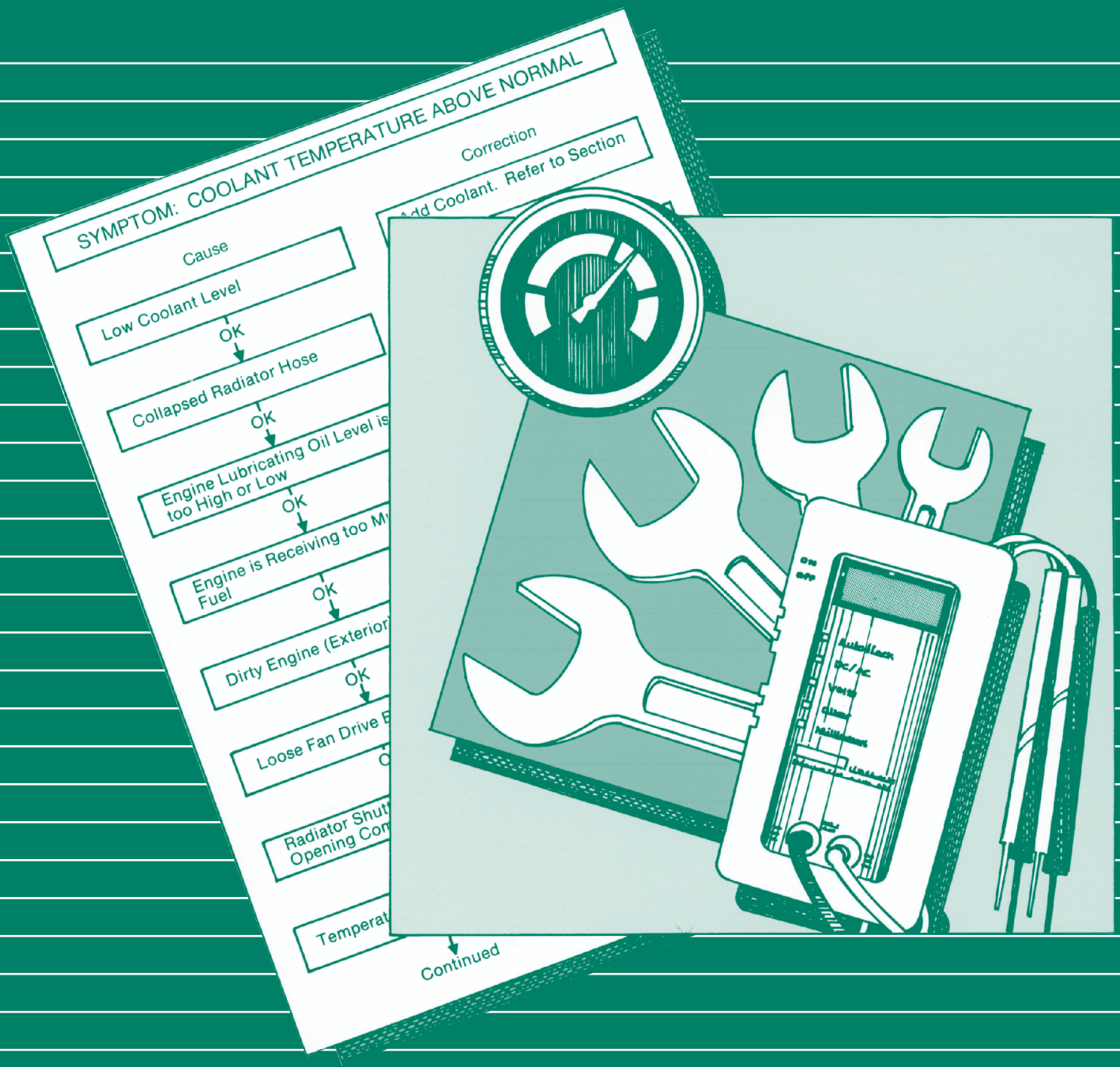
Service Manual
B3.9, B4.5, B4.5 RGT, and B5.9
Volume 2



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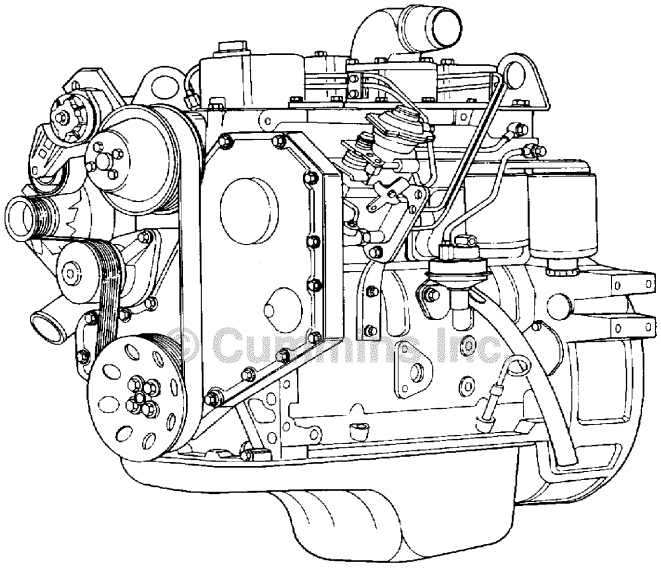
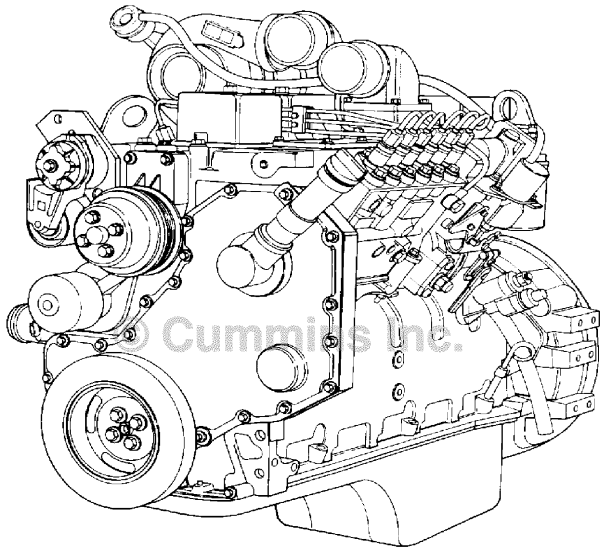


B3.9 and B4.5



B5.9

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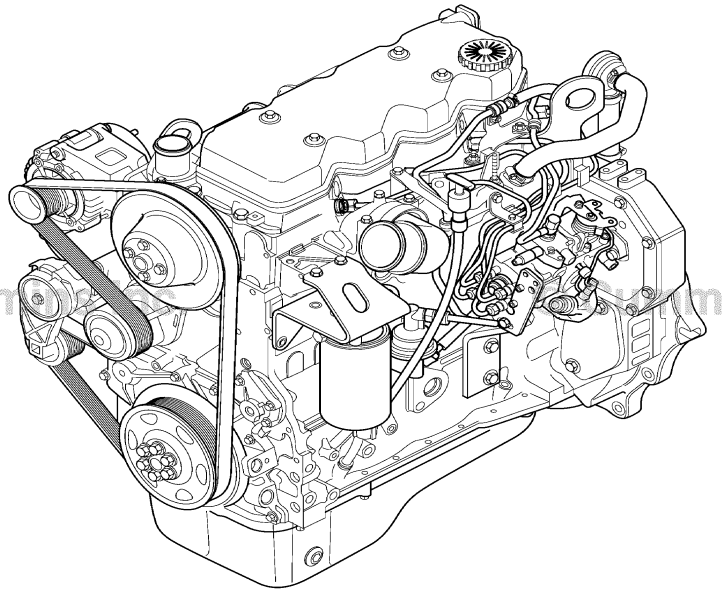

B4.5 RGT

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Foreword

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

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

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

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

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

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

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

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

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

Table of Contents

Section i - Introduction

Section Contents

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About the Manual

General Information

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

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

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

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

How to Use the Manual

General Information

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

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

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

Each section contains the following in sequence:

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

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

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

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

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

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

Symbols

General Information

The 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.

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

Indicates a **REMOVAL or DISASSEMBLY** step.

Indicates an **INSTALLATION or ASSEMBLY** step.

INSPECTION is required.

CLEAN the part or assembly.

PERFORM a mechanical or time **MEASUREMENT**.

LUBRICATE the part or assembly.

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

TIGHTEN to a specific torque.

PERFORM an electrical **MEASUREMENT**.

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

The component weighs 23 kg [50 lb] or more. To avoid personal injury, use a hoist or get assistance to lift the component.

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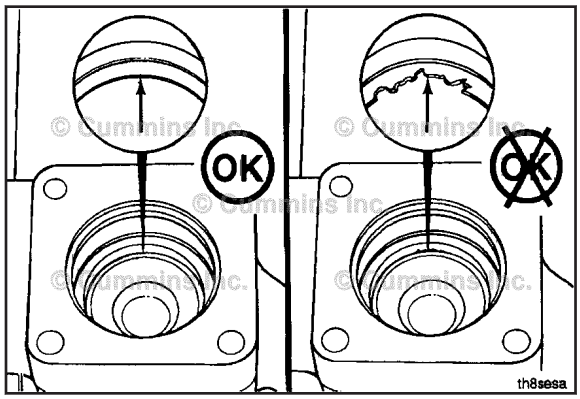
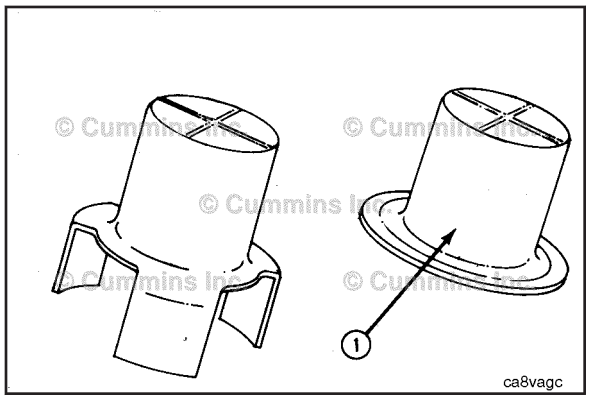


Illustrations

General Information

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



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

General Safety Instructions

Important Safety Notice

⚠ WARNING ⚠

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

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

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

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

General Repair Instructions

General Information

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

⚠ WARNING ⚠

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

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

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

- Use genuine Cummins new or ReCon® service parts and assemblies

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

- Follow the specified disassembly and assembly procedures to reduce the possibility of damage to the components

Welding on a Vehicle with an Electronic Controlled Fuel System

⚠CAUTION⚠

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

General Cleaning Instructions

Definition of Clean

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

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

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

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

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

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

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

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

Abrasive Pads and Abrasive Paper

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

⚠ WARNING ⚠

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

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

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

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

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

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

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

⚠WARNING⚠

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

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

Gasket Surfaces

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

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

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

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

Solvent and Acid Cleaning

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

⚠WARNING⚠

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

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

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

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

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

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

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

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

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

Steam Cleaning

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

⚠WARNING⚠

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

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

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

Plastic Bead Cleaning

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

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

△CAUTION△

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

△CAUTION△

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

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

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

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

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

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

⚠CAUTION⚠

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

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

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

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

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

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

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

Fuel System

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

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

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

Choose lint free towels for fuel system work.

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

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

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

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

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

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

Acronyms and Abbreviations

General Information

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

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

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

Notes

Section 5 - Fuel System - Group 05

Section Contents

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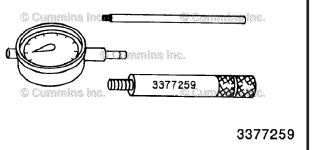
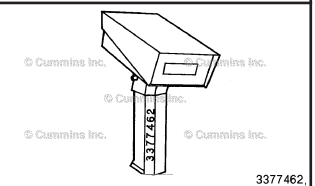
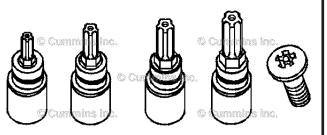
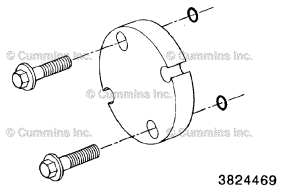
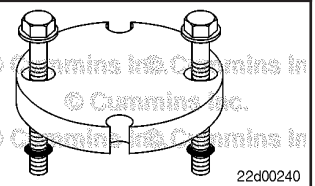
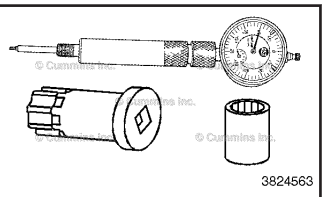
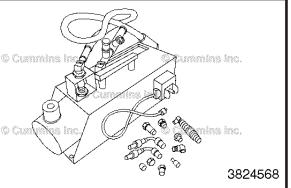
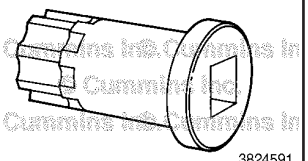
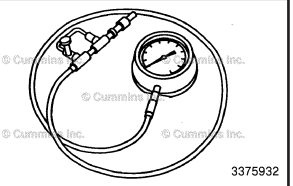
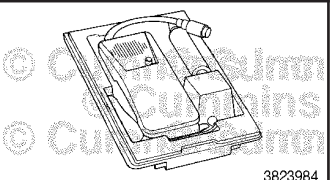
Service Tools

Fuel System

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

Tool No.	Tool Description	Tool Illustration
3377259	**Bosch® Timing Tool (VE Pump)** Used to time the Bosch® VE fuel pump.	 3377259
3377462	**Tachometer** Used to measure engine cranking speed.	 3377462,
3399870	**Tamper-Resistant Screw Removal Tool** Used to remove tamper-resistant screw on fuel pump.	 3399870
3824469	**Fuel Pump Gear Puller** Fuel pump gear puller, Part Number 3824469 has been obsoleted. This tool can be used with M8-1.25 x 50 capscrews, Part Number 3900633, grade 8.8 flange head capscrews or equivalent.	 3824469
3163381	**Fuel Pump Gear Puller** Used to pull the fuel pump gear. Includes Part Number 3900633 capscrews.	 22d00240
3824510	**QD Contact Cleaner** A nonpetroleum cleaner used to clean electrical connections.	 oi8togt

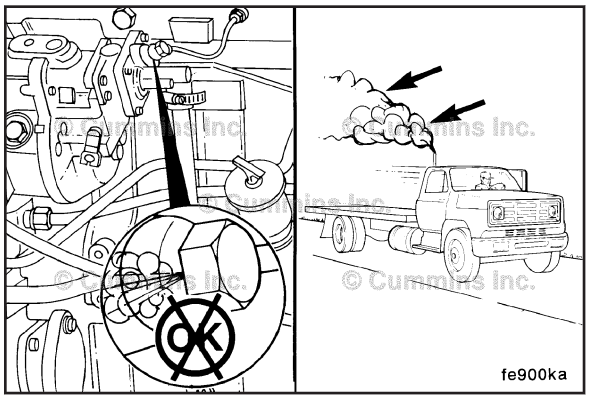
Tool No.	Tool Description	Tool Illustration
3162853	**Bosch® Lift Plunger Timing Tool (In-line pump)** Used to time the Bosch® in-line pump.	 3824563
3824568	**High-Pressure Spill Port Timing Tool** Used to check and compare fuel pump timing to engine timing.	 3824568
5299073	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	 3824591
3375932	**Pressure Gauge** Used to measure gas pressure after high pressure regulator.	 3375932
3823984	**Combustible Gas Detector** Used to detect combustible gas leaks.	 3823984

AFC Assembly (005-001)

General Information

Air-Fuel Control (AFC) Malfunctions

The 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 or 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.



Engine Fuel Heater, Electric (005-008)

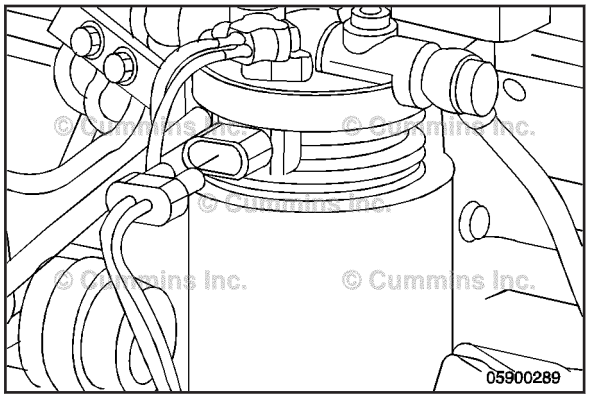
Initial Check

NOTE: The fuel heater is not controlled by the electronic control module (ECM). A bimetallic strip acts as a thermostat. The fuel heater will turn on at approximately 1°C [34°F] and turn off at approximately 18°C [64°F].

Remove the 2-pin connector from the fuel heater.

Using an ohmmeter, check the continuity of the fuel heater by placing the ohmmeter test leads across the pins of the fuel heater.

If the heater circuit is open, replace the fuel heater.

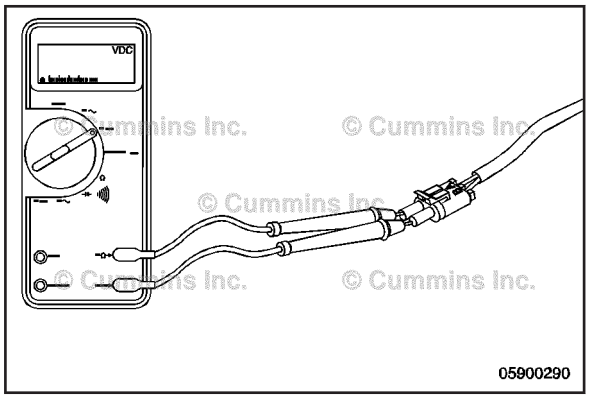


Check for proper voltage to the fuel heater.

Minimum Voltage

12 VDC

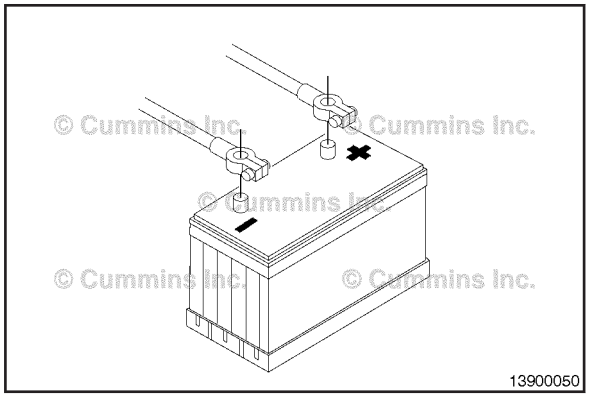
If the voltage is **not** within specifications, refer to OEM service manual.

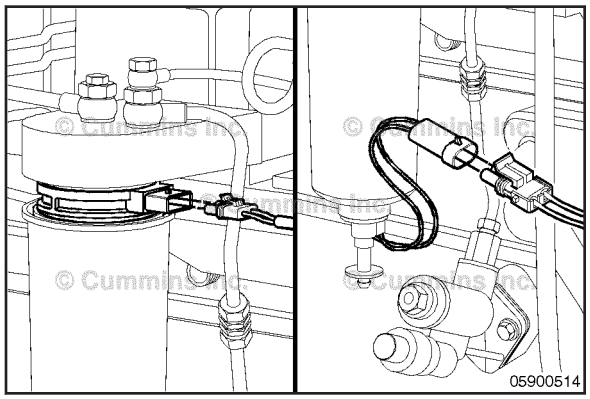


Preparatory Steps

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

- Disconnect the batteries.

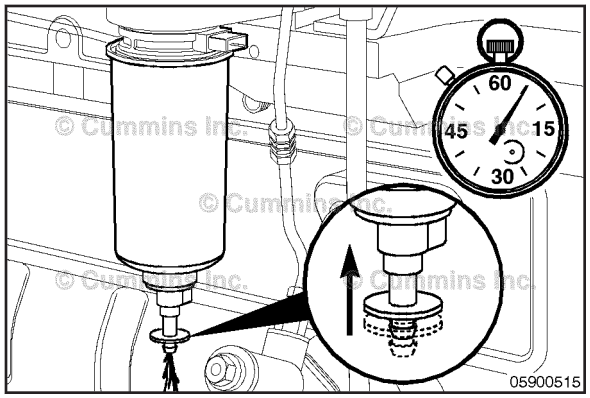




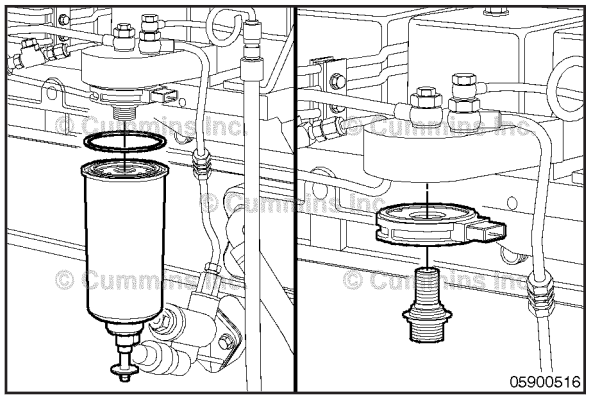
Remove

Disconnect the connector from the fuel heater.

Disconnect the connector from the water-in-fuel (WIF) sensor.



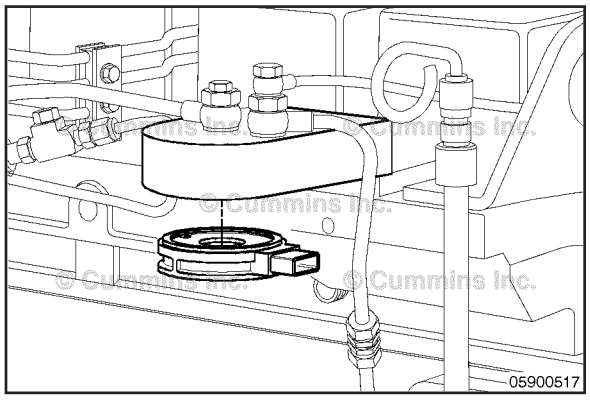
Push on the fuel drain valve for approximately 5 seconds to reduce fuel spillage during filter removal.



Remove the fuel filter.

Remove the fuel filter spud.

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



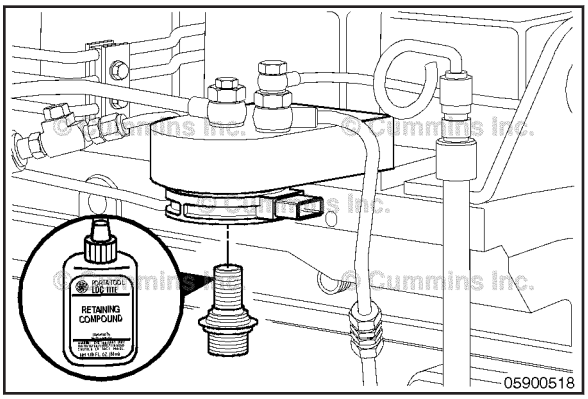
Install

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

Apply Loctite to the filter spud.

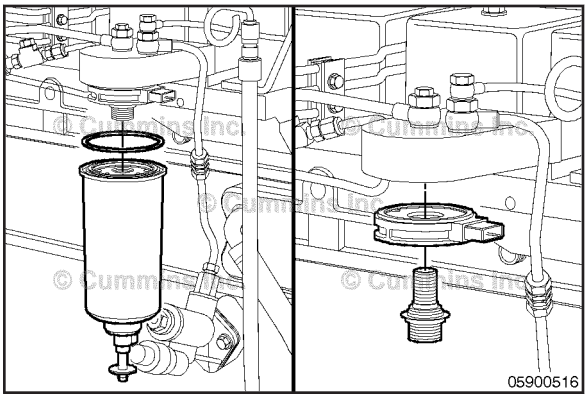
Install the fuel filter spud.

Torque Value: 27 N•m [20 ft-lb]



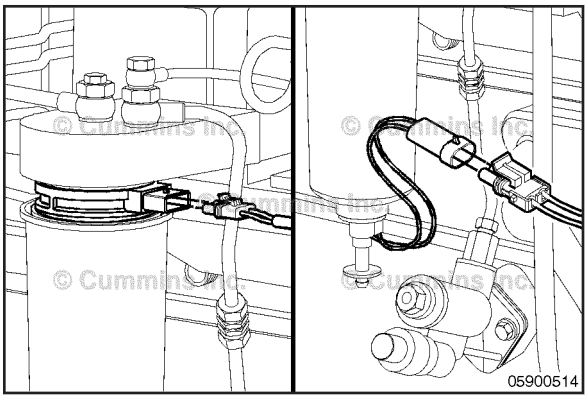
Install an o-ring between the fuel heater and the filter canister.

Install the fuel filter.



Connect the connector to the water-in-fuel sensor.

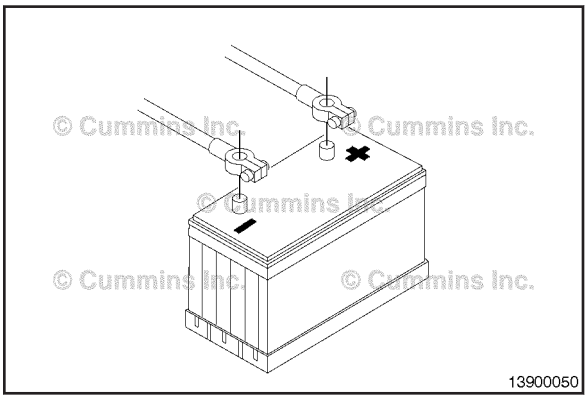
Connect the connector to the fuel heater.

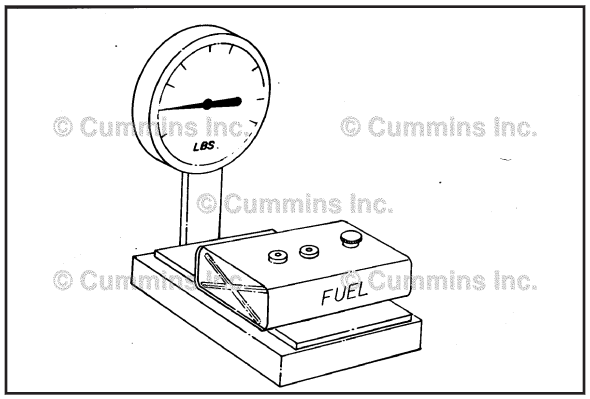


Finishing Steps

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

- Connect the batteries
- Operate the engine and check for leaks.





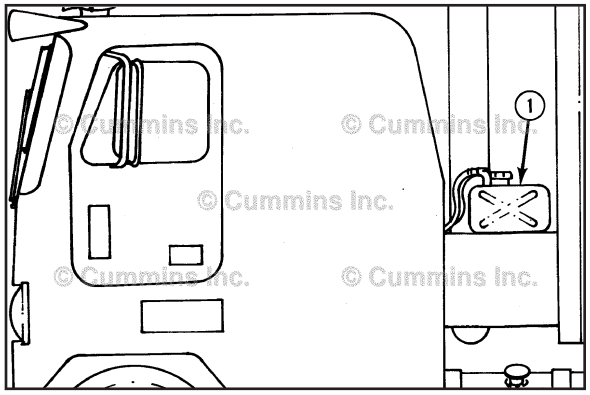
Fuel Consumption (005-010)

Measure

Refer to the fuel consumption checklist sheets in Procedure t00-004, in the back of Section TS.

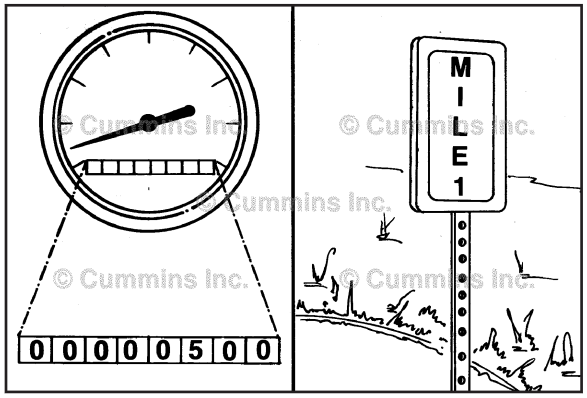
NOTE: The most accurate method to check the fuel consumption is to weigh the fuel used. Use a scale capable of measuring within 0.045 kg [0.1 lb] to weigh the fuel tank. Use a remote-mount tank with enough capacity to run 80 km [50 mi].

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

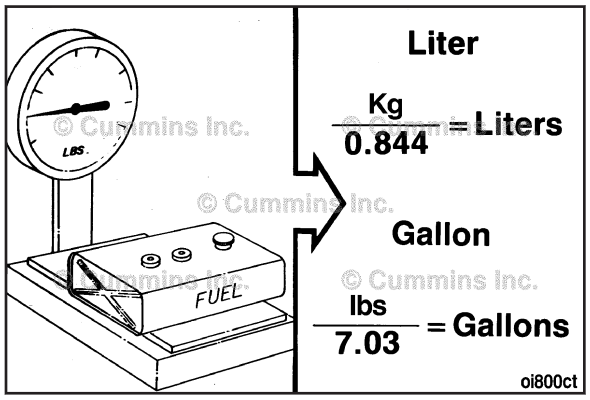


Install the remote tank (1).

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

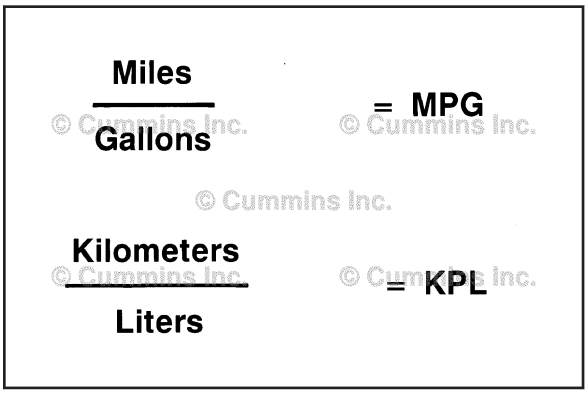


Measure the distance traveled with an accurate odometer. The odometer accuracy can be checked by using measured kilometers [miles].



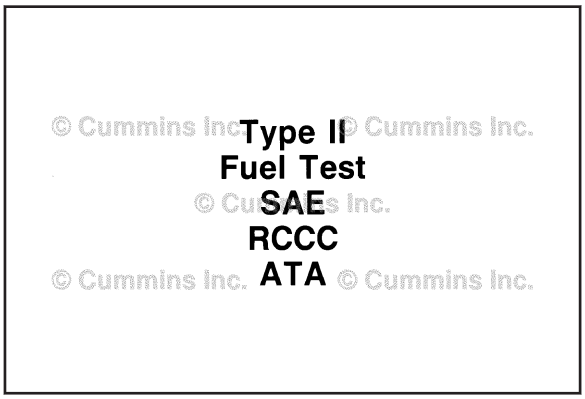
After traveling the route, remove the tanks, and weigh the remaining fuel. Compute the fuel used in liters [gallons] as required.

Compute the kilometers per liter or miles per gallon.



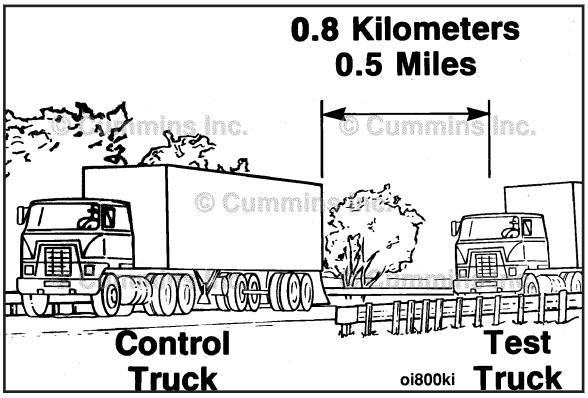
In addition to the measurement of the fuel used, the following factors provide points for running a test similar to the recognized Type II Society of Automotive Engineers Fuel Test.

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

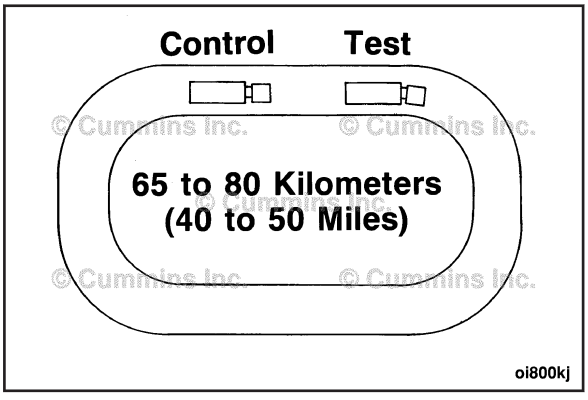


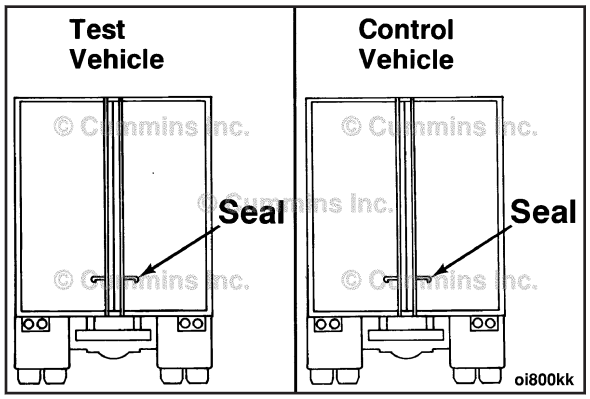
Perform the test with the test vehicle and a control vehicle. The control vehicle compensates for changes in traffic conditions.

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

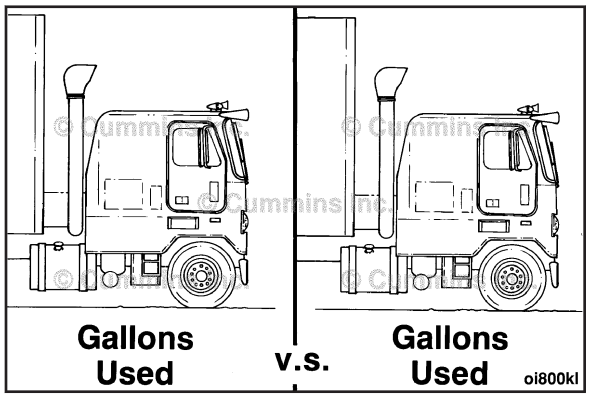


The test course **must** be 65 to 80 km [40 to 50 mi] long.

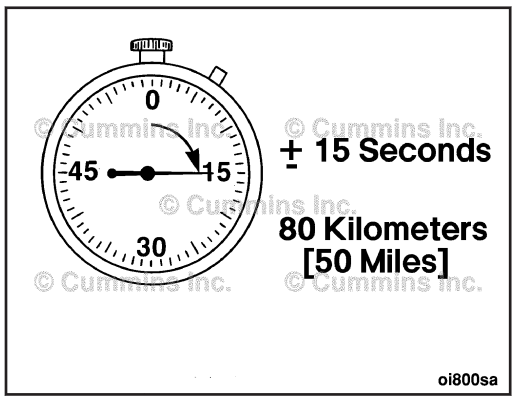




The test route and truck weights **must not** change during the test.

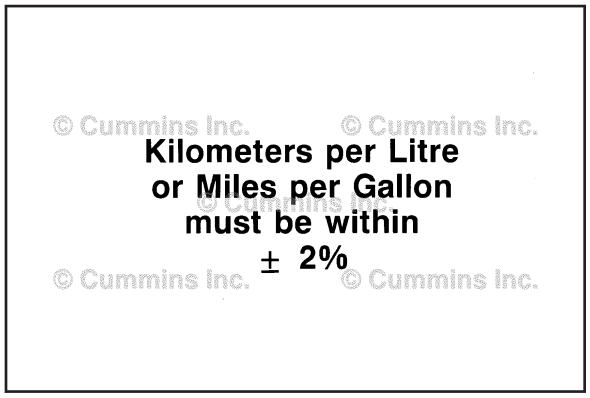


All of the test results are based on comparing the fuel used by the test truck to the fuel used by the control truck.



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

Difference in elapsed time between each test run can **only** be plus or minus 0.5 percent. This will be ±15 seconds on 80 km [50 mi] at 60 miles per hour.

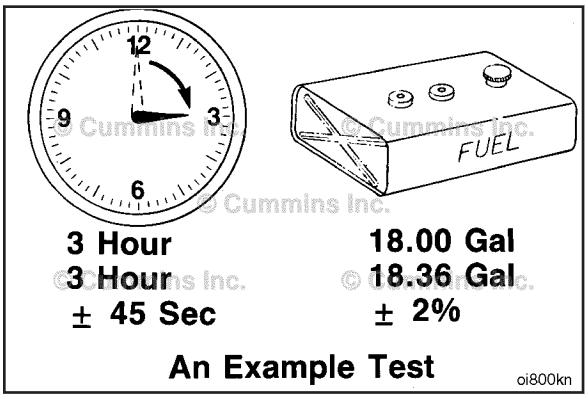


The fuel usage of the test truck between test drives **must** fall within a 2-percent range, e.g., 2.55 vs. 2.60 km/l [6.00 vs. 6.12 mpg].

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

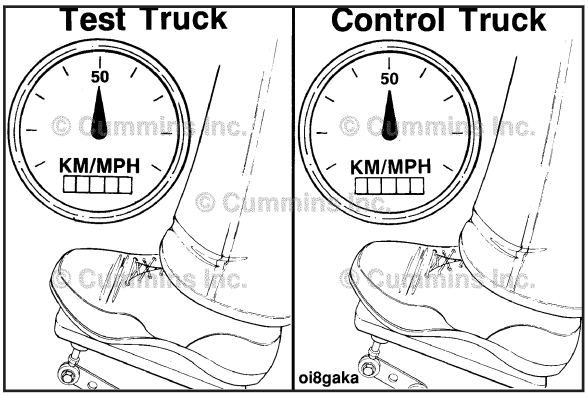
NOTE: The differences in traffic and driving practices can make the test drive fall out of the 2-percent range.

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



Use the same experienced drivers for all of the tests.

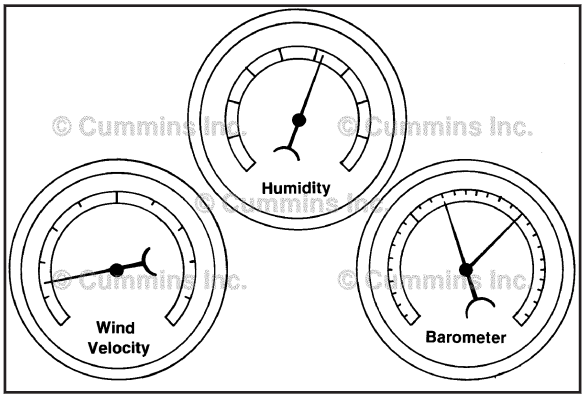
NOTE: The vehicle speeds **must** be representative of a typical operation.



During the test, record the following:

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

NOTE: Avoid testing under any extreme conditions.



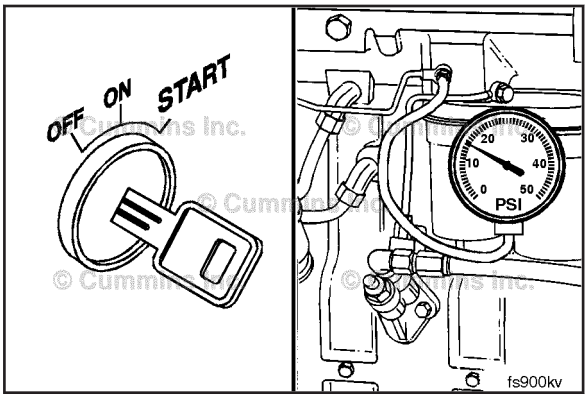
Fuel Flow (005-011)

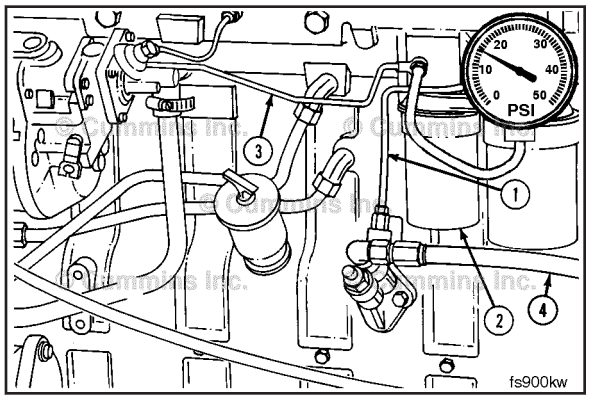
Pressure Test

Inspect to determine if the fuel transfer pump is delivering fuel. Measure the output pressure at the inlet of the injection pump.

Fuel Transfer Pump Output Pressure at Rated Speed

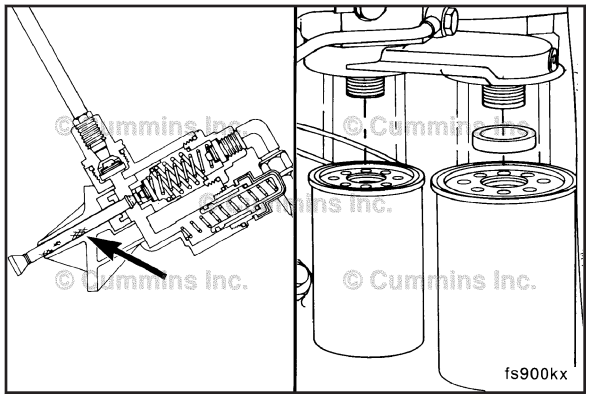
	kPa		psi
High-flow-automotive	172	MIN	25
Low-flow-industrial	83	MIN	12





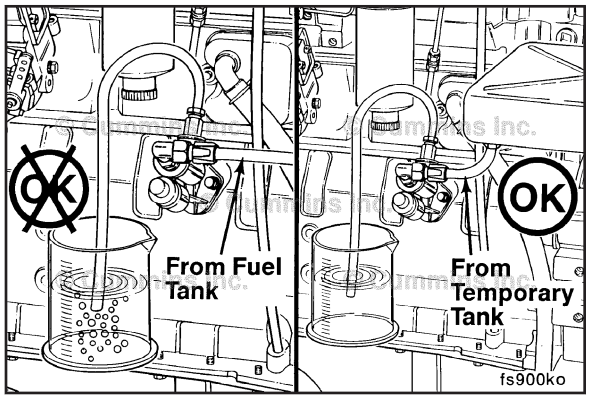
If the required volume is **not** being delivered, measure the transfer pump inlet restriction with a vacuum gauge between the transfer pump inlet and the supply line (4) from the fuel tank.

Fuel Transfer Pump Inlet Restriction		
kPa		in Hg
13.55	MAX	4

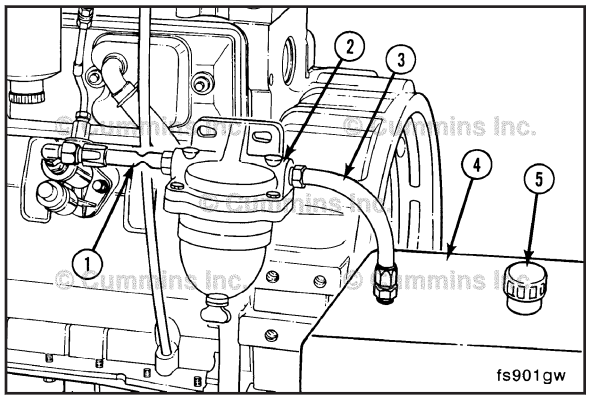


NOTE: Frequent fuel filter replacement to get full power from the engine can indicate a worn fuel lift pump.

The pressure drop across the filter(s) will increase as the filter removes contaminants from the fuel. A worn fuel lift pump will have reduced capacity to force fuel through a dirty filter. This can cause low engine power.



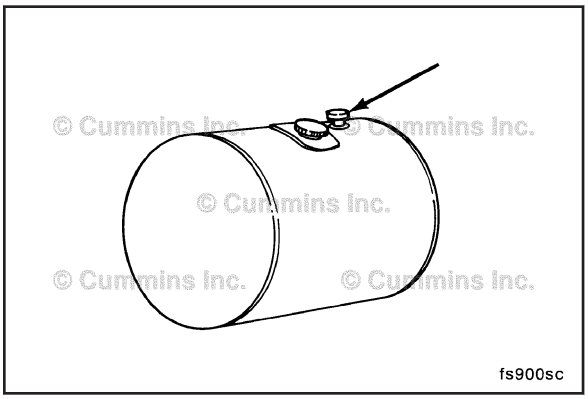
If the fuel is aerated or the volume is low, isolate the fuel transfer pump by connecting the fuel transfer pump inlet to a temporary supply, and perform the same check as above.



If the fuel transfer pump delivers the required volume of fuel from a temporary supply, check for restrictions or suction leaks in the fuel circuit to the fuel transfer pump:

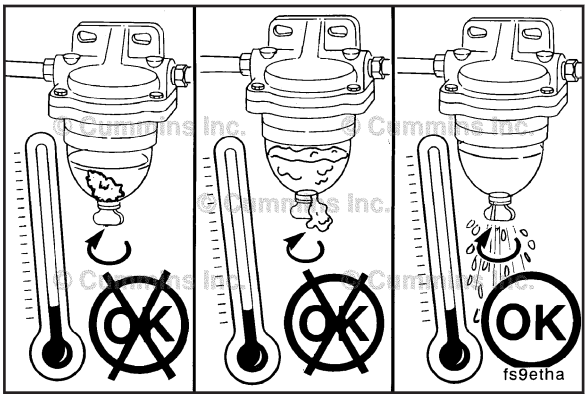
1. Supply line
2. Prefilter
3. Supply line
4. Supply tank
5. Tank vent.

Check for a plugged supply tank vent first.



In cold weather check for gelled diesel fuel blocking the prefilter.

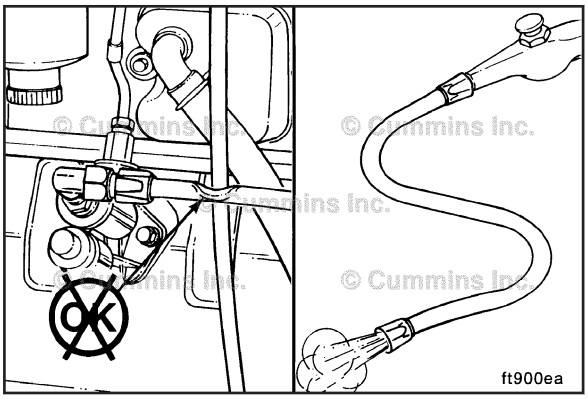
Clean or replace the prefilter.



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

Inspect the fuel supply lines for restrictions.

Remove and blow out the fuel supply lines with compressed air, if necessary.

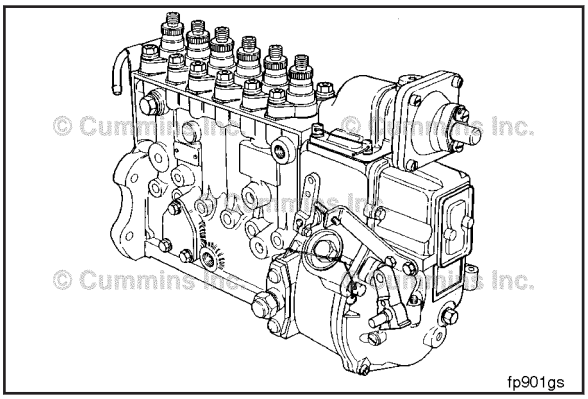


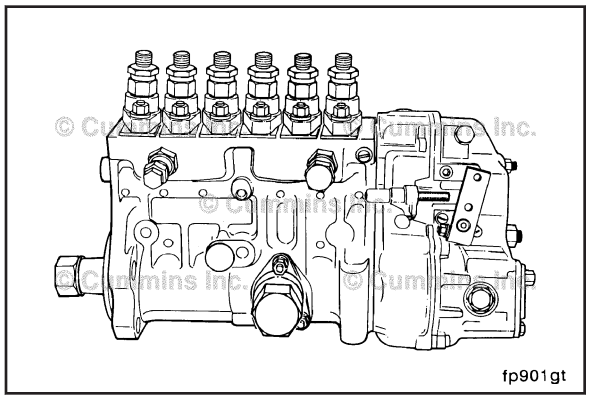
Fuel Injection Pumps, In-Line (005-012)

General Information

The Bosch® P7100 in-line fuel injection pump can be found on the following engine application:

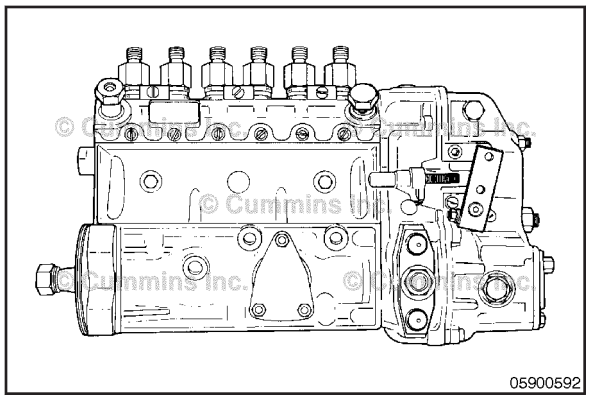
- 1991 high-horsepower automotive ratings
- 1994 automotive, all 6B ratings
- 1996 emissionized high-horsepower industrial ratings.





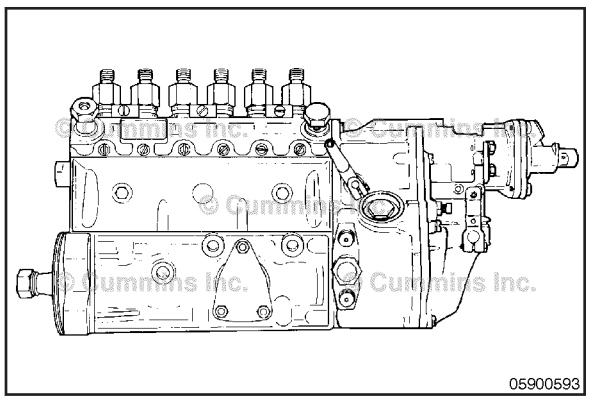
The Nippondenso EP-9 in-line fuel injection pump with the RSV governor can be found on the following engine application:

- Higher horsepower marine rating.



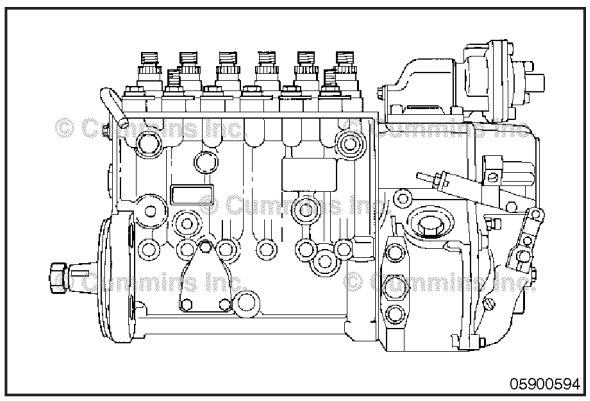
The Bosch® A-RSV in-line fuel injection pump can be found on the following engine application:

- Pre-1996 noncommissioned industrial ratings
- 1996 industrial emission ratings
- Marine
- Gensets.



The Bosch® MW/RSV and MW/RQV in-line fuel injection pump can be found on the following engine application:

- 1996 and higher industrial emission ratings.

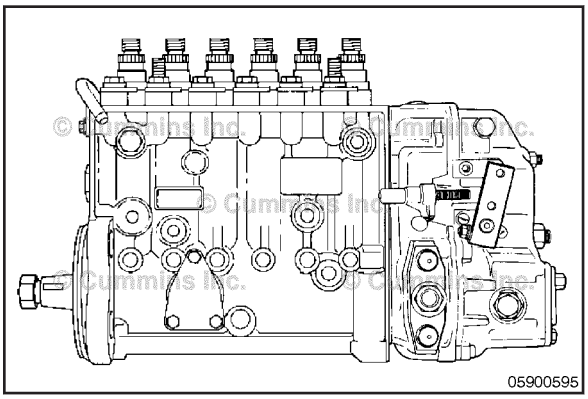


The Bosch® P3000/RQVK and P3000/RQV in-line fuel injection pump can be found on the following engine application:

- 1996 and higher high-horsepower industrial emission rating.

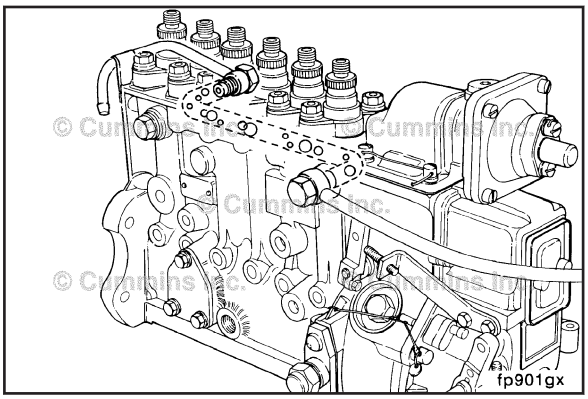
The Bosch® P3000/RSV In-line fuel injection pump can be found on the following engine application:

- 1996 and higher high-horsepower industrial emission ratings
- Marine.

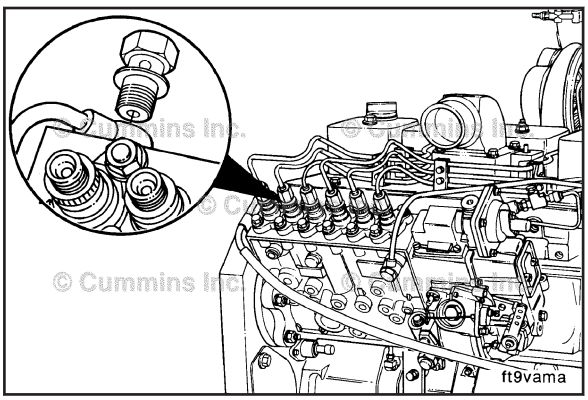


The pressure relief valve arrangement on the Bosch® P7100 fuel injection pump in the supply side of the fuel circuit creates a self-bleeding system for air introduced during replacement of the supply-side components.

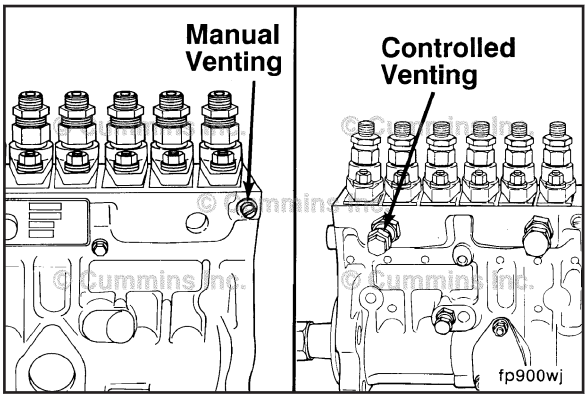
Small amounts of air can be bled from the pump by operating the hand primer on the fuel transfer pump or by cranking the engine.

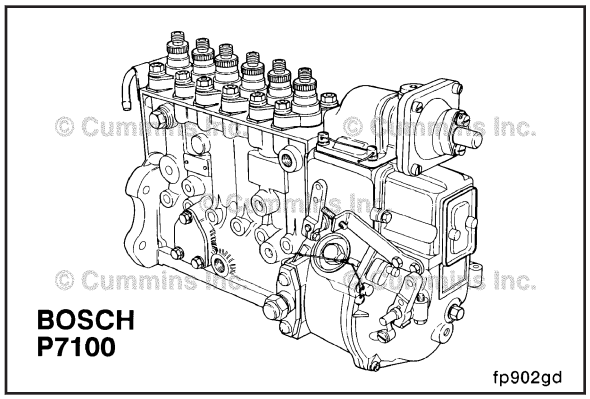


The Bosch® P7100 in-line fuel injection pump has a jump-over tube to route return fuel and entrapped air from the pressure relief valve directly to the supply tank.



The Nippondenso EP-9 in-line fuel injection pumps will require additional venting prior to initial start-up, pump replacement, or if engine fuel runs out.

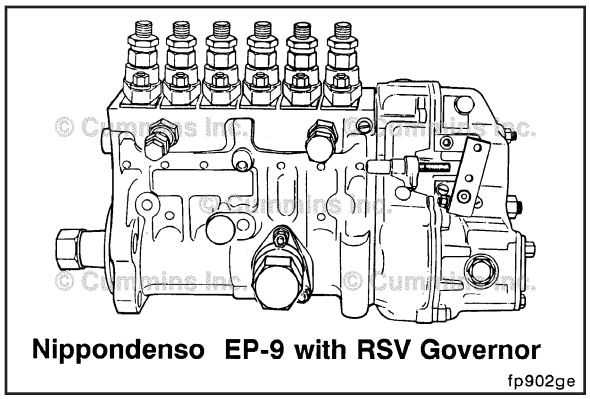




Fuel Injection Pump (In-Line Type)

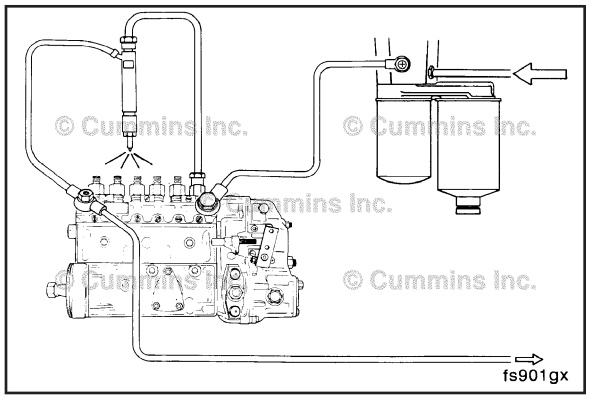
Beginning in 1991, the B Series engine used the Bosch® P7100 in-line fuel injection pump on higher horsepower automotive ratings. In 1994, all automotive 6B Series engines used the Bosch® P-7100 in-line fuel injection pump.

B Series industrial ratings and marine (after 1996) engines use the Bosch® “A” in-line fuel injection pumps.



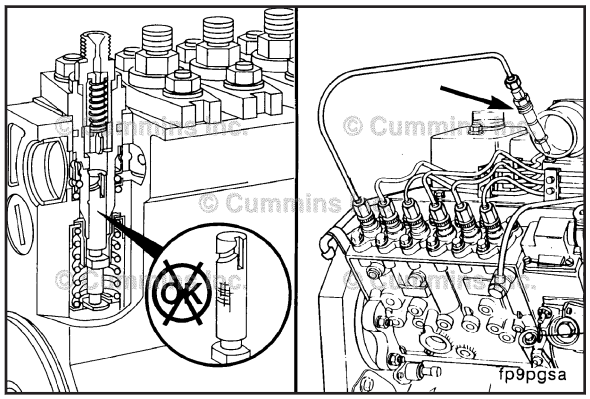
The B Series engine also uses the Nippondenso EP-9 with RSV governor on 1996 or earlier engines with a 250 and 300-horsepower marine rating.

Refer to the B Series Marine Operation and Maintenance Manual, Bulletin 3810466, for additional information.



The fuel injection pump performs the three basic functions of:

1. Metering the exact amount of fuel for each injection cycle
2. Producing the high fuel pressure required for injection
3. Delivering the high-pressure metered fuel to each cylinder at the precise time.



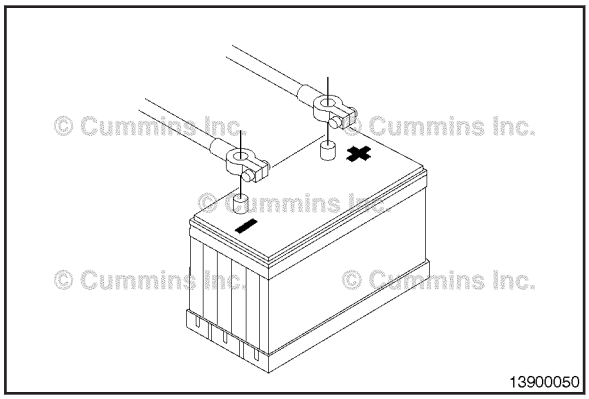
Individual plungers are used in the pumps to develop and distribute the high pressure required for injection.

A worn or damaged plunger in the pump will affect **only** one cylinder.

Preparatory Steps

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

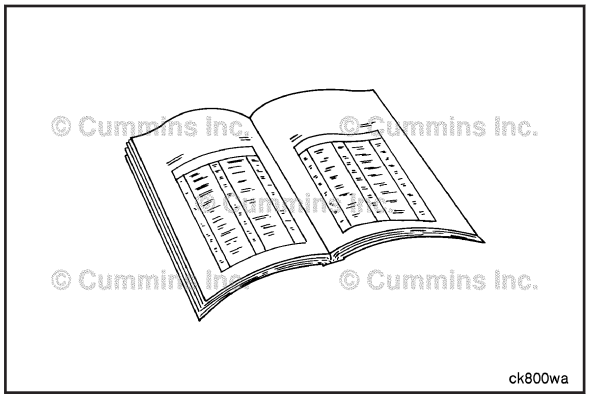
- Disconnect the batteries.



⚠WARNING⚠
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.

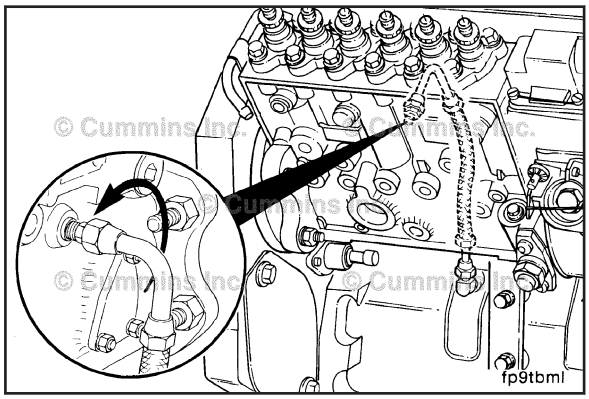
- Clean any debris from the fuel injection pump.
- Remove the fuel supply lines. Refer to Procedure 006-024.
- Remove the injector supply lines to the pump. Refer to Procedure 006-051.
- Remove the control linkage. See the OEM service manual.
- Remove the fuel shutoff valve. Refer to Procedure 005-043.
- Remove the air fuel control air tube. Refer to Procedure 006-001.
- Disconnect wastegate turbocharger control line (if applicable).

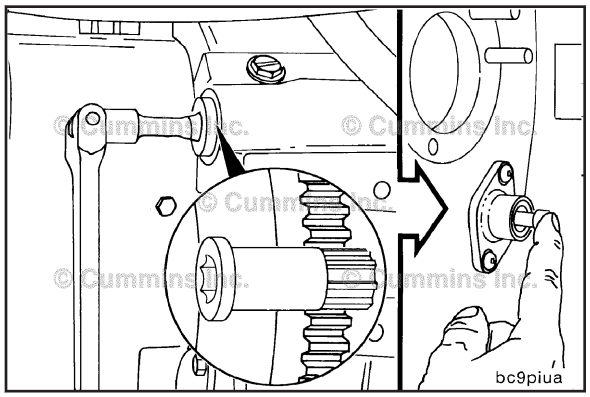


Remove

Disconnect the external oil feed line at the inboard side of the fuel injection pump (if applicable) and the main oil rifle.

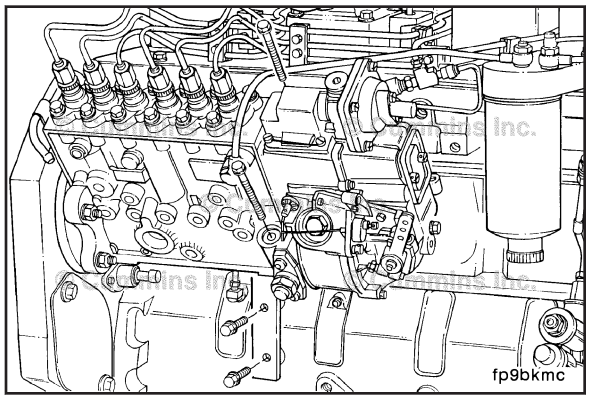
Disconnect the external oil feed line at the rear of the pump or AFC latchout if applicable.



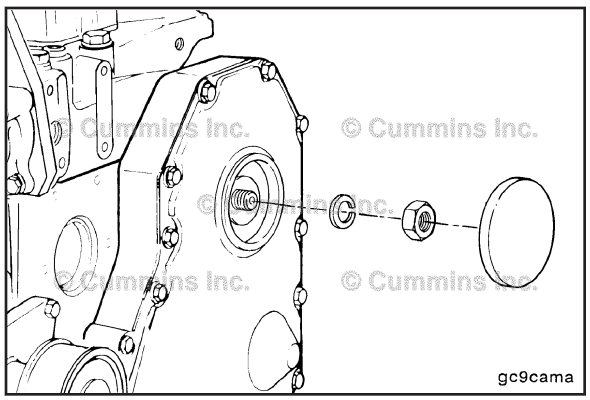


Locate top dead center for cylinder Number 1. Push the top dead center pin into the hole in the camshaft gear while slowly barring the engine.

NOTE: Be certain to disengage the timing pin after locating top dead center.



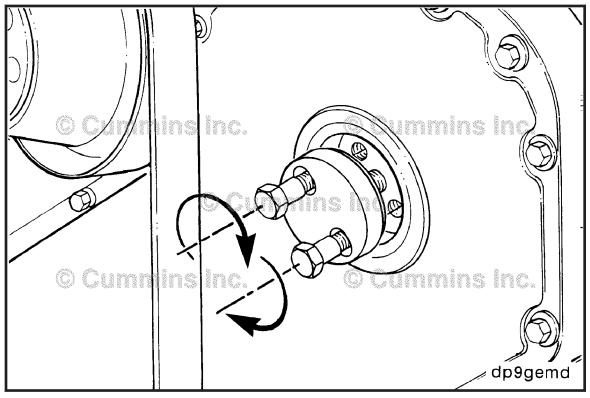
Remove the fuel injection pump mounting bracket, if applicable.



⚠CAUTION⚠
Do not drop the nut and washer. Dropping the nut and washer will result in the need to remove the front cover.

Remove the gear cover access cap.

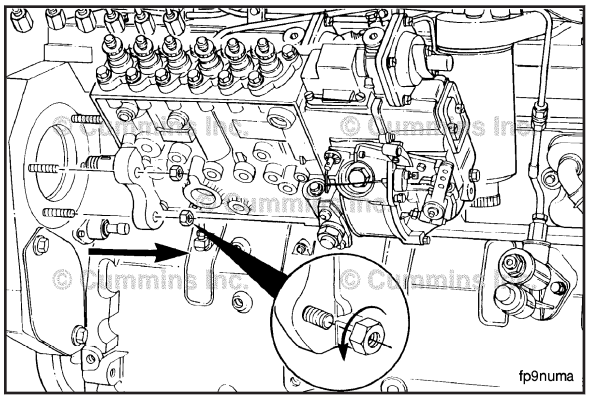
Remove the nut and washer from the fuel injection pump shaft.



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.

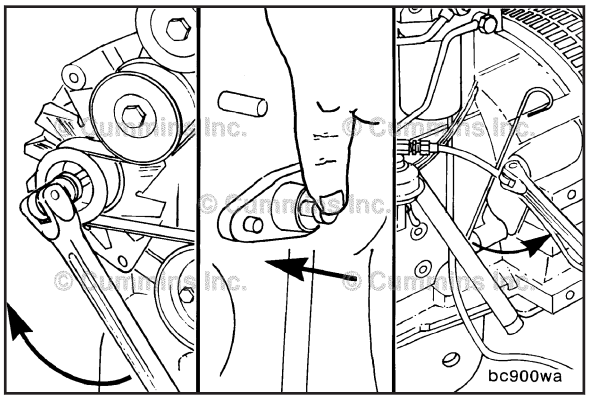
Remove the four mounting nuts.

Remove the fuel injection pump.

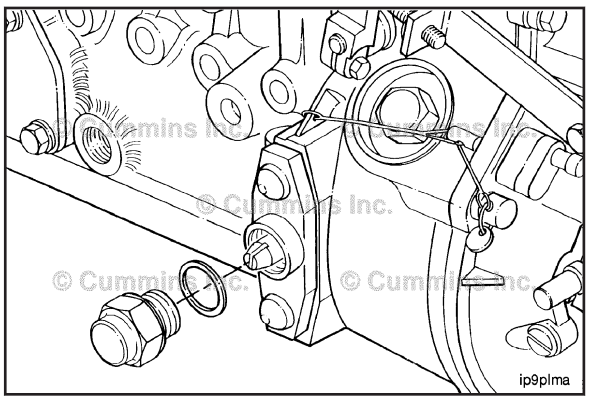


Install

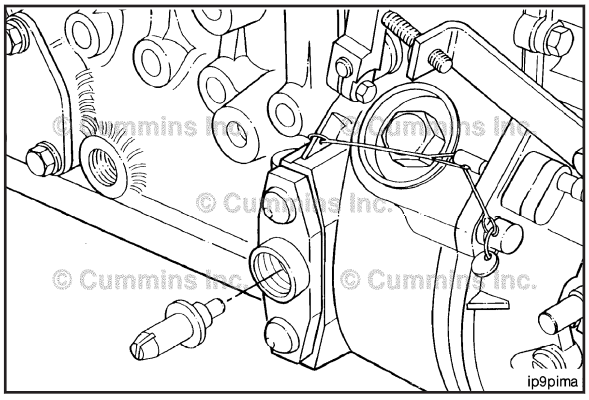
Make certain that the engine has cylinder Number 1 at top dead center.

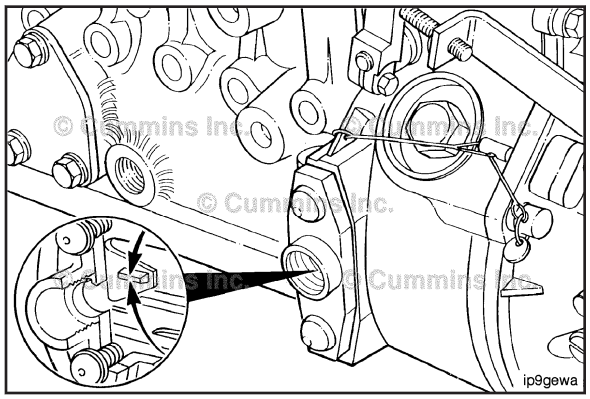


Remove the access plug.

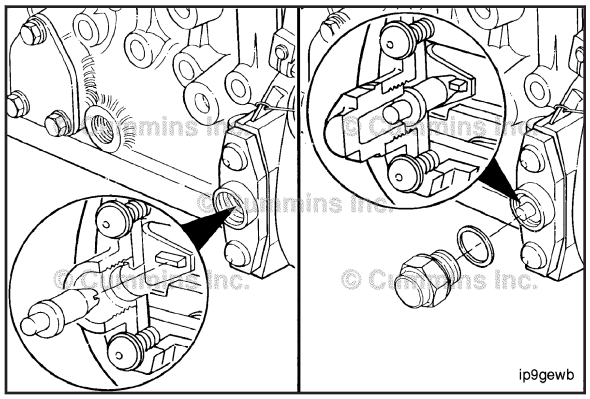


Remove the timing pin.



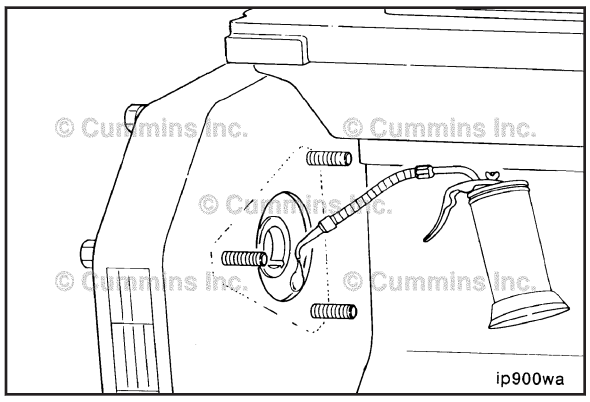


If the timing tooth is **not** aligned with the timing pin hole, rotate the fuel injection pump shaft until the timing tooth aligns.



Reverse the position of the timing pin so the slot of the timing pin will fit over the timing tooth in the pump.

Install and secure the timing pin with the access plug.



Use a 50/50 mixture of clean lubricating engine oil and STP, or equivalent, to lubricate the gear cover housing to make certain that the fuel injection pump will slide into the gear cover housing easily.

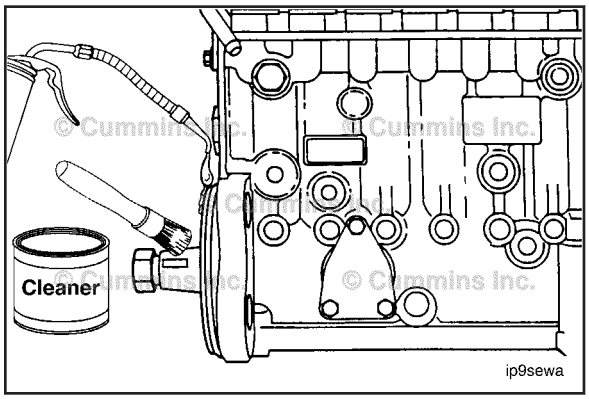
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

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

△CAUTION△
The fuel injection pump drive gear inside diameter and the shaft outside diameter must be clean and dry before installing the gear. Failure to do so can result in slipped timing.

NOTE: Before installing the fuel pump drive gear, clean the injection pump shaft and gear tapers with residue-free cleaner, Part Number 3824510, by spraying into the gap between the shaft and the gear. Dry with compressed air.

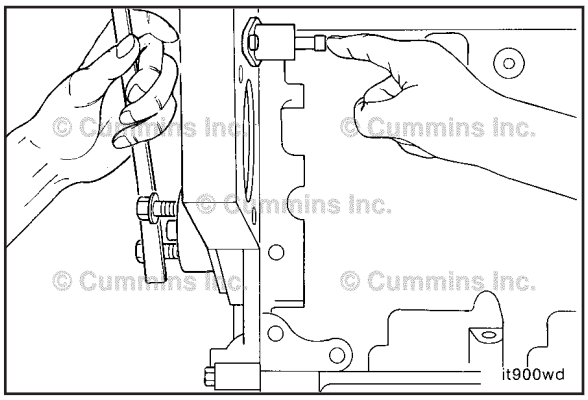
NOTE: The in-line fuel injection pump driveshaft has a provision for a Woodruff key: however, it is **not** required. Timing mark alignment is **not** required for the in-line drive gear.



NOTE: Make certain that the engine has cylinder Number 1 at top dead center.

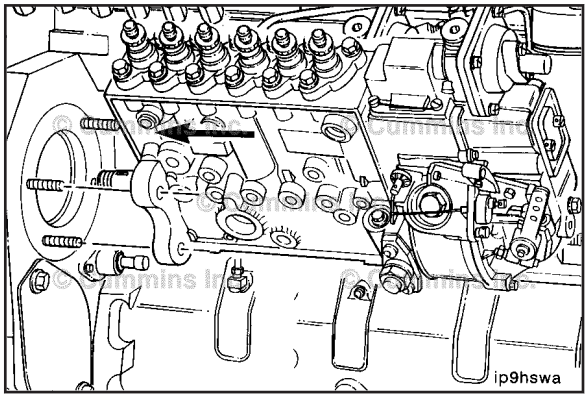
Make certain that the o-ring seals for the fill orifice and pilot are correctly installed and are **not** damaged.

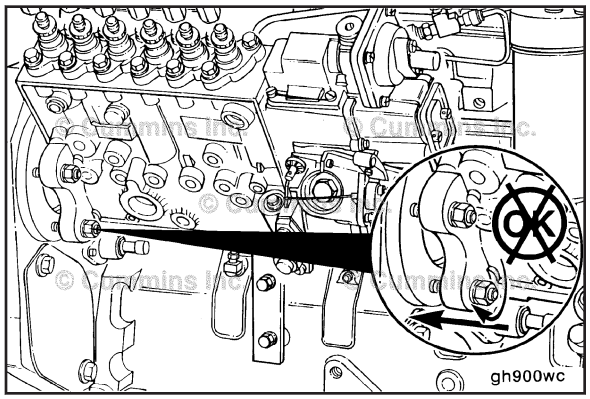
Install new pilot o-ring.



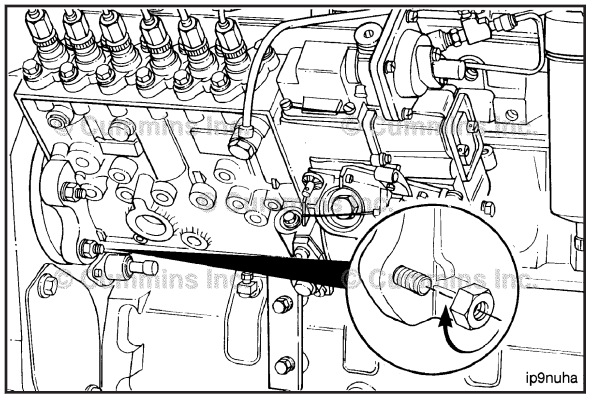
Slide the pump shaft through the drive gear and position the pump flange onto the mounting studs.

Push the pump forward until the mounting flange and o-ring are properly fitted into the gear housing bore.





⚠CAUTION⚠
Do not attempt to pull the pump flange into the gear housing with the mounting nuts as damage to housing can occur.

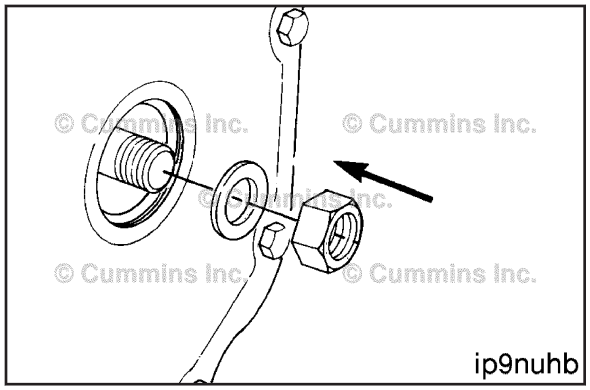


Install the mounting nuts.

Torque Value: 43 N•m [32 ft-lb]

Install the support bracket (if equipped).

Torque Value: 32 N•m [24 ft-lb]

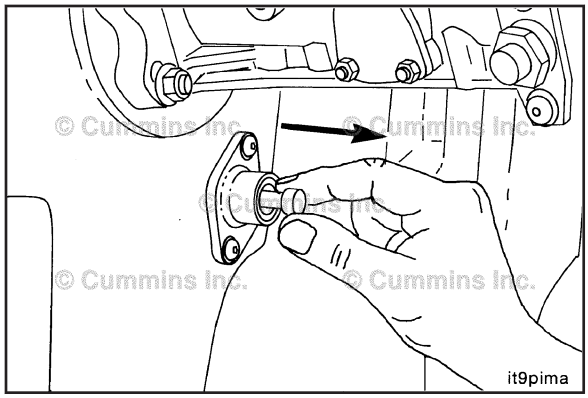


⚠CAUTION⚠
Do not drop the nut and washer. Dropping the nut and washer will result in the need to remove the front cover.

Install the retaining nut and washer.

Torque Value: 10 to 15 N•m [89 to 133 in-lb]

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.



Disengage the engine timing pin.

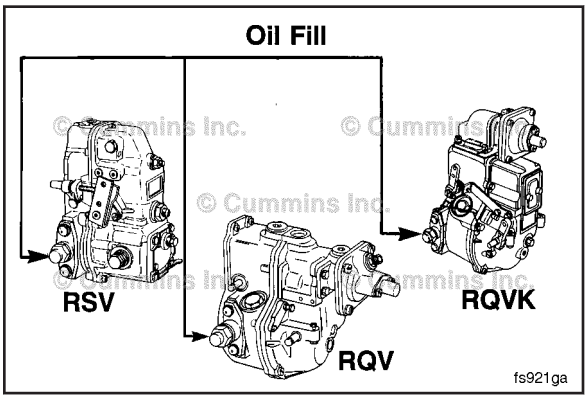
⚠CAUTION⚠

The governor housing must be prelubricated before engine operation. Failure to do so can result in premature governor wear.

Remove the access plug.

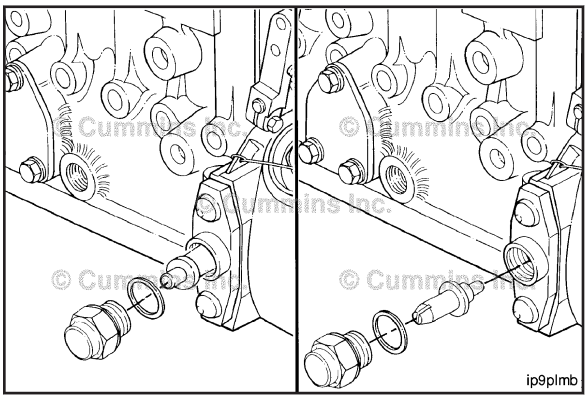
Add the following quantity of clean lubricating engine oil:

- RSV 450 mL [0.48 qt]
- RQV 750 mL [0.79 qt]
- RQVK 750 mL [0.79 qt]



Remove the fuel injection pump timing pin plug, reverse the position of the timing pin, and install the timing pin, plug, and sealing washer.

Torque Value: 27 N•m [20 ft-lb]

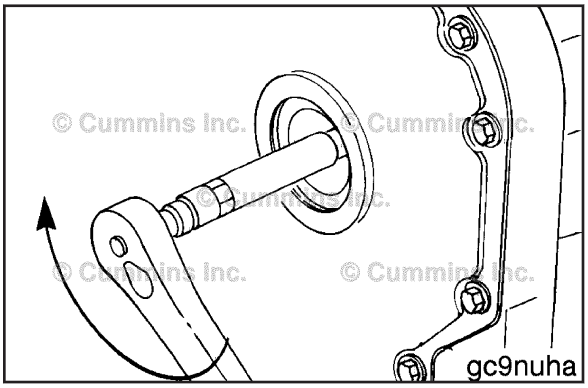


Tighten the fuel injection pump drive nut.

Torque Value:

"A" Pump	85 N•m	[63 ft-lb]
P3000 and P7100	195 N•m	[144 ft-lb]
Nippondenso	123 N•m	[91 ft-lb]

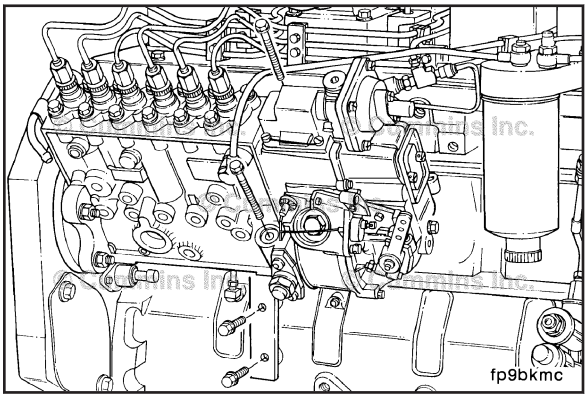
Install the gear cover access cap hand-tight.

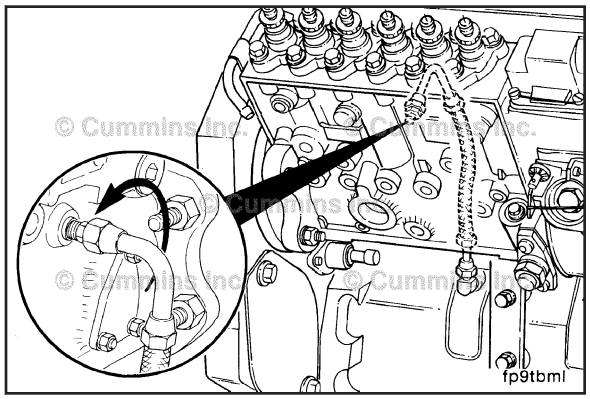


Install the fuel injection pump mounting bracket capscrews.

Tighten all capscrews by hand for proper alignment.

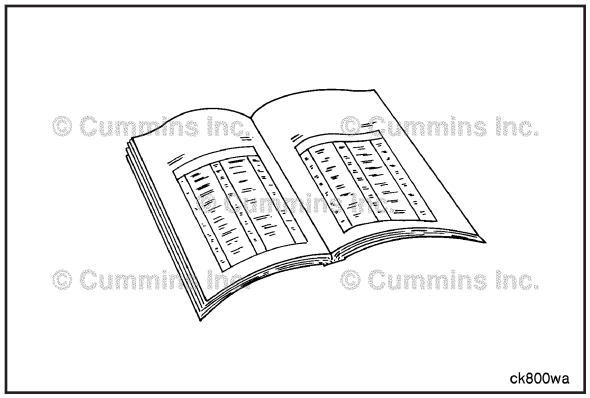
Torque Value: 24 N•m [18 ft-lb]





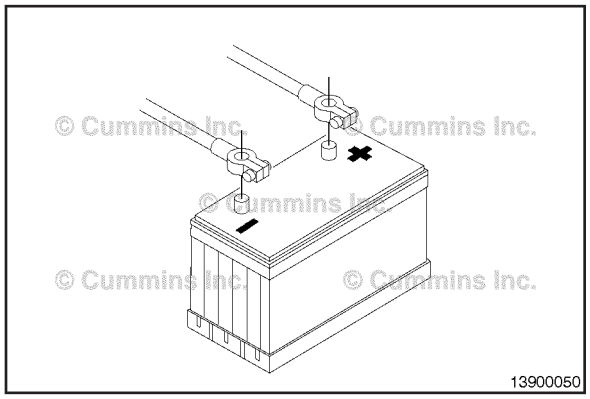
Connect the external oil feed line at the inboard side of the fuel injection pump (if applicable) and the main oil rifle.

Connect the external oil feed line at the rear of the pump or AFC latchout if applicable.



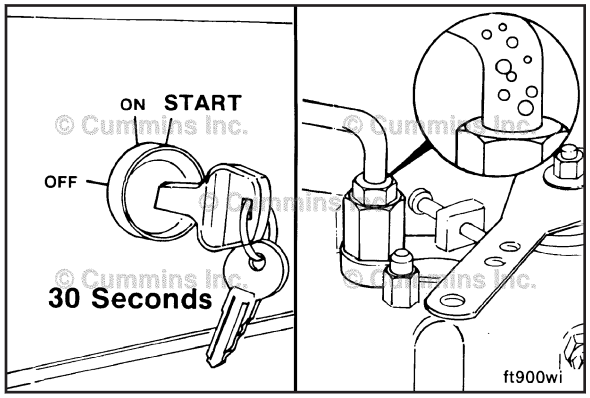
Finishing Steps

- Connect wastegate turbocharger control line (if applicable)
- Install the air fuel control air tube. Refer to Procedure 006-001
- Install the fuel shutoff valve. Refer to Procedure 005-043
- Install the control linkage. See the OEM service manual
- Install the injector supply lines to the pump. Refer to Procedure 006-051
- Install the fuel supply lines. Refer to Procedure 006-024.



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

- Connect the batteries
- Operate the engine and check for leaks.



Prime

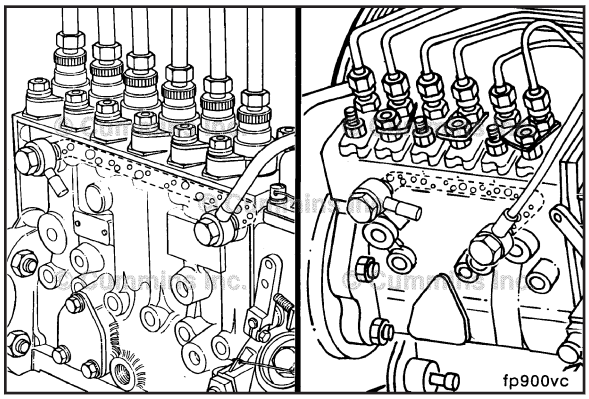
Replacing the fuel supply lines, fuel filters, fuel injection pump, high-pressure fuel lines, and injectors will let air enter into the fuel system. Follow the specified procedure to bleed the air from the system.

Refer to Procedure 006-015 Fuel Filter (Spin-On) for proper venting of the low pressure side of the fuel system.

Refer to Procedure 006-051 Injector Supply Lines (High Pressure) for venting of the high pressure side of the fuel system.

The MW, A, and P fuel injection pumps equipped with the engine-side fuel drain arrangement create a self-bleeding system for air introduced during replacement of the supply-side components.

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.



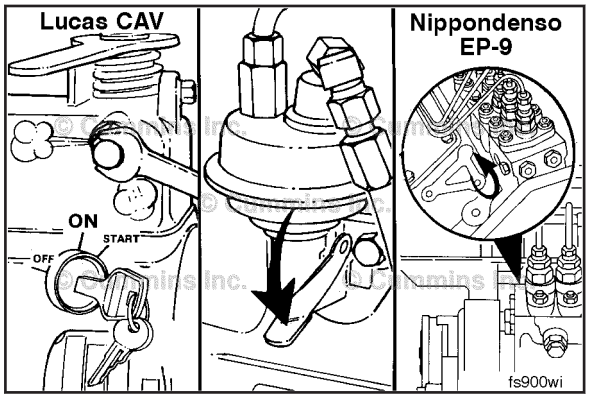
Injection Pumps - Venting

After priming the low pressure fuel lines (see Procedure 006-015, Fuel Filter — Spin-On Type), air/fuel can be vented from the illustrated vent locations on the Nippondenso EP-9 and the Lucas CAV fuel injection pumps. The Lucas CAV fuel injection pump requires that the fuel solenoid valve be energized before venting.

Loosen the vent screw, and operate the priming lever on the fuel transfer pump until the fuel injection pump is primed.

Tighten the vent screw.

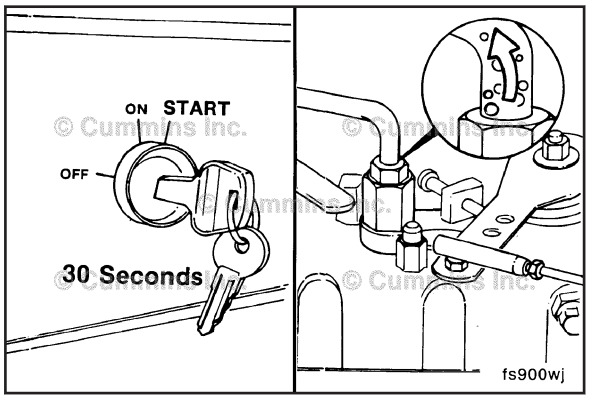
Torque Value: 9 N•m [80 in-lb]



⚠CAUTION⚠
It is necessary to turn the keyswitch to the ON position. Because the engine can start, be sure to follow all safety precautions. Use the normal engine starting procedure.

⚠CAUTION⚠
When using the starting motor to vent the system, do not engage it for more than 30 seconds, or starter damage will occur. Wait 2 minutes before starting the engine again.

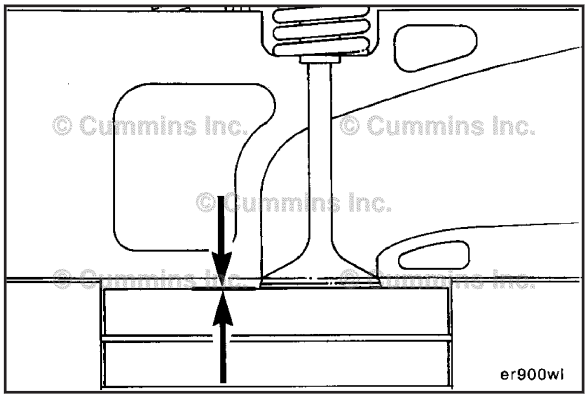
Air can also be vented through the fuel drain manifold line by operating the starting motor.

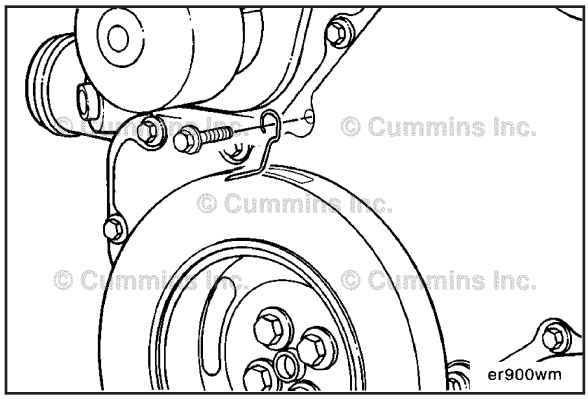


Fuel Injection Pump, In-Line, Spill Port Timing (005-013)

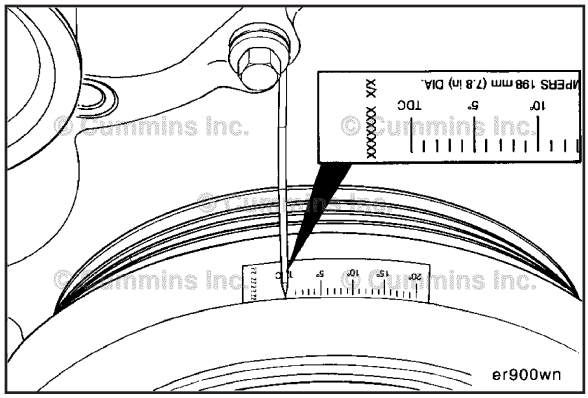
Time

Use the Number 1 intake valve to make sure the engine is at top dead center (TDC) on the compression stroke for cylinder Number 1.





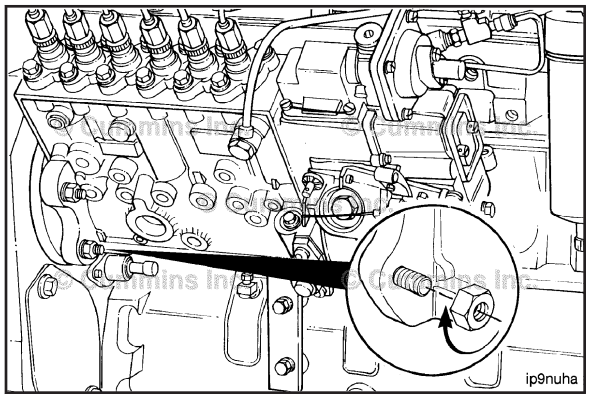
Fabricate a timing mark pointer for the front of the engine. This can be done by forming a piece of wire that can be tightened under one of the gear cover capscrews. Sharpen the wire at the vibration damper end so that it comes to a point for better accuracy.



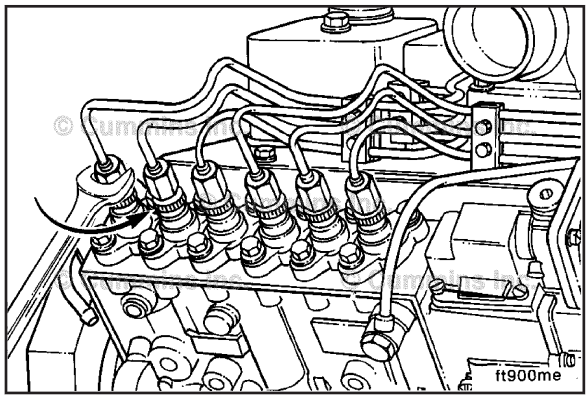
Attach a degree wheel or degree tape to the front of the vibration damper.

Line up the TDC mark with the pointer.

The degree wheel/tape **must** measure to an accuracy of at least 1 degree.



Install the fuel injection pump according to the procedures for a new fuel injection pump installation. If the fuel injection pump is already installed, continue the procedures.



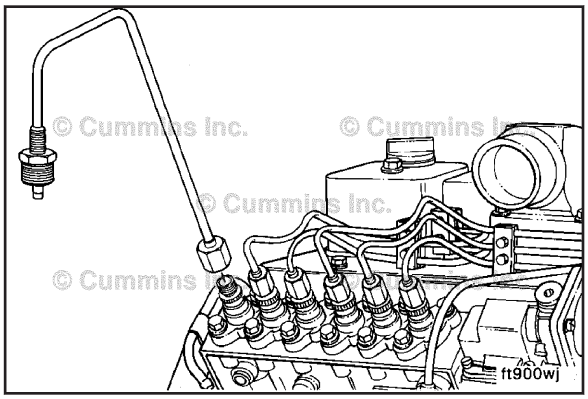
Remove the Number 1 high-pressure fuel line from the fuel injection pump.

NOTE: Lines 2 through 6 **must not** be removed or loosened.

⚠CAUTION⚠

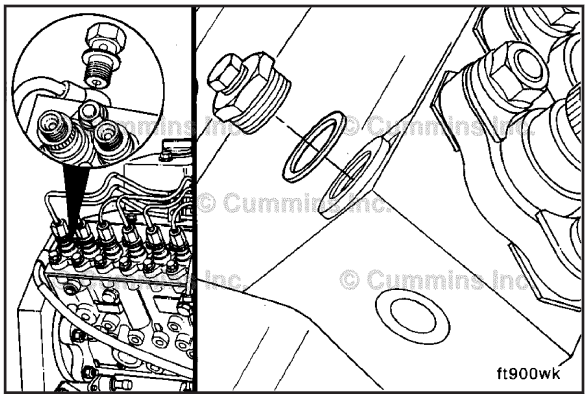
When attaching the fabricated tube, do not bend the Number 1 high-pressure fuel line. This could cause the inside of the fuel line to flake and cause injector failure.

A short length of high-pressure line that is compatible with the fuel lines used on the engine should 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 **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.



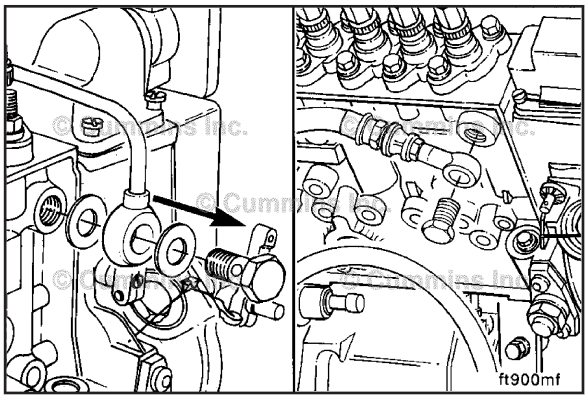
Remove the overflow valve from the fuel injection pump. Install a 14-mm [0.55-in] threaded plug and sealing washer into the fuel return port of the fuel injection pump.

NOTE: The fuel return port is located on the inboard front side of the fuel injection pump for automotive in-line application and on the outboard front side for most of the industrial applications.

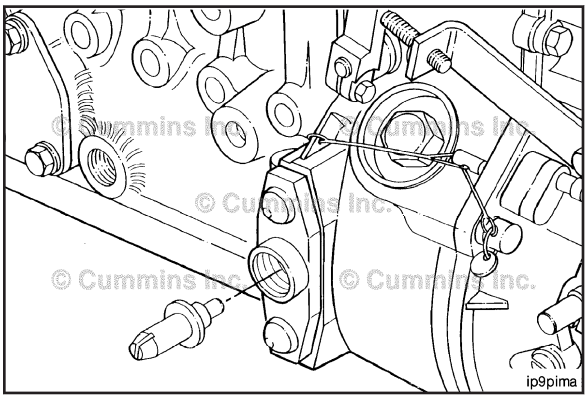


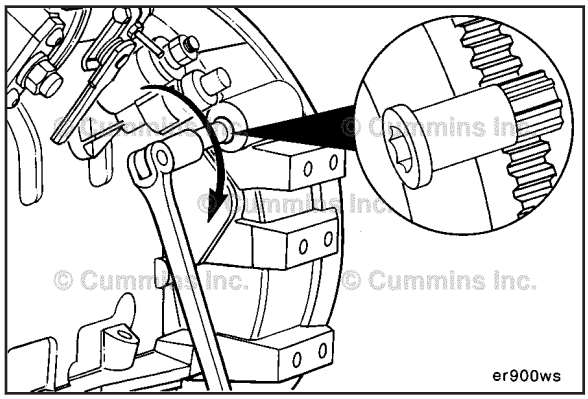
Remove the supply line from the fuel filter head to the fuel injection pump.

Attach the high-pressure outlet hose from the spill port to the fuel injection pump supply port.

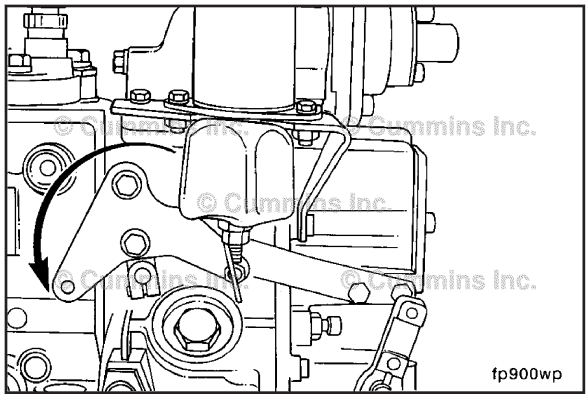


Before continuing, make sure the fuel injection pump lock-timing pin is disengaged.

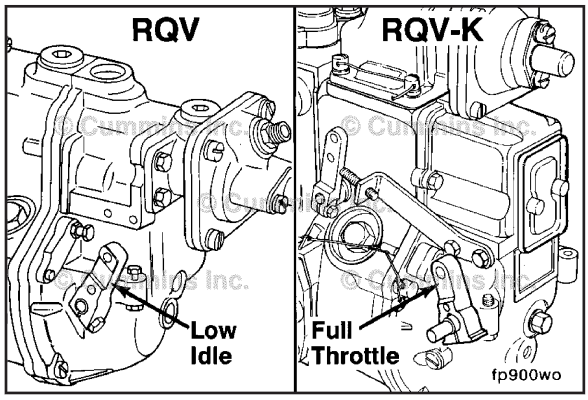




Rotate the crankshaft **counterclockwise**, as viewed from the front of the engine, to approximately 40 degrees before TDC.



Both the RQV and RQV-K governor require the shutdown lever to be in the full-run position.



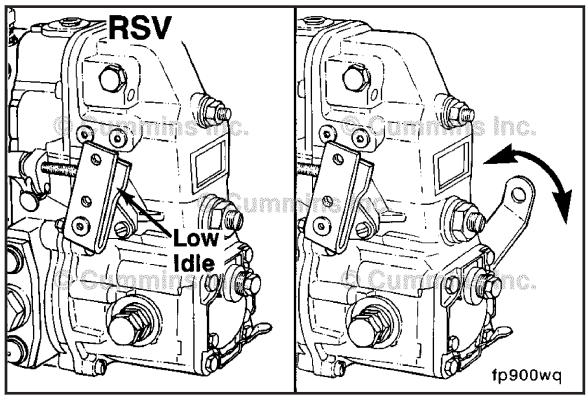
△CAUTION△
The governor lever must be positioned before pressurizing the fuel injection pump.

Governor Lever Positioning

The RQV governor throttle lever **must** be in the low-idle lever position.

The RQV-K governor throttle lever **must** be in the high-idle throttle position on automotive application.

The RQV-K industrial application **must** be in the low-idle position.

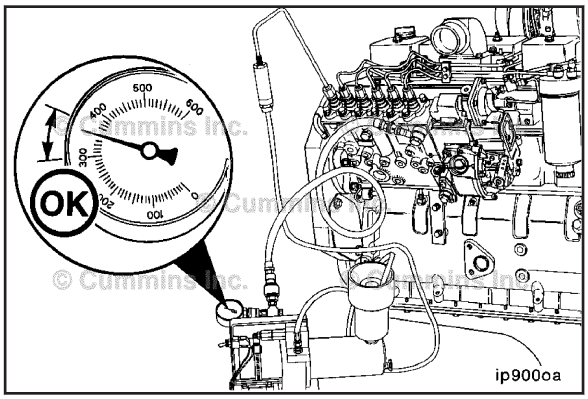


The RSV governor throttle lever **must** be in the low-idle position and the shutdown lever needs to be wired or locked in a suitable fashion to hold the shutdown lever in the 1/2-travel position.

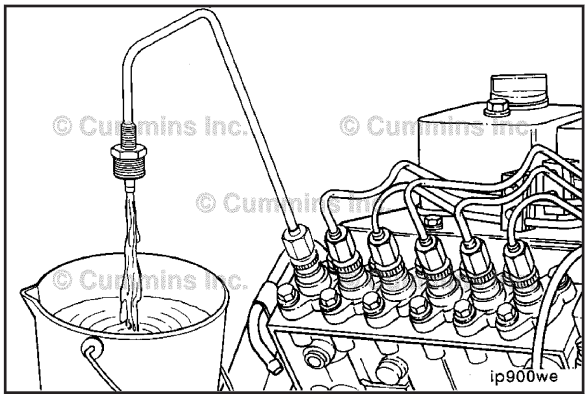
Turn on the spill timing cart pump.

Check the fuel pressure.

The pressure **must** be between 300 psi and 370 psi.

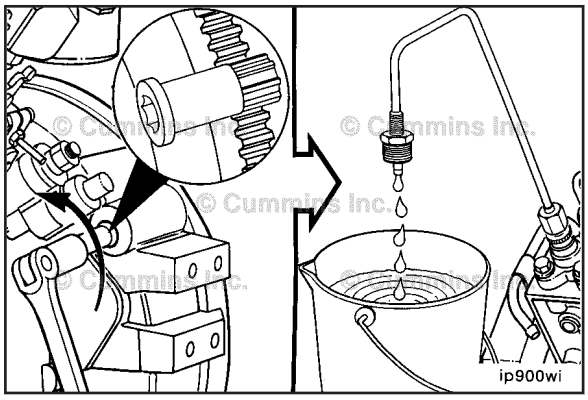


The fuel should be flowing out of the tube attached to the Number 1 cylinder of the fuel injection pump. If the fuel is **not** flowing, recheck the procedures carefully.



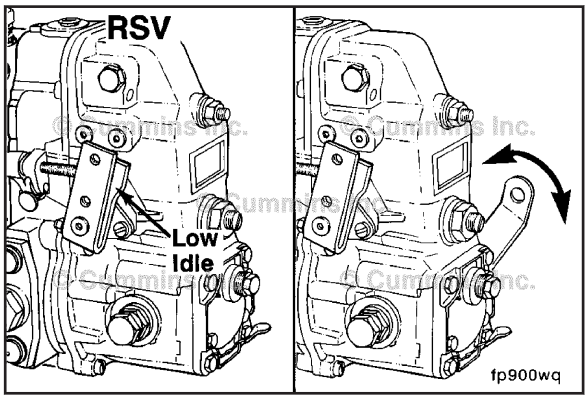
Slowly rotate the crankshaft in the **clockwise** direction, as viewed from the front of the engine, until the fuel flow from the Number 1 cylinder begins to reduce.

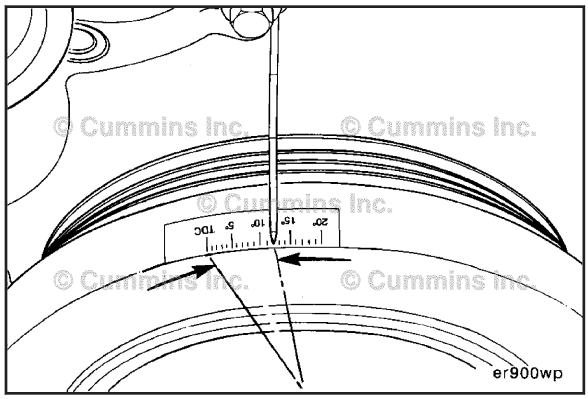
The Number 1 plunger element is now approaching "port closure." Continue to rotate the crankshaft slowly until the flow is reduced to a fast drip (more than one drip per second). At the point where the steady stream of flow changes from a solid flow to a fast drip, stop. This is the static timing position of the fuel injection pump.



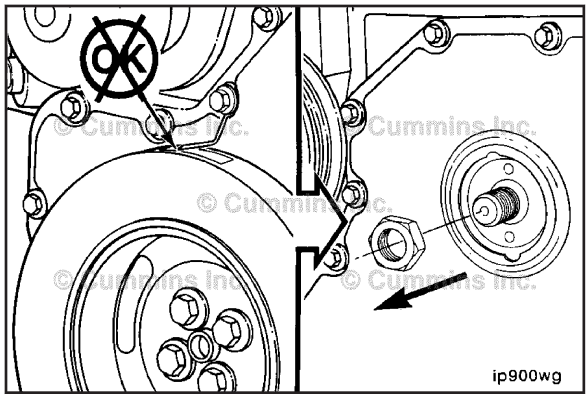
If the flow does **not** slow down to a drip, check the governor position. Also, make sure that the engine is before TDC on the compression stroke.

Turn off the spill port pump.



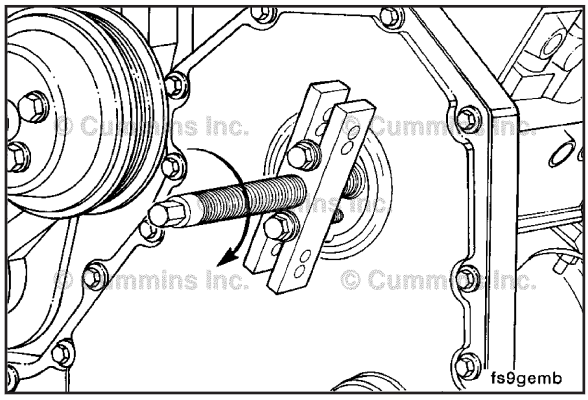


Check the degree wheel on the vibration damper to see what engine degree the timing pointer is indicating. This is spill port static timing. Compare this number to the timing specification for your particular application.



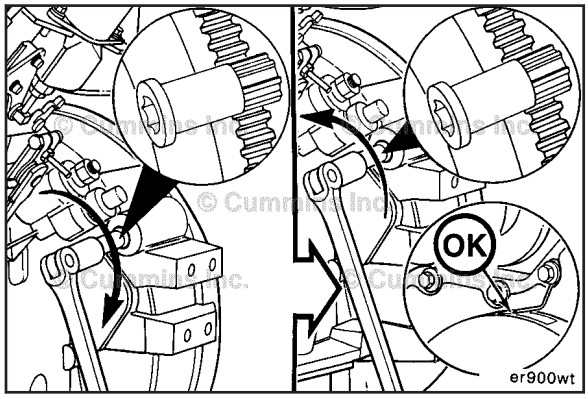
If the fuel injection pump static timing, as measured by the above method, does **not** agree with the specifications you have been given, remove the large nut that fastens the fuel injection pump camshaft to the fuel pump drive gear. If the crankshaft has rotated, turn on the spill port pump, and rotate the crankshaft to find port closure.

Turn off the spill port pump.



Fuel Pump Gear Puller, Part Number 3824469

Use a gear puller tool to 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 in the **clockwise** direction until the timing pointer is indicating the desired static timing.

QD Contact Cleaner, Part Number 3824510

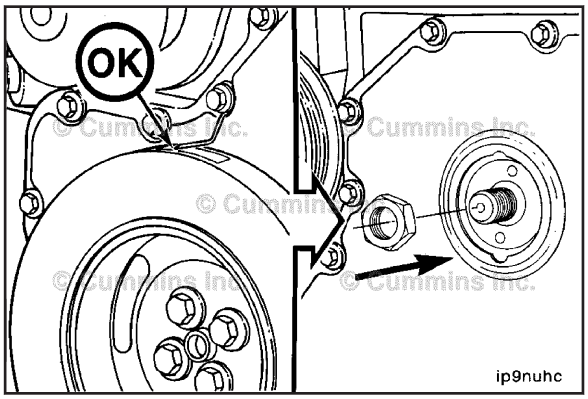
Clean the gear taper and pump taper with a nonpetroleum-based cleaner (electrical contact cleaner). Allow surface to dry before installing nut.

Tighten the fuel injection pump drive nut.

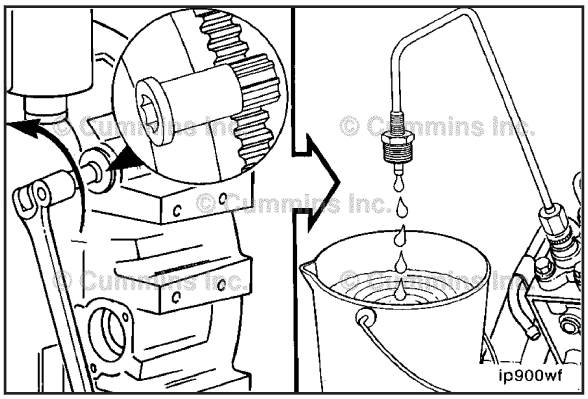
Make sure the static timing has **not** changed after the fuel injection drive nut is tightened to the required specification.

Torque Value:
A-Pump
Step 1 85 N•m [63 ft-lb]

Torque Value:
P3000/P7100
Step 1 195 N•m [144 ft-lb]



Repeat this procedure as needed until the timing is found to be in agreement with the specification.



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

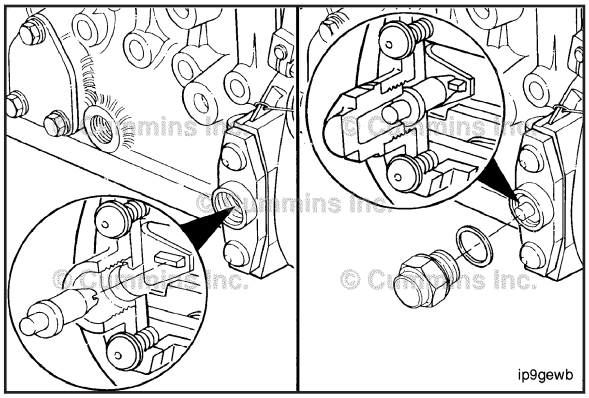
QD Contact Cleaner, Part Number 3824510

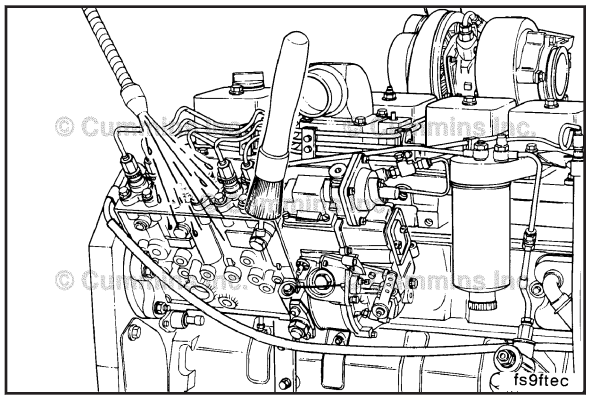
Torque Value:
Nippondenso
Step 1 123 N•m [91 ft-lb]

Torque Value:
Bosch® “A” Pump
Step 1 85 N•m [63 ft-lb]

Torque Value:
Bosch® In-Line (P3000/P7100) Pump
Step 1 195 N•m [144 ft-lb]

NOTE: Before installing the fuel pump drive gear, clean the injection pump shaft and gear tapers with a residue free cleaner (Cummins Part Number 3824510, or equivalent) by spraying into the gap between the shaft and the gear. Dry the taper surfaces with compressed air. Failure to clean and dry the shaft and gear tapers thoroughly can result in a timing shift to the retarded side after the engine is started and run under load. This will result in low power, smoke, and rough running.





Plunger Lift Timing

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

△CAUTION△
Do not allow any dirt, debris, or paint chips to enter the fuel system while it is open. If foreign material of any type is allowed into the pump, lines, or injectors during this process, it could result in an injection pump or fuel injector malfunction.

NOTE: This timing procedure can **only** be used on Bosch® P7100 fuel injection pumps.

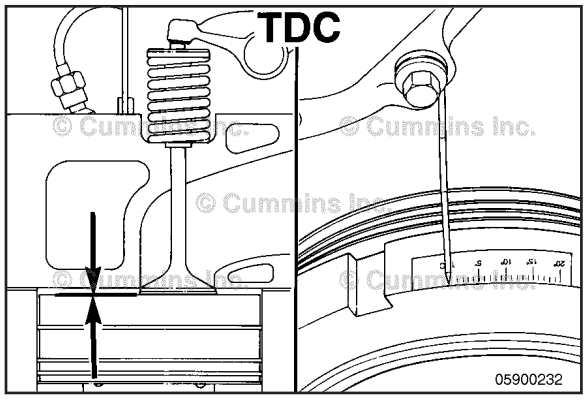
Plunger Lift Timing Kit, Part Number 3162853

The kit contains the following items:

- Dial indicator, Part Number 3824564
- Adapter, Part Number 3824565
- Special socket, Part Number 3824566
- Delivery valve seals, Part Number 3824567.

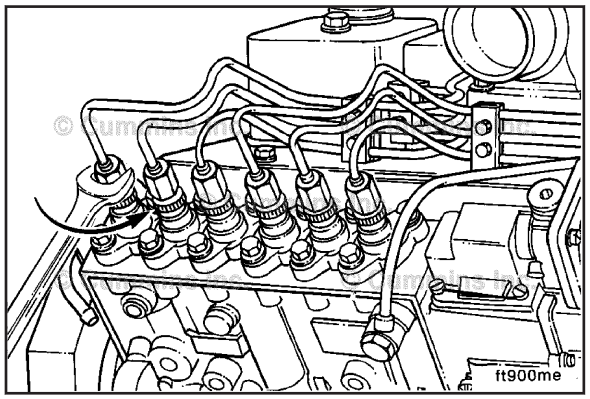
Step: 1

Thoroughly clean the engine and fuel system before attempting to remove any components. Pay special attention to the top of the fuel injection pump. Use compressed air to remove any water remaining on the fuel pump after the cleaning process.



Step: 2

Locate top dead center (TDC) of the compression stroke on cylinder Number 1. The following procedure uses the engine timing pin, but other alternate methods, such as the dropped valve method, can be used.



Step: 3

△CAUTION△
Do not bend the fuel lines. Bending the lines will cause line or injector failure.

If the injection lines have **not** already been removed, remove the Number 1 injection line.

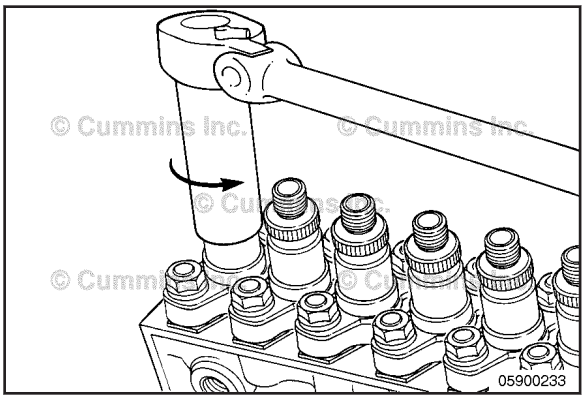
Step: 4

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

△CAUTION△
Do not loosen the two barrel flange nuts located below the delivery valve holder. Loosening of these nuts will void the fuel injection pump warranty.

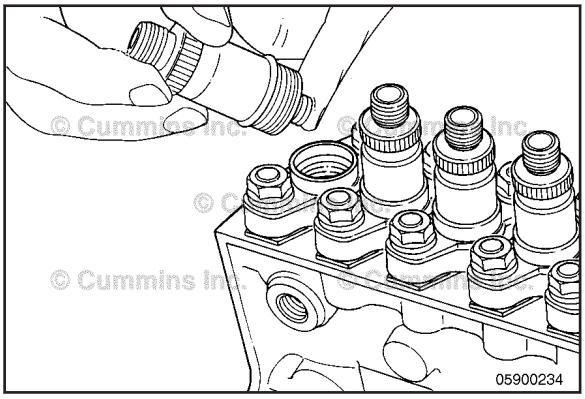
NOTE: There is an external o-ring on the holder to help prevent debris from getting into the pump; this can create a slight resistance as the holder is loosened.

With the engine at TDC, loosen, but do **not** remove the front (Number 1) delivery valve holder using the special socket provided in the timing kit. Use compressed air to remove any paint chips from around the delivery valve holder. Remove the special socket prior to removing the delivery valve holder from the fuel injection pump.

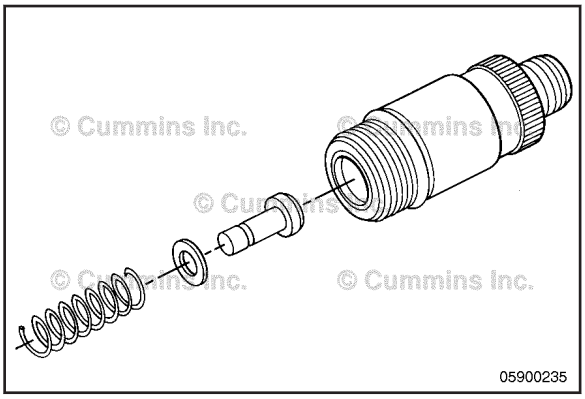


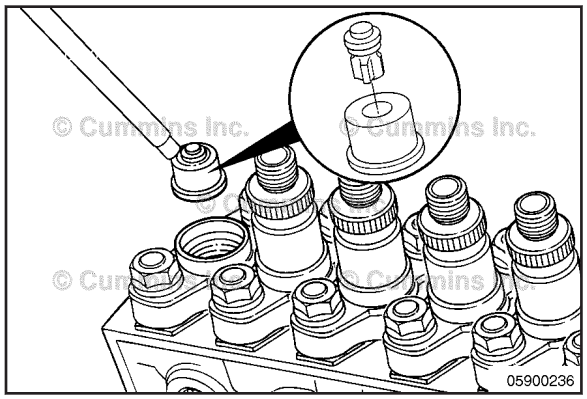
Step: 5

△CAUTION△
Use extreme care when removing the delivery valve holder and delivery valve components. Keep all parts together in the order in which they are removed from the fuel injection pump.



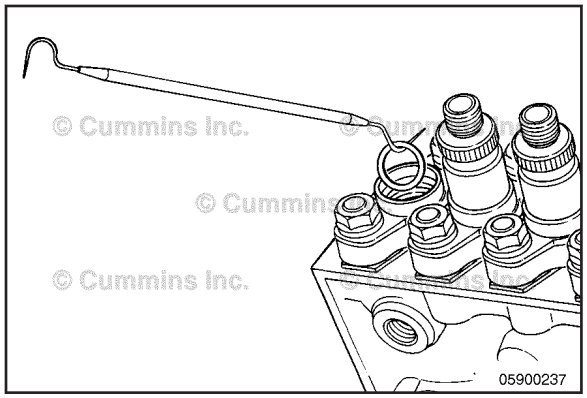
Remove the delivery valve holder by carefully tipping the holder outboard with one hand while using the other hand to hold the spring, fill piece, and any shims from slipping out of the holder. Place these as an assembly on a clean surface out of the way.





Step: 6

Using a magnet, remove the two-piece delivery valve assembly from the pump. Place these pieces on a clean surface with the delivery valve holder.

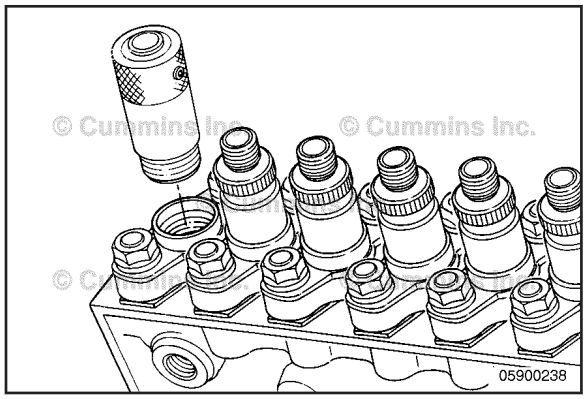


Step: 7

△CAUTION△
Do not scratch the top of the plunger/barrel assembly during gasket removal.

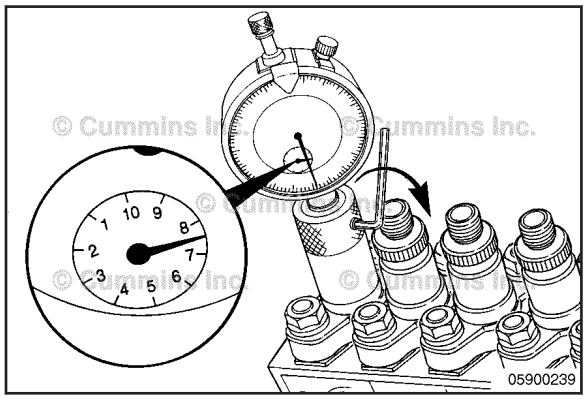
NOTE: The delivery valve gasket can be either bronze or steel, or on new injection pumps, there is often no gasket.

If the gasket is bronze, use a pick to remove it from the top of the pumping element; if the gasket is steel, use a pick or a magnet. Discard the used delivery valve gasket.



Step: 8

Install the dial indicator from the timing kit in place of the Number 1 delivery valve holder and tighten finger-tight.



Step: 9

Loosen the set screw on the dial indicator adapter, and install the dial indicator into the adapter. Position the dial indicator to read between 7.0 and 9.0 mm, and lightly tighten the set screw.

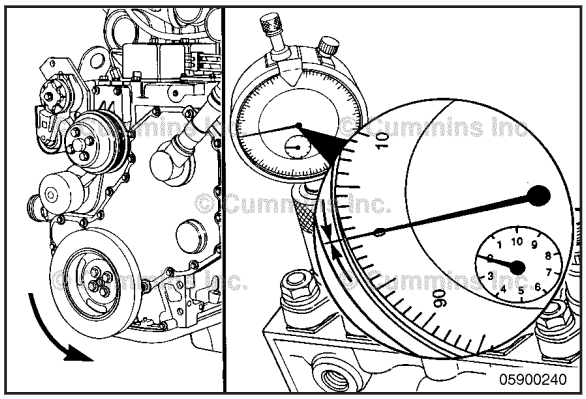
Overtightening the set screw will bind the dial indicator.

NOTE: The dial indicator is capable of measuring from 0 to 20.00 mm lift. The small inner dial is marked in increments of 1.00 mm; the large outer dial is marked in increments of 0.01 mm. One revolution of the outer dial is equal to 1.00 mm. The inner dial **only** indicates 0 to 10.00 mm, but will rotate twice as the indicator goes through the full range.

Step: 10

⚠CAUTION⚠
Be sure to disengage the timing pin before rotating the crankshaft to avoid damage to the timing pin.

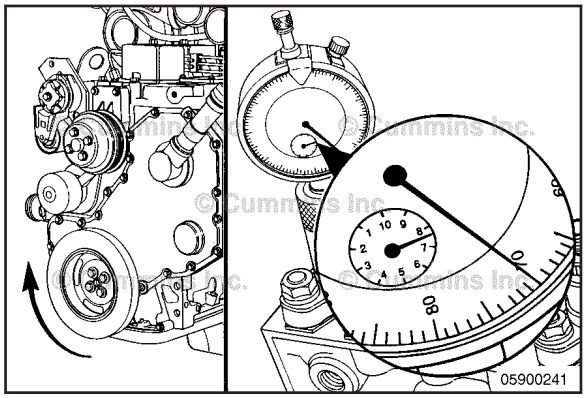
Use a barring tool to rotate the crankshaft in the direction opposite normal direction of crankshaft rotation (**counterclockwise** from front of the engine) 1/4 turn or until the dial indicator reading stops dropping. This is the inner base circle of the fuel injection pump camshaft. Zero “0” the indicator and note the reading on the small inner dial.



Step: 11

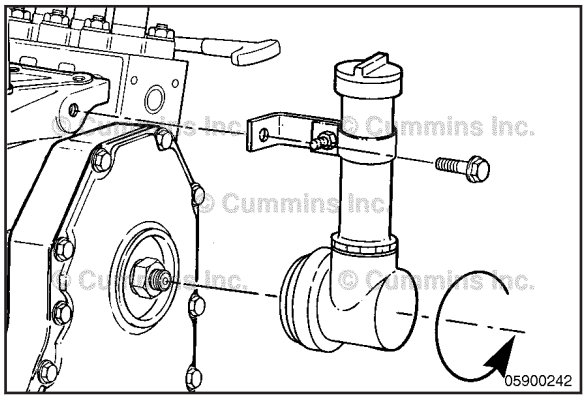
Rotate the crankshaft slowly to TDC in the direction of normal crankshaft rotation (**clockwise** from front of the engine).

The total lift **must** be within the specified lift for that CPL. The attached table lists the lift setting in millimeters (mm) that corresponds to the engine timing specification in degrees.



Step: 12

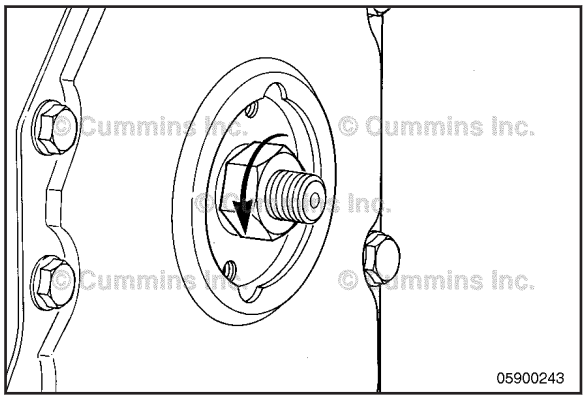
If a change in injection timing is required, remove the oil filler tube and adapter elbow or fuel injection pump gear access cap from the front of the gear housing.

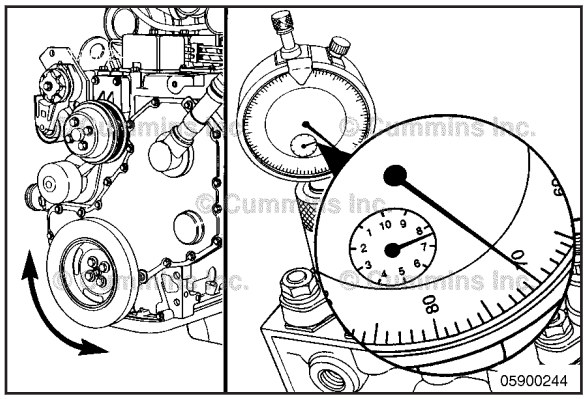


Step: 13

⚠CAUTION⚠
Be sure to disengage the timing pin before rotating the crankshaft to avoid damage to the timing pin.

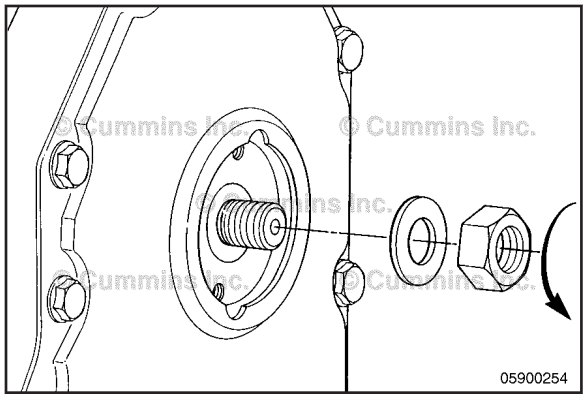
Loosen the injection pump shaft nut approximately 1/4 turn. The barring tool can be used to keep the crankshaft from rotating.





Step: 14

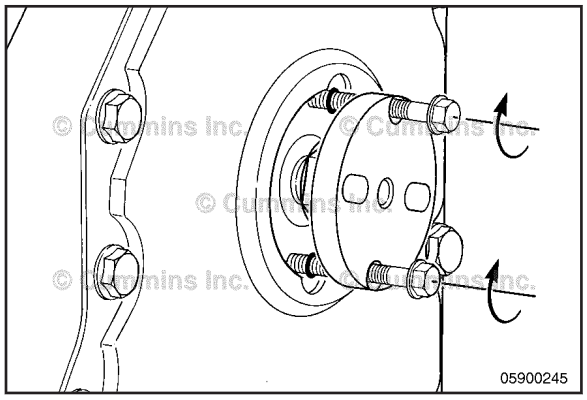
If the actual lift setting is **not** within specification, rotate the crankshaft to obtain the desired dial indicator setting (plunger lift).



CAUTION
Do not allow the drive nut or washer to drop inside the engine gear cover. Disassembly of the engine will be required for retrieval.

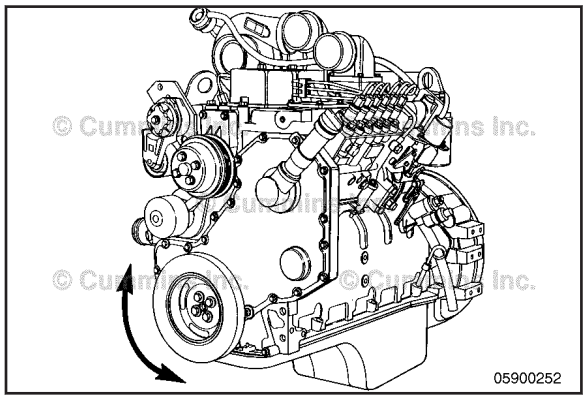
Remove the fuel injection pump driveshaft nut and lock washer.

Service Tip: Use a pointed object such as a metal awl and a magnet, to assist in the removal of the lock washer.



Step: 15

With the fuel injection pump positioned at the correct plunger lift setting, use the gear puller, Part Number 3824469, or equivalent, to pull the injection pump gear off the taper of the injection pump input shaft. Remove the gear puller.

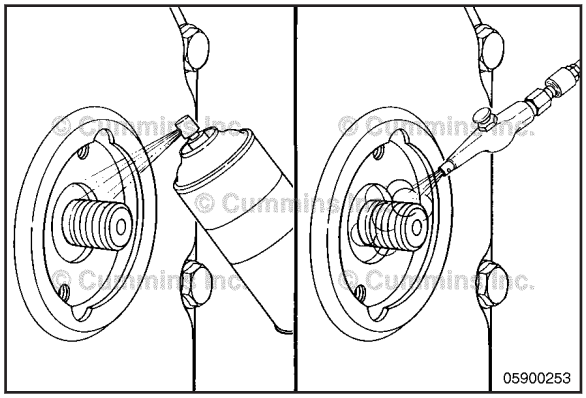


Step: 16

Rotate the crankshaft 20 degrees to 30 degrees opposite the direction of normal crankshaft rotation; then rotate the crankshaft back in the direction of normal crankshaft rotation to TDC. This step removes the backlash from the lower gear train.

Step: 17

Clean the fuel injection pump shaft and gear tapers with a residue-free cleaner (Cummins Part Number 3824510, or equivalent) by spraying into the gap between the shaft and gear. Dry the taper surfaces with compressed air. Failure to clean and dry the shaft and gear tapers thoroughly can result in a timing shift to the retarded side after the engine is started and run under load. This will result in low power, smoke, and rough running.



Step: 18

CAUTION
Be sure the timing pin is disengaged before the final tightening step to avoid damage to the timing pin.

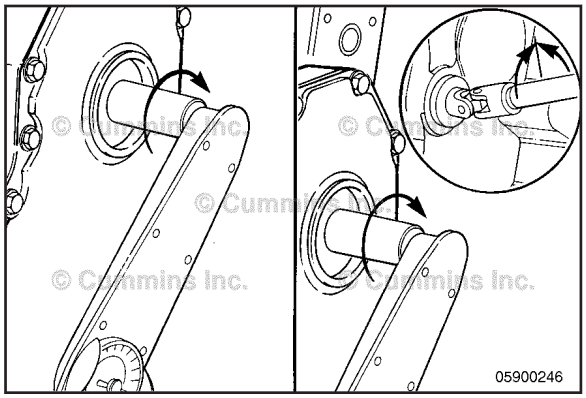
Install the input shaft lock washer and nut. Use a 2-step tightening process to tighten the fuel injection pump gear nut.

Torque Value: 15 N•m [133 in-lb]

This will seat the shaft taper.

Hold the crankshaft from rotating (using the barring tool or other means) on the final step of the tightening sequence.

Torque Value: 165 N•m [122 ft-lb]



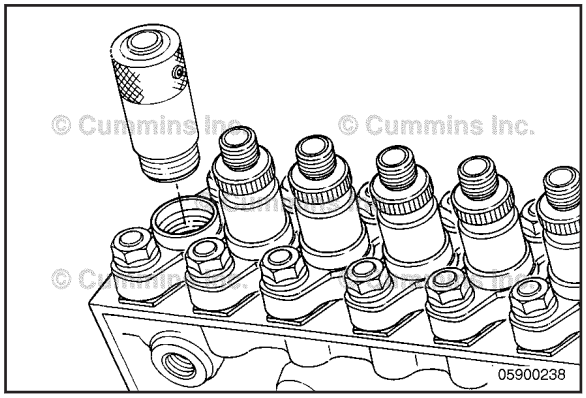
Step: 19

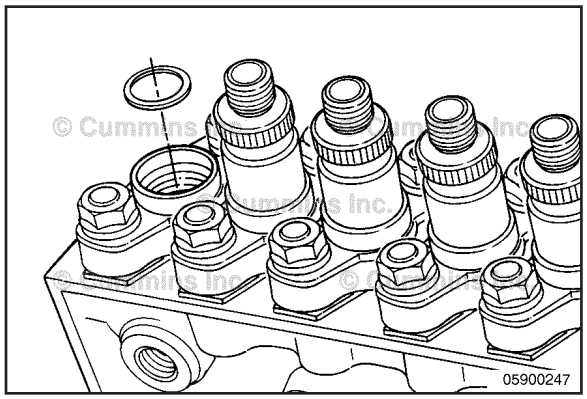
Repeat steps 10 and 11 to verify that the final timing setting is correct.

Step: 20

CAUTION
The following steps for installing and tightening the delivery valve and holder must be followed exactly. Improper installation will result in delivery valve damage or leaks.

Remove the dial indicator and adapter from the fuel injection pump.

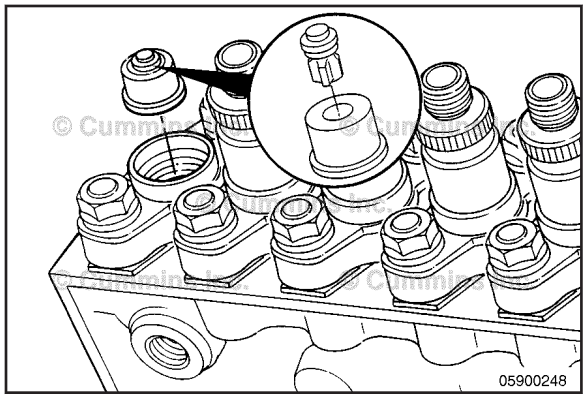




Step: 21

Inspect the fuel injection pump bore for debris. The bore **must** be free of debris.

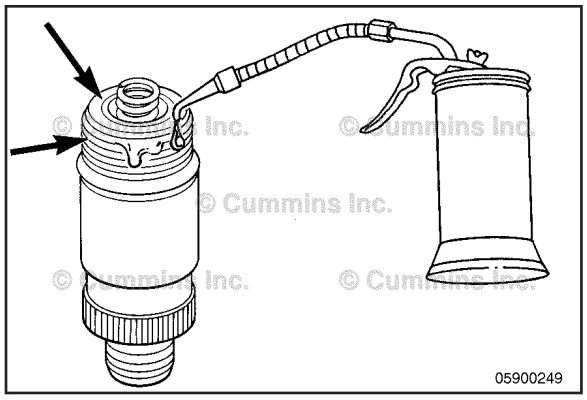
If a gasket was removed from under the delivery valve, install a new delivery valve gasket (Cummins Part Number 3824567) into the fuel injection pump. Do **not** use a gasket if this is a pump with gasketless delivery valves. See attached list of pumps that have or do **not** have delivery valve gaskets.



Step: 22

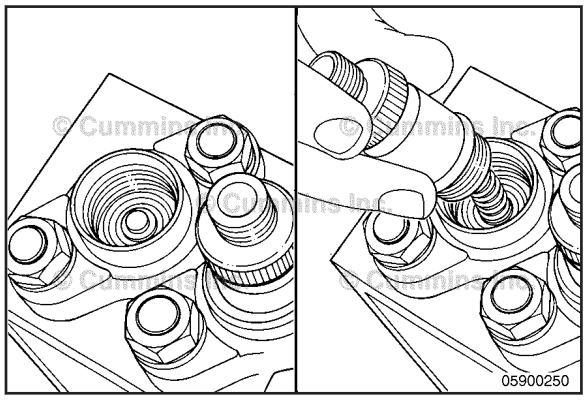
Clean the delivery valve parts with residue-free cleaner (Cummins Part Number 3824510, or equivalent) prior to reassembly.

Install the delivery valve assembly.



Step: 23

Lubricate the threads and clamping surface of the delivery valve holder with a few drops of SAE 90 hypoid gear oil. Do **not** lubricate the delivery valve gasket or its seating area.



Step: 24

Install the delivery valve holder assembly, taking care **not** to displace the delivery valve spring, fill piece, or any shims.

Step: 25

⚠WARNING⚠
Keep hands and body parts away from the high-pressure fuel lines. Fuel coming from the high-pressure fuel lines is under extreme pressure and can cause serious injury by penetrating the skin.

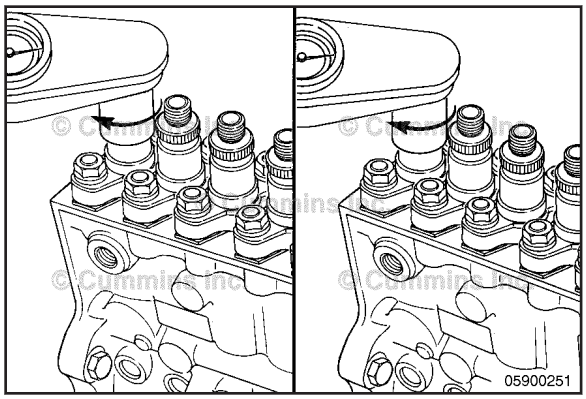
Use step 1 to initially tighten the holder; then, in one motion, use step 2 for the final torque value.

Torque Value:

Step 1	40 N•m	[29 ft-lb]
Step 2	115 N•m	[85 ft-lb]

Install the remaining engine components removed during the TDC location or timing process. Leave the injector side of the high-pressure fuel lines loose to facilitate bleeding the air out of the system.

Crank the engine until fuel is observed at the injectors. Tighten the high-pressure lines at the injector. Start the engine, and vent one line at a time until the engine runs smoothly. Check for leaks.



The following is a list of Bosch® P7100 fuel injection pumps that use delivery valve gaskets. Pumps used in ratings developed after these will use delivery valves without gaskets. If the pump was developed in North America and it is **not** on this list, it will be without gasket. If **not** sure about the type of pump, call the Technical Support Hotline, (812) 377-6517.

Part Number	
3913340	3921922
3916626	3922424
3916627	3921923
3916628	3921925
3916629	3921970
3917088	3922425
3917089	3922426
3918321	3922427
3919090	3922446
3921769	3922449
3921770	3922471
3921771	3924903
3921772	3925085
3921773	3925086
3921774	3926603
3921775	3927923
3921776	3927924
3921777	3928169
3921918	3928412
3921920	3928606

The following table supplies the lift specifications for the Bosch® P7100 fuel injection pumps **only**. The allowable tolerance range for timing is ± 0.1 mm.

Static Injection Timing (from engine dataplate, degrees BTDC)	987, 1261, 1262, 1263, 1406, 1422, 1582, 1618, 1850, 2118, 2196	1549, 1550, 1551, 1552, 1553, 1815, 1816, 1839, 1914, 1915, 1916, 1959	1863, 1968, 2022, 2174, 2265, 2268, 2308	2023, 2175	1563, 1566, 1569, 1658, 1812, 1905, 1917, 1918, 1920, 1922, 1923, 1949, 1950, 1972, 2034, 2101, 2103, 2104, 2106, 2107, 2108, 2150	1564, 1919, 2011, 2102, 2105, 2158, 2169, 2191
9.5	6.05	5.15	N/A	N/A	5.65	5.6
10	6.15	5.25	N/A	N/A	5.75	5.7
10.5	6.25	5.35	N/A	N/A	5.85	5.8
11	6.35	5.45	4.0	N/A	5.95	5.9
11.5	6.4	5.55	4.05	4.7	6.05	6
12	6.5	5.65	4.15	4.8	6.15	6.05
12.5	6.6	5.7	4.2	4.9	6.25	6.15
13	6.7	5.8	4.3	5	6.35	6.25
13.5	6.8	5.9	4.4	5.1	6.45	6.35
14	N/A	6.0	4.5	5.2	N/A	N/A
14.5	N/A	6.1	4.6	5.3	N/A	N/A
15	N/A	N/A	4.7	5.4	N/A	N/A

The following table supplies the lift specifications for the Marine Midrange engines. The nominal value for control parts list (CPL) 1975 is 22 degrees and CPL 2172 and 2208 is 24 degrees. The allowable range for timing remains at ± 1 degree of nominal.

Control Parts List		
Static Injection	**Marine B Series**	**Marine C Series**
Lift Value	CPL(s) 1975, 2208	CPL 2172
20.0	7.90	7.29
20.5	8.02	7.40
21.0	8.14	7.52
21.5	8.26	7.63
22.0	8.38	7.75
22.5	8.51	7.87
23.0	8.63	7.98
23.5	8.75	8.10
24.0	8.88	8.22
24.5	9.01	8.34
25.0	9.13	8.47
25.5	9.26	8.59
26.0	9.39	8.71

Fuel Injection Pump, Rotary (005-014)

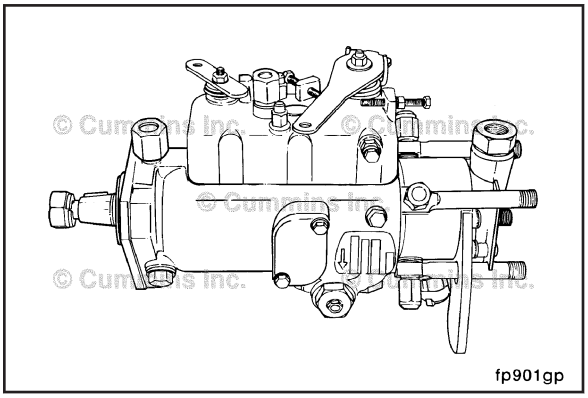
General Information

Fuel System Identification

The B Series engine uses many different fuel injection pumps, depending on the horsepower rating and application.

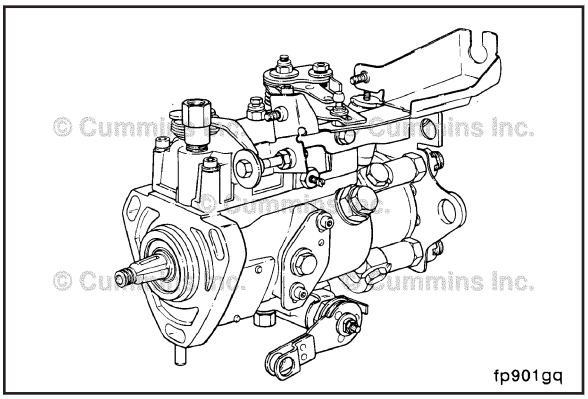
The Lucas CAV DPA distributor-type fuel injection pump can be found on the following engine applications:

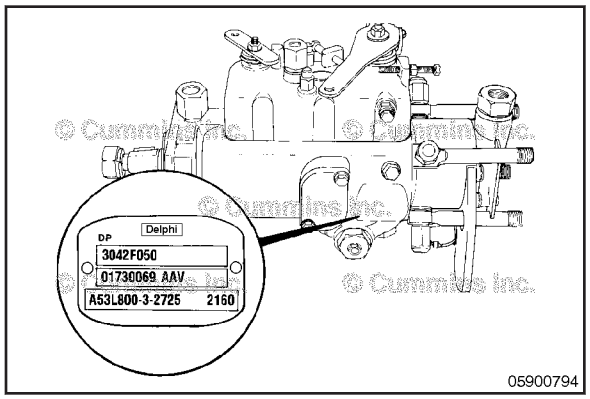
- Marine
- Industrial.



The Lucas CAV DPS distributor-type fuel injection pump can be found on the following engine application:

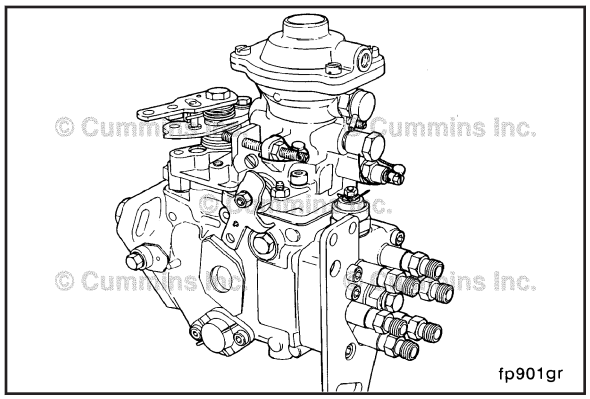
- European and U.K. automotive ratings.





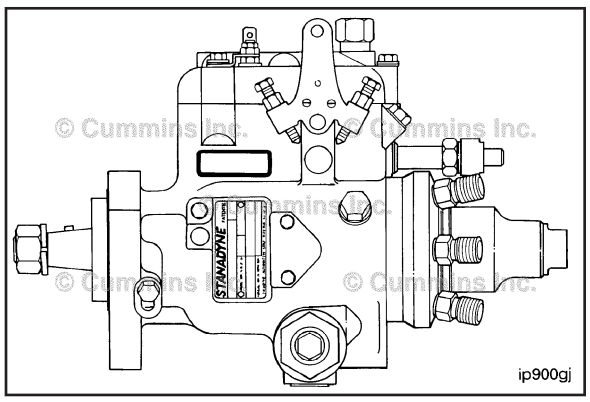
The Delphi DP210 distributor-type fuel injection pump can be found on the following applications:

- Industrial (Tier 2/Stage II Certified).



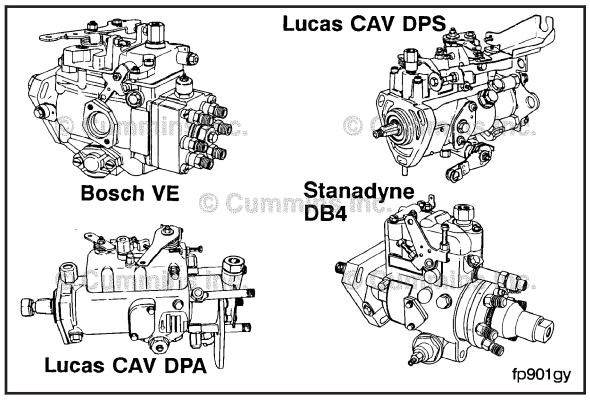
The Bosch® VE distributor-type fuel injection pump can be found on the following engine applications:

- Industrial
- 1991 low-horsepower automotive ratings.



The Stanadyne DB4 distributor-type fuel injection pump can be found on the following engine application:

- Gen Sets



Fuel Injection Pump (Distributor Type)

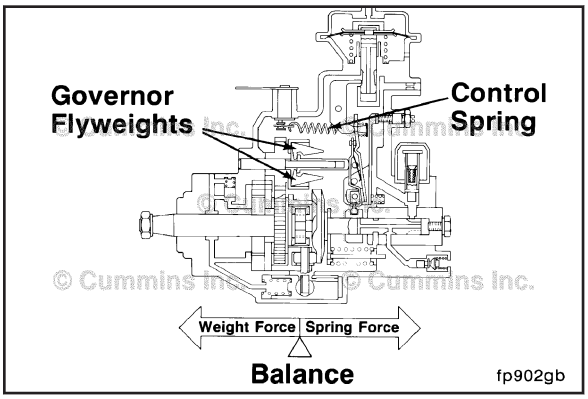
The fuel injection pumps, Bosch® VE, Lucas CAV DPA, Stanadyne DB4, Lucas CAV DPS, and Delphi DP210, are rotary distributor pumps. These pumps perform the four basic functions of:

1. Producing the high fuel pressure required for injection
2. Metering the exact amount of fuel for each injection cycle
3. Distributing the high-pressure, metered fuel to each cylinder at the precise time
4. Varying the timing relative to engine speed.

