



Troubleshooting and Repair Manual C Series Engines

SYMPTOM: COOLANT TEMPERATURE ABOVE NORMAL

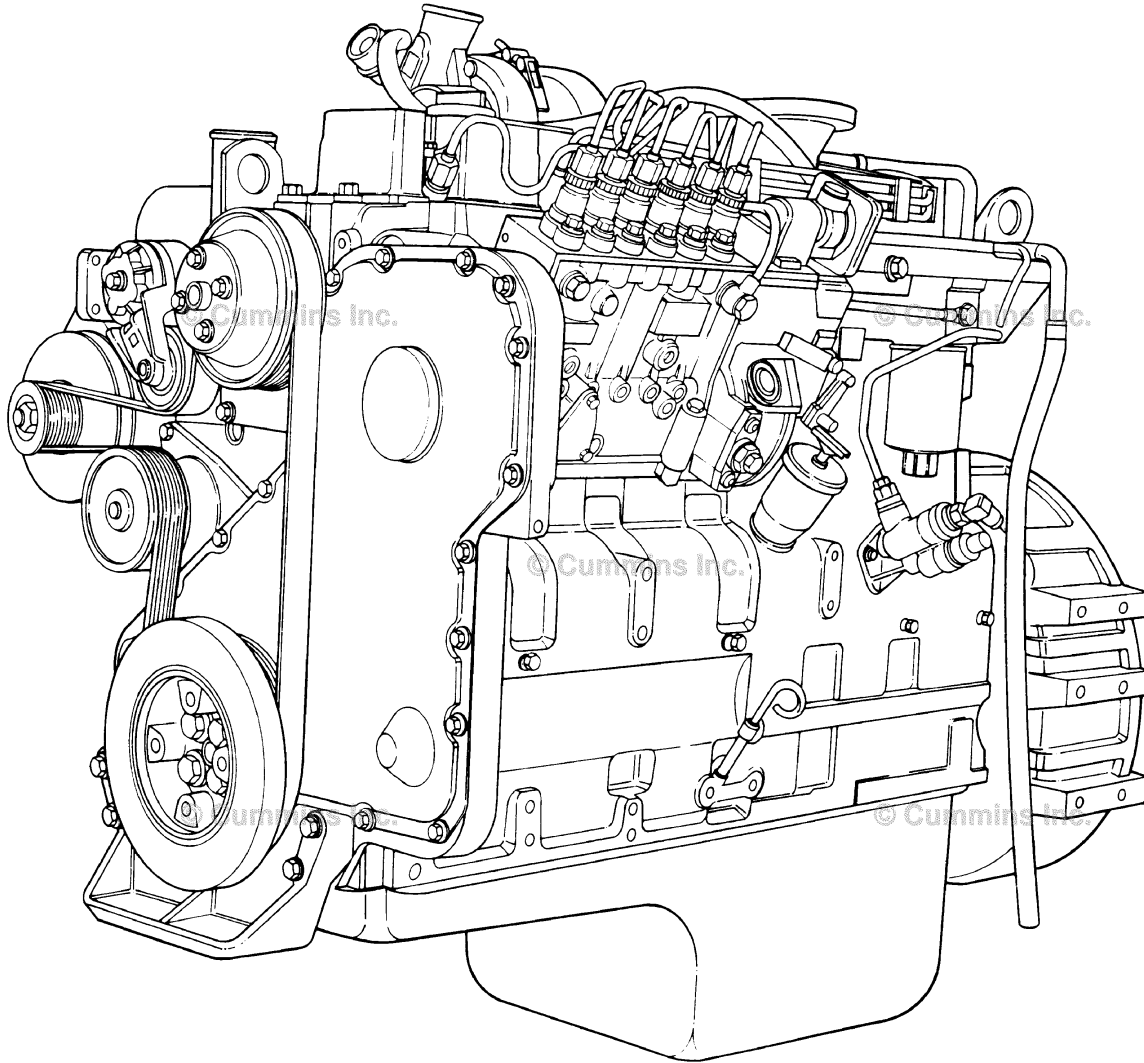
Cause	Correction
Low Coolant Level	Add Coolant. Refer to Section
Collapsed Radiator Hose	
Engine Lubricating Oil Level is too High or Low	
Engine is Receiving too Much Fuel	
Dirty Engine (Exterior)	
Loose Fan Drive Belt	
Radiator Shut Opening Closed	
Temperature Sensor Faulty	
Water Pump Faulty	
Thermostat Faulty	

Continued





Troubleshooting and Repair Manual C Series Engines



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Foreword

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

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

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

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

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

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

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

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

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About the Manual

General Information

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

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

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

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

How to Use the Manual

General Information

This manual is organized to provide an easy flow from problem identification to problem correction.

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














- 1 Locate the symptom on the Section Contents pages of Section TS.
 - Reference to the page number where the Troubleshooting Symptom Tree is found is made to the right of the symptom tree title.
- 2 The left column of boxes in the Troubleshooting Symptom Charts indicates a probable cause of the problem, starting at the top with the simplest and easiest to repair, and continuing downward to the most difficult.
 - The right column of boxes provides a brief description of the corrective action with a reference number to the correct procedure used to make the repair.
- 3 Locate the probable cause in the left column then turn to the procedure referenced in the right column.
- 4 The Troubleshooting Symptom Charts are based on the following assumptions:
 - The components have been installed according to the manufacturer's specifications.
 - The easiest repairs are done first.
 - All generic solutions are designed for the most common applications and Original Equipment Manufacturer (OEM).

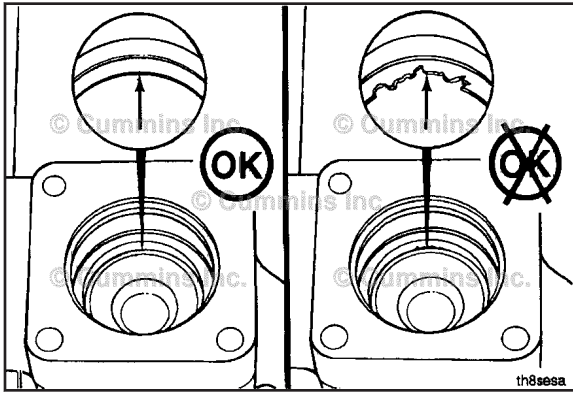
Refer to the Original Equipment Manufacturer's service manual for their specifications.

Symbols

General Information

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

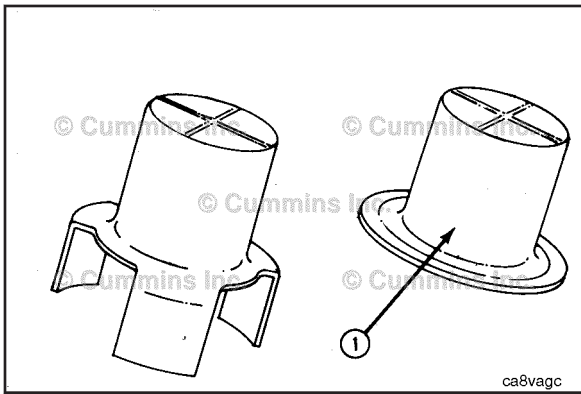
	WARNING - Serious personal injury or extensive property damage can result if the warning instructions are not followed.		PERFORM a mechanical or time MEASUREMENT .
	CAUTION - Minor personal injury can result or a part, an assembly, or the engine can be damaged if the caution instructions are not followed.		LUBRICATE the part or assembly.
	Indicates a REMOVAL or DISASSEMBLY step.		Indicates that a WRENCH or TOOL SIZE will be given.
	Indicates an INSTALLATION or ASSEMBLY step.		TIGHTEN to a specific torque.
	INSPECTION is required.		PERFORM an electrical MEASUREMENT .
	CLEAN the part or assembly.		Refer to another location in this manual or another publication for additional information.
			The component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.



Illustrations

General Information

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



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

General Safety Instructions

Important Safety Notice



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

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

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

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

General Repair Instructions

General Information

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



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

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

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

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

Welding on a Vehicle with an Electronic Controlled Fuel System

▲CAUTION▲

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

General Cleaning Instructions

Definition of Clean

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

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

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

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

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

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

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

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

Abrasive Pads and Abrasive Paper

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



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

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

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

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

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

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

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

WARNING

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

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

Gasket Surfaces

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

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

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

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

Solvent and Acid Cleaning

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

WARNING

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

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

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

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

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

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

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

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

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

Steam Cleaning

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



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

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

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

Plastic Bead Cleaning

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

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



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



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

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

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

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

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

⚠CAUTION⚠

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

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

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

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

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

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

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

Fuel System

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

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

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

Choose lint free towels for fuel system work.

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

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

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

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

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

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

Acronyms and Abbreviations

General Information

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

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

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

Section E - Engine and System Identification

Section Contents

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Engine Identification

Engine Dataplate

The engine dataplates show specific information about your engine. The engine serial number and control parts list (CPL) provide information for ordering parts and service manuals.

NOTE: The engine dataplate **must not** be changed unless approved by Cummins.

The dataplate is located on the top side of the gear housing. Have the following engine data available when communicating with a Cummins Authorized Repair Location. The information on the dataplate is **mandatory** when sourcing service parts.

<p>Cummins Engine Company, Inc. Columbus, Indiana 47202-3005 Assembled in U.S.A.</p>	CID/L.		CPL		Engine Serial No.		FEL	EPA
	Family				C/S		Nox	
	Valve lash						Timing -	
	Cold		Inch	Int.	Exh	Fuel rate at rated HP/Kw		
Firing Order		1 5 3 6 2 4			FR		Low Idle RPM	
Date of MFG. 20010501 Assembled in U.S.A. 3284906		Gross Rated HP/KW				at RPM		

Warnings: Injury can result and warranty is voided if fuel rate rpm or altitudes exceed published maximum values for this model and application.

00d00075


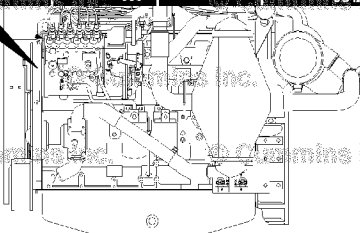
- 1 Control parts list (CPL)
- 2 Model
- 3 Engine serial number
- 4 Emissions certification
- 5 Horsepower and rpm rating.

Engine No. Moteur No.	Advant. HP Puiss. Indiquee(oh)	at	RPM	E.C.S.	NO	+	<p>IMPORTANT ENGINE INFORMATION: This engine conforms to U.S. EPA and California regulations applicable to 1998 Model Year New Heavy Duty Engines. This engine has a primary engine.</p> <p>This engine is certified to operate on diesel fuel certified for use in an urban bus as defined at 40 CFR 96.003-2. Scope of this engine for use in an urban bus is a violation of Federal law under the Clean Air Act.</p> <p>WARNING: Injury may result and warranty is voided if the engine is not properly installed and operated. ALWAYS SAFELY and CORRECTLY follow all instructions in the operator's manual and the engine's operating manual. Failure to follow maximum horsepower, peak or model or other limitation.</p>
Family	Peak Torque (FT-LB) Torque Ctrme	at	RPM	Inj. Timing Code Cylge direction	FEL	EPA	
Model	Fuel rate at Advant. HP Debit Combust a Puiss, Indiquee		mm ³ / stroke	G.I.D.L. Pouce Cube	CARB		
Date of Mfg. Date Fabrication	Valve Lash Cold Vlvs Soupapes a Froid		Exh. Ech.	CPL			
Idle Speed RPM Vitesse de Rotation	Tr. Se Course Inj.		Gov. Speed Vitesse Gouvernee		RPM		
Ref. No.					Cummins Engine Co., Inc. Made in U.S.A.		

00d00047

- 1 Engine Serial Number

- 2 Control Parts List
- 3 Model
- 4 Horsepower and rpm rating.

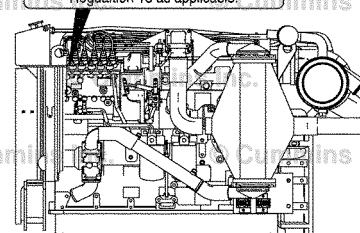
 Cummins Inc. Columbus, Indiana 47506-3005 Made in U.S.A.	Engine	GLDY L	GR	Engine Serial No.	45983742
	Cert. I.D.	505 8.3	2172	Family	M147A
Warning: Inlet air may result and measure is needed if fuel rate (rpm or altitude) exceed published maximum values for this model and application.	Timing TDC	23.5 DEGREES		Class. Spec.	341703
	Value both cold	0.012 ⁱⁿ	0.024 ⁱⁿ	Rated HP (Metric)	450 at 2600 rpm
	Firing order	1 5 3 6 2 4		Fuel inlet at IP	196 mm 3/8in
	Lean (kg /mm)	600 E.O.S.		Model Name	6CTA8.3-MS
Date of Mfg. 20000508 3383177					
00900309					

Marine Applications

Use the information from the engine dataplate when discussing service or the source of parts for your engine.

IMPORTANT ENGINE INFORMATION

This marine diesel engine conforms with the NOx requirements of the International Maritime Organization (IMO), MARPOL 73/78, Annex VI, Regulation 13 as applicable.



00900310

NOTE: This marine diesel engine conforms to the NOx requirements of the International Maritime Organization (IMO), MARPOL 73/78, Annex VI, Regulation 3 as applicable.

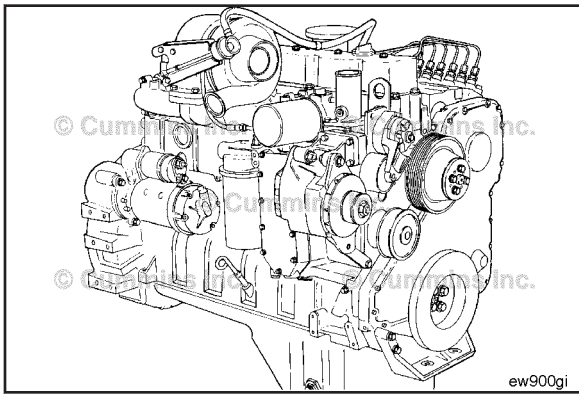
Marine Applications

Use the information from the engine dataplate when discussing service or the source of parts for your engine.

Cummins Inc. Columbus, Indiana 47202-3005 Made In U.S.A.	Engine	C.I.D./ L.	CPL	Engine Serial No.	45983742
	Cart. I.D.	505 8.3	2172	Family	M14TA
Warnings: Injury may result and warranty is voided if fuel rate rpm or altitudes exceed published maximum values for this model and application.	Timing-TDC	23.5 DEGREES		Cust. Spec.	341703
	Valve lash cold	0.012 ^{Int.}	0.024 ^{Exh.}	Rated HP (Metric)	450 at 2600 rpm
Date of Mfg.	20000508 3393177	Firing order	1 5 3 6 2 4	Fuel rated at HP	196 mm ³ /stroke
	Low Idle (rpm)	600	E.C.S.	Model Name	6CTA8.3-MS

00900311

- 1 Cubic inch displacement and liter displacement
- 2 Control Parts List Number
- 3 Engine serial number
- 4 Emission family identification
- 5 Customer specification - base engine part number
- 6 Rated horsepower at rpm
- 7 Fuel rated at horsepower
- 8 Model name
- 9 Emission control system (currently **not** used on marine)
- 10 Firing order
- 11 Valve lash cold
- 12 Timing - top dead center
- 13 Low idle (rpm)
- 14 Date of manufacturing
- 15 Warning tag
- 16 Cummins address:
 - Cummins Incorporated
 - Columbus, Indiana
 - 47202-3005
 - Made in U.S.A.
- 21 Engine certification identification (currently **not** used on marine).

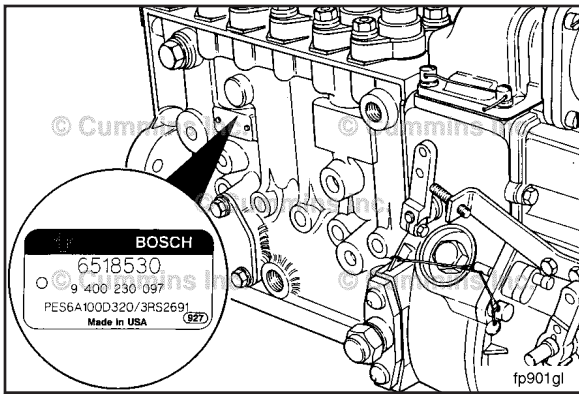


Cummins® Engine Nomenclature

Industrial Applications

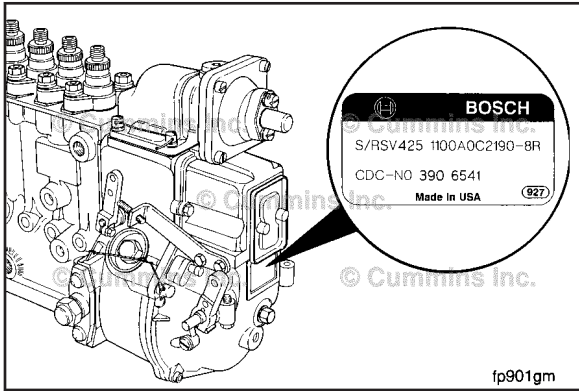
6CTAA8.3 Industrial Applications

- 8.3 = displacement in liters
- AA = charge air aftercooled
- T = turbocharged
- C = engine series
- 6 = number of cylinders

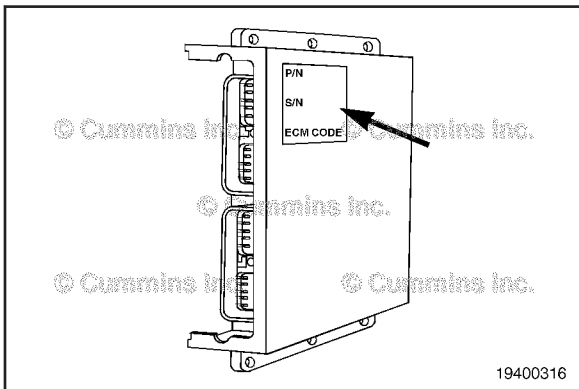


Fuel Injection Pump Dataplate

The Bosch® fuel injection pump dataplate is located on the side of the injection pump. It provides information for fuel pump calibration.



The Cummins part number for the fuel pump-governor combination is located on the governor dataplate.



ECM Dataplate

The external ECM dataplate is located on top of the ECM.

The dataplate contains the ECM part number (P/N), the ECM serial number (S/N), the manufacturing date code (D/C), the engine serial number (ESN), and the ECM code.

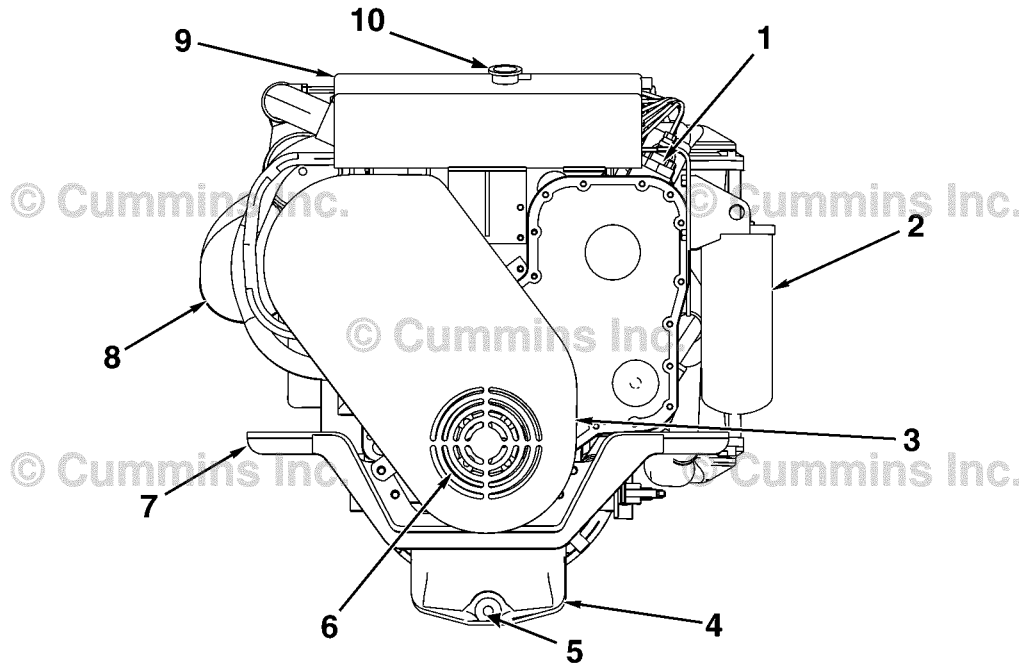
Engine Diagrams

Engine Views

Marine Applications

The following drawings illustrate the major components. Maintenance personnel **must** be familiar with each component to conduct the maintenance and service procedures discussed in this manual.

NOTE: The drawings in this section reflect a standard configuration. The engine can be equipped with optional accessories such as port-or starboard-side dipsticks. Location of optional items can be different from those shown.



Front View, C Series, Six-Cylinder Sea Water Aftercooled 450C

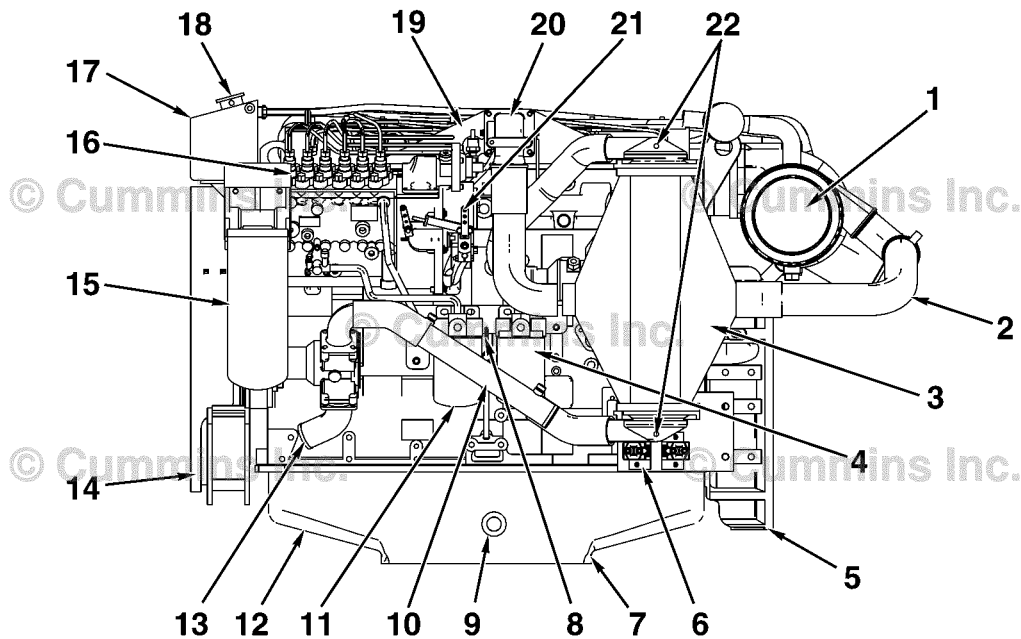
00900315

- 1 Fuel pump
- 2 Remote mounted oil filter (optional)
- 3 Belt guard
- 4 Oil pan
- 5 Engine oil drain, front
- 6 Vibration damper (behind cover)
- 7 Engine mount, front
- 8 Exhaust elbow
- 9 Expansion tank
- 10 Coolant fill.

Engine Diagrams

Engine Views

Marine Applications



Port View, C 8.3, Six-Cylinder Sea Water Aftercooled 450C

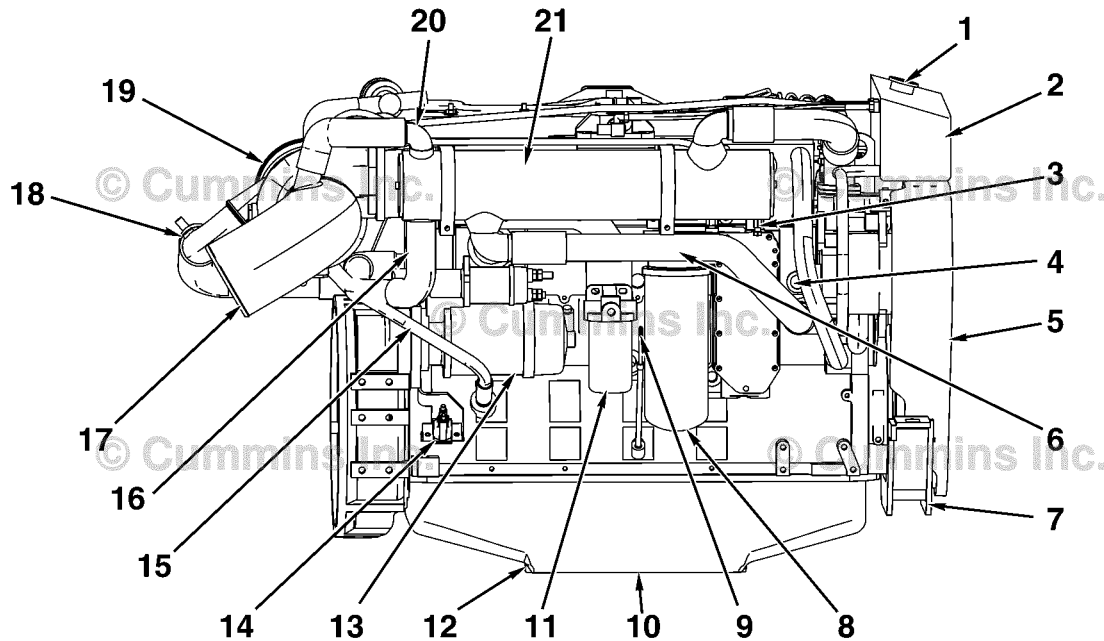
00900312

- 1 Air cleaner
- 2 Inlet air crossover tube
- 3 Aftercooler (sea water-type)
- 4 Water (coolant) filter
- 5 Flywheel housing
- 6 Air heater control solenoids
- 7 Engine oil drain, rear
- 8 Dipstick (engine oil) port-side standard
- 9 Oil pan heater location (if equipped)
- 10 Fuel cooler
- 11 Fuel filter (standard)
- 12 Oil pan
- 13 Sea water pump inlet (rotatable)
- 14 Belt guard
- 15 Remote mounted oil filter (optional)
- 16 Fuel pump
- 17 Expansion tank
- 18 Coolant fill
- 19 Stop lever
- 20 Air heater
- 21 Throttle lever
- 22 Zinc plugs (aftercooler).

Engine Diagrams

Engine Views

Marine Applications



Starboard View, C 8.3, Six-Cylinder Sea Water Aftercooled 450C

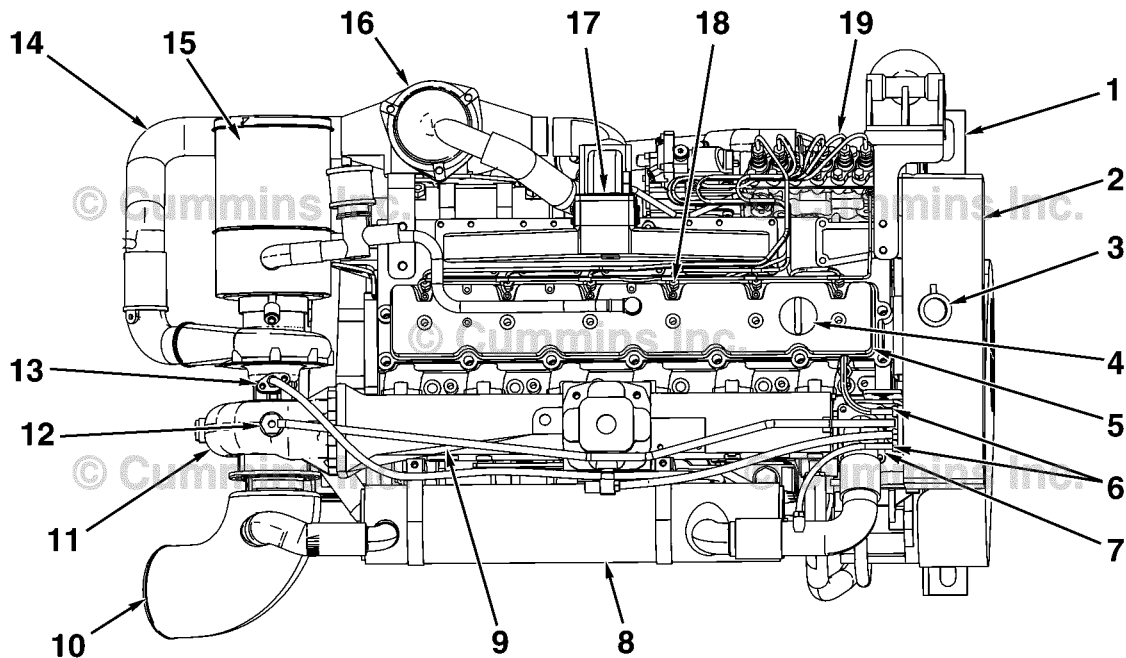
00900313

- 1 Coolant fill
- 2 Expansion tank
- 3 Zinc plug (heat exchanger)
- 4 Coolant temperature sensor (coolant drain)
- 5 Belt guard
- 6 Heat exchanger coolant outlet tube
- 7 Engine mount (front)
- 8 Engine oil filter
- 9 Engine oil dipstick (optional starboard-side)
- 10 Oil pan
- 11 Fuel filter (optional starboard-side)
- 12 Engine oil drain, rear
- 13 Starter
- 14 Starter auxiliary magnetic switch
- 15 Turbocharger oil drain tube
- 16 Sea water inlet to heat exchanger
- 17 Exhaust outlet elbow
- 18 Inlet air crossover tube
- 19 Turbocharger (water cooled)
- 20 Sea water outlet to exhaust
- 21 Heat exchanger.

Engine Diagrams

Engine Views

Marine Applications

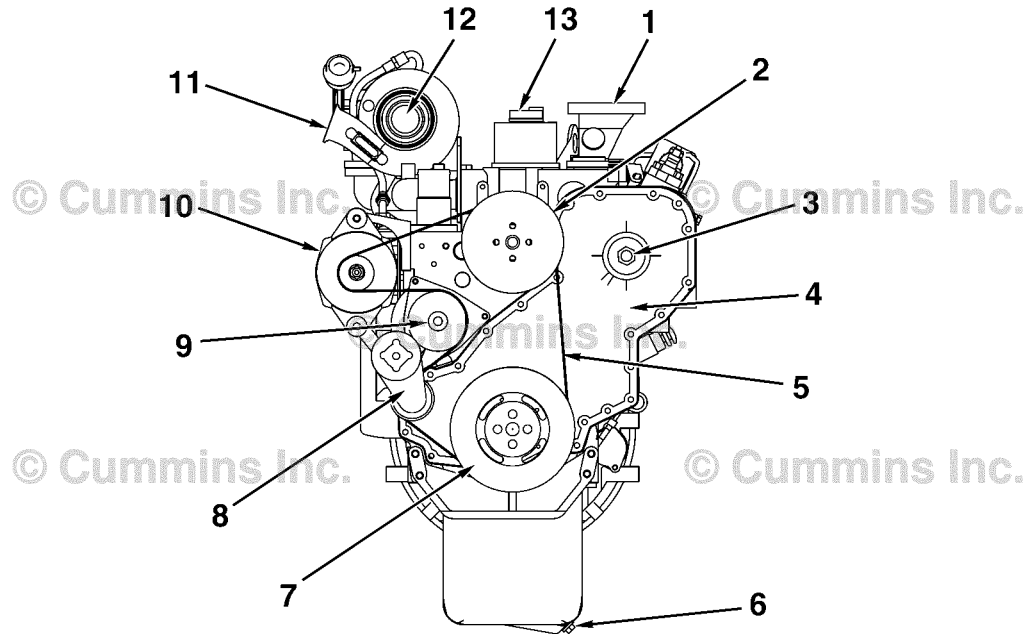


00900314

Top View, C Series, Six-Cylinder Sea Water Aftercooled 450C

- 1 Engine mount (front)
- 2 Expansion tank
- 3 Coolant fill
- 4 Engine oil fill
- 5 Valve cover
- 6 Coolant vent line connections
- 7 Coolant thermostat location
- 8 Heat exchanger
- 9 Exhaust manifold (water cooled)
- 10 Exhaust outlet elbow
- 11 Turbocharger (water cooled)
- 12 Turbocharger coolant vent line
- 13 Turbocharger oil inlet
- 14 Inlet air crossover tube
- 15 Air filter
- 16 Aftercooler (sea water-type)
- 17 Air heater
- 18 Fuel injector
- 19 Fuel pump.

Industrial Applications

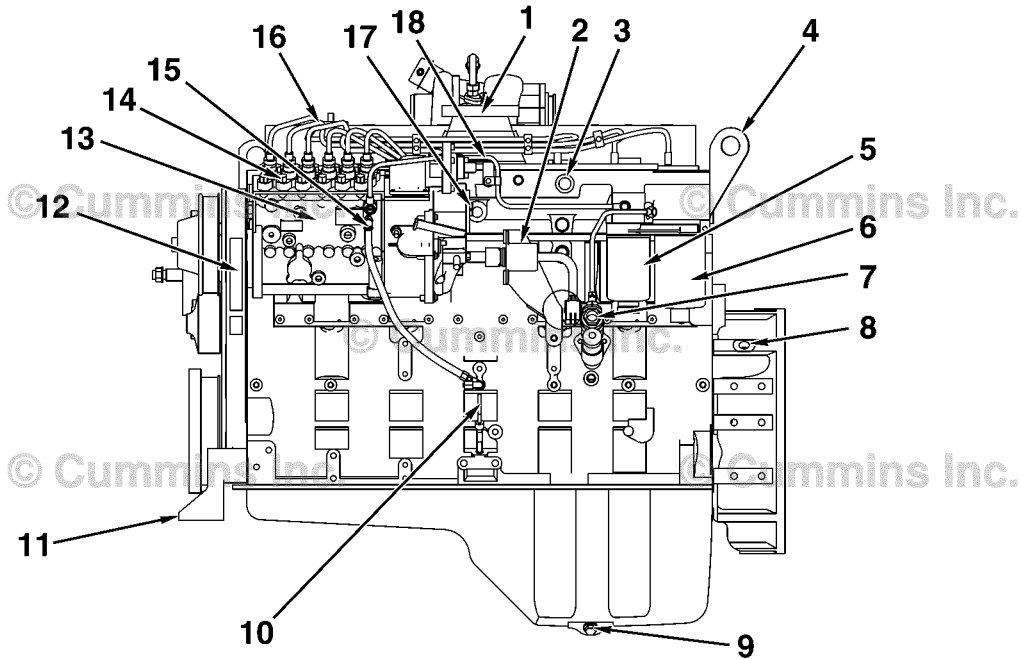


00900320

Front View - C8.3 - Industrial

- 1 Engine air inlet
- 2 Fan pulley
- 3 Fuel pump drive cover
- 4 Front gear cover
- 5 Drive belt
- 6 Lubricating oil pan drain plug
- 7 Vibration damper
- 8 Fan belt tensioner
- 9 Water pump
- 10 Alternator
- 11 Turbocharger air outlet
- 12 Turbocharger air inlet
- 13 Engine oil fill.

Industrial Applications

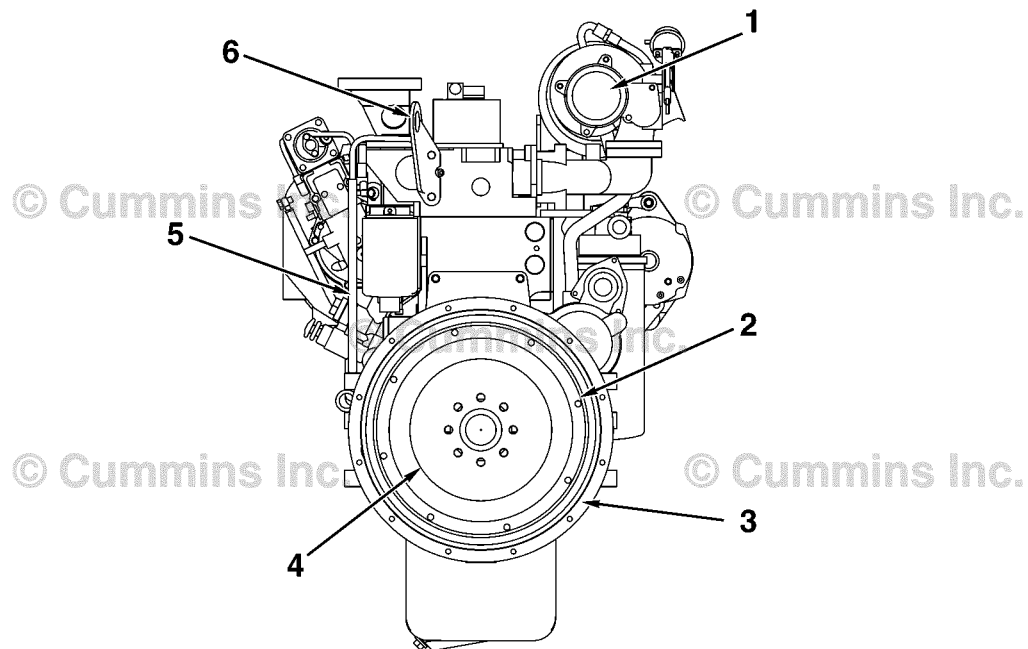


Left View - C8.3 - Industrial

00900322

- 1 Engine air inlet
- 2 Shutoff solenoid
- 3 M22 x 1.5 inlet (air)
- 4 Rear lifting bracket
- 5 Fuel filter
- 6 Fuel/water separator
- 7 Fuel transfer pump
- 8 3/4 x 16-inch UNF tap for magnetic pickup
- 9 Lubricating oil pan drain plug
- 10 Lubricating oil dipstick
- 11 Front engine mounting bracket
- 12 Engine dataplate
- 13 Fuel injection pump
- 14 Delivery valve
- 15 Fuel drain line
- 16 High-pressure fuel lines
- 17 1/2-inch NPTF inlet (air)
- 18 Intake air heater.

Industrial Applications

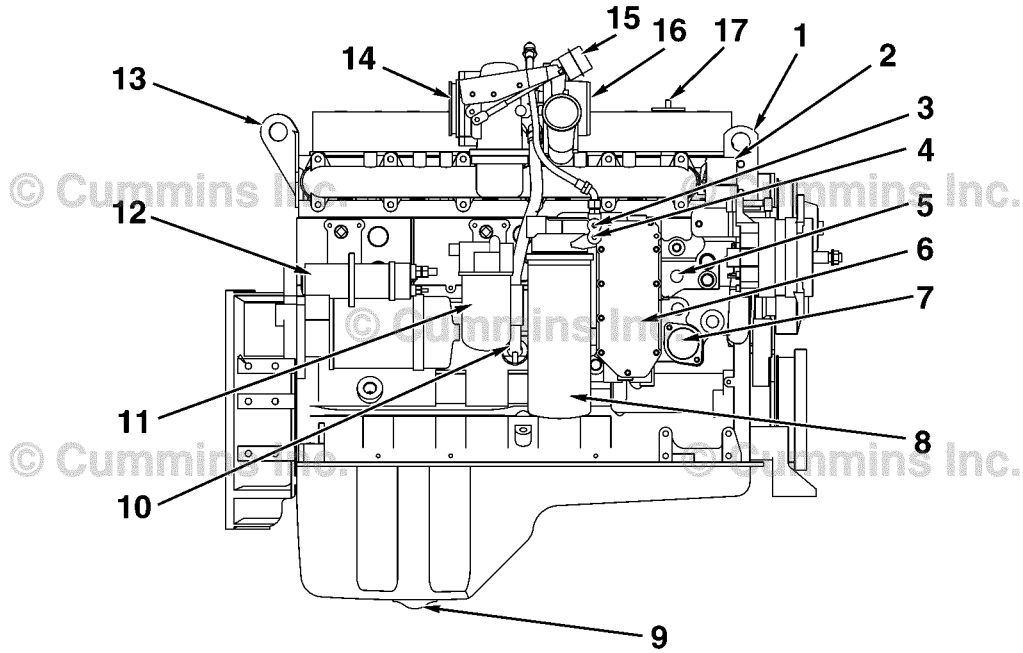


Rear View - C8.3 - Industrial

00900321

- 1 Turbocharger exhaust outlet
- 2 Flexplate mounting holes
- 3 Flywheel housing
- 4 Flywheel
- 5 Crankcase breather tube
- 6 Rear engine lifting bracket.

Industrial Applications

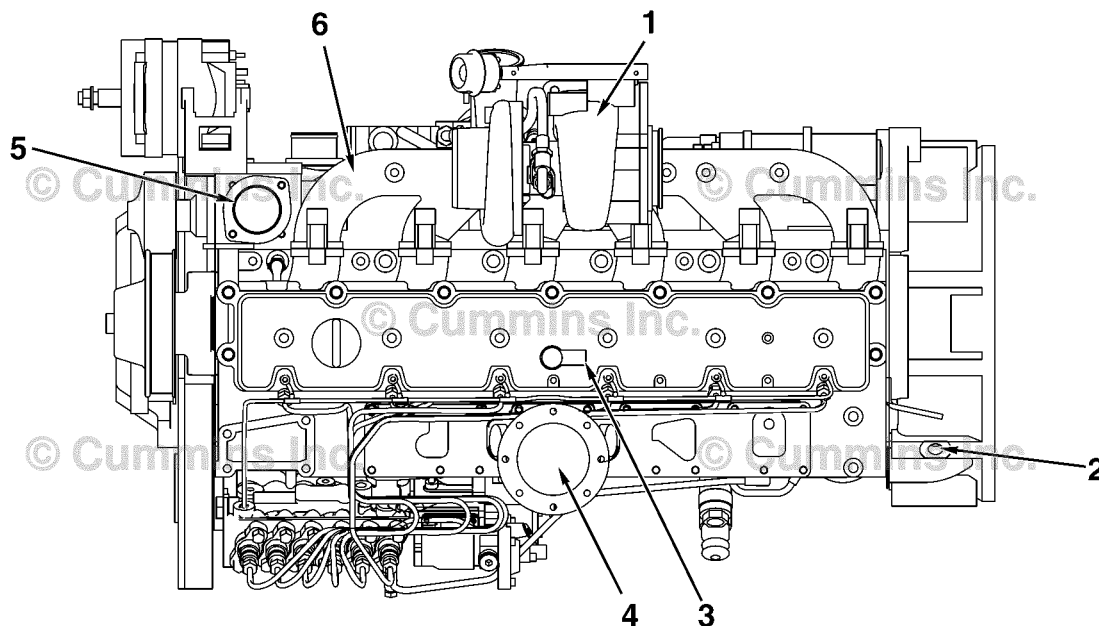


Right View - C8.3 - Industrial

00900323

- 1 Front engine lifting bracket
- 2 Water/coolant outlet connection
- 3 Lubricating oil pressure (after filter)
- 4 Lubricating oil pressure (before filter)
- 5 Coolant heater port
- 6 Lubricating oil cooler
- 7 Water/coolant inlet
- 8 Lubricating oil filter
- 9 Lubricating oil pan drain plug
- 10 Turbocharger oil drain
- 11 Coolant filter
- 12 Starting motor
- 13 Rear engine lifting bracket
- 14 Turbocharger exhaust outlet
- 15 Turbocharger wastegate actuator
- 16 Turbocharger air inlet
- 17 Engine oil fill.

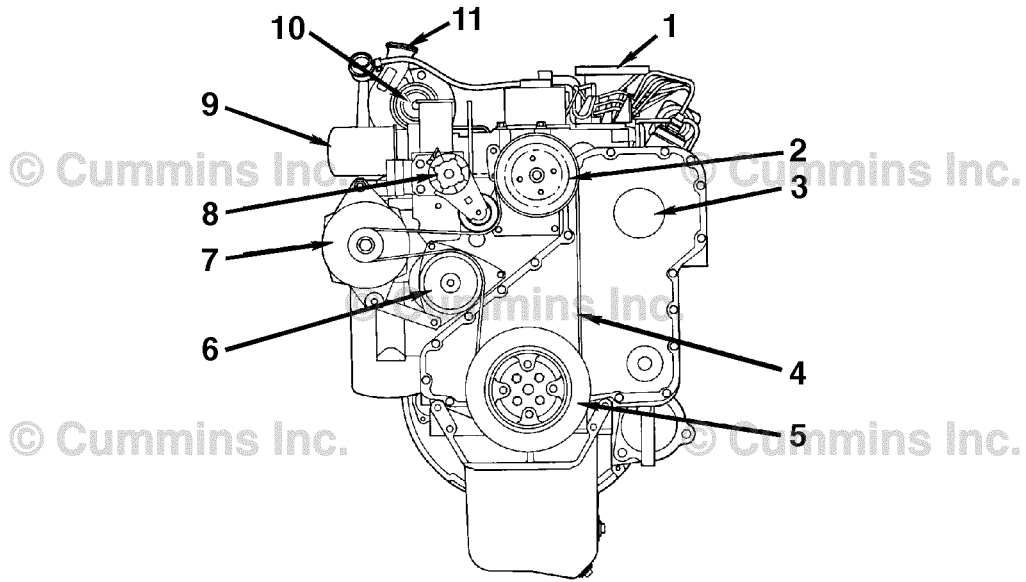
Industrial Applications



Top View - C8.3 - Industrial

00900324

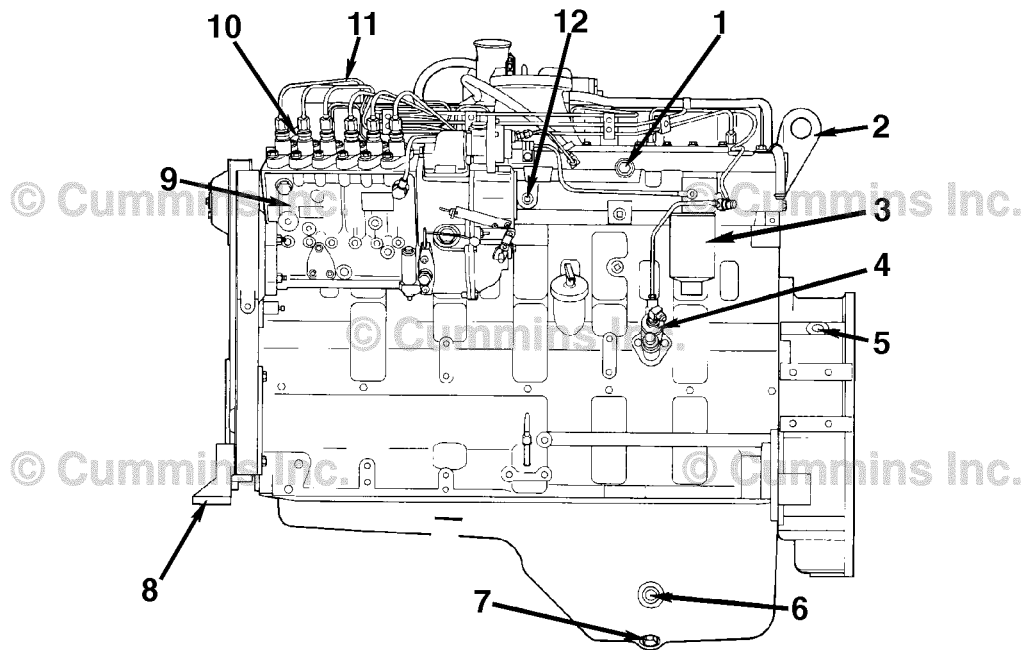
- 1 Turbocharger
- 2 3/4 x 16-inch UNF tap for magnetic pickup
- 3 Crankcase breather
- 4 Engine air inlet
- 5 Thermostat
- 6 Exhaust manifold.



18900030

Front View - C8.3 - Automotive

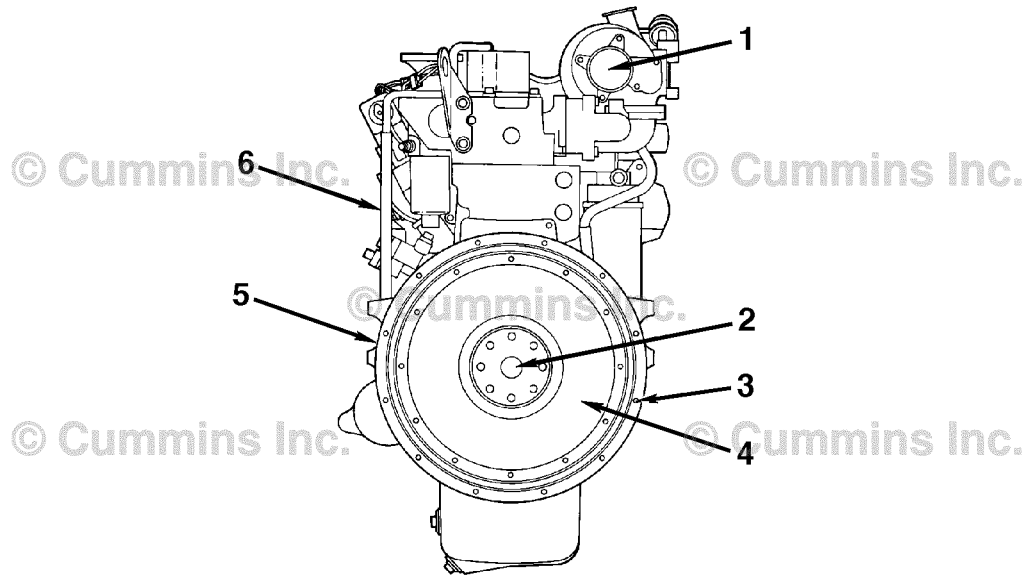
- 1 Engine air inlet
- 2 Fan pulley
- 3 Fuel pump drive cover
- 4 Drive belt
- 5 Vibration damper
- 6 Water pump
- 7 Alternator
- 8 Belt tensioner
- 9 Coolant filter
- 10 Turbocharger air inlet
- 11 Turbocharger air outlet.



Left View - C8.3 - Automotive

18900027

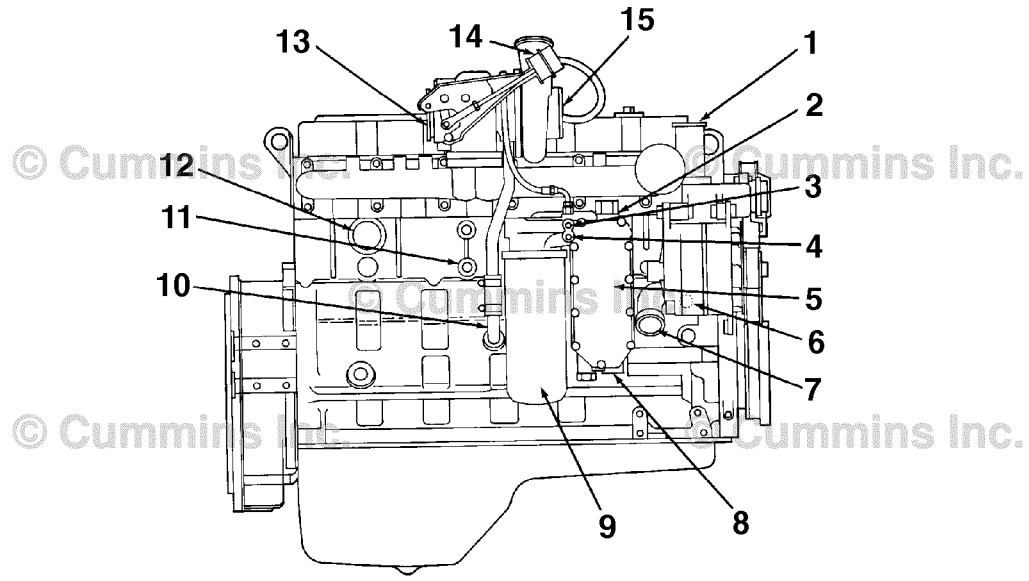
- 1 M22 X 1.50 intake (air)
- 2 Rear lifting bracket
- 3 Fuel filter/water separator
- 4 Fuel transfer pump
- 5 3/4 X 16-inch UNF tap for magnetic pickup
- 6 Provisions for oil heater
- 7 Lubricating oil drain plug
- 8 Front engine mounting bracket
- 9 Fuel injection pump
- 10 Distribution valve
- 11 High pressure fuel lines
- 12 1/4-inch NPTF intake (air).



18900029

Rear View - C8.3 - Automotive

- 1 Turbocharger exhaust outlet
- 2 Pilot bearing bore
- 3 Transmission mounting holes
- 4 Flywheel
- 5 Flywheel housing
- 6 Crankcase breather vent tube.



Right View - C8.3 - Automotive

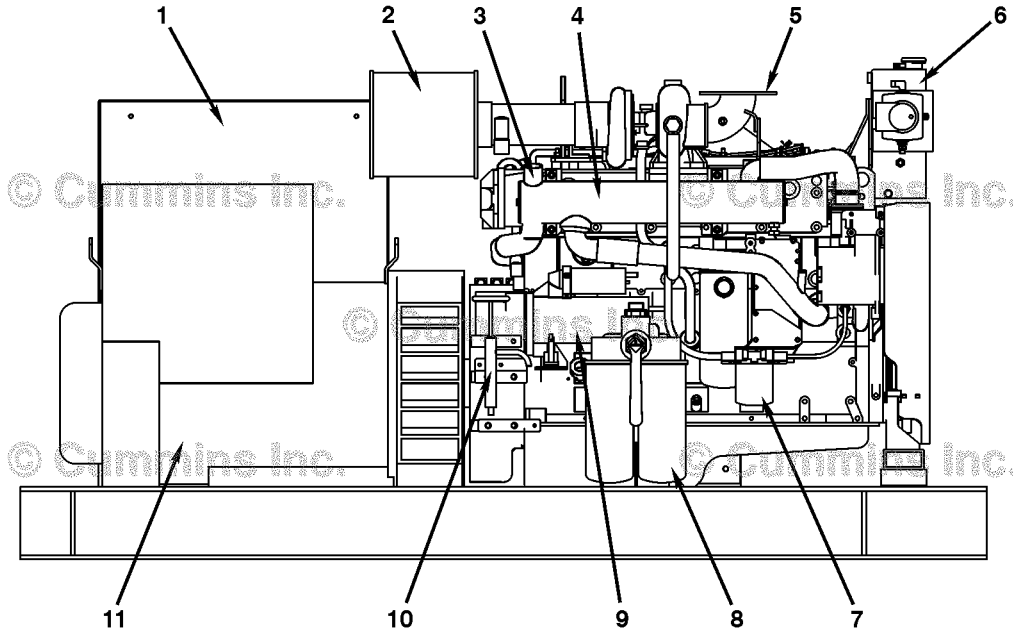
18900028

- 1 Water outlet connection
- 2 Lubricating oil temperature thermostat
- 3 Lubricating oil pressure (after filter)
- 4 Lubricating oil pressure (before filter)
- 5 Lubricating oil cooler
- 6 1/2-inch NPFT (coolant)
- 7 Coolant inlet
- 8 Lubricating oil temperature sensor
- 9 Lubricating oil filter
- 10 Turbocharger oil drain
- 11 Provision for cab heater
- 12 Provision for coolant heater
- 13 Turbocharger exhaust outlet
- 14 Turbocharger wastegate actuator
- 15 Turbocharger air inlet.

Generator Set Applications

The following drawings illustrate the major components. Maintenance personnel **must** be familiar with each component to conduct the maintenance and service procedures discussed in this manual.

NOTE: The drawings in this section reflect a standard configuration. The engine can be equipped with optional accessories such as port-or starboard-side dipsticks. Location of optional items can be different from those shown.

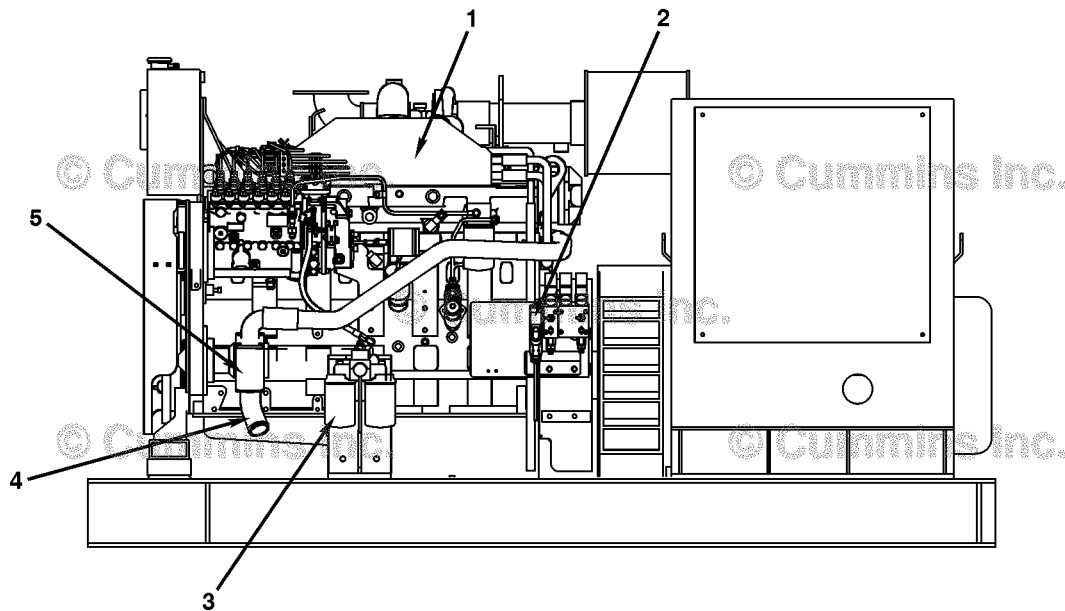


Right View - C Series - C Power Heat Exchanger Cooled

00900423

- 1 Local control panel
- 2 Air cleaner
- 3 Sea water outlet connection
- 4 Heat exchanger
- 5 Exhaust connection
- 6 Coolant expansion tank
- 7 Coolant filter
- 8 Duplex lubrication oil filters
- 9 Starter
- 10 Lubricating oil sump hand pump
- 11 Alternator.

Generator Set Applications

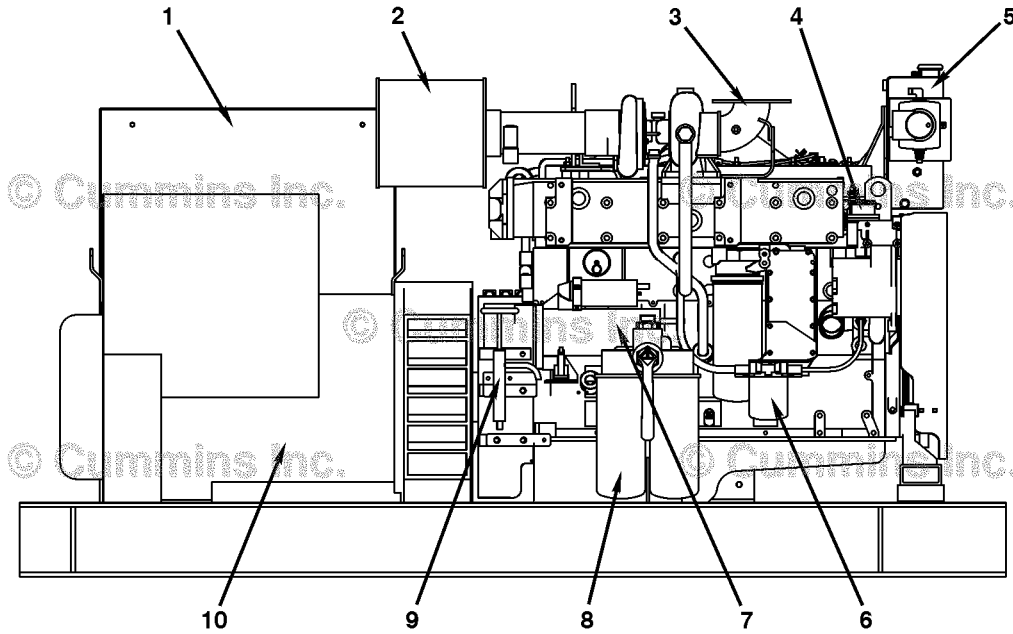


Left View - C8.3 - C Power Heat Exchanger Cooled

00900424

- 1 Aftercooler
- 2 Emergency shutdown sensors
- 3 Duplex fuel filters
- 4 Seawater inlet connection
- 5 Seawater pump

Generator Set Applications

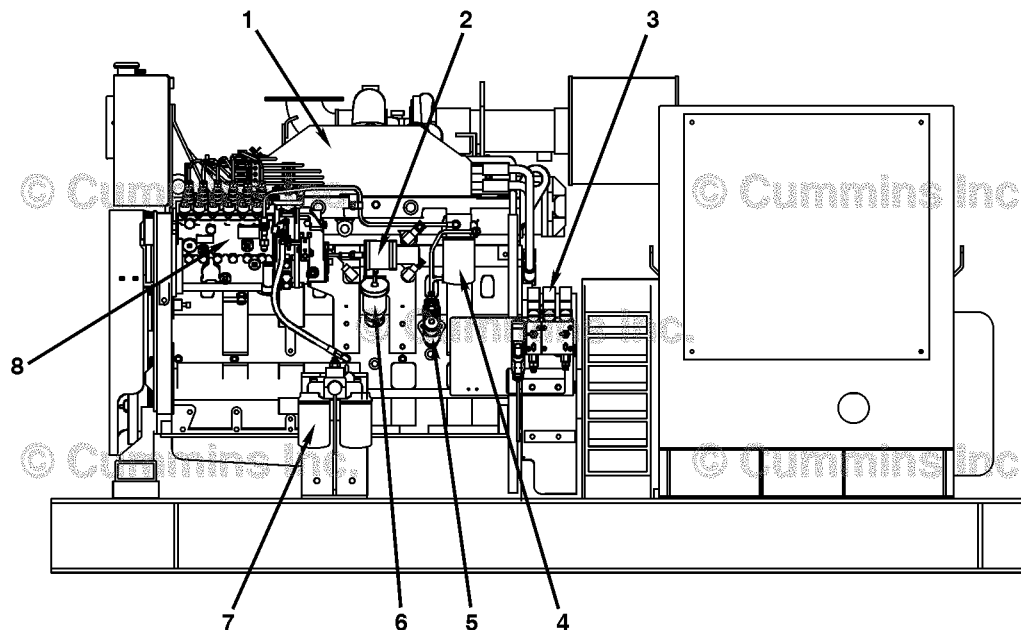


00900425

Right View - C 8.3 - C Power Keel cooler Cooled

- 1 Local control panel
- 2 Air cleaner
- 3 Exhaust connection
- 4 Coolant thermostat location
- 5 Coolant expansion tank
- 6 Coolant filter
- 7 Starter
- 8 Duplex lubricating oil filters
- 9 Lubricating oil sump hand pump
- 10 Alternator.

Generator Set Applications

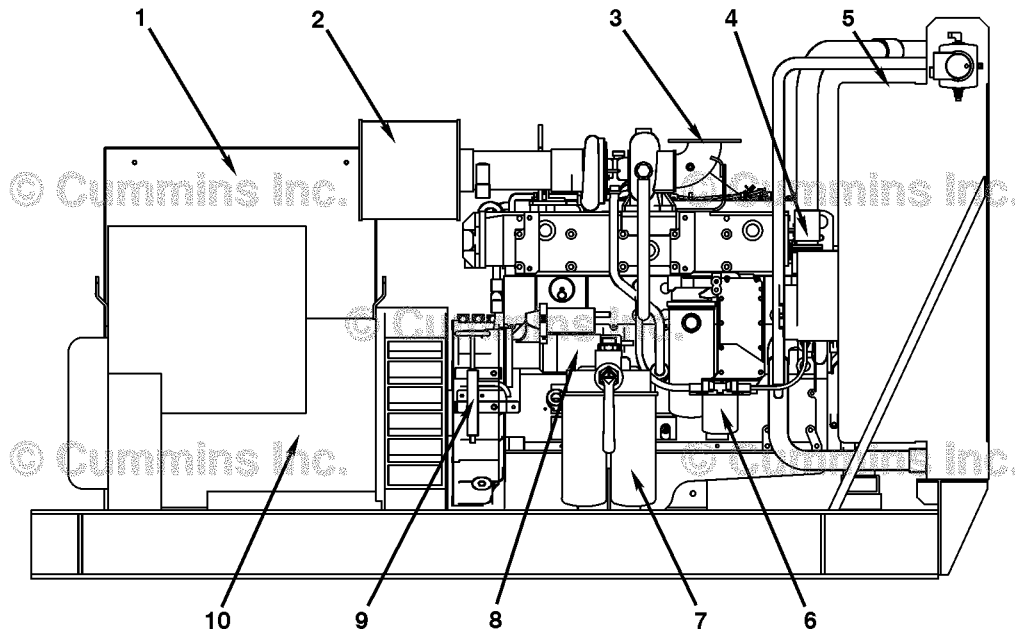


Left View - C8.3 - C Power Keel Cooler Cooled

- 1 Aftercooler
- 2 Governor control
- 3 Emergency shutdown sensors
- 4 Duplex fuel filter
- 5 Lift pump
- 6 Oil fill
- 7 Fuel filters
- 8 Fuel pump.

00900426

Generator Set Applications

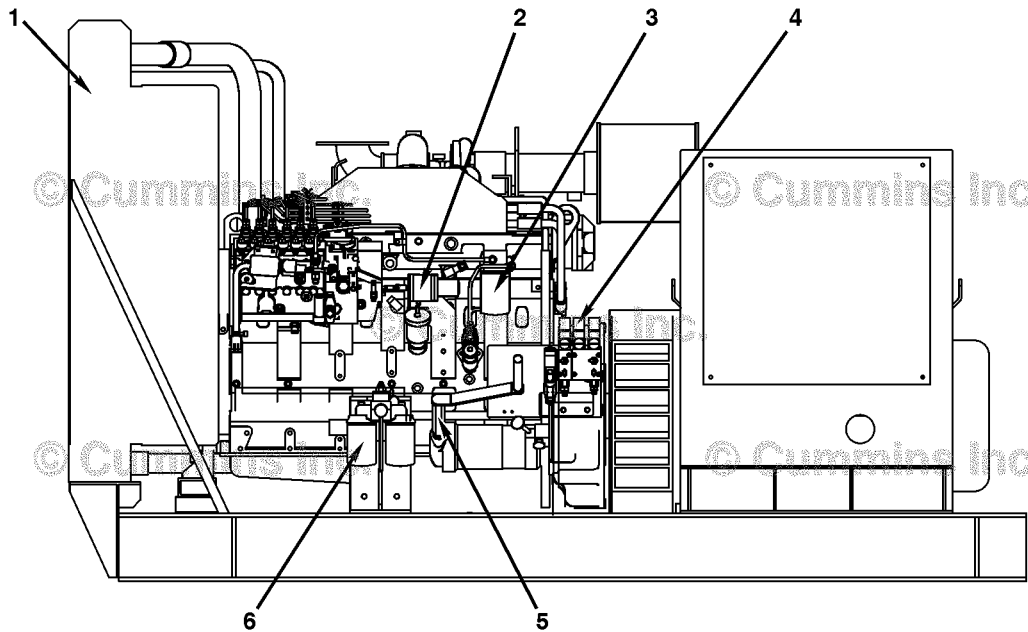


Right View - C 8.3 - C Safe Radiator Cooled

00900427

- 1 Local control panel
- 2 Air cleaner
- 3 Exhaust cConnection
- 4 Coolant thermostat location
- 5 Radiator fan drive shroud
- 6 Coolant filter
- 7 Duplex lubricating oil filter
- 8 Starter
- 9 Lubricating oil sump hand pump
- 10 Alternator.

Generator Set Applications



Left View - C8.3 - C Safe Radiator Cooled

00900428

- 1 Radiator and expansion tank
- 2 Governor control
- 3 Fuel filters
- 4 Emergency shutdown sensors
- 5 Sight glass
- 6 Duplex fuel filters.

Cummins® Service Engine Model Product Identification

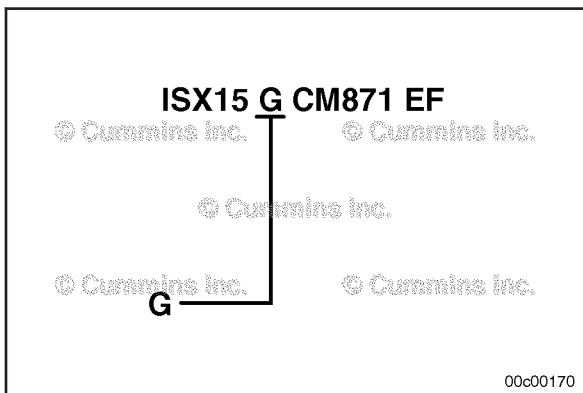
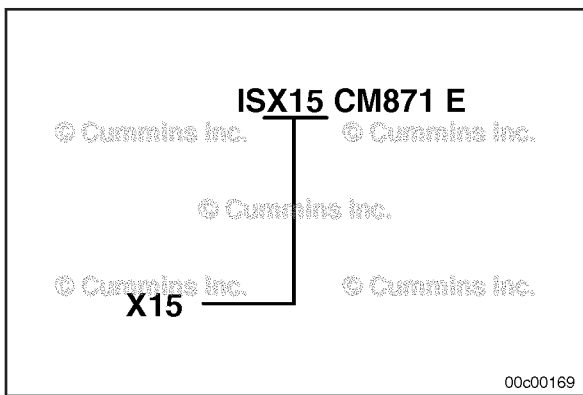
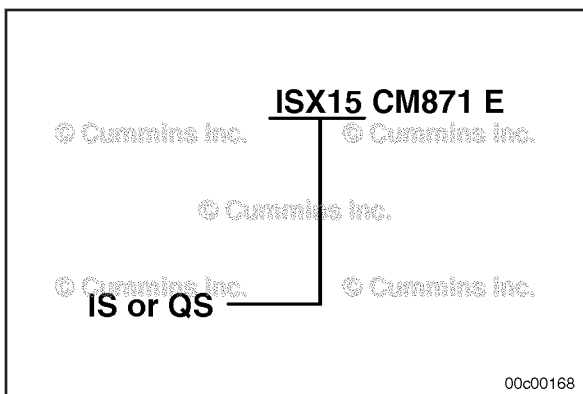
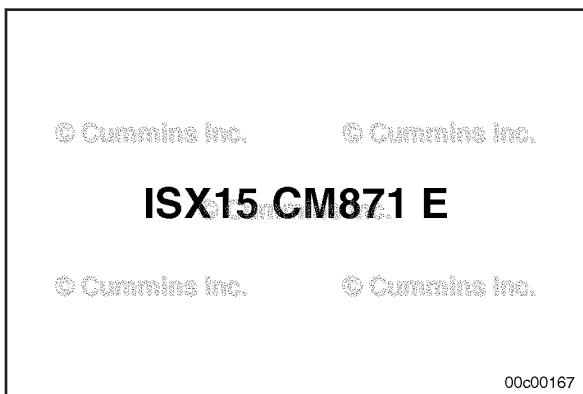
General Information

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

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

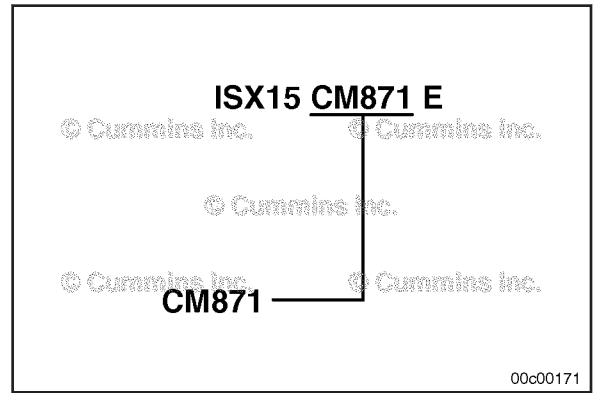
The third letter is the engine platform designation followed by the engine liter size.

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

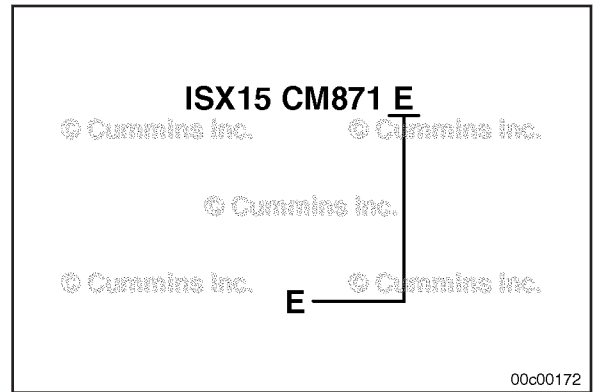


C Series
Section E - Engine and System Identification

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

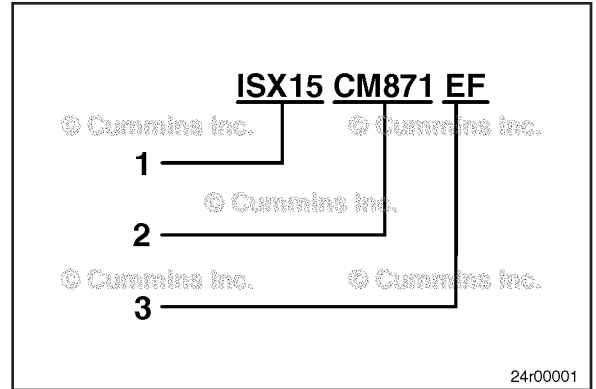


The technology identifier after the control system designates the prevailing technology used with the engine. (See table in this procedure for letter designations.)



Example:

- 1 On-Highway automotive "X" 15 liter engine
- 2 Control system number 871
- 3 Technology supported; Electric EGR and Diesel Particulate Filter



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

Section F - Familiarization

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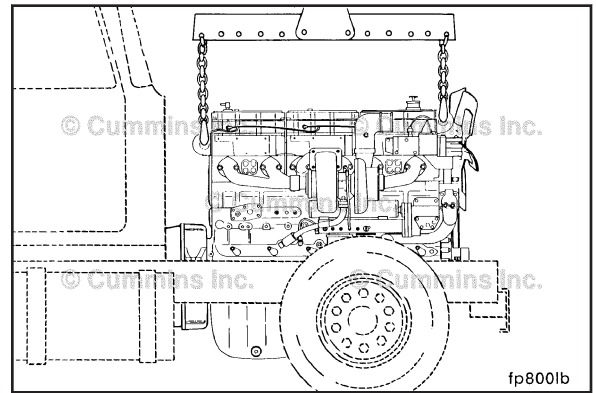
Complete Engine - Overview (000-999)



General Information

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

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



Cylinder Block - Overview (001-999)

General Information

Barring Mechanism

The barring mechanism is inside the front cover. The front cover **must** be removed from the engine to service or rebuild the barring mechanism.

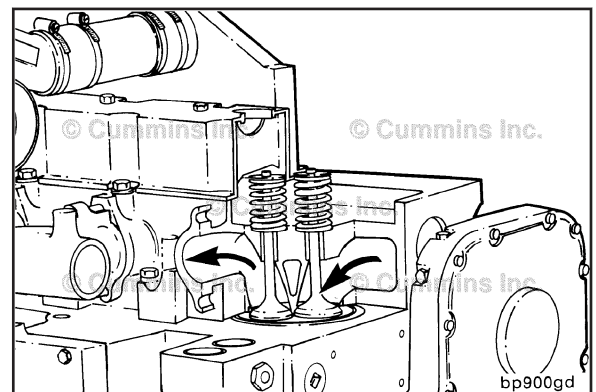
The barring mechanism contains a spring-loaded worm gear. The worm gear engages the camshaft gear when the barring shaft is pushed in the front cover and turned in a **counterclockwise** direction. The barring mechanism will **only** turn the engine in the direction of normal rotation. Turn the barring shaft in a **clockwise** direction to disengage the worm gear. If the worm gear remains engaged accidentally during engine start-up, engine rotation will disengage the barring mechanism without damage to it.

Cylinder Head - Overview (002-999)

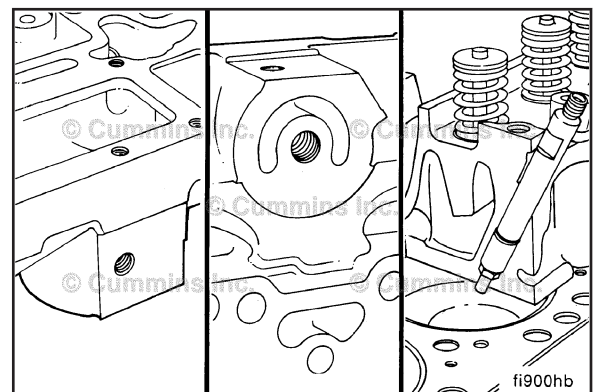
General Information

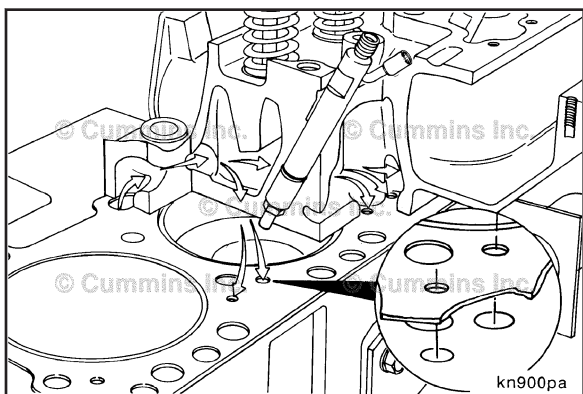
The cylinder head is a one-piece, cross-flow design with two valves per cylinder.

The valve guides and seats are replaceable.

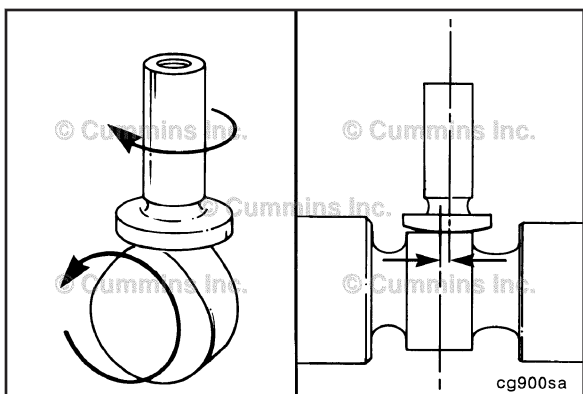


The cylinder head has a cast intake manifold and fuel filter head. The injectors are mounted in the head for direct injection into the cylinders.





The cylinder head gasket is a specialized metal design with a fire ring to seal the cylinder bores. The gasket also provides orifices to control coolant flow.

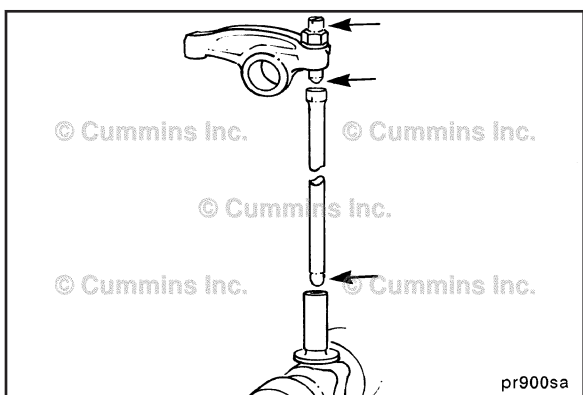


Cam Followers/Tappets - Overview (004-999)

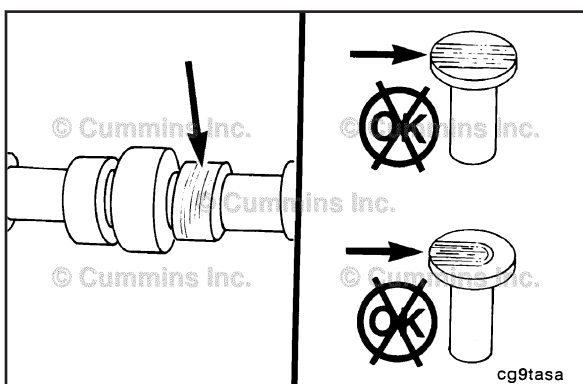
General Information

Valve Tappet

The valve tappets are mushroom-shaped. The offset position of the tappet against camshaft lobe causes the tappet to rotate as it lifts the push rod.



The ball end of the push rod fits into the ball socket in the tappet. The other end of the push rod has a ball socket in which the ball end of the rocker lever adjusting screw operates.



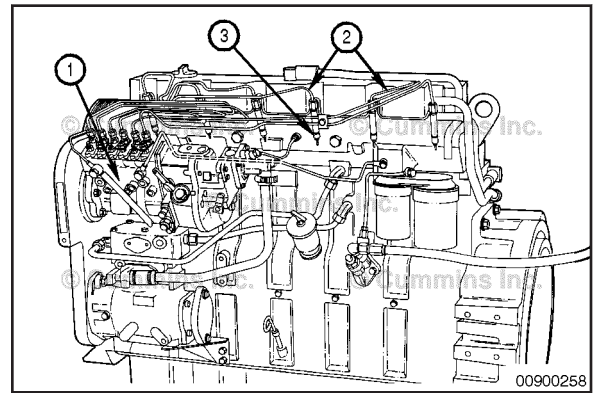
A loose rocker lever and the need to reset the valve clearance frequently can indicate camshaft lobe or tappet wear. If an inspection of the levers, valve stems, and push rods does **not** show wear, then tappet and/or camshaft lobe wear can be suspected.

Fuel System - Overview (005-999)

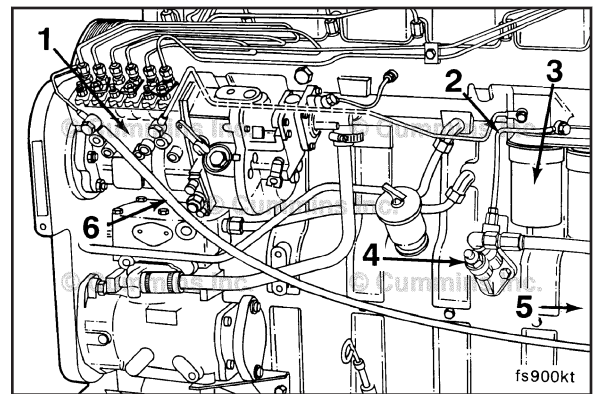
General Information

The function of the fuel system is to inject a metered quantity of clean atomized fuel into the engine cylinders at a precise time near the end of the compression stroke. The components of the fuel system contribute to the delivery of fuel to the cylinders.

1. Fuel injection pump
2. High-pressure fuel lines
3. Injectors.

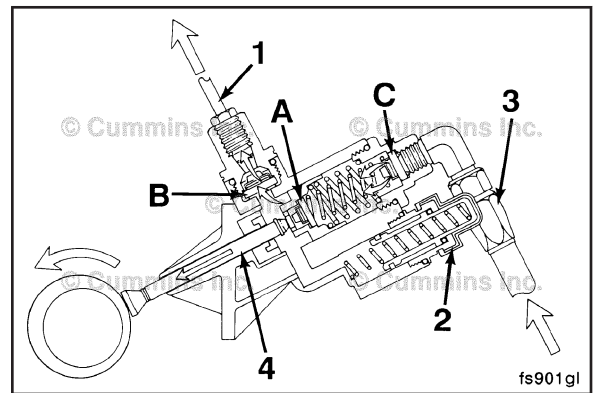


1. Fuel injection pump
2. Fuel supply line
3. Fuel filter
4. Fuel transfer pump
5. Fuel tank (**not** shown)
6. Fuel return line.



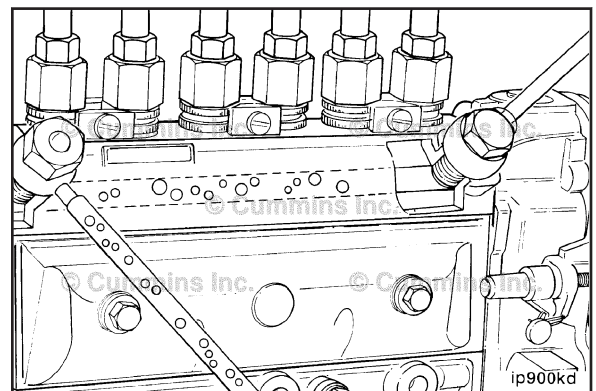
The fuel transfer pump is mechanically driven by a plunger running against a special lobe on the camshaft. The fuel transfer pump contains a pumping piston (A) and check valves (B) (C) to control the flow of fuel and bleed back during engine shutdown.

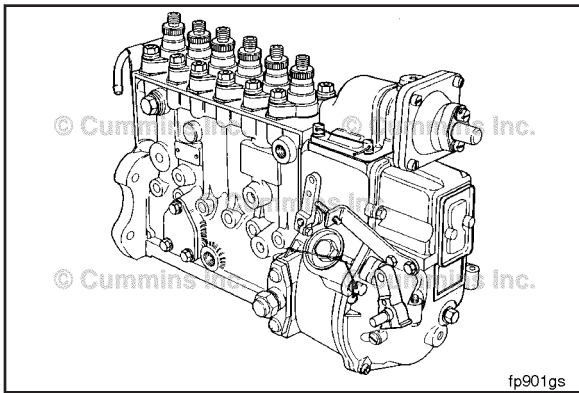
1. Low-pressure supply line
2. Priming pump
3. Fuel inlet line
4. Plunger.



The pressure relief valve arrangement in the supply side of the fuel circuit creates a self-bleeding system on the A-type fuel injection pump. Air introduced during replacement of any supply-side components will automatically bleed out of the fuel system.

Small amounts of air can be bled from the fuel injection pump by operating the hand primer on the fuel transfer pump or by cranking the engine.





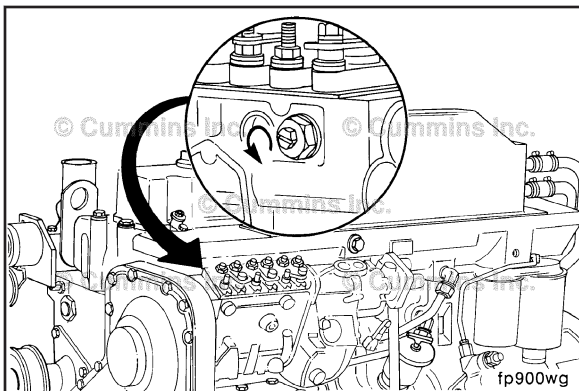
Marine 480C-E engines use a Bosch® P7100 mechanical fuel pump with a Bosch® RE30 governor. A mechanical, positive displacement fuel lift pump provides pressurized fuel to the fuel filter head inlet. A keyswitch-activated electric fuel shutoff valve is mounted on the outlet of the fuel filter head. Filtered and pressurized fuel is then routed back to the fuel pump inlet.

The purpose of the pressure relief system installed on the lift pump is to prevent over-pressurizing of the fuel filter assembly upon shutdown. When the engine is commanded to shut down, the keyswitch circuit is interrupted and causes the fuel shutoff valve to close. As the engine comes to a stop, fuel is still pumped to the fuel filter from the lift pump. It is possible that the pressure can climb high enough to cause the fuel filter seal or body to fail.

The system uses a relief valve in the banjo connection screw located at the outlet of the lift pump. A hose is connected to the banjo to direct the fuel back to the lift pump inlet. The relief valve is a ball and spring type and is set to open at 690 kPa [100 psi] +/- 70 kPa [10 psi] and is **not** adjustable. The relief valve should be open **only** after the engine has been commanded to stop.

If the relief valve becomes stuck or does **not** seat completely, fuel will continuously be bypassed back to the lift pump inlet. This causes low lift pump output pressure and leads to poor performance and hard starting.

Following the appropriate Troubleshooting Symptom charts in the Troubleshooting and Repair Manual will identify low lift pump pressure associated with a failed relief valve.

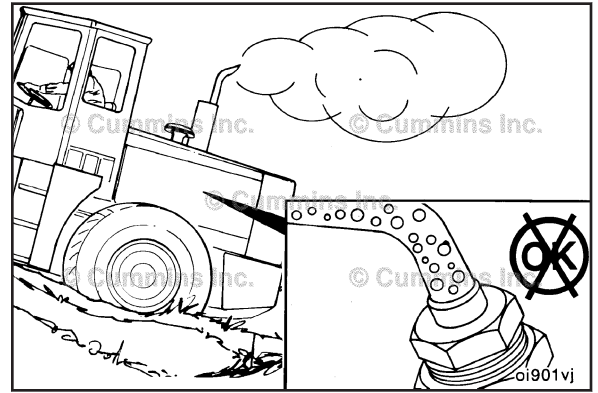


NOTE: MW-type fuel injection pumps without the fuel drain arrangement on the engine side will require additional venting prior to initial start-up, fuel injection pump replacement, or if the engine has been allowed to run out of fuel. Refer to Procedure 006-003 for more information.

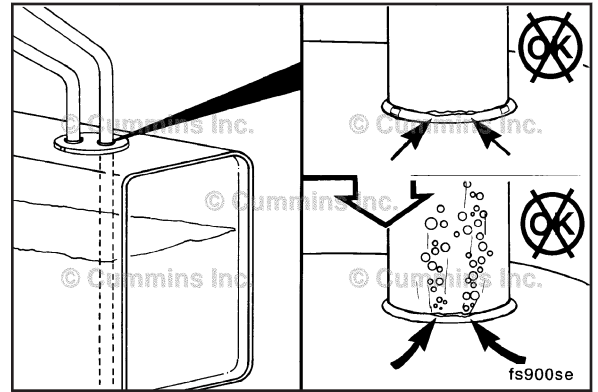
C Series
Section F - Familiarization

Air from uncorrected leaks in the supply circuit will make the engine:

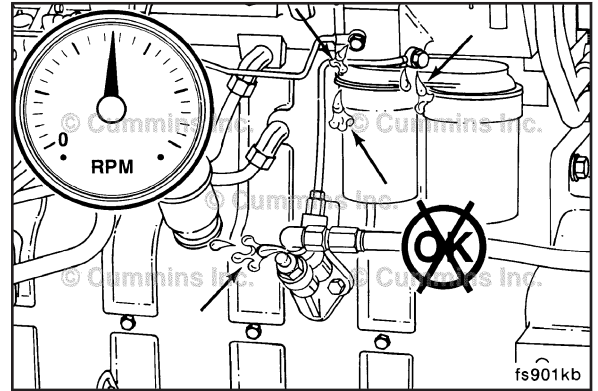
- Difficult to start
- Run rough
- Misfire
- Produce low power
- Emit excessive smoke
- Produce fuel knock.



A source, often overlooked for air to enter the fuel system, is between the inlet of the prefilter and the suction tube in the tank. Fuel tanks that have the outlet fitting at the top will have a suction tube that extends to the bottom of the tank. Cracks or pin holes in the weld that joins the tube to the fitting can allow air to enter the fuel system.

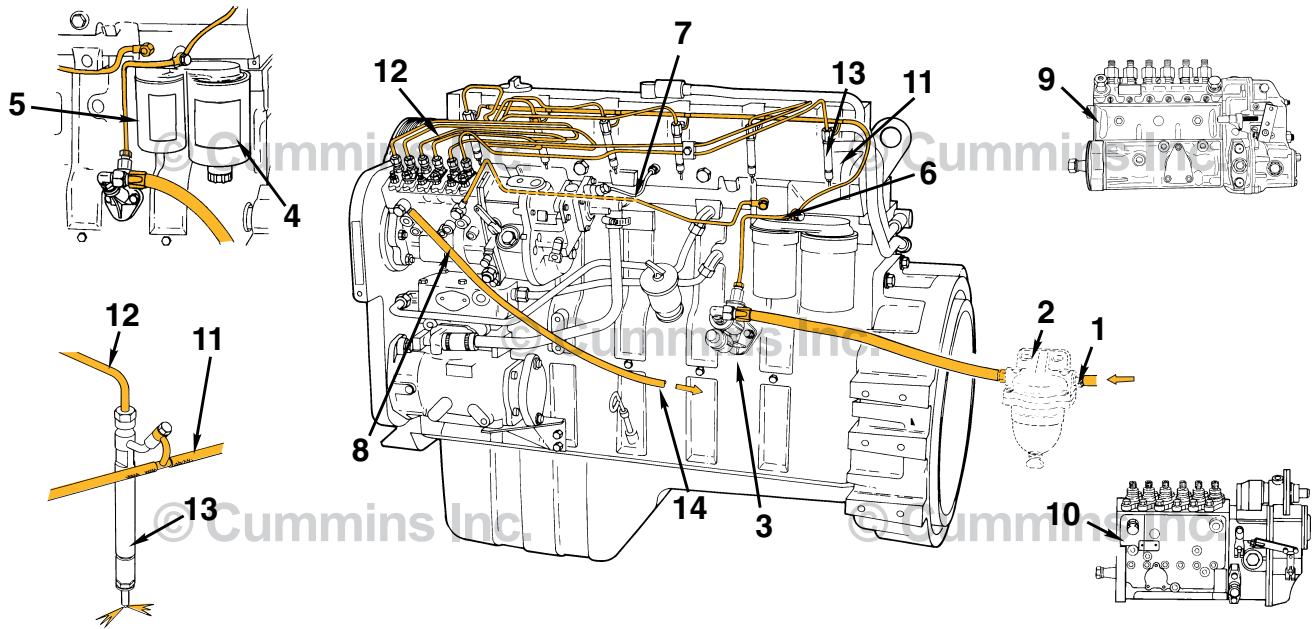


Since the fuel transfer pump provides positive pressure through the fuel filter and supply line to the fuel injection pump, loose connections or defective seals will show as a fuel leak.



Flow Diagram, Fuel System (200-001)

General Information



05900658

- 1 Fuel from supply tank
- 2 Prefilter or screen
- 3 Fuel transfer pump
- 4 Fuel/water separator
- 5 Fuel filter
- 6 Low-pressure supply line
- 7 Turbocharger boost control line
- 8 Bosch® PES.MW injection pump
- 9 Bosch® PES.A injection pump
- 10 Bosch® PES.P injection pump
- 11 Fuel drain manifold
- 12 High-pressure fuel lines
- 13 Hole-type injectors
- 14 Fuel return to supply tank.

Lubricating Oil System - Overview (007-999)

General Information

Use Cummins Premium Blue® 15W-40 multiviscosity oil, or equivalent, that meets API Classification CE for turbocharged engines.

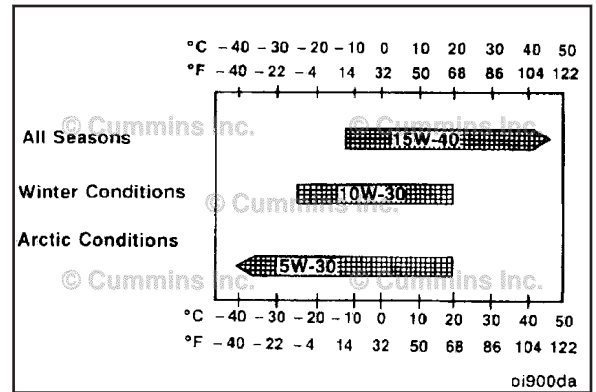
NOTE: CC/CD or CD/SF engine oils can be used in areas where CE oil is **not** yet available; however, the oil drain interval **must** be reduced by 50 percent.

⚠CAUTION⚠

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



pl800gb



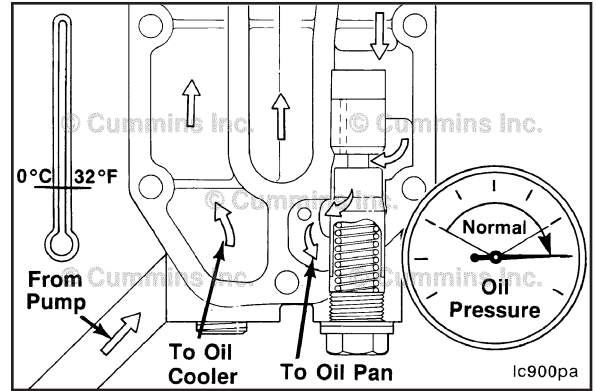
oi900da

Lubricating Oil System - Diagnosing Malfunctions

Make sure to check items related to oil pressure, such as gauges, high and low oil level, excessive contamination, and oil viscosity.

High Oil Pressure

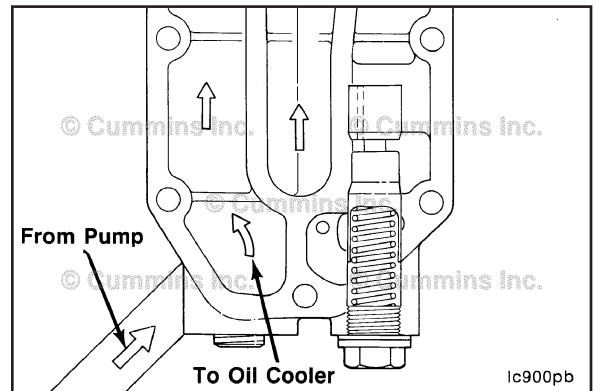
High oil pressure usually occurs after the engine is first started in cold weather. The lubrication system does **not** have a cold start relief valve. The pressure regulating valve components are machined to a size that will relieve the excessive pressure created by cold engine oil.



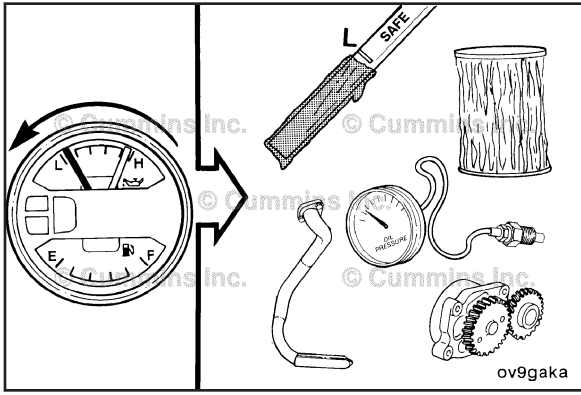
lc900pa

Oil Pressure Regulating Valve

The engine will have high oil pressure if the regulator sticks shut. Inspect the regulator for freedom of movement.

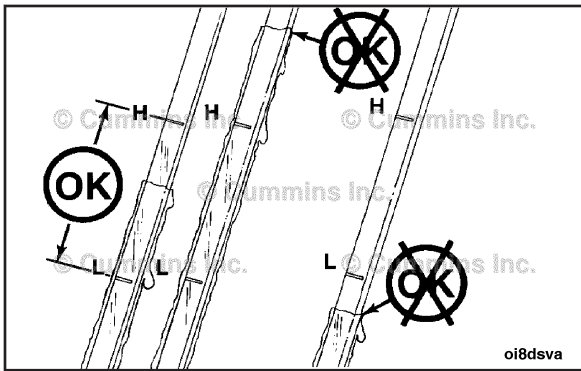


lc900pb



Low Oil Pressure

Low oil pressure can be caused by several lubrication system-related malfunctions. To begin the investigation, determine the engine operating conditions when the low pressure was first observed.

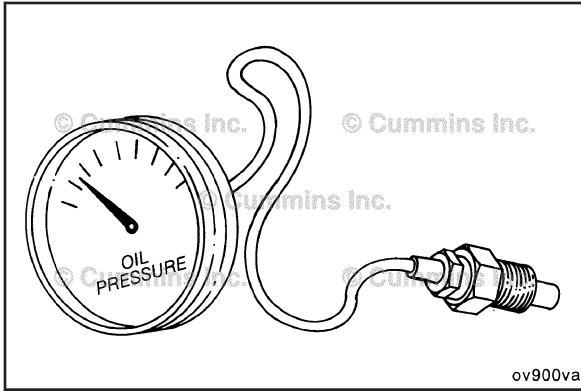


Oil Level

An improper lubricating oil level can cause low lubricating oil pressure.

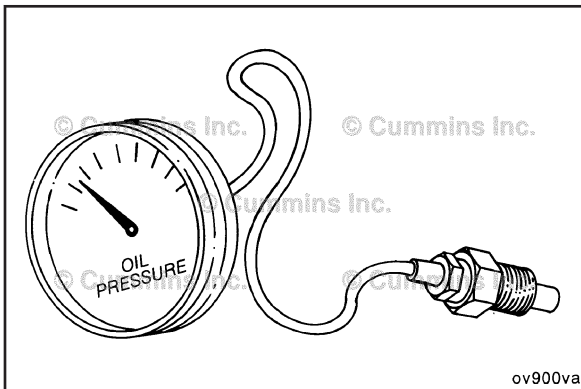
⚠ CAUTION ⚠

Never operate the engine with the oil level below the low (L) mark or above the high (H) mark.



Oil Filter

A plugged filter will cause a gradual loss of oil pressure by approximately 69 kPa [10 psi]. This will cause the bypass valve to open, allowing unfiltered oil to flow to internal engine components. The oil pressure will remain low until a new filter is installed.

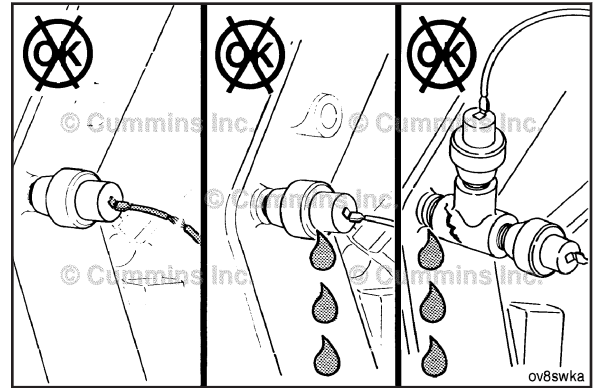


Oil Pressure Gauge - Inspection

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

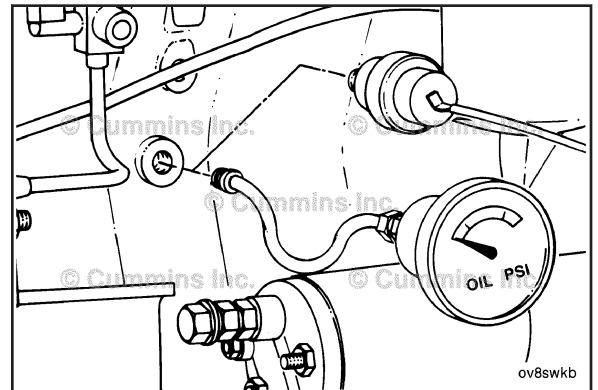
Inspect for the following defects:

- Electrical wiring broken
- Sending unit malfunction
- Plumbing loose or broken.



If a sending unit malfunction is found:

- Use a master gauge of known accuracy to verify the reading of the suspect gauge.
- Connect the line from the master gauge to the main oil rifle on the fuel pump side of the engine.
- Replace the sending unit if it is defective.

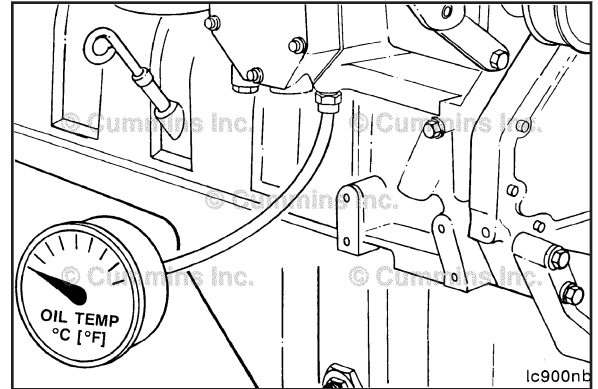


Oil Temperature Gauge - Inspection

Remove the pipe plug from the bottom of the oil cooler, and install the oil temperature gauge sending unit.

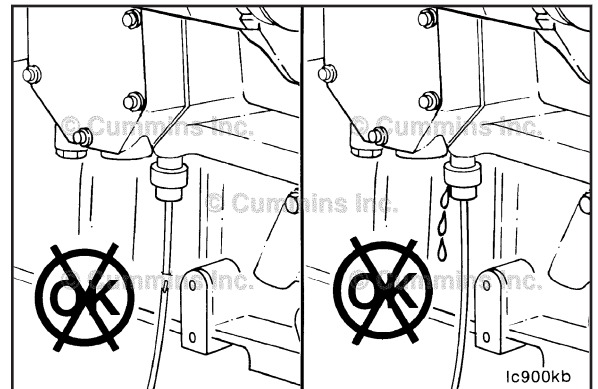
Oil Temperature at Rated Speed

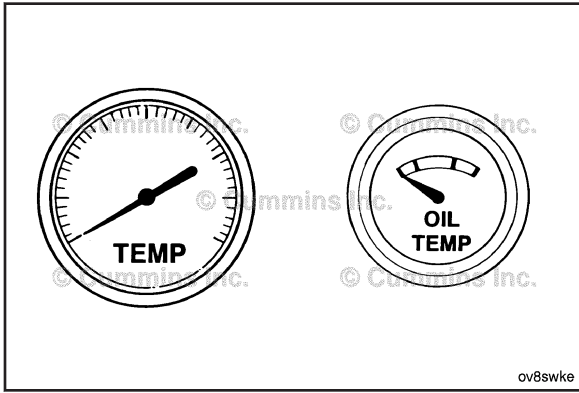
°C		°F
126.6	MAX	260



Inspect for the following defects:

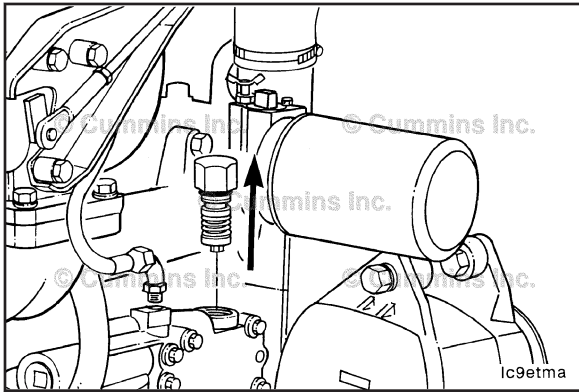
- Electrical wiring broken
- Sending unit malfunction.





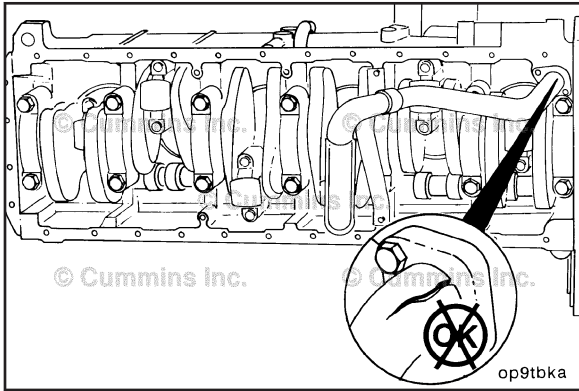
If a sending unit malfunction is found:

- Use a master gauge of known accuracy to verify the reading of the suspect gauge.
- Replace the sending unit if it is defective.



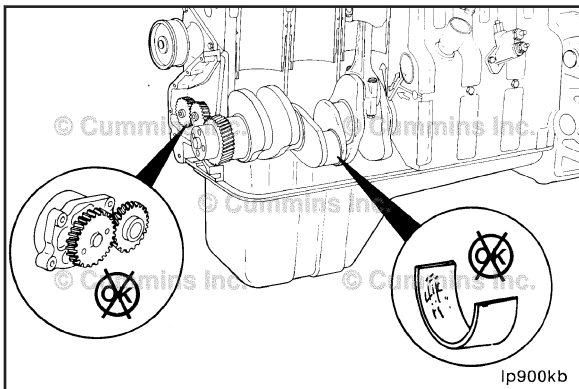
Oil Temperature Thermostat

NOTE: The oil temperature thermostat can **not** be checked in-chassis; it **must** be removed for testing; refer to Procedure 007-039.



Oil Suction Tube

A loose suction tube, damaged gasket, or crack in the suction tube can cause a temporary loss of prime for the oil pump. The engine will have low pressure or no oil pressure at starting, followed by normal or low pressure.



Bearings and Oil Pump

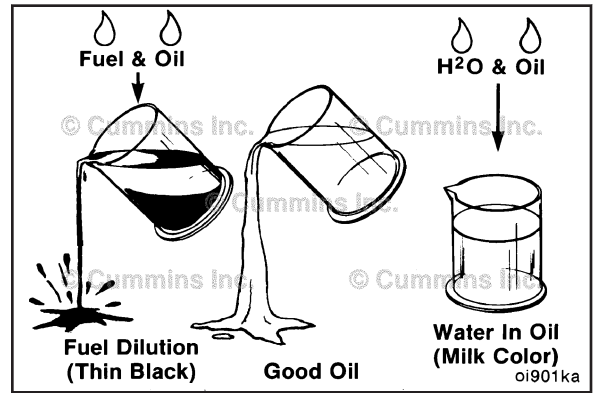
A steady decrease in oil pressure over a long period will be indicated by worn bearings or excessive oil pump wear. Refer to Procedure 007-051 to check for internal engine damage.

Oil Dilution

Diluted oil can cause severe engine damage.

Inspect the condition of the oil.

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



Coolant-Diluted Oil

Coolant in the oil results from a crack or leak between the coolant and oil circuits.

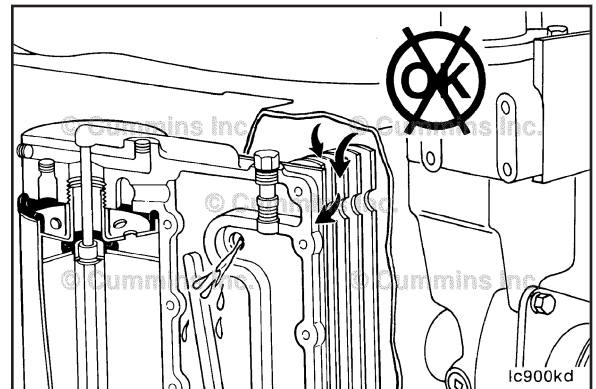
The possibility for intermixing can occur in these components:

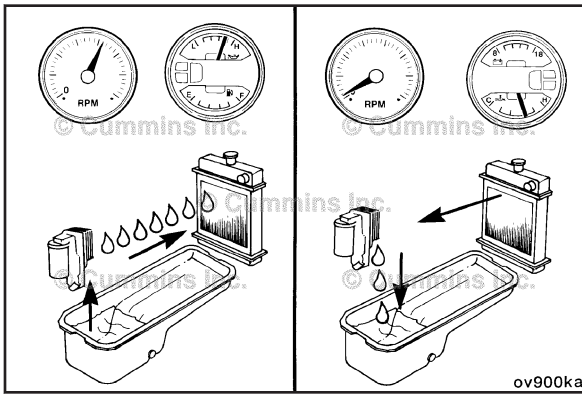
- Oil cooler
 - Aftercooler
 - Core plugs in cylinder head
 - Cylinder liner seals
 - Head gasket
 - Cylinder liner (crack)
-
- Cylinder head (cracked passage)
 - Cylinder block (cracked passage)
 - Air compressor (coolant cooled).

Oil Cooler

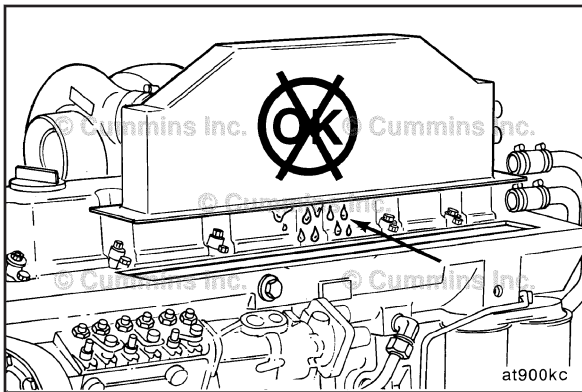
The oil cooler design does **not** require gaskets or seals to maintain the separation of oil and coolant.

If either the coolant or oil is contaminated, check for a leaking oil cooler element; refer to Procedure 007-007.





During operation the oil pressure will be higher than coolant pressure. A leak in the oil cooler will show as oil in the coolant. However, following an engine shutdown, the residual pressure in the cooling system can cause coolant to seep through the leak path into the oil.



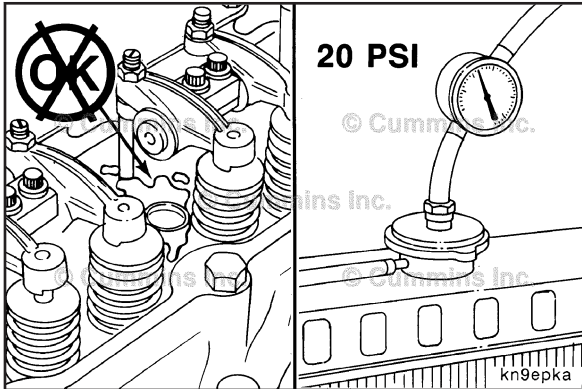
Aftercooler

The aftercooler is also a source from which coolant can leak into the lubricating oil.



Remove the aftercooler and look for evidence of leaking into the intake manifold.

Pressure test the aftercooler element; refer to Procedure 010-008.

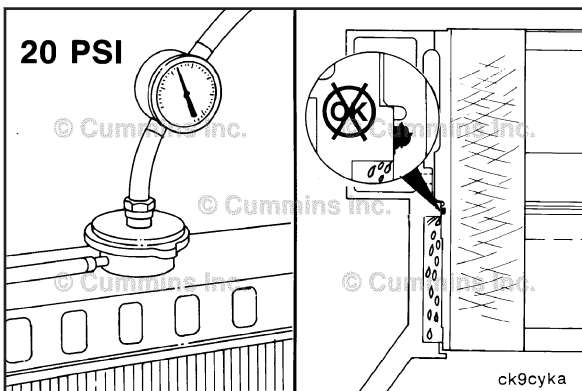


Cylinder Head Expansion Plugs

The expansion plugs in the cylinder head under the valve cover is another potential for oil dilution.

If possible, inspect for the leaks while the engine is warm. Remove the valve cover to look for signs of leaks.

Pressurize the coolant system to 140 kPa [20 psi], if necessary.



Cylinder Liner Seals

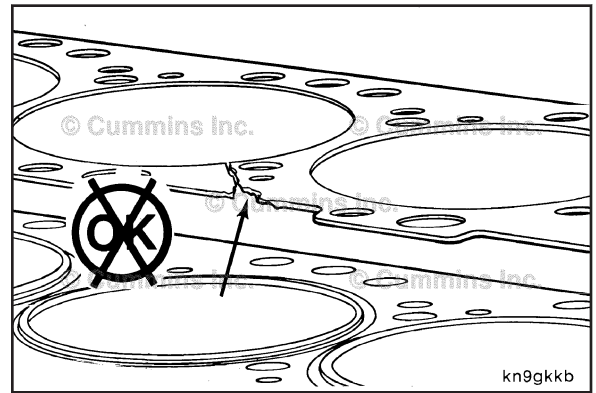
Coolant can enter the lubricating oil through a deteriorated or damaged liner seal.

Remove the oil pan and inspect the bottom side of liners with the cooling system pressurized.

Cylinder Head Gasket

Coolant in the oil can also be caused by a damaged cylinder head gasket.

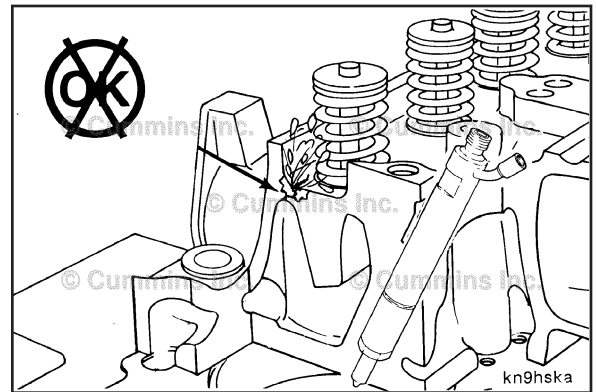
Pressurize the cooling system to check for leaks. Remove the oil pan to locate internal leaks, if necessary; refer to Procedure 007-025.



Cracked Cylinder Head

A crack in the head from the water jacket to an oil passage or to the top rocker lever area will cause oil dilution.

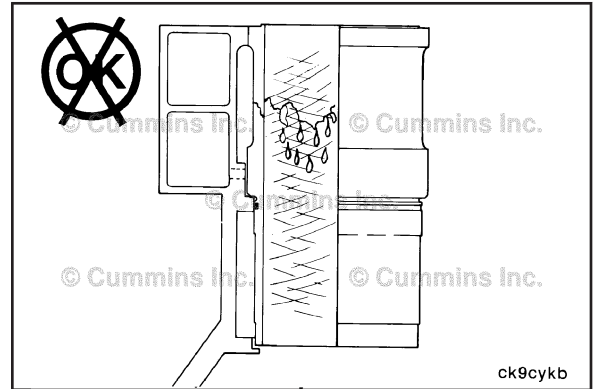
Pressurize the cooling system to 140 kPa [20 psi] and check for leaks.



Cracked Cylinder Liner

A cracked cylinder liner can leak coolant into the lubricating oil. Remove oil pan and look for coolant leaking from inside of liner bore.

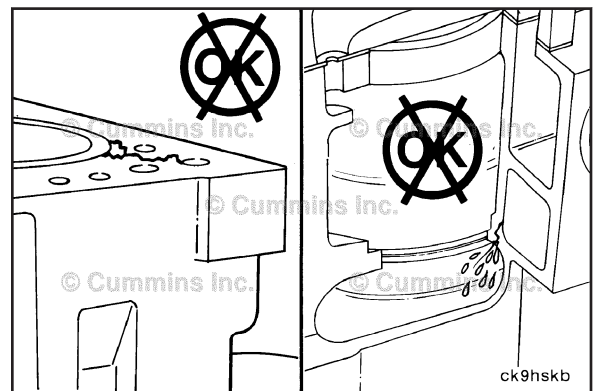
NOTE: Air compressor leaks will produce the same symptoms; refer to Procedure 012-019 before concluding that the leak is from the cylinder liner.

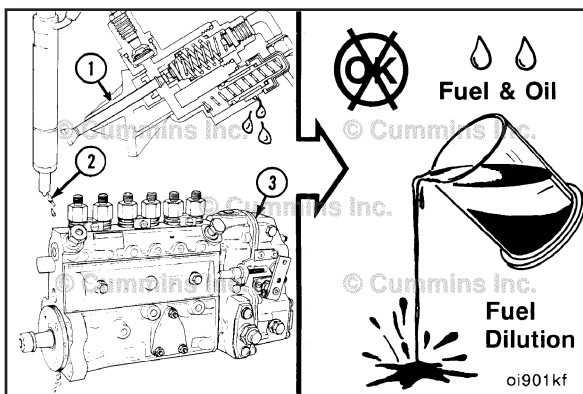


Cracked Cylinder Block

A crack in the cylinder block from an oil drilling or passage to the water jacket can cause oil dilution and can normally be found either as an external leak from a gasket (i.e., head gasket), or from the oil pickup tube with the oil pan off.

The cooling system **must** be pressurized to 140 kPa [20 psi] to detect leaks.

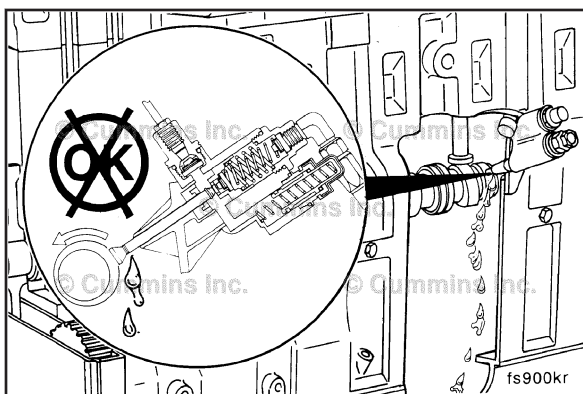




Fuel Diluted Oil

Fuel dilution can **only** come from three sources:

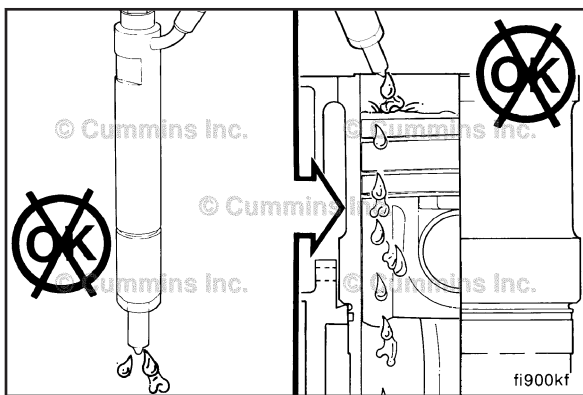
1. Fuel transfer pump
2. Fuel leaking over the rings
3. Injection pump internal wear.



Fuel Transfer Pump

NOTE: On nonautomotive engines, a worn or damaged seal around the plunger can allow fuel to leak into the oil pan.

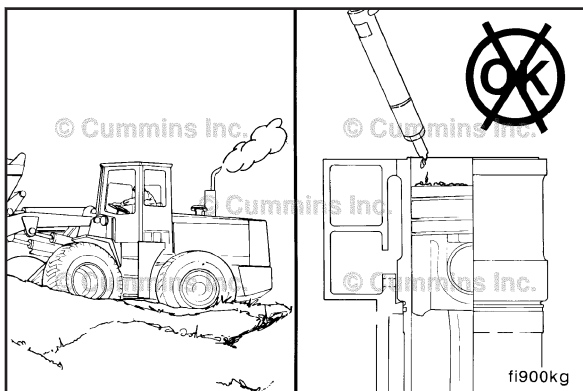
Automotive engines have a weep hole to allow the fuel to leak externally.



Fuel Leaking by Piston Rings

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.

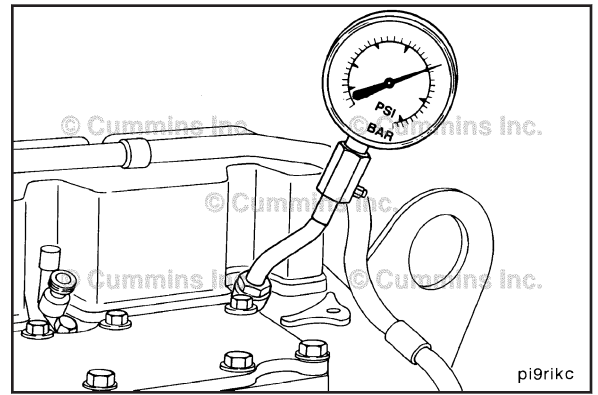


An increase in white exhaust smoke during the first start of the day is a symptom of an injector leaking.

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

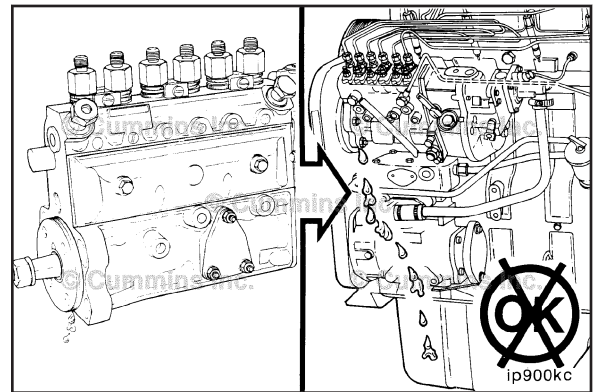
Remove and replace leaking injectors; refer to Procedure 006-026. Refer to the Shop Manual, C Series Engines, Bulletin No. 3810476, for test and repair instructions.

Perform a compression check to verify piston rings are properly sealed; refer to Procedure 001-999.



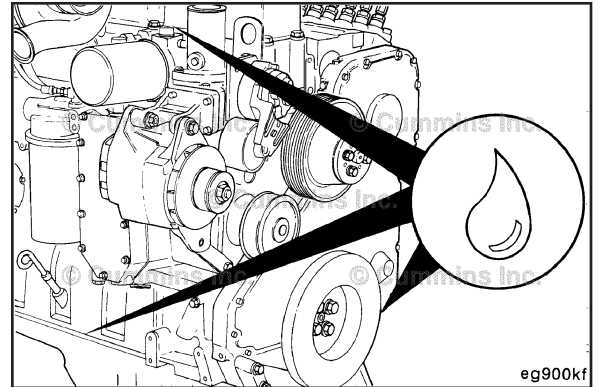
Injection Pump

A worn or damaged injection pump can allow fuel to leak into the lubricating oil as it passes through the pump.

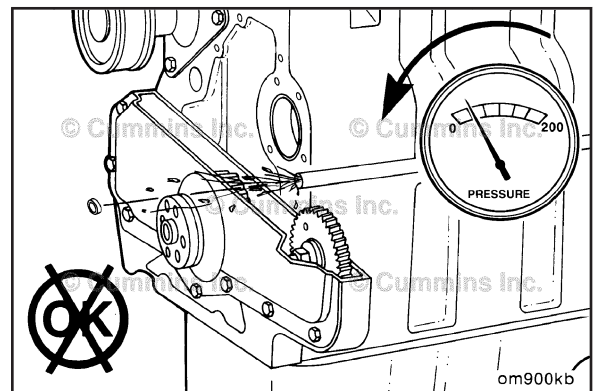


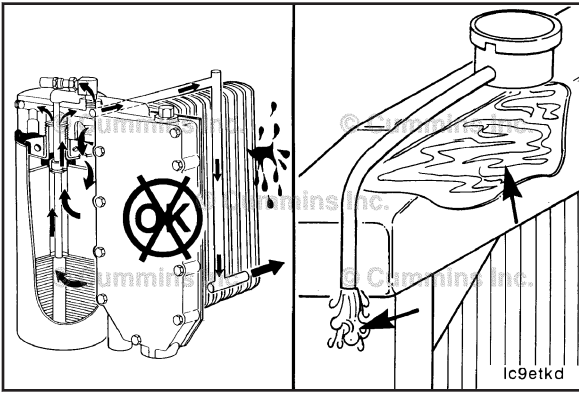
Oil Leaks

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

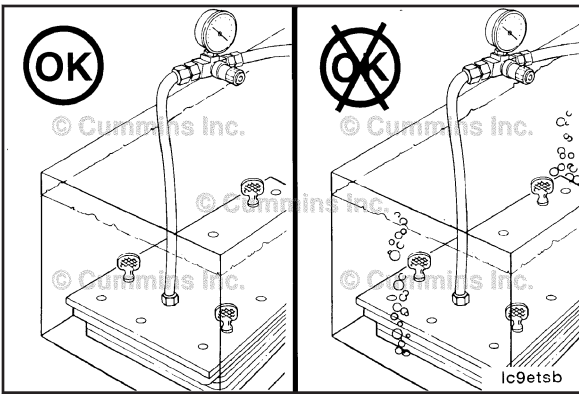


A damaged rocker assembly oil manifold or blown expansion plug can allow a large quantity of oil to escape, resulting in a sudden drop in the oil pressure.

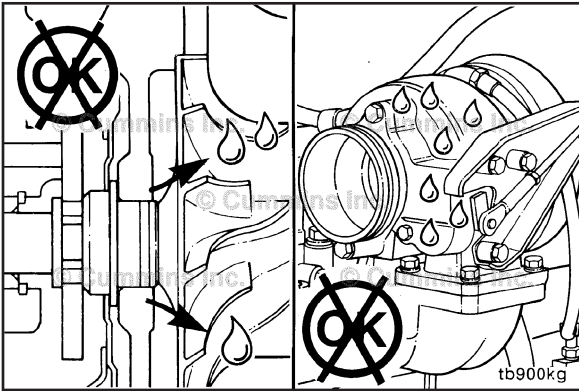




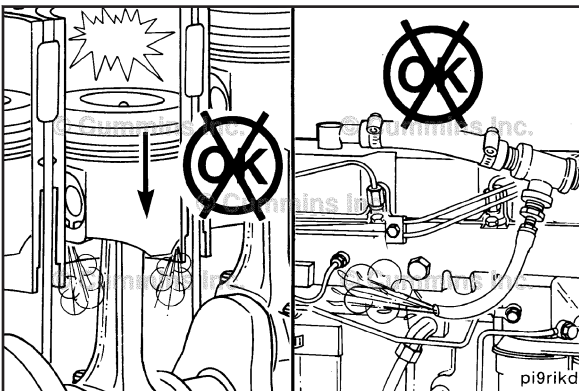
If the oil cooler element ruptures, the oil pressure will force oil into the cooling system. Oil in the coolant can be visible when the radiator cap is removed. As the oil is forced into the cooling system, coolant will be displaced through the radiator overflow.



Leaks can be verified by pressure testing the oil cooler element with lubricating oil cooler pressure test kit, Part No. 3823876. Apply 483 kPa [70 psi] air pressure to the element to check for leaks.



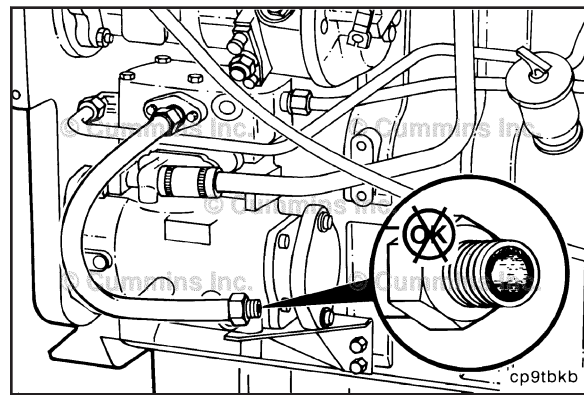
High intake air restriction and worn or damaged seals in the turbocharger can allow oil to leak into the air crossover pipe and be burned in the engine. This condition can be verified by removing the air crossover tube and looking for oil.



Inadequate sealing of the piston rings will result in combustion gas and oil droplets being blown out the crankcase breather tube and/or consumed by the engine. Refer to Procedure 014-010 for measuring crankcase gases (blowby).

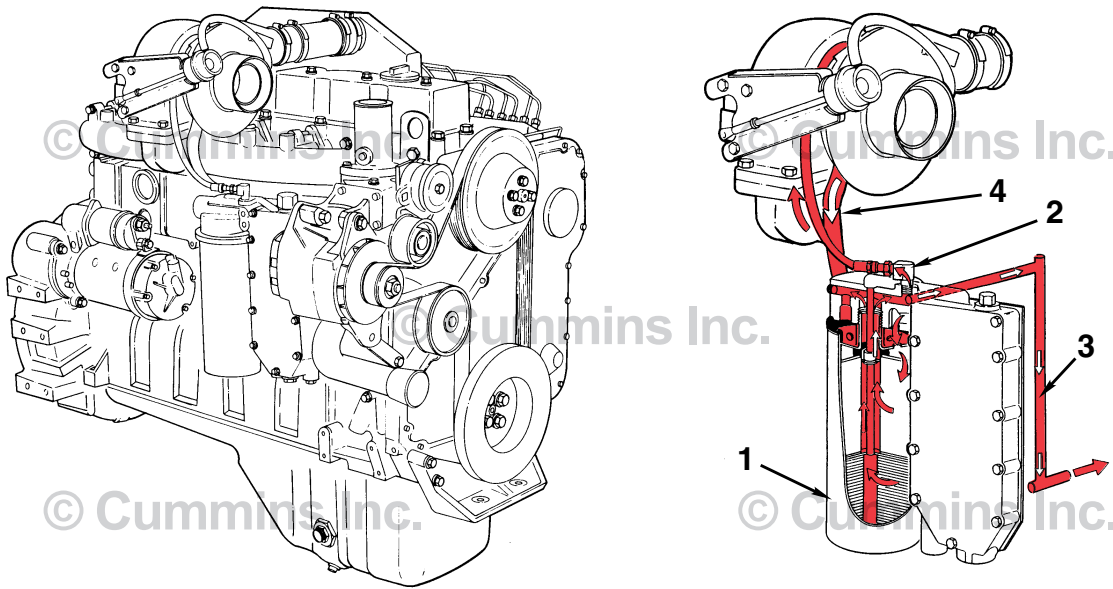
C Series
Section F - Familiarization

Oil can be lost through a worn or malfunctioning air compressor. Look for carbon buildup in the air line from the compressor to the air tank, and look for oil when draining the tank. Refer to Compressed Air for additional diagnostic procedures.



Flow Diagram, Lubricating Oil System (200-002)

Engine Views
All Applications

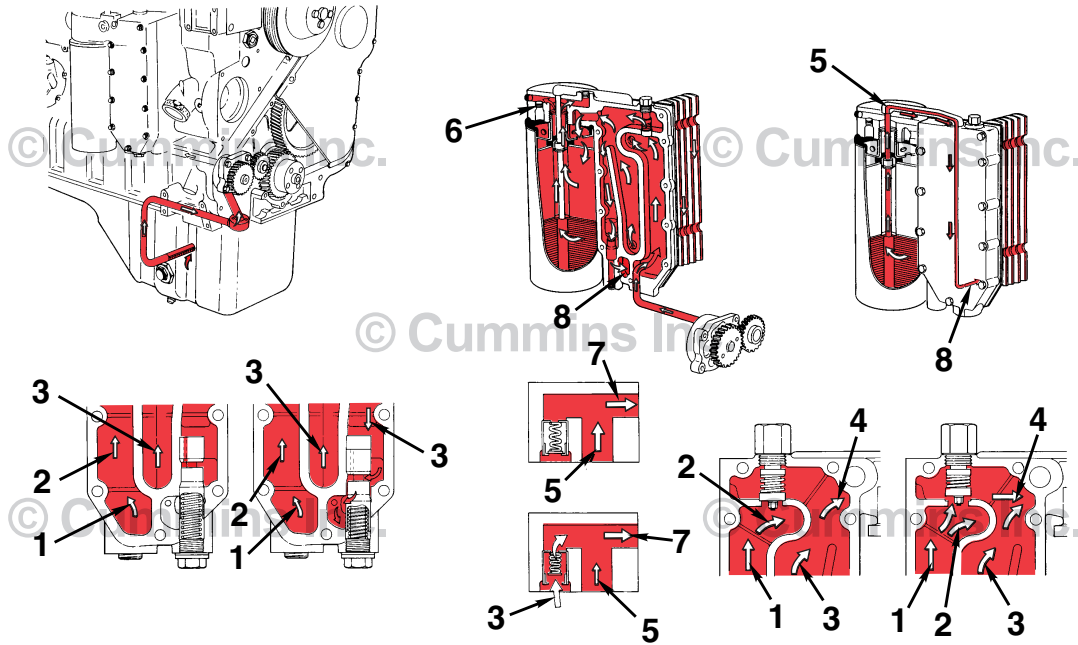


- 1 Oil filter
- 2 Turbocharger oil supply line
- 3 Flow to main oil rifle
- 4 Turbocharger oil drain line.

07900228

Flow Diagram, Lubricating Oil System (200-002)

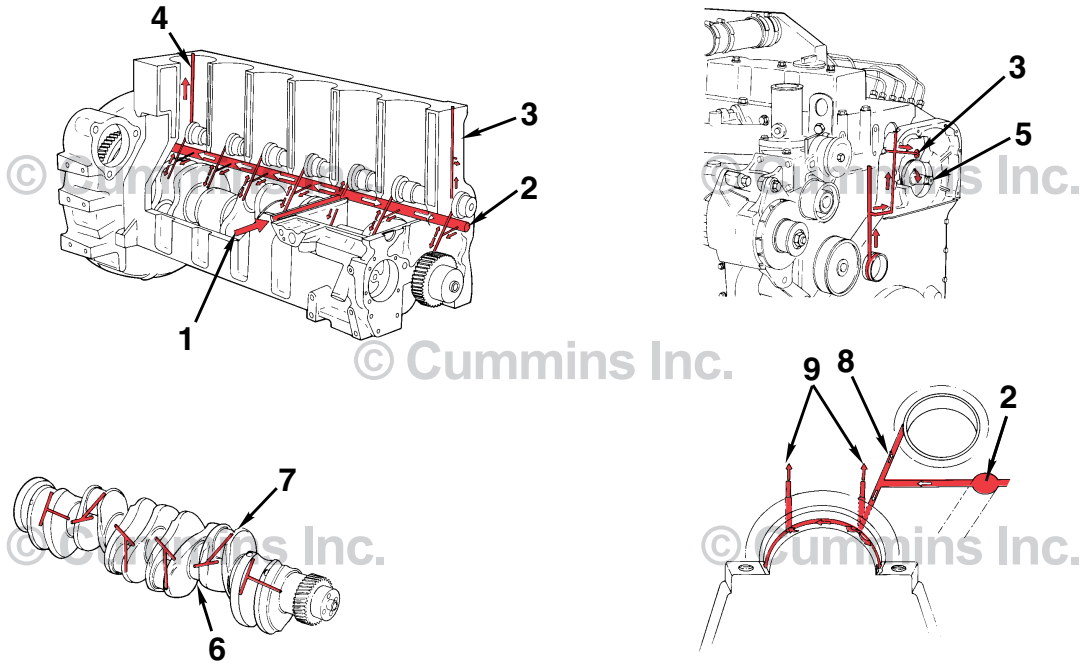
Engine Views All Applications



- 1 Flow from oil pump
- 2 Flow to oil cooler
- 3 Flow from oil cooler
- 4 Flow to oil filter
- 5 Flow from oil filter
- 6 Oil filter bypass valve
- 7 Flow to main oil rail
- 8 Flow to oil pan.

Flow Diagram, Lubricating Oil System (200-002)

Engine Views All Applications



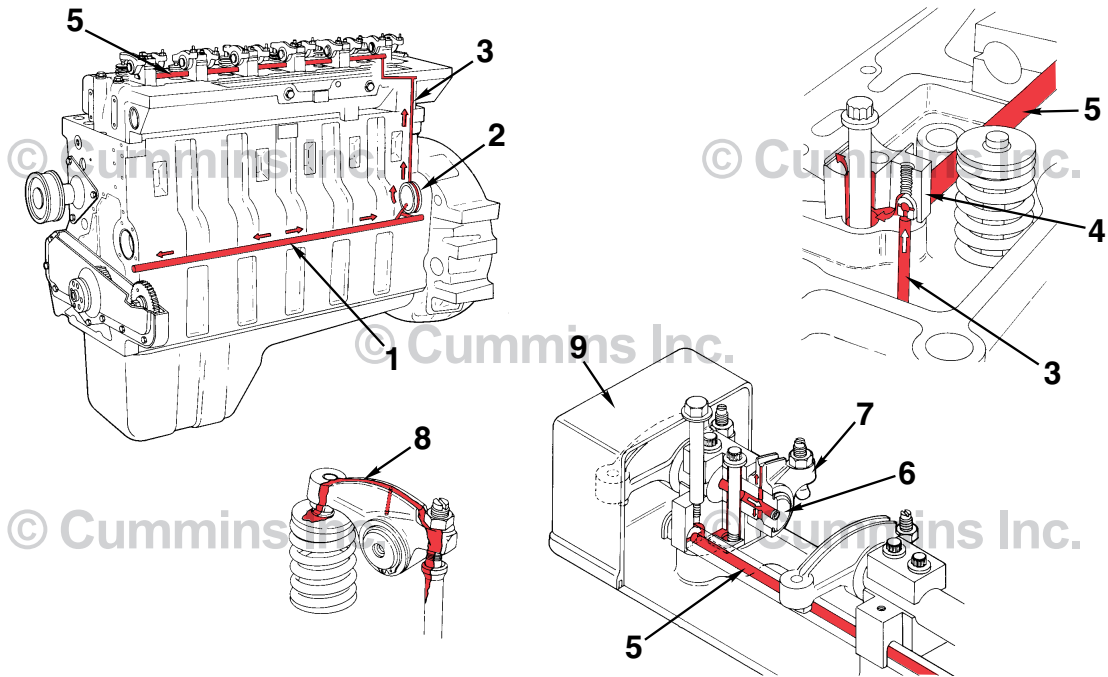
- 1 Flow from oil cooler
- 2 Main oil rifle
- 3 Flow to injection pump
- 4 Flow to overhead
- 5 Injection pump oil drain
- 6 Crankshaft main journal
- 7 Connecting rod journal
- 8 Flow to camshaft bore
- 9 Piston cooling nozzle.

07900230

Flow Diagram, Lubricating Oil System (200-002)

Engine Views

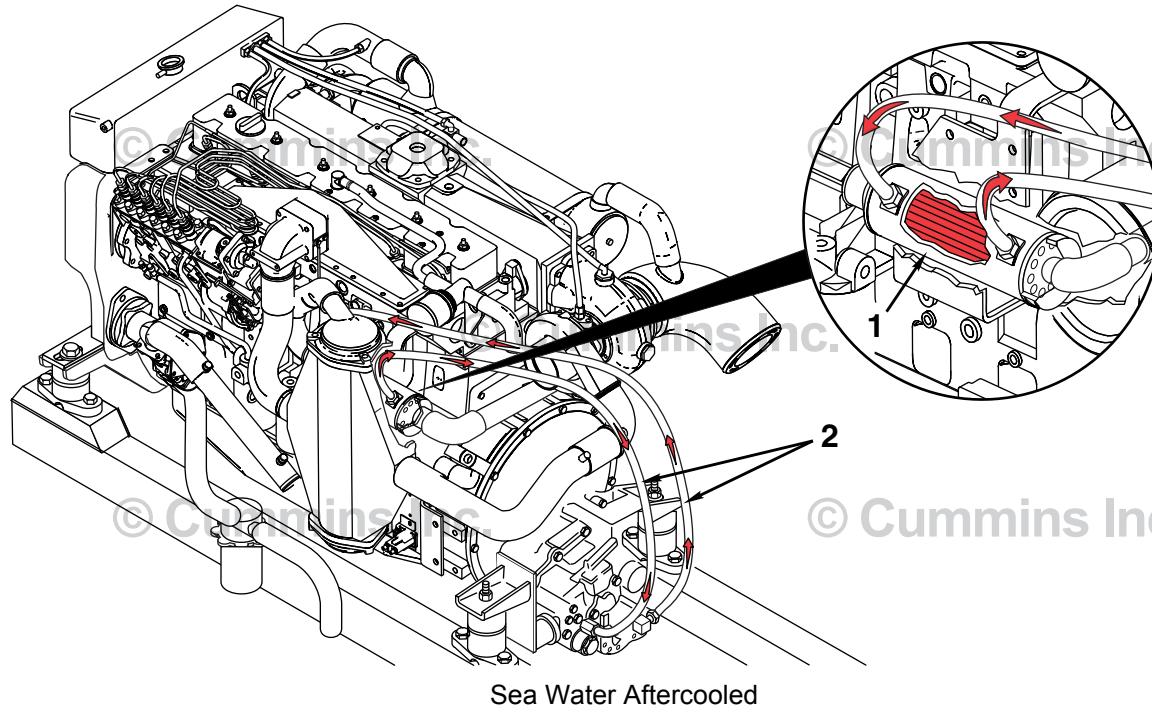
All Applications



- 1 Main oil rifle
- 2 Number 7 camshaft bushing
- 3 Flow from number 7 camshaft bore
- 4 Rocker lever support
- 5 Oil transfer tube
- 6 Rocker lever shaft
- 7 Rocker lever
- 8 Oil trough
- 9 Rocker lever cover.

07900231

Marine Applications



- 1 Marine gear oil cooler
- 2 Marine gear oil lines.

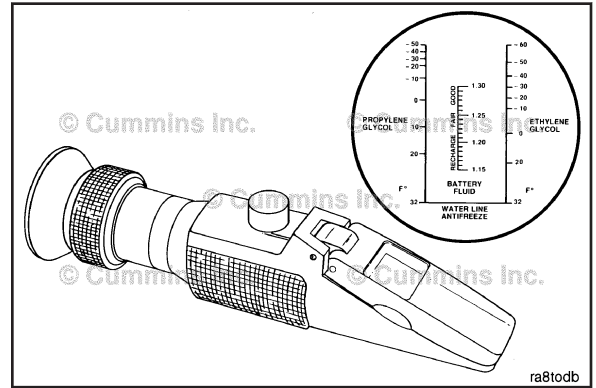
10900292

Cooling System - Overview (008-999) Coolant Blending and Mixing



Check the antifreeze concentration. Use ethylene-glycol base antifreeze to protect the engine to -37°C [-35°F] throughout the year.

Antifreeze is essential in all climates. It broadens the operating temperature range by lowering the coolant freezing point and by raising the coolant boiling point.



⚠️ CAUTION ⚠️

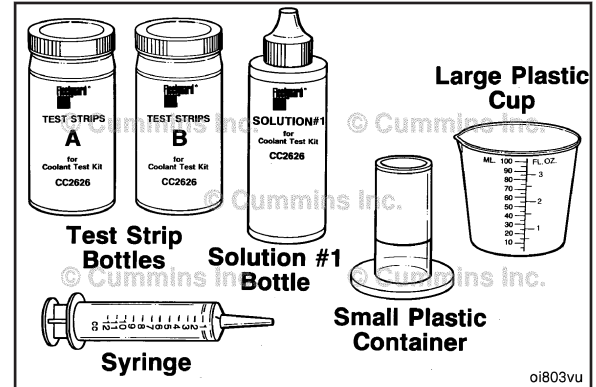
Inadequate concentration of the coolant additive can result in major corrosive damage to cooling system components. Overconcentration can cause formation of "gel" that can cause restriction, plugging of coolant passages, and overheating.

NOTE: If the engine coolant is changed, the coolant filters **must** also be changed.



The cooling system **must** contain the proper coolant additive units to provide the best chemical protection. Refer to the Engine Specifications (Section V).

DCA4 Test Kit: Use **only** DCA4 coolant test kit, Fleetguard® Part No. CC-2626, to check the coolant additive concentration in the cooling system.



Fleetguard® DCA4 Service Filters and Liquid Precharge



The correct coolant filter to be used is determined by the total cooling system capacity and other operational factors.

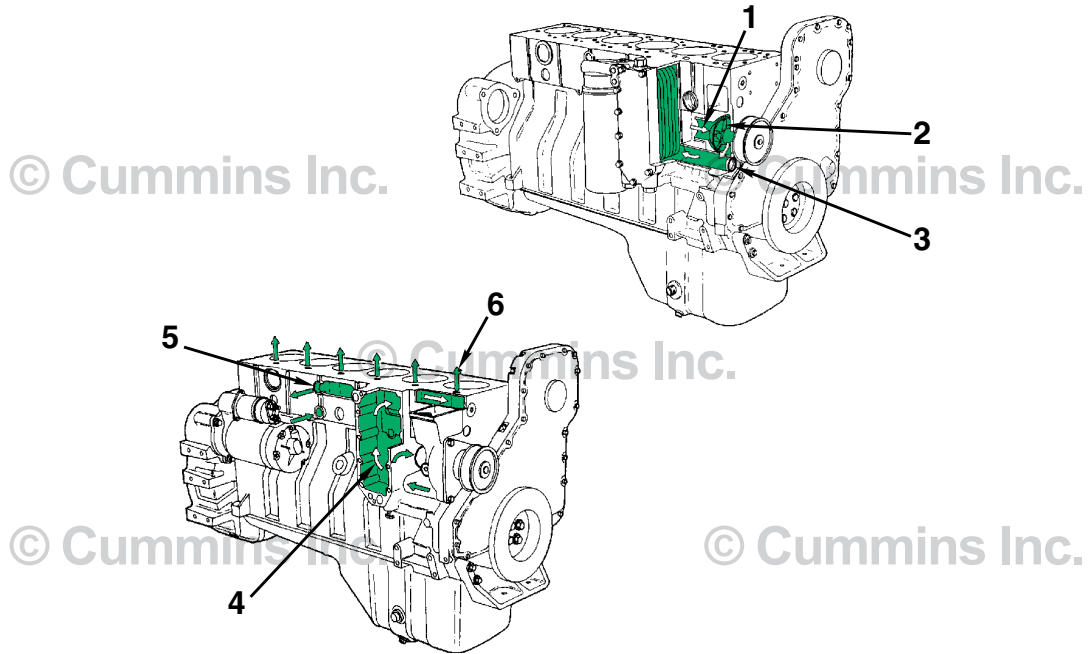
Refer to the DCA4 Maintenance Guide in Engine Specifications (Section V) for the correct selection of the filter.



Flow Diagram, Cooling System (200-003)

Engine Views

Industrial and Marine



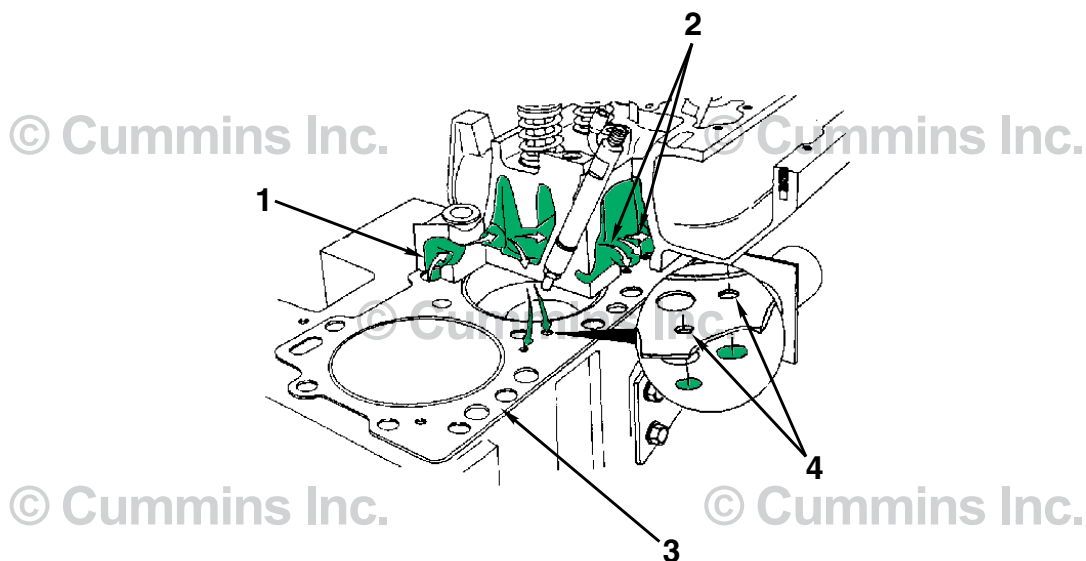
Cylinder Block

- | | |
|-------------------------------|-----------------------------------|
| 1. Coolant inlet | 4. Coolant flow past oil cooler |
| 2. Water pump impeller | 5. Upper coolant manifold |
| 3. Coolant flow to oil cooler | 6. Coolant flow to cylinder head. |

08900201

Flow Diagram, Cooling System (200-003)

Engine Views Industrial and Marine



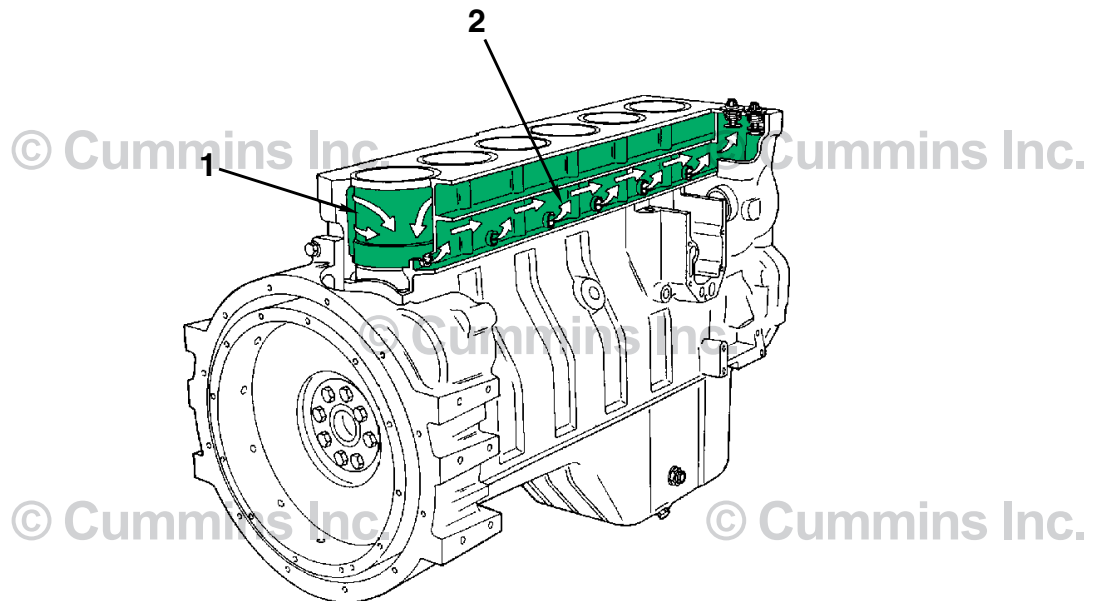
08900203

Cylinder Head

- | | |
|-------------------------------------|--------------------------|
| 1. Flow from upper coolant manifold | 3. Cylinder head gasket |
| 2. Flow to liner cavity | 4. Coolant flow orifice. |

Flow Diagram, Cooling System (200-003)

Engine Views Industrial and Marine



08900200

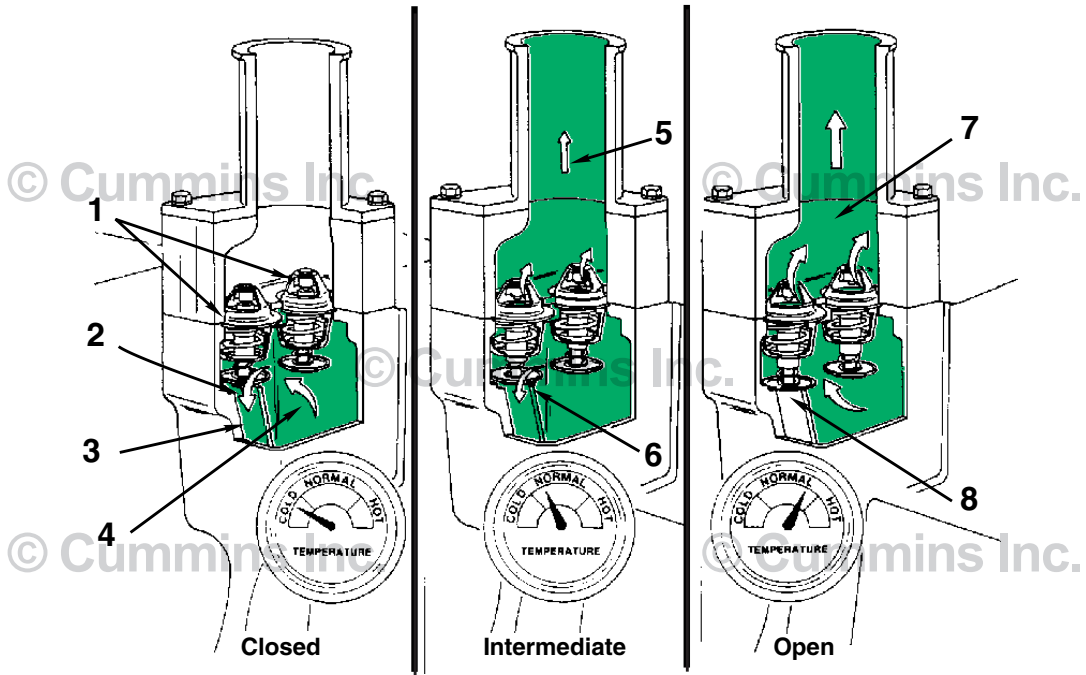
Cylinder Block

1. Flow past cylinder liners

2. Lower coolant manifold.

Flow Diagram, Cooling System (200-003)

Engine Views Industrial and Marine



08900202

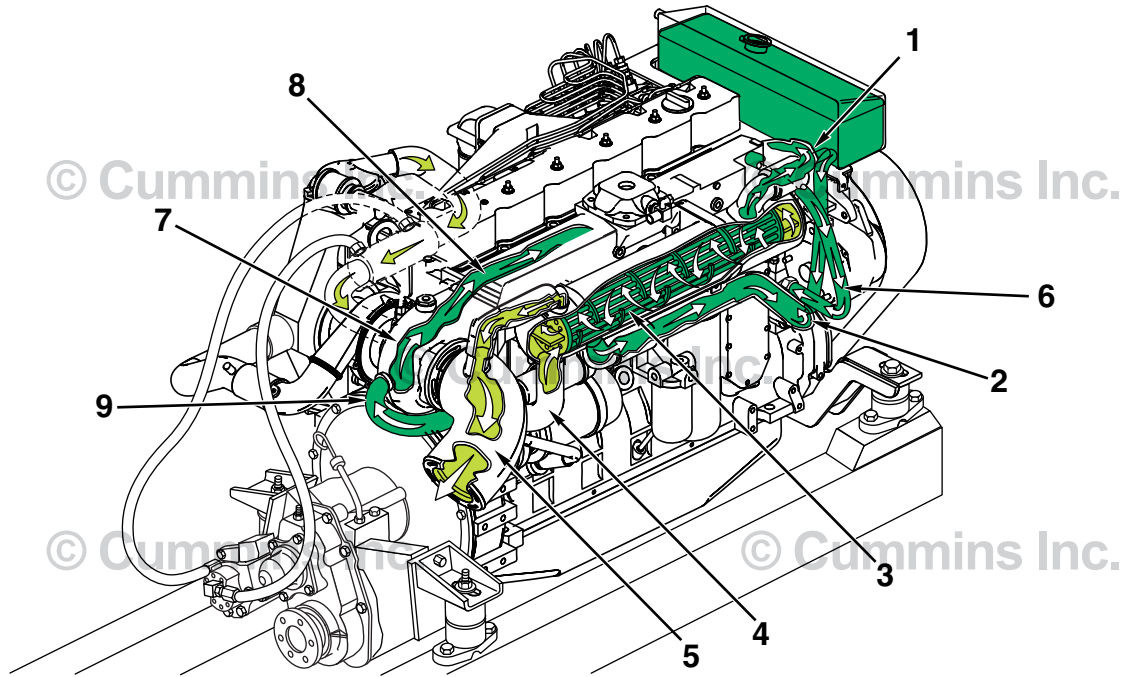
Thermostat

- 1. Thermostats
- 2. Flow to water pump inlet
- 3. Bypass passage open
- 4. Flow from lower coolant manifold
- 5. Partial coolant flow to radiator
- 6. Restricted flow to bypass
- 7. Flow to radiator
- 8. Bypass closed.

Flow Diagram, Cooling System (200-003)

Engine Views

Industrial and Marine



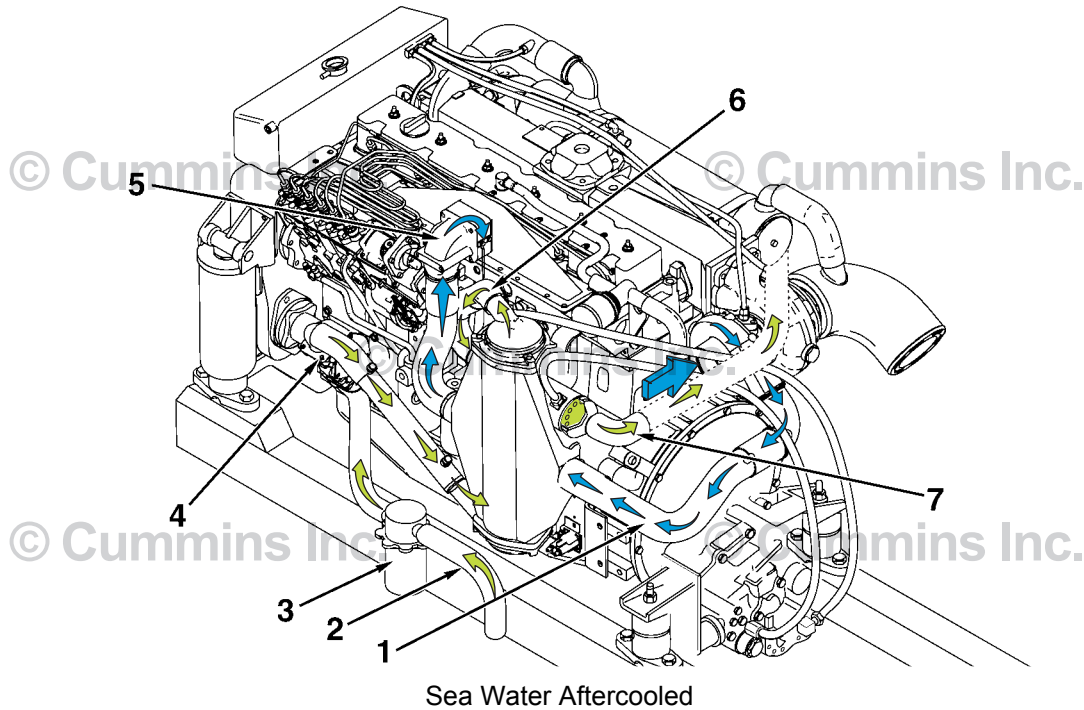
10900288

Sea Water Aftercooled

- | | |
|-------------------------------------|---|
| 1. From thermostat (coolant outlet) | 6. Coolant from exhaust manifold to block |
| 2. To water pump (coolant inlet) | 7. Turbocharger exhaust housing |
| 3. Heat exchanger | 8. Exhaust manifold |
| 4. Sea water from pump | 9. Coolant from block. |
| 5. Sea water outlet (in exhaust) | |

Flow Diagram, Cooling System (200-003)

Engine Views Industrial and Marine



10900289

1. Turbocharger air to aftercooler
2. Sea water inlet
3. Sea water strainer
4. Sea water pump

5. Cooled air to intake manifold
6. Sea water from aftercooler to gear cooler
7. Sea water from gear cooler to heat exchanger.

Air Intake System - Overview (010-999)

General Information

Air is pulled into the engine through an air filter. Clean air is very important to the life of the engine; dust and dirt can damage the cylinders very quickly.

Make sure that a high-quality air cleaner is used and that it is periodically replaced according to the manufacturer's recommendations.

Intake air for the naturally-aspirated engine flows through the air cleaner into the intake manifold. From the intake manifold, the air is pulled into the cylinders and used for combustion. After combustion, it is forced out of the cylinders and through the exhaust manifold.

On turbocharged engines, the intake air is drawn through the air cleaner into the compressor side of the turbocharger, through the crossover tube, and into the intake manifold. From the intake manifold, the air is forced into the cylinders and used for combustion.

On turbocharged engines, the energy from the exhaust is used to drive the turbine wheel of the turbocharger. The turbine wheel and shaft drive the compressor wheel, which forces more air into the cylinders for combustion. The additional air provided by the turbocharger allows more fuel to be injected to increase the power output of the engine.

On turbocharged, aftercooled engines, intake air from the turbocharger flows through the cooling fins of the aftercooler before entering the intake manifold. The cooled air becomes more dense and contains more oxygen; which allows more fuel to be injected, further increasing the power output from the engine.

The 1991 to 1994 automotive engines use a chassis-mounted charge-air cooler, rather than an engine-mounted aftercooler, to provide cooler intake air to the engine. This improves the engine performance and reduce emissions. The charge-air cooler system uses large piping to transfer the air from the turbocharger to the charge-air cooler; then to the engine intake manifold.

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

Some turbocharged engines use a wastegate turbocharger to limit the maximum boost pressure that the turbocharger can develop. Wastegate operation is controlled by an actuator that senses intake manifold pressure and balances it against a preset spring-load.

The wastegate valve is located in the turbine inlet passage. When open, it diverts a portion of the exhaust gas around the turbine wheel, thereby controlling the shaft speed and boost.

▲CAUTION▲

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

The turbine wheel, compressor wheel, and shaft are supported by two rotating bearings in the bearing housing. Passages within the bearing housing direct filtered, pressurized engine oil to the shaft bearings and thrust bearing. The oil is used to lubricate and cool the rotating components to provide for smooth operation. The oil then drains from the bearing housing to the engine sump through the oil drain line. A restricted or damaged oil drain line can cause the turbocharger bearing housing to be pressurized, causing oil to leak past the seals.

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

▲CAUTION▲

A catalyst is installed on all EPA- and CARB-approved automotive applications. Lubricating oil blending is not permitted. It will plug up and eventually damage the catalyst. High-sulfur fuels must not be used with the catalyst. No welding or modifications of the catalyst are permitted without permission of the catalyst manufacturer.

Theory of Operation

White smoke indicates cold combustion/cold engine operation. The intake manifold heater control module monitors the intake air temperature, engine rpm and keyswitch voltage.

The intake manifold heater elements operate in the preheat, post heat, and post heat recycle modes.

- In preheat, the ignition switch is in the RUN position but the engine has **not** been started.
- In post heat and post heat recycle, the engine is operating.

The proper operation of the intake manifold heater system and starting procedures will prevent excessive engine starter motor use and minimize white exhaust smoke when the engine is first started.



Ether starting systems or manually-induced starting fluids must not be used with electric air heater systems.

On C series marine applications, there are three phases of intake air heater operation: preheat (with keyswitch ON and engine **not** operating), post heat (after a successful engine start), and post heat recycle (after the termination of the post heat).

The preheat phase also controls the Optional WAIT TO START lamp to signify to the operator when it is appropriate to begin cranking the engine. In order to allow maximum current to be used by the starter, the heater elements are de-energized during cranking. The amount of time the heater stays in preheat, post heat, and post heat recycle is determined by the intake manifold temperature.

There is no preheat cycle above 35°C [95°F], no post heat cycle above 24°C [75°F] and no post heat recycle above the maximum duration for preheat and post heat (20 seconds) and post heat recycle (20 minutes). When the air intake temperature is below 35°C [95°F], the heating elements are energized in the preheat and post heat cycles, the voltage system current draw is approximately 200 amperes for a 12-VDC system and 100 amperes for a 24-VDC system.

During the post heat recycle mode the heater elements are energized in five-second intervals for a maximum duration of 20 minutes. There are three optional conditions that will interrupt the post heat recycle mode: Out of voltage range, exceeding operational rpm, and air intake temperature above 35°C [95°F]. Once the grid heater post heat recycle mode terminates because of timing out or over/under keyswitch voltage, the grid heater will **not** come back on unless the keyswitch has been cycled from OFF to ON.

If the engine rpm is advanced above the maximum set point (950 rpm for B series and 1200 rpm for C series engines), the post heat recycle will be terminated. Once the engine rpm is adjusted below maximum set point and air intake temperature is below 35°C [95°F], the post heat recycle will reset back to the beginning of the 20-minute cycle.

Heater Cycle Chart			
Battery voltage above 10.5 to 17 for 12-VDC			
Rpm: (B) 450 to 950, (C) 350 to 1200			
Engine Intake Manifold Temperature	Preheat Cycle Time Ignition Keyswitch ON before Crank Cycle	Postheat Cycle Occurs Ignition Keyswitch ON after Crank Cycle	Recycle Mode (After Post Heat)
Above 35°C [95°F]	None	None	None
24 to 35°C [75 to 95°F]	10 seconds	None	25/75% (1)
15.6 to 23°C [60 to 75°F]	10 seconds	20 seconds	50/50% (2)
1 to 15.5°C [32 to 60°F]	15 seconds	20 seconds	50/50% (2)
Below 0°C [32°F]	20 seconds	20 seconds	50/50% (2)

Heater Operating Modes (Parameter)								
Recycle Mode 12-VDC	Element (Heater)	5-Second Time Intervals						
(1) 25/75%	1	On	Off	Off	Off	On	Off	Off
	2	Off	Off	On	Off	Off	Off	On
(2) 50/50%	1	On	Off	On	Off	On	Off	On
	2	Off	On	Off	On	Off	On	Off

Recycle Mode 24-VDC	Element (Heater)	5-Second Time Intervals						
(1) 25/75%	1	On	Off	Off	Off	On	Off	On
(2) 50/50%	1	On	Off	On	Off	On	Off	On

The intake manifold heater option is installed between the aftercooler and intake manifold. The heater is totally electrically operated. The intake manifold heater aids in reducing white smoke at startup and the engine's startability at colder temperatures. Components required to operate the intake heater are:

- Ignition keyswitch
- Heater control module
- Temperature sensor
- Solenoids

- Intake heater grids
- Engine speed sensor
- Wiring.

The intake heater system operates in three modes as follows:

Preheat Cycle

The heater control module receives and monitors supply voltage from the keyswitch.

The heater control module receives electrical signals from sensors mounted on the engine.

The temperature sensor senses intake air manifold temperature and provides input to the heater control module circuit. Temperatures below 35°C [95°F] activate the heater control module heater circuit. This is known as the preheat cycle.

The heater control module provides signal voltage to activate the air heater solenoids. A cable connected to the battery side of the starter solenoid provides supply current/voltage to the air heater solenoid.

Intake air temperatures sensed by the temperature sensor dictate different preheat cycle times, up to a maximum of 20 seconds.

Both elements heat during this cycle.

After the preheat cycle, the starter can be engaged to start the engine.

If the starter is engaged before the cycle time is complete, the heater control module will automatically shut off the elements during cranking.

Post Heat Cycle

The engine speed sensor on the flywheel housing senses engine speed and activates the post heat cycle within a specified rpm range.

The engine **must** be operating in a given range.

Battery voltage is monitored by the heater control module system.

The temperature sensor continues to monitor intake air temperature.

This cycle can continue for up to 20 seconds maximum and does **not** have a rpm cutout.

Both elements heat during this cycle.

Post Heat Recycle

The post heat recycle mode occurs for a maximum of 20 minutes; as long as the heater control module senses specified range of the air temperature, voltage, and rpm.

The post heat recycle activates the heater elements in two sequence modes:

- 25/75: Both elements alternately cycle on and off with a five-second delay between element activation. Each activation lasts for five seconds. **Only** one element is activated at a time on a 12-VDC system.
- 50/50: Both elements cycle on and off for five seconds. **Only** one element is activated at a time.

Post heat recycle operates for a maximum of 20 minutes. This operating cycle can be interrupted at any time, if any one of the following conditions occur:

1. Engine exceeds specified rpm, intake air temperature, or voltage range
2. Intake manifold temperature exceeds 35°C [95°F]
3. Heater control module battery sensing voltage below 10.5 VDC or above 17 VDC.

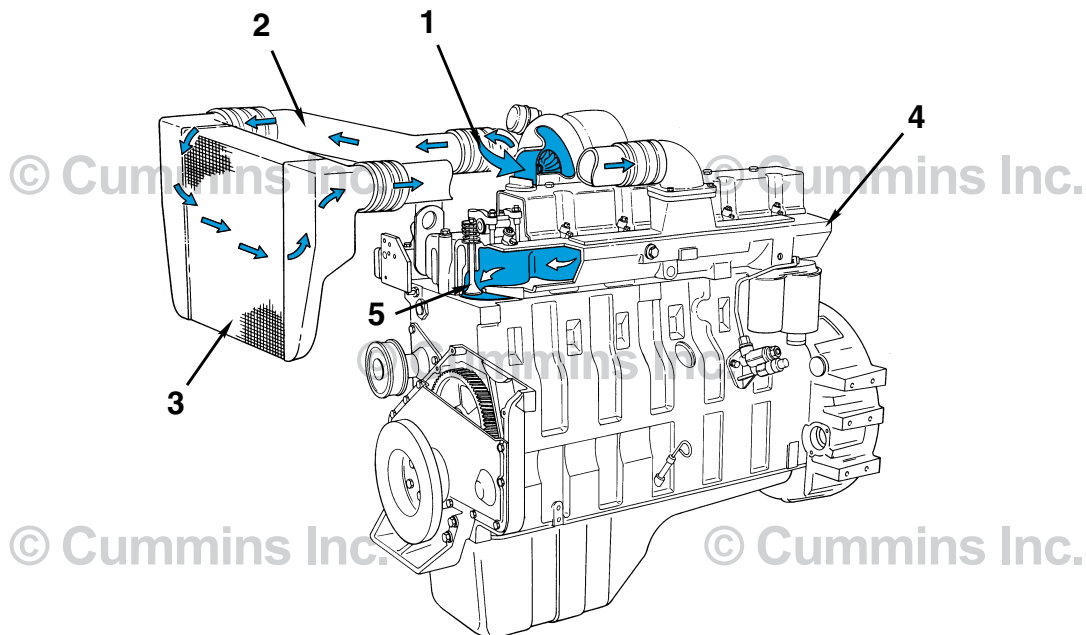
If the post heat recycle is interrupted during its 20-minute cycle, the cycle will restart, and reset for another 20 minutes if all of the following conditions occur:

1. Engine below 1000 rpm
2. Intake manifold temperature below 30°C [85°F]
3. Heater control module battery sensing voltage between 10.5 and 17 VDC.

Once the 20 minutes of post heat recycle has ended, the ignition key **must** be turned to the OFF position and back to the RUN position to restart the air heater cycles again.

Flow Diagram, Air Intake System (200-004)

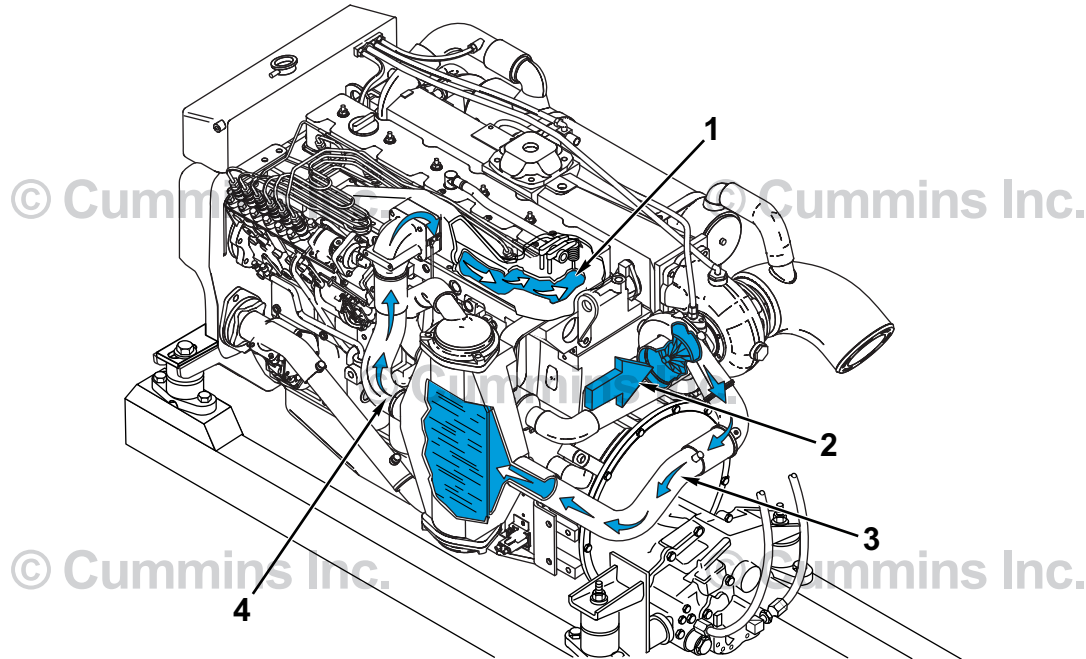
Engine Views Industrial Applications



10900277

- 1 Intake air inlet to turbocharger
- 2 Turbocharger air to charge air cooler
- 3 Charge air cooler
- 4 Intake manifold - integral part of cylinder head
- 5 Intake valve.

Marine Applications



Sea Water Aftercooled

- 1 Intake valve
- 2 Intake air inlet to turbocharger
- 3 Turbocharger air to aftercooler
- 4 Aftercooler to intake manifold.

Exhaust System - Overview (011-999)

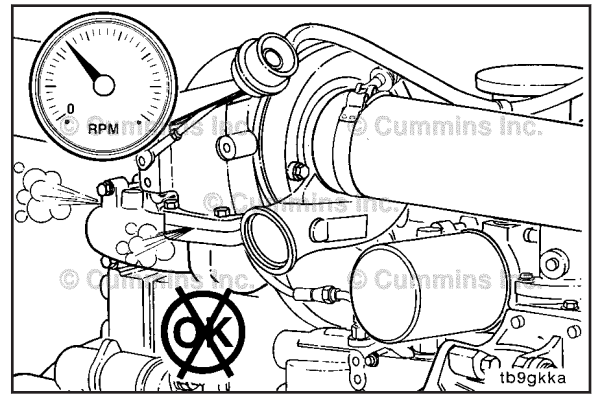
General Information

Turbocharged Engines - Exhaust Leaks

Inspect for exhaust leaks at the exhaust manifold, turbocharger, exhaust pipe(s), muffler, and catalyst restrictions.

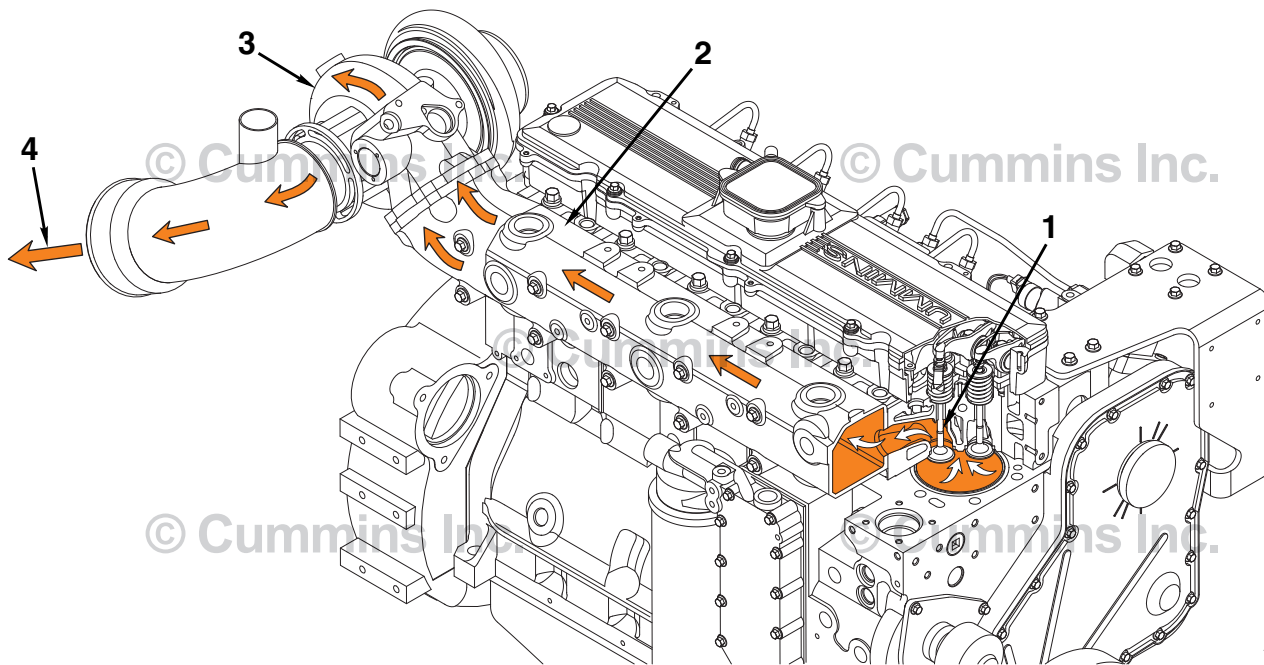
Leaks or restrictions will cause the turbine and impeller to operate at a lower speed and reduce the amount of air being forced into the cylinders. The symptoms of a restricted or leaking exhaust system are:

1. Excessive smoke
2. Low intake manifold pressure
3. Low power.



Flow Diagram, Exhaust System (200-005)

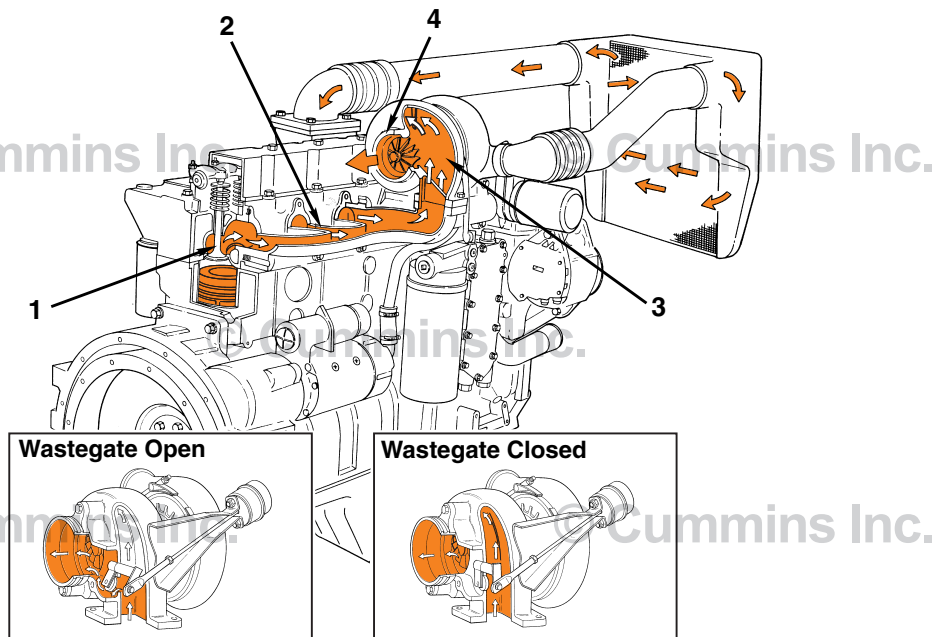
Engine Views Marine Applications



11d00119

- 1 Exhaust valve
- 2 Exhaust manifold
- 3 Turbocharger
- 4 Turbocharger exhaust outlet.

Industrial Applications

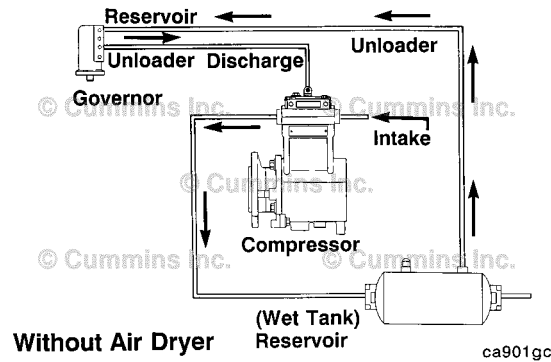


- 1 Exhaust valve
- 2 Exhaust manifold - pulse-type
- 3 Dual entry to turbocharger
- 4 Turbocharger exhaust outlet.

Compressed Air System - Overview (012-999)

General Information

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



The Holset® QE296 single-cylinder air compressor is an engine-driven, piston-type compressor that supplies compressed air to operate air-activated devices. The compressor runs continuously but has loaded and unloaded operating modes. The operating mode is controlled by a pressure-activated governor and the compressor unloading assembly.

The QE296 air compressor used on C Series engines uses an (E-type) unloader. The economy (E-type) unloader system was designed to reduce pumping losses and engine boost pressure losses through the compressor intake valve while operating in unloading mode.

When the air system reaches a predetermined pressure, the governor applies an air signal to the air compressor unloader assembly, causing the unloader cap to seal off incoming air at the intake valve, and compressed air stops flowing into the air system.

NOTE: System pressure **must** be maintained on the outlet side of the discharge valve to keep the discharge valve closed.

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

⚠CAUTION⚠

Vehicles equipped with air dryers vented to atmosphere during unloaded compressor operation, using the Holset® (E-type) air compressor, require the installation of an Econ valve to prevent excessive oil consumption.

If the air system pressure is **not** maintained on the discharge valve during unloaded operation, air will be pumped out of the compressor cylinder causing a low pressure (vacuum) condition to form in the cylinder. With the intake valve sealed off by the unloader cap and the exhaust valve being a one-way pressure actuated valve, no air will be allowed to enter the cylinder. When the air compressor cylinder pressure falls below crankcase pressure, oil will be drawn past the piston rings and pumped into the air system.

Other brands of air compressors can be used on C Series engines. Troubleshooting procedures are very similar for these air compressors compared to the Holset® QE296. Refer to the specific air compressor manufacturer's manual for detailed repair information and torque specifications.

The Holset® heavy-duty (HD) air compressors was designed for the C Series engine. Applications include industrial markets, such as transit buses, refuse trucks, on-off highway construction vehicles, and other.

The Holset® heavy-duty model air compressor is a continuous pump version of the QE model already released for the C Series engines. The air compressor crank housing and head are the same; however, the Holset® heavy-duty model does **not** have an integral unloader. Unloading is controlled at the air dryer by way of an internal or external air governor. A discharge line unloader is required for installations **without** air dryers.

The advantage of this air compressor is that the downstream plumbing is simplified because of the elimination of the unloader valve. Standard valves have been replaced with Reed valves to enable the air compressor to run continuously without valve endurance issues.

During unloaded operations, the air compressor's discharge air is continuously vented to the atmosphere through the air dryer's purge port.

The Holset® heavy-duty air compressors can **not** use turbocharged air and **must** be naturally aspirated to prevent loss of engine power. Inlet air for the air compressor **must** be sourced directly from the engine air cleaner, as close to the air cleaner as possible.

The Holset® heavy-duty model air compressors will be designated as the HD650 (QE296 derivative), and HD850 (QE338 derivative). The Holset® heavy-duty models will use the same coolant plumbing as the corresponding QE model.

The following table shows what Holset® heavy-duty model air compressor and part number that will replace the current QE model air compressor:

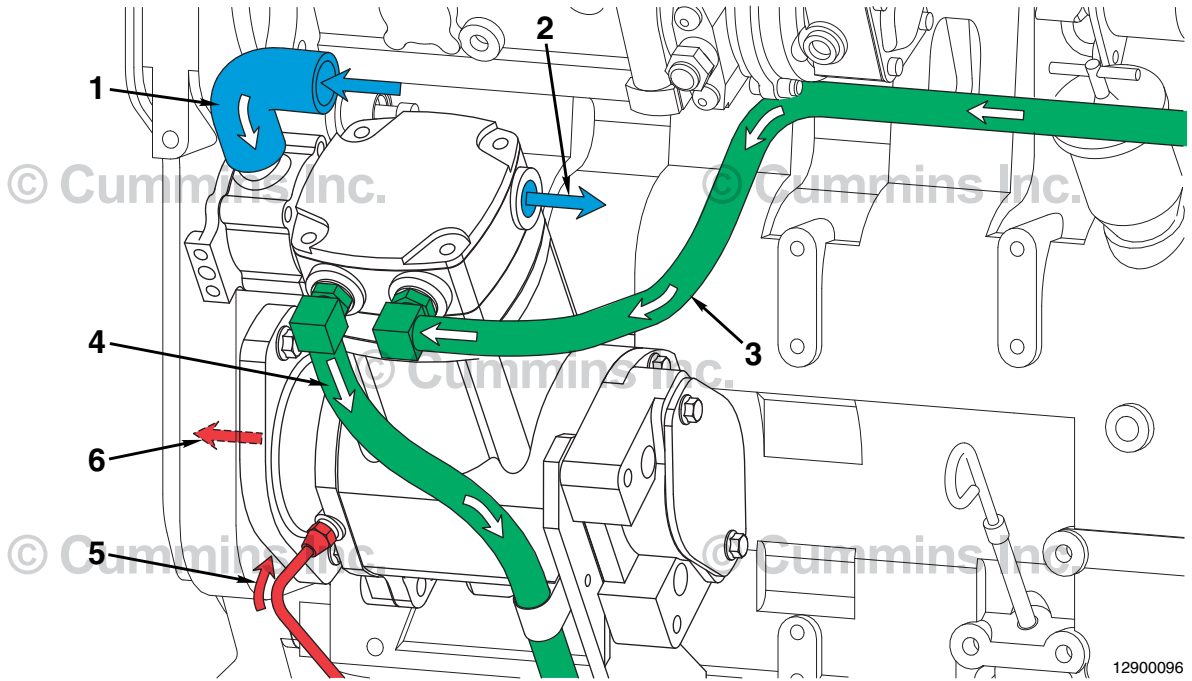
HD Model	Part No.	New Option No.	Replaces QE Model
HD650B	3558127	CP9202	3558049
HD650B	3558128	CP9203	3558097
HD850B	3558120	CP9204	3558050
HD850	3558121	CP9209	3558098
HD650C	3558129	CP9205 and CP9206	3558052
HD850C	3558122	CP9207 and CP9208	3558051

NOTE: The QE model air compressor is **not** becoming obsolete. The Holset® heavy-duty model will be available where the QE is **not** capable of supplying sufficient air quality on specific applications.

Flow Diagram, Compressed Air System (200-006)

Engine Views

Marine and Industrial Applications



1. Air in
2. Air out
3. Coolant in

4. Coolant out
5. Lubricating oil in
6. Lubricating oil drain.

Electrical Equipment - Overview (013-999)

General Information

⚠ WARNING ⚠

Batteries can emit explosive gases. To avoid 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 ⚠

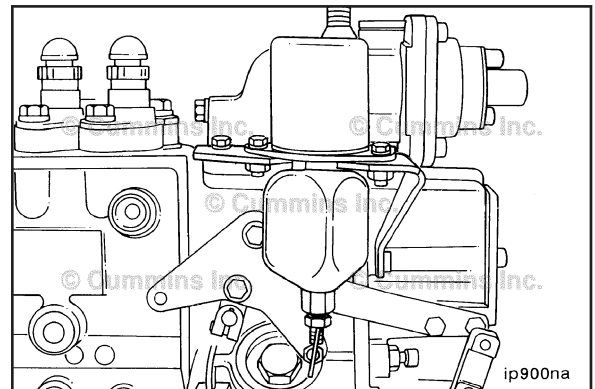
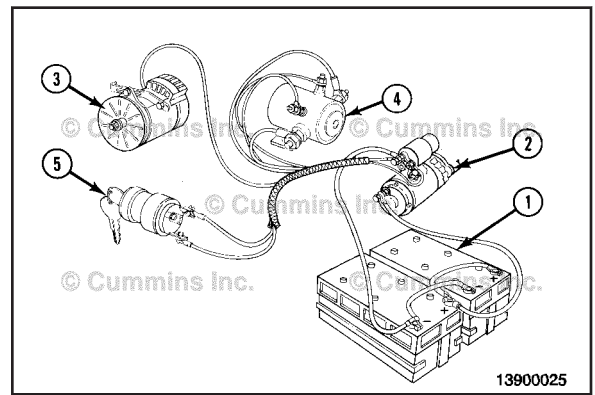
When the engine is running, do not wear loose-fitting or torn clothing, long hair, or jewelry that could entangle in moving parts and cause severe personal injury or death.

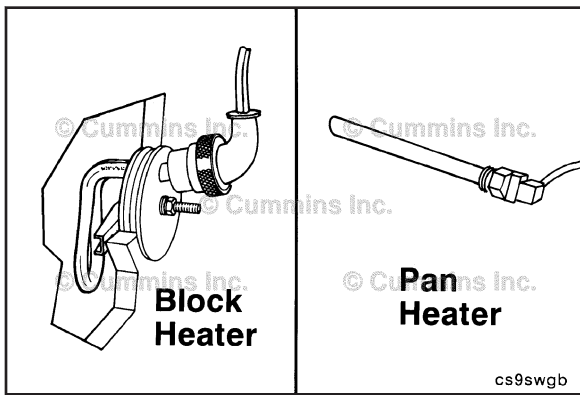
The basic electrical system consists of:

- Batteries (1)
- Starter motor (2)
- Alternator (3)
- Magnetic switch (4)
- Ignition switch (5)
- All necessary wiring.

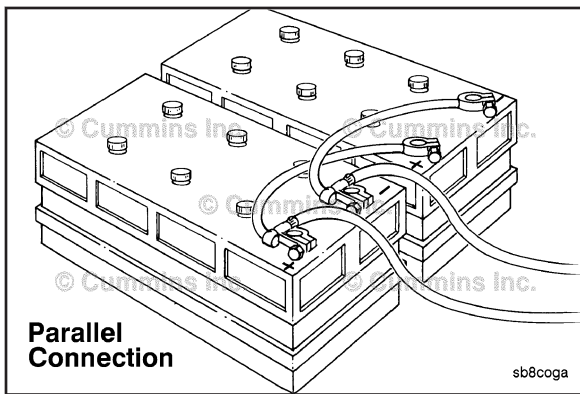
All components **must** be carefully matched.

The in-line injection pump uses an electronically activated solenoid shutdown system. The function of the valve is discussed in Section 5.



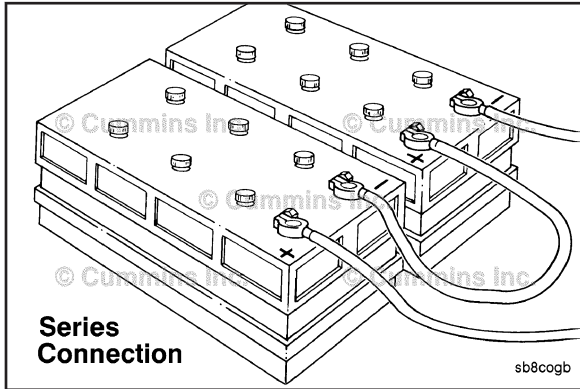


The engine can be fitted with a cylinder block heater, oil pan heater, and/or an intake manifold heater.



The accompanying illustrations show typical parallel and series battery connections:

- Parallel connection



- Series connection.

Engine Testing - Overview (014-999)

General Information

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

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

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

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

Section TS - Troubleshooting Symptoms

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Troubleshooting Procedures and Techniques

General Information

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

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

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

Follow these basic troubleshooting steps:

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

Troubleshooting Symptoms Charts

General Information

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



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

Troubleshooting Overview

Driveability/Low Power - Customer Complaint Form

Customer _____ Name/Company _____ Date _____

- 1 How did the problem occur? Suddenly _____ Gradually _____
- 2 At what hour/mileage did the problem begin? Hours _____ Miles _____ Since New _____
- After engine repair? Yes _____ No _____
- After equipment repair? Yes _____ No _____
- After change in equipment use? Yes _____ No _____
- After change in selected programmable parameters? Yes _____ No _____
- If so, what was repaired and when? _____
- Does the vehicle also experience poor fuel economy? Yes _____ No _____

Answer questions 4 through 8 using selections (A through F) listed below. Circle the letter or letters that best describe the complaint.

- A - Compared to fleet
- B - Compared to competition
- C - Compared to previous engine
- D - Personal expectation
- E - Will **not** pull on hill
- F - Will **not** pull on flat terrain

A B C D E F

A - Can the vehicle obtain the expected road speed? Yes _____ No _____

B - What is desired speed? rpm/mpH _____

C - What is achieved speed? rpm/mpH _____

D - Gross Vehicle Weight _____

A B C D

Is the vehicle able to pull the load? Yes _____ No _____

When?

_____ On hilly terrain

_____ With a loaded trailer

_____ On flat terrain

Other

IF QUESTION 4 OR 5 WAS ANSWERED NO, FILL OUT THE DRIVEABILITY/LOW-POWER/EXCESSIVE FUEL CONSUMPTION CHECKLIST AND GO TO THE LOW-POWER SYMPTOM TREE.

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

From a stop? Yes _____ No _____

After a shift? Yes _____ No _____ rpm _____

Before a shift? Yes _____ No _____ rpm _____

No shift? Yes _____ No _____ rpm _____

Does the vehicle hesitate after periods of long deceleration or coasting? Yes _____ No _____ rpm _____

IF QUESTION 6 OR 7 WAS ANSWERED YES, FILL OUT THE DRIVEABILITY/LOW-POWER/EXCESSIVE FUEL CONSUMPTION CHECKLIST AND GO TO THE POOR ACCELERATION/RESPONSE SYMPTOM TREE.

Additional Comments:

This page can be copied for convenience.

Driveability - General Information

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

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

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

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

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

Low power is **not** the inability of the vehicle to accelerate satisfactorily from a stop or the bottom of a grade. Refer to the Engine Power Output Low troubleshooting symptom tree in Section TS for the proper procedures to locate and correct a low-power problem. The chart starts off with basic items that can cause lower power.

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

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

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

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

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

Engine Noise Diagnostic Procedures - General Information

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

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

Engine noise can sometimes be isolated by performing a cylinder cutout test. If the volume of the noise decreases or the noise disappears, it is related to that particular engine cylinder.

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

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

Main Bearing Noise

- (Refer to the Engine Noise Excessive - Main Bearing troubleshooting symptom tree in Section TS)
- The noise caused by a loose main bearing is a loud, dull knock heard when the engine is pulling a load. If all main bearings are loose, a loud clatter will be heard. The knock is heard regularly every other revolution. The noise is the loudest when the engine is lugging or under heavy load. The knock is duller than a connecting rod noise. Low oil pressure can also accompany this condition.
- If the bearing is **not** loose enough to produce a knock by itself, the bearing can knock if the oil is too thin or if there is no oil on the bearing.
- An irregular noise can indicate worn crankshaft thrust bearings.
- An intermittent, sharp knock indicates excessive crankshaft end clearance. Repeated clutch disengagements can cause a change in the noise.

Connecting Rod Bearing Noise

- (Refer to the Engine Noise Excessive - Connecting Rod troubleshooting symptom tree in Section TS)
- Connecting rods with excessive clearance will knock at all engine speeds under both idle and load conditions. When the bearings begin to become loose, the noise can be confused with piston slap or loose piston pins. The noise increases in volume with engine speed. Low oil pressure can also accompany this condition.

Piston Noise

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

Oil Consumption

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

Cummins Engine Company, Inc. defines “acceptable oil usage” as outlined in the following table.

Acceptable Oil Usage									
Any Time During Coverage Period									
Engine Family	Hours per Quart	Hours per Liter	Hours per Imperial Quart	Miles per Quart	Miles per Liter	Miles per Imperial Quart	Kilometers per Quart	Kilometers per Quart	Kilometers per Imperial Quart
A	10.0	10.6	12.0	400	425	475	650	675	775
4B	10.0	10.6	12.0	400	425	475	650	675	775
6B	10.0	10.6	12.0	400	425	475	650	675	775
6C	10.0	10.6	12.0	400	425	475	650	675	775
V/VT-378	4.0	4.3	5.0	-	-	-	-	-	-
V/VT-504	4.0	4.3	5.0	250	265	310	400	425	485
V/VT-555	4.0	4.3	5.0	250	265	310	400	425	485
L Series	4.0	4.3	5.0	250	265	310	400	425	485
M Series	4.0	4.3	5.0	250	265	310	400	425	485
N Series	4.0	4.3	5.0	250	265	310	400	425	485
V/VT/ VTA-903	4.0	4.3	5.0	250	265	310	400	425	485

Lubricating Oil Added		
Last Mileage/Hours/Kilometers _____		
Minus Start Mileage/Hours/Kilometers _____		
Equals Test Mileage/Hours/Kilometers _____		
Divided by Oil Added _____		
Equals _____		
Usage Rate _____		
Customer Signature	Cummins Dealer	Cummins Distributor
Cummins Engine Company, Inc. Form 4755		



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

15200020

Oil Consumption Report	
Customer Name:	Dist/Dir:
Engine Model:	Mi/Km/Hr:
Engine Serial Number:	CPL Number:
Vehicle Make/Model:	Date:
Review of maintenance history: List any previous failures that could have had a detrimental effect on cylinder component life. Failures could include fuel, coolant, and/or foreign abrasives in the oil, second ring groove beat-out, filter plugging, etc.	
Lubrication Oil Used:	
Brand	
Viscosity	
Change Interval (mi/km/hr)	
Combination Oil Filter:	
Model	
Element	
Change Interval (mi/km/hr)	
Bypass Oil Filter:	
Model	
Element	
Change Interval (mi/km/hr)	
Full-Flow Oil Filter:	
Model	
Element	
Change Interval (mi/km/hr)	
Air Cleaner:	
Make and Model	
Change Interval	
List any external engine leaks.	
Check for any internal leaks and list them. Check turbocharger seals, valve guides, air compressor, and so forth.	
Had the fuel pump been tampered with? _____ What is maximum rail pressure readings? _____ If yes, the pump must be reset to factory specifications and the customer sent out to reevaluate the oil consumption rate. The eligibility requirements must be met again, also.	

Oil Consumption Report

Drain and refill oil pan to check dipstick markings and note findings.

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.

Only after above checks are completed, leaks corrected, and proper documentation completed, disassemble engine to determine cause of the failure and repair as required.

State reason for oil consumption.

Signed: _____

Air Compressor Air Pressure Rises Slowly

This is symptom tree t004

Cause

Correction

STEP 1

Air intake system restriction to air compressor is excessive

Replace the air compressor air cleaner (if installed). Check the air intake piping. Check engine air intake restriction if the air compressor inlet is plumbed to the vehicle or equipment intake system. Refer to Procedure 010-031.

OK

Go To Next Step

STEP 2

Air system leaks

Block the vehicle wheels and check the air system for leaks with spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, tanks, and valves. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121 and the OEM service manual.

OK

Go To Next Step

STEP 3

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

Check the air governor for correct operation. Make sure the air governor is located less than 0.6 m [2 ft] from the air compressor. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.

OK

Go To Next Step

STEP 4

Carbon buildup is excessive in the air discharge line, check valve, or cylinder head

Check for carbon buildup. Replace the air compressor discharge line, if necessary. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer to Procedure 010-033.

OK

Go To Next Step

STEP 5

Air system component is malfunctioning

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

OK

Go To Next Step

STEP 6

Unloader valve is malfunctioning

Check the unloader valve and unloader body seal. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.

OK

Go To Next Step

STEP 7

Air compressor intake or exhaust valve leaks air

Inspect the air compressor intake and exhaust valve assemblies. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.

Air Compressor Cycles Frequently

This is symptom tree t005

Cause	Correction
<p>STEP 1 Air compressor pumping time is excessive</p>	<p>Replace the desiccant cartridge on the Turbo/CR 2000 air dryer. Refer to the OEM service manual. Check the air compressor duty cycle. Install a larger air compressor, if necessary. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Air dryer outlet check valve is sticking</p>	<p>Lubricate or replace the air dryer outlet check valve assembly. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Air governor is malfunctioning or not set correctly</p>	<p>Check the air governor for correct operation. Make sure the air governor is located less than 0.6 m [2 ft] from the air compressor. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Air system component is malfunctioning</p>	<p>Check the operation of check valves, alcohol evaporators, air dryers, and other OEM-installed air system components. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Air system leaks</p>	<p>Block the vehicle wheels and check the air system for leaks with spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, tanks, and valves. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121 and the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Carbon buildup is excessive in the air discharge line, check valve, or cylinder head</p>	<p>Check for carbon buildup. Replace the air compressor discharge line, if necessary. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer to Procedure 010-033.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 E-type system is not plumbed correctly</p>	<p>Install an Econ valve, a check valve, and system hoses. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.</p>

Air Compressor Noise is Excessive

This is symptom tree t006

Cause	Correction
<p>STEP 1 Carbon buildup is excessive in the air discharge line, check valve, or cylinder head</p>	<p>Check for carbon buildup. Replace the air compressor discharge line, if necessary. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer to Procedure 010-033.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Ice buildup in the air system components</p>	<p>For all models, check for ice in low spots of the air discharge line, dryer inlet, and elbow fittings. On Holset® models, also check the Econ valve (if equipped). Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Air compressor mounting hardware is loose, worn, or broken</p>	<p>Check air compressor mounting hardware. Refer to Procedure 012-014.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Air compressor drive gear or engine gear train is worn or damaged</p>	<p>Inspect the drive gears and gear train and repair as necessary. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Air compressor timing is not correct</p>	<p>Check the air compressor timing. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Splined drive coupling or gear is excessively worn</p>	<p>Check the coupling for wear. Refer to Procedure 012-014.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Air compressor is excessively worn or internally damaged</p>	<p>Replace or rebuild the air compressor. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121. Replace the desiccant element on the Turbo/CR 2000 air dryer (if equipped). Refer to the manufacturer's instructions.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Air compressor is sending air pulses into the air tanks</p>	<p>Install a ping tank between the air dryer and the wet tank. Refer to the OEM service manual.</p>

Air Compressor Pumping Excess Lubricating Oil into the Air System

This is symptom tree t007

Cause

STEP 1

Air intake system restriction to air compressor is excessive

OK

Go To Next Step

STEP 2

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

OK

Go To Next Step

STEP 3

Lubricating oil drain line is restricted

OK

Go To Next Step

STEP 4

Carbon buildup is excessive in the air discharge line, check valve, or cylinder head

OK

Go To Next Step

STEP 5

Air compressor runs hot

OK

Go To Next Step

STEP 6

Contaminants are building up in the system reservoirs

OK

Go To Next Step

STEP 7

Crankcase pressure is excessive

OK

Go To Next Step

STEP 8

Engine angularity during operation exceeds specification

OK

Go To Next Step

Correction

Replace the air compressor air cleaner (if installed). Check the air intake piping. Check engine air intake restriction if the air compressor inlet is plumbed to the vehicle or equipment intake system. Refer to Procedure 010-031.

Install an Econ valve, a check valve, and system hoses. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.

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

Check for carbon buildup. Replace the air compressor discharge line, if necessary. Check the turbocharger for oil leaks. Check the intake tube for oil. Refer to Procedure 010-033.

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

Drain the reservoirs daily. Refer to the Operation and Maintenance Manual, C Series Engines, Bulletin 4021330.

Check for excessive blowby. Refer to the Crankcase Gases (Blowby) Excessive symptom tree.

Refer to the Engine Specifications data sheet.

Air Compressor Pumping Excess Lubricating Oil into the Air System

This is symptom tree t007

Cause

STEP 9

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

OK

Go To Next Step

STEP 10

Air compressor pumping time is excessive

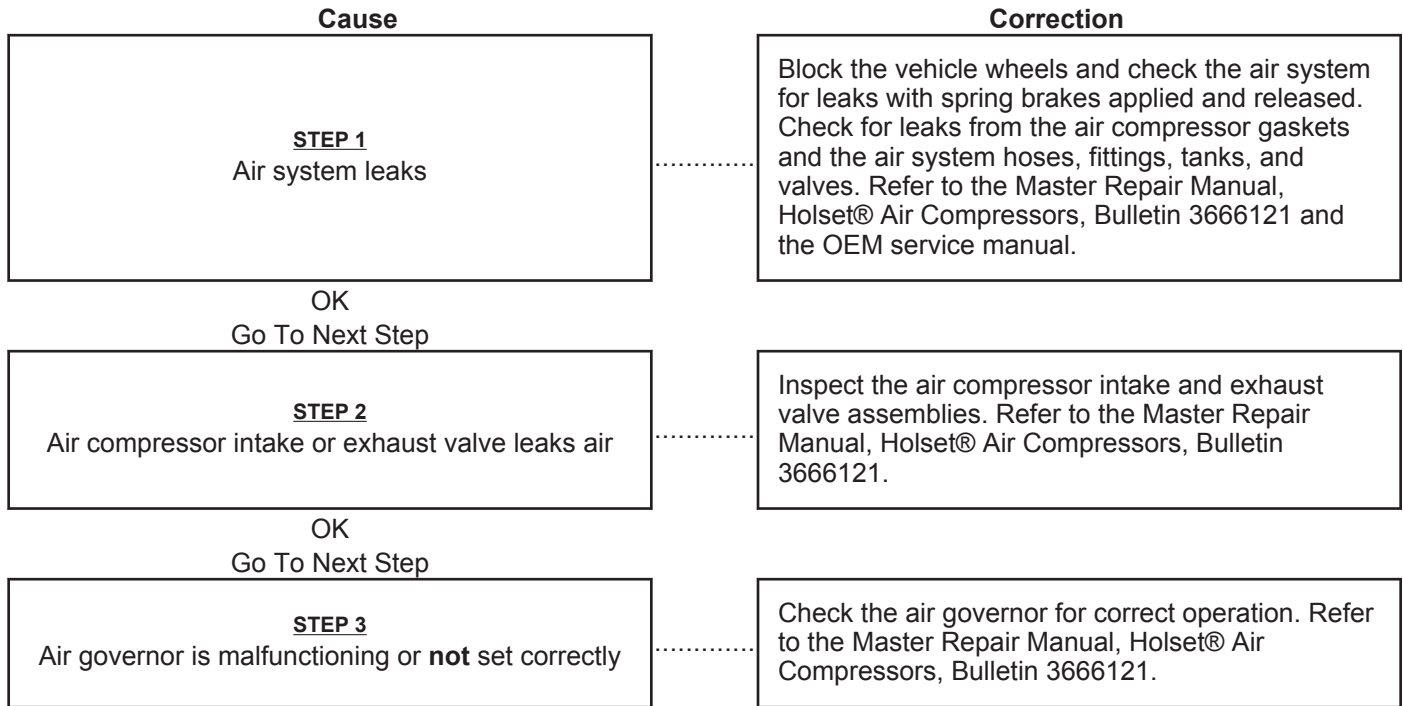
Correction

Inspect the drive gears and gear train and repair as necessary. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.

Replace the desiccant cartridge on the Turbo/CR 2000 air dryer. Refer to the OEM service manual. Check the air compressor duty cycle. Install a larger air compressor, if necessary. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.

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

This is symptom tree t008



Air Compressor Will Not Pump Air

This is symptom tree t009

Cause	Correction
<p>STEP 1 Air system leaks</p> <p>OK Go To Next Step</p>	<p>Block the vehicle wheels and check the air system for leaks with spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, tanks, and valves. Refer to Procedure 012-019 and the OEM service manual.</p>
<p>STEP 2 Air dryer desiccant cartridge is saturated</p> <p>OK Go To Next Step</p>	<p>Replace the desiccant cartridge on the air dryer. Refer to the OEM service manual.</p>
<p>STEP 3 Unloader valve is malfunctioning</p> <p>OK Go To Next Step</p>	<p>Check the unloader valve and unloader body seal. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.</p>
<p>STEP 4 Air governor is malfunctioning or not set correctly</p> <p>OK Go To Next Step</p>	<p>Check the air governor for correct operation. Make sure the air governor is located less than 0.6 m [2 ft] from the air compressor. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.</p>
<p>STEP 5 Splined drive coupling or gear is excessively worn</p> <p>OK Go To Next Step</p>	<p>Check the coupling for wear. Refer to Procedure 012-014.</p>
<p>STEP 6 Air compressor intake or exhaust valve leaks air</p> <p>OK Go To Next Step</p>	<p>Inspect the air compressor intake and exhaust valve assemblies. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.</p>
<p>STEP 7 Air compressor is excessively worn or internally damaged</p>	<p>Replace or rebuild the air compressor. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.</p>

Air Compressor Will Not Stop Pumping

This is symptom tree t010

Cause	Correction
<p>STEP 1 Air system leaks</p>	<p>Block the vehicle wheels and check the air system for leaks with spring brakes applied and released. Check for leaks from the air compressor gaskets and the air system hoses, fittings, tanks, and valves. Refer to Procedure 012-019 and the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Air governor is malfunctioning or not set correctly</p>	<p>Check the air governor for correct operation. Make sure the air governor is located less than 0.6 m [2 ft] from the air compressor. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Unloader valve is malfunctioning</p>	<p>Check the unloader valve and unloader body seal. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Air governor signal line or actuator line is plugged</p>	<p>Inspect the signal line and actuator line. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Air system component is malfunctioning</p>	<p>Check the operation of check valves, alcohol evaporators, air dryers, and other OEM-installed air system components. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Air compressor intake or exhaust valve leaks air</p>	<p>Inspect the air compressor intake and exhaust valve assemblies. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.</p>

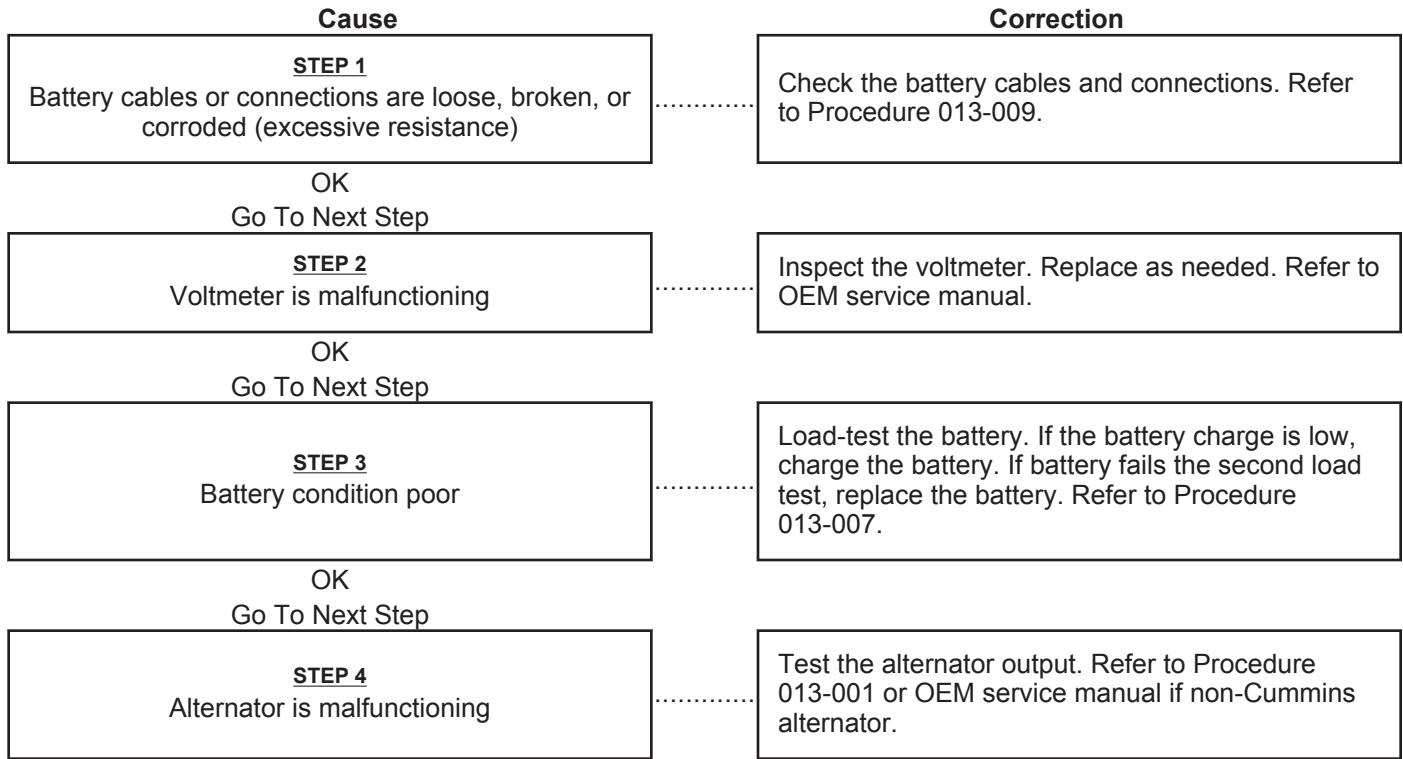
Alternator Not Charging or Insufficient Charging

This is symptom tree t013

Cause	Correction
<p>STEP 1 Voltmeter is malfunctioning</p>	<p>Inspect the voltmeter. Replace as needed. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Engine speed too low for charging</p>	<p>Move throttle to raise engine speed to 1200 rpm to excite the alternator. Refer to the Operation and Maintenance Manual Marine C Series, Bulletin 3381968.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Battery cables or connections are loose, broken, or corroded (excessive resistance)</p>	<p>Check the battery cables and connections. Refer to Procedure 013-009.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Battery condition poor</p>	<p>Load-test the battery. If the battery charge is low, charge the battery. If battery fails the second load test, replace the battery. Refer to Procedure 013-007.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Alternator belt is loose or missing</p>	<p>Check the alternator belt tension. Check pulleys in belt wrap, and repair, if necessary. Replace belt or belt tensioner, or both. Refer to Procedures 008-002 and 008-080.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Alternator pulley is loose on the shaft</p>	<p>Tighten the pulley. Refer to Procedure 013-006.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Alternator connection to ground is poor</p>	<p>Inspect the alternator mounting hardware for a proper electrical connection to the battery. Remove any paint and debris from the ground connection. Check mounting bracket bolts for proper torque. Refer to Procedure 013-001.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Alternator is malfunctioning</p>	<p>Test the alternator output. Refer to Procedure 013-001 or OEM service manual if non-Cummins alternator.</p>

Alternator Overcharging

This is symptom tree t014



Coolant Contamination

This is symptom tree t018

Cause

STEP 1

Coolant mixture of antifreeze and water is **not** correct

OK

Go To Next Step

STEP 2

Coolant is rusty and has debris

OK

Go To Next Step

STEP 3

Transmission oil cooler or torque converter cooler is leaking

OK

Go To Next Step

STEP 4

Lubricating oil leaks from lubricating oil cooler, head gasket, head, turbocharger, and cylinder block

Correction

Verify the concentration of antifreeze in the coolant. Add antifreeze or water to correct the concentration. Refer to Cummins Coolant Requirements, Bulletin 3666132.

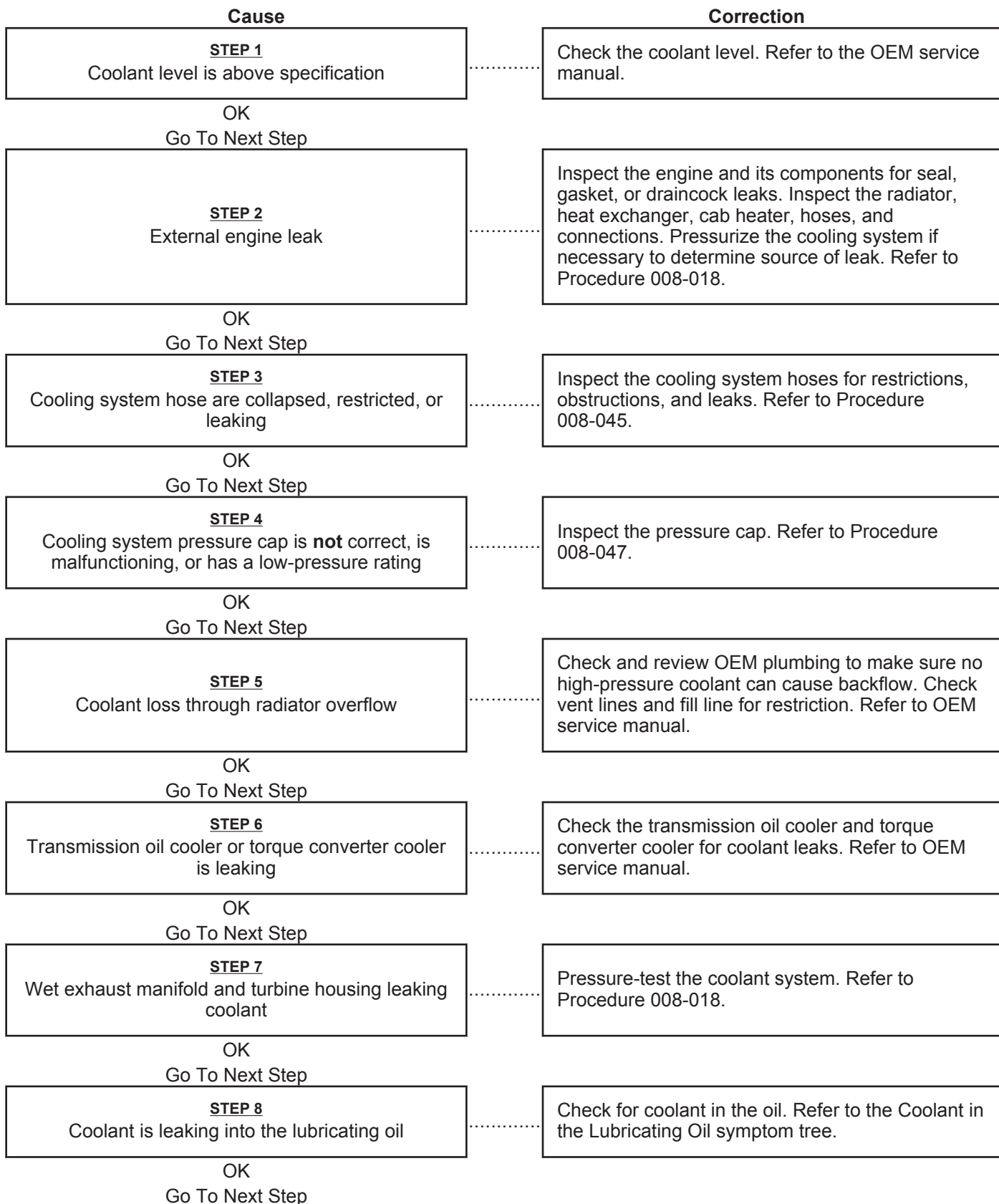
Drain and flush the cooling system. Fill with correct mixture of antifreeze and water. Refer to Procedure 008-018 and Cummins Coolant Requirements, Bulletin 3666132.

Check the transmission oil cooler and torque converter cooler for coolant leaks. Refer to the manufacturer's instructions.

Refer to the Lubricating Oil Consumption Excessive symptom tree.

Coolant Loss

This is symptom tree t019



Coolant Loss

This is symptom tree t019

Cause

STEP 9
Coolant is leaking into the combustion chamber

Correction

Remove the cylinder head, and inspect cylinder head, gasket, and pistons for evidence of coolant. Refer to Procedure 002-004.

Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

Cause

Correction

STEP 1

Electronic fault codes active or high counts of inactive fault codes

View and troubleshoot the fault codes with INSITE™. Refer to Section TF in the Marine Electronic Control System, C8.3 Engines, Troubleshooting and Repair Manual, Bulletin 4021442.

OK

Go To Next Step

STEP 2

Coolant level is below specification

Inspect the engine and cooling system for external coolant leaks. Repair if necessary. Add coolant. Refer to Procedure 008-018.

OK

Go To Next Step

STEP 3

Temperature gauge malfunction

Check or replace the temperature gauge. Refer to the OEM service manual.

OK

Go To Next Step

STEP 4

Radiator and charge air cooling fins plugged (nonmarine **only**)

Blow debris from fins.

OK

Go To Next Step

STEP 5

Airflow to the radiator is restricted (nonmarine engines **only**)

Check and repair fan shroud, shutters, shutterstat, sensor, fan clutch, and viscous fan as required. Refer to the OEM service manual.

OK

Go To Next Step

STEP 6

Sea water cooling system is malfunctioning

Troubleshoot the sea water system. Refer to the Coolant Temperature Above Normal - Sea Water Cooling System symptom tree.

OK

Go To Next Step

STEP 7

Cooling system pressure cap is **not** correct, is malfunctioning, or has a low-pressure rating

Inspect the pressure cap. Refer to Procedure 008-047.

OK

Go To Next Step

STEP 8

Belt(s) loose, tight, or **not** in alignment

Check the belt(s). Refer to Procedure 008-002 and 008-080.

OK

Go To Next Step

Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

Cause	Correction
<p>STEP 9 Cooling system hose are collapsed, restricted, or leaking</p>	<p>Inspect the cooling system hoses for restrictions, obstructions, and leaks. Refer to Procedure 008-045.</p>
<p>OK Go To Next Step</p>	
<p>STEP 10 Cooling system is contaminated with dirt, scale, or sludge</p>	<p>Clean the cooling system. Refer to Procedure 008-018.</p>
<p>OK Go To Next Step</p>	
<p>STEP 11 Coolant is contaminated with lubricating oil</p>	<p>Refer to the Lubricating or Transmission Oil in the Coolant symptom tree.</p>
<p>OK Go To Next Step</p>	
<p>STEP 12 Fan shroud is damaged or missing or the air recirculation baffles are damaged or missing</p>	<p>Inspect the shroud and the recirculation baffles. Repair, replace, or install, if necessary. Refer to Procedure 008-038 and the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 13 Coolant mixture of antifreeze and water is not correct</p>	<p>Verify the concentration of antifreeze in the coolant. Add antifreeze or water to correct the concentration. Refer to Procedure 008-018.</p>
<p>OK Go To Next Step</p>	
<p>STEP 14 Thermostat is not correct or is malfunctioning</p>	<p>Check the thermostat for the correct part number and for correct operation. Refer to Procedure 008-013.</p>
<p>OK Go To Next Step</p>	
<p>STEP 15 Air or combustion gases are entering the cooling system</p>	<p>Check for air or combustion gases in the cooling system. Refer to Procedure 008-019.</p>
<p>OK Go To Next Step</p>	
<p>STEP 16 Coolant pump is malfunctioning</p>	<p>Check the water pump for correct operation. Replace the water pump, if necessary. Refer to Procedure 008-062.</p>
<p>OK Go To Next Step</p>	
<p>STEP 17 Fuel injection pump timing is not correct</p>	<p>Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-012.</p>
<p>OK Go To Next Step</p>	

Coolant Temperature Above Normal - Gradual Overheat

This is symptom tree t022

Cause

Correction

STEP 18

Fuel injection pump is malfunctioning

Remove the fuel injection pump. Check the calibration of the fuel injection pump. Refer to Procedure 005-012.

OK

Go To Next Step

STEP 19

Plugged cooling passages in the cylinder head, head gasket, or cylinder block

Pressure-test the cooling system. Refer to Procedure 008-018.

OK

Go To Next Step

STEP 20

Cooling system has insufficient capacity

Refer to the OEM service manual.

Coolant Temperature Above Normal - Sudden Overheat

This is symptom tree t023

Cause	Correction
<p>STEP 1 Electronic fault codes active or high counts of inactive fault codes</p>	<p>View and troubleshoot the fault codes with INSITE™. Refer to Section TF in the Marine Electronic Control System, C8.3 Engines, Troubleshooting and Repair Manual, Bulletin 4021442.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Coolant level is below specification</p>	<p>Inspect the engine and cooling system for external coolant leaks. Repair if necessary. Add coolant. Refer to Procedure 008-018.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Belt(s) loose, tight, or not in alignment</p>	<p>Check the belt(s). Refer to Procedures 008-002 and 008-080.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Temperature gauge malfunction</p>	<p>Check or replace the temperature gauge. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Sea water cooling system is malfunctioning</p>	<p>Troubleshoot the sea water system. Refer to the Coolant Temperature Above Normal - Sea Water Cooling System symptom tree.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Airflow to the radiator is restricted (nonmarine engines only)</p>	<p>Check and repair fan shroud, shutters, shutterstat, sensor, fan clutch, and viscous fan as required. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Cooling system hose are collapsed, restricted, or leaking</p>	<p>Inspect the cooling system hoses for restrictions, obstructions, and leaks. Refer to Procedure 008-045.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Thermostat is not correct or is malfunctioning</p>	<p>Check the thermostat for the correct part number and for correct operation. Refer to Procedure 008-013.</p>
<p>OK Go To Next Step</p>	

Coolant Temperature Above Normal - Sudden Overheat

This is symptom tree t023

Cause	Correction
<p>STEP 9 Water pump is malfunctioning</p>	<p>Inspect the water pump for correct operation. Replace the water pump if necessary. Refer to Procedure 008-062.</p>
<p>OK Go To Next Step</p>	
<p>STEP 10 Water pump cavitation</p>	<p>If the engine was built with an external bypass thermostat, make sure an orificed plug is used in the bypass passage. If a rubber plug is used replace it with bypass plug, Part Number 3935234. Refer to Procedure 200-003.</p>
<p>OK Go To Next Step</p>	
<p>STEP 11 Fill line or vent lines are restricted, obstructed, or not routed correctly</p>	<p>Check the vent lines and the fill line for correct routing and for restriction. Refer to the OEM service manual and Procedure 008-017.</p>
<p>OK Go To Next Step</p>	
<p>STEP 12 Air or combustion gases are entering the cooling system</p>	<p>Check for air or combustion gases in the cooling system. Refer to Procedure 008-019.</p>
<p>OK Go To Next Step</p>	
<p>STEP 13 Plugged cooling passages in the cylinder head, head gasket, or cylinder block</p>	<p>Pressure-test the cooling system. Refer to Procedure 008-018.</p>
<p>OK Go To Next Step</p>	
<p>STEP 14 Cooling system has insufficient capacity</p>	<p>Refer to the OEM service manual.</p>

Coolant Temperature Below Normal

This is symptom tree t024

Cause	Correction
<p>STEP 1 Engine is operating at low ambient temperature</p>	<p>Check the shutters and engine compartment air. Refer to Operation of Diesel Engines in Cold Climates, Bulletin 3379009.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Airflow across radiator is excessive (nonmarine engines only)</p>	<p>Check and repair shutters, fan clutch, and viscous fan as required. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Temperature gauge malfunction</p>	<p>Check or replace the temperature gauge. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Excessive coolant flow through OEM plumbing, heater cores, etc.</p>	<p>Close valves to heater cores, etc. Run engine. If engine operates at a normal temperature, refer to the OEM dealer.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Thermostat is not correct or is malfunctioning</p>	<p>Check the thermostat for the correct part number and for correct operation. Refer to Procedure 008-013.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Fan drive or fan controls are malfunctioning (nonmarine engines only)</p>	<p>Check the fan drive and controls. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Coolant flow not correct to temperature sensor</p>	<p>Check and clean coolant passages.</p>

Coolant in the Lubricating Oil

This is symptom tree t025

Cause	Correction
<p>STEP 1 Lubricating oil cooler is leaking</p>	<p>Check the lubricating oil cooler for coolant leaks and cracks. Refer to Procedure 007-003.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Air compressor cylinder head is cracked or porous, or has a leaking gasket (nonmarine engines only)</p>	<p>Inspect the air compressor cylinder head and gasket. Refer to Procedure 012-019 or the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Aftercooler is leaking</p>	<p>Inspect and pressure-test the aftercooler for leaks. Refer to Procedure 010-002.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Cylinder head gasket is leaking</p>	<p>Check the cylinder head gasket. Refer to Procedure 002-004.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Cylinder head is cracked or porous</p>	<p>Remove intake and exhaust manifolds. Check for evidence of coolant leak. If necessary, operate engine at low idle. Pressure-test the cylinder head. Refer to Procedure 002-004.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Cylinder head expansion plugs leaking or misassembled</p>	<p>Inspect the cylinder head . Refer to Procedure 001-026.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Cylinder liner is cracked or porous</p>	<p>Inspect the cylinder liners for cracks and pitting. Refer to Procedure 001-028.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Cylinder block is cracked or porous</p>	<p>Inspect the cylinder block. Refer to Procedure 001-026.</p>

Coolant Temperature Above Normal - Sea Water Cooling System

This is symptom tree t026-156

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

Crankcase Gases (Blowby) Excessive

This is symptom tree t027

Cause

Correction

STEP 1

Air compressor is malfunctioning

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

OK

Go To Next Step

STEP 2

Cylinder head valve guides are excessively worn

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

OK

Go To Next Step

STEP 3

Piston or piston rings are worn or damaged

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

OK

Go To Next Step

STEP 4

Turbocharger oil seal is leaking

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

Engine Acceleration or Response Poor

This is symptom tree t033

Cause

Correction

STEP 1

Electronic fault codes active or high counts of inactive fault codes

View and troubleshoot the fault codes with INSITE™. Refer to Section TF in the Marine Electronic Control System, C8.3 Engines, Troubleshooting and Repair Manual, Bulletin 4021442.

OK

Go To Next Step

STEP 2

Interview the operator to verify the complaint

Refer to the Troubleshooting Overview in Procedure t00-004. Follow the instructions on the form before continuing with this tree.

OK

Go To Next Step

STEP 3

Operator technique is **not** correct

Explain correct engine operation to the operator. Refer to the Operation and Maintenance Manual, C Series Engine, Bulletin 4021330 or the Operation and Maintenance Manual, Recreational, High Output Marine Propulsion, C Series Engine, Bulletin 3381968.

OK

Go To Next Step

STEP 4

Fuel level is low in the tank

Fill the supply tank. Refer to the Operation and Maintenance Manual, C Series Engine, Bulletin 4021330.

OK

Go To Next Step

STEP 5

Fuel inlet restriction

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

OK

Go To Next Step

STEP 6

Fuel grade is **not** correct for the application or the fuel quality is poor

Operate the engine from a tank of high-quality fuel. Refer to Fuel for Cummins Engines, Bulletin 3379001.

OK

Go To Next Step

STEP 7

Fuel inlet temperature to pump is above specification

Fill the fuel tank, turn off or bypass the fuel heaters, and check the fuel cooler. Refer to the OEM service manual.

OK

Go To Next Step

STEP 8

Air intake system restriction

Check the air intake system for restriction. Refer to Procedure 010-031.

OK

Go To Next Step

Engine Acceleration or Response Poor

This is symptom tree t033

Cause	Correction
<p>STEP 9 Drivetrain is not correctly matched to the engine</p>	<p>Check for correct gearing and drivetrain components. Refer to the OEM vehicle specifications.</p>
<p>OK Go To Next Step</p>	
<p>STEP 10 Vessel is malfunctioning or parasitics are excessive</p>	<p>Check the vessel bottom, propeller, transmission, and driven accessories. Refer to the manufacturer's instructions.</p>
<p>OK Go To Next Step</p>	
<p>STEP 11 Clutch is malfunctioning or is not correct</p>	<p>Compare the drivetrain specifications to Cummins recommendations. Check the clutch for correct operation. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 12 Vehicle parasitics are excessive</p>	<p>Check the vehicle brakes for dragging, transmission malfunction, cooling fan operation cycle time, and engine-driven units. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 13 Propeller damaged or not at the correct pitch</p>	<p>Inspect or replace propeller. Refer to the manufacturer's instructions.</p>
<p>OK Go To Next Step</p>	
<p>STEP 14 Fuel leak</p>	<p>Check the fuel lines, fuel connections, and fuel filters for leaks. Check the fuel lines to the supply tanks. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 15 Fuel lift pump is malfunctioning</p>	<p>Check the fuel lift pump for correct operation. Check the pump output pressure. Replace the fuel lift pump if necessary. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 16 Fuel pump overflow valve is malfunctioning</p>	<p>Check the overflow valve. Refer to Procedure 006-044.</p>
<p>OK Go To Next Step</p>	
<p>STEP 17 Air in the fuel system</p>	<p>Check for air in the fuel system. Vent air from the system. Refer to Procedure 006-024.</p>
<p>OK Go To Next Step</p>	

Engine Acceleration or Response Poor

This is symptom tree t033

Cause	Correction
<p>STEP 18 Charge air cooler is restricted or leaking</p>	<p>Inspect the charge air cooler for air restrictions or leaks. Refer to Procedure 010-027.</p>
<p>OK Go To Next Step</p>	
<p>STEP 19 Aftercooler is restricted</p>	<p>Check the aftercooler for restriction. Refer to Procedure 010-002.</p>
<p>OK Go To Next Step</p>	
<p>STEP 20 Air intake or exhaust leaks</p>	<p>Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.</p>
<p>OK Go To Next Step</p>	
<p>STEP 21 Turbocharger is not correct</p>	<p>Check the turbocharger part number and compare it to the Control Parts List (CPL), Bulletin 3379133 or 4021327. Replace the turbocharger if necessary. Refer to Procedure 010-033.</p>
<p>OK Go To Next Step</p>	
<p>STEP 22 Turbocharger wastegate is malfunctioning (if equipped)</p>	<p>Check the wastegate for correct operation. Refer to Procedure 010-050.</p>
<p>OK Go To Next Step</p>	
<p>STEP 23 Exhaust brake adjustment is not correct</p>	<p>Check the exhaust brake adjustment. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 24 Exhaust system restriction is not within specification</p>	<p>Check the exhaust system for restrictions. Refer to Procedure 011-009.</p>
<p>OK Go To Next Step</p>	
<p>STEP 25 Turbocharger wheel clearance is out of specification</p>	<p>Check the radial bearing clearance and axial clearance. Inspect the turbocharger. Repair or replace the turbocharger if necessary. Refer to Procedures 010-038 and 010-047.</p>
<p>OK Go To Next Step</p>	
<p>STEP 26 Overhead adjustments are not correct</p>	<p>Measure and adjust the overhead settings. Refer to Procedure 003-004.</p>
<p>OK Go To Next Step</p>	

Engine Acceleration or Response Poor

This is symptom tree t033

Cause

Correction

STEP 27
Injectors are **not** correct

Remove the injectors and compare the part numbers to the Control Parts List (CPL), Bulletin 3379133 or 4021327. Replace the injectors if necessary. Refer to Procedure 006-026.

OK
Go To Next Step

STEP 28
Injector is malfunctioning

Inspect the injectors. Replace the injectors as necessary. Refer to Procedure 006-026.

OK
Go To Next Step

STEP 29
Fuel supply line restriction between the fuel pump and the injectors

Check the fuel supply line from the fuel pump to the cylinder head for sharp bends that can cause restrictions. Refer to Procedure 006-024.

OK
Go To Next Step

STEP 30
Fuel injection pump timing is **not** correct

Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-012.

OK
Go To Next Step

STEP 31
Fuel injection pump is malfunctioning

Remove and test the fuel injection pump. Replace the pump if necessary. Refer to Procedure 005-012.

OK
Go To Next Step

STEP 32
Internal engine damage

Analyze the oil and inspect the filters to locate an area of probable damage. Refer to Procedure 007-013.

Engine Difficult to Start or Will Not Start (Exhaust Smoke)

This is symptom tree t043

Cause	Correction
<p>STEP 1 Starting procedure is not correct</p>	<p>Verify the correct starting procedure. Refer to the Operation and Maintenance Manual, C Series Engines, Bulletin 4021330..</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Engine cranking speed is too slow</p>	<p>Make sure all drive units are disengaged. Check the engine cranking speed with a handheld tachometer or electronic service tool. If the cranking speed is slower than 150 rpm, refer to the Engine Will Not Crank or Cranks Slowly symptom tree.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Electrical or manual fuel shutdown binds</p>	<p>Check for loose wires and verify that the solenoid is functioning. Check to be sure manual shutoff lever is not binding at the injection pump. Refer to Procedure 005-018.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Starting aid is necessary for cold weather, or starting aid is malfunctioning</p>	<p>Check for correct operation of cold starting aid. Refer to the Operation of Diesel Engines in Cold Climates, Bulletin 3379009, and the Intake Manifold Air Heater System Malfunctioning symptom tree.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Intake air source is incorrect</p>	<p>If the vehicle is equipped with a valve to switch the intake source from under the hood to outside, position and set valve for the season.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Plugged air filter</p>	<p>Inspect the air cleaner element. Replace as needed. Refer to Procedure 010-031.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Intake air overheated</p>	<p>Inspect and clean any debris from the front of the charge air cooler. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Air in the fuel system</p>	<p>Check for air in the fuel system. Refer to Procedure 006-003.</p>
<p>OK Go To Next Step</p>	

Engine Difficult to Start or Will Not Start (Exhaust Smoke)

This is symptom tree t043

Cause

Correction

STEP 9

Fuel filter or fuel inlet restriction

Check the flow through the fuel filter. Replace the fuel filter if necessary. Refer to Procedure 006-015. Clean all prefilters and screens. Check the fuel suction line for restriction.

OK

Go To Next Step

STEP 10

Fuel quality is poor or diesel fuel grade number 1 is used above 0°C [32°F]

Number 1 diesel fuel and other light winter fuels are lower in heat content than number 2 diesel fuel and result in higher fuel consumption. Evaluate fuel consumption using number 2 diesel fuel. Fuel additives also result in lower heat content. Refer to Fuel for Cummins Engines, Bulletin 3379001.

OK

Go To Next Step

STEP 11

Fuel pump return overflow valve is malfunctioning

Inspect the return overflow valve. Replace if necessary. Refer to Procedure 006-044.

OK

Go To Next Step

STEP 12

Fuel return line improperly plumbed

Make sure the fuel return line is plumbed to the bottom of the fuel tank.

OK

Go To Next Step

STEP 13

Fuel transfer pump malfunctioning

Inspect the fuel transfer pump. Replace if necessary. Refer to Procedure 005-045.

OK

Go To Next Step

STEP 14

Fuel injection pump timing is **not** correct

Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-012 or 005-013.

OK

Go To Next Step

STEP 15

Charge air cooler restricted (if equipped)

Inspect the air cooler for internal and external restrictions. Replace the restricted cooler if necessary. Refer to Procedure 010-027.

OK

Go To Next Step

STEP 16

Valves are **not** sealing correctly

Check and adjust the valves. Refer to Procedure 002-020.

OK

Go To Next Step

STEP 17

Injectors worn or malfunctioning

Remove and test the injectors. Replace as necessary. Refer to Procedure 006-026.

OK

Go To Next Step

Engine Difficult to Start or Will Not Start (Exhaust Smoke)

This is symptom tree t043

Cause

Correction

STEP 18

Engine compression is low

Perform the compression check to identify the malfunction. Correct as required. Refer to Procedure 014-002.

OK

Go To Next Step

STEP 19

Fuel injection pump is malfunctioning

Remove the fuel pump. Refer to Procedure 005-012. Calibrate the fuel pump.

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

This is symptom tree t044

Cause	Correction
<p>STEP 1 Starting procedure is not correct</p>	<p>Verify the correct starting procedure. Refer to the Operation and Maintenance Manual, C Series Engines, Bulletin 4021330.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 No fuel in supply tank</p>	<p>Check and replenish fuel supply. Check fittings and hose connections and hose conditions.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Fuel shutoff valve is malfunctioning</p>	<p>Check for loose wires and verify that the fuel shutoff valve is functioning. Check to be sure manual shutoff lever is in the run position. Refer to Procedure 005-043.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Fuel transfer pump malfunctioning</p>	<p>Inspect the fuel transfer pump. Replace if necessary. Refer to Procedure 005-045.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Fuel filter or fuel inlet restriction</p>	<p>Check the flow through the fuel filter. Replace the fuel filter if necessary. Refer to Procedure 006-015. Clean all prefilters and screens. Check the fuel suction line for restriction.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Excessive water in the fuel filter</p>	<p>Drain the fuel water separator and replace the fuel filter. Refer to Procedure 006-015.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Intake and exhaust system restricted</p>	<p>Check the intake and exhaust systems for restrictions. Inspect the intake air filter and replace as necessary. Refer to Procedure 010-024.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Fuel injection pump not getting fuel or air in fuel</p>	<p>Check fuel flow or bleed fuel system. Refer to Procedure 006-003.</p>
<p>OK Go To Next Step</p>	
<p>STEP 9 Fuel return restriction excessive</p>	<p>Inspect the fuel return lines for restrictions. Refer to Procedure 006-012.</p>
<p>OK Go To Next Step</p>	

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

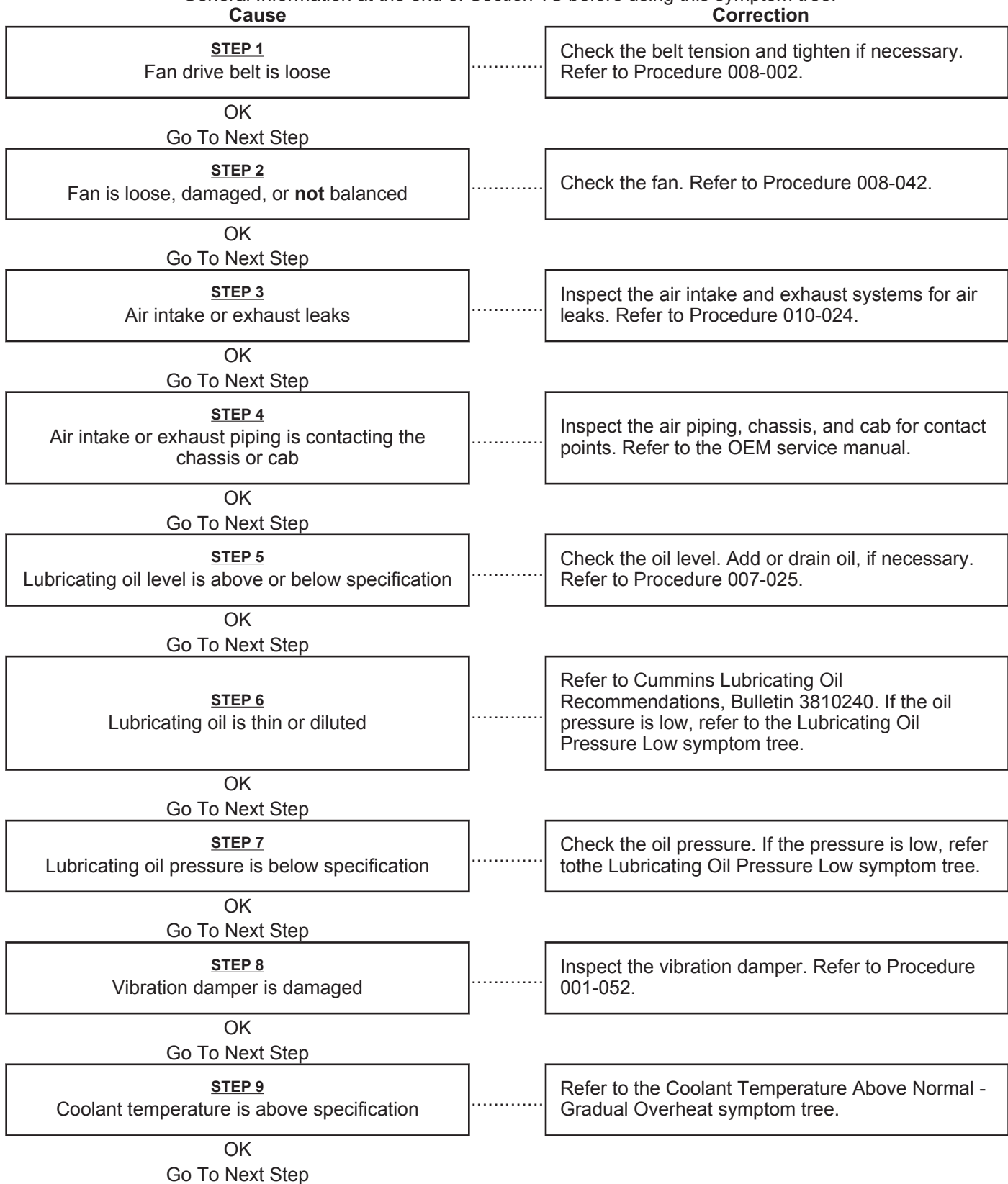
This is symptom tree t044

Cause	Correction
<p>STEP 10 Fuel pump return overflow valve is malfunctioning</p>	<p>Inspect the return overflow valve. Replace if necessary. Refer to Procedure 006-044.</p>
<p>OK Go To Next Step</p>	
<p>STEP 11 Fuel injection pump timing is not correct</p>	<p>Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-012.</p>
<p>OK Go To Next Step</p>	
<p>STEP 12 Fuel injection pump is malfunctioning</p>	<p>Remove the fuel injection pump. Check the calibration of the fuel injection pump. Refer to Procedure 005-012.</p>
<p>OK Go To Next Step</p>	
<p>STEP 13 Camshaft timing is not correct (after engine rebuild or repair)</p>	<p>Check the gear train timing alignment. Refer to Procedure 001-008.</p>

Engine Noise Excessive

This is symptom tree t047

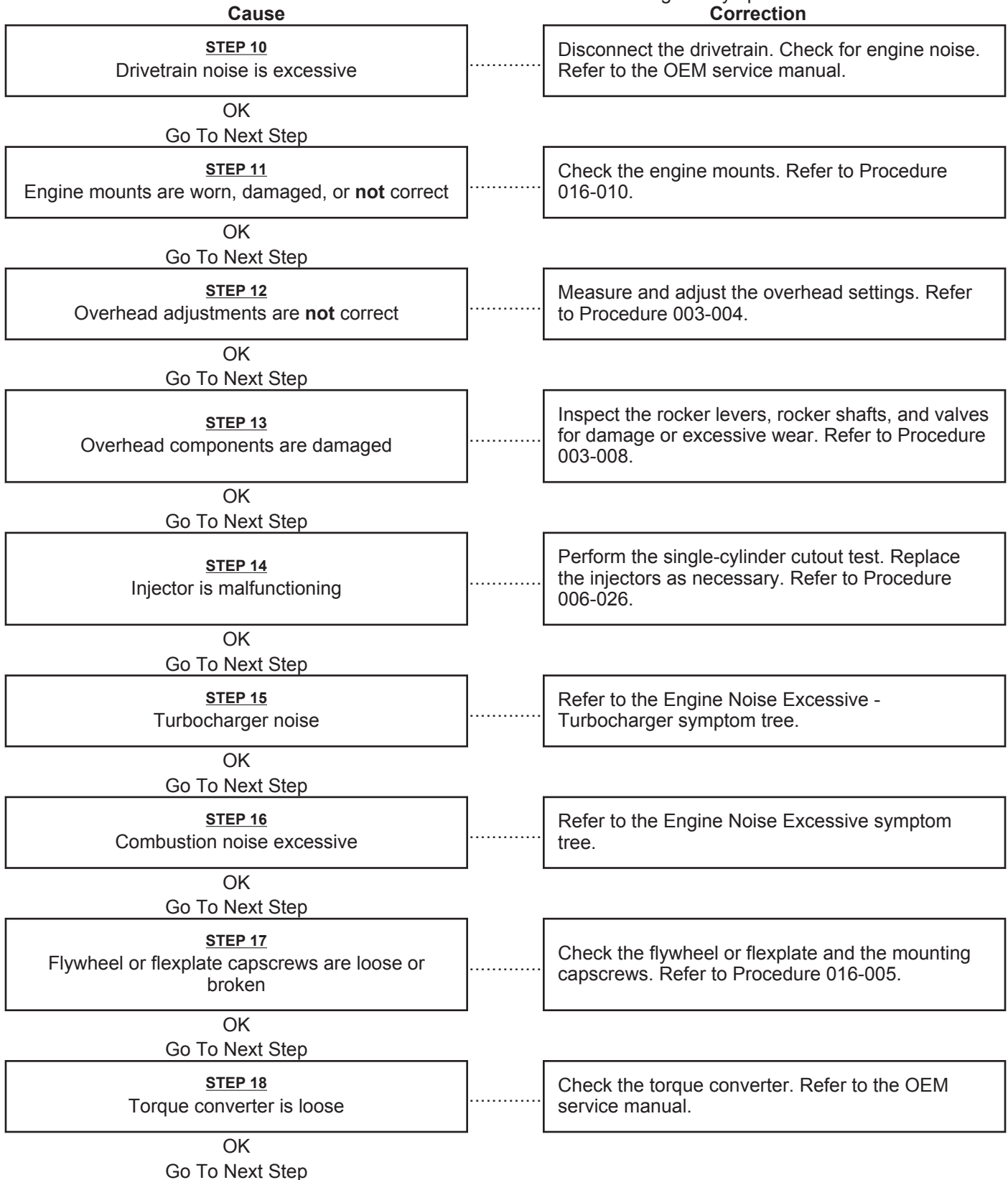
When troubleshooting engine noise complaints, make sure the engine accessories (air compressor, fan clutch, freon compressor, or hydraulic pump) are not the cause of the noise. Refer to Engine Noise Diagnostic Procedures - General Information at the end of Section TS before using this symptom tree.



Engine Noise Excessive

This is symptom tree t047

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



Engine Noise Excessive

This is symptom tree t047

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

Cause

Correction

STEP 19

Main bearing or connecting rod bearing noise

Refer to Procedure 001-005 and Procedure 001-006.

OK

Go To Next Step

STEP 20

Piston or piston rings are worn or damaged

Check for air intake system leaks. Check the pistons and piston rings for wear or damage. Refer to Procedures 010-024, 001-043, and 001-047.

Engine Noise Excessive — Combustion Knocks

This is symptom tree t048

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

Cause	Correction
<p>STEP 1 Ether starting aid is malfunctioning</p> <p>OK Go To Next Step</p>	<p>Repair or replace the ether starting aids. Refer to the OEM instructions.</p>
<p>STEP 2 Fuel grade is not correct for the application or the fuel quality is poor</p> <p>OK Go To Next Step</p>	<p>Operate the engine from a tank of high-quality fuel. Refer to Fuel for Cummins Engines, Bulletin 3379001.</p>
<p>STEP 3 Air in the fuel system</p> <p>OK Go To Next Step</p>	<p>Check for air in the fuel system. Vent air from the system. Refer to Procedure 006-024.</p>
<p>STEP 4 Coolant temperature is above specification</p> <p>OK Go To Next Step</p>	<p>Check the coolant level. Refer to Procedure 008-018.</p>
<p>STEP 5 Injector is malfunctioning</p> <p>OK Go To Next Step</p>	<p>Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedure 006-026.</p>
<p>STEP 6 Overhead adjustments are not correct</p>	<p>Measure and adjust the overhead settings. Refer to Procedure 003-004.</p>

Engine Noise Excessive — Connecting Rod

This is symptom tree t049

Cause	Correction
<p>STEP 1 Lubricating oil level is below specification</p>	<p>Check the oil level. Verify the dipstick calibration and the oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-009 and Procedure 007-025.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Lubricating oil pressure is below specification</p>	<p>Check the oil pressure. If the pressure is low, refer to Procedure 007-025.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Lubricating oil is thin or diluted</p>	<p>Refer to Cummins Lubricating Oil Recommendations, Bulletin 3810240 and the Lubricating Oil Contaminated symptom tree.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Crankshaft journals are damaged or out of round</p>	<p>Inspect the crankshaft journals. Refer to Procedure 001-016.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Connecting rod is bent or out of alignment</p>	<p>Remove and inspect the connecting rods. Refer to Procedure 001-014.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Connecting rod capscrews are loose or not tightened correctly</p>	<p>Check the torque on the connecting rod capscrews. Refer to Procedure 001-014.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Connecting rod bearings are damaged or worn, are not assembled correctly, or are the wrong bearings</p>	<p>Inspect the connecting rod bearings. Refer to Procedure 001-005.</p>

Engine Noise Excessive — Main Bearing

This is symptom tree t050

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

Cause	Correction
<p>STEP 1 Lubricating oil pressure is below specification</p> <p>OK Go To Next Step</p>	<p>Check the oil pressure. If the pressure is low, refer to Procedure 007-025.</p>
<p>STEP 2 Lubricating oil level is below specification</p> <p>OK Go To Next Step</p>	<p>Check the oil level. Verify the dipstick calibration and the oil pan capacity. Fill the system to the specified level. Refer to Procedure 007-025.</p>
<p>STEP 3 Lubricating oil is thin or diluted</p> <p>OK Go To Next Step</p>	<p>Refer to Procedure 007-025. If the oil pressure is low, refer to the Lubricating Oil Pressure Low symptom tree.</p>
<p>STEP 4 Main bearing capscrews are loose, worn or not tightened correctly</p> <p>OK Go To Next Step</p>	<p>Check the torque on the main bearing capscrews. Inspect the capscrews for wear. Refer to Procedure 001-016.</p>
<p>STEP 5 Main bearings are damaged or worn, or the wrong bearings are installed</p> <p>OK Go To Next Step</p>	<p>Inspect the main bearings for damage, excessive wear, and the correct part number. Refer to Procedure 001-006.</p>
<p>STEP 6 Crankshaft journals are damaged or out of round</p>	<p>Inspect the crankshaft journals. Refer to Procedure 001-016.</p>

Engine Noise Excessive — Piston

This is symptom tree t051

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

Cause	Correction
<p>STEP 1 Fuel grade is not correct for the application or the fuel quality is poor</p>	<p>Operate the engine from a tank of high-quality fuel. Refer to the Operation and Maintenance Manual, C Series Engines, Bulletin 4021330.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Injector is malfunctioning</p>	<p>Perform the automated cylinder performance test. Replace injectors as necessary. Refer to Procedure 006-026.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Overhead adjustments are not correct</p>	<p>Measure and adjust the overhead settings. Refer to Procedure 003-004.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Connecting rod is bent or out of alignment</p>	<p>Remove and inspect the connecting rods. Refer to Procedure 001-014.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Piston or piston rings are worn or damaged</p>	<p>Check for air intake system leaks. Check the pistons and piston rings for wear or damage. Refer to Procedure 001-043.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Piston pin or bushing is loose, worn, or not installed correctly</p>	<p>Remove the pistons and inspect the piston pin and bushing for damage, wear, and correct installation. Refer to Procedure 001-043.</p>

Engine Noise Excessive — Turbocharger

This is symptom tree t052

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

Cause	Correction
<p>STEP 1 Air intake system restriction is above specification</p>	<p>Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Air intake or exhaust piping is contacting the chassis or cab</p>	<p>Inspect the air piping, chassis, and cab for contact points. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Exhaust system restriction is not within specification</p>	<p>Check the exhaust system for restrictions. Refer to Procedure 011-009.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Turbocharger is not correct</p>	<p>Check the turbocharger part number and compare it to the Control Parts List (CPL), Bulletin 3379133 or 4021327. Replace the turbocharger if necessary. Refer to Procedure 010-033.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Turbocharger is worn or damaged</p>	<p>Check the turbocharger for damage. Measure the turbine and compressor wheel clearances. Refer to Procedure 010-033, 010-038 and 010-047.</p>

Engine Power Output Low

This is symptom tree t057

Cause

Correction

STEP 1

Electronic fault codes active or high counts of inactive fault codes

View and troubleshoot the fault codes with INSITE™. Refer to Section TF in the Marine Electronic Control System, C8.3 Engines, Troubleshooting and Repair Manual, Bulletin 4021442.

OK

Go To Next Step

STEP 2

Excessive load for engine horsepower rating

Reduce vehicle load or use low gear if the engine is industrial. If engine is marine, change propeller(s).

OK

Go To Next Step

STEP 3

Fuel shutoff lever (mechanical) partially engaged

Check for correct solenoid operation. Refer to Procedure 005-043.

OK

Go To Next Step

STEP 4

Engine will **not** reach full throttle

Make sure the throttle linkage is **not** misadjusted or damaged. Adjust and repair as necessary. Check the fuel lever for stop-to-stop travel. Refer to Procedure 005-029.

OK

Go To Next Step

STEP 5

Accelerator pedal or lever position sensor or circuit is malfunctioning

Check for accelerator pedal or lever restriction. Check the percent throttle reading on the electronic service tool or Cummins Digital Display. Check the position sensor and the circuit. Verify the accelerator position sensor provides 0- to 100-percent input to the ECM. Adjust as required. Refer to Section 19 in the Marine Electronic Control System, C8.3 Engines, Troubleshooting and Repair Manual, Bulletin 4021442.

OK

Go To Next Step

STEP 6

Poor fuel quality or wrong fuel grade

Verify by operating the engine from a temporary supply of number 2 diesel fuel. Check fuel specifications for proper fuel grade. Refer to Fuel for Cummins Engines, Bulletin 3379001.

OK

Go To Next Step

STEP 7

Fuel inlet temperature to pump is above specification

Fill the fuel tank, turn off or bypass the fuel heaters, and check the fuel cooler. Refer to the OEM service manual.

OK

Go To Next Step

Engine Power Output Low

This is symptom tree t057

Cause	Correction
<p>STEP 8 Fuel leak</p>	<p>Check the fuel lines, fuel connections, fuel delivery valve seals, and fuel filters for leaks. Check the fuel lines from the supply tank(s). Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 9 Air in the fuel system</p>	<p>Bleed the fuel system and check for suction leaks. Refer to Procedure 006-024.</p>
<p>OK Go To Next Step</p>	
<p>STEP 10 Fuel filter or fuel inlet restriction</p>	<p>Check the flow through the fuel filter. Replace the fuel filter if necessary. Refer to Procedure 006-015. Clean all prefilters and screens. Check the fuel suction line for restriction.</p>
<p>OK Go To Next Step</p>	
<p>STEP 11 Fuel drain line is restricted</p>	<p>Check the fuel drain lines for restriction. Clear or replace the fuel lines, check valves, or tank vents as necessary. Refer to Procedure 006-012.</p>
<p>OK Go To Next Step</p>	
<p>STEP 12 Fuel transfer pump malfunctioning</p>	<p>Inspect the fuel transfer pump. Replace if necessary. Refer to Procedure 005-045.</p>
<p>OK Go To Next Step</p>	
<p>STEP 13 Fuel pump return overflow valve is malfunctioning</p>	<p>Inspect the return overflow valve. Replace if necessary. Refer to Procedure 006-044.</p>
<p>OK Go To Next Step</p>	
<p>STEP 14 Lubricating oil level not correct</p>	<p>Check the oil level and correct. Refer to Procedures 007-009 and 007-037.</p>
<p>OK Go To Next Step</p>	
<p>STEP 15 Air intake system restriction is above specification</p>	<p>Check the air intake system for restriction. Clean or replace the air filter and inlet piping as necessary. Refer to Procedure 010-031.</p>
<p>OK Go To Next Step</p>	
<p>STEP 16 Intake air source is incorrect</p>	<p>If the vehicle is equipped with a valve to switch the intake source from under the hood to outside, position and set valve for the season.</p>
<p>OK Go To Next Step</p>	

Engine Power Output Low

This is symptom tree t057

Cause	Correction
<p>STEP 17 Air-fuel tube leaking, wastegate diaphragm ruptured, or wastegate plumbing damaged</p>	<p>Tighten the fittings, repair plumbing, replace wastegate diaphragm. Refer to Procedure 010-050.</p>
<p>OK Go To Next Step</p>	
<p>STEP 18 AFC plumbing obstructed</p>	<p>Check the AFC line and fitting between the intake manifold and fuel injection pump. Refer to Procedure 005-001.</p>
<p>OK Go To Next Step</p>	
<p>STEP 19 Intake air overheated</p>	<p>Inspect and clean any debris from the front of the charge air cooler. Refer to Procedure 010-027.</p>
<p>OK Go To Next Step</p>	
<p>STEP 20 Aftercooler restricted (if equipped)</p>	<p>Inspect for plugged passages in the aftercooler. Refer to Procedure 010-002.</p>
<p>OK Go To Next Step</p>	
<p>STEP 21 Charge air cooler restricted (if equipped)</p>	<p>Inspect the air cooler for internal and external restrictions. Replace the restricted cooler if necessary. Refer to Procedure 010-027.</p>
<p>OK Go To Next Step</p>	
<p>STEP 22 Exhaust system restriction is not within specification</p>	<p>Check the exhaust system for restrictions. Refer to Procedure 011-009.</p>
<p>OK Go To Next Step</p>	
<p>STEP 23 Air intake or exhaust leaks</p>	<p>Inspect the air intake and exhaust systems for air leaks. Refer to Procedure 010-024.</p>
<p>OK Go To Next Step</p>	
<p>STEP 24 Turbocharger wastegate is malfunctioning (if equipped)</p>	<p>Check the wastegate for correct operation. Refer to Procedure 010-033 and 010-050.</p>
<p>OK Go To Next Step</p>	
<p>STEP 25 Turbocharger is worn or malfunctioning</p>	<p>Check for the specified boost pressure. Inspect the turbocharger. Replace if necessary. Refer to Procedure 010-033.</p>
<p>OK Go To Next Step</p>	

Engine Power Output Low

This is symptom tree t057

Cause	Correction
<p>STEP 26 Fuel injection pump timing is not correct</p>	<p>Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-012.</p>
<p>OK Go To Next Step</p>	
<p>STEP 27 Valves are not sealing correctly</p>	<p>Check and adjust the valves. Refer to Procedure 003-004.</p>
<p>OK Go To Next Step</p>	
<p>STEP 28 Injector sealing washer not correct</p>	<p>Check to see if an extra sealing washer is installed under injector. Remove any additional sealing washer. Only one is required. Refer to Procedure 006-026.</p>
<p>OK Go To Next Step</p>	
<p>STEP 29 Injectors worn or malfunctioning</p>	<p>Check the injectors and replace any malfunctioning injectors. Refer to Procedure 006-026.</p>
<p>OK Go To Next Step</p>	
<p>STEP 30 Crankcase pressure is excessive</p>	<p>Measure the engine blowby. If blowby is above specification, refer to Procedure 014-002.</p>
<p>OK Go To Next Step</p>	
<p>STEP 31 Fuel injection pump is malfunctioning</p>	<p>Remove the fuel pump. Refer to Procedure 005-012. Calibrate the fuel pump.</p>

Engine Runs Rough at Idle

This is symptom tree t061

Cause	Correction
<p>STEP 1 Engine is cold</p>	<p>Allow the engine to warm to operating temperature. If the engine will not reach operating temperature, refer to the Coolant Temperature Below Normal symptom tree.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Idle speed is set too low for accessories</p>	<p>Check and adjust the low-idle screw. Refer to Procedure 005-029.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Engine mounts are worn, damaged, loose, or not correct</p>	<p>Verify the condition of the mounts. Refer to Procedure 016-010.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Intake manifold heater wiring harness malfunctioning</p>	<p>Check the wiring harness. Refer to Intake Manifold Air Heater System Malfunctioning troubleshooting tree.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Air in the fuel system</p>	<p>Bleed the fuel system and check for suction leaks. Refer to Procedure 006-024.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Fuel transfer pump malfunctioning</p>	<p>Inspect the fuel transfer pump. Replace if necessary. Refer to Procedure 005-045.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Fuel pump return overflow valve is malfunctioning</p>	<p>Inspect the return overflow valve. Replace if necessary. Refer to Procedure 006-044.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Fuel filter or fuel inlet restriction</p>	<p>Check the flow through the fuel filter. Replace the fuel filter if necessary. Refer to Procedure 006-044. Clean all prefilters and screens. Check the fuel suction line for restriction.</p>
<p>OK Go To Next Step</p>	
<p>STEP 9 Fuel injection pump timing is not correct</p>	<p>Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-013.</p>
<p>OK Go To Next Step</p>	

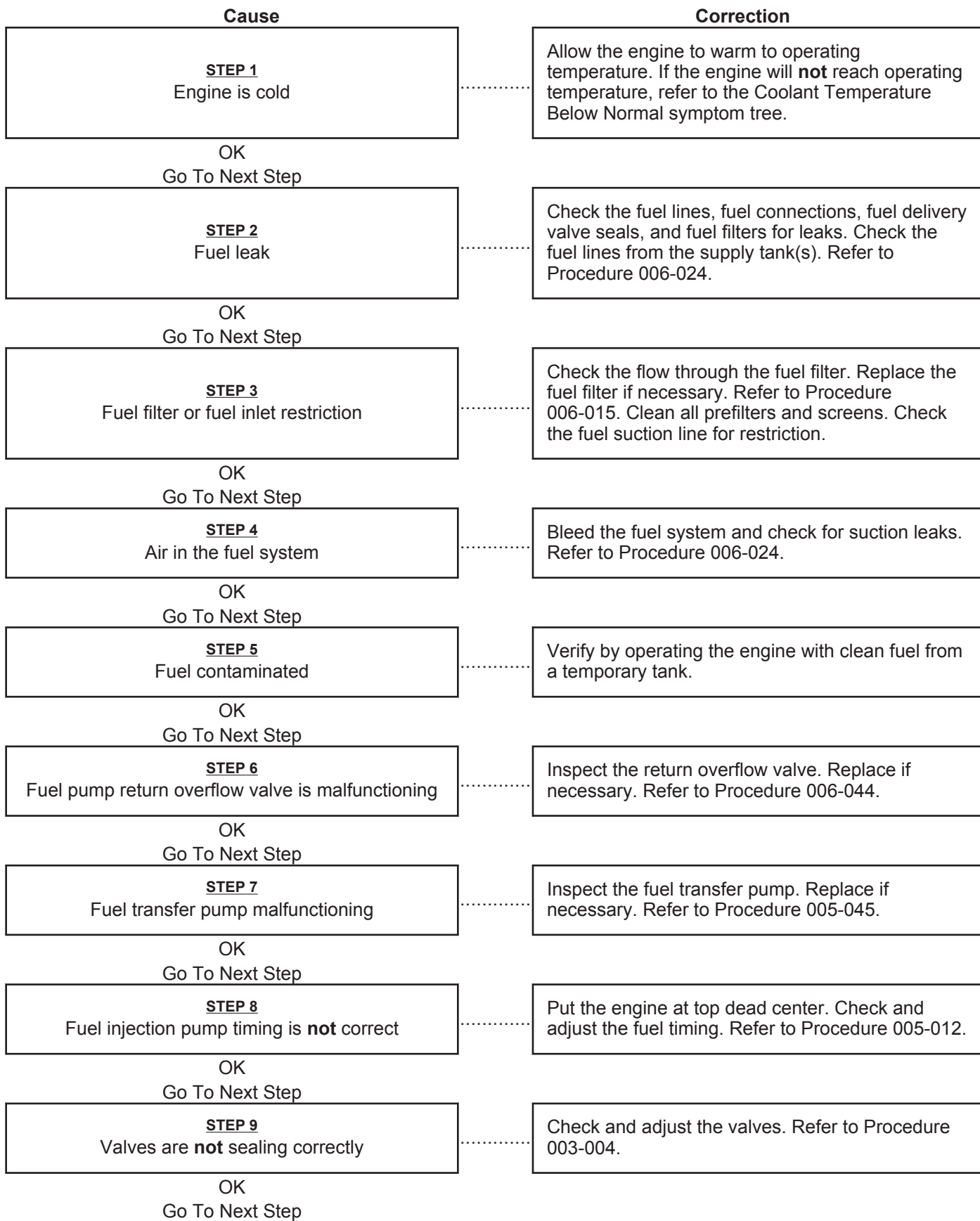
Engine Runs Rough at Idle

This is symptom tree t061

Cause	Correction
<p>STEP 10 Valves are not sealing correctly</p>	<p>Check and adjust the valves. Refer to Procedure 003-004.</p>
<p>OK Go To Next Step</p>	
<p>STEP 11 Engine compression is low</p>	<p>Perform the compression check to identify the malfunction. Correct as required. Refer to Procedure 014-002.</p>
<p>OK Go To Next Step</p>	
<p>STEP 12 Injector is malfunctioning</p>	<p>Inspect the injectors. Replace the injectors as necessary. Refer to Procedure 006-026.</p>
<p>OK Go To Next Step</p>	
<p>STEP 13 Fuel injection pump is malfunctioning</p>	<p>Remove the fuel pump. Refer to Procedure 005-012. Calibrate the fuel pump.</p>

Engine Runs Rough or Misfires

This is symptom tree t062



Engine Runs Rough or Misfires

This is symptom tree t062

Cause	Correction
<p>STEP 10 Injectors worn or malfunctioning</p>	<p>Check the injectors and replace any malfunctioning injectors. Refer to Procedure 006-026.</p>
<p>OK Go To Next Step</p>	
<p>STEP 11 Engine compression is low</p>	<p>Perform the compression check to identify the malfunction. Correct as required. Refer to Section 14.</p>
<p>OK Go To Next Step</p>	
<p>STEP 12 Fuel injection pump is malfunctioning</p>	<p>Remove the fuel pump. Refer to Procedure 005-012. Calibrate the fuel pump.</p>
<p>OK Go To Next Step</p>	
<p>STEP 13 Camshaft timing is not correct (after engine rebuild or repair)</p>	<p>Check the gear train timing alignment. Refer to Procedure 001-008.</p>
<p>OK Go To Next Step</p>	
<p>STEP 14 Camshaft, tappets, or pushrods are damaged</p>	<p>Inspect the camshaft and tappets. Refer to Procedure 001-008 or Procedure 004-015.</p>

Engine Speed Surges at Low or High Idle

This is symptom tree t066

Cause	Correction
<p>STEP 1 Fuel level is low in the tank</p>	<p>Fill the supply tank. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Engine under excessive load</p>	<p>Check for added loading from malfunctioning accessories or other engine-driven units, brakes dragging, or other changes in vehicle loading. Disengage engine-driven units.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Throttle linkage misadjusted or damaged</p>	<p>Adjust or repair the linkage. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Idle speed is set too low for accessories</p>	<p>Check and adjust the low-idle screw. Refer to 005-029.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Fuel leak</p>	<p>Check the fuel lines, fuel connections, fuel delivery valve seals, and fuel filters for leaks. Check the fuel lines from the supply tank(s). Refer to Procedure 006-024.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Fuel filter or fuel inlet restriction</p>	<p>Check the flow through the fuel filter. Replace the fuel filter if necessary. Refer to Procedure 006-015. Clean all prefilters and screens. Check the fuel suction line for restriction.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Air in the fuel system</p>	<p>Bleed the fuel system and check for suction leaks. Refer to Procedure 006-024.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Injectors worn or malfunctioning</p>	<p>Check the injectors and replace any malfunctioning injectors. Refer to Procedure 006-026.</p>
<p>OK Go To Next Step</p>	
<p>STEP 9 Fuel injection pump is malfunctioning</p>	<p>Remove the fuel injection pump. Check the calibration of the fuel injection pump. Refer to Procedure 005-012.</p>

Engine Starts But Will Not Keep Running

This is symptom tree t072

Cause	Correction
<p>STEP 1 Fuel level is low in the tank</p>	<p>Fill the supply tank. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Engine under excessive load</p>	<p>Check for added loading from malfunctioning accessories or other engine-driven units, brakes dragging, or other changes in vehicle loading. Disengage engine-driven units.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Fuel shutoff valve malfunctioning</p>	<p>Inspect the fuel shutoff valve (FSOV) hold coil resistance and supply voltage. Refer to Procedure 005-043.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Idle speed is set too low for accessories</p>	<p>Check and adjust the low-idle screw. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Air in the fuel system</p>	<p>Bleed the fuel system and check for suction leaks. Refer to Procedure 006-024.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Fuel filter or fuel inlet restriction</p>	<p>Check the flow through the fuel filter. Replace the fuel filter if necessary. Refer to Procedure 006-015. Clean all prefilters and screens. Check the fuel suction line for restriction.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Fuel is waxing due to cold weather</p>	<p>Check the fuel heater, if installed. Weather conditions sometimes require a fuel heater.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Excessive water in the fuel filter</p>	<p>Drain the fuel water separator and replace the fuel filter. Refer to Procedure 006-015.</p>
<p>OK Go To Next Step</p>	
<p>STEP 9 Fuel contaminated</p>	<p>Verify by operating the engine with clean fuel from a temporary tank.</p>
<p>OK Go To Next Step</p>	

Engine Starts But Will Not Keep Running

This is symptom tree t072

Cause

Correction

STEP 10
Fuel drain line is restricted

Check the fuel drain lines for restriction. Clear or replace the fuel lines, check valves, or tank vents as necessary. Refer to Procedure 006-015.

