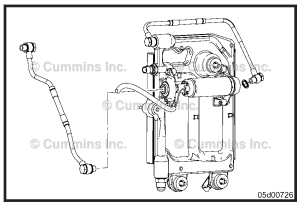
Torque Value:
4.5L and 6.7L High-Pressure Supply Line

Step 1	30 N•m	[22 ft-lb]

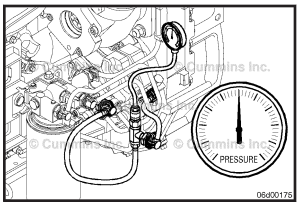
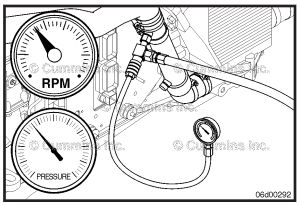
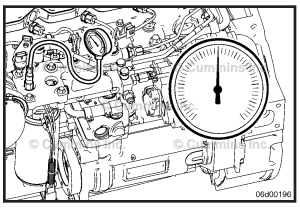
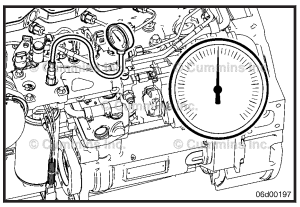
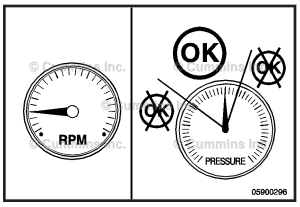
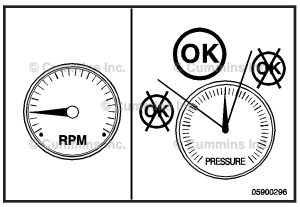
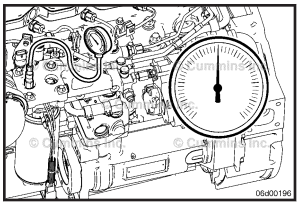


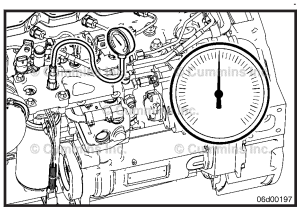
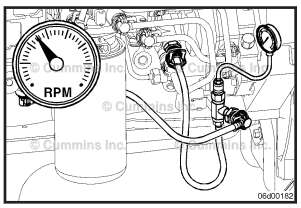
Frnt Gear Train Gear Retaining Nut	105 N•m	[77 ft-lb]



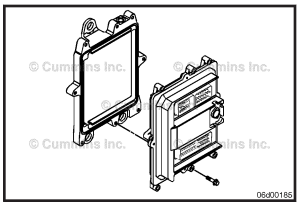
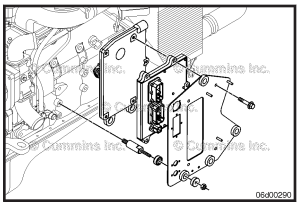
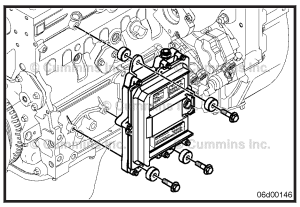
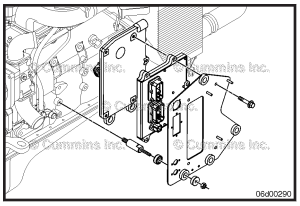
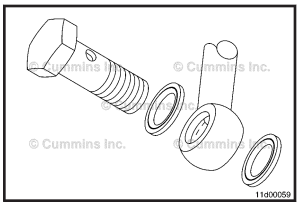
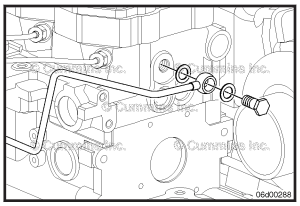
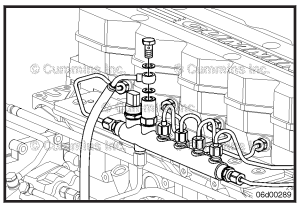
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Front Gear Train Fuel Pump Drive Access Cover.		8 N•m	[71 in-lb]	
Fuel Pump Mounting Nuts		25 N•m	[221 in-lb]	
Fuel Pump Drive Gear Retaining Nut		105 N•m	[77 ft-lb]	
Fuel Lift Pump (005-045)				
Fuel Lift Pump Mounting Capscrews		7 N•m	[62 in-lb]	
Fuel Lift Pump Outlet Fuel Line Fittings		24 N•m 25 N•m	[212 in-lb] [221 in-lb]	

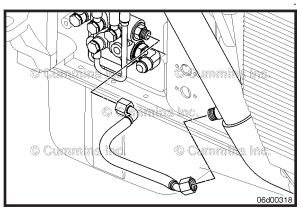
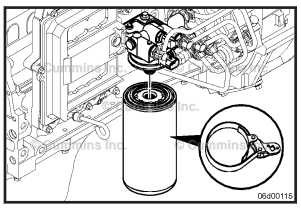
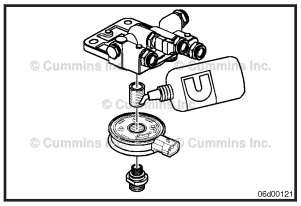
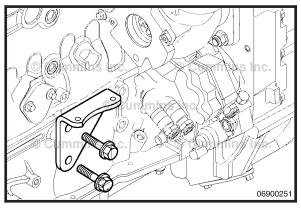
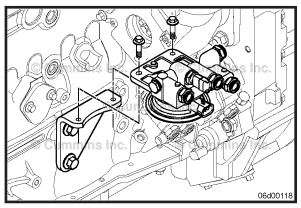
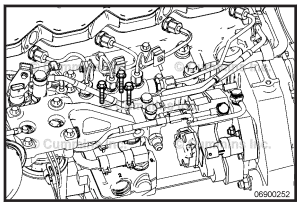
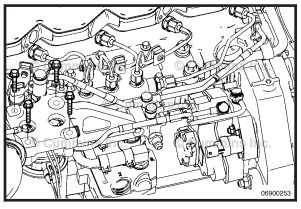
Injectors and Fuel Lines - Group 06 - Specifications

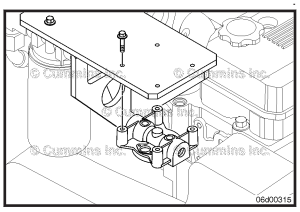
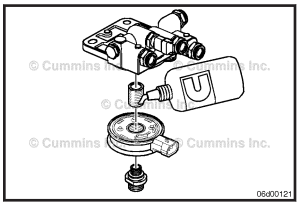
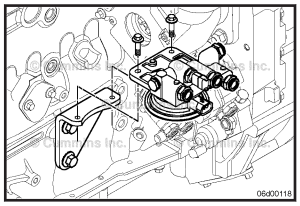
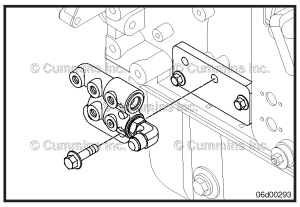
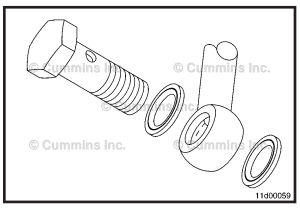
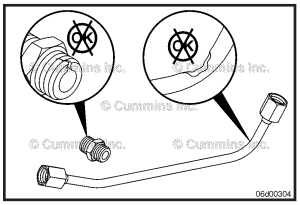
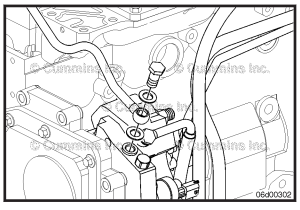
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Fuel Drain Line Restriction (006-012)					
Allowable Drain Line Restriction		20.0 kPa	MAX	2.9 psi	
Allowable Fuel Drain Line Restriction (Marine Engines)		14.0 kPa	MAX	4 in Hg	
Fuel Filter (Spin-On Type) (006-015)					
Fuel Pressure Range At Fuel Filter Inlet with Electric Lift Pump (Engine Running)		0 kPa	MIN	0 psi	
		79.9 kPa	MAX	11.6 psi	
Fuel Pressure Range At Fuel Filter Inlet with Electric Lift Pump (Engine Cranking)		0 kPa	MIN	0 psi	
		79.9 kPa	MAX	11.6 psi	
Fuel Pressure Range At Fuel Filter Outlet with Electric Lift Pump (Engine Running)		0 kPa	MIN	0 psi	
		79.9 kPa	MAX	11.6 psi	
Fuel Pressure Range At Fuel Filter Outlet with Electric Lift Pump (Engine Cranking)		0 kPa	MIN	0 psi	
		79.9 kPa	MAX	11.6 psi	
Maximum Pressure Drop Across Fuel Filter		34 kPa	MAX	5 psi	
Fuel Pressure Range At Fuel Filter Inlet without Electric Lift Pump (Engine Running)		503 kPa	MIN	73 psi	
		1303 kPa	MAX	189 psi	
Fuel Pressure Range At Fuel Filter Inlet without Electric Lift Pump (Engine Cranking)		303 kPa	MIN	44 psi	
		1103 kPa	MAX	160 psi	
Fuel Pressure Range At Fuel Filter Outlet without Electric Lift Pump (Engine Running)		503 kPa	MIN	73 psi	
		1303 kPa	MAX	189 psi	
Maximum Pressure Drop Across Fuel Filter		200 kPa	MAX	29 psi	
Fuel Pressure Range At Fuel Filter Inlet (Engine Running)		0 kPa	MIN	0 psi	
		79.9 kPa	MAX	11.6 psi	
Fuel Pressure Range At Fuel Filter Inlet (Engine Cranking)		0 kPa	MIN	0 psi	
		79.9 kPa	MAX	11.6 psi	

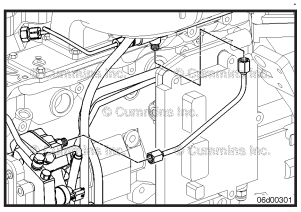
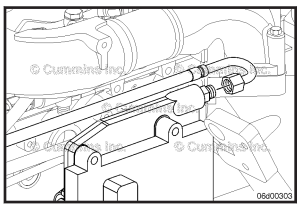
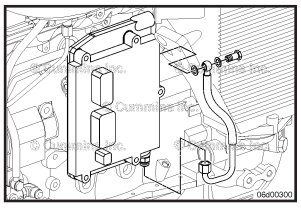
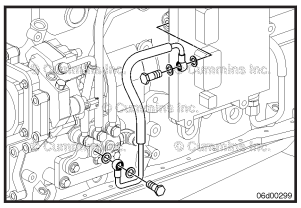
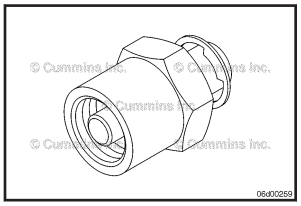
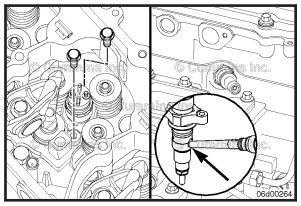
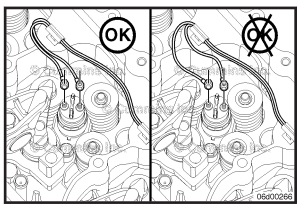
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Fuel Pressure Range At Fuel Filter Inlet (Engine Running)		0 kPa	MIN	0 psi	
		79.9 kPa	MAX	11.6 psi	
Fuel Pressure Drop Across Fuel Filter		34 kPa	MAX	5 psi	
Fuel Inlet Restriction (006-020)					
Without Electric Lift Pump		50.8	MAX	15.0	
With Electric Lift Pump		20.3	MAX	6.0	
Marine Applications		13.5	MAX	4.0	

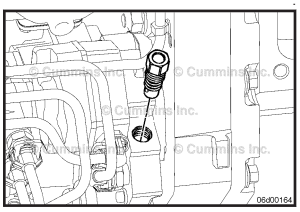
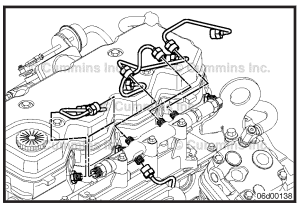
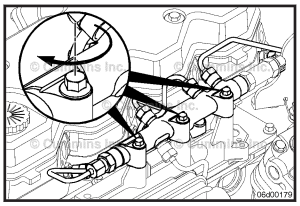
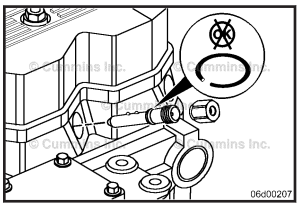
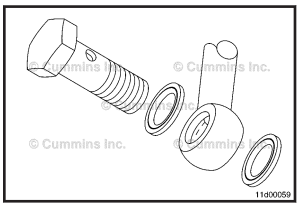
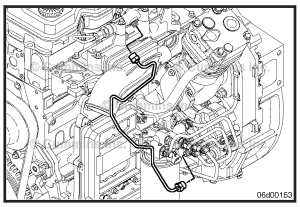
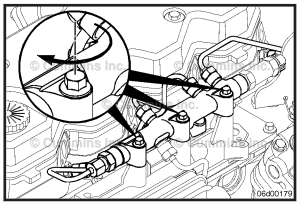
Injectors and Fuel Lines - Group 06 - Torque Values