Distributor-Type Pump Governor

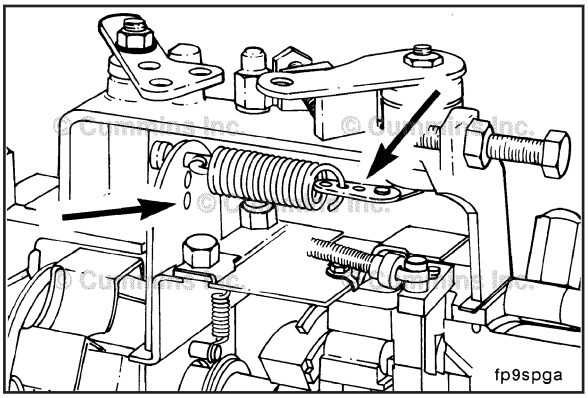
Balance between the governor flyweights and control lever position controls the metering of the amount of fuel to be injected.

The fuel injection pump governor performance and setting can affect engine power. Special equipment and qualified personnel are required to verify governor performance. If the seals are broken on the external Bosch® VE adjustment screw, the fuel rate can, perhaps, be out of adjustment.



The Lucas CAV DPA/DPS fuel injection pump uses a coded spring connection to change the governor setting. Incorrect connection of the governor spring can affect performance.

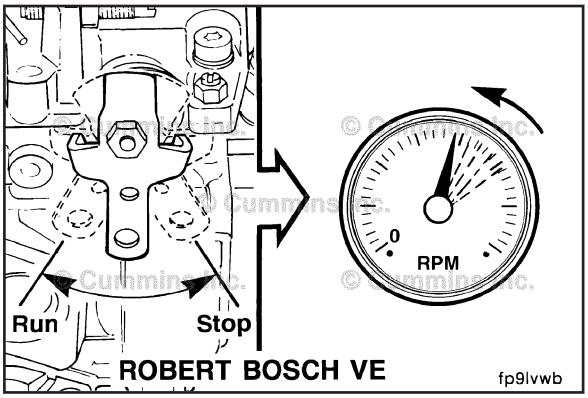
Adjustments and rating changes are described in the Master Repair Manual, Injector Pumps and Injectors, Bulletin 3666037.



Manual Shutdown Levers

Both fuel injection pumps are equipped with mechanical shutdown levers. These levers are spring-loaded in the run position. **Not** all applications will use these manual shutdown controls and there will be no cable or rod connected to the lever.

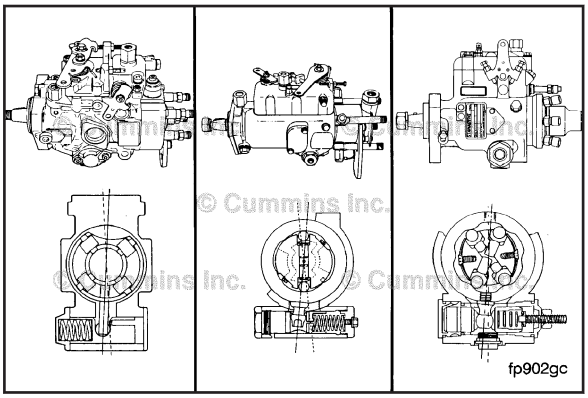
NOTE: Partial actuation of the mechanical shutdown levers will affect fuel flow and engine power.

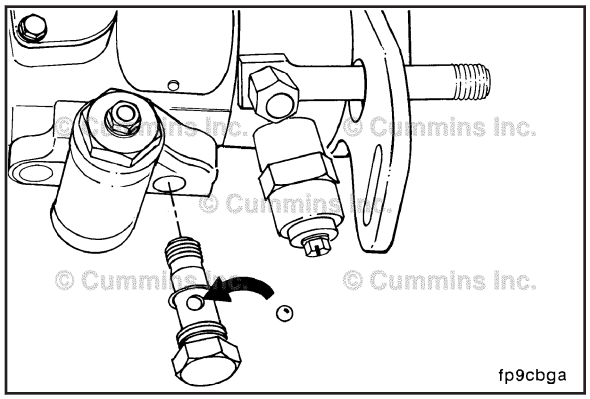


Advance Timing Mechanism

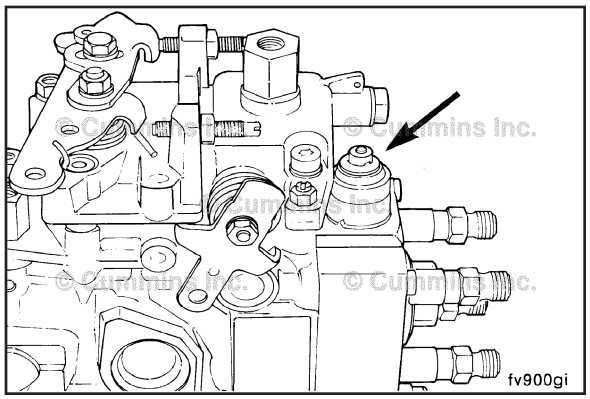
Regulated pressure produced by a vane supply pump in both fuel injection pumps is used to advance the timing as the engine speed increases. A return spring is used to retard the timing as the engine speed is reduced. If a spring breaks, the timing will go to the advance position, resulting in torque loss, fuel knock, and possible engine overheating.

Retarded (late) timing will result in torque loss, high fuel consumption, and white to black smoke.





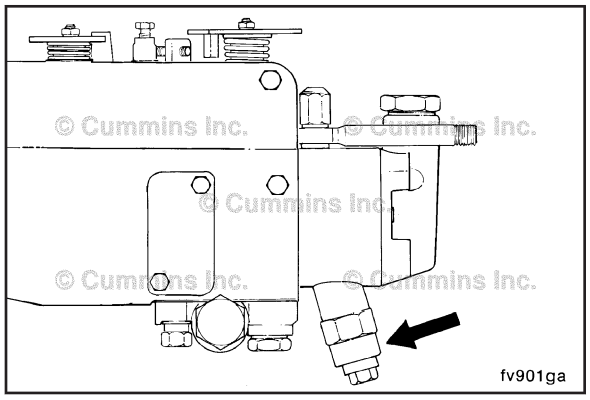
The Lucas CAV DPA/DPS advance timing mechanism uses a check ball in the circuit which, if omitted during assembly, will result in no timing advance. If the fuel injection pump has been replaced or the mechanism has been removed to fix a leak, the problem can be that the check ball is missing.



Electrical Shutoff Valves

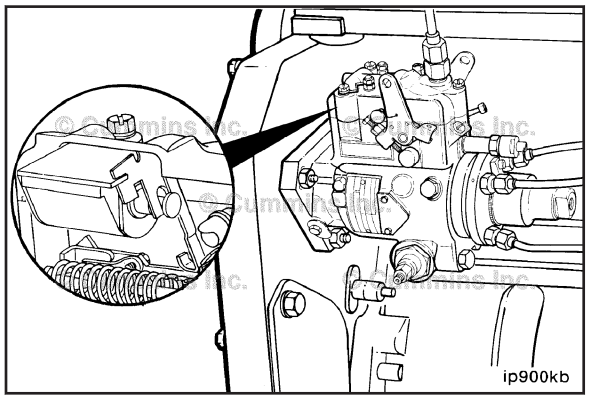
The fuel injection pumps are equipped with electrical shutoff valves. These solenoid-operated valves block the supply of fuel to the high-pressure pumping and distribution components.

The Bosch® VE shutoff valve is located at the top rear of the pump.



The Lucas CAV DPA/DPS shutoff valve is located at the bottom rear of the pump.

Both 12- and 24-VDC activate-to-run and activate-to-stop solenoids are available.



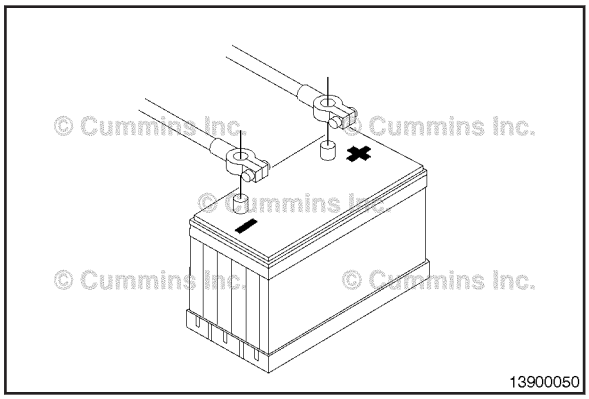
The Stanadyne DB4 shutdown solenoid is located under the governor cover.

Both 12-VDC and 24-VDC activate-to-run and activate-to-stop solenoids are available.

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.

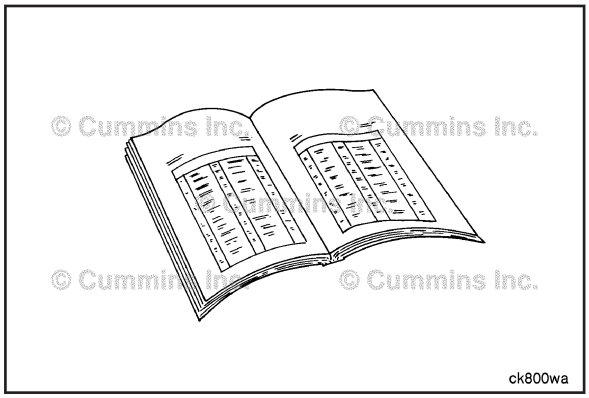


⚠CAUTION⚠
Do not remove the control lever. The fuel control lever on the Bosch® VE fuel injection pump is indexed to the shaft during pump calibration. If the lever has been removed and reinstalled incorrectly, engine speed and power will be affected.

Rotary Distributor Type Fuel Injection Pumps

Bosch® VE, Lucas CAV DPA, Stanadyne DB4, and Delphi DP210

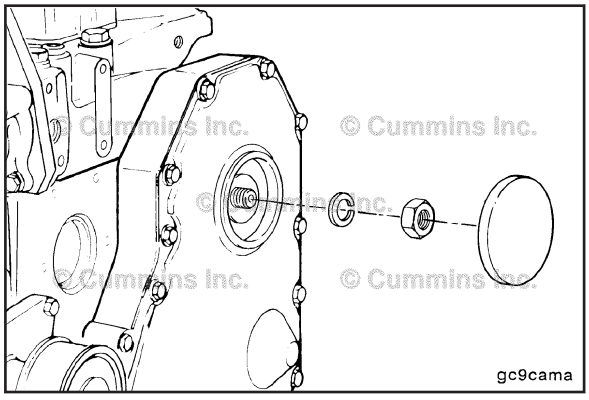
- Disconnect the fuel drain manifold. Refer to Procedure 006-021.
- Remove the injection pump supply line. Refer to Procedure 006-024.
- Remove the high-pressure lines. Refer to Procedure 006-051.
- Disconnect the electrical wire to the fuel shutoff valve. Refer to Procedure 005-043.
- Remove the fuel air control tube, if used. Refer to Procedure 006-001.
- Disconnect all control linkage. Refer to the OEM service manual
- Remove the pump support bracket. Refer to Procedure 005-033.

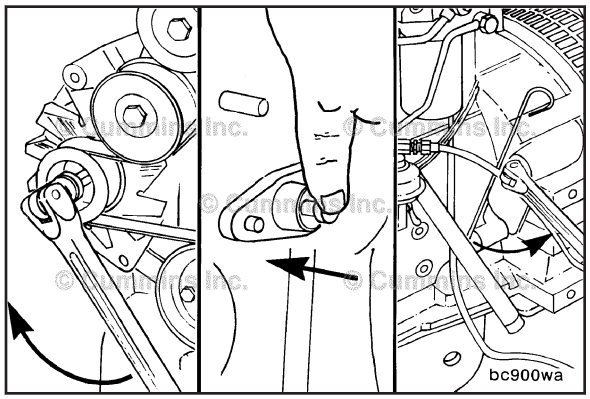


Remove

Front Gear Train

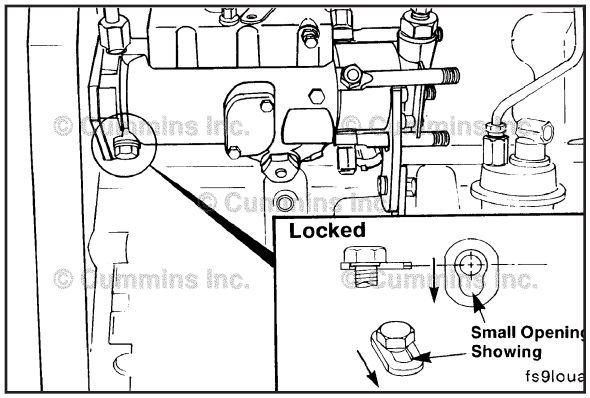
Remove the access cap, gear retaining nut, and washer.





NOTE: Be **sure** to disengage the pin after locating top dead center.

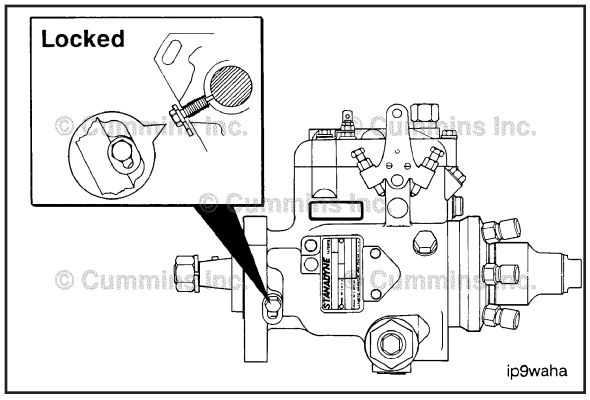
Locate top dead center for cylinder Number 1 by barring the engine slowly, while pushing in on the top dead center pin.



Lucas CAV DPA Pump and Delphi DP210

Loosen the CAV fuel injection pump lock screw and position the special washer; then tighten the lock screw against the pump drive shaft.

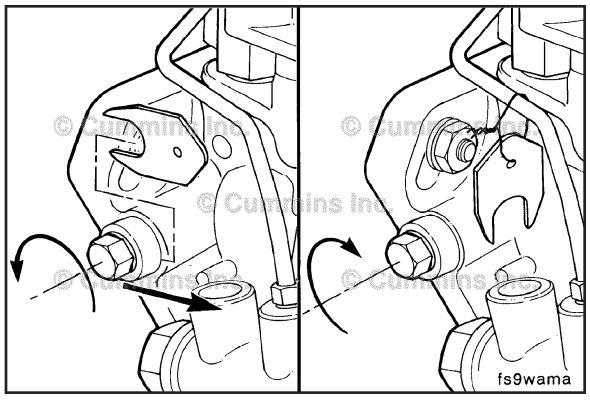
Torque Value: 7 N•m [62 in-lb]



Stanadyne DB4 Pump

Loosen the Stanadyne DB4 fuel injection pump lock screw and position the special washer. Tighten the lock screw until contact is made with the fuel injection pump drive shaft.

Torque Value: 12 N•m [106 in-lb]



Bosch® VE

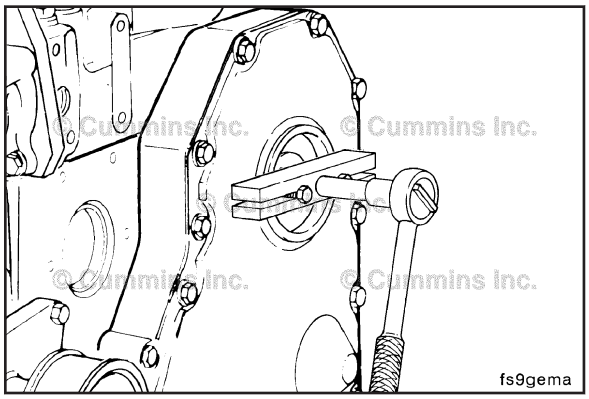
The special washer on the Bosch® VE injection pump **must** be removed so the lock screw can be tightened against the drive shaft.

Torque Value: 30 N•m [22 ft-lb]

NOTE: Wire the washer to the pump.

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

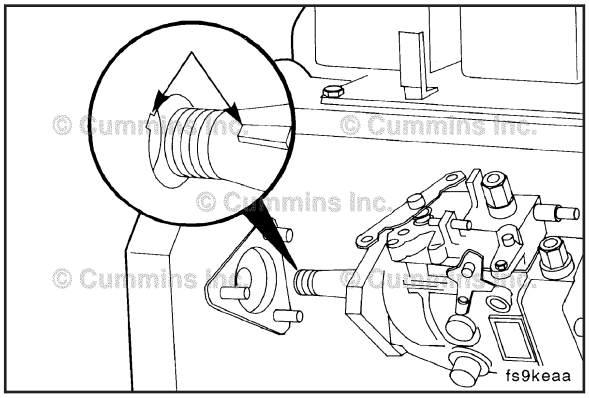
Use fuel pump gear puller, Part Number 3163381 or Part Number 3824469, with M8-1.25 x 50 capscrews, Grade 8.8 or equivalent.



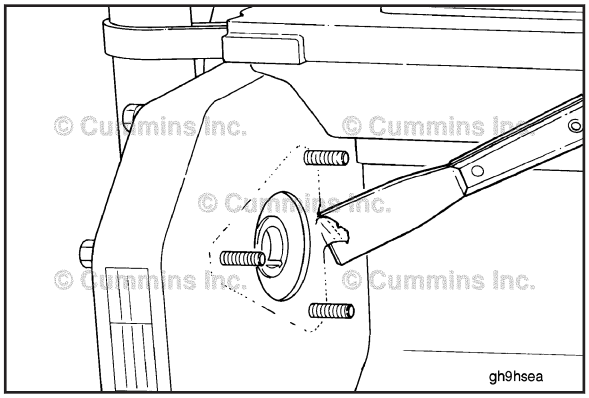
⚠CAUTION⚠
Do not drop drive gear key when removing the pump. Failure to do so can result in severe engine damage.

Remove the three mounting nuts and take off the fuel injection pump.

NOTE: Fuel pumps on engines designed to meet Tier 2/ Stage II Industrial emissions levels have straight holes (**not** kidney slots) and do **not** use a timing key.

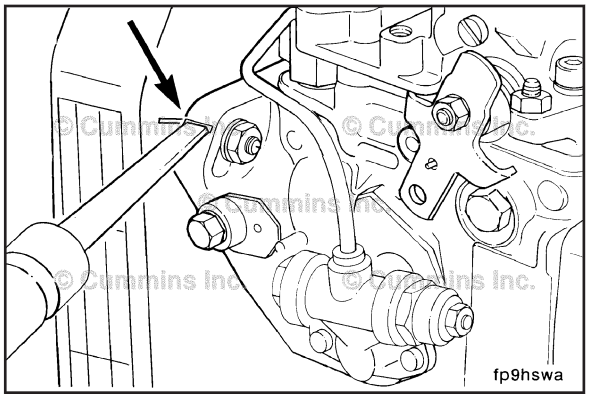


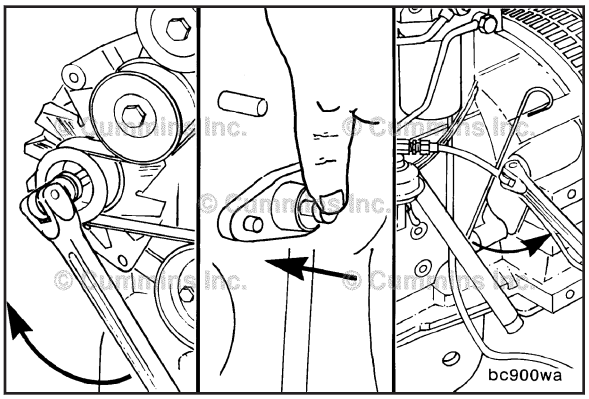
Remove the gasket and clean the surface.



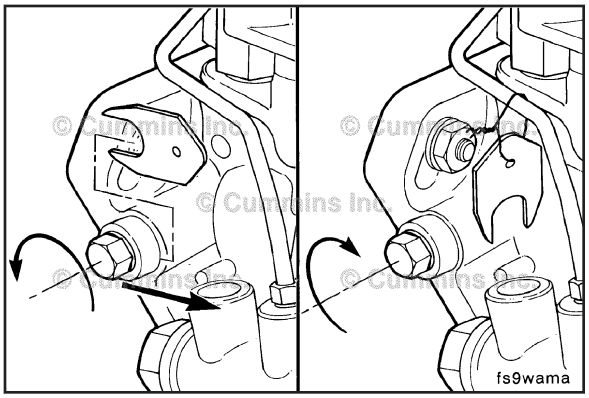
Rear Gear Train

Permanently mark the injection pump flange to match the mark on the fuel pump mounting plate.





Unlike the front gear train engine, do **NOT** remove the timing pin until completion of the repair. Failure to do so can result in difficult reassembly and incorrect timing of the fuel pump.



⚠CAUTION⚠
Failure to properly torque the lock screw will result in improper timing of the pump during reassembly.

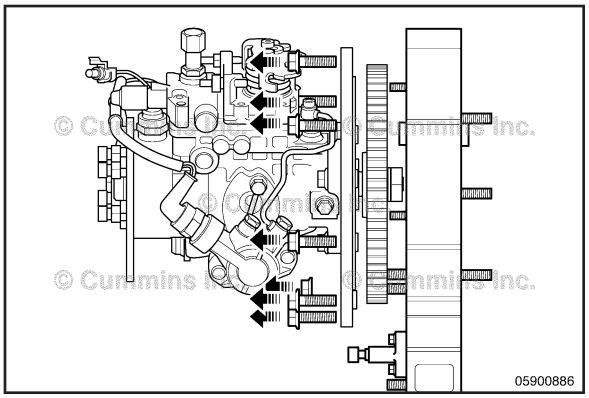
Bosch® VE

The special washer on the Bosch® VE injection pump **must** be removed so the lock screw can be tightened against the drive shaft.

Torque Value: 40 N•m [22 ft-lb]

NOTE: Wire the washer to the pump.

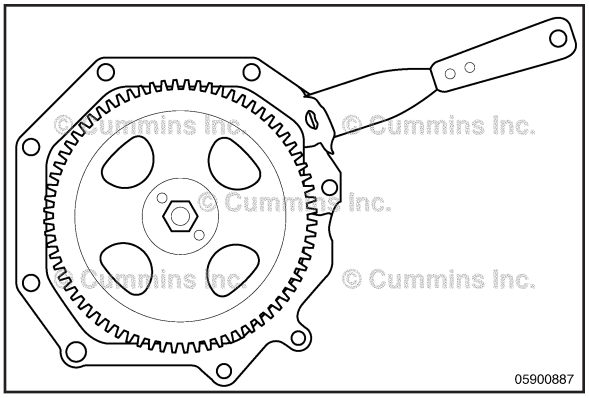
NOTE: The torque specification for the rear gear train engine is higher than the front gear train engine, to prevent rotation of the pump shaft during installation of the fuel pump gear retaining nut.



Remove the mounting nuts and bolts affixing the fuel pump mounting plate to the rear gear housing.

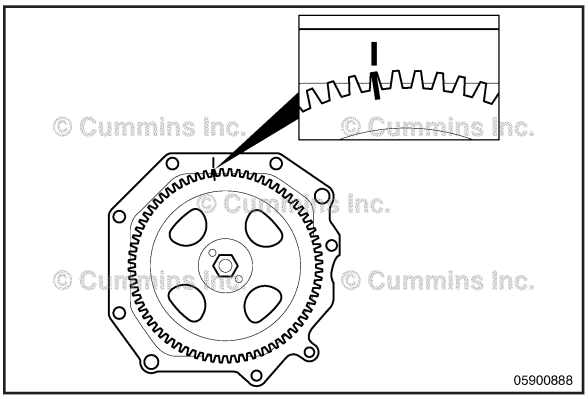
Take off the fuel injection pump, fuel pump mounting plate, and fuel pump gear as an assembly.

NOTE: Make sure the gear does **not** rotate during removal; failure to do so can result in incorrect timing of the pump during installation.



Remove the gasket and clean the surface.

Mark a tooth on the fuel gear pump relative to the fuel pump mounting plate.

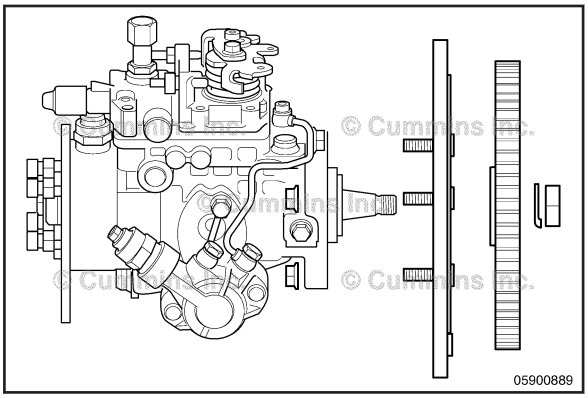


Remove the fuel pump retaining nut and washer.

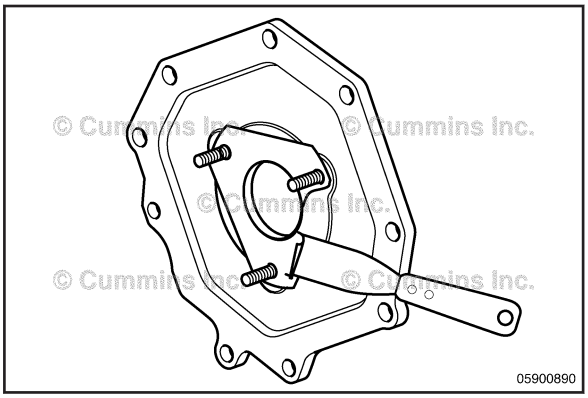
Remove the fuel pump gear.

Loosen the three mounting nuts attaching the fuel pump to the fuel pump mounting plate.

Remove the fuel pump from the fuel pump mounting plate.



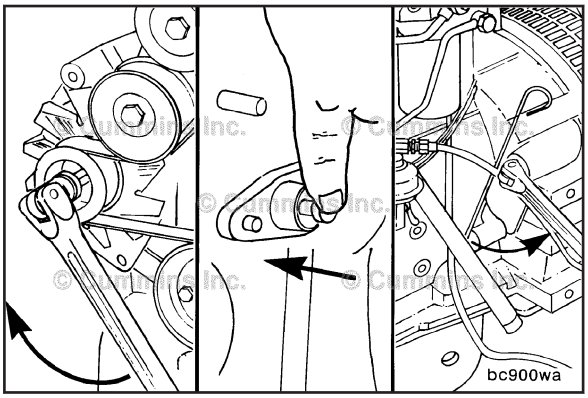
Remove the gasket material and clean the surface.

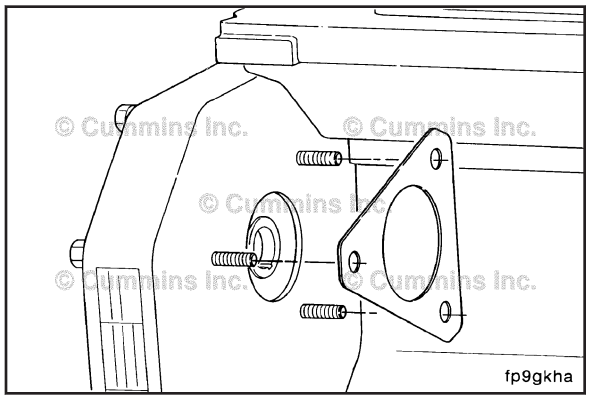


Install

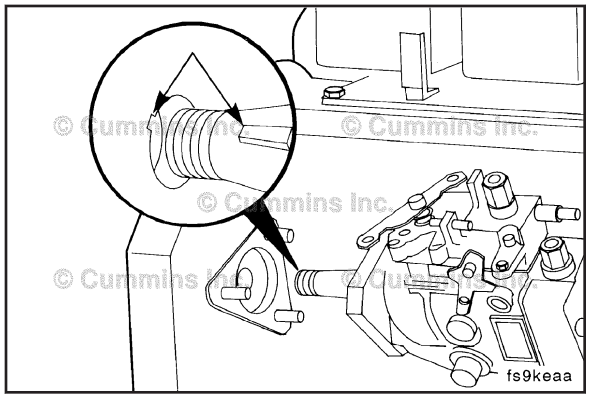
Front Gear Train

Verify cylinder Number 1 is at top dead center by barring the engine slowly while pushing in on the top dead center pin.





Install a new gasket.

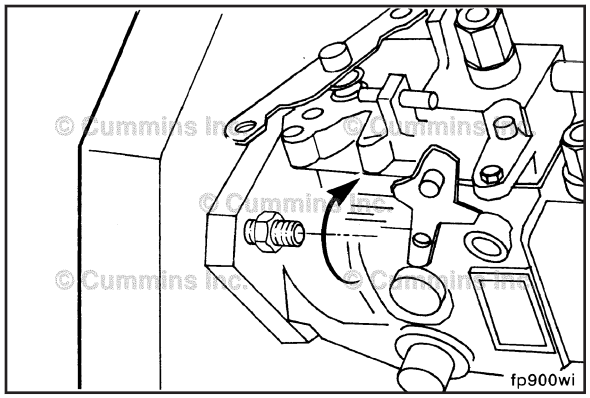


⚠CAUTION⚠
The drive shaft must be clean and free of all oil before installation. Failure to make certain the drive shaft is free of oil can result in the drive gear slipping on the shaft.

NOTE: The shaft of a new or reconditioned pump is locked so the key aligns with the drive gear keyway when cylinder Number 1 is at top dead center on the compression stroke.

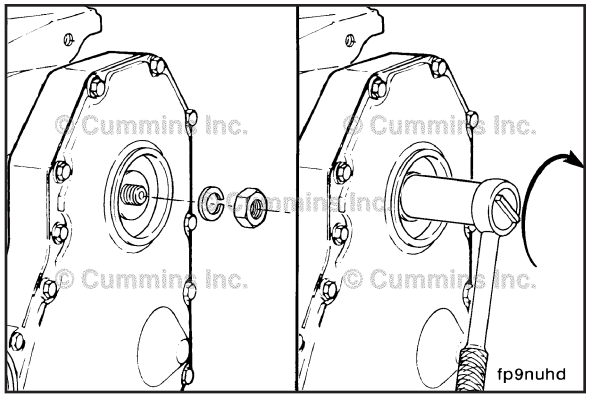
Install the pump. Make sure the key does **not** fall into the gear housing.

NOTE: Fuel pumps on engines designed to meet Tier 2/ Stage II Industrial emission levels do **not** use a timing key.



Hand tighten the three mounting nuts. The pump **must** be free to move in the slots.

NOTE: Fuel pumps on engines designed to meet Tier 2/ Stage II Industrial emissions levels have straight holes (**not** kidney slots) and do **not** use a timing key.



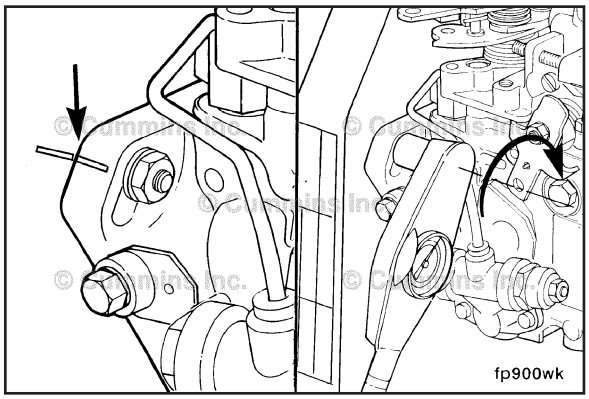
⚠CAUTION⚠
Be sure the timing pin is disengaged before the final torque step to avoid damage to the timing pin.

Install the pump drive shaft nut and spring washer. The pump will rotate slightly because of gear helix and clearance. This is acceptable, provided the pump is free to move on the flange slots and the crankshaft does **not** move.

Torque Value: 15 to 20 N•m [132 to 177 in-lb]

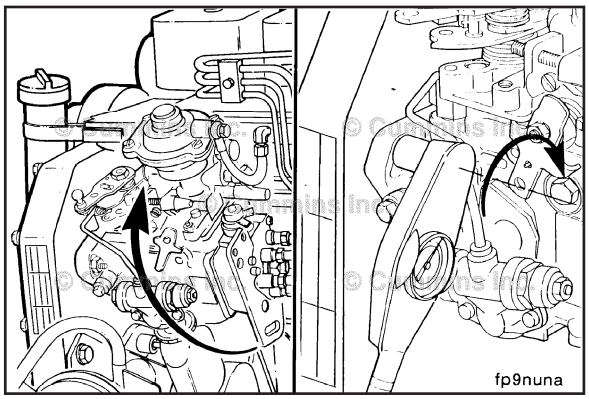
If installing the original pump, rotate the pump to align the scribe marks.

Torque Value: 24 N•m [18 ft-lb]

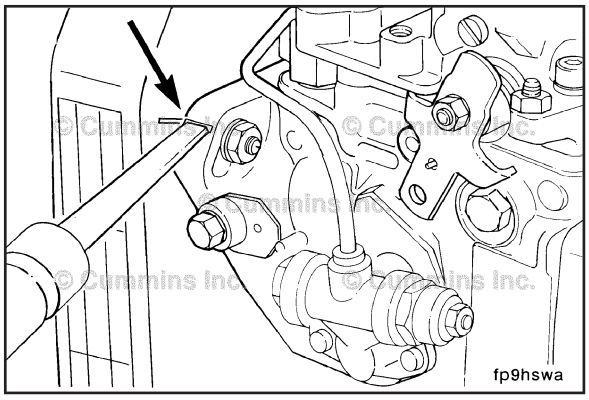


If installing a new or rebuilt pump without scribe marks, take up gear lash by rotating the pump against the direction of drive rotation. Tighten the flange mounting nuts.

Torque Value: 24 N•m [18 ft-lb]



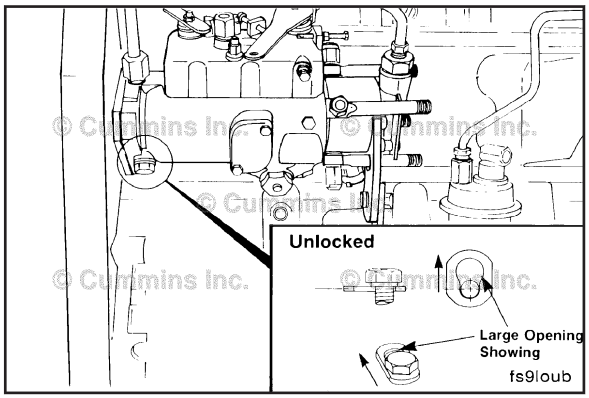
Permanently mark the injection pump flange to match the mark on the gear housing.

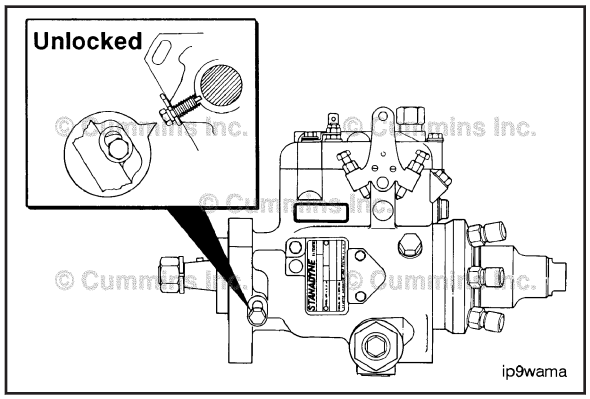


Lucas CAV DPA Pump and Delphi DP210

For CAV fuel injection pumps, loosen the lockscrew and position the special washer behind the lockscrew head.

Torque Value: 20 N•m [177 in-lb]

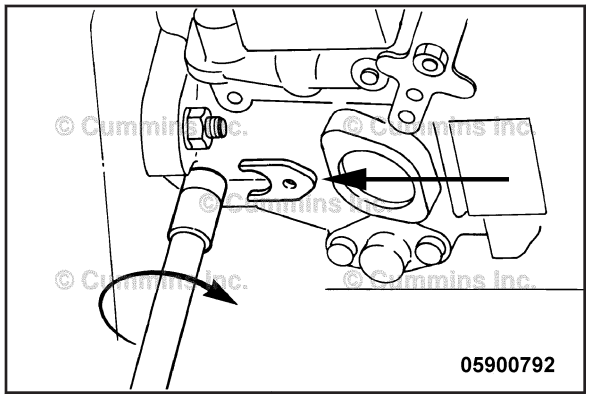




Stanadyne DB4 Pump

For Stanadyne DB4 fuel injection pumps, loosen the lock screw and position the special washer behind the lock screw head.

Tighten the lock screw.

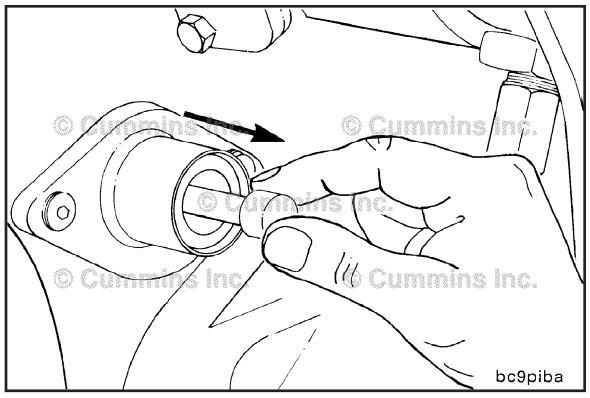


Bosch® VE

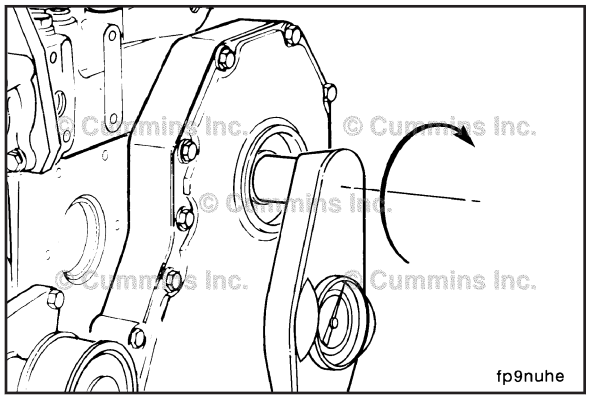
Loosen the Bosch® fuel pump lock timing screw and install the special washer that is wired to the fuel pump.

Tighten the Bosch® fuel pump lock timing screw.

Torque Value: 13 N•m [115 in-lb]



Disengage the timing pin before rotating the crankshaft.

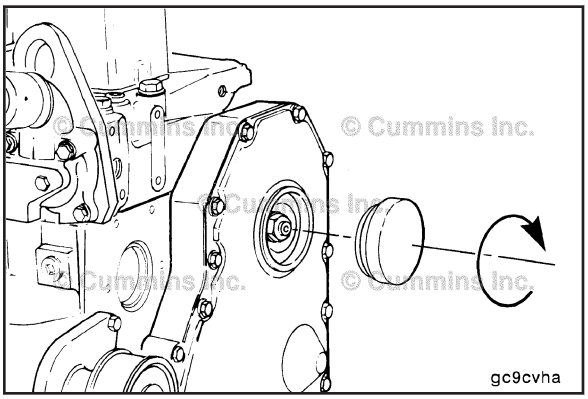


Tighten the pump retaining nut.

Torque Value:

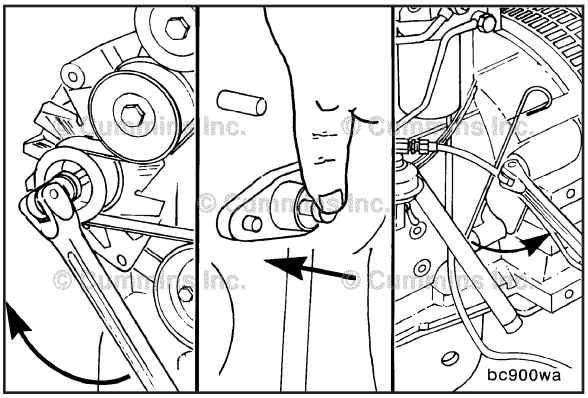
Bosch® VE (M14-1.5 nut)	98 N•m	[72 ft-lb]
Bosch® VE (M12 nut)	65 N•m	[48 ft-lb]
Lucas CAV/DPA	81 N•m	[60 ft-lb]
Stanadyne	65 N•m	[48 ft-lb]
Delphi DP21	93 N•m	[68 ft-lb]

Install the access cap.

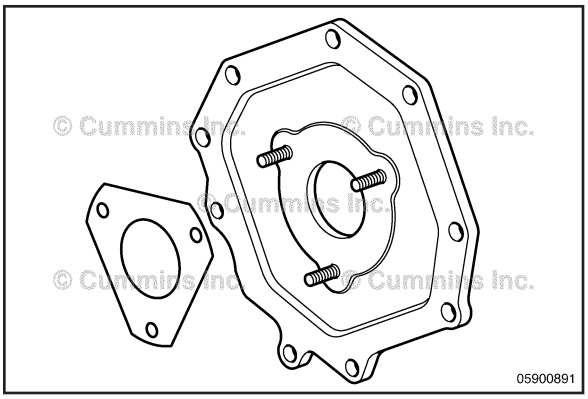


Rear Gear Train

Verify cylinder number 1 is at top dead center by barring the engine slowly while pushing in on the top dead center pin.

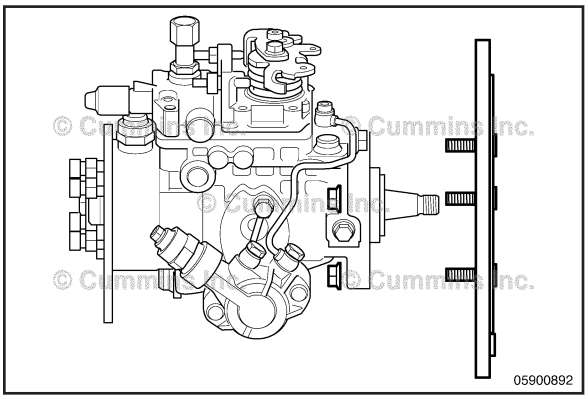


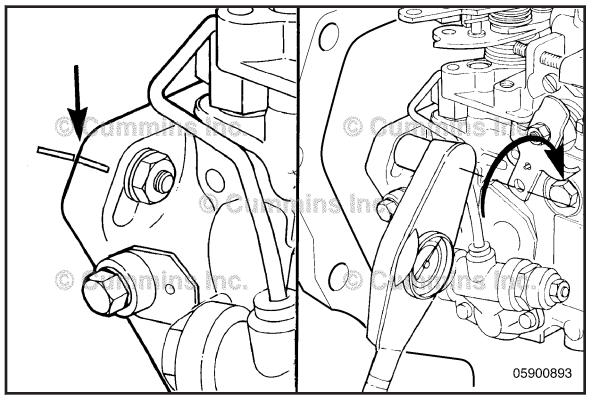
Install a new fuel pump gasket on the fuel pump mounting plate.



Install the fuel pump to the fuel pump mounting plate.

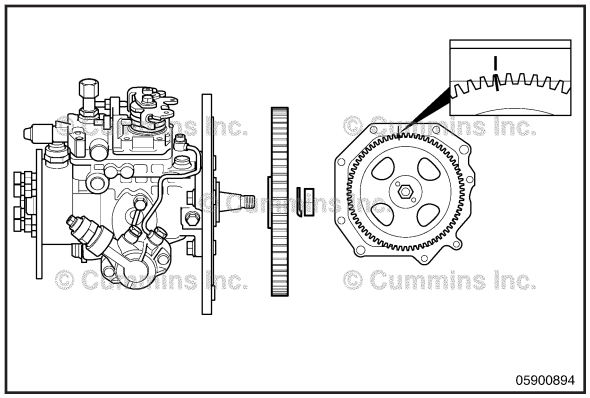
Torque Value: 18 N•m [159 in-lb]





If installing the original fuel pump, rotate the pump to align the scribe marks on the fuel pump mounting plate.

Torque Value: 18 N•m [159 in-lb]



⚠CAUTION⚠
The drive shaft must be clean and free from oil before installation. Failure to make certain the drive shaft is free of oil can result in the drive gear slipping on the shaft.

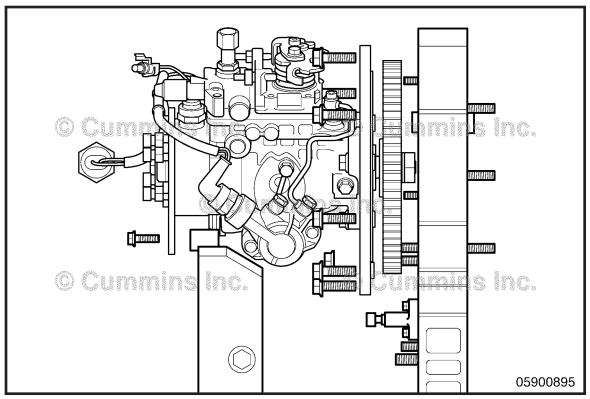
Install the fuel pump gear on the fuel pump shaft.

Align the mark on the fuel pump gear with the mark on the fuel pump mounting plate.

Install the fuel pump drive shaft nut and spring washer.

Tighten the pump retaining nut.

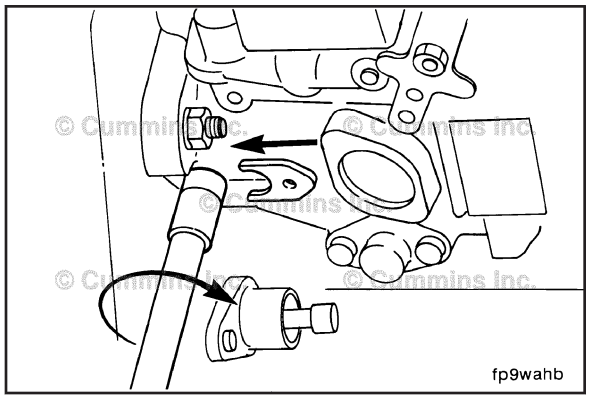
Torque Value: 98 N•m [72 ft-lb]



With a new fuel pump cover plate gasket, install the fuel pump, fuel pump mounting plate, and fuel pump gear assembly onto the rear gear housing.

Torque Value:

M8	18 N•m	[159 in-lb]
M10	30 N•m	[266 in-lb]

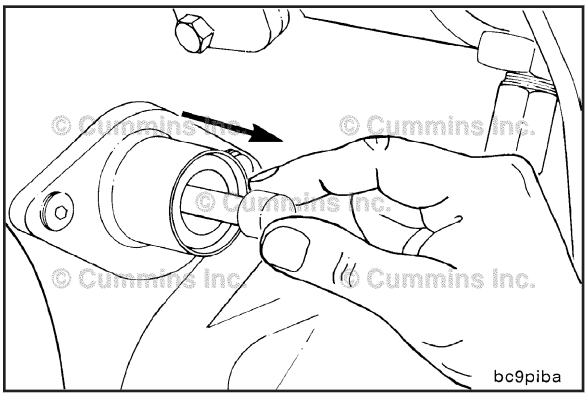


Loosen the Bosch® fuel pump lock timing screw and install the special washer that is wired to the pump.

Tighten the Bosch® fuel pump lock timing screw.

Torque Value: 13 N•m [115 in-lb]

Disengage the timing pin before rotating the crankshaft.



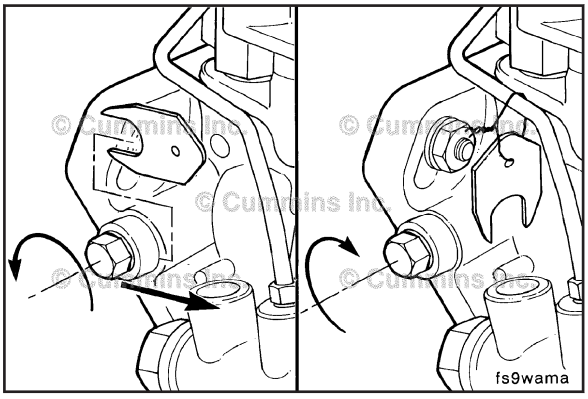
Time

Tier 2/Stage II Timing Adjustment

If the pump timing is out by more than the specified tolerance as determined in Procedure 005-037 it is possible on Tier 2/Stage II engines, which no longer use the keyway in the fuel pump shaft, that the fuel pump gear has slipped on the fuel pump shaft. The fuel pump gear to pump shaft taper will need to be broken so the pump timing can be reset.

NOTE: This procedure applies to front gear train Tier 2/ Stage II engines **only**. Refer to Procedure directions in 005-037, when adjusting the fuel pump timing of engines equipped with kidney slots.

The top dead center timing pin **must** be disengaged. Bar the engine in the **clockwise** direction, when viewed from the front of the engine, until the dial indicator reading reflects the plunger travel specified on the engine dataplate. This point will be beyond top dead center. Lock the pump drive shaft at this position. Refer to Procedure 100-001 Engine Identification in Section E, for the engine dataplate location.

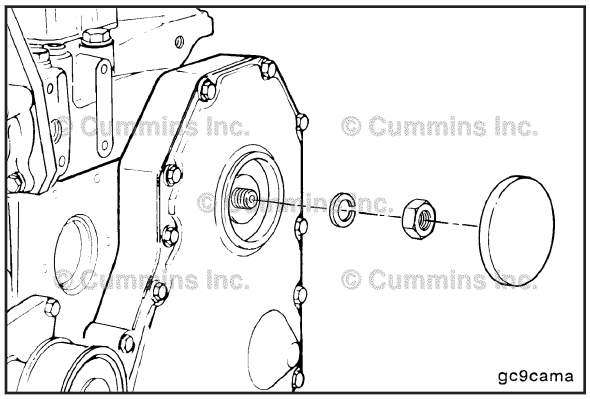


NOTE: If barring the engine past the specified timing plunger travel value, turn the engine in an **counterclockwise** direction, when viewed from the front of the engine, past top dead center at least one quarter turn, then bring the engine back toward top dead center in a **clockwise** direction when viewed from the front of the engine, until the desired timing value is achieved.

The special washer on the Bosch® VE injection pump **must** be removed so the lock screw can be tightened against the drive shaft.

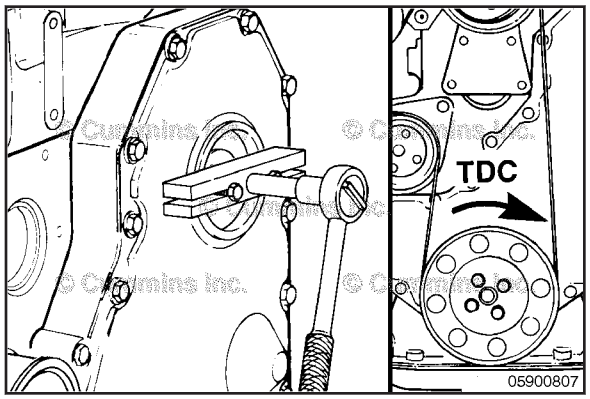
Torque Value: 30 N•m [22 ft-lb]

NOTE: Wire the washer to the fuel pump.



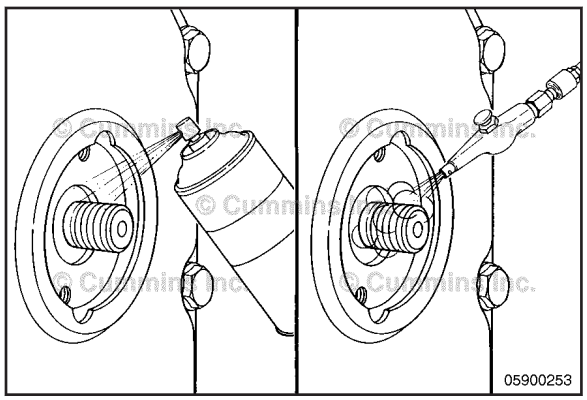
Remove the access cap.

Remove the fuel pump gear retaining nut and washer.



To remove the fuel pump gear, use gear puller, Part Number ST647 or 3163381, to separate the fuel pump gear from the shaft.

With the gear loose from the fuel pump drive shaft, bar the engine in the opposite direction of rotation, when viewed from the front of the engine, past top dead center at least one quarter turn. Then bar engine in the direction of rotation to top dead center until the timing pin engages the camshaft.

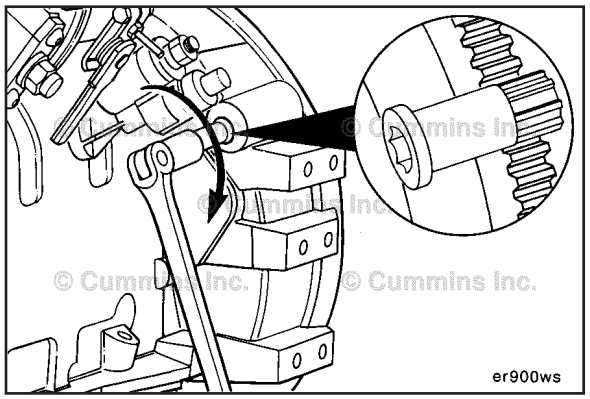


⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

Clean the fuel injection pump drive shaft taper and drive gear bore with a residue-free cleaner. Dry both surfaces with compressed air.

Failure to clean and dry the shaft thoroughly can result in further timing slip after the engine is run.



△CAUTION△
Prior to torquing the fuel pump gear nut, make sure the engine is locked and can not rotate during final torquing of the fuel pump nut.

This can be achieved by using the engine barring tool to prevent the engine from rotating. Make sure the fuel pump is locked at this stage.

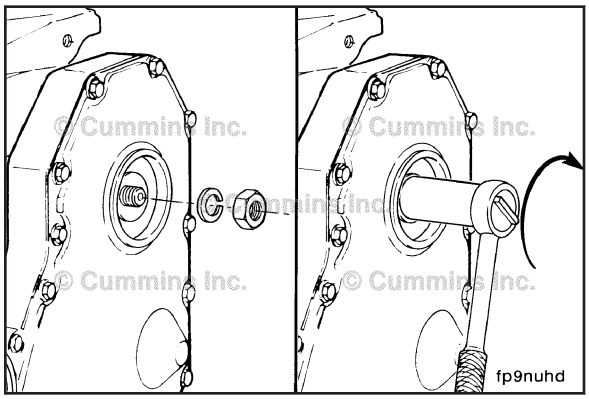
Push the fuel pump gear onto the shaft and assemble the washer and nut.

Remove the top dead center timing pin from the camshaft and the timing pin on the damper, if used.

Tighten the fuel pump retaining nut.

Torque Value:

Bosch® VE98 (M14-1.5 nut)	98 N•m	[72 ft-lb]
Bosch® VE (M12 nut)	65 N•m	[48 ft-lb]
Lucas CAV/DPA	81 N•m	[60 ft-lb]
Stanadyne	65 N•m	[48 ft-lb]
Delphi DP21	93 N•m	[68 ft-lb]

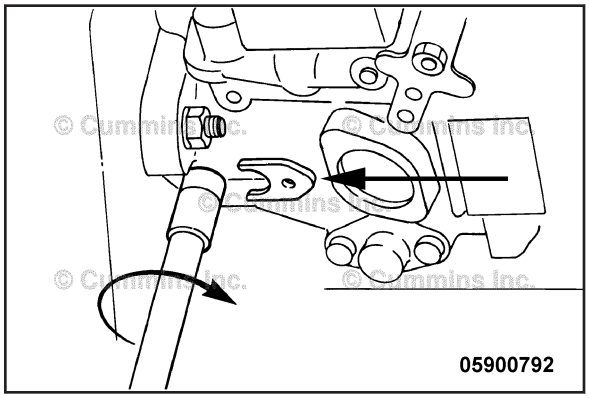


Bosch® VE

Loosen the Bosch® fuel pump lock timing screw and install the special washer that is wired to the fuel pump.

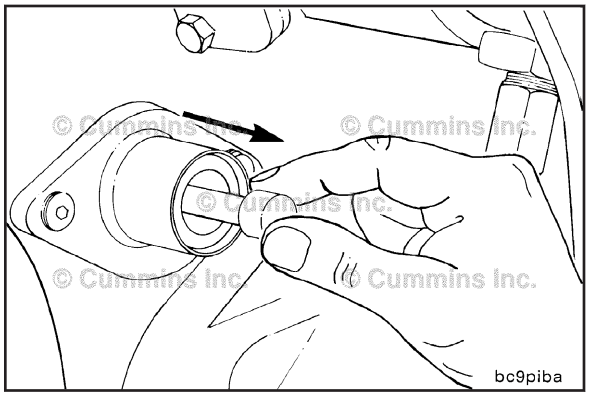
Tighten the Bosch® fuel pump lock timing screw.

Torque Value: 13 N•m [115 in-lb]



⚠CAUTION⚠
To reduce the possibility of engine or timing pin damage, you must disengage the timing pin before attempting to bar or crank the engine.

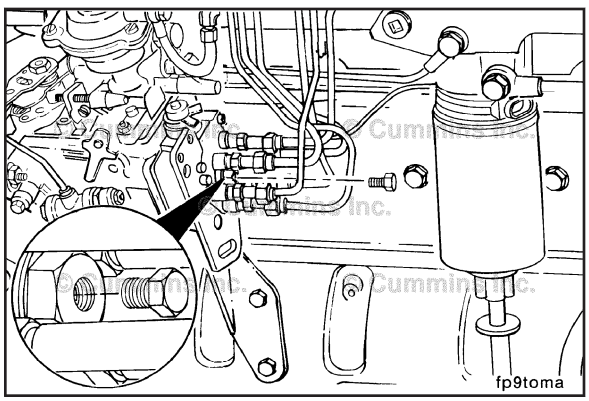
Disengage the timing pin before rotating the crankshaft.

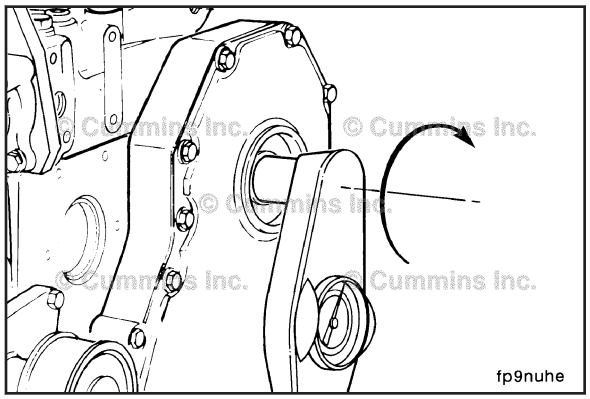


Install the access cap and check to make sure the engine barring tool is removed, then recheck the timing as described in the previous steps.

If the timing is within tolerance, remove the timing gauge from the fuel pump and replace the plug.

Torque Value: 10 N•m [89 in-lb]

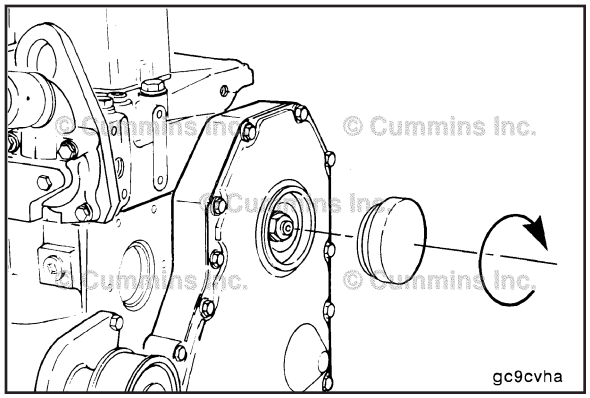




Tighten the gear pump retaining nut.

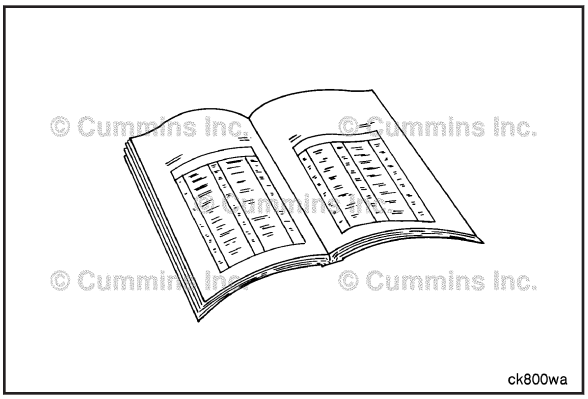
Torque Value:

Bosch® VE98 (M14-1.5 nut)	98 N•m	[72 ft-lb]
Bosch® VE (M12 nut)	65 N•m	[48 ft-lb]
Lucas CAV/DPA	81 N•m	[60 ft-lb]
Stanadyne	65 N•m	[48 ft-lb]
Delphi DP21	93 N•m	[68 ft-lb]



Install the access cap.

Finishing Steps



Rotary Distributor Type Fuel Injection Pumps

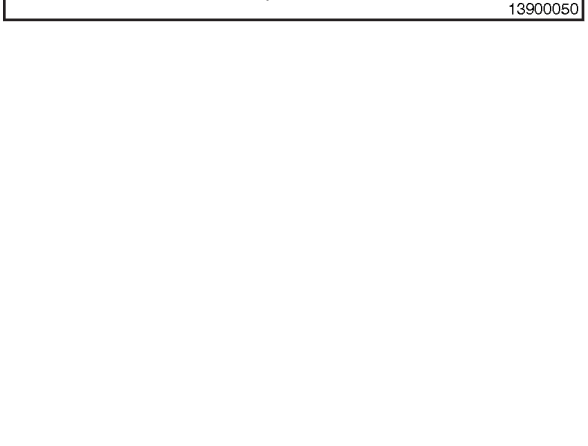
Bosch® VE, Lucas CAV DPA, Stanadyne DB4, and Delphi DP210

- Install the injection pump support bracket. Refer to Procedure 005-033
- Install all high-pressure fuel lines. Refer to Procedure 006-051
- Install the injection pump supply line. Refer to Procedure 006-024
- Connect the fuel drain manifold. Refer to Procedure 006-021
- Connect the electrical wire to the fuel shutoff valve. Refer to Procedure 005-043
- If required, install the air-to-fuel control valve. Refer to Procedure 006-001
- Disconnect all control linkage. Refer to OEM service manual.

NOTE: When connecting the cable and rod to the control lever, adjust the length so the lever has stop-to-stop movement. Adjust the length of the cable or rod to the mechanical shutdown lever so there is stop-to-stop movement.

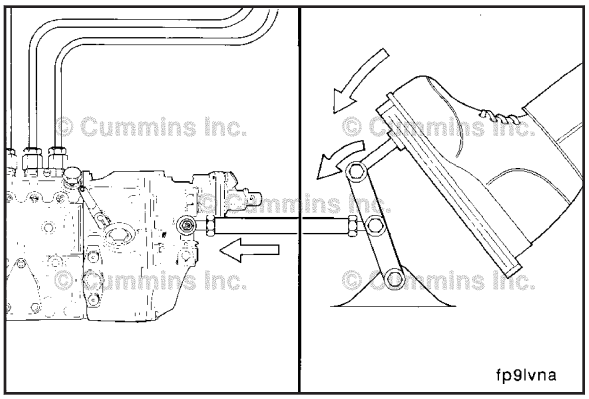
Replacing the fuel supply lines, fuel filters, fuel injection pump, high-pressure fuel lines, and injectors will let air enter the fuel system. Follow the specified procedure to bleed the air from the system.

- Refer to Procedure 006-015, Fuel Filter, Spin-On, for proper venting of the low pressure side of the fuel system
- Refer to Procedure 006-051, Injector Supply Lines (High Pressure), for venting of the high-pressure side of the fuel system.



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

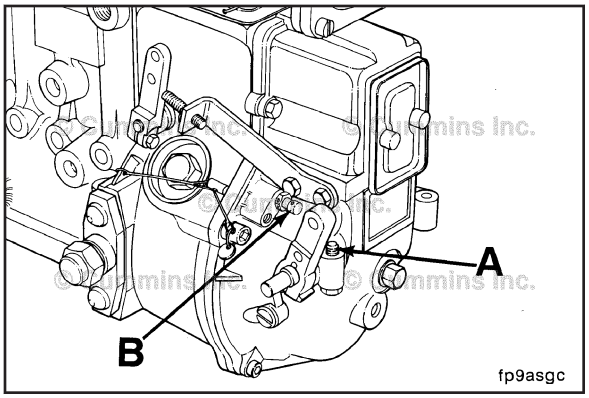
- Connect the batteries
- Operate the engine and check for leaks.



Fuel Pump Control Lever and Spring (005-018)

Adjust

The amount of fuel injected, and subsequently the speed and power from the engine, is controlled by the fuel control lever. Restricted travel of the lever can cause low power. **Always** check for full travel of the lever when diagnosing a low-power complaint.



Fuel Pump High Idle Speed (005-028)

General Information

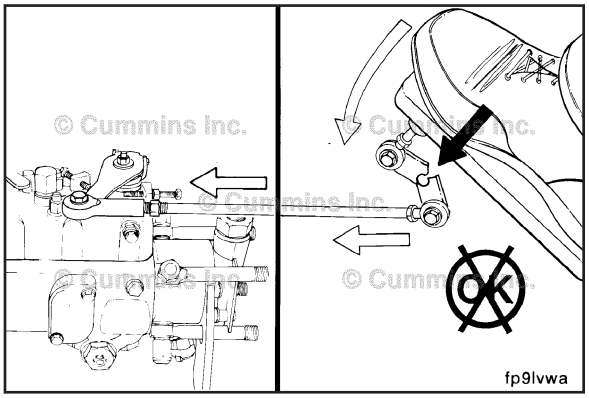
Fuel Injection Pump Idle Adjustment Screws

The idle adjustment screw provides a stop for the lever at low speed. The adjustment screw can be used to increase idle speed for accessory loading or, if required, to lower the idle speed.

The high-speed screw is set at the factory and can **only** be adjusted at a certified fuel pump shop.

A - Idle Screw

B - High-Idle Screw.

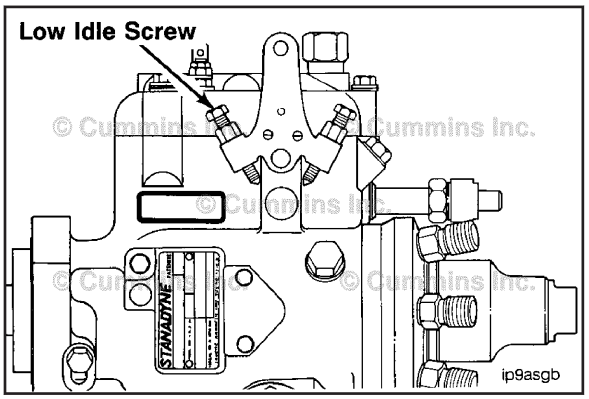


Fuel Pump Idle Speed (005-029)

Adjust

Fuel Control Lever Travel and Adjustment

The amount of fuel injected, and subsequently the speed and power from the engine, is controlled by the fuel control lever. Restricted travel of the lever can cause low power. **Always** check for full travel of the lever when diagnosing a low-power complaint.



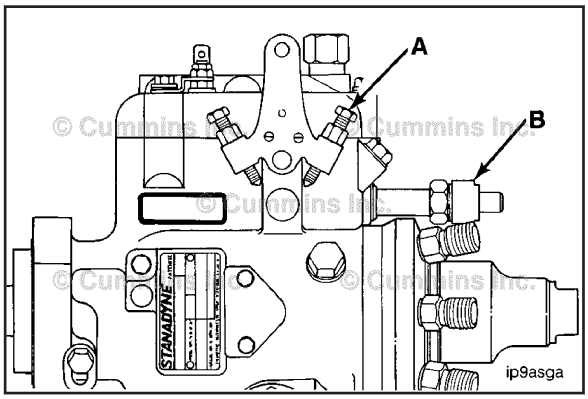
Stanadyne DB4 Fuel Injection Pump Adjustment Screw

The low-idle adjustment screw on the DB4 fuel injection pump is mounted on the control lever assembly. The adjustment screw can be used to increase the idle speed to compensate for accessory loading. The low-idle adjustment screw **must** be adjusted by an authorized service dealer and resealed.

NOTE: Never turn the idle adjusting screw out (reduce idle speed) on the speed drop governor-equipped fuel injection pump; this can result in disengagement of the throttle lever from the guide bushing.

The high-idle adjustment screw (A) is sealed. The adjustment screw on the DB4 fuel injection pump is mounted on the control lever assembly. The high-idle adjustment screw **must** be adjusted by an authorized service dealer.

The speed droop adjustment screw (B) is located above the delivery head. The fuel pump governor sensitivity can be adjusted to increase or decrease governor regulation.

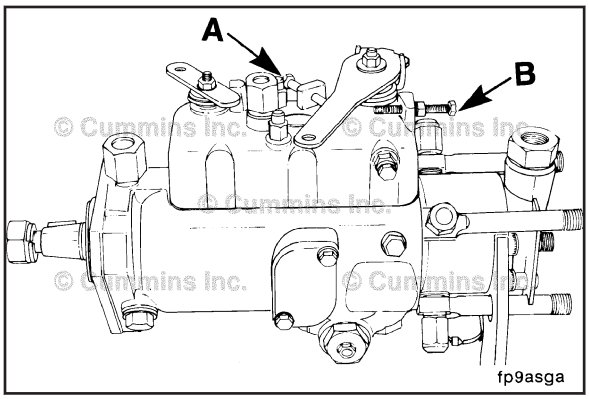


Lucas CAV DPA/DPS and Delphi DP210 Fuel Injection Pump Adjustment Screws

The idle adjustment screw provides a stop for the lever at low speed. The adjustment screw can be used to increase idle speed for accessory loading, or, if required, to lower the idle speed. The high-idle screw is sealed and **must** be adjusted by an authorized repair shop, and then resealed.

A - Idle screw

B - High-idle screw



⚠CAUTION⚠

The fuel control lever on the Bosch® VE fuel injection pump is indexed to the shaft during pump calibration. If the lever has been removed and reinstalled incorrectly, engine speed and power will be affected.

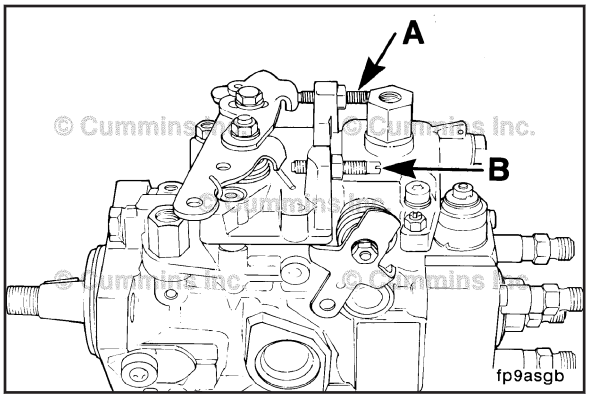
Bosch® VE Fuel Injection Pump Adjustment Screws

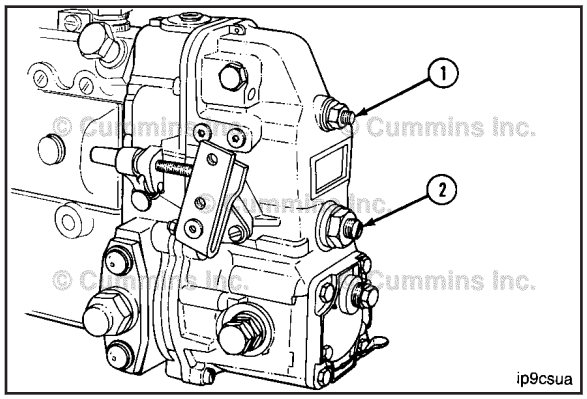
A - Idle Screw

B - High-Idle Screw

The high-speed adjustment screw on both fuel injection pumps provides the stop for full speed. The high-speed adjusting screws are sealed. Adjustment of this screw **must** be performed **only** by an authorized fuel injection pump service center, and then resealed.

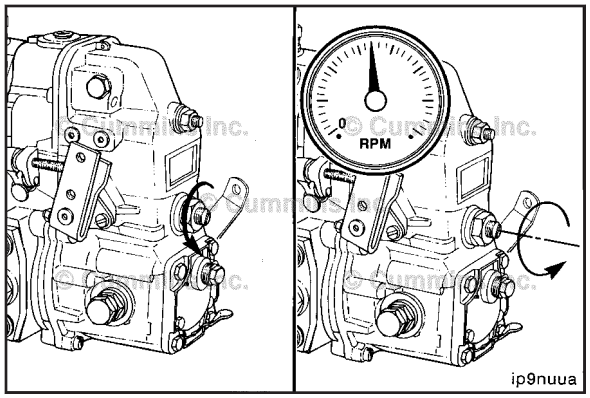
The high-speed adjusting screw can be used to derate engines.



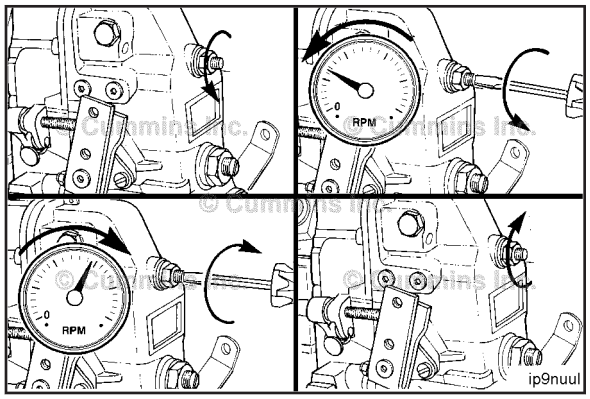


Bosch® RSV Governor

Idle speed adjustment for industrial engines requires the setting of both the low-idle speed screw (1) and the bumper spring screw (2).



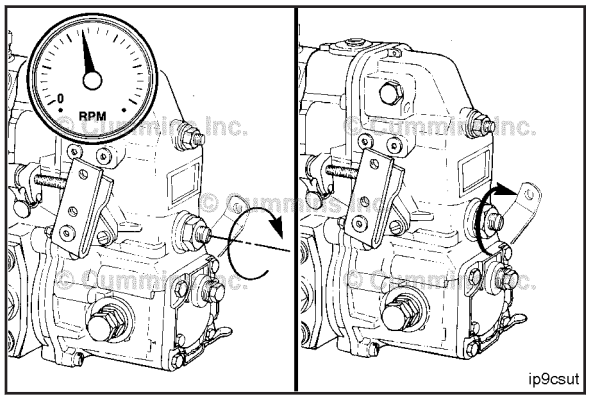
First, loosen the locknut; then, back out the bumper spring screw until there is no change in engine speed.



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 and **clockwise** to increase rpm.

Tighten the locknut.

Torque Value: 8 N•m [71 in-lb]



Turn the bumper spring screw **clockwise** until the desired idle speed is obtained.

Tighten the locknut.

Torque Value: 8 N•m [71 in-lb]

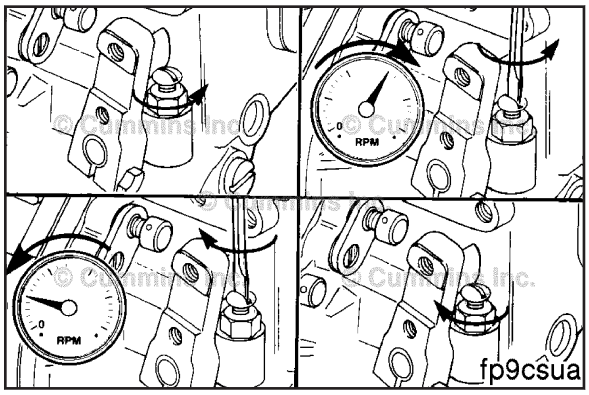
Bosch® RQV and RQV-K Governor

Idle speed adjustment on automotive fuel injection pumps requires setting of the stop screw.

Loosen the locknut, and turn the idle speed screw **counterclockwise** to increase the rpm and **clockwise** to decrease the rpm speed.

Tighten the locknut.

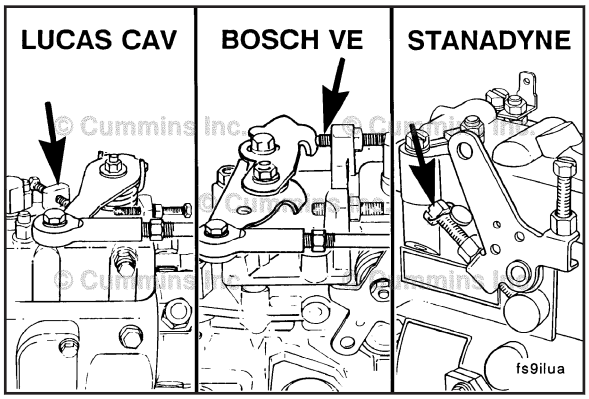
Torque Value: 8 N•m [71 in-lb]



⚠CAUTION⚠
Do not reduce idle speed from factory setting on the Stanadyne DB4 fuel injection pump. Internal damage can result.

Distributor Pumps

Loosen the adjusting screw locknut, and adjust the idle as required.

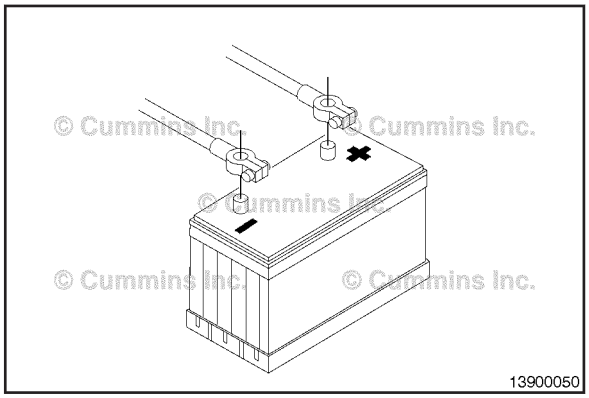


Fuel Pump Support Bracket (005-033)

Preparatory Steps

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

- Disconnect the batteries.



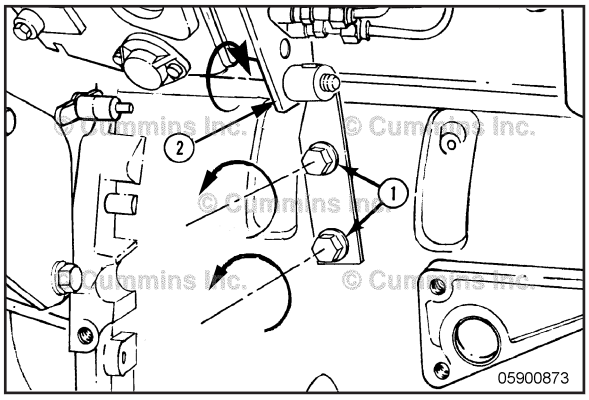
Remove

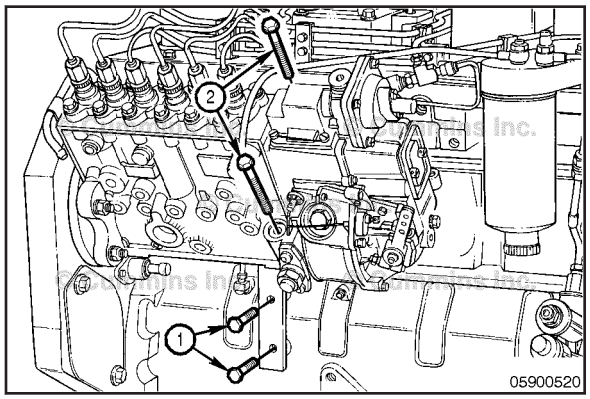
Front Gear Train

Bosch® and Stanadyne Rotary Pumps

10 mm

Remove the capscrew that is connected to the pump and the tail support bracket (2) first; then remove the capscrews from the bracket (1) and block.

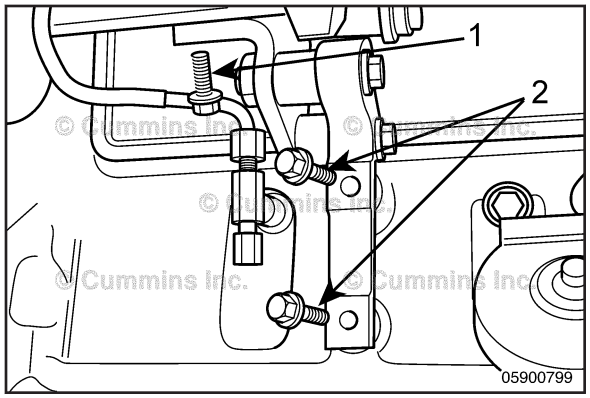




In-line Fuel Injection Pumps

10 mm

Remove the capscrew that is connected to the pump and the tail support bracket (2) first; then remove the capscrews from the bracket (1) and block.

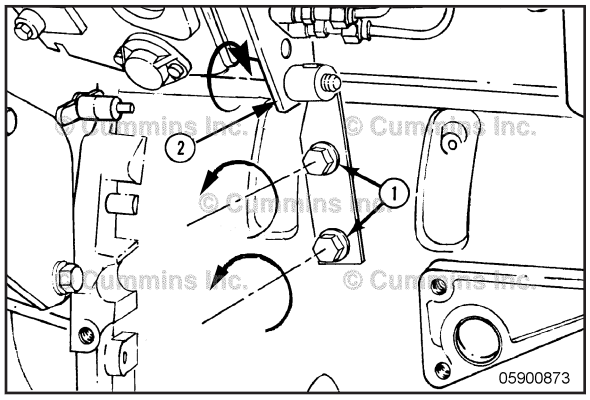


Four-Cylinder

Remove the capscrews (1) which mount support bracket assembly to fuel pump.

Remove the capscrews (2) which mount the support bracket assembly to the engine block.

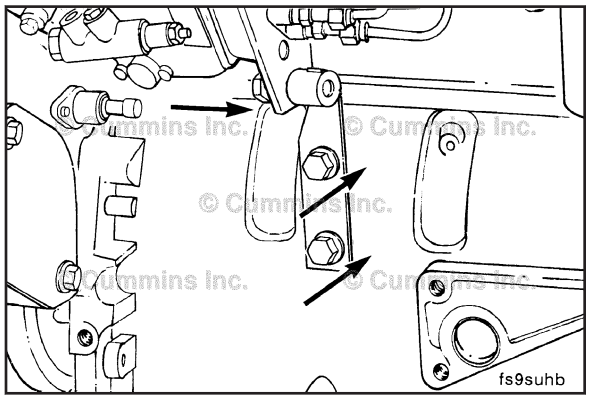
NOTE: Not all four cylinder engines are equipped with this style of bracket. If the engine is equipped with a two piece bracket, remove the bolts as depicted.



Rear Gear Train

10 mm

Remove the capscrew that is connected to the pump and the tail support bracket (2) first; then remove the capscrews from the bracket (1) and block.



Install

Front Gear Train

Bosch®; and Stanadyne Rotary Pumps

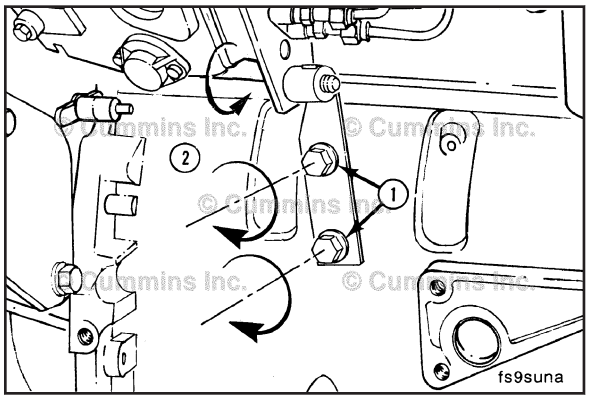
Install the tail support bracket finger-tight before final tightening.

NOTE: Tighten bracket to block before tightening the bracket to the pump.

10 mm

Tighten capscrew and bracket to the injection pump (2) first; then the capscrews to the bracket and block (1).

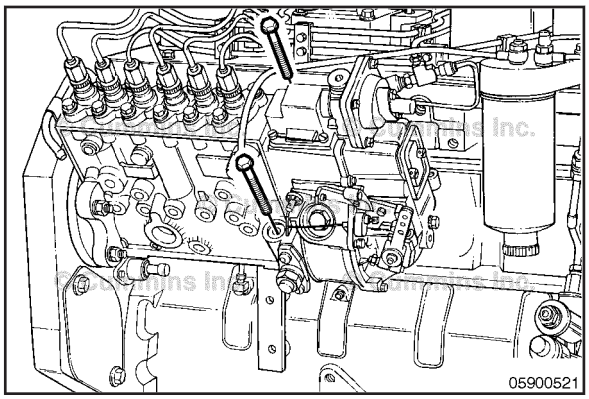
Torque Value: 24 N•m [18 ft-lb]



In-line Fuel Injection Pumps

Install the tail support bracket finger-tight before final tightening.

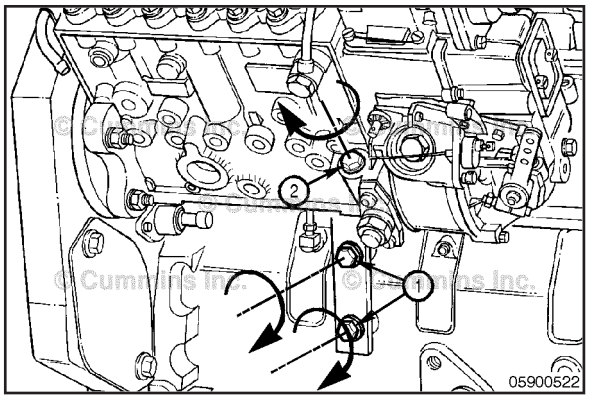
NOTE: Tighten bracket to block before tightening the bracket to the pump.



10 mm

Tighten bracket to the block (1) first; then to the injection pump (2).

Torque Value: 24 N•m [18 ft-lb]



Four-Cylinder

Install the tail support bracket finger-tight before final tightening.

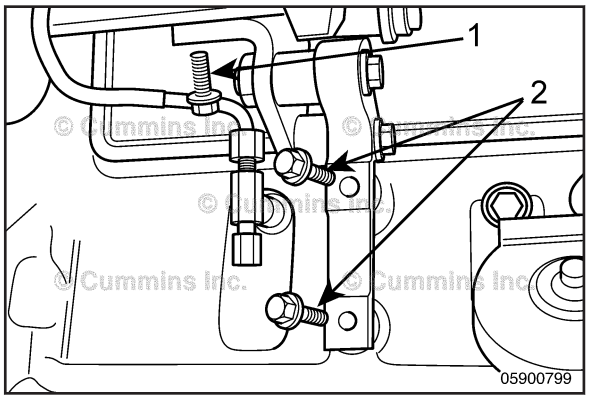
NOTE: Tighten bracket to block before tightening the bracket to the pump.

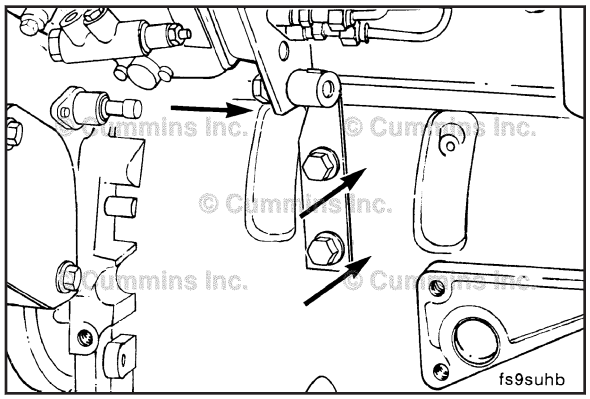
Tighten the capscrews (2) which mount the support bracket assembly to the engine block.

Tighten the capscrews (1) which mount support bracket assembly to fuel pump.

Torque Value: 24 N•m [18 ft-lb]

NOTE: Not all four cylinder engines are equipped with this style bracket. If the engine is equipped with a two piece bracket, install the bolts as depicted.

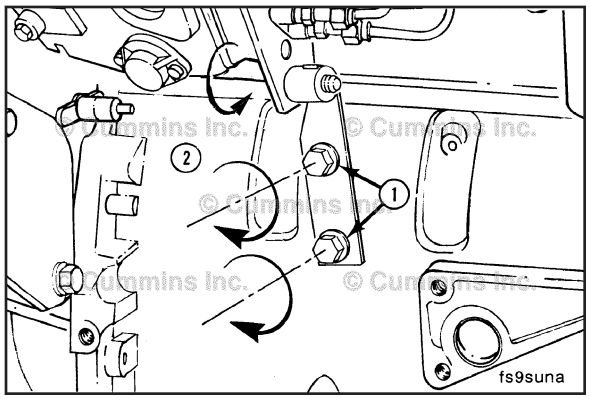




Rear Gear Train

Install the tail support bracket finger-tight before final tightening.

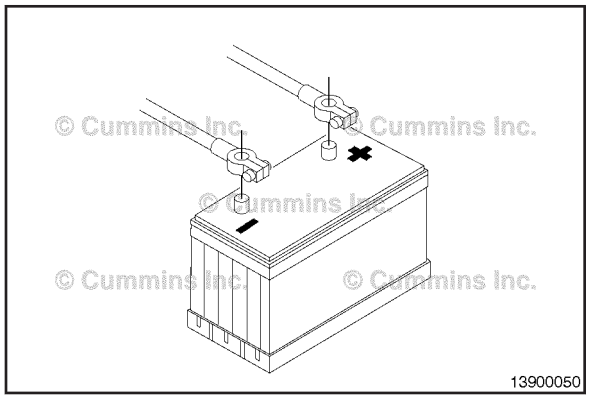
NOTE: Tighten bracket to block before tightening the bracket to the pump.



10 mm

Tighten capscrew and bracket to the injection pump (2) first; then the capscrews to the bracket and block (1).

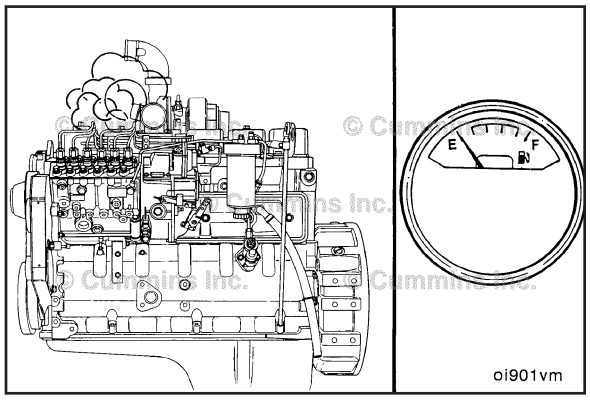
Torque Value: 24 N•m [18 ft-lb]



Finishing Steps

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

- Connect the batteries.



Fuel Pump Timing (005-037)

General Information

Pump-to-engine timing is extremely critical. Pump timing that is off by **only** a few crankshaft degrees will cause:

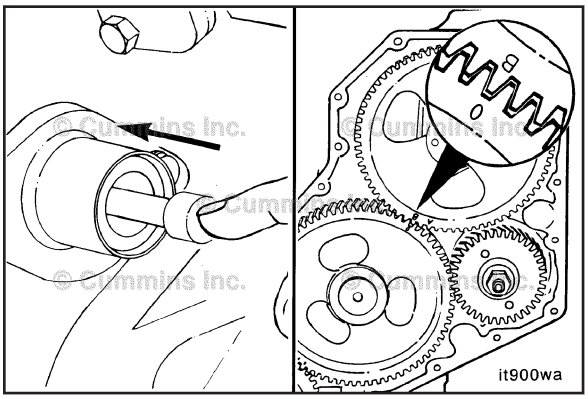
1. Poor performance - starting and power.
2. Excessive smoke.
3. Poor fuel economy.

Time

Engine pump timing begins with the timing of the fuel injection pump drive gear to the camshaft gear.

The first step is the location of TDC of the compression stroke for cylinder Number 1.

Then, depending on the engine configuration, an alpha character on the injection pump drive gear will possibly need to be aligned with the mark on the camshaft gear.



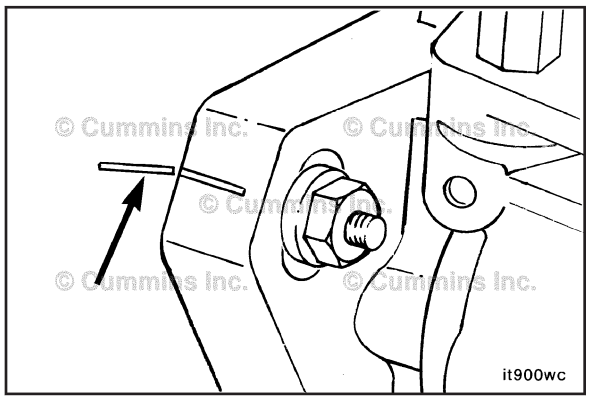
This table **must** be used to maintain proper fuel injection pump-to-engine timing. The Control Parts List (CPL) number from the engine dataplate and the Control Parts List Manual, Bulletin 3379133 or 4021327, **must** be used to determine whether the engine is certified, and if so, what year and regulating agency (EPA or CARB).

Given this information, use the following table to determine which letter on the fuel injection pump drive gear is aligned with the camshaft gear.

NOTE: Timing mark alignment is **not** required for the Nippondenso EP-9 or Bosch® in-line drive gear.

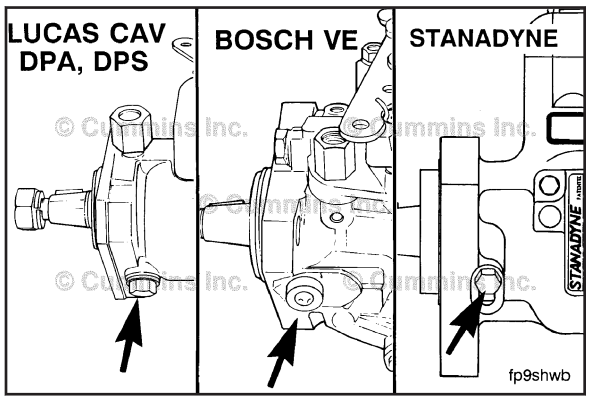
NOTE: The timing mark is **not** required for Bosch® VE and DP210 used on Tier II Industrial engines. For these engines, vary timing by using the Timing Check procedure.

Letter on Pump Gear	Engine Model	Injection Pump	Certification
A	4B3.9, 4BT3.9	Stanadyne pump	Noncertified
A	4B3.9, 4BT3.9, 4BTA3.9	Lucas CAV DPA pump	All noncertified
B	4B3.9, 4BTA3.9	Bosch® VE	1986, 1987 EPA, All pre-1986, All noncertified
C	6BT5.9, 6BTA5.9	Bosch® VE	1986, 1987 EPA, All pre-1986, All noncertified, CPL 600
D	6B5.9, 6BT5.9	Stanadyne	Noncertified
D	6B5.9, 6BT5.9, 6BTA5.9	Lucas CAV DPA	All noncertified
E	6BT5.9, 6BTA5.9	Bosch® VE	1986, 1987, 1988, 1989, 1990, 1991, 1992 CARB
F	4BT3.9, 4BTA3.9	Bosch® VE	1986, 1987, 1988, 1989, 1990, 1991, 1992 CARB, 1988, 1989, 1990, 1991, 1992 EPA
G	6BTA5.9	Lucas CAV DPA	All Fire Pumps
H	**Not** used at this time	N/A	N/A



To verify that the fuel injection pump is timed correctly, first check the alignment marks on the pump flange and gear housing.

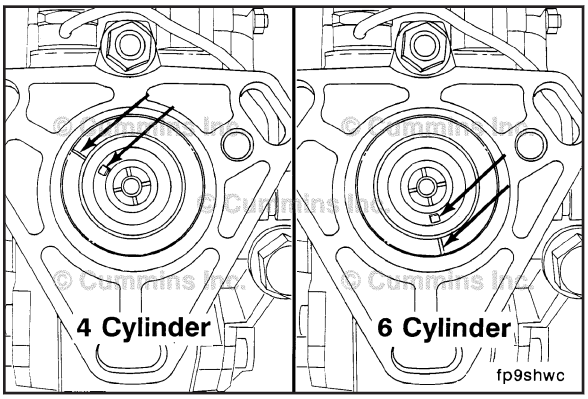
NOTE: 1 mm of rotation past the timing mark will advance or retard (depending on direction of rotation) the pump timing by 1 degree.



The Lucas CAV DPA, DPS, Delphi DP210, Stanadyne DB4, and the Bosch® VE fuel injection pumps all have a provision for locking the pump shaft at a position corresponding to top dead center for cylinder Number 1. New and reconditioned fuel injection pumps **must** be received with the shafts located in this position.

At the point of injection, the keyway of the shaft will align with the delivery valve receiving the injection and the illustrated hash mark on the seal housing.

NOTE: The illustrated mark is for reference **only** and **must not** be used for setting the fuel injection pump timing.

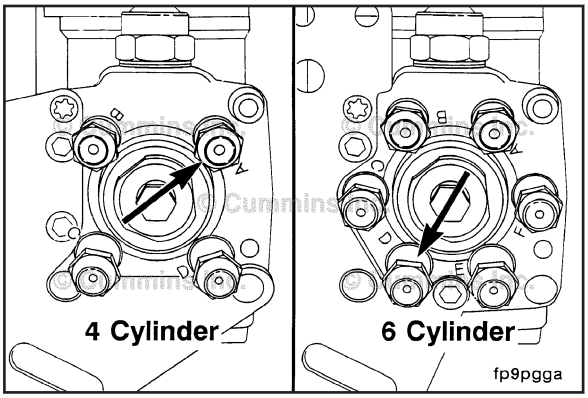


The Number 1 cylinder delivery valve is marked as illustrated.

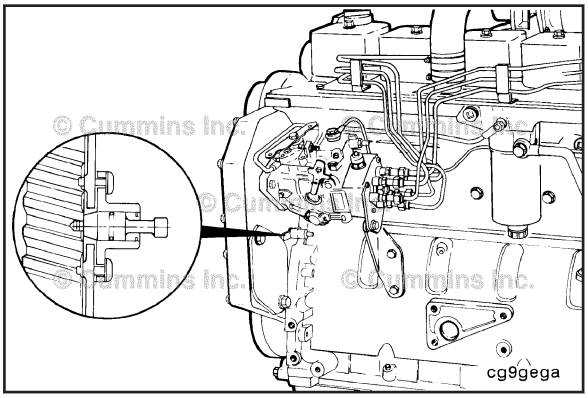
Four cylinder = A

Six cylinder = D

Firing Order	
Four Cylinder	**Six Cylinder**
A =1	D = 1
B = 3	E = 5
C = 4	F = 3
D = 2	A = 6
	B = 2
	C = 4



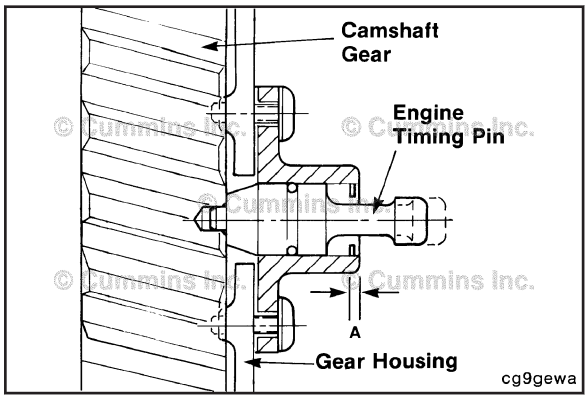
The engine is equipped with an engine timing pin to locate top dead center (TDC) for cylinder Number 1.

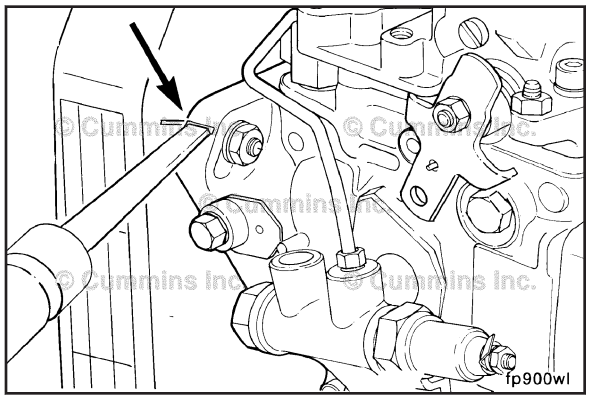


⚠CAUTION⚠
If the timing pin is incorrectly located on the gear housing, the pump will not be timed correctly.

After precisely locating TDC for cylinder Number 1, the factory positions the timing pin assembly to the gear housing, using the timing pin and the hole in the camshaft gear. If the gear housing or timing pin assembly are removed, the same precision is required to relocate it.

If the timing pin assembly is incorrectly located, reposition the timing pin.

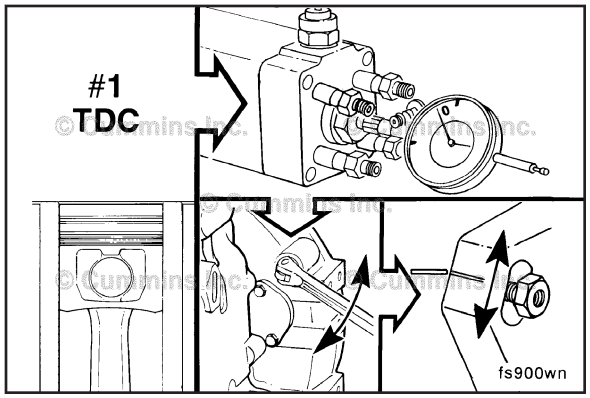




The flange of a replacement pump **must** be marked to align with the mark on the gear housing after installation.

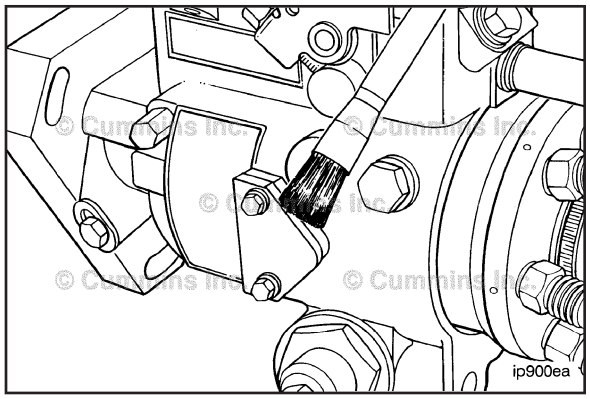
During production, after the locked pump is fitted to the engine with cylinder Number 1 at top dead center (TDC), a mark is stamped on the gear housing and the pump flange. Thereafter, when these marks are aligned, the pump is correctly timed to the engine.

NOTE: The marks on the gear housing and the pump flange are unique to each engine.



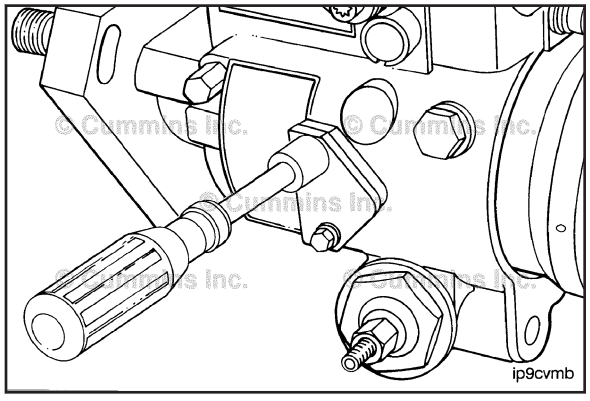
See Service Tool Instruction, Bulletin 3400196 and Service Tool Catalog, Bulletin 3377710 to determine the appropriate Bosch® timing tool and adapter kit part numbers.

A special indicator can be used to measure the position of the Bosch® VE fuel injection pump plunger to check pump timing.



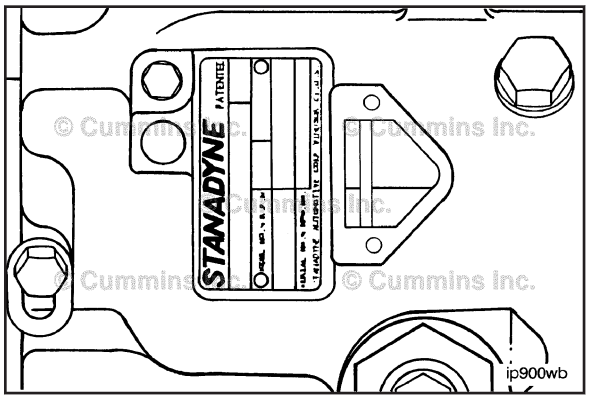
Stanadyne DB4 Fuel Injection Pump Timing

Clean all debris from around the fuel injection pump timing window cover.



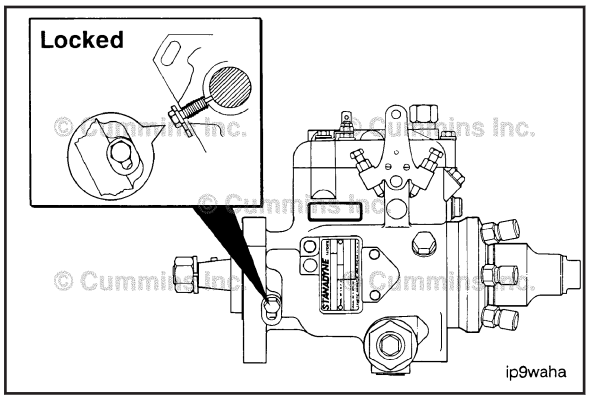
Remove the fuel injection pump timing cover.

Rotate the fuel injection pump driveshaft in the direction of pump rotation to align the timing line on the weight retainer hub with the line on the cam ring.

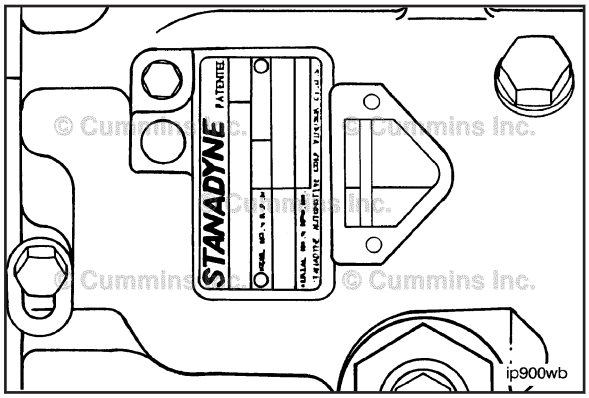


Position the fuel injection driveshaft locking key plate in the locked position. Turn the locking screw in until contact is made with the driveshaft.

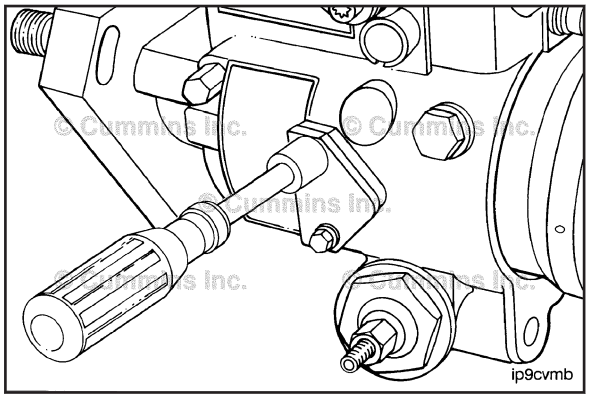
Torque Value: 11.9 N•m [105 in-lb]

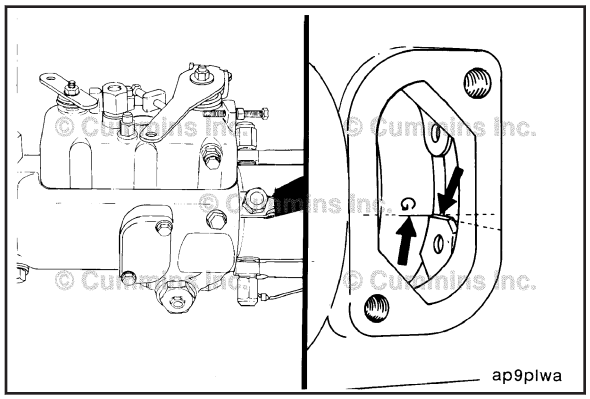


Verify the timing marks are aligned after timing is locked.



Install the fuel injection pump timing cover.





CAV DPA/DPS Fuel Injection Pump Timing

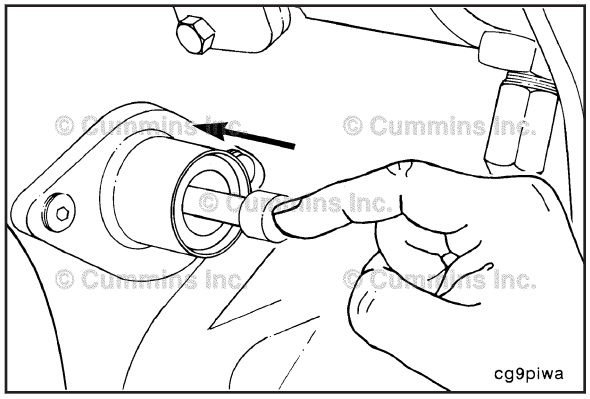
Correct timing of the Lucas CAV DPA/DPS fuel injection pump can be verified by removing the inspection plate.

NOTE: Special equipment in an authorized shop is required to time the Lucas CAV DPA fuel injection pump precisely. However, for troubleshooting and in an emergency, visual alignment of the timing mark is close enough for the engine to run.

Both of these checks are described in the fuel injection pump replacement. Refer to Procedure 005-012 (Fuel Injection Pumps, In-Line) in Section 5.

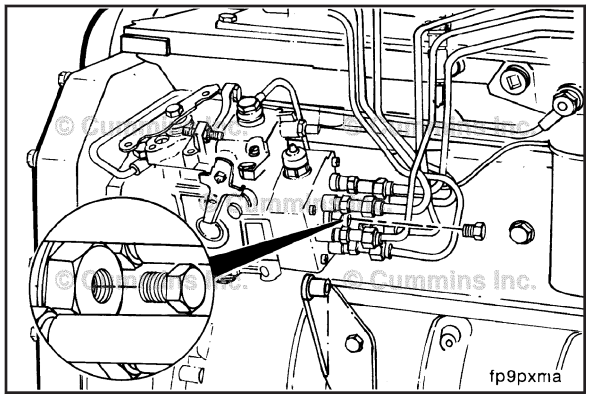
Refer to Procedure 005-014 (Fuel Injection Pump, Rotary) in Section 5.

Refer to Procedure 005-013 (Fuel Injection Pump, In-Line, Spill Port Timing) in Section 5 for installation of the timing pin.



Timing Check - (Bosch® VE Pump)

Rotate the crankshaft to top dead center (TDC).



Remove the plug from the end of the pump.

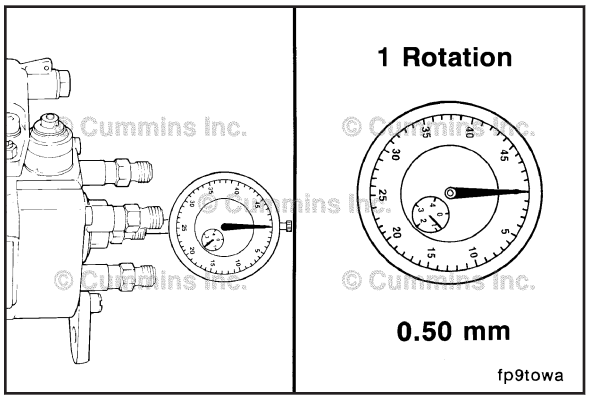
⚠CAUTION⚠
Do not bend the fuel lines. Doing so can result in fuel system failure.

See Service Tool Instruction, Bulletin 3400196 and Service Tool Catalog, Bulletin 3377710 to determine the appropriate Bosch® timing tool and adapter kit part numbers.

Install the timing indicator. Be sure to allow adequate travel for the indicator.

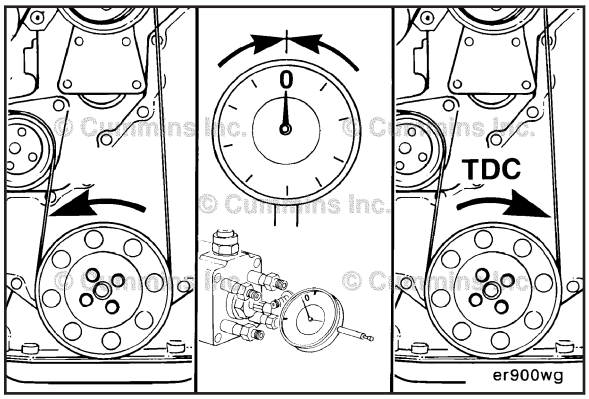
In order to install the timing indicator, it is often necessary to disconnect one or more of the fuel lines from the fuel pump.

NOTE: The indicator is marked in increments of 0.01 mm. 1 revolution of the indicator needle is equal to 0.50 mm.



Bar the crankshaft in the direction opposite engine rotation until the indicator needle stops moving. Adjust the indicator face to read 0.

Rotate the crankshaft back to top dead center (TDC), and count the number of revolutions of the indicator needle. The reading shown when the engine timing pin engages is the amount of plunger lift the pump has at that point.

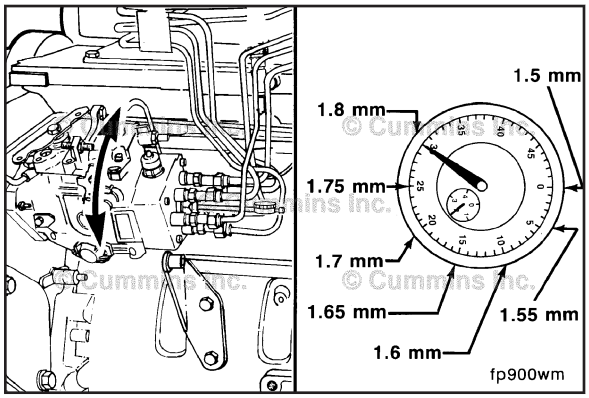


Bosch® VE Pumps with Slotted Mounting Holes

Rotate the pump on the mounting studs until the indicator reads the correct value for plunger lift. This illustration gives an example of the indicator readings for the various plunger lift values.

Tighten the flange mounting nuts.

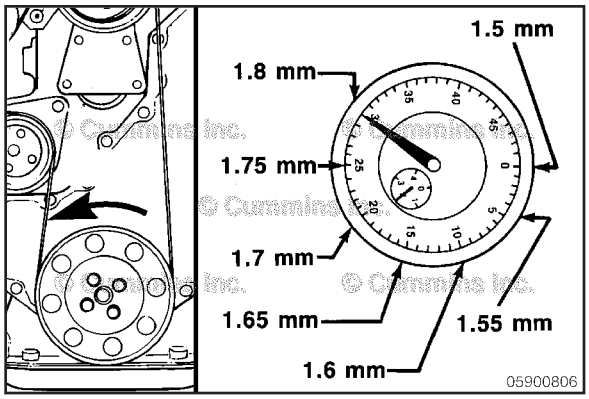
Torque Value: 24 N•m [18 ft-lb]

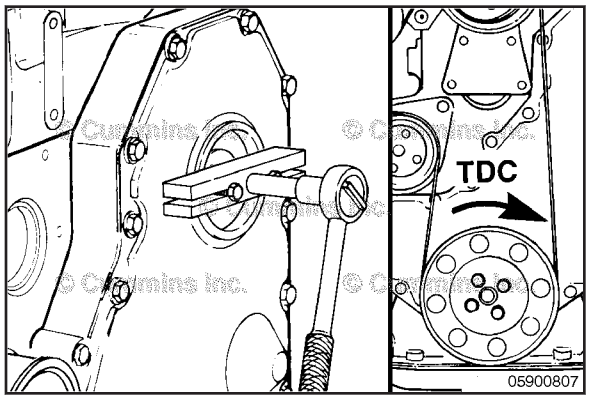


Bosch® VE Pumps with Round Mounting Holes

Rotate the engine until the plunger travel is at the desired location.

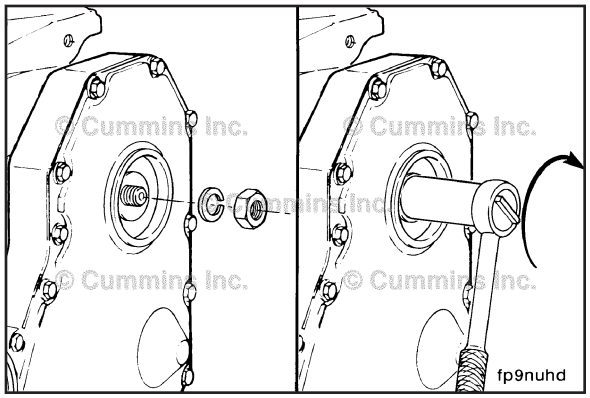
Lock the fuel pump. Refer to Procedure 005-014 (Fuel Injection Pump, Rotary) in Section 5.





Separate the fuel pump drive gear from the pump shaft. Refer to Procedure 005-014 (Fuel Injection Pump, Rotary) in Section 5

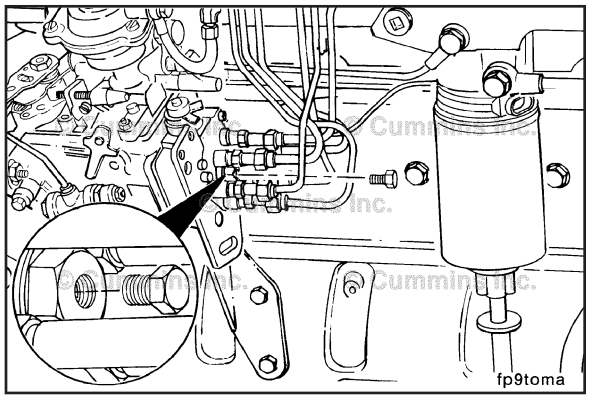
With the pump locked, rotate the engine back to TDC.



Torque the fuel pump drive nut. Refer to Procedure 005-014 (Fuel Injection Pump, Rotary) in Section 5.

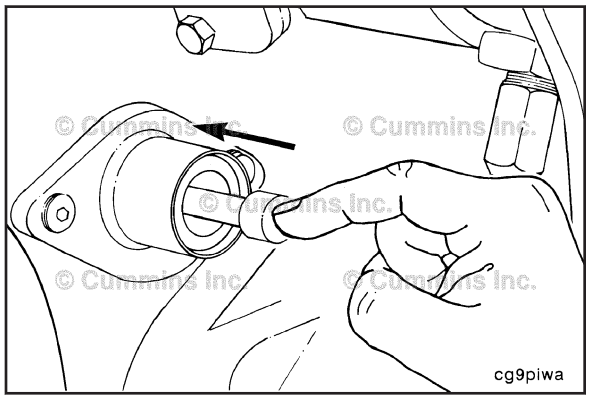
Unlock the fuel pump.

Verify the correct timing has been achieved by measuring the static timing.



Remove the timing indicator. Install the plug.

Torque Value: 10 N•m [89 in-lb]



Pump Timing - Lucas CAV DPA, Stanadyne DB4, Delphi DP210, Nippondenso EP-9, and Bosch® P7100

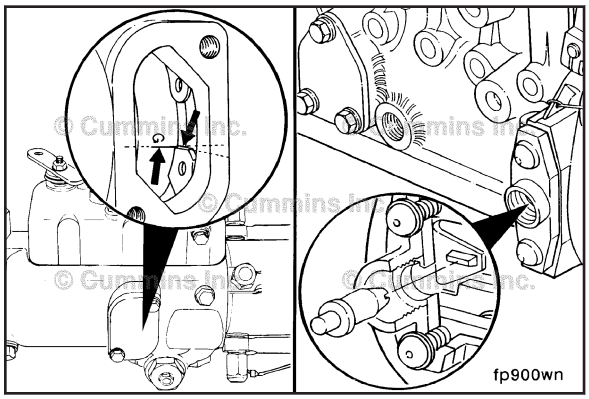
Rotate the engine to top dead center (TDC).

Correct timing of the Lucas CAV DPA and Stanadyne DB4 fuel injection pump can be verified by removing the timing window cover plate.

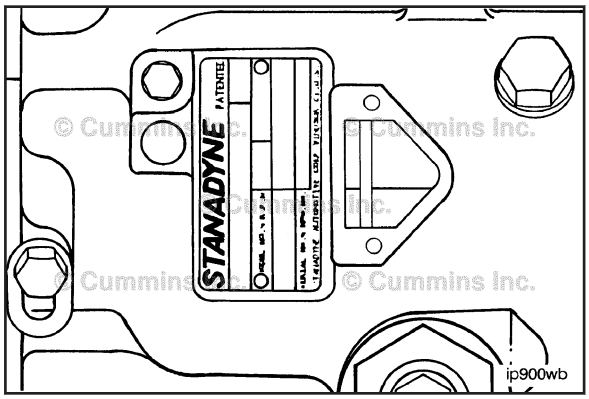
The Nippondenso EP-9 and Bosch® P-7100 fuel injection pumps are checked by removing the timing pin access plug and verifying the slot in the pin will fit over the timing tooth in the fuel injection pump.

NOTE: Special equipment in an authorized shop is required to time the Lucas CAV DPA fuel injection pump precisely. However, for troubleshooting and in an emergency, visual alignment of the timing mark is close enough for the engine to run.

To correct the timing on the Bosch® P-7100 and Nippondenso EP-9, see the replacement procedure for the respective pump.

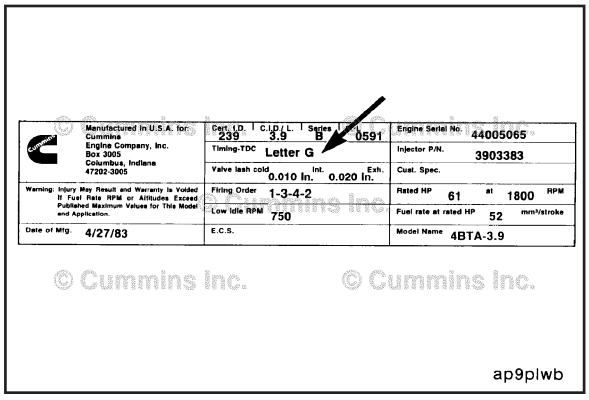


Two injection pump timing marks are used on the Stanadyne DB4 for timing injection of fuel into the Number 1 cylinder. One mark is located on the governor weight retainer hub. The other is located on the internal cam ring. These two marks **must** be aligned at Number 1 cylinder top dead center (TDC).



On the Lucas CAV DPA, the correct timing letter can be located on the engine dataplate as shown.

The letter G indicated refers to the correct timing letter alignment as shown in the previous frame.

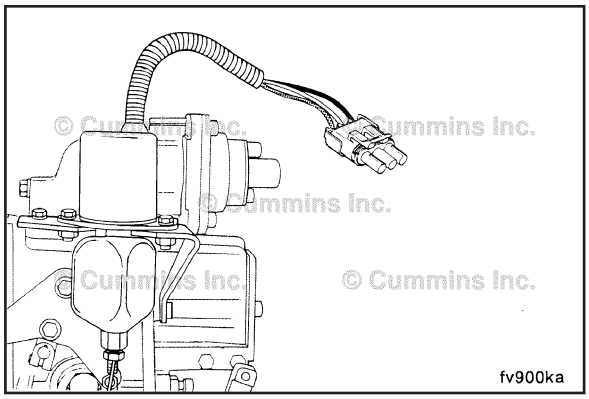


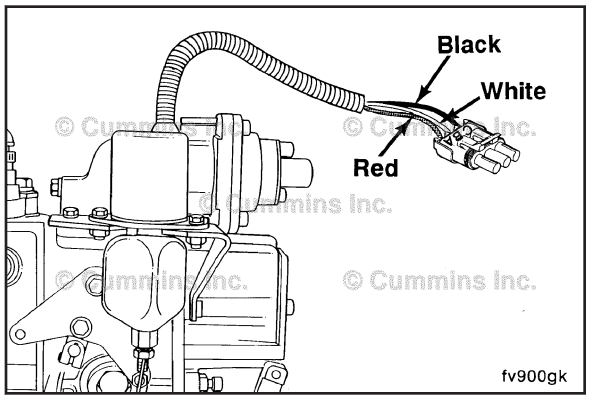
Fuel Shutoff Valve (005-043)

General Information

Shutdown Solenoid Troubleshooting (In-Line-Type Injection Pump)

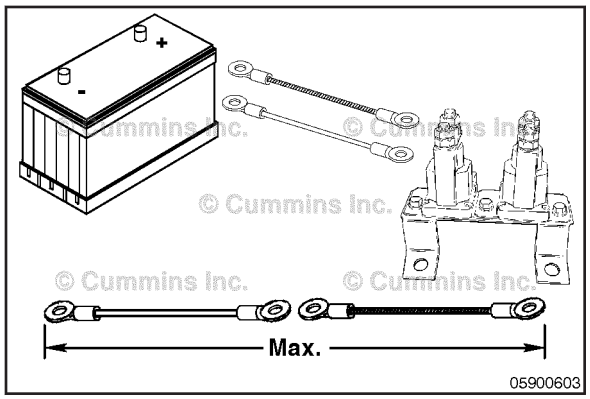
Engines using the in-line type of injection pumps are equipped with the Synchro-Start fuel shutoff solenoid to actuate the shutoff lever. Both 12-VDC and 24-VDC external fuel shutoff solenoids are available.





The Synchro-Start has a Weather-Pack connector with three wires in it.

Color	Description	Weather-Pack Port
Black	Ground	C
White	Pull-in	B
Red	Hold-in	A



Refer to the chart below to find the correct gauge size and length of continuous wire for the white (pull-in) wire which connects to the solenoid wiring.

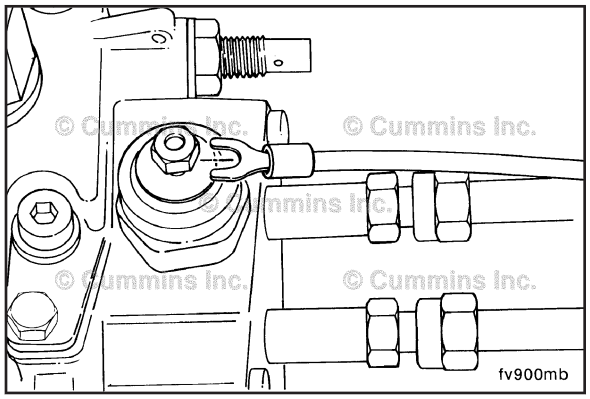
This is the total wire length from the battery to the solenoid and back to the battery. Both white and black wire length **must** be added.

Fourteen-gauge wire is required for the red (hold-in) wire, which connects to the “Run” terminal on the ignition switch.

The black (ground) wire **must** be the same size as the white (pull-in) wire.

Length of Wire - Maximum Length

Gauge	12 VDC	24 VDC
14	1.5-m [5-ft]	2.7-m [9-ft]
12	2.7-m [9-ft]	4.3-m [14-ft]
10	4.3-m [14-ft]	7.0-m [23-ft]



Preparatory Steps

Bosch® VE

Remove the electrical wire and complete the following steps.

Clean around the valve.

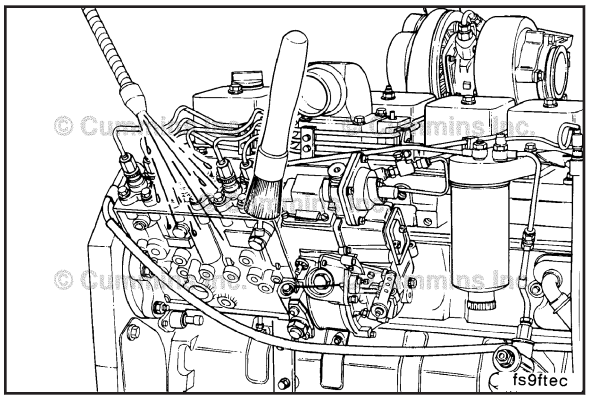
Bosch® A Pump with RSV Governor

This repair can be performed without removing the fuel pump from the engine.

Removal of the shutoff lever, filter, and supply line is **not** necessary if the solenoid can be accessed from the bottom of the fuel pump.

Remove the fuel filter and fuel supply line, if necessary. Refer to Procedures 006-015 and 006-024.

Disconnect the wire harness from the fuel shutoff solenoid.



Initial Check

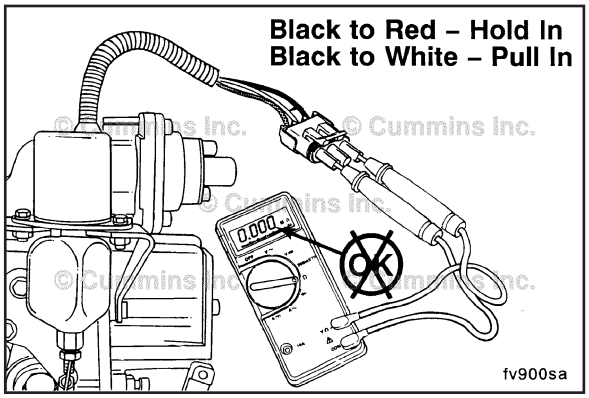
In-line Fuel Injection Pumps

⚠WARNING⚠
Wear protective clothing to reduce the possibility of personal injury. Solenoid surface temperature can exceed 175°C [347°F], which can cause serious burns to the skin in the event of contact.

NOTE: The following check is for all In-line fuel injector pumps.

Values are taken at 20°C [68°F] and rated voltage. Minimum values are for 25-mm [1.00-in] maximum plunger travel. As the temperature of the solenoid increases, the voltage and resistance requirements increase, while the amperage requirements decrease.

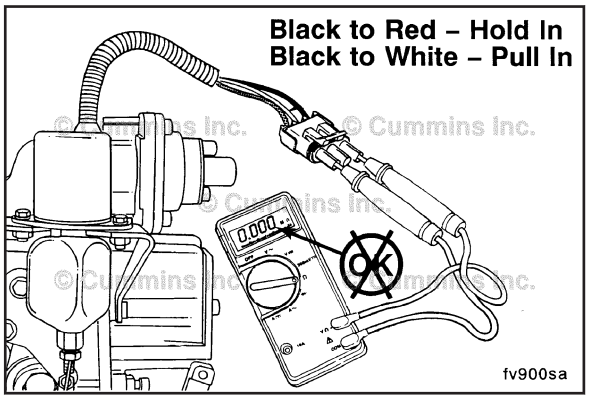
The solenoid resistance can be checked using a multimeter. Disconnect the wiring harness and check the solenoid resistance.



Synchro-Start solenoids with a 44.45-mm [1.75-in] diameter coil canister

Synchro-Start Solenoids 44.5-mm [1.75-in] Diameter Coil Canister

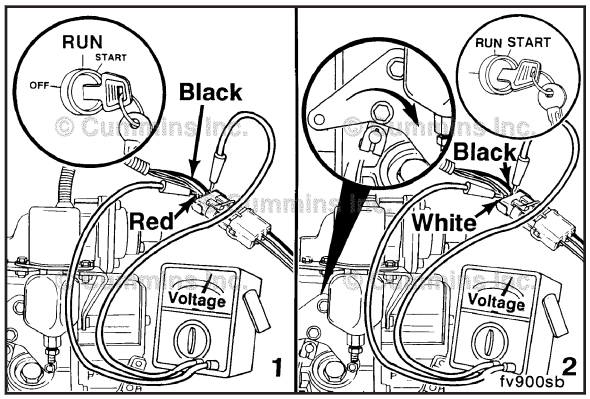
Solenoid Voltage	Acceptable Resistance Range in Ohms	
	Pull-in	Hold-in
12	0.198 to 0.242	10.00 to 12.21
24	0738 to 0.902	37.17 to 45.43



Synchro-Start Solenoids with a 50.8-mm [2.00-in] Diameter Coil Canister.

Synchro-Start Solenoids 50.8-mm [2.00-in] Diameter Coil Canister

Solenoid Voltage	Acceptable Resistance Range in Ohms	
	Pull-in	Hold-in
12	0.175 to 0.213	12.75 to 15.56
24	0.554 to 0.678	46.76 to 57.15



Voltage Checking

NOTE: The following check is for all In-line fuel injector pumps.

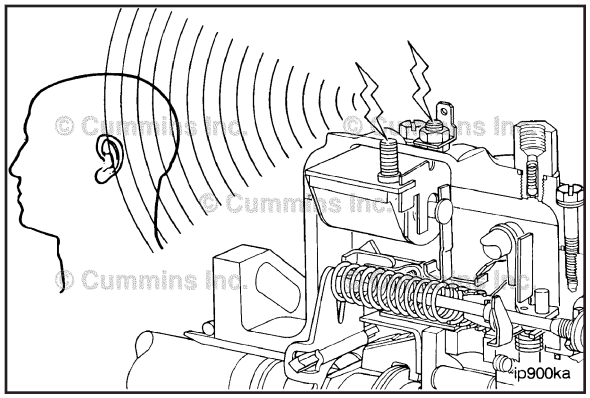
To perform the solenoid voltage check, disconnect the solenoid rod end from the shutdown lever on the fuel pump, connect the wiring harness, and apply voltage to the solenoid with the ignition key as follows:

1. With the key in the RUN position, check the hold-in voltage.
2. With the shutdown lever held in the shutdown position, move the key to the START position, and check the pull-in voltage.

Refer to the table for Synchro-Start voltage specification with solenoid at 20°C [68°F]. Voltage requirements will be higher as engine temperature rises; therefore, these values are **only** valid with the solenoid at normal ambient temperatures.

Synchro-Start Solenoids 20° C [68°F]

Solenoid Voltage	Minimum Voltage	
	Pull-in	Hold-In
12	8.5	5.2
24	17.0	9.4



Stanadyne DB4

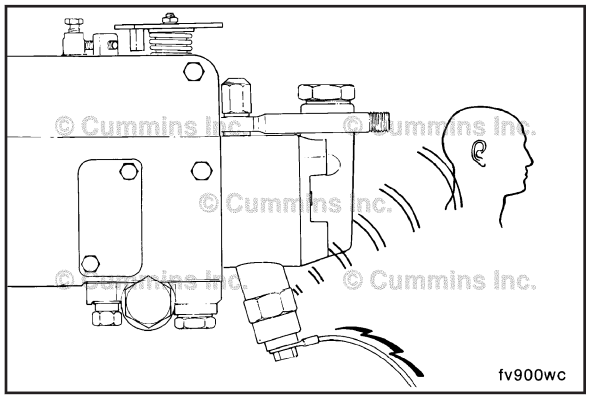
⚠CAUTION⚠
Do not check energize-to-run solenoid operation with governor cover removed from the fuel injection pump.

Test the shutdown solenoid on the Stanadyne DB4 fuel injection pump by applying an electrical current to the terminals and listening for a click. If a solid click is heard, the solenoid is operating freely.

Use the following values to check energize-to-run solenoids:

Standadyne DB4 Solenoid

VDC	VDC to Energize (Minimum)
12	8.8
24	17.6



Lucas CAV DPA or DPS

When the valve on the Lucas CAV DPA/DPS pump opens, a click can be heard.

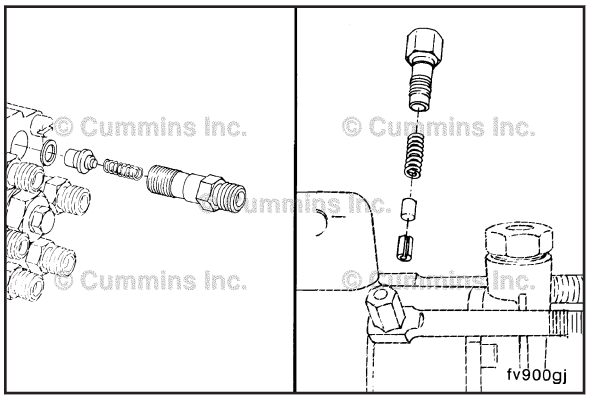
Use the following values to check the solenoid:

CAV Solenoid Values

VDC	Resistance Ohms	VDC to Energize (Minimum)
12	9 at 22°C [71.6°F]	9
24	36 at 22°C [71.6°F]	18

Delivery Valves (Back Leakage Valves on Lucas CAV Pumps)

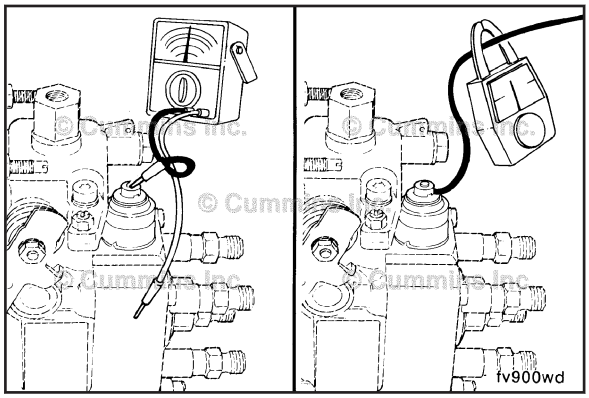
There is a valve for each discharge tube. The purpose of the valve is to control the residual pressure in the high-pressure line. A malfunctioning valve will cause an imbalance of the residual pressure resulting in rough engine operation or surging.



Bosch® VE

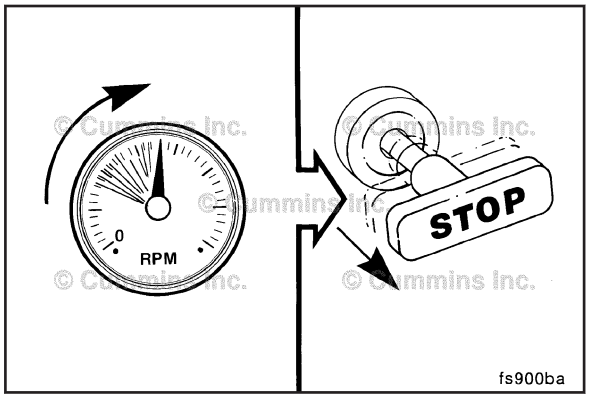
The Bosch® valve does **not** make a very loud sound when actuated, but it can be checked with an ohmmeter for the following values:

Bosch Shutdown Values	Resistance Ohms	Peak Amperes
12 VDC	7.4 + 0.5	2
24 VDC	29.5 + 2.5	1



⚠CAUTION⚠
Do not connect the electrical wire to the solenoid when the plunger has been removed. Without the plunger, the valve can be damaged.

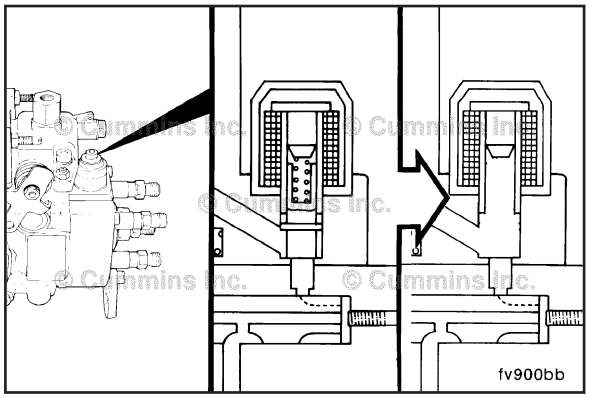
Malfunctioning valves and electrical wiring to the valve can be diagnosed by removing the plunger and spring, and then reinstalling the solenoid.

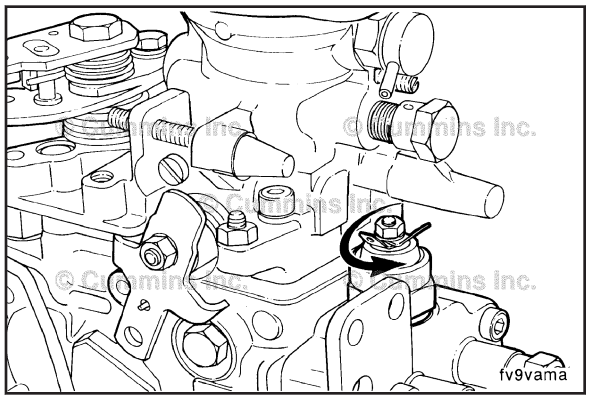


If the engine will start without the valve, the valve or the wiring to the valve is malfunctioning.

This method of removing the plunger to start the engine can be used, if necessary, to move the equipment to a service location.

Use the mechanical shutdown lever to stop the engine.



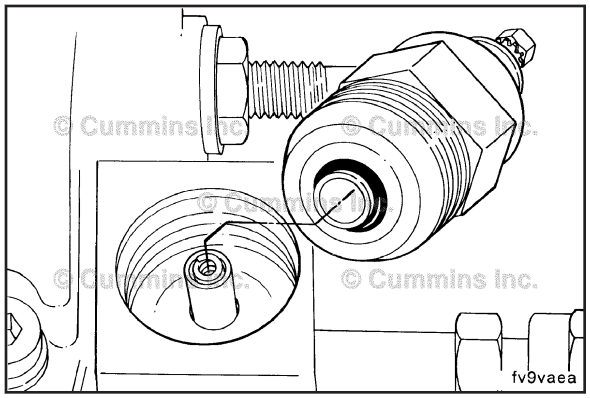


Remove

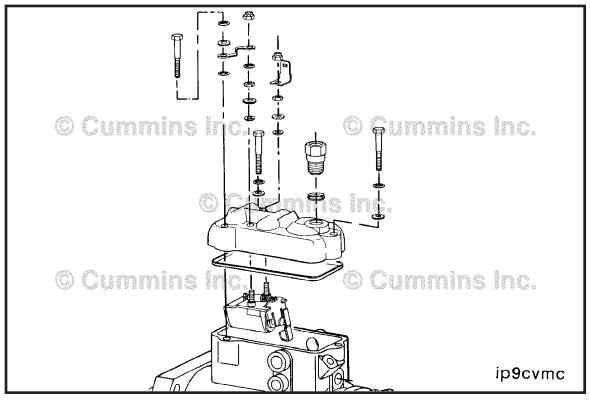
Bosch® VE

Remove the valve.

NOTE: The Bosch® VE valve is shown. The valve for Lucas CAV is located at the bottom of the pump.



⚠CAUTION⚠
When removing the valve, be careful not to drop the plunger and spring. Doing so can result in fuel pump damage.



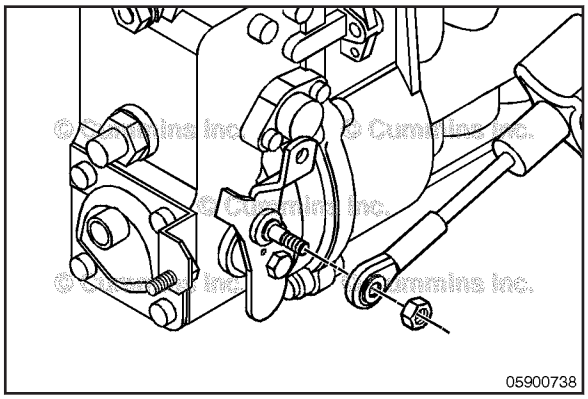
Stanadyne DB4

Tamper-Resistant Screw Removal Tool, Part Number 3399870

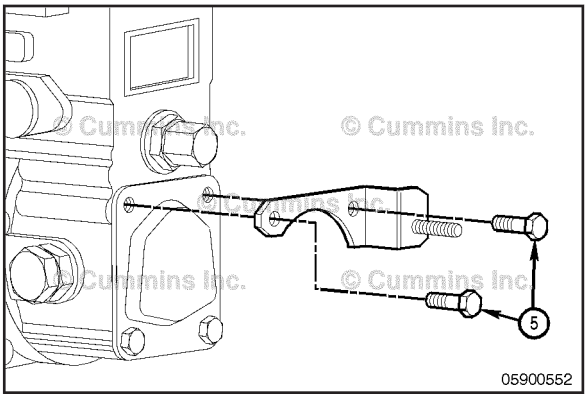
- Remove the electrical wiring.
- Remove the fuel drain line. Refer to Procedure 006-021.
- Remove the throttle and shutoff linkage. Refer to the OEM service manual.
- Remove tamper-resistant screws using service tool kit, Part Number. 3399870. Refer to Procedures 005-012 or 005-014.
- Remove the fuel injection pump top cover. Refer to the Master Repair Manual, Injector Pumps and Injectors, Bulletin 3666037.
- Disassemble the fuel injection pump top cover. Refer to the Master Repair Manual, Injector Pumps and Injectors, Bulletin 3666037.

Bosch® A Pump with RSV Governor

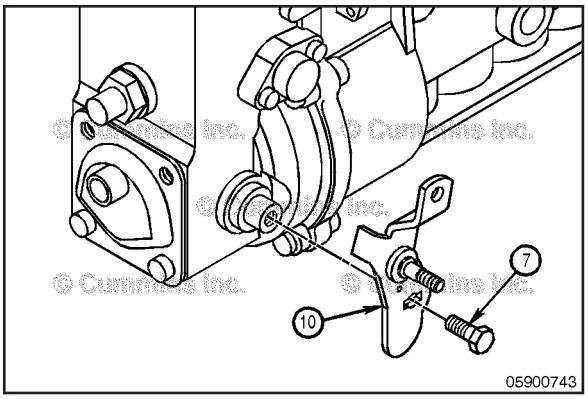
Remove the rod end from the shutoff lever.



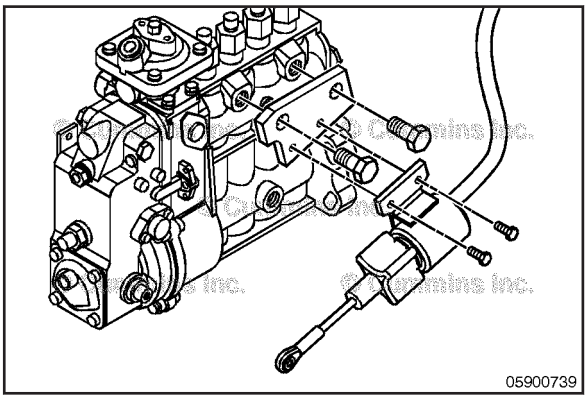
Remove the stop screw and bracket assembly.

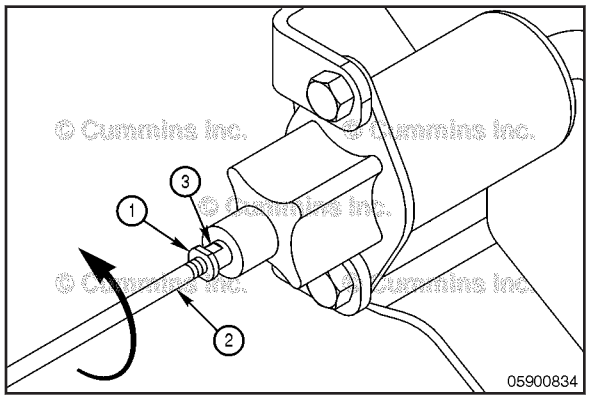


Remove the shutoff lever (10) over the shutoff shaft on the inboard side of the fuel pump.



Remove the solenoid from the solenoid bracket assembly and solenoid bracket assembly from the fuel pump. If the old 1-3/4 inch solenoid and bracket assembly is being replaced with the new 2-inch solenoid, discard the solenoid mounting capscrews.





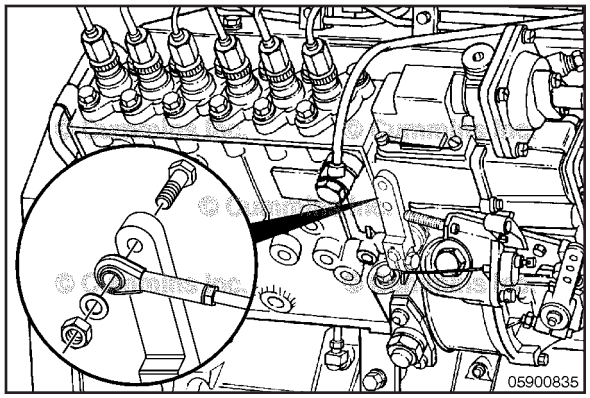
Bosch® P Pump with RQVK Governor

The solenoid does **not** have to be removed from engine to replace the control rod.

Loosen the locknut washer (1) from the solenoid (3).

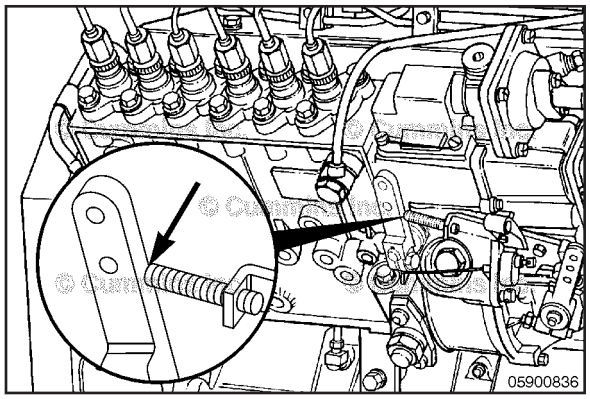
Disconnect the control rod (2) at the lever if control rod is **not** broken.

Unscrew the control rod while holding the solenoid swivel.



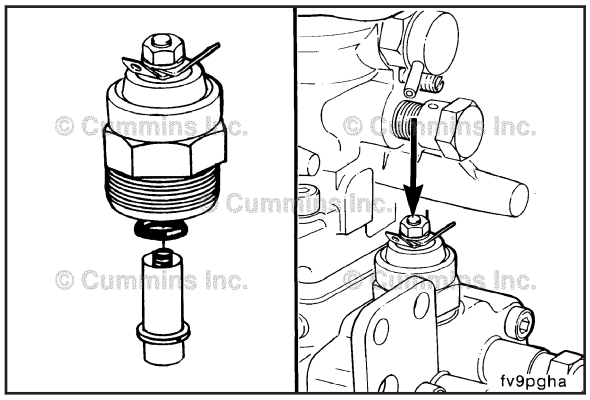
Loosen the capscrew and nut that holds the rod end onto the shutoff lever.

Retain the spacer between the rod end and the shutoff lever.



Check the shufoff lever stop lever stop bracket.

The lever **must** make contact with the stop screw on the stop screw bracket. If the lever does **not** touch the stop screw, adjust the stop screw out 1-1/2 turns past the point of contact between the stop screw and the shutoff lever.



Install

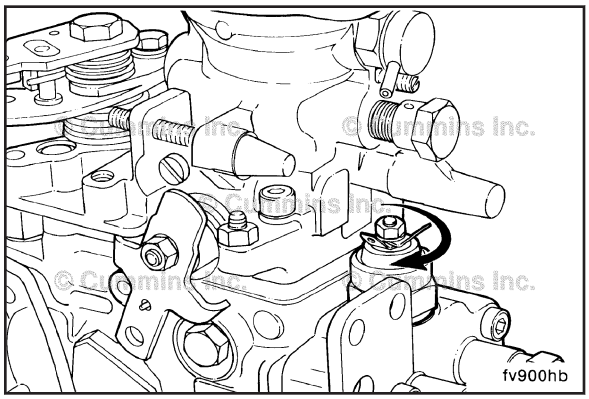
Bosch® VE

Package the solenoid, o-ring, spring, and plunger.

Tighten the solenoid securely.