OK
Go To Next Step

STEP 11
Intake and exhaust system restricted

Check the intake and exhaust systems for restrictions. Inspect the intake air filter and replace as necessary. Refer to Procedure 010-031.

Engine Vibration Excessive

This is symptom tree t075

Cause	Correction
<p>STEP 1 Engine not running smoothly</p>	<p>Refer to the Engine Runs Rough or Misfires symptom tree.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Fan is loose, damaged, or not balanced</p>	<p>Check the fan. Refer to Procedure 008-040.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Belt-driven accessories are malfunctioning</p>	<p>Check the fan hub, alternator, refrigerant compressor, and hydraulic pump for interference. Isolate belt-driven accessories and check for vibration. Refer to OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Vibration damper is damaged</p>	<p>Inspect the vibration damper. Refer to Procedure 001-052.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Engine mounts are worn, damaged, loose, or not correct</p>	<p>Verify the condition of the mounts. Refer to Procedure 016-010.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Alternator bearing worn or damaged</p>	<p>Clean and replace the alternator. Refer to Procedure 013-001.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Power components loose or broken</p>	<p>Inspect the crankshaft and rods for damage that causes an unbalance. Refer to Procedure 001-016 or 001-014.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Drivetrain components are malfunctioning or are not correct</p>	<p>Compare the Drivetrain components to the engine and equipment specifications. Isolate the Drivetrain components, and check for vibrations. Refer to OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 9 Flywheel housing is not aligned correctly</p>	<p>Check the flywheel housing alignment. Refer to Procedure 016-006.</p>
<p>OK Go To Next Step</p>	

Engine Vibration Excessive

This is symptom tree t075

Cause

STEP 10

Flywheel or flexplate capscrews are loose or broken

Correction

Check the flywheel or flexplate and the mounting capscrews. Refer to Procedure 016-005.

Engine Will Not Crank or Cranks Slowly

This is symptom tree t076

Cause	Correction
<p>STEP 1 Engine speed is low because of cold ambient temperature</p>	<p>Use a lubricating oil heater and the correct oil grade. Refer to Operation of Diesel Engines in Cold Climates, Bulletin 3379009.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Battery charge is low</p>	<p>Check battery. If the battery is low, check the alternator for proper charging. Charge the battery, and replace if necessary. Refer to Procedure 013-001.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Engine cranking speed is too slow</p>	<p>Check the engine cranking speed with a handheld tachometer or electronic service tool. If the cranking speed is slower than 150 rpm, refer to the Engine Will Not Crank or Cranks Slowly symptom tree.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Poor starter motor ground</p>	<p>Check for proper ground between starting motor and battery negative terminal. Repair or replace if necessary.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Cranking circuit or battery cable voltage drop excessive</p>	<p>Inspect the battery cables for loose or corroded connections, or broken cables. Check the voltage drop in the starting circuit. Repair or replace the battery cables if necessary. Refer to Procedure 013-009.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Starter relay voltage drop excessive</p>	<p>Check the voltage drop in the starting circuit. Refer to Procedure 013-017. Repair or replace starter relay if necessary.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Starter solenoid voltage drop is excessive and amperage drain is too high</p>	<p>Check the starter solenoid voltage and amperage drop. Refer to Procedure 013-019.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Engine rotation is restricted</p>	<p>Rotate the crankshaft using barring tool, Cummins Part number 3824591.</p>
<p>OK Go To Next Step</p>	

Engine Will Not Crank or Cranks Slowly

This is symptom tree t076

Cause

Correction

STEP 9

Starting motor pinion or ring gear is damaged

Remove the starting motor, and inspect the gear. Refer to Procedure 013-020 and the OEM service manual.

OK

Go To Next Step

STEP 10

Starter motor will **not** engage or failed

Replace starter motor. Refer to Procedure 013-020.

Engine Will Not Reach Rated Speed (RPM)

This is symptom tree t080

Cause	Correction
<p>STEP 1 Electronic fault codes active or high counts of inactive fault codes</p>	<p>View and troubleshoot the fault codes with INSITE™. Refer to Section TF in the Troubleshooting and Repair Manual, Marine Electronic Control System, C8.3 Engines, Bulletin 4021442.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Tachometer is not calibrated or is malfunctioning</p>	<p>Compare the tachometer reading with a handheld tachometer or an electronic service tool reading. Calibrate or replace the tachometer as necessary. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Engine under excessive load</p>	<p>Check for added loading from malfunctioning accessories or other engine-driven units, brakes dragging, or other changes in vehicle loading. Disengage engine-driven units.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Airflow to the radiator restricted</p>	<p>Check and repair fan shroud, viscous fan as required. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Engine will not reach full throttle</p>	<p>Make sure the throttle linkage is not misadjusted or damaged. Adjust and repair as necessary. Check the fuel lever for stop-to-stop travel. Refer to Procedure 005-018.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Accelerator pedal or lever position sensor or circuit is malfunctioning</p>	<p>Check for accelerator pedal or lever restriction. Check the percent throttle reading on the electronic service tool or Cummins Digital Display. Check the position sensor and the circuit. Verify the accelerator position sensor provides 0- to 100-percent input to the ECM. Adjust as required. Refer to Section TF in the Troubleshooting and Repair Manual, Marine Electronic Control System, C8.3 Engines, Bulletin 4021442.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Fuel shutoff lever (mechanical) partially engaged</p>	<p>Check for correct solenoid operation. Refer to Procedure 005-043.</p>
<p>OK Go To Next Step</p>	

Engine Will Not Reach Rated Speed (RPM)

This is symptom tree t080

Cause	Correction
<p>STEP 8 Poor fuel quality or wrong fuel grade</p>	<p>Verify by operating the engine from a temporary supply of number 2 diesel fuel. Check fuel specifications for proper fuel grade. Refer to Fuel for Cummins Engines, Bulletin 3379001.</p>
<p>OK Go To Next Step</p>	
<p>STEP 9 Fuel filter or fuel inlet restriction</p>	<p>Check the flow through the fuel filter. Replace the fuel filter if necessary. Refer to Procedure 006-015. Clean all prefilters and screens. Check the fuel suction line for restriction.</p>
<p>OK Go To Next Step</p>	
<p>STEP 10 Fuel pump return overflow valve is malfunctioning</p>	<p>Inspect the return overflow valve. Replace if necessary. Refer to Procedure 006-044.</p>
<p>OK Go To Next Step</p>	
<p>STEP 11 Manifold drain line restricted (Lucas CAV DPA only)</p>	<p>Check and remove restriction. Refer to Procedure 006-021.</p>
<p>OK Go To Next Step</p>	
<p>STEP 12 Fuel transfer pump malfunctioning</p>	<p>Inspect the fuel transfer pump. Replace if necessary. Refer to Procedure 005-045.</p>
<p>OK Go To Next Step</p>	
<p>STEP 13 Drivetrain or propeller is damaged or is not correctly matched to the engine</p>	<p>Check for the correct gearing, drivetrain components, or propeller. Refer to the manufacturer's specification.</p>
<p>OK Go To Next Step</p>	
<p>STEP 14 Turbocharger wastegate is malfunctioning (if equipped)</p>	<p>Check the wastegate for correct operation. Refer to Procedure 010-050.</p>
<p>OK Go To Next Step</p>	
<p>STEP 15 Fuel injection pump is malfunctioning</p>	<p>Remove the fuel injection pump. Check the calibration of the fuel injection pump. Refer to Procedure 005-012.</p>
<p>OK Go To Next Step</p>	

Engine Will Not Reach Rated Speed (RPM)

This is symptom tree t080

Cause

Correction

STEP 16
Base engine problem

Check the engine for high crankcase pressure, low compression, static injection timing, damaged pistons, camshaft, and other parts. Procedure 005-012

Engine Will Not Shut Off

This is symptom tree t081

Cause	Correction
<p>STEP 1 Engine is running on fumes drawn into the air intake</p>	<p>Check the air intake ducts. Locate and isolate the source of the fumes. Repair as necessary. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Fuel shutoff valve (FSOV) is malfunctioning</p>	<p>Stop the engine mechanically, by moving the manual shutoff lever to the STOP position. Check for correct solenoid operation. Refer to Procedure 005-043.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Fuel injection pump is malfunctioning</p>	<p>Remove the fuel pump. Refer to Procedure 005-012. Calibrate the fuel pump.</p>

Excessive Noise

This is symptom tree t081-001

Cause	Correction
<p>STEP 1 Drive belt is loose or has high loading</p>	<p>Check the drive belt tension. Adjust the tension if necessary. Check the accessory drive belts. Refer to Procedure 008-002.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Intake air or exhaust leaks</p>	<p>Refer to the Exhaust Black Smoke - Excessive symptom tree.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Turbocharger noise</p>	<p>Turbocharger fluttering noises can be heard during deceleration or quick throttle closing. This noise is normal.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Valve lash excessive</p>	<p>Adjust valves. Make sure the push rods are not bent or rocker levers not severely worn. Refer to Procedure 004-014 and 003-004.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Gear train backlash is excessive or the gear teeth are damaged</p>	<p>Check the gear backlash and the gear teeth. Refer to Procedure 001-023.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Power knock</p>	<p>Inspect rod bearings. Replace if necessary. Refer to Procedure 001-014.</p>

Fuel Consumption Excessive

This is symptom tree t087

Cause	Correction
<p>STEP 1 Engine under excessive load</p>	<p>Check for added loading from malfunctioning accessories or other engine-driven units, brakes dragging, or other changes in vehicle loading. Disengage engine-driven units.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Operator technique is not correct</p>	<p>Explain correct engine operation to the operator. Refer to Operation and Maintenance Manual, C Series Engines, Bulletin 3810248.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Fuel leak</p>	<p>Check the fuel lines, fuel connections, fuel delivery valve seals, and fuel filters for leaks. Check the fuel lines from the supply tank(s). Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Poor fuel quality or wrong fuel grade</p>	<p>Verify by operating the engine from a temporary supply of number 2 diesel fuel. Check fuel specifications for proper fuel grade. Refer to Fuel for Cummins Engines, Bulletin 3379001.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Intake and exhaust system restricted</p>	<p>Check the intake and exhaust systems for restrictions. Inspect the intake air filter and replace as necessary. Refer to Procedure 010-031.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Injectors worn or malfunctioning</p>	<p>Remove and test the injectors. Replace as necessary. Refer to Procedure 006-026.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Fuel injection pump timing is not correct</p>	<p>Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-013.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Fuel injection pump is malfunctioning</p>	<p>Remove the fuel pump. Refer to Procedure 005-012. Calibrate the fuel pump.</p>
<p>OK Go To Next Step</p>	
<p>STEP 9 Valves are not sealing correctly</p>	<p>Check and adjust the valves. Refer to Procedure 003-004.</p>

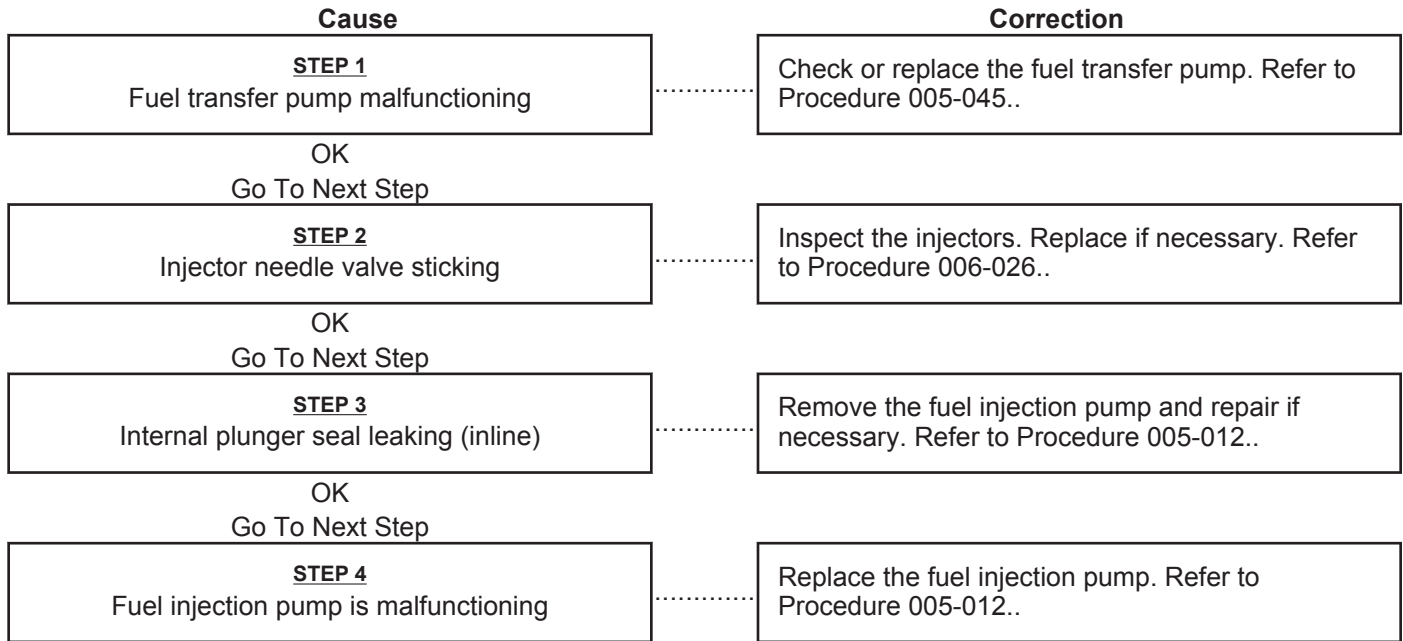
Fuel Knock

This is symptom tree t091-5

Cause	Correction
<p>STEP 1 Starting aid is necessary for cold weather or starting aid is malfunctioning</p>	<p>Check for the correct operation of the starting aid. Refer to the manufacturer's instructions. Refer to Operation and Maintenance Manual, C Series Engines, Bulletin 3810248.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Coolant temperature is above specification</p>	<p>Refer to the Coolant Temperature Above Normal - Gradual Overheat symptom tree.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Air in the fuel system</p>	<p>Bleed the fuel system and check for suction leaks. Refer to Procedure 006-024.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Poor fuel quality or wrong fuel grade</p>	<p>Verify by operating the engine from a temporary supply of number 2 diesel fuel. Check fuel specifications for proper fuel grade. Refer to Fuel for Cummins Engines, Bulletin 3379001.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Engine under excessive load</p>	<p>Check for added loading from malfunctioning accessories or other engine-driven units, brakes dragging, or other changes in vehicle loading. Disengage engine-driven units.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Injectors worn or malfunctioning</p>	<p>Remove and test the injectors. Replace as necessary. Refer to Procedure 006-026.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Fuel injection pump timing is not correct</p>	<p>Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-012.</p>

Fuel in the Lubricating Oil

This is symptom tree t092



Fuel or Lubricating Oil Leaking From Exhaust Manifold

This is symptom tree t093

Cause	Correction
<p>STEP 1 Engine is operating for extended periods under light or no-load conditions (slobbering)</p>	<p>Review the engine operating instructions. Refer to Section 1 in the Operation and Maintenance Manual, C Series Engines, Bulletin 3810248.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Intake and exhaust system restricted</p>	<p>Check the intake and exhaust systems for restrictions. Inspect the intake air filter and replace as necessary. Refer to Procedure 010-031.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Injector needle valve sticking</p>	<p>Check or replace the injector. Refer to Procedure 006-026.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Turbocharger oil drain line is restricted</p>	<p>Remove the turbocharger oil drain line and check for restriction. Clean or replace the oil drain line. Refer to Procedure 007-025.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Turbocharger oil seal is leaking</p>	<p>Check the turbocharger compressor and turbine seals. Refer to Procedure 010-031.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Worn piston rings</p>	<p>Check for excessive blowby. Refer to Procedure 003-004.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Valve guide seals are leaking</p>	<p>Inspect the valve guide seals. Replace if necessary. Refer to Procedure 002-016.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Fuel injection pump timing is not correct</p>	<p>Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-012.</p>

Intake Manifold Air Temperature Above Specification

This is symptom tree t096

Cause

STEP 1

Electronic fault codes active or high counts of inactive fault codes

OK

Go To Next Step

STEP 2

Intake manifold temperature sensor is malfunctioning

OK

Go To Next Step

STEP 3

Charge air cooler fins, radiator fins, or air conditioner condenser fins are damaged or obstructed with debris

OK

Go To Next Step

STEP 4

Cold weather radiator cover or winterfront is closed

OK

Go To Next Step

STEP 5

Vehicle speed is too low for adequate cooling with high engine load

OK

Go To Next Step

STEP 6

Fan shroud is damaged or missing or the air recirculation baffles are damaged or missing

OK

Go To Next Step

STEP 7

Drive belt is loose, tight, or **not** in alignment

OK

Go To Next Step

STEP 8

Radiator shutters are **not** opening completely, or the shutterstat setting is wrong

OK

Go To Next Step

Correction

View and troubleshoot the fault codes with INSITE™. Refer to Section TF in the Troubleshooting and Repair Manual, Marine Electronic Control System, C8.3 Engines, Bulletin 4021442.

Check the intake manifold temperature sensor. Refer to Procedure 019-061 in the Troubleshooting and Repair Manual, Marine Electronic Control System, C8.3 Engines, Bulletin 4021442.

Inspect the charge air cooler, air conditioner condenser, and radiator fins. Clean, if necessary. Refer to Procedures 010-027 and 008-042 and the OEM service manual.

Open the cold weather radiator cover or the winterfront. Maintain a minimum of 784 cm² [122 in²] or approximately 28 x 28 cm [11 x 11 in] of opening at all times. Refer to Operation of Diesel Engines in Cold Climates, Bulletin 3379009.

Reduce the engine load. Increase the engine (fan) rpm by downshifting.

Inspect the shroud and the recirculation baffles. Repair, replace, or install, if necessary. Refer to Procedure 008-038.

Check and adjust the drive belt as needed. Refer to Procedures 008-002 and 008-080.

Inspect the radiator shutters. Repair or replace if necessary. Check the shutterstat setting. Refer to the OEM service manual.

Intake Manifold Air Temperature Above Specification

This is symptom tree t096

Cause	Correction
<p>STEP 9 Exhaust system leaking hot air into engine compartment</p>	<p>Check the exhaust plumbing for leaks or broken components. Refer to Procedure 010-024.</p>
<p>OK Go To Next Step</p>	
<p>STEP 10 Fan drive or fan controls are malfunctioning</p>	<p>Check the fan drive and controls. Refer to Procedure 008-040 in the ISC Base Engine Troubleshooting and Repair Manual 3666245.</p>
<p>OK Go To Next Step</p>	
<p>STEP 11 Intake manifold pressure sensor is malfunctioning</p>	<p>Check the intake manifold pressure sensor. Refer to Procedure 019-061 in the Troubleshooting and Repair Manual, Electronic Control Systems, ISC, QSC8.3, and ISL Engines, Bulletin 3666271.</p>
<p>OK Go To Next Step</p>	
<p>STEP 12 Vehicle cooling system is not adequate</p>	<p>Verify that the engine and vehicle cooling systems are using the correct components. Refer to the OEM specifications.</p>
<p>OK Go To Next Step</p>	
<p>STEP 13 Fan is not an adequate size for the application</p>	<p>Verify that the fan is the correct size. Refer to the OEM specifications.</p>
<p>OK Go To Next Step</p>	
<p>STEP 14 Intake manifold temperature gauge is malfunctioning, if equipped</p>	<p>Test the temperature gauge. Refer to the OEM specification.</p>

Intake Manifold Air Heater System Malfunctioning

This is symptom tree t097-25

Cause	Correction
<p>STEP 1 Batteries have failed</p>	<p>Check the condition of the batteries, replace if necessary. Refer to Procedure 013-007.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Battery cables or connections are loose, broken, or corroded (excessive resistance)</p>	<p>Check the battery cables and connections. Refer to Procedure 013-009.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Fuse(s) malfunctioning</p>	<p>Replace the battery circuit fuse(s). Refer to Procedure 010-122.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Low voltage</p>	<p>Check wire gauge, check batteries. Refer to the Marine Recreational High Output Propulsion Units B and C Series Installation Directions, Bulletin 3884649 and Procedure 010-122.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Intake manifold heater wiring harness malfunctioning</p>	<p>Check the wiring harness. Refer to Procedure 010-122.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Solenoid valve is malfunctioning</p>	<p>Check for voltage at the solenoid valve. Procedure 010-126</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Intake air temperature sensor is malfunctioning</p>	<p>Check the intake air temperature sensor. Refer to Procedure 010-123.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Intake air heater element malfunctioning</p>	<p>Check and replace if necessary. Refer to Procedure 010-124.</p>
<p>OK Go To Next Step</p>	
<p>STEP 9 Engine speed sensor or circuit is malfunctioning</p>	<p>Check the engine speed sensor for correct adjustment and for debris on the sensor. Check the engine speed sensor circuit. Refer to Procedure 010-127.</p>
<p>OK Go To Next Step</p>	

Intake Manifold Air Heater System Malfunctioning

This is symptom tree t097-25

Cause

Correction

STEP 10
Heater control module malfunctioning

Check preheat, post heat, post heat recycle.
Replace heater control module, if necessary. Refer to Procedure 010-125.

Lubricating Oil Consumption Excessive

This is symptom tree t102

Cause	Correction
<p>STEP 1 Verify the oil consumption rate</p>	<p>Check the amount of oil added versus the hours of operation.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 External engine leak</p>	<p>Inspect the engine and its components for seal, gasket, tappet cover, oil cooler, or draincocks leaks.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Crankcase oil level above specification</p>	<p>Check dipstick calibration. If there is too much oil in the crankcase, drain the oil to within specification. Refer to Procedure 007-009 and 007-037.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Crankcase ventilation system is plugged</p>	<p>Check and clean the crankcase breather and vent tube. Refer to Procedure 003-018.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Lubricating oil does not meet specifications for operating conditions</p>	<p>Change the oil and filters. Refer to Procedure 007-013. Use the oil type recommended in Section V of the engine operation and maintenance manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Lubricating oil cooler is leaking</p>	<p>Check the lubricating oil cooler for coolant leaks. Refer to the Lubricating or Transmission Oil in the Coolant Symptom.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Turbocharger leaking lubricating oil to the air intake or exhaust</p>	<p>Inspect the air crossover tube for evidence of lubricating oil transfer. Refer to Procedure 010-019.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Air compressor is pumping lubricating oil into the air system</p>	<p>Check the air lines for carbon buildup and lubricating oil. Refer to Procedure 012-003.</p>
<p>OK Go To Next Step</p>	

Lubricating Oil Consumption Excessive

This is symptom tree t102

Cause	Correction
<p>STEP 9 Lubricating oil drain interval is excessive</p> <p>OK Go To Next Step</p>	<p>Verify the correct lubricating oil drain interval. Refer to the Operation and Maintenance Manual, Automotive, RV, Bus, and Industrial C8.3 Series, Bulletin 3810248, or the Operation and Maintenance Manual, C Series Recreational, High Output Marine Propulsion Unit, Bulletin 3381968.</p>
<p>STEP 10 Piston rings not sealing (blue smoke)</p> <p>OK Go To Next Step</p>	<p>Check for excessive blowby. Refer to Procedure 014-002.</p>
<p>STEP 11 Valve seals are worn</p>	<p>Inspect the valve seals. Replace the valve seals, if necessary. Refer to Procedures 002-016 and 002-020.</p>

Lubricating Oil Pressure High

This is symptom tree t104

Cause

Correction

STEP 1

Engine is cold

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

OK

Go To Next Step

STEP 2

Lubricating oil viscosity **not** correct

Make sure the correct lubricating oil is being used. Refer to Cummins® Engine Oil Recommendations, Bulletin 3810340.

OK

Go To Next Step

STEP 3

Lubricating oil filter is **not** correct

Make sure the correct oil filter is being used. Refer to the Operation and Maintenance Manual, C Series Engines, Bulletin 4021330.

OK

Go To Next Step

STEP 4

Pressure switch or gauge malfunctioning

Install a pressure gauge at main oil rifle. Verify the pressure switch is functioning correctly. Refer to the OEM service manual.

OK

Go To Next Step

STEP 5

Lubricating oil pump installation **not** correct

Verify that the correct lubricating oil pump and o-rings are installed. Refer to Procedure 007-031 in Section 7.

OK

Go To Next Step

STEP 6

Main oil pressure regulator is malfunctioning

Replace the main oil pressure regulator assembly. Refer to Procedure 007-029 in Section 7.

Lubricating Oil Pressure Low

This is symptom tree t105

Cause	Correction
<p>STEP 1 Pressure switch or gauge malfunctioning</p>	<p>Install a pressure gauge at main oil rifle. Verify the pressure switch is functioning correctly. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Lubricating oil level is above or below specification</p>	<p>Check the oil level. Add or drain oil, if necessary. Refer to Procedure 007-037 (Lubricating Oil System) in Section 7 and Procedure 007-009 (Lubricating Oil Dipstick) in Section 7.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Lubricating oil leak (external)</p>	<p>Inspect the engine for external oil leaks. Tighten the capscrews, pipe plugs, and fittings. Replace gaskets, if necessary. Refer to Procedure 007-001 (Engine Oil Heater) in Section 7. Refer to Procedure 007-003 (Lubricating Oil Cooler) in Section 7. Refer to Procedure 007-013 (Lubricating Oil Filter (Spin-On)) in Section 7. Refer to Procedure 007-025 (Lubricating Oil Pan) in Section 7. Refer to Procedure 007-037 (Lubricating Oil System) in Section 7.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Lubricating oil filter is not correct</p>	<p>Make sure the correct oil filter is being used. Refer to the Operation and Maintenance Manual, Automotive, Recreational Vehicle, and Transit Bus, C8.3 Series Engines, Bulletin 3810248.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Lubricating oil is contaminated with coolant or fuel</p>	<p>Refer to the Lubricating Oil Contaminated symptom tree.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Lubricating oil does not meet specifications for operating conditions</p>	<p>Change the oil and filters. Refer to Procedure 007-013 (Lubricating Oil Filter (Spin-On)) in Section 7. Refer to Procedure 007-037 (Lubricating Oil System) in Section 7. Use the oil type recommended in Section V of the operation and maintenance manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Engine angularity during operation exceeds specification</p>	<p>Refer to to the engine performance curves and data sheet.</p>
<p>OK Go To Next Step</p>	

Lubricating Oil Pressure Low

This is symptom tree t105

Cause	Correction
<p>STEP 8 Main oil pressure regulator is malfunctioning</p>	<p>Check the main oil pressure regulator assembly. Refer to Procedure 007-029 (Lubricating Oil Pressure Regulator (Main Rifle)) in Section 7.</p>
<p>OK Go To Next Step</p>	
<p>STEP 9 Lubricating oil suction or transfer tube is loose or broken, or the gasket or o-rings are leaking</p>	<p>Remove and inspect the oil pan or suction tube. Refer to Procedure 007-025 (Lubricating Oil Pan) in Section 7.</p>
<p>OK Go To Next Step</p>	
<p>STEP 10 Lubricating oil pump is malfunctioning</p>	<p>Inspect the lubricating oil pump. Refer to Procedure 007-031 (Lubricating Oil Pump) in Section 7.</p>
<p>OK Go To Next Step</p>	
<p>STEP 11 Lubricating oil cooler is plugged</p>	<p>Check the oil cooler. Refer to Procedure 007-003 (Lubricating Oil Cooler) in Section 7.</p>
<p>OK Go To Next Step</p>	
<p>STEP 12 Internal engine damage or internal lubricating oil leak</p>	<p>Analyze the lubricating oil. Inspect the oil filter. Check the main bearings, rod bearings, cam shaft bushings, and rocker lever bushings for excessive wear. Refer to Procedure 001-005 (Bearings, Connecting Rod) in Section 1. Refer to Procedure 001-006 (Bearings, Main) in Section 1. Refer to Procedure 001-010 (Camshaft Bushings) in Section 1. Refer to Procedure 007-051 (Lubricating Oil Analysis) in Section 7.</p>
<p>OK Go To Next Step</p>	
<p>STEP 13 Instant loss of lubricating engine oil</p>	<p>Inspect the connecting rod bearings, main bearings, turbocharger, lubricating oil pump, and lubricating oil cooler. Refer to Procedure 001-005 (Bearings, Connecting Rod) in Section 1, Procedure 001-006 (Bearings, Main) in Section 1, Procedure 007-003 (Lubricating Oil Cooler) in Section 7, Procedure 007-031 (Lubricating Oil Pump) in Section 7, Procedure 010-033 (Turbocharger) in Section 10, and Procedure 010-050 (Turbocharger Wastegate Actuator) in Section 10.</p>
<p>OK Go To Next Step</p>	

Lubricating Oil Pressure Low

This is symptom tree t105

Cause

STEP 14
Significant connecting rod and main bearing damage as a result of instant loss of lubricating engine oil

Correction

Inspect the air compressor bushings, camshaft bushings, connecting rods, crankshaft, pistons and cylinder liners. Refer to Procedure 001-010 (Camshaft Bushings) in Section 1, Procedure 001-014 (Connecting Rod) in Section 1, Procedure 001-016 (Crankshaft) in Section 1, Procedure 001-028 (Cylinder Liner) in Section 1, Procedure 001-043 (Piston) in Section 1, and Procedure 012-014 (Air Compressor) in Section 12.

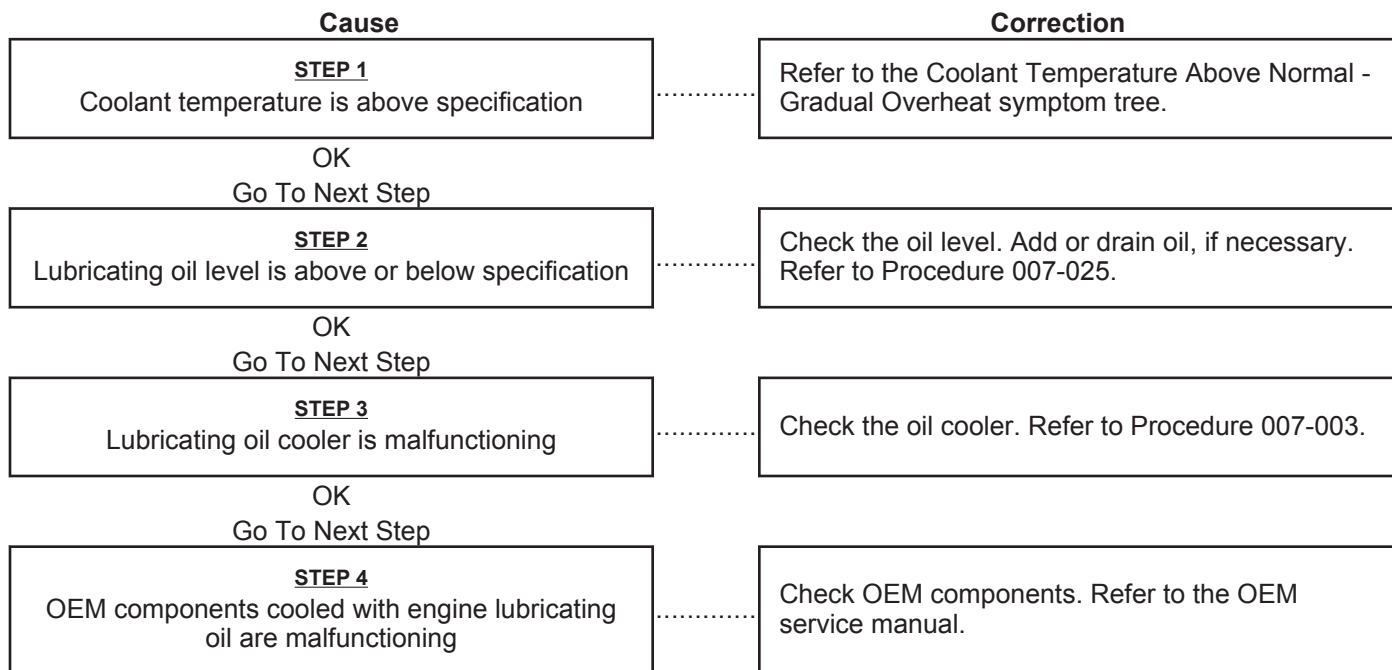
Lubricating Oil Sludge in the Crankcase Excessive

This is symptom tree t106

Cause	Correction
<p>STEP 1 Bulk oil supply is contaminated</p>	<p>Check the bulk oil supply. Drain the oil and replace with noncontaminated oil. Replace the oil filter(s). Refer to Procedure 007-025.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Coolant temperature is below specification</p>	<p>Refer to the Coolant Temperature Below Normal symptom tree.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Crankcase ventilation system is plugged</p>	<p>Check and clean the crankcase breather and vent tube. Refer to Procedure 003-008.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Fuel grade is not correct for the application or the fuel quality is poor</p>	<p>Operate the engine from a tank of high-quality fuel. Refer to Fuel for Cummins Engines, Bulletin 3379001.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Lubricating oil does not meet specifications for operating conditions</p>	<p>Change the oil and filters. Refer to Cummins Engine Oil Recommendations, Bulletin 3810340 and Procedure 007-025.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Lubricating oil drain interval is excessive</p>	<p>Verify the correct lubricating oil drain interval. Refer to the Operation and Maintenance Manual, C Series Engines, Bulletin 3810248.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Lubricating oil is contaminated with coolant or fuel</p>	<p>Change the oil and filters. Refer to the Lubricating Oil Contaminated symptom tree.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Crankcase pressure is excessive</p>	<p>Check for excessive blowby. Refer to the Crankcase Gases (Blowby) Excessive symptom tree.</p>

Lubricating Oil Temperature Above Specification

This is symptom tree t107



Lubricating or Transmission Oil in the Coolant

This is symptom tree t108

Cause	Correction
<p>STEP 1 Bulk coolant supply is contaminated</p>	<p>Check the bulk coolant supply. Drain the coolant and replace with noncontaminated coolant. Replace the coolant filters. Refer to Procedure 007-025.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Lubricating oil cooler is malfunctioning</p>	<p>Check the oil cooler. Refer to Procedure 007-003.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Torque converter cooler or hydraulic oil cooler is malfunctioning</p>	<p>Remove and inspect the cooler cores and o-rings. Refer to the OEM service manual.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Air compressor cylinder head is cracked or porous, or has a leaking gasket</p>	<p>Inspect the air compressor cylinder head and gasket. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 Cylinder head gasket is leaking</p>	<p>Check the cylinder head gasket. Refer to Procedure 002-004.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Cylinder head is cracked or porous</p>	<p>Remove intake and exhaust manifolds. Check for evidence of coolant leak. If necessary, operate engine at low idle. Pressure-test the cylinder head. Refer to Procedure 002-004.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Cylinder block is cracked or porous</p>	<p>Inspect the cylinder block. Refer to Procedure 001-026.</p>

Smoke, Black — Excessive

This is symptom tree t116

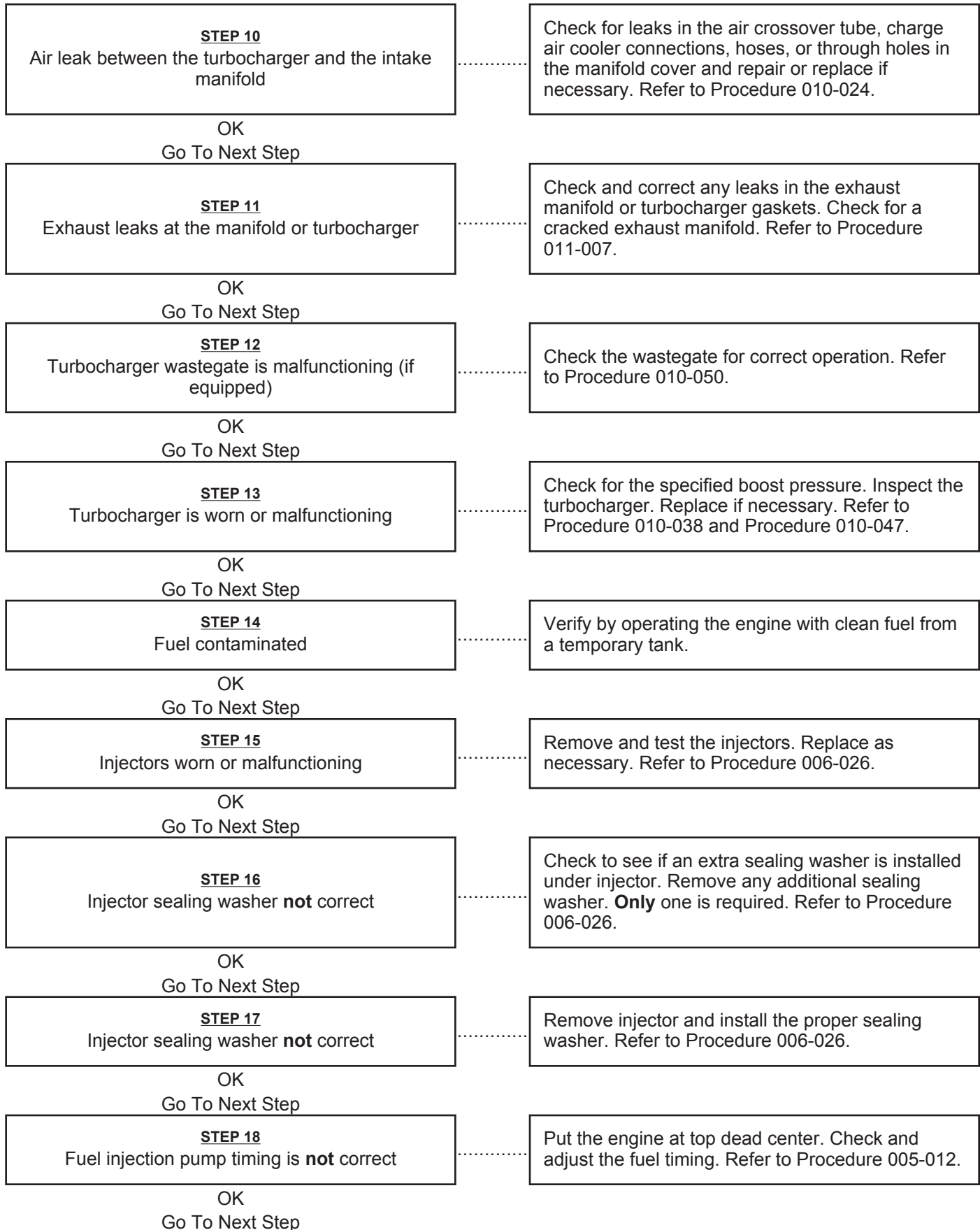
Cause	Correction
<p>STEP 1 Electronic fault codes active or high counts of inactive fault codes</p>	<p>View and troubleshoot the fault codes with INSITE™. Refer to Section TF in the Troubleshooting and Repair Manual, Electronic Control System, QST30 Engine, Bulletin 3666214.</p>
<p>OK Go To Next Step</p>	
<p>STEP 2 Engine is being lugged down</p>	<p>Use lower gear.</p>
<p>OK Go To Next Step</p>	
<p>STEP 3 Load is excessive</p>	<p>Reduce the load. Check and clean the vessel bottom, or change the propeller. Refer to manufacturer's instructions.</p>
<p>OK Go To Next Step</p>	
<p>STEP 4 Plugged air filter</p>	<p>Inspect the air cleaner element. Replace as needed. Refer to Procedure 010-031.</p>
<p>OK Go To Next Step</p>	
<p>STEP 5 AFC plunger not fully open</p>	<p>Inspect AFC air tube and fuel drain lines for restriction. Inspect the AFC operation.</p>
<p>OK Go To Next Step</p>	
<p>STEP 6 Intake air source is incorrect</p>	<p>If the vehicle is equipped with a valve to switch the intake source from under the hood to outside, position and set valve for the season.</p>
<p>OK Go To Next Step</p>	
<p>STEP 7 Aftercooler restricted (if equipped)</p>	<p>Inspect for plugged passages in the aftercooler. Refer to Procedure 010-002.</p>
<p>OK Go To Next Step</p>	
<p>STEP 8 Exhaust system restriction</p>	<p>Check the exhaust system for any restrictions. Refer to Procedure 011-009.</p>
<p>OK Go To Next Step</p>	
<p>STEP 9 Charge air cooler is restricted or leaking</p>	<p>Inspect the charge air cooler for air restrictions or leaks. Refer to Procedure 010-027.</p>
<p>OK Go To Next Step</p>	

Smoke, Black — Excessive

This is symptom tree t116

Cause

Correction



Smoke, Black — Excessive

This is symptom tree t116

Cause

Correction

STEP 19

Fuel injection pump is malfunctioning

Remove the fuel injection pump. Check the calibration of the fuel injection pump. Refer to Procedure 005-012.

OK

Go To Next Step

STEP 20

Piston rings **not** sealing (blue smoke)

Check for excessive blowby. Refer to Procedure 014-002.

Smoke, White — Excessive

This is symptom tree t118

Cause

Correction

STEP 1

Electronic fault codes active or high counts of inactive fault codes

View and troubleshoot the fault codes with INSITE™. Refer to the TF Section in the Troubleshooting and Repair Manual, Marine Electronic Control System, C8.3 Engines, 4021442.

OK

Go To Next Step

STEP 2

Starting procedure is **not** correct

Verify the correct starting procedure. Refer to the Operation and Maintenance Manual, Automotive, RV, Bus, and Industrial C8.3 Series (U. S.), Bulletin 3810248 or the Operation and Maintenance Manual, C Series Recreational, High Output Marine Propulsion Unit, Bulletin 3381968.

OK

Go To Next Step

STEP 3

Coolant temperature is below specification or the intake manifold air temperature is below specification

Refer to the Coolant Temperature Below Normal symptom tree.

OK

Go To Next Step

STEP 4

Intake manifold heater wiring harness malfunctioning

Check the wiring harness. Refer to Intake Manifold Air Heater System Malfunctioning troubleshooting tree.

OK

Go To Next Step

STEP 5

Poor fuel quality or wrong fuel grade

Verify by operating the engine from a temporary supply of number 2 diesel fuel. Check fuel specifications for proper fuel grade. Refer to Fuel for Cummins Engines, Bulletin 3379001.

OK

Go To Next Step

STEP 6

Fuel injection pump timing is **not** correct

Put the engine at top dead center. Check and adjust the fuel timing. Refer to Procedure 005-012 or 005-013.

OK

Go To Next Step

STEP 7

KSB is malfunctioning (Bosch VE pump **only**)

Refer to the OEM service manual.

OK

Go To Next Step

STEP 8

Injector sealing washer **not** correct

Remove injector and install the proper sealing washer. Refer to Procedure 006-026.

OK

Go To Next Step

Smoke, White — Excessive

This is symptom tree t118

Cause	Correction
<p>STEP 9 Injector sealing washer not correct</p>	<p>Remove injector and install the proper sealing washer. Refer to Procedure 006-026.</p>
<p>OK Go To Next Step</p>	
<p>STEP 10 Injectors worn or malfunctioning</p>	<p>Remove and test the injectors. Replace as necessary. Refer to Procedure 006-026.</p>
<p>OK Go To Next Step</p>	
<p>STEP 11 Coolant is leaking into the combustion chamber</p>	<p>Refer to the Coolant Loss - Internal symptom tree.</p>
<p>OK Go To Next Step</p>	
<p>STEP 12 Fuel injection pump is malfunctioning</p>	<p>Remove the fuel injection pump. Check the calibration of the fuel injection pump. Refer to Procedure 005-012.</p>

Section 0 - Complete Engine - Group 00

Section Contents

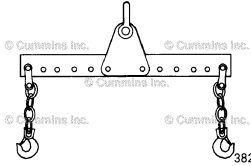
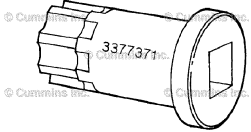
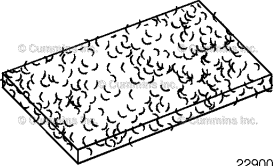
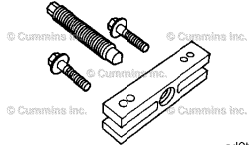
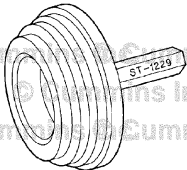
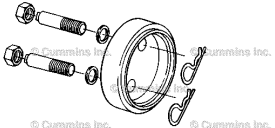
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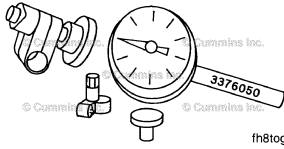
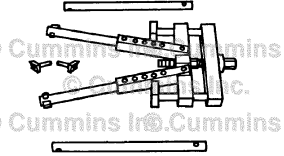
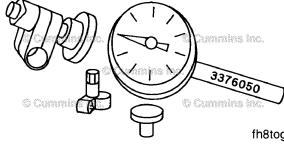
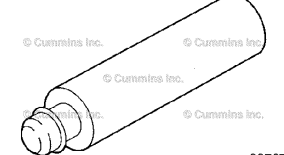

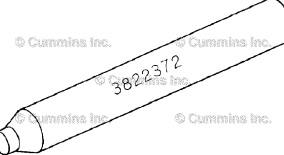
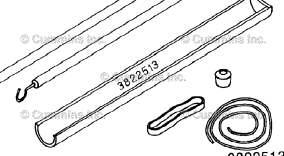
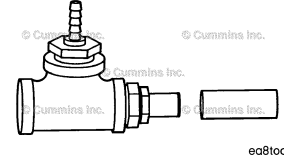
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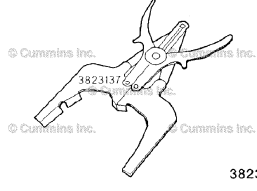
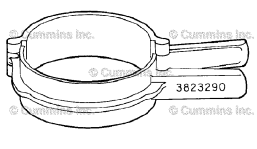
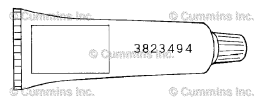
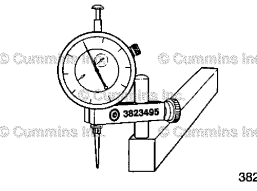




Service Tools

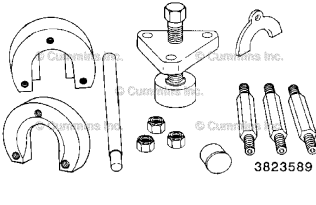
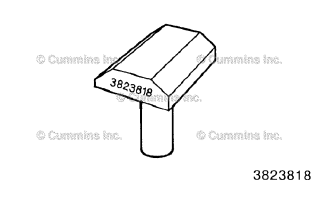

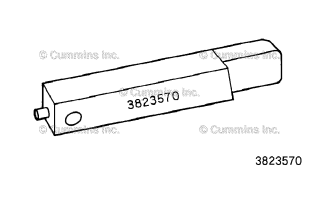
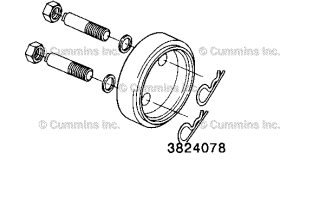
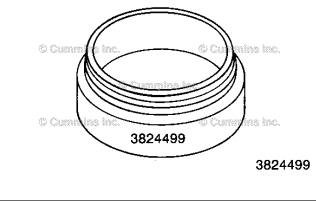
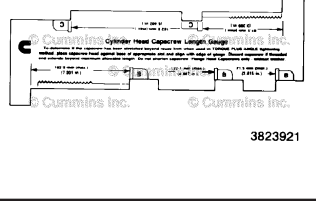

Engine Disassembly/Assembly

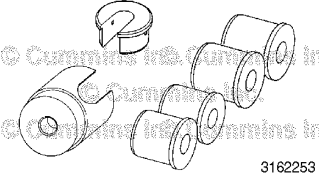
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

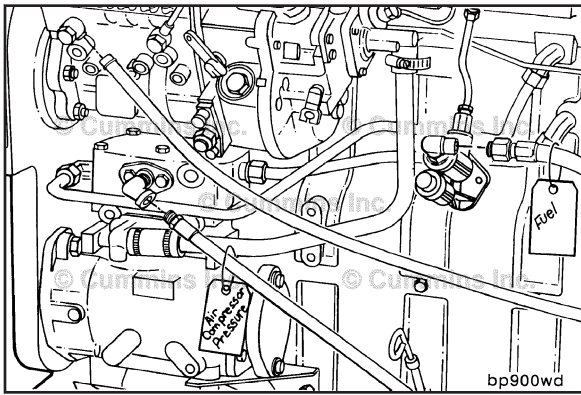
Tool No.	Tool Description	Tool Illustration
3163264	<p>Engine Lifting Fixture Used to lift the engine during the removal and installation procedures.</p>	 <p style="text-align: right;">3822512</p>
3377371	<p>Engine Barring Tool Used to engage the flywheel ring gear to rotate the crankshaft.</p>	 <p style="text-align: right;">3377371</p>
3823258	<p>Scotch-Brite® 7448 Abrasive Pad Used to clean carbon from the upper liner bores, remove rust, corrosion, burrs, and scuffing surfaces.</p>	 <p style="text-align: right;">22900039</p>
ST-647	<p>Standard Puller Used to remove drive pulleys, impellers, air compressor counterweights, etc.</p>	 <p style="text-align: right;">ad8toga</p>
ST-1229	<p>Cylinder Liner Driver Install cylinder liner into cylinder block.</p>	 <p style="text-align: right;">ST-1229</p>
3824500	<p>Wear Sleeve Installer Used to install the wear sleeve.</p>	 <p style="text-align: right;">3824500</p>

Tool No.	Tool Description	Tool Illustration
ST-1325	<p>Dial Gauge Attachment</p> <p>Attaches to crankshaft flange to provide measuring of flywheel and flywheel housing runout with dial bore gauge.</p>	 <p>fh8toge</p>
3376015	<p>Cylinder Liner Puller</p> <p>Removes cylinder liners from the cylinder block. Require two, Part No. 3376649 puller arm extension feet.</p>	 <p>ck8togr</p>
3376050	<p>Dial Indicator and Sleeve Assembly</p> <p>Used to measure flywheel and flywheel housing runout.</p>	 <p>fh8toge</p>
3376795	<p>Expansion Plug Driver Handle</p> <p>Used with all expansion plug drivers larger than 0.375-inch diameter.</p>	 <p>3376795</p>
3376816	<p>Expansion Plug Driver</p> <p>Install 1-inch expansion plug to specified depth. Used with expansion plug driver handle, Part No.3376795.</p>	 <p>ck8toge</p>
3822372	<p>Expansion Plug Driver</p> <p>Install 0.375-inch expansion plug to specified depth. Used with expansion plug driver handle, Part No. 3376795.</p>	 <p>3822372</p>
3822513	<p>Tappet Removal Tool Kit</p> <p>Used to remove and install valve tappets.</p>	 <p>3822513</p>
3822566	<p>Blowby Check Tool</p> <p>Used with manometer, Part No. ST-1111-3, to measure the engine crankcase pressure.</p>	 <p>eg8toge</p>

Tool No.	Tool Description	Tool Illustration
3823137	<p>Piston Ring Expander</p> <p>Used to install piston rings onto pistons without damaging or distorting the rings.</p>	 <p>3823137</p>
3823290	<p>Piston Ring Compressor</p> <p>Used to compress the piston rings while installing the pistons into the cylinder bores.</p>	 <p>3823290</p>
3823494	<p>Sealant, Three-Bond™ (150 Gram Tube)</p> <p>Used for sealing "T" joints and front gear cover.</p>	 <p>3823494</p>
3823495	<p>Gauge Block</p> <p>Measure cylinder liner protrusion on the cylinder block.</p>	 <p>3823495</p>
3823521	<p>Expansion Plug Driver</p> <p>Install 0.8125-inch expansion plug to specified depth. Used with expansion plug driver handle, Part No. 3376795.</p>	 <p>3823521</p>
3823522	<p>Expansion Plug Driver</p> <p>Install 1.1875-inch expansion plug to specified depth. Used with expansion plug driver handle, Part No. 3376795.</p>	 <p>3823522</p>
3823523	<p>Expansion Plug Driver</p> <p>Install 1.375-inch expansion plug to specified depth. Used with expansion plug driver handle, Part No. 3376795.</p>	 <p>3823523</p>
3823524	<p>Expansion Plug Driver</p> <p>Used to install 2.250-inch expansion plug to specified depth. Used with expansion plug driver handle, Part No. 3376795.</p>	 <p>3823524</p>

Tool No.	Tool Description	Tool Illustration
3823589	<p>Camshaft Gear Installation/Removal Tool Used to remove and install the camshaft gear from the camshaft with the camshaft installed.</p>	
3823818	<p>Main Bearing Rollout Tool Used to remove and install main bearings with the crankshaft installed.</p>	
3823567	<p>Cutter Plate Used with Part No. 3823558, cylinder liner counterbore tool.</p>	
3823570	<p>Cutter Bit Used with Part No. 3826567, cutter plate, to machine the cylinder liner counterbore ledge.</p>	
3824078	<p>Wear Sleeve Installation Tool Used to install the rear crankshaft lubricating oil seal wear sleeve.</p>	
3824499	<p>Lubricating Oil Seal Installation Tool Used to install the front lubricating oil seal in the front cover to a specified depth.</p>	
3823921	<p>Capscrew Length Gauge Used to measure capscrew free length.</p>	
3375068	<p>Cup Plug Sealant Used when installing pipe plugs and cup plugs to prevent leaks.</p>	

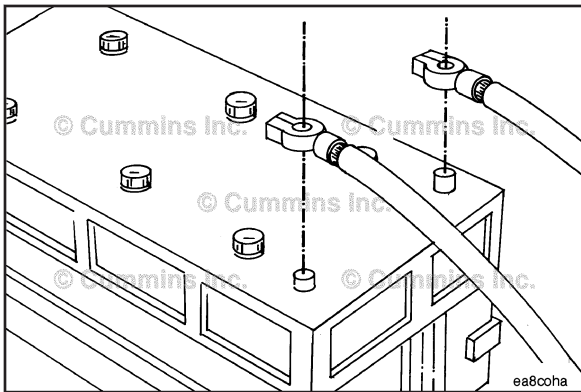
Tool No.	Tool Description	Tool Illustration
3162253	Camshaft Bushing Installation/Removal Kit Used to remove and install the camshaft busings.	 <p>The illustration shows several cylindrical bushings of varying sizes and orientations, along with a small circular component. The parts are arranged in a cluster. A copyright notice for Cummins Inc. is visible in the background of the illustration, and the part number 3162253 is printed in the bottom right corner of the illustration area.</p>



Engine Removal (000-001)

General Information

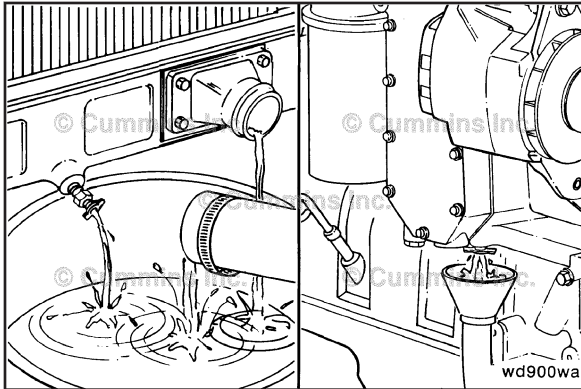
Place a tag on all hoses, lines, linkages, and electrical connections, as they are removed, to identify their locations on the engine.



▲ WARNING ▲

Batteries can emit explosive gases. To avoid 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 battery cables.

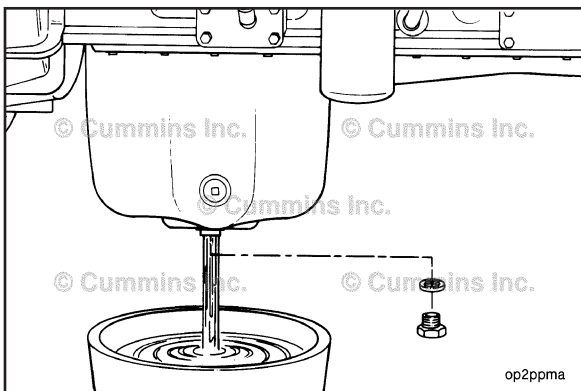


▲ WARNING ▲

Coolant is toxic. If not reused, dispose of in accordance with local environmental regulations.



Drain the engine coolant; refer to Procedure 008-018.



▲ WARNING ▲

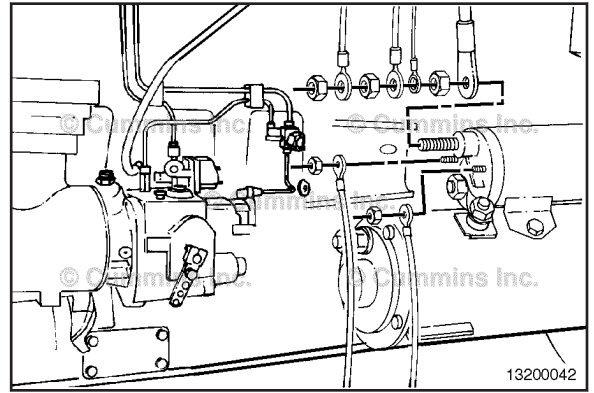
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.



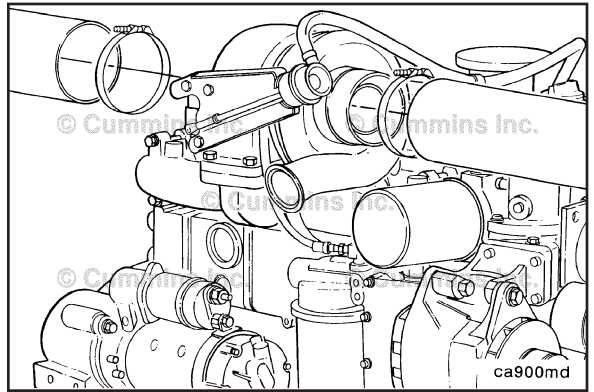
Drain the lubricating oil; refer to Procedure 007-037.

NOTE: Dispose of used oil in accordance with federal, state, and local laws and regulations.

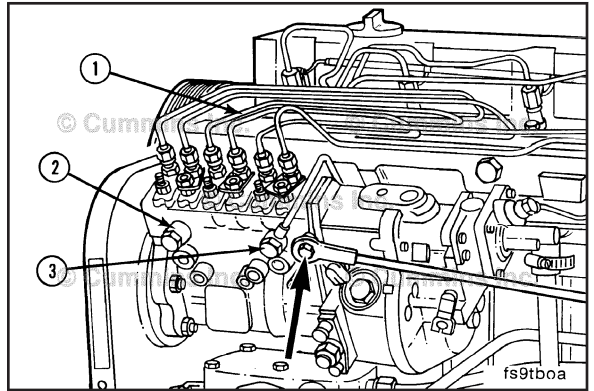
Disconnect the starting motor cable, the engine ground straps, the cab or chassis to engine hoses, the tubing, the electrical wires, and the hydraulic lines.



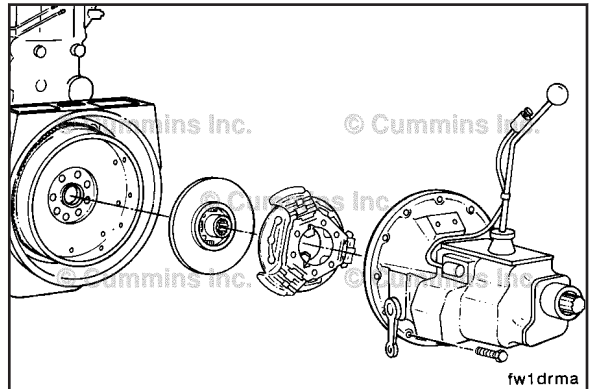
Disconnect the intake and the exhaust air pipes.
Disconnect all chassis-mounted "engine-driven" accessories.

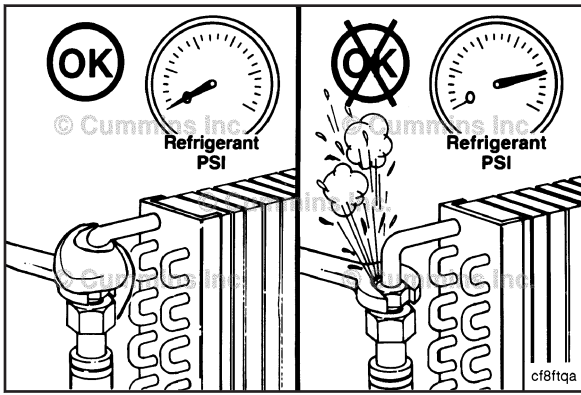


Disconnect the throttle linkage from the injection pump control lever; refer to the OEM service manual.



Disconnect the drive units from the flywheel.



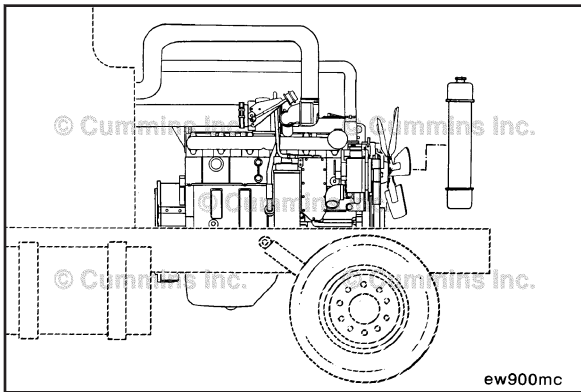


WARNING

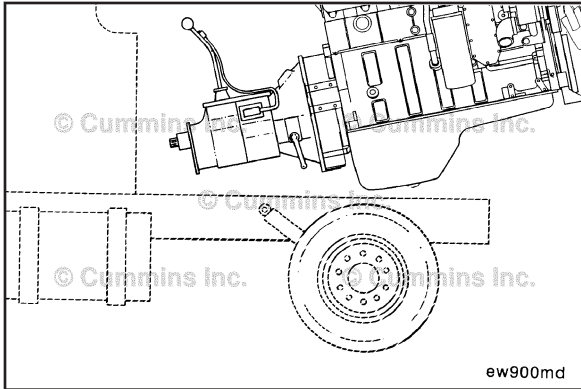
If a liquid refrigerant system (air conditioning) is used, wear eye and face protection, and wrap a cloth around the fittings before removing. Liquid refrigerant can cause serious eye and skin injuries.

CAUTION

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.



Remove all chassis components necessary to remove the engine from the equipment. Refer to the OEM's instructions.

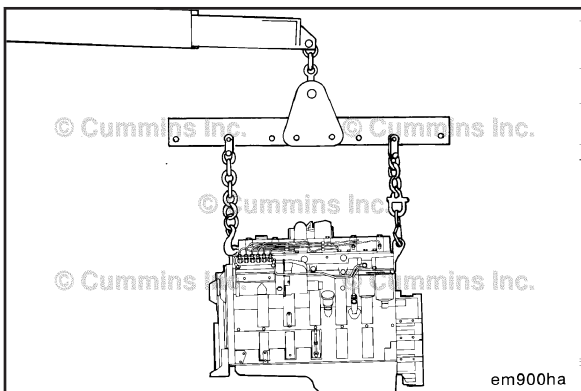


WARNING

This assembly weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this assembly.

The engine lifting equipment **must** be designed to lift the engine and transmission safely as an assembly.

NOTE: On applications where the rear engine mounts are attached to the transmission, it will probably be necessary to remove the engine and transmission as an assembly.



NOTE: Use a properly rated hoist and engine lifting fixture.



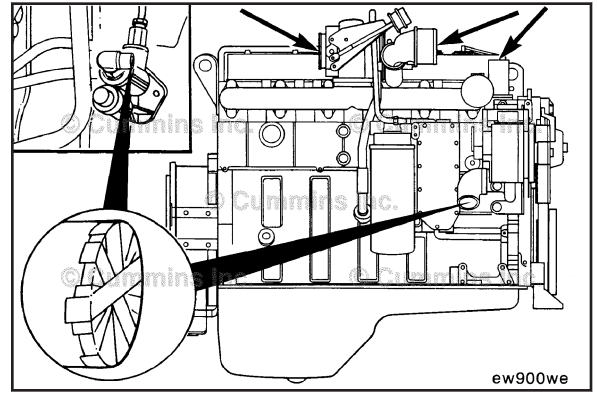
NOTE: If the transmission is **not** removed, place a support under the transmission to prevent it from falling.

Attach the engine lift fixture, Part No. 3163264, to the engine-mounted lifting brackets.

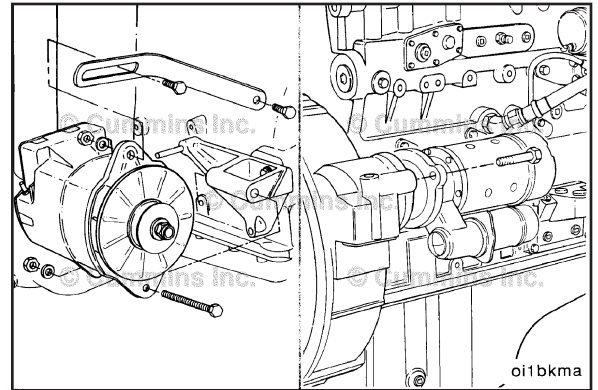
Remove the engine.

Cover all engine openings to prevent dirt and debris from entering the engine.

Place the engine on suitable engine support stands.

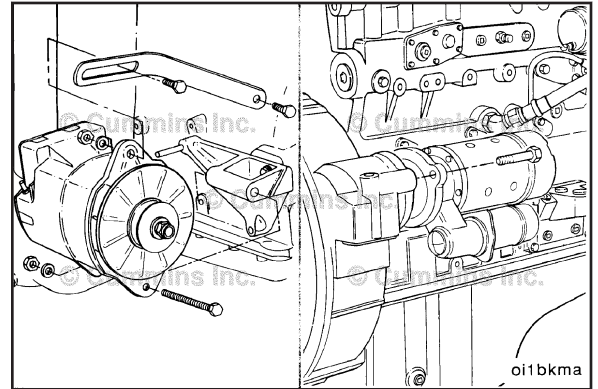


Remove all of the remaining accessories and brackets to use with the replacement engine.



Engine Installation (000-002) General Information

Install all accessories and brackets that were removed from the previous engine.



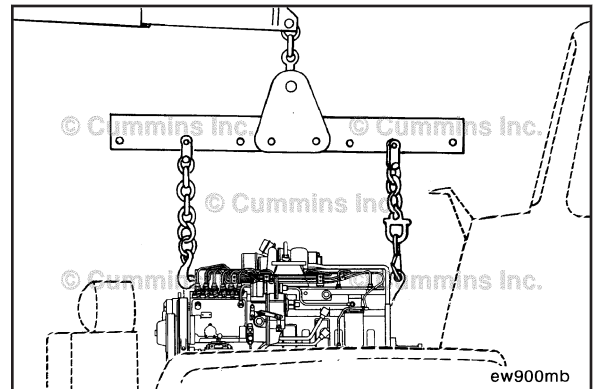
▲ WARNING ▲

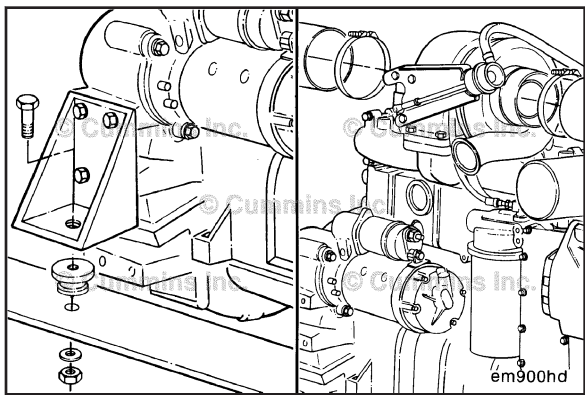
The engine lifting equipment must be designed to lift the engine and transmission safely as an assembly without causing personal injury.

NOTE: If the rear engine mounts are attached to the transmission, it will probably be necessary to install the engine and the transmission as an assembly.

Use a properly rated hoist and engine lift fixture, Part Number 3163264. Attach the lift fixture to the engine-mounted lifting brackets.

Install the engine.

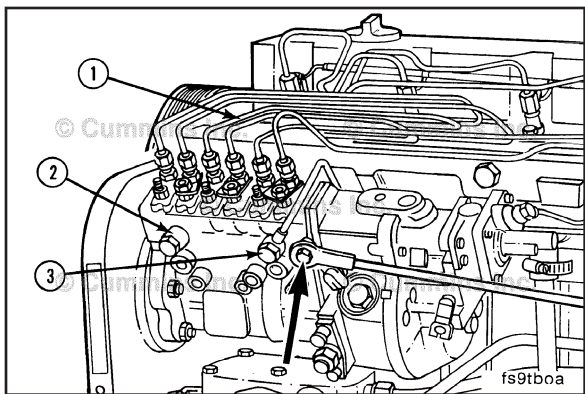




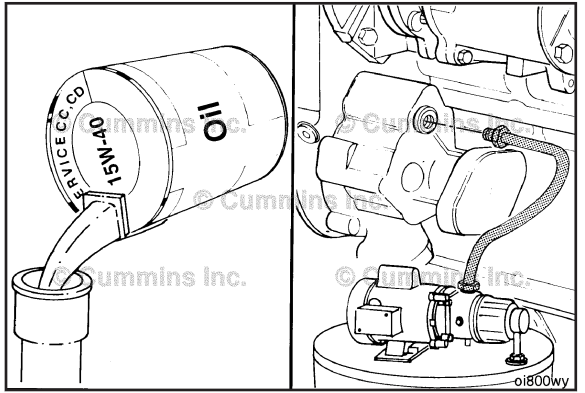
⚠ CAUTION ⚠
Make sure all lines, hoses, and tubes are correctly routed and fastened to prevent engine damage.

Align the engine in the chassis and tighten the engine mounting capscrews. Refer to the OEM's torque specifications.

Connect all engine and chassis-mounted accessories that were removed.



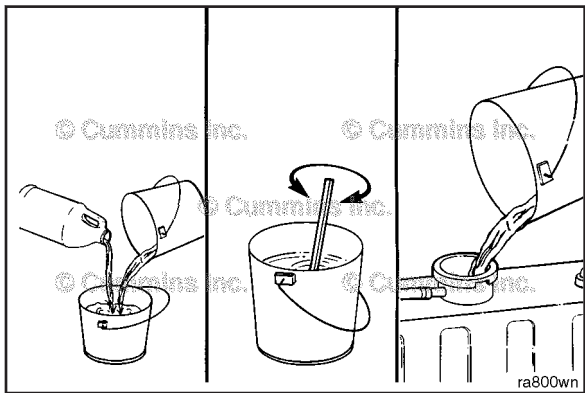
Install and adjust the throttle linkage to the injection pump control lever; refer to the OEM service manual.



NOTE: The total oil capacity of the standard engine, including combination full flow and bypass oil filters, is 23.6 liters [6.25 gal].

Fill the engine with clean engine lubricating oil. Refer to Procedure 007-037.

NOTE: The engine lubricating oil system **must** be pressurized before starting the engine.

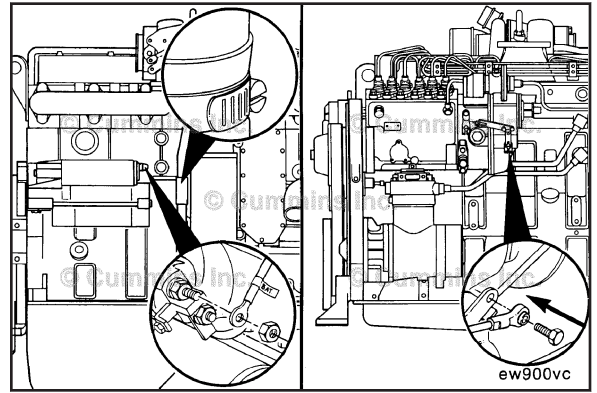


Fill the cooling system with 50-percent water, 50-percent ethylene glycol-base antifreeze, and proper amount of DCA corrosion protection. Refer to Procedure 008-018.

NOTE: The total coolant capacity (engine **only**) is 9.9 liters [2.25 gal] for air-aftercooled engines, and 10.9 liters [2.85 gal] for water-aftercooled engines.

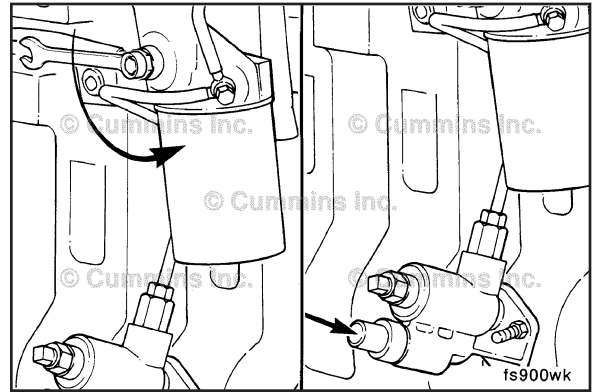
Refer to the OEM's specifications for radiator and system capacity.

Make a final inspection to make sure all hoses, wires, linkages, and components have been correctly installed and tightened.



Prime the low-pressure fuel system.

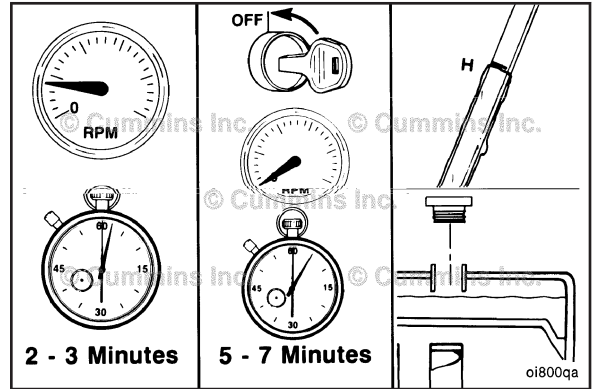
1. Open the bleed screw
2. Operate the plunger on the fuel transfer pump until the fuel flowing from the fitting is free of air.
3. Close the bleed screw.



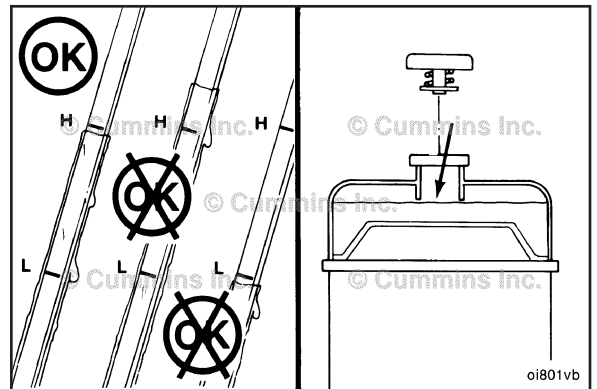
⚠ WARNING ⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

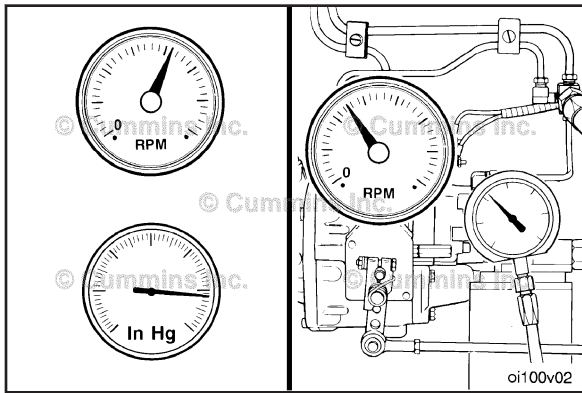


Operate the engine at low idle for 2 to 3 minutes.
Shut off the engine and wait 5 to 7 minutes for the oil to drain to the oil pan. Check the oil and coolant levels.



Fill the engine to the correct oil and coolant levels if necessary. Refer to Procedures 007-037 and 008-018.





Operate the engine at 1000 to 1200 rpm for 8 to 10 minutes to check for correct engine operation, unusual noises, and coolant, fuel, or lubricating oil leaks.



Repair all leaks and component problems as needed. Refer to the appropriate sections.

Refer to the following procedures for the Engine Run-in and Testing Procedures.

014-002

014-003

014-004

Engine Storage - Long Term (000-005)

General Information



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.



Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.



After 24 months in storage, the engine cooling system must be drained and flushed with a suitable solvent or a hot, lightweight mineral oil. Repeat flushing procedure a second time before being put back into service.

This procedure describes the proper method for the long-term (more than 6 months) storage of an engine that is currently in running condition. This procedure applies to this engine either remaining in chassis - or being removed out of chassis upon completion of the steps below.

Prepare the Engine for Long Term Storage



DO NOT use fuel system preservative oil on Natural Gas or Propane Engines.

- Operate the engine at high idle until the coolant temperature is 70°C [158°F].
- Turn the engine off.
- Drain the oil.
- Install the drain plugs.
- Fill the engine oil pan sump to the high mark using Tectyl™ 910 or equivalent engine preservative oil. This will provide long term engine rust protection. The oil **must** meet military specification MIL-PRF-21260, Type P-10, Grade 2, SAE 30.

Internal Preservation of the Fuel System with Mechanically and Electronically Actuated Injectors.



DO NOT use diesel fuel containing bio components for internal preservation of fuel system for engine storage. Fuel properties degradation may cause damages and lead to premature failure of fuel system components.

- Disconnect the fuel lines to the engine fuel filter and the injector return line.
- Use Diesel Pump and Injector calibration fluid that meets ISO 4113 standard, SAE J967d standard and Bosch VS 15665-OL standard.

NOTE: Using calibration fluid allows storage for up to 12 months. After 12 months the engine fuel system **must** be drained and flushed again with fresh calibration fluid. Repeat after each 12-month period.

Alternatively you can use the diesel fuel with 0 percent bio components content for Internal Preservation of the Fuel System.

NOTE: Using diesel fuel with 0 percent bio components content allows storage for up to 6 months. After 6 months, the engine fuel system **must** be drained and be flushed again with fresh diesel fuel with 0 percent bio components content. Repeat after each 6-month period.

- Start the engine.
- After the engine is operating smoothly, transfer the fuel supply line to the container of calibration fluid or the container of diesel fuel with 0 percent bio components content.
- Let the engine run for approximately 25 minutes at low idle in order to ensure that the engine preservative oil (Tectyl™ 910 E or equivalent) is distributed around the engine and its internal components and that the calibration fluid or the diesel fuel with 0 percent bio components content flows out of the injector return line.
- Turn the engine "OFF".
- Connect the fuel lines to the fuel filter and the injector return line.
- Drain all the preservative oil from the engine oil pan sump, the air compressor (if applicable), and drain all the oil filters and all the fuel filters.
- Install the drain plugs.

▲ CAUTION ▲

Before starting another Internal Preservation of the Fuel System procedure again (after passing a storage period) it is required to fill the engine oil pan sump to the high mark using Tectyl™ 910 or equivalent engine preservative oil.

- If the engine is being stored as a loose engine, drain the engine coolant and cover all cooling system openings with plastic and tape.
- If the engine is **not** being removed from chassis and the engine has an extended life coolant with rust inhibitor, then coolant does **not** need to be drained.
- If the engine will remain in storage for over 24 months, the engine cooling system **must** be drained and flushed with a suitable solvent or a hot, lightweight mineral oil. Repeat after each 24-month period.
- Remove the intake and exhaust manifolds.
- Spray preservative oil into the intake and exhaust ports in the cylinder heads and in the exhaust manifolds **only**. Do **not** use preservative oil on the intake manifold or any fuel system components as this may permanently damage sensors or valves.
- Spray preservative oil in the inlet port on the air compressor (if applicable).
- Remove the rocker lever covers.
- Spray the rocker levers, the valve stems, the springs, the valve guides, the crossheads, and the push rods with preservative oil.
- Install the rocker lever covers, intake and exhaust manifolds.
- Brush or spray the preservative oil on all the exposed metal surfaces that are **not** painted. Preservative oil should **not** be applied to any plastic, rubber, or similar surfaces. Make sure to coat the flywheel, flywheel housing and all other unpainted machined surfaces with this preservative oil. Use a rust preservative oil compound that meets military specification MIL-C-16173C, type P-2, Grade 1 or 2.
- For components containing exposed bearings that are **not** easily accessible e.g. Fan Hubs, remove the component to aid access. Brush or spray preservative oil on all surfaces that are **not** painted and refit the component. Use a rust preservative oil compound that meets military specification, MIL-C-16173C, type P-2, Grade 1 or 2
- Cover all the openings (engine and components) with heavy paper and tape to prevent dirt and moisture from entering the engine. Cover the entire engine with plastic.
- Put a warning tag on the engine. The tag **must** indicate:
 - Do **not** operate the engine.
 - Do **not** bar the crankshaft.
 - The engine has been treated with preservatives.
 - The coolant has been removed.
 - The date of treatment.
 - The date of the 6 week inspection if required.

△CAUTION△

The engine must be stored in an area that is dry and has uniform temperature.

- Remove any accessory drive belts to prevent localized stretching and deformation.
- If the engine can be stored inside a designated storage facility isolated from the external environment, ignore the following step.
- Excluding the crankshaft, ensure that all external dynamic engine components are rotated every 6 weeks. Ensure parts are free from corrosion, debris and water ingress. Record and date this on the engine tag created.

Remove the Engine from Long Term Storage

To remove the engine from long term storage, follow the following steps:

△CAUTION△

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

- Flush the engine preservative oil out of the engine by removing the plug from the main engine oil rifle and pumping a hot, lightweight mineral oil through it. Make sure that the engine crankshaft is barred at least three to four revolutions during this flushing procedure.
- Drain all the mineral oil that was used to flush the engine clean of the engine preservative oil.
- Install the drain plugs.
- Install new oil, fuel and coolant filters.
- Fill the engine to the high mark with engine oil.
 - If the engine has been in storage for less than 24 months and if the cooling system was drained, fill the cooling system with coolant. Refer to Procedure 018-004 in Section V for antifreeze, water, and SCA specifications.
 - If the engine has been in storage for 24 months, every 24 months the engine cooling system **must** be drained and flushed with a suitable solvent or a hot, lightweight mineral oil. Fill the cooling system with coolant. Refer to Procedure 018-004 in Section V for antifreeze, water, and SCA specifications.
 - If the engine has been in storage for less than 24 months and the engine has an extended life coolant with a rust inhibitor, drain the cooling system. Fill the cooling system with coolant. Refer to Procedure 018-004 in Section V for antifreeze, water, and SCA specifications.
- Adjust the engine brake (if applicable) and valve clearances. Reference the Overhead Set procedure in the corresponding base Troubleshooting and Repair Manual or Service Manual for the engine being serviced.
- Tighten the intake and exhaust manifold mounting capscrews.
- Prime the lubricating system.
- Reinstall any accessory drive belts that were removed.
- Replace all spark plugs. Reference the Spark Plugs procedure in the corresponding base Troubleshooting and Repair Manual or Service Manual for engine being serviced(if applicable).
- Make sure all fuel lines are securely tightened and all fuel shutoff valves are open prior to attempting to start the engine.
- Start the engine.
- Note that it might take multiple cranking attempts to start the engine. Do **not** crank the engine more than 30 seconds at a time as this might cause the starter to overheat and fail.
- Note that the engine might run rough until the fuel system is completely primed or until all residual fuel system preservative oil is completely flushed out of the fuel system (if the fuel has been treated with fuel system preservative oil).
- Install the exhaust aftertreatment components (if applicable).
- Force an active regeneration (if applicable).

Section 1 - Cylinder Block - Group 01

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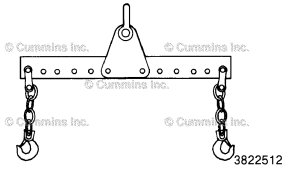
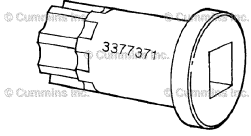
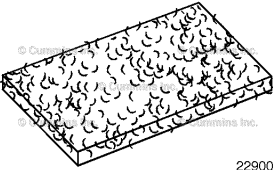
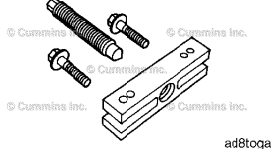
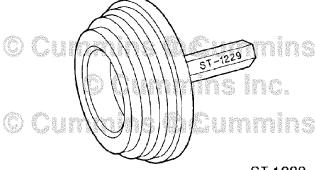
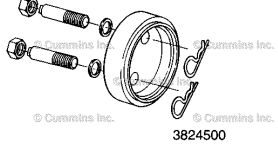
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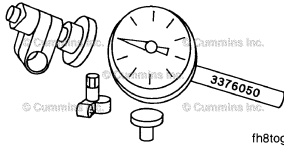
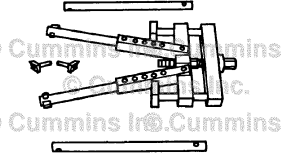
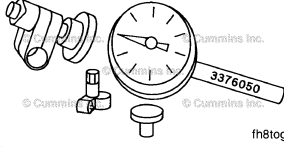
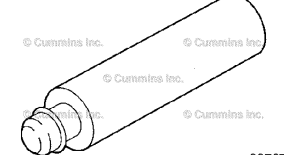

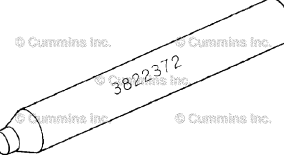
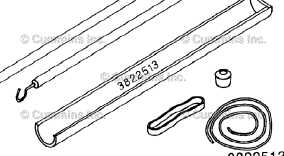
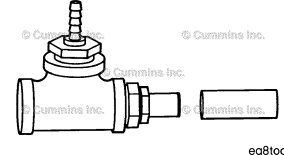
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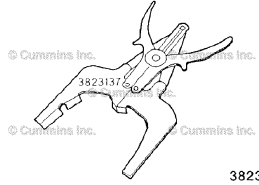
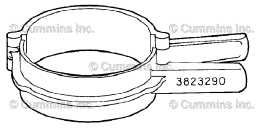

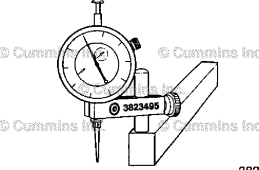




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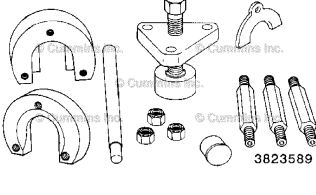


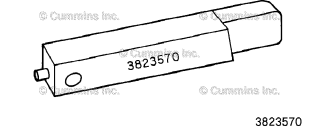
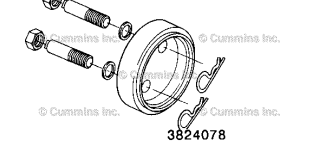

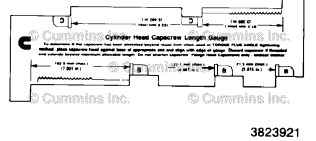

Service Tools

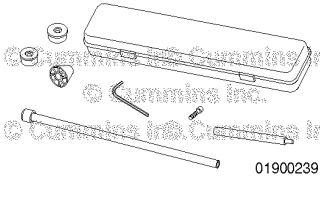
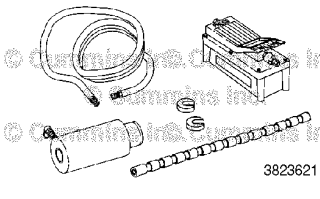
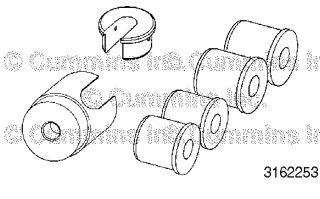
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3163264	<p>Engine Lift Fixture Used to lift the engine during the removal and installation procedures.</p>	
3377371	<p>Engine Barring Tool Used to engage the flywheel ring gear to rotate the crankshaft.</p>	
3823258	<p>Scotch-Brite™ 7448 Abrasive Pad Used to clean carbon from the upper liner bores, remove rust, corrosion, burrs, and scuffing surfaces.</p>	
ST-647	<p>Standard Puller Used to remove drive pulleys, impellers, air compressor counterweights, etc.</p>	
ST-1229	<p>Cylinder Liner Driver Install cylinder liner into cylinder block.</p>	
3824500	<p>Wear Sleeve Installer Used to install a wear sleeve to repair crankshafts that have grooves caused by the oil seal.</p>	

Tool No.	Tool Description	Tool Illustration
ST-1325	<p>Dial Gauge Attachment</p> <p>Attaches to crankshaft flange to provide measuring of flywheel and flywheel housing runout with dial bore gauge.</p>	 <p>fh8toge</p>
3376015	<p>Cylinder Liner Puller</p> <p>Removes cylinder liners from the cylinder block. Require two puller arm extension feet, Part Number 3376649.</p>	 <p>ck8togr</p>
3376050	<p>Dial Indicator and Sleeve Assembly</p> <p>Used to measure flywheel and flywheel housing runout.</p>	 <p>fh8toge</p>
3376795	<p>Expansion Plug Driver Handle</p> <p>Used with all expansion plug drivers larger than 0.375-inch diameter.</p>	 <p>3376795</p>
3376816	<p>Expansion Plug Driver</p> <p>Used to install 1-inch expansion plug to specified depth. Used with expansion plug driver handle, Part Number 3376795.</p>	 <p>ck8toge</p>
3822372	<p>Expansion Plug Driver</p> <p>Install 0.375-inch expansion plug to specified depth. Used with expansion plug driver handle, Part Number 3376795.</p>	 <p>3822372</p>
3822513	<p>Tappet Removal Tool Kit</p> <p>Used to remove and install valve tappets.</p>	 <p>3822513</p>
3822566	<p>Blowby Check Tool</p> <p>Used with manometer, Part Number ST-1111-3, to measure the engine crankcase pressure.</p>	 <p>eg8toge</p>

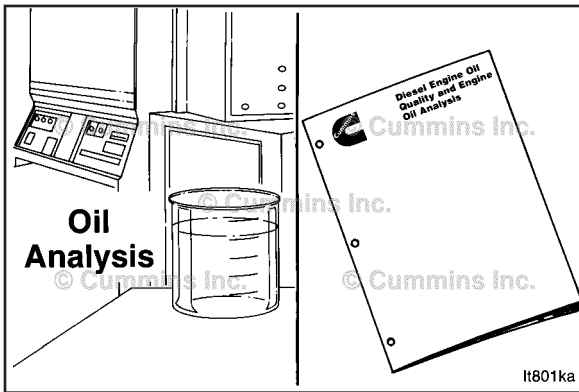
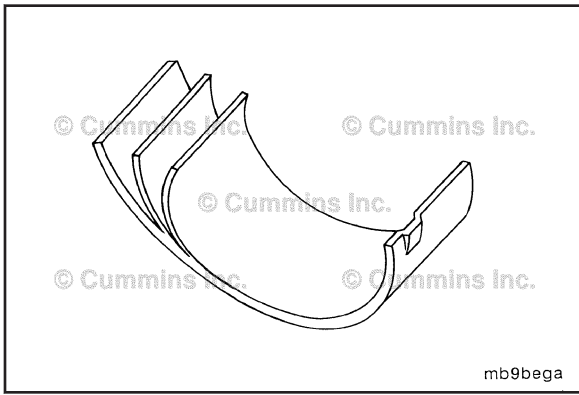
Tool No.	Tool Description	Tool Illustration
3823137	<p>Piston Ring Expander</p> <p>Used to install piston rings onto pistons without damaging or distorting the rings.</p>	 <p>3823137</p>
3823290	<p>Piston Ring Compressor</p> <p>Used to compress the piston rings while installing the pistons into the cylinder bores.</p>	 <p>3823290</p>
3823494	<p>Sealant, Three-Bond™ (150-Gram Tube)</p> <p>Used for sealing "T" joints and front gear cover.</p>	 <p>3823494</p>
3823495	<p>Gauge Block</p> <p>Measure cylinder liner protrusion on the cylinder block.</p>	 <p>3823495</p>
3823521	<p>Expansion Plug Driver</p> <p>Install 0.8125-inch expansion plug to specified depth. Used with expansion plug driver handle, Part Number 3376795.</p>	 <p>3823521</p>
3823522	<p>Expansion Plug Driver</p> <p>Install 1.1875-inch expansion plug to specified depth. Used with expansion plug driver handle, Part Number 3376795.</p>	 <p>3823522</p>
3823523	<p>Expansion Plug Driver</p> <p>Install 1.375-inch expansion plug to specified depth. Used with expansion plug driver handle, Part Number 3376795.</p>	 <p>3823523</p>
3823524	<p>Expansion Plug Driver</p> <p>Used to install 2.250-inch expansion plug to specified depth. Used with expansion plug driver handle, Part Number 3376795.</p>	 <p>3823524</p>

Tool No.	Tool Description	Tool Illustration
3823589	<p>Camshaft Gear Installation/Removal Tool Used to remove and install the camshaft gear from the camshaft with the camshaft installed.</p>	
3823818	<p>Main Bearing Rollout Tool Used to remove and install main bearings with the crankshaft installed.</p>	
3823567	<p>Cutter Plate Used with Part Number 3823558, cylinder liner counterbore tool.</p>	
3823570	<p>Cutter Bit Used with Part Number 3826567, cutter plate, to machine the cylinder liner counterbore ledge.</p>	
3824078	<p>Wear Sleeve Installation Tool Used to install the rear crankshaft lubricating oil seal wear sleeve.</p>	
3824499	<p>Lubricating Oil Seal Installation Tool Used to install the front lubricating oil seal in the front cover to a specified depth.</p>	
3823921	<p>Capscrew Length Gauge Used to measure capscrew free length.</p>	
3375068	<p>Cup Plug Sealant Used when installing pipe plugs and cup plugs to prevent leaks.</p>	

Tool No.	Tool Description	Tool Illustration
3165045	Camshaft Bushing Tool Used to replace camshaft bushings. NOTE: The following 2 kits are also available for this purpose.	 <p>01900239</p>
3823621	Hydraulic Actuator Kit Used to remove and install camshaft bushings.	 <p>3823621</p>
3162253	Camshaft Bushing Installation/Removal Kit Used to remove and install camshaft bushings.	 <p>3162253</p>

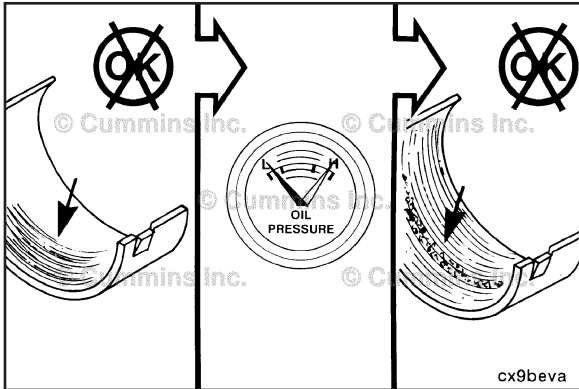
Bearings, Connecting Rod (001-005) General Information

The connecting rod bearings are a trimetal design with a steel backing.

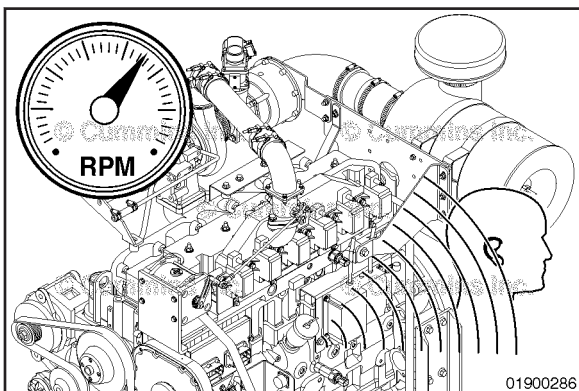


Improper maintenance of the lubrication system is the primary cause of reduced bearing life.

An oil analysis will aid in determining the extent of internal engine damage. Refer to Procedure 007-083 in Section 7 for more information. For additional oil analysis, refer to Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340.

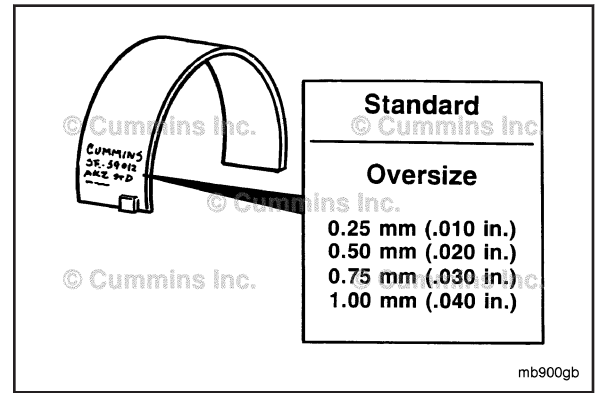


Normally, worn bearings can be detected by reduced oil pressure, but if this wear goes undetected, the excessive clearance will increase the impact between the bearing and crankshaft, causing a distinct knocking sound.



A connecting rod noise occurs when the engine is **not** loaded. Verify by first applying a load and then unloading and listening for the noise.

The connecting rod bearing shells are identified by steel-stamped characters on the back of the bearings. The characters indicate either standard (STD) or the amount of oversize (OS).



Preparatory Steps

⚠️ WARNING ⚠️

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

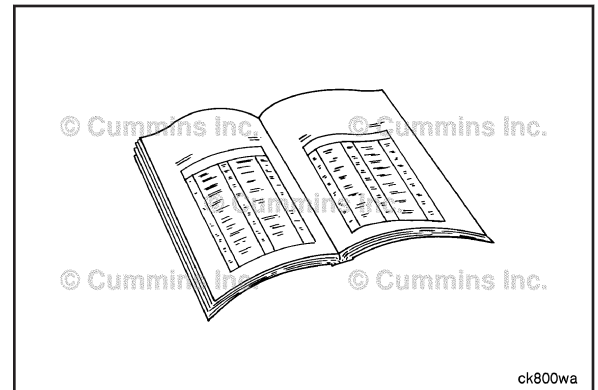
⚠️ WARNING ⚠️

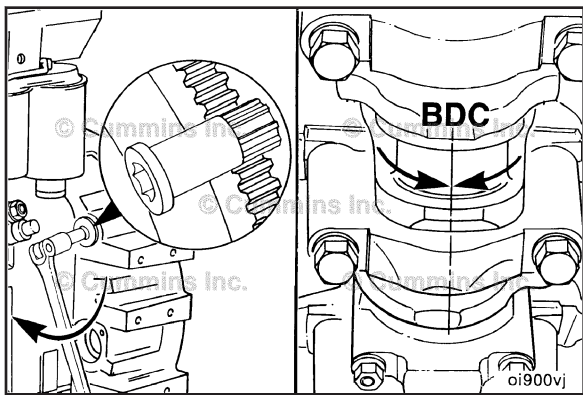
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠️ WARNING ⚠️

Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.

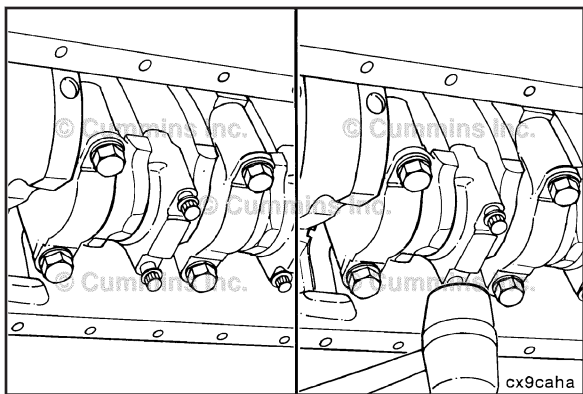
- Close the fuel supply valve. Refer to the OEM instructions.
- Disconnect the batteries. Refer to the OEM service manual.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan and gasket. Refer to Procedure 007-025 in Section 7.
- Remove the oil suction tube. Refer to Procedure 007-035 in Section 7.





Remove

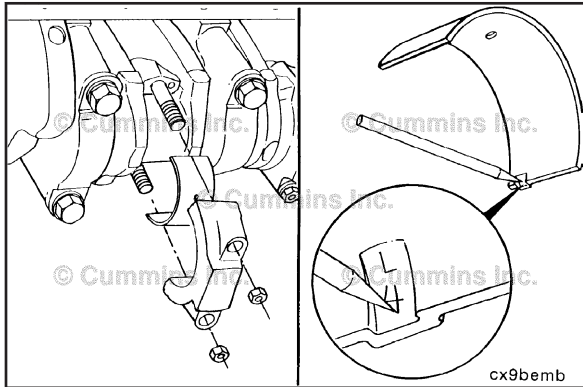
Rotate the crankshaft, using the engine barring gear, Part Number 3377371, to position two of the connecting rods at bottom dead center.



Loosen the connecting rod capscrew nuts.

Do **not** remove the capscrew nuts.

Hit the connecting rod capscrew nuts with a plastic hammer to loosen the rod caps.

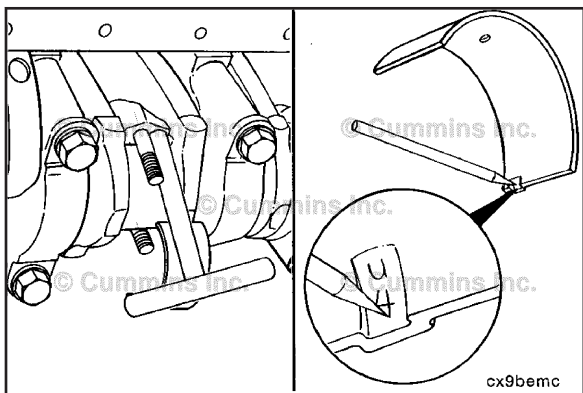


⚠CAUTION⚠

The connecting rod bearings must be installed in the same location they were removed from if they are reused. Failure to install the connecting rod bearings in the same location will cause engine damage.

Remove the connecting rod capscrew nuts and rod cap.

Remove the bearing shell from the rod cap, and mark it as the lower bearing shell from the connecting rod number from where it was removed.



Push the connecting rod up far enough to allow the upper bearing shell to be removed.

Remove the bearing shell, and mark it as the upper bearing shell and the connecting rod number from where it was removed.

Clean and Inspect for Reuse

⚠️ WARNING ⚠️

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

⚠️ WARNING ⚠️

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

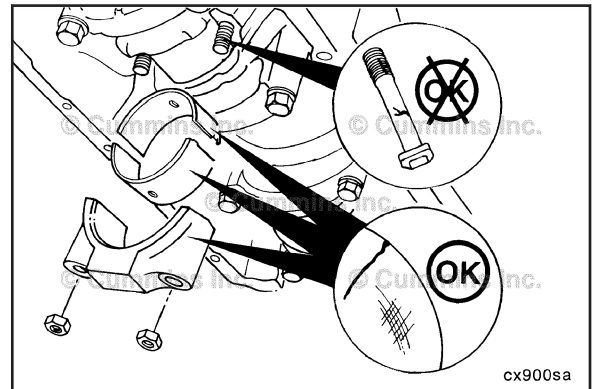
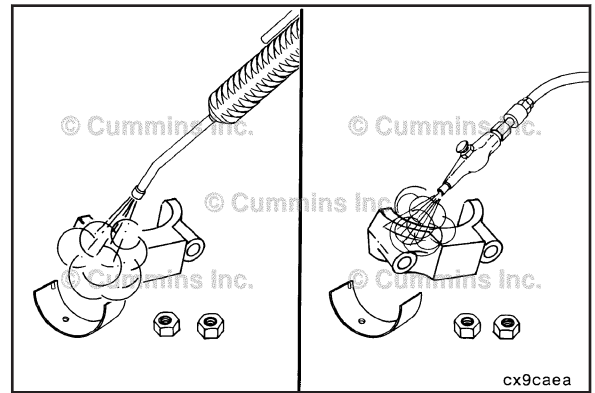
⚠️ WARNING ⚠️

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

Use solvent and a soft bristle brush or a steam cleaner to clean the cap, capscrews, and bearings.

Dry the connecting rod cap, bearings, and capscrews with compressed air.

Inspect the connecting rod caps, connecting rod bearing saddles, and capscrews for nicks, cracks, burrs, scratches, or fretting.

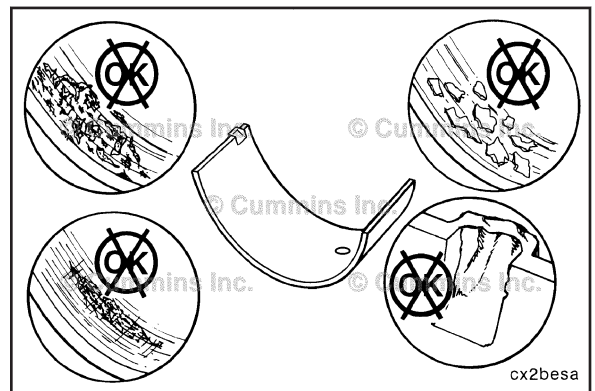


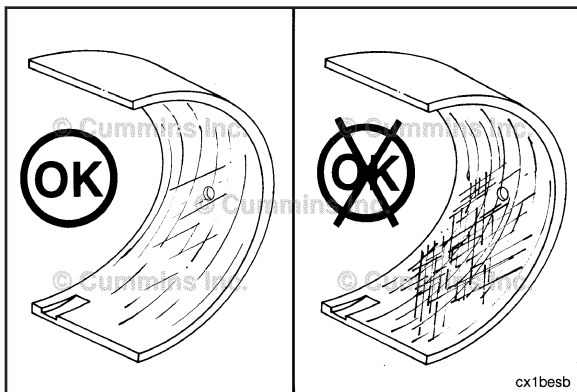
Inspect the bearings for damage. Refer to the Parts Reuse Guidelines, Bulletin 3810303, for information on bearing inspection.

Replace any bearings with lock tang damage or scratches deep enough to be felt with a fingernail.

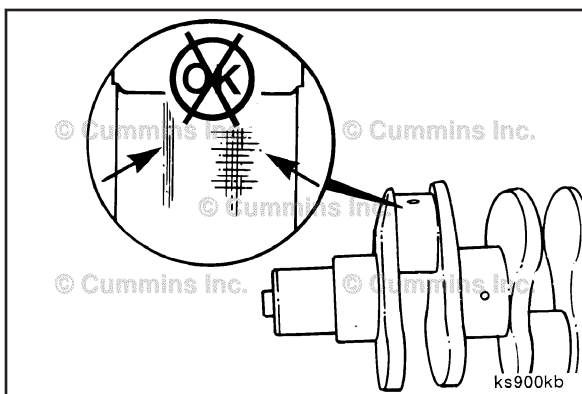
Replace any bearings that show pitting, flaking, or corrosion into the lining.

NOTE: If bearings are damaged, they **must** be replaced as a set.

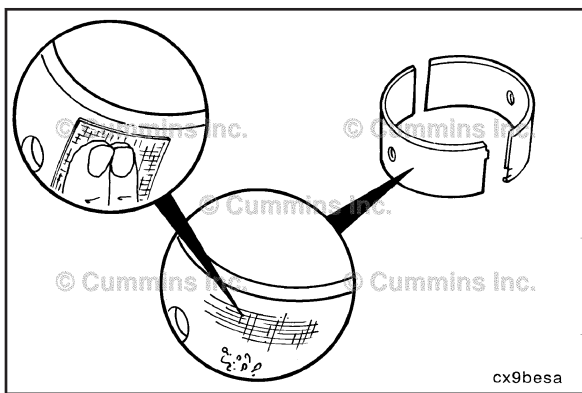




NOTE: Normal bearing wear produces a smooth finish that will wear into the lining. An exposed lining does **not always** indicate worn bearings. If large areas of the lining are visible in the bearings before the engine has accumulated 240,000 km [150,000 mi] or 3750 hours, inspect the engine for contamination from fine dirt particles, and correct the problem.



Inspect the crankshaft rod journals. Refer to Procedure 001-006 in Section 1.



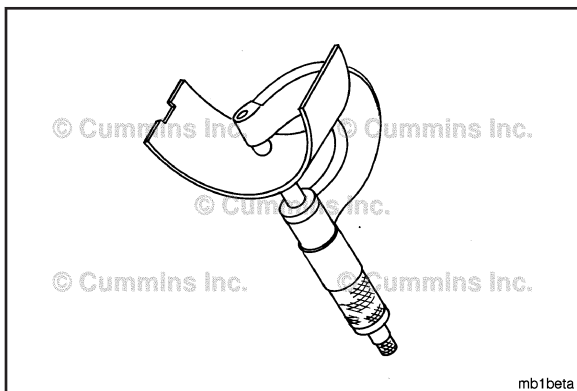
Inspect the bearing shell seating surface for nicks or burrs.



If nicks or burrs can **not** be removed with Scotch-Brite™ 7448, Part Number 3823258, the bearings **must** be replaced.



NOTE: For more detailed information on bearing damage, refer to Analysis and Prevention of Bearing Failures, Bulletin 3810387.



Measure the rod bearing shell thickness with an outside micrometer that has a ball tip.

Standard Connecting Rod Bearing Thickness (Used)

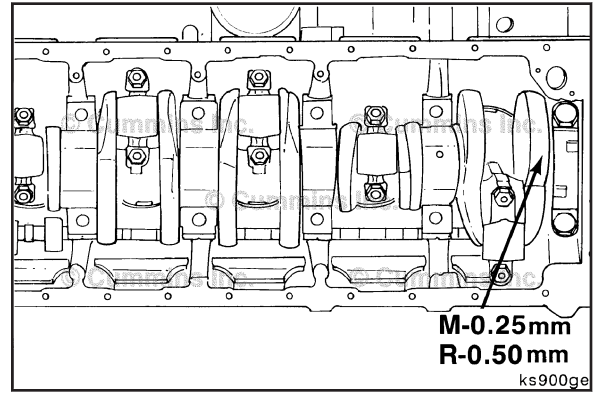
mm		in
2.43	MIN	0.096
2.47	MAX	0.097

The bearing **must** be replaced if it is below the minimum specification.

NOTE: Connecting rod bearings are identified with a part number and size stamped on the back.

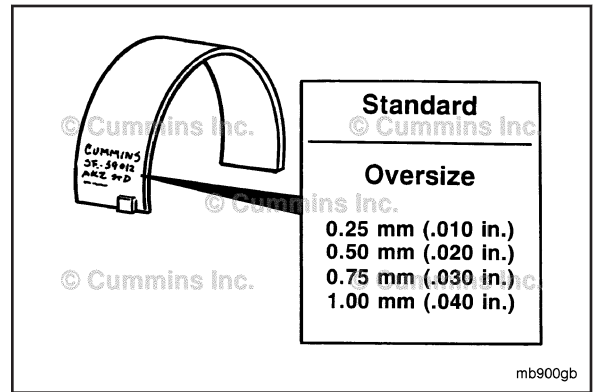
Determine the size of the removed rod bearing and obtain a set of new connecting rod bearings the same size.

NOTE: Oversize service rod bearings are available for use with crankshafts that have been machined undersize. See the appropriate parts catalog.



Crankshafts that are machined undersize in the connecting rod or main bearing journals are marked on the front counterweight. If the crankshaft is marked, check the bearing shell part number to make sure the correct bearing size is used.

Bearing shells are identified by steel-stamped characters on the back of the bearings to indicate either standard (STD) or amount oversize (OS).



Install

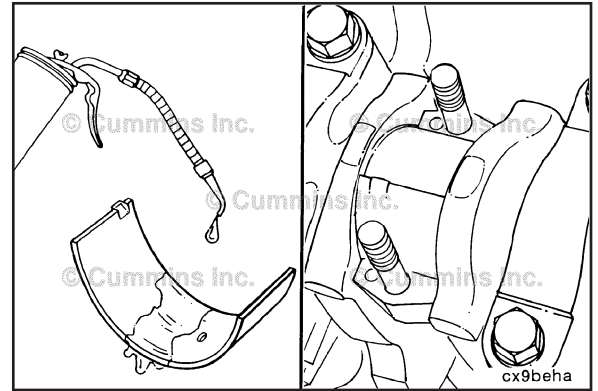
⚠ CAUTION ⚠

The connecting rod bearings must be installed in the same location they were removed from if they are reused. Failure to install the connecting rod bearings in the same location will cause engine damage.

Use clean engine oil to lubricate the crankshaft journal mating surface of the upper bearing shell.

Install the upper bearing shell in the connecting rod with the tang of the bearing in the slot of the rod.

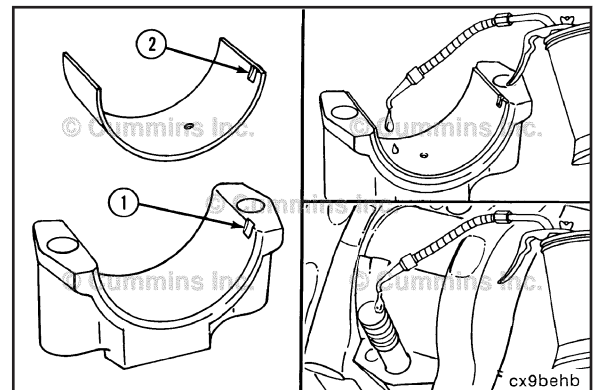
Pull the connecting rod against the crankshaft to hold the bearing in place.

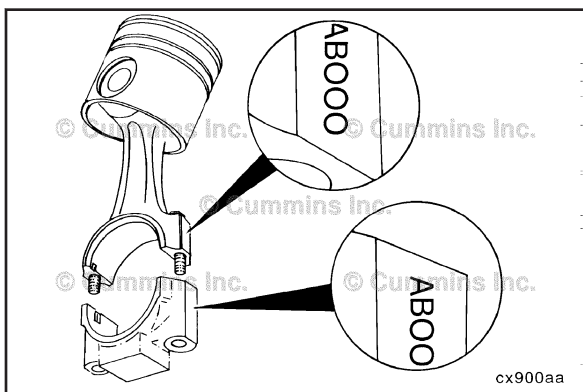


Install the bearing shell in the connecting rod cap with the tang (2) of the bearing in the slot (1) of the cap.

Use clean engine oil to lubricate the bearing shell to crankshaft journal mating surface.

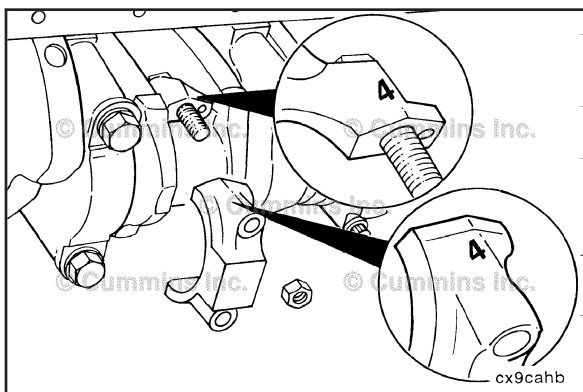
Use clean engine oil to lubricate the threads of the connecting rod capscrews.





NOTE: Unique serial numbers (**not** cylinder numbers) are stamped on the connecting rod and matching connecting rod cap.

When the connecting rods and connecting rod caps are installed in the engine, the numbers on the connecting rods and connecting rod caps **must** match and be installed on the same side of the engine.



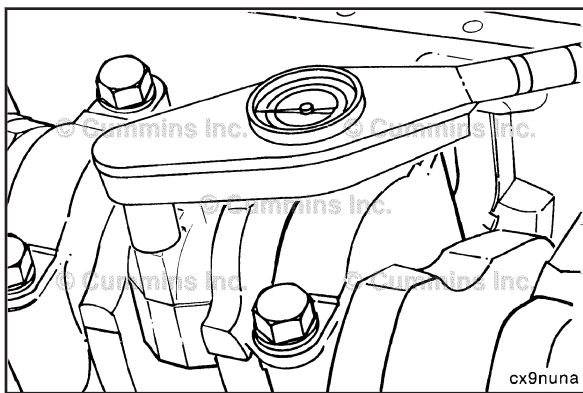
⚠ CAUTION ⚠

The connecting rod cap number must match the number on the connecting rod and must be installed with the numbers aligned to prevent damage to the connecting rods and the crankshaft. The locking tang of the connecting rod cap must be toward the camshaft side of the cylinder block.



Lubricate under the connecting rod capscrew nuts with clean engine oil.

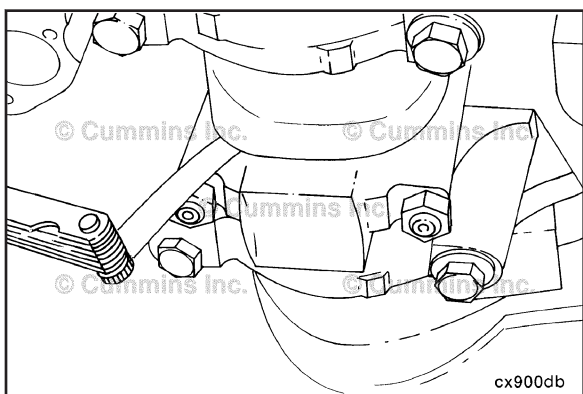
Install the connecting rod caps and rod capscrew nuts.



Tighten the connecting rod capscrew nuts in alternating sequence.

Torque Value:

Step 1	30 N•m	[22 ft-lb]
Step 2	70 N•m	[52 ft-lb]
Step 3	60° turn	



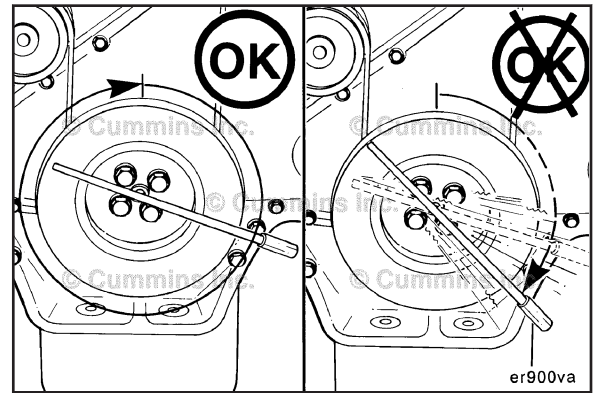
Measure the side clearance between the connecting rod and crankshaft.

Connecting Rod Side Clearance

mm		in
0.10	MIN	0.004
0.33	MAX	0.013

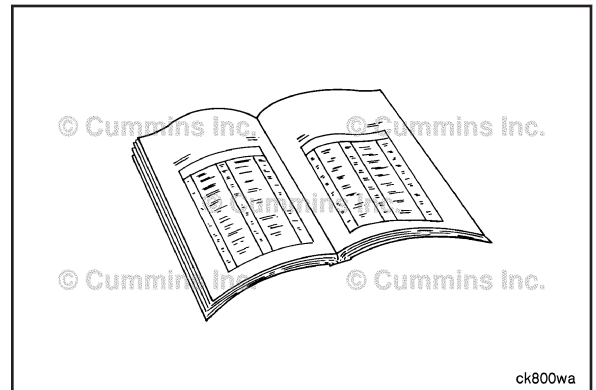
NOTE: The crankshaft **must** rotate freely.

Check for freedom of rotation as the caps are installed. If the crankshaft does **not** rotate freely, check the installation of the rod bearings and the bearing size.



Finishing Steps

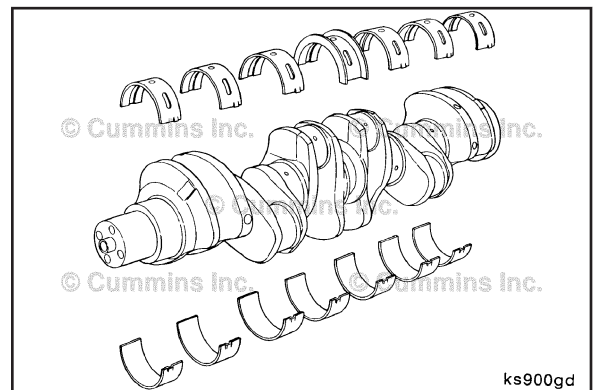
- Install the oil suction tube. Refer to Procedure 007-035 in Section 7.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Fill the oil pan with clean engine oil. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. Refer to the OEM service manual.
- Open the fuel supply valve. Refer to the OEM instructions.
- Operate the engine until the coolant temperature reaches 82°C [180°F], and check for leaks and proper operation.

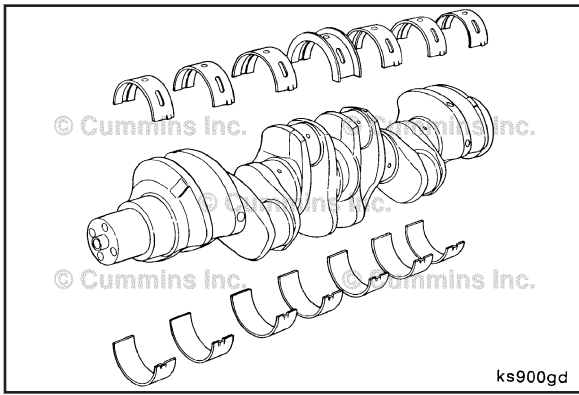


Bearings, Main (001-006)

General Information

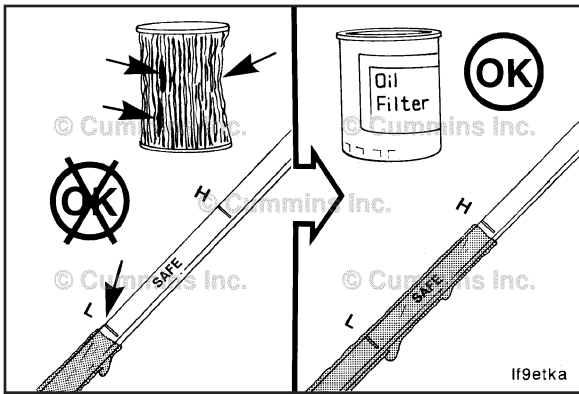
The C Series engine has seven main bearings. The lower bearing shells are all the same. The upper bearings do **not** have holes. All of the upper bearing shells are the same except for the Number 4 journal. The Number 4 journal uses a flanged upper bearing shell. The flanges on the bearing control the end thrust of the crankshaft.



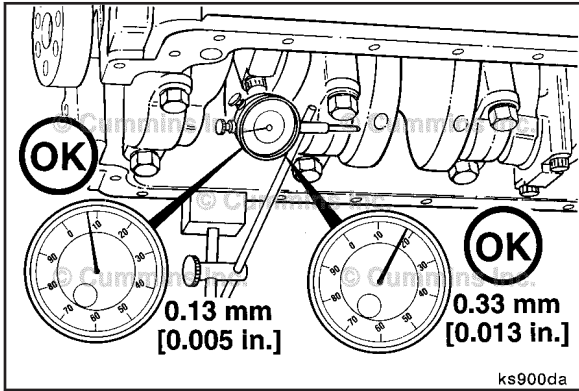


NOTE: Oversize service main bearings are available for reground crankshafts.

Main Bearing Sizes	
Standard	
Oversize	- 0.25 mm (0.009 in)
	- 0.50 mm (0.019 in)
	- 0.75 mm (0.029 in)
	- 1.00 mm (0.039 in)



Improper maintenance of the lubricating system is the primary cause of reduced main bearing life.



Increased end loading of the engine and its driven units at the front or rear of the engine can cause damage to the thrust bearings.

Preparatory Steps

⚠️ WARNING ⚠️

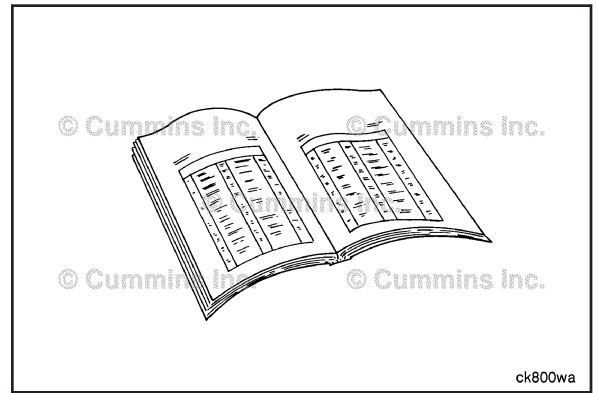
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠️ WARNING ⚠️

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

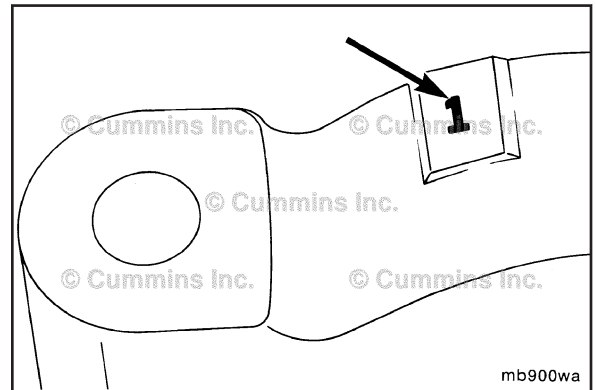
Drain the lubricating oil. Refer to Procedure 007-037.

Remove the lubricating oil pan and gasket. Refer to Procedure 007-025.



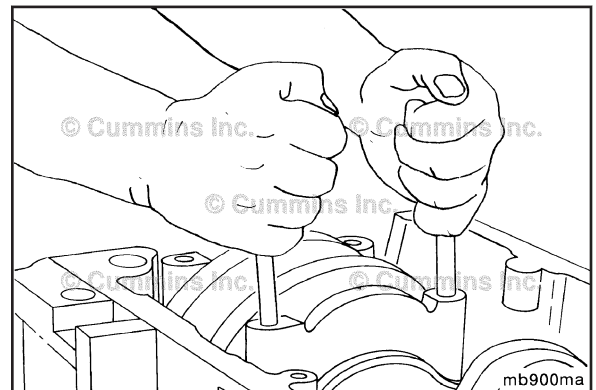
Remove

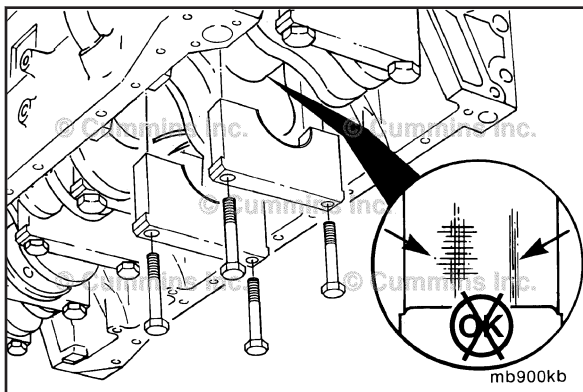
NOTE: Before removing the main bearing caps, make sure that the caps are clearly marked for their location on the lubricating oil cooler side of the main bearing cap.



NOTE: Do not pry on the main caps to free them from the cylinder block.

Use two of the main bearing cap bolts to “wiggle” the main cap loose. Try **not** to damage the bolt threads.

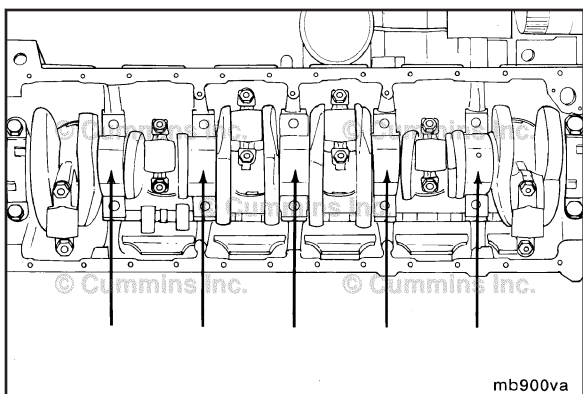




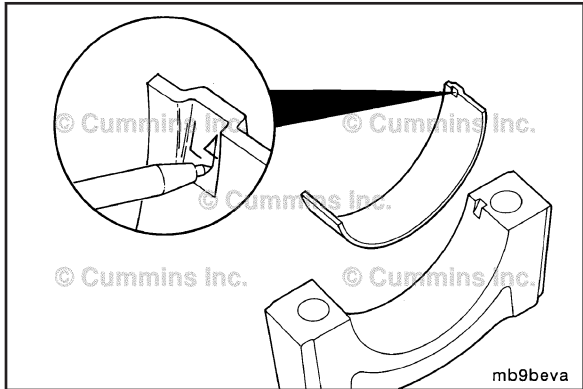
Remove the Number 2 and Number 3 main bearing caps; check the crankshaft journals for signs of overheating, deep scratches, or other damage. If there is no damage, there is no need to remove the other main bearing caps at this time.



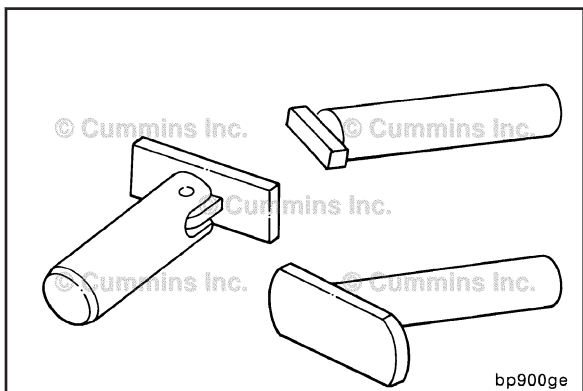
NOTE: The Number 4 main bearing cap has a thrust bearing.



If the main bearings are to be removed, remove all bearing caps except for cylinders Number 1 and 7.



Mark the main bearing shell with the letter L (lower) and the journal number from which it was removed.



⚠CAUTION⚠

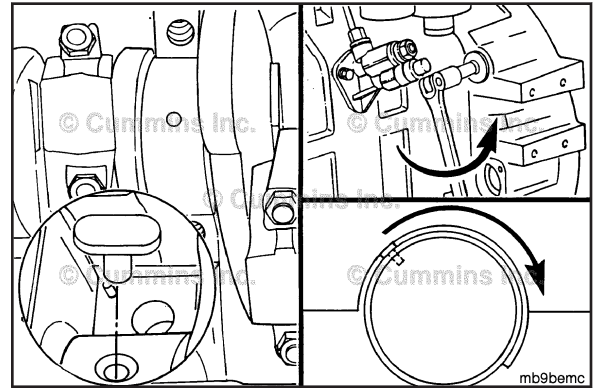
Do not use a capscrew or any hard metal object; they can damage the crankshaft and cause serious engine damage.

To remove the upper main bearing shell, install the main bearing rollout tool, Part Number 3823818, in the oil hole of the main bearing journal.

Using the engine barring tool, Part Number 3377371, rotate the crankshaft so the main bearing rollout tool, Part Number 3823818, pushes against the end of the bearing opposite the tang.

Continue rotating the engine to remove the bearing.

Follow this procedure to remove the other bearings.

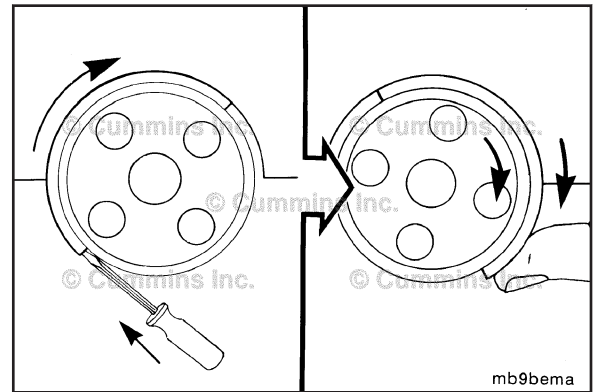


⚠CAUTION⚠

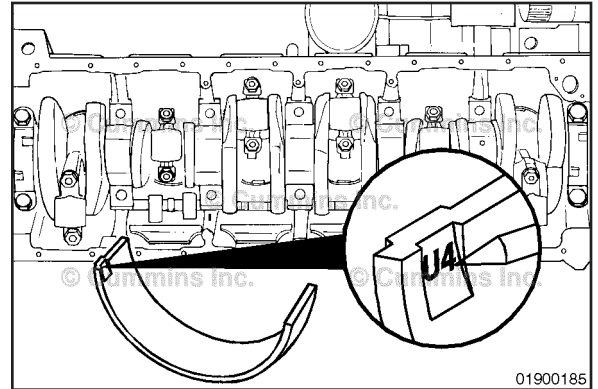
Use care so the screwdriver does not damage the crankshaft or cylinder block.

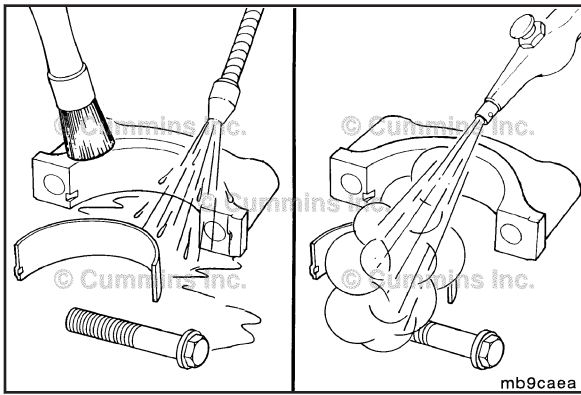
NOTE: The Number 1 main does **not** have a hole in the journal, so the bearing rollout tool can **not** be used to replace the bearing.

Use a flat-blade screwdriver. **Gently** bump the end of the bearing to loosen it from the block. Then, use finger-pressure against the bearing shell, and rotate the crankshaft to roll the bearing out.



Mark the main bearing shell with the letter U (upper) and the journal number from which it was removed.





Clean and Inspect for Reuse

⚠️ WARNING ⚠️

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

⚠️ WARNING ⚠️

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

⚠️ WARNING ⚠️

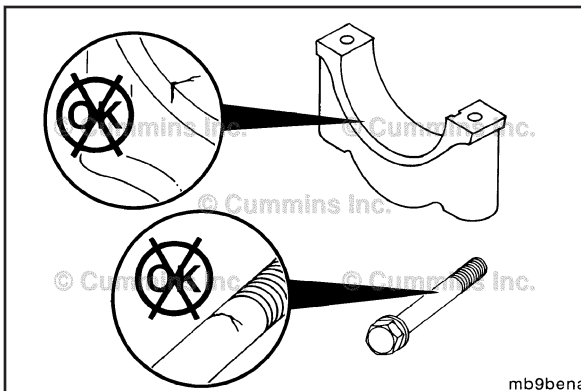
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠️ CAUTION ⚠️

Do not use a scraper or wire brush to clean the main bearing. Bearing damage can occur.

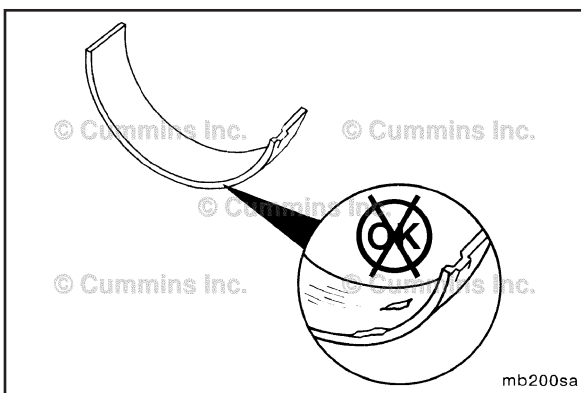
Use solvent and a soft bristle brush to clean the cap, capscrews, and bearings.

Dry the main bearing caps, capscrews, and main bearings with compressed air.



Inspect the main cap and capscrews for damage.

Inspect the bearing shells and the thrust bearings for nicks, scratches, or damage.



Inspect the main bearings for nicks, scratches, or damage.

Replace any bearing with the following damage:



- Pitting
- Flaking
- Corrosion
- Lock Tang Damage
- Scratches (deep enough to be felt with a fingernail).

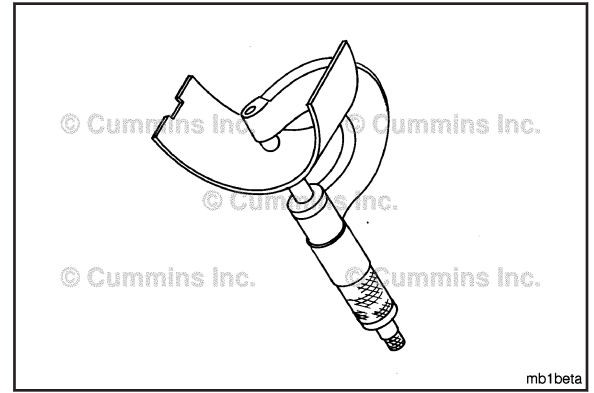
NOTE: For more detailed information on bearing damage, refer to Analysis and Prevention of Bearing Failures, Bulletin Number 3810387, or Parts Reuse Guidelines, Bulletin Number 3810303.

Use an outside diameter ball-tipped micrometer to measure the main bearing shell thickness.

Standard Main Bearing Shell Thickness

mm		in
3.446	MIN	0.1357
3.454	MAX	0.1360

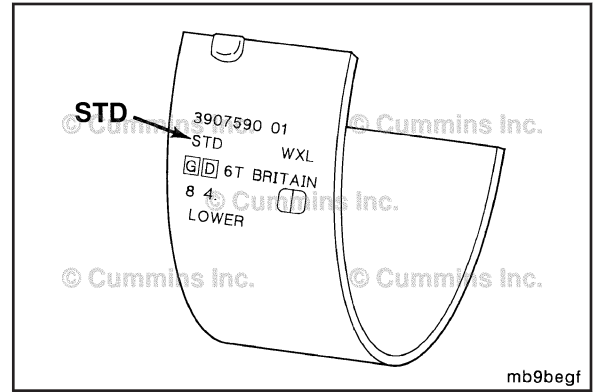
Discard any main bearing shell if it is below the minimum specification.



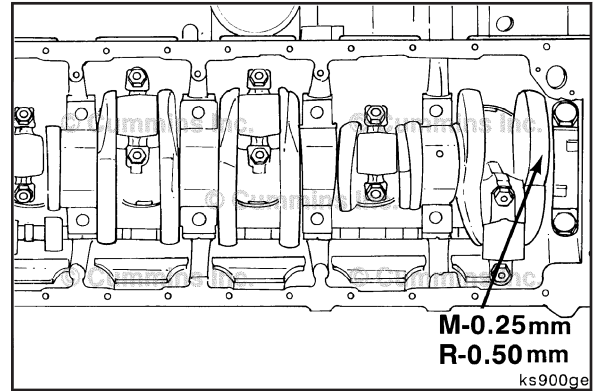
NOTE: The upper bearings contain two oil holes. The lower bearings do **not**.

The main bearings are marked on the back to indicate either standard (STD) or oversize (OS).

Determine the size of the bearing removed, and obtain the same size for installation.



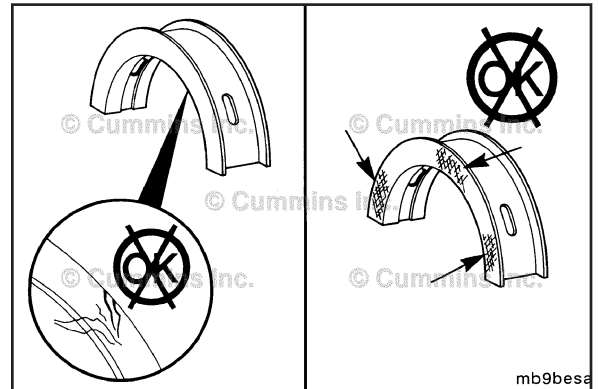
NOTE: Main bearing shells are available for crankshafts that are 0.50 mm [0.020 in] undersize. Crankshafts that are machined undersize in the connecting rod and main bearing journals are marked on the front counterweight. If the crankshaft is marked, check the bearing shell part number to make sure the correct bearing size is used.

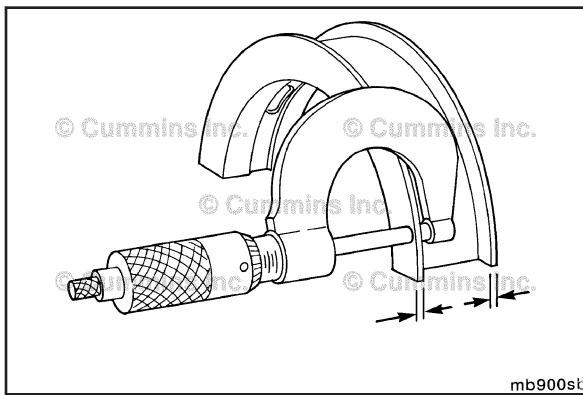


Thrust Bearing

Inspect the thrust bearings for wear, cracks, and damage on the front and rear face.

Inspect the crankshaft journal contact area.





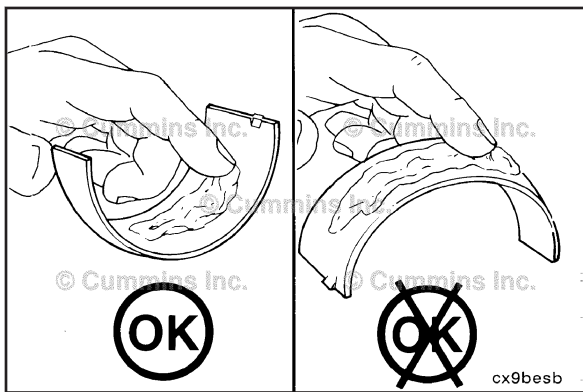
Measure the thrust bearing flange thickness. Measure both the front and rear flange of the thrust bearing.



Thrust Bearing Flange Thickness

mm		in
3.52	MIN	0.139
3.57	MAX	0.141

NOTE: The thrust bearings are available in 0.25-mm [0.010-in] and 0.50-mm [0.020-in] oversize thicknesses.



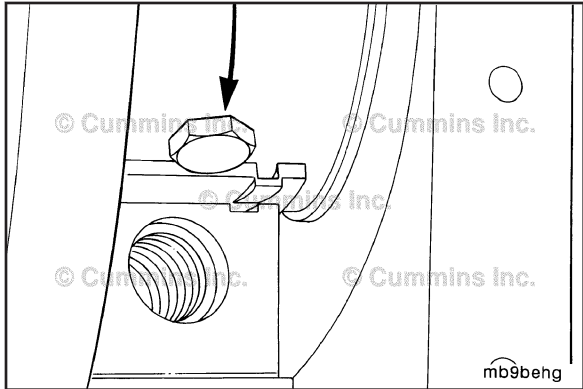
Install

⚠CAUTION⚠

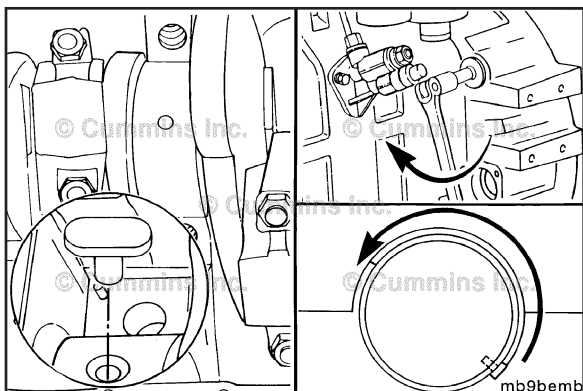
The cylinder block saddle and the main bearing cap mating surfaces must be clean and dry when the bearing shells are installed. Used bearings must be installed in their original location.

NOTE: Do not lubricate the back of the bearing shell.

Use clean engine oil to lubricate the upper main bearing shell to the crankshaft journal mating surface.



Position the new upper main bearing on the crankshaft and install as far as possible by hand.



⚠CAUTION⚠

Make sure the pin does not slide under the bearing and damage the crankshaft.

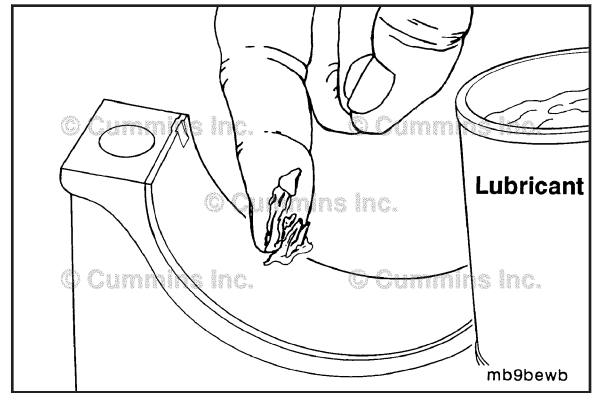
Use the main bearing rollout tool, Part Number 3823818, and the engine barring tool, Part Number 3377371, to finish pushing the bearing into position. Make sure the upper main bearing is aligned with the block and that the bearing tang aligns with the notch in the cylinder block.

C Series
Section 1 - Cylinder Block - Group 01

Install the lower main bearings into the bearing caps.

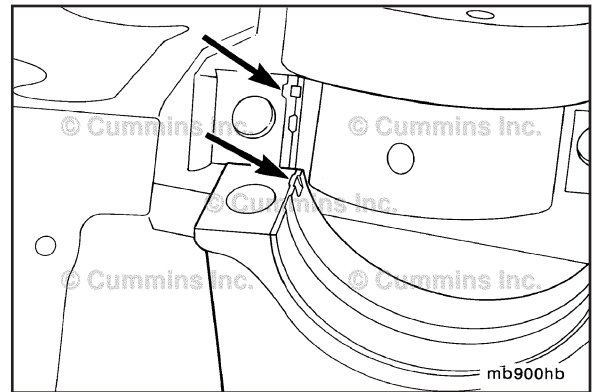
NOTE: Make sure the tang of the bearing shell is in the slot of the cap.

Use clean engine oil to lubricate the bearing shells.

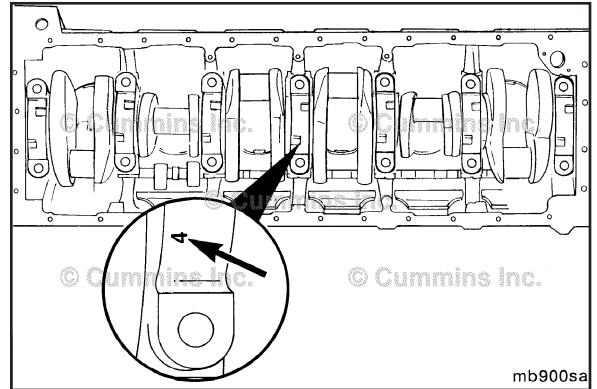


NOTE: The main bearing caps are numbered for location. Number 1 starts with the front of the block, and the numbers face the camshaft side of the engine.

When correctly installed, the tang (slots) will both be on the same side of the cylinder block.

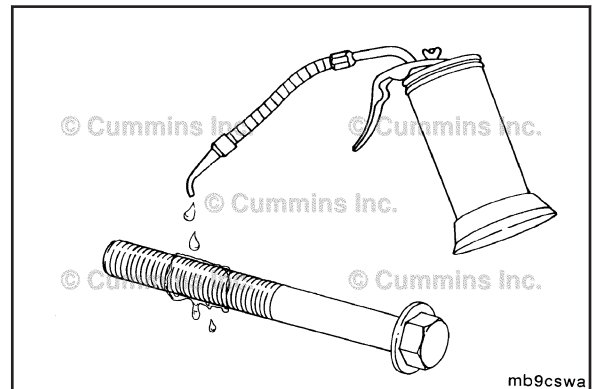


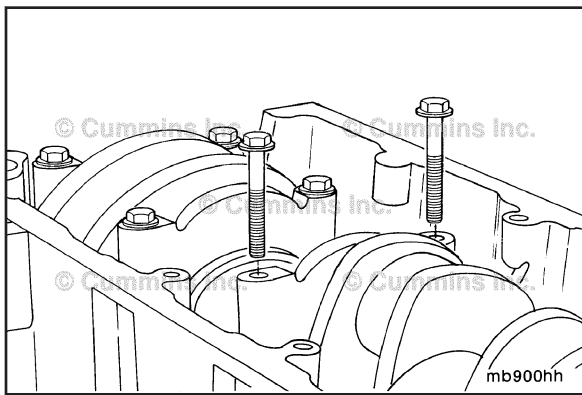
NOTE: The thrust bearing journal does **not** have locking tangs. Care **must** be taken to **make** sure that the number stamped on the main bearing cap is positioned facing the camshaft side of the engine.



Use clean engine oil to lubricate the capscrew threads.

Drain the excess oil from the capscrews before installing them.

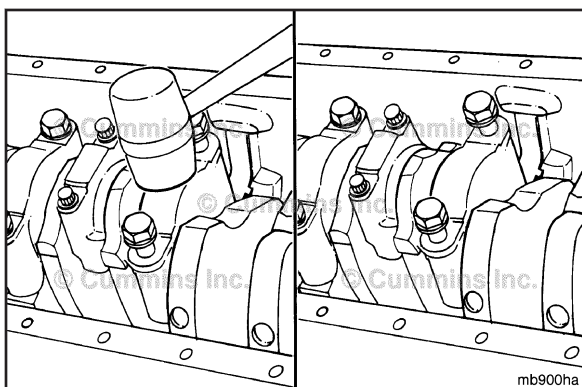




Tap the main bearing caps gently into position.

NOTE: Make sure the bearing does **not** become dislodged from the cap.

When seated, the main bearing cap bolts can be threaded by hand.



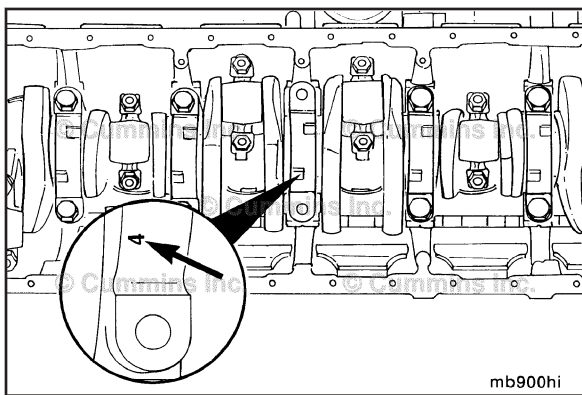
Install a main bearing cap after each upper bearing is installed to keep the bearing in place while the other uppers are installed.



NOTE: Do **not** tighten the main bearing cap capscrews to the final torque value at this time.

Tighten the capscrews to an initial torque.

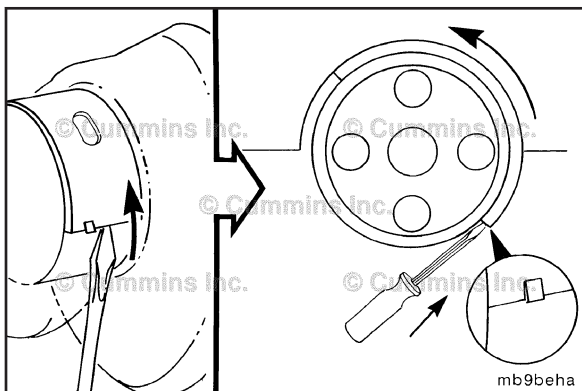
Torque Value: 50 N•m [37 ft-lb]



NOTE: The thrust journal does **not** have tangs or slots.

NOTE: Make sure the number stamped on the main bearing cap is positioned facing the camshaft side of the cylinder block.

Push the crankshaft toward the center of its end thrust position to allow clearance for the thrust bearing.

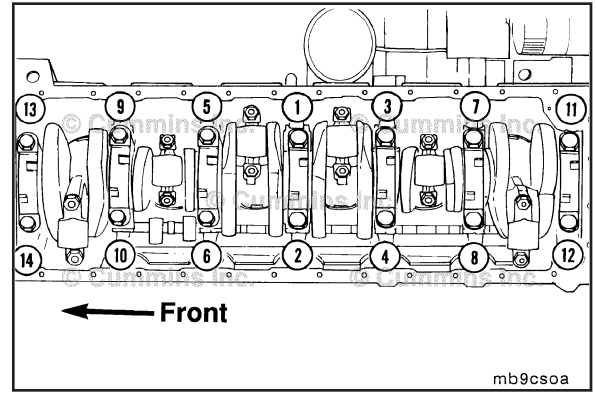


Since the main bearing rollout tool, Part Number 3323818, **cannot** be used for the Number 1 main bearing, use a blunt object or screwdriver to push the bearing into position as the crankshaft is rotated.

Tighten the capscrews evenly following the sequence shown.



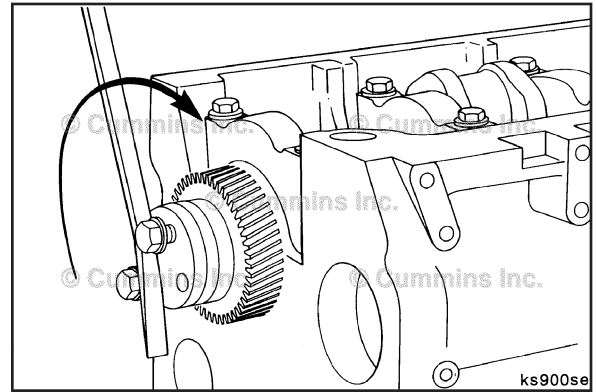
Torque Value: Step1	50 N•m	[37 ft-lb]
Step2	95 N•m	[70 ft-lb]
Step3	60° turn.	



NOTE: The crankshaft **must** rotate freely after the main bearings have been tightened.

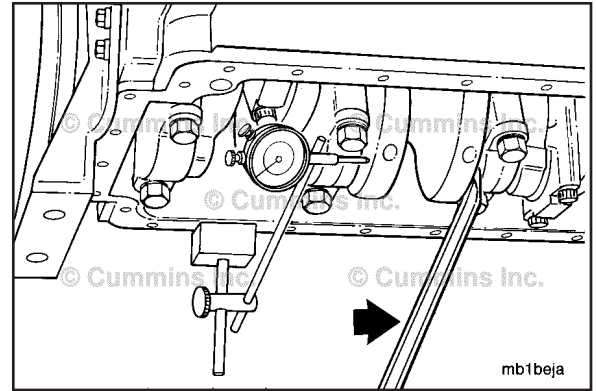


Check the main bearing installation and the size of the main bearings if the crankshaft does **not** rotate freely.

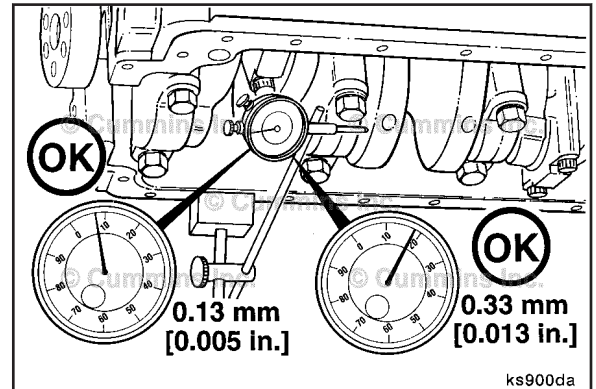


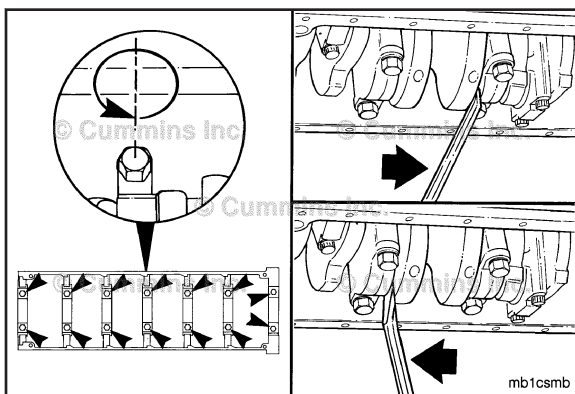
Measure the end clearance of the crankshaft as follows:

- Install a dial indicator onto the oil pan flange.
- Put the tip of the gauge against the crankshaft counterweight.
- Push the crankshaft toward the rear of the cylinder block.



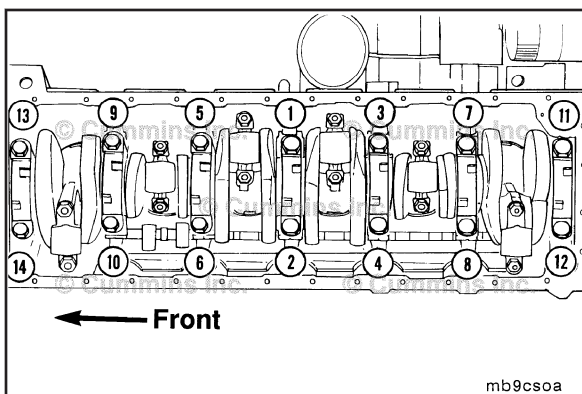
- Set the dial indicator at zero.
- Push the crankshaft toward the front of the cylinder block.





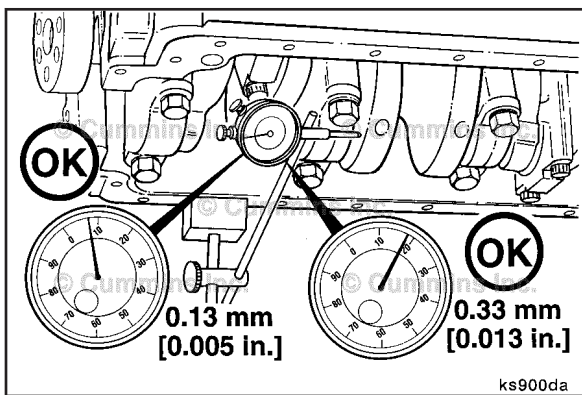
If the end clearance is less than 0.127 mm [0.005 in], do the following:

- Loosen the main bearing capscrews one turn.
- Push the crankshaft toward the front and then toward the rear of the cylinder block.



Tighten the main bearing capscrews in the sequence shown.

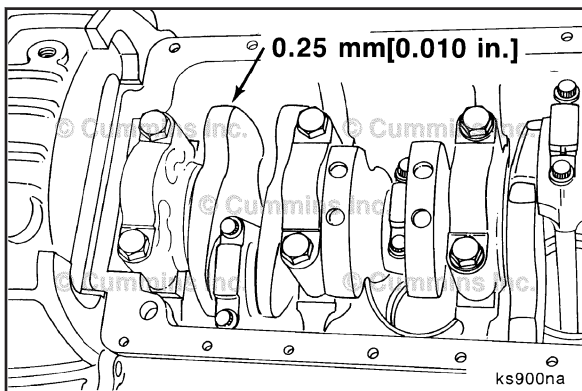
Torque Value:	Step1	50 N•m	[37 ft-lb]
	Step2	95 N•m	[70 ft-lb]
	Step3	60° turn.	



Measure the crankshaft end clearance.

Crankshaft End Clearance

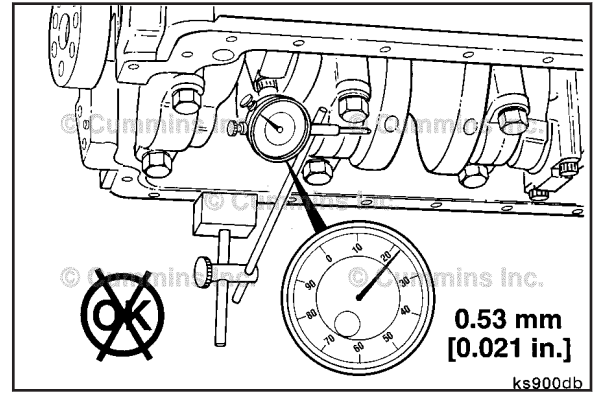
mm		in
0.127	MIN	0.005
0.330	MAX	0.013



NOTE: Crankshafts that have been reground on the thrust bearing surfaces are marked for oversize thrust bearings on the rear crankshaft counterweight. If the crankshaft counterweight is marked, check the thrust bearing part number to make sure the correct bearing size is used.

Example: 0.010 = 0.25 mm [0.010 in]

If the crankshaft end play is more than 0.330 mm [0.013 in] new, or 0.533 mm [0.021 in] used, the crankshaft **must** be removed from the engine and replaced.



Finishing Steps

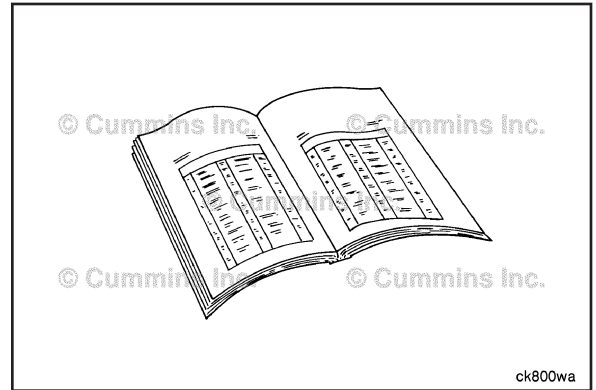
Install the oil suction tube. Refer to Procedure 007-035.

Install the oil pan. Refer to Procedure 007-025.

Fill the engine with lubricating oil. Refer to Procedure 007-037.

NOTE: Use **only** Cummins™ approved lubricating oil for natural gas engines to prevent premature engine damage.

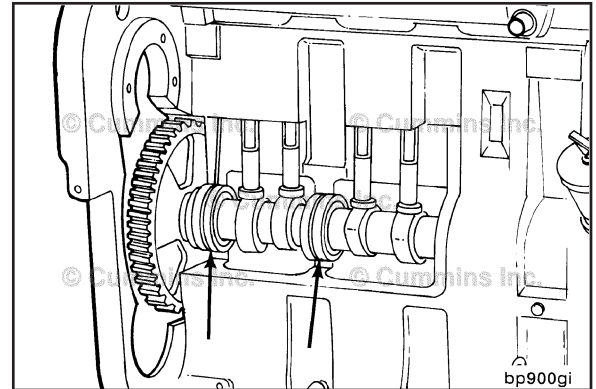
Operate the engine until the coolant temperature reaches 82°C [180°F], and check for lubricating oil leaks.



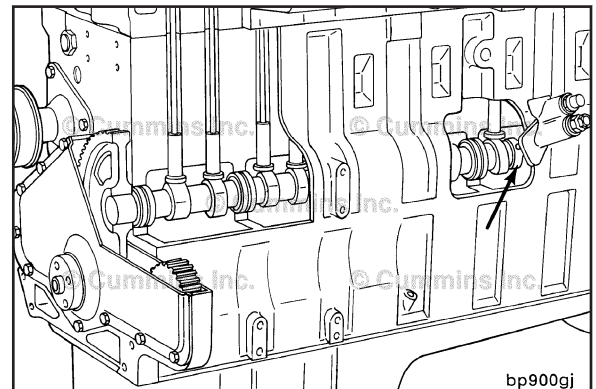
Camshaft (001-008)

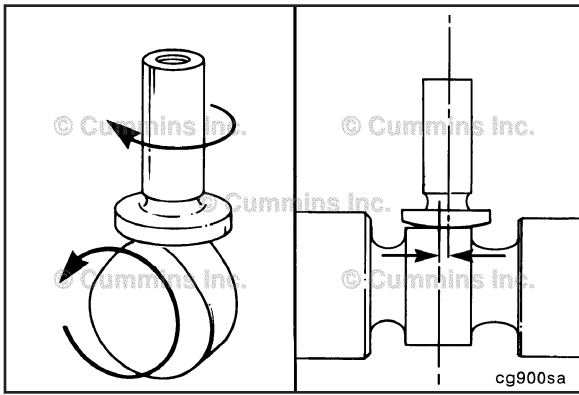
General Information

The camshaft is gear-driven from the crankshaft. A replaceable bushing is used for each of the camshaft journals.

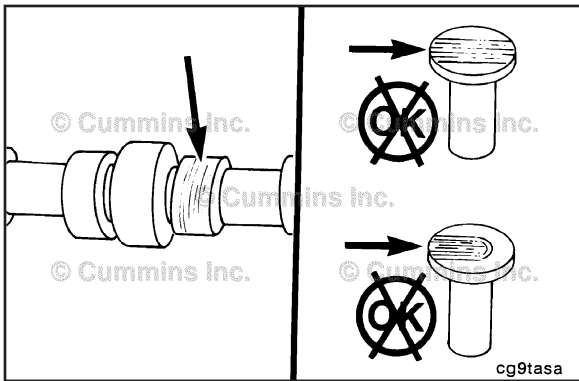


The camshaft has lobes to operate the intake and exhaust valves. The valve lobes contact the valve tappets, which operate the valves. The profile of the camshaft lobes is the same for all C Series engines.



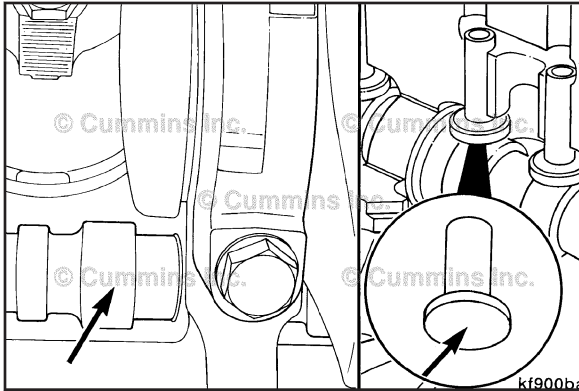


The tappets are mushroom-shaped. The offset position of the tappet against the camshaft lobe causes the tappet to rotate as it lifts the push rod.



Diagnosing Malfunctions

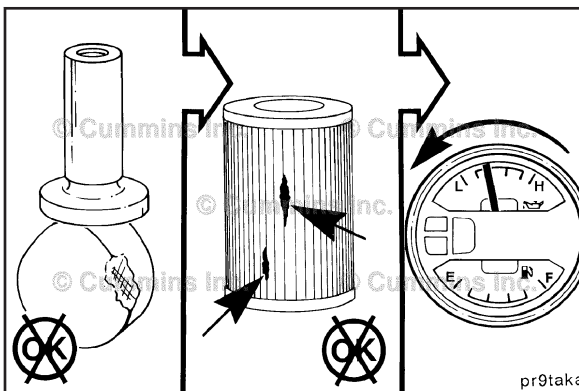
Loose rocker levers and the need to reset the valve clearance frequently can indicate camshaft lobe or tappet wear. If an inspection of the levers, valve stems, and push rods does **not** reveal wear, tappet or camshaft lobe wear should be suspected.



⚠CAUTION⚠

To reduce the possibility of engine damage, any time a new camshaft is installed new tappets and push rods must also be installed.

The camshaft lobes can be inspected after removing the oil pan. Similarly, the faces of the tappets can be inspected after removing the push rods and lifting the tappets.



A severely damaged camshaft journal(s) can generate small metal particles that can be found in the oil pan and oil filter. These metal particles will also be indicated as iron in an oil analysis. As the clearance in the journal(s) increases, a small decrease in oil pressure can be detected.

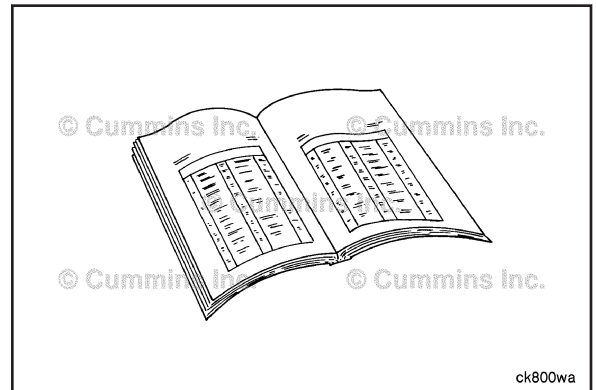
The camshaft end clearance is determined by the clearance between the camshaft and the thrust plate. The camshaft gear **must** be removed to adjust the camshaft end clearance.

NOTE: The camshaft does **not** have to be removed to remove the camshaft gear. Use the camshaft gear puller, Part Number 3376400.

Camshafts that are damaged or worn on the injector or valve lobes **must** be replaced. Cummins Inc. does **not** recommend grinding camshaft lobes.

Preparatory Steps

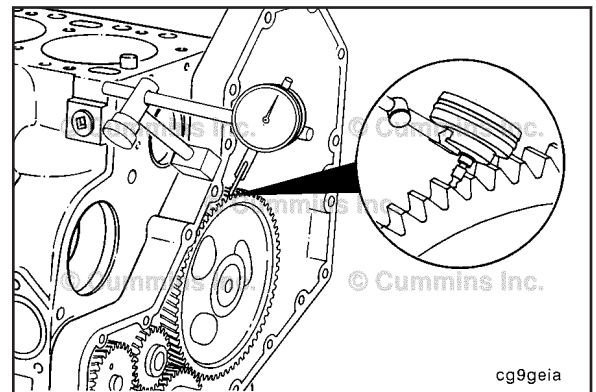
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the rocker levers. Refer to Procedure 003-008 in Section 3.
- Remove the push rods. Refer to Procedure 004-014 in Section 4.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the vibration damper. Refer to Procedure 001-052 in Section 1.
- Remove the front gear cover. Refer to Procedure 001-031 in Section 1.

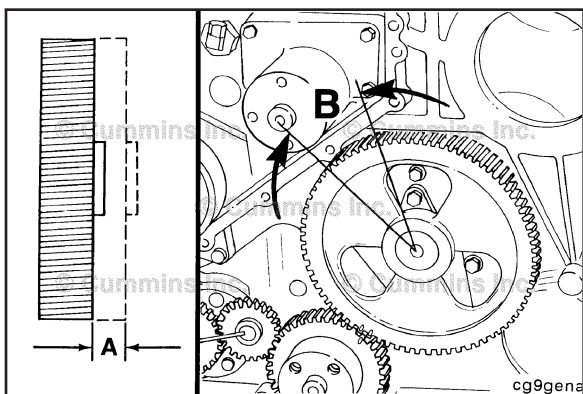


Initial Check

NOTE: If the camshaft or camshaft gear is replaced due to gear train noise, check the gear train backlash. Excessive gear backlash can be caused by worn camshaft bushings.

Position a dial indicator on a tooth of the camshaft gear.





Measure the camshaft end play and backlash.

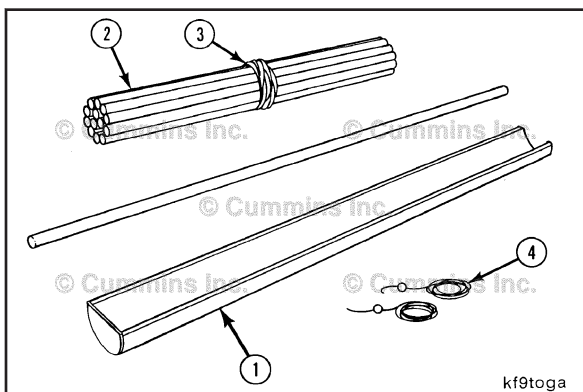
Camshaft End Play (A)

mm		in
0.12	MIN	0.005
0.46	MAX	0.018

Camshaft Gear Backlash (B)

mm		in
0.08	MIN	0.003
0.33	MAX	0.013

NOTE: Mark the camshaft gear and crankshaft gear for further analysis if the backlash or end clearance exceeds limits.

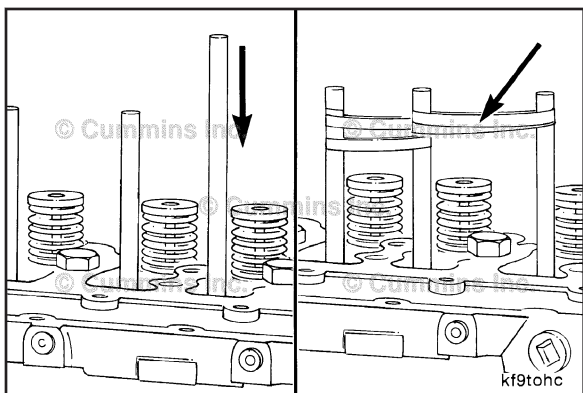


Remove

The tappet removal tool kit, Part Number 3822513, contains:

- 1 Valve tappet tray
- 2 Dowel rods
- 3 Rubber bands
- 4 Nylon string.

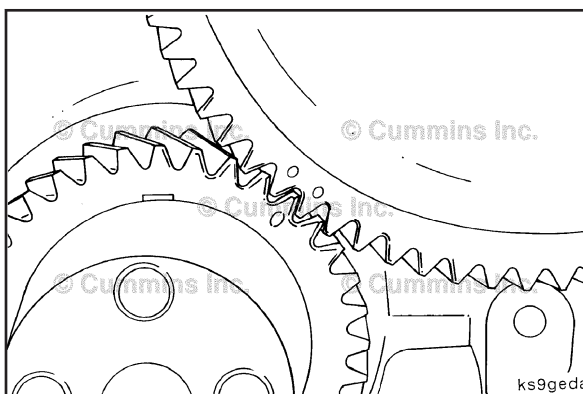
NOTE: This kit is used to lift the tappets so the camshaft can be removed.



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

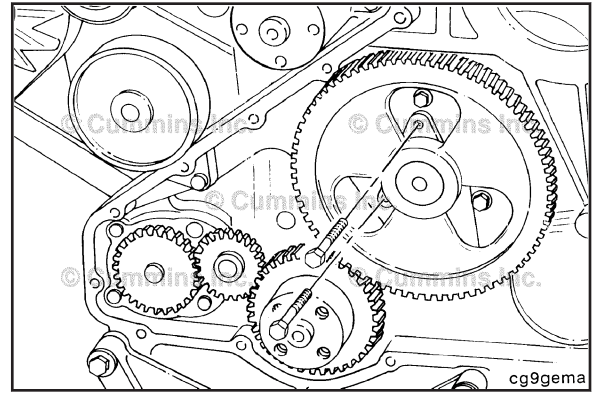


Pull each valve tappet up until it makes contact with the cylinder block. Put a rubber band around two dowels, this will hold the tappets up off the camshaft.



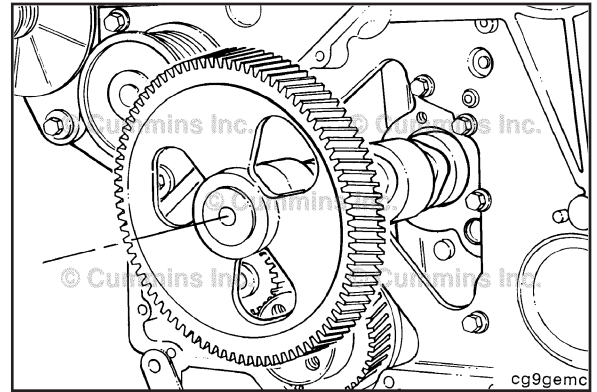
Rotate the crankshaft to align the timing marks before removing the camshaft.

Remove the camshaft thrust plate capscrews.
Remove the camshaft thrust plate.



Remove the camshaft from the cylinder block.

NOTE: Rotate the camshaft as it is being removed. Use extreme care to make sure that the camshaft bushings are **not** damaged during the camshaft removal process.



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 ⚠

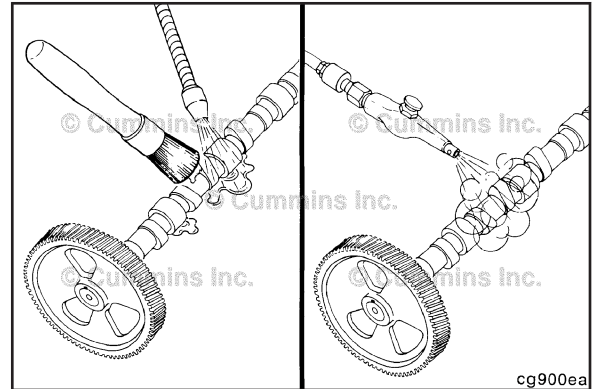
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

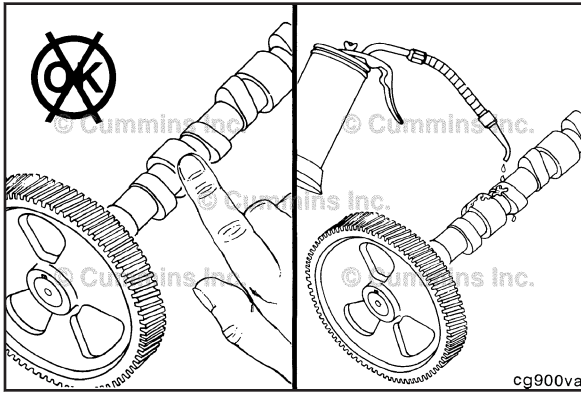
⚠ WARNING ⚠

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

Clean the camshaft with steam or solvent.

Dry the camshaft with compressed air.

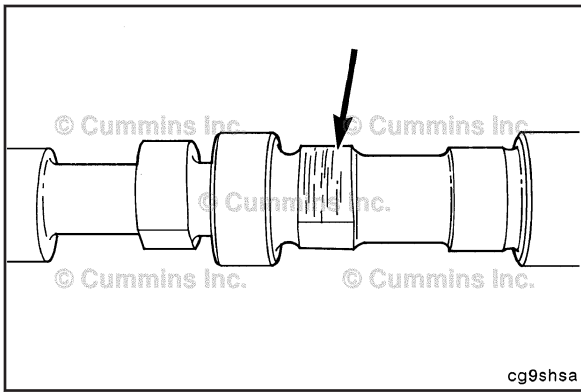




⚠ CAUTION ⚠

After the camshaft has been cleaned, do not touch the machined surfaces with bare hands; this will cause rust to form.

Lubricate the camshaft with clean engine oil before handling it.

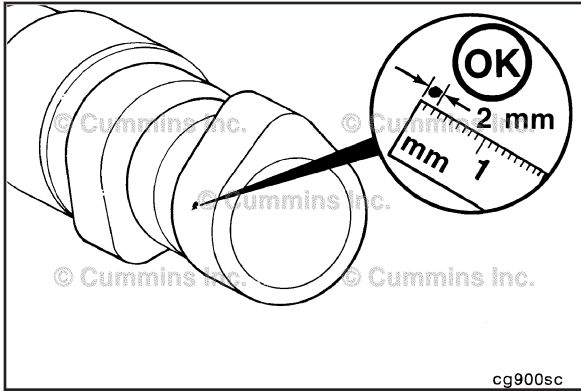


Inspect for Reuse

NOTE: If a new camshaft is installed on an engine that uses slider tappets, new tappets and push tubes **must** also be installed. If a new camshaft is installed on an engine that uses roller tappets, **only** the damaged roller tappets **must** be replaced.

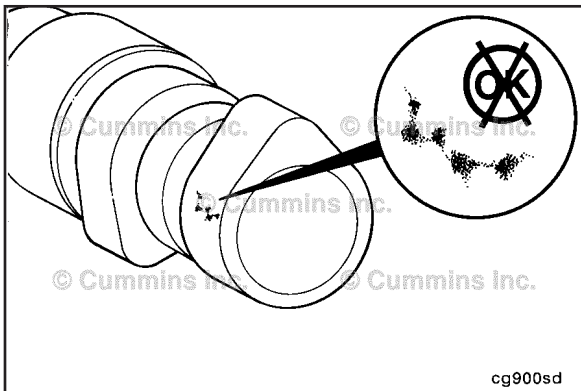
Inspect the valve lobes and bearing journals for wear, cracking, pitting, scratches, and other damage.

The following criteria define the size of the pits, allowable wear, and edge deterioration of the camshaft lobes.



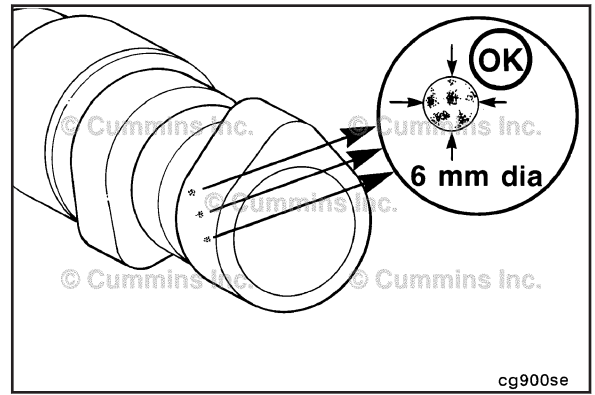
Pitting Reuse Criteria

A single pit **must not** be greater than the area of a 2-mm [0.079-in] diameter circle.

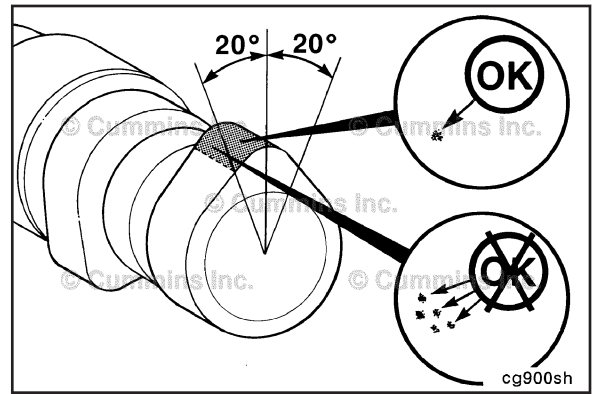


Interconnection of pits is **not** allowable and is treated as one pit.

The total pits, when added together, **must not** exceed a circle of 6-mm [0.236-in].

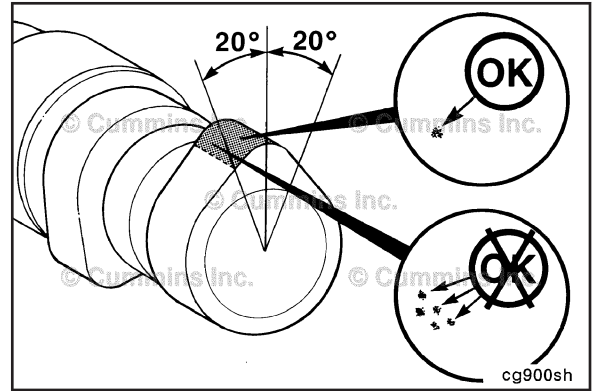


Only one pit is allowed within ± 20 degrees of the nose of the cam lobe.

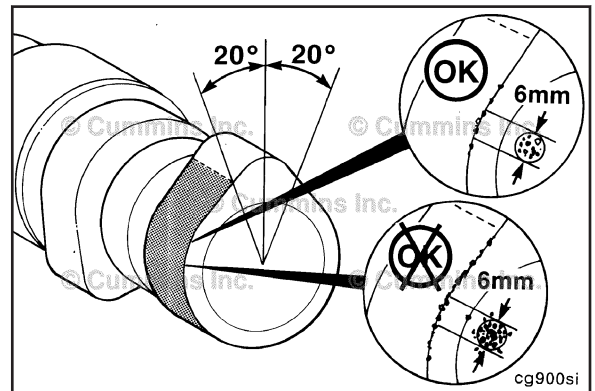


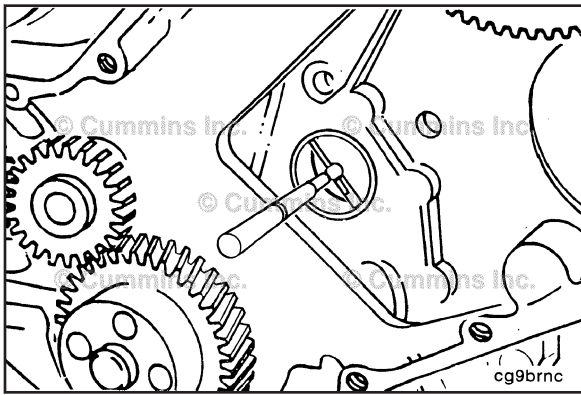
Edge Deterioration (Breakdown) Criteria

The area of edge deterioration can **not** be greater than the equivalent area of a 2-mm [0.079-in] circle within ± 20 degrees of the nose of the cam lobe.



Outside of the ± 20 degrees of the nose of the cam lobe, the areas of edge deterioration can **not** be greater than the equivalent area of a 6-mm [0.236-in] circle.





Measure the camshaft bushing bore. Use a bore gauge. The bores **must** be measured in two positions. Take a second measurement 90 degrees from the first measurement.

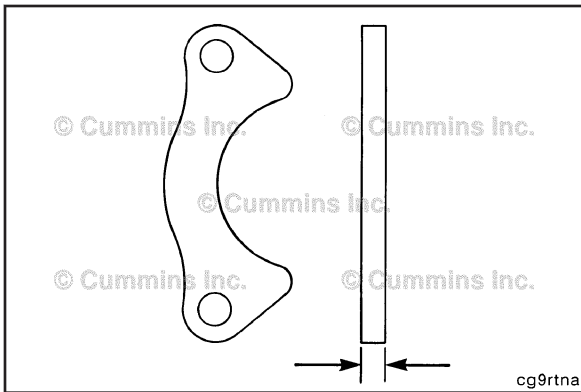


Camshaft Bushing Bore Inside Diameter

	mm		in
Bushing	60.12	MAX	2.367

If the bushing diameter is more than 60.12-mm [2.367-in], the camshaft bushings **must** be replaced.

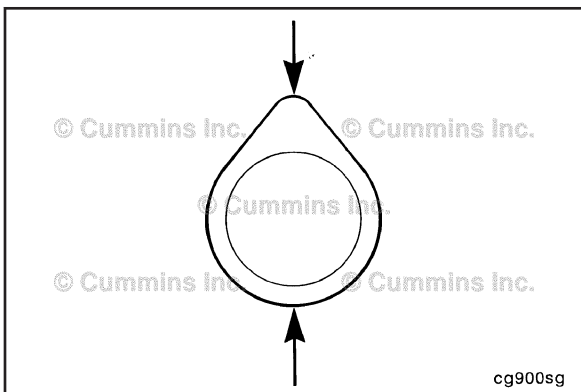
NOTE: The engine **must** be removed for camshaft bushing replacement. Refer to Procedure 000-001 in Section 0.



Measure the camshaft thrust plate thickness.

Camshaft Thrust Plate Thickness

	mm		in
	9.34	MIN	0.368
	9.58	MAX	0.377



Measure

Valve Lobe Wear Criteria

Measure across the peak of the valve lobe.

6C - Camshaft Lobe Wear Limits for Part Numbers 3924471, 3923388, and 3923478

	mm		in
Intake	49.940	MIN	1.966
Exhaust	48.916	MIN	1.926

6C - Camshaft Lobe Wear Limits for Part Numbers 3921176, 3914640, and 3919799

	mm		in
Intake	49.940	MIN	1.966
Exhaust	49.774	MIN	1.960

6C - Camshaft Lobe Wear Limits for Part Number 3930347

	mm		in
Intake	45.400	MIN	1.787
Exhaust	44.649	MIN	1.758

6C - Camshaft Lobe Wear Limits for Part Number 3927693

	mm		in
Intake	45.400	MIN	1.787
Exhaust	45.141	MIN	1.777

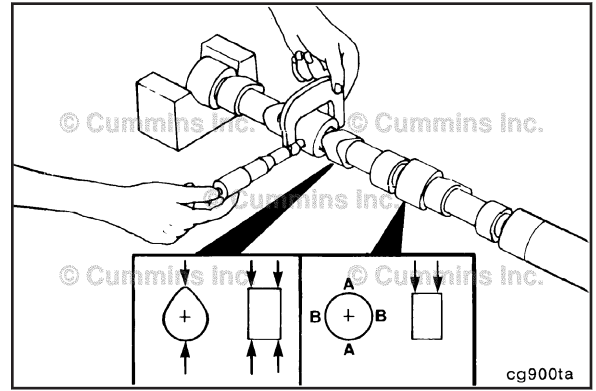
Camshaft Journal Diameter Wear Limits for Part Numbers 3924471, 3923388, 3921176, 3923478, 3914640, and 3919799

mm		in
59.967	MIN	2.3609
60.013	MAX	2.3627

Camshaft Journal Diameter Wear Limits for Part Numbers 3930347 and 3927693

mm		in
53.967	MIN	2.1247
54.013	MAX	2.1265

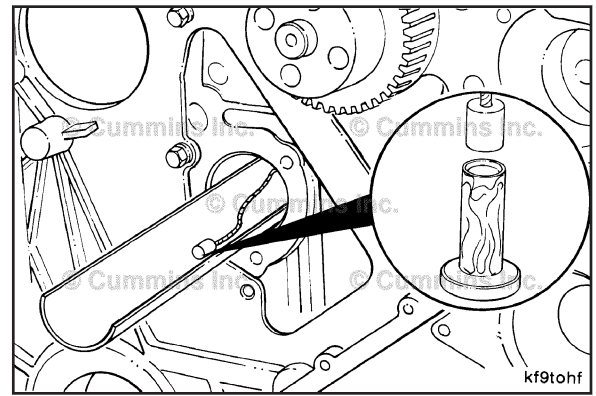
NOTE: Replace the camshaft if the outside diameter of any journal is below specification.



Install

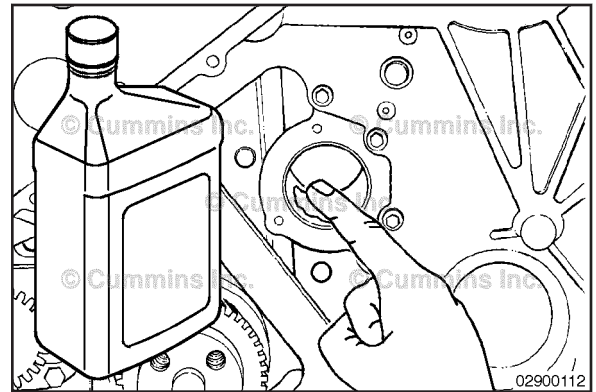
Install the tappets.

Refer to Procedure 004-015 in Section 4.

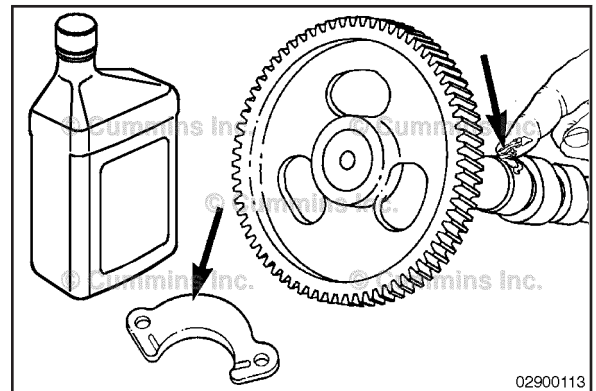


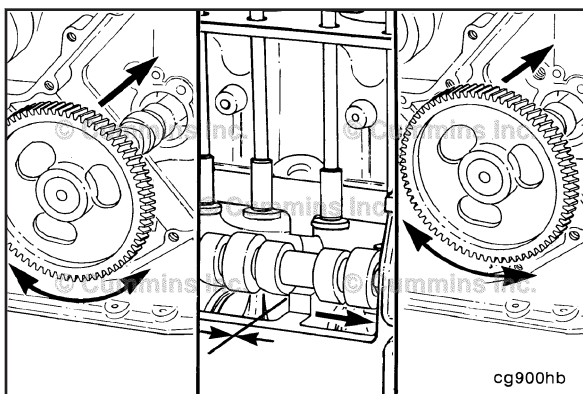
Apply a coat of clean engine oil to the front camshaft bore.

NOTE: The crankshaft **must** be positioned so the Number 1 cylinder is at approximately top dead center, so the camshaft does **not** hit the crankshaft counterweight during installation.

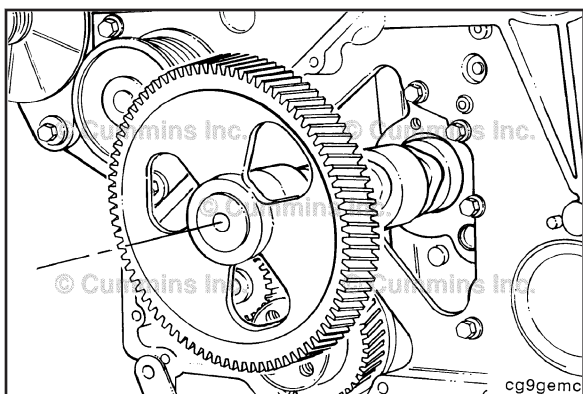


Lubricate the camshaft lobes, journals, and thrust washer with clean engine oil.

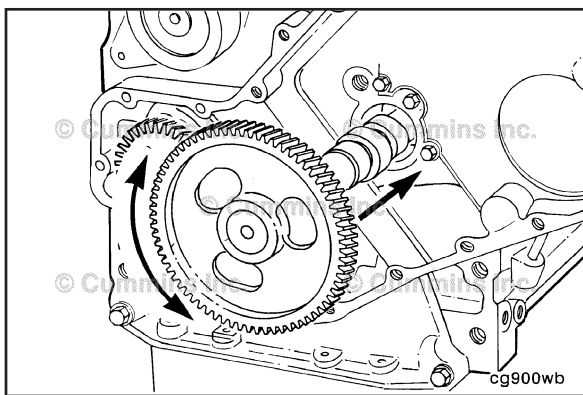




Install the camshaft. While pushing in slightly, rotate the camshaft and carefully work the camshaft through the camshaft bushings. As each camshaft journal passes through a bushing, the camshaft will drop slightly and the camshaft lobes will catch on the bushings. Rotating the camshaft will free the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

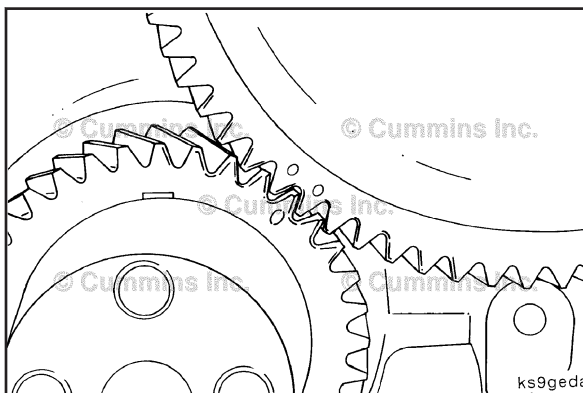


Position the camshaft and gear assembly into the cylinder block up to the last journal.



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

Before the camshaft gear engages the crankshaft gear, check the camshaft for ease of rotation. When installed properly, the camshaft will rotate freely.

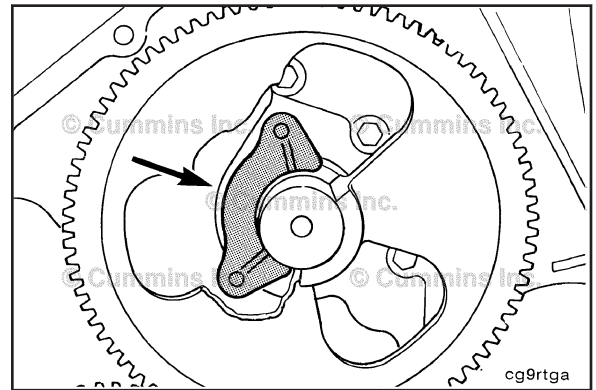


Align the timing marks on the camshaft with the timing marks on the crankshaft.

⚠ WARNING ⚠

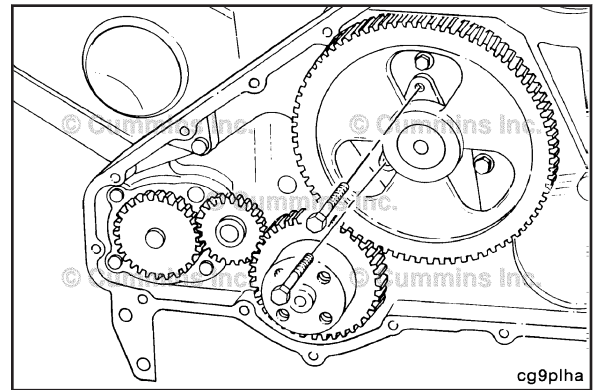
To reduce the possibility of personal injury, make sure the camshaft assembly does not drop on your fingers when installing the thrust plate.

Install the camshaft thrust plate.



Install and tighten the camshaft thrust plate capscrews.

Torque Value: 24 N•m [212 in-lb]



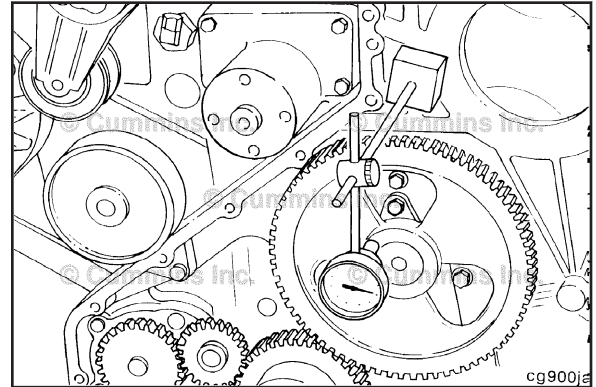
Measure camshaft end clearance with a dial indicator.

NOTE: End clearance is controlled by the thickness of the thrust plate and the groove in the camshaft.

Camshaft End Clearance

mm		in
0.12	MIN	0.005
0.46	MAX	0.018

NOTE: If the camshaft end clearance is greater than the above limit, the thrust plate **must** be replaced.



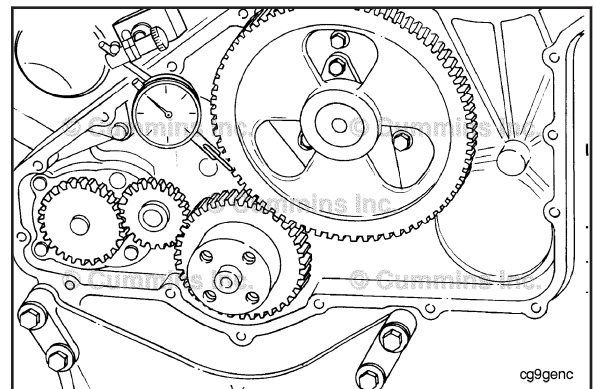
NOTE: Excessive gear backlash can be caused by worn camshaft bushings.

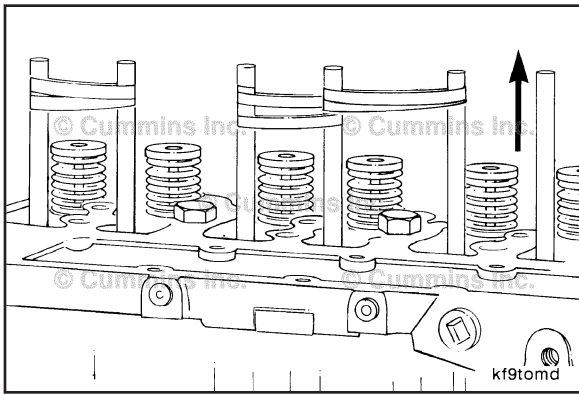
Put a dial indicator on the camshaft gear, and check the gear backlash between the camshaft gear and the crankshaft gear.

Camshaft Gear Backlash Limits (B)

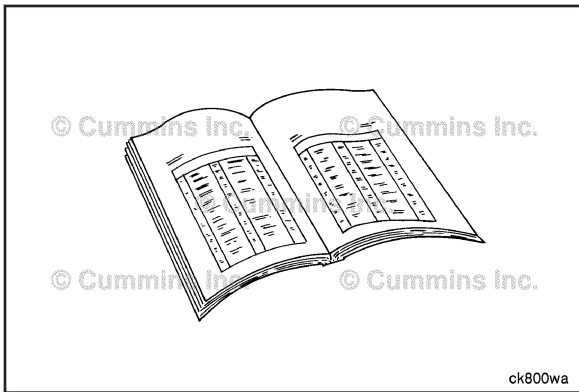
mm		in
0.08	MIN	0.003
0.33	MAX	0.013

NOTE: The gears **must** be replaced if the backlash is greater than the above limit.





Remove the wooden dowel rods from the valve tappets.



Finishing Steps

NOTE: Use **only** Cummins® approved lubricating oil for natural gas engines to prevent premature engine damage.



- Install the front gear cover. Refer to Procedure 001-031 in Section 1.
- Install the vibration damper. Refer to Procedure 001-052 in Section 1.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Install the push rods. Refer to Procedure 004-014 in Section 4.
- Install the rocker levers. Refer to Procedure 003-008 in Section 3.
- Adjust the valve lash. Refer to Procedure 003-004 in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Fill the engine oil. Refer to Procedure 007-037 in Section 7.
- Operate the engine until the coolant temperature reaches 82° C [180° F]. Check for leaks and proper operation.

Camshaft Bushings (001-010)

Preparatory Steps

⚠️ WARNING ⚠️

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

⚠️ WARNING ⚠️

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

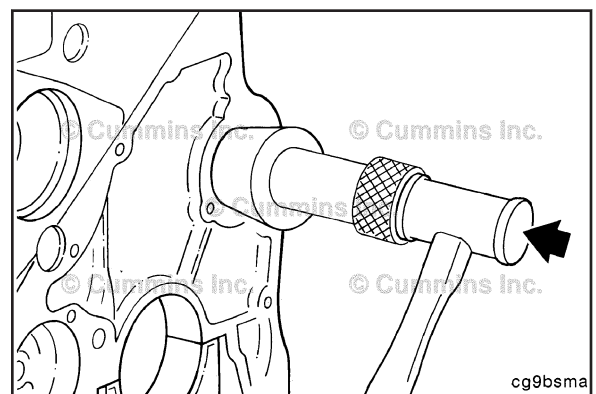
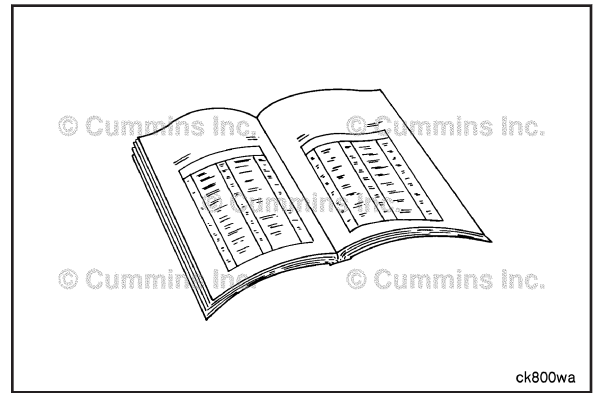
- Disconnect the battery cables. Refer to Procedure 013-009 in Section 13.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the rocker lever covers. Refer to Procedure 003-011 in Section 3.
- Remove the rocker levers. Refer to Procedure 003-008 in Section 3.
- Remove the push rods. Refer to Procedure 004-014 in Section 4.
- Remove the vibration damper. Refer to Procedure 001-052 in Section 1.
- Remove the gear cover. Refer to Procedure 001-031 in Section 1.
- Remove the camshaft. Refer to Procedure 001-008 in Section 1.

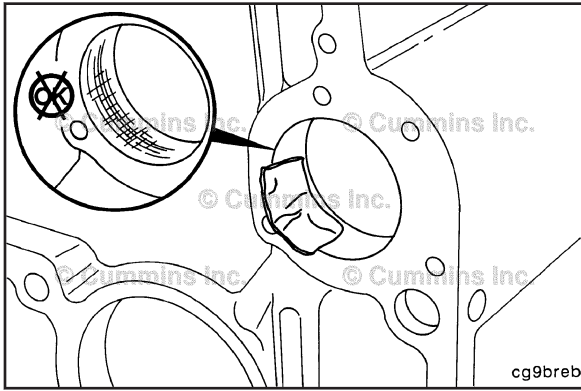
Remove

Drive the camshaft bushing from the cylinder block bore with camshaft bushing removal and installation tool, Part Number 3165045.

The following kits are also available for camshaft bushing installation and removal:

- Hydraulic Actuator Kit, Part Number 3823621
- Camshaft Bushing Kit, Part Number 3162253



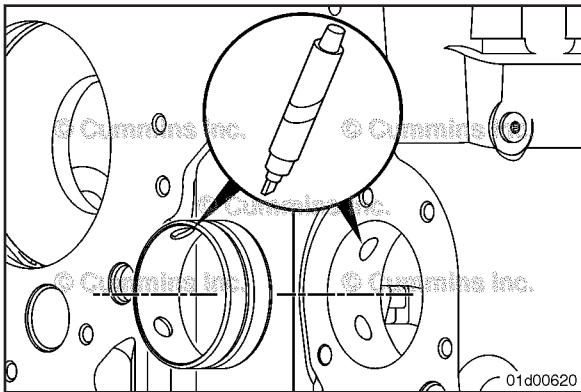


Clean

⚠️ WARNING ⚠️

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

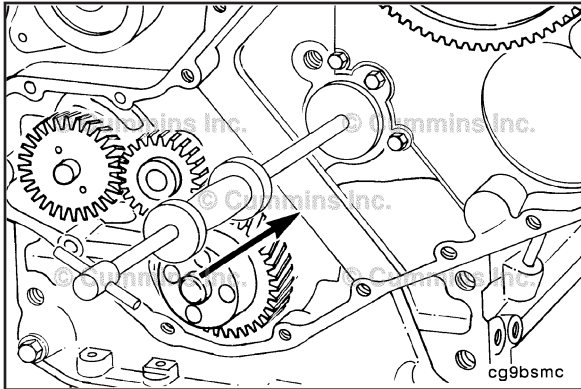
Use a fine emery cloth and solvent to remove any burrs and sharp edges from the camshaft bushing bores.



Install

Mark the camshaft bushing and cylinder block to aid in the alignment of align the lubricating oil hole in the cylinder block with the lubricating oil hole in the bushing.

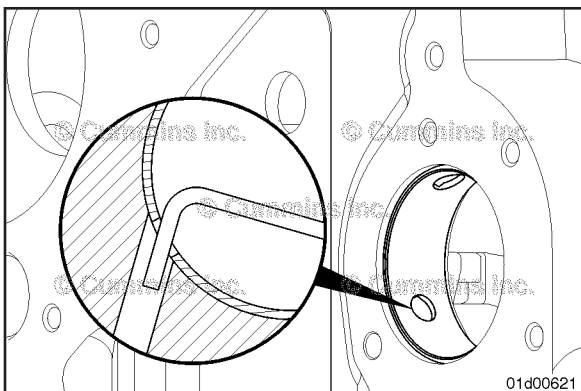
NOTE: The top hole on the front and rear camshaft bushings will **not** line up with the top hole of the cylinder block bores. **Only** the bottom hole will be line up for the front and rear camshaft bushings.



Use the camshaft bushing installation and removal tool, Part Number 3165045, to install the camshaft bushing so that it is even with the front face of the cylinder block.

For ease of bushing installation use Hydraulic Actuator Kit, Part Number 3823621, and Camshaft Bushing Kit, Part Number 3162253.

NOTE: The front camshaft bushing **must** be installed to a depth of 4.5 mm [0.177 in] below the front face of the cylinder block. All other bushings **must** be installed even with the web of the camshaft bores.



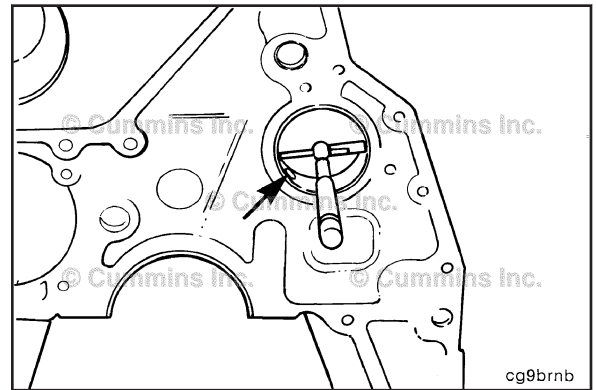
For the front and rear camshaft bushings, **only** the bottom hole will line up with the hole in the cylinder block. Make sure the lubricating oil hole is aligned.

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

Measure the installed diameter of the camshaft bushings.

Camshaft Bushing Bore Diameter - Installed

mm		in
60.06	MIN	2.365
60.12	MAX	2.367



Finishing Steps

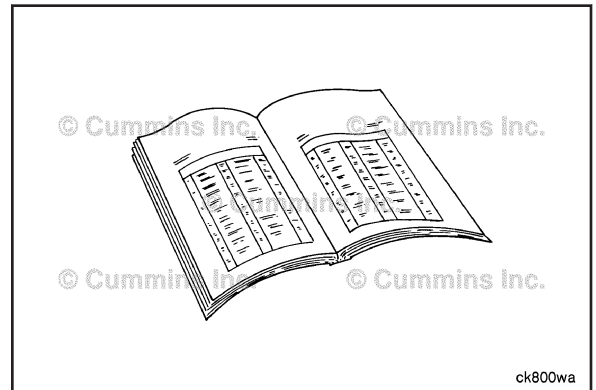
⚠ WARNING ⚠

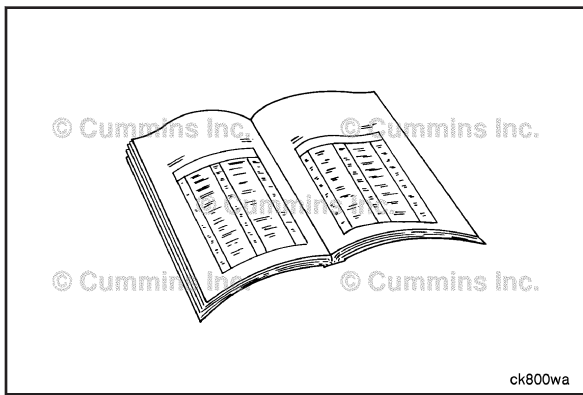
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠ 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.

- Install the camshaft. Refer to Procedure 001-008 in Section 1.
- Install the gear cover. Refer to Procedure 001-031 in Section 1.
- Install the vibration damper. Refer to Procedure 001-052 in Section 1.
- Install the push rods. Refer to Procedure 004-014 in Section 4.
- Install the rocker levers. Refer to Procedure 003-008 in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the battery cables. Refer to Procedure 013-009 in Section 13.
- Operate the engine and check for leaks.





Camshaft Gear (Camshaft Removed) (001-013)

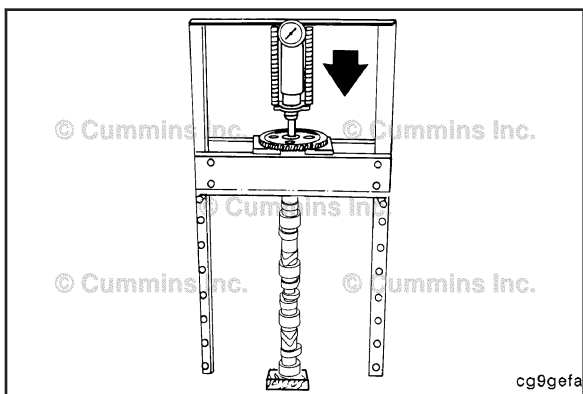
Preparatory Steps

Remove the fan pulley. Refer to Procedure 008-039.

Remove the vibration damper. Refer to Procedure 001-052.

Remove the front gear cover. Refer to Procedure 001-031.

Remove the camshaft. For C Series diesel engines, refer to Procedure 001-008 in Troubleshooting and Repair Manual, C Series Engines, Bulletin 3666003. For C Series gas engines, refer to Procedure 001-008 in Troubleshooting and Repair Manual, C8.3G (Natural Gas) Engines, Bulletin 3666206.

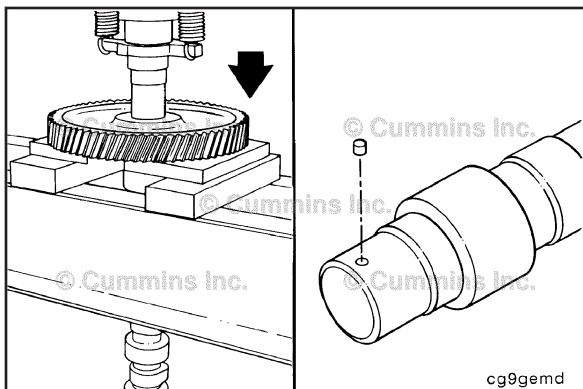


Remove

⚠ CAUTION ⚠

Place a wooden block under the camshaft to avoid damage as the camshaft drops free from the cam gear.

Place the camshaft and gear in a hydraulic press. Press the gear off the camshaft.



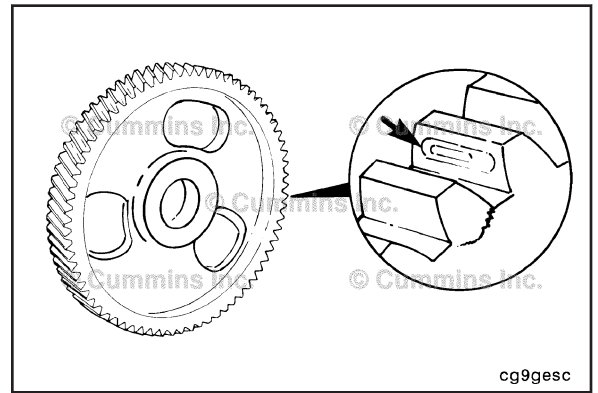
Remove the camshaft dowel pin.

Remove burrs with Scotch-Brite 7448, Part No. 3823258.

Inspect for Reuse

Inspect the camshaft gear for cracked, chipped, or broken teeth.

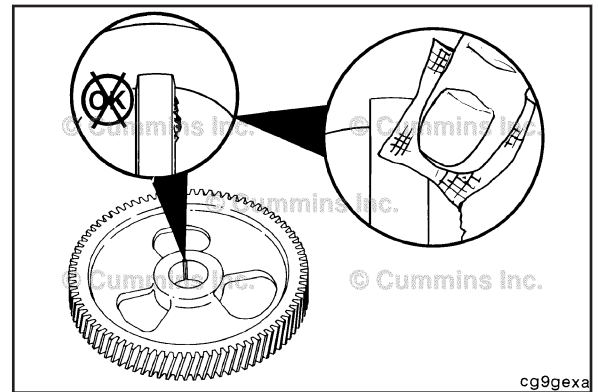
NOTE: If the fretting, burrs, or raised material can **not** be removed with Scotch-Brite 7448, Part No. 3823258, replace the camshaft gear.



Inspect the camshaft gear bore for fretting or burrs and the keyway for burrs.

Remove burrs with Scotch-Brite 7448, Part No. 3823258.

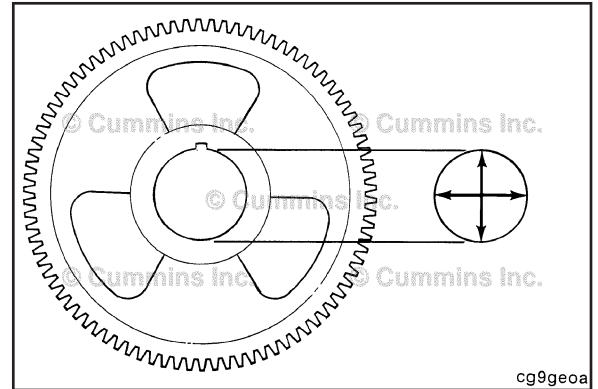
NOTE: If the keyway is damaged or the burrs can **not** be removed, the camshaft gear **must** be replaced.



Measure the camshaft gear bore inside diameter.

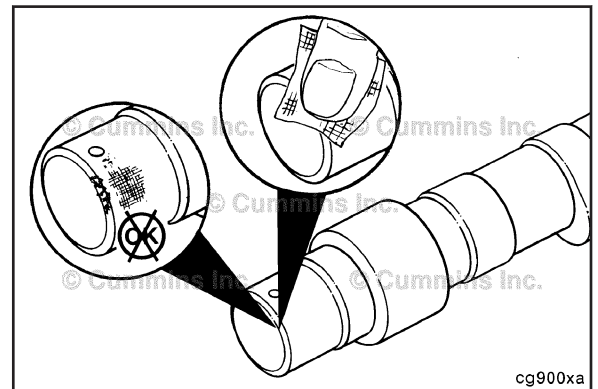
Camshaft Gear Bore Inner Diameter

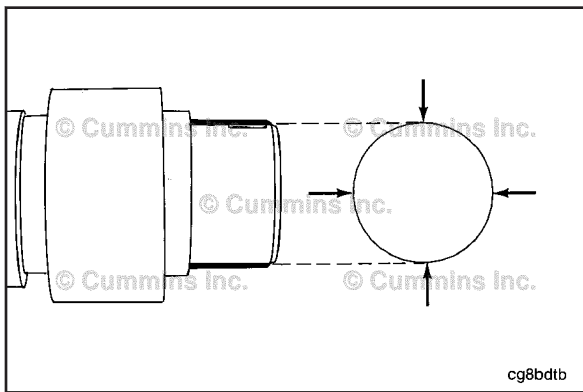
mm		in
41.48	MIN	1.633
41.51	MAX	1.634



Inspect the camshaft nose for fretting or burrs.

NOTE: If fretting or burrs can **not** be removed with Scotch-Brite 7448, Part No. 3823258, the camshaft **must** be replaced.

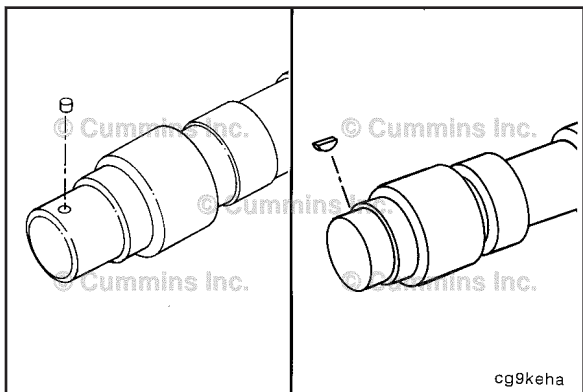




Measure the camshaft gear journal outside diameter.

Camshaft Gear Journal Outer Diameter

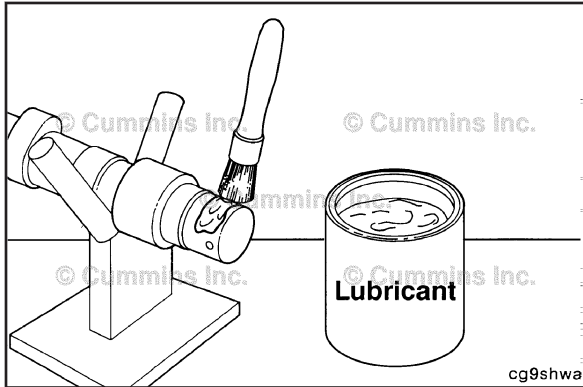
mm		in
41.56	MIN	1.636
41.58	MAX	1.637



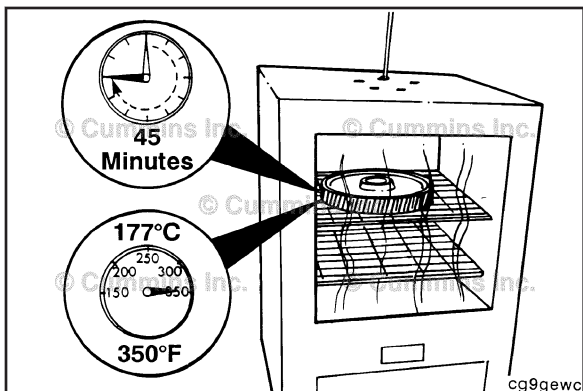
Install

Use a leather hammer to install the Woodruff key or dowel pin.

NOTE: The steel camshaft, Part No. 3923388, uses a dowel pin. The cast-iron camshaft, Part No. 3924471, uses a Woodruff key.



Lubricate the camshaft surface with clean engine oil.



⚠ WARNING ⚠
Wear protective gloves to prevent personal injury when handling parts that have been heated.

Steel Camshaft Gear

Heat the camshaft gear in a preheated oven for a minimum of 45 minutes; do **not** exceed 6 hours.

Temperature 177 °C [350 °F]

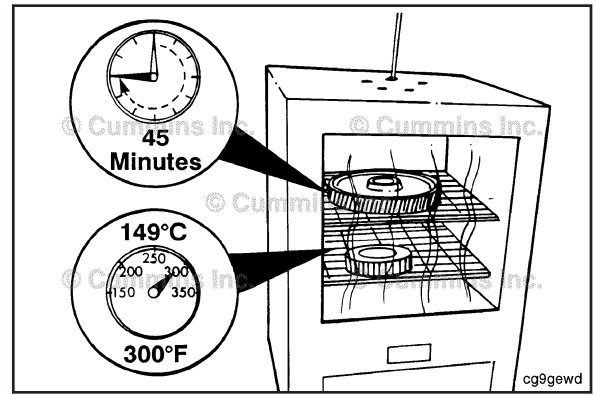
⚠CAUTION⚠

The gear will be permanently distorted if overheated. The oven temperature must never exceed the specification.

Tempered Camshaft Gear

NOTE: The steel camshaft, Part No. 3918777, uses a dowel pin. The cast-iron camshaft, Part No. 3924471, uses a Woodruff key.

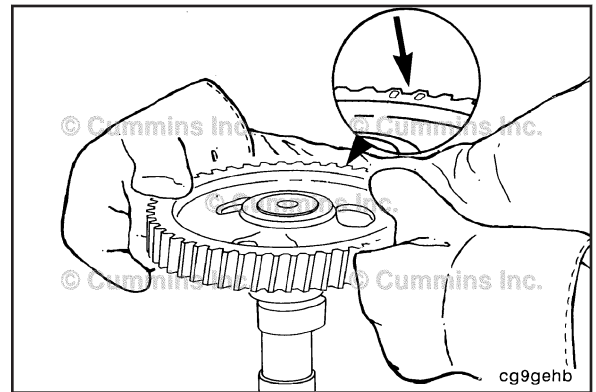
Temperature 149 °C [300 °F]



⚠WARNING⚠

Wear protective gloves to prevent personal injury when handling parts that have been heated.

Install the camshaft gear with the timing marks away from the camshaft.

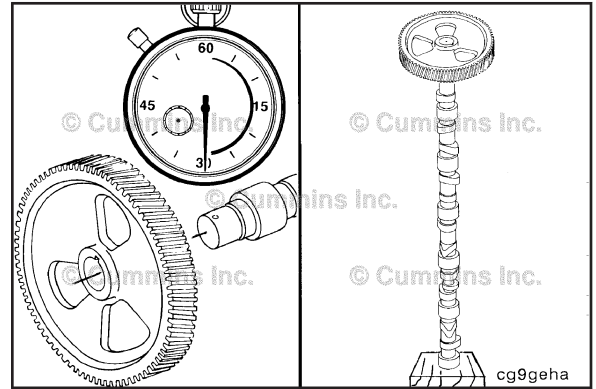


⚠CAUTION⚠

To prevent engine damage, the timing marks and gear part number must be facing away from the camshaft when the gear is installed. Keep the camshaft in a vertical position with the gear up until the gear has cooled. Do not use water to reduce the cooling time. Using water will crack the gear.

NOTE: The gear **must** be installed within 30 seconds after it is removed from the oven.

Remove the gear from the oven. Align the keyway in the gear with the dowel pin in the camshaft; install the gear on the camshaft. Make sure the gear is seated against the camshaft shoulder.



Finishing Steps

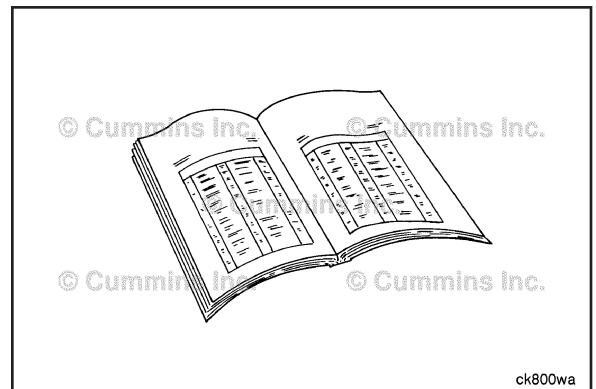
Install the camshaft. For C Series diesel engines, refer to Procedure 001-008 in Troubleshooting and Repair Manual, C Series Engines, Bulletin 3666003. For C Series natural gas engines, refer to Procedure 001-008 in Troubleshooting and Repair Manual, C8.3G (Natural Gas) Engines, Bulletin 3666206.

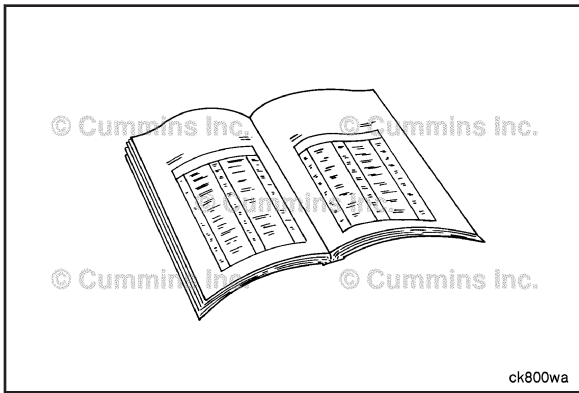
Install the front gear cover. Refer to Procedure 001-031.

Install the vibration damper. Refer to Procedure 001-052.

Install the fan pulley. Refer to Procedure 008-039.

Operate engine and check for leaks.





Connecting Rod (001-014)

Preparatory Steps

⚠️ WARNING ⚠️

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

⚠️ WARNING ⚠️

Coolant is toxic. If not reused, dispose of in accordance with local environmental regulations.

⚠️ WARNING ⚠️

Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.

⚠️ 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.

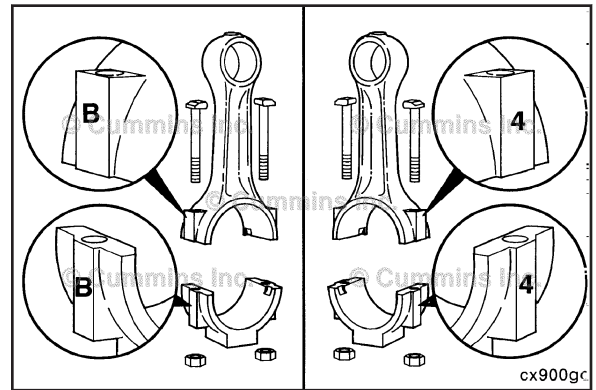
- Close the fuel supply valve. Refer to the OEM instructions.
- Disconnect the batteries. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13.
- Drain the coolant. Refer to Procedure 008-018 (Cooling System) in Section 8.
- Remove the cylinder head. Refer to Procedure 002-004 (Cylinder Head) in Section 2.
- Drain the lubricating oil. Refer to Procedure 007-037 (Lubricating Oil System) in Section 7.
- Remove the lubricating oil pan and gasket. Refer to Procedure 007-025 (Lubricating Oil Pan) in Section 7.
- Remove lubricating oil suction tube. Refer to Procedure 007-035 (Lubricating Oil Suction Tube (Block-Mounted)) in Section 7.
- Remove and disassemble the piston and connecting rod assemblies. Refer to Procedure 001-054 (Piston and Connecting Rod Assembly) in Section 1.

Clean and Inspect for Reuse

The letter or number on the connecting rod cap **must** be the same as the letter or number on the connecting rod.

Do **not** assemble a new cap to a used connecting rod, or a used cap to a new connecting rod.

Remove the connecting rod capscrew nuts and caps from the connecting rods.



⚠️ WARNING ⚠️

When using a steam cleaner, wear protective clothing and 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 and protective clothing to reduce the possibility of personal injury.

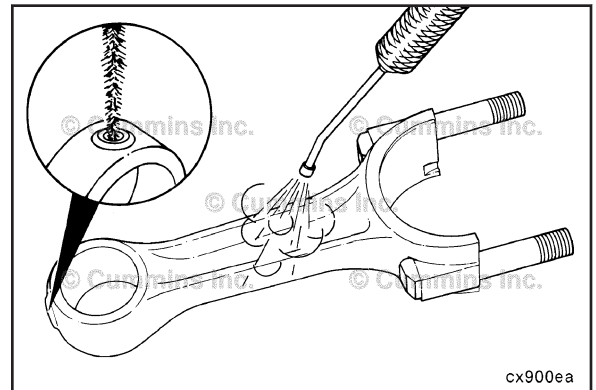
⚠️ WARNING ⚠️

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

Use solvent or steam to clean the rods.

Use a soft bristle brush to clean the oil drilling.

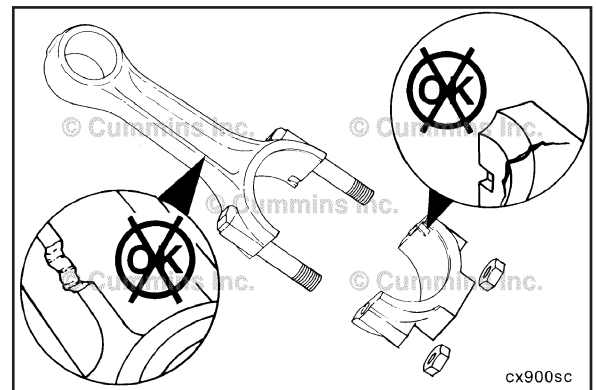
Dry with compressed air.

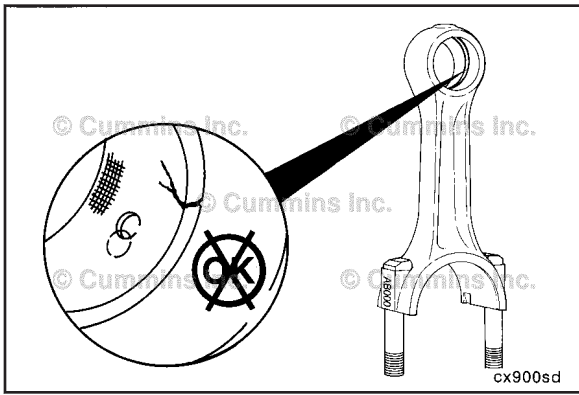


Inspect the connecting rod and cap for fretting damage on the mating surfaces.

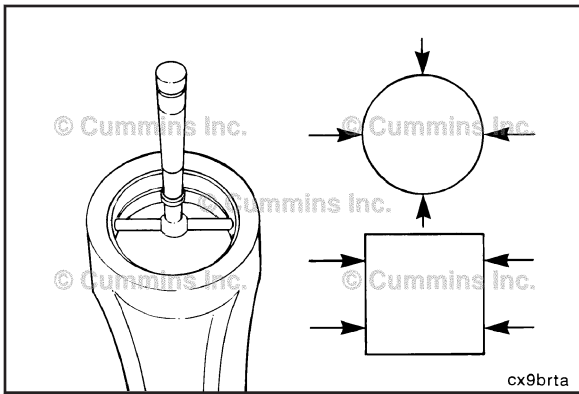
The rod and cap **must** be replaced as an assembly if any fretting damage is visible on either piece.

Replace the connecting rod if the I-beam is nicked or damaged.





Inspect the connecting rod pin bore bushing for damage or misalignment of the oil passage and bushing.



Measure the connecting rod piston pin bushing inside diameter.

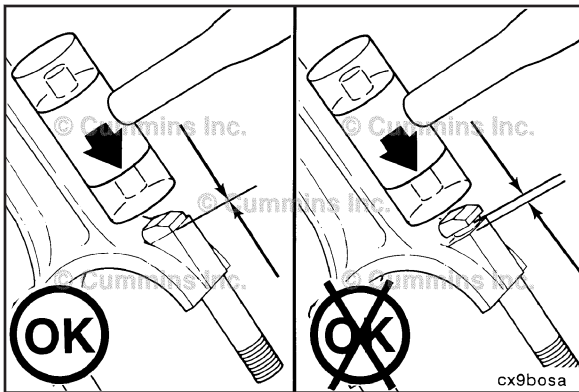
If the connecting rod piston pin bushings are **not** within the given specifications, the piston pin bushings can be replaced.

Connecting Rod Piston Pin Bore Diameter (Bushing Installed)

mm		in
45.023	MIN	1.7726
45.060	MAX	1.7740

NOTE: Service replacement rod bushings are available. See the appropriate parts catalog for part numbers.

The bushing **must** be precision machined after installation. If machining capability is available, the bushing can be replaced.

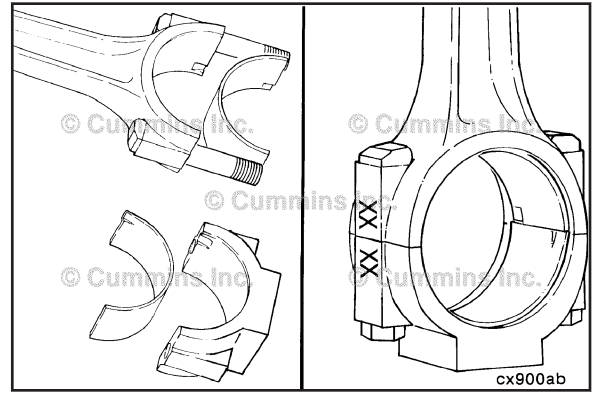


Tap the connecting rod bolts in until the head is aligned and seated on the flat machined surface of the connecting rod.

Install the bearing shells into the connecting rod and cap.
Use clean 15W-40 oil to lubricate the capscrew threads.
Install the connecting rod caps and connecting rod nuts.
The connecting rod cap number **must** match the number on the connecting rod and be installed with the numbers aligned.

Tighten the connecting rod nuts in alternating sequence.

Torque Value:	Step1	40 N•m	[30 ft-lb]
	Step2	80 N•m	[60 ft-lb]
	Step3	120 N•m	[88 ft-lb]



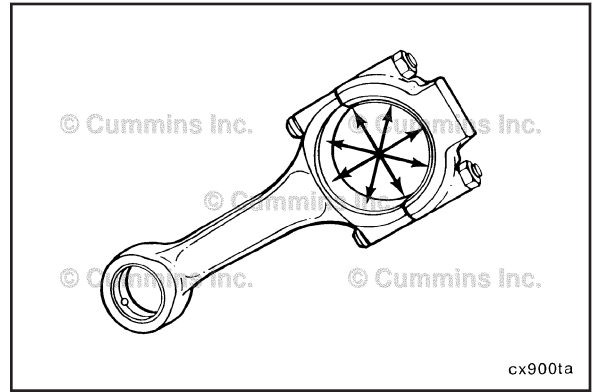
Measure the connecting rod crankshaft bore inside diameter.

Connecting Rod Crankshaft Bore I.D. (With Bearing)

mm		in
76.04	MIN	2.9939
76.104	MAX	2.9962

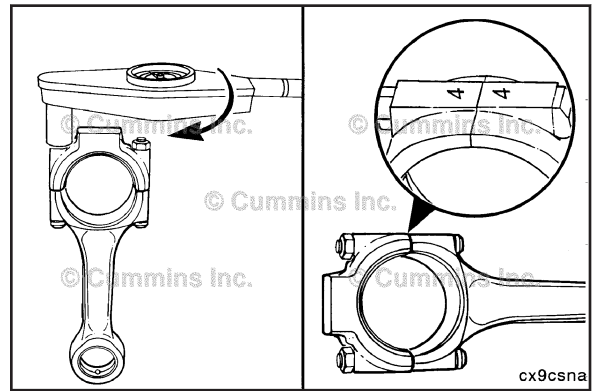
Connecting Rod Crankshaft Bore I.D. (Without Bearing)

mm		in
80.987	MIN	3.1885
81.013	MAX	3.1895



The connecting rod **must** be assembled with the capscrew nuts tightened to specifications before stamping the cylinder identification number on the connecting rod.

If a new connecting rod is installed, **always** stamp the new connecting rod with the cylinder number of the rod being replaced.

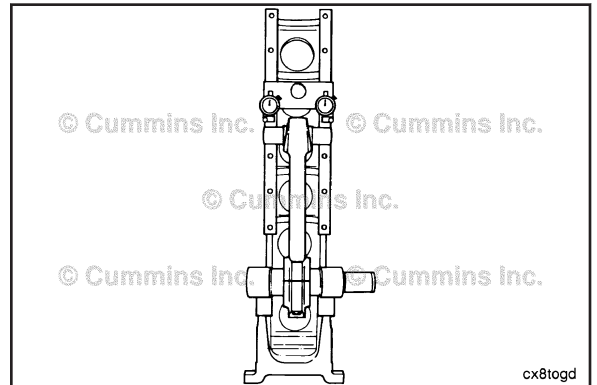


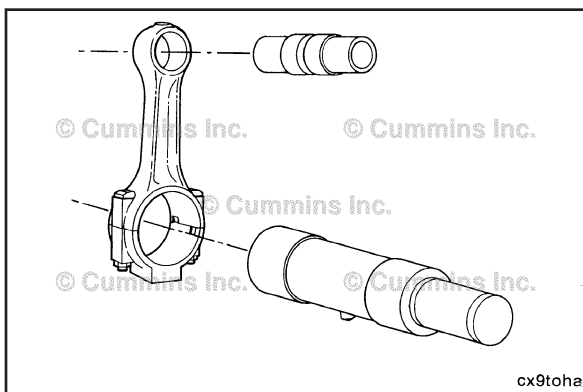
**Bend and Twist Inspect
Calibration Procedure**

Use a connecting rod checking fixture, Part Number ST-561, and a connecting rod mandrel set, Part Number 3823286, to inspect the bend and twist of the rods.

Calibrate the checking fixture with a new rod that has been measured for correct center to center length, 215.975 to 216.025 mm [8.5029 to 8.5040 in].

Assemble the connecting rod cap to the rod as described previously in this procedure.



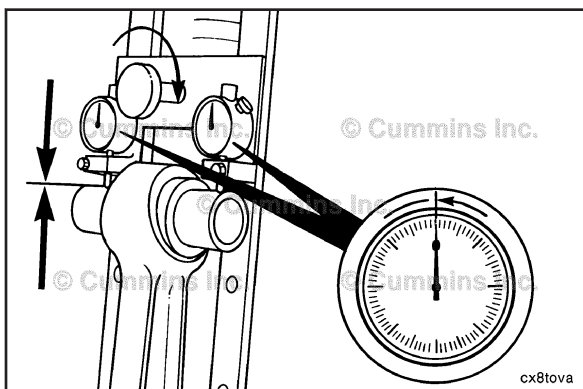


Install the piston pin mandrel from the connecting rod mandrel set, Part Number 3823286, into the piston pin bore.

NOTE: Use a mandrel, Part Number 3823283, if the piston bushing has been removed or mandrel, Part Number 3823284, if the bushing is still in place.

Install the mandrel, Part Number 3823303, into the crankshaft bore and expand the mandrel.

NOTE: Make sure the pin on the mandrel is pointed down and locked in position in the center of the connecting rod.

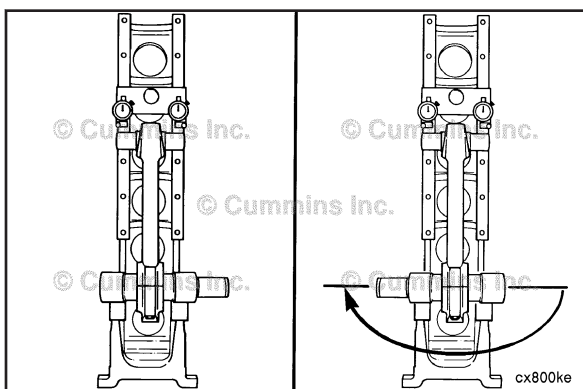


Install the connecting rod into the fixture.

Move the dial holder to position the contact points of the indicators on the mandrel in the piston pin bore.

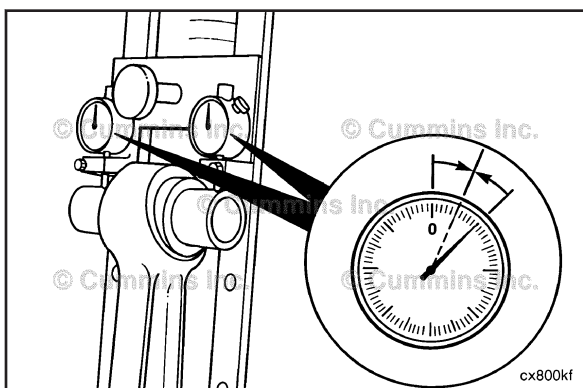
Tighten the bracket to hold the indicators in position.

Set the dial indicators to read zero.



Remove the connecting rod from the fixture.

Turn the rod 180 degrees horizontally, and install the rod into the fixture again.



Check the dial indicators for the zero position again.

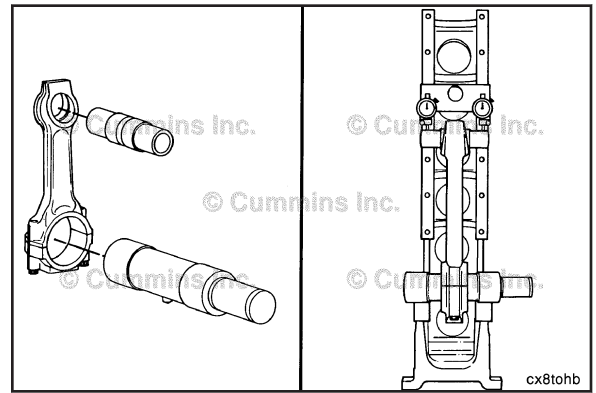
If the dial indicators show any change from zero, adjust the dials to half the indicated reading.

The fixture is now calibrated to allow the connecting rod to be installed into the fixture in either direction, and the dials will indicate an equal deflection on either side or zero.

Test

Install the mandrel and arbor into the connecting rod to be inspected.

Install the connecting rod into the fixture.



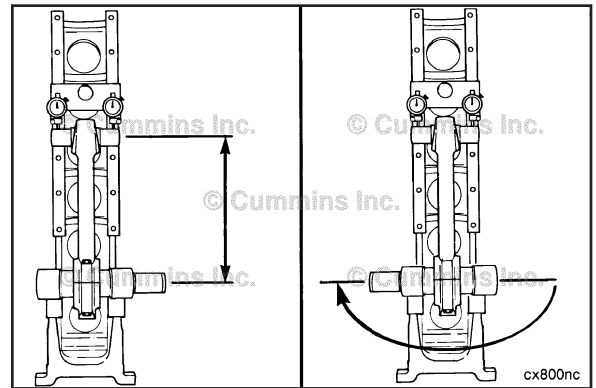
Measure the connecting rod length and bend (alignment).

Connecting Rod Length

		mm	in
215.975	MIN		8.5029
216.025	MAX		8.5049

Connecting Rod Bend (Alignment)

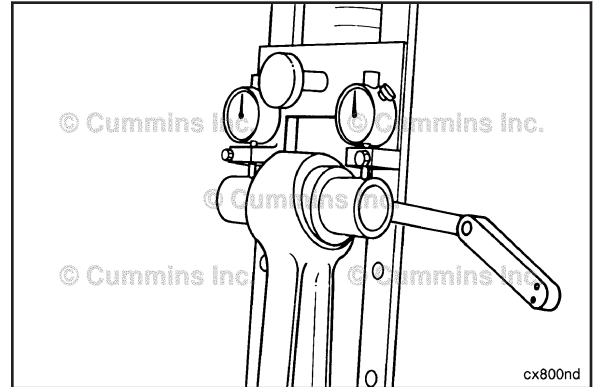
		mm	in
Bushing removed	0.20	MAX	0.008
Bushing installed	0.15	MAX	0.008

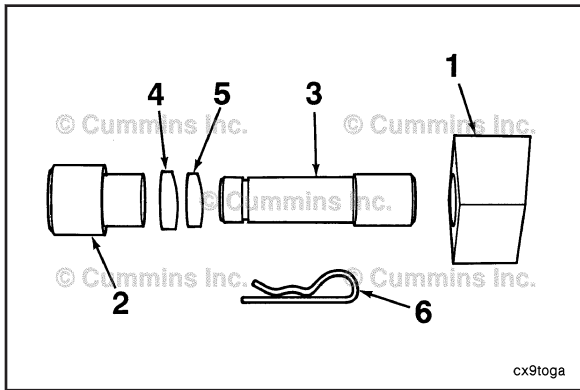


Install a feeler gauge between the mandrel and the dial indicator holding plate as shown.

Connecting Rod Bend (Alignment)

		mm	in
Bushing removed	0.50	MAX	0.020
Bushing installed	0.30	MAX	0.012

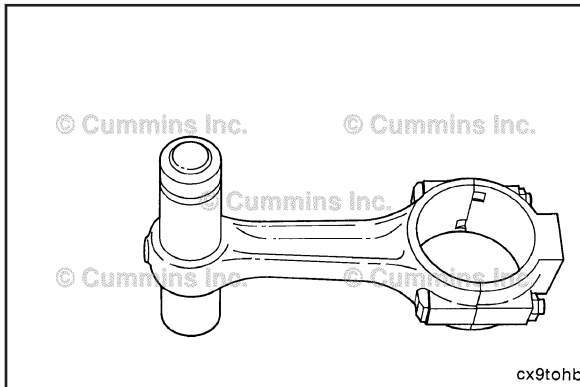




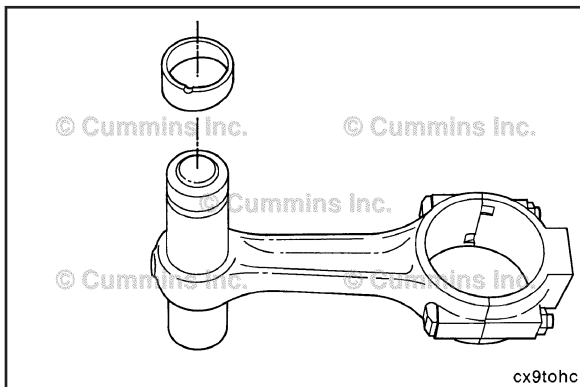
Replace

This tool is used to remove and install the bushings to the correct position.

Connecting Rod Pin Bore Bushing Removal/Installation Tool, Part Number 3823690			
Reference Number	Part Number	Description	Quantity
1	3823691	Anvil	1
2	3823693	Cup	1
3	3823692	Mandrel	1
4	3823694	Driver ring (thick)	1
5	3823695	Knock-out ring (thin)	1
6		Hair pin cotter pin	1



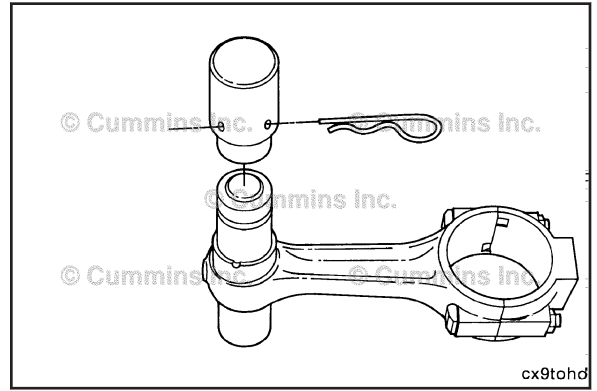
Place the pin bore end of the connecting rod on the mandrel.



Place the knock-out (thin ring) on the mandrel on top of the connecting rod.

Match up the angle surfaces.

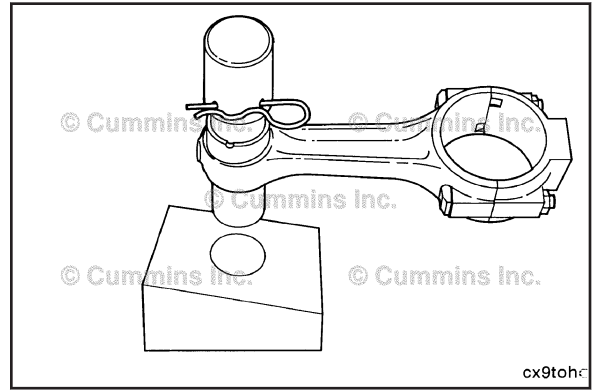
Install the cup on the mandrel and secure with the hair pin cotter pin.



Install the mandrel in the anvil.

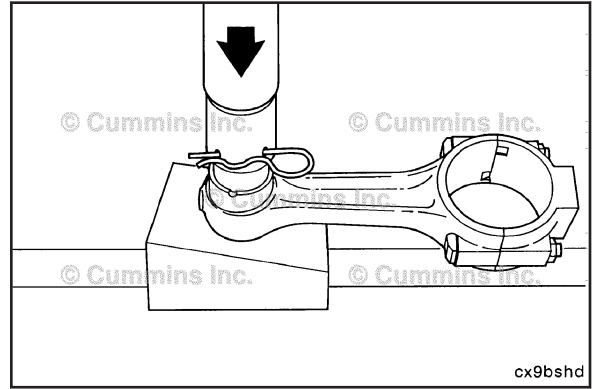
Place the connecting rod so the angle on the rod matches with the angle on the anvil.

The connecting rod will be in the horizontal position.



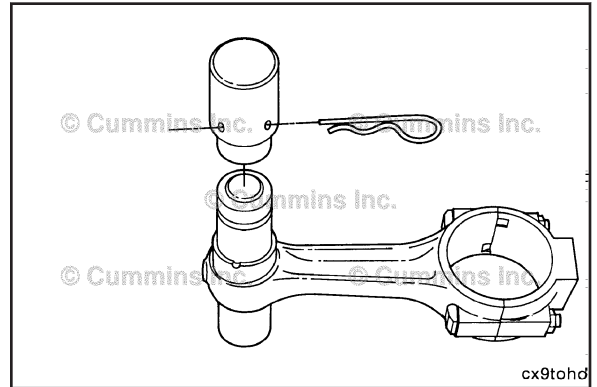
Press the connecting rod bushing out by applying force on top of the cup.

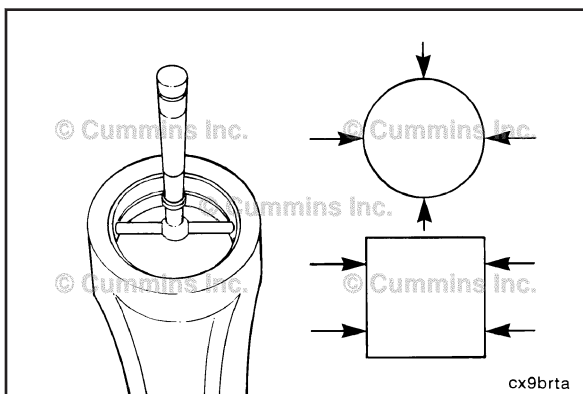
Press the bushing through the bore.



Remove the hair pin cotter pin.

Remove the cup and slide the connecting rod from the mandrel.



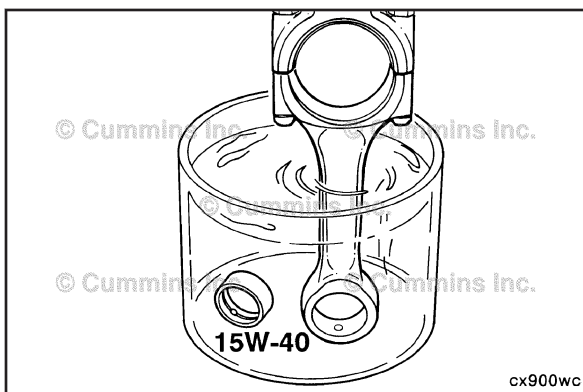


Measure the connecting rod bushing bore with the bushing removed.

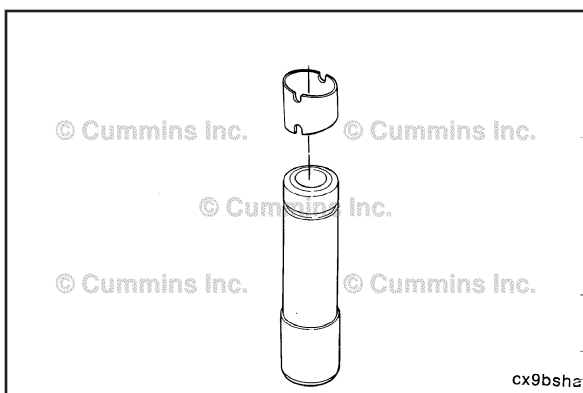
NOTE: If the connecting rod bushing bore is **not** within specifications, replace the connecting rod.

Connecting Rod Piston Pin Bore Diameter (Bushing Removed)

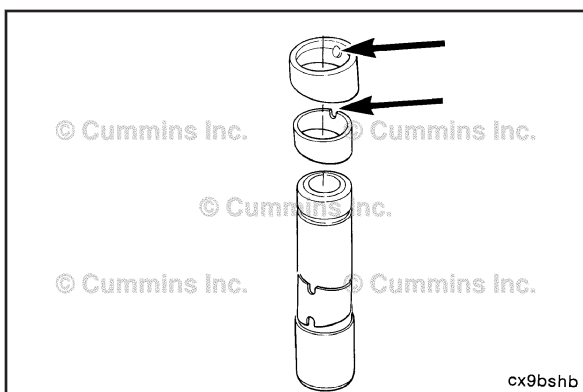
mm		in
48.988	MIN	1.9286
49.012	MAX	1.9296



Before installing the connecting rod bushing, submerge the bushing and connecting rod pin end in clean 15W-40 engine oil.



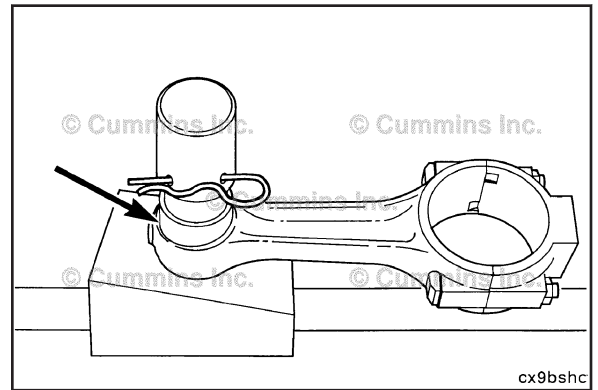
Place the connecting rod bushing on the mandrel.



Place the knock-out (thin ring) inside the driver ring.

Match the angles, place the angle side down and align the notch of the knock-out (thin ring) to the pin in the driver ring and slide on the mandrel.

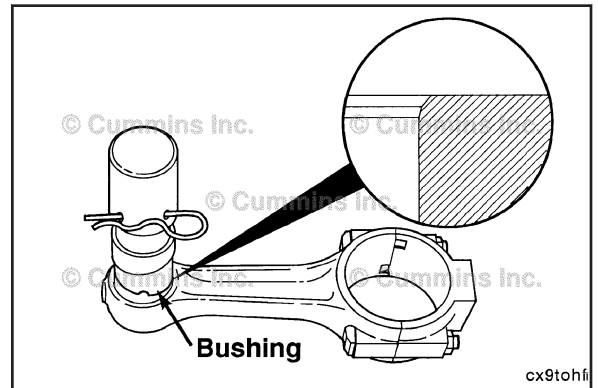
Install the cap and secure with the hair pin cotter pin.



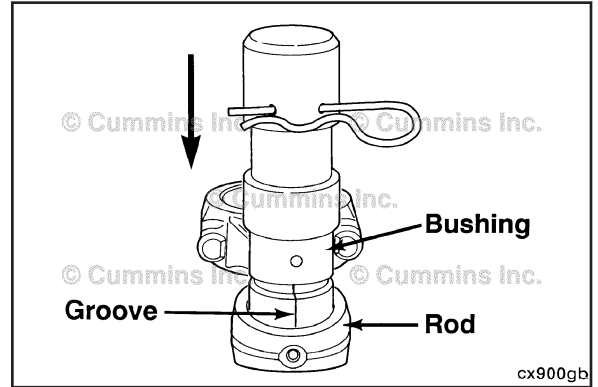
Insert the mandrel and components into the chamfered side of the connecting rod.

Align the angles of the bushing, connecting rod, and stop rings.

NOTE: Not all connecting rods have a double chamfer. A chamfer can be added to aid in the installation of the bushing, but **must not** result in an unsupported bushing area.



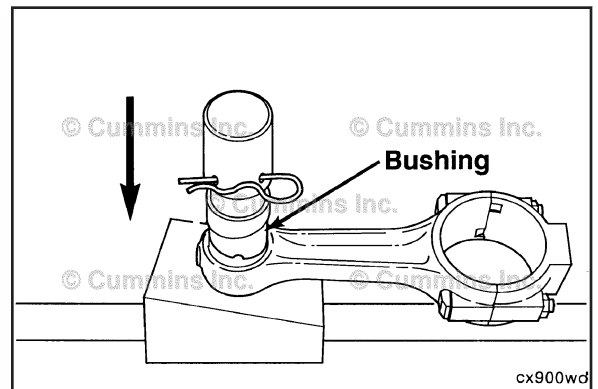
Align the oil hole in the bushing and connecting rod (use the groove in the mandrel) and push the mandrel and components into the pin bore of the connecting rod until contact is made. This contact helps maintain the alignment of the oil holes.

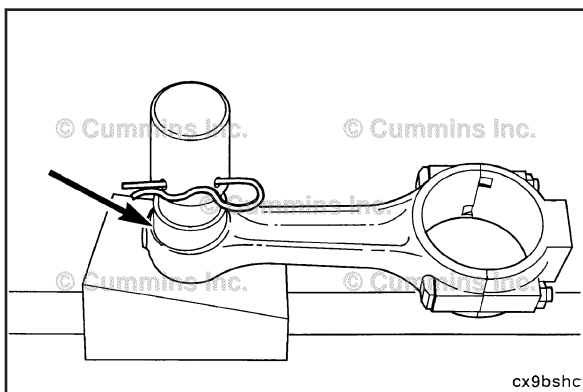


Place the connecting rod and mandrel assembly on the anvil.

Position it so that the angle on the connecting rod matches the angle on the anvil.

The connecting rod is in the horizontal position.

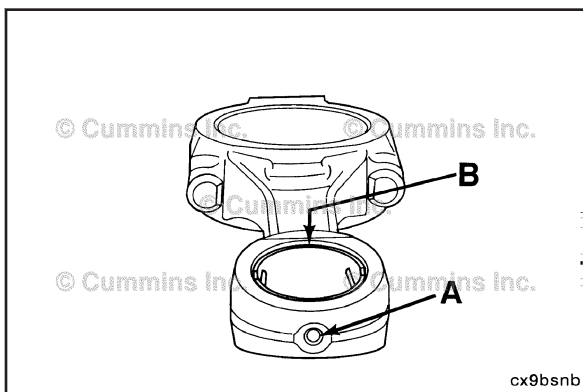




Press the bushing into the connecting rod by applying force on the top of the cup.

Use either an arbor or hydraulic press.

Push through in a continuous motion until the driver ring makes contact with the connecting rod.



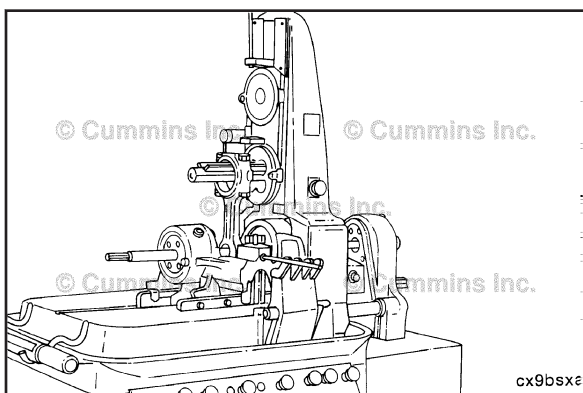
Check the alignment of the oil holes.

A 3 mm [0.118 in] diameter rod **must** move freely through the connecting rod and the bushing oil holes (A).

Check for clearance between the connecting rod bushing and the connecting rod.

Use a 0.025 mm [0.001 in] feeler gauge to make sure the bushing is properly seated.

The 0.025 mm [0.001 in] feeler gauge **must not** enter between the bushing and the connecting rod (B).

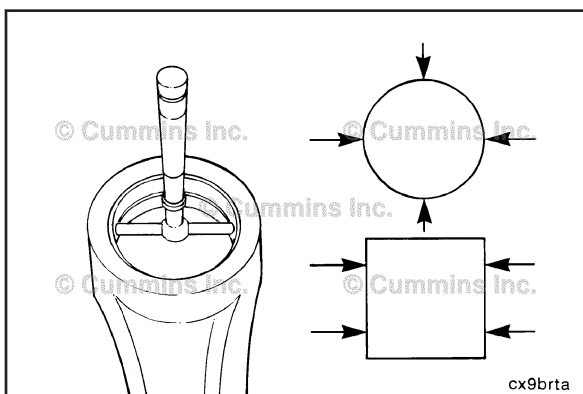


Machine

The inside diameter of new connecting rod bushings **must** be machined with a rod boring machine, such as Part Number 3823601 (Sunnen PM-300®) or Part Number 3375144 (Tobin Arp®).

When properly adjusted, a Sunnen PM-300®, or equivalent, connecting rod boring machine is capable of maintaining all the critical dimensions.

Do **not** use a "floating rod" type honing machine.



After machining the connecting rod bushings, it will be necessary to check all critical dimensions.

See the instructions within this procedure.

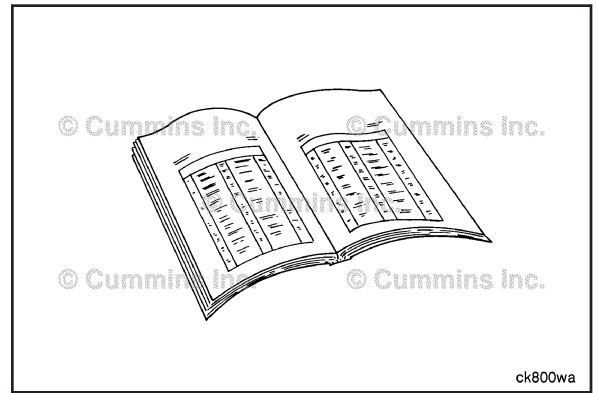


Finishing Steps

⚠ WARNING ⚠

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

- Assemble and install the piston and connecting rod assemblies. Refer to Procedure 001-054 (Piston and Connecting Rod Assembly) in Section 1.
- Install the lubricating oil suction tube. Refer to Procedure 007-035 (Lubricating Oil Suction Tube (Block-Mounted)) in Section 7.
- Install the lubricating oil pan and gasket. Refer to Procedure 007-025 (Lubricating Oil Pan) in Section 7.
- Install the cylinder head. Refer to Procedure 002-004 (Cylinder Head) in Section 2.
- Fill the lubricating oil pan. Refer to Procedure 007-037 (Lubricating Oil System) in Section 7.
- Fill the cooling system. Refer to Procedure 008-018 (Cooling System) in Section 8.
- Connect the batteries. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13.
- Open the fuel supply valve. Refer to the OEM instructions.
- Operate the engine to normal operating temperature and check for leaks.

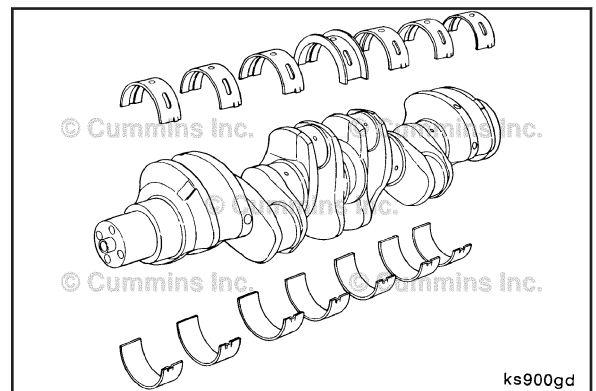


Crankshaft (001-016)

General Information

The crankshaft uses forged counterweights.

Oversize main bearings and thrust bearings are available for service. Cummins Engine Company, Inc., recommends regrinding **all** of the main or the connecting rod journals when one requires regrinding. Refer to the C Series Shop Manual, Bulletin No. 3666008.

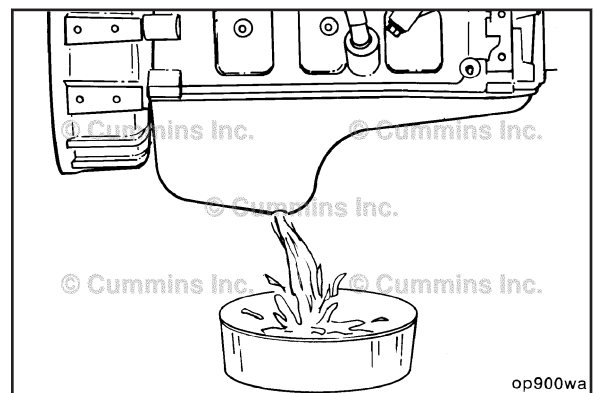


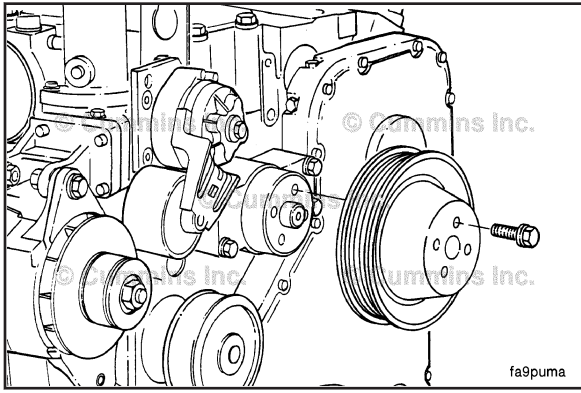
Preparatory Steps

⚠ WARNING ⚠

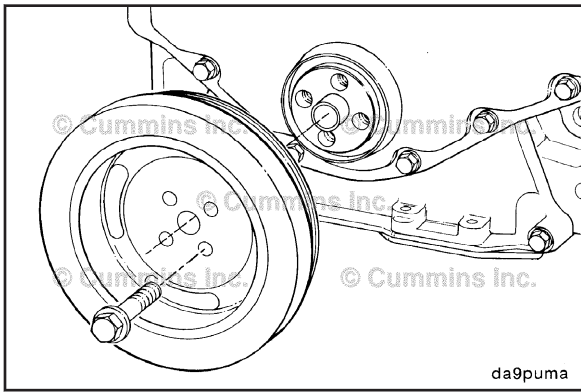
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.

Drain the lubricating oil; refer to Procedure 007-037.

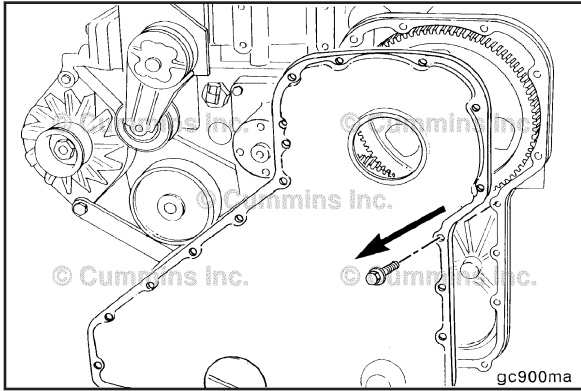




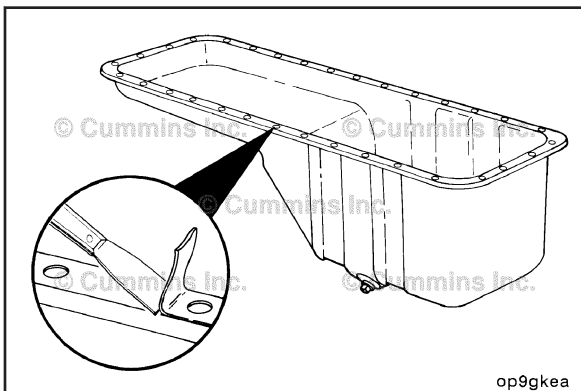
Remove the fan pulley; refer to Procedure 008-039.



Remove the vibration damper; refer to Procedure 001-052.

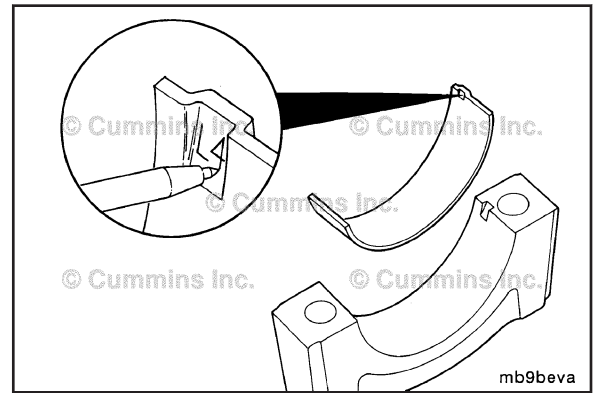


Remove the front gear cover; refer to Procedure 001-031.



Remove the lubricating oil pan; refer to Procedure 007-025.

Remove the main bearings; refer to Procedure 001-006.



Remove

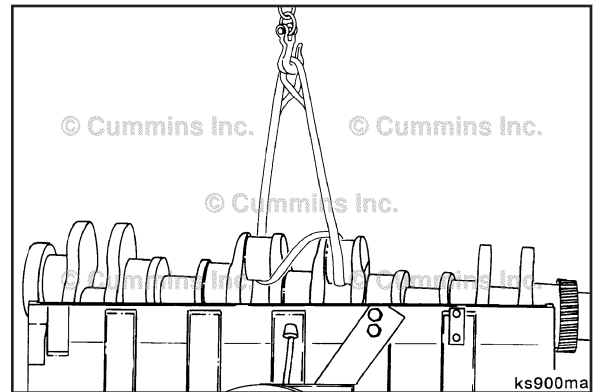
⚠ WARNING ⚠

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

NOTE: Lift the crankshaft straight up to avoid damage to the crankshaft and cylinder block.

Install nylon lift sling, Part No. 3375957, around the No. 3 and No. 4 rod bearing journals.

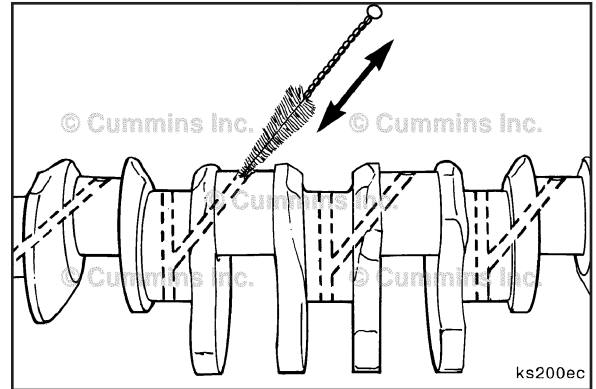
Attach the sling to a hoist; remove the crankshaft.



Clean

Use fine crocus cloth to polish the machined surfaces.

Use a bristle brush to clean the oil drillings.

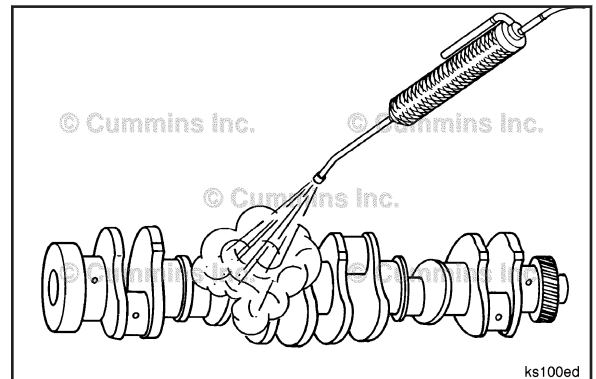


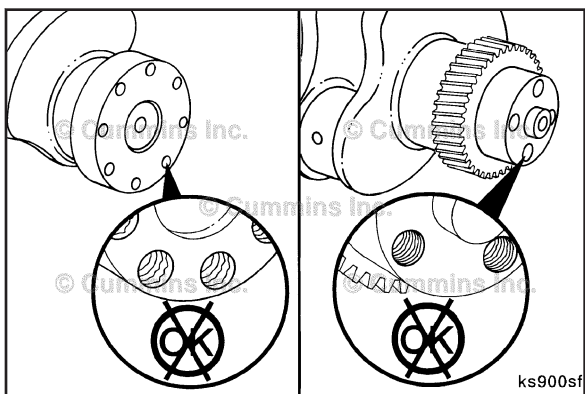
⚠ WARNING ⚠

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

Steam-clean the crankshaft and dry with compressed air.

Make sure to blow out the threaded holes on each end of the crankshaft and the oil drillings.





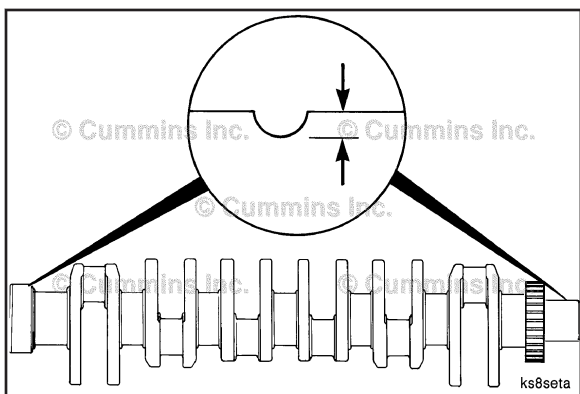
Inspect for Reuse

Inspect the threaded capscrew holes for damage.

Use one of the following methods to repair any threaded holes:

- Chase the threads
- Use the threaded insert kit, Part Number 3822709.

NOTE: If more than two threaded holes are damaged in one end, the crankshaft **must** be replaced.

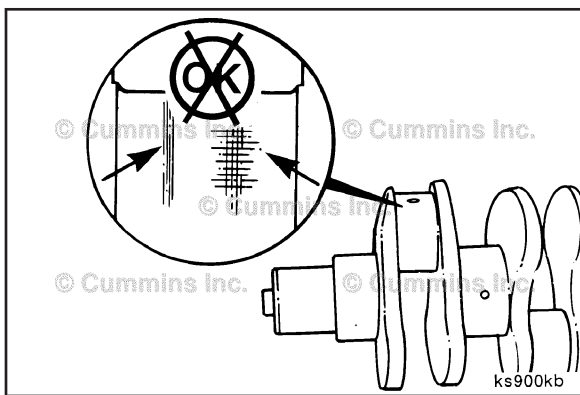


Measure the front and rear oil seal contact areas for a wear groove.

Crankshaft Front and Rear Oil Seal Wear Groove

mm		in
0.25	MAX	0.010

Front and rear wear sleeves are available for a crankshaft that is worn beyond the limit.



Inspect the crankshaft connecting rod and main journals for deep scoring, overheating, etc.

Use a micrometer to measure the connecting rod journal.