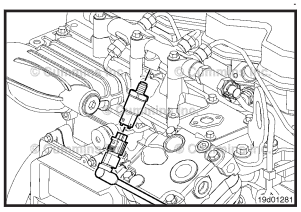
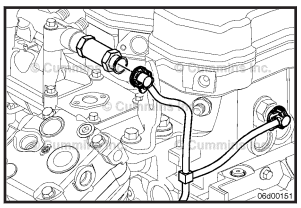
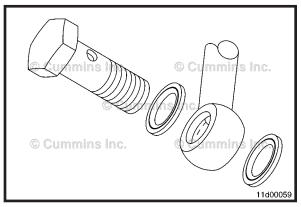
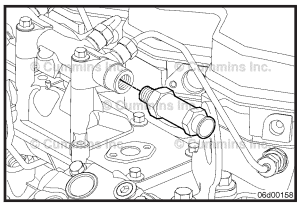
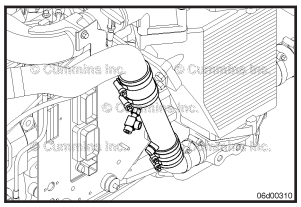
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
ECM Cooling Plate, Fuel Cooled (006-006)				
Ecm Cooling Plate Torque (Engines Without Lift Pump)		10 N•m	[89 in-lb]	
Ecm And Cooling Plate (Marine)		24 N•m	[212 in-lb]	
Ecm Cooling Plate Mounting Capscrews		24 N•m	[212 in-lb]	
Ecm Cooling Plate Assembly Mounting Capscrews		24 N•m	[212 in-lb]	
Fuel Drain Lines (006-013)				
Banjo Bolt Torque		24 N•m	[212 in-lb]	
Cylinder Head Fuel Drain Line Fitting And Check Valve		24 N•m 24 N•m	[212 in-lb] [212 in-lb]	
Fuel Pressure Relief Valve Drain Line		24 N•m 24 N•m	[212 in-lb] [212 in-lb]	

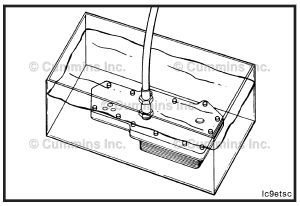
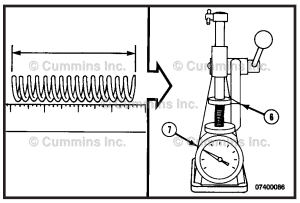
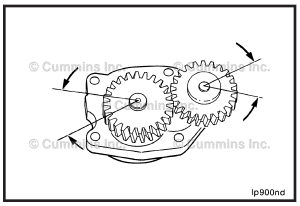
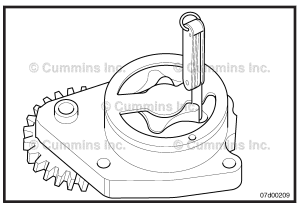
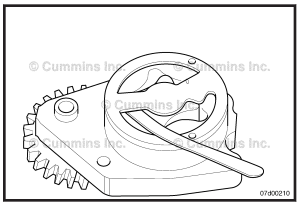
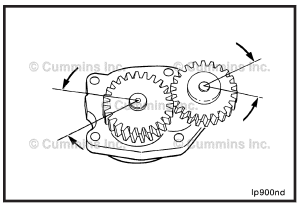
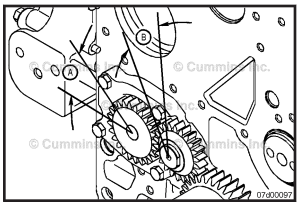
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Combined Fuel Manifold To Fuel Cooler Drain Line		24 N•m	[212 in-lb]	
Fuel Filter (Spin-On Type) (006-015) Fuel Filter (Spin-On)		23 N•m	[17 ft-lb]	
Fuel Filter Head (006-017) Fuel Filter Adapter		30 N•m	[22 ft-lb]	
Fuel Filter Head Bracket Mounting Capscrews		24 N•m	[212 in-lb]	
Fuel Filter Head Mounting Capscrews		24 N•m	[212 in-lb]	
Fuel Filter Head Bracket Mounting Capscrews		24 N•m	[212 in-lb]	
Fuel Filter Head Mounting Capscrews		24 N•m	[212 in-lb]	

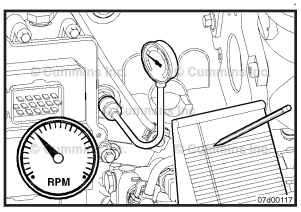
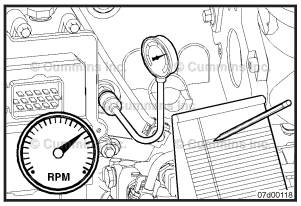
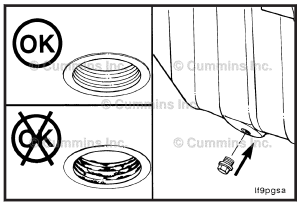
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Fuel Filter Head Mounting Capscrews		30 N•m	[25 ft-lb]	
Fuel Filter Head Bracket (006-018) Fuel Filter Adapter And Fuel Heater Capscrews		30 N•m	[22 ft-lb]	
Fuel Filter Head Mounting Bracket Capscrews		24 N•m	[212 in-lb]	
Fuel Manifold (Combined) (006-019) Combined Fuel Manifold Mounting Capscrews		77 N•m	[57 ft-lb]	
Fuel Supply Lines (006-024) Banjo Bolt Torque		24 N•m	[212 in-lb]	
Straigh Thread O-Ring Fitting.		37 N•m	[27 ft-lb]	
Torque Value: Fuel Filter Connection Step 1	37 N•m	[27 ft-lb]		
Torque Value: Banjo Bolt Connection Step 1	24 N•m	[221 in-lb]		

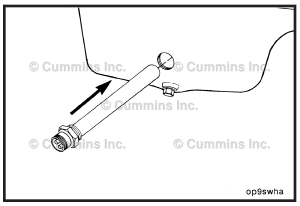
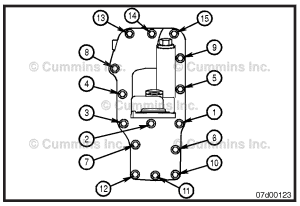
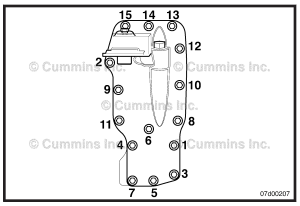
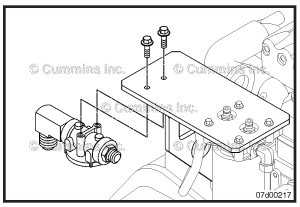
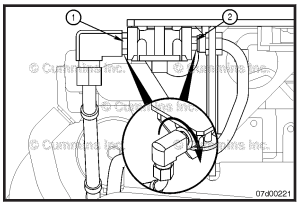
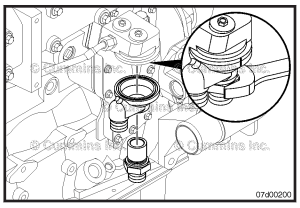
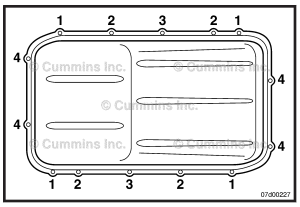
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Torque Value: Fuel Rail Fitting				
Step 1	37 N•m		[27 ft-lb]	
Torque Value: Fuel Pump Banjo Bolt				
Step 1	24 N•m		[221 in-lb]	
Torque Value: Fuel Line Straight Thread Connections				
Step 1	37 N•m		[27 ft-lb]	
Torque Value: P-Clips				
Step 1	24 N•m		[221 in-lb]	
Torque Value: Straight Thread Connection				
Step 1	37 N•m		[27 ft-lb]	
Torque Value: Banjo Bolt Connection				
Step 1	24 N•m		[221 in-lb]	
Torque Value: Banjo Bolt Connections				
Step 1	24 N•m		[221 in-lb]	
Injector (006-026)				
3.9L And 5.9L Injector Leakage Isolation Tool		30 N•m 35 N•m	[22 ft-lb] [26 ft-lb]	
		15 N•m	[133 in-lb]	
10 N•m	[89 in-lb]			
8 N•m	[71 in-lb]			
Injector Solenoid Wires Nuts.		1.5 N•m	[13 in-lb]	

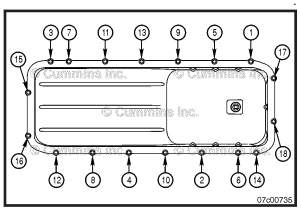
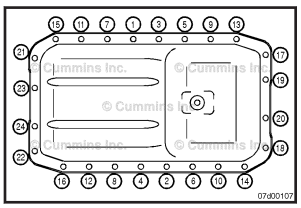
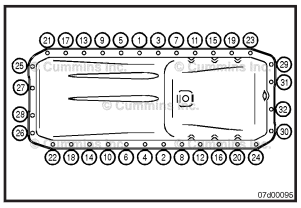
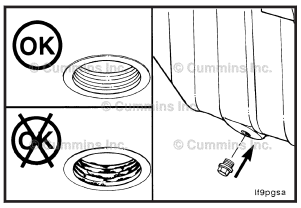
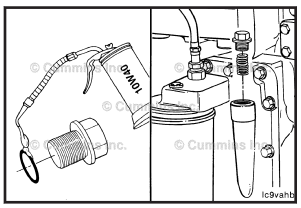
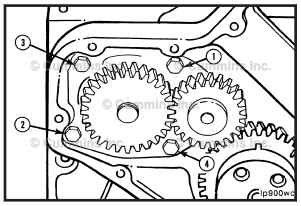
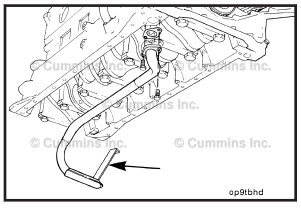
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Fuel Return Overflow Valve (006-044)				
Torque Value:				
Fuel Return Overflow Valve				
Step 1	20 N•m	[177 in-lb]		
Injector Supply Lines (High Pressure) (006-051)				
Injector High-Pressure Supply Lines For 3.9L And 5.9L Engines Without Electric Lift Pump		22 N•m 30 N•m 35 N•m	[195 in-lb] [22 ft-lb] [26 ft-lb]	
Injector Supply Line Brace Capscrews		24 N•m 24 N•m	[212 in-lb] [212 in-lb]	
Fuel Connector (Head Mounted) (006-052)				
Torque Value:				
Fuel Connector (cylinder head-mounted)				
Step 1	55 N•m	[41 ft-lb]		
Fuel Rail (006-060)				
Banjo Bolt Torque		24 N•m	[212 in-lb]	
	3.9L and 5.9L High-Pressure Supply Line 30 22 4.5L and 6.7L High-Pressure Supply Line 36 27			
		24 N•m	[212 in-lb]	
Fuel Rail Capscrews		24 N•m	[212 in-lb]	

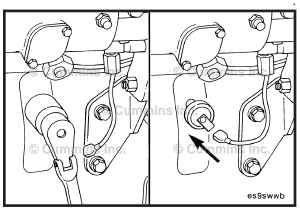
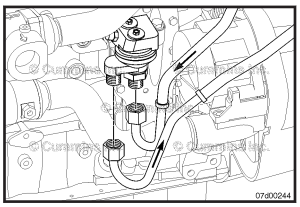
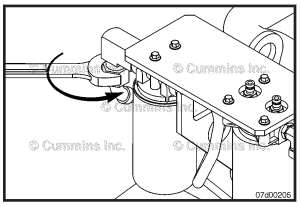
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Fuel Pressure Sensor		70 N•m	[52 ft-lb]	
Pressure Relief Valve		100 N•m	[74 ft-lb]	
Fuel Pressure Relief Valve (006-061)				
Banjo Bolt Torque		24 N•m	[212 in-lb]	
Pressure Relief Valve		100 N•m	[74 ft-lb]	
Fuel Cooler (006-062)				
Fuel Cooler Mounting Capscrew		24 N•m 3 N•m	[18 ft-lb] [30 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Lubricating Oil System - Group 07 - Specifications					
Lubricating Oil Cooler (007-003)					
Air Pressure Test		449 kPa 518 kPa	MIN MAX	65 psi 75 psi	
Lubricating Oil Pressure Regulator (Main Rifle) (007-029)					
@41.25 mm [1.624 in]		127	MIN	29	
@44.50 mm [1.752 in]		109	MIN	25	
Lubricating Oil Pump (007-031)					
Lubricating Oil Pump Gear Backlash Limits		0.170 mm 0.300 mm	MIN MAX	0.007 in 0.012 in	
Tip Limit		0.178 mm	MAX	0.007 in	
Gerotor Drive/Planetary to Port Plate Limit		0.127 mm	MAX	0.005 in	
Backlash Limits (used pump)		0.170 mm 0.300 mm	MIN MAX	0.007 in 0.012 in	
A		0.300 0.500	MIN MAX	0.011 0.019	
B		0.150 0.250	MIN MAX	0.005 0.009	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Lubricating Oil System (007-037)					
Oil Pressure at Low Idle		69 kPa	MIN	10 psi	
Oil Pressure at Rated Engine Speed		207 kPa	MIN	30 psi	
Marine Oil Pan Drain Plug Torque		50 N•m	MIN	37 ft-lb	