Connect the electric wire.

Torque Value: 43 N•m [32 ft-lb]

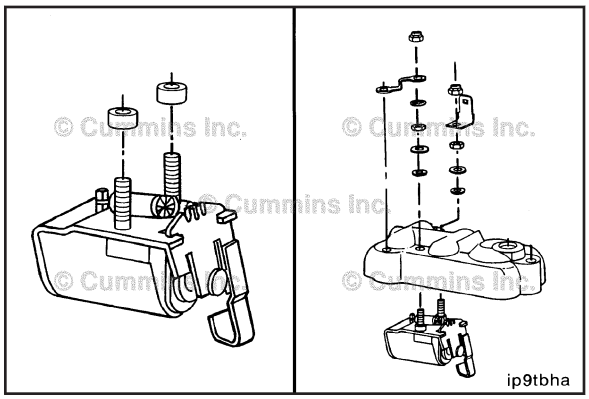


Stanadyne DB4

Install new insulating tubes onto the terminals on the terminal studs of the new solenoid.

Install the valve into the cover.

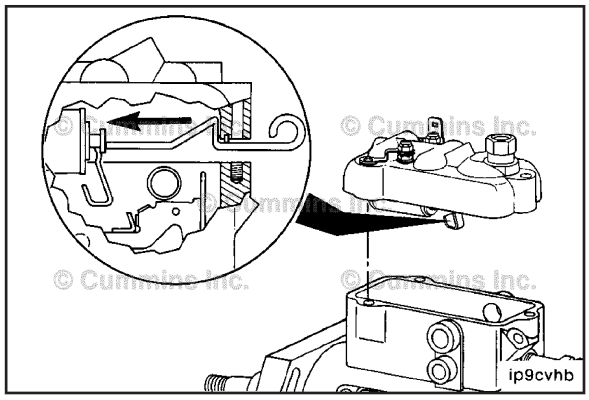
Torque Value: 14 N•m [124 in-lb]



Install the cover and gasket onto the fuel injection pump.

With the tool installed as shown, place the cover in position on the pump housing. Twist the tool to release it, and slide it out from between the cover and the housing.

Extreme care **must** be taken in assembling the cover to a fuel injection pump to make sure the shutoff arm is in proper contact with the linkage hook tab.

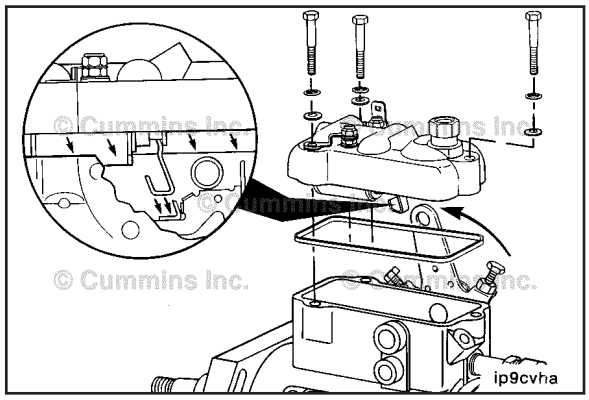


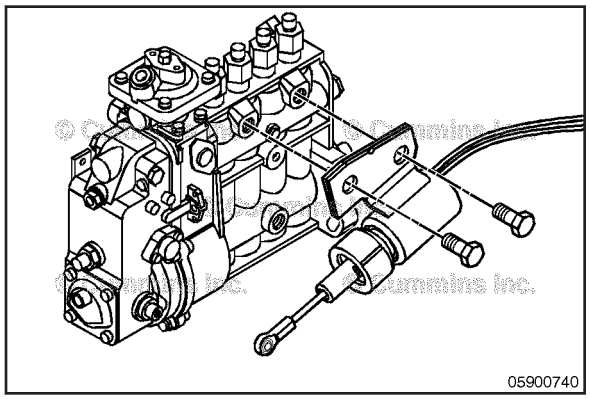
In the event the service tool is **not** available, the governor cover **must** be installed as follows:

Move the shutoff lever to the stop position.

Install the cover to pump at a downward angle from the driveshaft end of the fuel injection pump, then slide the cover horizontally into position.

Torque Value: 4.6 N•m [41 in-lb]





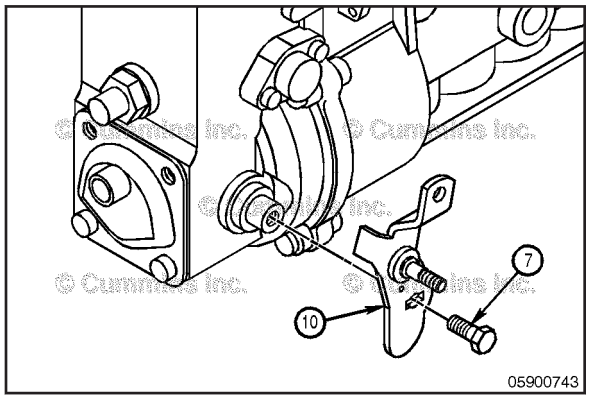
Bosch® A Pump with RSV Governor

⚠CAUTION⚠
Failure to observe proper cranking and fuel system priming procedures can cause solenoid failures.

Install the shutoff solenoid on the fuel pump using two new M16 x 1.5-16 capscrews. Apply Loctite™ to the capscrew threads. Tighten the capscrews just enough to hold the solenoid in place.

NOTE: New solenoid mounting capscrews have threadlocker pre-applied. Loctite™ application is **not** necessary when new capscrews are installed.

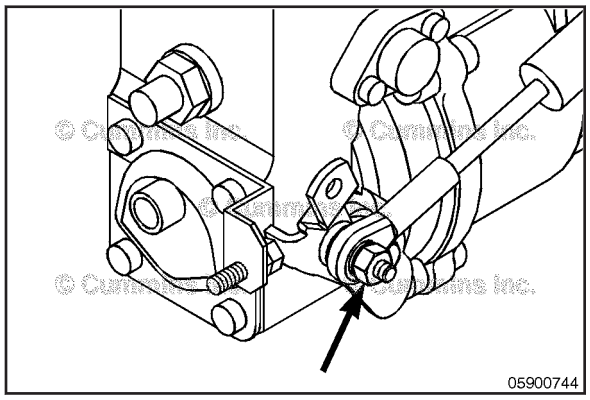
⚠CAUTION⚠
New solenoid mounting capscrews must be used if replacing an old 1-3/4-inch solenoid with a 2-inch solenoid. Insufficient thread engagement can cause damage to the pump and the solenoid.



Install the shutoff lever (10) over the shutoff shaft on the fuel pump.

Use the capscrew (7) previously removed to hold the shutoff lever in place.

Torque Value: 9 N•m [84 in-lb]



Connect the rod end of the solenoid to the shutoff lever.

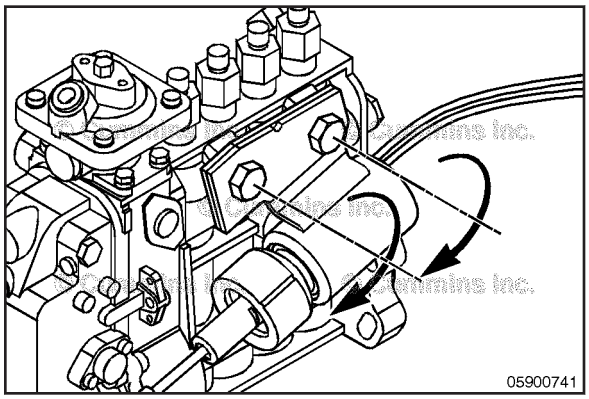
Tighten the shutoff lever nut.

Torque Value: 9 N•m [84 in-lb]

⚠CAUTION⚠
The solenoid mounting capscrews must not be overtightened. Distortion to the fuel pump body can result causing the rack to stick in the fuel pump.

Tighten the solenoid mounting capscrews.

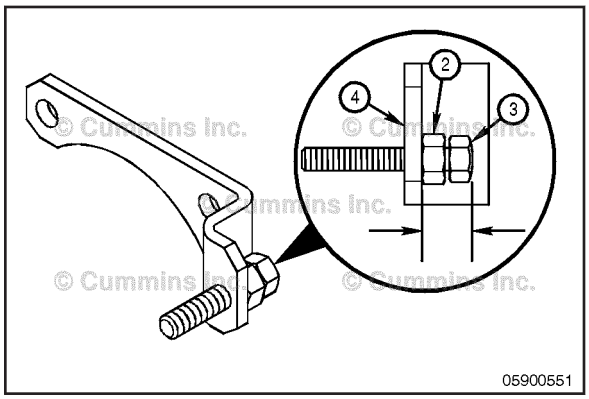
Torque Value: 24 N•m [212 in-lb]



NOTE: If the stop screw is **not** moved, readjustment may **not** be necessary.

Assemble the stop screw to the stop screw bracket. Adjust the stop screw (3) so the contact surface of the screw protrudes 10 mm beyond the surface of the stop bracket (4).

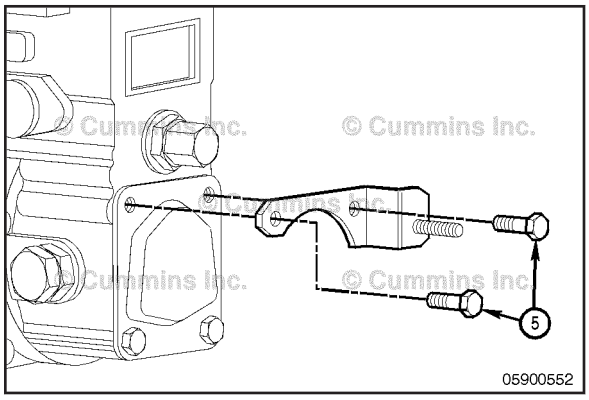
Tighten the nut (2) against the stop bracket to lock the stop screw in place.



Install the stop bracket assembly using two M6 x 1-16 capscrews (5).

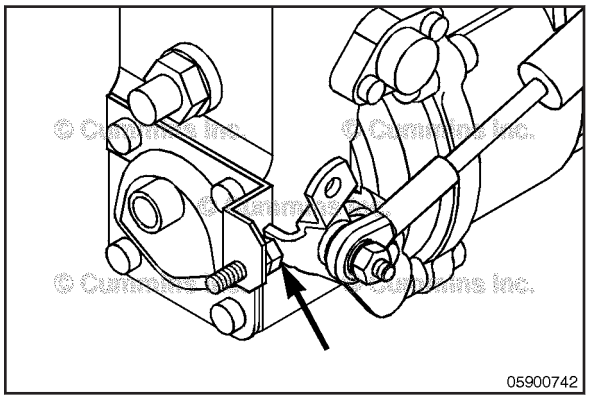
Tighten the capscrews.

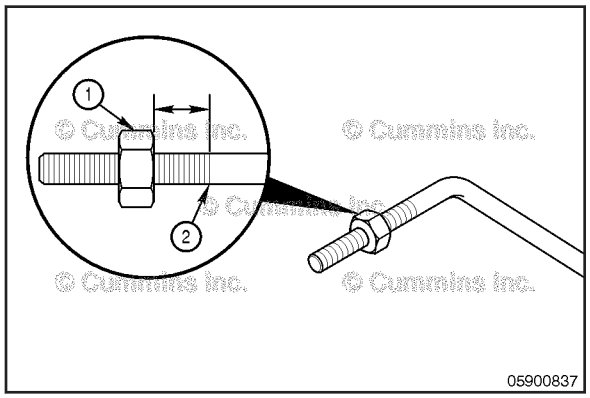
Torque Value: 7 N•m [60 in-lb]



⚠CAUTION⚠
The solenoid rod length is pre-set. Adjustment of the solenoid rod can cause damage to the solenoid or lead to a low power complaint.

Verify the shutoff lever is contacting the stop screw and is in the full stop position. If the shutoff lever does **not** contact the stop screw, verify the shutoff solenoid and stop screw bracket are assembled correctly. Loosen the solenoid mounting capscrews and readjust the solenoid, if necessary.

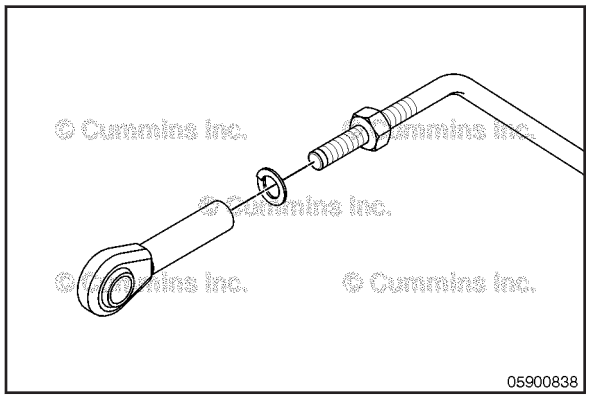




Bosch® P Pump with RQVK Governor

The rod end to control rod orientation is important. If the rod end is installed incorrectly, improper operation of the shutoff solenoid assembly can occur.

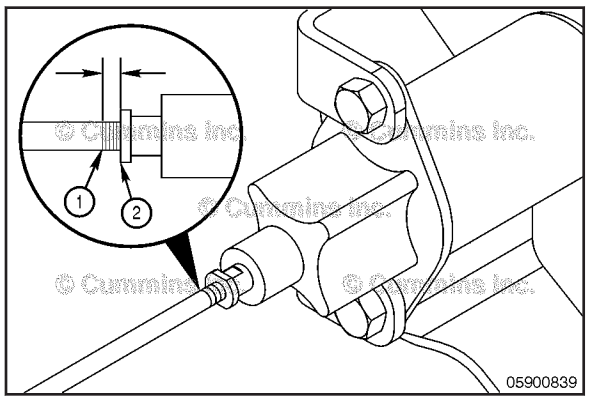
Install the locknut (1) onto the new control rod at the rod end until there is [13 mm] 7/16 inch between the start of the threads (2) and nut (1).



Install the lock washer.

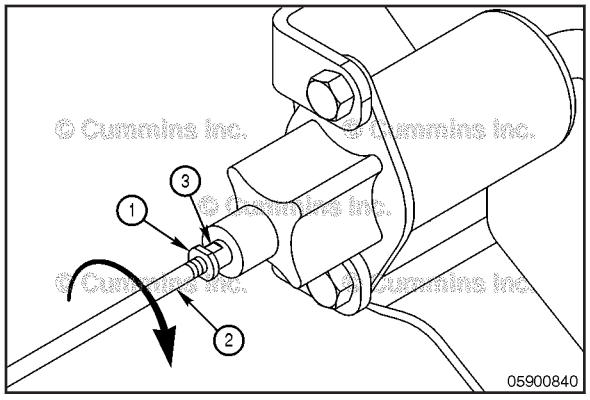
Screw the rod end onto the control rod, hand tightening and making certain **not** to move the locknut. Lay the control rod and rod end on a flat surface. Rotate the rod end so both the control rod and the rod end lay flat.

Tighten the locknut onto the rod end.



Install the locknut (2) on the control rod at the solenoid end until there is [6 mm] 1/4 inch between start of the threads (1) and locknut (2).

Install the lock washer and screw the control rod into the solenoid.



Install the control rod end capscrew onto the fuel pump shutoff lever to align the control rod.

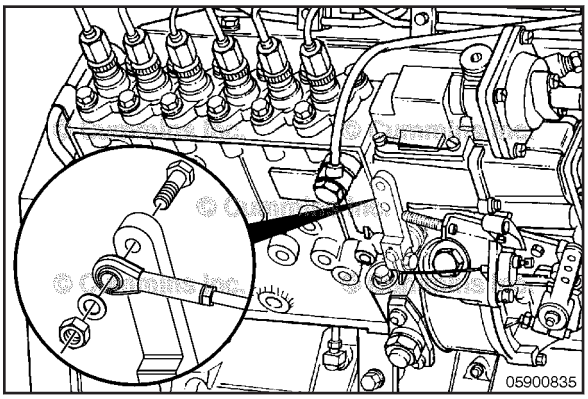
Tighten the locknut (1) while holding the solenoid swivel (3).

The solenoid is designed to allow rotation of the control rod.

Make certain to install the spacer between the rod end and the shutoff lever.

Tighten the capscrew and nut that holds the rod end onto the shutoff lever.

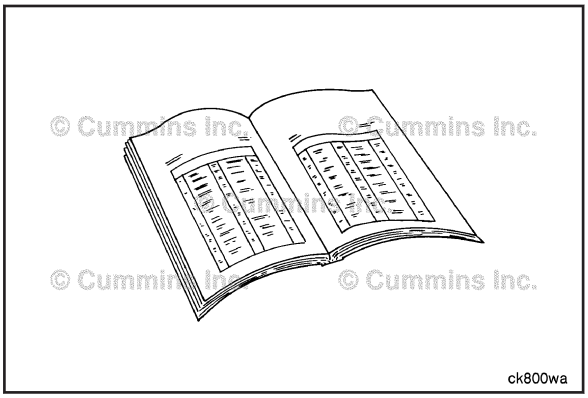
Torque Value: 9 N•m [80 in-lb]



Finishing Steps

Install all components removed, including the fuel filter and fuel supply line.

Connect the wire harness to the fuel shutoff solenoid.



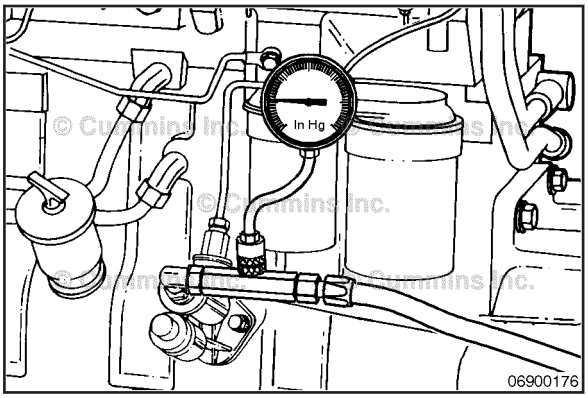
Fuel Lift Pump (005-045)

Initial Check

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.

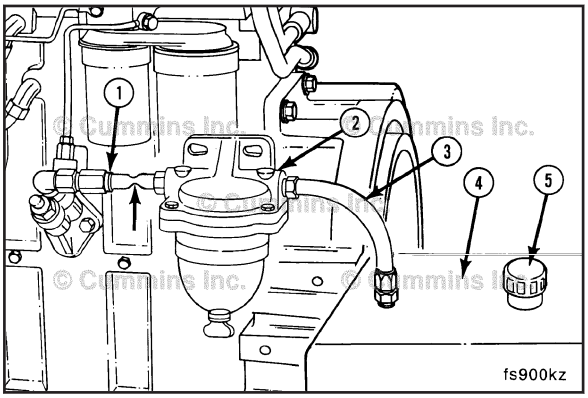
Fuel Lift Pump Inlet Restriction - Clean Fuel Filter		
kPa		in Hg
63.5	MAX	2.5

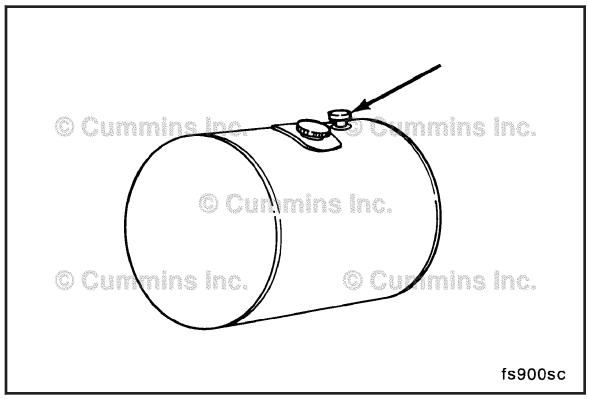
Fuel Lift Pump Inlet Restriction - Dirty Fuel Filter		
kPa		in Hg
100	MAX	4.0



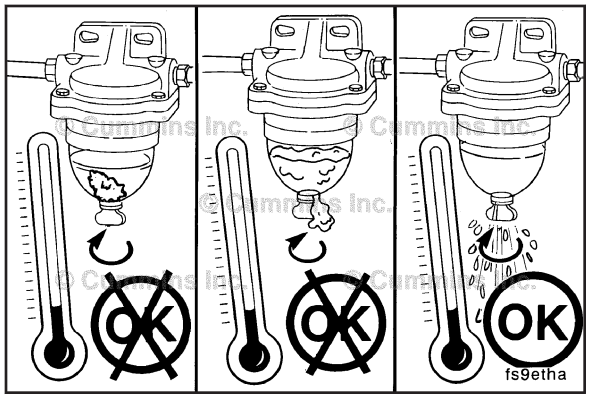
If the inlet restriction is above the maximum, check for restrictions or suction leaks in the fuel circuit to the fuel lift pump:

1 Supply line
2 Prefilter
3 Supply line
4 Supply tank
5 Tank vent.





Look for a plugged supply tank vent first.

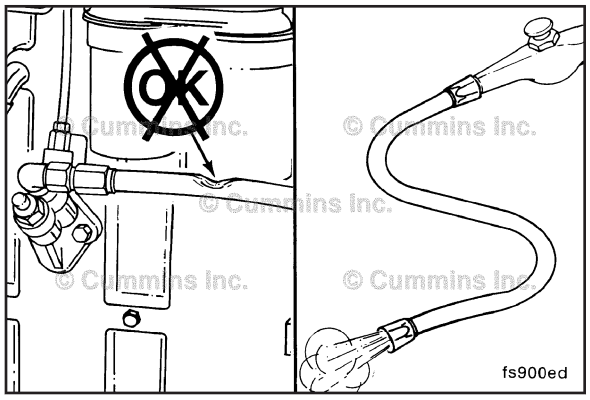


Fuel prefilters, in-line and water separator type, can become clogged and cause a loss of fuel flow.

Check the prefilter for clogs or restrictions.

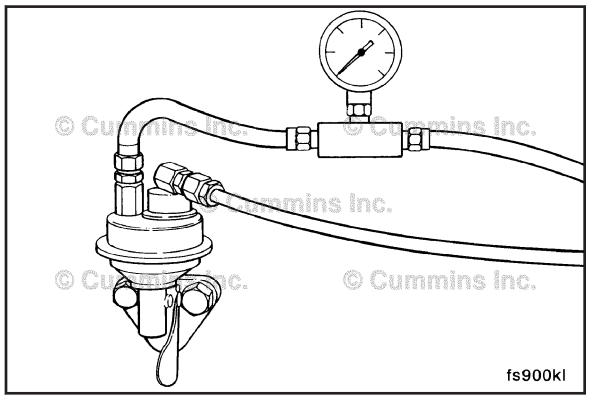
In cold weather, check the prefilter for gelled fuel.

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.



Test

Output Pressure Test (Diaphragm Style and Piston Style - Low Output)

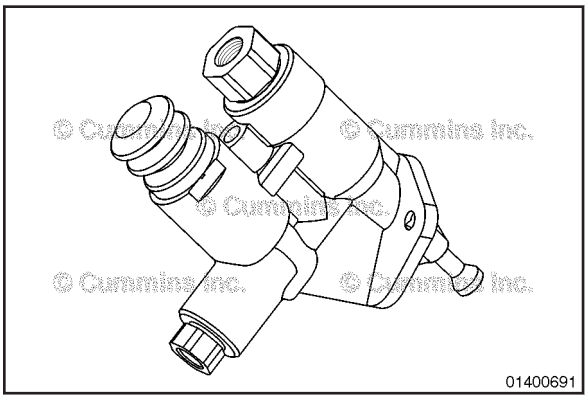
Operate the engine and measure the output pressure of the fuel lift pump using an in-line pressure gauge at the inlet to the injection pump.

The minimum pressure at high idle is 21 kPa [3 psi].

If the minimum pressure is not achieved, check for:

- Dirty fuel filter
- Damaged lift pump.

NOTE: On some engines, the diaphragm style pump may have been replaced by a low output piston style pump. The specifications below apply to both diaphragm and piston low output pumps. The low output piston pump is visually different from higher output piston pump. The outlet points downward on the low output piston pump.



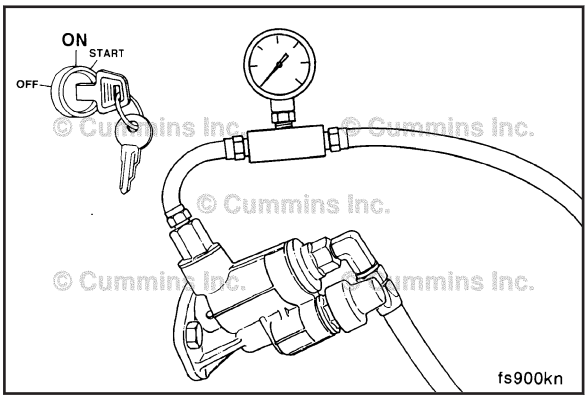
Output Pressure Test (Piston Style - High Output))

Operate the engine, and measure the output pressure of the fuel lift pump with an in-line pressure gauge at the inlet to the injection pump.

Minimum pressure at high idle is 124 kPa [18 psi].

If the minimum pressure is not achieved, check for:

- Dirty fuel filter
- Damaged lift pump.

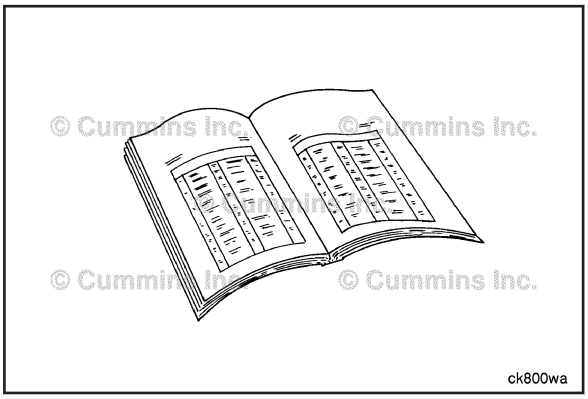


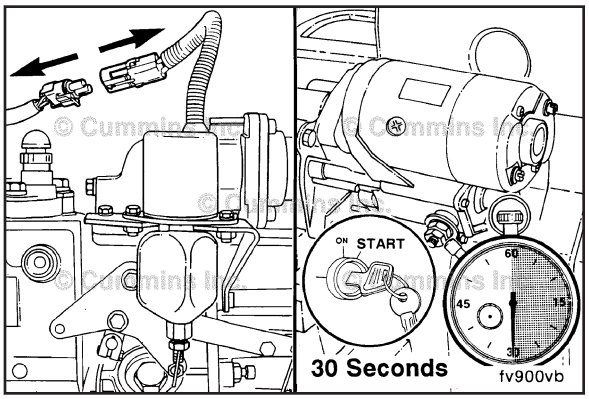
Preparatory Steps

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

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

- Clean the debris from the fuel line filters and the fule lift pump.
- Disconnect the low-pressure fuel lines. Refer to Procedure 006-024.

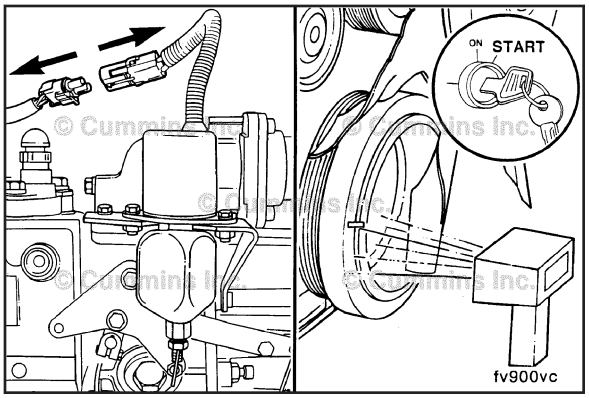




Remove

⚠CAUTION⚠
To prevent the engine from starting, disconnect the fuel shutdown wiring. Residual fuel in the injection pump can cause the engine to start.

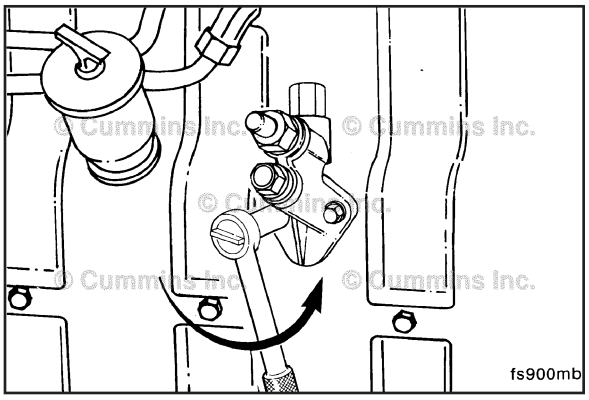
⚠CAUTION⚠
Do not crank the starter for more than 30 seconds at a time. Doing so can result in starter damage. Also, high voltage during cranking can damage the shutdown solenoid.



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.



Remove the two fuel lift pump mounting capscrews.

Remove the fuel lift pump.

Install

⚠CAUTION⚠
Alternately tighten the mounting capscrews. As the capscrews are tightened, the fuel lift pump plunger is pushed into the pump. Failure to tighten the capscrews in an even manner can result in the plunger being bent or broken, causing sticking and failure.

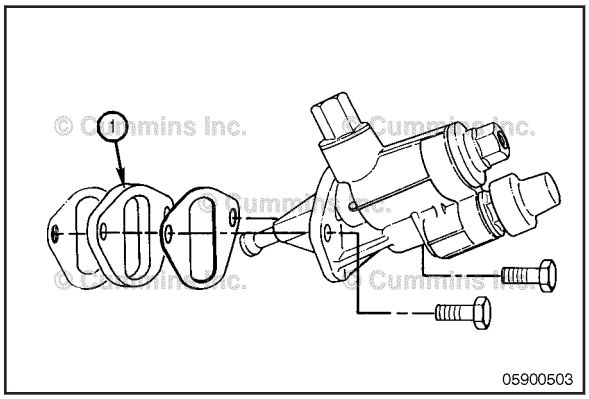
Diaphragm Style and Piston Style

Install the pump.

Torque Value: 24 N•m [212 in-lb]

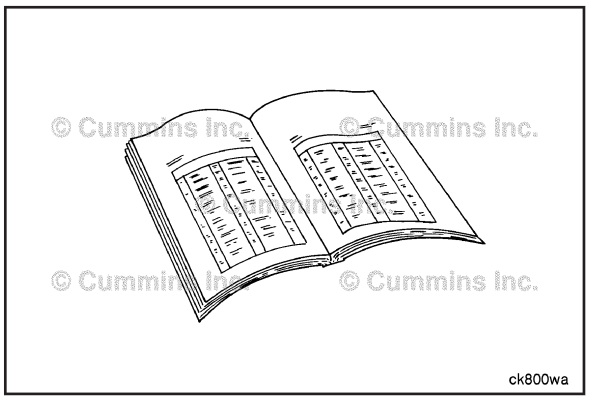
The 5 mm [0.20-in] spacer (1), Part Number 3914284, must be installed along with a new gasket, Part Number 3931348, on each side of the spacer.

NOTE: For some applications, a bracket used for supporting other options will replace the 5 mm [0.20-in] spacer.



Finishing Steps

- Install the low pressure fuel lines. Refer to Procedure 006-024 in Section 6.
- Vent the low-pressure fuel lines. Refer to Procedure 006-024 in Section 6.
- Operate the engine and check for leaks.



Cold Start Timing Advance System (KSB) Remote (005-046)

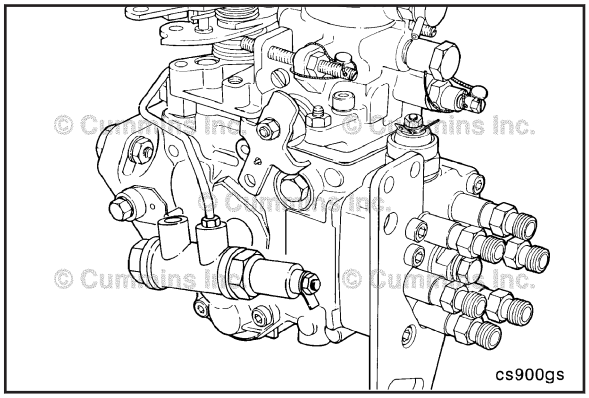
General Information

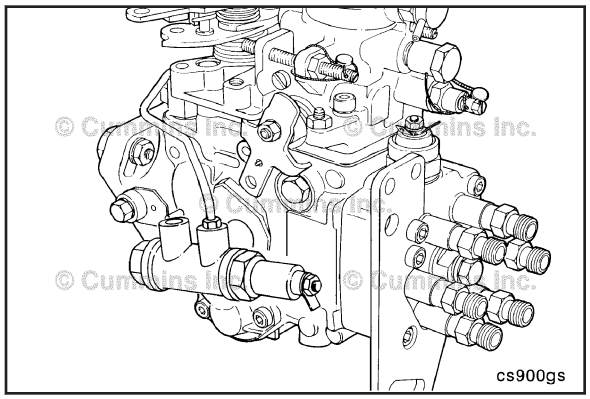
Wax-Motor Style

Cold Start Timing Advance System (KSB) - Wax Motor Style

The wax motor-style KSB is used on pre-1991 B Series automotive engine ratings using the Bosch® VE fuel pump.

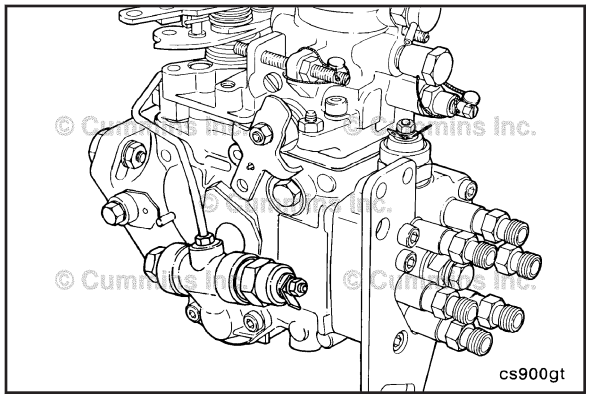
NOTE: The electrical solenoid-style KSB is used on 1991 model and newer B Series automotive engine ratings using the Bosch® VE fuel injection pump. See Procedure 005-070, Cold Start Timing Advance System (KSB) — Pump Mounted, for additional information.





Wax Motor Style KSB

NOTE: Temperature switch is located in the coolant jacket.

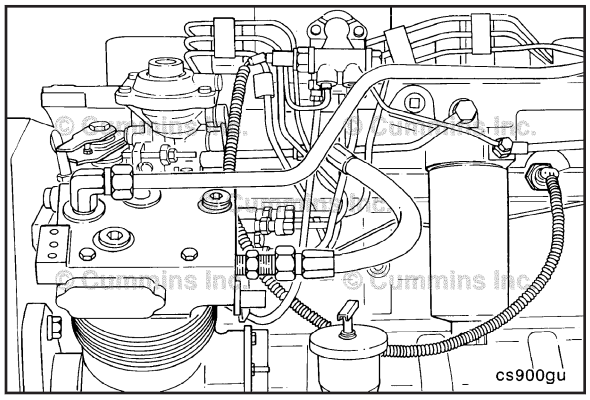


Electrical Solenoid-Style KSB

NOTE: Temperature switch is located in the intake manifold.

KSB Hardware Definition

There are currently two versions of pump-mounted wax motor-style KSBs released in the Cummins system and one remote-mounted version. The remote mounted option is necessary in applications where the pump-mounted KSB causes interference (i.e., with the air compressor).

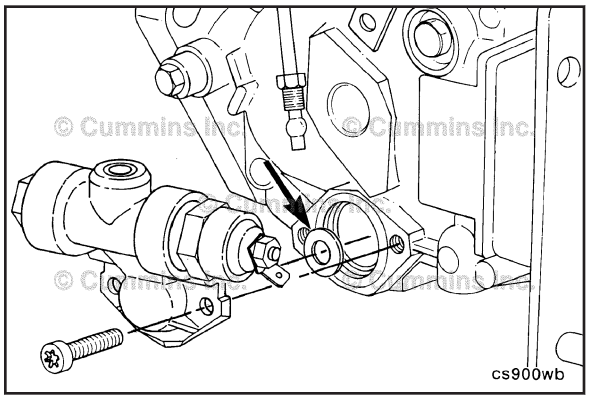


Remote Mounted KSB

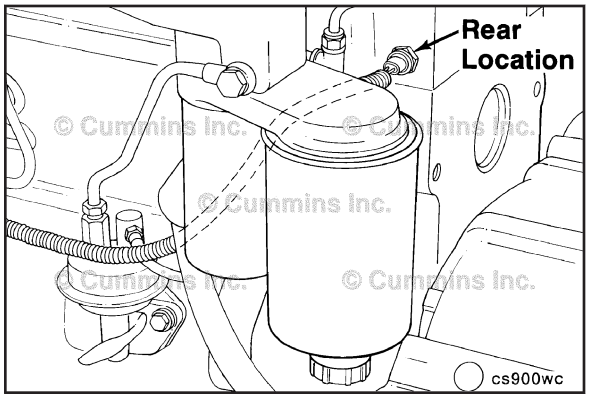
The remote-mounted KSB is used on B Series automotive engines that have an air compressor.

⚠CAUTION⚠

Most pumps will have a shim between the KSB and the timing piston. This shim must be reassembled between the cover plate and the timing piston. If this shim sticks to the KSB and is installed with the remote-mounting hardware, it will block the regulating valve drain path and damage the pump. This damage is usually evidenced by a fuel leak.



The four-cylinder engine using remote mounting requires the temperature switch to be installed in the cylinder head as illustrated.



Electrical Solenoid Style

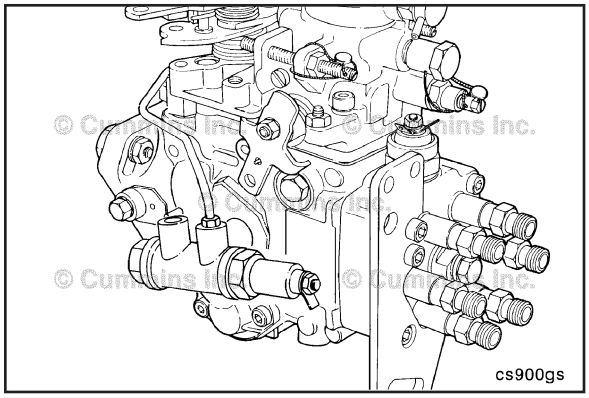
Cold Start Timing Advance System (KSB) - Electrical Solenoid Style

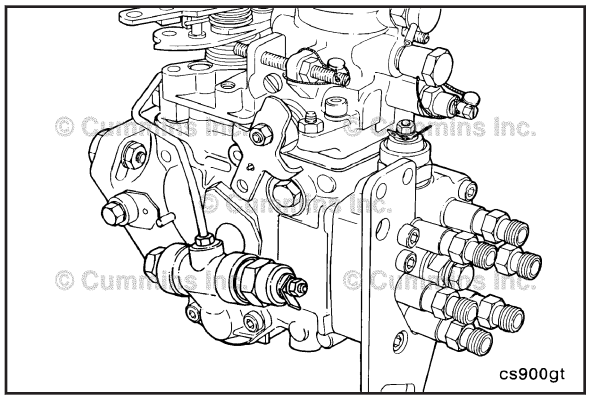
The electrical solenoid-style KSB is used on 1991 model and newer B Series automotive engine ratings using the Bosch® VE fuel pump.

NOTE: The wax motor-style KSB is used on pre-1991 B Series automotive engine ratings using the Bosch® VE fuel pump.

Wax Motor-Style KSB

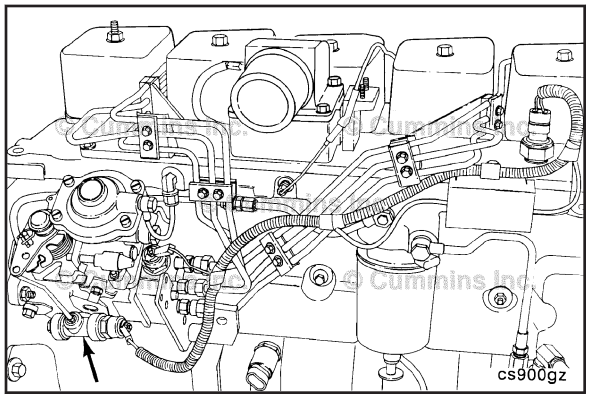
NOTE: The temperature switch is located in the coolant jacket.





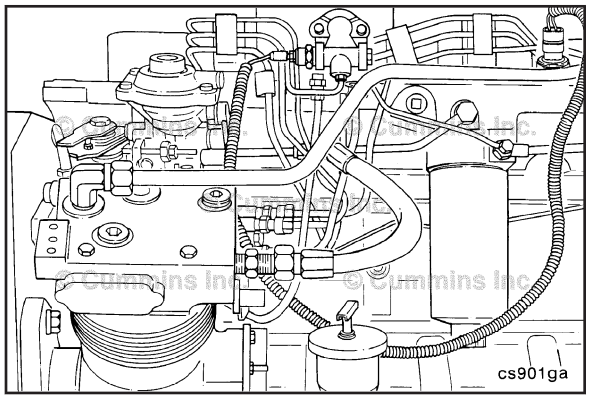
Electrical Solenoid-Style KSB

NOTE: Temperature switch is located in intake manifold.



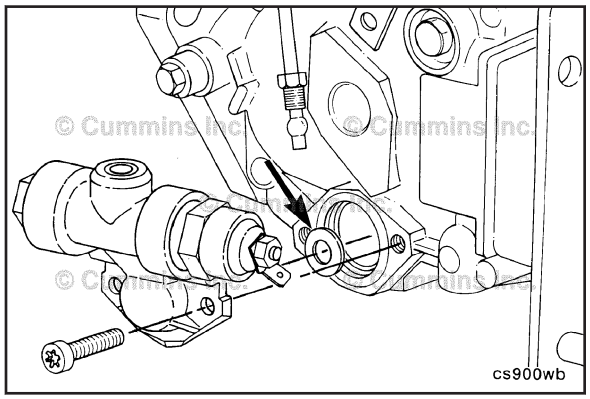
Two types of electrical solenoid-style KSB valves are available.

The first type is the pump-mounted KSB, as shown.



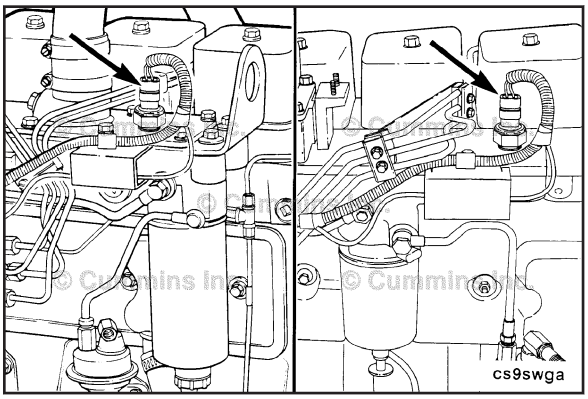
The second type is the remote-mounted KSB, as shown.

The remote-mounted KSB is used on B Series automotive engines that have an air compressor.



⚠CAUTION⚠
Most pumps will have a shim between the KSB and the timing piston. This shim must be reassembled between the cover plate and the timing piston. If this shim sticks to the KSB and is installed with the remote-mounting hardware, it will block the regulating valve drain path and damage the pump. This damage is usually evidenced by a fuel leak.

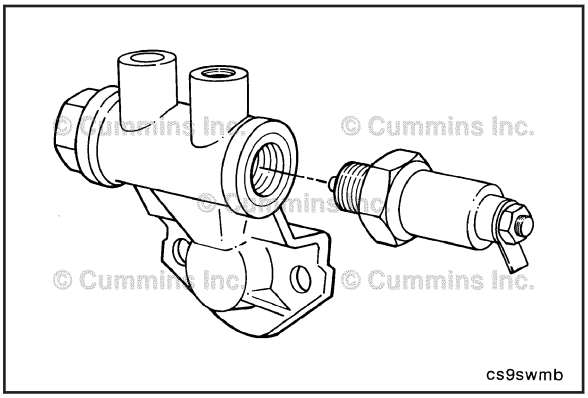
Both the four-and-six cylinder have the temperature switch mounted in the intake manifold, as shown.



Disassemble

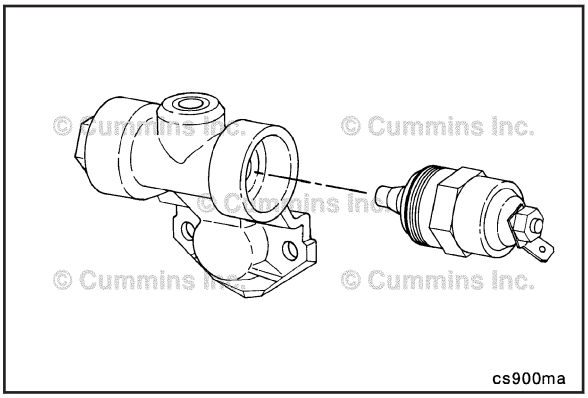
Wax-Motor Style

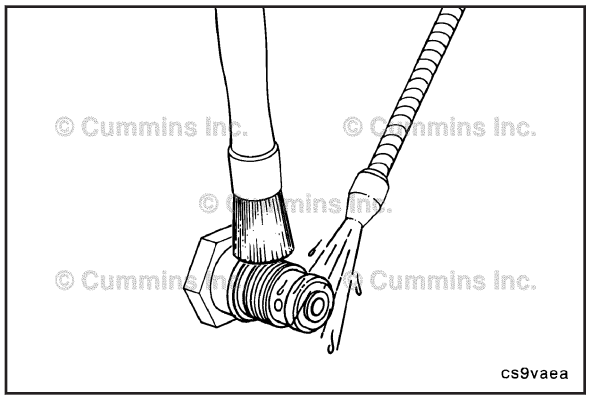
Loosen and remove the KSB electrical element from the KSB housing.



Electrical Solenoid Style

Remove the KSB electrical solenoid from the KSB housing.





Clean

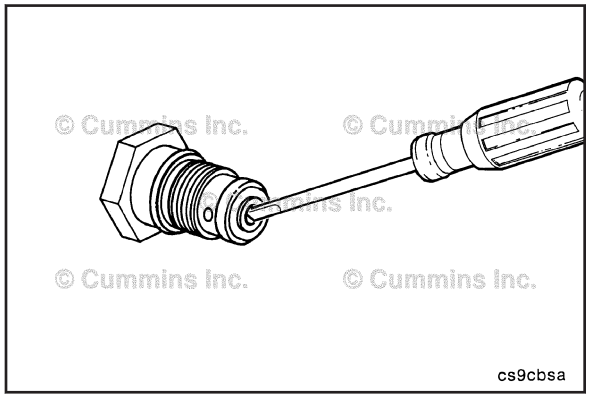
Electrical Solenoid Style

⚠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.

Thoroughly flush the pressure relief valve with cleaning solution.

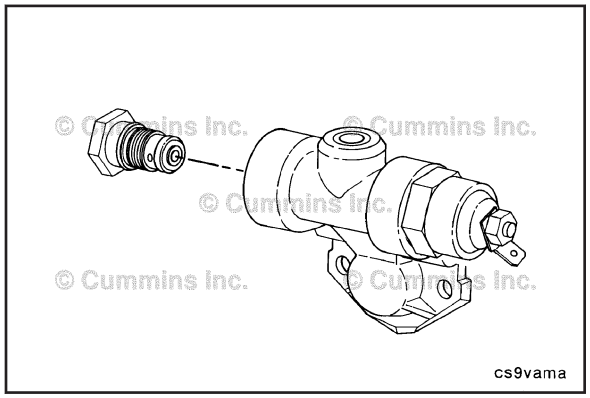
Dry with compressed air.



Use a very small screwdriver to be sure the check ball is **not** sticking.

NOTE: A sticking or malfunctioning pressure relief valve will result in either white smoke or a ruptured fuel pump housing.

Replace the pressure relief valve assembly, if necessary.



Install the original pressure relief valve or a replacement into the KSB housing.

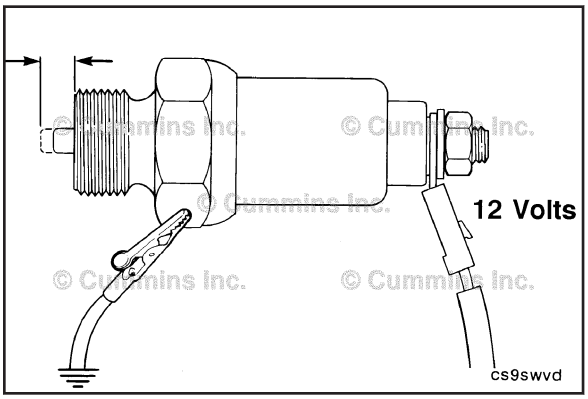
Torque Value: 13 N•m [115 in-lb]

Test

Wax-Motor Style

Apply 12 VDC to the electrical terminal and a ground strap to the hexagonal portion of the element. Check for extensional movement of the plunger. If the plunger does **not** move after approximately 1 minute, check to make sure the element has been correctly connected to ground. If all connections are correct and the plunger does **not** move, the element is defective and **must** be replaced.

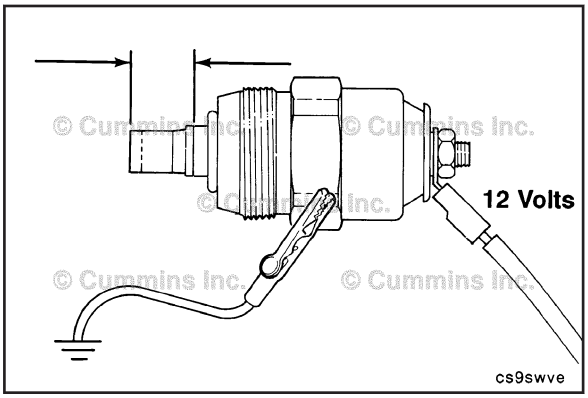
NOTE: The amount of plunger movement will vary depending upon the ambient temperature.



Electrical Solenoid Style

Apply 12 VDC to the electrical terminal, and ground the hexagonal portion of the element. The magnetic coil of the solenoid **must** push the plunger outward.

If the plunger does **not** push outward when voltage is applied, the solenoid is defective and **must** be replaced.

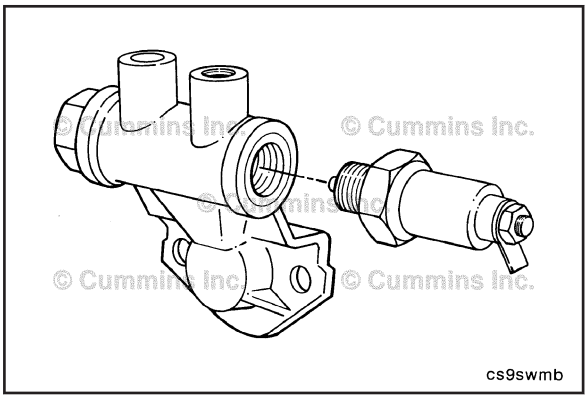


Assemble

Wax-Motor Style

Install the original element or a replacement into the KSB housing.

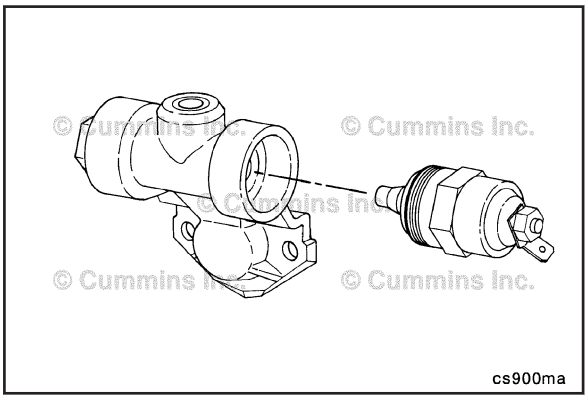
Torque Value: 22 N•m [16 ft-lb]

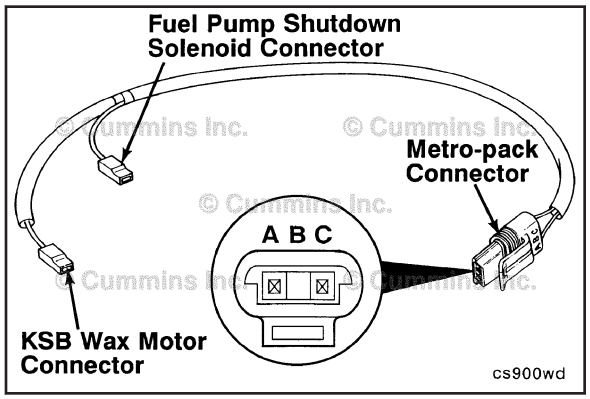


Electrical Solenoid Style

Install the original solenoid or a replacement into the KSB housing.

Torque Value: 22 N•m [16 ft-lb]



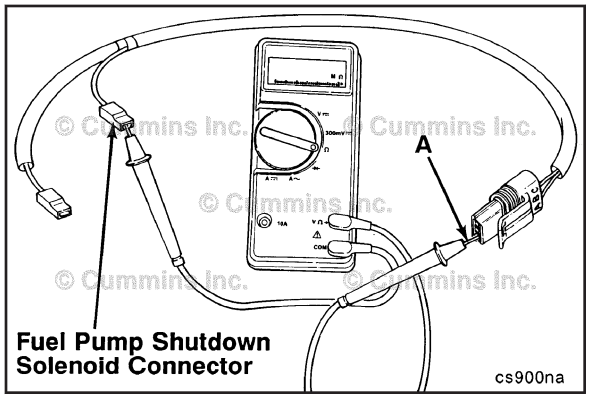


Resistance Check

Wax-Motor Style

The wiring harness used on the wax motor-style KSB can be inspected using a multimeter.

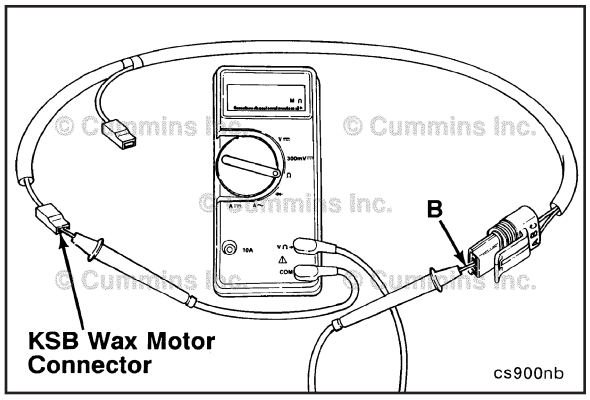
NOTE: Pin C of the metro-pack connector is blank on the wax motor style KSB wiring harness.



Use a multimeter to perform a continuity check between port A of the metro-pack connector and the female spade connector at the fuel pump shutdown solenoid connector.

Repair the wire if there is an open circuit.

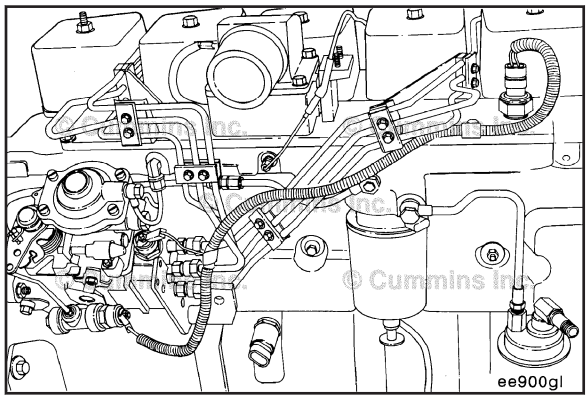
Ohms Resistance - Less than 10.



Use a multimeter to perform a continuity check between port B of the metro-pack connector and the female spade connector at the KSB wax motor connector.

Repair the wire if there is an open circuit.

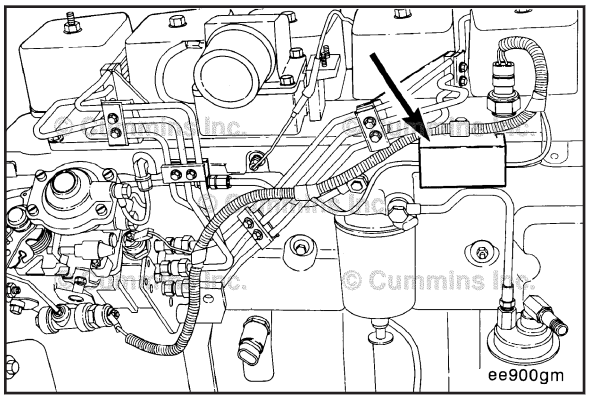
Ohms Resistance - Less than 10.



Electrical Solenoid Style

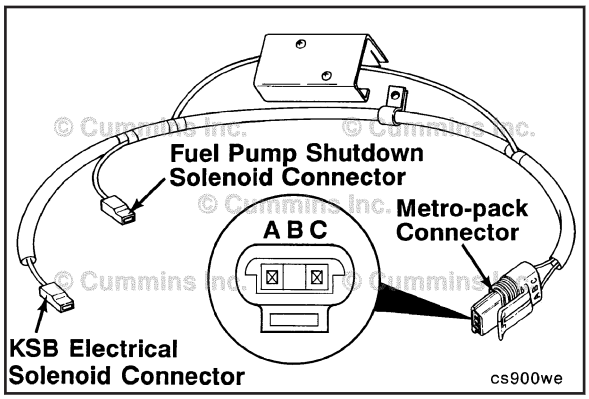
Engines with CPL 1579 do **not** have a resistor in the harness.

Engines with CPL 1351 **must** be wired with the resistor in the harness.



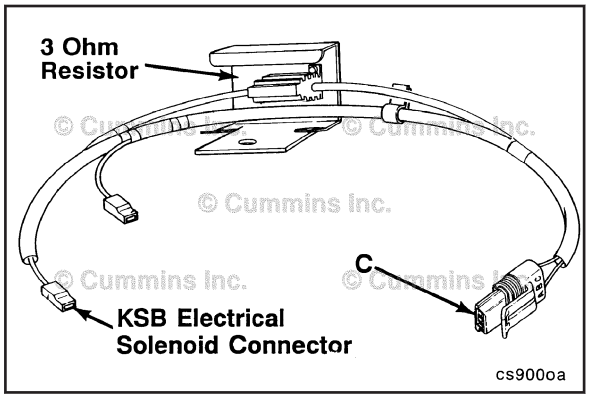
The wiring harness used on the electric solenoid-style KSB can be inspected using a multimeter.

NOTE: Pin B of the metro-pack connector is blank on the electric solenoid style KSB wiring harness.



The electric solenoid-style KSB wiring harness contains a 3-ohm resistor in the wire leading from port C of the metro-pack connector to the KSB electrical solenoid connector.

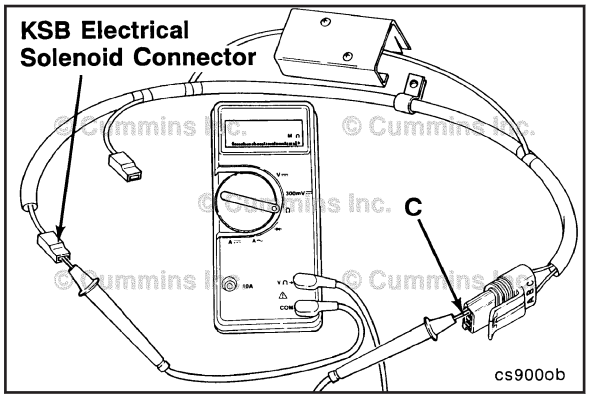
The 3-ohm resistor is mounted to a bracket that is utilized as a heat sink to absorb heat that is generated by the resistor.

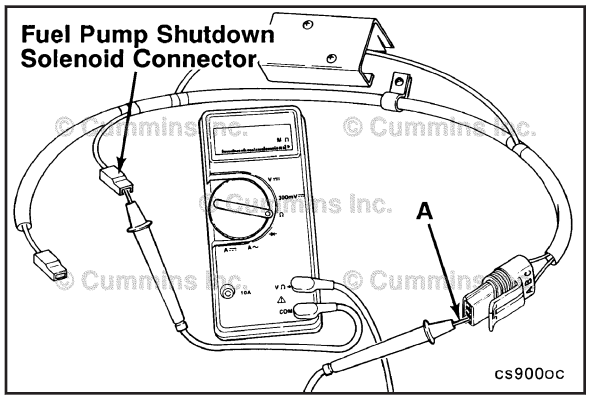


Use a multimeter to perform a continuity check between port C of the metro-pack connector and the KSB electrical solenoid connector.

Repair the wire if there is an open circuit.

(Spec = Less than 10 ohms).

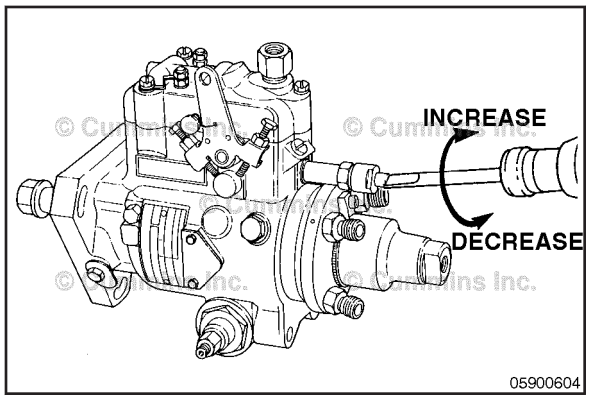




Use a multimeter to perform a continuity check between port A of the metro-pack connector and the fuel pump shutdown solenoid connector.

Repair the wire if there is an open circuit.

(Spec = Less than 10 ohms).



Speed Droop Governor (005-058)

Adjust

Stanadyne

Stanadyne DB4 (Generator Application) Speed Droop Governor

Governor regulation of 3 percent to 5 percent can be attained with the speed droop governor. Precise control of governor regulation is done by decreasing or increasing the effective length of the governor control spring; this also decreases or increases the spring control spring rate. The governor control spring is threaded into an adjusting cap assembly and is referred to as the control rod assembly. By turning the adjusting cap in the **clockwise** direction, as viewed from the fuel transfer pump end, the control rod spring shortens and becomes less sensitive, thereby increasing governor regulation. Turning the adjusting cap in the **counterclockwise** direction increases the control rod spring length and sensitivity, which will decrease governor regulation.

The external speed droop adjustment screw, located at the rear of the fuel injection pump housing, controls the governor sensitivity. The droop screw adjustment varies the governor regulation by changing the effective spring rate. This adjustment will affect both full-load and no-load frequency settings and can require the high-speed stop screw be reset.

Speed droop adjustments **must** be made while the engine is operating. After each adjustment of the droop screw, the engine **must** be shutdown briefly in order to allow the governor spring to unload and the adjusting mechanism to seek its final position in the spring. Turning the screw in shortens the control spring, making it less sensitive and increasing speed droop. Turning the adjusting screw out has the opposite effect. Speed droop is the fuel injection pump's ability to respond to changing engine loads.

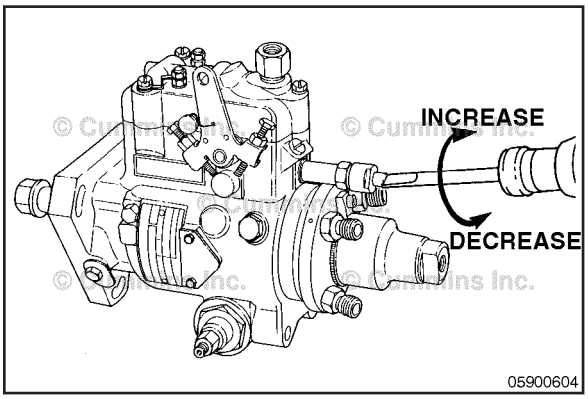
Speed Droop Adjustment

NOTE: If serious surging occurs during the warm-up period, turn the speed droop adjusting screw **clockwise** until the surging stops.

NOTE: When the speed droop adjustments are made, it is necessary to adjust the throttle position.

Adjust the governor as follows:

1. Operate the engine until normal operating temperature is obtained 91°C [195°F].
2. When the engine reaches operating temperature, position the throttle to attain rated speed, and apply 100-percent load. Adjust the throttle position as necessary to obtain 100 percent performance.
3. Remove the load, and check for the specified no-load or, in the case of a generator set, note the frequency. If the no-load speed is incorrect, loosen the locking cap, and adjust the speed droop adjusting screw (**clockwise** for increased droop, **counterclockwise** for less droop). If surging occurs when the load is removed, turn the adjusting cap **clockwise** to eliminate the surge. Tighten the locking cap to secure the adjusting screw.
4. Check the 100-percent load and no-load performance again, and make adjustments as necessary.

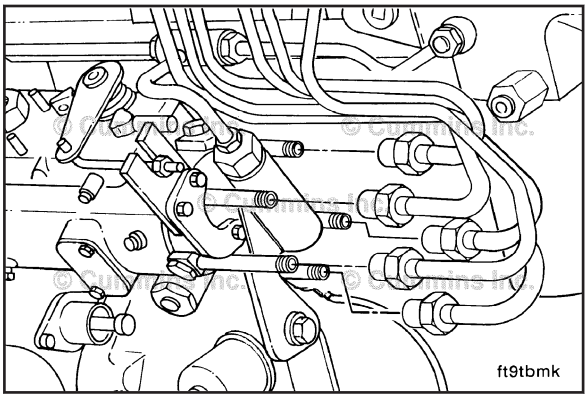


Fuel Pump Back Leakage Valve (005-059)

Preparatory Steps

Disconnect the high-pressure line. Refer to Procedure 006-051.

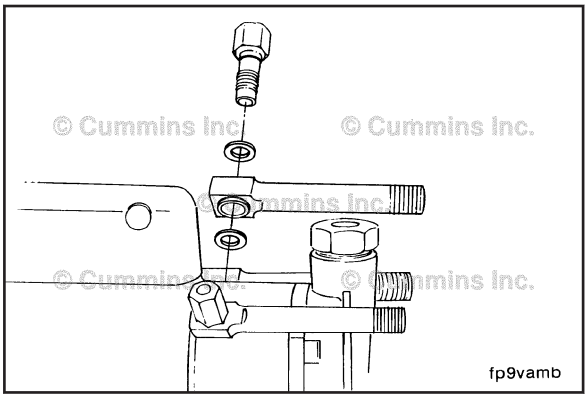
NOTE: Because the valves are installed 90 degrees to the pump axis, the pump will possibly need to be removed to change the valves close to the cylinder block.

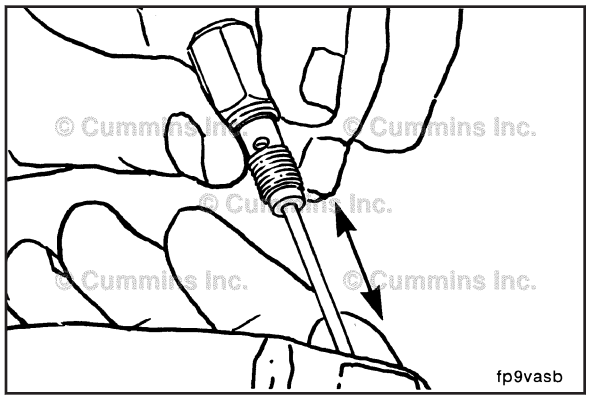


Remove

CAV

Remove the valve.

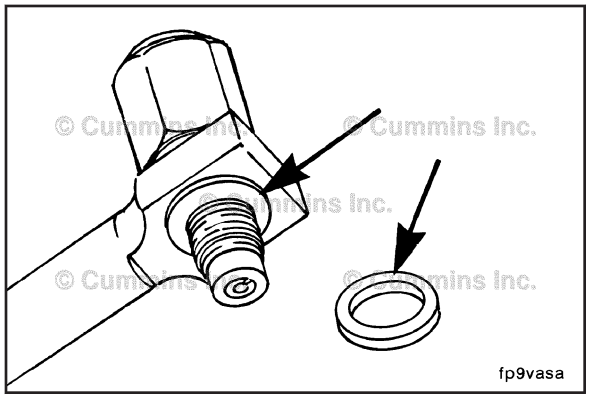




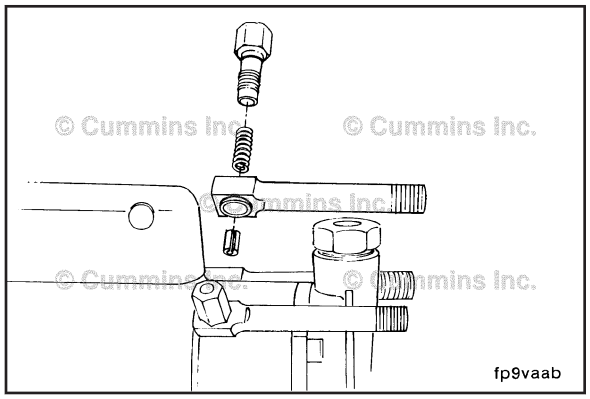
Inspect for Reuse

Stanadyne

Inspect the valve to be sure it is **not** stuck.



Inspect the sealing surfaces for possible leak paths.



Install

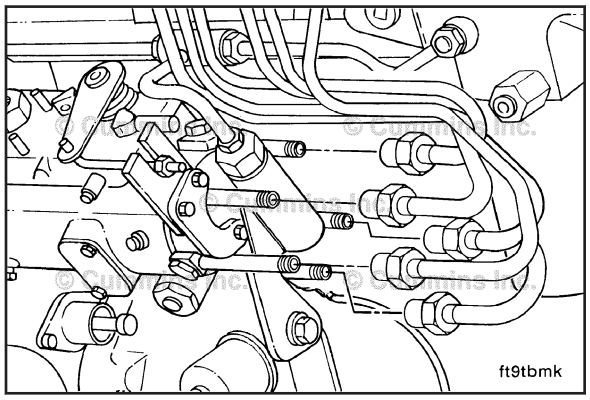
CAV

⚠CAUTION⚠
The installation torque is very critical. Overtightening can distort the bore in the pump hydraulic head, causing the rotor to seize in the bore. Never tighten the valve with the engine running.

Assemble the back leakage valve and new washers.

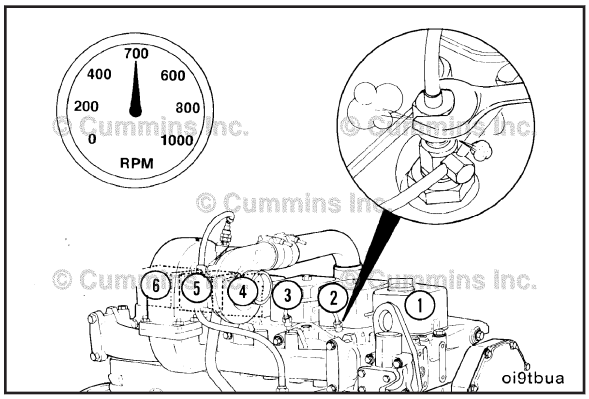
Tighten the valve.

Torque Value: 30 N•m [22 ft-lb]



Connect the high-pressure line. Refer to Procedure 006-051.

Start the engine, and vent one line at a time until the engine runs smoothly.

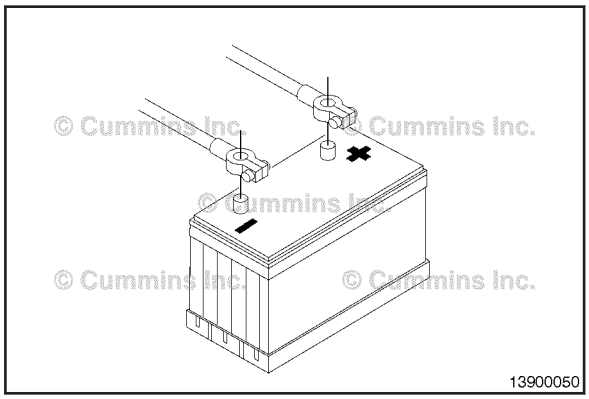


Fuel Pump Pressure Regulator (005-060)

Preparatory Steps

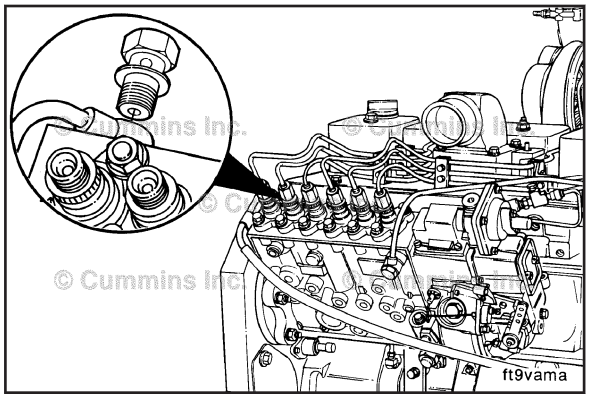
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries.



Remove

Remove the pressure relief valve and copper sealing washer.



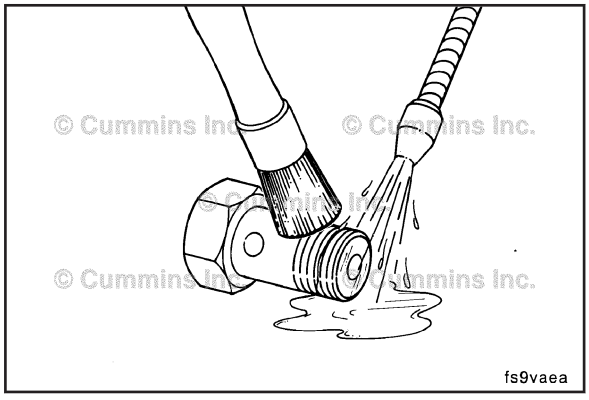
Clean and Inspect for Reuse

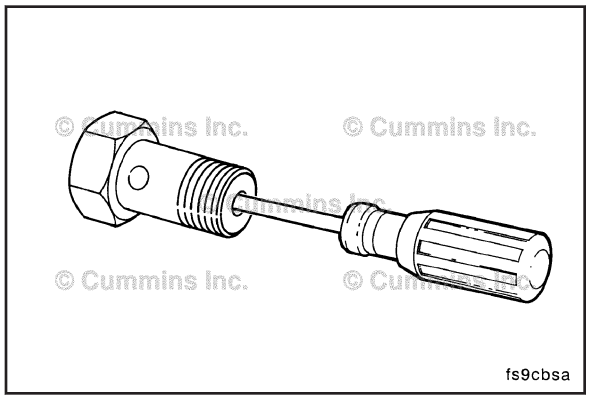
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

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

Thoroughly flush the high-pressure relief valve with a mixture of strong detergent and water or solvent.

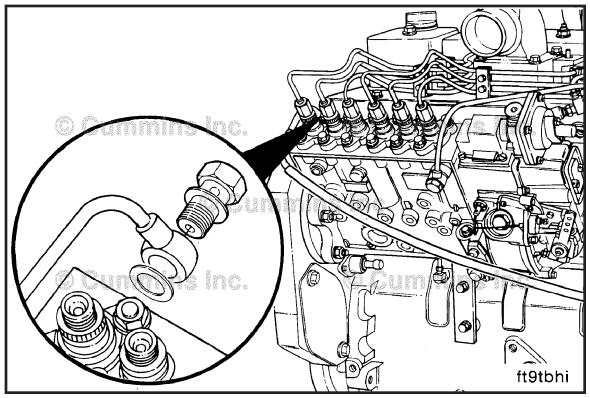
Dry with compressed air.





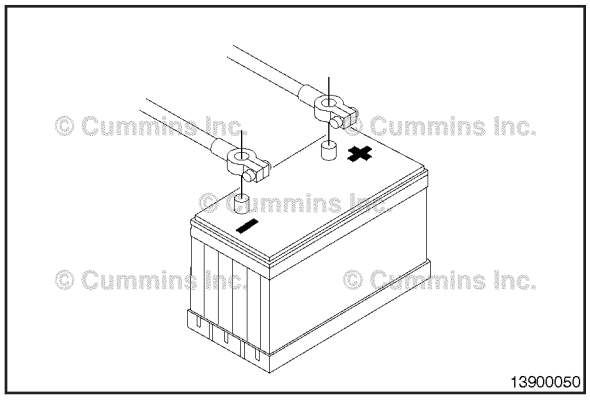
CAUTION
A sticky check ball can result in engine damage and low power.

Use a small screwdriver to check that the check ball is **not** sticking in the high-pressure relief valve assembly.



Install

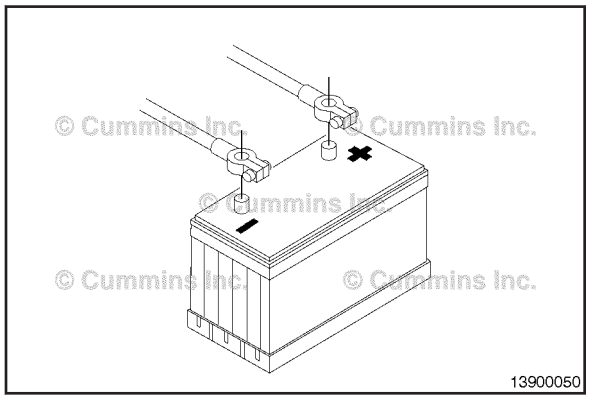
Install the high-pressure relief valve assembly.



Finishing Steps

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

- Connect the batteries
- Operate the engine and check for leaks.



Cold Start Timing Advance System Temperature Switch (005-069)

Preparatory Steps

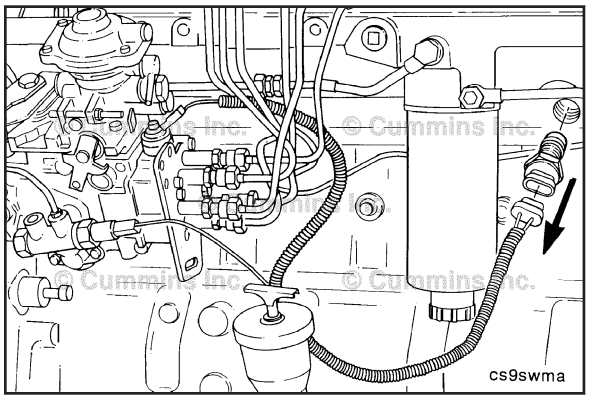
WARNING
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries.

Remove

Wax-Motor Style

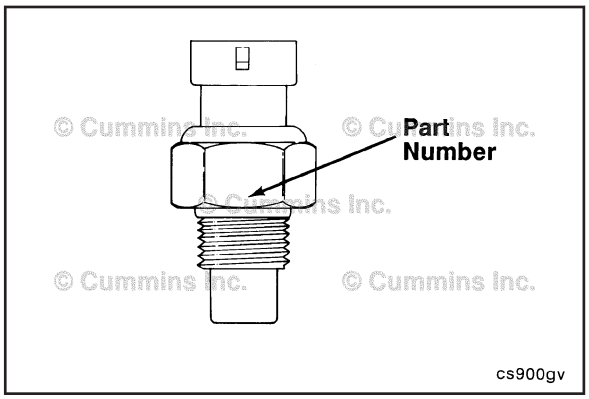
Remove the temperature switch.



⚠CAUTION⚠
The switches are not interchangeable. White smoke will be present if the wrong temperature switch is used.

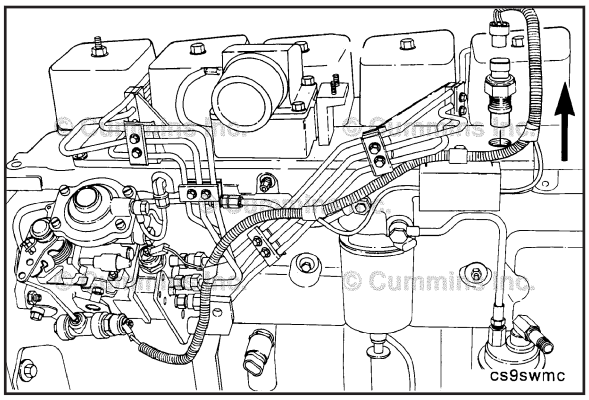
Notes:

1. The wax motor KSB (used on pre-1991 engines) uses a 71°C [160°F] normally open coolant temperature switch, Cummins Part Number 3915945.
2. The electrical solenoid-style KSB (used on '91 models and newer) uses a 32°C [90°F] normally closed intake manifold temperature switch, Cummins Part Number 3921642.



Electrical Solenoid Style

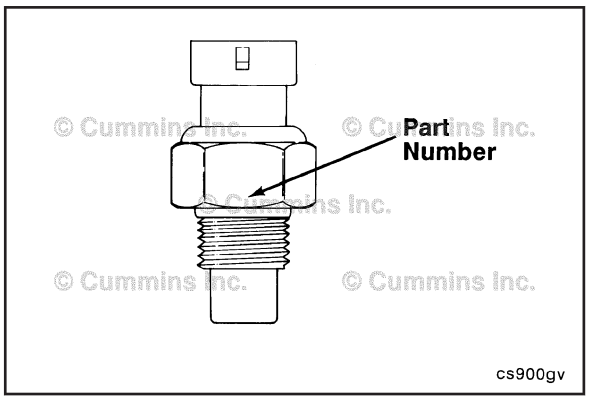
Remove the temperature switch from the intake manifold.

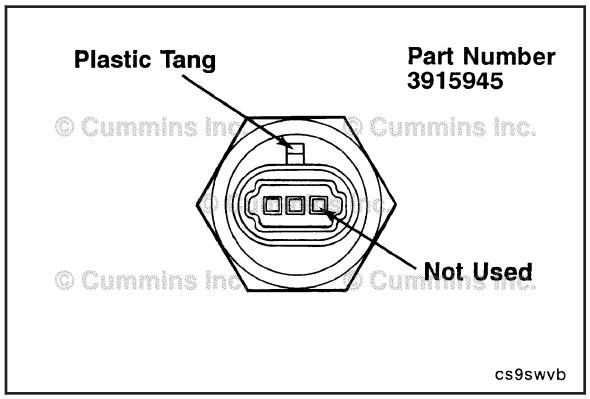


⚠CAUTION⚠
The switches are not interchangeable. White smoke will be present if the wrong temperature switch is used.

Check the part number to be sure the correct temperature switch is used.

NOTE: The electrical solenoid-style KSB (used on 1991 models and newer) uses a 32°C [90°F] normally closed intake manifold temperature switch, Part Number 3921642.



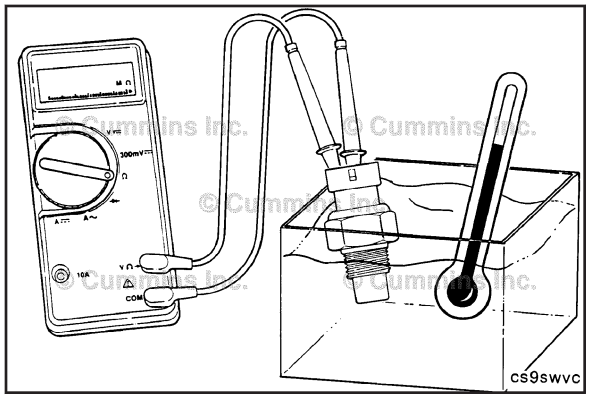


Test

Wax-Motor Style

The operation of the temperature switch for the wax motor style KSB can be checked by connecting a multimeter to the switch, placing the switch in water, and then heating the water to 71°C [160°F].

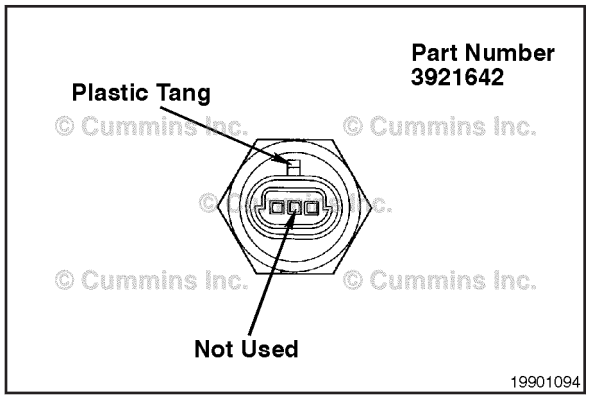
Connect the multimeter to the two pins on the left when viewed with the plastic tang on top.



Check the water temperature with a thermometer.

The multimeter **must** indicate an open circuit below 71°C [160°F] and a closed circuit above 71°C [160°F].

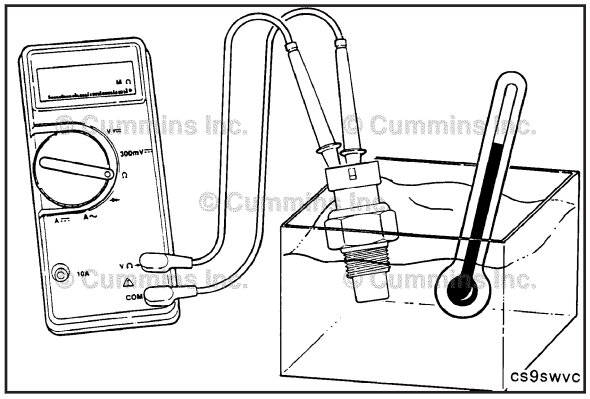
Replace the switch, if necessary.



Electrical Solenoid Style

Although the electrical solenoid-style KSB uses an intake manifold temperature switch, the operation of the switch can be checked by connecting a multimeter to the switch, placing the switch in ice water, and then heating the water to 32°C [90°F].

Connect the multimeter to the two outside pins of the temperature switch.



Check the water temperature with a thermometer.

The multimeter should indicate a closed circuit below 32°C [90°F] and an open circuit above 32°C [90°F].

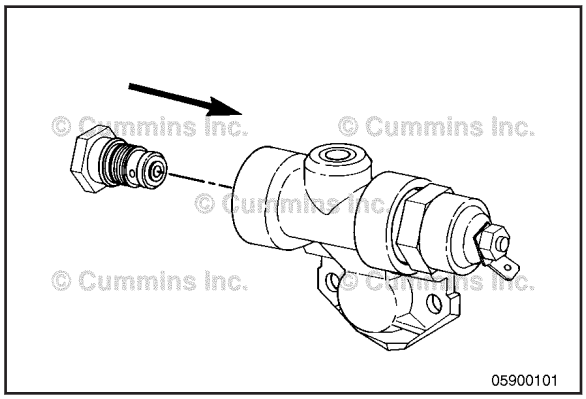
Replace the switch, if necessary.

Install

Electrical Solenoid Style

Install the original pressure relief valve or a replacement into the KSB housing.

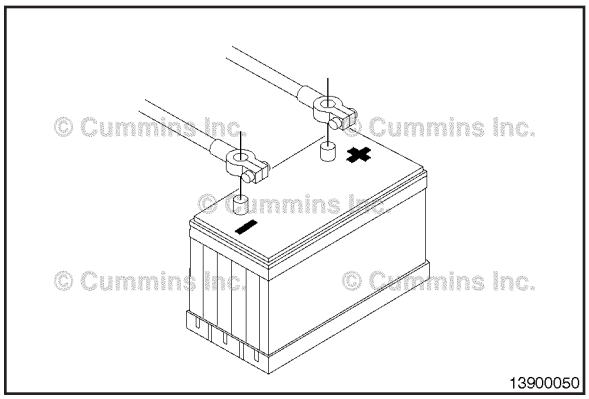
Torque Value: 13 N•m [115 in-lb]



Finishing Steps

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

- Connect the batteries
- Operate the engine and check for leaks.



Cold Start Timing Advance System Pump Mounted (005-070)

General Information

Wax-Motor Style

Need For KSB on 1988 VE Pumps

Emission requirements for 1988 prompted the need for a cold start timing advance system (KSB) to minimize white smoke.

After the engine starts, the wax motor-style KSB fully advances the ignition timing at low idle until the engine warms up. The KSB is **not** functional after the engine reaches 71°C [160°F] coolant temperature.

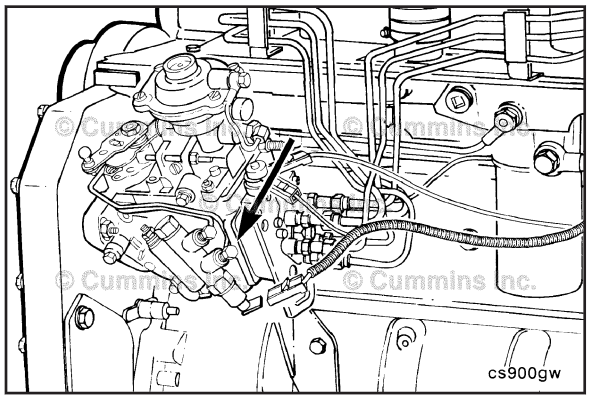
KSB Hardware Definition

There are currently two versions of pump-mounted wax motor-style KSBs released in the Cummins system and one remote-mounted version. The remote-mounted option is necessary in applications where the pump-mounted KSB causes interference with the air compressor.

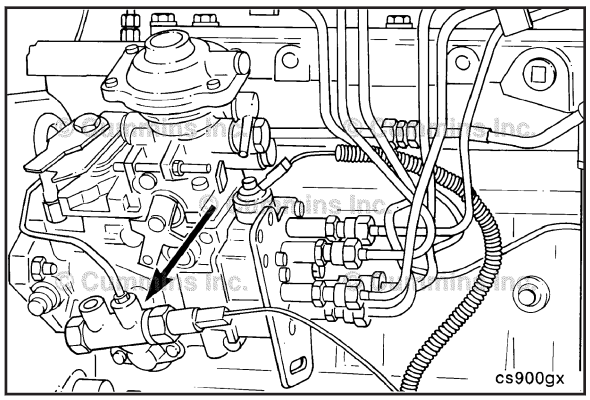
Pump-Mounted KSB

The early pump-mounted KSB is a different design using two control lines. The two-line version was superseded in mid-1988 with a one-control-line version, which is the design used for both production and service at the moment.

There is no remote-mounted hardware available for the two-control-line KSB, so they can **not** be remote mounted.



The illustration shows a two-control-line KSB



The illustration shows a one-control-line KSB

Cold Start Timing Advance System (KSB)

Wax Motor-Style

The wax motor-style KSB is used on pre-1991 B Series automotive engine ratings using the Bosch® VE fuel pump.

NOTE: The electrical solenoid-style KSB is used on 1991 model and newer B Series automotive engine ratings using the Bosch® VE fuel injection pump. Refer to Procedure 005-046, Cold Start Timing Advance System (KSB) - Electrical Solenoid Style, for additional information.

Cold Start Timing Advance System (KSB)

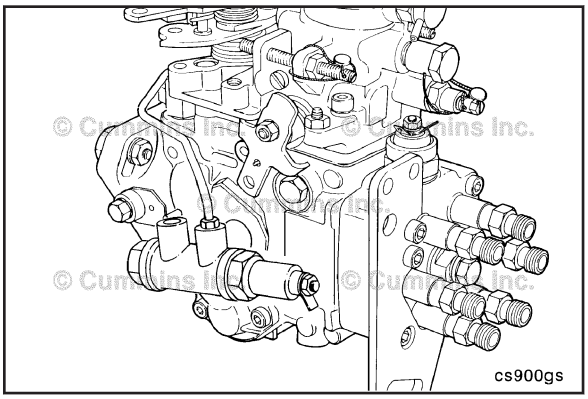
Electrical Solenoid Style

The electrical solenoid-style KSB is used on 1991 model and newer B Series automotive engine ratings using the Bosch® VE fuel pump.

NOTE: The wax motor-style KSB is used on pre-1991 B series automotive engine ratings using the Bosch® VE fuel pump.

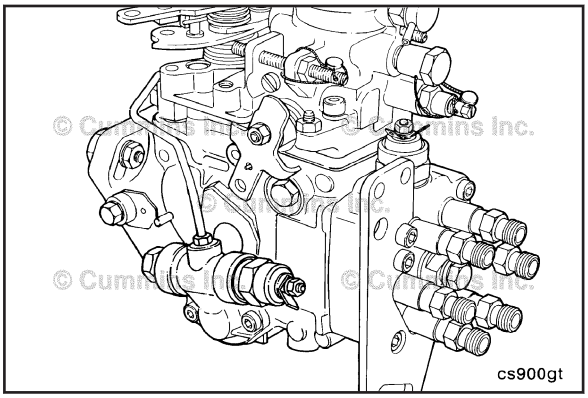
Wax Motor-Style KSB

NOTE: The temperature switch is located in the coolant jacket.



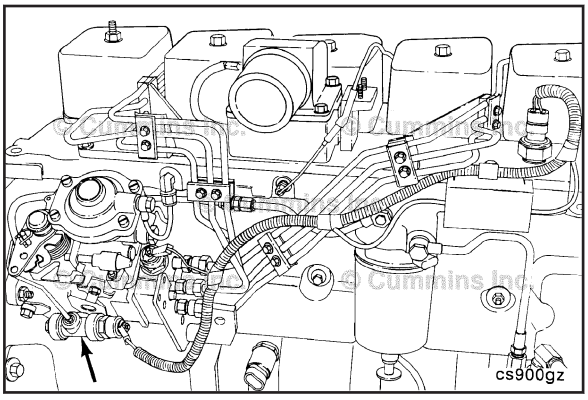
Electrical Solenoid-Style KSB

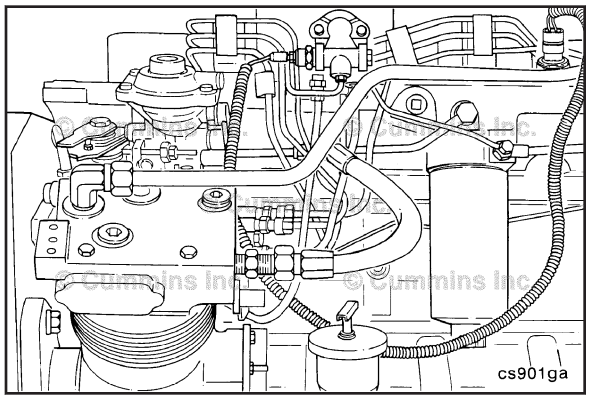
NOTE: The temperature switch is located in the intake manifold.



Two types of electrical solenoid-style KSB valves are available.

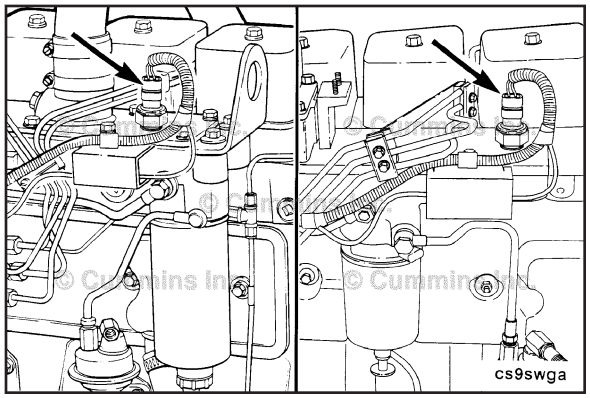
The first type is the pump-mounted KSB, as shown.



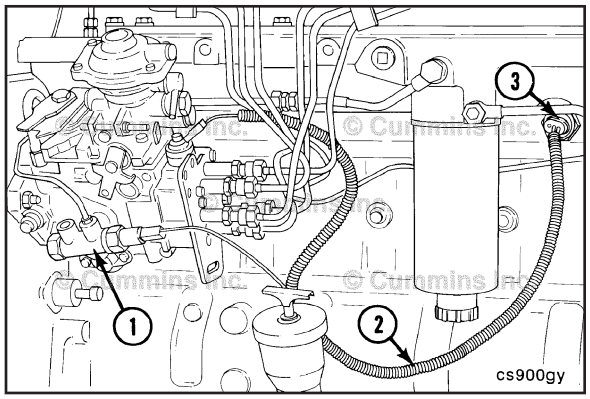


The second type is a remote-mounted KSB, as shown.

The remote-mounted KSB is used on the B Series automotive engines that have an air compressor.

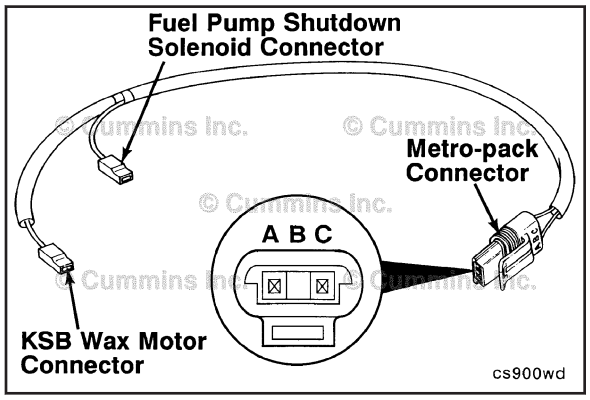


Both the four- and six-cylinder have the temperature switch mounted in the intake manifold as shown.



Pump-Mounted Wax Motor-Style KSB

1. KSB (one control line)
2. Wiring Harness, Cummins Part Number 3918364 (4B), Cummins Part Number 3918431 (6B)
3. 71°C [160°F] Temperature Switch, Cummins Part Number 3915945.



Resistance Check

Wax-Motor Style

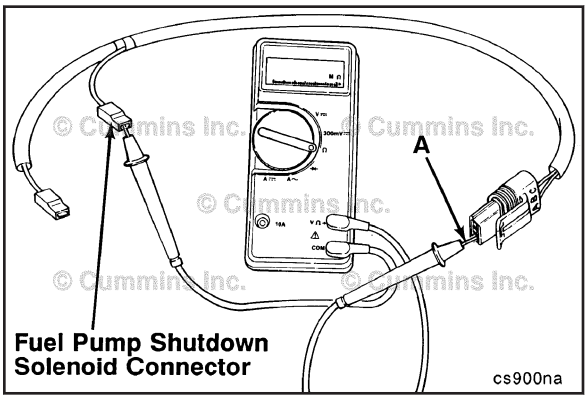
The wiring harness used on the wax motor-style KSB can be inspected using a multimeter.

NOTE: Pin C of the metro-pack connector is blank on the wax motor-style KSB wiring harness.

Use a multimeter to perform a continuity check between port A of the metro-pack connector and the female spade connector at the fuel pump shutdown solenoid connector.

Repair the wire if there is an open circuit.

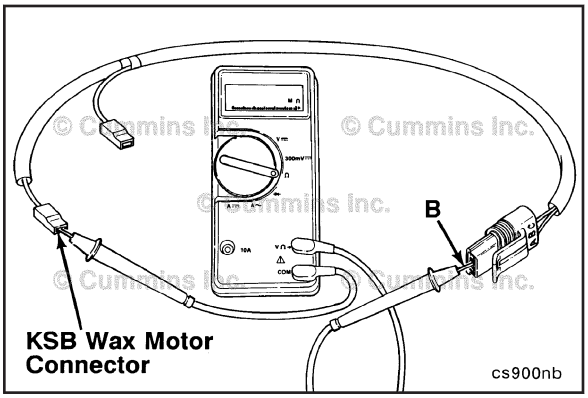
Ohms Resistance - Less than 10.



Use a multimeter to perform a continuity check between port B of the metro-pack connector and the female spade connector at the KSB wax motor connector.

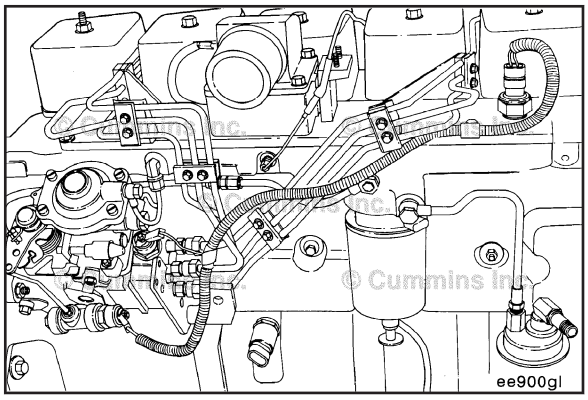
Repair the wire if there is an open circuit.

Ohms Resistance - Less than 10.

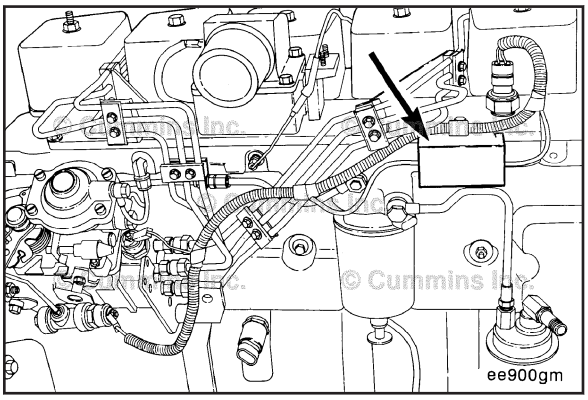


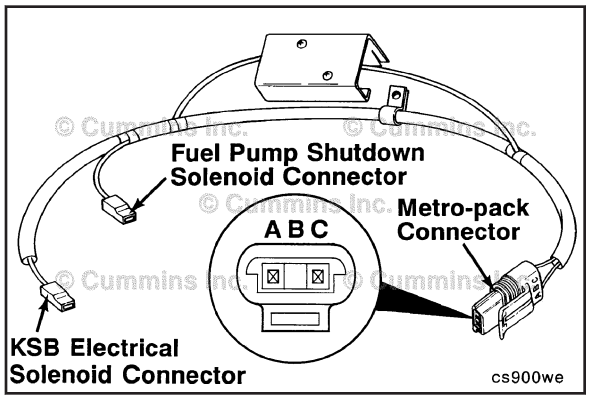
Electrical Solenoid Style

Engines with CPL 1579 do **not** have a resistor in the harness.



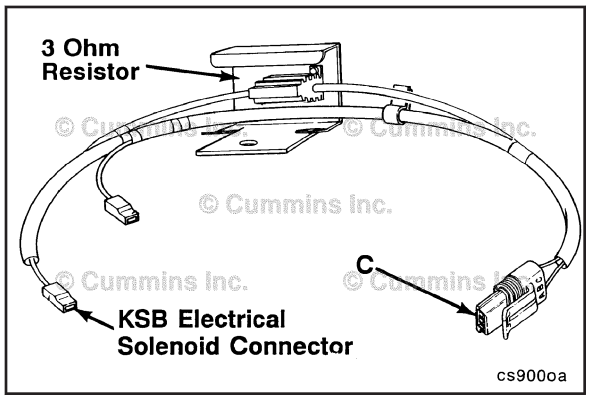
Engines with CPL 1351 **must** be wired with the resistor in the harness.





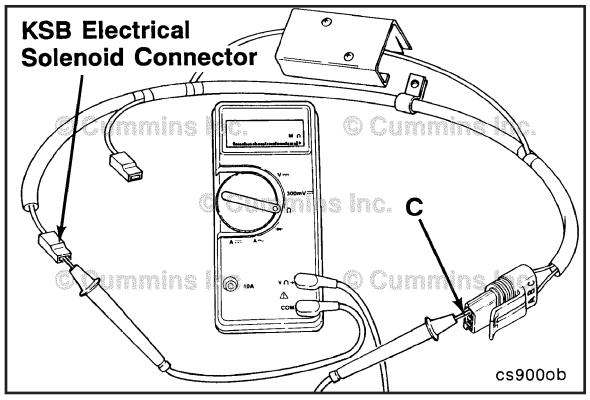
The wiring harness used on the electric solenoid-style KSB can be inspected using a multimeter.

NOTE: Pin B of the metro-pack connector is blank on the electric solenoid-style KSB wiring harness.



The electric solenoid-style KSB wiring harness contains a 3-ohm resistor in the wire leading from port C of the metro-pack connector to the KSB electrical solenoid connector.

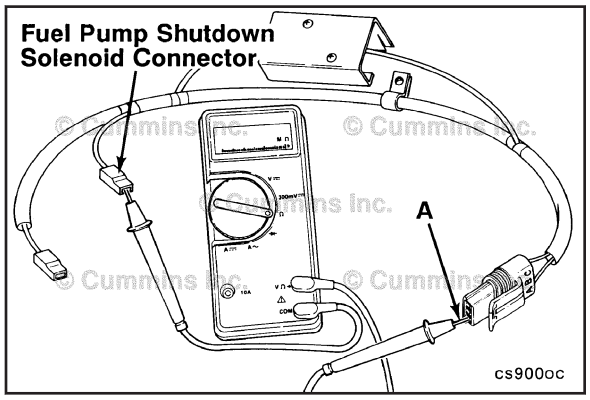
The 3-ohm resistor is mounted to a bracket that is used as a heat sink to absorb heat that is generated by the resistor.



Use a multimeter to perform a continuity check between port C of the metro-pack connector and the KSB electrical solenoid connector.

Repair the wire if there is an open circuit.

(Spec = Less than 10 ohms).



Use a multimeter to perform a continuity check between port A of the metro-pack connector and the fuel pump shutdown solenoid connector.

Repair the wire if there is an open circuit.

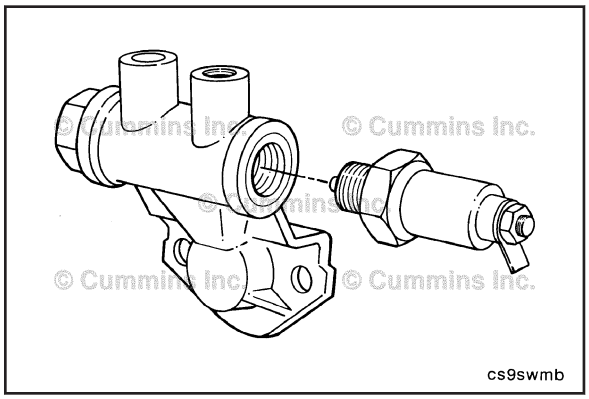
(Spec = Less than 10 ohms).

Disassemble

Wax-Motor Style

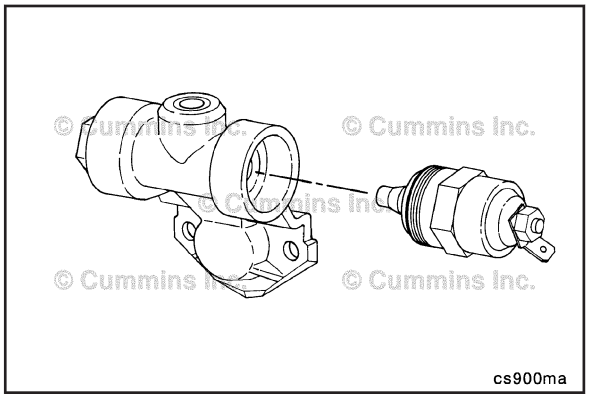
Loosen and remove the KSB electrical element from the KSB housing if equipped with a wax motor-style KSB.

NOTE: If equipped with a electrical solenoid-style KSB, proceed to the next step.



Electrical Solenoid Style

Remove the KSB electrical solenoid from the KSB housing.



Clean

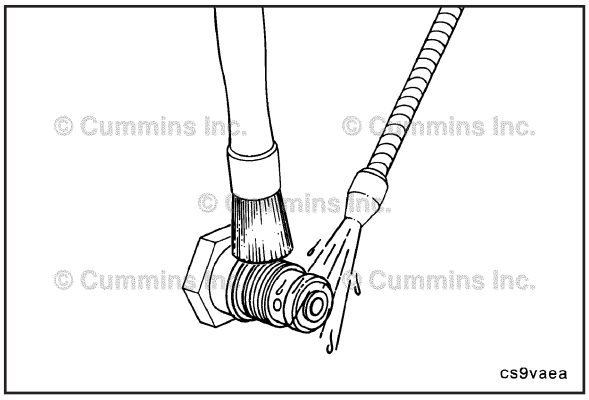
Electrical Solenoid Style

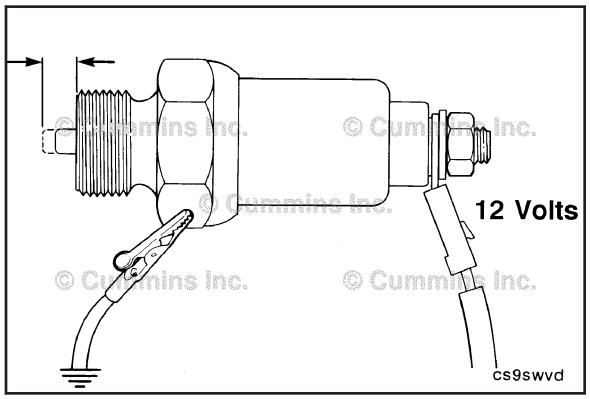
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to avoid personal injury.

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

Thoroughly flush the pressure relief valve with cleaning solution.

Dry with compressed air.





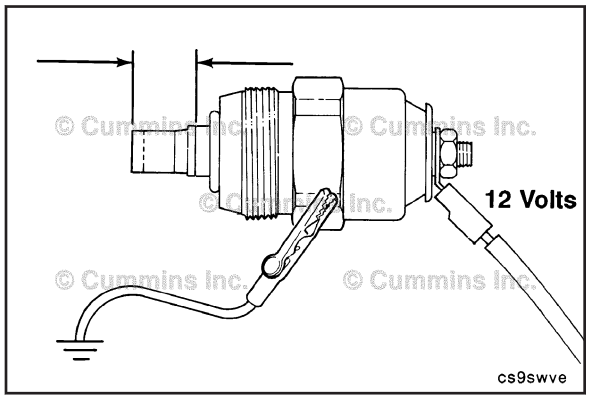
Test

Wax-Motor Style

KSB Electric Element

Apply 12 VDC to the electrical terminal and a ground strap to the hexagonal portion of the element. Look for extensional movement of the plunger. If the plunger does **not** move after approximately 1 minute, check to make sure the element has been correctly connected to ground. If all connections are correct and the plunger does **not** move, the element is defective and **must** be replaced.

NOTE: The amount of plunger movement will vary depending upon the ambient temperature.

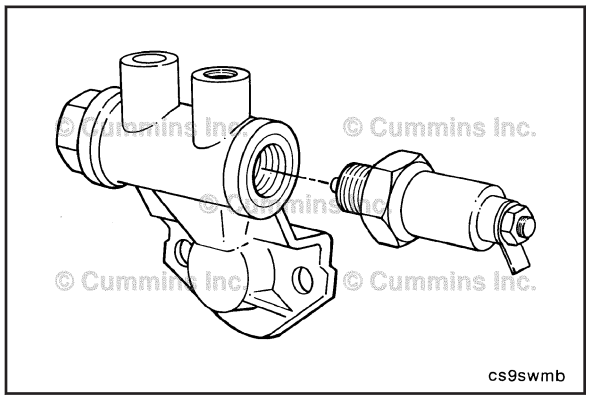


Electrical Solenoid Style

KSB Electric Solenoid

Apply 12 VDC to the electrical terminal, and ground the hexagonal portion of the element. The magnetic coil of the solenoid **must** push the plunger outward.

If the plunger does **not** push outward when voltage is applied, the solenoid is defective and **must** be replaced.

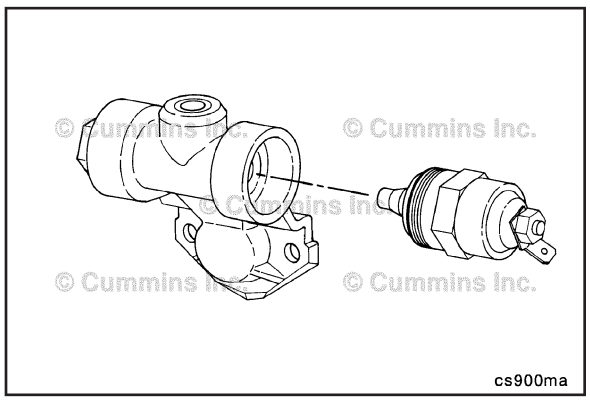


Assemble

Wax-Motor Style

Install the original element or a replacement into the KSB housing.

Torque Value: 22 N•m [16 ft-lb]



Electrical Solenoid Style

Install the original solenoid or a replacement into the KSB housing.

Torque Value: 22 N•m [16 ft-lb]

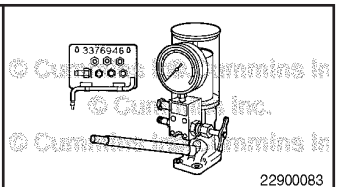
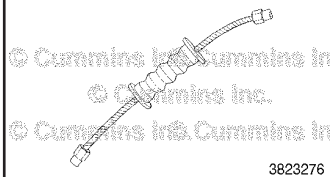
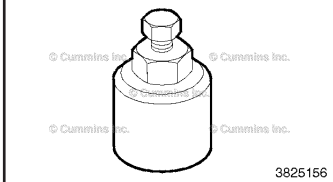
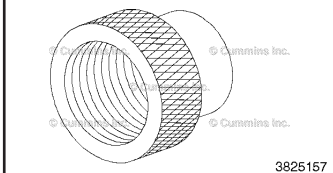
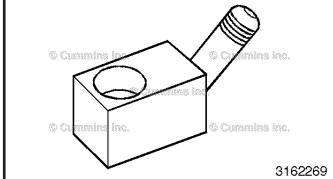
Section 6 - Injectors and Fuel Lines - Group 06

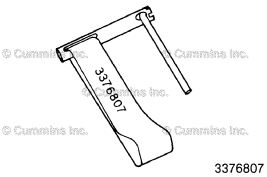
Section Contents

Service Tools

Injectors and Fuel Lines

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

Tool No.	Tool Description	Tool Illustration
3376946	**Injector Nozzle Tester** Used to test opening pressure, leakage, chatter and spray pattern of the nozzle type injectors.	 22900083
3376947	**Injector Nozzle Cleaning Kit** Contains components to clean the injector nozzles. Included are: scrapers for 5, 6, and 7 mm injector nozzles, wooden cleaner for the seating surfaces, brass wire brush holder for injector nozzles, nozzle or orifice cleaning tool and holder, cleaning needles and scraper for ring groove.	 22900082
3823276	**Injector Puller** Used to pull the injector. For use with externally mounted injectors.	 3823276
3825156	**Injector Puller** Used to pull the injector. For use with injectors mounted beneath the rocker lever cover.	 3825156
3825157	**Fuel Connector Puller** Used to pull the fuel connector.	 3825157
3162268	**Injector Holder** Used with injection nozzle tester, Part Number 3376946, to hold injector during test.	 3162269

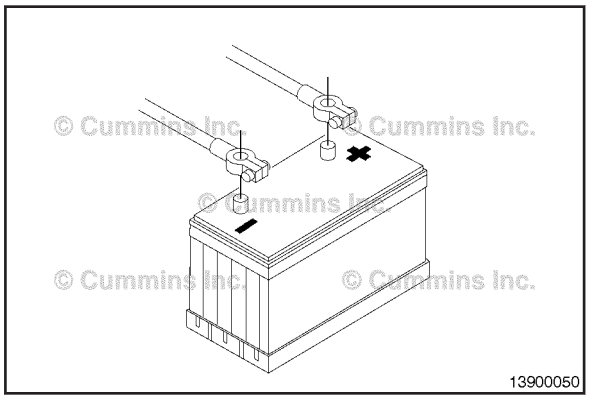
Tool No.	Tool Description	Tool Illustration
3822509	**Injector Bore Brush** Used to clean the injector bore.	 3822509
3376807	**Filter Wrench** Used to remove spin-on filters.	 3376807
3824879	**Anti-seize Lubricant** Used to speed assembly and disassembly of studs, bolts, and so forth.	 3824879

AFC Air Tube (006-001)

Preparatory Steps

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

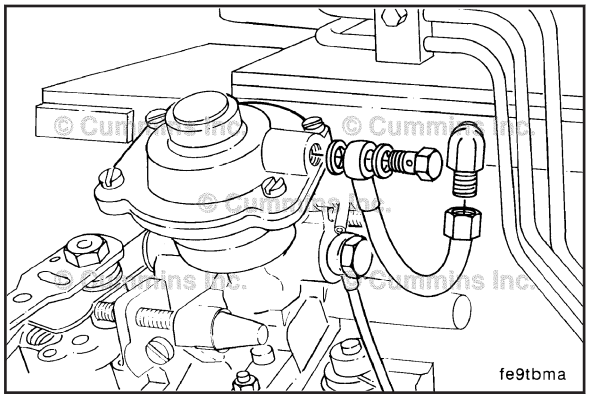
- Disconnect the batteries.



Remove

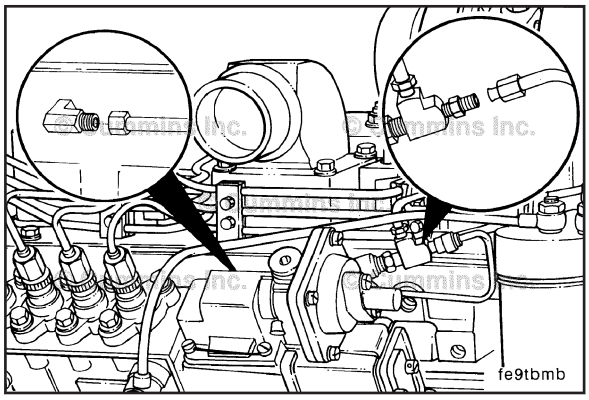
Distributor-Type Fuel Injection Pumps

Remove the fuel tube from the manifold fitting and the pump.



In-Line Pumps

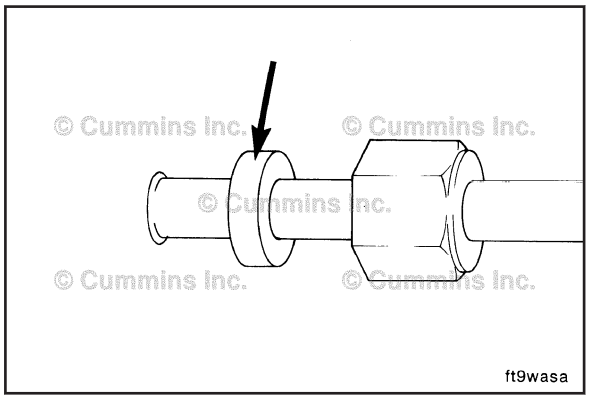
Remove the AFC tube.

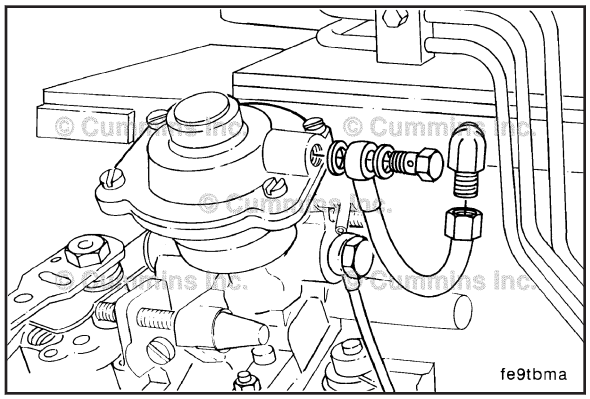


Inspect for Reuse

In-Line Pump

Inspect the rubber sealing washers, and replace as necessary.





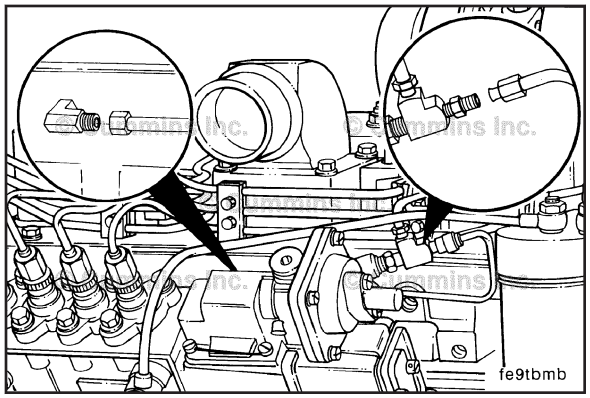
Install

Distributor-Type Pump

NOTE: Use new sealing washers when installing the tube.

Assemble in the reverse order of removal.

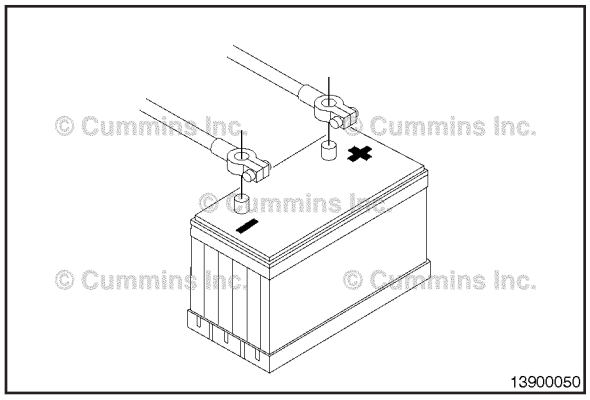
Torque Value: 9 N•m [80 in-lb]



In-Line Pump

Install the AFC tube in the reverse order of removal.

Torque Value: 24 N•m [18 ft-lb]



Finishing Steps

⚠WARNING⚠

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

- Connect the batteries
- Operate the engine and check for leaks.

Air in Fuel (006-003)

General Information

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

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

The low-pressure fuel system for a Cummins diesel installed in the vehicle consists of the fuel tank, lines between the tank and the engine, transfer pump and lines, and fuel filter and lines. Air or bubbles at the injection pump can cause the engine **not** to operate or erratic engine operation and/or subsequent malfunction of the fuel injection pump. Air can be introduced by leaks in the fuel system prior to the transfer pump since the fuel in the lines is under a vacuum and can draw air into the system. Bubbles can result from any number of restrictions in the system:

- Plugged fuel filter
- Crimped fuel line.

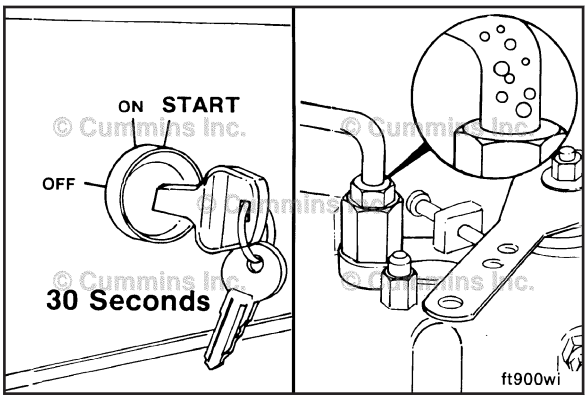
If sufficient fuel reaches the injection pump from the low-pressure system then solutions to engine operational problems are elsewhere. The following steps will aid in evaluating low-pressure fuel system performance.

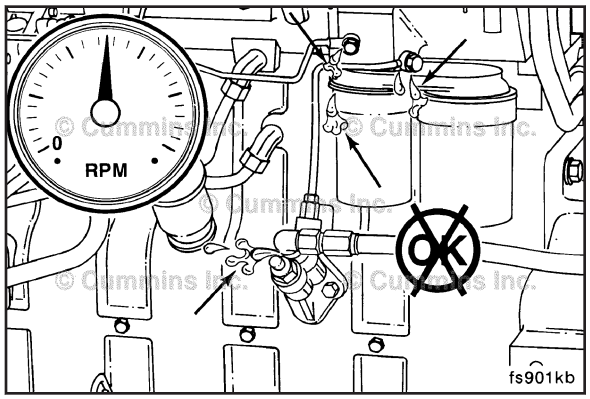
Replacing the fuel supply lines, fuel filters, fuel injection pump, high-pressure fuel lines, and injectors will let air enter into the fuel system. Follow the specified procedure to bleed the air from the system.

Refer to Procedure 006-015 Fuel Filter (Spin-On) for proper venting of the low pressure side of the fuel system.

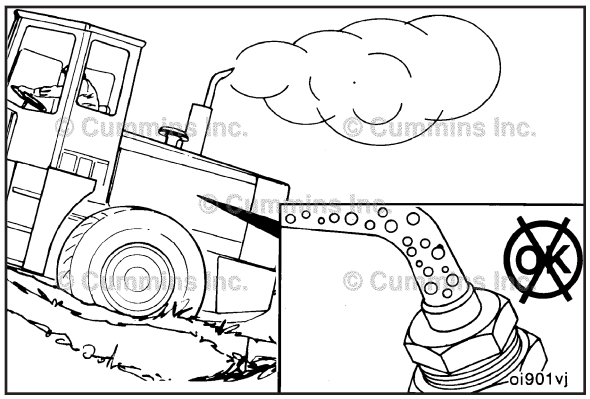
Refer to the Procedure 005-012, Fuel Injection Pumps, In-Line, or Procedure 005-014, Fuel Injection Pumps, Rotary to determine if venting the fuel pump is necessary.

Refer to Procedure 006-051 Injector Supply Lines (High Pressure) for venting of the high pressure side of the fuel system.





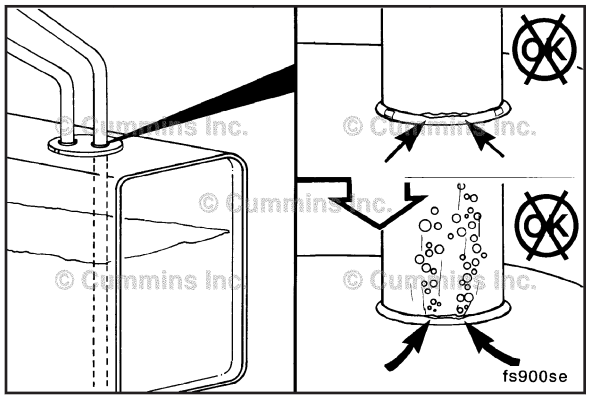
Since the fuel transfer pump provides positive pressure through the fuel filter and supply line to the fuel injection pump, loose connections or defective seals show as a fuel leak and **not** as an air leak.



Air in the fuel system will cause the following engine problems:

- Hard to start
- Run rough
- Misfire
- Fuel knock.

NOTE: If an excessive amount of air has entered into the system, the system will need to be vented. Follow the “Prime” sections referenced above.

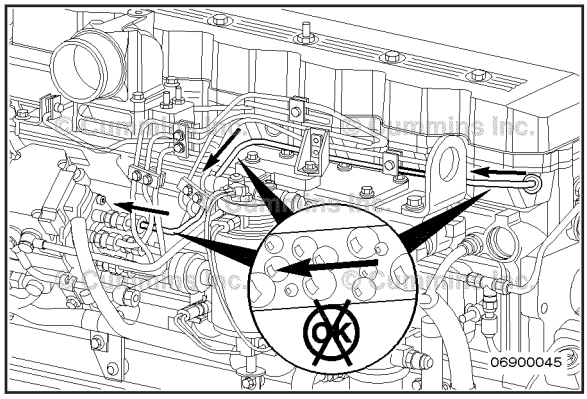


Test

A source that is 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 have a suction tube that extends to the bottom of the tank. Cracks or pin holes in the weld that join the tube to the fitting can let air enter the fuel system.

Also, check to make sure all the fittings from the fuel supply line on the tank to the inlet of the fuel transfer pump are tight.

Use a sight glass at the fuel lift pump inlet to check for air in the fuel supply lines.



A stuck-open injector can also blow combustion gas back into the pump and cause air to be present in the overflow. If the engine seems to be misfiring or running rough, break all the injector supply lines loose at the pump end.

NOTE: The injector supply lines **must** be loosened, and retightened, one at a time until the issue is resolved.

NOTE: Use two wrenches when loosening the lines at the fuel pump, one to hold the delivery valve and one to loosen the fuel line.

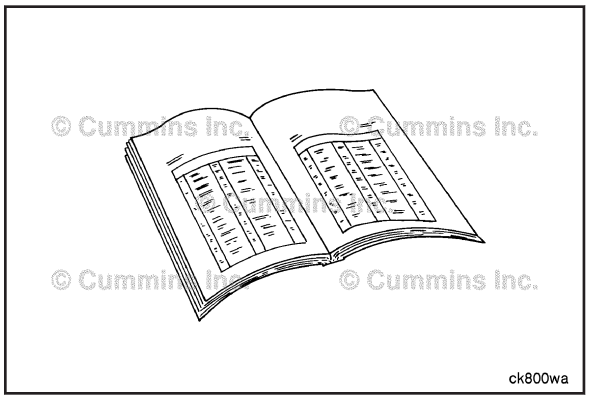
Tighten the fuel lines.

Torque Value: 24 N•m [212 in-lb]

Fuel Drain Line Restriction (006-012)

Preparatory Steps

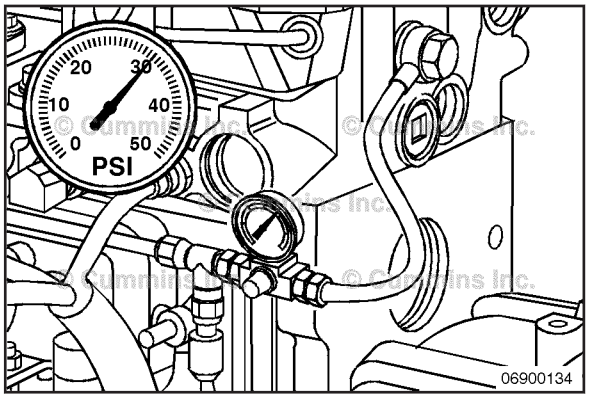
- Remove the capscrews from the hold-down clamps. Refer to Procedure 006-021
- Remove the fuel drain line banjo fitting capscrews and washers. Refer to Procedure 006-021
- Disconnect the fuel drain line fittings. Refer to Procedure 006-021.



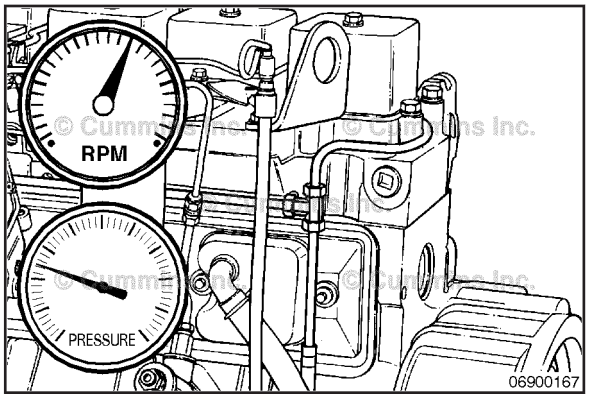
Measure

Install the 0 to 207-kPa [0 to 30-psi] pressure gauge.

NOTE: The disconnected return line tee (return from the pump) needs to be capped.

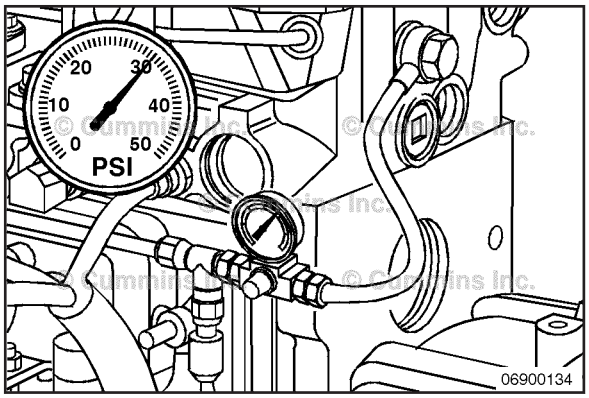


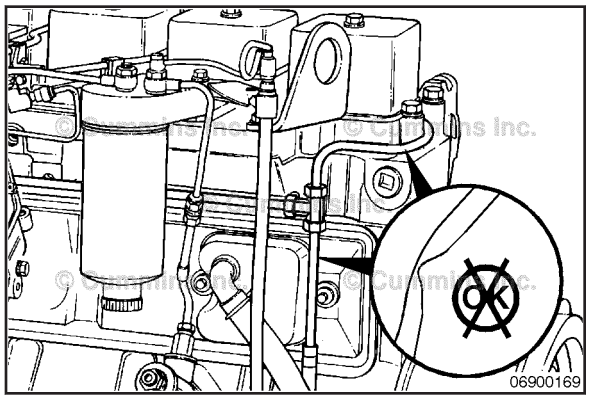
Operate the engine at rated speed and no load.



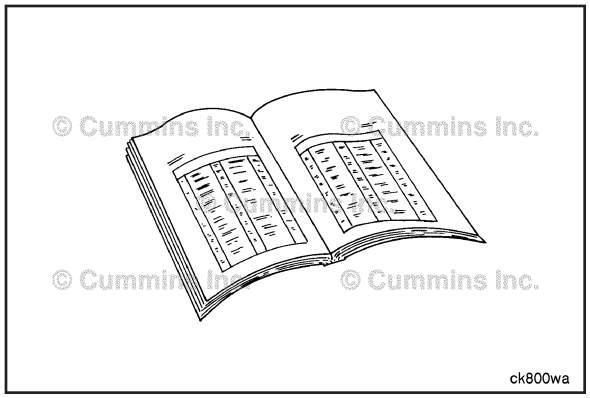
Observe the reading on the gauge.

Fuel Drain Line Restriction		
mm Hg		in Hg
518	MAX	20.4



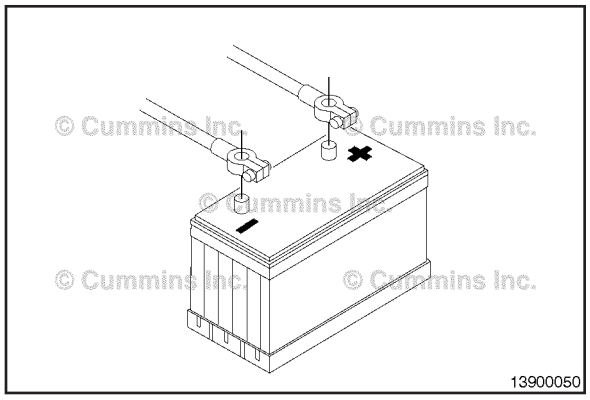


If the drain line pressure is out of specification, check for bends and kinks in the drain lines.



Finishing Steps

- Install the fuel drain line fittings. Refer to Procedure 006-021
- Install the fuel drain line banjo fitting capscrews and washers. Refer to Procedure 006-021
- Install the hold down clamp capscrews. Refer to Procedure 006-021.

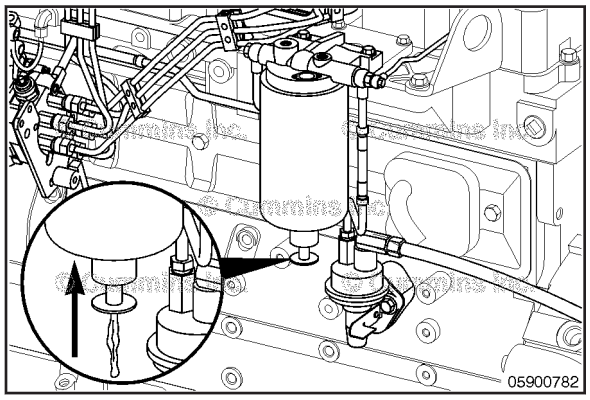


Fuel Filter (Spin-On Type) (006-015)

Preparatory Steps

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

- Disconnect the batteries.



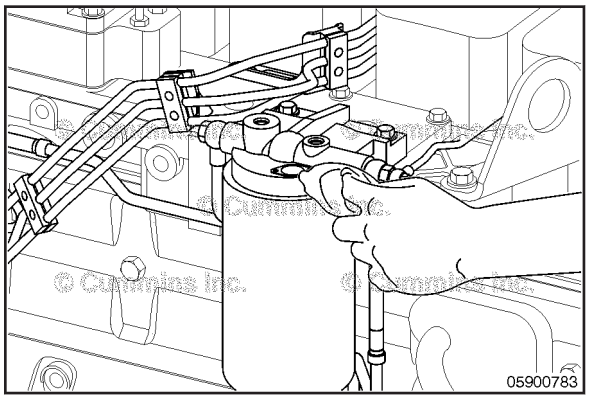
Drain

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

If equipped, use the filter drain valve to drain fuel out of the filter for approximately 5 seconds. This will eliminate fuel from running over the top of the filter upon removal.

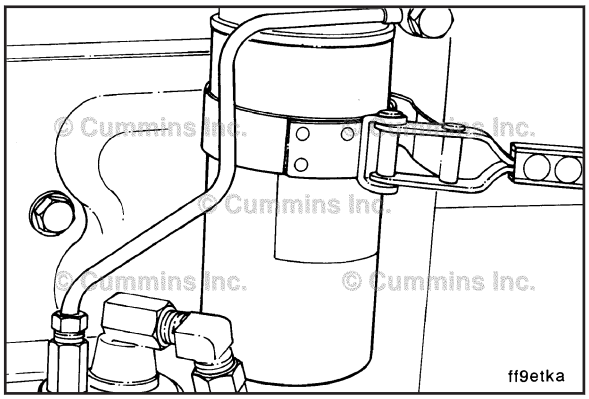
Remove

Clean the area around the fuel filter head.



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

Remove the fuel filter.

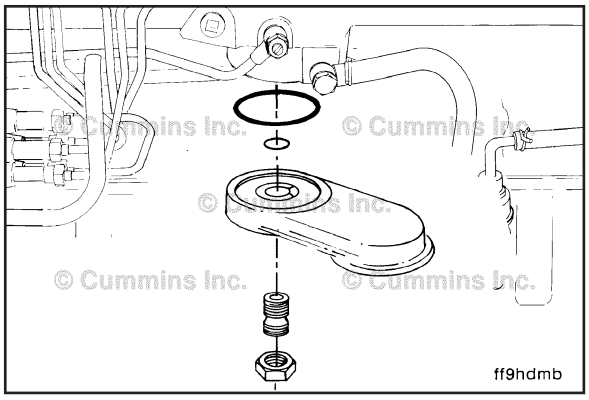


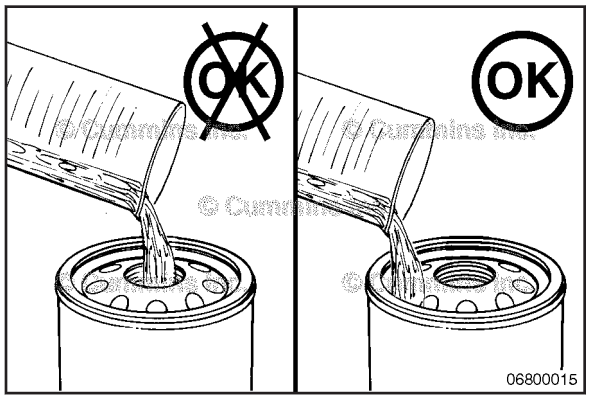
⚠WARNING⚠
Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

Remove the two filters from the dual-filter adapter (if equipped).

If a leak is found, replace the o-rings.

Torque Value: 32 N•m [24 ft-lb]



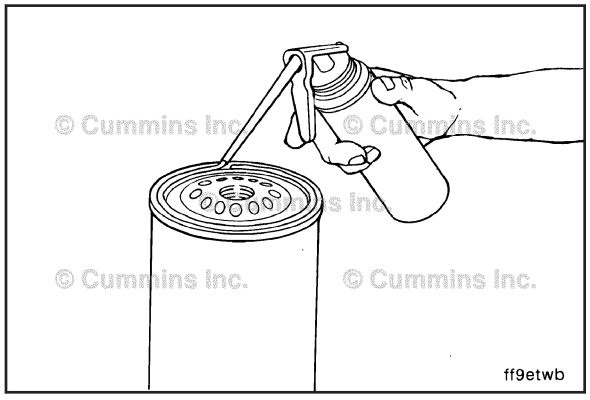


Install

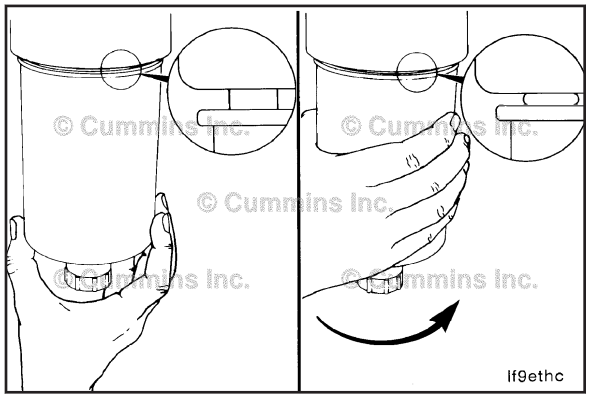
⚠WARNING⚠
Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

△CAUTION△
When pre-filling the filter do not pour fuel down the center (clean side) of the filter. Pour clean fuel into the outer openings (dirty side) of the filter. Use a clean side block off plug, if available, to prevent fuel from entering the clean side of the filter. Pre-filling on the clean side of the filter can result in debris entering the fuel system and damaging fuel system components.

Fill the new filter(s) with clean diesel fuel.



Lubricate the seal with clean lubricating engine oil.



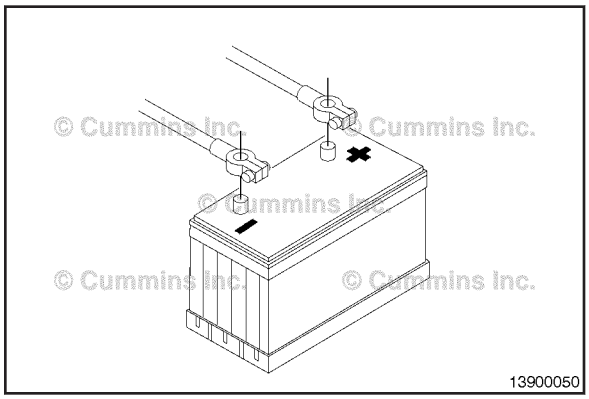
△CAUTION△
Mechanical overtightening can distort the threads as well as damage the filter element seal or filter can.

Install the fuel filter on the fuel filter head. Turn the filter until the gasket contacts the filter head surface.

Tighten the fuel filter an additional ½ to ¾ of a turn after the gasket contacts the fuel filter head surface, or as specified by the fuel filter manufacturer.

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

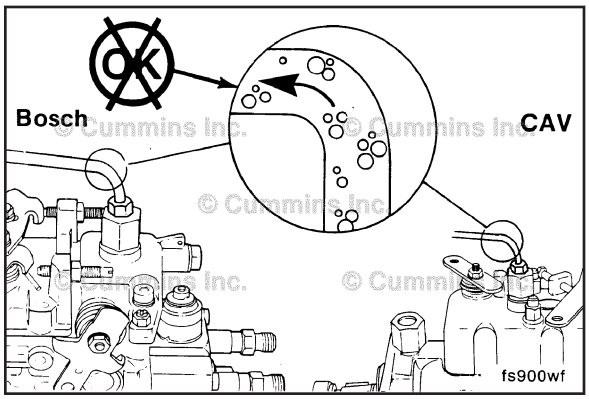
Connect the batteries.



Prime

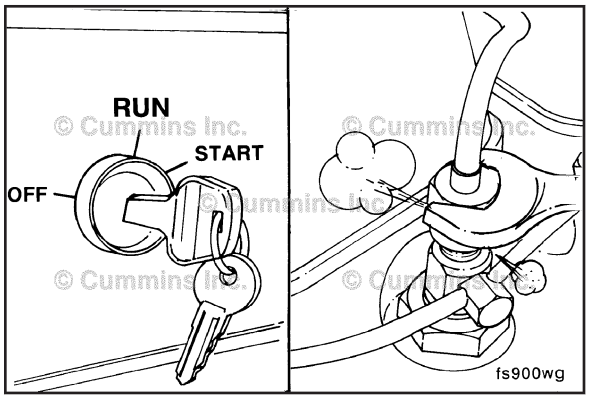
General Information

Controlled venting is provided at the injection pump through the fuel drain manifold. Small amounts of air introduced by changing the filters or injection pump supply line will be vented automatically if the fuel filter is changed in accordance with the instructions.



However, manual bleeding will be required if one of the following conditions exists:

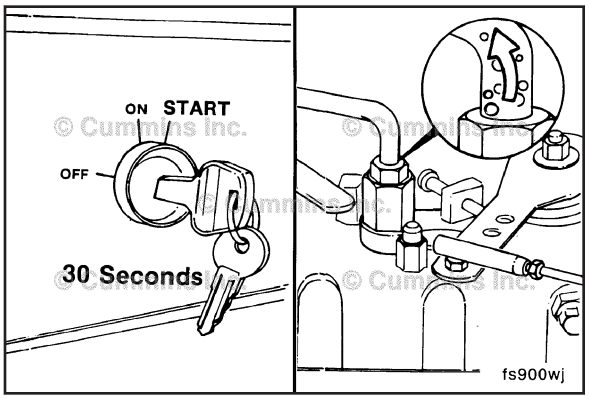
- The fuel filter is **not** filled prior to installation
- The fuel injection pump is replaced
- The high-pressure fuel line connections are loosened, or the lines are replaced
- It is an initial engine start-up or start-up after an extended period of no engine operation.



Refer to Procedure 006-015 (Fuel Filter (Spin-On)) in Section 6 for proper venting of the low pressure side of the fuel system.

Refer to the Procedure 005-012 (Fuel Injection Pumps, In-Line) in Section 5 to determine if venting the fuel pump is necessary. Or, refer to Procedure 005-014 (Fuel Injection Pumps, Rotary) in Section 5 to determine if venting the fuel pump is necessary.

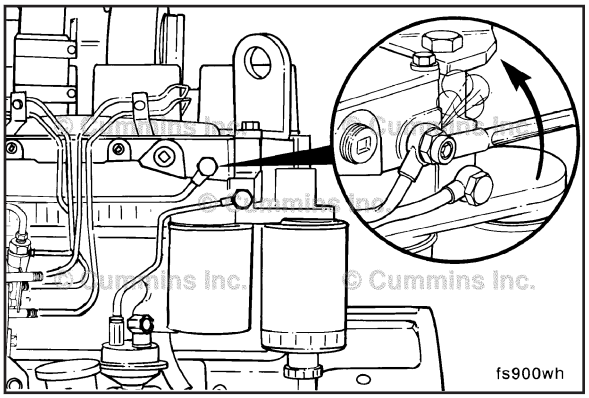
Refer to Procedure 006-051 Injector Supply Lines (High Pressure) in Section 6 for venting of the high pressure side of the fuel system.



⚠CAUTION⚠
It is necessary to turn the keyswitch to the ON position. Because the engine can start, be sure to follow all safety precautions. Use the normal engine starting procedure.

⚠CAUTION⚠
When using the starting motor to vent the system, do not engage the starter for more than 30 seconds, or starter damage will occur. Wait 2 minutes before starting the engine again.

Air can also be vented through the fuel drain manifold line by operating the starting motor.

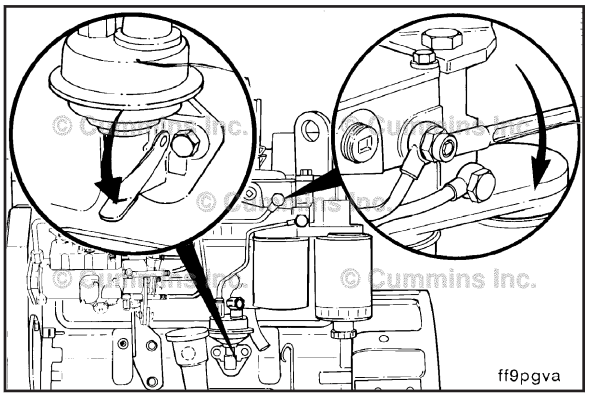


Low Pressure Fuel Line(s)

NOTE: For engines equipped with Distributor type pumps equipped with bleed screws.

Open the bleed screw.

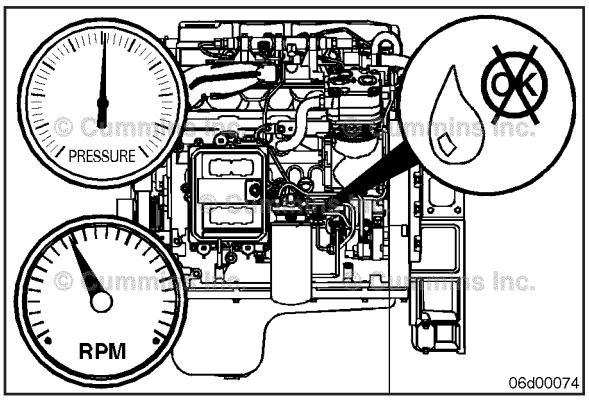
NOTE: If the engine is **not** equipped with a bleed screw, loosen the fitting on the low pressure supply line to the injection pump. Once priming has been completed, tighten the fitting to the specified torque.



Operate the hand lever until the fuel flowing from the fitting is free of air.

Tighten the bleed screw.

Torque Value: 9 N•m [80 in-lb]



Finishing Steps

- Operate the engine and check for leaks.

Fuel Filter Head (006-017)

General Information

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

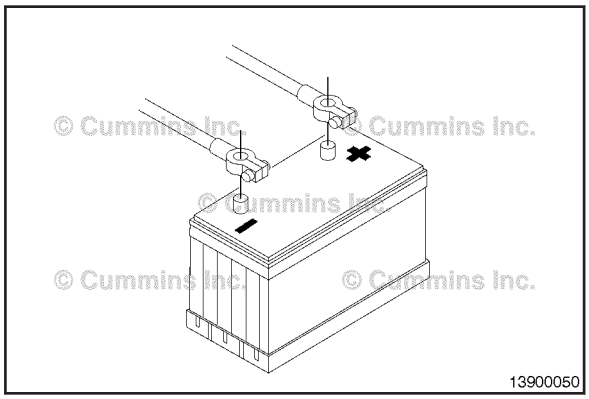
The fuel filter is integrated into the cylinder head on some engines. On other engines the fuel filter head and fuel filter head bracket may be one piece.

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

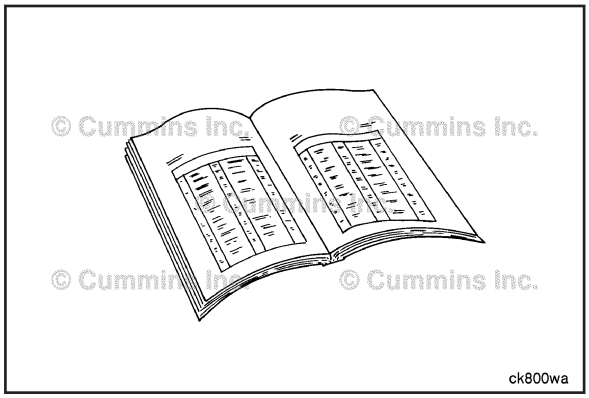
Preparatory Steps

⚠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 batteries.



- Remove the fuel supply and fuel return line connectors. Refer to Procedure 006-024
- Remove the fuel filter. Refer to Procedure 006-015
- Disconnect the fuel heater connector, if applicable.

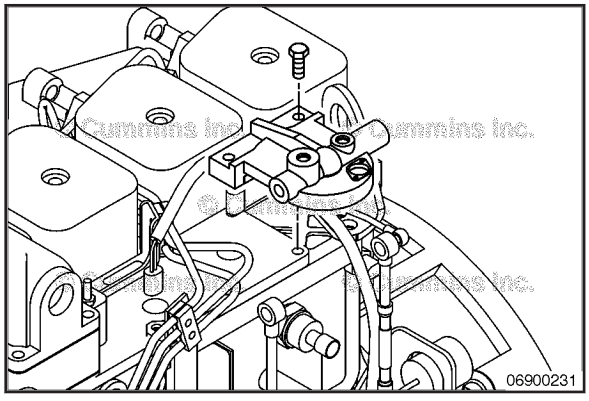


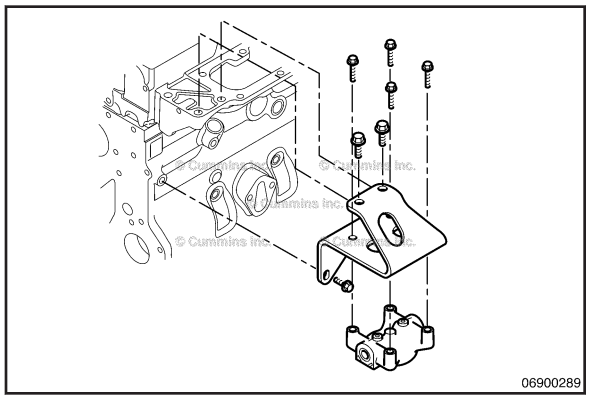
Remove

Front Gear Train

Remove the two capscrews retaining the filter head.