Connecting Rod Bearing Journal Diameter

	mm		in
Standard	75.96	MIN	2.991
Machined 0.25 mm	75.71	MIN	2.981
0.010 in			
Machined 0.50 mm	75.46	MIN	2.971
0.020 in			
Machined 0.75 mm	75.21	MIN	2.961
0.030 in			
Machined 1.00 mm	74.96	MIN	2.951
0.040 in			

Bearing Clearance = Connecting rod inside diameter with bearing installed minus crankshaft journal diameter.

Maximum Bearing Clearance: 0.117 mm [0.0046 in].

Connecting Rod Bearing Journal

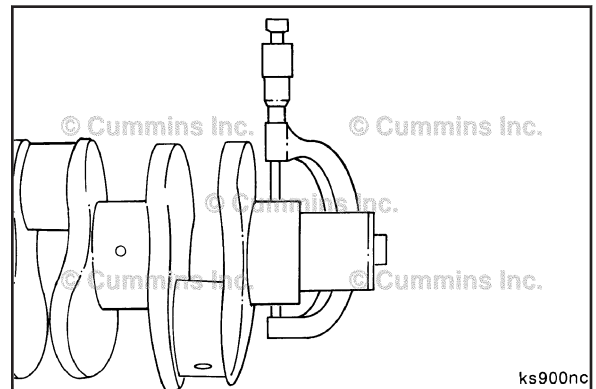
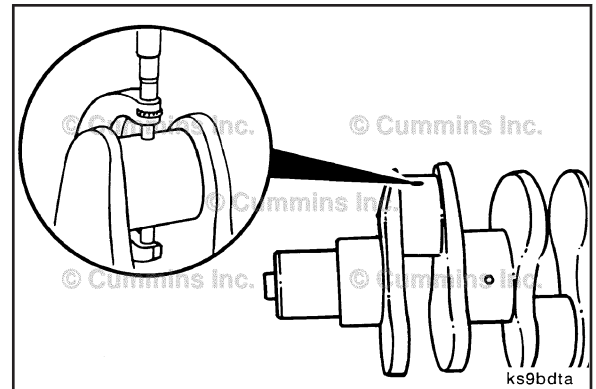
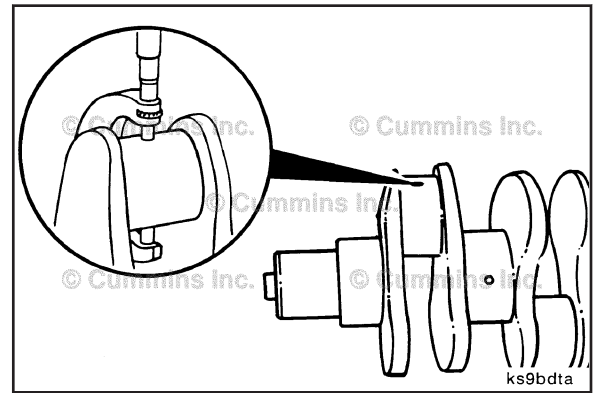
	mm		in
Out-of-Roundness	0.050	MAX	0.0020
Taper	0.013	MAX	0.0005

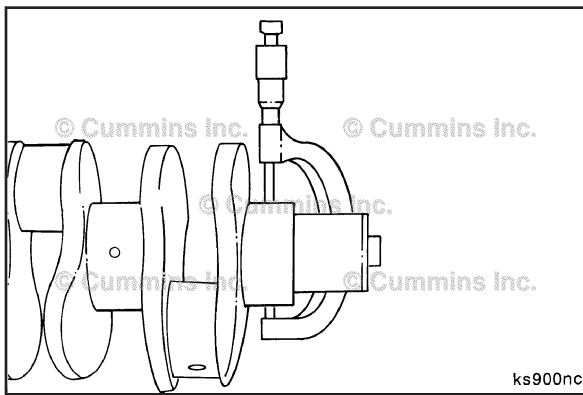
Main Bearing Journal Diameter

	mm		in
Standard	97.96	MIN	3.857
Machined 0.25 mm	97.71	MIN	3.847
0.010 in			
Machined 0.50 mm	97.46	MIN	3.837
0.020 in			

Bearing Clearance = Main bore diameter with bearing installed minus (-) crankshaft main journal diameter.

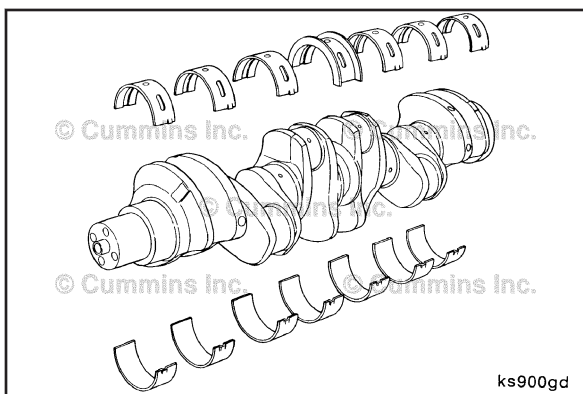
Maximum Bearing Clearance: 0.13 mm [0.005 in].





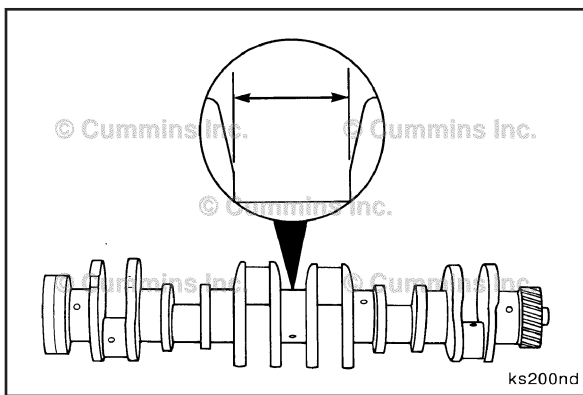
Crankshaft Main Bearing Journal

	mm		in
Out-of-Roundness	0.05	MAX	0.002
Taper	0.01	MAX	0.001



The following oversize service main and thrust bearings are available for crankshafts that have been machined undersize:

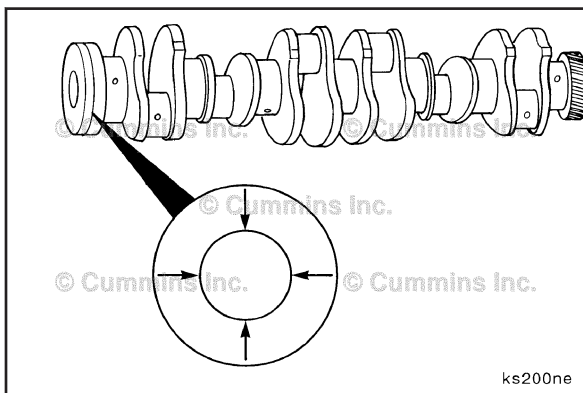
Thrust Size				
	Oversize	0.000	0.25 mm	0.50 mm
Journal	0.000	X	X	X
Diameter	0.25 mm	X	X	
	0.50 mm	X		X
	0.75 mm	X		
	1.00 mm	X		



Measure the thrust face width.

Crankshaft Thrust Face Width (Standard)

mm		in
42.98	MIN	1.692
43.08	MAX	1.696



Measure the rear oil seal flange outside diameter.

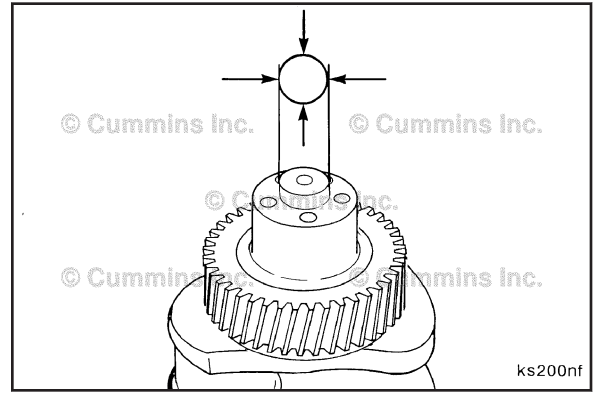
Crankshaft Rear Oil Seal Flange O.D.

mm		in
129.98	MIN	5.117
130.03	MAX	5.119

Measure the damper pilot outside diameter.

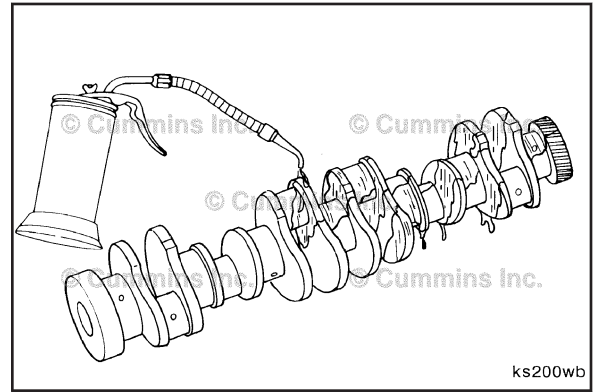
Crankshaft Damper Pilot O.D.

mm		in
23.92	MIN	0.942
24.00	MAX	0.945

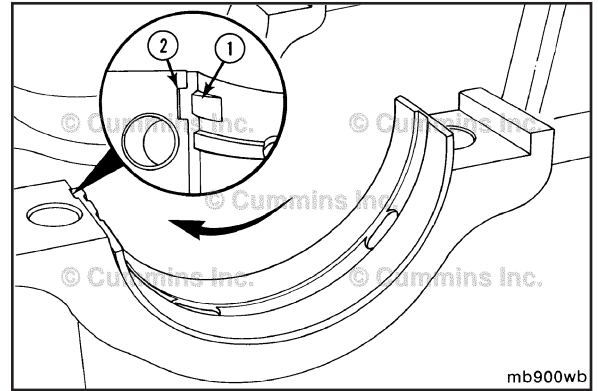


Use a light preservative oil to lubricate the crankshaft to prevent rust.

NOTE: If the crankshaft is **not** going to be used immediately, protect the part with a plastic cover to prevent dirt from sticking to the oil.

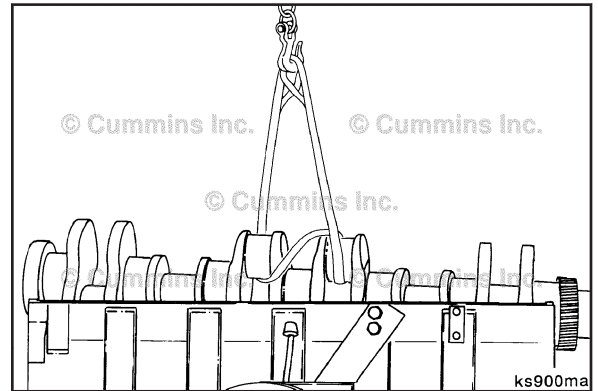


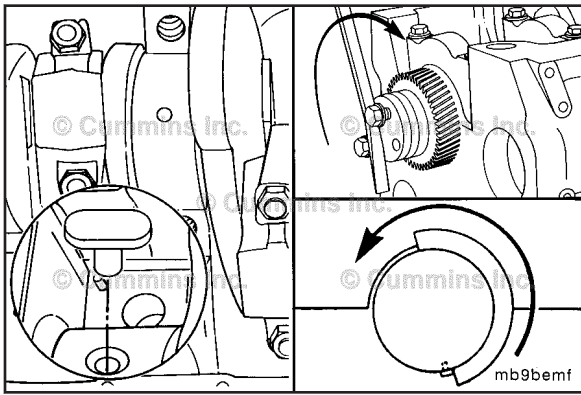
Install the upper main bearings; refer to Procedure 001-006.



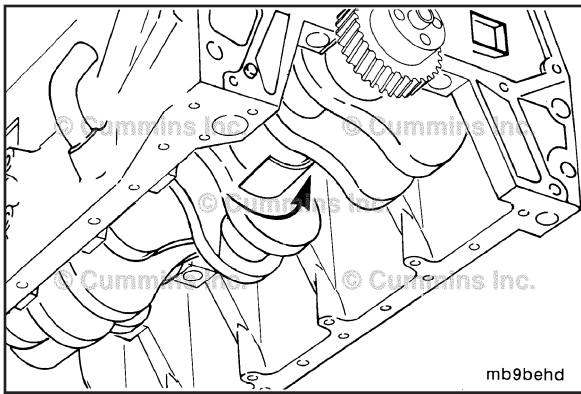
⚠ WARNING ⚠
This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this component.

Use a hoist and nylon lift sling, Part No. 3375957.
Install the sling around the No. 3 and No. 4 connecting rod bearing journals.
Install the crankshaft.

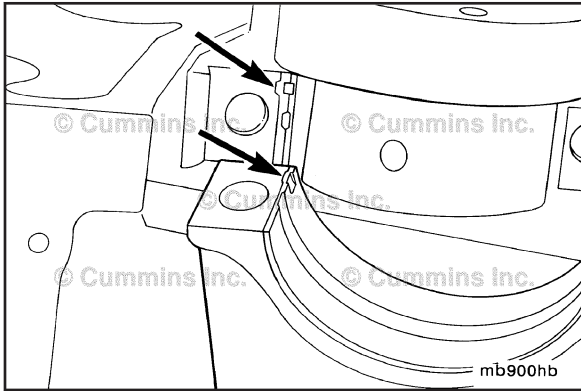




Install the upper thrust bearing; refer to Procedure 001-006.

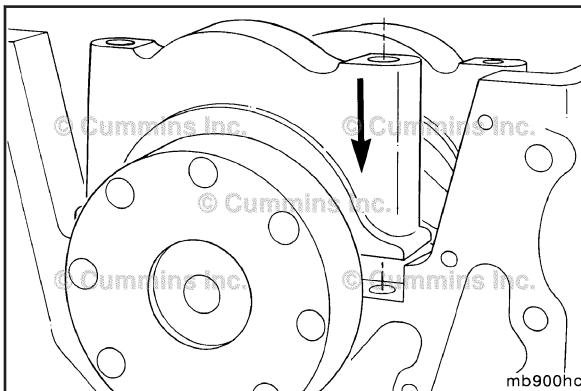


Install the lower main bearing; refer to Procedure 001-006.



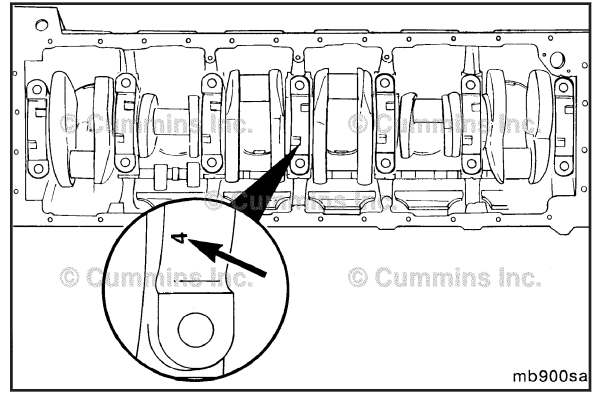
NOTE: The main bearing caps are numbered for location. No. 1 starts with the front of the cylinder block and the numbers **must** face the camshaft side of the engine.

When installed correctly, the main bearing tangs will both be on the same side.

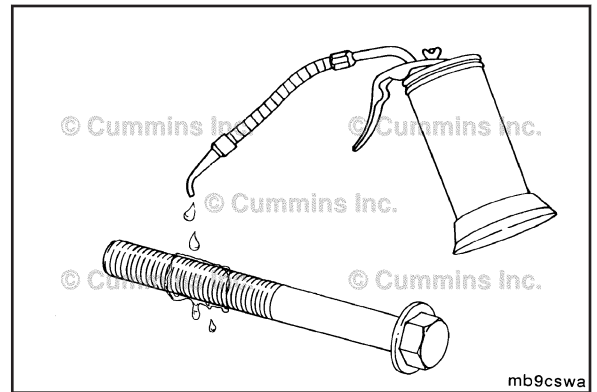


Position the main bearings and main bearing caps onto the crankshaft.

The thrust bearing journal does **not** have tangs or slots. Care **must** be taken to make sure the number stamped on the main bearing cap is positioned to the camshaft side of the engine.



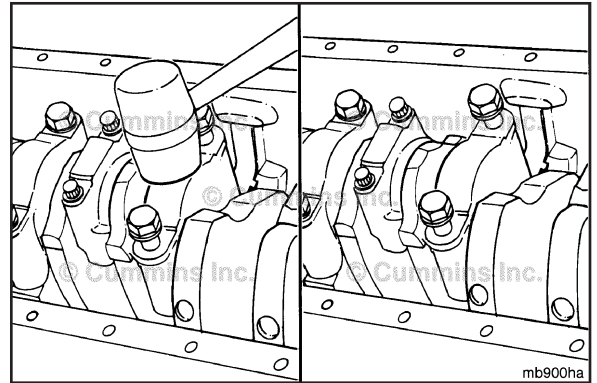
Lubricate the main bearing capscrew threads and underside of the capscrew head with clean engine oil.



Tap the main bearing cap gently into position.

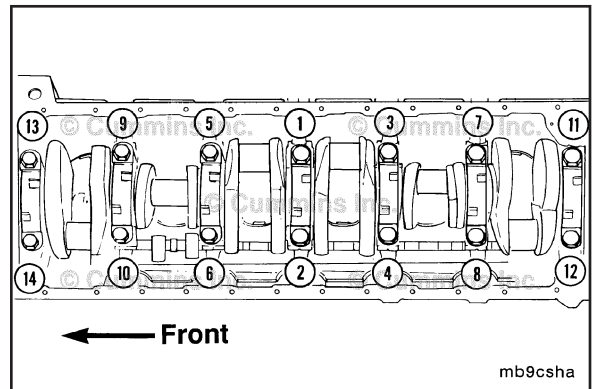
NOTE: Make sure the main bearing is still aligned with the cap.

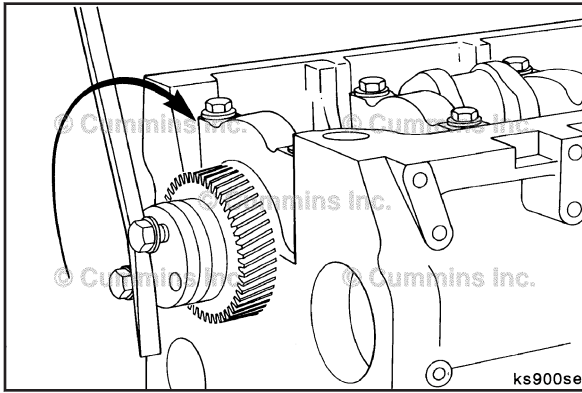
When seated, the main bearing capscrews can be threaded in by hand.



Tighten the main bearing capscrews evenly following the illustrated sequence.

Torque Value:	Step1	50 N•m	[37 ft-lb]
	Step2	95 N•m	[70 ft-lb]
	Step3	60°	





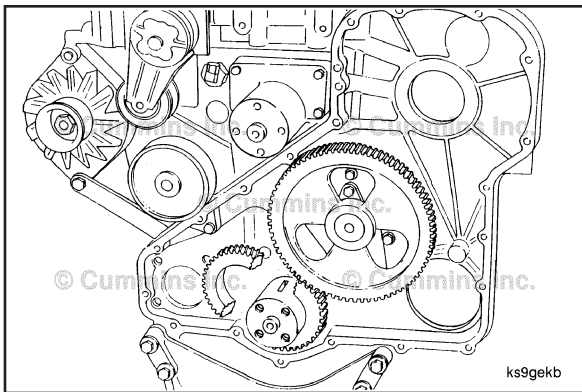
NOTE: The crankshaft **must** rotate freely after the main bearings have been installed.

Inspect the main bearing installations and the size of the main bearings if the crankshaft will **not** rotate freely.

Crankshaft Gear, Front (Crankshaft Installed) (001-018)

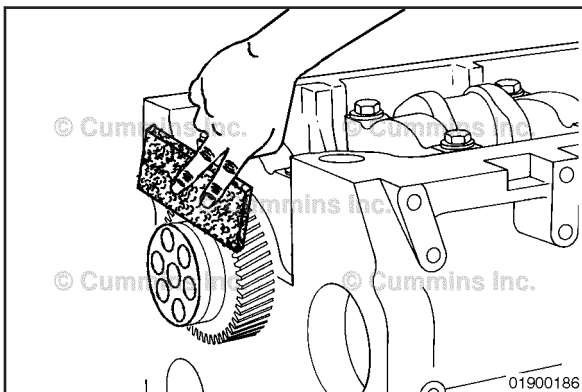
General Information

The front crankshaft gear has an interference fit with the crankshaft. If the gear is damaged, the crankshaft will also be damaged. If it is necessary to replace the front crankshaft gear, the crankshaft **must** be replaced. Refer to Procedure 001-016 in the Troubleshooting and Repair Manual, C8.3G, C Gas Plus, and L Gas Plus Engines, Bulletin 3666206 or Procedure 001-016 in the Troubleshooting and Repair Manual, C Series Engines, Bulletin 3666003.



Inspect for Reuse

Inspect the crankshaft gear for cracks and broken or chipped teeth.

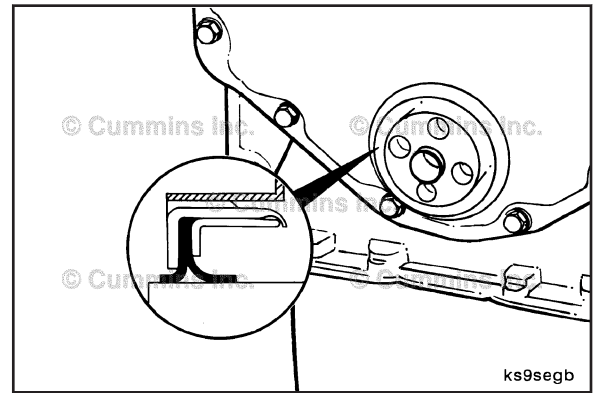


Remove any burrs with Scotch-Brite™ 7448 abrasive pad, Part Number 3823258.

Crankshaft Seal, Front (001-023)

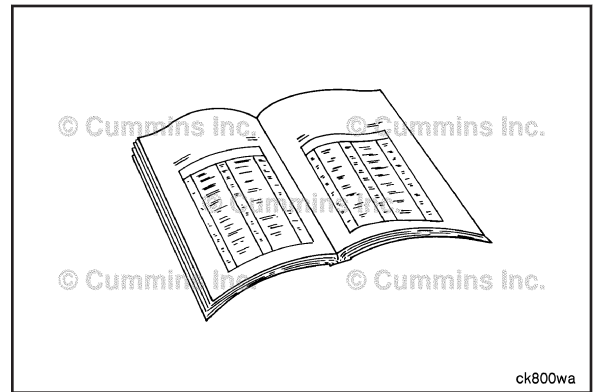
General Information

The front crankshaft seal is mounted in the front gear cover. A double-lipped Teflon™ seal is used. The sealing surface on the crankshaft **must** be clean and free of lubricating oil during assembly.



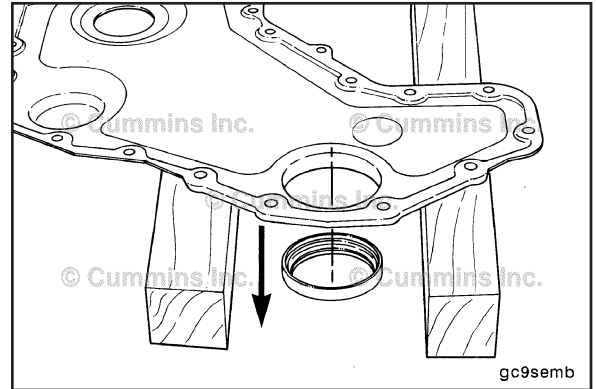
Preparatory Steps

- Disconnect the batteries. Refer to Procedure 013-009 (Battery Cables and Connections) in Section 13.
- Remove the drive belt. Refer to Procedure 008-002 (Drive Belt, Cooling Fan) in Section 8.
- Remove the vibration damper. Refer to Procedure 001-052 (Vibration Damper, Viscous) in Section 1.
- Remove the front gear cover. Refer to Procedure 001-031 (Gear Cover, Front) in Section 1.



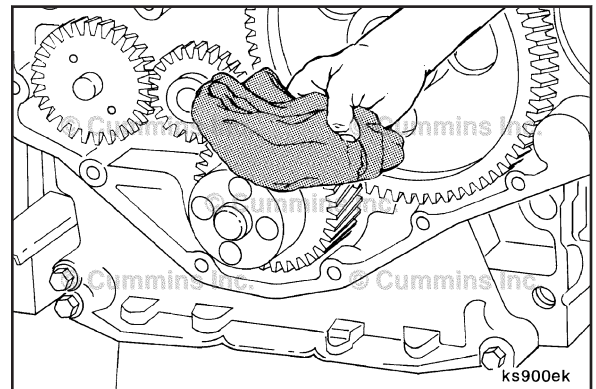
Remove

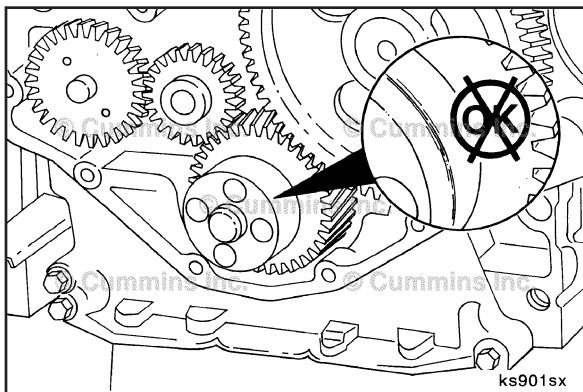
While supporting the gear cover, remove the oil seal from the gear cover. Drive the oil seal from the back side of the cover toward the front side of the cover.



Clean and Inspect for Reuse

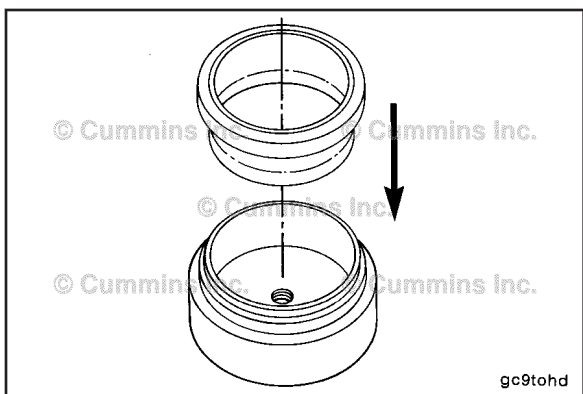
Clean the gear cover seal bore and the crankshaft surface of all oil, dirt, and seal residue.





Inspect the crankshaft for excessive wear.

If the crankshaft has excessive wear, a service wear sleeve is available.

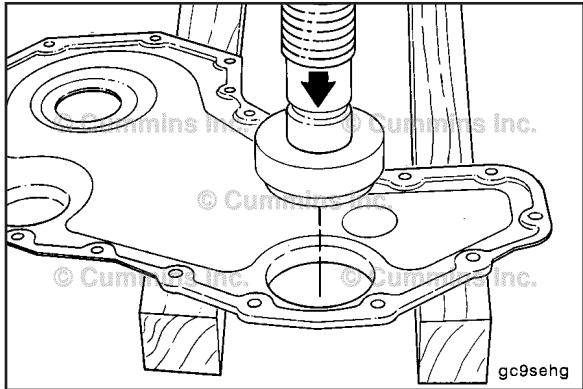


Install

Leave the plastic pilot installation tool in the lubricating oil seal.

Position the seal on the seal installer, Part Number 3824499, with the lubricating oil seal dust lip facing outward.

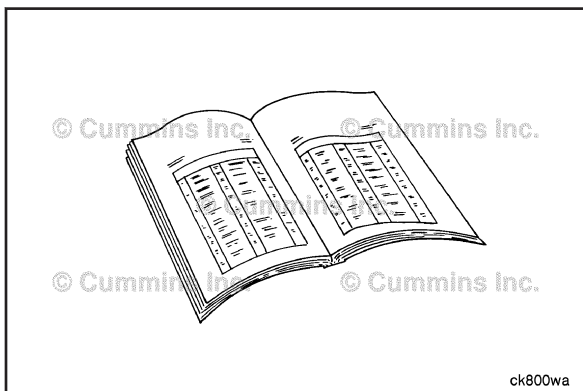
Apply a bead of Loctite 277, or equivalent, to the outside diameter of the seal before installation.



Properly support the front cover lubricating oil seal flange to prevent damage to the lubricating oil seal and front cover.

Press the lubricating oil seal into the front cover from the backside of the cover toward the front side of the cover.

Press the lubricating oil seal until the service tool bottoms against the front cover.



Finishing Steps

- Install the front gear cover. Refer to Procedure 001-031 (Gear Cover, Front) in Section 1.
- Install the vibration damper. Refer to Procedure 001-052 (Vibration Damper, Viscous) in Section 1.
- Install the 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 leaks.

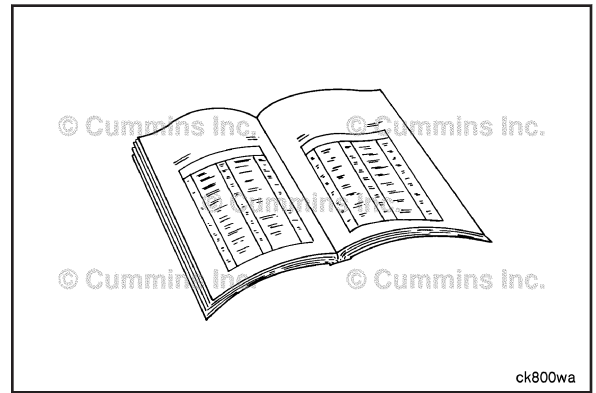


Crankshaft Seal, Rear (001-024)

Preparatory Steps

Disconnect the driveline and remove the transmission, if equipped; refer to the OEM's instructions.

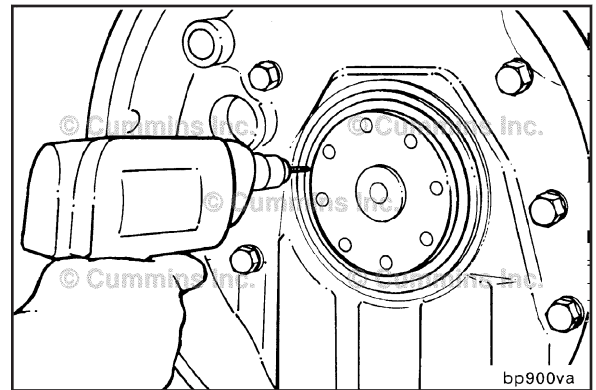
Remove the clutch and flywheel, if equipped. Refer to Procedure 016-005.



Remove

Drill two 3-mm [0.12-in] holes, 180 degrees apart, through the outside metal of the rear crankshaft seal.

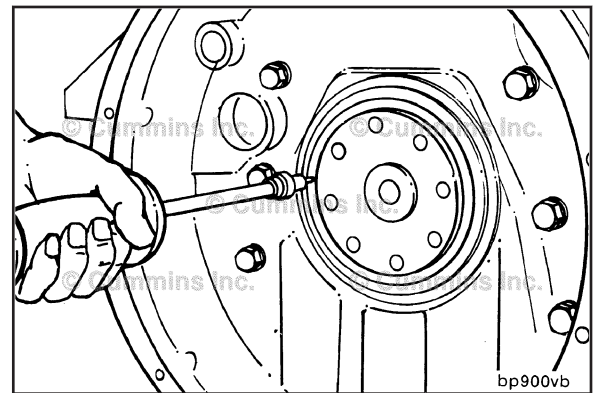
NOTE: Make sure **not** to damage the crankshaft when drilling the holes.



Install a Number 10 sheet metal screw into a slide hammer, Part Number 3823822.

Install the screw/slide hammer into the hole in the rear crankshaft seal.

Remove the seal.

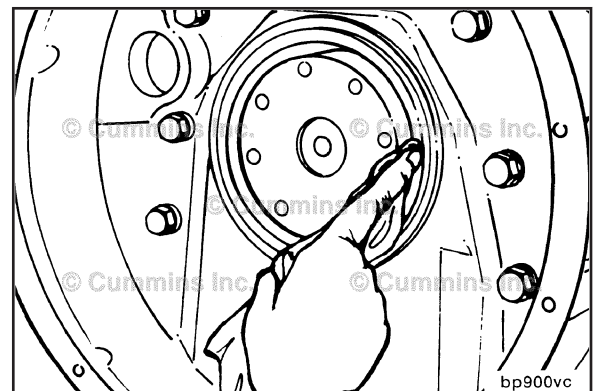


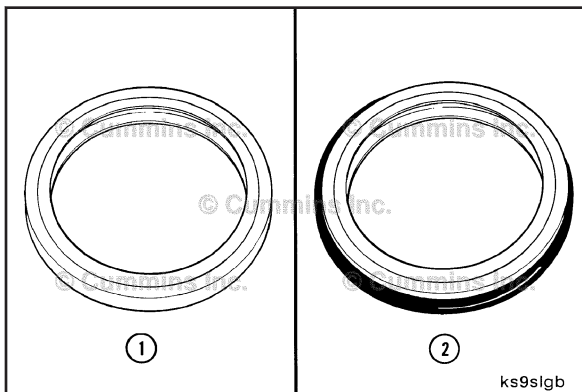
Clean

⚠ CAUTION ⚠

The seal lip and the sealing surface on the crankshaft must be free from all oil residue to prevent seal leaks.

Use Scotch-Brite™ 7448, Part Number 3823258, and a soft cloth to clean and dry the rear crankshaft sealing surface.



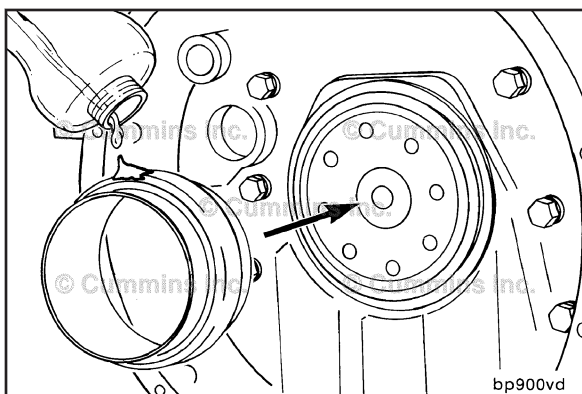


Install

NOTE: There are two rear seal configurations used:

- One for dry flywheel housings (1)
- One for wet flywheel housings (2).

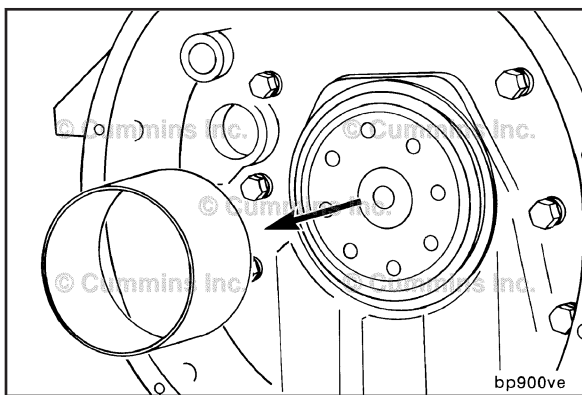
NOTE: The seal for dry flywheel housings has an aluminum case with a urethane coating. The seal for wet flywheel housings has a steel case with a silicone coating. Refer to the appropriate C Series Parts Catalog for the correct part number.



Install the pilot and seal from the seal replacement kit onto the crankshaft.

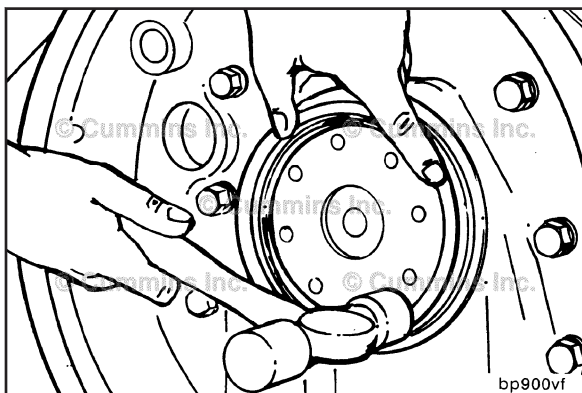
NOTE: For wet flywheel housings, apply a coat of mild soap to the outside of the seal case.

NOTE: For dry flywheel housings, nothing is required on the outside of the seal case.



Push the seal onto the pilot and into the bore of the flywheel housing.

Remove the pilot.



NOTE: Make sure the seal is completely installed into the rear housing.

Use the installation tool from the seal replacement kit to install the seal to the correct depth.



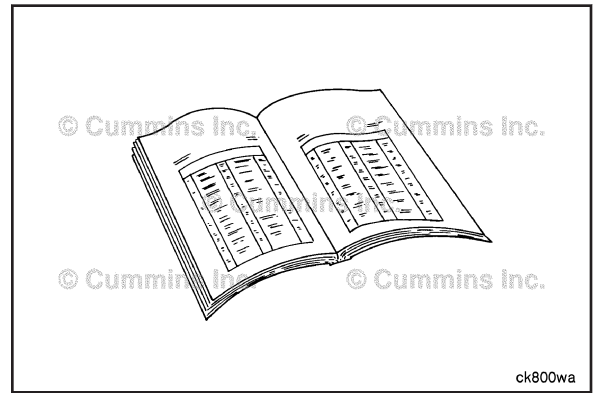
To prevent damage to the seal, hit the installation tool alternately at the 12-o'clock, 3-o'clock, 6-o'clock and 9-o'clock positions.

Finishing Steps

Install the flywheel and clutch, if equipped. Refer to Procedure 016-005.

Install the transmission and driveline; refer to the OEM's instructions.

Operate the engine until the coolant reaches 82°C [180°F], and check for leaks and proper operation.

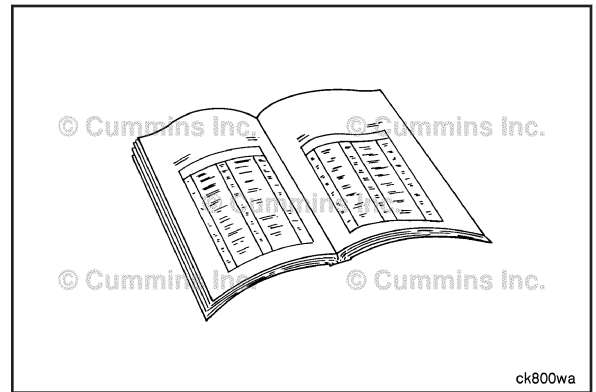


Crankshaft Wear Sleeve, Front (001-025)

Preparatory Steps

Remove the following:

- Drive belt. Refer to Procedure 008-002.
- Vibration damper. Refer to Procedure 001-052.
- Front gear cover. Refer to Procedure 001-031.



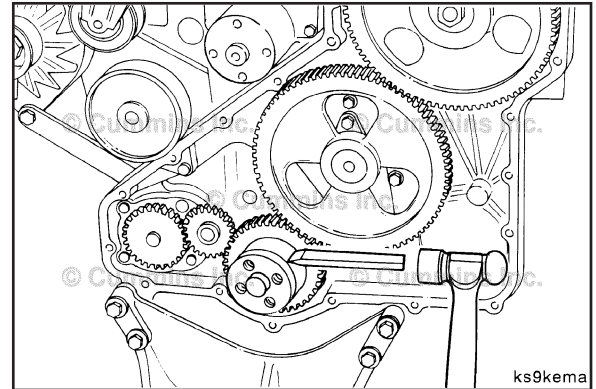
Remove

⚠ CAUTION ⚠

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

NOTE: Use a hammer and chisel that is **only** as wide as the wear sleeve.

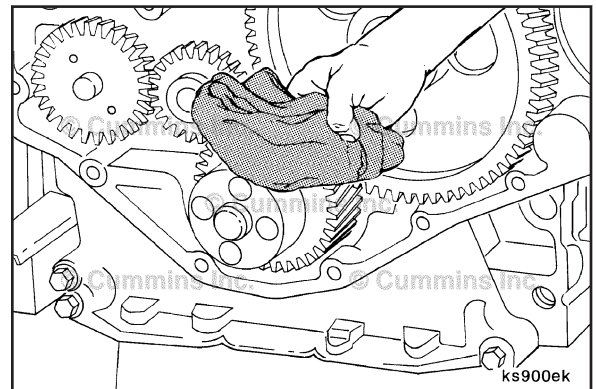
Make one or two chisel marks across the wear sleeve. This will expand the wear sleeve, allowing the sleeve to be removed.

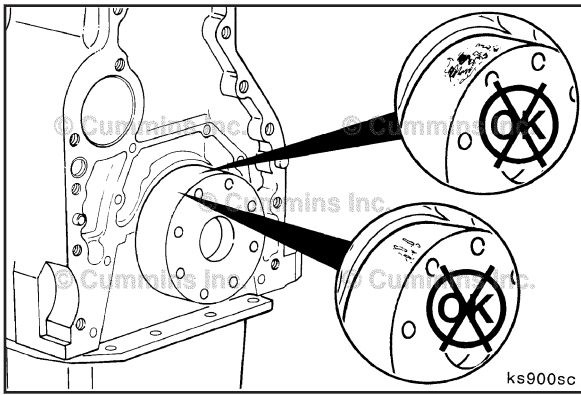


Clean and Inspect for Reuse

Use Scotch-Brite™ 7448, Part No. 3823258, to remove any rust or other deposits from the crankshaft flange.

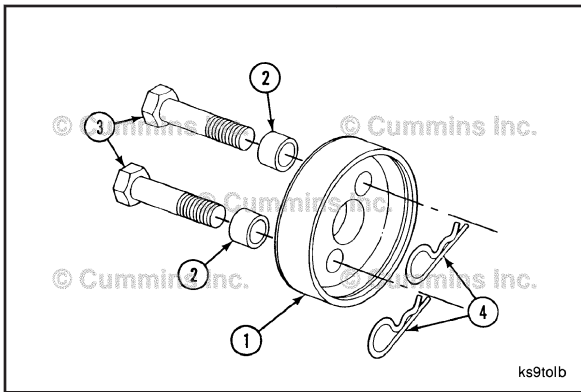
Use a clean cloth to clean the crankshaft flange.





Inspect the seal contact area on the crankshaft for a wear groove. If the seal has worn a groove deep enough to be felt with a sharp object or fingernail, it will be necessary to install a wear sleeve to prevent an oil leak.

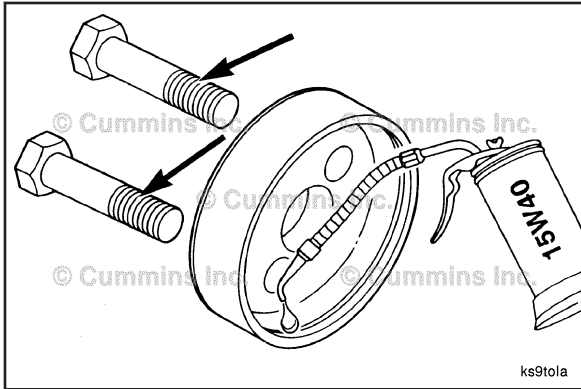
The oil seal used with the wear sleeve has a larger inside area than the standard seal. The two seals are **not** interchangeable.



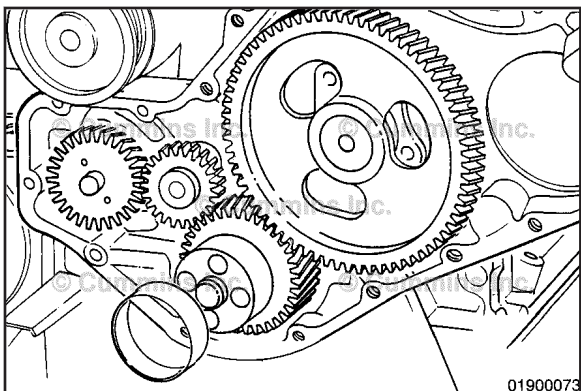
Install

Use the crankshaft front wear sleeve installation tool, Part No. 3823908, to install the wear sleeve to the correct position on the crankshaft. The tool kit consists of the following:

1. Driver - 1
2. Spacers - 2
3. Capscrews - M14x1.5x60 mm - 2
4. Hair Pin Cotter Pins - 2

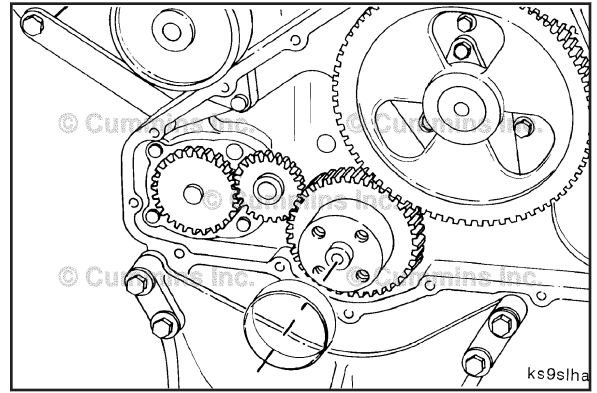


Apply a thin coat of clean engine oil to the inside of the driver and to the capscrew threads.

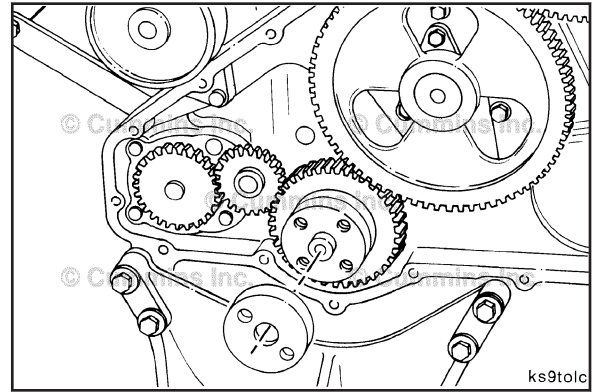


Apply a thin coat of clean engine oil to the crankshaft flange.

Position the chamfered end of the wear sleeve onto the end of the crankshaft.



Position the counterbore end of the driver onto the wear sleeve.



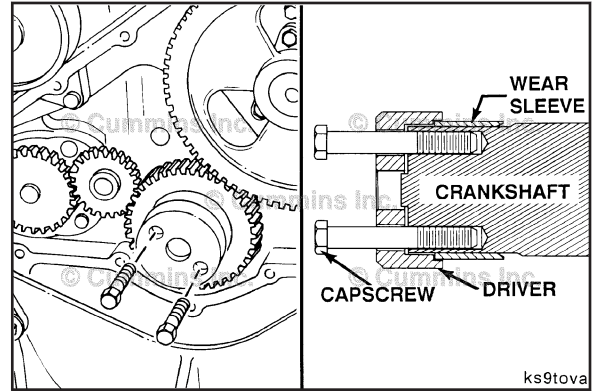
Install two M14x1.5x60 mm capscrews (without spacers or hairpin cotter pins) through the driver and into the crankshaft capscrew holes.



Align the wear sleeve and driver perpendicular with the crankshaft.



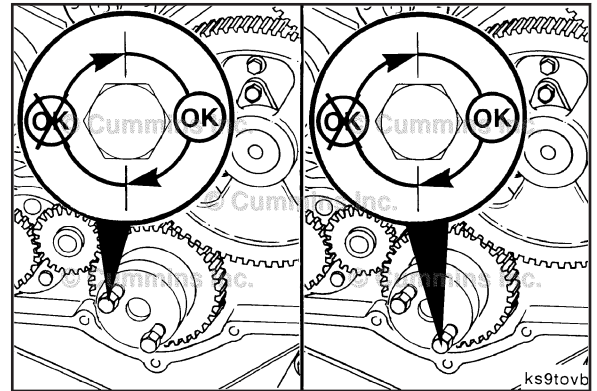
Tighten the capscrews "finger-tight."

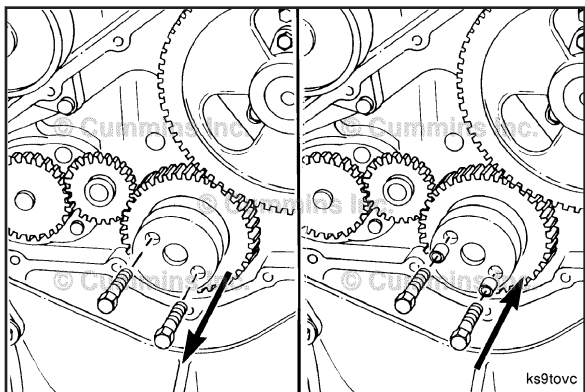


⚠CAUTION⚠
To prevent damage to the wear sleeve, do not exceed 1/2 of a revolution of each capscrew.

Alternately, tighten the capscrews until the sleeve is installed to a depth of approximately 16 mm [0.625 in].

Torque Value: 20 N•m [15 ft-lb]

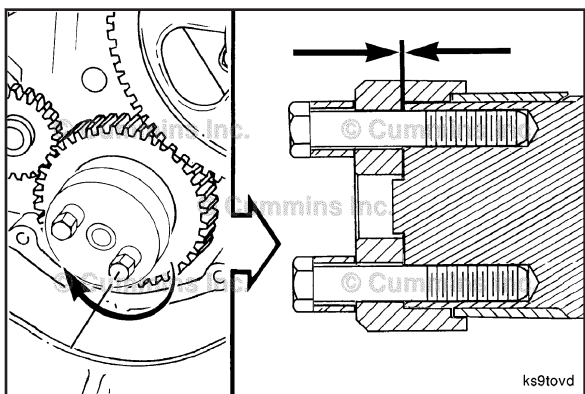




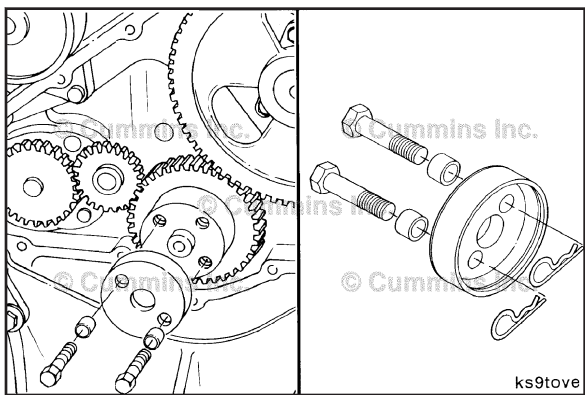
Remove the capscrews and install the spacer on each capscrew.



Install the two M14x1.5x60 mm capscrews.

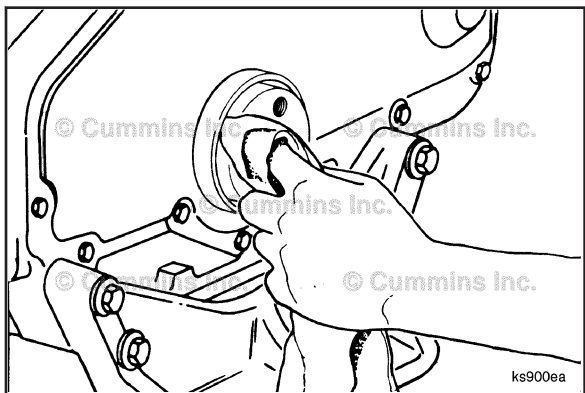


Continue to tighten the capscrews alternately until the bottom of the driver contacts the end of the crankshaft.



Remove the driver.

NOTE: Use the hairpin cotter pins to secure the capscrews and spacers to the tool during storage.



Clean the wear sleeve and crankshaft of any excess lubricants.

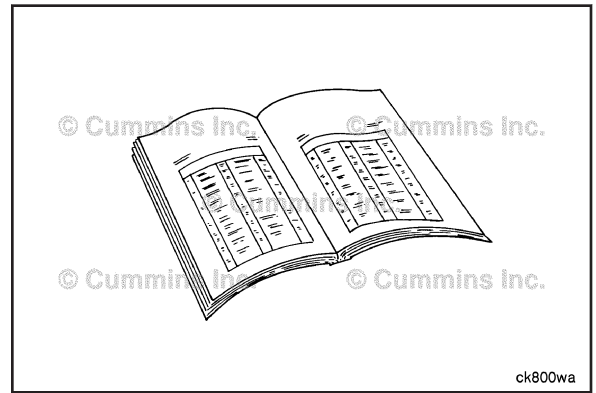
NOTE: The wear sleeve and oil seal mating surface **must** be clean and dry to allow proper oil sealing.

Finishing Steps

Install the following components:

- Front gear cover. Refer to Procedure 001-031.
- Vibration damper. Refer to Procedure 001-052.
- Fan pulley. Refer to Procedure 008-039.
- Drive belt. Refer to Procedure 008-002.

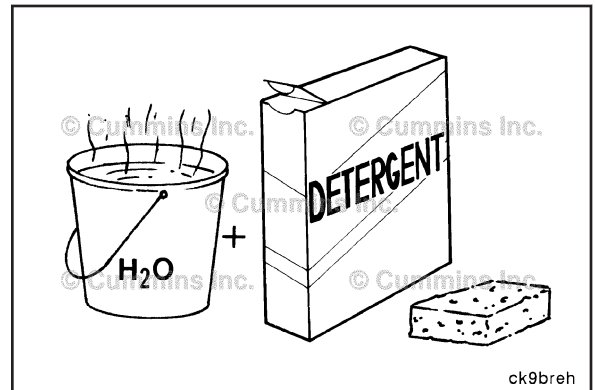
Operate the engine and check for leaks.



Cylinder Block (001-026)

Clean

Use a strong solution of hot water and detergent to clean the cylinder bores.



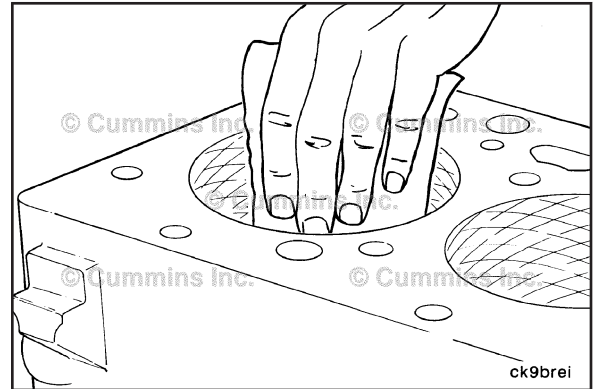
⚠ WARNING ⚠

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

NOTE: Clean the cylinder bores immediately after being deglazed.

Rinse the cylinder bores until the detergent is removed.

Dry the cylinder block with compressed air.



⚠ WARNING ⚠

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

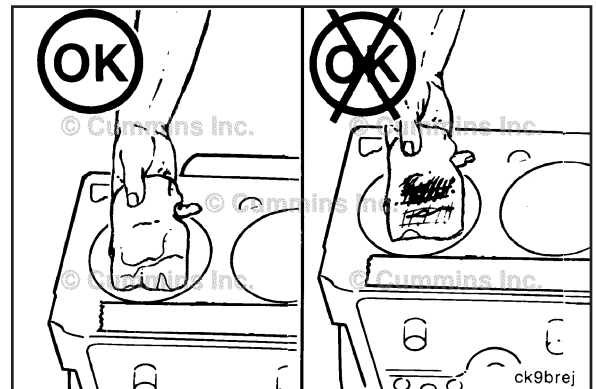
NOTE: Remove the tape that covers the tappet and lubricating oil holes after the cleaning process is complete.

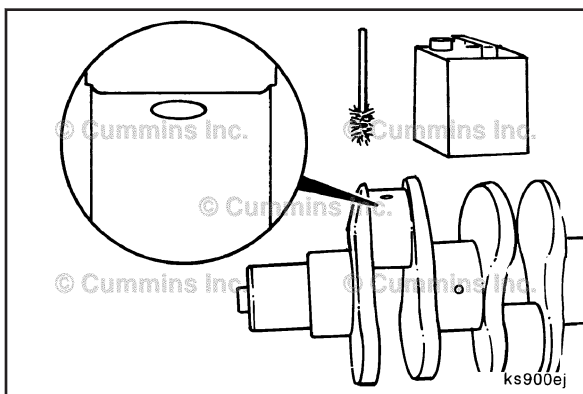
Check the cylinder bore cleanliness by wiping them with a white, lint-free, lightly oiled cloth.

If grit residue is still present, repeat the cleaning process until all residue is removed.

Wash the cylinder bores with solvent.

Dry the cylinder block with compressed air.

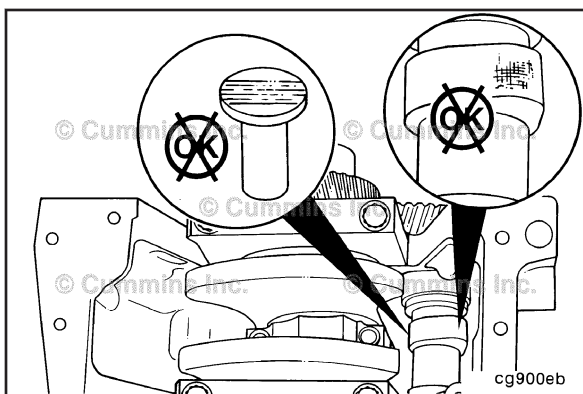




NOTE: Remove the covering from the piston cooling nozzles.

Remove the protective tape and cloth from the crankshaft journals.

Clean the crankshaft journals.

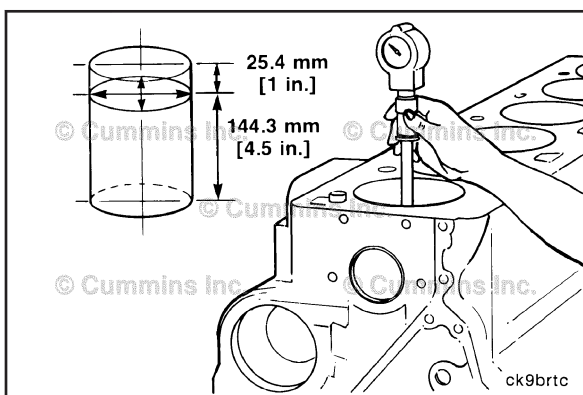


⚠ WARNING ⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.



Use solvent and a brush to clean any residue that possibly splashed on the camshaft.

NOTE: Inspect the camshaft lobes and tappet faces for signs of wear or damage. Refer to Procedure 001-008.



Inspect for Reuse

Measure the cylinder bore diameter at 25.4 mm [1 in] and 170.7 mm [5.5 in] from the top of the cylinder block.

Cylinder Bore Dimensions

	mm		in
Bore Inner Diameter	114.00	MIN	4.488
	114.04	MAX	4.990
Bore Out of Round	0.08	MAX	0.003
Bore Taper	0.02	MAX	0.001

NOTE: Do **not** proceed with in chassis overhaul if the cylinder bores are worn beyond specifications.

Cylinder Liner (001-028)

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 ⚠

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

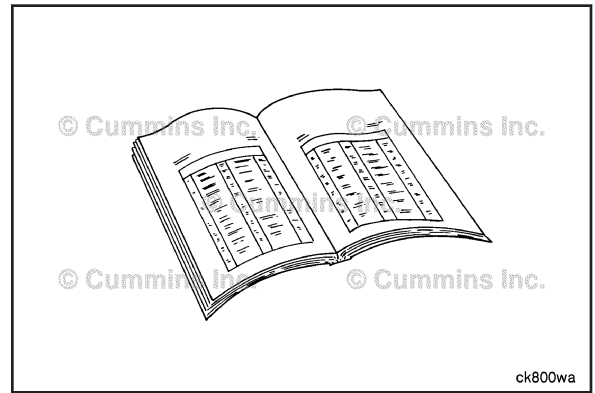
⚠ WARNING ⚠

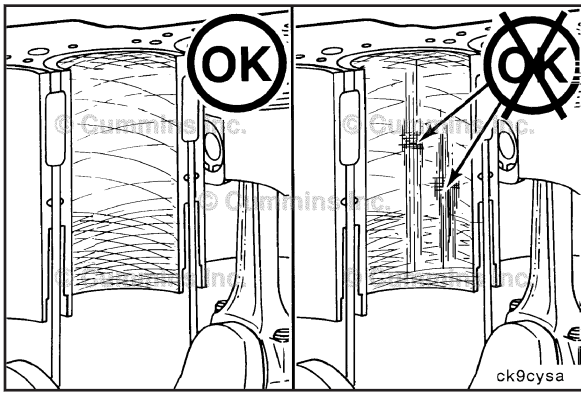
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠ WARNING ⚠

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

- Close the fuel supply valve. Refer to the OEM instructions.
- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Drain the cooling system. Refer to Procedure 008-018 in Section 8.
- Remove the cylinder head. Use the following procedure for C Series diesel engines. Refer to Procedure 002-004 in Section 2.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the piston and connecting rod assemblies. Refer to Procedure 001-043 in Section 1.





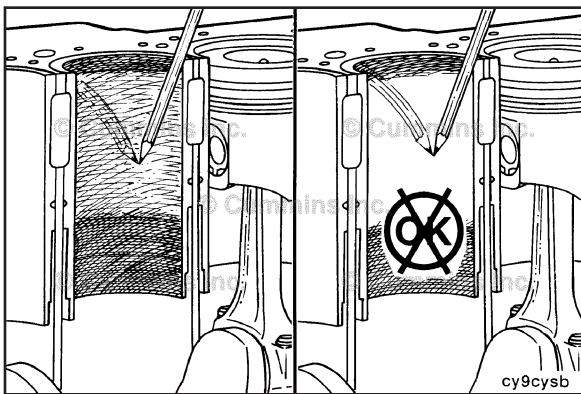
Initial Check

NOTE: Before removing the cylinder liners, inspect the condition to determine reusability.

Inspect the inside of the liner for cracking, scuffing, or scoring.

Inspect the inside for vertical scratches deep enough to be felt with a fingernail.

NOTE: If a fingernail catches in a scratch, the liner **must** be replaced.



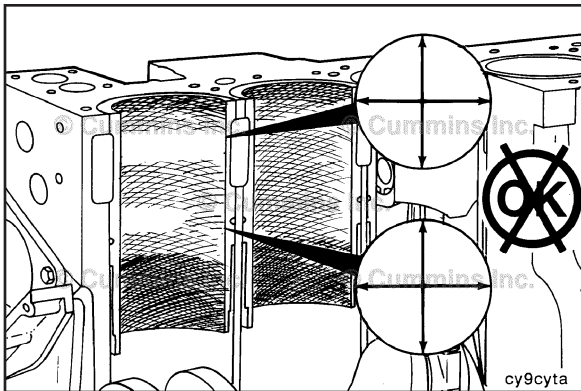
Inspect the inside of the liner bore for polishing.

NOTE: A moderate polish produces a bright mirror finish in the worn area with traces of the original hone marks or an indication of an etch pattern.

NOTE: A heavy polish produces a bright mirror finish in the worn area with no traces of hone marks or an etch pattern.

Do **not** reuse liners that have heavy polish or any indications of particle embedment from failure.

Inspect the liners for a ridge near the top of the liner. Severely worn liners will have a ridge near the top of the liner bore.

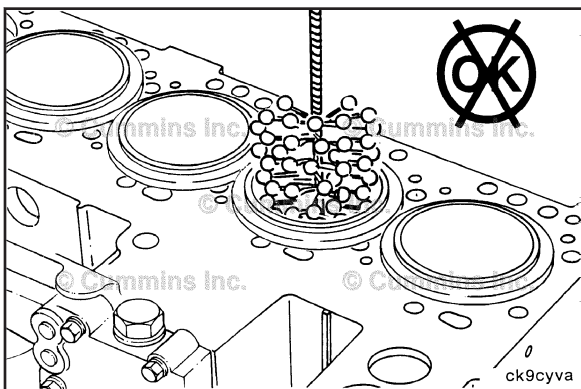


If the wear pattern indicates the liner bore is **not** straight or **not** round, use a dial bore gauge to measure the liner inside diameter in four places 90 degrees apart at the top and bottom of the piston travel area.



Cylinder Liner Dimensions

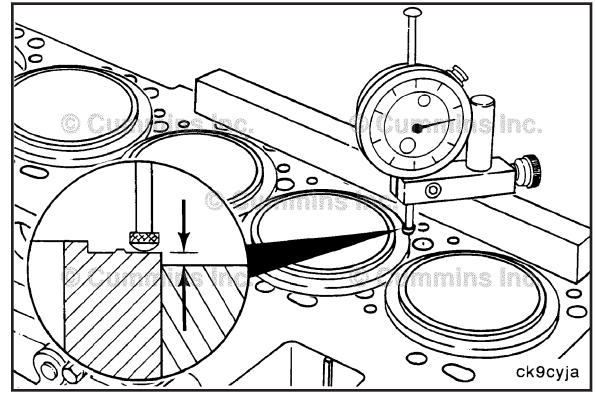
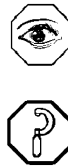
	mm		in
Out of Round	0.04	MAX	0.002
Taper	0.04	MAX	0.002
Bore Diameter	114.04	MAX	4.490



NOTE: If the liner bore is **not** acceptable for reuse, it **must** be replaced. Damaged liners can **not** be honed or deglazed. This will destroy the crosshatch pattern needed for oil control.

NOTE: Do **not** remove or disturb the liner seals for liners that pass the inspection criteria.

Cylinder liner protrusion is the distance the liner protrudes above the block face. Before removing the liners, check the protrusion, use the liner protrusion gauge, Part Number 3823495, in the unclamped state.



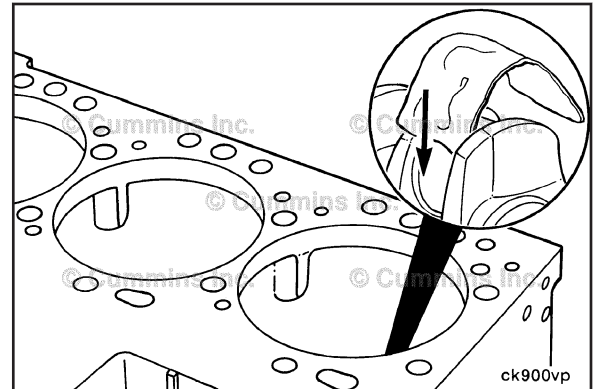
Cylinder Liner Protrusion

	mm		in
New Block and Liners	0.025	MIN	0.001
	0.122	MAX	0.005
Used Block and Liners	0.000	MIN	0.000
	0.122	MAX	0.005
New Block Used Liners	0.025	MIN	0.001
	0.122	MAX	0.005
Used Block New Liners	0.000	MIN	0.000
	0.122	MAX	0.005

NOTE: If the liner was installed correctly and the liner protrusion is out-of-limits, it will be necessary to machine the counterbore and add shims to restore to the original specifications.

Remove

NOTE: Use clean shop rags to cover the crankshaft to prevent debris from falling into the main journal area or into the connecting rod journal oil drilling.

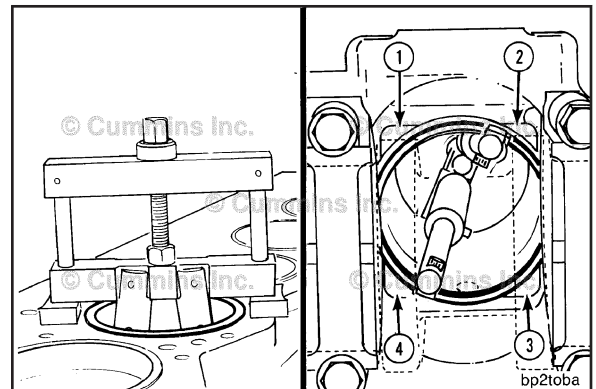


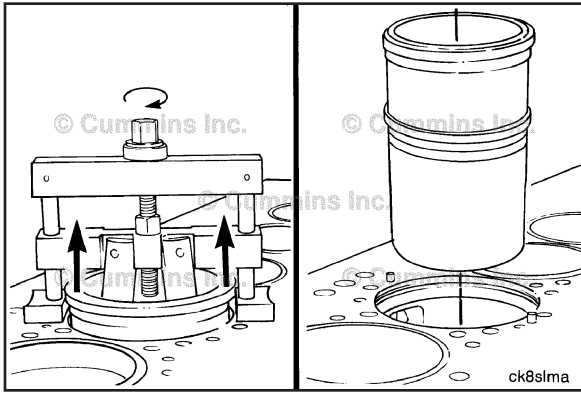
⚠CAUTION⚠

The liner puller must be installed and used as described to avoid damage to the cylinder block. The puller must not contact the block casting at points (1), (2), (3), or (4).



Insert the cylinder liner puller, Part Number 3376015, into the top of the cylinder block.

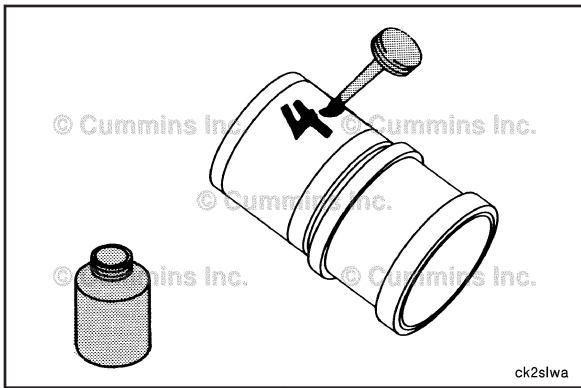




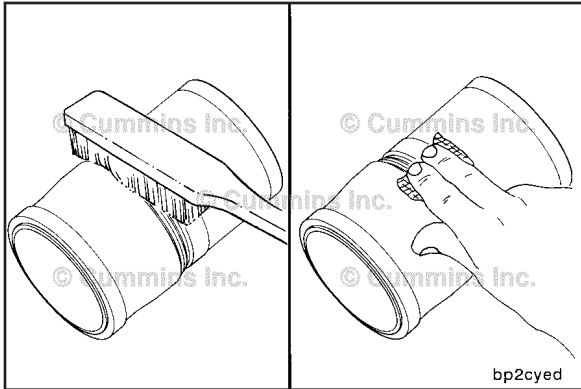
NOTE: The liner puller **must** be centered on the top of the cylinder block.

Turn the puller jackscrew **clockwise** to loosen the liner from the cylinder block.

Use both hands to remove the liner.



Mark the cylinder number on each liner.



Clean and Inspect for Reuse

⚠ CAUTION ⚠

Do not use any abrasives in the ring travel area of the liner. The liner can be damaged.

Use a soft wire brush or a fine fibrous abrasive pad such as Scotch-Brite® 7448, Part Number 3823258, to clean the flange seating area.

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

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

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

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

Use solvent or steam to clean the cylinder liners.

Dry the cylinder liners with compressed air.

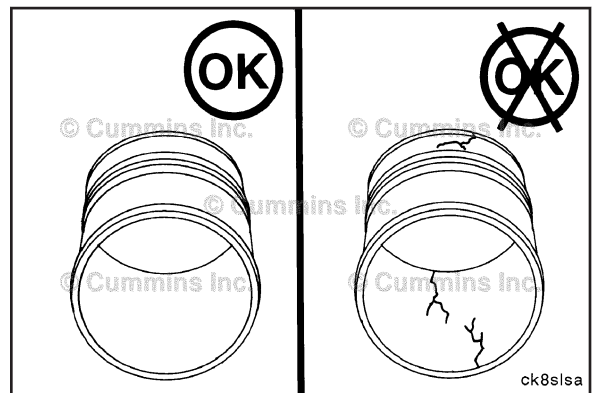
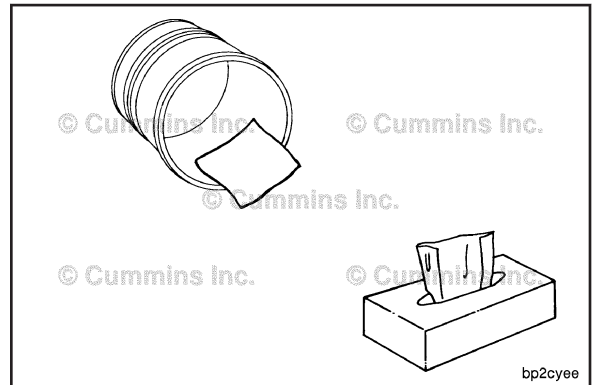
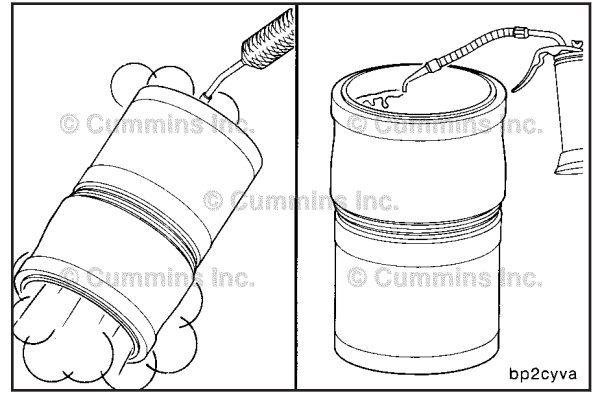
Use clean engine oil to lubricate the inside of the liners.

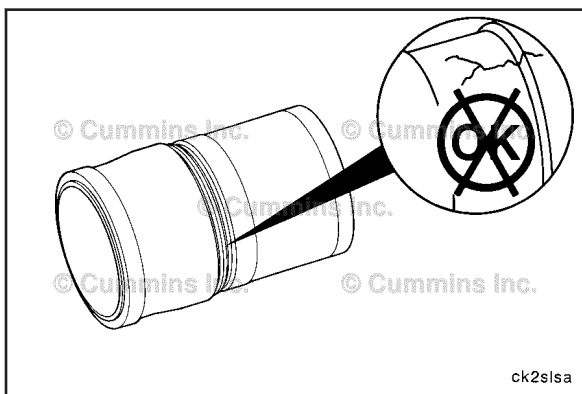
Allow the oil to soak in the liner for 5 to 10 minutes.

NOTE: Use lint-free paper towels to wipe the oil from the inside of the liners.

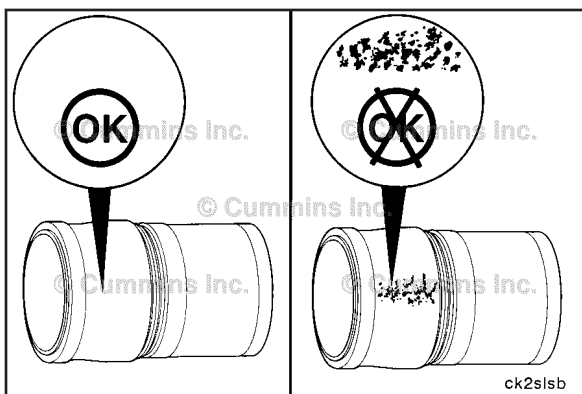
Continue to lubricate the inside surfaces of the liners and wipe clean until the paper towel shows no gray or black residue.

Inspect the liners for cracks on the inside and outside surfaces.





Inspect for cracks under the flange.



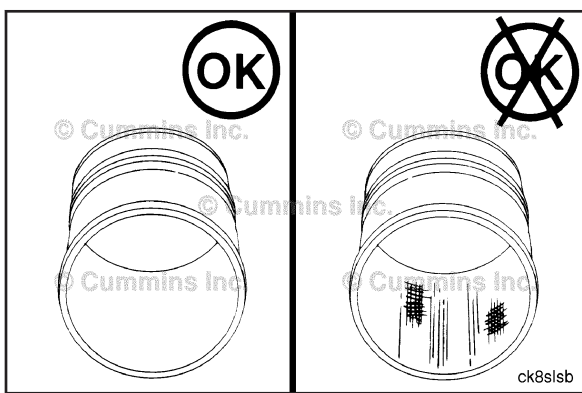
Inspect the outside and seat area for excessive corrosion or pitting.



NOTE: Pits **must not** be more than 1.6 mm [0.06 in] deep.

Replace the liner if the pits are too deep or if the corrosion can **not** be removed with Scotch-Brite® 7448, Part Number 3823258.

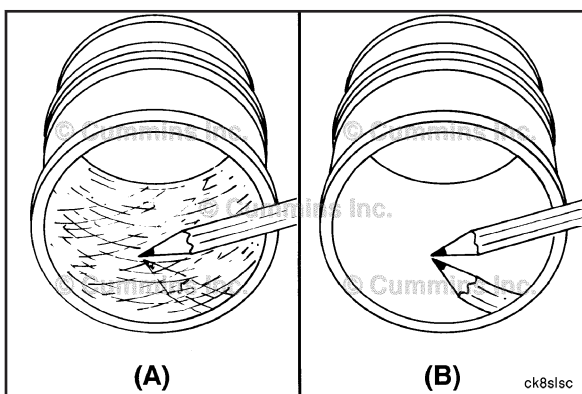
NOTE: Cylinder liner pitting is caused by poor coolant composition. Refer to the Operation and Maintenance Manual, GTA8.3 CM558/CM2358, Bulletin 4021640, for coolant specifications.



Inspect the inside surface for vertical scratches deep enough to be felt with a fingernail.

NOTE: If a fingernail catches in the scratch, the liner **must** be replaced.

Inspect the inside surface for scuffing or scoring.



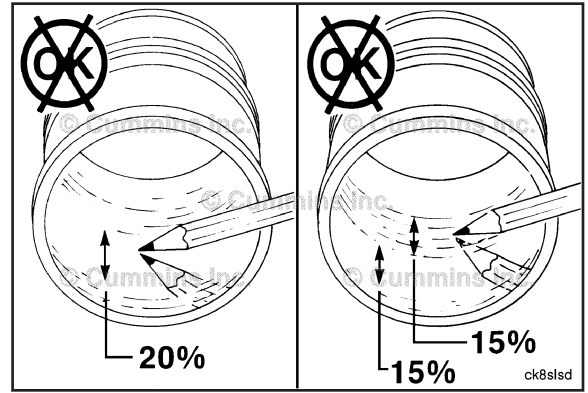
Inspect the inside surface for liner bore polishing.

NOTE: A moderate polish produces a bright mirror finish in the worn area with traces of the original hone marks or an indication of an etch pattern.

NOTE: A heavy polish produces a bright mirror finish in the worn area with no traces of hone marks or an etch pattern.

Replace the liner if:

- A heavy polish is present over 20 percent of the piston ring travel area.
- Both moderate and heavy polish over 30 percent of the piston ring travel area and one half (15 percent) is heavy polish.

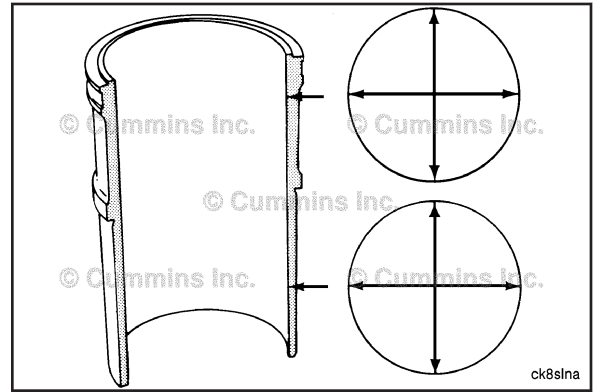


Measure the liner inside diameter with dial bore gauge, Part Number 3375072, in four places 90 degrees apart at the top and bottom of the piston travel area.



Cylinder Liner Inside Diameter

mm		in
114.00	MIN	4.488
114.04	MAX	4.490

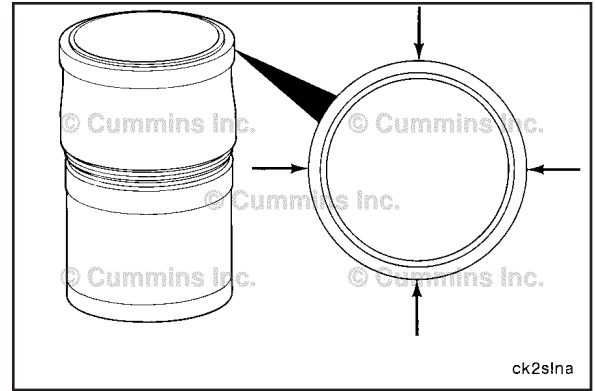


Measure the outside diameter of the liner top press fit area.



Cylinder Liner Outside Diameter (Top Press Fit)

mm		in
130.938	MIN	5.1550
130.958	MAX	5.1558

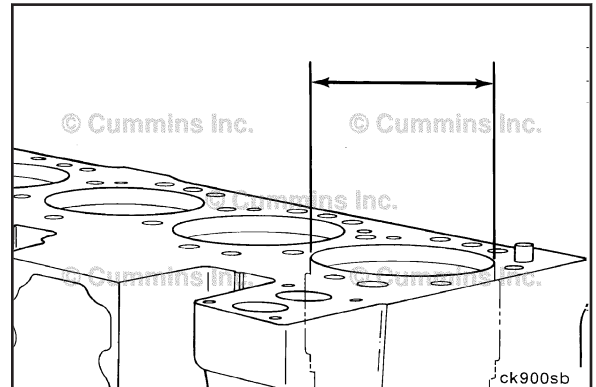


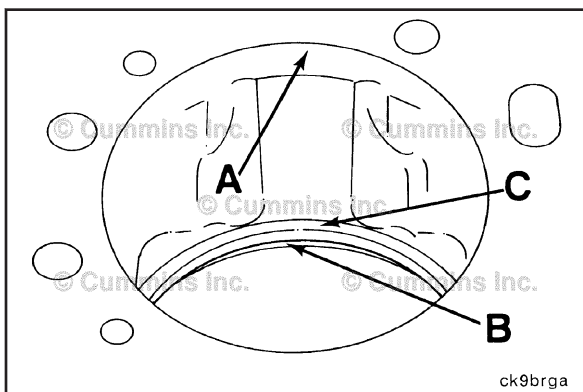
Measure the cylinder liner bore in the block.



Cylinder Liner Bore in Block (Press-Fit Bore)

mm		in
130.90	MIN	5.154
130.95	MAX	5.156





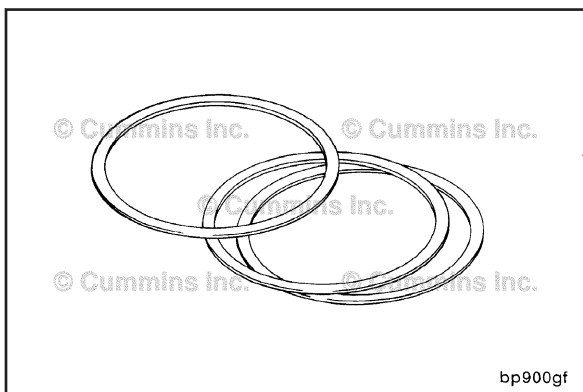
Install

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

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

Clean all deposits and debris from the sealing surfaces (A), (B), and (C). Use Scotch-Brite® 7448, Part Number 3823258, and cleaning solvent to polish the surfaces. Due to the critical machined tolerances, care **must** be taken **not** to remove any additional material.

If surface (C) has cracks or signs of extreme wear, the counterbore will require machining and the installation of shims for the correct liner protrusion.

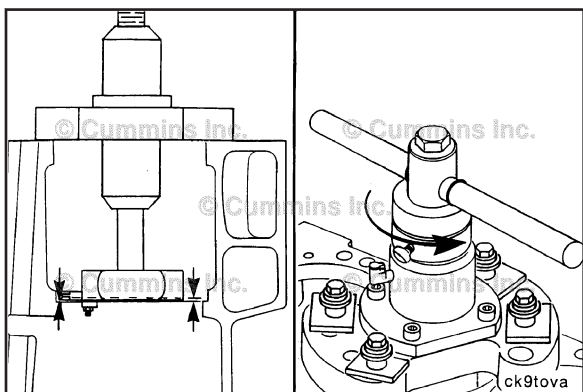


Cylinder liner shims are available as follows:

Cylinder Liner Shim Thickness - By Part Number

3924445	0.25 mm	[0.010 in]
3924446	0.38 mm	[0.015 in]
3924447	0.51 mm	[0.020 in]
3924448	0.76 mm	[0.030 in]
3924449	1.00 mm	[0.040 in]

Use a maximum of one shim.



Machine the counterbore with counterbore machining tool, Part Number 3823558; cutter plate, Part Number 3823567; and cutter bit, Part Number 3823570.

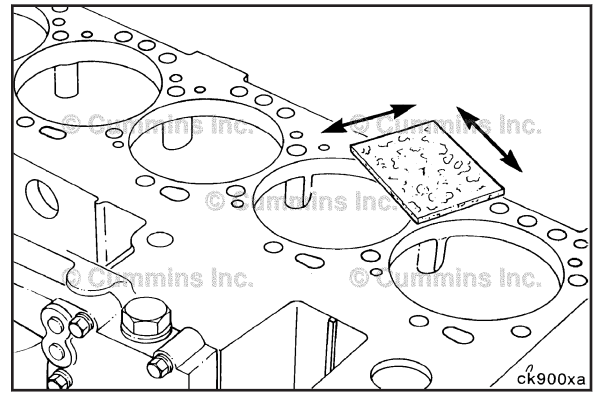
⚠ WARNING ⚠

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

⚠ WARNING ⚠

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

Clean the combustion deck with a gasket scraper or Scotch-Brite® 7448, Part Number 3823258, and solvent.



⚠ WARNING ⚠

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

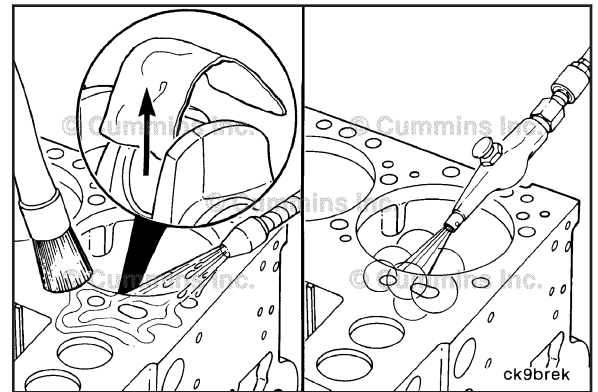
⚠ WARNING ⚠

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

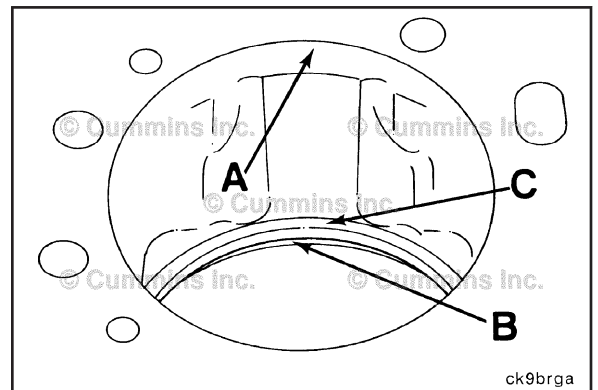
Thoroughly flush the block with mineral spirits or cleaning solvent.

Remove the shop rags and clean the crankshaft with a cleaning solvent.

Blow the cylinder bores and crankshaft dry, and wipe clean with a lint-free cloth.

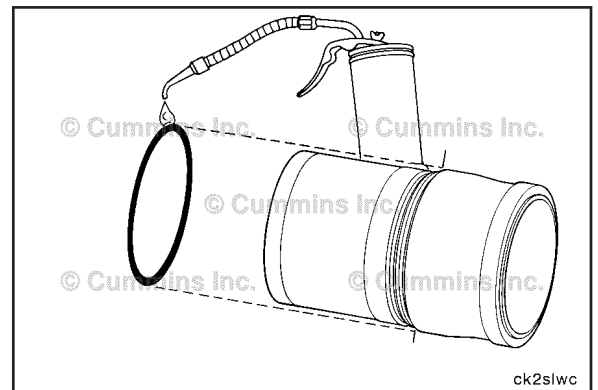


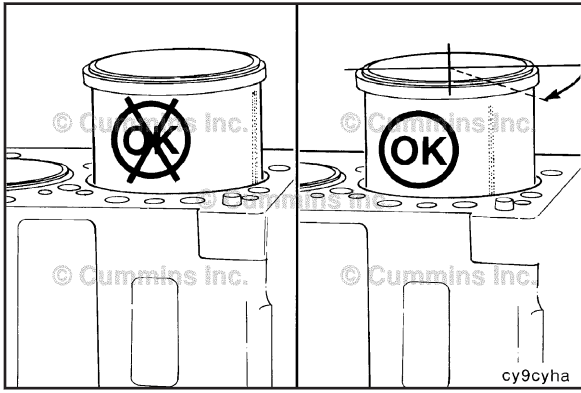
Lubricate surfaces (A) and (B) with clean engine oil.



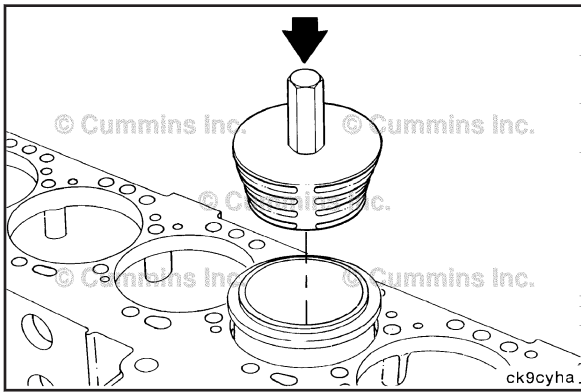
Use clean engine oil to coat the liner o-ring seals.

Install the new lubricated o-ring seals on the cylinder liners.





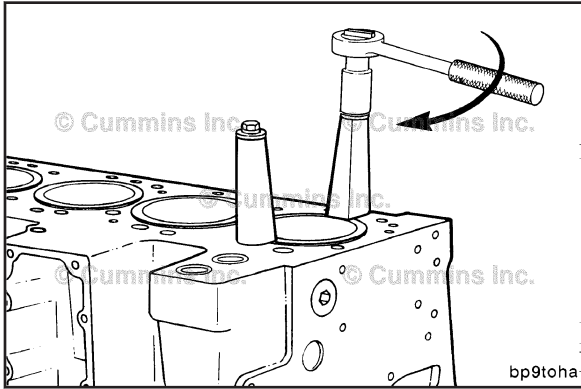
NOTE: When reusing liners, install them in the same cylinder from where they were removed, and rotate the liner 45 degrees (1/8 of a turn) from their original position. When correctly installed, any liner pitting can be positioned as illustrated so the pitted surface is rotated away from the location where pitting occurs.



Install the cylinder liners into the bore of the cylinder block, use cylinder liner driver, Part Number ST-1229, and a leather mallet.



NOTE: If the liner does **not** rest on the cylinder block counterbore seat, remove the liner. Inspect the counterbore seat and liner for nicks, burrs, or dirt. Install the liner again.



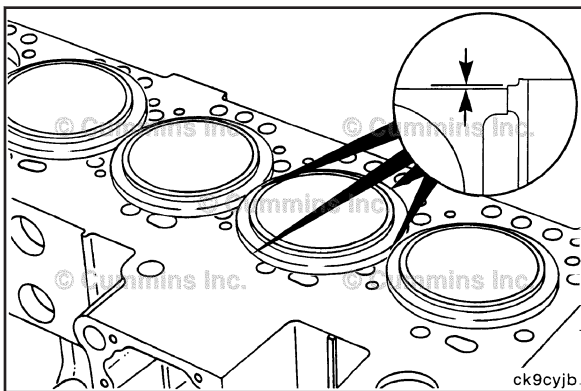
Use two cylinder head capscrews and position the two liner clamps, Part Number 3822503, as illustrated.

Tighten the capscrews.



Torque Value: 68 N•m [50 ft-lb]

Remove the clamps and repeat this procedure until all liners have been clamped and released.



Liner protrusion is the distance the liner protrudes above the block face.

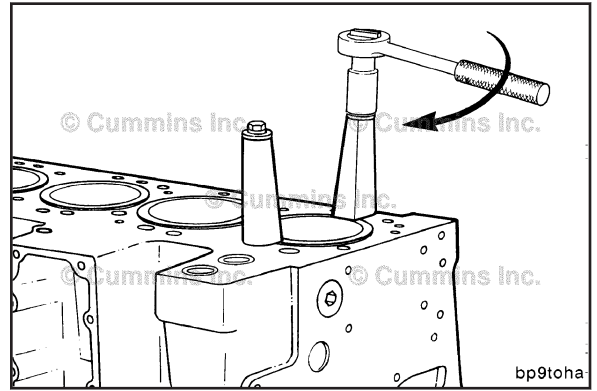
Measure the liner protrusion with the liner protrusion gauge, Part Number 3823495, at four points 90 degrees apart.

Cylinder Liner Protrusion

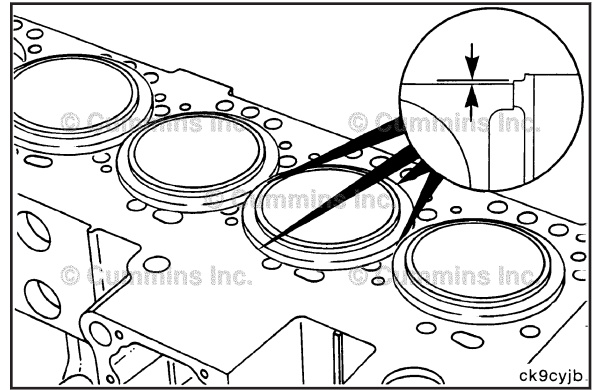
mm		in
0.025	MIN	0.001
0.122	MAX	0.005

NOTE: If the cylinder liner protrusion varies more than 0.025 mm [0.001 in] in 180 degrees:

- Install and tighten the cylinder liner clamps again.

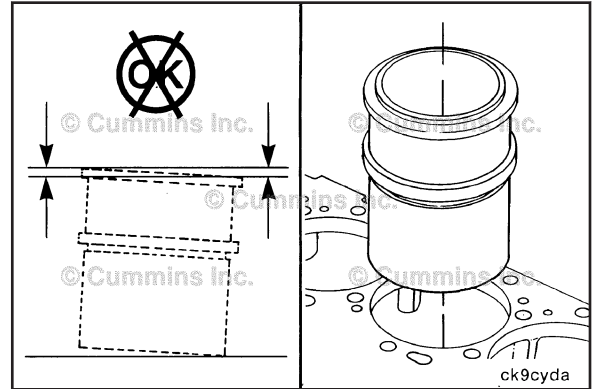


- Check the cylinder liner protrusion again.

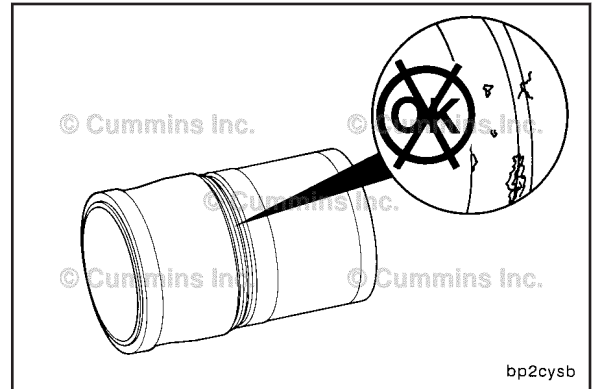


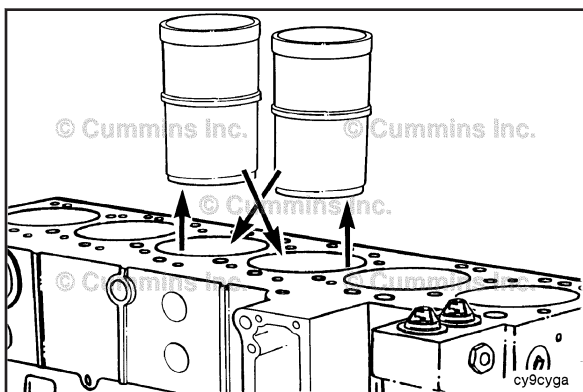
NOTE: If the protrusion still varies more than 0.025 mm [0.001 in]:

- Remove the cylinder liner.

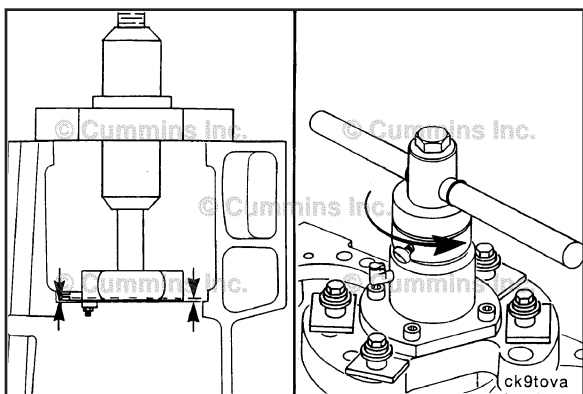


- Inspect the cylinder liner sealing edge for burrs, dirt, or damage.
- Replace the cylinder liner if it is damaged.
- Install the cylinder liner again.
- Check the cylinder liner protrusion.

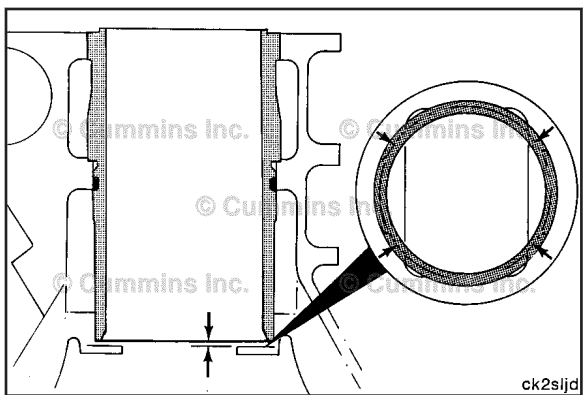




Service Tip: If the out-of-limit condition is minimal, tolerance stackup will allow the protrusion limits to be obtained by installing other new liners in the out-of-limit bore.



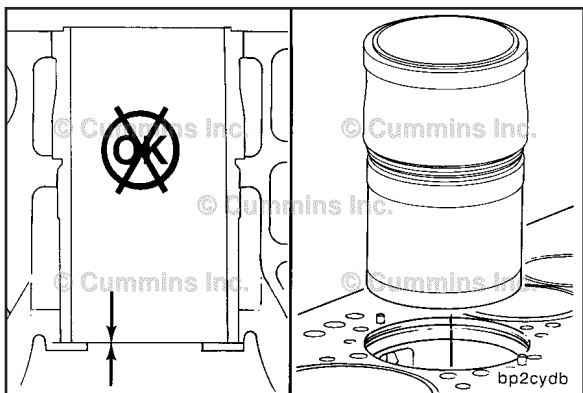
NOTE: If the liner protrusion still does **not** meet the specifications, machine the cylinder block liner bore for shims.



Use a feeler gauge to inspect the liner to block clearance at the four block casting points.

Cylinder-Liner-to-Block Clearance

mm		in
0.23	MIN	0.009

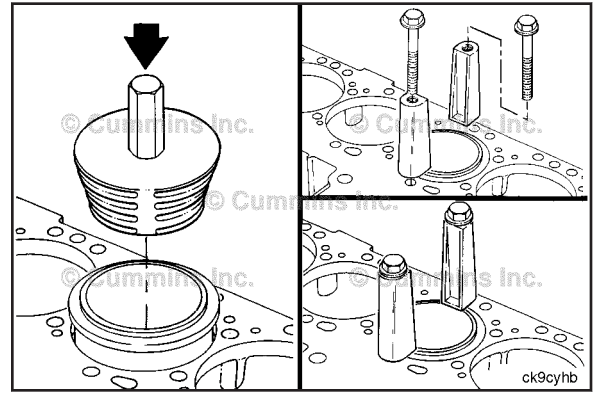


NOTE: If the clearance is less than 0.23 mm [0.009 in]:

- Inspect the liner and cylinder block for dirt or damage.
- Remove the liner.



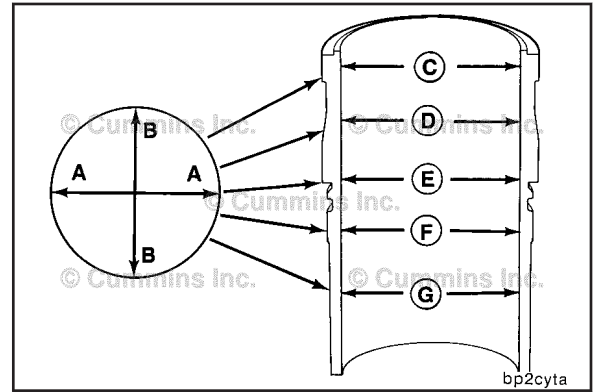
- Replace the liner if it is damaged.
- Install the liner again.



Measure the liner bore for out-of-roundness at points (C), (D), (E), (F), and (G).

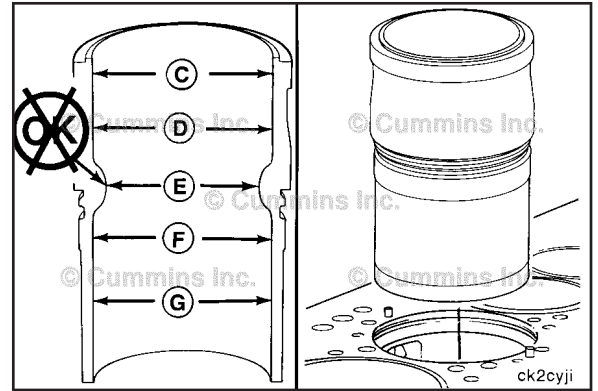


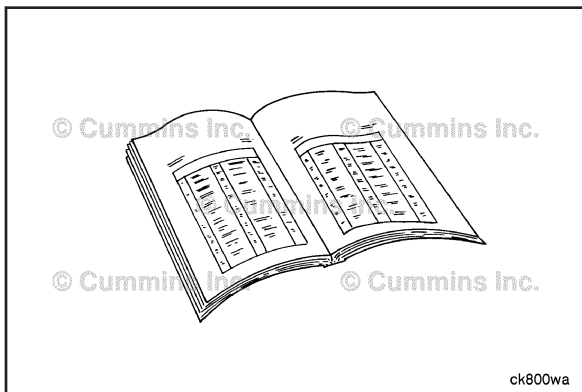
Measure each point in the direction (AA) and (BB). The bore **must not** be more than 0.08-mm [0.003-in] out of round.



NOTE: If the bore is more than 0.08-mm [0.003-in] out of round:

- Remove the liner so the cylinder block liner bore can be measured.





Finishing Steps



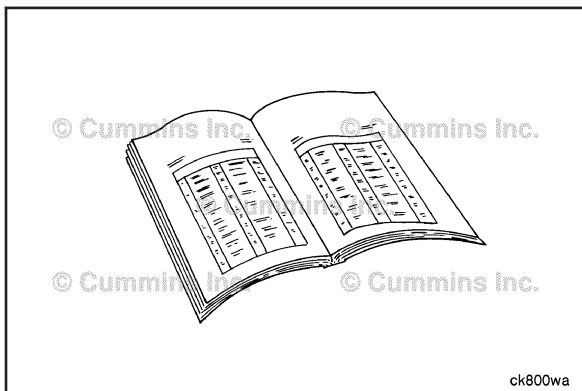
⚠ WARNING ⚠

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



NOTE: Do **not** interchange pistons from the original cylinder location.

- Install the piston and connecting rods. Refer to Procedure 001-043 in Section 1.
- Install the lubricating oil pan and suction tube. Refer to Procedure 007-025 in Section 7.
- Install the cylinder head. Use the following procedure for C Series diesel engines. Refer to Procedure 002-004 in Section 2.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Fill the lubricating system. Refer to Procedure 007-037 in Section 7.
- Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Open the fuel supply valve. Refer to the OEM instructions.
- Operate the engine until the coolant temperature reaches 82°C [180°F], and check for leaks and proper operation.



Gear Cover, Front (001-031)

Preparatory Steps



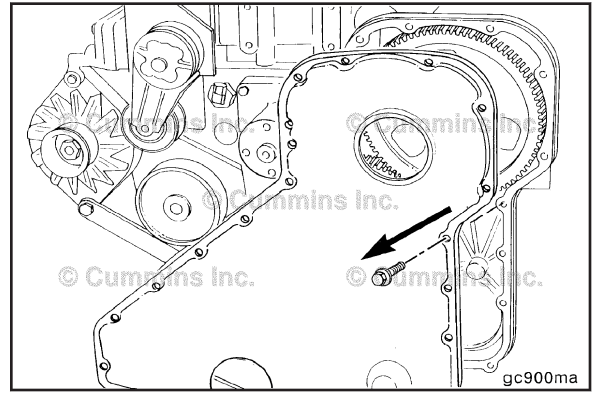
⚠ WARNING ⚠

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

- Close the fuel supply valve. Refer to the OEM instructions.
- Disconnect the batteries. Refer to Procedure 013-009 in Section 13.
- Remove the fan drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the fan pulley and spacer. Refer to Procedure 008-039 in Section 8.
- Remove the vibration damper and pulley. Refer to Procedure 001-052 in Section 1.
- Remove the crankshaft oil seal dust shield, if used.

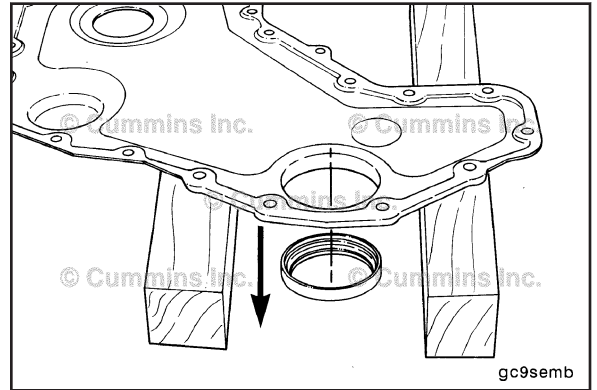
Remove

Remove the front gear cover mounting capscrews.
Remove the front gear cover.



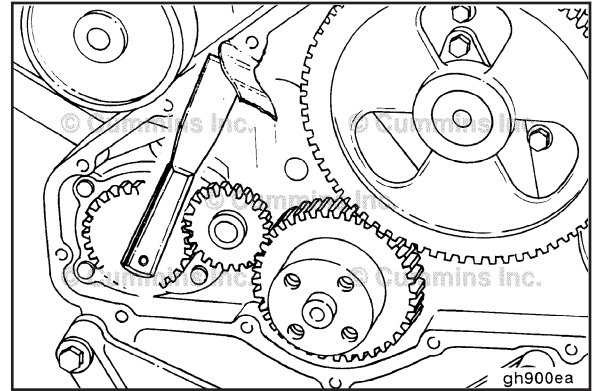
Disassemble

Remove the crankshaft seal. Refer to Procedure 001-023 in Section 1.



Clean and Inspect for Reuse

Clean the front gear housing gasket sealing surface.

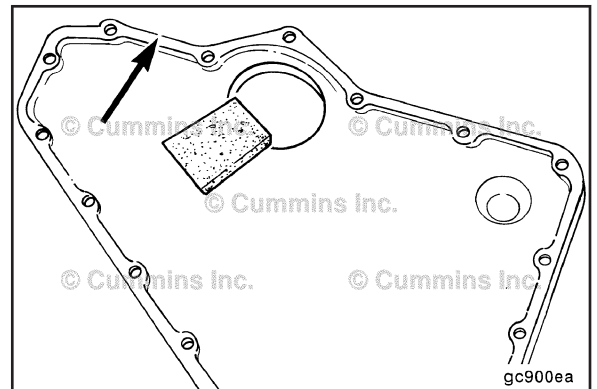


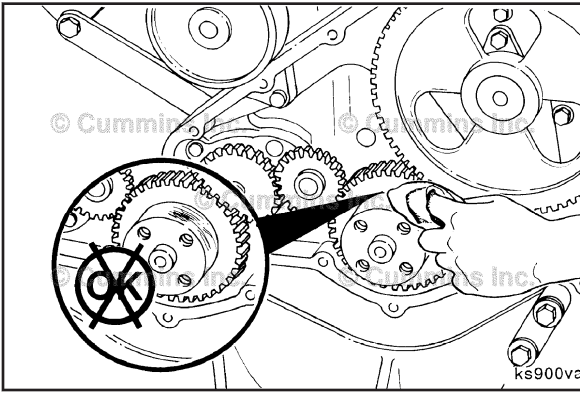
⚠CAUTION⚠

The seal lip and sealing surface on the crankshaft must be clean and free from all oil residue to prevent seal leaks.

Clean the gasket sealing surfaces and the surface between the oil seal and gear cover.

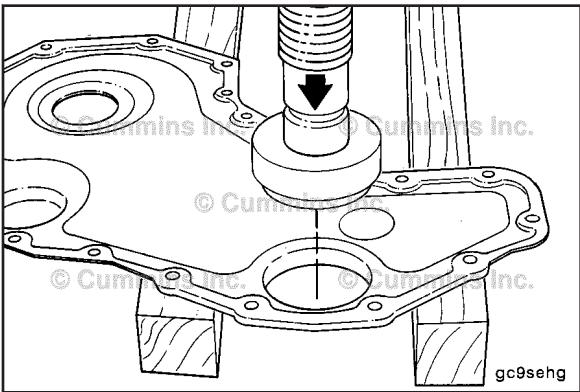
Thoroughly clean the seal contact area of the crankshaft.





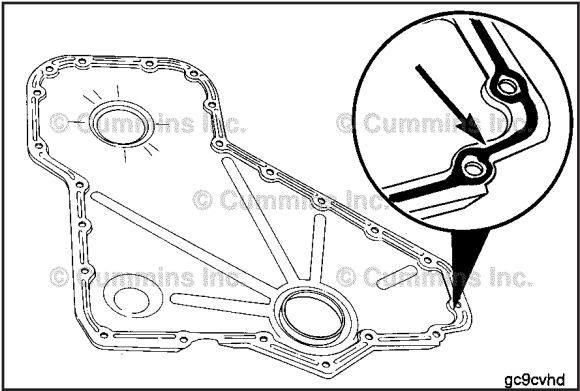
Inspect the gear cover for cracks, dents, and other damage.

Inspect the sealing surface of the crankshaft for wear. If the crankshaft has a groove due to the oil seal, a wear sleeve **must** be used to prevent seal leakage.



Assemble

Install a new crankshaft seal. Refer to Procedure 001-023 in Section 1.



Install

NOTE: Do **not** remove the plastic seal pilot tool from the lubricating oil seal at this time. Use the plastic seal pilot tool to guide the seal on the crankshaft.

NOTE: Install three guide pins, Part Number 3164977, to improve alignment of the front cover and front seal to the gear housing and crankshaft.

Apply a 4-mm wide bead of ThreeBond, Part Number 3823494, along the entire flange of the gear cover.

Follow the grooves in the flange; circle all of the capscrew holes with ThreeBond, Part Number 3823494. Do **not** use a paper gasket with the gear cover.

NOTE: The front cover **must** be installed and the capscrews tightened within 15 minutes from when the ThreeBond was applied. If the ThreeBond, Part Number 3823494, appears skinned over, it will **not** create a good seal. It **must** be cleaned from the front cover and new ThreeBond, Part Number 3823494, applied.

Install the front gear cover and tighten the capscrews.

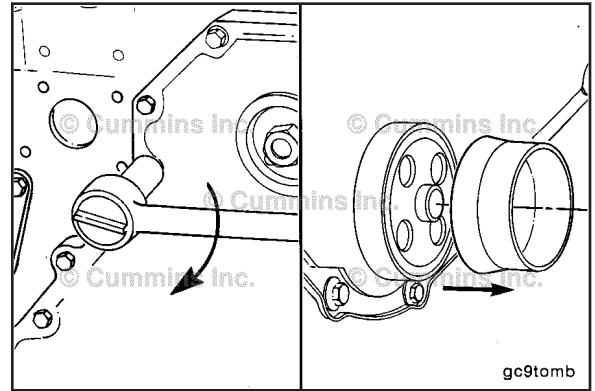
Tighten the long cover capscrews with 11-mm heads to:

Torque Value: 40 N•m [30 ft-lb]

Tighten the short cover capscrews with the 10-mm heads to:

Torque Value: 30 N•m [22 ft-lb]

Remove the plastic pilot tool from the crankshaft.



Finishing Steps

⚠ WARNING ⚠

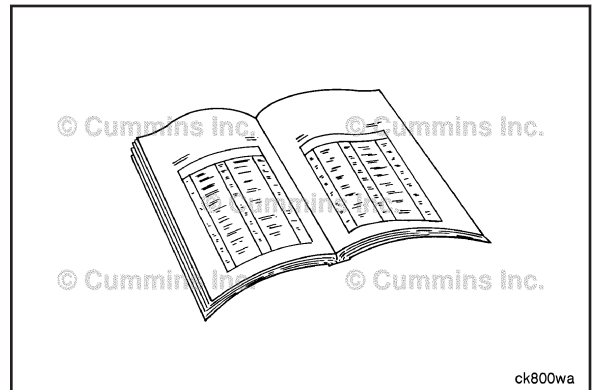
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Install the crankshaft oil seal dust shield, if used, as follows:

- Push the dust shield onto the crankshaft with the part number facing out away from the engine.
- The dust shield **must** contact the oil seal.

NOTE: No lubrication is required for installation.

- Install the vibration damper and pulley. Refer to Procedure 001-052 in Section 1.
 - Install the fan pulley and spacer. Refer to Procedure 008-039 in Section 8.
 - Install the fan drive belt. Refer to Procedure 008-002 in Section 8.
- 4 Connect the batteries. Refer to Procedure 013-009 in Section 13.
- Open the fuel supply valve. Refer to the OEM instructions.
 - Operate the engine 5 to 10 minutes to check for leaks and proper operation.

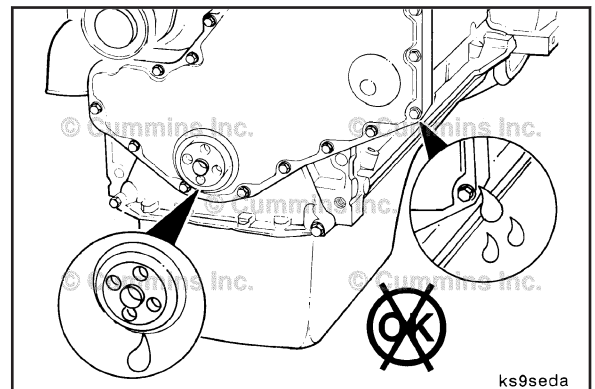


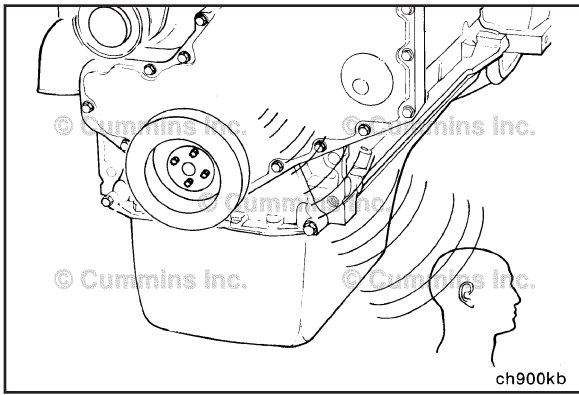
Gear Housing, Front (001-033)

General Information

Front Gear Housing and Gear Train

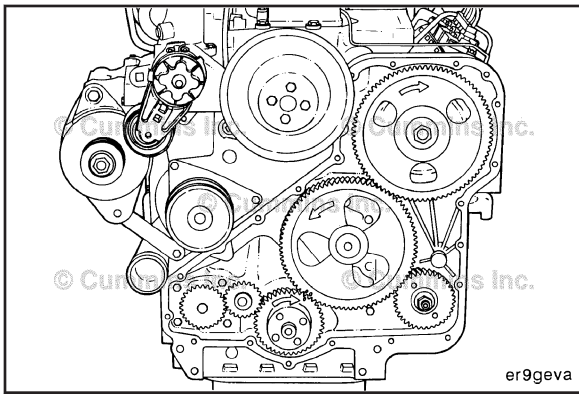
- Troubleshooting the front gear housing and gear train consists of checking for leaks at the gaskets (front cover, timing pin assembly, and fuel injection pump) and the front crankshaft lubricating oil seal, inspecting the gears, and measuring backlash, when required.
- Replace the front crankshaft oil seal. Refer to Procedure 001-023 (Crankshaft Seal, Front) in Section 1.





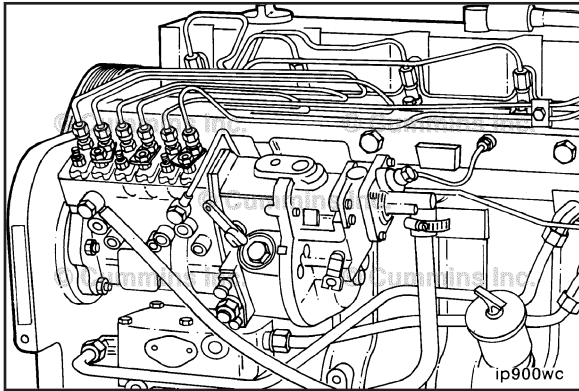
Gear noise emitted from the cover can indicate worn gear teeth.

NOTE: Excessive backlash can affect engine timing and engine performance.

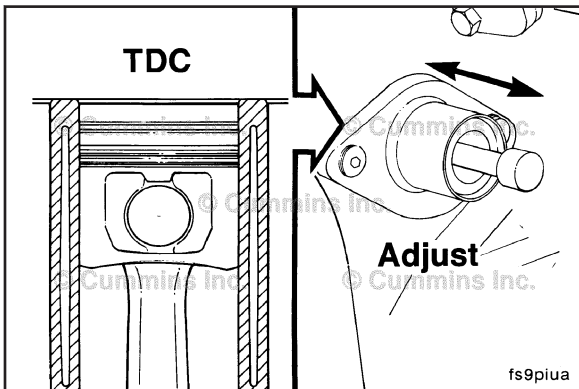


The gear train consists of:

1. Crankshaft Gear
2. Lubricating Oil Pump Gear
3. Idler Gear
4. Camshaft Gear
5. Fuel Injection Pump Gear
6. Accessory Drive Gear; if used.



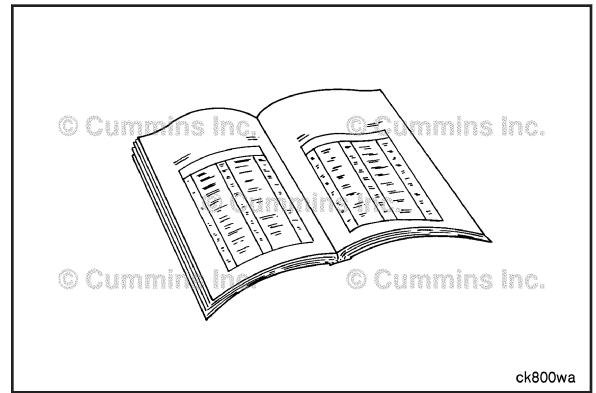
The gear housing provides a support for the fuel injection pump, the timing pin, and the accessory drive gear, if used.



Replacement of the gear housing or the timing pin assembly necessitates a realignment of the pin assembly on the housing to correspond to TDC for cylinder number 1. Refer to Procedure 001-049 (Timing Pin Housing) in Section 1.

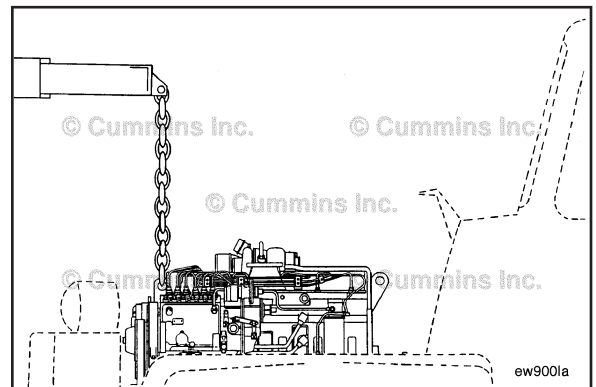
Preparatory Steps

- Remove the drive belt. Refer to Procedure 008-002 (Drive Belt, Cooling Fan) in Section 8.
- Remove the vibration damper. Refer to Procedure 001-052 (Vibration Damper, Viscous) in Section 1.
- Remove the front gear cover. Refer to Procedure 001-031 (Accessory Drive Seal) in Section 1.
- Remove the accessory drive or air compressor, if equipped. Refer to Procedure 012-014 (Air Compressor) in Section 12.
- Remove the rocker lever cover. Refer to Procedure 003-011 (Rocker Lever Cover) in Section 3.
- Remove the rocker lever assemblies. Refer to Procedure 003-008 (Rocker Lever) in Section 3.
- Remove the push rods. Refer to Procedure 004-014 (Push Rods or Tubes) in Section 4.
- Remove the camshaft. Refer to Procedure 001-008 (Engine Mounting Bolts) in Section 1.
- Remove the tappets. Refer to Procedure 004-015 (Tappet) in Section 4.



Remove

Support the front of the engine and remove the front engine mount.



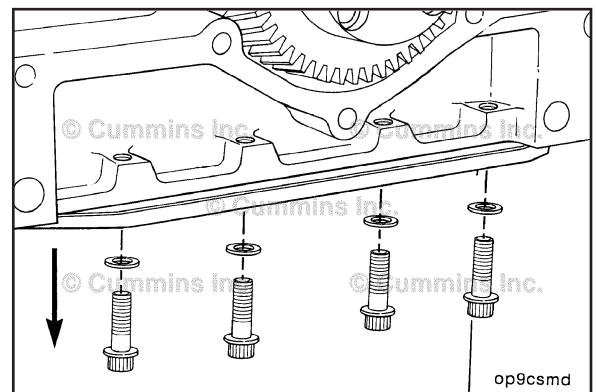
⚠CAUTION⚠

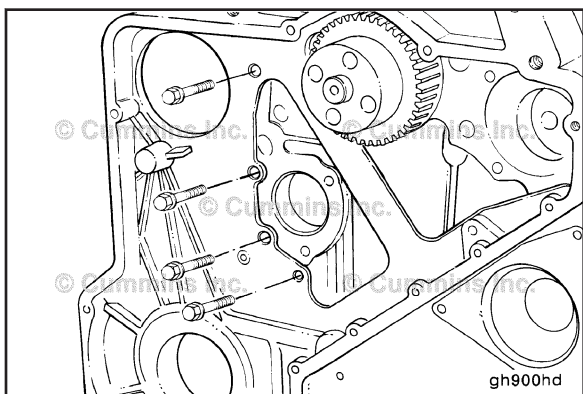
Use extreme care when releasing the oil pan gasket from the gear housing to prevent damage to the gasket. If the gasket is damaged, it will probably be necessary to remove the oil pan and replace the gasket.

Loosen all the oil pan mounting capscrews four to five turns.

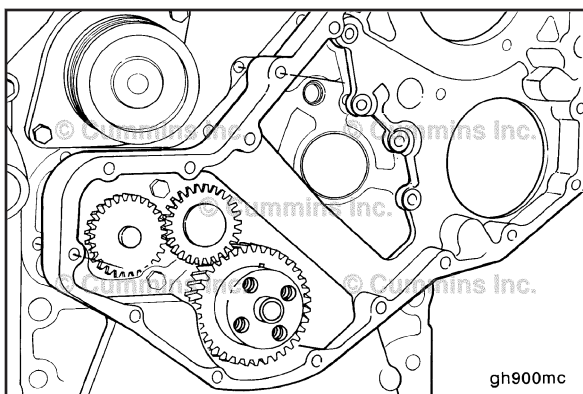
Remove the four front oil pan capscrews that secure the oil pan to the gear housing.

Insert a feeler gauge or a shim stock between the gear housing and the oil pan gasket. Move the feeler gauge or shim stock back and forth to release the gasket from the gear housing.

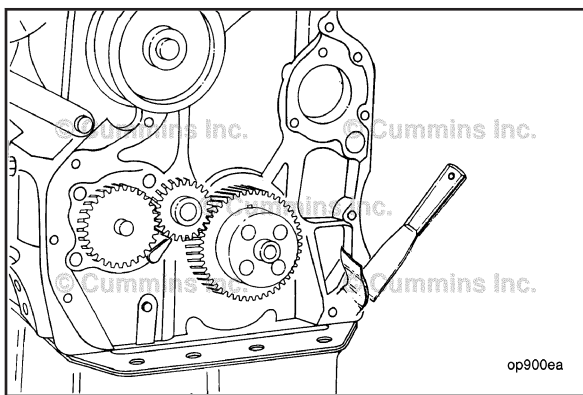




Remove the front gear housing capscrews.

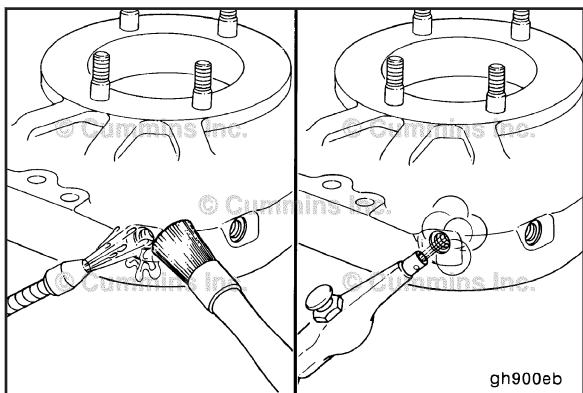


Remove the front gear housing.



Clean

Clean the gasket material from the cylinder block.



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

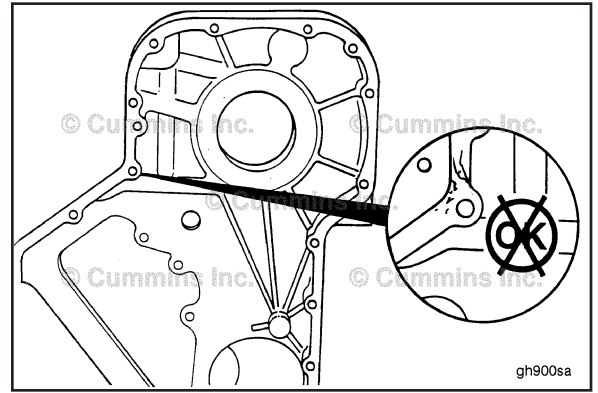
⚠ WARNING ⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

Use solvent and a nylon bristle brush to clean the oil drillings.

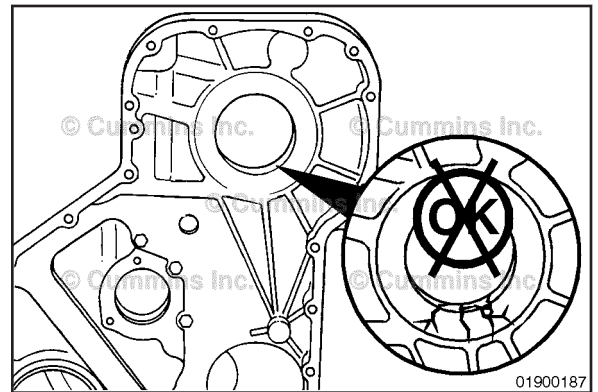
Dry the front gear housing with compressed air.

Inspect for Reuse

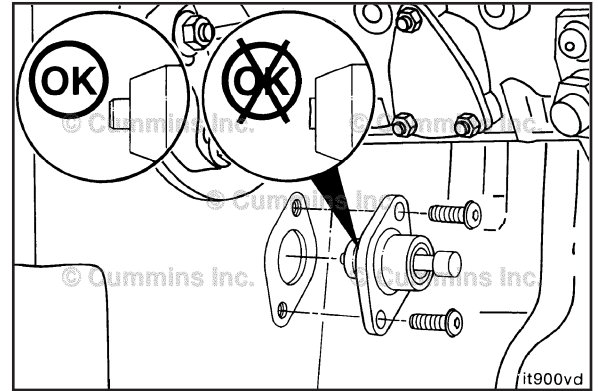
Inspect the front gear housing for cracks or damaged sealing surfaces.



If the front gear housing is cracked at the accessory drive hole, evaluate the accessory/air compressor installation practices.

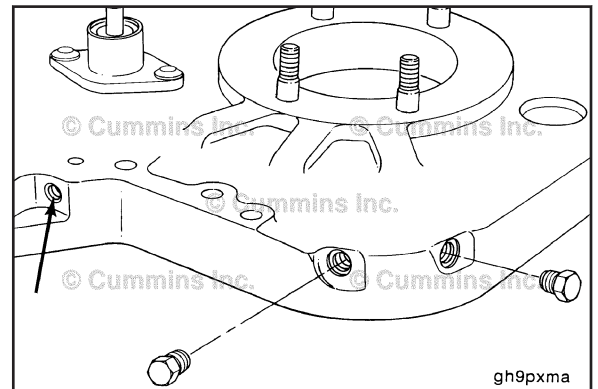


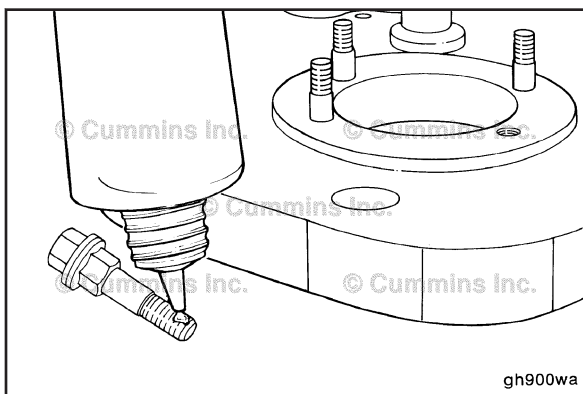
Inspect the timing pin housing and pin for damage.
Do **not** remove the timing pin assembly unless it is damaged or leaking, or if the gear housing is being replaced.



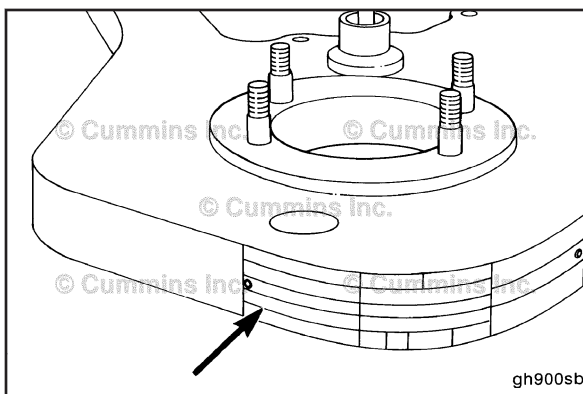
If the gear housing is being used again:

- Remove the pipe plugs from the oil drillings.

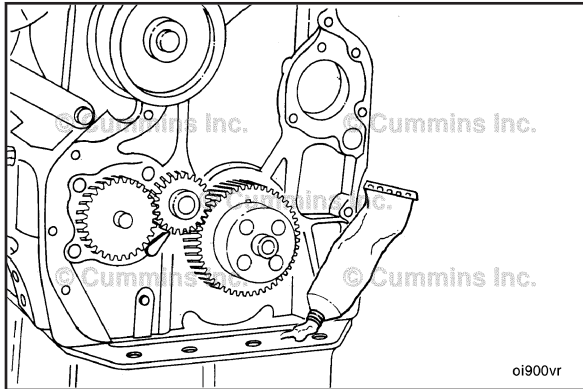




If the fuel injection pump studs are damaged or being installed in a new housing, coat the threads with Loctite® 242. Use two nuts, locked together, to remove and install the studs.



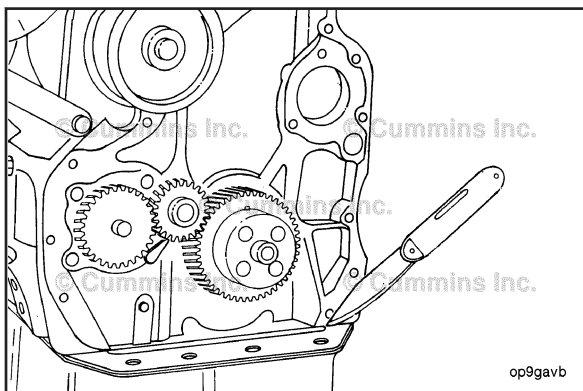
If the gear housing is being replaced, remove the engine data plate and install it on the new gear housing. Refer to Procedure 001-057 (Engine Data Plate) in Section 1.



Install

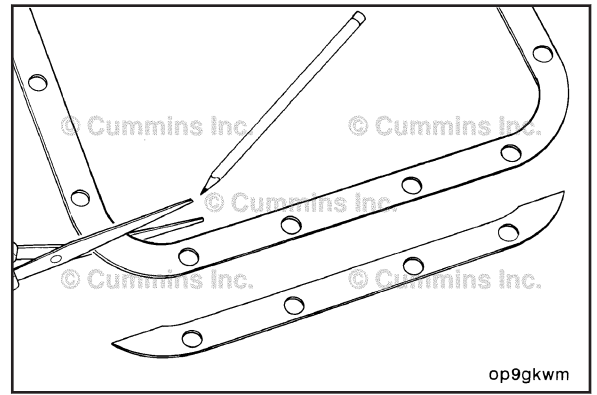
The gear housing oil pan capscrews **must** be tightened within 15 minutes after applying the sealant.

Inspect the oil pan gasket. If it is **not** torn, apply Three-Bond™ RTV sealant, Part Number 3823494, around the capscrew holes and at the joint of the gear housing.



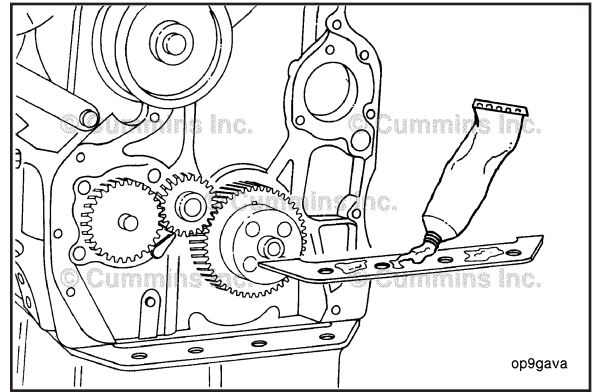
If the pan gasket is torn, it can be repaired. Cut the torn gasket off even with the front of the cylinder block.

Use the old gasket as a pattern, cut the front section of a new gasket to the same size.

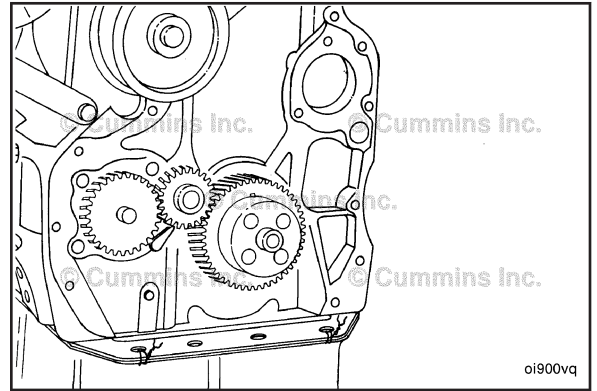


The gear housing and oil pan **must** be installed and tightened within 15 minutes after applying the sealant.

Clean the sealing surfaces and coat the new gasket on both sides with Three-Bond™ RTV sealant, Part Number 3823494.

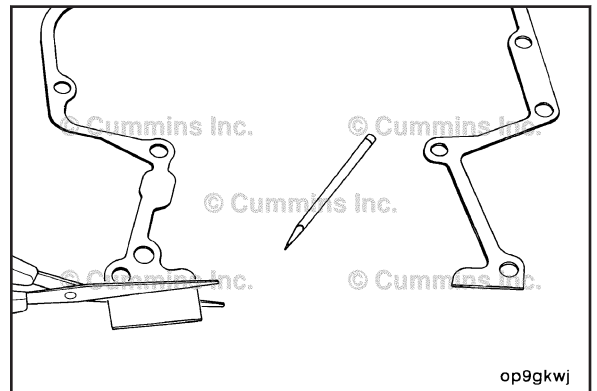


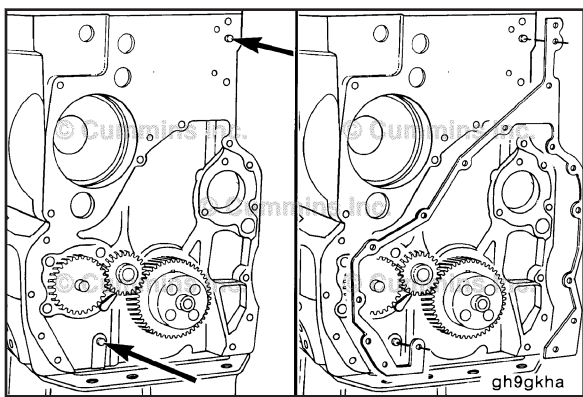
Use thread or a very fine wire to hold the new gasket splice in position as illustrated.



Mark and trim 1.6 mm [0.063 in] off the new gear housing gasket.

When properly trimmed, the gear housing gasket **must** be even with the lubricating oil pan gasket when installed.

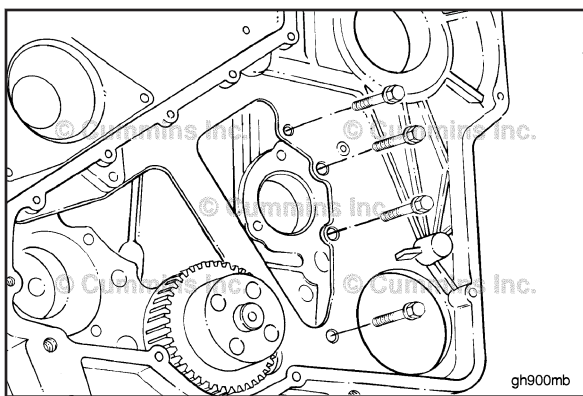




Position the gasket on the alignment dowels.

Use guide pins (M8 x 1.25 x 50) to assist in aligning the gasket and gear housing.

Make sure the guide pins are removed after alignment.

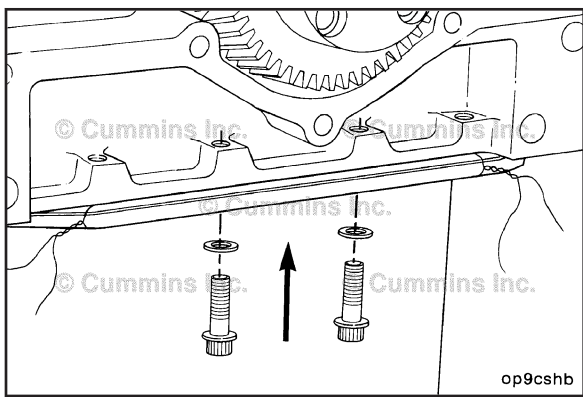


Carefully install the gear housing, making sure both gaskets are in place.

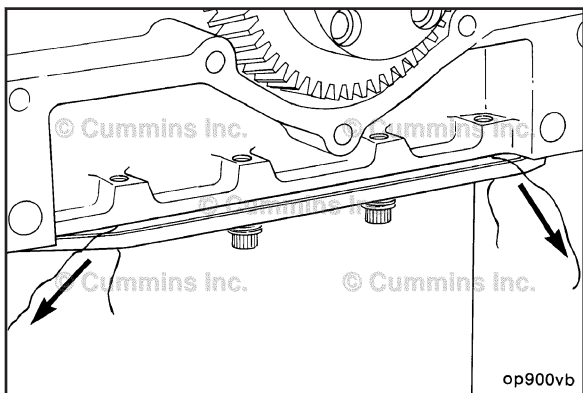
Install and tighten the gear housing mounting capscrews.



Torque Value: 24 N•m [212 in-lb]

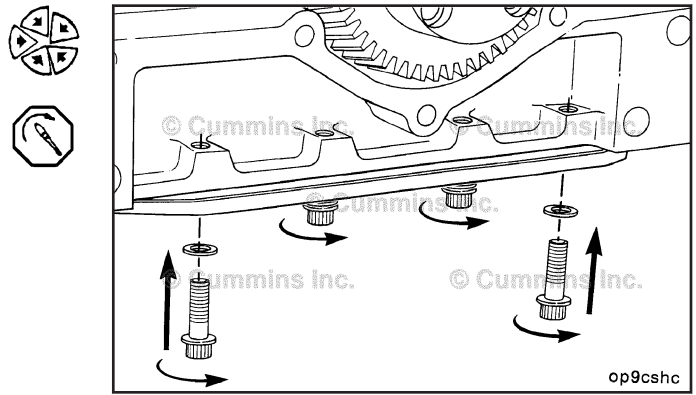


Start the oil pan capscrews in the holes **not** being used to tie the gasket in place.



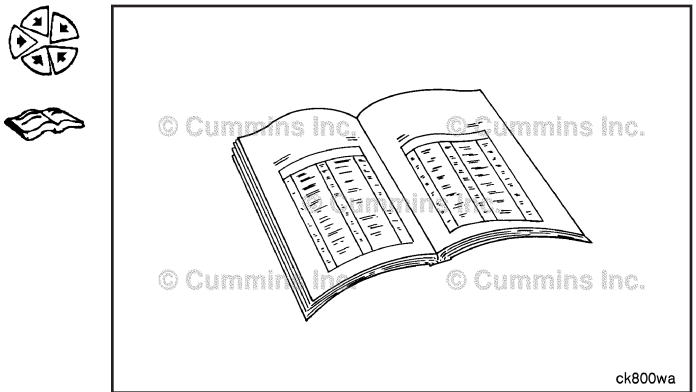
Remove the thread or wire holding the gasket in place.

Install the remaining two capscrews.
Tighten the oil pan capscrews.
Torque Value: 24 N•m [212 in-lb]



Finishing Steps

- Install the tappets. Refer to Procedure 004-015 (Tappet) in Section 4.
- Install the camshaft and camshaft thrust washer. Refer to Procedure 001-008 (Engine Mounting Bolts) in Section 1.
- Install the push rods. Refer to Procedure 004-014 (Push Rods or Tubes) in Section 4.
- Install the rocker levers. Refer to Procedure 003-008 (Rocker Lever) in Section 3. Adjust the valves. Refer to Procedure 003-004 (Overhead Set) in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 (Rocker Lever Cover) in Section 3.
- Install the accessory drive or air compressor. Refer to Procedure 012-014 (Air Compressor) in Section 12..
- Install the front gear cover. Refer to Procedure 001-031 (Accessory Drive Seal) in Section 1. Install the vibration damper. Refer to Procedure 001-052 (Vibration Damper, Viscous) in Section 1.
- Install the drive belt. Refer to Procedure 008-002 (Drive Belt, Cooling Fan) in Section 8..
- Operate the engine at idle for 5 to 10 minutes and check for leaks.

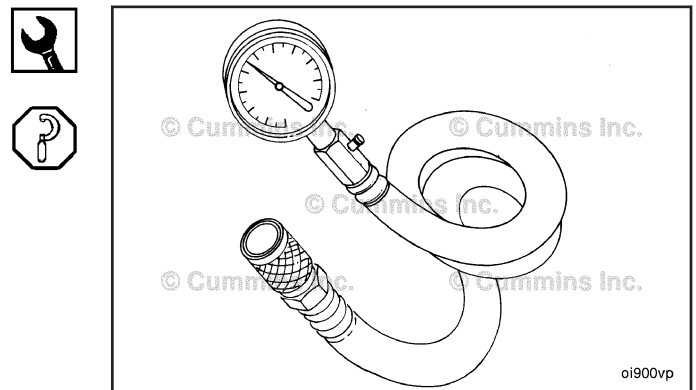


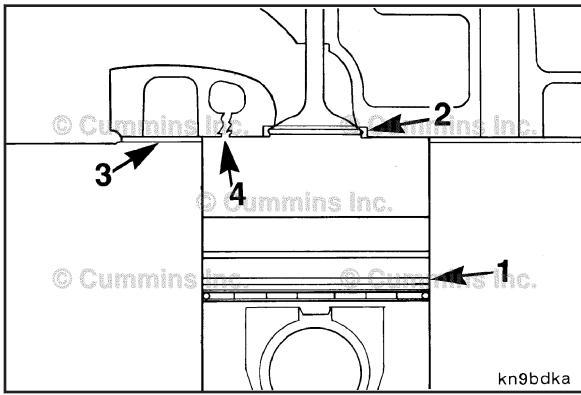
Piston (001-043)

Initial Check

Compression Gauge and Adapter

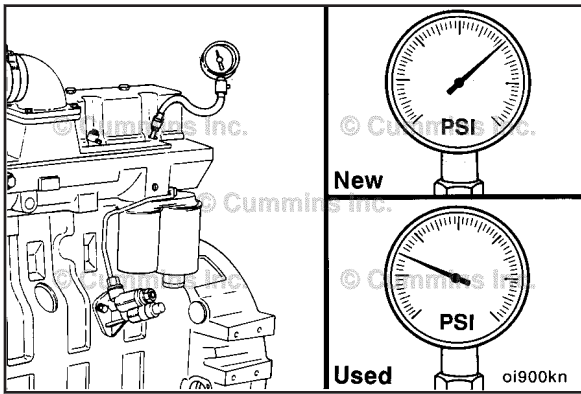
It is very time consuming and expensive to begin removing internal engine components to diagnose failures. A compression gauge can be used as an aid to check for proper functioning of the following components:





- 1 Piston ring sealing
- 2 Intake and exhaust valve sealing
- 3 Cylinder head gasket sealing
- 4 Cylinder head cracked.

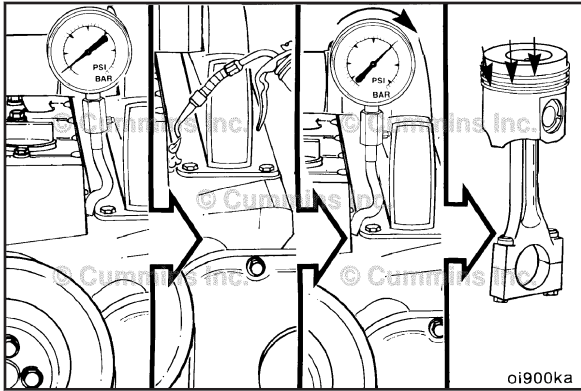
See the appropriate procedure in this manual for replacement of failed components.



NOTE: Due to variables such as starter and battery conditions that affect engine cranking speed, it is difficult to establish an absolute value for compression pressure; however, the following values can be used as guidelines:

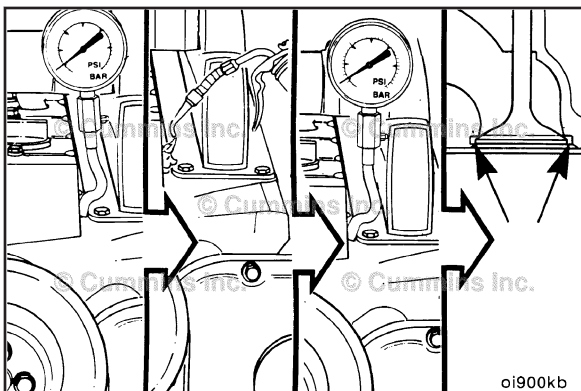
- New engine (cranking speed at 250 rpm) 2413 kPa [350 psi]
- Used engine (cranking speed at 250 rpm) 2068 kPa [300 psi].

It is recommended that the compression pressure be checked on all cylinders and then compared. All cylinders should be within 690 kPa [100 psi] of each other.



Piston Ring Sealing

If the compression is low but can be increased significantly by squirting oil into the cylinder, the cause of low compression is inadequate sealing between the rings and the cylinder walls. Use the following procedure for piston ring replacement. Refer to Procedure 001-047 in Section 1.

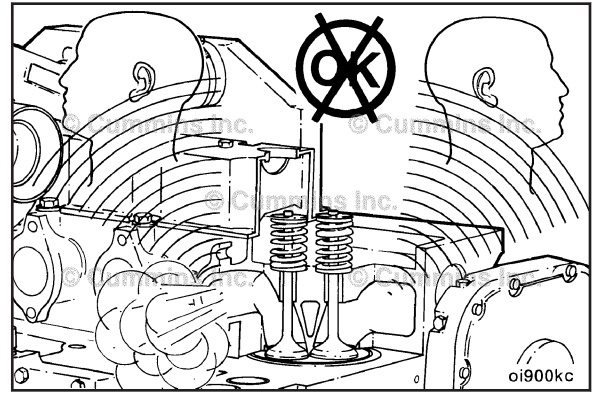


Intake and Exhaust Valve Sealing

If the compression is low on one or more nonadjacent cylinders and the pressure can **not** be increased by oiling the rings, poor valve sealing is to be suspected.

Refer to Procedure 002-004 in Section 2.

Valve leakage is often audible from the intake and exhaust manifold.

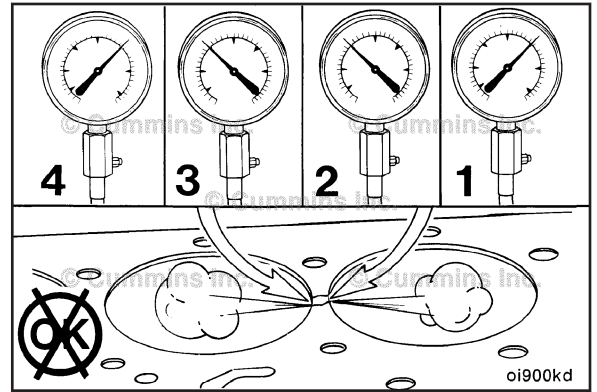


Cylinder Head Gasket Sealing

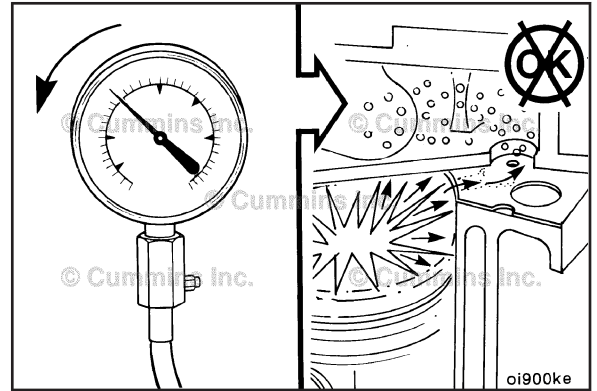
If the compression is low on adjacent cylinders and the pressure can **not** be increased by oiling the rings, the cylinder head gasket is probably leaking between the cylinders.



Refer to Procedure 002-021 in Section 2.



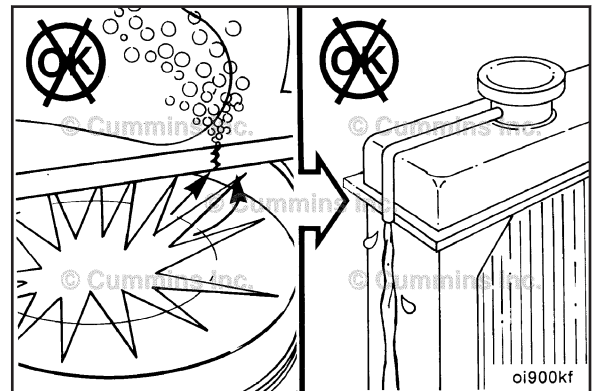
Low compression on a single cylinder can be caused by an external leak or a leak to a coolant passage. A leak to a coolant passage of this magnitude will also result in coolant in the cylinder.

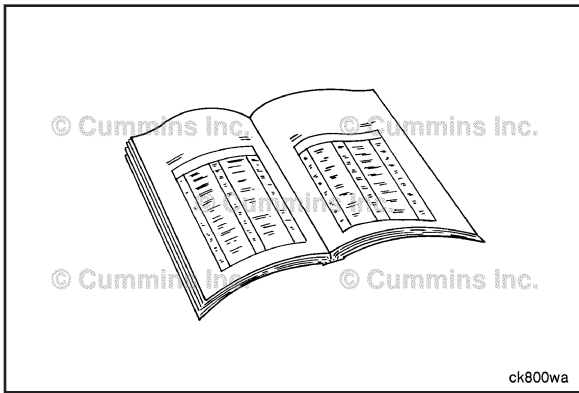


A compression leak to the coolant will normally be detected by loss of coolant as the coolant is blown from the cooling system.



Service Tip: Remove the drive belt from the water pump. Run the engine for 1 to 2 minutes and check for coolant being blown from the radiator by compression gases.





Preparatory Steps

⚠️ WARNING ⚠️

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

⚠️ WARNING ⚠️

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

⚠️ WARNING ⚠️

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

⚠️ WARNING ⚠️

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠️ WARNING ⚠️

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠️ 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.

- Close the fuel supply valve. Refer to the OEM service manual.
- Disconnect the batteries. Refer to the OEM service manual.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Drain the cooling system. Refer to Procedure 008-018 in Section 8.
- Drain the low temperature aftercooler (LTA) system. Refer to Procedure 008-134 in Section 8.
- Remove the cylinder head. Refer to Procedure 002-004 in Section 2.
- Remove and disassemble the piston and connecting rod assemblies. Refer to Procedure 001-054 in Section 1.
- Remove the piston rings. Refer to Procedure 001-047 in Section 1.

Clean and Inspect for Reuse

⚠️ WARNING ⚠️

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

⚠️ WARNING ⚠️

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

⚠️ CAUTION ⚠️

Make sure the cleaning solvent is approved for aluminum. Damage to the pistons can result.

Allow the pistons to soak for a minimum of 30 minutes in a tank containing an approved cleaning solvent for aluminum.

Use a hot, soapy solution and nonmetallic brush to remove carbon deposits.

⚠️ CAUTION ⚠️

Do not use a metal brush. A metal brush will damage the piston ring grooves. Do not use glass beads, walnut shells, or plastic bead blasting to clean the piston ring grooves or pin bores. This can cause the pin bore to crack or the rings not to seat.

⚠️ WARNING ⚠️

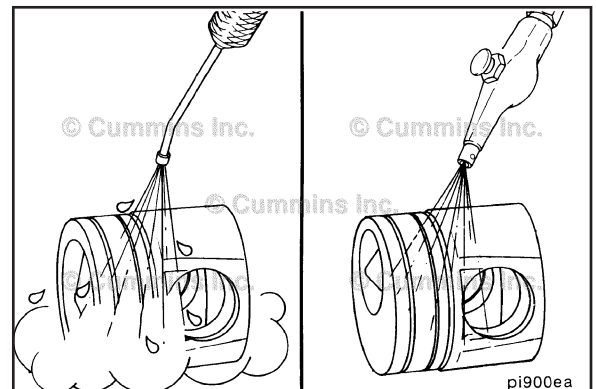
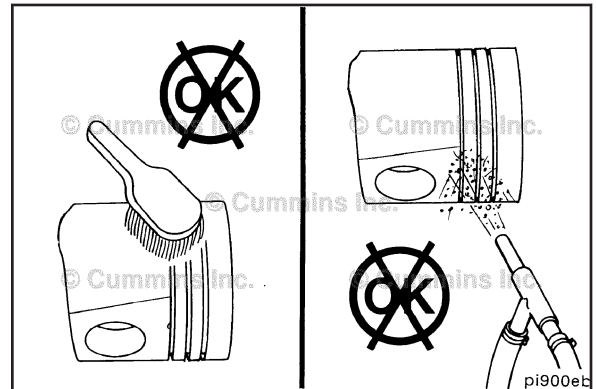
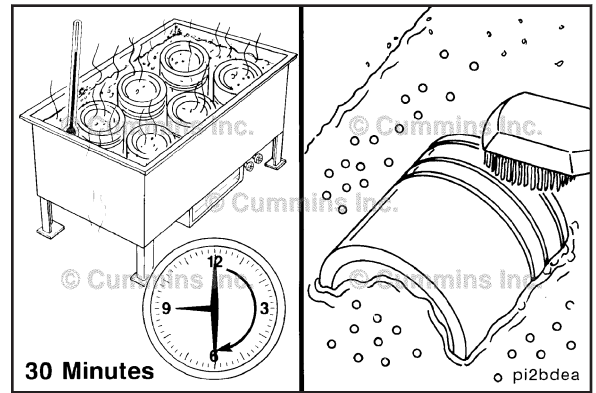
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

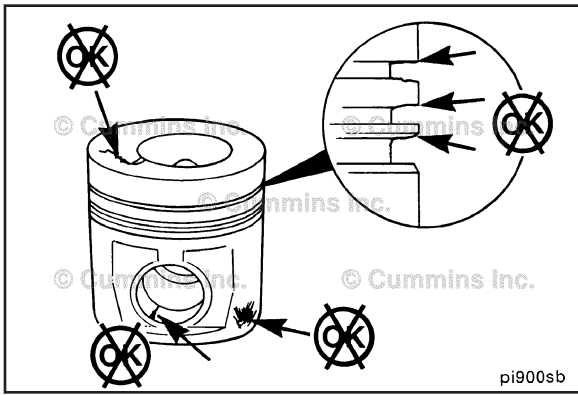
⚠️ WARNING ⚠️

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

Use steam to clean the pistons.

Dry with compressed air.

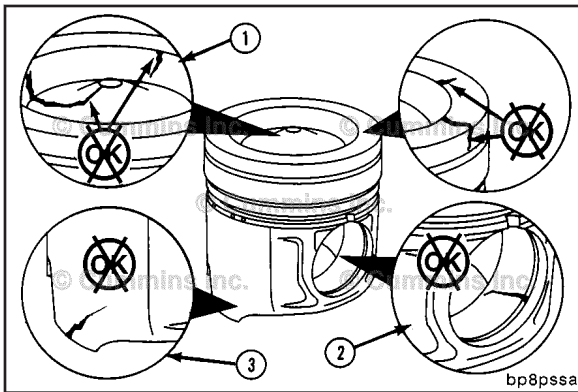




NOTE: Dimensional inspection of the piston is required **only** when the cause of the lack of sealing is **not** apparent.

Inspect the piston for damage and excessive wear. Check the top ring grooves, skirt, and pin bore.

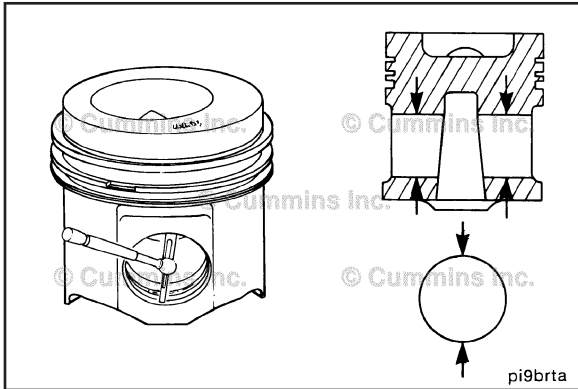
Inspect the piston for rolled edges on the ring lands. If the ring lands are rolled in, this indicates ring beat-in and can cause loss of sealing.



Inspect the piston bowl (1), pin bore (2), and skirt (3) for cracks or damage.

NOTE: Do **not** use pistons with cracks.

NOTE: If severe piston damage has occurred, check the turbocharger and other exhaust components for damage from debris.



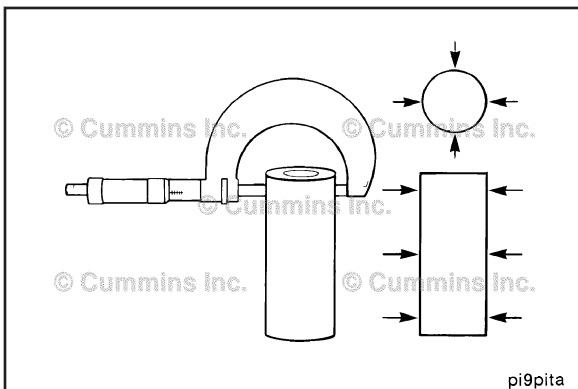
Measure the piston bore when the piston temperature is at 20°C [68°F].

Piston Pin Bore Inside Diameter

mm		in
45.01	MIN	1.772
45.03	MAX	1.773

NOTE: Add 0.013 mm [0.0005 in] to the piston pin bore inside diameter per 5°C [10°F] temperature rise up to 32°C [90°F].

The piston pin bore **must** be checked closer to the outside diameter of the piston since the piston pin bore is tapered.



Inspect the piston pin for scratches, grooves, or other damage.

Measure the piston pin outside diameter.



Piston Pin Diameter

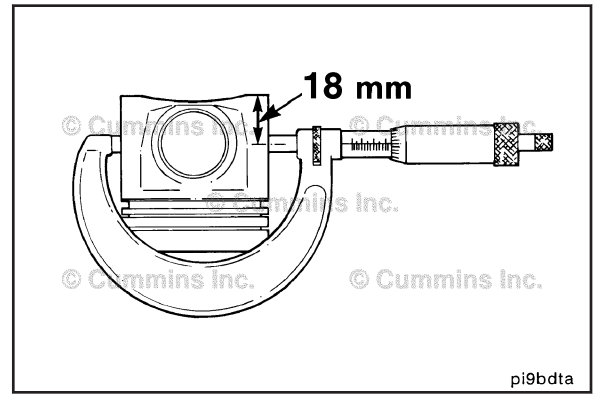
mm		in
44.99	MIN	1.771
45.00	MAX	1.772

NOTE: Discard the piston pin if it is more than 0.03 mm [0.001 in] out of round.

Measure the piston skirt diameter as illustrated.

Piston Skirt Diameter

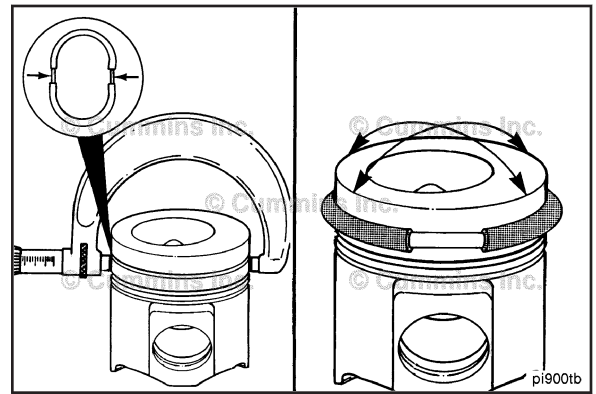
mm		in
113.81	MIN	4.481
113.88	MAX	4.484

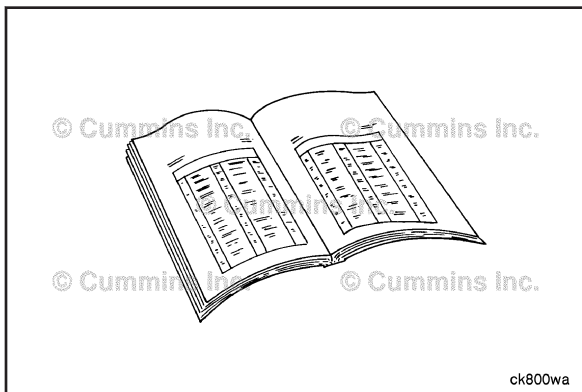


Use a micrometer and piston ring groove gauge, Part Number 3823966, to measure the wear of the top ring groove keystone angle. Use piston ring groove gauge, Part Number 3823965, to measure the wear of the intermediate ring groove keystone angle.

Piston Ring Groove (Keystone Angle)

	mm		in
Top Ring:	113.94	MIN	4.486
Intermediate Ring:	114.32	MIN	4.501





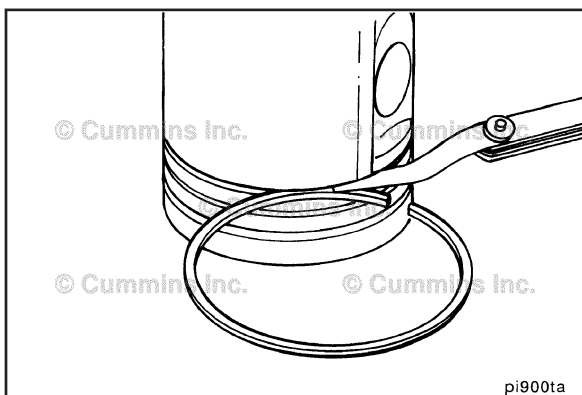
Finishing Steps

⚠️ WARNING ⚠️



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

- Install the piston rings. Refer to Procedure 001-047 in Section 1.
- Assemble and install the piston and connecting rod assemblies. Refer to Procedure 001-054 in Section 1.
- Install the cylinder head. Refer to Procedure 002-004 in Section 2.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Fill the engine with clean lubricating oil approved for natural gas engines. Refer to Procedure 007-037 in Section 7.
- Fill the low temperature aftercooler (LTA) system. Refer to Procedure 008-134 in Section 8.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to the OEM service manual.
- Open the fuel supply valve. Refer to the OEM service manual.
- Operate the engine and check for leaks.



Piston Rings (001-047)

Failure Analysis Inspection

Use a new piston ring and feeler gauge to measure the side clearance of the rectangular intermediate and oil control ring grooves.

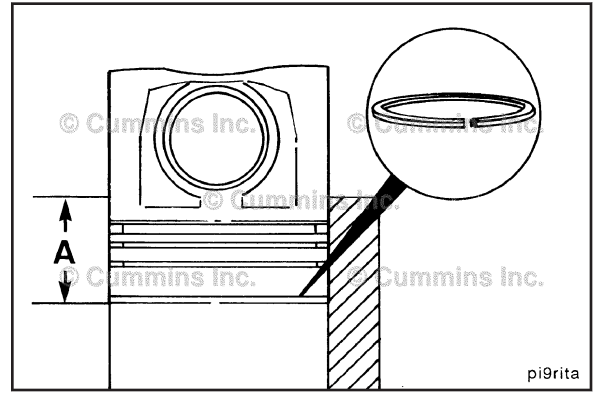
Piston Ring Side Clearance (Rectangular Grooves)

	mm		in
Intermediate Ring	0.07	MIN	0.003
	0.15	MAX	0.006
Oil Control Ring	0.02	MIN	0.001
	0.13	MAX	0.005

Measure the piston ring gap.

To measure the piston ring gap, use the top end of a piston to align the piston rings in the wear area of the cylinder where used.

A 80 mm [3.5 in]

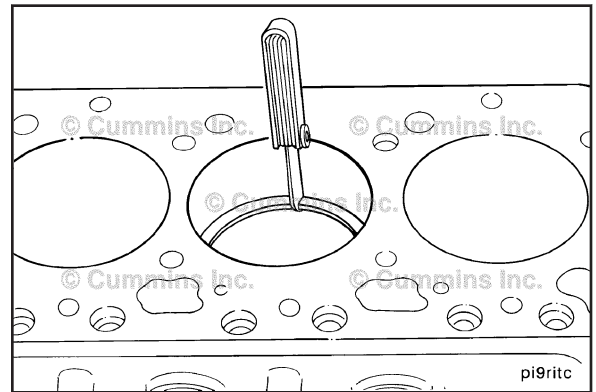


Use a feeler gauge to measure the piston ring end gap. Replace the ring if it does **not** meet the following specifications:

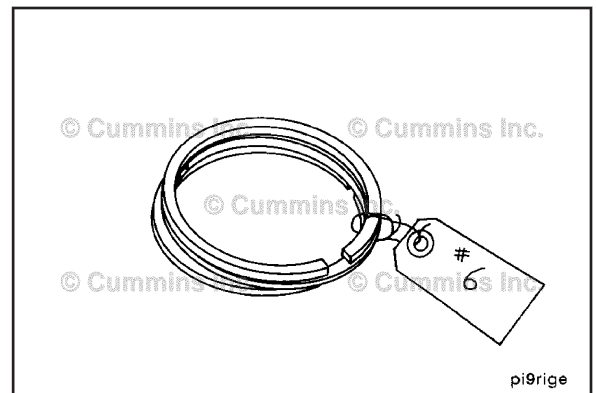
Ring Gap

	mm		in
Top	0.40	MIN	0.016
	0.70	MAX	0.028
Intermediate	0.25	MIN	0.010
	0.55	MAX	0.022
Oil Control	0.25	MIN	0.010
	0.55	MAX	0.022

NOTE: Add 0.09 mm [0.004 in] for every 0.03 mm [0.001 in] of bore wear, up to the maximum bore wear limit.



Identify the ring sets for installation in the cylinder where the end gap was measured.

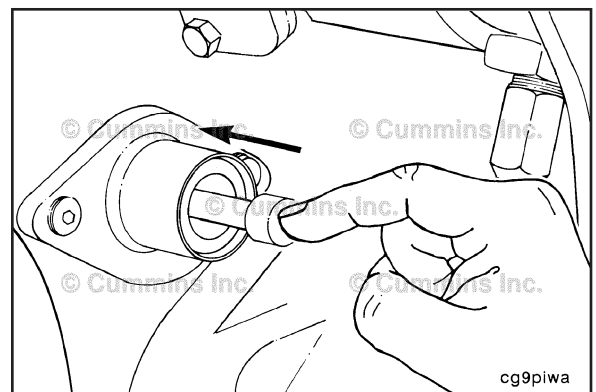


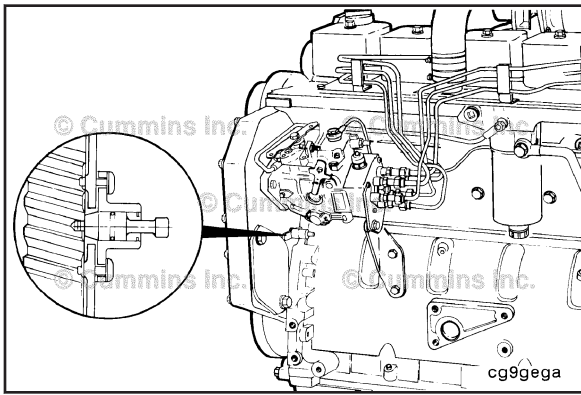
Timing Pin Housing (001-049)

Preparatory Steps

Locate top dead center for cylinder number 1 by barring crankshaft slowly while pressing on engine timing pin.

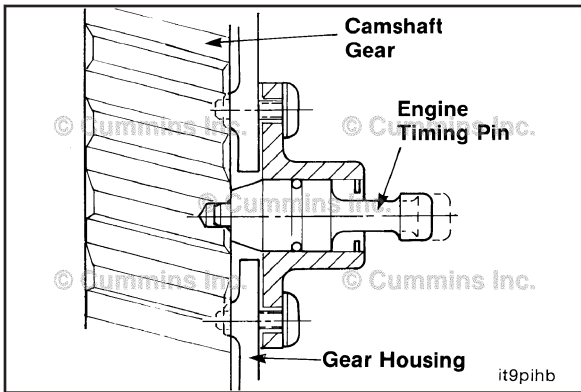
Service Tip: If the timing pin has been damaged and can **not** be used to locate top dead center, use the following steps to locate top dead center (TDC)..





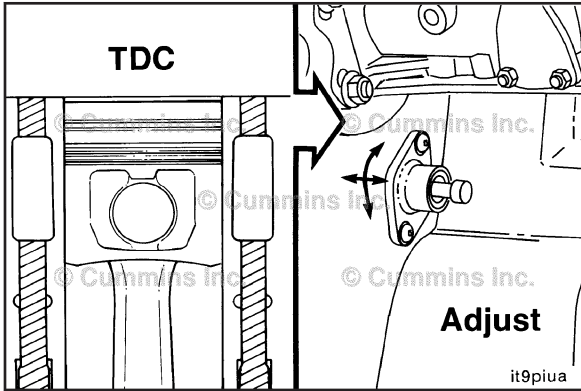
Remove

Remove the timing pin assembly and seal.



Install

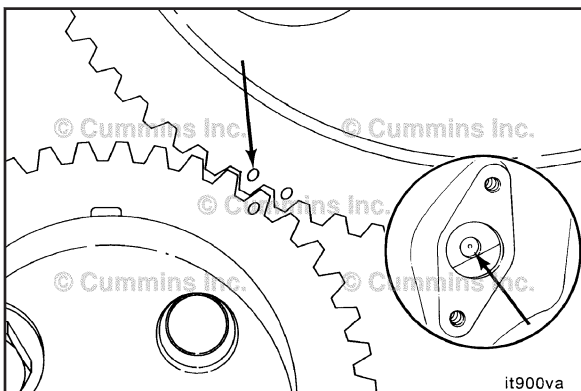
The timing pin assembly is precisely located on the gear housing to correspond to Top Dead Center (TDC) for cylinder number 1.



⚠CAUTION⚠

If a gear housing other than the original housing is installed, the timing pin assembly must be accurately aligned to correspond to TDC for cylinder number 1.

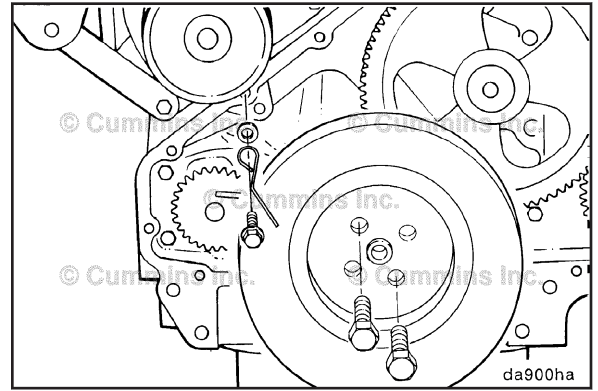
Failure to locate the timing pin assembly to TDC for cylinder number 1 will result in incorrect injection timing.



Verify that the number 1 cylinder is at or near TDC on the compression stroke by rotating the crankshaft until the engine timing pin engages in the camshaft gear hole or the hole is visible through the gear housing. Disengage the timing pin.

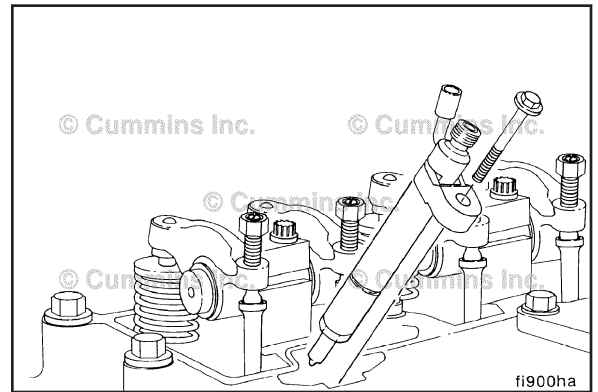
C Series
Section 1 - Cylinder Block - Group 01

Fabricate and install a wire pointer for the front of the engine. This can be done by forming a piece of wire that can be tightened under one of the gear housing capscrews. The wire **must** extend from the gear cover to a place on the crankshaft vibration damper that is easily seen.



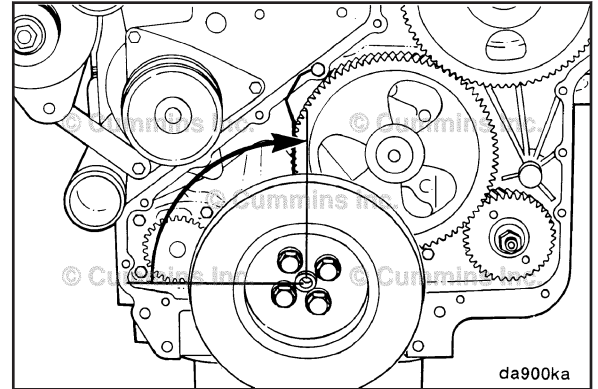
Remove all injectors. Refer to Procedure 006-026 (Injector) in Section 6.

This step is important to release cylinder pressure so the crankshaft can be rotated smoothly to locate TDC for cylinder number 1.



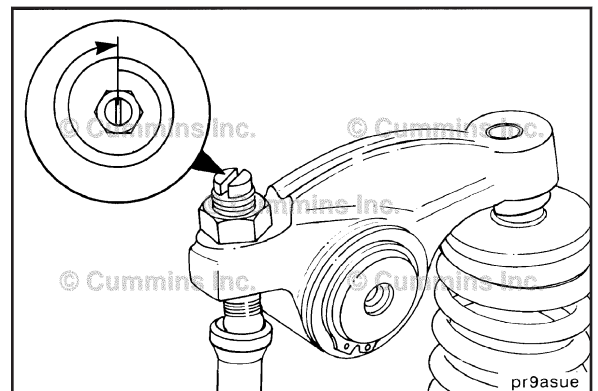
Use tool, Part Number 3377371, Engine Barring Gear.

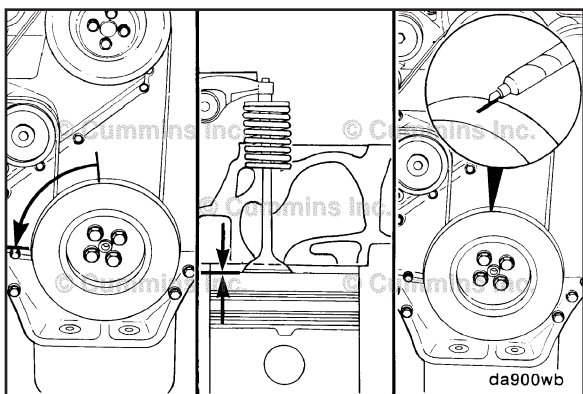
Rotate the crankshaft one-quarter revolution in the direction of normal engine rotation.



Tighten the adjusting capscrew for the number 1 intake valve to zero (0) lash plus 5 turns.

NOTE: Leave the adjusting screw in this position until TDC is established.

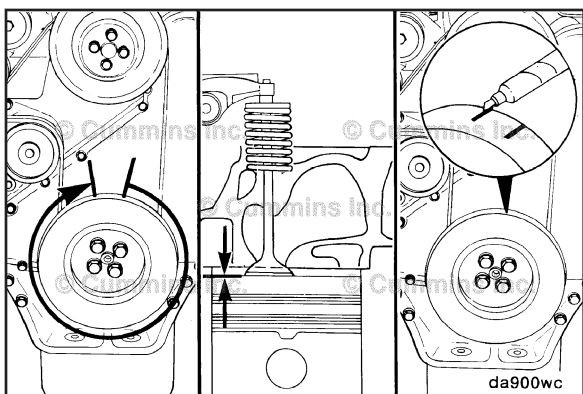




⚠CAUTION⚠
Use extreme care when rotating the crankshaft. Use of too much force could damage the valve or push rod.

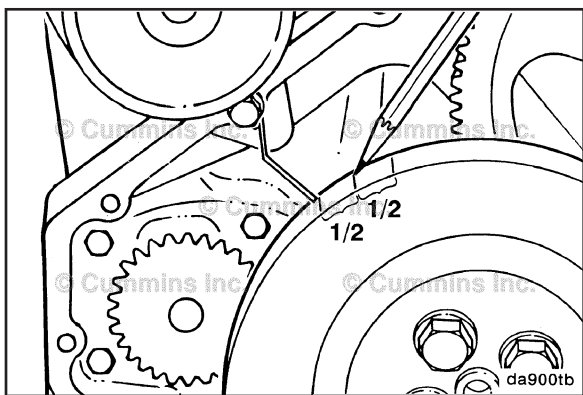
Rotate the crankshaft slowly in the opposite direction of normal engine rotation until the piston touches the intake valve.

Mark the vibration damper at the wire pointer.

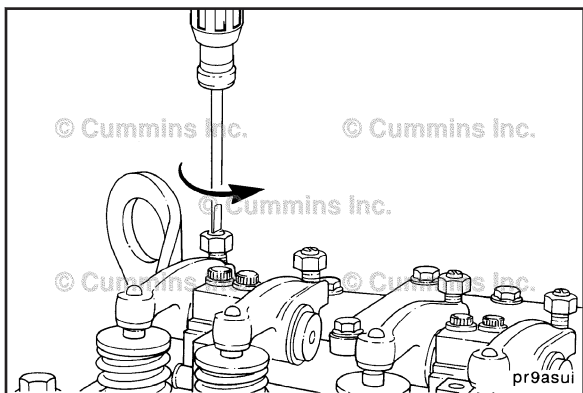


⚠CAUTION⚠
Make sure that the piston touches the intake valve with approximately the same amount of force as in the previous step.

- Rotate the crankshaft in the direction of normal engine rotation until the piston touches the intake valve.
- Mark the vibration damper at the wire pointer.

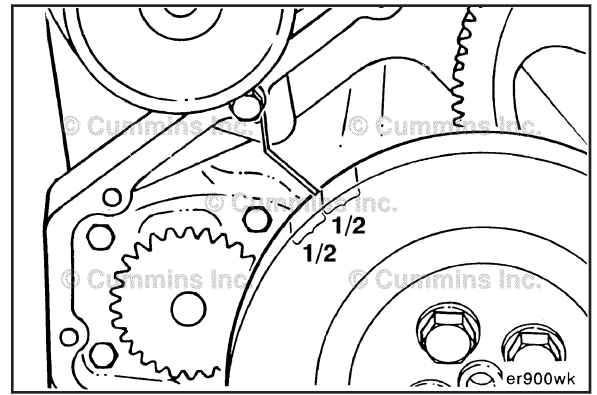


Measure the distance and mark the vibration damper at one-half the distance between the two marks. This mark is the TDC mark.

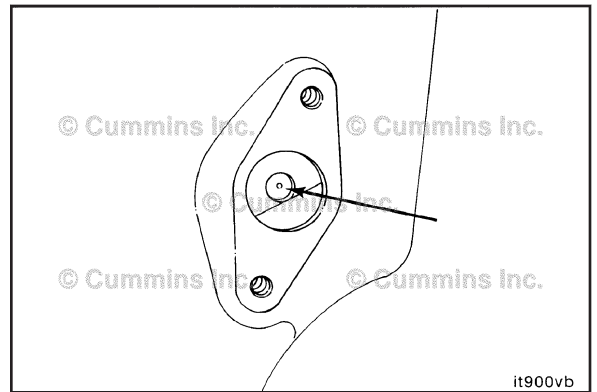


⚠CAUTION⚠
Completely loosen the intake valve adjusting screw. Failure to do so will result in damage to the intake valve or push rod when the crankshaft is rotated.

Rotate the crankshaft in the direction of normal engine rotation until the pointer is aligned with the TDC mark; then rotate the crankshaft one additional revolution.

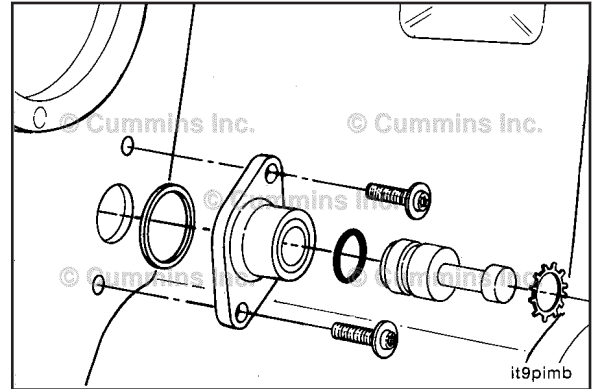


The timing pin hole in the camshaft gear **must** be visible, or felt through the back side of the gear housing. If not, the crankshaft **must** be rotated one revolution in the direction of engine rotation.



Install the o-ring into the groove on the timing pin assembly.

Lubricate the o-ring with 15W-40 engine oil.



Push the pin into the hole in the camshaft gear to align the housing.

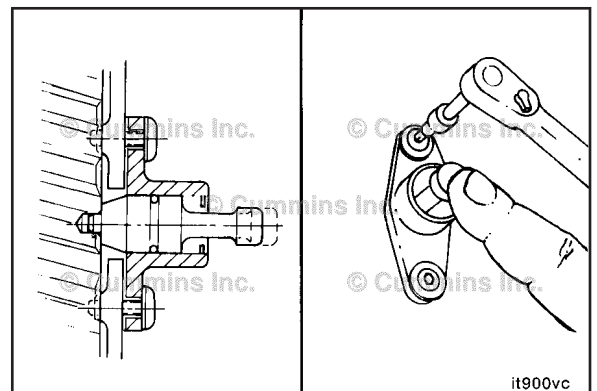
Hold the pin while tightening the Torx™ cap screws.

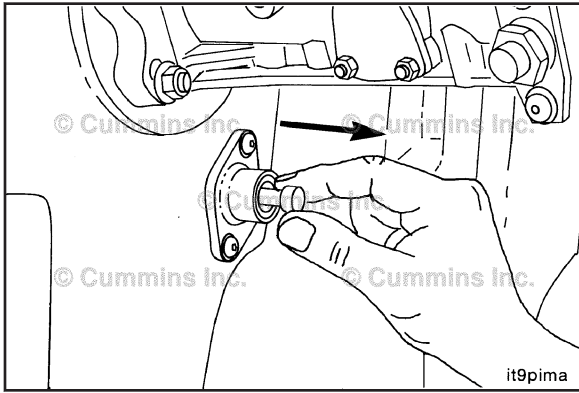
Torque Value:

Timing Pin 8 N•m [71 in-lb]

Torx™ Cap screw

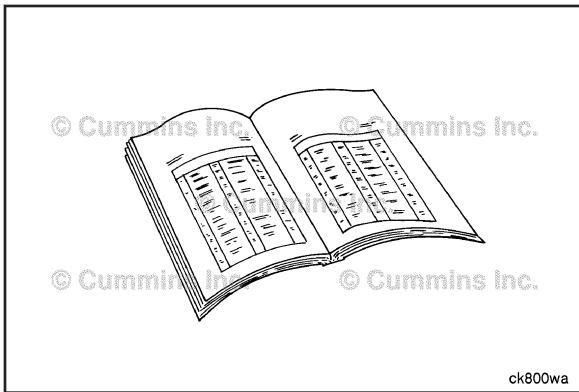
Check the pin to be sure it did **not** slip out of the camshaft gear hole when the cap screws were tightened.





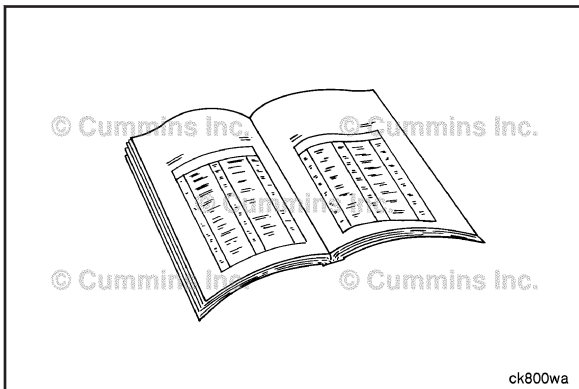
⚠ CAUTION ⚠

To prevent damage to the pin and gear, be sure the timing pin is disengaged before rotating the crankshaft.



Finishing Steps

- Install the vibration damper and wire pointer.
- Install the gear cover. Refer to Procedure 007-017 (Lubricating Oil Filter Head (Remote Mounted)) in Section 7.
- Install the vibration damper. Refer to Procedure 007-016 (Lubricating Oil Filter Head, Aluminum (Remote Mounted)) in Section 7.
- Remove the wire pointer.
- Adjust overhead. Refer to Procedure 003-004 (Overhead Set) in Section 3.
- Install all injectors. Refer to Procedure 006-026 (Injector) in Section 6.
- Operate the engine and check for leaks.



Vibration Damper, Rubber (001-051)

Preparatory Steps

⚠ WARNING ⚠

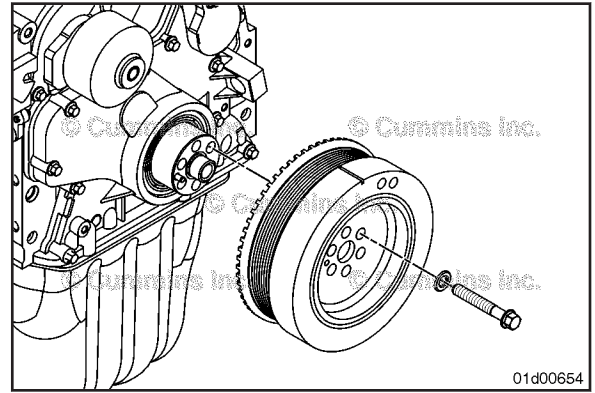
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to the OEM service manual.
- Remove the fan drive belt. Refer to Procedure 008-002 in Section 8.

Remove

NOTE: The crankshaft speed indicator ring is part of the vibration damper assembly and should **not** be removed from the vibration damper.

Remove the vibration damper/crankshaft speed indicator ring.

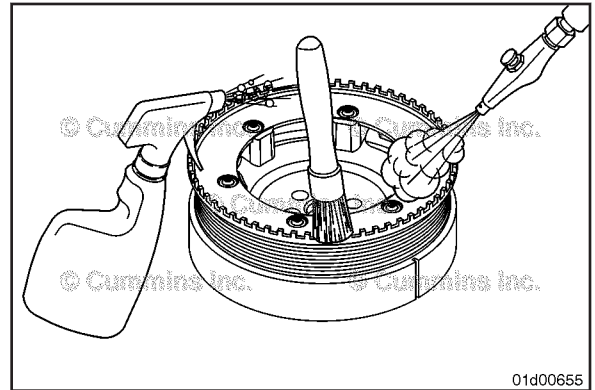


Clean and Inspect for Reuse

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

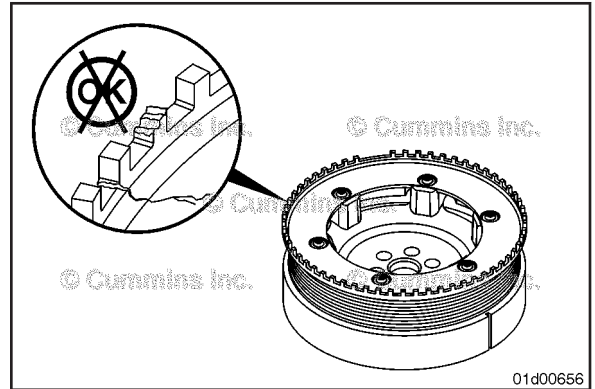
Use soapy water to clean any oil from the vibration damper/crankshaft speed indicator ring.

Dry the vibration damper/crankshaft speed indicator ring with compressed air.



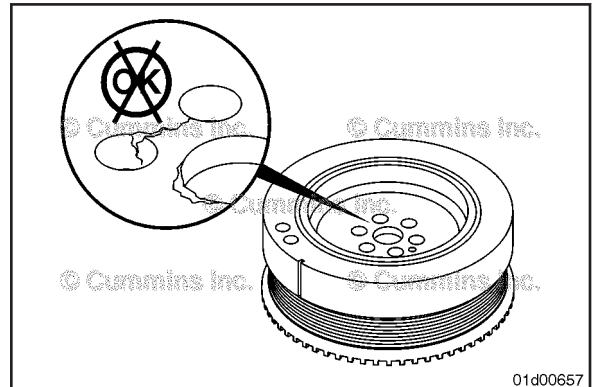
Inspect the crankshaft speed indicator ring for missing teeth, cracks, or damaged surfaces. If any damage is found, the crankshaft speed indicator ring **must** be replaced.

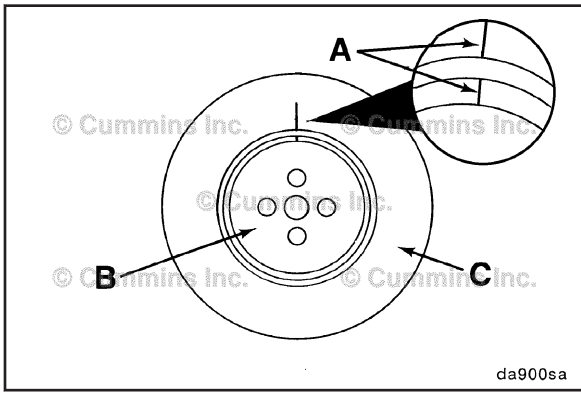
NOTE: If the crankshaft speed indicator ring is damaged, the whole vibration damper assembly **must** be replaced.



Check the mounting web for cracks.

Check the alignment marks on the inner and outer rings.



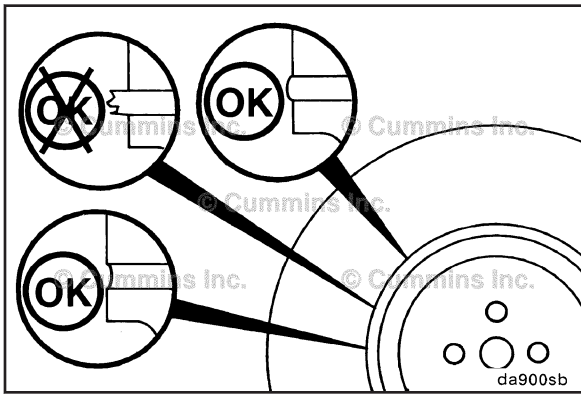


Check the index lines (A) on the damper hub (B) and the inertia member (C).

If the lines are more than 1.59 mm [1/16 in] out of alignment, replace the damper.

Inspect the vibration damper hub for cracks.

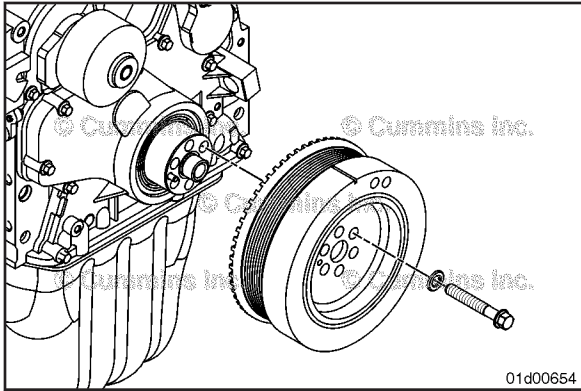
Replace the damper if the hub is cracked.



Inspect the rubber member for deterioration.

If pieces of rubber are missing or if the elastic member is more than 3.18 mm [1/8in] below the metal surface, replace the vibration damper.

NOTE: Check for forward movement of the damper ring on the hub. Replace the damper if any movement is detected.



Install

NOTE: Align the crankshaft speed indicator ring and vibration damper with the index pin located on the nose of the crankshaft.

Lubricate the capscrews with clean engine oil.

Install the vibration damper and crankshaft speed indicator ring.

Tighten the six vibration damper capscrews in a criss-cross pattern.

Torque Value:

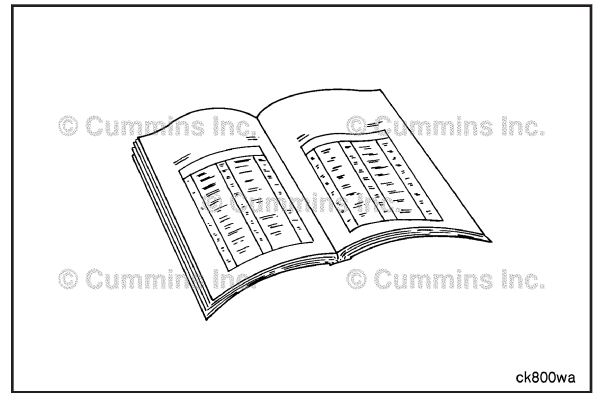
Step 1	50 N•m	[37 ft-lb]
Step 2	Rotate 90 degrees	

Finishing Steps

⚠ WARNING ⚠

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

- Install the fan drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for noise and proper operation.



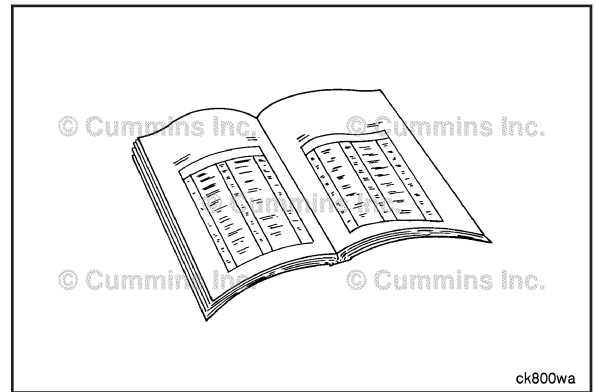
Vibration Damper, Viscous (001-052)

Preparatory Steps

⚠ WARNING ⚠

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

- Disconnect the batteries. Refer to the OEM service manual.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.

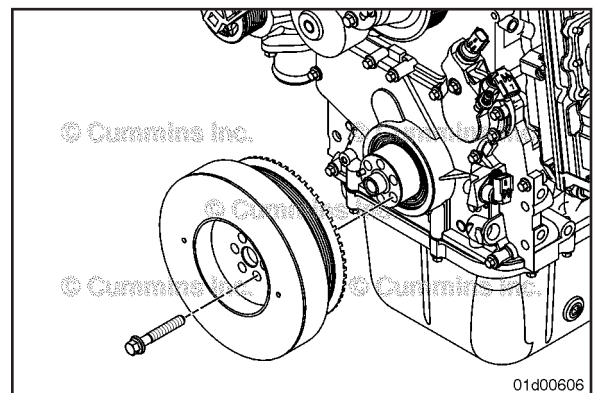


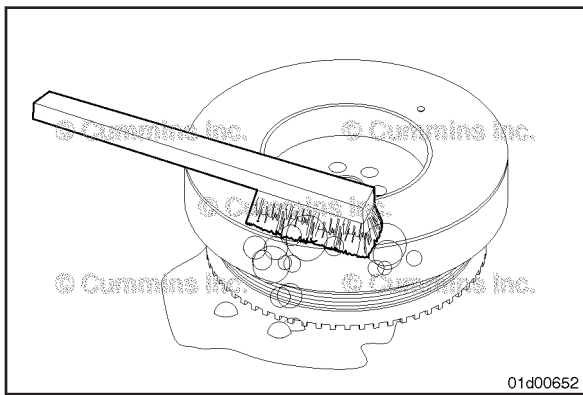
Remove

Remove the six capscrews.

NOTE: The crankshaft speed indicator ring is part of the vibration damper assembly and **must not** be removed from the vibration damper.

Remove the vibration damper/crankshaft speed indicator ring assembly.





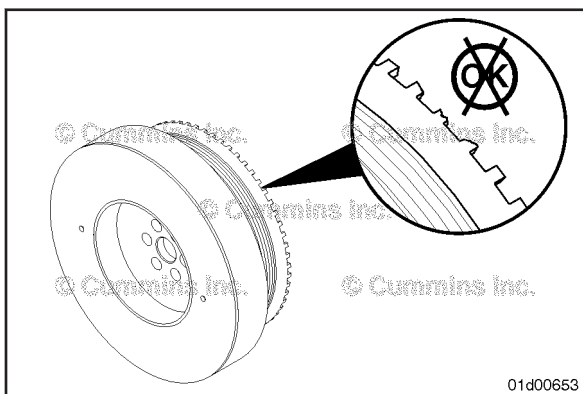
Clean and Inspect for Reuse

⚠ WARNING ⚠

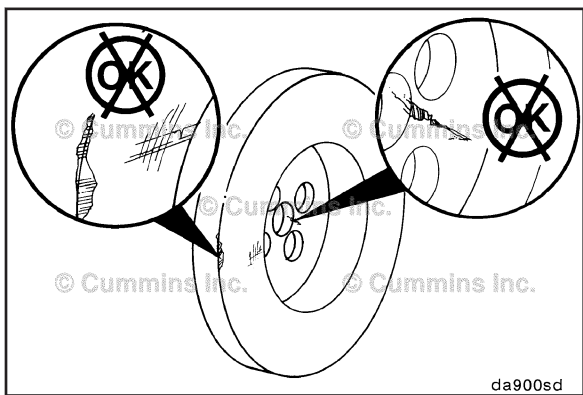
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use soapy water to clean any oil from the vibration damper/curlyshaft speed indicator ring assembly.

Dry the vibration damper/curlyshaft speed indicator ring assembly with compressed air.



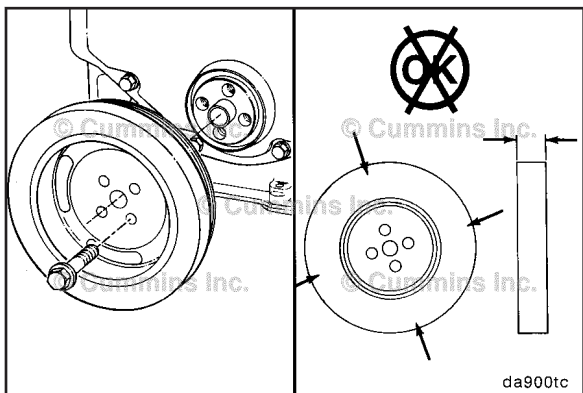
Inspect the curlyshaft speed indicator ring for missing teeth, cracks, or damaged surfaces. If any damage is found, the entire vibration damper/curlyshaft speed indicator ring assembly **must** be replaced.



Check the mounting web for cracks.

Check the housing for dents or raised surfaces.

Replace the damper if any of these defects are identified.



NOTE: The viscous damper is filled with a silicone fluid. After many hours of use, the silicone fluid can become thicker and expand.



To determine if the damper thickness is correct, remove the paint from the damper in four locations on either side of the damper.

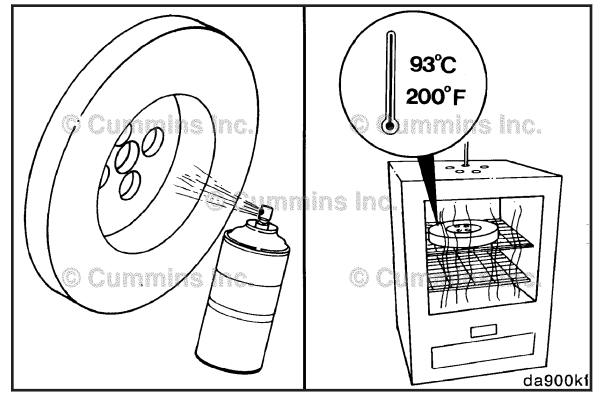
Measure and record the thickness of the damper in four places. Measure the thickness at 80.65 mm [3.175 in] from the outside of the damper.

Replace the damper if its thickness varies by more than 6.35 mm [0.25 in].

Spray the damper with spot check developer, type SKD-NF, or its equivalent.



Heat the damper in an oven, rolled-lip side down, at 93°C [200°F] for 2 hours.



⚠ WARNING ⚠

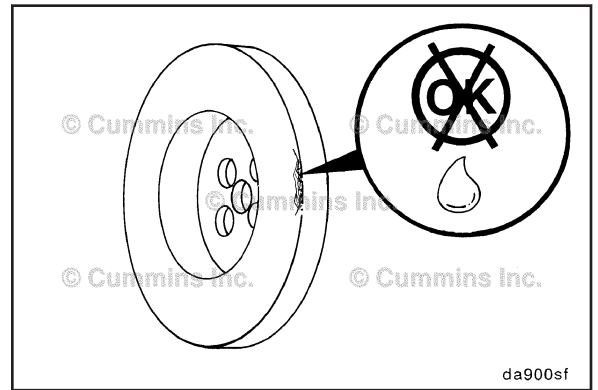
Wear protective gloves to reduce the possibility of personal injury when handling parts that have been heated.



Remove the damper from the oven and check for fluid leakage.



If there is any leakage, the vibration damper **must** be replaced.



Install

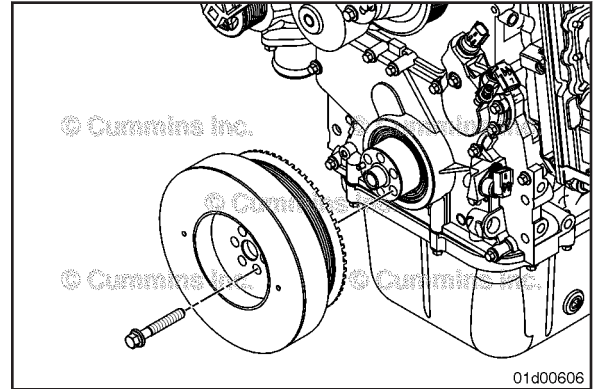
NOTE: Align the vibration damper/crankshaft speed indicator ring assembly with the index pin located on the nose of the crankshaft.



Lubricate the capscrews with clean engine oil.



Install the vibration damper/crankshaft speed indicator ring assembly.

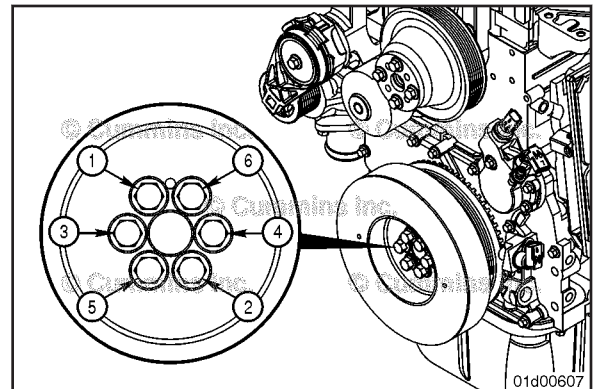


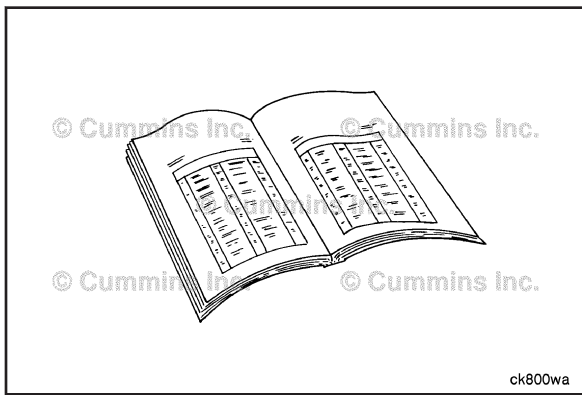
Tighten the six vibration damper capscrews in a criss-cross pattern.



Torque Value:

- Step 1 50 N•m [37 ft-lb]
- Step 2 Rotate 90 degrees





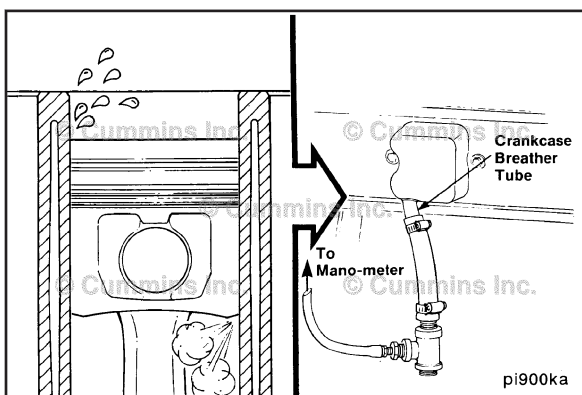
Finishing Steps

⚠ WARNING ⚠



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

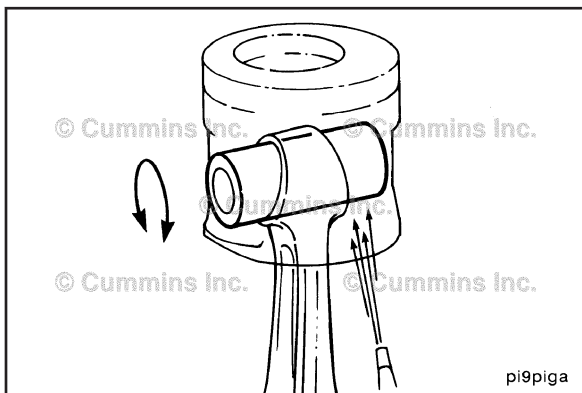
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for noise and proper operation.



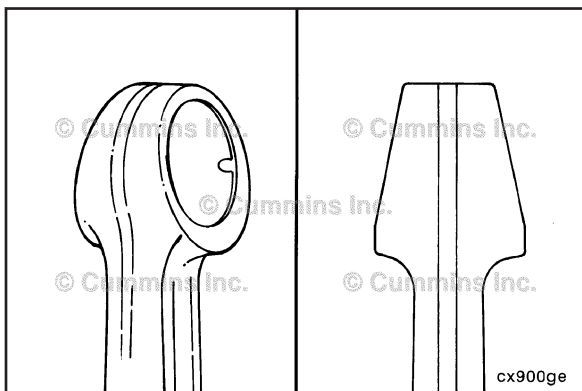
Piston and Connecting Rod Assembly (001-054)

General Information

There are a number of power-related problems, including excessive lubricating oil consumption, smoke, blowby, and poor performance that can be caused by inadequate sealing between the piston rings and the cylinder walls. A blowby measurement can help to detect these problems.



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



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

Preparatory Steps

⚠ WARNING ⚠

Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil.

⚠ 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. If not reused, dispose of in accordance with local environmental regulations.

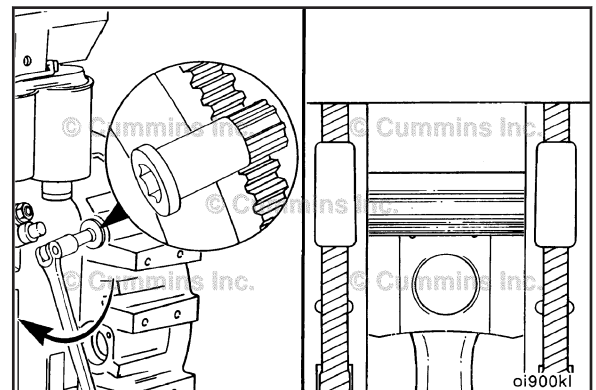
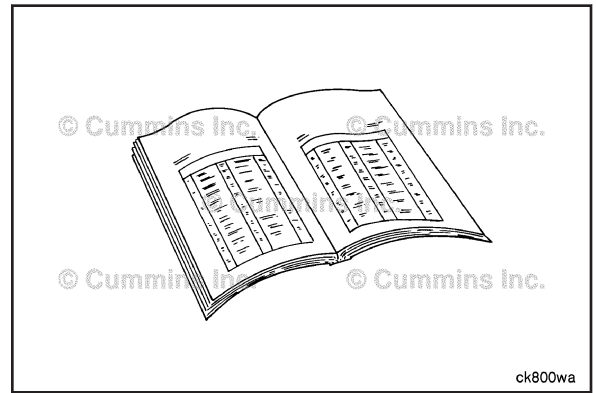
⚠ WARNING ⚠

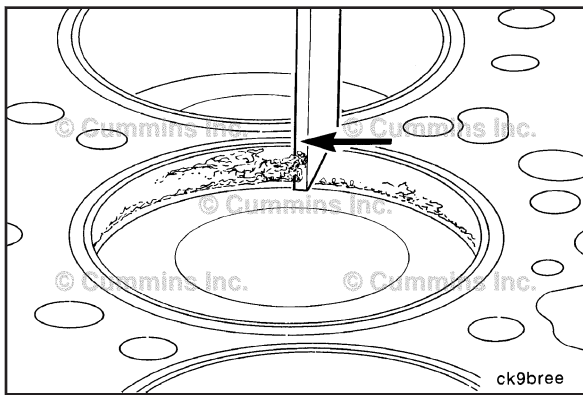
This component or assembly weighs greater than 23 kg [50 lb]. To prevent serious personal injury, be sure to have assistance or use appropriate lifting equipment to lift this component or assembly.

- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Remove the cylinder head. Refer to Procedure 002-004 in Section 2.
- Mark each connecting rod cap according to cylinder.

Remove

Rotate the crankshaft with engine barring tool, Part Number 3377371, until the pistons are below the carbon deposits that are found above the ring travel area.



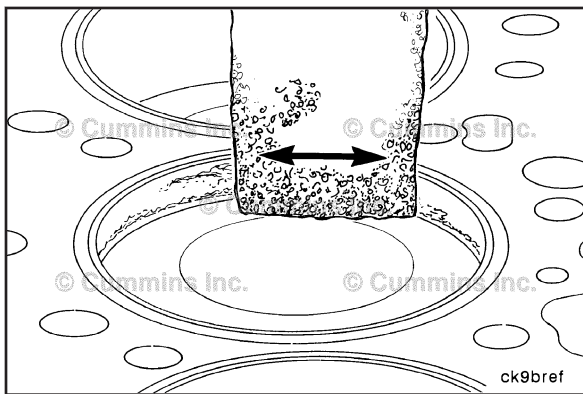


⚠ CAUTION ⚠

Do not use emery cloth or sandpaper to remove carbon from the cylinder liners. Aluminum oxide or silicon particles from emery cloth or sandpaper can cause serious engine damage. Do not use any abrasives in the ring travel area. The cylinder liner can be damaged.

Use a scraper or a blunt-edged instrument to loosen the carbon deposits. Do **not** damage the cylinder liner with the scraper.

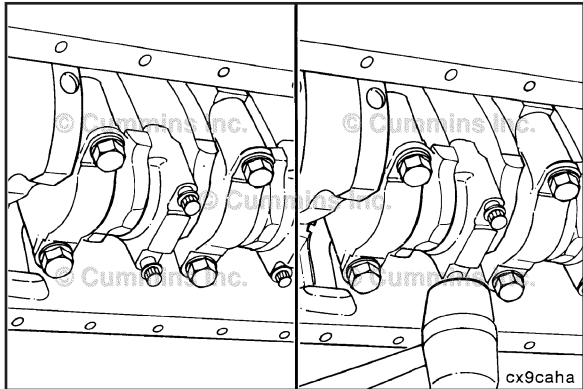
NOTE: Only scrape or sand above the piston travel area.



⚠ WARNING ⚠

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

Remove the remaining carbon with Scotch-Brite™ 7448 abrasive pad, Part Number 3823258, and solvent.

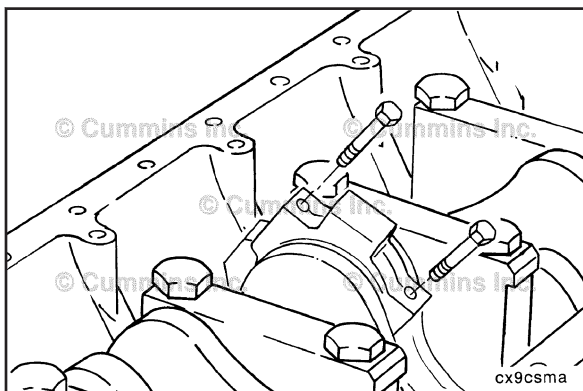


Rotate the crankshaft to position the connecting rod caps just before Top Dead Center for removal.

NOTE: Do **not** remove the capscrews from the connecting rods.

Loosen the connecting rod capscrew nuts.

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

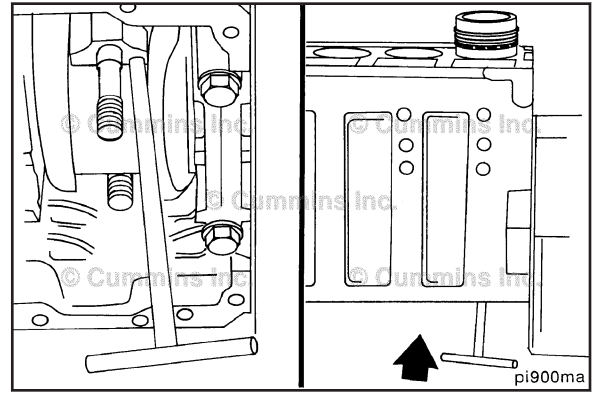


Remove the capscrew nuts, connecting rod cap, and connecting rod bearings.

Mark the connecting rod bearings with the cylinder number and "U" for the upper bearing and "L" for the lower bearings.

Use the T-handle piston pusher to push the rod away from the crankshaft.

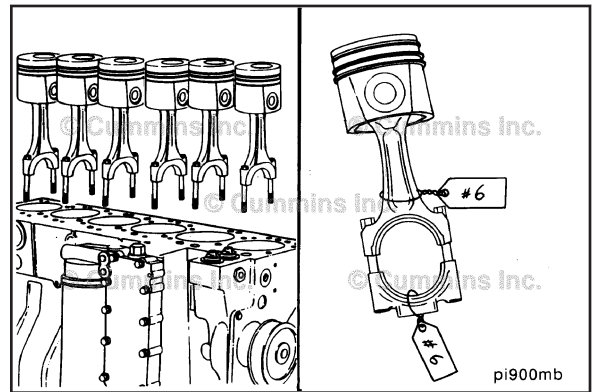
NOTE: Push the rod until the piston rings are outside the top of the cylinder liner.



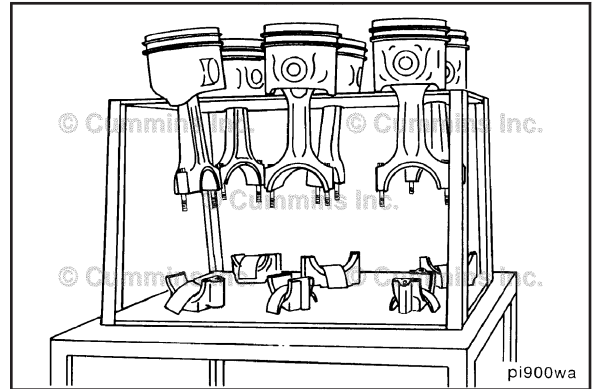
Use both hands to remove the piston and rod assembly.

NOTE: The piston and connecting rod assemblies **must** be installed in the same cylinder from which they were removed. This will allow for the proper fit of worn mating surfaces if the parts are used again.

Use a tag to mark the cylinder number from which each piston and rod assembly was removed.

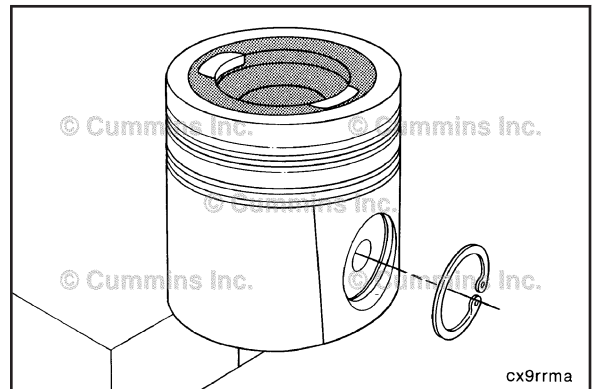


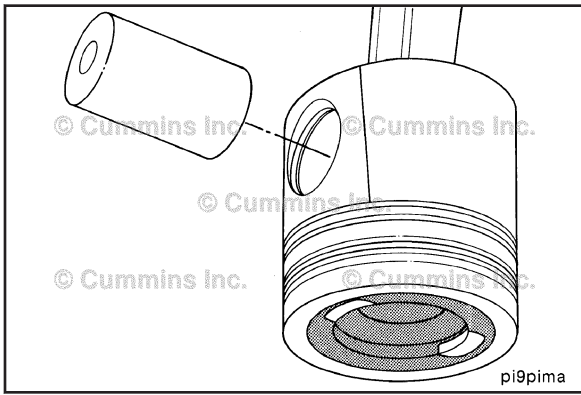
Place the connecting rod and piston assemblies in a container to protect them from damage.



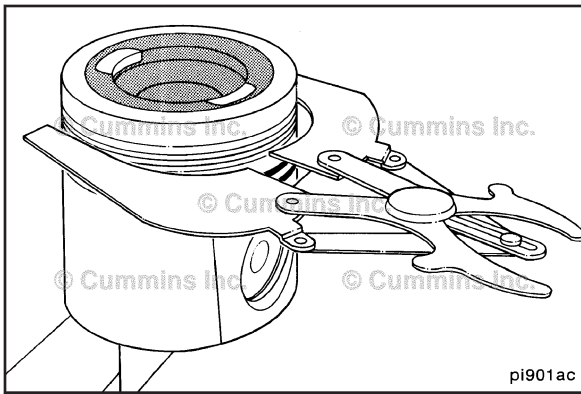
Disassemble

Remove the piston pin retaining rings.

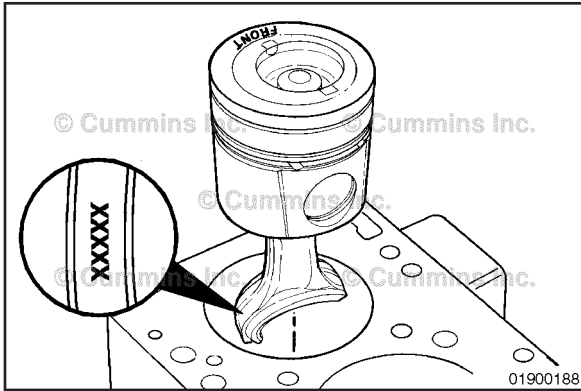




NOTE: Heating the piston is **not** required.
Remove the piston pin.

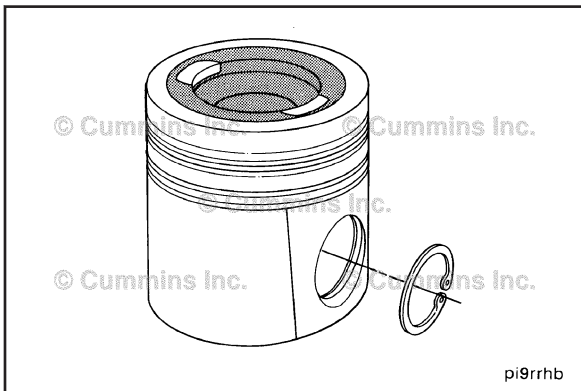


Remove the piston rings with piston ring expander, Part Number 3823137.



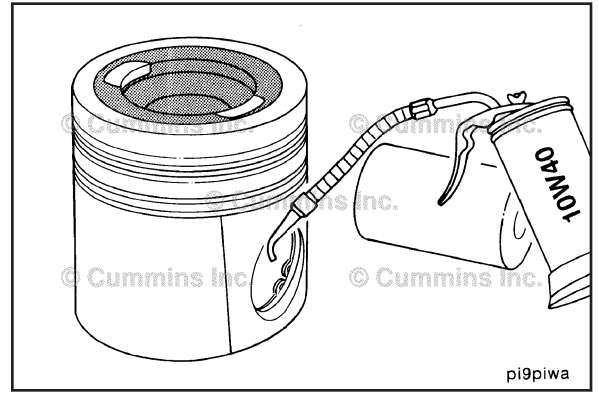
Assemble

Make sure FRONT marking on the piston and the numbers on the connecting rod and cap are oriented as illustrated.



Install the retaining ring in the piston pin groove on the front side of the piston.

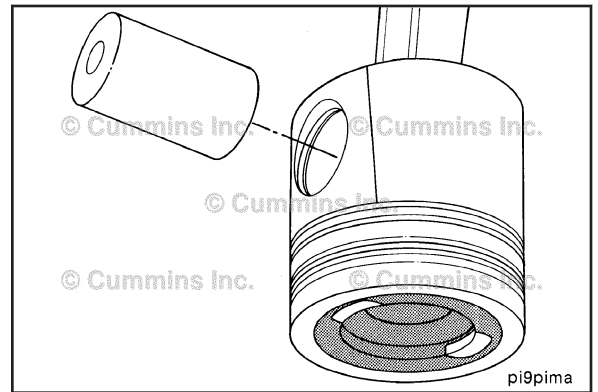
Lubricate the piston pin and piston pin bores with clean engine oil.



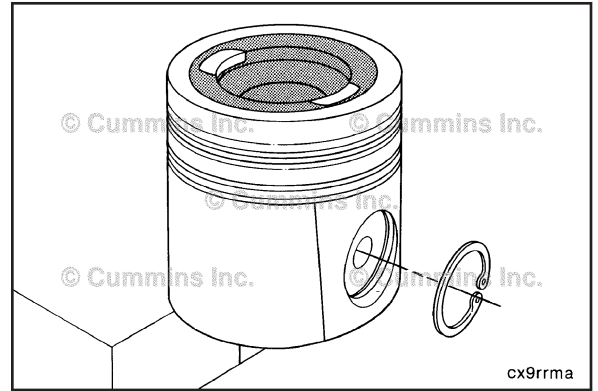
NOTE: Pistons do **not** require heating to install the pin; however, the pistons do need to be at room temperature or above.



Install the piston pin.



Install the second piston pin retaining ring.

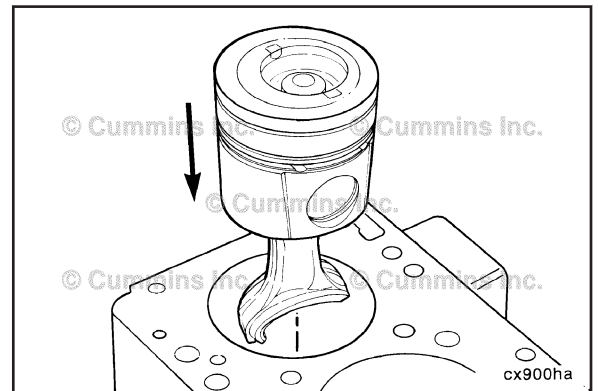


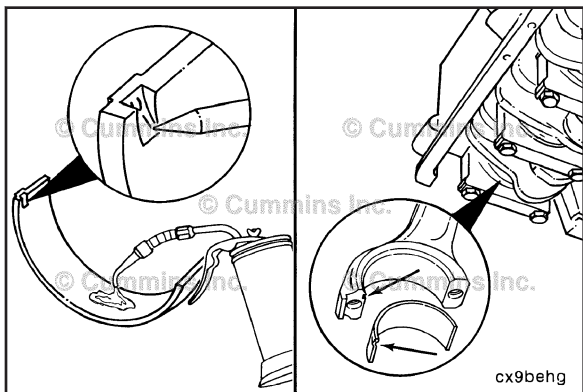
Piston Grading

When rebuilding an engine with the original cylinder block, crankshaft, and pistons, make sure the pistons are installed in the original cylinder. If replacing the piston(s), make sure the replacement piston(s) is the same grade as the original piston. If a new cylinder block or crankshaft is used, the piston grading procedure **must** be performed to determine the proper piston grade for each cylinder.



Install the connecting rod/piston assembly into the Number 1 cylinder without the rings installed.

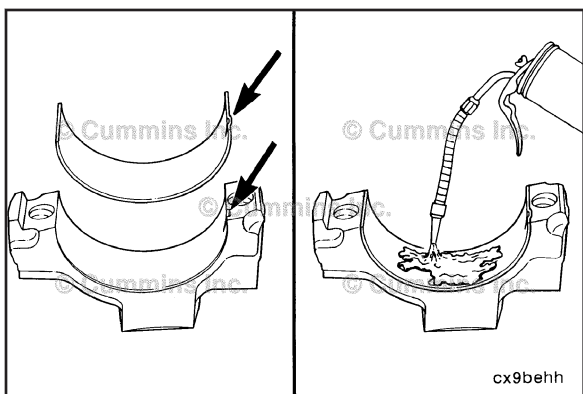




NOTE: The connecting rod bearings **must** be installed in the original connecting rod and cap.

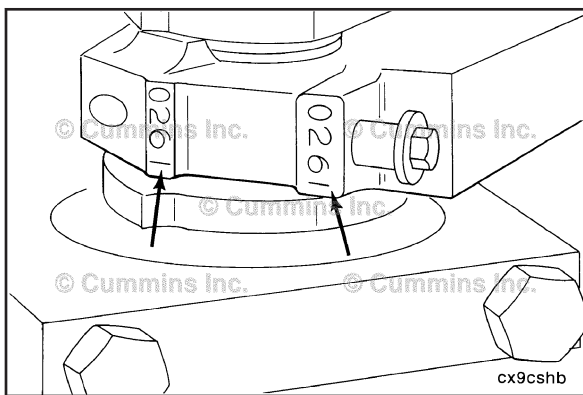
Install the upper bearing shell in the connecting rod with the tang of the bearing in the slot of the connecting rod.

Use clean lubricating oil to coat the inside of the connecting rod bearing shell.



Install the bearing shell in the connecting rod cap with the tang of the bearing in the slot of the cap.

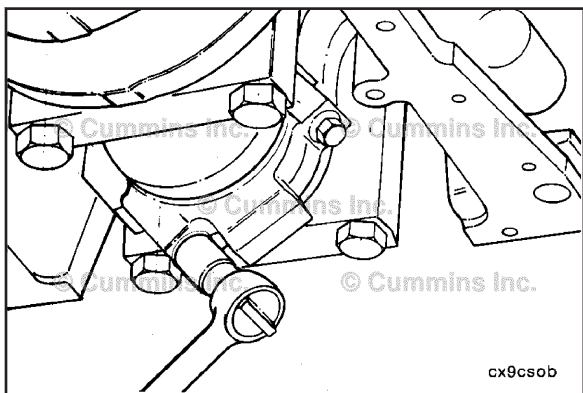
Use clean lubricating oil to coat the inside diameter of the connecting rod bearing shell.



The four-digit number stamped on the connecting rod and cap at the parting line **must** match and be installed on the same side in all cylinders.

Install the connecting rod cap and capscrews to the connecting rod.

NOTE: The word FRONT on the piston will now be toward the front of the block. The combustion bowl in the piston will be on the fuel pump side of the engine.



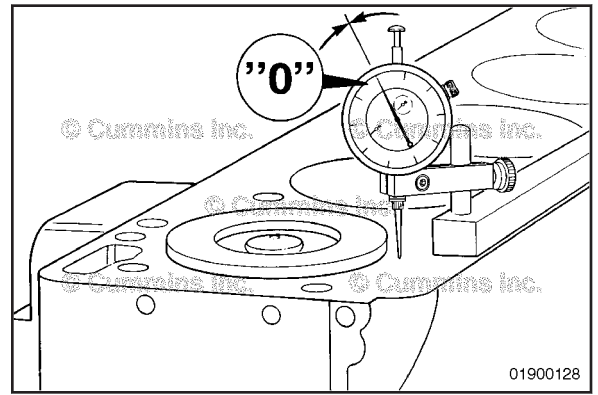
Tighten the two connecting rod capscrews.

Torque Value: 40 N•m [30 ft-lb]

C Series
Section 1 - Cylinder Block - Group 01

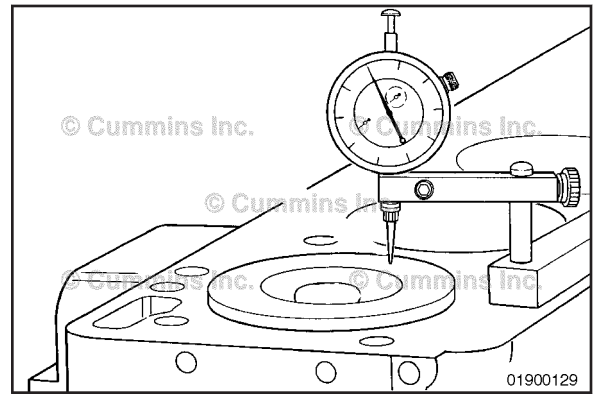
Use a fine-grit hone to remove any burrs from the cylinder block head deck.

Zero the dial indicator, Part Number 3823495, to the cylinder block head deck.



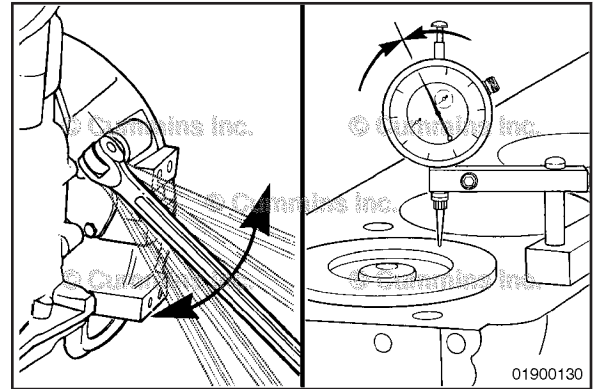
Move the dial indicator over the piston directly over the piston pin to eliminate any side-to-side movement.

Do **not** place the indicator tip on the anodized area.

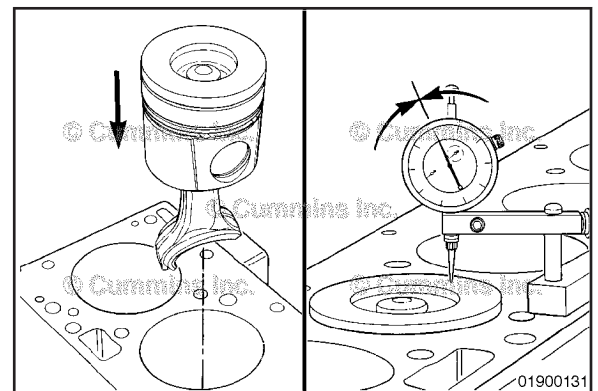


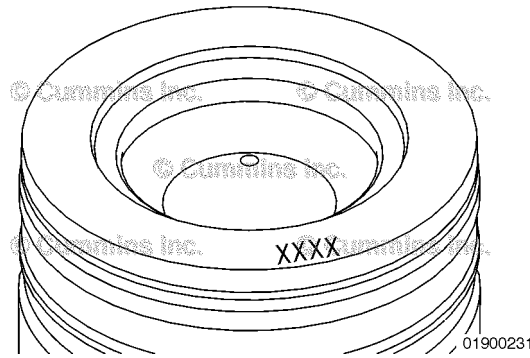
Rotate the crankshaft to top dead center. Rotate the crankshaft **clockwise** and **counterclockwise** to find the highest dial indicator reading.

Record the reading.



Remove the piston connecting rod assembly from the Number 1 cylinder, and install the assembly into the Number 2 cylinder. Repeat the procedure for every cylinder using the same piston connecting rod assembly.





Determine the grade of the piston being used by referring to the chart.

The four digits on top of the piston are the last four digits of the part number.

Piston Protrusion				
Measuring Piston	Measured Protrusion	Use Grade	210 to 250 hp	275 to 300 hp
A	0.58 to 0.65 mm [0.022 to 0.025 in]	A	3925878	3926961
A	0.51 to 0.58 mm [0.020 to 0.022 in]	B	3925879	3926962
A	0.44 to 0.51 mm [0.017 to 0.020 in]	C	3925880	3926963
A	0.37 to 0.44 mm [0.014 to 0.017 in]	D	3925881	3926964
B	0.65 to 0.72 mm [0.025 to 0.028 in]	A	3925878	3926961
B	0.58 to 0.65 mm [0.022 to 0.025 in]	B	3925879	3926962
B	0.51 to 0.58 mm [0.020 to 0.022 in]	C	3925880	3926963
B	0.44 to 0.51 mm [0.017 to 0.020 in]	D	3925881	3926964
C	0.72 to 0.79 mm [0.028 to 0.031 in]	A	3925878	3926961
C	0.65 to 0.72 mm [0.025 to 0.028 in]	B	3925879	3926962
C	0.58 to 0.65 mm [0.022 to 0.025 in]	C	3925880	3926963
C	0.51 to 0.58 mm [0.020 to 0.022 in]	D	3925881	3926964
D	0.79 to 0.86 mm [0.031 to 0.033 in]	A	3925878	3926961
D	0.72 to 0.79 mm [0.028 to 0.031 in]	B	3925879	3926962
D	0.65 to 0.72 mm [0.025 to 0.028 in]	C	3925880	3926963
D	0.58 to 0.65 mm [0.022 to 0.025 in]	D	3925881	3926964

Install

Piston Protrusion for Emission-Controlled Engines

	mm		in
Engines built after 1/1/1994	0.584	MIN	0.023
	0.635	MAX	0.025

Install the bearing shells into both the connecting rod and the connecting rod cap. Make sure the tang on the bearing shell is in the slot of the connecting rod cap and connecting rod.

NOTE: If used connecting rod bearing shells are to be installed, each bearing shell **must** be installed in its original location.

⚠CAUTION⚠

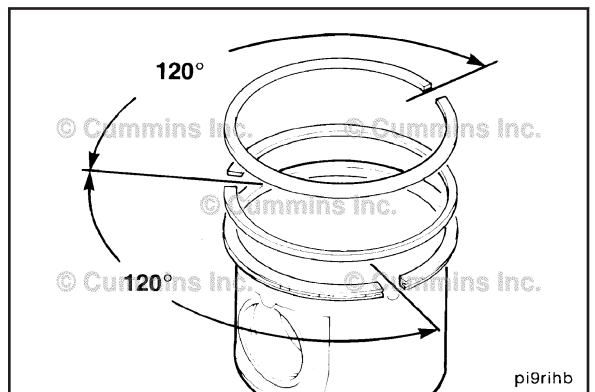
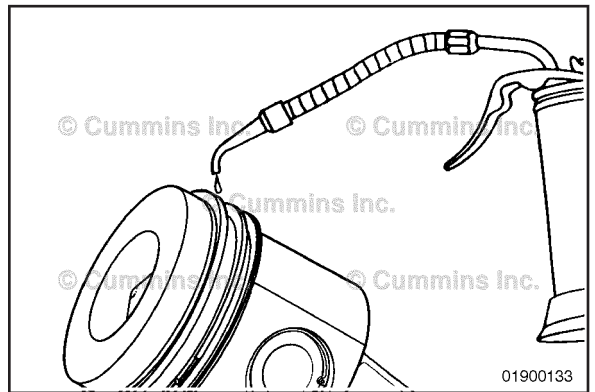
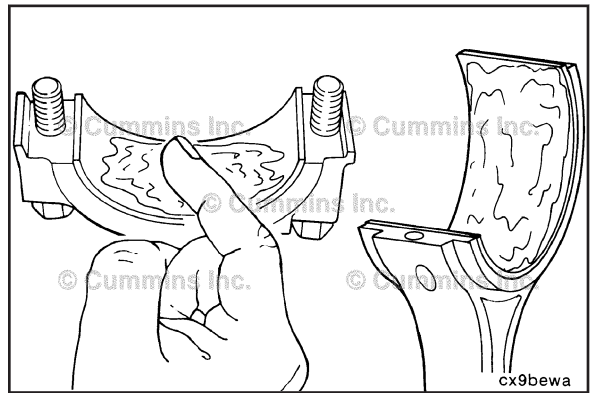
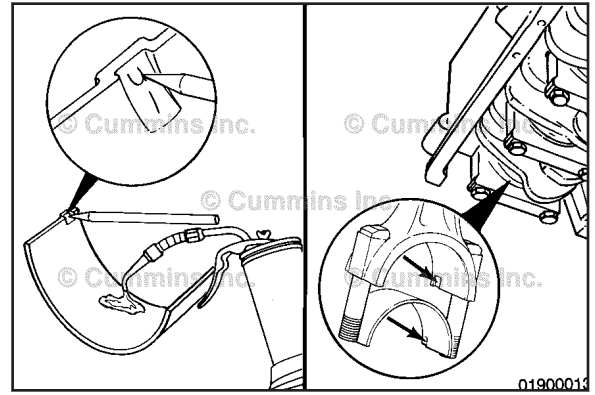
Do not lubricate the back of the connecting rod bearing. Prevent dirt from mixing with the lubricant. Dirty lubricant will accelerate connecting rod bearing wear.

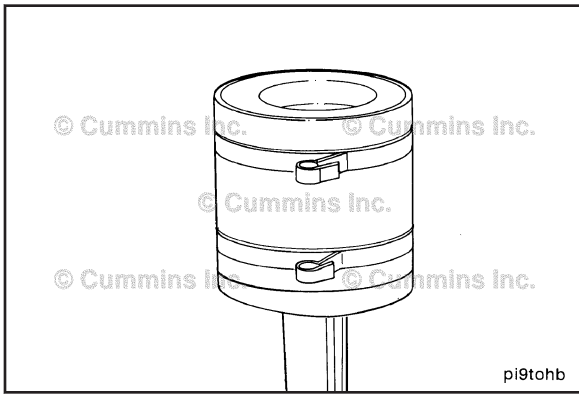
Lubricate the connecting rod bearings with a thin film of clean engine oil.

Install the piston rings. Refer to Procedure 001-047 in Section 1.

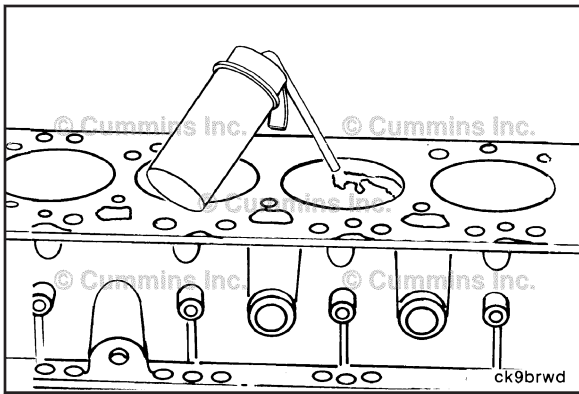
Lubricate the rings and piston skirts with clean engine oil.

Make sure the piston ring end gaps are positioned 120 degrees apart.

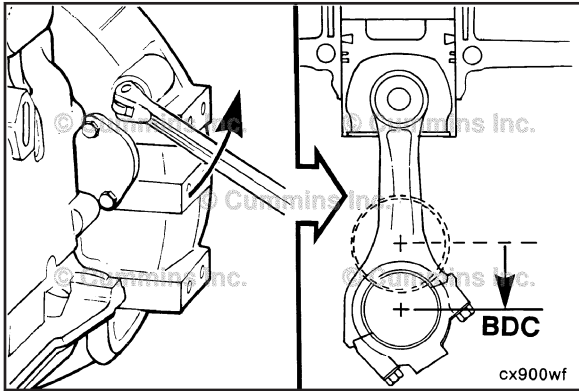




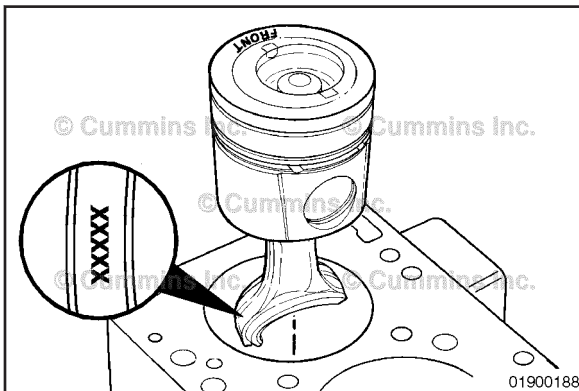
⚠CAUTION⚠
If using a strap-type ring compressor, make sure the inside end of the strap does not hook on a ring gap and break the ring.
Compress the rings.



Lubricate the cylinder bore with clean engine oil.



Position the connecting rod journal for the piston to be installed to Bottom Dead Center.

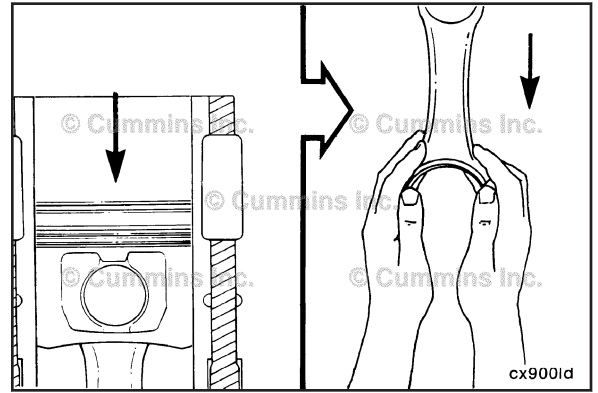


Take care **not** to damage the cylinder wall when inserting the connecting rod.

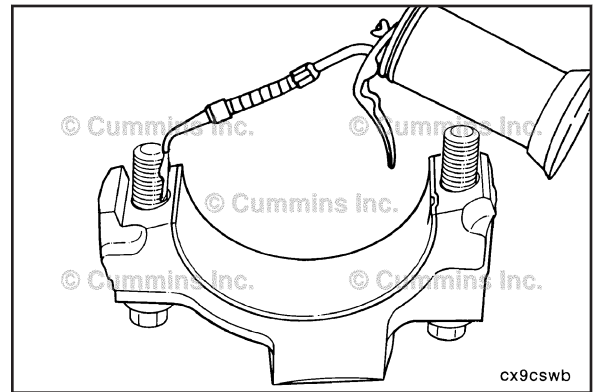


NOTE: The word FRONT stamped on the piston crown will be toward the front of the block. The piston bowl will then be on the fuel pump side of the engine.

Carefully push the piston into the bore while guiding the connecting rod to the crankshaft journal.

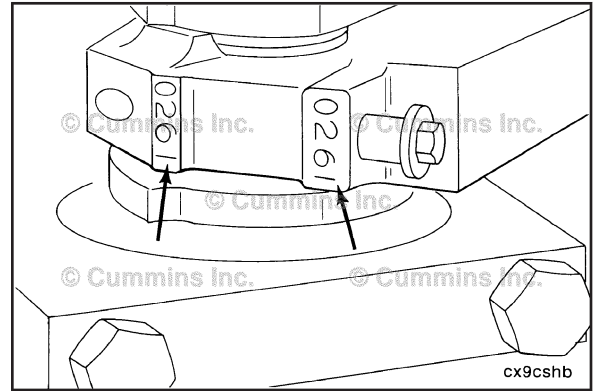


Lubricate the threads and underside of the connecting rod capscrew heads with clean engine oil.



⚠CAUTION⚠
The number stamped on the rod and cap at the parting line must match and be installed on the oil cooler side of the engine.

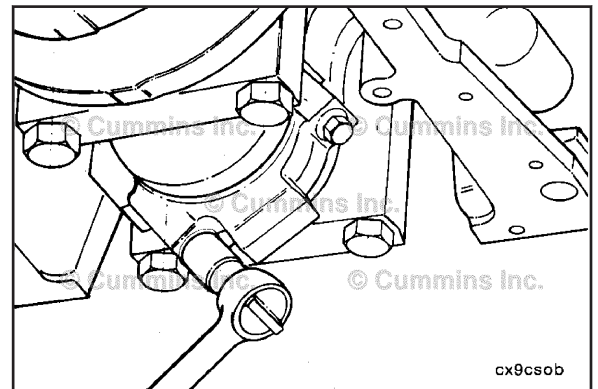
Install the connecting rod cap and capscrews to the connecting rod.

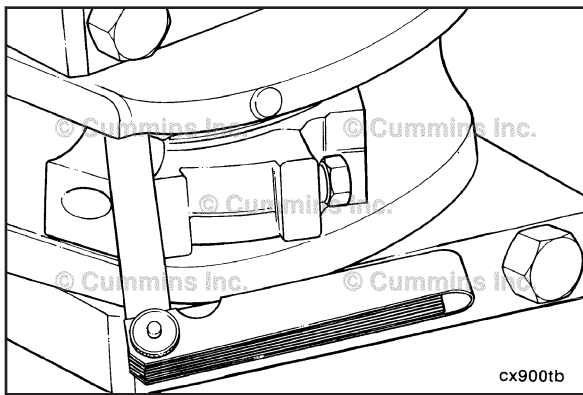


Alternately, tighten the two connecting rod capscrews.

Torque Value:

- | | | |
|--------|----------------|--------------|
| Step 1 | 30 N•m | [22 ft-lb] |
| Step 2 | 70 N•m | [52 ft-lb] |
| Step 3 | 90 degree turn | |



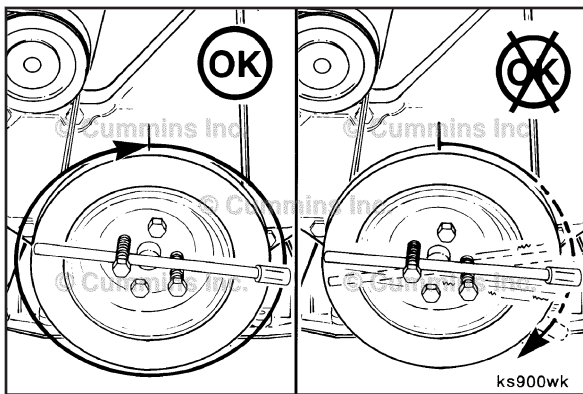


NOTE: Do **not** measure the clearance between the rod cap and crankshaft.

Measure the side clearance between the connecting rod and crankshaft.

Side Clearance Limits

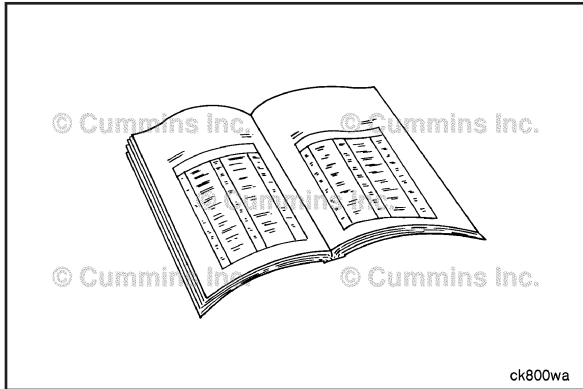
mm		in
0.10	MIN	0.004
0.33	MAX	0.013



NOTE: The crankshaft must rotate freely.

Check for freedom of rotation as the connecting rod caps are installed. If the crankshaft does **not** rotate freely, check the installation of the connecting rod bearings and the bearing size.

NOTE: If the connecting rod is **not** properly oriented (tang opposite the camshaft), it will contact the camshaft and lock the engine.



Finishing Steps

▲ 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.

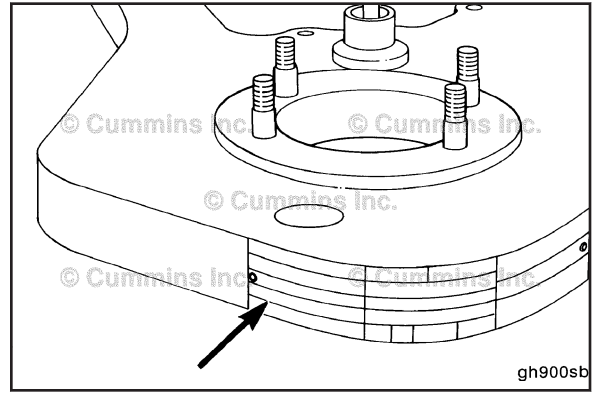
- Install the cylinder head. Refer to Procedure 002-004 in Section 2.
- Install the lubricating oil pan. Refer to Procedure 007-025 in Section 7.
- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- Fill the engine with clean lubricating oil. Refer to Procedure 007-037 in Section 7.

Operate the engine and check for leaks.

Engine Dataplate (001-057)

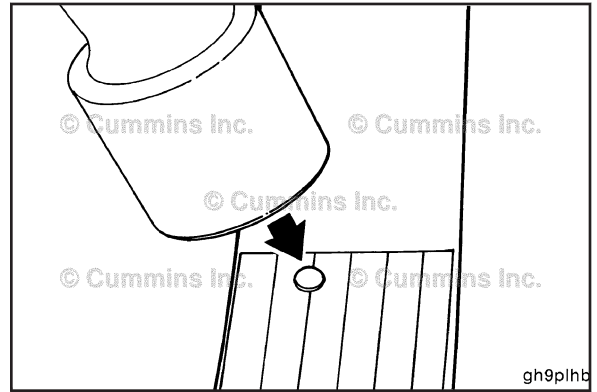
Remove

Remove the rivets that secure the dataplate to the gear housing.



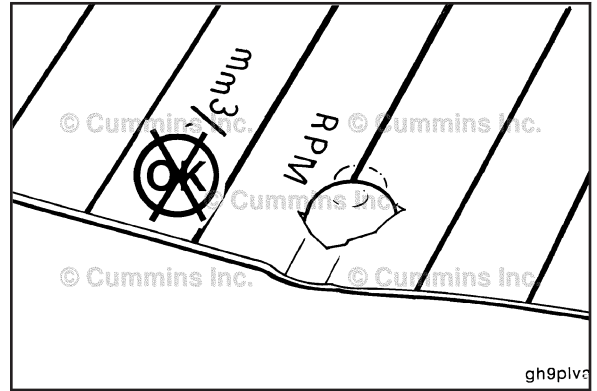
Install

Drive the rivets in until they contact the dataplate.

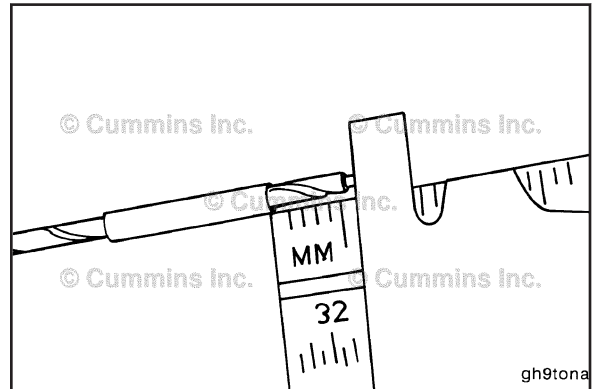


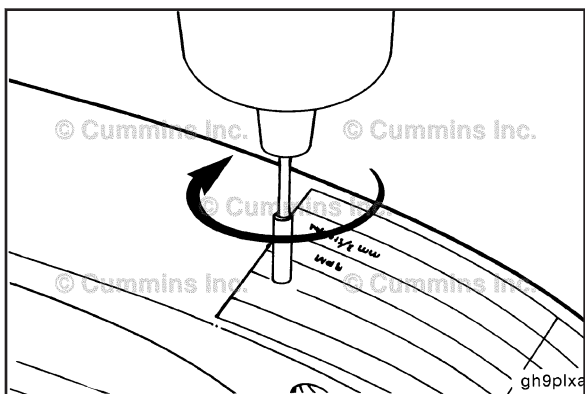
⚠ CAUTION ⚠

If the rivets are driven in too far, they will cut through the dataplates.

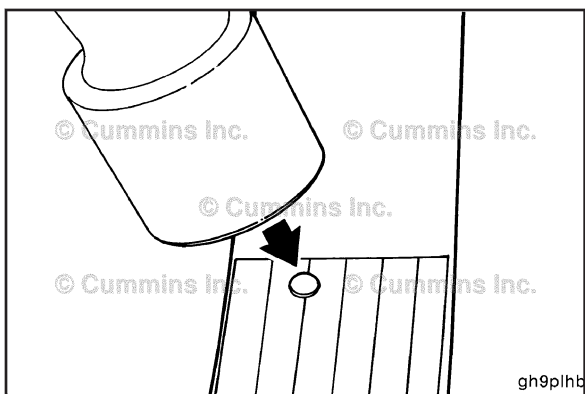


If the dataplate is loose or has been damaged, drill new holes, and attach with new rivets. Mark the drill bit at 6.0 mm [0.236 in] to avoid drilling too deeply into the gear housing.

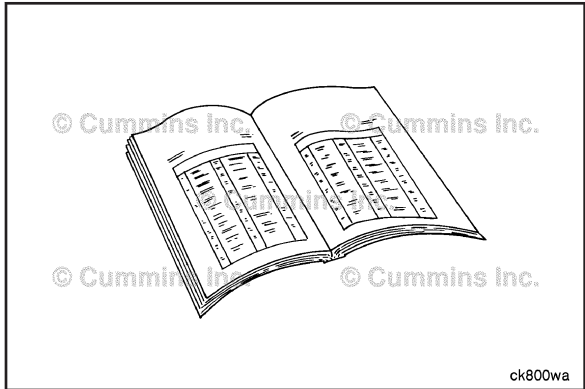




Drill the dataplate, taking care **not** to destroy any data printed on the dataplate.



Drive the rivets in until they contact the dataplate.



Crankshaft Wear Sleeve, Rear (001-067)



Preparatory Steps

⚠ CAUTION ⚠

Use extreme care when releasing the oil pan gasket from the rear cover to prevent damage to the gasket. If the gasket is damaged, the oil pan must be removed and the gasket replaced.

- Disconnect the driven equipment. Refer to the OEM instructions.
- Remove the flywheel. Refer to Procedure 016-005 (Flywheel) in Section 16.
- Remove the flywheel housing. Refer to Procedure 016-006 (Flywheel Housing) in Section 16.
- Loosen the lubricating oil pan mounting capscrews four revolutions.
- Insert a feeler gauge or shim stock between the rear cover and the oil pan gasket. Move the feeler gauge or the shim stock back and forth to release the gasket from the rear cover.
- Remove the capscrews from the rear cover, and remove the cover from the crankshaft flange.
- Remove the seal from the rear cover.

Remove

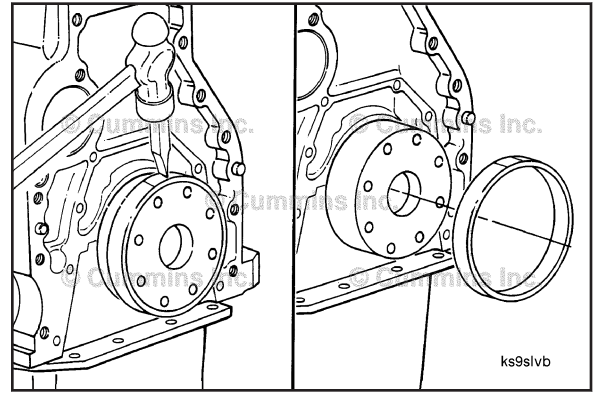
⚠ CAUTION ⚠

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

If the crankshaft presently has a wear sleeve, it **must** be removed before installing a new one.

Use a dull chisel that is **only** as wide as the wear sleeve.

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

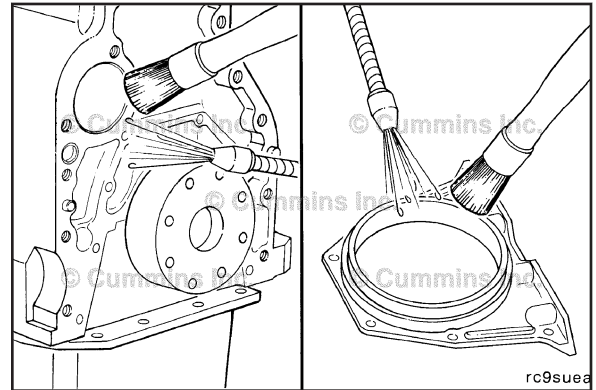


Clean and Inspect for Reuse

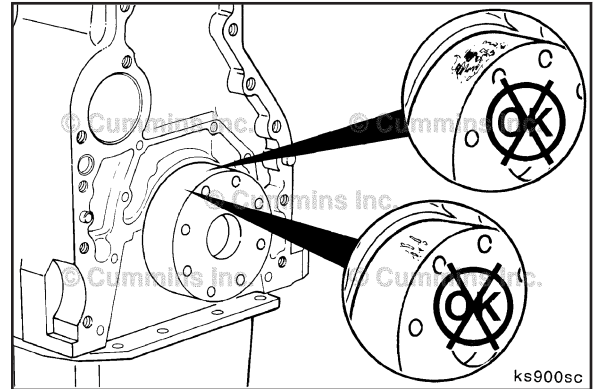
Clean the gasket surface of the cylinder block and rear cover.

Use a crocus cloth to remove any rust or other deposits from the crankshaft flange.

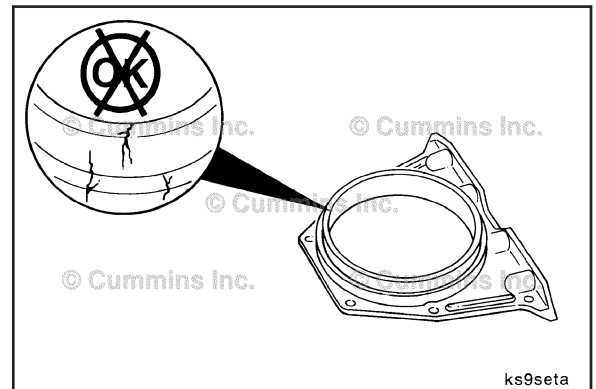
Use a clean cloth to clean the crankshaft flange.

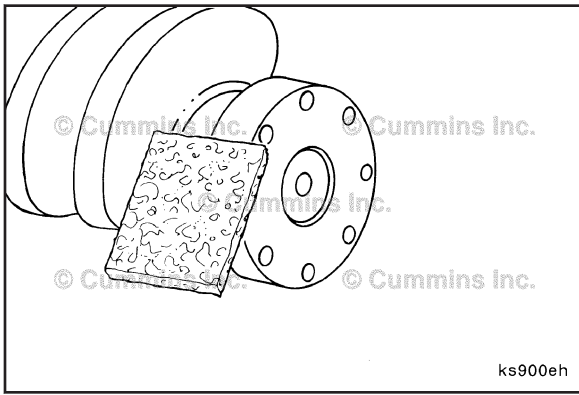


Inspect the crankshaft flange for dirt or nicks.



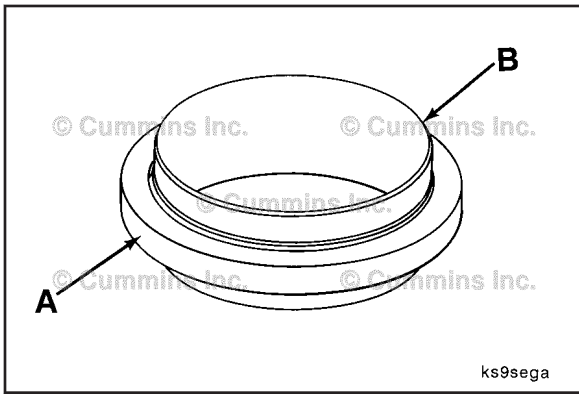
Inspect the rear cover for cracks or other damage.



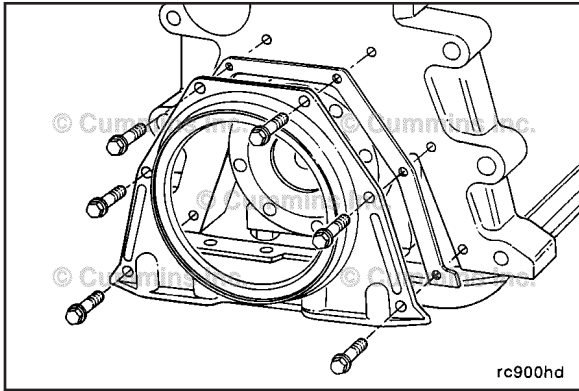


Install

Do **not** use any kind of lubricant to install the seal. The oil seal **must** be installed with the lip of the oil seal and the crankshaft clean and dry to secure proper oil sealing.



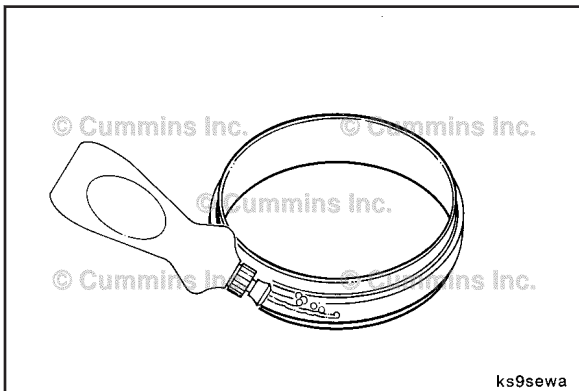
The combination crankshaft oil seal (A) wear sleeve (B) replacement kit for service usage is installed on the crankshaft as an assembly. The crankshaft rear oil seal **must not** be removed from the crankshaft rear seal wear sleeve.



Install the rear cover and gasket.

Install the rear cover capscrews. Do **not** tighten. If the oil pan is installed, loosen the oil pan capscrews to allow clearance for rear cover and gasket clearance.

The seal installation is being used to align the rear cover properly. Do **not** push or force the cover in any direction to prevent irregular seal lip position after seal installation.



The oil seal for a wet flywheel housing requires soap on the outside of the seal case. Nothing is required on the outside of the seal case for dry housings.

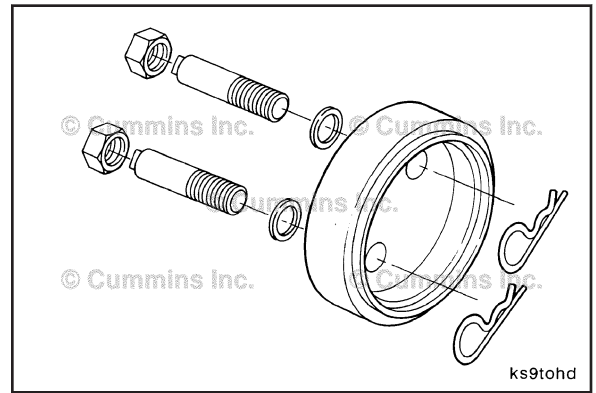
Use a crankshaft rear seal/wear sleeve installation tool, Part Number 3824078, to install the oil seal/wear sleeve assembly.



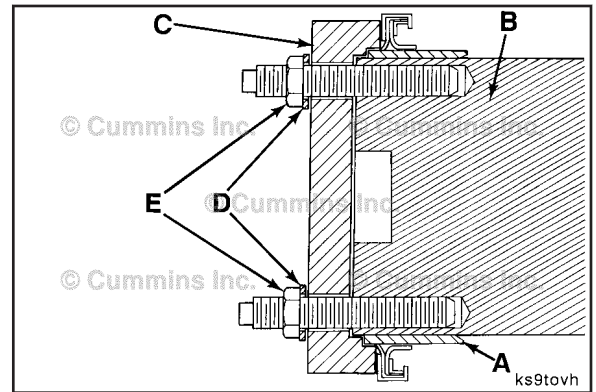
Install two (2) threaded studs into the crankshaft capscrew holes.



Apply a small amount of clean engine oil to the crankshaft, threaded studs, and inside of the crankshaft rear seal/wear sleeve installation tool.



Position the chamfered end of the wear sleeve (A) onto the end of the crankshaft (B). Position the counterbore end of the installation tool (C) over threaded studs and align with wear sleeve, perpendicular to the end of the crankshaft. Install the washers (D) and nuts (E) onto the threaded studs.



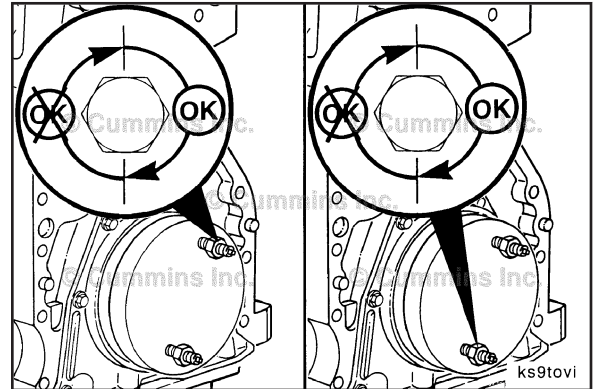
Alternately tighten the nuts until the installation tool contacts the end of the crankshaft.

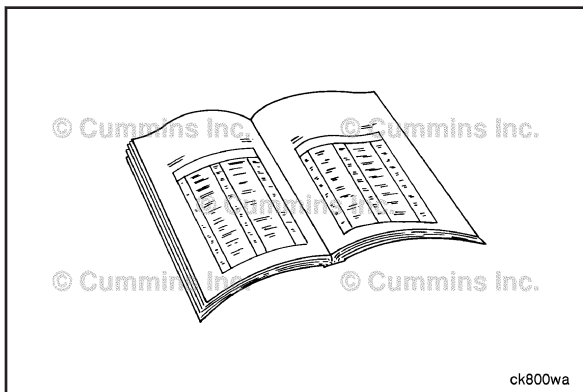
Do **not** exceed 1/2 revolution of each nut to prevent wear sleeve binding and irregular stretch.



Torque Value: 20 N•m [180 in-lb]

Remove the installation tool and threaded studs.





Align the rear cover even with both sides of the oil pan rail on the cylinder block.

The chart below shows the proper torque value when using either a 9.8 or a 10.9 grade bolt. The grade is embossed on the top of each bolt.

Apply Dri Lock to both part numbers below during installation. Dri Lock 205 is recommended. Use Dri Lock 204 or 211, when 205 is **not** available.

Tighten the rear cover capscrews.

Rear Seal Carrier				
Bolt Number	Bolt Size	Bolt Class	Torque	Dri-Lock
3913638	M-6	9.8	10 N•m [in-lb]	No
3991306	M-6	10.9	13 N•m [in-lb]	Yes

Trim the gaskets even with the oil pan mounting surface.

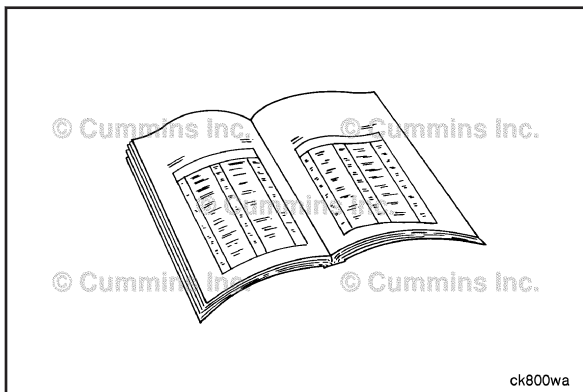
Make sure the gasket trim does **not** enter the engine.

Fill the joint between the lubricating oil pan rail and the rear cover with Three-Bond RTV sealant, Part Number 3823494.

Install the four rear oil pan mounting capscrews to the pan.

The lubricating oil pan capscrews **must** be tightened within 5 minutes after applying the sealant.

Torque Value: 24 N•m [212 in-lb]



Finishing Steps



▲ WARNING ▲

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



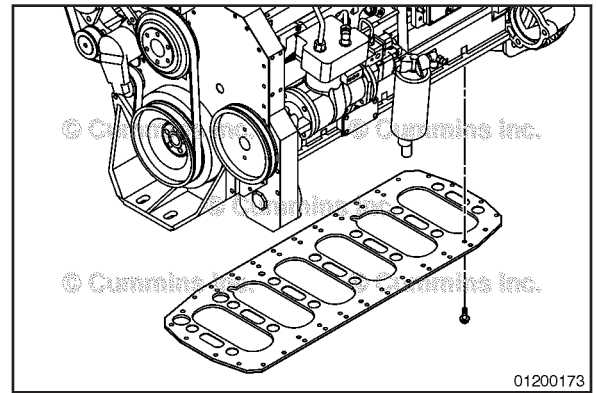
- Install the flywheel housing. Refer to Procedure 016-006 (Flywheel Housing) in Section 16.
- Install the flywheel. Refer to Procedure 016-005 (Flywheel) in Section 16.
- Connect the driven equipment. Refer to the OEM instructions.
- Operate the engine until the coolant temperature reaches 82°C [180°F]. Check for leaks and proper operation.



Block Stiffener Plate (001-089)

General Information

The block stiffener plate is **not** used on all engines.



Preparatory Steps

⚠ WARNING ⚠

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

⚠ WARNING ⚠

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

Drain engine oil. Refer to Procedure 007-037 in Section 7.

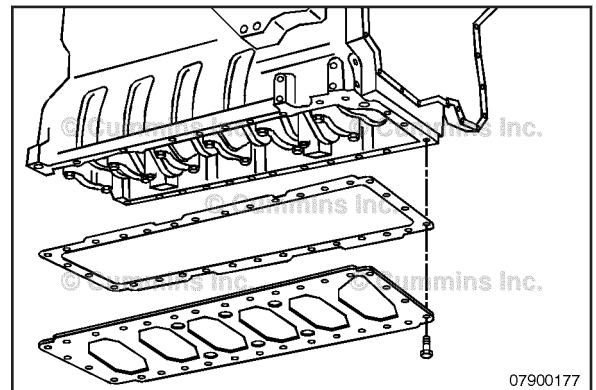
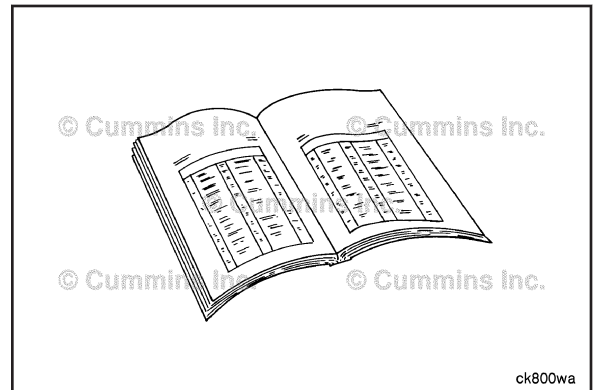
Remove the oil pan. Refer to Procedure 007-025 in Section 7.

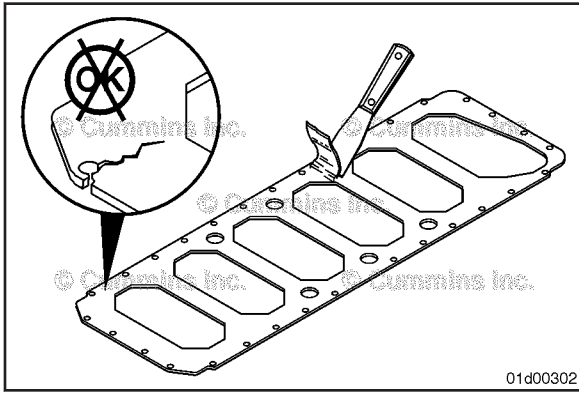
Remove the oil suction tube. Refer to Procedure 007-035 in Section 7.

Remove

Remove the block stiffener plate.

NOTE: The plate will be loose after the oil pan capscrews are removed.



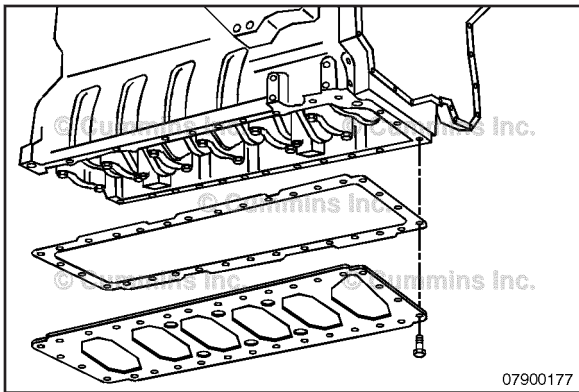


Clean and Inspect for Reuse

Remove all gasket material from both gasket surfaces.



Inspect the block stiffener plate for cracks or other damage.

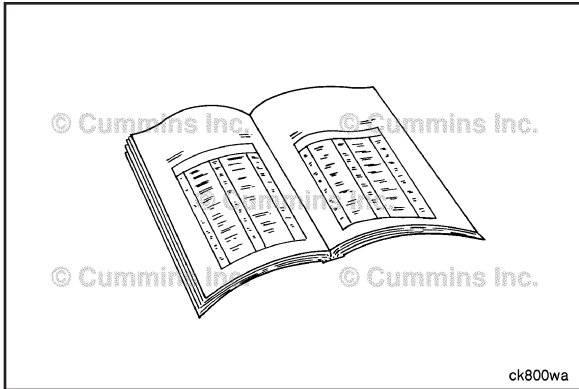


Install

Install the block stiffener plate. Use a new gasket and/or RTV sealant as required.

NOTE: The engines use a variety of combinations of gaskets and/or RTV sealant. Use the same combination of gaskets and/or RTV sealant as previously removed.