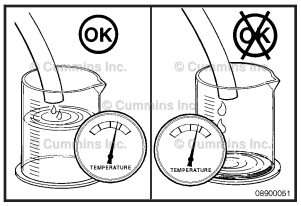
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Lubricating Oil System - Group 07 - Torque Values				
Engine Oil Heater (007-001)				
Heater Element		80 N•m	[59 ft-lb]	
Lubricating Oil Cooler (007-003)				
Lubricating Oil Cooler Capscrew		24 N•m	[212 in-lb]	
High Mount Lubricating Oil Cooler Capscrew		24 N•m	[212 in-lb]	
Lubricating Oil Filter Head (Remote Mounted) (007-017)				
Lubricating Oil Filter Head Assembly		18 N•m	[13 ft-lb]	
Lubricating Oil Filter Tube Locking Nut		76 N•m	[56 ft-lb]	
Lubricating Oil Filter Head Adapter (007-018)				
Lubricating Oil Filter Head Adapter		100 N•m	[74 ft-lb]	
Lubricating Oil Pan (007-025)				
Oil Pan Suspended - (Four Cylinder) Capscrew		26 N•m	[230 in-lb]	

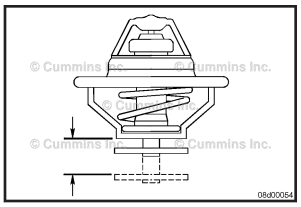
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Oil Pan, Suspended (Six-Cylinder) Capscrew		26 N•m	[230 in-lb]	
Four-Cylinder, Standard Capscrew		28 N•m	[249 in-lb]	
Six-Cylinder, Standard Capscrew		28 N•m	[249 in-lb]	
Lubricating Oil Pan Drain Plug		60 N•m	[44 ft-lb]	
Lubricating Oil Pressure Regulator (Main Rifle) (007-029)				
Pressure Regulator Valve Plug		80 N•m	[59 ft-lb]	
Lubricating Oil Pump (007-031)				
Lubricating Oil Pump Capscrews Initial		8 N•m	[70 in-lb]	
Torque		24 N•m	[212 in-lb]	
Lubricating Oil Suction Tube (Block-Mounted) (007-035)				
Suction Tube Capscrews		24 N•m	[212 in-lb]	

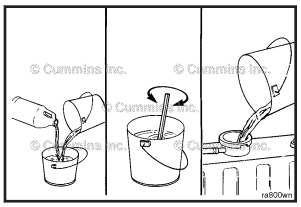
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Lubricating Oil Pressure Sensor, OEM (007-052)				
Torque Value: Installed into Cast Iron				
Step 1	16 N•m	[142 in-lb]		
Torque Value: Installed into Aluminum				
Step 1	10 N•m	[89 in-lb]		
Lubricating Oil Lines (007-092)				
Lubricating Oil Return Hose		76 N•m	[56 ft-lb]	
		76 N•m	[56 ft-lb]	
Lubricating Oil Supply And Return Hoses At Filter Head		76 N•m	[56 ft-lb]	

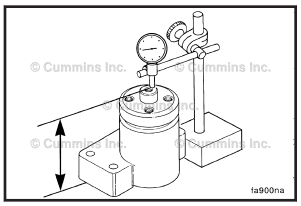
Cooling System - Group 08 - Specifications

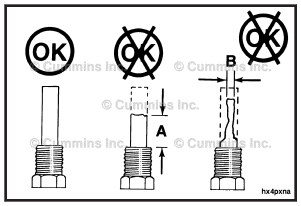
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Coolant Thermostat (008-013)				
Thermostat Initial Opening Temperature - Automotive Applications without EGR		81 °C	MIN	178 °F
		83 °C	MAX	182 °F
Thermostat Initial Opening Temperature - Automotive Applications with EGR		86 °C	MIN	186 °F
		89 °C	MAX	193 °F
Thermostat Initial Opening Temperature - Marine Applications		70 °C	MIN	158 °F
		72 °C	MAX	162 °F
Thermostat Initial Opening Temperature - Industrial Applications		87 °C	MIN	188 °F
		89 °C	MAX	192 °F
Initial Opening Temperature		81	MIN	178
		83	MAX	182
Fully Opened Temperature		94	MAX	202
Initial Opening Temperature		86	MIN	186
		89	MAX	193
Fully Opened Temperature		97	MAX	207
Initial Opening Temperature		87	MIN	188
		89	MAX	192
Fully Opened Temperature		96	MAX	205
Initial Opening Temperature		71	MIN	158
		72	MAX	162
Fully Opened Temperature		85	MAX	185
Cooling System (008-018)				
Engine only		10	MAX	2.6
Engine and heat exchanger		25	MAX	6.6
Fan Hub, Belt Driven (008-036)				
Fan Hub End Play		0.15 mm	MAX	0.006 in
Zinc Anode (008-059)				
A		19.0	MIN	0.750
New		51.0	MAX	2.000
B		6.4	MIN	0.250
New		16.0	MAX	0.630

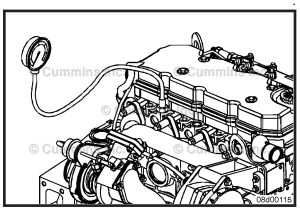




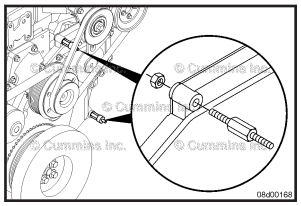
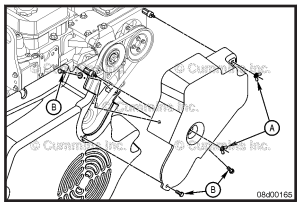
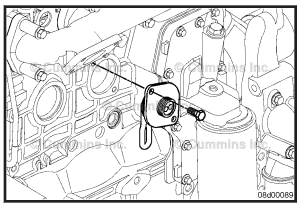
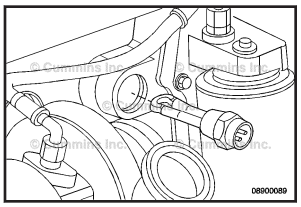
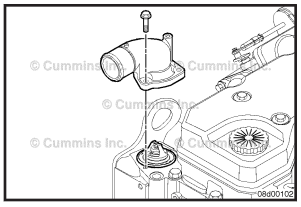
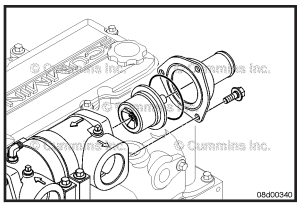
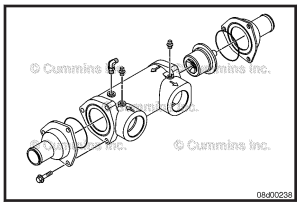


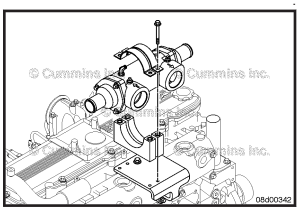
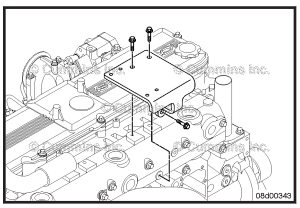
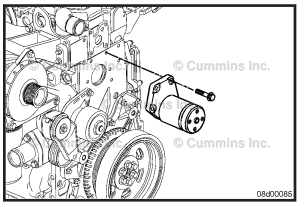
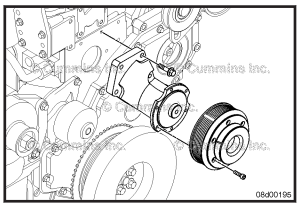
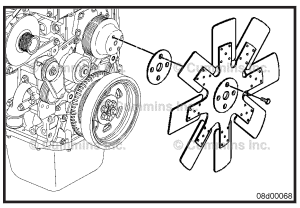
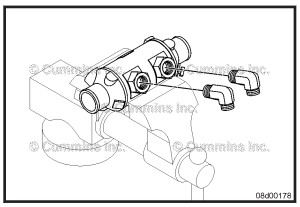
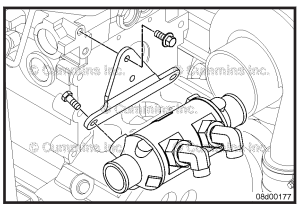


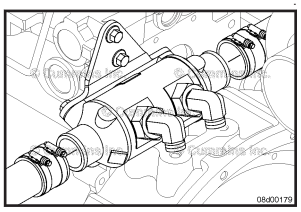
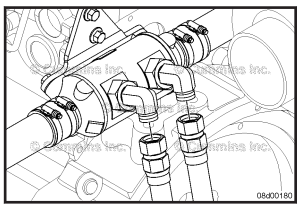
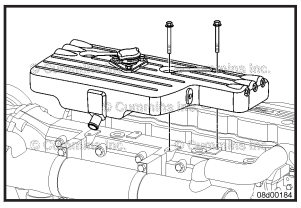
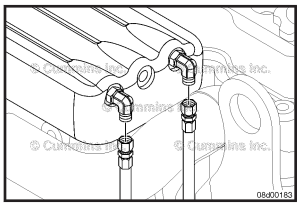
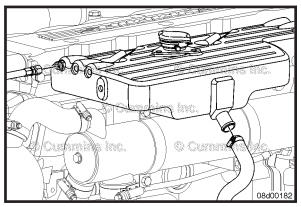
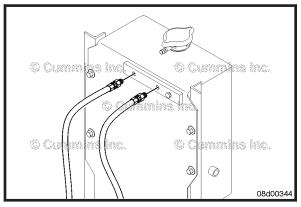
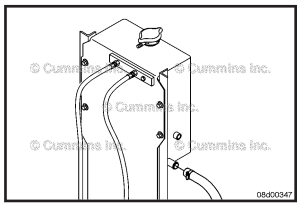


Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Water Pump (008-062) Minimum Pressure Gauge Capacity		207 kPa	MIN	30 psi	

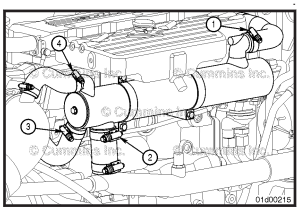
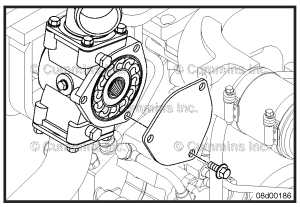
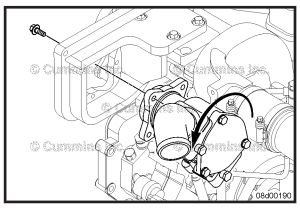
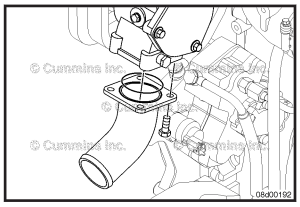
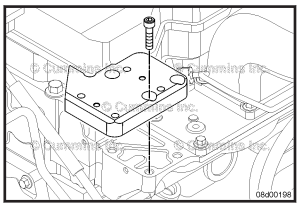
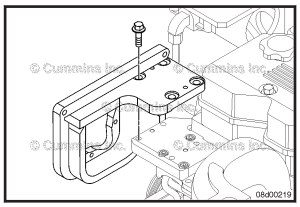
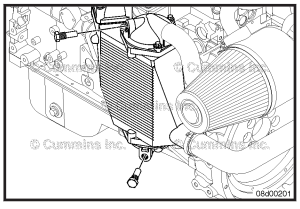
Cooling System - Group 08 - Torque Values

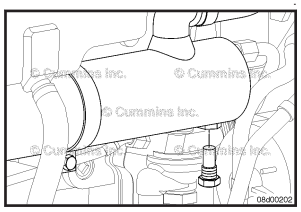
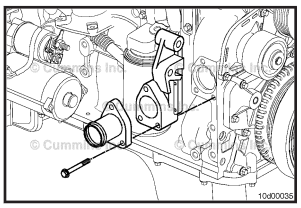
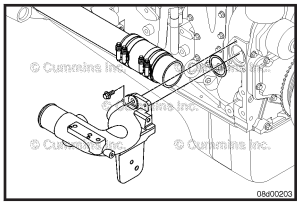
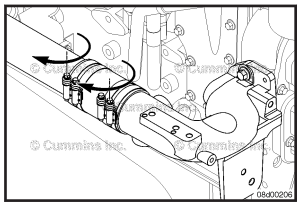
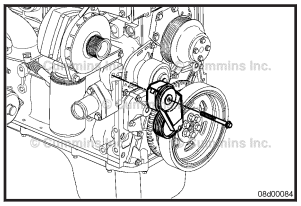
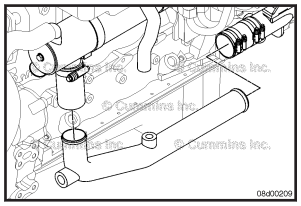
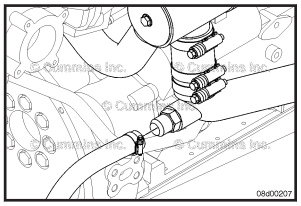
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Belt Guard (008-001)				
Belt Guard Mounting Studs		15 N•m	[133 in-lb]	
Upper Belt Guard Mounting Capscrews		5 N•m	[44 in-lb]	
Coolant Heater (008-011)				
Coolant Heater Retaining Capcsrews (Flange-Mounted)		24 N•m	[212 in-lb]	
Coolant Heater Mounting (Threaded)		55 N•m	[41 ft-lb]	
Coolant Thermostat (008-013)				
Water Outline Tube Mounting Capscrews		10 N•m	[89 in-lb]	
Keel Cooled Thermostat Housing Connection		24 N•m	[18 ft-lb]	
Coolant Thermostat Housing (008-014)				
Keel Cooled Water Inlet Connection		44 N•m 44 N•m 15 N•m	[32 ft-lb] [32 ft-lb] [133 in-lb]	