Remove the filter head from the engine.

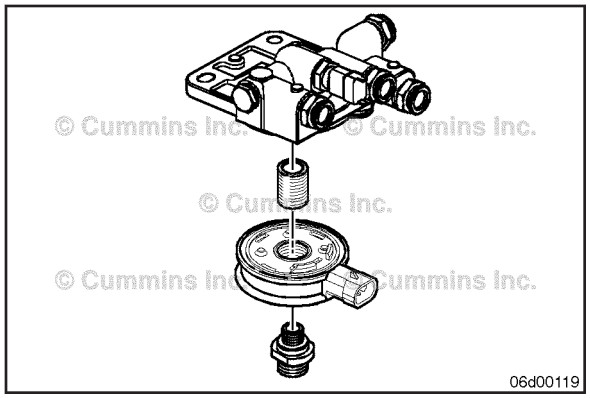




Rear Gear Train

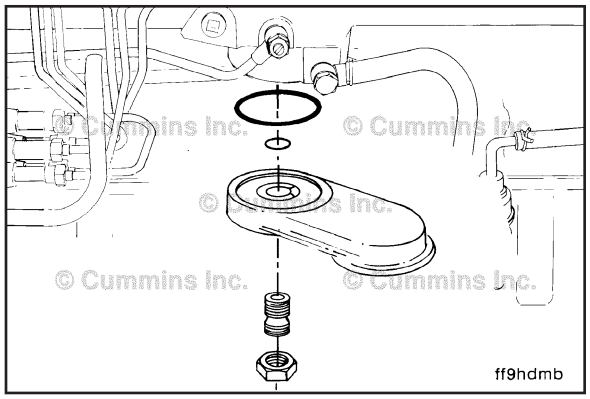
Remove the three capscrews holding the fuel filter bracket to the cylinder block.

Remove the four capscrews holding the fuel filter head to the fuel filter head bracket.

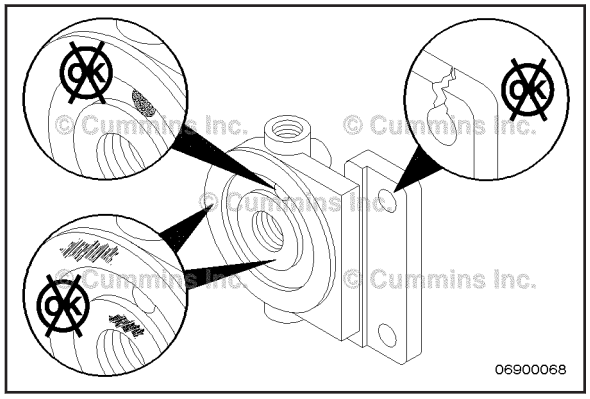


Disassemble

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



Remove the dual-filter adapter, (if equipped).



Clean and Inspect for Reuse

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

Assemble

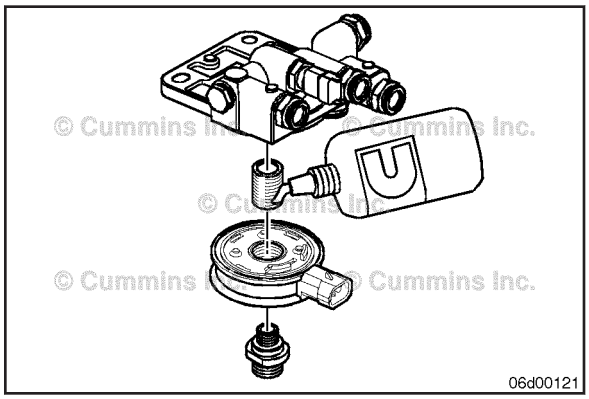
Apply threadlocker, Part Number 3375068, or equivalent, to the filter adapter threads that are engaging the filter head.

Assemble the filter head.

Install the filter adapter and fuel heater.

Torque Value: 27 N•m [20 ft-lb]

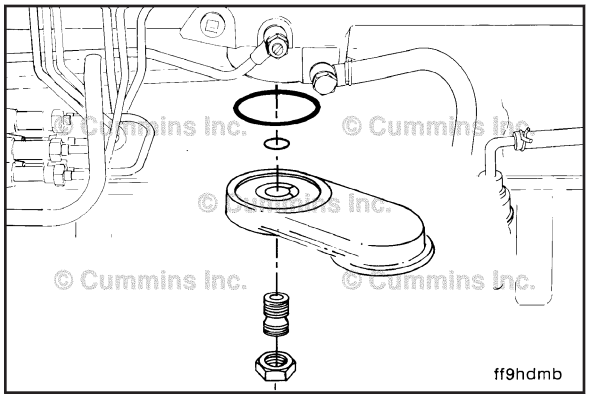
NOTE: Make sure there is an o-ring between the filter head and heater.



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

Install dual filter adapter (if equipped).

Torque Value: 32 N•m [24 ft-lb]



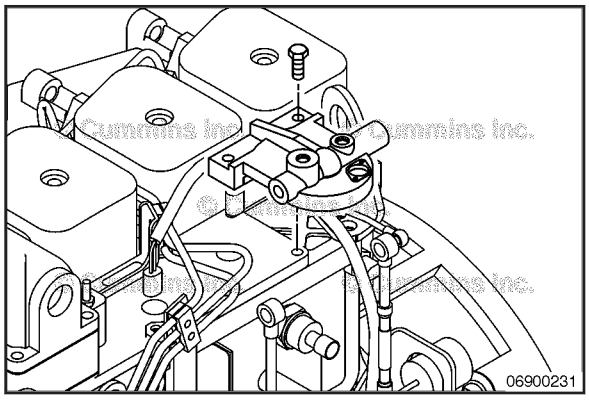
Install

Front Gear Train

Install the fuel filter head.

Tighten the two retaining capscrews.

Torque Value: 24 N•m [18 ft-lb]



Rear Gear Train

Tighten the four M8 capscrews fastening the fuel filter head to the fuel filter head bracket.

Torque Value:

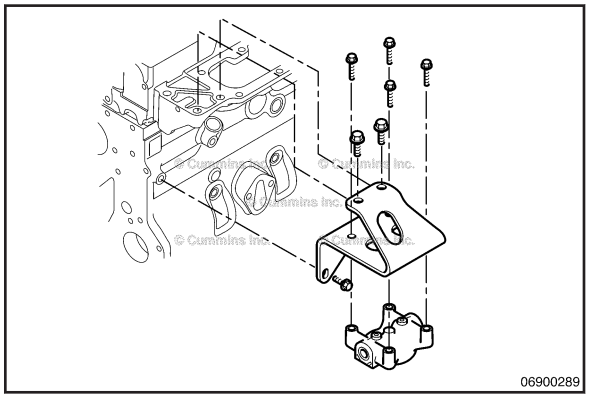
M8	18 N•m	[14 ft-lb]

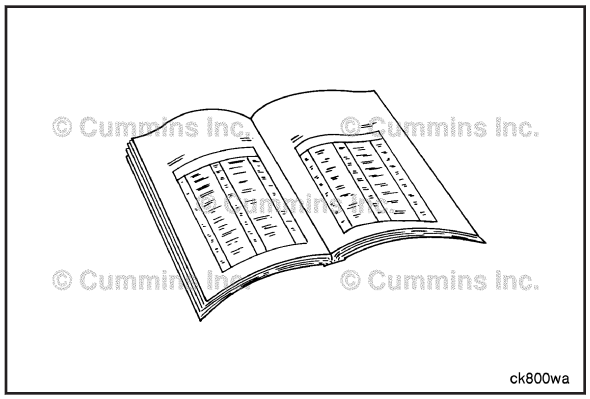
Install the fuel filter head bracket on the engine. Finger tighten the two M10 capscrews to the head and the remaining M8 capscrews into the cylinder block.

Tighten the fuel filter head bracket capscrews.

Torque Value:

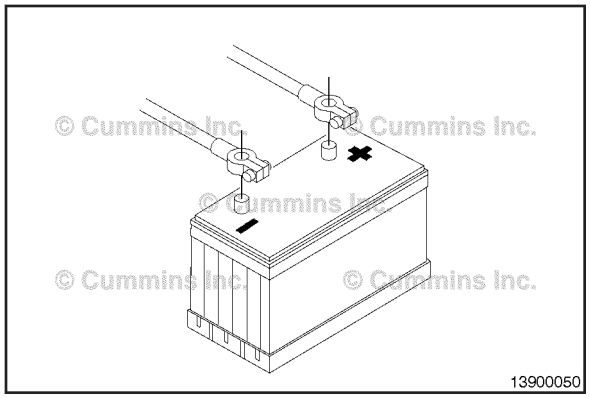
M8	23 N•m	[17 ft-lb]
M10	45 N•m	[33 ft-lb]





Finishing Steps

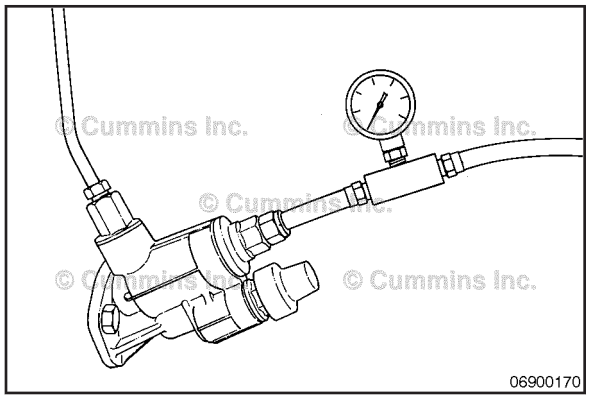
- Connect the fuel supply and return line connectors. Refer to Procedure 006-024
- Install the fuel filter. Refer to Procedure 006-015
- Connect the fuel heater connector, if applicable.



⚠WARNING⚠

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

- Connect the batteries
- Operate the engine and check for leaks.

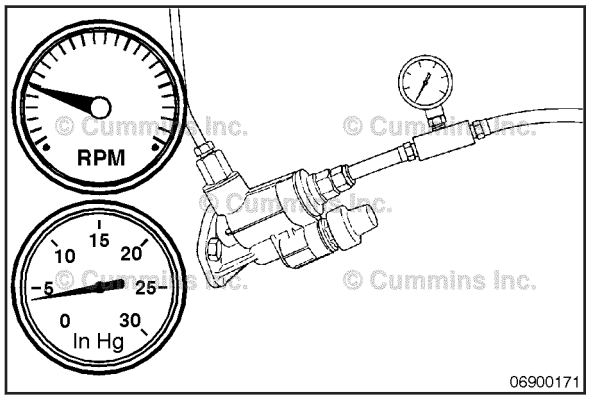


Fuel Inlet Restriction (006-020)

Initial Check

Install a fitting at the inlet transfer pump.

Install a vacuum gauge that has a range of at least 0 to 508 mm Hg [0 to 20 in Hg].

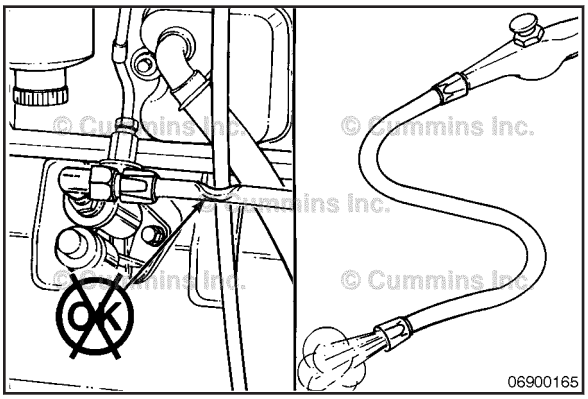


Start the engine, and run at low or high idle.

Allowable Inlet Restriction at Low/High Idle		
mm Hg		in Hg
101.6	MAX	4.0

If the fuel inlet restriction is too high, check to make sure that the OEM lines from the tank are sized properly, there are no kinks or bends in the lines, and the lines are **not** clogged.

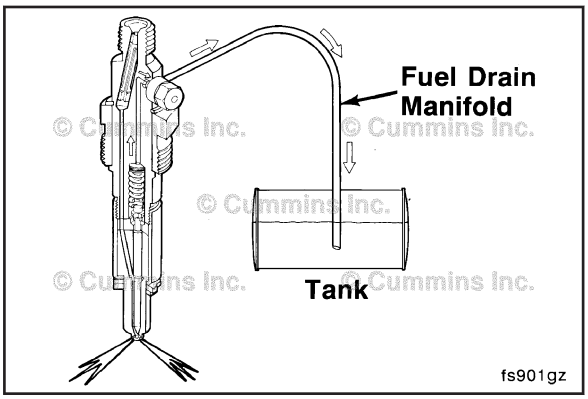
Make sure that there are no clogged fuel strainers or malfunctioning check valves.



Fuel Manifold (Drain) (006-021)

General Information

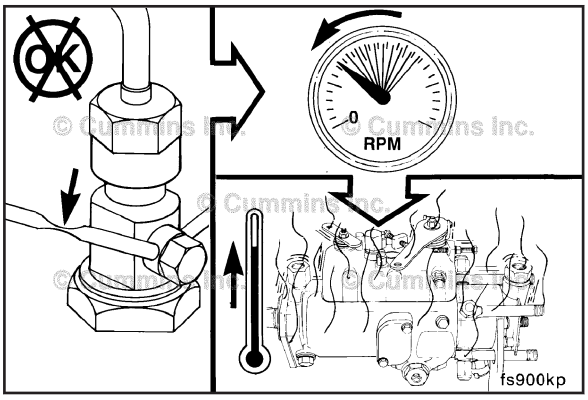
The fuel system is designed to use fuel to cool and lubricate the injection pump and injectors. Fuel is continually vented from the injection pump, and a small amount of fuel leaks near the injector needle valve during injection. This fuel is returned to the supply tank by the fuel drain manifold.



Restriction of the fuel drain manifold can affect the Lucas CAV DPA/DPS fuel injection pump metering controls and the operation of the injectors. Restricting the fuel drain manifold raises the case pressure of the fuel injection pump, which can prevent injection.

If the engine will restart after a waiting period following an unexplained shutdown, look for any restriction of the manifold drain line.

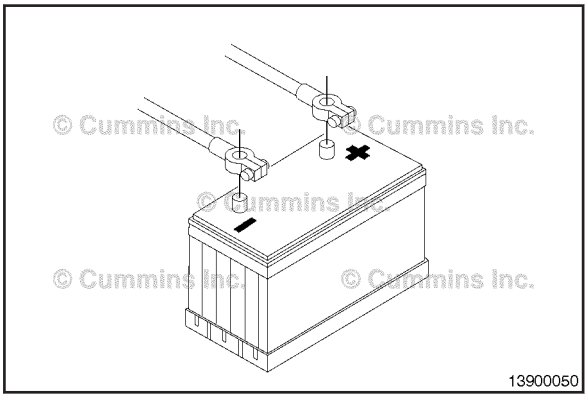
NOTE: Restriction can cause the fuel temperature to rise, reducing power from the engine.

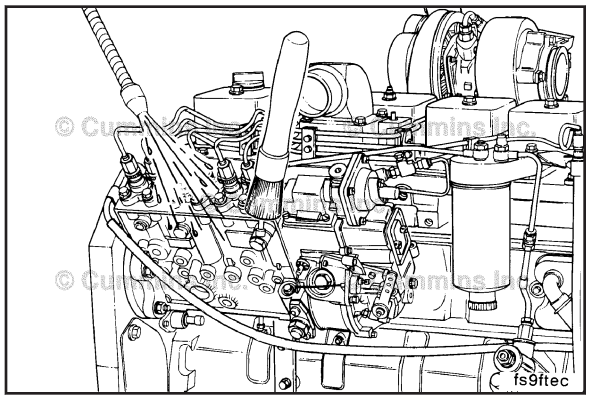


Preparatory Steps

⚠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 batteries.

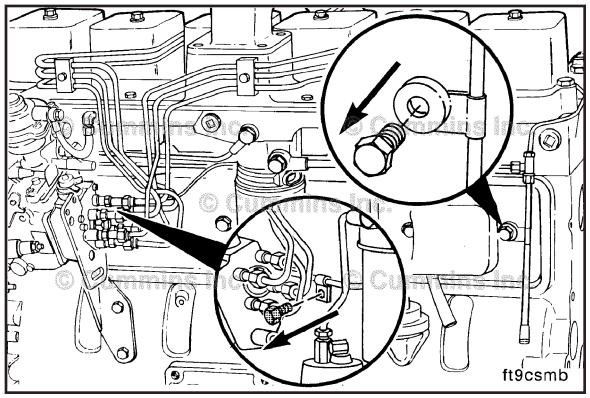




⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

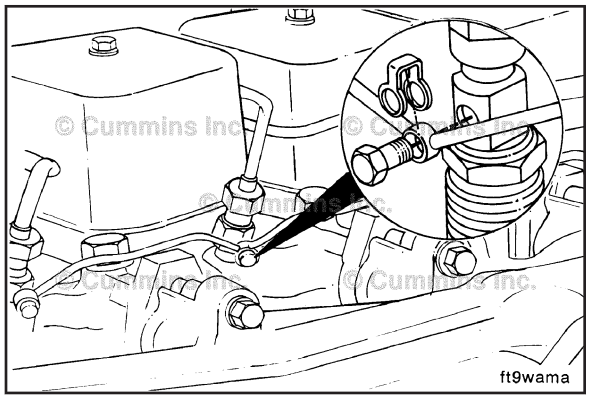
- Clean any debris.



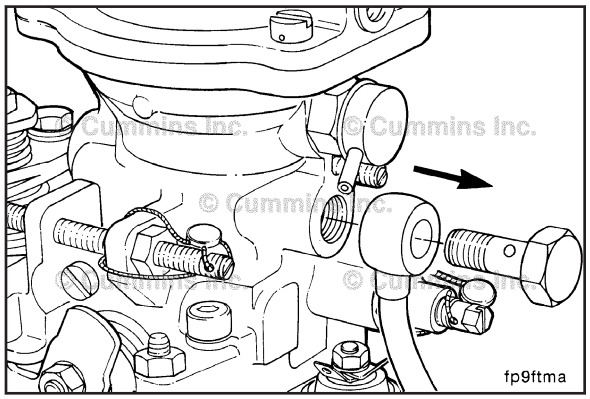
Remove

Distributor-Type Pump

Remove the capscrews from the hold-down clamps, and complete the following steps:



Remove the banjo fitting capscrews and washers.

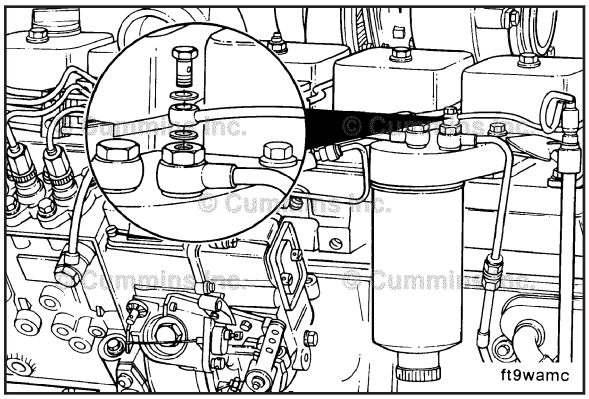


Disconnect the fuel drain line fittings.

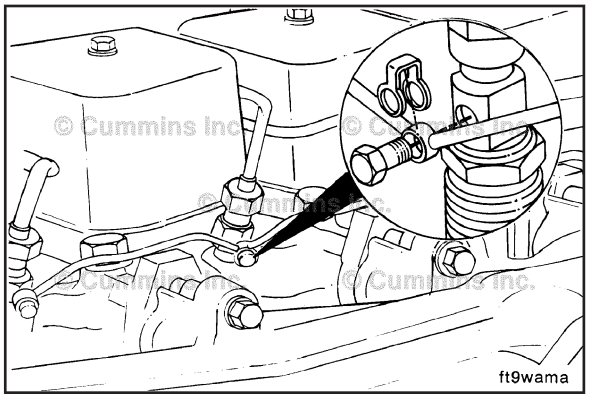
In-Line Pump

Remove the banjo capscrews and copper sealing washers at the fuel filter head.

Remove the fuel line support bracket capscrew from the intake manifold.



Remove the banjo capscrews and copper sealing washers from the injectors.



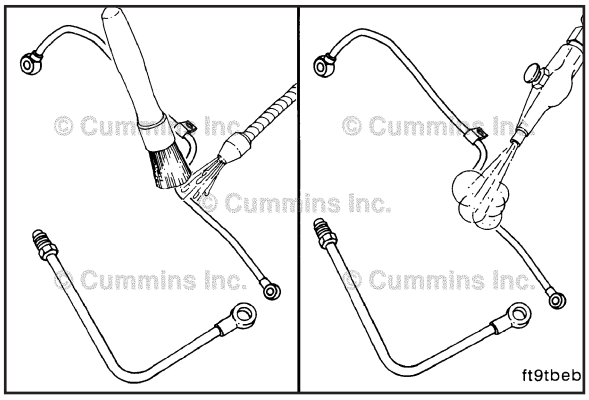
Clean and Inspect for Reuse

⚠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.

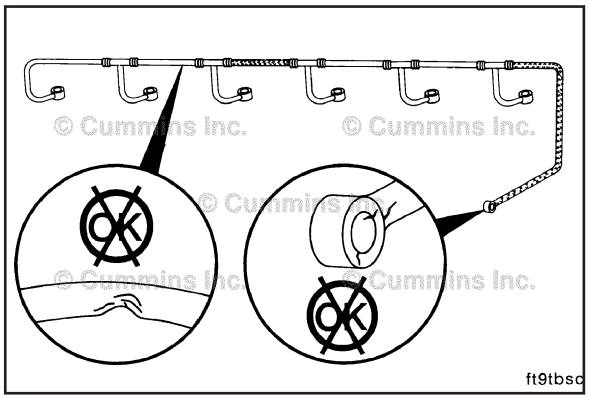
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

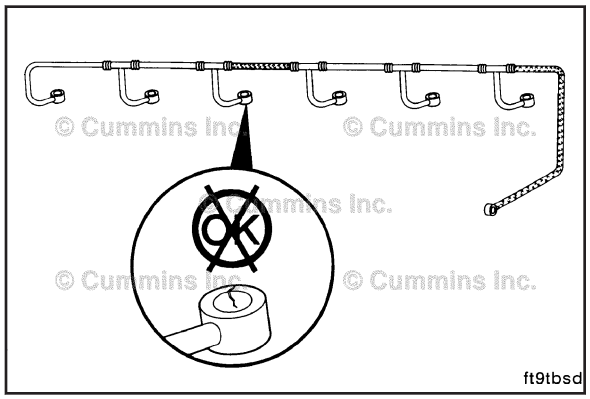
Wash the low-pressure fuel lines in solvent.

Dry the fuel lines with compressed air.



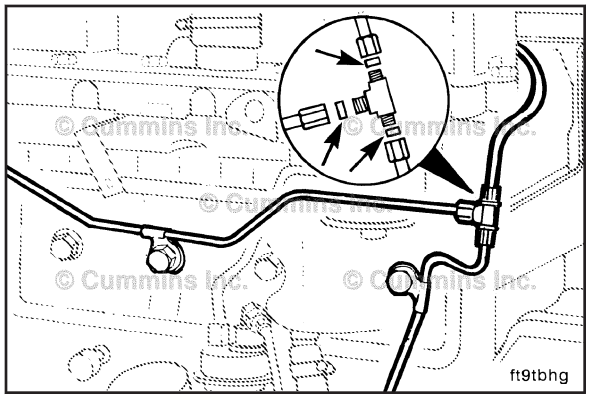
Inspect the fuel drain manifold for cracks and other damage.





Inspect the fuel drain manifold banjo connections.

NOTE: The banjo connection seals **must** be discarded when removed. The seals **must not** be used again.

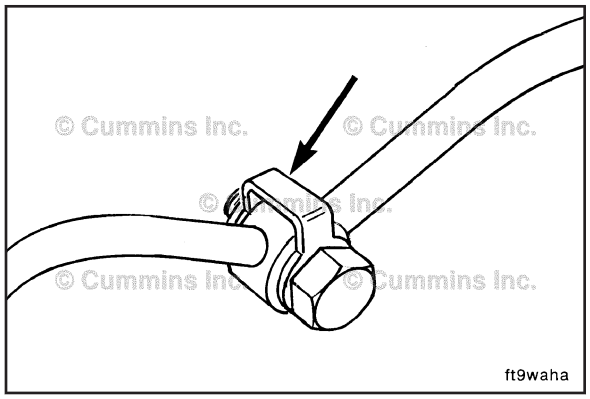


Install

Distributor-Type Pump

Assemble the fuel drain line and fuel drain manifold in the reverse order of disassembly.

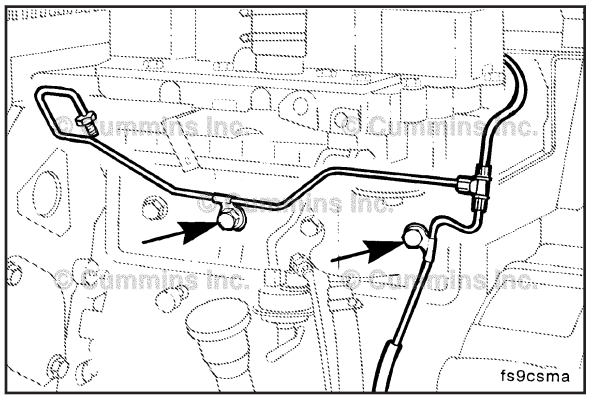
NOTE: Use new seals for the fittings.



The installation torque for the banjo fitting screw is as follows:

Torque Value: 9 N•m [80 in-lb]

NOTE: Use new sealing washers for the fuel drain manifold.



Install the clamp capscrews.

Torque Value: 24 N•m [18 ft-lb]

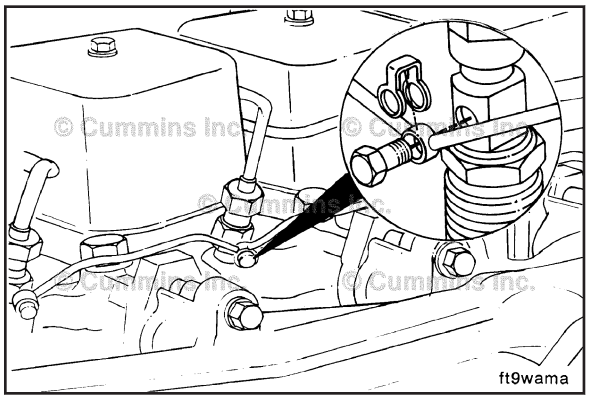
Bosch® In-Line pump

Install the fuel drain manifold in the reverse order of removal.

Torque Value:

Injector Banjo	9 N•m	[80 in-lb]
Fuel Filter Head	13 N•m	[115 in-lb]

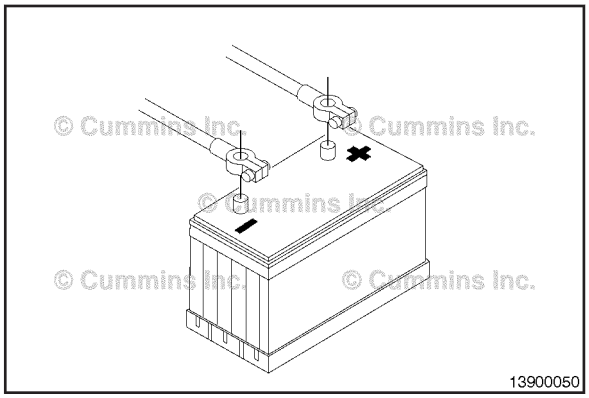
NOTE: The fuel line support bracket capscrew in the intake manifold requires liquid Teflon™ sealant.



Finishing Steps

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

- Connect the batteries
- Operate the engine and check for leaks.

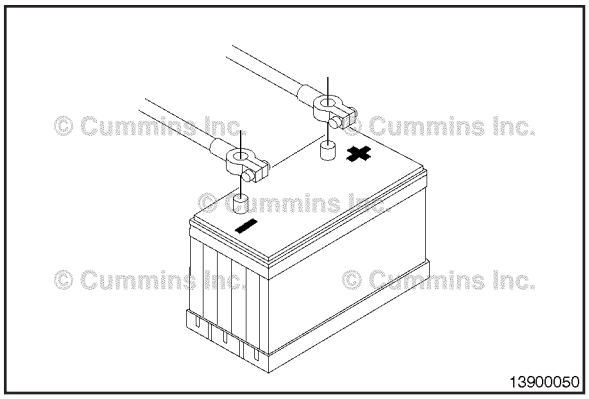


Fuel Supply Lines (006-024)

Preparatory Steps

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

- Disconnect the batteries.

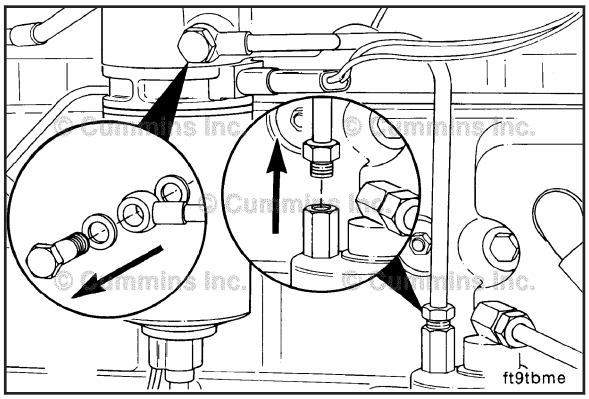


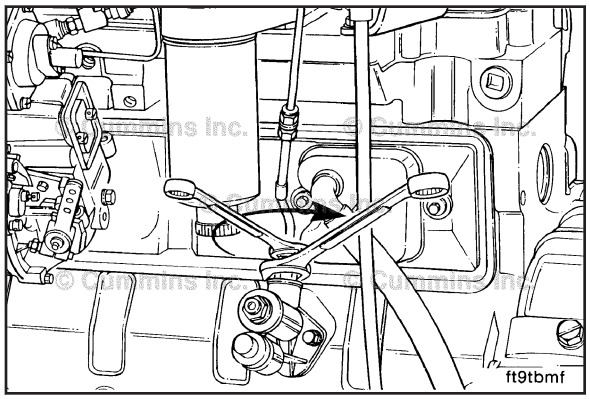
Remove

Low Pressure Fuel Line(s)

Low-Pressure Fuel Line Replacement - Distributor-Type Pumps

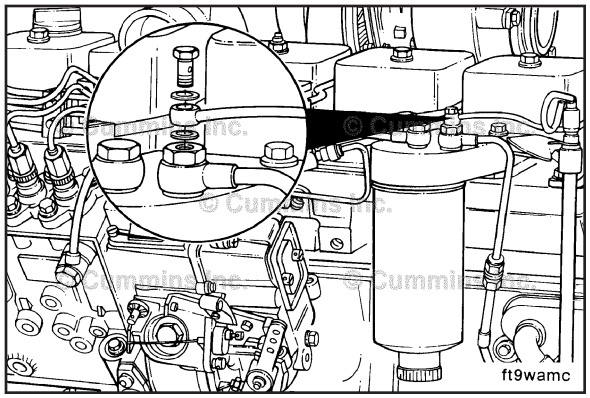
Remove the line from the fuel transfer pump and fuel filter head.



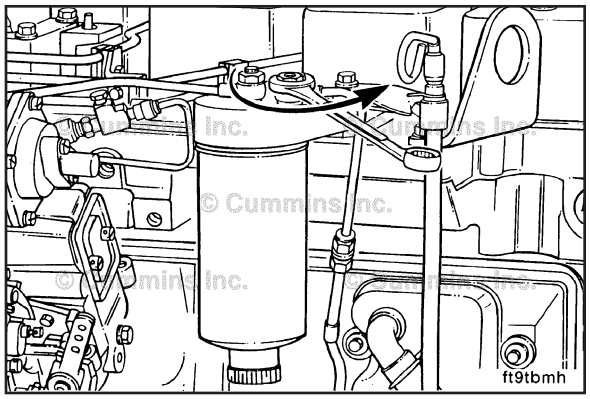


Bosch® In-Line Fuel Injection Pump Fuel Line

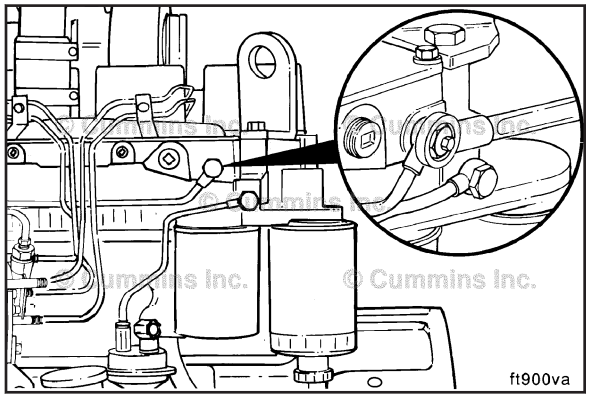
Remove the fuel line from the piston-style fuel transfer pump.



Remove the fuel drain manifold line at the filter head.



Remove the fuel line from the filter head.

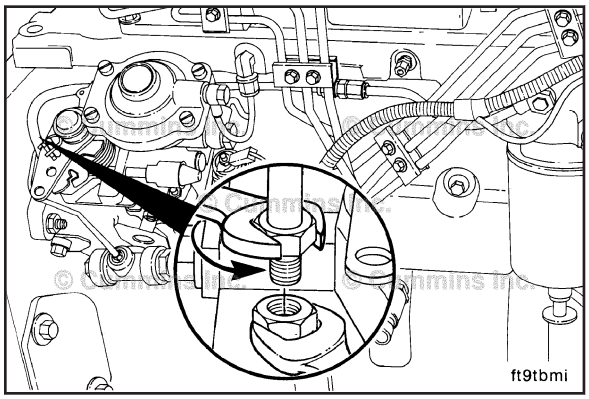


Fuel Injection Pump Supply Line - Distributor-Type Pumps

Remove the bleed screw banjo fitting, and complete the following steps:

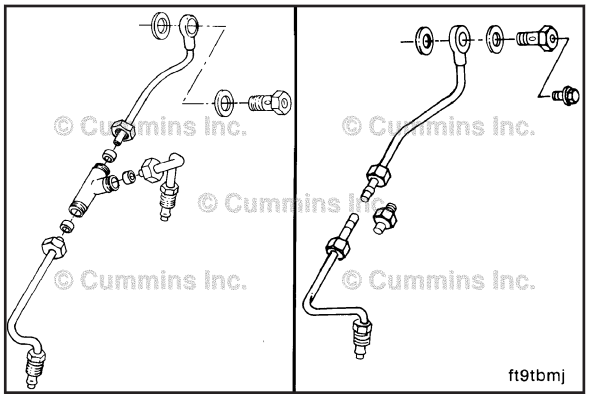
Remove the fuel line from the Bosch® fuel injection pump fitting.

NOTE: To prevent loosening the fuel injection pump inlet fitting, use two wrenches when removing the fuel supply line.



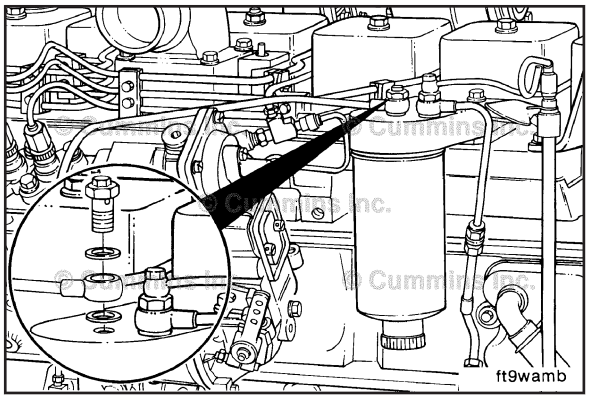
Remove the fuel supply line from the two Lucas CAV fuel injection pump fittings.

NOTE: Replace the seals in the fittings if the line is disassembled.

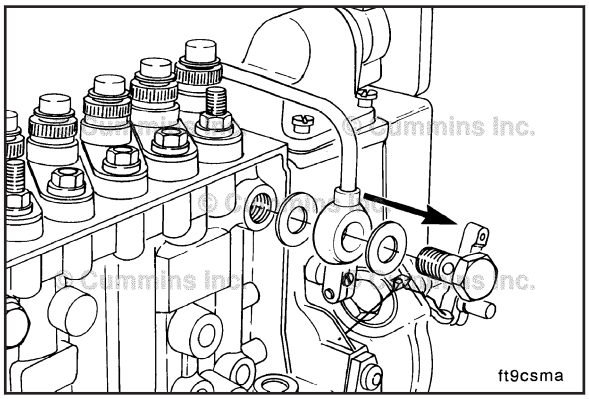


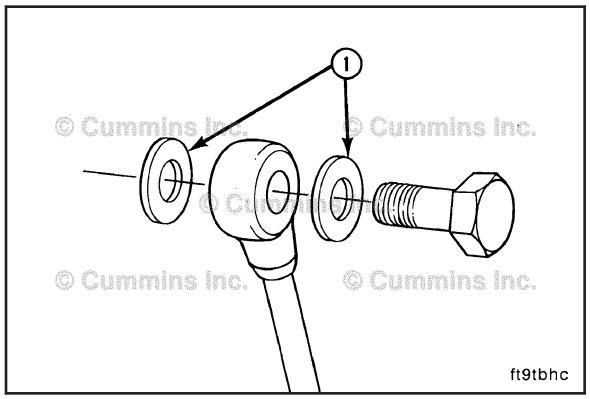
Pump Supply Line - Bosch® In-Line Pump

Remove the banjo capscrew and sealing washers at the filter head.



Remove the banjo capscrew and copper sealing washer at the fuel injection pump inlet.

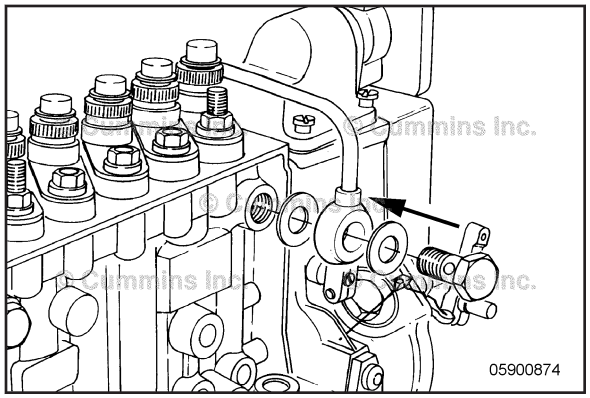




Install

Low Pressure Fuel Line(s)

NOTE: When replacing the fuel lines, replace the banjo fitting sealing washers (1) each time they are removed.



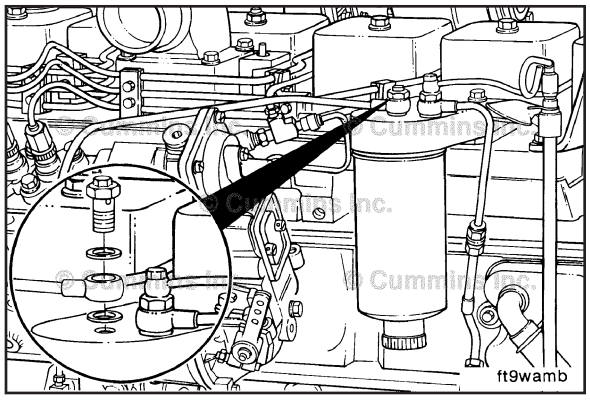
Fuel Pump Supply Line — Bosch® In-Line Pump.

Install the banjo capscrew and copper sealing washer at the fuel injection pump inlet.

NOTE: When replacing the fuel lines, replace the banjo fitting sealing washers each time they are removed.

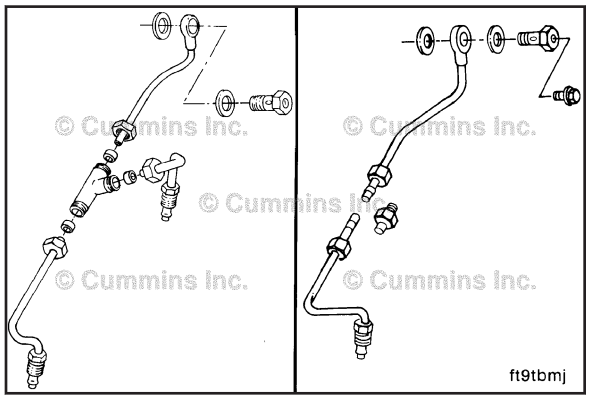
Install the fuel line and tighten.

Torque Value: 32 N•m [24 ft-lb]



Install the banjo capscrew and sealing washers at the filter head.

Torque Value: 24 N•m [18 ft-lb]



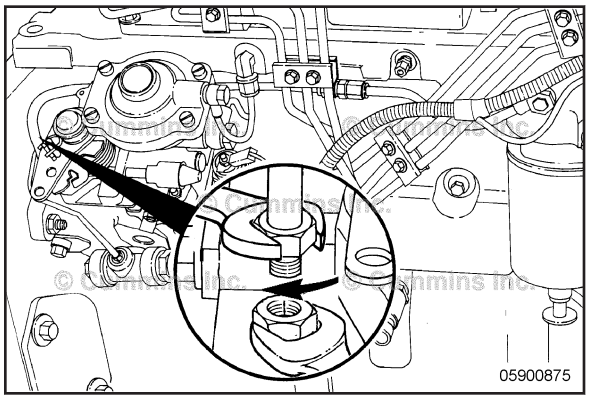
Install the fuel supply line to the two Lucas CAV fuel injection pumps.

Torque Value: 24 N•m [18 ft-lb]

Install the fuel line to the Bosch® fuel injection pump fitting.

NOTE: To prevent overtightening the fuel injection pump inlet fitting, use two wrenches when installing the fuel supply line.

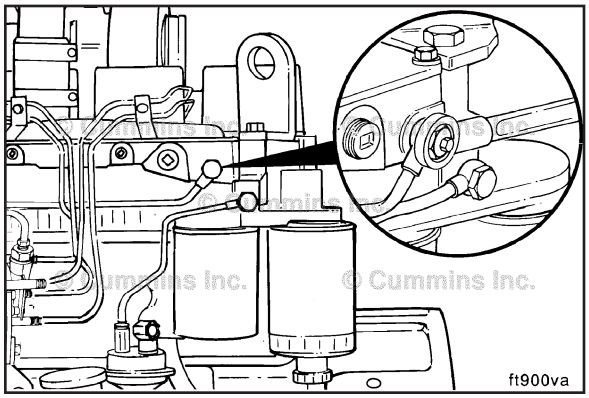
Torque Value: 32 N•m [24 ft-lb]



Fuel Injection Pump Supply Line — Distributor-Type Pumps.

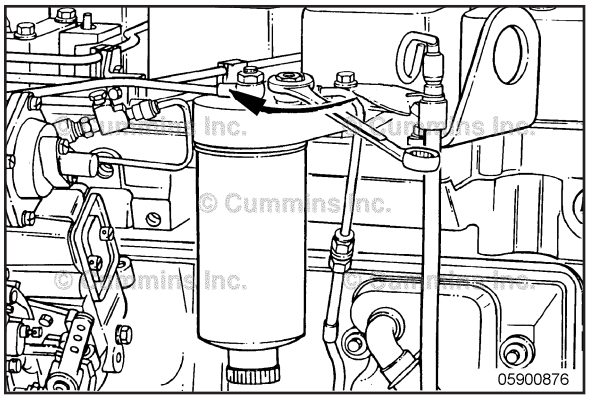
Install the bleed screw banjo fitting.

Torque Value: 24 N•m [18 ft-lb]



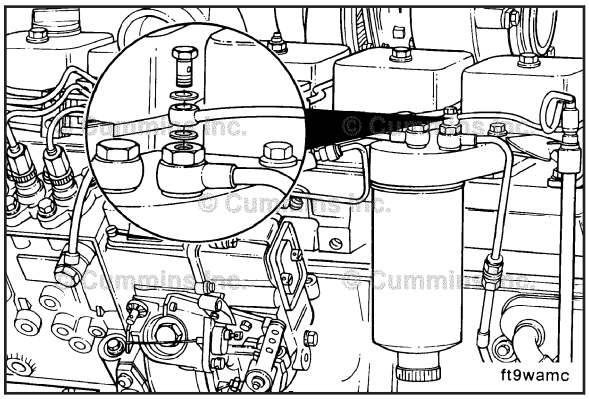
Install the fuel line to the filter head.

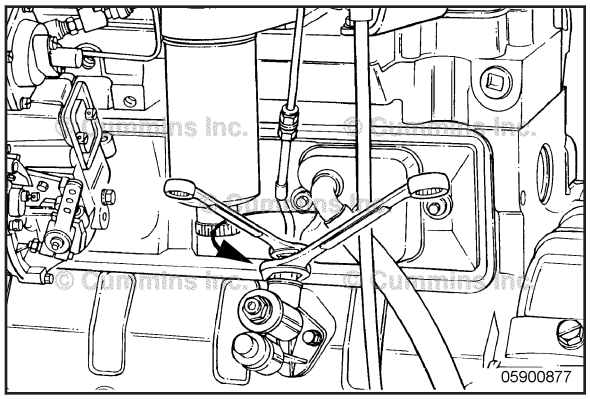
Torque Value: 24 N•m [18 ft-lb]



Install the fuel drain manifold line at the filter head.

Torque Value: 13 N•m [10 ft-lb]



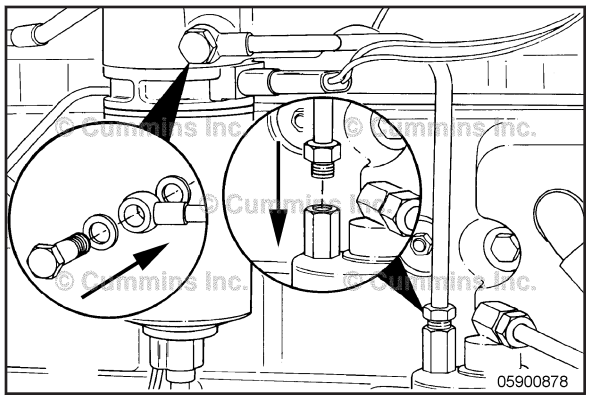


Bosch® In-Line Fuel Injection Pump Fuel Line.

Install the fuel line to the piston-style fuel transfer pump.

Torque Value: 24 N•m [18 ft-lb]

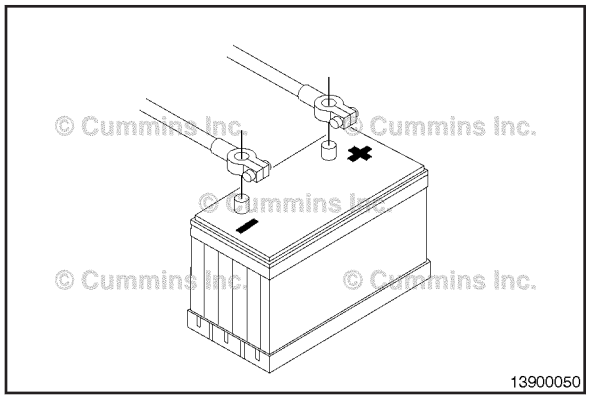
NOTE: To prevent overtightening the fuel injection pump inlet fitting, use two wrenches when installing the fuel supply line.



Low-Pressure Fuel Line Replacment — Distributor-Type Pumps.

Install the line from the fuel transfer pump and fuel filter head.

Torque Value: 24 N•m [18 ft-lb]

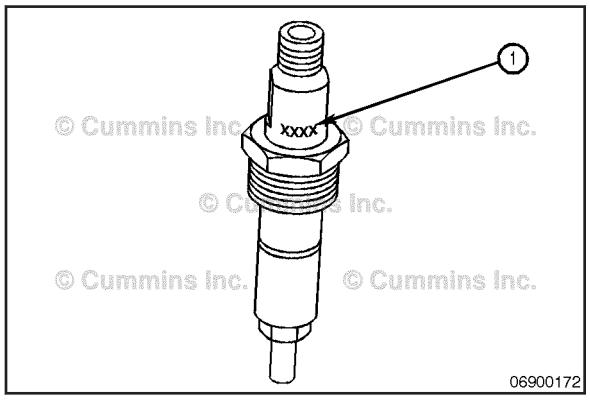


Finishing Steps

⚠WARNING⚠

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

- Connect the batteries
- Operate the engine and check for leaks.



Injector (006-026)

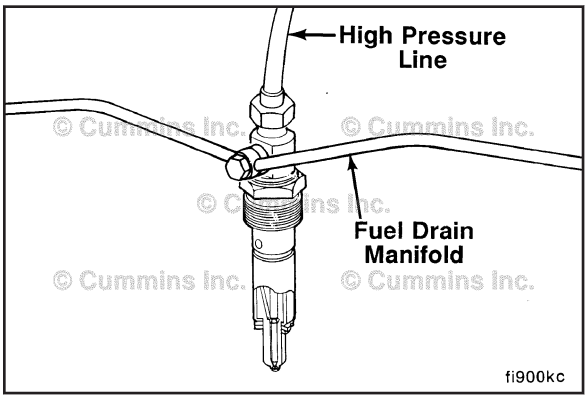
General Information

⚠CAUTION⚠

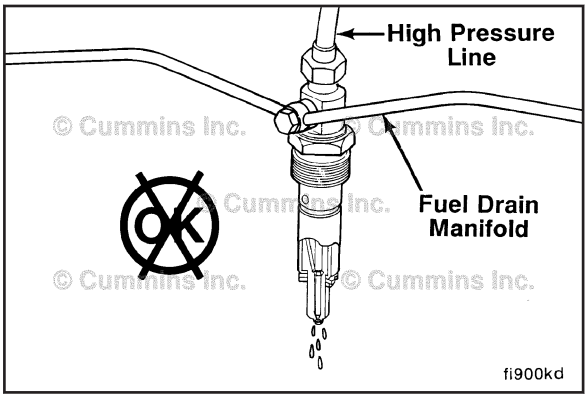
Use only the specified injector for the engine.

All engines use closed nozzle, hole-type injectors. However, the injectors can have different part numbers for different engine ratings. The last four digits of the Cummins® part number are used to identify the injectors.

During the injection cycle, high pressure from the injection pump rises to the operating (pop) pressure, which 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 pressure to seal off the nozzle after injection.



Failure of the needle valve to lift and close at the correct time or the needle valve stuck open can cause the engine to misfire and produce low power. Fuel leaking from the open nozzle can cause a fuel knock, poor performance, smoke, poor fuel economy, and rough running.

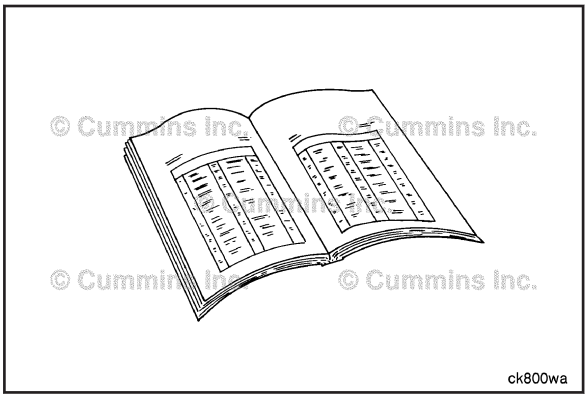


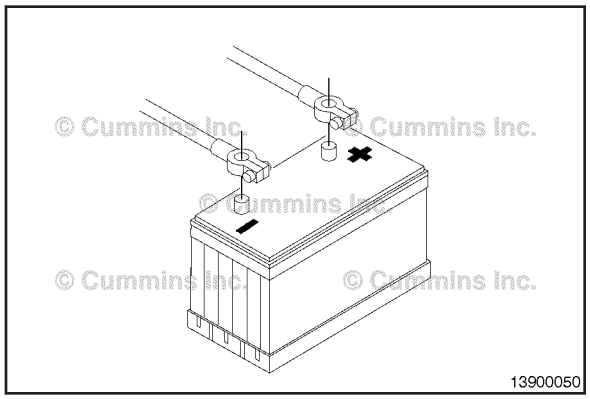
Preparatory Steps

Front Gear Train

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

- Disconnect the batteries.
- Clean around the injectors.
- Disconnect the high-pressure fuel supply lines. Refer to Procedure 006-051 in Section 6.
- Disconnect the fuel drain manifold. Refer to Procedure 006-021 in Section 6.

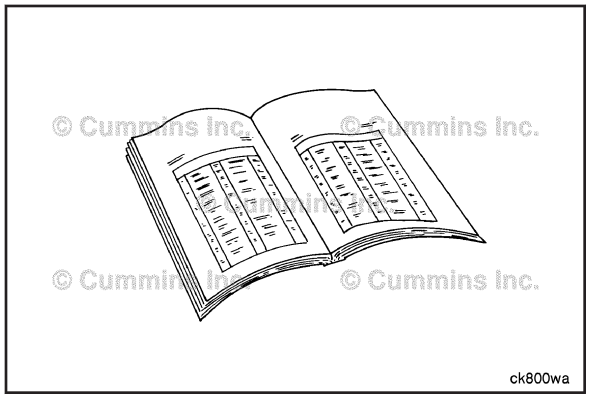




Rear Gear Train

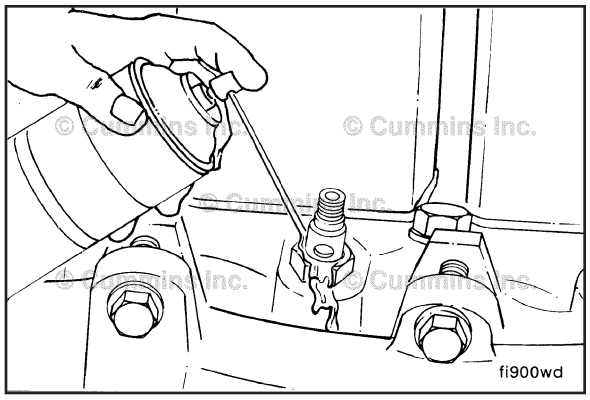
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries.



- Remove the rocker lever cover. Refer to Procedure 003-011 in Section 6.
- Remove the injector supply lines. Refer to Procedure 006-051 in Section 6.
- Remove the fuel connector. Refer to Procedure 006-052 in Section 6.

NOTE: The fuel connector **must** be removed before removing the injector or damage to the connector will result.



Remove

Front Gear Train

Rust-Penetrating Solvent

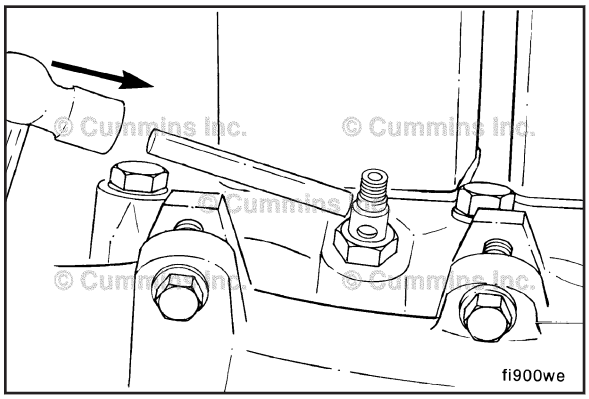
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

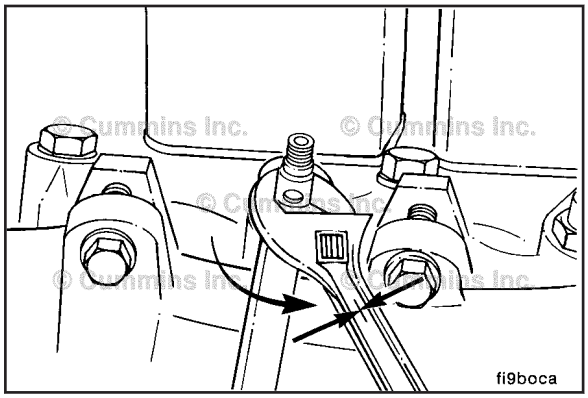
△CAUTION△
When rust has formed on the hold-down nut, the injector can turn in the bore when the nut is loosened. This can cause severe damage to the head by the injector locating ball cutting a groove in the bore.

Soak the hold-down nut with a rust-penetrating solvent for a minimum of 3 minutes.

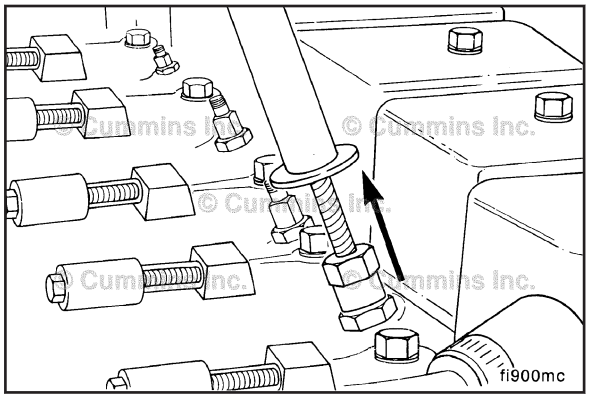
Hit the injector body with a drift pin to loosen any rust.



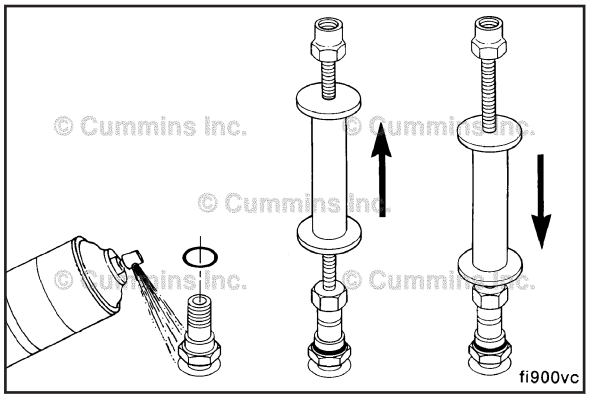
Hold the injector body with an adjustable wrench while loosening the hold-down nut with a 24-mm box wrench.

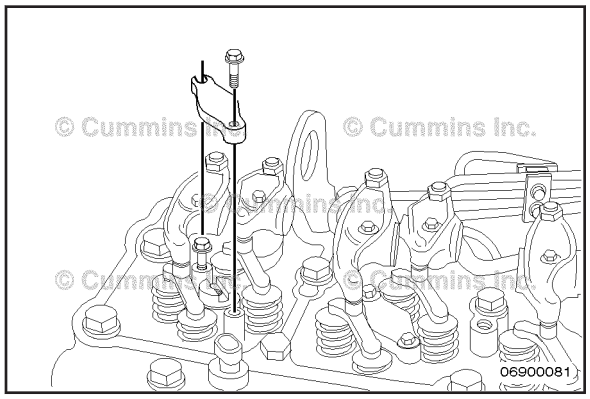


Use an injector puller, Part Number 3823276, to remove the injectors.



It is often necessary to tap the injector with the injector puller to work the injector up and down to remove it.

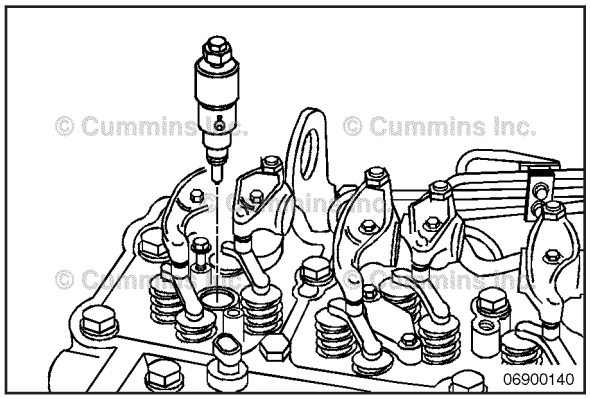




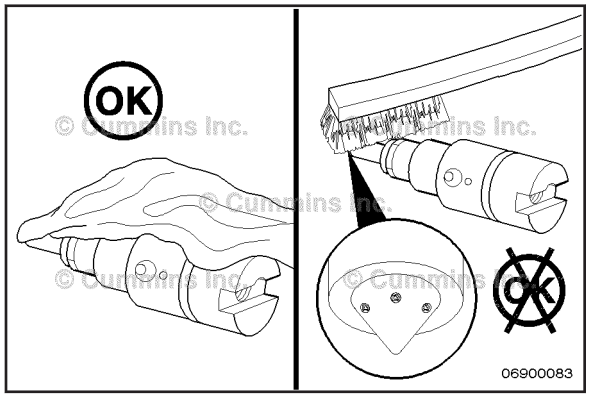
Rear Gear Train

Remove the injector hold-down capscrews.

Tilt the hold-downs up, and slide them out.



Use an injector puller, Part Number 3825156, to remove the injectors from the head.



Clean and Inspect for Reuse

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

△CAUTION△
Do not use any abrasives (such as glass beading, sand paper, emery cloth, Scotch-Brite™ pads, etc) or metallic items (including wire brushes made of any metallic material) to clean the injectors. The use of any cleaning method other than safety solvent and a soft, clean, lint-free cloth will damage the nozzle holes and cause performance issues.

Clean the injector tip and body with safety solvent and a soft, clean rag.

NOTE: If necessary, use a **brass** brush to clean off carbon.

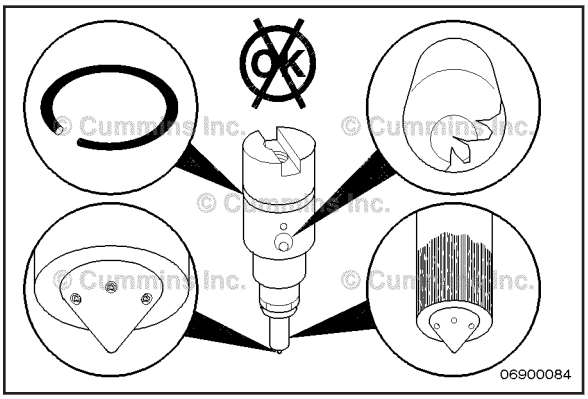
Inspect the injector for burrs on the inlet to the injector.

Inspect the nozzle holes for any signs of damage, such as erosion or plugging.

Inspect the nozzle color for signs of overheating.

NOTE: Overheating will cause the nozzle to turn a dark yellow/tan or blue color, depending on the degree of overheating.

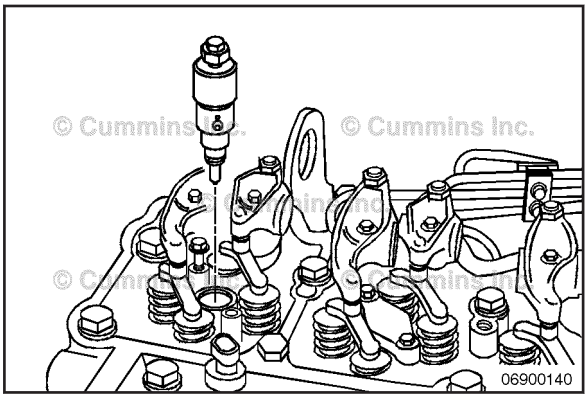
Inspect the o-ring for damage.



O-rings and Sealing Washers

If the high-pressure connectors are **not** damaged, remove the injectors and inspect the o-rings and sealing washers. If there is **any** damage to the injector parts, replace the o-ring or sealing washers.

Inspect the contact point of the sealing washers to the cylinder head.



Test

Front Gear Train

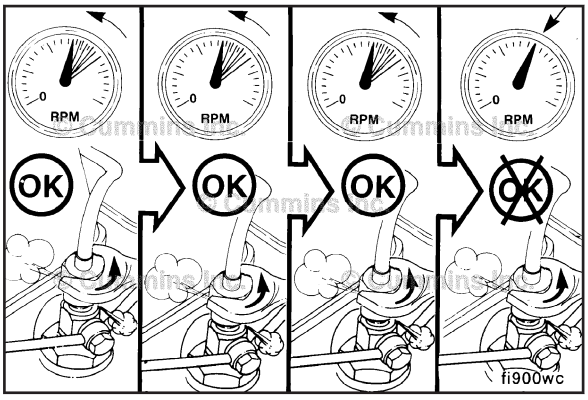
⚠WARNING⚠
Do not vent the fuel system on a hot engine; this can cause fuel to spill onto a hot exhaust manifold, which can cause a fire.

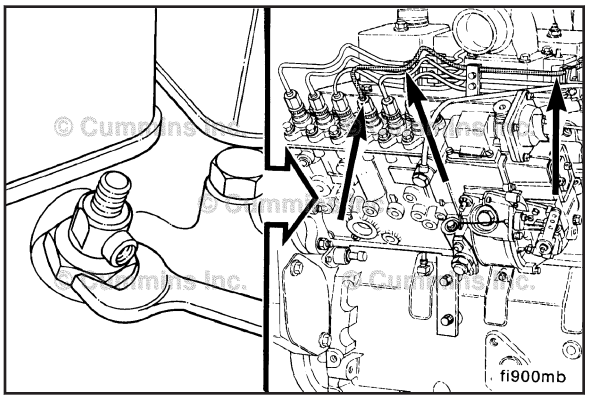
To determine which cylinder is misfiring, operate the engine, loosen the fuel line nut at one injector, and listen for a change in engine speed.

NOTE: A drop in engine speed indicates the injector was delivering fuel to the cylinder.

NOTE: Be sure to tighten the fuel line nut before proceeding to the next injector.

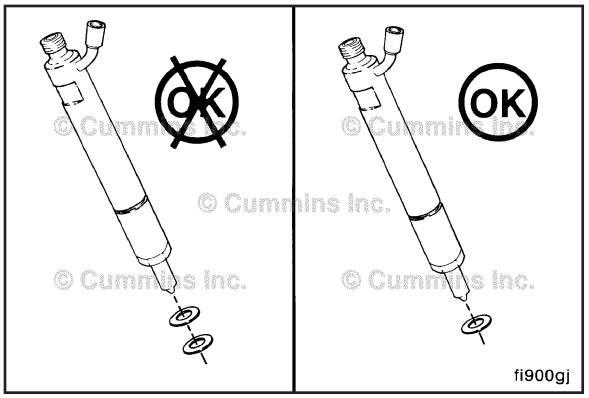
Check each cylinder until the malfunctioning injector is found.



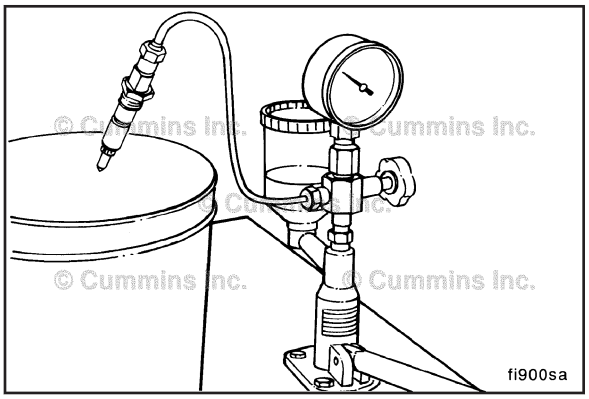


Remove the malfunctioning injector to test or replace it.

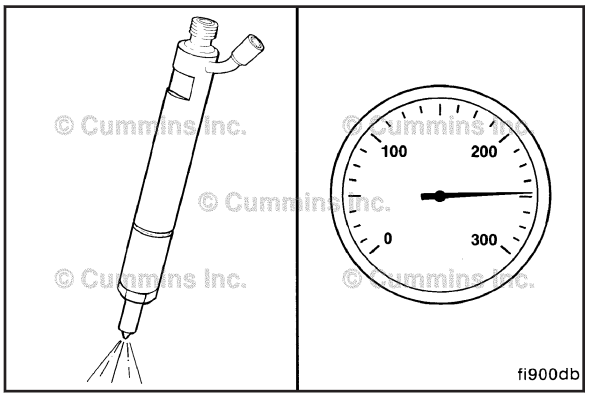
If the engine continues to misfire after replacing the injector, check for leaks in the high-pressure line. Also, check for a damaged delivery valve that lets the fuel drain back into the injection pump.



Check for an extra copper sealing washer on the injector.



Carbon buildup in the orifices in the nozzle will also cause low power from the engine. Remove and check the spray pattern, or replace the injectors.



⚠WARNING⚠
While testing the injectors, keep hands and body parts away from the injector nozzle. Fuel coming from the injector is under extreme pressure and can cause serious injury by penetrating the skin.

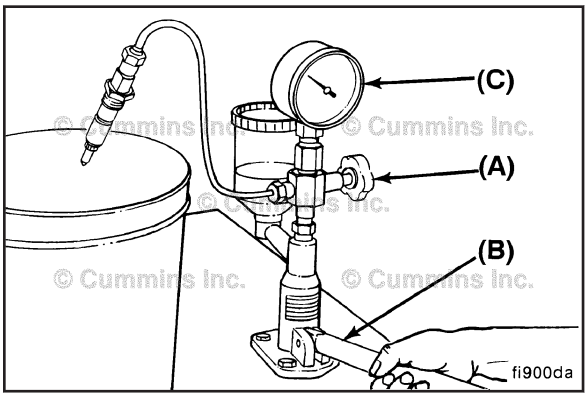
Use an injector nozzle tester, Part Number 3376946. All nozzles **must** be tested for opening pressure, chatter, and spray pattern.

Check the injector opening pressure.

1 Open the valve.

2 Operate the lever at one stroke every second.

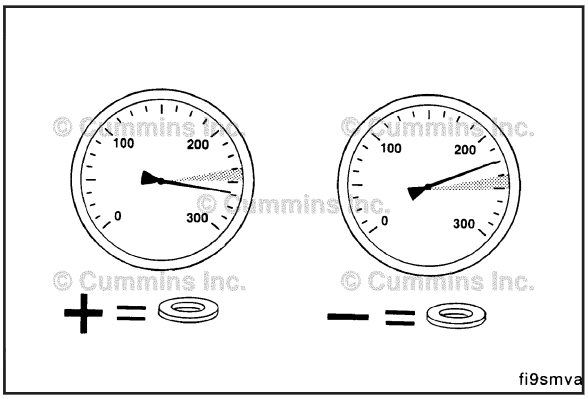
3 Read the pressure indicated when the injector spray begins.



If the opening pressure does **not** meet specifications, attempt one of the following solutions:

1 Add shims to increase pressure.

2 Remove shims to decrease pressure.

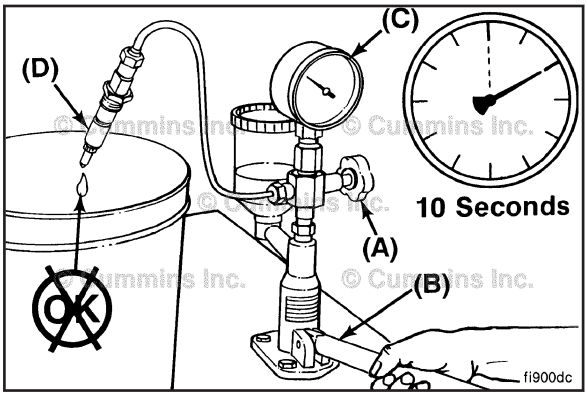


Leakage Test

1 Open the valve (A).

2 Operate the lever (B) to maintain a pressure of 20 bar [290 psi] below opening pressure (C).

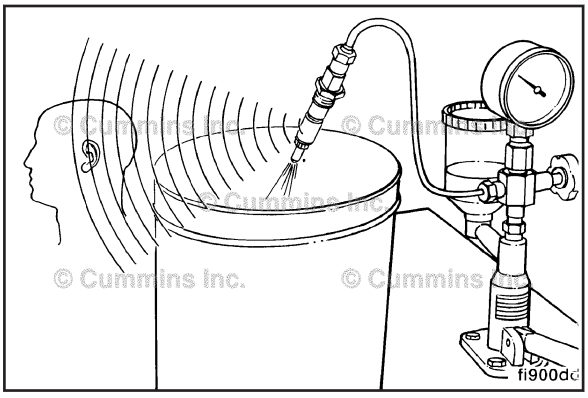
3 No drops should fall from the tip (D) within 10 seconds.

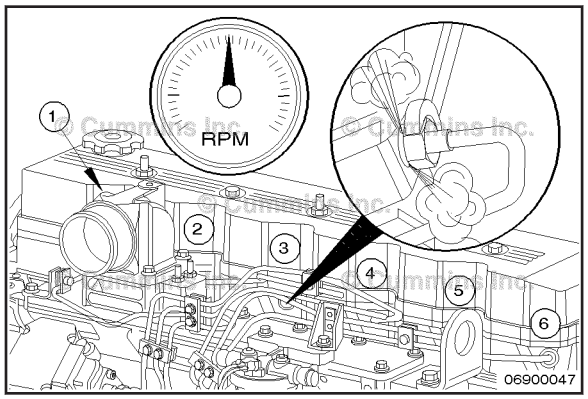


Chatter Test

The chatter test indicates the ability of the needle valve to move freely and atomize the fuel correctly. An audible sound will possibly be heard as the valve rapidly opens and closes. A well-optimized spray pattern can possibly be seen.

NOTE: Used nozzles **must not** be evaluated for chatter at lower speeds. A used nozzle can usually be used if it passes the leakage test.





Rear Gear Train

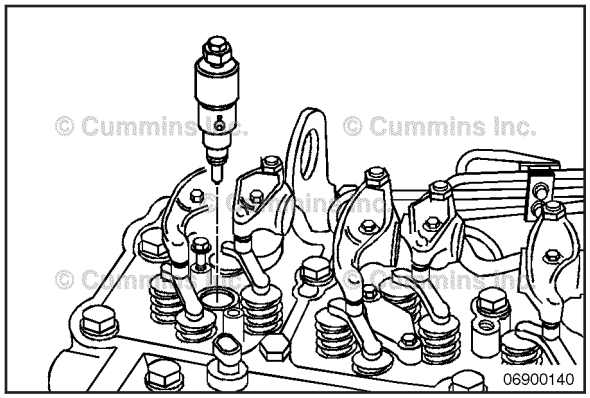
⚠WARNING⚠
Do not vent the fuel system on a hot engine; this can cause fuel to spill onto a hot exhaust manifold, which can cause a fire.

Test to determine which cylinder is misfiring, operate the engine, loosen the fuel line nut at one injector, and listen for a change in engine speed.

NOTE: A drop in engine speed indicates the injector was delivering fuel to the cylinder.

NOTE: Be sure to tighten the fuel line nut before proceeding to the next injector.

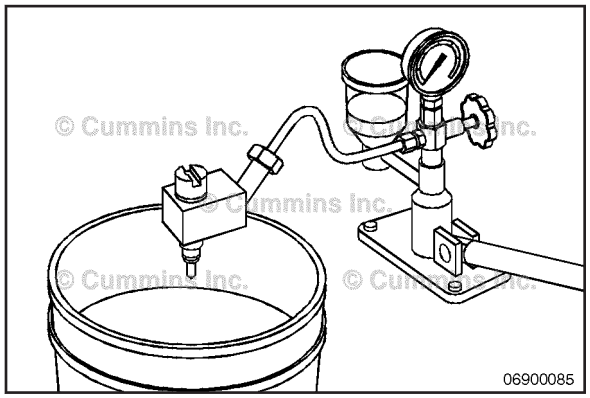
Check each cylinder until the malfunctioning injector is found.



Remove the malfunctioning injector to test or replace it.

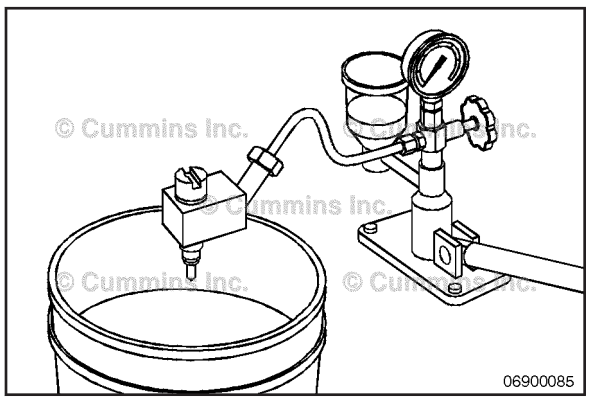
If the engine continues to misfire after replacing the injector, check for leaks in the high-pressure line.

Check for a defective delivery valve that allows the fuel to drain back into the injection pump.



Use an injector holder, Part Number 3162269, to install the injector on the injector test stand, Part Number 3376946.

Open the bypass valve for the pressure gauge so the spray pattern can be checked.



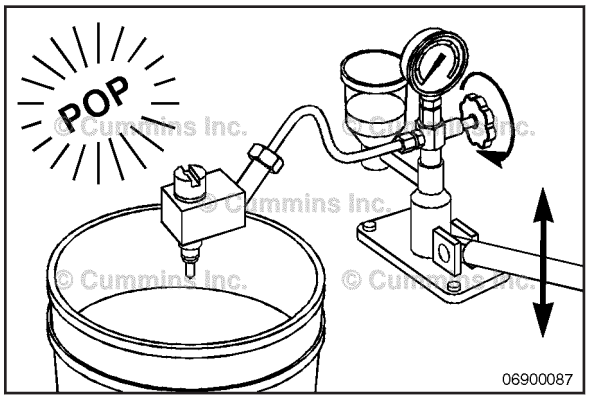
Operate the test stand lever quickly several times to check the spray pattern of the injectors. Verify that the correct number of plumes are present for the number of holes the injector has. Also, pay close attention to the size and shape of each plume. If possible, compare the spray pattern to that of a new injector with the same assembly number.

NOTE: The injector spray pattern is an excellent indicator of the nozzle hole condition. Check each plume carefully; it is possible that **only** a single hole has damage. Significant performance problems will result if there is damage to any number of the holes.

Close the bypass valve for the pressure gauge, and operate the test stand lever to check nozzle opening pressure.

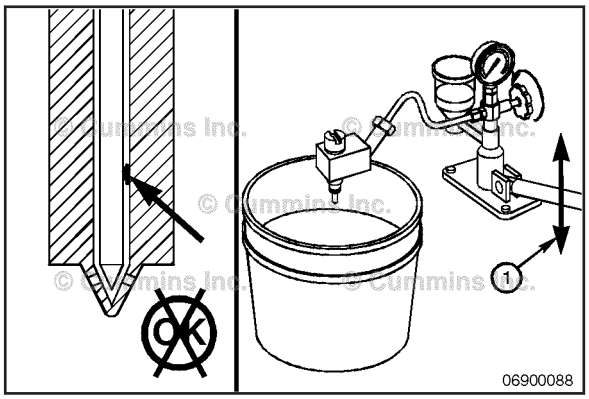
There is a good crisp "pop" when the nozzle opens. The pressure specification is 300 ± 10 Bar [4351 ± 145 psi].

NOTE: If the nozzle opening pressure is out of specification, it is possible to add or remove shims to the injector to modify the opening pressure.



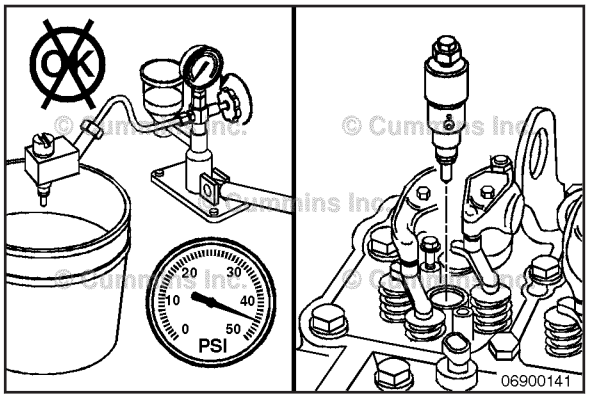
If the nozzle opening pressure is excessively low and/or the nozzle sprays excessive fuel, the injector needle is possibly sticking. The needle can be stuck because of poor lubrication or debris.

It is possible to unstick an injector needle by use of the injector test stand. Open the bypass valve for the pressure gauge and operate the test stand lever rapidly for 10 to 20 strokes.



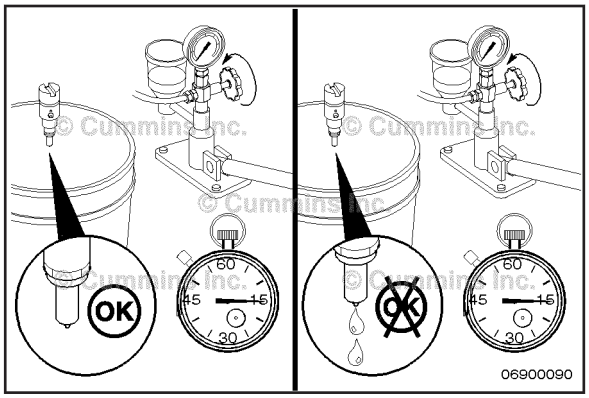
Check the nozzle opening pressure and spray pattern again to determine if the injector has returned to normal operation.

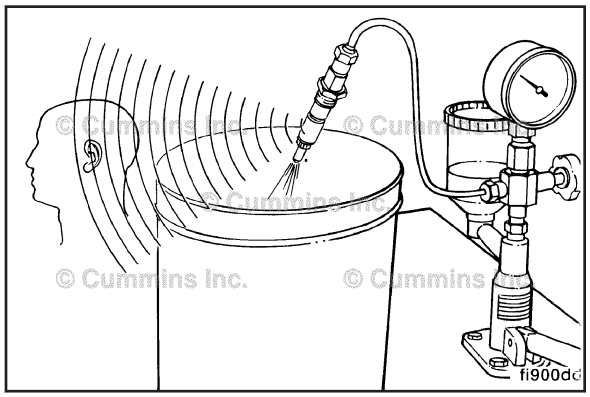
If the injector remains out of specification, replace the injector.



Inspect the injector for dripping and/or excessive leak down.

Close the bypass valve for the pressure gauge and build pressure to within 1000 kPa [145 psi] of the opening pressure of the nozzle.



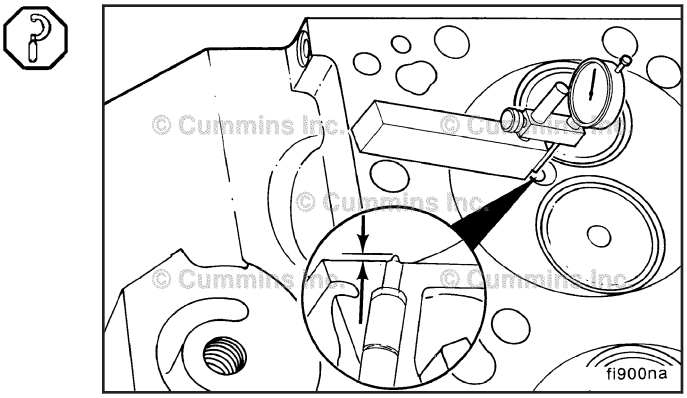


Chatter Test

The chatter test indicates the ability of the needle valve to move freely and atomize the fuel correctly. An audible sound can be heard as the valve rapidly opens and closes. A well-optimized spray pattern can also be observed.

NOTE: Used nozzles **must not** be evaluated for chatter at lower speeds. A used nozzle can usually be used if it passes the leakage test.

Measure



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

Install the depth gauge assembly, Tool Number 3164438, on the cylinder head combustion deck and zero it.

Rotate the depth gauge so that it measures the injector protrusion at the highest point on the injector.

Record the injector protrusion for each injector.

Injector Tip Protrusion B Series 1991 Automotive and CPL 1577

mm		in
3.5	MIN	0.1378
4.5	MAX	0.1772

Injector Tip Protrusion All Other B Series Pre 1991 Automotive and 1994 Automotive

mm		in
4.5	MIN	0.1772
5.5	MAX	0.2165

Injector Tip Protrusion Non-Automotive B Series

mm		in
3.0	MIN	0.1180
4.0	MAX	0.1575

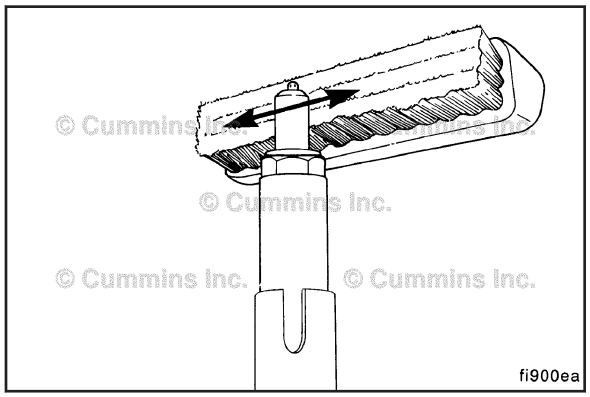
If the injector protrusion is not within the specifications, reference the injector seal thickness chart below for the available seal thicknesses.

Injector Seal Thickness

	mm		in
1.5 mm Seal	1.40	MIN	0.055
	1.68	MAX	0.066

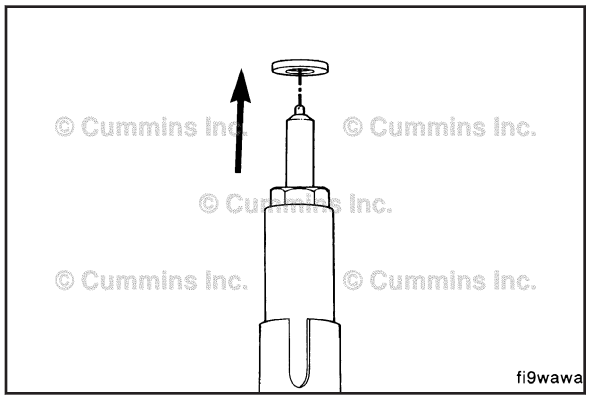
	mm		in
2.5 mm Seal	2.40	MIN	0.095
	2.68	MAX	0.106

	mm		in
3.0 mm Seal	2.90	MIN	0.114
	3.18	MAX	0.125

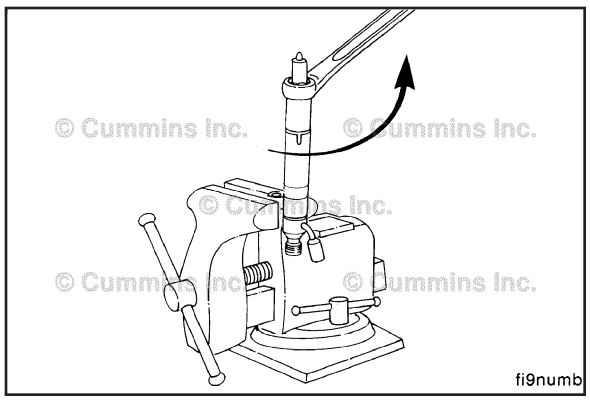


Disassemble

Clean the carbon residue from the injector nozzle. Use a brass wire brush and a piece of hardwood dipped in test oil.

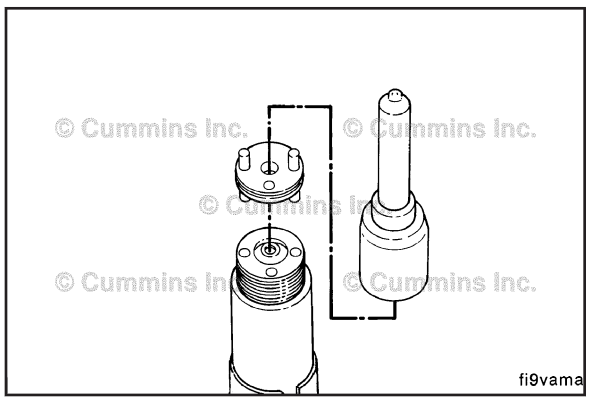


Remove the injector seal and discard the seal.



Clamp an injector hold-down clamp in a soft-jawed vise to hold the injector.

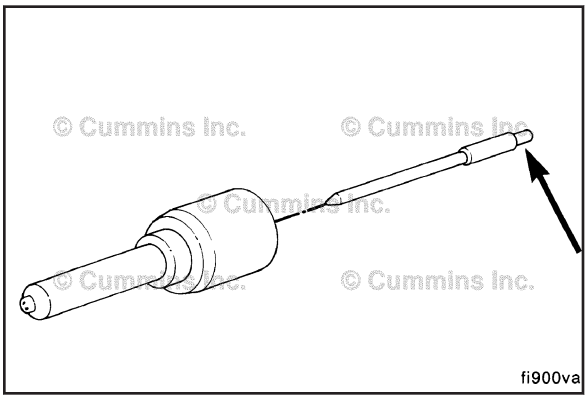
Remove the injector nozzle retaining nut.



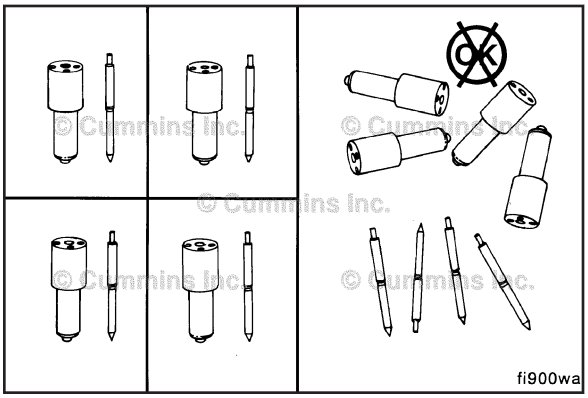
⚠CAUTION⚠
Place the injector nozzle and needle valve in a suitable bath of clean test oil or damage will occur.

Remove the nozzle needle valve and intermediate plate.

⚠CAUTION⚠
Hold the needle valve by the stem only. Contact from the skin will corrode the finely lapped surface.

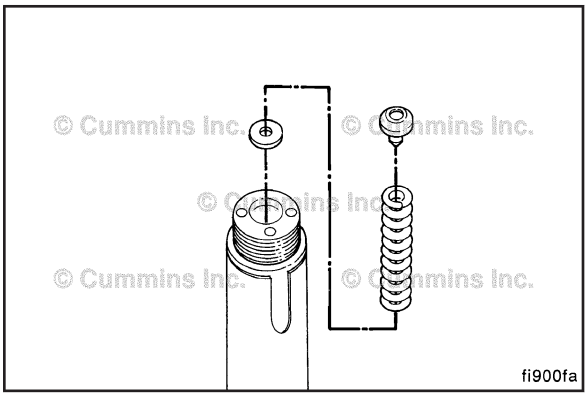


NOTE: The needle valve and nozzle tip are precisely matched for fit. The parts **must not** be intermixed.

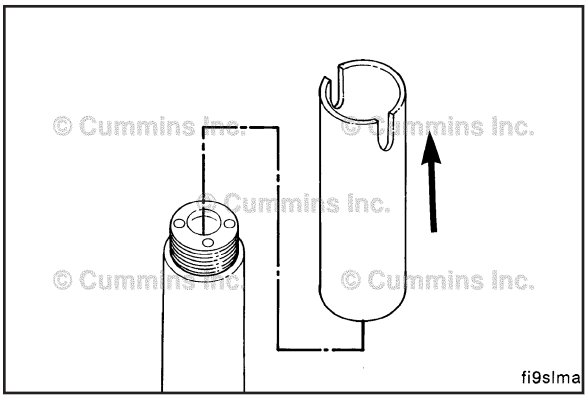


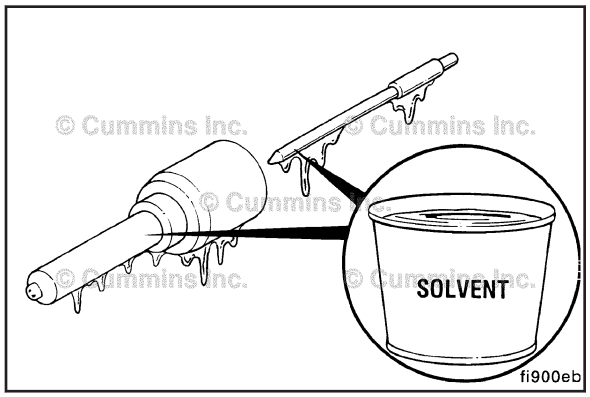
Remove the nozzle holder from the vise.

Remove the pressure spindle, pressure spring, and shims.



Remove and discard the injector sealing sleeve.

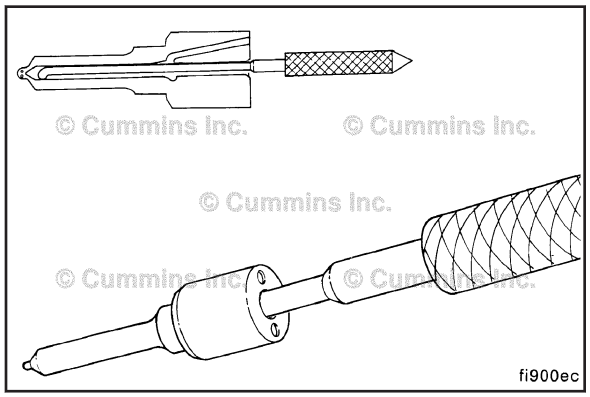




Clean

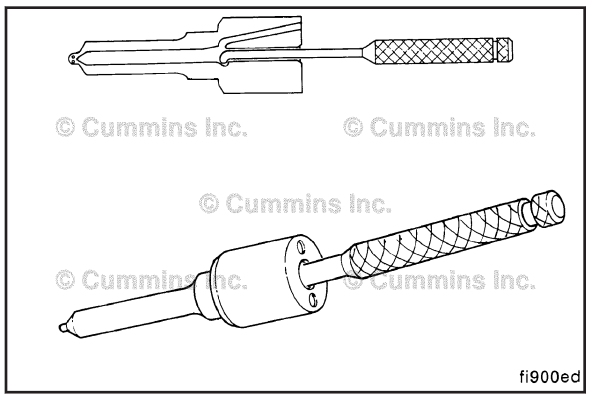
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

Rinse the nozzle bodies and needle valves in solvent to flush them thoroughly and completely remove all varnish and carbon deposits.



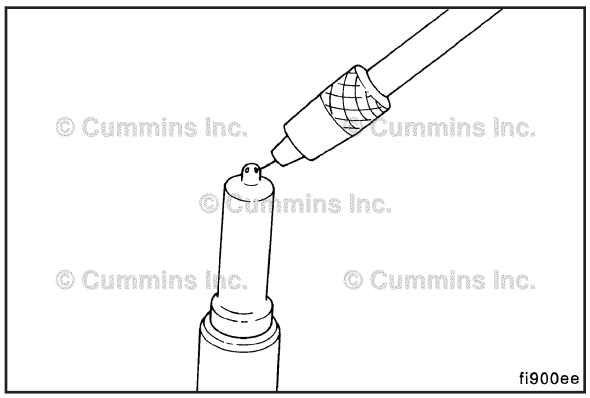
△CAUTION△
Never use emery paper, a steel brush, or any other metal scraper to clean the nozzle. The parts can be damaged.

Dip the nozzle seat in clean test oil, and use the nozzle cleaning kit, Part Number 3376947, to clean the nozzle seat. Polish the needle seat with a piece of hardwood dipped in 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 a scraper, as illustrated. Rinse the nozzle in solvent to remove all dirt and carbon residue, and dip it in clean test oil.



Clean the spray holes with an appropriate size cleaning needle, as illustrated.

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

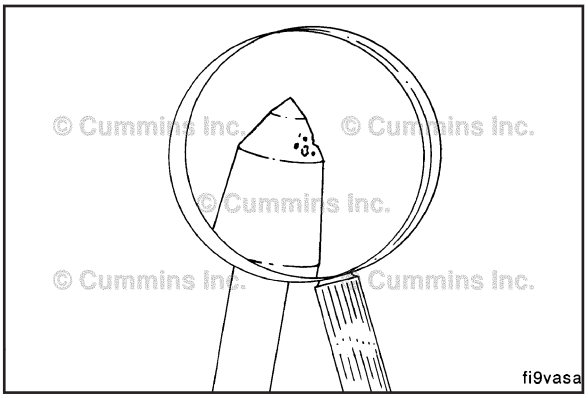
Front Gear Train

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 signs of overheating. Overheating will cause the nozzle to turn a dark yellow/tan or blue color, depending on the temperature of the overheat.

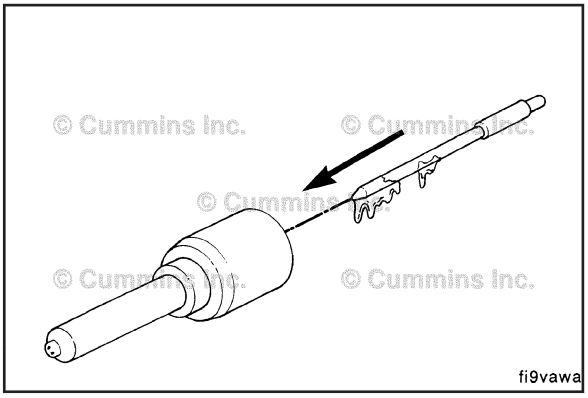
Inspect for rough surfaces and erosion. The pressure shoulder will normally have a rough machined appearance.

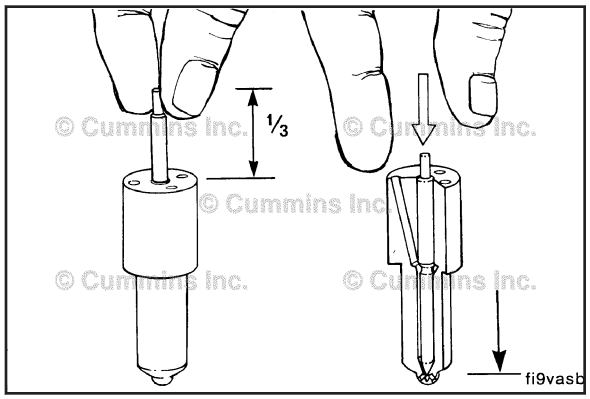
Inspect the injector bore for old sealing washers.

NOTE: Deteriorated needle valves **must** be replaced as a matched unit with their compatible nozzle body.



Dip the needle valve in clean test oil and insert the needle valve all the way into the nozzle body.

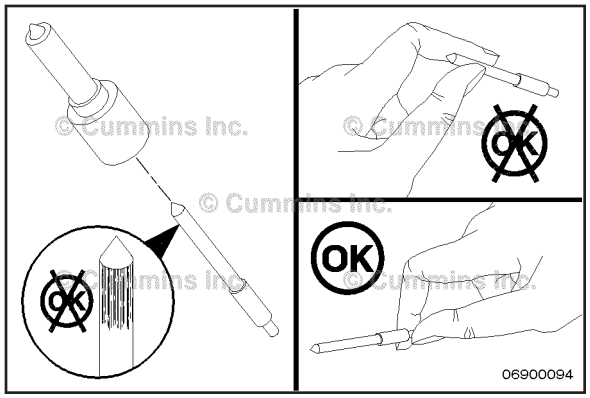




Pull the needle valve one-third of the way out of the nozzle body. With the needle valve in the vertical position, the needle valve **must** slide all the way back into the nozzle body under its own weight.

If the nozzle fails the slide test, clean and test the nozzle again.

NOTE: Any needle valve and nozzle body assembly that does **not** pass this test **must** be replaced.



Rear Gear Train

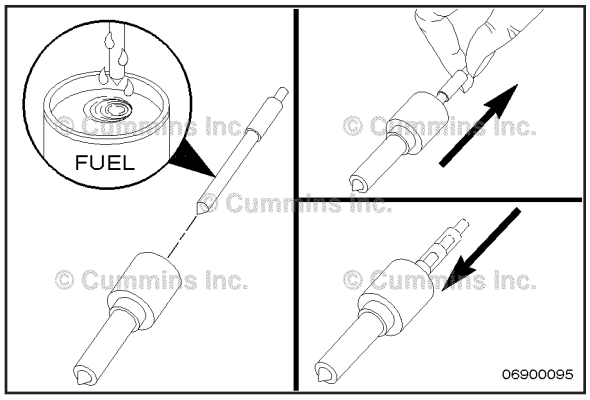
⚠CAUTION⚠

Do not touch the needle with your fingertips. Oil from your fingers will damage the needle. Hold the needle by the stem. If the needle is touched, wipe clean with a soft cloth and dip in clean diesel fuel.

Remove the needle from the nozzle tip and inspect the color.

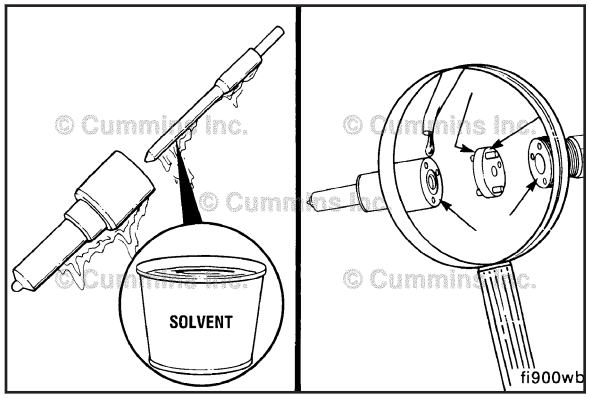
Check for signs of excessive carbon or overheating (dark yellow/tan or blue needle color).

Check for scuff marks on the needle.



Dip the needle in clean diesel fuel and insert it into the nozzle.

Hold the nozzle at a 45-degree angle and pull the needle 2/3 of the way out. Under its own weight, the needle **must** slide smoothly back into the nozzle.



Assemble

Front Gear Train

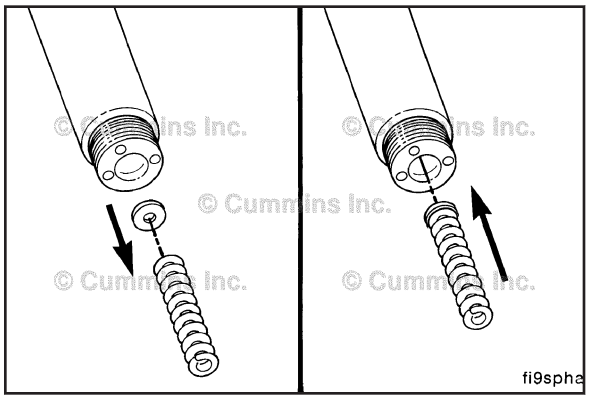
⚠WARNING⚠

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.

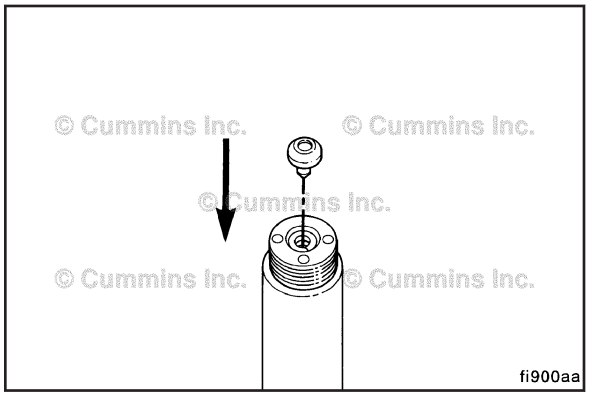
NOTE: Make sure that all mating surfaces and pressure faces are thoroughly cleaned and lubricated with test oil before assembly. New nozzles **must** be cleaned and lubricated before assembly.

NOTE: Install the same thickness of shims that were removed in disassembly. Use the pressure spring to make sure the shims are installed flat.

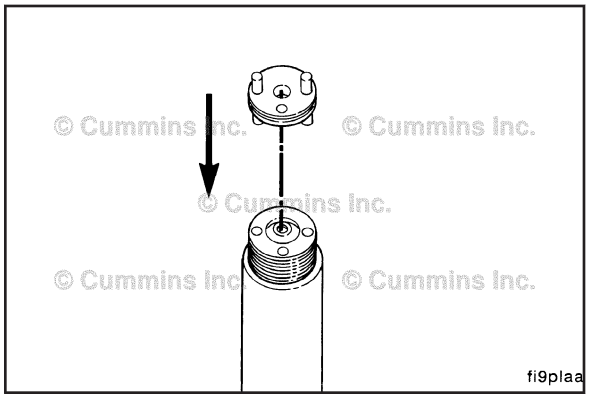
Install the shims and pressure spring.



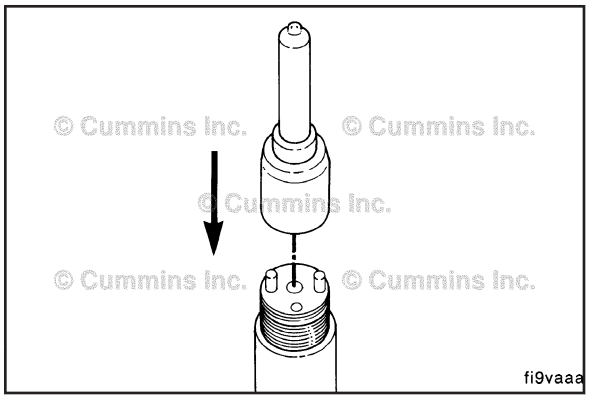
Install the spindle.

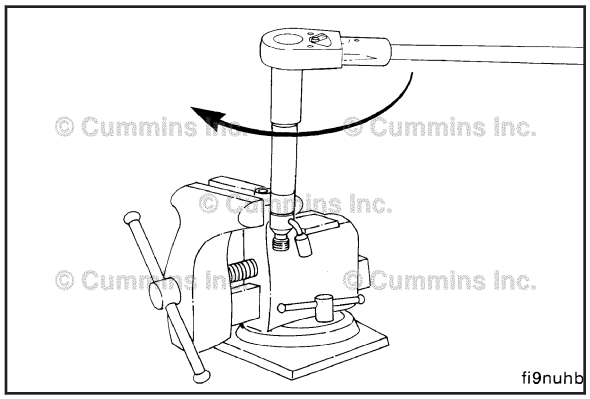


Install the intermediate plate.



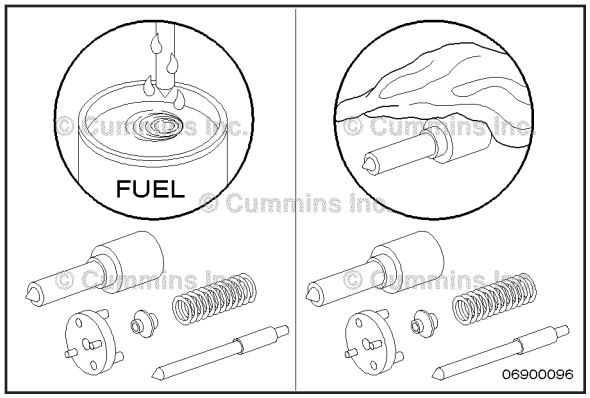
Install the needle valve and nozzle assembly.





Install the nozzle retaining nut.

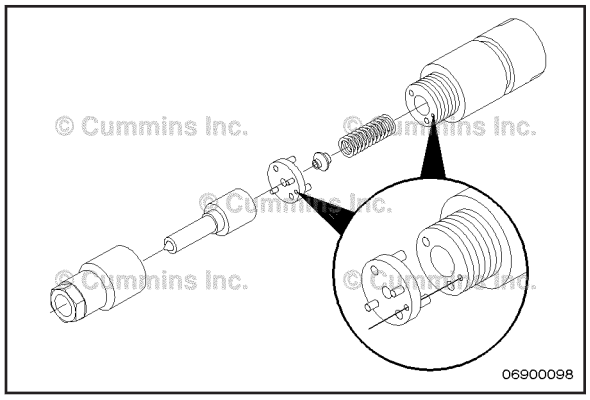
Torque Value: 30 N•m [22 ft-lb]



Rear Gear Train

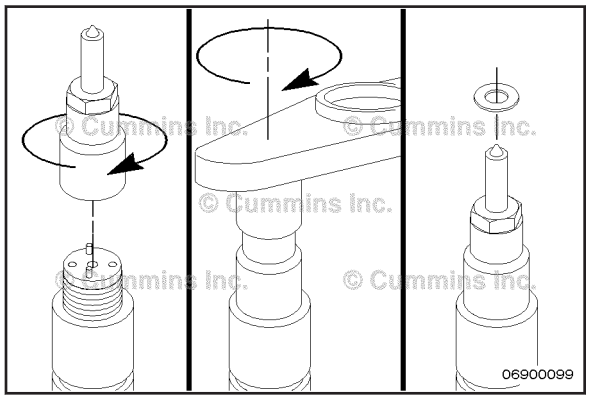
Clean the internal components of the injector with clean diesel fuel and a clean cloth.

Make sure there is **no** debris in the internal parts of the injector.



NOTE: Make sure the intermediate plate is in the correct orientation, with the supply hole on the plate lining up with the supply hole on the holder.

Install the spring, button, intermediate plate, and nozzle/ needle.



Install the retaining nut hand-tight.

Place the injector in the injector clamp.

Tighten the retaining nut.

Torque Value: 47 N•m [35 ft-lb]

Install the sealing washer.

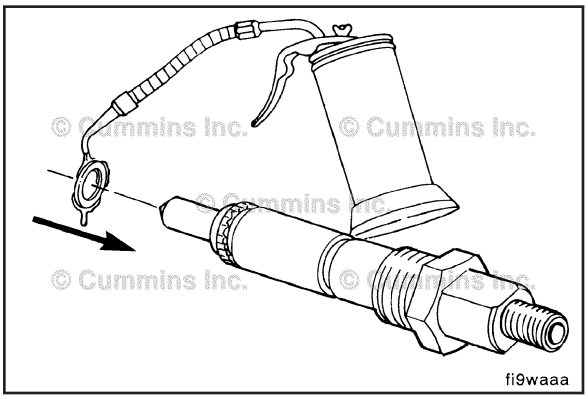
Install

Front Gear Train

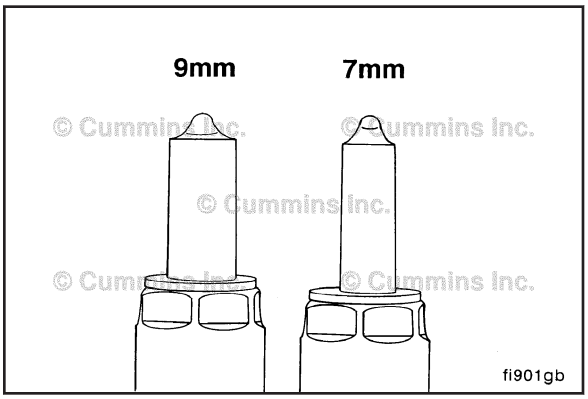
Assemble the injector and a new copper sealing washer.

Use **only** one copper washer.

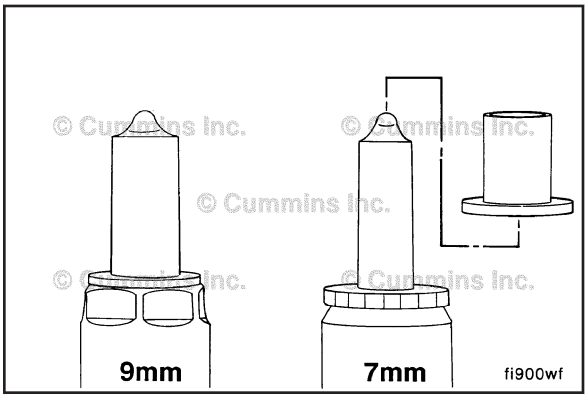
Service Tip: A light coat of clean lubricating engine oil between the washer and injector can help to keep the washer from falling during installation.



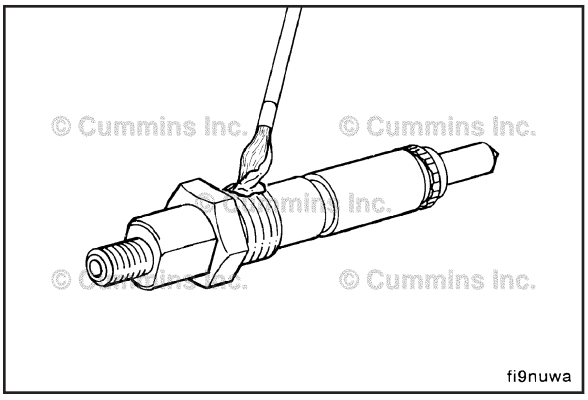
⚠CAUTION⚠
Early model injectors (pre-1991) have a 9-mm injector tip that can not be used in engines built in 1991 or later as these engines use a 7-mm injector tip.

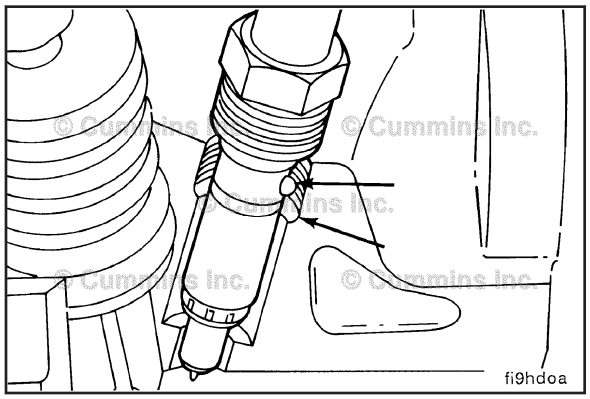


If the special adapter sleeve is installed onto the 7-mm injector tip, 7-mm injectors can be used in early model (9-mm) injector holes.



Apply a coat of anti-seize compound, Part Number 3824879, to the threads of the injector hold-down nut and between the top of the nut and the injector body.

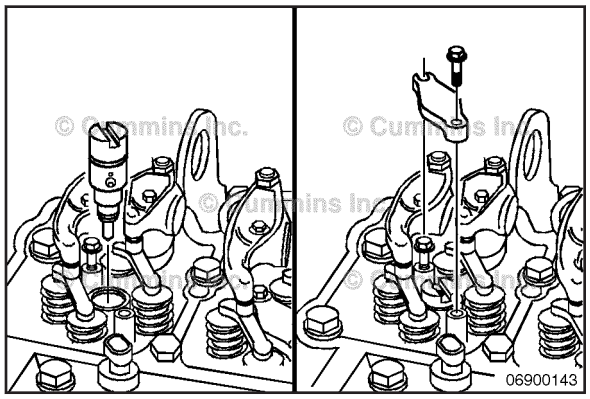




NOTE: Align the injector's protrusion with the notch in the bore.

NOTE: The present Bosch® injector has an o-ring located above the hold-down nut. After tightening the injector, be sure to push the o-ring into the groove.

Torque Value: 60 N•m [44 ft-lb]

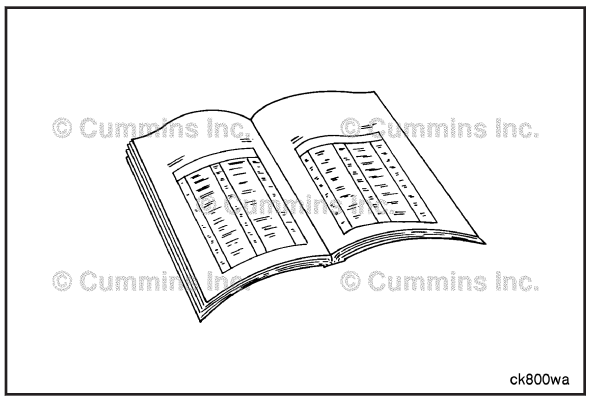


Rear Gear Train

Place the injector in the head in the proper orientation.

Install the injector hold-down and tighten.

Torque Value: 10 N•m [89 in-lb]



Finishing Steps

Front Gear Train

⚠WARNING⚠

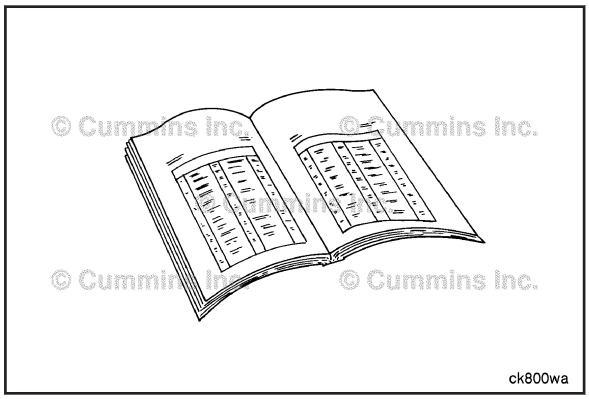
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Install the high-pressure fuel supply lines. Refer to Procedure 006-051 in Section 6.
- Install the fuel drain manifold. Refer to Procedure 006-021 in Section 6.
- Connect the batteries.
- Bleed all air from the fuel system. Refer to Procedure 006-051 in Section 6.
- Operate the engine and check for leaks.

Rear Gear Train

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

- Install the fuel connector. Refer to Procedure 006-052 in Section 6.
- Install the rocker lever cover. Refer to Procedure 003-011 in Section 3.
- Install the high-pressure fuel lines. Refer to Procedure 006-051 in Section 6.
- Connect the batteries.
- Bleed all the air from the fuel system. Refer to Procedure 006-051 in Section 6.
- Operate the engine and check for leaks.



Fuel-Water Separator (006-043)

Drain

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

Cummins Inc. requires a fuel-water separator or fuel filter be installed in the fuel supply system.

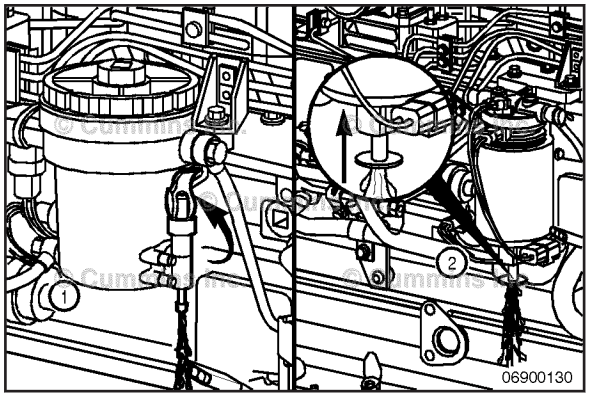
Drain the water and sediment from the separator daily.

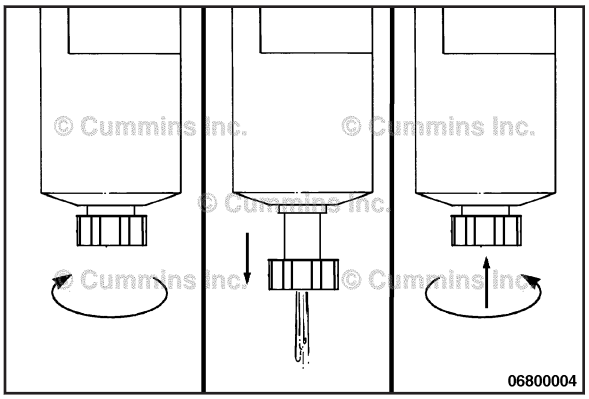
Canister Type

Shut off the engine.

Pull up on the drain valve lever until fluid drains out of the drain tube. Drain the filter sump until clear fuel is visible.

Push up on the drain valve until fluid drains out of the drain tube.





Spin-on Type

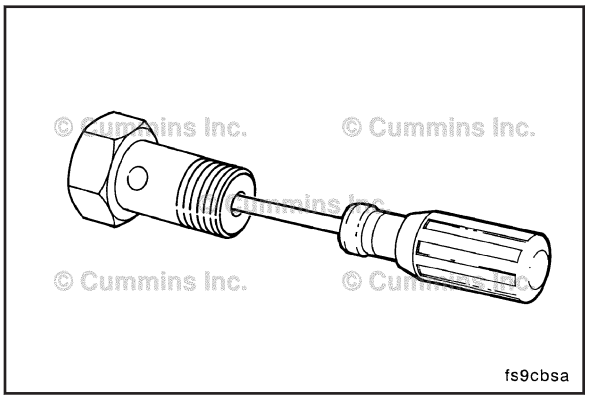
Shut off the engine.

Use your hand to open the drain valve. Turn the valve **counterclockwise** approximately 3½ turns until the valve drops down 25.4mm [1 in] and draining occurs.

Drain the filter sump until clear fuel is visible.

⚠CAUTION⚠
When closing the drain valve, do not overtighten the valve. Overtightening can damage the threads.

To close the valve, lift the valve and turn **clockwise** until it is hand-tight.

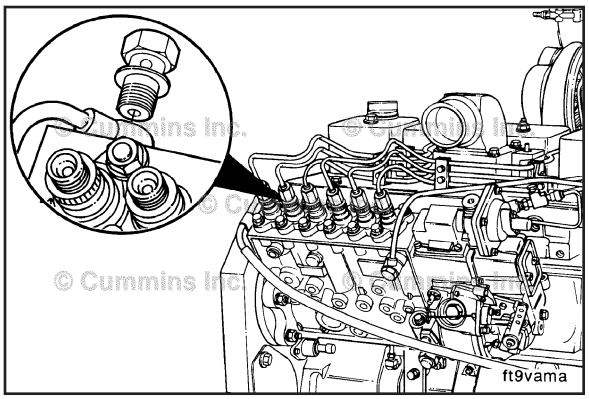


Fuel Return Overflow Valve (006-044)

Initial Check

⚠CAUTION⚠
A sticky check ball or spring will result in engine low power.

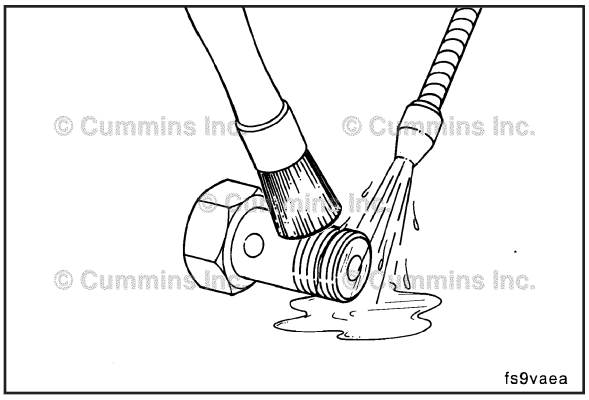
Use a small screwdriver to make sure that the check ball is **not** sticking in the high-pressure relief valve assembly.



Remove

Bosch® In-Line Pump: Remove pressure relief valve and washer.

Remove the pressure relief valve and sealing washer.



Clean

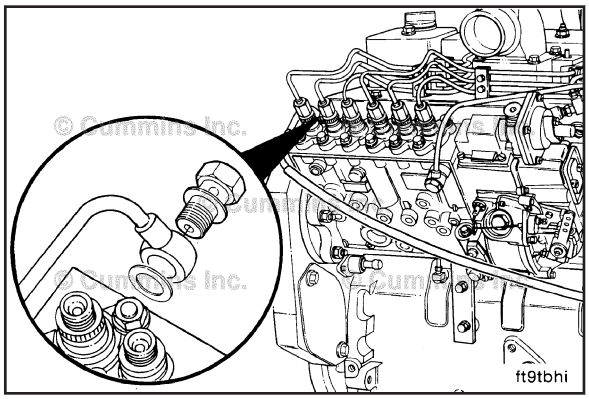
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

Thoroughly flush the high-pressure relief valve with cleaning solution.

Install

⚠CAUTION⚠
Do not use the center cap as a vent. This will cause damage to the overflow valve.

Install the high-pressure relief valve assembly in the reverse order of removal.



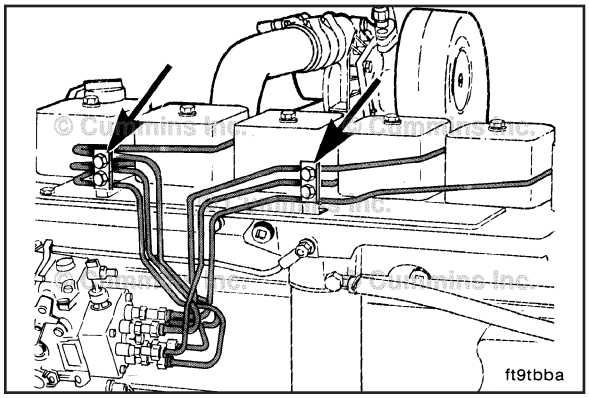
Injector Supply Lines (High Pressure) (006-051)

General Information

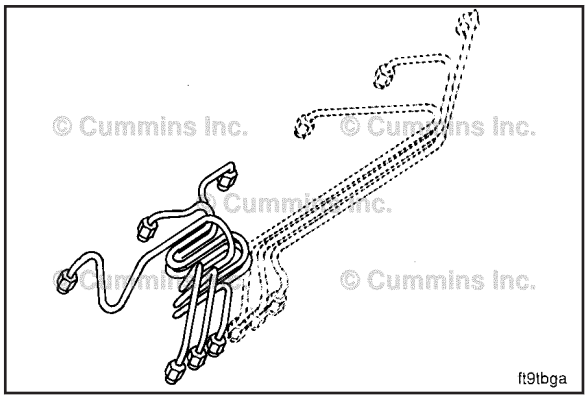
⚠CAUTION⚠
The high-pressure lines must be clamped securely and routed so they do not contact each other or any other components.

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.

Shown here are the high-pressure fuel lines for the distributor-type injection pump.



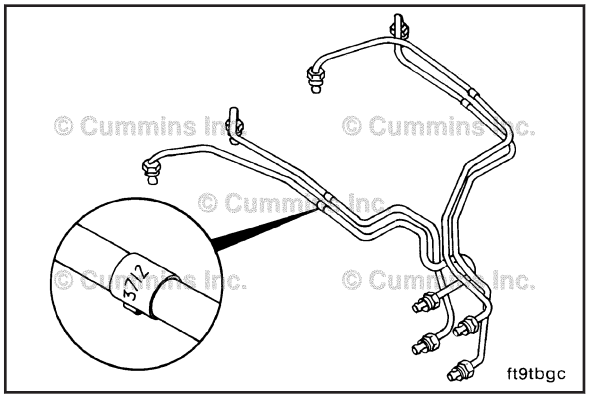
Shown here are the high-pressure fuel lines for the Bosch® in-line injection pump.

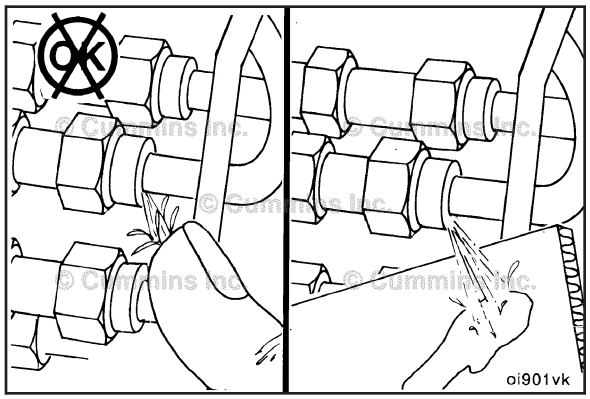


Do **not** weld or substitute lines; use **only** the specified part number for the engine.

The length, internal size, and rigidity of the lines are critical to smooth engine operation. An attached metal tag is used to identify each line with a part number.

A metal tag attached to each line identifies the line with a part number.

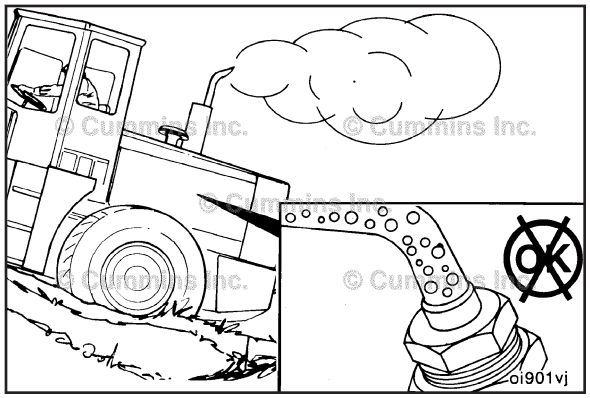




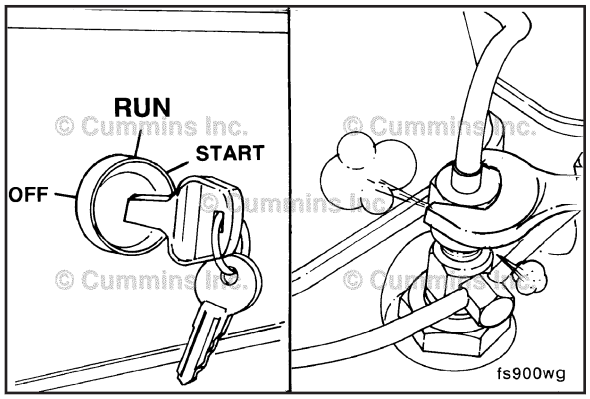
⚠WARNING⚠

Keep hands and body parts away from the high-pressure fuel lines. Fuel coming from the high-pressure fuel lines is under extreme pressure and can cause serious injury by penetrating the skin.

Use cardboard to check for cracks and leaks. 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.



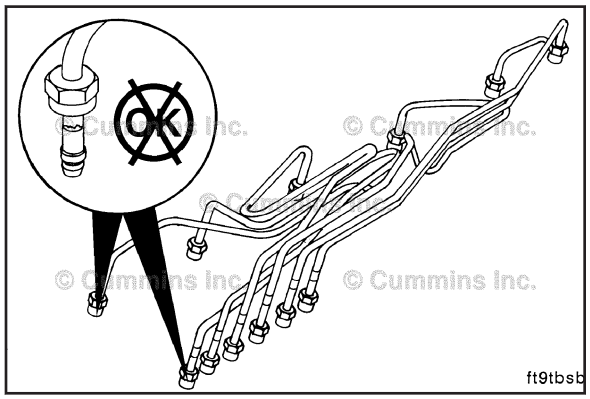
It is normal to have entrapped air in the fuel lines after replacing the pump or the lines. Air in the lines will cause the engine to run rough or produce a fuel knock.



Bleed the air from the high-pressure line at the fitting that connects the injector. Bleed one line at a time until the engine runs smoothly.

Follow the “Prime” step below for the proper procedure.

If the air can **not** be removed, check the pump and supply line for suction leaks. Refer to Procedure 006-003, Air In Fuel.



Initial Check

Inspect the lines for cracks, chafes, and leaks. Make sure that the lines are tightened to proper specification.

Pump Side Fitting:

Torque Value: 24 N•m [18 ft-lb]

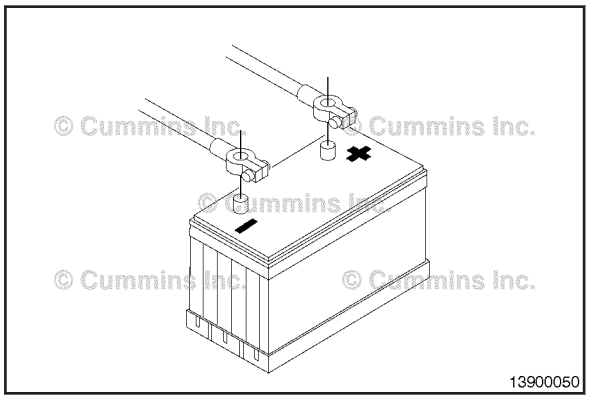
Fitting at Head:

Torque Value: 38 N•m [28 ft-lb]

Preparatory Steps

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

- Disconnect the batteries.



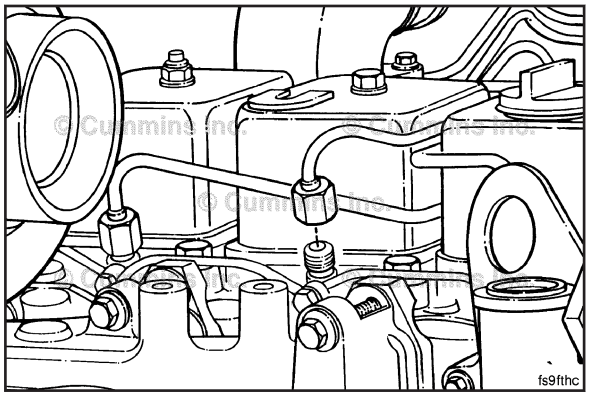
Remove

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

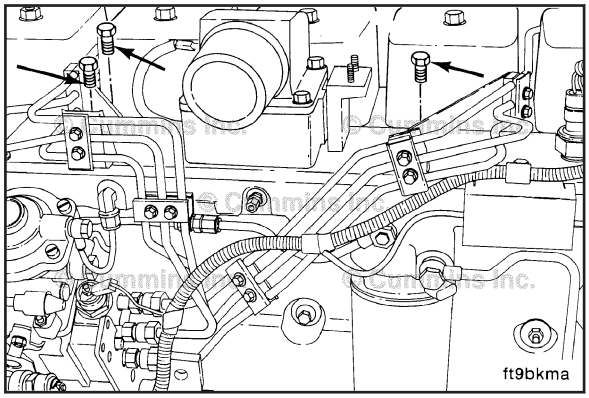
Distributor-Type Pumps

NOTE: Thoroughly clean the area around the fuel lines before removal.

Disconnect the high-pressure fuel lines from the injectors, and complete the following steps:

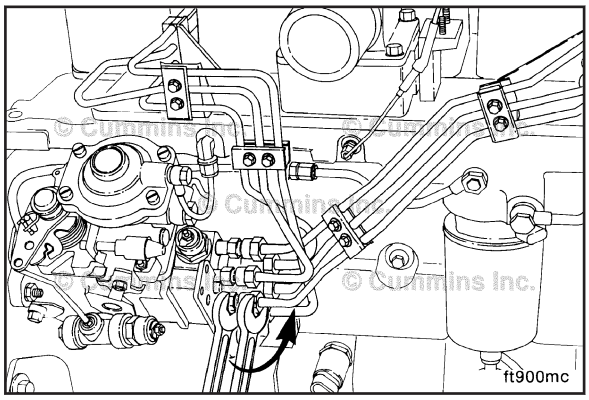


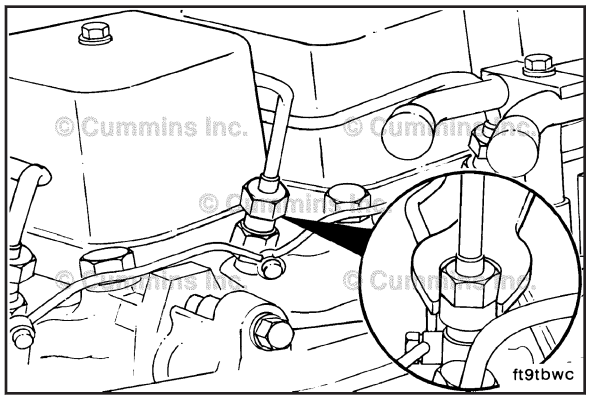
Remove the fuel line clamp capscrews from the intake cover.



Remove the fuel lines from the fuel injection pump.

NOTE: Use two wrenches to prevent the delivery valve holder from turning.

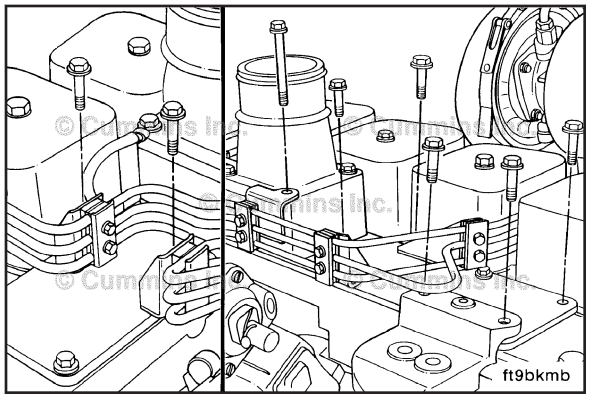




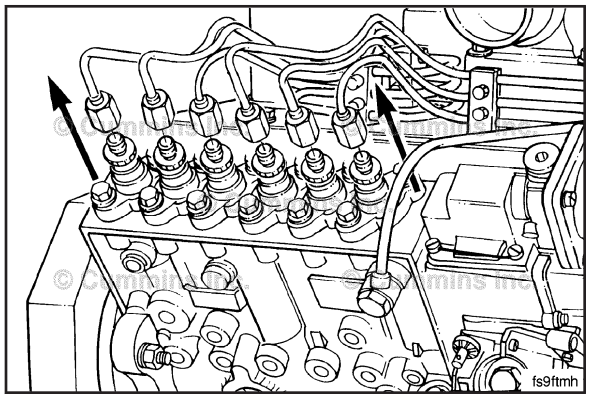
In-Line Pump

NOTE: If individual fuel lines are to be replaced, remove the support clamp from the set of fuel lines containing the line to be replaced.

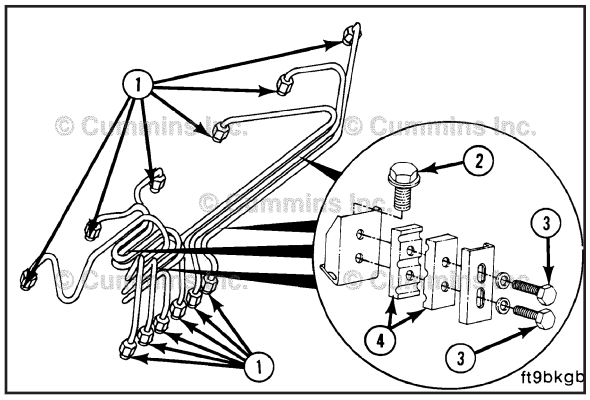
Disconnect the fuel line(s) from the injectors.



Remove the fuel line clamp capscrews from the intake cover.



Disconnect the fuel line(s) from the fuel injection pump.



Remove fuel line fittings (1), support bracket capscrews (2), vibration capscrew isolator (3), and isolators (4).

Clean and Inspect for Reuse

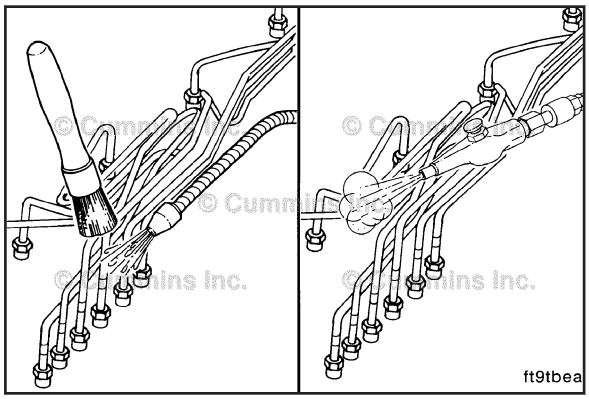
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

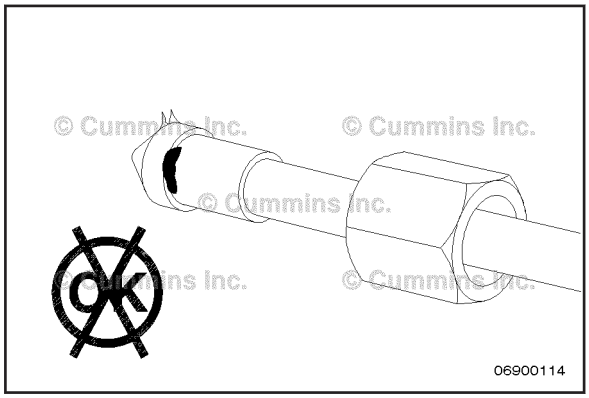
NOTE: Make sure that all paint chips are removed.

Wash the fuel lines in clean solvent.

Dry with compressed air.



Inspect the ferrules of the lines for any signs of burrs or foreign material.



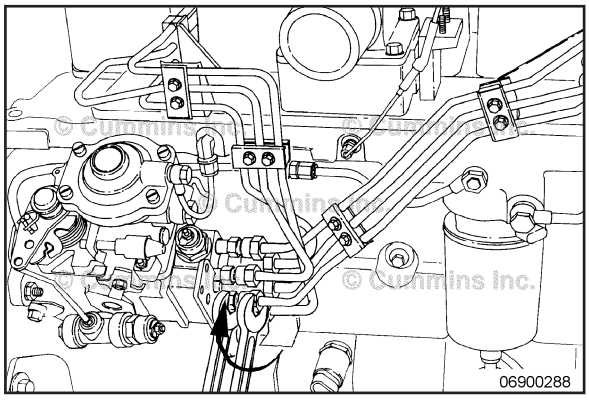
Install

Distributor-Type Pumps

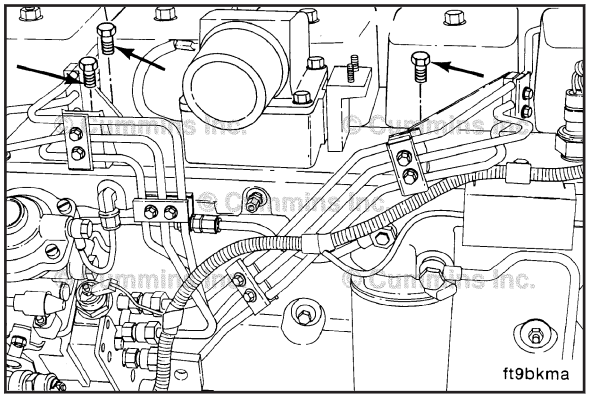
Install the fuel lines to the fuel injection pump.

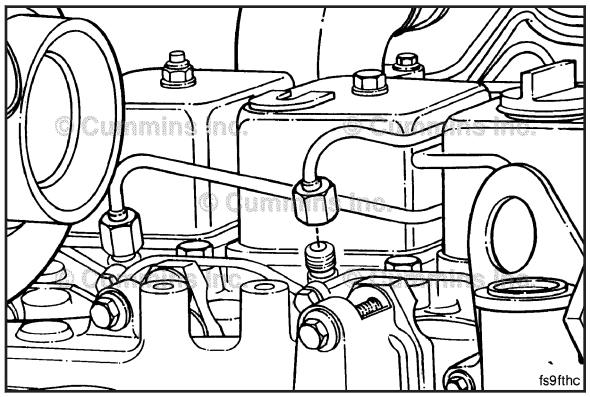
NOTE: Use two wrenches to prevent the delivery valve holder from turning.

Torque Value: 24 N•m [18 ft-lb]



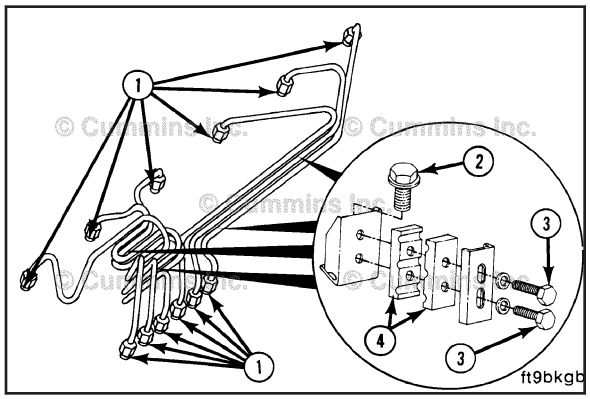
Install the fuel line clamp capscrews to the intake cover.





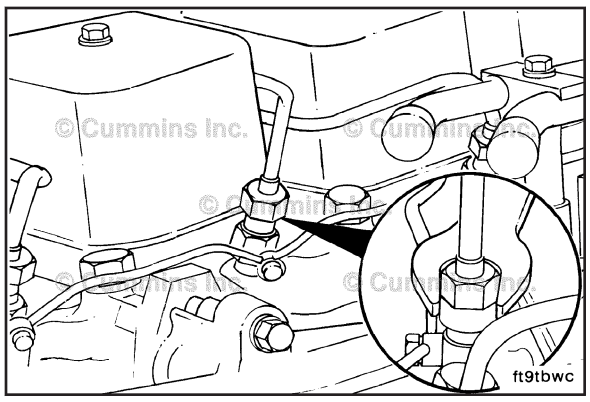
Connect the high-pressure fuel lines to the injectors.

Torque Value: 38 N•m [28 ft-lb]



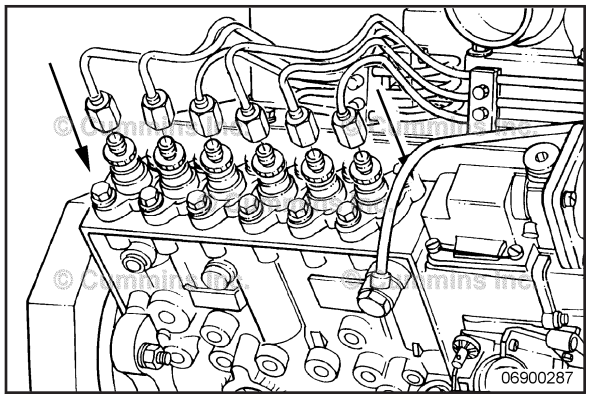
In-Line Pump

Install fuel line fittings (1), support bracket capscrews (2), vibration capscrew isolator (3), and isolators (4).



Connect the high-pressure fuel lines to the injectors.

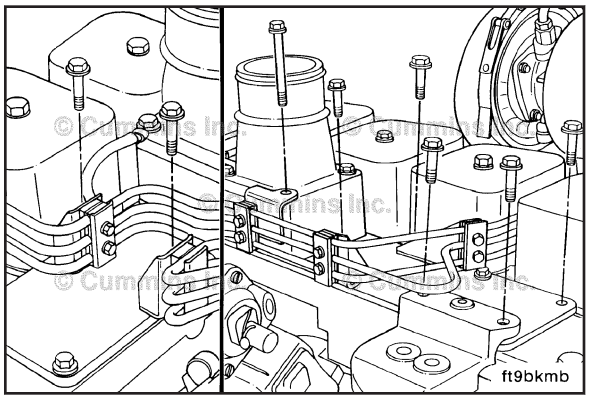
Torque Value: 38 N•m [28 ft-lb]



Connect the fuel line(s) to the fuel injection pump.

Torque Value: 24 N•m [18 ft-lb]

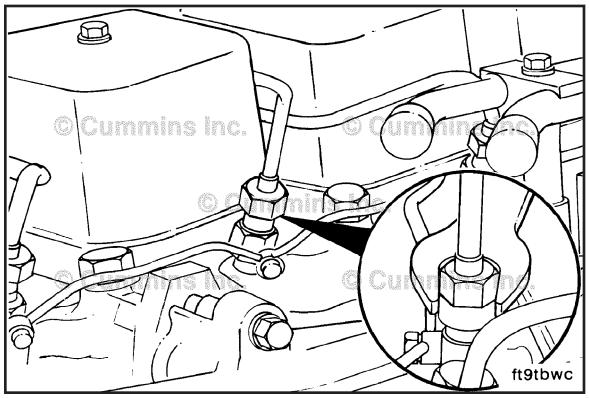
Install the fuel line clamp capscrews to the intake cover.



Connect the fuel line(s) to the injectors.

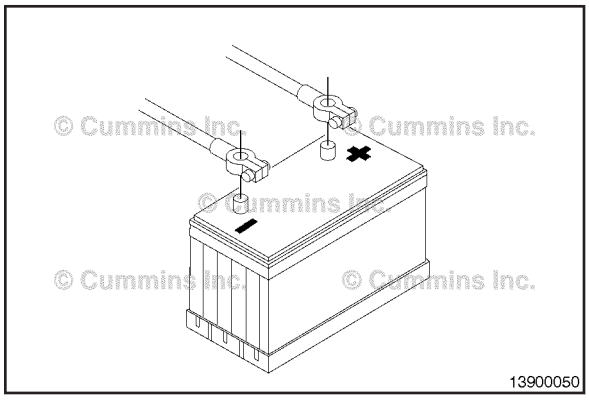
Torque Value: 38 N•m [28 ft-lb]

NOTE: If individual fuel lines have been replaced, install the support clamp to the set of fuel lines containing the line that has been replaced.



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

Connect the batteries.



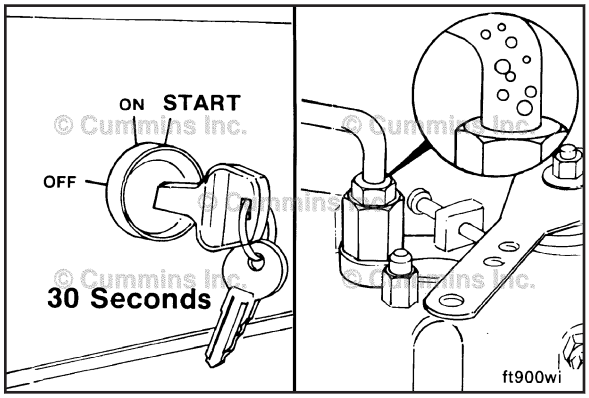
Prime

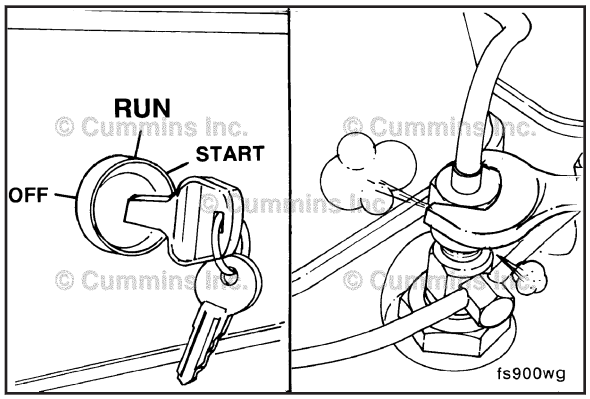
High Pressure Fuel Line(s)

Replacing the fuel supply lines, fuel filters, fuel injection pump, high-pressure fuel lines, and injectors will let air enter into the fuel system. Follow the specified procedure to bleed the air from the system.

Refer to Procedure 006-015 Fuel Filter (Spin-On) for proper venting of the low pressure side of the fuel system.

Refer to the Procedure 005-012, Fuel Injection Pumps, In-Line, or Procedure 005-014, Fuel Injection Pumps, Rotary to determine if venting the fuel pump is necessary.



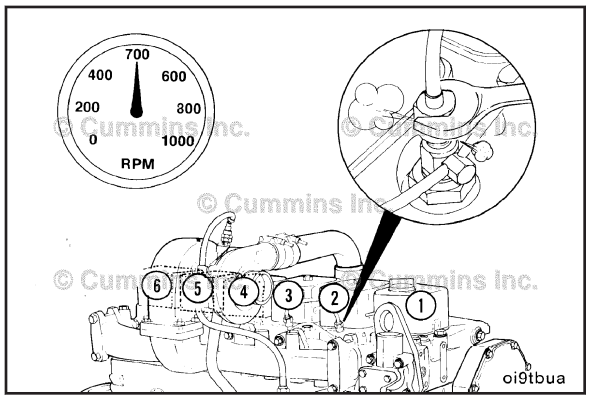


⚠WARNING⚠
The pressure of the fuel in the line is sufficient to penetrate the skin and cause serious personal injury. Wear gloves and protective clothing.

Check for air in the high-pressure lines by loosening the fittings at the cylinder head, and crank the engine to allow entrapped air to bleed from the line.

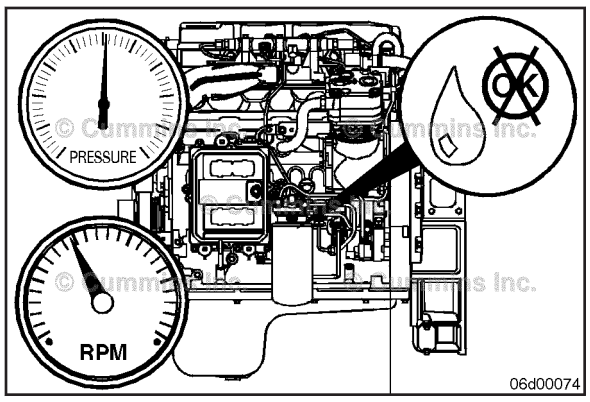
Tighten the fittings.