NOTE: The block stiffener plate **must** be held in place while the oil suction tube is installed. Use a few oil pan capscrews or wire ties to accomplish this



Finishing Steps

Install the oil suction tube. Refer to Procedure 007-035 in Section 7.



Install the oil pan. Refer to Procedure 007-025 in Section 7.



Fill the engine with oil. Refer to Procedure 007-037 in Section 7.

Operate the engine and check for leaks.

Section 2 - Cylinder Head - Group 02

Section Contents


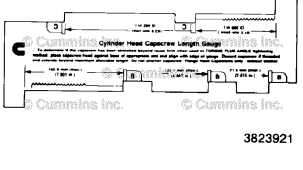
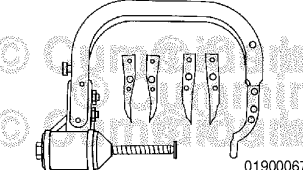
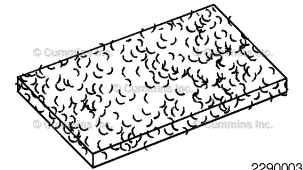
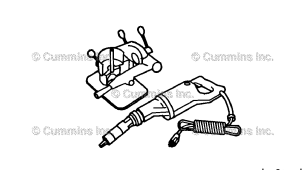
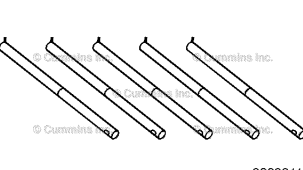
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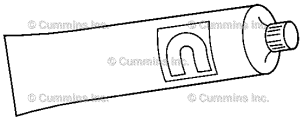
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Service Tools

Cylinder Head

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

Tool No.	Tool Description	Tool Illustration
3822509	<p>Injector Bore Brush Used to clean carbon from injector bores.</p>	 <p style="text-align: right;">3822509</p>
3823921	<p>Capscrew Length Gauge Used to measure capscrew free length.</p>	 <p style="text-align: right;">3823921</p>
3375962	<p>Valve Spring Compressor Used to remove and install valve collets.</p>	 <p style="text-align: right;">01900067</p>
3823258	<p>Scotch-Brite™ 7448 Used for cleaning carbon from the upper liner bores, removing rust and corrosion from parts, removing burrs from aluminum and other soft metals, and for scuffing surfaces prior to painting.</p>	 <p style="text-align: right;">22900039</p>
ST-685	<p>Valve Seat Grinding Machine Used to reface the valve seats in the cylinder head.</p>	 <p style="text-align: right;">kn8togi</p>
3375946	<p>Valve Guide Arbor Set Special tapered arbors used with the valve seat grinding machine, Part No. ST-685, to reface the valve seat in the cylinder head.</p>	 <p style="text-align: right;">02900114</p>

Tool No.	Tool Description	Tool Illustration
3375805	Fine Lapping Compound An abrasive compound used to lap the valves.	 <p>© Cummins Inc. © Cummins Inc. © Cummins Inc. © Cummins Inc.</p> <p>3377132</p>

Cylinder Head (002-004)

Preparatory Steps

⚠️ WARNING ⚠️

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

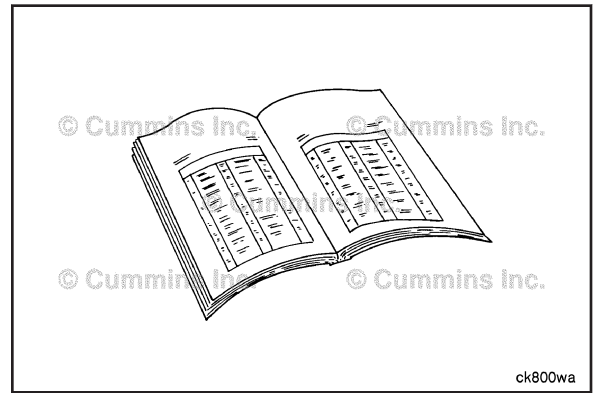
⚠️ WARNING ⚠️

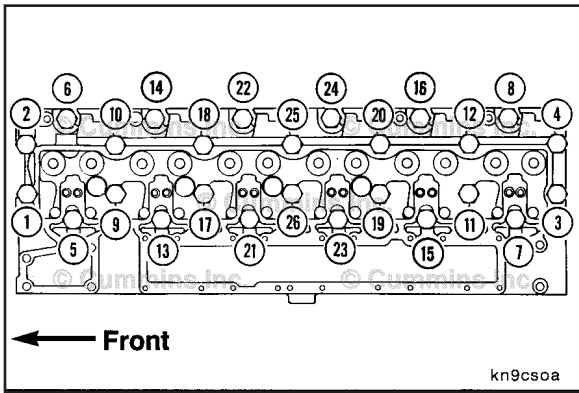
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Disconnect the batteries. Refer to the original equipment manufacturer (OEM) service manual.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove all of the coolant and heater hoses. Refer to the OEM service manual.
- Remove the turbocharger. Refer to Procedure 010-033 in Section 10.
- Remove the exhaust manifold. Refer to Procedure 011-007 in Section 11.
- Remove the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Remove the injectors. Refer to Procedure 006-026 in Section 6.
- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Remove the rocker lever assemblies. Refer to Procedure 003-008 in Section 3.
- Remove the push rods. Refer to Procedure 004-014 in Section 4.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.
- Remove the fan pulley and fan hub. Refer to Procedure 008-036 in Section 8.

NOTE: In some applications, it can be easier to remove the thermostat housing to gain access to the exhaust manifold capscrews on cylinder number 1.

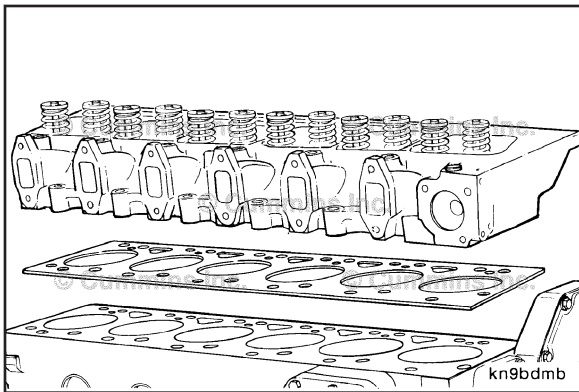
- Remove the thermostat housing. Refer to Procedure 008-014 in Section 8.
- Disconnect the coolant vent lines. Refer to Procedure 008-017 in Section 8.
- Remove the intake manifold cover and intake heater, if equipped. Refer to Procedure 010-023 in Section 10.





Remove

Remove the cylinder head capscrews in the sequence shown.



⚠ 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.

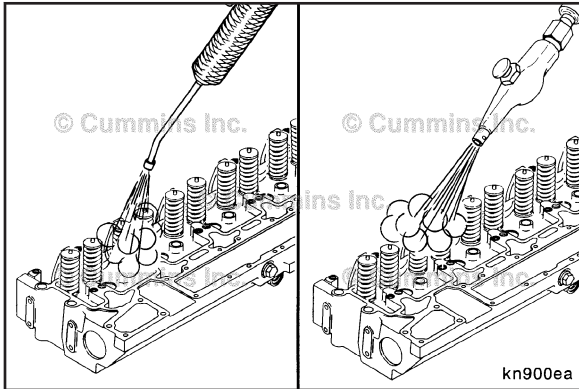


⚠ CAUTION ⚠

Do not lay the cylinder head on the combustion deck. This can damage the combustion deck.

Use a hoist or hydraulic arm to remove the cylinder head. Make sure the head is removed in a direct upward motion.

Remove the cylinder head gasket from the cylinder block.



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.

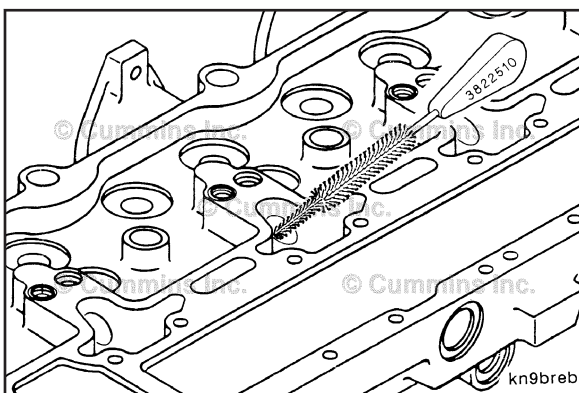
⚠ WARNING ⚠

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

Steam-clean the cylinder head.

NOTE: Make sure to blow out all the capscrew holes.

Dry the cylinder head with compressed air.

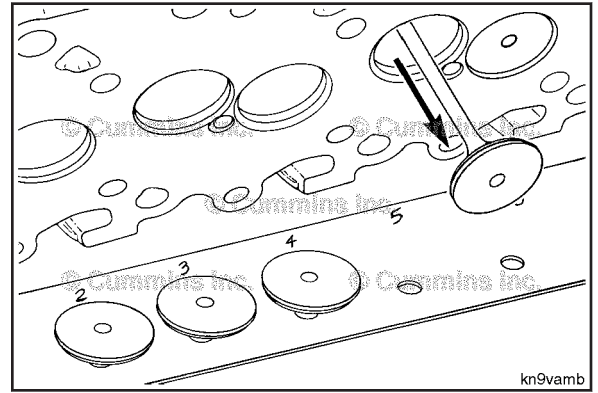


⚠ WARNING ⚠

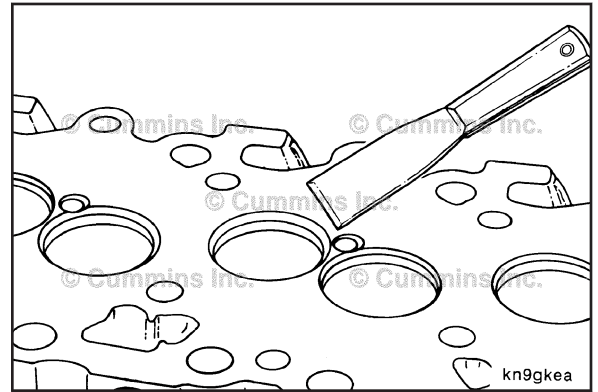
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

Clean the injector bores with a Cummins® injector bore brush, Part Number 3822510, and solvent.

Remove the valves from the cylinder head. Refer to Procedure 002-020.



Scrape the gasket material from all gasket surfaces on the block and head.



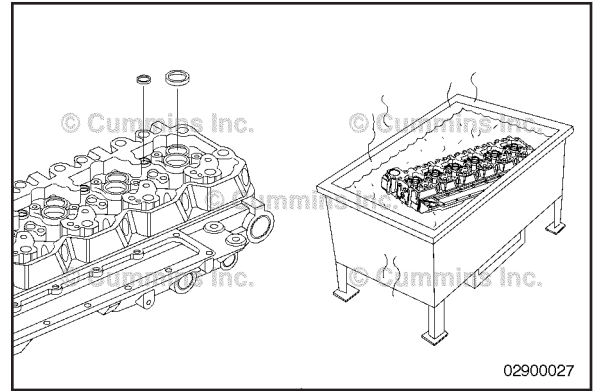
Clean the buildup of deposits from the coolant passages.

Inspect the area within 1/8-inch of the combustion seal ring diameter. Any wear that can be felt with a fingernail within the 1/8-inch area is unacceptable, making the cylinder head **not** reusable. Wear beyond this 1/8-inch area will have no effect on future combustion sealing and the usability of the cylinder head.

Clean carbon deposits from the valve pockets with a high quality steel wire wheel installed in a drill or a die grinder.

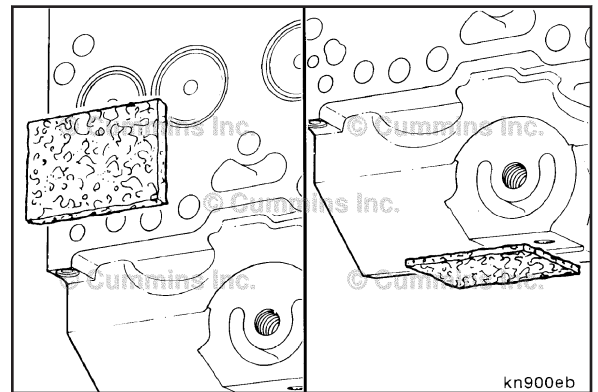
NOTE: An inferior quality wire wheel will lose steel bristles during operation, causing additional contamination.

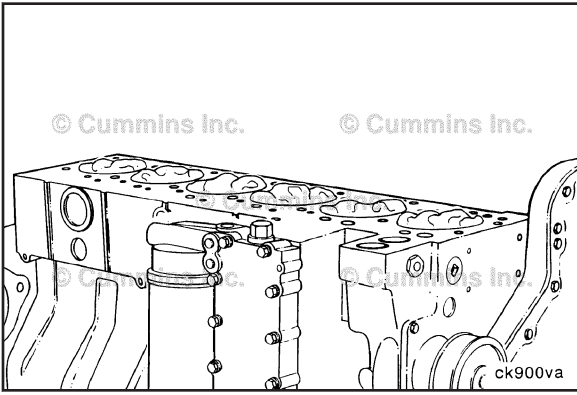
NOTE: Excessive deposits can be cleaned in an acid tank. The expansion plugs **must** be removed before putting the cylinder head into an acid tank.



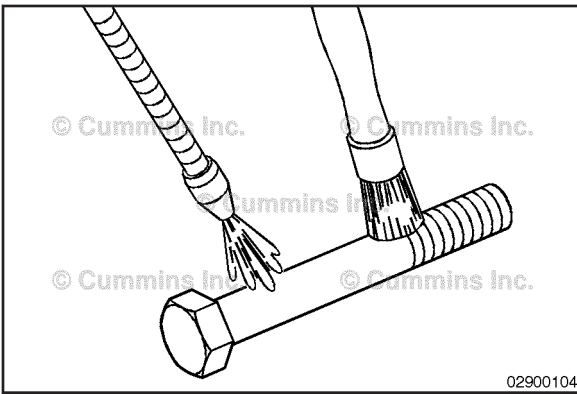
⚠ WARNING ⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

Clean the cylinder head combustion deck, exhaust manifold gasket surface, and valve cover gasket surface with Scotch-Brite™ 7448, Part Number 3823258, and diesel fuel or solvent.





Clean the cylinder block head deck surface. Refer to Procedure 001-026 in Section 1.

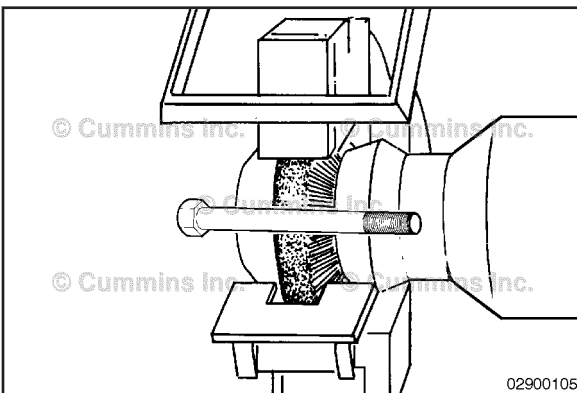


⚠ WARNING ⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

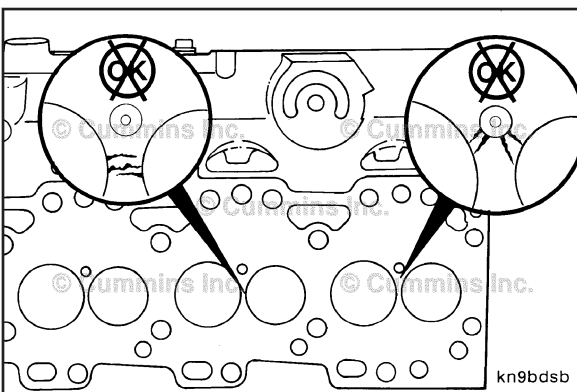
Cylinder Head Capscrews

⚠ CAUTION ⚠
Do not use caustic or acid solutions to clean the cylinder head capscrews. Use of these solutions can cause corrosion and damage to the cylinder head capscrews.

Use a petroleum-based solvent to clean the cylinder head capscrews.



Clean the capscrews thoroughly with a wire brush, a soft wire wheel, or use a non-abrasive bead blast to remove deposits from the shank and threads of the cylinder head capscrews.



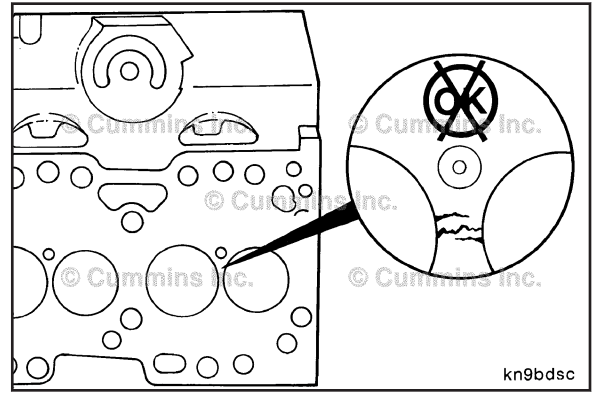
Cylinder Head
Inspect the cylinder head and valve seats for obvious damage that would prohibit reuse.



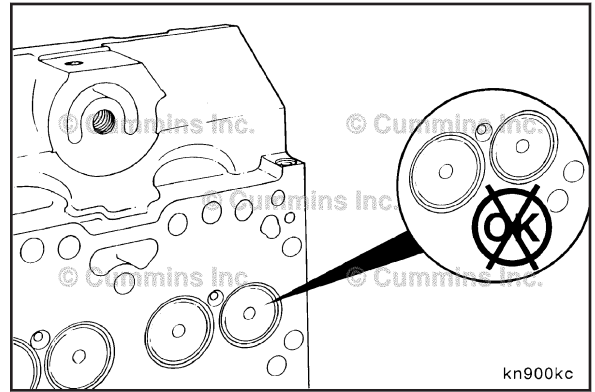
Inspect for cracks and damage to the deck surface that would result in loss of sealing.

NOTE: If a crack in the cylinder head is suspected, pressure-test the cylinder head.

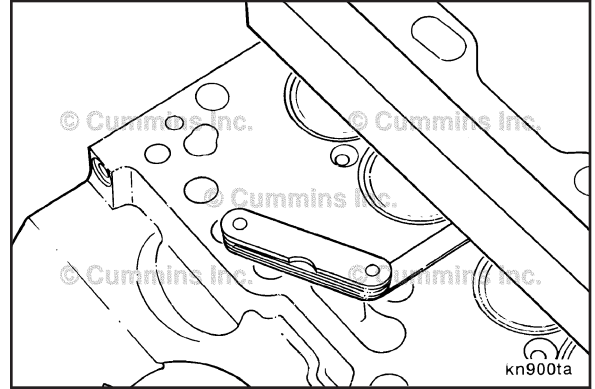
Cracks between the valve seats are **not** acceptable and the cylinder head **must** be replaced.



Inspect the valves for indications of leakage or burning.



Use a straightedge and feeler gauge to check the cylinder head combustion surface for flatness.

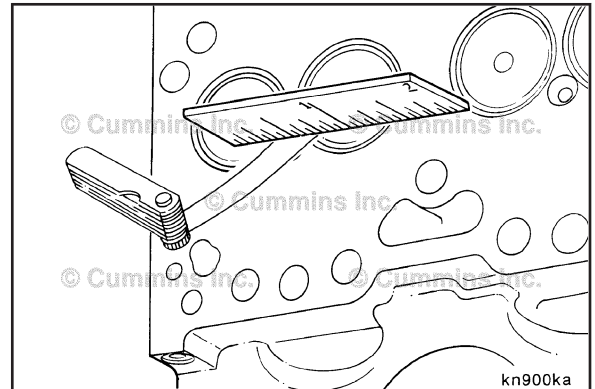


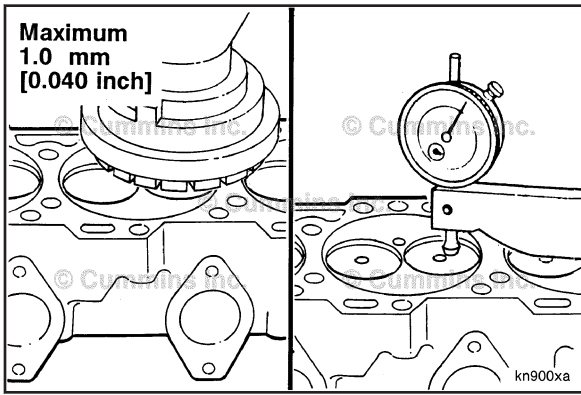
Cylinder Head Flatness Specifications

	mm		in
End-to-End	0.20	MAX	0.008
Side-to-Side	0.076	MAX	0.003



Use a small 51 mm [2 in] straightedge and a 0.0254-mm [0.001-in] feeler gauge to measure local flatness. Check between the cylinder bores and between the coolant passages. If the 0.001-inch feeler gauge fits under the 2-inch straightedge, the cylinder head **must** be replaced or resurfaced.





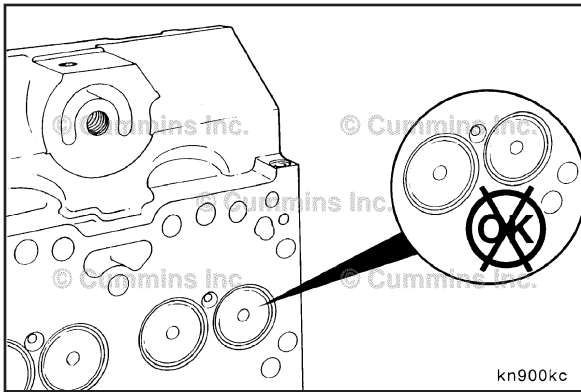
NOTE: A maximum of 1 mm [0.040 in] can be machined from the combustion surface of the cylinder head.



If the cylinder head is machined, place the valve in the respective bore and check the valve depth dimension. If the depth is less than the minimum specification, the valve seat will require machining. Refer to the Shop Manual, C Series Engines, Bulletin 3666008.

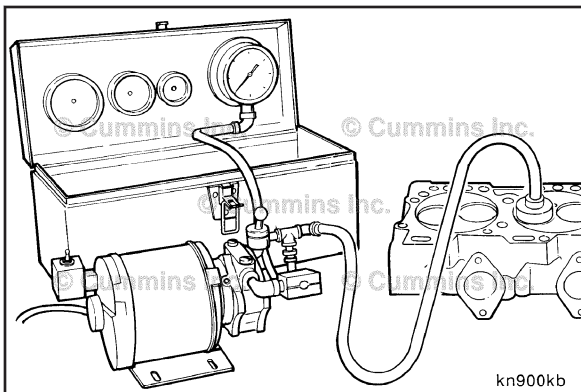
Valve Recess in Cylinder Head

	mm		in	
Exhaust	1.09	MIN	0.0430	
	1.62	MAX	0.064	
Intake	0.59	MIN	0.023	
	1.12	MAX	0.044	



Valve and Seat Leakage Test

Inspect the valves for indications of leakage or burning.

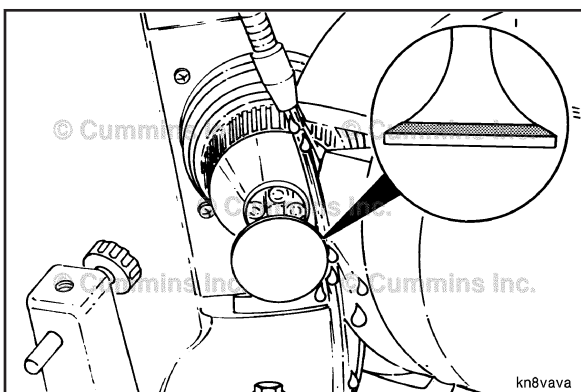


NOTE: If a leaking valve is suspected, vacuum test the valves and valve seats. The vacuum **must not** drop more than 25.4 mm Hg [1.0 in Hg] in 5 seconds.



Valve to Valve Seat Vacuum

	mm Hg		in Hg	
Used	457	MIN	18	
New	635	MIN	25	

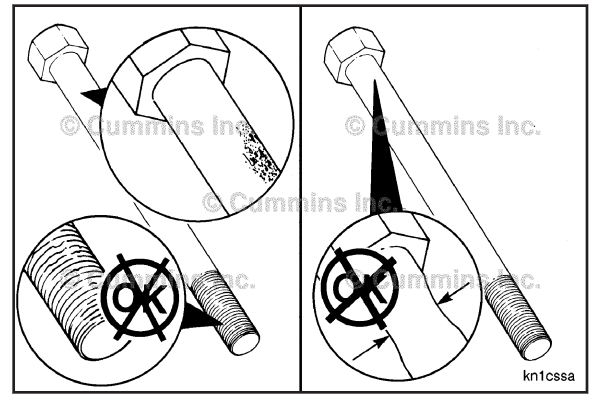


NOTE: If vacuum does **not** meet the specifications, the face of the valves and the valve seat inserts **must** be resurfaced. Refer to the Shop Manual, C Series Engines - Applicable to Engines Built in 1991 and After, Bulletin 3666008.

Cylinder Head Capscrews

Inspect the cylinder head capscrews for damaged threads, corroded surfaces, or a reduced diameter.

NOTE: A reduced diameter is caused by capscrew stretching.



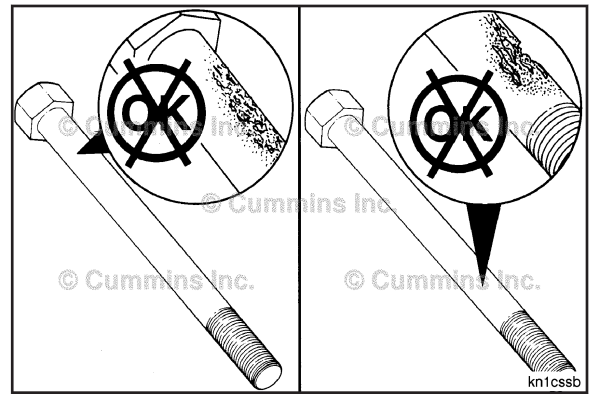
Do **not** reuse cylinder head capscrews under the following conditions:

- Visible corrosion or pitting exceeds 1 cm² [0.155 in²] in area.

Example:

- Acceptable - 9.53 mm [3/8 in] x 9.53 mm [3/8 in]
- Unacceptable - 12.7 mm [1/2 in] x 12.7 mm [1/2 in]
- Visible corrosion or pitting exceeds 0.12 mm [0.005 in] in depth.

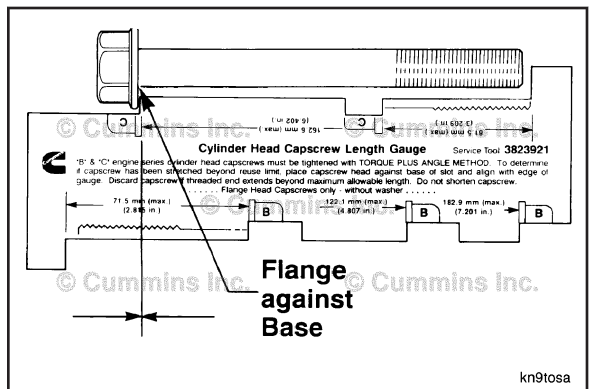
NOTE: Do **not** reuse a capscrew that has damaged threads or a reduced diameter.



- Visible corrosion or pitting that is located within 3.2 mm [0.126 in] of the fillet.
- Visible corrosion or pitting that is located within 3.2 mm [0.126 in] of the threads.
- Stretched beyond the “free-length” specifications.

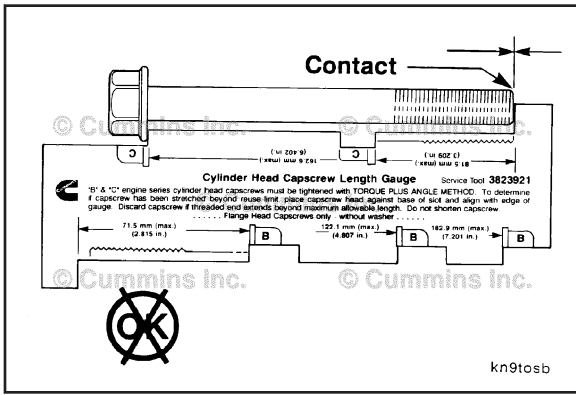
NOTE: If the capscrews are **not** damaged, they can be reused throughout the life of the engine, unless the capscrew stretches beyond the “free-length” specification.

Use capscrew length gauge, Part Number 3823921, to measure the cylinder head capscrew.

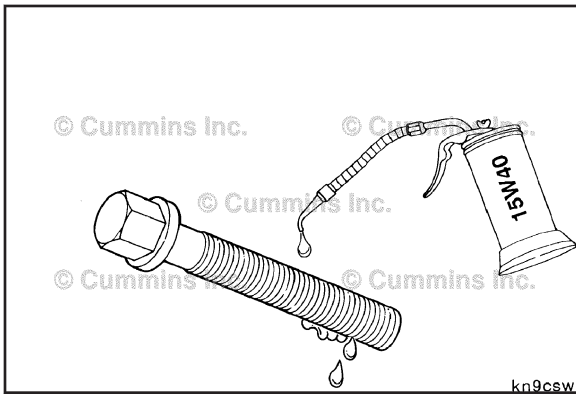


Cylinder Head Capscrew Free Length

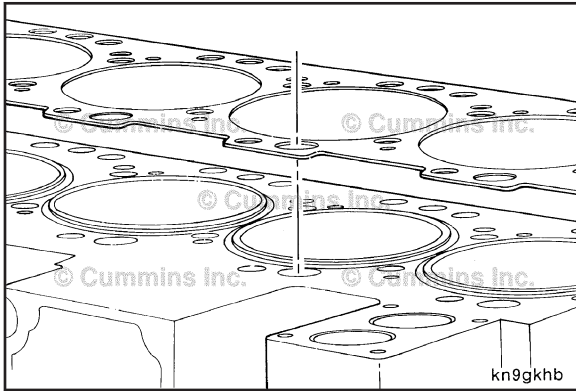
	mm		in
Short Capscrews	81.5	MAX	3.2
Long Capscrews	162.6	MAX	6.4



Place the flange of the capscrew against the base of the slot on the capscrew length gauge. If the end of the capscrew touches the foot of the gauge, it is too long and the capscrew **must** be discarded.



Immediately after cleaning and inspecting the capscrews, apply a light film of clean engine oil to all of the capscrews that are to be reused.

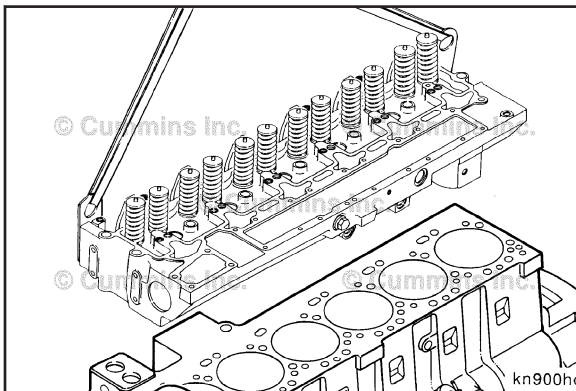


Install



CAUTION
Make sure the cylinder head gasket is correctly aligned with holes in the cylinder block. If not aligned properly, it can cause engine damage.

Position the new cylinder head gasket over the dowels.



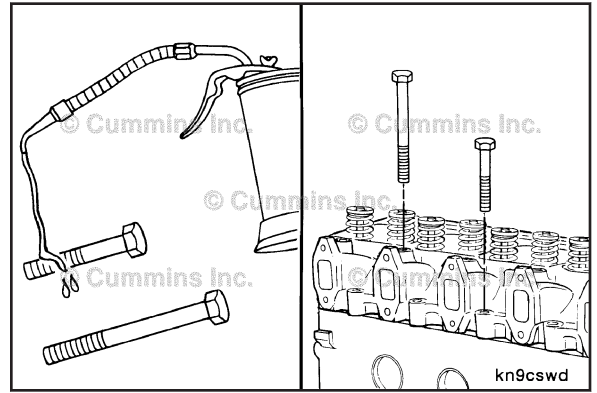
WARNING
This component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this component.



Carefully put the cylinder head straight down onto the cylinder block, and seat it onto the dowels.

Lubricate the threads and under the heads of the remaining cylinder head capscrews with engine oil.

Install the capscrews hand-tight.



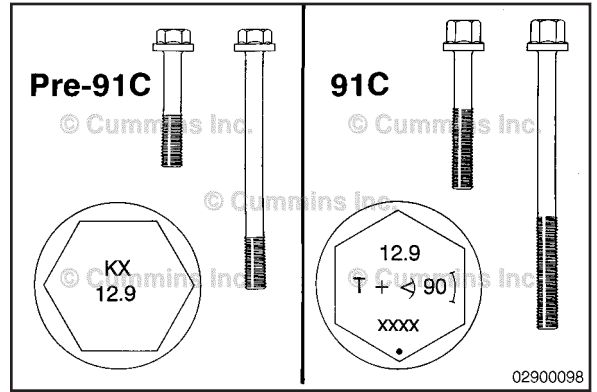
⚠CAUTION⚠

Do not use pre-1991 certification capscrews in a 1991 or later certification level engine because of differences in cap screw length and thread engagement. Damage to the engine will result if the wrong capscrews are used.

Post 1991 - New Cylinder Block or New Capscrews

Always use the following procedure when you are using new capscrews or a new cylinder block.

NOTE: Each 1991 and later certification cap screw has been marked with symbols and an angle specification. The cap screw part numbers can be identified by inspecting the marks on the cap screw head.

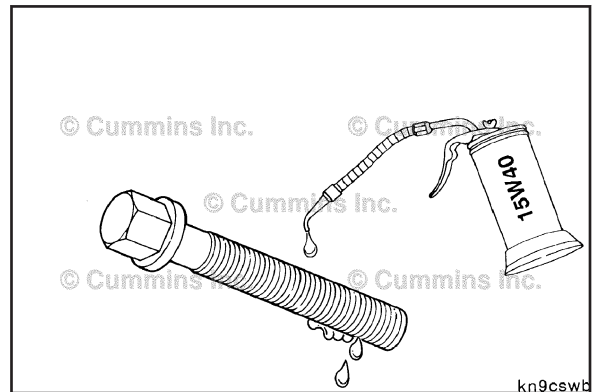


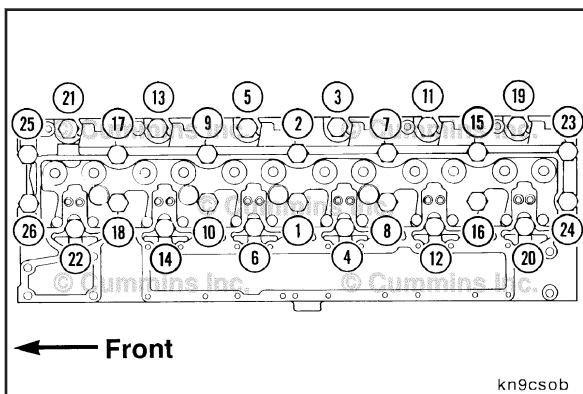
Cylinder Head Cap screw Part Numbers			
Pre-91 Cap screw Part Number	Length	1991 Cap screw Part Number	Length
3907234	Short	3917729	Short
3907233	Long	3917728	Long

⚠CAUTION⚠

This procedure is to be used only with the use of a new cylinder block or new cylinder head cap screws.

- 1 Apply a thin film of clean engine lubricating oil to the cap screw threads and underside of the cap screw head flange.





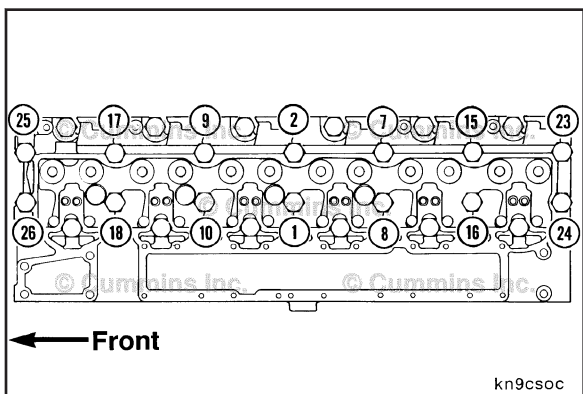
1 Follow the numbered torque sequence; tighten all cap screws.



2 Follow the numbered torque sequence; check the torque on all cap screws a second time.



Torque Value: 95 N•m [70 ft-lb]



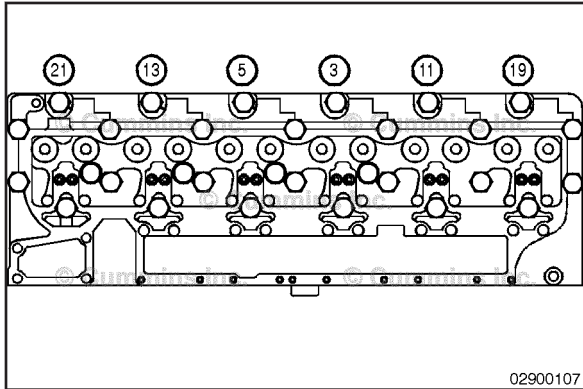
1 Follow the numbered sequence; tighten the 14 long cap screws (two center rows) **only**.



2 Follow the numbered sequence; check the torque on all 14 long cap screws a second time.



Torque Value: 145 N•m [107 ft-lb]



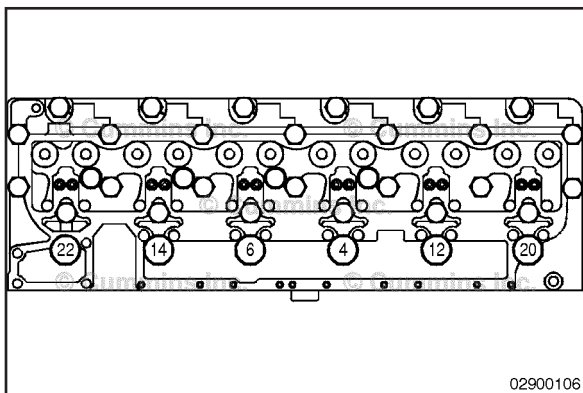
1 Follow the numbered sequence; tighten the six short cap screws (exhaust side) **only**.



2 Follow the numbered sequence; check the torque on all six short cap screws a second time.



Torque Value: 105 N•m [77 ft-lb]



1 Follow the numbered sequence; tighten the six short cap screws (intake side) **only**.

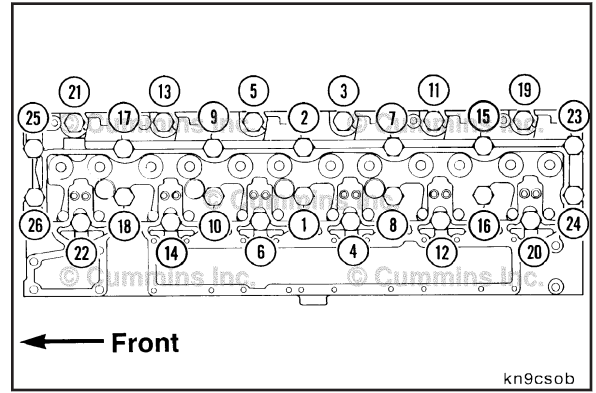


2 Follow the numbered sequence; check the torque on all six short cap screws a second time.

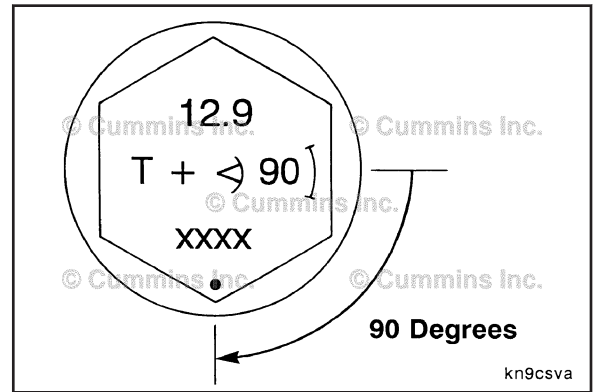


Torque Value: 95 N•m [70 ft-lb]

- 1 Recheck the torque on all capscrews.
 - Follow the numbered sequence; check the 14 long capscrews from step 4.
 - Follow the numbered sequence; check the 6 short capscrews (exhaust side) from step 6.
 - Follow the numbered sequence; check the 6 short capscrews (intake side) from step 8.

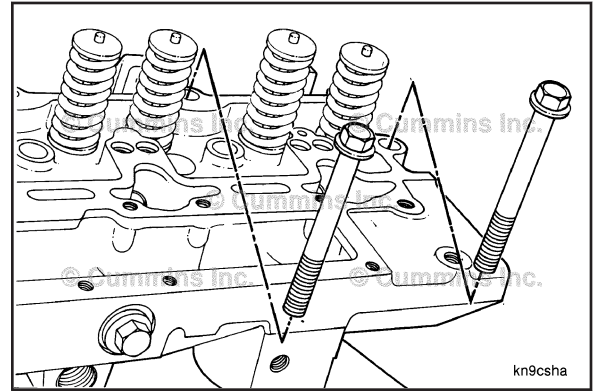


- 1 Follow the numbered sequence; from step 2, turn the capscrews 90 degrees as indicated on the capscrew head.

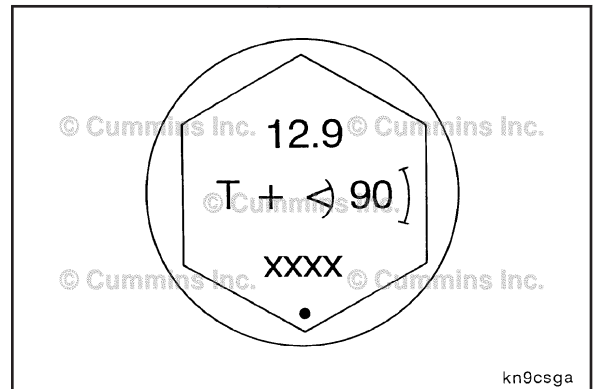


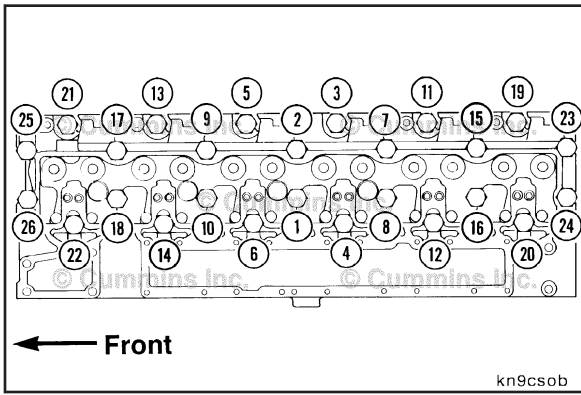
Post 1991 - Used Cylinder Block and Used Capscrews

NOTE: If using a new cylinder block or new capscrews, do **not** use this procedure. Reference the new cylinder block or new capscrews in this section.



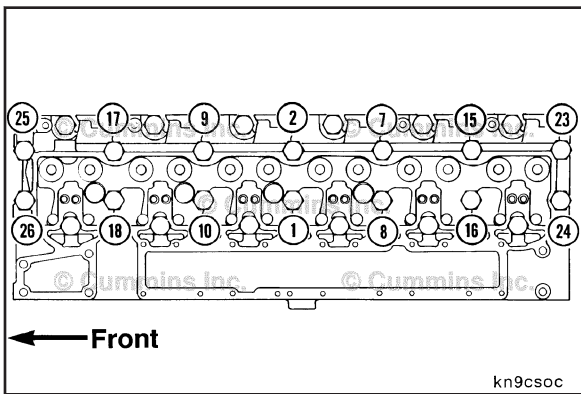
The top of the cylinder head capscrew is identified with an angle marking. The cylinder head capscrews **must** be tightened by the five-step "torque plus angle" method, as described here.





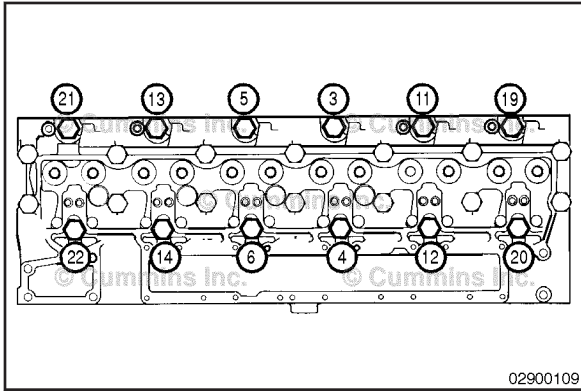
1. Follow the numbered sequence and tighten all 26 cap screws.

Torque Value: 70 N•m [52 ft-lb]



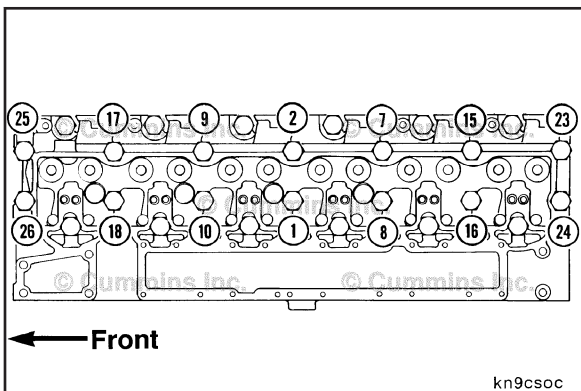
2. Follow the numbered sequence and tighten **only** the 14 long cap screws. (Number 1, 2, 7, 8, 9, 10, 15, 16, 17, 18, 23, 24, 25, and 26.)

Torque Value: 145 N•m [107 ft-lb]



3. Retighten the short cap screws: Number 3, 4, 5, 6, 11, 12, 13, 14, 19, 20, 21, and 22 because of cylinder head relaxation and to obtain proper cylinder head torque requirements.

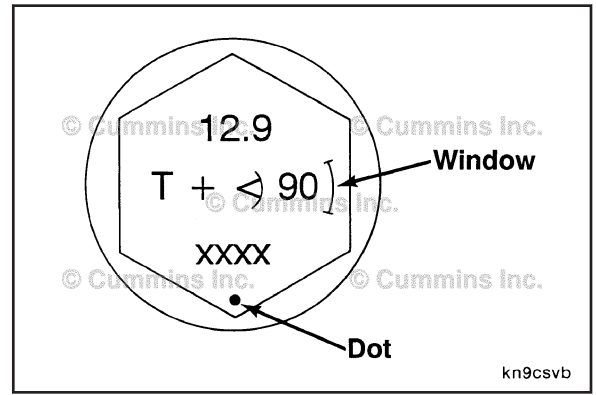
Torque Value: 70 N•m [52 ft-lb]



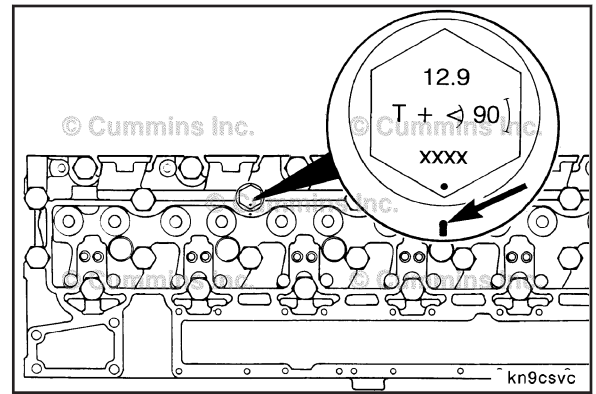
4. Follow the numbered sequence and retighten **only** the 14 long cap screws. (Number 1, 2, 7, 8, 9, 10, 15, 16, 17, 18, 23, 24, 25, and 26.)

Torque Value: 145 N•m [107 ft-lb]

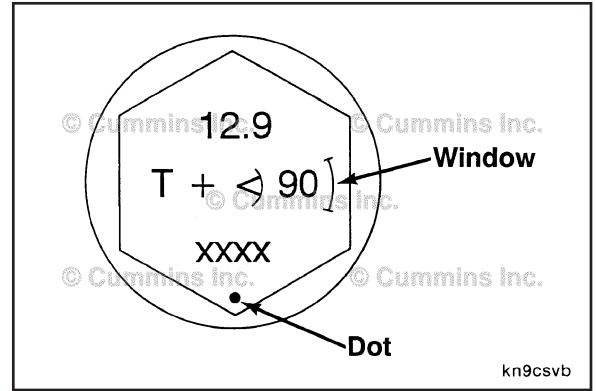
NOTE: To turn the capscrew accurately to the desired angle, orientate according to the small “dot” and “window” marked on the capscrew head, or use the torque angle gauge for ½-inch drive, Part Number 3823878, or torque angle gauge for ¾-inch drive, Part Number 3823879.



Mark the cylinder head adjacent to the dot on the capscrew head. This mark will serve as an indexing aid.



5. Rotate the capscrew until the mark that has been made on the cylinder head falls into the window on the capscrew head.



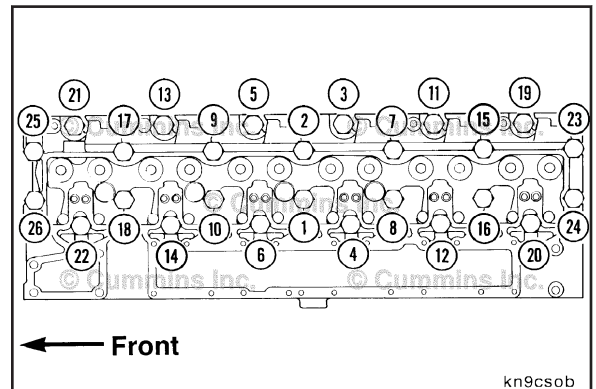
Pre - 1991 Certifications

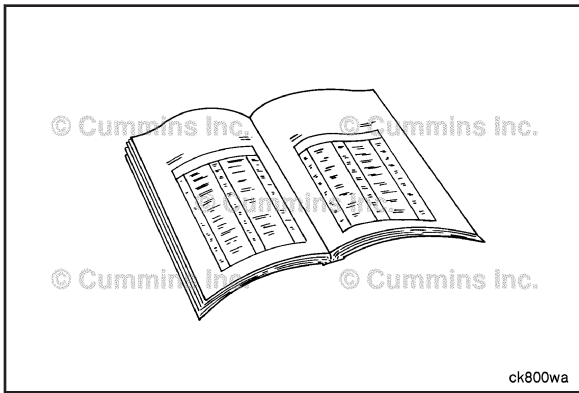
1 Follow the numbered sequence and tighten all capscrews:



Torque Value:

Step 1	40 N•m	[30 ft-lb]
Step 2	150 N•m	[111 ft-lb]
Step 3	220 N•m	[162 ft-lb]





Finishing Steps

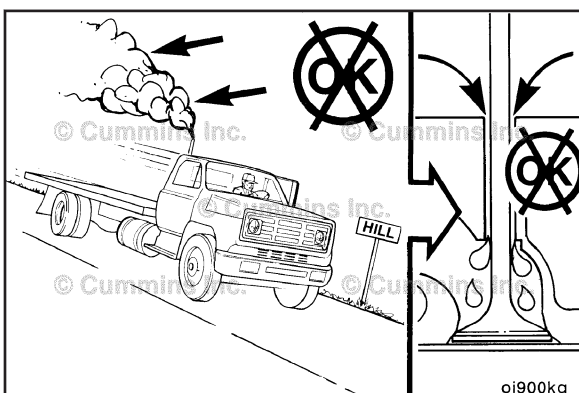


⚠️ WARNING ⚠️

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 thermostat housing. Refer to Procedure 008-014 in Section 8.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Install the exhaust manifold. Refer to Procedure 011-007 in Section 11.
- Install the rocker lever assemblies. Refer to Procedure 003-008 in Section 3.
- Install the push rods. Refer to Procedure 004-014 in Section 4.
- Adjust the valve lash. Refer to Procedure 003-004 in Section 3.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the turbocharger. Refer to Procedure 010-033 in Section 10.
- Install the injectors. Refer to Procedure 006-026 in Section 6.
- Install the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Connect the coolant vent lines. Refer to Procedure 008-017 in Section 8.
- Install the fan pulley and fan hub. Refer to Procedure 008-036 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 at idle 5 to 10 minutes to check for leaks and proper operation.

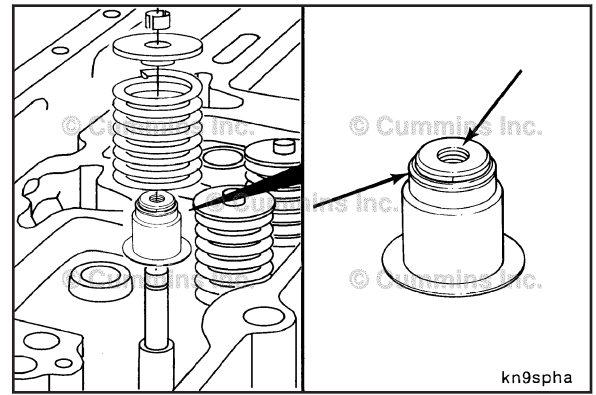


Valve Guide Seal, Cylinder Head (002-016)

Initial Check

Worn valve stem seals are typically detected by excessive smoke at idle, or when the engine is unloaded and the vehicle is going downhill.

Hardening of the material and wear or damage to the sealing surfaces will cause the valve seals to leak.



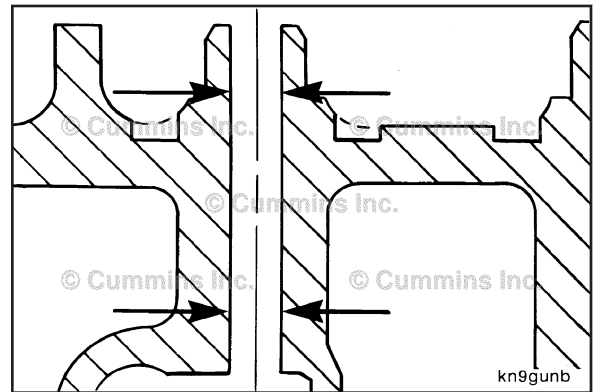
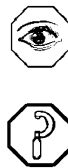
Valve Guide, Cylinder Head (002-017) Inspect for Reuse

Measure the inside diameter of the valve guide bore in the cylinder head.

Valve Guide Bore without Pin, Inside Diameter

mm		in
15.931	MIN	0.6272
15.971	MAX	0.6288

If the valve guide bore is worn larger than the maximum specified, the cylinder head **must** be replaced.

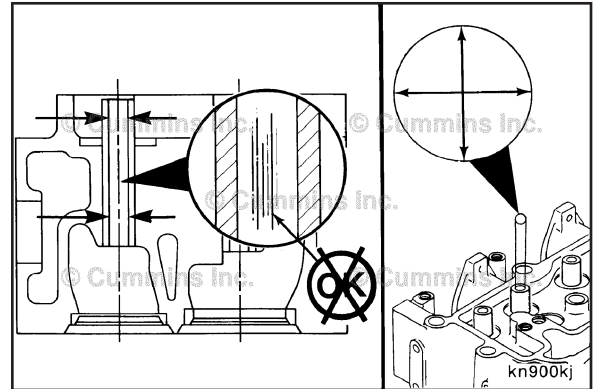
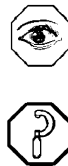


Inspect the valve guides for scuffing, scoring, chips, or cracks.

Measure the valve guide inside diameter.

Valve Guide Bore with Pin, Inside Diameter

mm		in
9.539	MIN	0.3755
9.559	MAX	0.3763

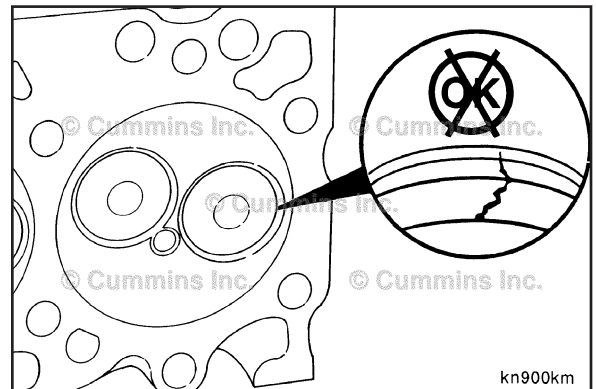


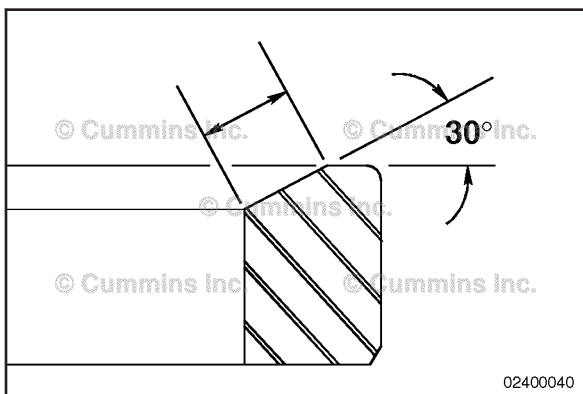
Valve Seat Insert, Cylinder Head (002-019) Inspect for Reuse

Inspect the valve seats for cracks and burn spots.

NOTE: Service valve seats are available for valve seats that can **not** be ground within specification.

NOTE: If a valve seat can **not** be cleaned up by grinding it, the valve seat **must** be replaced; refer to the Shop Manual, C Series Engines, Bulletin 3666008.

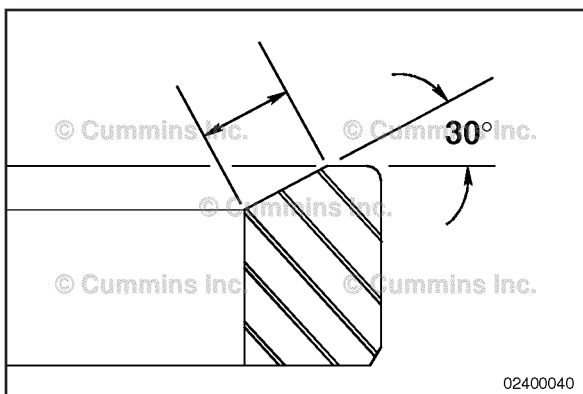




Grind

Use valve seat grinding machine, Part No. ST-685, and valve guide arbor set, Part No. 3375946, to grind the valve seat inserts.

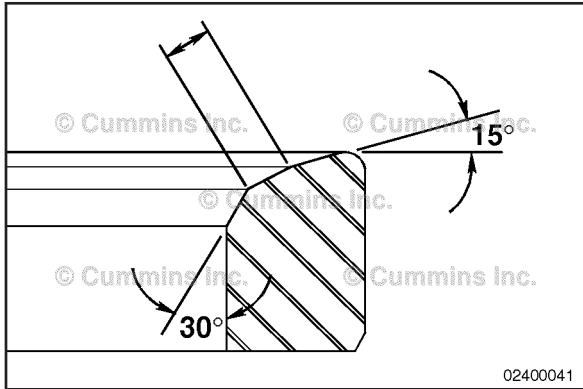
Grind the valve seats at a 30-degree angle.



Measure the valve seat width.

Valve Seat Width

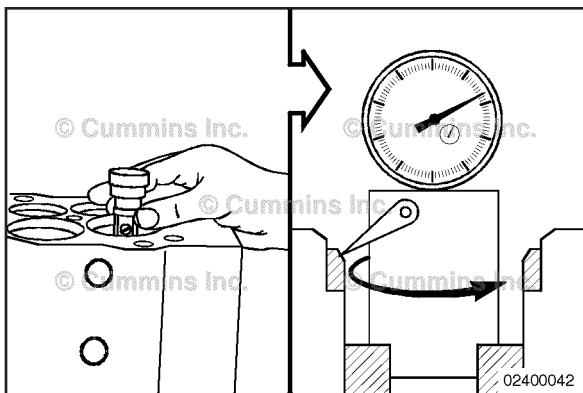
	mm		in
Intake	3.05	MIN	0.120
	3.55	MAX	0.140
Exhaust	1.52	MIN	0.060
	2.54	MAX	0.100



If the width of the valve seat is **not** within specifications, remove surface material on the inner diameter and the outer diameter to decrease the width of the seat.



NOTE: If the valve seat specifications are **not** obtained by grinding the valve seat, the insert **must** be replaced.



Measure the valve-seat-to-valve-guide concentricity.

Valve-Seat-to-Valve-Guide Concentricity



mm		in
0.05	MAX	0.002

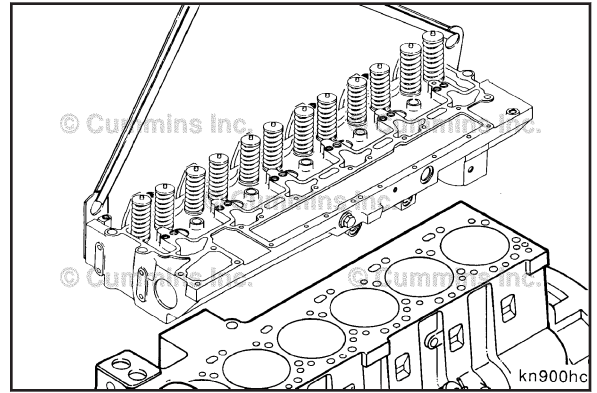
Valve, Cylinder Head (002-020)

Preparatory Steps

⚠ WARNING ⚠

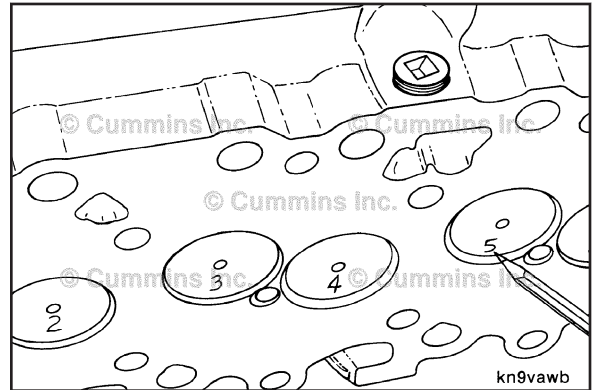
This component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

Remove the cylinder head; Refer to Procedure 002-004.



Remove

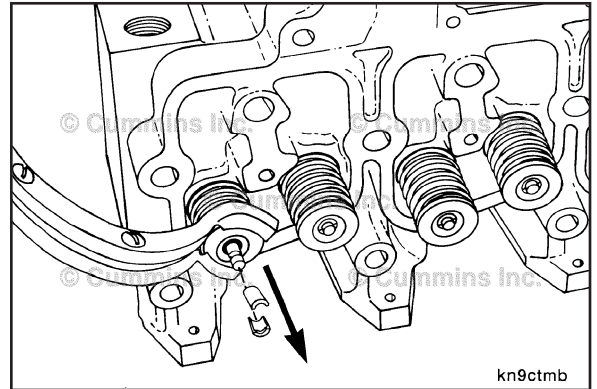
Mark the valves to identify their location.



NOTE: If the valve springs, collets, retainers, and valve guide seals are to be used again, they **must** be installed in their original location.

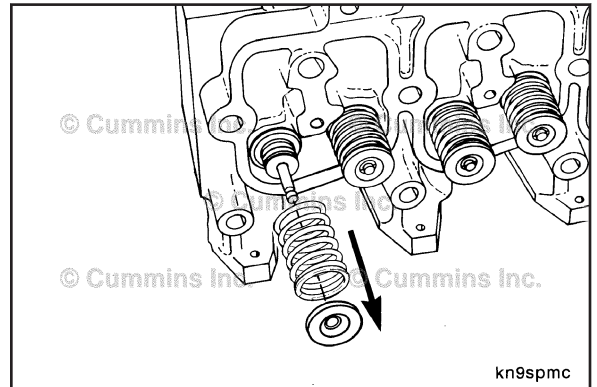
Compress the valve springs with valve spring compressor, Part Number 3375962.

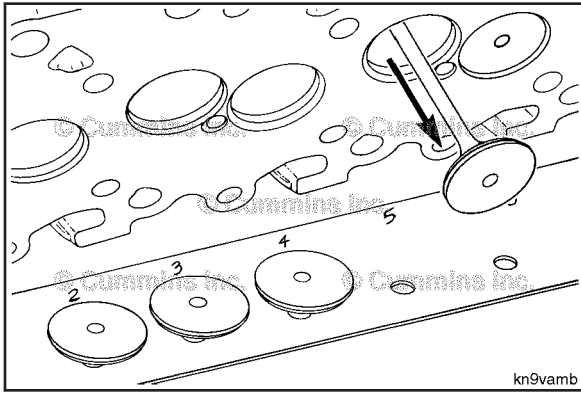
Remove the valve stem collets.



Release the valve spring and remove the valve spring retainer and valve spring.

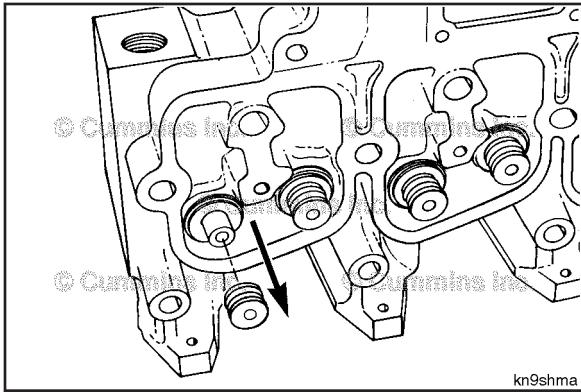
Remove the valve.



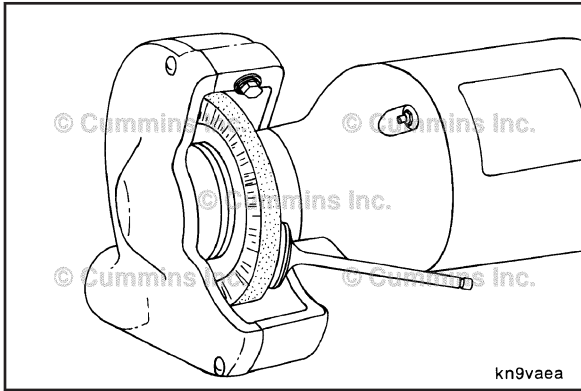


NOTE: Keep the valves in a labeled rack for a correct match with the companion seats while inspecting the cylinder head.

Remove the remaining collets, retainers, springs, and valves.



Remove the valve stem seals.



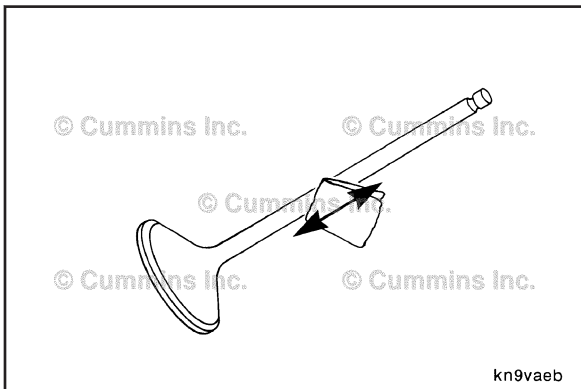
Clean

⚠ WARNING ⚠

Wear protective eye covering when cleaning the valves. Failing to do so can cause injury to eyes.

Clean the valve heads with a soft wire wheel.

NOTE: Keep the valves in a labeled rack to prevent mixing prior to making measurements.



Polish the valve stem with a Scotch-Brite™ 7448 abrasive pad, Part Number 3823258, and solvent.

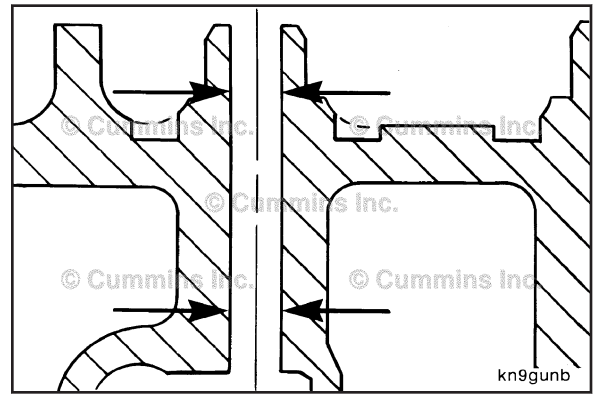
Inspect for Reuse

Inspect the valve guides for scuffing or scoring.
Measure the valve guide bore.

Valve Guide Bore Diameter

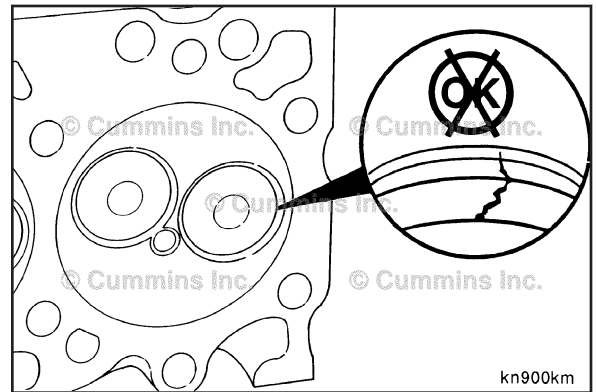
mm		in
15.988	MIN	0.6294
16.000	MAX	0.6299

If the inspection reveals damaged valve guides, refer to the Alternative Repair Manual, Bulletin 3810234.

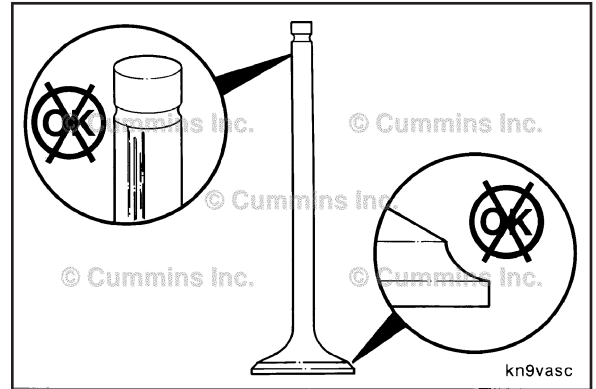


Inspect the valve seats for cracks or burned spots.

Refer to the following reuse guidelines for any cracks discovered. Service valve seats are available for seats with burned spots that will require more than 0.254 mm [0.010 in] grinding to clean up. Refer to the C Series Alternative Fuel Shop Manual, Bulletin 3810234, for valve seat installation procedures.



Inspect for abnormal wear on the head and stem of the valves.

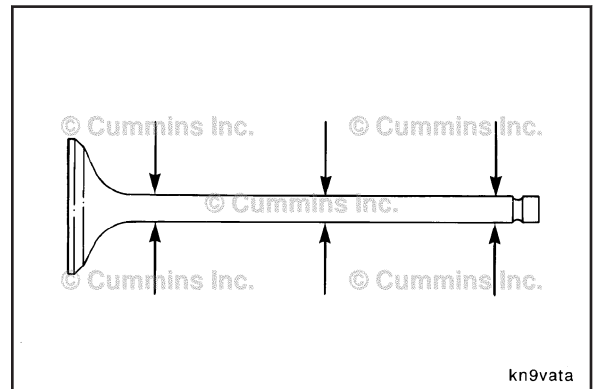


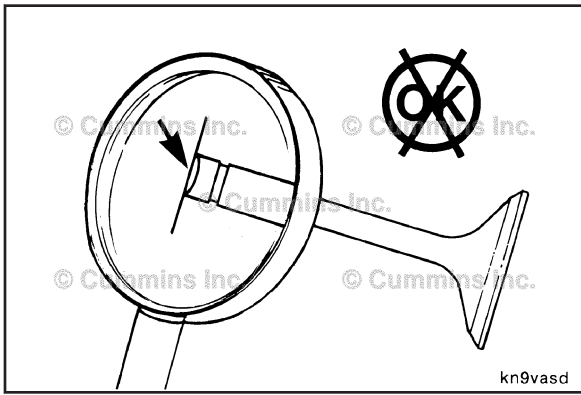
Measure the valve stem diameter.

Valve Stem Diameter

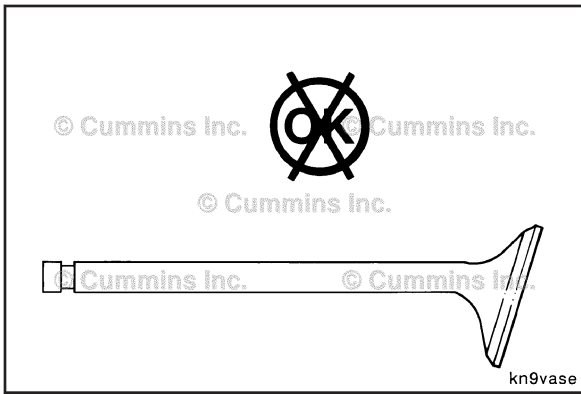
mm		ft-lb
9.48	MIN	0.373
9.50	MAX	0.374

NOTE: If the valve is **not** within specification, it **must** be replaced.

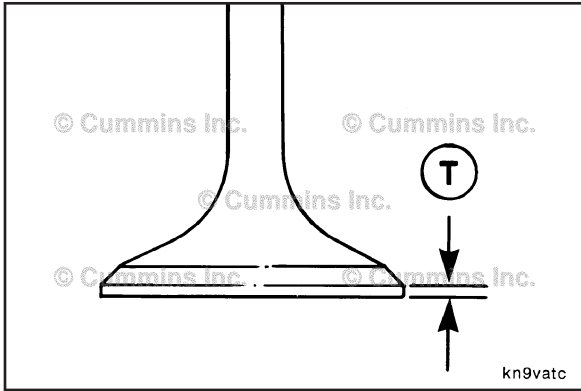




Check the valve stem tip for flatness.



Inspect for bent valves.



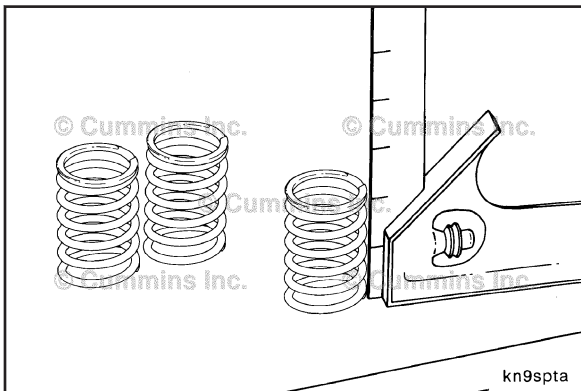
Measure the rim thickness to determine if there is enough stock to grind the valve.



Valve Rim Thickness Limit

mm		in
2.21	MIN	0.087

NOTE: If the valves are determined to be suitable for resurfacing, refer to the Shop Manual, C Series Engines, Bulletin 3666008.



Inspect the valve springs.
Measure the valve spring.

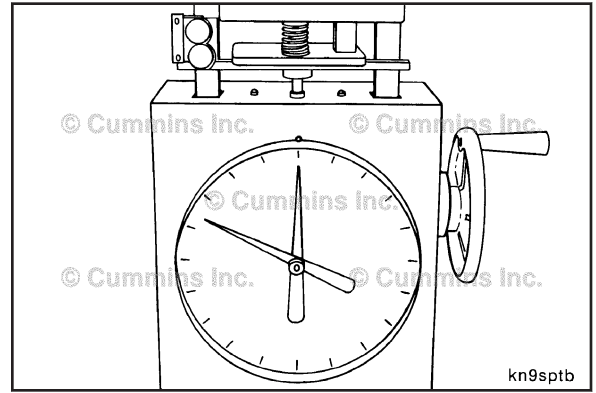
Approx. Free Length (L):
1996

65.66 mm [2.585 in]

Measure the valve spring load.

Valve Spring Load

	N•m		ft-lb
@ 49.25 mm [1.94 in]	359	MIN	80.7
	397	MAX	89.2

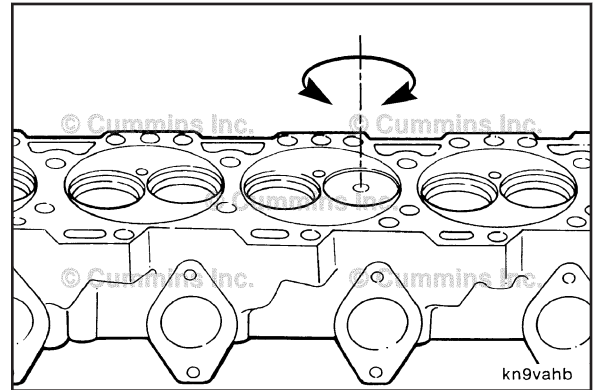


Lap

Apply a thin, even coating of fine lapping compound, Part No. 3375805, on the valve face.

NOTE: Use a power or hand suction lapping tool to provide pressure in the center of the valve.

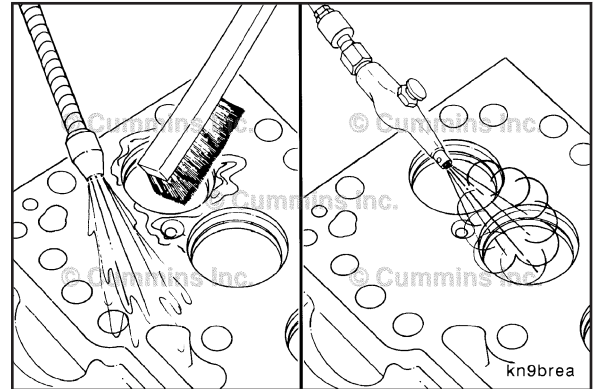
Turn the valve back and forth. Continue lapping the valve until the compound shows a continuous contact pattern on both the valve face and valve seat.



⚠CAUTION⚠

Lapping compound is an abrasive material. Failure will result if the cylinder head, valves, and valve seats are not cleaned thoroughly.

Clean the lapping compound from the cylinder head, valves, and valve seats.

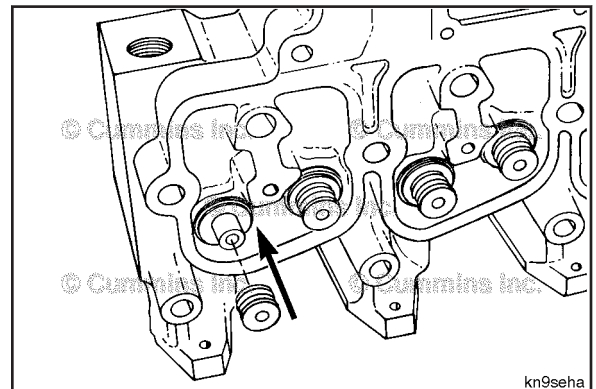


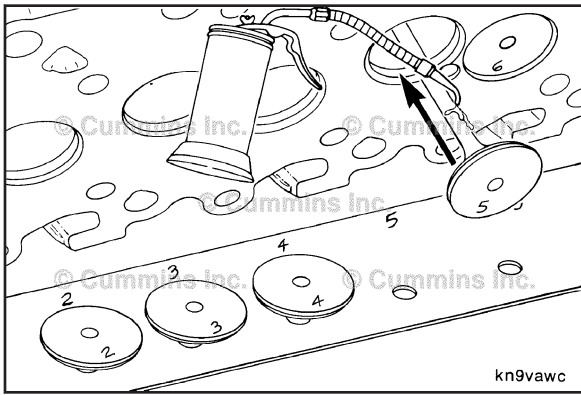
Install

NOTE: All cylinder head components **must** be clean before installing them.

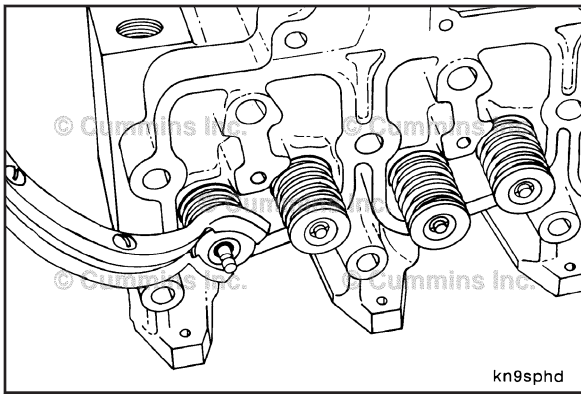
Install the valve stem seals.

NOTE: The intake and exhaust valve stem seals are the same.

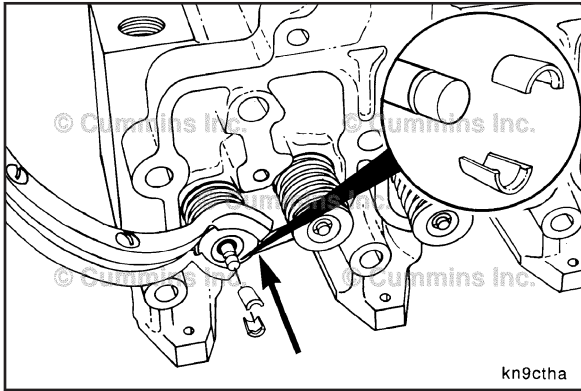




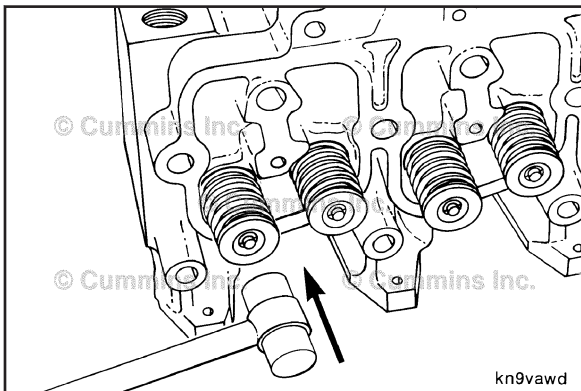
Lubricate the valve stems with clean SAE 90W oil.
Install the valves in their original locations.



Assemble the valve spring and retainer.
Install and compress the valve spring retainer assembly,
using valve spring compressor, Part No. 3375962.



Install the valve collets and release the valve spring
compressor tension.



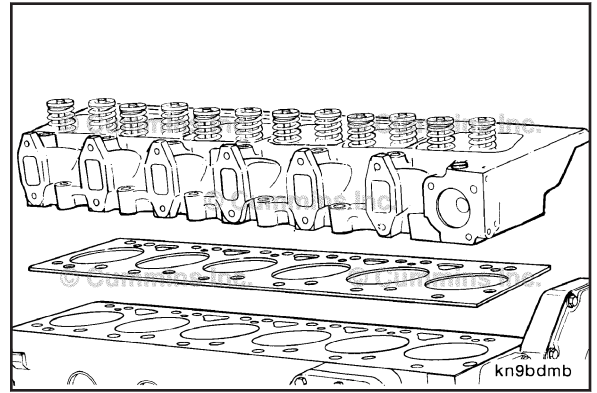
⚠ WARNING ⚠
To avoid personal injury wear eye protection when
installing valve collets. If the collets are not correctly
installed, they can fly out when the stems are hit with
the hammer.

After assembly, hit the valve stems with a plastic hammer
to make sure that the collets are installed properly.

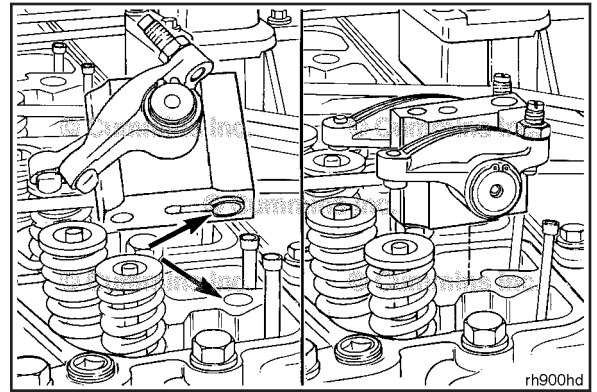
⚠ WARNING ⚠

This assembly weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift this assembly.

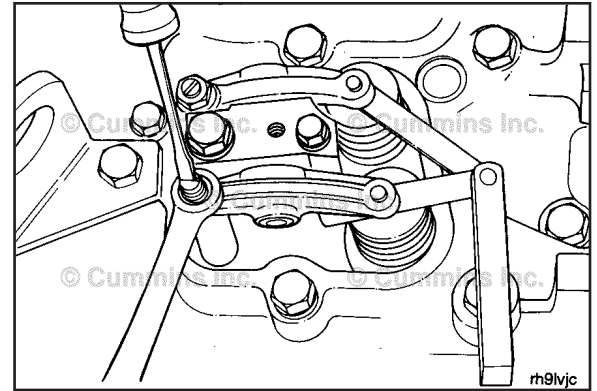
Install the cylinder head and gasket; Refer to Procedure 002-004.



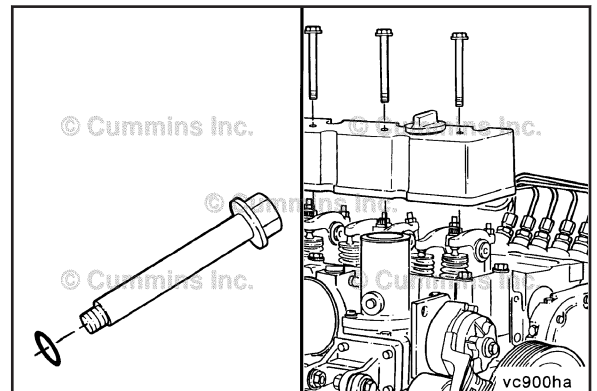
Install the rocker levers; Refer to Procedure 003-008.

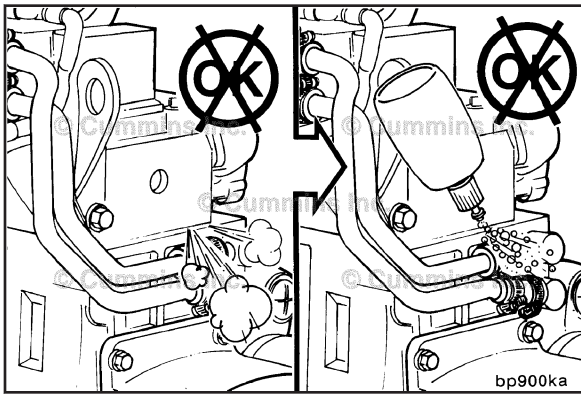


Adjust the valve lash; refer to Procedure Refer to Procedure 003-004.



Install the rocker lever cover; Refer to Procedure 003-011.





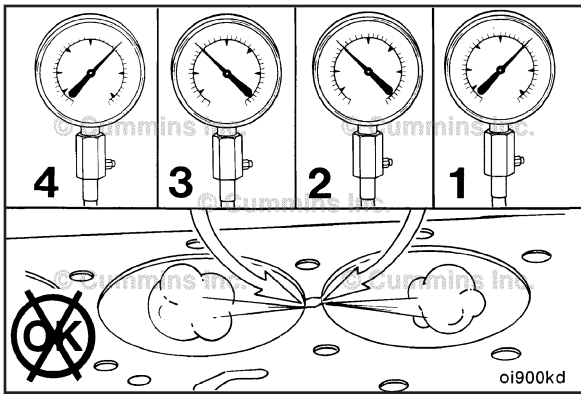
Cylinder Head Gasket (002-021)

General Information

External head gasket leaks can be detected visually. Liquid soap can be used to locate external leaks.

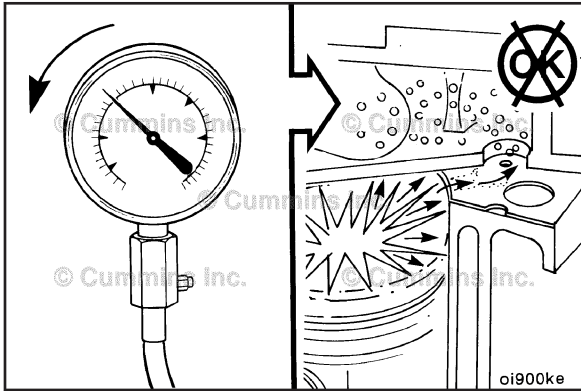
Define a leak as follows:

- Lubricating oil
- Coolant
- Compression.



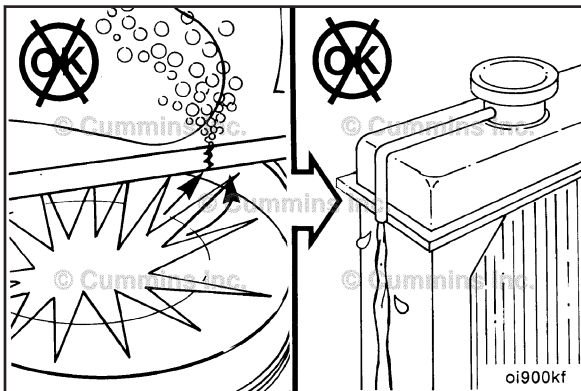
Internal head gasket leaks can be detected by performing a compression check; refer to Procedure 014-012.

If the compression is found to be low on adjacent cylinders and the pressure can **not** be increased by oiling the piston rings, the head gasket is probably leaking between cylinders.



Low compression on a single cylinder can be caused by a compression leak into a coolant passage.

NOTE: A compression leak into a coolant passage can result in coolant in the cylinder.



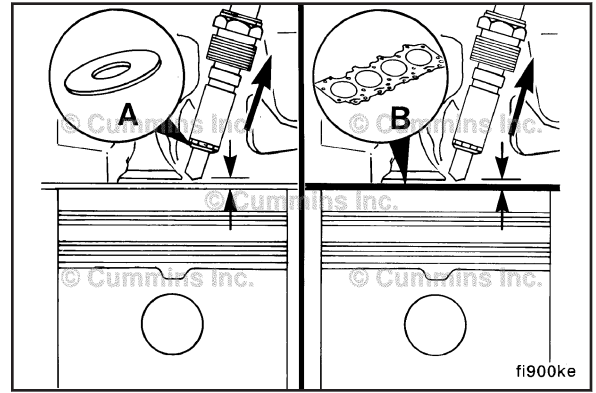
A compression leak into the cooling system can normally be detected by a loss of coolant. Coolant will be blown from the cooling system because of the extra pressure in the system.

Service Tip: Remove the drive belt from the water pump. Run the engine for 1 to 2 minutes and check for coolant being blown from the cooling system.

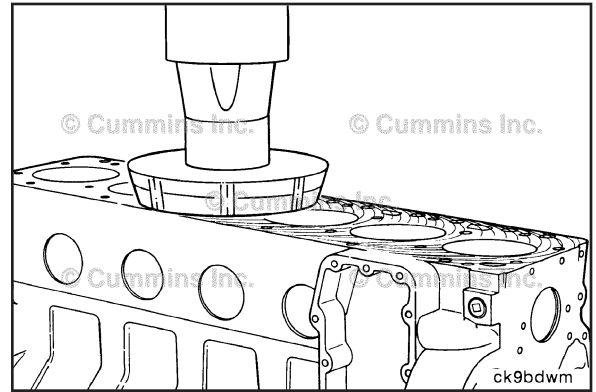
Injector Protrusion (002-022)

General Information

Injector protrusion can affect the amount of power that is output from the engine. In addition to a single sealing washer (A) on the injector, the thickness (B) of the head gasket also controls the injector protrusion.

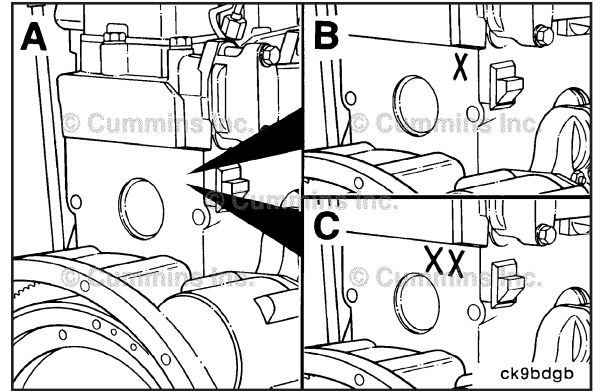


Thicker service head gaskets are used if the cylinder head combustion surface or the cylinder block head deck has been machined.

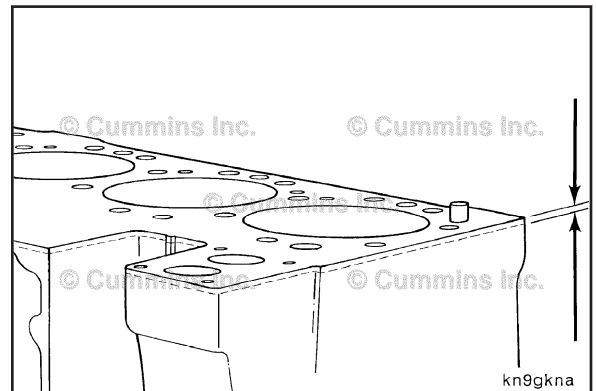


After machining, the block is identified as follows:

- A. StandardNone
- B. 0.25 mm [0.010 in] UndersizedX
- C. 0.50 mm [0.020 in] UndersizedXX



After determining the amount of machining that has been performed, refer to the parts catalog for the proper oversize head gasket.



Section 3 - Rocker Levers - Group 03

Section Contents

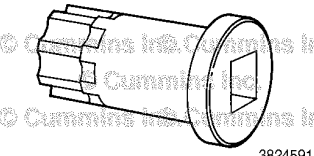
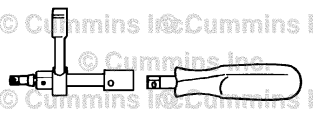
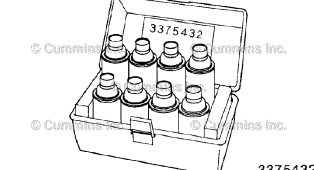
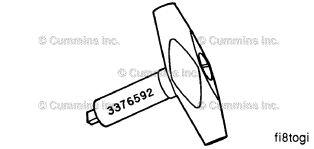

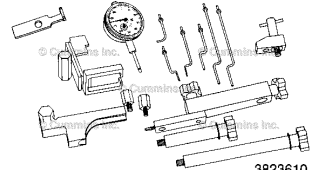
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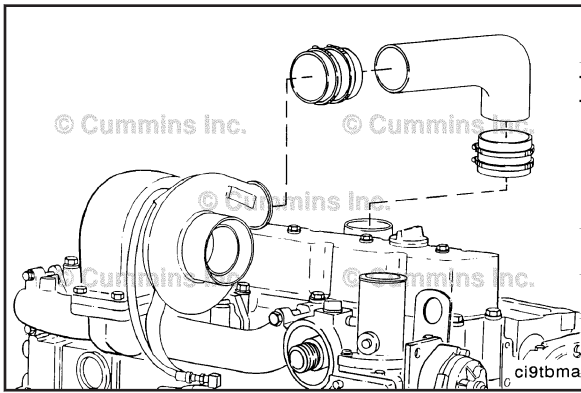
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Service Tools

Rocker Levers

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

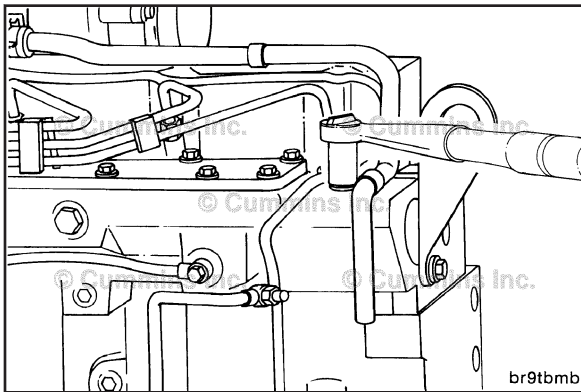
Tool No.	Tool Description	Tool Illustration
3824591	<p>Engine Barring Tool Used to engage the flywheel ring gear to rotate the crankshaft.</p>	 <p style="text-align: right;">3824591</p>
ST-669	<p>Torque Wrench Adapter Tighten rocker lever adjusting screws.</p>	 <p style="text-align: right;">rh8togb</p>
3375432	<p>Crack Detection Kit Used to clean and inspect components for cracks.</p>	 <p style="text-align: right;">3375432</p>
3376592	<p>Inch Pound Torque Wrench Can be used as an optional valve set. Screwdriver socket, Part Number ST-669-13, must be used with this tool.</p>	 <p style="text-align: right;">fi8togi</p>
3823348	<p>STC Tappet Adjusting Tool Used to set overhead on STC engines.</p>	 <p style="text-align: right;">3823348</p>
3823610	<p>Injector Travel Measurement Kit Used to measure injector travel lash.</p>	 <p style="text-align: right;">3823610</p>



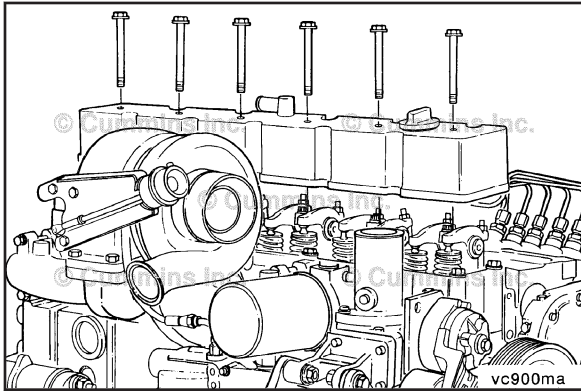
Overhead Set (003-004)

Adjust

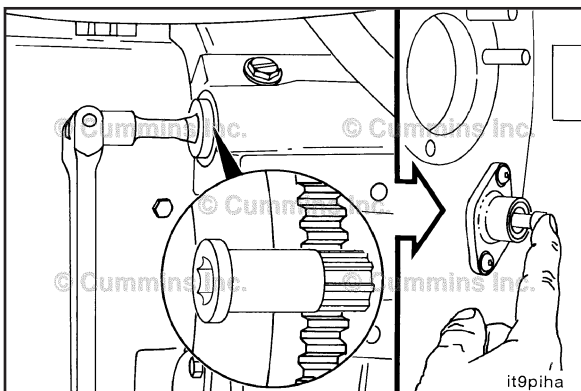
Remove the air crossover tube from the engine if equipped.



Disconnect the support clamps, hose clamp, and wastegate sensing line. Remove the crankcase vent tube and any other parts that would prevent removal of the valve cover.



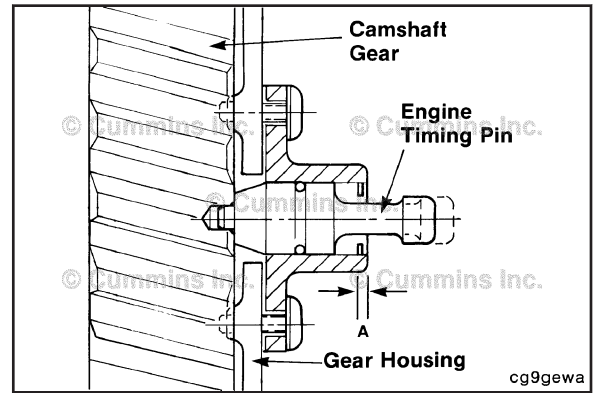
Remove valve cover.



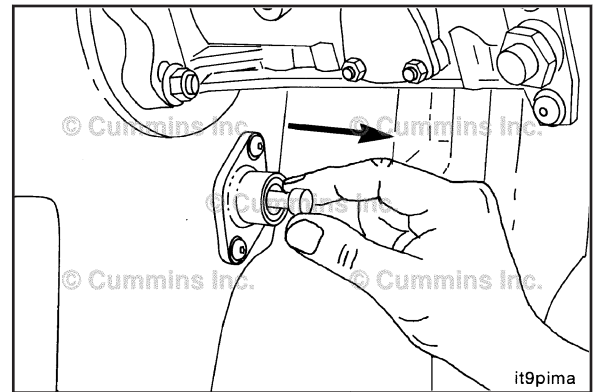
Locate top dead center for cylinder Number 1 by rotating the crankshaft slowly while pressing on the engine timing pin.

The barring gear inserts into the flywheel housing and engages the flywheel ring gear. The engine can then be rotated by hand using a 127-cm [1/2-in] ratchet or breaker bar.

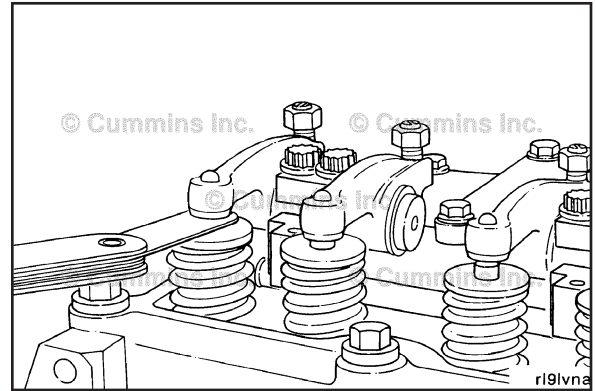
When the engine timing pin engages the hole in the camshaft gear, cylinder Number 1 is at top dead center on the compression stroke.



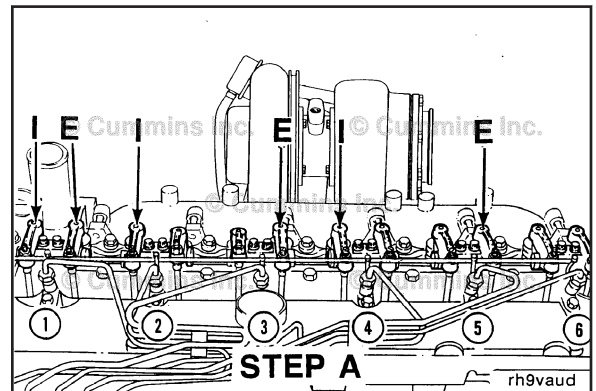
⚠ CAUTION ⚠
Be sure to disengage the engine timing pin after locating top dead center to prevent damage to the engine timing pin.

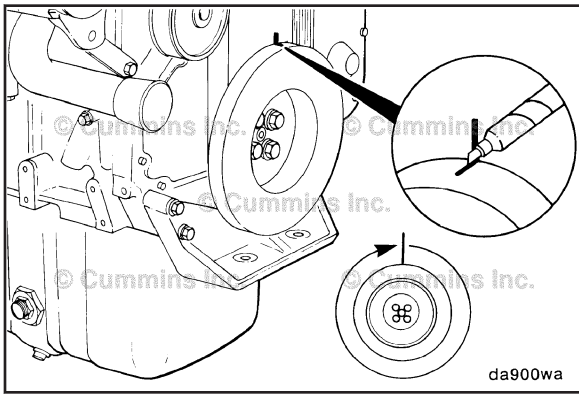


Intake clearance: 0.30 mm [0.012 in].
Exhaust clearance: 0.61 mm [0.024 in].
Check/set valves with engine cold - below 60°C [140°F].
NOTE: The clearance is correct when some resistance is "felt" when the feeler gauge is slipped between the valve stem and the rocker lever.



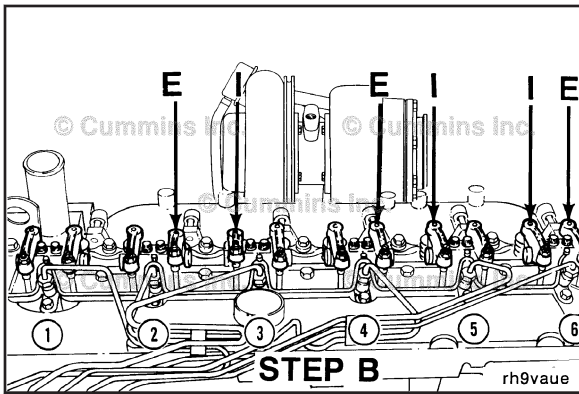
Locate top dead center for cylinder Number 1.
Check/adjust the valves indicated for STEP A (I = intake; E = exhaust).
After tightening the rocker lever locknut, check the valve clearance to make sure the valve clearance has **not** changed.
Torque Value: 24 N•m [212 in-lb]





⚠ CAUTION ⚠
Be sure the engine timing pin is disengaged to prevent damage to the engine timing pin.

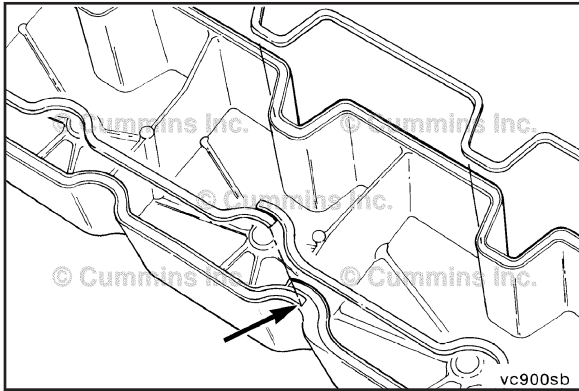
Mark vibration damper and rotate the crankshaft 360 degrees.



Set the valves indicated for STEP B.

After tightening the rocker lever locknut, check the valve clearance to make sure the valve clearance has **not** changed.

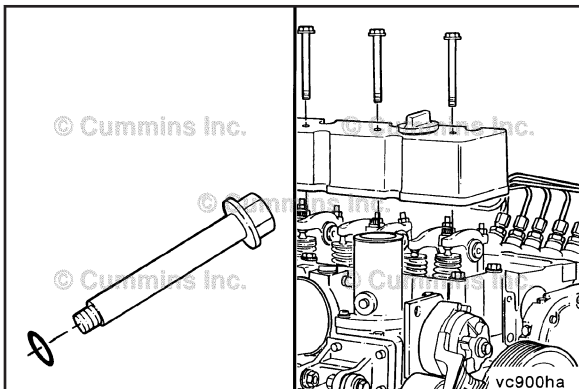
Torque Value: 24 N•m [212 in-lb]



NOTE: If the seal is **not** damaged, it can be used again. If the seal is damaged, install a new seal.

Install the rubber seal into the groove in the valve cover. Start the installation at the overlap area shown in the illustration. Do **not** stretch the rubber seal.

If the seal has more overlap than shown in the illustration, trim the length to provide the correct overlap.



Install new sealing o-rings on the capscrews.

Install the valve cover and wastegate sensing tube.

Torque Value: 24 N•m [212 in-lb]

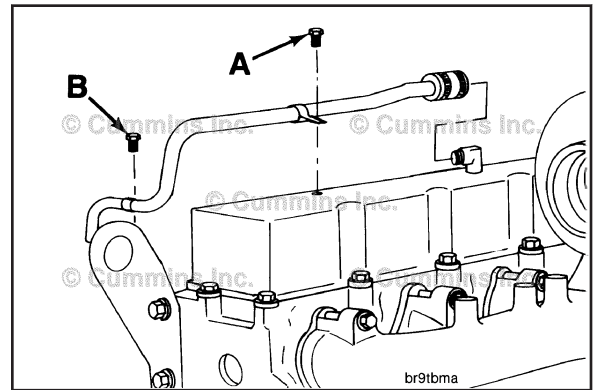


Install the crankcase vent tube, and secure with the support clamps and hose clamp.

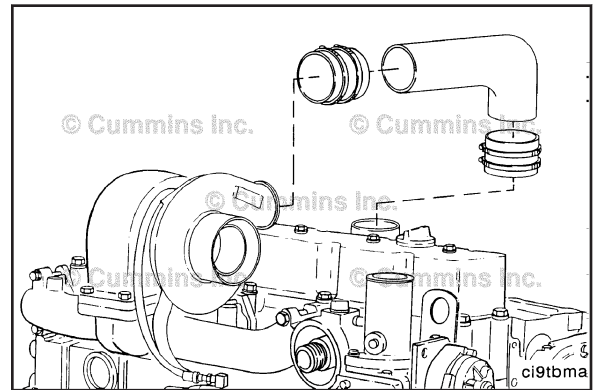
Torque Value:

A = 24 N•m [212 in-lb].

B = 43 N•m [32 in-lb].



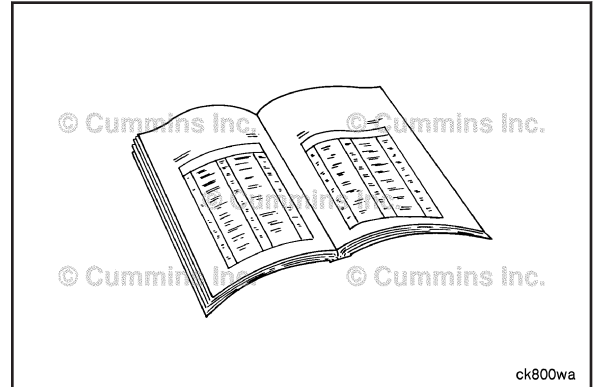
Install the air crossover tube and any other parts previously removed to gain access to the valve cover.



Rocker Lever (003-008)

Preparatory Steps

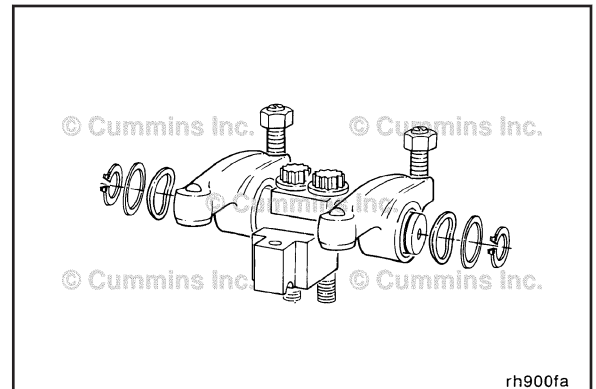
- Remove the crankcase breather tube and hose. Refer to Procedure 003-018.
- Remove the rocker lever cover. Refer to Procedure 003-011.
- Loosen the adjusting screw locknuts. Loosen the adjusting screws until they stop.
- Remove the capscrews, retaining clamps, rocker lever assemblies, and supports.

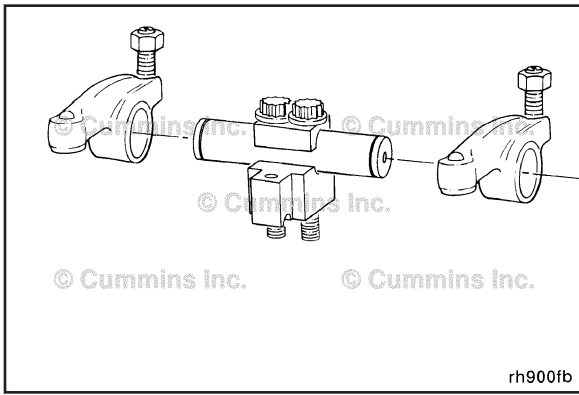


Remove

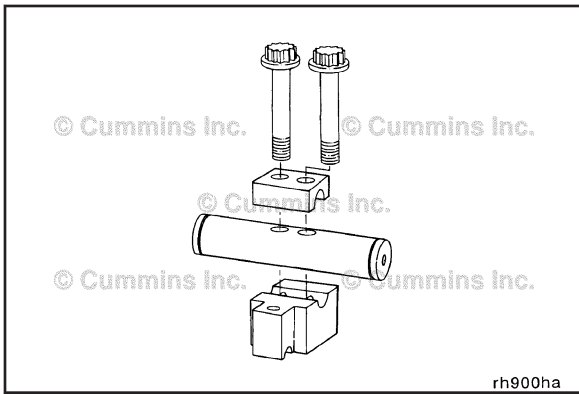
If the rocker lever and push rods are to be inspected for reuse, follow these steps.

Remove the retaining rings and thrust washers.

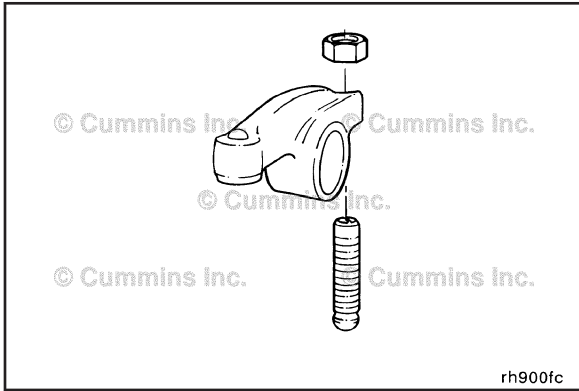




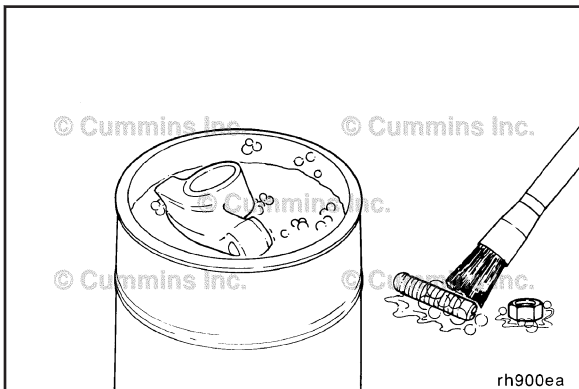
Remove the rocker levers.



Remove the pedestal assembly.



Remove the locknut and adjusting screw.



Clean and Inspect for Reuse

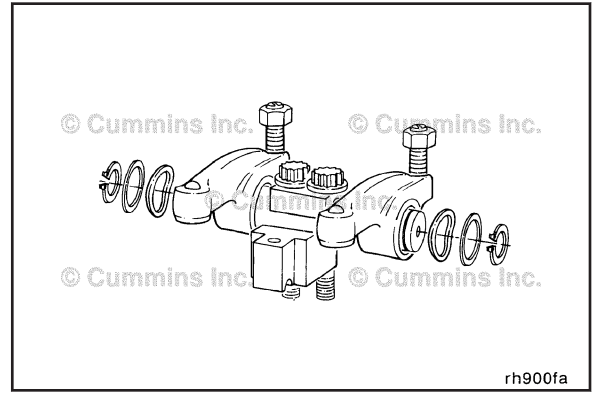
Clean all parts in a strong solution of laundry detergent in hot water.

⚠ WARNING ⚠

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

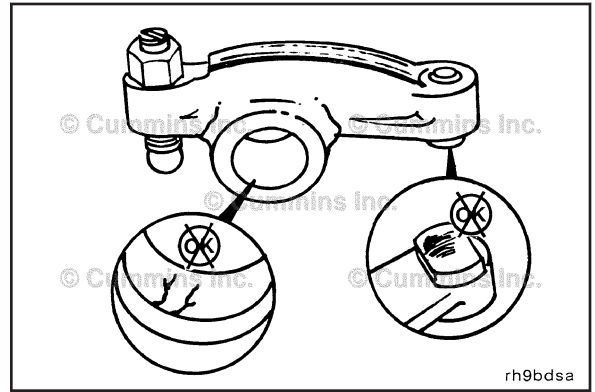
Use compressed air to dry the parts after rinsing in clean hot water.

NOTE: The pedestals are made from powdered metal and will continue to show wetness after they have been cleaned and dried.



rh900fa

Inspect for cracks and excessive wear in the bore and the contact surface of the valve stem.

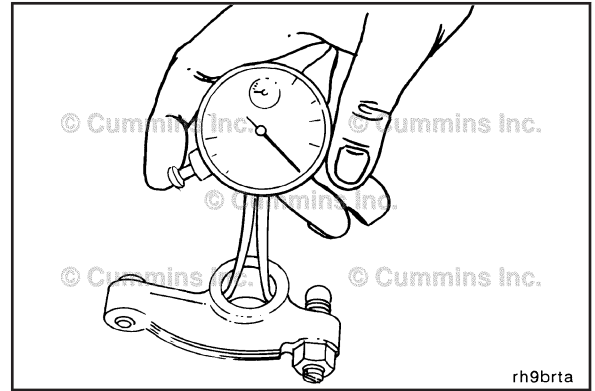


rh9bdsa

Measure the rocker lever bore.

Rocker Lever Bore Diameter

mm		in
22.301	MAX	0.878

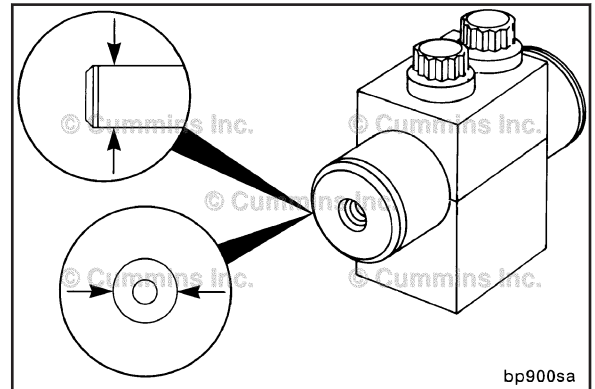


rh9brta

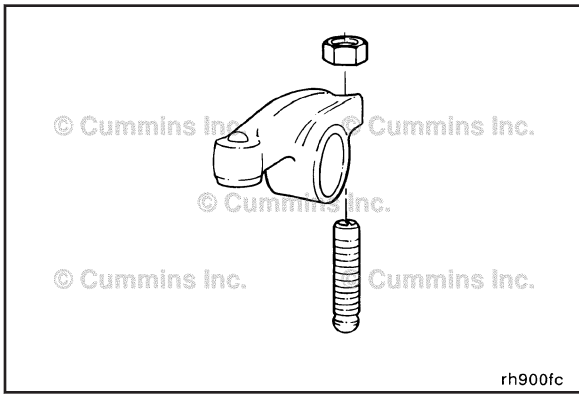
Measure the rocker lever shaft diameter.

Rocker Lever Shaft Diameter

mm		in
22.199	MIN	0.874

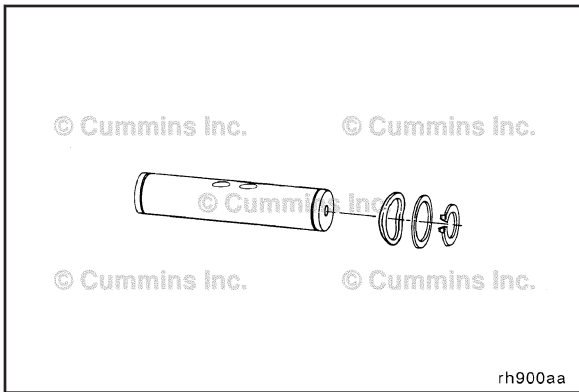


bp900sa

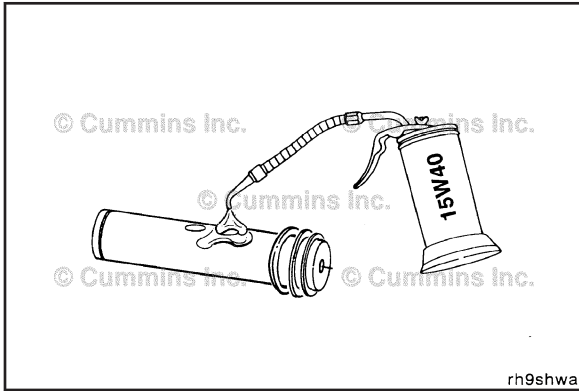


Install

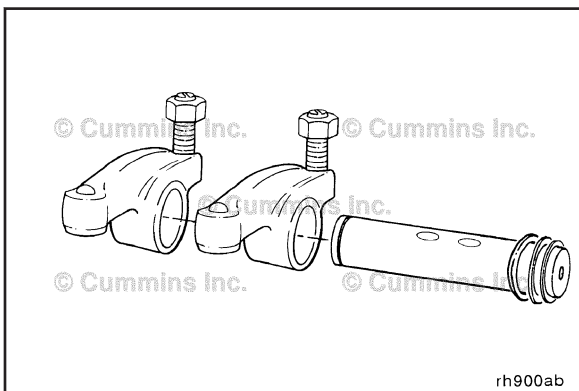
Install the adjusting screw and locknut.



Install a retaining ring, thrust washer, and wavy spring washer as illustrated.

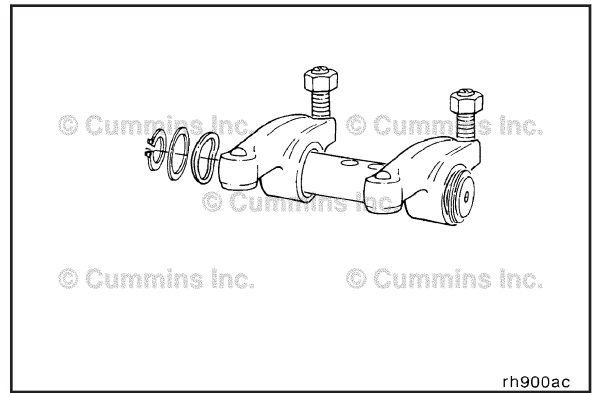


Lubricate the shaft with clean engine lubricating oil.

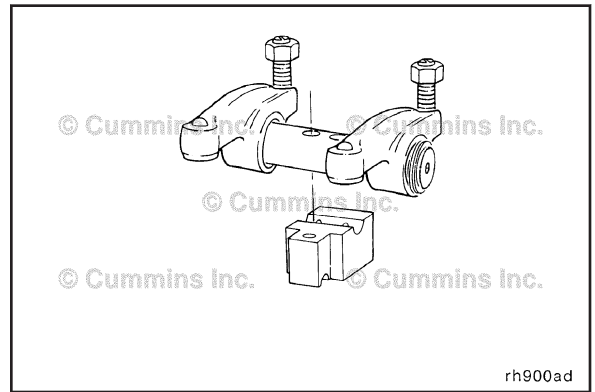


Position the levers on the rocker shaft.

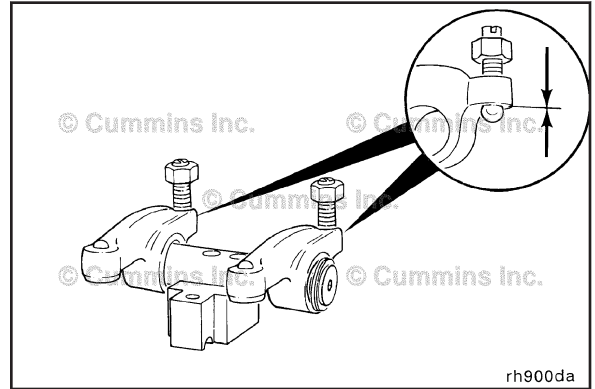
Install the remaining wavy spring washer, thrust washer, and retaining ring as illustrated.



Compress the wavy spring washers and install the bottom half of the pedestal as illustrated.

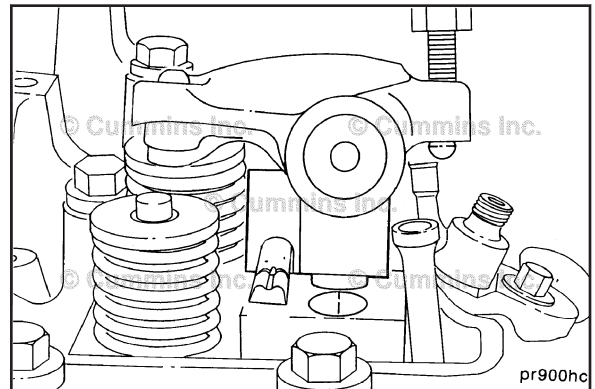


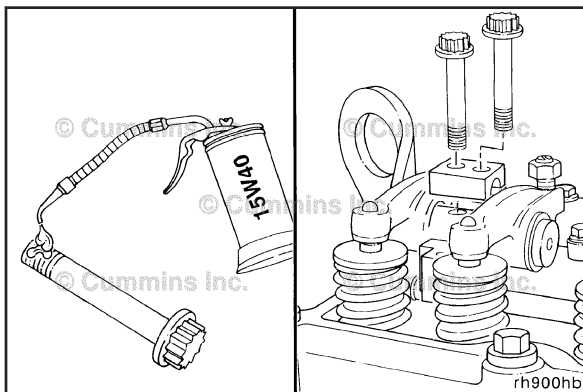
Make sure the rocker lever adjusting screws are completely backed out.



Install the support and rocker lever assemblies over the rocker lever oil manifold.

Make sure the dowel rings in the pedestals are installed into the dowel bores.

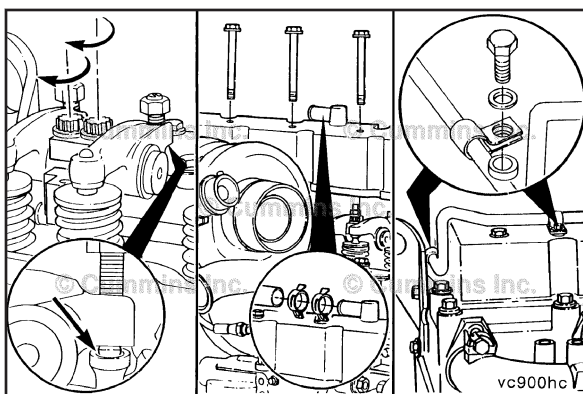




Use clean engine oil to lubricate the threads and under the heads of the pedestal capscrews.



Install the retaining clamps and cap screws.



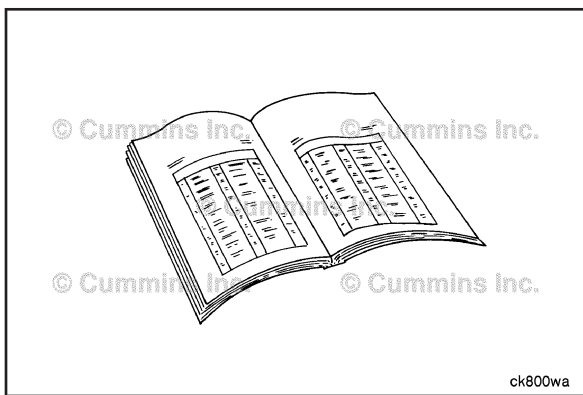
⚠CAUTION⚠

To prevent damage to the rocker lever and push rod, make sure the adjusting screw ball is positioned in the socket of the push rods when tightening.



Tighten the pedestal capscrews.

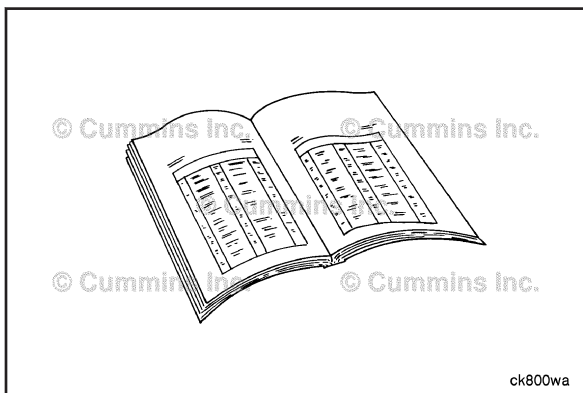
Torque Value: 55 N•m [41 ft-lb]



Finishing Steps



- Adjust the intake and exhaust valve lash. For C Series diesel engines, refer to Procedure 003-004 in the Troubleshooting and Repair Manual, C Series Engines, Bulletin 3666003. For C Series gas engines, refer to Procedure 003-004 in the Troubleshooting and Repair Manual, C8.3G, C Gas Plus, and L Gas Plus Engines, Bulletin 3666206.
- Install the rocker lever cover. Refer to Procedure 003-011.
- Install the crankcase breather tube and hose. Refer to Procedure 003-011.



Rocker Lever Cover (003-011)

Preparatory Steps

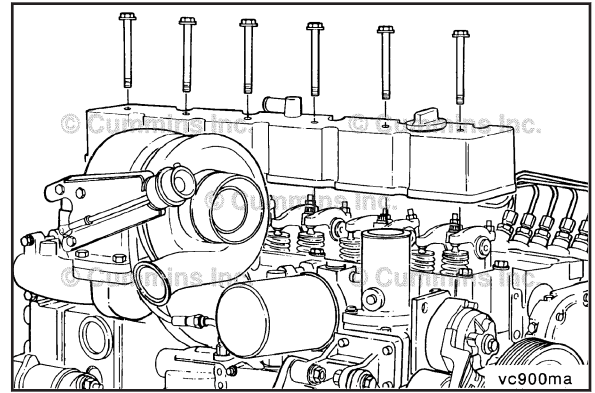
Remove the crankcase breather tube and hose. Refer to Procedure 003-018.

Remove the air crossover tube (off-highway vehicles). Refer to Procedure 010-019.

Remove the capscrew from the support bracket for the turbocharger wastegate actuator hose (on-highway vehicles).

Remove

Remove the six valve cover mounting capscrews.
Discard the sealing o-rings.



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.

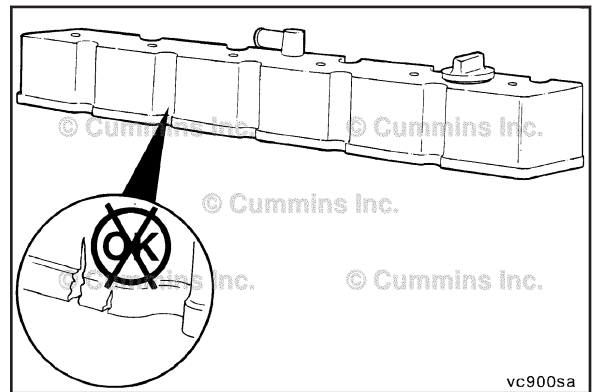
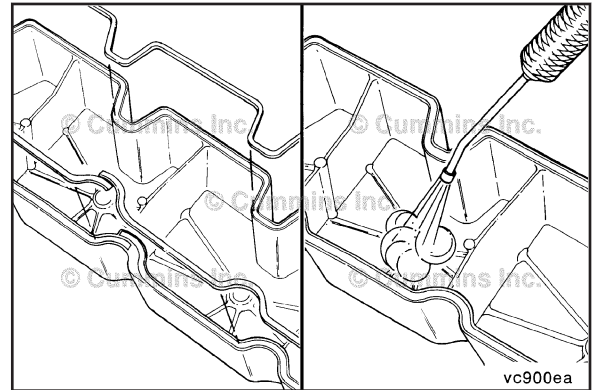
⚠ WARNING ⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Inspect the seal for damage.

NOTE: The gasket can be reused if it is **not** damaged.

Steam-clean and dry with compressed air.

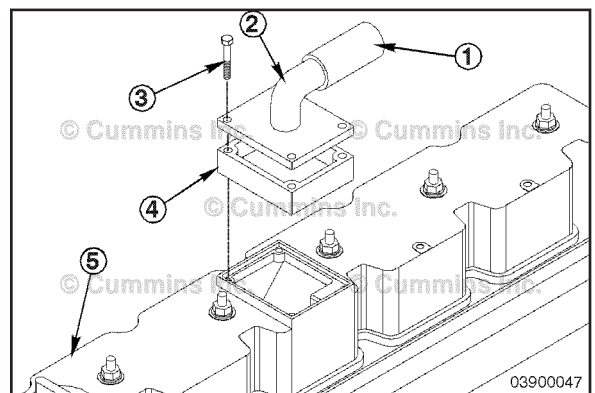
Inspect the cover for cracks or damage and replace if necessary.

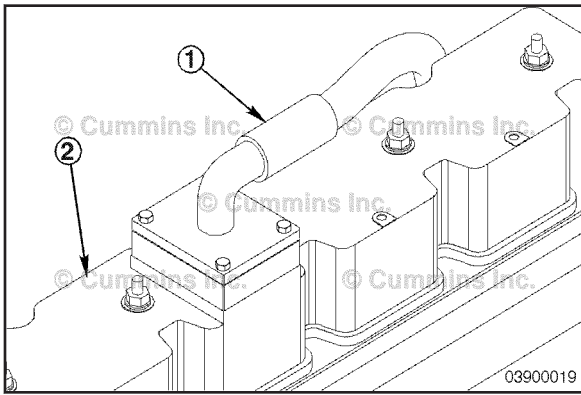


Install

Rocker Lever Cover and Crankcase Breather Assembly Components

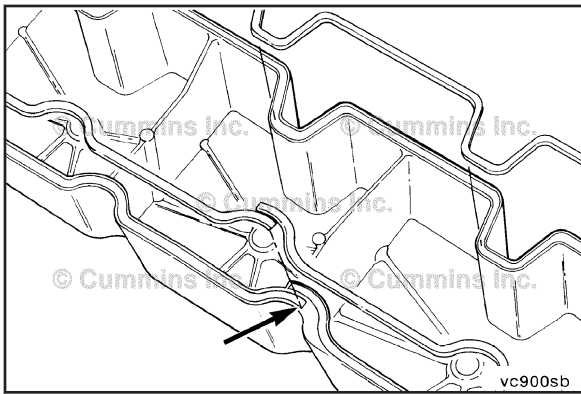
1. Hose
2. Breather
3. Capscrew (self tapping)
4. Mounting Flange
5. Rocker Lever Cover.





Rocker Lever Cover and Crankcase Breather Assembly

1. Breather
2. Rocker Lever Cover.

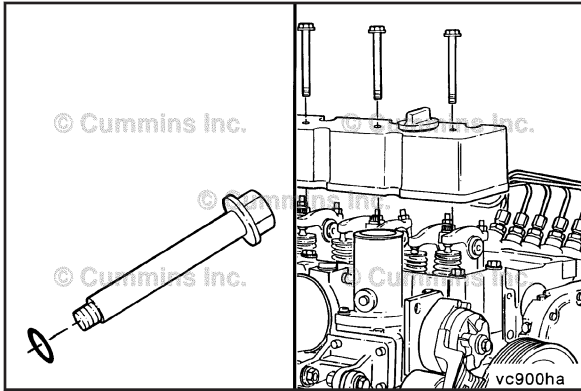


NOTE: If the rocker lever gasket is **not** damaged, it can be reused.

If the rocker lever gasket is damaged, install a new gasket.

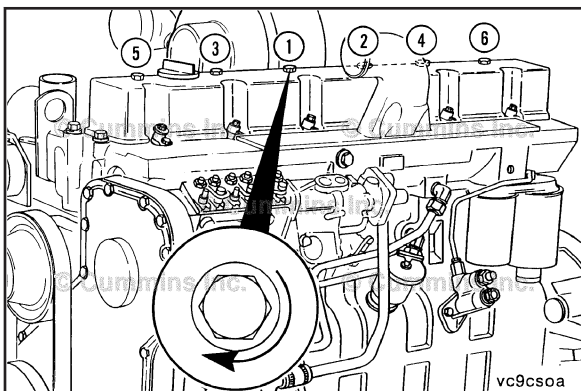
Install the rocker lever gasket into the groove in the rocker lever cover. Start the installation at the overlap area shown in the illustration. Do **not** stretch the rubber rocker lever gasket.

If the rocker lever gasket has more overlap than shown in the illustration, trim the length to provide the correct overlap.



Install new sealing o-rings on the capscrews.

Install the six capscrews into the cover.



Tighten the capscrews in the sequence shown.

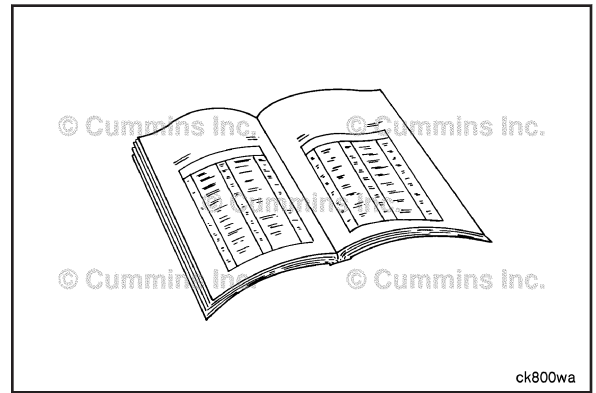
Torque Value: 24 N•m [18 ft-lb]

Finishing Steps

Install the capscrew into the support bracket for the turbocharger wastegate actuator hose (on-highway vehicles).

Temporarily install the crankcase breather tube and hose. Refer to Procedure 003-018.

Install the air crossover tube (off-highway vehicles).

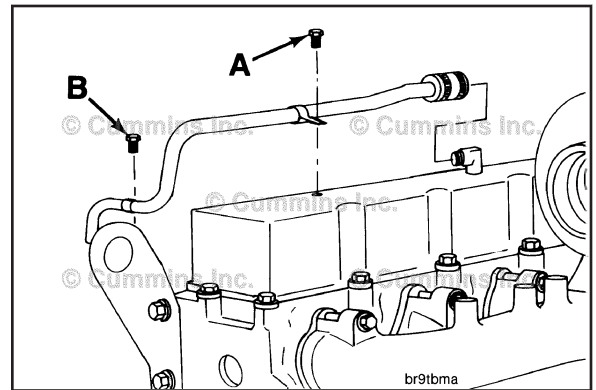


Crankcase Breather Tube (003-018)

Remove

Remove the two hose clamps from the crankcase breather.

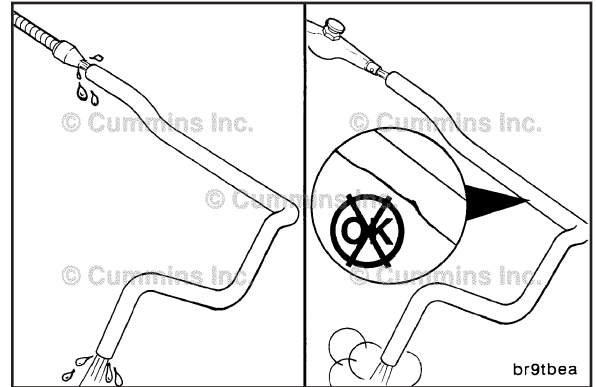
Remove the two breather tube support bracket capscrews (A and B).



Inspect for Reuse

Inspect the hose and tube for restrictions, cracks, or other damage.

Replace the hose and tube if damaged.

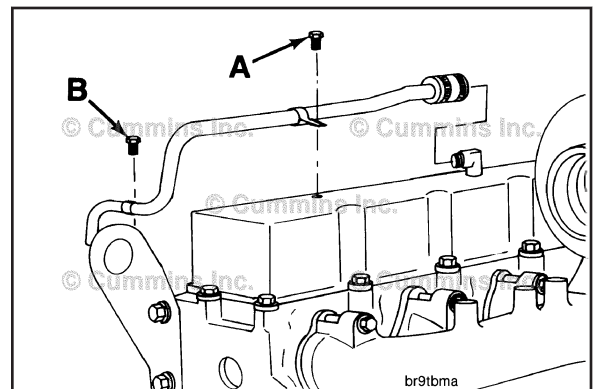


Install

Install the breather tube and hose clamps with the outlet oriented to allow the best routing of a 2.54 cm [1 in] diameter breather hose to the oil pan flange.

Tighten the capscrews for the breather tube support brackets.

Torque Value: Step1 24 N•m [18 ft-lb]
 Step2 43 N•m [32 ft-lb]



Section 4 - Cam Followers/Tappets - Group 04

Section Contents

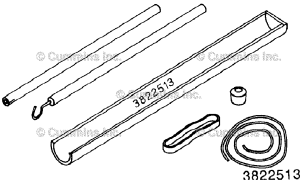
	Page
Push Rods or Tubes	4-2
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Inspect for Reuse.....	4-2
Install.....	4-3
Preparatory Steps.....	4-2
Remove.....	4-2
Service Tools	4-1
Cam Followers/Tappets.....	4-1
Tappet	4-4
Clean and Inspect for Reuse.....	4-8
Finishing Steps.....	4-14
General Information.....	4-4
Install.....	4-9
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Remove.....	4-5

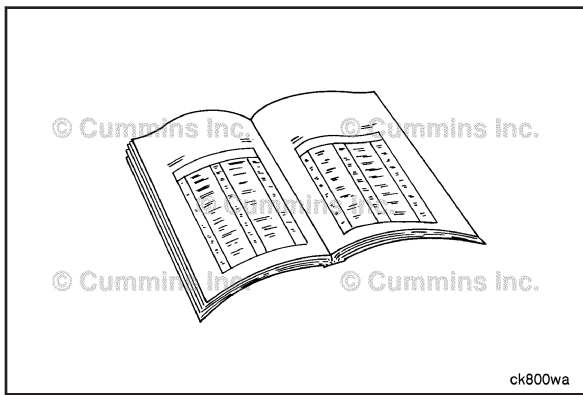
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Service Tools

Cam Followers/Tappets

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

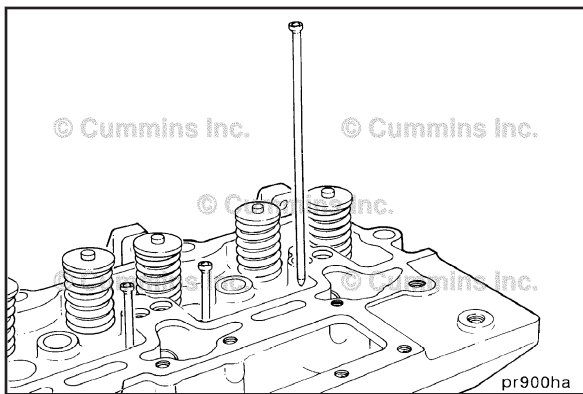
Tool No.	Tool Description	Tool Illustration
3822513	Tappet Removal Tool Kit Used to remove and install valve tappets.	 <p>The illustration shows the components of the Tappet Removal Tool Kit. It includes two long, thin rods, one of which has a hook at one end. There is also a small circular spring, a coiled spring, and a small cylindrical component. The number 3822513 is printed on the rods and at the bottom right of the illustration.</p>



Push Rods or Tubes (004-014)

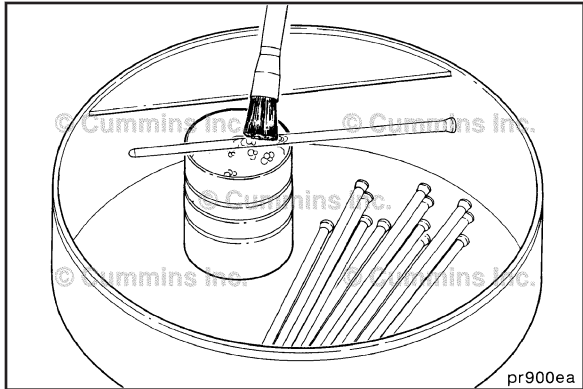
Preparatory Steps

- Remove the crankcase breather tube and hose. Refer to Procedure 003-018
- Remove the rocker lever cover. Refer to Procedure 003-011.
- Loosen the rocker lever adjusting screw locknuts and loosen the adjusting screws until they stop.
- Remove the rocker lever assemblies. Refer to Procedure 003-008.



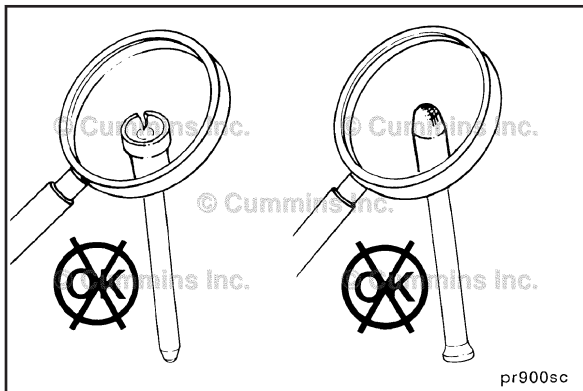
Remove

Mark the push rods to identify their location.
Remove the push rods.



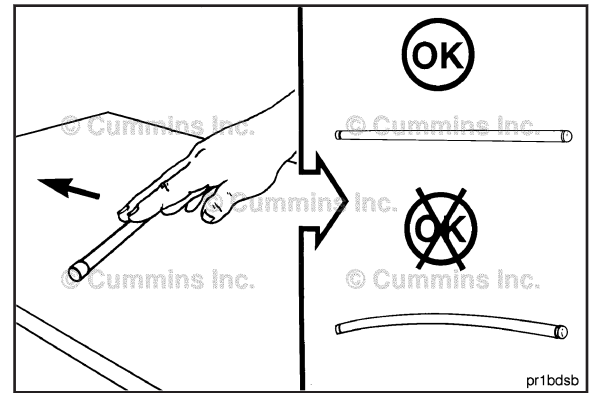
Inspect for Reuse

Clean the push rods in hot, soapy water.



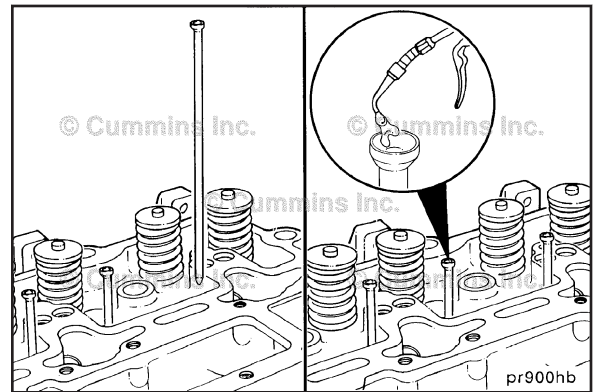
Inspect the push rod ball and socket for signs of scoring.
Check for cracks where the ball and the socket are pressed into the tube.

Check the push rods for roundness and straightness.

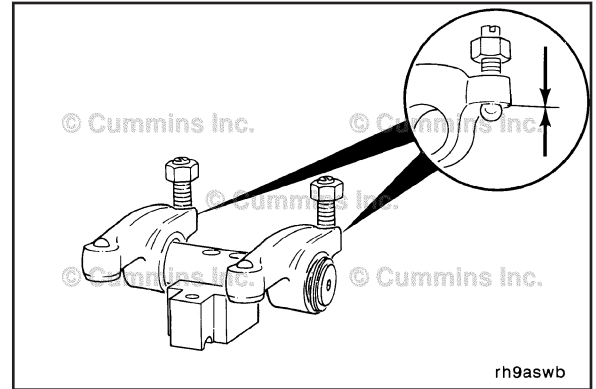


Install

Install the push rods into the sockets of the valve tappets.
Lubricate the push rod sockets with clean engine oil.



Make sure the rocker lever adjusting screws are completely backed out.



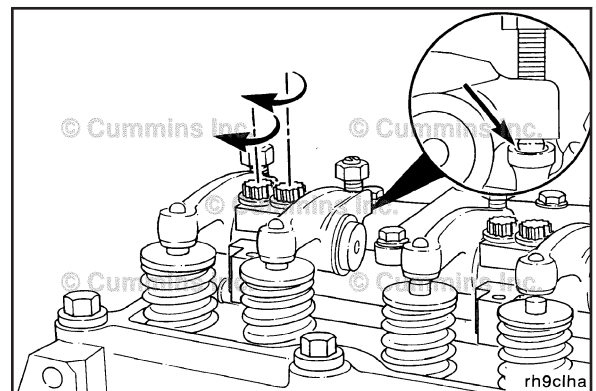
To prevent damage to the rocker lever or push rod, make sure the adjusting screw ball is positioned in the socket of the push rods when tightening.

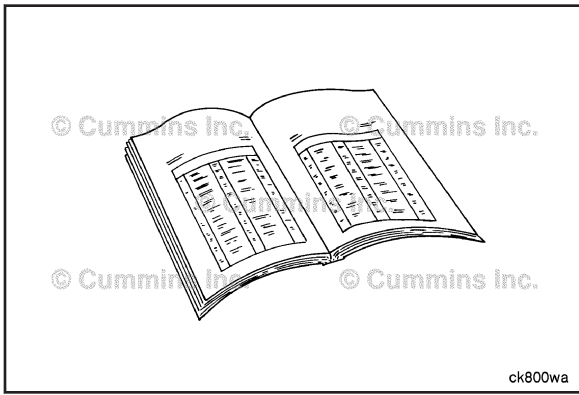


Install the rocker lever assemblies. Refer to Procedure 003-008.



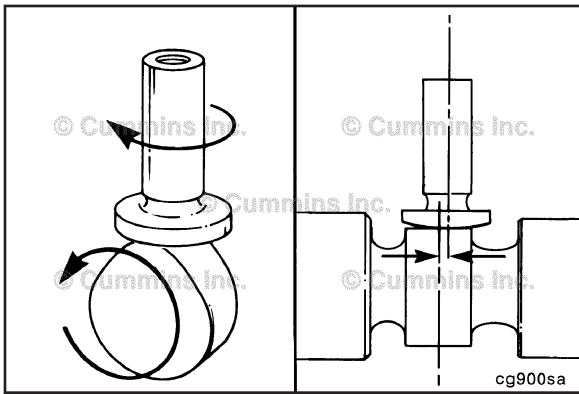
Adjust the valve lash. For C Series diesel engines, refer to Procedure 003-004 in Troubleshooting and Repair Manual, C Series Engines, Bulletin 3666003. For C Series gas engines, refer to Procedure 003-004 in Troubleshooting and Repair Manual, C8.3G (Natural Gas) Engines, Bulletin 3666206.





Finishing Steps

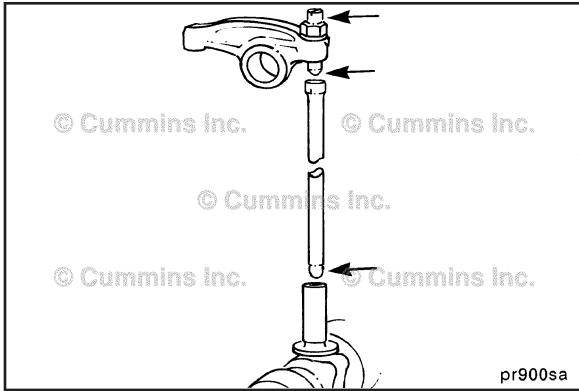
- Install the rocker lever cover and gasket. Refer to Procedure 003-011.
- Install the crankcase breather tube. Refer to Procedure 003-018.



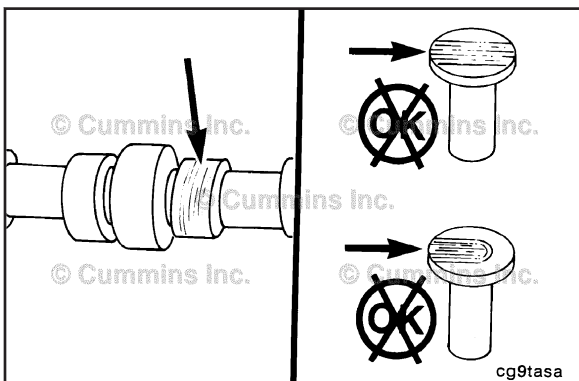
Tappet (004-015)

General Information

The valve tappets are mushroom shaped. The offset position of the tappet against the camshaft lobe causes the tappet to rotate as it lifts the push rod.



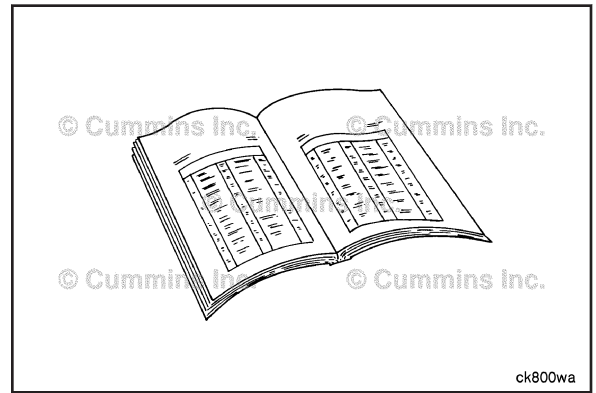
The ball end of the push rod fits into the ball socket in the tappet. The other end of the push rod has a ball socket in which the ball end of the rocker lever adjusting screw operates.



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

Preparatory Steps

- Remove the crankcase breather. Refer to Procedure 003-018.
- Remove the rocker lever cover. Refer to Procedure 003-011.
- Remove the rocker levers. Refer to Procedure 003-008.
- Remove the push rods. Refer to Procedure 004-014.
- Remove the crankshaft pulley/vibration damper. Refer to Procedure 001-052.
- Remove the front gear cover. Refer to Procedure 001-031.



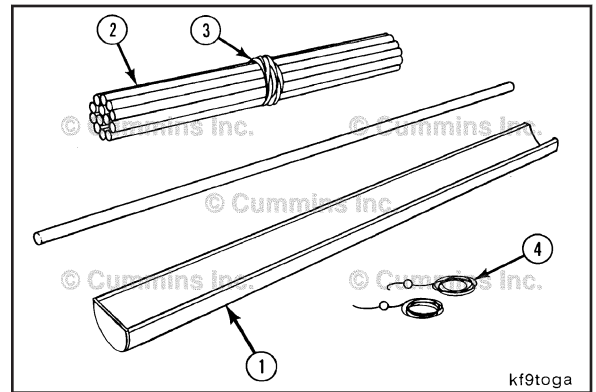
Remove

Oil Pan Installed

The valve tappets can be removed with the oil pan installed by using tappet removal tool kit, Part Number 3822513.

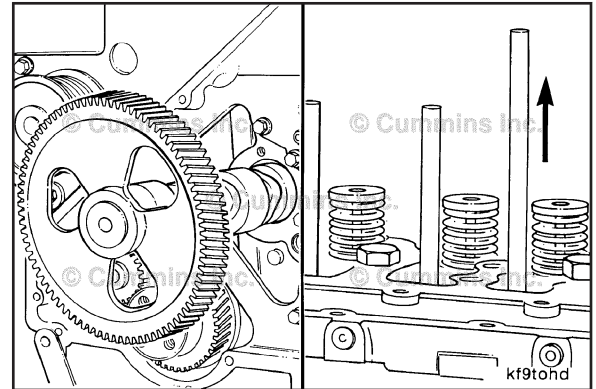
The kit consists of:

1. Valve Tappet Tray - Quantity 1
2. Dowel Rods - Quantity 12
3. Rubber Bands - Quantity 12
4. Nylon String - Quantity 1.

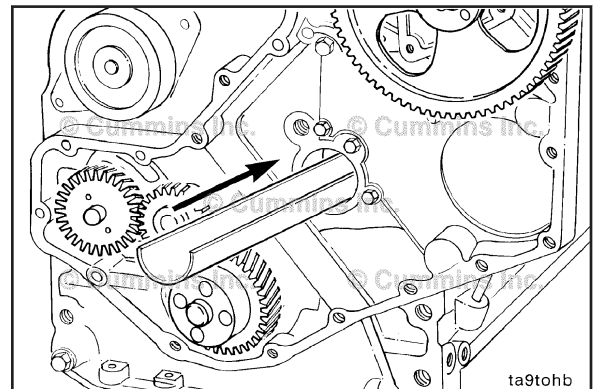


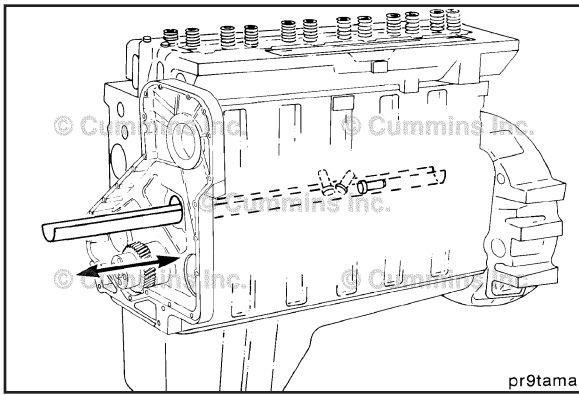
NOTE: Number each tappet with the cylinder number position as it is removed. The tappets **must** be installed in the same position as removed.

Remove the camshaft. For C Series diesel engines, refer to Procedure 001-008 in Troubleshooting and Repair Manual, C Series Engines, Bulletin 3666003. For C Series gas engines, refer to Procedure 001-008 in Troubleshooting and Repair Manual, C8.3G (Natural Gas) Engines, Bulletin 3666206.

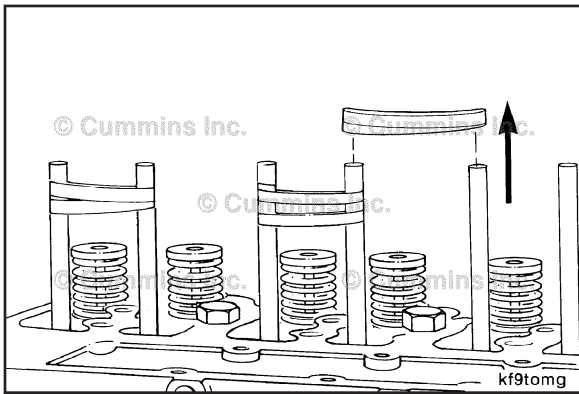


Insert the valve tappet tray.



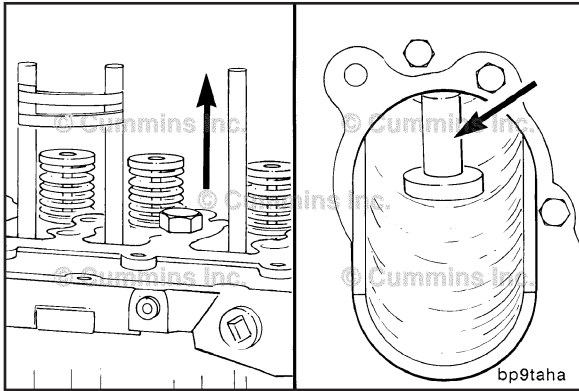


Make sure the valve tappet tray is positioned so it will catch the tappet when the wooden dowels are removed.

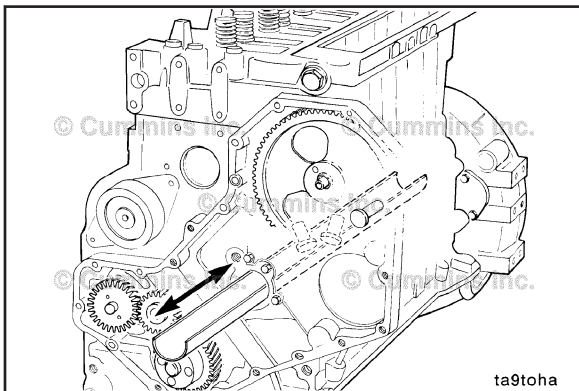


Only remove one tappet at a time.

Remove the rubber band from the two companion tappets, securing the tappet **not** to be removed with the rubber band.

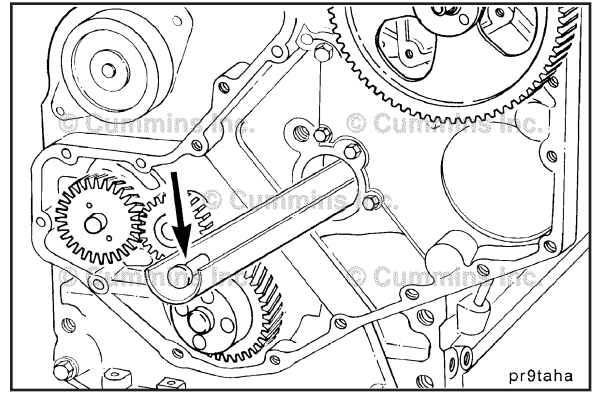


Pull the wooden dowel from the tappet bore, allowing the tappet to fall into the plastic tray.



NOTE: The tappet **must** be in the horizontal position to remove it from the camshaft bore. When the tappet is dropped into the tray, it will fall into the horizontal position. If it does **not**, gently shake the tray to allow the tappet to fall over.

Carefully pull the tray and tappet from the cam bore and remove the tappet. Repeat the process until all tappets are removed.



Oil Pan Removed

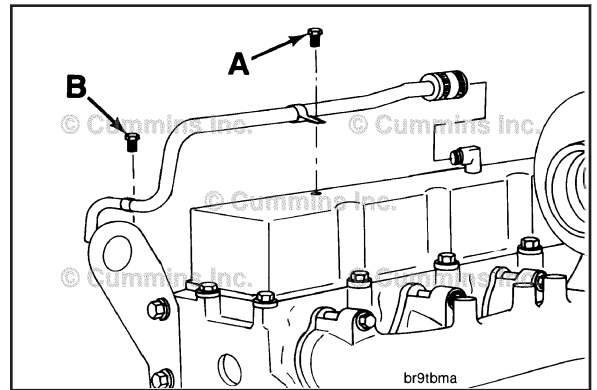


To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.



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

Remove the oil pan. Refer to Procedure 007-025.

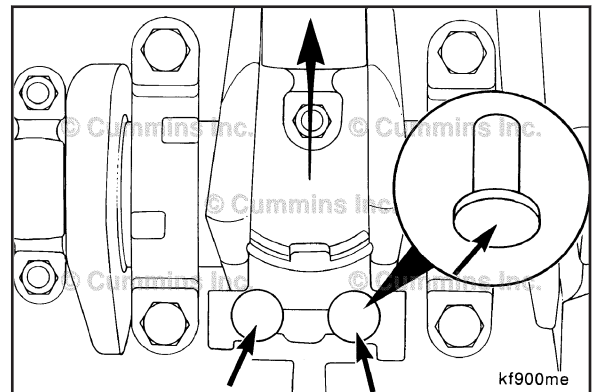


Rotate the crankshaft with engine barring gear, Part Number 3377371, to access the tappets.

NOTE: Only four tappets are accessible at one time.

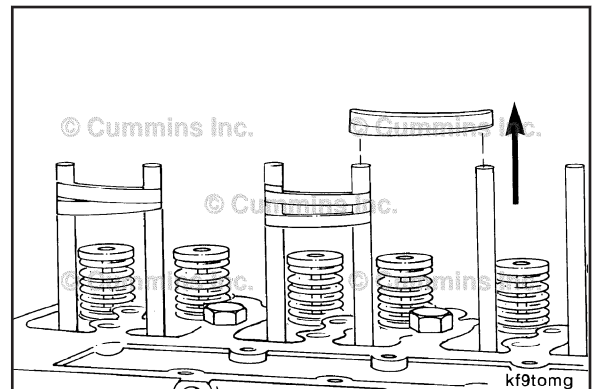
The crankshaft **must** be rotated three times to access all of the tappets.

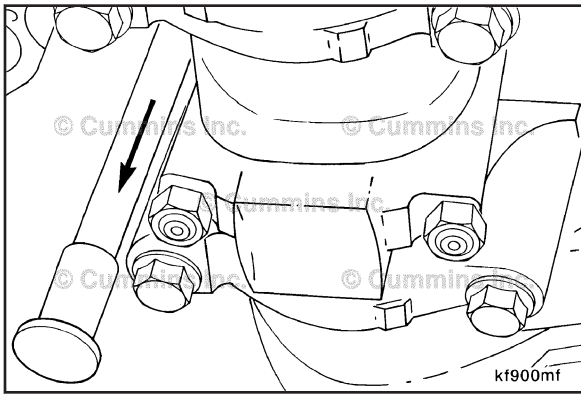
NOTE: Number each tappet with the cylinder number position as it is removed. The tappets **must** be installed in the same position as removed.



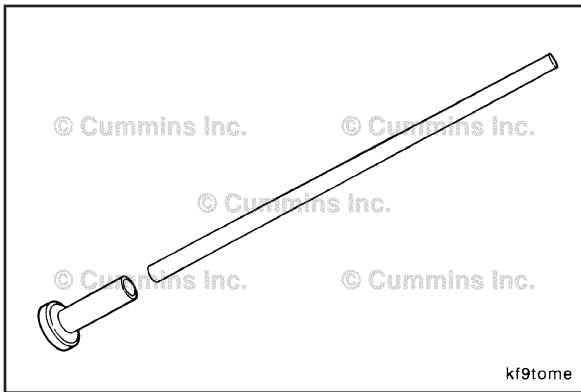
Remove the rubber bands from the wooden dowels that are used to hold the tappets up during camshaft removal.

NOTE: Only remove the rubber bands from the accessible tappets.

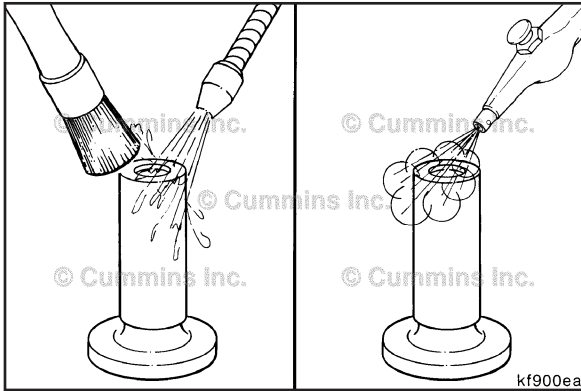




Remove the accessible tappets and dowels.



Remove the tappets from the wooden dowels.



Clean and Inspect for Reuse

⚠ WARNING ⚠

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

⚠ WARNING ⚠

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

Clean the tappets with solvent.

Dry the tappets with compressed air.



⚠ CAUTION ⚠

Anytime a new camshaft is installed, new tappets and push rods must also be installed.

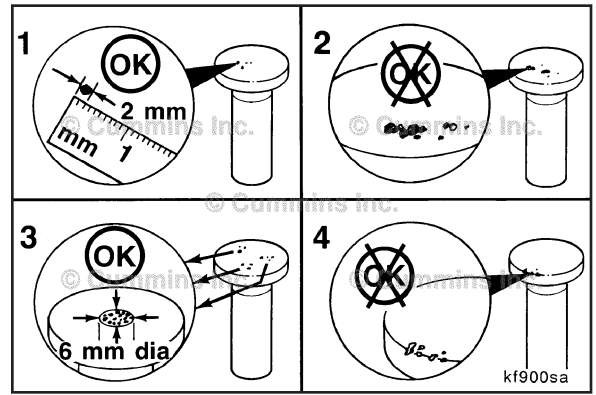
⚠ CAUTION ⚠

If a tappet is replaced, the corresponding push rods must also be replaced. Failure to do this can cause major engine damage.

Pit marks on the tappet face are acceptable.

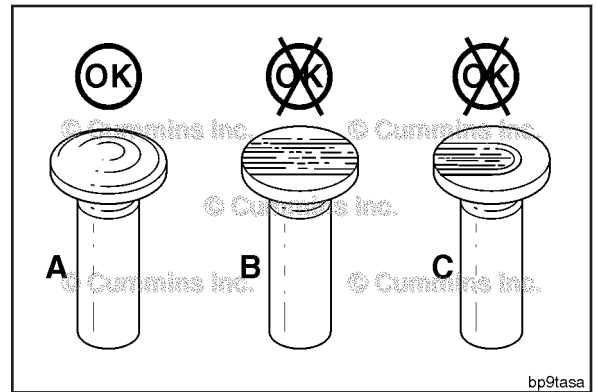
The following criteria define the size of the pits allowed:

1. A single pit can **not** be greater than 2 mm [0.078 in].
2. Interconnection of pits is **not** allowed.
3. Total pits added together **must not** exceed 6-mm [0.236-in] diameter or a total of 4 percent of the tappet face.
4. No pitting is allowed on the edges of the wear face of the tappet.



Inspect the socket, stem, and face for excessive wear, cracks, and other damage.

Visual Limits	
(A) - Normal Contact (exaggerated)	
(B) and (C) - Irregular Contact: Do not reuse.	

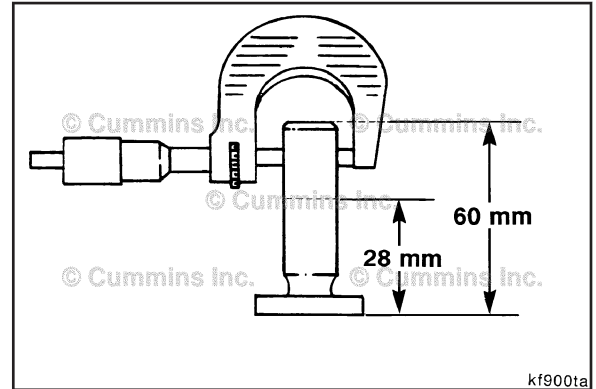


Measure the valve tappet stem diameter.

Valve Tappet Stem Diameter		
mm		in
15.93	MIN	0.627
15.98	MAX	0.629

Measure the valve tappet height.

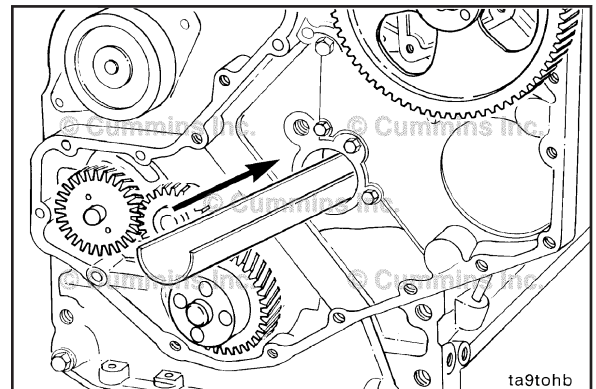
Valve Tappet Height		
mm		in
60	MAX	2.36

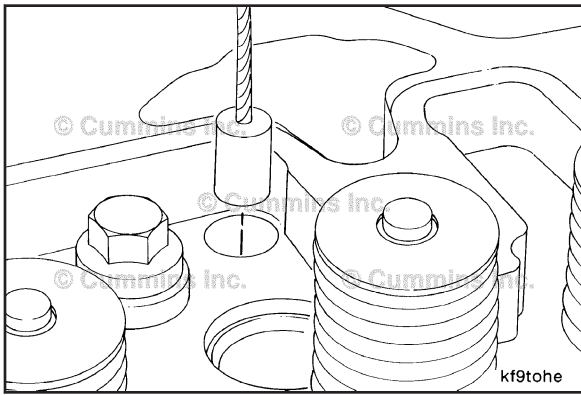


Install

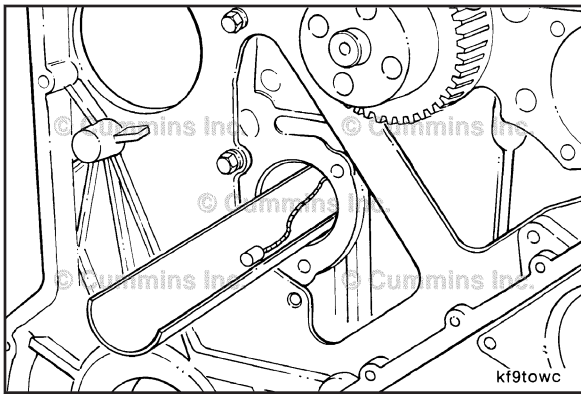
Oil Pan Installed

Insert the valve tappet tray the full length of the cam bore.

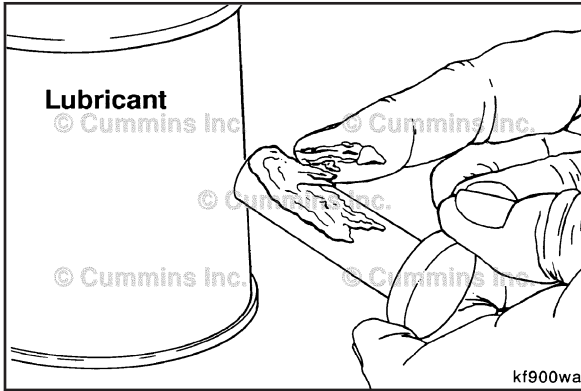




Lower the tappet installation tool down the push tube hole, through the tappet bore, and into the tray.

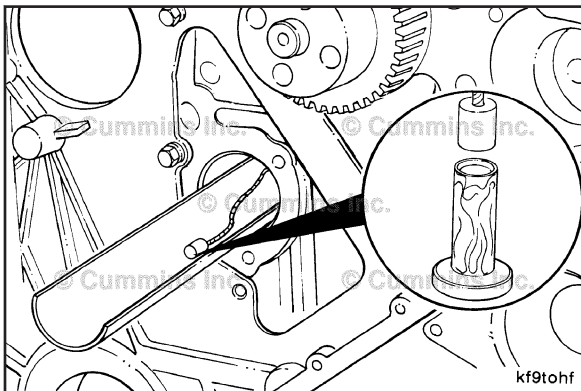


Feed the installation tool through the cam bores by carefully pulling the plastic tray/installation tool out the front of the cylinder block.



NOTE: If the tappets to be installed have been previously used, each tappet **must** be installed in the same position as it was removed from the engine.

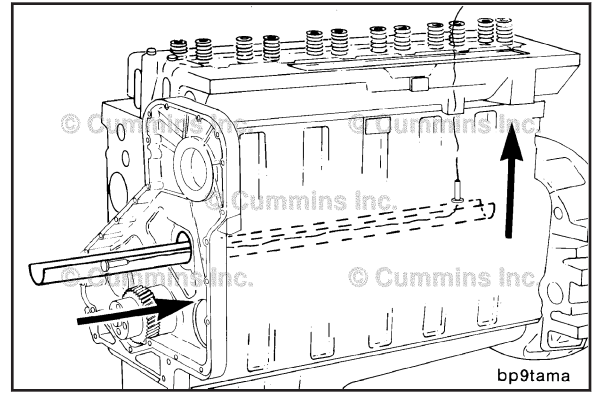
Lubricate the tappets with clean engine oil.



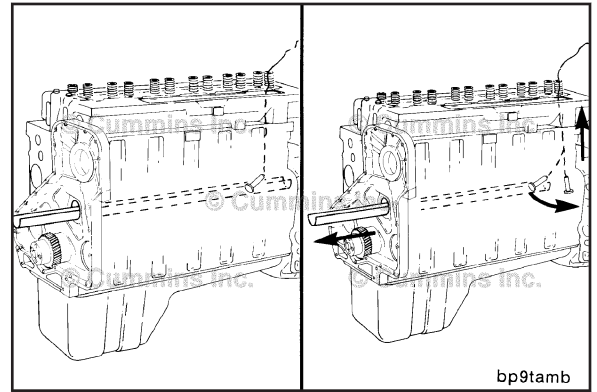
NOTE: To aid in removing the installation tool after the tappet is installed, work the tool in and out of the tappet several times before installing the tappets.

Insert the installation tool into the tappet.

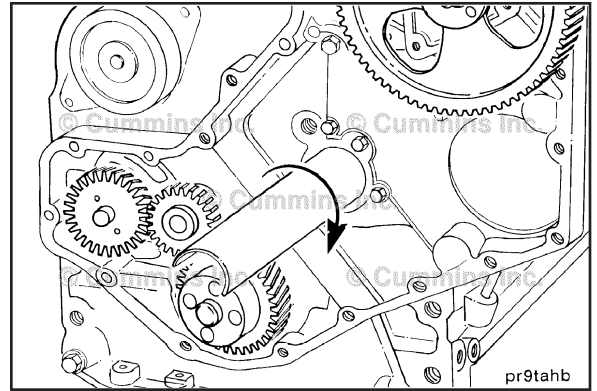
Pull the installation tool and tappet through the cam bore and up into the tappet bore.



NOTE: If difficulty is experienced in getting the tappet to make the bend from the tray up to the tappet bore, pull the tray out enough to allow the tappet to drop down and align itself; then pull the tappet up into the bore.



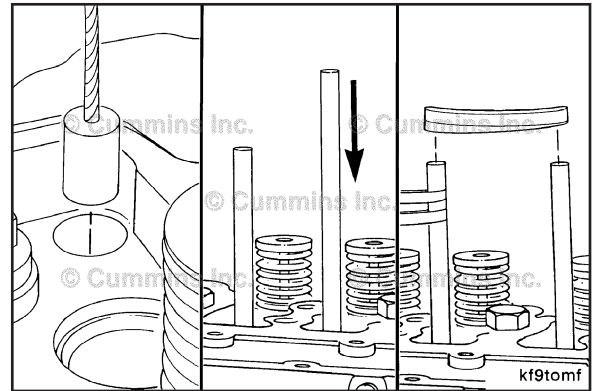
After the tappet has been pulled up into position, slide the tray back into the cam bore and rotate it a 1/2 turn. This will position the round side of the tray up and hold the tappet in place.

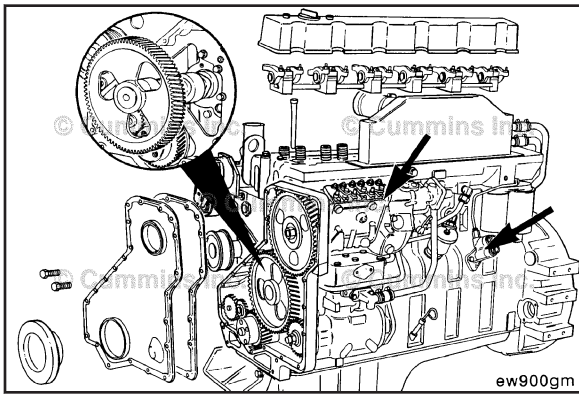


Remove the installation tool from the tappet.

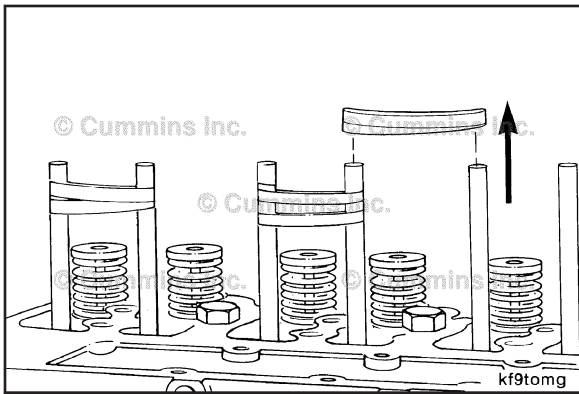
Install a wooden dowel into the top of the tappet. Wrap rubber bands around the wooden dowels to secure the tappets.

Repeat this process until all tappets have been installed.

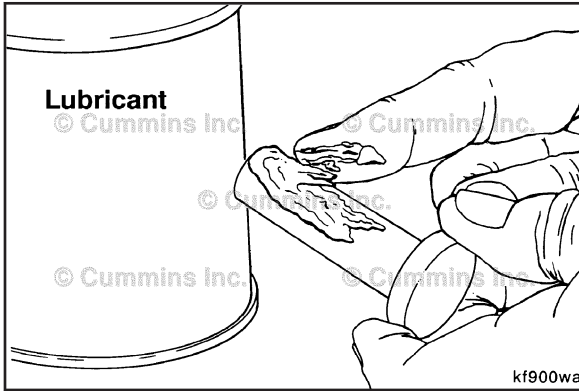




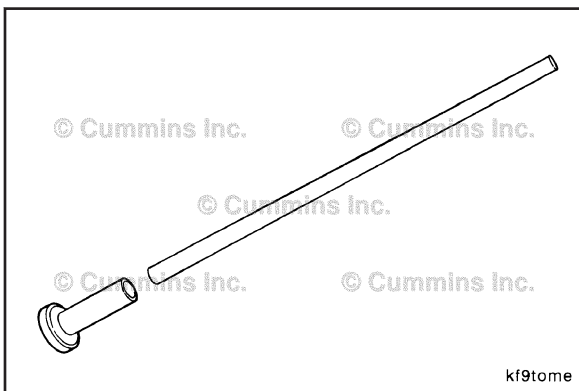
Install the camshaft. For C Series diesel engines, refer to Procedure 001-008 in Troubleshooting and Repair Manual, C Series Engines, Bulletin 3666003. For C Series gas engines, refer to Procedure 001-008 in Troubleshooting and Repair Manual, C8.3G (Natural Gas) Engines, Bulletin 3666206.



Remove the dowel rods and release the tappets in the tappet bores.

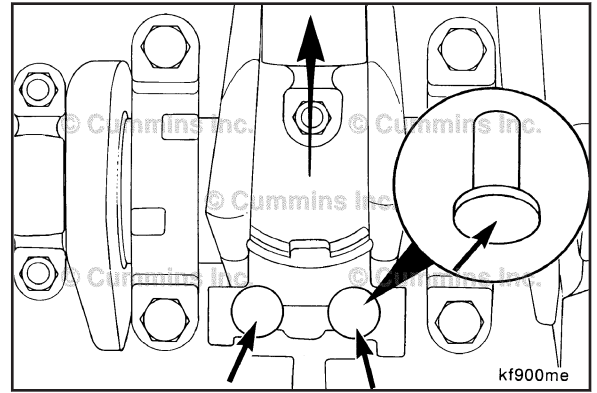


Oil Pan Removed
Lubricate the tappets with clean engine oil.



Insert the wooden dowel rods used for holding the tappets up during camshaft installation into the tappets.

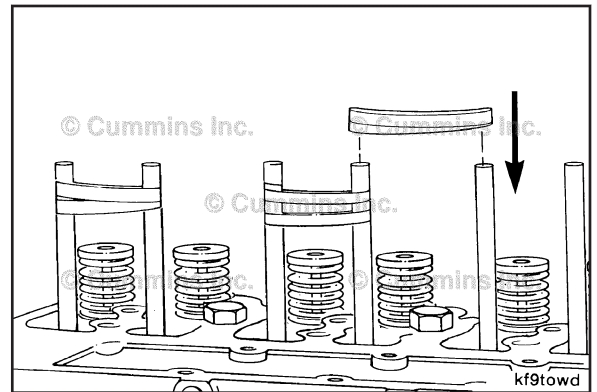
NOTE: The crankshaft **must** be rotated during the installation process. **Only** four tappets can be installed at each crankshaft position.



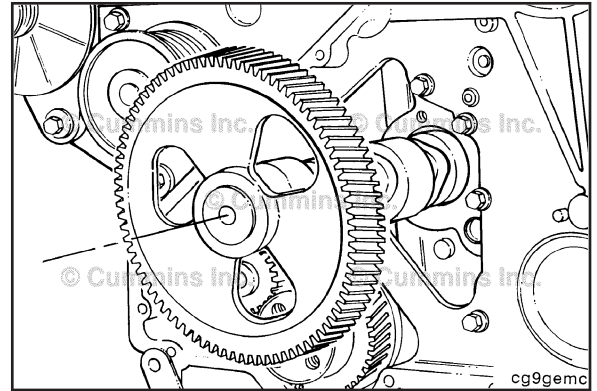
Wrap rubber bands around the wooden dowels to secure the tappets.



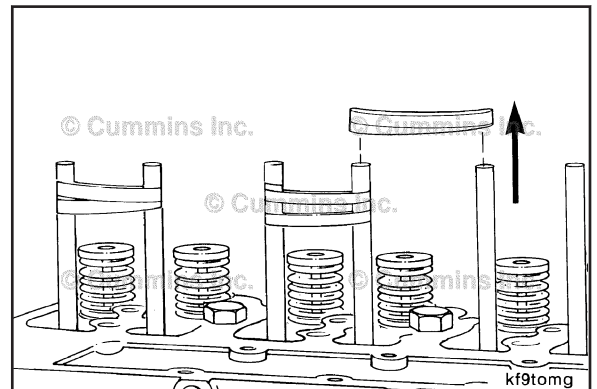
Repeat this process until all tappets have been installed.

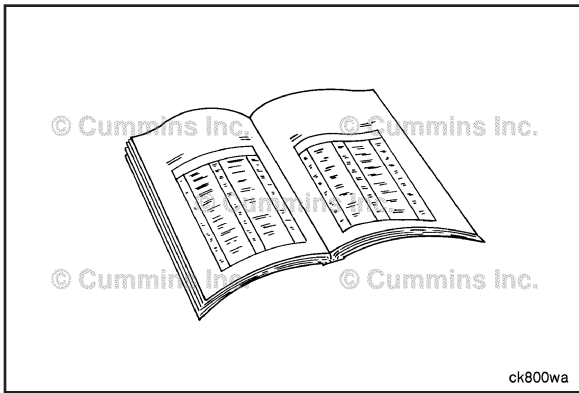


Install the camshaft. For C Series diesel engines, refer to Procedure 001-008 in Troubleshooting and Repair Manual, C Series Engines, Bulletin 3666003. For C Series gas engines, refer to Procedure 001-008 in Troubleshooting and Repair Manual, C8.3G (Natural Gas) Engines, Bulletin 3666206.



Remove the dowel rods and release the tappets in the tappet bores.





Finishing Steps

- Install the oil pan. Refer to Procedure 007-025.
- Fill the engine with clean engine oil. Refer to Procedure 007-037.
- Install the front gear cover. Refer to Procedure 001-031.
- Install the push rods. Refer to Procedure 004-014.
- Install the rocker levers. Refer to Procedure 003-008.
- Adjust the overhead set. For C Series diesel engines, refer to Procedure 003-004 in Troubleshooting and Repair Manual, C Series Engines, Bulletin 3666003. For C Series gas engines, refer to Procedure 003-004 in Troubleshooting and Repair Manual, C8.3G (Natural Gas) Engines, Bulletin 3666206.
- Install the rocker lever cover. Refer to Procedure 003-011.

Operate the engine until the coolant temperature reaches 82°C [180°F], and check for leaks and proper operation.

Section 5 - Fuel System - Group 05

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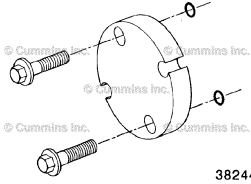
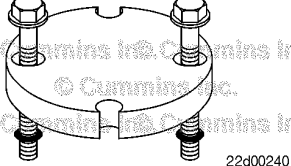
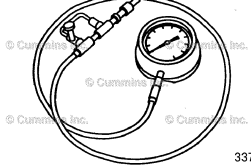
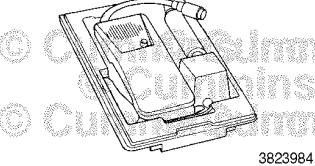

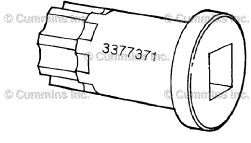
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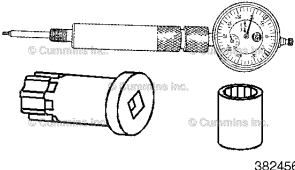
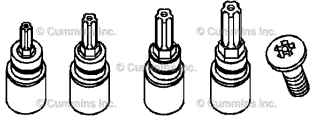
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Service Tools

Fuel System

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

Tool No.	Tool Description	Tool Illustration
3824469	<p align="center">Fuel Pump Gear Puller</p> <p>Fuel pump gear puller, Part Number 3824469 has been obsoleted. This tool can be used with M8-1.25 x 50 capscrews, Part Number 3900633, grade 8.8 flange head capscrews or equivalent.</p>	 <p align="right">3824469</p>
3163381	<p align="center">Fuel Pump Gear Puller</p> <p>Used to pull the fuel pump gear. Includes Part Number 3900633 capscrews.</p>	 <p align="right">22d00240</p>
3375932	<p align="center">Pressure Gauge</p> <p>Used to measure gas pressure after high-pressure regulator.</p>	 <p align="right">3375932</p>
3823984	<p align="center">Combustible Gas Detector</p> <p>Used to detect combustible gas leaks.</p>	 <p align="right">3823984</p>
3824510	<p align="center">QD Contact Cleaner</p> <p>A nonpetroleum cleaner used to clean electrical connections.</p>	 <p align="right">oi8togt</p>
3377371	<p align="center">Engine Barring Tool</p> <p>Used to rotate the crankshaft.</p>	 <p align="right">3377371</p>

Tool No.	Tool Description	Tool Illustration
<p>3824563</p>	<p align="center">Lift Plunger Timing Tool</p> <p>Used to time the lift plunger.</p>	 <p align="right">3824563</p>
<p>3399870</p>	<p align="center">Tamper Screw, Removal Tool</p> <p>Used to remove the tamper screws.</p>	 <p align="right">3399870</p>

AFC Assembly (005-001)

General Information

⚠CAUTION⚠

The AFC is a performance part and must not be tampered with after adjustment at the factory. Tampering with the AFC can cause poor fuel economy and failure to meet regulatory emissions laws.

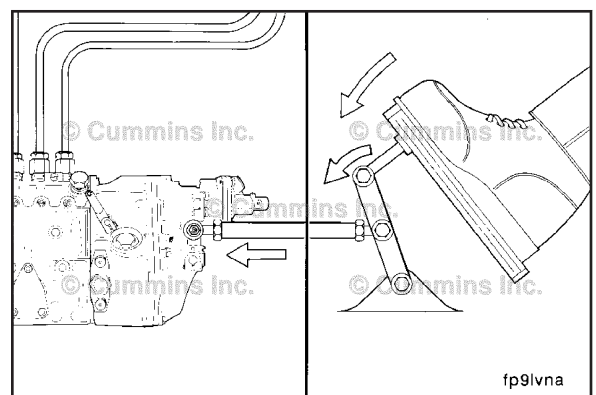
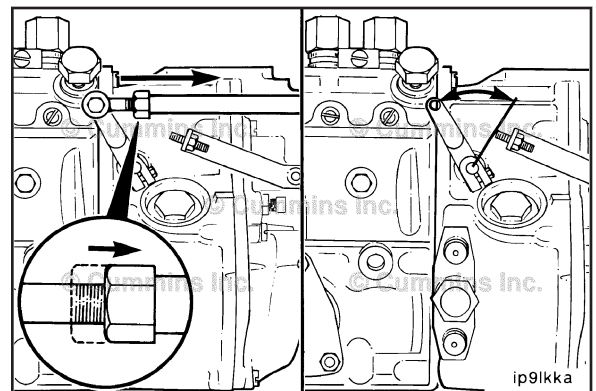
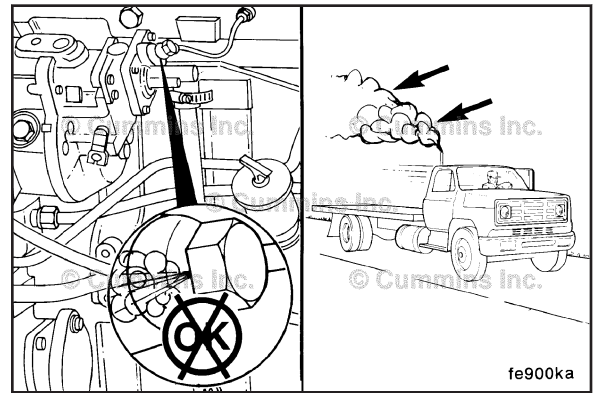
The RSV, RQV, and RQVK governors are equipped with an air-fuel control (AFC) device to help control emissions. The AFC regulates the fuel-to-air mixture by sensing manifold pressure. A malfunction of the AFC can cause low power and excessive exhaust smoke under load. Leaks at the fittings or a restriction in the tube from the intake manifold to the AFC can also cause low power and excessive smoke.

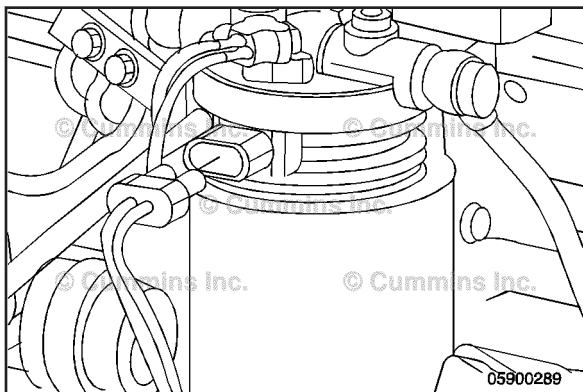
Manual Shutdown Levers

The mechanical shutdown lever is located on the governor. These levers are spring-loaded in the run position except the electrical direct link shutdown solenoid. **Not** all applications will use these manual shutdown controls.

NOTE: Partial actuation of the mechanical shutdown lever will affect fuel flow and engine power.

Low power or the inability to stop the engine with the manual shutdown control can be corrected by adjusting the cable/rod length to permit stop-to-stop lever travel.





Engine Fuel Heater, Electric (005-008) Initial Check



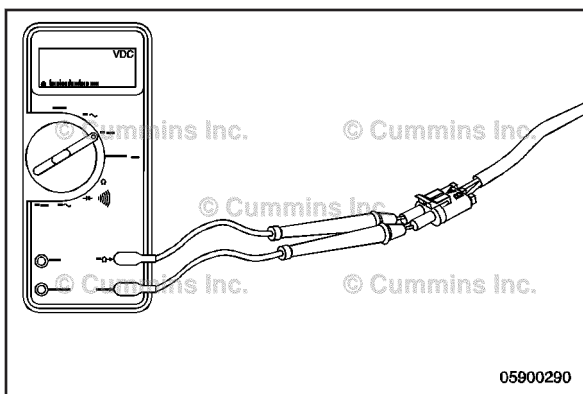
NOTE: A bimetallic strip on the filter head acts as a thermostat. The fuel heater will turn on at approximately 1°C [34°F] and turn off at approximately 18°C [65°F].



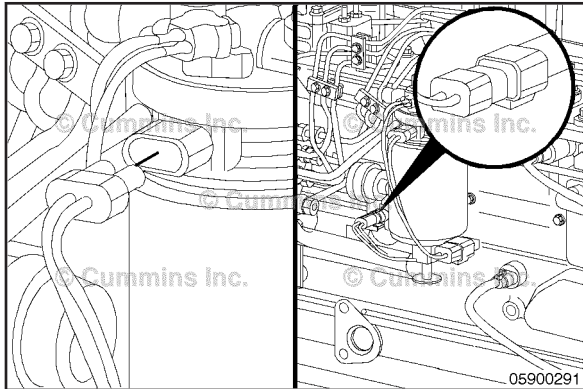
Remove the 2-pin connector from the fuel heater. Check for the proper voltage at the fuel heater connector.

Fuel Heater - Voltage12 VDC

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

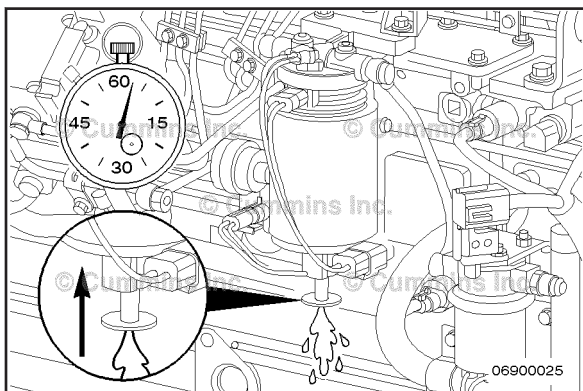


Use a multimeter to check the continuity of the fuel heater. Place the multimeter leads across the pins of the fuel heater; if the heater circuit is open, replace the fuel heater.



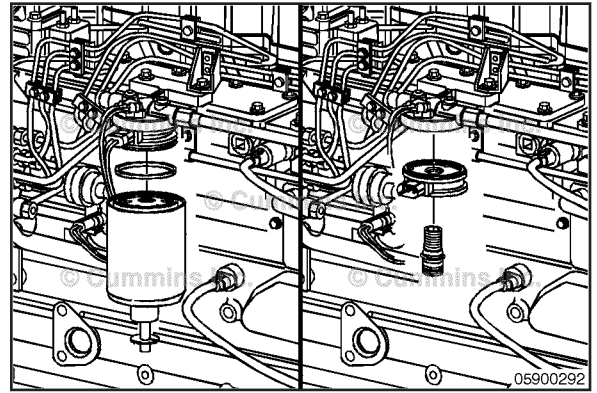
Remove

Disconnect the 2-pin connector from the fuel heater.
Disconnect the connector from the water-in-fuel sensor.



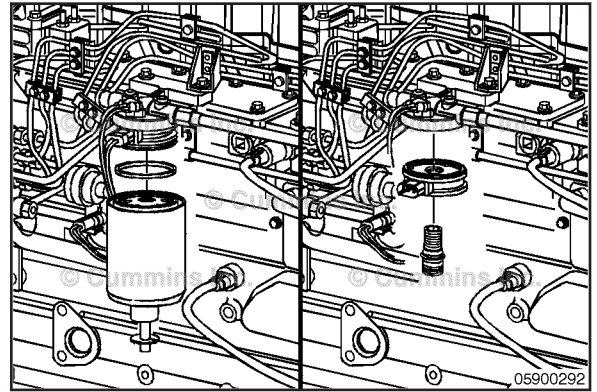
Push on the fuel drain valve for approximately 5 seconds to reduce fuel spillage during filter removal.

Remove the fuel filter.
Remove the fuel filter spud.
Remove the fuel heater from the filter head.
NOTE: The fuel heater should pull off the fuel filter head.

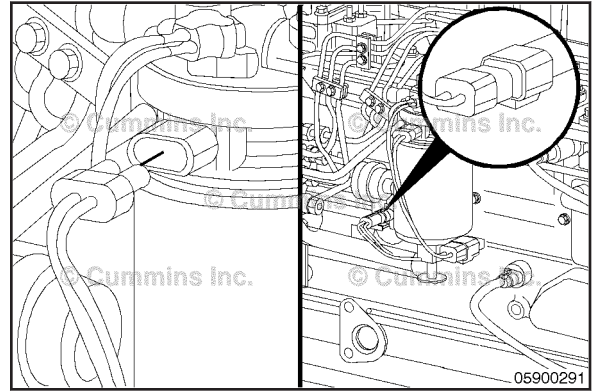


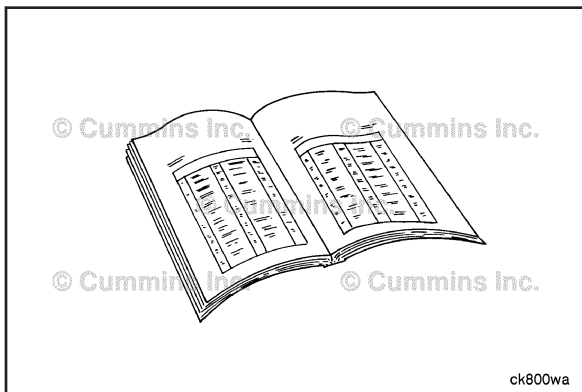
Install

Install the fuel heater to the filter head.
Install the fuel filter spud.
Install the fuel filter.
NOTE: The fuel heater should push onto the fuel filter head with hand-pressure.



Connect the fuel heater 2-pin connector.
Connect the water-in-fuel sensor connector.





Fuel Injection Pumps, In-Line (005-012)

Preparatory Steps

⚠️ WARNING ⚠️

Fuel is flammable. Keep all cigarettes, flames, pilot lights, arching 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 ⚠️

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.

- Clean any debris from the fuel injection pump.
- Remove the fuel supply lines. Refer to Procedure 006-024.
- Remove the injector supply lines. Refer to Procedure 006-051.
- Remove the control linkage. Refer to the OEM service manual.
- Remove the fuel shutoff solenoid. Refer to Procedure 005-043.
- Remove the air fuel control air line.
- Remove the governor oil supply line.

Time

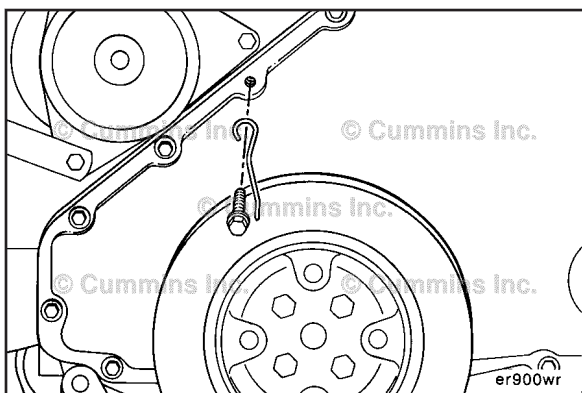
Marine Applications

⚠️ CAUTION ⚠️

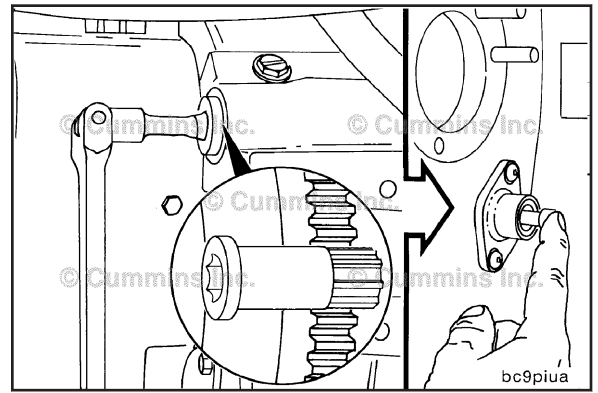
Do not use the timing pin to locate engine top dead center for marine applications. This can result in incorrect timing, poor engine performance, and engine smoke problems.

To locate actual top dead center, fabricate a timing mark pointer for the front of the engine.

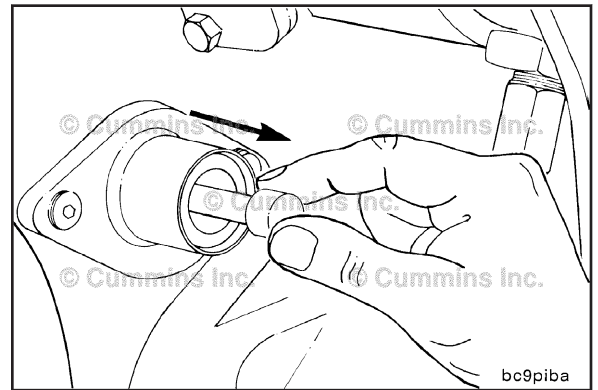
NOTE: This can be done by forming a piece of 16 gauge wire that can be tightened under one of the gear cover capscrews. Sharpen the wire at the vibration damper end so that it comes to a point for better accuracy.



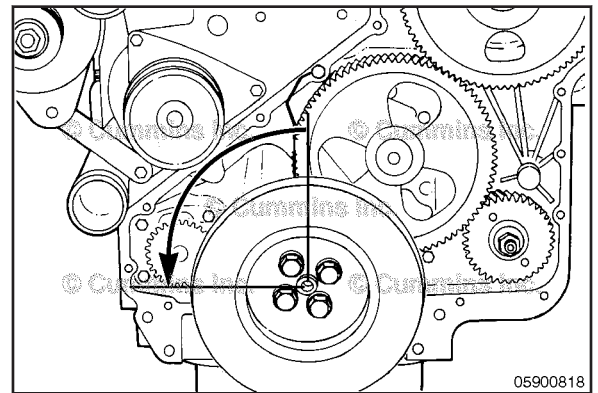
Locate top dead center for cylinder Number 1 by barring crankshaft slowly while pressing on the engine timing pin. Barring the engine is recommended from the flywheel on the rear of the engine using barring tool, Part Number 3824591.



To prevent damage to the engine or timing pin, you **must** disengage the timing pin after locating top dead center.

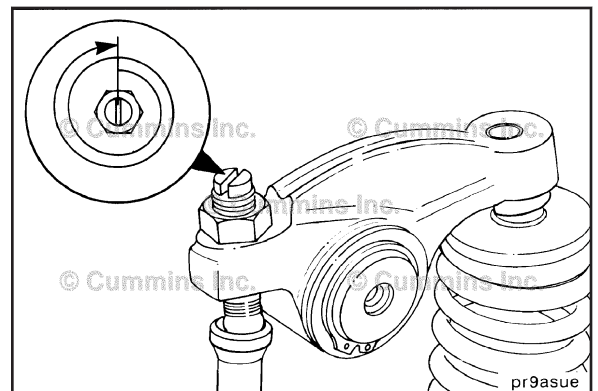


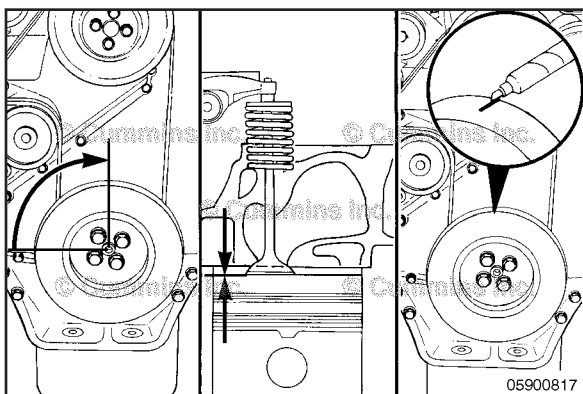
Rotate the crankshaft 90 degrees in the direction opposite normal rotation (**counterclockwise**).



Tighten the adjusting screw for the intake valve on number 1 cylinder three complete turns of the screw.

NOTE: Leave the adjusting screw in this position until top dead center is established.

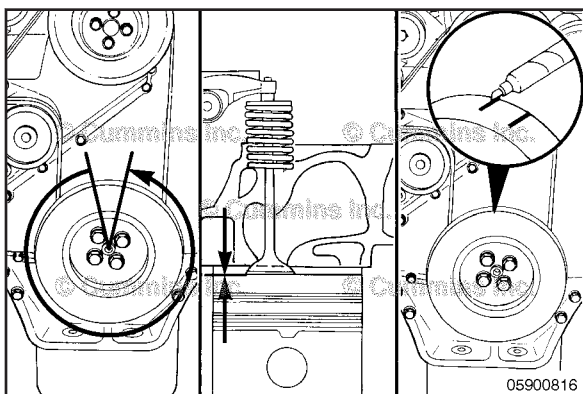




⚠CAUTION⚠
Use extreme care that the piston does not push against the valve with so much force that it bends the push rod or valve.

Rotate the crankshaft slowly in the direction of the engine rotation until the piston touches the intake valve.

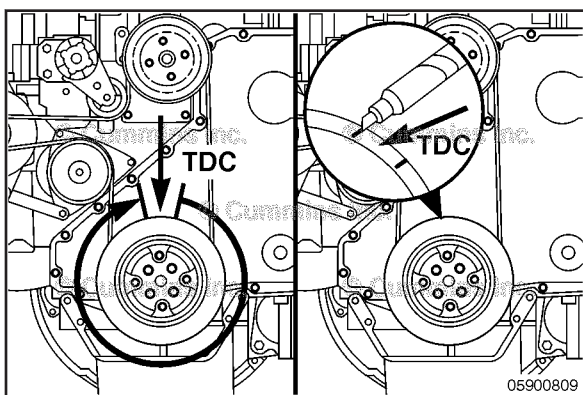
Place a mark on the vibration damper at the tip of the pointer.



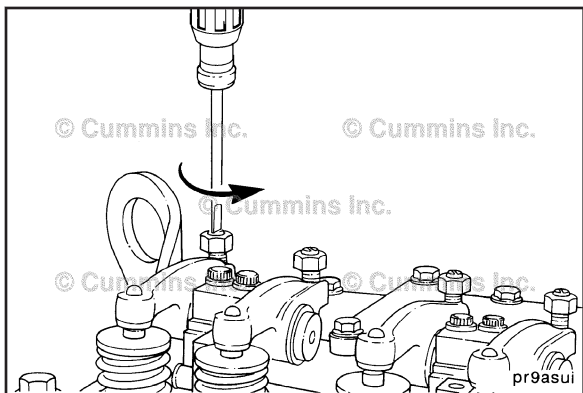
⚠CAUTION⚠
Make certain that the piston does not push against the valve with so much force that it bends the push rod or valve.

Rotate the crankshaft in the opposite direction until the piston touches the intake valve.

Place a mark on the vibration damper at the tip of the pointer.



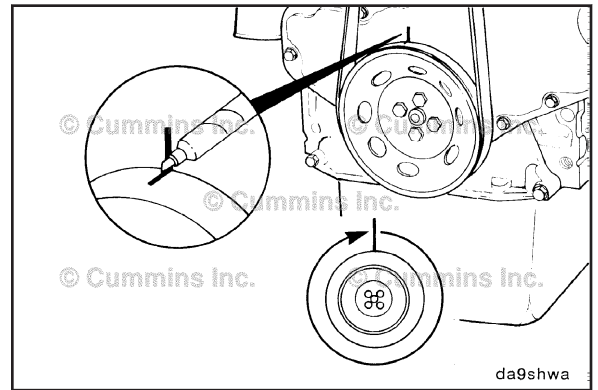
Measure the distance and mark the damper at one-half the distance between the two marks. This mark is the top dead center mark.



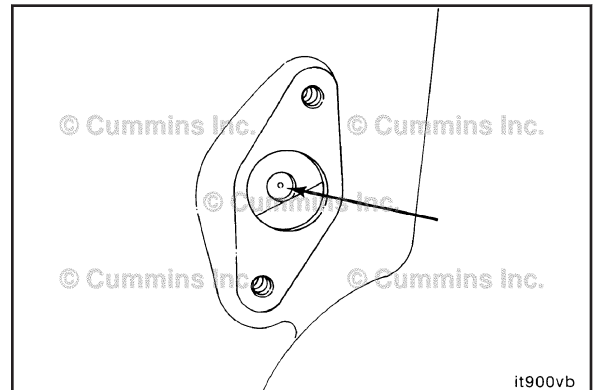
⚠CAUTION⚠
Failure to loosen the adjusting screw will result in bending the push rod and/or valve stem when the crankshaft is rotated.

Loosen the intake valve adjusting screw and reset the valve to the proper clearance. Refer to Procedure 003-004.

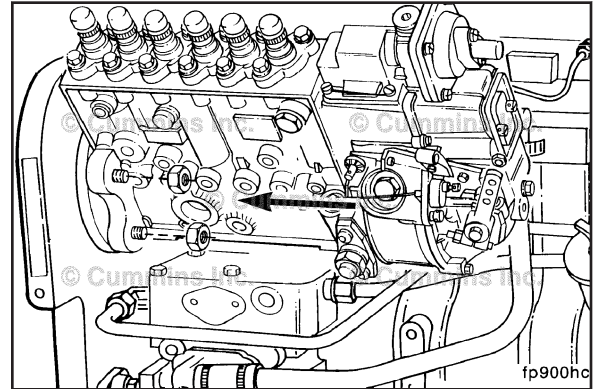
Rotate the crankshaft in the direction of the engine rotation until the pointer is aligned with the top dead center.



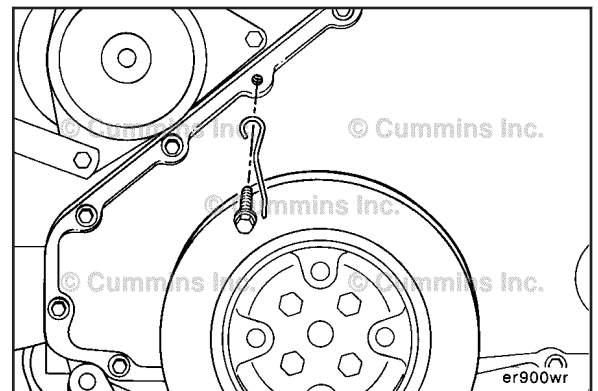
Look through the back side of the gear housing for the timing pin hole in the camshaft gear. If the hole is **not** visible, the crankshaft **must**, be rotated one revolution.

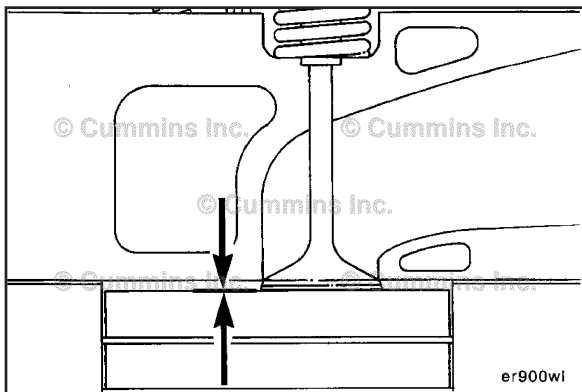


The engine is at the proper top dead center and the fuel pump can be installed for the correct timing. See the Install procedure.



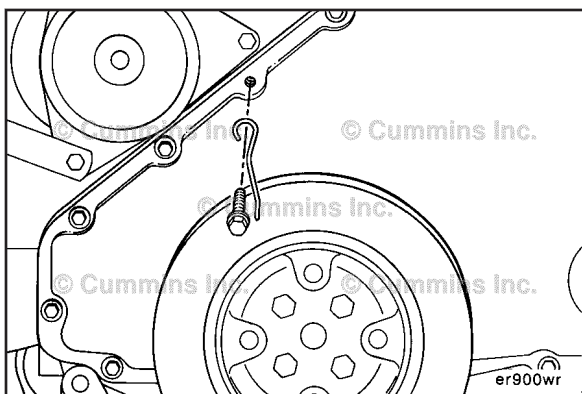
Remove the timing mark pointer from the front gear cover.





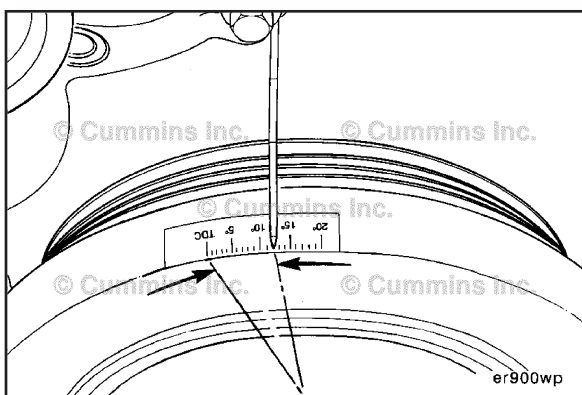
Automotive and Industrial

Use cylinder number 1 intake valve to make certain that the engine is at top dead center on the compression stroke for cylinder number 1. Refer to Procedure 001-049.



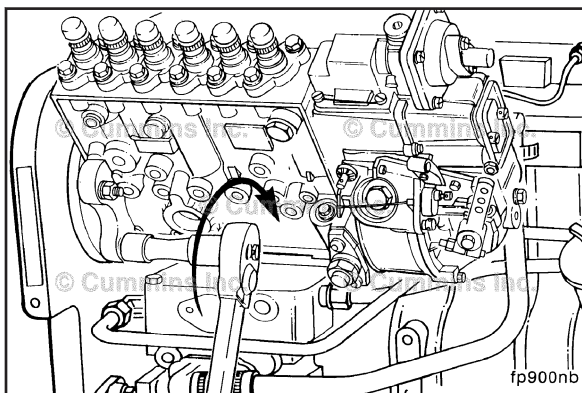
Fabricate a timing marker for the front of the engine.

NOTE: This can be done by forming a piece of 16 gauge wire that can be tightened under one of the gear cover capscrews. Sharpen the wire at the vibration damper end so that it comes to a point for better accuracy.



Attach a degree wheel or degree tape to the front of the vibration damper. Line the top dead center mark up with the pointer.

The degree wheel/tape **must** measure to an accuracy of at least ± 1 degree.



⚠ WARNING ⚠



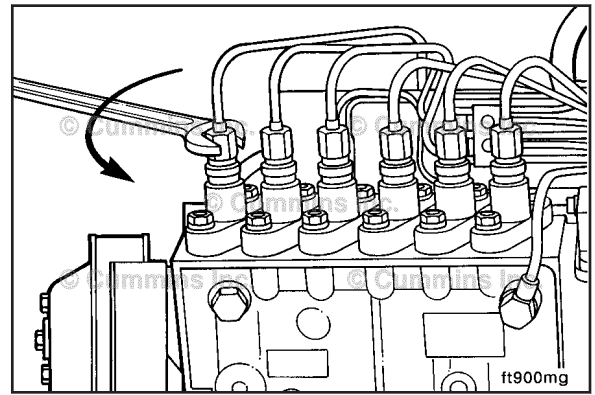
Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

Install the fuel injection pump. See the Install section.

If the fuel injection pump is already installed, continued the procedure.

Remove the number 1 high-pressure fuel line from the fuel injection pump.

NOTE: Lines 2 through 6 **must not** be removed or loosened.



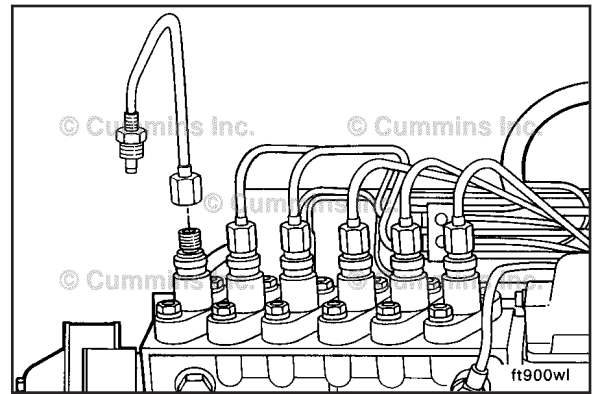
⚠CAUTION⚠

When attaching the fabricated tube, do not bend the number 1 high-pressure fuel line. This can cause the inside of the fuel line to flake and cause injector failure.

A short length of high-pressure line that is compatible with the fuel lines used on the engine **must** be bent in a "U" shape and installed onto the delivery valve holder of the fuel injection pump.

The line is used to observe when the fuel is or is **not** flowing through the delivery valve holder assembly.

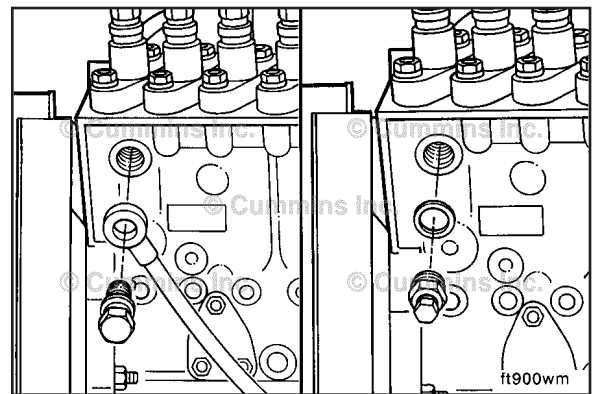
Place a container under the tube to catch the fuel or drain the fuel back into the spill port pump.



Remove the overflow valve from the fuel injection pump.

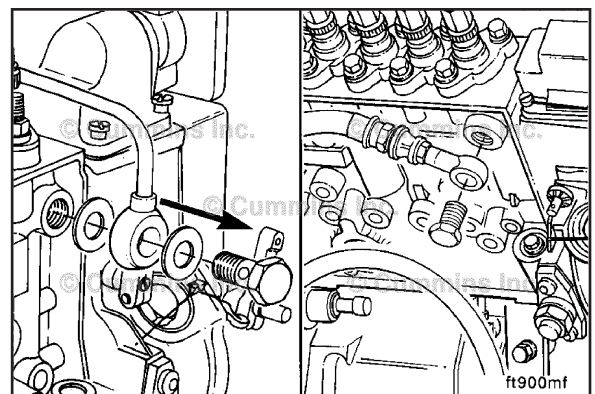
Install a 14-mm threaded plug and sealing washer into the fuel return port of the fuel injection pump.

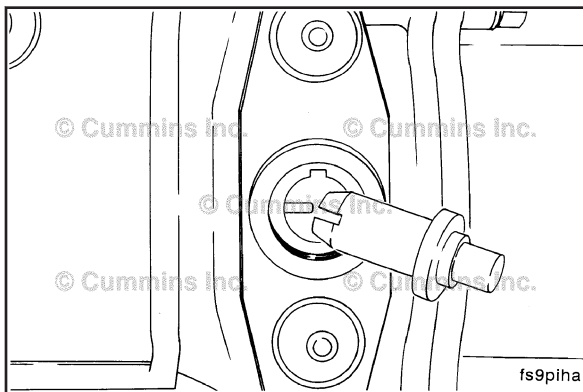
NOTE: The fuel return port is located on the inboard front side of the fuel injection pump for automotive in-line applications and on the outboard front side for most industrial applications



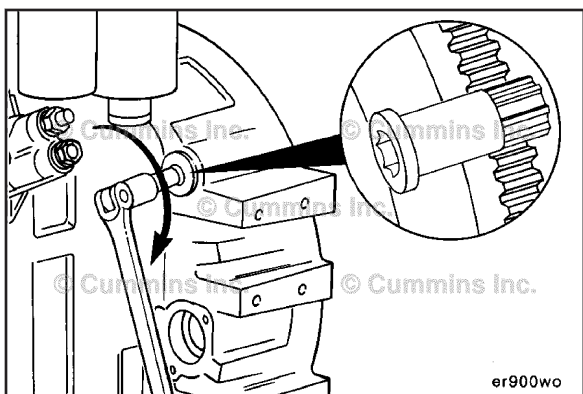
Remove the fuel supply line between the fuel filter head and the fuel injection pump.

Attach the high-pressure outlet hose from the spill port pump cart to the fuel injection pump supply port.

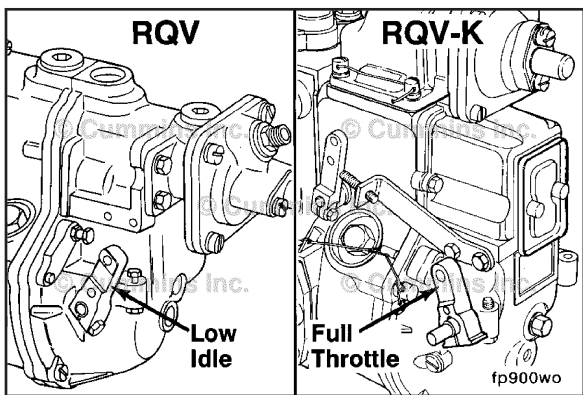




Before continuing, make certain that the fuel injection pump timing pin is disengaged.



Rotate the crankshaft **counterclockwise**, as viewed from the front of the engine, to approximately 40 degrees before top dead center.



Adjust Governor

▲ WARNING ▲
Fuel is flammable. Keep all cigarettes, flames, pilot lights, arching 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.

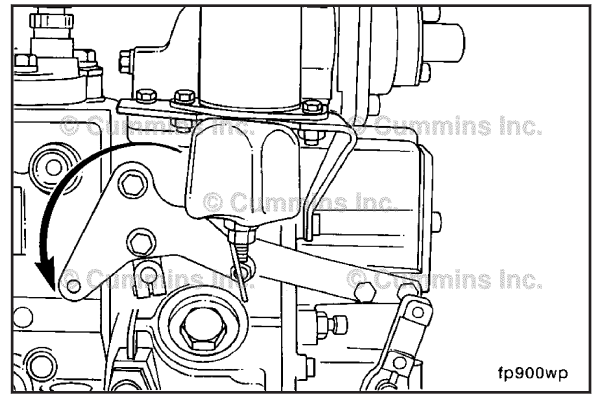
NOTE: The governor lever **must** be positioned before pressuring the fuel injection pump.

The RQV governor throttle lever **must** be in the low-idle lever position.

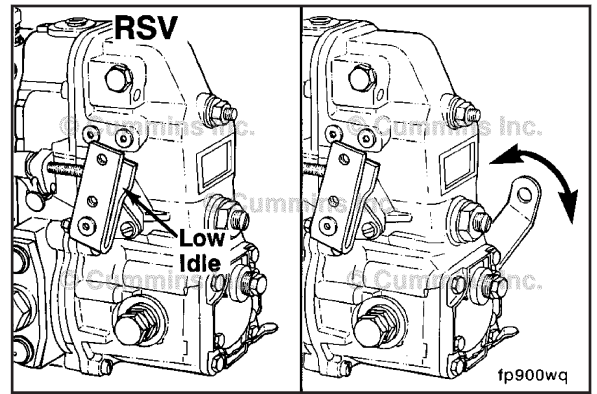
Automotive engines with a RQV-K governor throttle lever **must** be in the high-idle throttle position.

Industrial engines with a RQV-K governor throttle lever **must** be in the low-idle throttle position.

Both the RQV and RQV-K governor **must** have the shutdown lever in the full-run position.



The RSV governor throttle lever **must** be in the low-idle position and the shutdown lever needs to be wired or locked in the 1/2-travel position.

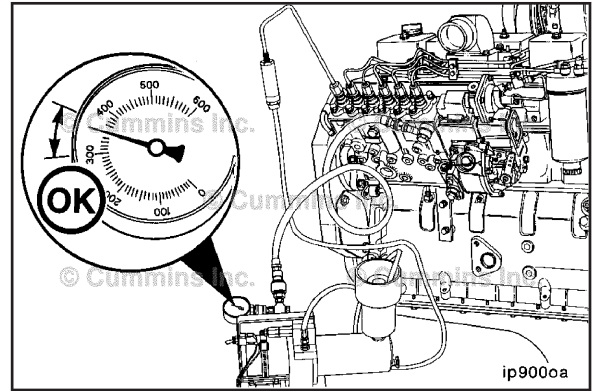


Turn on the spill timing cart pump.
 Check the fuel pressure.

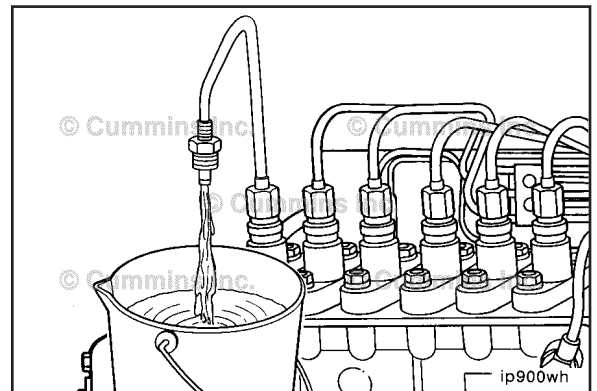
Fuel Spill Timing Cart - Fuel Pressure

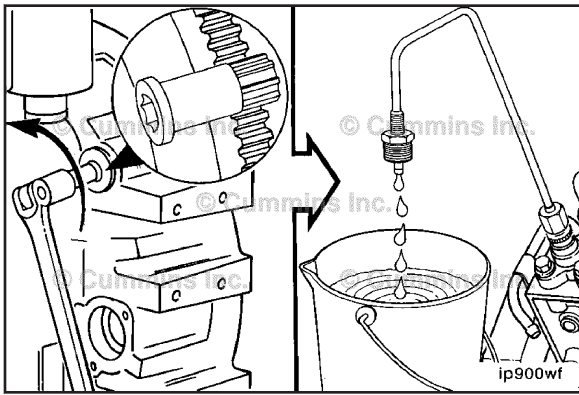
kPa		psi
2068	MIN	300
2551	MAX	370

NOTE: The shutdown lever **must** be held in the required position before turning the spill cart pump on.



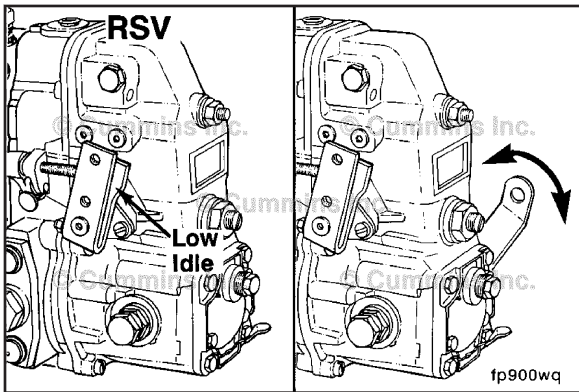
Fuel **must** be flowing out of the tube attached to the fuel injection pump. If the fuel is **not** flowing, check the procedures again carefully.





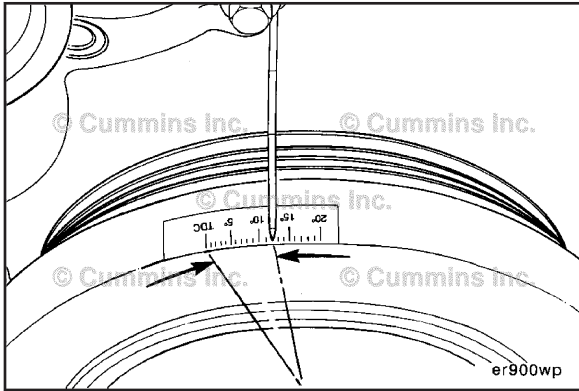
Slowly rotate the crankshaft **clockwise**, as viewed from the front of the engine, until fuel flow from cylinder number 1 begins.

The plunger number 1 element is now approaching port closure. Continue to rotate the crankshaft slowly until the flow is reduced to a drip. At the point that the steady stream of flow changes from a solid flow to a drip, stop. This is the static timing position of the fuel injection pump.

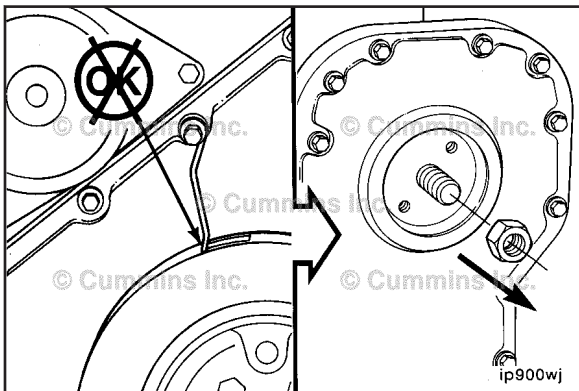


If the flow does **not** slow down to a drip:

- Check the position of the governor lever.
- Make certain that the cylinder number 1 is before top dead center on the compression stroke.
- Turn off the spill port pump.



Check the degree wheel on the vibration damper to see what engine degree the timing pointer is indicating. This is spill port static timing. Compare this number to the timing specification for your particular application.

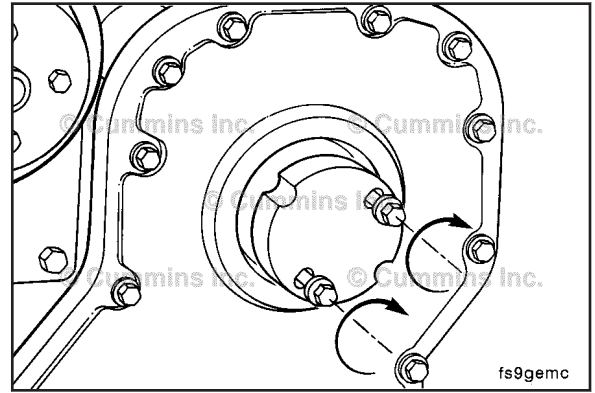


If the fuel injection pump static timing, as measured by the above method, is **not** within specification, remove the large nut that fastens the fuel injecting pump camshaft to the fuel pump drive gear.

If the crankshaft has rotated, turn on the spill port pump and rotate the crankshaft to find port closure.

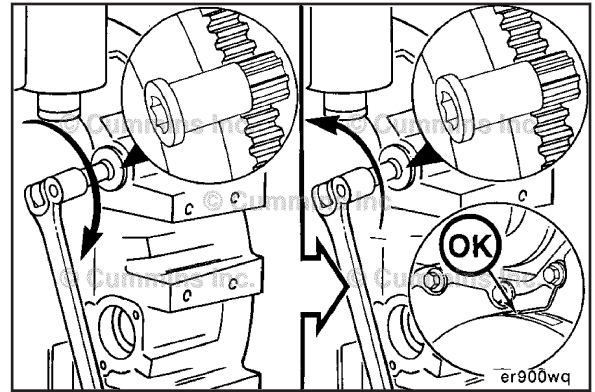
Turn off the spill port pump.

Use fuel pump gear puller, Part Number 3163381 or Part Number 3824469 with M8-1.25 x 50 capscrews, grade 8.8 or equivalent. Pull the fuel injection pump drive gear loose from the shaft.



Slowly rotate the crankshaft **counterclockwise** about 40 degrees past the desired static timing specification.

Slowly rotate the crankshaft **clockwise** until the timing pointer indicates the desired static timing.

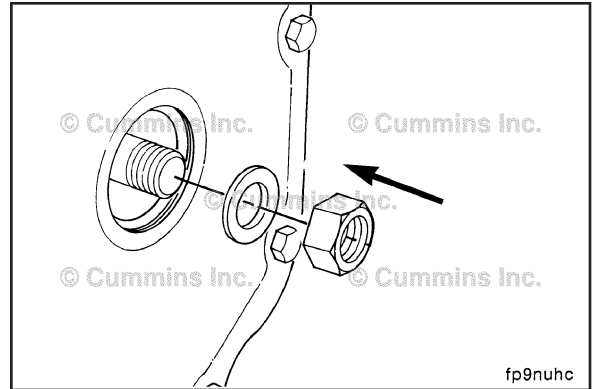


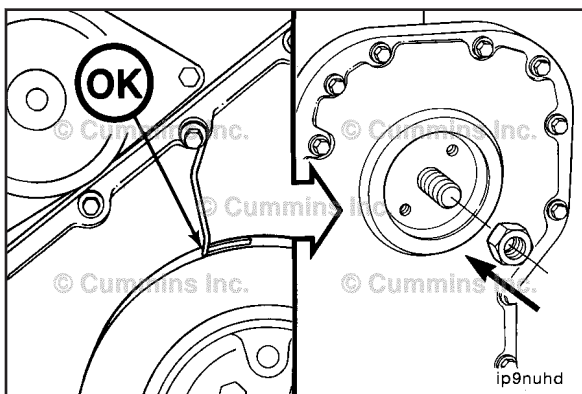
⚠CAUTION⚠

To prevent damage to the timing pins, do not exceed the torque value given. This is not the final torque value for the retaining nut.

Install and tighten the retaining nut and washer.

Torque Value 12 N•m [106 in-lb]





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

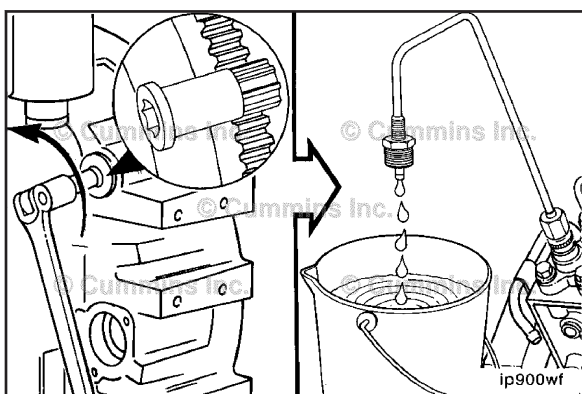
⚠ WARNING ⚠
When using solvents, acids, or alkaline materials for cleaning, follow manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠ CAUTION ⚠
Failure to clean and dry the shaft and gear tapers thoroughly can result in timing shift to the retarded side after the engine is started and running under a load. This will result in low power, smoke, rough running, and engine damage.

Tighten the fuel injection pump drive nut.

Make certain that the static timing has **not** changed after the fuel injection drive nut is tightened to the required specification.

Before installing the fuel pump drive gear, clean the injection pump shaft and gear tapers with QD Contact Cleaner, Part Number 3824510, by spraying into the gap between the shaft and the gear. Dry the surface with compressed air.



Tighten the fuel injection pump drive gear nut.

Torque Values:

Torque Value:

Nippondenso
Step 1 123 N•m [91 ft-lb]

Torque Value:

Bosch A Pump
Step 1 85 N•m [63 ft-lb]

Torque Value:

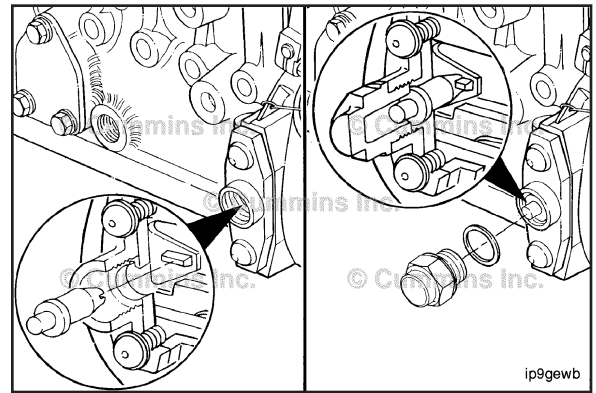
Bosch MW Pump
Step 1 105 N•m [77 ft-lb]

Torque Value:

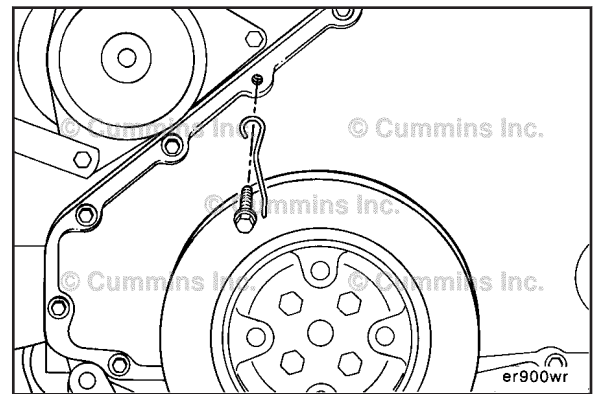
Bosch P3000/P7100
Step 1 195 N•m [144 ft-lb]

Repeat this procedure as needed until the timing matches the specification.

The fuel injection pump timing pin **must** fit over the injection pump pointer when the engine is at top dead center or on the compression stroke for the cylinder number 1. If it does **not**, the fuel injection pump **must** be adjusted by an authorized fuel injection pump shop or the fuel injection pump was installed incorrectly.



Remove the degree wheel and timing mark pointer.



Remove

Automotive and Industrial

⚠️ WARNING ⚠️

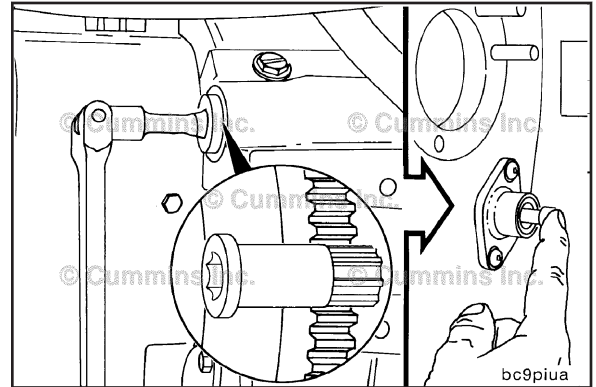
Fuel is flammable. Keep all cigarettes, flames, pilot lights, arching equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

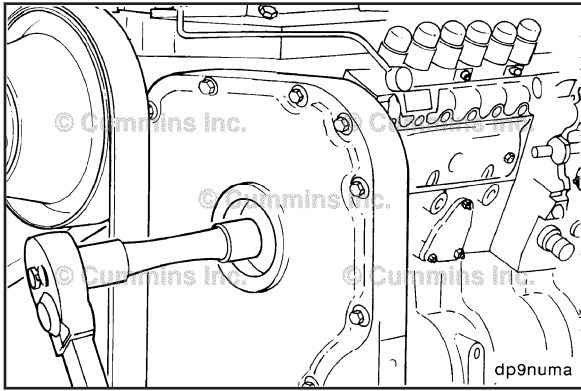
⚠️ CAUTION ⚠️

Do not use the timing pin to locate engine top dead center for marine applications. This can result in incorrect timing, poor engine performance, and engine smoke problems.

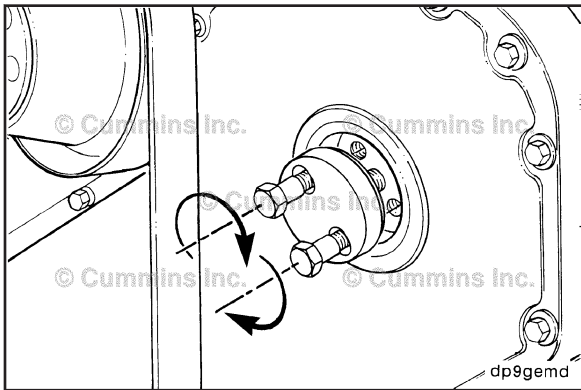
Locate top dead center for cylinder Number 1. Push the timing pin into the hole in the camshaft gear while slowly rotating the crankshaft with the barring tool, Part Number 3377371.

NOTE: Make certain that the timing pin is disengaged after locating top dead center.

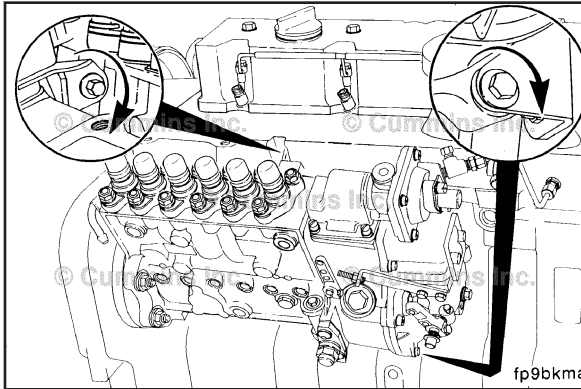




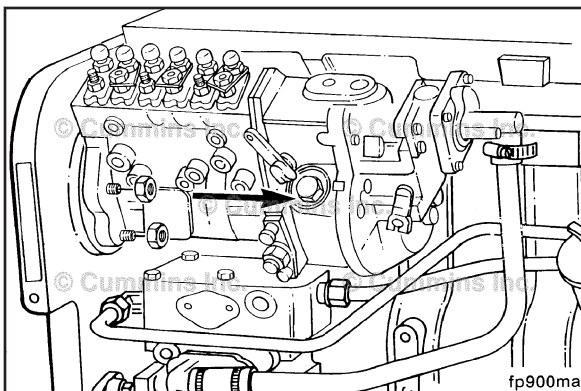
Remove the front gear cover access cap.
Remove the nut and washer from the fuel injection pump shaft.



Use fuel pump gear puller, Part Number 3163381 or Part Number 3824469 with M8-1.25 x 50 capscrews, grade 8.8 or equivalent. Pull the fuel injection pump drive gear loose from the shaft.



Engines equipped with the P7100, P3000, A, and MW fuel injection pump are equipped with support brackets that **must** be removed.



Remove the four fuel injection pump mounting nuts.
Remove the fuel injection pump.

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 ⚠

Do not use the timing pin to locate engine top dead center for marine applications. This can result in incorrect timing, poor engine performance, and engine smoke problems.

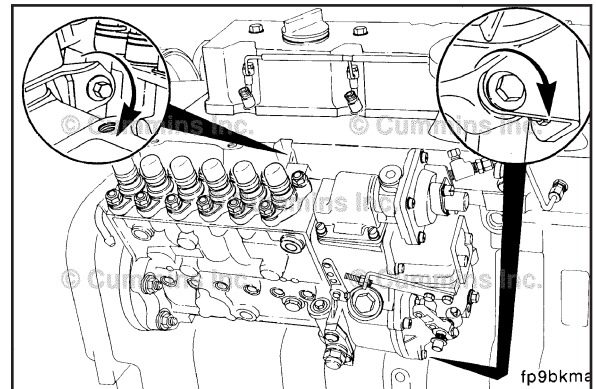
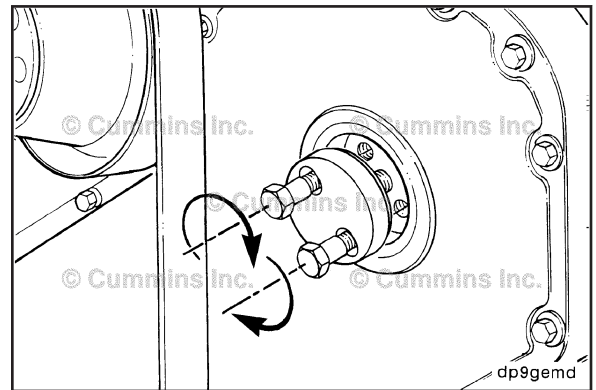
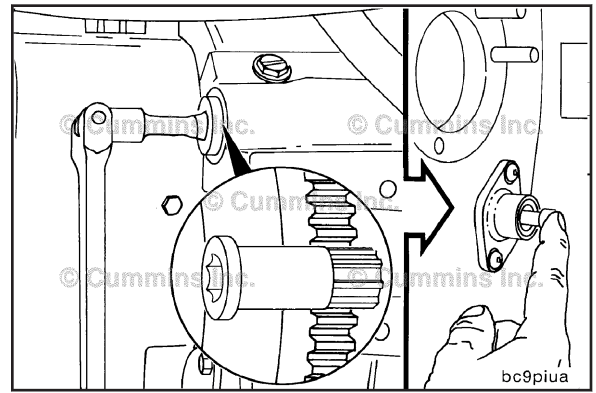
Locate top dead center for cylinder number 1. See the Time, Marine Applications section.

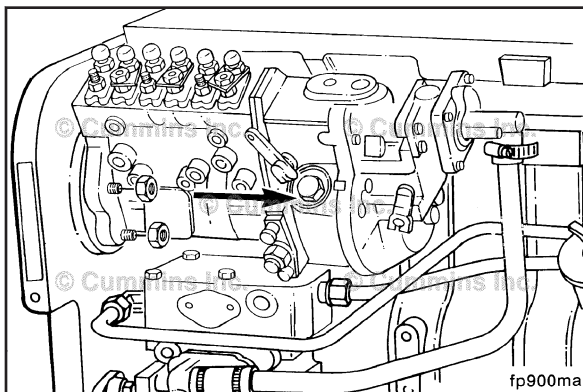
Remove the front gear cover access cap.

Remove the nut and washer from the fuel injection pump shaft.

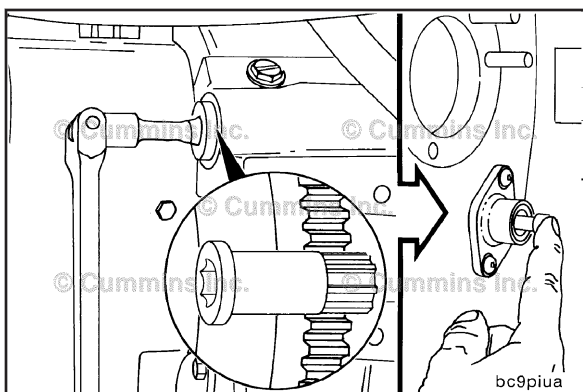
Use fuel pump gear puller, Part Number 3163381 or Part Number 3824469 with M8-1.25 x 50 capscrews, grade 8.8 or equivalent. Pull the fuel injection pump drive gear loose from the shaft.

Engines equipped with P7100, P3000, A, or MW fuel injection pumps are equipped with support brackets that **must** be removed.





Remove the four fuel injection pump mounting nuts.
Remove the fuel injection pump.



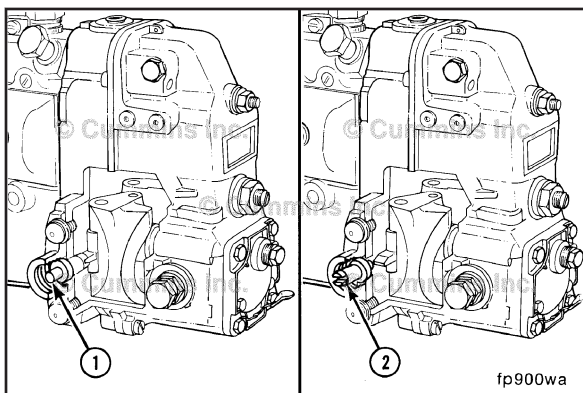
Install

Automotive and Industrial

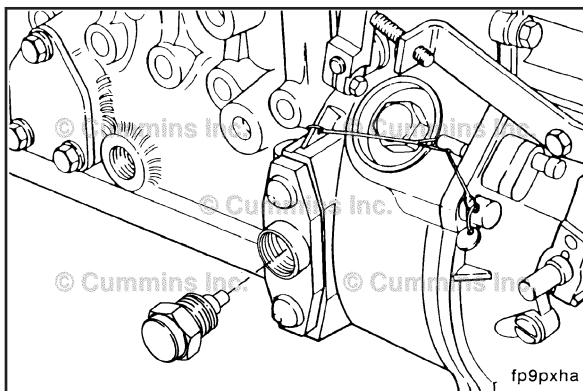
⚠CAUTION⚠

Do not use the timing pin to locate engine top dead center for marine applications. This can result in incorrect timing, poor engine performance, and engine smoke problems.

Make certain that the cylinder Number 1 is at top dead center.

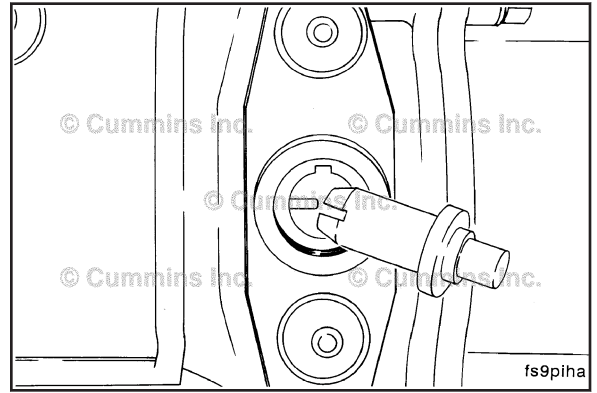


The fuel injection pump also has a timing pin (1), located in the governor housing, to position the fuel injection pump shaft to correspond with top dead center for cylinder Number 1. The timing pin **must** be reversed and stored in the housing (2) after the fuel injection pump is installed.

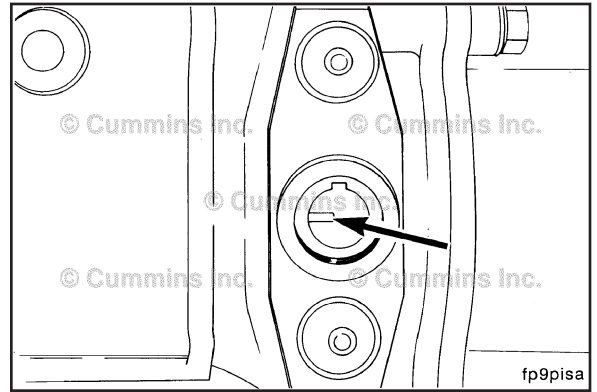


Remove the fuel injection pump timing pin access plug.

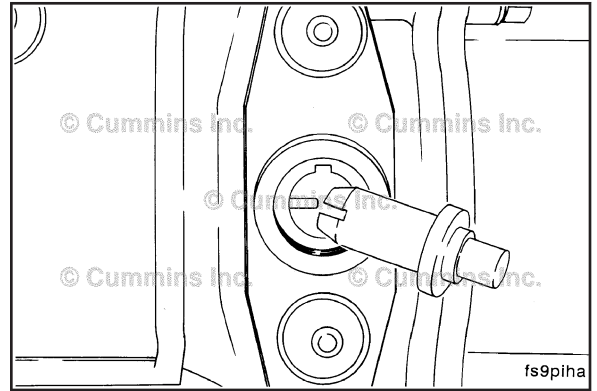
Remove the timing pin.



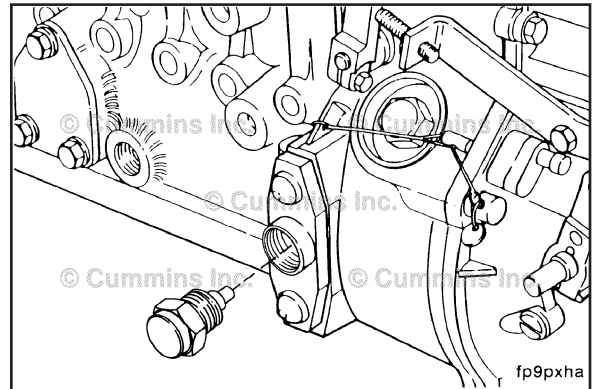
If the timing tooth is **not** aligned with the timing pin hole, rotate the fuel injection pump shaft until the timing tooth aligns.

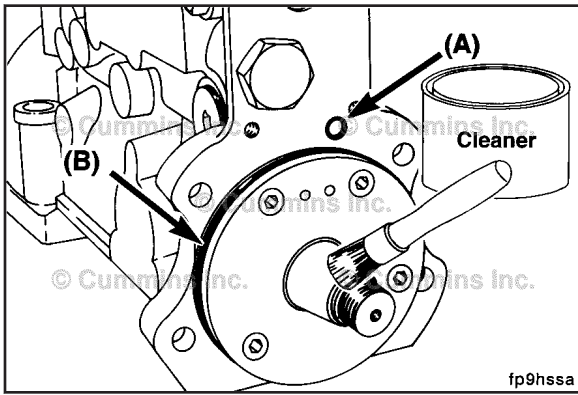


Reverse the position of the timing pin so that the slot of the timing pin will fit over the timing tooth in the fuel injection pump.



Install and secure the timing pin with the access plug.





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



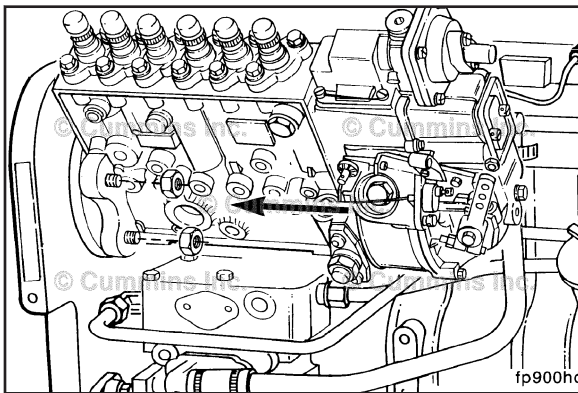
Make certain that the o-ring seals for the fill orifice and pilot are correctly installed and are **not** damaged.



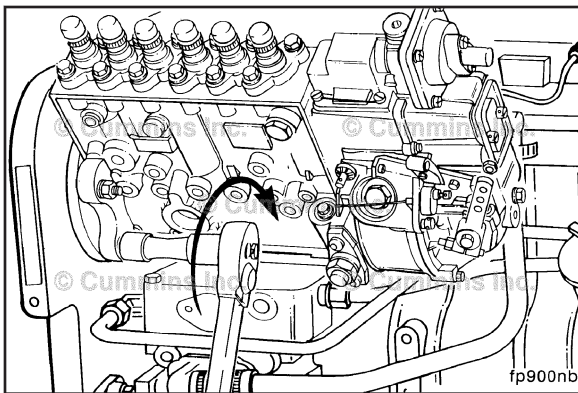
Lubricate the mounting flange with clean lubricating engine oil.

Before installing the fuel pump drive gear, clean the injection pump shaft and gear tapers with QD Contact Cleaner, Part Number 3824510, by spraying into the gap between the shaft and the gear.

Dry the surface with compressed air.



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



CAUTION
Do not pull the injection pump into the gear housing with the mounting nuts. Damage to the gear housing and fuel pump can result.



Install the fuel injection pump mounting nuts.

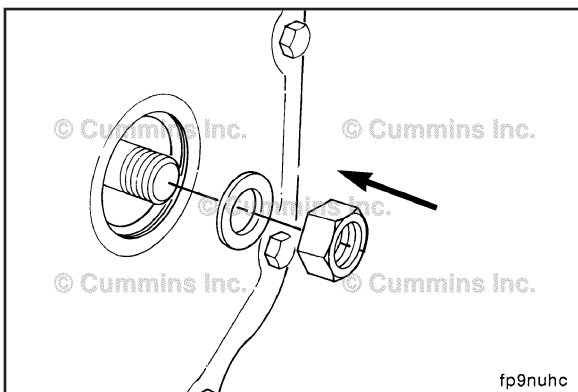
Install the support bracket, if equipped.

Torque Value:

Mounting nuts
Step 1 44 N•m [32 ft-lb]

Torque Value:

Support bracket nuts
Step 1 32 N•m [24 ft-lb]



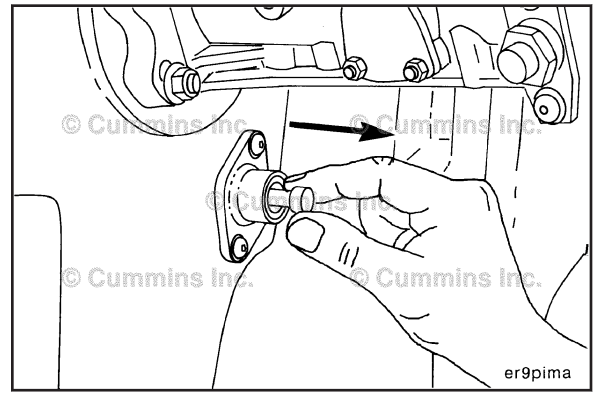
NOTE: To prevent damage to the timing pins, do **not** exceed the torque value given. This is **not** the final torque value for the retaining nut.



Install and tighten the fuel injection pump retaining nut and washer.

Torque Value: 12 N•m [106 in-lb]

Disengage the engine timing pin.

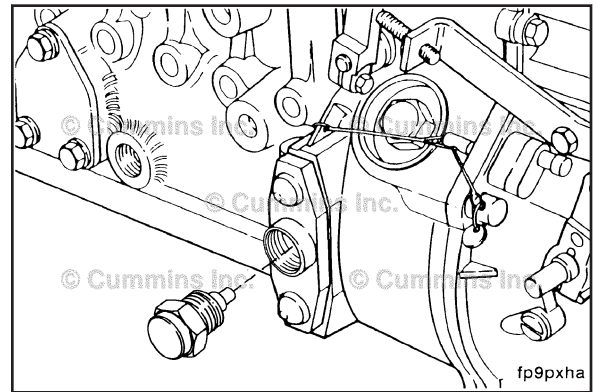


⚠CAUTION⚠
The governor housing must be pre-lubricated before engine operation. Failure to do so will result in premature governor wear.

Remove the access plug.

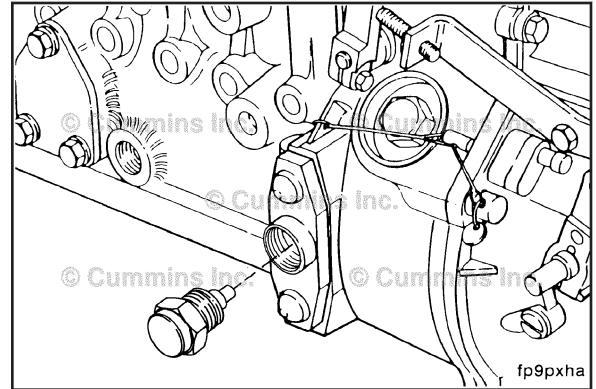
Add the following quantity of clean engine oil:

- RSV 450 ml [0.48 qt]
- RQV 750 ml [0.79 qt]
- RQVK 750 ml [0.79 qt].



Install the access plug.

Torque Value: 28 N•m [21 ft-lb]



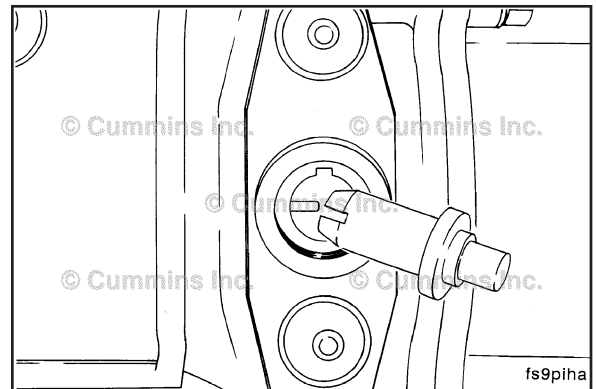
Remove the fuel injection pump timing pin plug.

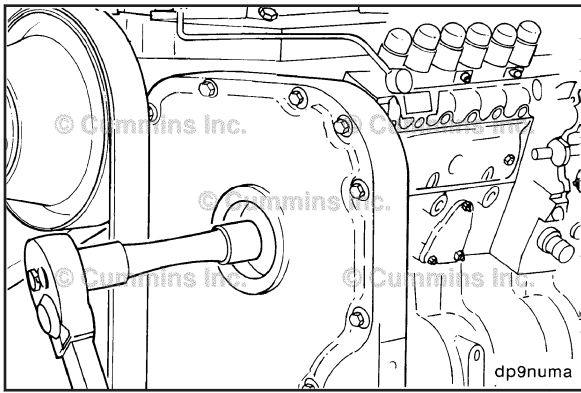
Reverse the position of the timing pin.

Install the timing pin, plug, and sealing washer.

Tighten the timing pin plug.

Torque Value: 15 N•m [133 in-lb]





⚠CAUTION⚠

Failure to clean and dry the shaft and gear tapers thoroughly can result in timing shift to the retarded side after the engine is started and running under a load. This will result in low power, smoke, rough running, and engine damage.



Tighten the fuel injection pump drive gear nut.



Torque Value:

Nippondenso
Step 1 123 N•m [91 ft-lb]

Torque Value:

Bosch® A pump
Step 1 85 N•m [63 ft-lb]

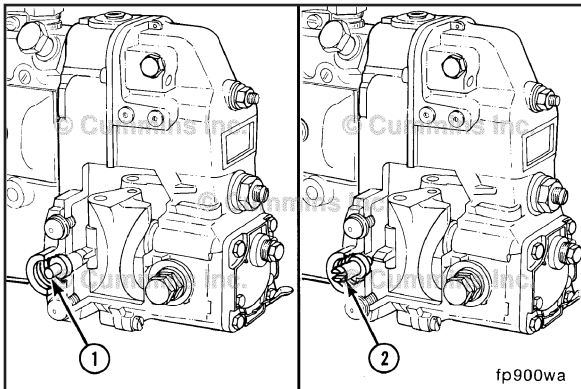
Torque Value:

Bosch® MW pump
Step 1 105 N•m [77 ft-lb]

Torque Value:

Bosch® P3000/P7100
Step 1 195 N•m [144 ft-lb]

Install the gear cover access cap hand-tight.



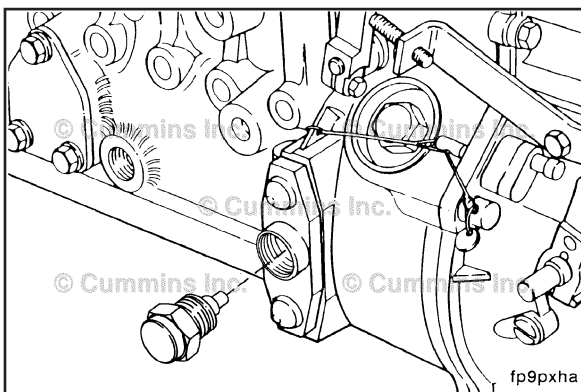
Marine Applications

⚠CAUTION⚠

Do not use the timing pin to locate engine top dead center for marine applications. This can result in incorrect timing, poor engine performance, and engine smoke problems.

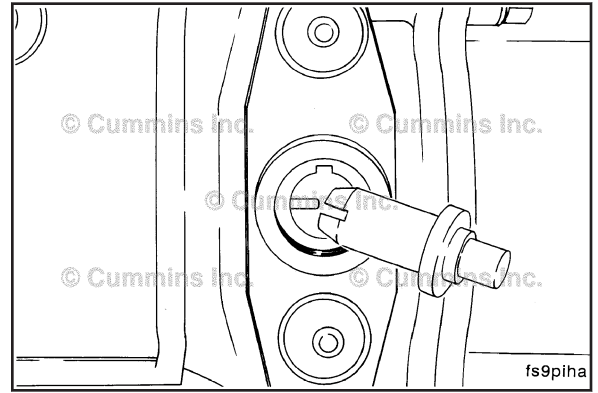
Make certain that the cylinder number 1 is at top dead center. See the Time, Marine Application procedure.

The fuel injection pump also has a timing pin (1), located in the governor housing, to position the fuel injection pump shaft to correspond with top dead center for cylinder number 1. The timing pin **must** be reversed and stored in the housing (2) after the fuel injection pump is installed.

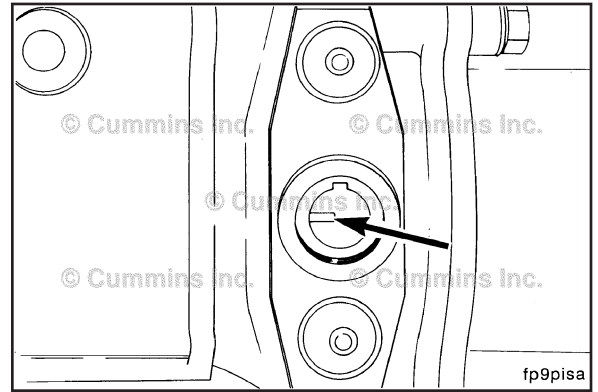


Remove the fuel injection pump timing pin access plug.

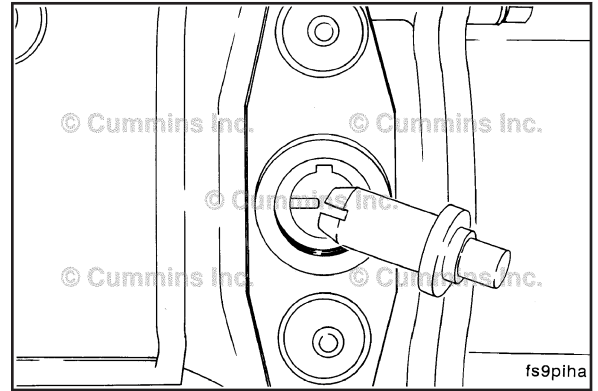
Remove the timing pin.



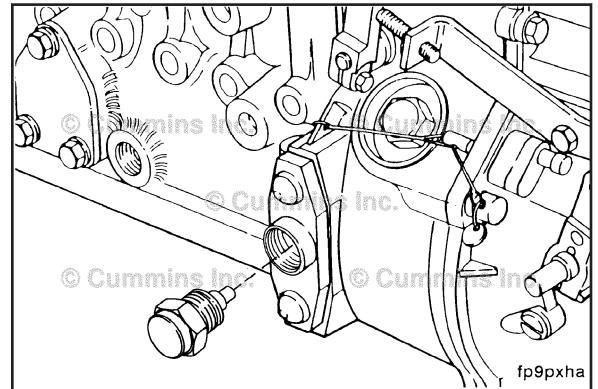
If the timing tooth is **not** aligned with the timing pin hole, rotate the fuel injection pump shaft until the timing tooth aligns.

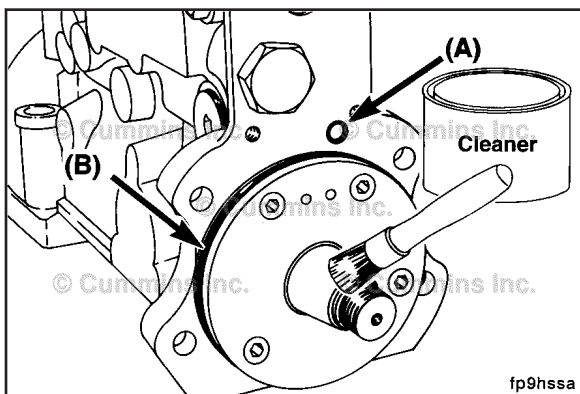


Reverse the position of the timing pin so that the slot of the timing pin will fit over the timing tooth in the fuel injection pump.



Install and secure the timing pin with the access plug.





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



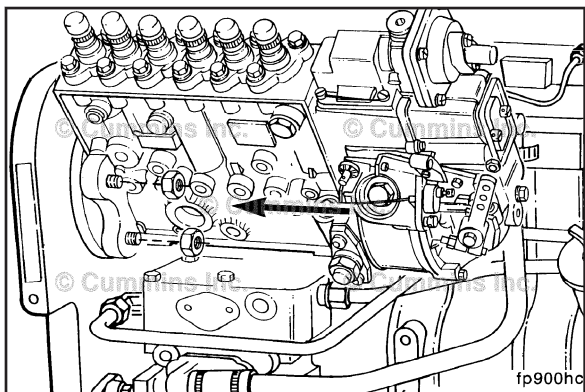
⚠ WARNING ⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.



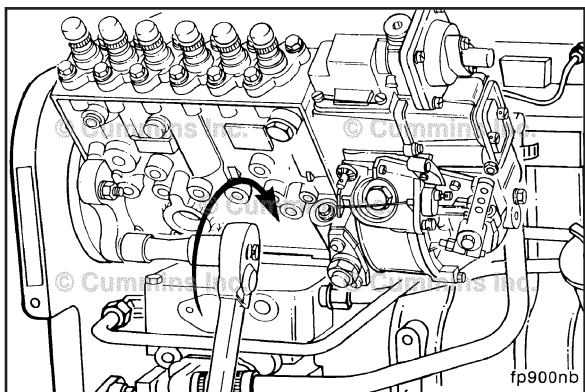
Make certain that the o-ring seals for the fill orifice and pilot are correctly installed and are **not** damaged.

Lubricate the mounting flange with clean lubricating engine oil.

Before installing the fuel pump drive gear, clean the injection pump shaft and gear tapers with QD Contact Cleaner, Part Number 3824510, by spraying into the gap between the shaft and gear. Dry the surface with compressed air.



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



⚠ CAUTION ⚠
Do not pull the injection pump into the gear housing with the mounting nuts. Damage to the gear housing and fuel pump can result.



Install the fuel injection pump mounting nuts.

Install the support bracket, if equipped.

Torque Value:

Mounting nuts
Step 1 44 N•m [32 ft-lb]

Torque Value:

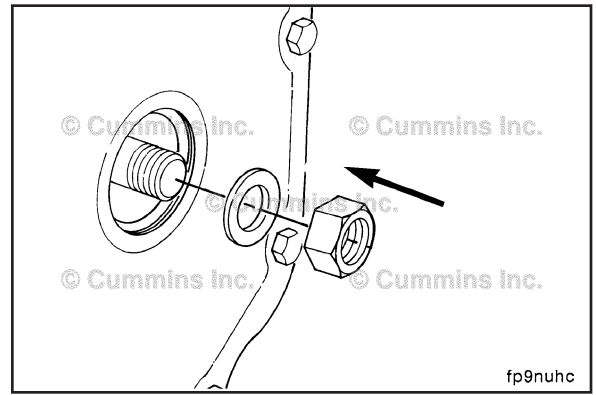
Support bracket nuts
Step 1 32 N•m [24 ft-lb]

⚠CAUTION⚠

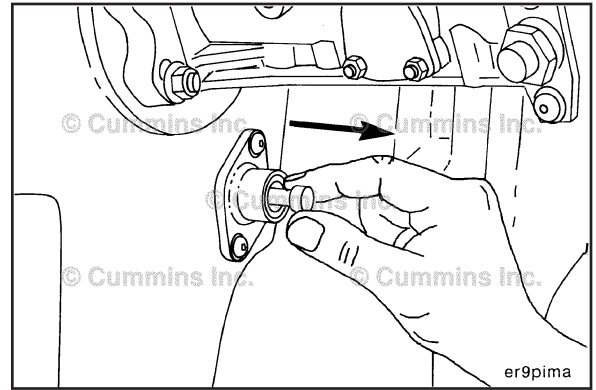
To prevent damage to the timing pins, do not exceed the torque value given. This is not the final torque value for the retaining nut.

Install and tighten the fuel injection pump retaining nut and washer.

Torque Value: 12 N•m [106 in-lb]



Disengage the engine timing pin.



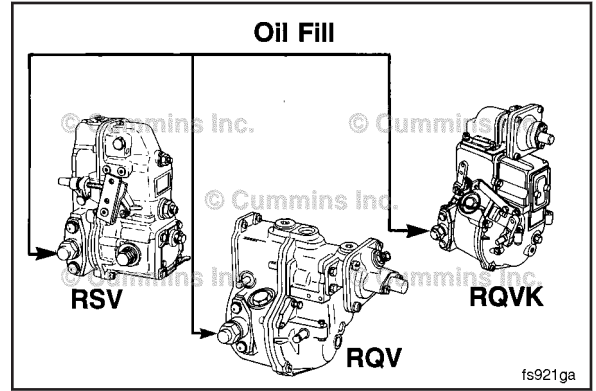
⚠CAUTION⚠

The governor housing must be pre-lubricated before engine operation. Failure to do so will result in premature governor wear.

Remove the access plug.

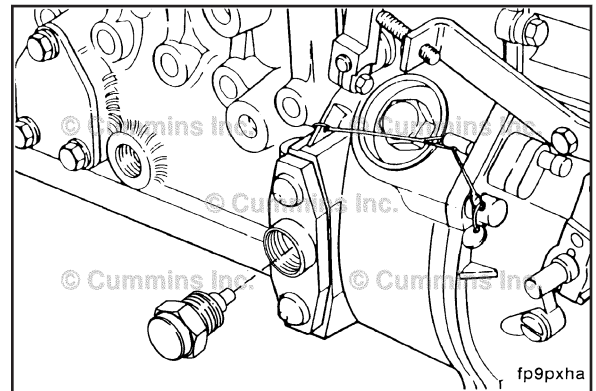
Add the following quantity of clean engine oil.

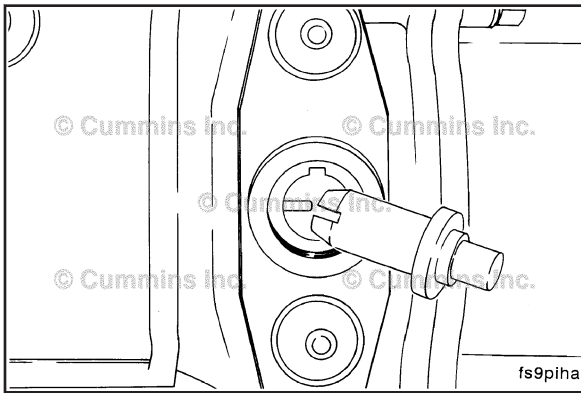
- RSV 450 ml [0.48 qt]



Install the access plug.

Torque Value: 28 N•m [21 ft-lb]





Remove the fuel injection pump timing pin plug.

Reverse the position of the timing pin.

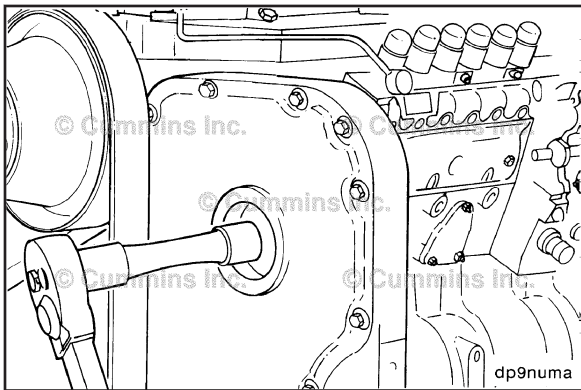


Install the timing pin, plug, and sealing washer.

Tighten the timing pin plug.



Torque Value: 15 N•m [133 in-lb]



⚠CAUTION⚠

Failure to clean and dry the shaft and gear tapers thoroughly can result in timing shift to the retarded side after the engine is started and running under a load. This will result in low power, smoke, rough running, and engine damage.



Tighten the fuel injection pump drive gear nut.



Torque Value:

Nippondenso

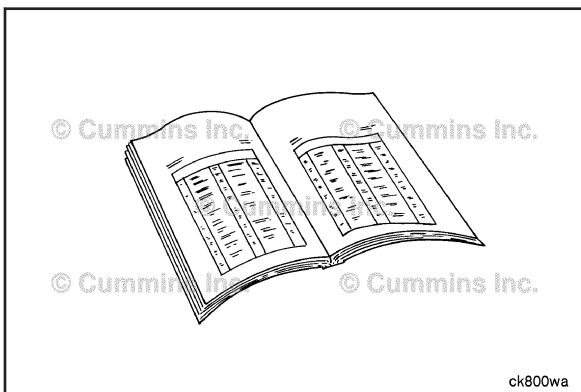
Step 1 123 N•m [91 ft-lb]

Torque Value:

Bosch® P3000/P7100

Step 1 195 N•m [144 ft-lb]

Install the gear cover access cap hand-tight.