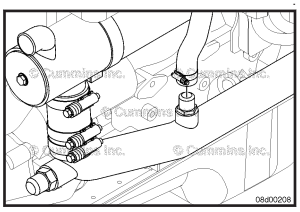
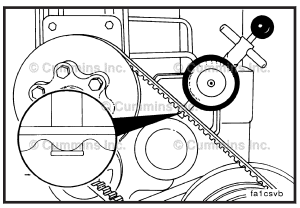
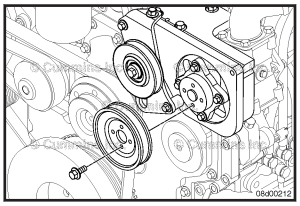
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Keel Cooled Thermostat Housing Clamps		44 N•m	[32 ft-lb]	
Coolant Thermostat Housing Support (008-015)				
Thermostat Housing Support Bracket		44 N•m	[32 ft-lb]	
Fan Hub, Belt Driven (008-036)				
Fan Hub Mounting Capscrews		33 N•m	[24 ft-lb]	
Hub Mounting Capscrews		33 N•m 12 N•m	[24 ft-lb] [106 in-lb]	
Fan Spacer and Pulley (008-039)				
Torque Value:				
M6				
Step 1	10 N•m	[89 in-lb]		
Torque Value:				
M10				
Step 1	43 N•m	[32 ft-lb]		
Torque Value:				
M12				
Step 1	77 N•m	[57 ft-lb]		
Marine Gear Oil Cooler (008-041)				
Marine Gear Oil Cooler Fitting Locknuts		24 N•m	[18 ft-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]	
Expansion Tank (008-052) Expansion Tank Mounting Capscrews		43 N•m	[32 ft-lb]	
Expansion Tank Vent Lines		14 N•m	[124 in-lb]	
Expansion Tank Turbocharger Vent Tube		14 N•m 8 N•m	[124 in-lb] [70 in-lb]	
Coolant Vent Lines		14 N•m	[124 in-lb]	
Coolant Make-Up Hose Clamp		8 N•m	[70 in-lb]	

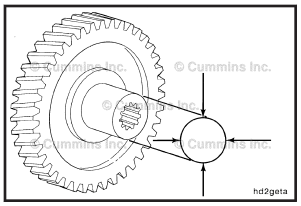
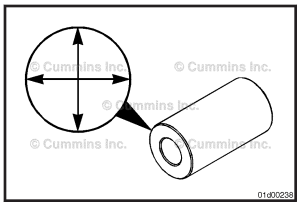
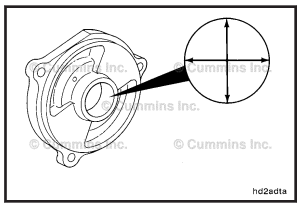
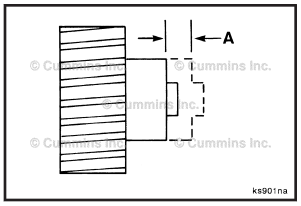
8 N•m [71 in-lb]

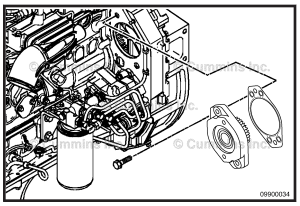
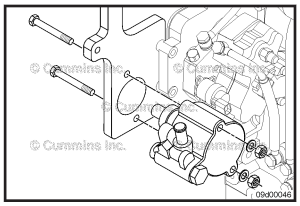
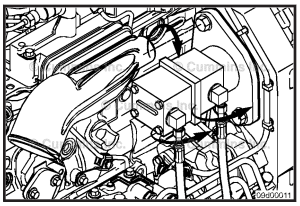
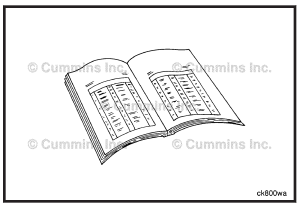
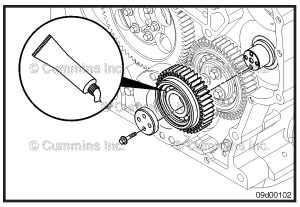
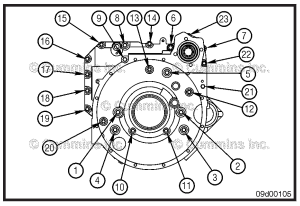
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Heat Exchanger (008-053)				
Heat Exchanger Hose Clamps		8 N•m 44 N•m	[71 in-lb] [32 ft-lb]	
Sea Water Pump (008-057)				
Sea Water Pump Cover Capscrews		24 N•m	[212 in-lb]	
24 N•m [212 in-lb] Sea Water Pump Mounting Capscrews		24 N•m	[18 ft-lb]	
Sea Water Pump Hose Connection Capscrews		24 N•m	[18 ft-lb]	
Sea Water Pump Support (008-058)				
Sea Water Pump Mounting Bracket Capscrews		44 N•m	[32 ft-lb]	
Sea Water Pump Support Bracket		44 N•m	[32 ft-lb]	
Zinc Anode (008-059)				
Aftercooler Zinc Anodes		45 N•m	[35 ft-lb]	

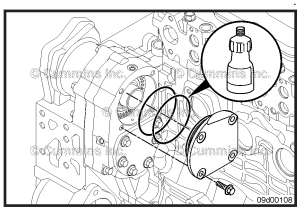
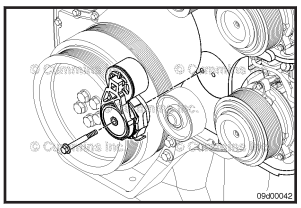
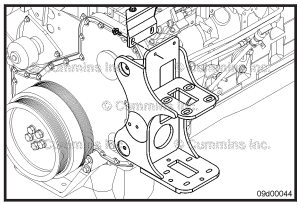
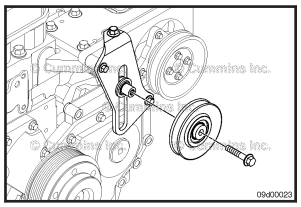
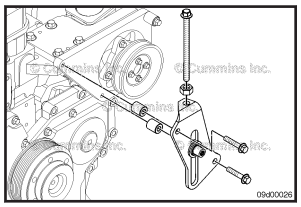
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Heat Exchanger Zinc Anode		45 N•m	[35 ft-lb]	
24 N•m [212 in-lb] 30 N•m [22 ft-lb]				
Water Inlet Connection (008-082)				
Torque Value: M10 Step 1	43 N•m	[32 ft-lb]		
Torque Value: M12 Step 1	80 N•m	[59 ft-lb]		
Water Inlet Mounting Capscrews		43 N•m	[32 ft-lb]	
Water Inlet Connection Hose Clamps		8 N•m	[71 in-lb]	
Cooling Fan Belt Tensioner (008-087) Belt Tensioner Mounting Capscrew		43 N•m	[32 ft-lb]	
Coolant Return Junction Block (008-113) Junction Block Hose Clamps		8 N•m	[71 in-lb]	
Turbocharger Water Drain Hose		8 N•m	[71 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Expansion Tank Fill Line Tube		8 N•m	[71 in-lb]	
Drive Belt, Sea Water Pump (008-126)				
Sea Water Pump Belt Idler Pulley		45 N•m	[33 ft-lb]	
Sea Water Pump Pulley (008-127)				
Sea Water Pump Pulley Mounting Capscrews		10 N•m	[89 in-lb]	

Drive Units - Group 09 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Accessory Drive (009-001)					
Accessory Drive Gear Bore Inside Diameter (Accessory Drive Adapter)		38.920 mm	MIN	1.5323 in	
		38.945 mm	MAX	1.5333 in	
Accessory Drive Shaft Outside Diameter (Accessory Drive Adapter)		39.008 mm	MIN	1.5357 in	
		39.020 mm	MAX	1.5362 in	
Bearing Bore Inside Diameter (Accessory Drive Adapter)		67.759 mm	MIN	2.6755 in	
		67.983 mm	MAX	2.6765 in	
Accessory Drive Gear End Play		0.5 mm	MIN	0.020 in	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Drive Units - Group 09 - Torque Values				
Accessory Drive (009-001)				
Accessory Drive To Rear Gear Housing Capscrews		62 N•m	[46 ft-lb]	
Hydraulic Pump Drive (009-016)				
Hydraulic Pump Mounting Bolts		41 N•m	[30 ft-lb]	
Mounting Capscrews		62 N•m	[46 ft-lb]	
		33 N•m	[288 in-lb]	
Hose Sleeve Nut 27 239 Hose Clamp 6 50				
		77 N•m	[57 ft-lb]	
		47 N•m	[35 ft-lb]	
		24 N•m	[212 in-lb]	
		47 N•m	[35 ft-lb]	
		43 N•m	[32 ft-lb]	
		35 N•m	[26 ft-lb]	
REPTO (009-022)				
		12 N•m	[106 in-lb]	
		85 N•m	[63 ft-lb]	
		49 N•m	[36 ft-lb]	

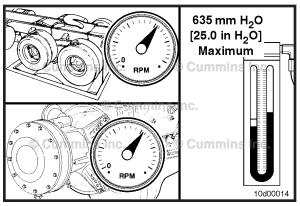
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
		35 N•m	[26 ft-lb]	
Belt Tensioner, Refrigerant Compressor, Automatic (009-053)				
Belt Tensioner Capscrew		43 N•m	[32 ft-lb]	
Refrigerant Compressor Mounting Bracket (009-055)				
Refrigerant Compressor Mounting Bracket		46 N•m	[34 ft-lb]	
Idler Pulley Sea Water Pump (009-057)				
Sea Water Idler Pulley		44 N•m	[32 ft-lb]	
Idler Pulley Mounting Bracket (009-058)				
Sea Water Pump Idler Pulley Mounting Bracket		44 N•m	[32 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.

Air Intake System - Group 10 - Specifications

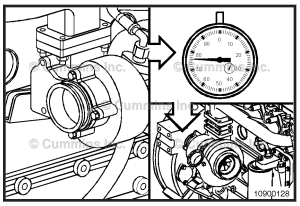
Air Intake Restriction (010-031)

Air Intake Restriction	635 mm H_2O	MAX	25 in H_2O



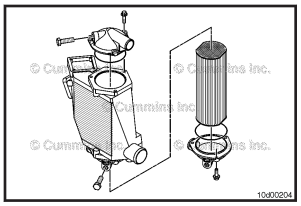
Turbocharger (010-033)

HE221W, HE211W, and HE201W - Axial Clearance	0.010 mm	MIN	0.0004 in
	0.076 mm	MAX	0.0030 in
HX40, H1E, HY30W, HX35W, and HY35W - Axial Clearance	0.038 mm	MIN	0.0015 in
	0.093 mm	MAX	0.0037 in
HX27/25W - Axial Clearance	0.057 mm	MIN	0.0022 in
	0.103 mm	MAX	0.0040 in
Variable Geometry, HY35V - Axial Clearance	0.038 mm	MIN	0.0015 in
	0.093 mm	MAX	0.0037 in

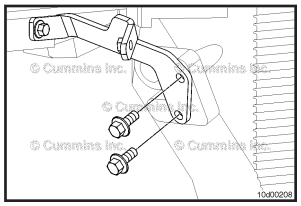


Air Intake System - Group 10 - Torque Values

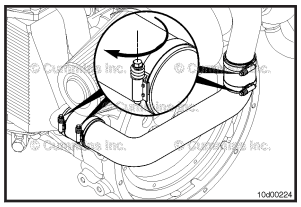
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
Aftercooler Assembly (010-005)			
Aftercooler Assembly End Cap		43 N•m	[32 ft-lb]
		43 N•m	[32 ft-lb]



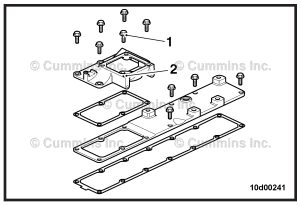
Torque Value:			
Aftercooler to Flywheel Housing			
Step 1	60 N•m	[44 ft-lb]	
Torque Value:			
Aftercooler to Cylinder Head			
Step 1	77 N•m	[57 ft-lb]	
Torque Value:			
Aftercooler to Bracket			
Step 1	35 N•m	[26 ft-lb]	



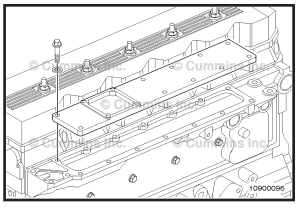
Air Crossover (010-019)		
Air Crossover Hose Clamps	8 N•m	[71 in-lb]