Torque Value: 38 N•m [28 ft-lb]



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

Operate the engine, and vent one line at a time until the engine runs smoothly.



Finishing Steps

- Operate the engine and check for leaks.

Fuel Connector (Head Mounted) (006-052)

General Information

B4.5 RGT Engines

NOTE: This procedure applies to B4.5 RGT engines only.

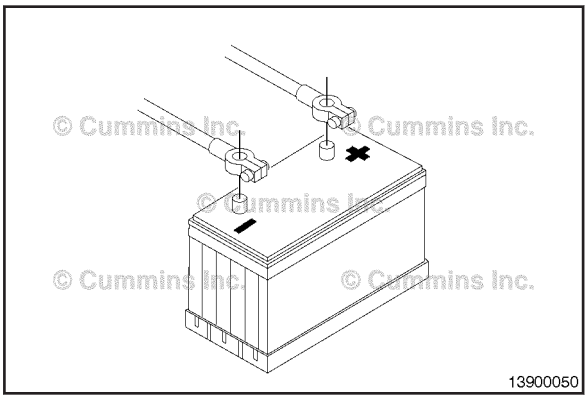
If fuel flow is present at the fuel drain manifold exit in the rear of the head, then a leak exists between the fuel connector and the injector. Under normal conditions only a few drops of fuel should be present.

Preparatory Steps

B4.5 RGT Engines

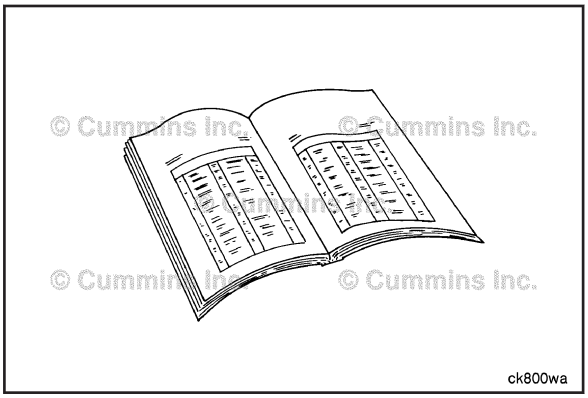
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries.



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

- Remove the injector supply lines from the fuel injection pump to the fuel connectors. Refer to Procedure 006-051.



Remove

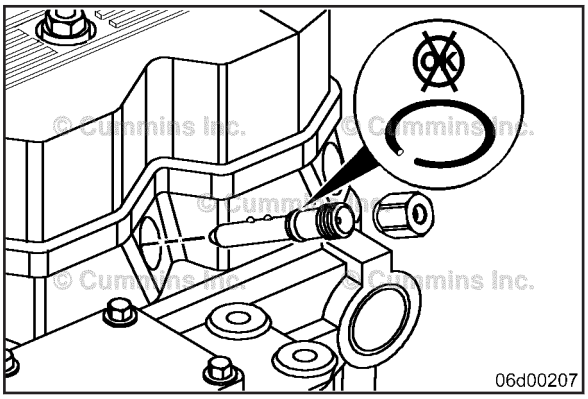
B4.5 RGT Engines

Remove the fuel connector retaining nut.

Install the fuel connector remover, Part Number 3164025.

NOTE: When removing the fuel connector from the cylinder head, care **must** be taken to make sure the connector o-ring is **not** damaged.

Remove the fuel connector from the cylinder head.



Clean and Inspect for Reuse

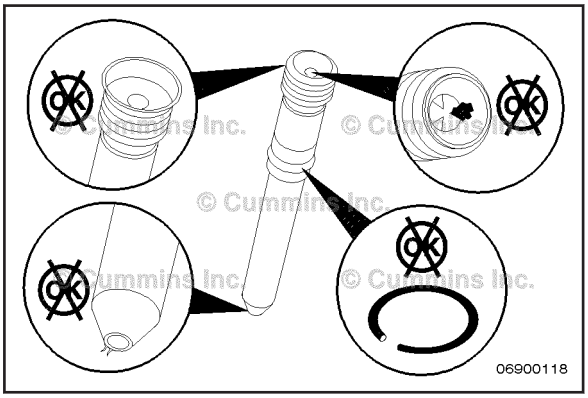
B4.5 RGT Engines

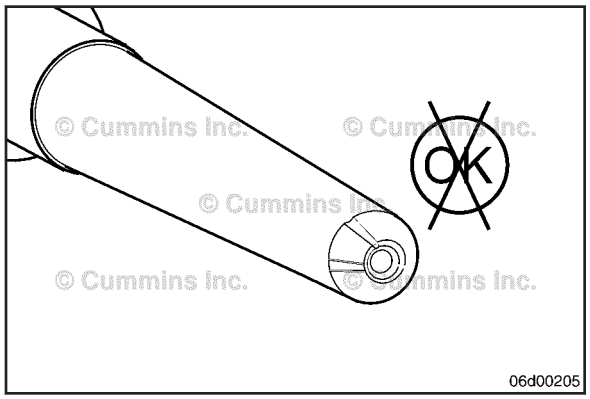
A new high-pressure connector **must** be installed if a new injector is being installed.

Inspect the fuel connector. Look for burrs or deformation around the inlet and outlet sides of the connector.

Check the edge filter for signs of plugging or material contamination. Do **not** reuse a high-pressure fuel connector if debris is present.

Check the o-ring for tearing or deterioration.

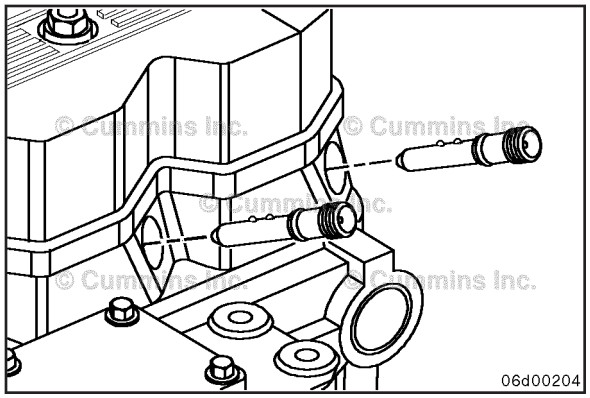




Inspect the outlet sealing surface of the high-pressure connector for wear, an uneven seating surface, or signs of leakage.

When a high-pressure fuel leak is present, small lines or cuts in the connector will be eroded into the seating surface.

The high-pressure connector and injector **must** be replaced when this failure is observed.



Install

B4.5 RGT Engines

A new fuel connector **must** be used when replacing the injector.

Lubricate the fuel connector o-ring and the threads on the fuel connector retaining nut.

Carefully insert the fuel connector, aligning the guide ball with the slot in the cylinder head at the 12-o'clock position.

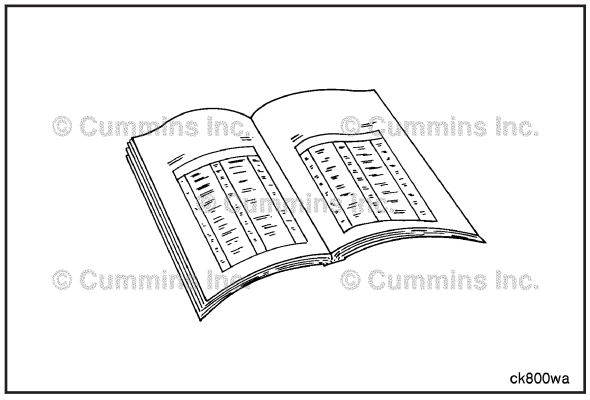
NOTE: Use even axial force when installing to prevent the possibility of damage. Make sure **not** to tear the o-ring as the connector is being installed.

NOTE: If the injector was removed along with the high-pressure connector, the installation steps outlined in Procedure 006-026 **must** be followed.

Tighten the fuel connector retaining nut.

Torque Value:

Fuel Connector (cylinder head-mounted)	50 N•m	[37 ft-lb]



Finishing Steps

B4.5 RGT Engines

⚠ WARNING ⚠

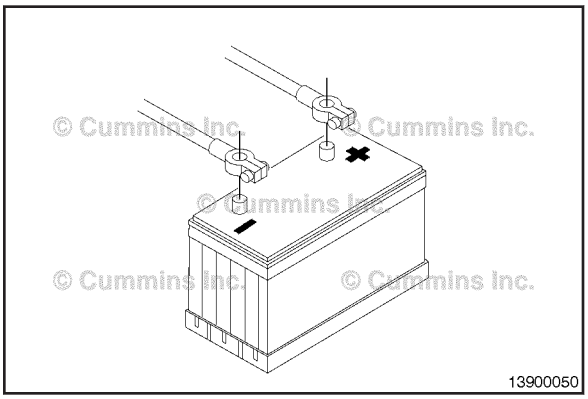
Fuel is flammable. Keep all cigarettes, flames, pilot lights, arcing equipment, and switches out of the work area and areas sharing ventilation to reduce the possibility of severe personal injury or death when working on the fuel system.

- Install the injector supply lines from the fuel injection pump to the fuel connectors. Refer to Procedure 006-051.

⚠WARNING⚠

Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the 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 batteries
- Operate the engine and check for leaks.



Notes

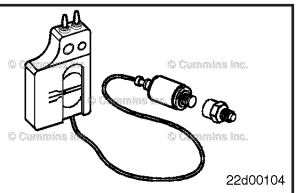
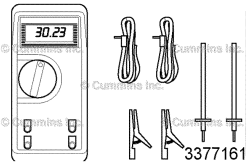
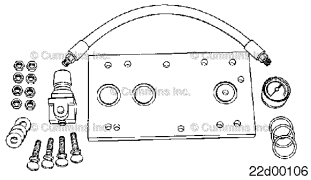
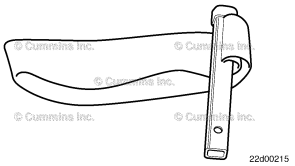
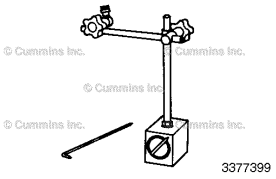
Section 7 - Lubricating Oil System - Group 07

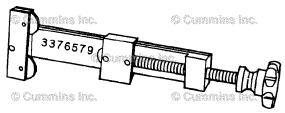
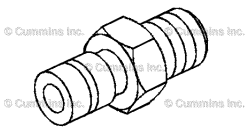
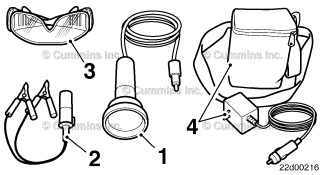
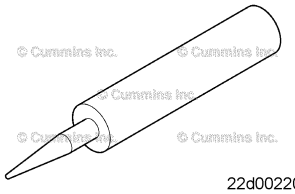
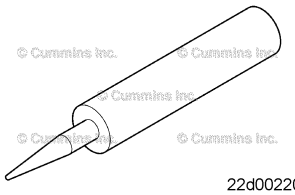
Section Contents

Service Tools

Lubricating Oil System

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

Tool No.	Tool Description	Tool Illustration
3164491	**Pressure/Vacuum Module** Used to measure fuel pressure and restriction. Use with multimeter, Part Number 3164488 or 3164489.	 22d00104
3164488	**Digital Multimeter** Used to measure electrical circuits: Voltage (volts), resistance (ohms), and current (amps).	 3377161
3823876	**Lubrication Oil Cooler Test Kit** Used to test the lubrication oil cooler for leaks.	 22d00106
3823875	**Dipstick Install/Remove** Used to remove and install the lubrication oil dipstick.	 22d00107
3400158	**Oil Filter Wrench** Used to remove oil filter.	 22d00215
3377399	**Magnetic Base** Can be used with Metric Indicator Part Number 3824564 or SAE Indicator Part Number 4918289.	 3377399

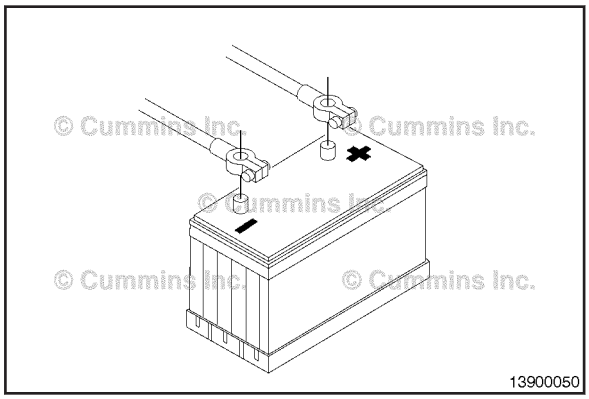
Tool No.	Tool Description	Tool Illustration
3376579	**Tube (Filter) Cutter** Used to cut open the filter to permit inspection of the filter element.	 3376579
3824842	**Compucheck® Fitting** Used to measure fuel inlet restriction.	 22d00083
3163338	**Black Light Lamp (12VDC)** Black light with rechargeable battery and charger used with fluorescent tracer to locate oil and/or coolant leaks. Oil tracer Part Number 3376891, coolant tracer Part Number 3377438.	
3164067	**RTV Sealant** Used in most locations requiring RTV sealant.	 22d00220
3164070	**RTV Sealant** Used to seal rear gear housing to block, front cover to block, oil pan T-Joints and intake manifold to cylinder head joints. For rear gear train engines.	 22d00220

Engine Oil Heater (007-001)

Preparatory Steps

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

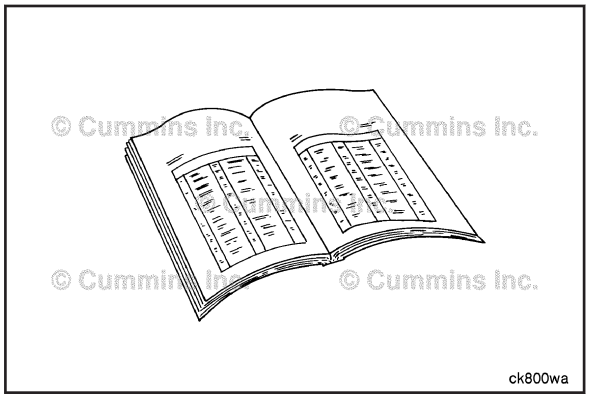
- Disconnect the batteries.



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

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

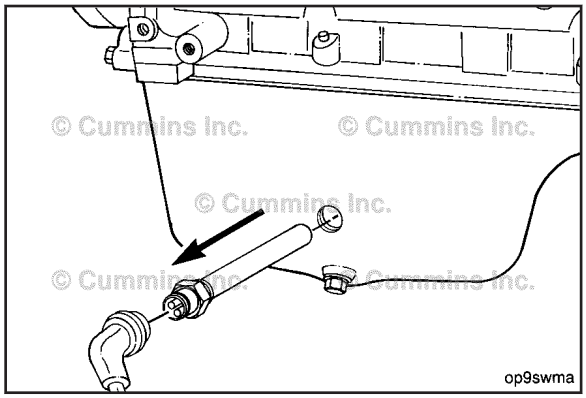
- Drain the lubricating oil. Refer to Procedure 007-037.



Remove

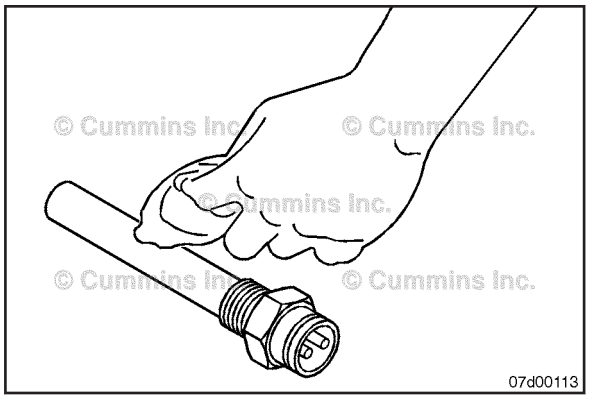
Disconnect the oil heater electrical cord.

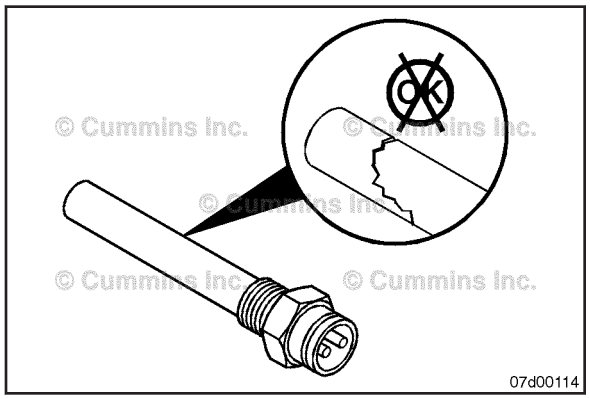
Remove the heater element.



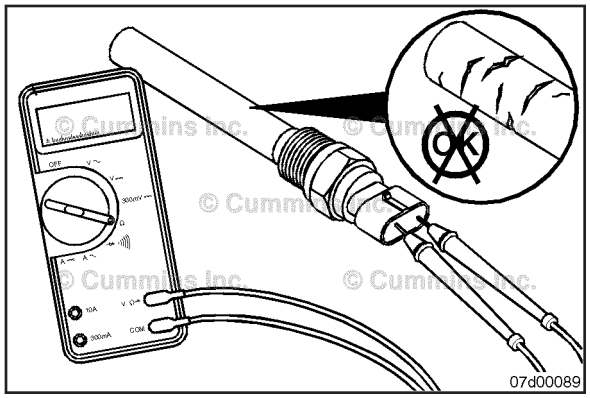
Clean and Inspect for Reuse

Clean the heater element with a dry, clean towel.





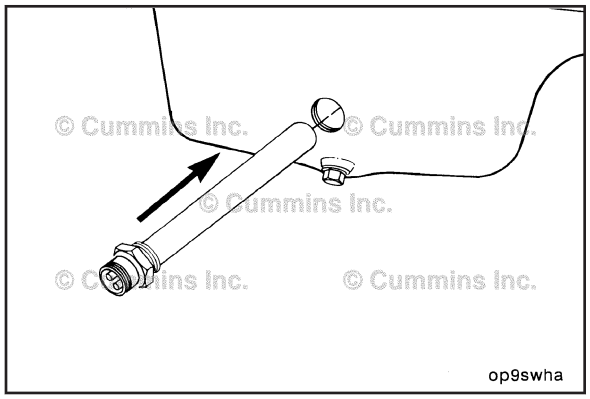
Check for cracks in the heating element.



Test

Perform a resistance test on the engine lubricating oil heater element.

The readings **must** be a minimum of 91 ohms to a maximum 101 ohms.

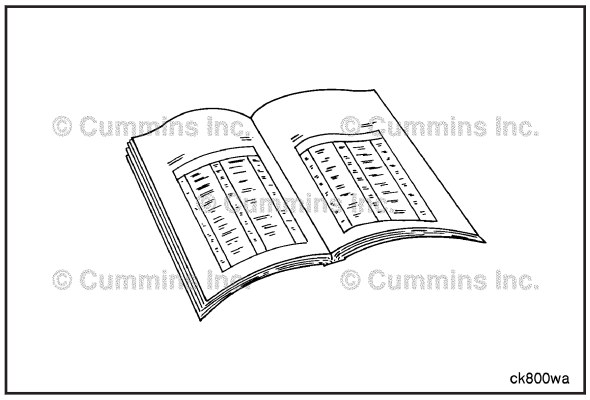


Install

Replace the heater element.

Torque Value: 80 N•m [59 ft-lb]

Connect oil heater electrical cord.

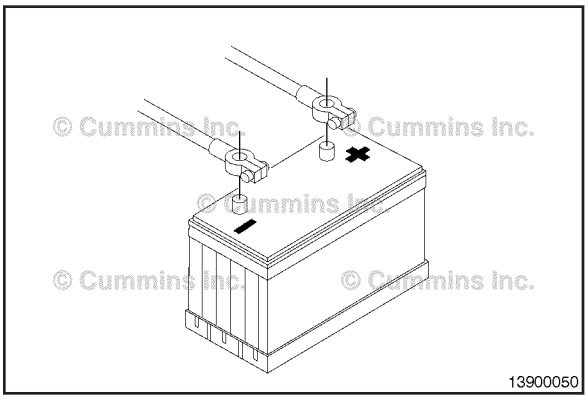


Finishing Steps

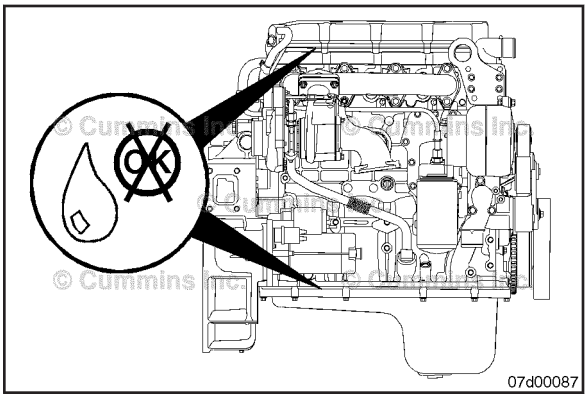
- Refill the engine with clean oil to the correct level. Refer to Procedure 007-037.

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

- Connect the batteries.



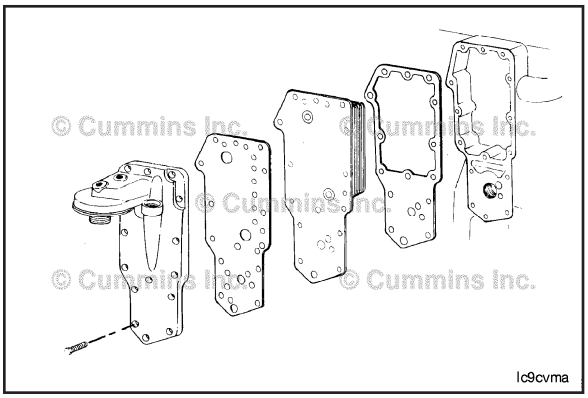
- Operate the engine and check for leaks.



Lubricating Oil Cooler (007-003)

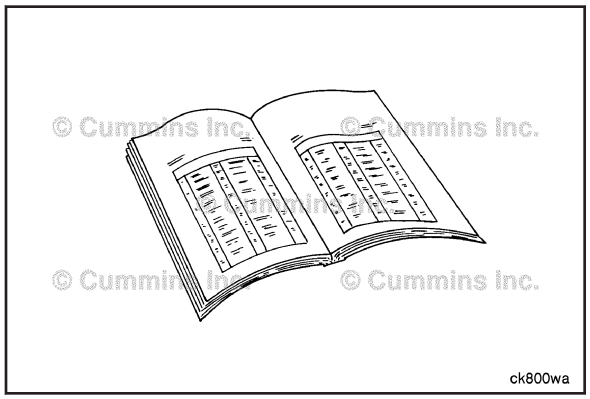
General Information

The lubricating oil cooler is mounted between the lubricating oil cooler cover and the cylinder block. Since neither the lubricating oil cooler or lubricating oil cooler cover can be removed without removing and installing the other, this procedure covers the removal and installation of both components.



Preparatory Steps

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



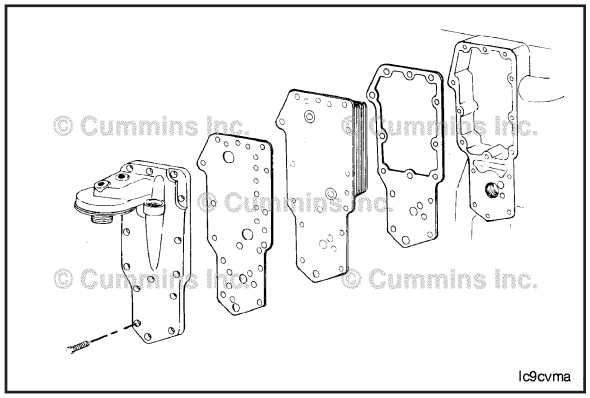
⚠WARNING⚠
Coolant is toxic. Keep away from pets and children. If not reused, dispose of in accordance with local environmental regulations.

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

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

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

- Disconnect the batteries.
- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Clean around the lubricating oil cooler cover
- Remove the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- If equipped, disconnect the turbocharger oil supply line. Refer to Procedure 010-046 in Section 10.



Remove

Remove the lubricating oil cooler housing capscrews, housing, gaskets, and cooler element.

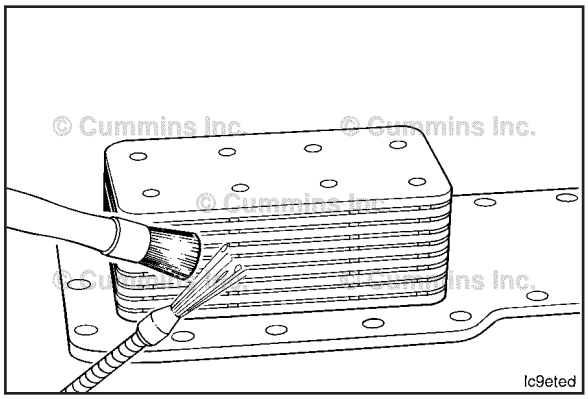
Clean and Inspect for Reuse

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

△CAUTION△
Use a solvent that will not harm copper to clean the oil cooler elements.

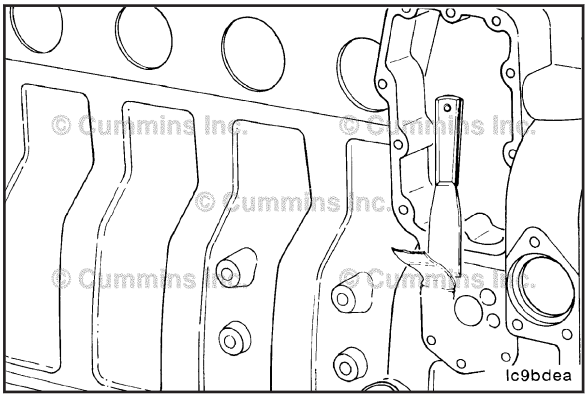
Use solvent to clean the oil cooler housing and cover.

NOTE: Replace the lubricating oil cooler if any debris is found or the engine has had a debris-causing failure.

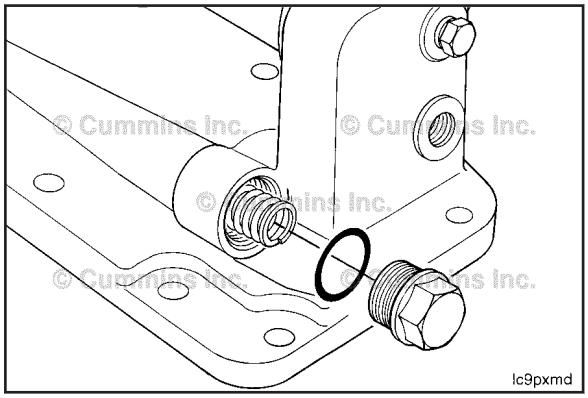


Clean the sealing surfaces.

When cleaning the oil cooler cover, be sure to clean the lubricating oil bypass valve.

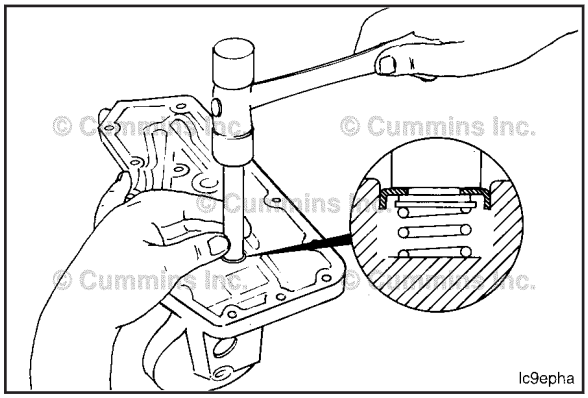


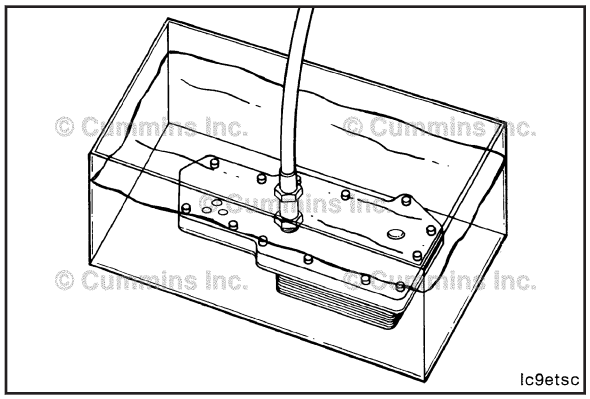
If any debris is suspected to have gone through the engine or troubleshooting a lubricating oil pressure issue, remove and inspect the lubricating oil pressure regulator located in the lubricating oil cooler cover. Replace if necessary. Refer to Procedure 007-029 in Section 7.



If any debris is suspected to have gone through the engine, inspect oil filter bypass valve located in the lubricating cooler cover. Make sure the valve is fully seated and opens and closes freely. Replace if necessary.

NOTE: The bypass valve requires a 345 kPa [50 psi] pressure differential to open.

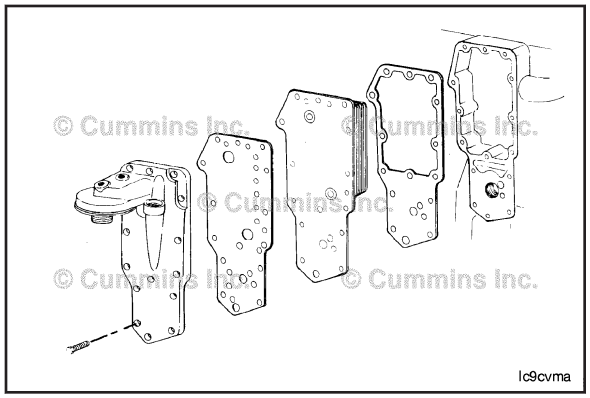




Leak Test

Use the lubricating oil cooler pressure test kit, Part Number 3823876, to pressure-test the element to check for leaks. If leaks are detected, replace the element.

Air Pressure Test		
kPa		psi
449	MIN	65
518	MAX	75



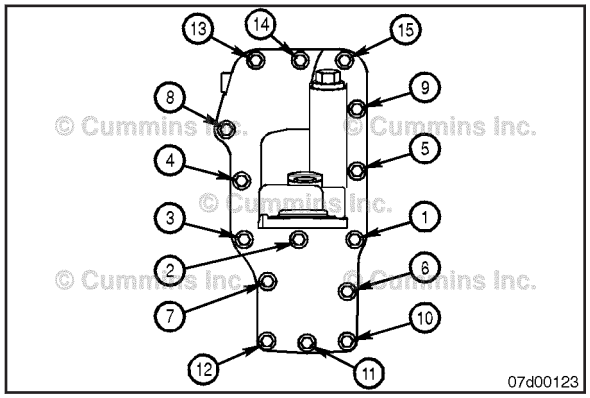
Install

NOTE: Be sure to remove the shipping plugs from the oil cooler element.

NOTE: When installing a new lubricating oil cooler be sure to use the correct part number. Replace with the same part number or use the engine serial number and QuickServe™ OnLine to ensure the use of the correct part.

NOTE: To make sure of the use of compatible gasket combinations, it is essential that the technicial confirms both the oil cooler and filter head gaskets correctly mate with all fluid passages on the cylinder block, oil cooler element (both sides), and the filter head surfaces. This must be done by placing the gaskets on each of these surfaces, in turn, to confirm compatibility prior to final assembly.

Assemble the lubricating oil cooler cover, capscrews, gaskets, and oil cooler.



If the engine uses a lubricating oil cooler cover in which the lubricating oil filter is mounted low, use the torque sequence shown.

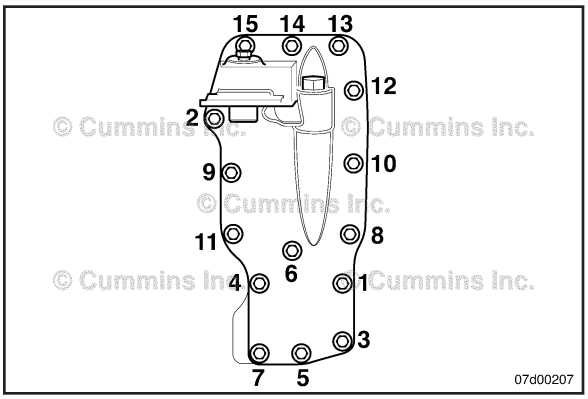
NOTE: Snug capscrew numbers six and eight, then tighten in the sequence shown.

First Stage Torque Value	17 Nm	150 in-lb
Second Stage Torque Value	28 Nm	248 in-lb

If the engine uses a lubricating oil cooler cover in which the lubricating oil filter is mounted high, use the torque sequence shown.

NOTE: Snug capscrew numbers six and eight, then tighten in the sequence shown.

First Stage Torque Value	17 Nm	150 in-lb
Second Stage Torque Value	28 Nm	248 in-lb



Finishing Steps

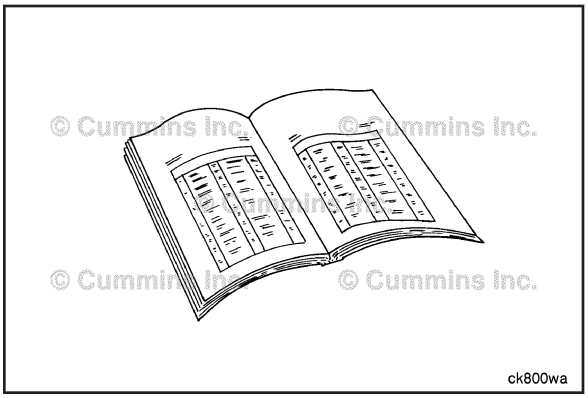
⚠ WARNING ⚠

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

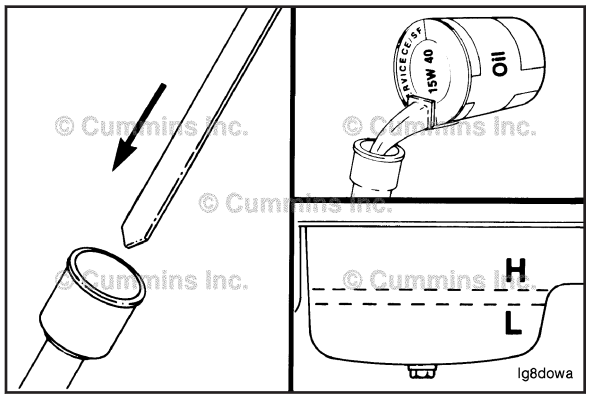
△ CAUTION △

If the engine does not produce oil pressure in 15 seconds after starting the engine, shut off the engine to avoid component damage.

- If equipped, connect the turbocharger lubricating oil supply line. Refer to Procedure 010-046 in Section 10.
- Install the lubricating oil filter. Refer to Procedure 007-013 in Section 7.
- Fill the engine with clean lubricating oil. Refer to Procedure 007-037 in Section 7.
- Fill the cooling system. Refer to Procedure 008-018 in Section 8.



- Connect the batteries
- Operate the engine and check for leaks
- Stop the engine, and check the coolant and lubricating oil level.



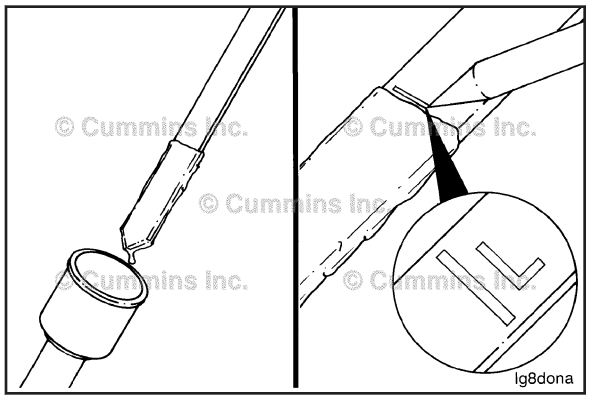
Lubricating Oil Dipstick (007-009)

Calibrate

NOTE: This procedure **must** begin with the oil pan drained. Refer to Procedure 007-037.

Install the dipstick in the dipstick tube housing.

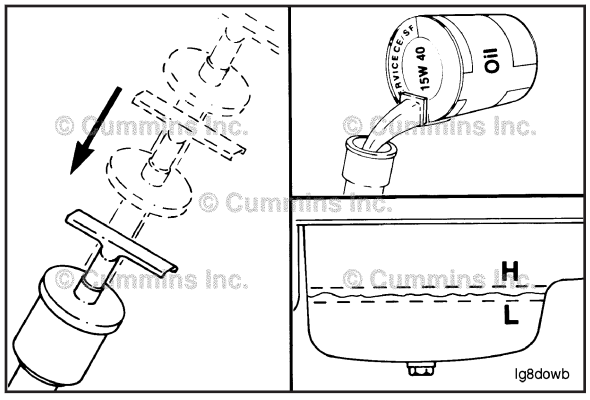
Use clean lubricating engine oil to fill the oil pan to the specified "low" oil level. Refer to Procedure 018-017 (Lubricating Oil System - Specifications) in Section V for the correct engine oil capacity.



CAUTION
Use care when marking the dipstick, or the dipstick will break if the scribe mark is too deep.

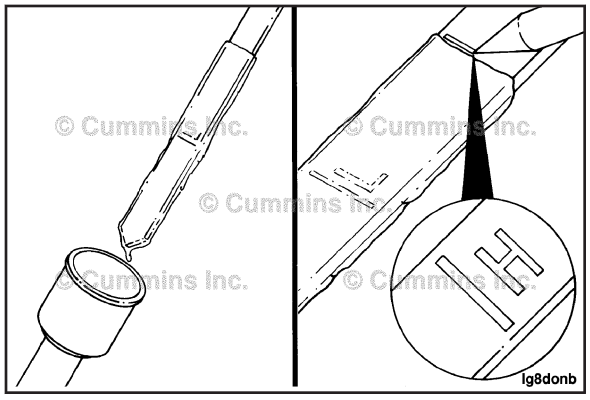
Remove the dipstick and scribe a mark across the stick at the oil level. Label the mark with an "L" to indicate the "low" oil level.

NOTE: If a new blank dipstick is being used, cut the dipstick off approximately 38 mm [1.5 in] below the "low" oil level mark.



Wipe off the dipstick, and install it in the dipstick tube housing.

Fill the oil pan to the specified "high" oil level. Refer to Procedure 018-017 (Lubricating Oil System - Specifications) in Section V for the correct engine oil capacity.



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)

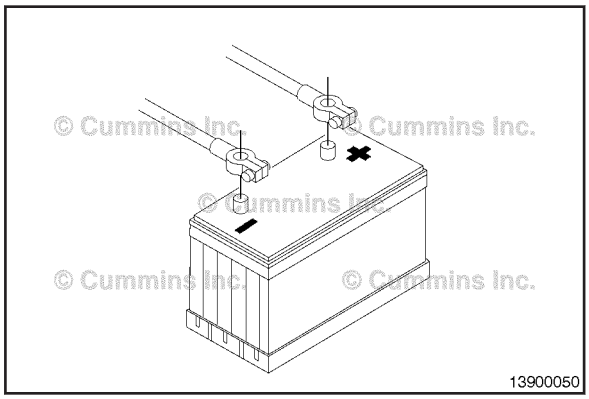
General Information

Due to the number of dipstick tube options, the following procedure has been generalized to cover common dipstick tube procedures. The illustrations may **not** match the engine being serviced.

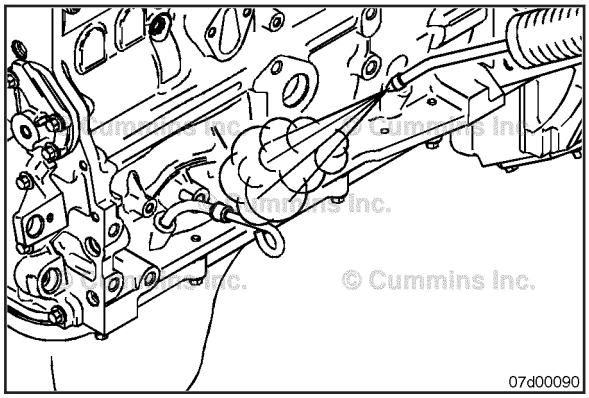
Preparatory Steps

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

- Disconnect the batteries.

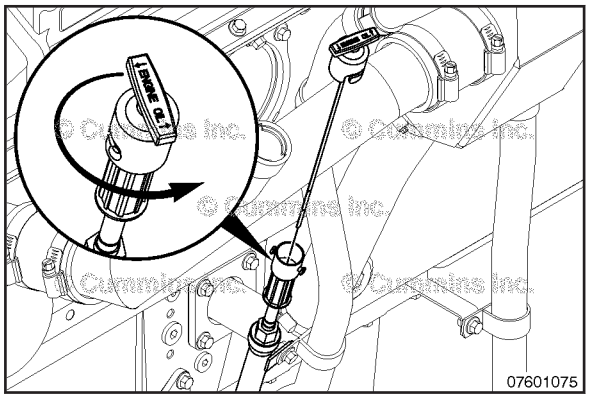


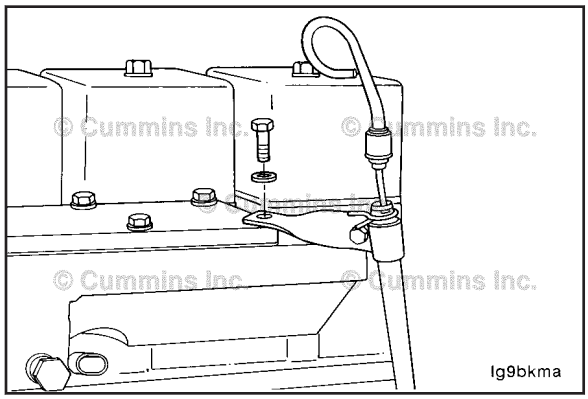
- Clean the area around the dipstick tube before removing to prevent debris from entering the oil system.



Remove

If equipped with a locking dipstick, twist the handle counter-clockwise to unlock. Pull up to remove.

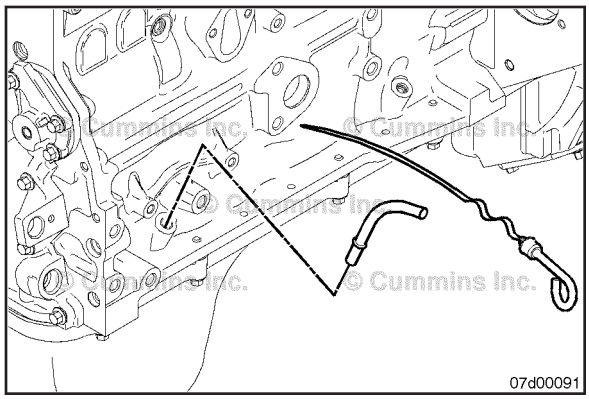




Remove dipstick from the dipstick tube.

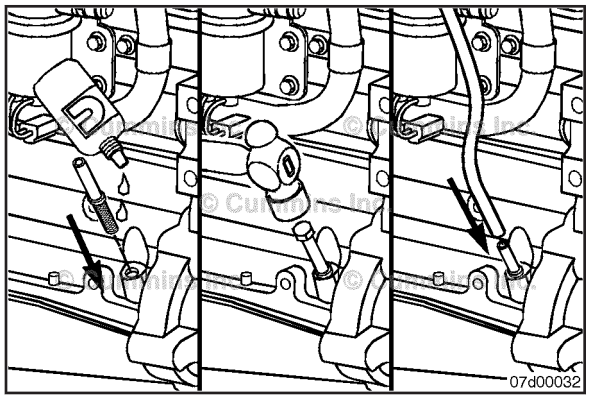
If equipped, remove any dipstick tube supports and clamps.

If equipped, remove the flexible portion of the dipstick tube.



If required, remove the dipstick tube block insert:

1. Use a dent puller and a M8 x 1.25 x 21-mm self-tapping capscrew. Thread the capscrew into the dipstick tube block insert, and remove the tube
2. With the oil pan removed, drive the dipstick tube block insert out with a suitable punch.



Install

Apply a thin bead of thread sealant around the bottom of the knurled end of the tube.

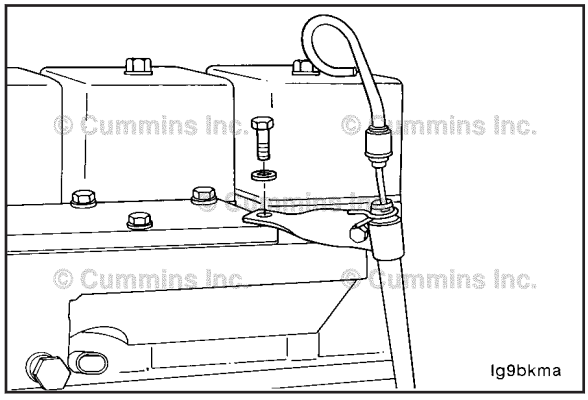
Place knurled end of tube into the dipstick tube bore in the cylinder block.

Use the dipstick tube installer tool, Part Number 3823875, to install the dipstick tube into the cylinder block.

Lightly drive the dipstick tube until it seats against the block casting.

If equipped, install the flexible portion of the dipstick tube and secure with clamps.

NOTE: If a flexible tube is to be used, soak the end of the nylon tube in hot water to help ease the installation.



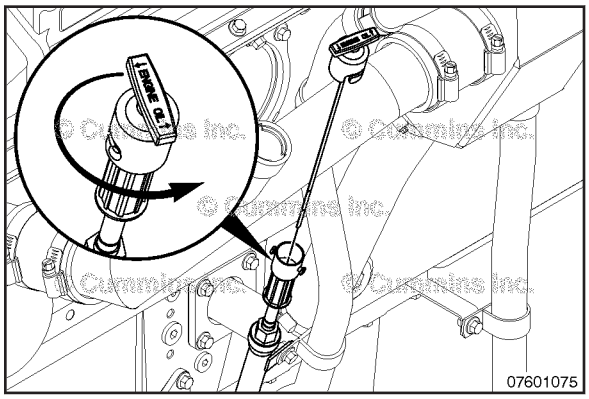
If equipped, install any dipstick tube supports and clamps.

Install dipstick into the dipstick tube.

If equipped with a locking dipstick, insert the dipstick into the dipstick tube and line up the locking pins on the tube with the dipstick handle.

While pushing down on the handle, turn the dipstick handle clockwise.

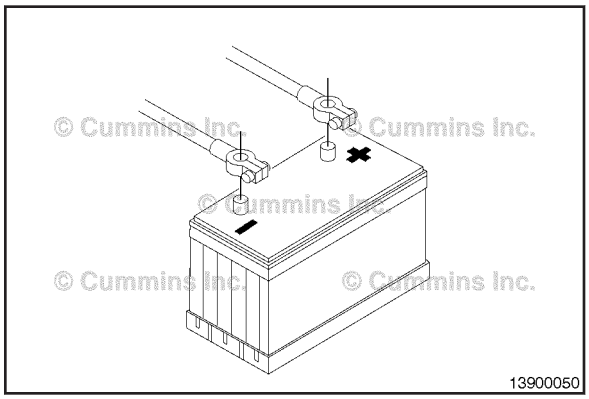
If required, calibrate the dipstick. Refer to Procedure 007-009.



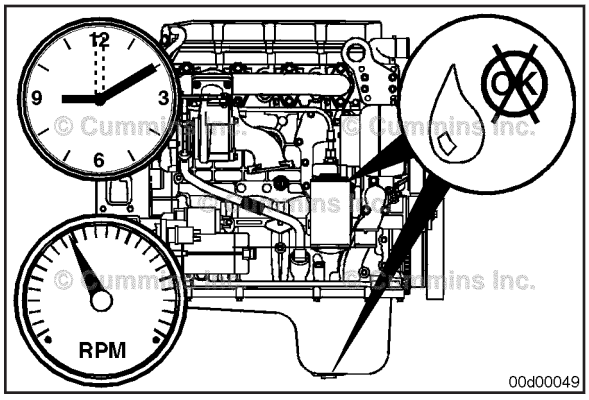
Finishing Steps

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

- Connect the batteries.



- Operate the engine and check for leaks.



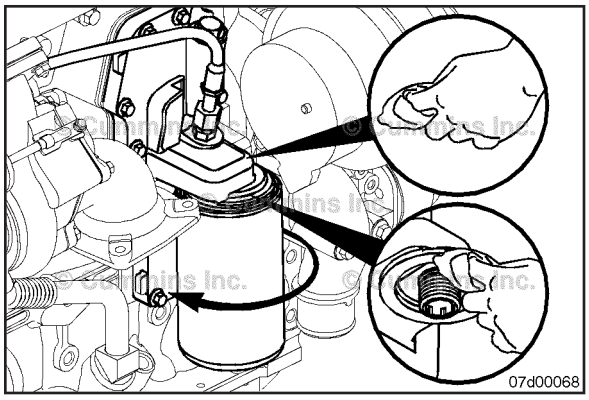
Lubricating Oil Filter (Spin-On) (007-013)

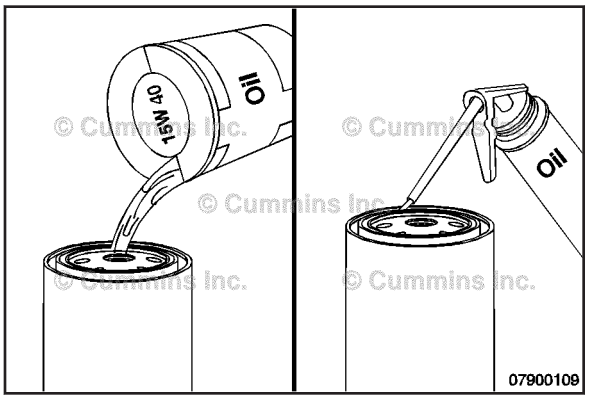
Remove

Clean the area around the lubricating oil filter head.

Use the oil filter wrench, Part Number 3400158, to remove the filter.

Clean the sealing surface of the filter head.





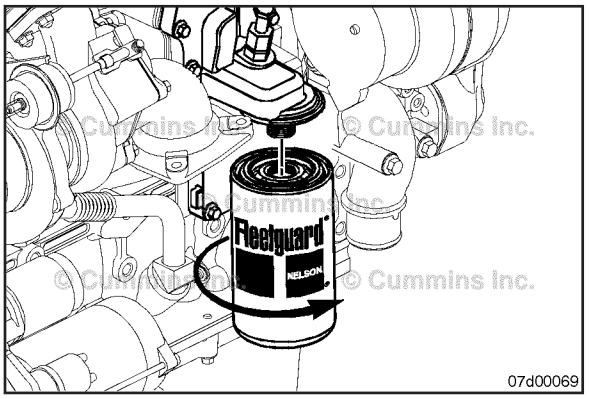
Install

⚠CAUTION⚠
The lack of lubrication during the delay until the filter is pumped full of oil at start-up can damage the engine.

Use clean 15W-40 oil to coat the gasket surface of the filter.

Fill the filter with clean 15W-40 oil.

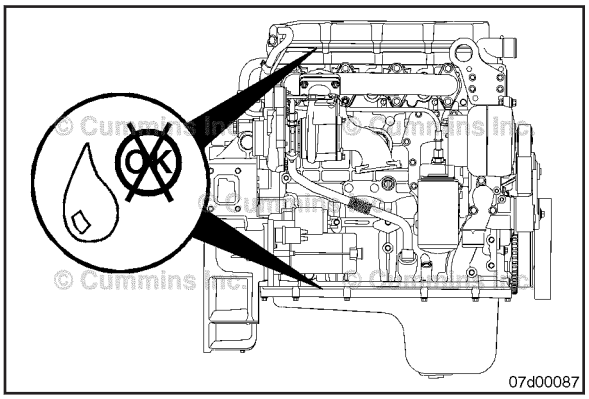
NOTE: Be careful that no debris is poured into the filter. If using an oil supply with a metallic or plastic seal under the cap, be careful to peel the seal back. Puncturing the seal with a knife or sharp object can create debris in the oil container.



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

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

Tighten 3/4 turn to 1 turn after gasket makes contact with the filter head.

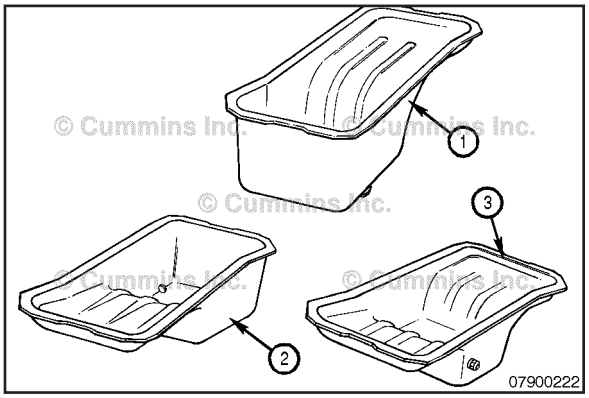


Finishing Steps

⚠CAUTION⚠
If the engine does not produce oil pressure in 15 seconds after starting the engine, shut off the engine to avoid component damage.

Operate the engine and check for leaks.

Shut down the engine and check the oil level. Refer to Procedure 007-037.

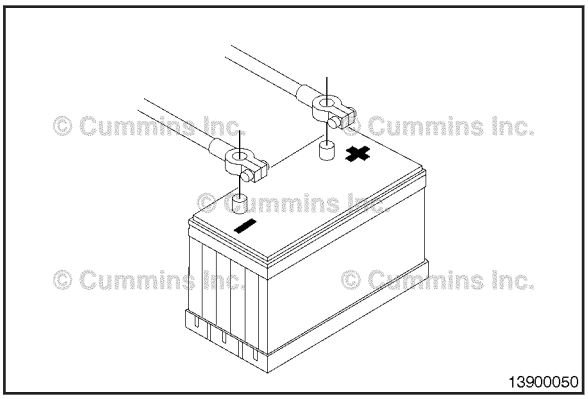


Lubricating Oil Pan (007-025)

General Information

A front sump (1), rear sump (2), or center sump (3) lubricating oil pan can be used, depending on the application. The mounting of the lubricating oil pick-up tube will vary with the lubricating oil pan used.

Preparatory Steps



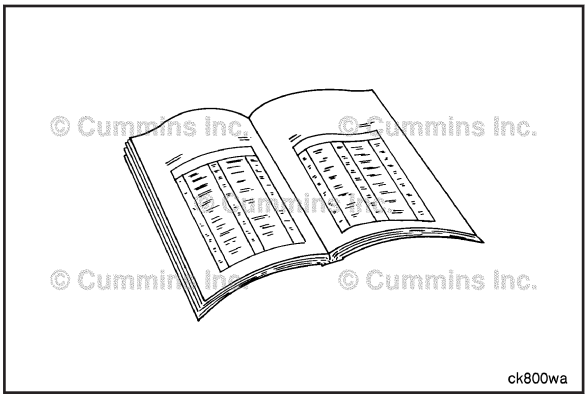
⚠ WARNING ⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to the OEM service manual.

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

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

- Drain the lubricating oil. Refer to Procedure 007-037 in Section 7.

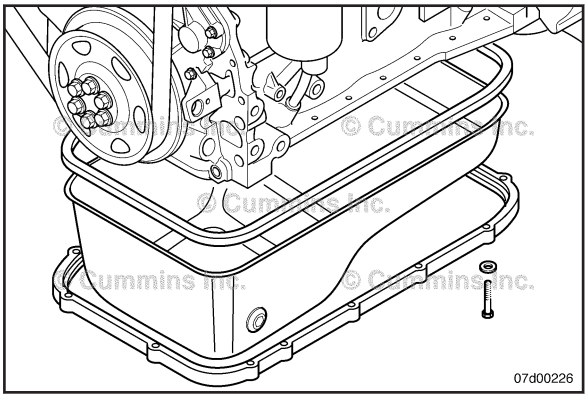


Remove

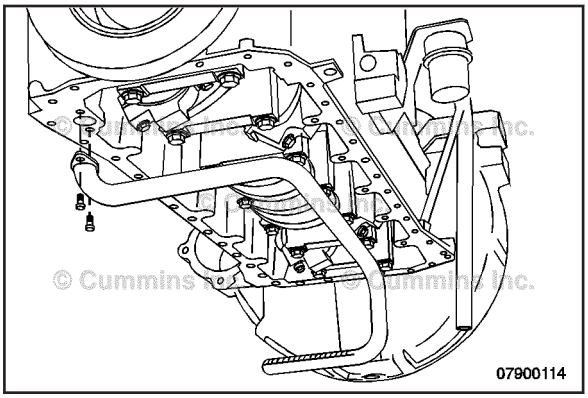
Rear Gear Train

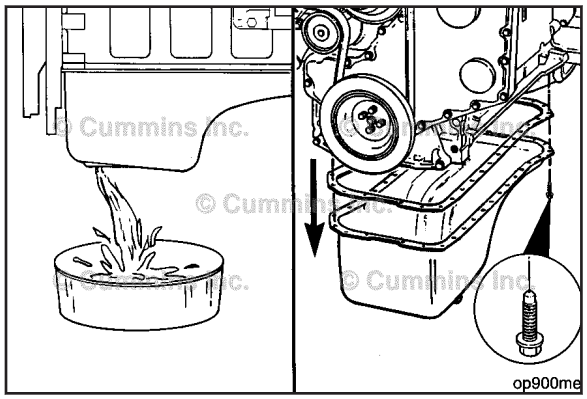
NOTE: Rear gear train engines use a suspended oil pan that consists of the oil pan, mounting flange, and a flexible gasket.

Remove the oil pan mounting capscrews, oil pan, mounting flange, and flexible gasket.



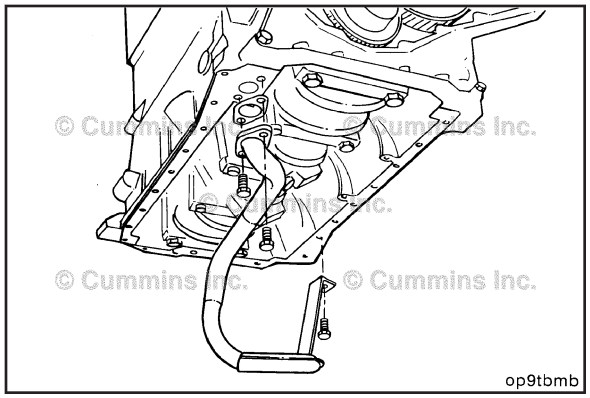
Remove the suction tube, if necessary. Refer to Procedure 007-035 in Section 7.





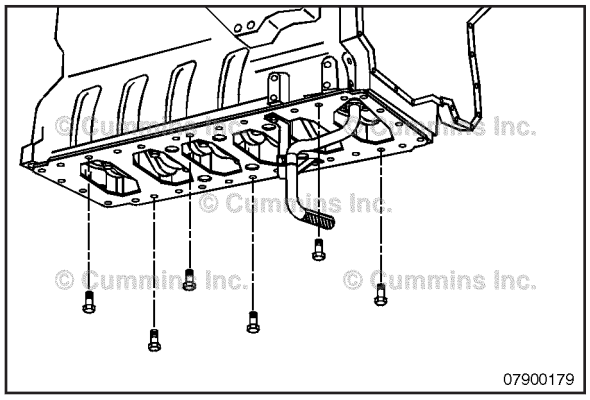
Front Gear Train

Remove the lubricating oil pan and gasket.



Remove the lubricating oil suction tube, if necessary. Refer to Procedure 007-035 in Section 7.

NOTE: For front gear train engines, the suction tube **must** be removed in order to remove the bedplate.

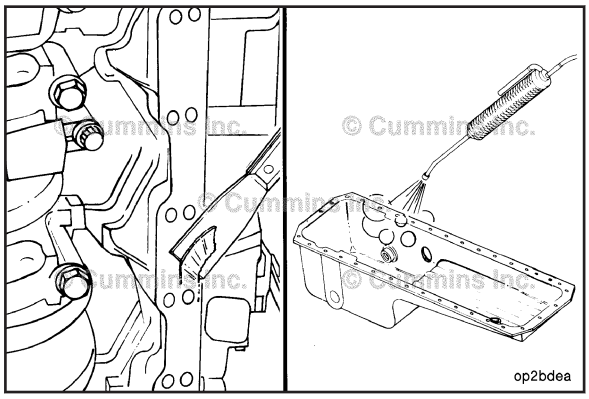


Remove the bedplate (if equipped).

Remove the capscrews securing the bedplate.

A knife may be required to cut the sealant between the bedplate and the 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.

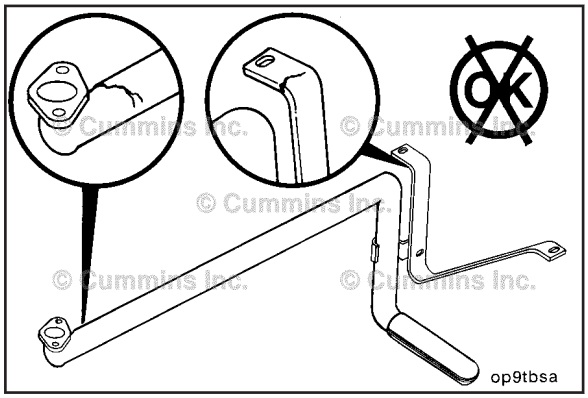
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the gasket surfaces.

Remove all gasket material from the cylinder block and oil pan sealing surface.

Steam clean the oil pan. Dry the oil pan with compressed air.

For front gear train engines, degrease the bedplate (if equipped) on both sides.

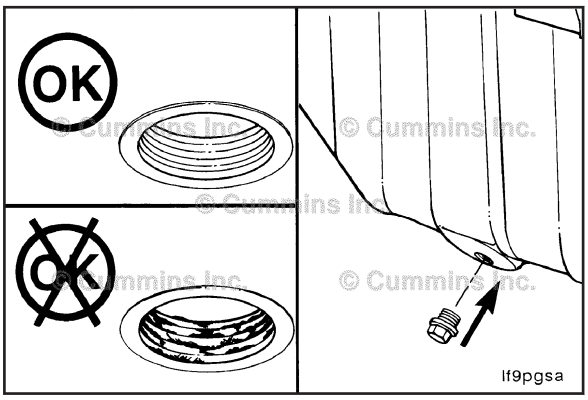


Inspect the oil pan, suction tube, bedplate, and tube braces for damage.

For suspended oil pans, inspect the mounting flange for damage.

NOTE: If cracks are found, replace the damaged part. Do **not** attempt to repair the oil pan by welding.

Replace the suction tube, if necessary. Refer to Procedure 007-035 in Section 7.



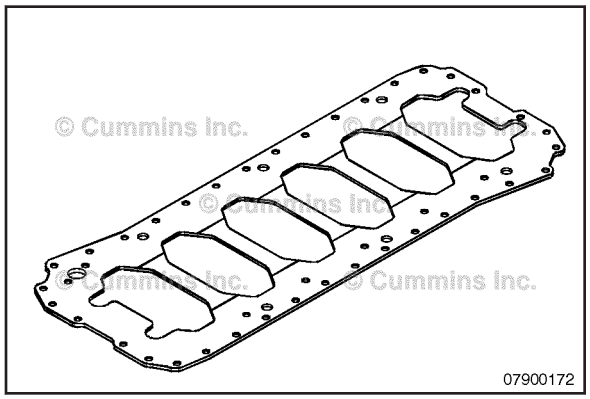
Clean and check the lubricating oil drain plug threads and sealing surface. Use new sealing washer, if damaged.

Install the lubricating oil pan drain plug.

Torque Value:
Steel Oil Pan Plug Torque M18
Step 1 60 N•m [44 ft-lb]

Torque Value:
Steel Oil Pan Plug Torque M22
Step 1 80 N•m [59 ft-lb]

Torque Value:
Cast Aluminum Oil Pan Plug Torque M22
Step 1 60 N•m [44 ft-lb]

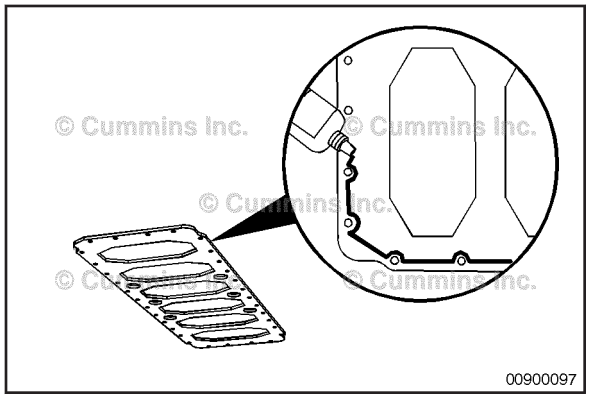


Install

Front Gear Train

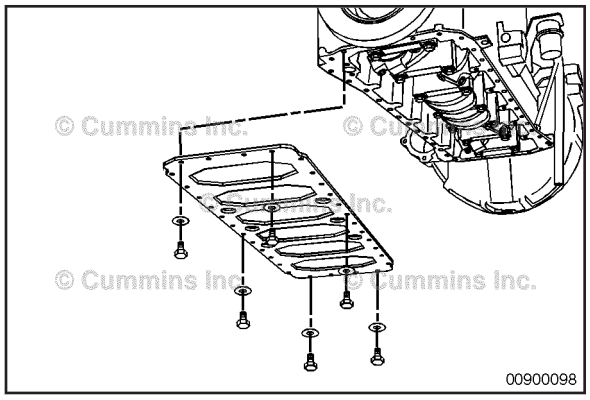
If the engine is equipped with a bedplate, install the bedplate first.

NOTE: The bedplate will **only** install one way. The center ribs are stamped offset to clear the main bearing caps.

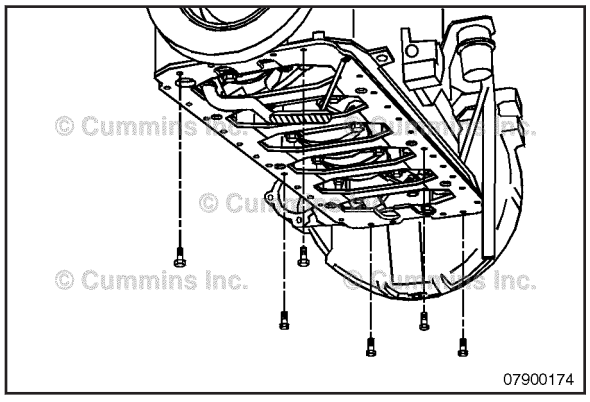


Apply a 1 to 2 mm [0.4 to 0.08 in] bead of RTV, Part Number 3164067, to the block side of the plate.

NOTE: The bedplate **must** be installed within 5 minutes of applying RTV sealant to obtain the proper seal.

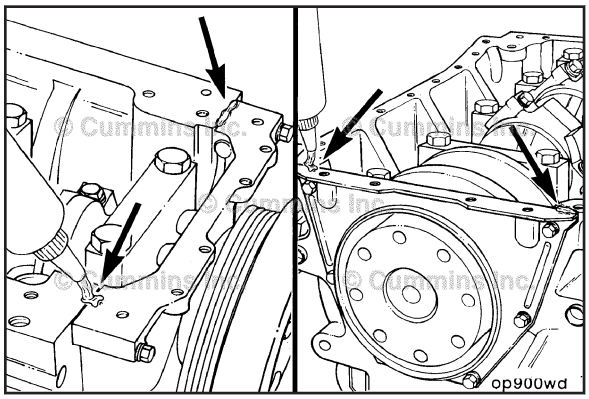


Install the bedplate to the block. Use six oil pan capscrews to hold the bedplate temporarily in place.

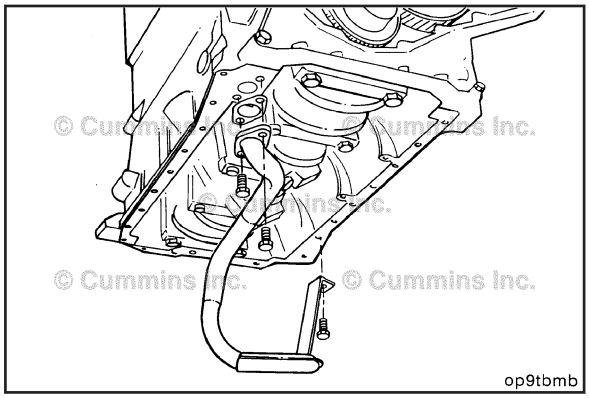


Remove the temporary capscrews.

If the engine does **not** require a bedplate, use RTV sealant, Part Number 3164067, to fill the joints between the lubricating oil pan rail, gear housing, or the rear seal housing.



If the suction tube has been removed in order to remove the bedplate, install the suction tube. Refer to Procedure 007-035 in Section 7.

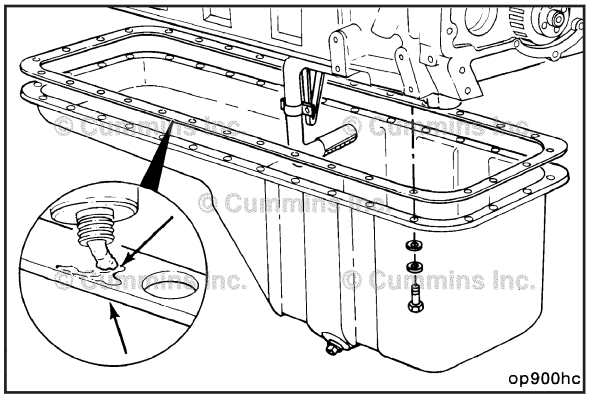


Apply a 2-mm [0.063-in] bead of RTV, Part Number 3164067, to both sides of the new lubricating pan gasket.

NOTE: Install three guide pins, Part Number 3164977, to improve alignment of the oil pan sealing components to the cylinder block.

Install the gasket and lubricating oil pan.

Torque Value: 24 N•m [212 in-lb]

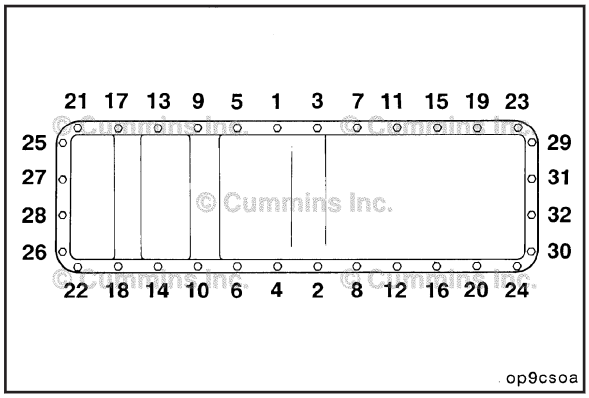


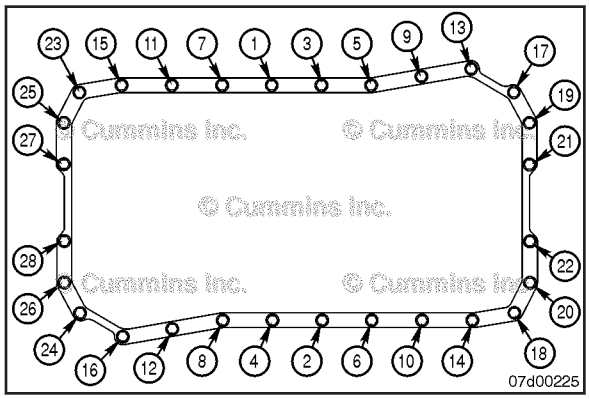
Six-Cylinder

Assemble the washers and capscrews to secure the lubricating oil pan as illustrated.

Tighten all capscrews in the sequence shown in the accompanying chart.

Torque Value: 24 N•m [212 in-lb]



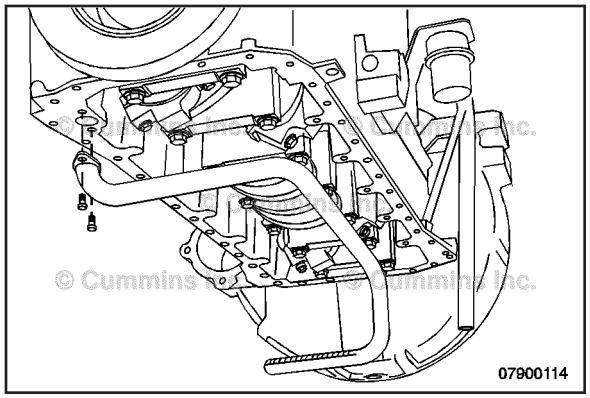


Four-Cylinder

Assemble the washers and capscrews to secure the lubricating oil pan as illustrated.

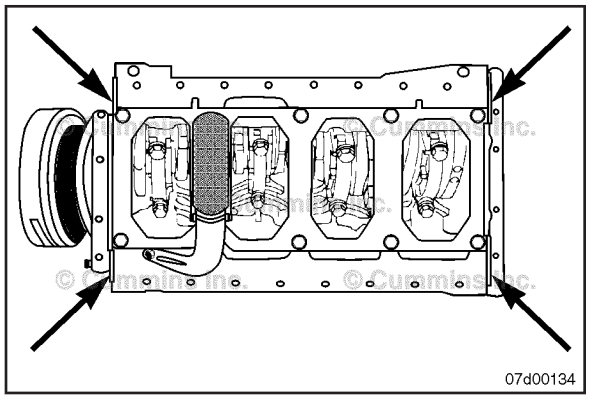
Tighten all capscrews in the sequence shown in the accompanying chart.

Torque Value: 24 N•m [212 in-lb]

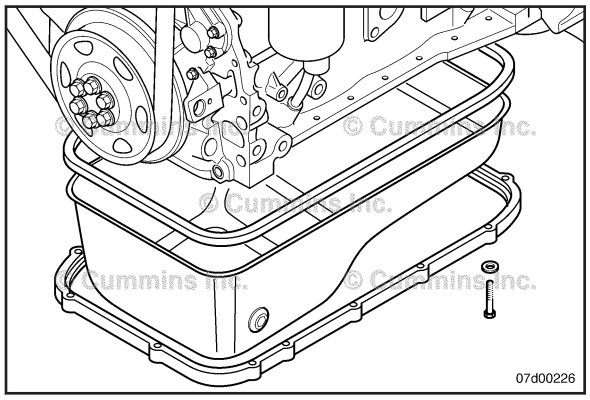


Rear Gear Train

Install the suction tube, if has been removed. Refer to Procedure 007-035 in Section 7.



Prior to installing the oil pan, apply RTV sealant, Part Number 3164070, to the joints between the lubricating oil pan rail-rear gear housing, and the lubricating oil pan rail-front gear cover.



Assemble the new flexible gasket onto the oil pan.

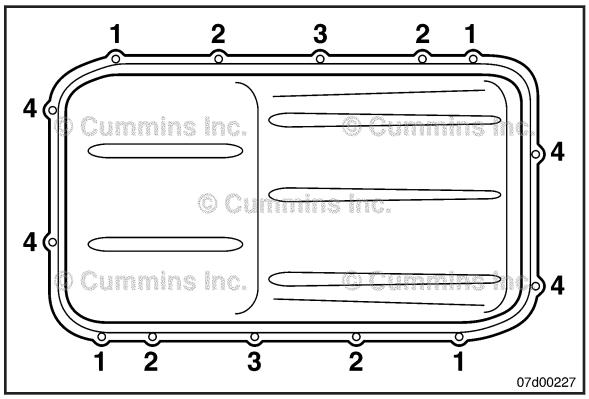
Install the mounting flange over the oil pan/gasket assembly.

Install the oil pan assembly and mounting capscrews.

Tighten all capscrews in the sequence shown.

Torque Value:

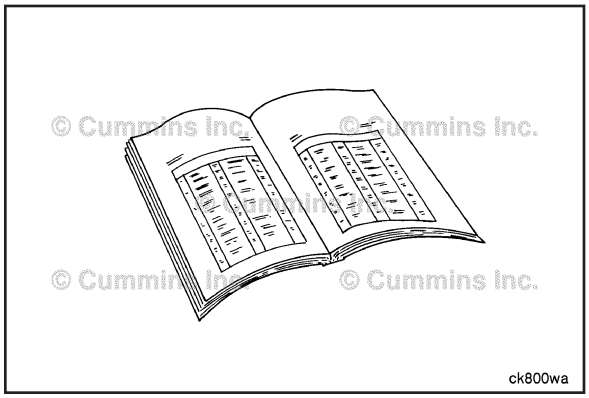
Step 1	24 N•m	[212 in-lb]



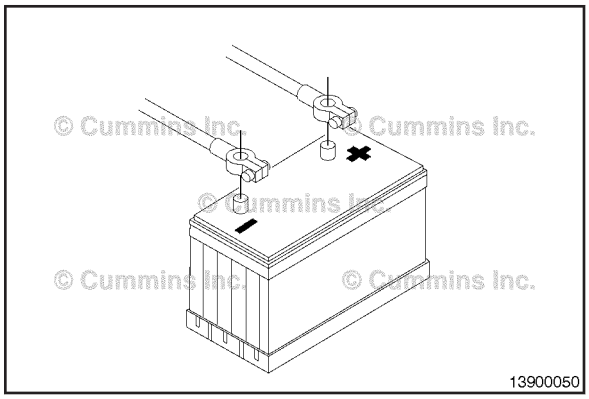
Finishing Steps

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

- Fill the engine with clean lubricating oil. Refer to Procedure 007-037 in Section 7.



- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.

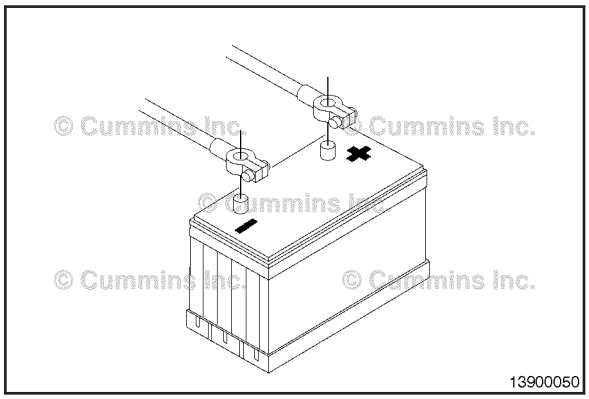


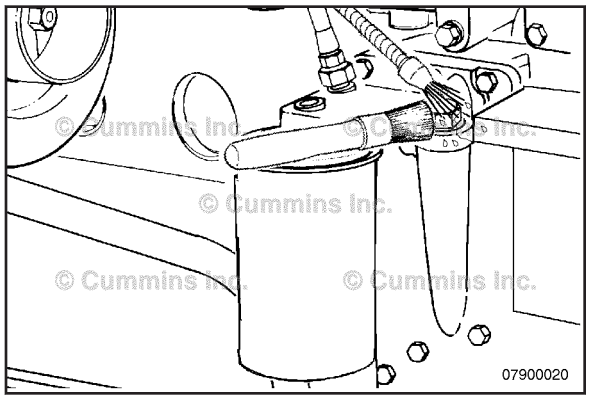
Lubricating Oil Pressure Regulator (Main Rifle) (007-029)

Preparatory Steps

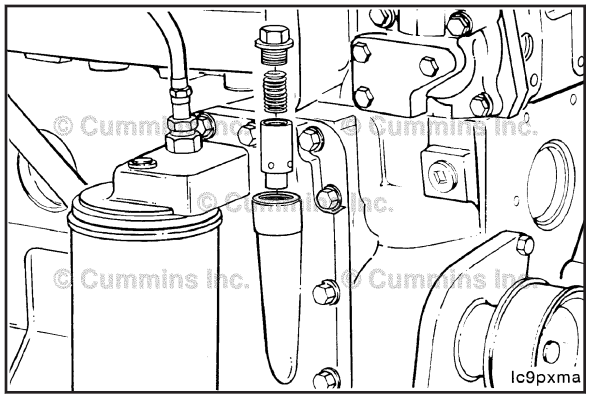
⚠ WARNING ⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries.





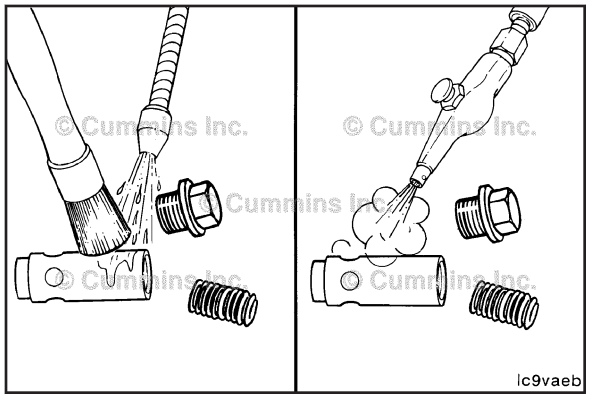
Thoroughly clean the area around the pressure regulator plug to prevent debris from falling into the plunger bore when the plug is removed.



Remove

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 up. If the plunger can **not** be removed in this manner, the plunger is probably stuck and will require removal of the housing for plunger removal and cleaning.



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. 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.

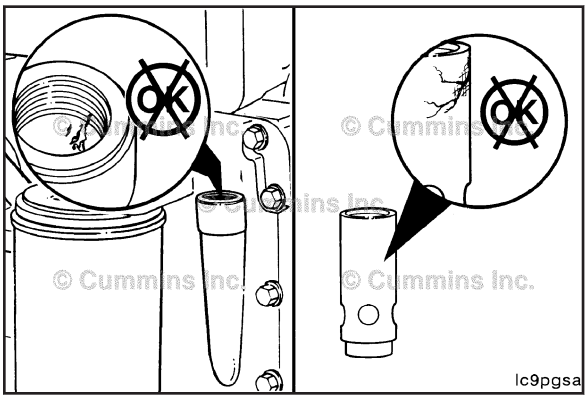
△CAUTION△
Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Failure to do so can cause engine component damage.

Thoroughly clean all components with clean solvent.

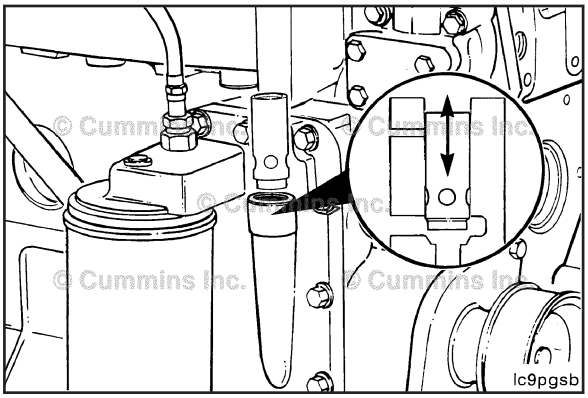
Dry with compressed air.

NOTE: If the plunger bore requires cleaning, remove the housing so as **not** to flush debris into the engine.

Inspect the plunger and plunger bore. Polished areas on the plunger and bore are acceptable.



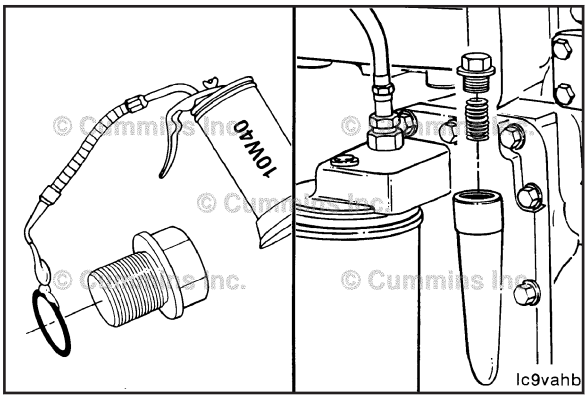
Verify the plunger moves freely in the bore.



Install

Install a new sealing o-ring on the threaded plug and lubricate with clean lubricating engine oil. Install the pressure regulator assembly.

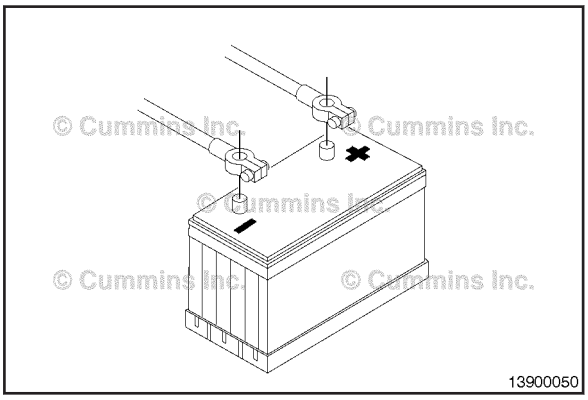
Torque Value: 80 N•m [59 ft-lb]

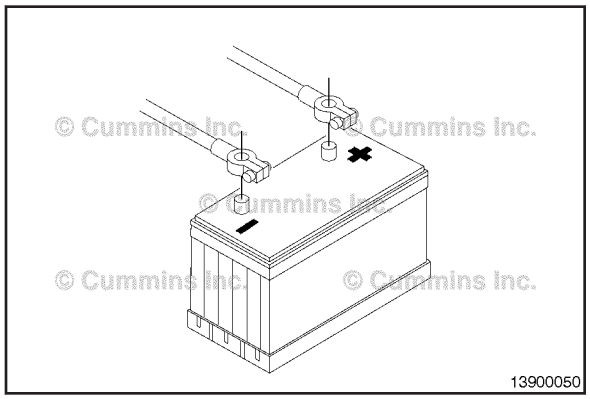


Finishing Steps

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

- Connect the batteries.



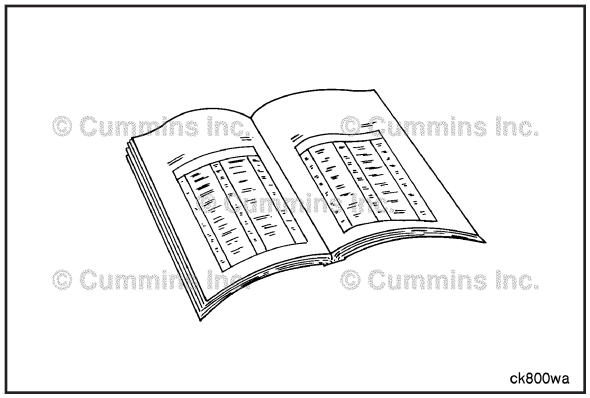


Lubricating Oil Pump (007-031)

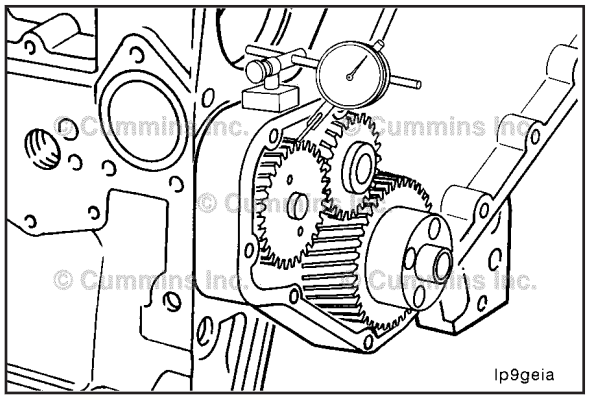
Preparatory Steps

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

- Disconnect the batteries.



- Remove the drive belt. Refer to Procedure 008-002
- Remove the vibration damper/crankshaft pulley. If equipped with a viscous damper refer to Procedure 001-052. If equipped with a rubber damper refer to Procedure 001-051. If equipped with crankshaft pulley only, refer to Procedure 001-022
- Remove the front gear cover. Refer to Procedure 001-031.



Initial Check

NOTE: The oil pump gear backlash limits for rear gear train engines and front gear train engines are different. Rear gear train engine use a lubricating oil pump with straight cut gears and front gear train engines use a lubricating oil pump with helical cut gears.

Use gauge, Part Number 3824564, and magnetic base, Part Number 3377399, measure the lubricating pump driven gear backlash.

Rear Gear Train Lubricating Oil Pump Gear Backlash Limits

mm		in
0.170	MIN	0.007
0.300	MAX	0.012

Front Gear Train Lubricating Oil Pump Gear Backlash Limits

mm		in
0.076	MIN	0.003
0.330	MAX	0.013

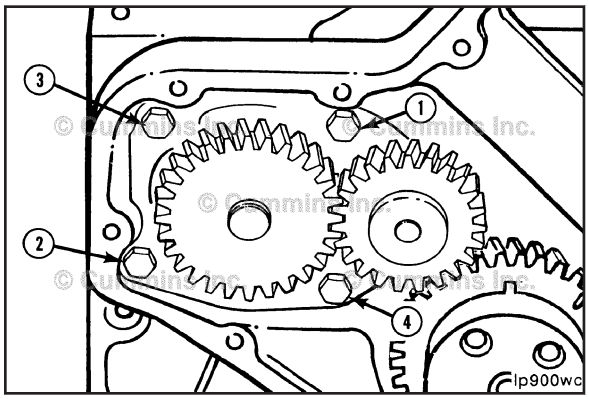
If the backlash is out of specification, the lubricating oil pump **must** be replaced.

NOTE: If the adjoining gear moves when you measure the backlash, the reading will be incorrect.

Remove

Remove the four mounting capscrews (1, 2, 3, and 4).

Remove the lubricating oil pump from the bore in the cylinder block.



Clean and Inspect for Reuse

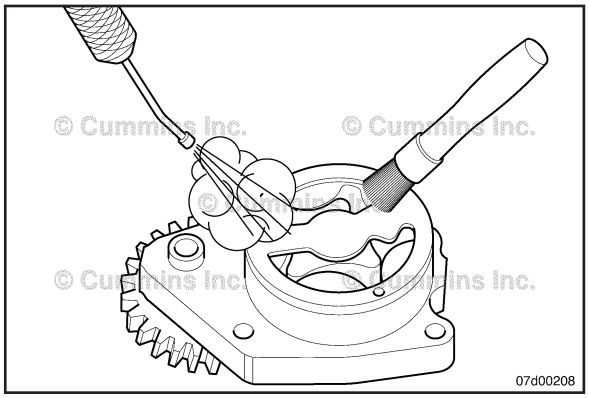
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

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

Clean the lubricating oil pump with solvent.

Dry with compressed air.



⚠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.

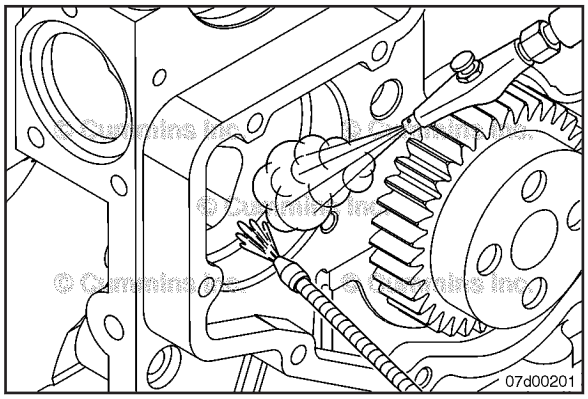
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

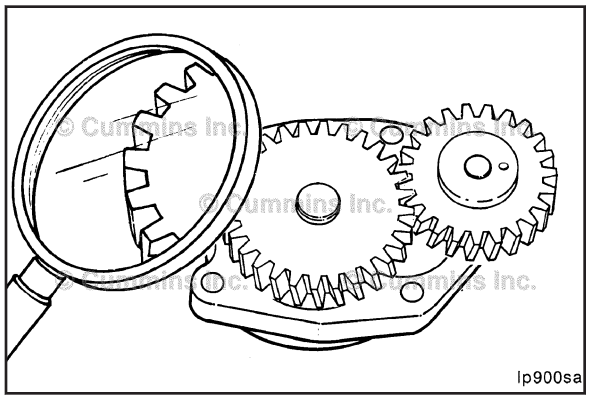
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

With the pump removed use solvents to clean the cylinder block cavity.

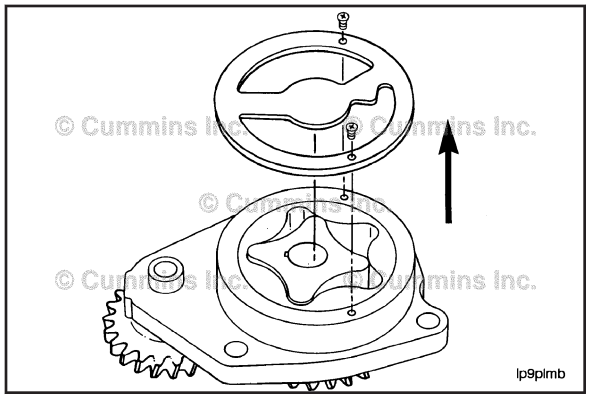
Dry with compressed air.

NOTE: Do **not** allow solvents to enter the lubricating oil system when cleaning the cylinder block cavity.



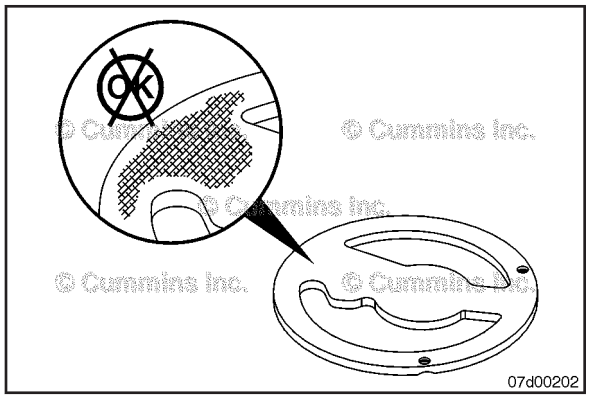


Inspect the lubricating oil pump gears for chips, cracks, or excessive wear.

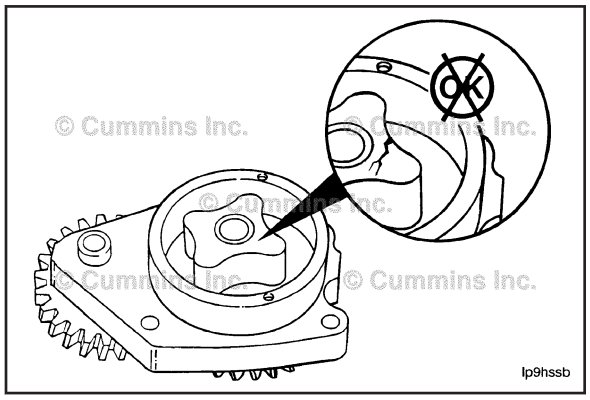


If debris has been expected to have gone through the lubricating oil pump, the rear cover plate can be removed to inspect for internal damage.

NOTE: The lubricating oil pump is serviced/replaced as an assembly. No internal parts are available for rebuild/ replacement.



Inspect the rear cover plate for scoring or grooves. If the cover is scored or grooved too badly, the lubricating oil pump **must** be replaced.



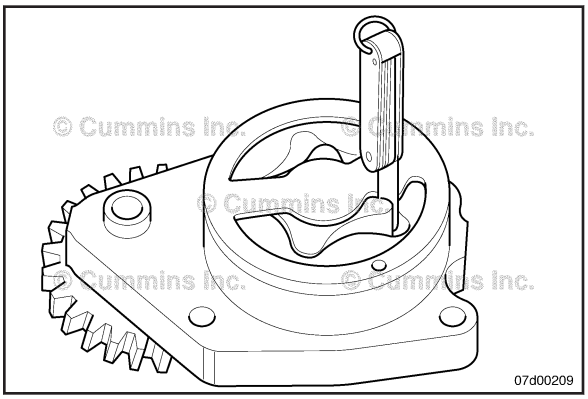
Inspect the lubricating oil pump housing and gerotor drive for damage and excessive wear.

If the lubricating oil pump is damaged, the lubricating oil pump **must** be replaced.

Measure

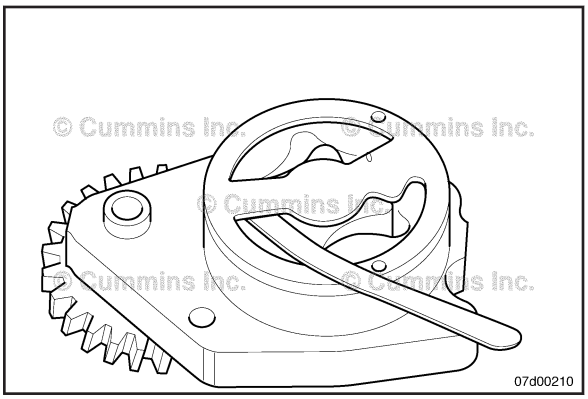
Measure the tip clearance.

Tip Limit		
mm		in
0.178	MAX	0.007



Measure the clearance of the gerotor drive/gerotor planetary to port plate.

Gerotor Drive/Planetary to Port Plate Limit		
mm		in
0.127	MAX	0.005

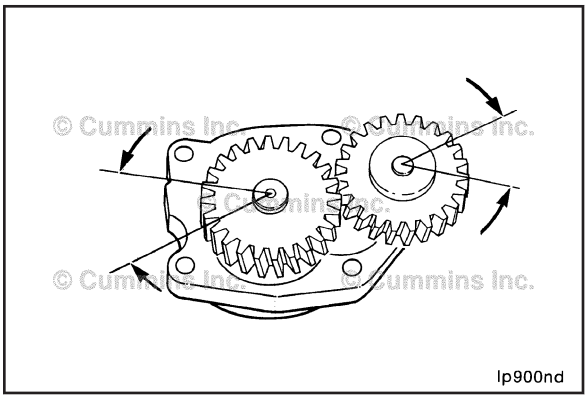


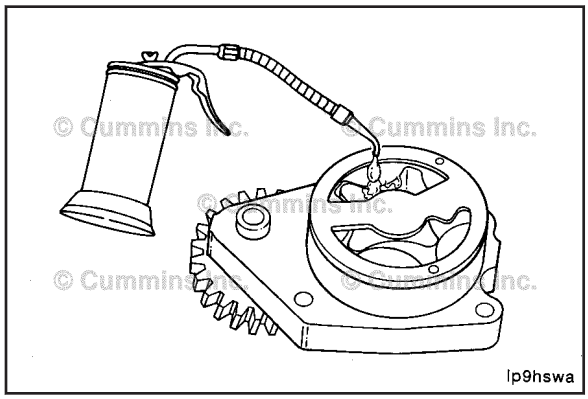
NOTE: The oil pump gear backlash limits for rear gear train engines and front gear train engines are different. Rear gear train engine use a lubricating oil pump with straight cut gears and front gear train engines use a lubricating oil pump with helical cut gears.

Measure the gear backlash.

Rear Gear Train Backlash Limits (used pump)		
mm		in
0.170	MIN	0.007
0.300	MAX	0.012

Front Gear Train Backlash Limits (used pump)		
mm		in
0.076	MIN	0.003
0.330	MAX	0.013

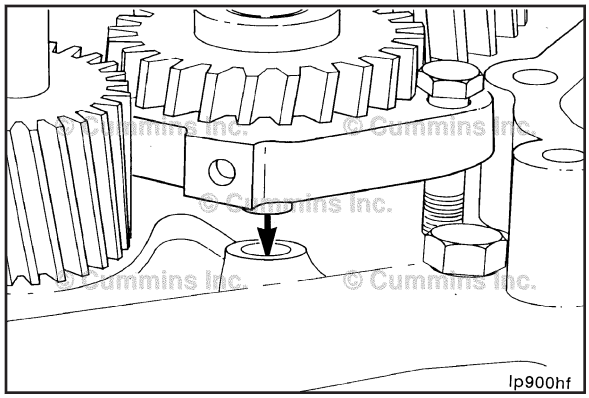




Install

⚠CAUTION⚠
Failure to fill the pump with oil during installation can result in a slow prime at initial engine start-up, resulting in severe engine damage.

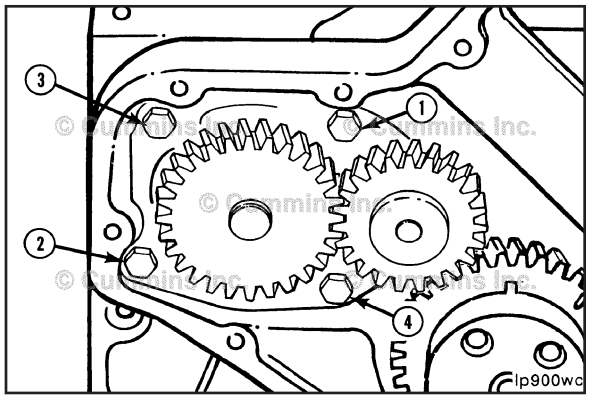
Lubricate the lubricating oil pump with clean 15W-40 engine oil.



⚠CAUTION⚠
To reduce the possibility of engine damage, make sure the idler gear pin is installed in the locating bore in the cylinder block.

Install the lubricating oil pump.

NOTE: If installing a new lubricating oil pump ensure that the pump is correct for your engine. For example, lubricating oil pumps for 4 and 6 cylinder engines are physically interchangeable, but have different flow characteristics.



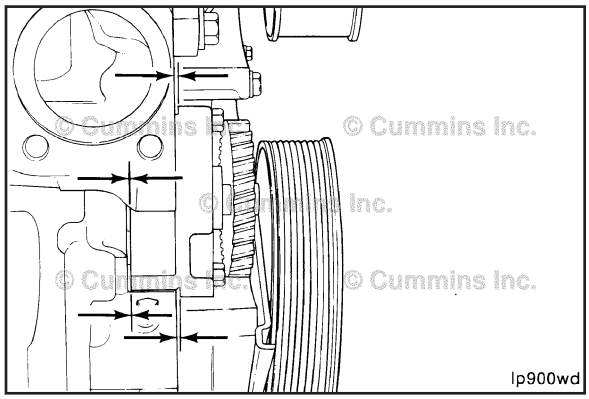
Using the sequence shown, torque the capscrews in the following sequence:

Initial Torque

Torque Value: 8 N•m [70 in-lb]

Final Torque

Torque Value: 24 N•m [212 in-lb]



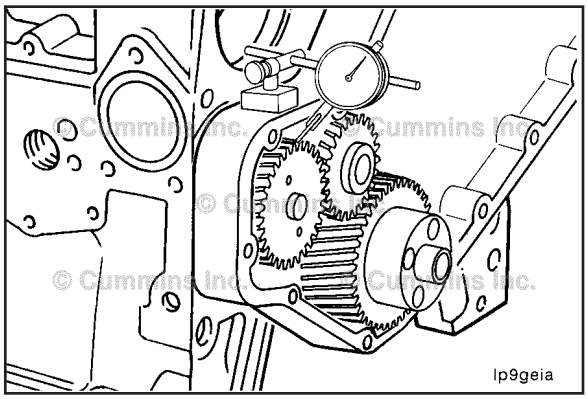
NOTE: The back plate on the pump seats against the bottom of the bore in the cylinder block. When the lubricating oil pump is correctly installed, the flange on the lubricating oil pump will **not** touch the cylinder block.

NOTE: Be sure to check if gear backlash is correct when installing a new lubricating oil pump.

Use gauge, Part Number 3824564, and magnetic base, Part Number 3377399, measure the lubricating pump driven gear backlash.

NOTE: The oil pump driven gear backlash limits for rear gear train engines and front gear train engines are different. Rear gear train engine use a lubricating oil pump with straight cut gears and front gear train engines use a lubricating oil pump with helical cut gears.

NOTE: If the adjoining gear moves when you measure the backlash, the reading will be incorrect.



Oil Pump Driven Gear Backlash Limits (new pump)

	mm		in
Rear Gear Train	0.300	MIN	0.011
	0.500	MAX	0.019
Front Gear Train	0.076	MIN	0.003
	0.330	MAX	0.013

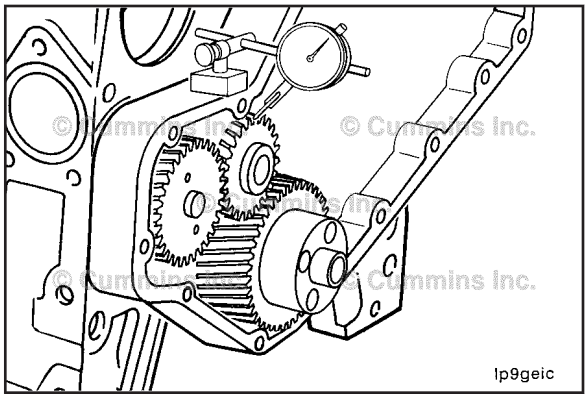
NOTE: If you are reinstalling a used pump and have already measured the backlash you do **not** need to complete this step.

NOTE: Be sure to check if gear backlash is correct when installing a new lubricating oil pump.

Use gauge, Part Number 3824564, and magnetic base, Part Number 3377399, measure the lubricating pump idler gear backlash.

NOTE: The oil pump idler gear backlash limits for rear gear train engines and front gear train engines are different. Rear gear train engine use a lubricating oil pump with straight cut gears and front gear train engines use a lubricating oil pump with helical cut gears.

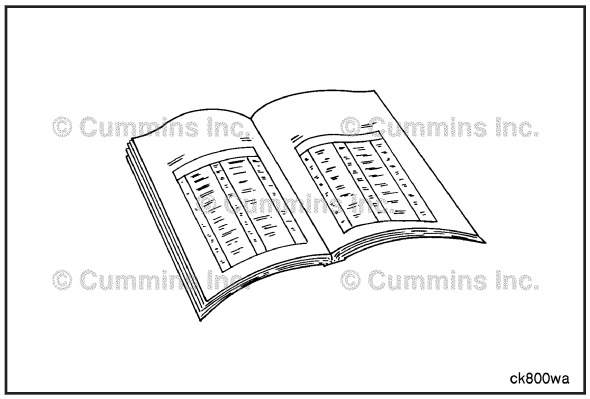
NOTE: If the adjoining gear moves when you measure the backlash, the reading will be incorrect.



Oil Pump Idler Gear Backlash Limits (new pump)

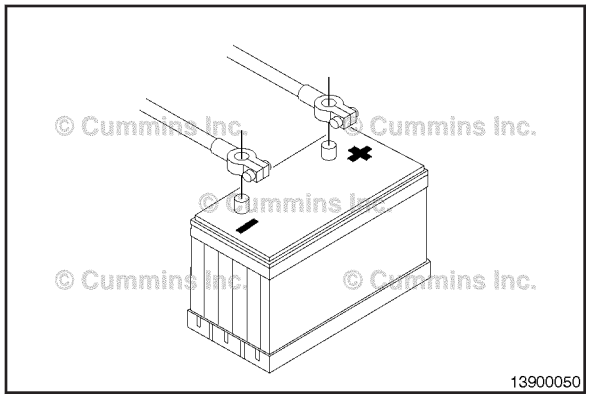
	mm		in
Rear Gear Train	0.150	MIN	0.005
	0.250	MAX	0.009
Front Gear Train	0.076	MIN	0.003
	0.330	MAX	0.013

NOTE: If you are reinstalling a used pump and have already measured the backlash you do **not** need to complete this step.



Finishing Steps

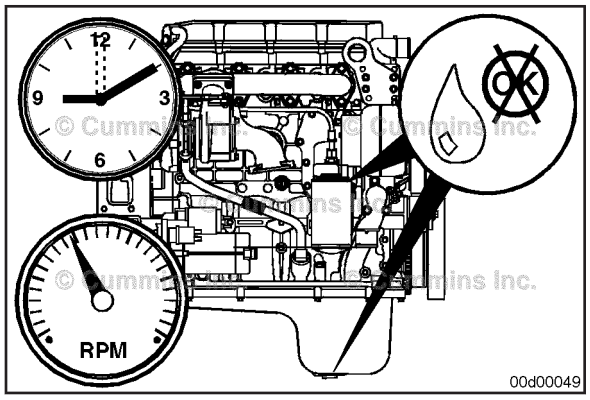
- Install the front gear cover. Refer to Procedure 001-031
- Install the vibration damper/crankshaft pulley. If equipped with a viscous damper, refer to Procedure 001-052. If equipped with a rubber damper, refer to Procedure 001-051. If equipped with a crankshaft pulley only, refer to Procedure 001-022
- Install the belt. Refer to Procedure 008-002.



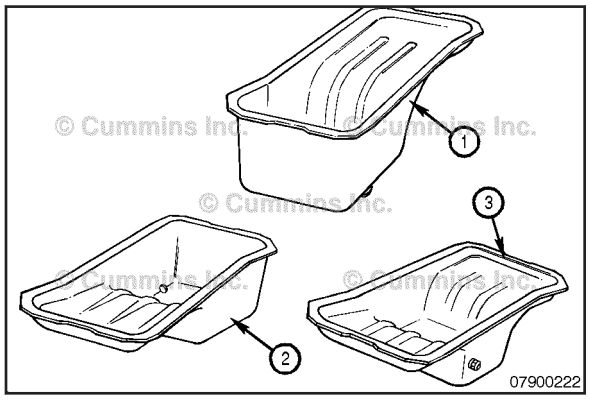
⚠WARNING⚠

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

- Connect batteries.



- Operate the engine and check for leaks.



Lubricating Oil Suction Tube (Block-Mounted) (007-035)

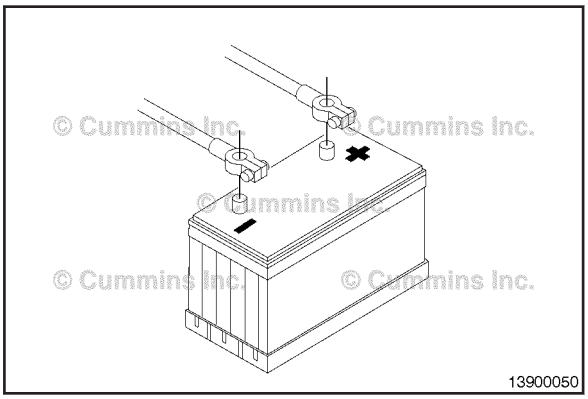
General Information

A front sump (1), rear sump (2), or center sump (3) lubricating oil pan option can be used depending on the application. The type and mounting of the lubricating oil suction tube will vary with the lubricating oil pan used.

Preparatory Steps

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

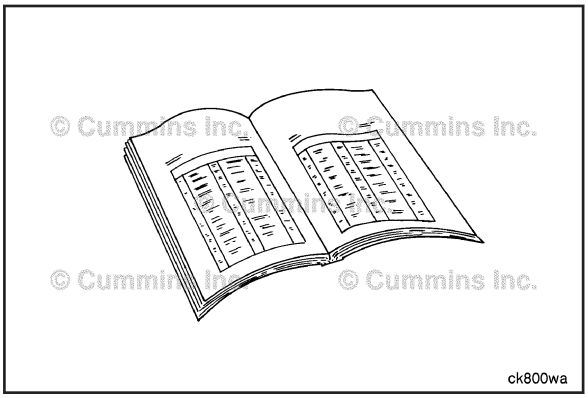
- Disconnect the batteries.



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

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

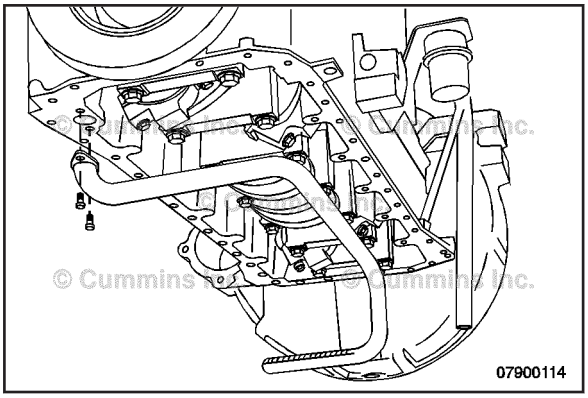
- Drain the lubricating oil. Refer to Procedure 007-037
- Remove the lubricating oil pan and gasket. Refer to Procedure 007-025.



Remove

Remove the suction tube mounting capscrews.

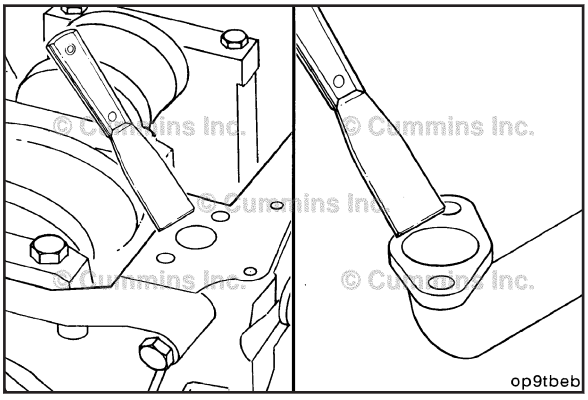
Remove the suction tube.

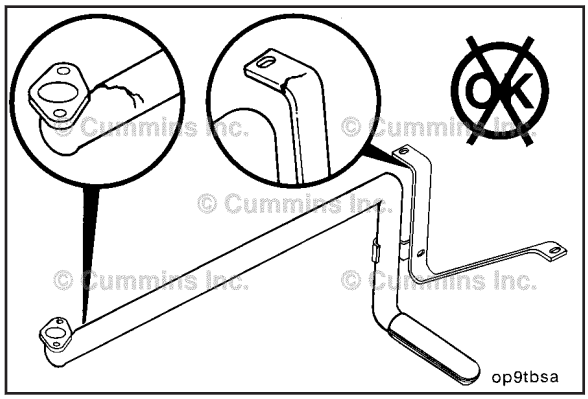


Clean and Inspect for Reuse

Using a putty knife, clean the gasket surfaces.

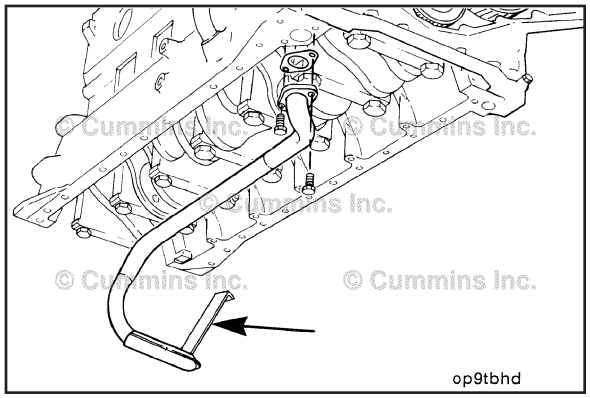
Clean the suction tube surface with hot, soapy water.





Inspect the suction tube for cracks.

Replace the suction tube if any damage is found.



Install

⚠CAUTION⚠

The suction tube gasket is not symmetrical. Failure to install it properly can result in low oil pressure and engine damage.

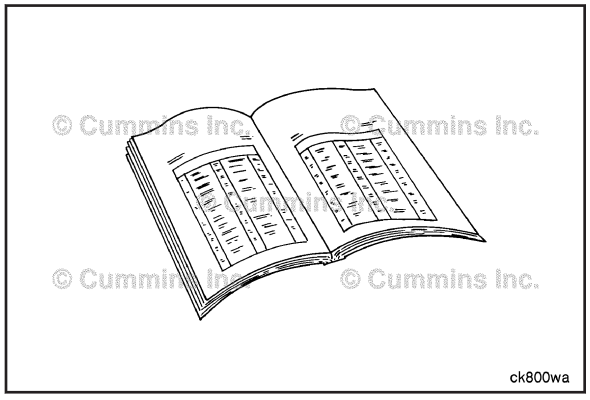
NOTE: For front gear train engines with a bedplate, the bedplate **must** be installed before the suction tube is installed. Also for front gear train engines, the bedplate **must** be installed in sequence with the oil pan. Refer to Procedure 007-025.

Install the lubricating oil suction tube gasket and suction tube.

Install and tighten the suction tube mounting capscrews.

Torque Value: 24 N•m [212 in-lb]

NOTE: Take care to ensure the oil suction tube gasket openings align with both the oil suction tube and the block.

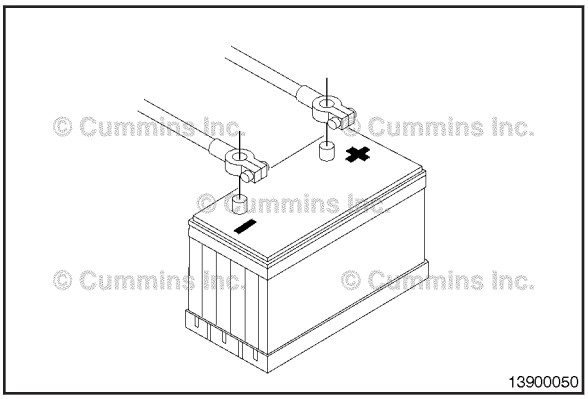


Finishing Steps

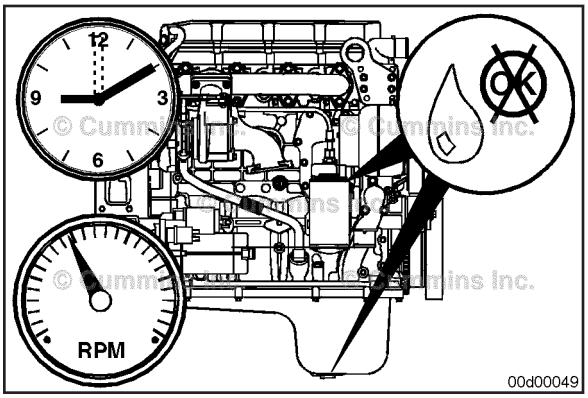
- Install oil pan and gasket. Refer to Procedure 007-025
- Fill the engine with lubricating oil. Refer to Procedure 007-037.

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

- Connect the batteries.



- Operate the engine and check for leaks
- Stop the engine, and check the lubricating oil level with the dipstick.



Lubricating Oil System (007-037)

Measure

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

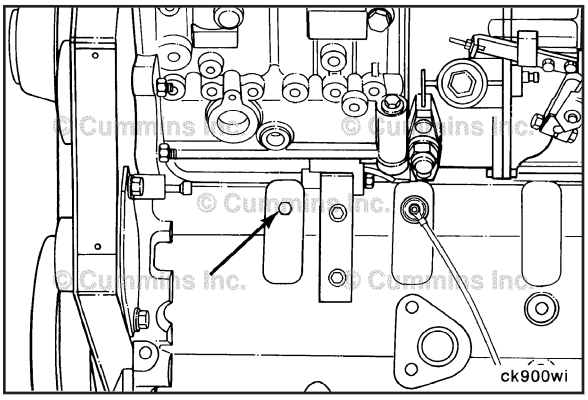
⚠WARNING⚠
To reduce the possibility of personal injury, avoid direct contact of hot oil with your skin.

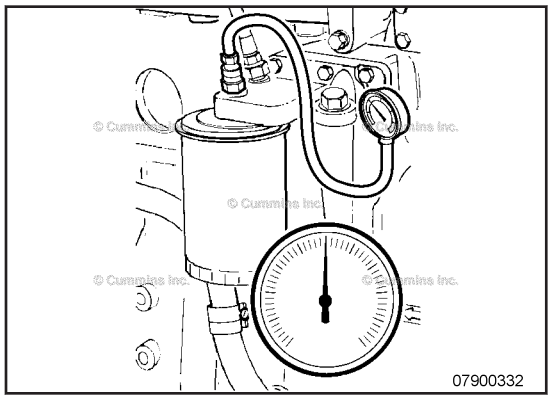
Locate the appropriate port for measuring oil pressure. On most engines a port can be found along the main oil gallery. If this port is **not** accessible, another port can be located on the top of the oil filter head.

Remove the plug.

NOTE: It is preferred that oil pressure be checked at the main oil gallery, if accessible.

Install a Compuchek® fitting.

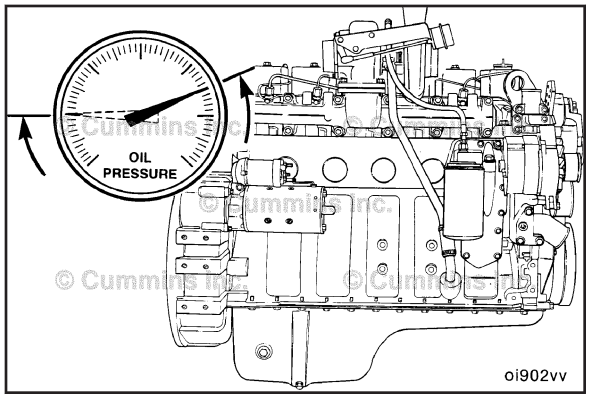




CAUTION

If the lubricating oil pressure does not develop within 15 seconds, shut down the engine to reduce the possibility of internal damage.

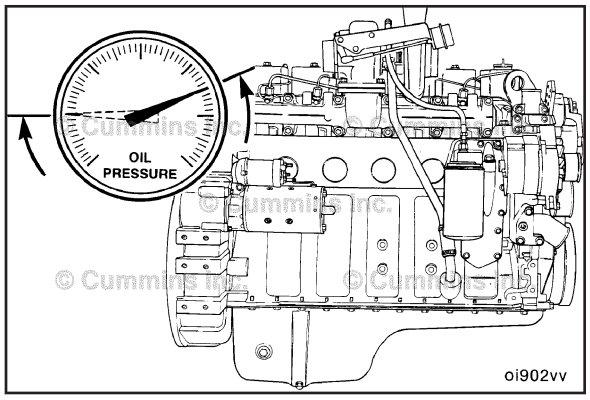
Connect a pressure gauge. Start the engine.



Allow the engine to run and achieve operating temperature. Check for leaks.

Record the lubricating oil pressure readings at idle.

Oil Pressure at Low Idle		
kPa		psi
69	MIN	10



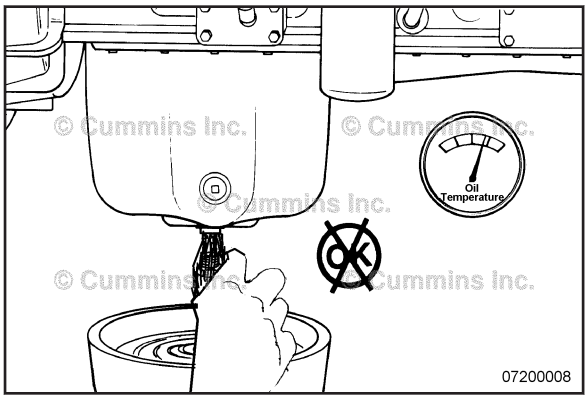
Increase engine speed to rated speed and hold for 30 seconds.

Record the lubricating oil pressure readings at rated engine speed.

Oil Pressure at Rated Engine Speed		
kPa		psi
207	MIN	30

Remove the oil pressure gauge/Compuchek® fitting and install the previously removed plug. For pipe plugs, refer to Procedure 017-007. For straight thread plugs, refer to Procedure 017-011.

Drain



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

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

NOTE: For most engines use a container that can hold at least 20 liters [21 qt] of lubricating oil. Some engines may be equipped with an increased capacity oil pan requiring a container that can hold 28 liters [30 qt] of lubricating oil.

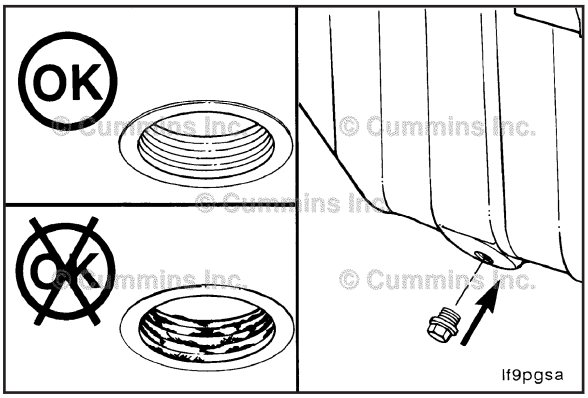
Operate the engine until the coolant temperature reaches 60°C [140°F].

Shut off the engine.

Remove the oil drain plug. Drain the oil immediately to be sure all the oil and suspended contaminants are removed from the engine.

If performing an oil drain as part of a service maintenance interval, remove and replace the oil filter. Refer to Procedure 007-013.

Fill



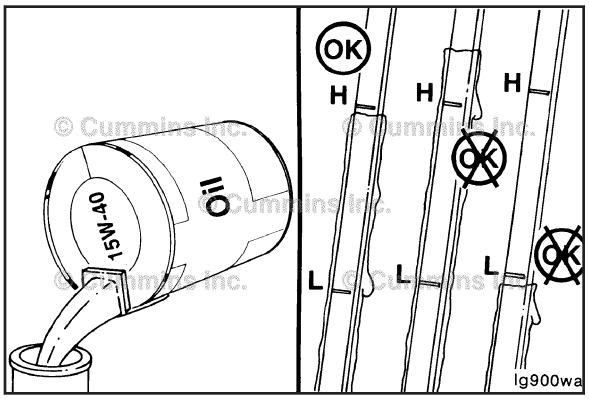
Clean and check the lubricating oil drain plug threads and sealing surface. Use new sealing washer, if damaged.

Install the lubricating oil pan drain plug.

Steel Oil Pan Drain Plug Torque			
	N•m		ft-lb
M18	60	MIN	44
M22	80	MIN	59

Cast Aluminum Oil Pan Drain Plug Torque			
	N•m		ft-lb
M22	60	MIN	44

NOTE: Use a high-quality 15W-40 multiviscosity oil, such as Cummins Premium Blue®, or its equivalent, in Cummins® engines. Choose the correct oil for your operating climate. Refer to Cummins Engine Oil Recommendations, Bulletin 3810340

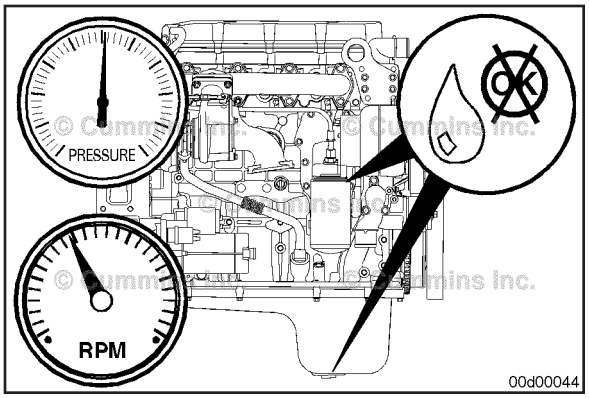


Fill the lubricating oil pan with clean 15W-40 lubricating oil to the low level. Refer to Procedure 018-017 (Lubricating Oil System in Section V) for common lubricating oil pan capacities, or by looking up the oil pan option for the engine serial number on QuickServe OnLine.

NOTE: When filling the oil pan, use the fill tube on the side of the engine rather than on top of the rocker lever cover.

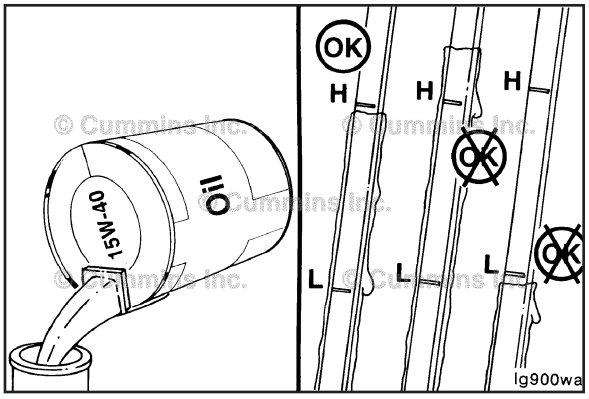
NOTE: If the engine is **not** equipped with a side-fill, wait at least 5 minutes before measuring the oil level with the dipstick to allow the oil to drain to the pan.

Service Tip: If the oil capacity of the oil pan is **not** known, fill the lubricating oil pan to the smallest oil pan capacity listed in Procedure 018-017 (Lubricating Oil System in Section V) for the engine being worked on. Then add 1 quart of oil at a time until it reaches the high mark on the dipstick. Record the number of quarts added so that capacity is known the next time the oil is drained.



Idle the engine to inspect for leaks at the drain plug and, if replaced, the oil filter seal.

NOTE: Engine oil pressure **must** be indicated on the gauge within 15 seconds after starting. If oil pressure is **not** registered within 15 seconds, shut off the engine immediately to avoid engine damage. Confirm that the correct oil level is in the oil pan.



Shut off the engine. Wait approximately 5 minutes to let the oil drain from the upper parts of the engine. Check the level again.

Add oil as necessary to bring the oil level to the H (high) mark on the dipstick.

Lubricating Oil Contamination (007-044)

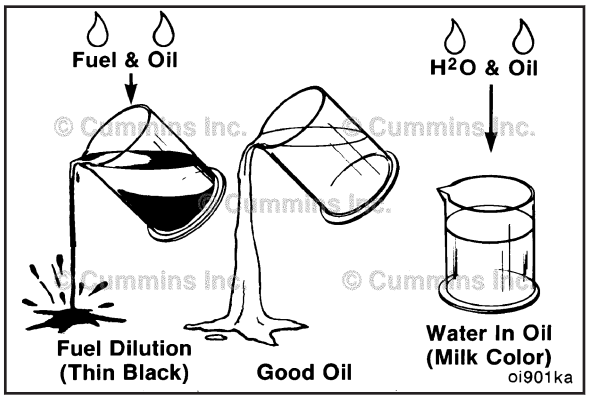
General Information

Lubricating Oil Dilution

⚠CAUTION⚠
Diluted oil can cause severe engine damage.

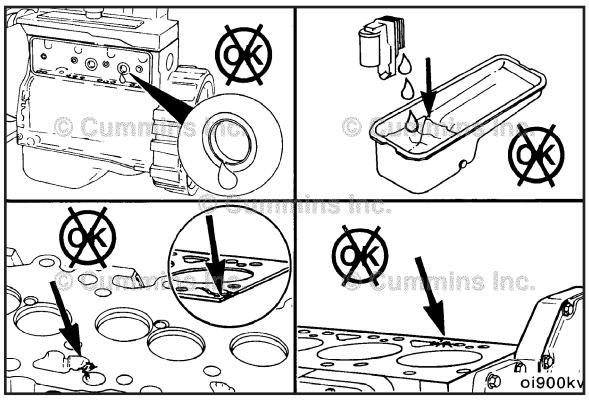
Check the condition of the lubricating oil.

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



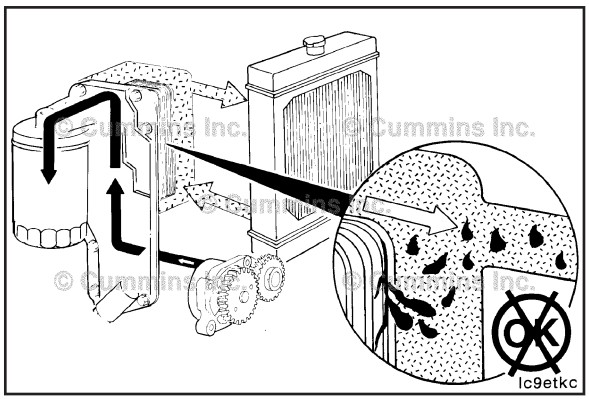
Coolant in the oil can be caused by:

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



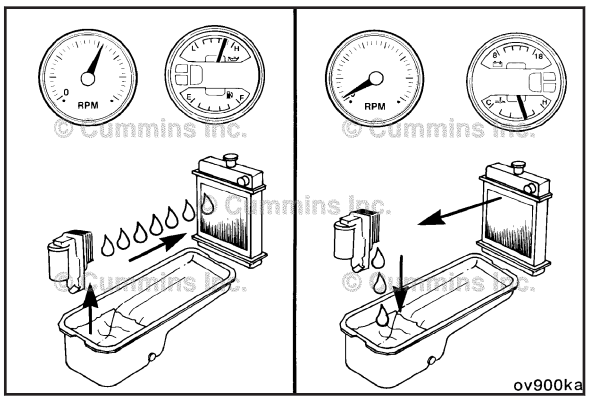
Coolant-Diluted Lubricating Oil

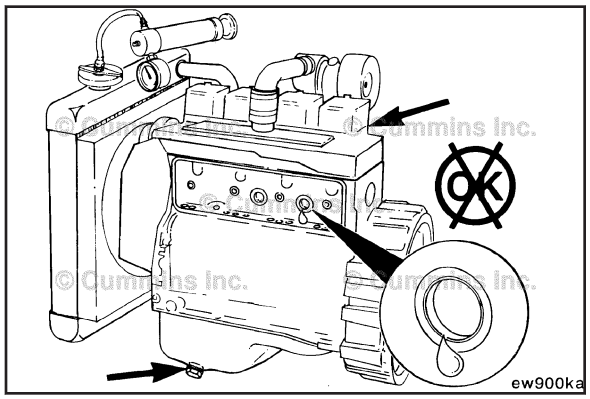
Since the lubricating oil cooler design does**not** require gaskets or seals to maintain the separation of oil and coolant, the element itself **must** leak to allow mixing of the fluids. Refer to Procedure 007-003.



During operation, the lubricating oil pressure will be higher than coolant pressure. A leak in the lubricating oil cooler will show as lubricating oil in the coolant.

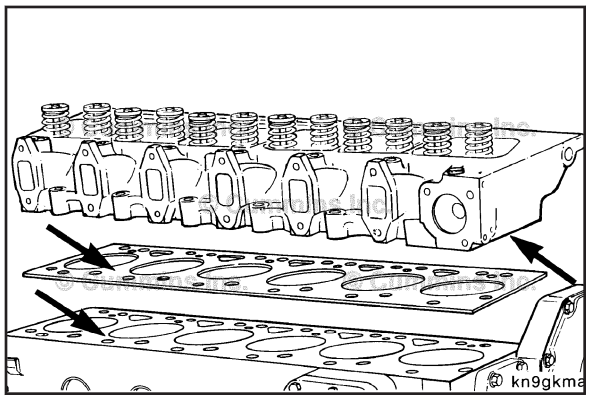
However, following an engine shutdown, the residual pressure in the coolant system can cause coolant to seep through the leak path into the lubricating oil.





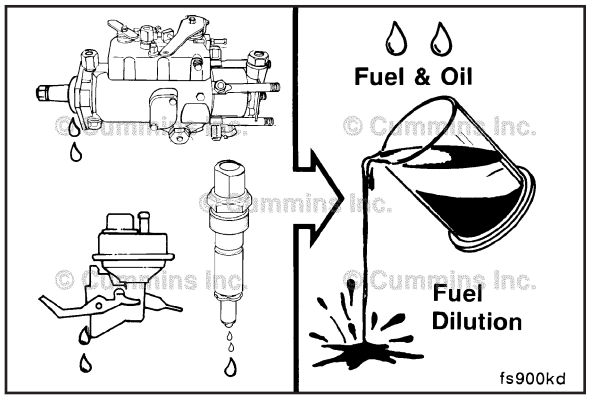
To check for leaks, pressurize the cooling system to 140 kPa [20 psi]. With the system pressurized, remove the following components, and inspect for leaks.

- Valve covers (leaks indicate cracked head)
- Lubricating oil drain plug (leaks indicate defective lubricating oil cooler, head gasket, cracked head or block)
- Tappet cover (expansion plug leak).



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

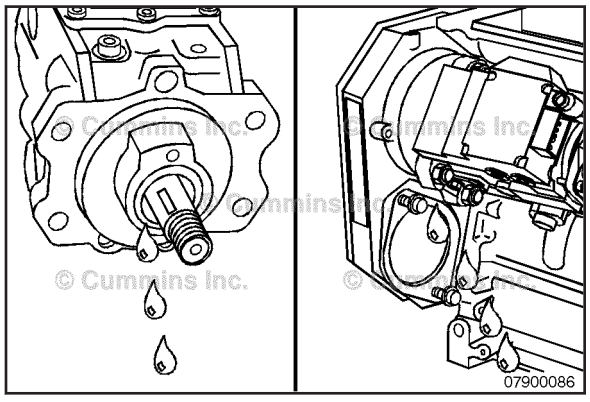
Remove the cylinder head and gasket, and inspect for cracks or damage.



Fuel-Diluted Lubricating Oil

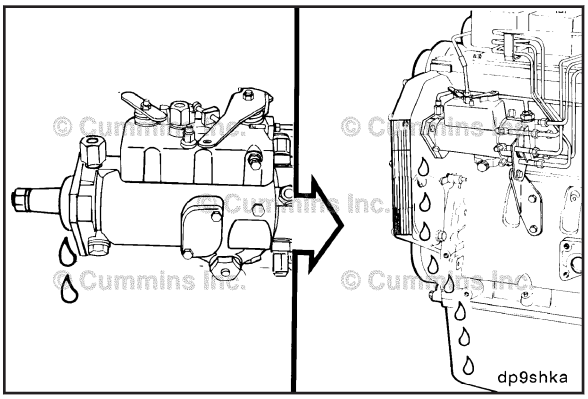
Fuel dilution is limited to five sources:

1. Injection pump shaft seal
2. Fuel leaking by the rings
3. Fuel transfer pump
4. A crack in the cylinder head from the fuel filter location to the air intake
5. Injector leakage.



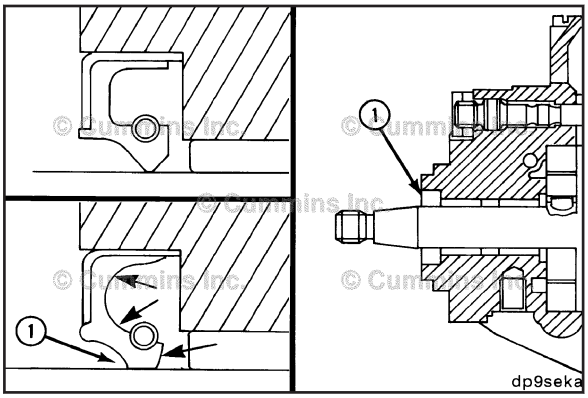
Use the following logic to determine the source of the oil dilution with fuel:

A worn or damaged fuel injection pump shaft seal will allow fuel to leak into the gear housing and then into the lubricating oil pan.

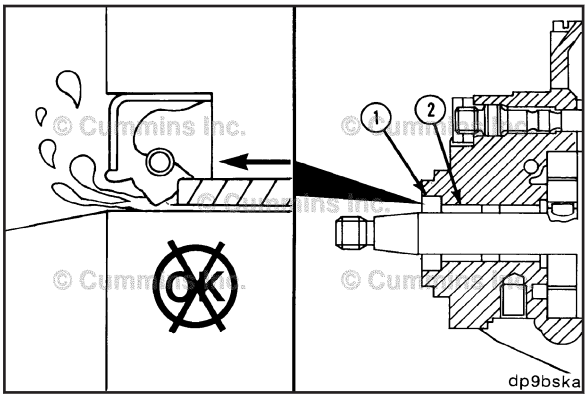


The seal is designed to provide increased sealing as the pump case pressure increases. Pressure forces the lip (1) tighter around the shaft.

A worn seal could leak during start-up and shutdown when case pressure is low. A worn seal can **not** easily be detected by pressurizing the pump.

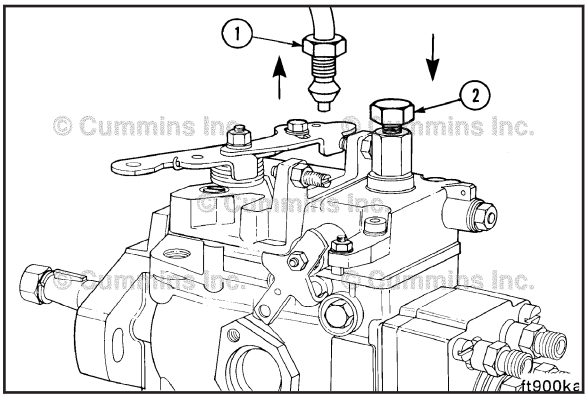


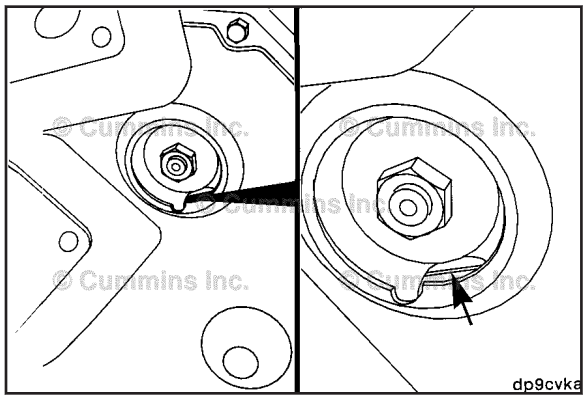
The bushing (2) in the Bosch® VE fuel injection pump can cause a seal leak. If the bushing is loose in the housing, it will move toward the seal raising the lip (1) and providing a leak path for fuel.



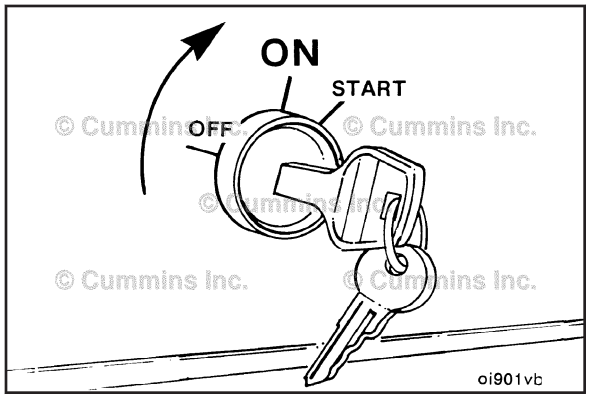
NOTE: The following steps only apply to front gear train engines. For rear gear train engines, there is no adequate access to check for fuel pump seal leakage on engine.

To check for such a leak, or a damaged seal (Bosch® VE **only**), remove the fuel drain manifold connection (1) at the pump, and install a plug (2).

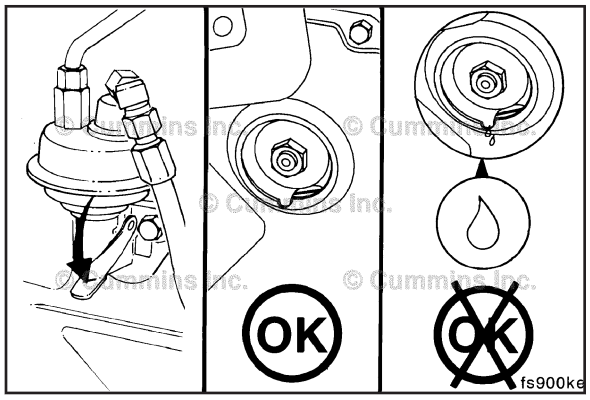




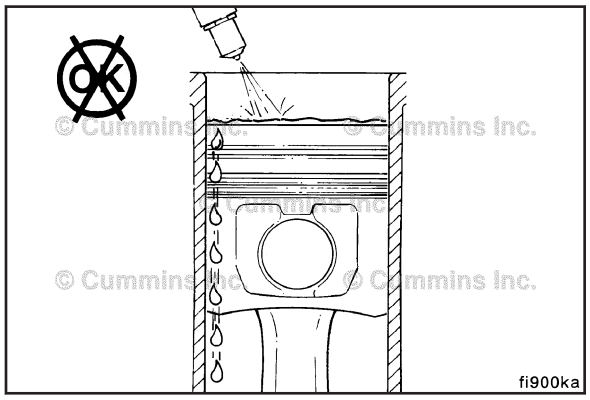
Remove the access cover, and rotate the engine so one of the holes in the fuel injection pump gear exposes the back gear housing.



Activate the fuel shutdown valve by turning the switch to the ON position.



Use a small mirror to check for leaks while pumping the priming lever on the lift pump. If a leak is found, replace the injection pump. Refer to Procedure 005-014.



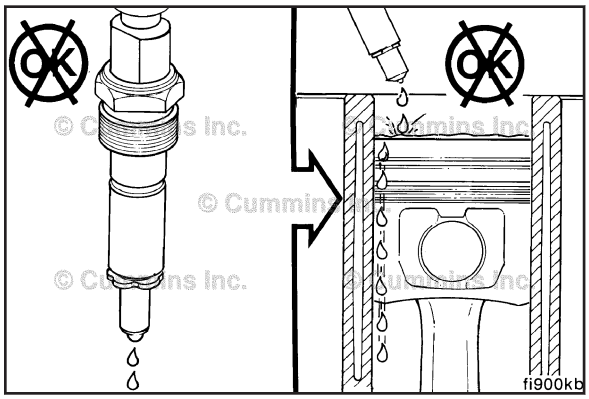
Incomplete combustion in the cylinders can result in unburned fuel draining into the oil pan.

This condition can be caused by a leaking injector or reduced compression caused by inadequate piston ring sealing.

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

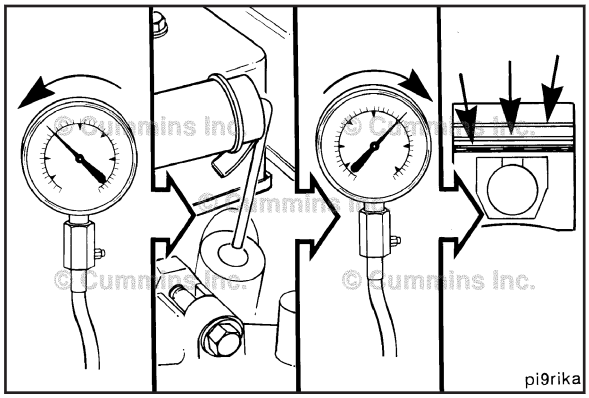
An injector leak will also cause the engine to run rough and have low power.

Remove and repair or replace leaking injectors. Refer to Procedure 006-026.



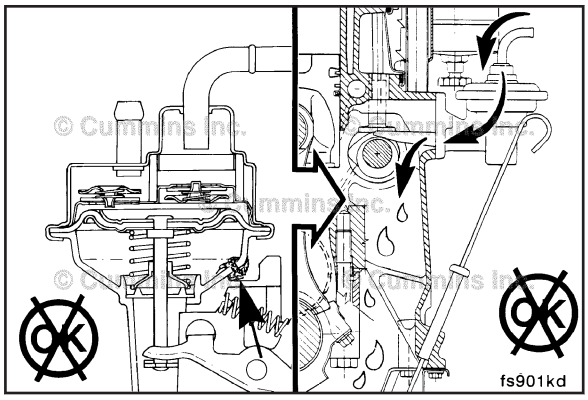
For two valve per cylinder engines, perform a compression check to verify piston ring sealing. Refer to Procedure 014-008.

For four valve per cylinder engines, perform a blow-by check. Refer to Procedure 014-010.

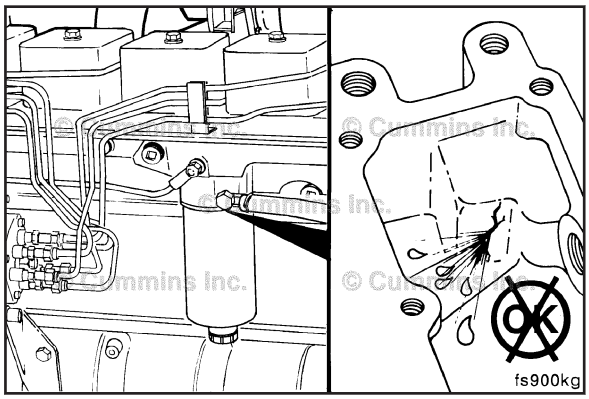


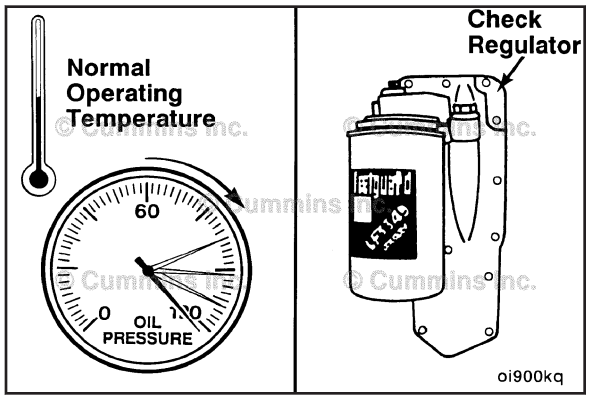
There is a remote possibility for fuel to drain into the oil from the diaphragm-type fuel transfer pump.

For this to happen, the diaphragm in the pump will break and the drain hole will need to be plugged.



On engines with head mounted fuel filters, another remote possibility, is that a crack or porosity in the head casting will allow fuel to leak to the air intake and onto the cylinders.





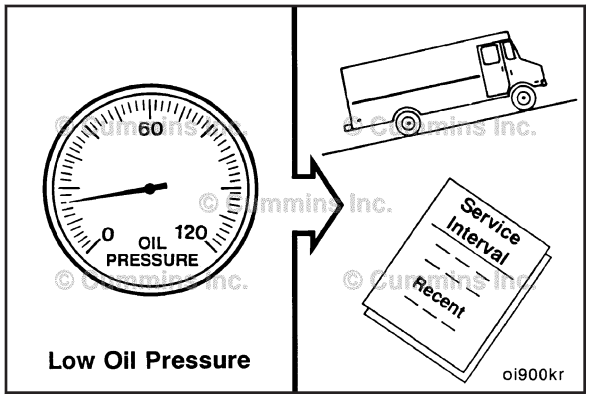
Lubricating Oil System Diagnostics (007-048)

General Information

Lubricating Oil Pressure Regulating Valve

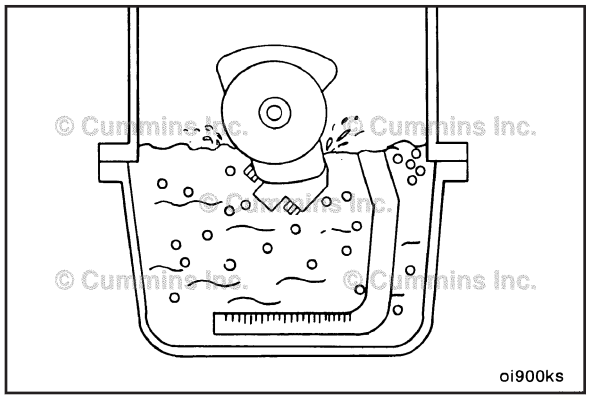
The engine will have high oil pressure at normal operating temperature if the regulator sticks in the closed position. Check the regulator for freedom of movement.

Refer to Procedure 007-029 in Section 7.



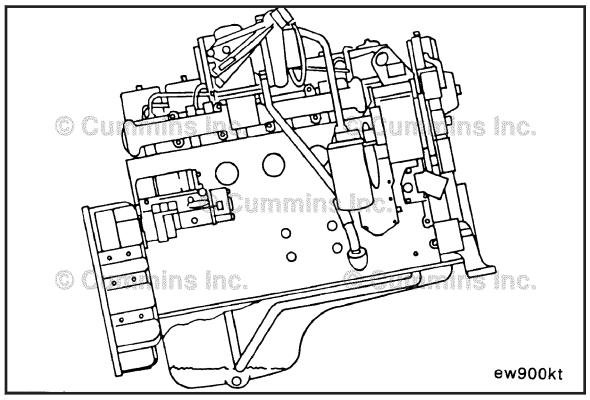
Low-Lubricating Oil Pressure

Low-lubricating oil pressure (or no 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; i.e., following a service interval, at idle **only**, or while operating on a steep grade.



Lubricating Oil Level

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



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

Lubricating Oil Coolers

The engines use full-flow, plate-type oil coolers. The oil flows through a cast passage in the cooler cover and through the element, where it is cooled by engine coolant flowing past the plates of the element.

Depending on the engine configuration, the number of lubricating oil cooler element plates will vary.