Finishing Steps

- Install the governor oil supply line.
- Install the air fuel control air line.
- Install the fuel shutoff solenoid. Refer to Procedure 005-043.
- Install the control linkage. See the OEM service manual.
- Install the injector supply lines. Refer to Procedure 006-051.
- Install the fuel supply lines. Refer to Procedure 006-024.

The MW-type fuel injection pump **not** equipped with engine-side fuel return option **must** be vented after installation. Loosen the vent screw located near the front on the side nearest the engine. Place the fuel control in the run position. Crank the engine so that air can bleed from the fuel injection pump. Then, tighten the vent screw.

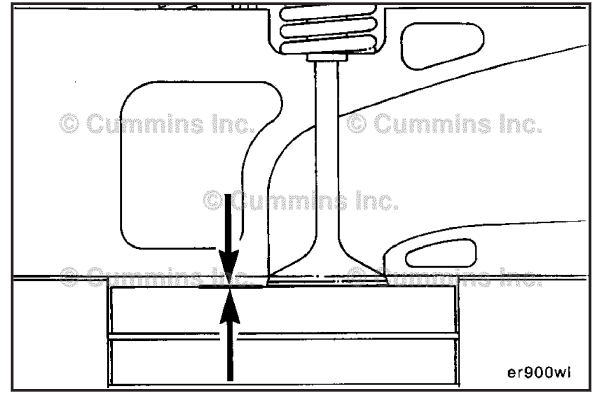
Earlier MW-type fuel injection pumps were **not** equipped with a vent screw. Remove the large plug from the location described above to vent the fuel injection pump.

A-type fuel injection pumps are self-venting. All P-type pumps were assembled with the engine-side vent option.

Fuel Injection Pump, In-Line, Spill Port Timing (005-013)

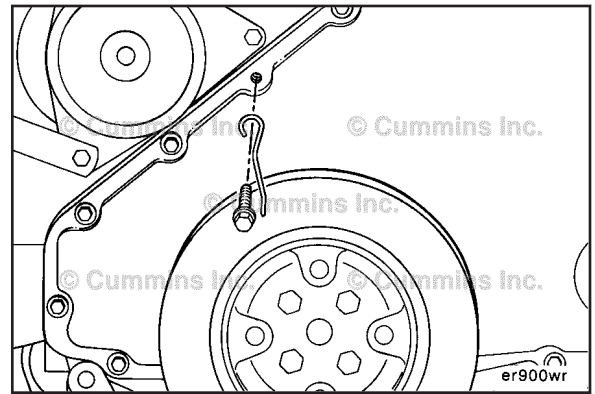
Adjust

Use Cylinder No. 1 intake valve to make sure the engine is at top dead center on the compression stroke for Cylinder No. 1. Refer to Procedure 001-049.



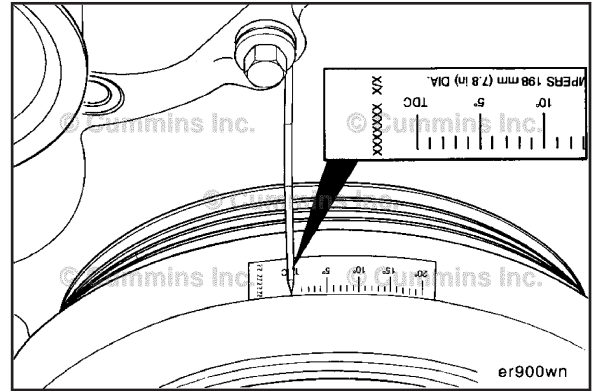
Fabricate a timing mark pointer for the front of the engine.

NOTE: This can be done by forming a piece of wire that can be tightened under one of the gear cover capscrews. Sharpen the wire at the vibration damper end so that it comes to a point for better accuracy.



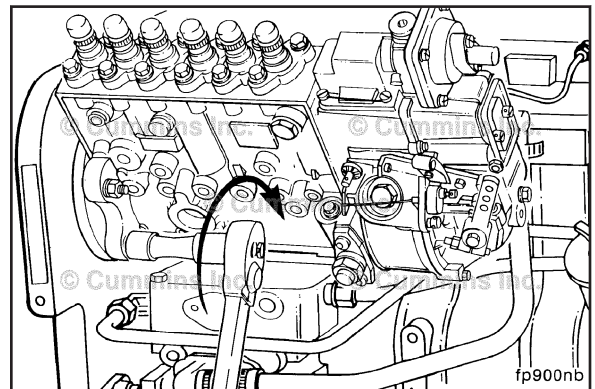
Attach a degree wheel or degree tape to the front of the vibration damper. Line the top dead center mark up with the pointer.

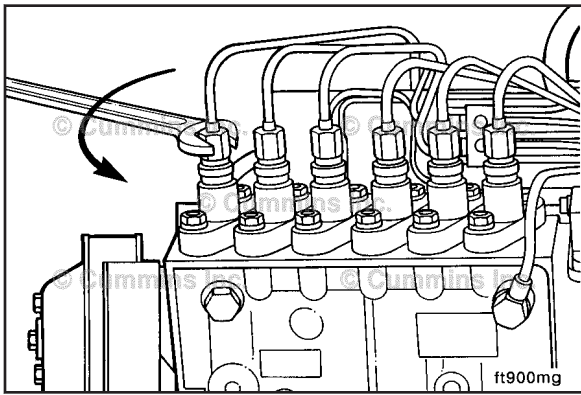
The degree wheel/tape **must** measure to an accuracy of at least ± 1 degree.



Install the fuel injection pump; refer to Procedure 005-012.

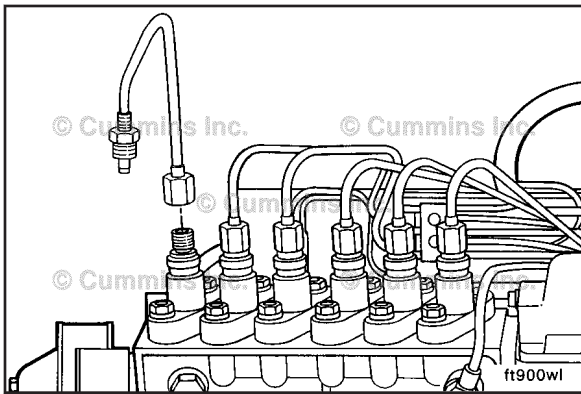
If the fuel injection pump is already installed, continue the procedures.





Remove the No. 1 high-pressure fuel line from the fuel injection pump.

NOTE: Lines 2 through 6 **must not** be removed or loosened.



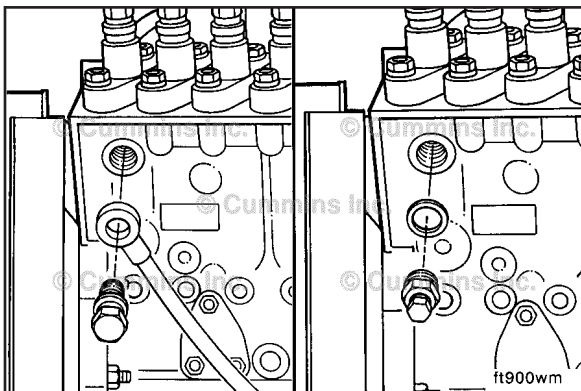
⚠CAUTION⚠

When attaching the fabricated tube, do not bend the No. 1 high-pressure fuel line. This can cause the inside of the fuel line to flake and cause injector failure.

A short length of high-pressure line that is compatible with the fuel lines used on the engine **must** be bent in a "U" shape and installed onto the delivery valve holder of the fuel injection pump.

NOTE: The line is used to observe when the fuel is or is not flowing through the delivery valve holder assembly.

Place a container under the tube to catch the fuel or drain the fuel back into the spill port pump.

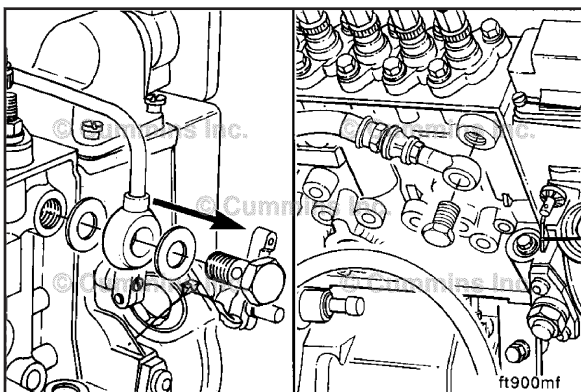


Remove the overflow valve from the fuel injection pump.

Install a 14-mm threaded plug and sealing washer into the fuel return port of the fuel injection pump.



NOTE: The fuel return port is located on the inboard front side of the fuel injection pump for automotive in-line applications and on the outboard front side for most industrial applications.

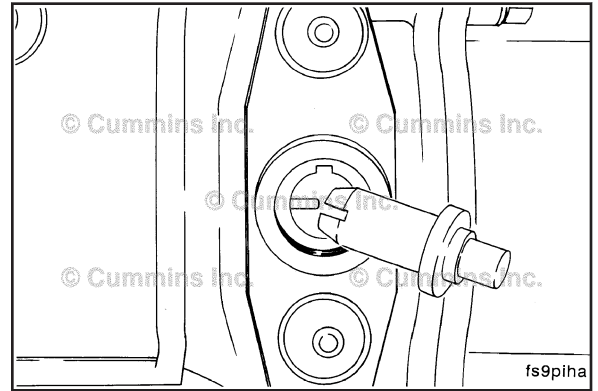


Remove the fuel supply line between the fuel filter head and the fuel injection pump.

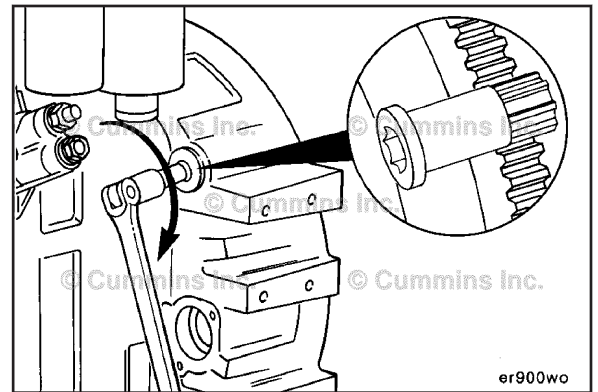


NOTE: Attach the high-pressure outlet hose from the spill port to the fuel injection pump supply port.

Before continuing, make sure the fuel injection pump timing pin is **disengaged**.



Rotate the crankshaft **counterclockwise**, as viewed from the front of the engine, to approximately 40 degrees before top dead center.



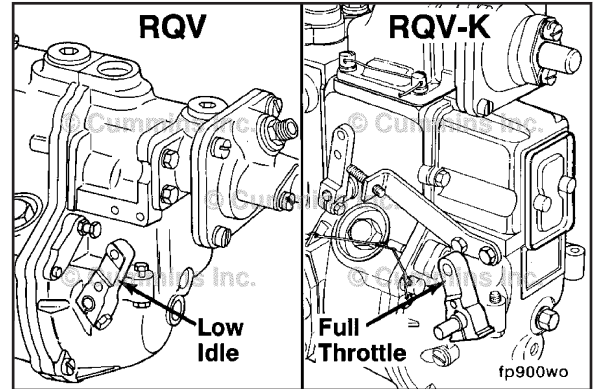
Governor Lever Positioning

NOTE: The governor lever **must** be positioned before pressurizing the fuel injection pump.

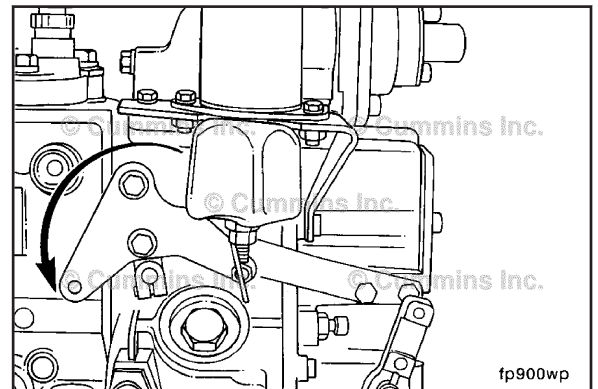
The RQV governor throttle lever **must** be in the **low-idle** lever position.

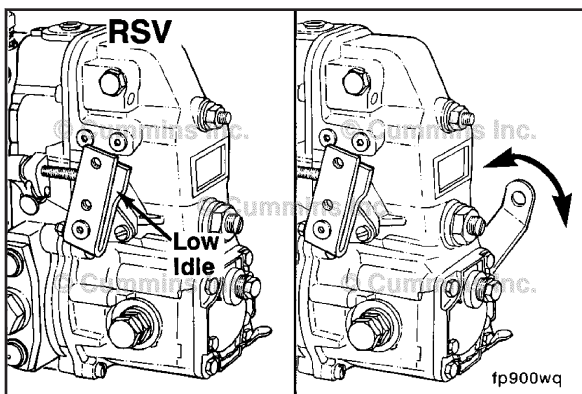
Automotive engines with an RQV-K governor throttle lever **must** be in the **high-idle** throttle position.

Industrial engines with an RQV-K governor throttle lever **must** be in the low-idle throttle position.

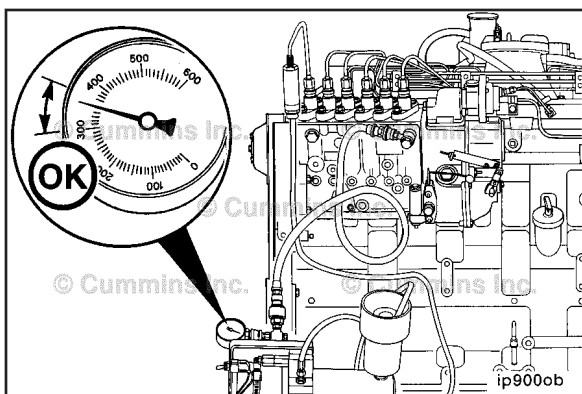


Both the RQV and RQV-K governor **must** have the shutdown lever in the **full-run** position.





The RSV governor throttle lever **must** be in the low-idle position and the shutdown lever needs to be wired or locked in the 1/2-travel position.

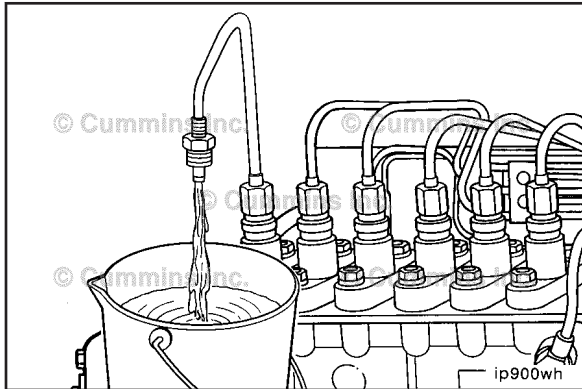


Turn on the spill timing cart pump.
Check the fuel pressure.

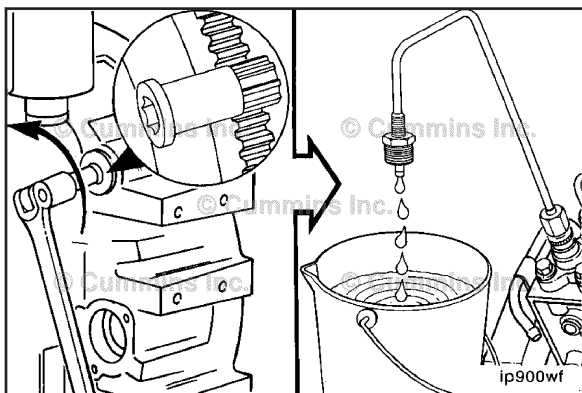
Fuel Spill Timing Cart - Fuel Pressure

kPa		psi
2068	MIN	300
2551	MAX	370

NOTE: The shutdown lever **must** be held in the required position before turning the spill cart pump on.



Fuel **must** be flowing out of the tube attached to the fuel injection pump. If the fuel is **not** flowing, recheck the procedures carefully.

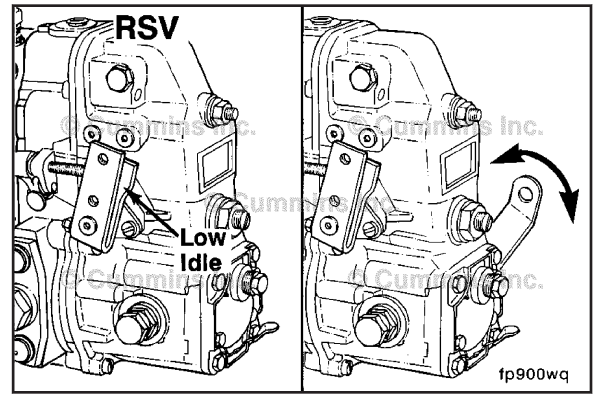


Slowly rotate the crankshaft **clockwise**, as viewed from the front of the engine, until fuel flow from cylinder No. 1 begins.

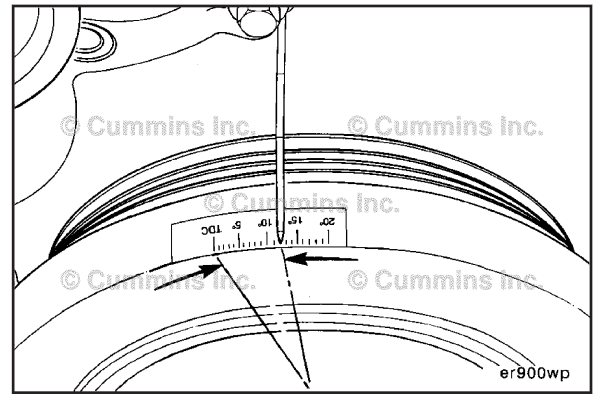
The plunger No. 1 element is now approaching port closure. Continue to rotate the crankshaft slowly until the flow is reduced to a drip. At the point that the steady stream of flow changes from a solid flow to a drip, **stop**. This is the static timing position of the fuel injection pump.

If the flow does **not** slow down to a drip:

1. Check the position of the governor levers.
2. Make sure cylinder No. 1 is before top dead center on the compression stroke.
3. Turn off the spill port pump.



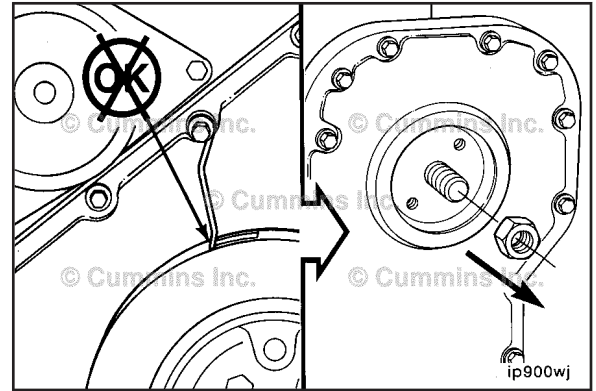
Check the degree wheel on the vibration damper to see what engine degree the timing pointer is indicating. This is spill port static timing. Compare this number to the timing specification for your particular application.



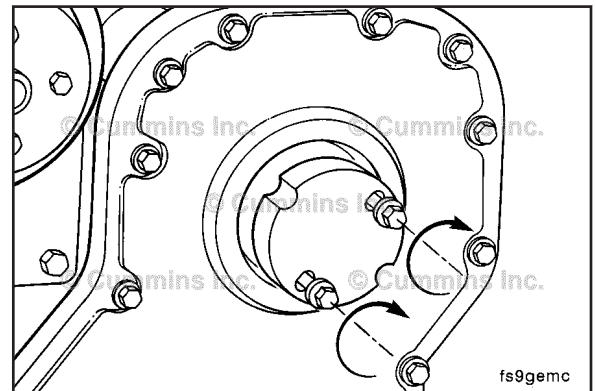
If the fuel injection pump static timing, as measured by the above method, is **not** within specification, remove the large nut that fastens the fuel injection pump camshaft to the fuel pump drive gear.

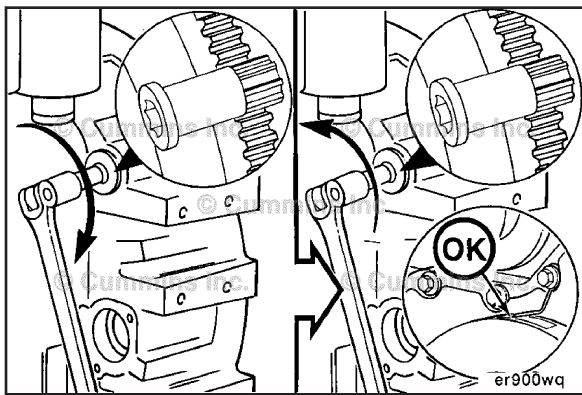
If the crankshaft has rotated, turn on the spill port pump and rotate the crankshaft to find port closure.

Turn off the spill port pump.



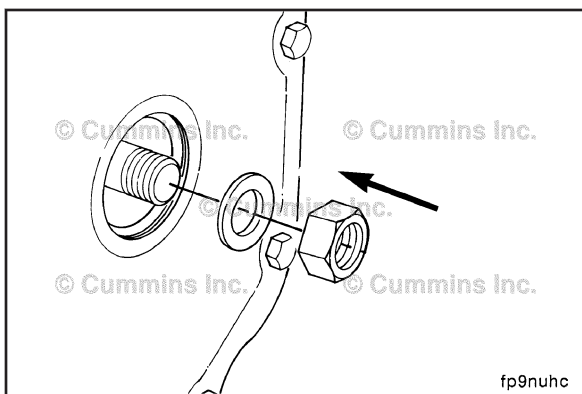
Using the fuel pump gear puller, Part No. 3824469, pull the fuel injection pump drive gear from the fuel injection pump camshaft taper.





Slowly rotate the crankshaft **counterclockwise** about 40 degrees past the desired static timing specification.

Slowly rotate the crankshaft **clockwise** until the timing pointer indicates the desired static timing.

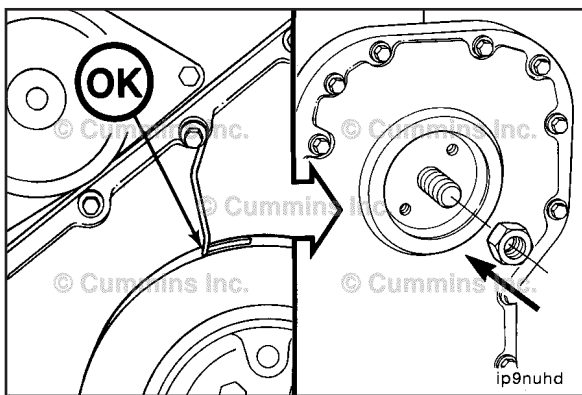


Install and tighten the retaining nut and washer.

Torque Value: 12 N•m [106 in-lb]



NOTE: To prevent damage to the timing pins, do **not** exceed the torque value given. This is **not** the final torque value for the retaining nut.



⚠ WARNING ⚠

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

Tighten the fuel injection pump drive nut.

Make sure the static timing has **not** changed after the fuel injection drive nut is tightened to the required specification.

NOTE: Before installing the fuel pump drive gear, clean the injection pump shaft and gear tapers with residue-free cleaner, Part No. 3824510, by spraying into the gap between the shaft and the gear. Dry the surface with compressed air.

⚠ CAUTION ⚠

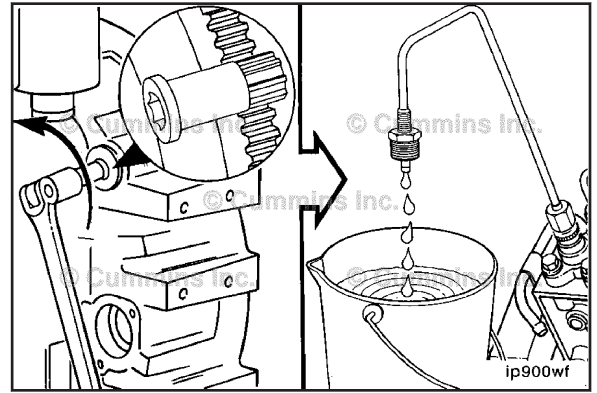
Failure to clean and dry the shaft and gear tapers thoroughly can result in timing shift to the retarded side after the engine is started and running under a load. This will result in low power, smoke, rough running, and engine damage.

Tighten the fuel injection pump drive gear nut.

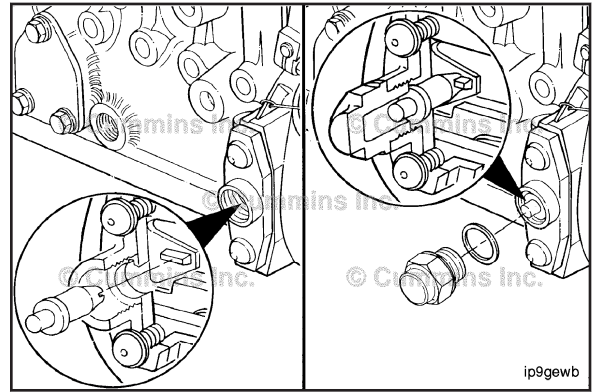
Torque Value:

Nippondenso	123 N•m	[92 ft-lb]
Bosch A pump	85 N•m	[63 ft-lb]
Bosch MW pump	105 N•m	[77 ft-lb]
Bosch P3000/195	105 N•m	[77 ft-lb]
P7100		[144 ft-lb]

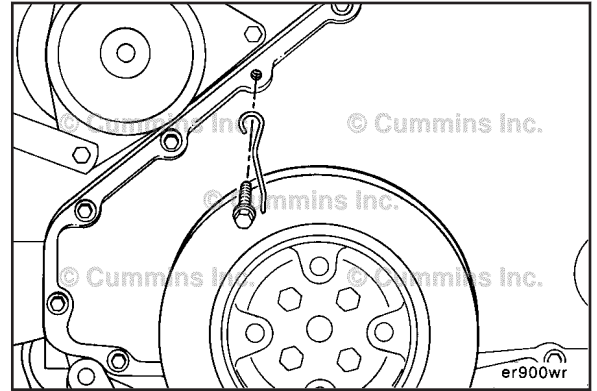
Repeat this procedure as needed until the timing matches the specification.



The fuel injection pump timing pin **must** fit over the injecting pump pointer when the engine is at top dead center or on the compression stroke for the cylinder No. 1. If it does **not**, the fuel injection pump **must** be adjusted by an authorized fuel injection pump shop or the fuel injection pump was installed incorrectly.



Remove the degree wheel and timing mark pointer.



Fuel Pump Control Lever and Spring (005-018)

General Information

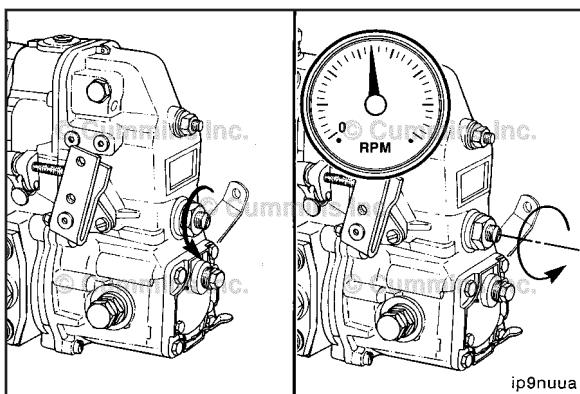
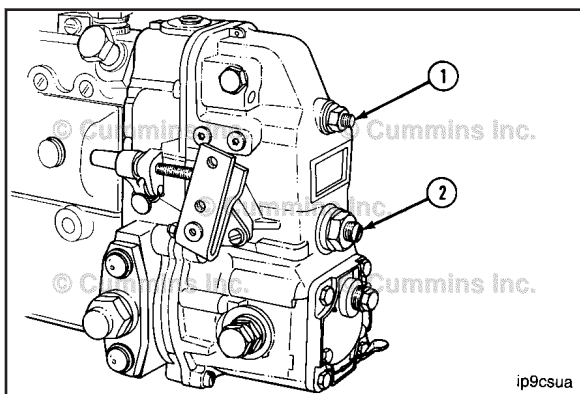
Cummins Inc. uses a wide variety of fuel pump control lever and spring configurations. Refer to the OEM for service and repair information.

Fuel Pump Idle Speed (005-029)

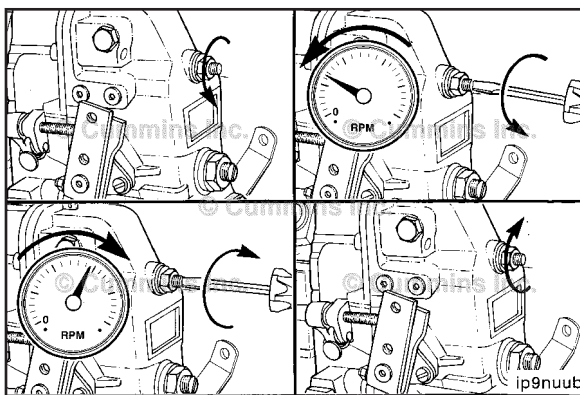
Adjust

RSV Governor Solenoid

Idle speed adjustment for engines with RSV governors requires the setting of both the low-idle speed screw (1) and the bumper spring screw (2).



Loosen the locknut and back out the bumper spring screw until there is no change in engine speed.



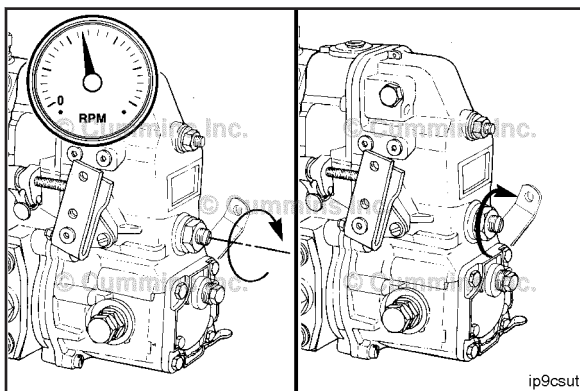
Loosen the locknut and adjust the idle speed screw to 40 to 50 rpm less than the desired speed.

Turn the idle speed screw:

Counterclockwise to decrease rpm
Clockwise to increase rpm.

Tighten the locknut.

Torque Value: 8 N•m [72 in-lb]



Turn the bumper spring screw **clockwise** until the desired idle speed is obtained.

Tighten the locknut.

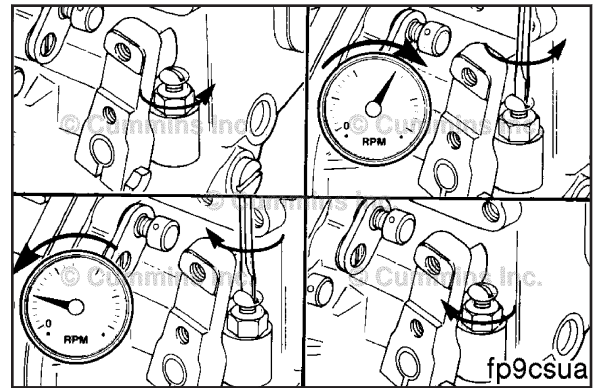
Torque Value: 8 N•m [72 in-lb]

RQVK Governor Solenoid

Idle speed adjustment on fuel injection pumps with RQV or RQVK governors requires setting **only** the stop screw.

Turn the idle stop screw:

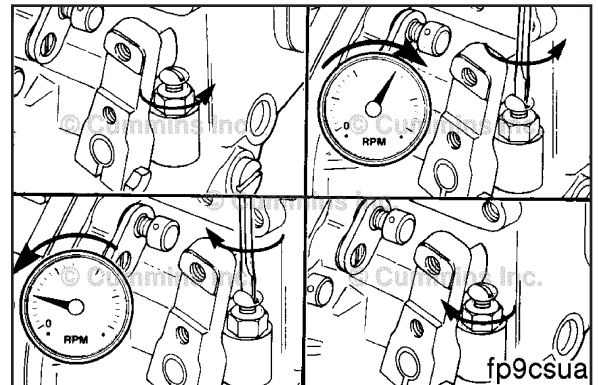
- Counterclockwise** to raise the rpm
- Clockwise** to decrease the idle speed.



Loosen the locknut and turn the idle speed screw to the desired idle speed.

Tighten the locknut.

Torque Value: 8 N•m [72 in-lb]



Fuel Shutoff Valve (005-043)

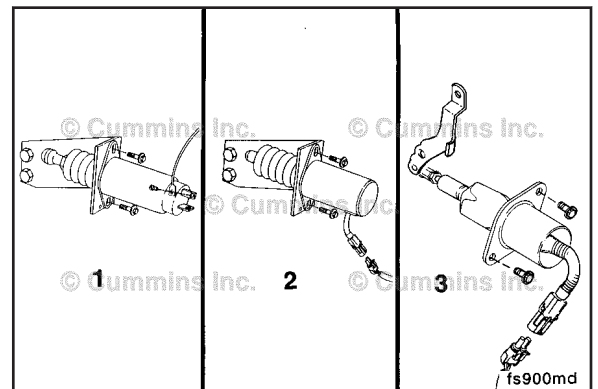
Preparatory Steps

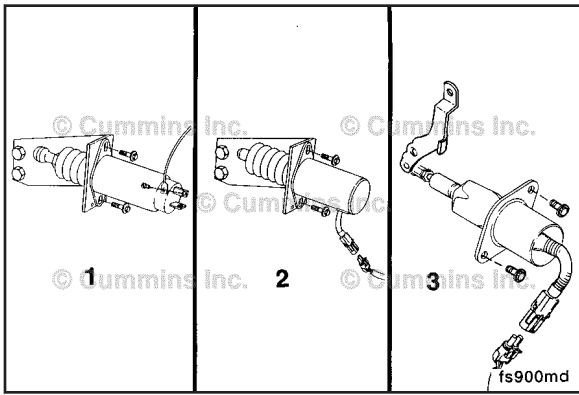
Label and disconnect the wiring.

Remove

Remove the two mounting capscrews, and remove the solenoid from the bracket.

1. Synchro-start
2. Trombetta
3. Direct link.





Install

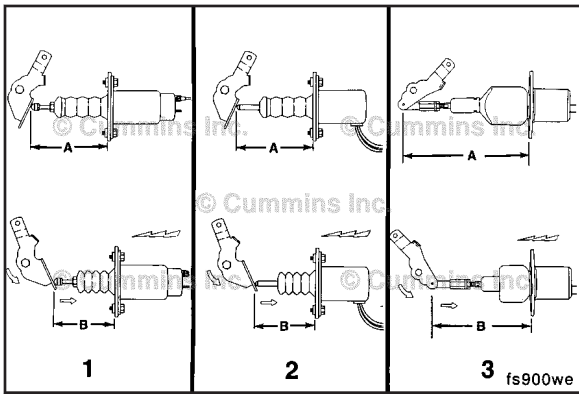
NOTE: Make sure the acorn nut is tightened to be snugly on the fuel shutoff solenoid shaft (Synchro-start **only**).



Install the new fuel shutoff solenoid to the bracket, and connect the wires. Make sure the wiring harness on the Trombetta solenoid is installed in the six-o'clock position.

Torque Value: 10 N•m [89 in-lb]

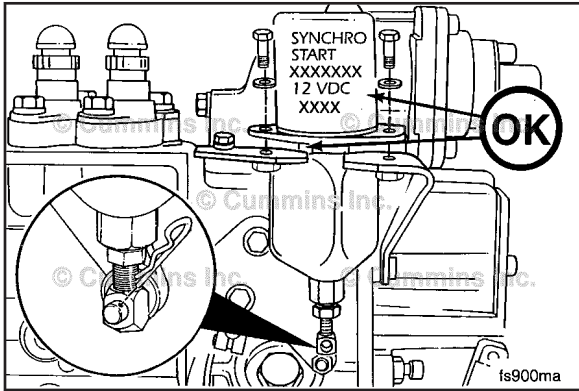
1. Synchro-start
2. Trombetta
3. Direct link.



Activate the switch and check the plunger travel.

	Synchro-start	Trombetta	Direct link
A =	86.8 mm [3.4 in]	91.4 mm [3.6 in]	
B =	60.2 mm [2.4 in]	63.5 mm [2.5 in]	117.1 mm [4.61 in]

The plunger **must** be retracted when the fuel shutoff solenoid is activated to the RUN position B. The fuel shutoff solenoid **must** operate without binding.

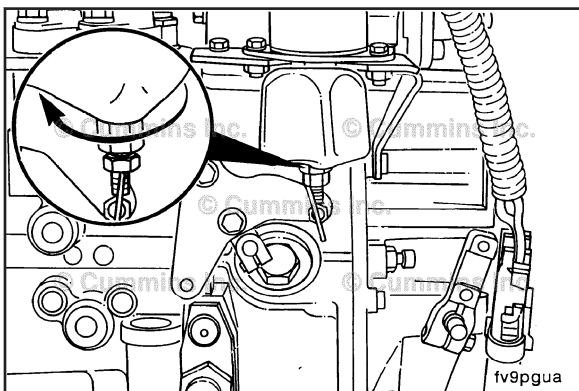


Remove the hitch pin clip, the mounting capscrews, and the fuel shutoff solenoid.



Install the new solenoid in reverse order of removal, and connect the wires.

Torque Value: 10 N•m [89 in-lb]



Adjust the solenoid linkage as necessary so that the plunger is magnetically held in with the shutoff lever in the absolute full-run position. Turn the large hex nut on the end of the plunger to make adjustments, and secure in place with a locknut.

Fuel Lift Pump (005-045)

Initial Check

Measure the pressure drop across the fuel filter at low idle. If the filter restriction is above the maximum, it **must** be replaced.

Pressure Drop Across Filter

	kPa		psi
Piston Lift Pump	34	MAX	5

Check for a restriction between the fuel lift pump and the fuel injection pump.

1. Supply line to fuel filter
2. Fuel filter
3. Supply line to fuel injection pump
4. Fuel inlet line from tank.

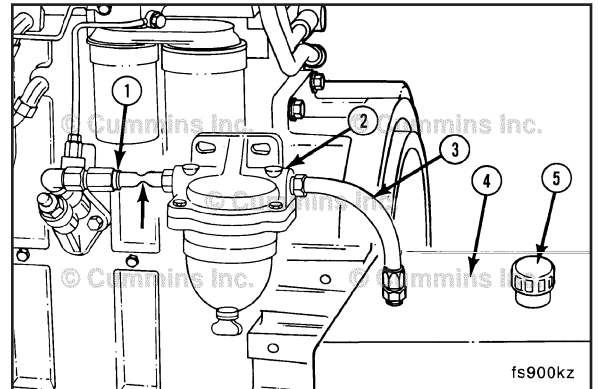
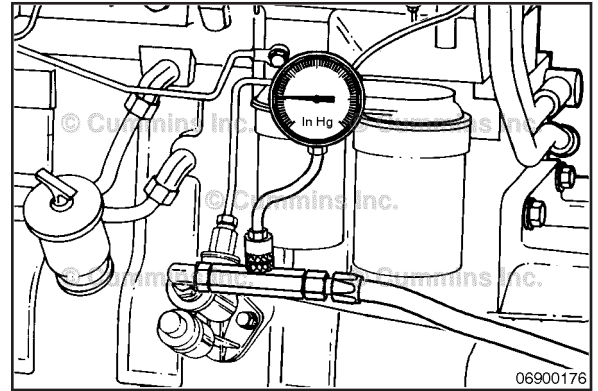
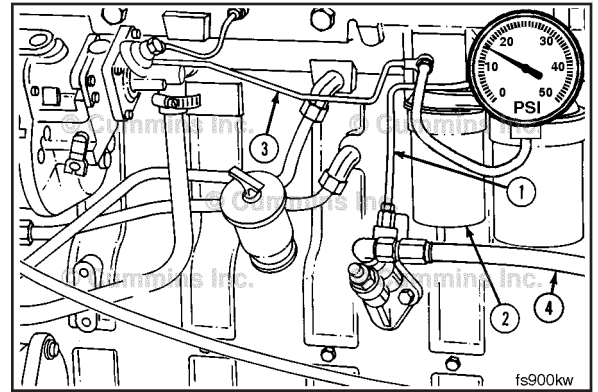
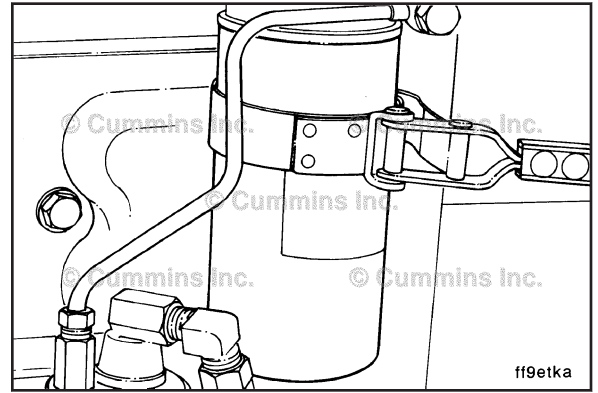
Measure the fuel lift pump inlet restriction with a vacuum gauge between the fuel lift pump inlet and the supply line (4) from the fuel tank.

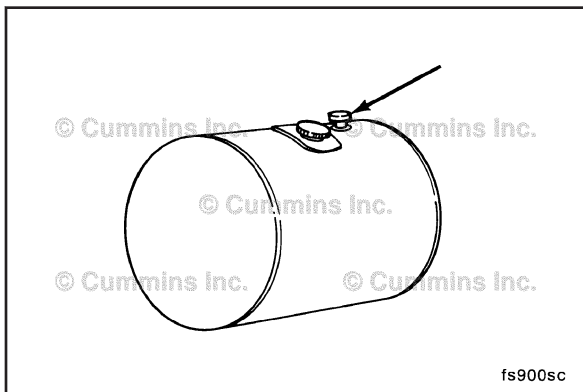
Fuel Lift Pump Inlet Restriction

kPa		in Hg
27	MAX	8

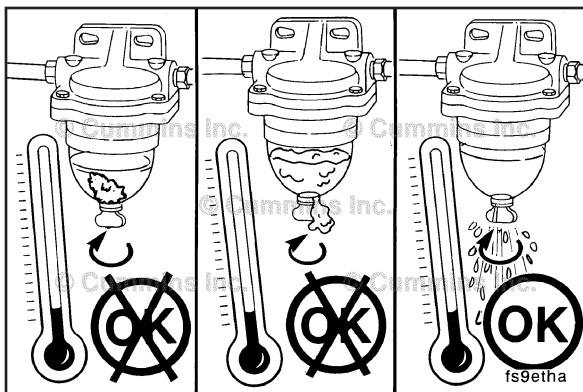
If the inlet restriction is above the maximum, check for restrictions or suction leaks in the fuel circuit to the fuel lift pump:

1. Supply line
2. Prefilter
3. Supply line
4. Supply tank
5. Tank vent.





Look for a plugged supply tank vent first.



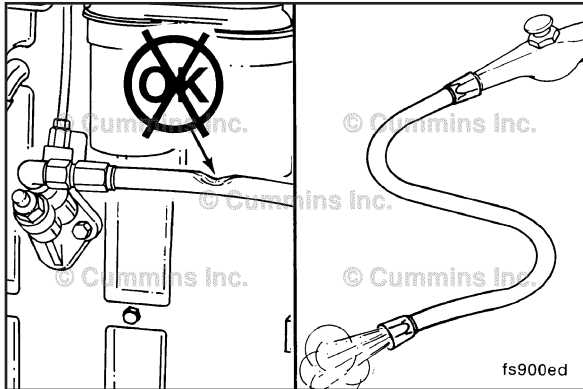
Fuel prefilters, inline and water separator type, can become clogged and cause a loss of fuel flow.

Check the prefilter for clogs or restrictions.



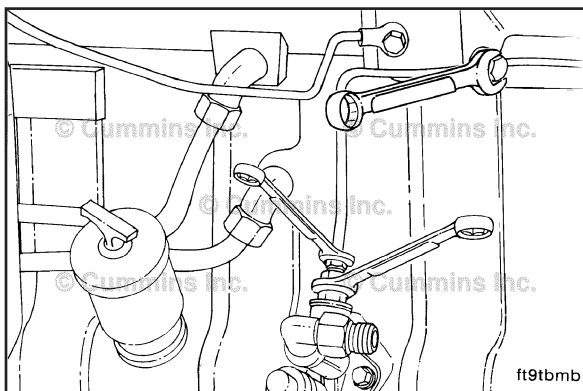
In cold weather, check the prefilter for gelled fuel.

Clean or replace the prefilter, if necessary.



Check for kinks or bends in the fuel supply line that can cause a restriction in the fuel flow.

Remove and blow out the fuel supply lines.



Preparatory Steps



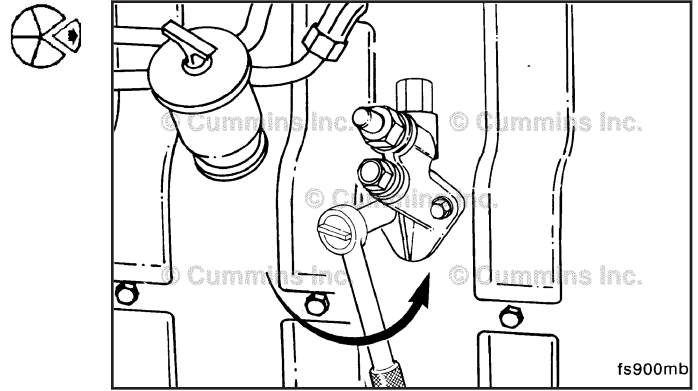
⚠ WARNING ⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.



- Clean debris from the fuel line fittings and the fuel lift pump.
- Disconnect the low-pressure fuel lines. Refer to Procedure 006-024.

Remove

Remove the two fuel lift pump mounting capscrews.
Remove the fuel lift pump.

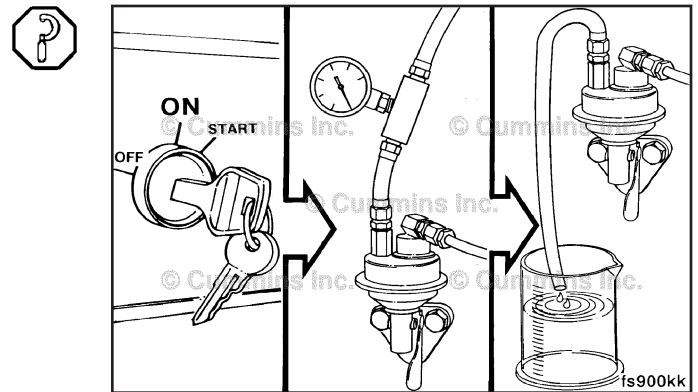


Test

The output of the fuel lift pump can be checked in two ways:

Test 1: Measure the output pressure using an in-line pressure gauge installed between the filter head and the fuel injection pump.

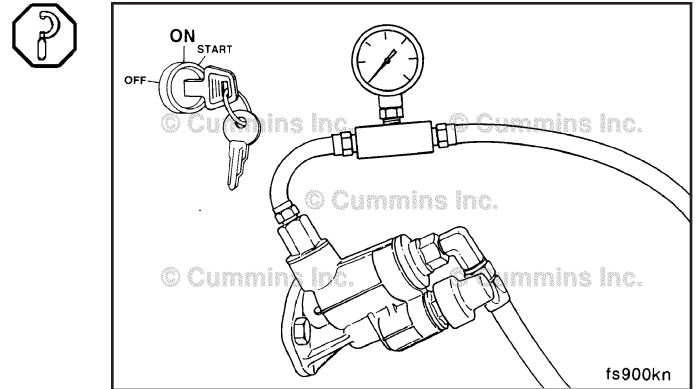
Test 2: Measure the flow volume.



Test 1: Output Pressure Test (Piston Style)

Operate the engine and measure the output pressure of the fuel lift pump using an in-line pressure gauge at the inlet to the injection pump.

Minimum pressure at high idle is 138 kPa [20 psi].



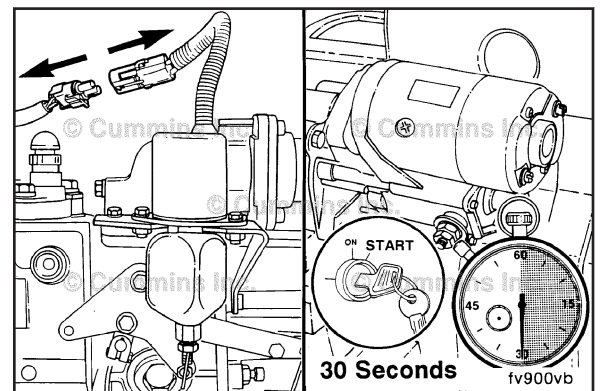
Test 2: Flow Volume Test (Piston Style)

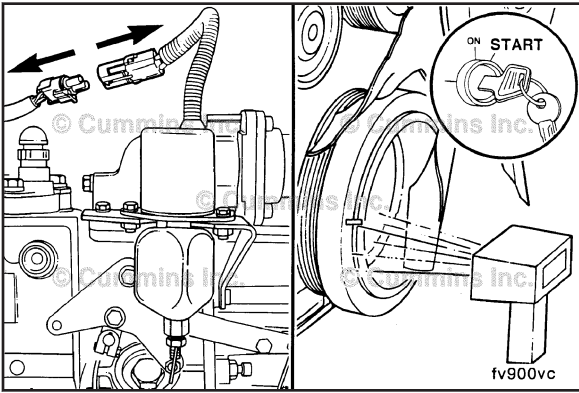
⚠CAUTION⚠

To prevent the engine from starting, disconnect the fuel shutdown wiring. Residual fuel in the injection pump can cause the engine to start.

⚠CAUTION⚠

Do not crank the starter for more than 30 seconds at a time. Doing so can result in starter damage. Also, high voltage during cranking can damage the shutdown solenoid.

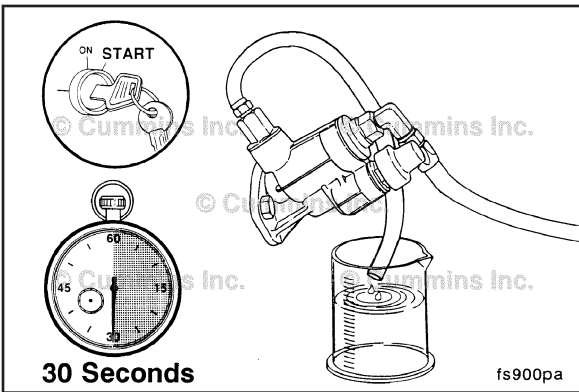




Disconnect the fuel shutdown solenoid wire.

Measure the engine cranking speed with a handheld tachometer, Part Number 3377462.

The minimum cranking speed is 120 rpm.



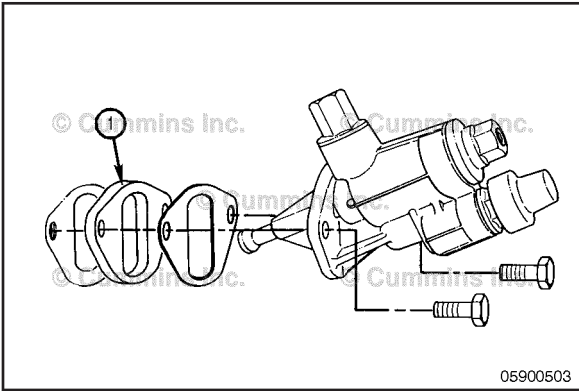
⚠CAUTION⚠

Leave the shutdown solenoid disconnected for the following check:

Disconnect the output pressure line from the fuel lift pump and run it into a container.

Crank the engine for 30 seconds and measure the fuel lift pump flow volume.

The minimum flow volume is 150 mL [5 oz].



Install

⚠CAUTION⚠

Alternately tighten the mounting cap screws. As the cap screws are tightened, the fuel lift pump plunger is pushed into the pump. Failure to tighten the cap screws in an even manner can result in the plunger being bent or broken, causing sticking and failure.

Piston Style

Install the pump.

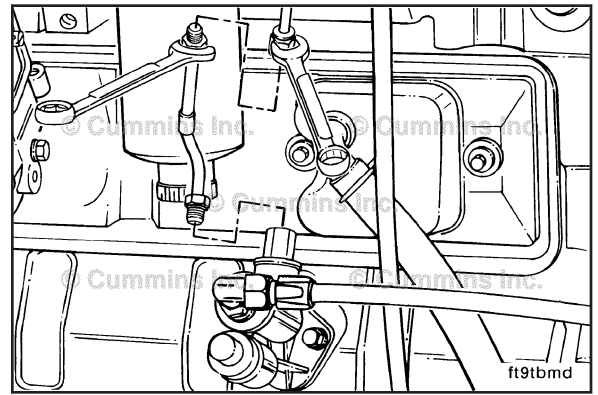
Torque Value: 24 N•m [18 ft-lb]

The 5-mm [0.20-in] spacer (1), Part Number 3914284, **must** be installed along with a gasket, Part Number 3931348, on each side of the spacer.

NOTE: For some applications, a bracket used for supporting other options will replace the 5-mm spacer.

Finishing Steps

- Install the fuel line to the fuel lift pump and fuel filter head. Refer to Procedure 006-024.
- Vent the low-pressure fuel lines. Refer to Procedure 006-024.



Section 6 - Injectors and Fuel Lines - Group 06

Section Contents

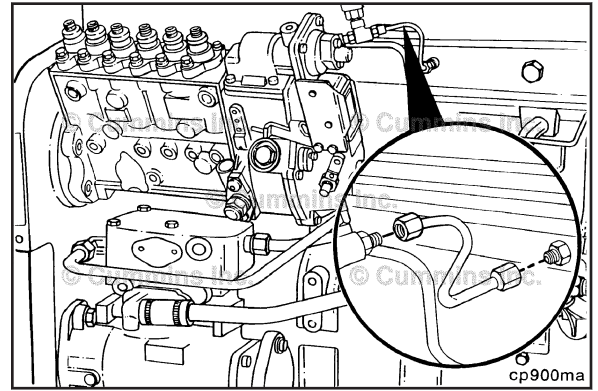
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AFC Air Tube (006-001)

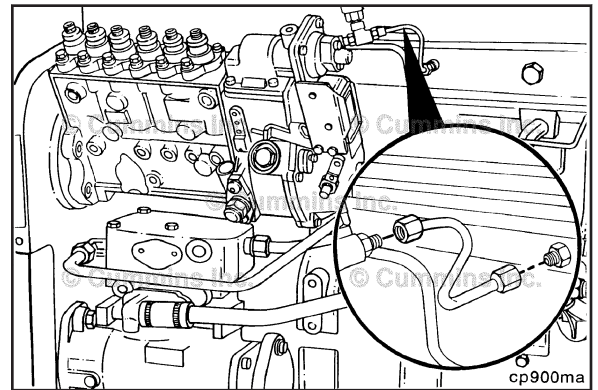
General Information

The AFC (air-fuel control) tube allows intake manifold pressure to adjust the fuel metering. Therefore, if the engine is equipped with a turbocharger, the fuel pump meters more fuel for additional horsepower.



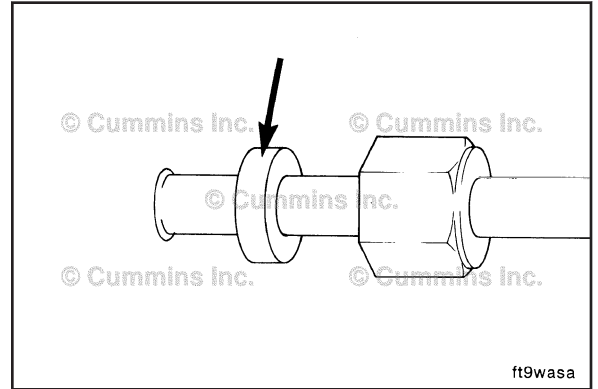
Remove

Remove the AFC tube.



Inspect for Reuse

Inspect the rubber sealing washers.
Replace as necessary.

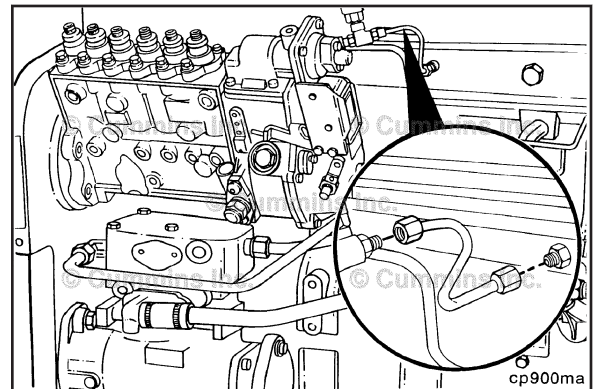


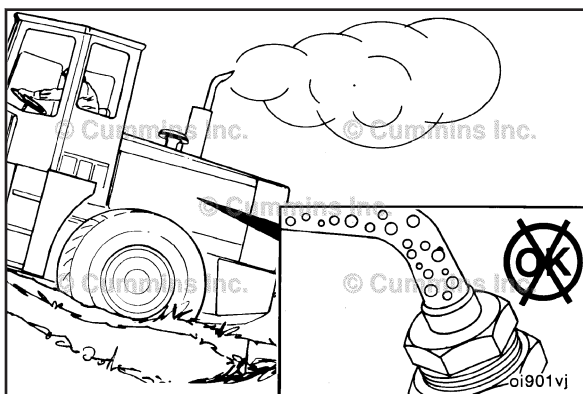
Install

Use new copper washers for the banjo fitting.
Install the AFC tube.

Torque Value:

Banjo Fitting	24 N•m	[18 ft-lb]
Threaded Fitting	8 N•m	[71 in-lb]



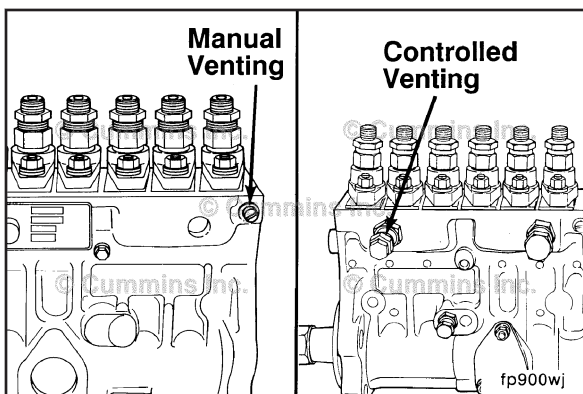


Air in Fuel (006-003)

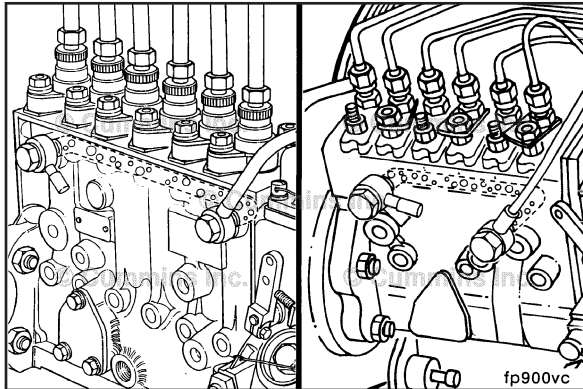
General Information

Air from uncorrected leaks in the supply circuit will make the engine:

1. Difficult to start
2. Run rough
3. Misfire
4. Produce low power
5. Emit excessive smoke
6. Produce fuel knock.

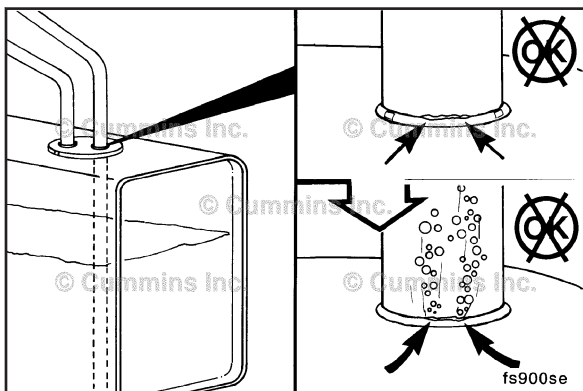


The Nippondenso EP-9 in-line fuel injection pumps will require additional venting prior to initial start-up, pump replacement, or if the engine has been run out of fuel.



The MW, A, and P fuel injection pumps equipped with engine-side fuel drain arrangement create a self-bleeding system for air introduced during replacement of the supply-side components.

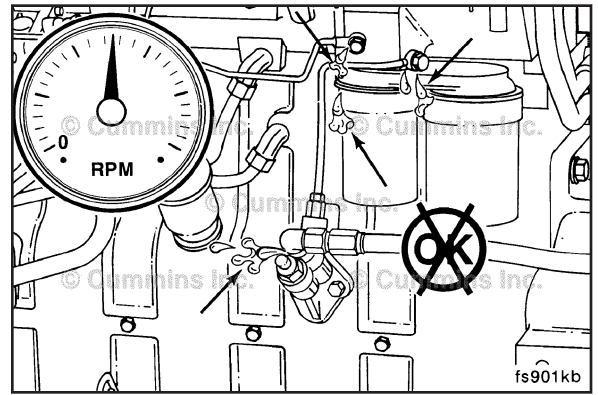
NOTE: For faster air purge, small amounts of air can be bled from the pump by operating the hand primer on the fuel transfer pump or by cranking the engine.



A source often overlooked for air to enter the fuel system is between the inlet of the prefilter and the suction tube in the fuel tank. Fuel tanks that have the outlet fitting at the top will have a suction tube that extends to the bottom of the fuel tank. Cracks or pin holes in the weld that join the suction tube to the fitting can let air enter the fuel system.

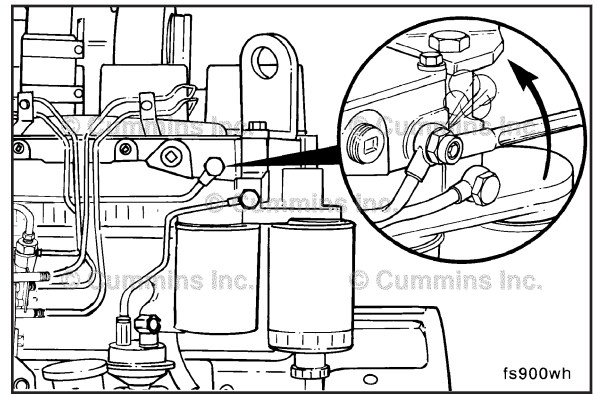
Check all the fittings from the fuel supply on the fuel tank to the fuel inlet of the fuel transfer pump; make sure they are all tight. Use a sight glass at the fuel transfer pump inlet to check for air in the supply line.

Since the fuel transfer pump provides a positive pressure through the fuel filter and supply line to the fuel injection pump, loose connections or defective seals will show as a fuel leak and **not** as an air leak.



Vent

Open the banjo bleed screw to bleed the low pressure fuel line.

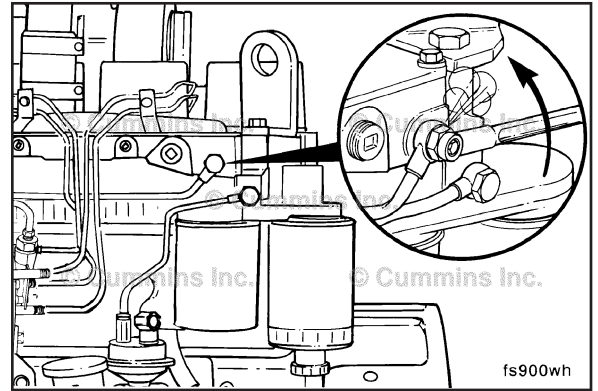


⚠ WARNING ⚠

The pressure of the fuel in the line is sufficient to penetrate the skin and cause serious injury.

To check for air in the high-pressure lines, loosen the fittings at the head. Crank the engine to allow entrapped air to bleed from the fuel line. Tighten the fittings.

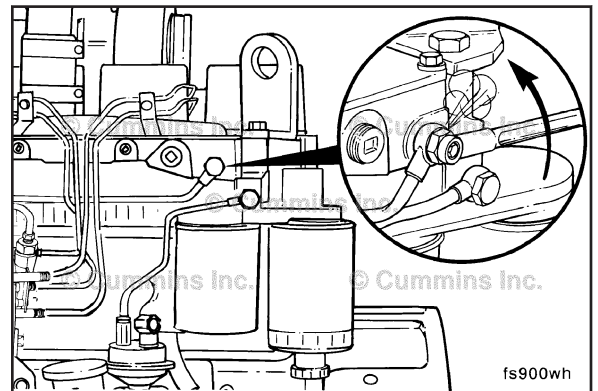
Torque Value: 38 N•m [28 ft-lb]

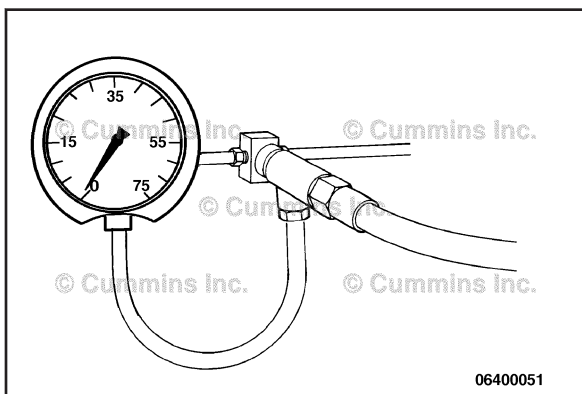


⚠ CAUTION ⚠

Do not bleed a hot engine, as this could cause fuel to spill onto a hot exhaust manifold, creating a danger of fire.

Operate the engine and bleed one fuel line at a time until the engine runs smoothly.





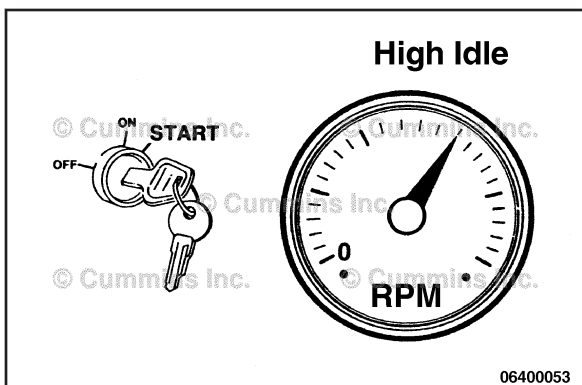
Fuel Drain Line Restriction (006-012)

Test



Remove the fuel drain hose.

Install the adapter, Part Number ST-434-2, and pressure gauge, Part Number ST-1273, between the fuel drain hose and the engine fuel drain fitting.

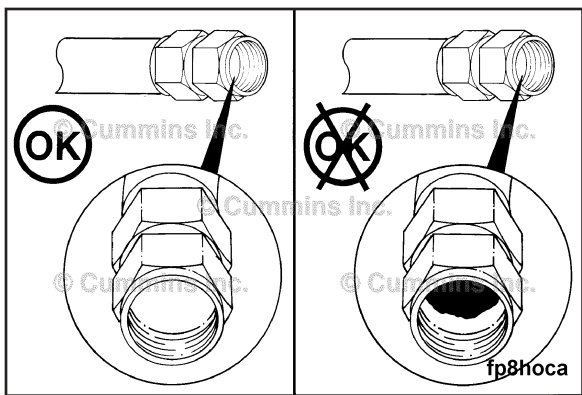


Start and operate the engine at high idle, no load.

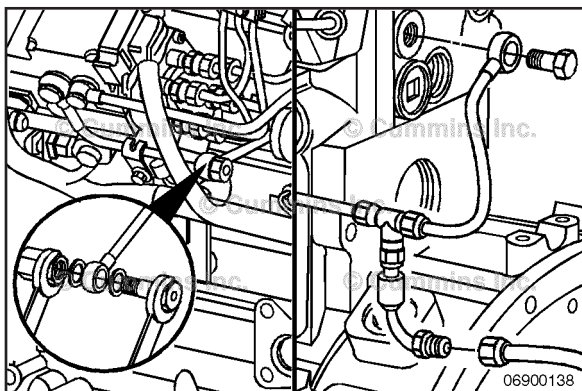


Fuel Drain Restriction

mm Hg		in Hg
508	MAX	20.0



If the fuel drain line restriction is above specifications, inspect the fuel drain line. Refer to Procedure 006-013.



Remove the gauge.

Install the fuel drain line.

Tighten the fuel drain line.



Torque Value: 23 N•m [204 in-lb]



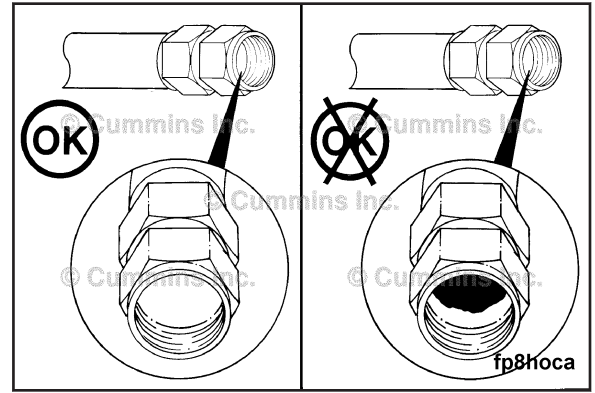
Fuel Drain Lines (006-013) Inspect for Reuse

Engine-to-Fuel Tank

Inspect the inside of the hose.

- The inner lining of the hose can separate from the center hose section.
- A separation of flap can cause a restriction in the fuel flow.

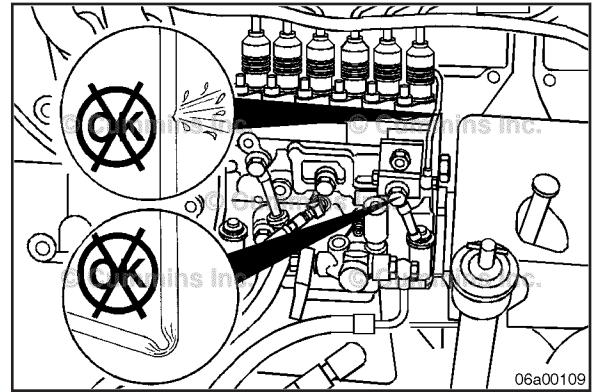
Make sure that the hose does **not** have pinches or loops that would obstruct the flow.



Fuel Drain Lines - Inspect

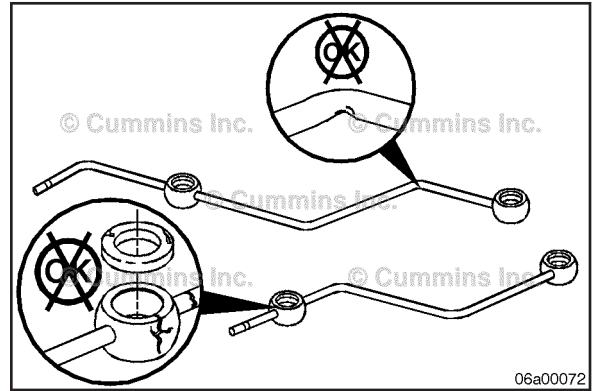
Inspect the fuel line for cracks that can cause a loss of pressure.

Inspect the fuel line for sharp bends that can cause a restriction in pressure.



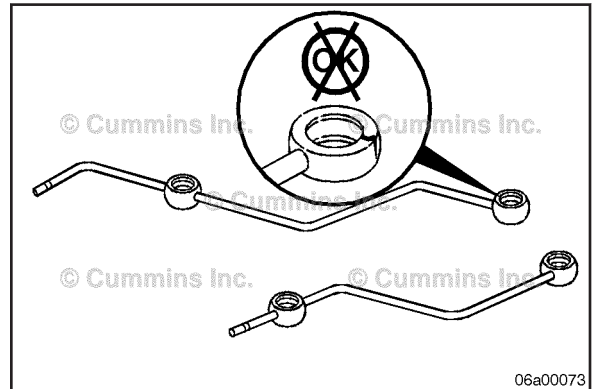
Fuel Drain Manifold - Inspect

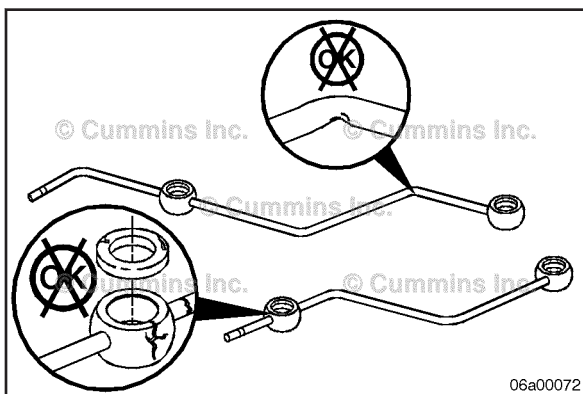
Inspect the fuel drain manifold for cracks or visible damage. The manifold **must** be replaced if it is cracked or damaged.



Inspect the sealing surfaces for leak paths.

The manifold **must** be replaced if the sealing surfaces are damaged.

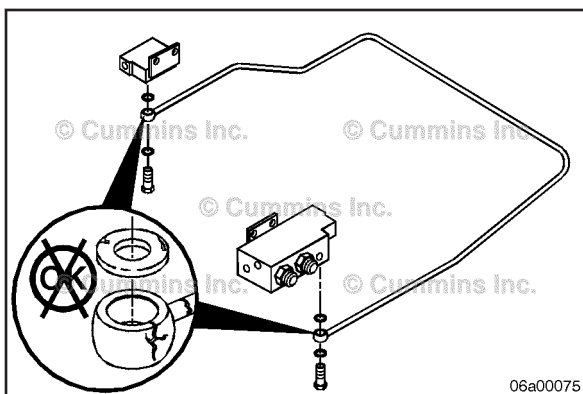




Inspect the rubber seals. Replace any damaged seals and any seals that are hard or brittle.



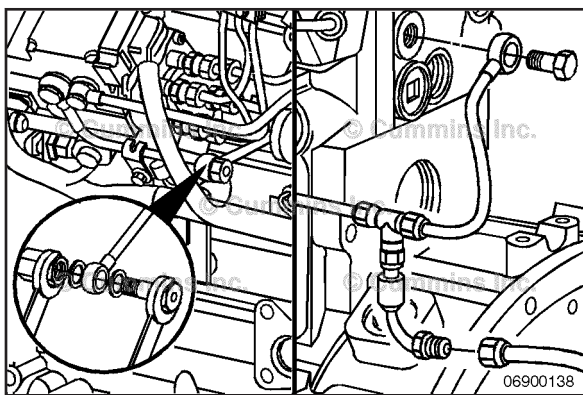
Service Tip: Lubricate the seals with clean engine oil to facilitate the installation.



Inspect the rubber seals. Replace any damaged seals and any seals that are hard or brittle.



Service Tip: Lubricate the seals with clean engine oil to facilitate the installation.



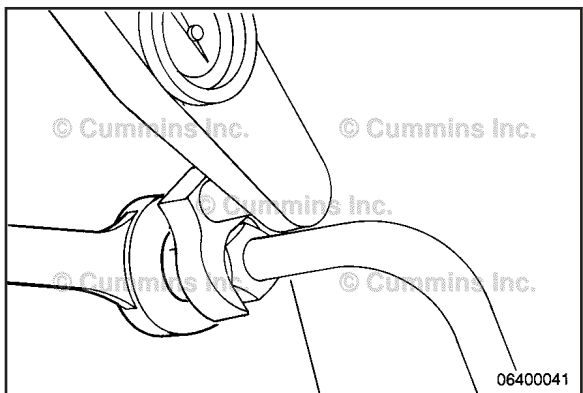
Install

Engine-to-Fuel Tank



Install and tighten the drain hose at the main fuel connection block.

Torque Value: 23 N•m [204 in-lb]



Fuel Drain Line

If the fuel drain line has been removed, install and tighten the line. Refer to Procedure 006-024.



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

General Information

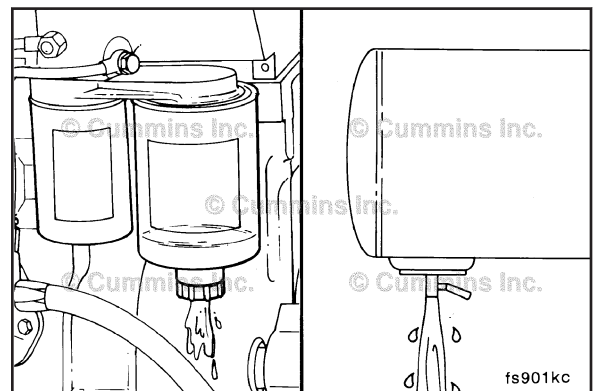
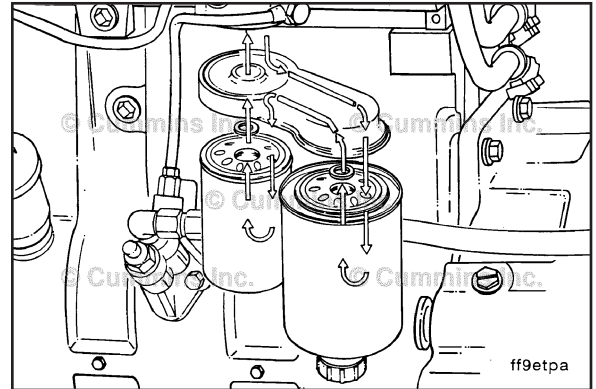
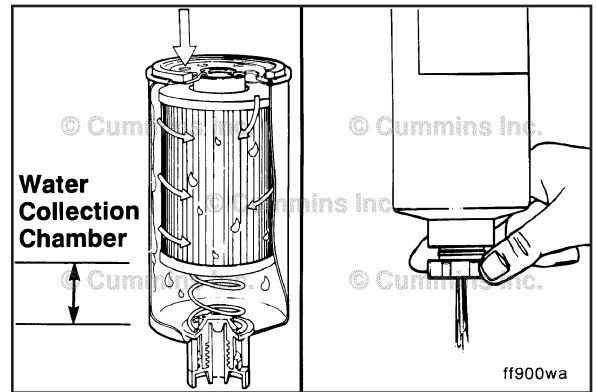
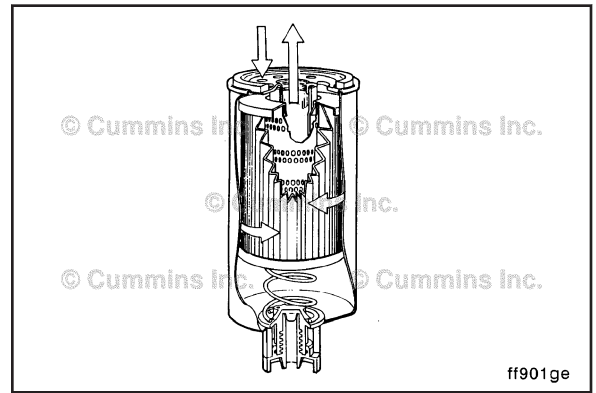
Filtration and separation of water from the fuel is important for trouble-free operation and long life of the fuel system. Some of the clearances between the fuel injection pump parts are very close. For this reason the parts can easily be damaged by rust formation, contaminants, or loss of the lubricating film of the fuel.

NOTE: Make sure to use the correct fuel filter element for your engine.

The fuel filter element has a valve that **must** be opened daily to drain any collected water.

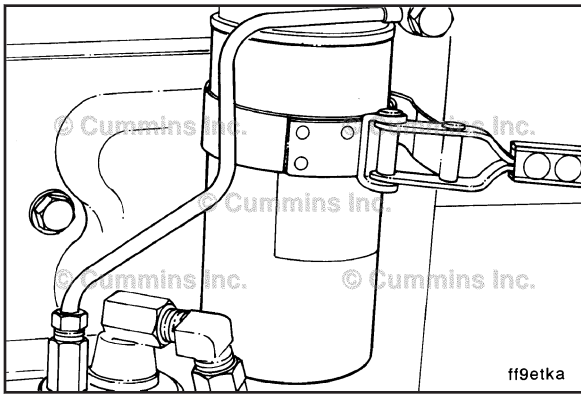
A dual water separator/filter adapter provides additional filtering capacity. The fuel flows through the adapter to a larger combination fuel/water separator filter, and back to the fuel filter for final filtering.

Regular maintenance, including draining moisture from the fuel/water separator and filter and supply tanks, is essential to keep water out of the fuel system.



Preparatory Steps

Clean all debris from the fuel filter.

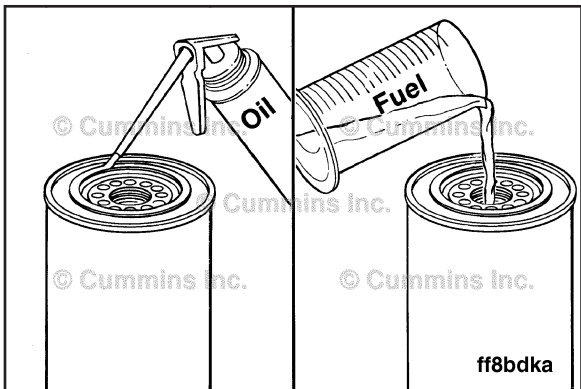


Remove

Remove the combination water separator/fuel filter with filter wrench, Part Number 3376807.



Remove the two fuel filters from the dual-filter adapter, if equipped, with filter wrench, Part Number 3376807.

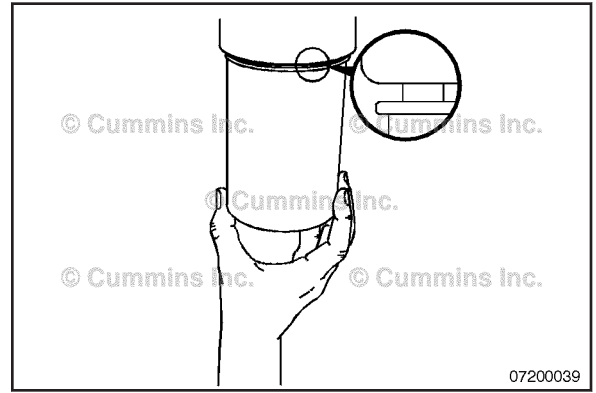


Install

Lubricate the fuel filter gasket with clean engine oil.
Fill the fuel filter with clean diesel fuel.

Install the fuel filter on the filter head.

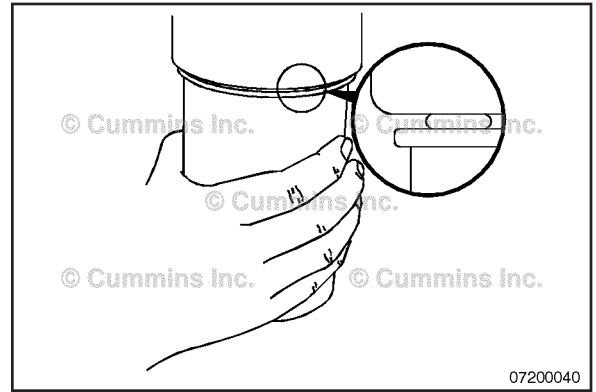
Turn the filter until the gasket contacts the filter head surface.



⚠CAUTION⚠

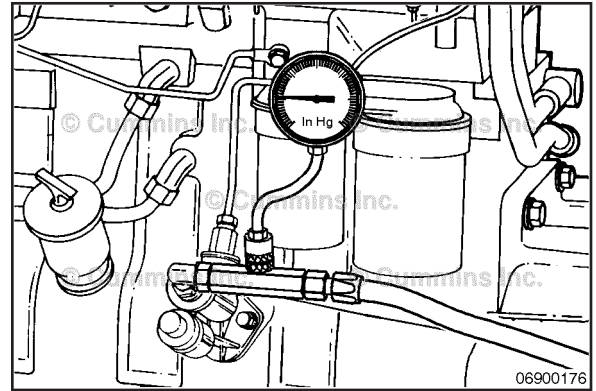
Mechanical overtightening of the fuel filter can distort the threads and damage the fuel filter.

Tighten the fuel filter an additional 1/2 to 3/4 of a turn after the gasket contacts the fuel filter head surface, or as specified by the fuel filter manufacturer.



**Fuel Inlet Restriction (006-020)
Initial Check**

Install a fitting at the inlet of the transfer pump.
Install a vacuum gauge, Part No. 3375274.



Vacuum Gauge Range

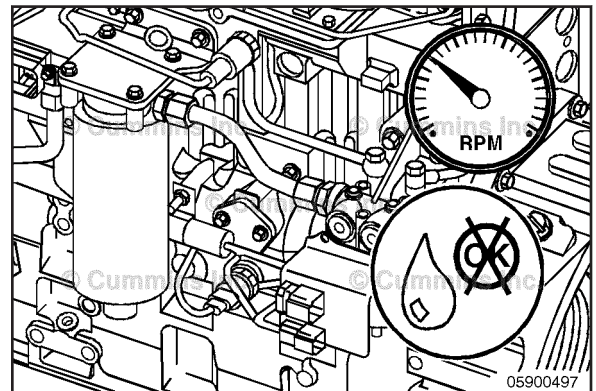
mm Hg		in Hg
0 to 508	MIN	0 to 20

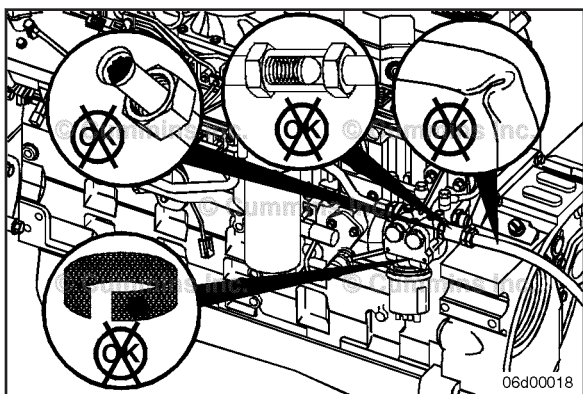
Start the engine.

Run at low or high idle.

Inlet Restriction at Low/High Idle

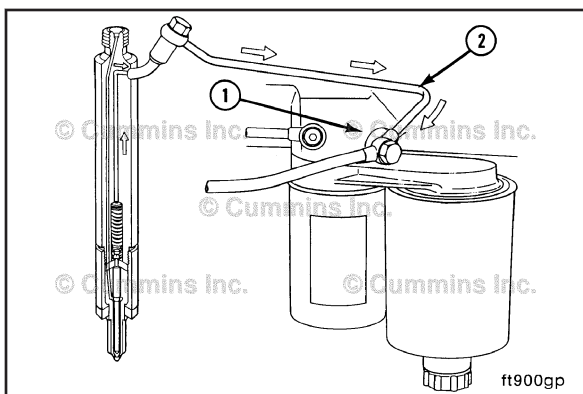
mm Hg		in Hg
101.6	MAX	4.70





If the fuel inlet restriction is above specification, check the OEM fuel lines from the fuel tank for proper size, kinks and bends, and clogged fuel lines.

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



Fuel Manifold (Drain) (006-021)

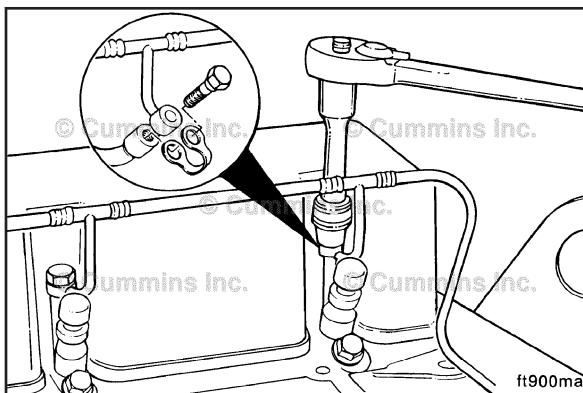
General Information

The fuel system is designed to use fuel to cool and lubricate the fuel injection pump plungers and injectors. Fuel is continually vented from the fuel injection pump and a small amount of fuel leaks by the injector needle valve during injection. This fuel is returned to the fuel filter head (1) by the fuel drain manifold (2).



Preparatory Steps

Clean all debris from around the fuel drain manifold.

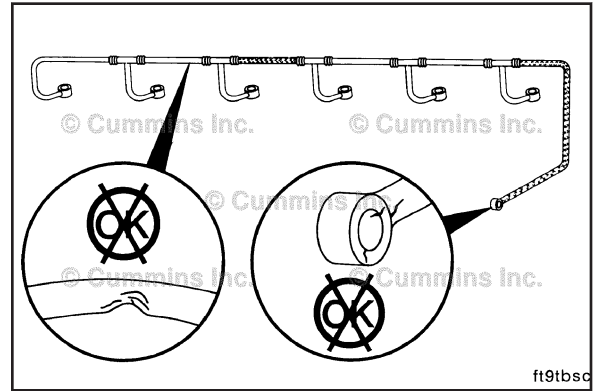


Remove

Remove the banjo capscrews from the injectors and fuel filter head.

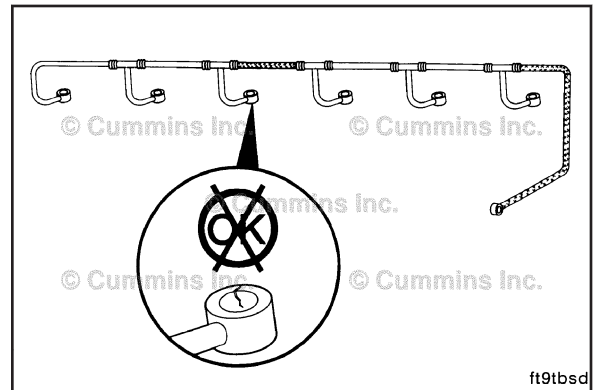
Inspect for Reuse

Inspect the fuel drain lines for cracks and/or damage.



Inspect the fuel drain line banjo connections.

NOTE: The banjo connection seals **must** be discarded when removed. The seals **must not** be reused.

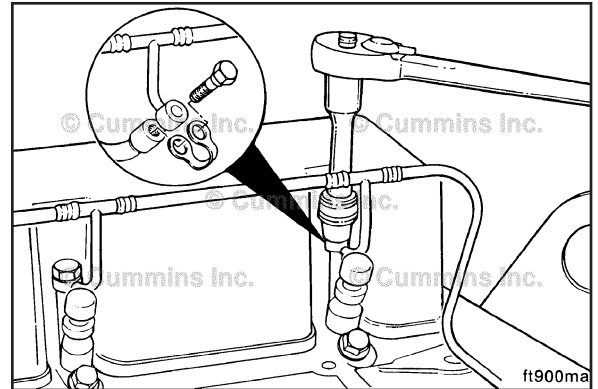


Install

Install the fuel drain manifold in the reverse order of removal.

Torque Value:

Filter Head Banjo 15 N•m [133 in-lb]
Injector Banjo 9 N•m [80 in-lb]



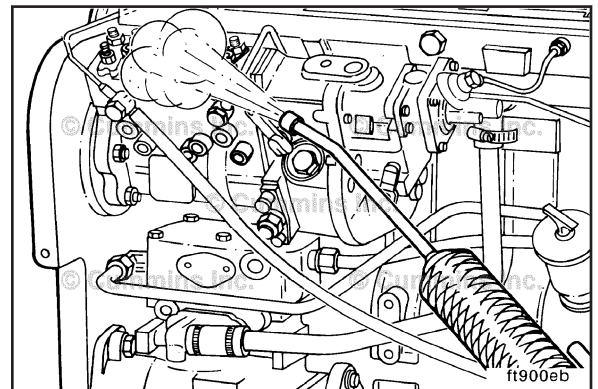
Fuel Supply Lines (006-024)

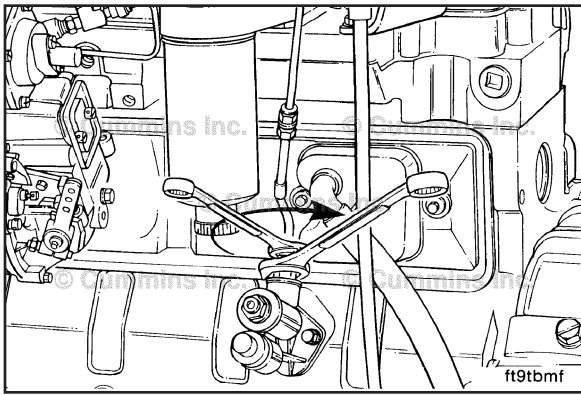
Preparatory Steps

Low Pressure Fuel Line(s)

Clean any debris from the fittings.

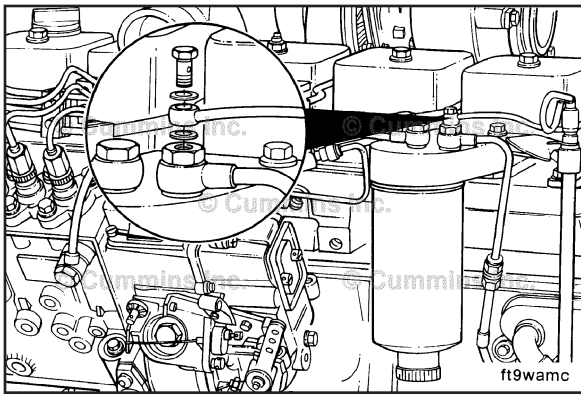
NOTE: Thoroughly clean all fittings and components before removal. Make sure that the debris, water steam, or cleaning solution does **not** get inside the fuel system.



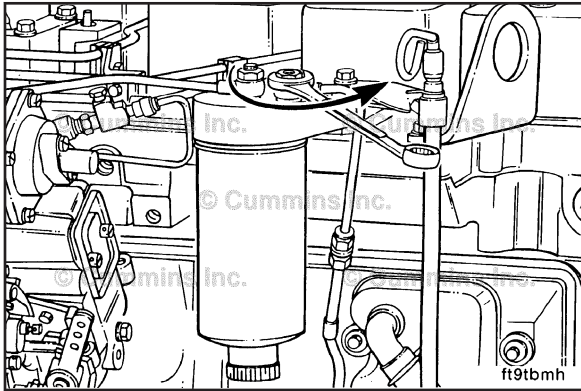


**Remove
In-line Fuel Injection Pumps**

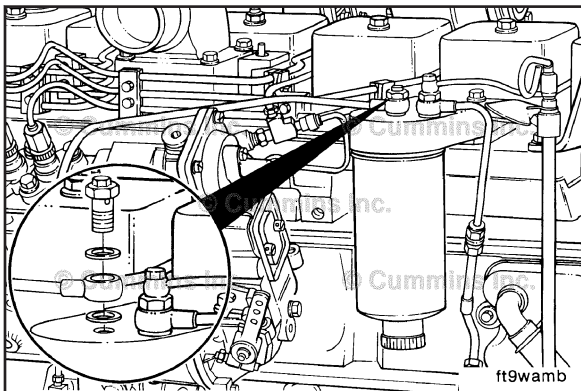
Remove the fuel line from the piston-style fuel transfer pump.



Remove the fuel drain manifold line at the fuel filter head.



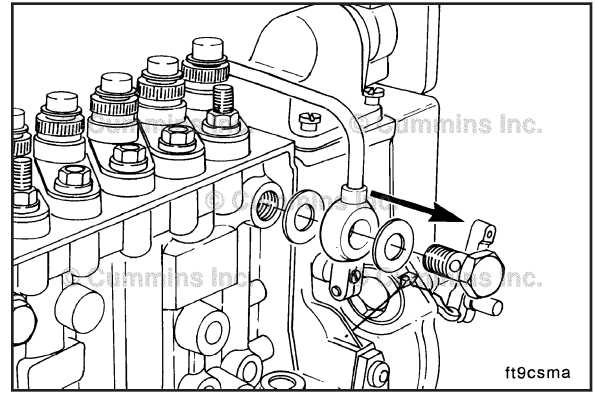
Remove the fuel line from the filter head.



Bosch® In-line

Remove the banjo capscrew and sealing washers at the fuel filter head.

Remove the banjo capscrew and copper sealing washer at the fuel injection pump inlet.



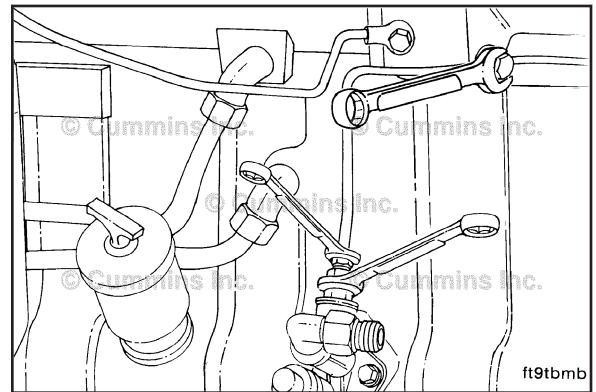
Install

⚠ CAUTION ⚠

Do not overtighten the fuel supply line fittings. A fuel leak can occur.

Install the fuel line between the fuel lift pump and the fuel filter head. Use two wrenches to tighten the connection on the fuel lift pump.

Torque Value: 24 N•m [18 ft-lb]



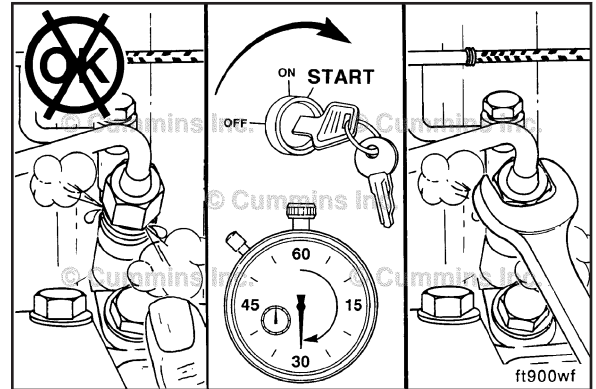
Vent

⚠ WARNING ⚠

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

Vent the high-pressure fuel lines. Loosen the fitting at the injector Number 1. Place the fuel control in the RUN position. Crank the engine so air can bleed from the fuel lines then tighten the fitting.

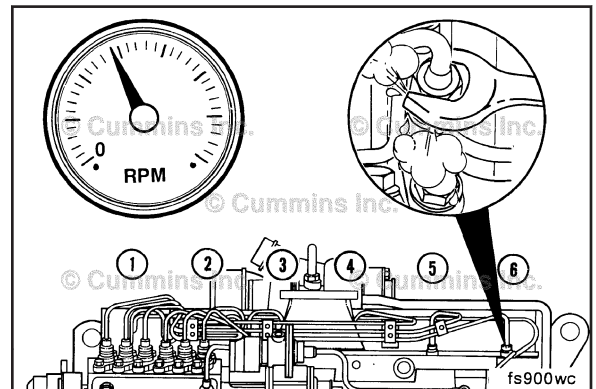
Torque Value: 30 N•m [22 ft-lb]

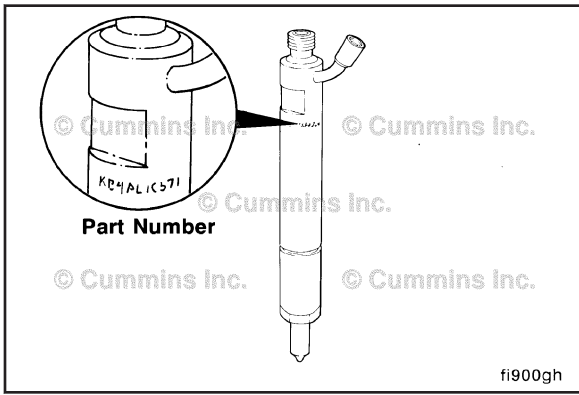


⚠ WARNING ⚠

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

Vent each high-pressure line separately until the engine runs smoothly.



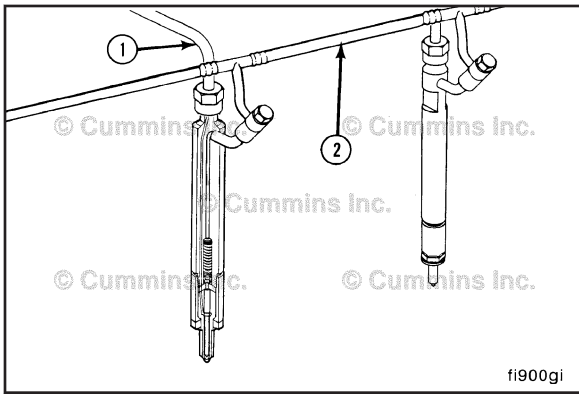


Injector (006-026)

General Information

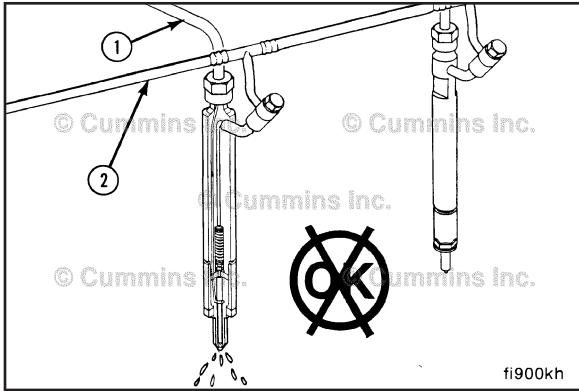
All engines use 7-mm closed nozzles, hole-type injectors. However, the injectors can have different part numbers for different engine ratings. The last four digits of the Cummins part number is used to identify the injectors.

Use **only** the specified injector for the engine.



During the injection cycle, fuel under high pressure from the fuel injection pump rises to the operating (pop-off) pressure that causes the needle valve in the injector to lift. Fuel is then injected into the cylinder. A shimmed spring is used to force the needle valve closed as the injection pressure drops below the pop-off pressure. The shimmed spring seals off the nozzle after injection.

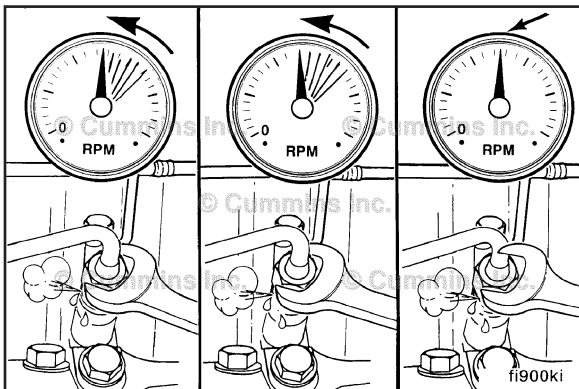
1. High-Pressure Fuel Line
2. Fuel Drain Manifold.



Failure of the needle valve to lift and close at the correct time, or the needle valve sticks open, can cause the engine to misfire and produce low power.

Fuel leaking from the open nozzle can cause:

1. Fuel knock
2. Poor performance
3. Smoke
4. Poor fuel economy
5. Rough-running engine.



Initial Check

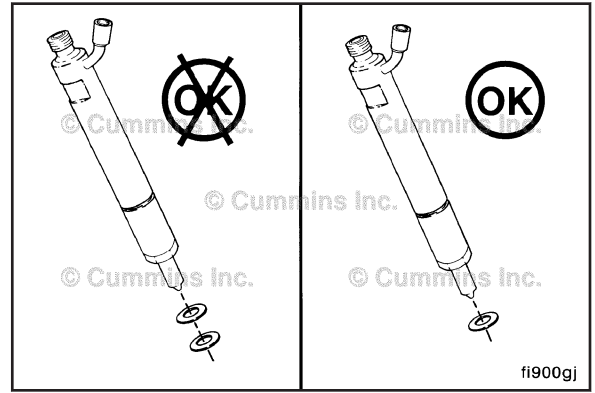
To find which cylinder is misfiring, operate the engine and loosen the fuel line nut at one injector, and listen for a change in engine speed.

A drop in engine speed indicates the injector was delivering fuel to the cylinder.

Inspect each cylinder until the malfunctioning injector is found.

Make sure to tighten the fuel line nut before proceeding to the next injector.

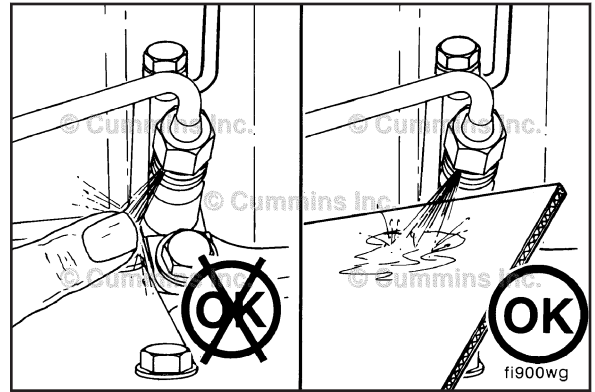
Remove the malfunctioning injector to test it.
Check for an extra copper sealing washer on the injector.



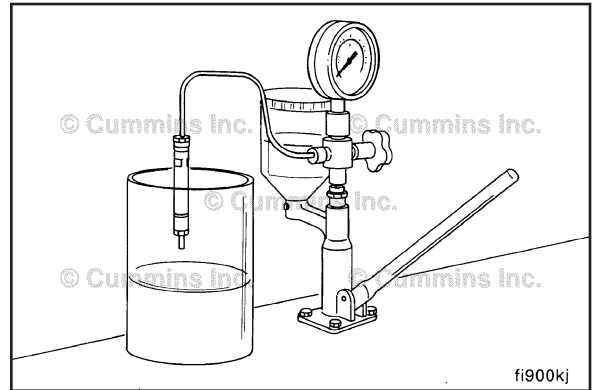
⚠ WARNING ⚠
While testing injectors, keep hands and body parts away from the injector nozzle. Fuel coming from the injector is under extreme pressure and can cause serious injury by penetrating the skin.

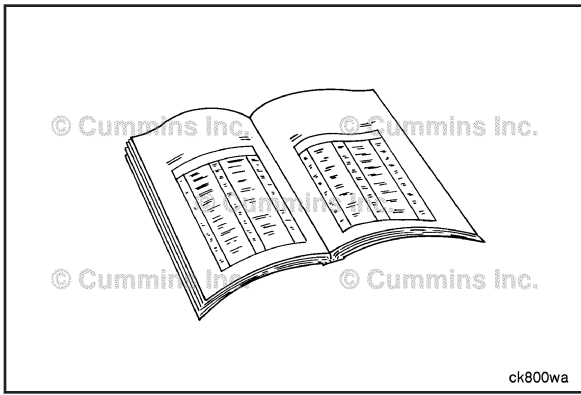
⚠ WARNING ⚠
The pressure of the fuel in the line is sufficient to penetrate the skin and cause serious personal injury. Wear gloves and protective clothing.

If the engine continues to misfire, use cardboard to check for fuel leaks in the high-pressure lines. With the engine running, move the cardboard over the fuel lines, and look for fuel spray on the cardboard. Fuel leaks can cause poor engine performance. Also, check for a defective delivery valve that lets the fuel drain back into the injection pump.



Carbon buildup in the orifices in the nozzle can also cause low power from the engine. Remove the injectors and check the spray pattern, or replace the injectors.





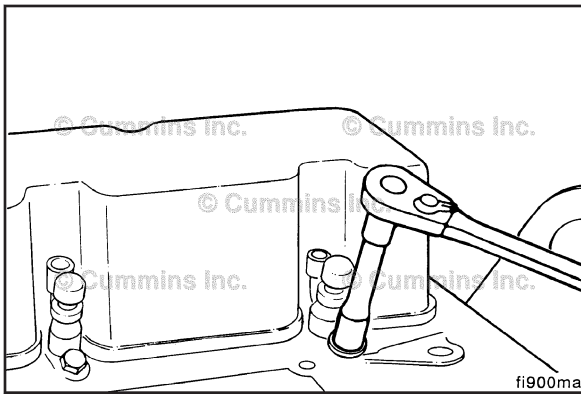
Preparatory Steps

Thoroughly clean around the injectors.



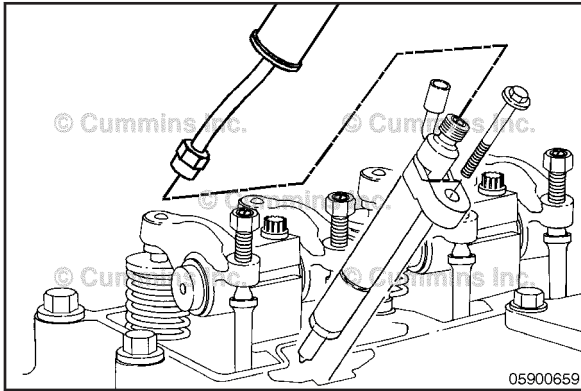
Disconnect the high-pressure injector supply lines; refer to Procedure 006-051.

Disconnect the fuel drain manifold; refer to Procedure 006-021.



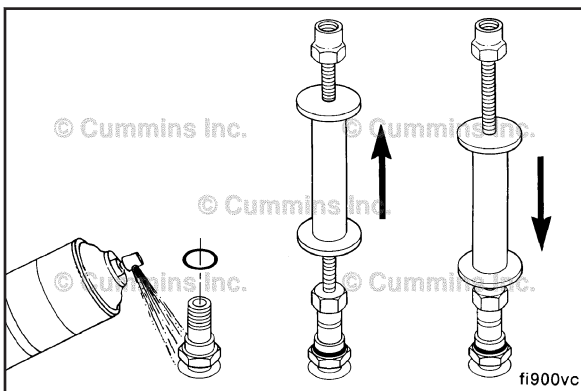
Remove

Remove the injector hold-down clamp.



Use injector puller, Part Number 3823276 or 3164706, to remove the injectors.

Remove the injectors.

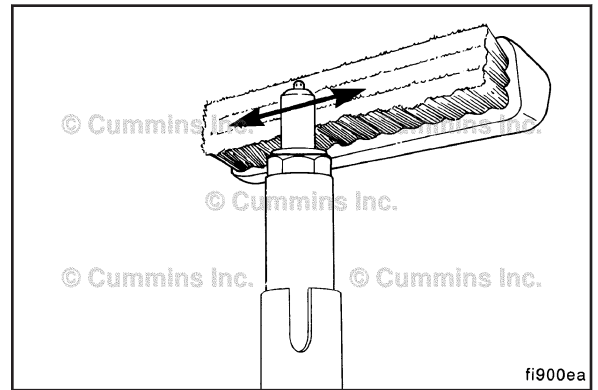


To remove some injectors, it will probably be necessary to:

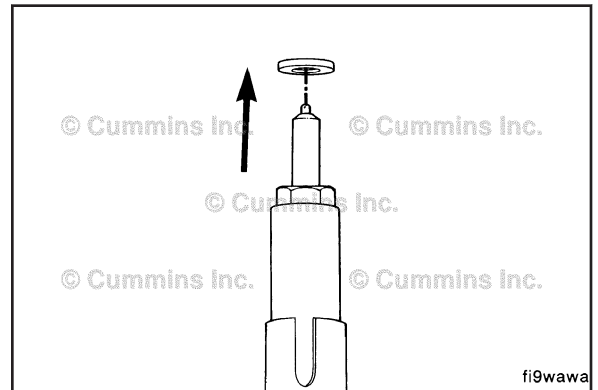
- Tap the injector with the injector puller
- Work the injector up and down.

Disassemble

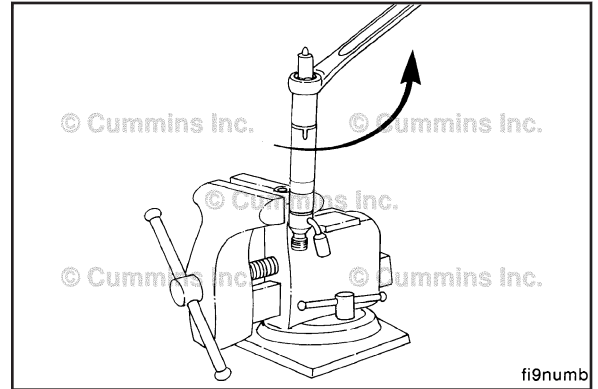
Clean the carbon residue from the injector nozzle, using a brass wire brush and a piece of hardwood dipped in test oil.



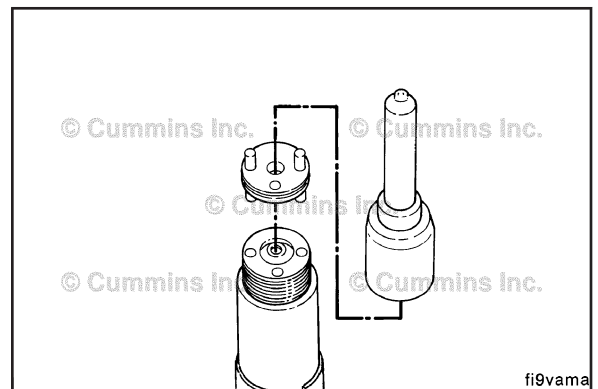
Remove and discard the injector seals.

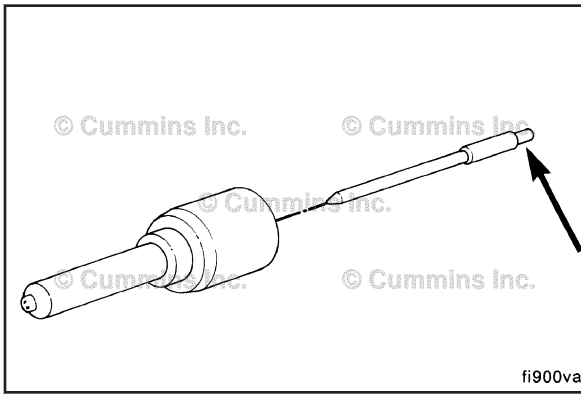


Clamp the injector hold-down clamp in a soft-jawed vise. Remove the injector nozzle retaining nut.

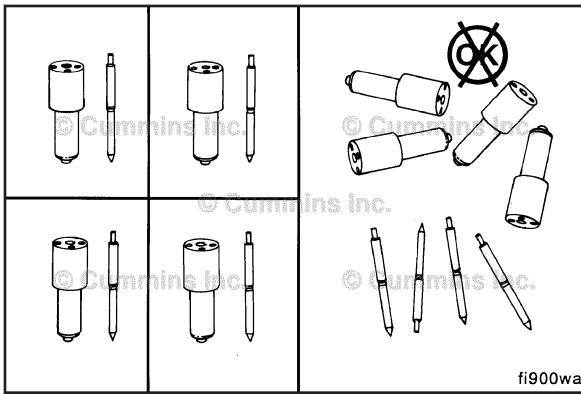


Remove the nozzle needle valve and intermediate plate. To avoid damage, place the injector nozzle and needle valve in a suitable bath of clean test oil.

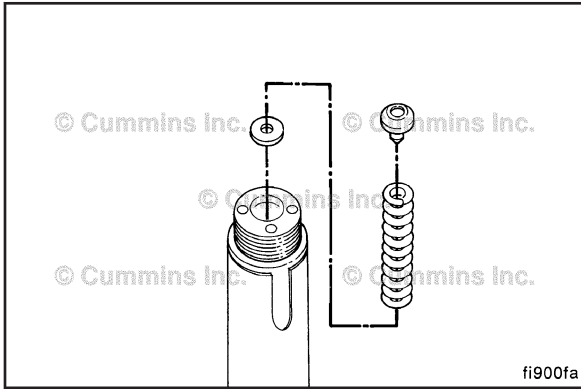




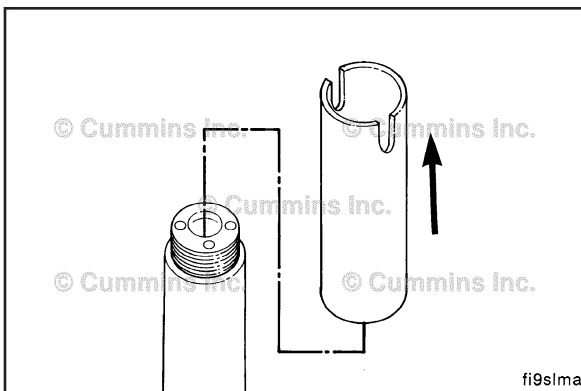
⚠CAUTION⚠
Hold the needle valve by the stem only. Secretions from the skin will corrode the finely lapped surfaces.



The needle valve and nozzle tip are precisely matched for fit. The parts **must not** be intermixed.



Remove the nozzle holder from the vise.
Remove the pressure spindle, pressure spring, and shims.



Remove and discard the injector sealing sleeve.

Test

⚠ WARNING ⚠
While testing 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.

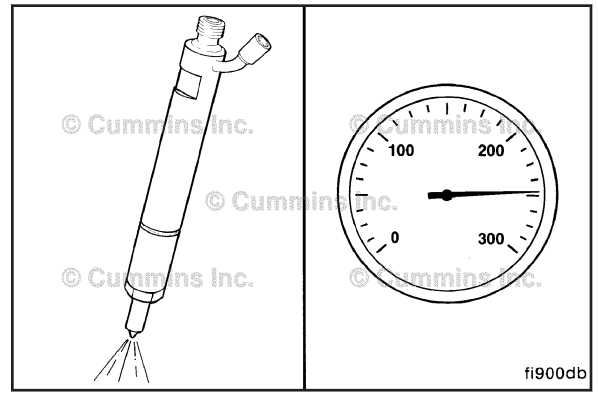
⚠ WARNING ⚠
The pressure of the fuel in the line is sufficient to penetrate the skin and cause serious personal injury. Wear gloves and protective clothing.

Injector Opening Pressure Test

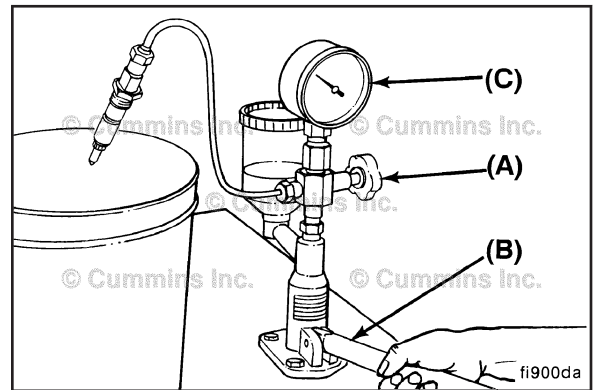
All nozzles **must** be tested for opening pressure, chatter, and spray pattern.

Inspect the injector opening pressure using injector nozzle tester, Part Number 3376946:

- A. Open valve.
- B. Operate the lever at one stroke per second.
- C. Read the pressure indicated when the injector spray begins.



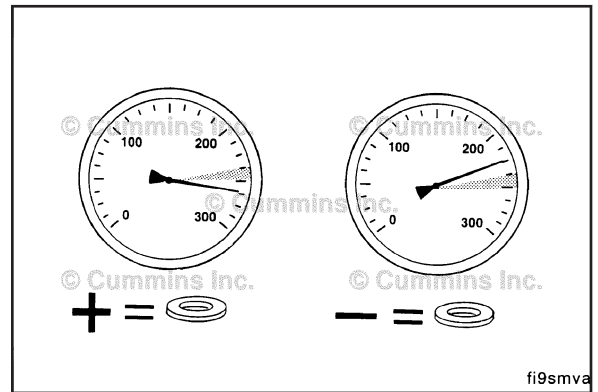
fi900db



fi900da

If the opening pressure does **not** meet specifications:

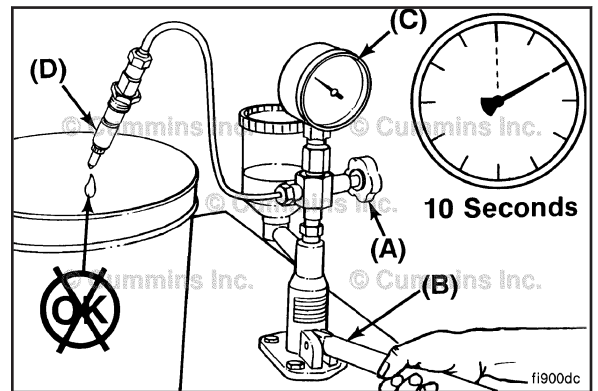
1. Add shim(s) to increase pressure.
2. Remove shim(s) to decrease pressure.



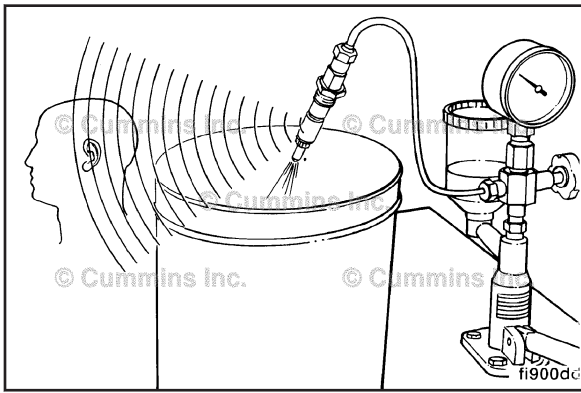
fi9smva

Leakage Test

1. Open valve (A).
2. Operate the lever (B) to maintain a pressure of 20 bar [290 psi] below opening pressure (C).
3. No drops can fall from the tip (D) within 10 seconds.



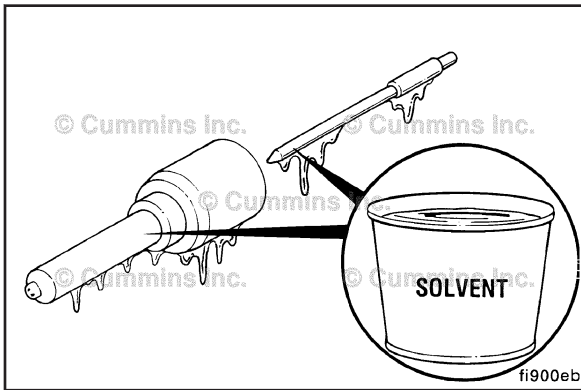
fi900dc



Chatter Test

The chatter test indicates the ability of the needle valve to move freely and atomize the fuel correctly. A sound will be heard as the valve rapidly opens and closes. A well-optimized spray pattern will be seen.

Used nozzles can **not** be evaluated for chatter at lower speeds. A used nozzle can generally be used if it passes the leakage test.

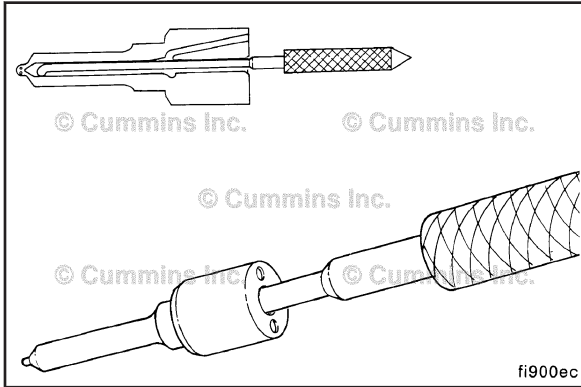


Clean and Inspect for Reuse

⚠ 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.

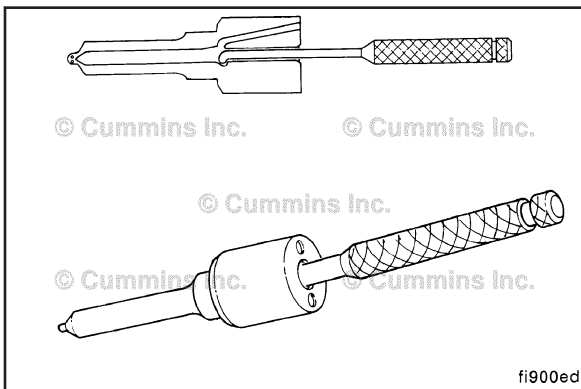
Rinse the nozzle bodies and needle valves in solvent to flush and remove thoroughly and completely all varnish and carbon deposits.



⚠ CAUTION ⚠

Never use emery paper or any other metal scraper to clean the nozzle. The parts can be damaged.

Dip the nozzle seat in clean test oil, and use nozzle cleaning kit, Part Number 3376947, to clean. Polish the needle seat with the piece of hardwood dipped in the test oil.



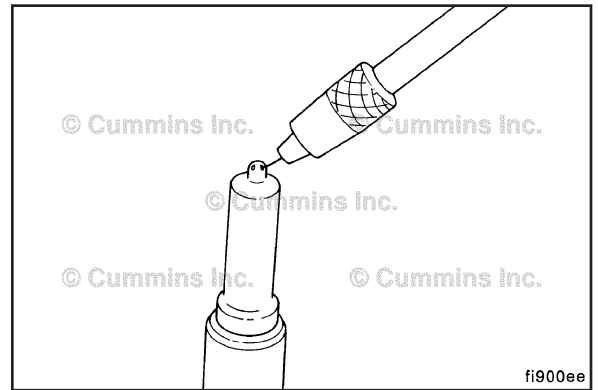
⚠ WARNING ⚠

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 interior ring groove of the nozzle with the scraper as shown. Rinse in solvent to remove all dirt and carbon residue and dip in clean test oil.

Clean the spray holes as shown with the appropriate-size cleaning needle.

Remove burned-on combustion deposits on all nozzles with a commercially available cleaner. Rinse all parts in clean test oil.



Clean the needle valve tip with a brass brush. Inspect for rough surfaces or erosion. The pressure shoulder will normally have a rough machined appearance.

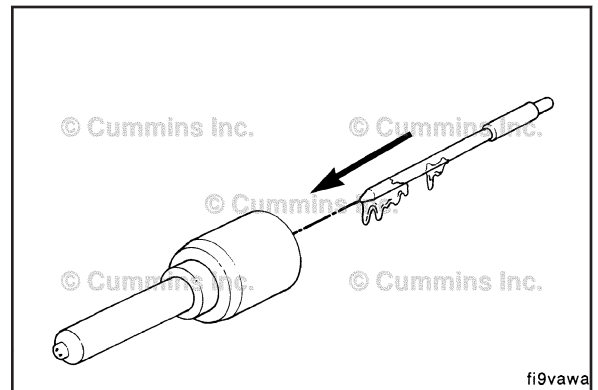
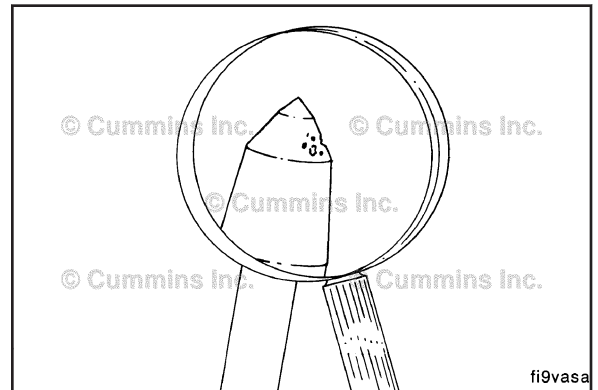
Deteriorated needle valves **must** be replaced as a matched unit with their compatible nozzle body.

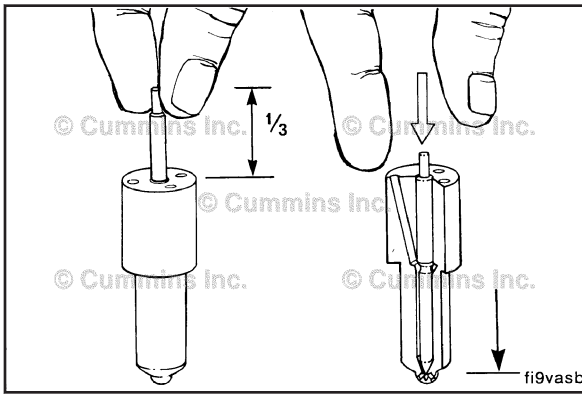
Inspect the injector. Inspect the o-ring for damage. Inspect for burrs on the inlet to the injector. Check the nozzle holes for any signs of damage, such as hole erosion or hole plugging. Also, check the nozzle color for sign of overheating. Overheating will cause the nozzle to turn a dark yellow and tan or blue color, depending on the temperature of the overheat.

Inspect for rough surfaces or erosion. The pressure shoulder will normally have a rough machined appearance.

Inspect the injector bore for old sealing washers.

Dip the needle valve in clean test oil, and insert the needle valve all the way into the nozzle body.

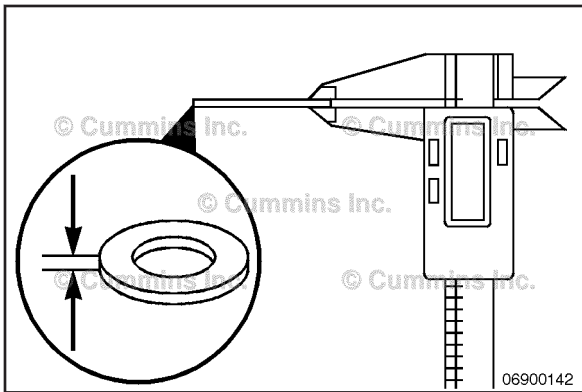




Pull the needle valve one-third of the way out of the nozzle body. With the needle valve in the vertical position, the needle valve **must** slide all the way back into the nozzle body under its own weight.

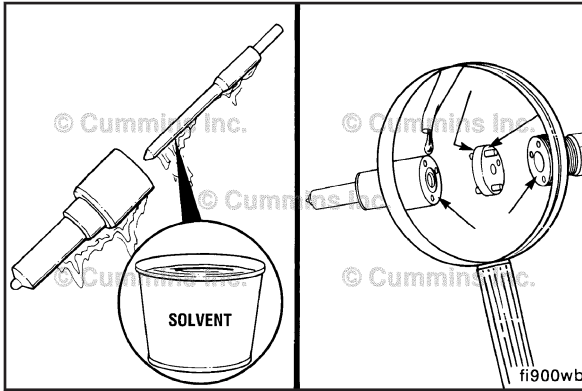
If the nozzle does **not** pass this test, clean and test it an additional time.

Any needle valve and nozzle body assembly that does **not** pass this test **must** be replaced.



Verify that the injector sealing washer is the correct thickness. The incorrect sealing washer can cause high-pressure fuel leaks, and/or performance problems due to incorrect injector protrusion.

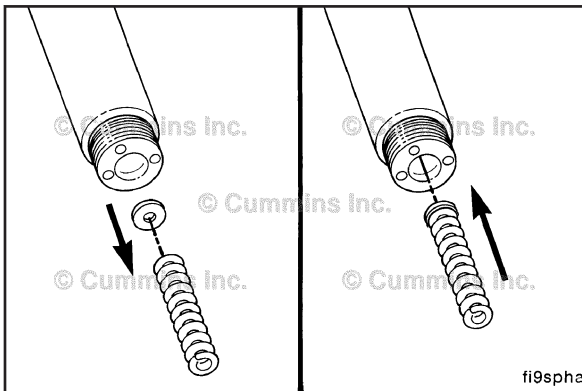
Injector Sealing Washer 1.5 mm [0.06 in]



Assemble

Make sure all mating surfaces and pressure faces are thoroughly cleaned and lubricated with test oil before assembly.

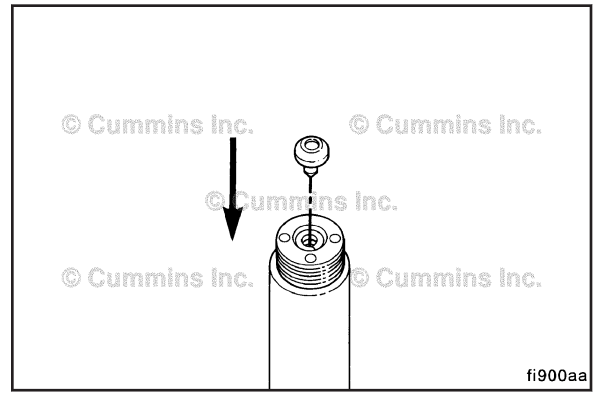
New nozzles **must** be cleaned and lubricated before assembly.



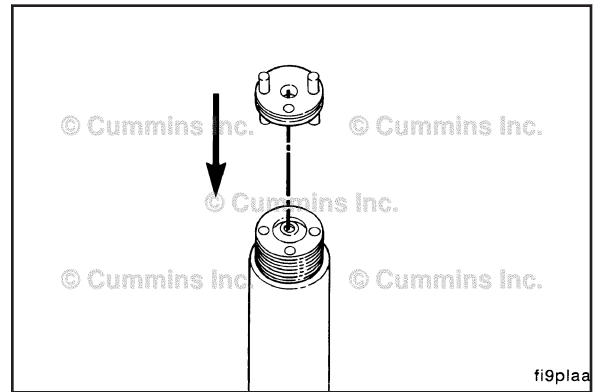
Install the shim(s) and pressure spring.

Install the same thickness of shim(s) that were removed in disassembly. Use the pressure spring to make sure the shim(s) are installed flat.

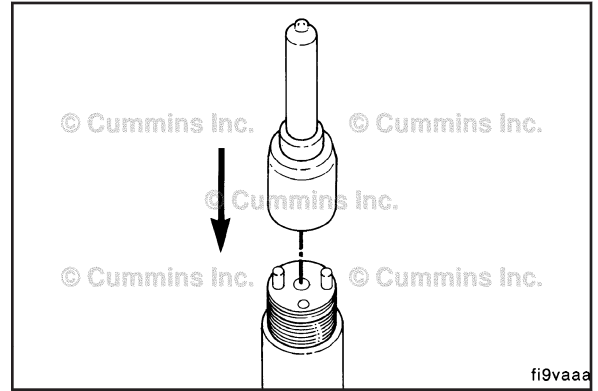
Install the spindle.



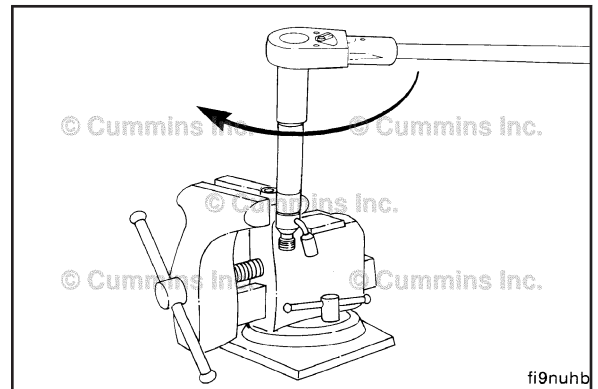
Install the intermediate plate.



Install the needle valve and nozzle assembly.



Install and tighten the nozzle retaining nut.
Torque Value: 30 N•m [22 ft-lb]

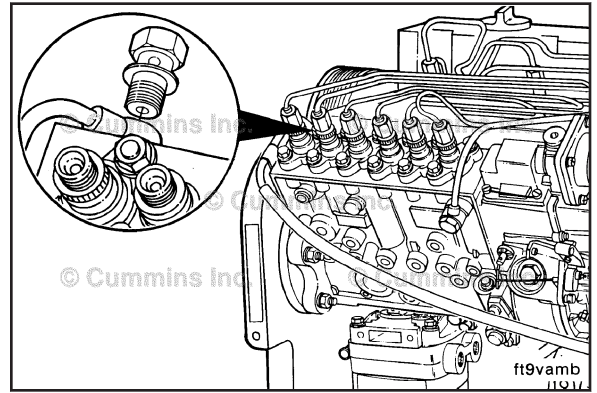


Fuel Return Overflow Valve (006-044)

Remove

19-mm Wrench

Remove the pressure relief valve and copper sealing washers.



Clean

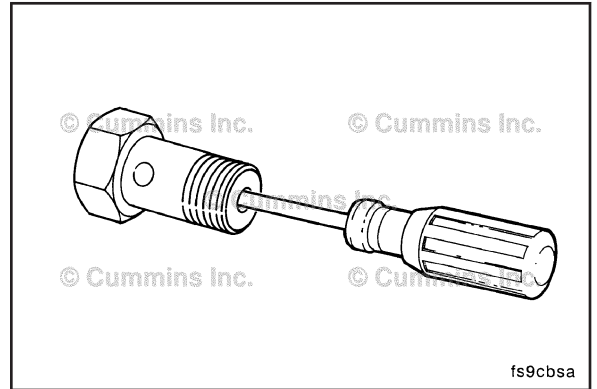
Thoroughly flush the high-pressure relief valve with cleaning solution.



Inspect for Reuse

NOTE: A sticky check ball will result in low engine power.

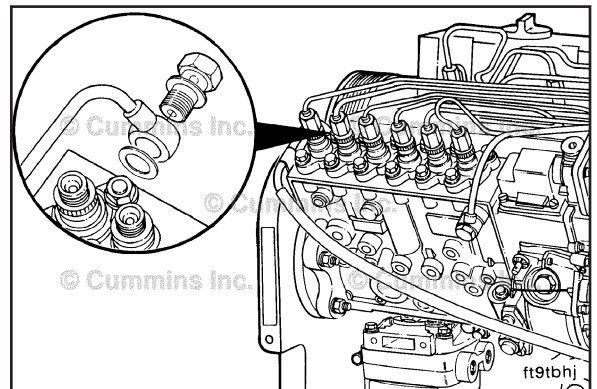
Use a small screwdriver to verify that the check ball is **not** sticking in the high-pressure relief valve assembly.

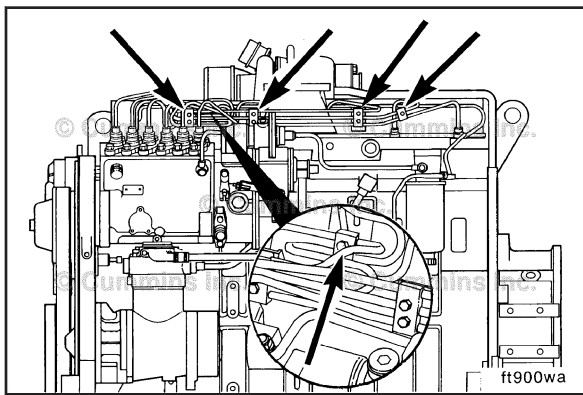


Install

Install the high-pressure relief valve assembly in the reverse order of removal.

NOTE: Make sure to replace the used sealing washers with new sealing washers.





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

General Information

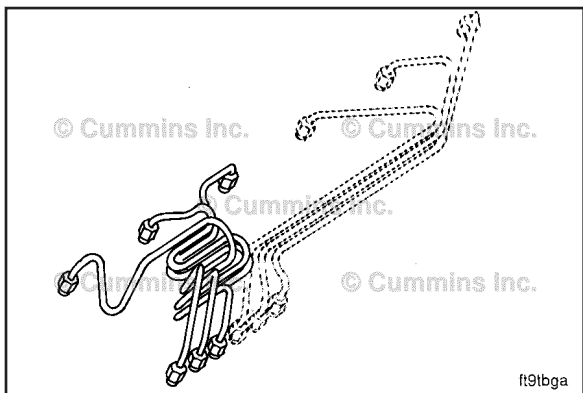
⚠ CAUTION ⚠

The high-pressure fuel lines will be damaged, unless they are clamped securely and routed so they do not contact each other or any other components.

The high-pressure fuel lines are designed and manufactured to deliver fuel at injection pressure to the injectors. The high-pressure pulses will cause the lines to expand and contract during the injection cycle.

The length, internal size, and rigidity of the high-pressure fuel lines is critical to smooth engine operation. An attached metal tag is used to identify each line with a part number.

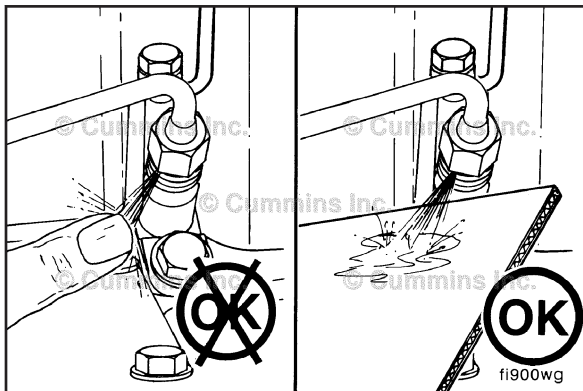
NOTE: Do **not** weld or substitute line. Use **only** the specified part number for the engine.



⚠ WARNING ⚠

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

Use cardboard to check for cracks and leaks in the high-pressure fuel lines. With the engine running, move the cardboard over the fuel lines and look for fuel spray on the cardboard. Fuel leaks can cause poor engine performance.



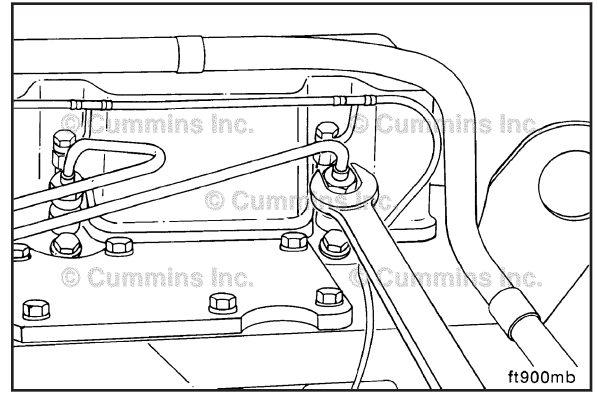
Preparatory Steps

Clean all debris from around the fuel lines.

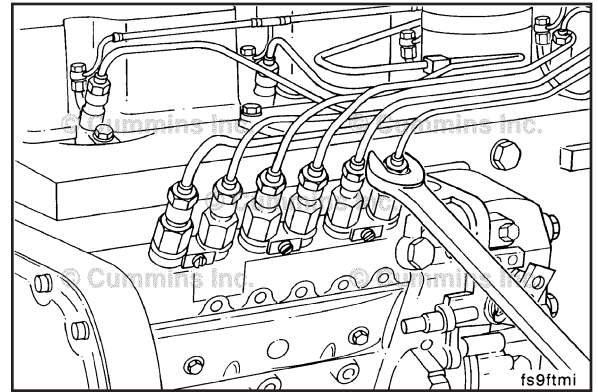
Remove

NOTE: If individual lines are to be replaced, remove the vibrations isolators from the set of lines containing the line to be replaced.

Disconnect the line(s) from the injector(s).



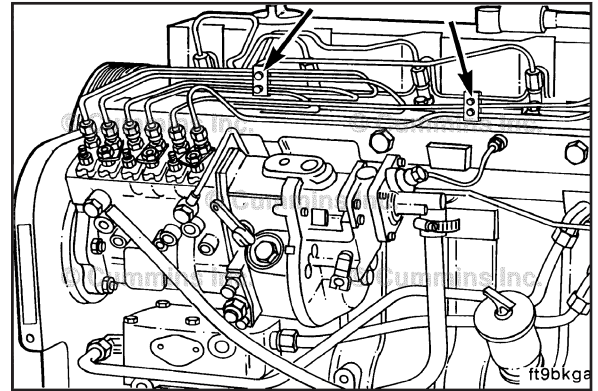
Disconnect the line(s) from the fuel injection pump.



⚠CAUTION⚠

The high-pressure fuel lines will be damaged if they are not clamped securely and routed so they do not contact each other or any other component.

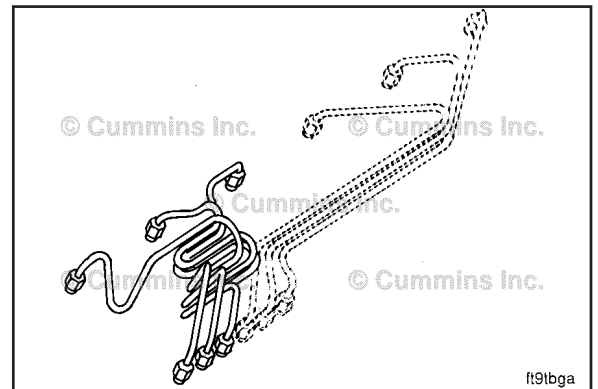
The high-pressure fuel lines are designed and manufactured to deliver fuel at injection pressure to the injectors. The high-pressure pulses cause the lines to expand and contract during the injection cycle.

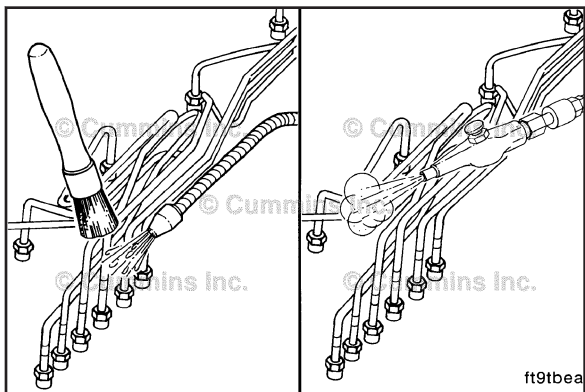


⚠CAUTION⚠

Do not weld or substitute lines. Use only the specified part number for the engine.

The length, internal size, and rigidity of the lines are critical for smooth engine operation. An attached metal tag is used to identify each line with a part number.





Clean



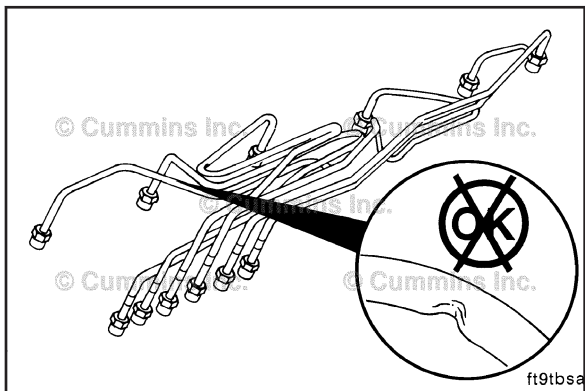
⚠ WARNING ⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

Wash the fuel lines in clean solvent.

Dry the fuel lines with compressed air.

NOTE: Make sure all paint chips are removed when cleaning the fuel lines.

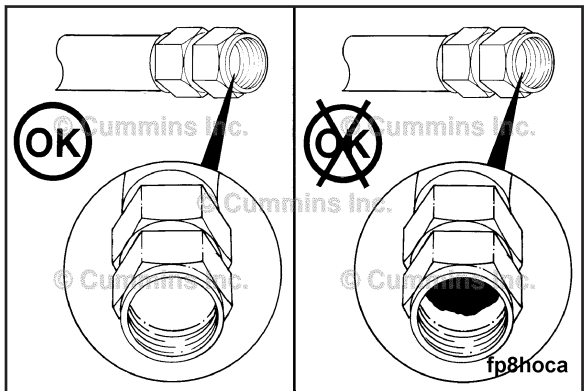


Inspect for Reuse

Inspect the high-pressure fuel lines for obvious damage, such as lines that have been bent to facilitate injector removal.

NOTE: High-pressure pulses expand and contract the injector lines that result in internal flaking at the bent areas.

Bent lines **must** be replaced.

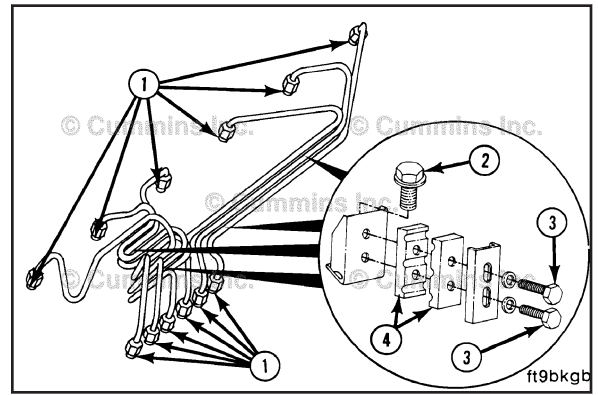


Inspect the high-pressure fuel lines for cracks at both ends.

Inspect all fuel line fittings (1), support bracket capscrews (2), vibration isolator capscrews (3), and isolators (4), for wear and damage.



Any damaged parts **must** be replaced.

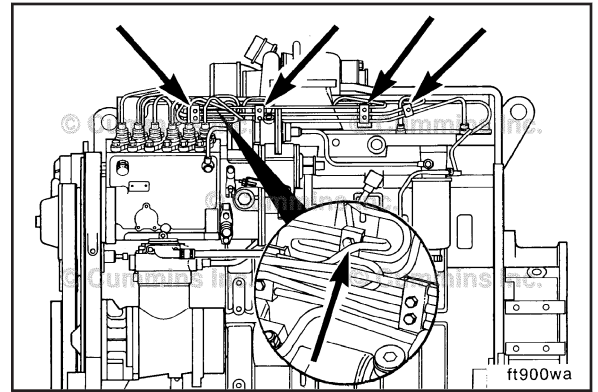


Install

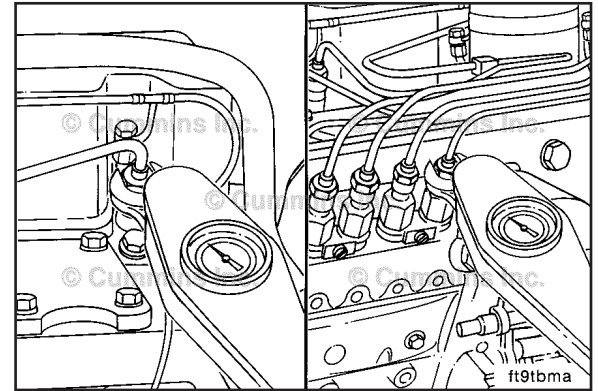
Loosen the vibration isolator capscrews so the fuel lines can be easily moved.



NOTE: To prevent breakage to the high-pressure fuel lines, they **must** be connected to the injector and the fuel injection pump in a free state, without forcing the connecting nuts since the fuel lines are properly sized for specific application.



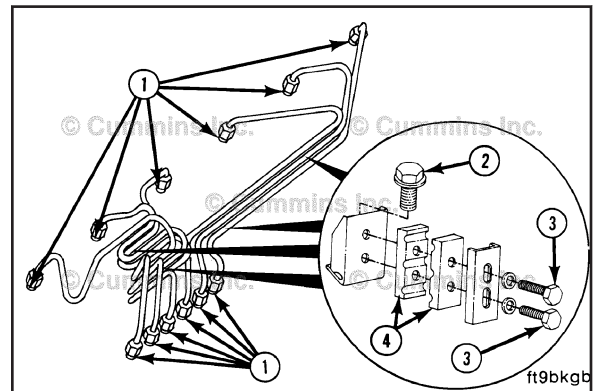
NOTE: If removed, install the support clamps in their original positions and make sure the high-pressure fuel lines do **not** contact each other or other components.

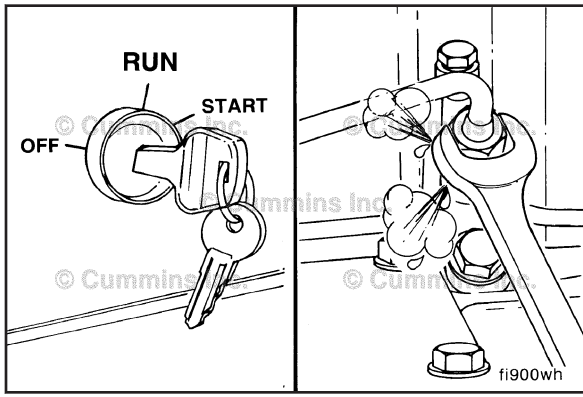


Tighten all fittings and mounting hardware.

Torque Value:

Fuel line connections	24 N•m	[18 ft-lb]
Support Bracket Capscrews	24 N•m	[18 ft-lb]
Isolator Capscrews	6 N•m	[53 in-lb]





Vent

Bleed the air from the high-pressure fuel lines at the injector connections. Bleed one line at a time until the engine runs smoothly.

NOTE: If the air can **not** be removed, check the fuel injection pump and supply line for suction leaks.

Section 7 - Lubricating Oil System - Group 07

Section Contents

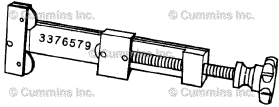
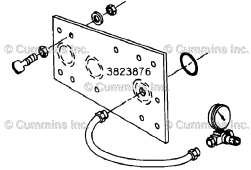
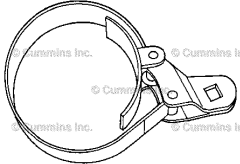
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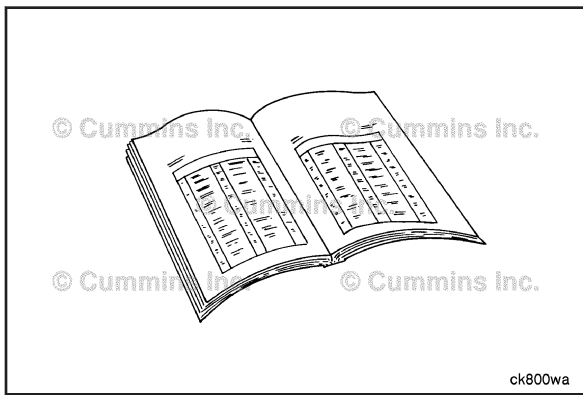
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Service Tools

Lubricating Oil System

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

Tool No.	Tool Description	Tool Illustration
3376579	<p>Tube (Filter) Cutter Used to cut open the filter to permit inspection of the filter element.</p>	 <p style="text-align: right;">3376579</p>
3823876	<p>Lubricating Oil Cooler Pressure Test Kit Used to seal and pressurize the lube oil cooler to test for leaks.</p>	
3375049	<p>Oil Filter Wrench Used to install and/or remove the large spin-on lubricating oil or fuel filters.</p>	 <p style="text-align: right;">3375049</p>



Engine Oil Heater (007-001)

Preparatory Steps

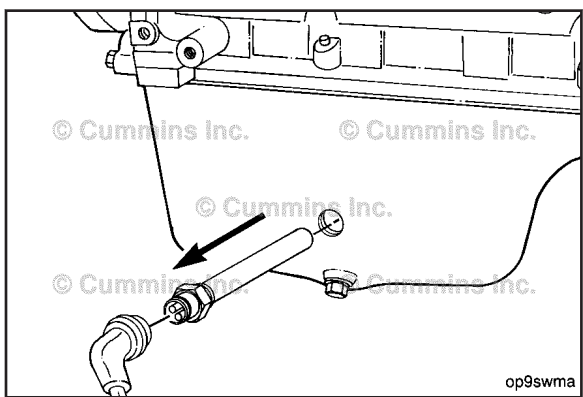


To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.



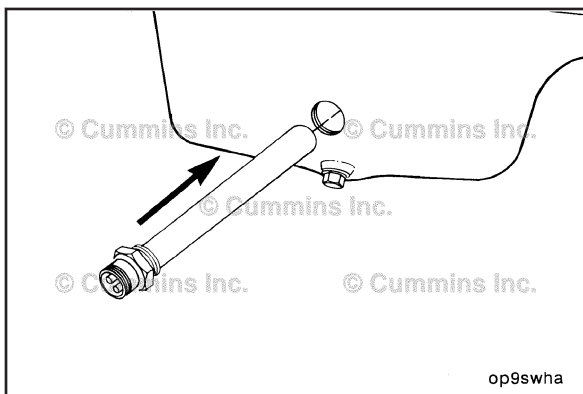
Some state and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

Drain the lubricating oil. Refer to Procedure 007-037.



Remove

Disconnect the oil heater electrical cord and remove the heater element. Refer to the OEM service manual.

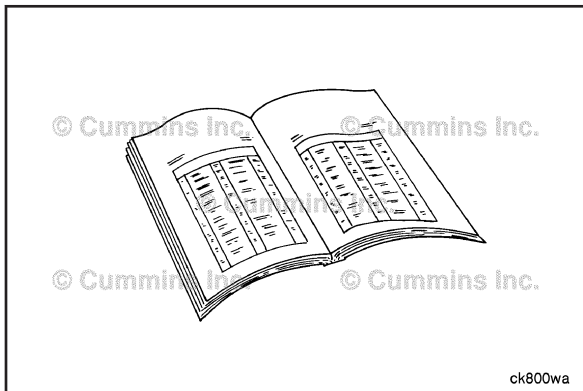


Install

Replace the heater element; refer to the OEM's service manual.



Torque Value: 80 N•m [59 ft-lb]



Finishing Steps

Fill the engine to the correct oil level. Refer to Procedure 007-037.

Connect the oil heater electrical cord.

Operate the engine and check for leaks.

Lubricating Oil Cooler (007-003)

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.

⚠ WARNING ⚠

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

⚠ WARNING ⚠

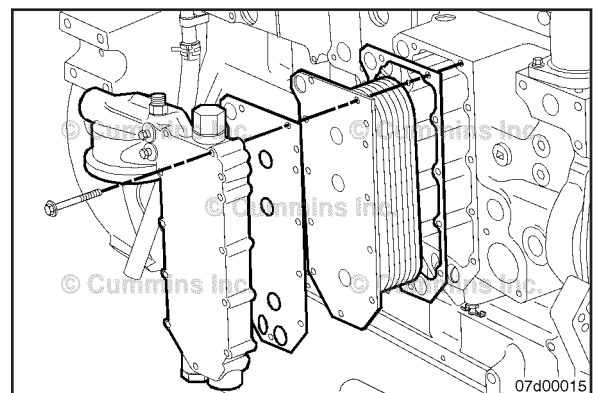
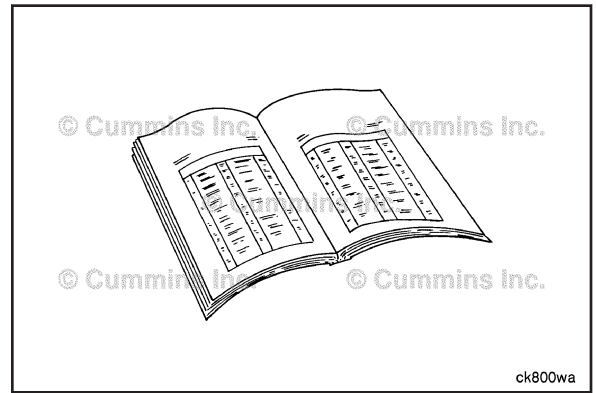
State and federal agencies have determined that used engine oil can be carcinogenic and cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

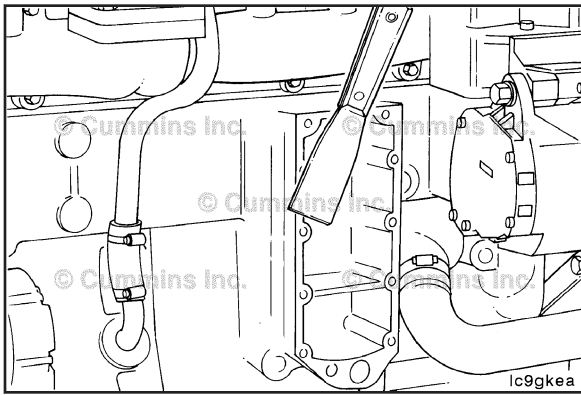
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Clean the area around the lubricating oil cooler cover.
- Remove the coolant filter head. Refer to Procedure 008-007 in Section 8.
- Remove the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Remove the turbocharger oil supply line. Refer to Procedure 010-046 in Section 10.

Remove

Remove the lubricating oil cooler cover, gaskets, and cooler element.

Discard the gaskets.





Clean and Inspect for Reuse

⚠️ WARNING ⚠️

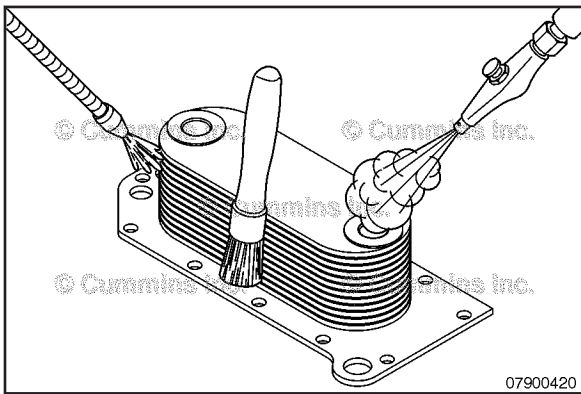
When using solvent, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠️ CAUTION ⚠️

Use a solvent that will not harm copper to clean the oil cooler elements.

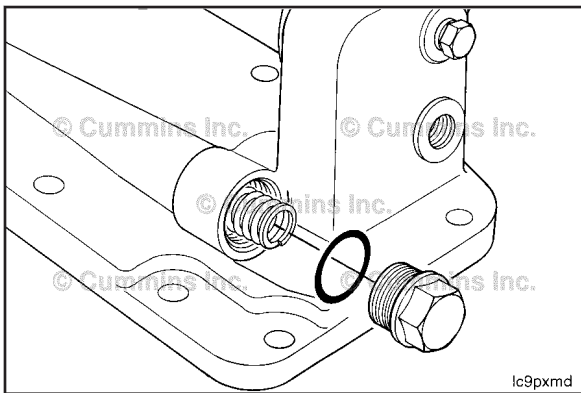
Clean the sealing surfaces of the cylinder block and the oil cooler cover.

NOTE: Replace the lubricating oil cooler if any debris is found or if the engine has had a debris-generating failure.

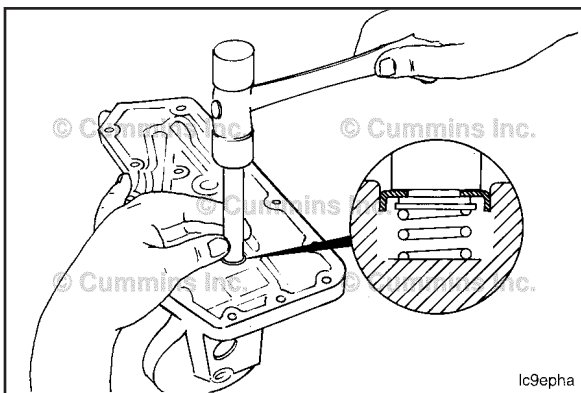


⚠️ CAUTION ⚠️

Do not reuse an oil cooler core after a debris related engine malfunction since there is no practical method for cleaning the cooler core. Metal particles which can circulate through the lubricating oil system can remain in the cooler core and cause engine damage.



If any debris is suspected to have gone through the engine, or if troubleshooting a lubricating oil pressure issue, remove and inspect the lubricating oil pressure regulator located in the lubricating oil cooler cover. Replace if necessary. Refer to Procedure 007-029 in Section 7.

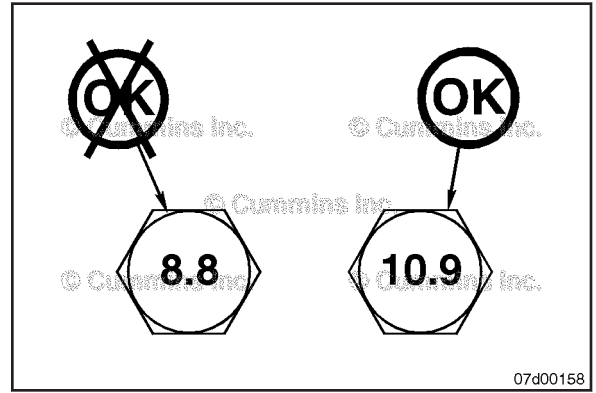


If any debris is suspected to have gone through the engine, inspect the oil filter bypass valve located in the lubricating cooler cover. Make sure the valve is fully seated and opens and closes freely. Replace if necessary.

The bypass valve requires a 345 kPa [50 psi] pressure differential to open.

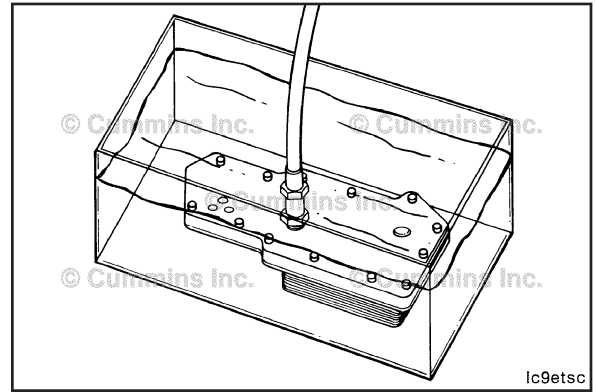
Inspect the capscrews. If they are Grade 10.9 or higher, they can be reused.

If the capscrews are lower than Grade 10.9, they **must** be replaced with Grade 10.9 or higher capscrews.



Leak Test

Use Leak Test Kit, Part Number 3823876, to pressure-test the lubricating oil cooler element.



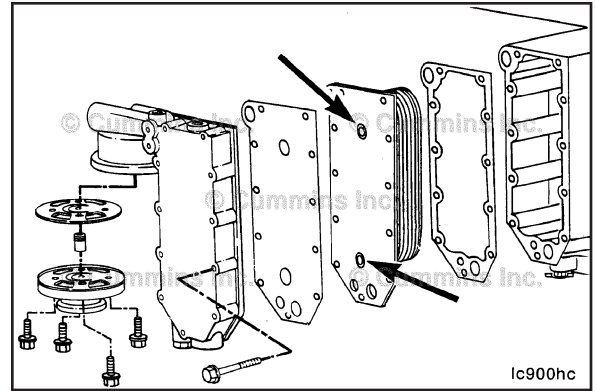
Air Pressure Test

kPa		psi
449	MIN	65
518	MAX	75

Install

NOTE: Make sure to remove the shipping plugs from a new element.

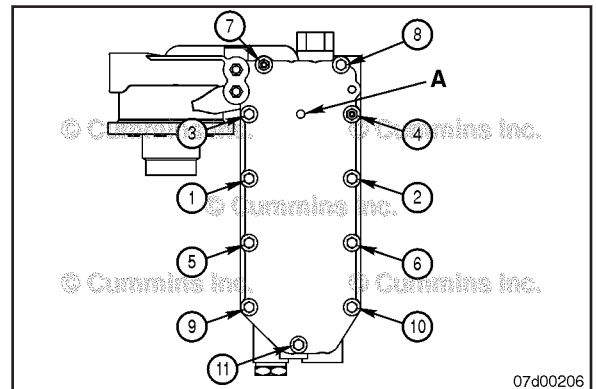
Assemble the lubricating oil cooler gaskets, element, and cooler cover. Use new gaskets.



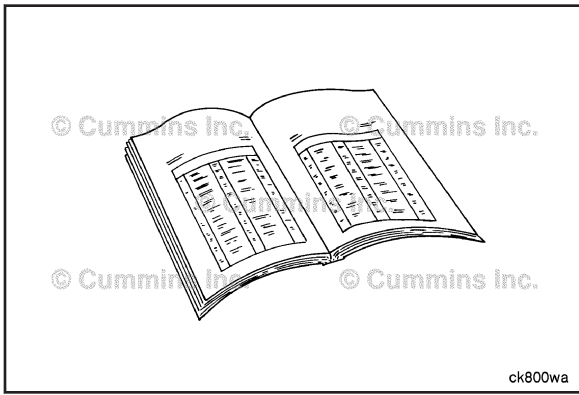
Tighten the capscrews in the sequence shown in the illustration, in two steps. The arrow (A) points to the dimple.

Torque Value:

Step 1	24 N•m	[212 in-lb]
Step 2	32 N•m	[24 ft-lb]



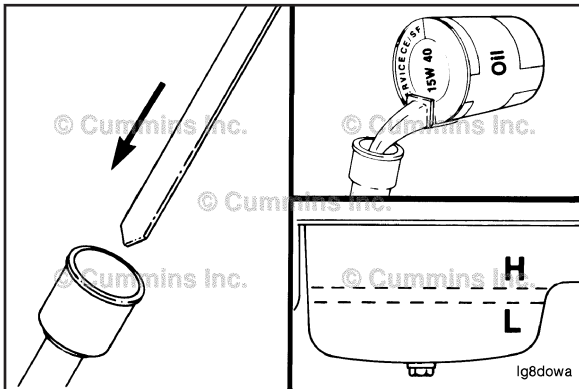
07d00206



Finishing Steps



- Install the turbocharger oil supply line. Refer to Procedure 010-046 in Section 10.
- Install the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Install the coolant filter head. Refer to Procedure 008-007 in Section 8.
- Fill the engine with coolant. Refer to Procedure 008-018 in Section 8.
- Operate the engine and check for leaks.
- Shut the engine OFF and check the coolant and lubricating oil levels.



Lubricating Oil Dipstick (007-009)

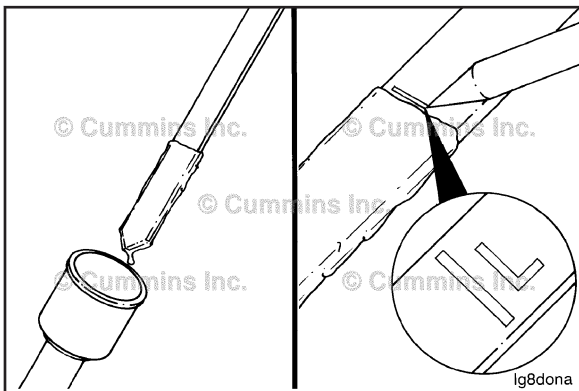
Calibrate



NOTE: This procedure **must** begin with the oil pan drained. Refer to Procedure 007-037 (Lubricating Oil System) in Section 7.

Install the dipstick in the dipstick tube housing.

Use clean engine oil to fill the oil pan to the specified low oil level. Refer to Procedure 018-017 (Lubricating Oil System) in Section V for the correct engine oil capacity.



⚠CAUTION⚠

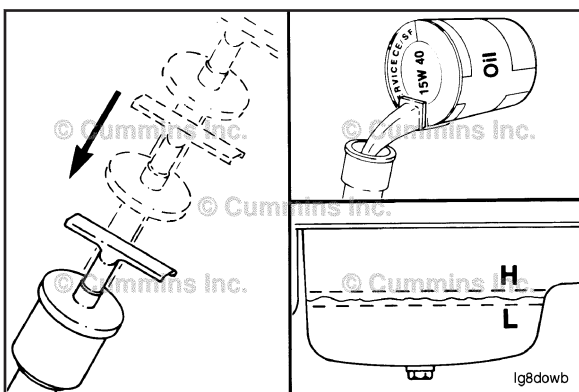
Use care when marking the dipstick. The dipstick will break if the scribe mark is too deep.



Remove the dipstick and scribe a mark across the stick at the oil level.

Label the mark with an "L" to indicate the low oil level.

NOTE: If a new blank dipstick is being used, cut the dipstick off approximately 38 mm [1.5 in] below the low oil level mark.



Wipe off the dipstick and install it in the dipstick tube housing.

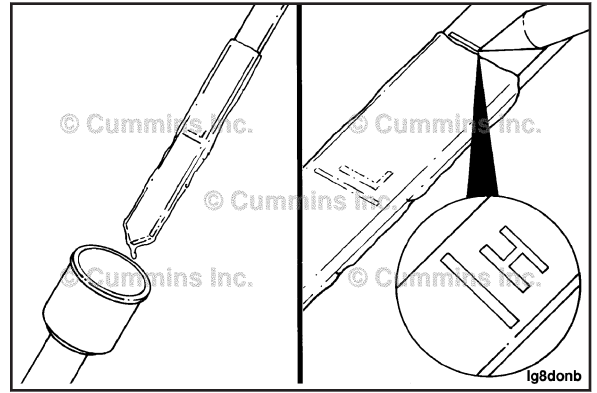


Fill the oil pan to the specified high oil level. Refer to Procedure 018-017 (Lubricating Oil System) in Section V for the correct engine oil capacity.

⚠CAUTION⚠

Use care when marking the dipstick. The dipstick will break if the scribe mark is too deep.

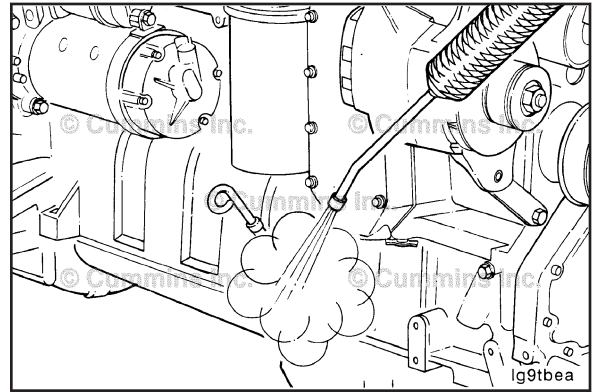
Remove the dipstick and scribe a mark across the stick at the oil level. Label the mark with an "H" to indicate the high oil level.



Lubricating Oil Dipstick Tube (007-011)

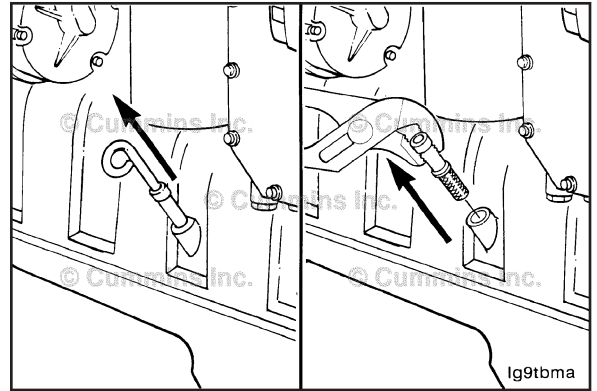
Remove

Clean the area around the dipstick tube before removing to prevent debris from entering the oil system.



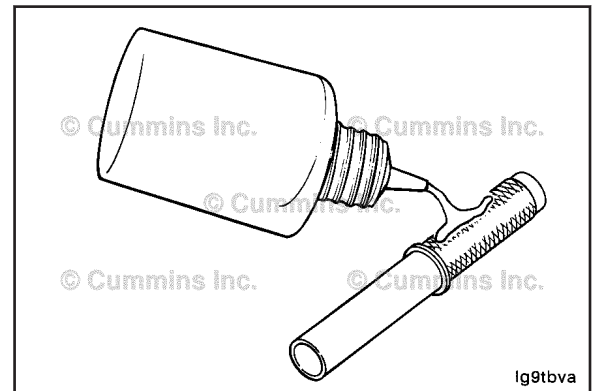
Remove the dipstick from the dipstick tube.
Remove the dipstick tube from the cylinder block.

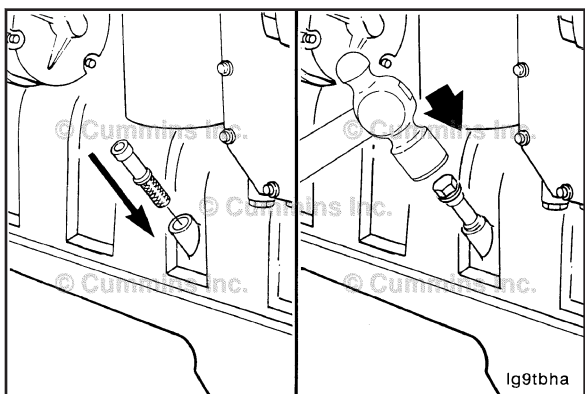
Service Tip: Use a dent puller and a M8 x 1.25 x 21-mm self-tapping capscrew. Thread the capscrew into the dipstick tube and remove the tube.



Install

Apply a thin bead of Loctite™ 277 around the knurled end of the dipstick tube.

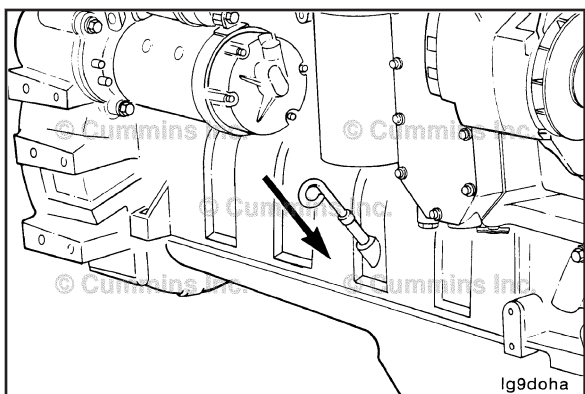




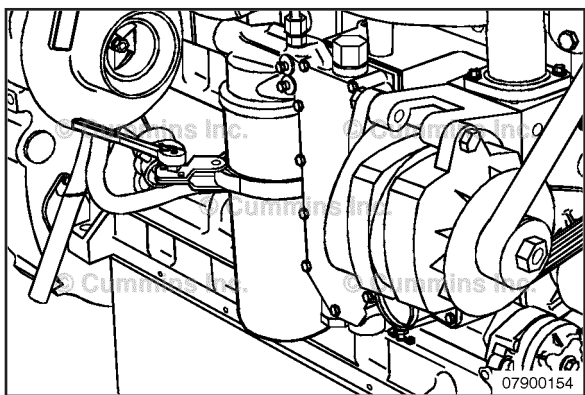
Place the knurled end of the dipstick tube into the dipstick tube bore in the cylinder block.

NOTE: Use a flat washer and hex head capscrew to drive the tube into the cylinder block.

Lightly drive the dipstick tube until it seats against the block casting.



Install the dipstick into the dipstick tube.



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

Measure

Remove the oil plugs from the lubricating oil cooler housing at the filter inlet and outlet pressure ports and install manual gauges.

The following parts, or equivalent, are available for use:

Part Number	Description
3377244	Compuchek™ fitting (1/8 inch 27 NPT)
3376920	Compuchek™ coupling (1/4 inch pipe thread)
3164491	Electronic pressure adapter for multimeter (1/4-NPT pipe)
3164488 or 3164489	Electronic digital multimeter

Engine Information	
Oil Filter Type	
Miles on Filter	
Oil Type	

Operate the engine at each rpm indicated and record the corresponding pressure values:

	Engine RPM	Oil Pressure Filter Inlet	Oil Filter Pressure Outlet	Inlet - Outlet = Differential Pressure	INSITE™ electronic service tool
Low Idle					
High Idle					

A pressure drop greater than 172 kPa [25 psi], at operating temperature using 15W-40 oil, indicates the filter is plugged.

Identify the causes of a plugged filter. Verify the Cummins Inc. maintenance guidelines are being met.

Use the following procedure to check for possible fluid contamination. Refer to Procedure 007-083 in Section 7.

Change both the lubricating oil and the lubricating oil filter, if the filter is plugged.

See the following bulletin for additional information about lubricating oil filter plugging.

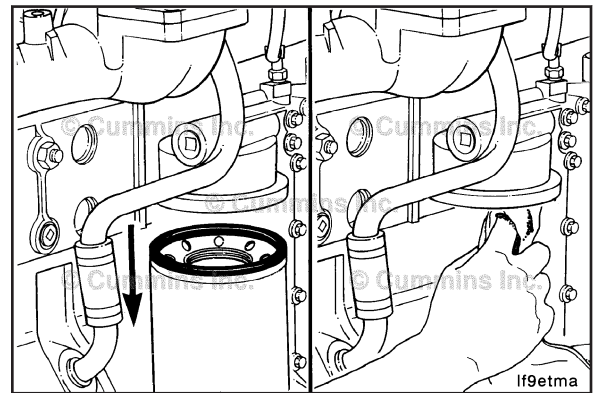
Refer to Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340.

Remove

Clean the area around the lubricating oil filter head.

Remove the oil filter with oil filter wrench, Part No. 3375049.

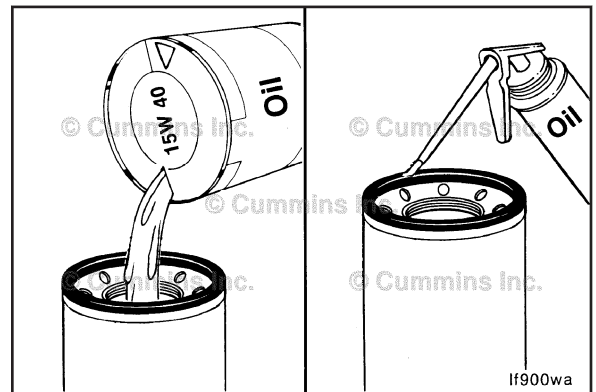
Clean the gasket surface of the filter head.



Install

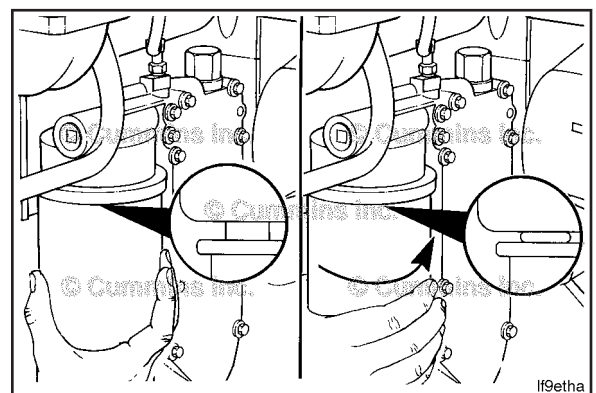
Lubricate the oil filter gasket with clean engine oil.

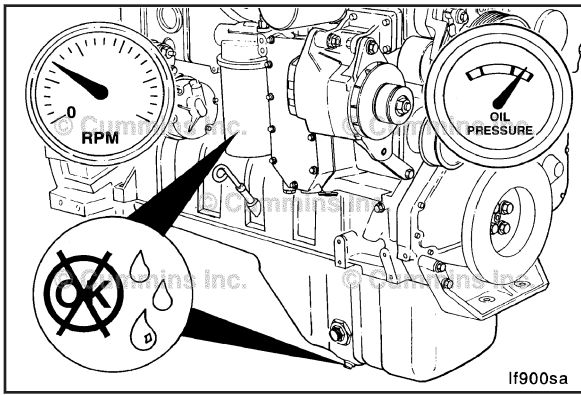
Fill the oil filter with clean engine oil.



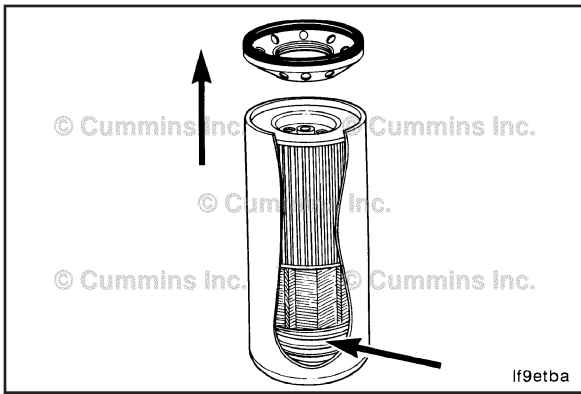
Install the filter on the oil filter head. Tighten the filter until the gasket contacts the filter head surface.

Use oil filter wrench, Part No. 3375049, to tighten the filter an additional 1/2 to 3/4 of a turn, or follow the instructions supplied with the oil filter.





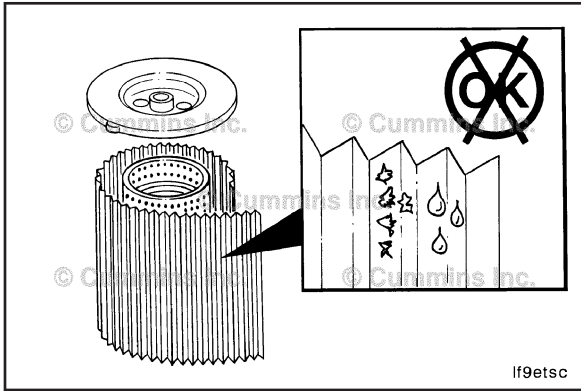
Operate the engine and check for leaks.



Inspect

⚠ WARNING ⚠

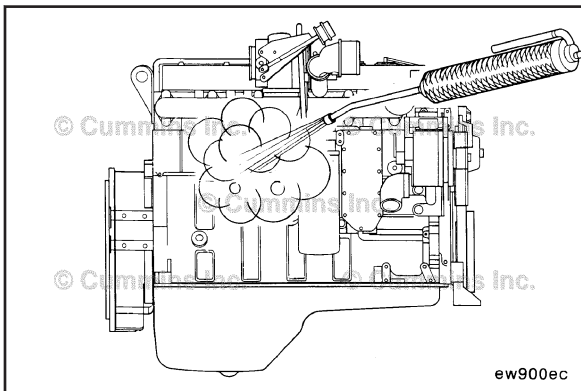
Carefully cut the full-flow oil filter (upper section of combination filter) open. The filter element spring is under compression and can cause personal injury.



Use the tube cutter, Part No. 3376579, to open the full-flow oil filter (upper section of the bypass filter).

Inspect the filter element for evidence of moisture or metal particles.

Metal	Probable Source
Copper	Bearings and bushings
Chromium	Piston rings
Iron	Cylinder liners
Lead	Bearing overlay material
Aluminum	Piston wear or scuffing



Lubricating Oil Leaks (007-024)

Initial Check

External

⚠ WARNING ⚠

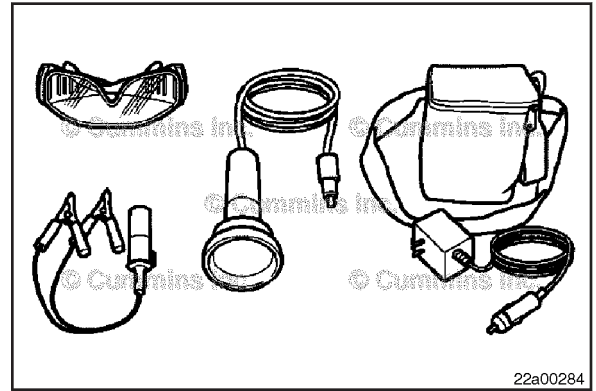
Wear safety glasses or a face shield, as well as protective clothing, to prevent personal injury when using a steam cleaner or high-pressure water.

The first step in diagnosing excessive lube oil consumption is to verify that there are no external oil leaks.

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.

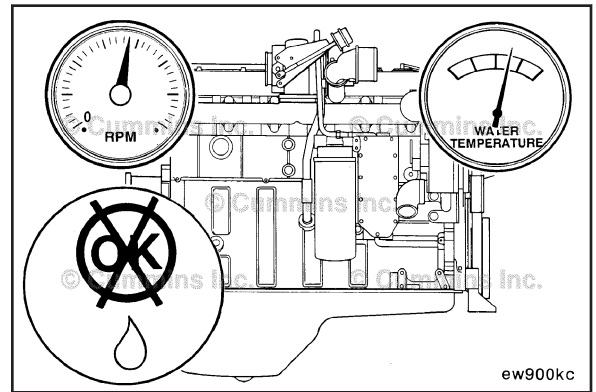
Add the fluorescent tracer, Part Number 3376891, before running the engine. The tracer will be highlighted by the black light to help identify the source of the leak.



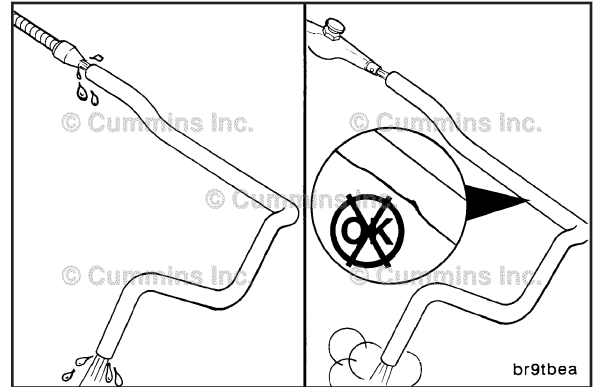
Operate the engine until the coolant temperature reaches 82°C [180°F]. If necessary, run the engine under load to recreate the conditions of the oil leak. Perform a stall test, or a road test. Inspect the exterior of the engine for leaking gaskets, seals, o-rings, pipe plugs, or fittings.



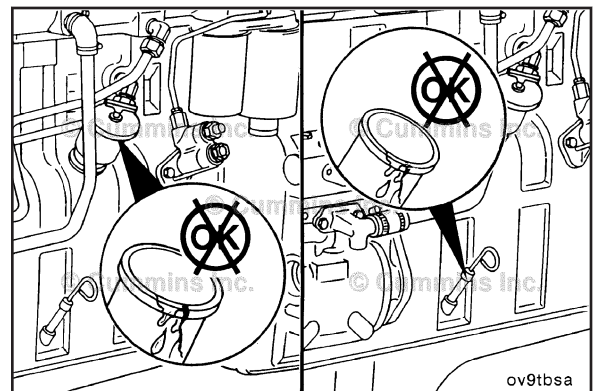
NOTE: Before replacing any gaskets, check the capscrews to make sure they are tightened to the correct torque values. Refer to Procedure 018-009 in Section V.

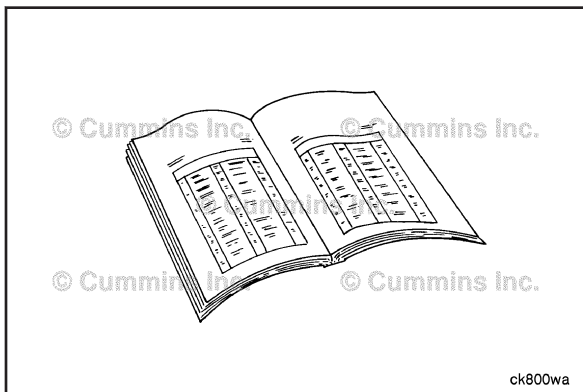


Inspect the engine crankcase breather tube and hose for restriction. Refer to Procedure 003-018 in Section 3.



Check for a loose or missing oil dipstick tube, dipstick, or oil fill cap.





Lubricating Oil Pan (007-025)

Preparatory Steps



⚠ WARNING ⚠

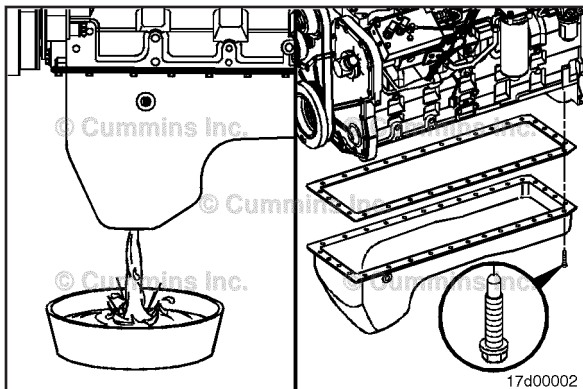
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

⚠ WARNING ⚠

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

NOTE: C and L Series engines use a variety of combinations of gaskets and/or RTV for sealing. When installing the oil pan, use the same combinations of gasket and/or RTV that were on the pan.

- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.
- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.



Remove

Remove the lubricating oil pan and gasket.



Remove the suction tube, if required. 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.

⚠️ CAUTION ⚠️

When scraping gasket material from the front gear housing, do not gouge into the surface. Damage to the component can occur.

Remove all gasket material from the cylinder block and oil pan surfaces.

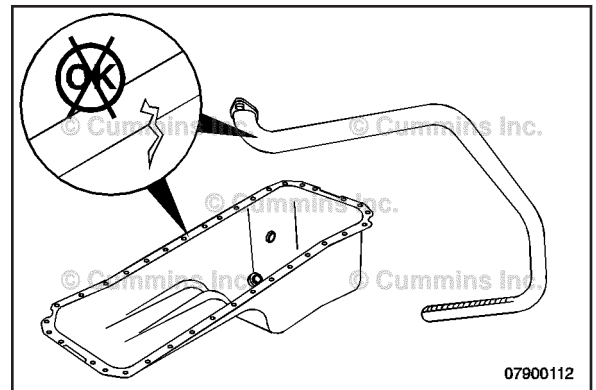
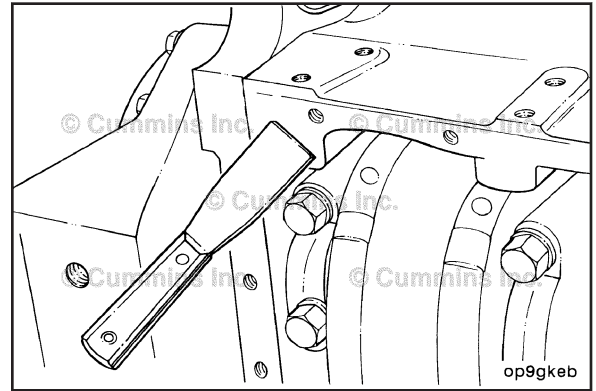
Steam clean the oil pan.

Dry with compressed air.

Inspect the lubricating oil pan, suction tube, and tube braces for other damage.

If cracks are found, replace the damaged part. Do **not** attempt to repair the oil pan by welding.

Install the suction tube, if required. Refer to Procedure 007-035 in Section 7.



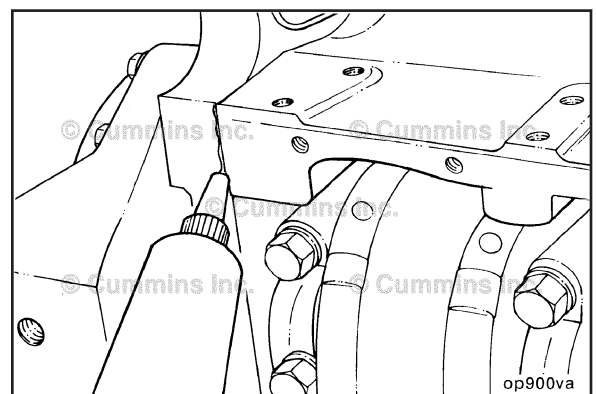
Install

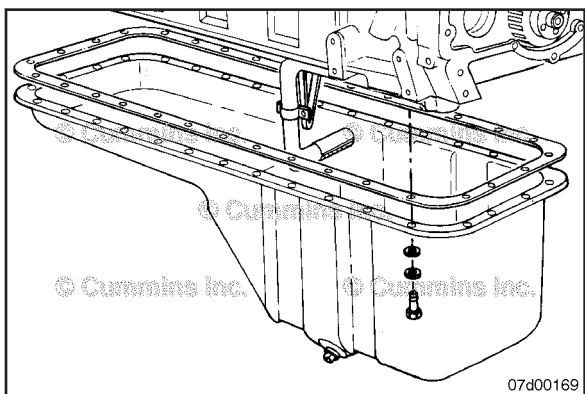
NOTE: C and L Series engines use a variety of combinations of gaskets and/or RTV for sealing. When installing the oil pan, use the same combinations of gasket and/or RTV that were on the pan.

NOTE: Install three guide pins, Part Number 3164977, to improve alignment of the oil pan sealing components to the cylinder block.

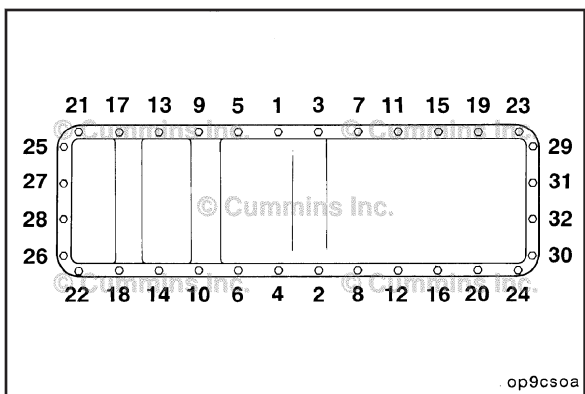
Use RTV sealant, or equivalent, to fill the joints between the lubricating oil pan rail, gear housing, and rear seal housing.

Install the suction tube, if removed. Refer to Procedure 007-035 in Section 7.





Install the gasket and lubricating oil pan.
Install the oil pan corner braces, if equipped.



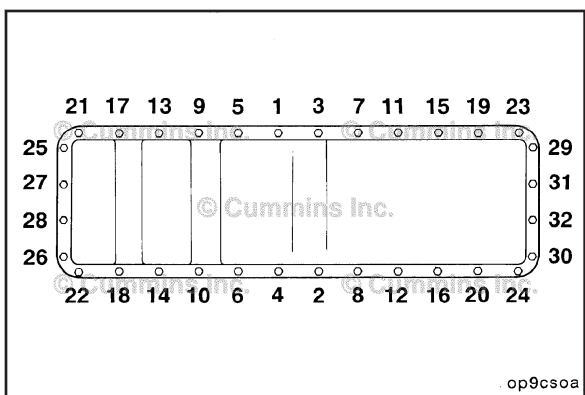
Assemble the washers and capscrows to secure the lubricating oil pan, as illustrated.

Remove the guide pins and install the capscrows.



Tighten all capscrows in the sequence shown in the accompanying chart.

Torque Value: 24 N•m [212 in-lb]

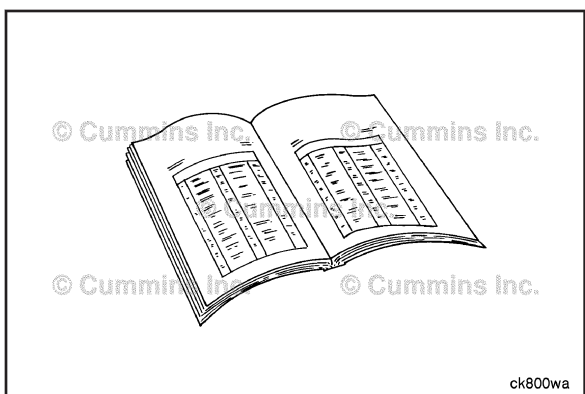


Hand tighten all the capscrows, to secure the oil pan to the engine, before tightening the capscrows.

Tight all the capscrows in the sequence shown in the illustration.



Torque Value: 23 N•m [204 in-lb]



Finishing Steps

- Fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Fill the lubricating oil system. Refer to Procedure 007-037 in Section 7.
- Operate the engine and check for leaks.



Lubricating Oil Pressure Regulator (Main Rifle) (007-029)

Remove

⚠ WARNING ⚠

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

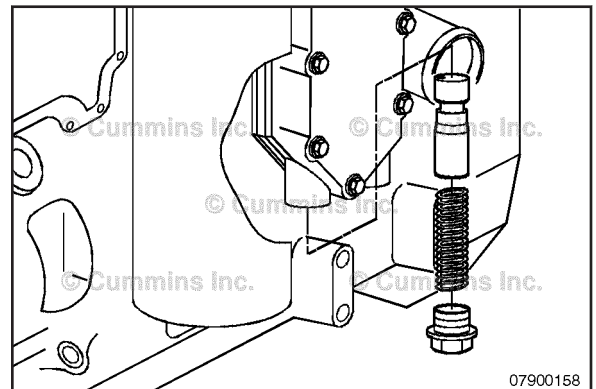
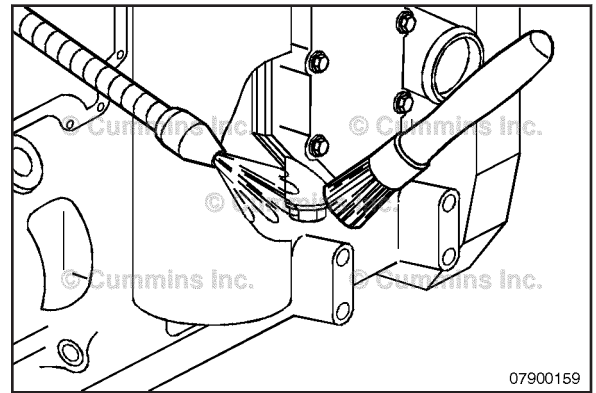
⚠ WARNING ⚠

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

Thoroughly clean the area around the pressure regulator plug with clean solvent to prevent debris from falling into the plunger bore when the plug is removed.

Remove the threaded plug, spring, and plunger.

Service Tip: The plunger normally can be removed by inserting one finger into the plunger bore until snug and pulling down. If the plunger can **not** be removed in this manner, the plunger is probably stuck and will require removal of the housing for cleaning the plunger.



Clean and Inspect for Reuse

⚠ WARNING ⚠

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

⚠ WARNING ⚠

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

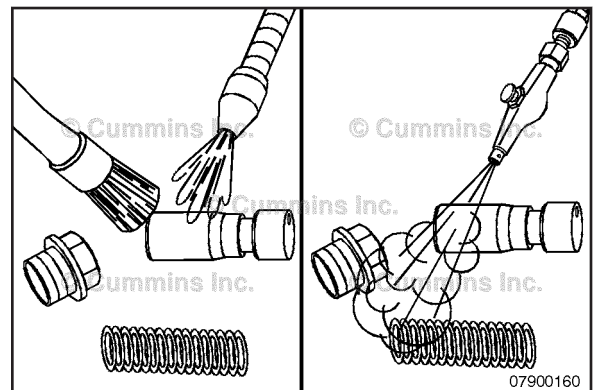
⚠ WARNING ⚠

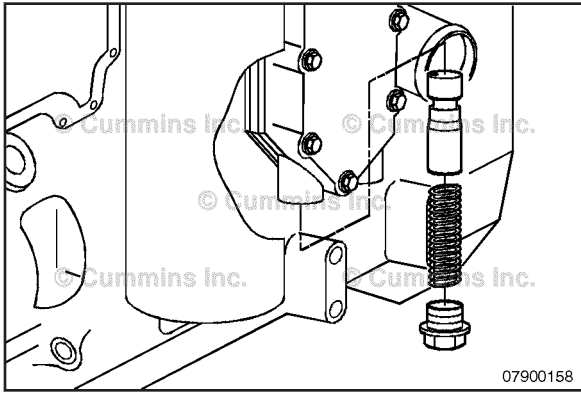
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

NOTE: If the plunger bore requires cleaning, remove the housing to avoid flushing debris into the engine.

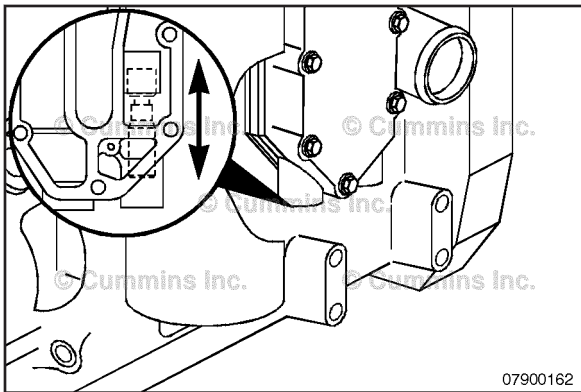
Thoroughly clean all components with clean solvent.

Dry with compressed air.

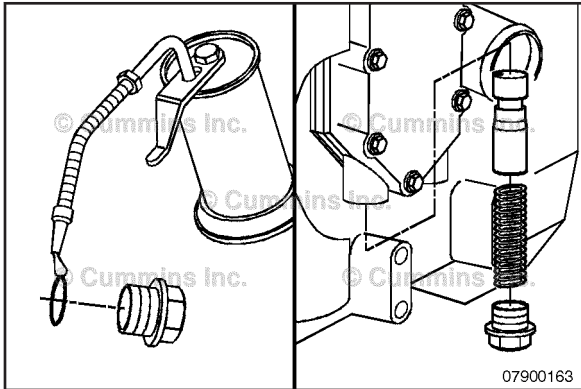




Inspect the plunger and plunger bore. Polished areas on the plunger and bore are acceptable.



Verify that the plunger moves freely in the bore.

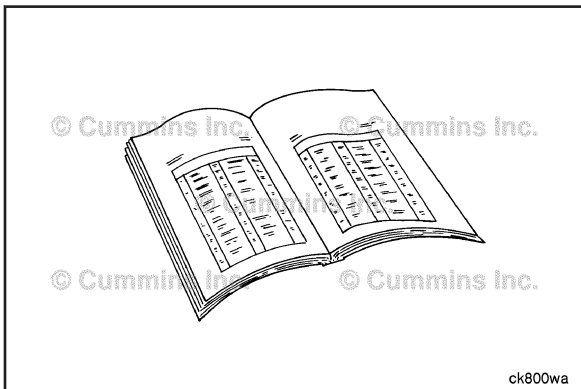


Install

Install a new sealing o-ring on the threaded plug and lubricate with clean engine oil. Install the pressure regulator assembly.



Torque Value: 80 N•m [59 ft-lb]



Lubricating Oil Pump (007-031)

Preparatory Steps

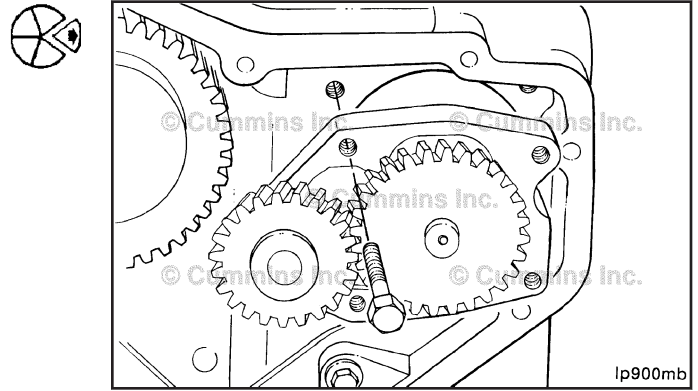
Remove the front drive belt. Refer to Procedure 008-002.

Remove the vibration damper/crankshaft pulley. Refer to Procedure 001-052.

Remove the front gear cover. Refer to Procedure 001-031.

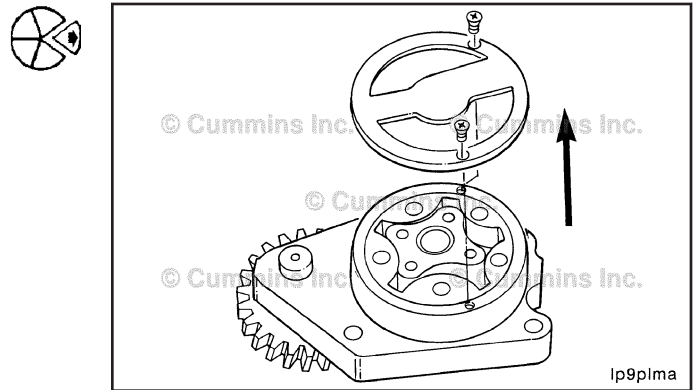
Remove

Remove the four oil pump mounting capscrews.
Remove the oil pump from its bore in the cylinder block.

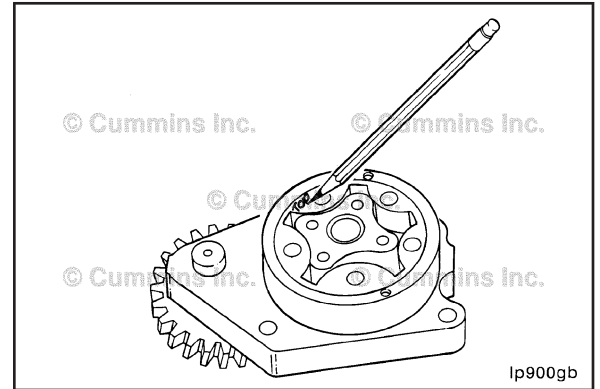


Disassemble

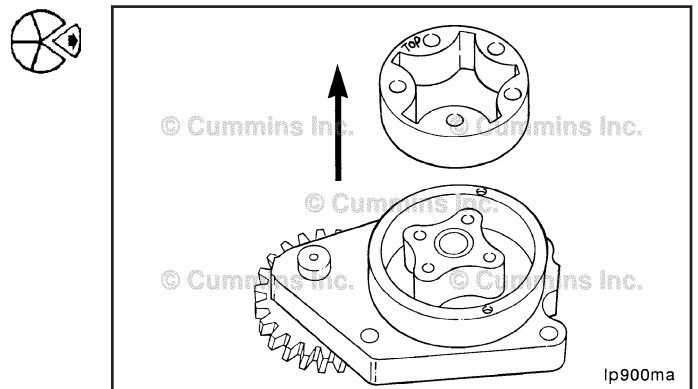
Remove the oil pump back plate.

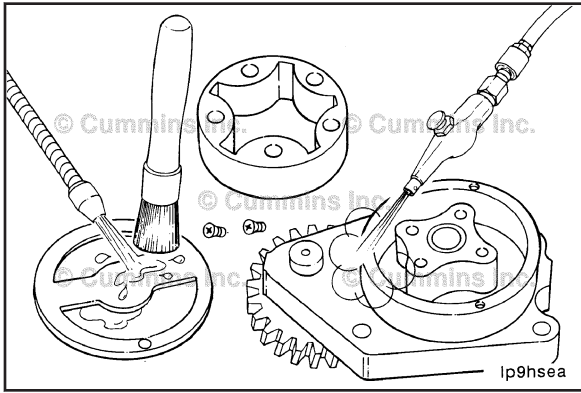


Mark "TOP" on the gerotor planetary.



Remove the gerotor planetary.





Clean and Inspect for Reuse

▲ WARNING ▲

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

▲ WARNING ▲

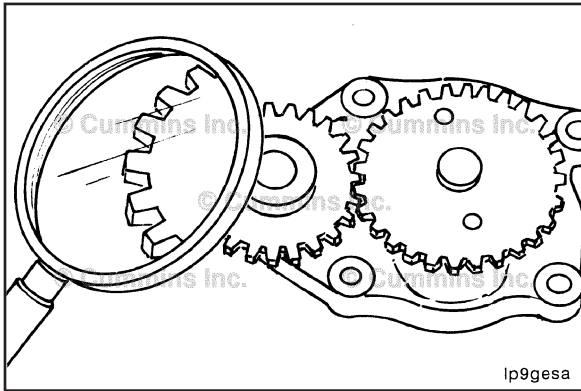
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

▲ WARNING ▲

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

Clean all of the oil pump parts in solvent.

Dry all of the oil pump parts with compressed air.

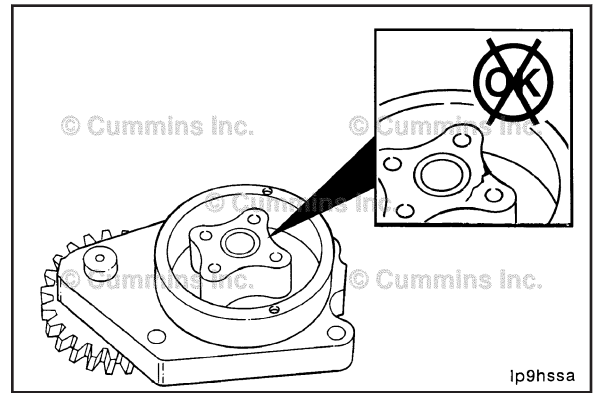


Inspect the lubricating oil pump gears for chips, cracks, or excessive wear.



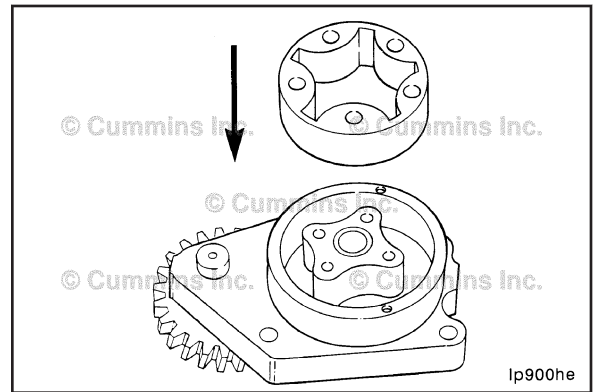
Inspect the gerotor planetary for excessive wear or damage.

Inspect the lubricating oil pump housing and gerotor drive for damage and excessive wear.



Assemble

Install the gerotor planetary with the top mark in the correct position.

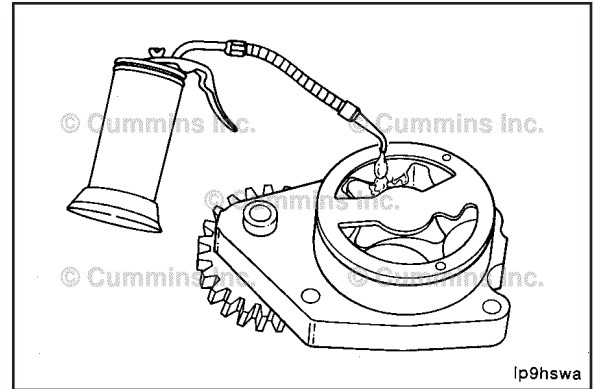


Install

⚠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.

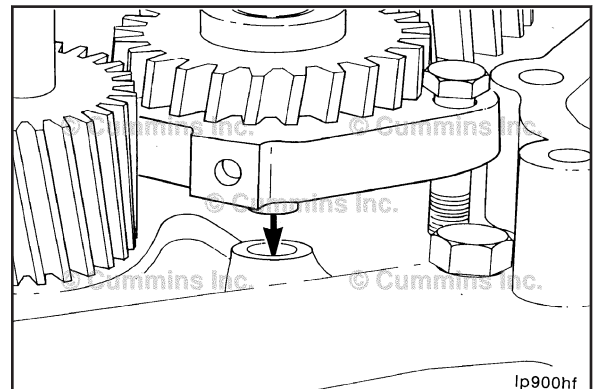
Lubricate the lubricating oil pump with clean engine oil.

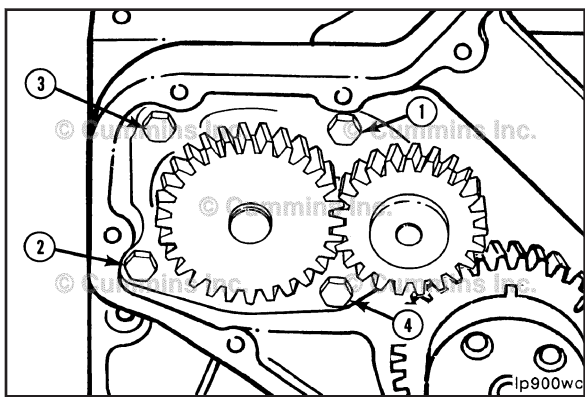


⚠CAUTION⚠

Make sure the idler gear pin is installed in the locating bore in the cylinder block. This can damage the pump.

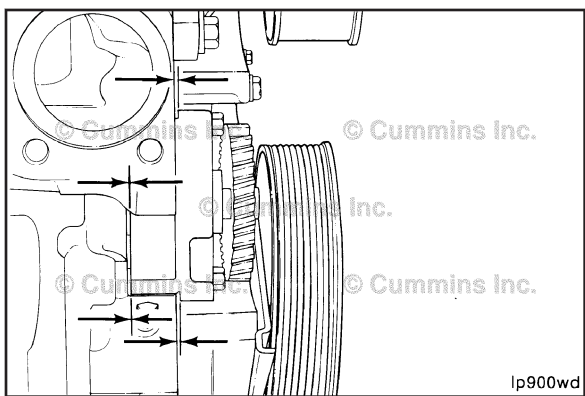
Install the lubricating oil pump.



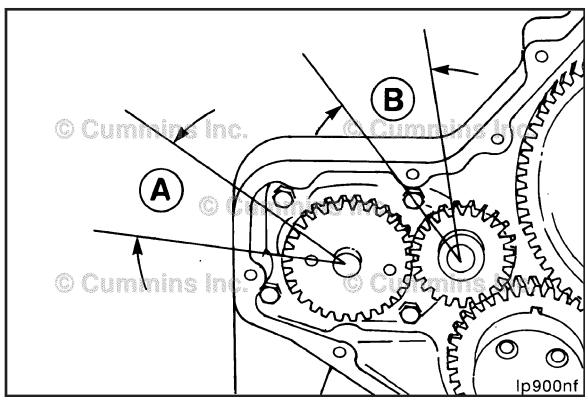


Tighten the oil pump mounting capscrews in the sequence shown.

Torque Value: 24 N•m [18 ft-lb]



NOTE: The back plate on the oil pump seats against the bottom of the bore in the cylinder block. When the lubricating oil pump is correctly installed, the flange on the oil pump will **not** touch the cylinder block.

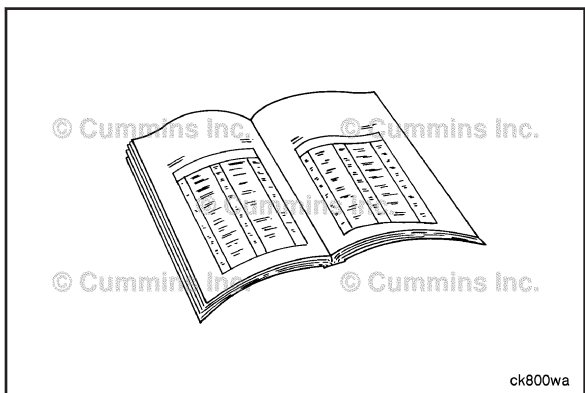


Measure the oil pump gear backlash.

Backlash Limits

	mm		in	
A	0.076	MIN	0.003	
	0.330	MAX	0.013	
B	0.076	MIN	0.003	
	0.330	MAX	0.013	

NOTE: If the adjoining gear moves when you measure the backlash, the reading will be incorrect.



Finishing Steps

Install the front gear cover and gasket. Refer to Procedure 001-031.

Install the front cover access cap and seal.

Install the crankshaft pulley/vibration damper. Refer to Procedure 001-052.

Install the drive belt. Refer to Procedure 008-002.

Fill the oil pan. Refer to Procedure 007-037.

Lubricating Oil Suction Tube (Block-Mounted) (007-035)

Preparatory Steps

⚠️ WARNING ⚠️

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

⚠️ WARNING ⚠️

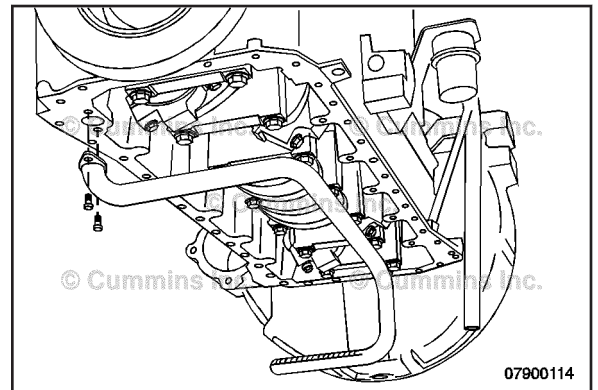
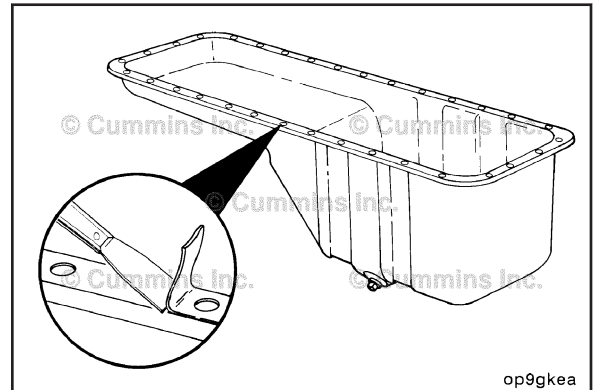
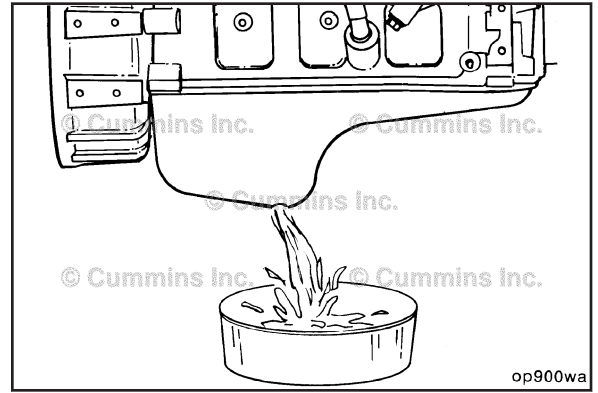
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

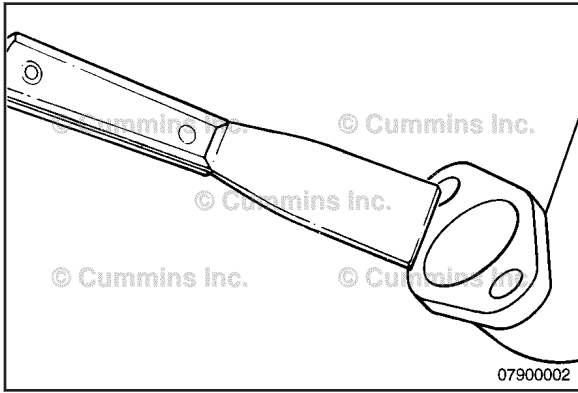
Drain the lubricating oil. Refer to Procedure 007-037.

Remove the lubricating oil pan and gasket. Refer to Procedure 007-025.

Remove

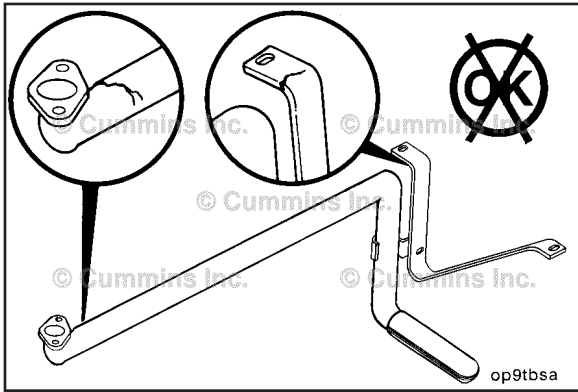
Remove the lubricating oil suction tube and support bracket mounting capscrews. Remove the lubricating oil suction tube and support bracket.





Clean and Inspect for Reuse

Clean the gasket surfaces.



Inspect the suction tube and support bracket for cracks.

Install

NOTE: Some engines use 10-mm capscrews and others use 6-mm capscrews. Follow the torque procedure based on the capscrew size.

Install the lubricating oil suction tube and a new gasket.

1. Install all capscrews finger tight and check for correct alignment.
2. Torque the lubricating oil suction tube to the block.

6-mm Capscrews

Torque Value: 10 N•m [89 in-lb]

10-mm Capscrews

Torque Value: 24 N•m [18 ft-lb]

3. Torque the lubricating oil suction tube support bracket to the block.

6-mm Capscrews

Torque Value: 10 N•m [89 in-lb]

10-mm Capscrews

Torque Value: 24 N•m [18 ft-lb]

4. Torque the lubricating oil suction tube to the support bracket.

6-mm Capscrews

Torque Value: 10 N•m [89 in-lb]

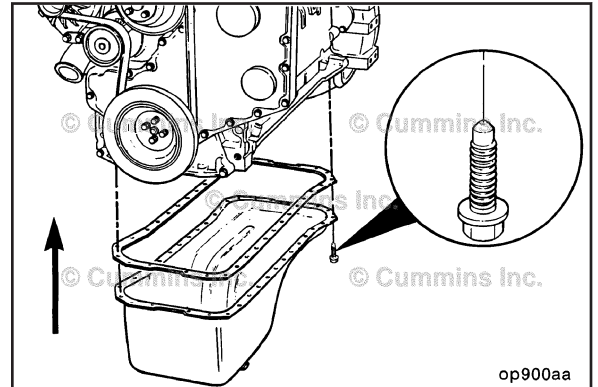
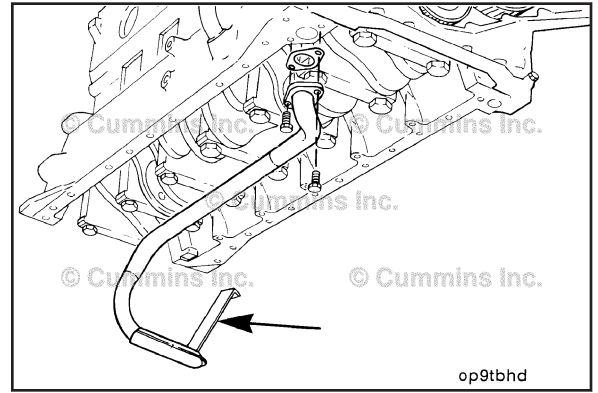
10-mm Capscrews

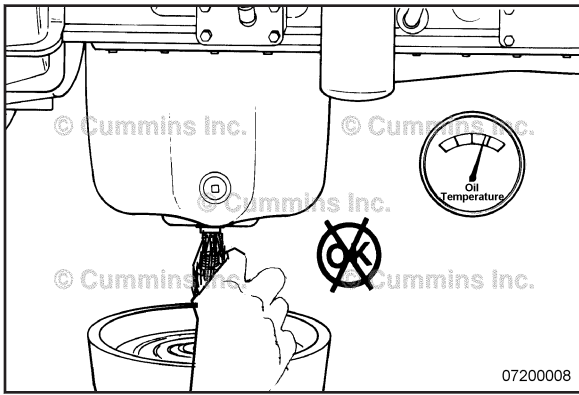
Torque Value: 24 N•m [18 ft-lb]

Finishing Steps

Install the lubricating oil pan and gasket. Refer to Procedure 007-025. Fill with lubricating oil. Refer to 007-037

Operate the engine and check for leaks.





Lubricating Oil System (007-037)

Drain

⚠️ WARNING ⚠️

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

⚠️ WARNING ⚠️

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

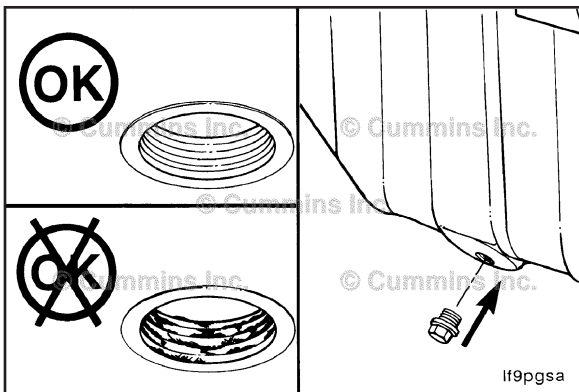
Operate the engine until the coolant temperature reaches 60°C [140°F].

Shut the engine off.

Remove the oil drain plug.

Drain the oil immediately to make sure all the oil and suspended contaminants are removed from the engine.

Use a container with a capacity of at least 23.6 liters [25 qt] of lubricating oil.



Fill

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



Install the lubricating oil pan drain plug.



Torque Value

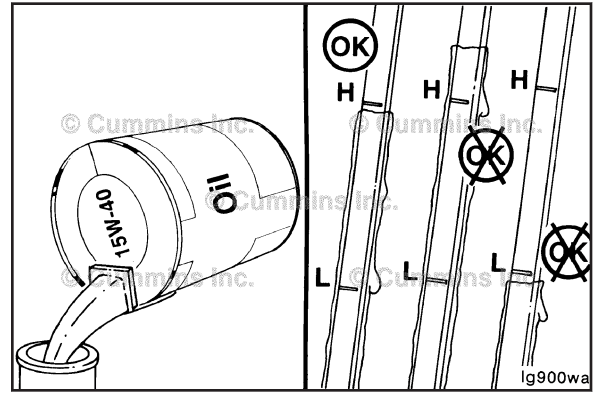
	N•m	[ft-lb]
Steel Oil Pan	80	59
Cast Aluminum Oil Pan	60	45



Use a high-quality 15W-40 multiviscosity oil, such as Cummins Premium Blue, or equivalent, in Cummins engines.

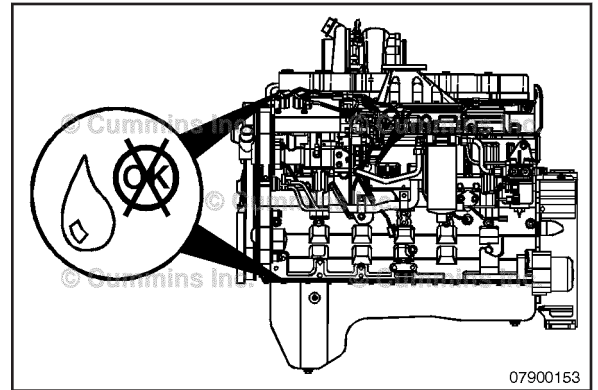
Choose the correct oil for your application and climate as outlined in the Operation and Maintenance Manual, or Cummins Engine Oil Recommendations, Bulletin 3810340.

Fill the engine with clean lubricating oil to the proper level.
When filling the oil pan, use the fill tube on the side of the engine rather than on top of the rocker lever cover.
Refer to Section V for lubricating oil pan capacities.

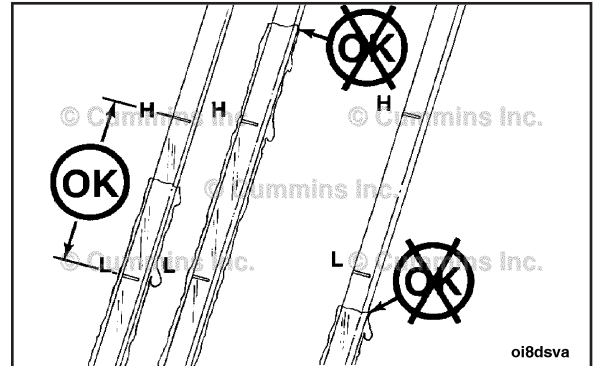


⚠CAUTION⚠
If no oil pressure is noted within 15 seconds after the engine is started, shut down the engine to reduce the possibility of internal damage.

Idle the engine and inspect for leaks at the drain plug.



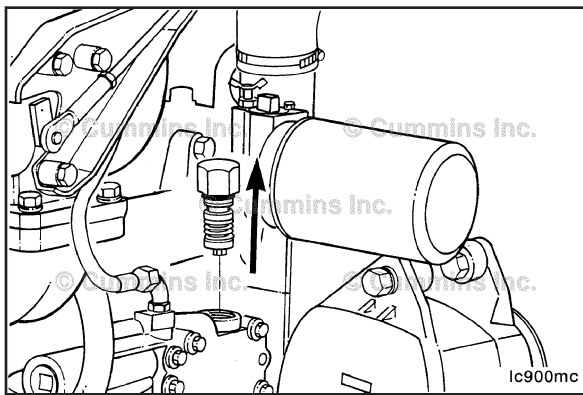
Shut off the engine.
Wait approximately 10 minutes to let the oil drain from the upper parts of the engine and check the level again.
Add oil as necessary to bring the oil level to the "H" (high) mark on the dipstick.



Lubricating Oil Thermostat (007-039) Preparatory Steps

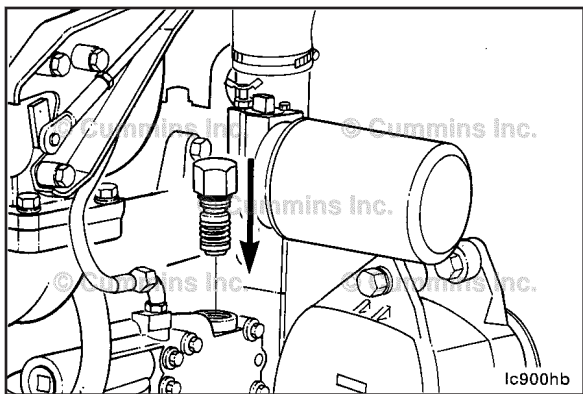


Clean debris from oil thermostat.



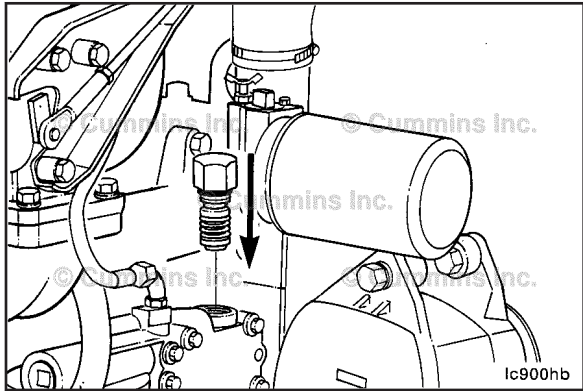
Remove

Remove the lubricating oil thermostat.



Clean

Clean and inspect the lubricating oil thermostat bore before assembly.

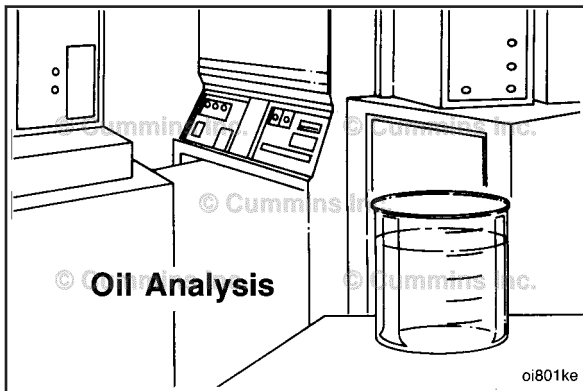


Install

Install and tighten the oil cooler bypass valve.



Torque Value: 50 N•m [37 ft-lb]



Lubricating Oil Analysis (007-051)

General Information

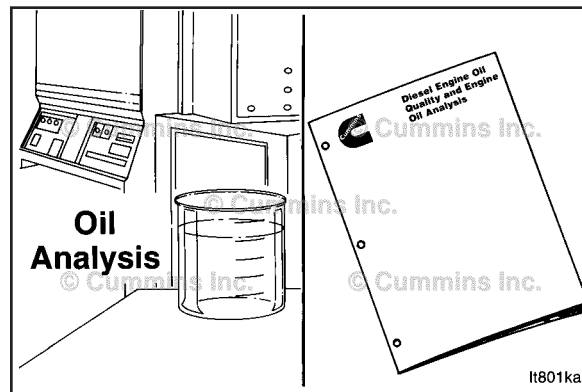
An analysis of used oil can help diagnose internal engine damage and determine if it was caused by one of the following:

- Intake air filter malfunction
- Coolant leaks
- Oil diluted with fuel
- Metal particles causing wear.

For additional oil analysis information, refer to Cummins Engine Oil Recommendations, Bulletin No. 3810340.



NOTE: Do **not** disassemble an engine for repair based **only** on the results of an oil analysis. Inspect the oil filters also. If the oil filter, shows evidence of internal damage, find the source of the problem and repair the damage. Refer to the appropriate procedure(s).



Section 8 - Cooling System - Group 08

Section Contents

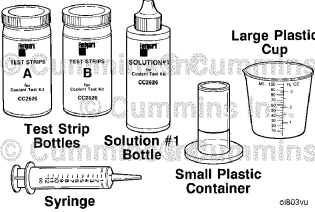
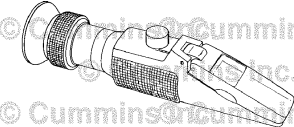
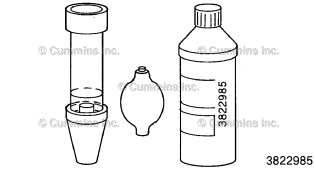
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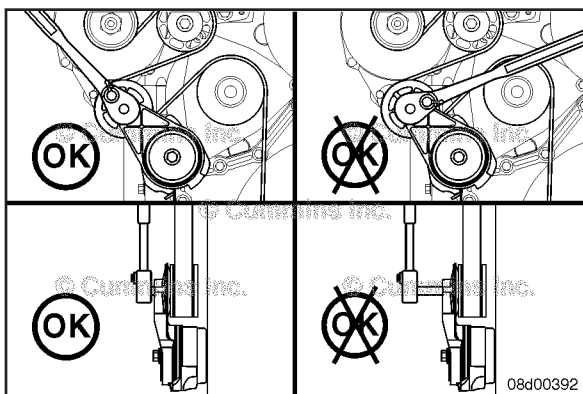
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Service Tools

Cooling System

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

Tool No.	Tool Description	Tool Illustration
<p style="text-align: center;">CC-2626</p>	<p>Cooling System Test Kit</p> <p>The Fleetguard® coolant test kit is used to inspect the concentration of coolant additives in the cooling system.</p>	 <p>© Cummins Inc. 080304</p>
<p style="text-align: center;">CC-2800</p>	<p>Refractometer</p> <p>The Fleetguard® refractometer is used to measure the freezing point protection and antifreeze concentration.</p>	 <p>© Cummins Inc. 081005</p>
<p style="text-align: center;">3822985</p>	<p>Combustion Gas Leak Test Kit</p> <p>Includes Part No. 3822986, test fluid; Part No. 3822987, adapter; and Part No. 3877612, instructions.</p>	 <p>© Cummins Inc. 3822985</p>



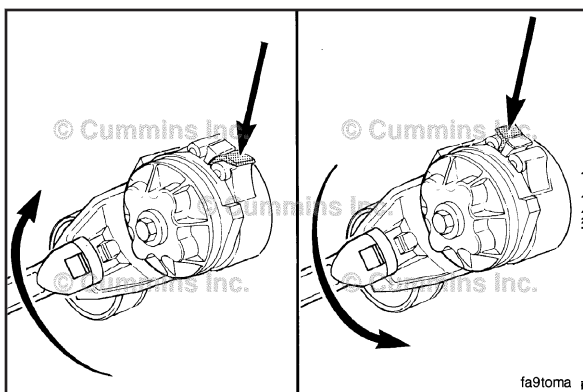
Drive Belt, Cooling Fan (008-002)

Remove

⚠CAUTION⚠

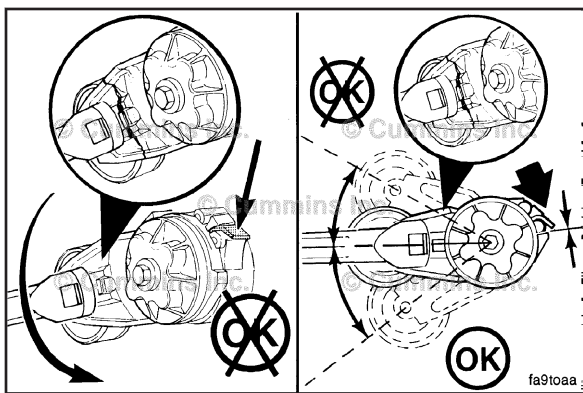
Using a socket extension is not recommended because it can cause axial twisting damage to the belt tensioner.

NOTE: If a socket extension is necessary, support the head of the ratchet with one hand to prevent the belt tensioner arm from being subjected to unintended loading.



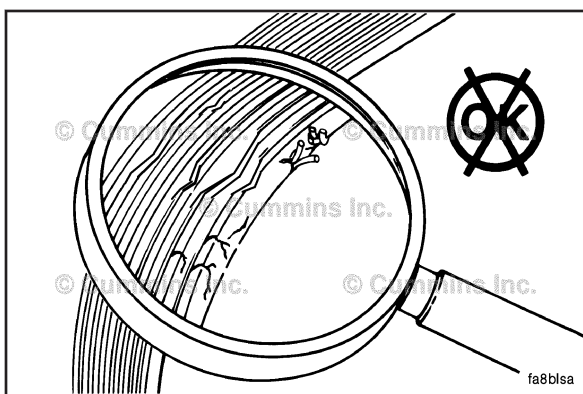
Lift the tensioner to remove the drive belt.

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 break.



Inspect for Reuse

Inspect the drive belt for:

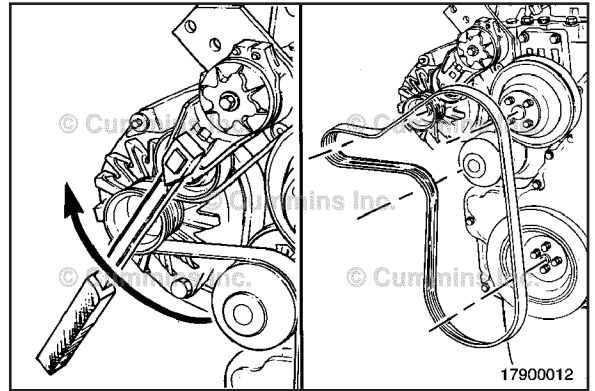
- Cracks
- Glazing
- Tears or cuts
- Hardening
- Excessive wear.

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 the tensioner to install the drive belt.



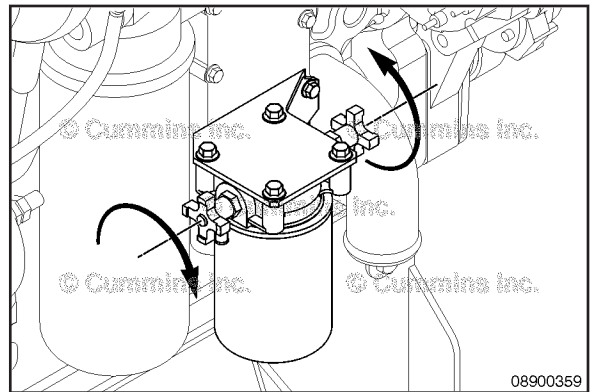
Coolant Filter (008-006)

Remove

⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

Close the coolant inlet and outlet valves on the coolant filter head by rotating the valves **clockwise**.



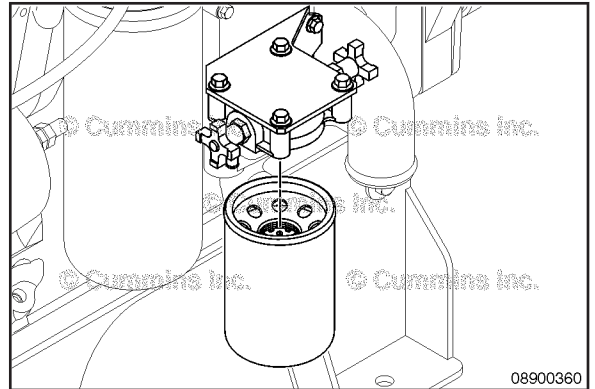
⚠ WARNING ⚠

A small amount of coolant can leak when servicing the coolant filter with the shutoff valve in the OFF position. To reduce the possibility of personal injury, avoid contact with hot coolant.

⚠ WARNING ⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

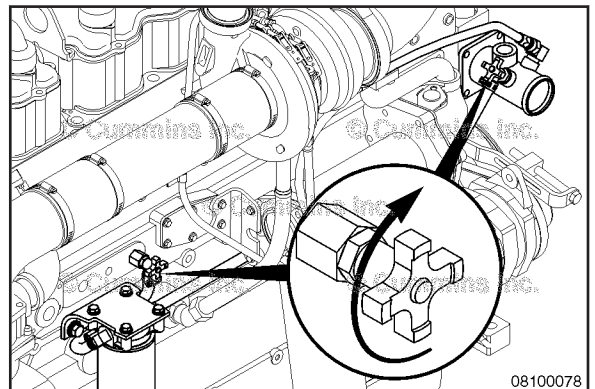
Use coolant filter wrench, Part Number 3376807, to remove the coolant filter. Discard the coolant filter.

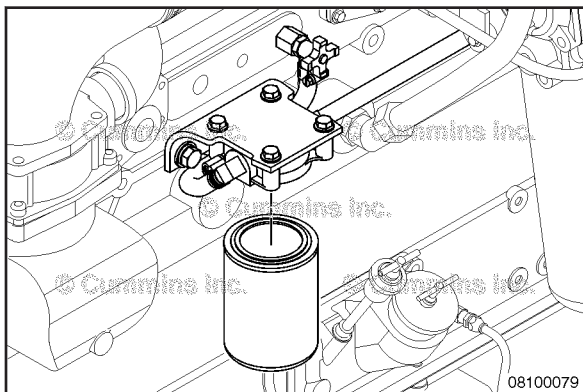


⚠ WARNING ⚠

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.

Turn the shutoff valve to the OFF position by rotating the knobs in a **clockwise** direction until the valves are fully closed.





⚠ WARNING ⚠

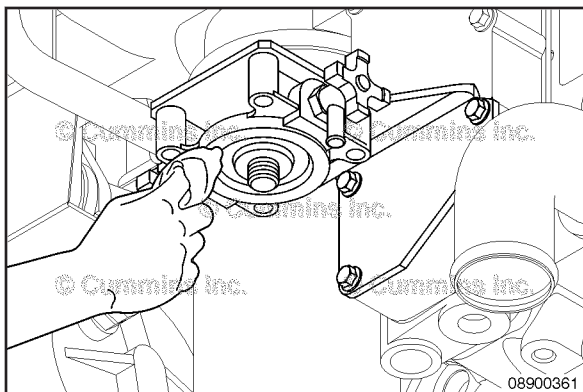
A small amount of coolant can leak when servicing the coolant filter with the shutoff valve in the OFF position. To reduce the possibility of personal injury, avoid contact with hot coolant.



⚠ WARNING ⚠

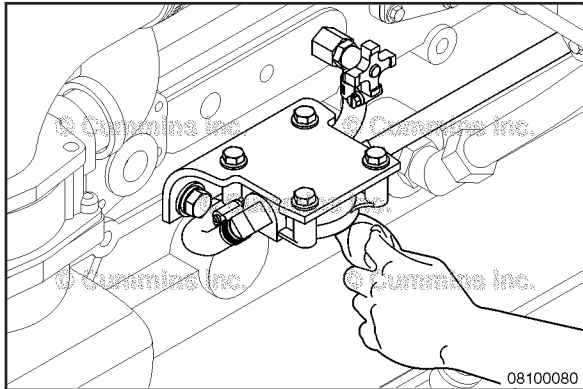
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Remove and discard the coolant filter.



Clean

Clean the gasket surface.



Clean the gasket surface.



Install

⚠ CAUTION ⚠

Do not allow oil to get into the filter. Oil will damage the DCA.



⚠ CAUTION ⚠

Mechanical overtightening can distort the threads or damage the filter head.



Apply a thin film of lubricating oil to the gasket sealing surface before installing the new coolant filter.

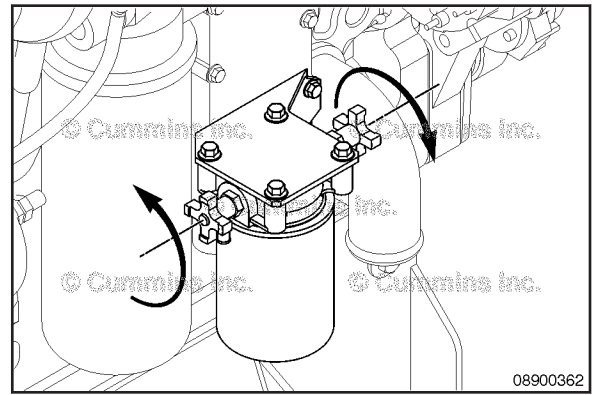
Install the coolant filter on the filter head. Tighten the filter until the gasket contacts the filter head surface.

Tighten the coolant filter an additional ½ to ¾ of a turn, or as specified by the filter manufacturer.

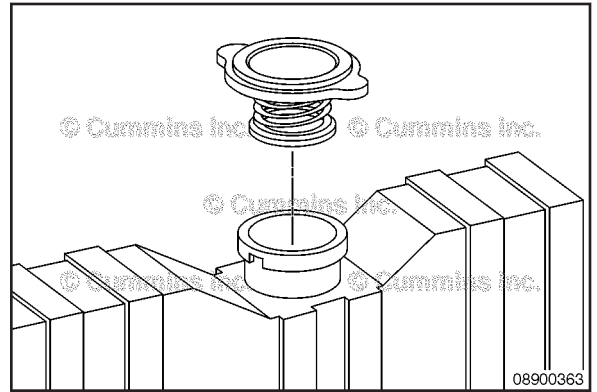
⚠CAUTION⚠

The valve must be in the ON position to prevent engine damage.

Open the coolant inlet and outlet valves on the coolant filter head by rotating the valves **counterclockwise**.

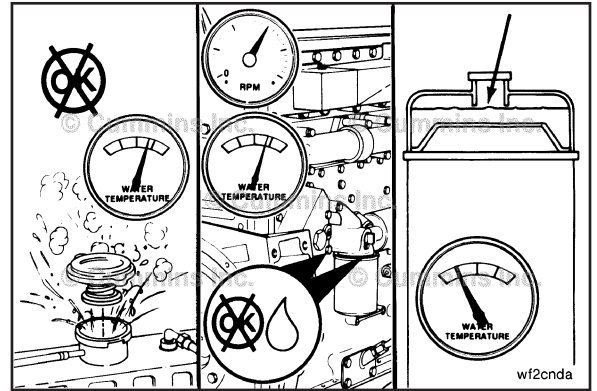


Install the coolant system pressure cap.



Operate the engine and check for coolant leaks.

After the air has been purged from the system, check the coolant level.



⚠CAUTION⚠

Do not allow oil to get into the filter. Oil will damage the DCA.

⚠CAUTION⚠

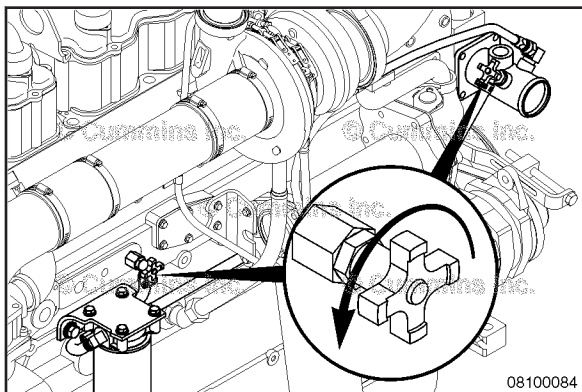
Mechanical overtightening can distort the threads of damage the filter head.

Apply a thin film of lubricating oil to the gasket sealing surface before installing the new coolant filter.

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

Tighten the coolant filter an additional 1/2 to 3/4 of a turn, or as specified by the filter manufacturer.

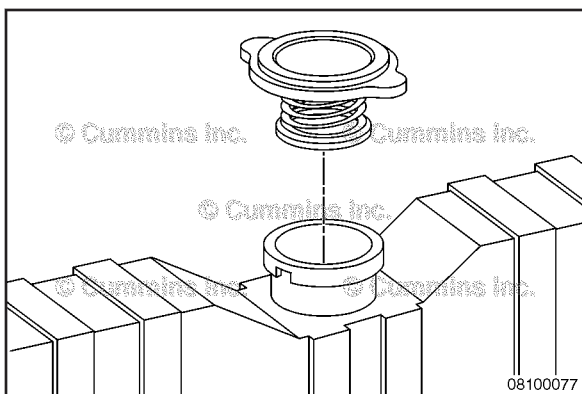




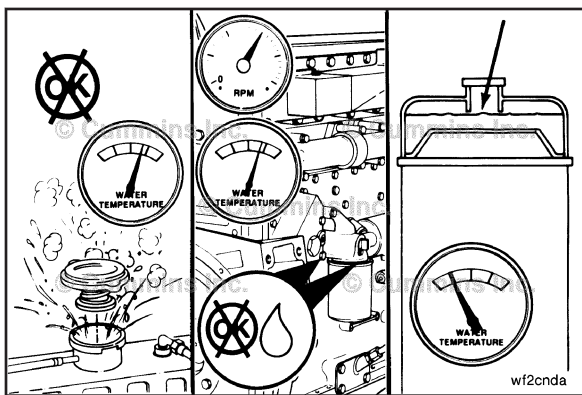
⚠ CAUTION ⚠

The valve must be in the ON position to prevent engine damage.

Turn the shutoff to the ON position by rotating the knobs in the counter-clockwise direction until the valves are fully open.

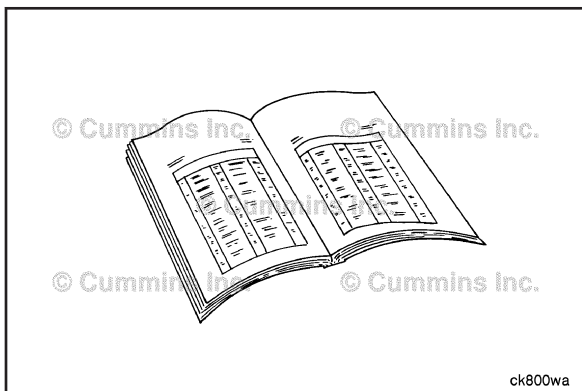


Install the coolant system pressure cap.



Operate the engine and check for coolant leaks.

After the air has been purged from the system, check the coolant level again.



Coolant Filter Head (008-007)

Preparatory Steps

⚠ 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 ⚠

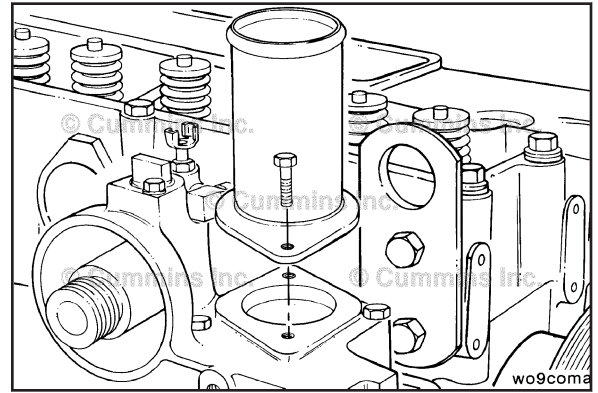
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Remove the coolant filter. Refer to Procedure 008-006.

Remove

Remove the coolant outlet connection.

NOTE: If the coolant filter head is remote mounted; refer to the OEM service manual.

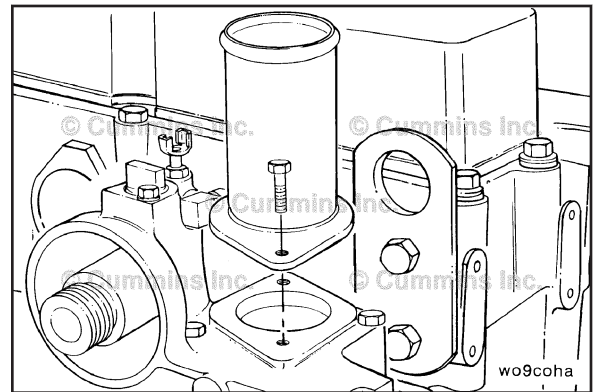


Install

Install a new gasket and the coolant outlet connection.

Tighten the thermostat housing and coolant connection capscrews.

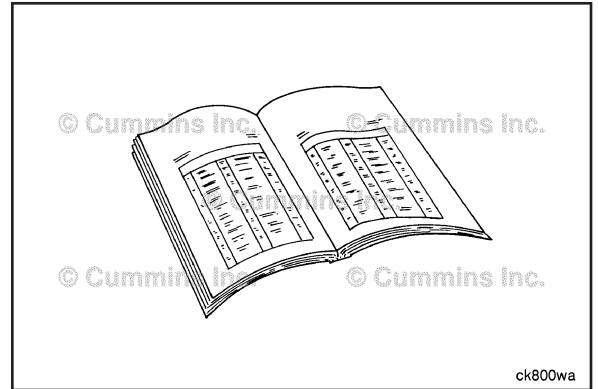
Torque Value: 24 N•m [18 ft-lb]



Finishing Steps

Fill the cooling system. Refer to Procedure 008-018.

Operate the engine and check for leaks.

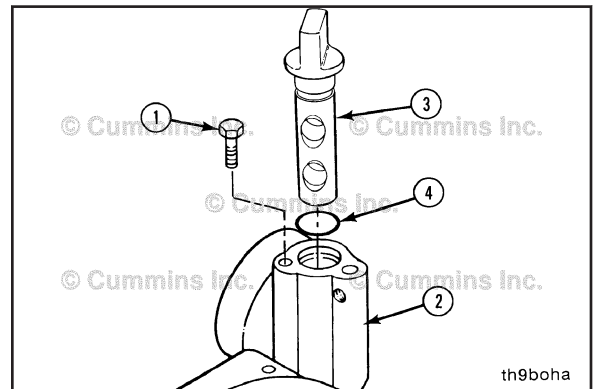


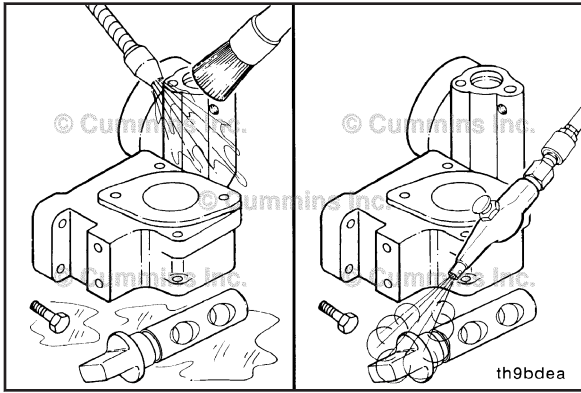
Coolant Filter Valve (008-009)

Remove

Remove the retaining capscrew (1) from the thermostat housing (2) and remove the shutoff valve (3).

Remove and discard the o-ring (4).





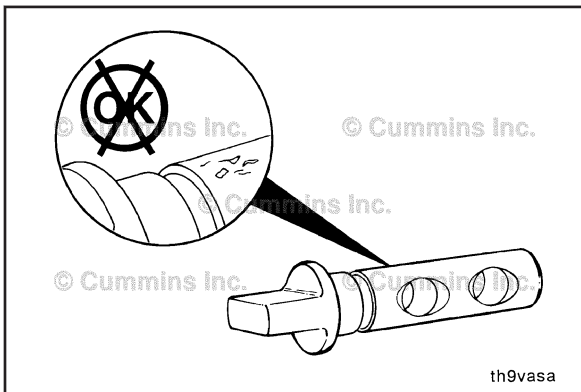
Clean

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

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

Use solvent to clean the parts.

Dry with compressed air.

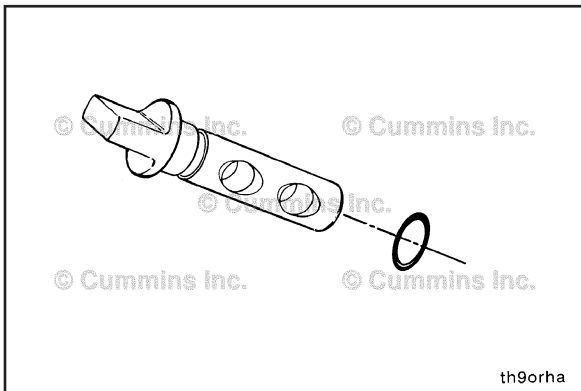


Inspect for Reuse

Inspect the water passages in the shutoff valve.

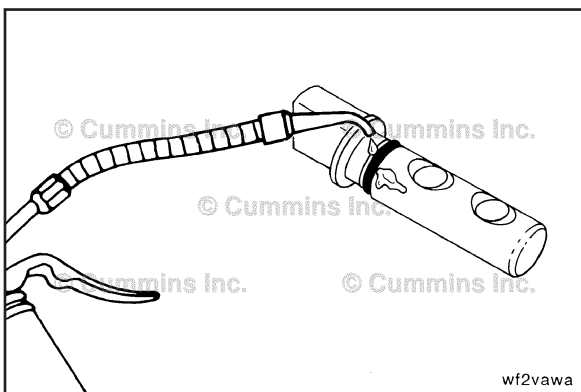
Inspect the shaft for corrosion or pitting. Use 240-grit aluminum oxide paper to remove the corrosion.

If the parts are cracked or damaged, the filter head assembly **must** be replaced.



Install

Install a new o-ring in the groove of the shaft.



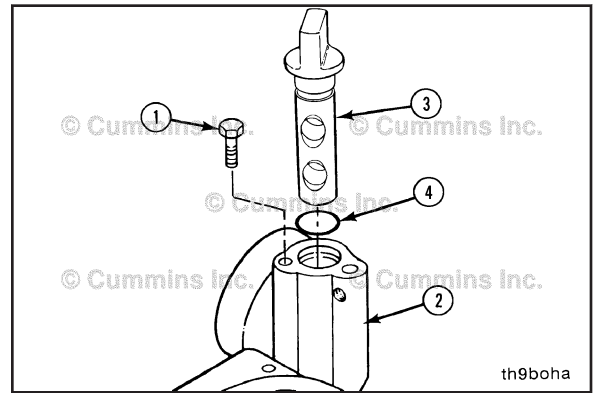
Use clean engine oil to lubricate the shaft and o-ring.

Install the shutoff valve shaft (3) in the thermostat housing (2).

Install the retaining ring capscrew (1) in the thermostat housing.

Tighten the retaining ring capscrews.

Torque Value: 7 N•m [60 in-lb]



Coolant Thermostat (008-013)

Initial Check

⚠ 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.

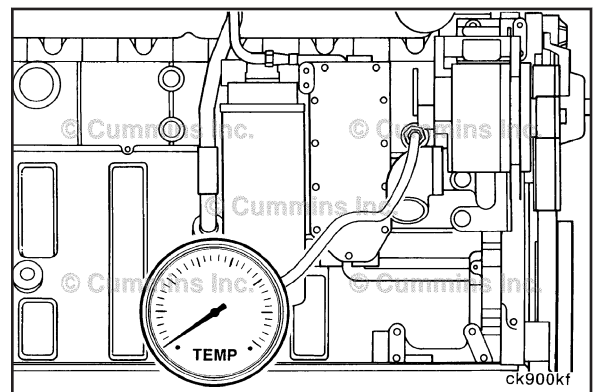
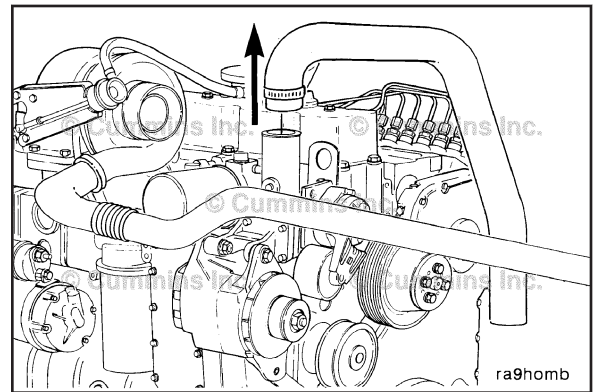
⚠ WARNING ⚠

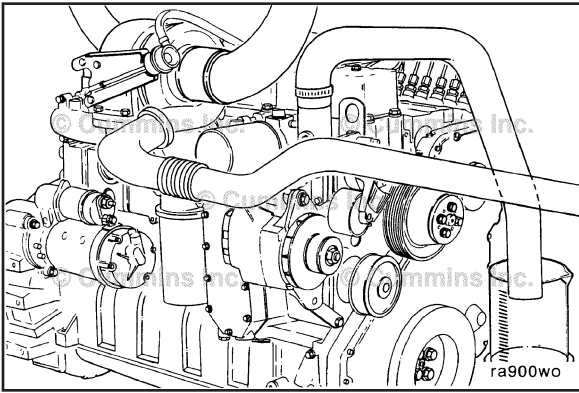
Complete this test with the engine coolant temperature below 49°C [120°F]. Hot steam can cause serious personal injury.

Drain 2 liters [2.1 qt] of coolant. Refer to Procedure 008-018.

Remove the cooling system hose from the thermostat housing.

Install a thermocouple or temperature gauge, which is known to be accurate, in the 3/4-inch pipe plug located at the front of the cylinder block.



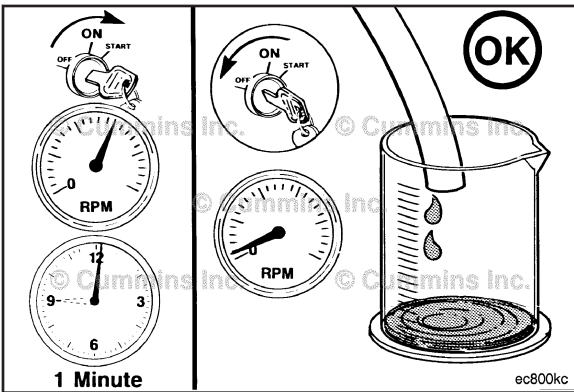


Install a hose of the same size on the thermostat housing outlet that is long enough to reach a remote, dry container used to collect coolant.

Install and tighten a hose clamp on the housing outlet.

Torque Value: 6 N•m [50 in-lb]

Insert the end of the hose in a dry container.

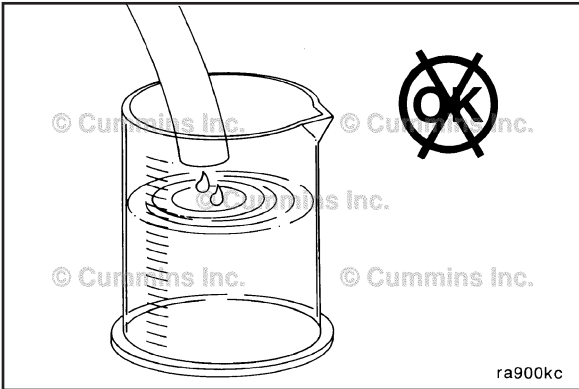


Operate the engine at rated speed for 1 minute.

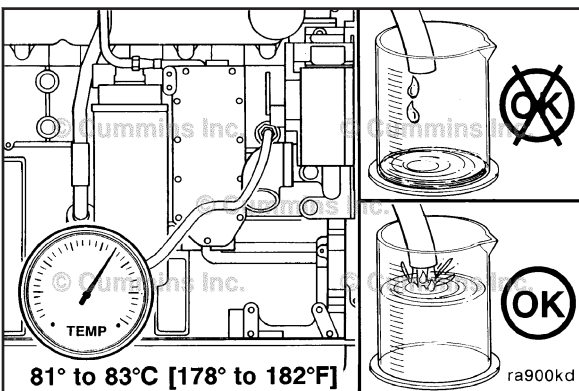
Shut off the engine and measure the amount of coolant collected in the container.

Thermostat Leak Test - Allowable Leakage

ml		fl-oz
150	MAX	5



If more than 150 ml [5 fl-oz] of coolant is collected, the thermostats are leaking and **must** be replaced.



Complete the following in-chassis test to determine the thermostat opening temperature.

Start the engine and monitor the water temperature gauge and the container. The thermostat initial opening temperature is:

81 to 83°C [178 to 182°F]

Shut off the engine when the coolant starts to flow.

NOTE: If coolant does **not** start flowing into the container during the initial opening temperature range, the thermostat **must** be replaced.

Preparatory Steps

⚠️ WARNING ⚠️

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠️ WARNING ⚠️

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

⚠️ WARNING ⚠️

Batteries can emit explosive gases. To avoid 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.

Drain 2 liters [2.1 qt] of coolant. Refer to Procedure 008-018.

Remove the upper radiator hose from the outlet connection.

Remove the drive belt. Refer to Procedure 008-002.

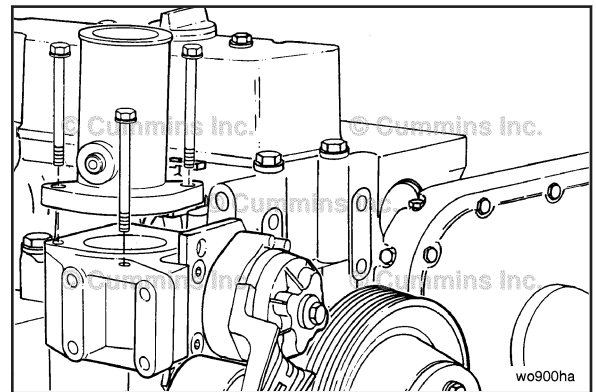
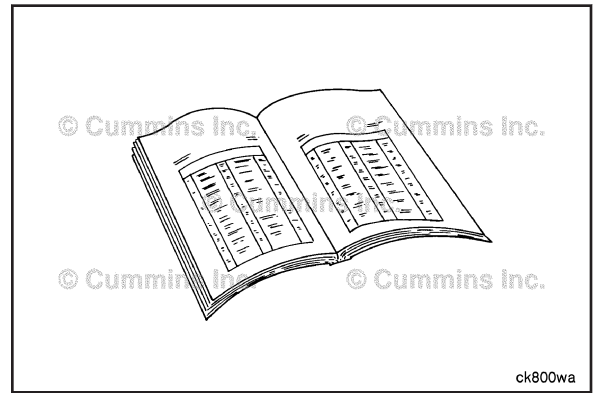
Disconnect the batteries.

Remove the alternator. Refer to Procedure 013-001.

Remove

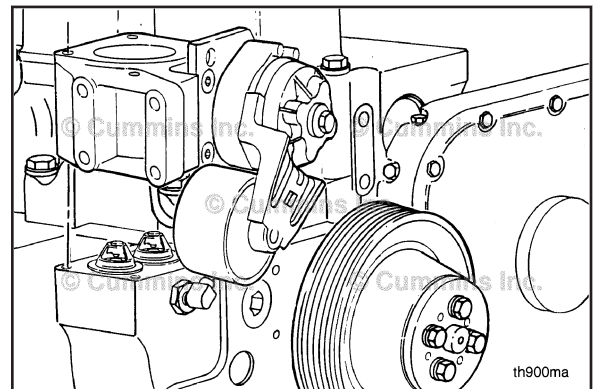
Remove the capscrews from the thermostat housing.

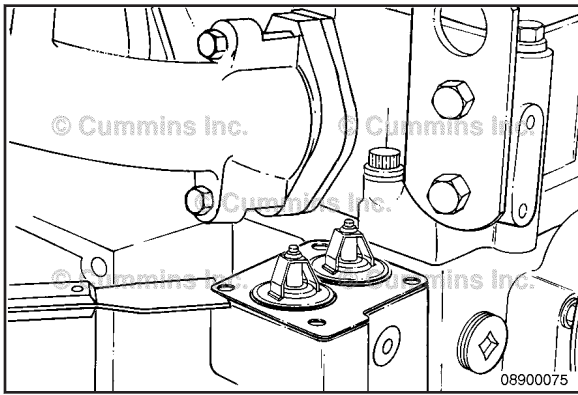
Remove the water outlet connection.



Remove the thermostat housing and belt tensioner assembly.

NOTE: If the vehicle is equipped with an external bypass system, the thermostat housing support (between the thermostat housing and cylinder block) **must** be removed.

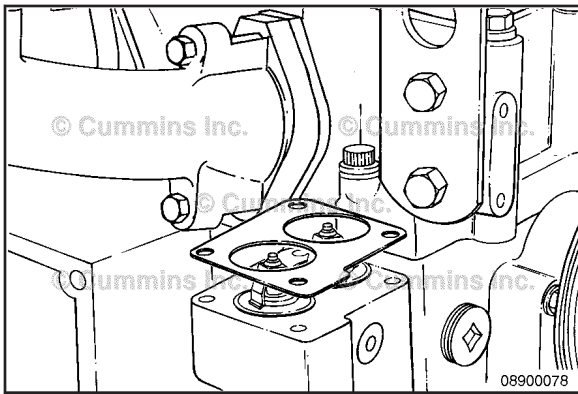




⚠ CAUTION ⚠
Debris in the cooling system can cause damage to the engine.



Remove the thermostat gasket and clean the gasket surface.

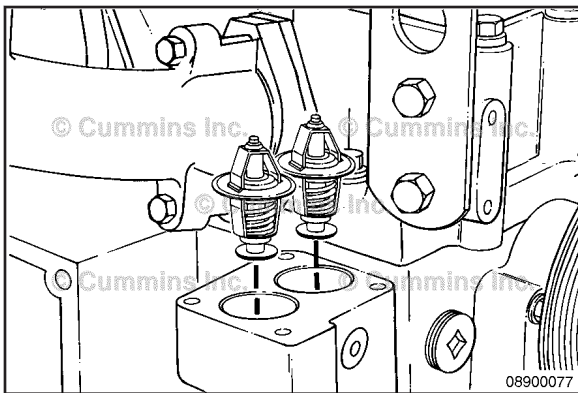


⚠ CAUTION ⚠
Do not shim the thermostats beyond the top of the block.

Measure the distance from the thermostat flange to the top of the block surface of each thermostat to determine the proper shim(s) to use.

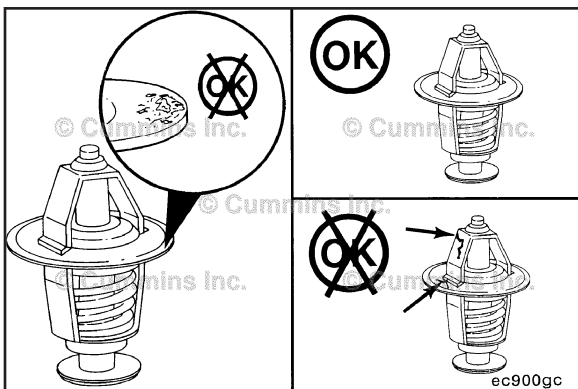
NOTE: The service shims included are 0.25 mm [0.010 in], 0.50 mm [0.020 in], 0.75 mm [0.030 in], and 1 mm [0.040 in].

Select the appropriate combination that will bring the thermostat height as close to the top of the block as possible.



NOTE: Any combination of shims can be used, but stacking is limited to a maximum of two shims per bore.

Remove each thermostat and insert the selected shims into each bore, making sure each shim is seated properly in the bore.



Inspect for Reuse

Inspect the thermostats for damage.

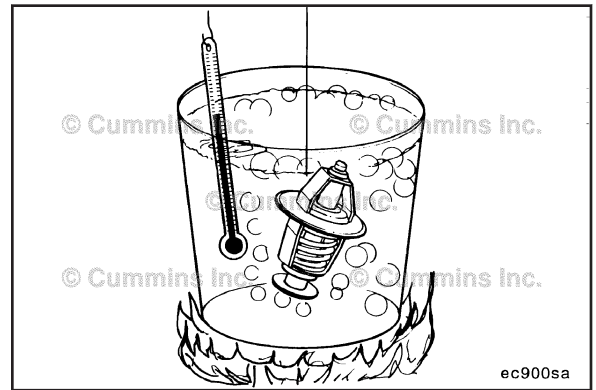
Make sure both thermostats are clean and free from corrosion.

Suspend the thermostats and a 100°C [212°F] thermometer in a container of water.

NOTE: Do **not** allow the thermostats or thermometer to touch the container.

Heat the water slowly so the wax element in the thermostats has sufficient time to react to the rising water temperature.

NOTE: The normal operating temperature is stamped on the thermostat.

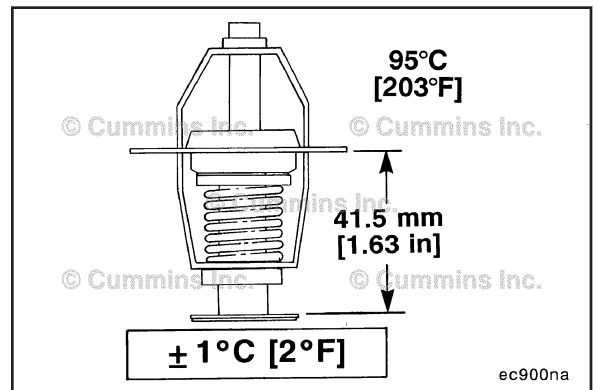


Inspect the thermostats as follows:

- Thermostat **must** begin to open within 1°C [2°F] of 82°C [180°F].
- Thermostat **must** be fully open within 1°C [2°F] of 95°C [203°F].