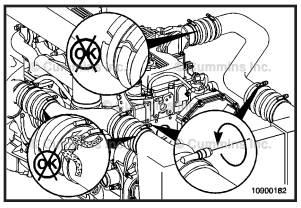
Air Intake Manifold (010-023)		
Torque Value:		
Air Intake Manifold Cover		
Step 1	24 N•m	[18 ft-lb]

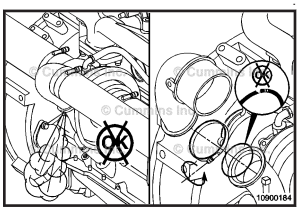
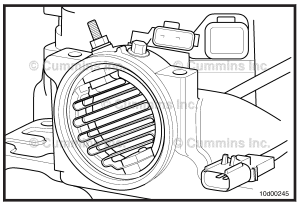
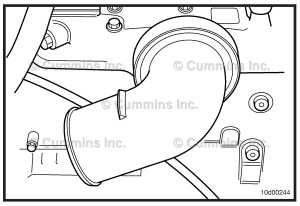
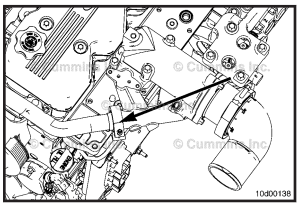
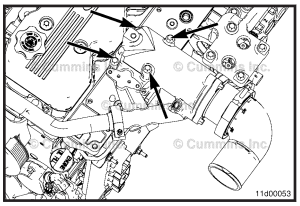
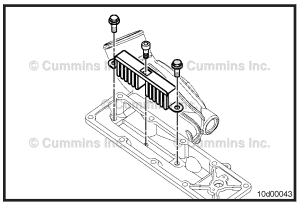
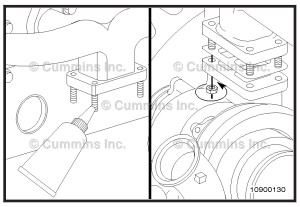


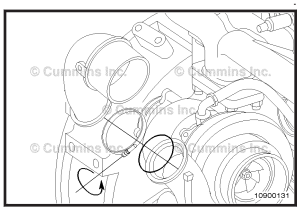
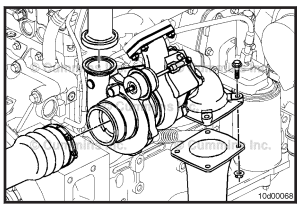
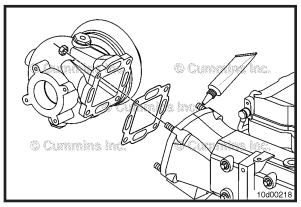
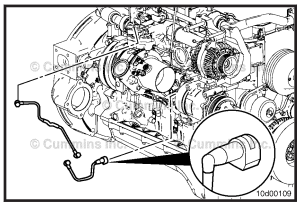
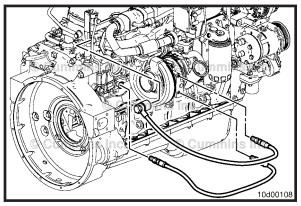
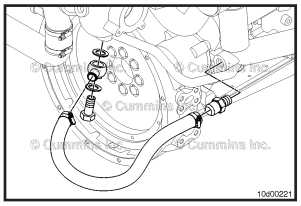
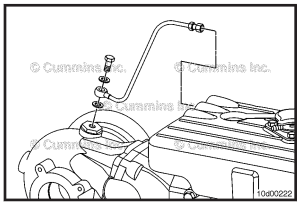
Torque Value:		
Air Intake Manifold Cover		
Step 1	24 N•m	[18 ft-lb]

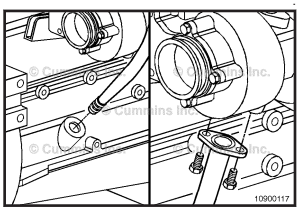
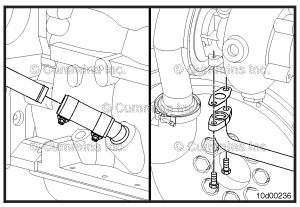
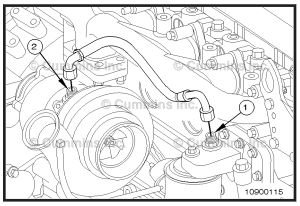
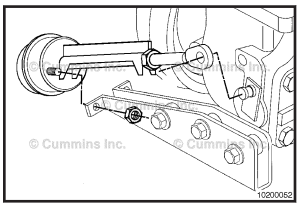
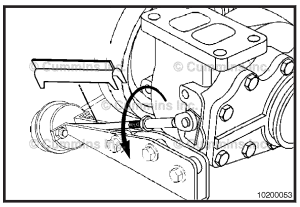
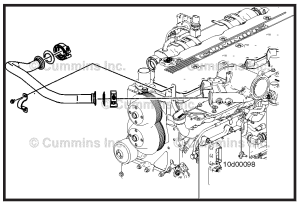
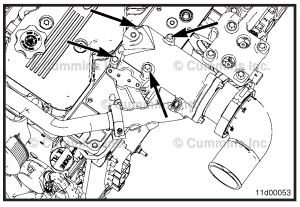


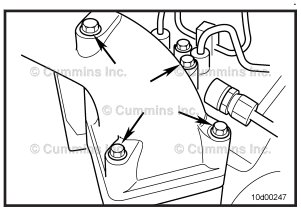
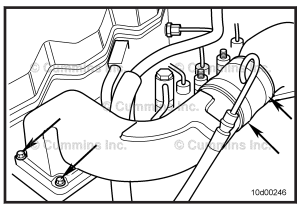
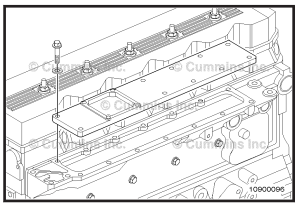
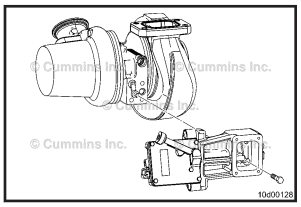
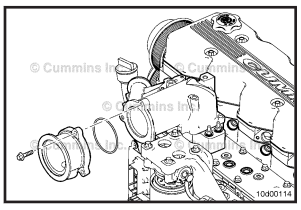
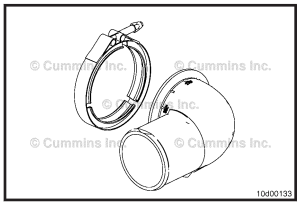
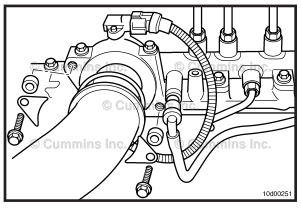
Air Leaks, Air Intake and Exhaust Systems (010-024)		
Intake Air System Clamps Torque	10 N•m	[89 in-lb]

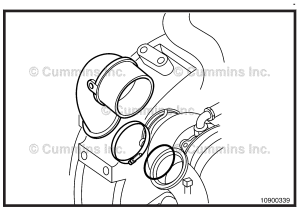


Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Turbo Outlet Connection Clamp Torque		10 N•m	[89 in-lb]	
Cold Starting Aid (010-029)				
Cold Aid Start Terminal		8 N•m 8 N•m	[71 in-lb] [71 in-lb]	
Air Intake Connection Adapter V-Band		10 N•m	[89 in-lb]	
		11 N•m	[97 in-lb]	
		24 N•m	[212 in-lb]	
Cold Start Capscrew Torque		14 N•m	[124 in-lb]	
Turbocharger (010-033)				
Automotive Turbocharger Mounting Nuts		43 N•m	[32 ft-lb]	

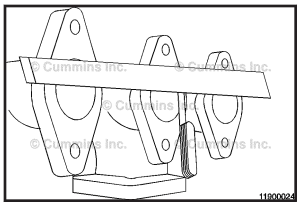
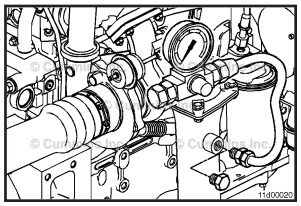
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Turbocharger Compressor Discharge Outlet Clamp		8 N•m	[71 in-lb]	
Turbocharger Compressor Inlet Clamp		8 N•m 8 N•m	[71 in-lb] [71 in-lb]	
Marine Turbocharger Mounting Nuts		43 N•m	[32 ft-lb]	
Turbocharger Coolant Hoses (010-041) **Torque Value:** 10-mm banjo fittings Step 1 15 N•m [133 in-lb]				
Torque Value: 14-mm banjo fittings Step 1 24 N•m [212 in-lb]				
Turbocharger Turbine Housing Drain Elbow		24 N•m 8 N•m	[212 in-lb] [71 in-lb]	
Coolant Vent Line Turbocharger Connection		24 N•m 24 N•m	[212 in-lb] [212 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Turbocharger Oil Drain Line (010-045)				
Turbocharger Oil Drain Line Capscrews		10 N•m 23 N•m	[89 in-lb] [204 in-lb]	
Turbocharger Oil Drain Line Connection		23 N•m 8 N•m	[204 in-lb] [71 in-lb]	
Turbocharger Oil Supply Line (010-046)				
Turbocharger Oil Supply Line		28 N•m	[21 ft-lb]	
Turbocharger Wastegate Actuator (010-050)				
Wastegate Control Rod Retaining Clip		8 N•m	[71 in-lb]	
Wastegate Control Rod Jam Nut		8 N•m	[71 in-lb]	
Air Intake Connection (010-080)				
Intake Manifold Cover Capscrews		11 N•m	[97 in-lb]	
Intake Manifold Cover Capscrews		24 N•m	[212 in-lb]	

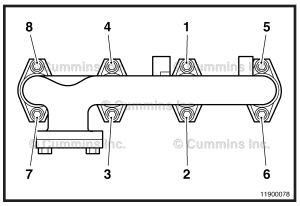
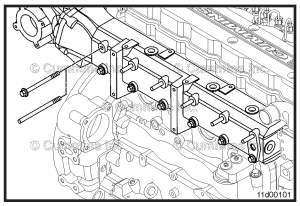
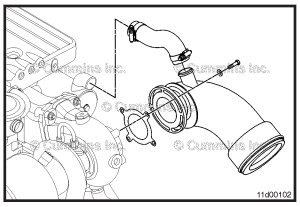
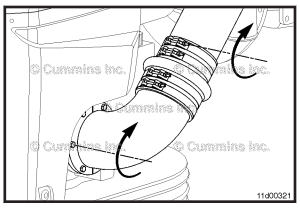
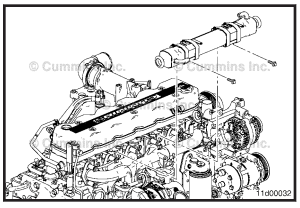
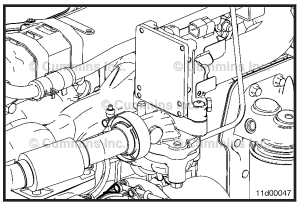
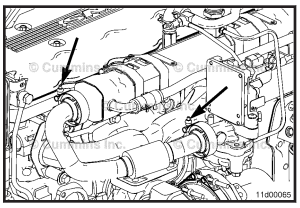
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Air Intake Connection Rear Portion Capscrews		15 N•m	[133 in-lb]	
Air Intake Connection Front Portion Capscrews		15 N•m 8 N•m	[133 in-lb] [71 in-lb]	
Air Intake Manifold Cover (010-108)		24 N•m	[212 in-lb]	
Variable Geometry Turbo Actuator (010-113) Turbocharger Actuator Mounting		17 N•m	[150 in-lb]	
Air Intake Connection Adapter (010-131) Two Piece Air Intake Connection Adapter Capscrews.		24 N•m	[212 in-lb]	
Two Piece Air Intake Connection Adapter V Band Clamp		8 N•m	[71 in-lb]	
Single Piece Air Intake Connection Adapter		10 N•m	[89 in-lb]	

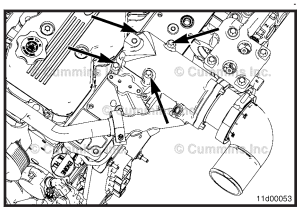
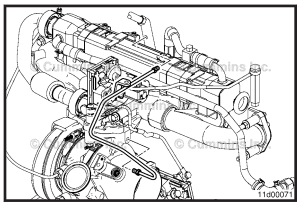
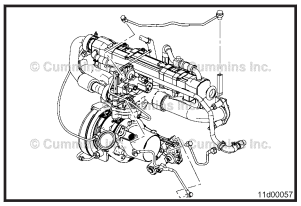
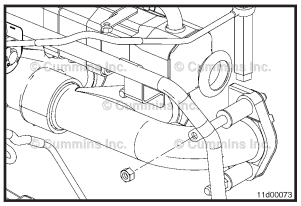
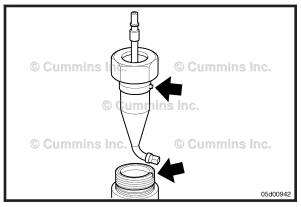
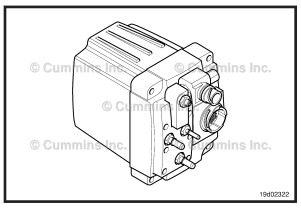
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Turbocharger Compressor Outlet Connection (010-132)				
Turbocharger Compressor Outlet Connection Clamp.		10 N•m	[89 in-lb]	