For front gear train engines:

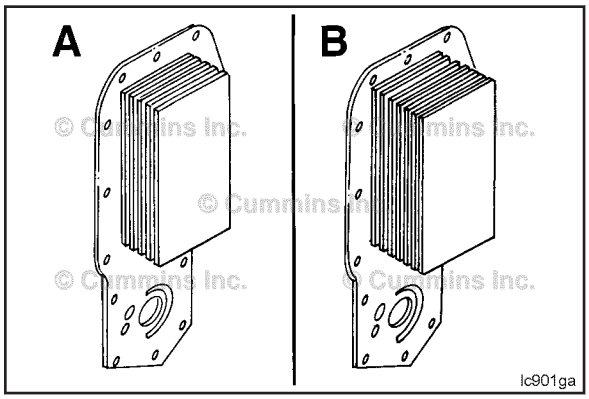
- Four-cylinder engines use an element with five plates (A)
- Six-cylinder engines use an element with seven plates (B).

For rear gear train engines:

- Four-cylinder engines use an element with seven plates (**Not** Shown).

Because of the differences in plate restriction and oil pump capacities, the oil cooler components are **not** interchangeable between the four-cylinder and six-cylinder engines or between the front and rear gear train engines. The use of incorrect components can cause high or low oil temperature, varnish, and sludge buildup.

NOTE: Prior to October 10, 1986, six-cylinder engines were assembled with nine-plate oil cooler elements.



Lubricating Oil Filter Bypass Valve

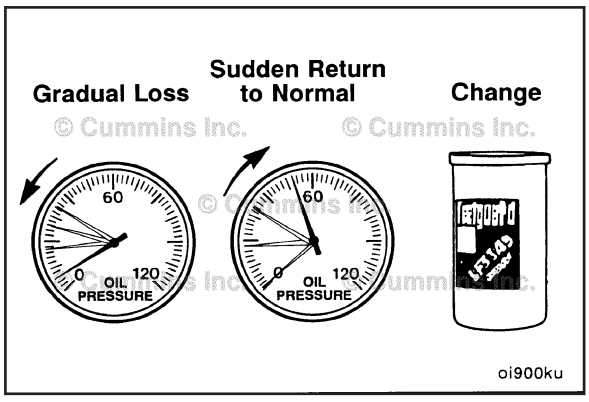
The lubricating oil cooler cover contains a bypass valve that will let the lubricating oil flow bypass a plugged filter. The valve is designed to open when the pressure drop across the filter becomes too high, as with a plugged filter, and lets the lubricating oil continue on through the engine. When a filter becomes plugged, an oil pressure decrease of 60 kPa [9 psi] or less from the normal operating pressure can be observed on the vehicle lubricating oil pressure gauge. This allows unfiltered oil into the engine. This condition should be avoided by changing the filter at each oil drain interval, as described in the Operation and Maintenance Manual.

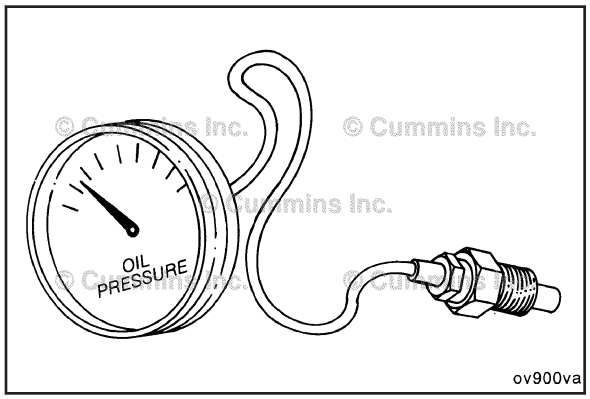
⚠CAUTION⚠
Using a filter for a six-cylinder engine on a four-cylinder engine does not allow extended change interval. Never use a filter for a four-cylinder engine on a six-cylinder engine because of the reduced material holding capability and increased chance of plugging. Failure to do so can cause engine damage.

Lubricating Oil Filter

After the oil is cooled, it flows through the full-flow oil filter.

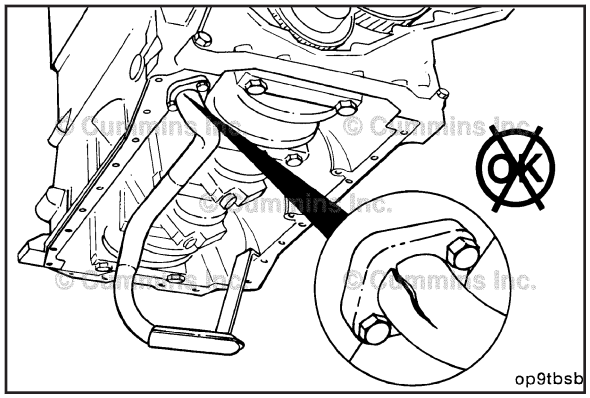
A plugged filter will cause a gradual loss of oil pressure by approximately 69 kPa [10 psi]. The pressure will return to normal when the filter bypass valve opens. If **not** corrected, this will result in severe engine wear, as the engine is running on unfiltered oil when the bypass valve is open.





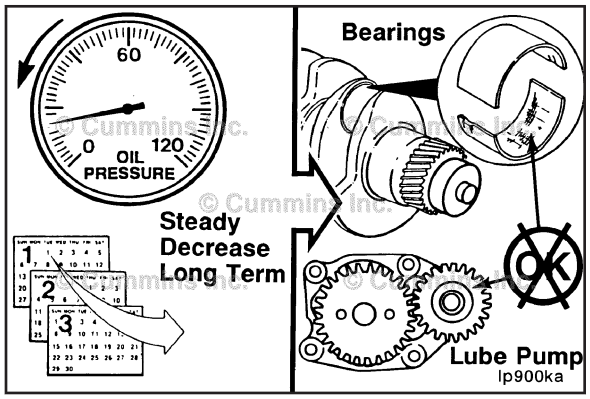
Lubricating Oil Gauge

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



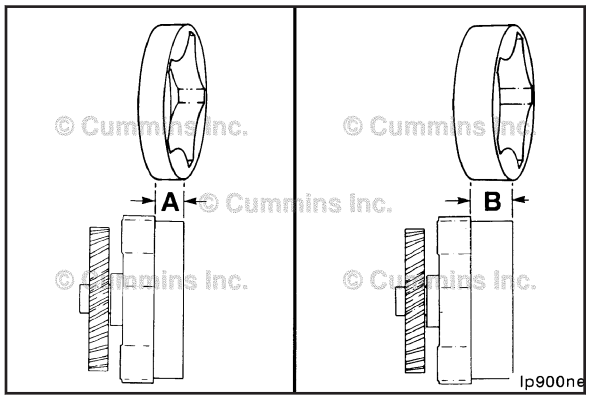
Lubricating Oil Suction Tube

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 oil pressure.



Bearings and Lubricating Oil Pump

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



Incorrect Lubricating Oil Pump

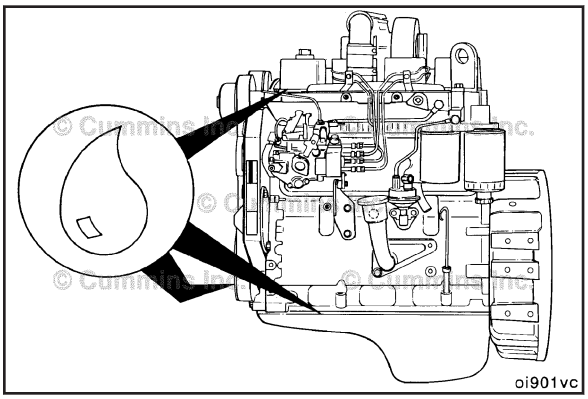
The capacity of the six-cylinder oil pump is greater than the four-cylinder. If low or high pressure occurs after changing the pump, verify that the correct pump was used. Refer to Procedure 007-031 in Section 7.

The flow capacity of a lubricating oil pump is typically controlled by the gerotor thickness, shown by A and B in the illustration.

NOTE: Earlier model B Series engines used lower capacity pumps. Check to be sure the correct model pump is used.

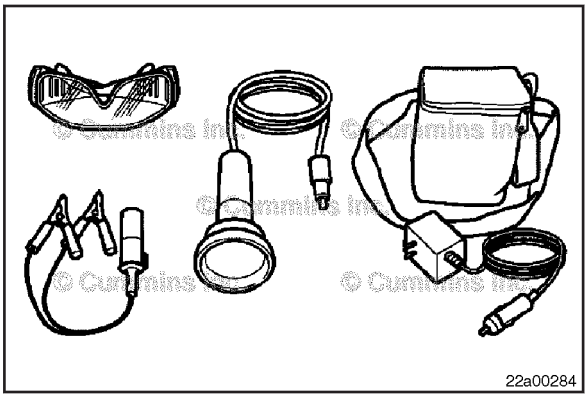
Lubricating Oil Leaks

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



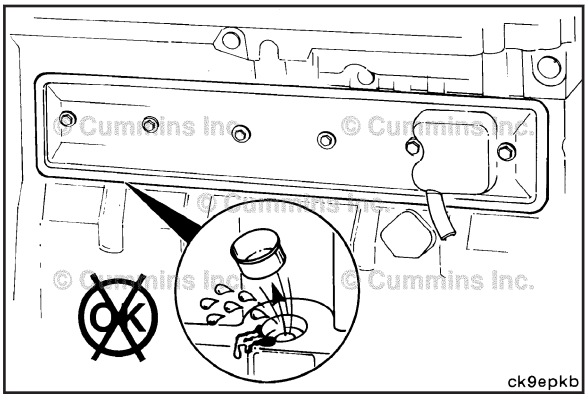
A black light kit, Part Number 3163338, can be very helpful when locating the source of an oil leak.

The fluorescent tracer, Part Number 3376891, will be highlighted by the black light to help identify the source of the leak.



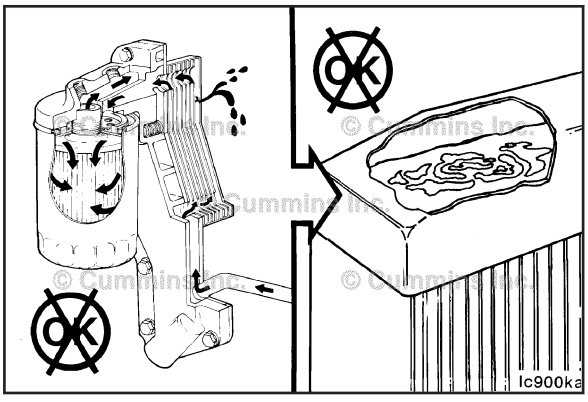
A blown expansion plug can allow a relatively large quantity of lubricating oil to escape, resulting in a sudden drop in the lubricating oil pressure.

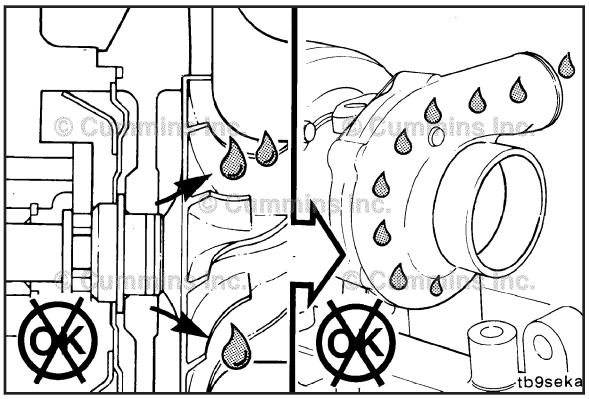
For front gear train engines, when checking for such a leak, be sure to check the expansion plug behind the tappet cover. Lubricating oil blowing out the breather is a good sign of a blown expansion plug. This is usually more obvious on a four-cylinder engine. Refer to Procedure 004-017 in Section 4 to remove the tappet cover.



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

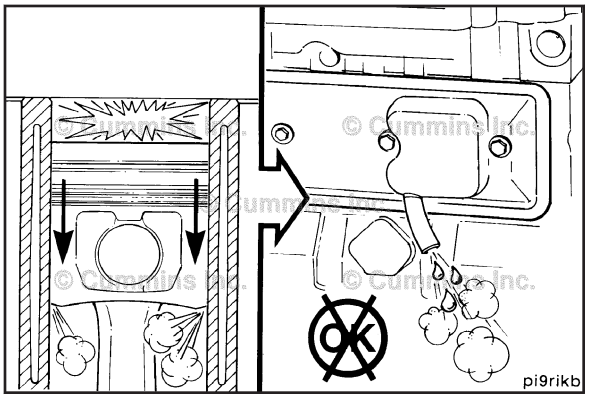
Refer to Procedure 007-003 in Section 7 to inspect the lubricating oil cooler.



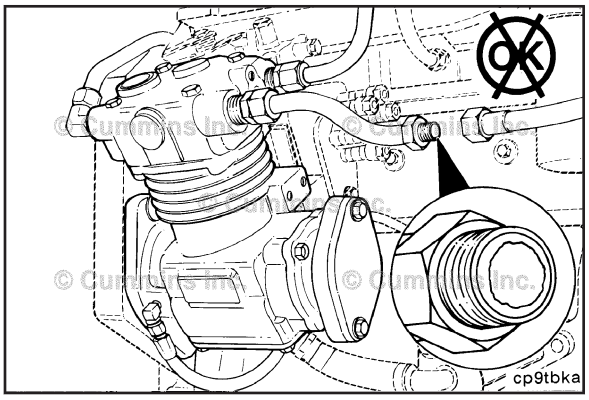


If equipped, worn or damaged seals in the turbocharger can also allow lubricating oil to leak into the air crossover pipe and be burned in the engine.

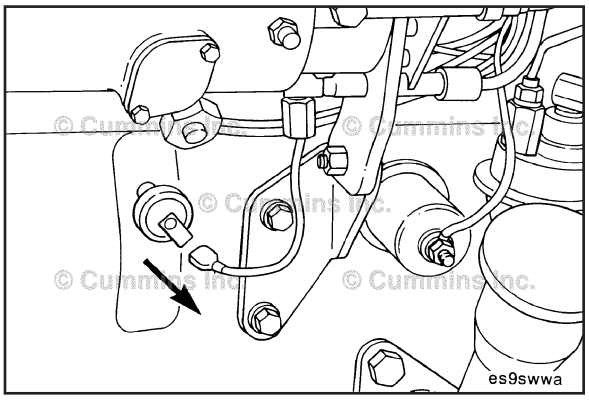
The condition can be verified by removing the air crossover tube or charge air cooler tubing and looking for oil.



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



If equipped, lubricating oil can also be lost through a worn or malfunctioning air compressor. Look for carbon buildup in the air line from the compressor to the air tank. Also, a failed air compressor head or head gasket can allow oil to leak into the coolant or coolant to leak into the oil during hot shutdown. Refer to Procedure 012-003 in Section 12.



Lubricating Oil Pressure Sensor, OEM (007-052)

Remove

Disconnect the wire from the sending unit.

NOTE: The sending units illustrated can be different from those installed by the equipment manufacturer.

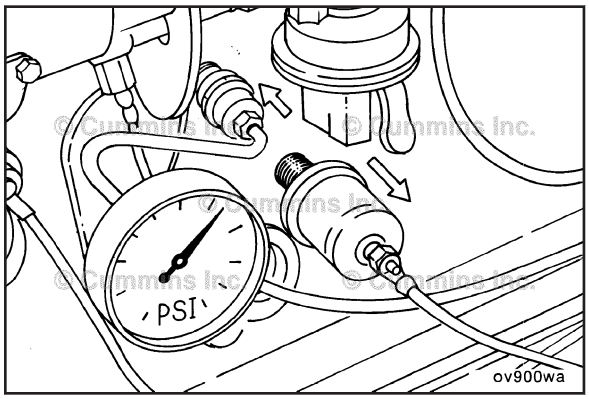
Inspect for Reuse

Remove the lubricating oil pressure switch, install a gauge, start the engine, and measure the lubricating oil pressure. Minimum lubricating oil pressure:

Low Idle (675 to 725 rpm) 69 kPa [10 psi]

High Idle 207 kPa [30 psi]

NOTE: The Pressure switch is set to actuate when oil pressure drops to 55 kPa [8 psi].



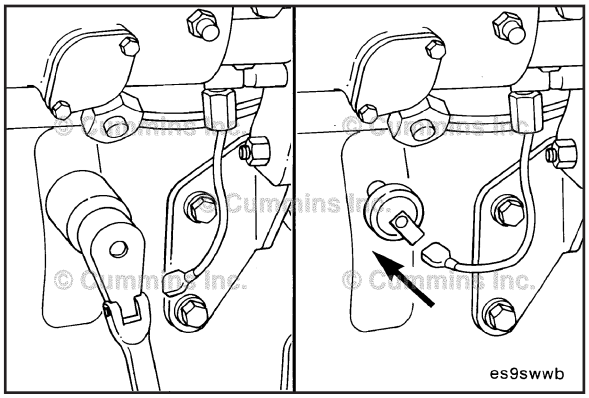
Install

Install the sending unit.

Connect the wire to the sending unit.

Torque Value:

(Installed Cast Iron)	into16 N•m	[142 in-lb]
(Installed Aluminum)	into10 N•m	[89 in-lb]

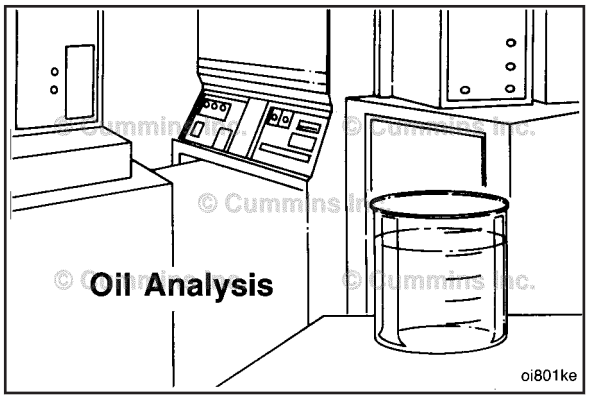


Lubricating Oil and Filter Analysis (007-083)

Inspect

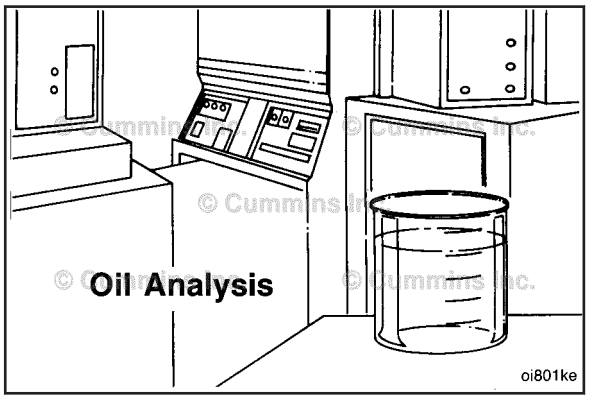
An analysis of used oil can help diagnose internal engine damage and determine if it was caused by one of the following:

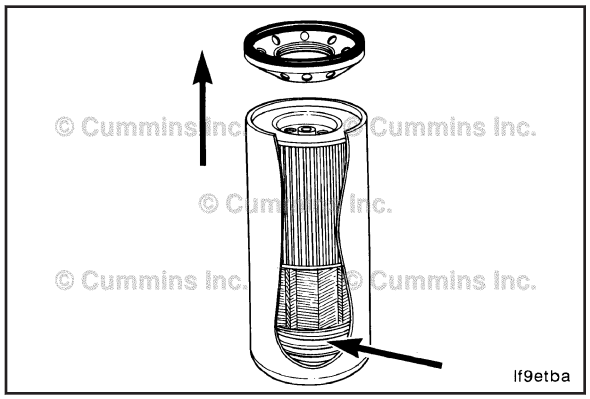
- Intake air filter malfunction
- Coolant leaks
- Oil diluted with fuel
- Metal particles causing wear.



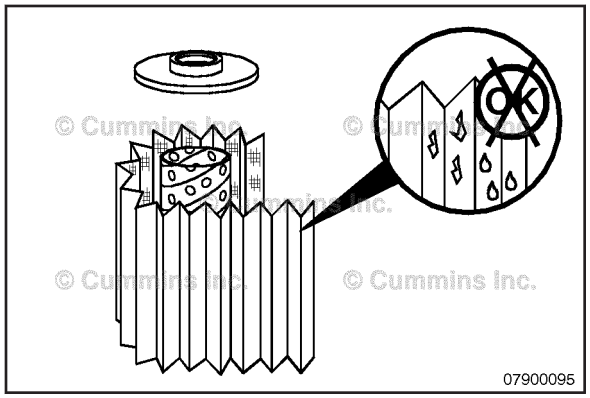
For additional oil analysis information, refer to Cummins® Engine Oil and Oil Analysis Recommendations, Bulletin 3810340.

NOTE: Do **not** disassemble an engine for repair based solely on the results of an oil analysis. Inspect the oil filters. If an oil filter shows evidence of internal engine damage, find the source of the problem and repair the damage. Reference the appropriate procedure(s) based on the following oil filter inspection.





⚠WARNING⚠
Restrain the full flow lubricating oil filter and use care when cutting open the upper section of the combination filter. The filter element spring is under compression and can cause personal injury.



Use tube cutter, Part Number 3376579, to open the upper section of the bypass full-flow oil filter.

Inspect the filter element for evidence of moisture or metal particles.

Metal	Possible Source
Copper	Bearings and bushings
Chromium	Piston rings
Iron	Cylinder liners
Lead	Bearing overlay material
Aluminum	Piston wear or scuffing

Section 8 - Cooling System - Group 08

Section Contents

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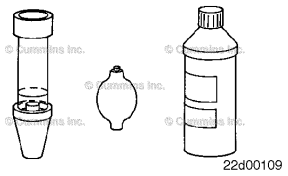
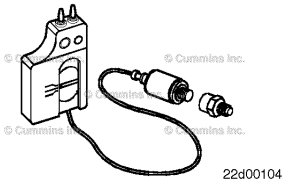
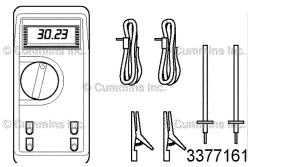
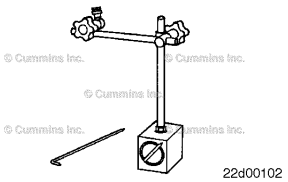
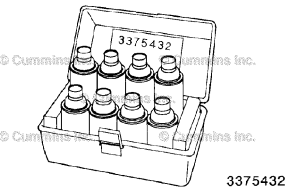
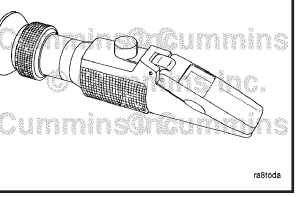
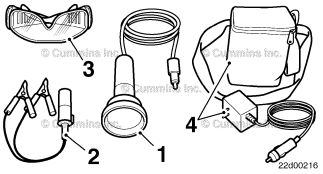
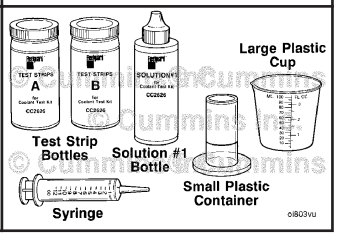
Service Tools

Cooling System

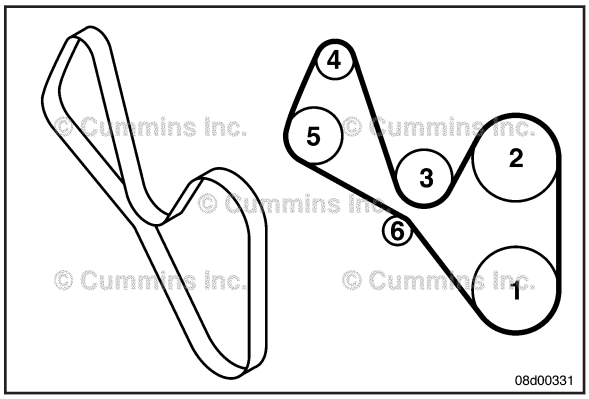
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3822985	**Combustion Gas Leak Tester** Used to test for combustion gasses in the cooling system.	
3164491	**Pressure/Vacuum Module** Used to measure fuel pressure and restriction. Use with multimeter, Part Number 3164488 or 3164489.	
3164488 or 3164489	**Multimeter** Used to measure electrical circuits: Voltage (volts), resistance (ohms), and current (amps). 3164488 — Standard meter. 3164489 — Automotive meter with built in temperature adapter and tachometer.	
3377399	**Magnetic Base Indicator Holder** Used in conjunction with Dial Indicator. Metric — Part Number 3824564. SAE — Part Number 4918289.	
3375432	**Crack Detection Kit** Used to detect cracks in engine components.	
CC-2800	**Refractometer** The Fleetguard® refractometer is used to check the charge condition of a conventional battery.	

Tool No.	Tool Description	Tool Illustration
3824319	**Coolant Dam/Pressure Tester** Using shop air pressure the coolant dam creates a vacuum, holding the coolant in with little or no coolant loss.	
3163338	**Black Light Lamp (12VDC)** Used with fluorescent tracer to locate coolant and/or oil leaks. Lamp operates off vehicle battery or portable rechargeable battery included in kit. Oil tracer Part Number 3376891, coolant tracer Part Number 3377438.	
CC-2626	**Cooling System Test Kit** The Fleetguard® coolant test kit is used to inspect the concentration of coolant additives in the cooling system.	

Drive Belt, Cooling Fan (008-002)

General Information



Due to the number of cooling fan drive belt arrangements, this procedure does not cover all available cooling fan drive belt routings.

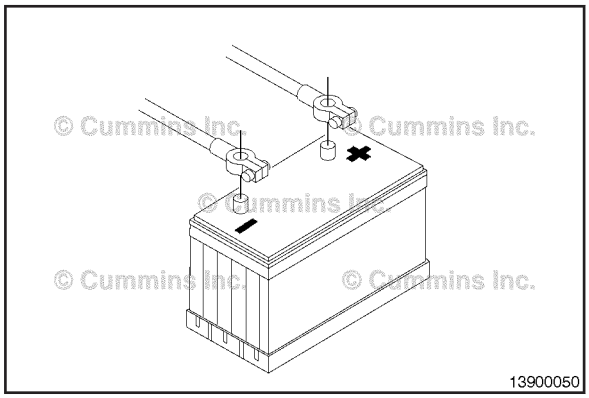
To ensure the cooling fan drive belt is routed correctly upon installation, make a diagram of the cooling fan belt routing prior to removing the belt as shown in the illustration.

The cooling fan belt routing typically consists of the following components, but may not include all of them:

1. Crankshaft Pulley/Vibration Damper
2. Fan Pulley
3. Water Pump Pulley
4. Alternator Pulley
5. Refrigerant Compressor Pulley
6. Belt Tensioner Pulley
7. Idler Pulley(s) (**not** shown)

NOTE: Some engine driven belts are installed/supplied by the vehicle's OEM. See the OEM's service manual on removal and installation procedures.

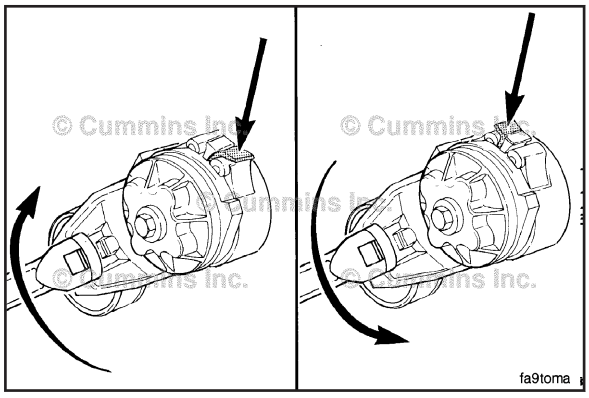
Preparatory Steps



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

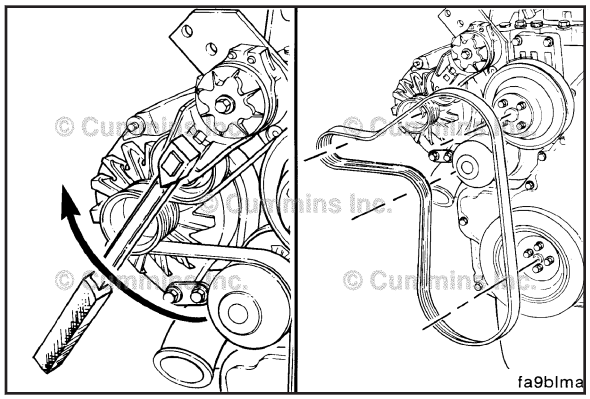
- Disconnect the batteries.

Remove



⚠CAUTION⚠
The belt tensioner is spring-loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

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

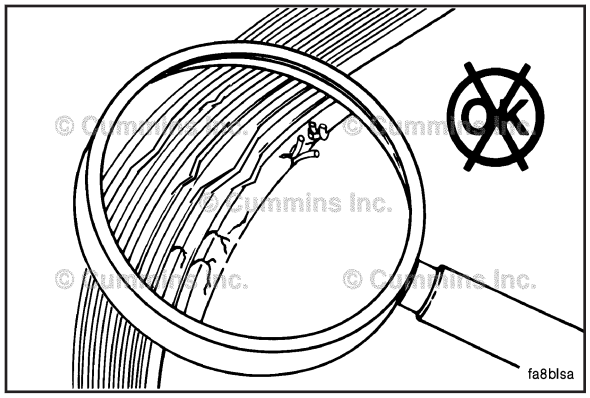


CAUTION
Applying excessive force in the opposite direction of windup or after the tensioner has been wound up to the positive stop can cause the tensioner arm to crack or break.

NOTE: Make a diagram of the belt arrangement prior to removing the drive belt to aid in installation and ensure proper routing of the cooling fan drive belt.

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

Remove the drive belt.

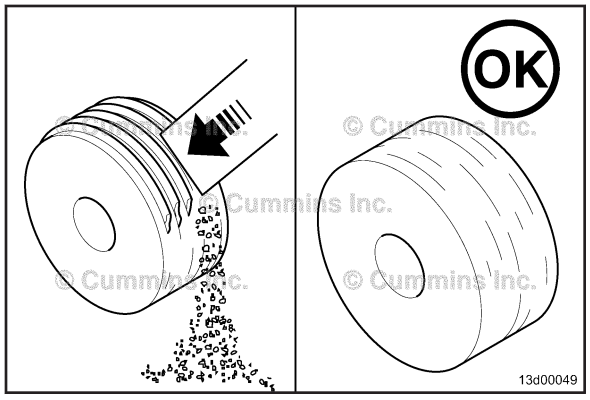


Inspect for Reuse

Inspect the belt for:

- Cracks
- Glazing
- Tears or cuts
- Excessive wear.

Replace the belt if any damage is found.



Inspect the idler and drive pulleys for wear or cracks.

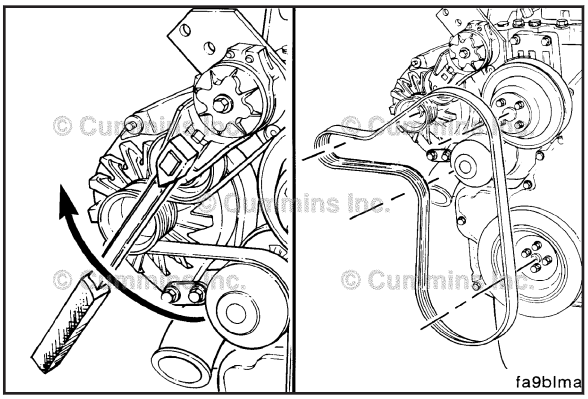
Plastic pulleys often have a build-up of road dirt and belt material that is **not** to be confused with wear.

The dirt can be removed with a suitable tool to check for wear.

Clean, check and reuse idlers with a build up of dirt, rather than replacing.

Inspect the belt tensioner. Refer to Procedure 008-087.

Install



⚠CAUTION⚠
The belt tensioner is spring-loaded and must be pivoted away from the drive belt. Pivoting in the wrong direction can result in damage to the belt tensioner.

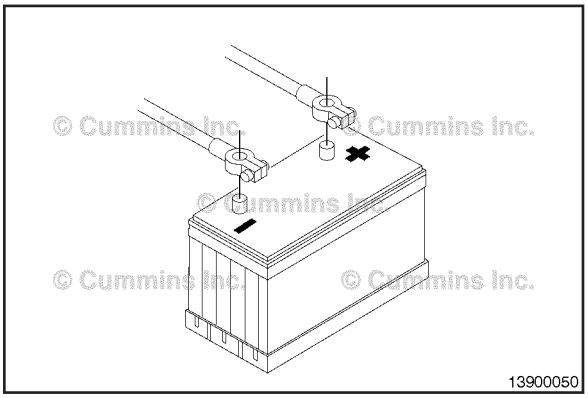
Route the drive belt on the engine using the belt diagram created in the remove step. Do **not** install the belt over the water pump pulley at this time.

Pivot the tensioner in the direction of the spring tang and install the drive belt, slipping the belt over the water pump pulley last.

Release the tensioner to apply tension to the drive belt.

Check the alignment of the belt with the tensioner and the rest of the front end auxiliary drive.

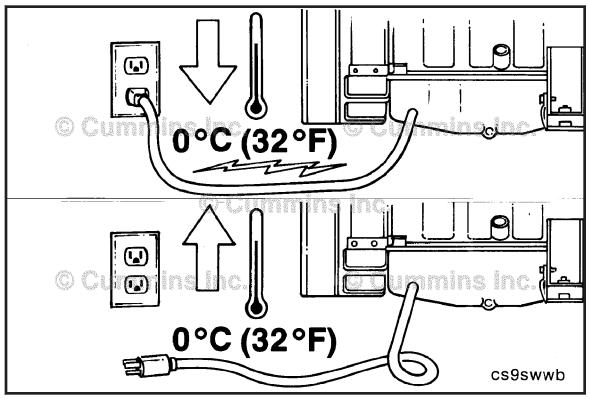
Finishing Steps



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

- Connect the batteries.

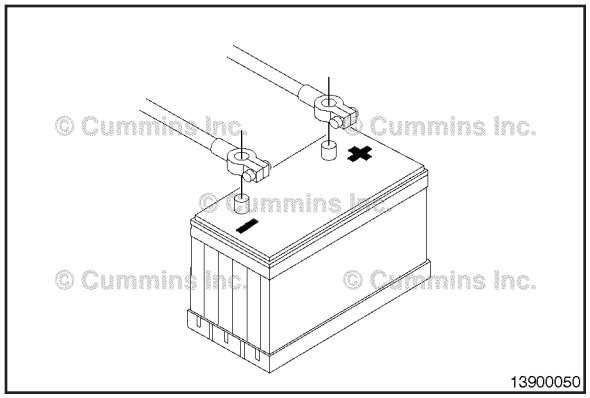
- Operate the engine and check for belt squeal. Excessive belt squeal indicates belt slippage.
- If belt squeal is present, check the routing of the belt and make sure that the belt is installed correctly on each pulley.



Coolant Heater (008-011)

General Information

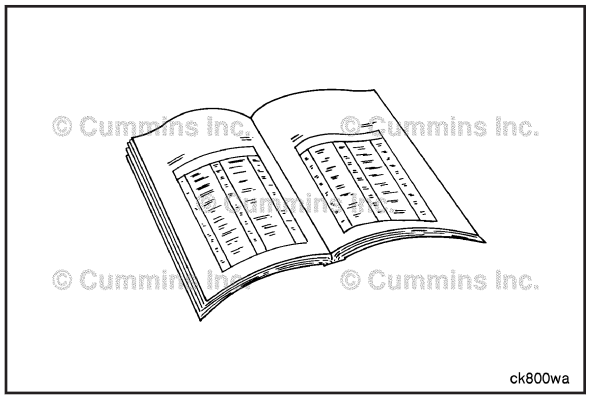
Some heaters will operate continuously when plugged into the correct voltage electrical socket. Operate them **only** when the ambient temperature is below 0°C [32°F].



Preparatory Steps

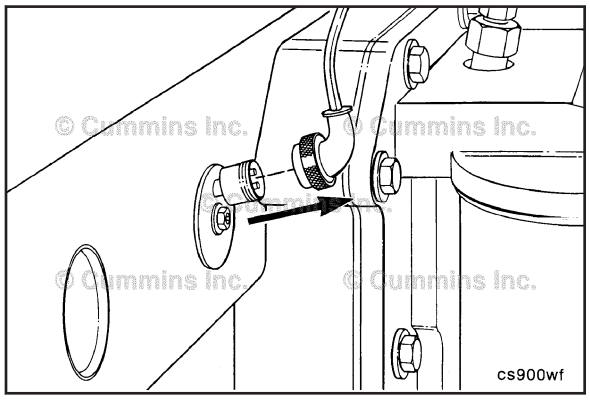
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries.



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

- Drain at least 19 liters [5 US Gal]. Refer to Procedure 008-018.



Remove

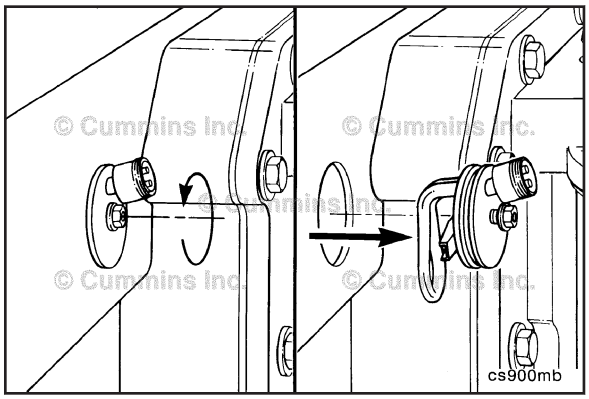
Front Gear Train

Disconnect the block heater electrical cord.

NOTE: Depending on the type of cylinder block, there are two types of coolant heaters used. A bolted coolant heater and a threaded coolant heater. Both are located adjacent to the lubricating oil cooler.

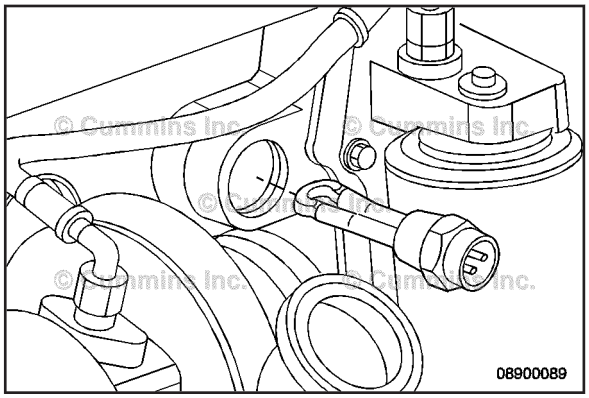
For bolted coolant heaters, loosen the block heater retaining nut.

Remove the coolant heater from the block.



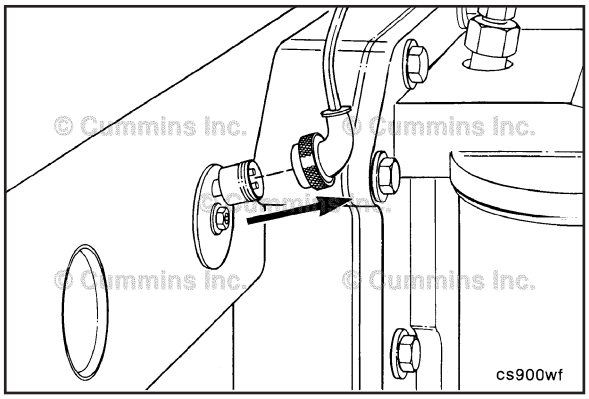
For threaded coolant heaters, unthread the coolant heater from the block.

Remove the coolant heater from the block.



Rear Gear Train

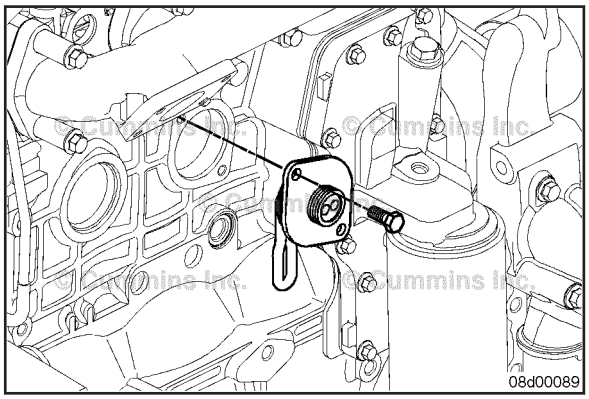
Disconnect the block heater electrical cord.

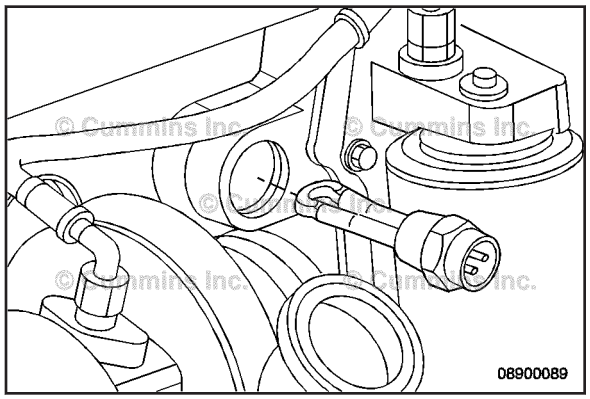


NOTE: Depending on the type of cylinder block, there are two types of coolant heaters used. A flange mounted coolant heater and a threaded coolant heater.

For flange mount coolant heaters, remove the two retaining capscrews.

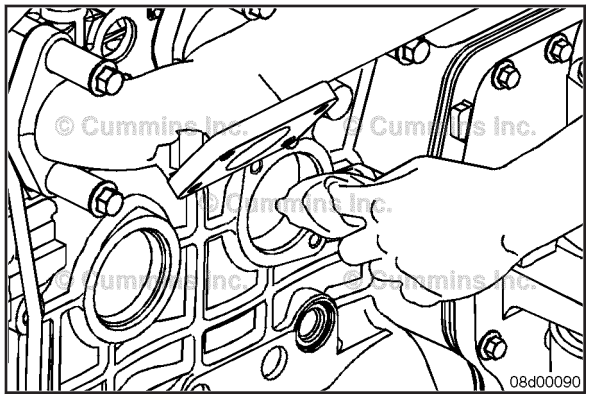
Remove the coolant heater from the block.





For threaded coolant heaters, unthread the coolant heater from the block.

Remove the coolant heater from the block.

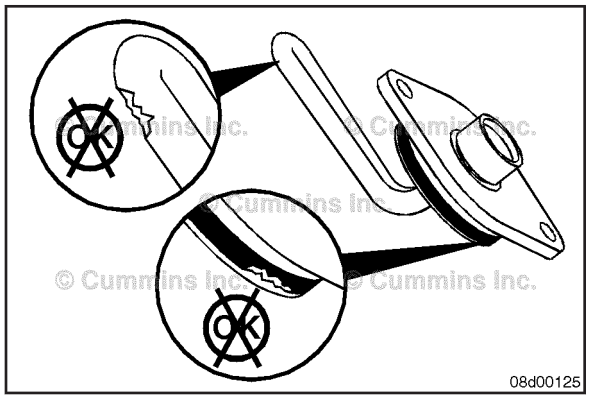


Clean and Inspect for Reuse

Clean the cup plug bore (or hole) thoroughly with a clean rag.

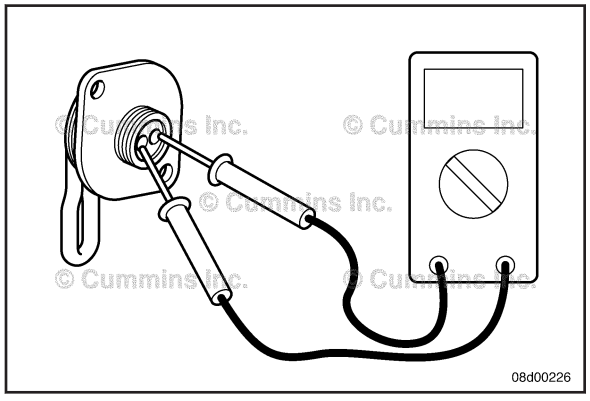
Make sure there are no burrs, metal shavings, or sharp edges that can possibly cut the o-ring.

Clean the coolant heater thoroughly with a clean rag. Make sure the heating element is free of debris and buildup and the sealing area is clean.



Check the coolant heater for cracks on the element.

Check the o-ring for cracks.



⚠WARNING⚠
To reduce the possibility of personal injury, due to electrical shock, do not touch the electrical supply wires or component while the testing procedure is in action.

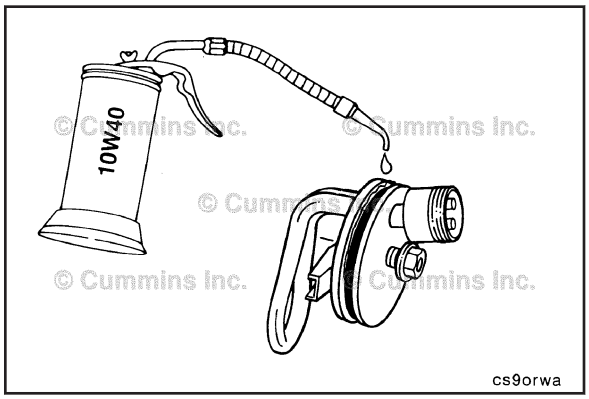
Test the coolant heater resistance. The resistance **must** read between minimum 18.2 to maximum 21.1 ohms.

Coolant Heater Resistance (Ohms)	
MIN	**MAX**
18.2 Ohms	21.1 Ohms

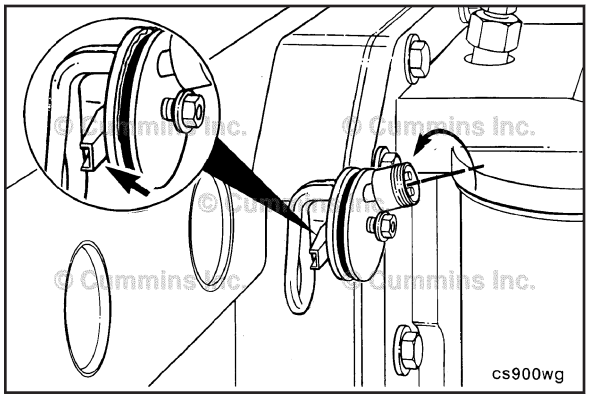
Install

Front Gear Train

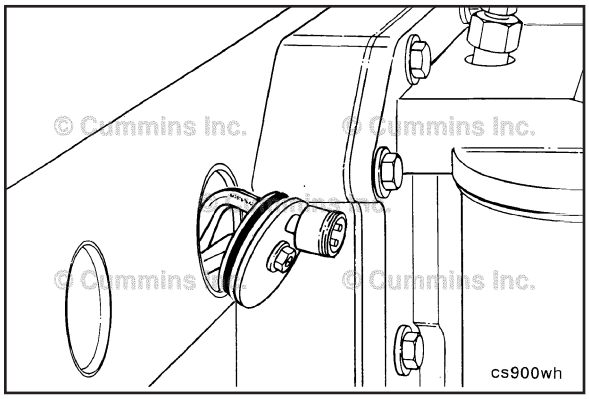
For bolted coolant heaters, lubricate the new heater o-ring with clean lubricating engine oil.



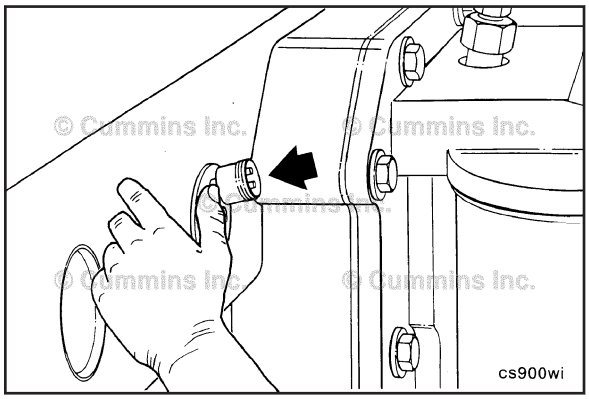
The locking channel (T-bar) should be threaded out to the end of the bolt. If so equipped, do **not** remove the retaining wire used to position the channel (T-bar).

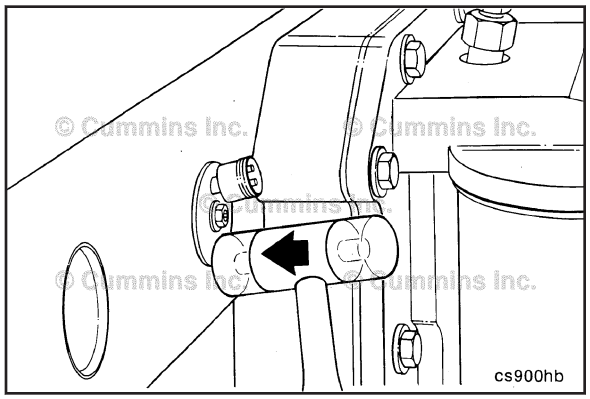


Hook the element and one leg of the channel (T-bar) into the hole as illustrated.

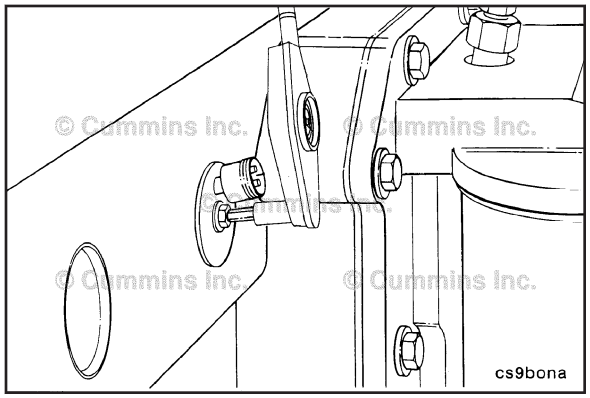


Hook the other leg of the channel in the hole, and push the heater into the hole as far as possible by hand.





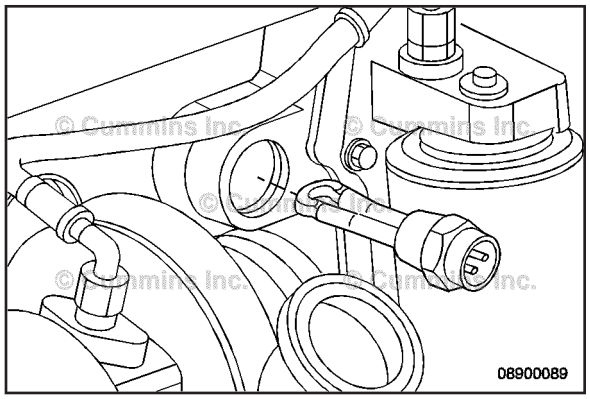
If necessary, use a plastic hammer to tap the heater in until the shoulder contacts the block.



Torque Value:

Minimum:	1.3 N•m	[12 in-lb]
Maximum:	2.8 N•m	[25 in-lb]

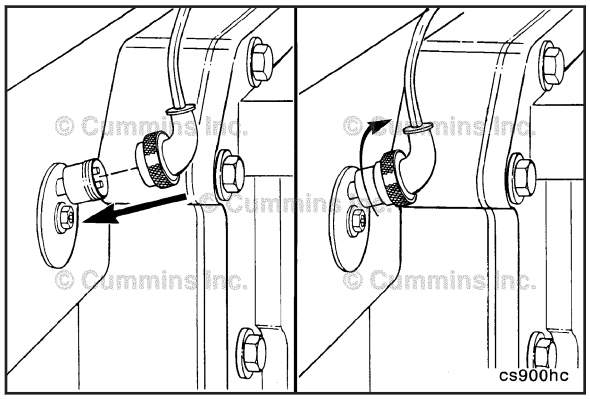
NOTE: Do **not** overtighten.



For threaded coolant heaters, apply pipe sealant, Part Number 3375066, to threads of the coolant heater.

Install the coolant heater into the cylinder block and tighten.

Torque Value: 55 N•m [41 ft-lb]

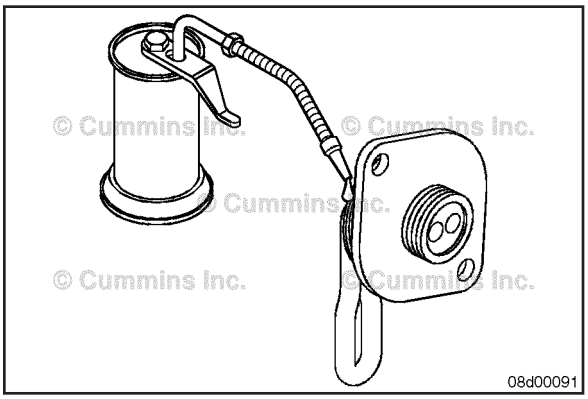


Insert the power cord into the socket being careful to align the pins with the sockets of the power cord. Tighten the retaining nut by hand.

NOTE: Do **not** apply power until the cooling system is filled, and has run long enough for the thermostat to open and allow the air to escape.

Rear Gear Train

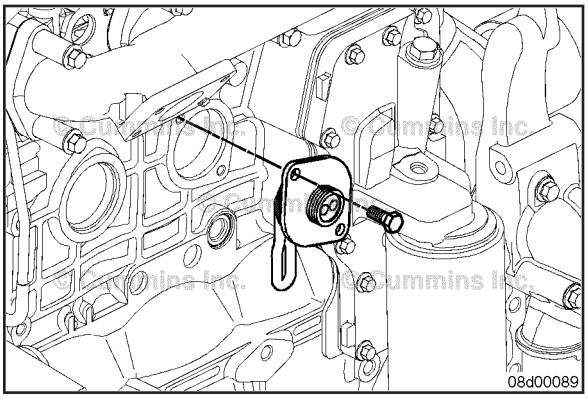
For flange mounted coolant heaters, lubricate the new heater o-ring with clean 15W-40 engine oil.



Install the coolant heater and retaining capscrews.

Tighten the two retaining capscrews.

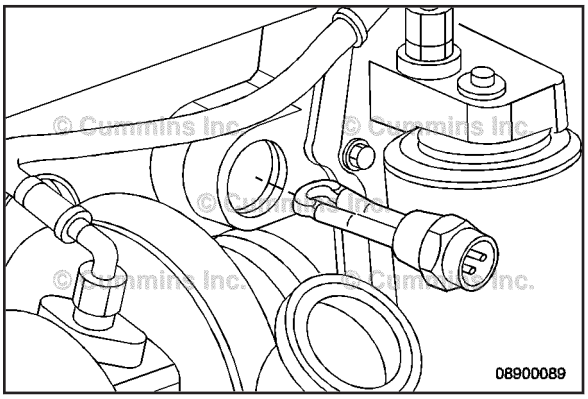
Torque Value: 24 N•m [212 in-lb]



For threaded coolant heaters, apply pipe sealant, Part Number 3375066, to threads of the coolant heater.

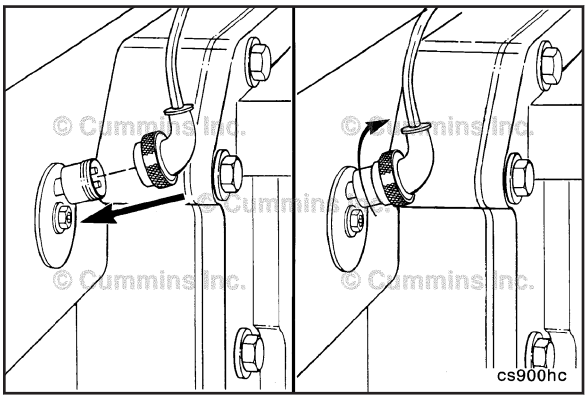
Install the coolant heater into the cylinder block and tighten.

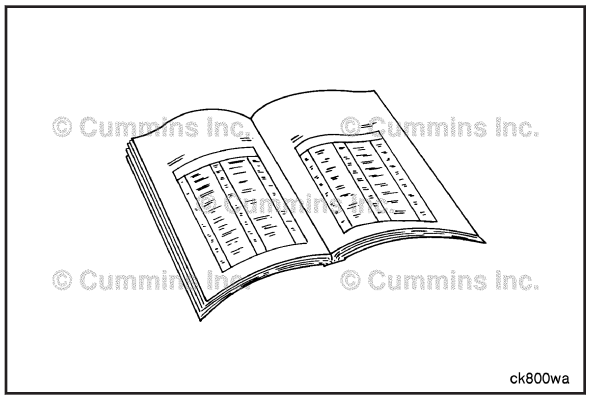
Torque Value: 55 N•m [41 ft-lb]



Insert the power cord into the socket being careful to align the pins with the sockets of the power cord. Tighten the retaining nut by hand.

NOTE: Do **not** apply power until the cooling system is filled, and has run long enough for the thermostat to open and allow the air to escape.

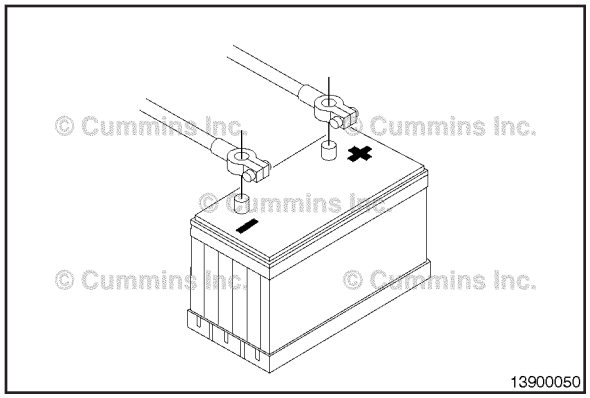




Finishing Steps

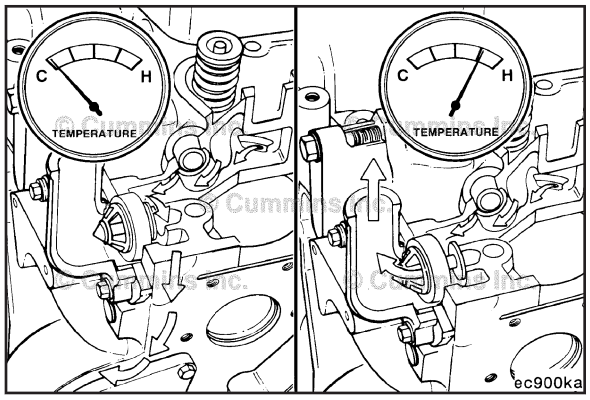
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

- Fill the engine cooling system. Refer to Procedure 008-018.



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

- Connect batteries
- Operate engine and check for leaks.

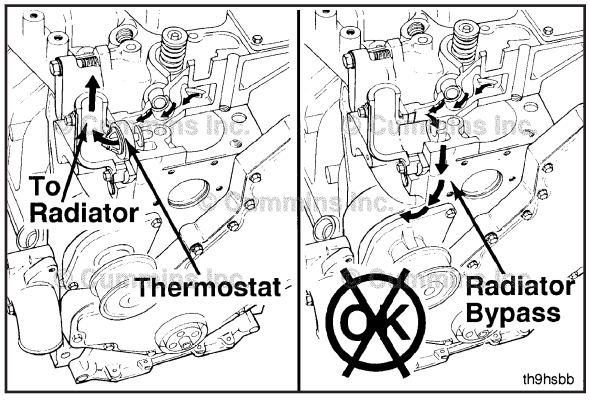


Coolant Thermostat (008-013)

General Information

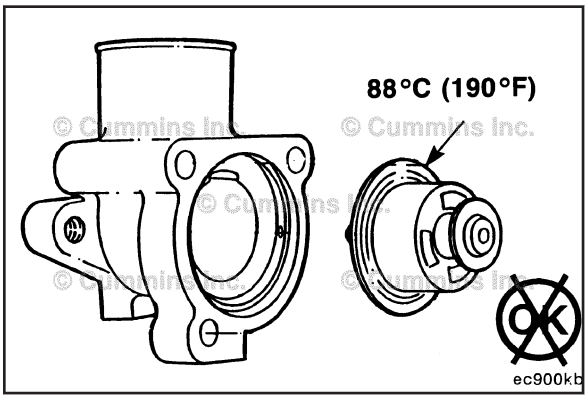
Front Gear Train

The thermostat controls the coolant temperature. When the coolant temperature is below the operating range, coolant is bypassed back to the inlet of the water pump. When the coolant temperature reaches the operating range, the thermostat opens, sealing off the bypass, forcing coolant to flow to the radiator.

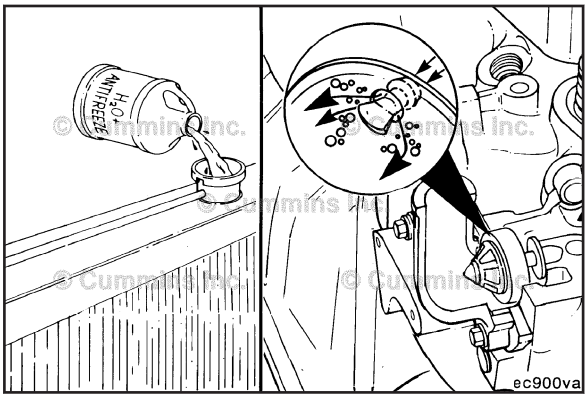


△CAUTION△
Always use the correct thermostat, and never operate the engine without a thermostat installed. The engine can overheat if operated without a thermostat because the path of least resistance for the coolant is through the bypass to the pump inlet.

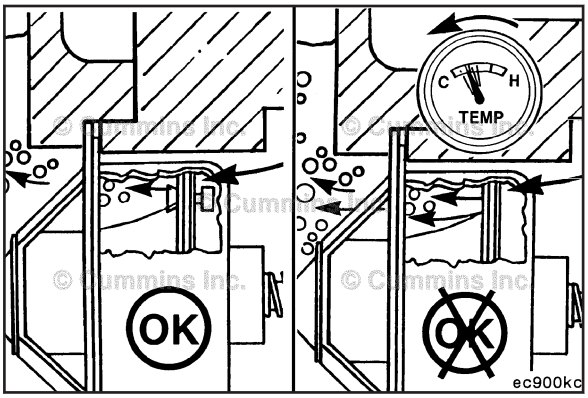
An incorrect or malfunctioning thermostat can cause the engine to overheat or run too cold.



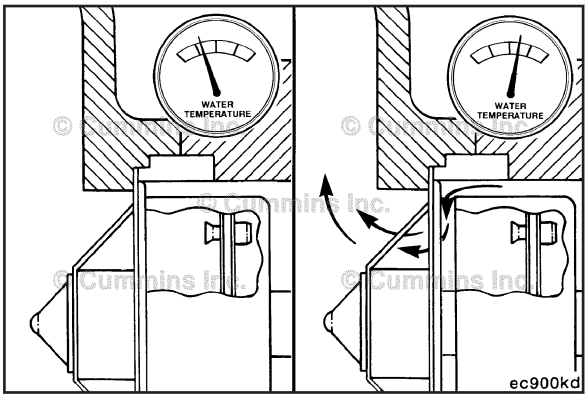
As described in the coolant discussion, jiggle pins vent air during filling of the coolant system.

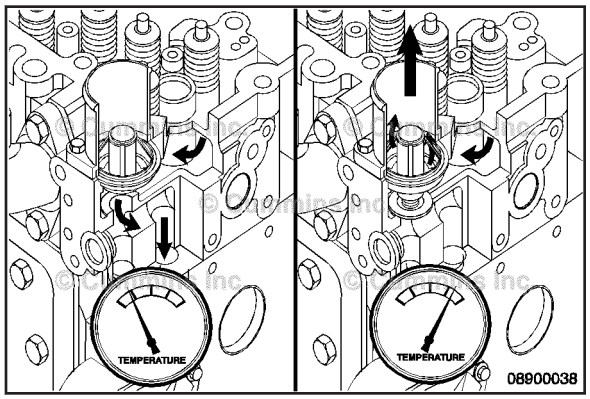


After the engine is vented and filled, the jiggle pins act as check valves to block the flow of coolant through the opening during engine operation.



With the jiggle pins sealing the openings, the flow to the radiator is controlled by the thermostat opening in response to the engine coolant temperature.

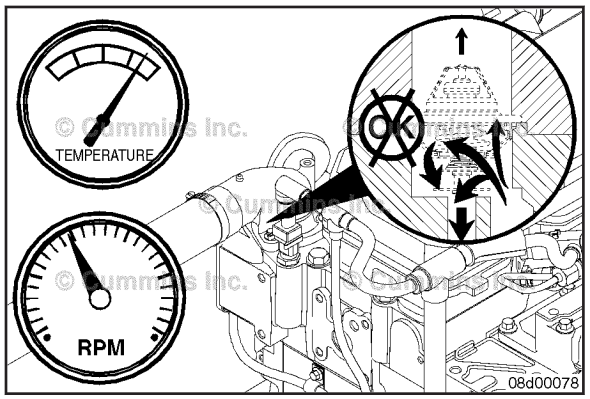




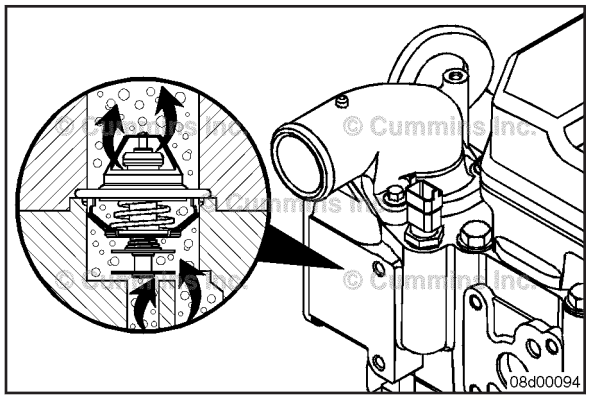
Rear Gear Train

The thermostat controls the engine coolant temperature. When the coolant temperature is below the operating range, engine coolant is bypassed back to the inlet of the water pump. When the engine coolant temperature reaches the operating range, the thermostat opens, sealing off the bypass, forcing engine coolant to flow to the radiator or heat exchanger.

An incorrect or malfunctioning thermostat can cause the engine to run too hot or too cold.



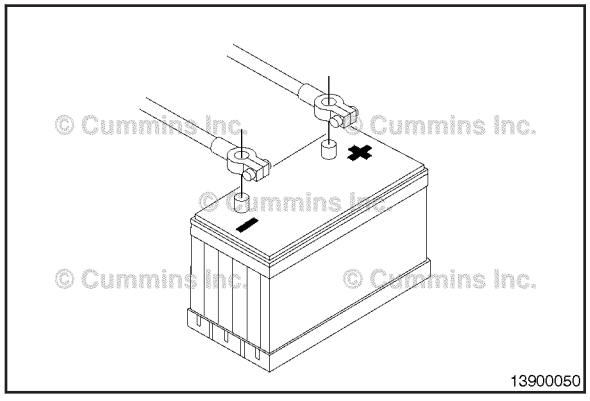
⚠CAUTION⚠
Never operate the engine without a thermostat. Without a thermostat, the path of least resistance for the coolant is through the bypass to the water pump inlet. This can cause the engine to overheat.



⚠CAUTION⚠
A missing check ball can cause the engine to run cold, resulting in engine damage.

The thermostat contains two check balls to vent air past the thermostat when it is closed. This is needed for the cooling system to fill.

NOTE: Some off-highway applications use a thermostat with one check ball. When servicing a thermostat always be sure to replace with the same part number. Though an incorrect thermostat will physically fit, it will lead to improper engine operation.



Preparatory Steps

Front Gear Train

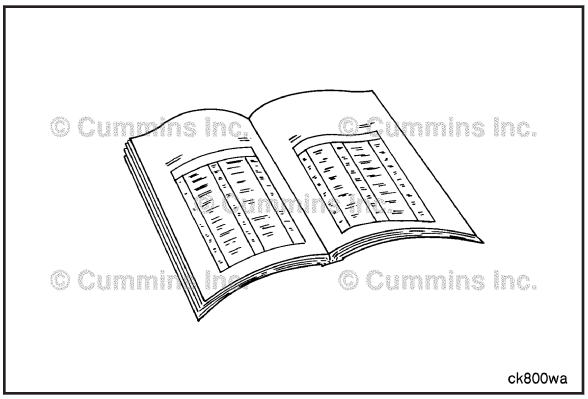
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries.

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

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

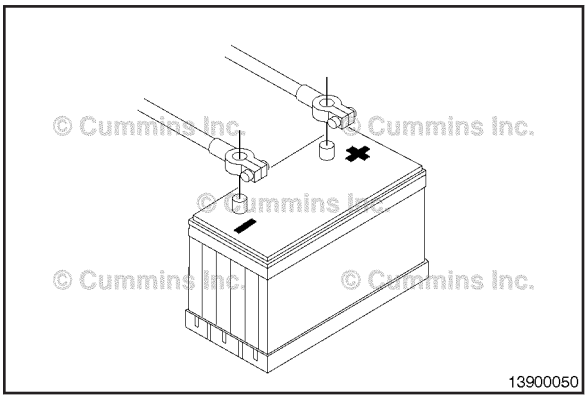
- Drain the coolant. Refer to Procedure 008-018
- Disconnect the upper radiator hose. Refer to Procedure 008-045
- Remove the coolant fan drive belt. Refer to Procedure 008-002.



Rear Gear Train

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

- Disconnect the batteries.

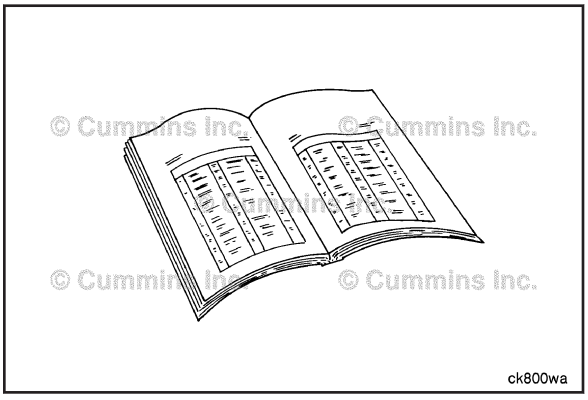


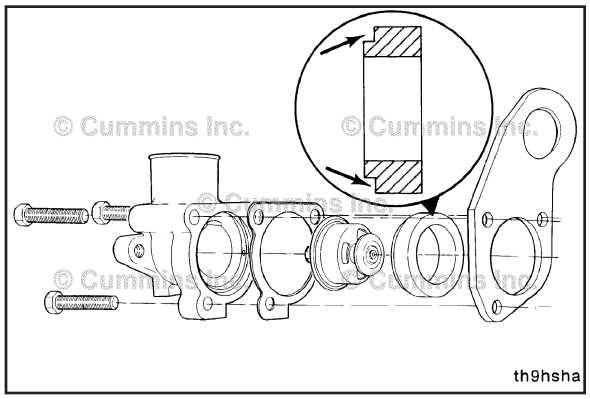
⚠WARNING⚠
Coolant is toxic. Keep away from children and pets. If not reused, dispose of in accordance with local environmental regulations.

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

⚠CAUTION⚠
Use caution when draining coolant that coolant is not spilled or drained into the bilge area. Do not pump the coolant overboard. If the coolant is not reused, it must be discarded in accordance with local environmental regulations.

- Drain the coolant below the level of the thermostat. Refer to Procedure 008-018
- Disconnect the upper radiator hose. Refer to Procedure 008-045.

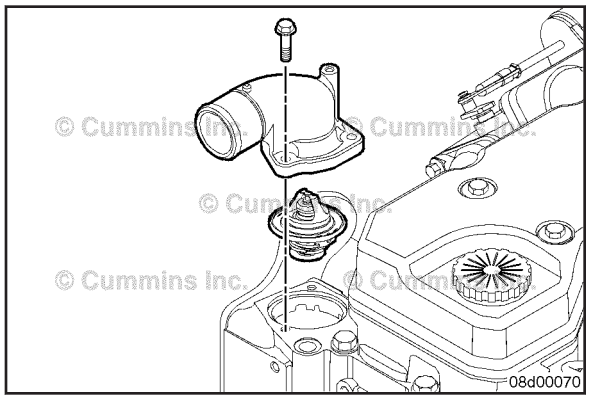




Remove

Front Gear Train

Remove three capscrews, the thermostat housing, lifting bracket, thermostat, and thermostat seal.

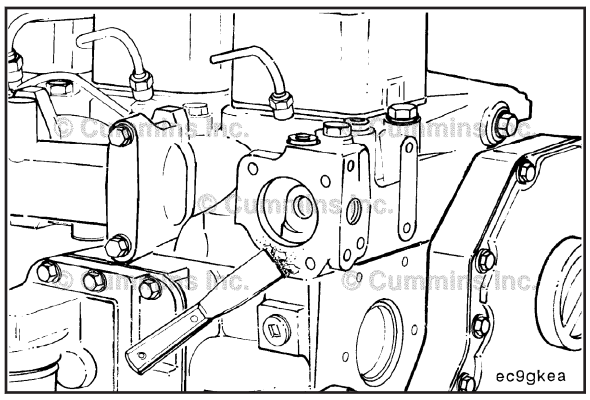


Rear Gear Train

Remove the water outlet connection capscrews.

Remove the water outlet connection.

Remove the thermostat.

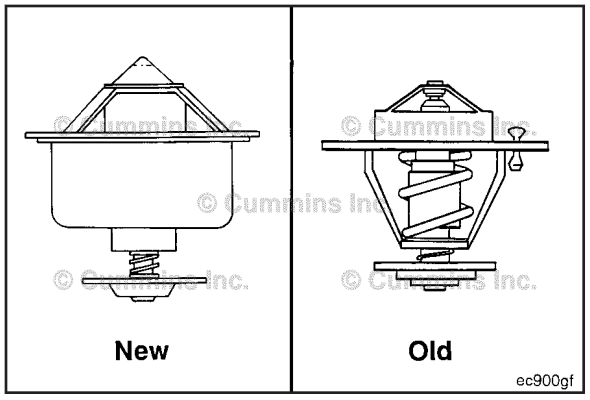


Clean and Inspect for Reuse

Front Gear Train

Clean the mating surfaces.

NOTE: Do **not** let any debris fall into the thermostat cavity when cleaning the gasket surfaces.



Inspect the thermostat for obvious damage such as obstructions caused by debris, broken springs, or stuck or missing vent pins.

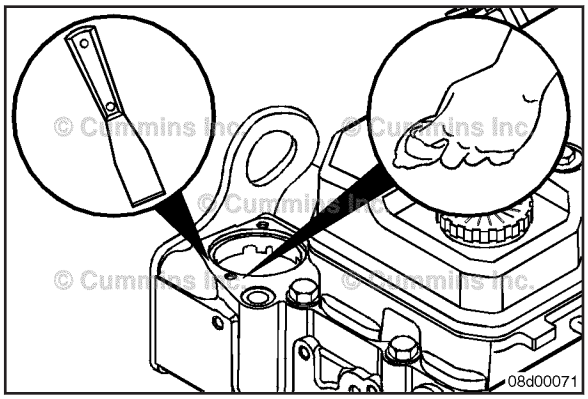
Make sure the thermostat is clean and free from corrosion.

Rear Gear Train

⚠CAUTION⚠

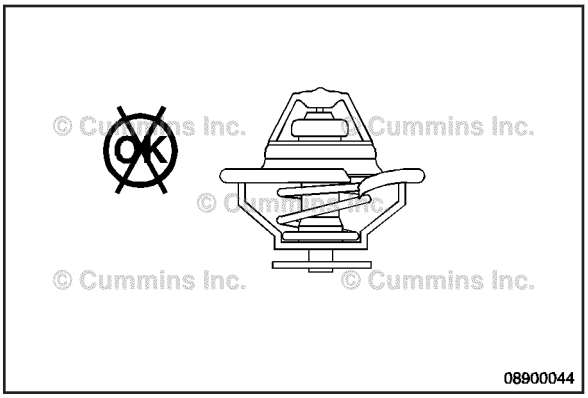
Do not let any debris fall into the thermostat cavity when cleaning the gasket surfaces. Damage to the cooling system and engine can occur.

Clean the mating surfaces with a gasket scraper and a clean cloth.



Inspect the thermostat for cracks, tears, damage, missing soft seat.

Remove and discard the gasket.



Test

Front Gear Train

Suspend the thermostat and a 100°C [212°F] thermometer in a container of well-mixed water.

NOTE: Do **not** allow the thermostat or thermometer to touch the side of the container.

Heat the water slowly so the wax element in the thermostat has sufficient time to react to the rising water temperature.

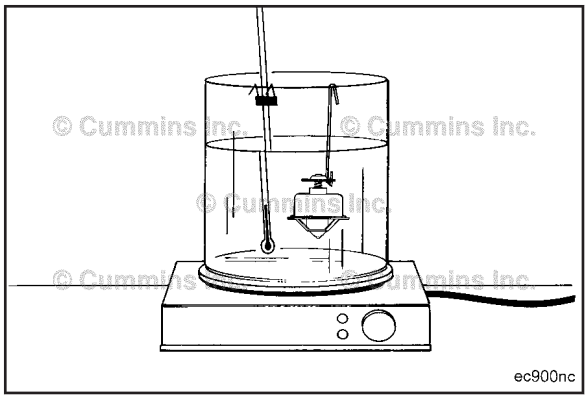
Check the thermostat as follows:

Requirements

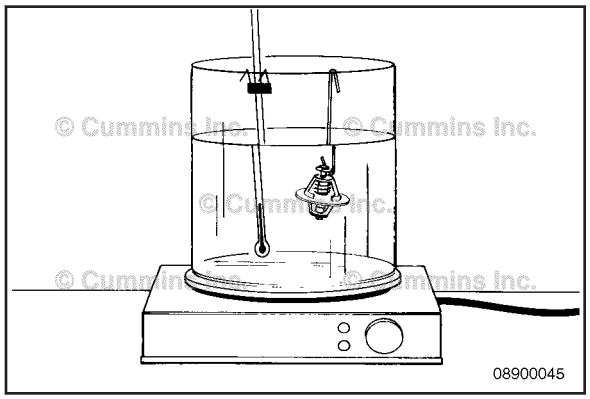
Starts to open within 1°C [34°F] of 83°C [181°F].

Fully open within 1°C [34°F] of 95°C [203°F].

A full-open clearance between the thermostat flow valve and flange.



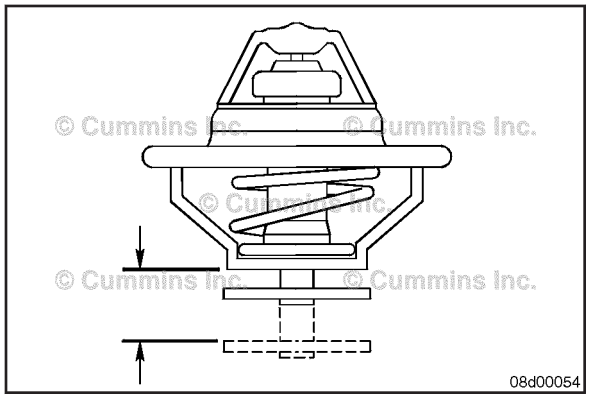
Flow Valve and Flange Clearance		
mm		in
6.6	MIN	0.26



Rear Gear Train

NOTE: Do **not** allow the thermostat or thermometer to touch the container.

Suspend the thermostat and a 100°C [212°F] thermometer in a container of water.



Heat the water and check the thermostat as follows:

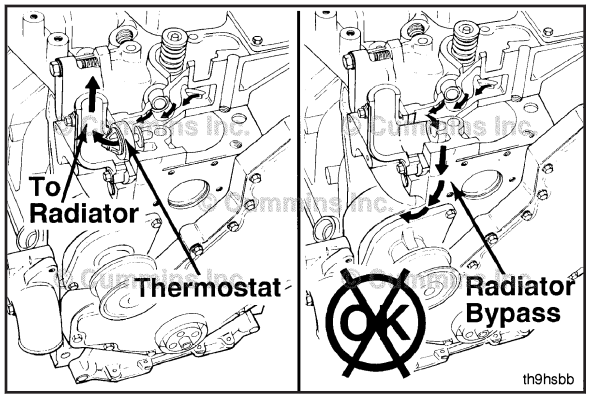
The nominal operating temperature is stamped on the thermostat. The thermostat **must** meet the following criteria:

- It **must** begin to open within 1°C [2°F] of nominal temperature.
- It **must** be fully open within 12°C [22°F] of nominal temperature.

Thermostat Opening Temperatures - Industrial Engines

	°C		°F
Initial Opening Temperature	87	MIN	188
	89	MAX	192
Fully Opened Temperature	96	MAX	205

NOTE: The fully open distance between the thermostat flange and housing is 14.3 mm [0.563 in] minimum.



Install

Front Gear Train

⚠CAUTION⚠

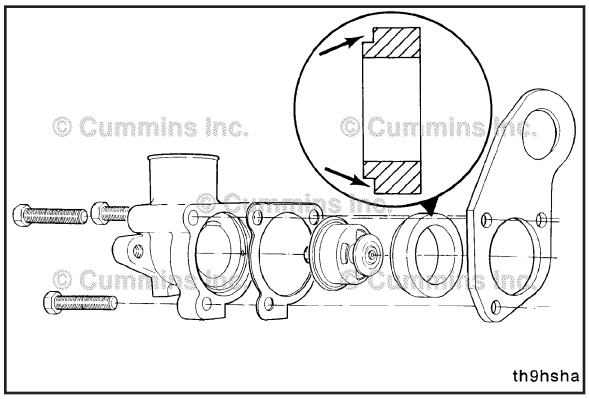
Always use the correct thermostat, and never operate the engine without a thermostat installed. The engine can overheat if operated without a thermostat because the path of least resistance for the coolant is through the bypass to the pump inlet. An incorrect thermostat can cause the engine to overheat or run too cold.

Position the thermostat as shown in the illustration.

Package the lifting bracket and thermostat gasket to the thermostat and thermostat housing.

Make sure the gasket is aligned with the capscrew holes. Install the capscrews and finger tighten.

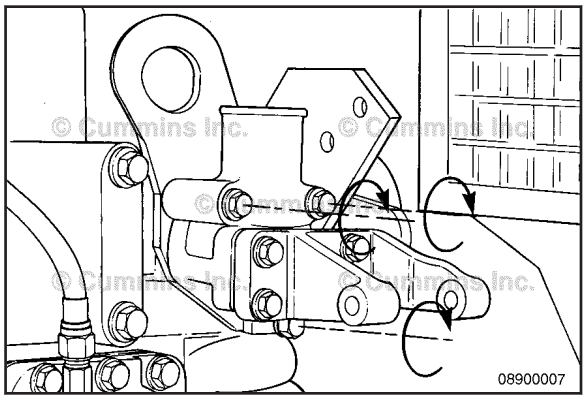
The notched end of the rubber thermostat seal points away from the cylinder head.



Install the removed parts in the reverse order of removal.

Install the thermostat, thermostat seal, thermostat housing, gasket, lifting bracket, and three capscrews.

Torque Value: 24 N•m [18 ft-lb]

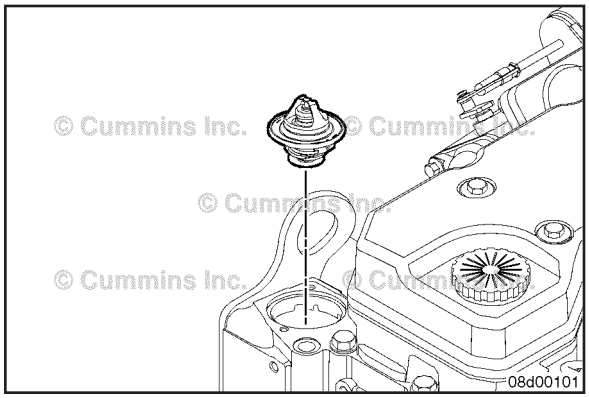


Rear Gear Train

⚠CAUTION⚠
Always use the correct thermostat and do not operate the engine without a thermostat installed. The engine can overheat if operated without a thermostat because the path of least resistance for the coolant is through the bypass to the pump inlet. An incorrect thermostat can cause the engine to overheat or run too cold.

Install the thermostat into the thermostat housing.

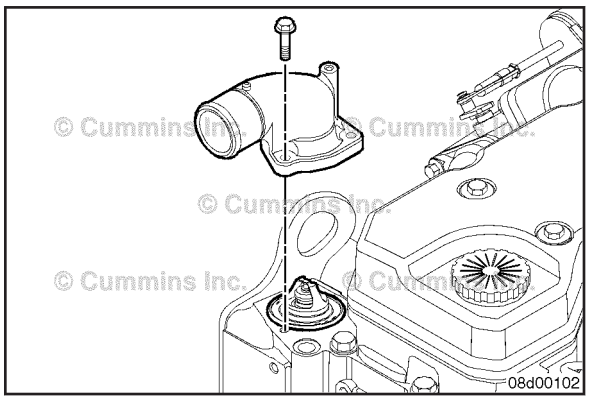
NOTE: Make sure a new thermostat seal is installed on the outer lip of the thermostat flange every time the thermostat is reinstalled.

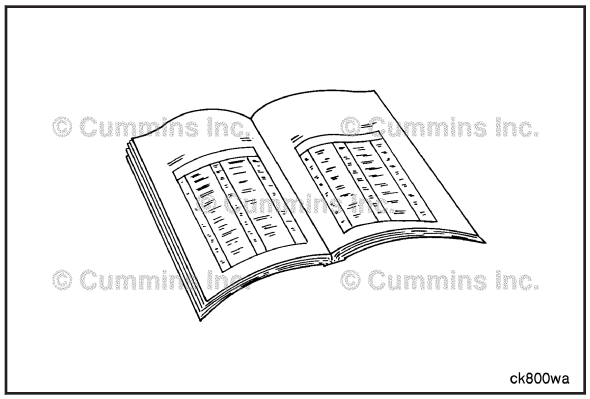


Install the water outlet connection and mounting capscrews.

Tighten the capscrews.

Torque Value: 10 N•m [89 in-lb]

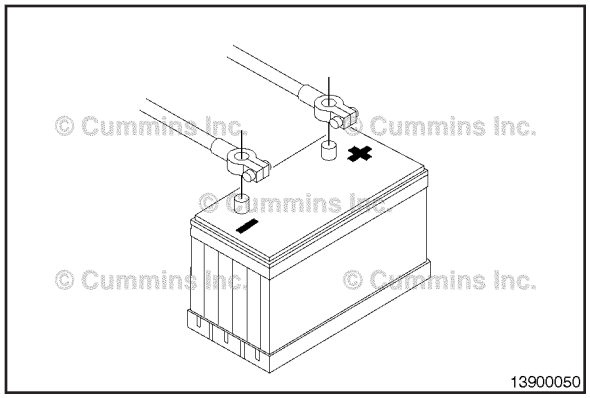




Finishing Steps

Front Gear Train

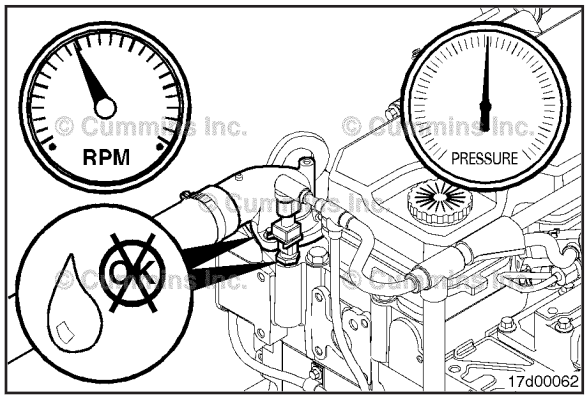
- Install the alternator. Refer to Procedure 013-001
- Install the cooling fan drive belt. Refer to Procedure 008-002
- Connect the upper radiator hose. Refer to Procedure 008-045
- Fill the cooling system. Refer to Procedure 008-018.



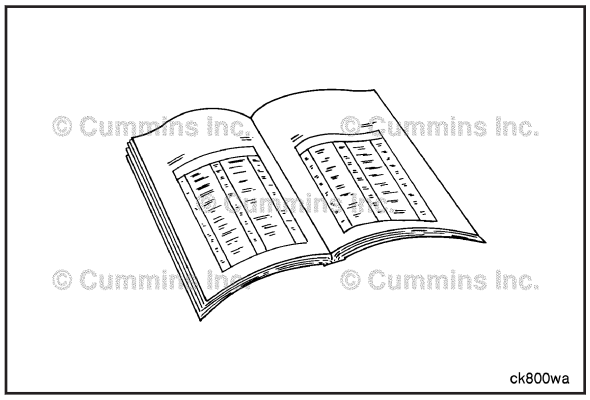
⚠WARNING⚠

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

- Connect the batteries.



- Operate the engine and check for leaks.



Rear Gear Train

- Connect the upper radiator hose. Refer to Procedure 008-045

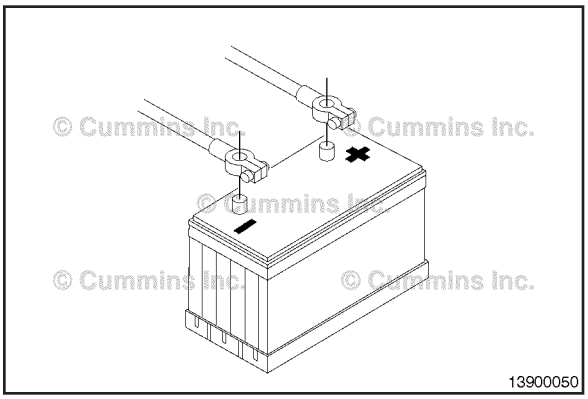
△CAUTION△

Always vent the engine during filling to remove air from the coolant system, or overheating can result.

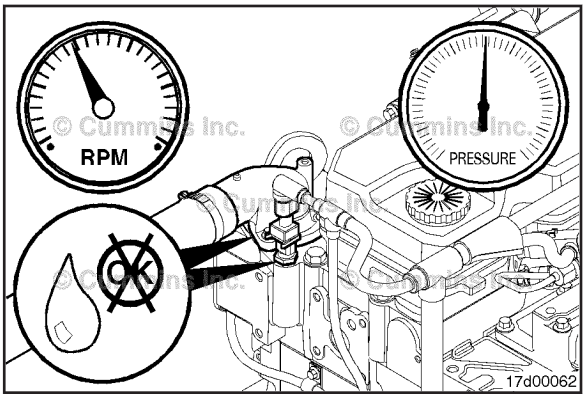
- Fill the cooling system. Refer to Procedure 008-018

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

- Connect the batteries.



- Operate the engine and check for leaks.



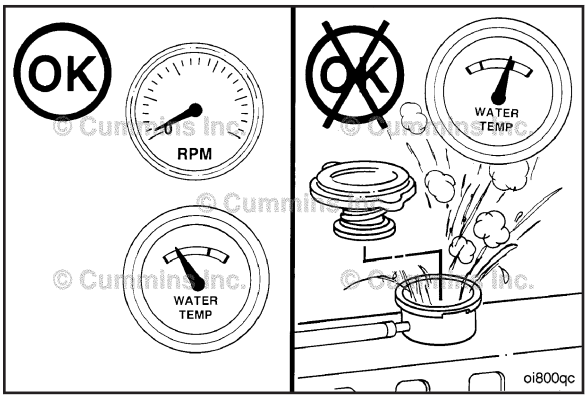
Cooling System (008-018)

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.

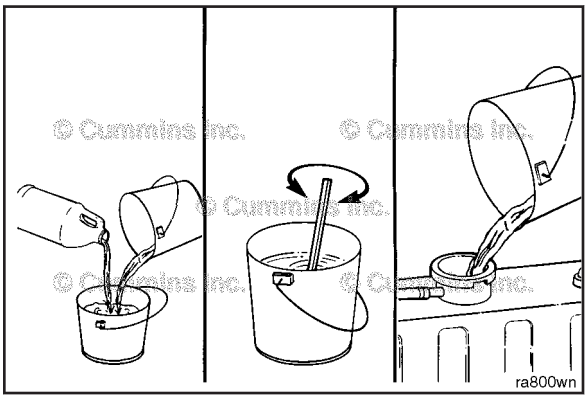
NOTE: Never use a sealing additive to stop leaks in the coolant system. This can result in coolant system plugging and inadequate coolant flow, causing the engine to overheat.

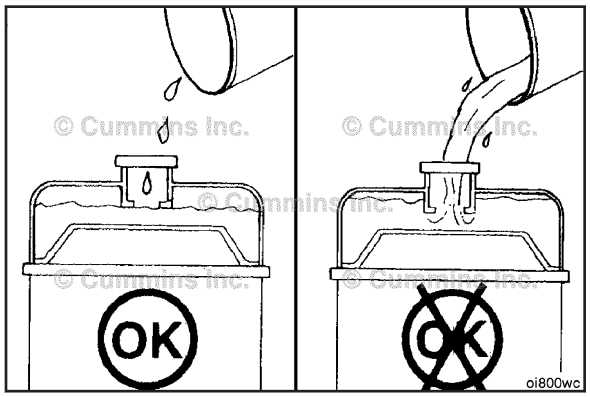
The coolant level **must** be checked daily.



⚠CAUTION⚠
Do not add cold coolant to a hot engine. Engine castings can be damaged. Allow the engine to cool to below 50°C [120°F] before adding coolant.

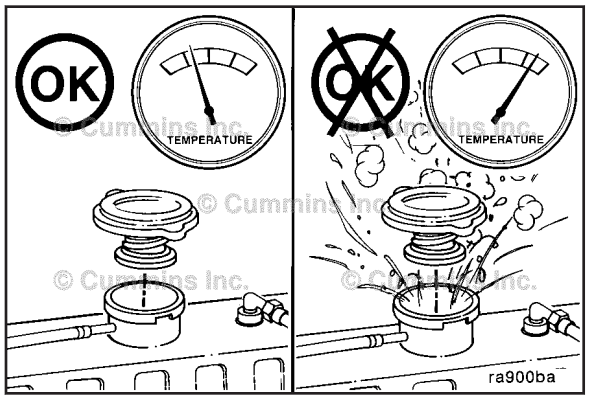
NOTE: On applications that use a coolant recovery system, check to make sure the coolant is at the appropriate level on the coolant recovery tank, depending on engine temperature.





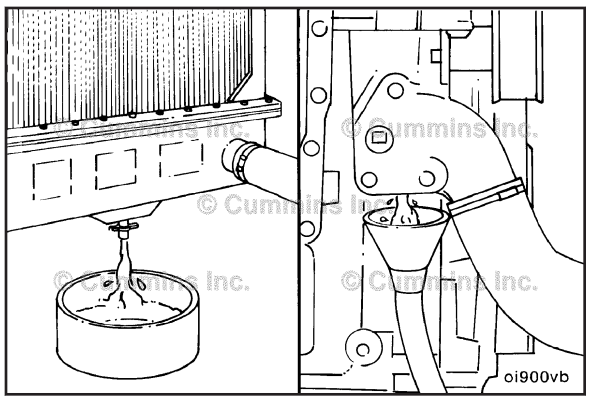
Fill the cooling system with coolant to the bottom of the fill neck in the radiator fill or expansion tank.

NOTE: Some radiators have two fill necks, both of which **must** be filled when the cooling system is drained.



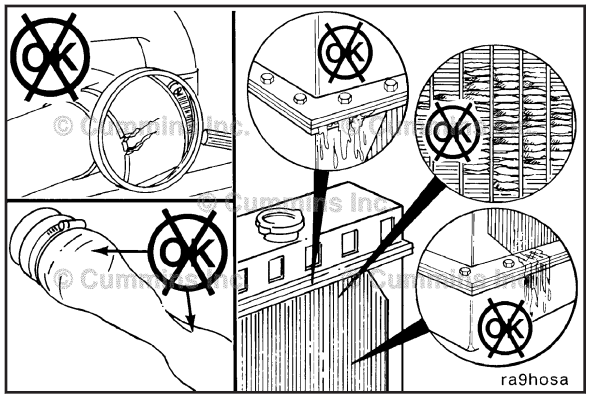
Drain

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



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

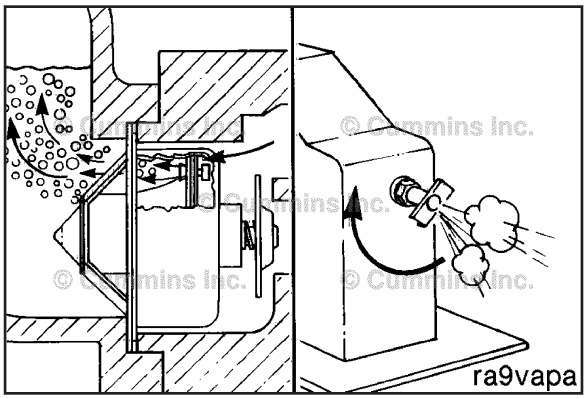
Drain the cooling system by opening the drain valve on the radiator and removing the plug in the bottom of the water inlet. A drain pan with a capacity of 19 liters [5 gal] will be adequate in most applications.



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

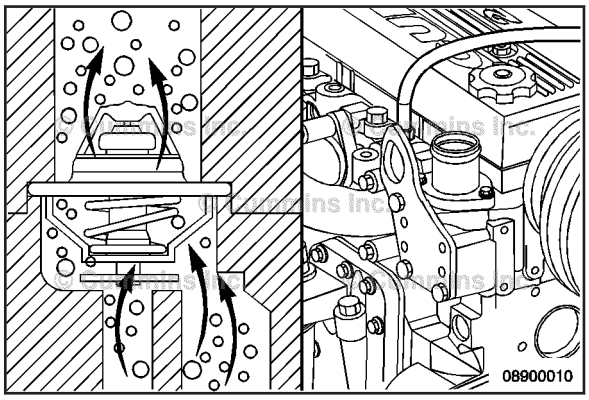


⚠CAUTION⚠
During filling, air must be vented from the engine coolant passages. The air vents through the jiggle pin openings to the top radiator hose and out the fill opening. Additional venting is provided for engines equipped with an aftercooler. Open the petcock during filling.

For front gear train engines with aftercoolers, open the petcock during filling for additional venting.

For front gear train engines without aftercoolers, the air vents through the jiggle pin openings in the thermostat to the top radiator hose and out the fill opening.

This provides adequate venting for a fill rate of 19 liters per minute [5 U.S. gallons per minute].



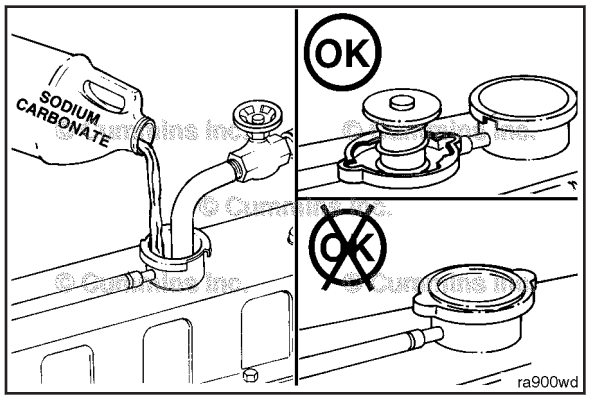
⚠CAUTION⚠
The system must be filled properly to prevent air locks. During filling, air must be vented from the engine coolant passages. Wait 2 to 3 minutes to allow air to be vented then add mixture to bring the level to the top.

For rear gear train engines, a dearation port next to the water outlet connection vents air to the top tank of the cooling system.

This provides adequate venting for a fill rate of 19 liters per minute [5 U.S. gallons per minute].

NOTE: An alternative to using sodium carbonate, as outlined in this procedure, is to use RESTORE™.

RESTORE™ is a heavy-duty cooling system cleaner that removes corrosion products, silica gel, and other deposits. The performance of RESTORE™ is dependant 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 RESTORE Plus™. Up to twice the recommended concentration levels of RESTORE™ can be used safely. RESTORE Plus™ **must** be used only at its recommended concentration level. Extremely scaled or fouled systems can require more than one cleaning.

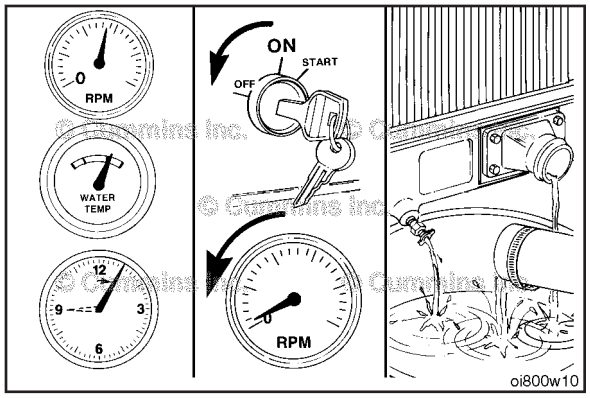


⚠CAUTION⚠

Do not install the radiator cap. The engine is to be operated without the cap for this process.

Fill the system with a mixture of sodium carbonate and water (or a commercially available equivalent).

NOTE: Adequate venting is provided for a fill rate of 19 liters per minute [5 U.S. gallons per minute].

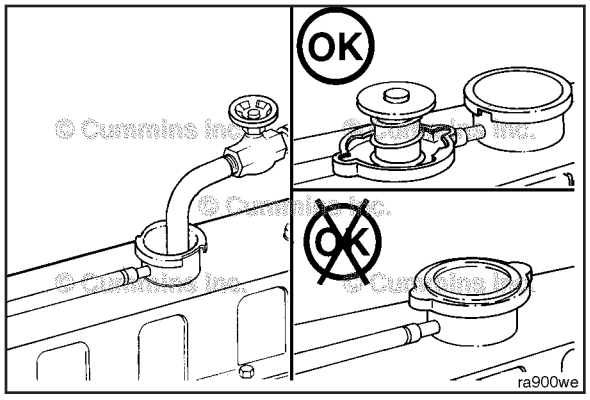


⚠WARNING⚠

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].

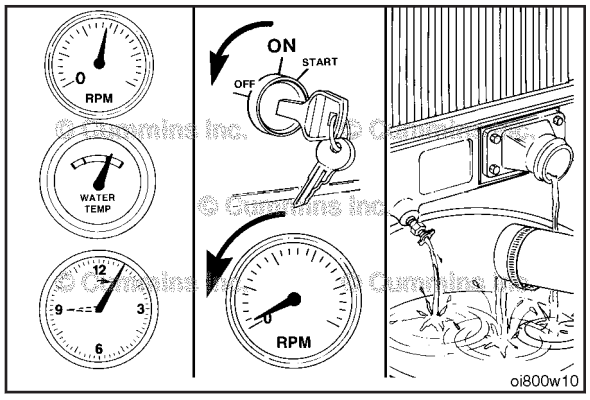
Shut the engine off, and drain the cooling system.



Fill the cooling system with clean water.

NOTE: Be sure to vent the engine and aftercooler, if equipped, for complete filling.

NOTE: Do **not** install the radiator cap.

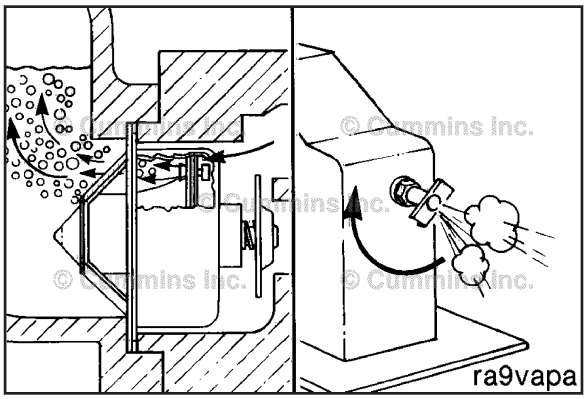


Operate the engine for 5 minutes with the coolant temperature above 80°C [176°F].

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 is clean.

Fill

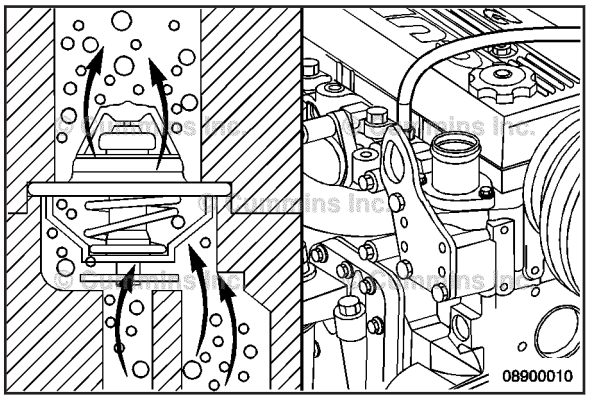


⚠CAUTION⚠
During filling, air must be vented from the engine coolant passages. The air vents through the jiggle pin openings to the top radiator hose and out the fill opening. Additional venting is provided for engines equipped with an aftercooler. Open the petcock during filling.

For front gear train engines with aftercoolers, open the petcock during filling for additional venting.

For front gear train engines without aftercoolers, the air vents through the jiggle pin openings in the thermostat to the top radiator hose and out the fill opening.

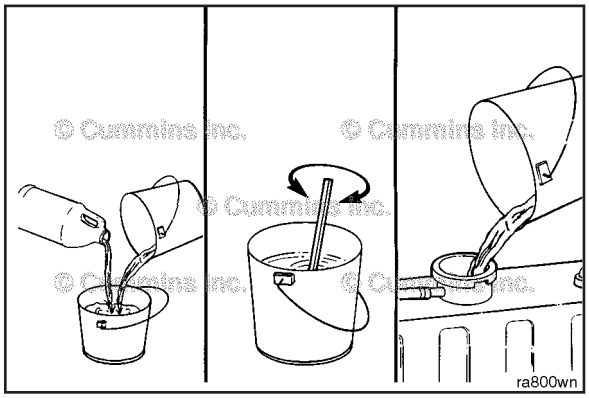
This provides adequate venting for a fill rate of 19 liters per minute [5 U.S. gallons per minute].



⚠CAUTION⚠
The system must be filled properly to prevent air locks. During filling, air must be vented from the engine coolant passages. Be sure to open the petcock on the aftercooler for aftercooled engines. Wait 2 to 3 minutes to allow air to be vented; then add mixture to bring the level to the top.

For rear gear train engines, a dearation port next to the water outlet connection vents air to the top tank of the cooling system.

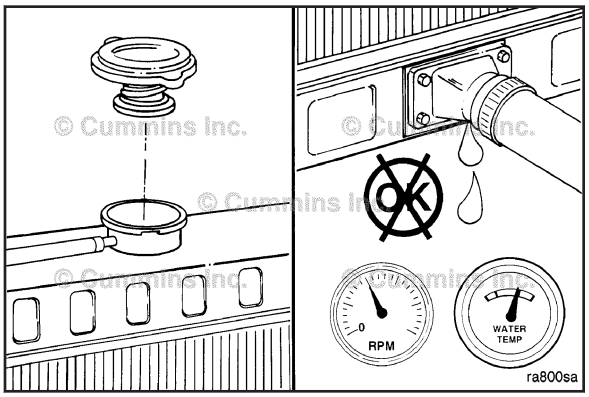
This provides adequate venting for a fill rate of 19 liters per minute [5 U.S. gallons per minute].



⚠CAUTION⚠
Never use water alone for coolant. Damage from corrosion can be the result of using water alone for coolant.

Use a mixture of 50-percent water and 50-percent ethylene glycol or propylene glycol antifreeze to fill the cooling system. Refer to the Cummins Coolant Requirements and Maintenance, Bulletin 3666132 for engine coolant specifications.

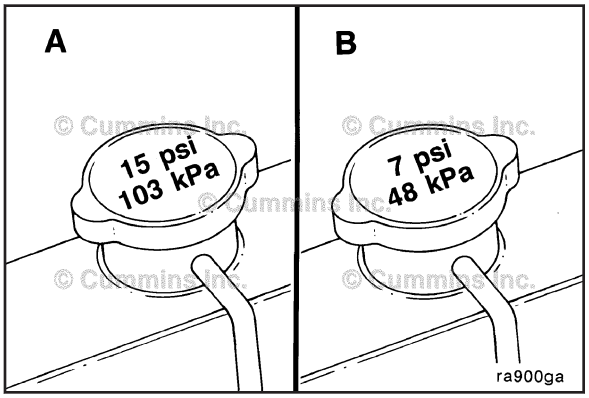
For system capacity, refer to Procedure 018-018 (Cooling System) in Section V.



⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [122°F]. Failure to do so can cause personal injury from heated coolant.

Install the pressure cap. Operate the engine until it reaches a temperature of 80°C [180°F], and check for coolant leaks.

Check the coolant level again to make sure system is full of coolant, or that the coolant level has risen to the hot level in the recovery bottle on the system, if equipped.

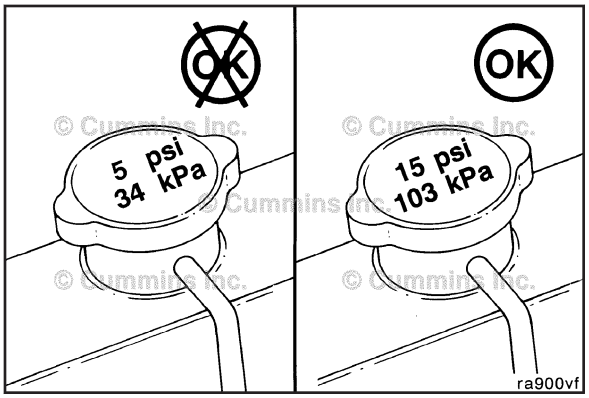


Pressure Test

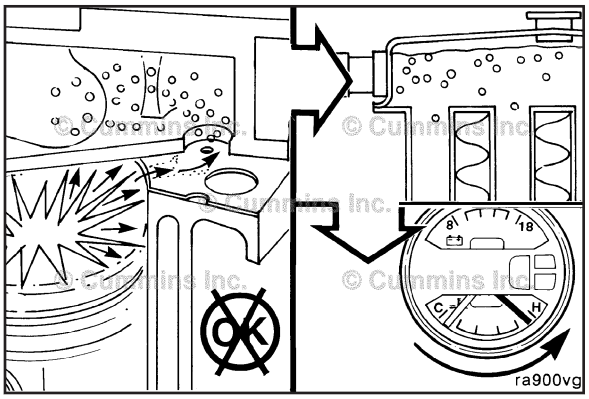
The system is designed to use a pressure cap to prevent boiling of the coolant.

Different caps are specified for the two recommended systems:

Radiator Cap Pressure Test		
	System	**Cap**
A-Normal-Duty	104°C [219°F]	103 kPa [15 psi]
B-Light-Duty	99°C [210°F]	48 kPa [7 psi]



An incorrect or malfunctioning cap can result in the loss of coolant and the engine running hot.

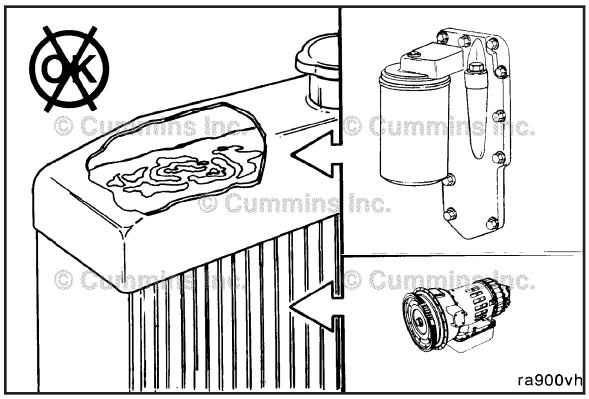


Air in the coolant can result in loss of coolant from the overflow when the aerated coolant is hot. The heated air expands, increasing the pressure in the system, causing the cap to open.

Similarly, coolant can be displaced through the overflow if the head gasket leaks compression gases to the coolant system.

The operating pressure of the coolant system and the lubricating system can result in the mixing of the fluids if there is a leak between the systems: head gasket, oil cooler, etc. (Refer to Cummins Engine Oil Recommendations, Bulletin 3810340.)

NOTE: Transmission fluid can also leak into the coolant through radiator bottom tank transmission oil coolers. Refer to the OEM service manual.



Cooling System - Air or Combustion Gas Test (008-019)

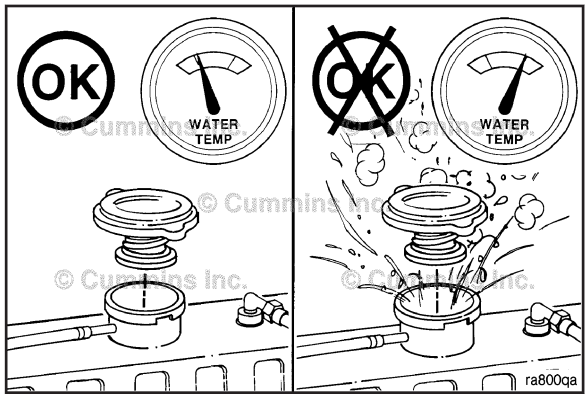
General Information

Overflow Method

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [122°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

Air in Cooling System

Allow the engine to cool, and remove the radiator cap.

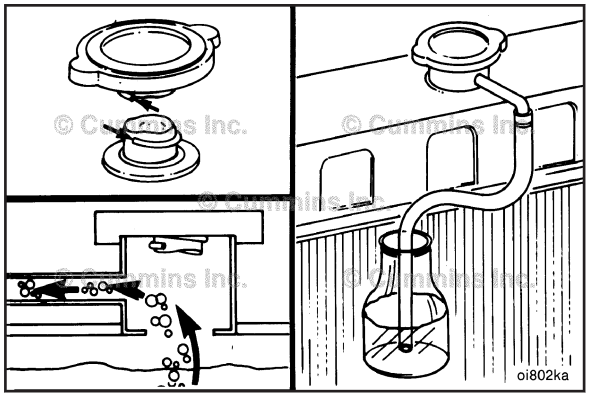


NOTE: The pressure cap **must** make a tight seal.

Install a radiator pressure cap that has had the spring and pressure relief valve removed.

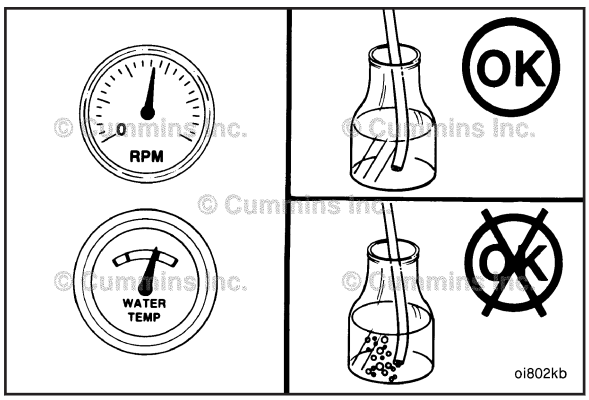
Attach a rubber hose to the radiator overflow connection.

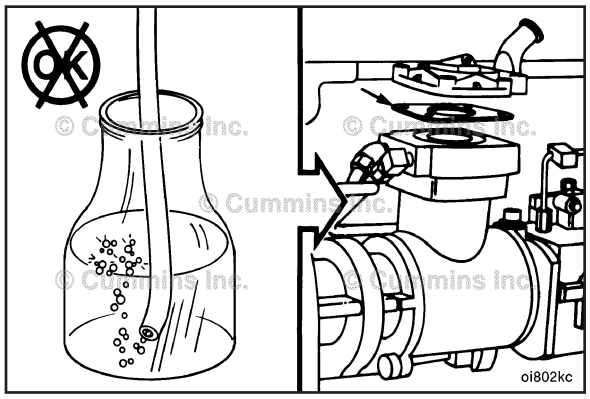
Place the free end of the hose in a container of water.



Operate the engine at rated rpm until it reaches a temperature of 80°C [176°F] with the thermostat open.

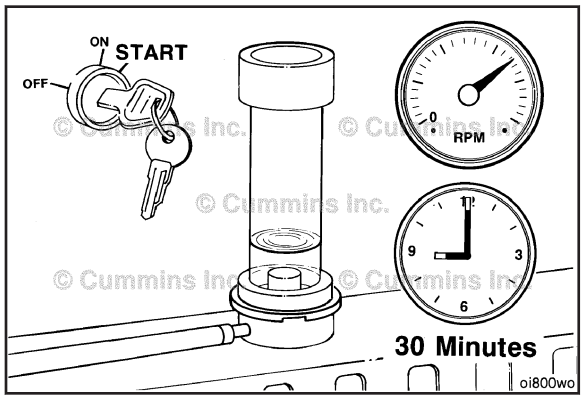
Check for a continuous flow of air bubbles from the hose in the water container.



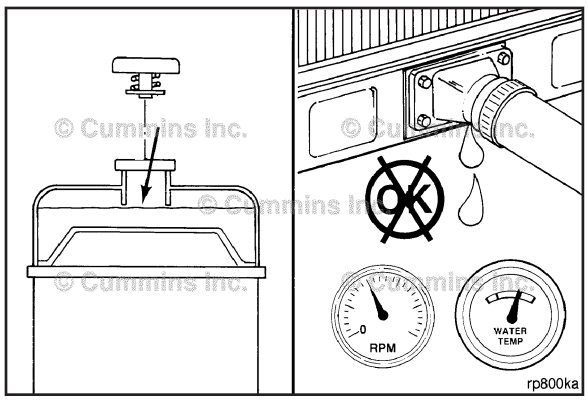


A continuous flow of air bubbles can be caused by one of the following:

- Fan, shutter, or heater air control thermostat valve leaking air.
- An air compressor cylinder head leak. Refer to Procedure 012-019 for air compressor leak test.

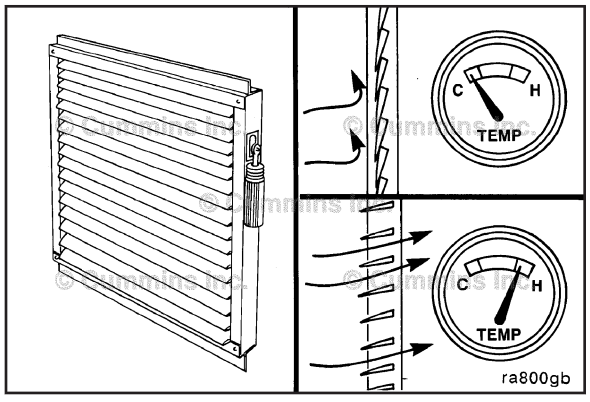


If one of the air control valves or the air compressor was **not** the source of air entering the cooling system, perform the Combustion Gas Leak test.



If no air is found in the cooling system, do the following:

- Remove the test equipment.
- Check the coolant level, and fill if necessary.
- Install the radiator pressure cap.
- Operate the engine until it reaches a temperature of 80°C [176°F], and check for coolant leaks.



Combustion Gas Leak

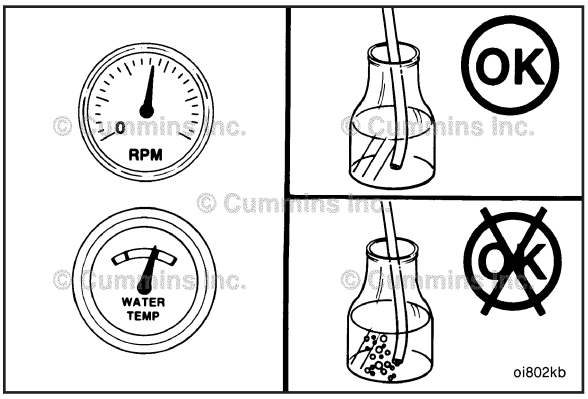
Fan, Shutter, or Heater Air Control Valve

⚠CAUTION⚠

The engine can overheat with the fan control or the shutter air control valve disconnected. Monitor the engine coolant temperature while performing this test. The coolant temperature must not exceed 100°C [212°F].

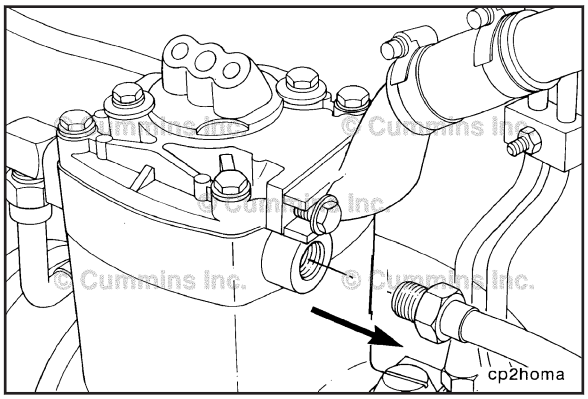
Repeat the test for air in the cooling system as previously described. If no air is found in the cooling system with the air control valve(s) isolated, install a new control valve.

NOTE: Start the engine, and run for 5 minutes before testing for air in the coolant. This will allow any trapped air to purge from the system.

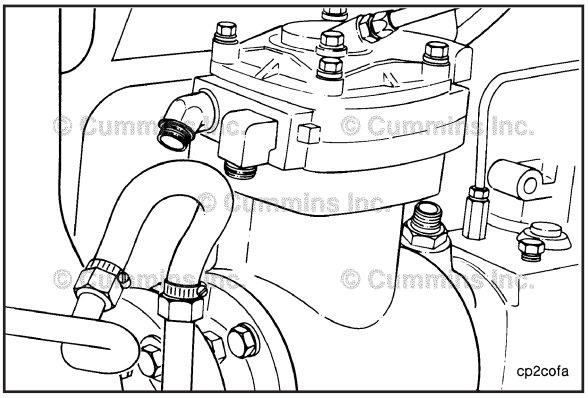


Air Compressor

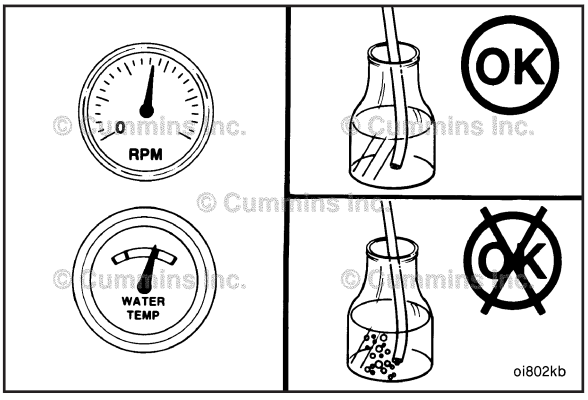
⚠CAUTION⚠
The air compressor discharge line must be disconnected at the compressor to allow the compressor to discharge air to the atmosphere to prevent the compressor from overheating during this next test. Do not run the engine over 5 minutes with components isolated from the cooling system. Component damage can occur.

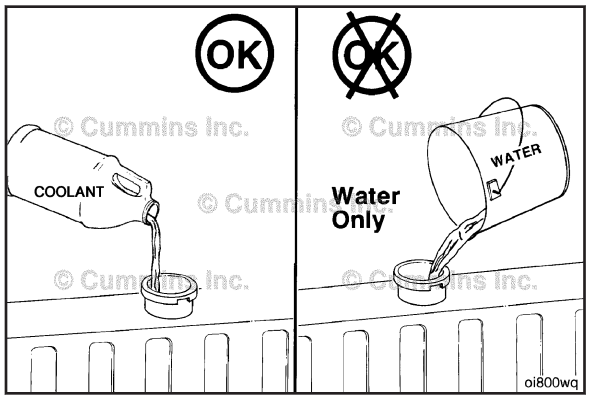


Disconnect the coolant supply and the return tubes from the air compressor. Use a short piece of hose to connect the tubes together to prevent coolant loss during engine operation.



Repeat the test for air in the cooling system as previously described. If no air is found in the cooling system with the air compressor isolated, repair or replace the air compressor. Refer to Procedure 012-101.

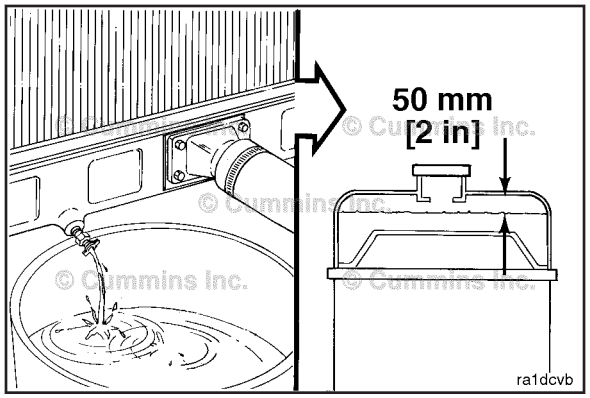




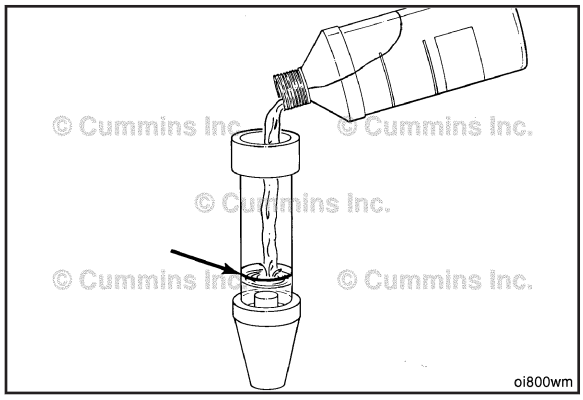
Combustion Gas Leak Test Kit, Part Number 3822985

Use combustion gas leak test kit, Part Number 3822985, or equivalent, to test for combustion gases in the cooling system.

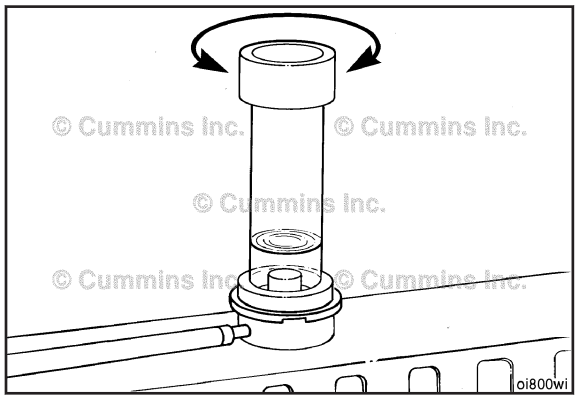
It is recommended that the cooling system contain a mixture of 50-percent antifreeze and 50-percent water during the combustion gas leak test. The use of water **only** can result in a color change in the test fluid from blue to turquoise or light green during the test. This is **not** an indication of a combustion gas leak.



Drain the coolant level down approximately 50 mm [2 in] below the radiator cap seal ledge in the radiator fill neck.

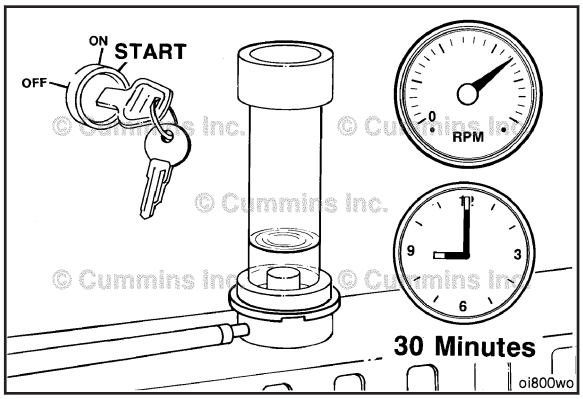


Pour the test fluid into the combustion gas leak test instrument until it is up to the yellow fill line on the instrument.

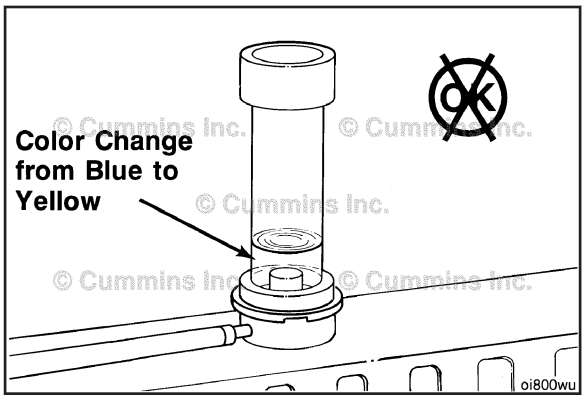


Insert the rubber tip of the combustion gas leak test instrument in the radiator fill neck. Hold the instrument down firmly while turning back and forth to make sure that an air tight seal is formed between the tester and radiator fill neck.

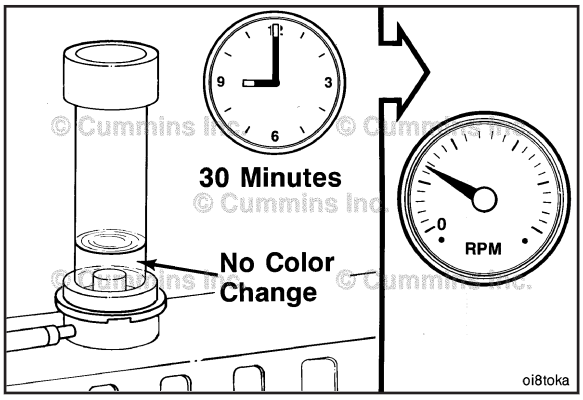
Start the engine, and run at high idle for approximately 30 minutes. Monitor the engine temperature and color of the test fluid during engine operation. Do **not** allow the engine temperature to exceed 100°C [212°F] during the test.



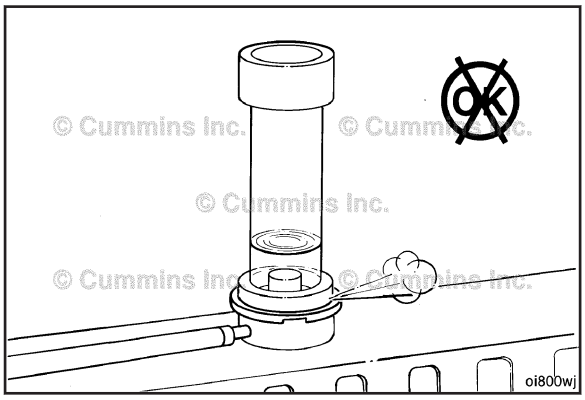
If the color of the test fluid changes from blue to yellow anytime during the test, combustion gases are leaking into the cooling system. Discontinue the test if the color of test fluid changes from blue to yellow.

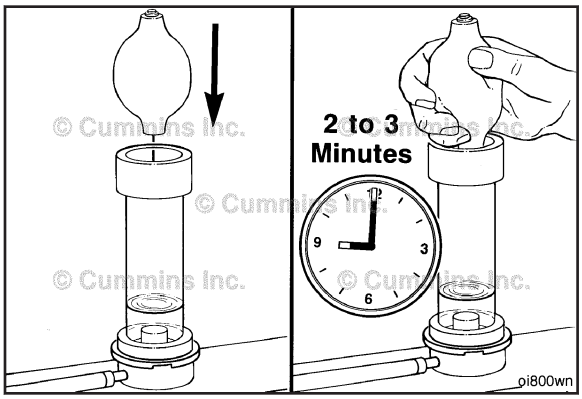


If the color of the test fluid does **not** change from blue to yellow during the 30-minute test period, return the engine to low idle.



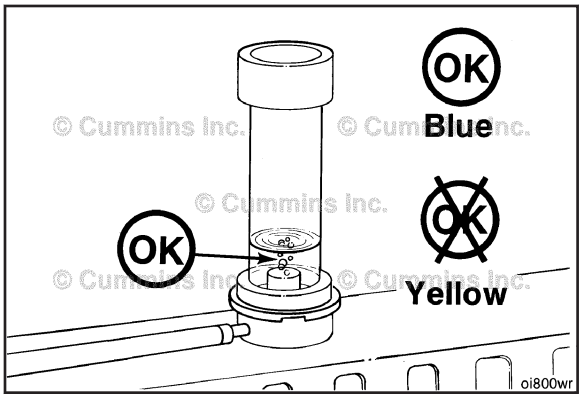
Check the test instrument to make sure that it is firmly sealed in the radiator fill neck.



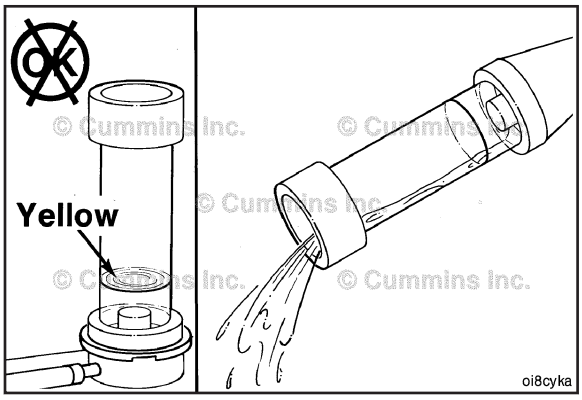


Insert the tip of the rubber ball into the hole in the top of the test instrument. Squeeze the rubber ball 2 to 3 minutes to draw air from the radiator through the test fluid.

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, combustion gases are entering the cooling system. Further investigation is required to determine the source of the combustion leak.



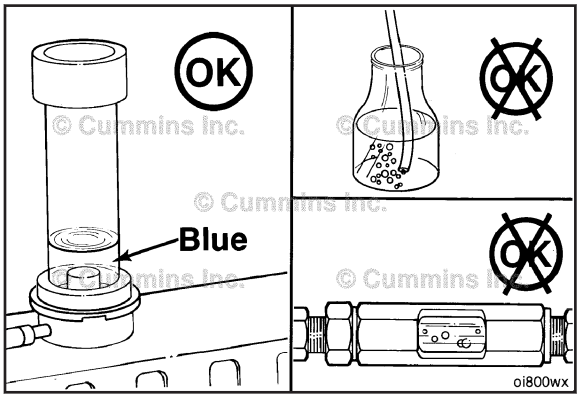
As the cooling system warms up to operating temperature, air will be expelled through the combustion gas tester in the form of bubbles in the test fluid. This is due to normal expansion of the coolant. Do **not** mistake the presence of air bubbles in the tester as combustion gases, or air leaks into the cooling system. A change in the color of the test fluid from blue to yellow is the **only** indication of combustion gas in the cooling system.



A positive result from the combustion gas leak tester indicates the following:

- Cylinder head gasket or cylinder head casting leakage. Refer to Procedure 002-004

NOTE: Discard the test fluid if it has indicated positive.



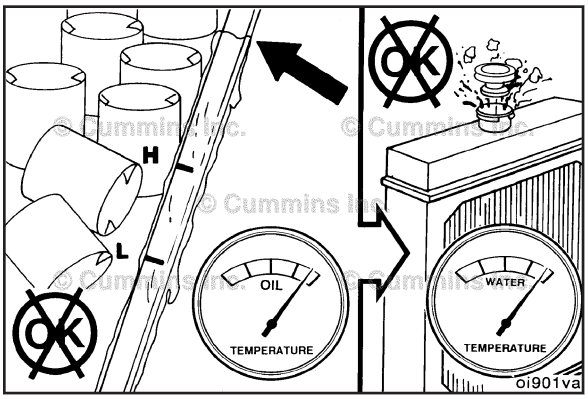
A negative result from the combustion gas leak tester, coupled with continuous flow of air bubbles from the previous test, indicates the following:

- Defective fan, shutter, or heater air control valve
- Air compressor head or head gasket leakage
- Air entrained due to a bad radiator check valve or incorrect fill.

Cooling System Diagnostics (008-020)

General Information

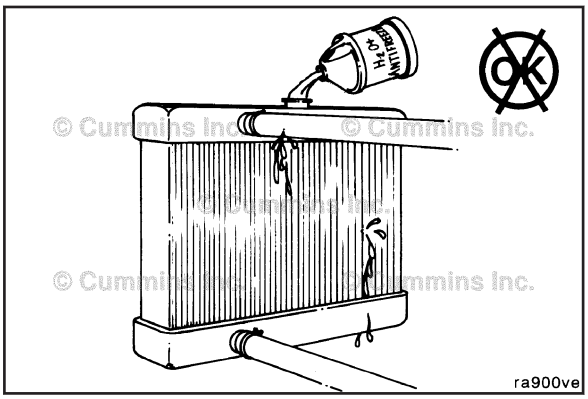
When you troubleshoot overheating, remember that too much oil in the oil pan can cause additional heat from friction when the rod journals are submerged in oil.



Overfilling with oil raises the oil temperature that is transferred to the coolant system at the oil cooler.

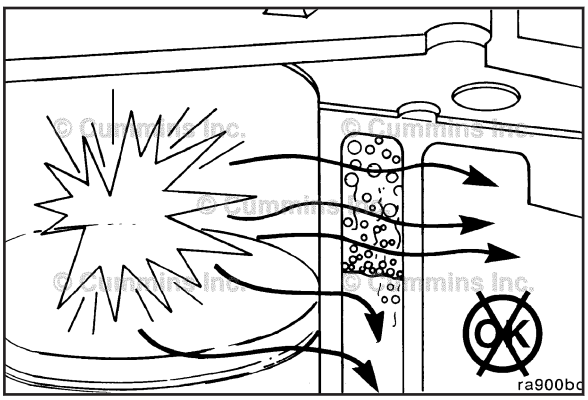
The system is designed to use a specific quantity of coolant. If the coolant level is low, the engine will run hot.

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



⚠CAUTION⚠
The engine coolant passages must be completely filled with coolant.

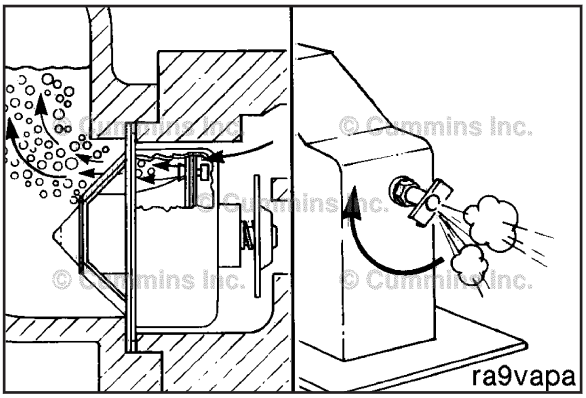
During operation, entrapped air mixes with the coolant, which results in cavitation corrosion and poor heat transfer. Highly aerated coolant can cause localized overheating of the cylinder head and block, which can result in a cracked head, scored cylinder, or blown head gasket.

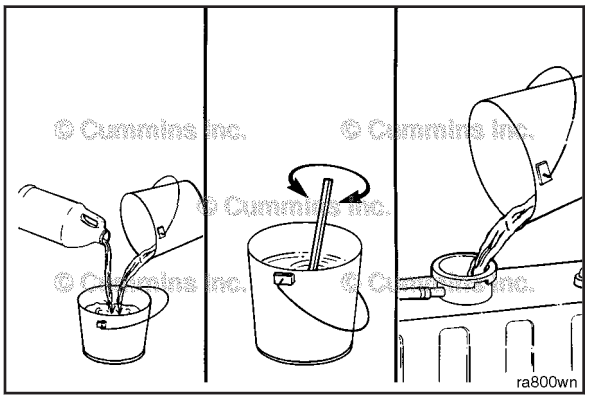


During filling, air **must** be vented from the engine coolant passages. The air vents through the jiggle pin openings to the top radiator hose and out the fill opening. Additional venting is provided for engines equipped with an aftercooler. Open the petcock during filling.

NOTE: Adequate venting is provided for a fill rate of 14 liters per minute [3.7 gallons per minute].

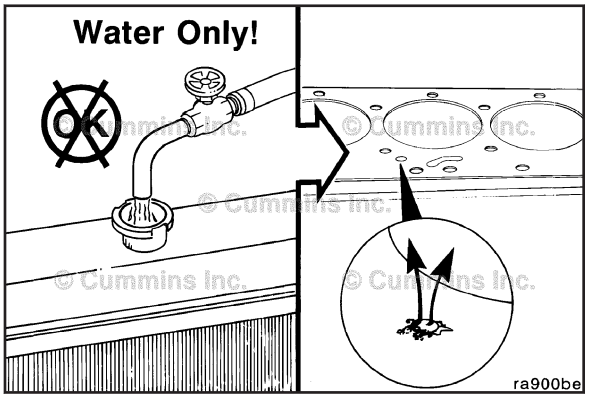
NOTE: Excess air in the cooling system can lead to overheating and low coolant levels.





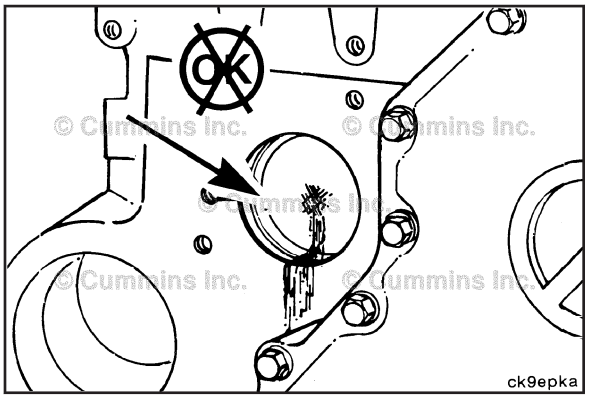
NOTE: A 50-percent mixture of antifreeze and water **must** be premixed before filling the system. The ability of antifreeze to remove heat from the engine is **not** as good as water, so pouring antifreeze into the engine first could contribute to an overheated condition before the liquids are completely mixed.

A mixture of 50-percent ethylene-glycol base antifreeze is required for operation of the engine in temperature environments above -37°C [-35°F]. A mixture of 40-percent water and 60-percent antifreeze is recommended for temperatures below -37°C [-35°F]. **Never** use more than 60-percent antifreeze.



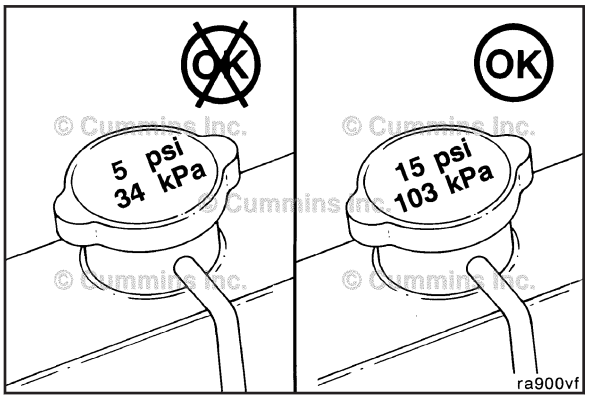
⚠CAUTION⚠
Never use water alone for coolant. Damage from corrosion can be the result of using water alone for coolant. The small holes in the head gasket are especially susceptible to plugging. These holes are orifices and their size is critical. Do not enlarge the size of the orifices. To do so will disturb the coolant flow and will not solve an overheating problem.

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



Also, water used as a coolant for even a relatively short period can result in the cup plugs rusting through, allowing the coolant to leak.

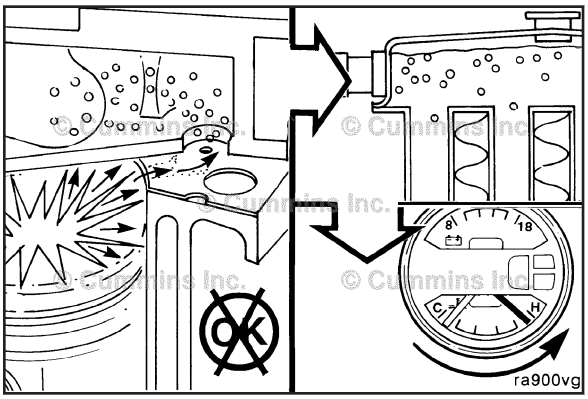
NOTE: A sudden loss of coolant from a heavily loaded engine can result in severe damage to the pistons and cylinder bore.



An incorrect or malfunctioning cap can result in the loss of coolant and the engine running hot. Refer to Procedure 008-047.

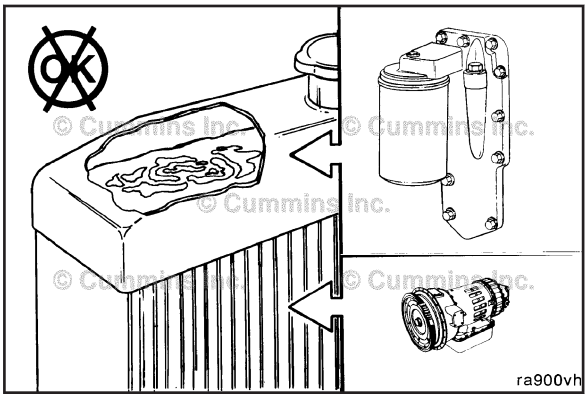
Air in the coolant can result in loss of coolant from the overflow when the aerated coolant is hot. The heated air expands, increasing the pressure in the system, causing the cap to open.

Similarly, coolant can be displaced through the overflow if the head gasket leaks compression gases to the coolant system.



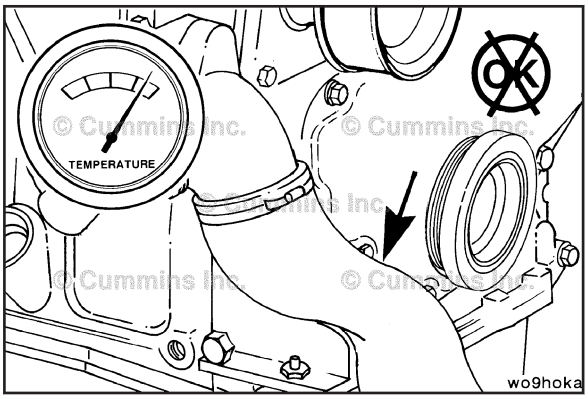
The operating pressure of the coolant system and the lubricating system can result in the mixing of the fluids if there is a leak between the systems: head gasket, oil cooler, etc. (refer to Procedure 007-037, Lubricating Oil System in Section 7).

NOTE: Transmission fluid can also leak into the coolant through radiator bottom tank transmission oil coolers. Refer to the OEM service manual.

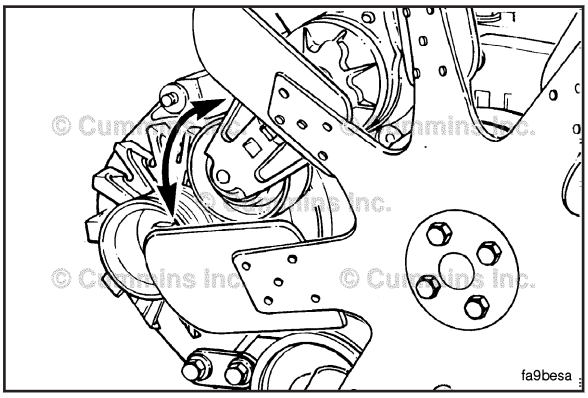


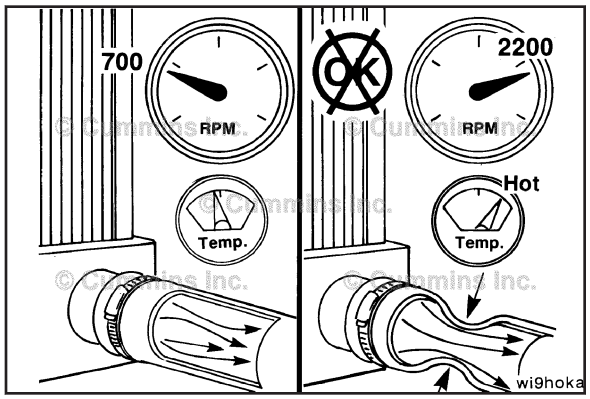
Water Pump

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. Reduced or interrupted flow will result in the engine running hot.



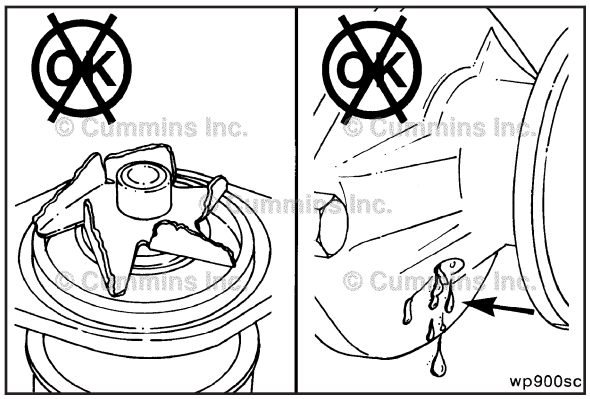
The pump is belt-driven from the crankshaft pulley. An automatic belt tensioner is used to prevent the belt from slipping on the pump pulley. A malfunction of the tensioner will cause the water pump impeller to rotate at a slower speed, reducing the amount of coolant flow.



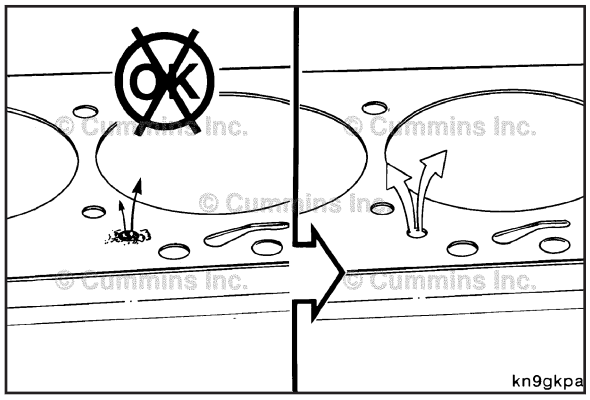


The coolant flow can also be reduced if the inlet hose to the water pump collapses. A hose will usually **not** collapse while the engine is running at low speed. Check the hose while the engine is running at rated speed.

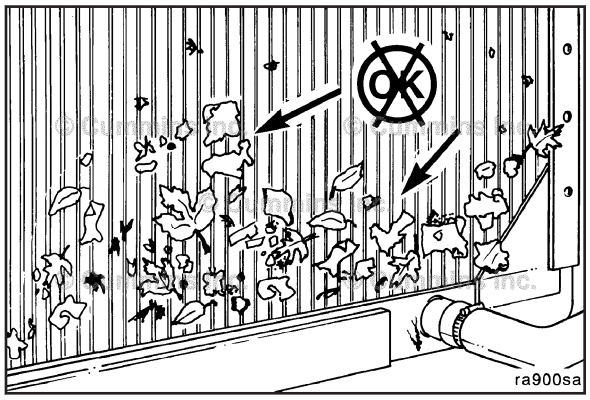
NOTE: Be sure the engine is warm, a minimum of 95°C [203°F], so the thermostat is open.



A worn or malfunctioning water pump will **not** produce the flow required to prevent the engine from running hot. However, be sure to check the other possibilities indicated in the Troubleshooting Logic before checking the flow or replacing the pump. Refer to Procedure 008-062.



As stated in the coolant discussion, an obstruction in the passages can interrupt flow.

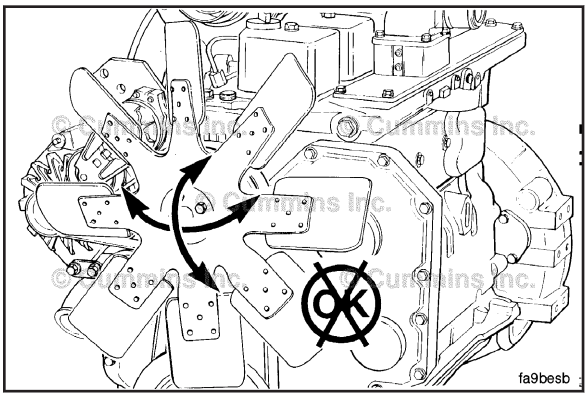


Radiator, Fans, and Shutters

Air forced through the fins of the radiator by a fan cools the coolant pumped through the radiator. Environmental debris (paper, straw, lint, dust, etc.) can obstruct the fins and stop the flow of air, which will reduce the cooling effect of the radiator.