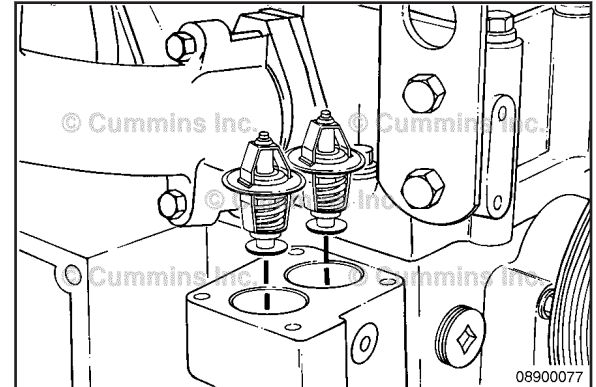


NOTE: The fully open clearance between the thermostat flow valve and flange **must** be 41.5 mm [1.63 in] minimum.

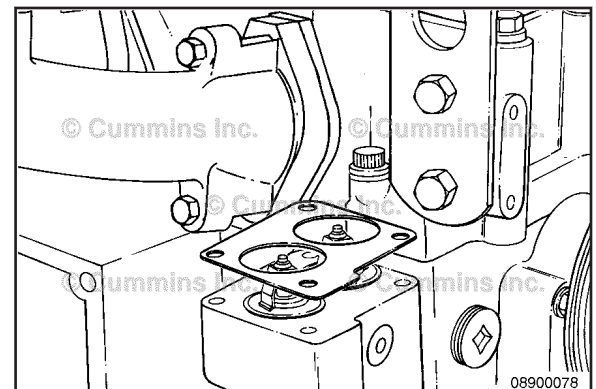


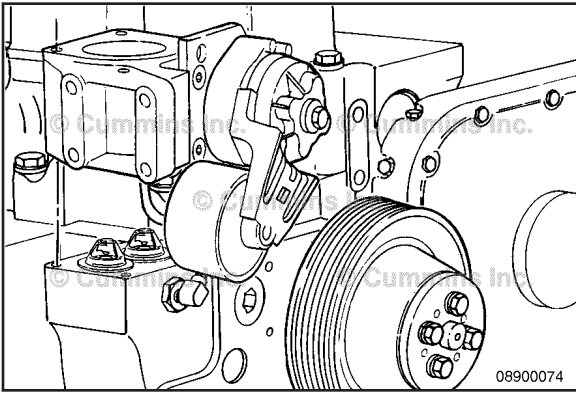
Install

Install the thermostats on top of the service shim(s) in the thermostat flanges. They can be within 0.23 mm [0.009 in] of flush with the top of the block, without being above the top of the block.



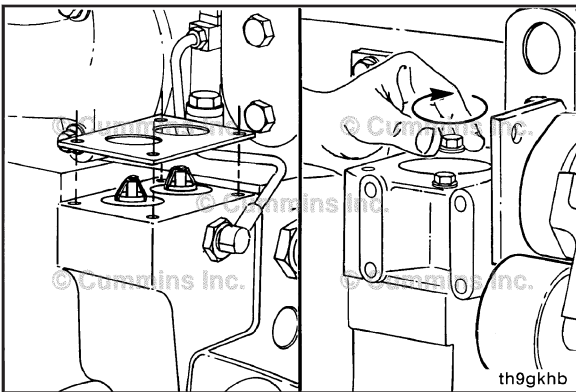
Install a new thermostat gasket.



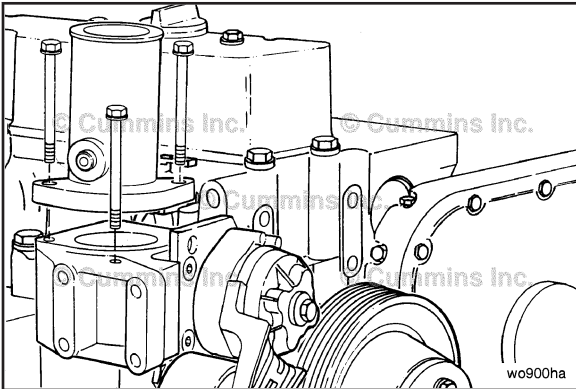


Position the thermostat housing and belt tensioner over the thermostats and gasket.

NOTE: If an external bypass system is used, the thermostat housing support (between the thermostat housing and cylinder block) **must** be installed.



Make sure the gasket is aligned with the capscrew holes. Install the capscrews and finger-tighten.



Install the water outlet connection. Tighten all capscrews.



Torque Value: 24 N•m [212 in-lb]

Finishing Steps

⚠ WARNING ⚠

Batteries can emit explosive gases. To avoid 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 alternator. Refer to Procedure 013-001.

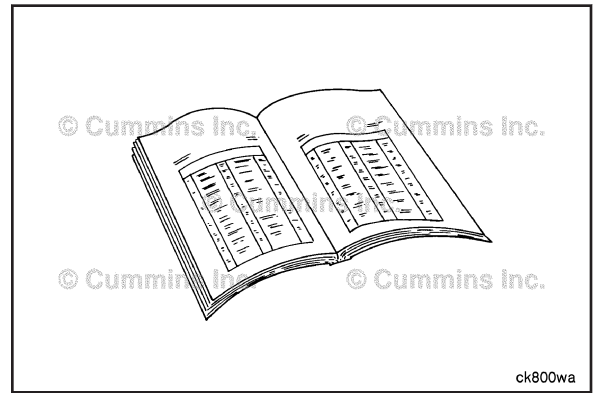
Install the drive belt. Refer to Procedure 008-002.

Install and tighten the battery's electrical connections.

NOTE: During filling, air **must** be vented from the engine's coolant passages. Open the engine vent petcock, if equipped. Make sure to open the petcock on the aftercooler for aftercooled engines. The system **must** be filled slowly to prevent air locks. Wait 2 to 3 minutes to allow air to be vented; then add coolant to bring the level to the bottom of the radiator filler neck.

Fill the cooling system. Refer to Procedure 008-018.

Operate the engine to normal operating temperature and check for leaks.

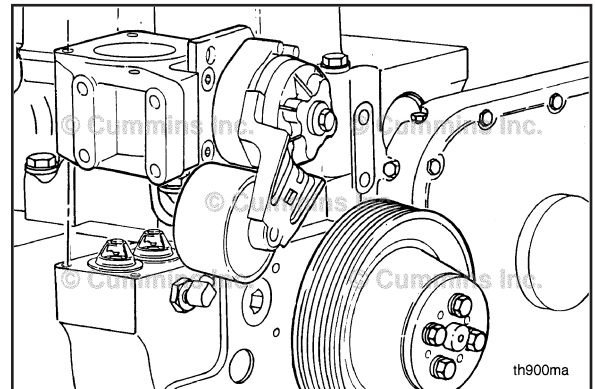


Coolant Thermostat Housing (008-014) Remove

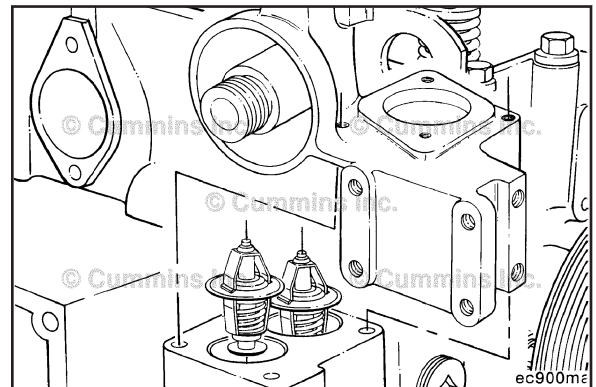


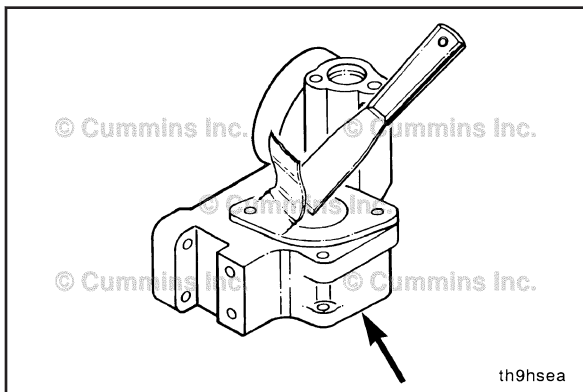
Remove the thermostat housing and and belt tensioner assembly.

Refer to Procedure 008-013.



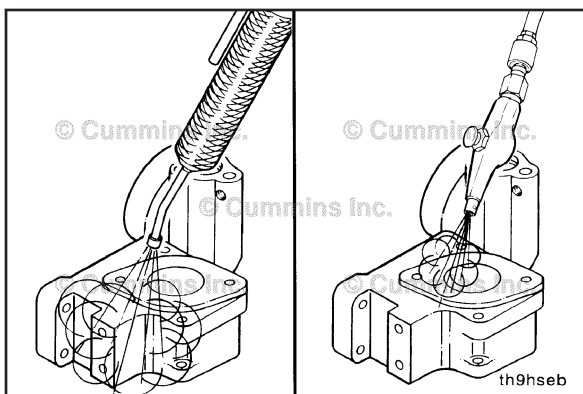
Remove the thermostats.





Clean

Use a gasket scraper to remove the gasket material from the mating surfaces of the housing.



⚠️ WARNING ⚠️

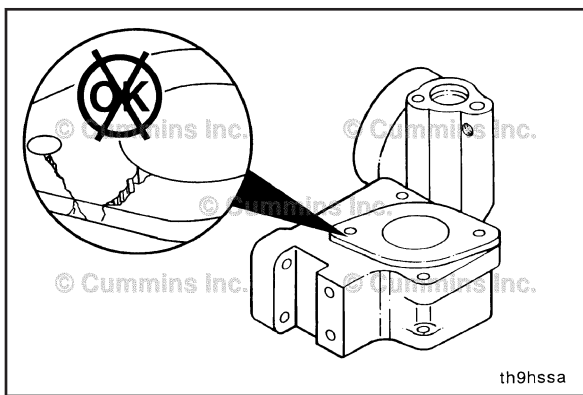
When using a steam cleaner, wear protective clothing and safety glasses or a face shield. Hot steam will cause serious personal injury.

⚠️ WARNING ⚠️

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

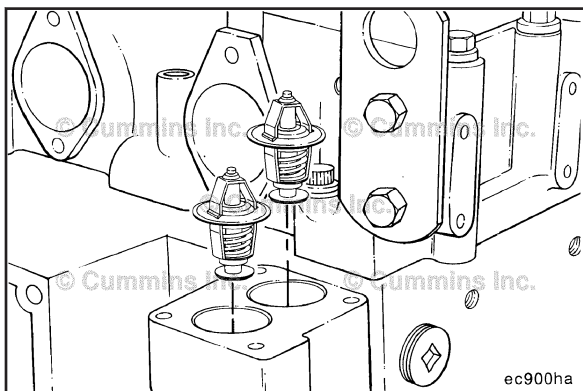
Use solvent or steam to clean the parts.

Dry with compressed air.



Inspect for Reuse

Inspect the thermostat housing for cracks, corrosion, or damage. Replace the thermostat housing if damaged.

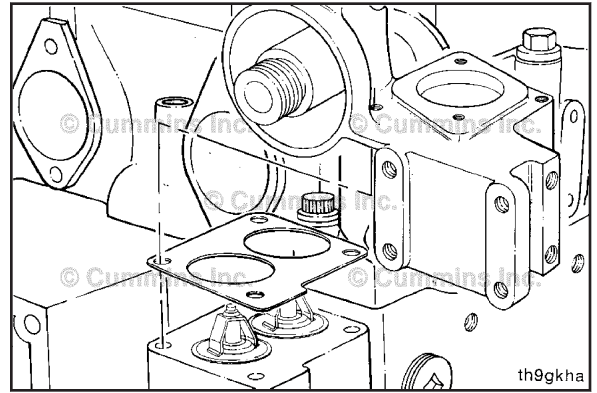


Install

Install the thermostats; refer to Procedure 008-013.



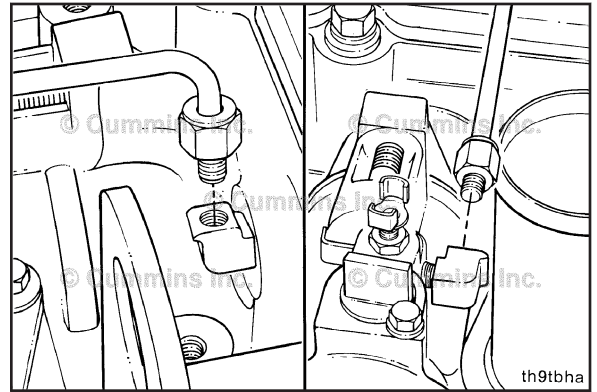
Install a new thermostat gasket and the thermostat housing. Install two capscrews. Do **not** tighten the capscrews until after the coolant outlet connection is installed.



Coolant Vent Lines (008-017)

Remove

Remove the coolant vent line.



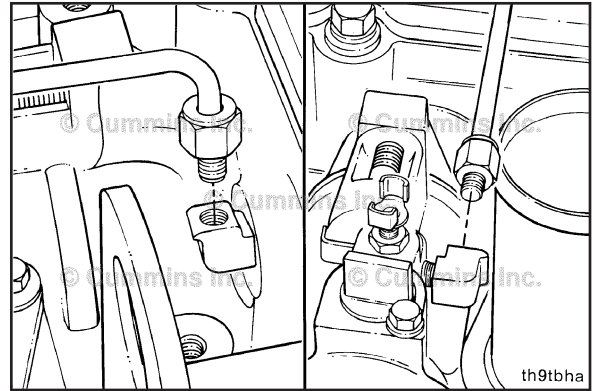
Install

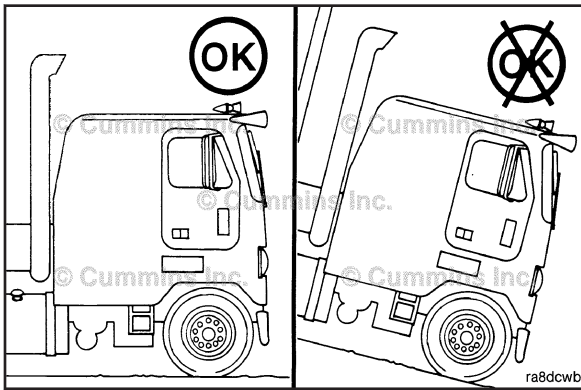
Coat the threads of the coolant vent line with Teflon™.

Install the coolant vent line.

Tighten the coolant vent line fittings.

Torque Value: 8 N•m [71 in-lb]





Cooling System (008-018)

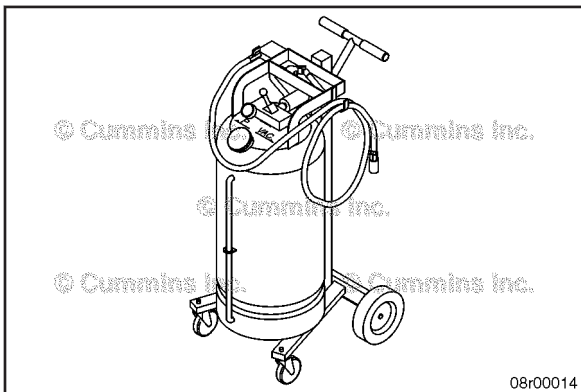
Coolant Replacer Method

Evacuation

The following steps are used to evacuate the cooling system using the coolant replacer tool, Part Number 2892459.

NOTE: When the vehicle/equipment or engine is equipped with a quick disconnect fitting in the cooling system package, the Coolant Replacer Method is the preferred method for coolant removal. Use the coolant replacer tool, Part Number 2892459. If the vehicle/equipment or engine does **not** have a quick disconnect fitting presently installed, one can be installed in the cooling system package to utilize the Coolant Replacer Method; otherwise the coolant drain and fill method **must** be used.

Position the equipment on level ground.



⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ CAUTION ⚠

Do not use the coolant replacement tool to evacuate contaminated coolant or a system that is suspected of contamination. This could result in cross contamination of coolant. The coolant drain method should be used for removing contaminated coolant. Refer to the manufacturer's manual for specific instructions on cleaning the tool of contaminants.

NOTE: 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.

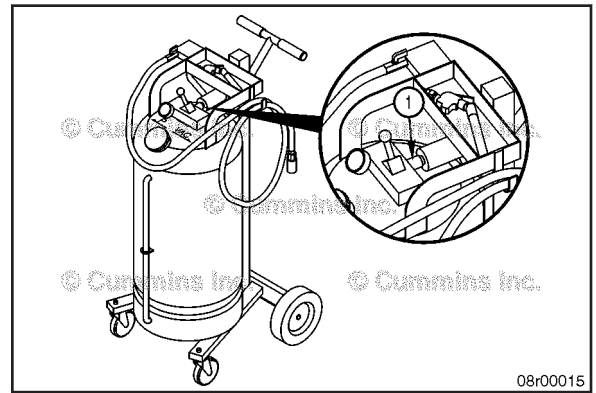
Remove the radiator cap.

⚠ 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 liters [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.

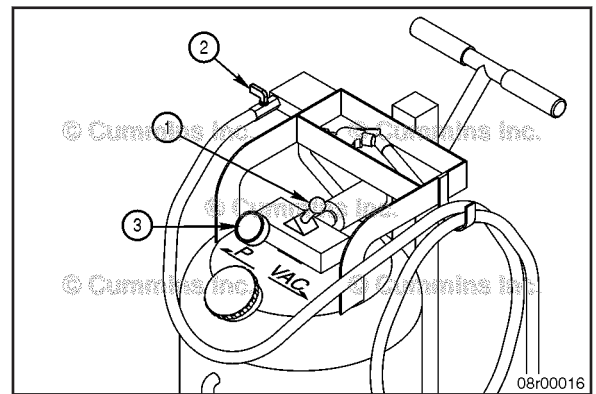


Connect the coolant replacement tool to a shop air supply regulated at 621 kPa [90 psi].

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.

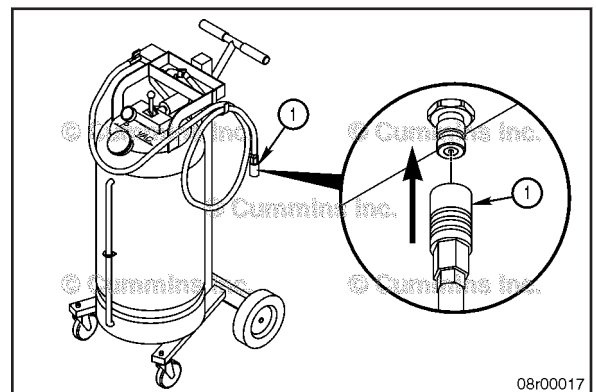
Monitor the gauge (3) and build a vacuum of approximately 508 mm-Hg [20 in-Hg] in the coolant replacement tool tank. Once the vacuum has been achieved, move the control valve lever (1) to the middle position.

Maintain approximately a 508 mm-Hg [20 in-Hg] vacuum to achieve a faster drain.



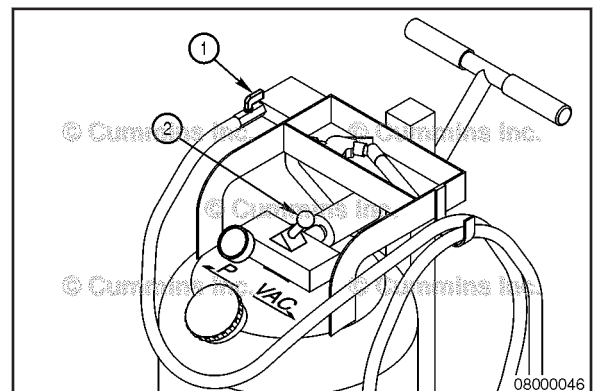
Attach the fill hose quick disconnect coupling (1) of the coolant replacement tool to the quick disconnect fitting. Location of the fitting may vary between OEMs, but the fitting is generally located in the lowest point of the vehicle/equipment cooling system package.

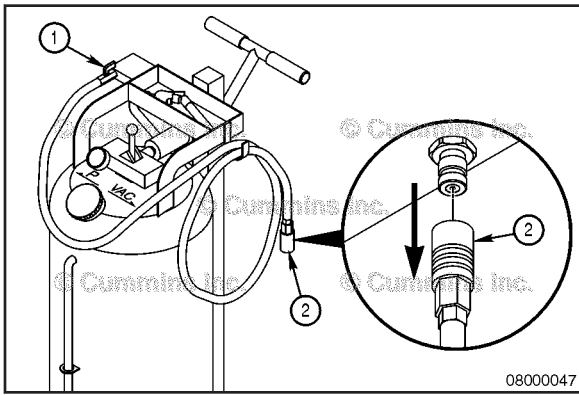
NOTE: Most Volvos are equipped with a different style fitting located in the radiator. An adapter hose is needed to connect the Cummins® coolant replacement tool to the fitting. The adapter hose is included in the accessory kit.



Open the service hose valve (1) by turning it **clockwise** until it is completely open (approximately 1/4 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.



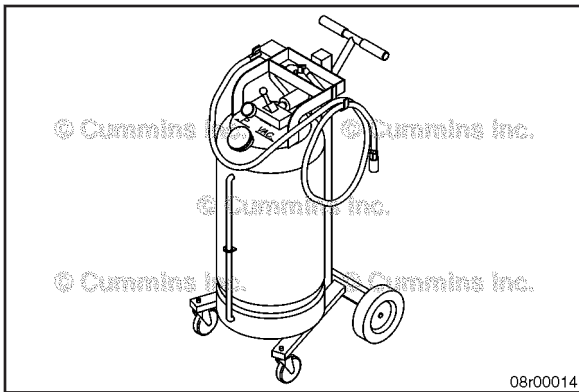


When the cooling system has been evacuated, a coolant and air mixture will be visible in the clear section of the coolant replacement tool fill hose.

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 COMPLETE™. It is available in glycol forms (ethylene and propylene) and complies with TMC RP329 and RP330 standards.

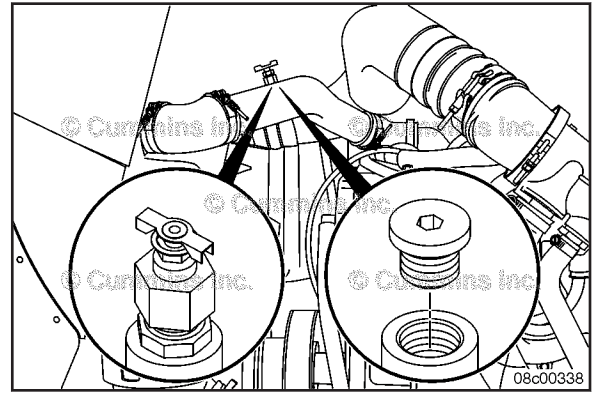
Refer to Cummins® Coolant Requirement and Maintenance, Bulletin 3666132, for more engine coolant specifications.

⚠CAUTION⚠

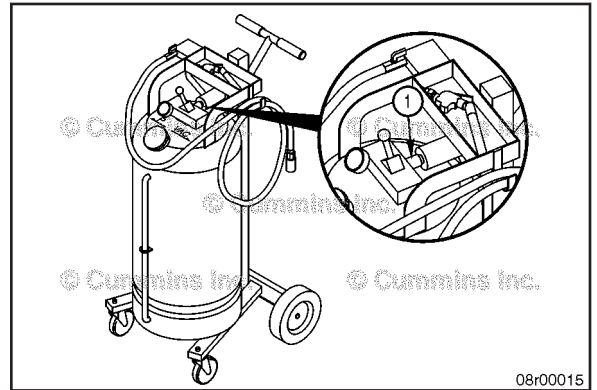
Opening the manual bleed valve or removing the pipe plug on applicable installations is critical. Failure to do so can result in engine damage.

NOTE: Some applications can have a manual bleed valve or pipe plug that is required to be opened to properly fill the system. The upper radiator pipe is a common location.

If applicable, open the manual bleed valve or remove the pipe plug before filling the cooling system.



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.



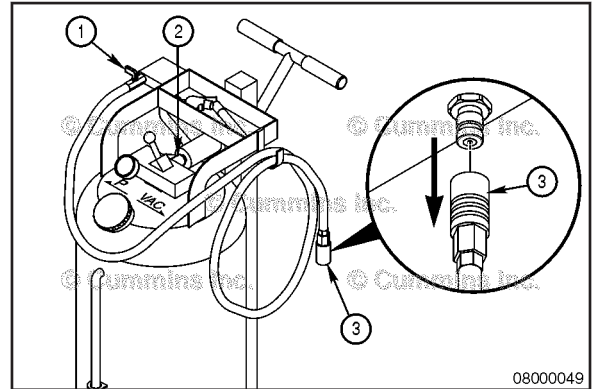
Connect the coolant replacement tool to a shop air supply regulated at 621 kPa [90 psi].

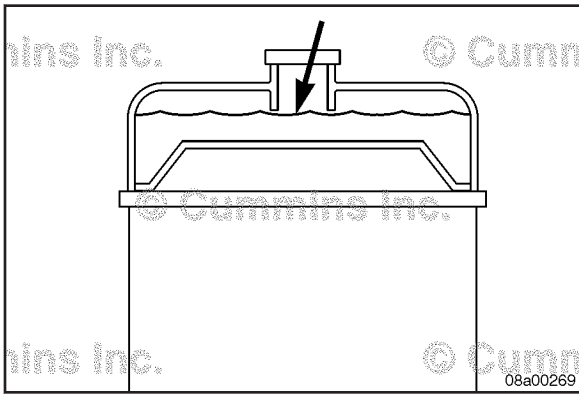
Attach the fill hose quick disconnect coupling (1) of the coolant replacement tool to the quick disconnect fitting located in the vehicle/equipment cooling system package.

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.



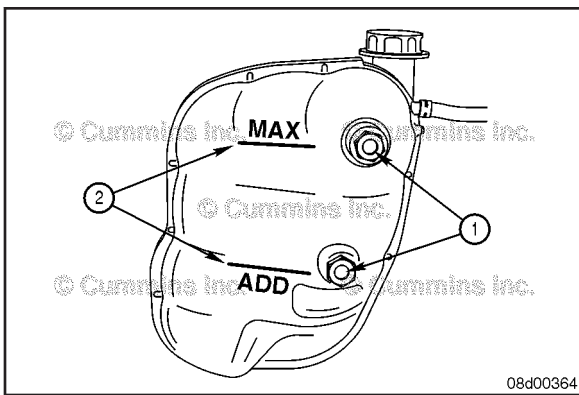


Fill the cooling system with coolant to the bottom of the fill neck in the radiator fill or recovery/expansion tank or until the coolant replacer tool is empty (whichever occurs first).

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⚠

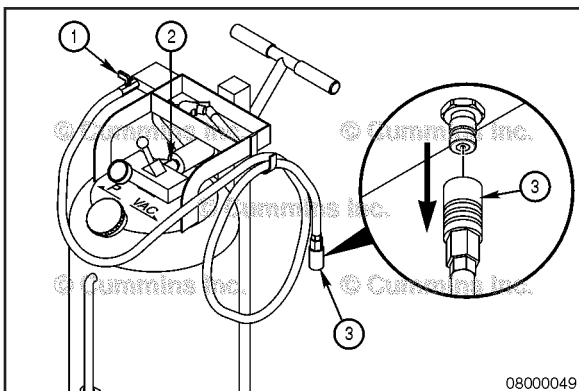
The cooling system must be filled properly to prevent air locks or serious engine damage can result.

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).

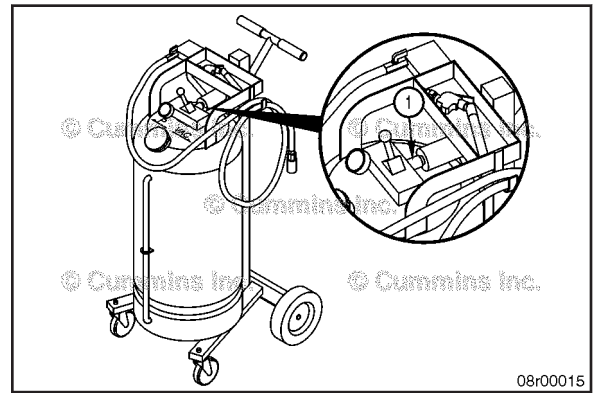
Disconnect the service hose quick disconnect coupling (3) from the quick disconnect fitting of the vehicle/equipment.

Vacuum

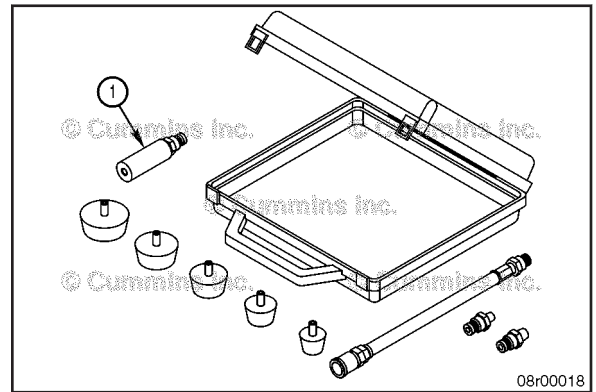
The following steps are used to place a vacuum on the cooling system using the coolant replacer tool, Part Number 2892459.

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.



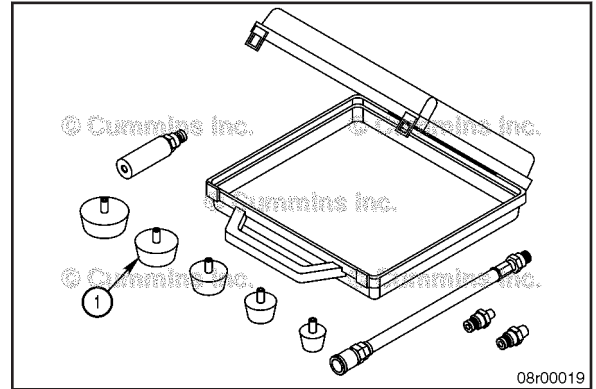
Attach the coolant dam handle (1) to the fill hose of the coolant replacement tool.

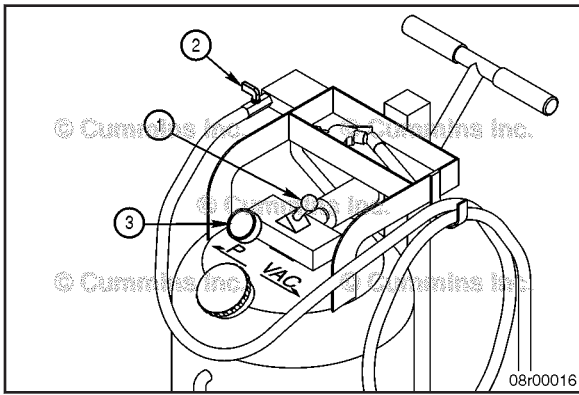


Attach the appropriate size coolant dam rubber adapter (1) onto the coolant dam handle.

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.

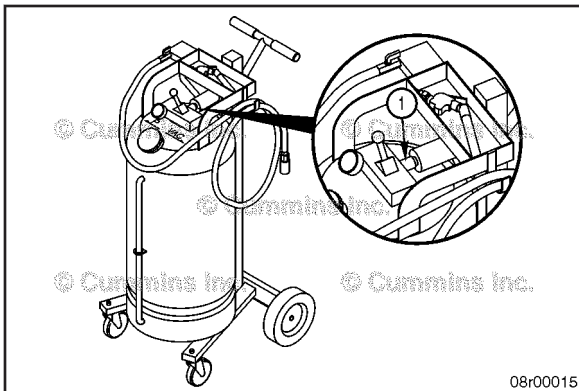
The size of the fill neck will differ between OEMs. Choose the appropriate sized coolant dam rubber adapters.

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.

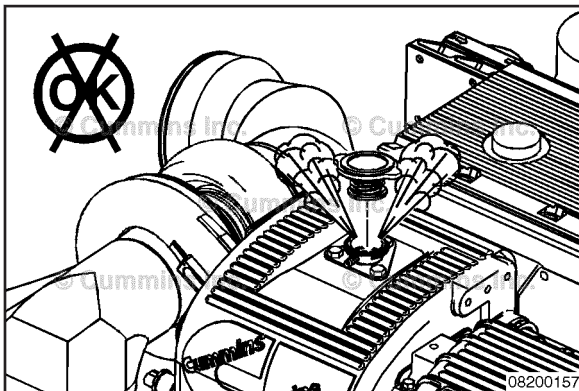


When air bubbles are no longer being drawn to the top of the cooling system move the control lever to the middle position. Remove the vacuum on the coolant replacement tool tank by opening the pressure relief valve located on the control block of the coolant replacement tool (1).

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

Marine Applications

▲ WARNING ▲

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

▲ WARNING ▲

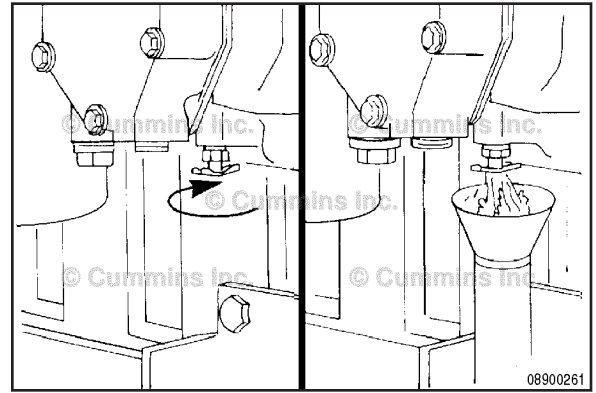
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Avoid excessive contact, and wash thoroughly after contact.
- Keep out of reach of children.

⚠ CAUTION ⚠

Use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

Drain the engine cooling system by opening the drain valve on the engine oil cooler (exhaust side of engine). A drain pan with a capacity of 31.7 liters (8 gal) will be adequate in most installations. Remove the pressure cap to allow the coolant to drain properly. After the cooling system is completely drained, close the drain valve.



All Applications Except Marine

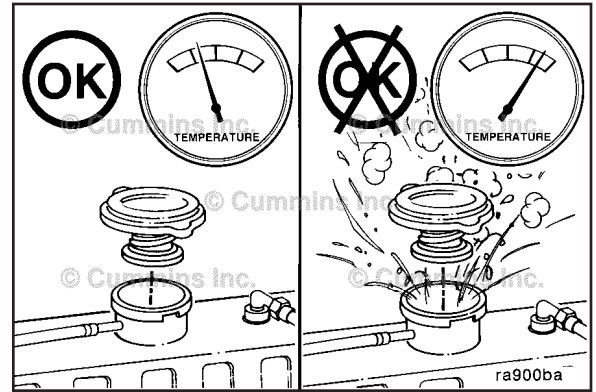
⚠ WARNING ⚠

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

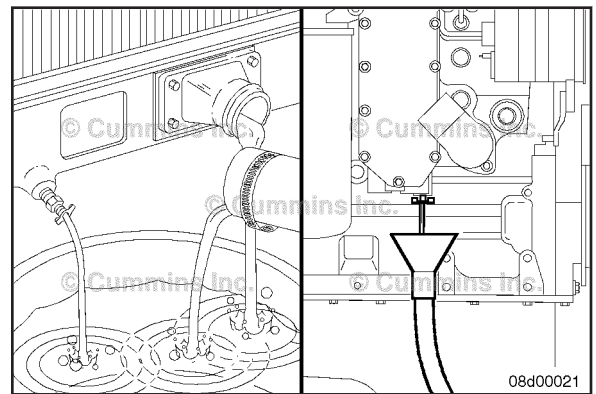
⚠ WARNING ⚠

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Avoid excessive contact, and wash thoroughly after contact.
- Keep out of reach of children.



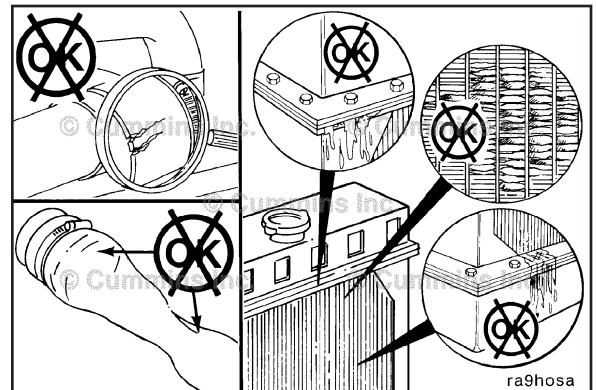
Drain the cooling system by opening the drain valve on the radiator and removing the plug in the bottom of the water inlet hose. A drain pan with a capacity of 19 liters [5 gal] will be adequate for most applications.



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.

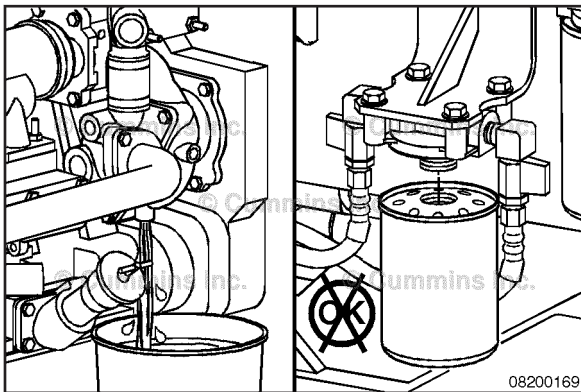




Flush

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, or longer cleaning times 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.

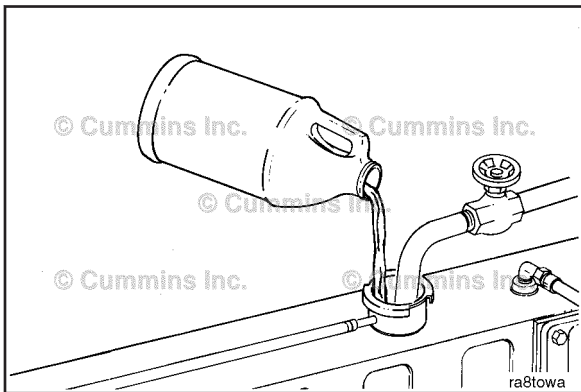


⚠️ WARNING ⚠️

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 information above in "Cooling System - Drain" step. Do **not** allow the cooling system to dry out.

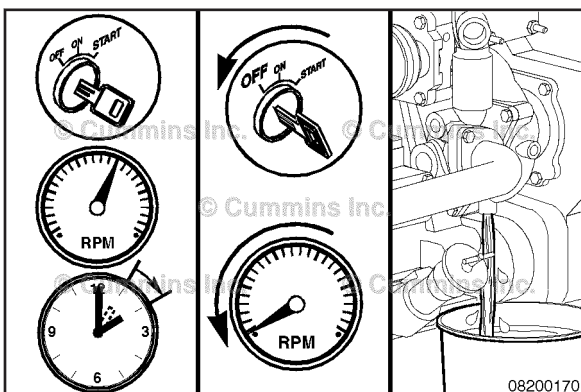
Do **not** remove the coolant filter.



⚠️ CAUTION ⚠️

Fleetguard® RESTORE™ contains no antifreeze. Do **not** allow the cooling system to freeze during the cleaning operations.

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.



Operate the engine at normal operating temperatures, at least 85°C [185°F], for 1 to 1½ hours.

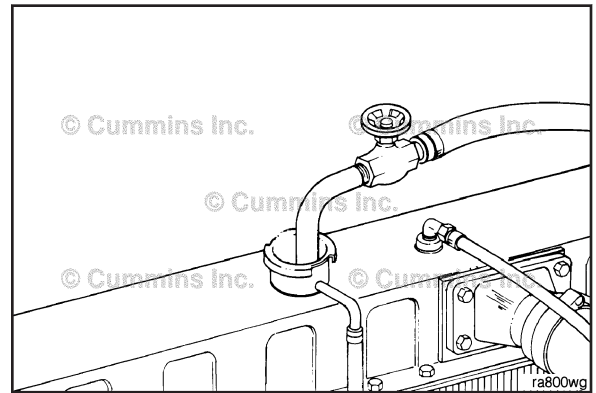
Shut the engine OFF, allow to cool to 50°C [122°F], and drain the cooling system.

The system has a design fill rate of 19 liters per minute [5 gallon per minute].



Marine engines **must** be vented at the coolant outlet housing and at the rear of the expansion tank during filling.

Fill the cooling system with clean, good quality water.

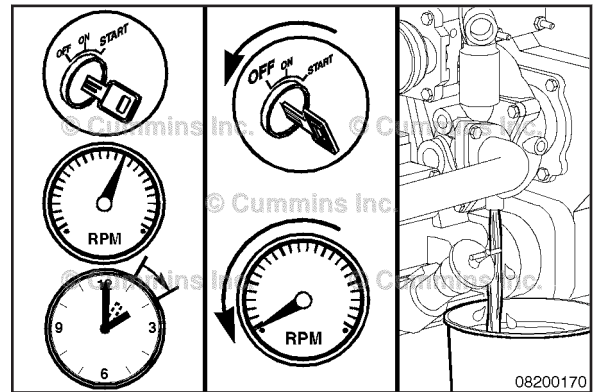


Operate the engine for 5 minutes with the coolant temperature above 85°C [185°F].



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 comes out clean.

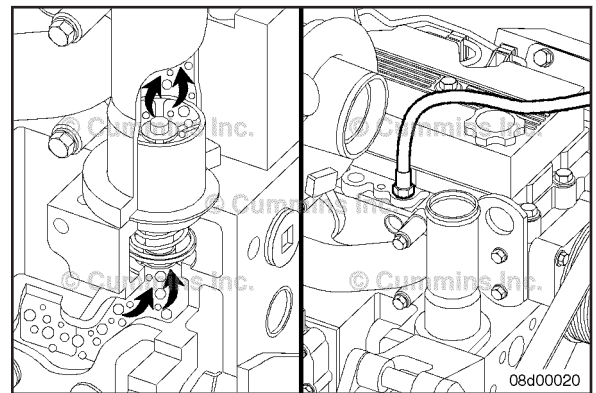


All Applications Except Marine

⚠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 the air to be vented; then add coolant mixture to bring the level to the top.

NOTE: Adequate venting is provided for a fill rate of 19 liters [5 gal] per minute.

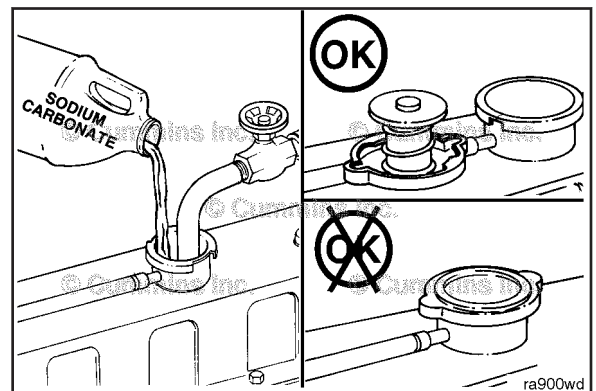


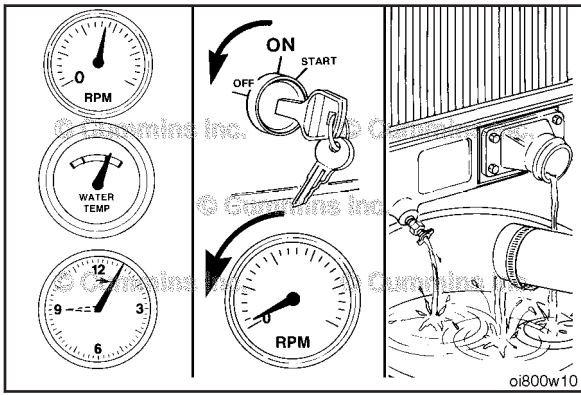
⚠CAUTION⚠

Do not install the radiator cap. The engine is to be operated without the cap for this process.

Fill the system with a mixture of sodium carbonate and water (or a commercially available equivalent).

NOTE: Use 0.5 kg [1 lb] of sodium carbonate for every 23 liters [6 gal] of water.

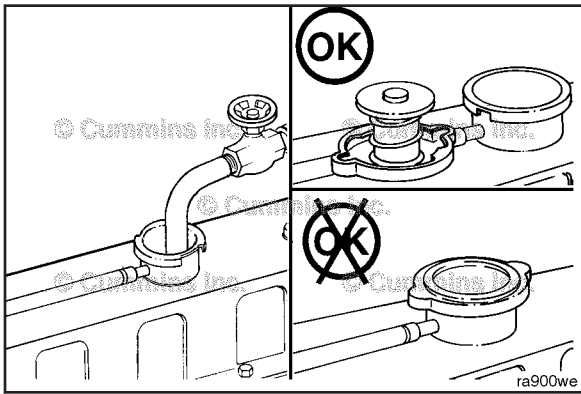




⚠ WARNING ⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Operate the engine for 5 minutes with the coolant temperature above 80°C [176°F].

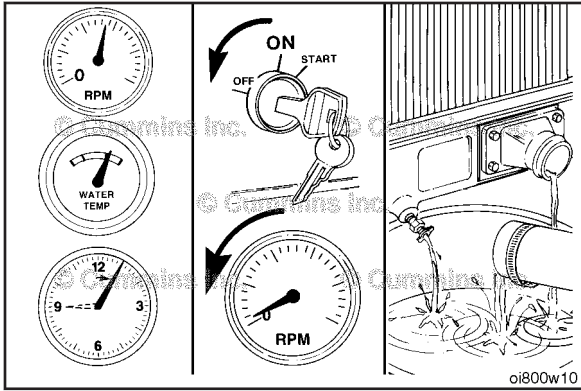
Shut the engine OFF, and drain the cooling system.



NOTE: Make sure to vent the engine and aftercooler for complete filling.

NOTE: Do **not** install the radiator cap or the new coolant filter.

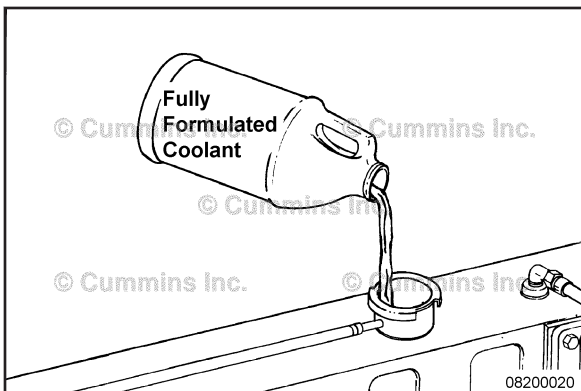
Fill the cooling system with clean, good, and quality water.



Operate the engine for 5 minutes with the coolant temperature above 80°C [176°F].

Shut the engine OFF, and drain the cooling system.

NOTE: If the water being drained is still dirty, the system **must** be flushed again until the water comes out clean.



Fill
Marine Applications



QSC8.3 and QSL9 Engines with Heat Exchangers

The system has a design fill rate of 19 liters per minute [5 gallons per minute].

Marine engines **must** be vented at the coolant outlet housing, and at the rear of the expansion tank during filling.

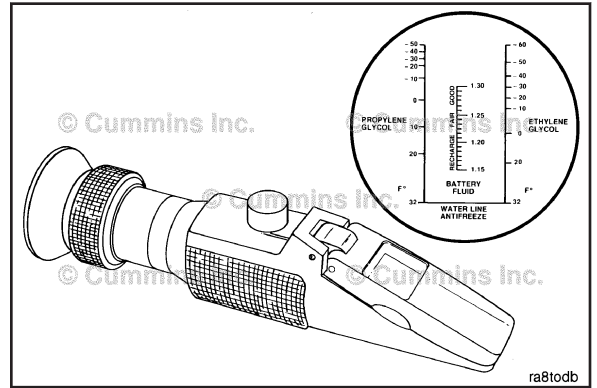
Fill the cooling system with fully formulated coolant or a 50/50 mixture of recommended antifreeze and clean, good quality water, as outlined in the Owners Manual.

Install the pressure cap. Operate the engine to 50°C [122°F], and check for coolant leaks.

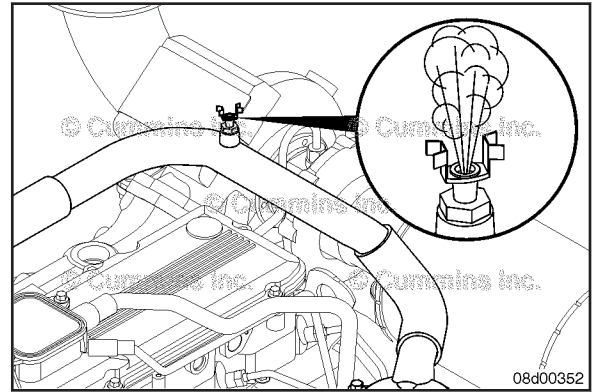
The freeze point protection **must** be checked after coolant is added to the cooling system.

The Fleetguard® refractometer, Part Number C2800, provides a reliable, easy-to-read, and accurate measurement of freeze point protection and antifreeze concentration.

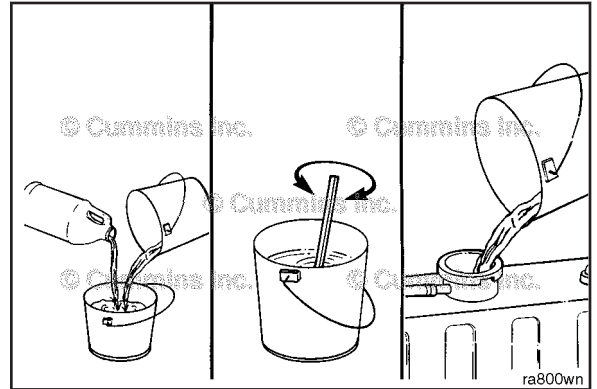
Refer to the OEM instructions for the correct operation instructions for the Fleetguard® refractometer, Part Number C2800.

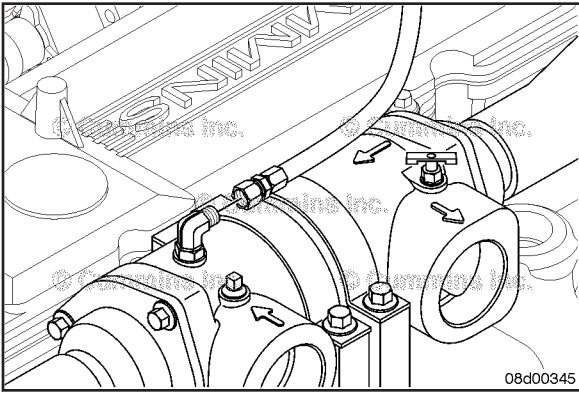


On QSL9 Keel Cooled Engines, open all engine mounted petcocks and remote heater petcocks.



Fill the cooling system with fully formulated coolant or a 50/50 mixture of recommended antifreeze and clean, good quality water, as outlined in the Owners Manual.





NOTE: The timing and sequence of this action will depend on the height of the petcocks in the cooling system.

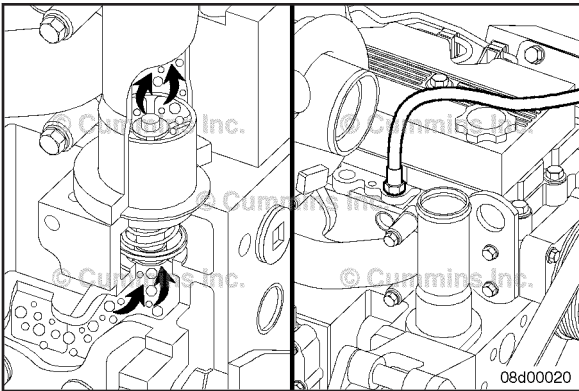
Fill the engine until a solid stream of coolant is visible from the keel cooler thermostat housing, heat transfer tube, and remote mounted heater petcocks. Close the petcocks.

Fill until the coolant expansion tank is filled to the proper level and the low coolant level sensor is covered.

Start the engine. Monitor the coolant level and the low coolant alarm until all air is purged from the system. Operate the engine for 5 minutes with the pressure cap removed, however, do **not** exceed 50°C [122°F].

Shut down the engine and check the coolant level again. Add coolant if needed.

Install the pressure cap. Start the engine and monitor the low coolant alarm during the initial startup test.



All Applications Except Marine

⚠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 the air to be vented; then add coolant mixture to bring the level to the top.

⚠CAUTION⚠

During all coolant fill procedures, all coolant flow valves to equipment heating systems must be opened in order to purge air from those systems as well as from the base engine cooling system. These valves must remain open during the engine cooling system de-aeration process. Make sure adequate coolant levels are maintained in the coolant reservoir during the entire fill procedure. Special care must be taken when filling EGR cooler-equipped engines to make sure all air is purged from the system.

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

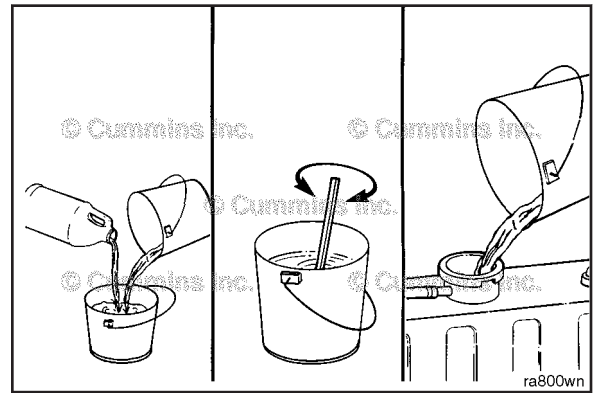
If frequent addition of coolant is necessary, the engine or system has a leak. Find and repair the leak.

The system has a designed fill rate of 19 liters [5 gal] per minute.

⚠ CAUTION ⚠

Never use water alone for coolant. This can result in damage from corrosion.

Use a mixture of 50-percent water and 50-percent ethylene glycol or propylene glycol antifreeze to fill the cooling system.



⚠ WARNING ⚠

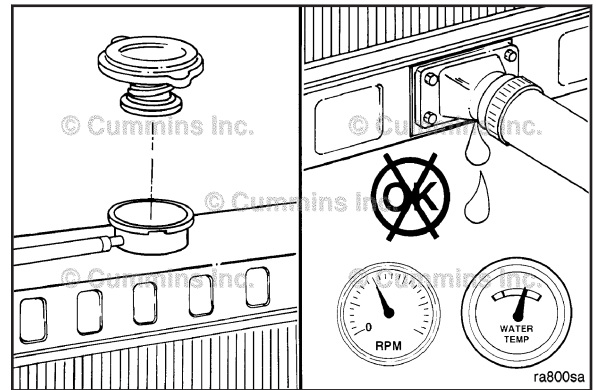
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

Install the pressure cap. Operate the engine until the coolant reaches a temperature of 80°C [176°F], and check for coolant leaks.

Operate the engine at idle for 25 minutes to purge the air from the cooling system.

Turn all cab heater temperature switches, if equipped, to high to allow maximum coolant flow through the heater core(s). The blower does **not** have to be on.

Check the coolant level again to make sure the system is full of coolant or that the coolant level has risen to the hot level in the recovery bottle on the system, if so equipped.



Cooling System - Air or Combustion Gas Test (008-019)

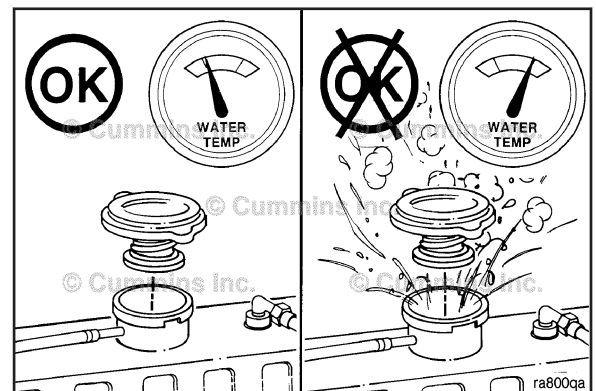
General Information

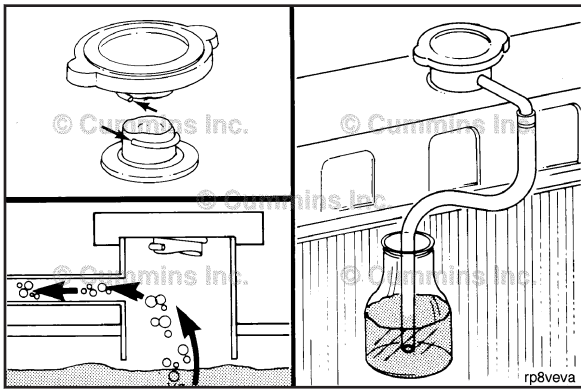
Overflow Method

⚠ 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 cooling system pressure cap.





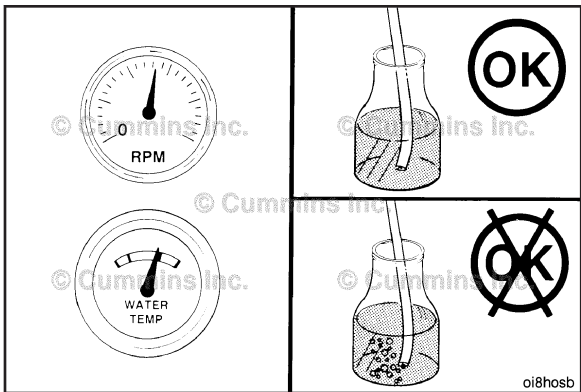
Install a pressure cap that has the spring and the pressure relief valve removed to allow free flow from the overflow tube.

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.

NOTE: A gasket may need to be installed in order to properly seal this interface. If the pressure cap is **not** properly sealed then any air bubbles that may be present will **not** show up during the test.



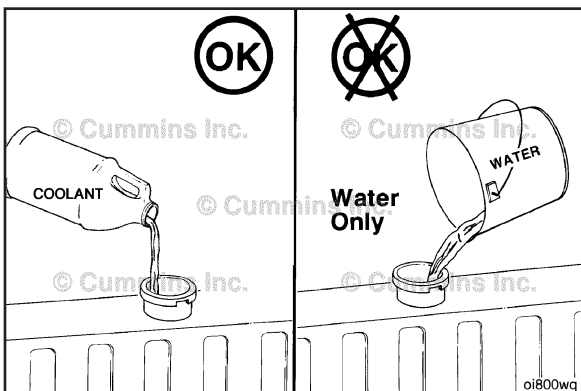
Operate the engine at rated rpm until it reaches a temperature of 82°C [180°F].

Check for air bubbles in the water container. A combustion gas leak is present if a continuous flow of air bubbles is present or air is entering the coolant system.

NOTE: The engine coolant temperature **must** be stable to perform this test. An increasing coolant temperature will give a false indication of air because of the expansion of the coolant in the system.

A continuous flow of air bubbles may indicate one of the following:

- A cylinder head combustion gas leak
- Incorrect cylinder liner protrusion
- Cracked or broken cylinder liners
- Damaged aftercooler.



Combustion Gas Leak

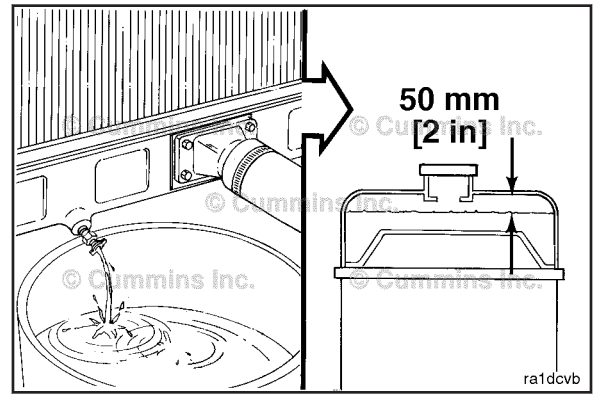
Use combustion gas tester, Part Number 3822985, to test for combustion gases in the cooling system.

NOTE: It is recommended that the cooling system contain a premixture 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.

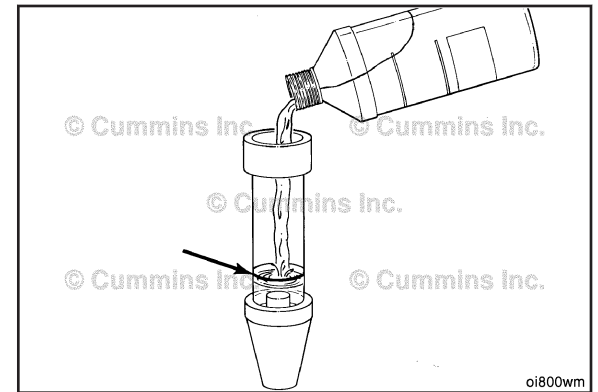
⚠ WARNING ⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠ WARNING ⚠
Coolant is toxic. If not reused, dispose of in accordance with local environmental regulations.

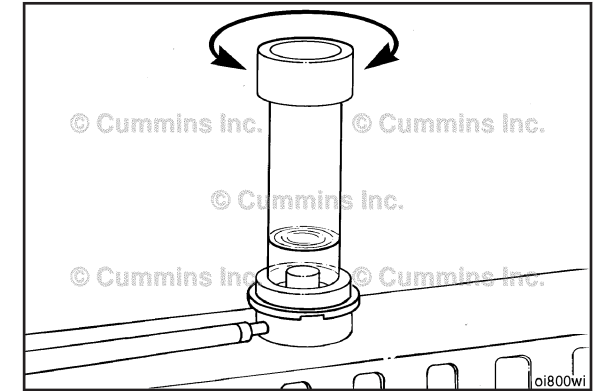
Drain the coolant level down approximately 50 mm [2 in] below the radiator cap seal ledge in the radiator fill neck. Refer to Procedure 008-018 in Section 8.



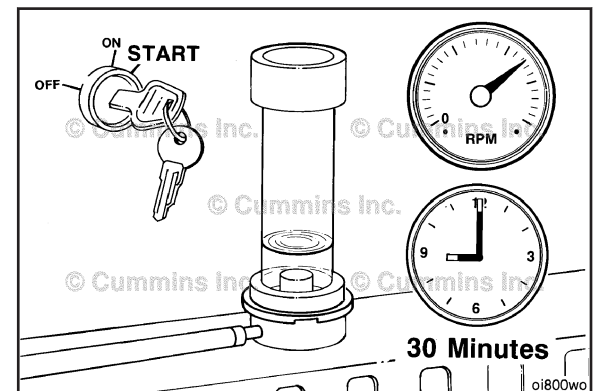
Pour the test fluid into the combustion gas test instrument until it is up to the yellow fill line on the instrument.

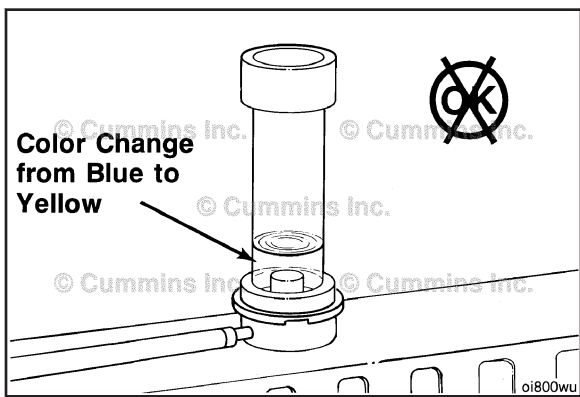


Insert the rubber tip of the combustion gas leak test instrument in the radiator fill neck. Hold the instrument down firmly and turn back and forth to make sure that an airtight seal is formed between the tester and radiator fill neck.

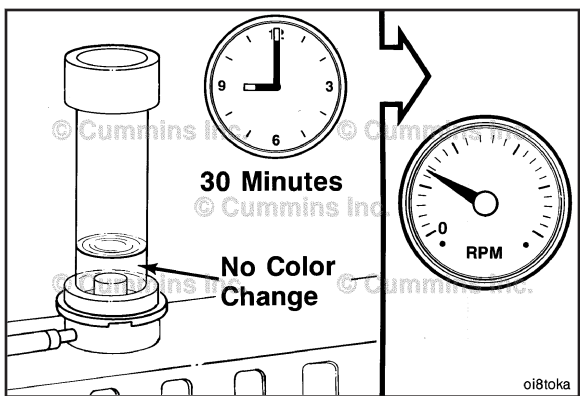


Start the engine and operate at high idle for approximately 30 minutes. Monitor the engine temperature and color of the test fluid during engine operation. Do **not** allow the engine temperature to exceed 100°C [212°F] during the test.

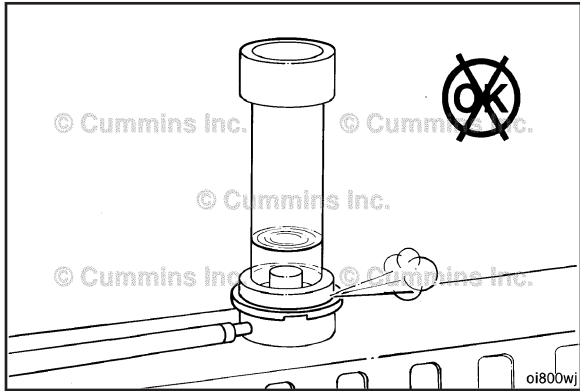




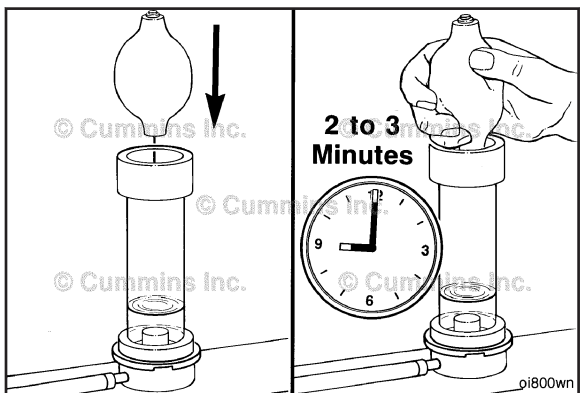
If the color of the test fluid changes from blue to yellow or green anytime during the test, combustion gases are leaking into the cooling system. Discontinue the test if the color of test fluid changes from blue to yellow.



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.



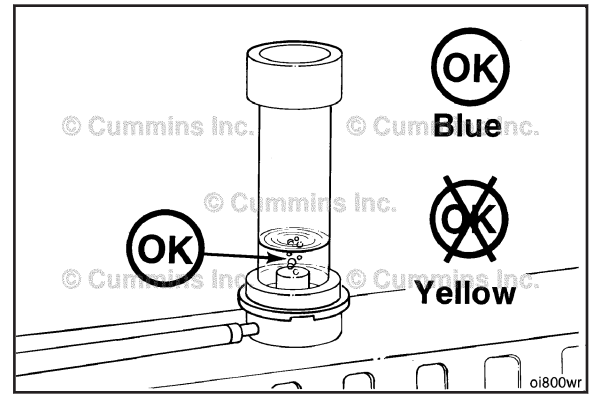
Insert the tip of the rubber ball into the hole in the top of the test instrument. Squeeze the rubber ball 2 to 3 minutes to draw air from the radiator through the test fluid.



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.

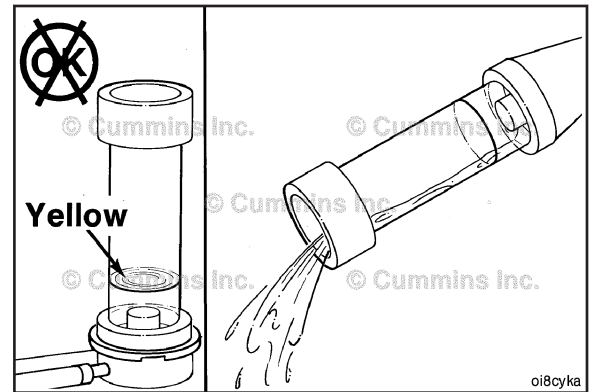
NOTE: As the cooling system warms up to operating temperature, air will be expelled through the combustion gas tester in the form of bubbles in the test fluid. This is due to normal expansion of the coolant. Do **not** mistake the presence of air bubbles in the tester for combustion gases or air leaking 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 leak tester indicates one or more of the following:

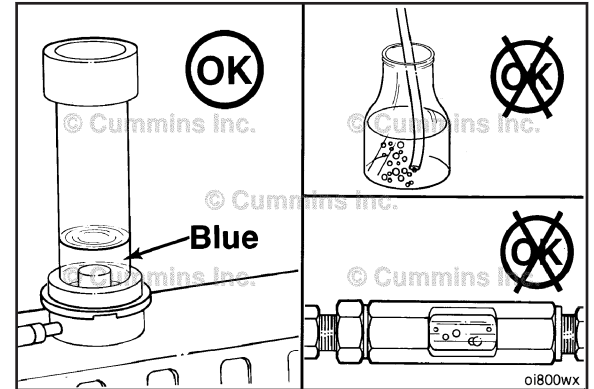
- Cracked cylinder head
- Cylinder head or gasket leakage
- Air compressor head or gasket leak.

NOTE: Discard the test fluid if it has indicated positive.

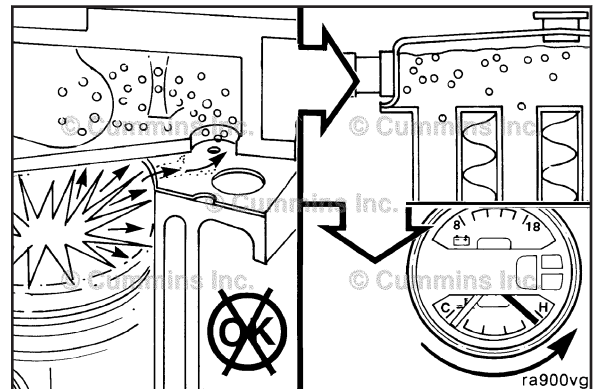


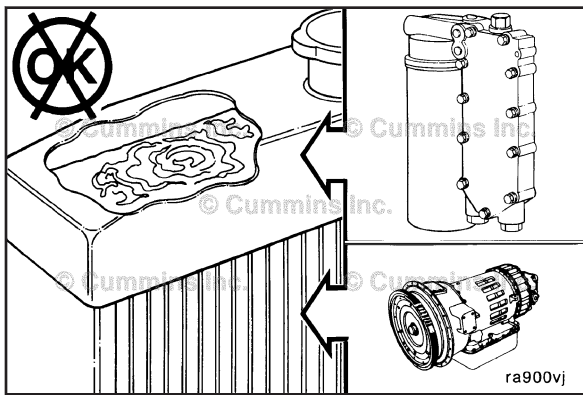
A negative result from the combustion leak tester, coupled with a continuous flow of air bubbles from the previous test, indicates the following:

- Air entrained because of a faulty thermostat jiggle pin, incorrect fill, or faulty coolant system plumbing.



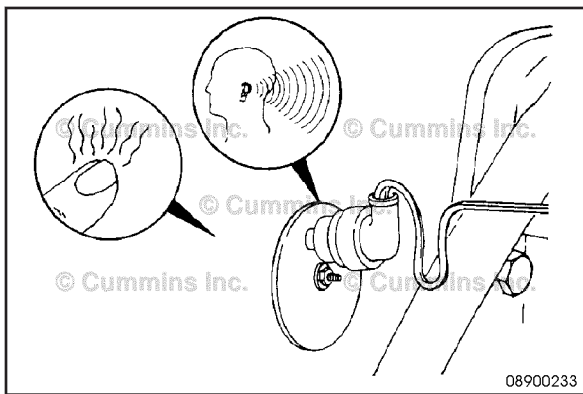
- Air in the coolant can result in loss from the overflow when the aerated coolant is hot. The heated air expands, increasing the pressure in the system and causing the cap to open.
- Similarly, coolant can be displaced through the overflow if the head gasket leaks compression gases into the cooling system.





NOTE: If the cooling system is contaminated with oil, it **must** be cleaned and flushed. Refer to Procedure 008-018.

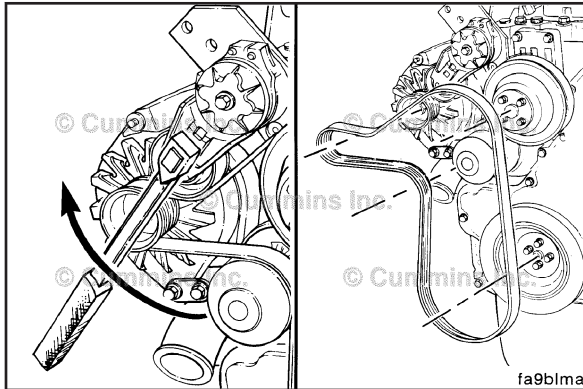
- The operating pressure of the cooling system and the lubricating system can result in the mixing of the fluids if there is a leak between the systems: head gasket and oil cooler.
- Transmission fluid **can** also leak into the cooling system through transmission oil coolers.



Engine Coolant Heater (008-023) Maintenance Check

If your engine is equipped with an optional coolant heater, it should be checked periodically, especially when cold weather nears.

When operating, the engine block heater will make an audible sound and the engine block will be warm to the touch in the water jacket areas. The coolant heater works on shore power.

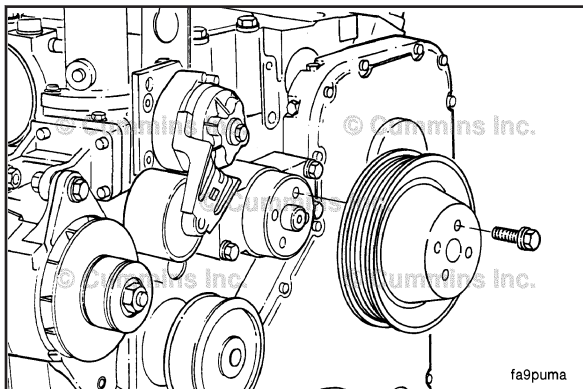


Fan Drive Idler Pulley Assembly (008-030) Preparatory Steps



Remove the drive belt; refer to Procedure 008-002.

Service Tip: Loosen the capscrews before removing the belt, and tighten the capscrews to the proper torque specification after the belt is installed.



Remove

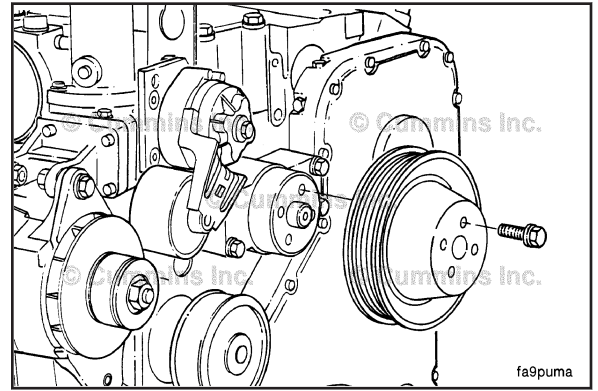
Remove the four capscrews, fan, and spacer.

Install

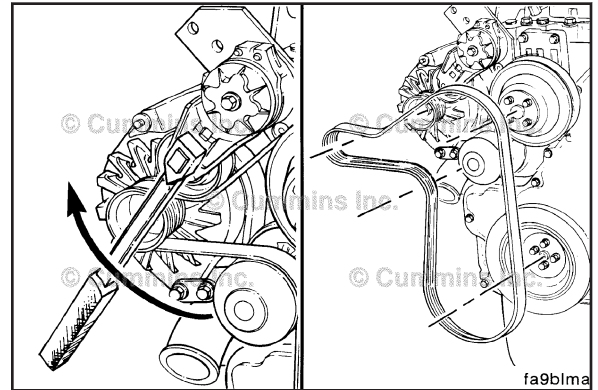
Install the spacer, fan, and four mounting capscrews.

Tighten the mounting capscrews.

Torque Value: 43 N•m [32 ft-lb]



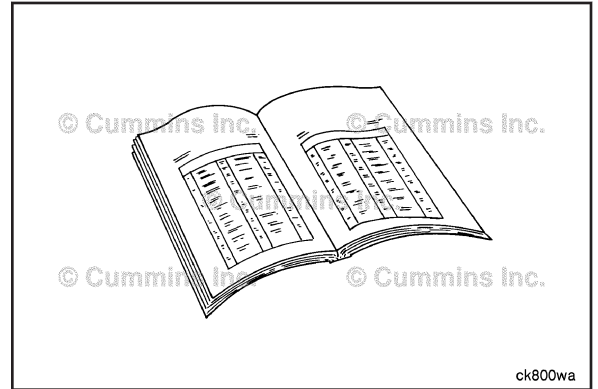
Install the drive belt; refer to Procedure 008-002.



Fan Hub, Belt Driven (008-036)

Preparatory Steps

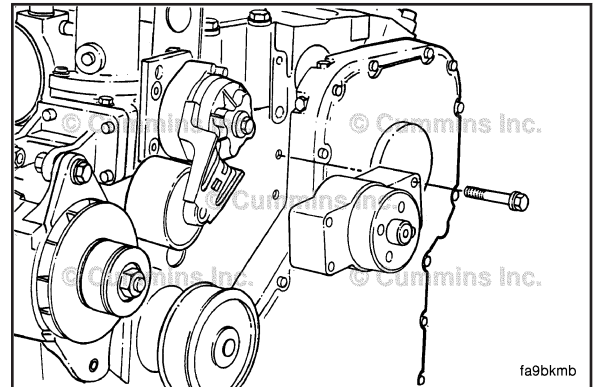
- Remove the drive belt. Refer to Procedure 008-002 (Drive Belt, Cooling Fan) in Section 8.
- Remove the fan pulley. Refer to Procedure 008-030 (Fan Drive Idler Pulley Assembly) in Section 8.

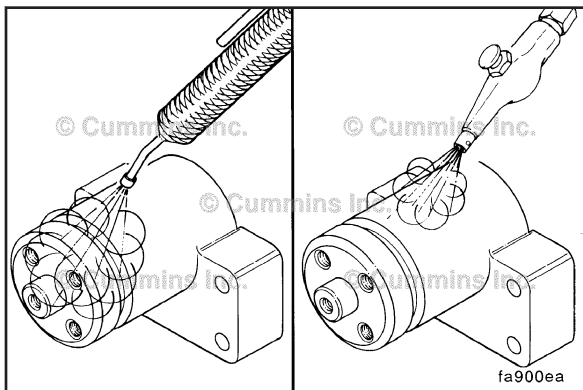


Remove

Remove the four fan hub mounting capscrews.

Remove the fan hub.





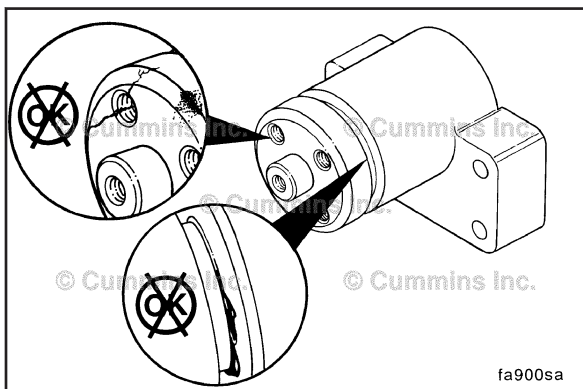
Clean and Inspect for Reuse

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

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

Steam clean the exterior of the fan hub.

Dry with compressed air.

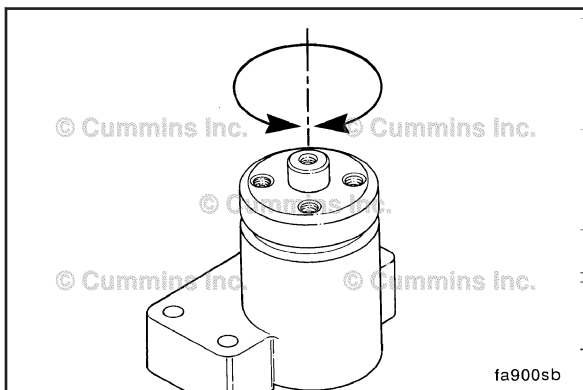


Inspect the fan hub for indications of oil seal leakage.

Inspect the fan hub for cracks or other damage.

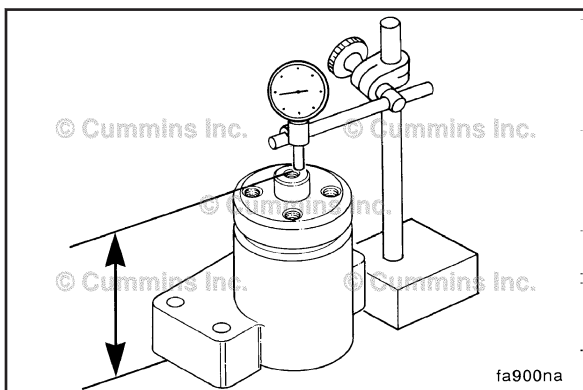
Inspect the fan hub chamfer and fan pulley mating surface for damage.

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

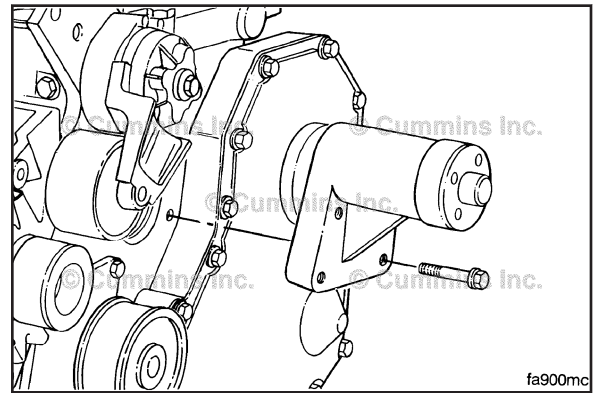
NOTE: Some fan hub assemblies can be rebuilt with new bearings and related components. Check for part availability before disassembling the fan hub.

Install

Install the fan hub and four capscrews.

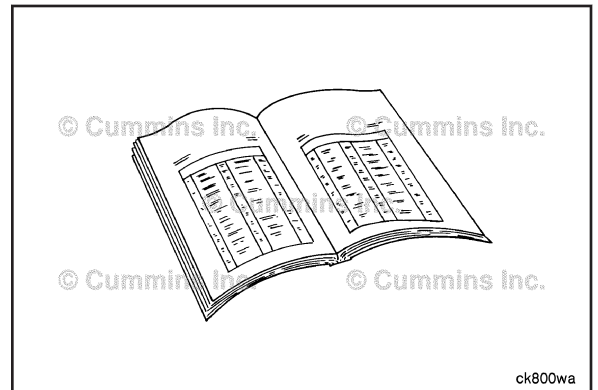
Tighten the capscrews.

Torque Value: 24 N•m [212 in-lb]



Finishing Steps

- Install the fan pulley. Refer to Procedure 008-030 (Fan Drive Idler Pulley Assembly) in Section 8.
- Install the drive belt. Refer to Procedure 008-002 (Drive Belt, Cooling Fan) in Section 8.
- Operate the engine and check for proper operation.



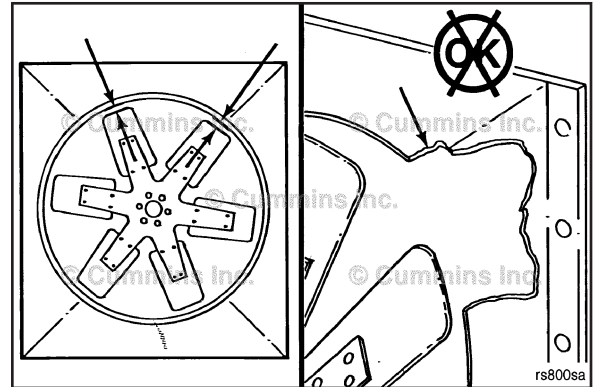
Fan Shroud Assembly (008-038)

Initial Check

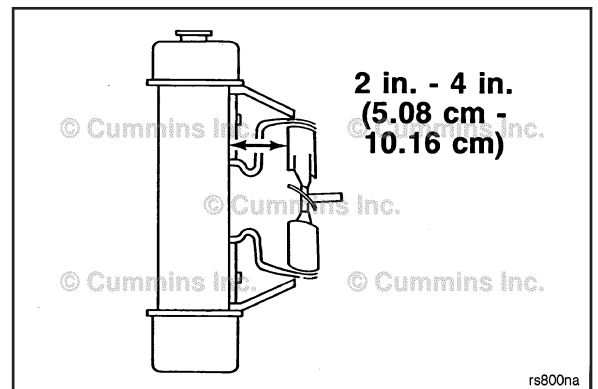
⚠ CAUTION ⚠

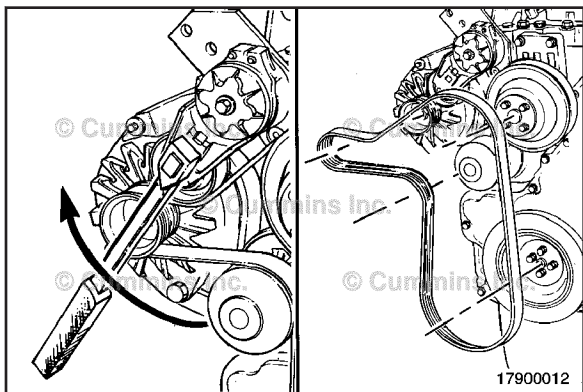
The fan shroud must be installed correctly, be in good condition, and the shroud-to-fan clearance must be within the manufacturer's specifications for proper airflow through the radiator to provide adequate engine cooling.

Inspect the fan shroud for proper fan clearance, cracks, air leaks, or damage. Replace, if necessary. Refer to the equipment manufacturer's service manual for instructions.



Cummins Inc. recommends fan clearance be 5.08 to 10.16 cm [2 to 4 in] from the radiator core. Refer to the equipment manufacturer's service manual for alternative positions.



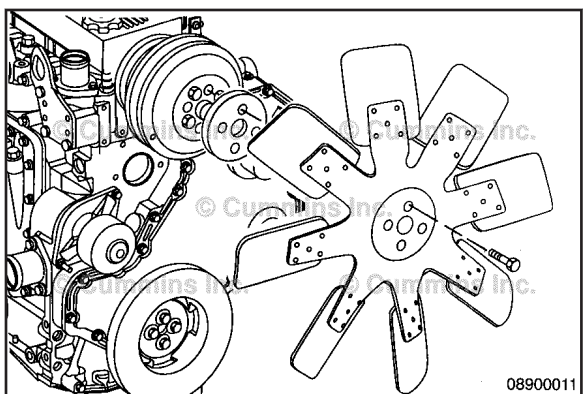


Fan Spacer and Pulley (008-039)

Preparatory Steps

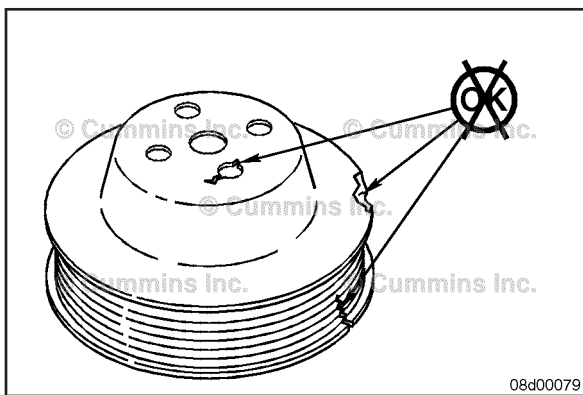
- Remove the drive belt.

NOTE: Loosen the capscrews before removing the belt, and tighten the capscrews after the belt is installed.



Remove

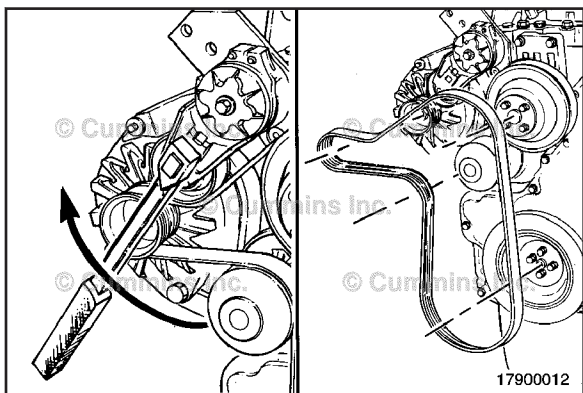
Remove the four capscrews, fan, and spacer.



Inspect for Reuse

Inspect the fan pulley for cracks near bolt holes.

Check for cracks, loose rivets, and bent or loose blades.



Install

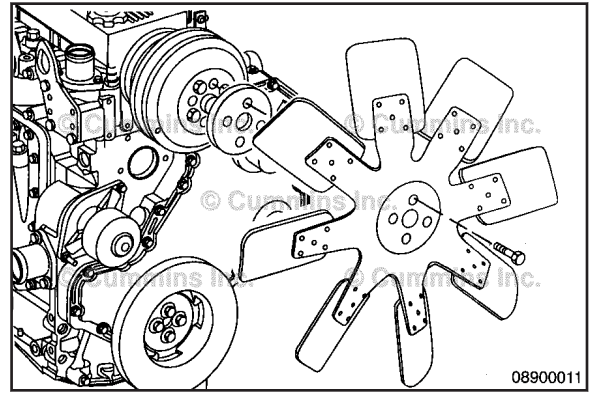
Lift the tensioner, and install the belt.

Service Tip: If difficulty is experienced installing the drive belt (the belt seems too short), position the belt over the grooved pulleys first; then, while holding the tensioner up, slide the belt over the water pump pulley.

Install the four capscrews, fan, and spacer.

Torque Value: 24 N•m [212 in-lb]

Torque Value: 43 N•m [32 ft-lb]

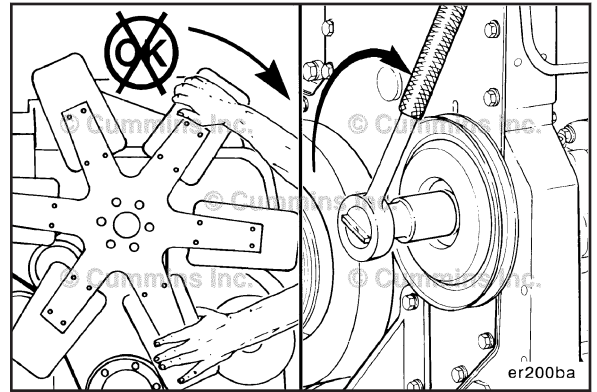


Fan, Cooling (008-040)

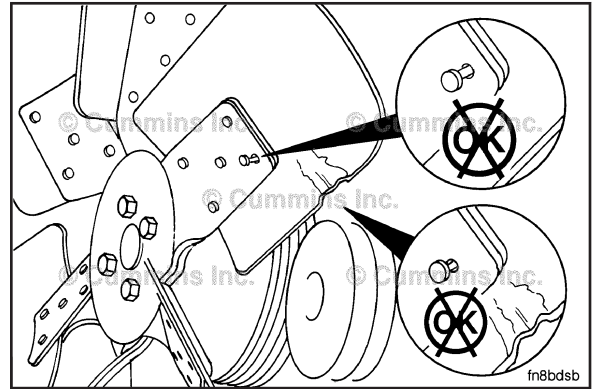
Inspect for Reuse

⚠ 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.

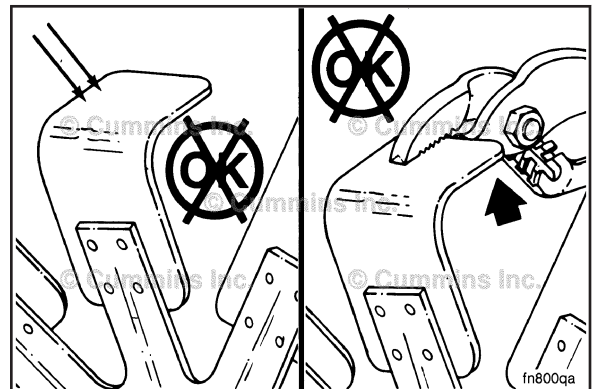


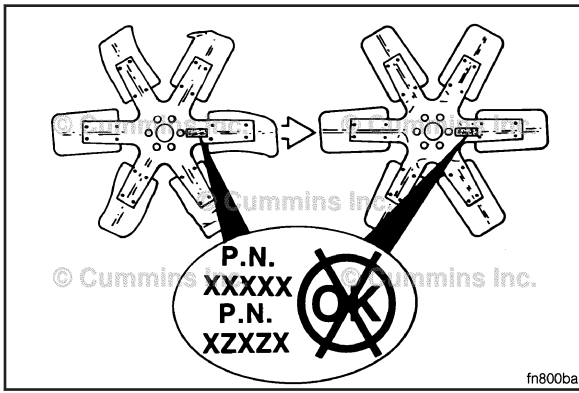
A visual inspection of the cooling fan is required daily. Check for cracks, loose rivets, and bent or loose blades. Check the fan to make sure it is securely mounted. Tighten the capscrews, if necessary.



⚠ WARNING ⚠

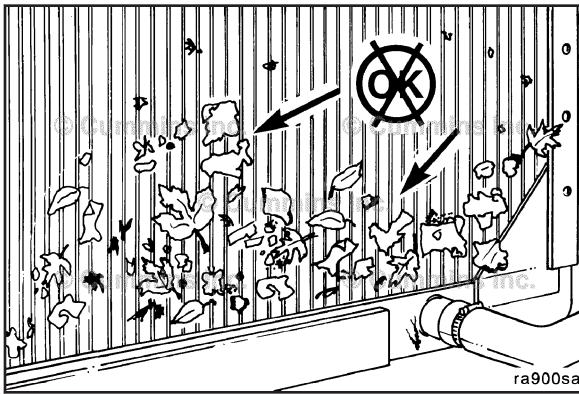
Do not straighten a bent fan blade or continue to use a damaged fan. A bent or damaged fan blade can fail during operation and cause personal injury or property damage.





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.

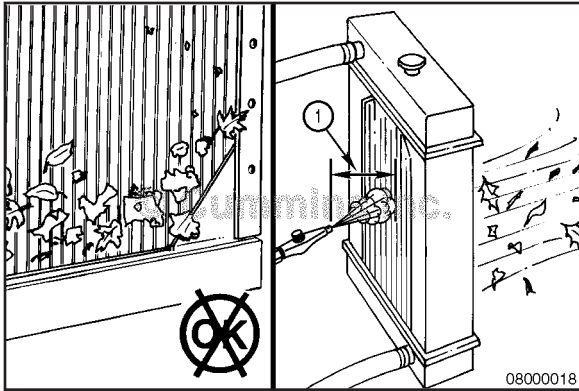
Refer to the vehicle or equipment manufacturer's specifications for capscrew torque.



Radiator (008-042)

General Information

Air forced through the fins of the radiator by a fan cools the coolant pumped through the radiator. Environmental debris (such as paper, straw, lint, and dust) can obstruct the fins and stop the flow of air, which will reduce the cooling effect of the radiator.



Initial Check

⚠ WARNING ⚠

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



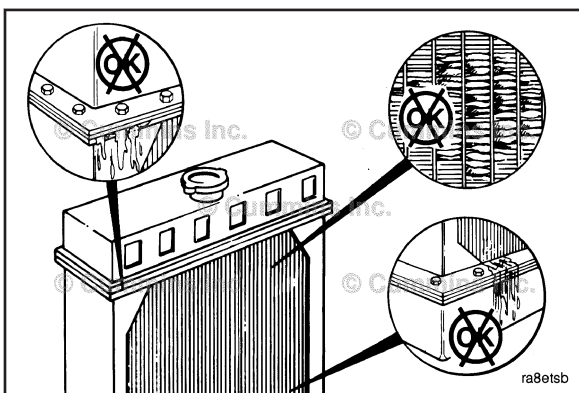
⚠ CAUTION ⚠

Keep the compressed air nozzle a minimum of 15cm [6 in] from the radiator core to avoid damaging the fins. See call out 1 in the illustration

Inspect for plugged radiator fins.

Use compressed air to blow out the dirt and debris.

Air Pressure: 552 kPa [80 psi]



Inspect the radiator for bent or broken fins.

Inspect the radiator core and gasket for leaks.



If the radiator **must** be replaced, refer to the OEM service manual replacement procedures.

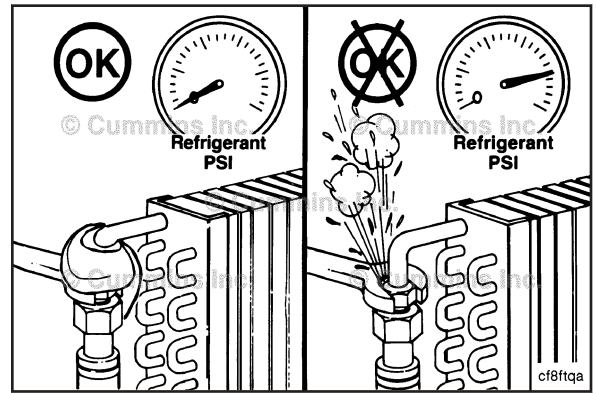
⚠ WARNING ⚠

If a liquid refrigerant system (air conditioning) is used, wear eye and face protection, and wrap a cloth around the fittings before removing. Liquid refrigerant can cause serious eye and skin injuries.

⚠ WARNING ⚠

To protect the environment, liquid refrigerant systems must be properly emptied and filled using equipment that prevents the release of refrigerant gas into the atmosphere. Federal law requires capturing and recycling the refrigerant.

Use care in removing the refrigerant system, if equipped, before removing the radiator.



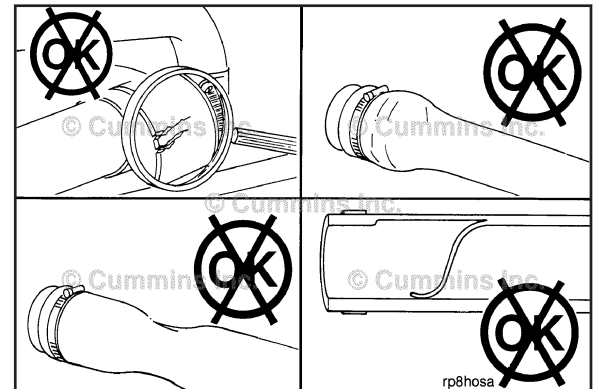
Radiator Hoses (008-045)

Maintenance Check

Check all hoses for cracks, cuts, or collapsing.

NOTE: The silicone engine coolant hose will exhibit swelling due to the elasticity of the hose.

If damage is found, replace damaged hoses. Contact your local Cummins Authorized Repair Location.



Radiator Pressure Cap (008-047)

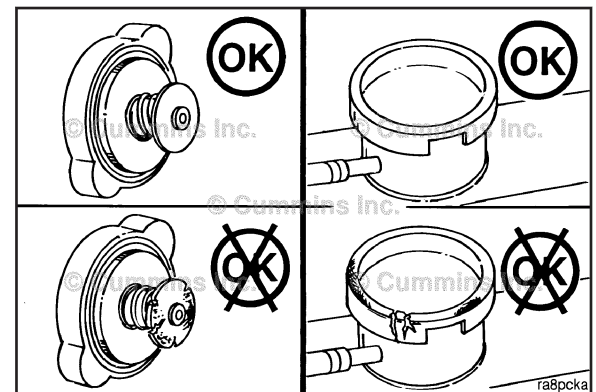
Inspect for Reuse

Be sure the correct radiator cap is being used. Refer to Procedure 018-018 in the Troubleshooting and Repair Manual, C8.3G, C Gas Plus and L Gas Plus Engines, Bulletin 3666206 or Procedure 018-018 in the Troubleshooting and Repair Manual, C Series Engines, Bulletin 3666003.

Inspect the rubber seal of the pressure cap for damage.

Inspect the radiator fill neck for cracks or other damage.

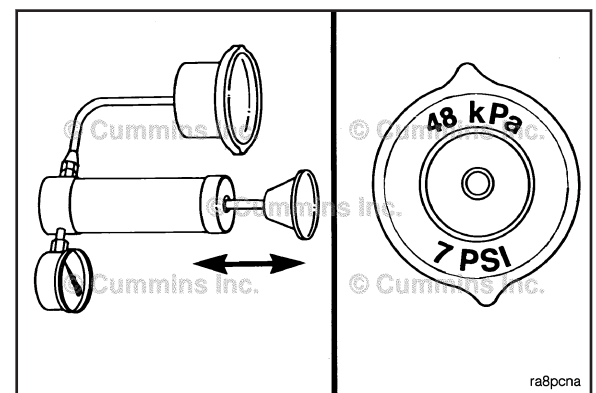
Refer to the equipment manufacturer's service manual for instructions if the fill neck is damaged.



Pressure-test the radiator cap.

The pressure cap **must** seal within 14 kPa [2 psi] of the value stated on the cap, or it **must** be replaced.

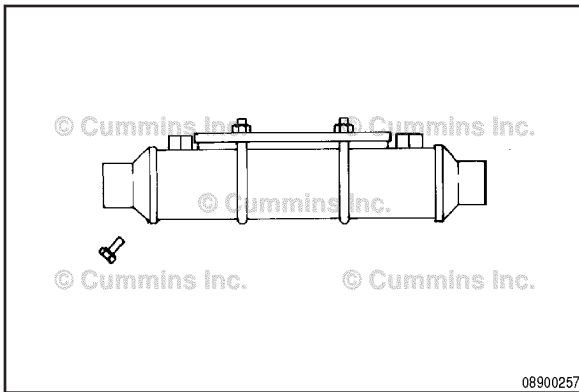
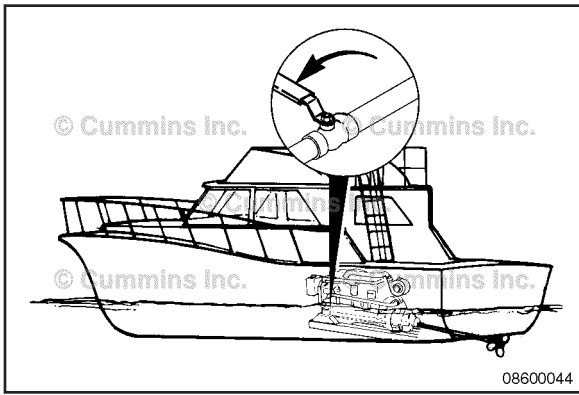
Refer to the equipment manufacturer's service manual for radiator cap test procedure.



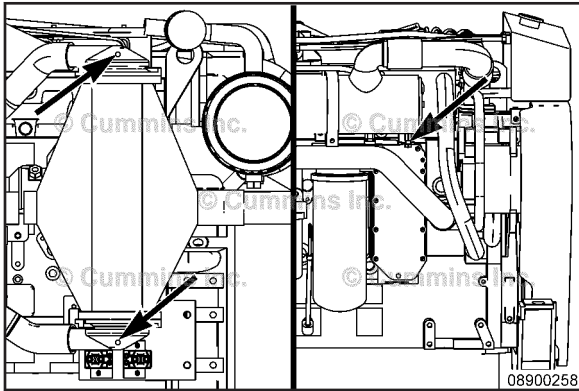
Heat Exchanger (008-053)

Flush

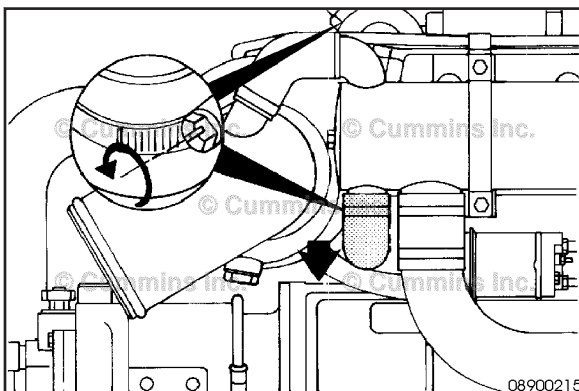
Shut off the sea water valve on the vessel hull.



To flush the marine gear oil cooler, refer to Procedure 008-041 (Marine Gear Oil Cooler) in Section 5.



Remove the zinc plugs from the aftercooler and heat exchanger.



Typical hose connections are shown.

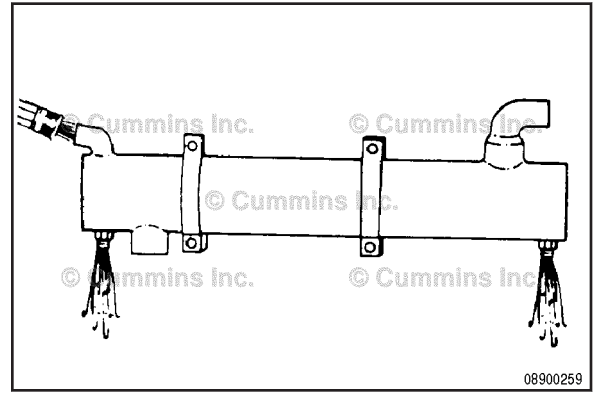
Refer to 100-002 (Engine Diagrams) in Section E.



Disconnect the sea water inlet and outlet connection from the heat exchanger.

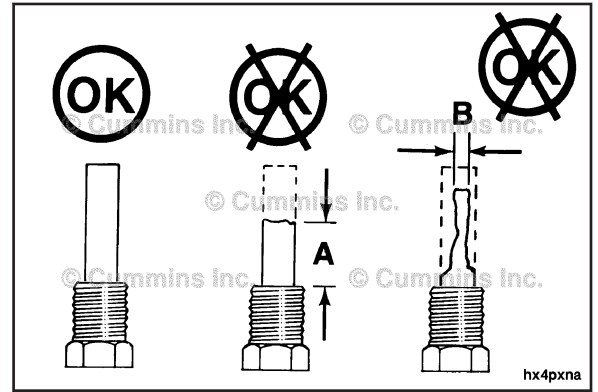
Use clean low-pressure water to backflush the heat exchanger.

Connect the hose to the heat exchanger sea water outlet to allow the water to backflush the system. This will remove and flush away any loose debris. Make sure the end cavities are cleared of all debris.



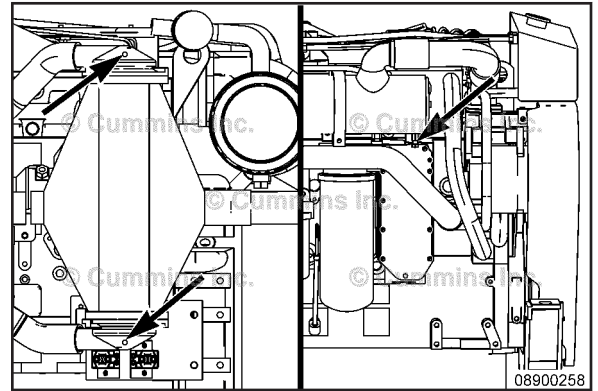
Inspect each plug. If either plug has eroded over 50 percent, it **must** be replaced.

Erosion Limits	New
A = Approximately 19 mm [0.75 in]	51 mm [2 in]
B = Approximately 6.4 mm [0.25 in]	16 mm [0.63 in]



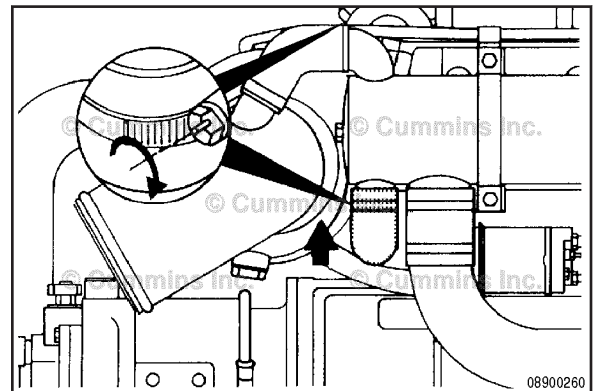
NOTE: Do **not** use thread sealant on the zinc plugs. They **must** be grounded to the component to function properly.

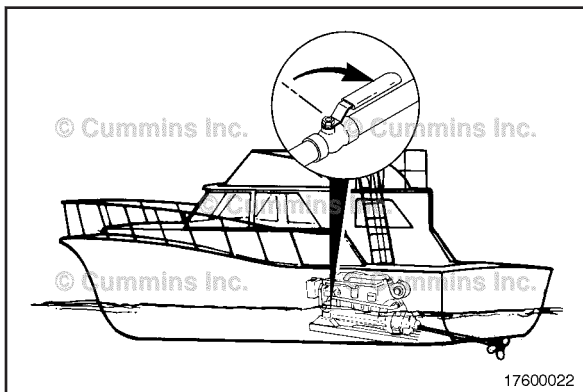
Install the zinc plugs in the aftercooler and heat exchanger. Refer to Procedure 008-059 (Zinc Anode).



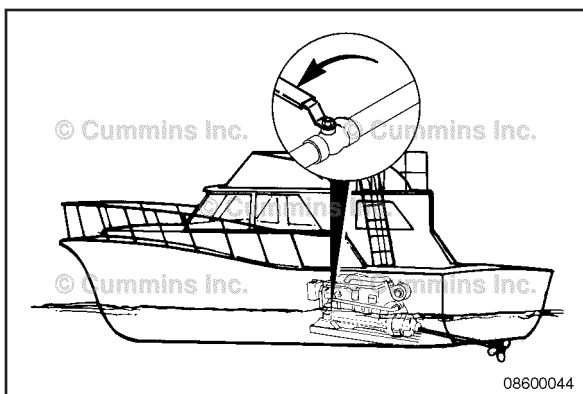
Install the sea water inlet and outlet connections.

Torque Value: 5 N•m [44 in-lb]



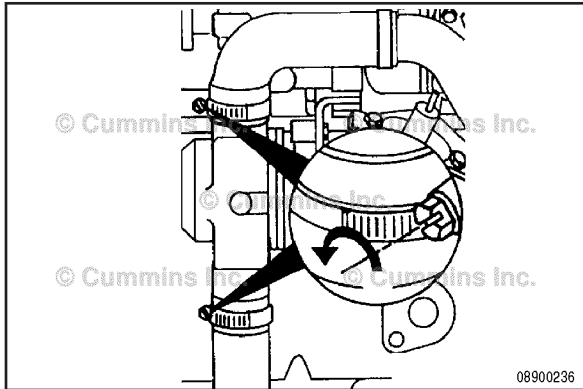


Open the sea water valve on the vessel hull.
Operate the engine and check for leaks.

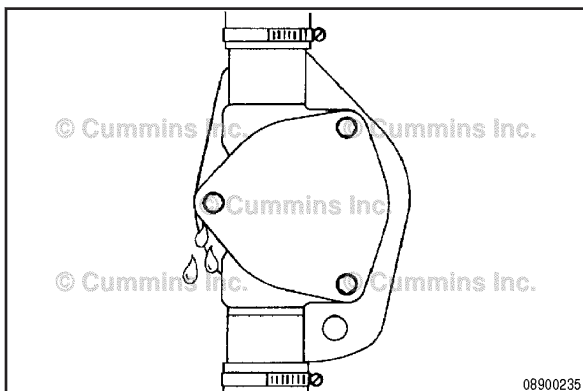


Sea Water Pump (008-057) Preparatory Steps

Shut off the sea water inlet valve on the vessel hull.



Remove the inlet and outlet hose and drain the water from the pump.



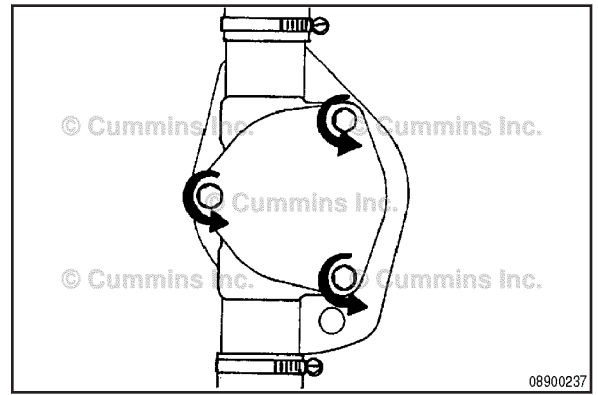
Remove

⚠CAUTION⚠

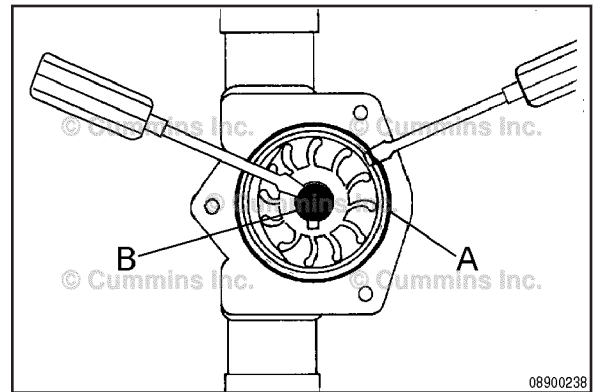
If the impeller has failed and pieces are missing, all pieces must be retrieved. The engine heat exchanger, gear oil cooler, and sea water aftercooler (if equipped) must be flushed. Refer to the procedures for flushing these components in other headings of this section. Failure to do so can result in 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.

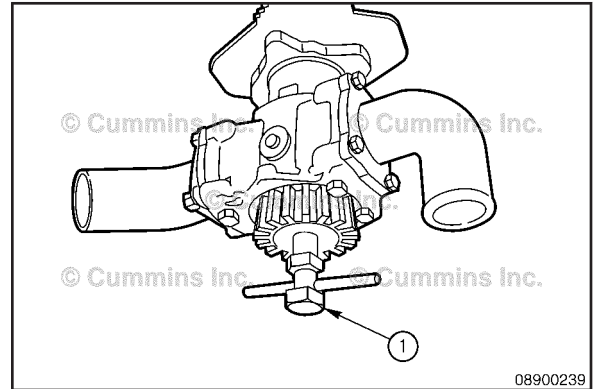


⚠CAUTION⚠
Do not pry against the pump housing to remove the impeller as this can cause damage to the liner.

Be sure to note the direction of impeller fins for proper re-installation. Mark the outer surface.

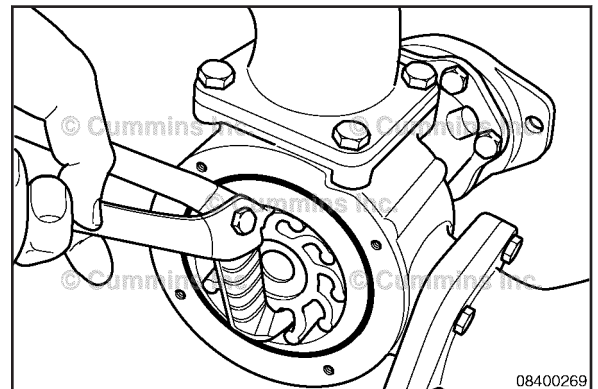
An impeller removal tool is available from Sherwood Pumps, Part Number 23631.

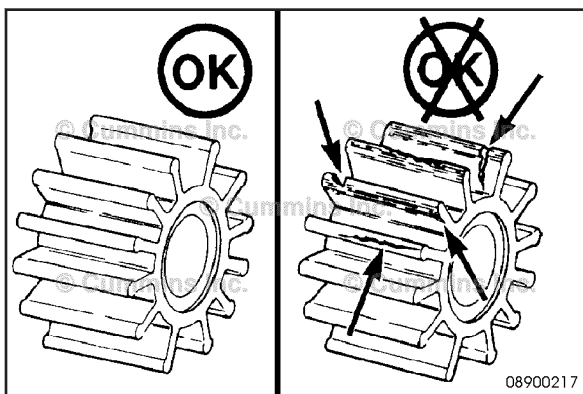
If the impeller is equipped with a threaded insert, use the special tool or a 3/4-NFT bolt (1) to insert in the impeller to pull the impeller out.



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.



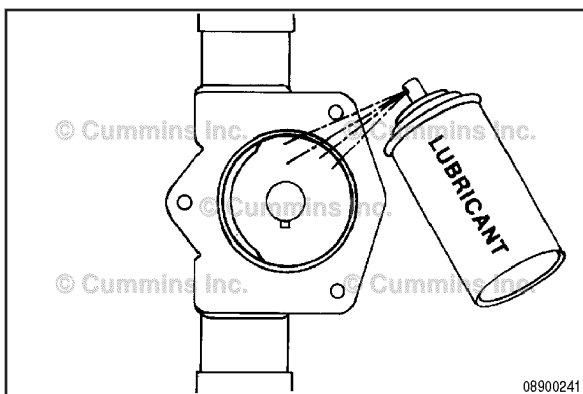


Clean and Inspect for Reuse

Inspect for damage such as rips, tears, chunks of material missing, or wear on the edges of the blades.



Replace as necessary.

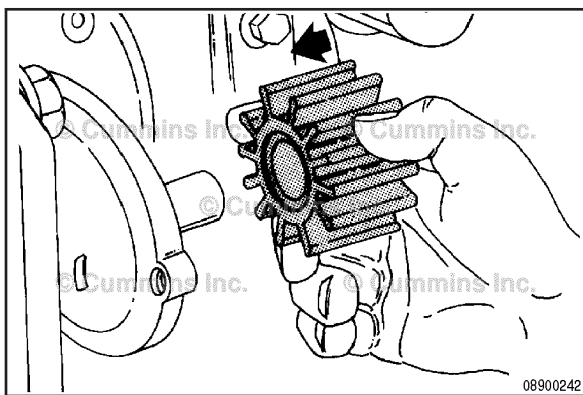


Clean the internal pump surfaces.

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.

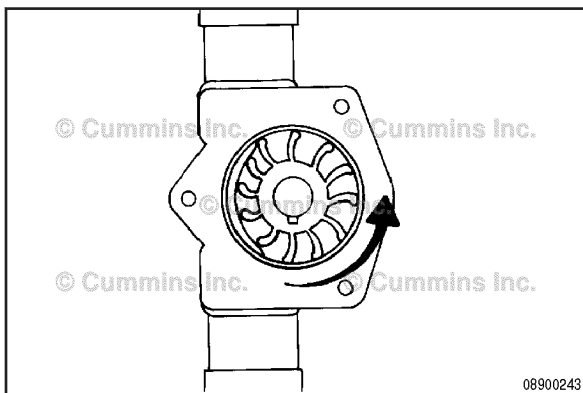


Install

If the impeller is in good shape and will be reused, install it in the same direction from which it was removed. Refer to the mark you made during removal.



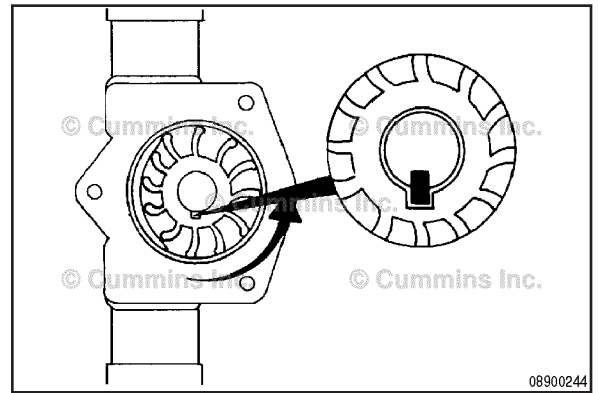
If the impeller was **not** marked and the original rotation or direction can **not** be determined, replace the impeller with a new one.



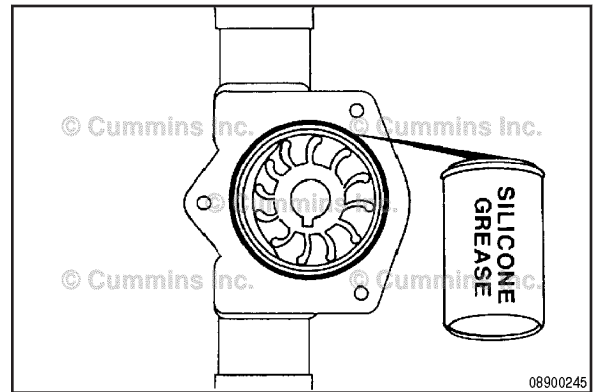
An oil filter strap wrench or even plastic wire straps can be used as an installation aid to hold the vanes.

Guide the impeller into the housing, twisting it **counterclockwise** as it is advanced so that the vanes will be deflected in the proper direction.

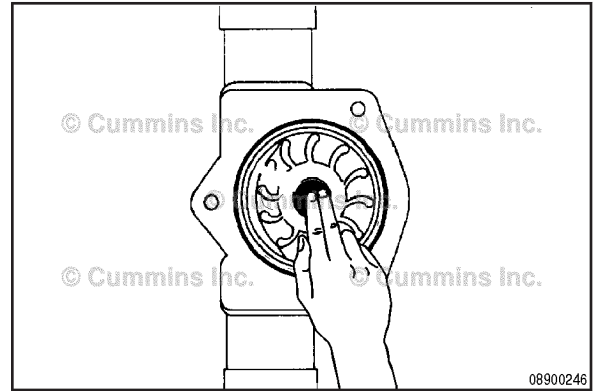
Continue to turn the impeller while pushing it into the housing. It will slide all the way in when the keyway lines up with the key.



Insert the new o-ring into the impeller housing. Use a little silicone grease to hold it in place.

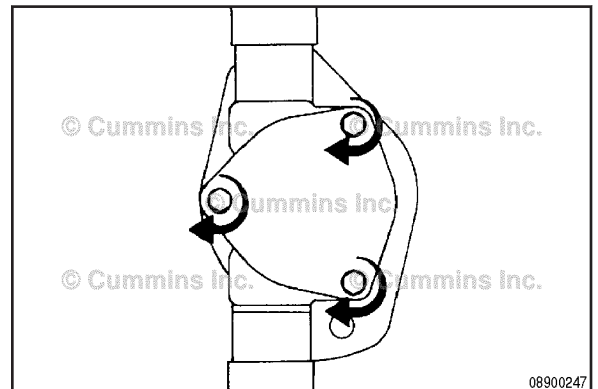


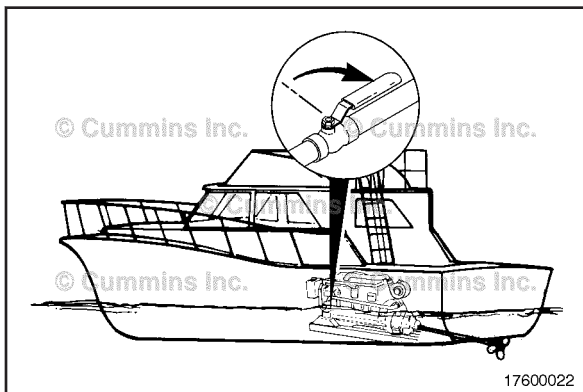
Install the rubber impeller cap into the center hub of the impeller.



Install a new gasket, cover plate, and capscrews.
Tighten the capscrews.

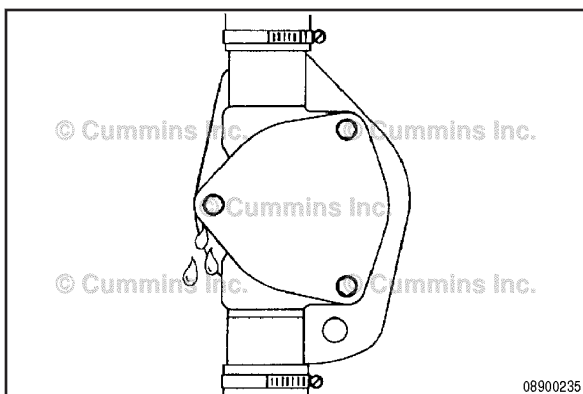
Torque Value: 24 N•m [212 in-lb]



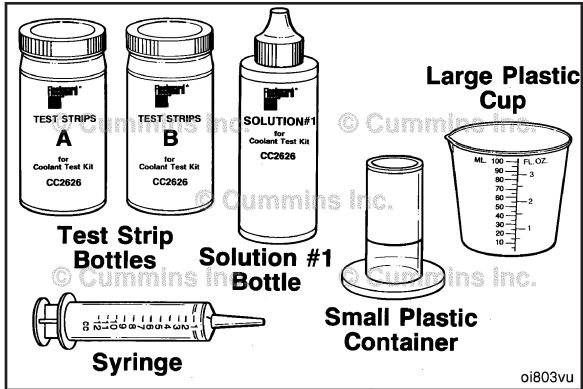


Finishing Steps

Install the inlet and outlet hose to the pump.
Open the sea water inlet valve and check for leaks.



If you have a wet exhaust system, start the engine and check for water flow from the exhaust. Also, check the sea water pump and plumbing for leaks.



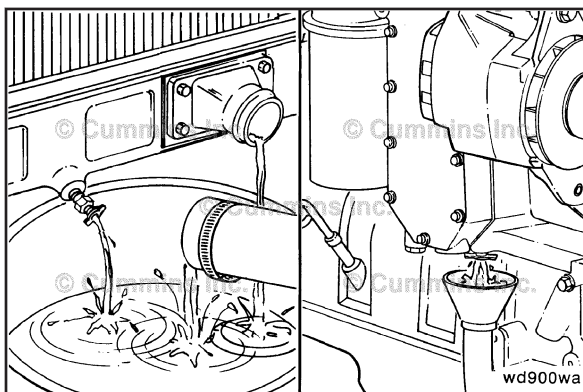
Supplemental Coolant Additive (SCA) (008-060)

Initial Check

Additive Concentration - Checking

The cooling system **must** contain the proper coolant additive units to provide the best chemical protection. Refer to the Operation and Maintenance Manual, C Series Engines, Bulletin No. 3666183.

DCA4 Test Kit: Use **only** DCA4 coolant test kit, Fleetguard® Part No. CC-2626, to measure the coolant additive concentration in the cooling system.



Water Pump (008-062)

Preparatory Steps

⚠️ WARNING ⚠️

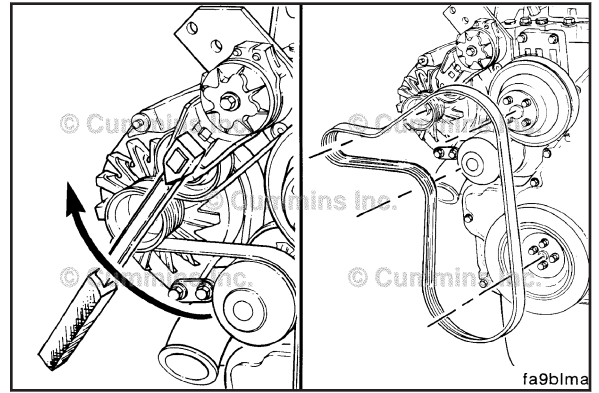
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

⚠️ WARNING ⚠️

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

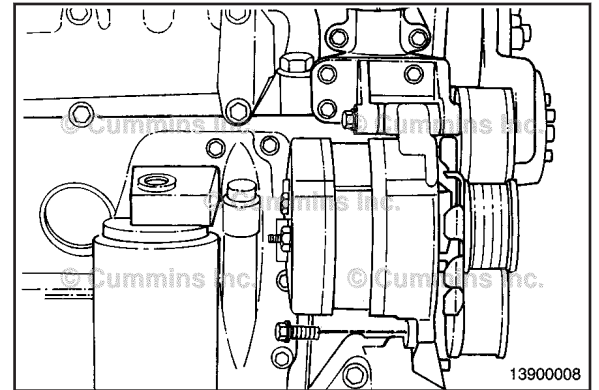
Drain the coolant. Refer to Procedure 008-018.

Remove the drive belt. Refer to Procedure 008-002.

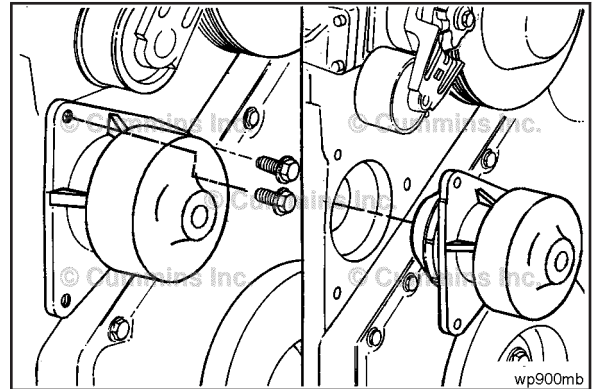


Remove

Remove the alternator link; refer to Procedure 013-001.



Remove the water pump mounting capscrews, and water pump.

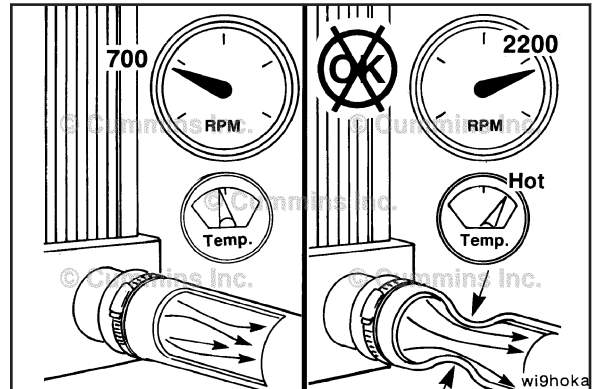


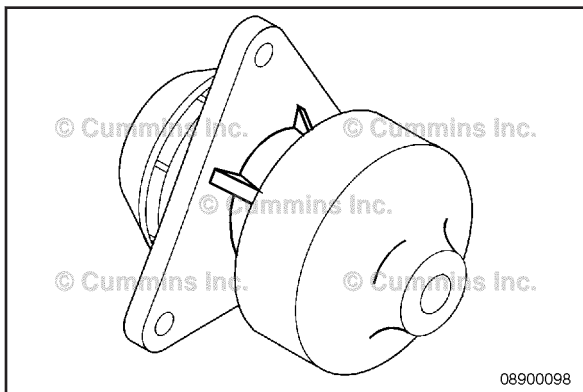
Inspect for Reuse

Inspect the coolant hose. The coolant flow can also be reduced if the inlet hose to the water pump collapses. A hose will usually **not** collapse while the engine is running at low speed. Inspect the hose while the engine is running at rated speed.

Make sure that the engine is warm, so the thermostat is open.

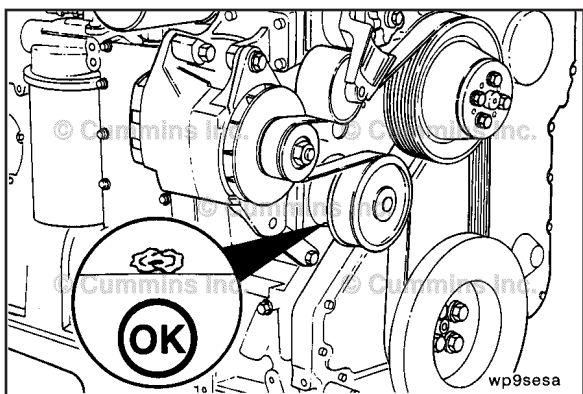
Engine Temperature 88 °C [190 °F]





The water pump pulls coolant from the bottom of the radiator and pumps it through the engine back to the top of the radiator for cooling.

A worn or malfunctioning water pump will **not** produce the flow required to prevent the engine from running hot. Make sure to inspect the other possibilities indicated in the Troubleshooting Logic Chart before inspecting the flow or replacing the water pump.

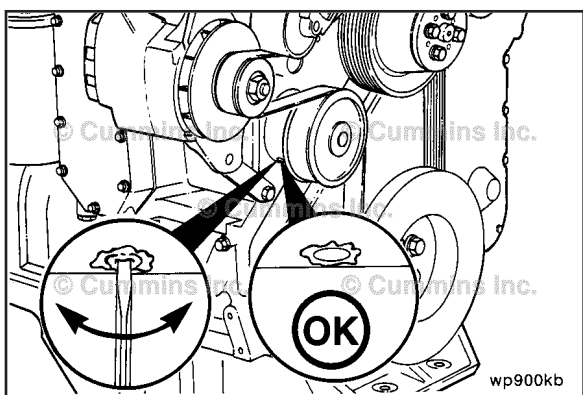


Check the water pump seal weep hole.

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.

NOTE: A streak or chemical buildup at the weep hole is **not** justification for water pump replacement.

Use the following guidelines to determine if water pump replacement is necessary:

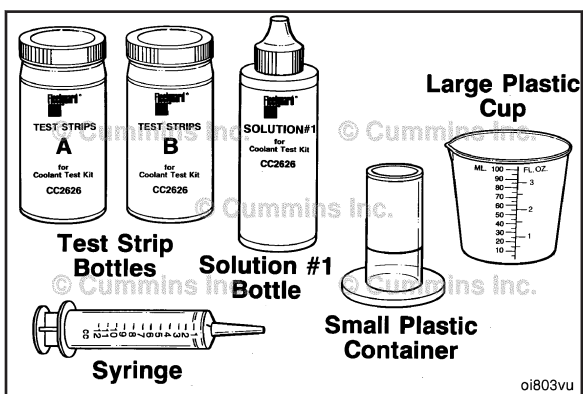


Make sure the weep hole is open.

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.



If coolant is seen dripping from the weep hole:

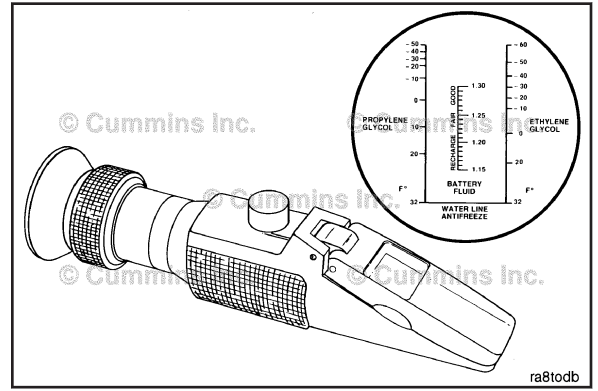
- Use Fleetguard® coolant test kit, Part Number CC-2626, to check the coolant inhibitor level, and adjust the inhibitor level according to the test kit chart.

NOTE: Supplemental coolant additive concentrations exceeding 2 units per gallon will cause water pump seal leakage.

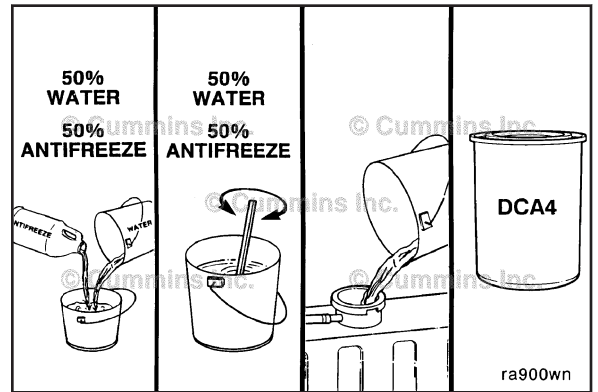
- Use Fleetguard® refractometer, Part Number CC-2800, to check the antifreeze level of the coolant.



NOTE: Ethylene-glycol-type antifreeze concentration levels exceeding 70 percent will lessen the freezing point protection and will contribute to water pump seal leakage.



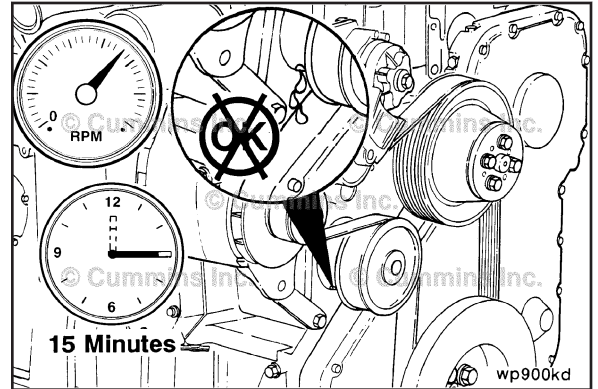
If the antifreeze concentration is above 60 percent, drain all the coolant and add makeup water to bring the antifreeze concentration between a minimum of 40 percent to a maximum of 60 percent. Replace the coolant filter and add new coolant inhibitor to the recommended levels as outlined in the Operation and Maintenance Manual, C Series Engines, Bulletin Number 3666183.



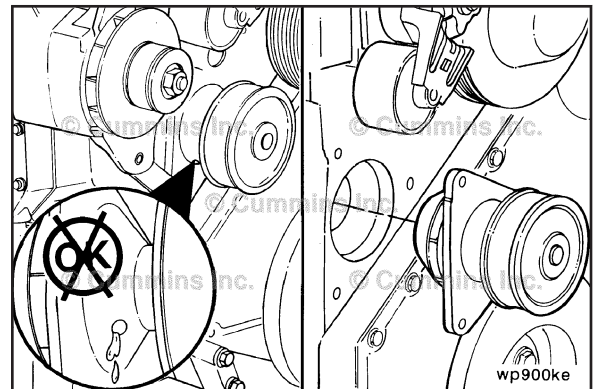
⚠CAUTION⚠

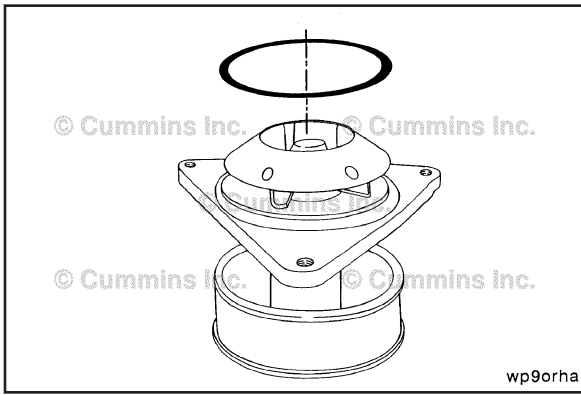
If the coolant leakage is observed as a steady stream upon start-up, stop the engine immediately and replace the water pump.

Operate the engine at high idle for 15 minutes with the proper inhibitor and antifreeze levels, and inspect the water pump for leakage.



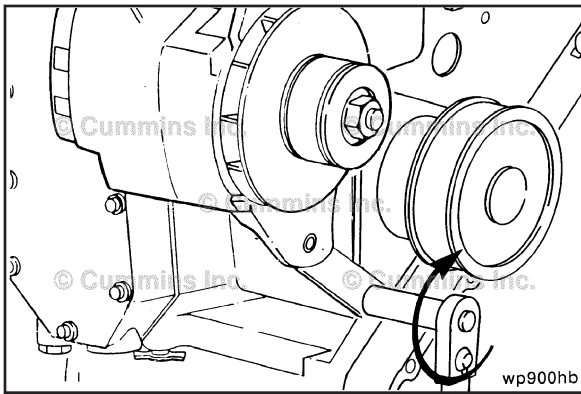
If the coolant is leaking after the above inspections, replace the water pump.





Install

Install a new o-ring into the groove in the water pump.

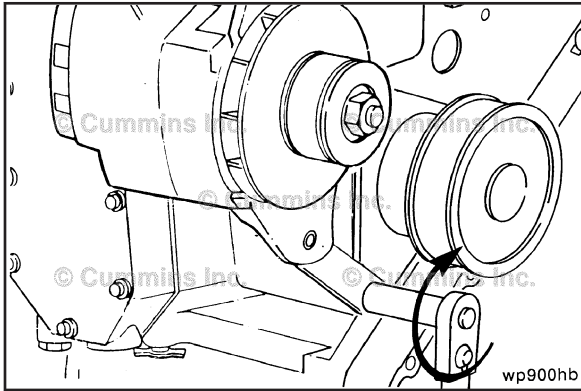


Install the water pump and water pump mounting cap screws.

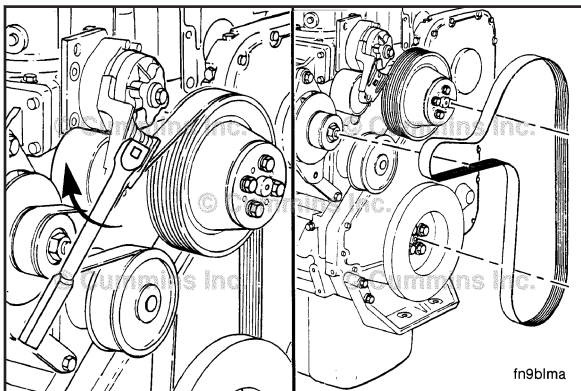
Tighten the water pump mounting cap screws.



Torque Value: 24 N•m [212 in-lb]



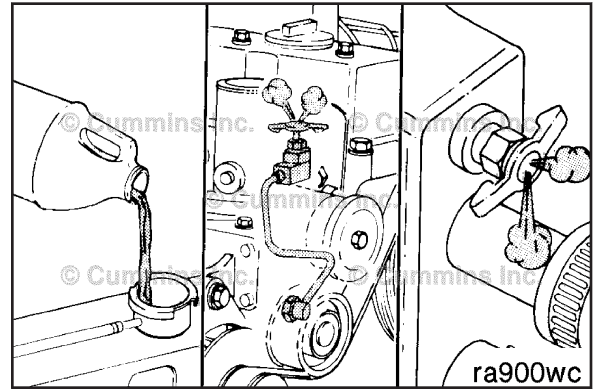
Install and tighten the alternator link; refer to Procedure 013-001.



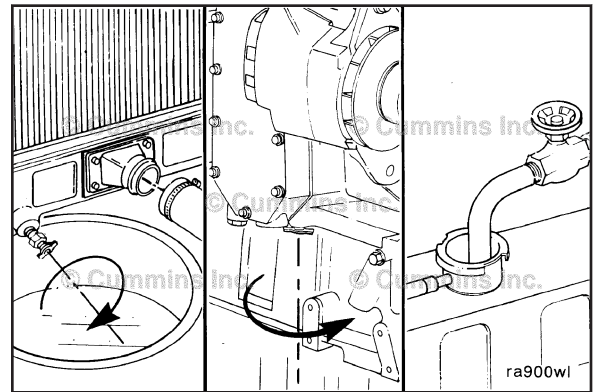
Install the drive belt; refer to Procedure 008-002.

During filling, air **must** be vented from the engine coolant passages. Open the engine vent petcock if equipped. Also, be sure to open the petcock on the aftercooler for aftercooled engines.

NOTE: Venting will permit a fill rate of 19 liters/min. [5 gal/min.].



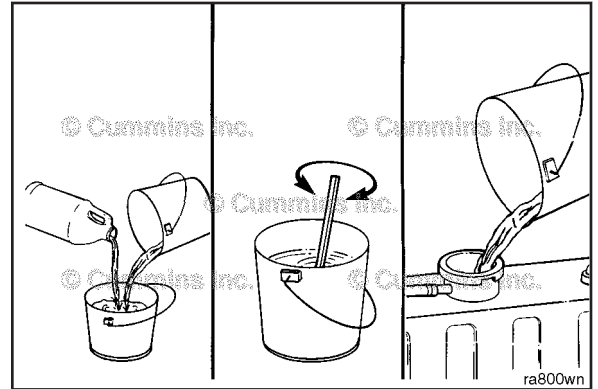
Close the drain valves.
Install all hoses previously removed.



Fill the cooling system with a premixture of 50-percent water and 50-percent ethylene-glycol antifreeze; refer to Procedure 008-018.

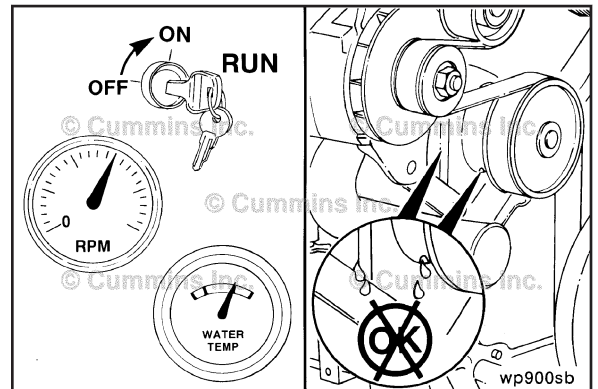


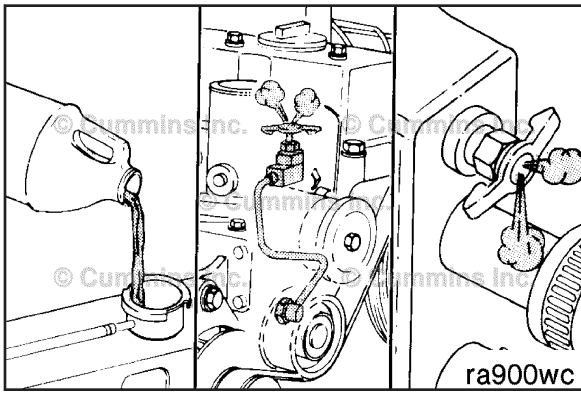
NOTE: The ability of antifreeze to remove heat from the engine is **not** as good as water; pouring antifreeze into the engine first can contribute to an overheated condition before the liquids are completely mixed.



Install the pressure cap.

Operate the engine until it reaches a temperature of 80°C [180°F], and inspect for coolant leaks.

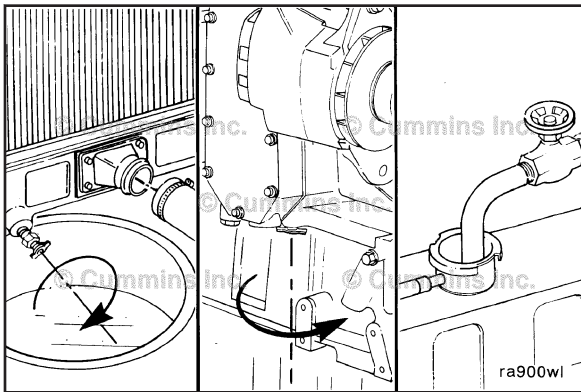




Fill

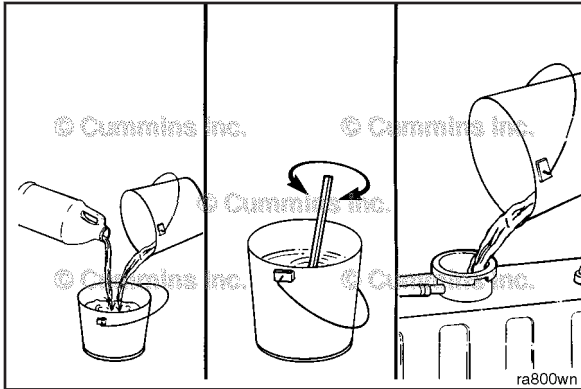
During filling, air **must** be vented from the engine coolant passages. Open the engine vent petcock if equipped. Also, be sure to open the petcock on the aftercooler for aftercooled engines.

NOTE: Venting will permit a fill rate of 19 liters/min. [5 gal/min.].



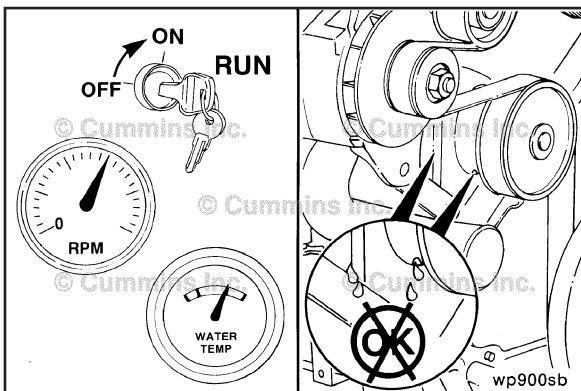
Close the drain valves.

Install all hoses previously removed.



Fill the cooling system with a premixture of 50-percent water and 50-percent ethylene-glycol antifreeze; refer to Procedure 008-018.

NOTE: The ability of antifreeze to remove heat from the engine is **not** as good as water; pouring antifreeze into the engine first can contribute to an overheated condition before the liquids are completely mixed.



Install the pressure cap.



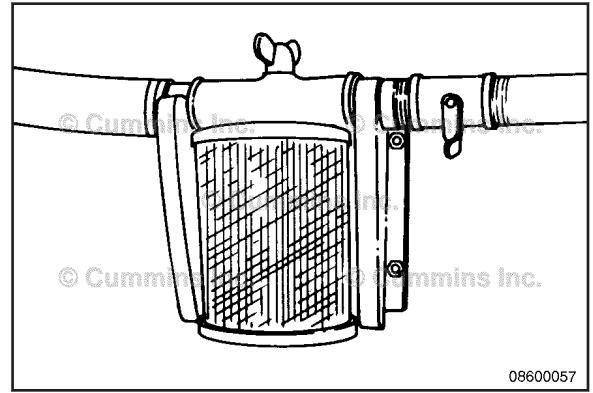
Operate the engine until it reaches a temperature of 80°C [176°F], and inspect for coolant leaks.

Sea Water Strainer (008-067)

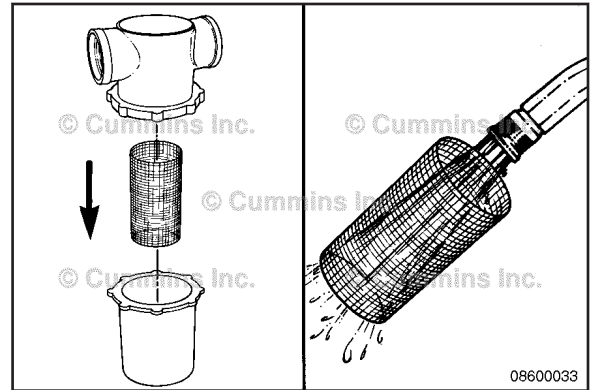
General Information

Marine Applications

NOTE: Most sea water systems for heat exchanger cooled engines use a sea water strainer. The strainer removes debris from the sea water before it enters the sea water pump.



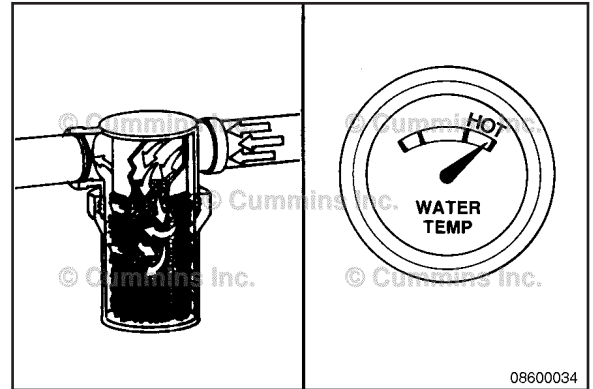
NOTE: Sea water strainer arrangements may differ. Inspect the sea water strainer daily for any foreign objects that could restrict water flow.



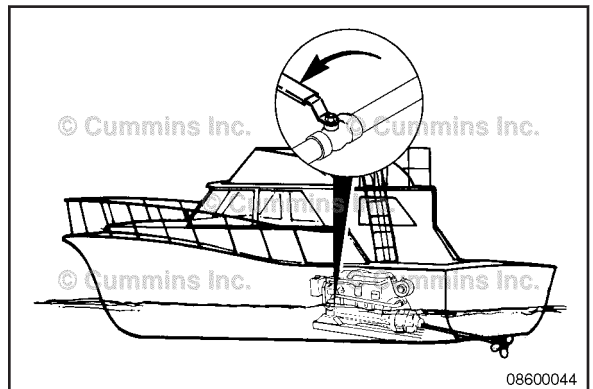
⚠ CAUTION ⚠
A restricted or clogged sea water strainer can result in hotter than normal, or overheated, engine coolant and marine gear oil temperatures.

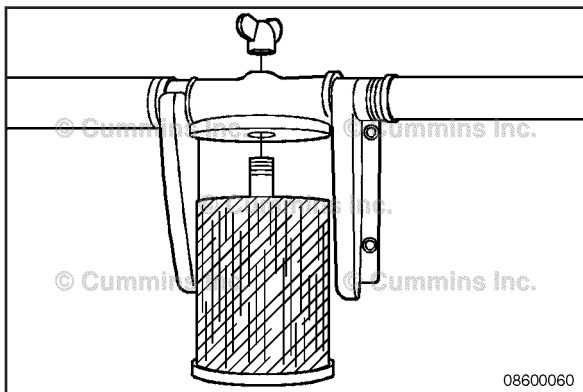


For more detailed information, refer to Sea Water Strainer Cleaning in this section.



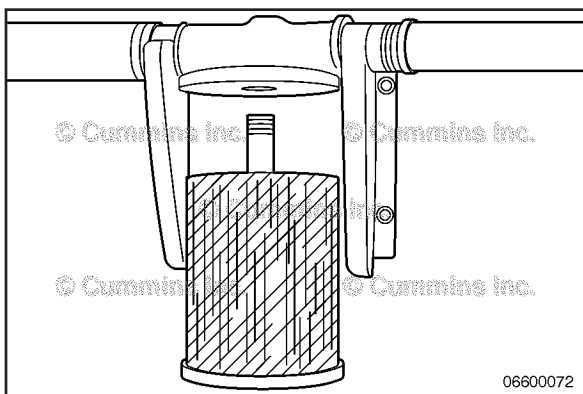
NOTE: If the sea water strainer is below the water level, close the sea water inlet valves before servicing the sea water strainer.



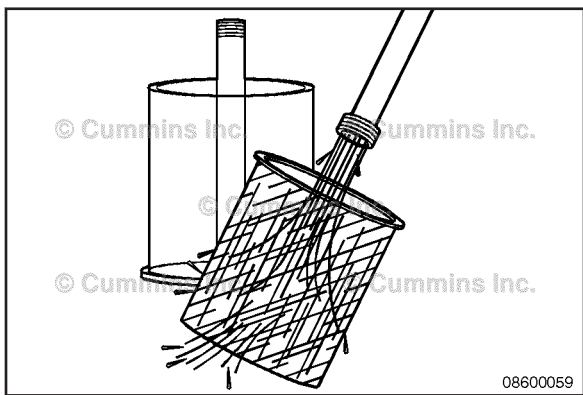


Disassemble
Marine Applications

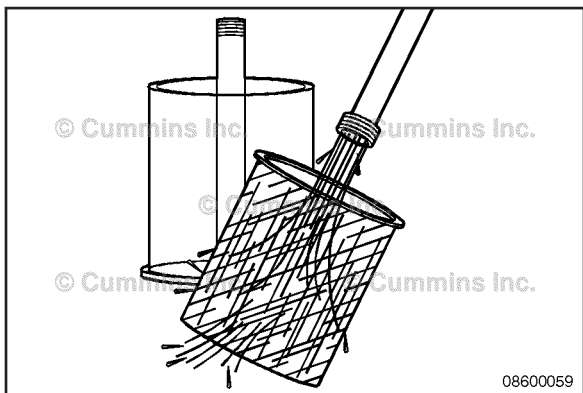
Loosen and remove the sea water strainer wing nut(s) as required.



Remove the sea water strainer assembly. Be careful **not** to damage o-ring. Retain and inspect for damage.



Remove the sea water strainer basket.



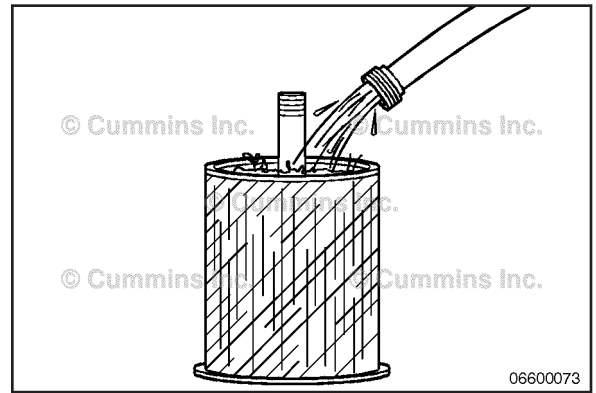
Clean
Marine Applications

Empty all debris from the sea water strainer basket.
Clean the sea water strainer.

Prime

Marine Applications

Prime the sea water strainer with clean water.

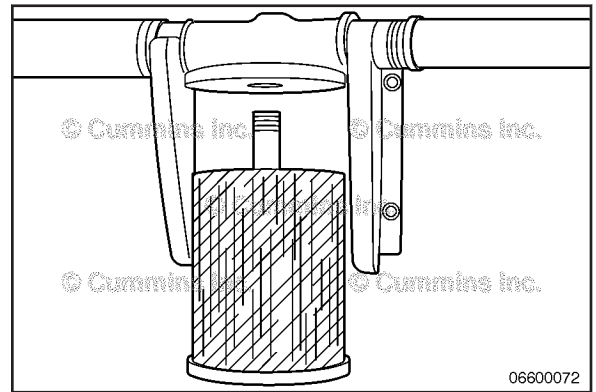


Assemble

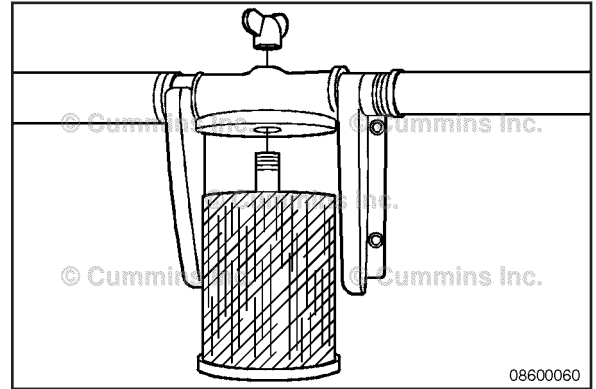
Marine Applications

Install the sea water strainer.

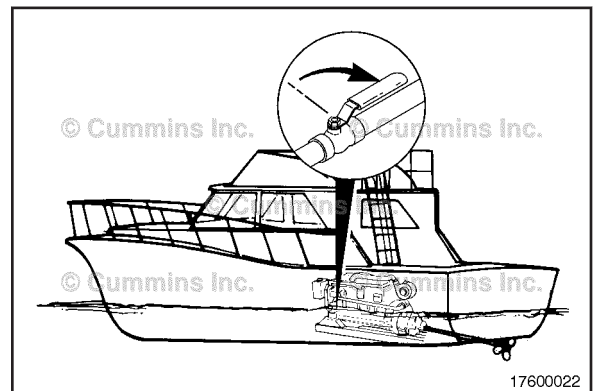
Inspect o-ring seal for tears or damage. Replace if necessary. Be sure o-ring is seated properly.

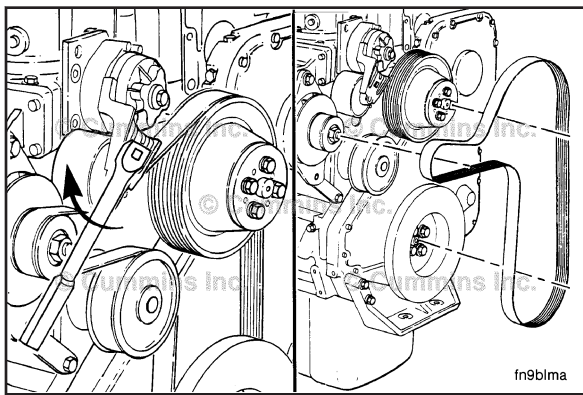


Install and tighten the wing nut(s).



Open the sea water inlet valves.



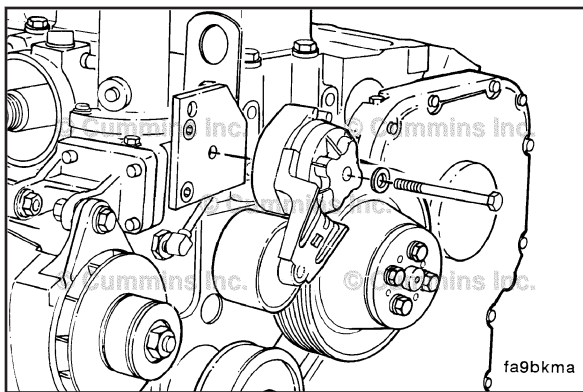


Belt Tensioner, Automatic (Water Pump) (008-080)

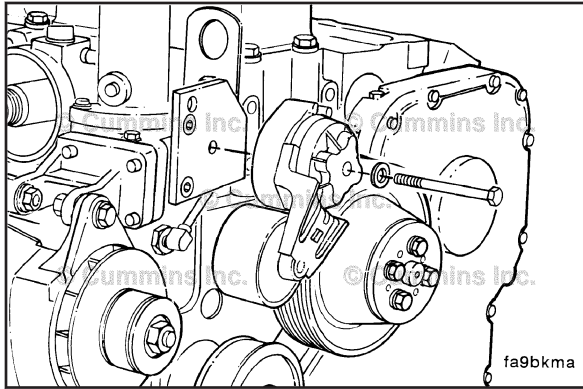


Remove

Remove the drive belt. Refer to Procedure 008-002.



Remove the belt tensioner from the bracket.



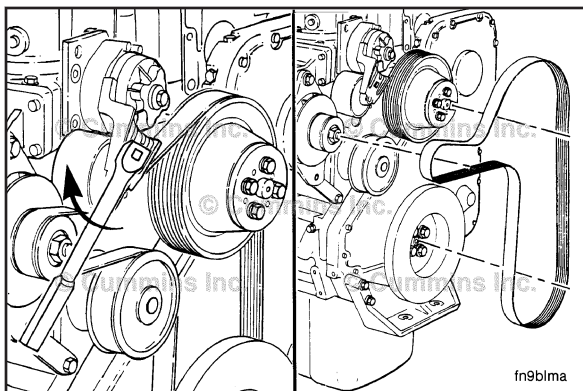
Install

Install the belt tensioner.



Install and tighten the belt tensioner mounting capscrew.

Torque Value: 43 N•m [32 ft-lb]



Install the drive belt. Refer to Procedure 008-002.



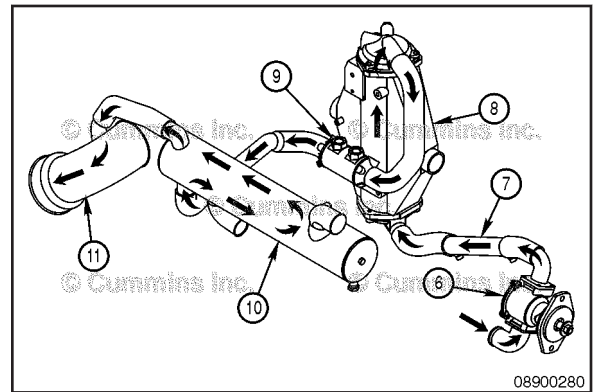
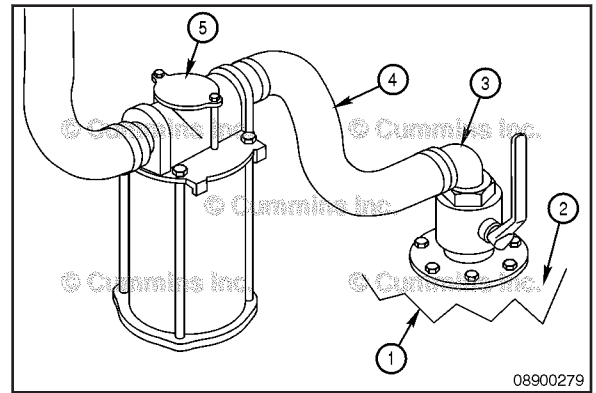
Sea Water System Diagnostics (008-103)

General Information

Typical sea water cooling system

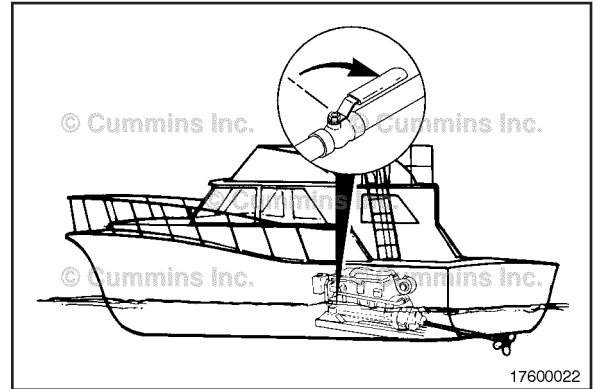
1. Grate-type strainer located on the bottom of the boat hull
2. Vessel bottom/hull
3. Sea water inlet valve
4. Hose
5. Sea water strainer

6. Sea water pump
7. Fuel cooler
8. Aftercooler
9. Transmission oil cooler
10. Heat exchanger
11. Sea water outlet.



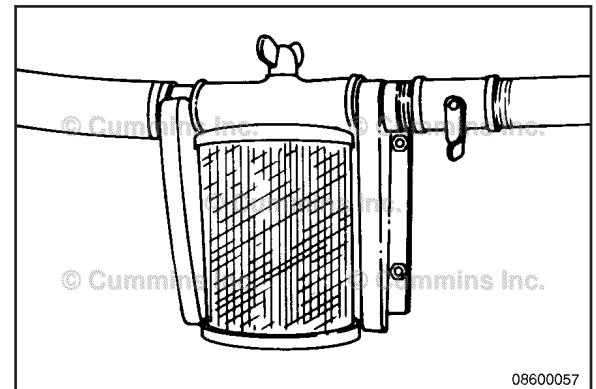
Initial Check

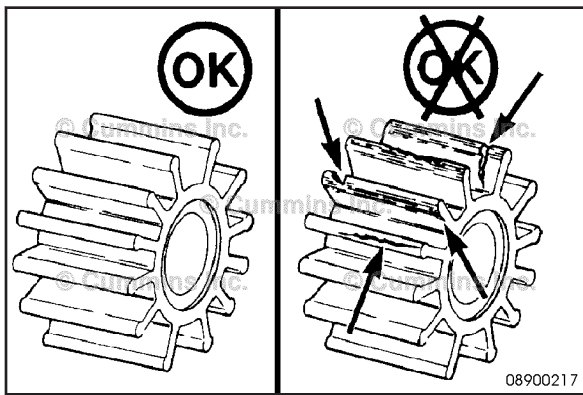
Locate and verify that the sea water inlet valve is in the full open position. If it is closed or partially closed, open the valve and recheck the engine temperature.



Inspect the sea water strainer for foreign objects that could restrict the water flow.

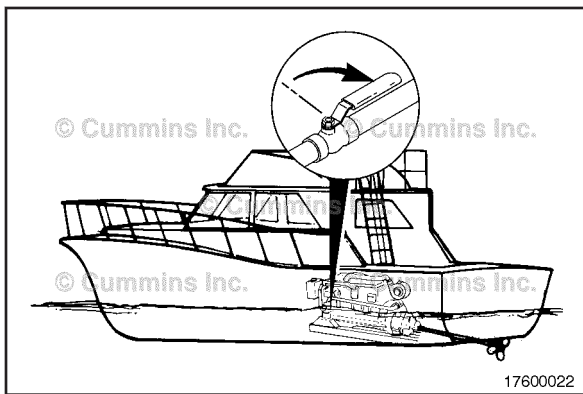
Some strainers have clear covers for easy inspection. If the strainer has to be opened for inspection, refer to Procedure 008-067.



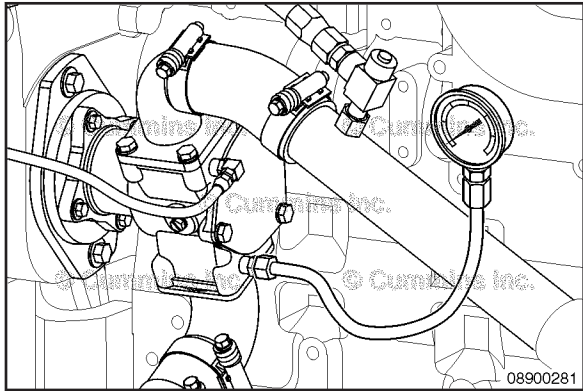


If the engine was run with the sea water system highly restricted due to a closed off sea water inlet valve or a clogged sea water strainer, it is advisable that the sea water impeller **must** be inspected for damage.

If the age of the sea water impeller is unknown, inspection of the sea water impeller is advisable. Refer to Procedure 008-057.

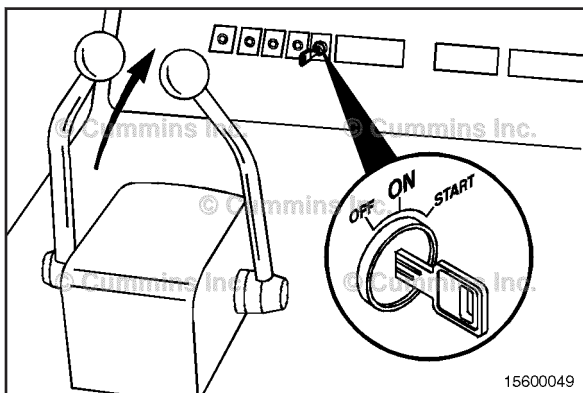


If the engine continues to overheat, perform the following procedures. If the engine does **not** overheat at the dock, perform a sea trial and check for overheating under way.



Test

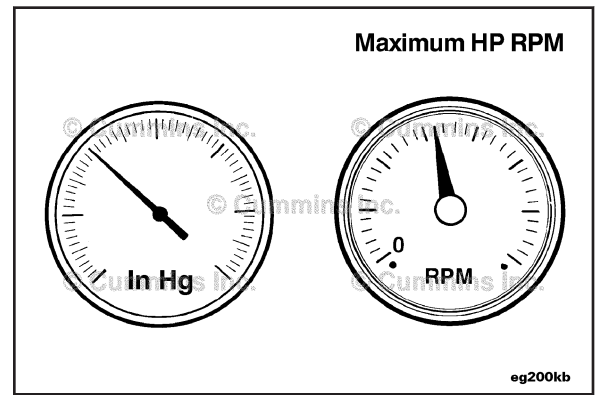
Attach a vacuum gauge to the inlet side of the sea water pump.



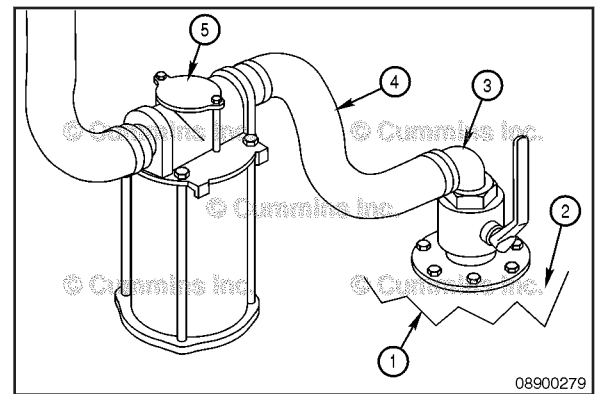
Start the engine.

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.

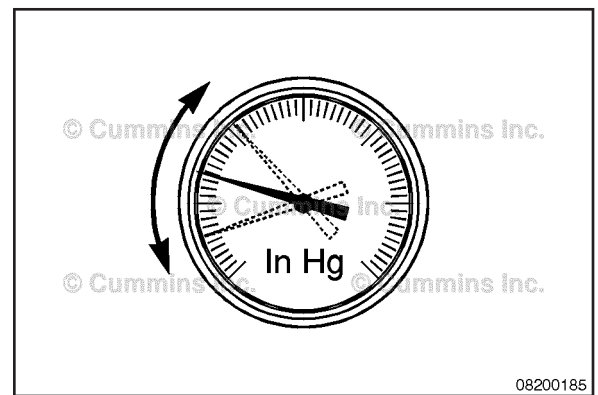
Refer to Procedure 018-018 for Marine engine specifications.



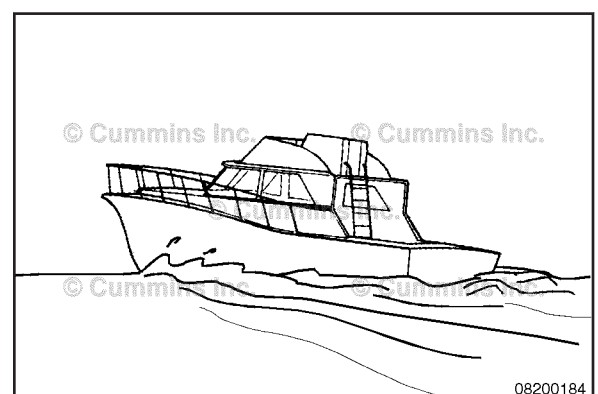
If the sea water inlet restriction is above specification, the source of the restriction **must** be found. Troubleshooting and repair of excessive sea water restriction is a boat manufacturer or boat owner responsibility. Refer to the vessel's OEM service manual. If the inlet restriction is within the specification and the complaint can **not** be verified at the dock, the test **must** be repeated underway.

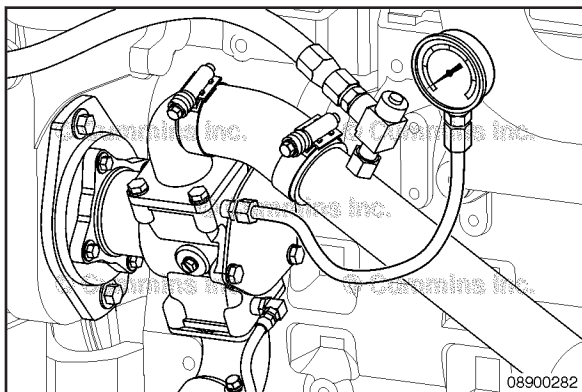


If the sea water inlet restriction readings fluctuate during the test, inspect the sea water supply for leaks or air intrusion. Troubleshooting and repair for sea water aeration is **not** covered under Cummins warranty.



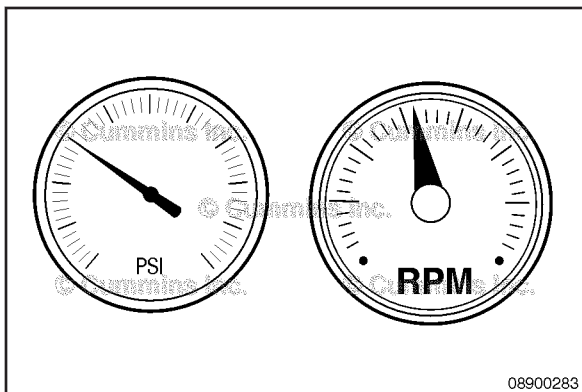
It is possible that aeration (gauge fluctuation) will **only** occur while the vessel is underway due to the introduction of air.





Pressure Test

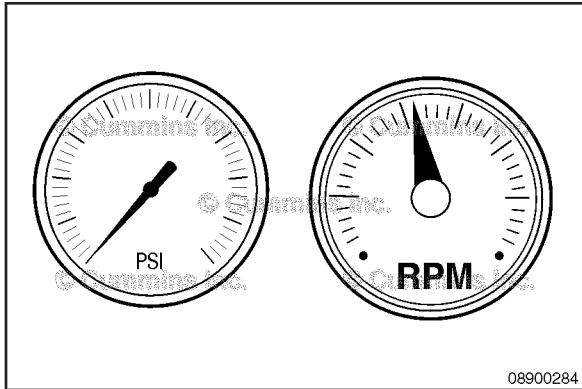
Attach a pressure gauge to the outlet side of the sea water pump to check pump outlet pressure.



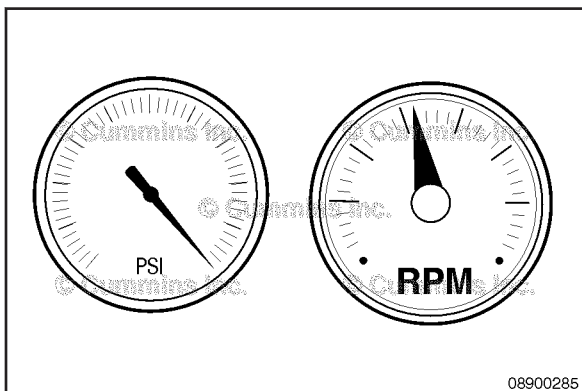
Start the engine and record the sea water outlet pressure from low idle to rated speed at 500 rpm increments. This test can be conducted while the vessel is at dock and **not** in gear or underway.

Refer to Procedure 018-018 for Marine engine specifications.

If the sea water pump outlet pressure is within specifications, refer to the Temperature Differential Test in this procedure.



If sea water pressure is **not** present, check the pump for damage. Refer to Procedure 008-057.



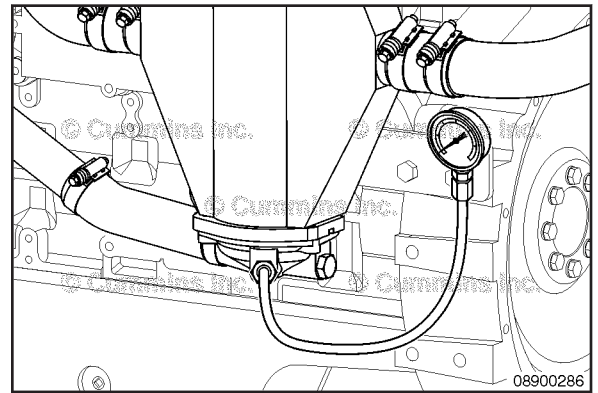
If the sea water pump outlet pressure is above the maximum specification test the individual sea water system components for excessive pressure drop as described in the Pressure Differential Test step.

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 fuel cooler plumbing as necessary.

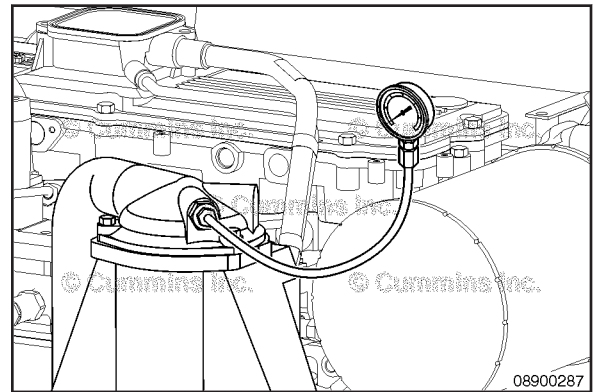
Refer to Procedure 018-018 for Marine engine specifications.



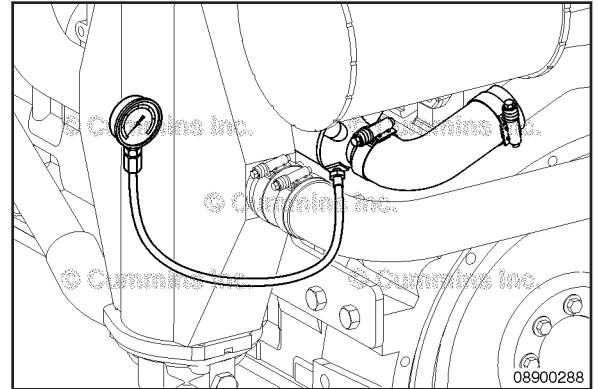
If the pressure drop is within specification, check the sea water pressure at the discharge side of the aftercooler. Record the reading.

If the pressure drop between the inlet side of the aftercooler exceeds the maximum, check for blockage in the aftercooler. Clean or replace if necessary.

Refer to Procedure 018-018 for Marine engine specifications.

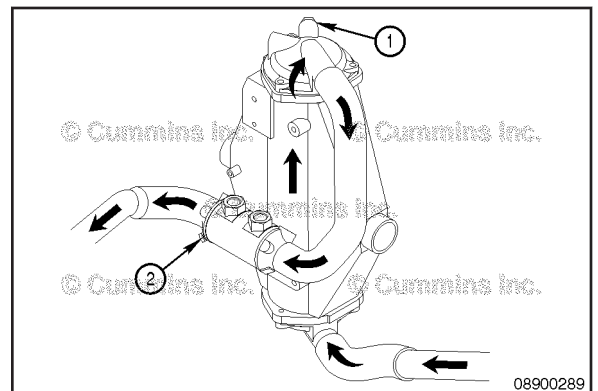


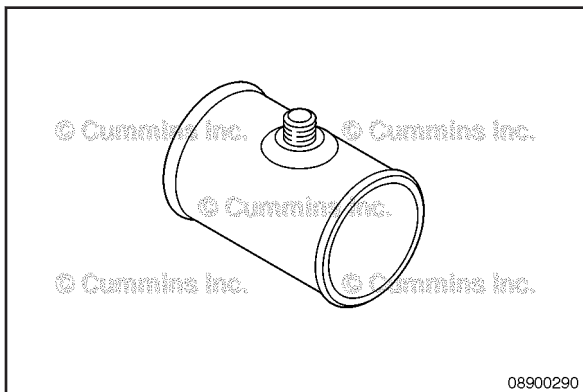
If the pressure drop between the inlet side of the aftercooler and the outlet side of the aftercooler is within specification, attach the pressure gauge to the gear oil cooler drain plug located on the outlet side and check for pressure drop across the gear oil cooler.



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.

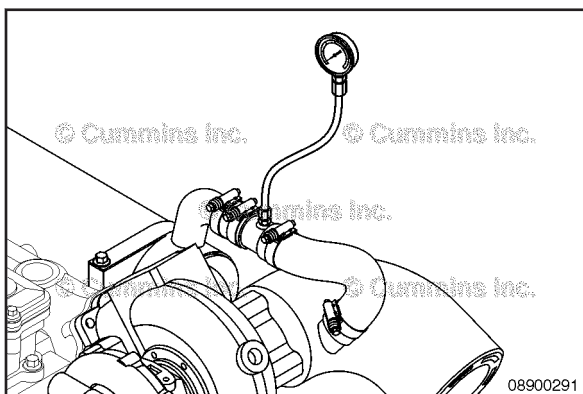
Refer to Procedure 018-018 for Marine engine specifications.





If the pressure drop in the gear oil cooler is within specification, test the pressure drop across the engine heat exchanger.

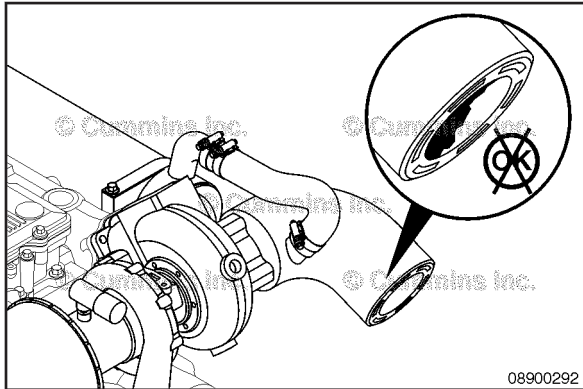
Fabricate a sea water test tool by using a 44 mm [1 3/4 in] pipe with a fitting in the center to connect a pressure gauge.



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.

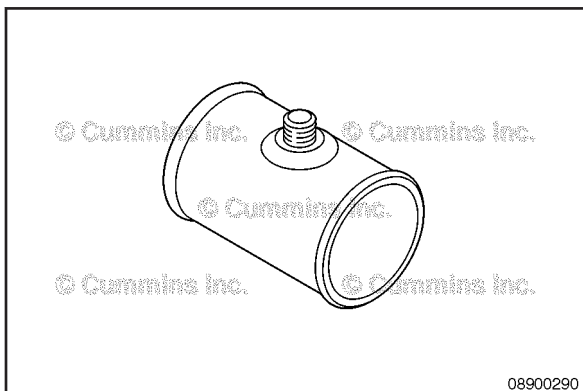
If the pressure drop is greater than the maximum specification, check for blockage in the heat exchanger. Clean or replace if necessary.

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 from 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.

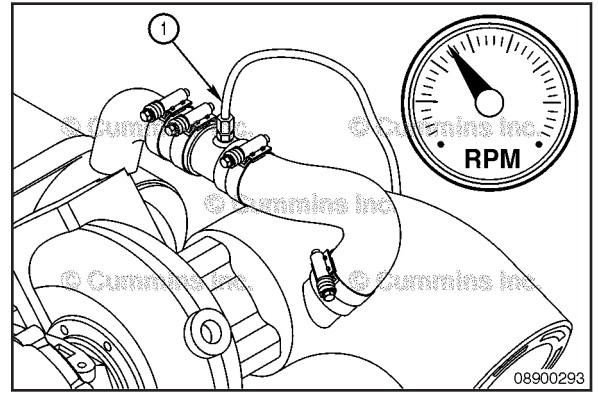
Refer to Procedure 018-018 for Marine engine specifications.



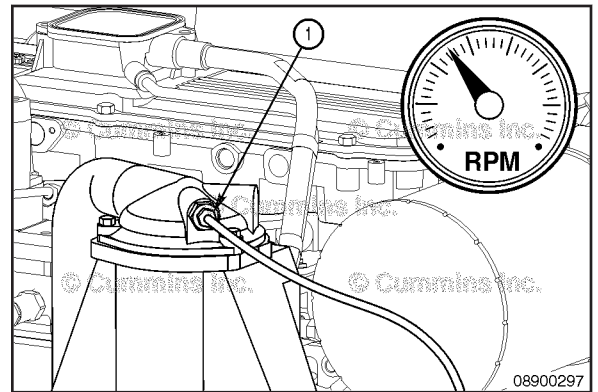
Temperature Differential Test

Fabricate a sea water test tool by using a [1 3/4 in] pipe with a fitting in the center to connect a temperature probe.

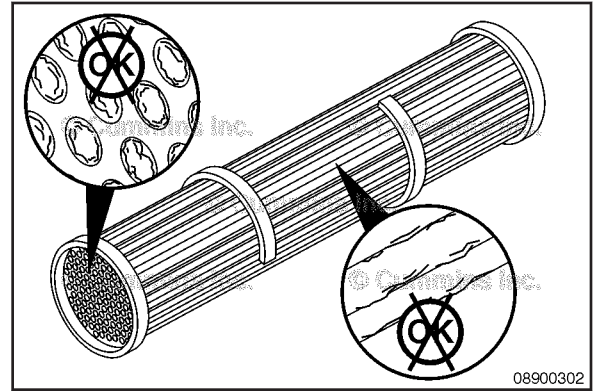
Install the sea water test tool with a temperature probe between the outlet side of the heat exchanger and the exhaust elbow (1). Operate the engine at rated rpm and load and record the temperature.



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.



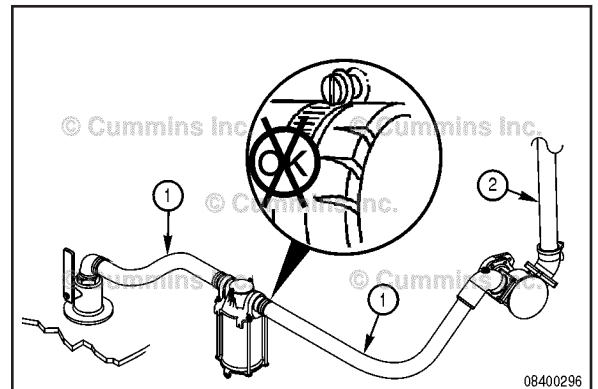
If the sea water temperature difference is less than 3° C [5° F], check the heat exchanger for possible plating to the heat exchanger core. Excessive plating or coating to the inside or outside of the cooling tubes will affect the efficiency of the heat exchanger.



Sea Water Hoses (008-104)

Inspect

Start engine, and inspect all hoses and connections for deterioration or leaks. Replace damaged hoses and clamps, if necessary.



Section 10 - Air Intake System - Group 10

Section Contents

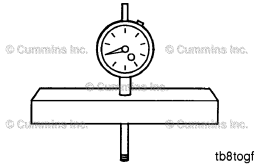
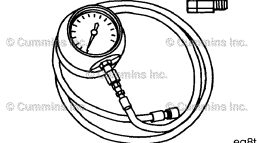
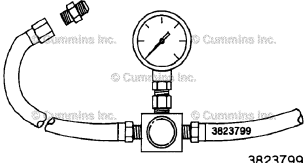
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Service Tools

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
<p style="text-align: center;">ST-537</p>	<p>Dial Depth Gauge Used to measure turbocharger axial motion.</p>	 <p style="text-align: right;">tb8togf</p>
<p style="text-align: center;">ST-1273</p>	<p>Pressure Gauge (0 to 75 in Hg) Used to measure the intake manifold pressure and exhaust back pressure.</p>	 <p style="text-align: right;">eg8togi</p>
<p style="text-align: center;">3823799</p>	<p>Turbocharger Wastegate Pressure Setting Kit Used to set wastegate pressure.</p>	 <p style="text-align: right;">3823799</p>



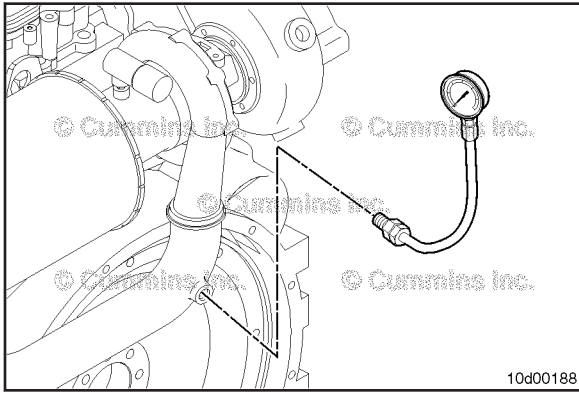
Aftercooler Assembly (010-002)

Initial Check

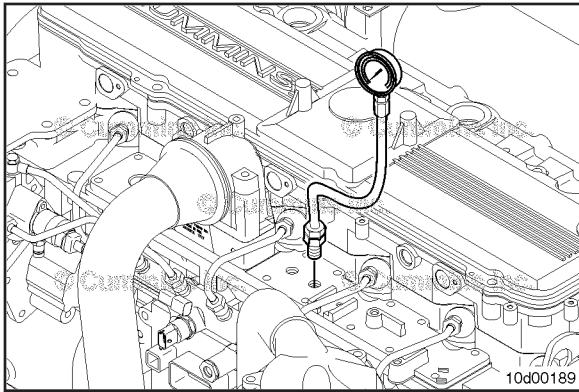
Test

NOTE: For marine seawater aftercooler **only**.

Install pressure gauge, Part Number ST-1273, in the turbocharger boost pressure fitting in the elbow at the turbocharger outlet.



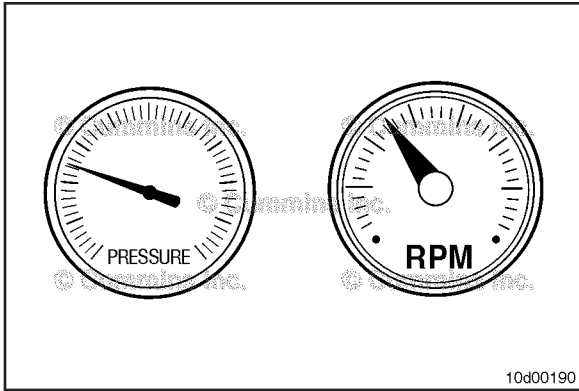
Install another pressure gauge, Part Number ST- 1273, in the intake manifold on the outlet side of the aftercooler.



Operate the engine at rated rpm and load. Record the readings on the two gauges.

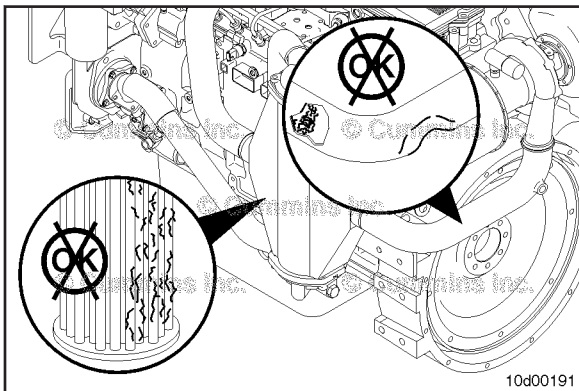


Aftercooler - Pressure Differential	
380 mm Hg	15 in Hg



If the pressure differential is greater than the specification, inspect the aftercooler and associated piping for plugging.

Clean or replace if necessary.



Preparatory Steps

Automotive and Industrial

⚠️ 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.

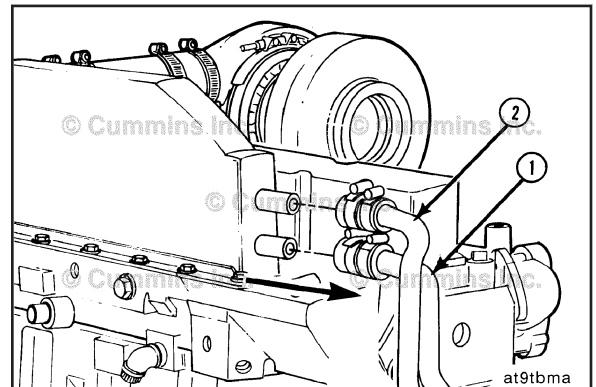
Disconnect the cold starting aid, if used. Refer to the OEM service manual.

Remove the air crossover tube. Refer to Procedure 010-019.

Drain 2 liters [2 qt] of coolant. Refer to Procedure 008-018.

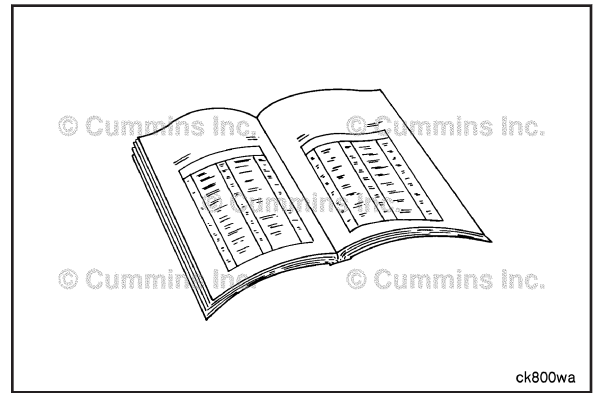
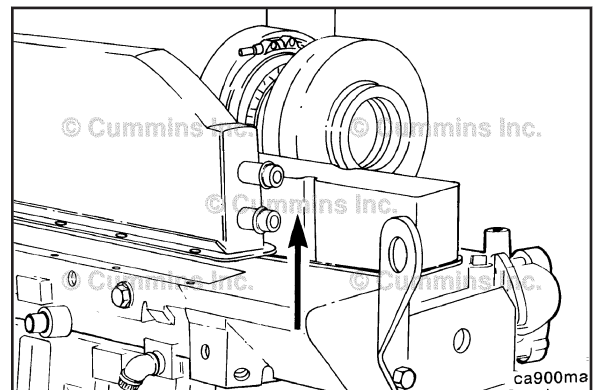
Remove

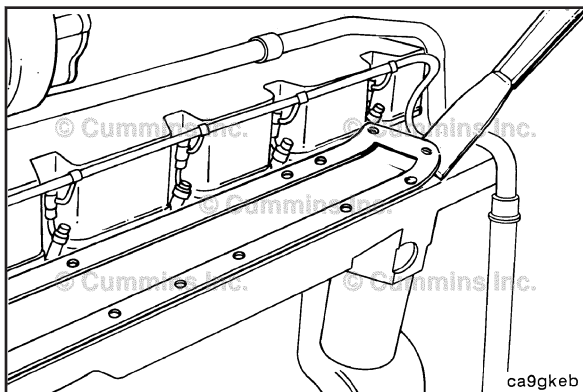
Remove the coolant supply tube (1) and the coolant return tube (2) from the aftercooler.



Remove the aftercooler housing mounting capscrews.
Remove the aftercooler housing and gasket.

NOTE: For a form-in-place gasket, cut the aftercooler gasket to remove.

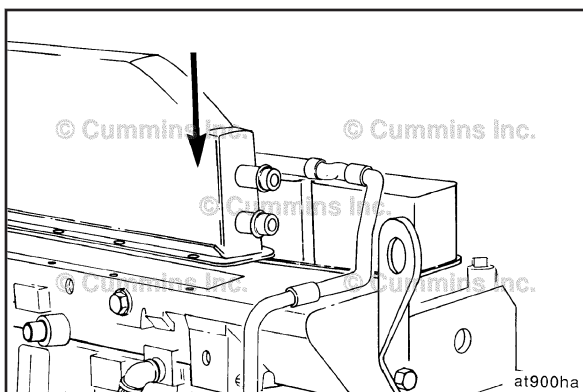




Clean

Clean the aftercooler housing sealing surfaces.

Keep the gasket material and all other materials out of the intake manifold.



Install

Use silicone sealant, Part Number 3823494, on both sides of the aftercooler housing gasket.

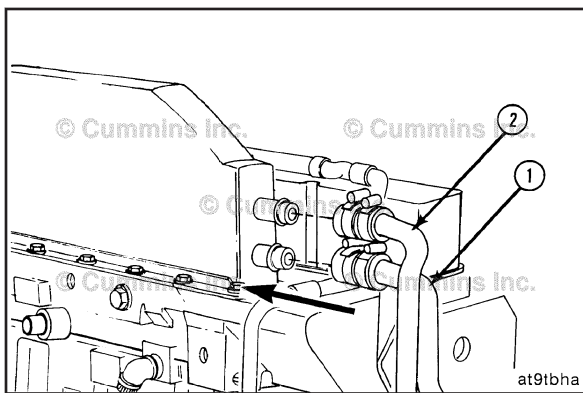


Install the aftercooler housing and new gasket.

NOTE: For aftercoolers with a form-in-place gasket, apply a 4-mm bead of sealant to the cylinder head.

Install and tighten the aftercooler housing mounting capscrews.

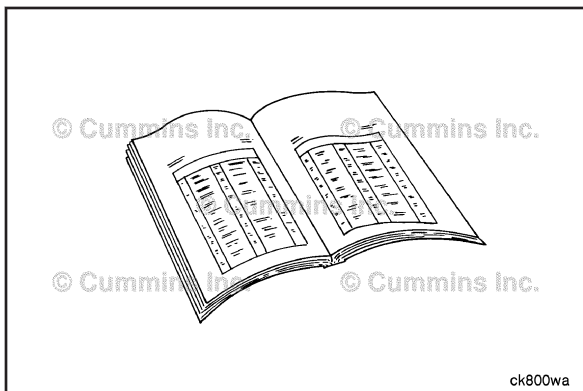
Torque Value: 24 N•m [18 ft-lb]



Install the coolant supply tube (1) and coolant return tube (2).



Torque Value: 5 N•m [44 in-lb]



Finishing Steps

⚠ CAUTION ⚠

During filling, air must be vented from the engine coolant passages. Open the engine vent petcock. Make sure to open the petcock on the aftercooler for aftercooled engines. The system must be filled slowly to prevent air locks. Wait two to three minutes to allow air to be vented; then add coolant to bring the level to the bottom of the radiator filler neck.

Connect the cold starting aid, if used. Refer to the OEM service manual.

Install the air crossover tube. Refer to Procedure 010-019.

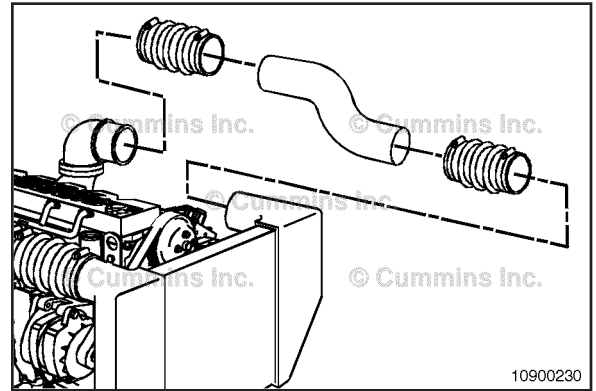
Fill the cooling system. Refer to Procedure 008-018.

Air Crossover (010-019)

Remove

Loosen the hose clamps, and position the crossover tube so that it can be removed.

Remove the tube.



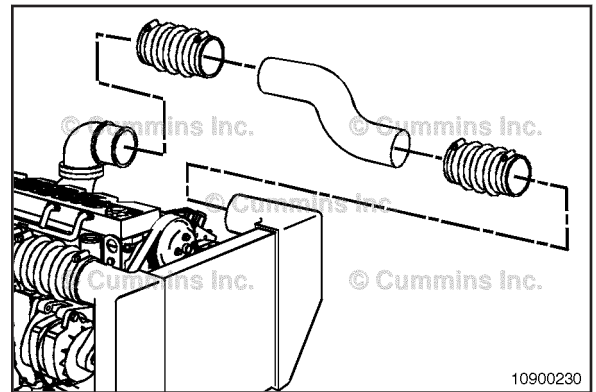
Inspect for Reuse

Check the crossover tube for cracks, holes, and worn sections.

Also check for poor sealing between the hose and tube.

Inspect the clamps for wear.

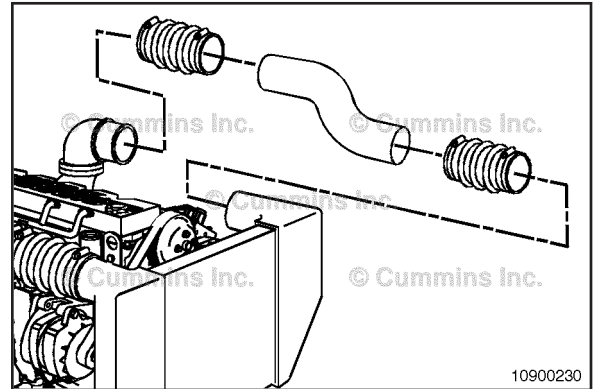
Replace with a new hose and clamps if necessary.



Install

Install the crossover tube and clamps in the reverse order of removal.

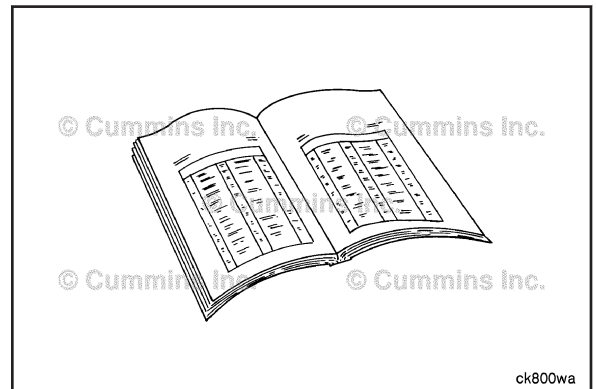
Tighten the clamps. Refer to the OEM manual for torque specification.

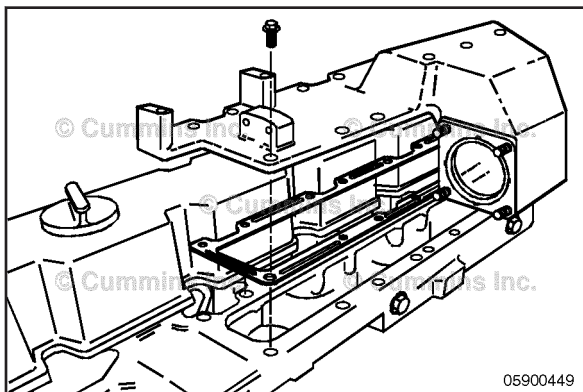


Air Intake Manifold (010-023)

Preparatory Steps

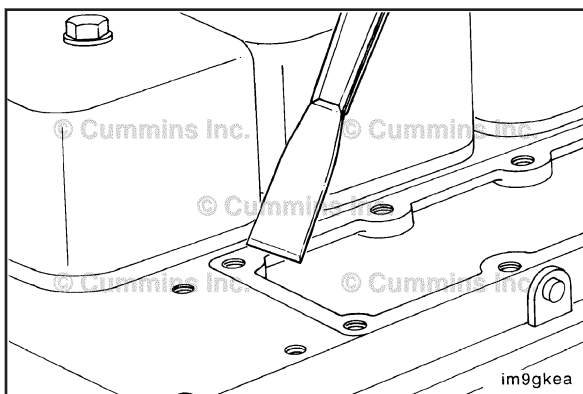
- Disconnect the cold starting aid, if used. Refer to the OEM service manual.
- Remove the air crossover tube, if used. Refer to Procedure 010-019.
- Disconnect the charge air cooler hose, if used. Refer to Procedure 010-027.
- Remove the high-pressure fuel lines. Refer to Procedure 006-051.





Remove

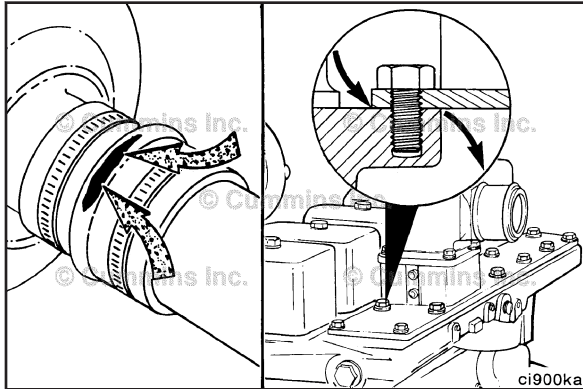
Remove the intake manifold cover, gasket, and grid heater, if equipped.



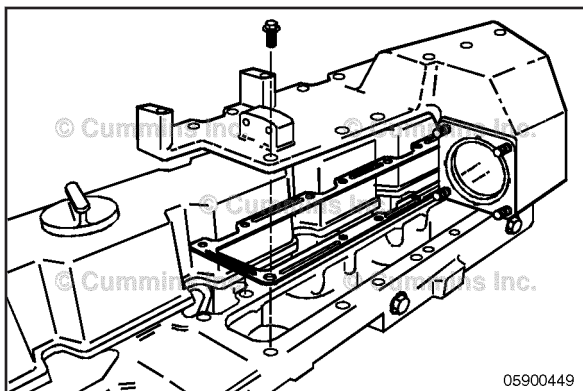
Clean and Inspect for Reuse

Clean the intake manifold sealing surfaces.

NOTE: Keep the gasket material and all other material out of the intake manifold.



Inspect the air intake manifold for cracks and holes.
Replace the air intake manifold if necessary.



Install

Install a new gasket and intake manifold cover.

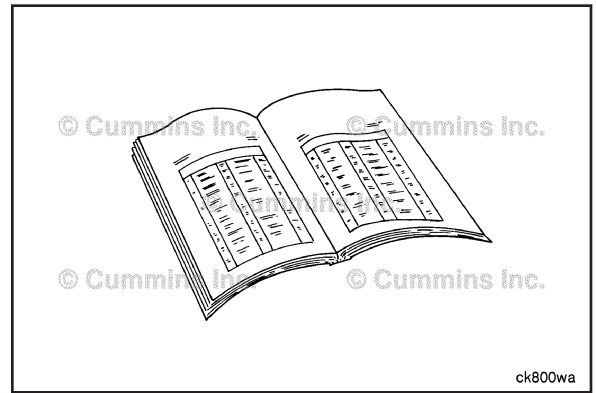
Install and tighten the intake manifold capscrews.

Torque Value: 24 N•m [18 ft-lb]



Finishing Steps

- Install the high-pressure fuel lines. Refer to Procedure 006-051.
- Connect all of the charge air cooler hoses, if used. Refer to Procedure 010-027.
- Install the air crossover tube. Refer to Procedure 010-019.
- Connect the cold starting aid, if used. Refer to the OEM service manual.

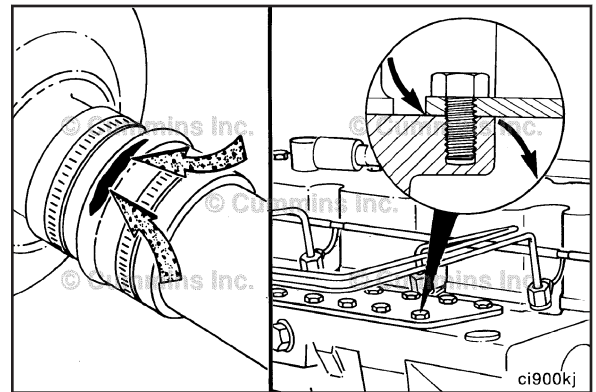


Air Leaks, Air Intake and Exhaust Systems (010-024)

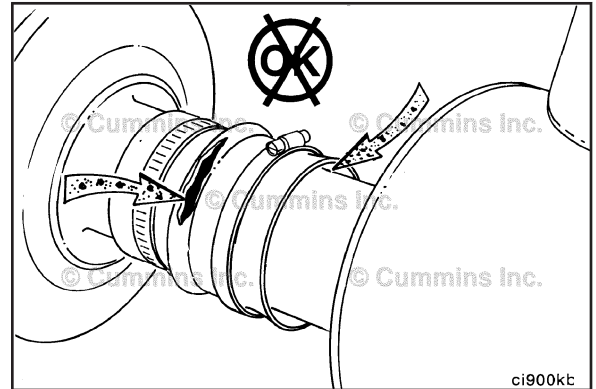
General Information

Loose connections or cracks in the suction side of the intake pipe can allow debris to be ingested by the engine, causing rapid wear in the cylinders.

Leaks at the intake manifold, unsealed bolt holes, or manifold cover gasket allow dust and dirt to be ingested into naturally aspirated engines.

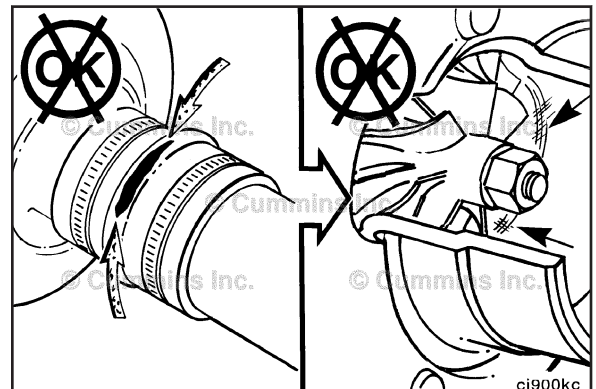


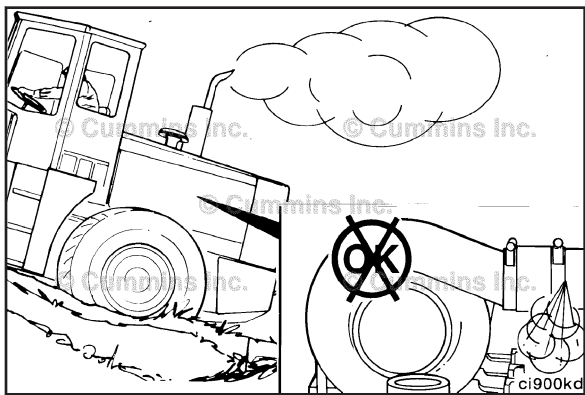
Loose connections or cracks in the suction side of the intake pipe on turbocharged engines allow debris to be ingested into the turbocharger compressor and then forced into the engine.



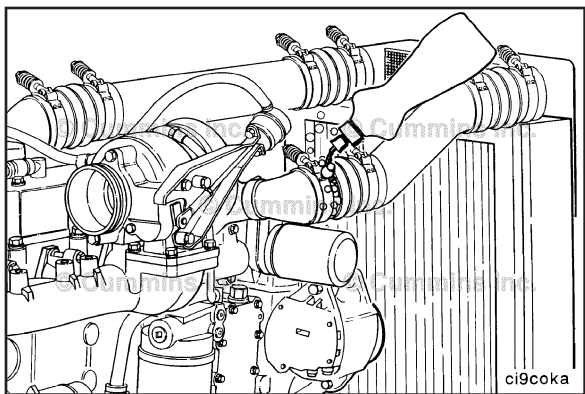
Debris drawn into the air suction side can damage the compressor blades, causing an imbalance resulting in bearing failure.


NOTE: To verify a bearing failure or damaged compressor, remove the intake and exhaust piping and check for contact. The rotor assembly **must** rotate freely and **must not** be damaged. Measurement of axial and radial clearance is described in this section.

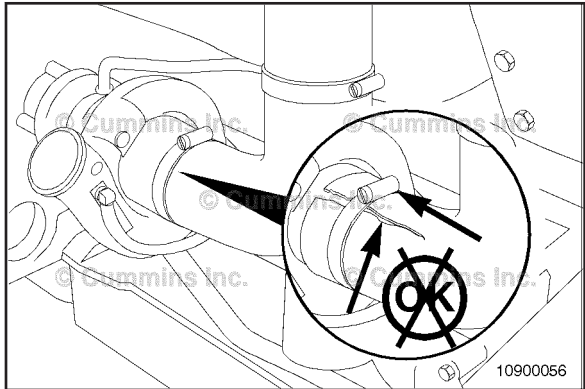




Excessive smoke and low power from a turbocharged engine can be caused by pressurized air leaking from loose connections, or cracks in the crossover tube or intake manifold. This can cause a noise problem.

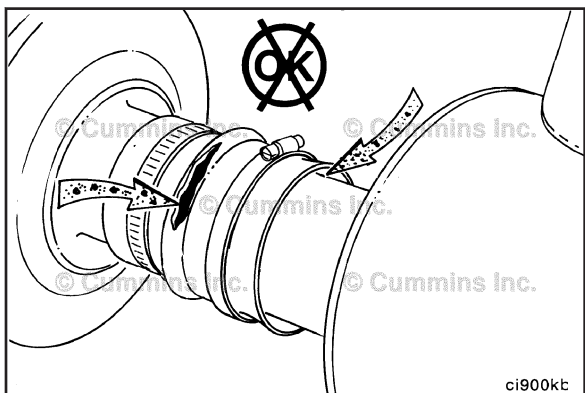



 In addition to the inspection for cracks and loose fittings, liquid soap can be applied to the charge-air cooler connections and the manifold cover sealing surfaces to find the leaks. The leaks will create bubbles that are easier to detect. Measurement of manifold pressure is described in this section.



 **Initial Check**
⚠CAUTION⚠
Engine intake air must be filtered to prevent dirt and debris from entering the engine. If intake air piping is damaged or loose, unfiltered air will enter the engine and cause premature wear.

Inspect the intake air piping for cracked hoses, damage, or loose clamps.



 Replace damaged pipes and tighten loose clamps as necessary to make sure the air intake system does **not** leak.

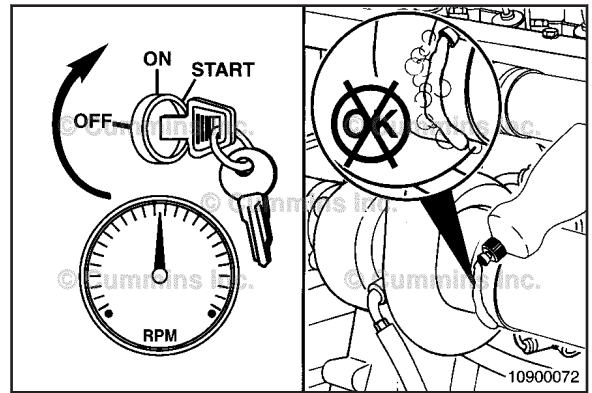
Torque Value: 8 N•m [71 in-lb]

Check for corrosion of the intake system piping under all clamps and hoses. Corrosion can allow corrosive products and dirt to enter the intake system. Disassemble and clean as required.



Operate the engine at high idle and use a solution of soapy water to spot intake air leaks.

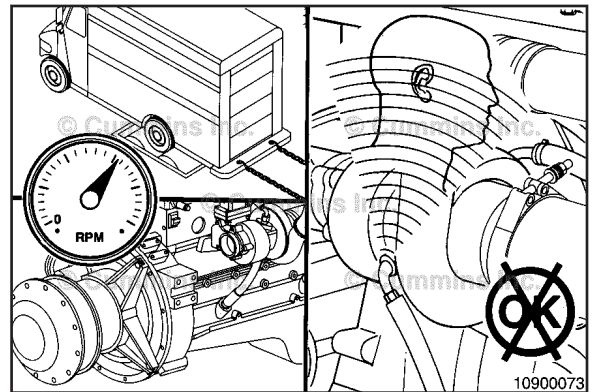
NOTE: If an air leak exists, the soap bubbles will be drawn in with the air.



Operate the engine at full throttle and rated rpm under maximum load conditions.



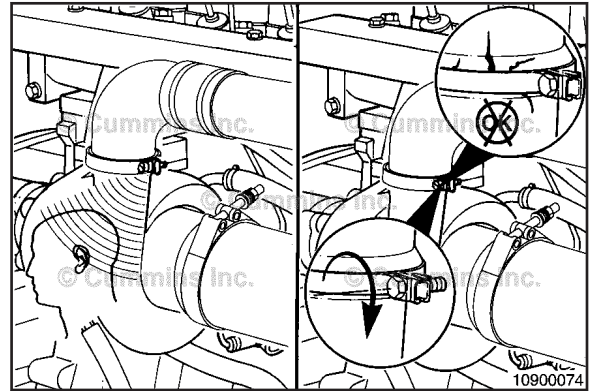
Listen for a high-pitched whistling noise from the turbocharger, nearby piping, and connections.



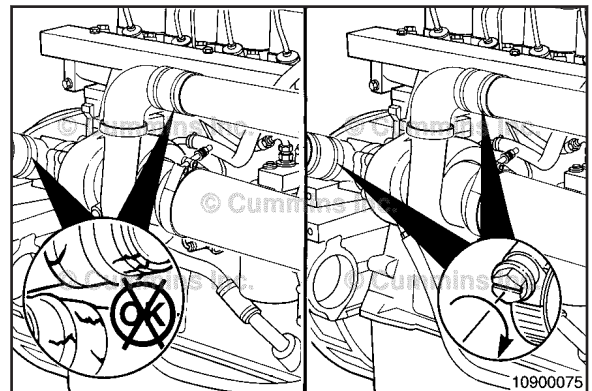
The noise can be caused by an air leak from the:

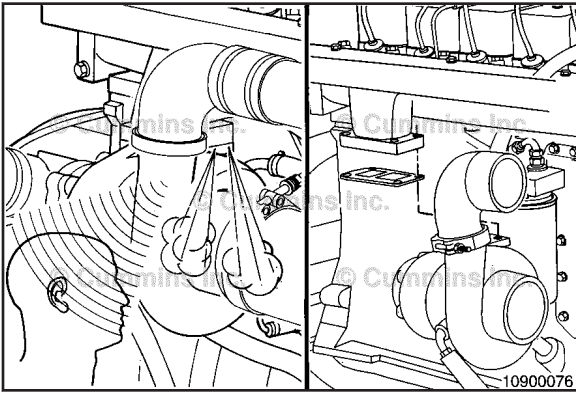
1. Turbocharger-to-discharge-elbow connection
 - Inspect for damage. Tighten loose clamps.

Torque Value: 8 N•m [71 in-lb]

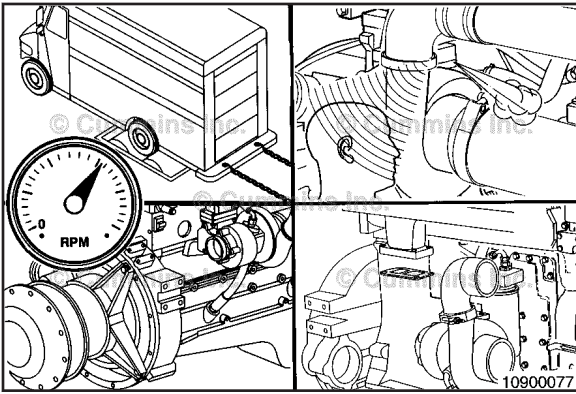


2. Any charge-air cooler tubing or connecting hoses
 - Inspect the hose and tubing for damage.
 - Tighten the hose clamps.
 - Refer to the manufacturer's specifications for the correct torque value.





3. Turbocharger-to-exhaust-manifold mounting gasket
- Replace the gasket. Refer to Procedure 010-033.

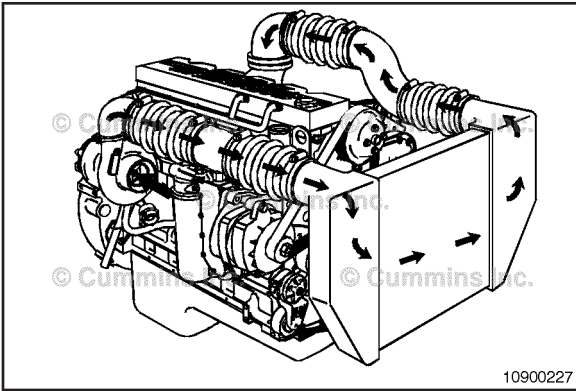


Operate the engine at full throttle and rated rpm under maximum load conditions.

Listen for leaks.



Replace the turbocharger if the air piping is **not** damaged and the noise can still be heard; refer to Procedure 010-033.

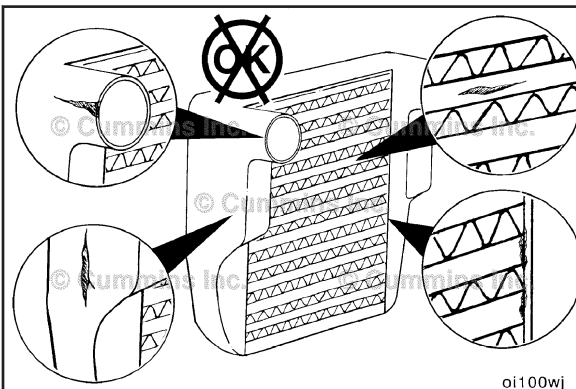


Charge-Air Cooler (010-027)

General Information

The long-term integrity of the charge-air cooler system is the responsibility of the vehicle and component manufacturers; however, the following can be checked by any Cummins® Authorized Repair Facility.

NOTE: If the engine experiences turbocharger damage or any other occasion where oil or debris is put into the charge-air cooler, the charge-air cooler **must** be cleaned.



Initial Check

Inspect the charge-air cooler for cracks, holes, and other damage.

Inspect the tubes, fins, and welds for tears, breaks, or other damage. If any damage causes the charge-air cooler to fail the air leak check, the charge-air cooler **must** be replaced.

Inspect the charge-air cooler plumbing for cracks and damage.

Remove

⚠️ WARNING ⚠️

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

⚠️ WARNING ⚠️

Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

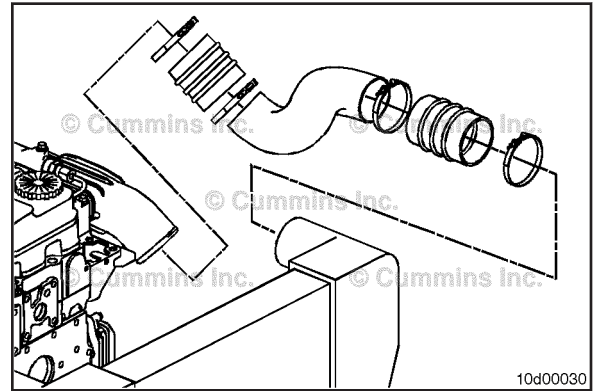
⚠️ WARNING ⚠️

Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

Drain the coolant.

Remove the charge air cooler plumbing and cooler. Refer to original equipment manufacturer (OEM) service manual.

Use compressed air to clean debris from the outside of the charge-air cooler.



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 ⚠️

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

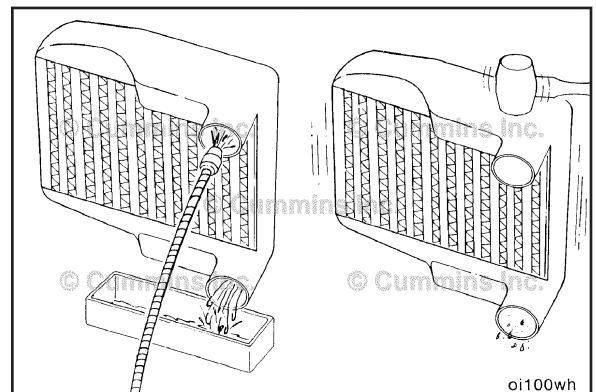
⚠️ CAUTION ⚠️

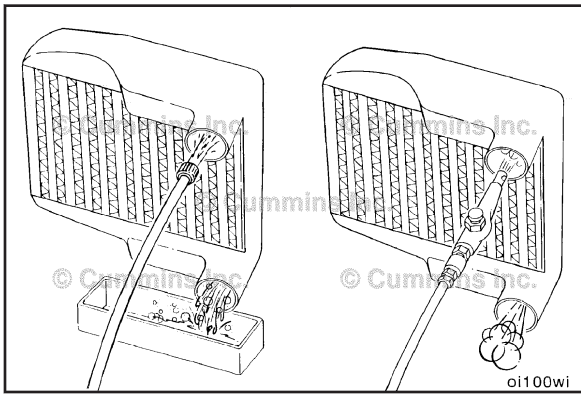
Do not use caustic cleaners to clean the charge air cooler. Damage to the charge air cooler will result.

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 ⚠

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 ⚠

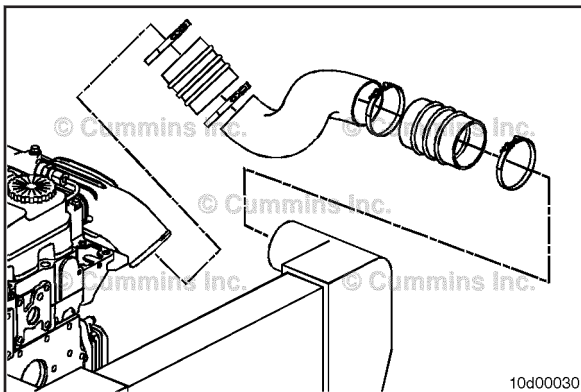
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

⚠ CAUTION ⚠

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.

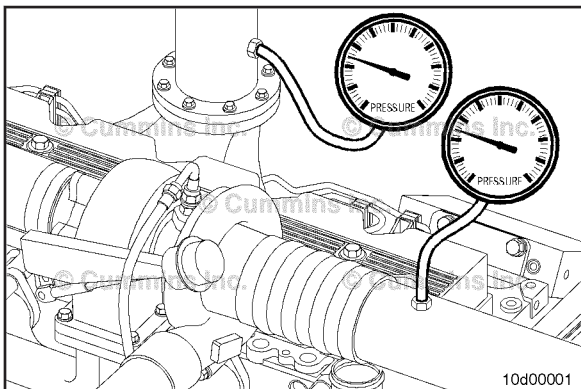


Install

Install the charge-air cooler.



Install the charge-air cooler plumbing. Refer to the OEM service manual for instructions.



Pressure Test

Install the pressure gauge, Part Number ST-1273, or equivalent, to the fitting in the turbocharger outlet.



Install another pressure gauge, Part Number ST-1273, or equivalent, in the intake manifold.



Operate the engine at rated rpm and load. Record the readings on the two gauges.

If the differential pressure is greater than 21 kPa [3 psi], check the charge-air cooler for plugging. 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.

Install a plug or cap over the outlet side of the cooler. Install a pressure gauge and a regulated shop air supply line with 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.

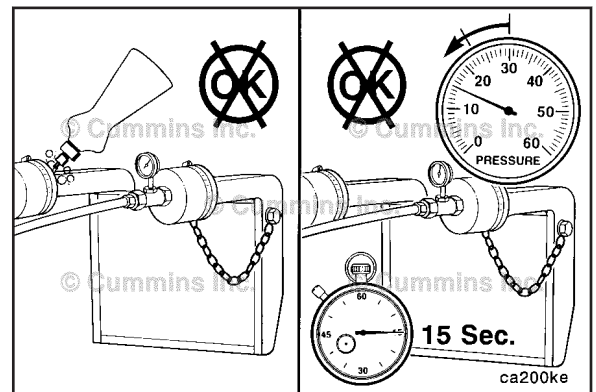
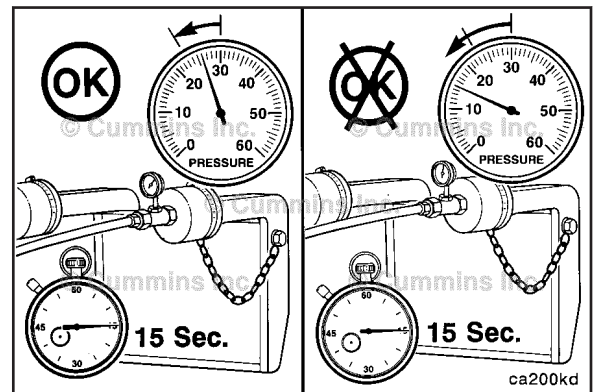
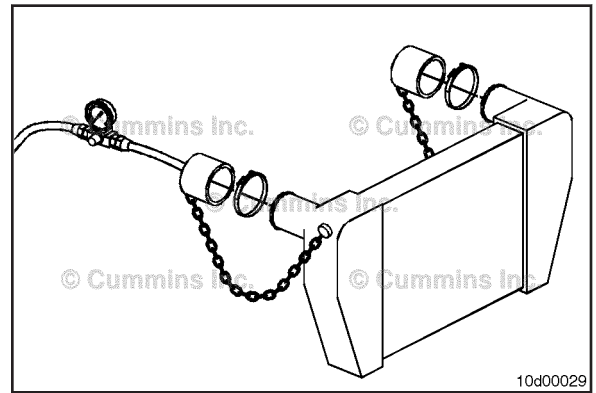
If the pressure drop is 48 kPa [7 psi] or less in 15 seconds, the cooler is operational.

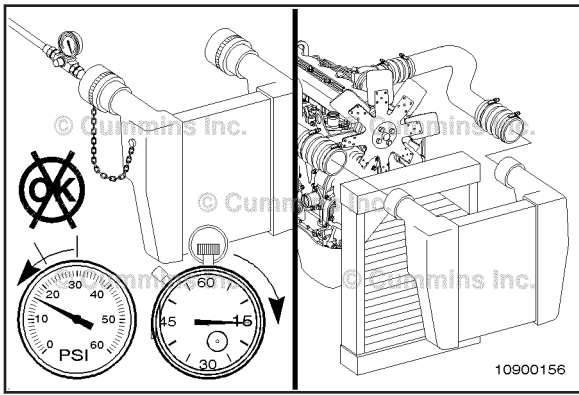
If the pressure drop is greater than 48 kPa [7 psi] in 15 seconds, check all connections again.

Determine if the pressure drop is caused by a leaky charge-air cooler or a leaky connection. Spray soapy water on 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.

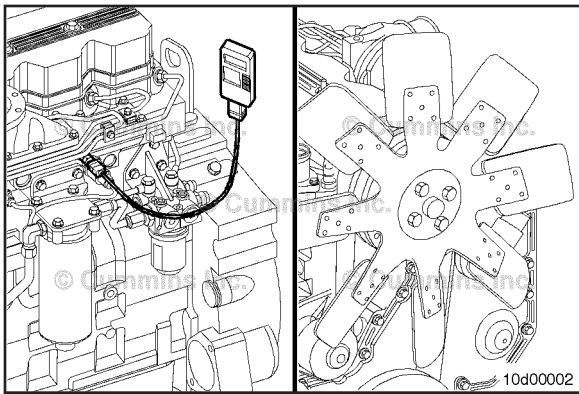




If the pressure drop is greater than 48 kPa [7 psi] in 15 seconds, the charge-air cooler **must** be replaced.

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.



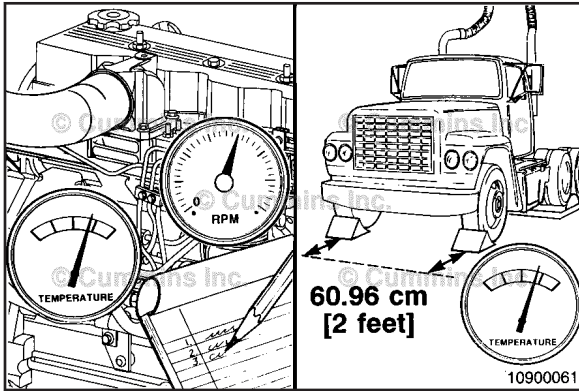
Temperature Differential Test

Install a temperature gauge in the intake manifold.



Lock the fan drive in the ON mode to prevent erratic test results. This can be done by installing a jumper across the temperature switch or supplying shop air to the fan. Refer to the OEM service manual for the lockup procedure.

NOTE: Some applications have a manual switch that will lock the fan on.



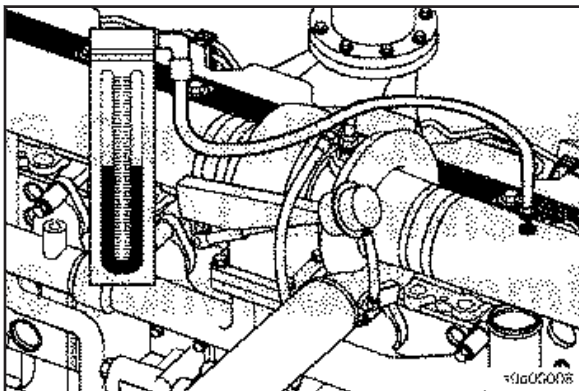
Operate the engine at rated rpm and load. Record the intake manifold temperature.

Measure the ambient temperature at least 2 feet in front of the vehicle.



The maximum temperature differential **must not** be greater than 25°C [77°F].

If the temperature differential is greater than 25°C [77°F], check the charge-air cooler for dirt and debris on the fins, and clean as necessary. If the problem still exists, check the cooler for internal contamination or plugging.



Air Intake Restriction (010-031)

Measure

NOTE: For naturally aspirated engines, measure the intake restriction just before the intake manifold.

Install a vacuum gauge or water manometer, Part Number ST-1111-3, in the intake air piping.

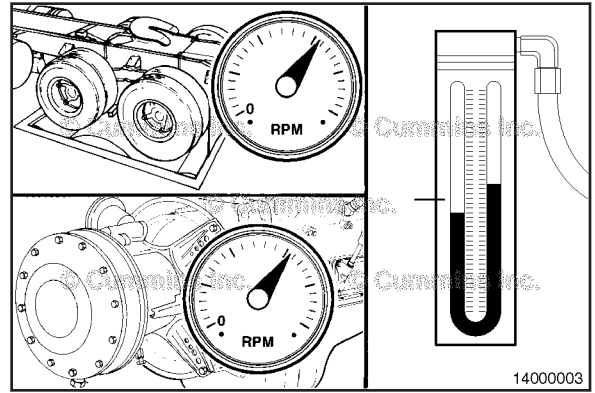
The gauge adapter **must** be installed at a 90-degree angle to the airflow in a straight section of pipe, one pipe diameter before the turbocharger.

Operate the engine at full throttle and rated rpm with maximum load.

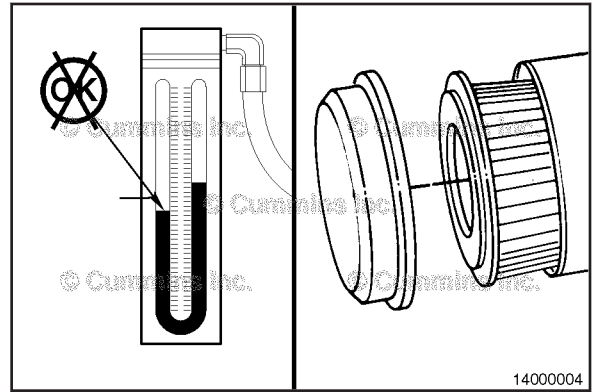
Record the data on the gauge or manometer.

Inlet Air Restriction

mm H ₂ O		in H ₂ O
635	MAX	25

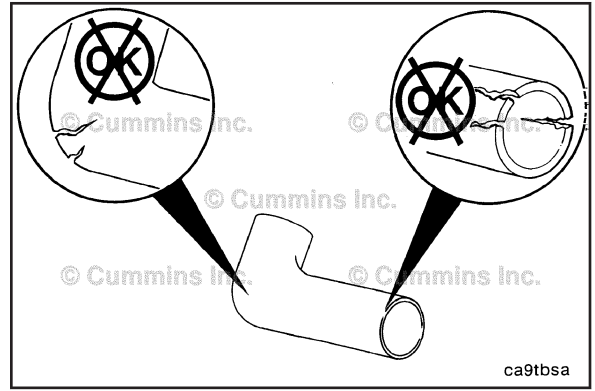


If restriction exceeds specifications, replace or clean the air filter element. Refer to the equipment manufacturer's instructions.



Inspect the intake piping for damage. Refer to the equipment manufacturer's repair instructions.

Remove the test equipment.



Turbocharger (010-033)

Initial Check

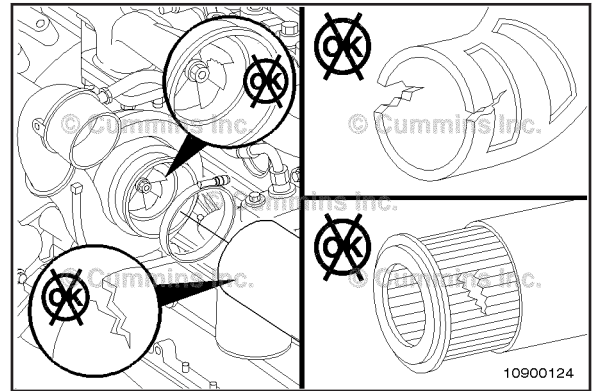
Remove the intake pipe from the turbocharger. See the Remove step in this procedure.

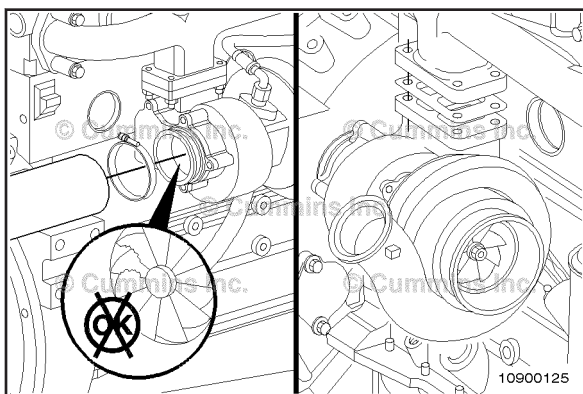
Inspect the turbocharger compressor impeller blades for damage.

Replace the turbocharger if damage is found. See the Remove and Install steps in this procedure.

If the compressor impeller is damaged, inspect the intake piping and filter element for damage.

Repair any damage before operating the engine.



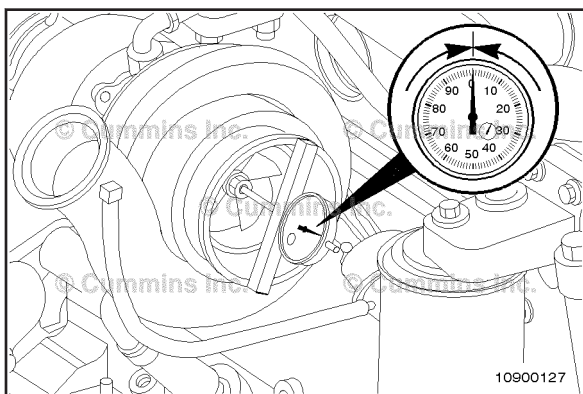


Remove the exhaust pipe from the turbocharger. See the Remove step in this procedure.



Inspect the turbine wheel for damage.

Replace the turbocharger if damage is found. See the Remove and Install steps in this procedure.

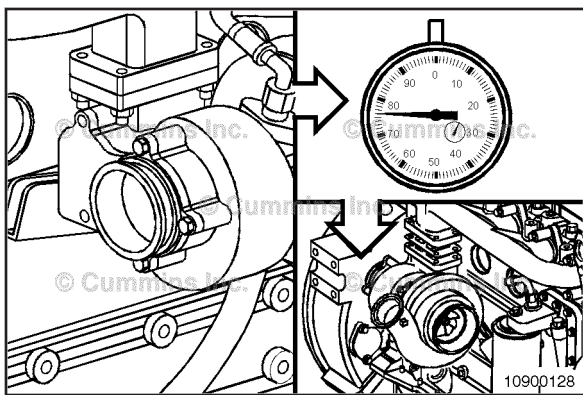


Axial Clearance Check

Use dial depth gauge, Part Number ST-537.

Push the rotor assembly away from the gauge.

Set the gauge on zero.



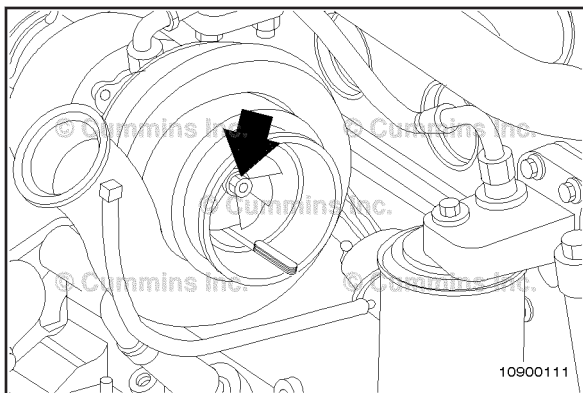
Push the rotor assembly toward the gauge and record the reading.



Axial Clearance

mm		in
0.038	MIN	0.0015
0.093	MAX	0.0037

Replace the turbocharger if the clearance does **not** meet the specifications. See the Remove and Install steps in this procedure.



Radial Clearance Check

Use a wire-type feeler gauge to measure the clearance between the compressor wheel and housing.

Gently push the compressor wheel toward the compressor housing and gauge.

Record the clearance.

With the feeler gauge in the same location, gently push the compressor wheel away from the compressor housing and measure the clearance between the compressor wheel and housing.

Subtract the smaller clearance from the larger clearance. This is the radial bearing clearance.

Radial Bearing Clearance

mm		in
0.30	MIN	0.012
0.46	MAX	0.018

Repeat the procedure on the turbine wheel.

Replace the turbocharger if the radial bearing clearance does **not** meet specifications. See Remove and Install steps in this procedure.

Leak Check

Inspect the compressor intake and discharge for oil.

If oil is present in the compressor intake as well as in the discharge, check upstream in the turbocharger for the source of the oil.

If oil is present **only** in the discharge side, install the air intake and CAC piping.

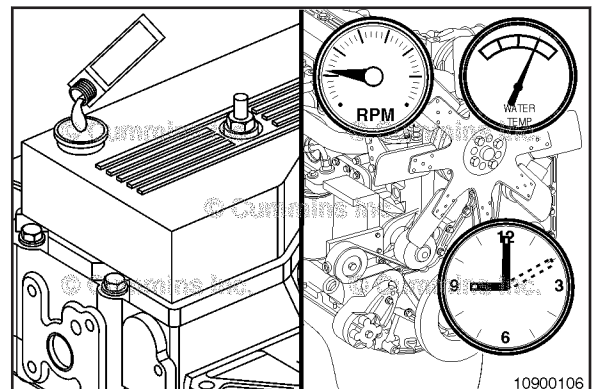
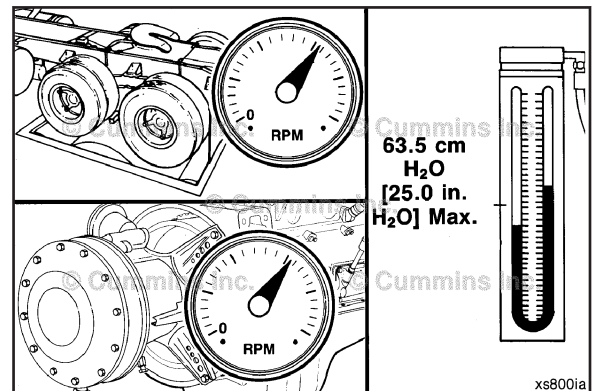
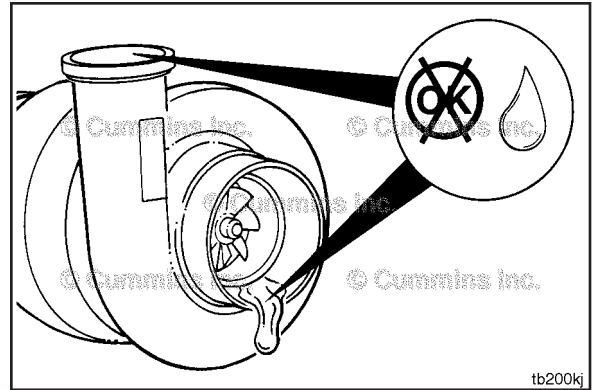
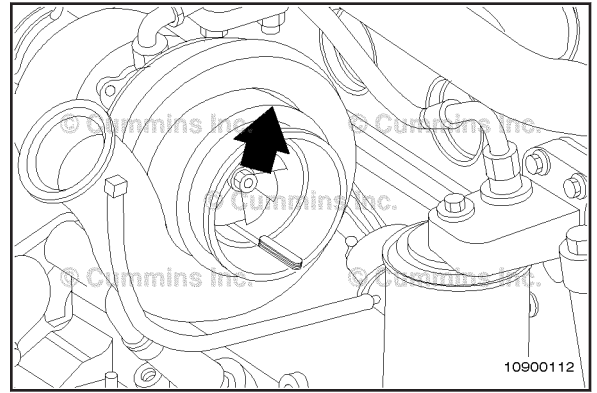
Check for intake restriction. Refer to Procedure 010-031.

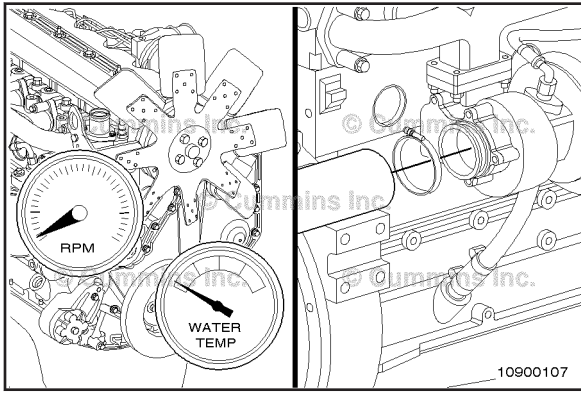
If excessive intake restriction is **not** found, replace the turbocharger. See the Remove and Install steps in this procedure.

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. Refer to Procedure 010-027.

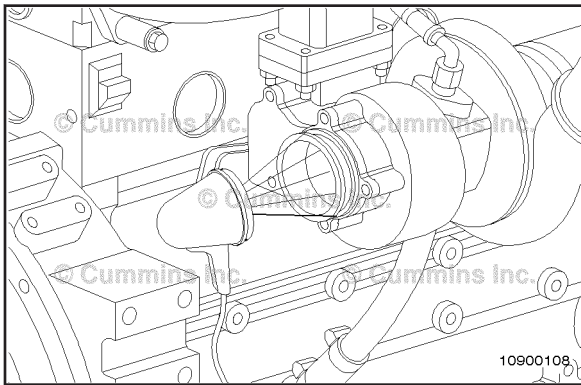
Add 1 unit of fluorescent tracer, Part Number 3376891, to each 38 liters [10.0 gal] of engine lubricating oil.

Operate the engine at low idle for 10 minutes.

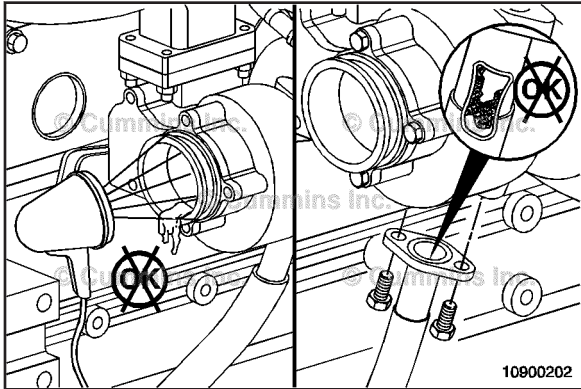




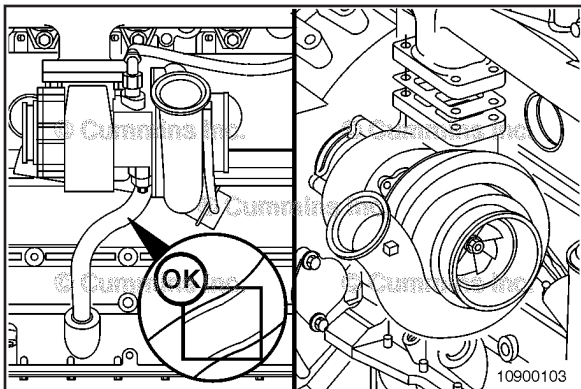
Shut off the engine.
Allow the turbocharger to cool.
Remove the exhaust pipe from the turbine housing. See the remove step in this procedure.



Use a high-intensity black light, Part Number 3163339, to inspect the turbine outlet for leaks.
A yellow glow indicates an oil leak. A dark blue glow indicates fuel in the oil.



If oil is found on the turbine housing, remove the oil drain line and check for restrictions. Refer to Procedure 010-045.
Clear any restrictions found.
Install the turbocharger oil drain line and new o-ring seals into the engine block. Refer to Procedure 010-045.



If the oil drain line was **not** restricted, remove the turbocharger. See the Remove step in this procedure.

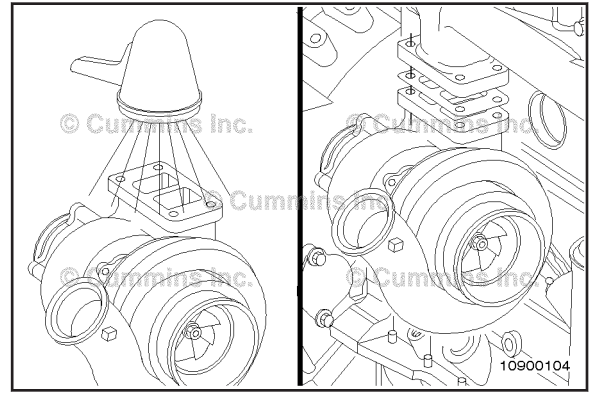
Use a high-intensity black light, Part Number 3163339, to inspect the turbine inlet for leaks.



A yellow glow indicates an oil leak from the engine.



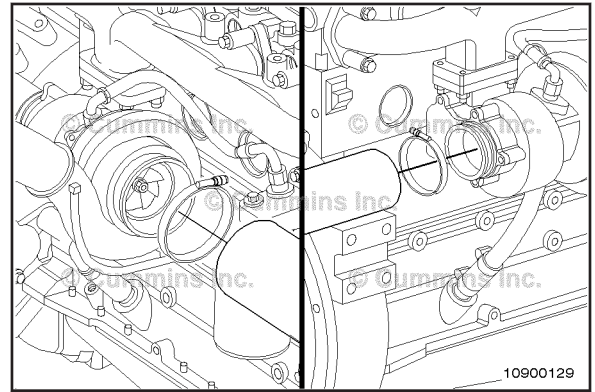
If a yellow glow is **not** seen in the turbine inlet, replace the turbocharger. See the Remove and Install steps in this procedure.



Install the exhaust pipe to the turbocharger turbine outlet and tighten the clamp. See the Install step in this procedure.

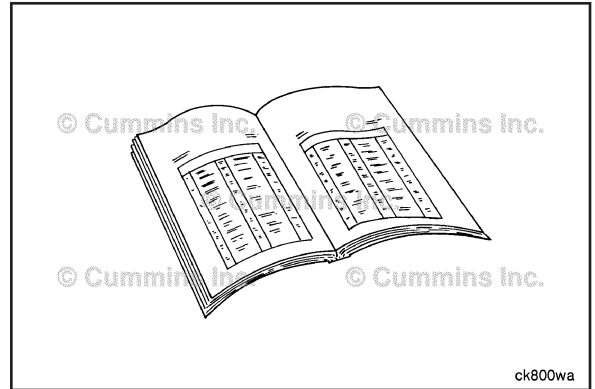


Install the intake pipe to the turbocharger compressor inlet and tighten the clamp. See the Install step in this procedure.



Preparatory Steps

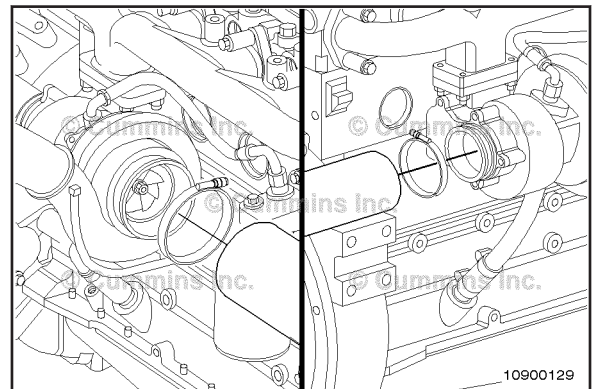
- Remove the air crossover if equipped. Refer to Procedure 010-019.
- Disconnect the charge air cooler hose. Refer to the OEM service manual.
- Remove the oil supply line from the turbocharger. Refer to Procedure 010-046.
- Remove the oil drain line from the turbocharger. Refer to Procedure 010-045.
- Remove the intake manifold pressure supply line from the boost capsule, if equipped.

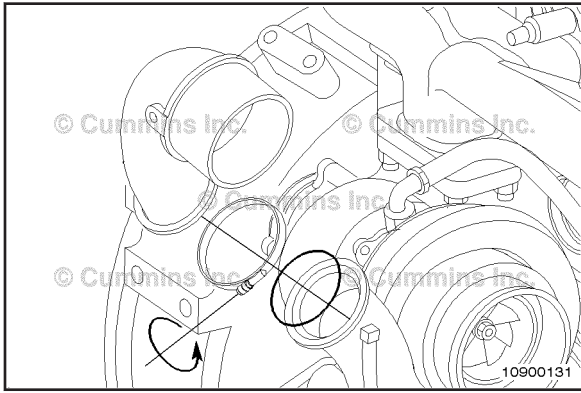


Remove

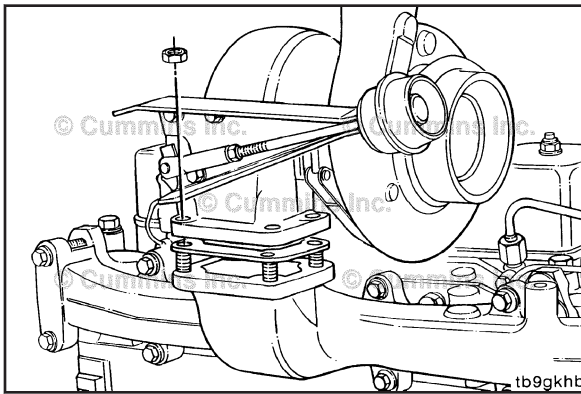
Remove the exhaust piping.

Remove the turbocharger compressor air inlet pipe.

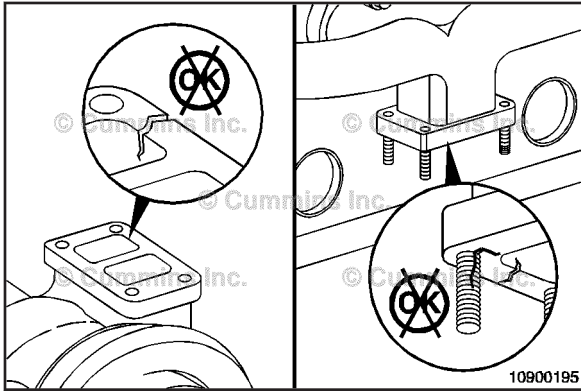




Remove the turbocharger compressor outlet elbow, v-band clamp, and o-ring from the turbocharger compressor outlet.



Remove the four turbocharger mounting nuts.
Remove the turbocharger and gasket.



Clean and Inspect for Reuse

Clean the turbocharger and exhaust manifold gasket surfaces.



Inspect the turbocharger and exhaust manifold gasket surfaces, and mounting studs for cracks and damage.



Replace the turbocharger if any cracks are found on the mounting flange surface. See the Remove and Install steps in this procedure.

Replace the exhaust manifold if any cracks are found on the mounting flange surface. Refer to Procedure 011-007.

⚠ 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.

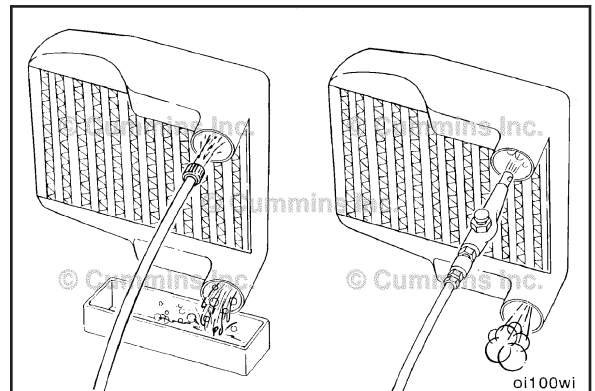
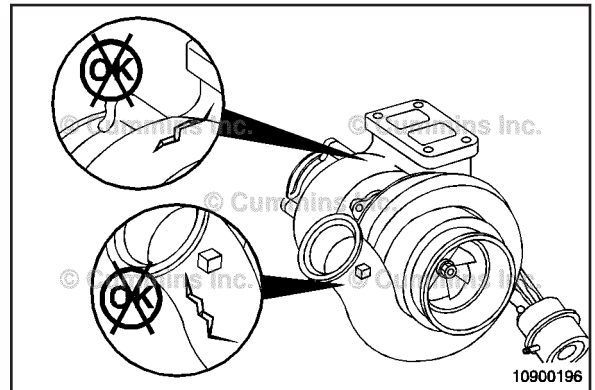
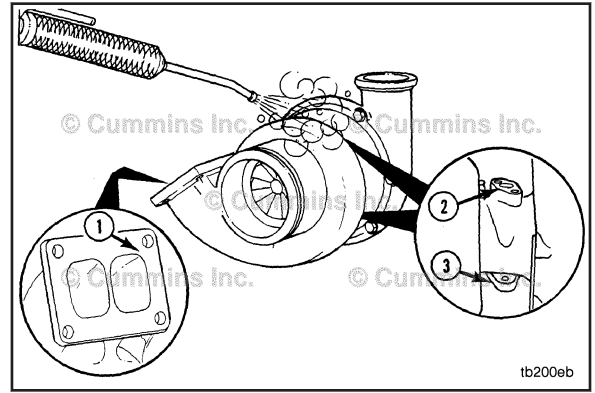
Dry with compressed air.

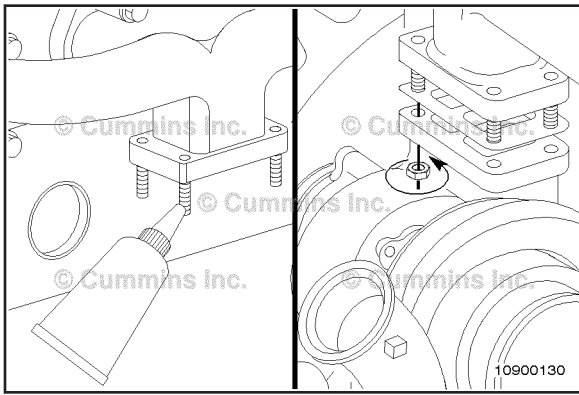
Inspect the turbine and compressor housings.

If cracks that go all the way through the outer walls are found, the turbocharger **must** be replaced.

NOTE: A charge air cooler failure can cause progressive damage to the turbine housing. If the turbine housing is damaged, check the charge air cooler. Refer to Procedure 010-027.

NOTE: If the engine experiences a turbocharger failure or any other occasion where oil or debris is put into the charge air system, the charge air system **must** be inspected and cleaned. Refer to Procedure 010-027.





Install

Apply a film of high-temperature anti-seize compound to the turbocharger mounting studs.



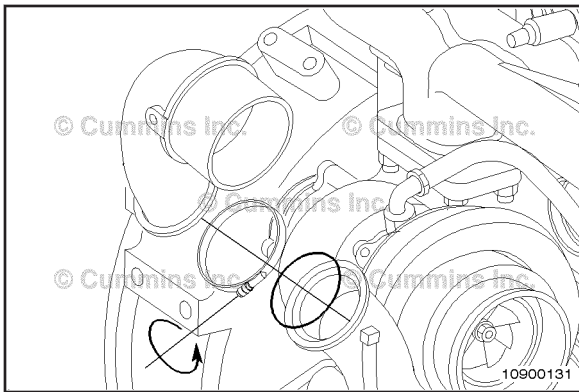
Use a new gasket and install the turbocharger.

Install and tighten the four mounting nuts.



NOTE: The torque values given have been established using anti-seize compound as a lubricant.

Torque Value: 45 N•m [33 ft-lb]

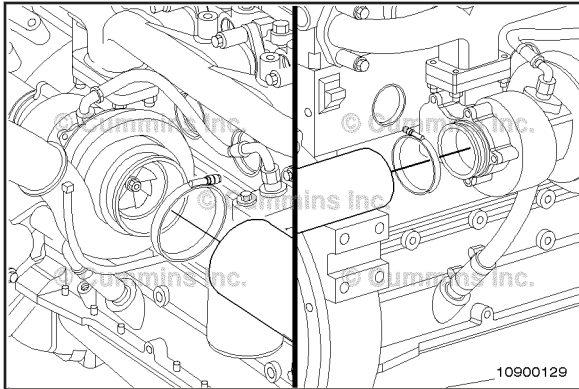


Install the turbocharger compressor outlet elbow, v-band clamp, and new o-ring seal on the turbocharger compressor discharge outlet.



Tighten the clamp.

Torque Value: 8 N•m [71 in-lb]



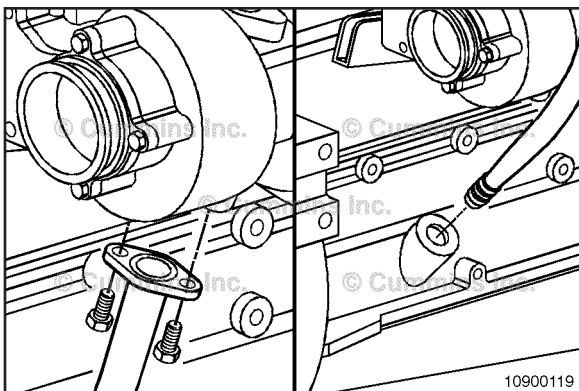
Install the intake pipe to the turbocharger compressor inlet and tighten the clamp.

Torque Value: 8 N•m [71 in-lb]



Install the exhaust pipe to the turbocharger turbine outlet and tighten the clamp.

Torque Value: 8 N•m [71 in-lb]



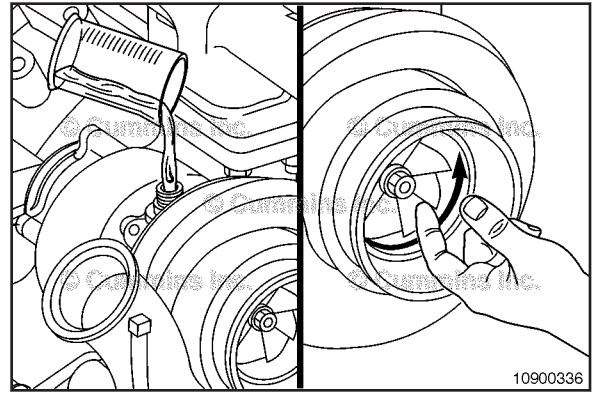
Prime

Install the turbocharger oil drain line. Refer to Procedure 010-045.



Lubricate the bearings by pouring 59 to 89 ml [2 to 3 oz] of clean 15W40 engine oil into the turbocharger oil supply line fitting. Rotate the turbine wheel to allow oil to enter the bearing housing.

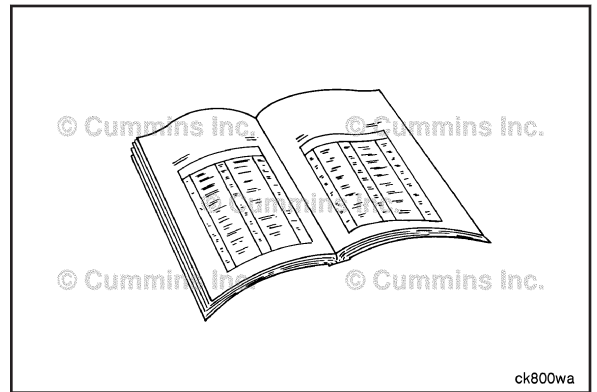
Install the turbocharger oil supply line. Refer to Procedure 010-046.



10900336

Finishing Steps

- Install the intake manifold pressure supply line to the boost capsule, if equipped.
- Connect the charge air cooler hose. Refer to the OEM service manual.
- Install the air crossover, if equipped. Refer to Procedure 010-019.
- Operate the engine and check for leaks.

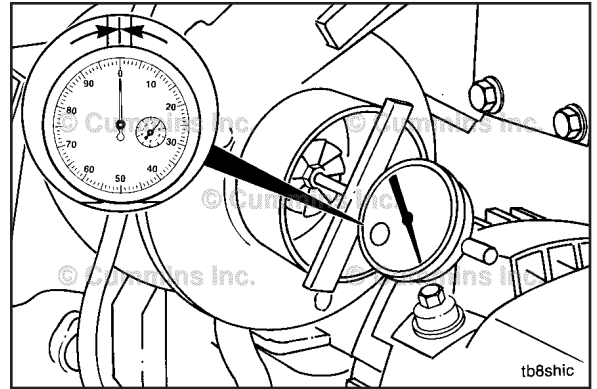


ck800wa

Turbocharger Axial Clearance (010-038)

Measure

Measure the turbocharger shaft end play; refer to the Turbocharger Manual, Bulletin 3810321.



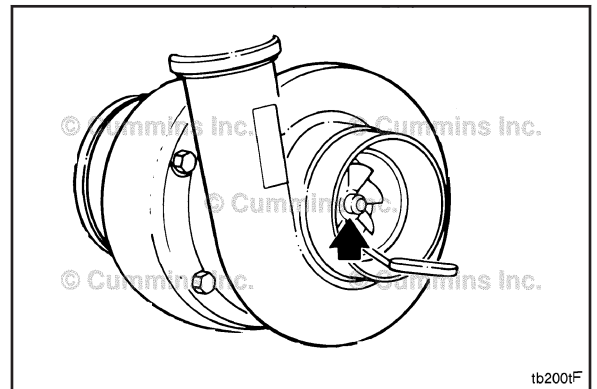
tb8shic

Measure radial clearance of the turbocharger shaft.

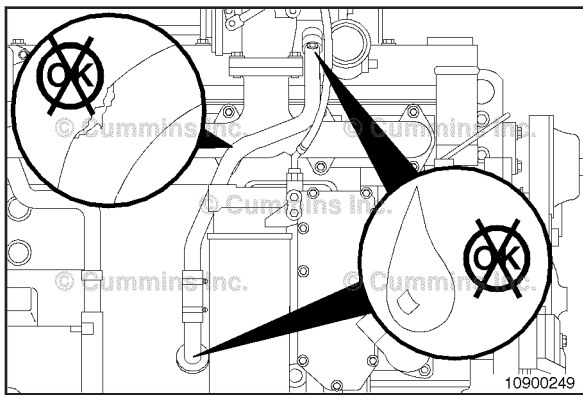
Turbocharger Axial Clearance

mm		in
0.30	MIN	0.012
0.46	MAX	0.018

The turbocharger **must** be replaced if the clearances are beyond these limits. Refer to Procedure 010-033.



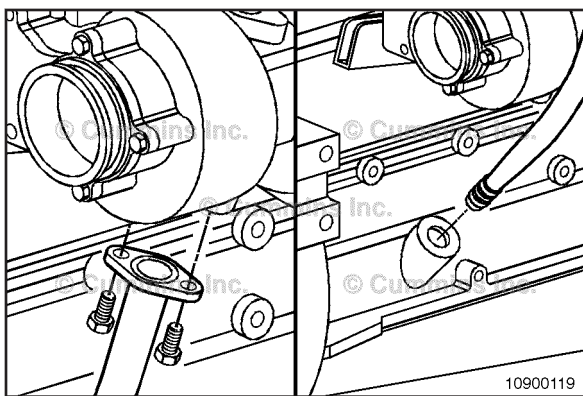
tb200tF



Turbocharger Oil Drain Line (010-045) Initial Check

Inspect the turbocharger oil drain line for oil leaks or damage.

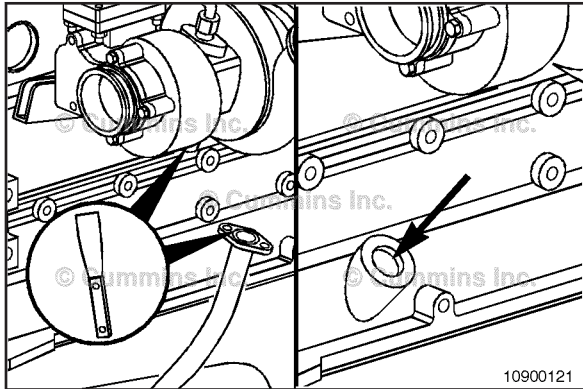
Repair as necessary.



Remove

Remove the capscrews from the oil drain tube.

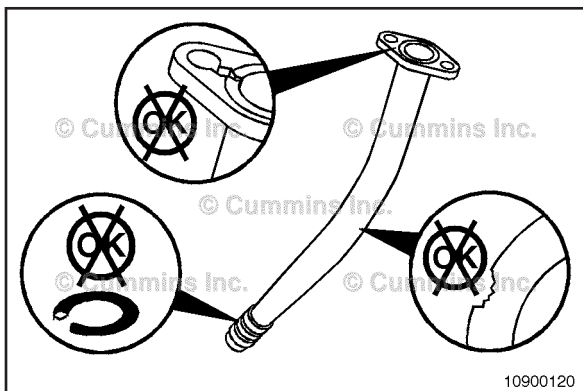
Pull the drain line out of the drain line boss.



Clean and Inspect for Reuse

Clean the gasket sealing surfaces.

Clean the o-ring seating bore and make sure it is free of dirt and debris.



Inspect the line for cracks, wear, and damage.

Inspect the o-ring for fretting and cracking. Replace if necessary.

Check the rubber section of the drain line for deterioration.

Install

Apply a thin film of oil to the drain line o-rings.

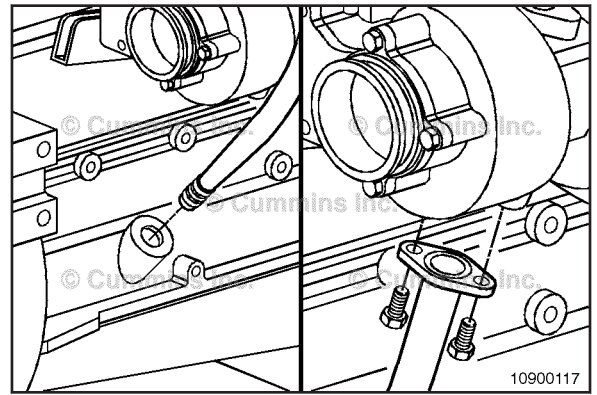
Push the drain line into the drain line boss. Be sure both o-rings are completely seated in the bore.

Install a new gasket.

Install and tighten the turbocharger oil drain line.

Torque Value: 27 N•m [20 ft-lb]

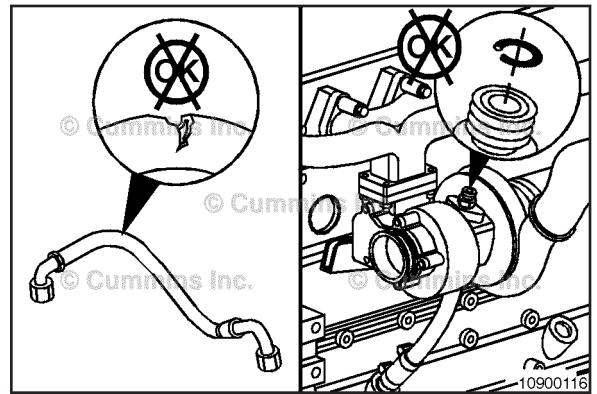
Operate the engine and check for leaks.



Turbocharger Oil Supply Line (010-046)

Initial Check

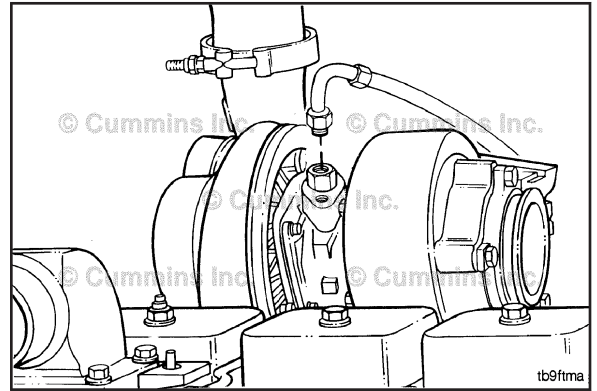
Inspect the line for oil leaks or damage. Replace as necessary.



Remove

Remove the oil supply line from the oil filter head (1).

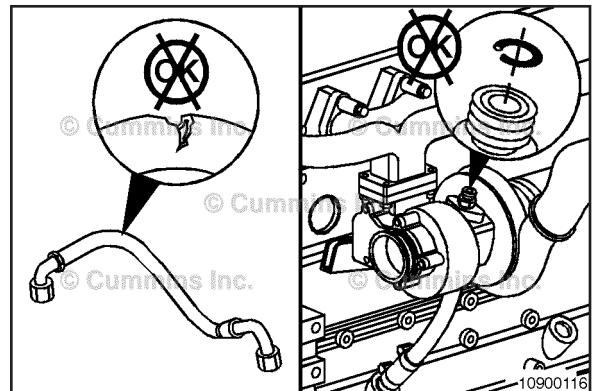
Remove the oil supply line from the turbocharger bearing housing (2).

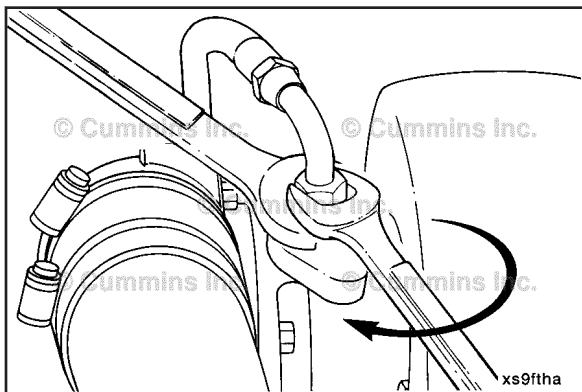


Inspect for Reuse

Inspect the line for cracks, wear, and damage.

Inspect o-rings for cracking and fretting. Replace as necessary.





Install

⚠ CAUTION ⚠



Maintain a minimum distance of 10 mm [0.39 in] between the oil supply line and the turbine housing or exhaust manifold, and 5 mm [0.20 in] between the oil supply line and other components to prevent oil line high temperature damage and chafing.



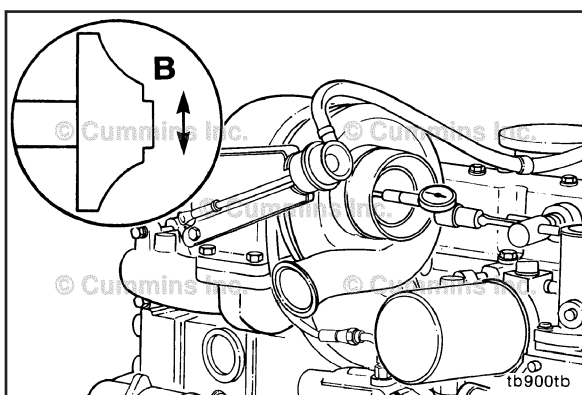
Apply a thin film of oil to the o-ring seals.

Fill the turbocharger oil inlet with clean oil.