Exhaust System - Group 11 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Exhaust Manifold, Dry (011-007)					
Exhaust Manifold Flatness		0.20 mm	MAX	0.008 in	
Exhaust Restriction (011-009)					
Exhaust Restriction		75 mm Hg	MAX	40 in H_2O	

Exhaust System - Group 11 - Torque Values

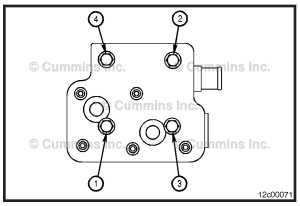
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Exhaust Manifold, Dry (011-007)				
Exhaust Manifold Capscrews Torque		53 N•m 43 N•m	[39 ft-lb] [32 ft-lb]	
Exhaust Manifold, Wet (011-008)				
Exhaust Manifold Mounting Capscrews		43 N•m	[32 ft-lb]	
Exhaust Outlet Connection (011-017)				
Exhaust Outlet Connection		24 N•m 24 N•m	[212 in-lb] [212 in-lb]	
Exhaust Outlet Connection Lower Elbow Hose Clamps		6 N•m 23 N•m	[53 in-lb] [204 in-lb]	
Exhaust Gas Recirculation Cooler (011-019)				
Egr Cooler Mounting Bracket Capscrews		33 N•m	[24 ft-lb]	
EGR Valve (011-022)				
Egr Valve V-Band Connection		11 N•m 43 N•m 43 N•m	[100 in-lb] [32 ft-lb] [32 ft-lb]	
EGR Cooler Connection (011-024)				
Egr Cooler V-Band Connection		11 N•m 24 N•m	[100 in-lb] [212 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
EGR Connection Tubes (011-025)		11 N•m 24 N•m 24 N•m	[100 in-lb] [212 in-lb] [212 in-lb]	
Exhaust Pressure Sensor Tube (011-027)		10 N•m	[89 in-lb]	
EGR Valve Coolant Lines (011-030) **Torque Value:** 10-mm Banjo Step 1 15 N•m [133 in-lb] **Torque Value:** Vent Fitting Banjo Step 1 15 N•m [133 in-lb]				
EGR Cooler Coolant Lines (011-031) Coolant Line Bracket Nut		45 N•m	[33 ft-lb]	
Aftertreatment Nozzle (011-040) Aftertreatment Nozzle Retaining Nut.		60 N•m	[44 ft-lb]	
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]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.

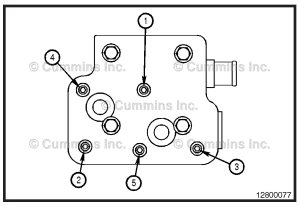
Compressed Air System - Group 12 - Torque Values

Air Compressor Cylinder Head, Single Cylinder (012-007)



Torque Value:

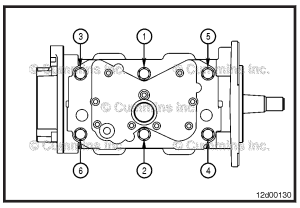
Step 1	25 N•m	[221 in-lb]
Step 2	Rotate 90 degrees	



Torque Value:

Step 1	6 N•m	[53 in-lb]
Step 2	Rotate 90 degrees.	

Air Compressor Cylinder Head, Two Cylinder (012-008)



Torque Value:

Step 1 - All capscrews

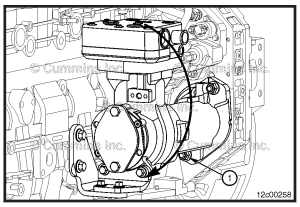
Step 1	20 N•m	[177 in-lb]

Torque Value:

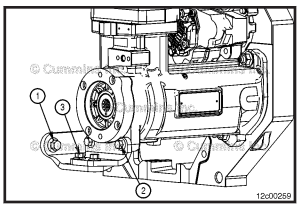
Step 2 - All capscrews

Step 1	33 N•m	[24 ft-lb]
	160 N•m	[118 ft-lb]
	77 N•m	[57 ft-lb]

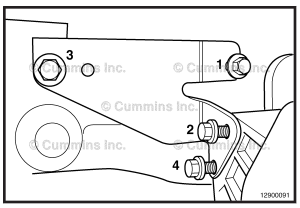
Air Compressor (012-014)



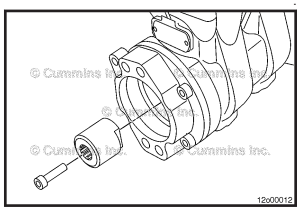
	77 N•m	[57 ft-lb]



	24 N•m	[212 in-lb]
	43 N•m	[32 ft-lb]
	77 N•m	[57 ft-lb]
77 N•m		[57 ft-lb]



	24 N•m	[212 in-lb]
22 N•m		[195 in-lb]

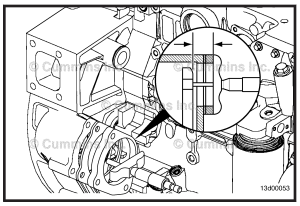
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Air Compressor Rear Bearing Housing, Two Cylinder (012-112)		25 N•m	[221 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.

Electrical Equipment - Group 13 - Specifications

Starting Motor (013-020)

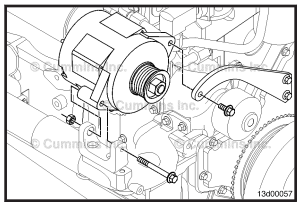
Starting Motor Spacing	49.28 mm	MIN	1.94 in
	52.32 mm	MAX	2.06 in



Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.

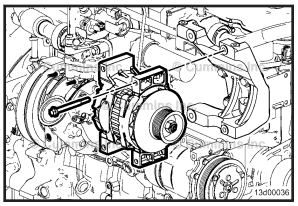
Electrical Equipment - Group 13 - Torque Values

Alternator (013-001)



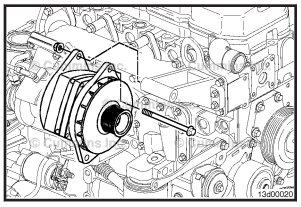
Torque Value:
Lower Mounting Capscrew
Step 1 40 N•m [30 ft-lb]

Torque Value:
Upper Link Mounting Capscrew
Step 1 24 N•m [212 in-lb]

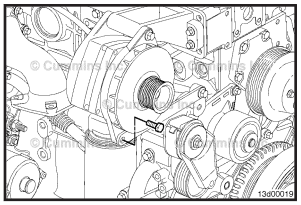


Torque Value:
M10 Capscrew
Step 1 36 N•m [27 ft-lb]

Torque Value:
M12 Capscrew
Step 1 64 N•m [47 ft-lb]



Alternator Capscrew 40 N•m [30 ft-lb]



Alternator Link Capscrew 24 N•m [212 in-lb]

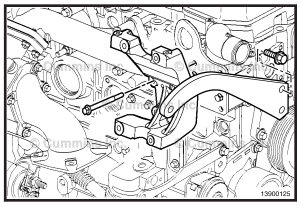
Torque Value:
Capscrews (1,3)
Step 1 44 N•m [33 ft-lb]

Torque Value:
Capscrew (2)
Step 1 35 N•m [26 ft-lb]

Alternator Bracket (013-003)

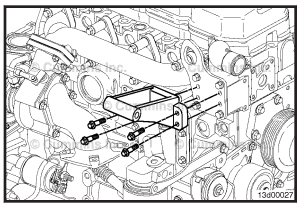
Spool Mount Upper And Lower Alternator Bracket Mounting Capscrews M8 24 N•m [18 ft-lb] 43 N•m [32 ft-lb]

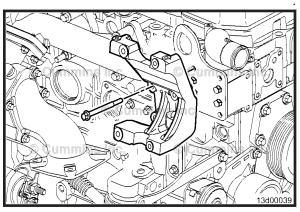
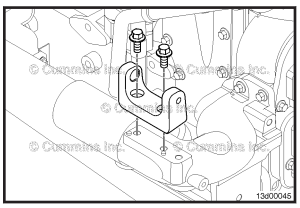
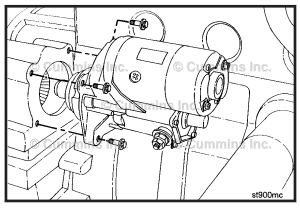
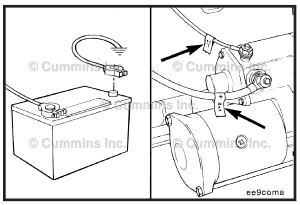
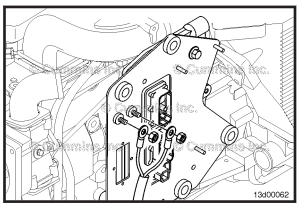
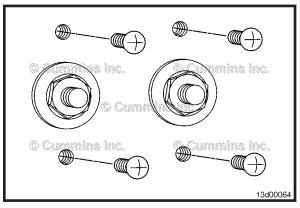
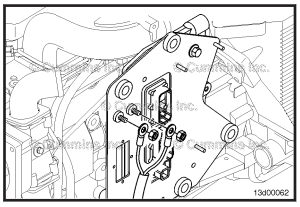
Spool Mount Upper And Lower Alternator Bracket Mounting Capscrews M10



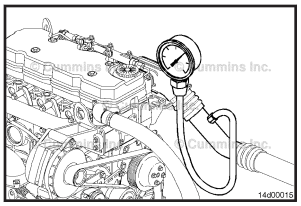
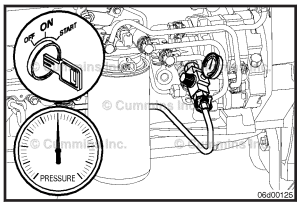
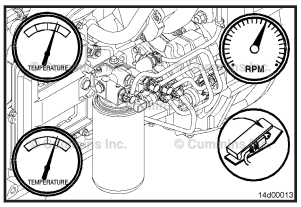
Hinge Mount Upper And Lower Alternator Bracket Mounting Capscrews M8 24 N•m [18 ft-lb] 43 N•m [32 ft-lb]

Hinge Mount Upper And Lower Alternator Bracket Mounting Capscrews M10



Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Alternator Bracket Mounting Capscrews		45 N•m	[33 ft-lb]	
Alternator Mounting Bracket Capscrews		54 N•m	[40 ft-lb]	
Starting Motor (013-020) Starting Motor Mounting Capscrews		43 N•m	[32 ft-lb]	
Torque Value: M5 Step 1	4 N•m	[35 in-lb]		
Torque Value: M10 Step 1	21 N•m	[185 in-lb]		
ECM Unswitched Power Terminal Blocks (013-047)		5 N•m	[45 in-lb]	
		3.5 N•m	[30 in-lb]	
		5 N•m	[45 in-lb]	

Engine Testing - Group 14 - Specifications

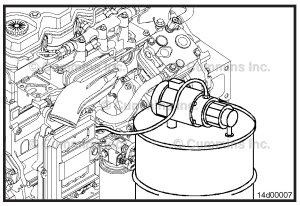
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Engine Testing (Engine Dynamometer) (014-005)					
Pressure Gauge Capacity		276 kPa	MIN	40 psi	
Fuel Filter Restriction Pressure Gauge Capacity		1379 kPa	MIN	200 psi	
Engine Run-in (Engine Dynamometer) (014-006)					
Lubricating Oil Temperature		90 °C	MIN	194 °F	
Fuel Temperature		32 °C	MAX	90 °F	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.