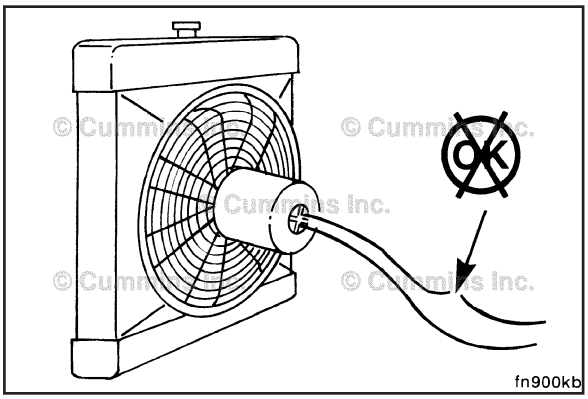
If the fan is belt-driven, a slipping belt will result in slower fan speed and reduced cooling. A malfunctioning automatic belt tensioner can be the problem.

NOTE: Check the bearings in the fan hub and other pulleys to make sure they are **not** causing excessive belt vibration and slippage.



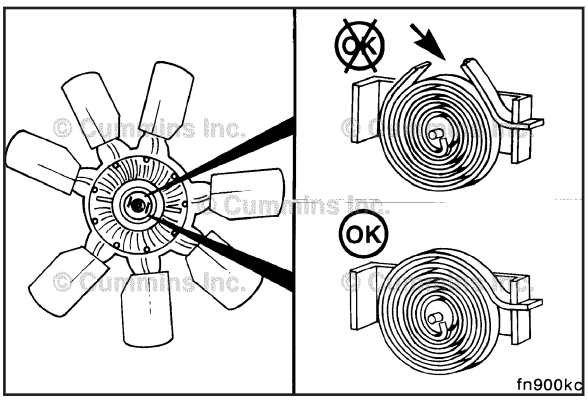
Interruption of the circuit to an electrically driven fan can result in insufficient airflow and cause the engine to run hot.

NOTE: Make sure the temperature sensor is functioning correctly.



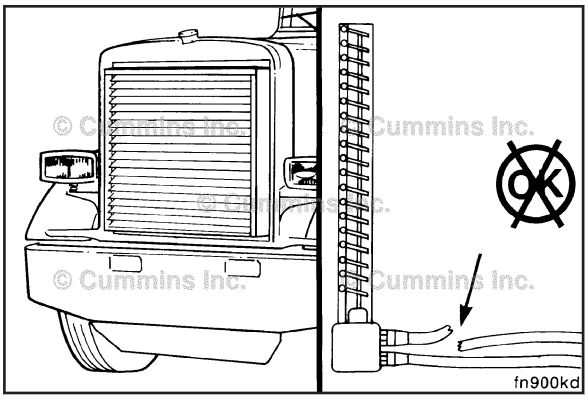
Some applications use thermatic fans. These fans operate **only** as needed to keep the coolant at the correct temperature. If the fan does **not** operate when the coolant temperature increases, the engine will run hot. If the fan does **not** shut off when coolant temperature decreases, the engine will run cold.

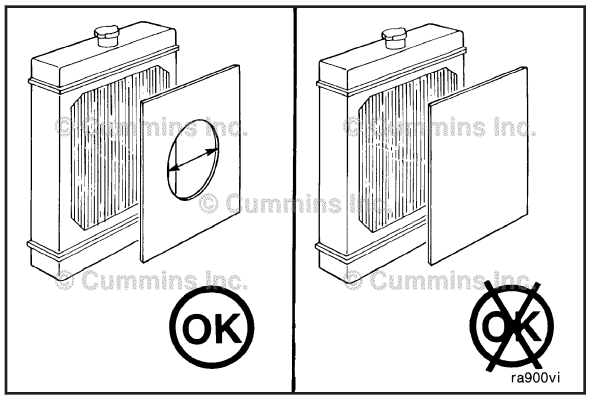
NOTE: Make sure the coolant temperature sensor is functioning correctly.



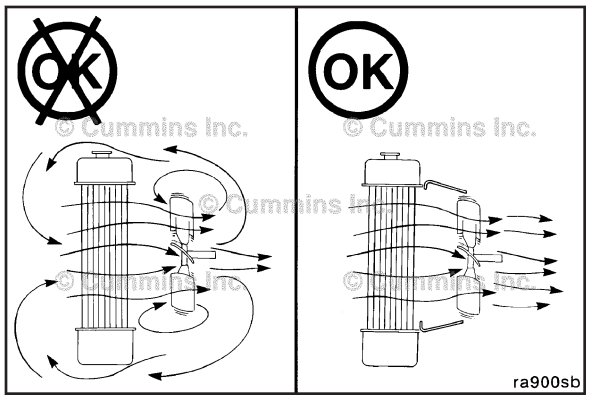
Shutters are designed to control airflow across the radiator. If the shutters fail to open when needed, the engine can run hot. Failure of the shutters to close can result in too much airflow and the engine running cold.

NOTE: Make sure that the air temperature sensor is functioning correctly. Check the air-operated shutter controls. Check for air leaks.



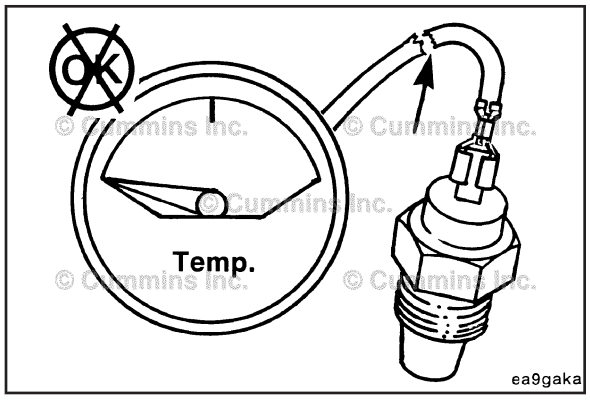


Winterfronts can be used on a charge air cooled engine, but **must** be designed to cover the frontal area of the cooling system partially. A minimum of 120 square inches of charge air cooled frontal area **must** be left open to airflow.



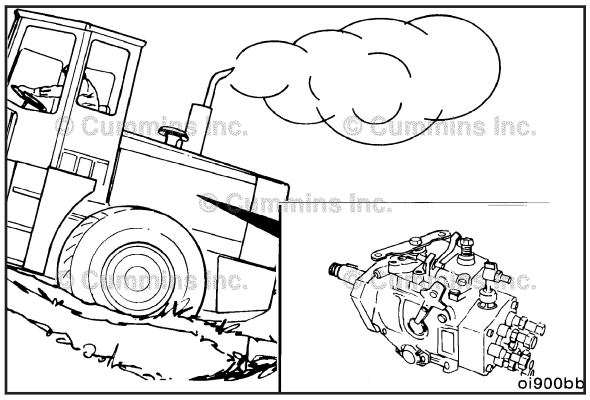
An incorrect fan shroud or obstructions can reduce airflow and cause the engine to run hot.

NOTE: Check to be sure air is **not** recirculating. Check for missing baffles.



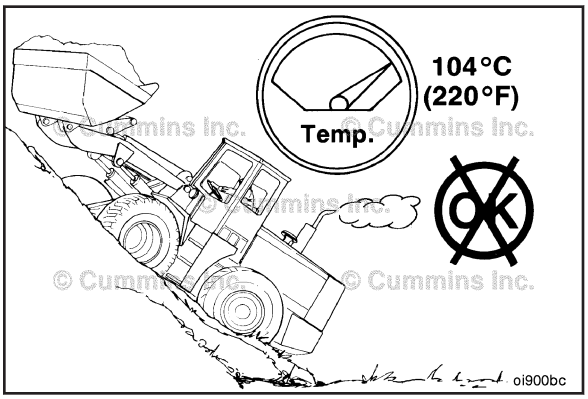
Gauges, Overfueling, and Loading

Gauges and sensors are used in the system to measure the coolant temperature. These can malfunction and provide an incorrect temperature indication.



⚠CAUTION⚠
Overfueling can cause the engine to overheat. Make sure that the fuel pump is calibrated correctly.

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

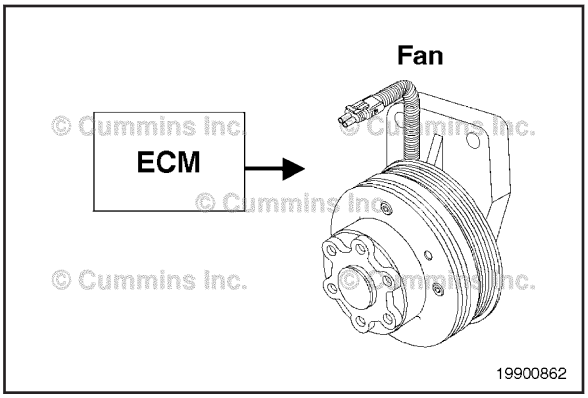


Fan Clutch, Electric (008-026)

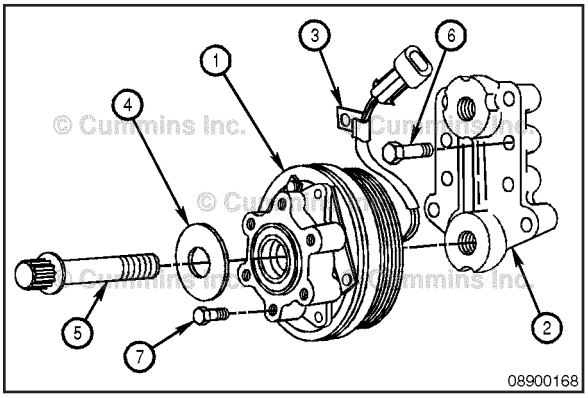
General Information

⚠WARNING⚠
The cooling fan will engage when the engine is started. To prevent serious personal injury, keep your hands clear of the fan's path when starting the engine and during engine operation.

The Cummins®-developed electromagnetic fan clutch product is an integrated package with the clutch, bracket, shaft, bearings, pulley, and fan spacer designed as a unit. An engine coolant sensor and/or a refrigerant pressure sensor (if equipped with air conditioning) will engage and disengage the clutch. The fan clutch engages when the coolant temperature sensor or the refrigerant switch is closed. It disengages when either of these sensors returns to the open position. The most common temperature switch is set to close at 91°C [195°F]. Contact the OEM for recommended temperature switches. The temperature **must** be set above the opening point of the thermostat. When cooling is needed, a powerful electromagnet engages the fan. The fan is either fully engaged or fully disengaged. The OEM could have a manual override switch to engage the clutch manually at the operator's command. The electromagnetic fan clutch is driven by a poly-vee drive belt and is available with an accessory drive for vee-drive belts.

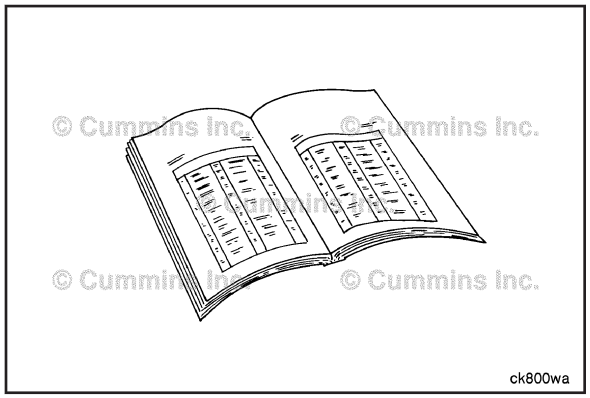


Clutch wires **must** be oriented at 2 o'clock instead of 12 o'clock. The following table lists the component parts of the electric fan clutch.



The following parts have been released for B Series production and service:

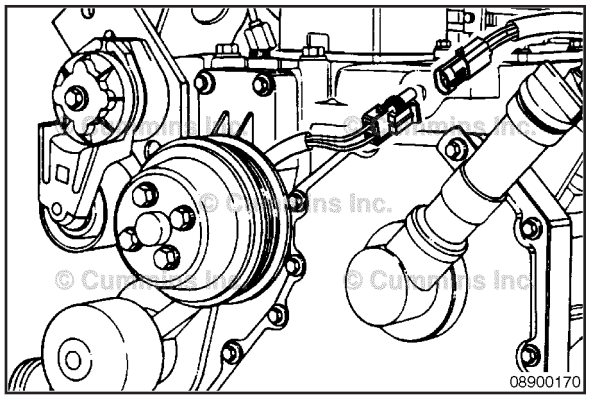
Parts Breakdown				
	Part Number	**Part Name**	**Description**	**Comments**
1	3922954	Clutch	B Series with Accessory Drive	1.25:1 Ratio
1	3922773	Clutch	B Series without Accessory Drive	1.25:1 Ratio
2	3922869	Bracket	Fan Center 343 or 393.5 mm [13.5 or 15.5 in]	1 per Assembly
3	3920348	P-Clip		1 per Assembly
4	3922952	Washer		1 per Assembly
5	3922953	Capscrew 12 Point		1 per Assembly
N/A	3862596	Warning Label *		Per Installation
6	3900678	Capscrew		4 per Assembly
7	3903464	Fan Bolts	40-mm [1.6-in] length	6 per Assembly
7	3900634	Fan Bolts	50-mm [1.9-in] length	6 per Assembly
7	3904446	Fan Bolts	70-mm [2.8-in] length	6 per Assembly
7	3900067	Fan Bolts	80-mm [3.15-in] length	6 per Assembly
7	3916069	Fan Bolts	90-mm [3.54-in] length	6 per Assembly
* Each 3862496 warning label kit contains two labels. One label **must** be installed on both sides of the fan shroud.				



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 cooling fan and spacers. Refer to the OEM service manual.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.



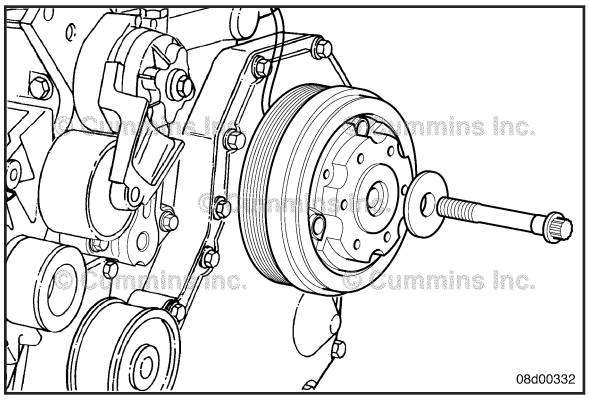
Remove

Disconnect the fan clutch connector on the base harness from the fan clutch.

NOTE: As the electric fan clutch mounting fastener is loosened, make sure to support the clutch.

NOTE: The electric fan clutch mounting capscrew has an external Torx™ head.

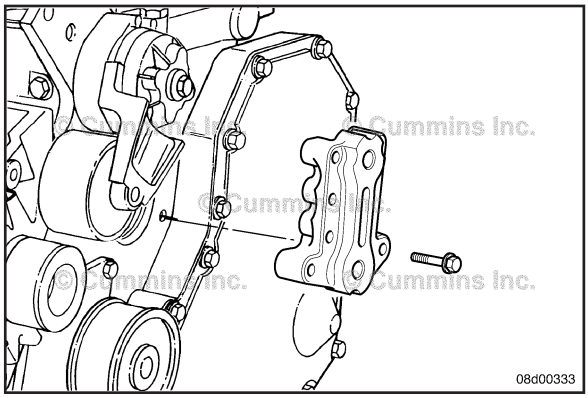
Remove the electric fan clutch mounting capscrew, washer and electric fan clutch.



NOTE: Prior to removing the electric fan clutch support bracket, note the mounting location and orientation of the bracket. The mounting bracket can be installed in different orientations for different fan drive arrangements.

NOTE: Note the location of the P-clip for the electric fan clutch wiring harness pigtail.

Remove the electric fan clutch support bracket and mounting capscrews.



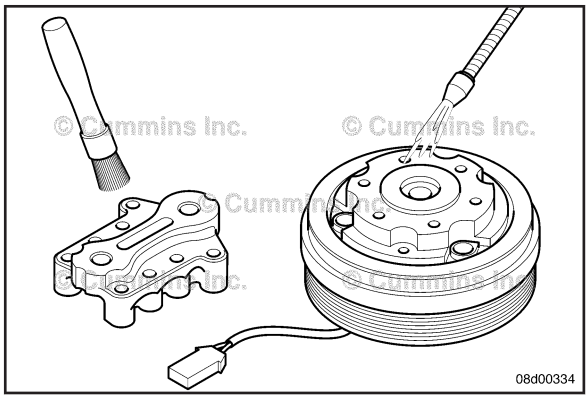
Clean and Inspect for Reuse

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

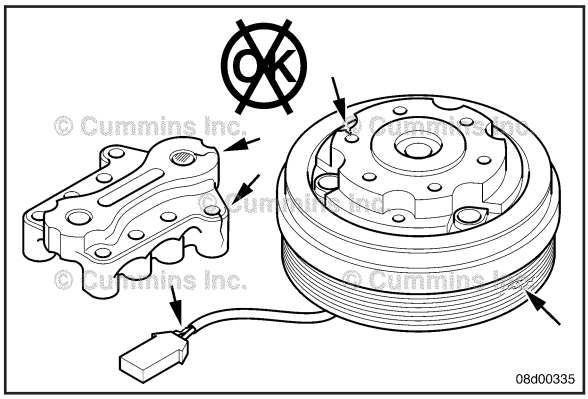
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

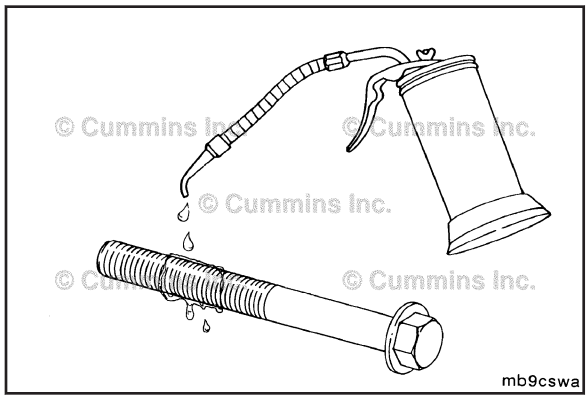
Clean the fan clutch and bracket with solvent.

Dry with compressed air.



Inspect the fan clutch and bracket for damage.



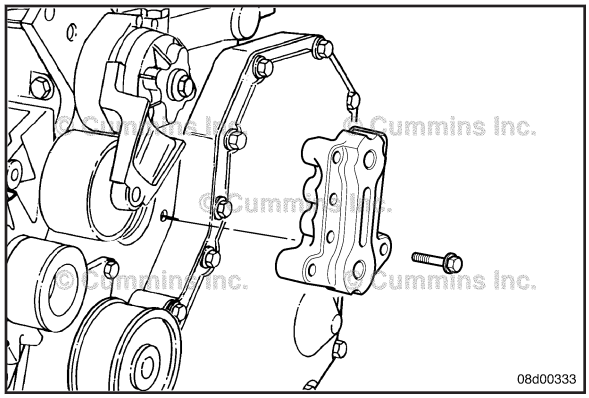


Install

Do **not** use Loctite™ or any other thread locking compounds. Make sure capscrew head surface and threads are clean and free of debirs.

Use new capscrew if any damage is fouund.

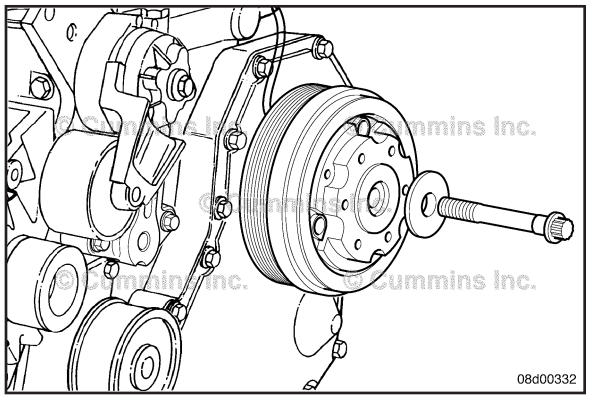
Lubricate the threads and underside of the capscrew head with clean 15W-40 engine lubricating oil.



NOTE: Make sure to install the electric fan clutch mounting bracket in the same orientation and location as removed. The mounting bracket can be installed in different orientations for different fan drive arrangements.

Install the electric fan clutch support bracket, wiring harness pigtail P-clip and mounting capscrews.

Torque Value: 33 N•m [24 ft-lb]



NOTE: The electric fan clutch mounting capscrew has an external Torx™ head.

Install the electric fan clutch, washer and mounting capscrew.

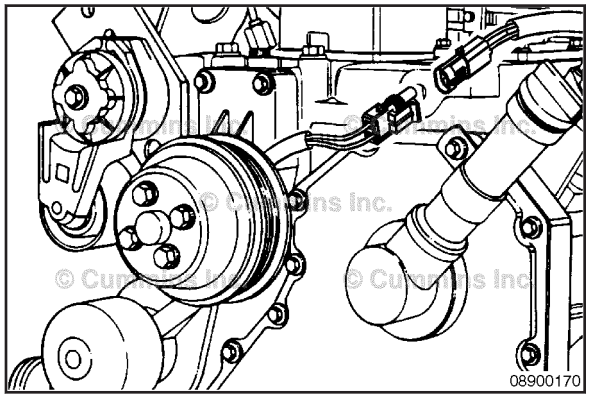
Prior to tightening the capscrew, rotate the fan clutch so that the wires coming out of the back of the fan clutch are captured by the P-clip. Bend the P-clip over by hand to secure the wires.

NOTE: Make sure that wires are **not** being pulled at the fan clutch.

Tighten the fan clutch mounting capscrew.

Torque Value:

Step 1	102 N•m	[75 ft-lb]
Step 2	Rotate 60 degrees	

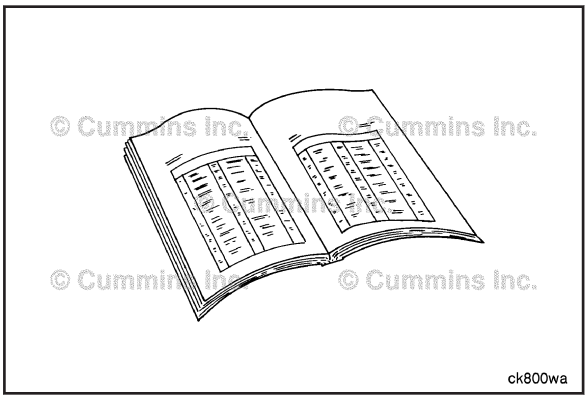


Connect the fan clutch connector on the base harness to the fan clutch.

Finishing Steps

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

- Install the drive belt. Refer to Procedure 008-002 in Section 8.
- Install the cooling fan and spacers. Refer to the OEM service manual.
- Connect the batteries. Refer to the OEM service manual.



Fan Hub, Belt Driven (008-036)

Preparatory Steps

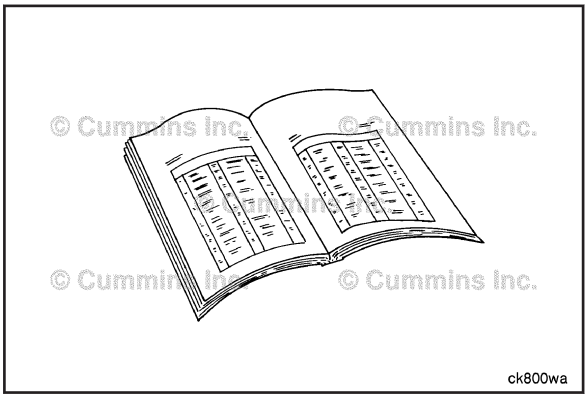
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to Procedure 013-007 (Batteries) in Section 13.
- Remove the drive belt. Refer to Procedure 008-002 (Drive Belt, Cooling Fan) in Section 8.

NOTE: If equipped with Cummins® Electric Fan Clutch option, refer to Procedure 008-026 (Fan Clutch, Electric) in Section 8.

NOTE: Some applications do **not** have a cooling fan or the cooling fan is located elsewhere on the application.

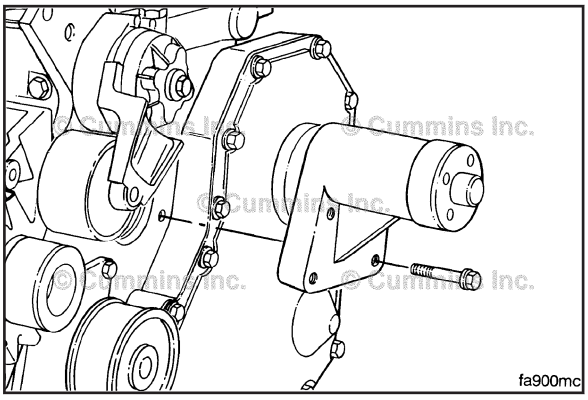
- If required, remove the cooling fan. Refer to OEM service manual for instructions
- Remove the fan pulley and spacer. Refer to Procedure 008-039 (Fan Spacer and Pulley) in Section 8.

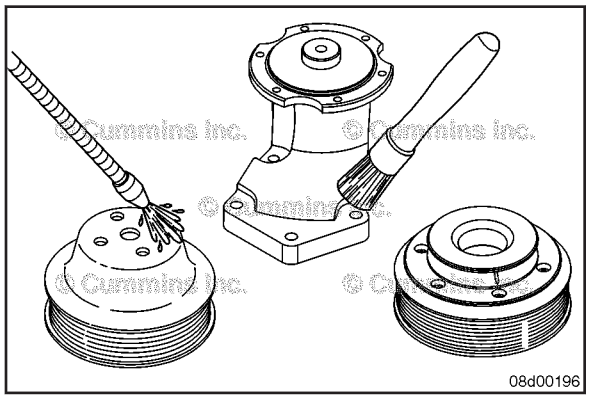


Remove

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

Remove the four capscrews and the fan hub.





Clean and Inspect for Reuse

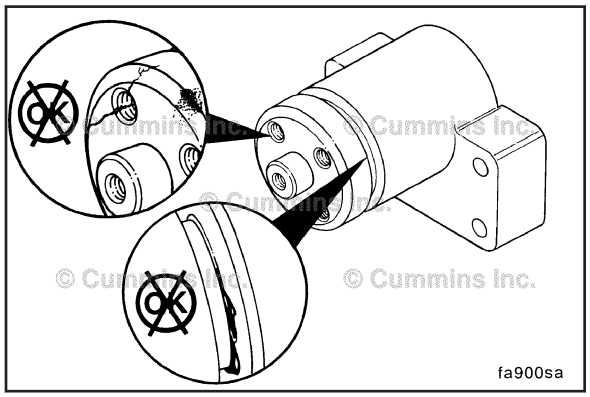
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

△CAUTION△
Do not expose the cooling fan drive belt to solvents, acids, or alkaline materials for cleaning. Belt damage can result.

Clean the fan hub and fan pulley with solvent.

Dry with compressed air.

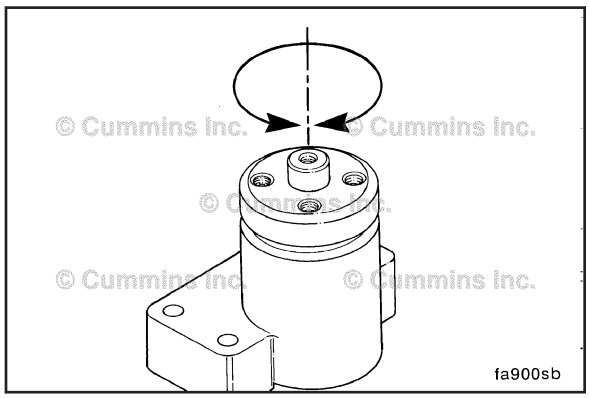


Inspect the fan hub for indications of oil seal leakage.

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.

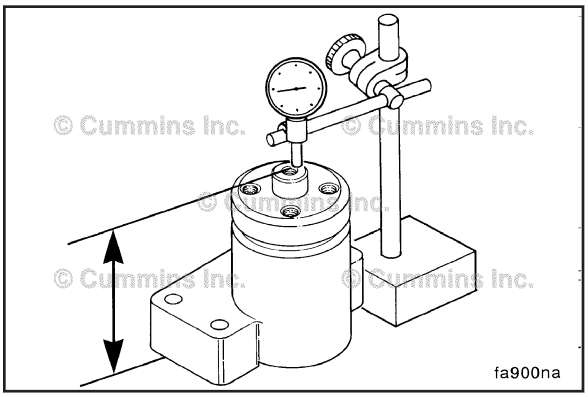
The fan hub **must** spin freely without any wobble or excessive end clearance.

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.

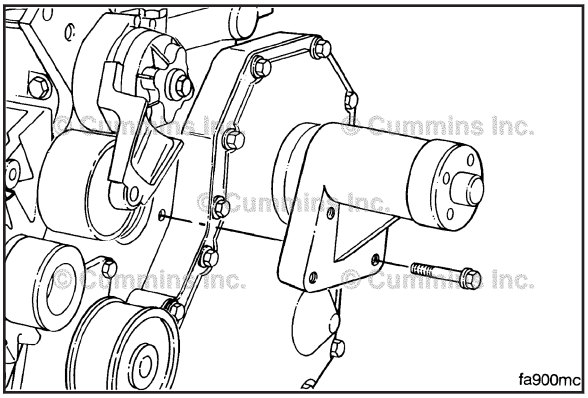
Fan Hub End Play		
mm		in
0.15	MAX	0.006



Install

Install the fan hub and four capscrews.

Torque Value: 24 N•m [212 in-lb]



Finishing Steps

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

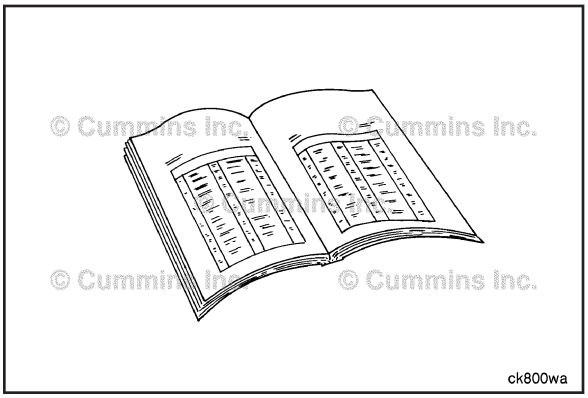
- Install the fan pulley and spacer. Refer to Procedure 008-039 (Fan Spacer and Pulley) in Section 8.

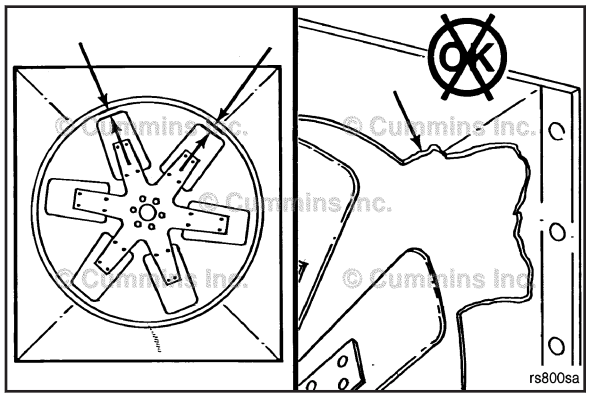
NOTE: Some applications do **not** have a cooling fan or the cooling fan is located elsewhere on the application.

- If removed, install the cooling fan. Refer to OEM service manual for instructions
- Install the drive belt. Refer to Procedure 008-002 (Drive Belt, Cooling Fan) in Section 8.

NOTE: If equipped with Cummins® Electric Fan Clutch option, refer to Procedure 008-026 (Fan Clutch, Electric) in Section 8.

- Connect the batteries. Refer to Procedure 013-007 (Batteries) in Section 13.
- Operate the engine and check for proper operation.





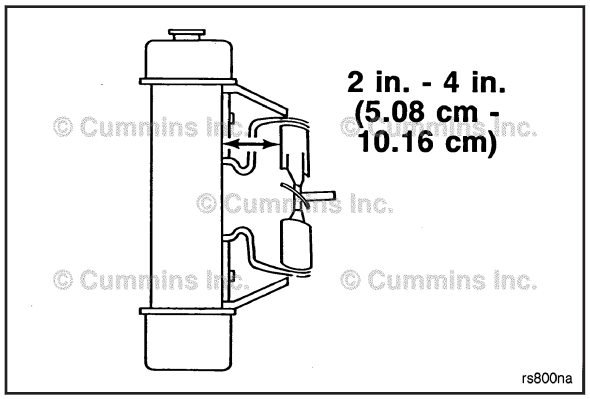
Fan Shroud Assembly (008-038)

Initial Check

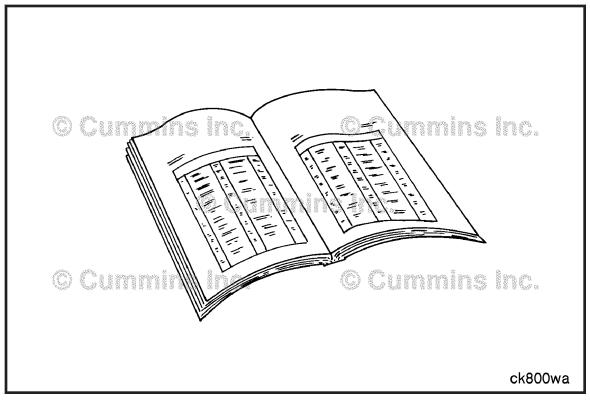
⚠CAUTION⚠

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 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

⚠WARNING⚠

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

- Disconnect the batteries. Refer to Procedure 013-007 (Batteries) in Section 13.

NOTE: If equipped with Cummins® Electric Fan Clutch option, refer to Procedure 008-026 (Fan Clutch, Electric) in Section 8.

NOTE: Prior to removing the drive belt, loosen the fan pulley and cooling fan (if equipped) mounting capscrews.

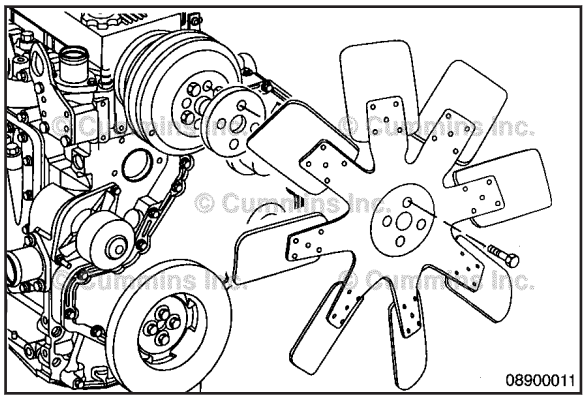
- Remove the drive belt. Refer to Procedure 008-002 (Drive Belt, Cooling Fan) in Section 8.

Remove

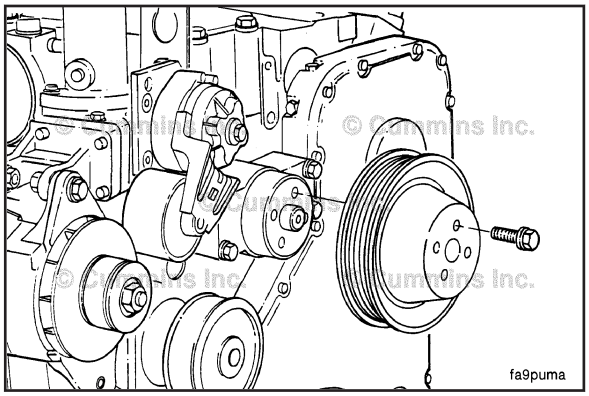
NOTE: Some applications do **not** have a cooling fan or the cooling fan is located elsewhere on the application.

If equipped, remove the cooling fan. Refer to the OEM service manual for instructions.

For engines equipped with an engine driven cooling fan, the fan holds the fan pulley and spacer in place. Remove the fan pulley and spacer.



If the engine is **not** equipped with an engine driven cooling fan, remove the fan pulley mounting capscrews and fan pulley.

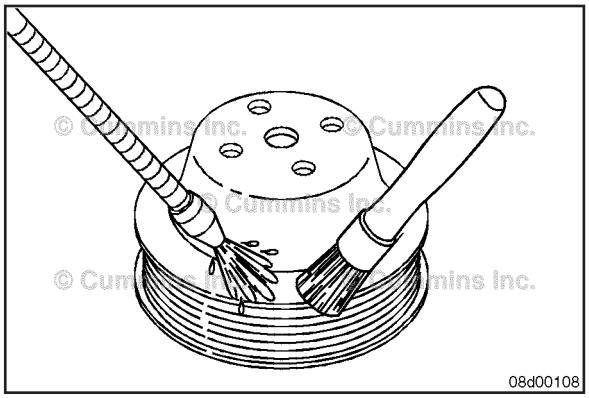


Clean and Inspect for Reuse

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

⚠WARNING⚠
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.

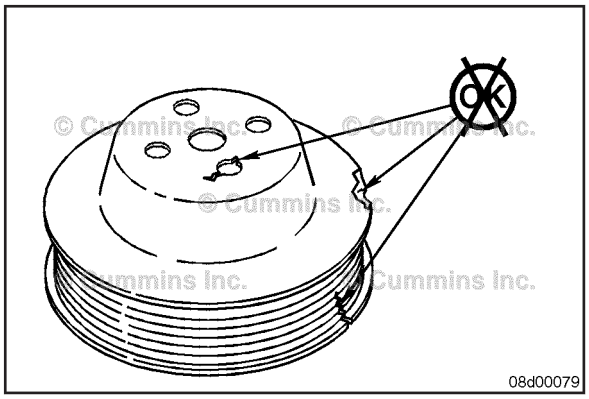
Clean the fan pulley and spacer with solvent and dry with compressed air.

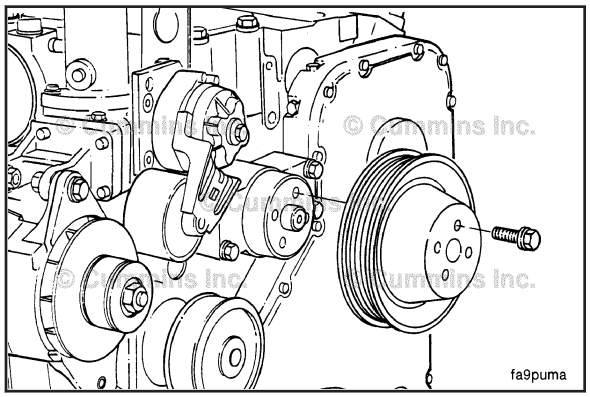


Inspect the fan pulley for cracks near bolt holes and for damage at the drive belt contact surface.

If damage is found on the fan pulley, the fan hub **must** also be inspected. Refer to Procedure 008-036 (Fan Hub, Belt Driven) in Section 8.

Replace the pulley if any damage is found.





Install

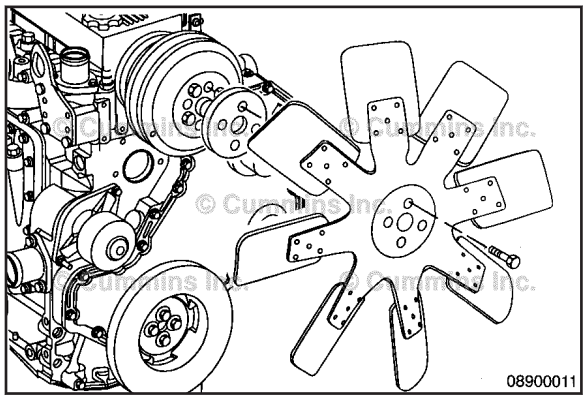
If the engine is **not** equipped with an engine driven cooling fan, install the fan pulley mounting capscrews and fan pulley.

NOTE: Use the tension of the drive belt to hold the cooling fan in place when tightening the mounting capscrews. Do **not** hold the fan blades to keep the cooling fan from rotating.

Do **not** tighten the mounting capscrews at this time. Tighten the mounting capscrews after the drive belt is installed.

Torque Value:

M6	10 N•m	[89 in-lb]
M10	43 N•m	[32 ft-lb]
M12	77 N•m	[57 ft-lb]



NOTE: Some applications do **not** have a cooling fan or the cooling fan is located elsewhere on the application.

For engines equipped with an engine driven cooling fan, the fan holds the fan pulley and spacer in place. Install the fan pulley and spacer.

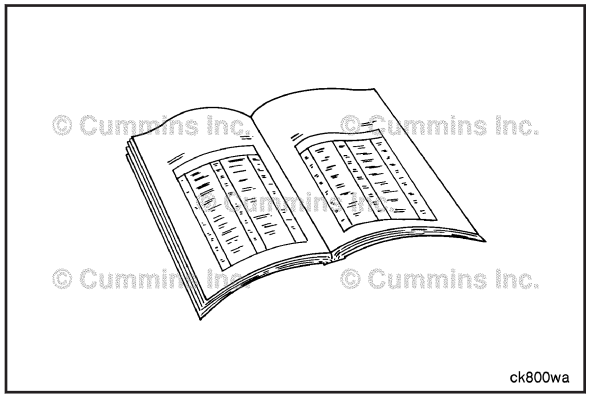
If removed, install the cooling fan. Refer to the OEM service manual for instructions.

NOTE: Use the tension of the drive belt to hold the cooling fan in place when tightening the mounting capscrews. Do **not** hold the fan blades to keep the cooling fan from rotating.

Do **not** tighten the mounting capscrews at this time. Tighten the mounting capscrews after the drive belt is installed.

Torque Value:

M6	10 N•m	[89 in-lb]
M10	43 N•m	[32 ft-lb]
M12	77 N•m	[57 ft-lb]



Finishing Steps

⚠ WARNING ⚠

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

- Install the drive belt. Refer to Procedure 008-002 (Drive Belt, Cooling Fan) in Section 8.

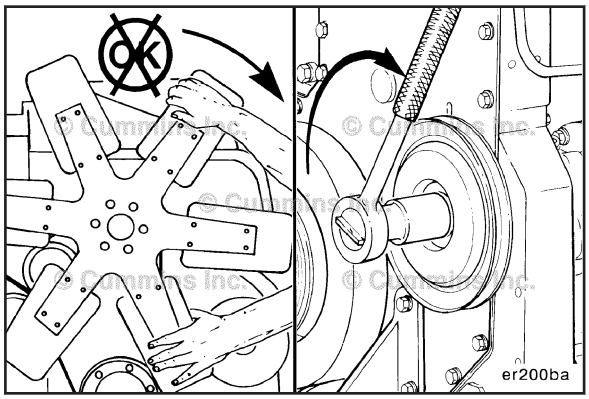
NOTE: Tighten the fan pulley and cooling fan (if equipped) mounting capscrews.

- Connect the batteries. Refer to Procedure 013-007 (Batteries) in Section 13.
- Operate the engine and check for proper operation.

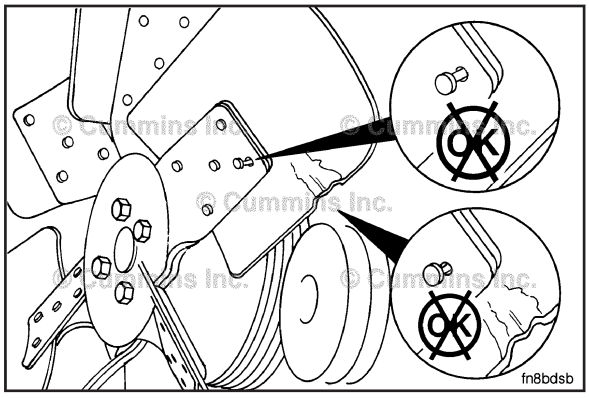
Fan, Cooling (008-040)

Inspect for Reuse

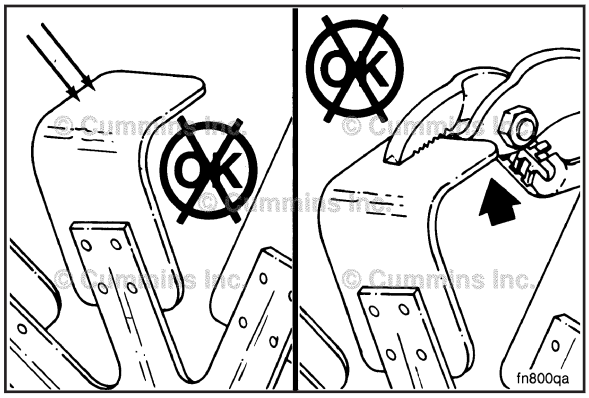
⚠WARNING⚠
Do not rotate the engine by pulling or prying on the fan. The fan blade(s) can be damaged and cause the fan to fail and cause personal injury or property damage. Use the accessory drive shaft or the crankshaft barring tool to rotate the crankshaft.



A visual inspection of the cooling fan is required daily. Check for cracks, loose rivets, and bent or loose blades. Check the fan to make sure it is securely mounted. Tighten the capscrews, if necessary.

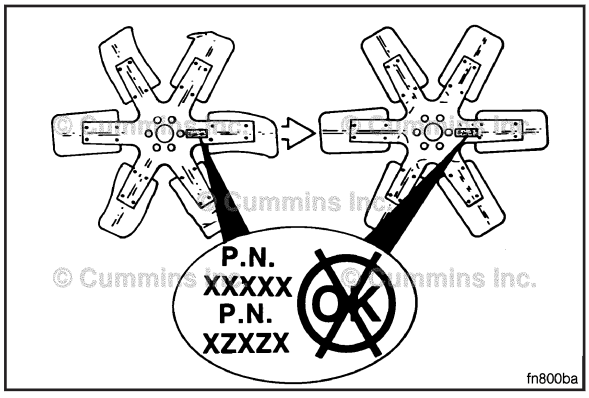


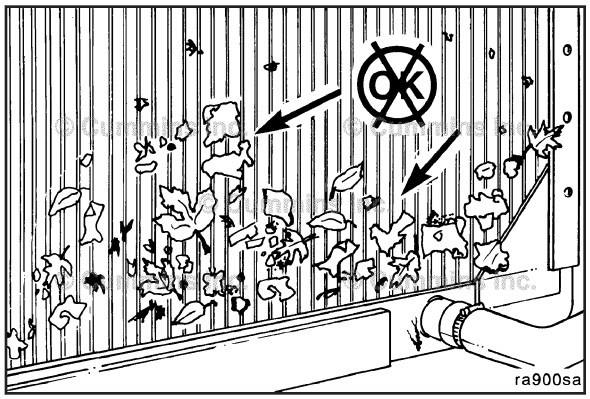
⚠WARNING⚠
Do not straighten a bent fan blade or continue to use a damaged fan. A bent or damaged fan blade can fail during operation and cause personal injury or property damage.



Replace original equipment fan that is damaged with a fan of the identical part number. Cummins Inc. **must** approve any other fan changes to be covered under warranty.

Refer to the vehicle or equipment manufacturer's specifications for capscrew torque.

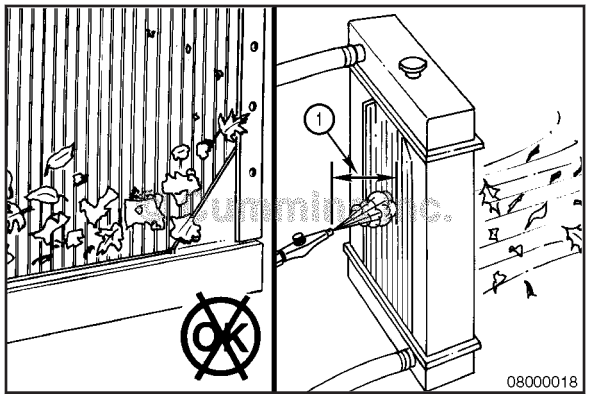




Radiator (008-042)

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

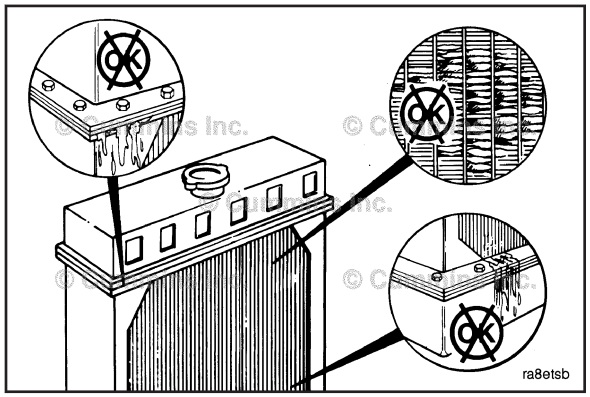
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

△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.

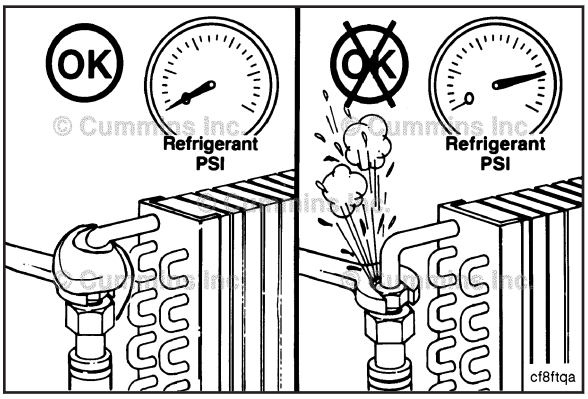
Inspect the radiator core and gasket for leaks.

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.

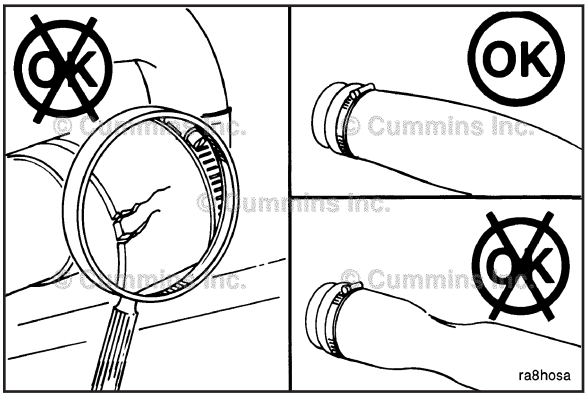


Radiator Hoses (008-045)

Inspect for Reuse

Inspect all hoses for cracks, cuts, or collapsing.

NOTE: The silicone engine coolant hose will exhibit swelling due to the elasticity of the hose.



Radiator Pressure Cap (008-047)

General Information

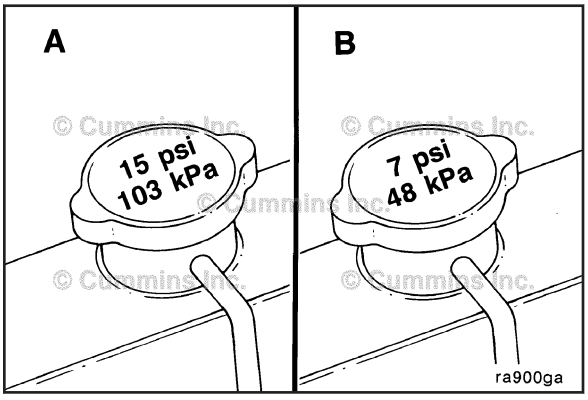
Pressure Caps

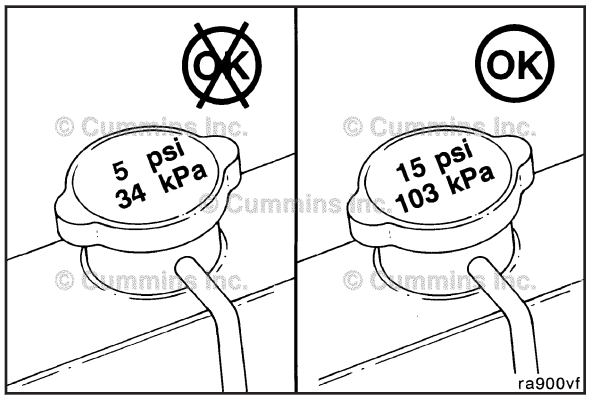
The system is designed to use a pressure cap to prevent boiling of the coolant.

Different caps are specified for the two recommended systems:

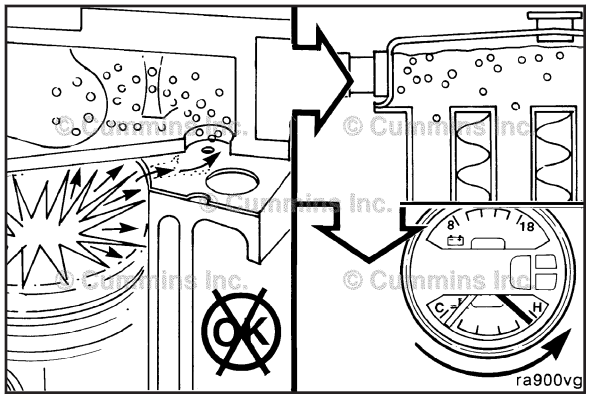
Radiator Cap Pressure Test		
	System	**Cap**
A (Normal-Duty)	104°C [219°F]	103 KPa [15 psi]
B (Light-Duty)	99°C [210°F]	48 KPa [7 psi]

NOTE: An incorrect or malfunctioning cap can result in the loss of coolant and the engine running hot.



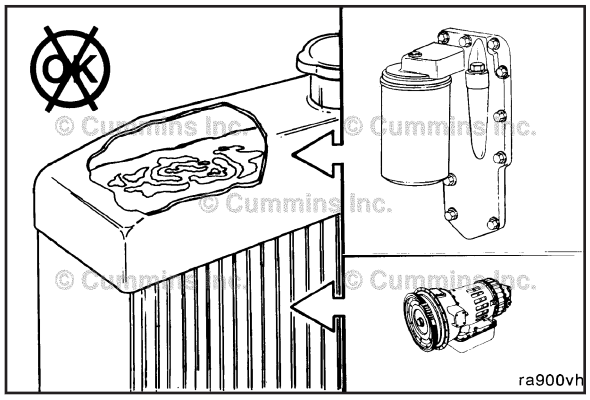


An incorrect or malfunctioning cap can result in loss of coolant and the engine running hot.



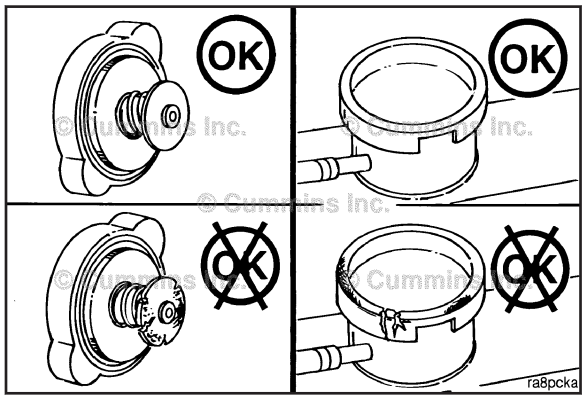
Air in the coolant can result in loss of coolant from the overflow when the aerated coolant is hot. The heated air expands, increasing the pressure in the system, causing the cap to open.

Similarly, coolant can be displaced through the overflow if the head gasket leaks compression gases to the coolant system.



The operating pressure of the coolant system and the lubricating system can result in the mixing of the fluids if there is a leak between the systems, such as the head gasket or oil cooler (refer to Procedure 007-037 Lubricating Oil System in Section 7).

NOTE: Transmission fluid can also leak into the coolant through radiator bottom tank transmission oil coolers. Refer to the OEM service manual.



Inspect for Reuse

Be sure the correct radiator cap is being used. Refer to (Cooling System) in Section V - Specifications.

Inspect the rubber seal of the pressure cap for damage.

Inspect the radiator fill neck for cracks or other damage.

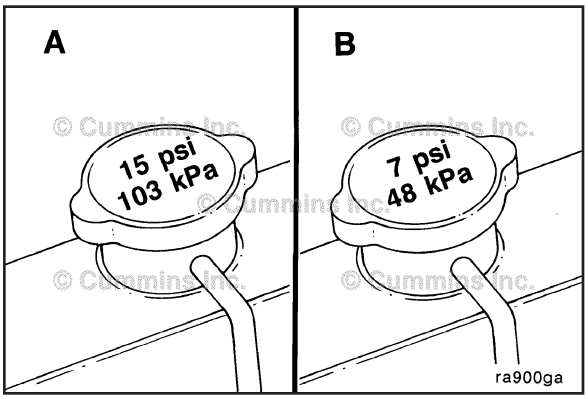
Refer to the radiator manufacturer for instructions if the fill neck is damaged.

Pressure Test

The system is designed to use the pressure cap to prevent boiling of the coolant.

Different caps are specified for the two recommended systems:

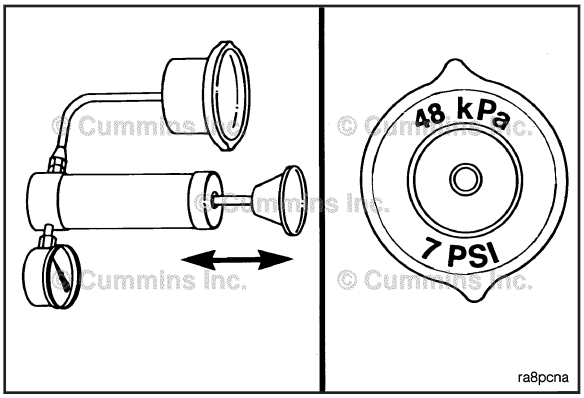
System	Cap
A-Normal-Duty 104°C [219°F]	103 kPa [15 psi]
B-Light-Duty 99°C [210°F]	48 kPa [7 psi]



Pressure-test the radiator cap.

The pressure cap **must** seal within the value stated on the cap, or it **must** be replaced.

NOTE: An incorrect or malfunctioning cap can result in loss of coolant and the engine running hot.

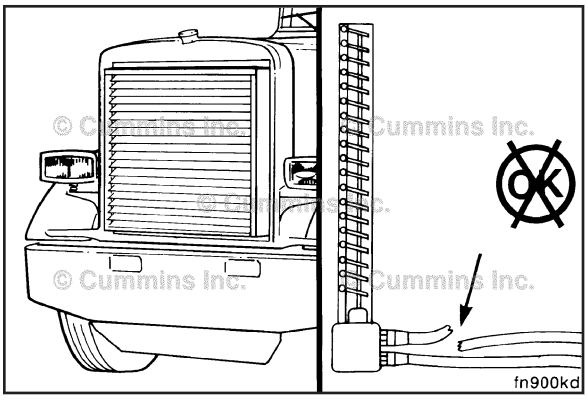


Radiator Shutter Assembly (008-049)

General Information

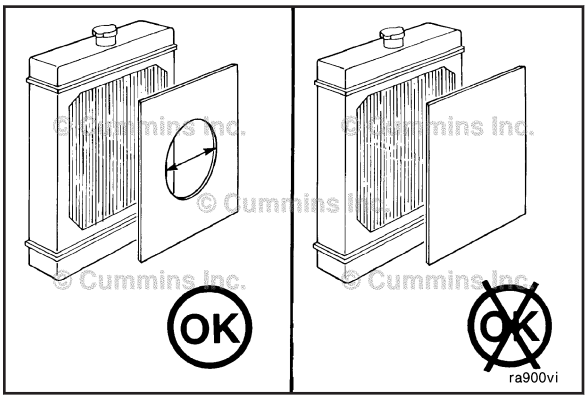
Shutters are designed to control airflow across the radiator. If the shutters fail to open when needed, the engine can run hot. Failure of the shutters to close can result in too much airflow and the engine running cold.

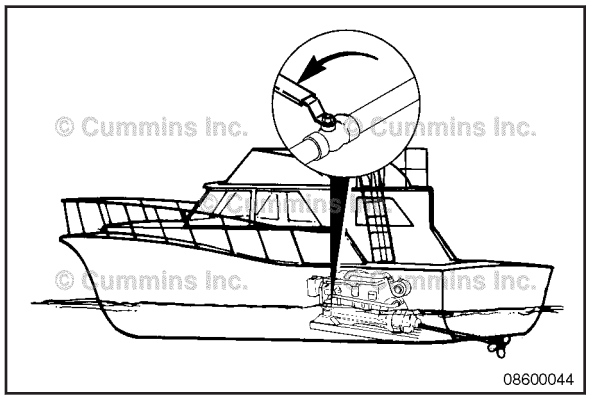
NOTE: Make sure the air temperature sensor is functioning correctly. Check the air-operated shutter controls. Check for air leaks. Refer to the equipment manufacturer's service manual.



Winterfronts can be used on a charge air cooled engine, but **must** be designed to cover the frontal area of the cooling system partially. A minimum of charge air cooled frontal area **must** be left open to air flow.

Winterfronts: 302² mm [60² in]

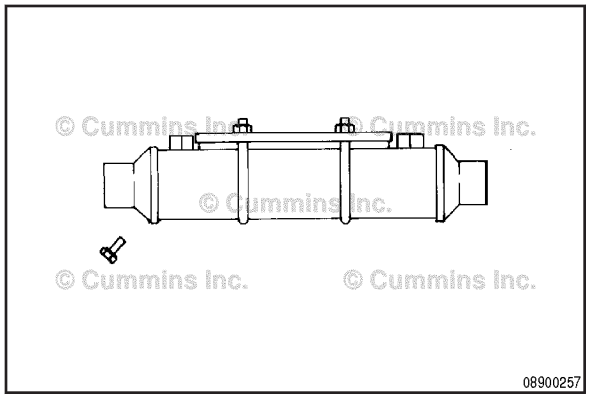




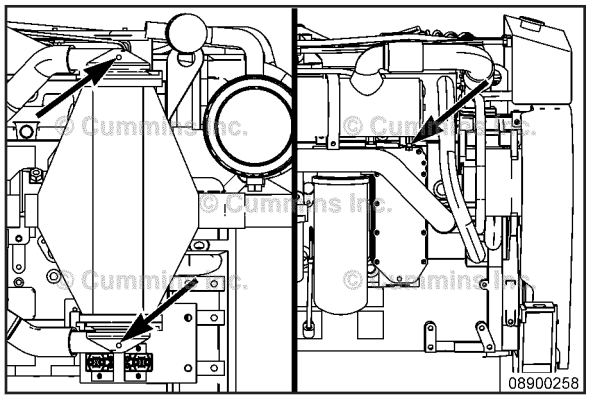
Heat Exchanger (008-053)

Flush

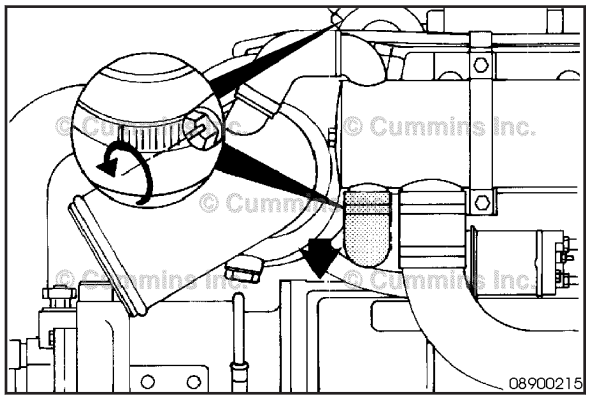
Shut off the sea water valve on the vessel hull.



To flush the marine gear oil cooler refer to Procedure 008-041 (Marine Gear Oil Cooler) in Section 5.



Remove the zinc plugs (1) from the aftercooler and heat exchanger.



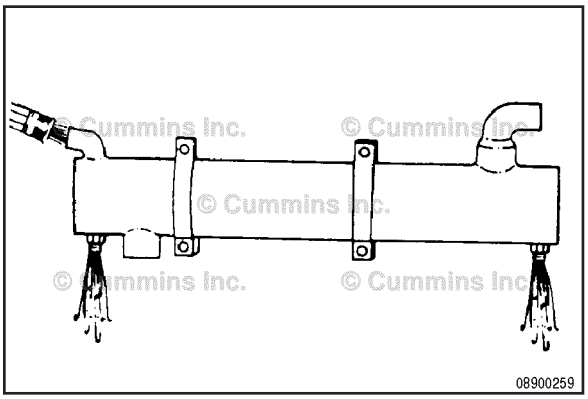
Typical hose connections are shown.

Refer to 100-002 (Engine Diagrams) in Section E.

Disconnect the sea water inlet and outlet connection from the heat exchanger.

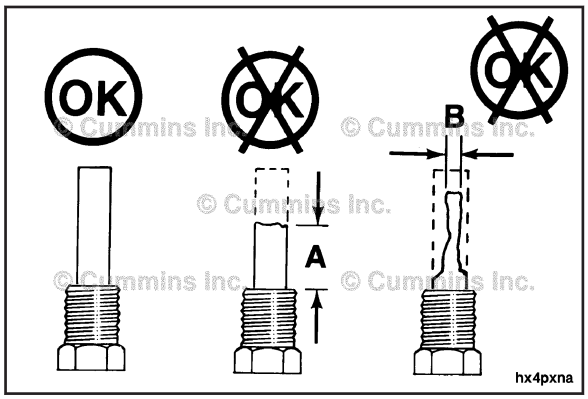
Use clean low-pressure water to back flush the heat exchanger.

Connect the hose to the heat exchanger sea water outlet to allow the water to back flush 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.

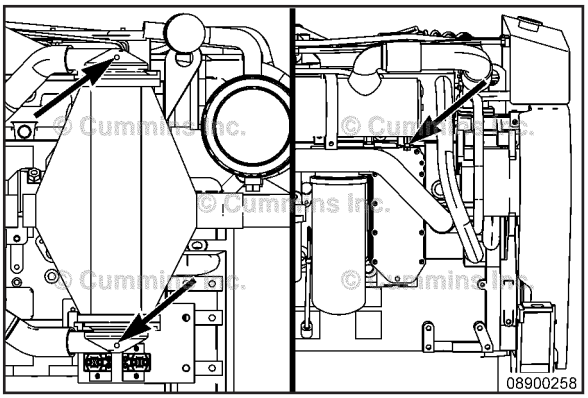
Erosion Limits	New
A = Approximately 19 mm [0.75 in]	51 mm [2 in]
B = Approximately 6.4 mm [0.25 in]	16 mm [0.63 in]



NOTE: Do **not** use thread sealant on the zinc plugs. They **must** be grounded to the component to function properly.

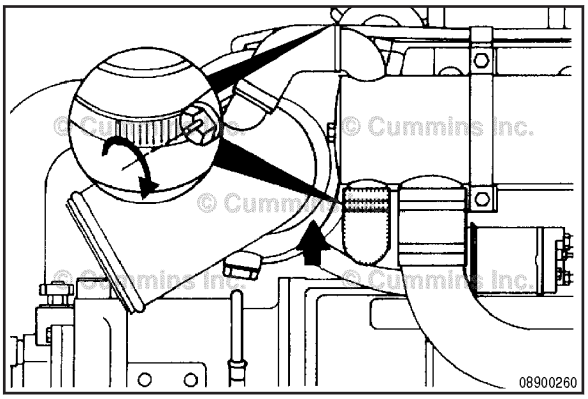
Install the zinc plugs in the aftercooler and heat exchanger.

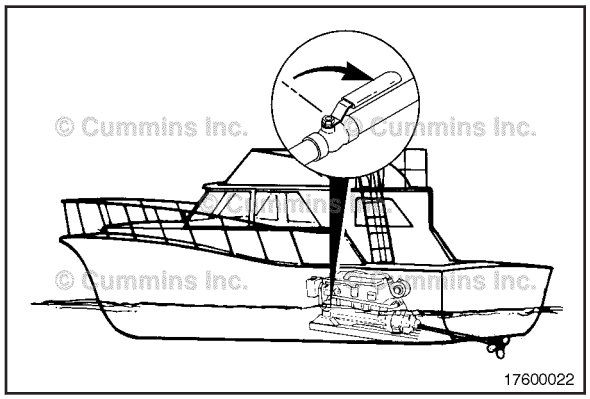
Torque Value: 22 N•m [196 in-lb]



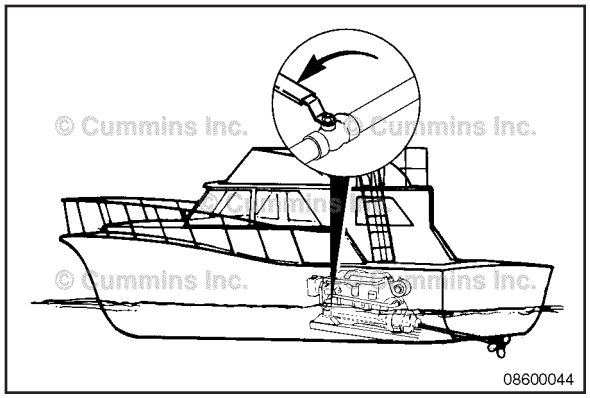
Install the sea water inlet and outlet connections.

Torque Value: 5 N•m [44 in-lb]





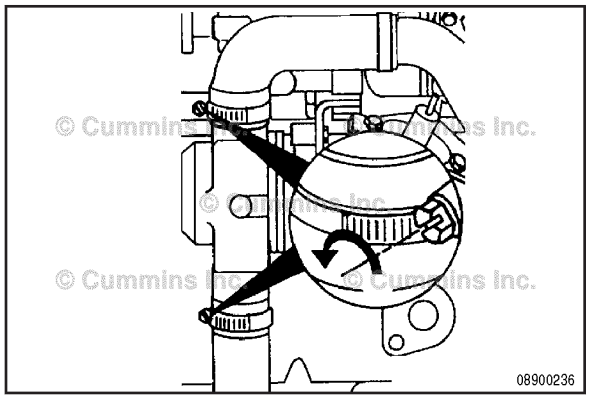
Open the sea water valve on the vessel hull.



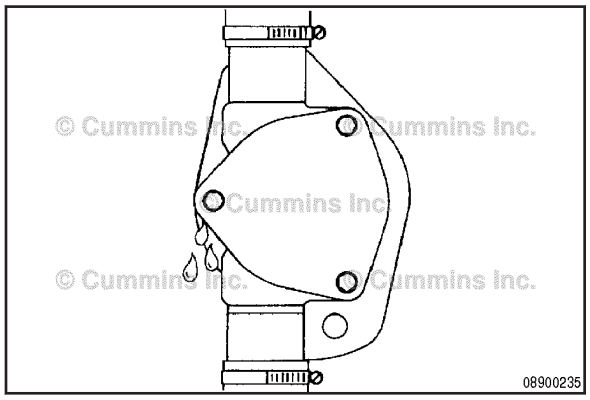
Sea Water Pump (008-057)

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.



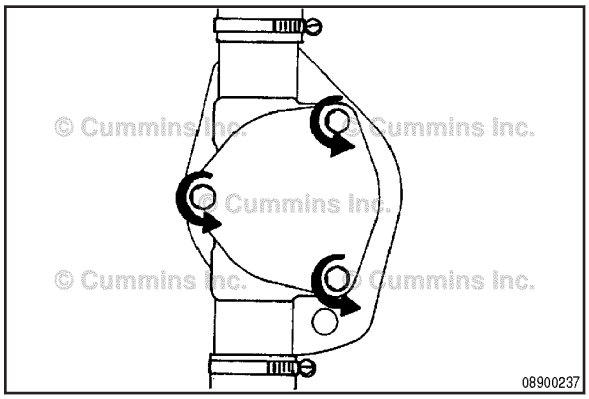
Remove

⚠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.

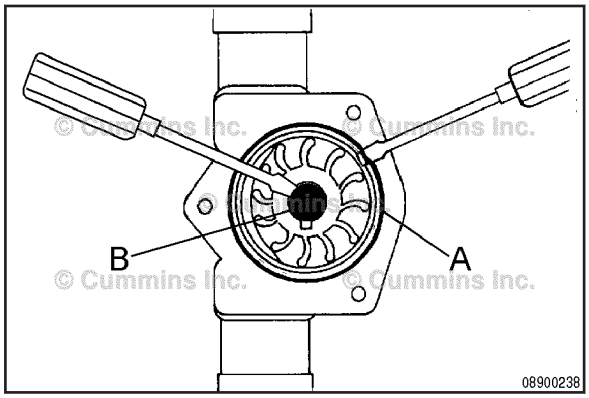
Remove the capscrews. Lift off the cover.



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.

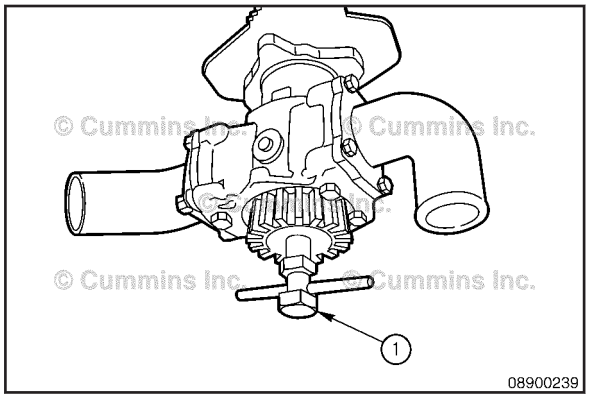


⚠CAUTION⚠
Do not pry against the pump housing to remove the impeller as this can cause damage to the liner.

Be sure to note the direction of impeller fins for proper installation. Mark the outer surface.

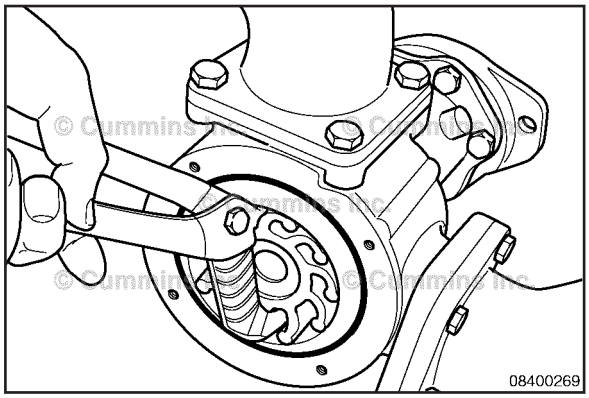
An impeller removal tool is available from Sherwood Pumps, Part Number 23631.

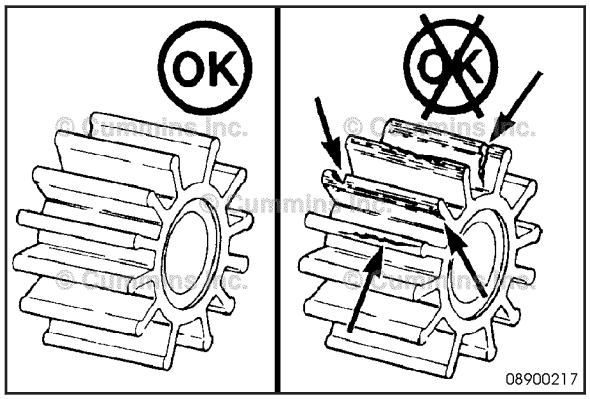
If the impeller is equipped with a threaded insert, use the special tool or a ¾-NFT bolt (1) to insert in the impeller to pull the impeller out.



Be sure to note the direction of impeller fins for proper 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.

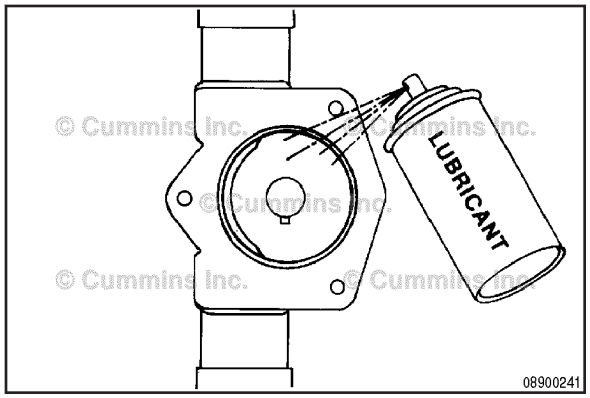




Clean and Inspect for Reuse

Inspect for damage such as rips, tears, chunks of material missing, or wear on the edges of the blades.

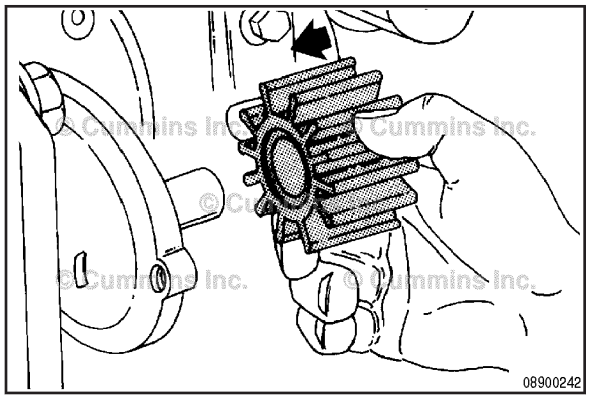
Replace as necessary.



Clean the internal pump surfaces.

Lubricate the housing with silicone or glycerine non-petroleum-based lubricant. Petroleum-based lubricant will damage the rubber impeller.

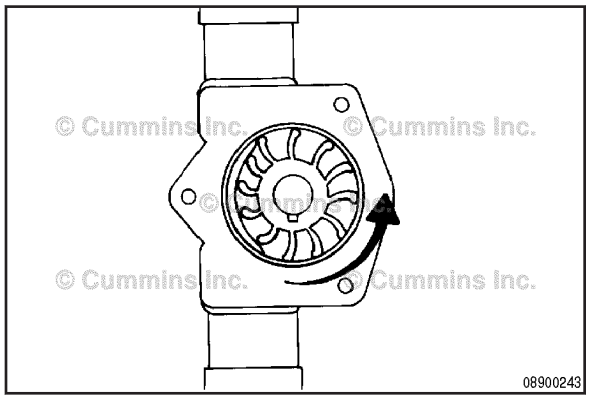
If non-petroleum-based lubricant is **not** readily available, use soapy water to ease installation.



Install

If the impeller is in good shape and will be reused, install it in the same direction from which it was removed. Use the mark you made during removal.

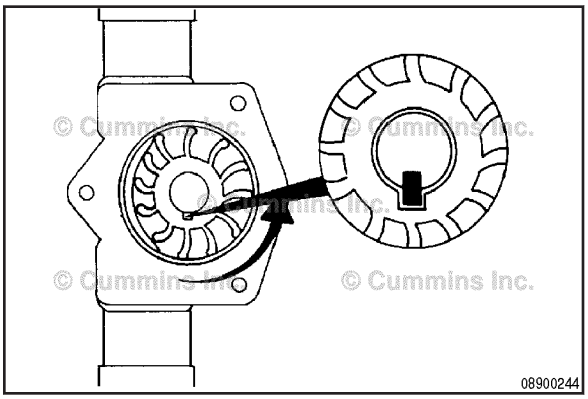
If the impeller was **not** marked and the original rotation or direction can **not** be determined, replace the impeller with a new one.



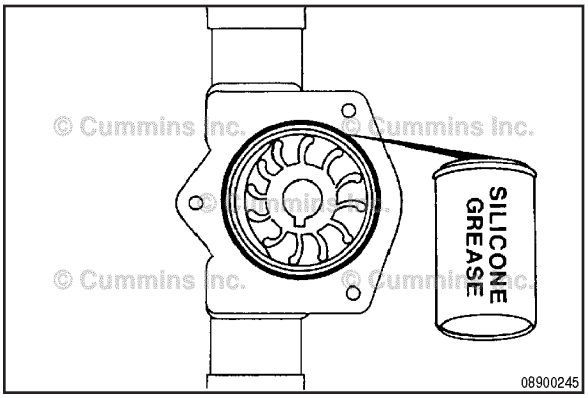
An oil filter strap wrench or even plastic wire straps can be used as an installation aid to hold the vanes.

Guide the impeller into the housing, twisting it **counterclockwise** as it is advanced so that the vanes will be deflected in the proper direction.

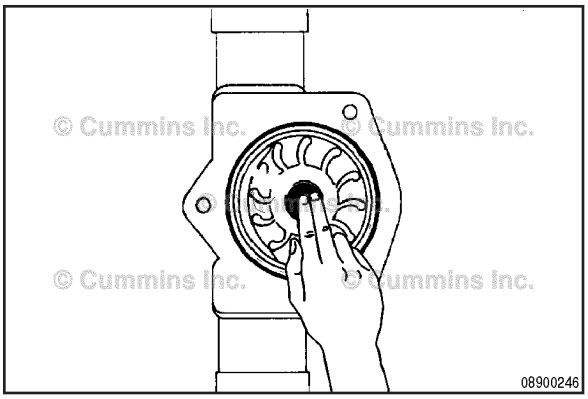
Continue to turn the impeller while pushing it into the housing. It will slide all the way in when the keyway lines up with the key.



Insert the new o-ring into the impeller housing. Use a little silicone grease to hold it in place.



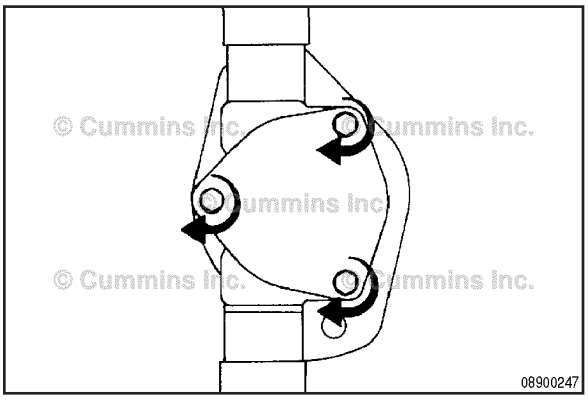
Install the rubber impeller cap into the center hub of the impeller.

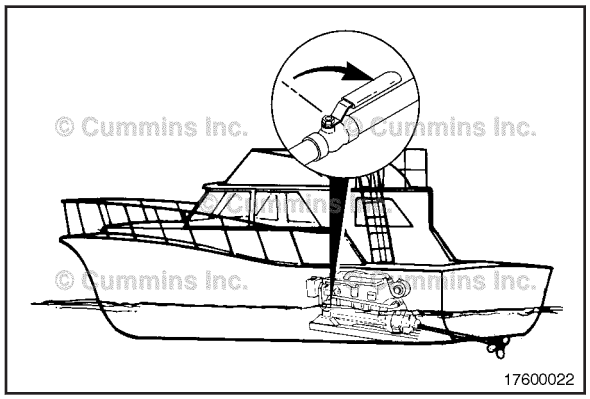


Install a new gasket, cover plate, and capscrews.

Tighten the capscrews.

Torque Value: 24 N•m [212 in-lb]

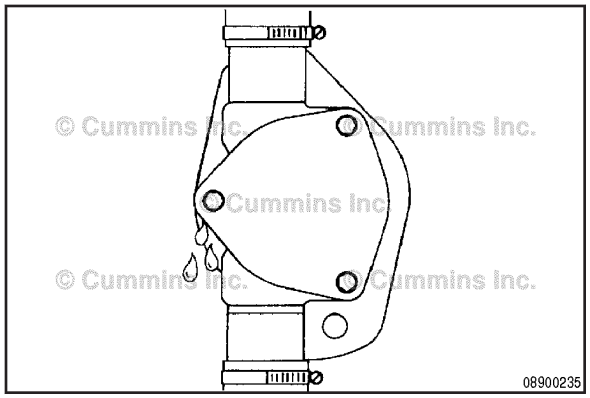




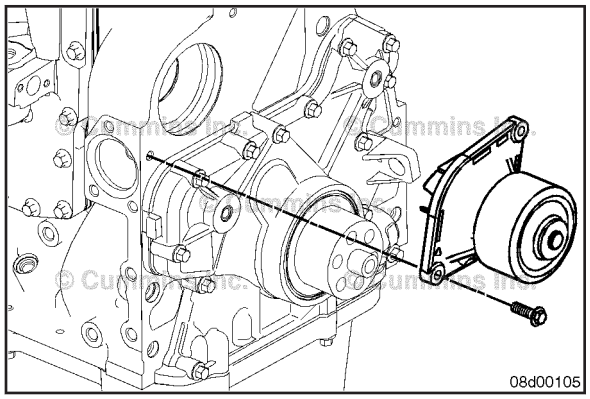
Finishing Steps

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.

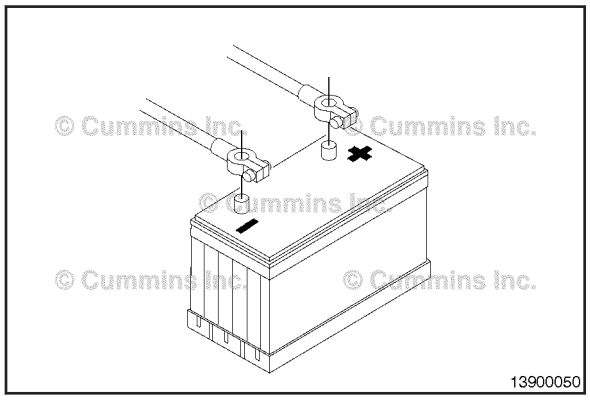


Water Pump (008-062)

General Information

The water pump is a belt-driven, centrifugal-type pump with the inlet and bypass as integral parts of the cylinder block.

NOTE: It is **not** practical to replace the components of the water pump; the water pump is serviced as an assembly.



Preparatory Steps

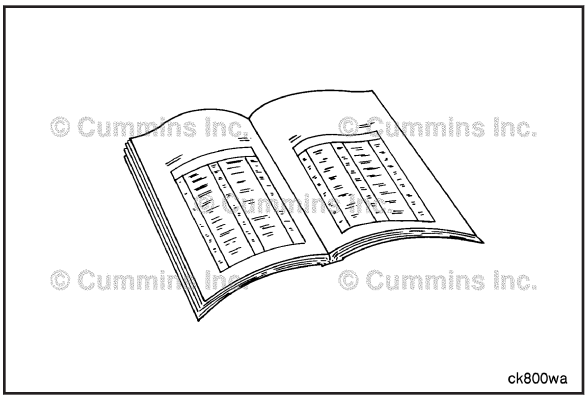
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries. Refer to the OEM service manual.

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

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

- Drain the coolant. Refer to Procedure 008-018 in Section 8.
- Remove the drive belt. Refer to Procedure 008-002 in Section 8.



Initial Check

Inspect the water pump housing for cracks and/or damage.

Check the water pump seal weep hole. The water pump seal design requires a coolant film for lubrication and cooling. Therefore, it is normal to observe a minor chemical buildup or streaking at the weephole.

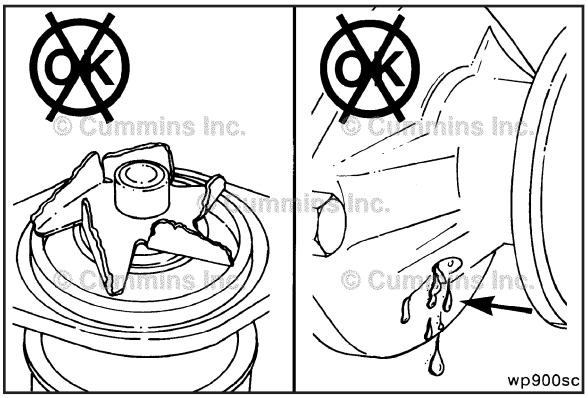
Use the following guidelines to determine if water pump replacement is necessary:

NOTE: A streak or chemical buildup at the weep hole is **not** justification for water pump replacement.

Make sure the weep hole is open.

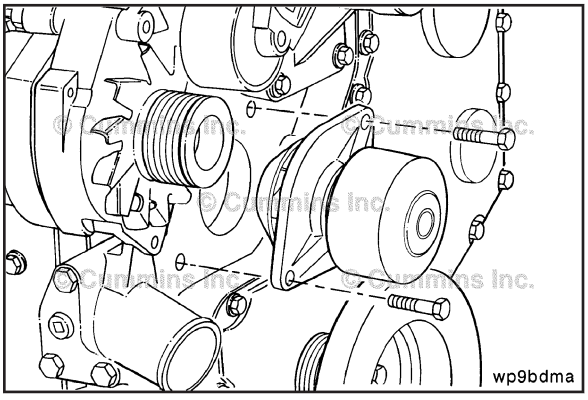
NOTE: A small screwdriver or a similar tool can be used to remove any debris.

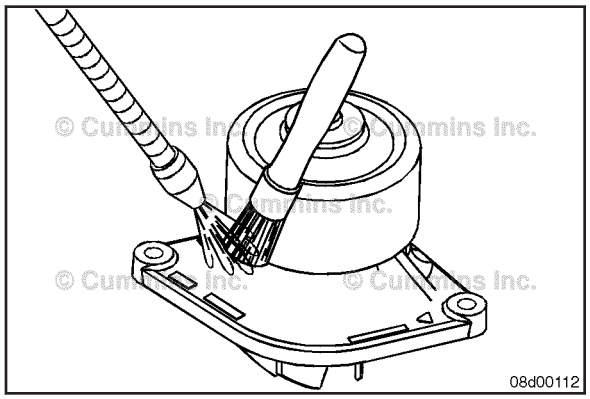
If no leakage is observed from the weep hole under operating conditions, do **not** replace the water pump.



Remove

Remove the two mounting capscrews, water pump, and seal.



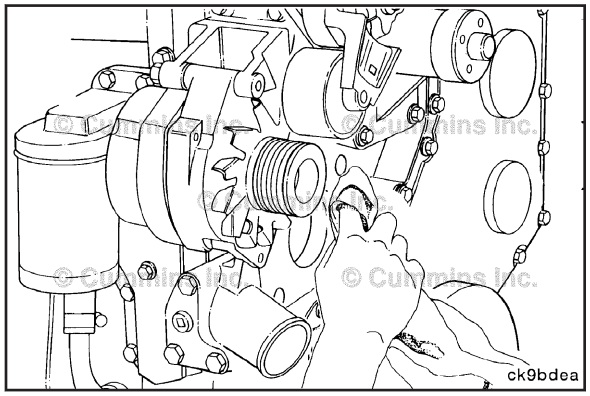


Clean and Inspect for Reuse

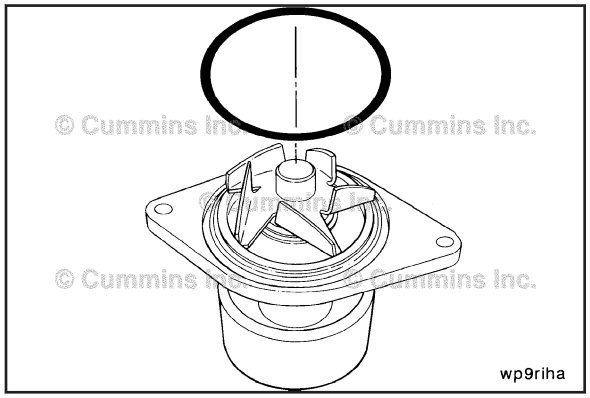
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

Clean the water pump with solvent. Dry with compressed air.

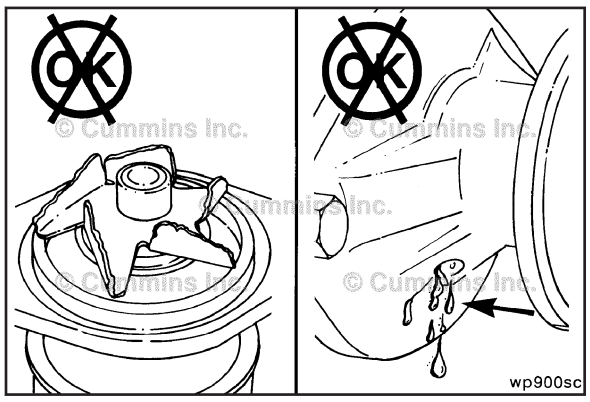


Clean the sealing surface on the cylinder block.



Clean the o-ring sealing surface on the water pump housing.

Inspect the sealing surface for damage. Replace the water pump if any damage is found.



Inspect the impeller for cracks, missing blades, slippage on the shaft, and other types of damage.

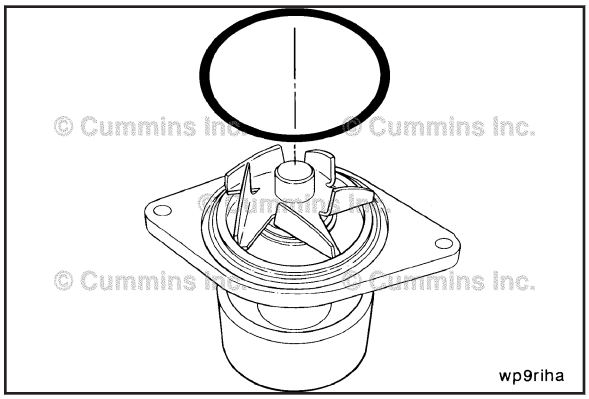
NOTE: If any damage to the impeller blades is found, make sure to inspect the cylinder block for damage.

Inspect the water pump housing for damage and cracks.

Replace the water pump if any damage is found.

Install

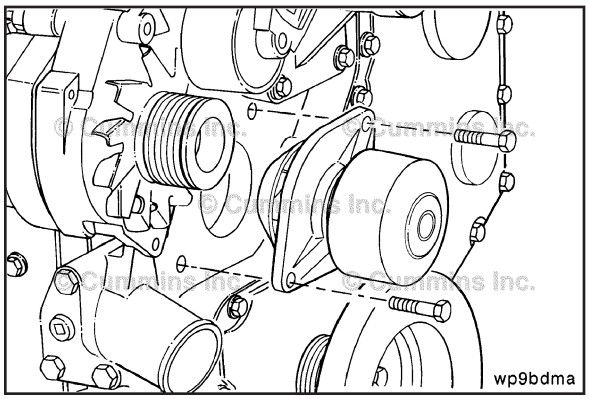
Install the new sealing ring into the pump groove.



Install the water pump (with seal) and mounting capscrews.

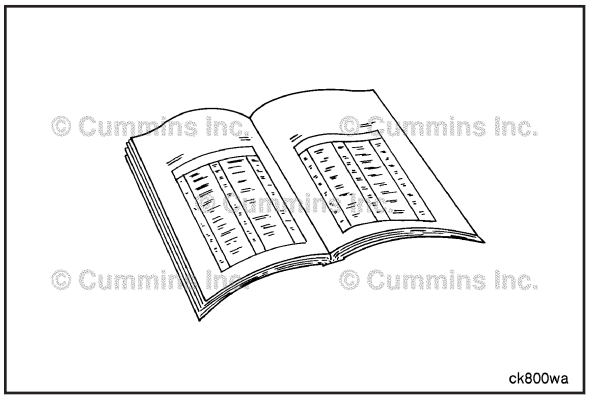
Torque Value:
9.8 Grade
Step 1 24 N•m [212 in-lb]

Torque Value:
10.9 Grade
Step 1 30 N•m [22 ft-lb]



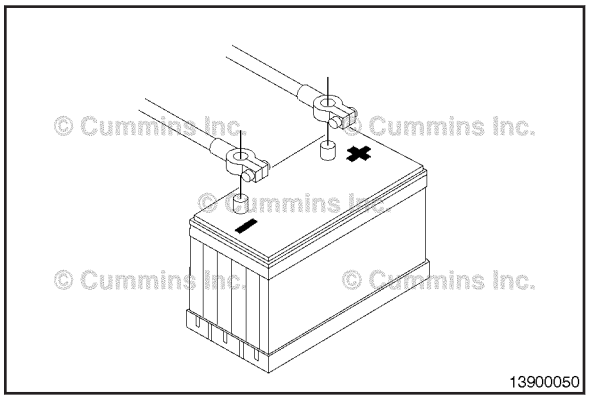
Finishing Steps

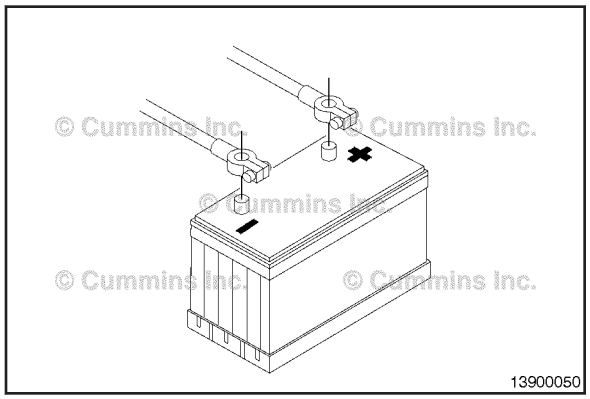
- Install the drive belt. Refer to Procedure Procedure 008-002 in Section 8.
- Fill the cooling system. Refer to Procedure Procedure 008-018 in Section 8.



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

- Connect the batteries. Refer to the OEM service manual.
- Operate the engine and check for leaks.



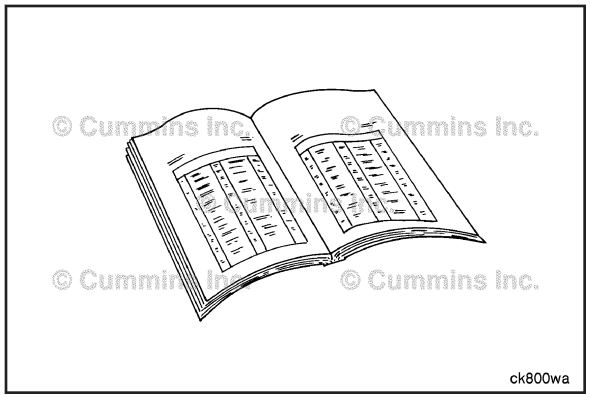


Coolant Temperature Sensor (008-070)

Preparatory Steps

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

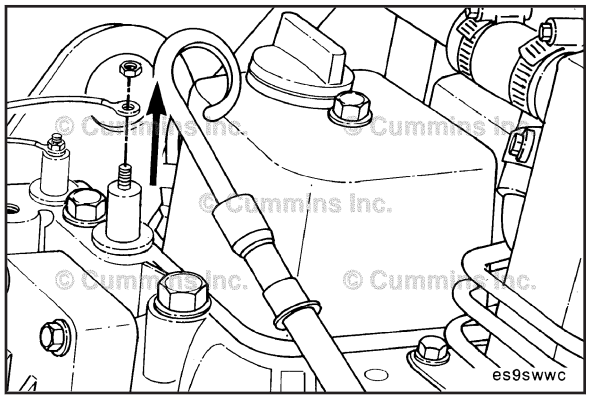
- Disconnect the batteries.



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

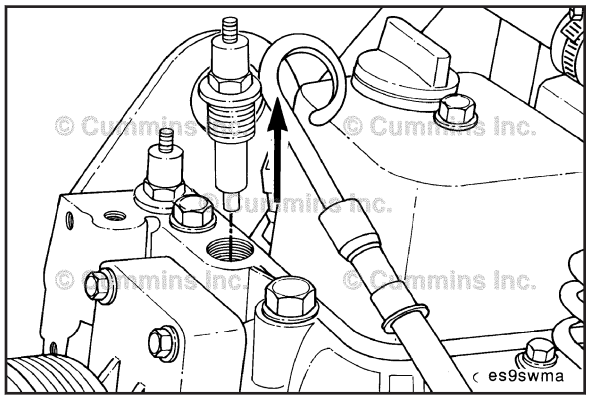
⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the temperature is below 50°C [122°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

- Drain the coolant. Refer to Procedure 008-018 (Cooling System) in Section 8.



Remove

Disconnect the temperature sensor wiring.

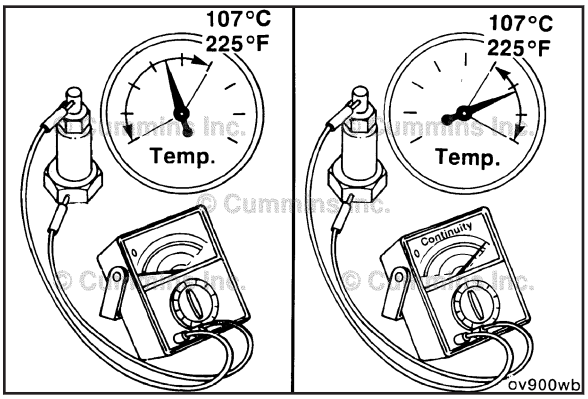


Remove the temperature sensor.

Inspect for Reuse

Check for continuity. The sensor will have continuity **only** when coolant temperature is reached.

Sensor: 107 °C [225 °F]



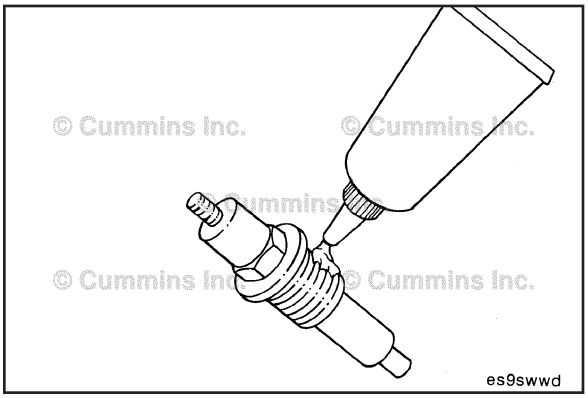
Install

Apply liquid Teflon sealant to the threads when installing the temperature sensor.

Reconnect the wiring.

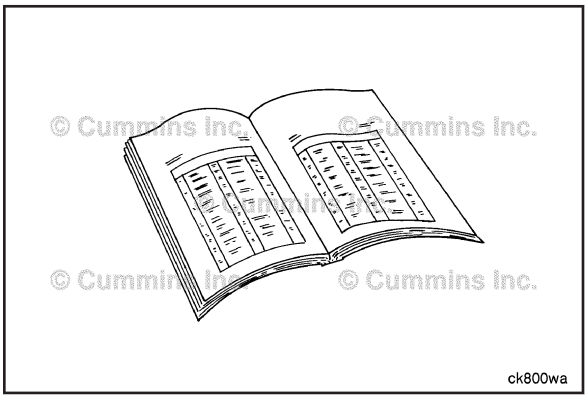
Torque Value:

(Installed Cast Iron)	into50 N•m	[37 ft-lb]
(Installed Aluminum)	into30 N•m	[22 ft-lb]



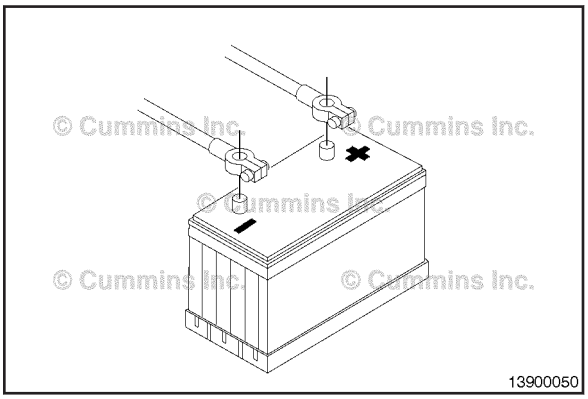
Finishing Steps

- Fill coolant to proper level. Refer to Procedure 008-018 (Cooling System) in Section 8.



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

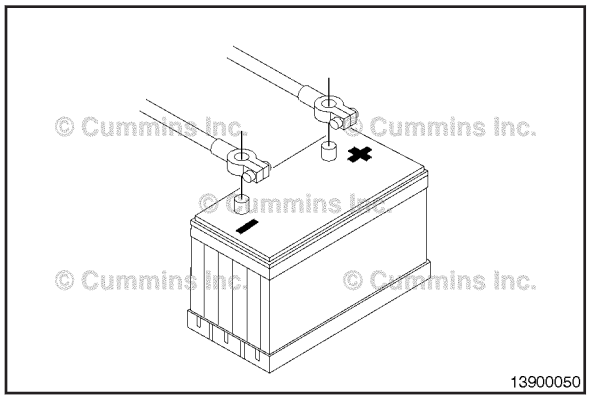
- Connect the batteries
- Operate the engine and check for leaks.



Water Inlet Connection (008-082)

General Information

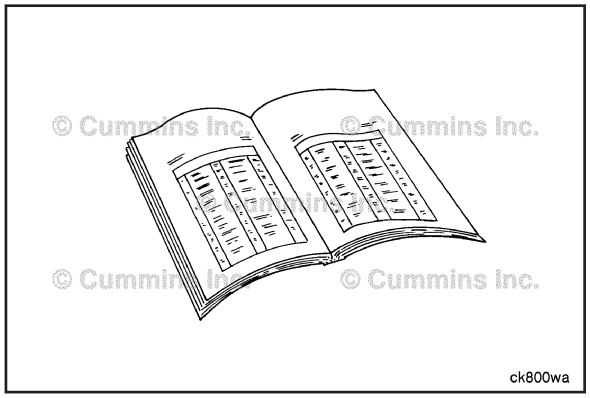
NOTE: Due to the number of water inlet connection options, the following procedure has been commonized. The illustrations may **not** match the engine being serviced, but the procedures are the same.



Preparatory Steps

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

- Disconnect the batteries.



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

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

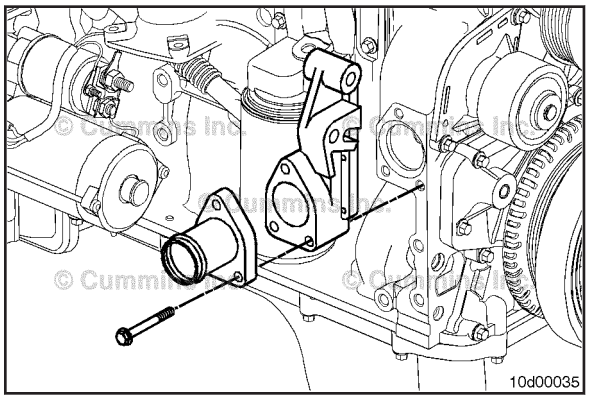
- Drain the cooling system. Refer to Procedure 008-018.

NOTE: Some belt tensioners are mounted to the water inlet connection.

- If required, remove the cooling fan drive belt. Refer to Procedure 008-002
- If required, remove the fan belt tensioner. Refer to Procedure 008-087
- Remove the lower radiator hose. Refer to Procedure 008-045
- If required, disconnect any OEM coolant hoses. Refer to the OEM service manual
- If required, remove the alternator and alternator mounting brackets. Refer to Procedure 013-001 and Procedure 013-003.

Remove

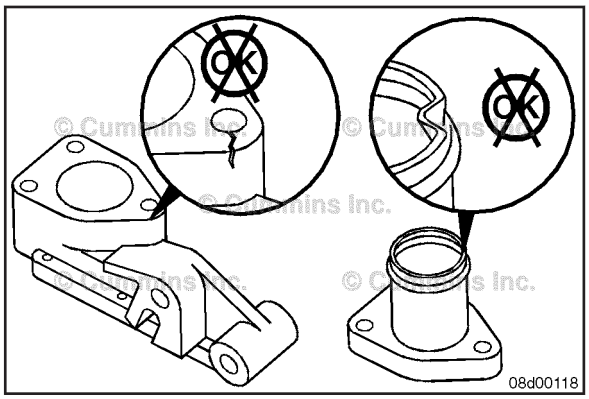
Remove the capscrews, water inlet connection, gasket, and rectangular sealing ring.



Clean and Inspect for Reuse

Inspect the rectangular sealing ring for cracks.

If evidence of leaking exists, replace the rectangular sealing ring.



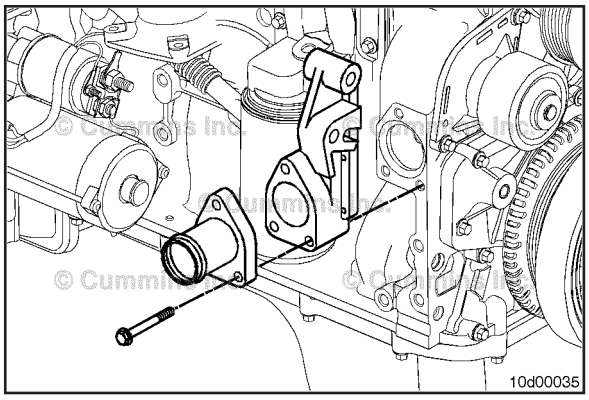
Install

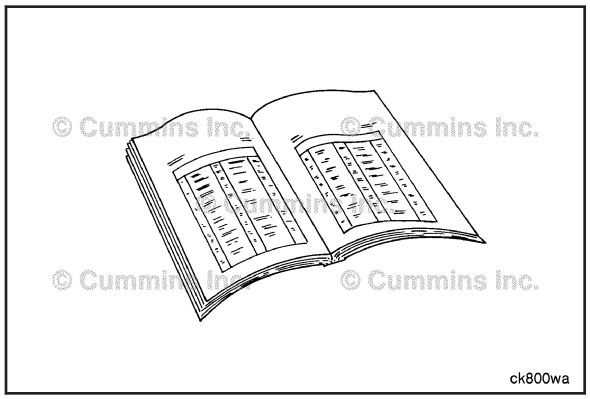
Install the capscrews, water inlet connection, gasket, and rectangular sealing ring.

Align the roll pins against the front face of the cylinder block and tighten the capscrews.

Torque Value:

M10	43 N•m	[32 ft-lb]
M12	80 N•m	[59 ft-lb]



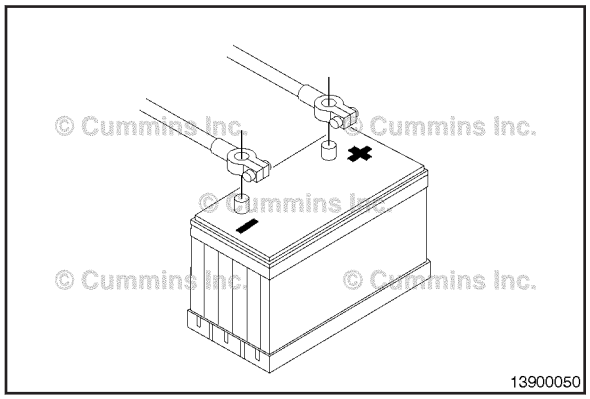


Finishing Steps

⚠WARNING⚠

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

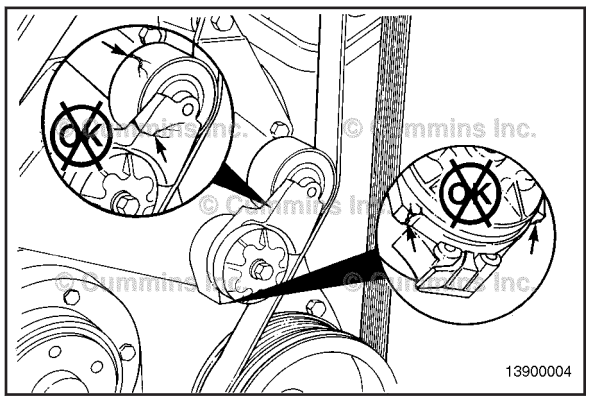
- If removed, install the fan belt tensioner. Refer to Procedure 008-087
- If removed, install the cooling fan drive belt. Refer to Procedure 008-002
- If removed, connect any OEM coolant hoses. Refer to OEM service manual
- Connect the lower radiator hose. Refer to Procedure 008-045
- If removed, install the alternator and alternator mounting brackets. Refer to Procedure 013-001 and Procedure 013-003
- Fill the cooling system. Refer to Procedure 008-018.



⚠WARNING⚠

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

- Connect the batteries
- Operate the engine and check for leaks, alignment, and tension on the drive belt.



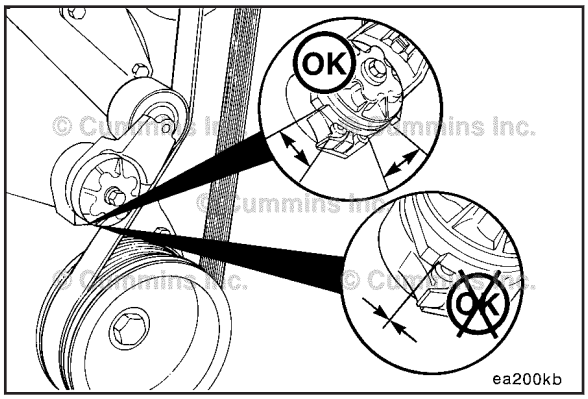
Cooling Fan Belt Tensioner (008-087)

Initial Check

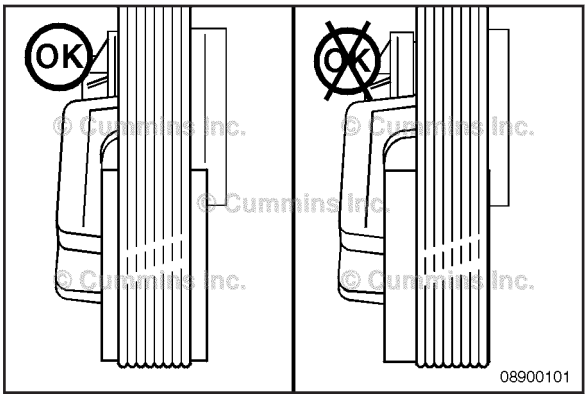
Check the tensioner arm, pulley, and stops for cracks. If any cracks are noticed, the tensioner **must** be replaced.

With the belt on, verify that neither tensioner arm stops are in contact with the spring casing stop. If either stop is touching, the drive belt **must** be replaced.

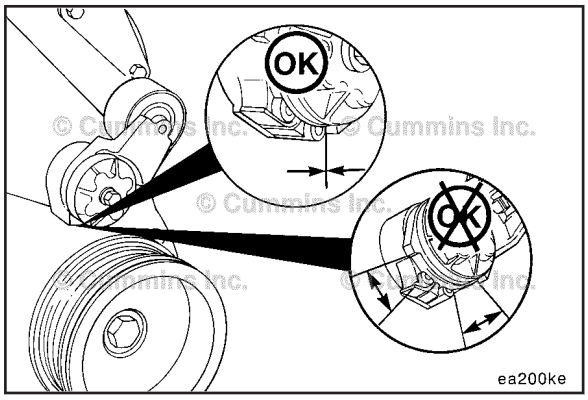
After replacing the belt, if the tensioner arm stops are still in contact with the spring case stop, replace the tensioner.



Check the location of the drive belt on the belt tensioner pulley. The belt should be centered on, or close to the middle of, the pulley. Unaligned belts, either too far forward or backward, can cause belt wear, belt roll-off failures, or increase uneven tensioner bushing wear.



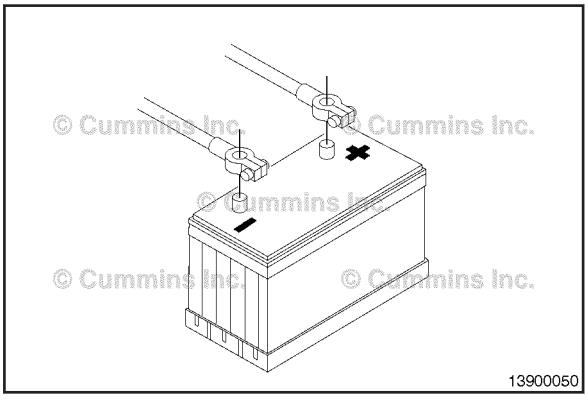
With the belt removed, verify that the tensioner arm stop is in contact with the spring case stop. If these two are **not** touching, the tensioner **must** be replaced.

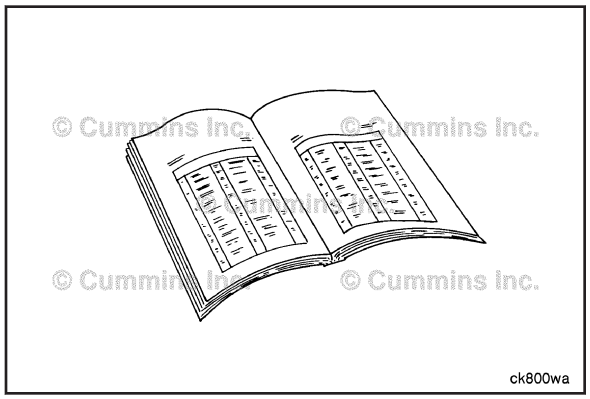


Preparatory Steps

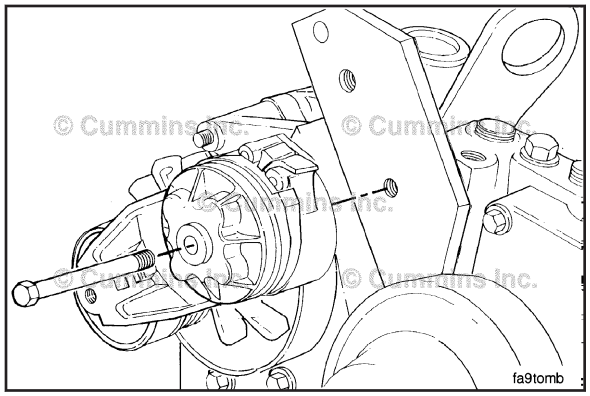
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries.





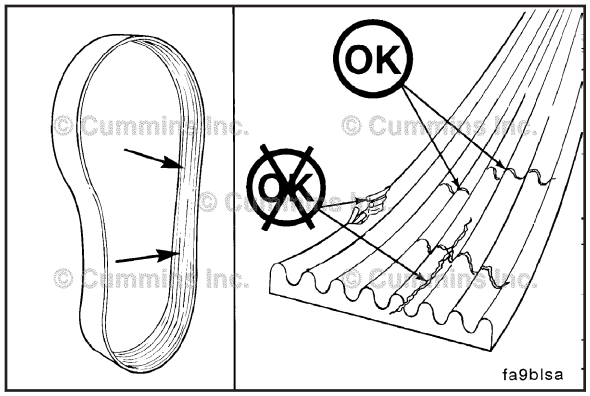
- Remove the drive belt. Refer to Procedure 008-002.



Remove

Remove the capscrew and belt tensioner from the bracket.

NOTE: Some belt tensioners are mounted to the water inlet connection.



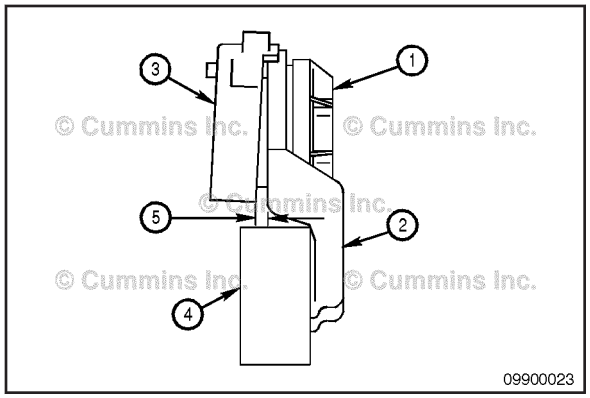
Clean and Inspect for Reuse

Check the belt for damage.

Transverse (across the belt width) cracks are acceptable.

Longitudinal (direction of the belt length) cracks that intersect with transverse cracks are **not** acceptable.

If the belt is frayed or has any piece of material missing, the belt is unacceptable and needs to be replaced.

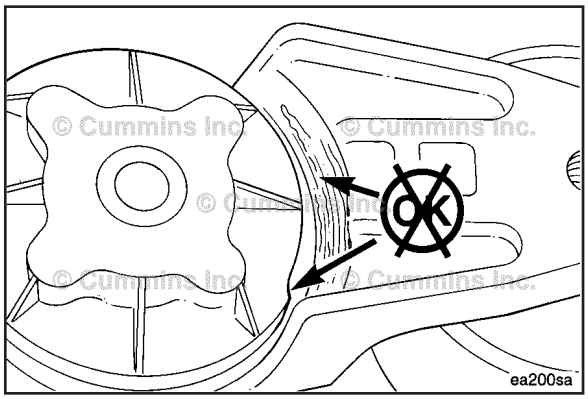


Measure the clearance between the tensioner spring case and the tensioner arm to verify tensioner wear-out and uneven bearing wear. If the clearance exceeds 3 mm [0.12 in] at any point, the tensioner failed and **must** be replaced as a complete assembly.

Experience has revealed that tensioners generally will show a larger clearance gap near the lower portion of the spring case, resulting in the upper portion rubbing against the tensioner arm. **Always** replace the belt when a tensioner is replaced.

1. Tensioner cap
2. Tensioner arm
3. Spring case
4. Tensioner pulley
5. Clearance gap.

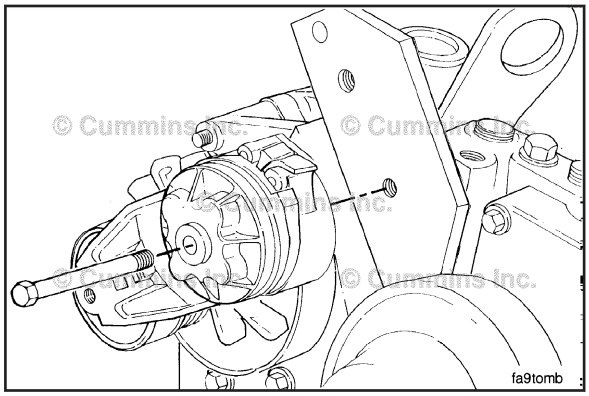
Inspect the tensioner for evidence of the tensioner arm contacting the tensioner cap. If there is evidence of the two areas making contact, the pivot tube bushing has failed and the tensioner **must** be replaced.



Install

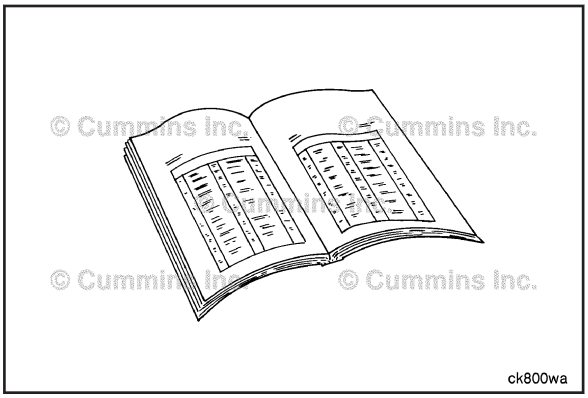
Install the tensioner and capscrew.

Torque Value: 43 N•m [32 ft-lb]



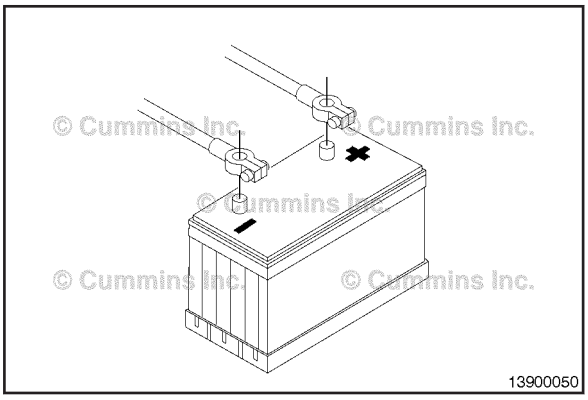
Finishing Steps

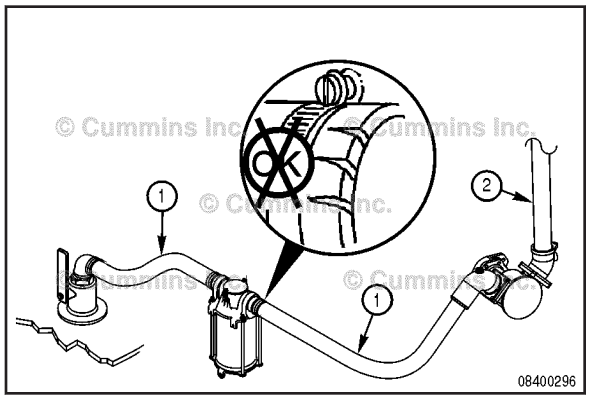
- Install the drive belt. Refer to Procedure 008-082.



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

- Connect the batteries.





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 9 - Drive Units - Group 09

Section Contents

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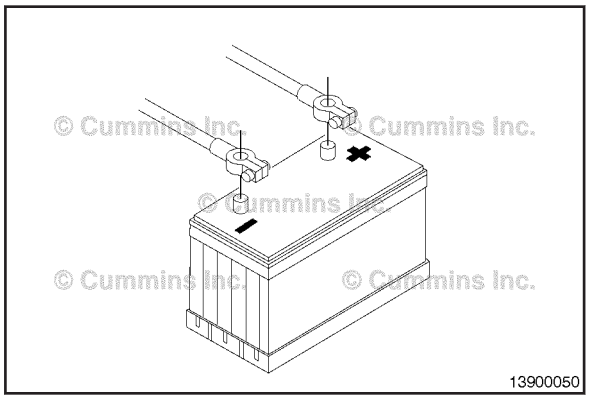
Accessory Drive (009-001)

Preparatory Steps

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

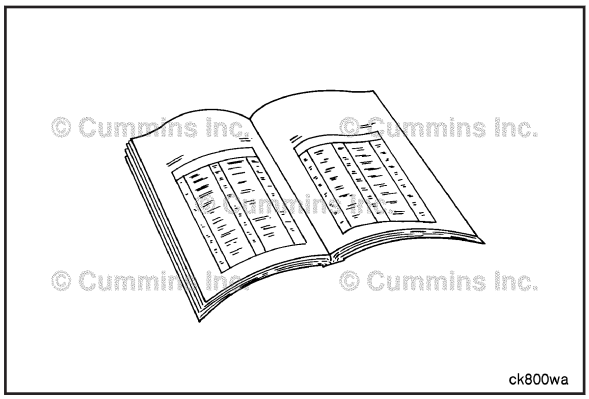
- Disconnect the batteries.



- Remove the driven accessory. Refer to the OEM instructions

NOTE: Typically the driven accessory is a hydraulic pump.

- Refer to Procedure 009-016 for general removal instructions.

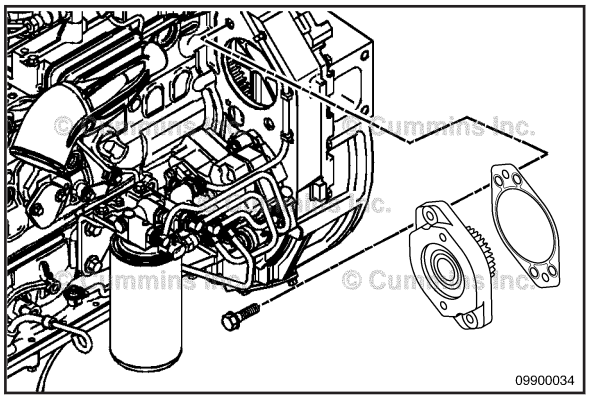


Remove

Remove the two capscrews securing the accessory drive to the rear gear housing.

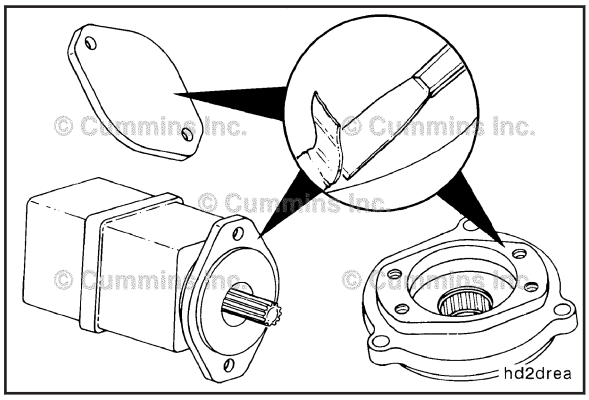
Remove the accessory drive and gasket.

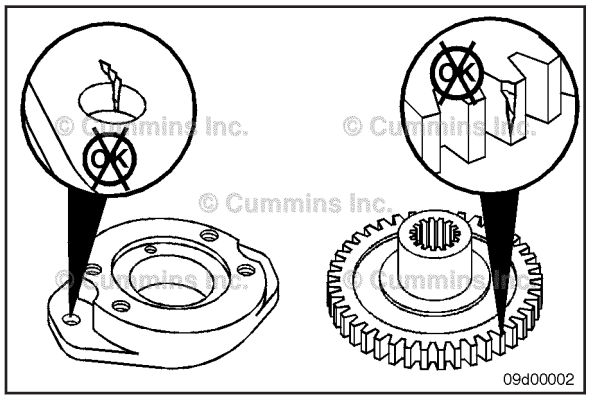
NOTE: For front gear train engines it may be necessary to remove the external oil supply tube.



Clean and Inspect for Reuse

Remove any residual gasket material from the mounting surfaces of the accessory drive, driven accessory/ hydraulic pump, and, if equipped, the cover plate surface.





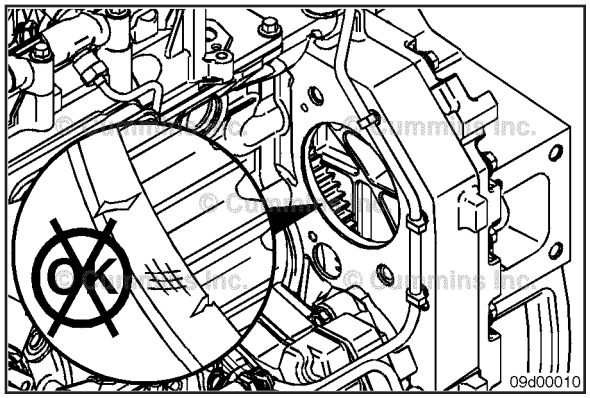
NOTE: If equipped, make sure the oil supply hole in the accessory drive housing is open and free of debris.

Inspect the accessory drive housing for cracks.

Inspect the accessory drive gear and shaft splines for cracks, broken teeth, and other damage.

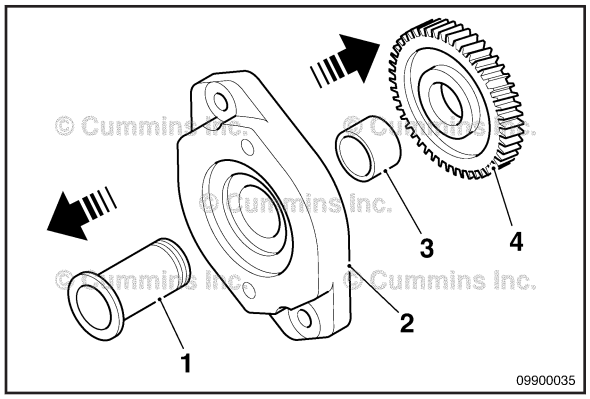
NOTE: If there is damage to the accessory drive gear teeth or there are signs of excessive heat, make sure to inspect the associated camshaft and fuel pump gears for damage. Measure camshaft gear backlash upon installation.

Replace any damaged components. See the Disassemble step of this procedure.



NOTE: For rear gear train engines, make sure the oil supply hole in the gear housing is open and free of debris.

Inspect the inside diameter of the drive gear bore for excessive wear or damage; replace if necessary.



Disassemble

If damage was found to a component of the accessory drive during the Clean and Inspect for Reuse step, the following components of the accessory drive, if damaged, may be replaced by disassembling the accessory drive.

1. Accessory Drive Shaft
2. Accessory Drive Housing
3. Accessory Drive Bearing
4. Accessory Drive Gear.

NOTE: Before disassembling the accessory drive, check to make sure the parts for the specific accessory drive being serviced are available. If **not**, replace the accessory drive as an assembly.

Use a hydraulic press and proper support to disassemble the accessory drive in the following order.

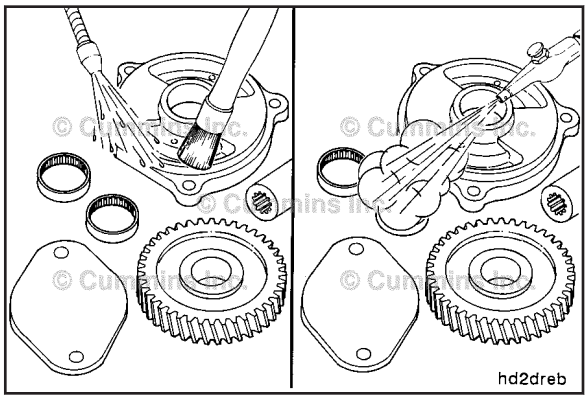
1. Press the drive shaft from the drive gear and housing
2. Press the bearing from the housing.

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

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

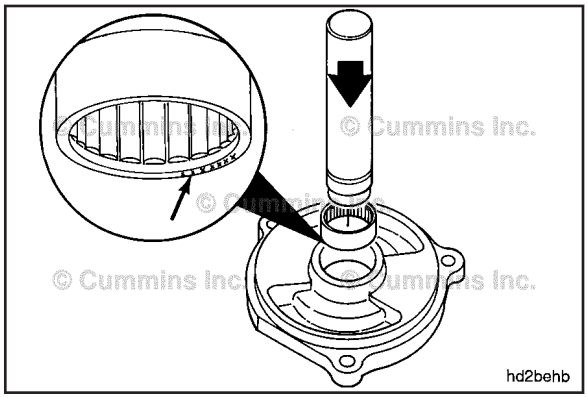
Clean the accessory drive components with solvent.

Dry with compressed air.



Inspect the bearing for binding, seizing, and excessive noise when spun.

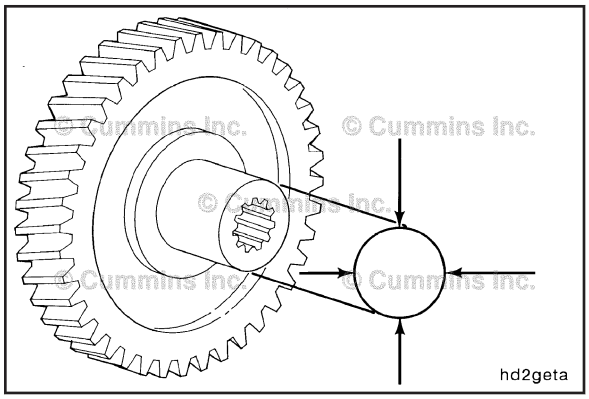
Replace if any damage is found.



Measure the inside diameter of the accessory drive gear bore.

Accessory Drive Gear Bore Inside Diameter (Accessory Drive Adapter)		
mm		**in**
38.920	MIN	1.5323
38.945	MAX	1.5333

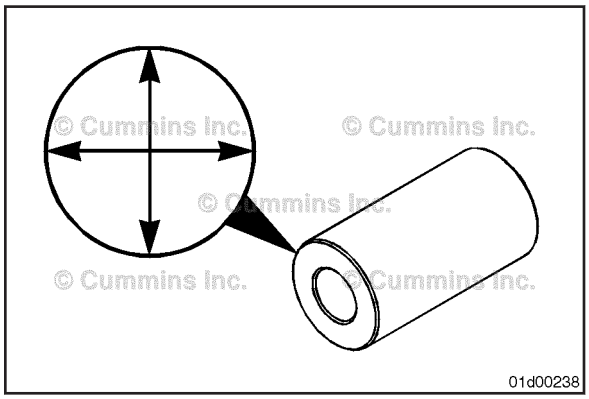
If out of specification, replace the accessory drive gear.

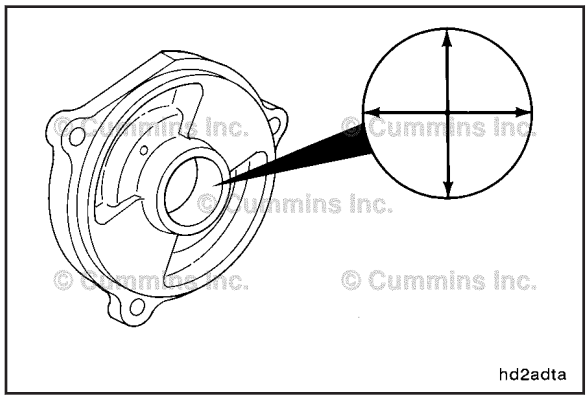


Measure the outside diameter of the accessory drive shaft at multiple locations along the shaft.

Accessory Drive Shaft Outside Diameter (Accessory Drive Adapter)		
mm		**in**
39.008	MIN	1.5357
39.020	MAX	1.5362

If out of specification, replace the accessory drive shaft.

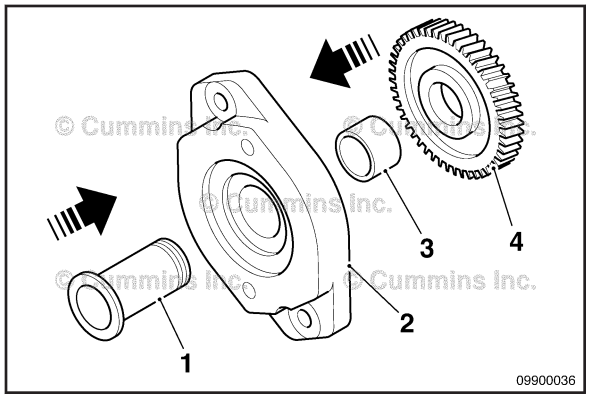




Measure the inside diameter of the bearing bore in the accessory drive adapter housing.

Bearing Bore Inside Diameter (Accessory Drive Adapter)		
mm		**in**
67.759	MIN	2.6755
67.983	MAX	2.6765

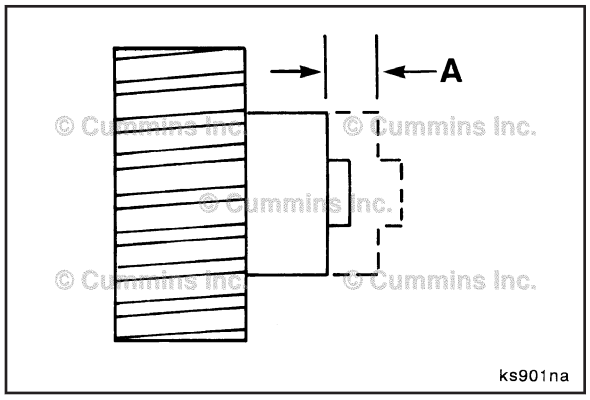
If out of specification, replace the housing.



Assemble

Use a hydraulic press and proper support to assemble the accessory drive in the following order:

1. Press the accessory drive shaft into the bearing, while supporting the bearing inner race, until the drive shaft bottoms on the inner race
2. Press the outer race of the bearing, with drive shaft, into the accessory drive housing, until the outer race bottoms in the housing
3. Press the accessory drive gear onto the shaft while supporting the bottom of the drive shaft. Press until gear bottoms against inner bearing race.



Measure

Using gauge, Part Number 3824564, and magnetic base, Part Number 3377399, check the accessory drive gear end play.

Accessory Drive Gear End Play		
mm		**in**
0.5	MIN	0.020

If the end plays is out of specification:

1. If just assembled, check if the drive gear and bearing were completely pressed onto the drive shaft
2. If **not** previously disassembled, disassemble the accessory drive and inspect for damage. Replace as necessary
3. Replace the accessory drive assembly.

Initial Check

Rear Gear Train

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

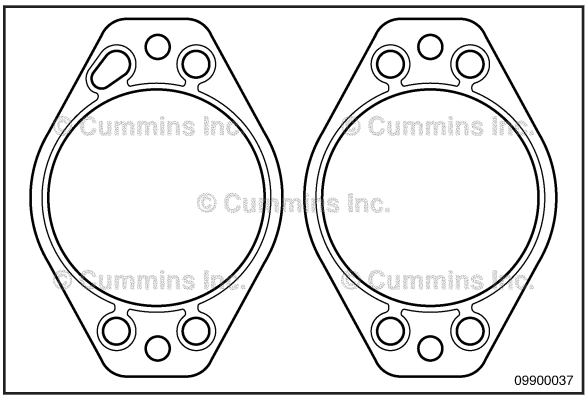
Prior to installing the accessory drive, identify which gasket is going to be installed so that, if necessary, the gasket can be properly oriented.

There are two types of accessory drive gasket:

1. Three round oil supply passages and one elongated oil supply passage
2. Four round oil supply passages.

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

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



Install

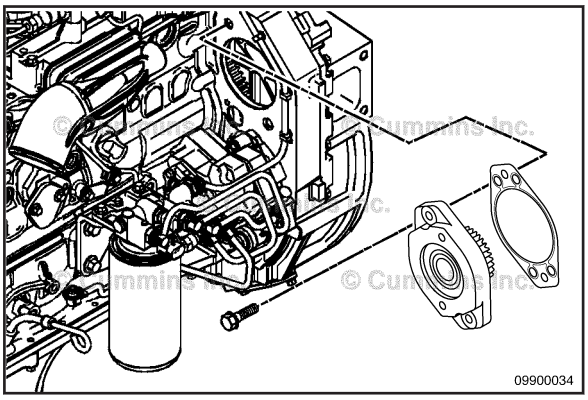
⚠CAUTION⚠
Failure to line up the oil supply hole to the accessory drive properly will result in accessory drive damage.

Install the accessory drive and new gasket.

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

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

Torque Value: 62 N•m [46 ft-lb]

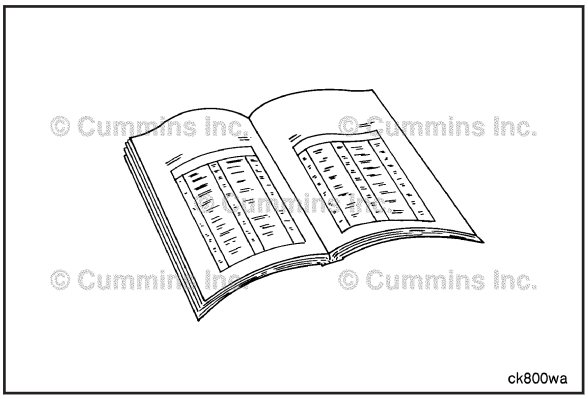


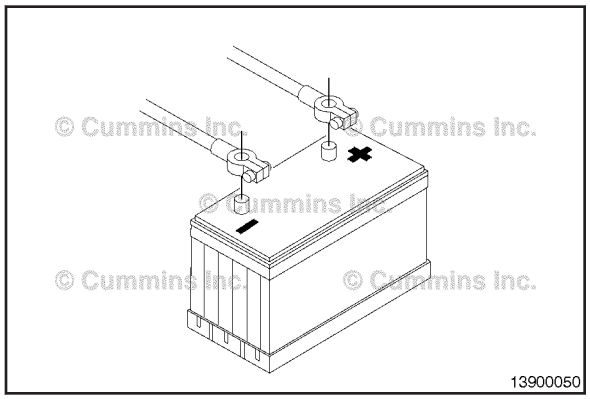
Finishing Steps

- Install the driven accessory. Refer to the OEM instructions.

NOTE: Typically the driven accessory is a hydraulic pump.

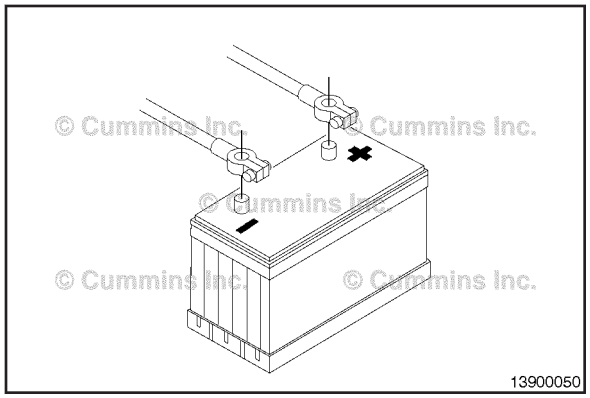
- Refer to Procedure 009-016 for general installation instructions.





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

- Connect the batteries
- Operate the engine and check for leaks.

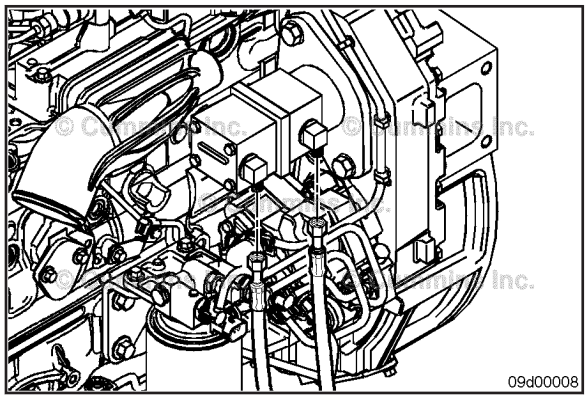


Hydraulic Pump Drive (009-016)

Preparatory Steps

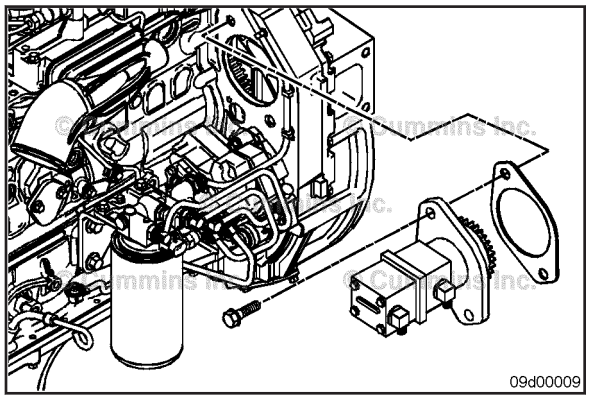
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries.



Remove

Disconnect all hydraulic lines from the pump.

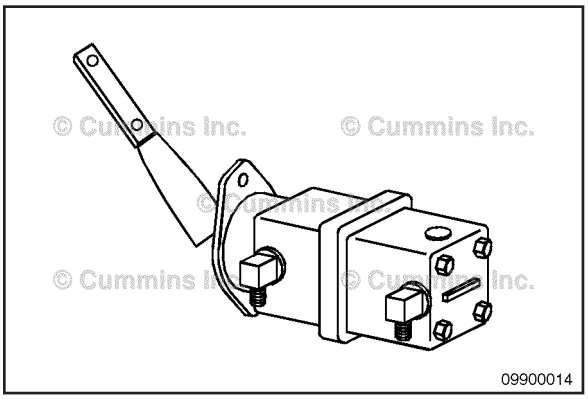


NOTE: Refer to the OEM service manual for removal procedures.

Remove the hydraulic pump and gear assembly.

Clean and Inspect for Reuse

Clean the gasket material from the hydraulic pump with a putty knife and a clean rag.

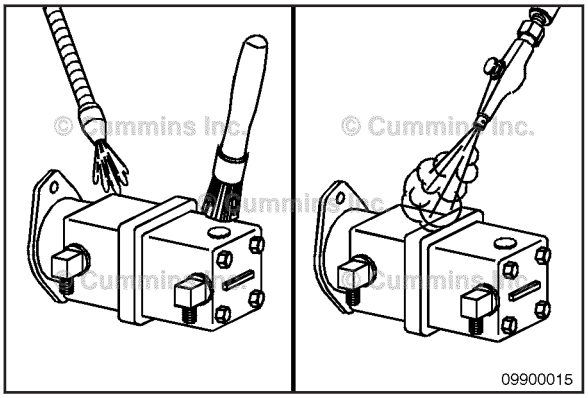


⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

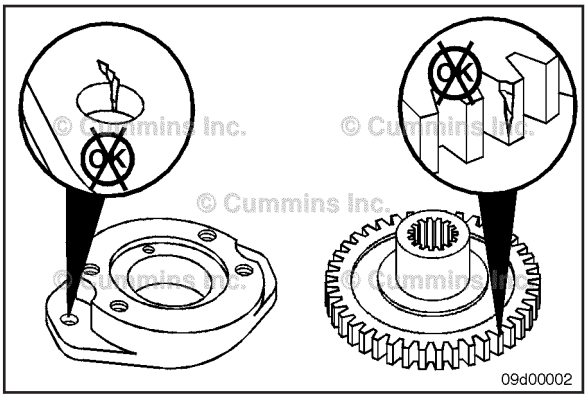
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Clean the hydraulic pump gear with solvent.

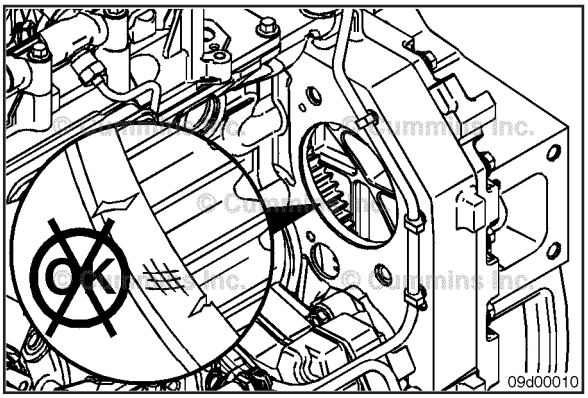
Dry with compressed air.

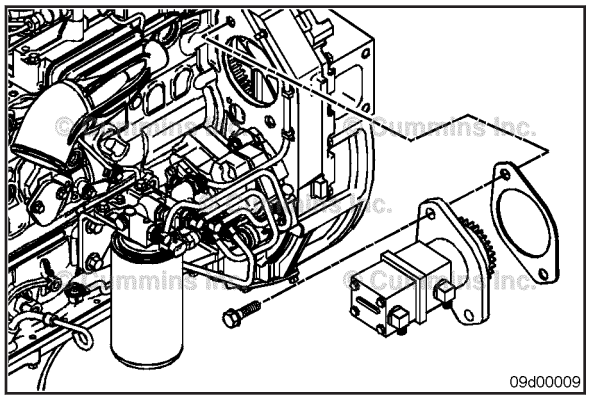


Inspect the hydraulic pump drive gear for cracks, broken teeth, and other damage.



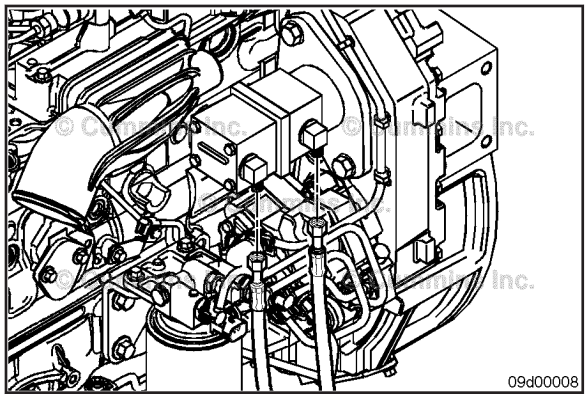
Inspect the inside diameter of the drive gear bore for excessive wear or damage; replace if necessary.



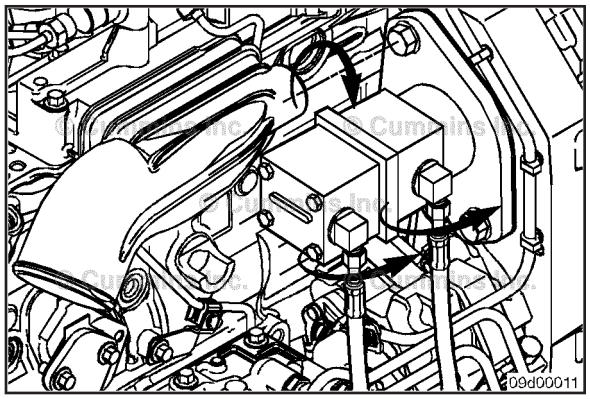


Install

Use a new gasket and install the hydraulic pump.

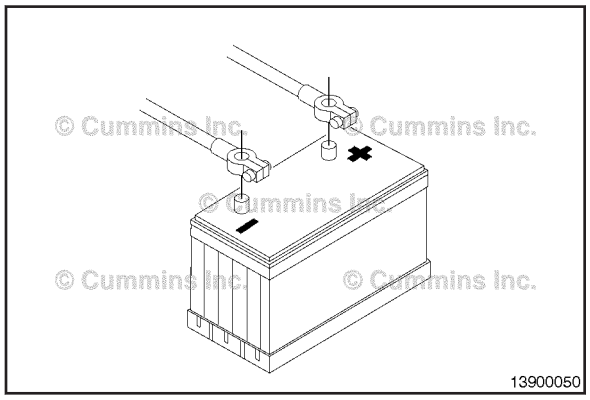


Connect all hydraulic lines to the pump.



Tighten mounting capscrews.