Install the oil supply line at both the filter head and the turbo bearing housing.

Tighten the oil supply line to final torque.

Torque Value: 24 N•m [212 in-lb]



Turbocharger Radial Bearing Clearance (010-047)



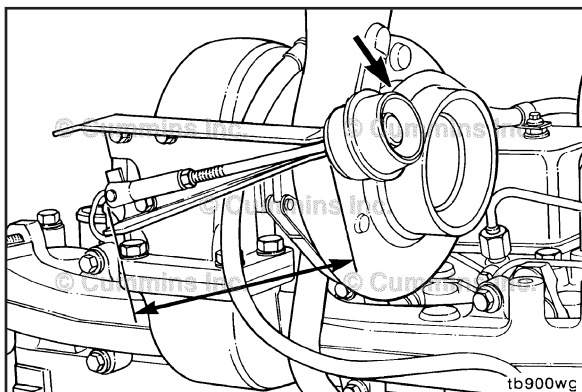
Measure

Measure the radial clearance of the shaft.

Turbocharger Radial Clearance (B)

mm		in
0.30	MIN	0.012
0.46	MAX	0.018

The turbocharger **must** be removed for replaced if the clearances are out of specification. Refer to Procedure 010-033.



Turbocharger Wastegate Actuator (010-050)

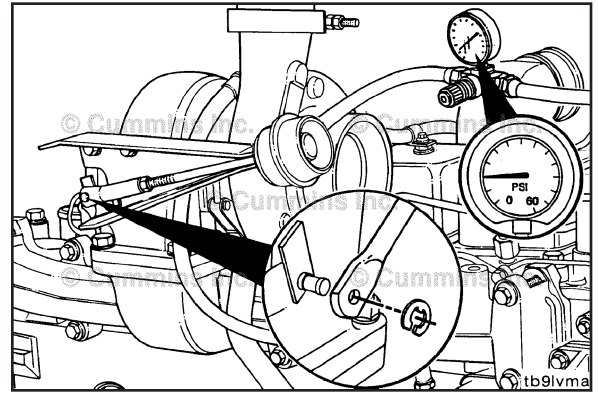
Remove

NOTE: Prior to removal, note the position of the control rod from the boost capsule housing and orientation of the boost capsule hose connector in relation to the mounting bracket.

Remove the retaining clip from the control lever.

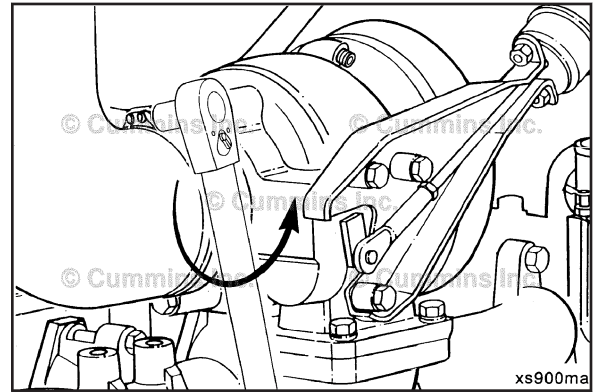
Disconnect the boost capsule actuator rod end from the turbocharger wastegate lever. This can be accomplished by applying regulated air pressure to the boost capsule in a sufficient amount to activate control rod movement.

Disconnect the control rod from the turbocharger wastegate lever pin.



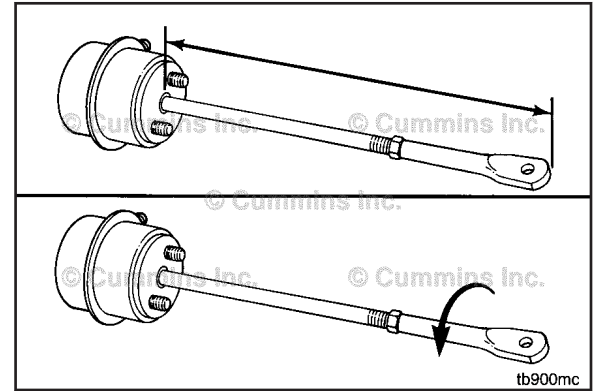
NOTE: If the boost capsule diaphragm material is ruptured and will **not** hold air pressure other than by hand, manually pull the control rod outward to overcome boost capsule spring tension for removal of the control rod from the turbocharger wastegate lever pin.

Loosen the boost capsule mounting capscrews, disconnect the air supply hose, and remove assembly from the mounting bracket.



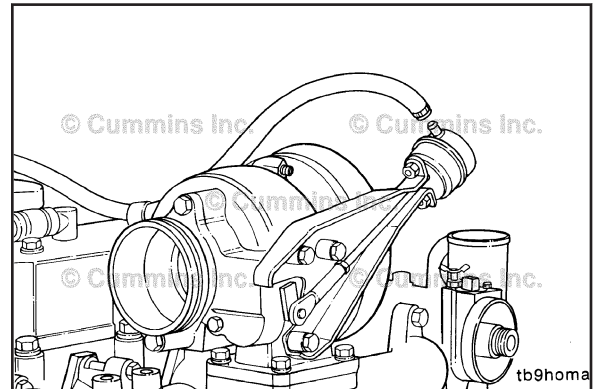
Record the length of adjusting link prior to removal.

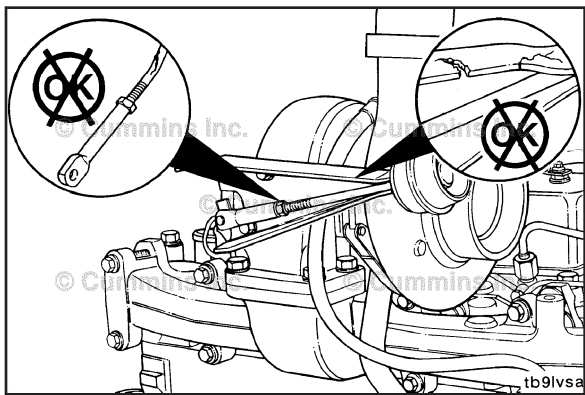
Loosen the nut and remove the adjusting link end from the boost capsule actuator.



Inspect for Reuse

Inspect the wastegate actuator hose for cracks or holes. Replace the hose if damaged.

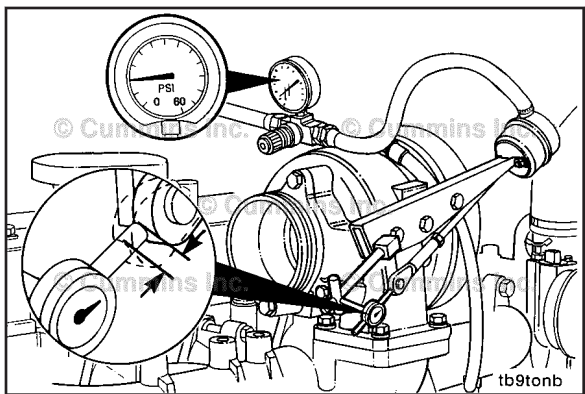




Inspect the wastegate mounting bracket, actuator rod, and lever for damage.

A bent wastegate mounting bracket, actuator rod, or lever can cause improper operation.

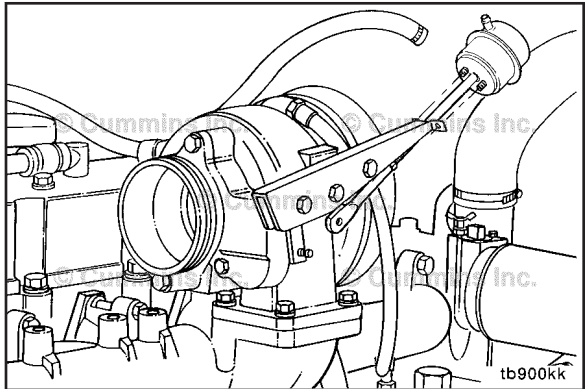
If the wastegate mounting bracket, actuator rod, or lever is bent, it **must** be replaced.



Pressure Test

Connect regulated air pressure and an accurate pressure gauge to the capsule. Apply 180 kPa [26 psi] to make sure the wastegate is functioning properly. The actuating rod **must** move approximately 5 mm [0.2 in] without any sticking or air leakage.

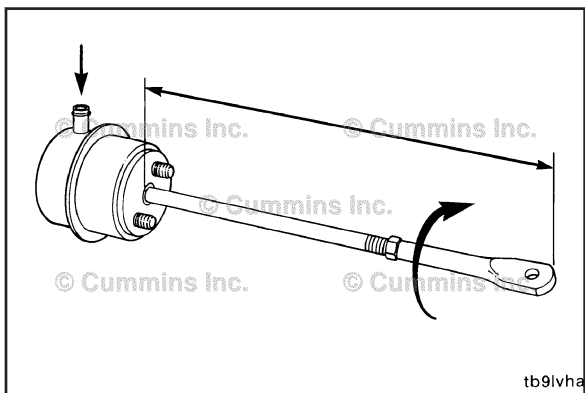
NOTE: A small amount of travel when air pressure is first applied is normal; the tolerance is being removed from the system.



Replace the actuator if no movement of the actuator rod and lever is detected.



If repair is **not** correct, refer to Turbocharger Wastegate Actuator - Calibration in this section.



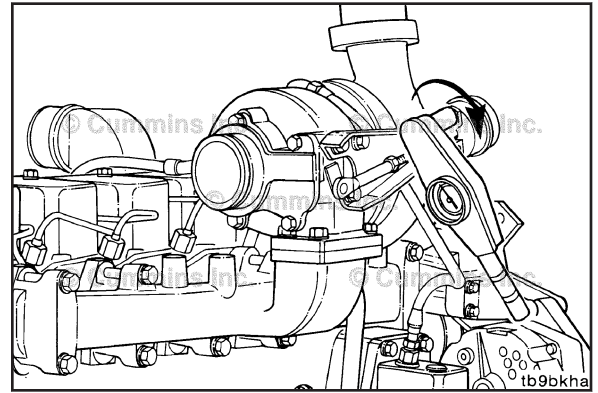
Install

Install the adjusting link end onto the boost capsule actuator assembly.

Adjust the rod to approximately the same length as when removed.

Fit the new boost capsule actuator assembly to the actuator mounting bracket, and install the mounting capscrews.

Torque Value: 4.5 N•m [40 in-lb]



Calibrate

NOTE: The wastegate is set accurately from the factory. Adjustment is **not** necessary unless the capsule is removed.

Connect clean, regulated air pressure to the boost capsule.

Regulate the air pressure to the wastegate capsule according to the following table.

Model Year	Rating (hp)	Application	Pressure (kPa)	Pressure (psi)
'96	190 to 230	Automotive	198	29

Measure the actuator travel:

Wastegate Actuator Travel Measurement

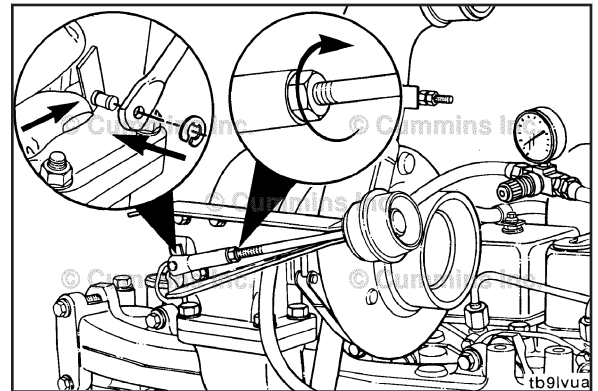
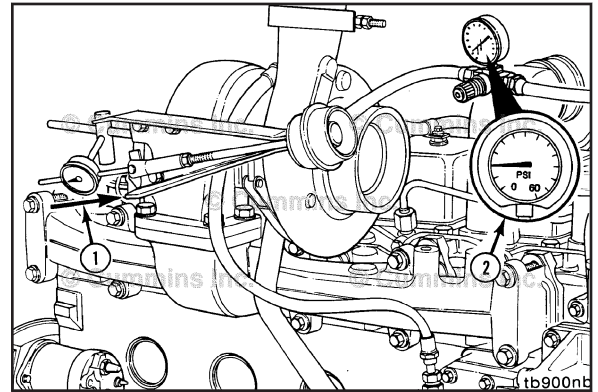
mm		in
0.33	MIN	0.013
1.30	MAX	0.051

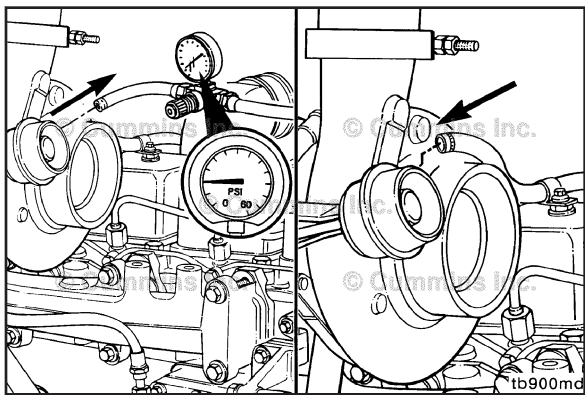
⚠ CAUTION ⚠

Do not pull, push, or force alignment of the clevis pin. This can damage the wastegate.

Adjust the wastegate, if necessary, to achieve specified travel.

- Pull the wastegate lever to the foremost closed position (lever toward boost capsule).
- Adjust the length of the clevis end of the control rod to where the clevis pin hole aligns to the wastegate lever.
- Install the adjusting link and retaining clip.
- After adjustment is complete, tighten actuator rod jam nuts.



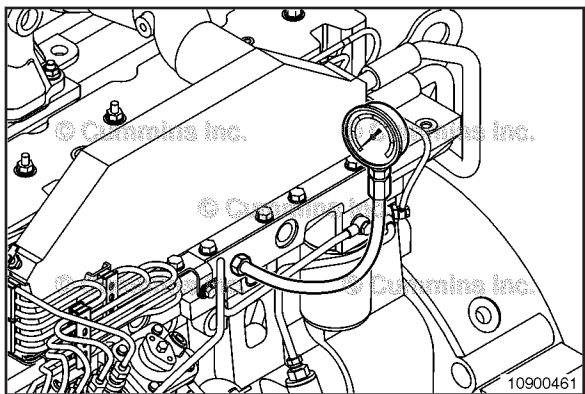


Disconnect the regulated air pressure line from the boost capsule.



Connect the turboboost line to the boost capsule, and secure with hose clamps.

NOTE: If possible, a more accurate method of wastegate adjustment is to inspect the manifold pressure at rated rpm.



Intake Manifold Pressure (010-057) Measure

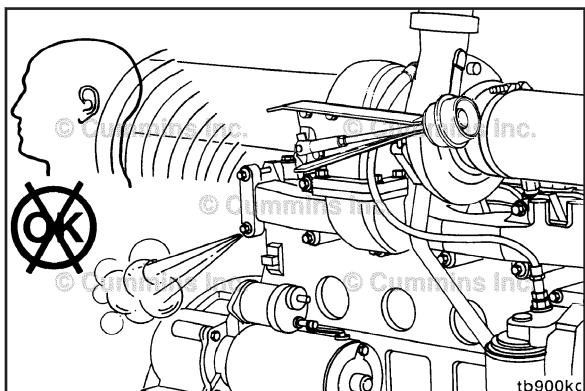


Measure boost pressure at the intake manifold. Use one of the tapped or plugged intake access holes shown in the illustration.

Refer to the specifications in Procedure 018-019 (Air Intake System) in Section V.

If the specifications for the engine are **not** listed, see the engine data sheet.

NOTE: If the engine has charge-air-cooling, the charge-air-cooler **must** be tested for leaks and turbocharger boost pressure restriction. Refer to Procedure 010-027 (Charge-Air Cooler) in Section 10 for charge-air-cooler testing.



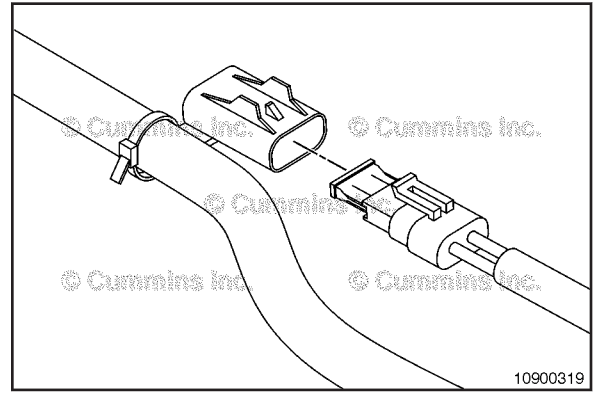
Exhaust leaks can typically be detected audibly, or visually by a discoloration caused by escaping hot gases.

Exhaust restriction can cause low power. If exhaust gases can **not** flow freely, the turbocharger will **not** operate efficiently.

Intake Manifold Air Heater Wiring Harness (010-122)

Initial Check

Remove and check the fuse in the power circuit to the heater control module.



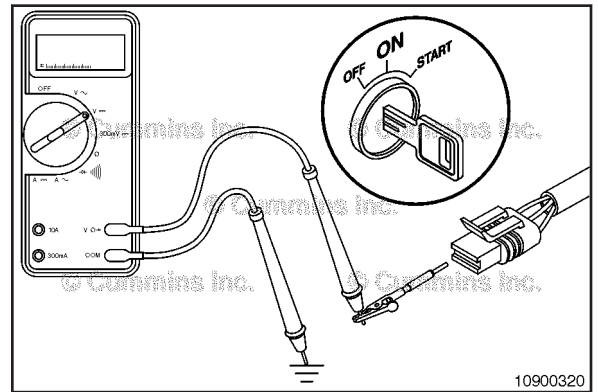
With the keyswitch in the ON position, verify the voltage from the keyswitch circuit to the fuse.



Voltage	
System	VDC
12-VDC	10.5 to 17
24-VDC	22 to 29

If no or low voltage is indicated, the wiring and connections from the keyswitch to the fuse holder **must** be checked.

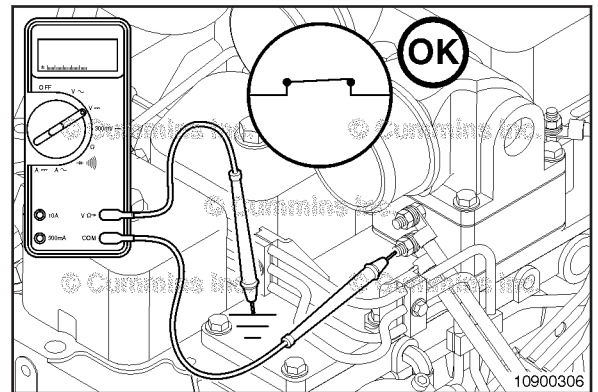
The air heater will **not** function properly unless the specified voltage is obtained.

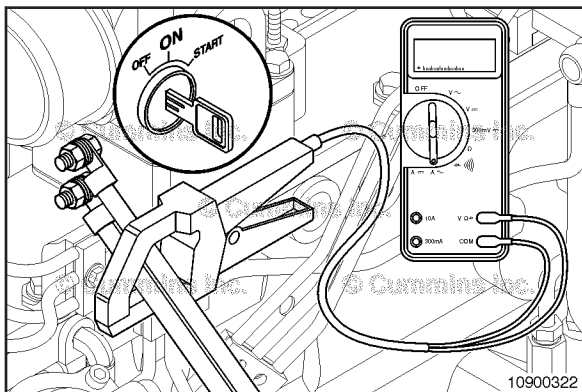


Voltage Check

Connect the positive lead of the multimeter to the air heater element terminals.

Ground the negative lead to a good known ground.





WARNING
Heater grids and studs can get hot enough to burn skin.



CAUTION
Do not recycle the keyswitch repeatedly in a short period of time. This may cause damage to the grids or the wiring.

Attach a multimeter to the heater element wires.

Clamp the multimeter current probe around both wires to the air heater.

The following test will **only** last up to 20 seconds. Refer to the preheat cycle time in the General Information section.

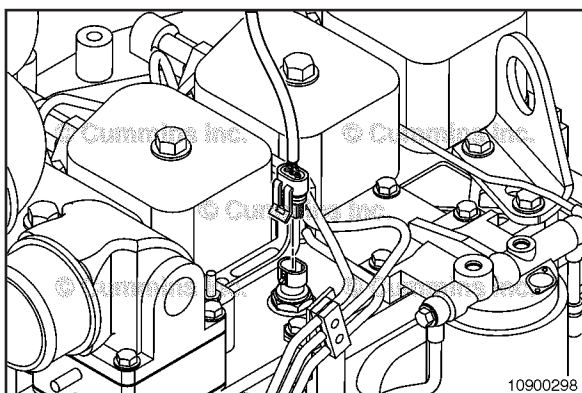
System Voltage	Voltage Range	Amperage Range
12	10.5 to 17	80 to 110 (1 grid)
12	10.5 to 17	160 to 220 (2 grids)
24	22 to 29	80 to 110

Turn the keyswitch to the ON position. Do **not** crank the engine.

Record both the voltage and amperage readings.

The keyswitch **must** be turned OFF and ON again in order to recycle.

Voltage and amperage readings **must** be within the specified limits.



If no voltage is detected, disconnect the intake temperature sensor.

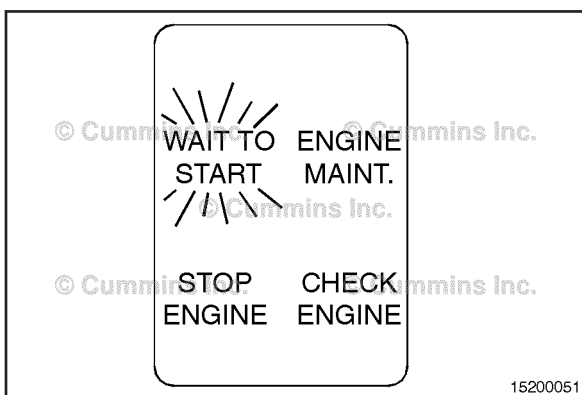


Disconnecting the intake temperature sensor simulates intake manifold temperature of less than 0°C [32°F]. This overrides the temperature circuit if the intake manifold temperature is too hot to allow the heater to turn on.

Turn the keyswitch OFF, then ON again.

Recheck the voltage and ampere readings.

Refer to Section E for the sensor location.



Verify the preheat cycle. After 20 seconds the voltage and amperage should drop to zero when the cycle ends.

The WAIT TO START lamp, if equipped, will stay on for 20 seconds. After 20 seconds, the lamp will begin to flash indicating the heater cycle has turned off. The lamp will continue to flash as long as the intake temperature sensor is disconnected indicating an open circuit.

C Series
Section 10 - Air Intake System - Group 10

If no voltage is detected at the heater grid with the intake temperature sensor disconnected, check the voltage to the solenoid.



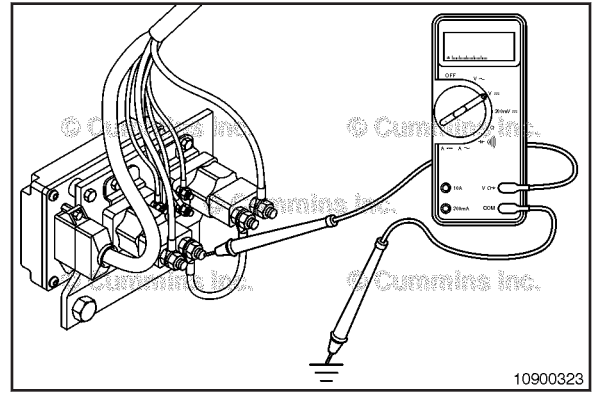
Connect the multimeter and check the supply voltage to the solenoid secondary circuit (large terminal).



If no voltage is present, repair the wiring to the solenoid.

If voltage is present, check the solenoid.

Refer to Procedure 010-126, Intake Manifold Air Heater Solenoid Switch.

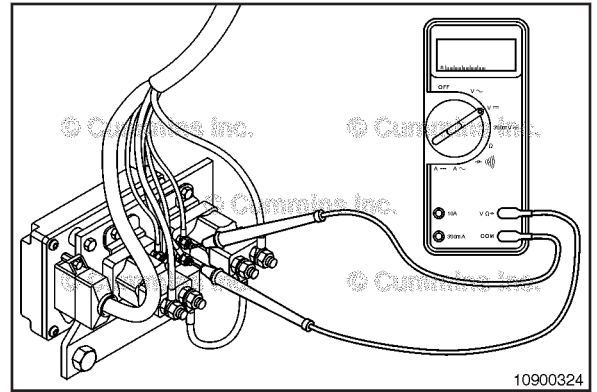


Check the voltage on the primary side of the solenoid, small terminal to small terminal.



If no voltage is present, check the ground.

If voltage is present at both terminals, replace the solenoid.

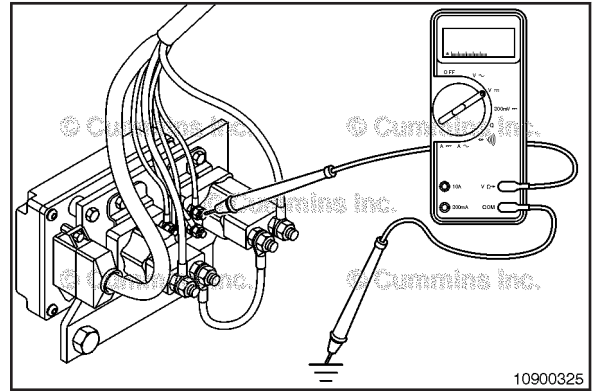


Check the voltage from the solenoid positive primary circuit to a good known ground.



If no voltage is present, check the voltage to the heater control module.

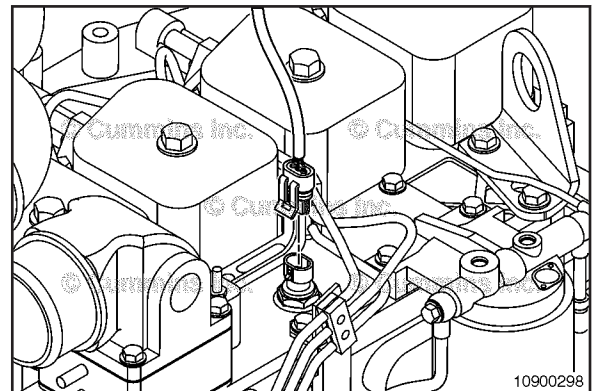
If voltage is present, restore the ground to the solenoid.

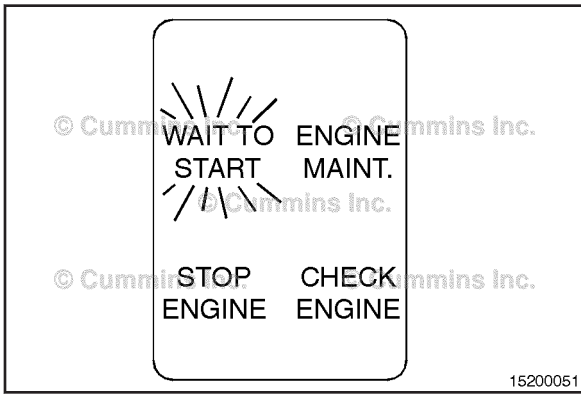


The solenoid and heater control module share the same ground.



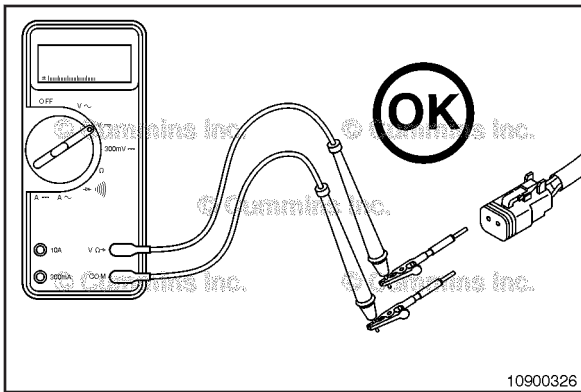
Check the wire or clean the connectors.





Check the voltage to the heater control module.

The WAIT TO START lamp, if equipped, will stay on if there is no voltage to the heater control module.

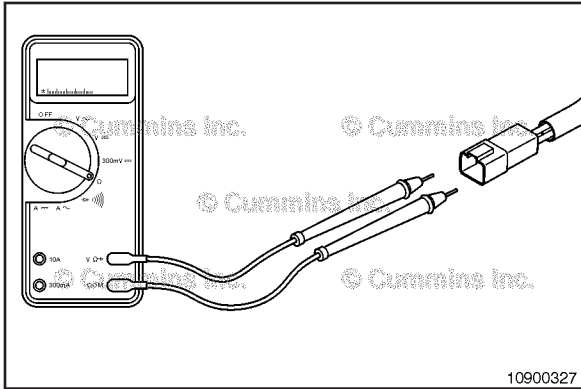


If there is no WAIT TO START lamp, check the voltage at the resistor in the supply wire from the fuse to the heater control module.



If no voltage is present, repair the wiring harness.

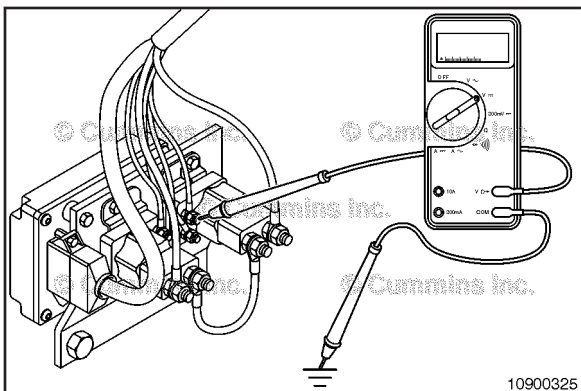
Refer to the wiring diagram.



If voltage is present, check the resistor with an ohmmeter.

Replace the resistor if necessary.

Resistance: 15.8k ohms at 12-VDC



Check the voltage at both positive leads at the connection to the heater control module.

If voltage is **not** present, repair the wiring harness.

If voltage is present, replace the heater control module.

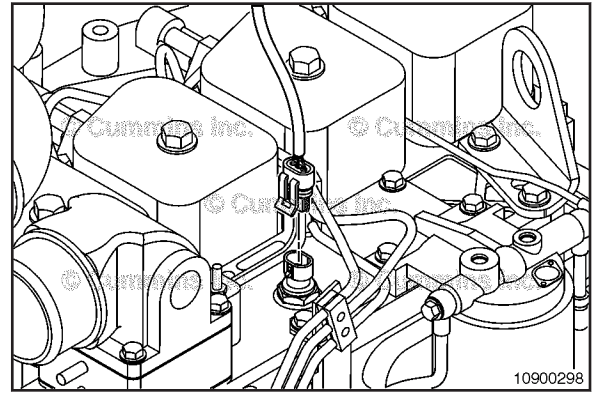
Intake Manifold Air Heater Temperature Sensor (010-123)



Initial Check

The intake air temperature sensor is located in the intake manifold.

Disconnect the harness connector from the temperature sensor.



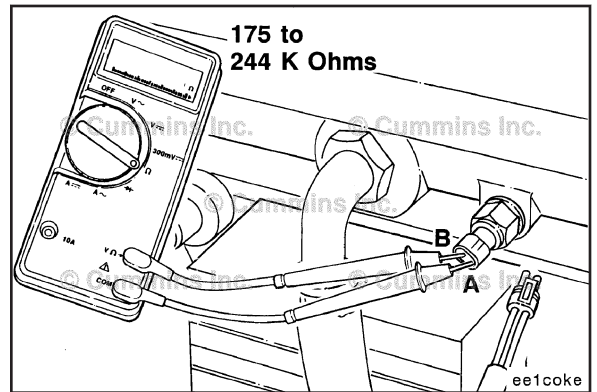
Resistance Check

Use an ohmmeter to measure the resistance between the two pins of the intake air temperature sensor.

If the resistance is **not** correct, replace the sensor.

If the resistance is correct, the sensor **must** be checked for a short to ground.

The resistance value is temperature-dependent.

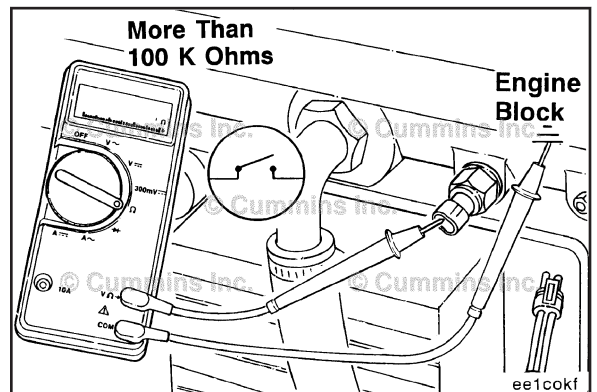


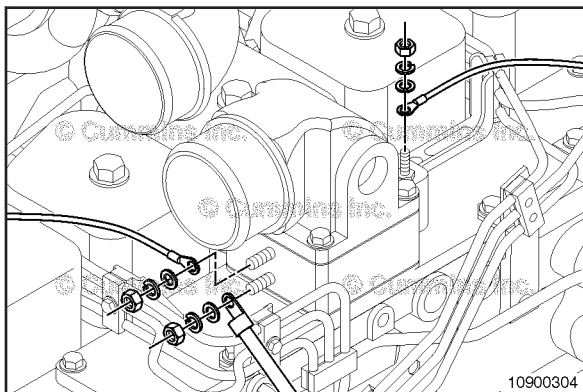
Temperature (°C)	Temperature (°F)	Acceptable Resistance Range (ohms)
0	32	30k to 36k
25	77	9k to 11k
50	122	3k to 4k
75	167	1350 to 1500
100	212	600 to 675

Measure the resistance from each pin of the intake air temperature sensor to the engine block.

The ohmmeter **must** show an open circuit (more than 100k ohms).

If the circuit is **not** open, replace the sensor.

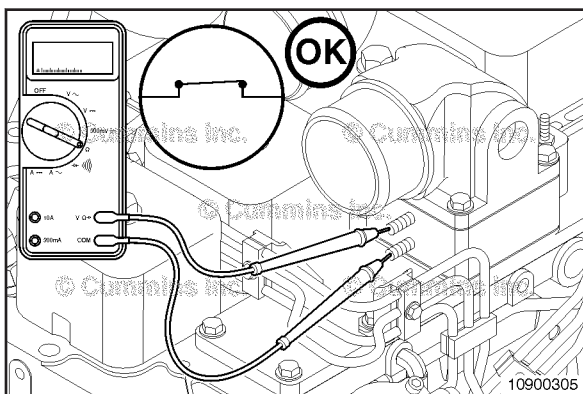




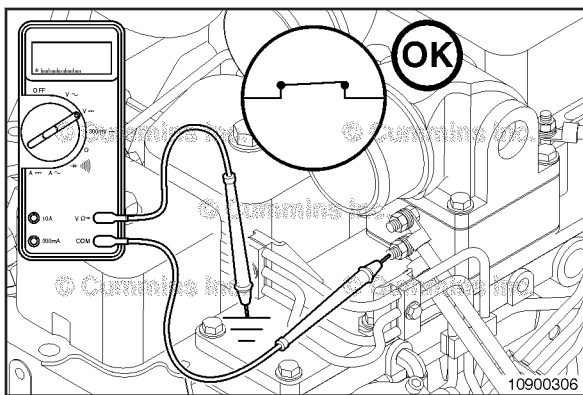
Intake Manifold Air Heater Element (010-124)

Resistance Check

Disconnect the ground cable from the battery. Remove all wires from the intake manifold air heater.



Use an ohmmeter to check the resistance across both terminals.

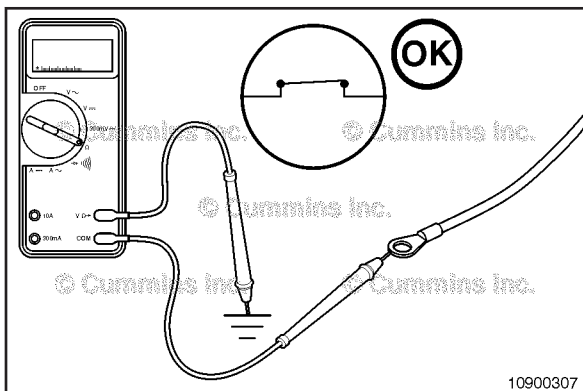


Use an ohmmeter to check the resistance from the ground of each positive heater terminal.

The resistance should indicate zero ohms.

If high ohms are indicated, inspect and clean or repair all heater electrical connections and grounds and recheck for zero ohms.

- A. Meter reads zero = good heater (both elements)
- B. Meter does **not** move = defective heater
- C. Meter indicates, but **not** zero = dirty or corroded connections. Clean and repair, as necessary.

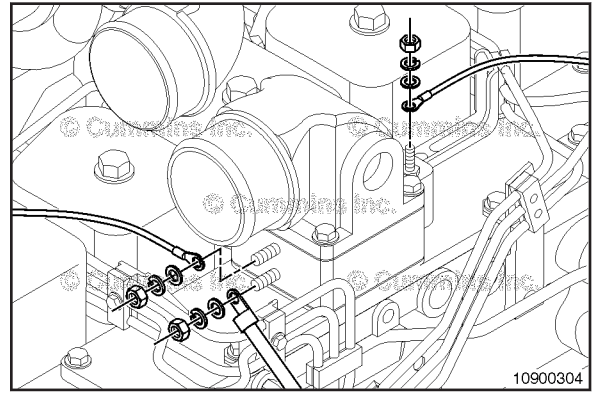


Check the resistance from the ground wire to a known good ground.

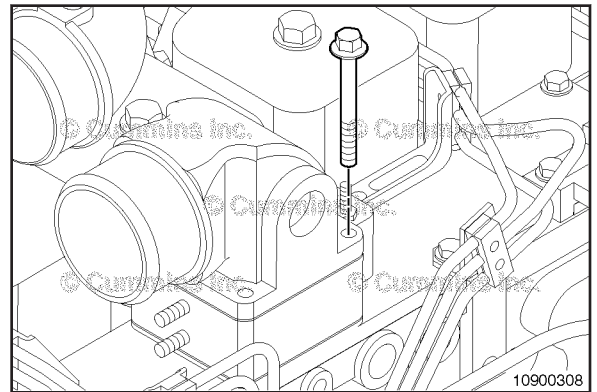
The reading should be less than 10 ohms. If **not**, replace the heater ground wire.

Remove

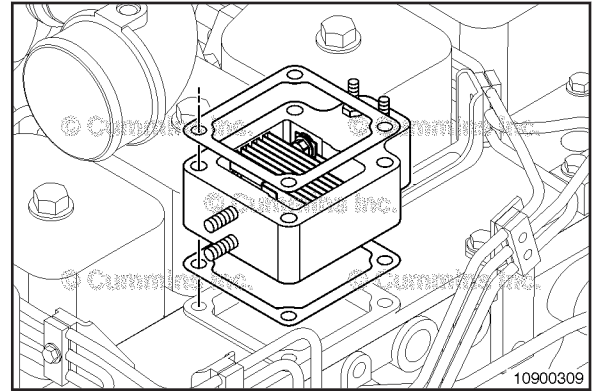
Remove all three electrical leads from the intake manifold heater.



Remove the four capscrews that attach the air-crossover connection and heater.

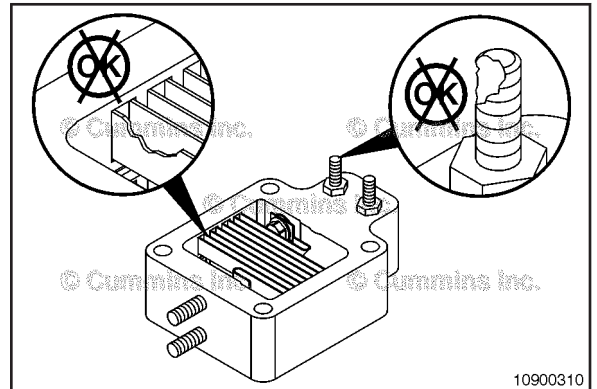


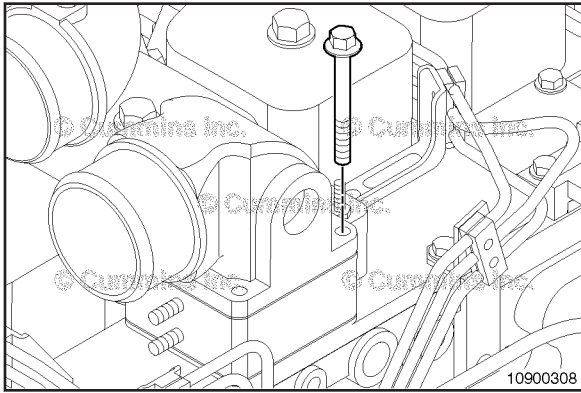
Remove the heater and gaskets.
Clean the mounting surface.



Inspect for Reuse

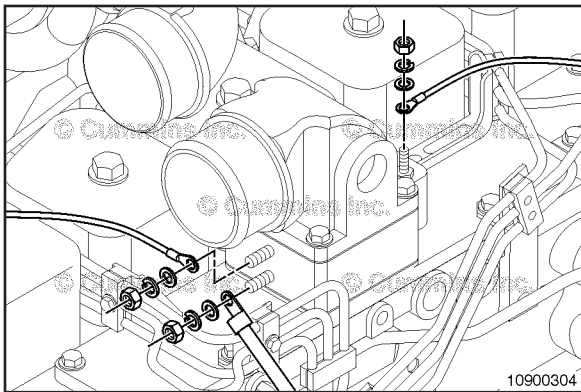
Check the intake manifold heater leads and grids for corrosion and damage.



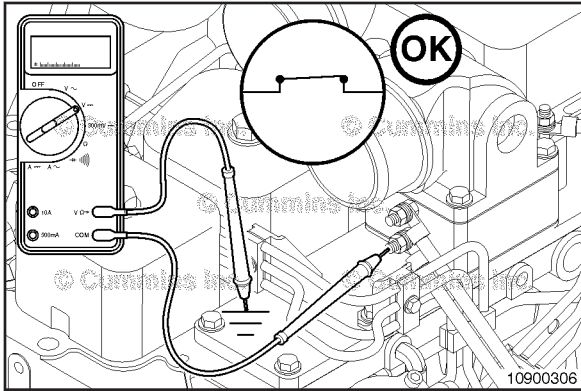


Install

Install new gaskets and the intake manifold heater.
Install the four cap screws and the single black (ground) heater lead.



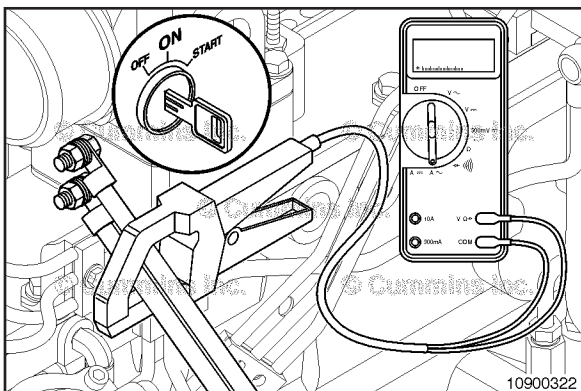
Install the intake manifold heater leads on the terminals.



Intake Manifold Air Heater Control Module (010-125)

Initial Check

Connect the positive lead of the multimeter to the heater terminals.
Ground the negative lead to the engine block.



Attach a multimeter to the heater wires.
Clamp the ammeter current probe around both wires to the air heater.
Turn the keyswitch to the ON position, but do **not** start the engine.

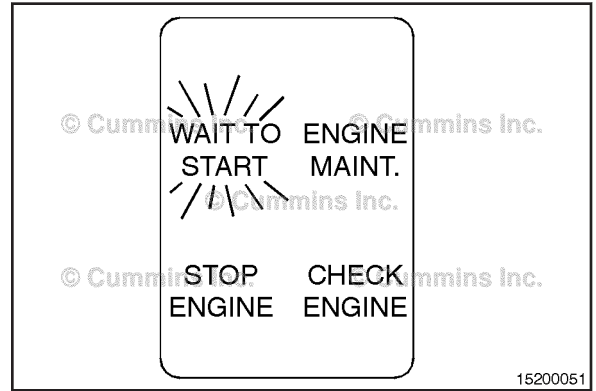
If there is no voltage to the heater control module, check the system voltage. Refer to Procedure 010-122.

The air heater will preheat as long as the intake manifold temperature is below 35°C [95°F].

This will repeat each time the keyswitch is turned from the OFF to the ON position.

The multimeter and ammeter should indicate the cycle for proper voltage and amperage.

Refer to the Intake Manifold Air Heater System General Information in Section F to verify the proper cycle.



15200051

If no voltage was detected, disconnect the intake temperature sensor.

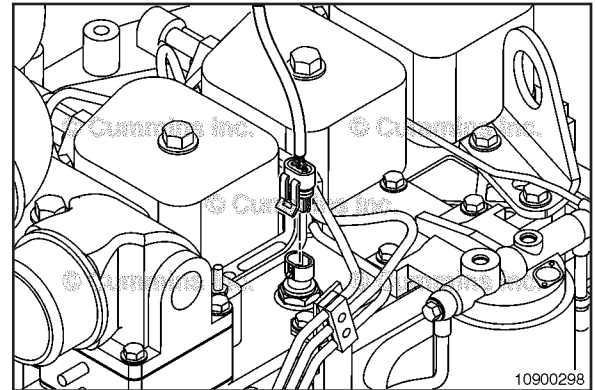
Disconnecting the intake temperature sensor simulates an intake manifold temperature of less than 0°C [32°F].

This overrides the temperature circuit if the intake manifold temperature is too hot to allow the heater to turn on.

Turn the keyswitch OFF, then ON again.

Recheck the voltage and ampere readings.

Refer to Section E for the sensor location.



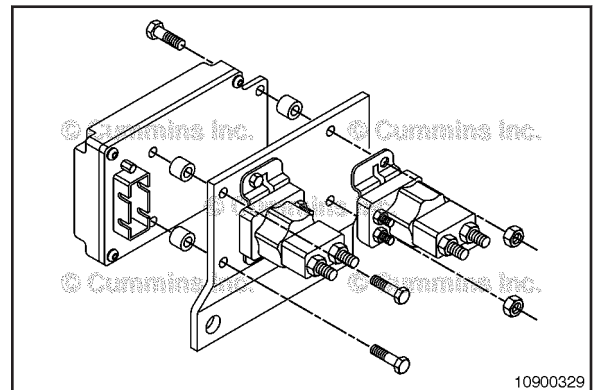
10900298

System Voltage	Voltage Range	Amperage Range
12	10.5 to 17	80 to 110 (1 grid)
12	10.5 to 17	160 to 220 (2 grids)
24	22 to 29	80 to 110

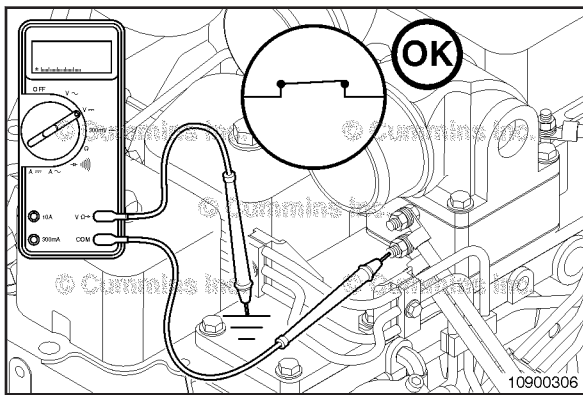
If no voltage and no amperage are detected, check the following:

- Intake air heater solenoid switch, refer to Procedure 010-126
- Intake manifold air heater element, refer to Procedure 010-124.

If all systems check out properly and the preheat does **not** cycle according to the heater cycle chart, replace the heater control module.

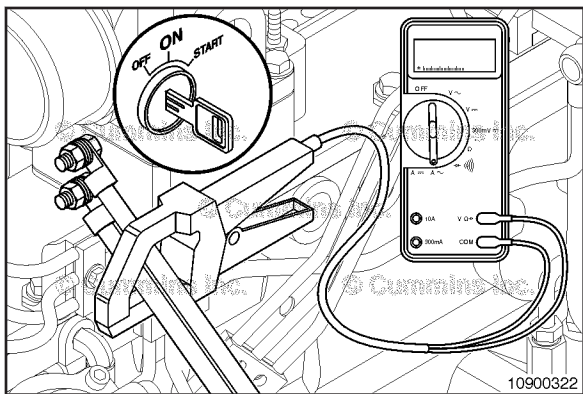


10900329

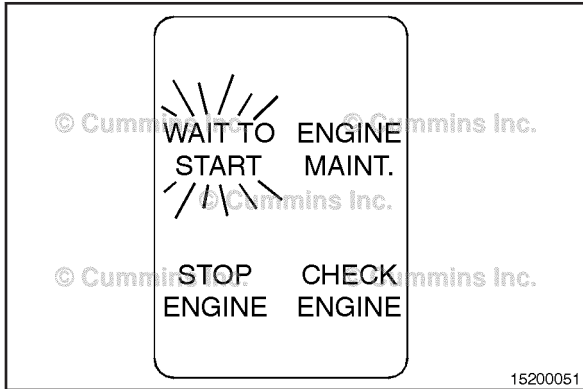


Post Heat Cycle

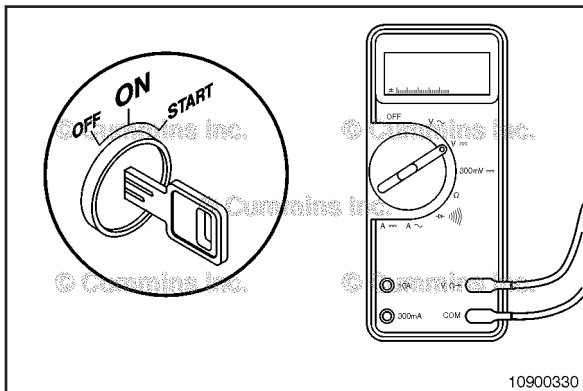
Connect the positive lead of the multimeter to the heater element terminal.
Ground the negative lead to the engine block.



Attach a multimeter to the heater wires.
Clamp the ammeter current probe around both wires to the air heater.



Before starting the engine, allow the preheat cycle to operate.



Start the engine.

Verify the voltage and amperage are cycling on and off according to the Heater Cycle Chart for Post Heat Cycle.



Refer to the Intake Manifold Air Heater System General Information in Section F to verify the proper cycle.

The intake manifold temperature **must** be below 35°C [95°F] for the air heater to operate.

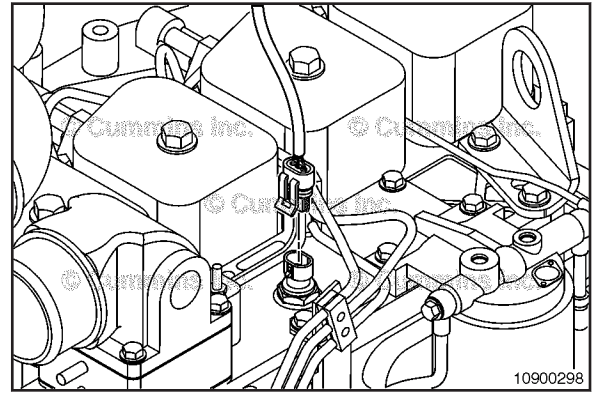
If no voltage is detected, disconnect the intake manifold air temperature sensor.

Disconnecting the temperature sensor simulates intake manifold temperature of less than 0°C [32°F]. This overrides the temperature circuit if the intake manifold temperature is too hot to allow the heater to turn on.

Turn the keyswitch OFF, then ON again.

Recheck the voltage and ampere readings.

Refer to Section E for the sensor location.



System Voltage	Voltage Range	Amperage Range
12	10.5 to 17	80 to 110 (1 grid)
12	10.5 to 17	160 to 220 (2 grids)
24	22 to 29	80 to 110

Post heat cycle is dependent on temperature, voltage, and rpm. All **must** be in the specified normal operating range.

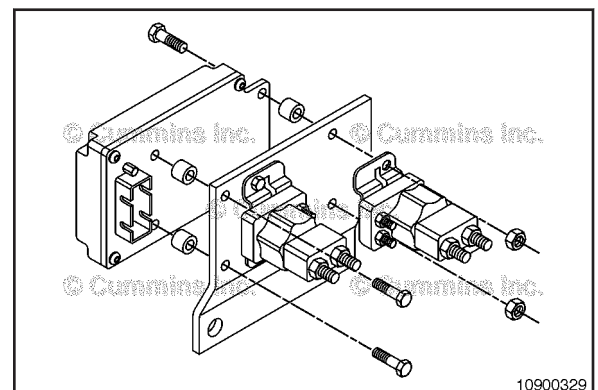
If the intake manifold temperature, voltage, or engine rpm exceed system parameters prior to the 20 second time cycle completion, the system will reset and a new 20 second heat cycle will begin.

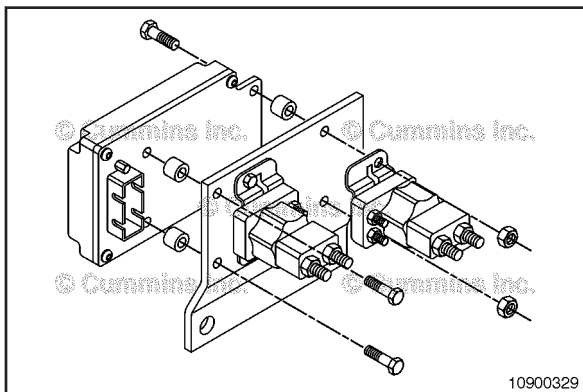
Refer to the Intake Manifold Air Heater System General Information in Section F to verify the proper cycle.

If no voltage and no amperage are detected, check the following:

- Engine rpm is in the correct range
- Intake manifold air heater system voltage, refer to Procedure 010-122
- Intake air heater solenoid switch, refer to Procedure 010-126
- Intake manifold air heater element, refer to Procedure 010-124.

If all systems check out properly and the post heat does **not** cycle according to the heater cycle chart, replace the heater control module.





Post Heat Recycle

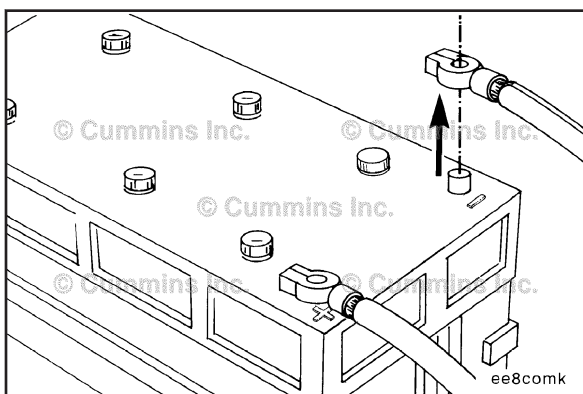
If the intake manifold temperature, voltage, or engine rpm exceeds the test parameters prior to 20 minutes time cycle completion, the system will reset and a new 20 minute post heat recycle will be available.

Perform these checks with the engine running under the same engine rpm, intake manifold temperature, and voltage condition as during the post cycle check.

The post heat recycle will operate for 20 minutes, then shut off. Refer to the Intake Manifold Air Heater System General Information in Section F to verify the proper cycle.

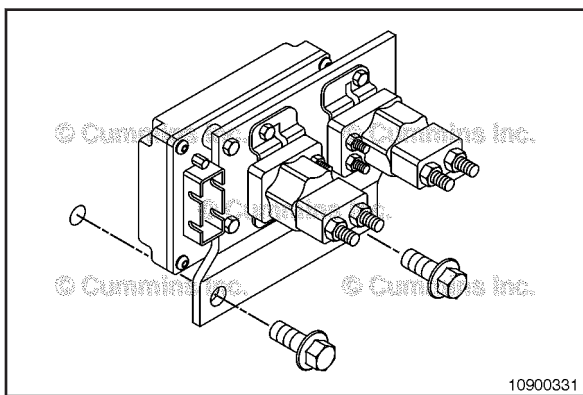
Verify that the heater control module is functioning to the known temperature value being simulated for the intake manifold sensor.

If the system is **not** operating at these known values, replace the heater control modules.



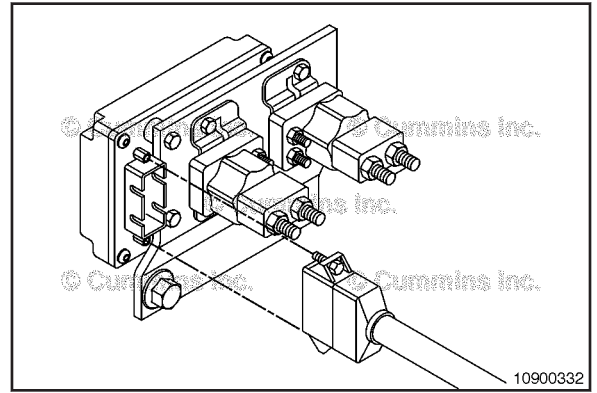
Remove

Disconnect the ground cable from the battery terminal.

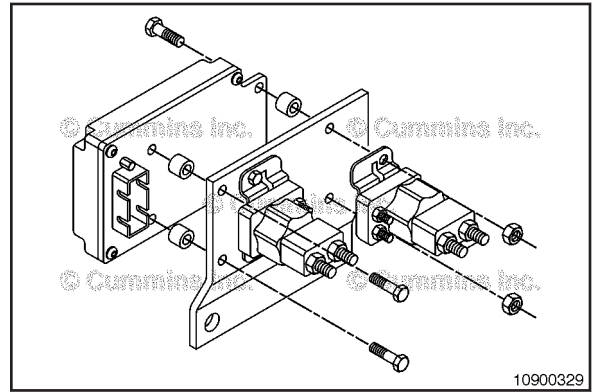


Remove the two mounting capscrews that hold the bracket to the engine block.

Remove the plug from the heater control module.

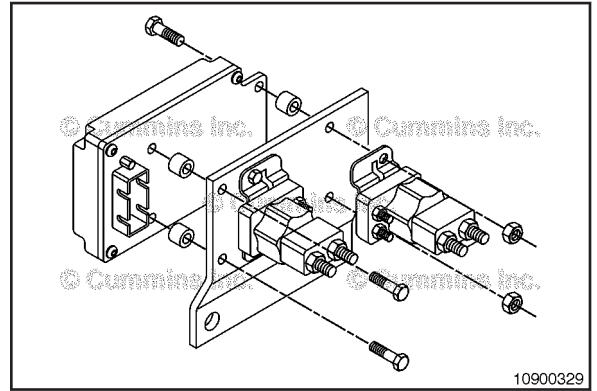


Remove the nut from the top right solenoid bracket.
Remove the heater control module mounting capscrews and spacers.

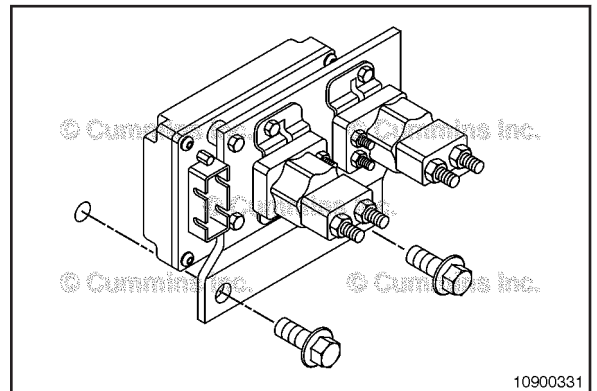


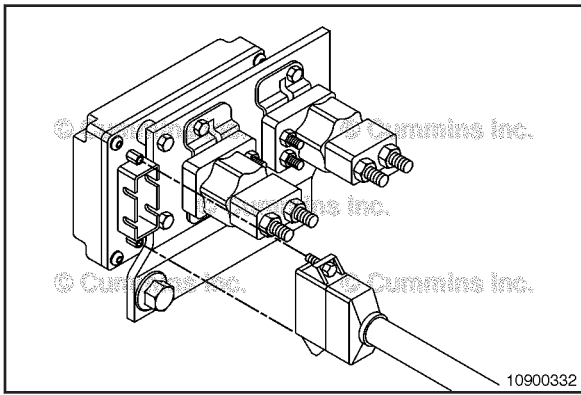
Install

Install the new heater control module on the bracket.

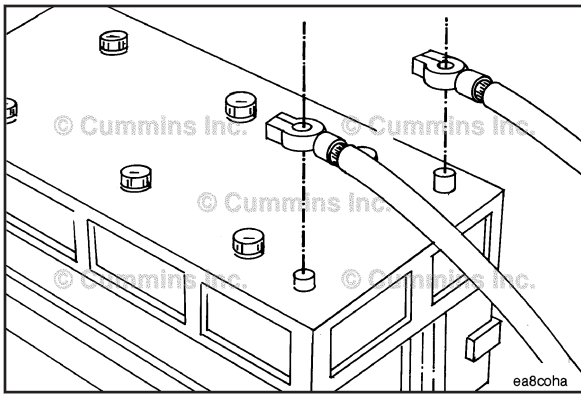


Install the bracket on the engine block.

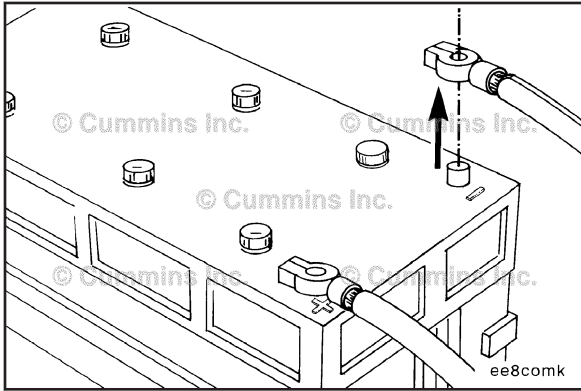




Install the heater control module plug.
Torque the hold down screws hand tight.

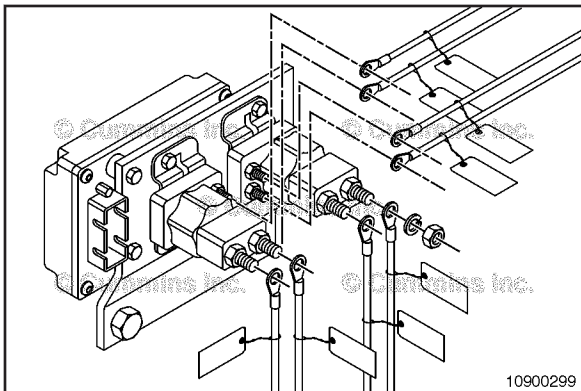


Connect the ground cable to the battery terminals.



Intake Manifold Air Heater Solenoid Switch (010-126) Resistance Check

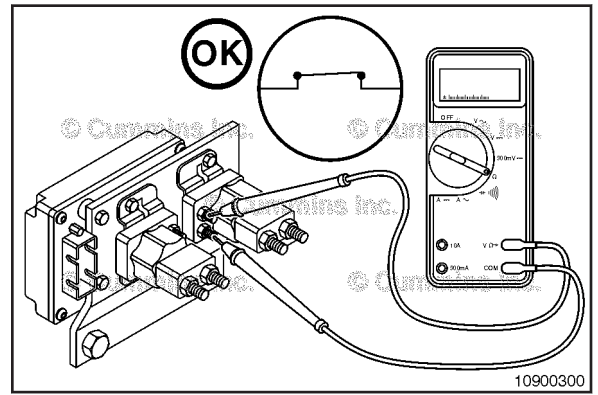
Disconnect the ground cable from the battery terminal.



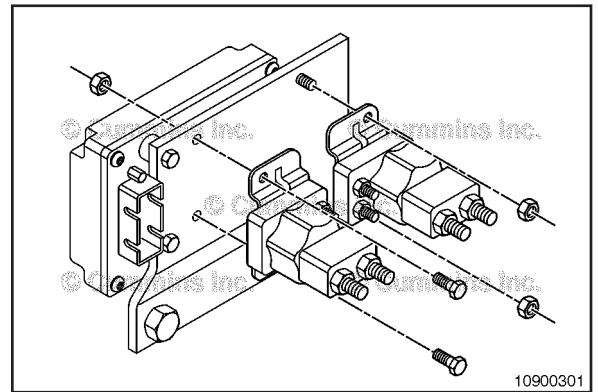
Label and remove the leads on the air heater solenoid(s) to be tested.

Use an multimeter to check the continuity between the small terminals at the base of the solenoid.

Continuity: 50 to 100 ohms

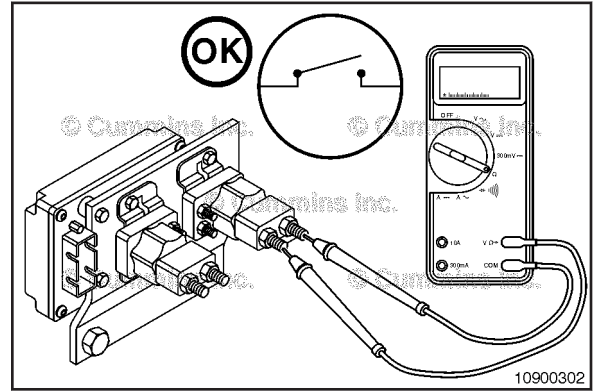


If the circuit is open, replace the solenoid.

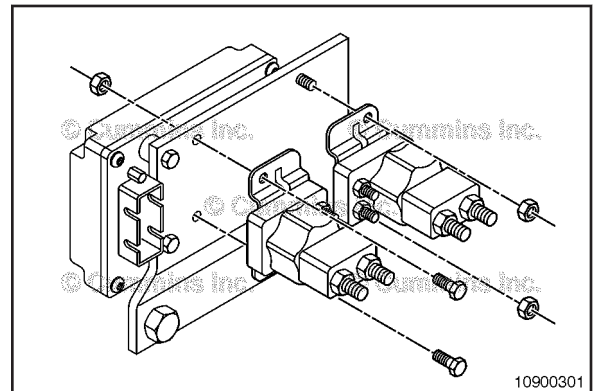


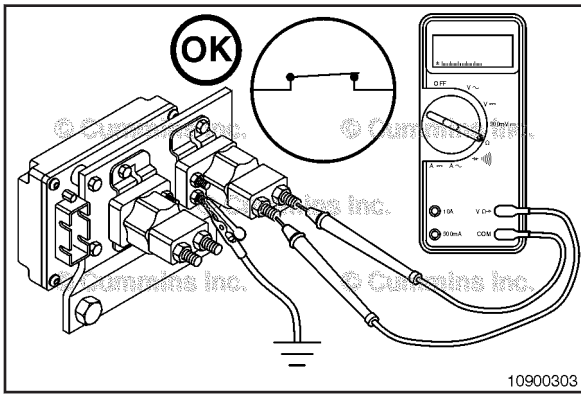
Check for continuity between the two large terminals on the top of the solenoids.

The multimeter should indicate an open circuit.



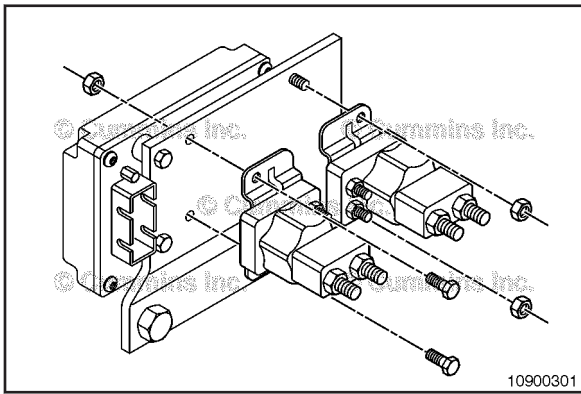
If any resistance or continuity is detected, replace the solenoids.



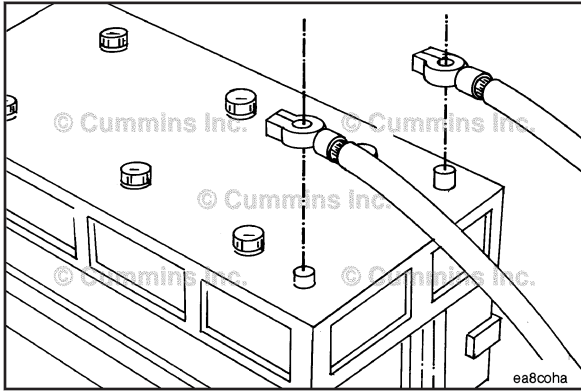


Test

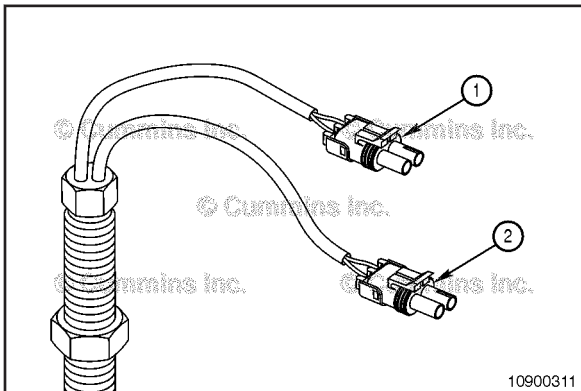
Check the solenoid for proper operation.
Connect an multimeter to the two large terminals.
Ground one of the small terminals to the battery ground.
Apply system voltage to the other small terminal.
The multimeter should indicate zero ohms.



If the multimeter detects an open circuit, replace the solenoid.



Reconnect the ground cable to the battery terminal.



Intake Manifold Air Heater Speed Sensor (010-127)

Initial Check

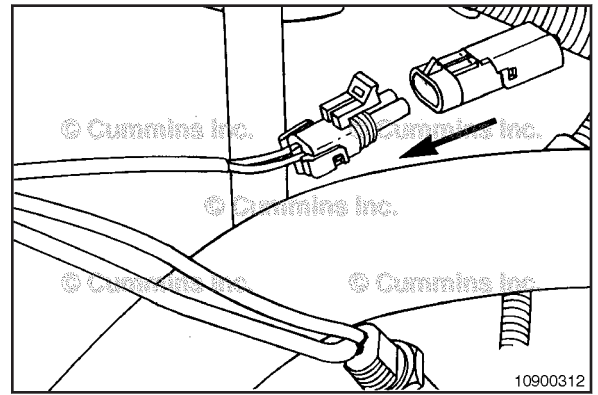
There are two connections coming from the sensor, one is for the engine tachometer and the other is for the air intake heater system.

1. White and green: to engine wiring harness
2. Red and black: to air heater control harness.

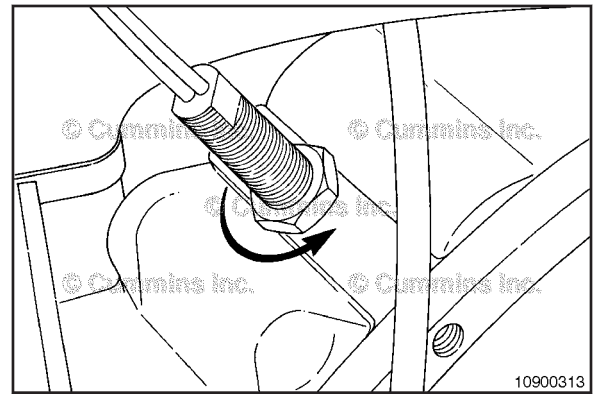
Check to verify they are connected.

Remove

Disconnect the engine speed sensor from the engine wiring harness.



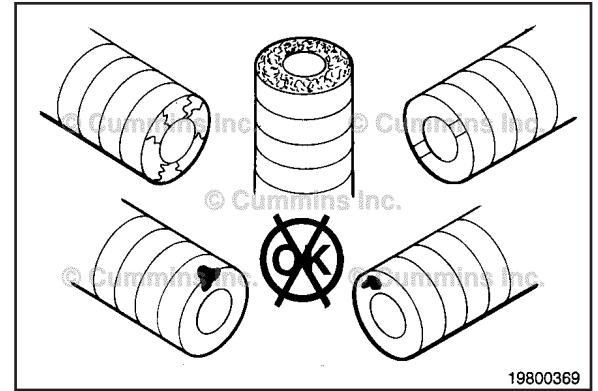
Remove the sensor from the flywheel housing.



Inspect for Reuse

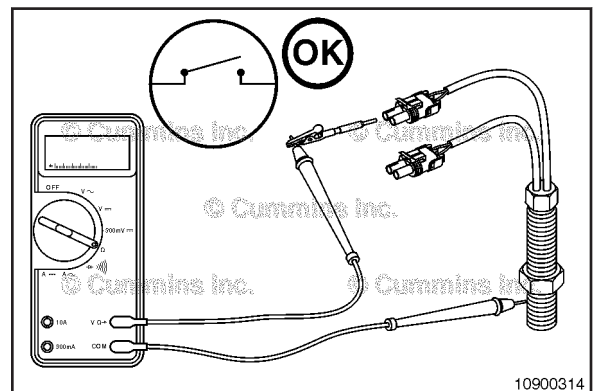
Inspect the engine speed sensor for debris, cracked or chipped potting, and damage from contact with the flywheel.

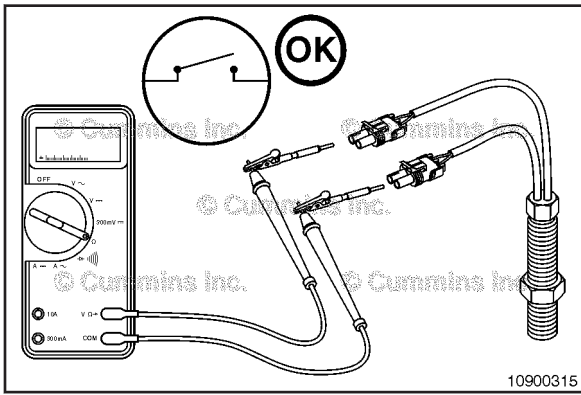
Clean or replace the engine speed sensor if necessary.



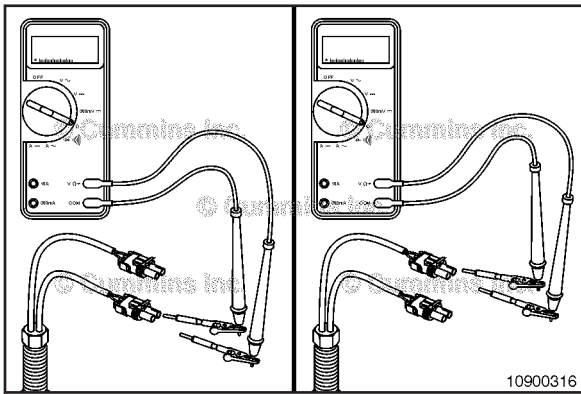
Test

1. Short Circuit to Ground: Measure the resistance of each connector (Pin A or B) of both circuits to ground (sensor body) with a multimeter. The multimeter **must** show an open circuit (100k ohms or more). If fewer than 100k ohms are measured, there is a short circuit to the sensor. Replace the sensor.



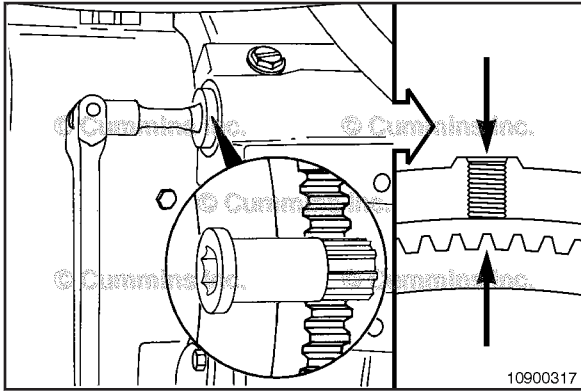


2. Short Circuit Between Coils: Check the resistance between connectors (Pin A to Pin A and Pin B to Pin B) with a multimeter. The multimeter **must** show an open circuit (100k ohms or more). If fewer than 100k ohms are measured, there is a short circuit in the sensor. Replace the sensor.



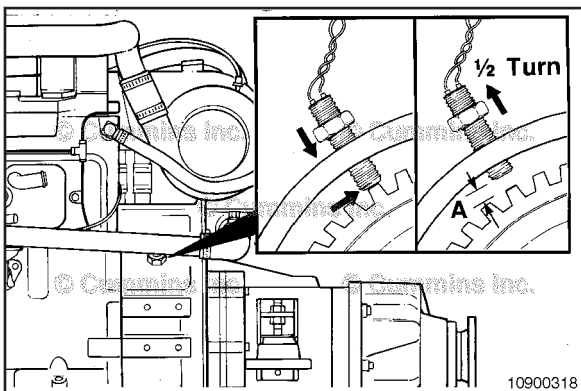
3. Coil Resistance: Check the resistance between the pins of each connector (Pin A to Pin B).

Resistance Specification	
First coil	750 to 1100 ohms
Second coil	1100 to 1500 ohms



Install

Use a barring gear, Part Number 3377371, to rotate the crankshaft so that a ring gear tooth is at the center of the hole for the engine speed sensor.



Insert the engine speed sensor and turn it until the end touches the ring gear tooth.

Back off a half turn and tighten the locknut while holding the engine position sensor.



Torque Value: 34 to 47 N·m [25 to 35 ft-lb]

Overtightening will damage the sensor.

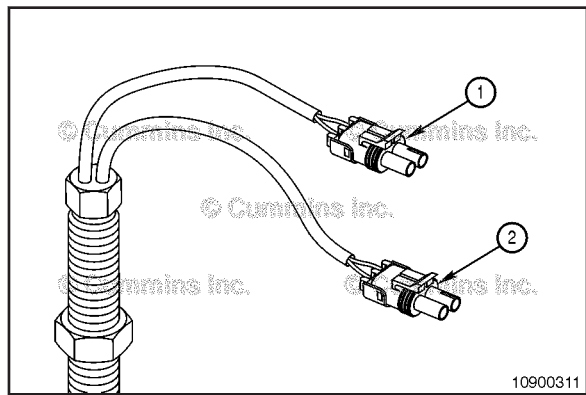
C Series
Section 10 - Air Intake System - Group 10

Install the engine speed sensor receptacle with red and black leads on the air intake heater control harness plug.



The white and green wire plug is connected to the wiring harness for the tachometer sensing.

1. White and green: to engine wiring harness
2. Red and black: to air heater control harness.



Section 11 - Exhaust System - Group 11

Section Contents

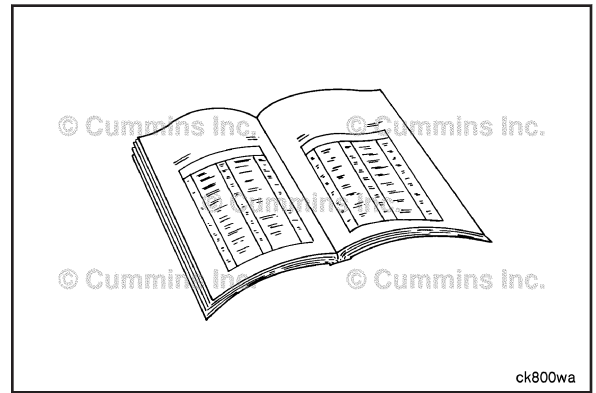
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Exhaust Manifold, Dry (011-007)

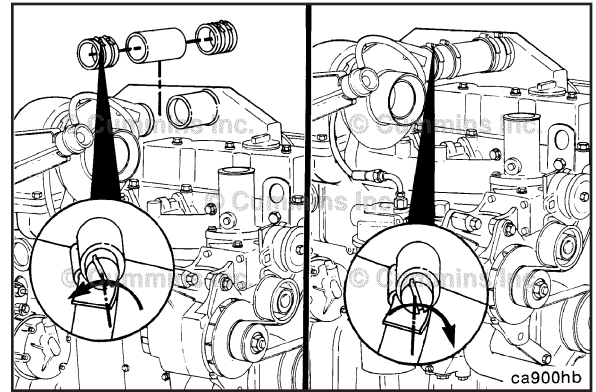
Preparatory Steps

Disconnect the batteries. Refer to Procedure 013-009 in Section 13.



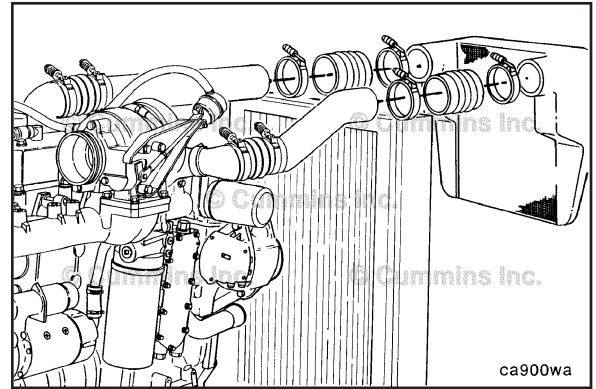
Remove

Remove the air crossover tube, if equipped. Refer to Procedure 010-019 in Section 10.

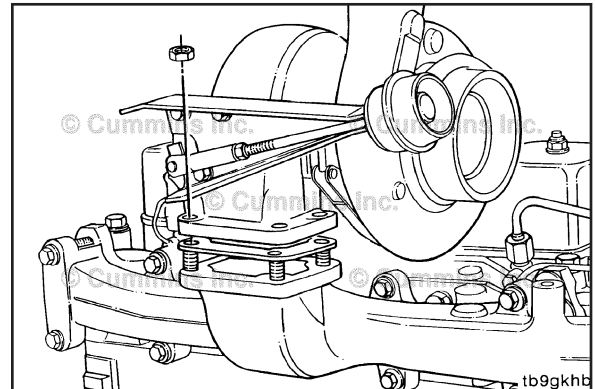


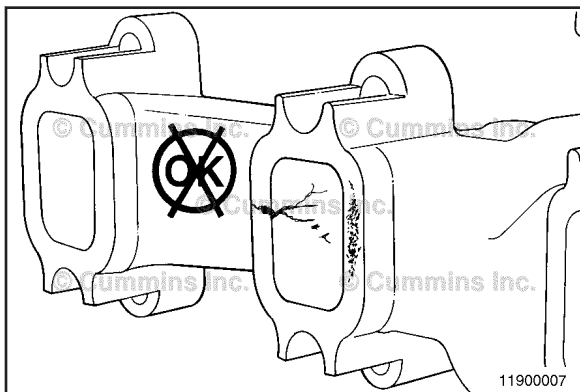
Disconnect the charge-air cooler hoses, if equipped. Refer to Procedure 010-027 in Section 10.

Disconnect the air intake and exhaust piping. Refer to the OEM service manual.



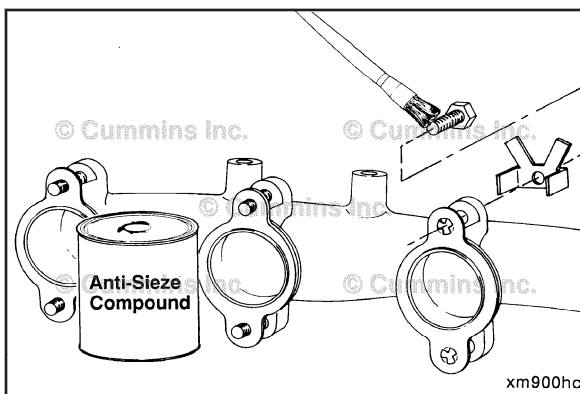
Remove the turbocharger, if equipped. Refer to Procedure 010-033 in Section 10.





Inspect for Reuse

Inspect the exhaust manifold for cracks, burnout, or damaged threads in the bosses.

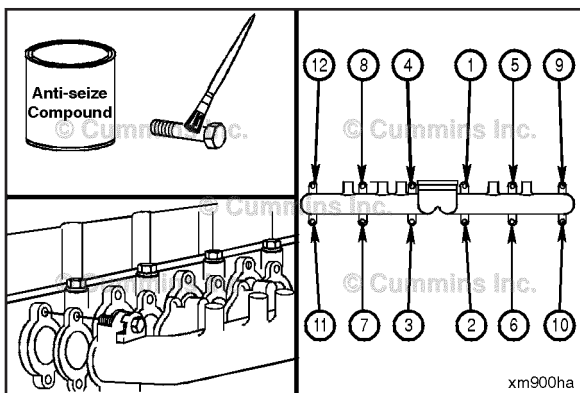


Install

Assemble the exhaust manifold capscrews, lock plates, and new gaskets onto the exhaust manifold.

Apply a thin coat of anti-seize compound, Part Number 3824879, to the cap screw threads.

NOTE: The exhaust manifold gaskets are nondirectional.

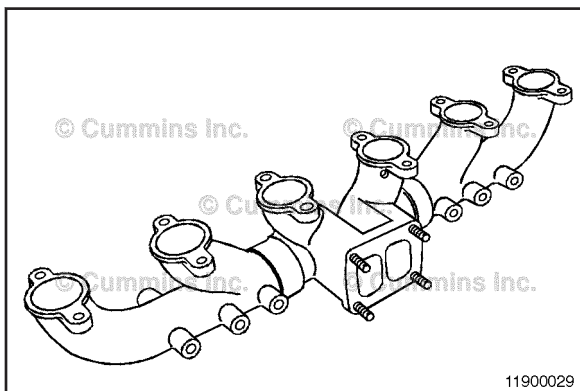


Install the exhaust manifold, new gaskets, and lock plates.

Torque Value: 43 N•m [32 ft-lb]

Follow the tightening sequence shown in the illustration.

Apply anti-seize compound to the exhaust manifold bolts upon assembly.

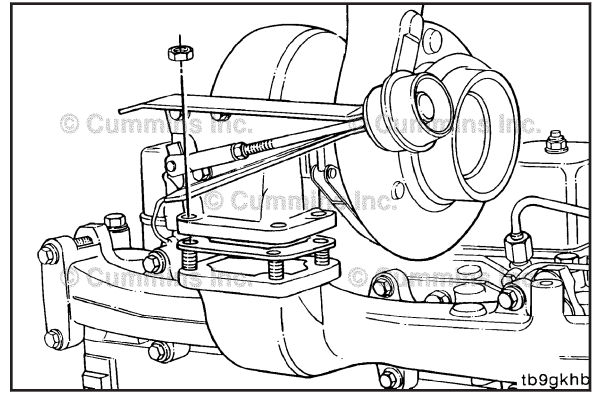


Three-Piece Manifold

If required, the end sections can be oiled, allowing the center section to slide.

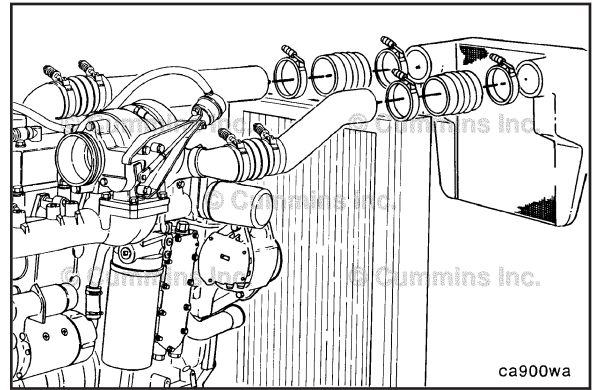
NOTE: The manifolds are oxide-coated and can leak slightly on start-up. It will seal within the first few hours of use.

Install the turbocharger, if equipped. Refer to Procedure 010-033 in Section 10.

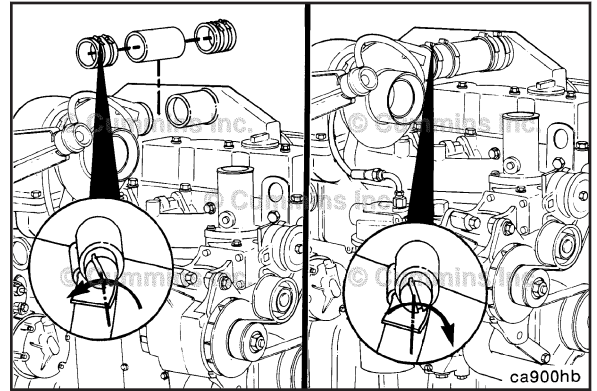


Connect the charge-air cooler hoses, if equipped. Refer to Procedure 010-027 in Section 10.

Connect the air intake and exhaust piping. Refer to the OEM service manual.



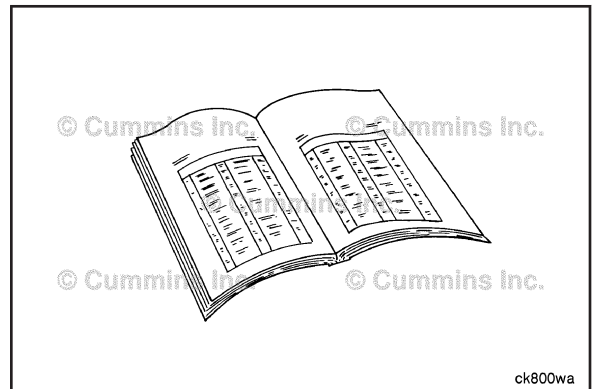
Install the air crossover tube, if equipped. Refer to Procedure 010-019 in Section 10.

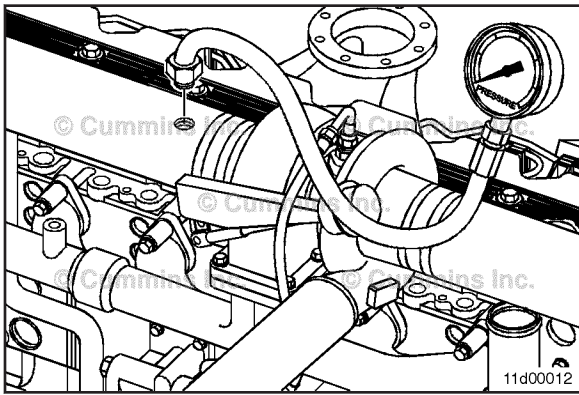


Finishing Steps

Connect the batteries. Refer to Procedure 013-009 in Section 13.

Operate the engine and inspect for leaks.





Exhaust Restriction (011-009)

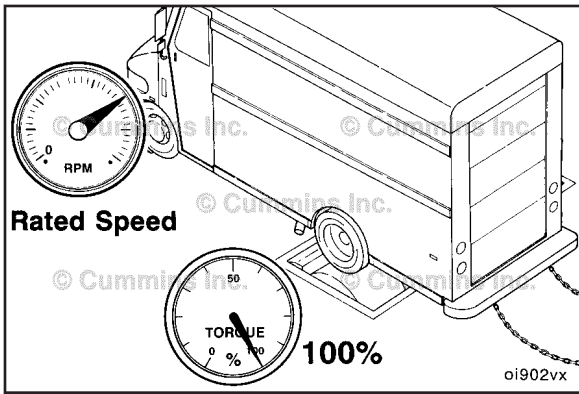
Measure



Automotive, Industrial, and Generator Drive

Install pressure gauge, Part Number ST 1273, to the pressure tap in the exhaust head pipe or at the inlet to the catalyzer or muffler assembly.

Operate the engine at rated speed and load. Record the exhaust restriction.

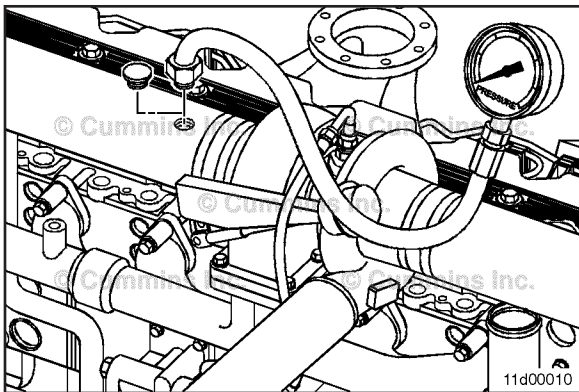


If restriction exceeds specification, inspect the oxidation catalyzer and/or muffler and replace according to vehicle manufacturer instructions.



Exhaust Restriction

	mm		in Hg
1996 EPA Certification with Oxidation Catalyzer	61	MIN	2.4
1996 EPA Certification with Oxidation Catalyzer	101	MAX	4
1995 EPA Certification with Oxidation Catalyzer	61	MIN	2.4
1995 EPA Certification with Oxidation Catalyzer	127	MAX	5
All others with or without Oxidation Catalyzer	61	MIN	2.4
All others with or without Oxidation Catalyzer	127	MAX	5



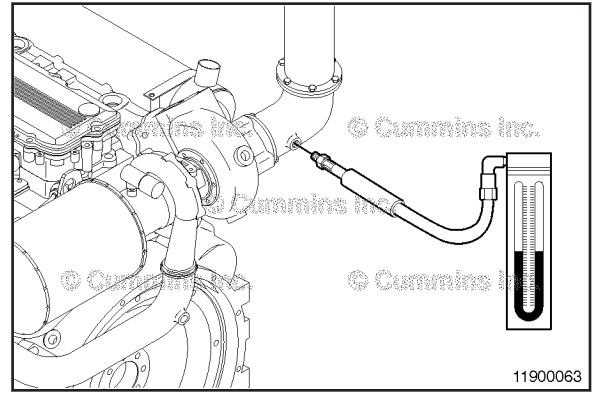
Remove the test equipment.
Install the pipe plug.



Marine Applications

Connect a manometer to the turbocharger exhaust connection.

Use a minimum of 305 mm [12 in] of metal tubing extending from the exhaust connection to protect the hose from heat.

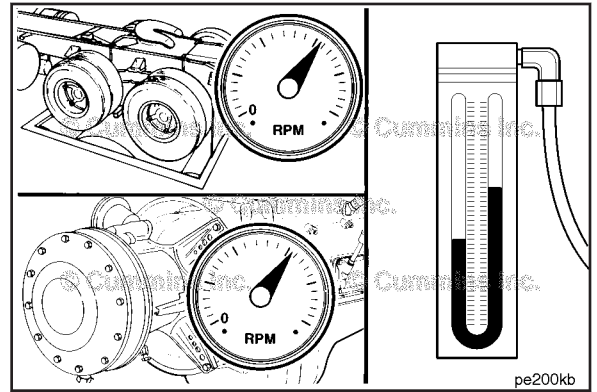


11900063

Operate the engine at rated rpm and load.
Record the reading on the manometer.

Exhaust Restriction Hg		
mm		in
75	MAX	3

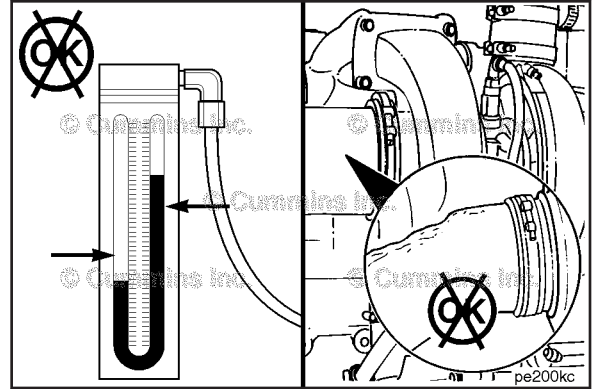
Exhaust Restriction H ₂ O		
mm		in
1016	MAX	40



pe200kb

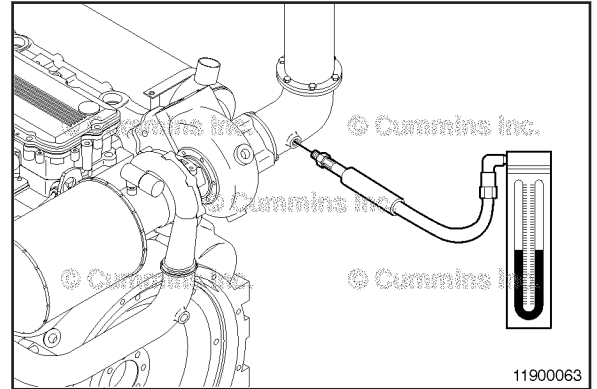
If exhaust restriction exceeds specifications, inspect the exhaust system for damage.

Refer to the original equipment manufacturer (OEM) repair instructions.



pe200kc

Remove manometer from the turbocharger exhaust connection.



11900063

Section 12 - Compressed Air System - Group 12

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Measure.....	12-1
Air Governor (Air Compressor Pumps Continuously)	12-11
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Air Governor (Air Compressor Will Not Pump)	12-9
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Air Leaks, Compressed Air System	12-13
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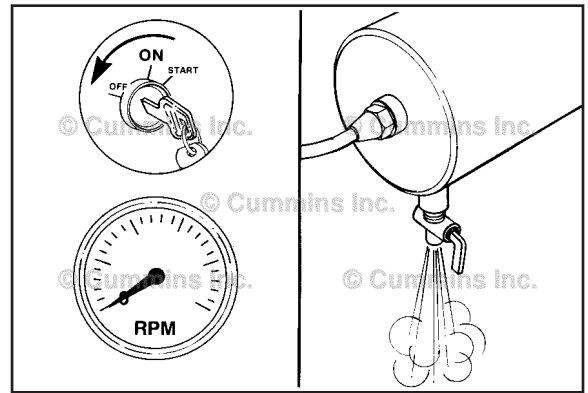
Air Compressor Carbon Buildup (012-003)



Measure

Shut off the engine.

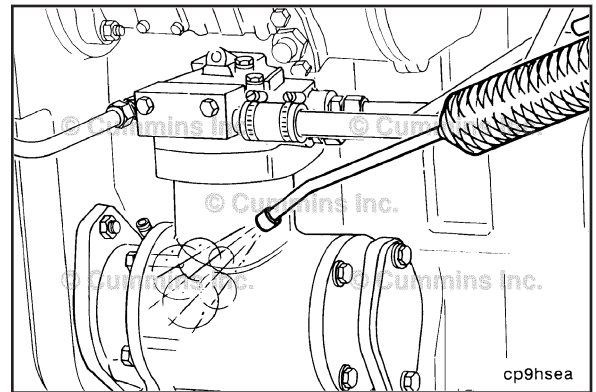
Open the draincock on the wet tank to release compressed air from the system.



⚠️ 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.

Steam-clean the air compressor.

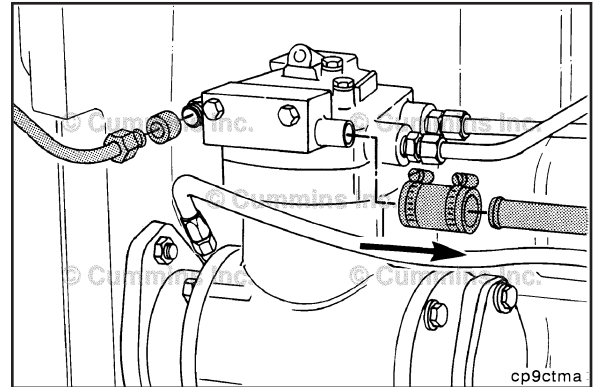


⚠️ WARNING ⚠️

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

Use compressed air to dry the air compressor.

Remove the air inlet and outlet connections from the air compressor.

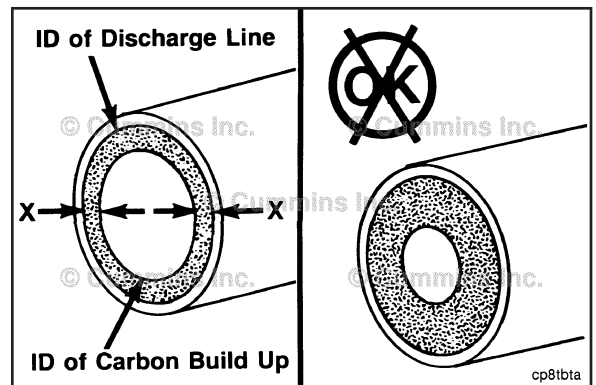


Measure the total carbon deposit thickness inside the air discharge line as shown.

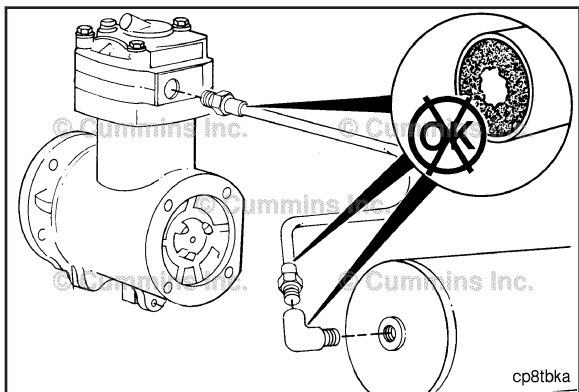
Air Compressor Discharge Line Carbon Deposits

mm		in
1.6	MAX	0.063

NOTE: If the total carbon deposit (x) exceeds the specifications, clean and inspect the cylinder head, valve assembly, and discharge line. Replace if necessary. Contact your Cummins Authorized Repair Location for procedures.



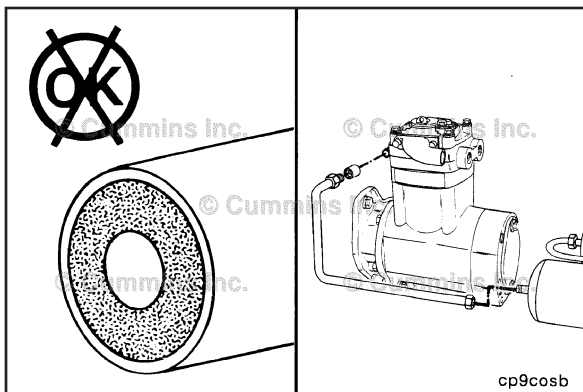
cp81bta



If the total carbon deposit exceeds specification, inspect the air discharge line connections, up to the first tank or until the carbon deposit is less than 1.6 mm [0.063 in].



Clean or replace the lines or connections that exceed this specification.



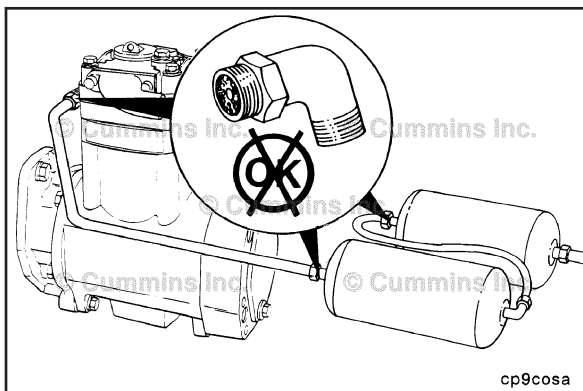
WARNING
The air discharge line must be capable of withstanding extreme heat and pressure to prevent personal injury and property damage. Refer to the OEM's specifications.



NOTE: If the total carbon deposit thickness exceeds specification:

- Remove and clean or replace the air discharge line. Refer to manufacturer's material specifications.
- Remove the air compressor from engine; refer to Procedure 012-014.

- Inspect the underloader components; refer to the Air Compressor Shop Manual, Bulletin 3810242, for detailed instructions on servicing the unloader components.



WARNING
The air discharge line must be capable of withstanding extreme heat and pressure to prevent personal injury and property damage. Refer to the OEM's specifications.



Continue to inspect for carbon buildup in the air discharge line connections up to the first or wet tank.

Clean or replace any lines and fittings with carbon deposits greater than 1.6 mm [0.063 in]. Refer to the OEM's specifications for cleaning or replacement instructions.

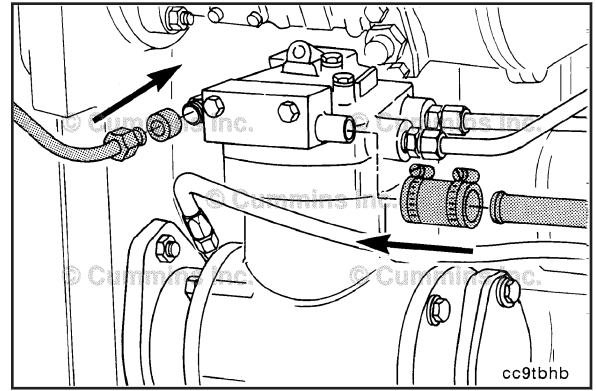
Install and tighten the air inlet and outlet connections.

Torque Value:

Inlet Connection	5 N•m	[48 in-lb]
Outlet Connection	24 N•m	[18 ft-lb]

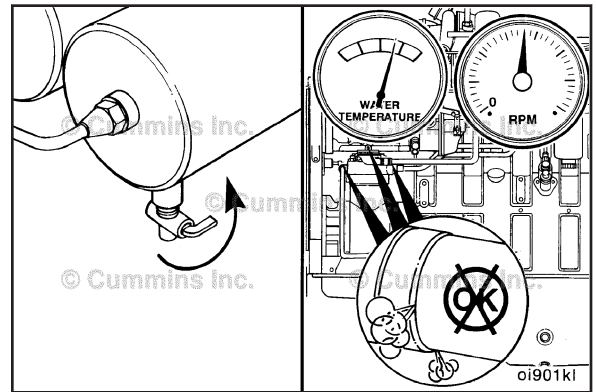
½-NPT fitting in compressor cylinder head.

NOTE: The torque value for the discharge line depends on the size and type of line. Refer to the OEM for the correct torque value.



Close the wet tank draincock.

Operate the engine and inspect for any air leaks.



Air Compressor (012-014)

Leak Test



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

- Park the vehicle. Use wheel chocks or an appropriate anti-roll device to stabilize the vehicle.
- Drain the vehicle air system.
- Remove the air discharge hose and air governor signal hose from the air compressor. Install pipe plugs into the air compressor unloader signal ports.
- Plumb the air compressor discharge hose into an external pressure tank. The external pressure tank **must** be equipped with a pressure gauge and pressure relief valve. Make sure that the fittings are install with appropriate thread sealant and do **not** leak.

Start the engine and operate at rated engine speed.

Verify that the air compressor will build pressure in the external tank. If air pressure fails to build in the pressure tank, the air compressor has malfunctioned. Refer to Procedure 012-013 in Section 12.

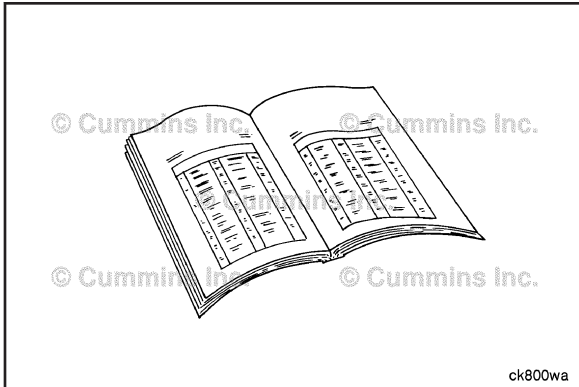
NOTE: Once the external pressure tank pressure reaches 689 kPa [100 PSI], shut the engine down.

Monitor the pressure gauge on the external tank for rapid leak down of the air pressure. If the air tank loses more than 138 kPa [20 PSI] in a 5 minute period, the pressure relief valve, intake valve, or exhaust valve has malfunctioned. The air compressor cylinder head intake and exhaust valves are **not** serviceable. Replace the air compressor cylinder head. Refer to Procedure 012-007 in Section 12.

NOTE: Do not cycle air accessories such as seats, doors, wipers, air bags, etc.

- If there is any noticeable decrease of the air gauge readings or the air dryer cycled during the 10 minute test, repair the leaks

NOTE: Leaks in systems that hold pressure for 5 to 10 minutes may be hard to find.



Preparatory Steps



⚠ WARNING ⚠

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

⚠ WARNING ⚠

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.

⚠ 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 ⚠

Coolant is toxic. Keep away from pets and children. If not reused, dispose of in accordance with local environmental regulations.

⚠ WARNING ⚠

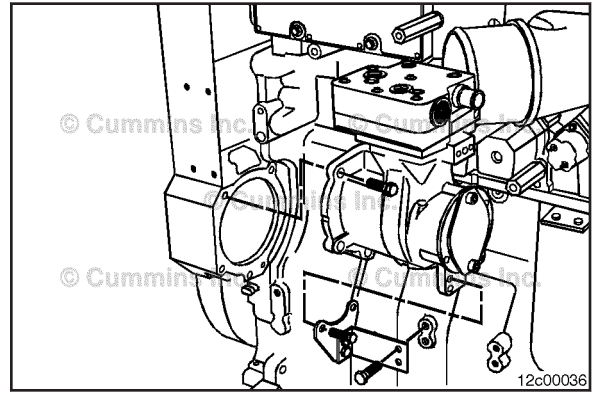
Do not remove the pressure cap from a hot engine. Wait until the temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

- Disconnect the batteries. Refer to the OEM service manual.
- Steam clean the air compressor. Refer to Procedure 000-009 in Section 0.
- Drain the engine cooling system. Refer to Procedure 008-018 in Section 8.
- Refer to the OEM service manual or remove the hydraulic pump, if equipped. Refer to Procedure 009-016 in Section 9.
- Remove any attachments on the rear of the air compressor. Refer to the OEM service manual.
- Remove the coolant lines from the air compressor. Refer to Procedure 012-004 in Section 12.
- Remove the air connections from the air compressor.
- Remove the air inlet and air outlet connections from the air compressor.
- Remove the air compressor oil supply line. Refer to Procedure 012-110 in Section 12.

Remove

Remove the air compressor support brackets and capscrews.

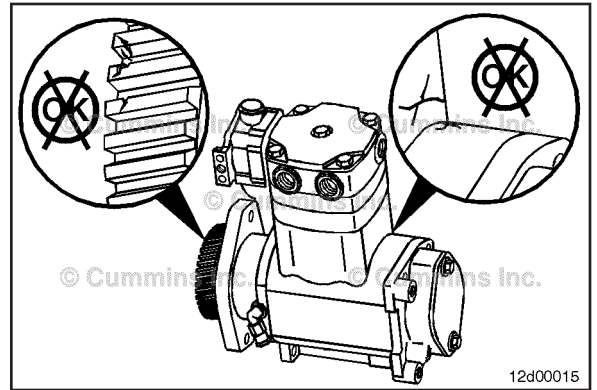
Remove the two capscrews and the air compressor.



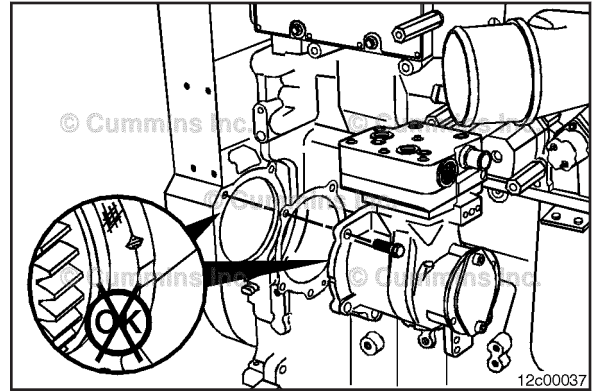
Clean and Inspect for Reuse

Inspect the compressor housing for cracks or other damage.

Inspect the drive gear for cracks or other damage.

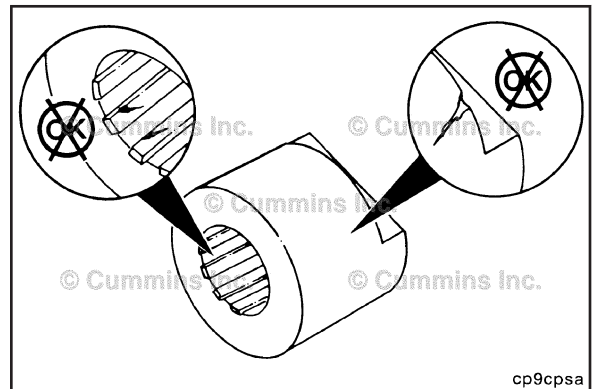


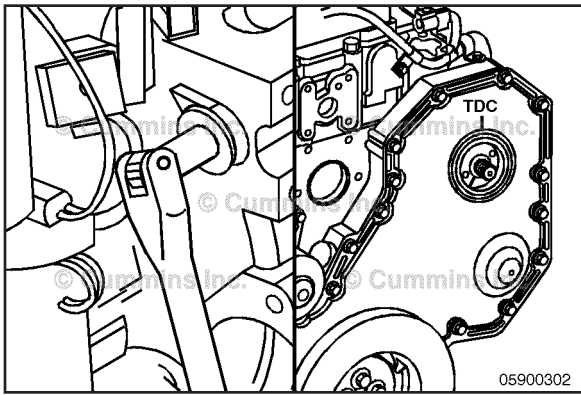
Make sure the gasket surfaces of the front gear housing and air compressor are clean and **not** damaged.



Inspect the air compressor adapter at the rear of the air compressor.

Replace the adapter, if worn. Use air compressor adapter replacer, Part Number 3165101, for 11-tooth adapters or air compressor adapter replacer, Part Number 3165102, for 13-tooth adapters.

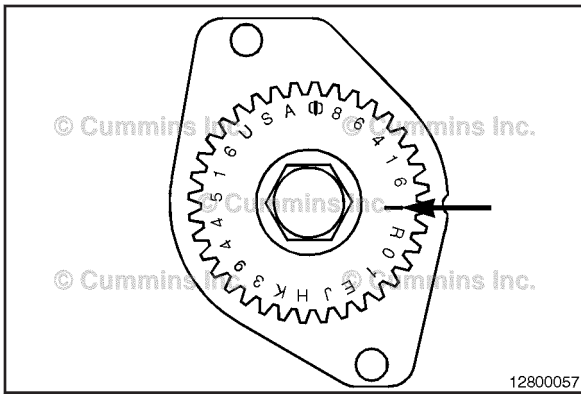




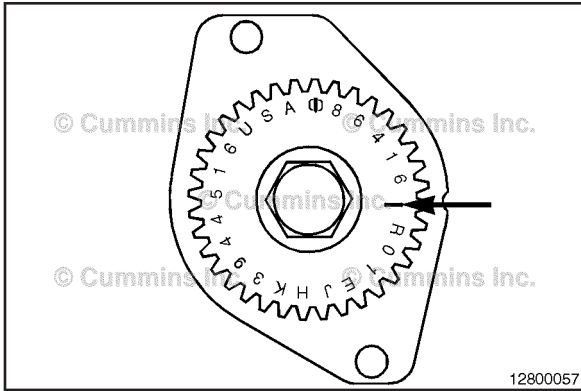
Install

Air Compressor Timing (for Single-Cylinder Air Compressor Only).

Rotate the engine so that the number 1 cylinder is at top dead center (TDC) on the compression stroke. This is done by aligning the timing mark on the fuel pump gear with the TDC mark.

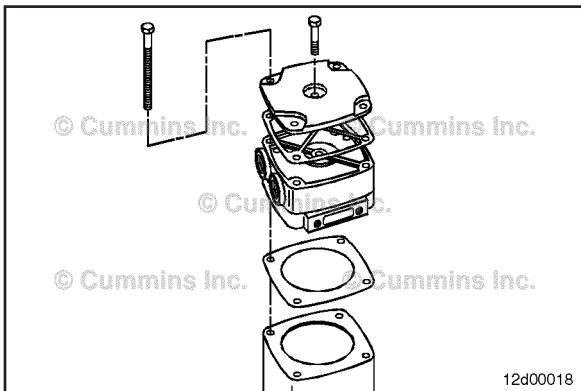


NOTE: There are two similar marks on the air compressor gear that look like "[I]" and "I". The timing mark to be used when timing the air compressor to the engine is "I".



Cummins® Single-Cylinder AirCompressors

Viewing the compressor from the gear end (with the compressor in a vertical position), rotate the gear so the "I" timing mark is at the 3-o'clock position. The Cummins® single-cylinder air compressor will have a divot on the housing at the 3-o'clock position to aid in timing the compressor. Once the timing mark is at the 3-o'clock position, this will set the compressor at 60-degrees before top dead center of the compressor's compression stroke.

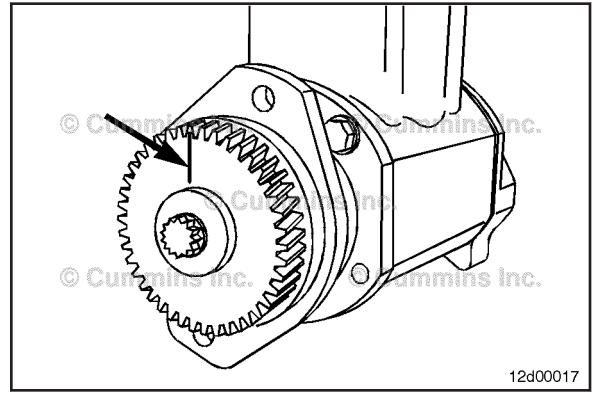


Air Compressor Timing (for Single-Cylinder Air Compressor Only, Other than Holset® or Cummins®)

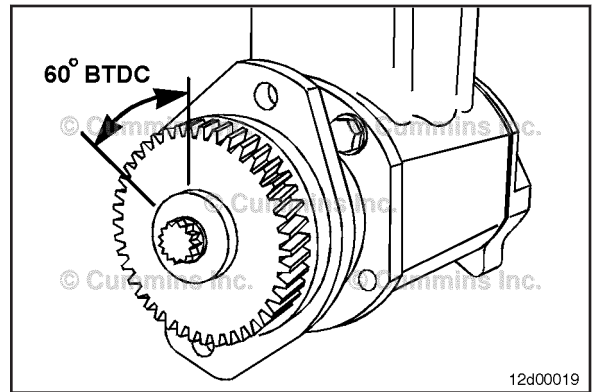


Locate TDC on the compressor crankshaft by removing the unloader valve or head. (Refer to the air compressor manual.) TDC does **not** have to be exact. The system is tolerant of some misalignment.

Use ink or dykem to mark the air compressor gear face at TDC (12-o'clock position when viewed from the front).

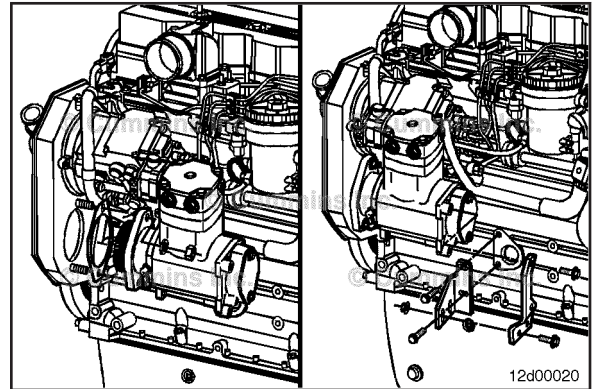


Rotate the compressor TDC mark to 60 degrees, or six teeth on a 36-tooth gear, before TDC. This is approximately 10-o'clock when viewed from the front of the air compressor.



Install the air compressor and new gasket to the gear housing.

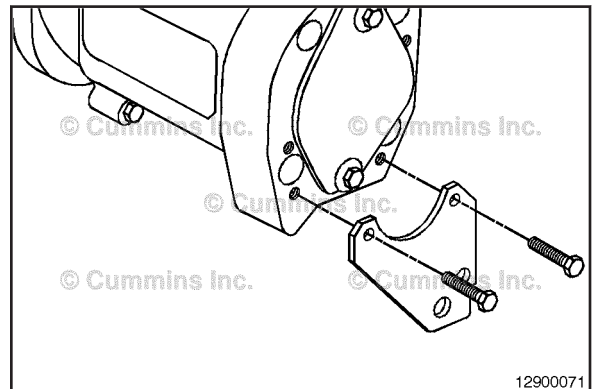
Torque Value: 77 N•m [57 ft-lb]

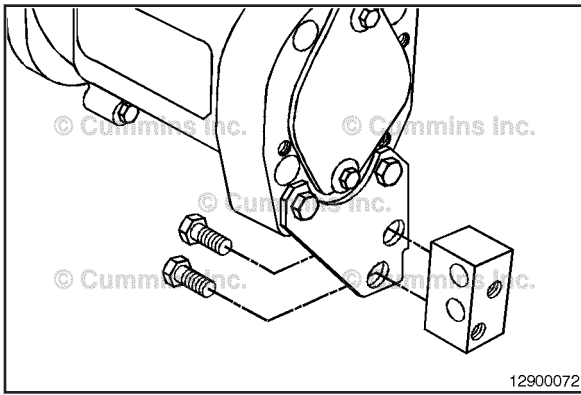


Install the brace to the air compressor.

Tighten the capscrews.

Torque Value: 43 N•m [32 ft-lb]

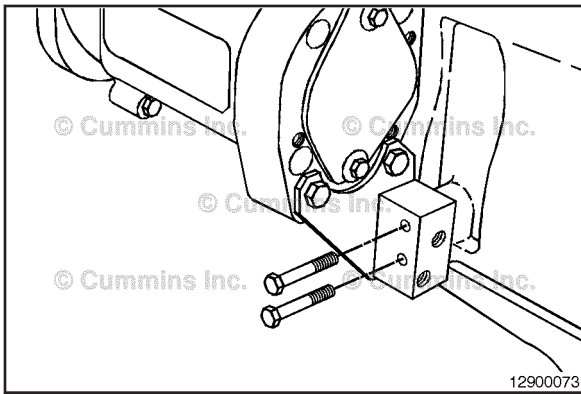




Install the spacer to brace capscrews and hand-tighten. Make sure there are no gaps between the spacer and the brace, and no gaps between the spacer and the cylinder block.

Tighten the capscrews.

Torque Value: 43 N•m [32 ft-lb]



Install the capscrews that connect the spacer to the cylinder block and hand-tighten.

Make sure there are no gaps between the spacer and the brace, and no gaps between the spacer and the cylinder block.

Tighten the capscrews.

Torque Value: 43 N•m [32 ft-lb]

Finishing Steps

⚠️ WARNING ⚠️

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

⚠️ WARNING ⚠️

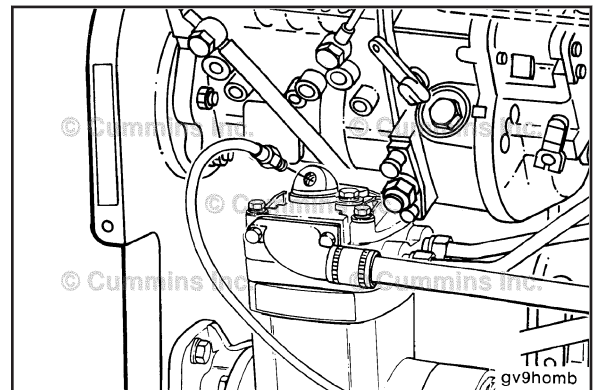
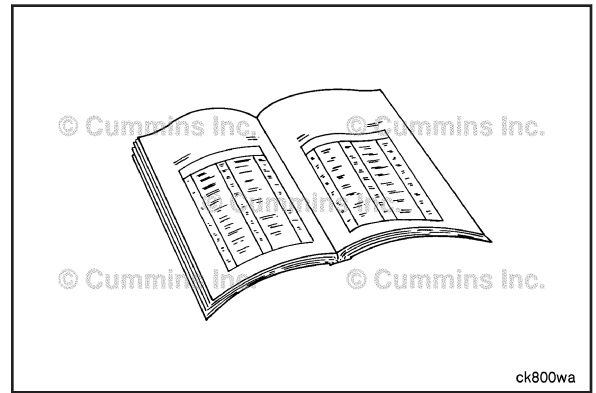
Coolant is toxic. Keep away from pets and children. If not reused, dispose of in accordance with local environmental regulations.

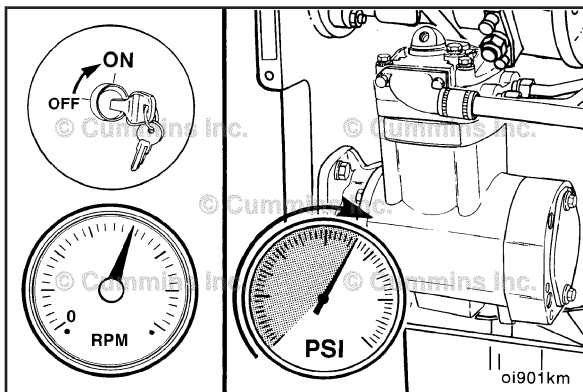
- Install the oil supply line. Refer to Procedure 012-110 in Section 12.
- Install the air inlet and air outlet connections to the air compressor.
- Install the air governor or air governor signal line, if necessary. Refer to the OEM service manual.
- Install the air compressor coolant lines. Refer to Procedure 012-004 in Section 12.
- Install the air lines.
- Install any attachments to the rear of the air compressor. Refer to the OEM service manual.
- Fill the engine cooling system. Refer to Procedure 008-018 in Section 8.
- Connect the batteries. Refer to the OEM service manual.
- Operate the engine to activate the air compressor and check for leaks.

Air Governor (Air Compressor Will Not Pump) (012-017)

Test

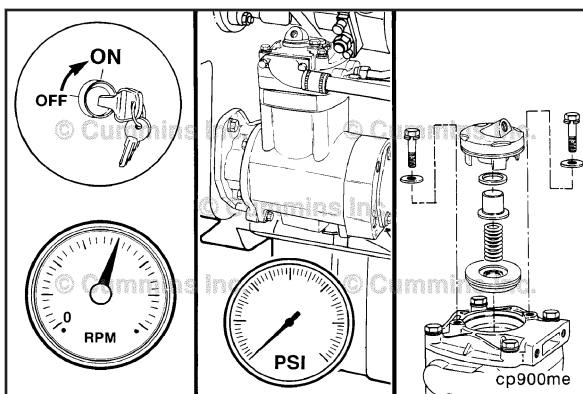
Remove the air governor hose from the air compressor unloader body.



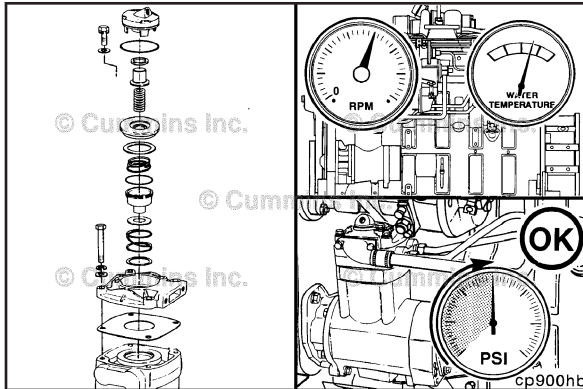


⚠CAUTION⚠
During this test, do not exceed maximum vehicle air system pressure or 1035 kPa [150 psi], whichever is lower. Read the manufacturer's specifications.

Operate the engine to activate the air compressor.



If the air compressor does **not** pump, remove the air compressor, clean, and inspect the air compressor unloader valve assembly. Refer to the Master Repair Manual, Holset Air Compressors, Bulletin 3666121.

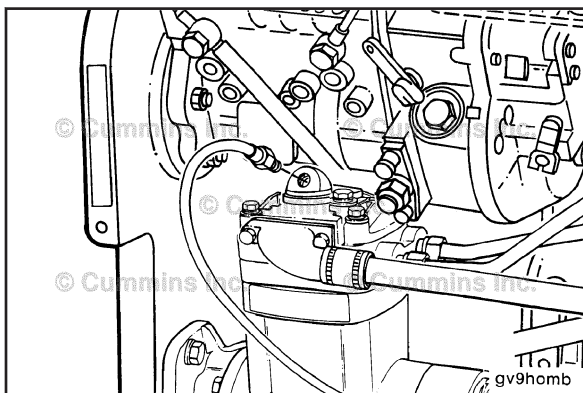


⚠CAUTION⚠
During this test, do not exceed maximum vehicle air system pressure or 1035 kPa [150 psi], whichever is lower. Read the manufacturer's specifications.

Install the air compressor; refer to Procedure 012-014.



Operate the engine and inspect air compressor operation with the air governor removed.



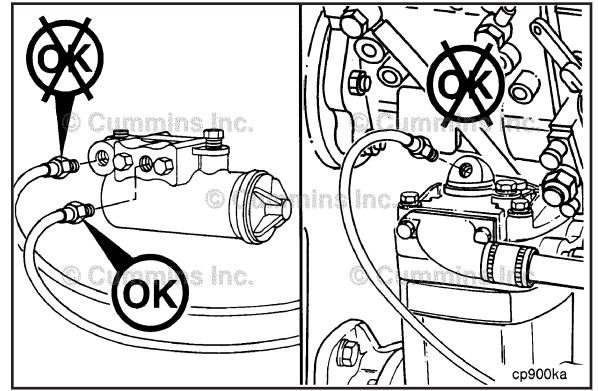
Install the air governor line to the unloader body and tighten.

Air Governor (Air Compressor Pumps Continuously) (012-018)

Test

Remove the accessory air lines from the air governor unloader port.

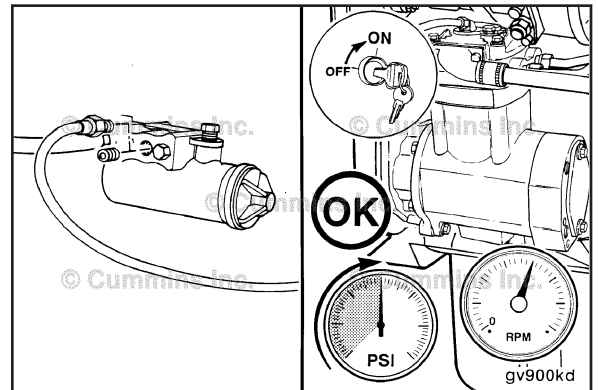
NOTE: Do **not** disconnect the line from the air compressor unloader valve. Do **not** disconnect the reservoir air line from the air governor.



Install pipe plugs in the air governor unloader ports where the accessory air lines were removed.

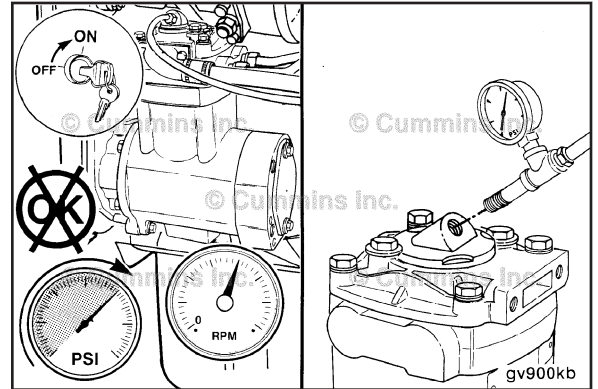
Operate the engine to activate the air compressor.

If the air compressor stops pumping (air pressure stops rising) at the governed air pressure, there is a leak in an accessory or an accessory air line. Refer to the OEM's instructions for troubleshooting and repair instructions.



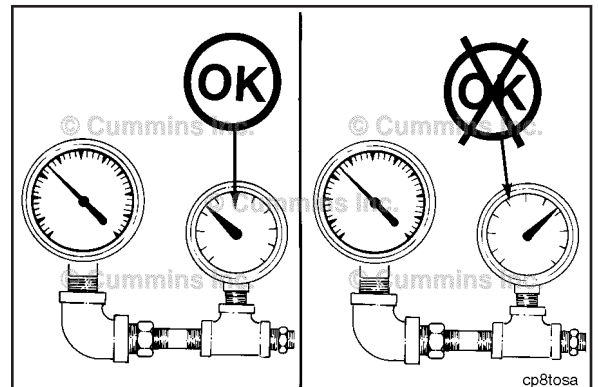
If the air compressor does **not** stop pumping (air pressure continues to rise) at the governed air pressure, connect a regulated shop air pressure line to the air compressor unloader valve port.

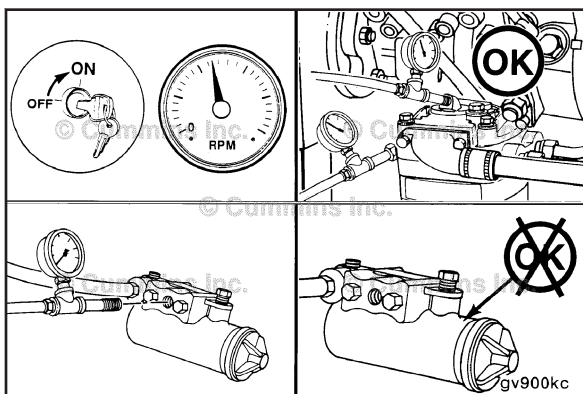
NOTE: Make sure the signal line from the air governor to the compressor unloader is **not** leaking.



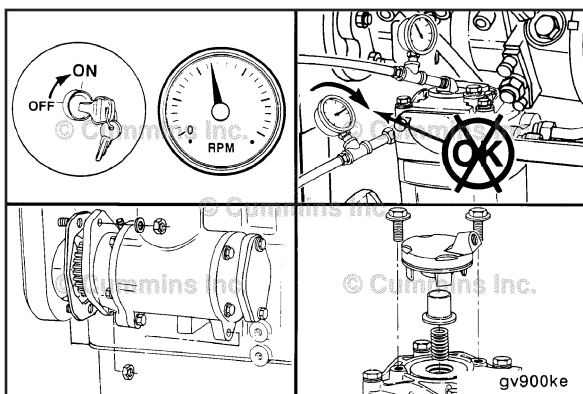
NOTE: Make sure the air pressure gauge is accurate and the supply line and fittings are in good condition before performing any air pressure checks.

Use a master gauge of known accuracy to measure the air pressure gauge.

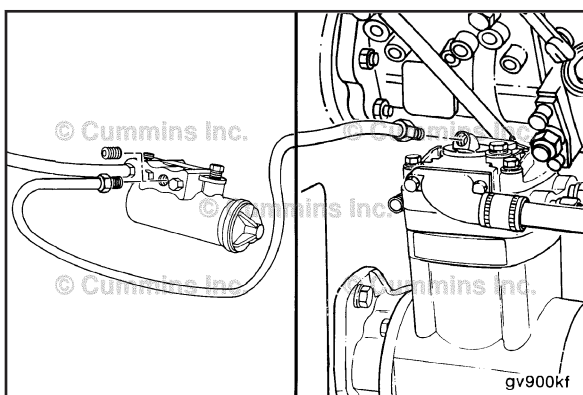




Apply 690 kPa [100 psi] air pressure to the unloader port.
If the air compressor stops pumping (air pressure stops rising), the air governor is malfunctioning and **must** be repaired or replaced. Refer to the OEM's instructions.



If the air compressor continues to pump (air pressure continues to rise), the unloader valve is malfunctioning and **must** be repaired or replaced. Remove the air compressor for repair; refer to Procedure 012-014.



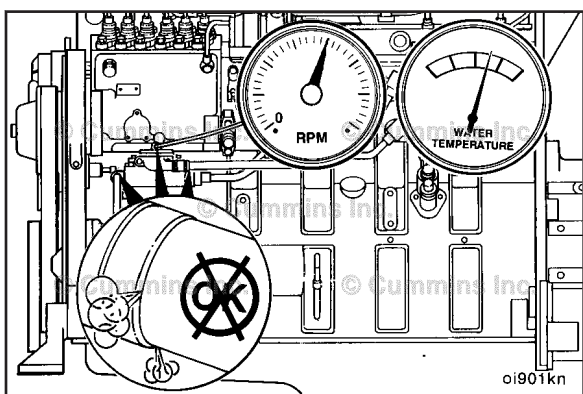
Remove the pipe plug from the governor port used for the accessory air line.

Remove the regulated shop air.



Install and tighten the accessory air line.

Connect the line between the compressor unloader valve and the air governor.



Operate the engine and inspect for air leaks.

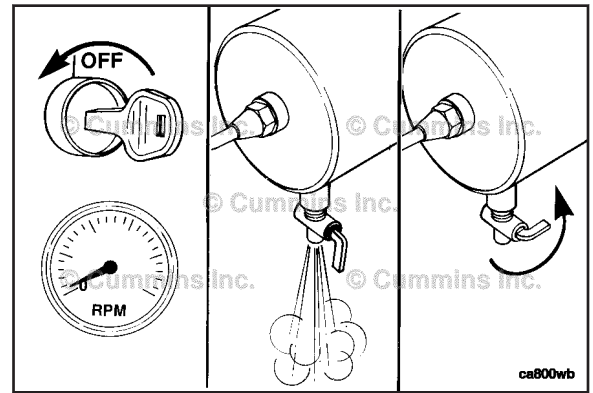
Air Leaks, Compressed Air System (012-019)

Leak Test

Shut off the engine.

Open the draincock on the wet tank to release air from the system.

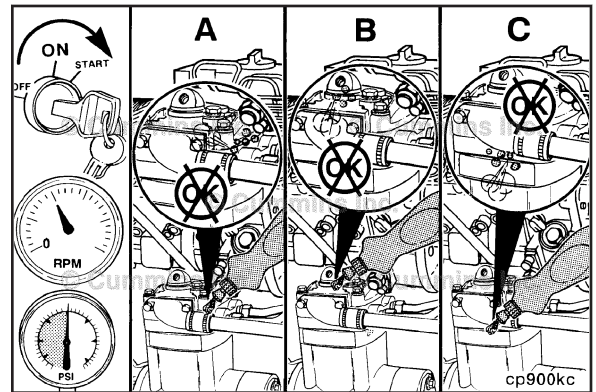
Close the draincock after the pressure is released.



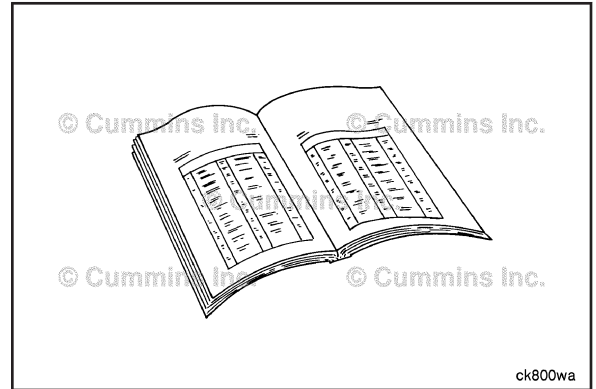
Operate the engine to activate the air compressor.

With the air compressor pumping between 550 to 690 kPa [80 to 100 psi], use a solution of soapy water to inspect for air leaks in the following areas:

- Air compressor cover gasket
- Unloader body o-ring
- Air compressor cylinder head gasket.



If air leaks are found, refer to Procedure 012-014. The compressor will have to be removed for service.



Section 13 - Electrical Equipment - Group 13

Section Contents

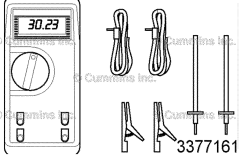
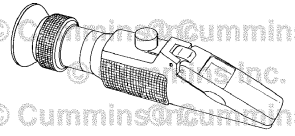

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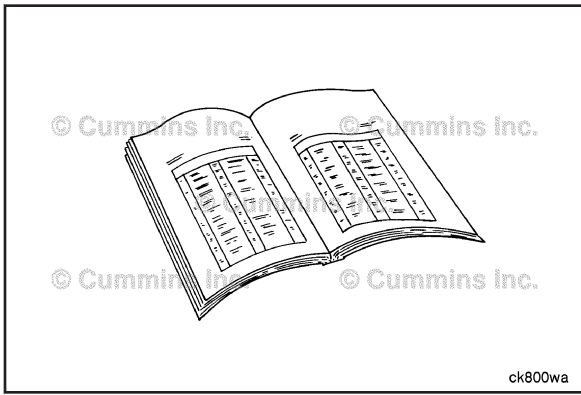
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Service Tools

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
<p style="text-align: center;">3377161</p>	<p>Digital Multimeter Used to measure voltage and resistance (ohms) in a circuit.</p>	
<p style="text-align: center;">CC-2800</p>	<p>Refractometer The Fleetguard® refractometer is used to measure the charge condition of a conventional battery.</p>	
<p style="text-align: center;">3377193</p>	<p>Systems Analyzer/Battery Tester Used to test the output amperage of the charging system and of the batteries.</p>	



Alternator (013-001)

Preparatory Steps

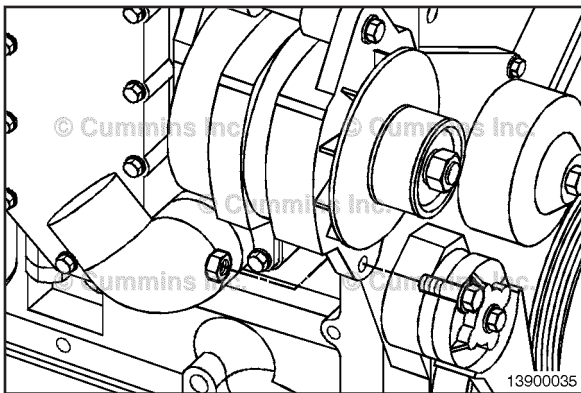
▲ WARNING ▲

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 ground cable from the battery terminal.

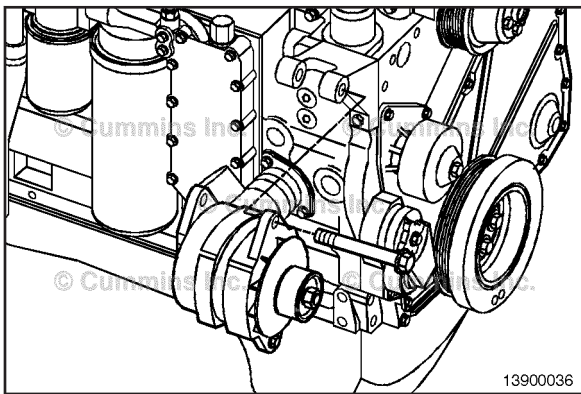
Remove and tag all wires.

Remove the drive belt from the alternator pulley.



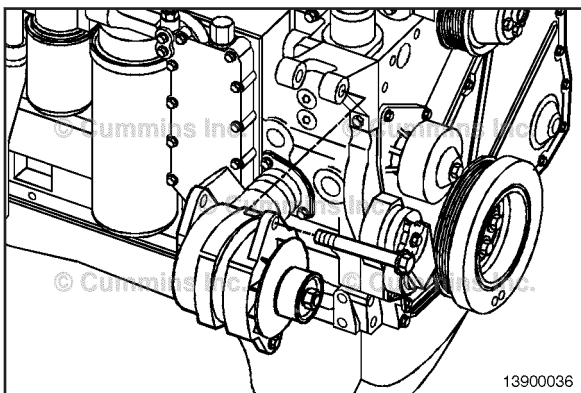
Remove

Remove the alternator link capscrew.



Remove the alternator mounting capscrew.

Remove the alternator.



Install

To install the alternator, the alternator mounting components **must** be tightened in the following sequence:

1. Alternator-to-alternator bracket capscrew
2. Lower brace-to-alternator capscrew
3. Lower alternator brace-to-water pump capscrew
4. Water inlet-to-block capscrews.

NOTE: The wrench size and torque value is determined by the make and model of the alternator.

Finishing Steps

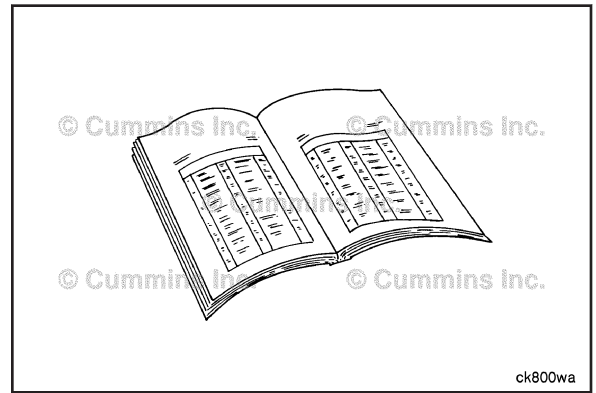
⚠ WARNING ⚠

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 from the alternator pulley.

Install and tag all wires.

Connect the ground cable from the battery terminal.

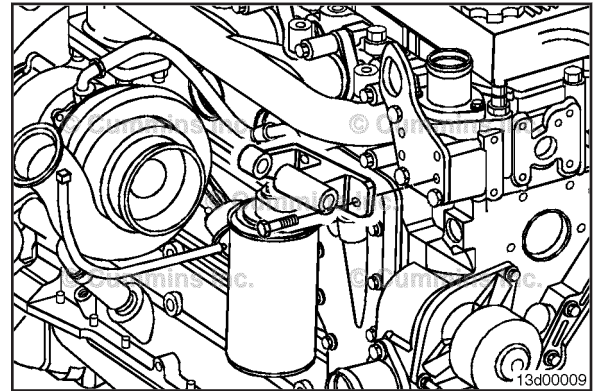


Alternator Bracket (013-003)

Remove

Remove the alternator bracket mounting capscrews.

Remove the alternator bracket.

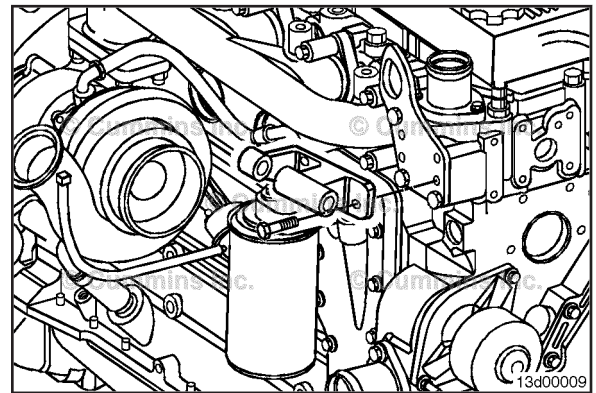


Install

Install the alternator bracket.

Install and tighten the alternator mounting capscrews.

Torque Value: 24 N•m [212 in-lb]



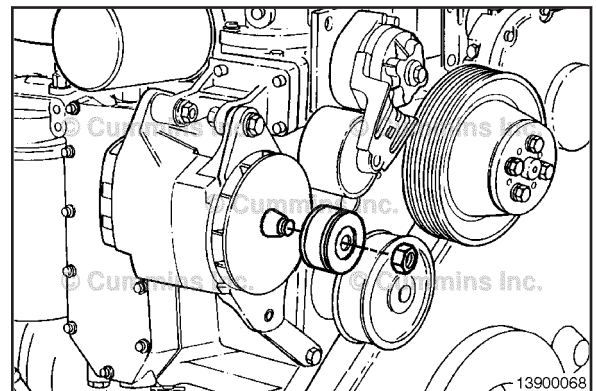
Alternator Pulley (013-006)

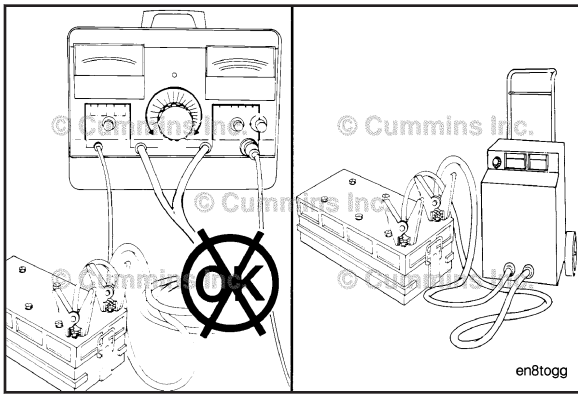
Install

Install the alternator pulley.

Install and tighten the alternator pulley mounting nut.

Torque Value: 80 N•m [59 ft-lb]





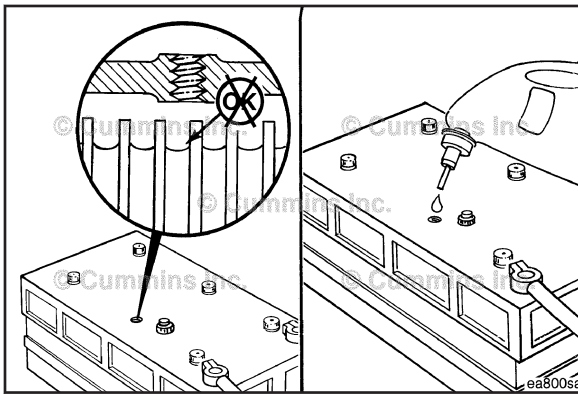
Batteries (013-007)

Inspect



Use an inductive charging and cranking system analyzer to load-test the state of charge of maintenance-free batteries. If the state of charge 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 the battery will **not** maintain a charge.



If conventional batteries are used, remove the cell caps or covers and check the electrolyte (water and sulfuric acid solution) level.



⚠ WARNING ⚠

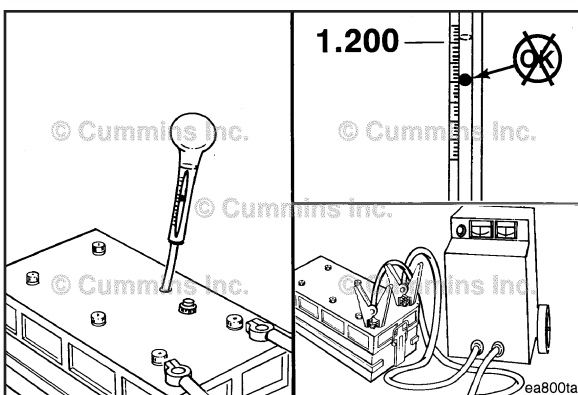
Batteries can emit explosive gas. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the battery (-) negative cable first and attach the battery negative cable last.

NOTE: Maintenance-free batteries are sealed and do **not** require the addition of water.

Fill each battery cell with water. Refer to the manufacturer's specifications.

Refer to the accompanying table to determine the battery state of charge based on the specific-gravity readings.

Battery State of Charge	Specific Gravity @ 27°C [80°F]
100%	1.260 to 1.280
75%	1.230 to 1.250
50%	1.200 to 1.220
25%	1.170 to 1.190
Discharged	1.110 to 1.130



Use a hydrometer to measure the specific gravity of each cell.

NOTE: If the specific gravity of any cell is below 1.200, the battery **must** be charged.

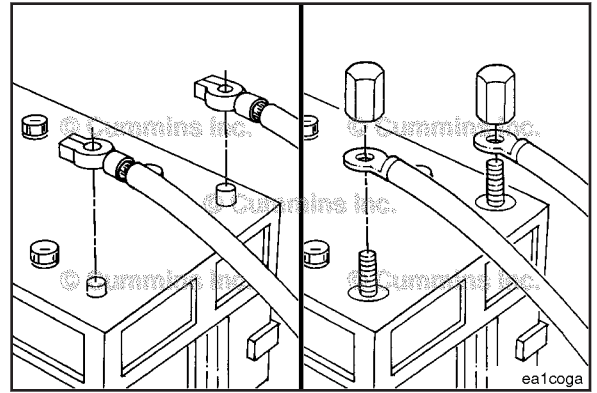
NOTE: Do **not** attempt to check the specific gravity of a battery immediately after adding water. If it is necessary to add water to allow use of the hydrometer, charge the battery several minutes at a high rate to mix the electrolyte.

Battery Cables and Connections (013-009)

Initial Check

There are two possible heavy-duty battery connections:

- Battery terminal and clamp (1)
- Threaded battery terminal and nut (2).

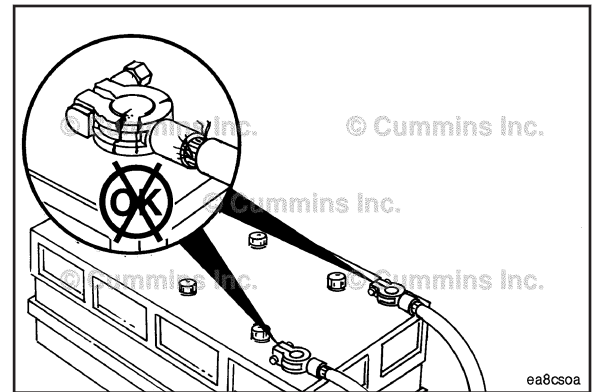


⚠ WARNING ⚠

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

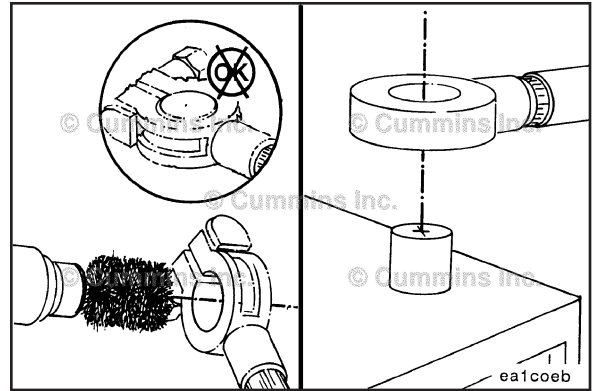
Remove and inspect the battery cables and connections for cracks or corrosion.

Replace broken terminals, connectors, or cables.



If the connections are corroded, use a battery brush or wire brush to clean the connections until shiny.

Make sure all debris is removed from the connecting surfaces.

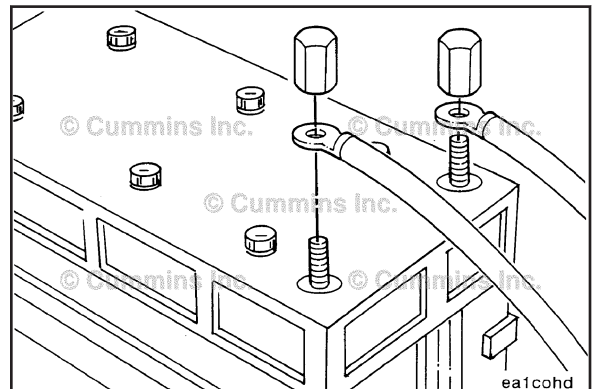


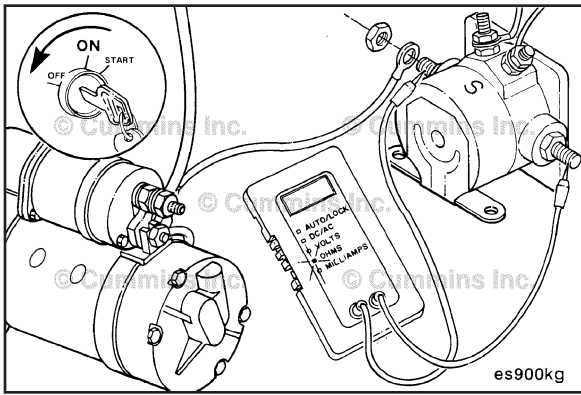
⚠ WARNING ⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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 cables and tighten the battery connections.

Coat the terminals with grease to prevent corrosion.





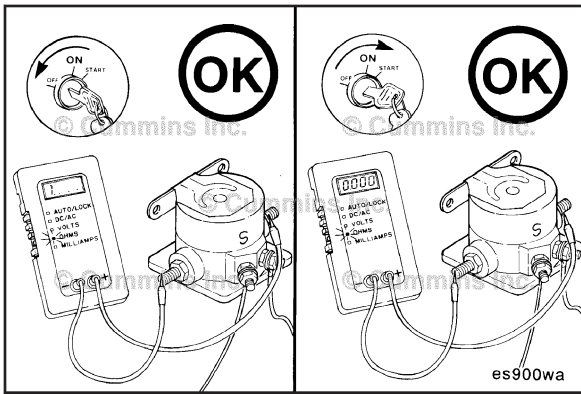
Starter Magnetic Switch (013-017) Resistance Check



WARNING
Make sure the starting motor switch is in the OFF position to prevent electrical shock and personal injury.

Remove the cable connecting the magnetic switch to the starting motor solenoid from the magnetic switch terminal.

Connect the leads of digital multimeter, Part No. 3377161, to the two large switch terminals.



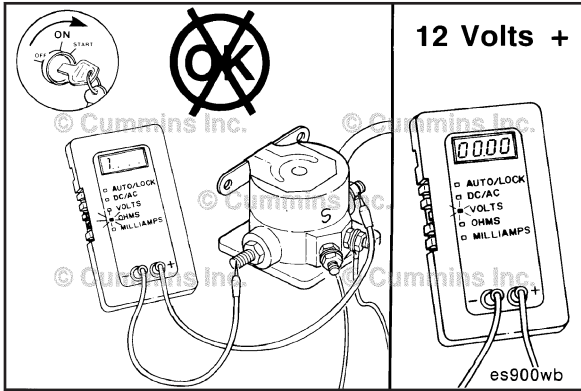
Set the multimeter to measure resistance (ohms).

With the starting motor switch in the OFF position, the multimeter **must** indicate infinity.



Turn the starting motor switch to the START position.

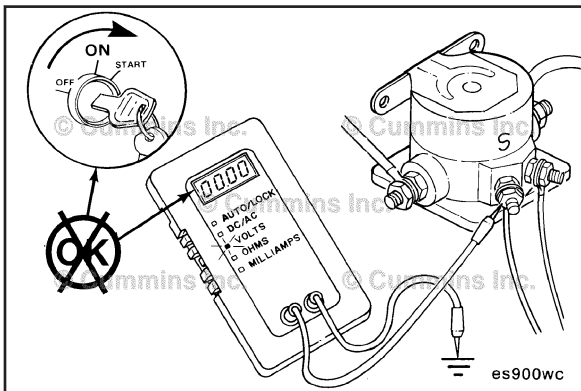
The multimeter **must** indicate zero or very little resistance.



Voltage Check

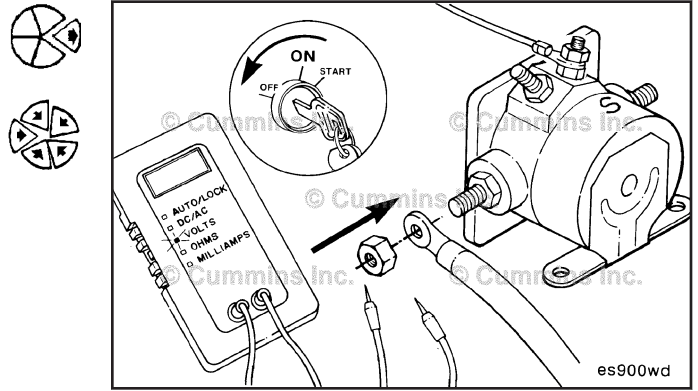
If the multimeter indicates resistance at infinity with the starting motor switch in the START position:

- Turn the starting motor switch to the OFF position.
- Set the multimeter scale to read DC voltage.



- Connect one multimeter lead to the magnetic switch terminal marked S and the other lead to a good ground.
- Turn the starting motor switch to the START position.
- If the multimeter indicates no voltage, the magnetic switch is **not** the cause of the complaint. Refer to Starter Motor Switch - Test in this section.
- If the multimeter indicates voltage, the magnetic switch is defective and **must** be replaced.

- Turn the starting motor switch to the OFF position.
- Remove the multimeter leads and connect the magnetic switch to the starting motor solenoid wire.



Starter Switch (013-018)

Test

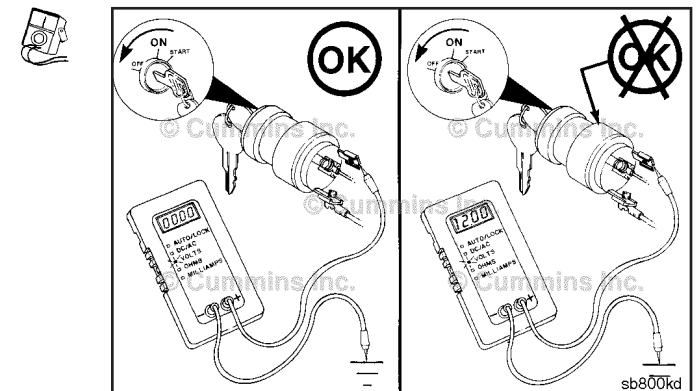
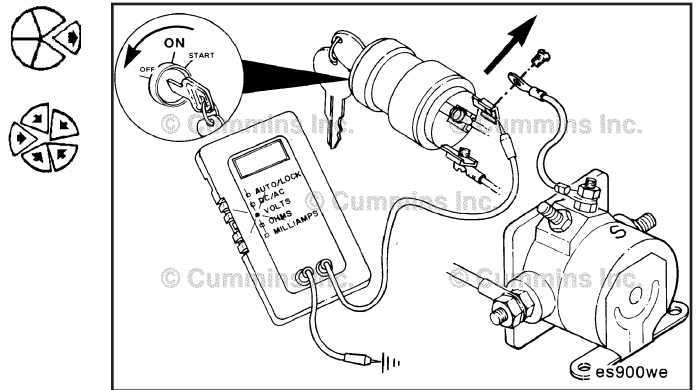
⚠ WARNING ⚠

Make sure the starting motor switch is in the OFF position to prevent electrical shock and personal injury.

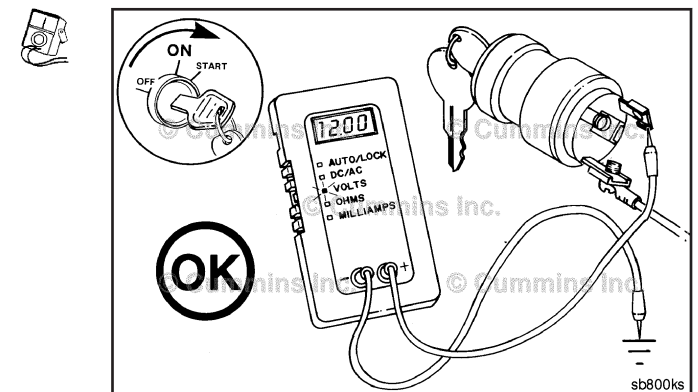
Remove the wire connecting the starting motor switch to the magnetic switch (marked S or START) from the starting motor switch terminal.

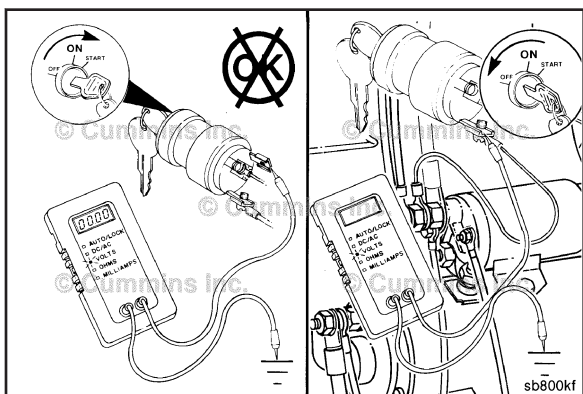
Connect the positive (+) lead of digital multimeter, Part Number 3377161, to the starting motor switch terminal and the negative (-) lead to a chassis or engine ground location.

NOTE: With the starting motor switch in the OFF position, there **must not** be voltage at the starting motor switch terminal. If the multimeter indicates voltage, the starting motor switch is malfunctioning and **must** be replaced.



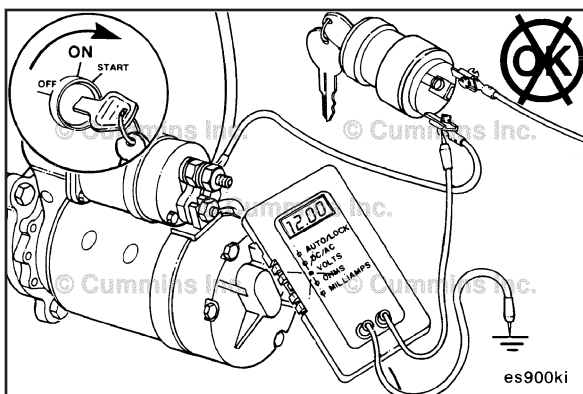
Turn the starting motor switch to the START position. The multimeter **must** indicate system voltage.





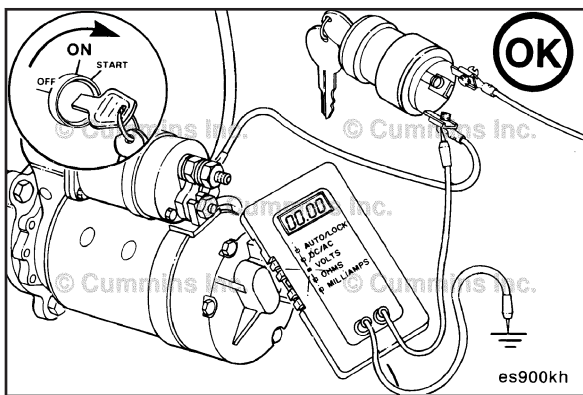
If there is no voltage:

- Turn the starting motor switch to the OFF position.
- Connect the multimeter positive lead to the starting motor switch terminal having a wire connecting the starting motor switch to the starting motor solenoid B terminal.

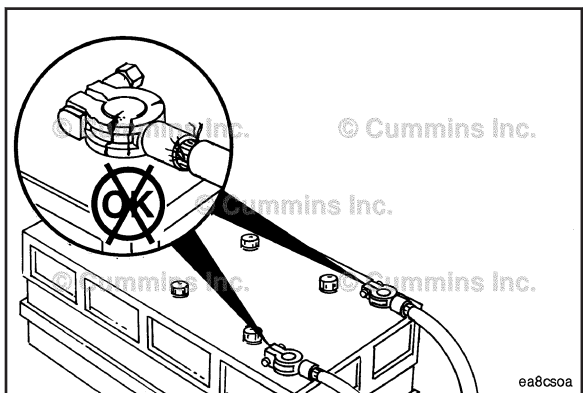


Turn the starter switch to the START position. If the multimeter indicates system voltage at the starting motor switch input terminal, the starting motor switch is **not** the cause of the complaint.

Inspect the wiring from the starting motor switch to the starting motor solenoid B terminal and from the starting motor solenoid to the battery from damaged or broken wires.



If the multimeter indicates no voltage, the switch is defective and **must** be replaced.

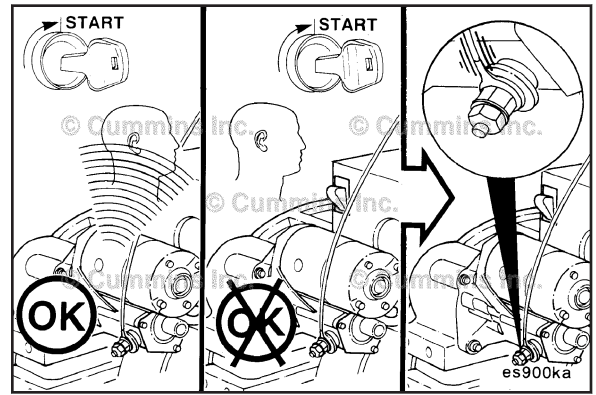


Starter Solenoid (013-019)

Initial Check

Before troubleshooting the starting motor, make sure the battery terminals are **not** loose or corroded.

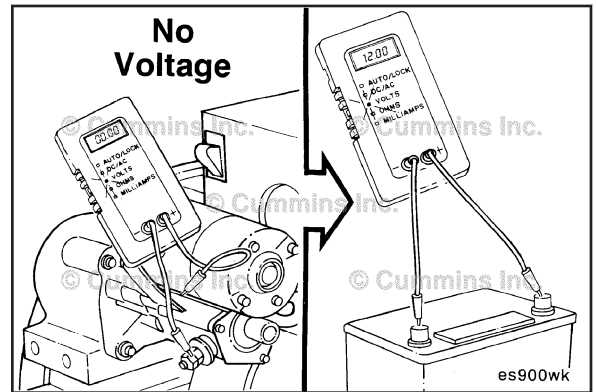
If the starting motor solenoid does **not** make an audible sound, check for loose wiring connections.



Use a digital multimeter, Cummins Part Number 3164488, or equivalent, to set the voltage scale.



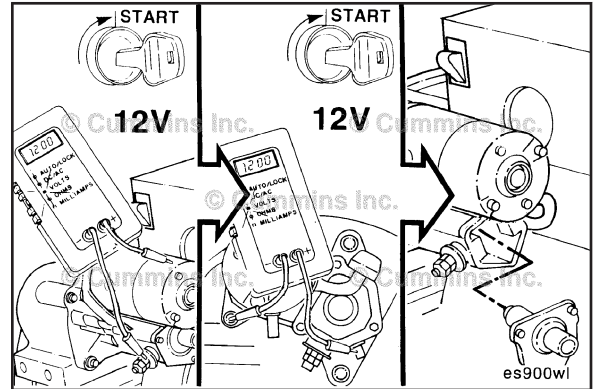
Check for system voltage at the starting motor solenoid battery terminal.



If the multimeter indicates system voltage at the starting motor battery terminal, check the voltage at the starting motor solenoid S terminal, when the starting switch is energized.

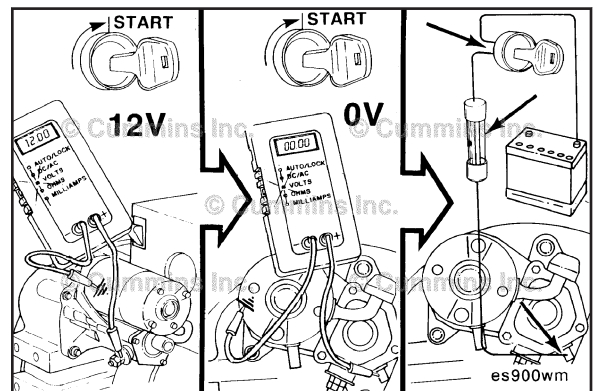


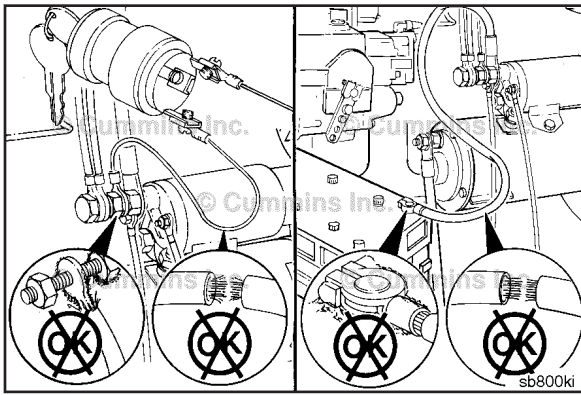
If the multimeter indicates system voltage at the S terminal, but the starter does **not** engage, the starting motor solenoid is malfunctioning and the starter **must** be replaced. Refer to Procedure 013-020.



If the multimeter does **not** indicate system voltage at the S terminal, check:

- Fuses
- Voltage to the ignition switch and magnetic switch. Refer to "Starting Motor Switch and Magnetic Switch - Checking" in this section. Refer to Procedures 013-017 and 013-018
- Application safety shutoff systems





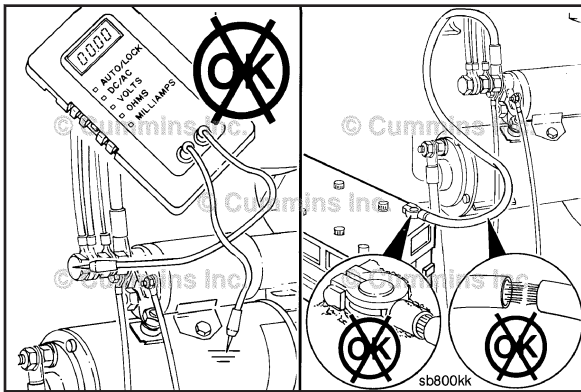
Voltage Check

Set the digital multimeter, Part Number 3164488, to measure DC voltage.



Connect the multimeter positive (+) lead to the starter solenoid positive cable terminal and the negative (-) lead to a chassis or engine ground location.

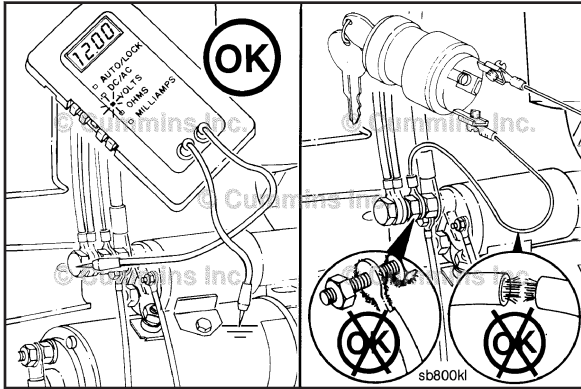
The multimeter **must** show a voltage with the starter switch "OFF" to be normal.



If the multimeter does **not** indicate a voltage, check the cable connecting the starter solenoid and battery for breaks.



Also check for loose or corroded connections.



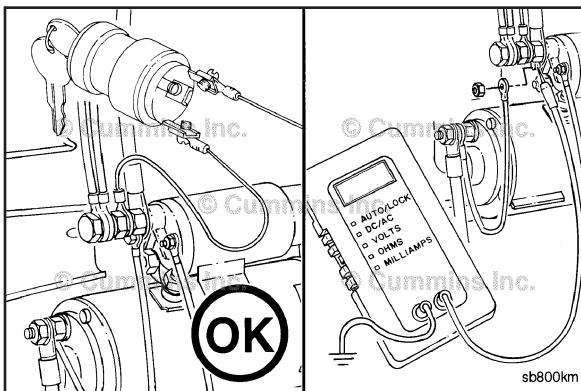
If the multimeter indicates a voltage, but the starter will **not** operate, check the wire connecting the starter solenoid to the starter switch for breaks.



Also check for loose or corroded connections.

Be sure to check for:

- Fuses
- Application engine shutoff systems.



If the wire connecting the starter solenoid and starter switch is **not** loose or damaged, and the starter will **not** operate, remove the cable connecting the starter and starter solenoid from the solenoid terminal.

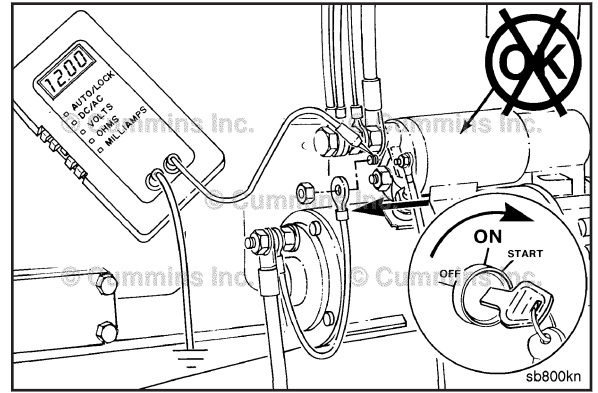


Connect the multimeter positive (+) lead to the solenoid positive (+) terminal and the negative (-) lead to the chassis or an engine ground location.

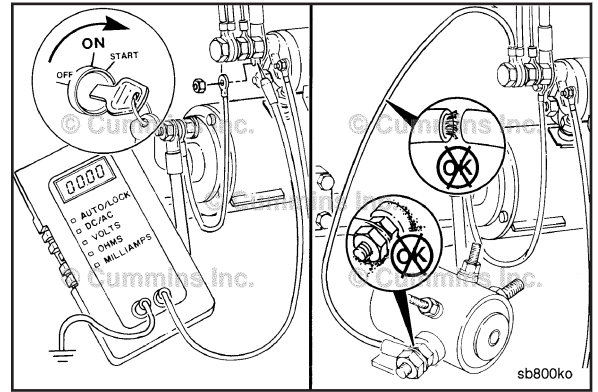


Turn the starter switch to the "START" position.

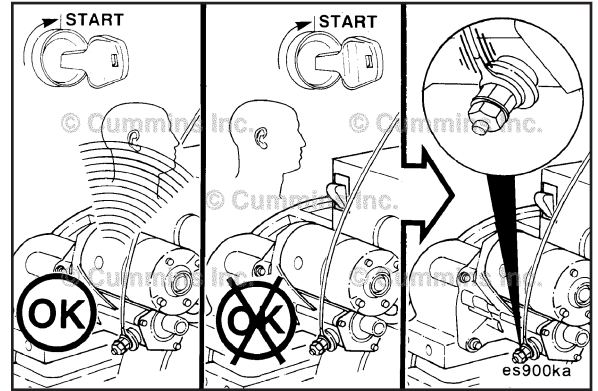
If the multimeter indicates a voltage, the starter solenoid is malfunctioning and **must** be replaced.



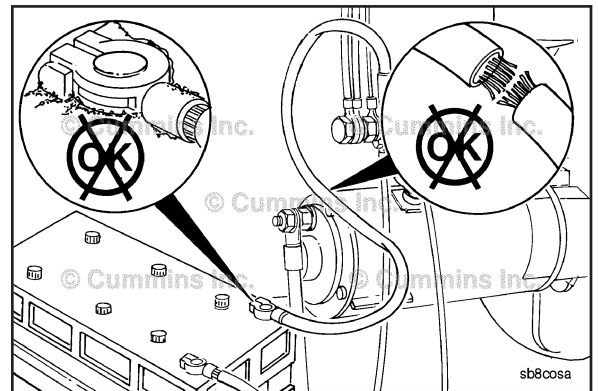
If the multimeter does **not** indicate a voltage, check the wire connecting the starter solenoid to the magnetic switch for breaks, and for loose or corroded connections.

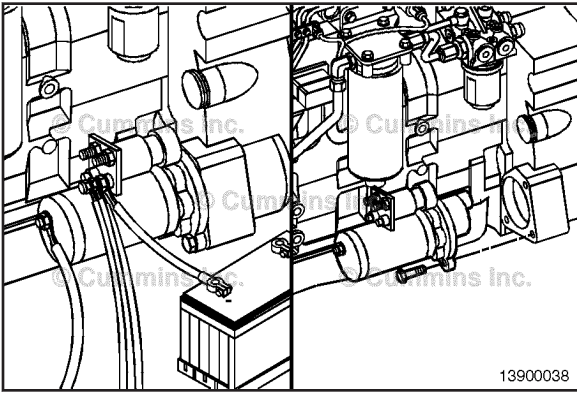


If the wire connecting the starter solenoid to the magnetic switch is **not** loose or damaged and the starter will **not** operate, check the cable connecting the starter solenoid to the starting motor for breaks, and for loose or corroded connections.

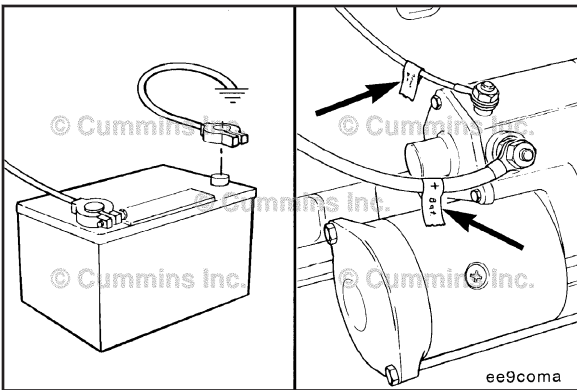


Check the cable connecting the starting motor to the battery for breaks, and for loose or corroded connections.





If the cables are **not** loose or damaged, the starting motor is defective and **must** be replaced. Refer to Procedure 013-020.

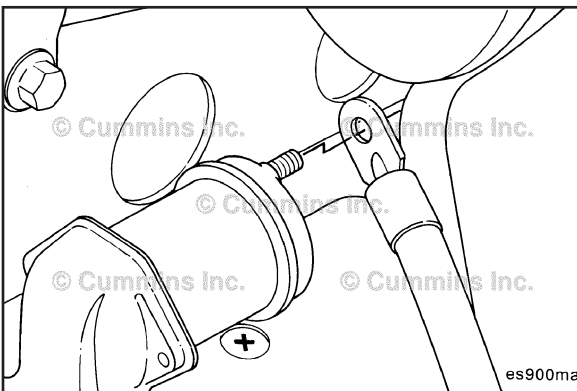


Starting Motor (013-020) Preparatory Steps

⚠ WARNING ⚠

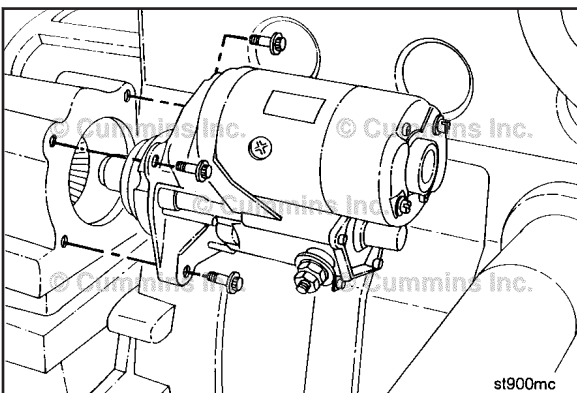
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the ground cable from the battery terminal.
- Identify each electrical wire with a tag indicating location.



Remove

Remove the battery cable from the solenoid.
Remove all other wires connected to the starter.



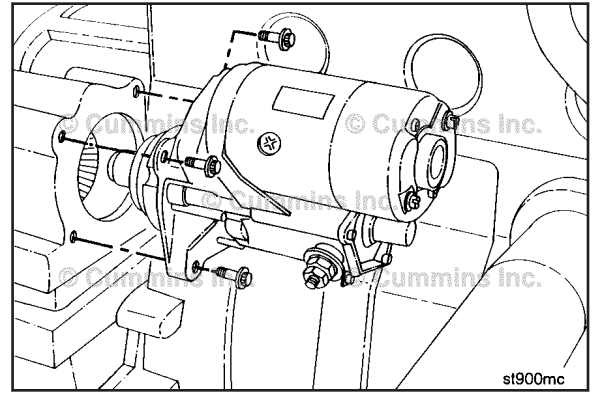
Remove the starter motor.

Install

Install the starter motor.

Torque Value: 43 N•m [32 ft-lb]

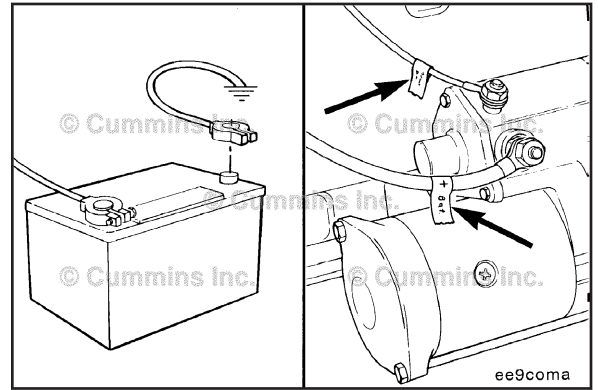
Connect all cables and all other wires connected to the starter.



Finishing Steps

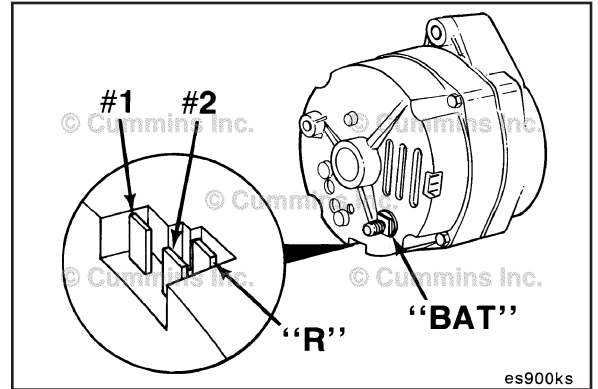
⚠ WARNING ⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Connect the ground cable from the battery terminal.

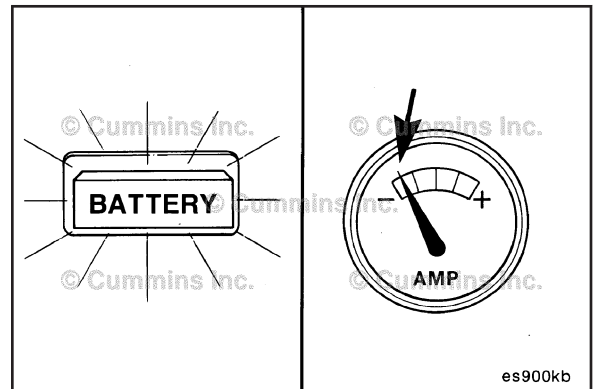


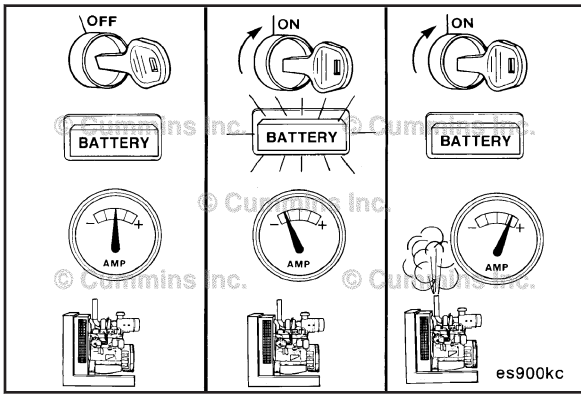
Charging System Indicator (013-023) Initial Check

Be sure the correct terminals are being used on the alternator. The R terminal (Delco®) or W terminal (Bosch® K1) provide half of the system voltage and is used to operate accessories such as the tachometer on generator sets.



Trouble with the starting system can be indicated by the indicator lamp or ampmeter.

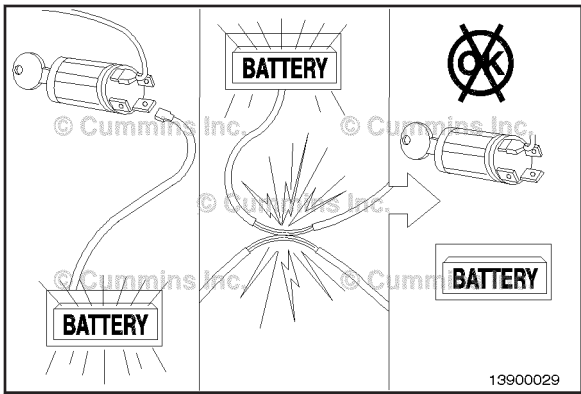




Check the indicator lamp for normal operation as shown below:

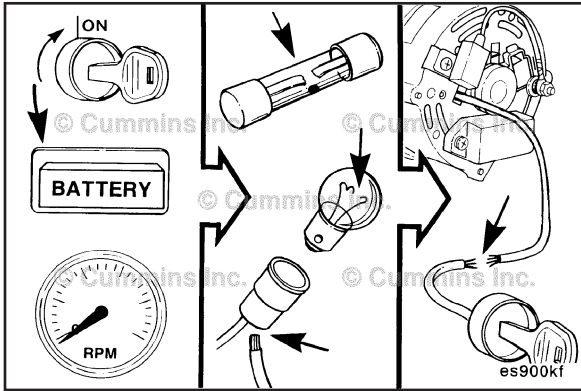


Engine	Switch	Lamp	Ammeter
Stopped	OFF	OFF	0
Stopped	ON	ON	-
Running	ON	OFF	+



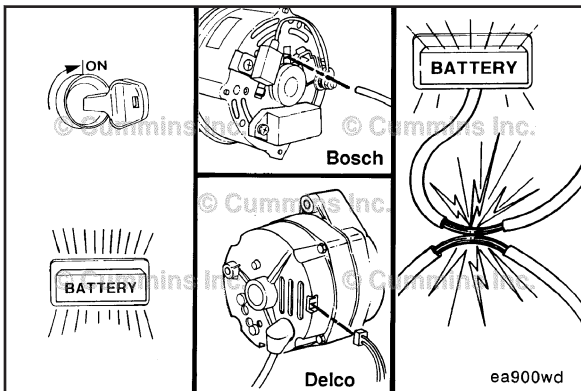
If the lamp is on when the switch is OFF and the engine is **not** running, disconnect the lamp lead at the ignition switch.

- If the lamp stays on, there is a short to a positive wire.
- If the lamp goes out, there is a short in the switch.



If the lamp goes off when the switch is ON and the engine is **not** running, there can be an open in the circuit.

Check for a blown fuse, a burned out bulb, defective bulb socket, or an open in the No. 1 or D (+) lead circuit between alternator and ignition switch.



If the lamp is on when the switch is ON and the engine is running, disconnect the lead to the alternator.



- If the lamp stays on, there is a short to the ground in the lamp circuit.
- If the lamp goes out, inspect the alternator.

Section 14 - Engine Testing - Group 14

Section Contents

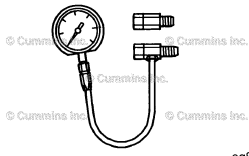
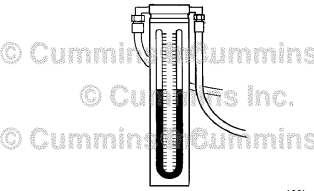


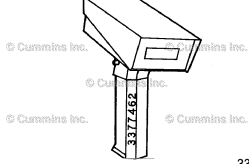
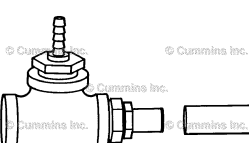
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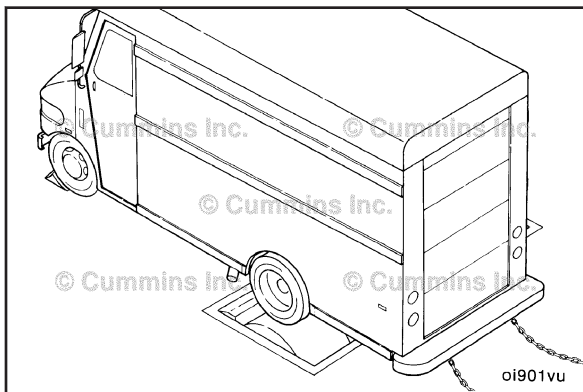
Service Tools

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
<p style="text-align: center;">ST-434</p>	<p>Vacuum Gauge Used to inspect fuel filter restriction during the engine performance test. Hose adapter, Part No. ST-434-2, and vacuum gauge, Part No. ST-434-12, are used to perform the test.</p>	 <p style="text-align: right;">eg8t0gc</p>
<p style="text-align: center;">ST-1111-3</p>	<p>Manometer Used with the blowby inspection tool to measure engine crankcase pressure.</p>	 <p style="text-align: right;">eg100ja</p>
<p style="text-align: center;">ST-1273</p>	<p>Pressure Gauge Used to measure the engine intake manifold pressure.</p>	 <p style="text-align: right;">eg8t0gi</p>
<p style="text-align: center;">3375275</p>	<p>Pressure Gauge (0 to 160 psi) Used to measure lubricating oil pressure.</p>	 <p style="text-align: right;">3375275</p>
<p style="text-align: center;">3377462</p>	<p>Digital Optical Tachometer Used to measure engine speed (rpm).</p>	 <p style="text-align: right;">3377462</p>
<p style="text-align: center;">3822566</p>	<p>Blowby Checking Tool Used with manometer, Part No. ST-1111-3, to measure the engine crankcase pressure.</p>	 <p style="text-align: right;">eg8t0ge</p>

Engine Testing (Chassis Dynamometer) (014-002) Setup

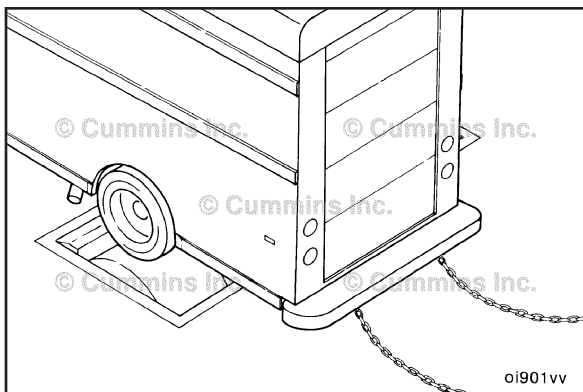


The performance of an engine installed in on-highway vehicles can be tested on a chassis dynamometer.

NOTE: Because of driveline efficiency and engine-driven accessories, the engine horsepower when measured at the rear wheels will be reduced by approximately:

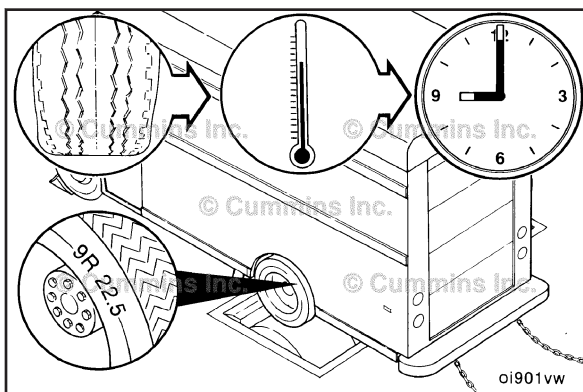
- 20 percent for single-axle vehicles
- 25 percent for tandem-axle vehicles
- 35 percent for recreational vehicles.

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.

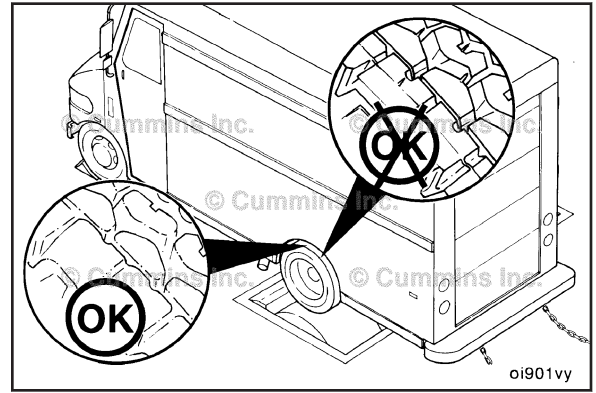


⚠ CAUTION ⚠

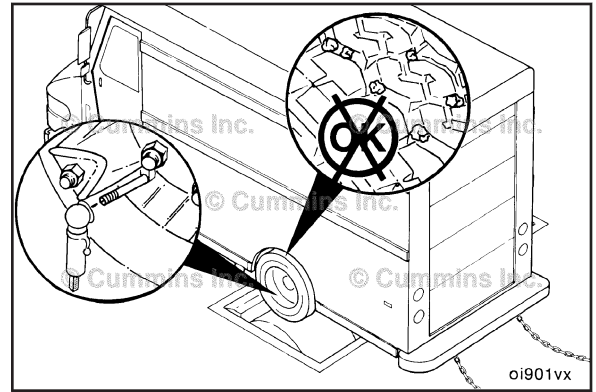
Low-profile tires are more sensitive to heat than bias ply tires. Excessive operating time at full load can damage the tires due to overheating. Check the tire manufacturer's recommendations for the maximum allowable chassis dynamometer operating time.

While operating the chassis dynamometer, follow the general safety precautions listed below:

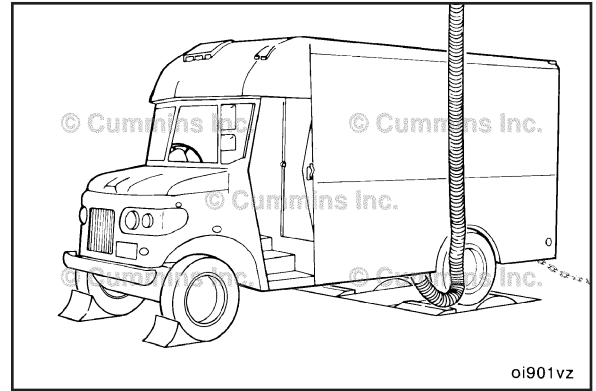
- Use tires that have more than 160 km [100 mi] of use. Do **not** use new tires.
- Do **not** use recapped tires or tires of different sizes or designs.



- 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.

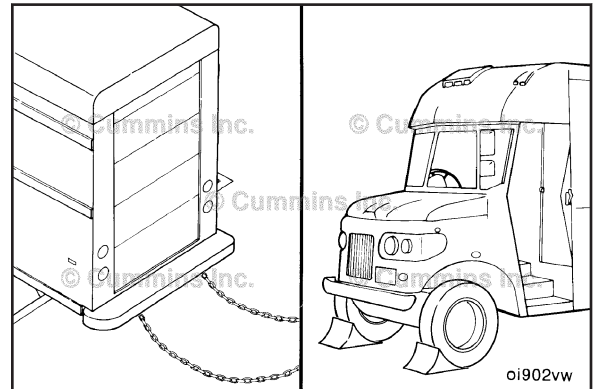


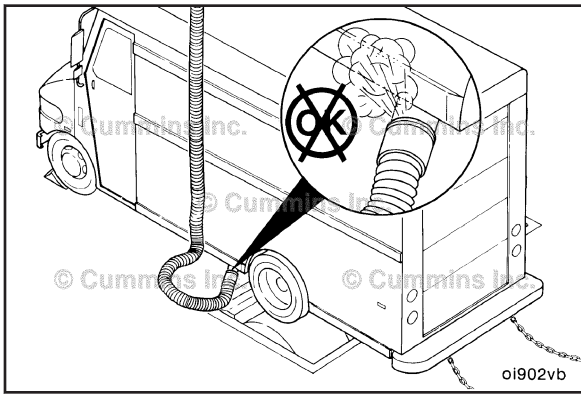
- Make sure there is correct overhead clearance for exhaust stacks, air deflectors, or other attachments above the cab.



⚠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 ⚠

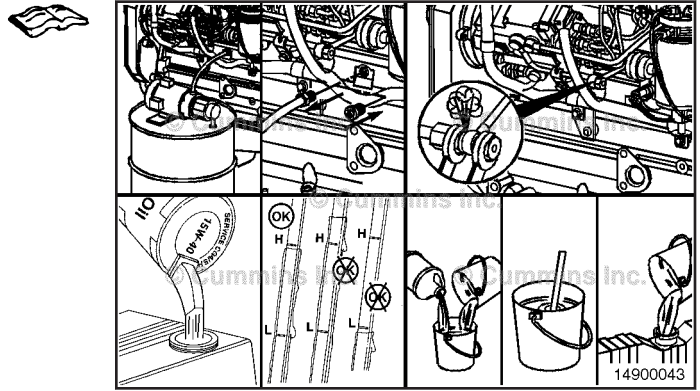
Check the coolant level only when the engine is stopped. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Failure to do so can cause personal injury from heated coolant spray.

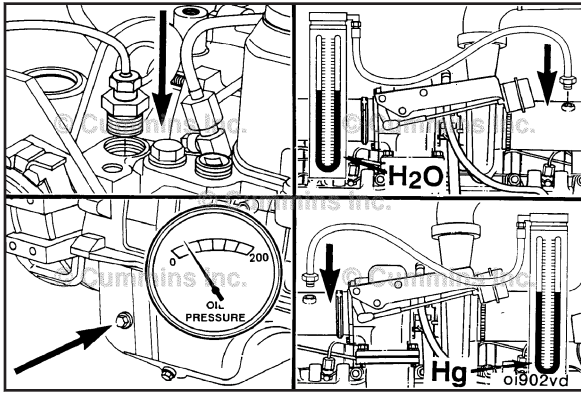
The following procedure assumes that the lubricating oil and fuel systems were correctly primed, the dipstick calibrated, and the engine filled to the correct levels with lubricating oil and coolant during installation of the engine into the chassis. If these systems were **not** serviced during installation 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.

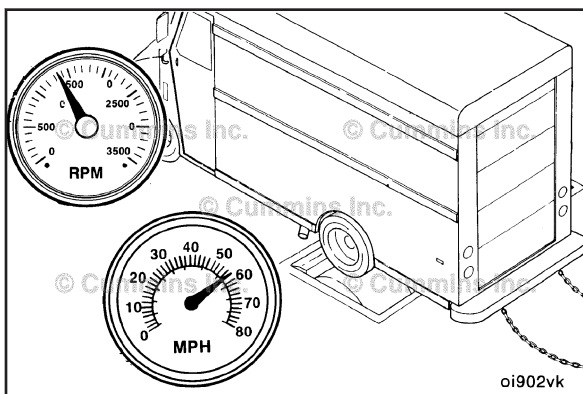
Reference the Operation and Maintenance Manual for instructions on filling the lubricating oil and the cooling systems.





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.



Engine Run-in (Chassis Dynamometer) (014-003)

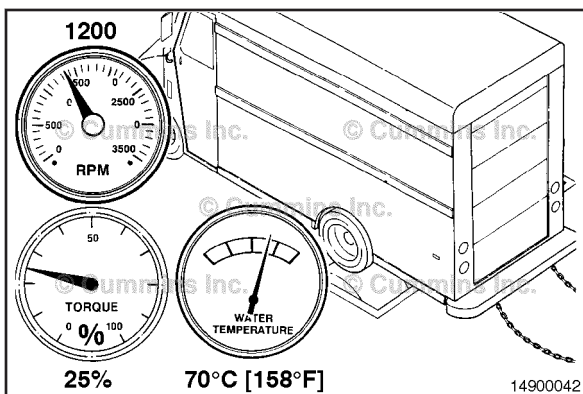


Test

⚠ CAUTION ⚠

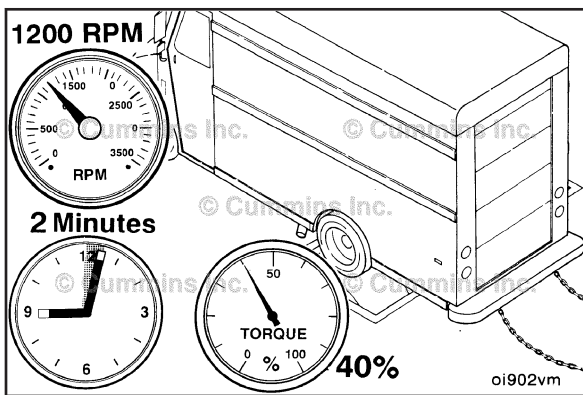
Refer to General Engine Test Procedures - (Chassis Dynamometer) (014-002) before operating the engine to avoid internal component damage.

NOTE: Operate the vehicle in a gear that produces a road speed of 90 to 95 km/h [55 to 60 mph].



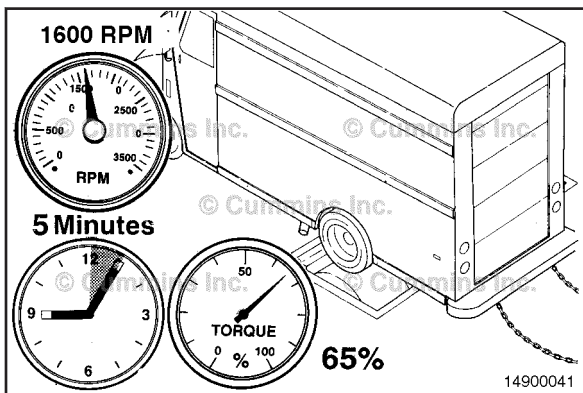
Operate the engine at 1200 rpm and 25 percent of torque peak load until the water temperature reaches 70°C [160°F].

Check all of the gauges, and record the readings.



Operate the engine at 1200 rpm and 40 percent of torque peak load for 2 minutes.

Check all of the gauges, and record the readings.



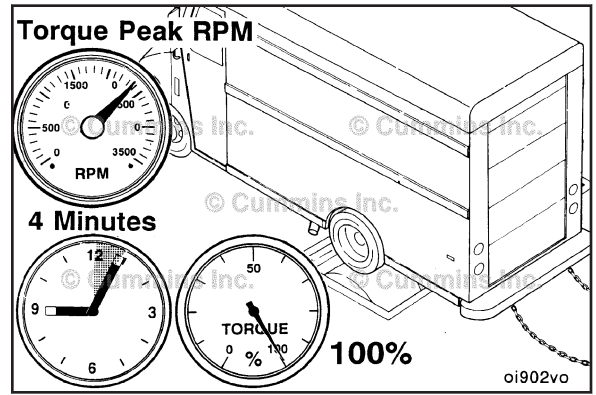
Operate the engine at 1600 rpm and 65 percent of torque peak load for 5 minutes.

Check all of the gauges, and record the readings.

Operate the engine at torque peak rpm and full load for 4 minutes.

Check all of the gauges, and record the readings.

NOTE: Refer to the engine data sheet for the torque peak rpm of the engine model being tested.

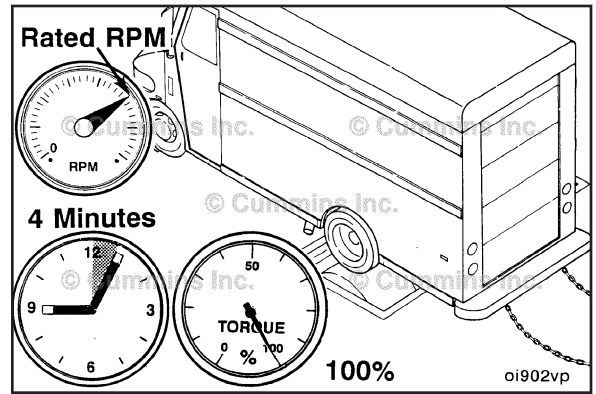


Operate the engine at rated speed (rpm) and full load for 4 minutes.

Check all of the gauges, and record the readings. Compare the readings to those published on the appropriate engine data sheet.

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 internal component damage.

Make sure to remove all dynamometer instrumentation from the vehicle.



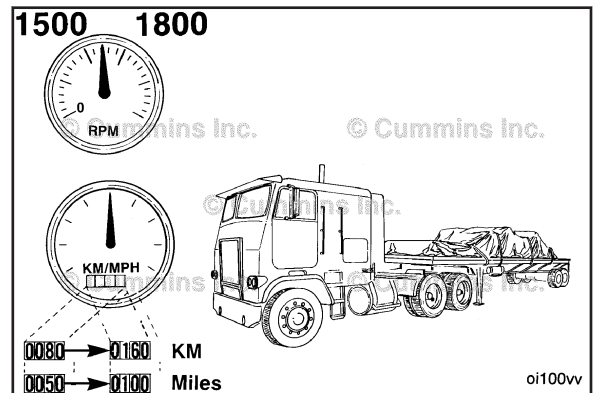
Engine Run-in (Without Dynamometer) (014-004)

Test

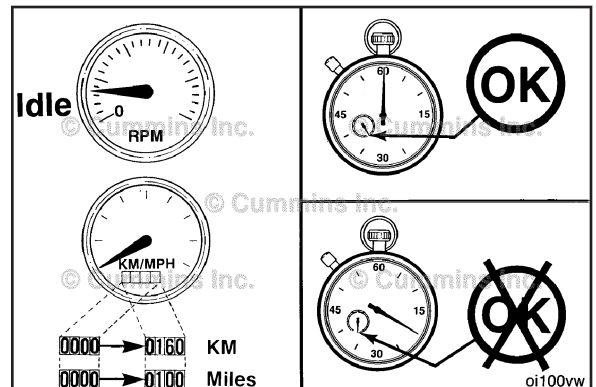
On-Highway Applications

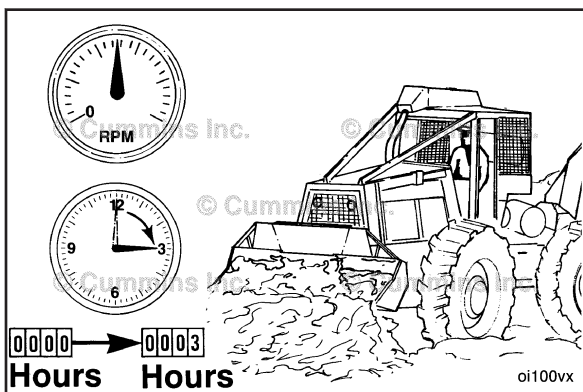
CAUTION
Refer to Chassis Dynamometer - General Engine Test before operating the engine to avoid internal component damage.

Operate the engine at 1500 to 1800 rpm in high gear for the first 80 to 160 km [50 to 100 mi] after rebuild.



CAUTION
Do not idle the engine for more than 5 minutes at any one time during the first 160 km [100 mi] of operation.

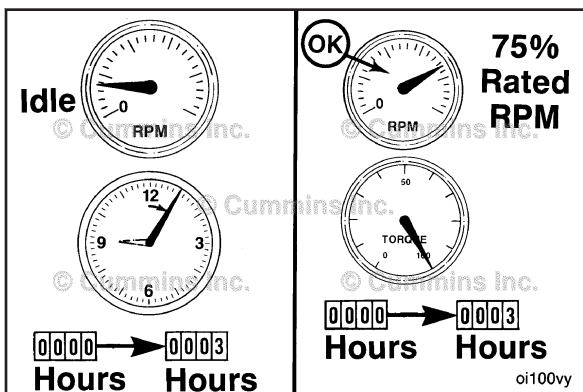




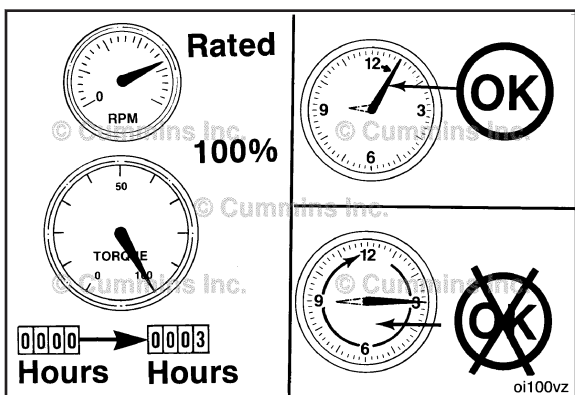
Off-Highway Applications

⚠ CAUTION ⚠
Refer to Chassis Dynamometer - General Engine Test before operating the engine to avoid internal component damage.

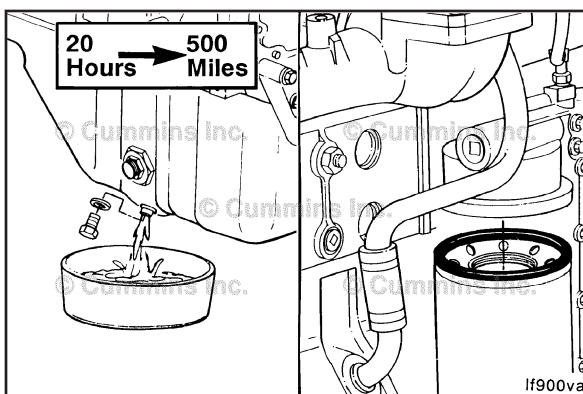
Operate the engine as follows during the first 3 hours after rebuild:



1. Do **not** idle the engine for more than 5 minutes at any one time.
2. Operate the engine at 75-percent throttle while loaded.



3. Do **not** operate the engine at rated speed (rpm) and full load for more than 5 minutes at any one time.



Change the lubricating oil and oil filter after 800 km [500 mi] or 20 hours of operation; refer to Procedure 007-037.

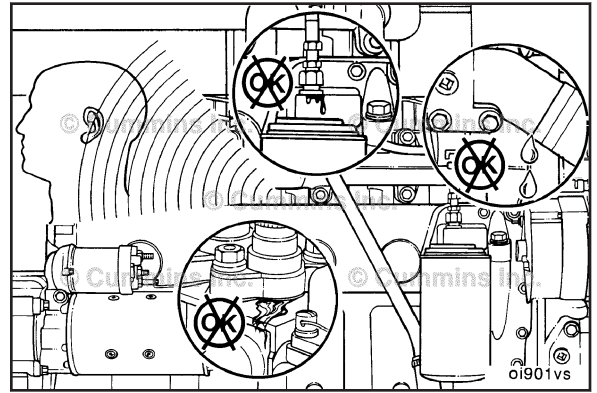
Engine Run-in (Engine Dynamometer) (014-006)



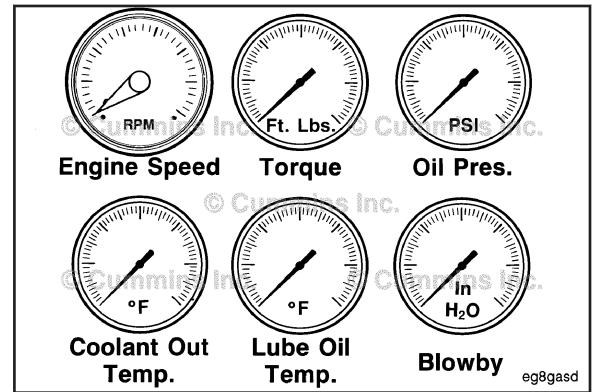
Run-In Instructions

The engine run-in period allows the tester to detect assembly errors and to make final adjustments needed for performance that meets specifications.

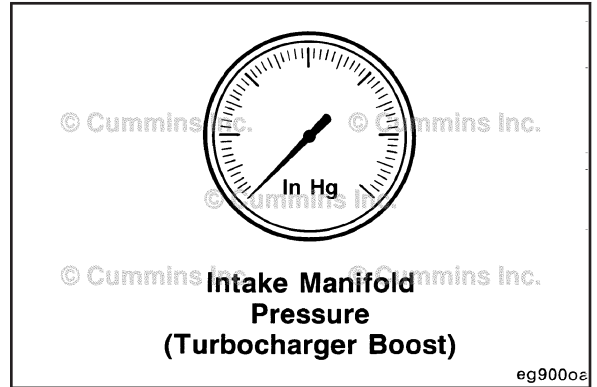
NOTE: The amount of time specified for the following engine run-in phases are minimums. Additional time can be used, if desired, at each phase except engine idle periods.



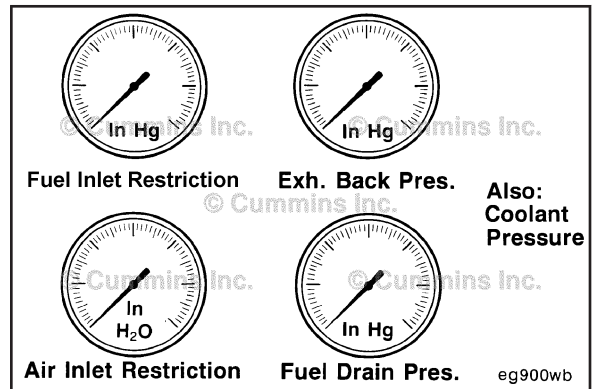
Measurements from these indicators and gauges **must** be observed closely during all phases of the engine run-in period.

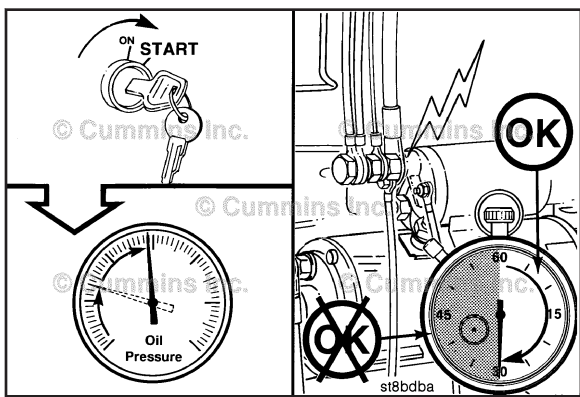


To correctly evaluate the engine performance, this additional measurement **must** be observed during engine run-in phases.



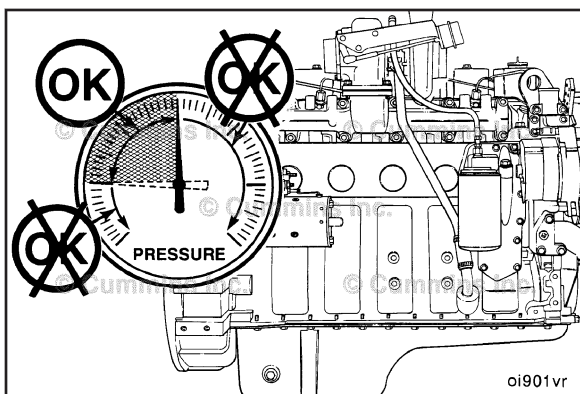
It is good practice to observe these measurements even if engine performance meets specifications. If engine performance does **not** meet specifications, these measurements can indicate possible reasons for under performance.





⚠CAUTION⚠
Do not crank the engine for more than 30 seconds. Excessive heat will damage the starting motor.

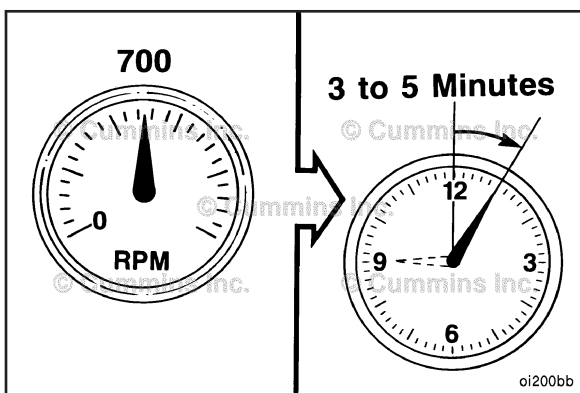
Crank the engine and observe the lubricating oil pressure when the engine starts. If the engine fails to start within 30 seconds, allow the starting motor to cool for 2 minutes before cranking the engine again.



⚠CAUTION⚠
If the lubricating oil pressure is not within specifications, shut off the engine immediately. Low lubricating oil pressure will cause engine damage.

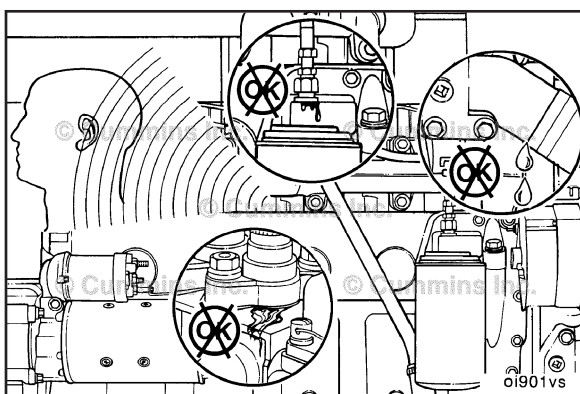
Engine lubricating oil pressure **must** be at least 70 kPa [10 psi] at 700 rpm.

Correct the problem if the lubricating oil pressure is **not** within specifications.



⚠CAUTION⚠
Do not operate the engine at idle speed longer than specified during engine run-in. Excessive carbon formation will cause damage to the engine.

Operate the engine at approximately 700 rpm for 3 to 5 minutes.



Listen for unusual noises; watch for coolant, fuel, and lubricating oil leaks; and check for correct engine operation in general.

Repair all leaks or component problems before continuing the engine run-in.

C Series
Section 14 - Engine Testing - Group 14

Move the throttle to obtain 1,200 rpm engine speed, and set the test load to 25 percent of the rated load.

Operate the engine at this speed and load level until the coolant temperature is 70° C [160° F]. Check all gauges and record the data.

Do **not** proceed to the next step until a steady blowby reading is obtained.



1200

Test Load

70°C [160°F]

oi802vr

Open the throttle to the speed at which peak torque occurs, and adjust the dynamometer load to 50 percent of torque peak load. Operate the engine at this speed and load level for 2 minutes.

Check all gauges and record the data.

Do **not** proceed to the next step until blowby is stable within specifications.



Torque Peak

2x (Test Load)
(50% Rated Load)

2 Minutes

oi804vh

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.

Do **not** proceed to the next step until blowby is stable within specifications.



Torque Peak

3x (Test Load)
(75% Rated Load)

2 Minutes

oi804vi

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.

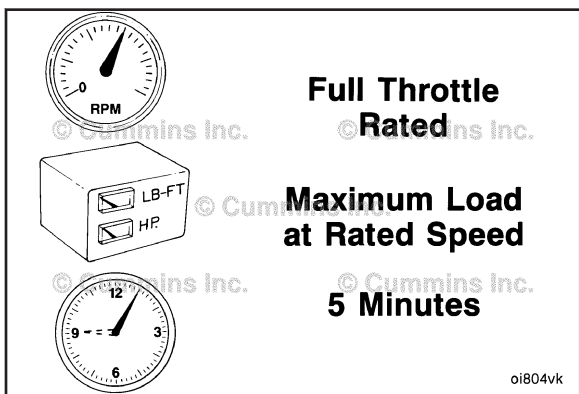


Full Throttle
Torque Peak

Maximum Load

10 Minutes

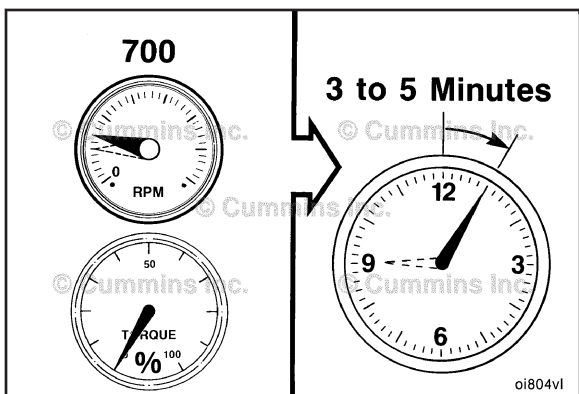
oi804vj



Reduce the dynamometer load until the engine speed increases to the engine's rated rpm.

Operate the engine at rated rpm for 5 minutes.

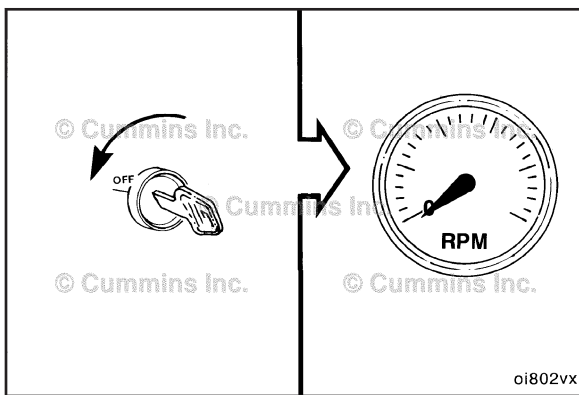
Check all gauges and record the data.



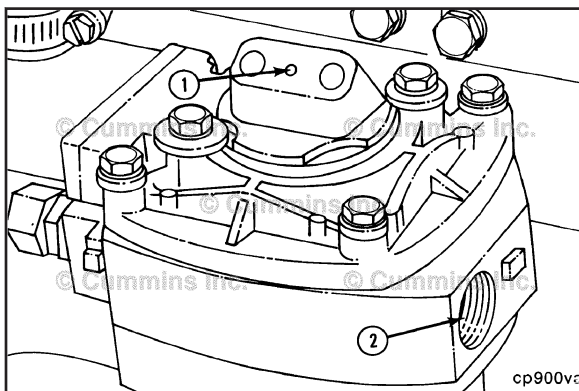
CAUTION

Shutting off the engine immediately after operating at full load will damage the turbocharger and internal components. Always allow the engine to cool before shutting it off.

Remove the dynamometer load completely, and operate the engine at 700 rpm for 3 to 5 minutes. This period will allow the turbocharger and other components to cool.



Shut off the engine.



Engine Dynamometer Test - Performance Checking

Make sure the air compressor is unloaded during the performance check.

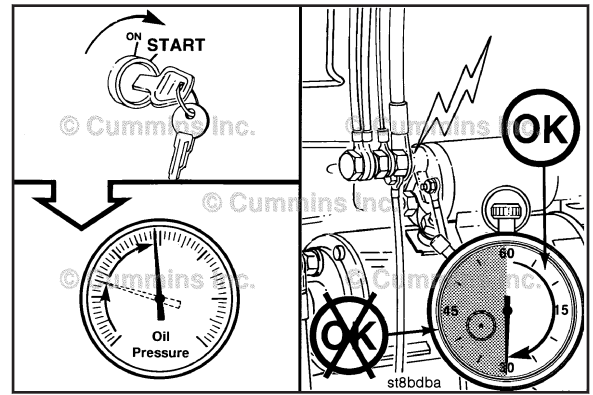
Apply regulated air pressure of 655 kPa [95 psi] to the air compressor unloader (1).

The compressed air load in the accompanying illustration **must** be attached to the air compressor outlet (2).

⚠CAUTION⚠

Do not crank the engine for more than 30 seconds. Excessive heat will damage the starting motor.

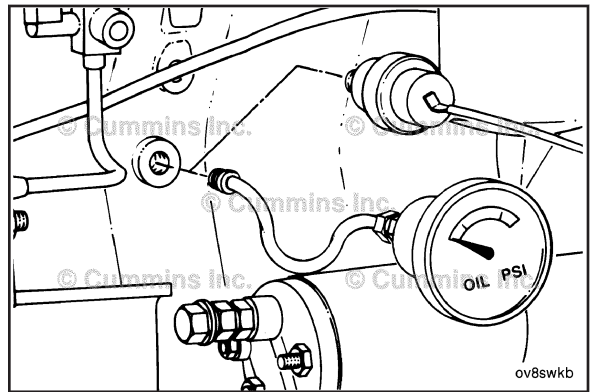
Crank the engine and observe the oil pressure when the engine starts. If the engine fails to start within 30 seconds, allow the starting motor to cool for 2 minutes before cranking the engine again.



⚠CAUTION⚠

If the lubricating oil pressure is not within specifications, shut off the engine immediately. Low lubricating oil pressure will cause engine damage. 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.



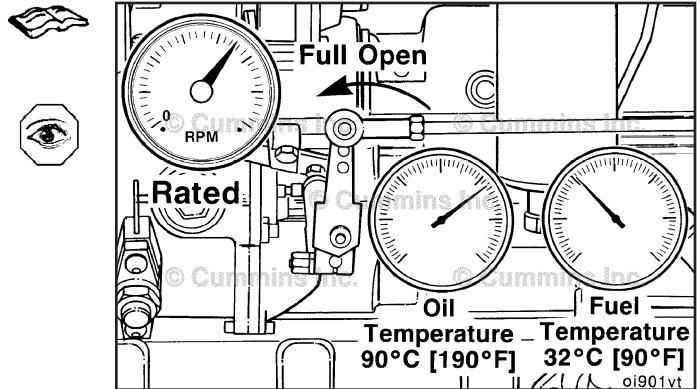
Make sure the engine is at operating temperature.

Move the throttle lever to the "FULL OPEN" position. Adjust the dynamometer load until the engine maintains the rated rpm.

Allow the readings to stabilize. Read the horsepower.

Check all the gauges, and record the readings.

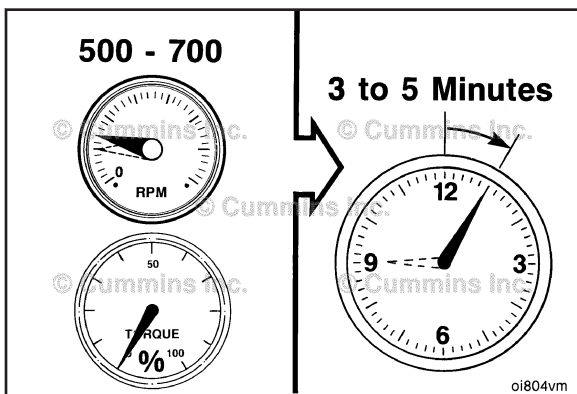
The horsepower reading will **not** be accurate if the lubricating oil temperature and fuel temperature are **not** within specifications.



Lubricating Oil Temperature		
°C		°F
90	MAX	190

Fuel Temperature		
°C		°F
32	MAX	90

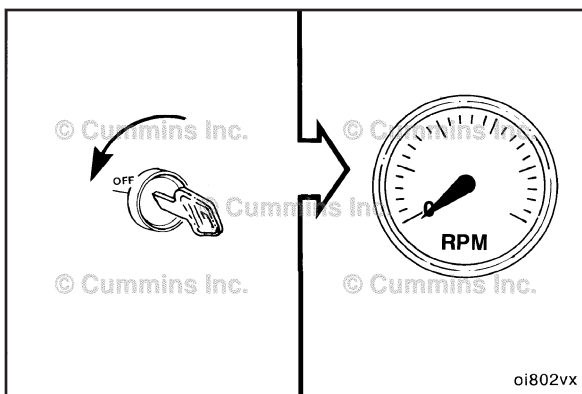
Check all gauges and record the data.



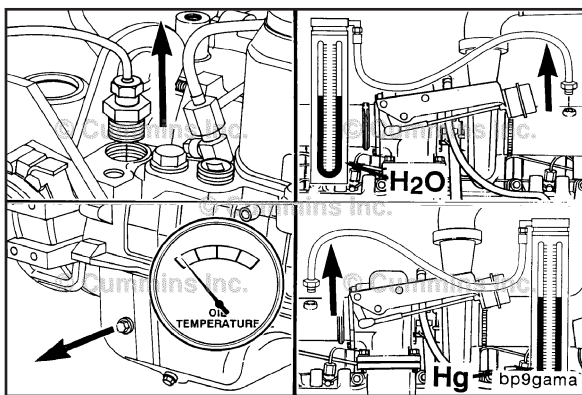
⚠ CAUTION ⚠
Do not shut off the engine immediately after it has been loaded. It must be allowed to sufficiently cool.

Remove the dynamometer load completely, and operate the engine at idle speed for 3 to 5 minutes. This will allow the turbocharger and other components to cool.

Idle periods longer than 5 minutes are to be avoided.



Shut off the engine after the cool down period.



Remove all test instrumentation. Remove the engine from the dynamometer.

If the engine is to be stored temporarily and does **not** have permanent type antifreeze, it is necessary to drain all coolant.

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.

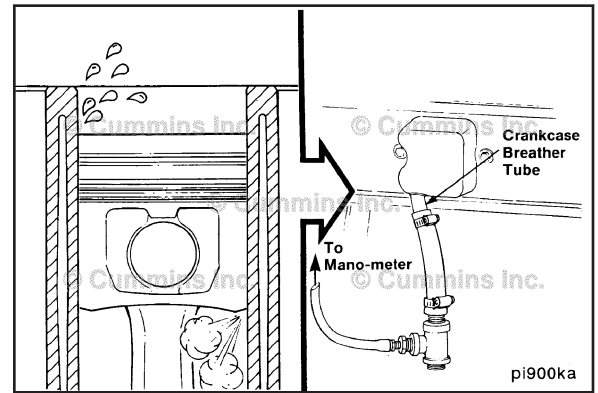
Blowby is typically measured for the following situations:

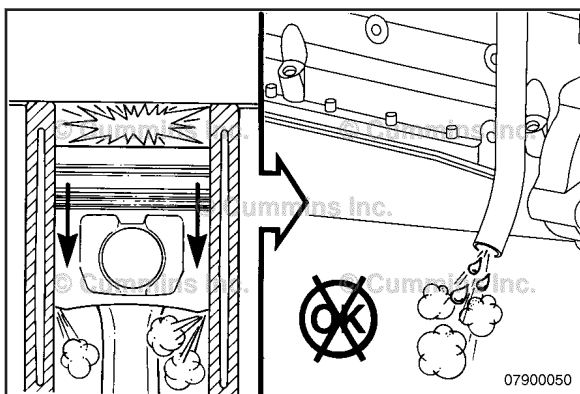
- Verifying engine break-in after an engine rebuild
- Troubleshooting for excessive lubricating oil out of the crankcase breather tube, commonly referred to as oil carryover (for open crankcase ventilation systems)
- Troubleshooting oil in the air intake system (for closed crankcase ventilation systems)
- 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.





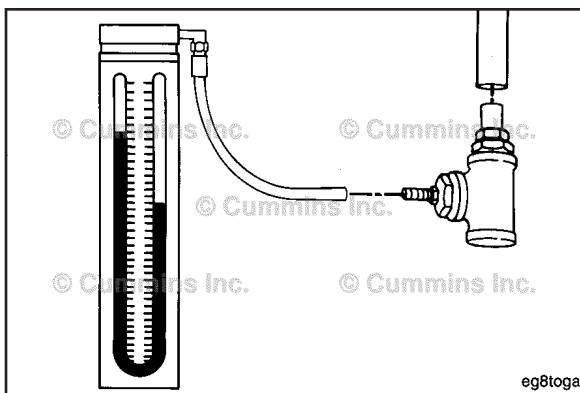
It is important to note that the terms blowby and carryover (oil out of the breather tube) are commonly used interchangeably.

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 water manometer, Part Number ST1111-3, or equivalent, pressure gauge, or transducer to the blowby tool.

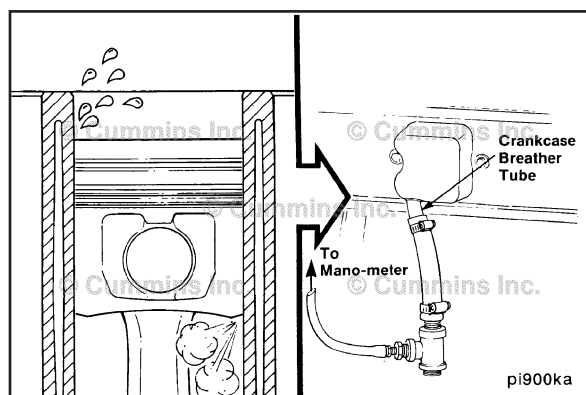
NOTE: Water manometer, Part Number ST1111-3, can measure a maximum of 944 mm [36 in] of water.

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 H₂O	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 [4.273]
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 H₂O	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 ₂ O	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.

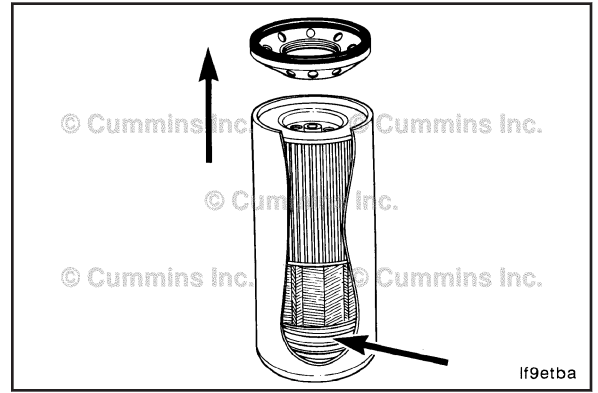
Measuring blowby **must only** be considered when confirming engine break-in after a rebuild or if another symptom is present. These symptoms can include:

- 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 ₂ O		Blowby Specification For Troubleshooting - mm [in] H ₂ O	
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		101.6 [4]		254 [10]
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	

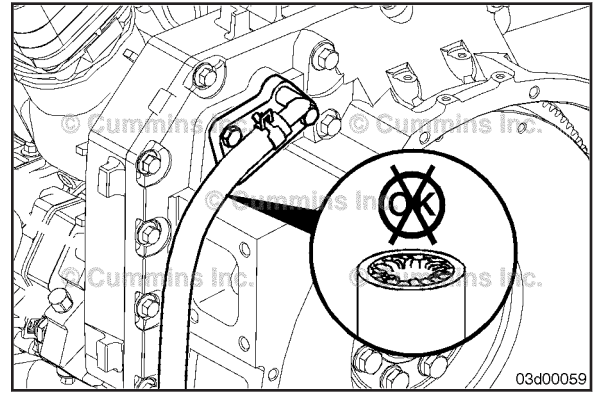
Initial Check

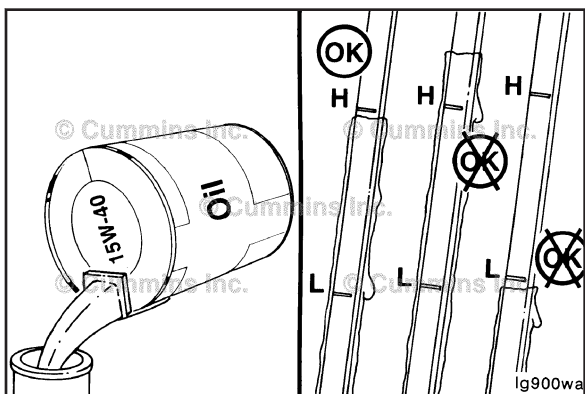
NOTE: The location and type of crankcase breathers vary by engine configuration (Front Gear Train or Rear Gear Train) and/or engine application (Marine, Industrial, and Automotive).

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.

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.

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]

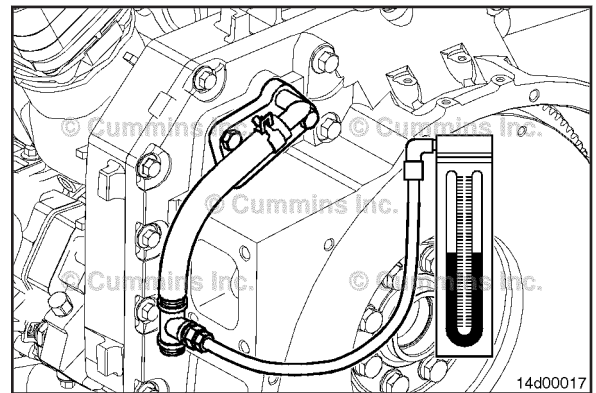
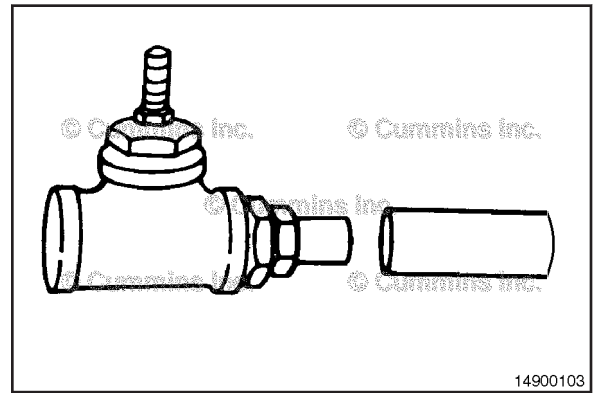
NOTE: Either service tool can be used to measure blowby, as long as the blowby measurement is correctly matched to the correct flow rate. Reference the flow rate conversion tables in this procedure for the correct orifice.

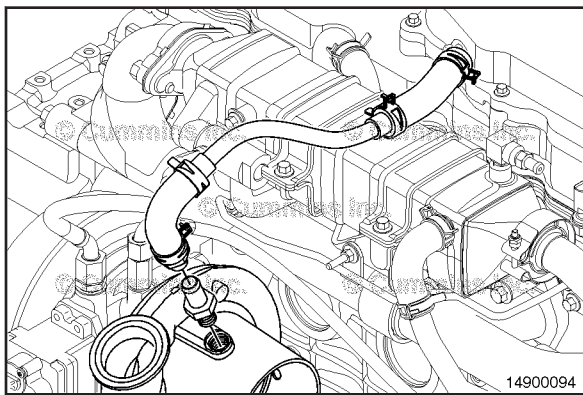
To measure the crankcase blowby pressure, connect a water manometer, Part Number ST1111-3, pressure gauge, or transducer to the blowby measurement service tool.

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 (Engine Identification) for crankcase breather tube locations.

Install the appropriate blowby service tool(s):

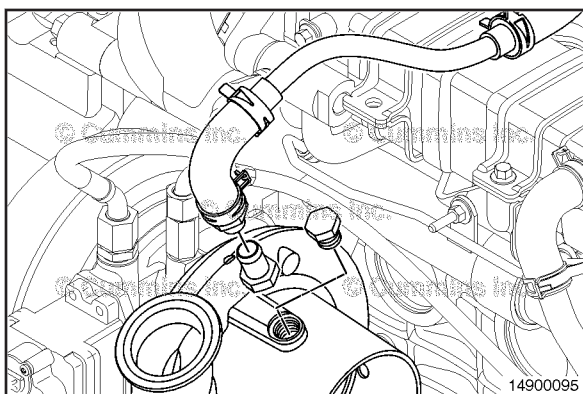
- For typical open crankcase breather/ventilation systems, connect the appropriate blowby service tool to the end of the crankcase breather tube. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.
- For engines with closed crankcase ventilation systems (without a crankcase 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.





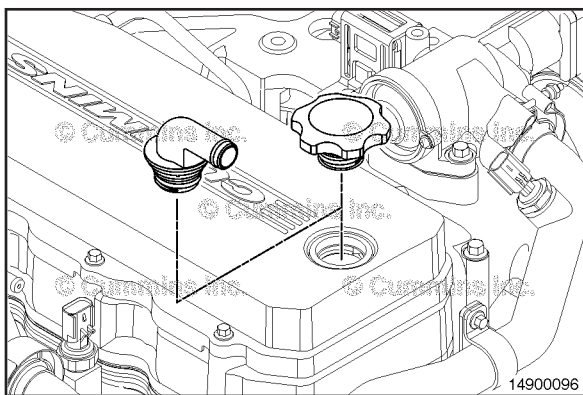
For ISB CM2150 engines that have the crankcase ventilation filter located on top of the rocker lever cover, use the following steps to connect the blowby measurement tools.

- 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.

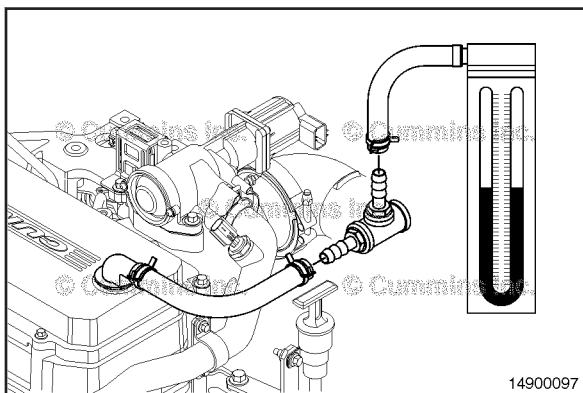


- If the crankcase ventilation line is connected to the turbocharger housing, install a straight thread plug, Part Number 3089567. Plug the crankcase ventilation line with a suitable fitting.

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.

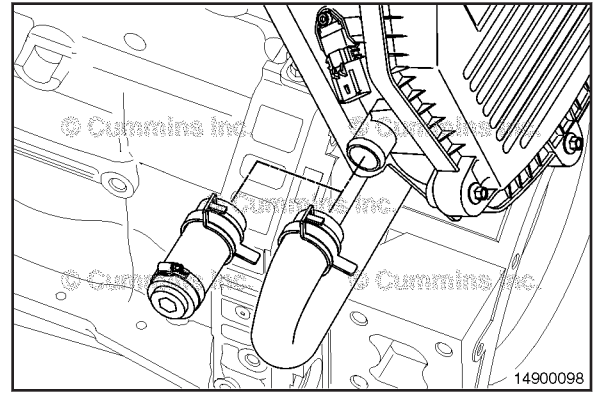


- Connect the appropriate blowby service tool to the outlet of the oil fill adapter. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.

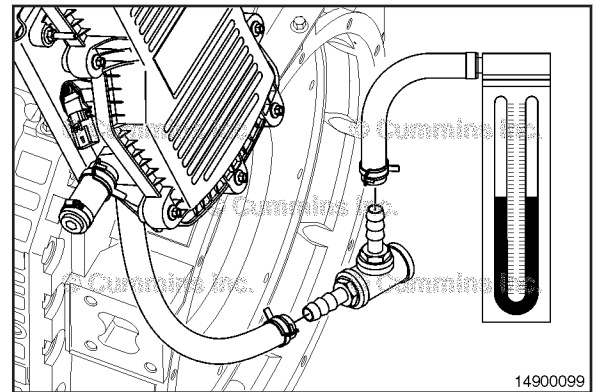
For ISB CM2150 engines that have the crankcase ventilation filter located at the rear of the engine, use the following steps to connect the blowby measurement tools.



- Disconnect the crankcase ventilation line from the crankcase ventilation filter housing. Plug or cap the crankcase ventilation filter housing.



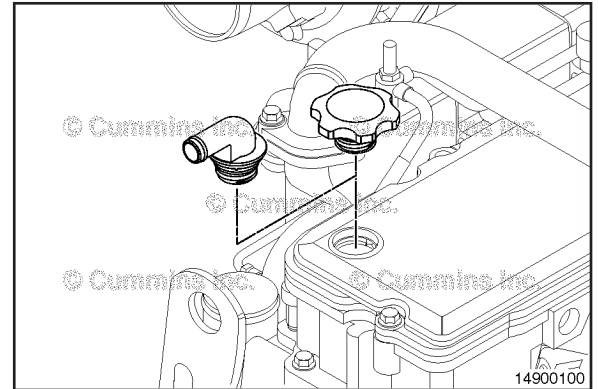
- Connect the appropriate blowby service tool to the crankcase ventilation line exiting the flywheel housing. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.



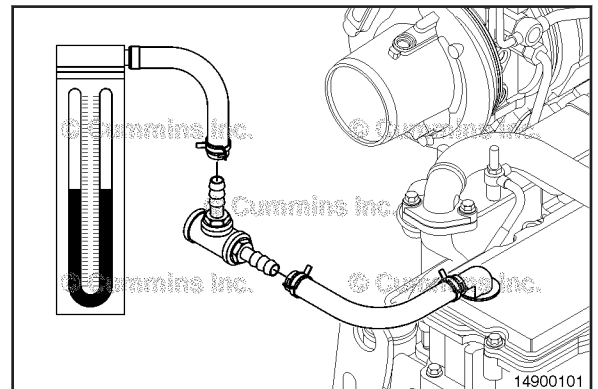
For ISC and ISL CM2150 engines, use the following steps to connect the blowby measurement tools.

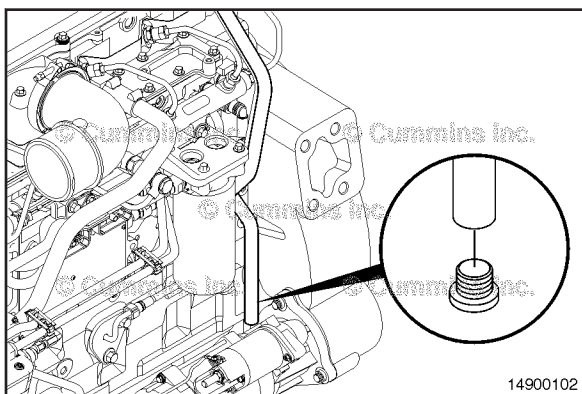


- Remove the oil fill cap from the rocker lever cover. Install an oil fill adapter, Part Number 3990099.

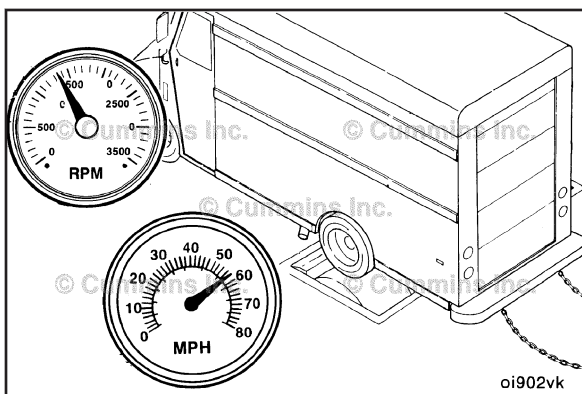


- Connect the appropriate blowby service tool to the outlet of the oil fill adapter. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.





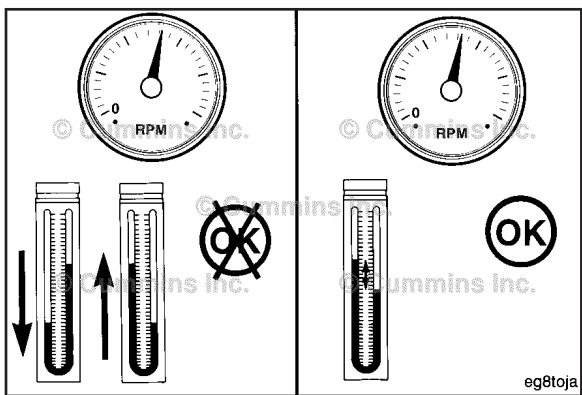
- Use a suitable fitting to plug the crankcase breather tube.



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.

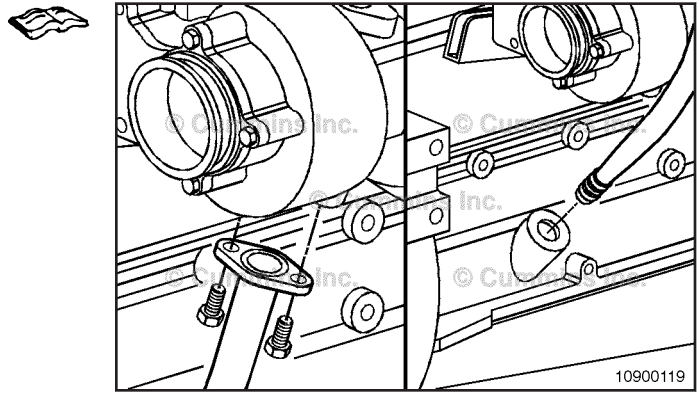
Remove the engine blowby service tool and the water manometer, pressure gauge, or transducer, if the blowby is within specification.

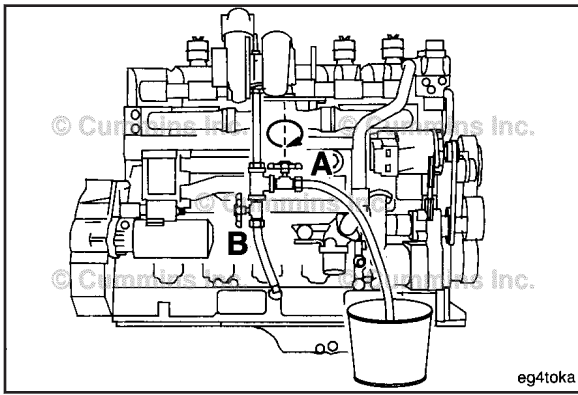
Turbocharger Blowby Contribution:

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.





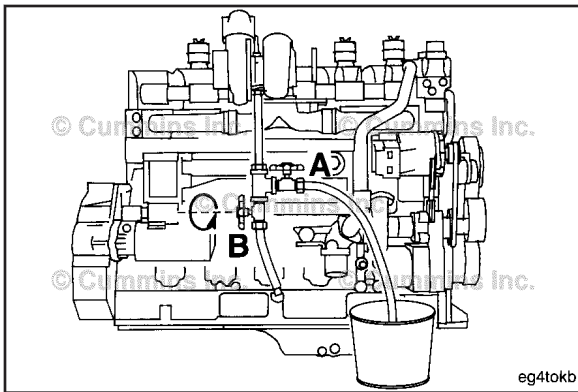
Preferred Turbocharger Isolation Method:

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.

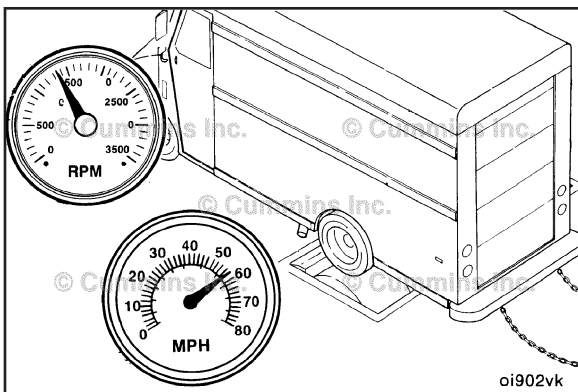


Operate the engine at rated speed and under load by either:

- 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:

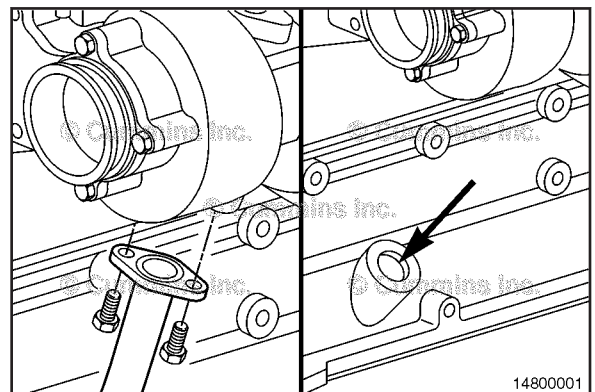
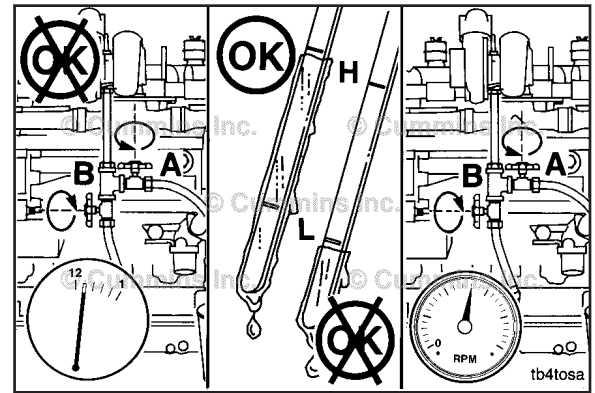
With the turbocharger oil drain line disconnected from the cylinder block, run the turbocharger drain line into a large container.

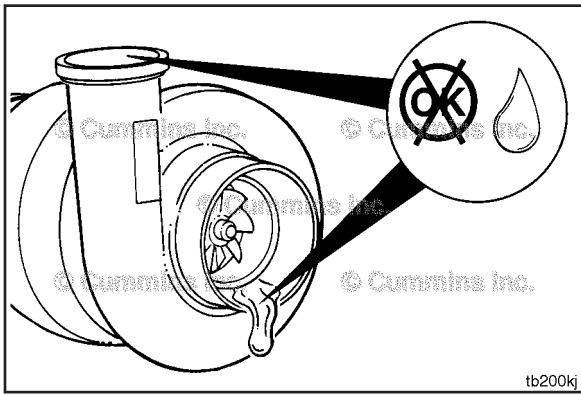
Plug the turbocharger oil drain port in the cylinder block.

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.

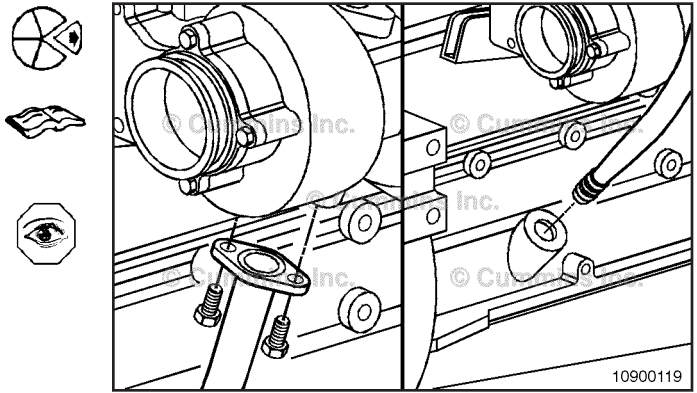
- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 010-033 in Section 10.
- Use the 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.

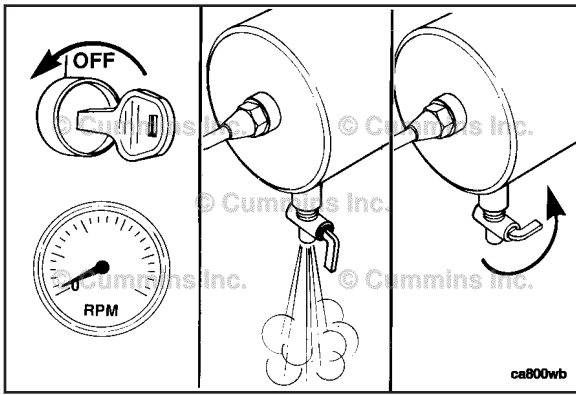
C Series
Section 14 - Engine Testing - Group 14

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.

Check the engine oil level and add oil if necessary.



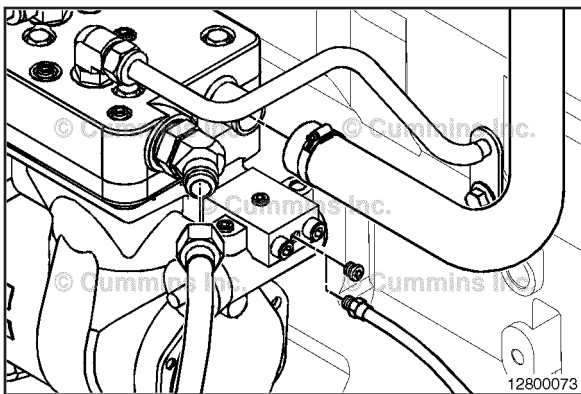


⚠ WARNING ⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

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.

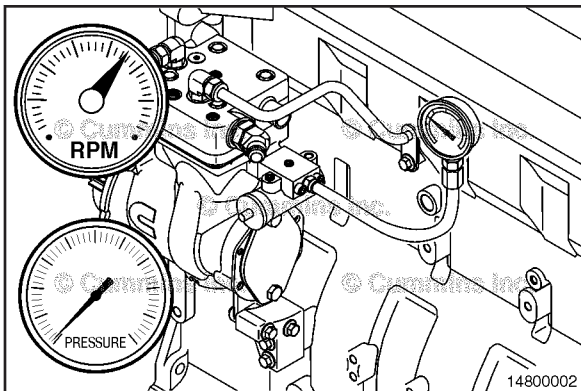


NOTE: The air compressor governor/unloader location can vary on each engine application. The air governor/unloader can be air compressor mounted or chassis mounted.

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.

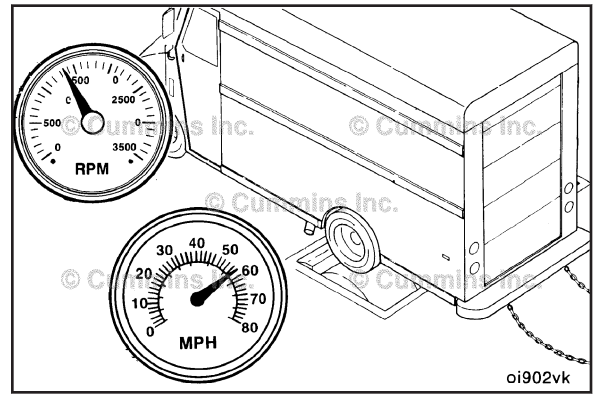


Operate the engine at rated speed and under load by either:

- 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.



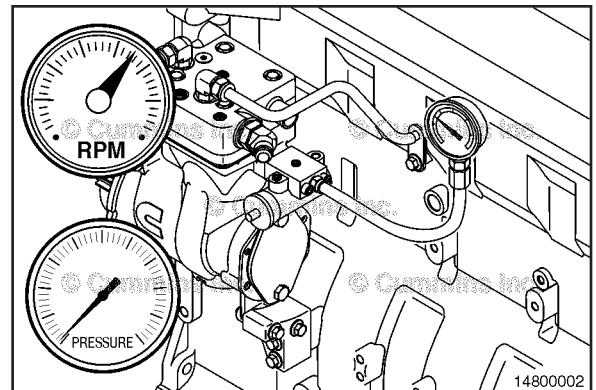
Continue operating the engine at rated speed and load.

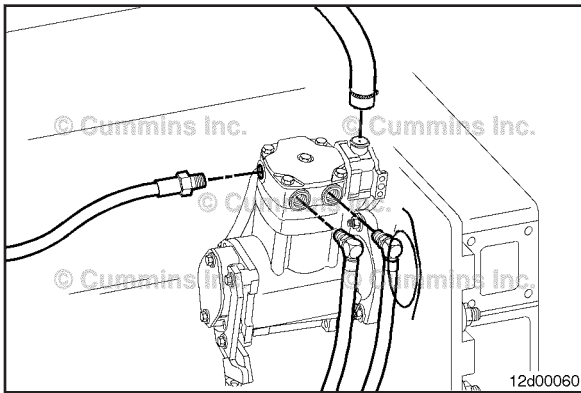
Increase the signal pressure (system pressure stops rising at this point). Use the pressure value recorded previously as a set point.



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

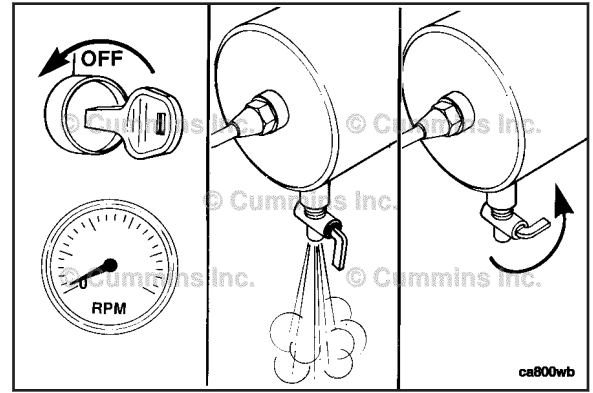
If the air compressor blowby contribution is out of specification, replace the air compressor.

- 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.

⚠ 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.



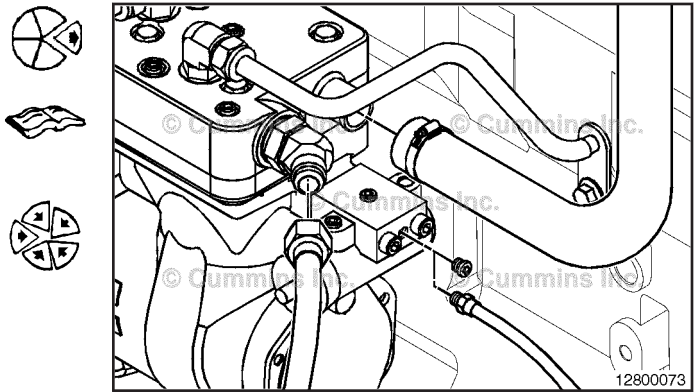
Disconnect the regulated shop air pressure line, with pressure gauge, from the air compressor governor/unloader air signal port.

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.

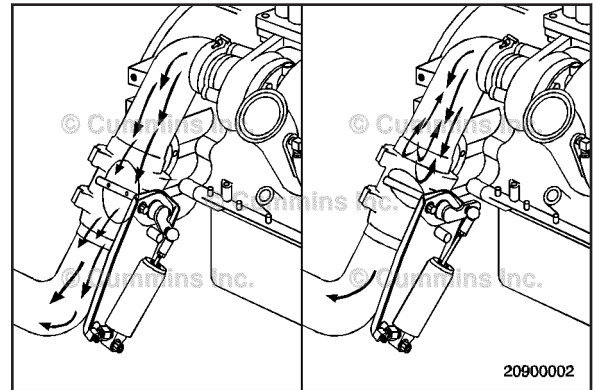


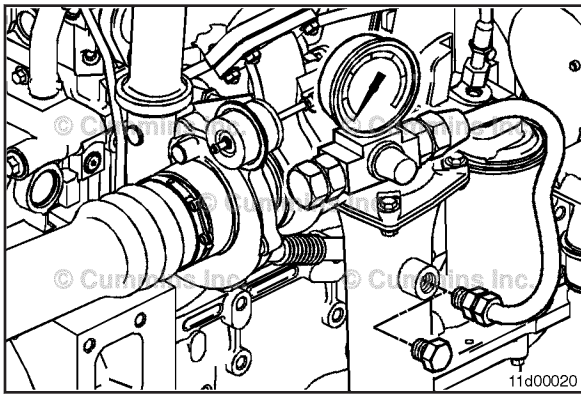
Exhaust Brake Blowby Contribution:

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.

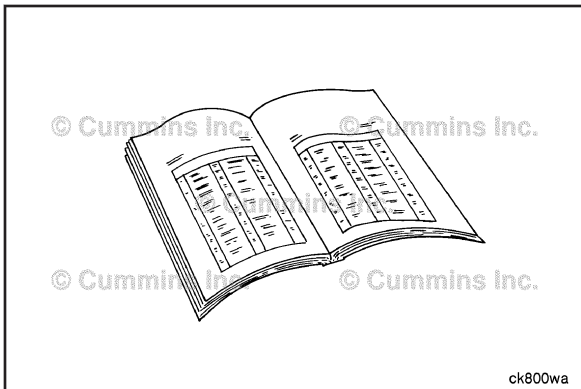
If blowby pressure is above specification during exhaust brake operation and exhaust back pressure is above specification, repair or replace the exhaust brake. See the manufacturer's instructions.

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.

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.

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.
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- 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.
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- 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.

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.
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- 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.

Engine Compression (014-012)

Measure

It is very time-consuming and expensive to begin removing internal engine components to diagnose failures. A compression gauge, Part Number 3164627, and adapter, Part Number 3164840, can be used as an aid to check for proper functioning of the following components:

1. Piston ring sealing
2. Intake and exhaust valve sealing
3. Cylinder head gasket sealing
4. Cylinder head cracked

Refer to the appropriate procedure in this section for replacement of failed components.

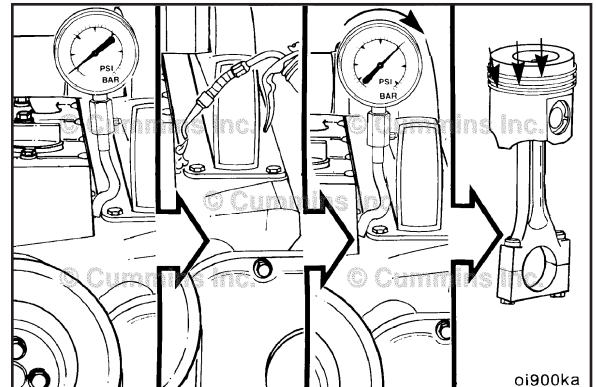
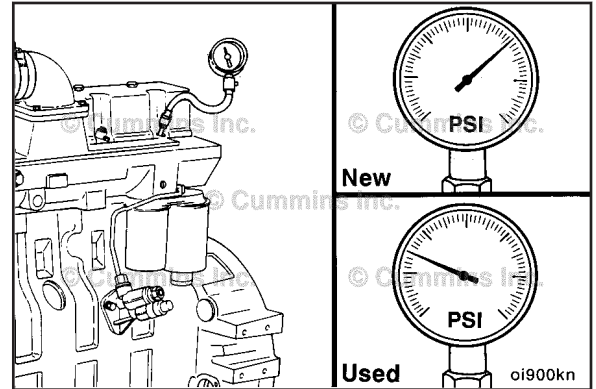
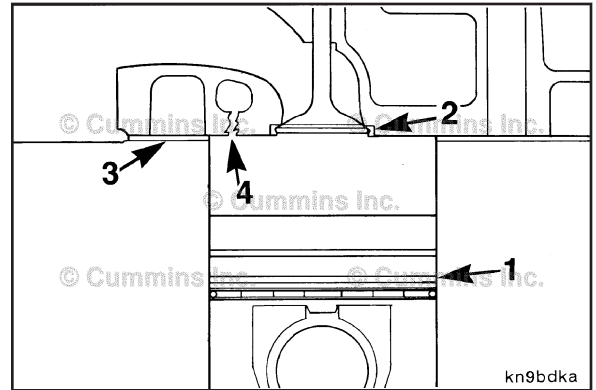
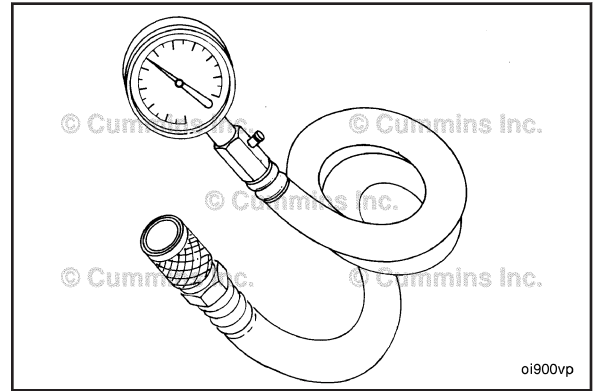
NOTE: Due to variables such as starter and battery conditions that affect engine cranking speed, it is difficult to establish an absolute value for compression pressure; however, the following values can be used as guidelines:

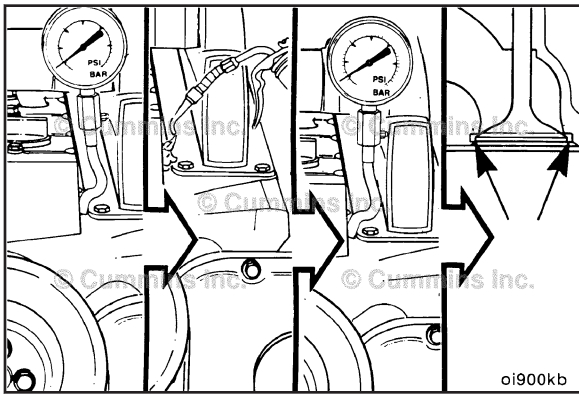
- New engine (cranking speed at 250 rpm) 2413 kPa [350 psi]
- Used engine (cranking speed at 250 rpm) 2068 kPa [300 psi]

It is recommended that the compression pressure be checked on all cylinders and then compared. All cylinders should be within 690 kPa [100 psi] of each other.

Piston Ring Sealing

If the compression is low but can be increased significantly by squirting oil into the cylinder, the cause of low compression is inadequate sealing between the rings and the cylinder walls. Refer to procedure 007-013 for piston ring replacement.

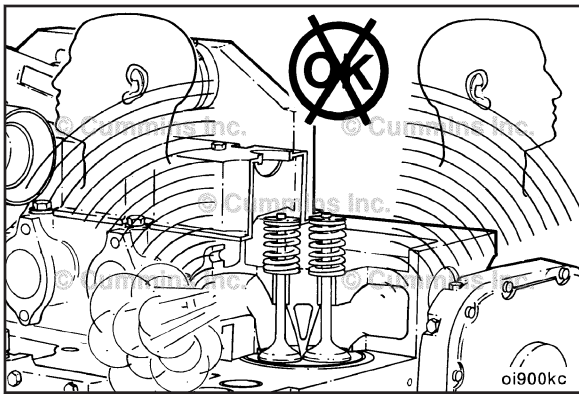




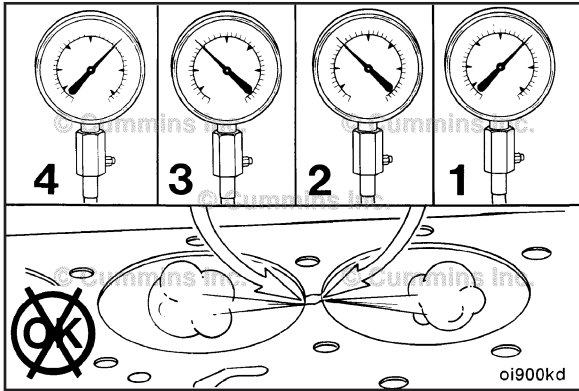
Intake and Exhaust Valve Sealing

If the compression is low on one or more non-adjacent cylinders and the pressure can **not** be increased by oiling the rings, poor valve sealing is to be suspected.

Refer to Procedure 007-009 for cylinder head replacement.



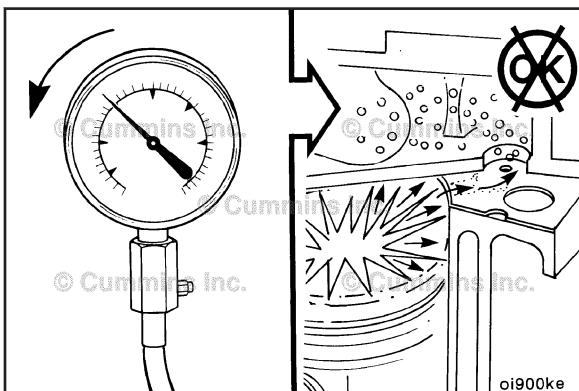
Valve leakage is often audible from the intake and exhaust manifold.



Cylinder Head Gasket Sealing

If the compression is low on adjacent cylinders and the pressure can **not** be increased by oiling the rings, the cylinder head gasket is probably leaking between the cylinders.

Refer to Procedure 007-009 for cylinder head gasket replacement.



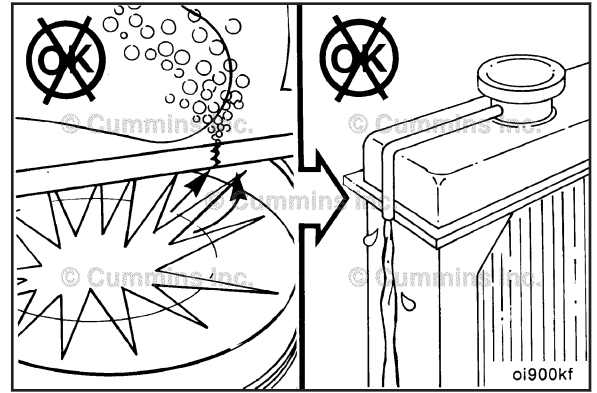
NOTE: Low compression on a single cylinder can be caused by an external leak to a coolant passage. A leak to a coolant passage of this magnitude will also result in coolant in the cylinder.

⚠ 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.

A compression leak to the coolant normally will be detected by loss of coolant as the coolant is blown from the cooling system.

NOTE: Remove the drive belt from the water pump. Run the engine for 1 to 2 minutes and check for coolant being blown from the radiator by compression gases.



Section 16 - Mounting Adaptations - Group 16

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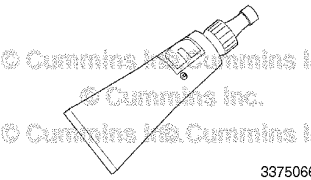
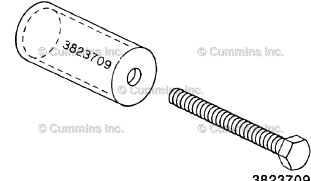
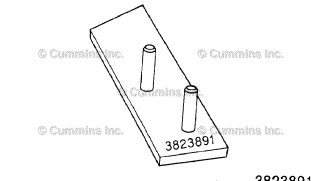
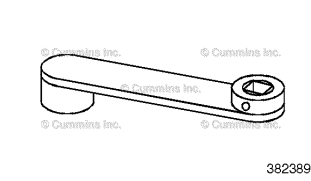
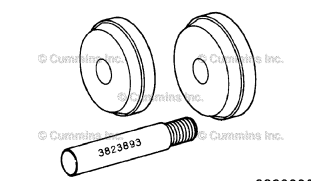
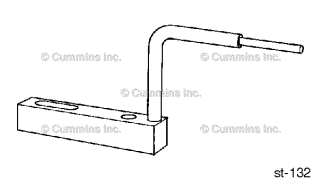
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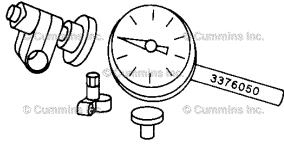
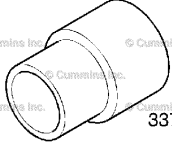


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Service Tools

Mounting Adaptations

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

Tool No.	Tool Description	Tool Illustration
3375066	<p>Pipe Sealant Used on capscrew threads and pipe plugs.</p>	 <p style="text-align: right;">3375066</p>
3823709	<p>Idler Shaft Puller and Capscrew Used to remove idler shaft from idler gear and flywheel housing.</p>	 <p style="text-align: right;">3823709</p>
3823891	<p>Gear Locking Tool Used to prevent rotation of the power take-off output shaft while tightening the output flange capscrew.</p>	 <p style="text-align: right;">3823891</p>
3823892	<p>Offset Wrench (C Series Engine) Used to tighten the hidden capscrews in the REPTO flywheel housing.</p>	 <p style="text-align: right;">3823892</p>
3823893	<p>Bearing Race Driver Used to install output shaft bearing races.</p>	 <p style="text-align: right;">3823893</p>
ST-1325	<p>Dial Indicator Attachment Used to attach to crankshaft flange to provide measuring of flywheel and flywheel housing runout with dial bore gauge.</p>	 <p style="text-align: right;">st-1325</p>

Tool No.	Tool Description	Tool Illustration
3375068	<p>Cup Plug Sealant Used when installing cup plugs.</p>	 <p>3375068</p>
3376050	<p>Dial Indicator and Sleeve Assembly Used with dial gauge attachment, Part Number ST-1325, to measure flywheel and flywheel housing runout.</p>	 <p>3376050</p>
3376812	<p>Cup Plug Driver Used to install cup plug in flywheel housing.</p>	 <p>3376812</p>
3801048	<p>Cummins Sealant Used to seal mating surfaces.</p>	 <p>3823494</p>
3823494	<p>Three-bond™ Sealant Used on heavy-duty silicone type of cup plug sealant.</p>	 <p>3823494</p>

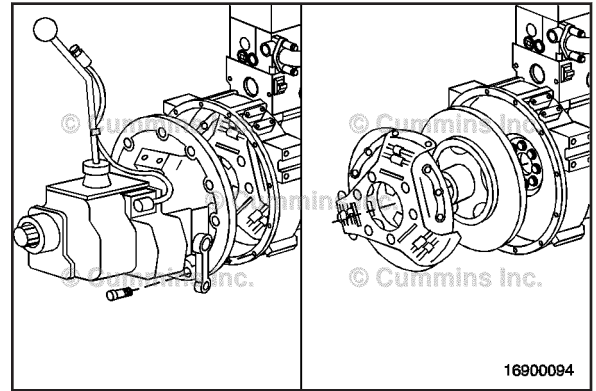
Flywheel (016-005)

Remove

Remove the vehicle driveline and transmission. Refer to the manufacturer's instructions.