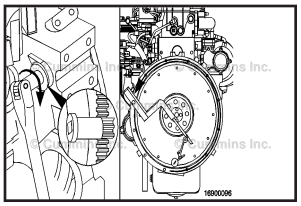
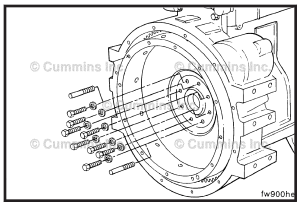
Engine Testing - Group 14 - Torque Values

Engine Testing (Engine Dynamometer) (014-005)

Main Oil Rifle Plug	6 N•m	[53 in-lb]



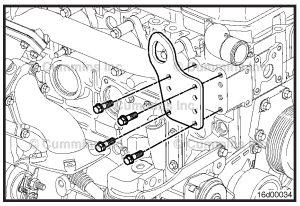
Mounting Adaptations - Group 16 - Specifications

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 Bore Runout		0.127 mm	MAX	0.005 in	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	

Mounting Adaptations - Group 16 - Torque Values

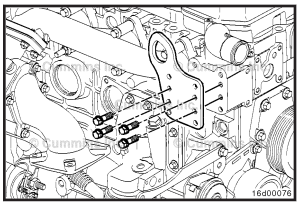
Engine Lifting Brackets (016-001)



Torque Value:
M8
Step 1 24 N•m [18 ft-lb]

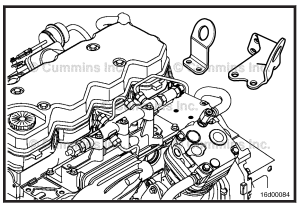
Torque Value:
M10
Step 1 43 N•m [32 ft-lb]

Pad-Mounted Alternators Front Bracket Capscrews				32 N•m	[24 ft-lb]

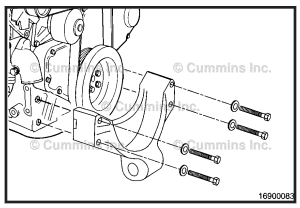


Torque Value:
M10
Step 1 43 N•m [32 ft-lb]

Torque Value:
M12
Step 1 77 N•m [57 ft-lb]



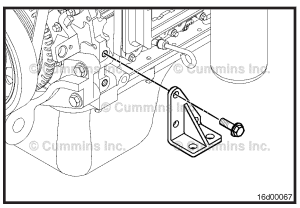
Engine Support Bracket, Front (016-002)



Torque Value:
Grade 8.8
Step 1 80 N•m [60 ft-lb]

Torque Value:
Grade 10.9
Step 1 115 N•m [85 ft-lb]

Torque Value:
Grade 12.9
Step 1 125 N•m [95 ft-lb]

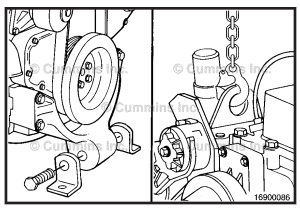


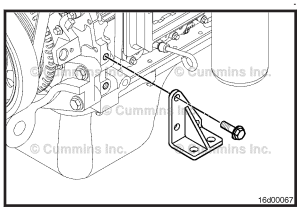
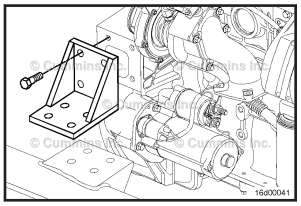
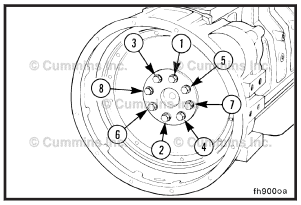
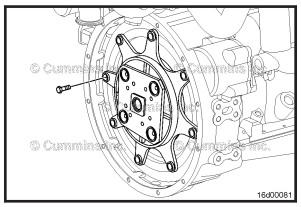
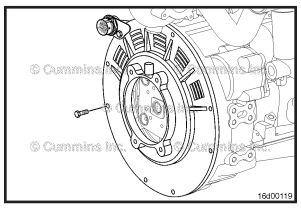
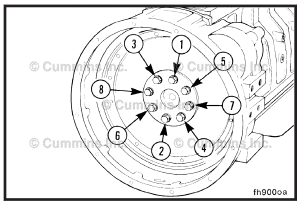
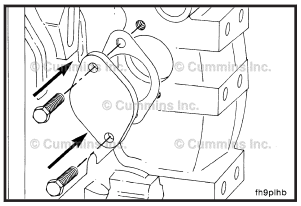
Torque Value:
Grade 8.8
Step 1 80 N•m [60 ft-lb]

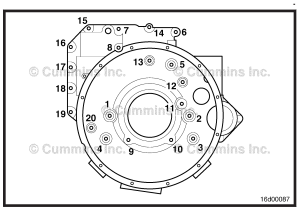
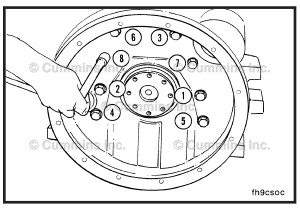
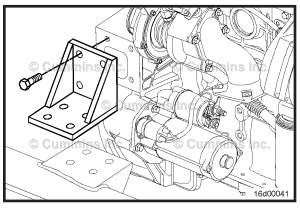
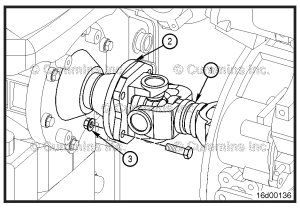
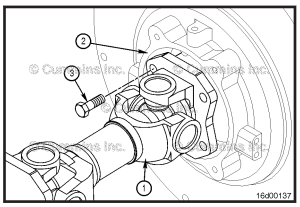
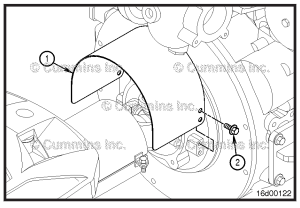
Torque Value:
Grade 10.9
Step 1 115 N•m [85 ft-lb]

Torque Value:
Grade 12.9
Step 1 125 N•m [95 ft-lb]

Cummins Engine Support Bracket Mounting Bolts				350 N•m	[258 ft-lb]



Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Marine Front Engine Support Bracket Mounting Capscrews		150 N•m	[111 ft-lb]	
Engine Support Bracket, Rear (016-003)				
Support Bracket Capscrew		77 N•m	[57 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]	
Flywheel (016-005)				
Torque Value:				
Step 1	30 N•m	[22 ft-lb]		
Step 2	Plus 60-degree turn			
Flywheel Housing (016-006)				
Access Cover Capscrews		24 N•m	[18 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Torque Value: M10 Step 1	49 N•m	[36 ft-lb]		
Torque Value: M12 Step 1	85 N•m	[63 ft-lb]		
Marine Flywheel Housing Capscrews		77 N•m	[57 ft-lb]	
Rear Engine Support Bracket Capscrews		77 N•m	[57 ft-lb]	
Engine Drive Shaft (016-027)		149 N•m	[110 ft-lb]	
		149 N•m	[110 ft-lb]	
36 N•m 23 N•m	[27 ft-lb] [204 in-lb]	36 N•m	[27 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.

Miscellaneous - Group 17 - Torque Values

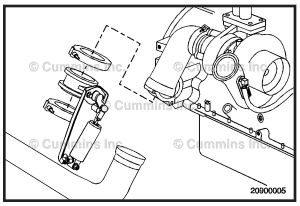
10 N•m	[89 in-lb]
20 N•m	[177 in-lb]
25 N•m	[221 in-lb]
35 N•m	[25 ft-lb]
45 N•m	[33 ft-lb]
18 N•m	[160 in-lb]
25 N•m	[221 in-lb]
30 N•m	[22 ft-lb]
40 N•m	[30 ft-lb]
50 N•m	[37 ft-lb]

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.

Vehicle Braking - Group 20 - Torque Values

Engine Exhaust Brake (020-016)

Exhaust Clamp		9 N•m	[80 in-lb]



General Engine

Specifications

Automotive and Industrial

Listed below are the general specifications for the engines covered by this manual.

Horsepower.....Refer to engine dataplate
Bore and Stroke
for 3.9 liters [238 C.I.D] and 5.9 liters [360 C.I.D] Engines.....102 mm [4.02 in] X 120 mm [4.72 in]
for 4.5 liters [275 C.I.D] and 6.7 liters [409 C.I.D] Engines.....107 mm [4.21 in] X 124 mm [4.88 in]
Displacement (four-cylinder engine).....3.9 liters [238 C.I.D] and 4.5 liters [275 C.I.D]
Displacement (six-cylinder engine).....5.9 liters [360 C.I.D] and 6.7 liters [409 C.I.D]
Firing Order (four-cylinder engine).....1-3-4-2
Firing Order (six-cylinder engine).....1-5-3-6-2-4
Approximate Engine Weight (with standard accessories):
Without EGR
Dry Weight for 3.9 Liters [238 C.I.D.].....370 kg [816 lb]
Dry Weight for 5.9 Liters [360 C.I.D.].....470 kg [1036 lb]
Dry Weight for 4.5 Liters [275 C.I.D.].....375 kg [827 lb]
Dry Weight for 6.7 Liters [409 C.I.D.].....475 kg [1047 lb]
Approximate Engine Weight (with standard accessories):
With EGR
Dry Weight for 5.9 Liters [360 C.I.D.].....519 kg [1144 lb]
Crankshaft Rotation (viewed from the front of the engine)..... **Clockwise**
Valve Clearance:
Intake.....0.254 mm [0.010 in]
Exhaust.....0.508 mm [0.020 in]
Maximum Overspeed Capability (15 seconds maximum).....4200 rpm
Minimum Ambient Air Temperature for Unaided Cold Start.....-12.2°C [10°F]
Minimum Engine Cranking Speed.....150 rpm
Engine Idle Speed.....Minimum 600 to maximum 800 rpm
Altitude Maximum Before Derate Occurs
for engines 3.9 liters and 5.9 liters Engines without EGR.....2000 m [6562 ft]
for engines 3.9 liters and 5.9 liters Engines with EGR.....3658 m [12000 ft]
for engines 4.5 liters and 6.7 liters Engines without EGR.....3048 m [10000 ft]
Oil Carryover:
Open-crankcase ventilation system.....Less than 2 grams/hour [0.07 oz/hour]
Engine Blowby:
New.....1 kPa [4 in H_2O]
Used.....2.49 kPa [10 in H_2O]

NOTE: The engine features a no-adjust overhead. The valve train is designed such that adjustment of the valve lash is **not** required for normal service until the first overhead set adjustment recommended under the Maintenance Schedule in Section 2 of this manual. The valve train operates acceptably within the limits of 0.152- to 0.381-mm [0.006- to 0.015-in] intake valve lash and 0.381- to 0.762-mm [0.015- to 0.030-in] exhaust valve lash.

Marine Applications

Listed below are the general specifications for this engine.

Horsepower.....Refer to engine dataplate
Compression Ratio.....17.2:1
Firing Order.....1-5-3-6-2-4
Crankshaft Rotation (viewed from the front of the engine)..... **Clockwise**
Displacement.....5.9 liters [360 C.I.D.]
Bore and Stroke.....102 mm [4.02 in] X 120 mm [4.72 in]
Dry Weight, Engine with Heat Exchanger System - Average.....612 kg [1350 lb]
Overhead Adjustment
Intake Valve.....0.254 mm [0.010 in]
Exhaust Valve.....0.508 mm [0.020 in]
Maximum Overspeed Capability.....4200 rpm
Minimum Engine Cranking Speed.....150 rpm
Engine Idle Speed Minimum.....600 rpm

NOTE: The engine features a no-adjust overhead. The valve train is designed such that adjustment of the valve lash is **not** required for normal service, until the first overhead set adjustment recommended under the Maintenance Schedule in Section 2 of this manual. The valve train operates acceptably within the limits of 0.152- to 0.381-mm [0.006- to 0.015-in] intake valve lash and 0.381- to 0.762-mm [0.015- to 0.030-in] exhaust valve lash.

Fuel System

Specifications

Automotive and Industrial

For performance and fuel rate values, refer to the Engine Data Sheet.

Maximum Fuel Inlet Restriction
With gear pump **only** (no engine mounted electric fuel lift pump) (at gear pump inlet).....50.7 kPa [15 in-Hg]
With engine mounted electric fuel lift pump (at electric fuel lift pump inlet).....20.3 kPa [6 in-Hg]
Rail Pressure
3.9 liters [238 C.I.D.] and 5.9 liter [360 C.I.D.] Engines Without EGR.....250 to 1400 bar [3626 to 20,305 psi]
5.9 liters [360 C.I.D.] Engines With EGR.....250 to 1600 bar [3626 to 23,206 psi]
4.5 liters [275 C.I.D], and 6.7 liters [409 C.I.D.] Engines without EGR.....250 to 1600 bar [3626 to 23,206 psi]
Fuel Pressure Range at Fuel Filter Outlet (engine cranking)
With gear pump **only** (no electric lift pump).....303 to 1103 kPa [44 to 160 psi]
With electric lift pump.....0.0 to 0.8 bar [0.0 to 11.6 psi]
Fuel Pressure Range at Fuel Filter Inlet (engine running)
With gear pump **only** (no electric lift pump).....503 to 1303 kPa [73 to 189 psi]
With electric lift pump.....0 to 80 kPa [0 to 11.6 psi]
Maximum Pressure Drop across Fuel Filter
With gear pump **only** (no electric lift pump).....200 kPa [29 psi]
With electric lift pump.....34 kPa [5 psi]
Maximum Fuel Drain Line Restriction.....20 kPa [2.9 psi]
Maximum Fuel Inlet Temperature.....70°C [158°F]

Marine Applications

For performance and fuel rate values, refer to the Engine Data Sheet.