Remove the clutch discs and the pressure plate. Refer to the manufacturer's instructions.

NOTE: Use the barring tool, Part Number 3824591, to hold the flywheel to prevent rotation.



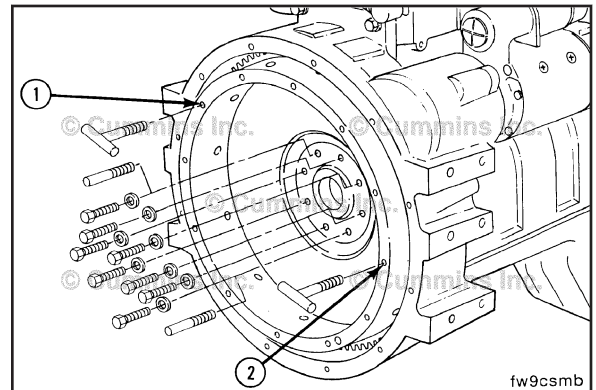
Remove two capscrews 180 degrees apart.

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).

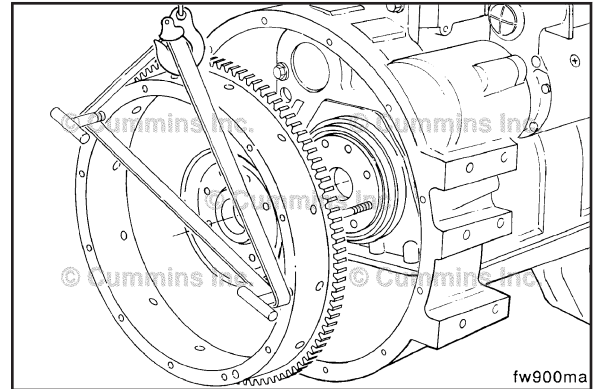
Remove the remaining six flywheel mounting capscrews.

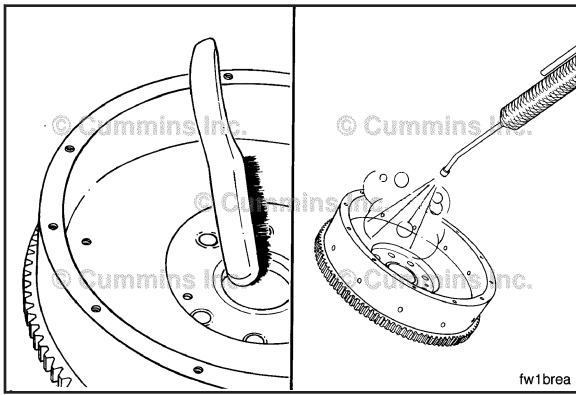


▲ WARNING ▲

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.

Remove the flywheel from the guide pins.





Clean

⚠ WARNING ⚠

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

⚠ WARNING ⚠

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.

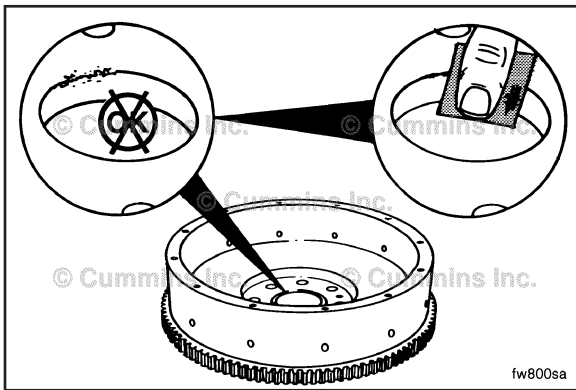
⚠ WARNING ⚠

Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

Use a wire brush to clean the crankshaft pilot bore.

Use steam or solvent to clean the flywheel.

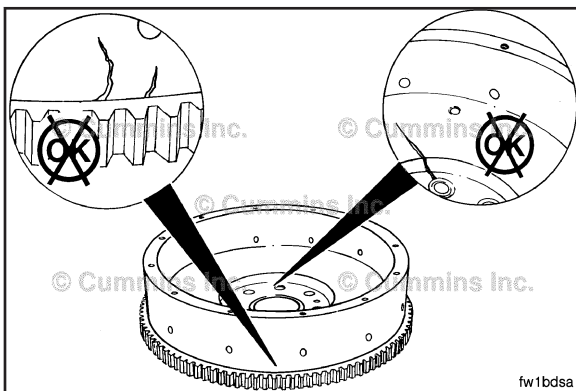
Dry with compressed air.



Inspect for Reuse

Inspect for nicks or burrs.

Use Scotch-Brite™ 7448, or equivalent, to remove small nicks and burrs.



⚠ WARNING ⚠

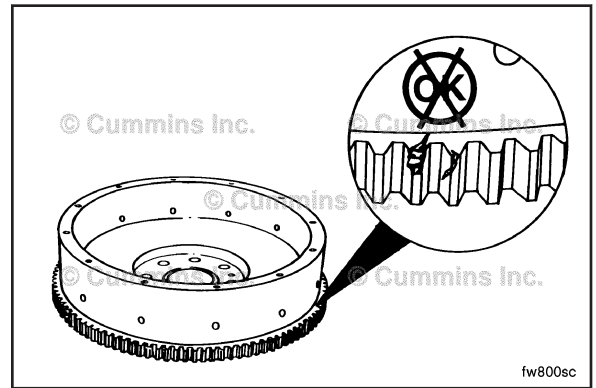
Do not use a cracked or resurfaced flywheel. These can break, causing serious personal injury or property damage.



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.

NOTE: If the ring gear teeth are cracked or broken, the ring gear **must** be replaced. Refer to Procedure 016-008.



Measure

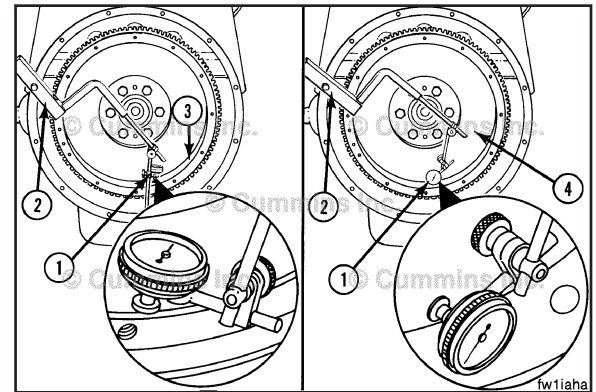
Flywheel Bore Runout

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.

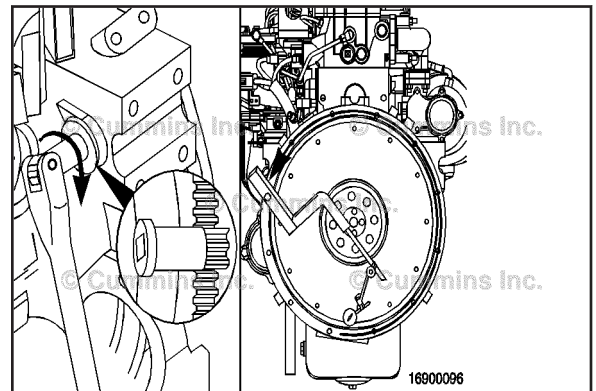
Install the gauge on the attachment.

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.

NOTE: The total indicator reading (TIR) **must not** exceed 0.127 mm [0.0050 in].

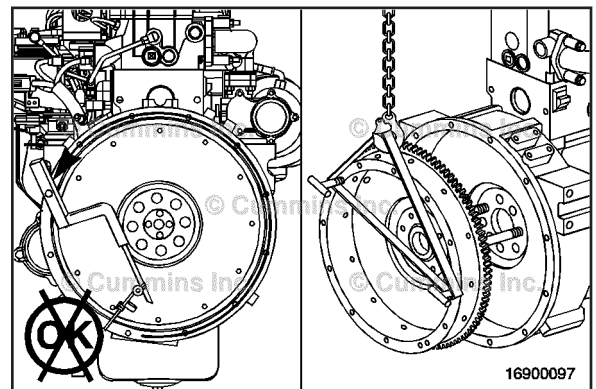


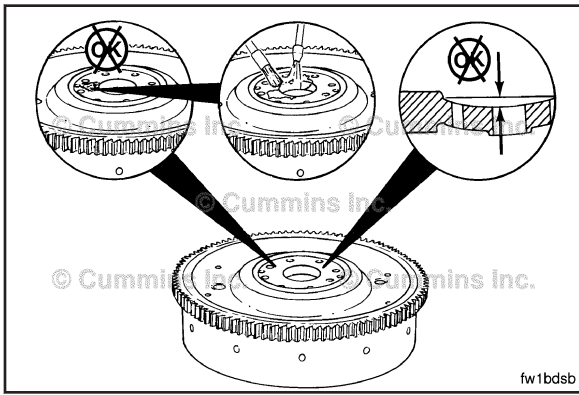
▲ WARNING ▲

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.

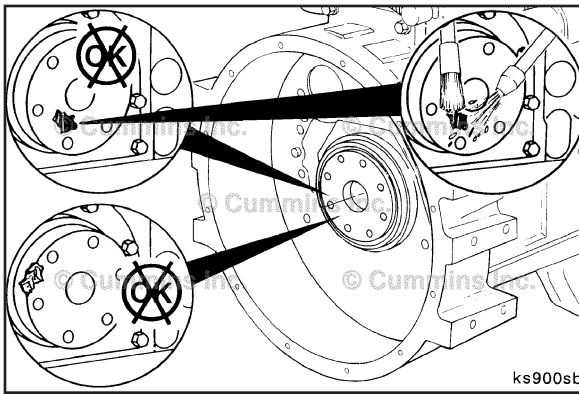
NOTE: If the total indicator reading (TIR) is greater than the specification, do the following:

- Remove the flywheel.

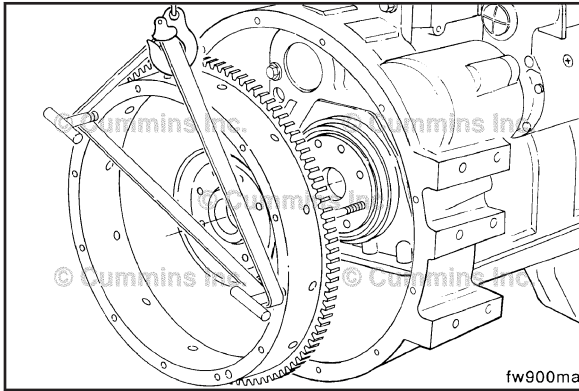




- Inspect the flywheel mounting surface for dirt or damage.



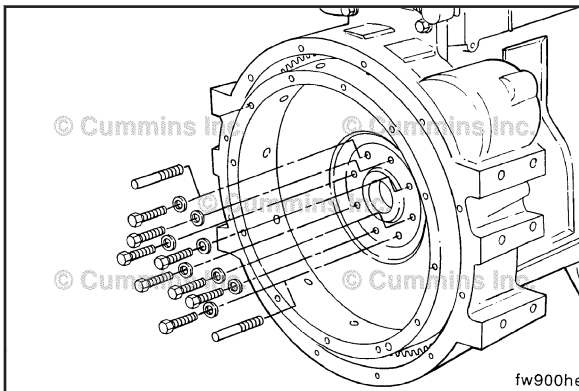
- Inspect the crankshaft for dirt or damage.



⚠ WARNING ⚠
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.



- Install the flywheel.
- Inspect the bore runout again.



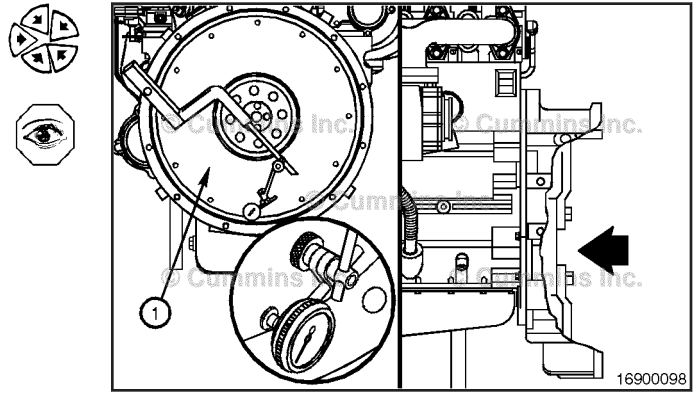
- Replace the flywheel if the runout does **not** meet specifications.

Flywheel Bore Runout		
mm		in
0.127	MAX	0.005

Flywheel Face Runout

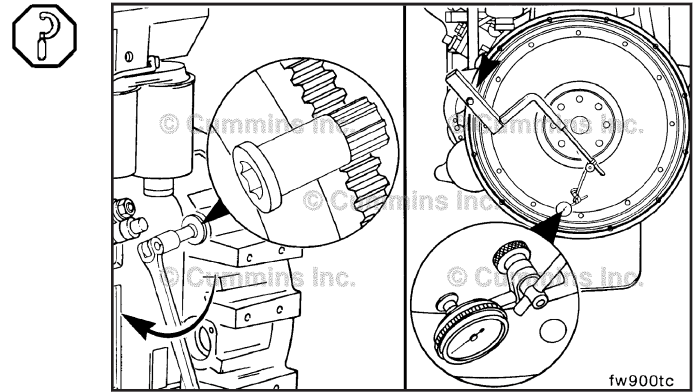
Install the contact tip of the indicator against the flywheel face, as close to the outside diameter as possible, to inspect the face (1) runout.

NOTE: Push the flywheel forward to remove the crankshaft end clearance. Adjust the dial on the indicator until the needle points to zero.



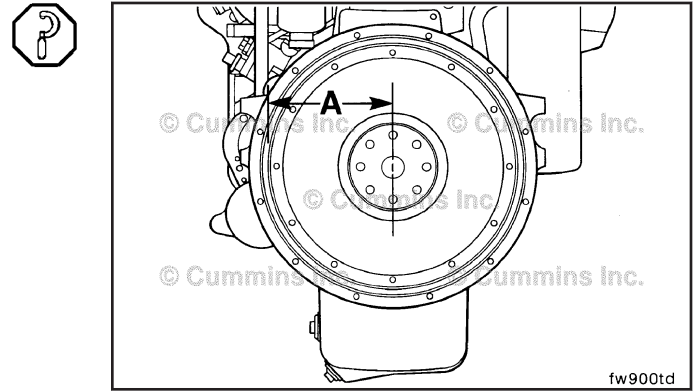
Use the barring tool, Part Number 3824591, to rotate the crankshaft one complete revolution. Measure the flywheel runout at four equal points on the flywheel.

NOTE: The flywheel **must** be pushed toward the front of the engine to remove the crankshaft end clearance each time a point is measured.

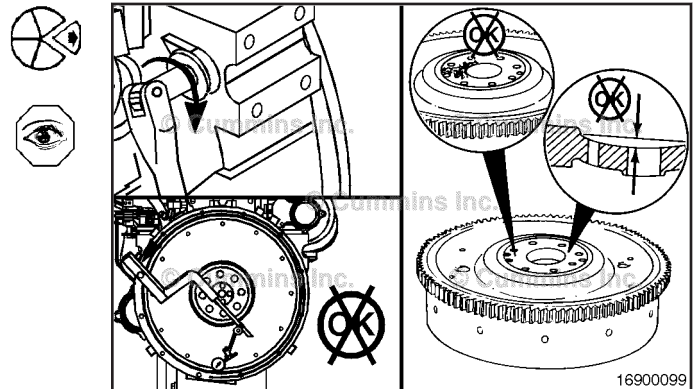


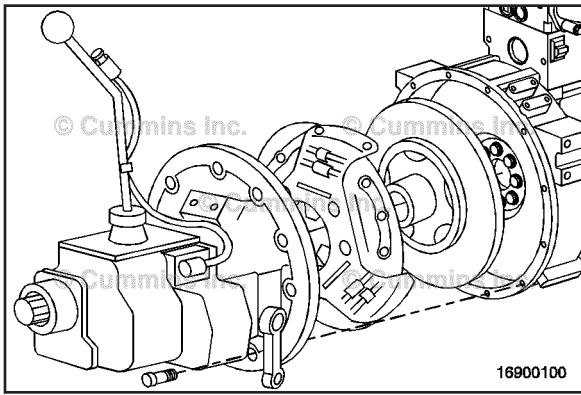
The total indicator reading (TIR) **must not** exceed the following specifications:

Flywheel Radius (A)		Maximum of Flywheel Face	
mm	in	mm	in
203	8	0.203	0.008
254	10	0.254	0.010
305	12	0.305	0.012
356	14	0.356	0.014
406	16	0.406	0.016



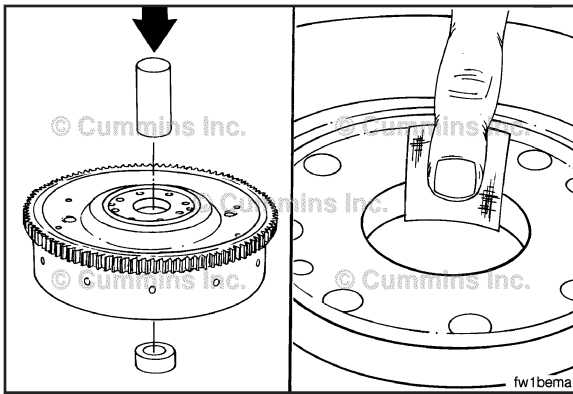
If the flywheel face runout is **not** within specifications, remove the flywheel. Check for nicks, burrs, or foreign material between the flywheel mounting surface and the crankshaft flange.





Install the clutch discs, pressure plate, transmission, and driveline (if equipped) in reverse order of removal. Refer to the manufacturer's instructions.

NOTE: Align the universal joints on each end of the driveshaft to prevent vibration.



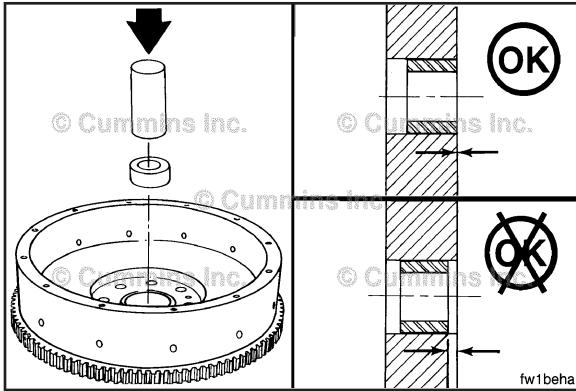
Install

NOTE: Use a new pilot bearing when installing a new or rebuilt clutch.



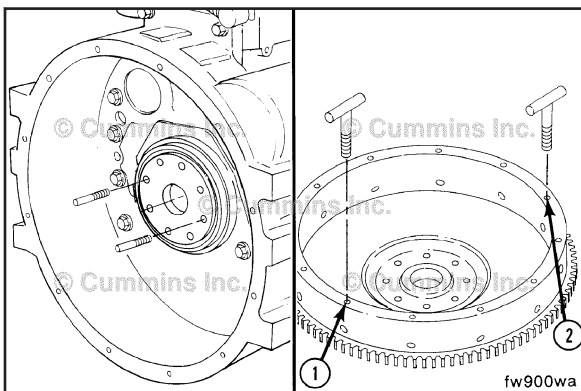
Use a mandrel and hammer to remove the pilot bearing.

Use a Scotch-Brite™ 7448, or equivalent, to clean the pilot bore.



Use a mandrel and hammer to install the pilot bearing.

NOTE: The pilot bearing **must** be installed evenly with the pilot bore surface.



Install two M12 x 1.25 x 90-mm guide pins into the crankshaft flange 180 degrees apart.

NOTE: If a clutch is used in the equipment, the threads in the clutch pressure plate mounting capscrew holes can be metric or standard. Be **sure** to use the correct capscrews.

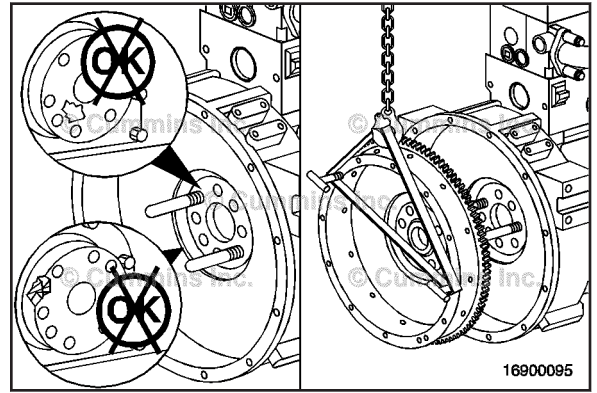
Determine the capscrew thread design and size, and install two t-handles into the flywheel (at points 1 and 2).

⚠ WARNING ⚠

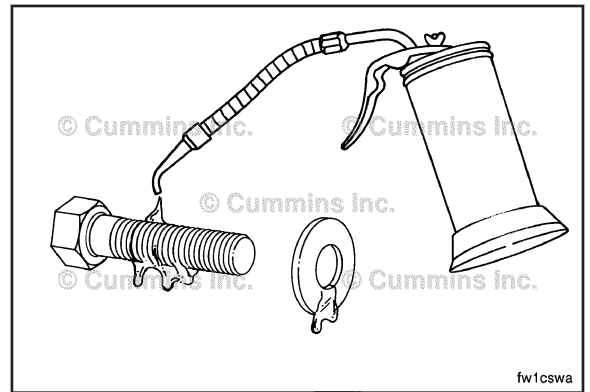
The component weighs 23 kg [51 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift the component.

Inspect the rear face of crankshaft and flywheel mounting flange for cleanliness and raised nicks or burrs.

Install the flywheel on the guide pins.



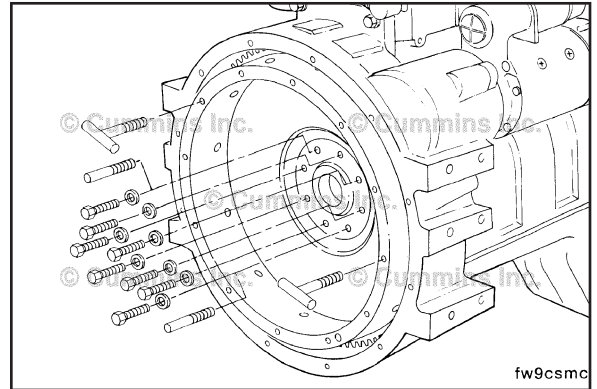
Lubricate the threads of the capscrews and the surface of the washers with clean lubricating engine oil.



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.



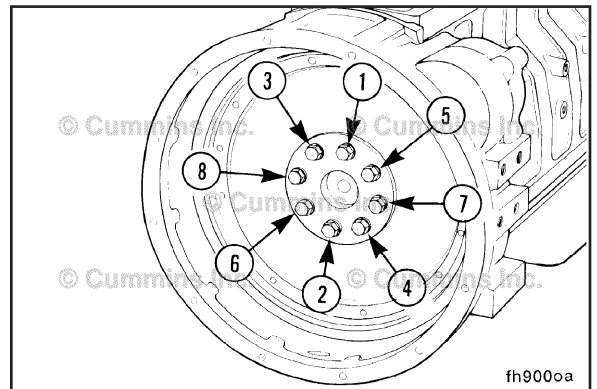
Barring Tool, Part Number 3824591

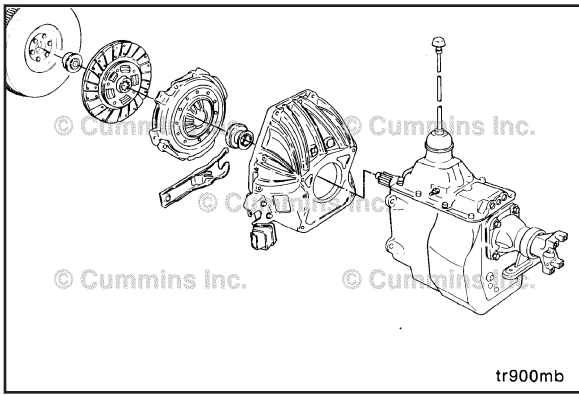
Hold the crankshaft when tightening the flywheel capscrews.

Tighten the capscrews in a star pattern.

Torque Value: 137 N·m [101 ft-lb]

Refer to the equipment manufacturer's procedures to install the transmission.



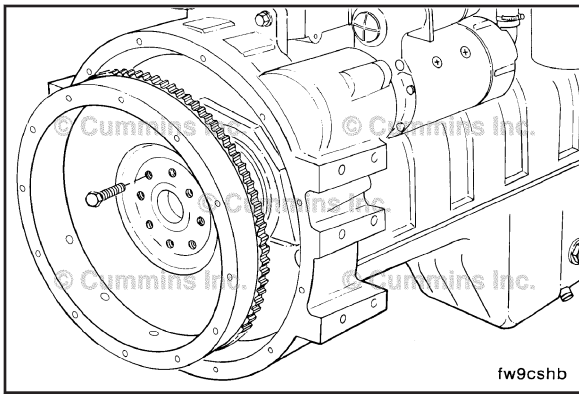


Flywheel Housing (016-006)

Remove



Remove the transmission, clutch, and all related components (if equipped). Refer to the manufacturer's instructions.

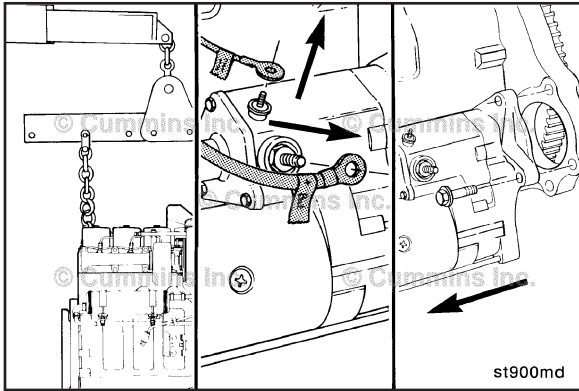


⚠ WARNING ⚠

The component weighs 23 kg [51 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.



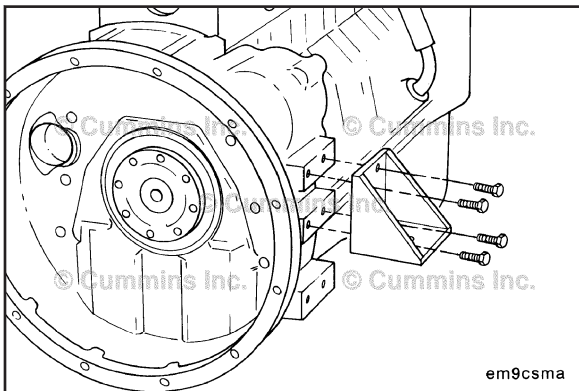
Remove the flywheel/ring gear assembly. Refer to Procedure 016-005.



Adequately support the engine to prevent damage.

Disconnect the battery cables.

Remove the starter motor.

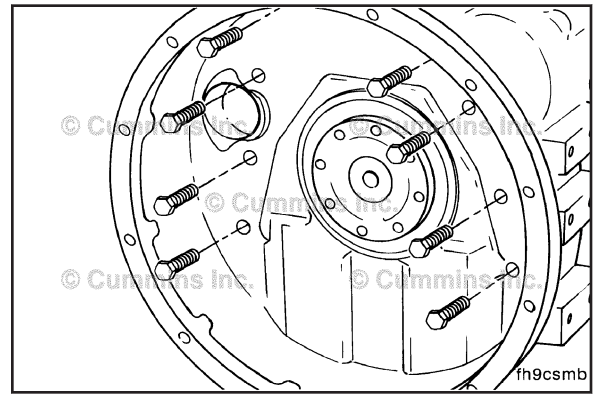


Remove the capscrews and both rear engine mounts.

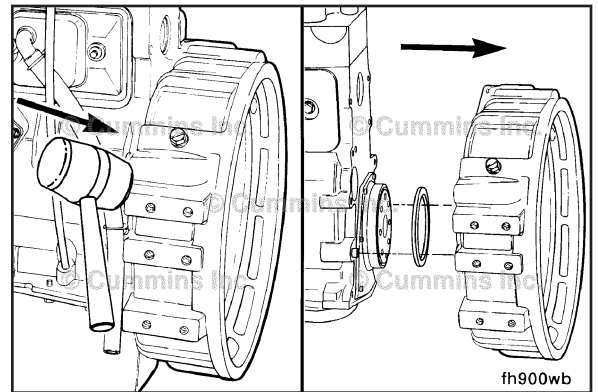
⚠ WARNING ⚠

The component weighs 23 kg [51 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

While supporting the flywheel housing, remove the mounting capscrews.



Use a rubber hammer to loosen the flywheel housing.
Remove the flywheel housing and rectangular seal.



Clean

⚠ 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 ⚠

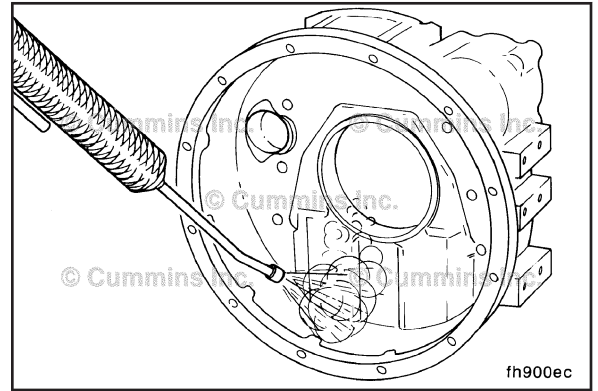
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles, as well as protective clothing, to avoid personal injury.

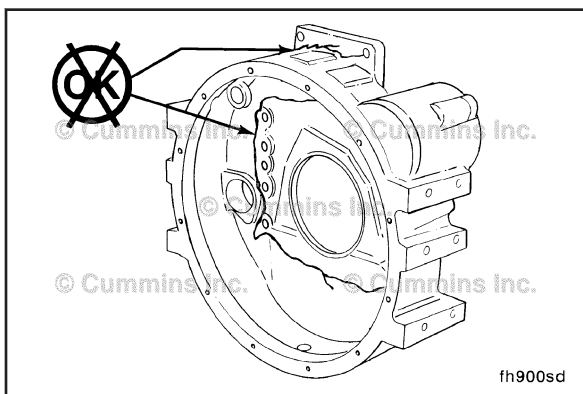
⚠ WARNING ⚠

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 avoid personal injury.

Use steam or solvent to clean the flywheel housing.

Dry with compressed air.



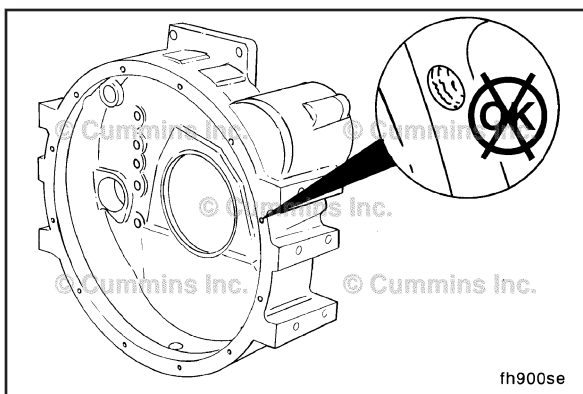


Inspect for Reuse

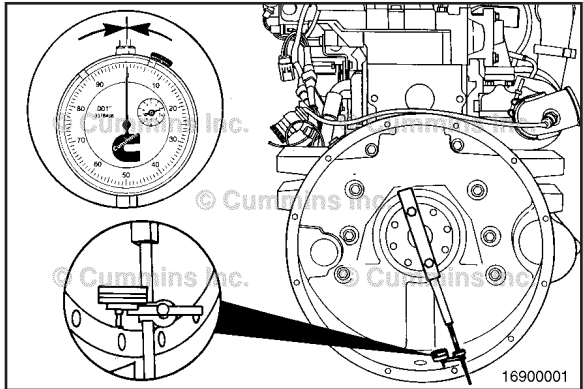
Inspect the flywheel housing for cracks, especially in the bolt pattern area.

Inspect all surfaces for nicks, burrs, or cracks.

Use fine crocus cloth to remove small nicks and burrs.



Inspect for damaged threads commonly caused by cross-threaded capscrews or installing an incorrect capscrew. Helicoils are available to repair damaged threads.



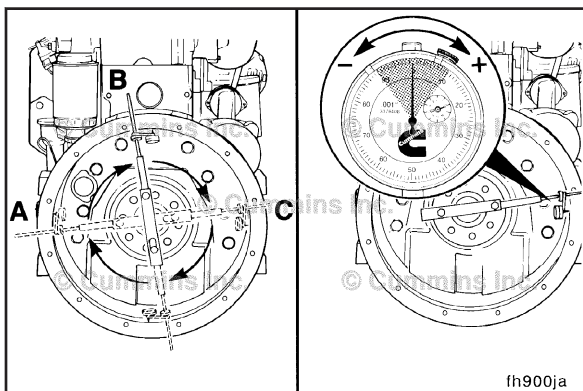
Measure

Bore Alignment



Attach the dial indicator gauge, Part No. 3376050, to the crankshaft. The dial indicator can be mounted by any method that holds the extension bar of the indicator rigid, so it does **not** sag. If the bar sags or the indicator slips, the readings obtained will **not** be accurate.

Position the indicator in the six-o'clock position, and zero the gauge.



Slowly rotate the crankshaft. Record the readings obtained at the nine-o'clock, twelve-o'clock, and three-o'clock positions as [a], [b], and [c] in the concentricity work sheet. Recheck zero at the six-o'clock position.

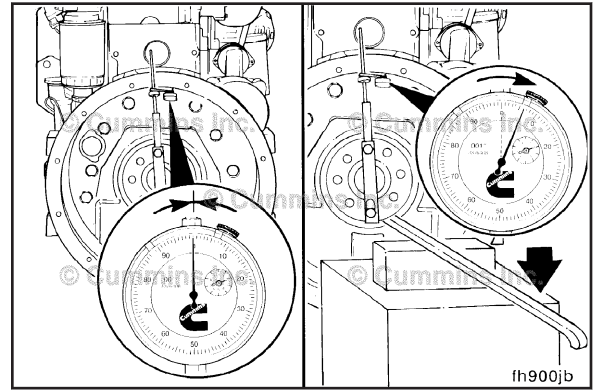
The values for (a), (b), and (c) could be positive or negative. Refer to the accompanying figure to determine the correct sign when recording these values.

⚠ CAUTION ⚠

Do not force the crankshaft beyond the point where the bearing clearance has been removed. Do not pry against the flywheel housing. These actions could cause false bearing clearance readings.

Rotate the crankshaft until the dial indicator is at the twelve 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) in the concentricity work sheet. This is the vertical bearing clearance adjustment and will **always** be positive.



Using the concentricity work sheet, determine the values for the "total vertical" and "total horizontal" values.

The total horizontal is equal to the nine-o'clock reading (a), minus the three-o'clock reading (c).

The total vertical is equal to the twelve-o'clock reading (b), plus the bearing clearance (d).

Example:

Six o'clock = ref = 0, Nine o'clock = (a) = 0.004, Twelve o'clock = (b) = 0.003, Three o'clock = (c) = -0.002

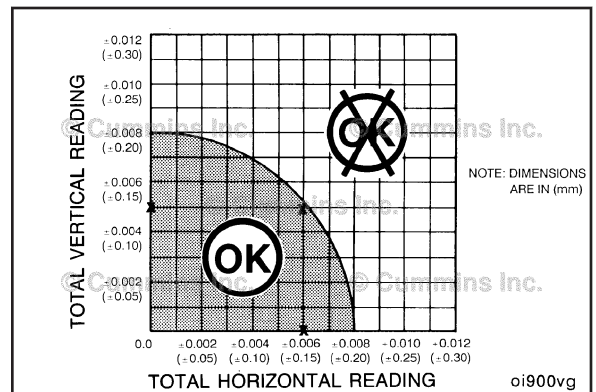
Using the work sheet and the numbers from the example, the total horizontal value equals 0.006 and the total vertical value equals 0.005.

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

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.



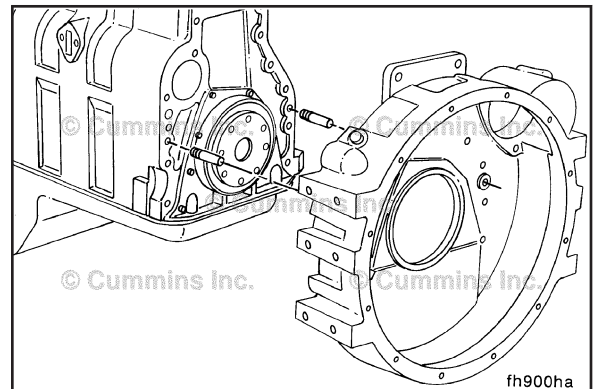
If the intersection point falls outside the shaded area, the ring dowels **must** be removed and the housing repositioned.

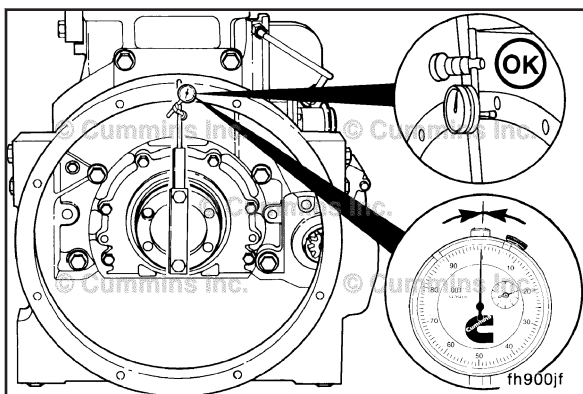
NOTE: The ring dowels are **not** required to maintain concentricity of the housing; the clamping force of the capscrews holds the housing in place.

After the ring dowels are discarded, install the flywheel housing on the engine.

To position the housing, tighten the capscrews enough to hold the flywheel housing in place, but loose enough to allow small movement when struck lightly with a mallet.

Recheck the concentricity. When concentricity is within specification, tighten the capscrews to the specified torque value.





⚠ CAUTION ⚠

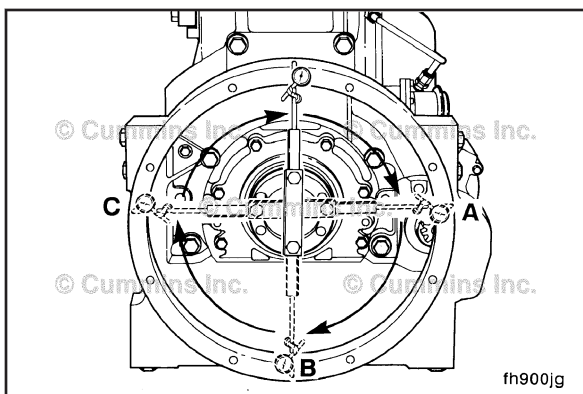
The dial indicator tip must not enter the capscrew holes, or the gauge will be damaged.



Face Alignment

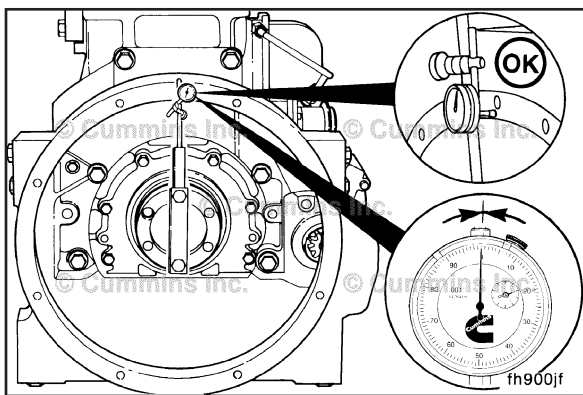
Install the dial indicator gauge, Part No. 3376050, as illustrated.

NOTE: The extension bar for the indicator **must** be rigid for an accurate reading. It **must not** sag. Position the indicator at the twelve-o'clock position. Adjust the dial until the needle points to zero.

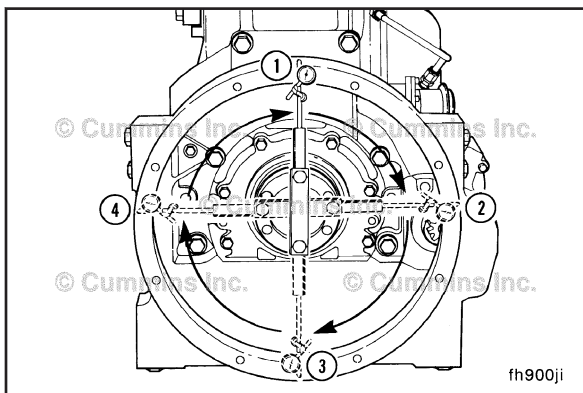


Slowly rotate the crankshaft. Record the readings at the three-o'clock, six-o'clock, and nine-o'clock positions.

NOTE: The crankshaft **must** be pushed toward the front of the engine to remove the crankshaft end clearance each time a position is measured.



Continue to rotate the crankshaft until the indicator is at the twelve-o'clock position. Check the indicator to make sure the needle points to zero. If it does **not**, the readings will be incorrect.



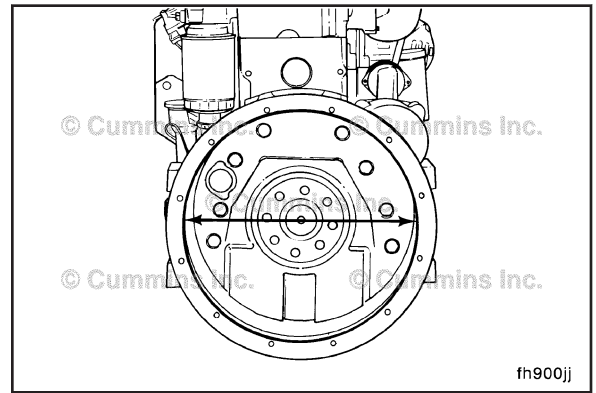
Determine the total indicator reading (TIR).

Example:	mm	in
12 o'clock	0.00	0.000
3 o'clock	+0.08	+0.003
6 o'clock	-0.05	-0.002
9 o'clock	+0.08	+0.003
Equals TIR	0.13	0.005

The maximum allowable total indicator reading (TIR) is determined by the diameter of the housing bore. If out of specifications, replace the housing.



SAE No.	Bore Diameter		TIR	
	mm	in	mm	in
2	447.68 to	17.625 to	0.20	0.008
	447.80	17.30		
3	409.58 to	16.125 to	0.20	0.008
	409.70	16.130		

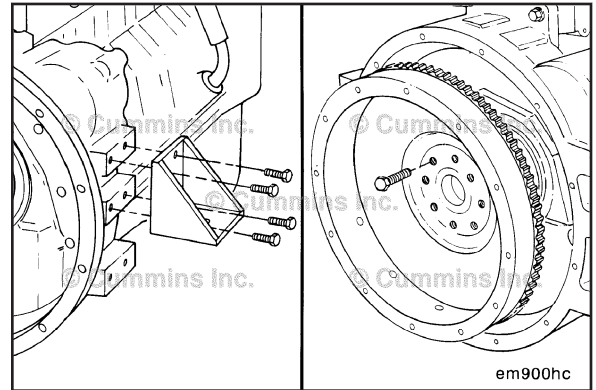


Install

Install both rear engine mounts.

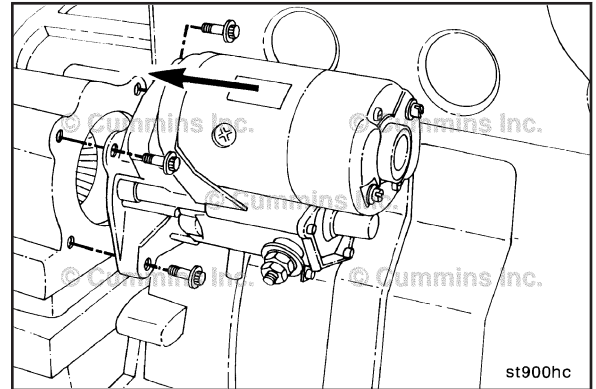
Install the flywheel and clutch (if equipped). Refer to the manufacturer's instructions.

Install the transmission and related components. Refer to the manufacturer's instructions.



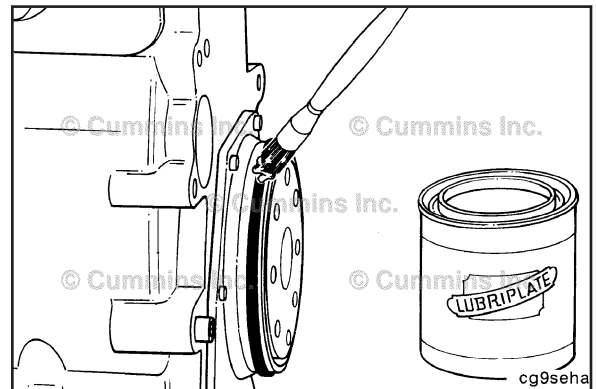
Install the starter motor. Refer to Procedure 013-020.

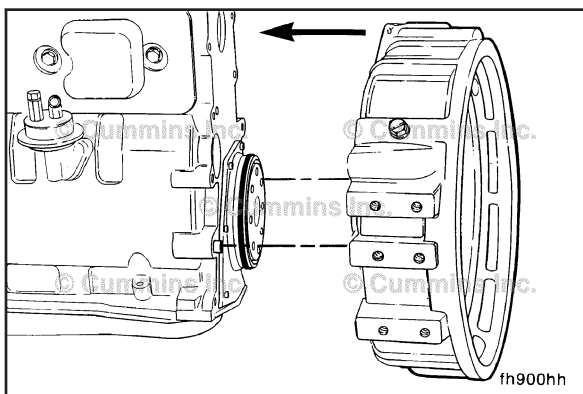
Connect the battery cables. Refer to Procedure 013-009.



Dry Clutch Application

Install rectangular seal, and lubricate with Lubriplate™ 105, or equivalent.



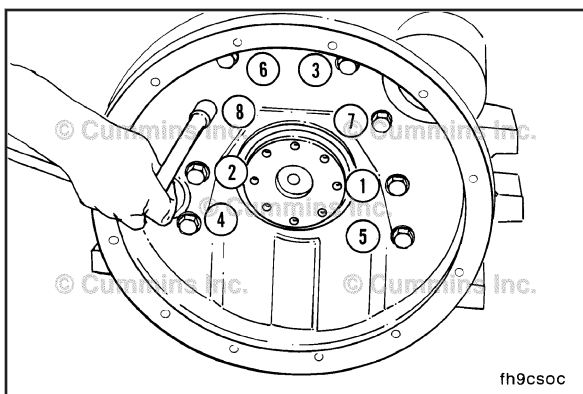


Inspect the rear face of the cylinder block and flywheel housing mounting surface for cleanliness and raised nicks or burrs.



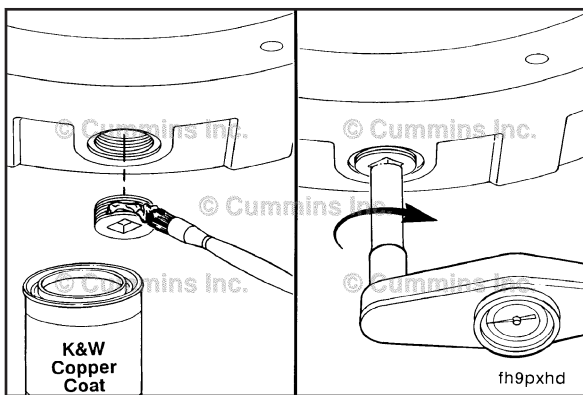
Install the flywheel housing over the two ring dowels.

NOTE: Be sure the sealing ring is **not** damaged during installation.



Tighten the flywheel housing capscrews in the sequence shown.

Torque Value: 77 N•m [57 ft-lb]

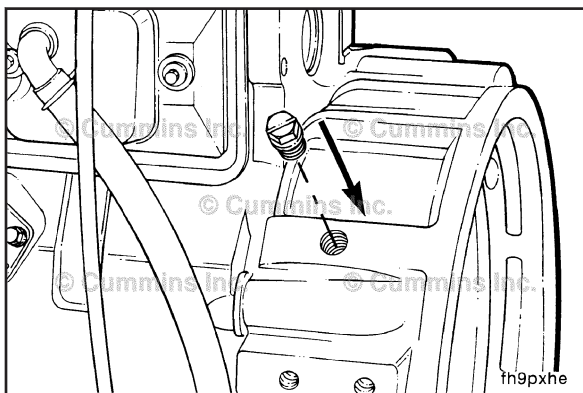


Wet Clutch Application

Perform all the steps in the procedure for dry clutch installation, in addition to the following:



- Coat the flywheel housing drain plug with pipe sealant, and install in the hole in the bottom of the flywheel housing.
- Tighten the plug.
- Refer to the pipe plug torque values in Section 17 for different plug sizes.

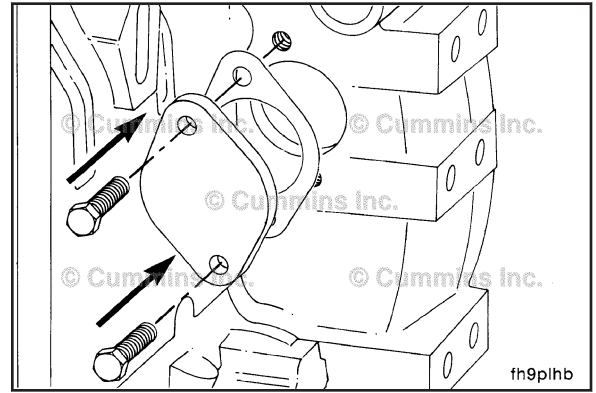


Install the plastic plug in the tachometer drive access hole.

Install the access plate and new gasket.

Install the capscrews and tighten.

Torque Value: 24 N•m [18 ft-lb]



⚠ WARNING ⚠

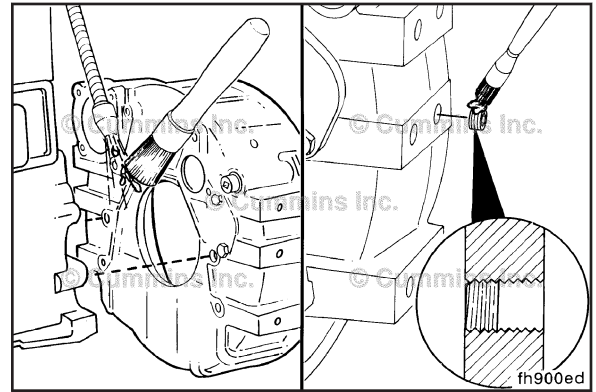
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

⚠ WARNING ⚠

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

Thoroughly clean the flywheel housing and cylinder block mating surfaces. These surfaces **must** be clean of oil and debris.

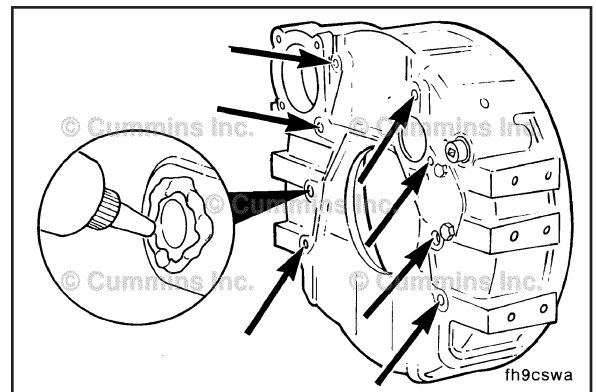
NOTE: The capscrew holes on the mounting pads are drilled through. Coat set screws with Loctite 277 and install into holes.

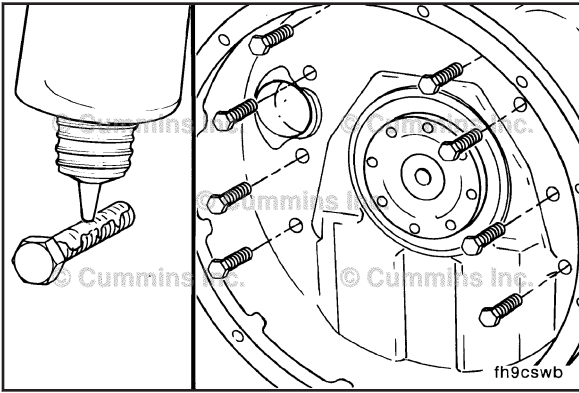


Set Screw Installation Depth (Flywheel Housing)

mm		in
3.00	MAX	0.118

Apply a continuous bead of Three-Bond™ around all capscrew holes on the mounting surface of the flywheel housing.



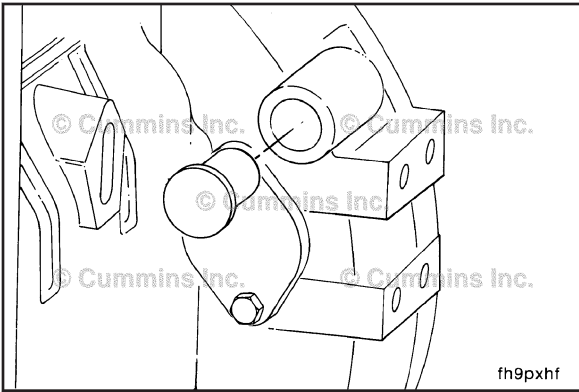


Coat the threads of the mounting capscrews with Loctite 277.

Install and tighten the capscrews.



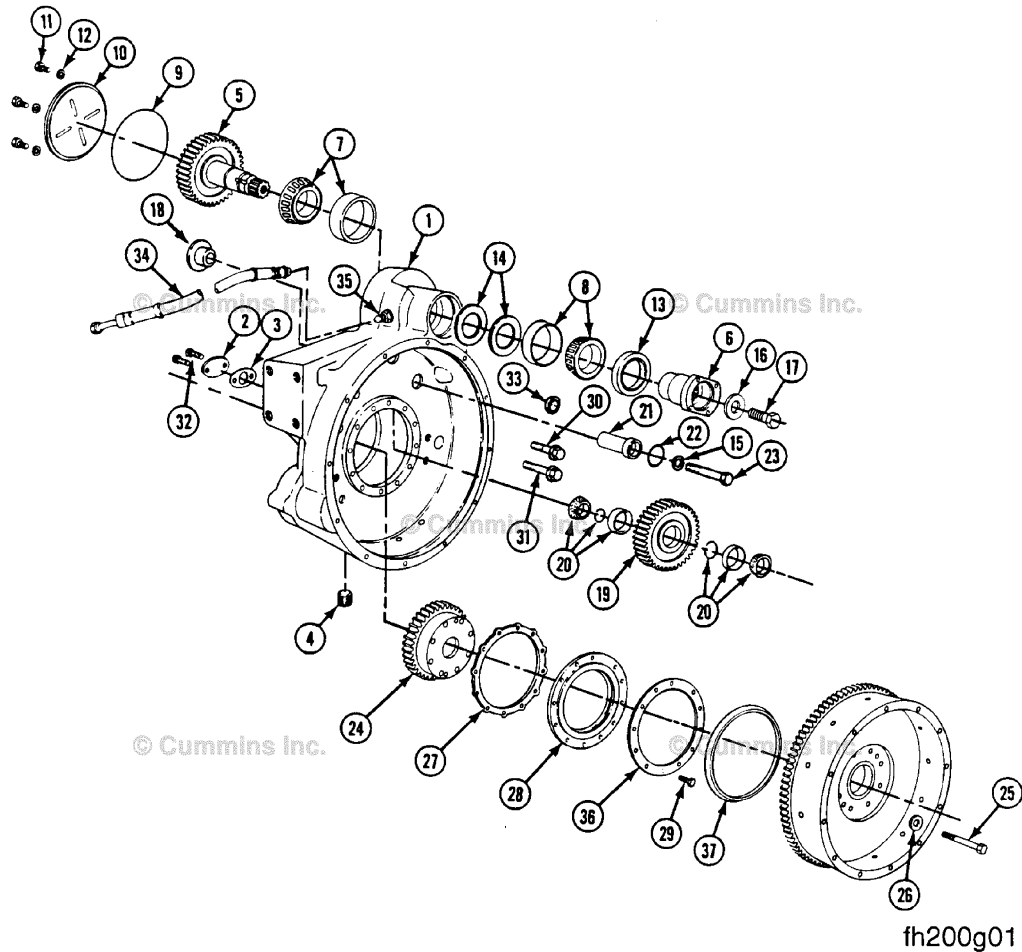
Torque Value: 77 N•m [57 ft-lb]



Install the plug into the barring gear hole.

Flywheel Housing, REPTO (016-007)

Exploded View

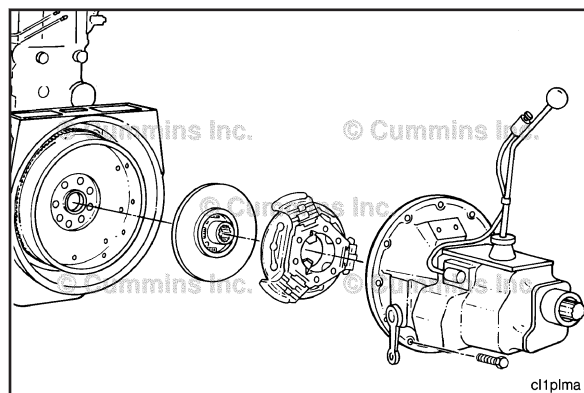


- 1 Housing, Flywheel - 1
- 2 Cover, Access Hole - 1
- 3 Gasket, Cover Plate - 1
- 4 Plug, Threaded Drain - 1
- 5 Shaft, Accessory Drive Output - 1
- 6 Flange, Power Takeoff - 1
- 7 Bearing, Roller (Large) - 1
- 8 Bearing, Roller (Medium) - 1
- 9 Seal, Rectangular Ring (Tetra) - 1
- 10 Plate, Cover (Ribbed) - 1
- 11 Capscrew - 4
- 12 Washer, Plain - 4
- 13 Seal, Oil (Output Shaft) - 1
- 14 Shims (See next page)
- 15 Washer, Plain - 1

- 16 Washer, Plain (PTO Flange) - 1
- 17 Screw, Hexagon Head Cap - 1
- 18 Retainer, Shaft - 1
- 19 Gear, Idler - 1
- 20 Assembly, Bearing and Race - 1
- 21 Shaft, Idler - 1
- 22 Seal, O-ring - 2
- 23 Screw, Hexagon Head Cap - 1
- 24 Gear, Crankshaft - 1
- 25 Screw, Hexagon Head Cap - 8
- 26 Washer, Plain - 8
- 27 Gasket, Carrier - 1
- 28 Kit, Seal - 1
- 29 Screw, Captive Washer Cap - 12
- 30 Screw, Hexagon Head Cap - 5
- 31 Screw, Hexagon Head Cap - 7
- 32 Screw, Hexagon Head Cap - 2
- 33 Plug, Expansion - 1
- 34 Hose, Flexible Oil Supply - 1
- 35 Connection, Mate Oil Supply - 1
- 36 Ring, Clamping - 1
- 37 Seal, Dust - 1

There are 7 shims available. A given REPTO could have any combination of these shims.

Ref. No.	Description	mm	in
14	Shim	0.127	0.005
14	Shim	0.254	0.010
14	Shim	0.381	0.015
14	Shim	0.051	0.002
14	Shim	0.076	0.003
14	Shim	0.508	0.020
14	Shim	1.016	0.040



Remove

▲ WARNING ▲



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



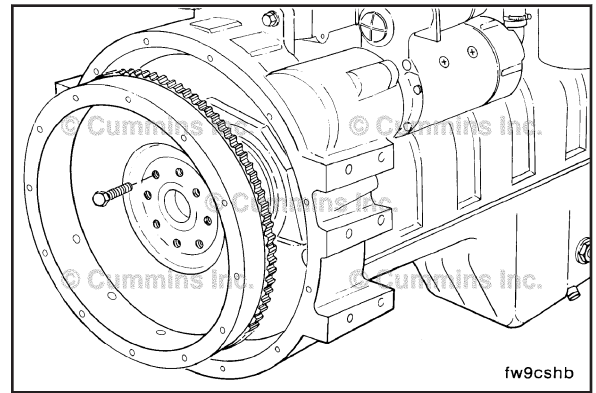
Remove the transmission, clutch, and related components, if equipped.

Refer to the OEM's instructions.

⚠ WARNING ⚠

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

Remove the flywheel. Refer to Procedure 016-005 in Section 16.

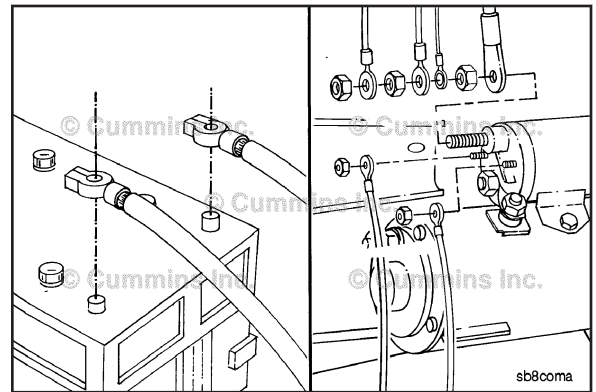


⚠ WARNING ⚠

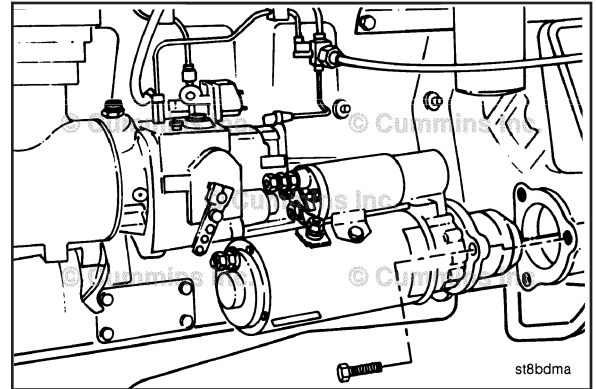
Batteries can emit explosive gases. To avoid personal injury, always ventilate the compartment before servicing the batteries. To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Disconnect the electrical connections from the battery.

Tag and disconnect the electrical connections from the starting motor.



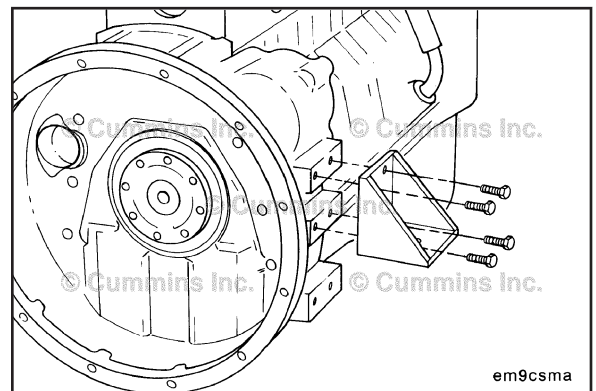
Remove the starter; refer to Refer to Procedure 013-020 in Section 13.

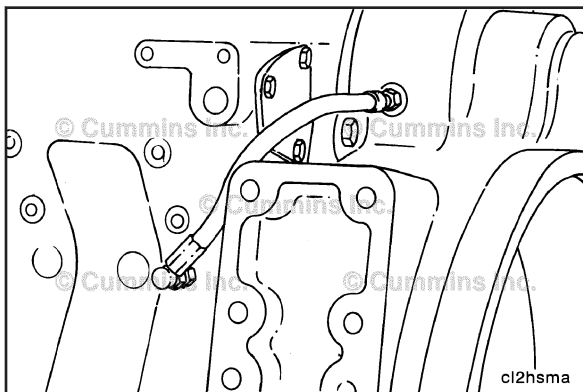


⚠ WARNING ⚠

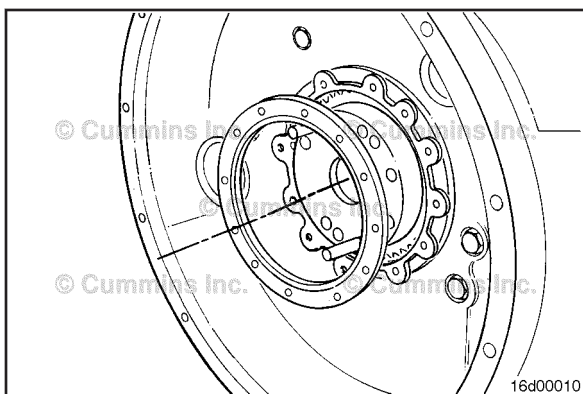
Use a floor jack or other suitable lifting fixture to support the engine. Personal injury can result.

Remove the capscrews and both rear engine mounts.

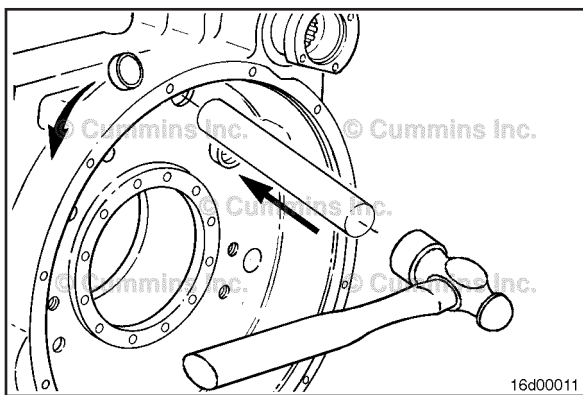




Remove the REPTO oil supply line.



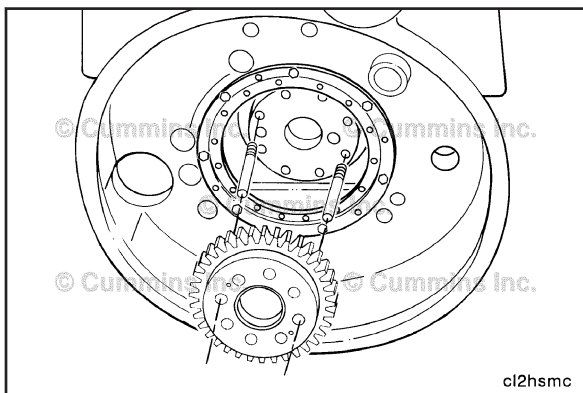
Remove the oil seal capscrews, the oil seal, and the gasket.



To gain access to the housing capscrews, use a drift to drive the cup plugs straight through into the housing.

NOTE: Do **not** attempt to back the plugs out or rotate the plugs out. The cup plug bore will be damaged and oil leakage will occur.

Retrieve the plugs from inside the housing.



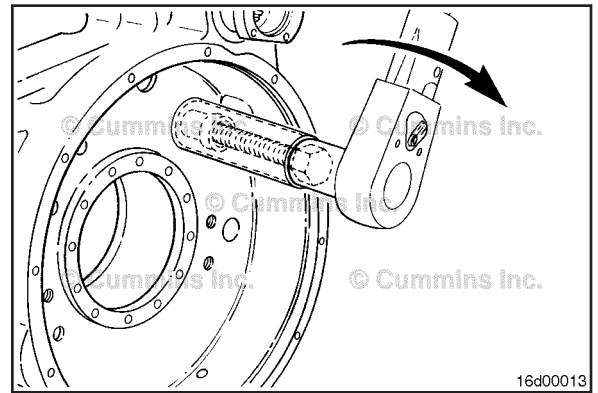
Install two crankshaft locator studs, Part Number 3822784, into the crankshaft flywheel mounting flange 180 degrees apart.



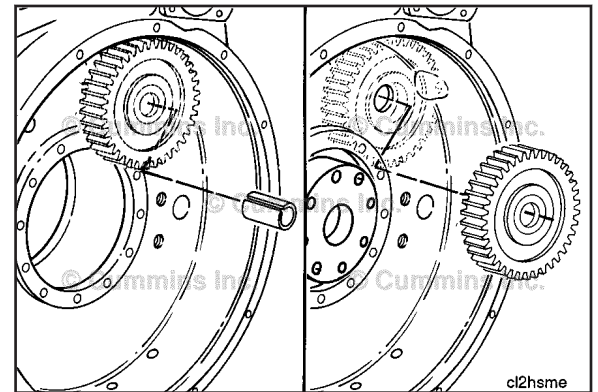
Remove the crankshaft drive gear.

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Section 16 - Mounting Adaptations - Group 16

Use the idler shaft puller, Part Number 3823709, to remove the idler shaft.



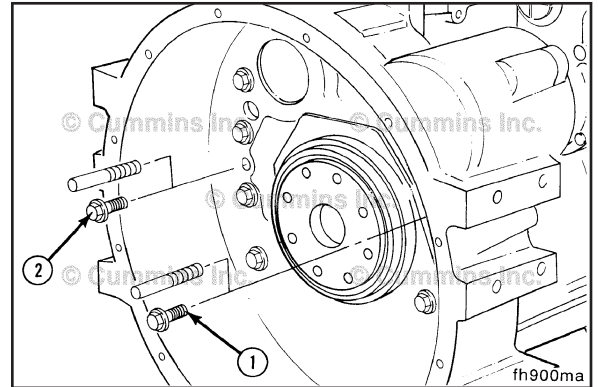
Remove the idler gear to gain access to the rest of the housing capscrews.



Remove two of the capscrews and install two guide pins, Part Number 3376638, to support the housing during removal.



Use offset wrench, Part Number 3823892, to remove the capscrews which are **not** in view.



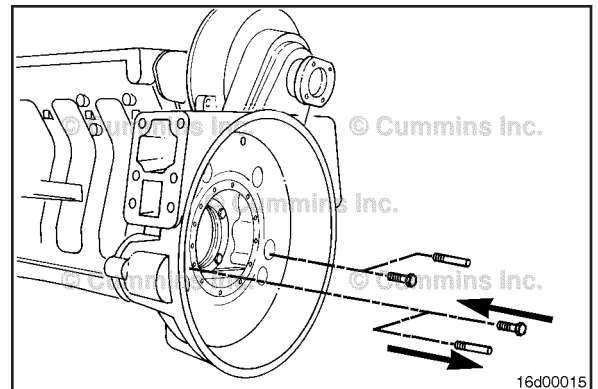
⚠ WARNING ⚠
This assembly weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the assembly.

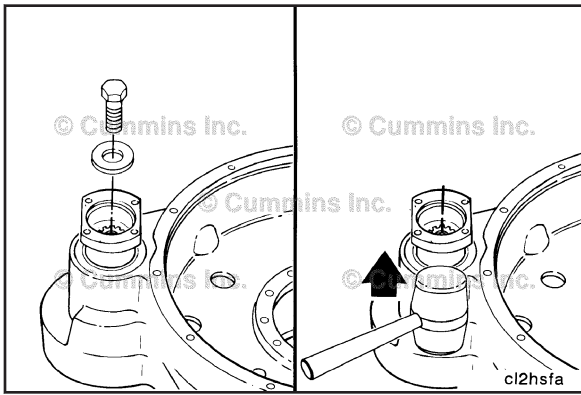


Remove the remaining capscrews. Use a rubber hammer to loosen the housing.



Remove the housing.



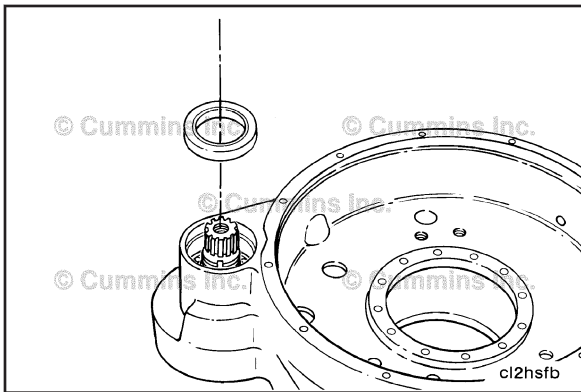


Disassemble

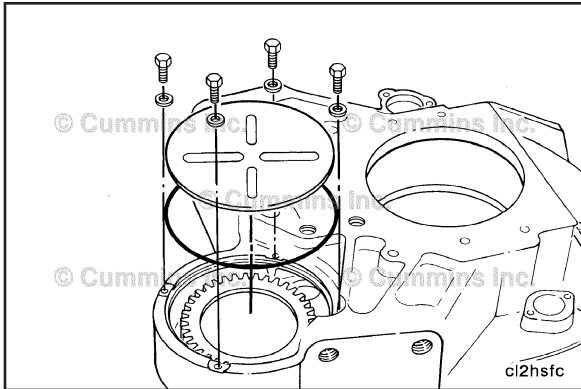
NOTE: Use gear locking tool, Part Number 3823891, to prevent the output shaft from turning when removing the retainer capscrew.

Remove the capscrew and washer that secures the output flange to the output shaft.

Use a rawhide hammer to remove the output flange and flat washer from the output shaft.



Use a dent puller to remove the seal. Do **not** damage the surface of the housing or seal bore.

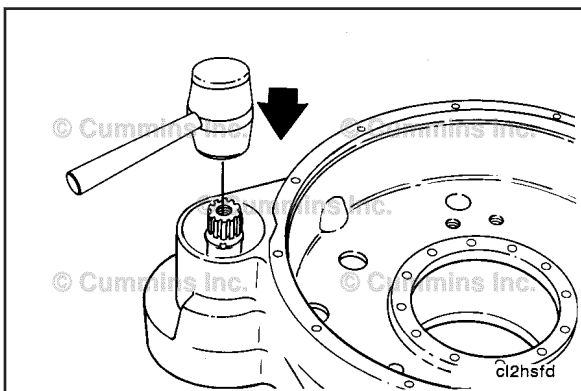


NOTE: When the housing is turned over, the bearing will fall out. Do **not** allow the bearing to be damaged.

Turn the housing over so the four cover plate capscrews are accessible. Be careful **not** to damage the output shaft.

Remove the capscrews and ribbed cover plate from the output gear housing.

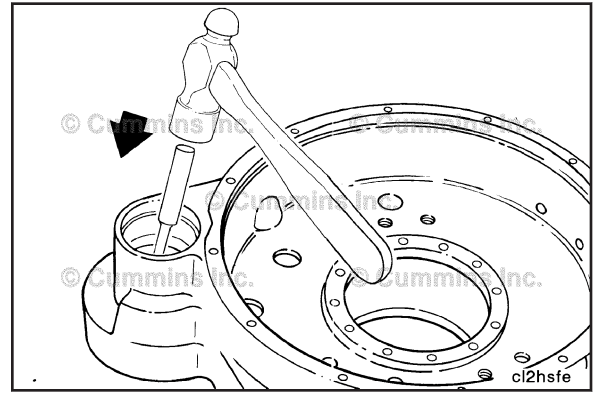
Remove and discard the square cut o-ring seal.



NOTE: Save the original shims for rebuild purposes. They will be used to set the proper end clearance on the output shaft and bearing assembly.

Turn the housing over and use a rawhide hammer to hit the end of the output shaft to remove the output shaft subassembly from the REPTO housing.

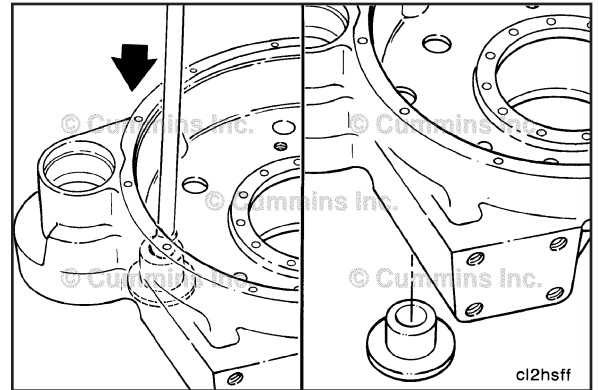
With the housing positioned so the cylinder block mating surface is down, use a hammer and brass punch to drive the bearing outer races out of the output shaft housing bore.



Support the housing in a press with the cylinder block mating surface down.

With a long mandrel, press out the idler shaft bushing.

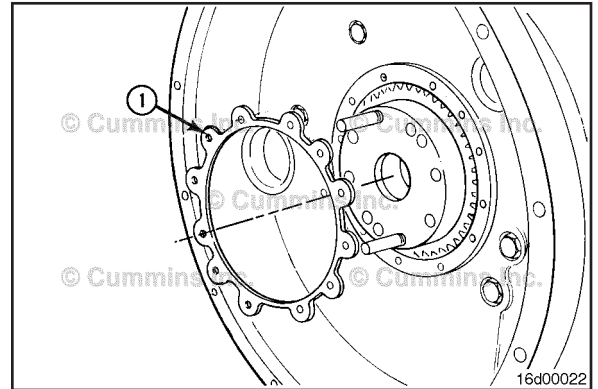
Remove and discard o-ring.



NOTE: Save the original shims for rebuild purposes, to set the proper end clearance on the output shaft and bearing assembly.

Use a hammer and brass drift to remove the two bearing outer races from the bore of the idler gear. Discard the outer races.

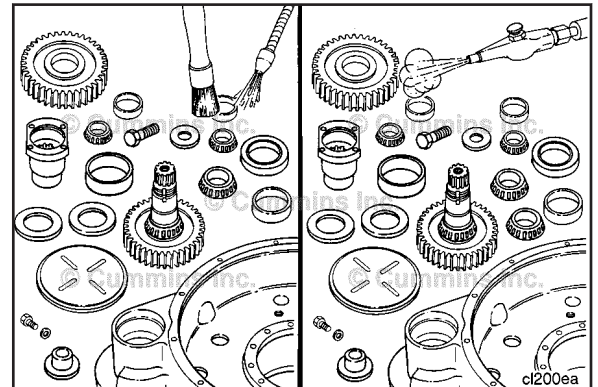
Remove the large spacer ring from the center groove of the gear. Discard the spacer ring.

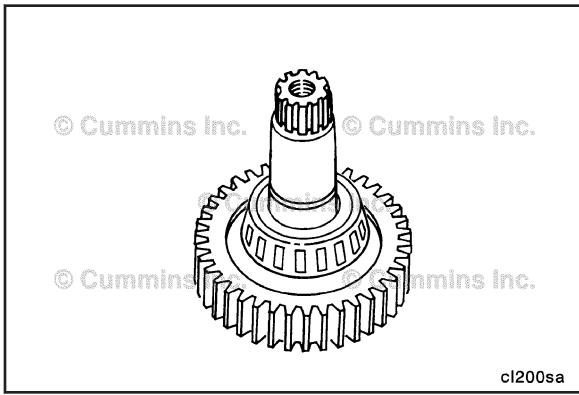


Clean

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

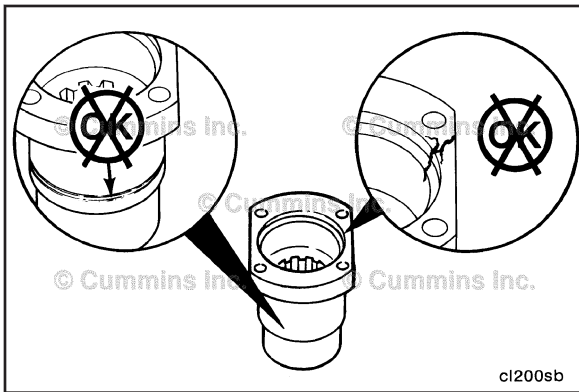
Use a steam cleaner to clean all areas of the idler gear.



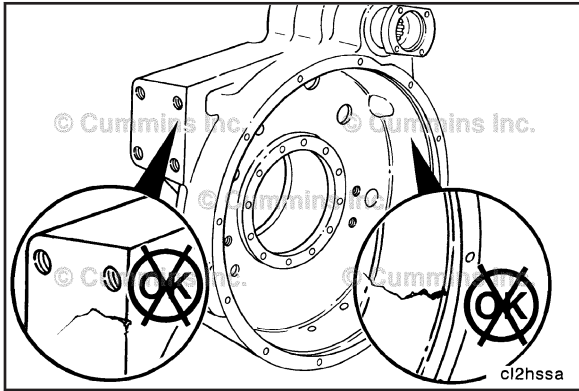


Inspect for Reuse

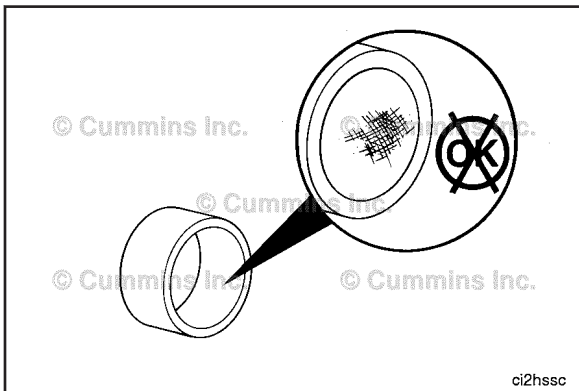
Inspect the output shaft and bearings for wear.
Inspect the output gear for damage.
Replace if defective.



Inspect the output flange for damage or wear grooves from the oil seal.
Replace if defective.



Inspect the REPTO housing for cracks at the rear engine mounting surfaces and the flywheel bore.
Replace the housing if cracked.

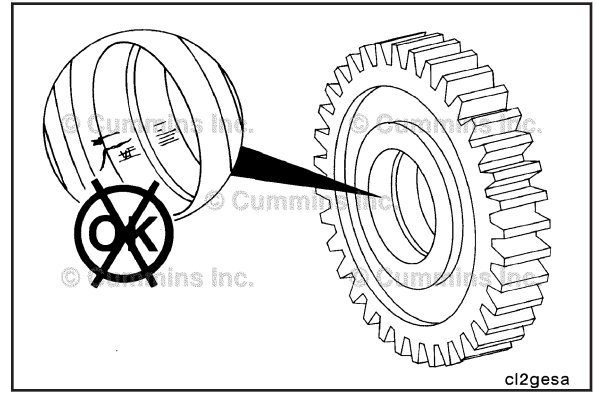


Inspect the idler shaft bushing for wear.
Replace the bushing if worn.

Closely inspect the bore, the side faces and the teeth of the idler gear.



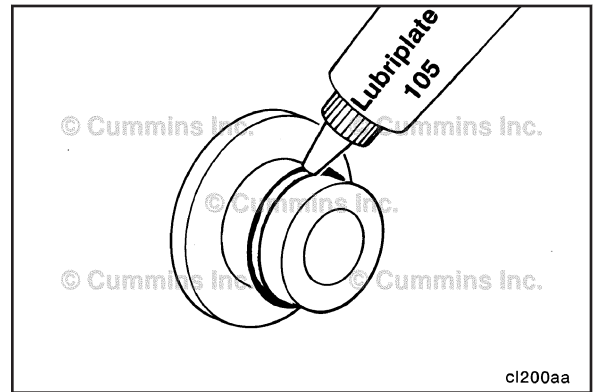
Replace the gear if there are cracks, discoloration from excessive heat or other damage.



Assemble

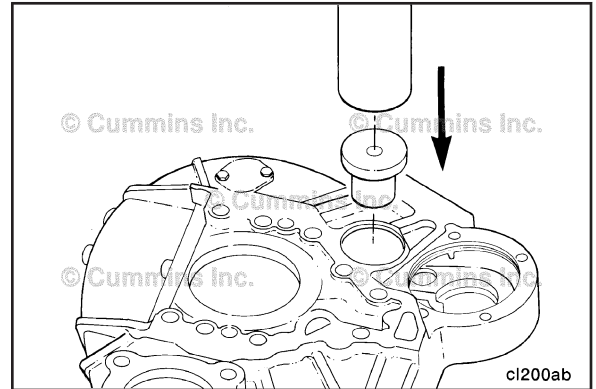
Install a new o-ring on the idler shaft bushing.

Use Lubriplate™ 105 to lubricate the o-ring.



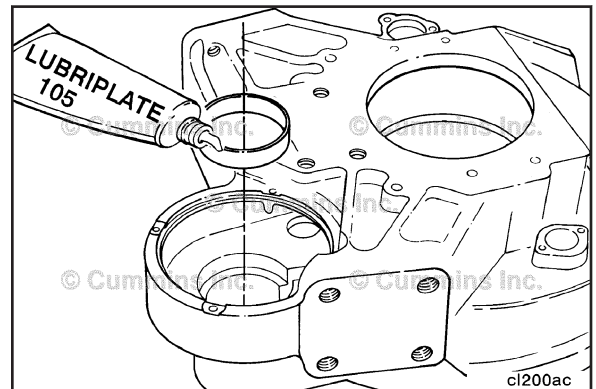
Support the housing evenly with the engine mating surface up.

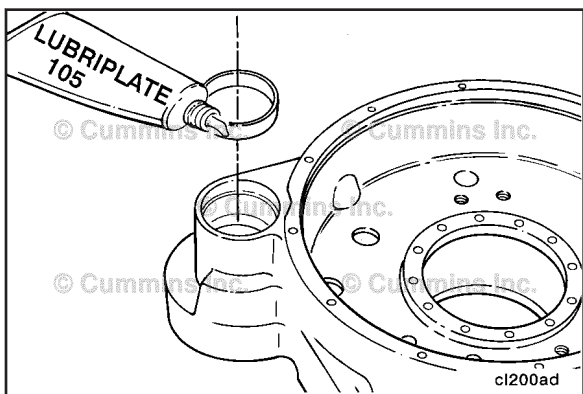
Press the new bushing into the housing until it is below the surface of the cylinder block mating surface.



Use Lubriplate™ 105 to lubricate the larger bearing race.

Use the larger end of driver, Part Number 3823893, to press the bearing race to the shoulder in the housing.



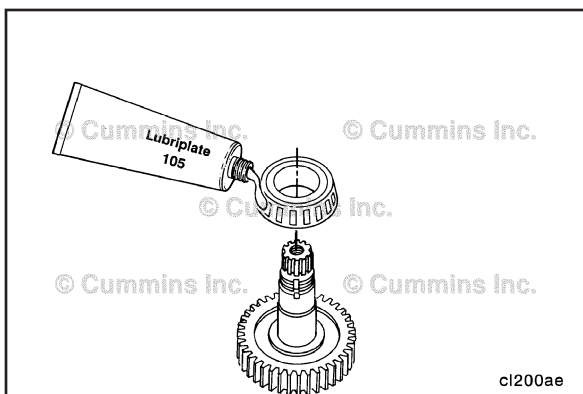


Turn the housing over and support evenly in the press.

Use Lubriplate™ 105 to lubricate the smaller bearing race.

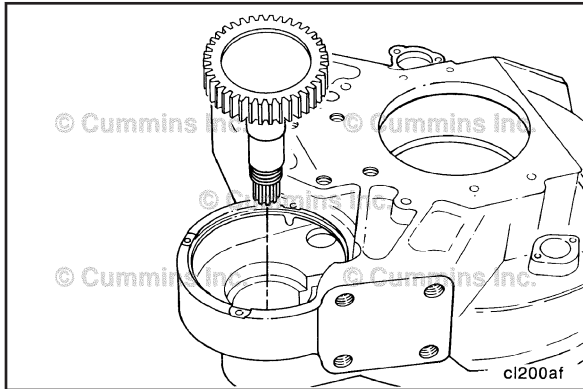


Use the smaller end of driver, Part Number 3823893, to press the bearing race to the shoulder in the housing.



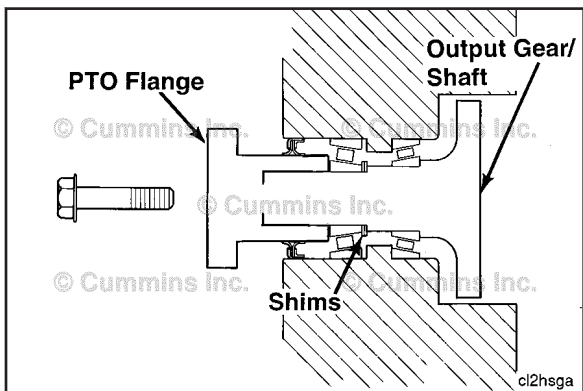
Use Lubriplate™ 105 to lubricate the output shaft and larger bearing.

Install the larger bearing onto the output shaft.



Position the housing on the table so the cylinder block mating surface is up.

Install the output shaft assembly into the housing.



The correct end clearance (rolling resistance) is determined by the number and thickness of shims used between the two bearings.

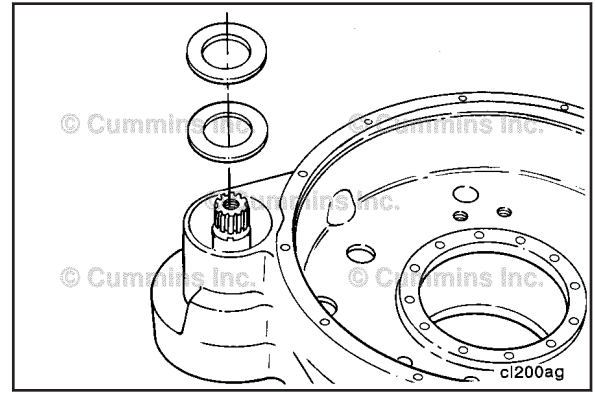
When the shim thickness is increased, there is more shaft end clearance and less rolling resistance.

When the shim thickness is decreased, there is less shaft end clearance and more rolling resistance.

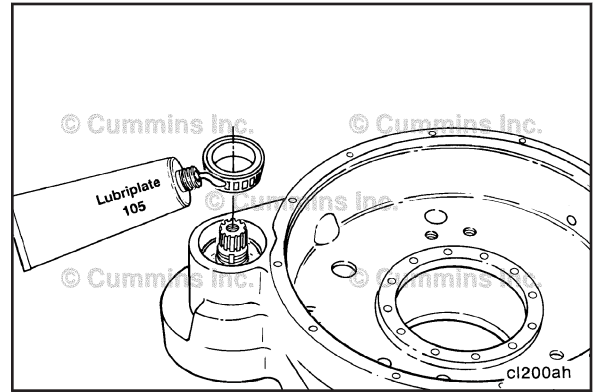
Turn the housing over with engine mating surface down, while holding the output shaft and gear in place.

NOTE: If the original thickness of shims is **not** available for reuse, beginning thickness of 1.47 mm [0.058 in] can be used as a starting point.

Install the original thickness of shims.

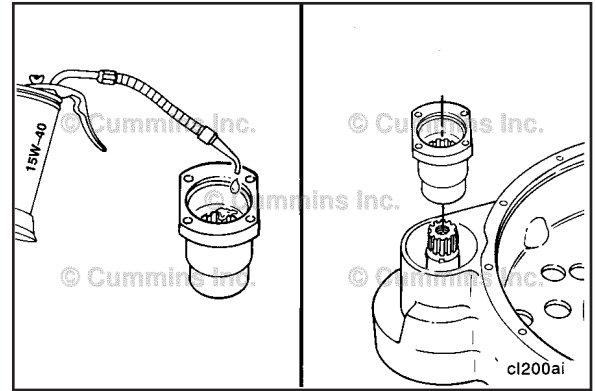


Use Lubriplate™ 105 to lubricate the smaller bearing.
Install the smaller bearing onto the shaft.



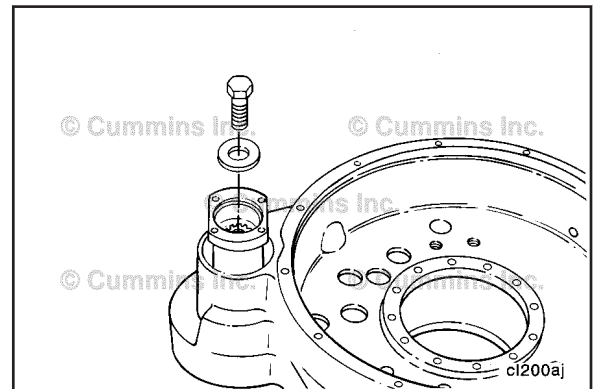
Temporarily install the output flange, before installing the oil seal.

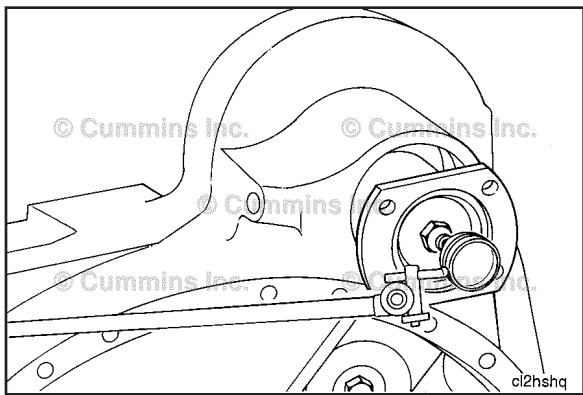
Use clean 15W-40 oil to lubricate the splines.



Install the flat washer and capscrew. Use the gear locking tool, Part Number 3823891, to hold the output shaft while tightening the capscrew.

Torque Value: 205 N•m [150 ft-lb]

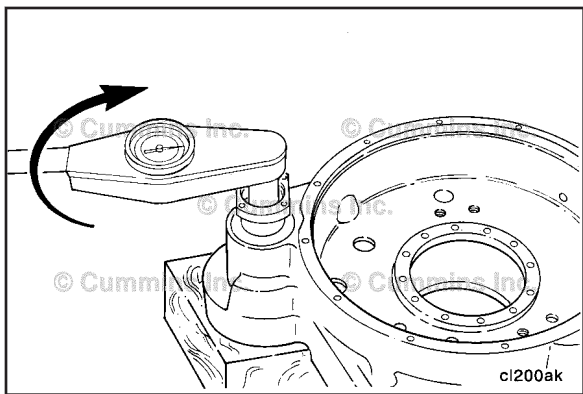




Measure shaft end play.

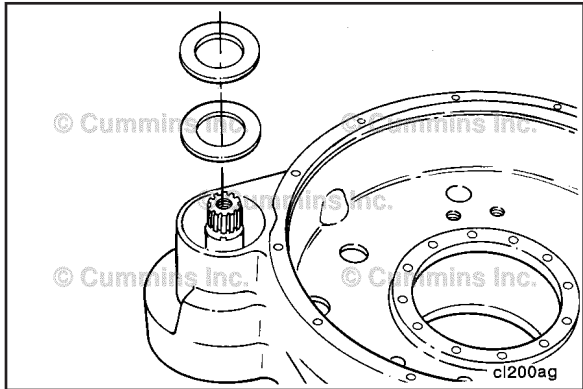
Output Shaft End Play

mm		in
0.00	MIN	0.000
0.03	MAX	0.001



Check the output shaft rolling resistance with a torque wrench.

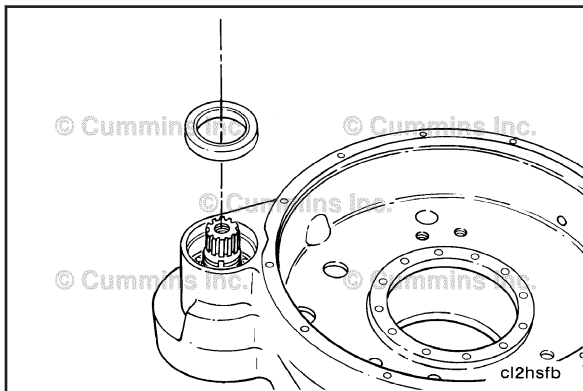
Rolling resistance **must** be between 0.6 to 1 N•m [5 to 10 in-lb].



If the rolling resistance is **not** within specification, remove the output flange and smaller bearing.

Add or subtract shims to obtain the correct rolling resistance.

NOTE: Adding more shims will decrease the resistance and removing shims will increase resistance. Any combination of shims can be used.



Once the correct rolling resistance is obtained, remove the output flange and install a new oil seal.

Press the oil seal flush with the housing surface.

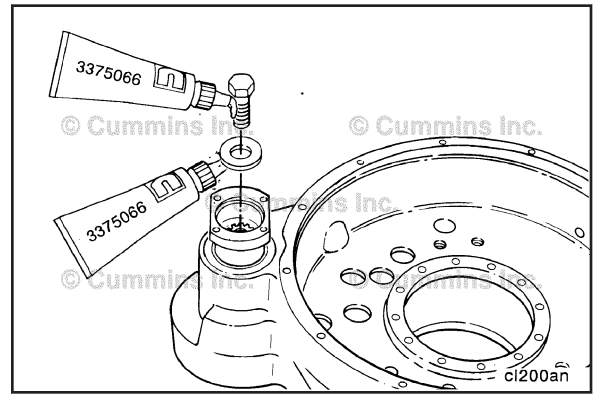
C Series
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Apply pipe sealant, Part Number 3375066, to the output flange capscrew and under the washer.

Install the output flange flat washer and capscrew.

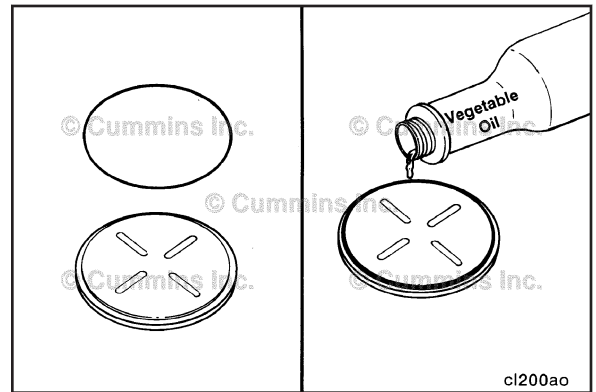
Tighten the capscrew.

Torque Value: 205 N•m [150 ft-lb]



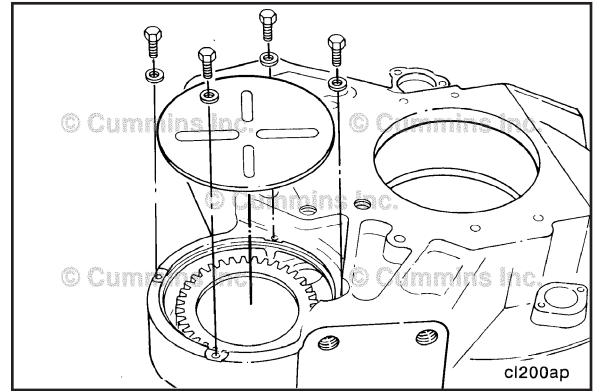
Install a new o-ring on the bearing housing cover.

Use clean vegetable oil to lubricate the o-ring.



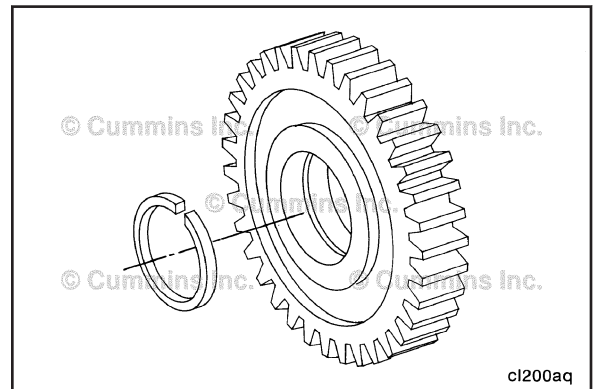
Install and tighten the cover and four capscrews.

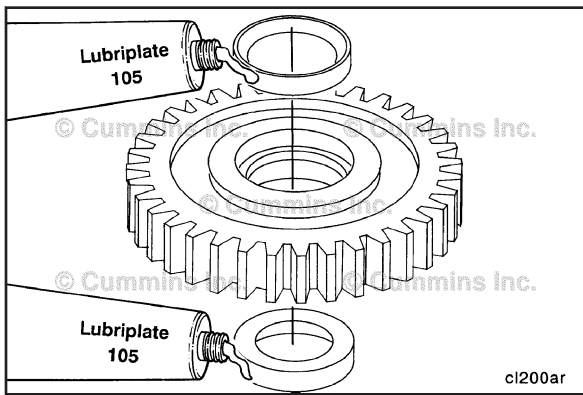
Torque Value: 18 N•m [14 ft-lb]



Insert a new spacer ring into the bore of the idler gear.

Push it in until it snaps into place in the center groove.



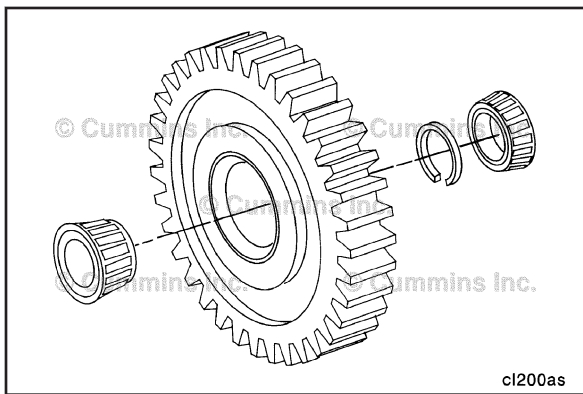


Use Lubriplate™ 105 or equivalent to lubricate the bearing outer races.



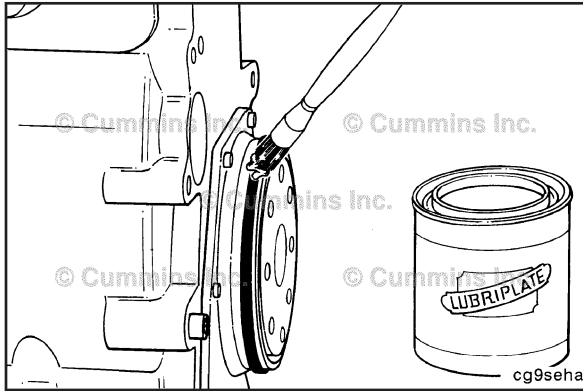
Press the two new bearing outer races into the bore of the idler gear.

The larger side of the taper **must** face toward the outside of the gear.



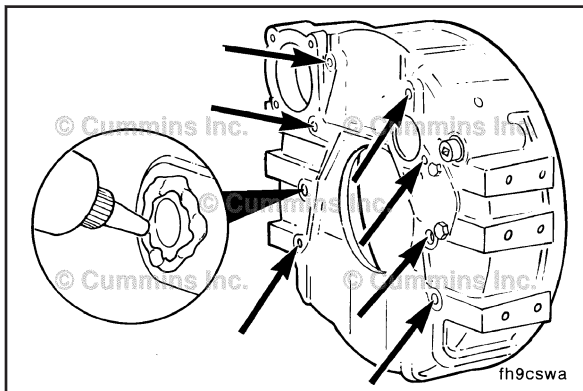
NOTE: Do **not** interchange individual parts that make up the idler gear bearing assembly. Rebuild the idler gear with bearings that are packaged together.

Keep the two roller bearing assemblies and the spacer ring with the idler gear.



Install

Install rectangular seal and lubricate with Lubriplate™ 105, or equivalent.



Apply a continuous bead of ThreeBond™, or equivalent, around all capscrew holes on the mounting surface of the flywheel housing.

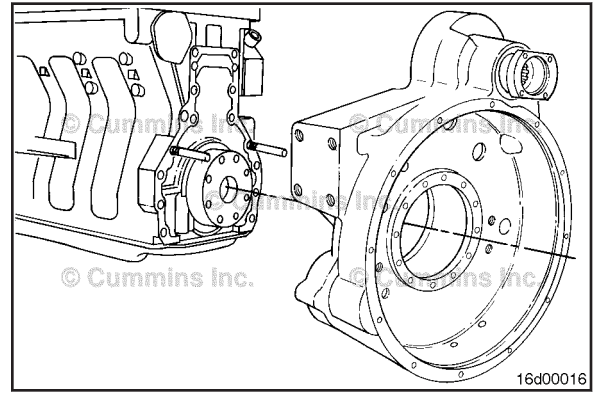
⚠ WARNING ⚠

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

Inspect the rear face of the cylinder block and flywheel housing mounting surface for cleanliness and nicks or burrs.

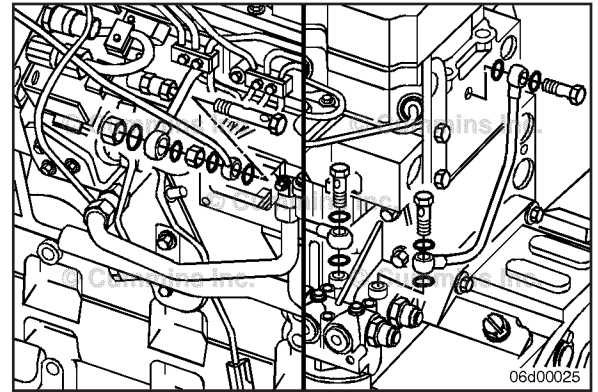
Install the flywheel housing over the two ring dowels.

NOTE: Be sure the sealing ring is **not** damaged during installation.

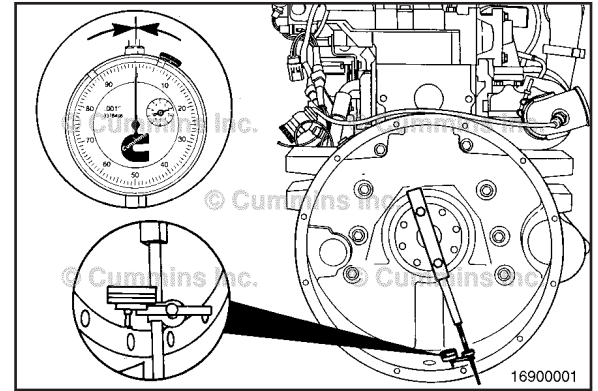


Install the capscrews and tighten with the sequence shown, using offset wrench, Part Number 3823892, for capscrews hidden from view.

Torque Value: 60 N•m [45 ft-lb]



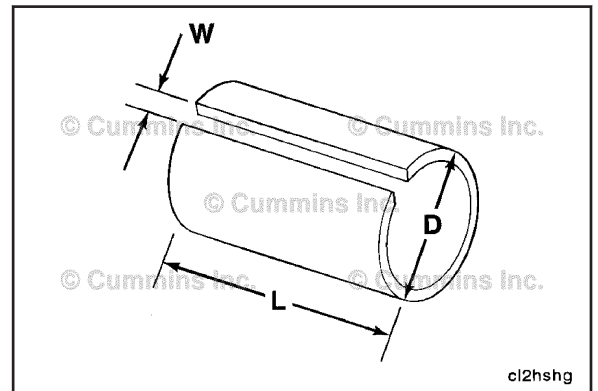
NOTE: Before installing the idler gear, measure the flywheel housing bore and face alignment. Refer to Procedure 016-006.

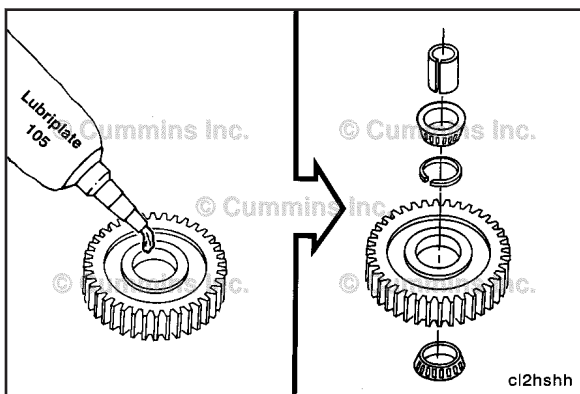


Fabricate a sleeve from 38.10 mm [1.50 in] PVC (or equivalent) to the following dimensions.

Length - 25.4 mm [1.0 in]

Slot - 12.70 mm [0.50 in]

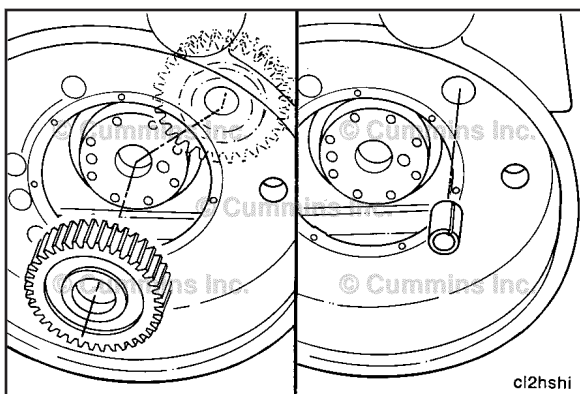




NOTE: The outer bearing races of new replacement gears are already pressed into the gear.

Apply a thin film of Lubriplate™ 105 or equivalent on the outer races and the bearings.

Install the bearing and spacer into the idler gear. Use a plastic sleeve to hold the bearing assembly together when installing the idler gear assembly.

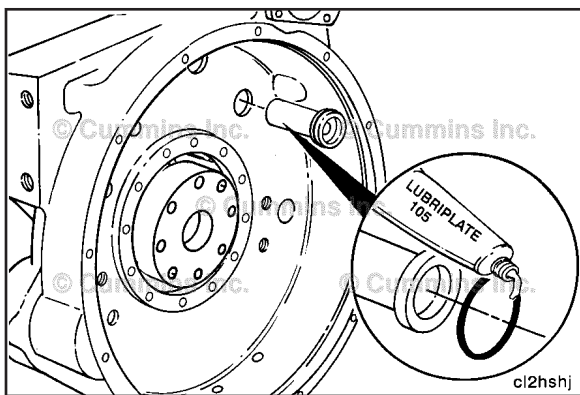


Apply a thin film of Lubriplate™ 105 or equivalent into the idler shaft bore of the housing and on the idler shaft.

Install the idler gear assembly into the flywheel housing.



Hold the idler gear and bearing in place and remove the plastic sleeve.

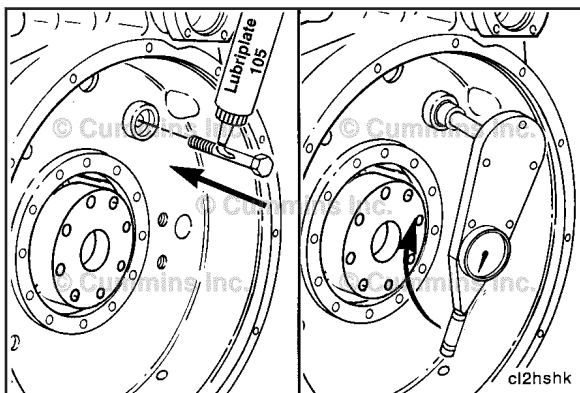


Use clean Lubriplate™ 105 to lubricate the idle shaft o-ring and install the o-ring into the shaft.

Hold the gear assembly in place and insert the idler shaft through the housing and idler gear bearings.



NOTE: Do **not** use a hammer when installing the idler shaft and capscrew or the part can be damaged.



Apply Lubriplate™ 105 under the head of the idler shaft capscrew. Insert the capscrew through the idler shaft. Tighten the installation capscrew with a torque wrench.

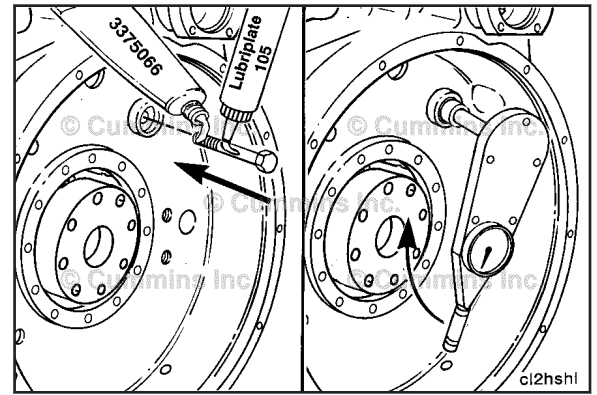


NOTE: The torque needed to draw the idler shaft in place **must not** exceed 88 N•m [65 ft-lb]. If installation torque exceeds this amount, it is an indication of misalignment between the bore and the shaft. Remove the idler shaft and install it again.

When the idler shaft has been seated, remove the capscrew.

Apply pipe sealant, Part Number 3375066, to the threads of the idler shaft capscrew. Apply Lubriplate™ 105 under the head of the capscrew and tighten to it's final torque value.

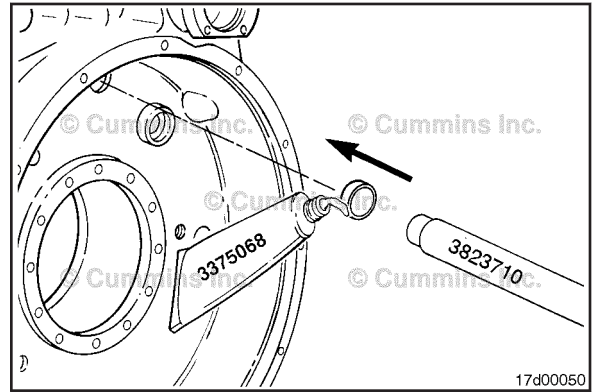
Torque Value: 105 N•m [75 ft-lb]



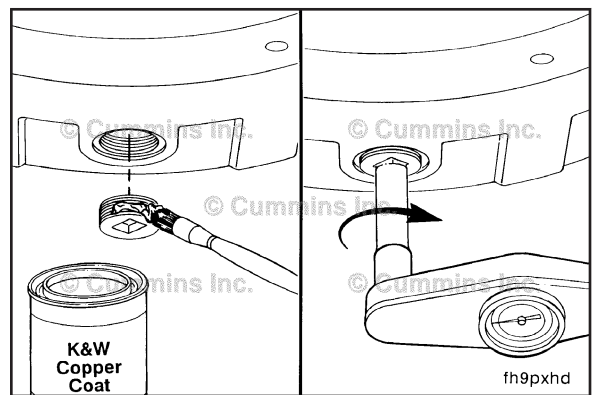
Apply a film of cup plug sealant, Part Number 3375068, to the outside diameter of the cup plugs.

Use a driver, Part Number 3823710, to install the cup plugs into the housing as shown.

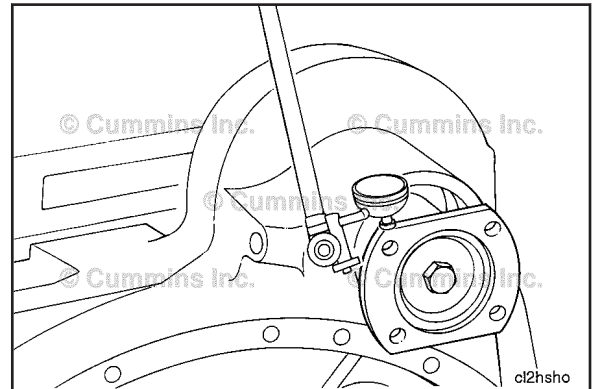
NOTE: When installing cup plugs, make sure they are flush with the spot face on the flywheel housing and are **not** crooked.

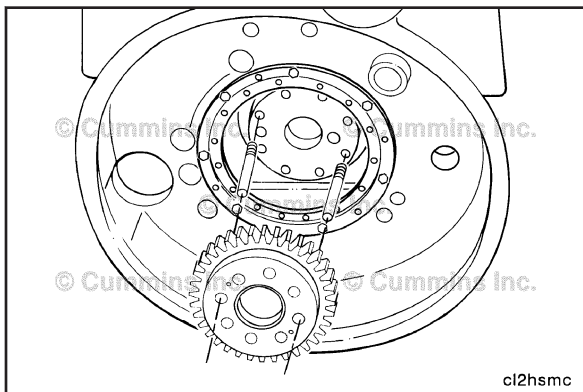


- Coat the flywheel housing drain plug with pipe sealant and install in the hole in the bottom of the flywheel housing.
- Tighten the plug.
- Refer to the pipe plug torque values in section 017 for different plug sizes.



Turn the output flange so that the flat sides are on the top and bottom. This prevents any interference when the transmission is installed onto the housing.

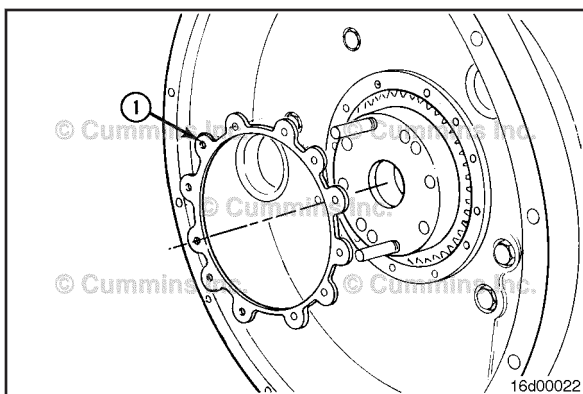




Install two crankshaft locator studs, Part Number 3822784, into the crankshaft flywheel mounting flange 180 degrees apart.

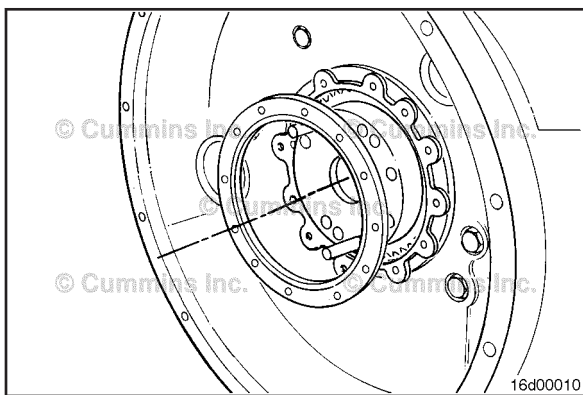


Make sure the crankshaft and crankshaft gear is clean.
Install the crankshaft gear in the locator studs.

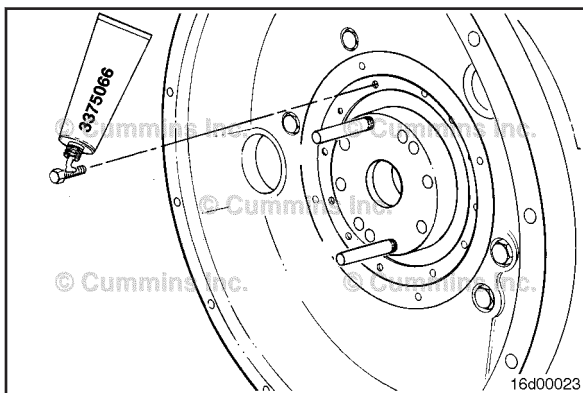


NOTE: Do **not** use any kind of lubricant to install the seal. The oil seal **must** be installed with the crankshaft gear seal contact surface and the lip of the seal clean and dry to provide a proper oil sealing surface.

Install a new gasket (1) in the flywheel housing.



Install a new seal over the crankshaft gear seal contact surface.



Apply sealant, Part Number 3375066, to seal retainer capscrews.

Install the capscrews, and tighten in a star pattern.



Torque Value:

Step 1	7 N•m	[60 in-lb]
Step 2	19 N•m	[170 in-lb]

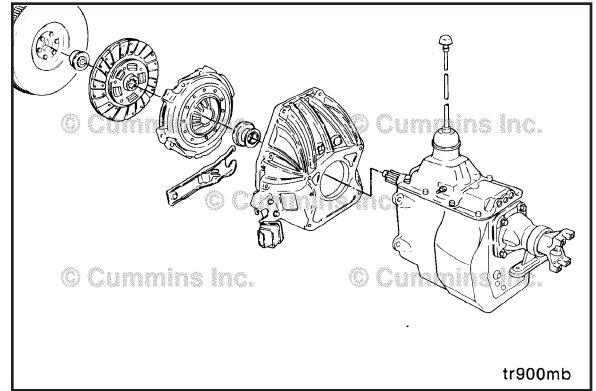


Flywheel Ring Gear (016-008)

Preparatory Steps

Remove the transmission.

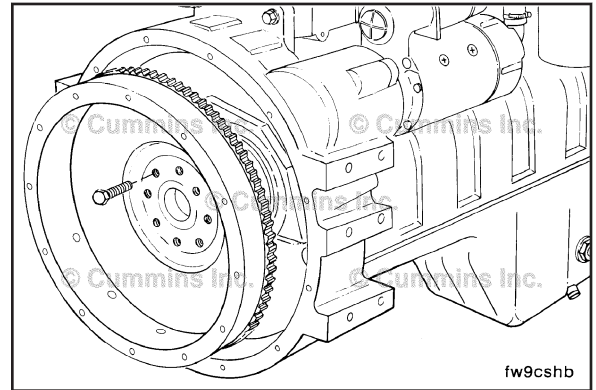
Refer to equipment manufacturer's instructions.



Initial Check

Inspect the ring gear teeth for cracks and chips.

NOTE: If the ring gear teeth are damaged, the ring gear **must** be replaced.

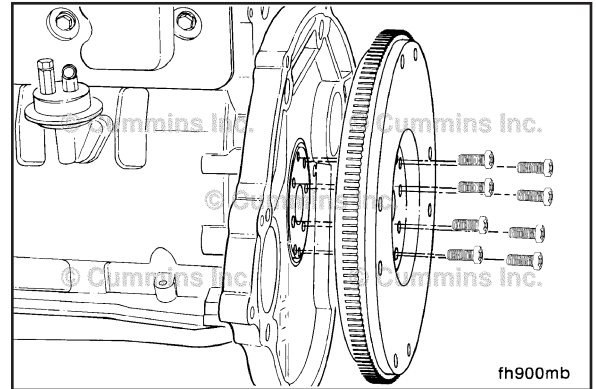


Remove

⚠ 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.

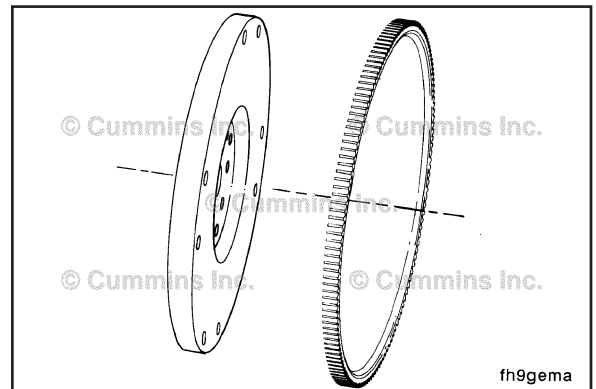
Remove the flywheel. Refer to Procedure 016-005.

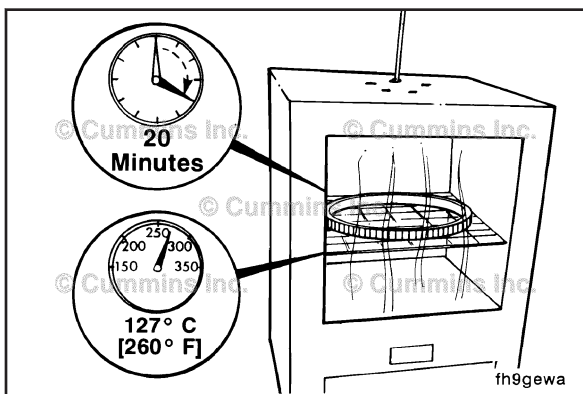


⚠ WARNING ⚠

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.

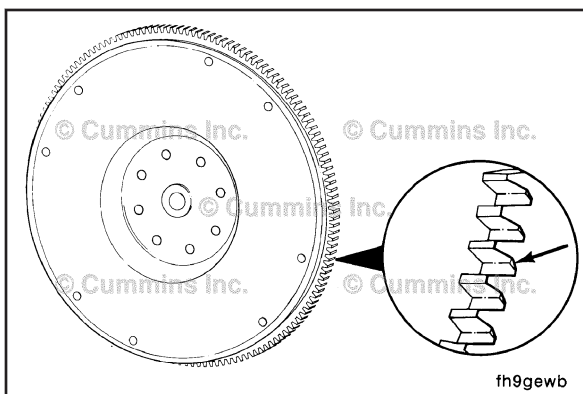
Use the brass drift pin to drive the ring gear from the flywheel.





Install

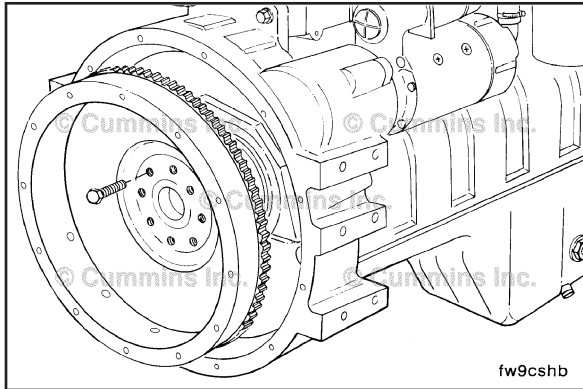
Heat the new ring gear for 20 minutes in an oven preheated to 127°C [260°F].



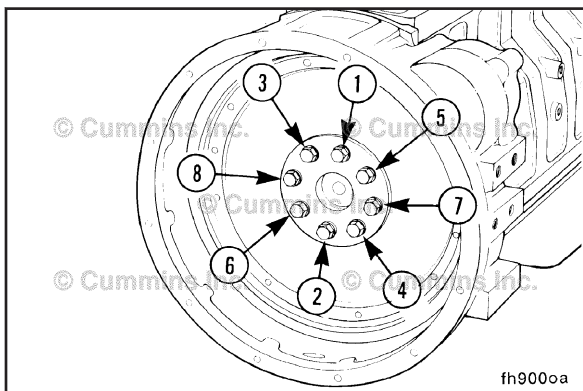
WARNING
To reduce the possibility of severe burns, wear protective gloves when installing the heated gear.

NOTE: The ring gear **must** be installed so the bevel on the teeth is toward the crankshaft side of the flywheel.

Install the ring gear.



Use two capscrews and the barring tool, Part Number 3824591, in the front of the crankshaft to hold the crankshaft when the flywheel capscrews are being tightened.



Tighten the capscrews in the sequence shown.

Torque Value: 137 N•m [101 ft-lb]



Engine Mounts (016-010)

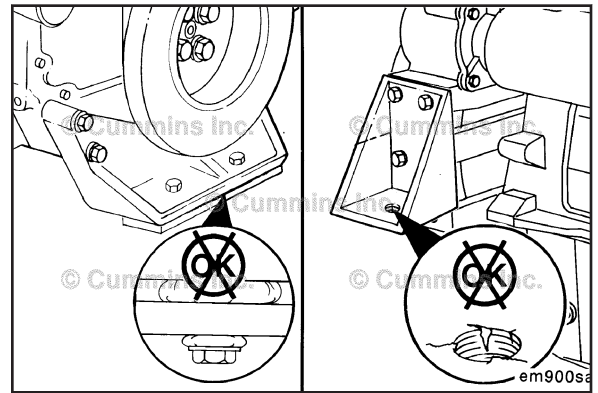
Inspect for Reuse

⚠CAUTION⚠

Damaged engine mounts and brackets can cause engine misalignment. Drivetrain component damage will possibly result in vibration complaints.

Inspect all rubber-cushioned mounts for cracks or damage.

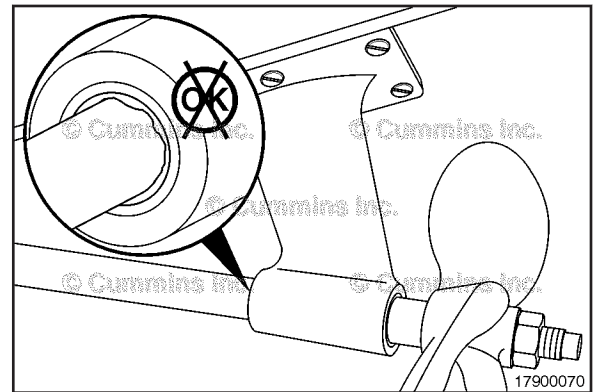
Inspect all mounting brackets for cracks or damaged bolt holes.



Propeller Shaft (016-025)

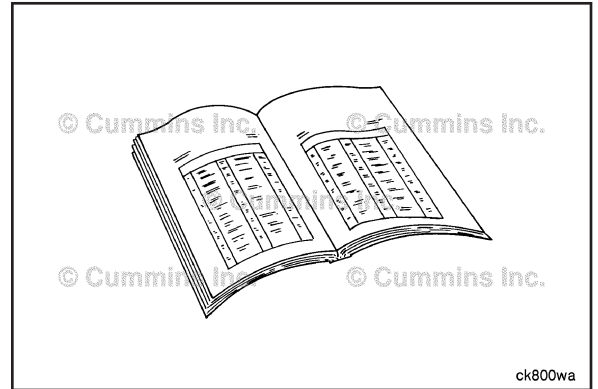
General Information

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

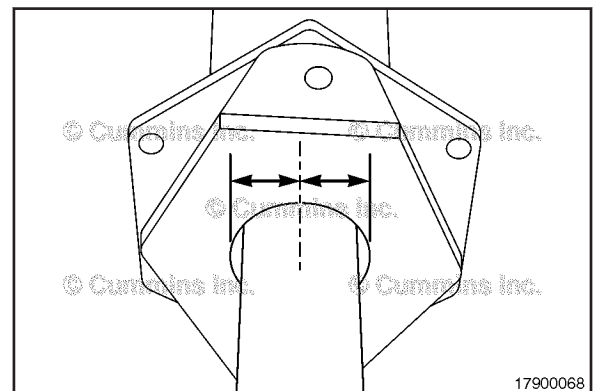
Shaft alignment is checked when isolators are replaced, adjusted, or any time excessive vibration has been noticed. Also, any time the vessel has been taken out of the water and stored or blocked minor changes can take place in the shape of the hull. The shaft is checked and realigned as necessary after the vessel has been placed back in the water.

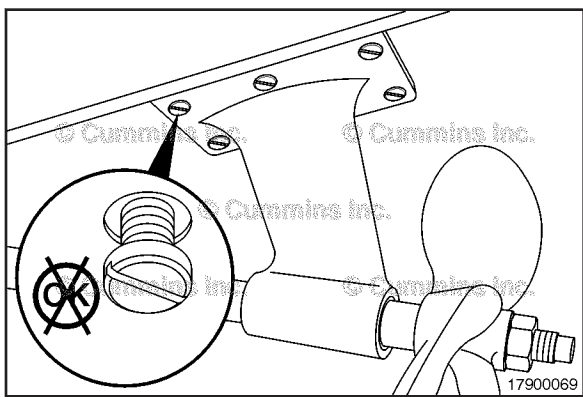


Out of Water

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.

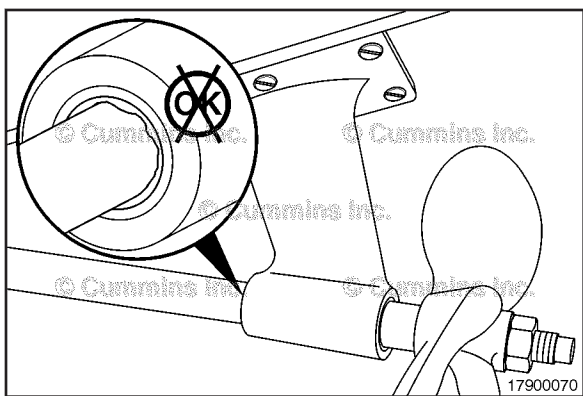




Inspect the strut. Make sure the strut is mounted solidly to the hull.

Check that the shaft is aligned with the cutlass bearing, and that the bearing is **not** worn.

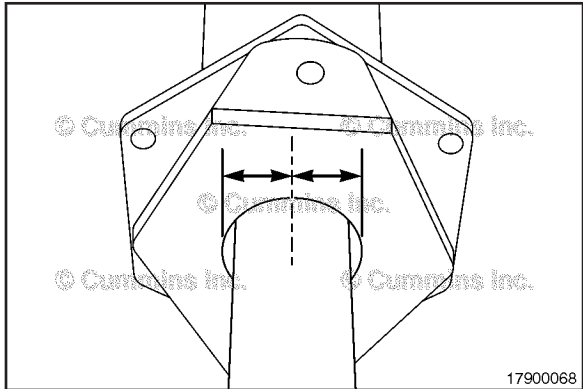
If any problems are noted, refer to an authorized OEM service location.



A misaligned shaft will cause uneven wear of the cutlass bearing.

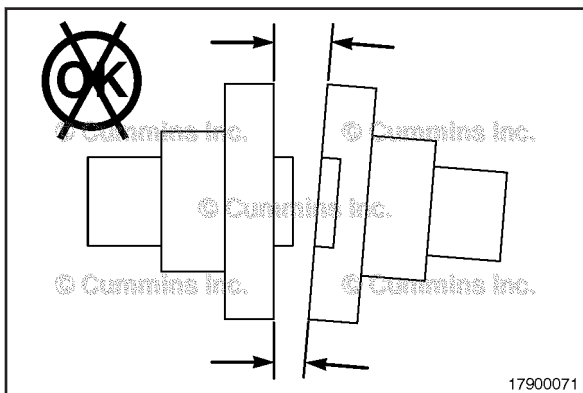
If the strut or cutlass bearing needs to be repaired or replaced, refer to an authorized OEM service location.

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.

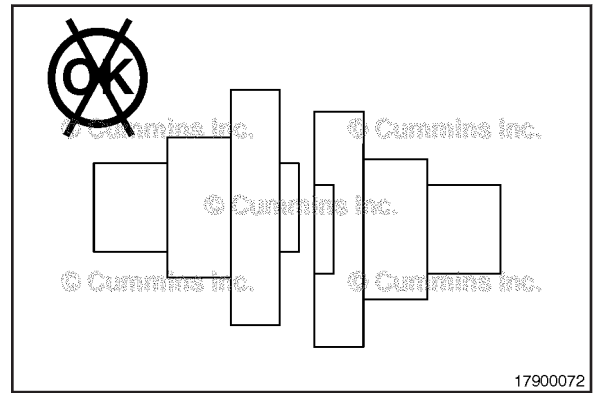


Unbolt the propeller shaft coupling from the marine gear coupling.

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

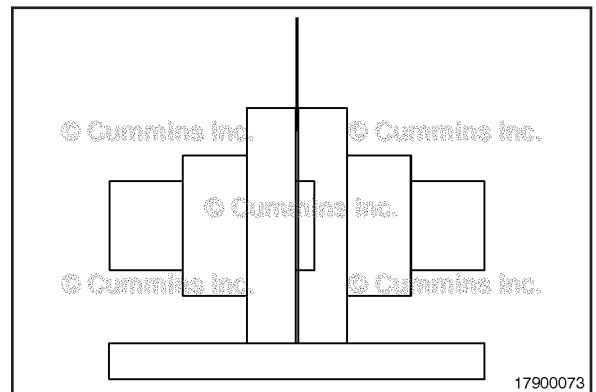


Use a feeler gauge (3) to check the alignment of the coupling in four different places, 90 degrees apart. The variation is to be within 0.051 to 0.102 mm [0.002 to 0.004 in].

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.

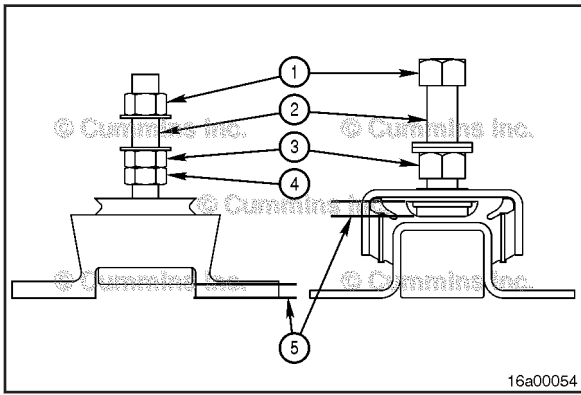
Bolt the coupling in place and torque to the specifications for the capscrew and bolt size.



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)

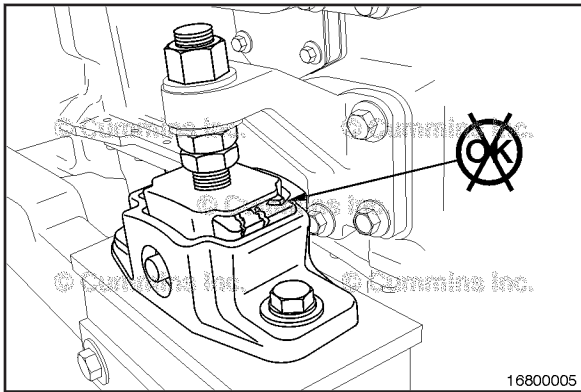
General Information

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.

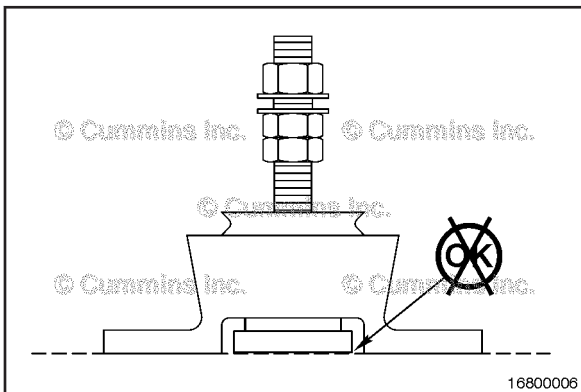
Isolators of different designs should **not** be mixed in the same installation.



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.

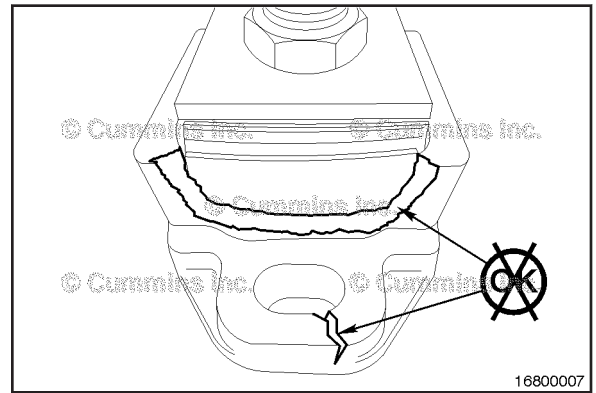
If two isolators that are both on one side of the engine or both at the front or rear of the engine are fully compressed, then the isolators will need to be replaced.

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.

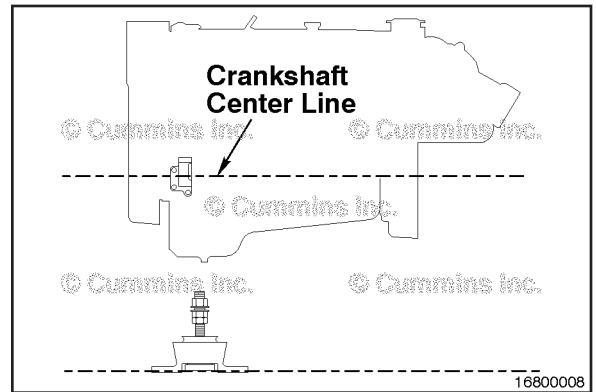


Check that the isolator mounting base is parallel with the engine crankshaft centerline and that the stud is perpendicular to the base, when looking from the side of the engine. The oil pan flange can be used as a visual reference. The engine support brackets **must** also be parallel.



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.

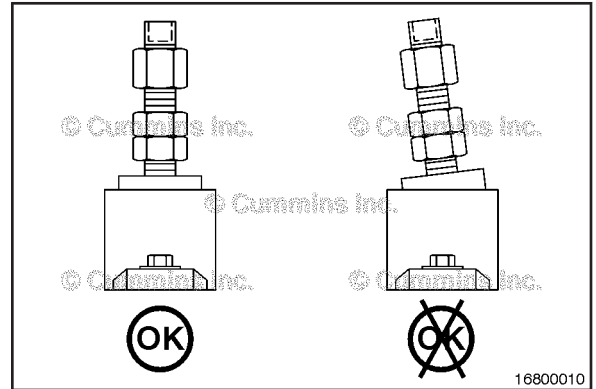


Check that the isolator mounting base is parallel to the transverse crankshaft centerline and that the stud is perpendicular to the base when looking from the front or back of the engine. The engine support brackets **must** also be parallel.



The alignment of the isolator base to the transverse crankshaft centerline should be within two degrees of parallel.

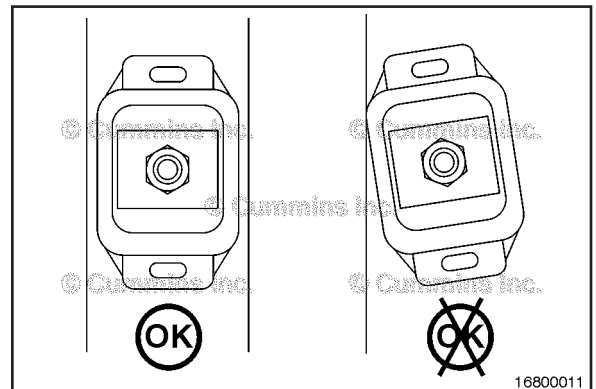
The alignment of the isolator stud to the base should be within two degrees of perpendicular.

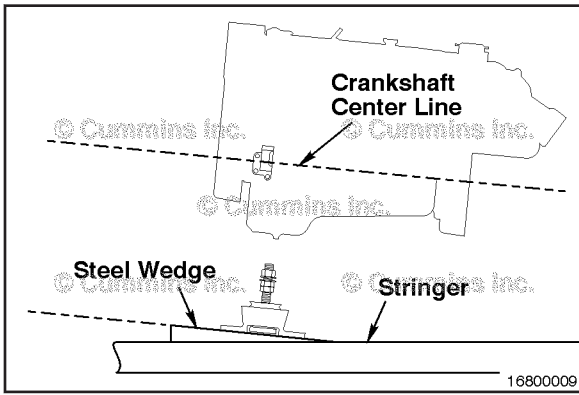


Check that the isolator mounting base is parallel to the crankshaft centerline when looking from the top of the engine.

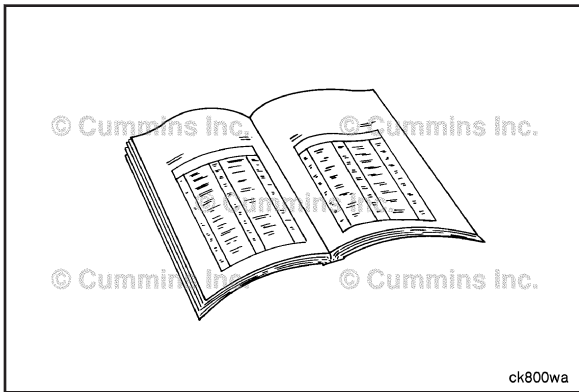


The alignment of the isolator base to the crankshaft centerline should be within two degrees of parallel.





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 or 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.

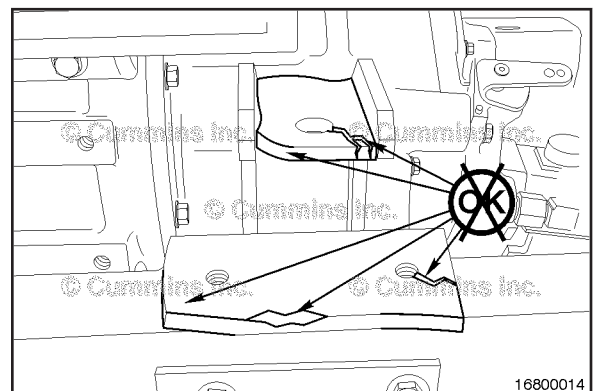
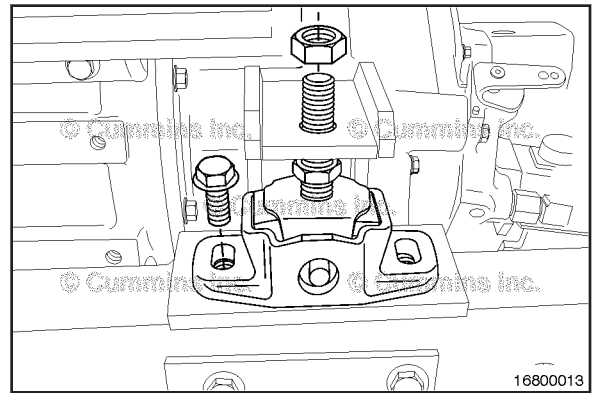
If reusing the isolator, mark the position of the isolator relative to the engine to make sure of installation in the same location.

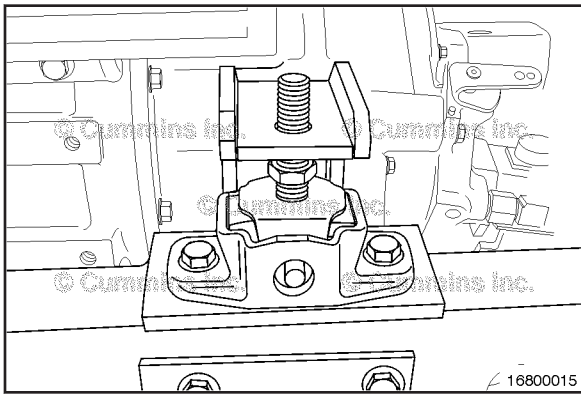
If replacing the worn or damaged isolator with a new isolator, measure the height of the adjusting nut on the stud to assist in setting the new isolator adjusting nut height.

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.

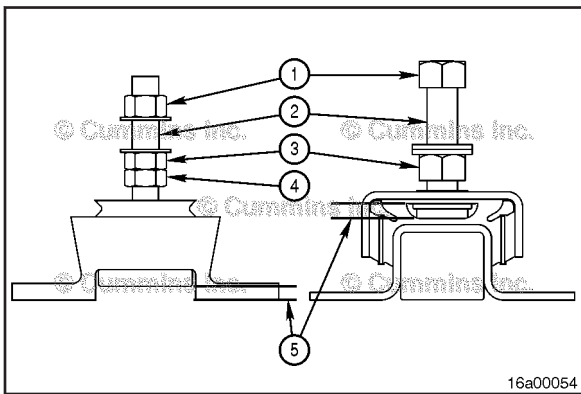


Set the adjusting nut at the approximate height of the isolator removed.

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.

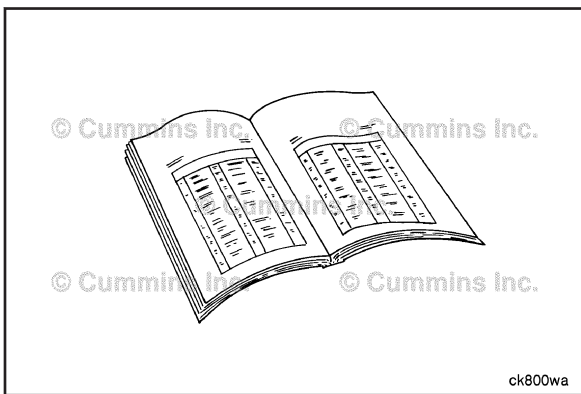
The engine will be heavier at either the front or back, depending on the configuration. Therefore, the isolators on the heavier end will be compressed more.

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.

Section 17 - Miscellaneous - Group 17

Section Contents

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Cup Plug (017-002)

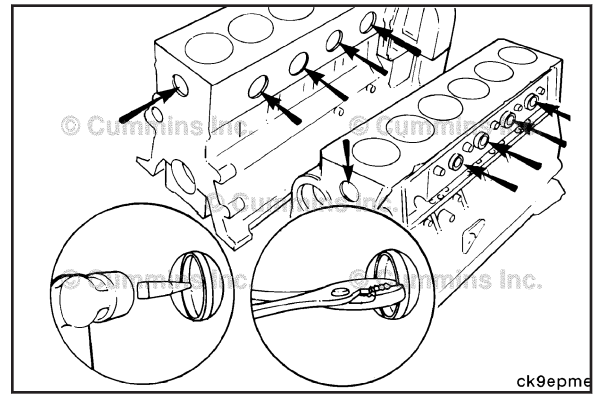
Remove

⚠ CAUTION ⚠

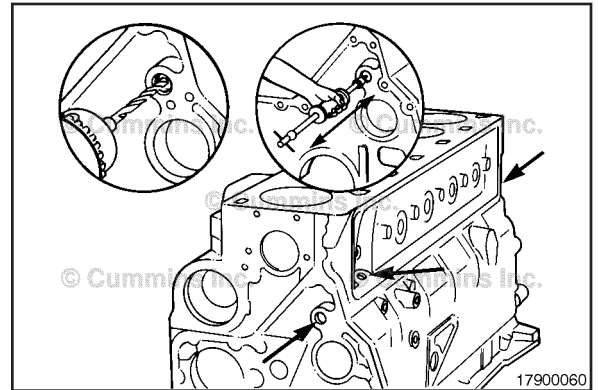
Do not allow metal shavings to fall in the engine when drilling a hole in the cup plug. Damage to engine components can occur.

Use a center punch to mark the cup plug for drilling.

Drill a 1/8-inch hole into the cup plug.



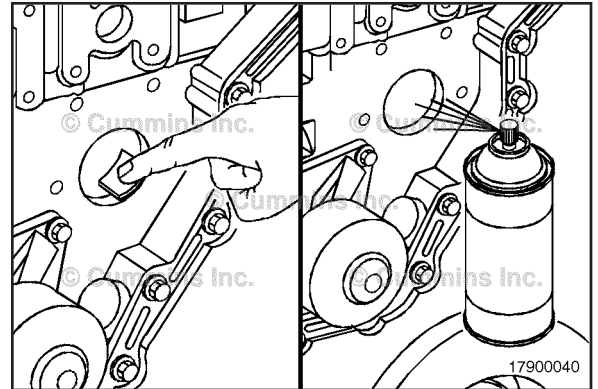
Use a dent puller to remove the plug.



Clean

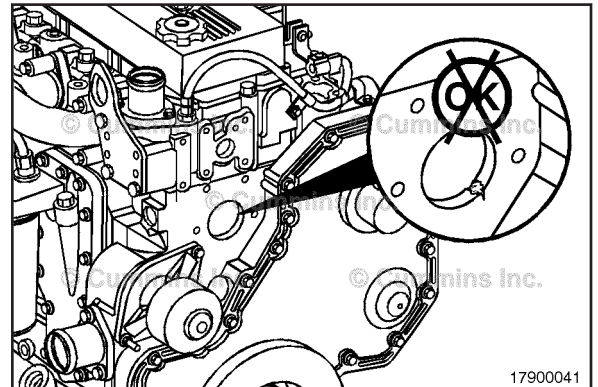
Thoroughly clean the cup plug hole using Scotch-Brite™, or equivalent.

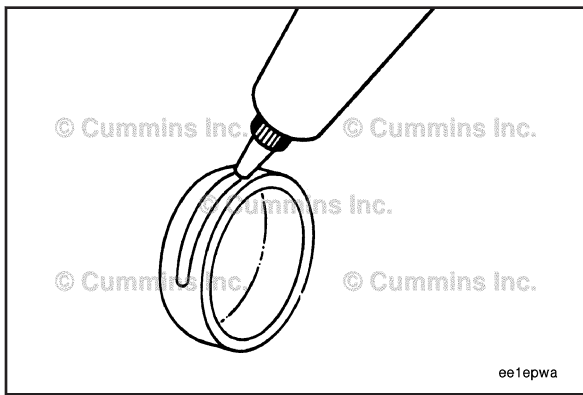
Use spray cleaner, Part Number 3375433, or equivalent, to clean the bore for the final time.



Inspect for Reuse

Inspect the cup plug bores for damage.





Install

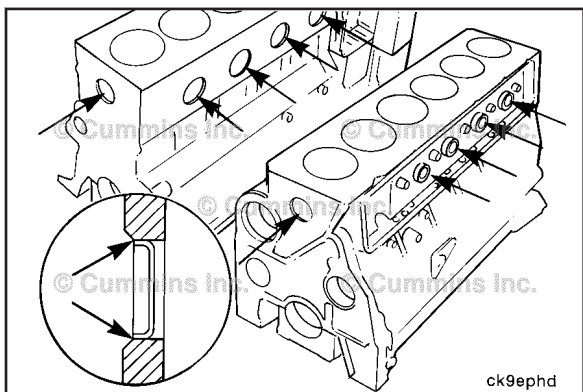


⚠CAUTION⚠

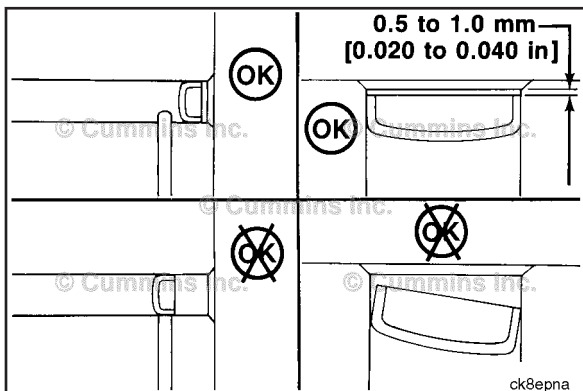
Excessive sealant can run back into the engine and cause damage to other components. Allow the sealant to dry for a minimum of 2 hours before operating the engine. The plug can come out of the bore if the sealant is not dry.

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. Refer to the Service Products Catalog, Bulletin 3377710.

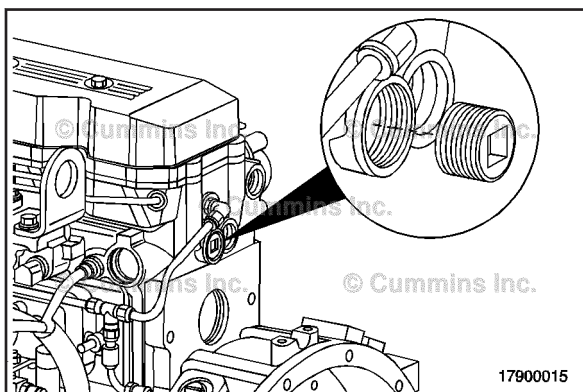


⚠CAUTION⚠

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.



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.



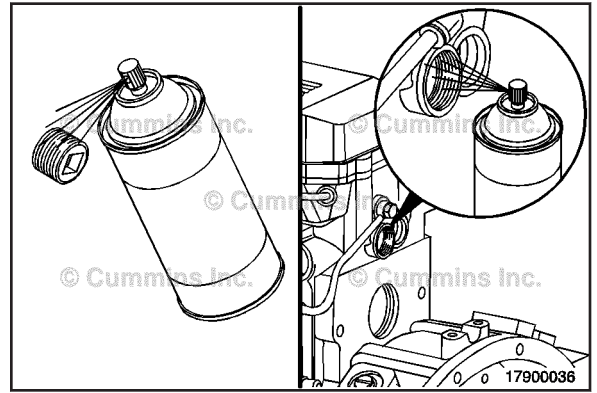
Pipe Plug (017-007)

Remove

Remove the pipe plug.

Clean

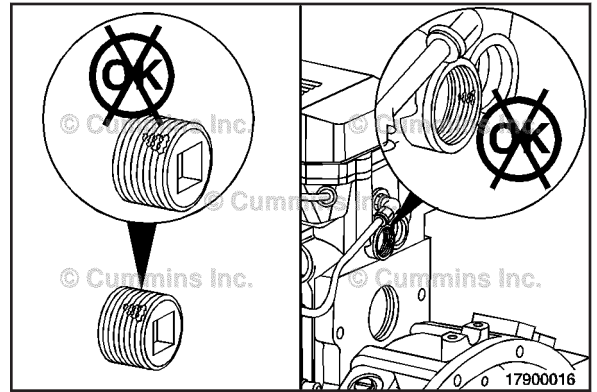
Use spray cleaner, Part Number 3375433, or equivalent, to clean the threads of the pipe plugs and threaded bores.



Inspect for Reuse

Inspect the threads of the pipe plugs for mutilation or damage.

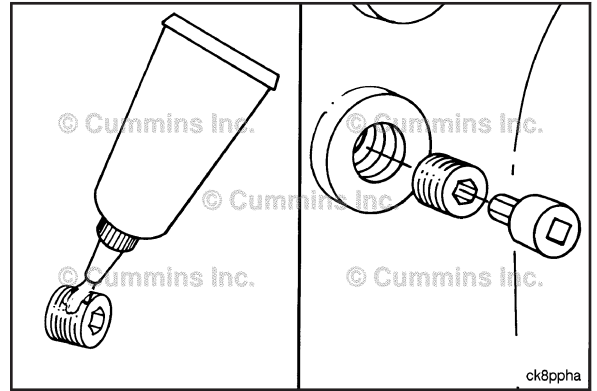
Inspect the threaded bores for damage.



Install

Apply a film of pipe plug sealant, Part Number 3375066, or equivalent, to the threads.

Install the pipe plugs.

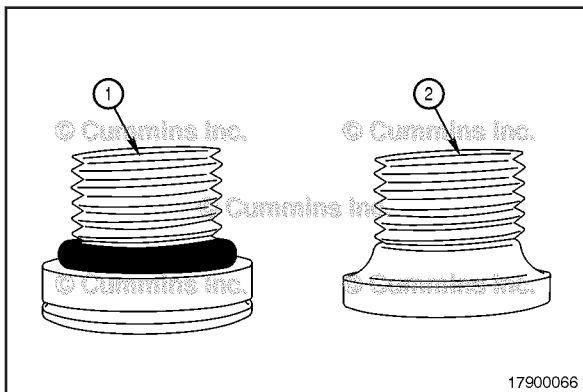


Tighten the pipe plugs. Refer to the adjoining chart for the appropriate torque values.



Pipe Plug Torque Values						
Thread	Size		Torque		Torque	
	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]
1 1/4	42.2	[1.66]	75	[55]	115	[85]
1 1/2	48.3	[1.90]	85	[65]	135	[100]

ck8ppoa



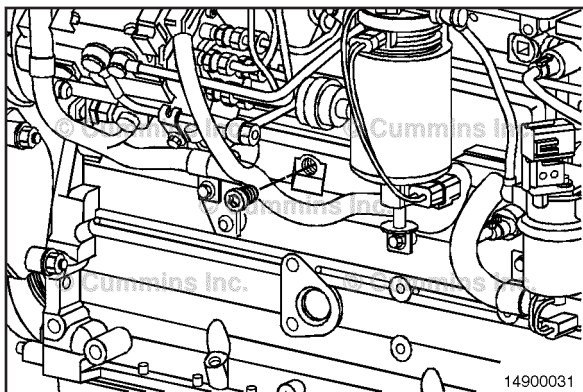
Straight Thread Plug (017-011)

General Information

Two types of straight thread plugs are used:

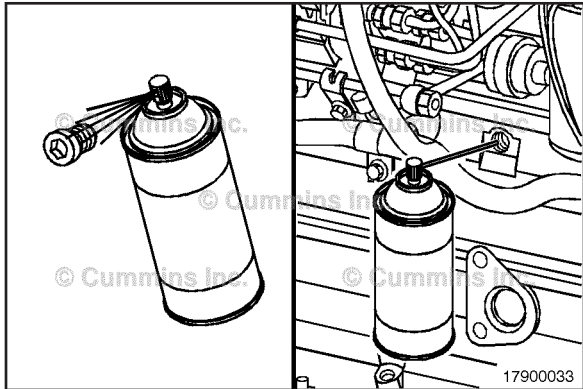
- 1 Straight thread plug with o-ring
- 2 Straight thread plug with formed in-place sealant.

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.



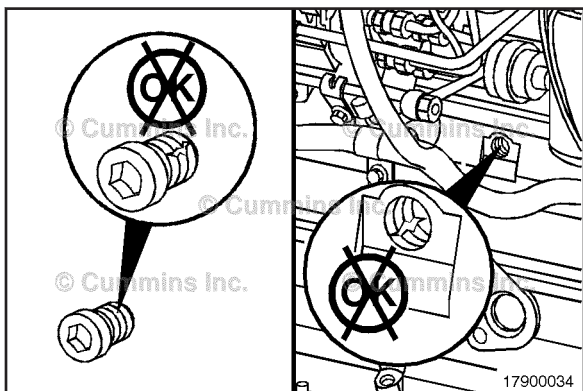
Remove

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.

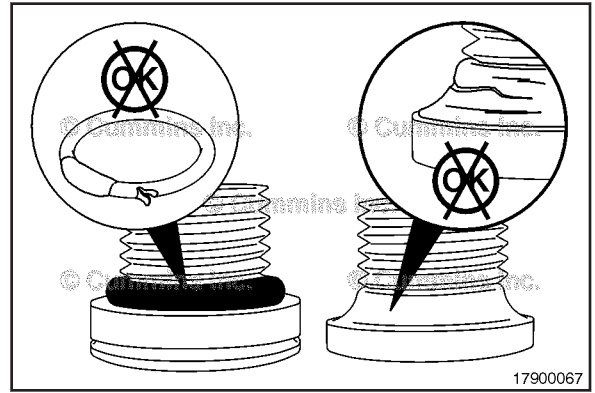
Inspect the threaded bores for damage.

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.



17900067

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.

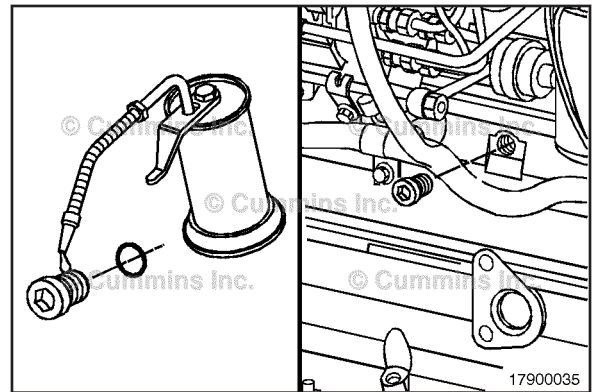
Torque Value:
M10 10 N•m [89 in-lb]

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]



17900035

If equipped with a straight thread plug with formed in-place sealant, install and tighten the plug.

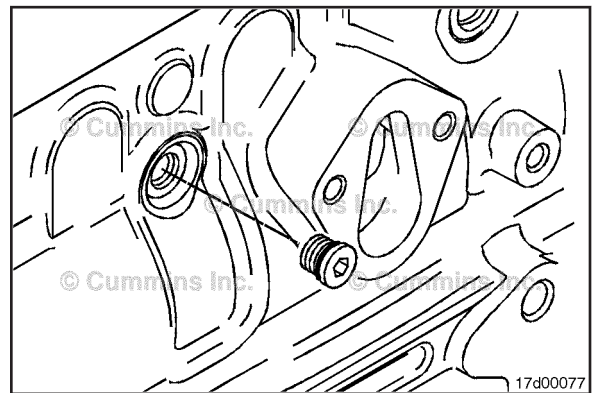
Torque Value:
M10 18 N•m [160 in-lb]

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]



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Section 21 - Main Power Generator - Group 21

Section Contents

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Generator, Main	21-1
General Information.....	21-1



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Generator, Main (021-009)

General Information

Alternator - The alternator is a Newage Stamford, 4 pole, three phase, 60hz design. It is brushless rotating field design and is built to meet BS5000 Part 3 and international standards. The alternator is self-excited with excitation power from a permanent magnet generator (PMG) powered excitation system. The service alternator is, Part Number 397205. It will be connectable for varying voltage outputs. The procedure for connecting is included in the manuals which ship with the alternator.

The manufacturer's Installation, Service and Maintenance Manual is available on the manufacturer's website at: <http://www.newage-avkseg.com/english/content/download/newage/manuals/uc/UC224-274English.pdf>

NOTE: To access this document, copy the URL above and paste it into your web browser address bar.

Generator Control Panels - There are five different generator control panel options consisting of four types of panels. A Classed Panel is one which is classified by a maritime classification society. These panels are referred to as "classed panels". An Un-Classed Panel is one which has **not** been classified by a maritime classification society. These panels are referred to as the "un-classed panels".

The following is a breakdown of the generator control panels options:

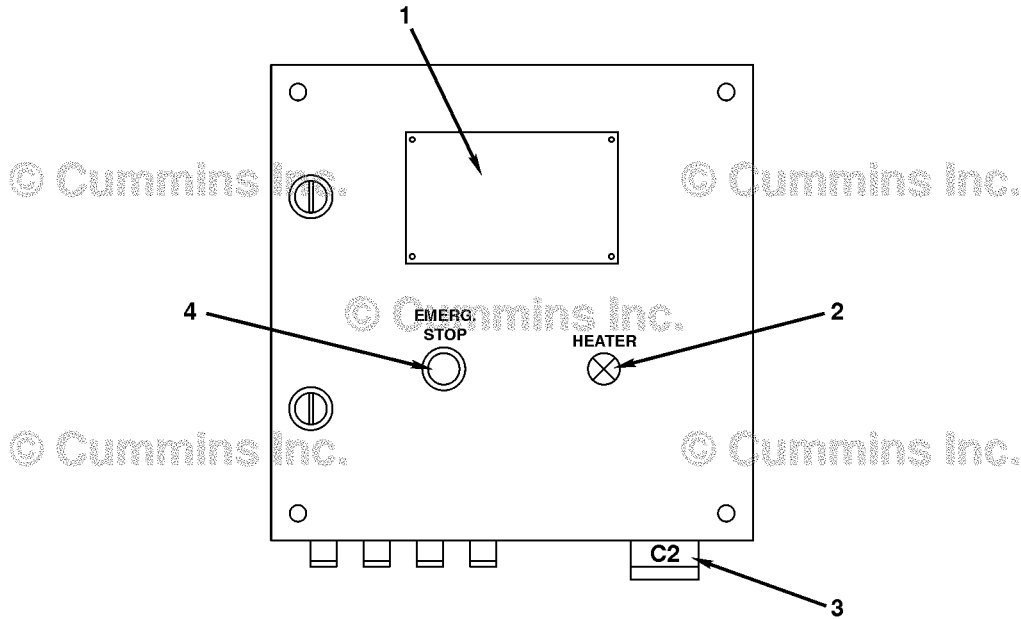
Classed Options			
Option Number	Panels Used	Quantity	Description
GP 9012	3976554	1	Base Panel
GP 9013	3976554	1	Base Panel
	3972970	1	Remote Panel
GP 9014	3976554	1	Base Panel
	3972970	2	Remote Panel

Un-Classed Options			
Option Number	Panels Used	Quantity	Description
GP 9023	3974732	1	Base Panel
GP 9024	3974732	1	Base Panel
	3976575	1	Remote Panel

The User's Manuals for the panels are available for download to the public for free at the Cummins Marine website. The address of the manuals is: http://marine.cummins.com/public_cummins/content.jhtml?tlald=5&anchorId=37&contentId=43&marketId=13&menuId=1

NOTE: To access the documents, copy the URL above and paste it into your web browser address bar.

The classed base panel mounts on the control cabinet as shown in Figure 1.



21900001

Figure 1, Classed Base Panel Cabinet.

- | | |
|----------------------------------|---------------------------|
| 1. Control Panel | 3. Cable Connection |
| 2. Block Heater Indicator Button | 4. Emergency Stop Button. |

Classed Base Control Panel - The classed base panel is an electronic control unit for controlling and monitoring diesel engines used as propulsion engines or generator sets. The classed base panel monitors the following data:

- Oil Pressure
- Oil Temperature
- Intake Manifold Pressure
- Coolant Temperature
- Battery Voltage
- Engine Speed
- Exhaust Temperature
- Total Engine Hours
- Number of Starts.

The panel is also equipped with an event log which records a history of the last 500 events such as alarms, startups, and shutdowns. The classed base control panel in cabinet is shown in Figure 2.

Generator, Main (021-009)

General Information

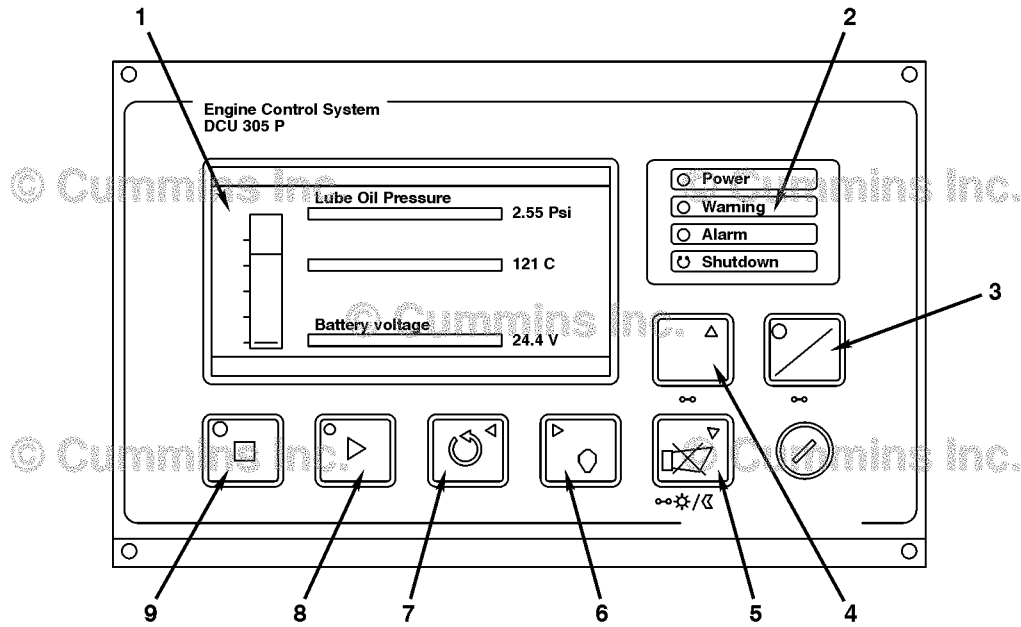


Figure 2, Classed Base Control Panel.

1. Digital display
2. LED indicator lights
3. Button A: Toggles between instrument view and alarm list view
4. Button B: Toggles between two instrument views
5. Alarm silence
6. Backlight on/off
7. Alarm acknowledge
8. Start button
9. Stop button.

The classed base panel has built in alarms. See Table 2.

Table 2: Classed Base Panel Built in Alarms.	
Alarm	Description
Low Battery Voltage	Low voltage at the start battery
Secondary Battery Low Voltage	Low voltage at the secondary battery source
Overspeed	Engine running faster than the overspeed set-point
Engine Stopped	Engine stopped for no known reason
Engine Failed to Stop	60 seconds after issuing the stop command, the engine has still not stopped
Start Failure	Engine failed to start after the last start attempt
Pickup Failure	Unable to read the pickup signal while engine is running
Output Circuit Overload	Short circuit in one of the +24 volt terminals
Analog Sensor Failure	Detailed information on which analog channel has failed
Broken Wire	Detailed information on which terminal experienced the broken wire

Operation of the Classed Base Panel - The classed base panel has several different screens or views. The views include two instrument views, alarm list view, information view, and event log view.

To toggle between instrument view and alarm list view, press button A (See Figure 2).

To toggle between two instrument views, press button B (See Figure 2).

To go to information view, press and hold button A for approximately one second.

To go to event log view, press and hold button B for approximately one second.

When connected to the classed remote panel, both the classed remote panel and the classed base panel can control the engine. However, it is possible to lock out the classed remote panel and allow control **only** from the classed base panel.

To lock out the classed remote panel:

1. Go to INFO view
2. Press and hold BUZZER ON/OFF for two seconds until a beep is heard. The screen will change to toggle Local Mode ON/OFF. When ON, this disables the remote panel commands.

Stop Button - To stop the unit, press and hold the red button labeled STOP until the unit has stopped. If the Stop Button is held for less than one half of a second, the engine will **not** stop. The control unit stops the generator set by pulling the stop solenoid. When the red LED in the stop button is lit it indicates that the control unit is pulling the stop solenoid.

Start Button - Manual start is activated with the green button labeled Start. Press and hold the button until the engine has started.

A running engine is indicated by the green LED in the Start button and the text Running in the far left status field on the Digital Display. The RPM-meter will indicate the engine speed.

Standby and Manual Mode Button - The Standby button is a toggle button, meaning that for every other keypress, the unit is set to Standby or Manual. A green LED in the Standby button indicates that the unit is set to Standby. The right most status field also indicates the chosen mode by displaying either Standby or Manual.

Acknowledge (Reset) Button - In case of alarms, a press on the acknowledge button, labeled Ackn, will reset the alarm(s). At the same time, the buzzer will be silenced. In the Alarm List view, Ackn will reset all alarms, whereas, in the Instrument view, Ackn will reset the alarm in the top of the screen **only**.

Buzzer OFF Button - Press the Buzzer OFF button to silence the built-in buzzer signal that is activated when an alarm occurs. The alarm that activated the buzzer remains active until acknowledged.

Classed Remote Panel Digital Display - The classed remote panel is a touch screen display that shows most of the data available from the classed base panel. It can also execute many of the same commands as the base panels. It connects to the supplied terminals on the engine cabinet with six wires. Four wires are for communication and two are for power supply. See Figure 3 for the Classed Remote Panel Digital Display.

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Generator, Main (021-009)

General Information

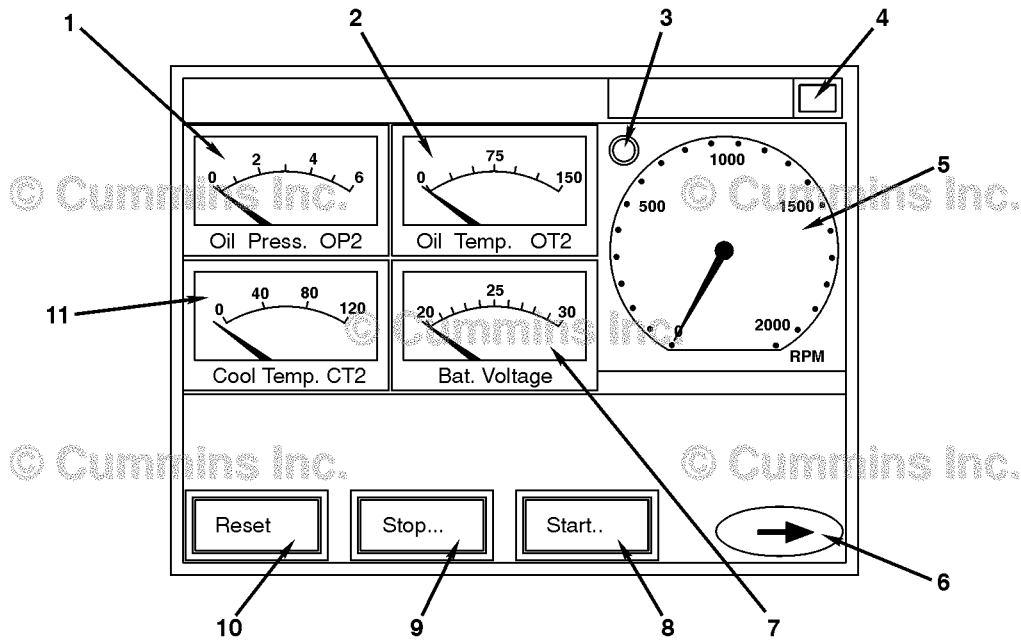


Figure 3, Classed Remote Panel Digital Display.

- | | |
|------------------------------------|-------------------------------|
| 1. Oil pressure gauge | 7. Battery voltage gauge |
| 2. Oil temperature gauge | 8. Start button |
| 3. Indicator light | 9. Stop button |
| 4. Button to access the alarm list | 10. Reset button |
| 5. Engine rpm | 11. Coolant temperature gauge |
| 6. Navigate between pages | |

21900003

The following analog values are available from the classed remote panel.

Value Description	Range and Units	
Oil Pressure	0.0 - 6.0 Bar	0 - 87 PSI
Oil Temperature	0 - 150°C	32 - 302°F
Coolant Temperature	0 - 130°C	32 - 266°F
Battery Voltage	20 -30 Volts	
Engine Speed	0 - 2000 RPM	
Exhaust Stack Temperature	0 - 600°C	32 - 112°F
Total Engine Hours	0 - 99999 Hours	
Trip Engine Hours	0 - 999 Hours	
Starter Counter	0 - 99999 Starts	

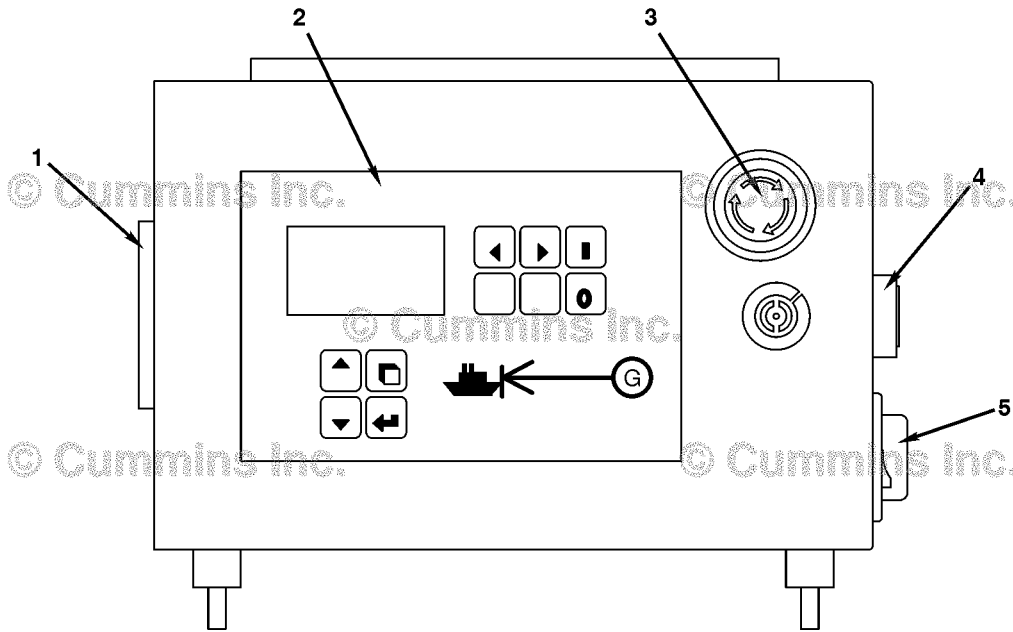
The following shows the commands that can be executed with the classed remote panel.

Command	Description
Engine Start	Brings up a dialog to confirm engine start
Engine Stop	Brings up a dialog to confirm engine stop. An ongoing start attempt can be cancelled by pressing stop
Acknowledge Alarms	Will acknowledge all pending alarms in the Classed Base Panel
Set to Standby	The Classed Base Panel will do automatic start attempts
Set to Manual	The Classed Base Panel will not do automatic start attempts

The following lists the alarms shown by the Classed Remote Panel.

Alarm Description	Comment
Low Oil Pressure	1.7 Bar [25 psi]
High Coolant Temperature	106°C [223°F]
Emergency Stop/Start Disabled	Manual emergency stop is operated. Start is disabled.
Low Coolant Pressure	0.7 Bar [10 psi]
Power Failure	Either the primary or the secondary (backup) voltage supply to the DCU 305 R2 is too low
Overspeed	50 Hz overspeed = 1725 RPM, 60 Hz overspeed = 2070 RPM
Oil Pressure	2.4 Bar [35 psi]
Oil Temperature	120°C [248°F]
Coolant Temperature	104°C [219°F]
Start Failure	When set to Standby only .

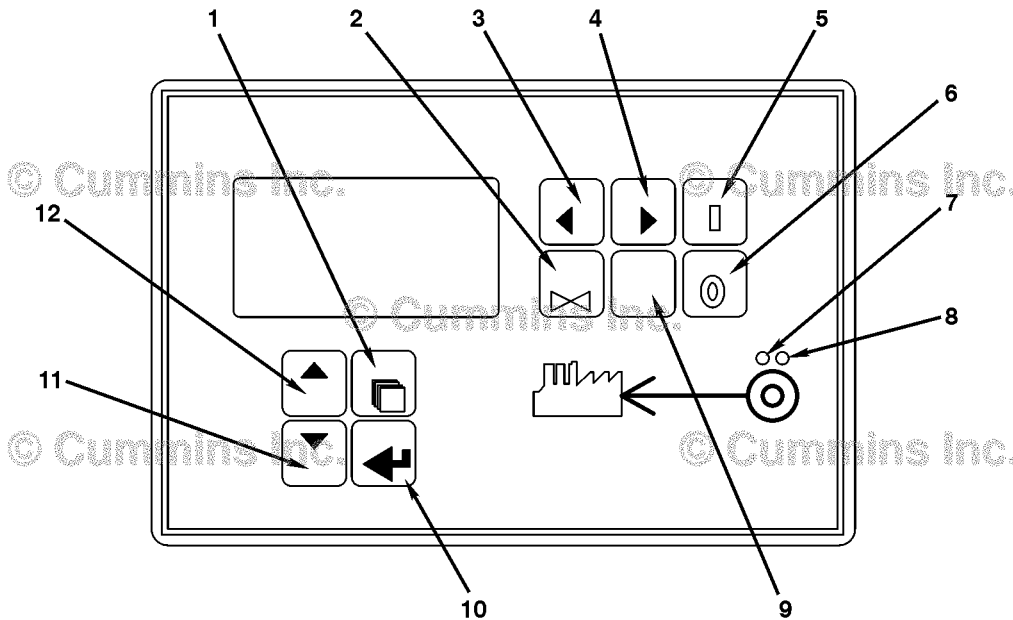
Un-Classed Base Panel - The un-classed base panel mounts in the cabinet as shown.



21900004

- 1. Engine harness connector
- 2. Control panel
- 3. Emergency stop button
- 4. Alarm horn
- 5. Cabinet power switch.

Un-Classed Base Panel Digital Display - The un-classed base panel is a comprehensive controller for single engine sets. The un-classed base panel is equipped with a graphic display showing icons, symbols and bar-graphs for intuitive operation. The un-classed base panel automatically starts and stops the engine on external signal from the un-classed remote panel or by pressing push buttons on the base panel itself. The un-classed base panel automatically checks engine conditions and protects against out-of-limit operation.



21900005

Un-Classed Base Panel Digital Display

- | | |
|--|---|
| 1. Page Button - Cyclic selection of the display mode (MEASUREMENT>ADJUSTMENT>HISTORY) | 7. Indicator Light - On = no alarm |
| 2. Horn Reset Button - Deactivates the Horn | 8. Indicator Light - Flashing = generator failure, Steady On = Alarm still active, Off = No alarm active. |
| 3. Mode - Cyclic backward selection of the generator set operation mode (AUT>MAN>OFF) | 9. Fault Reset Button - Acknowledges faults and alarms |
| 4. Mode - Cyclic forward selection of the generator set operation mode (OFF>MAN>AUT) | 10. Enter Button - Confirm set-point value |
| 5. Start Button - Starts the generator set | 11. Select the set-point, select the screen, or decrease the set-point value |
| 6. Stop Button - Stops the generator set | 12. Select the screen or select set-point |

The following is a guide to the menus and operation of the push buttons:

To select the generator set mode, use button 3 or 4 to select the requested generator set operation mode (OFF - MAN - AUT).

Display Menus - There are two display menus available: MEASUREMENT and ADJUSTMENT. Each menu consists of several screens. Press button 1 repeatedly to select the requested menu.

To view measured data: Use button 1 repeatedly to select the MEASUREMENT menu. Use buttons 1 and 7 to select the screen with the requested data.

To view and edit set points:

1. Press button 2 repeatedly to select the adjustment menu
2. Use button 11 and 12 to select the requested set-points group
3. Press button 8 to confirm
4. Use buttons 11 and 12 to select requested set-points
5. Set points marked with an asterisk are password protected
6. Press button 10 to edit
7. Use buttons 11 and 12 to modify the set-point. When buttons 11 or 12 are pressed for two seconds, auto repeat function is activated
8. Press button 10 to confirm or button 1 to leave without change
9. Press button 1 to leave selected set-points group.

To change the display contrast: Press button 10 and either button 11 or 12 at the same time to adjust for the best display contrast.

Function Description:

OFF mode - No start of the generator set is possible. Outputs STARTER and FUEL SOLENOID are **not** energized. No reaction if buttons START or STOP are pressed.

MAN mode - START - starts the generator set.

STOP - stops the generator set.

Hints - The engine can run without load unlimited time. The controller does **not** automatically stop the running generator set in MAN mode. The controller does **not** start the generator set when binary input REM START/STOP is closed

Start-stop sequence (simplified).

MODE = MAN (Engine start/stop request is given by pressing buttons START and STOP)

MODE = AUT (Engine start/stop request is given by binary input REM START/STOP)

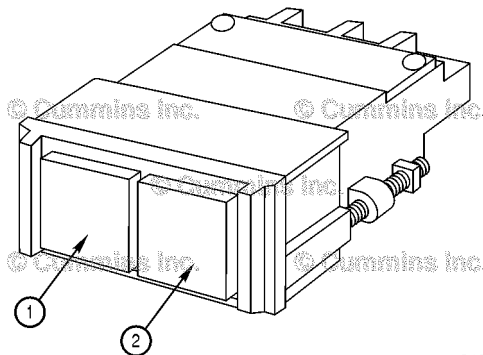
State	Condition of Transition	Action	Next State
Ready	Start request	PRESTART on Prestart time counter started	Prestart
	RPM greater than 2 or oil pressure greater than starting prestart oil		Stop (Stop failure)
	OFF mode selected or shutdown alarm active		Not Ready
Not Ready	RPM less than 2, oil pressure less than starting prestart oil, no shutdown alarm active, other than OFF mode selected		Ready
Prestart	Prestart time elapsed	STARTER on, FUEL SOLENOID on, Maximum Crank time counter started	Cranking

State	Condition of Transition	Action	Next State
Cranking	RPM greater than Start RPM	STARTER off, PRESTART off	Starting
	D+ input activated or oil pressure detected or Generator voltage greater than 25% voltage nominal	STARTER off, PRESTART off	Cranking
	Maximum Crank time elapsed, first attempt	STARTER off, FUEL SOLENOID off, STOP SOLENOID on Crank Failure pause timer started	Crank pause
	Max Crank time elapsed, last attempt	STARTER off, PRESTART off	Shutdown (Start failure)
Crank pause	Crank Fail pause elapsed	STARTER on, FUEL SOLENOID on, STOP SOLENOID off, Maximum Crank time counter started	Cranking
Starting	80% Nominal speed reached	READY TO LOAD on Minimum, Maximum Stabilizer Time counter started	Running
	RPM 0 or an other shutdown condition	FUEL SOLENOID off, STOP SOLENOID on	Shutdown
	60 second Elapsed	FUEL SOLENOID off, STOP SOLENOID on	Shutdown (Start failure)
Running	Stop request	READY TO LOAD off, Cooling time timer started	Cooling
	RPM equal to 0 or any other shutdown condition	FUEL SOLENOID off, STOP SOLENOID on	Shutdown
Cooling	Cooling time elapsed	FUEL SOLENOID off, STOP SOLENOID on	Stop
	RPM equal to 0 or any other shutdown condition	FUEL SOLENOID off, STOP SOLENOID on	Shutdown
	Start request	READY TO LOAD on	Running
Stop	RPM equal to 0, Oil pressure less than Starting PRESTART Oil		Ready
	60 second Elapsed		Stop (Stop failure)

Hint - Threshold level for D+ input is 80 percent supply voltage.

AUT mode - The controller does **not** respond to buttons START or STOP. Engine start/stop request is given by binary input REM START/STOP.

Un-Classed Remote Panel - The un-classed remote panel consists of one maintained action, two part, illuminated push-button switch. The two part, illuminated push-button has a snap-action switching function and serves to start and stop the generator engine. See Figure 4.



21900006

Figure 4, Un-Classed Remote Panel.

1. Start/Stop Button
2. Generator Run Indicator Light.

Radiator - The package can be configured with three different cooling options, which includes a seawater heat exchanger, a keel cooler, or a fan drive and radiator.

Base Rail - Because the engine and alternator are being offered as a complete set, another new option is the Sub Base. The Sub Base option includes all the vibration damping and fastening hardware necessary to mount the engine and alternator onto the base rail. See Figure 5.

The base rail is Cummins Part Number 3976557, and is part of option number RB 9045 and RB 0944.

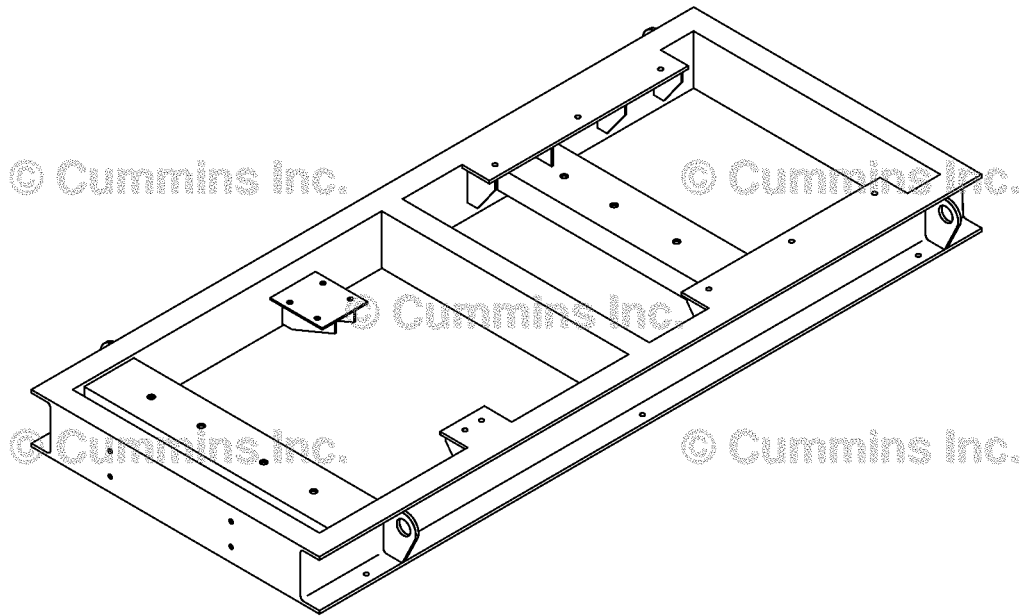


Figure 5, Base Rail

2190007

Section L - Service Literature

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Cummins Customized Parts Catalog	L-3
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Contact Information.....	L-2

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Additional Service Literature General Information

The following publications can be purchased by contacting the nearest local distributor.

Bulletin Number	Title of Publication
3666008	C Series Engine Shop Manual
3666021	C Series Specifications Manual
3379001	Fuel for Cummins Engines Bulletin
3666132	Coolant Requirements and Maintenance Bulletin
3379009	Operation, Cold Weather
3810340	Cummins Engine Oil Recommendations Bulletin
3666109	Alternative Repair Manual, B and C Series Engines
3379000	Air for Your Engines
3381700	Worldwide Service Locations
3666109	C Series Alternative Repair Manual

Service Literature Ordering Location Contact Information

Region

United States and Canada

Ordering Location

Cummins Distributors

or

Credit Cards at 1-800-646-5609

or

Order online at www.powerstore.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 contains 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. Your name and engine model identification even appears on the catalog spine. Everybody will know that Cummins created a catalog specifically for you.

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 the Cummins Electronic Parts Catalog or the Cummins Parts Microfilm System.

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 customers can contact their Cummins Distributor or call Gannett Direct Marketing Services at 1-800-646-5609 and order by credit card. Outside North America order on-line or make an International call to Gannett at (++)502-454-6660.

Ordering On-Line

The Customized Parts Catalog can be ordered On-Line from the Cummins Powerstore by credit card.

Contact GDMS or the CUMMINS POWERSTORE for the current price; Freight may be an additional expense.

Information we need to take your Customized Parts Catalog Order. This information drives the cover content of the CPC.

- Customer Name
- Street Address
- Company Name (optional)
- Telephone no.
- Credit Card No.
- Cummins Engine Serial Number (located on the engine data plate)
- Please identify the required media: Printed Catalog, CD-ROM, or PDF File

Unfortunately not all Cummins Engines can be supported by this parts catalog. 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.

Section V - Specifications

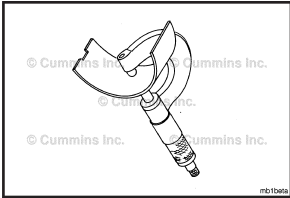
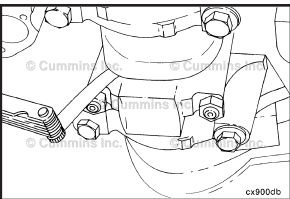
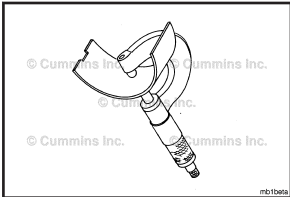
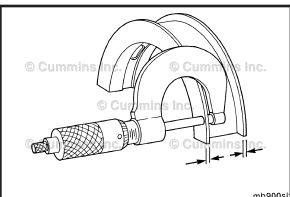
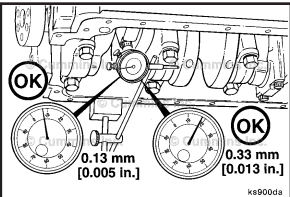
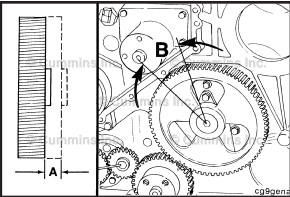
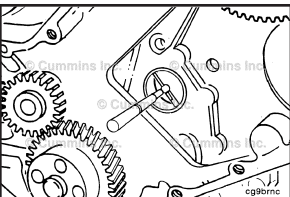
Section Contents

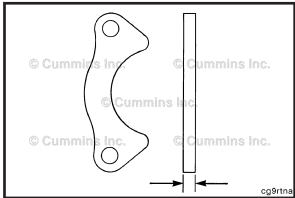
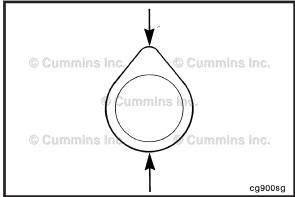
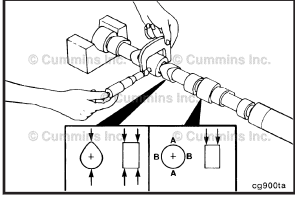
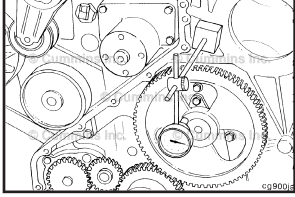
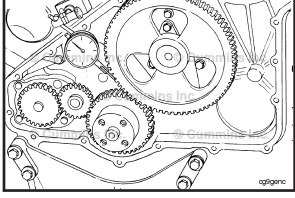
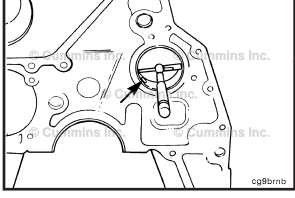
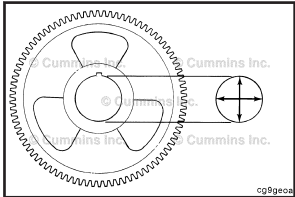
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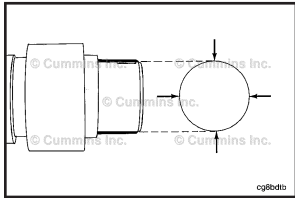
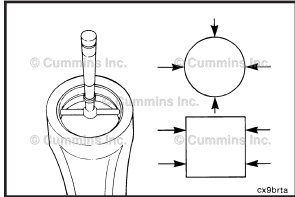
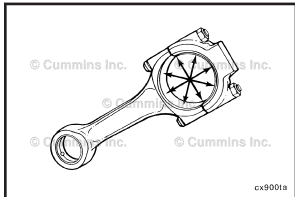
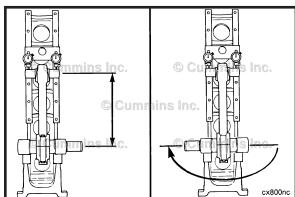
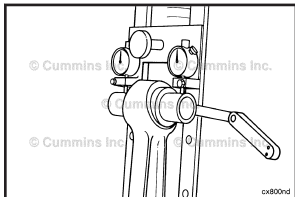
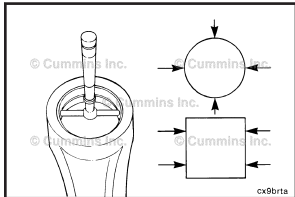
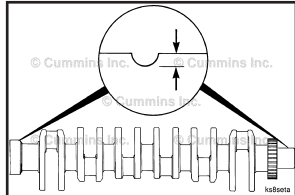

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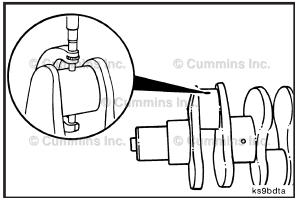
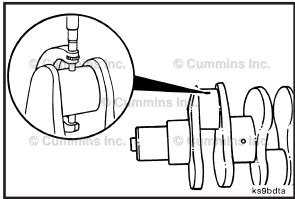
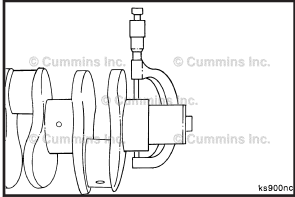
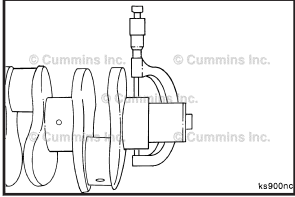
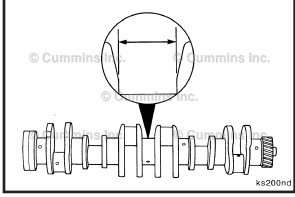
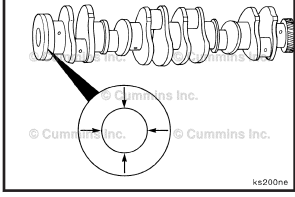
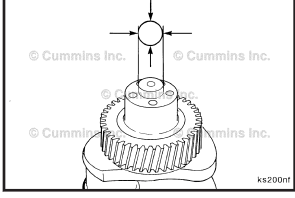
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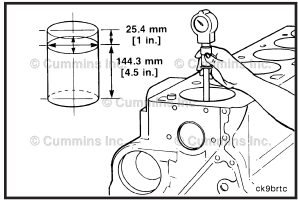
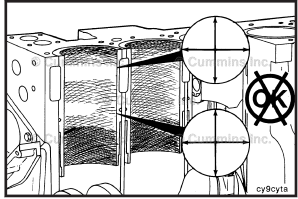
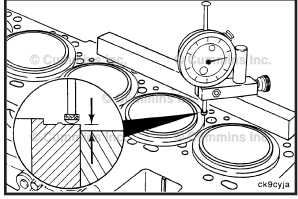
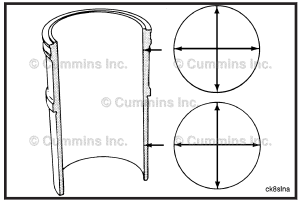
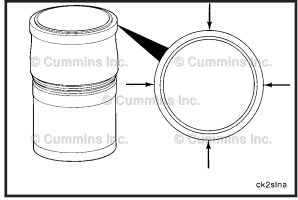
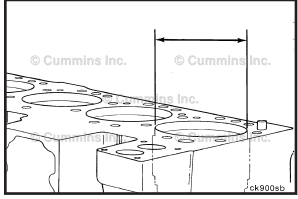
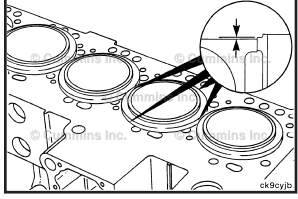
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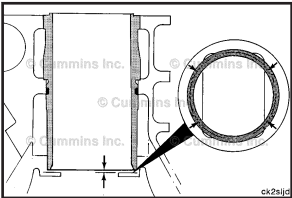
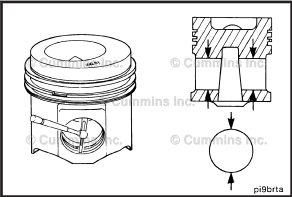
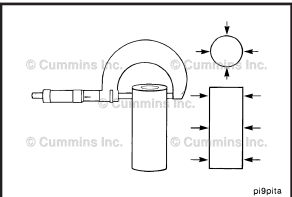
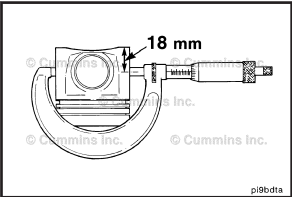
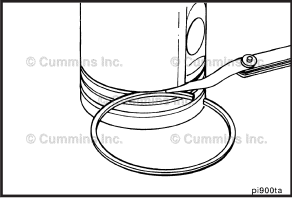
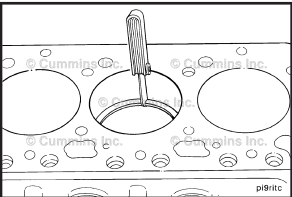
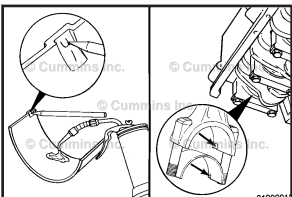
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Cylinder Block - Group 01 - Specifications				
Bearings, Connecting Rod (001-005)				
Standard Connecting Rod Bearing Thickness (Used)		2.43 mm 2.47 mm	MIN MAX	0.096 in 0.097 in
				
Connecting Rod Side Clearance		0.10 mm 0.33 mm	MIN MAX	0.004 in 0.013 in
				
Bearings, Main (001-006)				
Standard Main Bearing Shell Thickness		3.446 mm 3.454 mm	MIN MAX	0.1357 in 0.1360 in
				
Thrust Bearing Flange Thickness		3.52 mm 3.57 mm	MIN MAX	0.139 in 0.141 in
				
Crankshaft End Clearance		0.127 mm 0.330 mm	MIN MAX	0.005 in 0.013 in
				
Camshaft (001-008)				
Camshaft End Play (A)		0.12 mm 0.46 mm	MIN MAX	0.005 in 0.018 in
Camshaft Gear Backlash (B)		0.08 mm 0.33 mm	MIN MAX	0.003 in 0.013 in
				
Bushing		60.12	MAX	2.367
				

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Camshaft Thrust Plate Thickness		9.34 mm 9.58 mm	MIN MAX	0.368 in 0.377 in	
Intake		49.940	MIN	1.966	
Exhaust		49.774	MIN	1.960	
Intake		45.400	MIN	1.787	
Exhaust		44.649	MIN	1.758	
Intake		45.400	MIN	1.787	
Exhaust		45.141	MIN	1.777	
Camshaft Journal Diameter Wear Limits for Part Numbers 3930347 and 3927693		53.967 mm 54.013 mm	MIN MAX	2.1247 in 2.1265 in	
Camshaft End Clearance		0.12 mm 0.46 mm	MIN MAX	0.005 in 0.018 in	
Camshaft Gear Backlash Limits (B)		0.08 mm 0.33 mm	MIN MAX	0.003 in 0.013 in	
Camshaft Bushings (001-010) Camshaft Bushing Bore Diameter - Installed		60.06 mm 60.12 mm	MIN MAX	2.365 in 2.367 in	
Camshaft Gear (Camshaft Removed) (001-013) Camshaft Gear Bore Inner Diameter		41.48 mm 41.51 mm	MIN MAX	1.633 in 1.634 in	

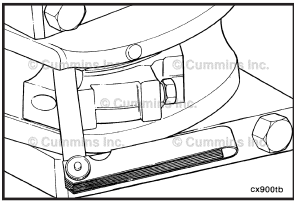
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.		
Camshaft Gear Journal Outer Diameter		41.56 mm 41.58 mm	MIN MAX	1.636 in 1.637 in	
Connecting Rod (001-014)					
Connecting Rod Piston Pin Bore Diameter (Bushing Installed)		45.023 mm 45.060 mm	MIN MAX	1.7726 in 1.7740 in	
Connecting Rod Crankshaft Bore I.D. (With Bearing)		76.04 mm 76.104 mm	MIN MAX	2.9939 in 2.9962 in	
Connecting Rod Crankshaft Bore I.D. (Without Bearing)		80.987 mm 81.013 mm	MIN MAX	3.1885 in 3.1895 in	
Connecting Rod Length		215.975 mm 216.025 mm	MIN MAX	8.5029 in 8.5049 in	
Connecting Rod Bend (Alignment)					
Bushing removed		0.50	MAX	0.020	
Bushing installed		0.30	MAX	0.012	
Connecting Rod Piston Pin Bore Diameter (Bushing Removed)		48.988 mm 49.012 mm	MIN MAX	1.9286 in 1.9296 in	
Crankshaft (001-016)					
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.	
Connecting Rod Bearing Journal Diameter				
Standard		75.96 MIN	2.991	
Machined 0.25 mm 0.010 in		75.71 MIN	2.981	
Machined 0.50 mm 0.020 in		75.46 MIN	2.971	
Machined 0.75 mm 0.030 in		75.21 MIN	2.961	
Machined 1.00 mm 0.040 in		74.96 MIN	2.951	
Connecting Rod Bearing Journal Out-of-Roundness		0.050 MAX	0.0020	
Taper		0.013 MAX	0.0005	
Main Bearing Journal Diameter				
Standard		97.96 MIN	3.857	
Machined 0.25 mm 0.010 in		97.71 MIN	3.847	
Machined 0.50 mm 0.020 in		97.46 MIN	3.837	
Crankshaft Main Bearing Journal Out-of-Roundness		0.05 MAX	0.002	
Taper		0.01 MAX	0.001	
Crankshaft Thrust Face Width (Standard)		42.98 mm MIN 43.08 mm MAX	1.692 in 1.696 in	
Crankshaft Rear Oil Seal Flange O.D.		129.98 mm MIN 130.03 mm MAX	5.117 in 5.119 in	
Crankshaft Damper Pilot O.D.		23.92 mm MIN 24.00 mm MAX	0.942 in 0.945 in	

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.		
Cylinder Block (001-026)					
Cylinder Bore Dimensions					
Bore Inner Diameter		114.00 MIN 114.04 MAX	4.488 4.990		
Bore Out of Round		0.08 MAX	0.003		
Bore Taper		0.02 MAX	0.001		
Cylinder Liner (001-028)					
Out of Round		0.04 MAX	0.002		
Taper		0.04 MAX	0.002		
Bore Diameter		114.04 MAX	4.490		
New Block and Liners		0.025 MIN	0.001		
		0.122 MAX	0.005		
		Used Block and Liners	0.000 MIN		0.000
		0.122 MAX	0.005		
		New Block Used Liners	0.025 MIN		0.001
		0.122 MAX	0.005		
Used Block New Liners		0.000 MIN	0.000		
		0.122 MAX	0.005		
Cylinder Liner Inside Diameter		114.00 mm MIN	4.488 in		
		114.04 mm MAX	4.490 in		
Cylinder Liner Outside Diameter (Top Press Fit)		130.938 mm MIN	5.1550 in		
		130.958 mm MAX	5.1558 in		
Cylinder Liner Bore in Block (Press-Fit Bore)		130.90 mm MIN	5.154 in		
		130.95 mm MAX	5.156 in		
Cylinder Liner Protrusion		0.025 mm MIN	0.001 in		
		0.122 mm MAX	0.005 in		

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Cylinder-Liner-to-Block Clearance		0.23 mm	MIN	0.009 in	
Piston (001-043)					
Piston Pin Bore Inside Diameter		45.01 mm 45.03 mm	MIN MAX	1.772 in 1.773 in	
Piston Pin Diameter		44.99 mm 45.00 mm	MIN MAX	1.771 in 1.772 in	
Piston Skirt Diameter		113.81 mm 113.88 mm	MIN MAX	4.481 in 4.484 in	
Piston Rings (001-047)					
Piston Ring Side Clearance (Rectangular Grooves)					
Intermediate Ring		0.07 0.15	MIN MAX	0.003 0.006	
Oil Control Ring		0.02 0.13	MIN MAX	0.001 0.005	
Ring Gap					
Top		0.40 0.70	MIN MAX	0.016 0.028	
Intermediate		0.25 0.55	MIN MAX	0.010 0.022	
Oil Control		0.25 0.55	MIN MAX	0.010 0.022	
Piston and Connecting Rod Assembly (001-054)					
Engines built after 1/1/1994		0.584 0.635	MIN MAX	0.023 0.025	

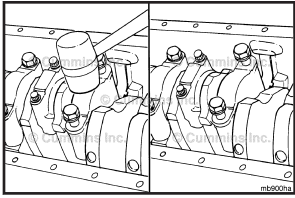
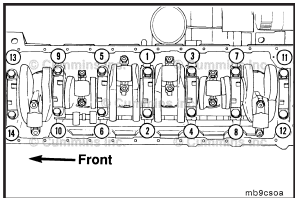
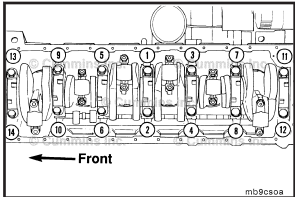
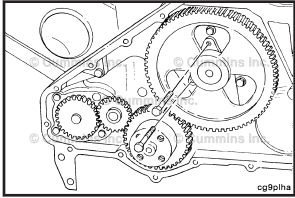
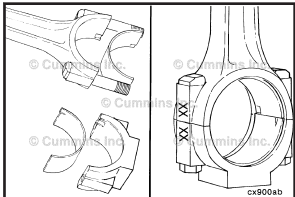
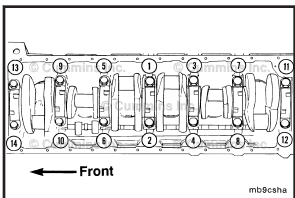
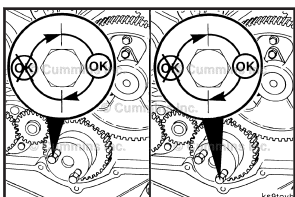
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
Side Clearance Limits		0.10 mm MIN 0.33 mm MAX	0.004 in 0.013 in

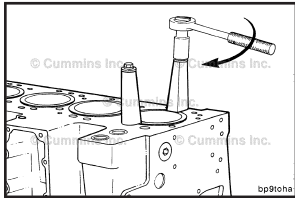
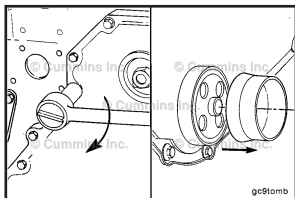
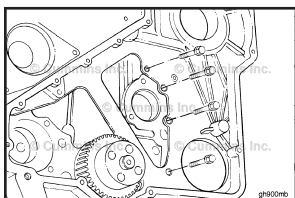
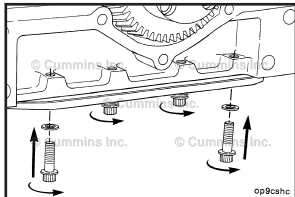
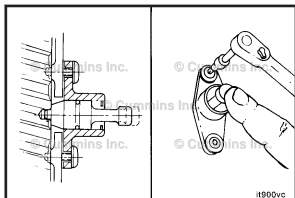
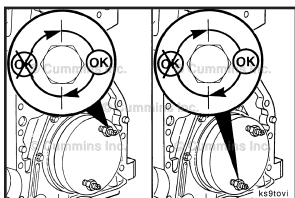
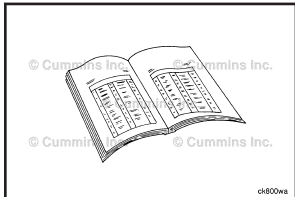


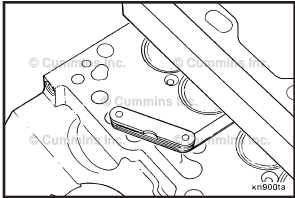
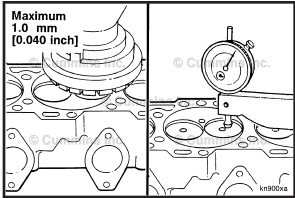
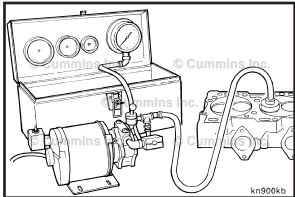
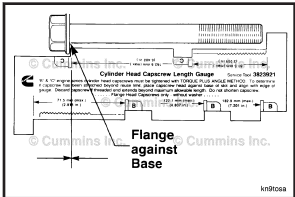
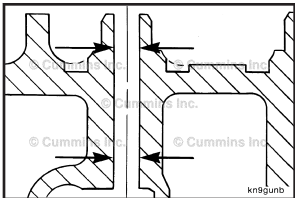
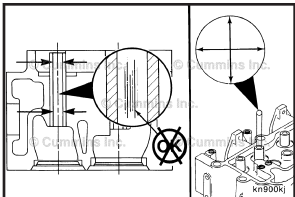
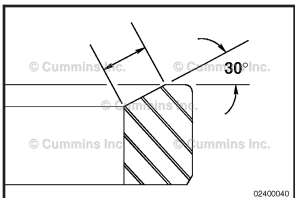
The image is a technical drawing of a cylinder block assembly, showing a cross-section of the block and the piston. The drawing is a line drawing with some shading to indicate depth. It shows the piston rings, the piston pin, and the cylinder bore. The drawing is labeled with 'Cummins Inc.' in several places. In the bottom right corner of the drawing, there is a small label 'cx900rb'.

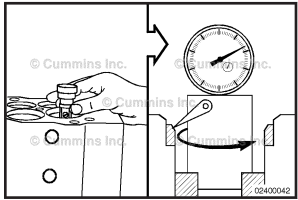
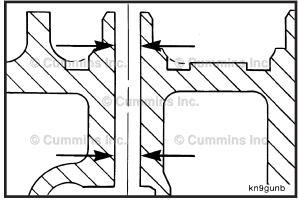
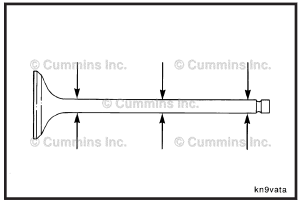
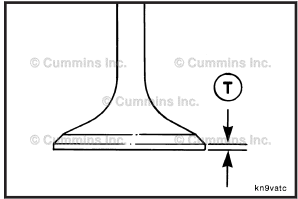
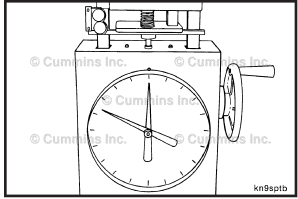
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Cylinder Block - Group 01 - Torque Values

Bearings, Main (001-006) Initial Torque Value		50 N•m	[37 ft-lb]	
Main Bearing Capscrews	1	50 N•m	[37 ft-lb]	
	2	95 N•m	[70 ft-lb]	
	3	60° turn.		
Main Bearing Capscrews	1	50 N•m	[37 ft-lb]	
	2	95 N•m	[70 ft-lb]	
	3	60° turn.		
Camshaft (001-008) Thrust Plate Capscrews		24 N•m	[212 in-lb]	
Connecting Rod (001-014)	1	40 N•m	[30 ft-lb]	
	2	80 N•m	[60 ft-lb]	
	3	120 N•m	[88 ft-lb]	
Crankshaft (001-016)	1	50 N•m	[37 ft-lb]	
	2	95 N•m	[70 ft-lb]	
	3	60°		
Crankshaft Wear Sleeve, Front (001-025) Wear Sleeve Capscrew		20 N•m	[15 ft-lb]	

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Cylinder Liner (001-028)		68 N•m	[50 ft-lb]	
Gear Cover, Front (001-031) Front Gear Cover Capscrews (11-Mm Heads)		40 N•m 30 N•m	[30 ft-lb] [22 ft-lb]	
Gear Housing, Front (001-033) Gear Housing Capscrew Torque		24 N•m	[212 in-lb]	
Capscrew Torque		24 N•m	[212 in-lb]	
Timing Pin Housing (001-049) Timing Pin Torx™ Capscrew		8 N•m	[71 in-lb]	
Crankshaft Wear Sleeve, Rear (001-067) Wear Sleeve Threaded Stud Nuts		20 N•m	[180 in-lb]	
Rear Oil Pan Mounting Capscrews		24 N•m	[212 in-lb]	

Component or Assembly (Procedure)	Ref.No./Steps	Metric		U.S.	
Cylinder Head - Group 02 - Specifications					
Cylinder Head (002-004)					
End-to-End		0.20	MAX	0.008	
Side-to-Side		0.076	MAX	0.003	
Exhaust		1.09	MIN	0.0430	
		1.62	MAX	0.064	
Intake		0.59	MIN	0.023	
		1.12	MAX	0.044	
Used		457	MIN	18	
New		635	MIN	25	
Short Capscrews		81.5	MAX	3.2	
Long Capscrews		162.6	MAX	6.4	
Valve Guide, Cylinder Head (002-017)					
Valve Guide Bore without Pin, Inside Diameter		15.931 mm	MIN	0.6272 in	
		15.971 mm	MAX	0.6288 in	
Valve Guide Bore with Pin, Inside Diameter		9.539 mm	MIN	0.3755 in	
		9.559 mm	MAX	0.3763 in	
Valve Seat Insert, Cylinder Head (002-019)					
Valve Seat Width					
Intake		3.05	MIN	0.120	
		3.55	MAX	0.140	
Exhaust		1.52	MIN	0.060	
		2.54	MAX	0.100	

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Valve-Seat-to-Valve-Guide Concentricity		0.05 mm	MAX 0.002 in	
Valve, Cylinder Head (002-020)				
Valve Guide Bore Diameter		15.988 mm 16.000 mm	MIN 0.6294 in MAX 0.6299 in	
Valve Stem Diameter		9.48 mm 9.50 mm	MIN 0.373 ft-lb MAX 0.374 ft-lb	
Valve Rim Thickness Limit		2.21 mm	MIN 0.087 in	
@ 49.25 mm [1.94 in]		359 397	MIN 80.7 MAX 89.2	

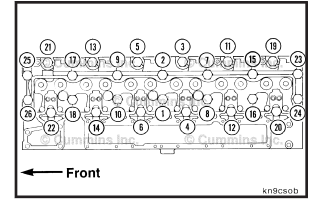
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Cylinder Head - Group 02 - Torque Values

Cylinder Head (002-004)
 Cylinder Head Capscrews

95 N•m

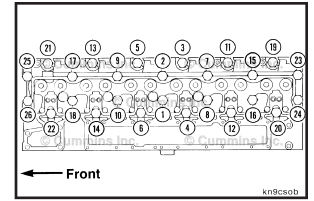
[70 ft-lb]



Cylinder Head Capscrews

70 N•m

[52 ft-lb]

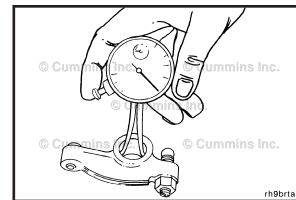


Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Rocker Levers - Group 03 - Specifications

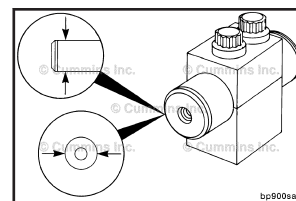
Rocker Lever (003-008)
Rocker Lever Bore Diameter

22.301
mm MAX 0.878 in



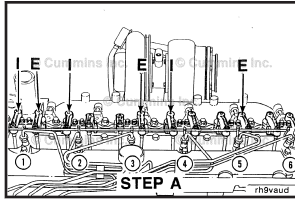
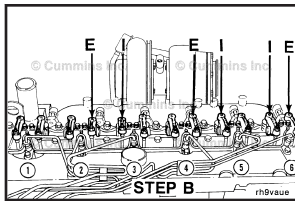
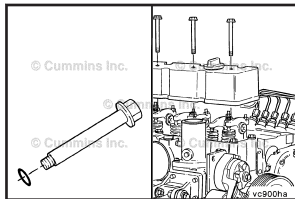
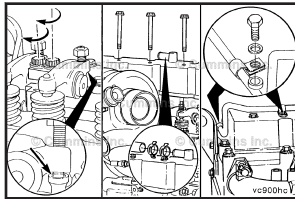
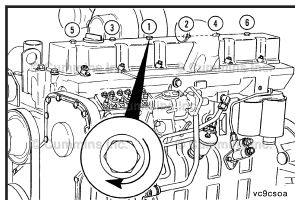
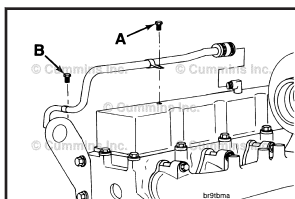
Rocker Lever Shaft Diameter

22.199
mm MIN 0.874 in



Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Rocker Levers - Group 03 - Torque Values

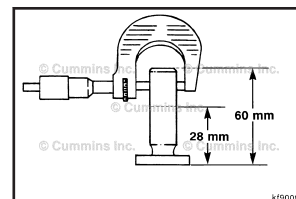
Overhead Set (003-004)		24 N•m	[212 in-lb]	
		24 N•m	[212 in-lb]	
		24 N•m	[212 in-lb]	
Rocker Lever (003-008) Pedestal Mounting Capscrews		55 N•m	[41 ft-lb]	
Rocker Lever Cover (003-011) Rocker Lever Cover Capscrews		24 N•m	[18 ft-lb]	
Crankcase Breather Tube (003-018) Breather Tube Support Bracket Capscrews	1 2	24 N•m 43 N•m	[18 ft-lb] [32 ft-lb]	

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Cam Followers/Tappets - Group 04 - Specifications

Tappet (004-015)

Valve Tappet Stem Diameter	15.93 mm	MIN	0.627 in
	15.98 mm	MAX	0.629 in
Valve Tappet Height	60 mm	MAX	2.36 in

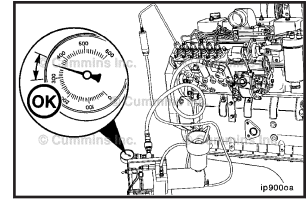


Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Fuel System - Group 05 - Specifications

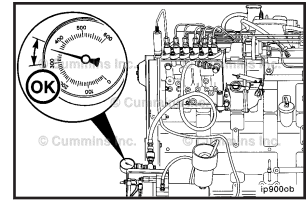
Fuel Injection Pumps, In-Line (005-012)

Fuel Spill Timing Cart - Fuel Pressure		2068 kPa	MIN	300 psi
		2551 kPa	MAX	370 psi



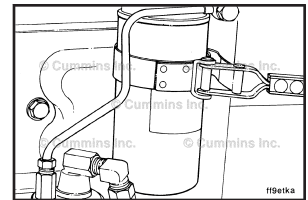
Fuel Injection Pump, In-Line, Spill Port Timing (005-013)

Fuel Spill Timing Cart - Fuel Pressure		2068 kPa	MIN	300 psi
		2551 kPa	MAX	370 psi



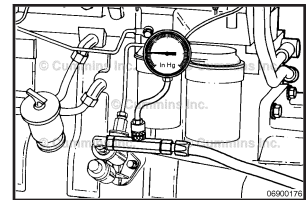
Fuel Lift Pump (005-045) Pressure Drop Across Filter Piston Lift Pump

	34	MAX	5
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Fuel Lift Pump Inlet Restriction

	27 kPa	MAX	8 in Hg
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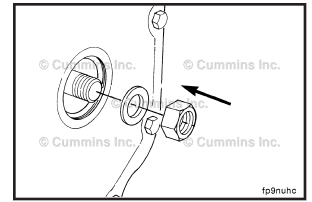


Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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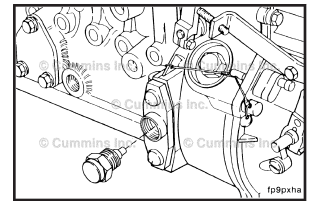
Fuel System - Group 05 - Torque Values

Fuel Injection Pumps, In-Line (005-012)

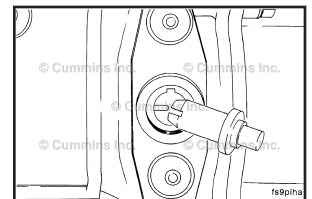
12 N•m [106 in-lb]



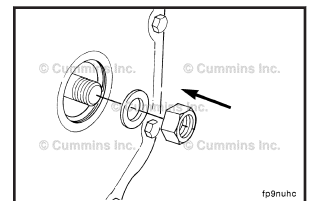
28 N•m [21 ft-lb]



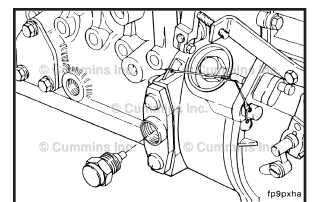
15 N•m [133 in-lb]



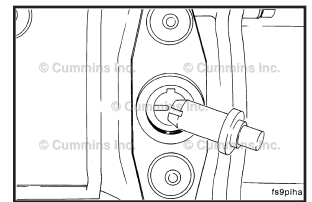
12 N•m [106 in-lb]



28 N•m [21 ft-lb]

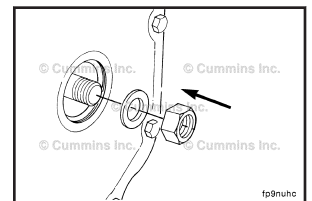


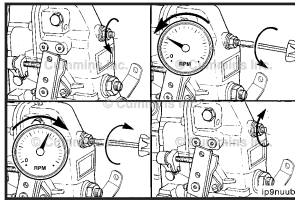
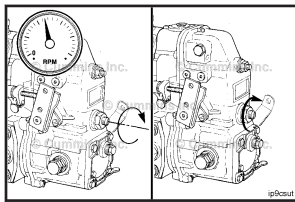
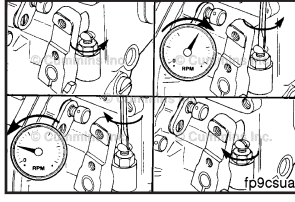
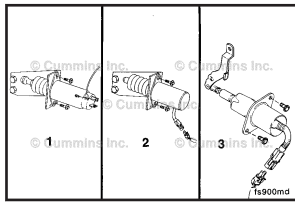
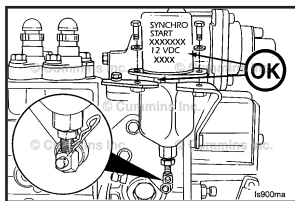
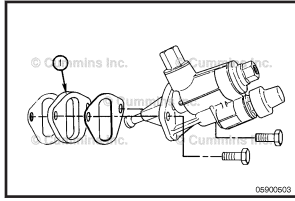
15 N•m [133 in-lb]



Fuel Injection Pump, In-Line, Spill Port Timing (005-013)

12 N•m [106 in-lb]



Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Nippondenso		123 N•m	[92 ft-lb]	
Bosch A Pump		85 N•m	[63 ft-lb]	
Bosch MW Pump		105 N•m	[77 ft-lb]	
Bosch P3000/P7100		195 N•m	[144 ft-lb]	
Fuel Pump Idle Speed (005-029)		8 N•m	[72 in-lb]	
		8 N•m	[72 in-lb]	
Idle Speed Screw Locknut		8 N•m	[72 in-lb]	
Fuel Shutoff Valve (005-043)		10 N•m	[89 in-lb]	
		10 N•m	[89 in-lb]	
Fuel Lift Pump (005-045) 10 Mm Fuel Line		24 N•m	[18 ft-lb]	

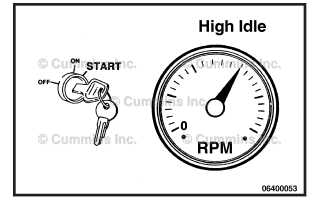
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Injectors and Fuel Lines - Group 06 - Specifications

Fuel Drain Line Restriction (006-012)

Fuel Drain Restriction

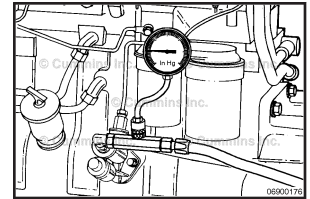
508 mm Hg MAX 20.0 in Hg



Fuel Inlet Restriction (006-020)

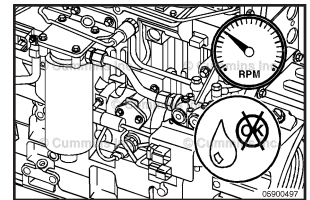
Vacuum Gauge Range

0 to 508 mm Hg MIN 0 to 20 in Hg



Inlet Restriction at Low/High Idle

101.6 mm Hg MAX 4.70 in Hg



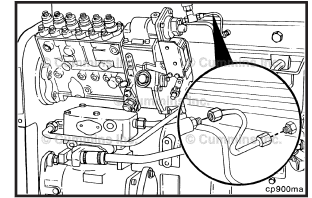
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Injectors and Fuel Lines - Group 06 - Torque Values

AFC Air Tube (006-001)

Afc Tube Connection Banjo Fitting
Afc Tube Connection Threaded Fitting

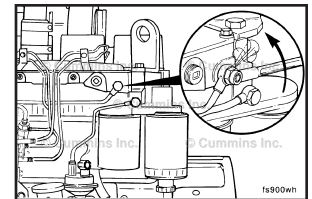
24 N•m [18 ft-lb]
8 N•m [71 in-lb]



Air in Fuel (006-003)

Injector Connection

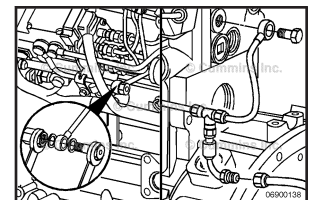
38 N•m [28 ft-lb]



Fuel Drain Lines (006-013)

Engine-To-Fuel Tank Drain Hose

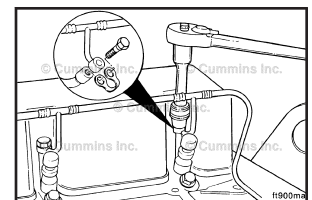
23 N•m [204 in-lb]



Fuel Manifold (Drain) (006-021)

Fuel Drain Line Connections Filter Head Banjo
Fuel Drain Line Connections Injector Banjo

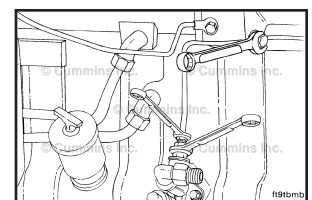
15 N•m [133 in-lb]
9 N•m [80 in-lb]



Fuel Supply Lines (006-024)

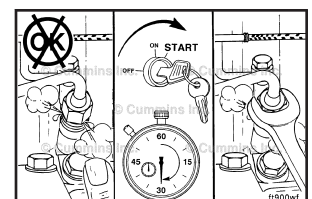
Fuel Supply Connections

24 N•m [18 ft-lb]



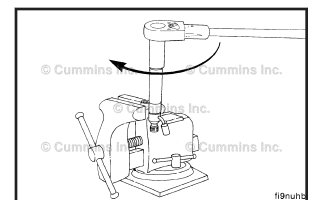
Fuel Line Fitting At Injector

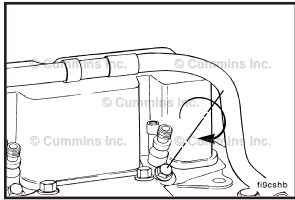
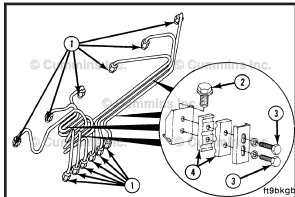
30 N•m [22 ft-lb]



Injector (006-026)

30 N•m [22 ft-lb]



Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.	
Injector Supply Lines (High Pressure) (006-051) Fuel Line Connections Support Bracket Capscrews Isolator Capscrews		28 N•m 24 N•m 24 N•m 6 N•m	[21 ft-lb] [18 ft-lb] [18 ft-lb] [53 in-lb]	 

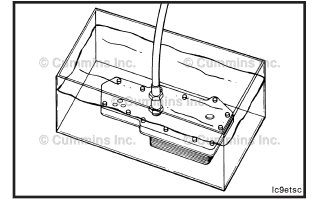
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Lubricating Oil System - Group 07 - Specifications

Lubricating Oil Cooler (007-003)

Air Pressure Test

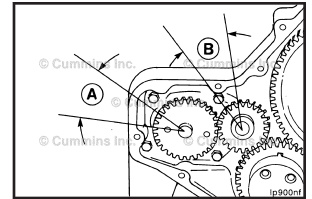
449 kPa	MIN	65 psi
518 kPa	MAX	75 psi



Lubricating Oil Pump (007-031)

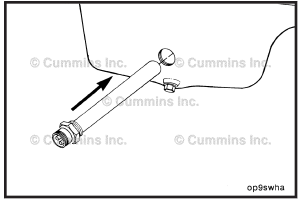
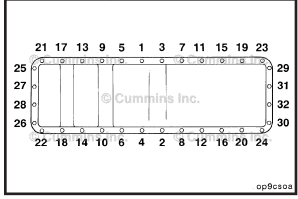
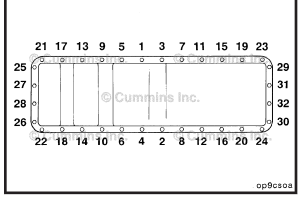
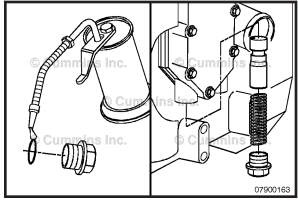
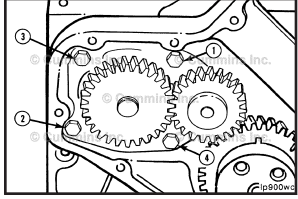
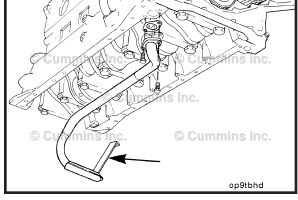
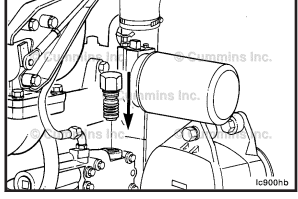
Backlash Limits

A	0.076	MIN	0.003
	0.330	MAX	0.013
B	0.076	MIN	0.003
	0.330	MAX	0.013



Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Lubricating Oil System - Group 07 - Torque Values

Engine Oil Heater (007-001) Lubricating Oil Heater Element		80 N•m	[59 ft-lb]	
Lubricating Oil Pan (007-025) Lubricating Oil Pan Mounting Capscrews		24 N•m	[212 in-lb]	
Lubricating Oil Pan Mounting Capscrews		23 N•m	[204 in-lb]	
Lubricating Oil Pressure Regulator (Main Rifle) (007-029) Lubricating Oil Pressure Regulator (Main Rifle)		80 N•m	[59 ft-lb]	
Lubricating Oil Pump (007-031) Lubricating Oil Pump Mounting Capscrew		24 N•m	[18 ft-lb]	
Lubricating Oil Suction Tube (Block-Mounted) (007-035) 6-Mm Capscrews Suction Tube To Block		10 N•m 24 N•m 10 N•m 24 N•m 10 N•m 24 N•m	[89 in-lb] [18 ft-lb] [89 in-lb] [18 ft-lb] [89 in-lb] [18 ft-lb]	
Lubricating Oil Thermostat (007-039)		50 N•m	[37 ft-lb]	

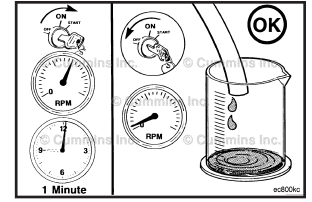
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Cooling System - Group 08 - Specifications

Coolant Thermostat (008-013)

Thermostat Leak Test - Allowable Leakage

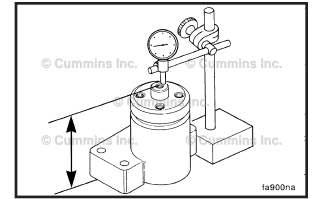
150 ml MAX 5 fl-oz



Fan Hub, Belt Driven (008-036)

Fan Hub End Play

0.15 mm MAX 0.006 in

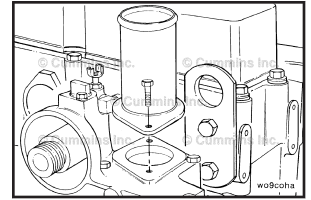


Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Cooling System - Group 08 - Torque Values

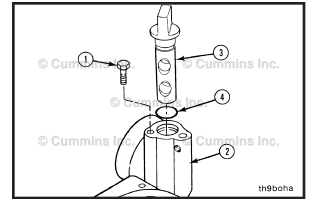
Coolant Filter Head (008-007)
Coolant Connection Mounting Capscrews

24 N•m [18 ft-lb]



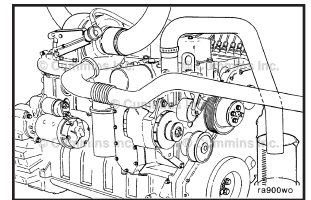
Coolant Filter Valve (008-009)

7 N•m [60 in-lb]



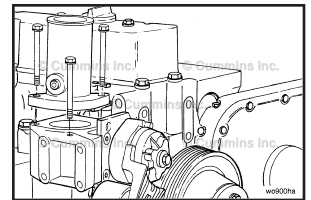
Coolant Thermostat (008-013)
Cooling System Hose Clamps

6 N•m [50 in-lb]



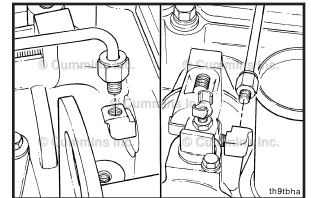
Water Outlet Connection

24 N•m [212 in-lb]



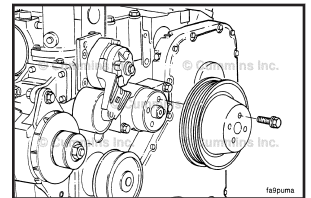
Coolant Vent Lines (008-017)
Coolant Vent Line Fittings

8 N•m [71 in-lb]



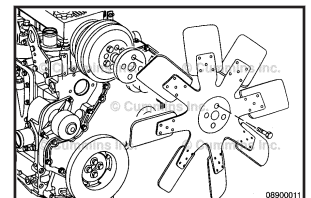
Fan Drive Idler Pulley Assembly (008-030)

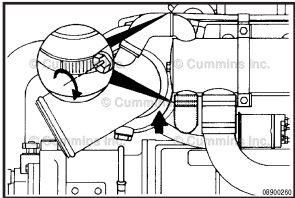
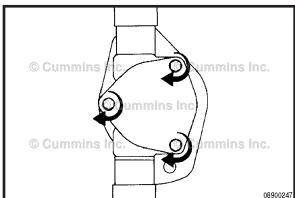
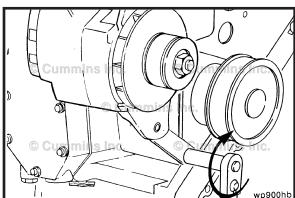
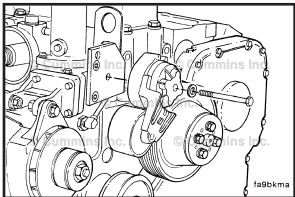
43 N•m [32 ft-lb]



Fan Spacer and Pulley (008-039)
Fan And Fan Spacer Capscrew Torque

24 N•m [212 in-lb]
43 N•m [32 ft-lb]



Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Heat Exchanger (008-053) Seawater Inlet And Outlet Connections		5 N•m	[44 in-lb]	 A technical line drawing of a heat exchanger assembly. Two arrows point to the inlet and outlet connections on the left side of the unit. The drawing includes various components like pipes, flanges, and bolts.
Sea Water Pump (008-057)		24 N•m	[212 in-lb]	 A technical line drawing of a sea water pump. Two curved arrows indicate the direction of rotation for the pump's shaft. The drawing shows the pump housing and internal components.
Water Pump (008-062) Water Pump Mounting Capscrews		24 N•m	[212 in-lb]	 A technical line drawing of a water pump. It shows the pump housing, a drive pulley, and a belt. The drawing is labeled with 'wp002b' in the bottom right corner.
Belt Tensioner, Automatic (Water Pump) (008-080) Belt Tensioner Mounting Capscrew		43 N•m	[32 ft-lb]	 A technical line drawing of an automatic belt tensioner. It shows the tensioner mechanism, including a spring and a pulley. The drawing is labeled with 'fa0bkma' in the bottom right corner.

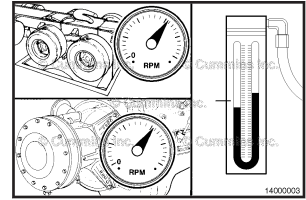
Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Air Intake System - Group 10 - Specifications

Air Intake Restriction (010-031)

Inlet Air Restriction

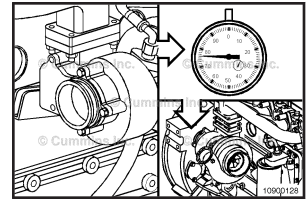
635 mm H₂O MAX 25 in H₂O



Turbocharger (010-033)

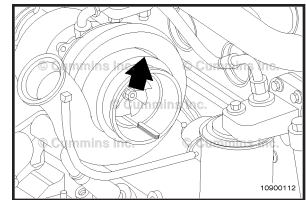
Axial Clearance

0.038 mm MIN 0.0015 in
0.093 mm MAX 0.0037 in



Radial Bearing Clearance

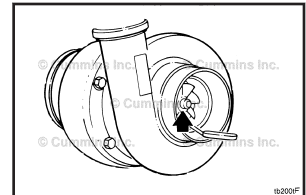
0.30 mm MIN 0.012 in
0.46 mm MAX 0.018 in



Turbocharger Axial Clearance (010-038)

Turbocharger Axial Clearance

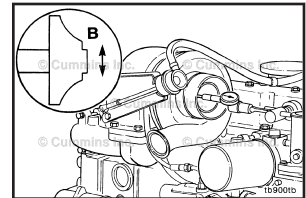
0.30 mm MIN 0.012 in
0.46 mm MAX 0.018 in



Turbocharger Radial Bearing Clearance (010-047)

Turbocharger Radial Clearance (B)

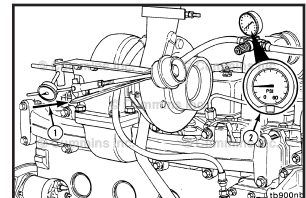
0.30 mm MIN 0.012 in
0.46 mm MAX 0.018 in



Turbocharger Wastegate Actuator (010-050)

Wastegate Actuator Travel Measurement

0.33 mm MIN 0.013 in
1.30 mm MAX 0.051 in



Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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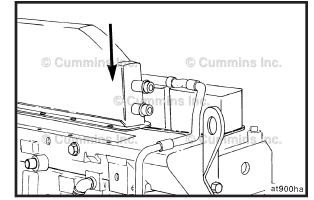
Air Intake System - Group 10 - Torque Values

Aftercooler Assembly (010-002)

Aftercooler Housing Mounting Capscrews

24 N•m

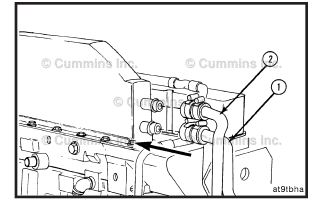
[18 ft-lb]



Coolant Supply And Return Tube

5 N•m

[44 in-lb]

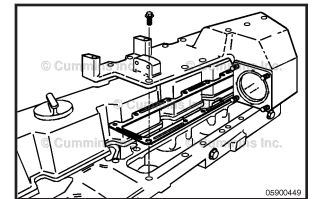


Air Intake Manifold (010-023)

Intake Manifold Mounting Capscrews

24 N•m

[18 ft-lb]

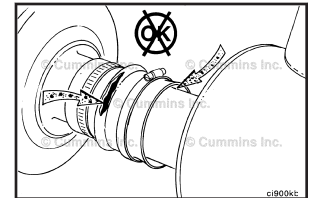


Air Leaks, Air Intake and Exhaust Systems (010-024)

Air Intake Piping Clamps

8 N•m

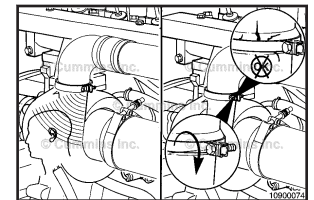
[71 in-lb]



Clamps

8 N•m

[71 in-lb]

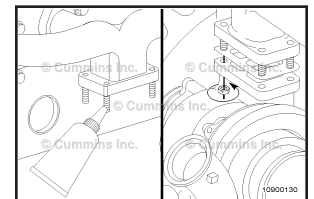


Turbocharger (010-033)

Turbocharger Mounting Nuts

45 N•m

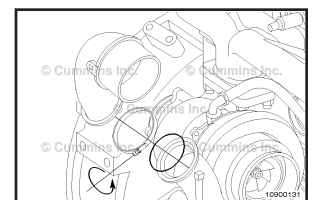
[33 ft-lb]

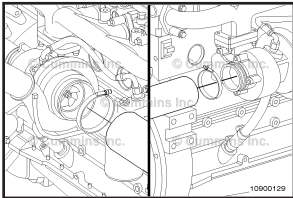
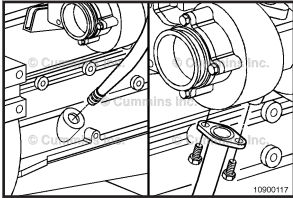
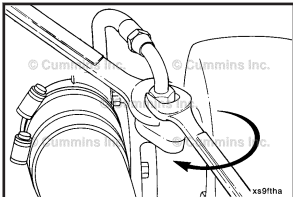
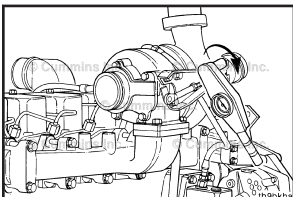
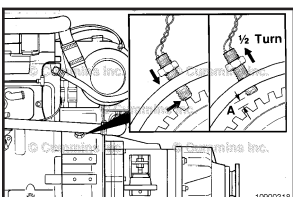


Turbocharger Compressor Outlet V-Band

8 N•m

[71 in-lb]



Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Turbocharger Compressor Inlet		8 N•m 8 N•m	[71 in-lb] [71 in-lb]	
Turbocharger Oil Drain Line (010-045) Turbocharger Oil Drain Line		27 N•m	[20 ft-lb]	
Turbocharger Oil Supply Line (010-046) Turbocharger Oil Supply Line Torque		24 N•m	[212 in-lb]	
Turbocharger Wastegate Actuator (010-050) Boost Capsule Actuator Mounting Capscrews		4.5 N•m	[40 in-lb]	
Intake Manifold Air Heater Speed Sensor (010-127) Engine Speed Sensor Locknut		34 to 47 N•m	[25 to 35 ft-lb]	

Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Exhaust System - Group 11 - Specifications

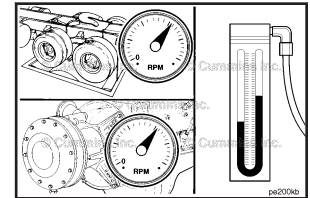
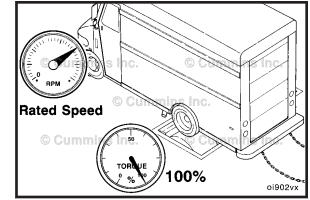
Exhaust Restriction (011-009)

Exhaust Restriction

1996 EPA Certification with Oxidation Catalyst	61	MIN	2.4
1996 EPA Certification with Oxidation Catalyst	101	MAX	4
1995 EPA Certification with Oxidation Catalyst	61	MIN	2.4
1995 EPA Certification with Oxidation Catalyst	127	MAX	5
All others with or without Oxidation Catalyst	61	MIN	2.4
All others with or without Oxidation Catalyst	127	MAX	5

Exhaust Restriction Hg 75 mm MAX 3 in

Exhaust Restriction H2O 1016 mm MAX 40 in



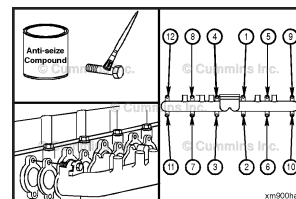
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
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Exhaust System - Group 11 - Torque Values

Exhaust Manifold, Dry (011-007)

43 N•m

[32 ft-lb]

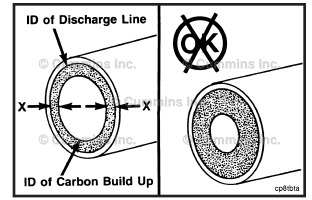


Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
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Compressed Air System - Group 12 - Specifications

Air Compressor Carbon Buildup (012-003)
 Air Compressor Discharge Line Carbon
 Deposits

1.6 mm MAX 0.063 in



Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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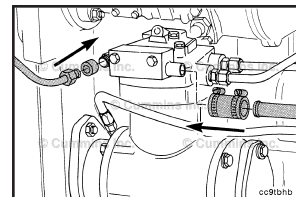
Compressed Air System - Group 12 - Torque Values

Air Compressor Carbon Buildup (012-003)

Inlet Connection
Outlet Connection

5 N•m
24 N•m

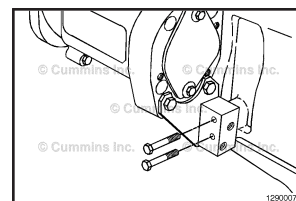
[48 in-lb]
[18 ft-lb]



Air Compressor (012-014)

43 N•m

[32 ft-lb]



Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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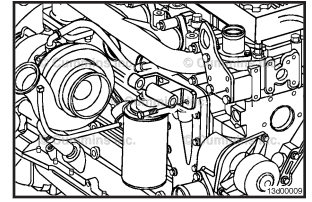
Electrical Equipment - Group 13 - Torque Values

Alternator Bracket (013-003)

Alternator Bracket Mounting Capscrews

24 N•m

[212 in-lb]

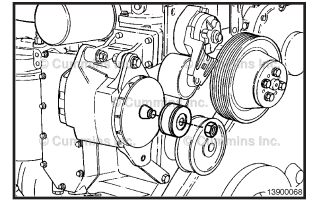


Alternator Pulley (013-006)

Alternator Pulley Mounting Nut

80 N•m

[59 ft-lb]

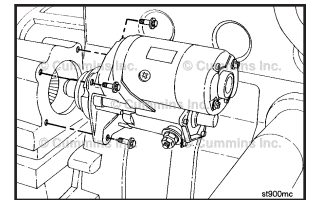


Starting Motor (013-020)

Starting Motor Mounting Capscrews

43 N•m

[32 ft-lb]

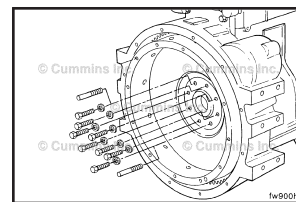


Component or Assembly (Procedure)	Ref.No./Steps	Metric	U.S.
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Mounting Adaptations - Group 16 - Specifications

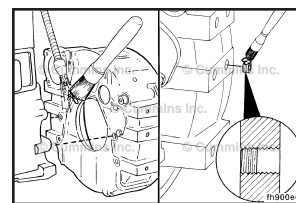
Flywheel (016-005)
Flywheel Bore Runout

0.127 mm MAX 0.005 in



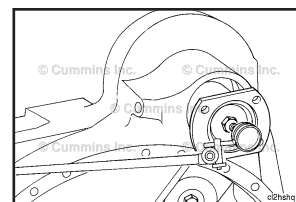
Flywheel Housing (016-006)
Set Screw Installation Depth (Flywheel Housing)

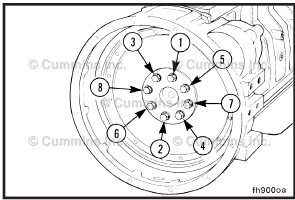
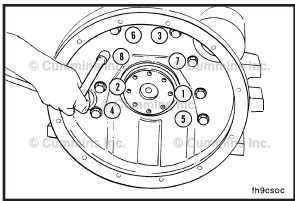
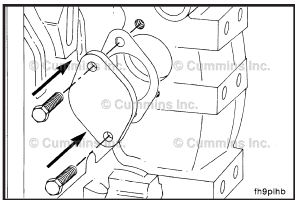
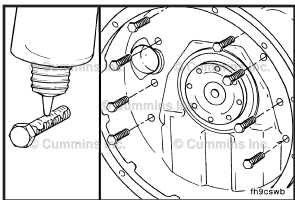
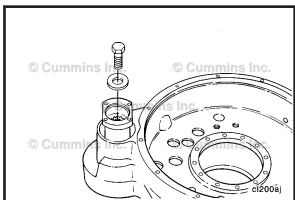
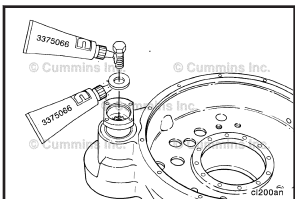
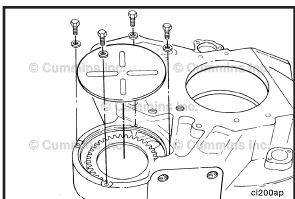
3.00 mm MAX 0.118 in

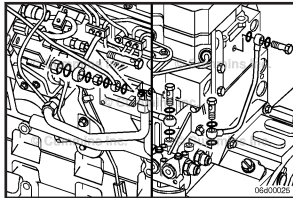
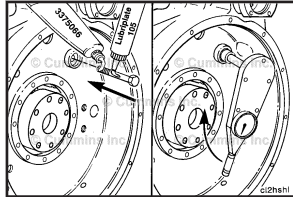
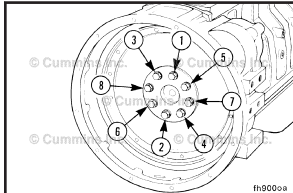


Flywheel Housing, REPTO (016-007)
Output Shaft End Play

0.00 mm MIN
0.03 mm MAX 0.000 in
0.001 in



Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Mounting Adaptations - Group 16 - Torque Values				
Flywheel (016-005) Flywheel Capscrew Torque		137 N•m	[101 ft-lb]	
Flywheel Housing (016-006) Flywheel Housing Capscrew Torque		77 N•m	[57 ft-lb]	
Flywheel Housing Access Plate Capscrew		24 N•m	[18 ft-lb]	
		77 N•m	[57 ft-lb]	
Flywheel Housing, REPTO (016-007) Output Shaft Capscrew		205 N•m	[150 ft-lb]	
Output Flange Capscrew		205 N•m	[150 ft-lb]	
Cover Mounting Capscrews		18 N•m	[14 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Repto Flywheel Housing Mounting Capscrews		60 N•m	[45 ft-lb]	
Idler Shaft Capscrew		105 N•m	[75 ft-lb]	
Flywheel Ring Gear (016-008) Flywheel Capscrews Torque		137 N•m	[101 ft-lb]	

General Engine

Specifications

Industrial

Bore.....	114 mm [4.49 in]
Stroke.....	135 mm [5.32 in]
Displacement.....	8.27 liters [504.7 C.I.D.]
Engine Weight (dry) with Standard Accessories.....	603 to 612 kg [1330 to 1350 lb]
Wet Weight.....	635 to 658 kg [1400 to 1450 lb]
Firing Order.....	1-5-3-6-2-4

Valve Clearances:

Intake.....	0.30 mm [0.012 in]
Exhaust.....	0.61 mm [0.024 in]
Rotation, Viewed from the Front of the Engine.....	Clockwise

Compression Ratio:

Naturally Aspirated.....	16.4:1
Turbocharged.....	17.3:1
Turbocharged/Aftercooled.....	16.5:1
Charge Air Cooled.....	18.0:1

Marine

Type.....	Four cycle, in-line, six cylinder
Bore and Stroke.....	114 mm [4.49 in] x 135 mm [5.32 in]
Displacement.....	8.3 liters [504.5 C.I.D.]

Engine Mounting:

Maximum Allowable Bending Moment at Rear Face of Block.....	1356 N•m [1000 ft•lb]
Minimum/Maximum Static Installation Angle for In-line Drives (front up).....	0 degrees/12 degrees
Minimum/Maximum Static Installation Angle for V-Drives (front up).....	3 degrees/12 degrees

NOTE: "Front up" refers to front of engines. In V-drives it faces the back of the boat.

Automotive

Bore.....	114 mm [4.49 in]
Stroke.....	135 mm [5.32 in]
Displacement.....	8.27 liters [504.7 C.I.D.]
Engine Weight (dry) with Standard Accessories.....	603 to 612 kg [1330 to 1350 lb]
Wet Weight.....	635 to 658 kg [1400 to 1450 lb]
Firing Order.....	1-5-3-6-2-4

Valve Clearances:

Intake.....	0.30 mm [0.012 in]
Exhaust.....	0.61 mm [0.024 in]
Rotation, Viewed from the Front of the Engine.....	Clockwise

Compression Ratio:

6C8.3.....	16.4:1
6CT8.3.....	17.3:1
6CTA8.3.....	16.5:1
C8.3.....	17.3:1 (low torque) or 18:1 (high torque)

Fuel System

Specifications

Industrial

Maximum Fuel Filter Pressure Drop across Filters.....	34 kPa [5 psi]
Maximum Inlet Restriction to Fuel Transfer Pump.....	100 mm Hg [4 in Hg]
Maximum Allowable Return Line Restriction.....	518 mm Hg [20.4 in Hg]

Automotive

Maximum Fuel Filter Pressure Drop across Filters.....	34 kPa [5 psi]
Maximum Inlet Restriction to Fuel Transfer Pump.....	100 mm Hg [4 in Hg]
Maximum Allowable Return Line Restriction.....	518 mm Hg [20.4 in Hg]

Marine

Maximum Allowable Restriction to Fuel Pump - with Clean Filter.....	63.5 mm Hg [2.5 in Hg]
Maximum Allowable Restriction to Fuel Pump - with Dirty Filter.....	100 mm Hg [4 in Hg]
Maximum Allowable Return Line Pressure.....	518 mm Hg [20.4 in Hg]

Lubricating Oil System

Specifications

Industrial Applications

Oil Pressure

At Idle Speed - Minimum.....	69 kPa [10 psi]
Normal Operating Speed.....	205 kPa to 517 kPa [30 psi to 75 psi]
Regulated Pressure.....	517 kPa [75 psi]
Maximum Allowable Temperature.....	120°C [250°F]

Maximum Operational Angularity of Oil Pan (see engine mounting)

Front Down.....	45 degrees
Front Up.....	35 degrees
Side to Side.....	45 degrees

Oil Capacity of Standard Engine:

Standard Oil Pan (Pan Only).....	18.9 liters [20 qt]
Standard Oil Pan with Cylinder Block Stiffener Plate (Pan Only).....	19.9 liters [21 qt]

Oil Pan Low to High:

Standard Oil Pan.....	15.1 to 18.9 liters [16 to 20 qt]
Standard Oil Pan with Cylinder Block Stiffener Plate.....	16.1 to 19.9 liters [17 to 21 qt]
Total System Capacity.....	19.9 liters [21 qt]
Total System Capacity (excluding bypass Filter).....	21.9 liters [23.2 qt]

NOTE: Some applications have a slightly different oil pan capacity. Contact the local Cummins Distributor if there are any questions.

Marine Applications

Oil Pressure

At Idle Speed - Minimum.....	55 kPa [8 psi]
Normal Operating Range.....	205 to 517 kPa [30 to 75 psi]
Maximum Allowable Oil Temperature.....	120°C [250°F]
Oil Pan Capacity High/Low.....	17/13 liters [18/14 qt]
Total System Capacity (excluding bypass filter).....	21.9 liters [23.2 qt]

Automotive Applications

Oil Pressure

At Idle Speed - Minimum.....	69 kPa [10 psi]
Normal Operating Range.....	207 kPa [30 psi]
Maximum Allowable Oil Temperature.....	120°C [250°F]
Oil Pan Capacity High/Low.....	18.9/15.1 liters [20/16 qt]
Total System Capacity (excluding bypass filter).....	18.9 liters [20 qt]
Regulating Valve Pressure.....	518 kPa [75 psi]
Differential Pressure to Open the Filter Bypass Valve.....	172 kPa [25 psi]

Cooling System

Specifications

Industrial

Coolant Capacity (engine only).....	10.9 liters [11.5 qt]
Standard Modulating Thermostat - Range.....	84 to 91°C [184 to 195°F]
Maximum Allowable Operating Temperature.....	100°C [212°F]
Minimum Recommended Operating Temperature.....	70°C [158°F]
Minimum Recommended Pressure Cap.....	50 kPa [7 psi]

Marine

Coolant Capacity — Engine Only	12.3 liters [13 qt]
Coolant Capacity - Engine with Heat Exchanger.....	28.9 liters [30.5 qt]
Maximum External Pressure Loss in Cooling System.....	35 kPa [5 psi]
Maximum Static Pressure of Coolant (exclusive of pressure cap).....	103 kPa [15 psi]
Standard Thermostat (modulating) Range.....	71 to 83°C [160 to 181°F]
Maximum Coolant Temperature.....	96°C [205°F]
Minimum Allowable Coolant Expansion Space.....	5 percent of System Capacity
Minimum Coolant Makeup Capacity.....	2.5 liters [2.6 qt]
Maximum Sea Water Pressure.....	172 kPa [25 psi]
Maximum Sea Water Inlet Restriction.....	- 127 mm Hg [- 5 in Hg]

Automotive

Coolant Capacity (engine only) for 6C8.3, 6CT8.3, 6CTA8.3, C8.3.....	9.9 liters [10.5 qt]
Standard Modulating Thermostat - Range for 6C8.3, 6CT8.3, 6CTA8.3, C8.3.....	81°C to 95°C [178°F to 203°F]
Maximum Allowable Operating Temperature for 6C8.3, 6CT8.3, 6CTA8.3, C8.3.....	100°C [212°F]
Minimum Recommended Operating Temperature for 6C8.3, 6CT8.3, 6CTA8.3, C8.3.....	70°C [158°F]
Minimum Recommended Pressure Cap for 6C8.3, 6CT8.3, 6CTA8.3, C8.3.....	50 kPa [7 psi]

Air Intake System

Specifications

Industrial

Maximum Intake Restriction

Clean Air Filter Element.....	.254 mm H ₂ O [10.0 in H ₂ O]
Dirty Air Filter Element.....	.635 mm H ₂ O [25.0 in H ₂ O]

Marine

Maximum Allowable Intake Restriction

Clean Air Filter Element.....	.380 mm H ₂ O [15.0 in H ₂ O]
Dirty Air Filter Element.....	.635 mm H ₂ O [25.0 in H ₂ O]

Maximum Air Cleaner Inlet Temperature Rise over Ambient..... 17°C [30°F]

Automotive

Maximum Intake Restriction

Clean Air Filter Element.....	.254 mm H ₂ O [10.0 in H ₂ O]
Dirty Air Filter Element.....	.635 mm H ₂ O [25.0 in H ₂ O]

Exhaust System

Specifications

Industrial

Maximum Exhaust Back Pressure.....76 mm Hg [3 in Hg]

Marine

Maximum Allowable Exhaust Back Pressure.....75 mm Hg [3 in Hg]

Automotive

Maximum Allowable Exhaust Back Pressure

Without Catalyst Restriction.....76.2 mm Hg [3 in Hg]

With Catalyst Restriction.....152 mm Hg [6 in Hg]

Electrical System

Specifications

Industrial

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	1250	360	1875	360
24 VDC ⁽²⁾	625	180	900	180

- 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 [80°F] can supply 25 amperes at 10.5 volts or greater.
- CCA ratings are based on two 12-VDC batteries in series.

Marine

12-VDC System

Minimum Recommended Battery Capacity:

Cold Cranking Amperes (CCA) Rating.....	1250 CCA
Marine Cranking Amperes (MCA) Rating.....	1563 MCA
Reserve Capacity (discharging 25 amps at 27°C [80°F]).....	320 minutes
Maximum Allowable Resistance of Starting Circuit.....	0.00075 ohms
Maximum Allowable Voltage Drop of Starting Circuit.....	0.075 VDC
Wiring Diagram Number.....	3920281

24-VDC System

Minimum Recommended Battery Capacity:

Cold Cranking Amperes (CCA) Rating.....	625 CCA
Marine Cranking Amperes (MCA) Rating.....	781 MCA
Reserve Capacity (discharging 25 amps at 27°C [80°F]).....	320 minutes
Maximum Allowable Voltage Drop of Starting Circuit.....	0.2 VDC
Maximum Allowable Resistance of Starting Circuit.....	0.002 ohms
Wiring Diagram Number.....	3920281

Auto

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	1250	360	1875	360
24 VDC ⁽²⁾	625	180	900	180

- 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 [80°F] can supply 25 amperes at 10.5 volts or greater.
- CCA ratings are based on two 12-VDC batteries in series.

Batteries (Specific Gravity)

Specific Gravity at 27°C [80°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

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Compressed Air System

Specifications

Holset® SS296 A/C Model

Compressor Swept Volume at 1250 RPM.....	6.2 liters per second [13.20 CFM]
Piston Displacement.....	296 cc [18.06 C.I.D.]
Bore.....	92.08 mm [3.625 in]
Stroke.....	44.45 mm [1.750 in]
Speed.....	1.135 times greater than Engine Speed
Cooling.....	Engine Coolant
Lubrication.....	Engine Lubricating Oil

Plumbing Line Sizes

Coolant Inlet and Outlet (Pipe Fitting)	3/8 in NPTF
Air Inlet (Inside Diameter).....	19 mm [0.750 in]
Air Outlet (Minimum Inside Diameter).....	1/2 in NPTF 12.7 mm [0.50 in]
Height, Overall (Approximate).....	23.5 mm [9.25 in]
Width, Overall (Approximate).....	14.6 cm [5.75 in]
Length, Overall (Approximate).....	26.7 cm [10.5 in]
Weight (Approximate).....	18 kg [40.0 lb]

Engine Testing

Specifications

NOTE: Due to variations in rating of different engine models, refer to the specific engine data sheet for the particular engine model being tested.

Maintain the following limits during a chassis dynamometer test:

Intake Restrictions: (Maximum)

Clean Filter.....	380 mm H ₂ O [15 in H ₂ O]
Dirty Filter.....	635 mm H ₂ O [25 in H ₂ O]
Air Inlet Temperature (Maximum).....	38°C [100°F]
Exhaust Temperature.....	700°C [1290°F]

Exhaust Back Pressure: (Maximum)

Industrial.....	76 mm Hg [3.0 in Hg]
EPA Certified.....	114 mm Hg [4.5 in Hg]

Smoke:

Bosch® Smoke Meter (Maximum).....	2.5 Units
Celesco Smoke Meter (Maximum).....	4% Opacity
Coolant Temperature (Maximum).....	100°C [212°F]
Lubricating Oil Temperature (Maximum).....	126.6°C [260°F]

Lubricating Oil Pressure:

Low Idle (Minimum Allowable).....	69 kPa [10 psi]
Rated Speed (Minimum Allowable).....	207 kPa [30 psi]

Fuel Filter Restriction: (Maximum)

Dirty Filter.....	89 mm Hg [3.5 in Hg]
Fuel Return Restriction (Maximum).....	35 kPa [5 psi]

* Blowby:

6C8.3 (Maximum).....	New: 44 liters/minute; Worn: 88 liters/minute
6CT8.3 (Maximum).....	New: 113 liters/minute; Worn: 226 liters/minute
6CTA8.3 (Maximum).....	New: 113 liters/minute; Worn: 226 liters/minute

* The blowby checking tool, Part Number 3822566, has a special 7.67 mm [0.302 in] orifice that **must** be used to obtain an accurate reading.

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

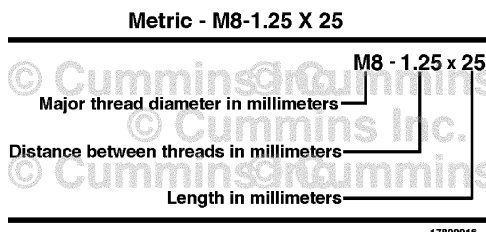
General Information



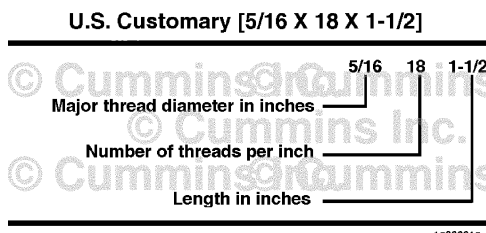
When replacing capscrews, always use a capscrew of the same measurement and strength as the capscrew being replaced. Using the wrong capscrews can result in engine damage.

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.
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Capscrew Markings and Torque Values - Metric

Commercial Steel Class

8.8

10.9

12.9

Capscrew Head Markings





17800014

Body Size	Torque				Torque				Torque			
	Cast Iron		Aluminium		Cast Iron		Aluminium		Cast Iron		Aluminium	
Diameter	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			
	Cast Iron		Aluminium		Cast Iron		Aluminium		Cast Iron		Aluminium	
	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
8	23	17	18	14	33	25	18	14	40	29	18	14
10	45	33	30	25	65	50	30	25	70	50	30	25
12	80	60	55	40	115	85	55	40	125	95	55	40
14	125	90	90	65	180	133	90	65	195	145	90	65
16	195	140	140	100	280	200	140	100	290	210	140	100
18	280	200	180	135	390	285	180	135	400	290	180	135
20	400	290	—	—	550	400	—	—	—	—	—	—

Capscrew Markings and Torque Values - U.S. Customary

SAE Grade Number 5 8

Capscrew Head Markings   17800015

These are all SAE Grade 5 (3 line)

Capscrew Torque - Grade 5 Capscrew

Capscrew Torque - Grade 8 Capscrew

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 Size	Tap Size		Drill Size	Tap Size		Drill Size	Tap Size		Drill Size
60%	75%		60%	75%		60%	75%		60%	75%	
		48			4.40mm						13.25mm
		1.95mm			16						17/32
		5/64		12-24	4.50mm						13.50mm
		47			15						13.75mm
	3-48	2.00mm			4.60mm						35/64
	M2.5x.45	2.05mm		12-24	14						14.00mm
		46			13						14.25mm
	3-48	45			4.70mm						9/16
		2.10mm			4.75mm						14.50mm
	M2.5x.45	2.15mm		M5.5x.9	3/16						37/64
	3-56	44		12-28	12						14.75mm
		2.20mm			4.80mm						15.00mm
	M2.6x.45	2.25mm			11						19.32
	4-36	43			4.90mm						15.25mm
		2.30mm			10						39/64
	4-40	2.35mm			9						15.50mm
		42			5.00mm						15.75mm
	4-48	3/32			8						5/8
		2.40mm			5.10mm						16.00mm
	4-48	41			7						16.25mm
		2.45mm			13/64						41/64
	M3x.6	40			6						16.50mm
		2.50mm			5.20mm						21/32
	M3x.6	39			5						16.75mm
		38			5.25mm						17.00mm
		2.60mm			5.30mm						43/64
	M3x.5	37			4						17.25mm
	5-40	2.70mm			5.40mm						11/16
		36			3						17.50mm
	5-44	2.75mm			5.50mm						17.75mm
		7/64			7/32						45/64
		35			5.60mm						18.00mm
		2.80mm			2						18.25mm
	6-32	34			5.70mm						23/32
		33			5.75mm						18.50mm
		2.90mm			1						47/64
	M3.5x6	32			5.80mm						18.75mm
		3.00mm			5.90mm						19.00mm
	6-40	31			A						3/4
		3.10mm			15/64						19.25mm
		1/8			6.00mm						49/64
		3.20mm			B						19.50mm
		3.25mm			6.10mm						25/32
		30			6.20mm						19.75mm
		3.30mm			C						20.00mm
	M4x.75	3.40mm			D						51/64
		29			6.25mm						20.25mm
		3.50mm			6.30mm						20.50mm
		28			E						13/16
		9/64			1/4						20.75mm
		3.60mm			6.40mm						21.00mm
		27			6.50mm						53/64
		3.70mm			F						21/25mm
		26			6.60mm						27/32
		3.75mm			G						21.50mm
		25			6.70mm						21.75mm
		3.80mm			17/64						55/64
		24			6.75mm						22.00mm
		3.90mm			H						7/8
		23			6.80mm						22.25mm
		5/32			6.90mm						22.50mm
		22			11.75mm						57/64
		4.00mm			I						22.75mm
		21			7.00mm						23.00mm
		20			J						29/32
		4.10mm			7.10mm						23.25mm
		4.20mm			9/32						59/64
		19			7.20mm						23.50mm
		4.25mm			7.25mm						23.75mm
		4.30mm			7.30mm						15/16
		18			L						
		11/64			7.40mm						
		17			M						

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 ₂ O	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 ₂ O	millimeters of water	mm H ₂ O	25.40	0.039370
	bars	bars	kilopascals	kPa	100.001	0.00999
	bars	bars	millimeters of mercury	mm Hg	750.06	0.001333
Temperature	fahrenheit	°F	centigrade	°C	(°F-32) ÷1.8	(1.8 x °C) +32
Torque	pound force per foot	ft-lb	Newton-meter	N•m	1.35582	0.737562
	pound force per inch	in-lb	Newton-meter	N•m	0.113	8.850756
Velocity	miles/hour	mph	kilometers/hour	kph	1.6093	0.6214
Volume: liquid displacement	gallon (U.S.)	gal.	liter	l	3.7853	0.264179
	gallon (Imp*)	gal.	liter	l	4.546	0.219976
	cubic inch	in ³	liter	l	0.01639	61.02545
	cubic inch	in ³	cubic centimeter	cm ³	16.387	0.06102
Weight (mass)	pounds (avoir.)	lb	kilograms	kg	0.4536	2.204623
Work	British Thermal Unit	BTU	joules	J	1054.5	0.000948
	British Thermal Unit	BTU	kilowatt-hour	kW-hr	0.000293	3414
	horsepower hours	hp-hr	kilowatt-hour	kW-hr	0.746	1.341

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