Engine Idle Speed.....Minimum 600 rpm
Maximum Fuel Inlet Restriction (to lift pump).....14 kPa [4 in-Hg]
Rail Pressure.....250 to 1440 bar [3626 to 20,885 psi]
Fuel Pressure Range at Fuel Filter Outlet (engine cranking).....0 to 79.9 kPa [0 to 11.6 psi]
Fuel Pressure Range at Fuel Filter Inlet (engine running).....0.0 to 79.9 kPa [0.0 to 11.6 psi]
Maximum Pressure Drop across Fuel Filter.....34 kPa [5 psi]
Maximum Fuel Drain Line Restriction.....34 kPa [5 psi]
Maximum Fuel Inlet Temperature.....60°C [140°F]
Minimum Engine Cranking Speed.....150 rpm
Primary Off engine fuel filter element.....10 Micron
Secondary On engine fuel filter element.....3 Micron

Lubricating Oil System

Specifications

Automotive and Industrial

Oil Pressure:
- Low idle (minimum allowed)....69 kPa [10 psi]
- At rated (minimum allowed)....207 kPa [30 psi]

Oil-regulating valve-opening pressure range....448 kPa [65 psi] to 517 kPa [75 psi]
Oil filter differential pressure to open bypass....345 kPa [50 psi]
Lubricating Oil Filter Capacity....0.95 liters [1 qt]

Oil Capacity of Standard Engine (four-cylinder):
3.9 liters [238 C.I.D.] Engines (Low Capacity Oil Pan)
- Pan **only** ....7.9 liters [8.3 qt]
- Total system....10 liters [10.6 qt]
- High to low (on dipstick)....2.2 liters [2.3 qt]

Oil Capacity of Standard Engine (four-cylinder):
3.9 liters [238 C.I.D.] Engines (Suspended Oil Pan)
- Pan **only** ....11 liters [11.6 qt]
- Total system....13 liters [13.7 qt]
- High to low (on dipstick)....2.0 liters [2.1 qt]

Oil Capacity of Standard Engine (four-cylinder):
4.5 liters [275 C.I.D.] Engines (Suspended Oil Pan)
- Pan **only** ....11 liters [11.6 qt]
- Total system....13 liters [13.7 qt]
- High to low (on dipstick)....1.9 liters [2.0 qt]

Oil Capacity of Standard Engine (four-cylinder):
4.5 liters [275 C.I.D.] Engines (Aluminium Oil Pan)
- Pan **only** ....13 liters [13.7 qt]
- Total system....15 liters [15.9 qt]
- High to low (on dipstick)....3.0 liters [3.2 qt]

Oil Capacity of Standard Engine (four-cylinder):
4.5 liters [275 C.I.D.] Engines (High Capacity Oil Pan)
- Pan **only** ....16 liters [16.9 qt]
- Total system....18 liters [19.0 qt]
- High to low (on dipstick)....6.0 liters [6.3 qt]

Oil Capacity of Standard Engine (six-cylinder):
5.9 liters [360 C.I.D] Engines (Low Capacity Oil Pan)
- Pan **only** ....11.0 liters [11.6 qt]
- Total System....13.0 liters [13.7 qt]
- High to Low (on dipstick)....3.3 liters [3.5 qt]

Oil Capacity of Standard Engine (six-cylinder):
5.9 liters [360 C.I.D] Engines (Suspended Oil Pan)
- Pan **only** ....17.5 liters [18.5 qt]
- Total System....19.5 liters [20.6 qt]
- High to Low (on dipstick)....2.0 liters [2.1 qt]

Oil Capacity of Standard Engine (six-cylinder):
5.9 liters [360 C.I.D] Engines (Standard Oil Pan)
- Pan **only** ....14.2 liters [15.0 qt]
- Total System....16.7 liters [17.6 qt]
- High to Low (on dipstick)....1.9 liters [2.0 qt]

Oil Capacity of Standard Engine (six-cylinder):
6.7 liters [409 C.I.D] Engines (Standard Oil Pan)
- Pan **only** ....14.2 liters [15.0 qt]
- Total System....16.7 liters [17.6 qt]
- High to Low (on dipstick)....1.9 liters [2.0 qt]

Oil Capacity of Standard Engine (six-cylinder):
6.7 liters [409 C.I.D] Engines (Suspended Oil Pan)
- Pan **only** ....17.2 liters [18.5 qt]
- Total System....19.7 liters [20.8 qt]
- High to Low (on dipstick)....2.8 liters [3.0 qt]

Oil Capacity of Standard Engine (six-cylinder):
6.7 liters [409 C.I.D] Engines (High Capacity Oil Pan)
- Pan **only** ....23.9 liters [25.3 qt]

Total System.....26.4 liters [27.9 qt]
High to Low (on dipstick).....7.4 liters [7.8 qt]

Maximum Oil Temperature:

Without EGR

for 3.9 liters [238 C.I.D.] and 5.9 liters [360 C.I.D.] Engines.....120°C [248°F]
for 4.5 liters [275 C.I.D.] and 6.7 liters [409 C.I.D.] Engines.....138°C [280°F]

Maximum Oil Temperature:

With EGR

for 5.9 liters [360 C.I.D.] Engines.....135°C [275°F]

NOTE: If the type/oil capacity of the oil pan is **not** known:

1 Contact a Cummins® Distributor/Dealer.

2 Determine the capacity of the oil pan option for the engine being serviced by using QuickServe™ OnLine and the engine serial number.

3 Fill the lubricating oil pan to the lowest oil pan capacity listed for the engine being serviced. Then add 0.95 liters [1 qt] of oil at a time until it reaches the high mark on the dipstick. Record the number of quarts added so the capacity is known the next time the oil is drained.

Marine Applications

Oil Pressure

At Low Idle (minimum allowable).....55 kPa [8 psi]
At Rated Speed (minimum allowable).....193 kPa [28 psi]

Lubricating Oil Filter Capacity..... 0.95 liters [1 qt]

Oil Pan Capacity, Standard Oil Pan

Low.....12.3 liters [13 qt]
High.....14.2 liters [15 qt]

Total System Capacity (Oil Pan and New Oil Filter)

Standard Oil Pan.....15.1 liters [16 qt]

Cooling System

Specifications

Automotive and Industrial

Coolant Capacity (four-cylinder engine **only**).....8.5 liters [2.2 gal]
Coolant Capacity (six-cylinder engine only)
Without EGR.....10 liters [2.6 gal]
With EGR.....11 liters [2.9 gal]
Standard Modulating Thermostat - Range
Automotive Applications
Without EGR.....82 to 92°C [180 to 198°F]
With EGR.....88 to 97°C [190 to 207°F]
Standard Modulating Thermostat - Range
Industrial Applications
Without EGR.....88 to 97°C [190 to 207°F]
Maximum Allowed Operating Temperature
Automotive Applications
Without EGR.....100°C [212°F]
With EGR.....107°C [225°F]
Maximum Allowed Operating Temperature
Industrial Applications
Without EGR.....107°C [225°F]
Minimum Recommended Operating Temperature.....71°C [160°F]
Minimum Recommended Pressure Cap
Automotive Applications
Without EGR.....50 kPa [7 psi]
With EGR .....103 kPa [15 psi]
Minimum Recommended Pressure Cap
Industrial Applications
Without EGR.....50 kPa [7 psi]
Marine Applications

Coolant Capacity
Engine Only.....10 liters [2.6 gal]
Engine Including Heat Exchanger and Wet Manifold.....25 liters [6.6 gal]
Standard Thermostat Modulating Thermostat Range.....74° to 85°C [165° to 185°F]
Minimum Recommended Pressure Cap.....103 kPa [15 psi]
Maximum External Pressure Loss in Cooling System.....35 kPa [5 psi]
Maximum Static Pressure of Coolant (exclusive of pressure cap).....103 kPa [15 psi]
Maximum Coolant Temperature.....96°C [205°F]
Minimum Allowable Coolant Expansion Space.....5 percent of System Capacity
Minimum Coolant Makeup Capacity.....1.5 liters [1.6 qt]
Maximum Sea Water Pressure.....172 kPa [25 psi]
Maximum Sea Water Inlet Restriction.....− 127 mm Hg [− 5 in Hg]

Air Intake System

Specifications

Automotive and Industrial

Maximum Intake Restriction (clean air filter element).....254 mm H_2O [10 in H_2O]
Maximum Intake Restriction (dirty air filter element).....635 mm H_2O [25 in H_2O]
Charge Air Cooler Temperature Differential:
Minimum Differential (Intake manifold — Ambient air temperature).....21°C [38°F]
Maximum Charge Air Cooler Pressure Difference.....20.6 kPa [3 psi]
Marine Applications
Maximum intake restriction (clean air filter element)..... 381 mm H_2O [15 in H_2O]
Maximum intake restriction (dirty air filter element).....635 mm H_2O [25 in H_2O]

Exhaust System

Specifications

All Applications Except Marine

Maximum Back Pressure from Piping and Silencer (combined):

Hg.....76 mm [3 in]
H_2O.....1016 mm [40 in]

Exhaust Pipe Size (normally acceptable inside diameter).....76 mm [3 in]

Marine Applications

Maximum Back Pressure from Piping and Silencer (combined):

Hg.....127 mm [5 in]
H_2O.....1763 mm [68 in]
kPa.....17
PSI.....2.5

Electrical System

Specifications

Recommended Battery Capacity

System Voltage	Ambient Temperature			
	-18°C [0°F]	-29°C [-20°F]		
	Cold Cranking Amperes	Reserve Capacity (minutes) [1]	Cold Cranking Amperes	Reserve Capacity (minutes) [1]
12 VDC	800	260	950	260
24 VDC [2]	400	130	475	130

The number of plates within a given battery size determines reserve capacity. Reserve capacity is the length of time for which a battery at 27°C [81°F] can supply 25 amperes at 10.5 VDC or greater. Cold cranking amp ratings are based on two 12-VDC batteries in series.

Specific Gravity at 27°C [81°F]	State of Charge
1.260 to 1.280	100%
1.230 to 1.250	75%
1.200 to 1.220	50%
1.170 to 1.190	25%
1.110 to 1.130	Discharged

Cummins®/Fleetguard® Filter Specifications

General Information

Cummins Filtration Inc. is a subsidiary of Cummins Inc. Cummins Filtration™ filters are developed through joint testing at Cummins Inc. and Cummins Filtration Inc..

Fleetguard® filters are standard on new Cummins® engines. Cummins Inc. recommends their use.

Fleetguard® 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 Inc. high 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.

Automotive and Industrial

Filter Part Numbers				
	Lubricating Oil Filter Without EGR (ISBe 4 and 6 cylinder CM800)	**Lubricating Oil Filter With EGR (ISB CM850)**	**Fuel Filter Without EGR (ISBe 4 and 6 cylinder CM800)**	**Fuel Filter With EGR (ISB CM850)**
Cummins® Part Number	4989314	3937736	4897833	3954904
Fleetguard® Part Number	LF16015	LF3970	FF5485	FS19596

Marine Applications

NOTE: Only use cellulose filters on marine engines. Do **not** use StratoPore™ filters on marine engines.

Filter Part Numbers		
	Lubricating Oil Filter	**Fuel Filter**
Cummins® Part Number	3937743	3959612
Fleetguard® Part Number	LF3959	FF5488

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.

Capscrew Markings and Torque Values

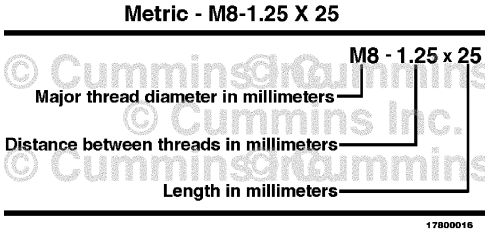
General Information

⚠CAUTION⚠

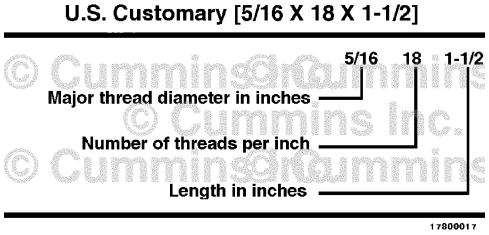
When replacing capscrews, always use a capscrew of the same measurement and strength as the capscrew being replaced. Using the wrong capscrews can result in engine damage.

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:

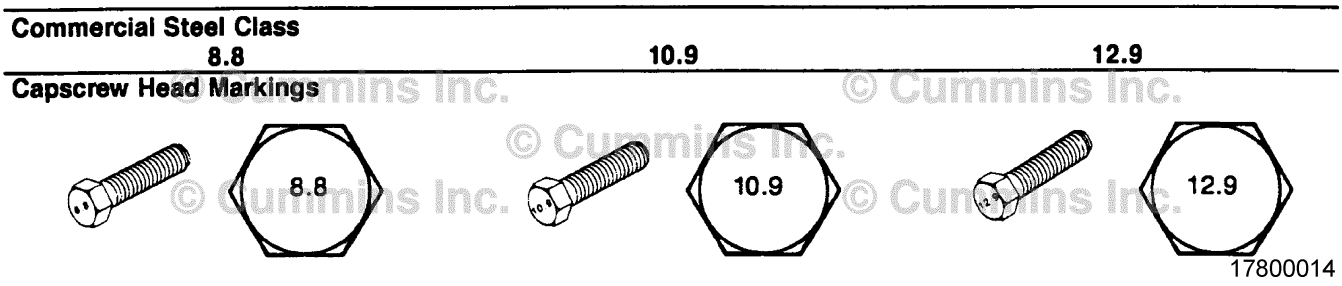


- **Always** use the torque values listed in the following tables when specific torque values are **not** available.
- Do **not** use the torque values in place of those specified in other sections of this manual.
- The torque values in the table are based on the use of lubricated threads.
- When the 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.

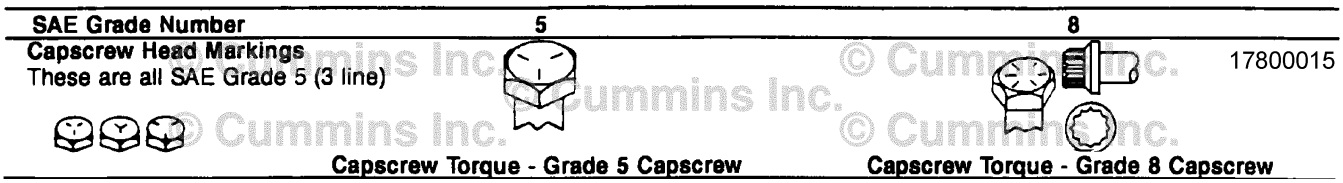
Capscrew Markings and Torque Values - Metric



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

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



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

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.					

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

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

Notes

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