Torque Value: 62 N•m [46 ft-lb]



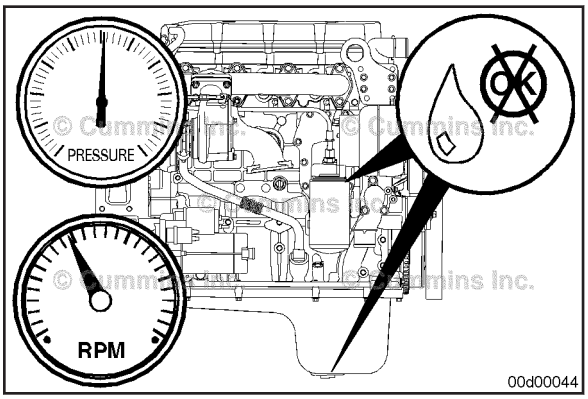
Finishing Steps

⚠WARNING⚠

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

- Connect the batteries.

- Operate the engine and check for leaks.

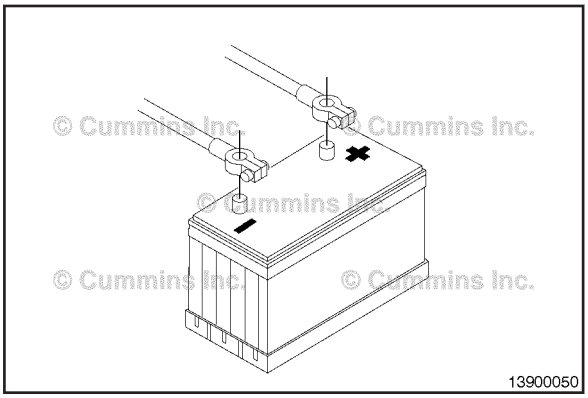


Accessory Drive Cover (009-039)

Preparatory Steps

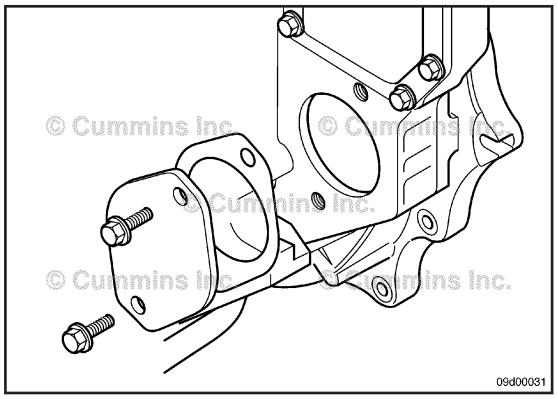
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries.



Remove

Remove the accessory drive cover, mounting capscrews and gasket.



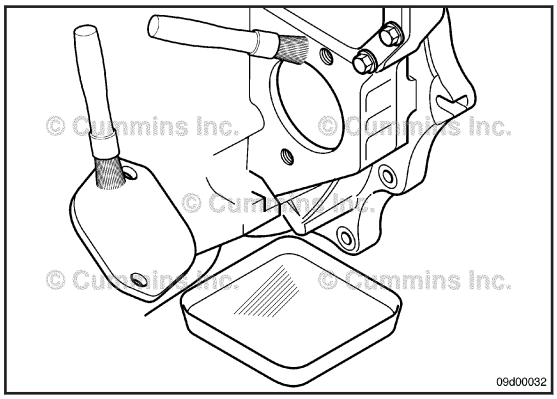
Clean

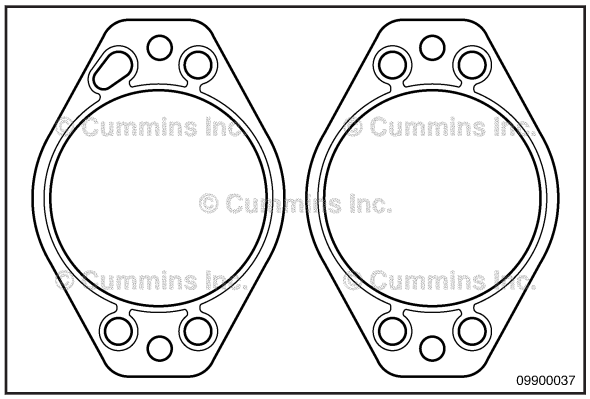
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

Clean the accessory drive cover and rear gear housing mounting surface with solvent.

Dry with compressed air.





Install

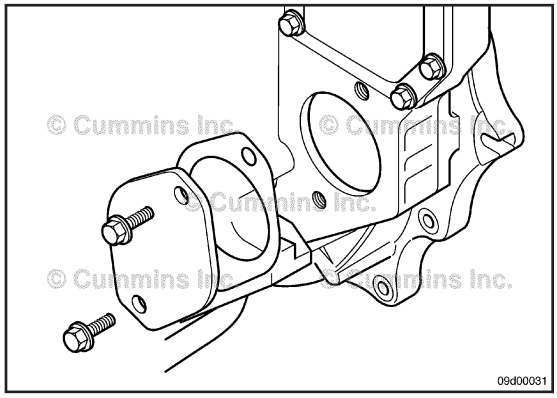
Prior to installing the accessory drive cover, identify which style of gasket is going to be installed so that, if necessary, the gasket can be properly oriented.

There are two types of accessory drive cover gaskets:

1. Three round oil supply passages and one elongated oil supply passage
2. Four round oil supply passages.

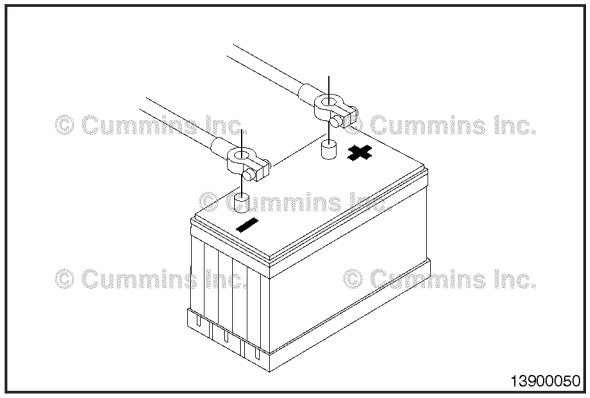
It is preferred that, when installing the accessory drive, the gasket with the four round oil supply passages be used. The gasket can be installed in any orientation.

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



Install the accessory drive cover, gasket and mounting capscrews. Tighten the mounting capscrews.

Torque Value: 50 N•m [40 ft-lb]



Finishing Steps

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

- Connect the batteries
- Operate the engine and check for leaks.

Section 10 - Air Intake System - Group 10

Section Contents

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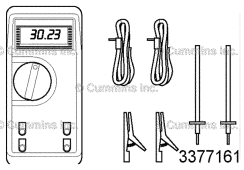
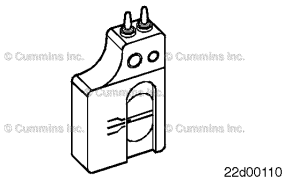
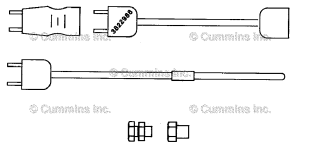
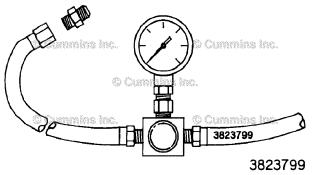
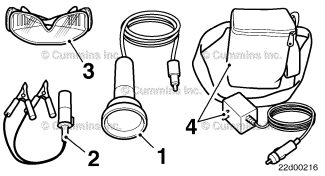
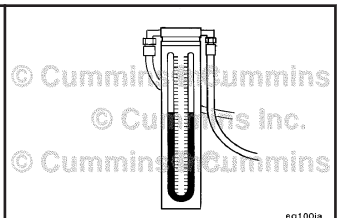
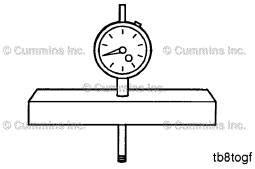
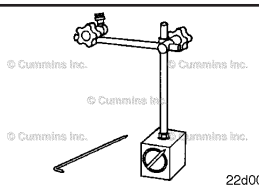
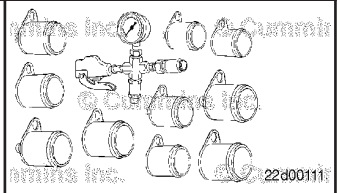
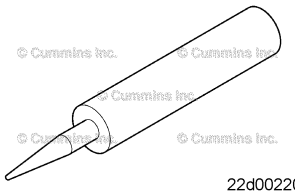
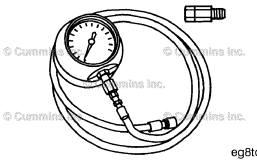
Service Tools

Air Intake System

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

Tool No.	Tool Description	Tool Illustration
3164488, 3164489	**Digital Multimeter** Used to measure electrical circuits: Voltage (volts), resistance (ohms), and current (amps). 3164488 — Standard Meter, 3164489 — Automotive Meter with built in temperature adapter and tachometer.	
3164499	**Digital Thermometer** Used to measure ambient air temperature. Use with digital multimeter, Part Number 3164488.	
3164498	**Bead Probe** Used with digital thermometer, Part Number 3164499.	
3823799	**Turbocharger Wastegate Pressure-Setting Kit** Used to apply regulated pressure to wastegate actuator during troubleshooting and calibrating procedures.	
3163338	**Black Light Lamp (12VDC)** Used with fluorescent tracer to locate coolant and/or oil leaks. Lamp operates off vehicle battery or portable rechargeable battery included in kit. Oil tracer Part Number 3376891, coolant tracer Part Number 3377438.	
3824524	**Black Light (AC)** Used to inspect for oil or fuel leak.	

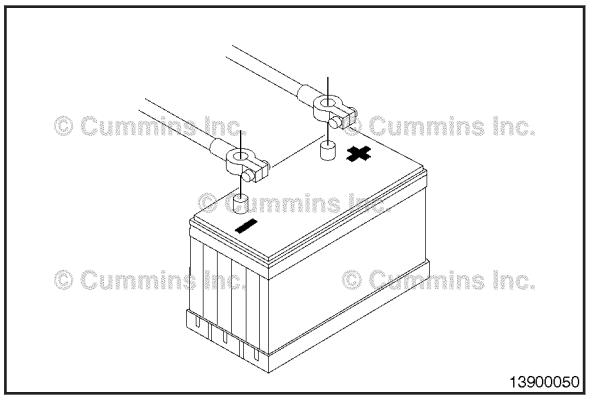
Tool No.	Tool Description	Tool Illustration
ST-1111-3	**Manometer** Used to measure pressure and restriction 0 to 2.5 kPa [0 to 36 in H_2O] pressure differential with more accuracy.	
ST-537	**Dial Depth Gauge** Measure turbocharger axial motion.	
3377399	**Magnetic Base Indicator Holder** Used in conjunction with dial indicator, Metric — Part Number 3824564. SAE — Part Number 4918289.	
3824556	**Charge Air Cooler Tester** Used to pressure test charge air coolers.	
3164070	**RTV Sealant** Used to seal rear gear housing to block, front cover to block, oil pan T-Joints and intake manifold to cylinder head joints. For rear gear train engines.	
ST1273	**Pressure Gauge [0 to 75 in Hg]** Used to measure the intake manifold pressure and exhaust back pressure.	

Aftercooler (010-001)

Preparatory Steps

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

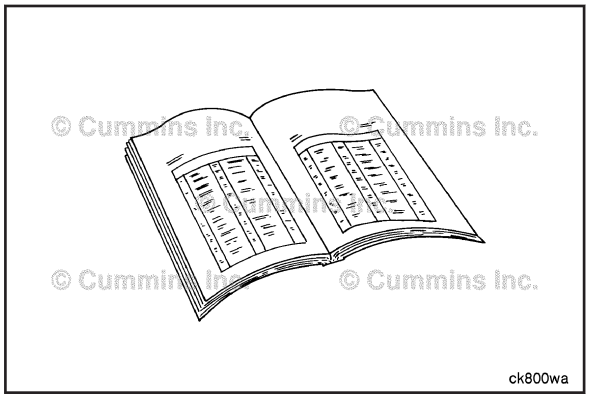
- Disconnect the batteries.



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

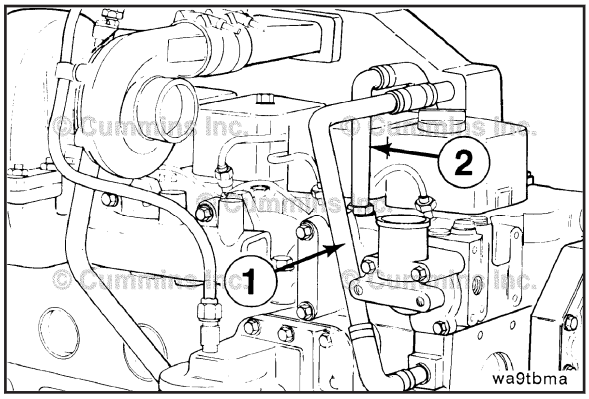
⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

- Disconnect the cold starting aid (if equipped). Refer to the OEM manual.
- Remove the air crossover tube. Refer to Procedure 010-019.
- Drain 2 liters [2.1 qt] of coolant. Refer to Procedure 008-018.

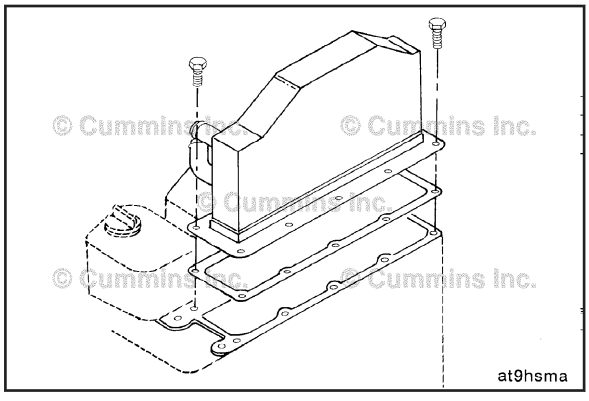


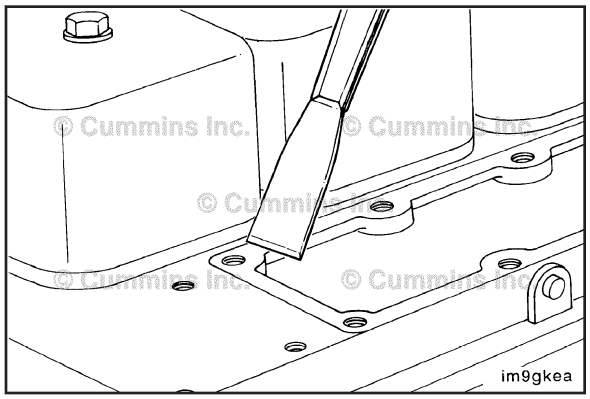
Remove

Remove the coolant supply tube (1) and the coolant return tube (2).



Remove the aftercooler housing and gasket.

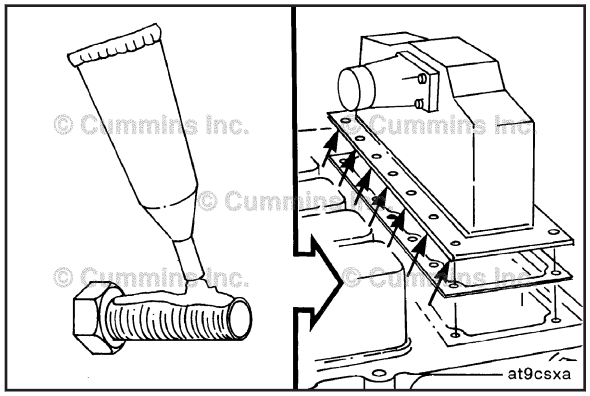




Clean

Clean the sealing surface.

NOTE: Keep the gasket material and any other material out of the air intake.

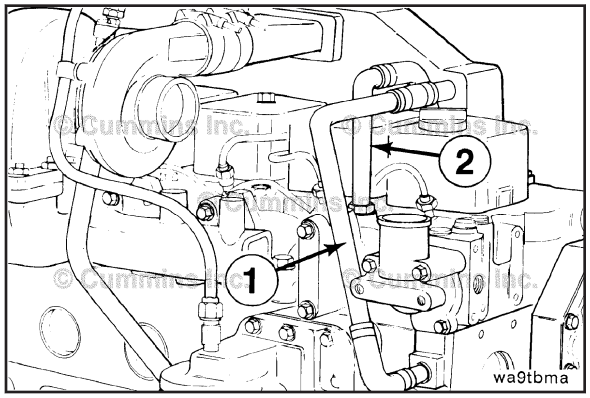


Install

NOTE: The holes shown in the illustration are drilled through. Apply liquid Teflon™ sealant to the capscrews.

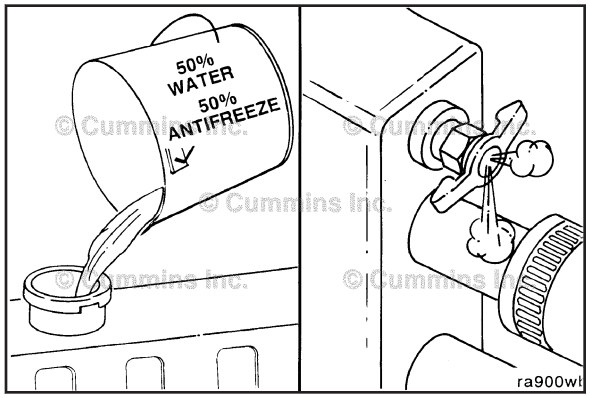
Install the aftercooler housing and a new gasket.

Torque Value: 24 N•m [18 ft-lb]



Install the coolant supply tube (1) and coolant return tube (2).

Torque Value: 8 N•m [71 in-lb]



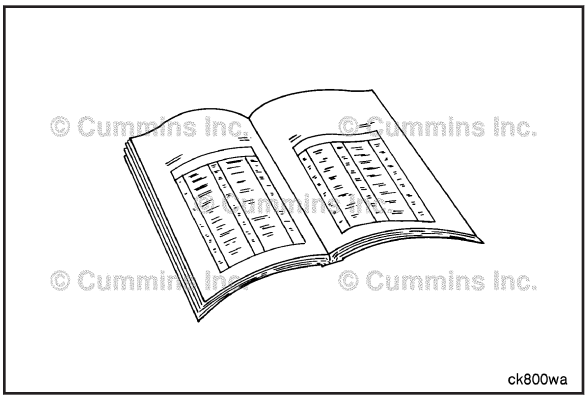
Fill

⚠CAUTION⚠
During filling, air must be vented from the engine cooling 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 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. Failure to do so will cause entrapment of air in cooling system and will cause engine to overheat.

Fill the coolant system with a premixture of 50-percent water and 50-percent ethylene-glycol-type antifreeze.

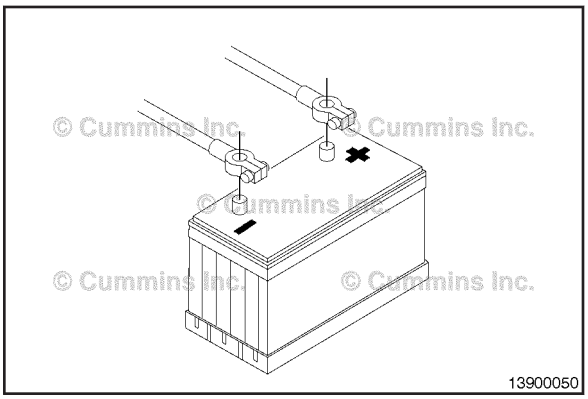
Finishing Steps

- Install the air crosover tube. Refer to Procedure 010-019
- If removed, connect the cold starting aid. Refer to OEM manual.



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

- Connect the batteries
- Operate the engine and check for leaks.

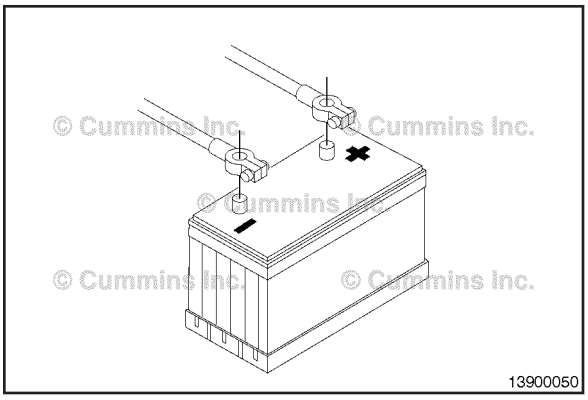


Air Crossover (010-019)

Preparatory Steps

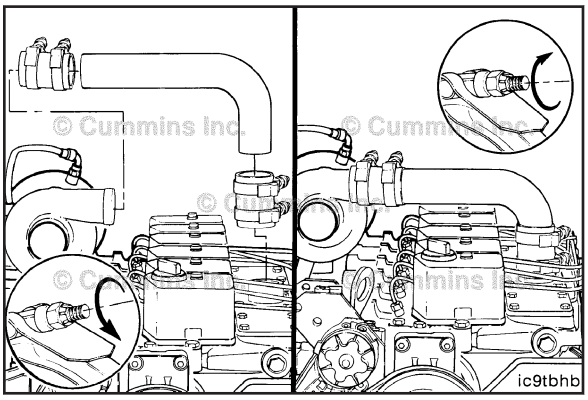
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

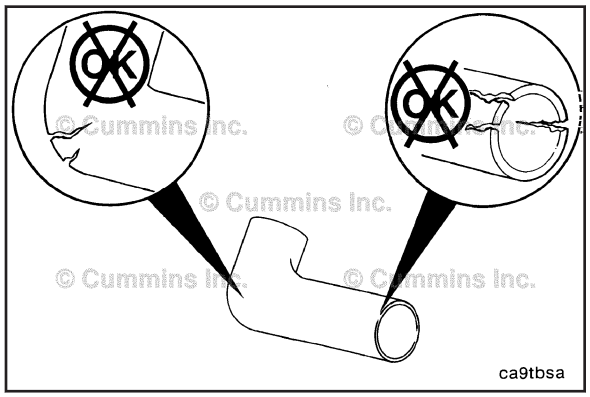
- Disconnect the batteries.



Remove

Loosen the hose clamps, and position the hose so the crossover tube can be removed.

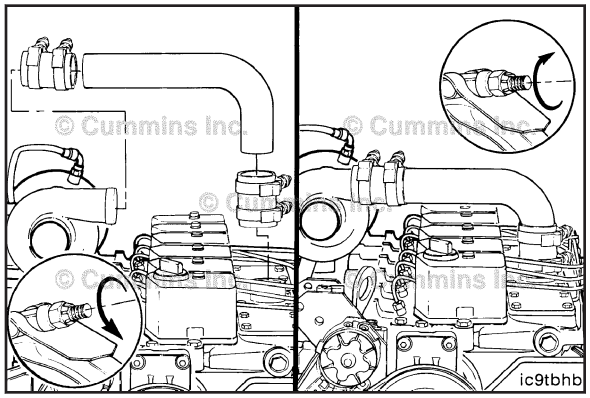




Inspect for Reuse

Check the crossover tube for cracks, holes, and worn sections.

Replace with a new hose and clamps, if necessary.

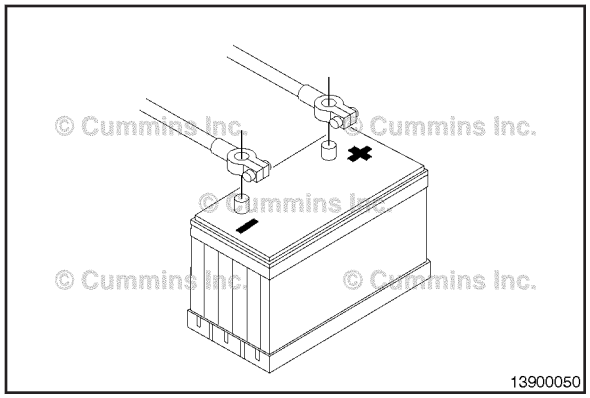


Install

Install the crossover tube and clamps in the reverse order of removal.

Tighten the clamps.

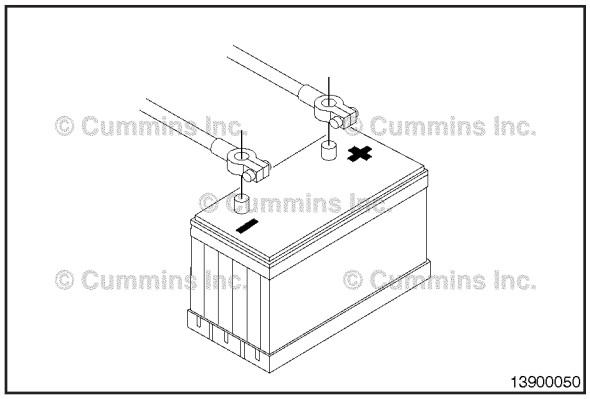
Torque Value: 8 N•m [71 in-lb]



Finishing Steps

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

- Connect the batteries
- Operate the engine and check for leaks.



Air Intake Manifold (010-023)

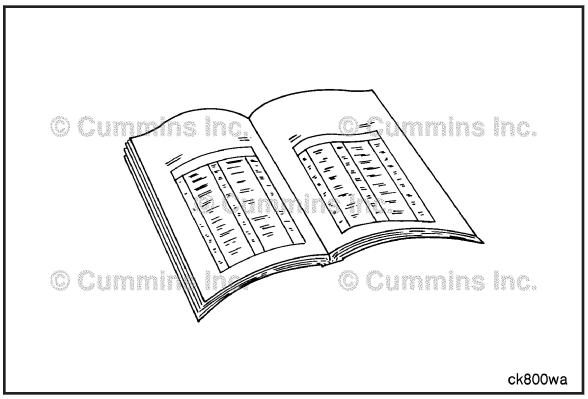
Preparatory Steps

Front Gear Train

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

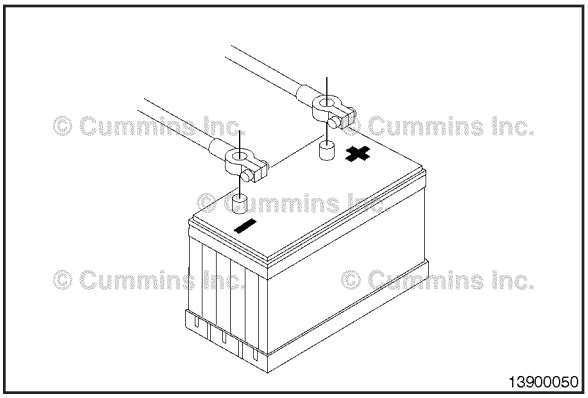
- Disconnect the cold starting aid (if equipped). Refer to the OEM manual
- Remove the air crossover tube (if equipped). Refer to Procedure 010-019
- Disconnect the charged air cooler hose (if equipped). Refer to Procedure 010-027
- Remove the high-pressure fuel lines. Refer to Procedure 006-051
- Remove the air intake piping. Refer to Procedure 010-024.



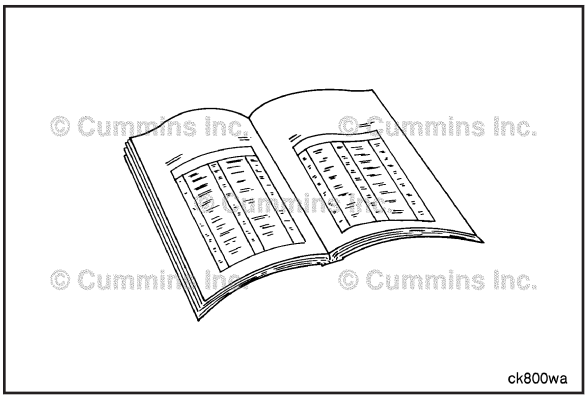
Rear Gear Train

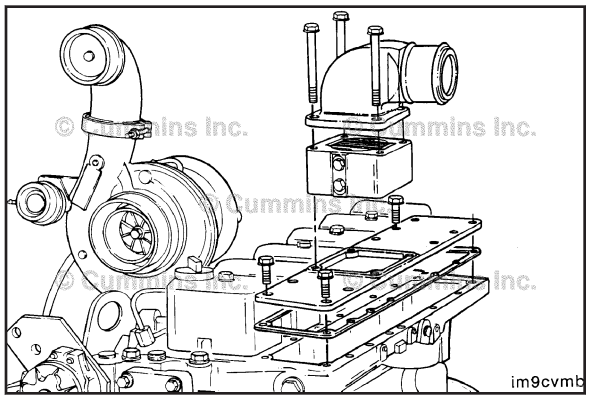
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries.



- Remove the air intake piping. Refer to Procedure 010-024
- Remove the closed crankcase ventilation hose. Refer to Procedure 003-024
- Disconnect the cold starting aid. Refer to the OEM manual
- Remove the air intake connection adapter. Refer to Procedure 010-131
- If required, remove the air intake heater element. Refer to Procedure 010-124
- Remove the dipstick tube. Refer to Procedure 007-011
- Remove the fuel supply line. Refer to Procedure 006-024
- Remove the fuel drain line. Refer to Procedure 006-021
- Remove the high pressure fuel lines. Refer to Procedure 006-051.

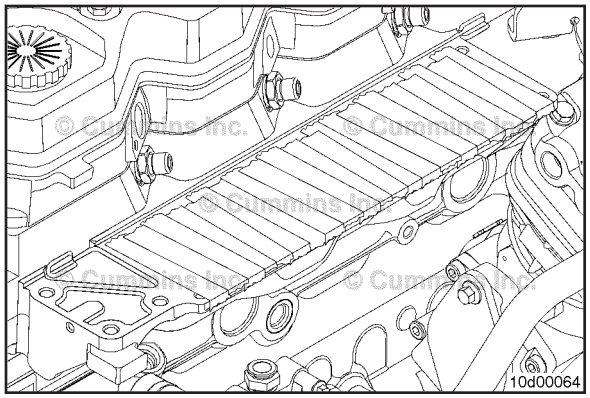




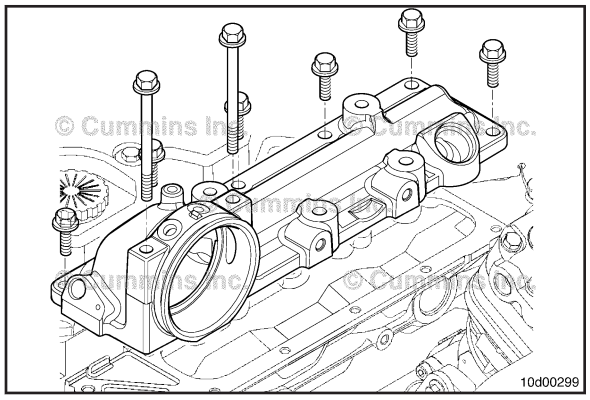
Remove

Front Gear Train

Remove the manifold cover, gasket, and grid heater (if equipped).



If the air intake manifold will be off for a prolonged period of time, tape off the intake manifold opening to prevent debris from entering the intake system.

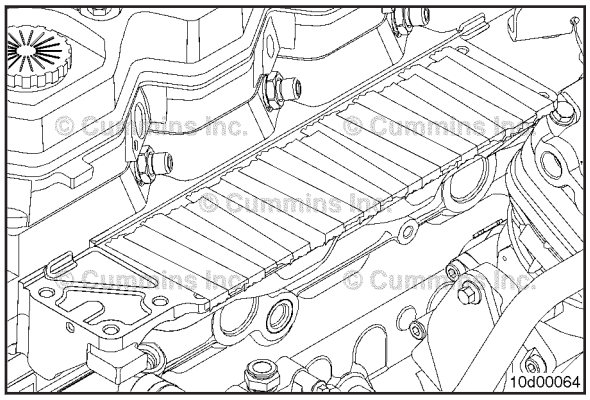


Rear Gear Train

Remove the intake manifold mounting capscrews.

NOTE: The intake manifold uses RTV sealant between the manifold and cylinder head. Be careful **not** to damage the intake manifold and sealing surfaces when removing the intake manifold.

Remove the intake manifold.



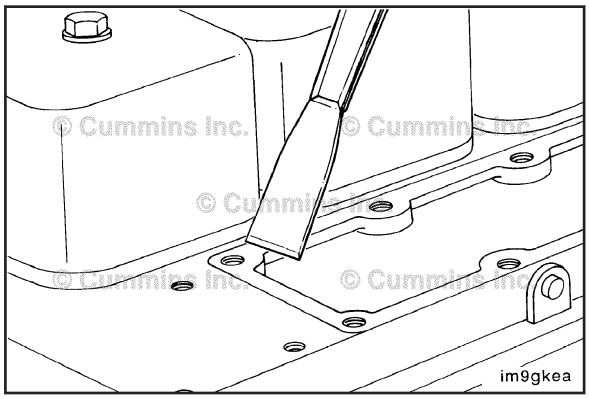
If the air intake manifold will be off for a prolonged period of time, tape off the intake manifold opening to prevent debris from entering the intake system.

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.

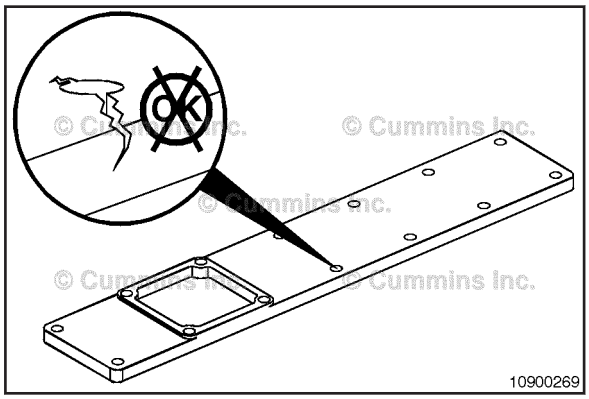
Clean the air intake manifold and cylinder head sealing surfaces with a gasket scraper and solvent.

NOTE: Keep the gasket material and any other material out of the air intake.



Check the air intake manifold for damage.

Replace the air intake manifold, if necessary.

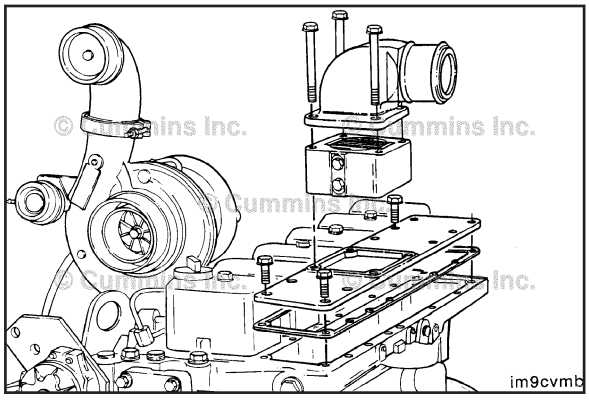


Install

Front Gear Train

Install the cover and a new gasket.

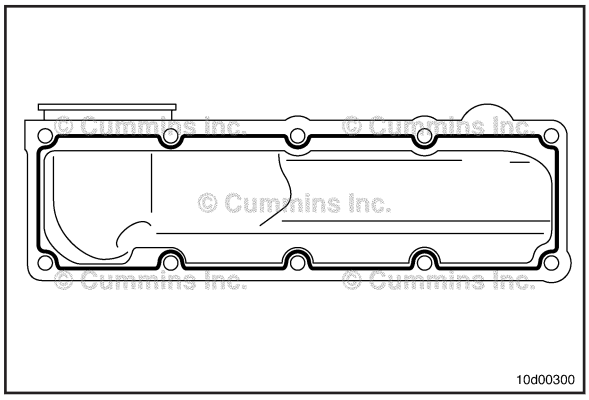
Torque Value: 24 N•m [18 ft-lb]

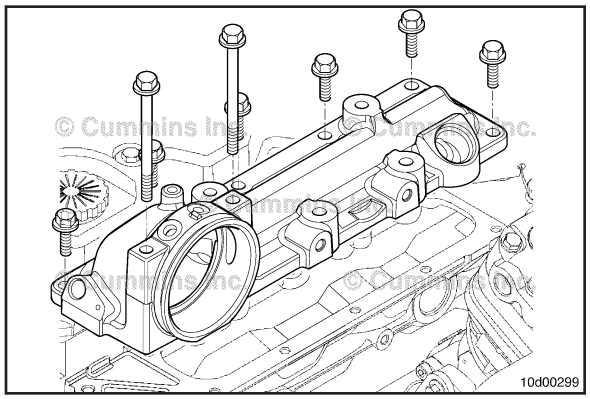


Rear Gear Train

Apply RTV sealant, Part Number 3164070, to the intake manifold in the path illustrated.

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

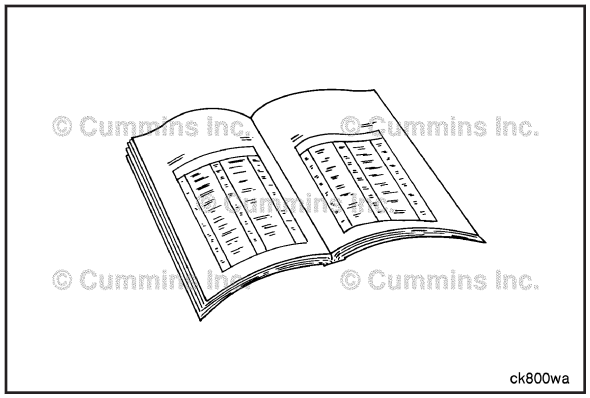




Install the intake manifold and mounting capscrews.

Tighten the mounting capscrews.

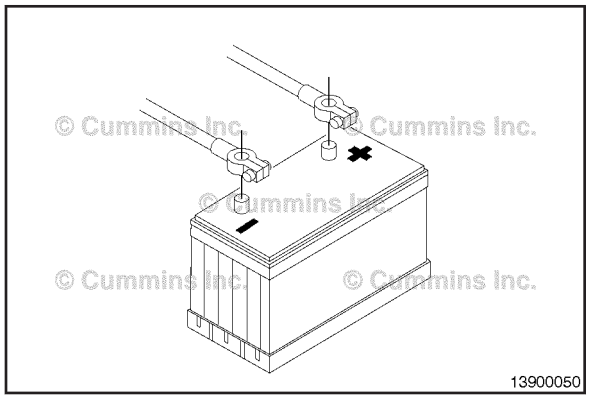
Torque Value: 24 N•m [18 ft-lb]



Finishing Steps

Front Gear Train

- Install the high-pressure fuel lines. Refer to Procedure 006-051
- Install the air intake piping. Refer to Procedure 010-024
- Install the air crossover tube (if removed). Refer to Procedure 010-019
- Install the charged air cooler hose (if removed). Refer to Procedure 010-027
- Connect the cold starting aid (if removed). Refer to the OEM manual.



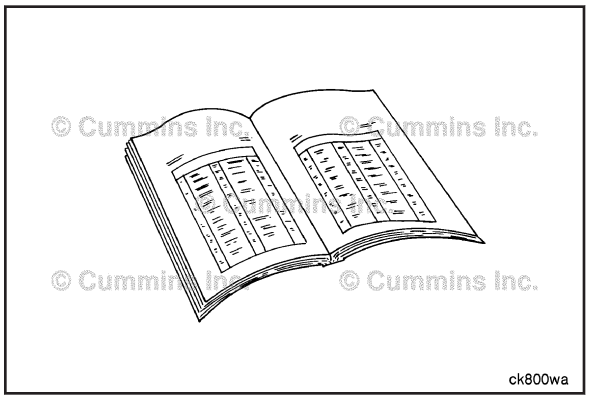
⚠WARNING⚠

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

- Connect the batteries.

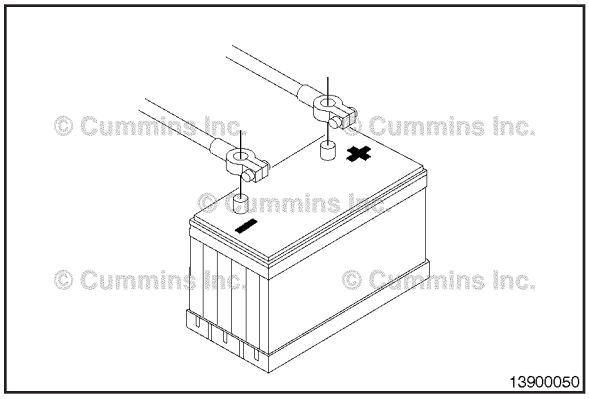
Rear Gear Train

- Install the high pressure fuel lines. Refer to Procedure 006-051
- Install the fuel supply line. Refer to Procedure 006-024
- Install the fuel drain line. Refer to Procedure 006-021
- Install the dipstick tube. Refer to Procedure 007-011
- If removed, install the air intake heater element. Refer to Procedure 010-124
- Install the air intake connection adapter. Refer to Procedure 010-131
- Install the closed crankcase ventilation hose. Refer to Procedure 003-024
- Connect the cold starting aid. Refer to the OEM manual
- Install the air intake piping. Refer to Procedure 010-024



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

- Connect the batteries
- Operate engine and check for leaks.



Air Leaks, Air Intake and Exhaust Systems (010-024)

Initial Check

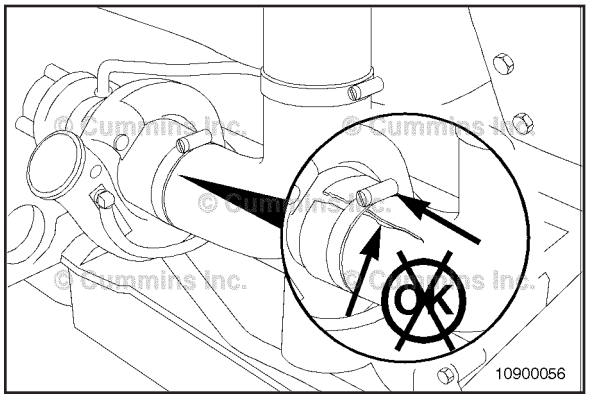
⚠CAUTION⚠
Engine intake air must be filtered to prevent dirt and debris from entering the engine. If intake air piping is damaged or loose, unfiltered air will enter the engine and cause premature wear.

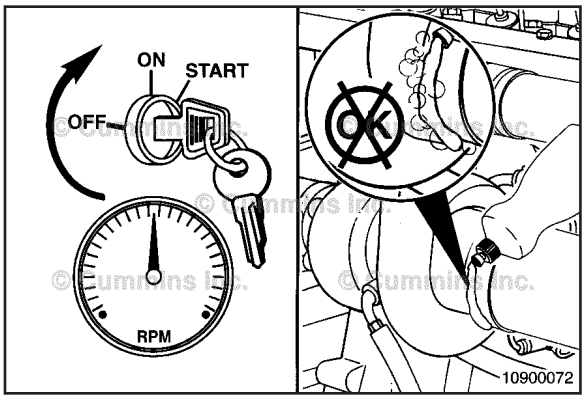
Inspect the intake air piping for cracked hoses, damage, or loose clamps.

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]

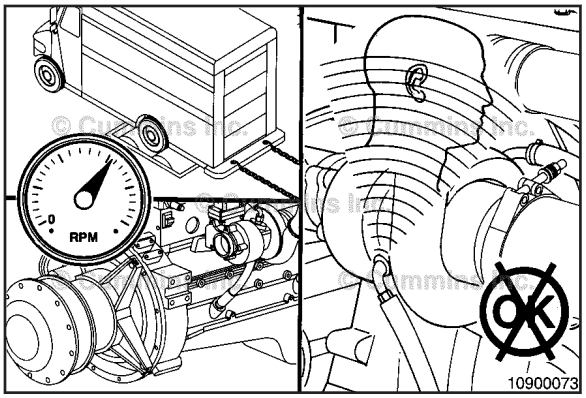
Check for corrosion of the intake system piping under the clamps and hoses. Corrosion can allow corrosive products and dirt to enter the intake system. Disassemble and clean, as required.





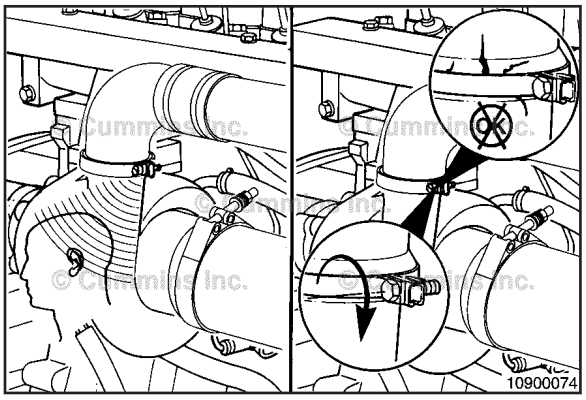
Operate the engine at high idle, and use a solution of soapy water to spot intake air leaks.

If an air leak exists, the soap bubbles will be drawn in with the air.



Operate the engine at full throttle and rated rpm with maximum load.

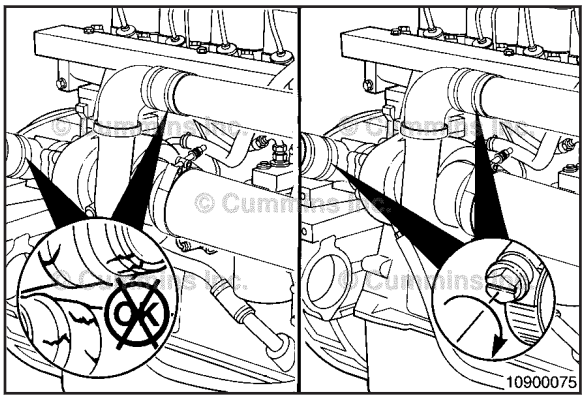
Listen for a high-pitched whistling noise from the turbocharger, nearby piping, and connections.



The noise can be caused by an air leak from the:

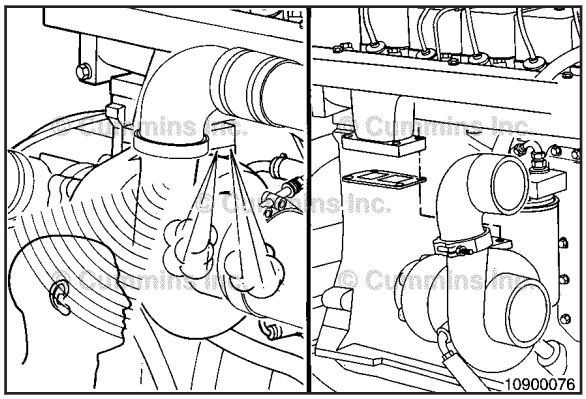
1. Turbocharger-to-discharge elbow connection.
   - Inspect for damage. Tighten loose clamps.

Torque Value: 8 N•m [71 in-lb]



1. 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.

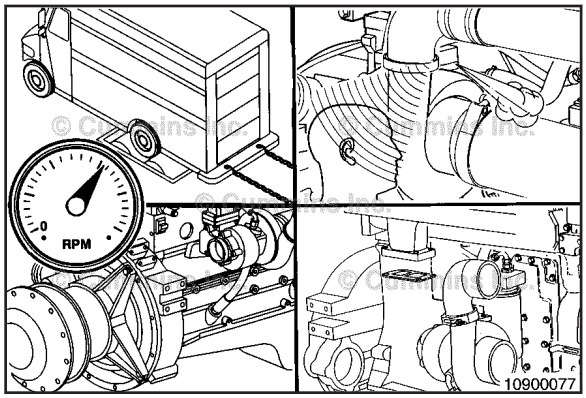
1. Turbocharger-to-exhaust-manifold mounting gasket.
   - Replace the gasket. Refer to Procedure 010-033.



Operate the engine at full throttle and rated rpm with maximum load.

Listen again for leaks.

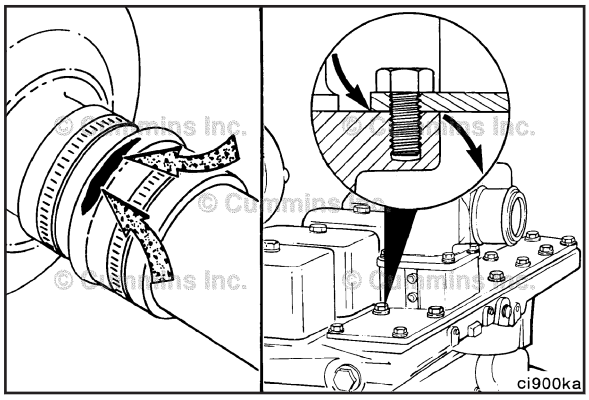
Replace the turbocharger if the air piping is **not** damaged and the noise can still be heard. Refer to Procedure 010-033.



Damage from Nonfiltered Air

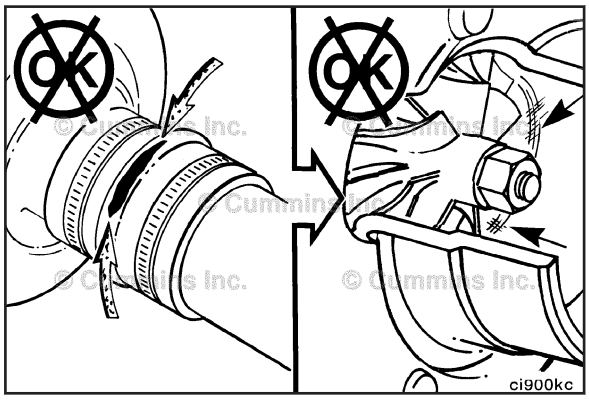
Loose connections or cracks in the suction side of the intake pipe and after the air filter can allow debris to be ingested by the engine, causing rapid wear in the cylinders.

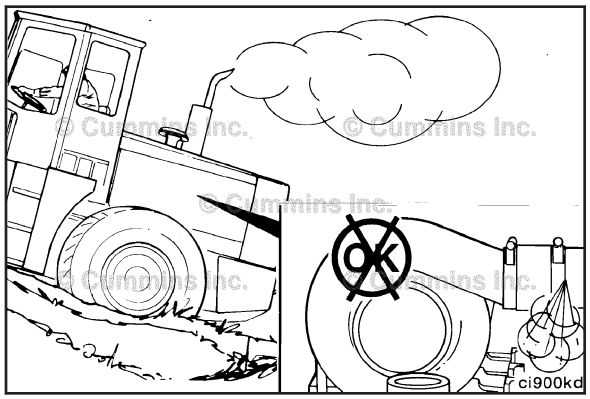
Leaks at the intake manifold, unsealed bolt holes, or manifold cover gasket can also allow dust and dirt to be ingested into naturally aspirated engines.



Debris drawn into the air suction side can damage the compressor blades, causing an imbalance resulting in bearing failure.

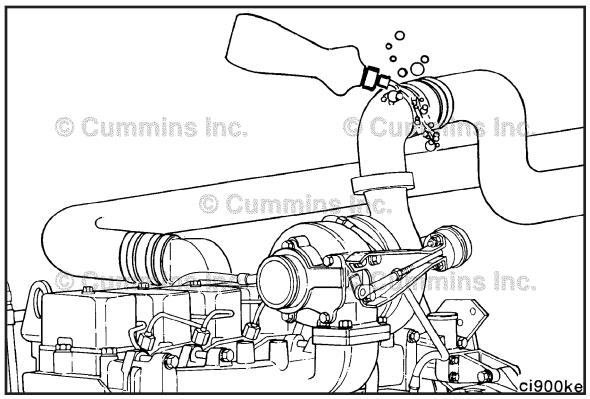
To verify a bearing failure or damaged compressor, remove the intake and exhaust piping, and check for contact. The rotor assembly **must** rotate freely and should **not** be damaged. Measurement of axial and radial clearance is described in this section.



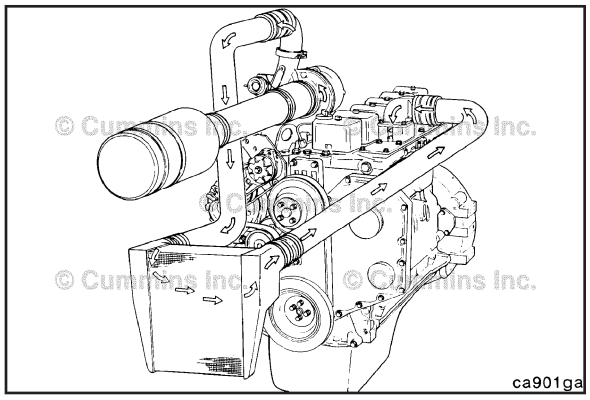


Turbocharger Engines — Air Leaks, Pressure Side

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 also cause a noise problem.



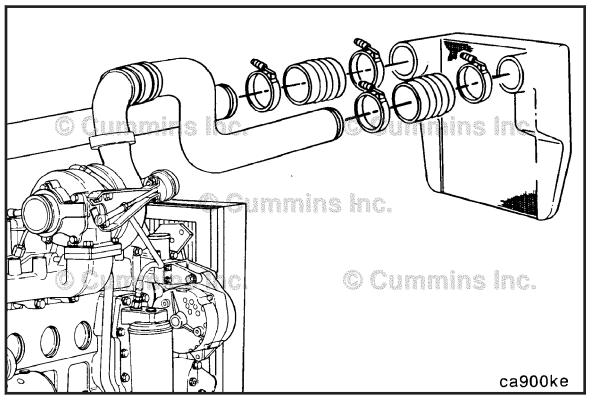
In addition to the inspection for cracks and loose fittings, liquid soap can be applied to the charge air cooler, connections, and the manifold cover sealing surfaces to find the leaks. The leaks will create bubbles that are easier to detect. Measurement of manifold pressure is described in this section.



Charge-Air Cooler (010-027)

General Information

NOTE: 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 Location.



Clean and Inspect for Reuse

If the engine experiences a turbocharger failure or any other occasion where oil or debris is put into the charge air cooler, the charge air cooler **must** be cleaned and inspected for reuse.

Remove the charge air cooler from the vehicle. Refer to the vehicle manufacturer's instructions.

⚠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.

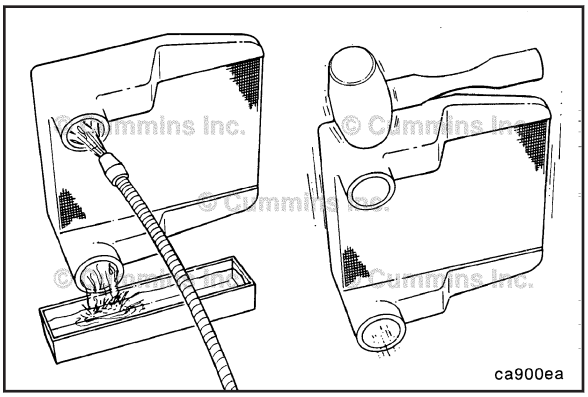
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

△CAUTION△
If internal debris can not be removed, scrap the charge air cooler.

△CAUTION△
Do not use caustic cleaners to clean the charge air cooler. Damage to the charge air cooler can 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.

Use a flashlight and mirror to inspect the charge air cooler for internal debris.

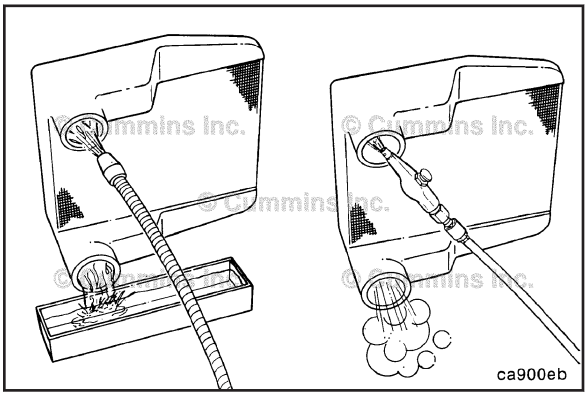


⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

△CAUTION△
The charge air cooler must be rinsed and dried, and free of solvent, oil, and debris or engine damage will result.

After the charge air cooler has been thoroughly cleaned of all oil and debris with solvent, wash the charge air cooler internally with hot, soapy water to remove the remaining solvent. Rinse thoroughly with clean water.

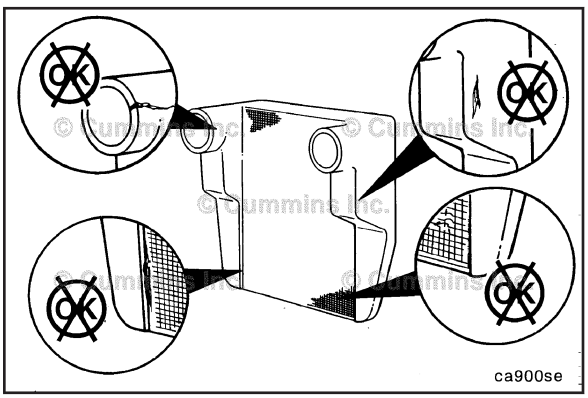
Blow compressed air into the charge air cooler in the opposite direction of normal airflow until the charge air cooler is dry internally.

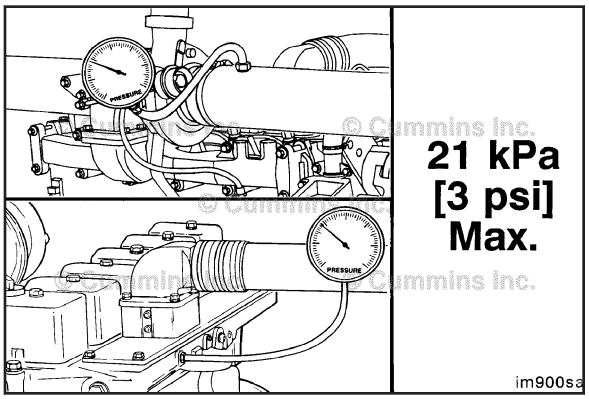


Inspect the charge air cooler for cracks, holes, or damage.

Inspect the tubes, fins, and welds for tears, breaks, or other damage.

Refer to Procedure 010-024 for the leak check procedure.





Pressure Test

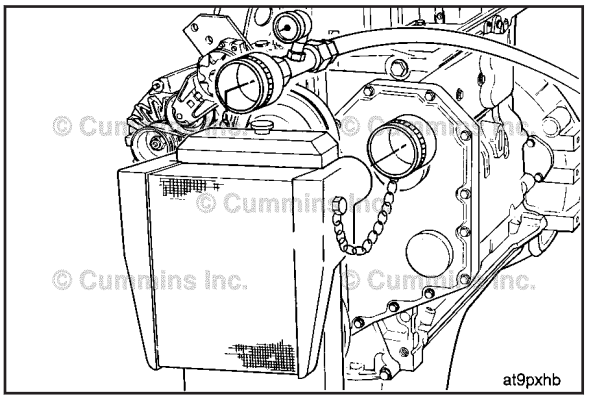
Install pressure gauge, Part Number ST-1273, to the fitting in the turbocharger outlet.

Install another pressure gauge, Part Number ST-1273, 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.

Differential Pressure: 21 kPa [3 psi]

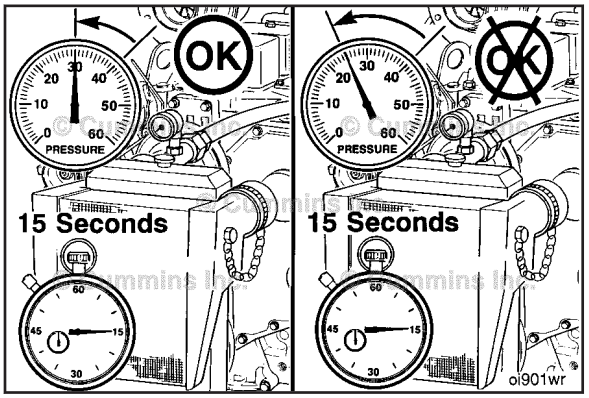


Leak Test

⚠WARNING⚠
To reduce the possibility of injury from either plug blowing off during the test, secure the safety chains on the test plugs to any convenient capscrew on the radiator assembly. This test must be performed with securely fastened safety chains.

Charge Air Cooler Test Kit, Part Number 3824556

Install a cap over the outlet side of the charge air cooler. Install a pressure gauge, air supply, and air pressure regulator to the inlet side of the cooler.

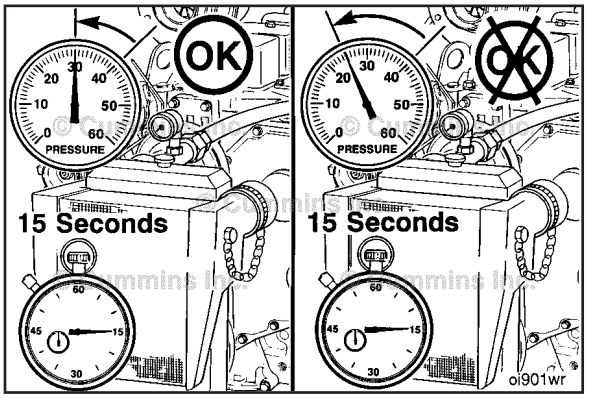


Apply 207 kPa [30 psi] of air pressure to the charge air cooler. Close the air pressure regulator.

Monitor the pressure gauge and determine the rate of pressure decay with a stopwatch.

If the pressure decay is 49 kPa [7 psi] or less in 15 seconds, the cooler is okay. If the pressure drop is greater than 49 kPa [7 psi] in 15 seconds, check all connections again.

Determine if the pressure decay is caused by a leak in the charge air cooler or from a leaky connection. Use a spray bottle filled with soapy water applied to all hose connections, and watch for bubbles to appear at the location of the leak.

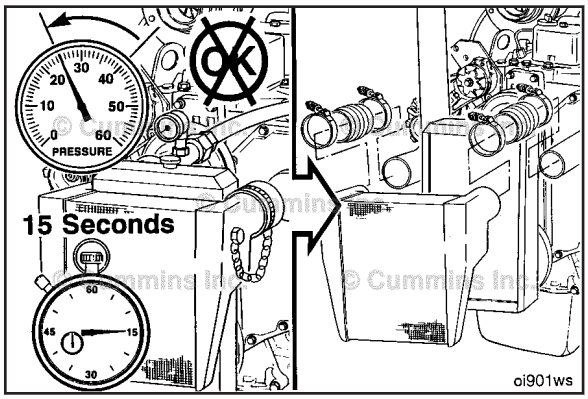


If the pressure decay is caused by a leaky connection, repair the connection and repeat the test. If the leak is within the charge air cooler, repeat the test to verify the accuracy of the pressure decay measurement. Similar pressure decay readings **must** be obtained at least three consecutive tests before the reading can be considered accurate.

If the pressure drop is greater than 49 kPa [7 psi] in 15 seconds, the charge air cooler **must** be replaced.

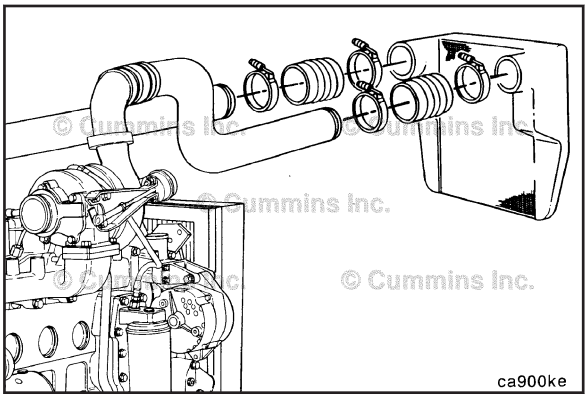
Refer to the OEM service manual for replacement instructions.

NOTE: Charge air coolers are **not** designed to be 100-percent leak-free. If the pressure decay is less than 49 kPa [7 psi] in 15 seconds, then the charge air cooler does **not** need to be replaced.



⚠CAUTION⚠
Debris trapped in the charge air cooler, if not cleaned, will cause internal engine damage.

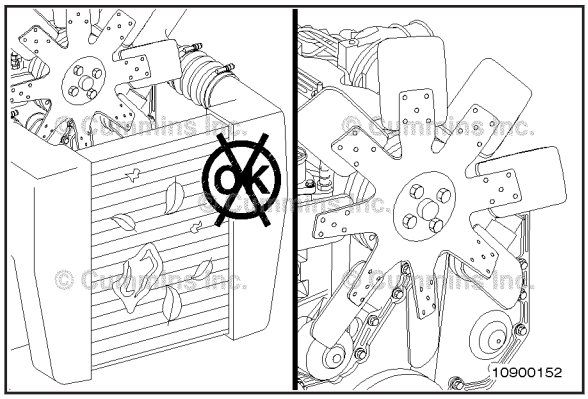
The charge air cooler **must** be cleaned following any turbocharger or air cleaner malfunction.



Temperature Differential Test

Inspect the charge air cooler fins for obstructions to airflow. Remove obstructions such as a winterfront or debris. Manually lock shutters in the open position, if equipped.

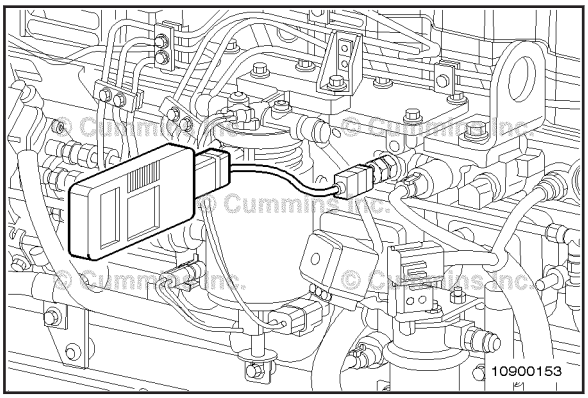
Lock the fan drive in the ON mode to prevent erratic test results. This can be done by installing a jumper wire across the temperature switch.

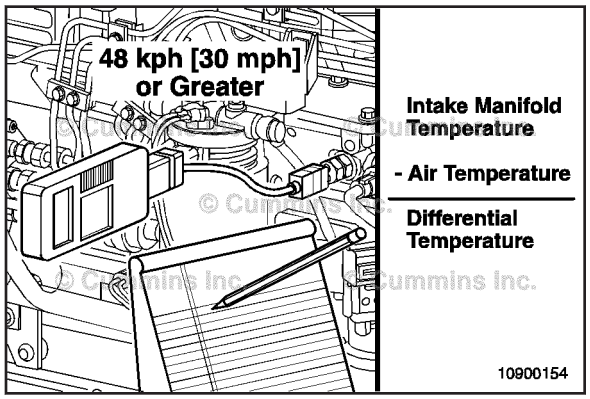


Install fluke digital thermometer, Part Number 3822666, and thermocouple wire kit, Part Number 3822988, into the intake manifold at the 1/8-inch NPT tap near the air horn connection with the intake manifold.

Another alternative would be to use the monitor mode on the INSITE™ service tool.

Install another thermocouple at the air cleaner inlet to measure ambient air temperature.



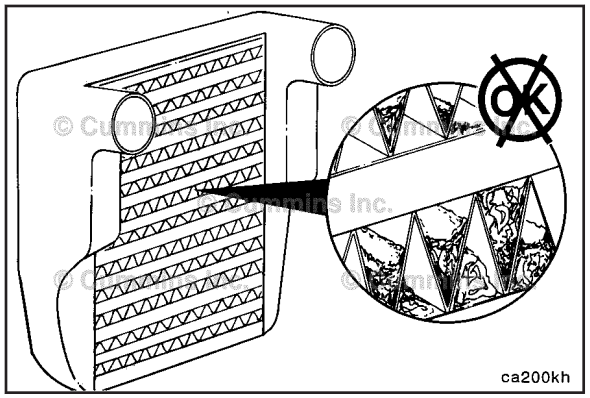


Perform a road test with the engine at peak power and a vehicle speed of 48 kph [30 mph] or greater.

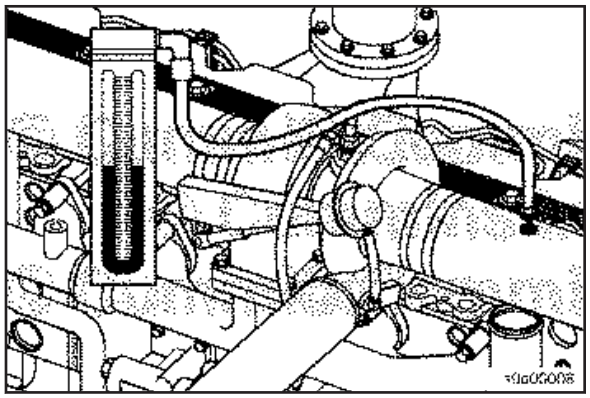
Record the intake manifold temperature and the ambient air temperature.

Calculate the differential temperature:

Intake manifold temperature - ambient air temperature = differential temperature. Maximum differential temperature = 28°C [82°F].



If the temperature differential is greater than the specifications, check the charge air cooler for dirt and debris on the fins and clean as necessary. If the problem still exists, check the charge air cooler for debris in the fins or between the charge air cooler and radiator. Confirm full-fan engagement.



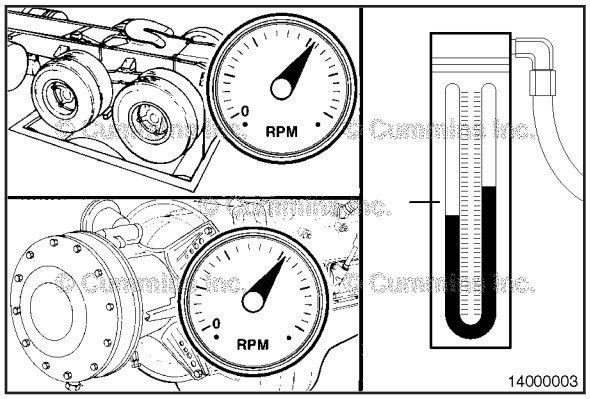
Air Intake Restriction (010-031)

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.

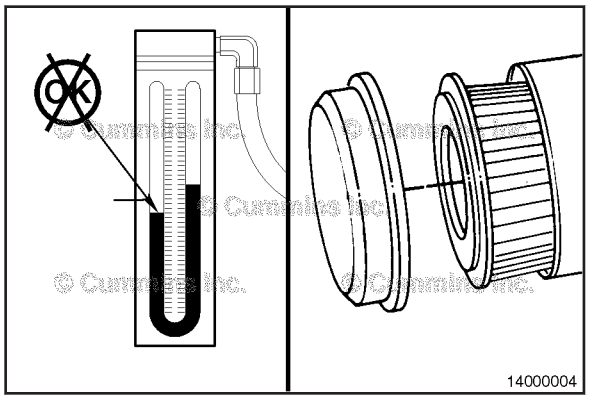


Operate the engine at full throttle and rated rpm with maximum load.

Record the data on the gauge or manometer.

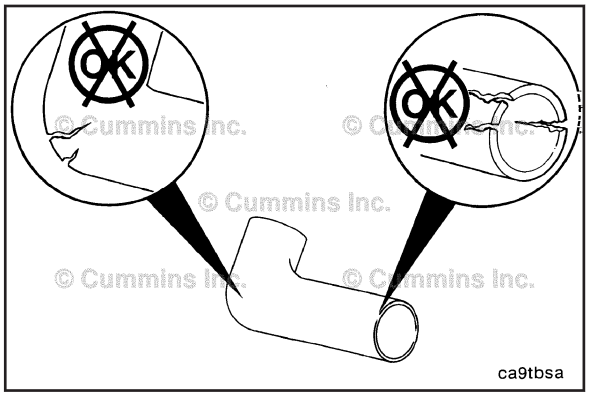
Inlet Air Restriction		
mm H_2O		in H_2O
635	MAX	25

If restriction exceeds specifications, replace or clean the air filter element. Refer to the equipment manufacturer's instructions.



Inspect the intake piping for damage. Refer to the equipment manufacturer's repair instructions.

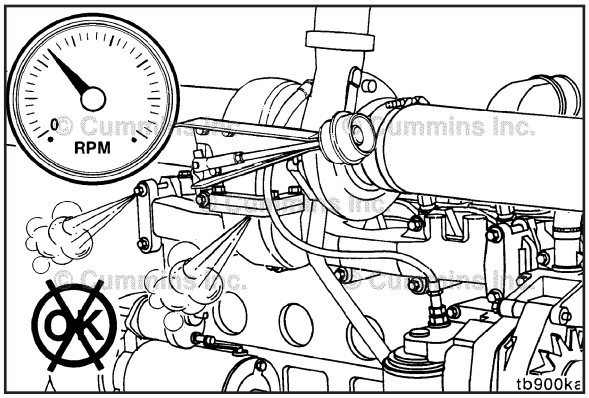
Remove the test equipment.



Turbocharger (010-033)

Initial Check

Inspect for exhaust leaks at the exhaust manifold, exhaust pipe, and turbocharger gasket. Check for muffler or 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. Again, the symptom will be excessive smoke, low-manifold pressure, and low power.

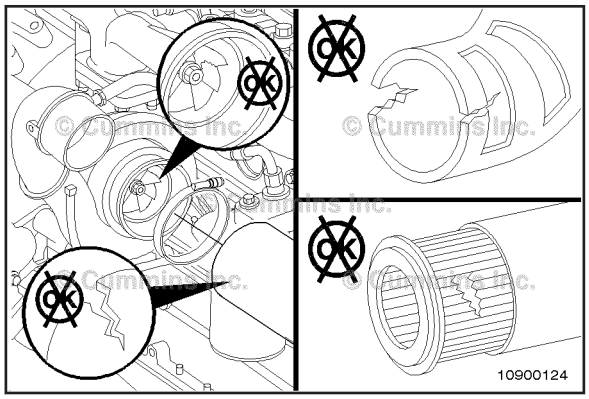


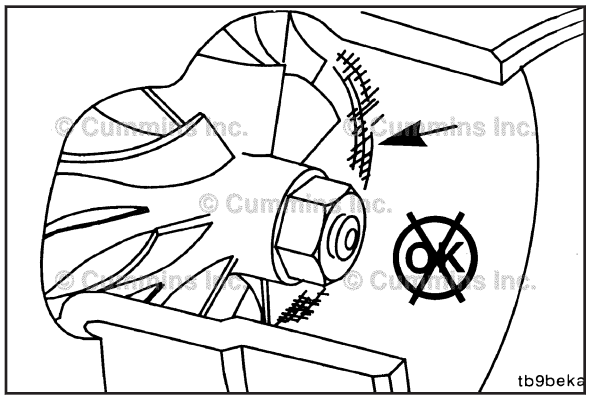
Remove the intake pipe from the turbocharger.

Inspect the turbocharger compressor impeller blades for damage.

If the compressor impeller is damaged, inspect the intake piping and filter element for damage.

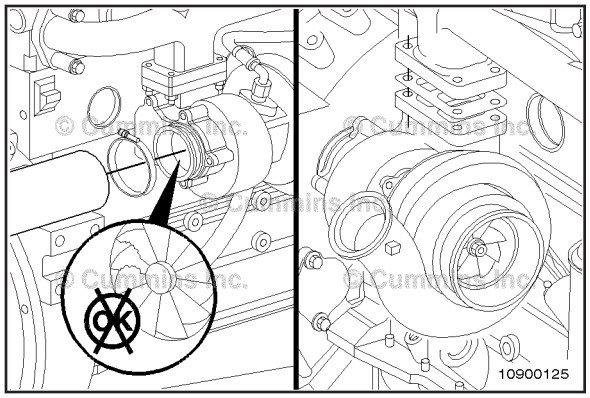
Replace the turbocharger if damage is found.





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

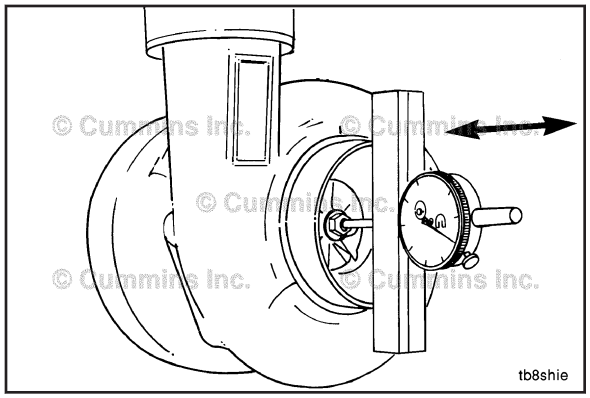
Malfunctioning turbocharger wastegate failure or miscalibration of the turbocharger wastegate can result in excessively high or low boost pressures. Low boost pressures can cause excessive smoke and low power. High boost pressures can cause major engine damage.



Remove the exhaust pipe from the turbocharger. See the Remove and Install steps in this procedure.

Inspect the turbine wheel for damage.

Replace the turbocharger, if damage is found.



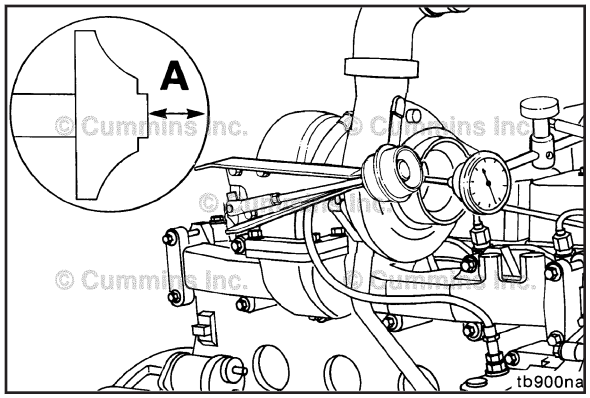
Axial Clearance Check

Measure the turbocharger shaft end clearance with the dial depth gauge, Part Number ST537.

Push the rotor assembly away from the gauge.

Set the gauge on zero.

Push the rotor assembly toward the gauge and record the data.



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.

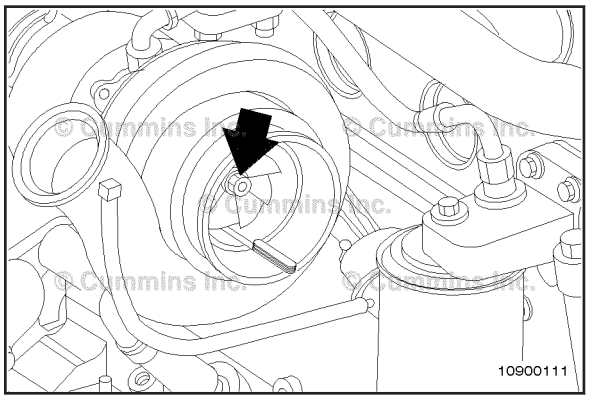
Radial Clearance Check

Measure radial clearance of the shaft.

Use a narrow blade or a wire-type feeler gauge to measure the clearance between the compressor wheel and housing.

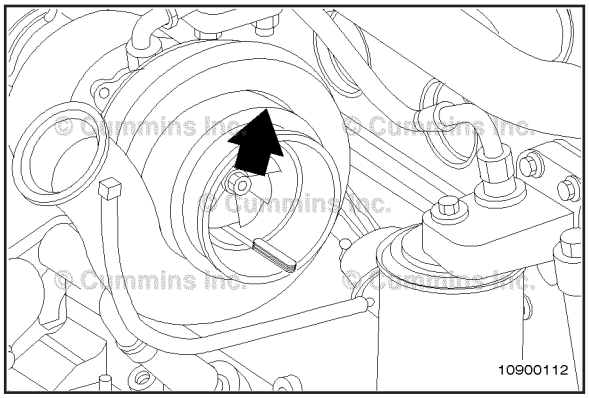
Gently push the compressor wheel toward the compressor housing and gauge.

Record this 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.

Record this clearance.

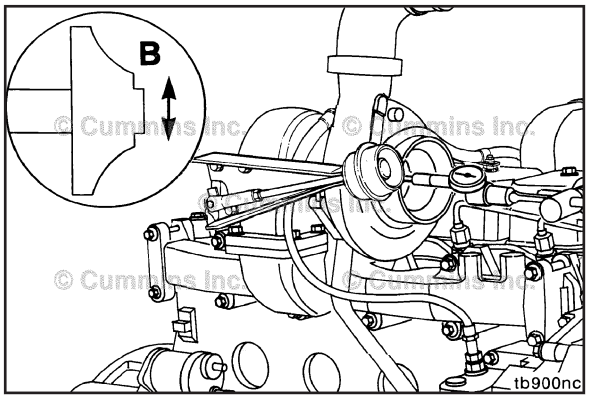


Subtract the smaller clearance from the larger clearance. This is the radial bearing clearance.

Radial Bearing Clearance

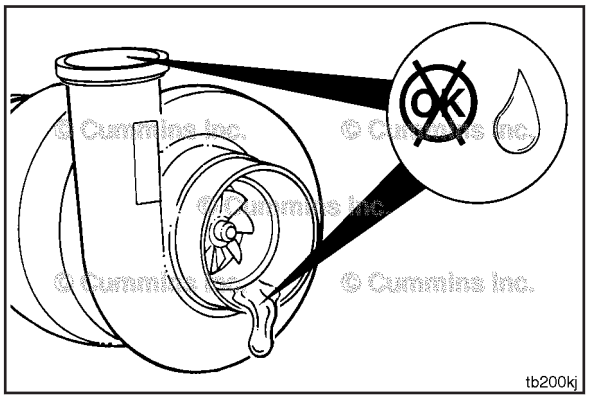
mm		in
0.30	MIN	0.012
0.46	MAX	0.018

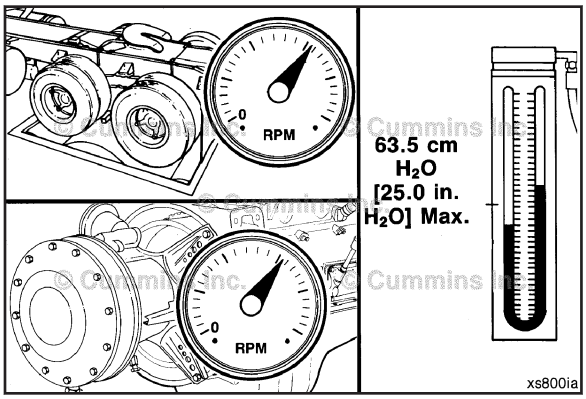
The turbocharger **must** be removed for replacement or rebuild if the clearances are beyond these limits. See the Remove step in this procedure or refer to the Turbocharger Master Repair Manual, Bulletin 3580555, for rebuild procedures.



Inspect the turbocharger compressor intake and discharge for oil.

If oil is present in the compressor intake, as well as in the discharge, check upstream of the turbocharger for the source of the oil.



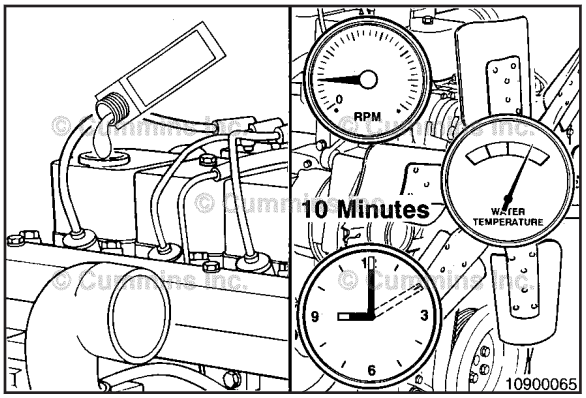


If oil is present **only** in the discharge side, install the air intake and charge air cooler piping. Refer to the OEM service manual.

Check for intake restriction. Refer to Procedure 010-031.

If no intake restriction is found, replace the turbocharger.

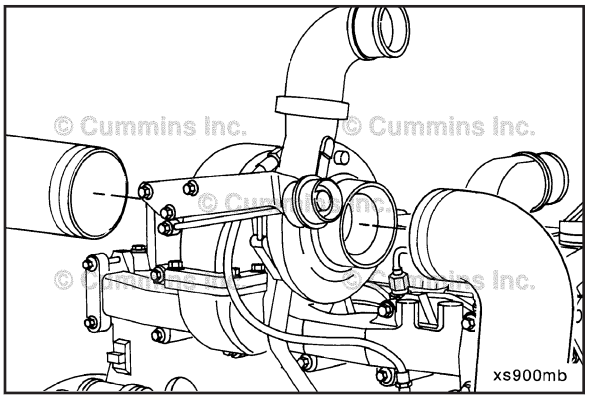
NOTE: If the engine experiences a turbocharger failure or any other occasion where oil is put into the charge air system, the charge air system **must** be inspected and cleaned. Refer to Procedure 010-027.



Leak Test

Add 1 unit of fluorescent tracer, Part Number 3376891, to each 38 liters [10 gal] of engine lubricating oil.

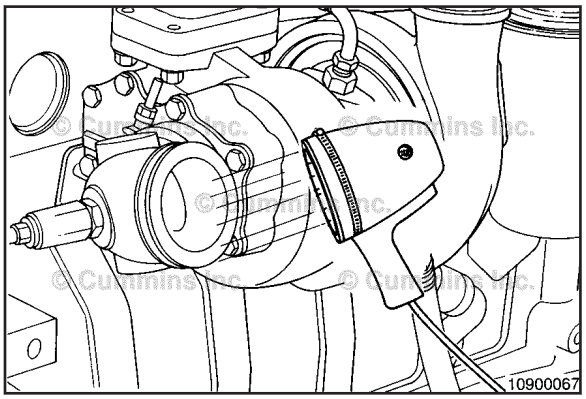
Operate the engine at low idle for 10 minutes.



Shut off the engine.

Allow the turbocharger to cool.

Remove the exhaust pipe from the turbine housing.

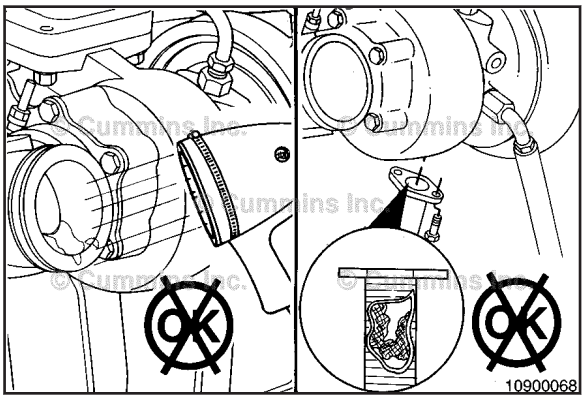


Use a high-intensity black light, Part Number 3824754 or 3824524, to inspect the turbine outlet for leaks.

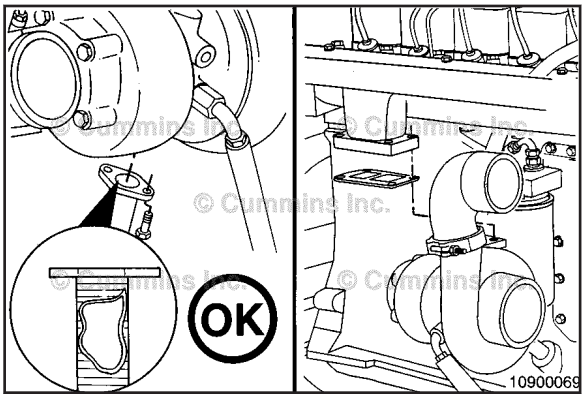
A dark blue glow indicates a fuel leak. Refer to Procedure 007-044. A yellow glow indicates an oil leak.

If oil is found on the turbine housing, remove the oil drain line, and check for restrictions. Clear any restrictions found, or replace damaged components as required.

If the engine is equipped with a turbocharger oil drain fitting with a screen, remove the fitting, and check to make sure the screen is clean.



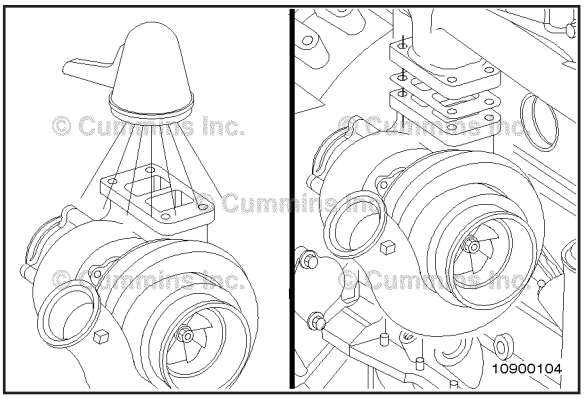
If the oil drain line is **not** restricted, remove the turbocharger. See the Remove step in this procedure.



Use a high-intensity black light, Part Number 3829754 or 3824524, 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.



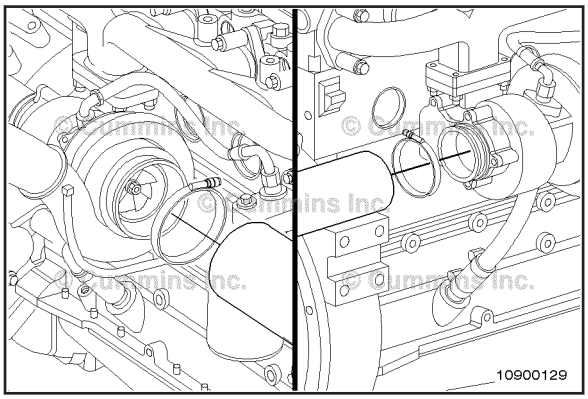
Install the intake pipe to the turbocharger compressor inlet and tighten the clamp.

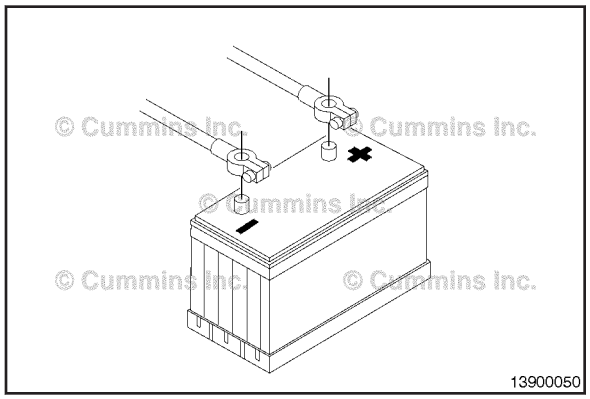
Torque Value: 8 N•m [71 in-lb]

Install the exhaust pipe to the turbocharger turbine outlet and tighten the clamp.

Torque Value: 8 N•m [71 in-lb]

See the Install step in this procedure.

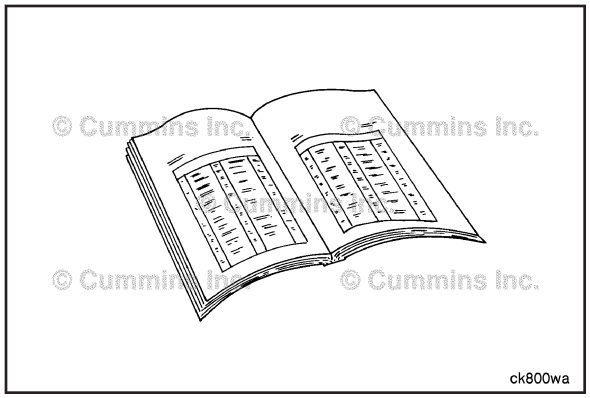




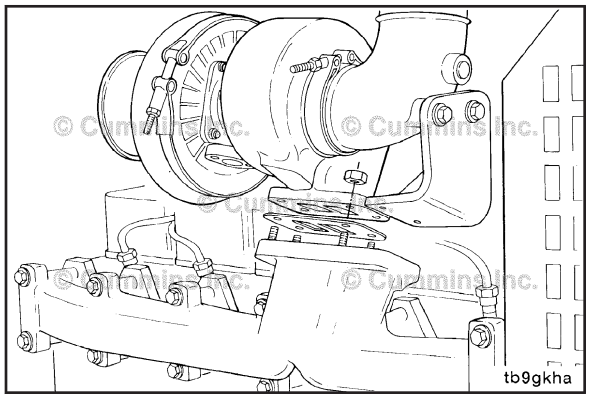
Preparatory Steps

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

- Disconnect the batteries.



- Remove air crossover tube, if equipped. Refer to Procedure 010-019.
- Remove boost capsule actuator hose.
- Remove oil supply line from the turbocharger. Refer to Procedure 010-046.
- Remove oil drain line from the turbocharger. Refer to Procedure 010-045.



Remove

Remove the exhaust piping.

Disconnect 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 exhaust clamp, turbocharger mounting nuts, turbocharger, and gasket.

Clean and Inspect for Reuse

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

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

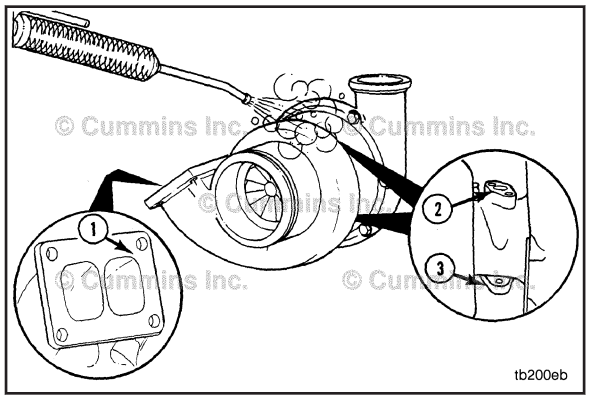
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

△CAUTION△
Tape or plug all openings to prevent solvent or steam from damaging the oil cavities in the turbocharger.

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.

NOTE: If the turbocharger is **not** to be immediately replaced, cover the opening to prevent any material from falling into the manifold.

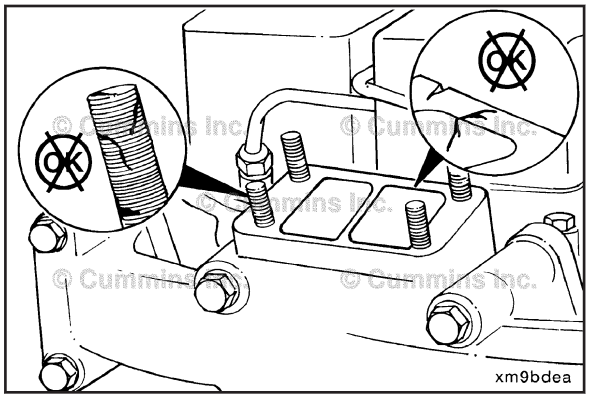


Clean the turbocharger and exhaust manifold gasket surfaces.

Inspect the turbocharger and exhaust manifold gasket surfaces and mounting studs for cracks and damage.

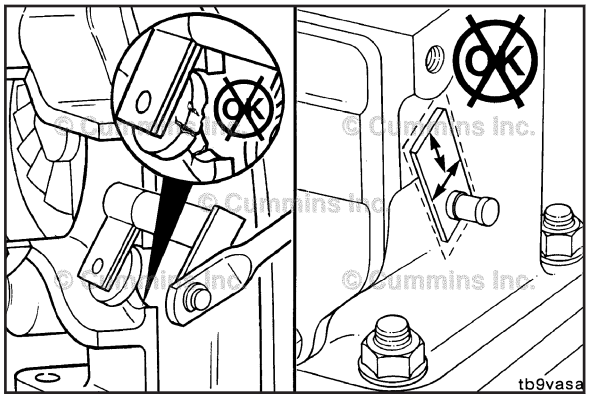
Replace the turbocharger if any cracks are found on the mounting flange surface. See the Remove and Install steps in this procedure.

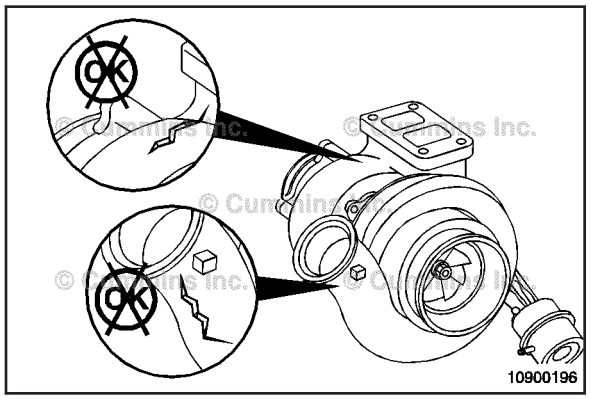
Replace the exhaust manifold if any cracks are found on the mounting flange surface. Refer to Procedure 011-007.



Inspect turbocharger wastegate linkage, valve shaft, module, and pressure signal line.

Check or calibrate wastegate. Refer to Procedure 010-050 or to the Turbocharger Shop Manual, Bulletin 3810321.

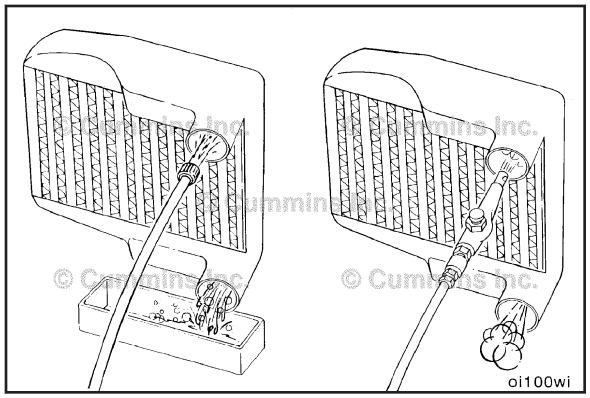




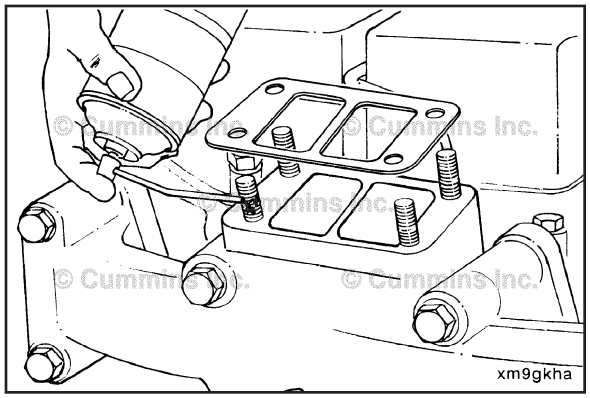
Inspect the turbine and compressor housings.

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.

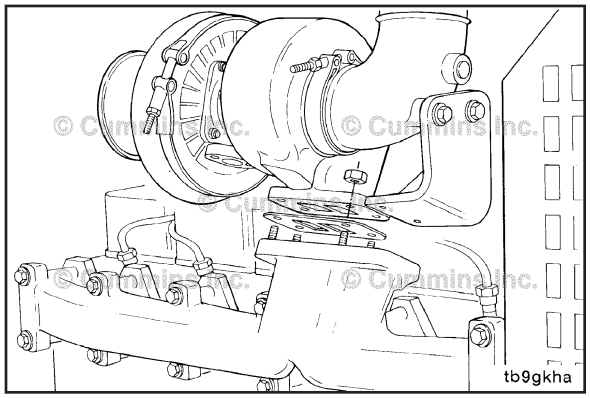


NOTE: If the engine experiences a turbocharger failure or any other occasion where oil is put into the charge air system, the charge air system **must** be inspected and cleaned. Refer to Procedure 010-027.



Install

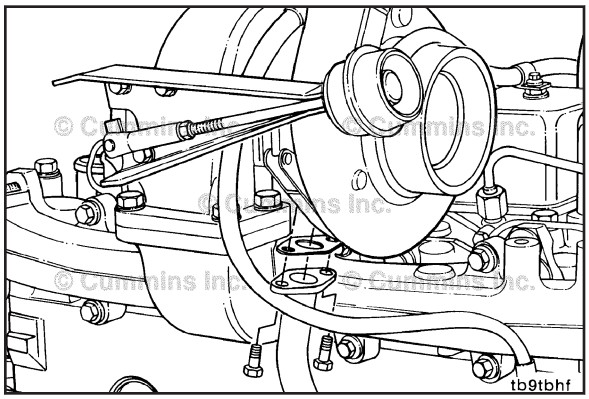
Install a new gasket, and apply anti-seize compound to the mounting studs.



Install the turbocharger.

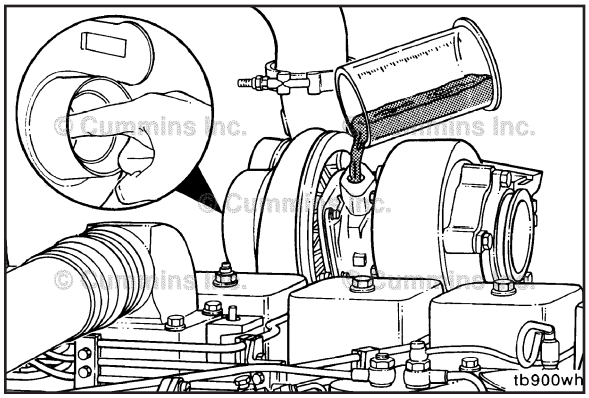
Torque Value: 45 N•m [33 ft-lb]

Install the turbocharger oil drain line. Refer to Procedure 010-046.

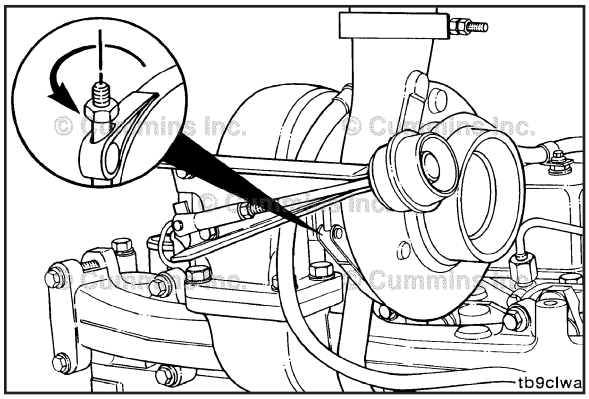


Lubricate the bearings by pouring 59 to 89 ml [2 to 3 oz] of clean 15W40 engine oil into the turbocharger oil supply line fitting.

Rotate the turbine wheel to allow oil to enter the bearing housing.



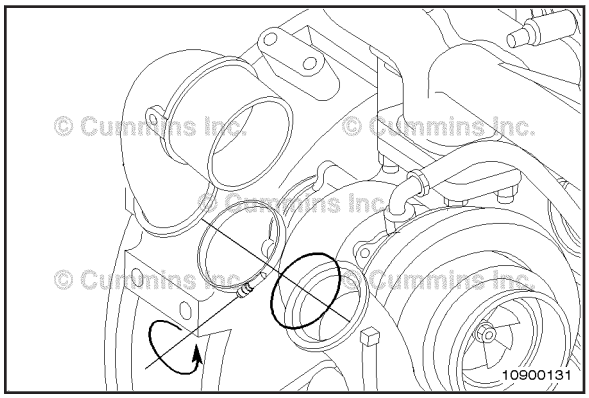
If required, loosen the compressor housing v-band clamp and position the housing to align with the turbocharger air outlet tube.

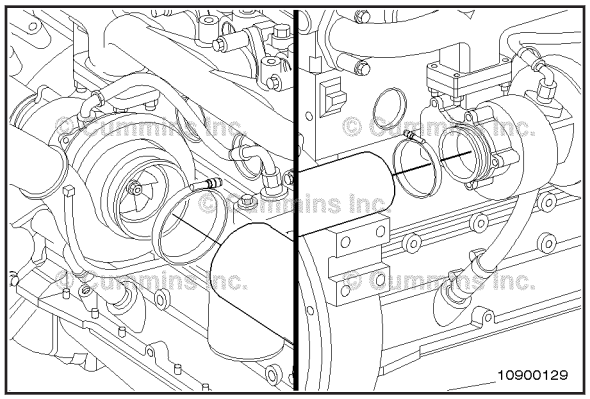


Install the turbocharger compressor outlet elbow, v-band clamp, and new o-ring seal on the turbocharger compressor discharge outlet.

Tighten the clamp.

Torque Value: 8 N•m [71 in-lb]



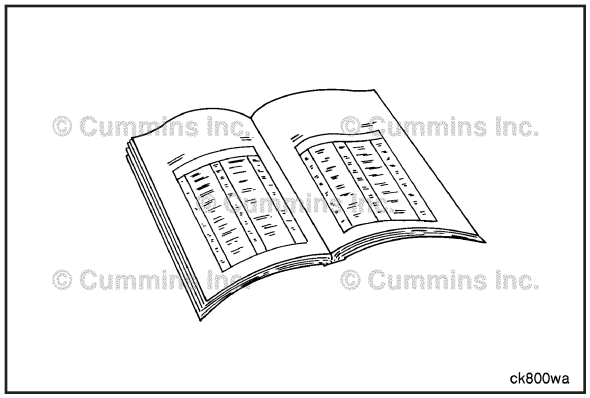


Install the intake pipe to the turbocharger compressor inlet and tighten the clamp.

Torque Value: 8 N•m [71 in-lb]

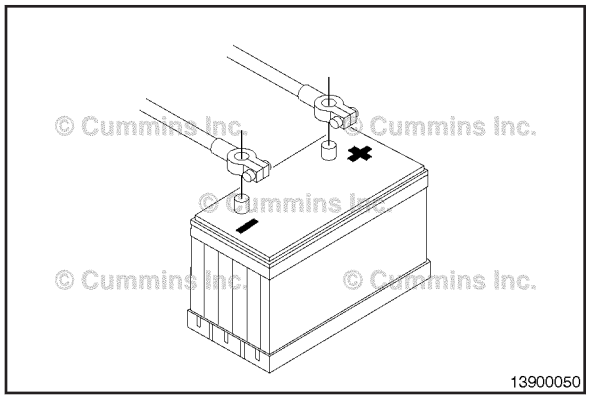
Install the exhaust pipe to the turbocharger turbine outlet and tighten the clamp.

Torque Value: 8 N•m [71 in-lb]



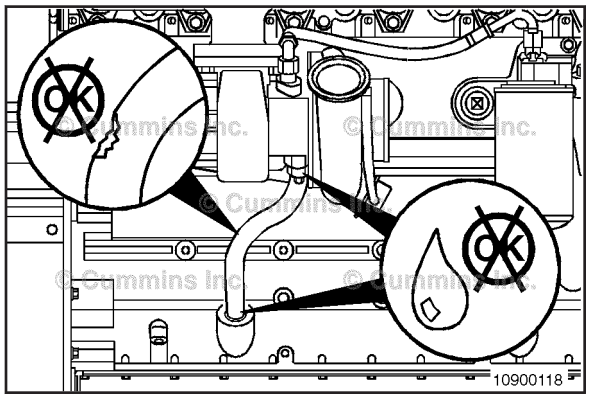
Finishing Steps

- Install the turbocharger oil supply line. Refer to Procedure 010-045
- Install the air crossover tube, if used. Refer to Procedure 010-019
- Install the boost capsule actuator hose.



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

- Connect the batteries
- Operate the engine and check for leaks.



Turbocharger Oil Drain Line (010-045)

Initial Check

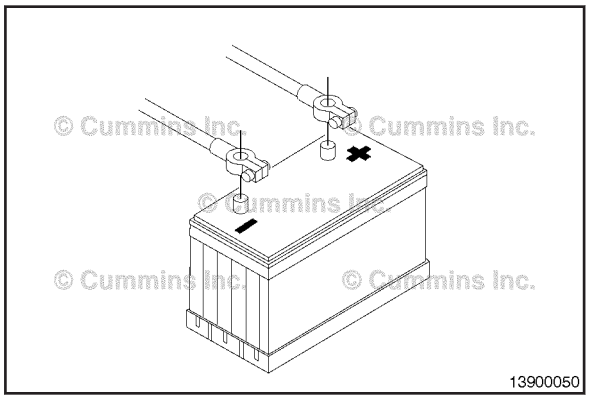
Inspect the line for oil leaks or damage.

Repair or replace as necessary.

Preparatory Steps

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

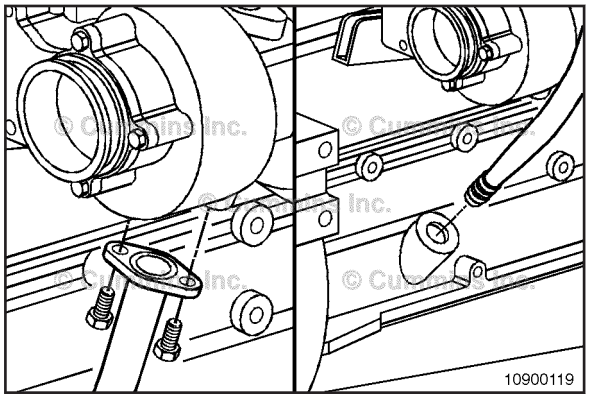
- Disconnect the batteries.



Remove

Remove the capscrews from the turbocharger oil drain tube.

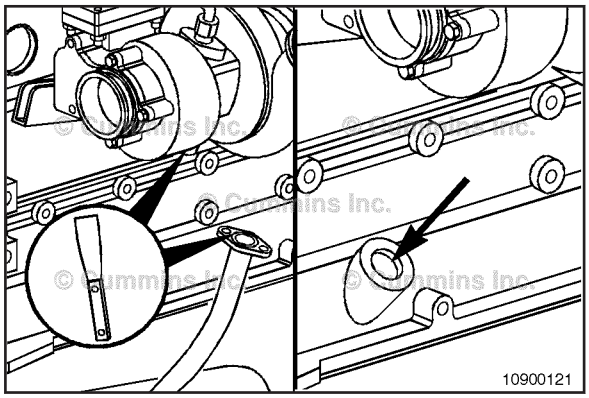
Pull the drain line out of the drain line boss.



Clean and Inspect for Reuse

Clean the gasket sealing surfaces (first frame).

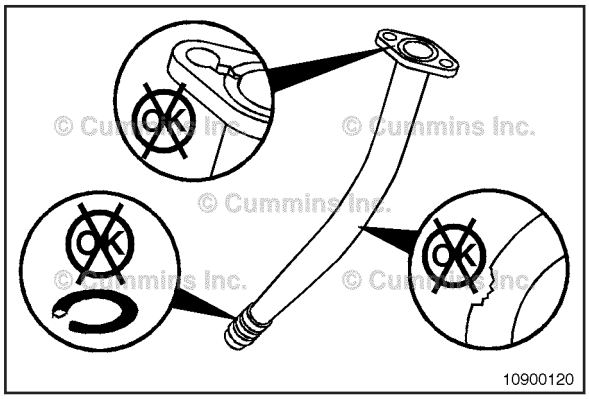
Clean the o-ring seating bore, and make sure it is free of dirt and debris.

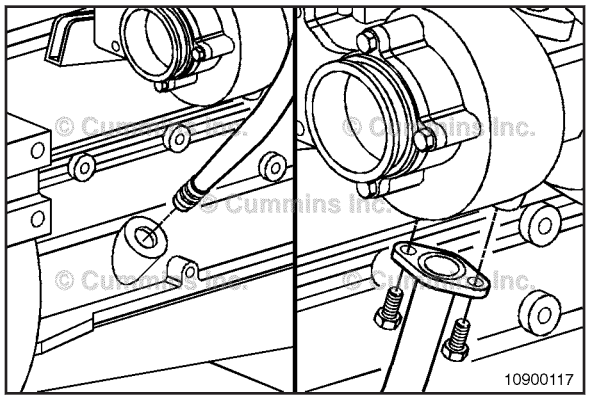


Inspect line for cracks, wear, and damage.

Inspect the o-ring for fretting and cracking, and replace as necessary.

Check the rubber section of the drain line for deterioration.





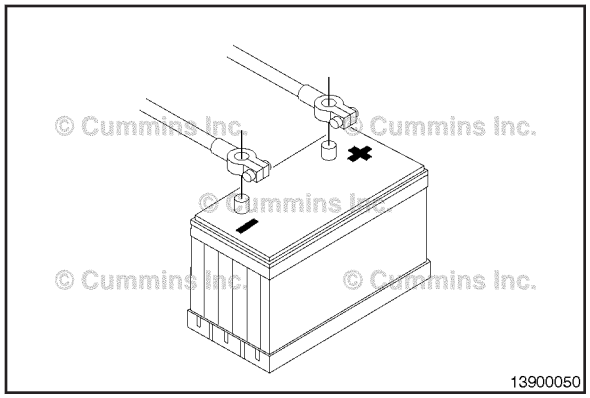
Install

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 the drain line capscrews with a new gasket.

Torque Value: 24 N•m [18 ft-lb]

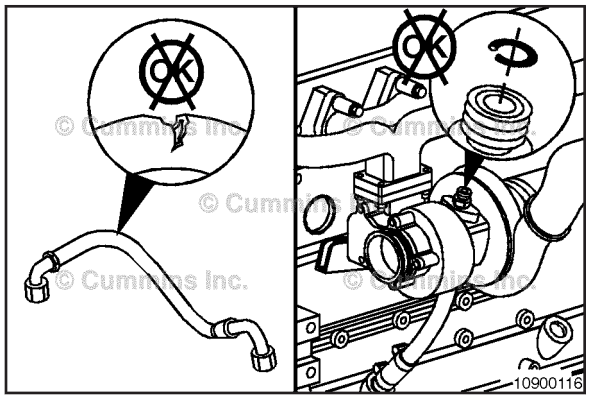


Finishing Steps

⚠WARNING⚠

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

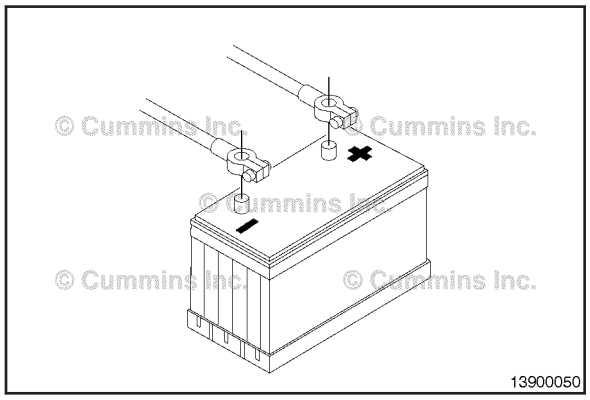
- Connect the batteries
- Operate the engine, and check for leaks.



Turbocharger Oil Supply Line (010-046)

Initial Check

Inspect the line for oil leaks or damage. Replace as necessary.



Preparatory Steps

⚠WARNING⚠

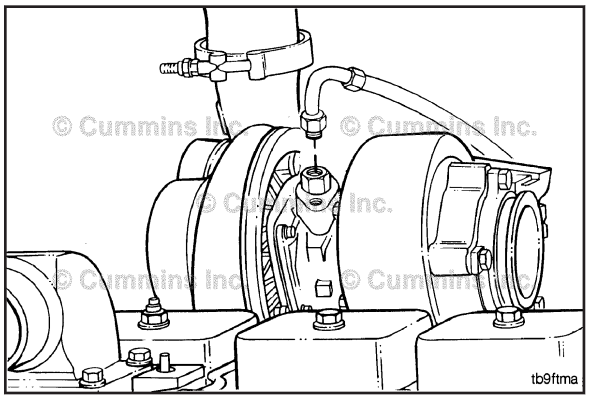
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries.

Remove

Remove the oil supply line from the oil filter head.

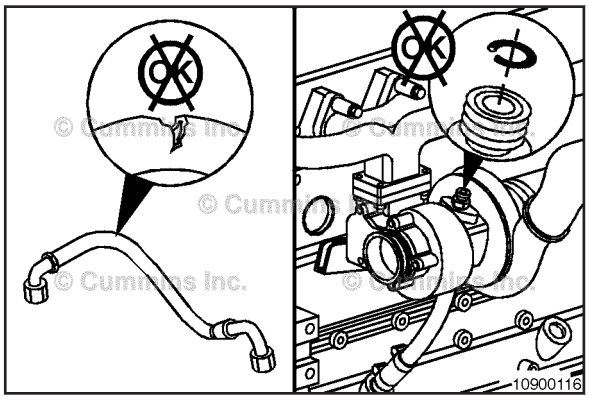
Remove the oil supply line from the turbocharger bearing housing.



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.

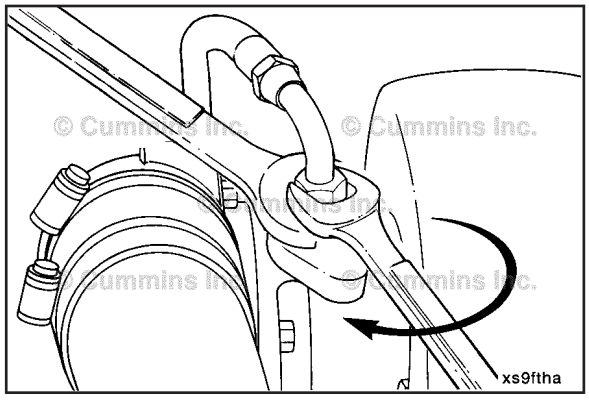
Apply a thin film of oil to the o-ring seals.

Fill the turbocharger oil inlet with clean oil.

Install the oil supply line at both the filter head and the turbocharger bearing housing.

Tighten the oil supply line to final torque.

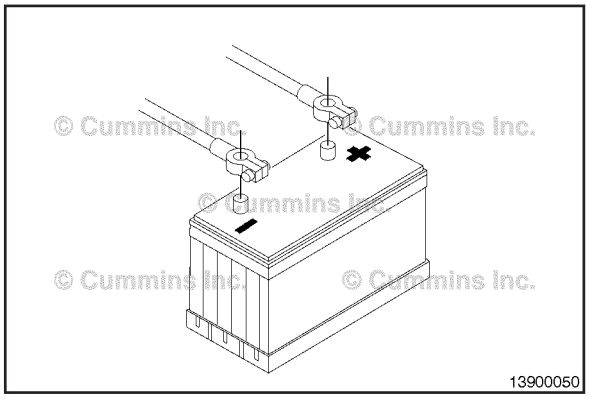
Torque Value: 24 N•m [212 in-lb]

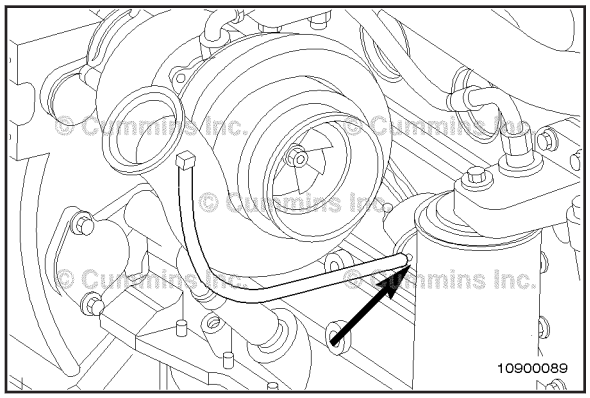


Finishing Steps

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

- Connect the batteries
- Operate the engine and check for leaks.





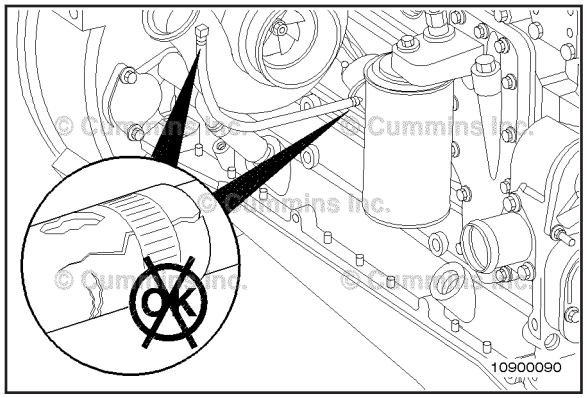
Turbocharger Wastegate Actuator (010-050)

Initial Check

NOTE: This procedure applies to actuators that are adjustable before pre-1998 B Series engines. B Series engines after January 1998 are **not** adjustable and the actuators are tamper proof.

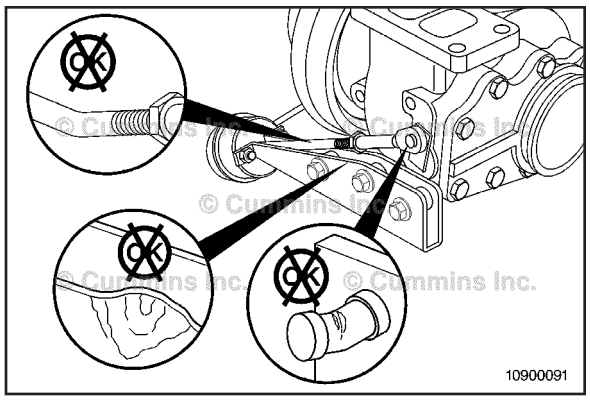
Some versions of B Series engines are equipped with wastegated turbochargers to limit the peak boost level and increase engine response at low rpm.

The integral wastegate line takes boost from the turbocharger compressor outlet to the wastegate capsule.



Inspect the integral wastegate actuator hose for cracks or holes.

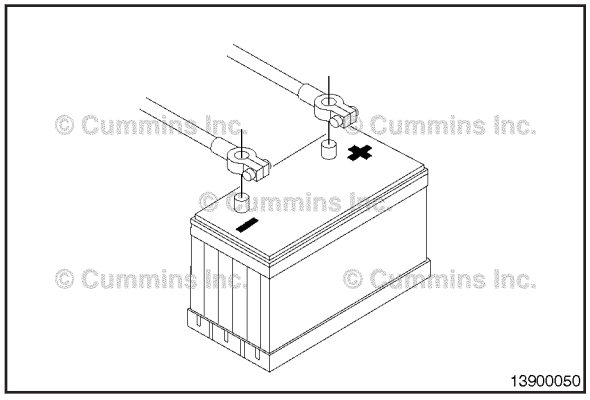
Replace the hose if damaged.



CAUTION
A bent wastegate mounting bracket, actuator rod, or lever can cause improper operation.

Inspect the wastegate mounting bracket, actuator rod, and lever for damage.

If the wastegate mounting bracket, actuator rod, or lever is bent, it **must** be replaced.



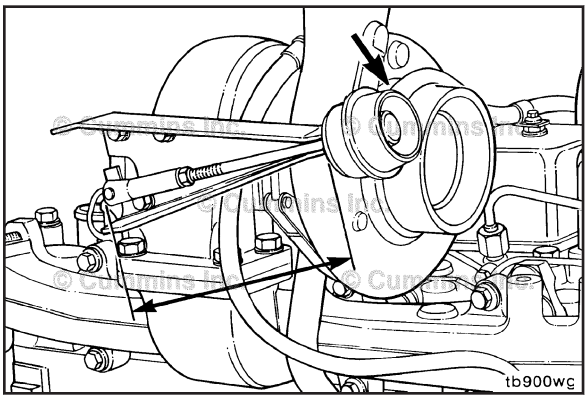
Preparatory Steps

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

- Disconnect the batteries.

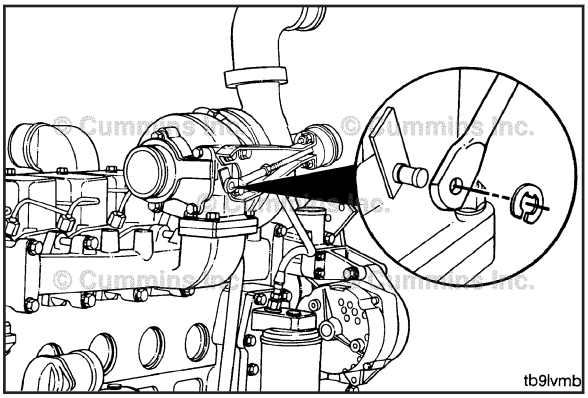
Remove

NOTE: Prior to removal, note position length of the control rod from the boost capsule housing and orientation of the boost capsule hose connector in relation to the mounting bracket.



Turbocharger Wastegate Pressure Setting Kit, Part Number 3823799

Remove the retaining clip from the control lever.

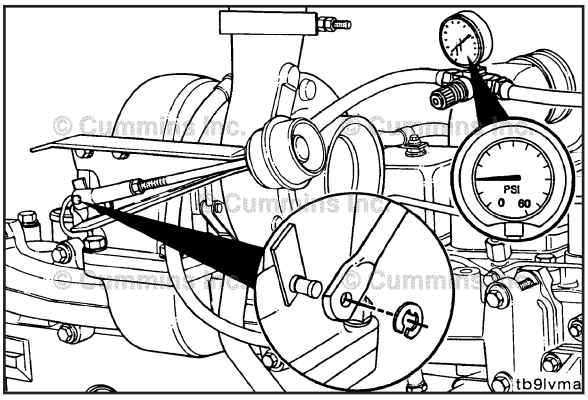


⚠CAUTION⚠
Be careful not to bend the control lever.

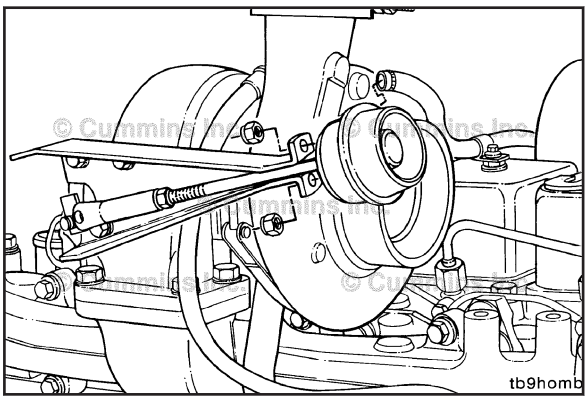
Disconnect the boost capsule actuator rod end from the turbocharger wastegate lever. This can be accomplished by applying regulated air pressure to the boost capsule in a sufficient amount to activate control rod movement.

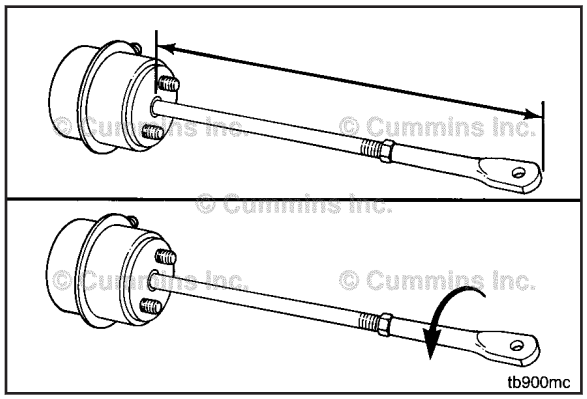
Disconnect the control rod from the turbocharger wastegate lever pin.

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 in order to overcome boost capsule spring tension for removal of the control rod from the turbocharger wastegate lever pin.



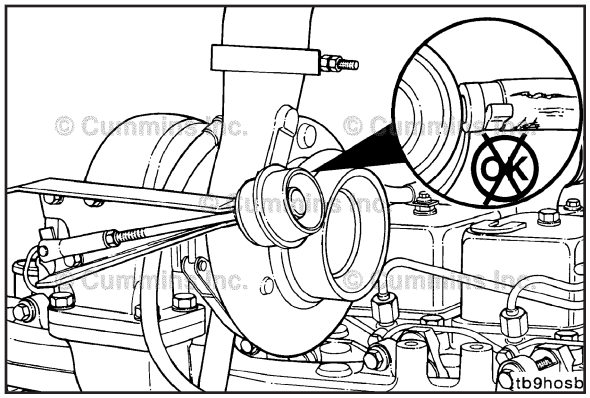
Loosen the boost capsule mounting capscrews, disconnect the air supply hose, and remove assembly from the mounting bracket.





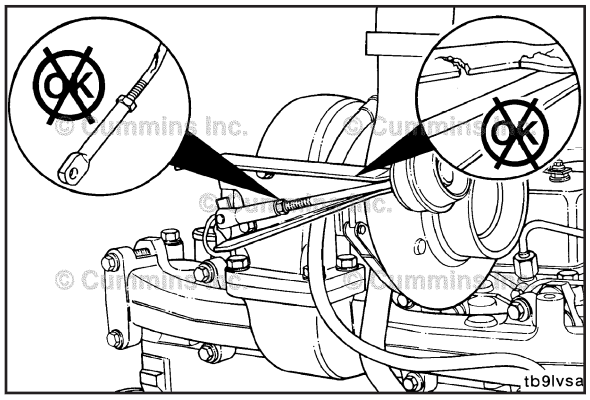
Note length of adjusting link prior to removal.

Loosen 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.

Test

Functional Check

Attach a dial indicator as shown, so that its shaft is in line with the wastegate actuator rod. Set the indicator to zero, with no air pressure applied to the wastegate capsule.

Connect clean, regulated air pressure and a pressure gauge to the capsule. Apply air pressure to make sure the wastegate is functioning properly.

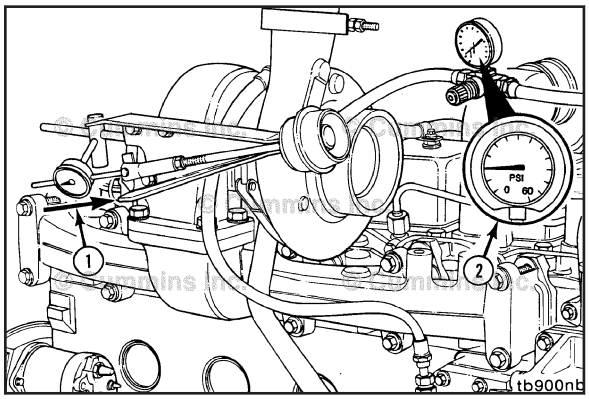
Air Pressure: 200 kPa [29 psi]

The rod should move **without** any sticking or air leakage.

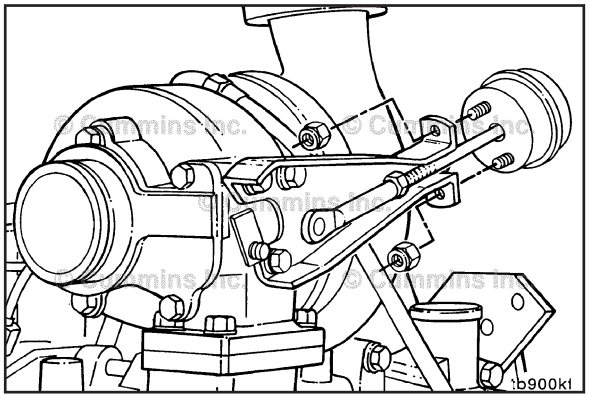
Rod: 0.33 to 1.27 mm [0.013 to 0.050 in]

NOTE: No air should be heard leaking through a functional wastegate capsule.

NOTE: A small amount of travel when air pressure is first applied is normal; the tolerance is being removed from the system.

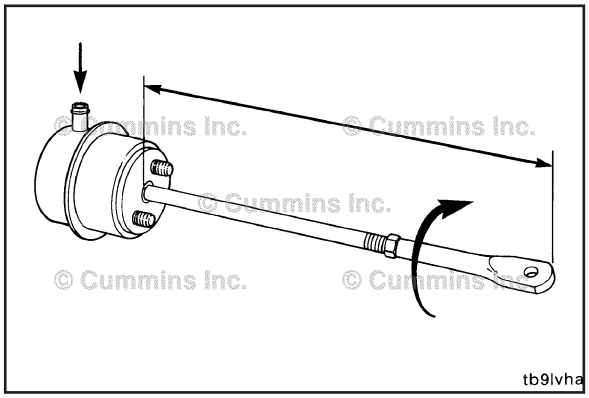


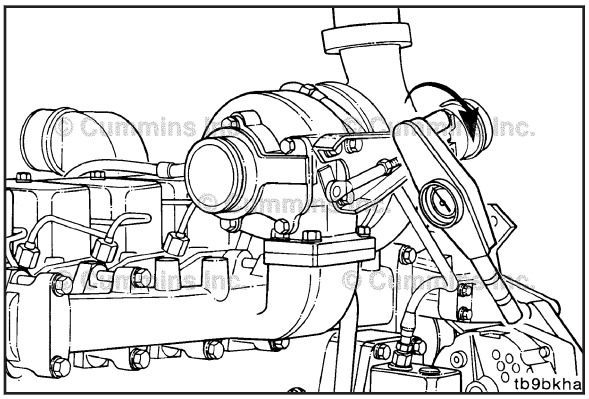
Replace the actuator if no movement of the actuator rod and lever is detected.



Install

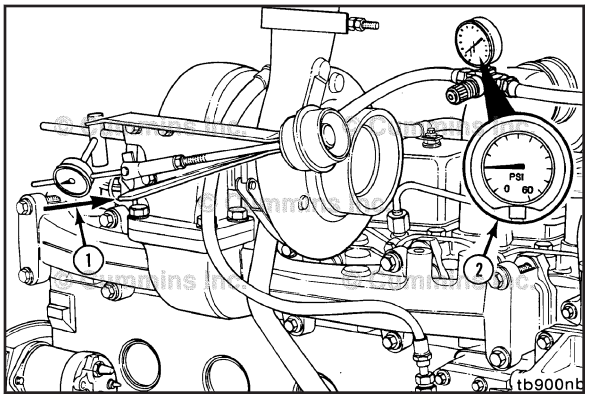
Install the adjusting link end onto the boost capsule actuator assembly. Adjust the rod to approximately the same length as when removed.





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]

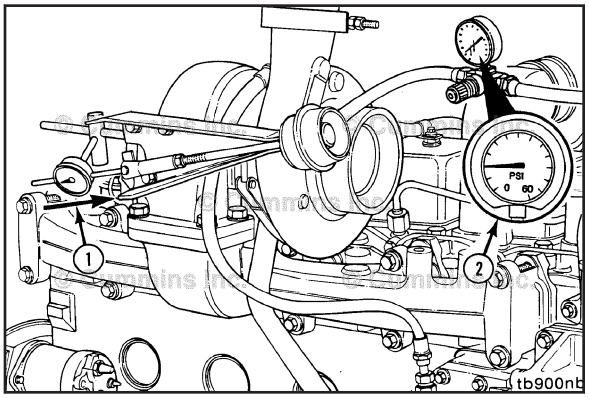


Calibrate

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.

Engine Serial Number	Rating (HP)	Pressure (kPa)	Pressure (psi)
Before 45278518	195	83	12
After and Including 45278518	195	83	12
All	150	48	7



NOTE: Wastegate actuator adjustment is **not** a shortcut to diagnosing low boost. Use the appropriate symptom tree to diagnose the cause of the low boost before calibrating the wastegate actuator, if turbo boost is suspected.

This actuator travel specification applies to the 4B and 6B engine applications.

NOTE: If the measured wastegate actuator travel is within specification, do **not** make any adjustment.

Wastegate Actuator Travel Measurement		
mm		**in**
0.033	MIN	0.013
1.27	MAX	0.050

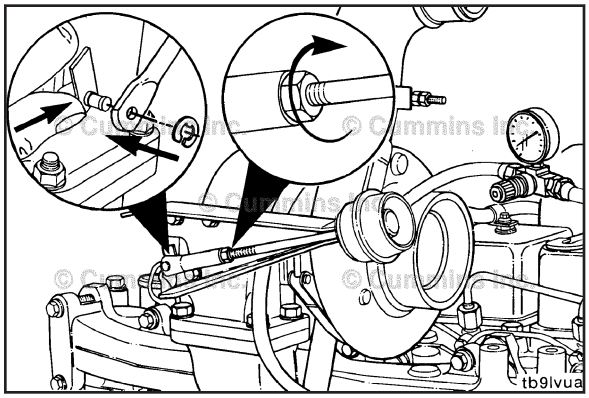
NOTE: Adjustment on wastegate actuators is **not** possible for engines that were built after January 1998 because tamper proof actuator links are used. The first engine serial number is 4536369. If the actuator needs to be replaced, the whole capsule has to be changed. You can **not** adjust the wastegate actuator.

⚠CAUTION⚠

Do not pull, or push, or force alignment of the clevis pin. Failure to do so can cause component damage.

Adjust the wastegate, if necessary, to achieve specified travel.

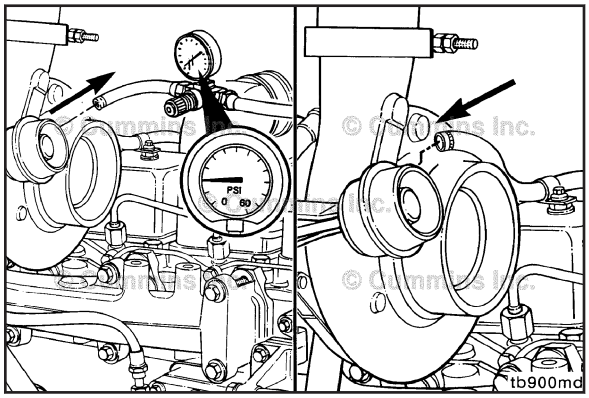
- Pull the wastegate lever to the foremost closed position (lever toward boost capsule).
- Adjust the length of the clevis end of the control rod to where the clevis pin hole aligns to the wastegate lever.
- Install the adjusting link and retaining clip.
- After adjustment is completed, tighten actuator rod jam nuts.



Disconnect regulated air pressure line from the boost capsule.

Connect the turbocharger boost line to the boost capsule, and secure the hose clamp.

If possible, a more accurate method of wastegate adjustment is to check the manifold pressure at rated rpm according to turbocharger boost pressure specifications.

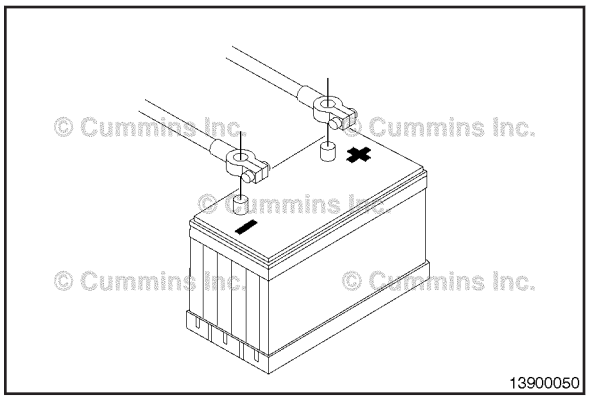


Finishing Steps

⚠WARNING⚠

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

- Connect the batteries
- Operate the engine and check for leaks.



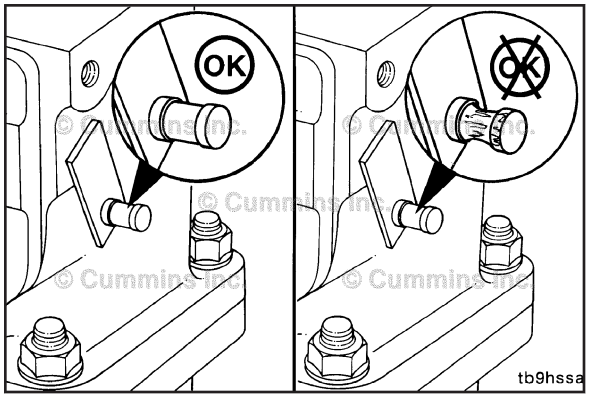
Turbocharger Wastegate Valve Body (010-055)

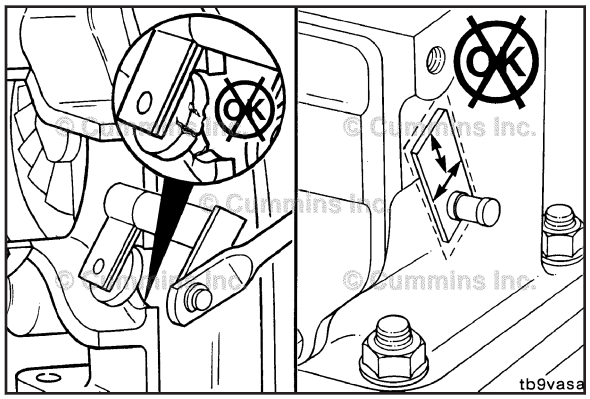
Inspect for Reuse

Inspect the lever pin.

Replace the turbine housing assembly if worn excessively.

Refer to the Turbocharger Master Repair Manual, Bulletin 3580555.

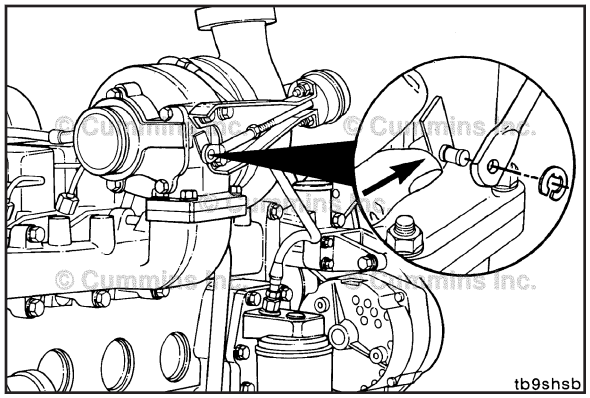




Inspect the valve and valve seat for cracks or erosion.

Replace the turbine housing assembly if worn excessively.

Refer to the Turbocharger Master Repair Manual, Bulletin 3580555.

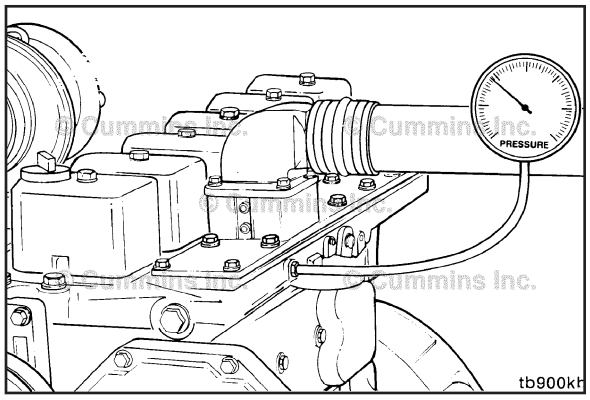


Actuate the lever by hand to be sure that the shaft rotates freely and is **not** seized.

Check for excessive movement between the shaft and bushing.

Replace the turbine housing if the shaft and bushing are damaged or seized.

Refer to the Turbocharger Master Repair Manual, Bulletin 3580555.

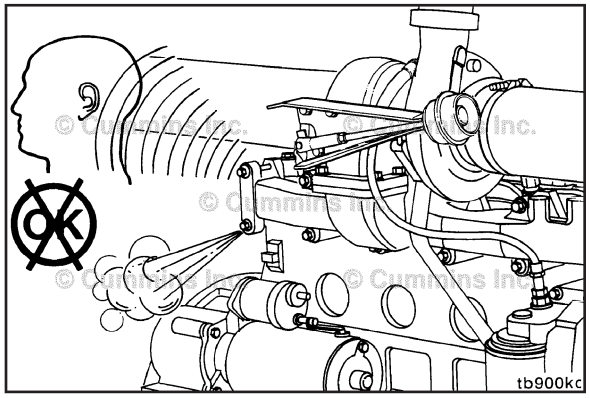


Intake Manifold Pressure (010-057)

Measure

Measure the boost pressure at the intake manifold by using 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) for the engine being worked on. If the specifications for the engine being worked on are **not** listed, see the engine data sheet.

NOTE: If the engine has charge-air-cooling, testing **must** be done to make certain that the charge-air-cooler system is **not** leaking or restricting the turbocharger boost pressure. Refer to Procedure 010-027 for charge-air-cooler testing.



Exhaust leaks can usually be detected audibly or visually by a discoloration caused by the escaping hot gases.

Do **not** overlook exhaust restriction as a cause of low power. If the exhaust gases can **not** flow freely, the turbocharger will **not** operate efficiently.

Air Intake Manifold Heater (010-072)

General Information

This procedure covers intake manifold heater element components for 1991 and 1994 Automotive and Industrial engine ratings. This procedure also covers upfit of intake manifold heater element components on engines **not** originally built with an intake heater option (front gear train engines only).

⚠ WARNING ⚠

To reduce the possibility of personal injury and property damage, never use starting fluid with the air intake manifold heater. Starting fluid, which contains ether, can cause an explosion.

⚠ WARNING ⚠

Starting fluid is highly flammable and explosive. Keep flames, sparks, and arcing switches away from starting fluid. This combination can cause an explosion and bodily injury.

Warning labels, Part Number 3927335, **must** be installed in locations obvious to the operator, near the most likely point of entry of ether, and on a visible side of the heater. The sun visor and the air cleaner intake is two examples.

The 12-VDC B Series charge air cooled, turbocharged, and naturally aspirated engines (6BTAA, 6BT, and 6B) use the air intake manifold heater as a cold weather starting aid. There is no air intake manifold heater for the water jacket aftercooled engine (6BTA) or 24-VDC electrical system at this time, and the air intake manifold heater is **not** compatible with marine applications.

Benefits from an air intake manifold heater include:

- Quicker start times
- Smoother engine running after starting
- Replaces ether as a starting aid
- Extends starter and battery life through less cranking.

The air intake manifold heater is very similar to the popular light-duty truck application grid heater in use since 1988. This heater electronically controls the two heating elements to optimize cold weather starts and improved cold engine running.

Engine mounted hardware includes:

- Air intake manifold heater
- Temperature sensor
- Controller
- Wiring harness.

NOTE: The kit does **not** include 6 AWG wire or ring terminals needed for the battery and other connections.

White smoke indicates unburned fuel during cold engine operation.

The intake manifold heater system is **not** directly connected to the fuel system, but it monitors the temperature of the air to the engine. The thermistor sends varying resistance values to the electronic control module (ECM), or equivalent. The ECM in turn controls the WAIT-TO-START lamp and the heater solenoids.

The intake manifold heater elements operate in both the preheat and postheat modes.

- In preheat, the ignition switch is on, but the engine has **not** been started.
- In postheat, the engine is running.

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

Normal Operation of the Intake Manifold Heater System				
Temperature	**Condition**	**Elements**	**Duration**	**Duty Cycle Percent ON/ OFF**
Below -19°C [-2°F]	Preheat	Both	30 seconds	Continuous
	Postheat	Both	15 seconds	Continuous
		One	15 seconds	Continuous
		One	40 seconds	50/50
		One	106 seconds	25/75
-19 to -8°C [-2 to 18°F]	Preheat	Both	20 seconds	Continuous
	Postheat	Both	20 seconds	Continuous

Normal Operation of the Intake Manifold Heater System				
Temperature	**Condition**	**Elements**	**Duration**	**Duty Cycle Percent ON/ OFF**
		One	20 seconds	Continuous
		One	20 seconds	Continuous
		One	40 seconds	50/50
		One	106 seconds	25/75
-8 to 8°C [18 to 46°F]	Preheat	Both	10 seconds	Continuous
	Postheat	Both	10 seconds	Continuous
		One	10 seconds	Continuous
		One	10 seconds	Continuous
		One	40 seconds	50/50
		One	106 seconds	25/75
Below 8°C [46°F]	Preheat	None		
	Postheat	None		
Amperage Draw - 95 amps per element				
To prevent excessive drain on the batteries, the electric heater controller has incorporated a battery monitoring feature. If the battery VDC were dropped too low, the heater controller will delay the postheat cycle, preventing further drain on the batteries. This battery protection feature is **only** activated on vehicles with weak or drained batteries.				

*Heater control modules or electronic control modules with serial numbers below 0080000A will **not** have a preheat cycle during this cycle.

Battery Size Requirements for B Series Engines (automotive and industrial ratings)

1991 and 1994 6BTAA and 4BTAA automotive ratings

NOTE: Unaided starting down to 0°C [+32°F] or intake heater equipment*

4BTAA Engine		
Heavy accessory	Cold Cranking Amps (CCA)	Reserve Minutes
Light accessory	900	160
	750	169
* Intake heater equipment option requires a 95-amp alternator or larger.		

6BTAA Engine		
	Cold Cranking Amps (CCA)	**Reserve Minutes**
Heavy accessories	1000	160
Light accessories	850	160
* Intake heater equipment option requires a 95-amp alternator or larger.		

NOTE: Unaided starting down to -12°C [10°F].

4BTAA Engine		
	Cold Cranking Amps (CCA)	**Reserve Minutes**
Heavy accessories	1350	320
Light accessories	1125	320

6BTAA Engine		
	Cold Cranking Amps (CCA)	**Reserve Minutes**
Heavy accessories	1500	320
Light accessories	1250	320

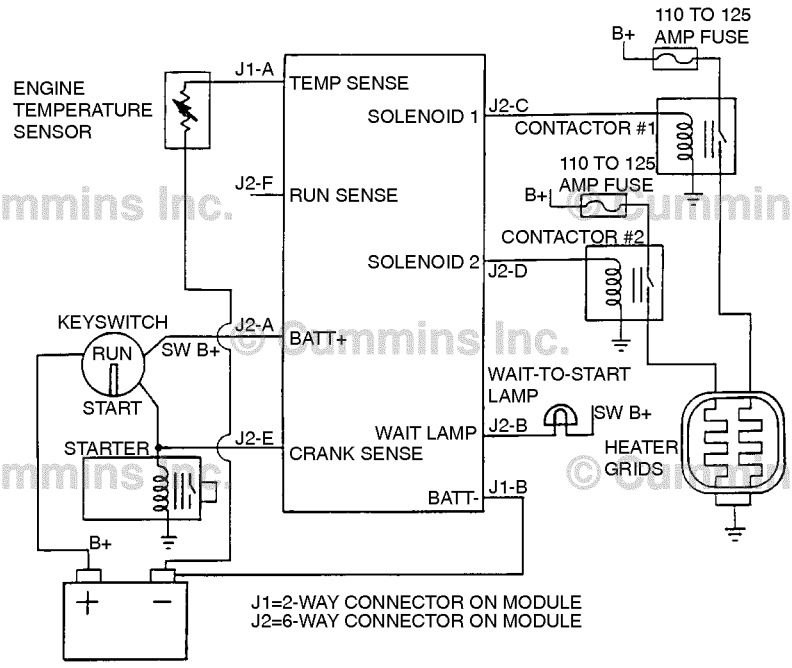
1994 6BTAA and 4BTAA industrial ratings

4BTAA Engine		
	Cold Cranking Amps (CCA)	**Reserve Minutes**
Heavy accessories	800	160
Light accessories	625	160

6BTAA Engine		
	Cold Cranking Amps (CCA)	**Reserve Minutes**
Heavy accessories	950	160
Light accessories	800	160

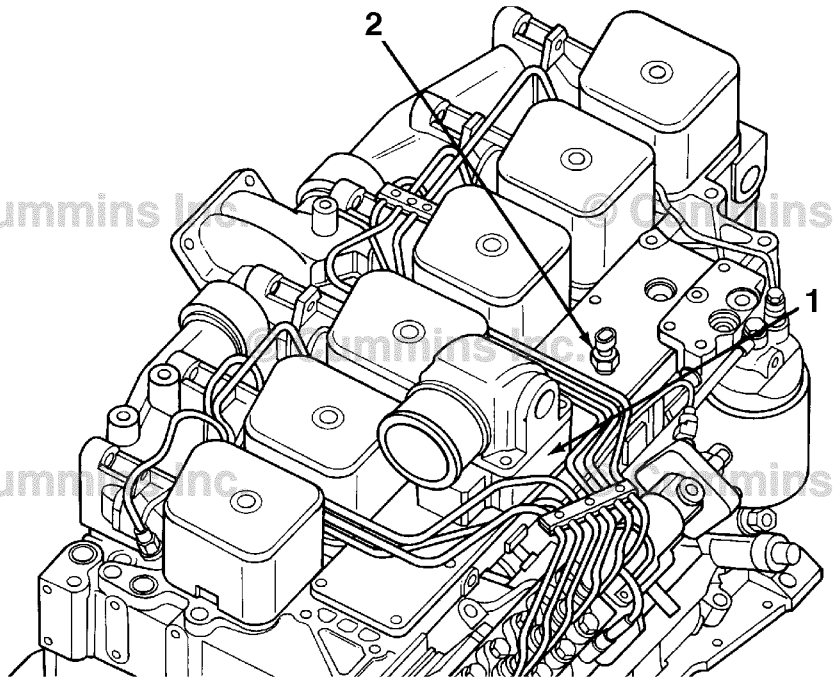
NOTE: Typical “light accessories” include alternator, small steering pump, and disengaged clutch.

NOTE: Typical “heavy accessories” include hydraulic pump and torque convertor.



10900270

Air Intake Heater Controller Interconnection Diagram



10900271

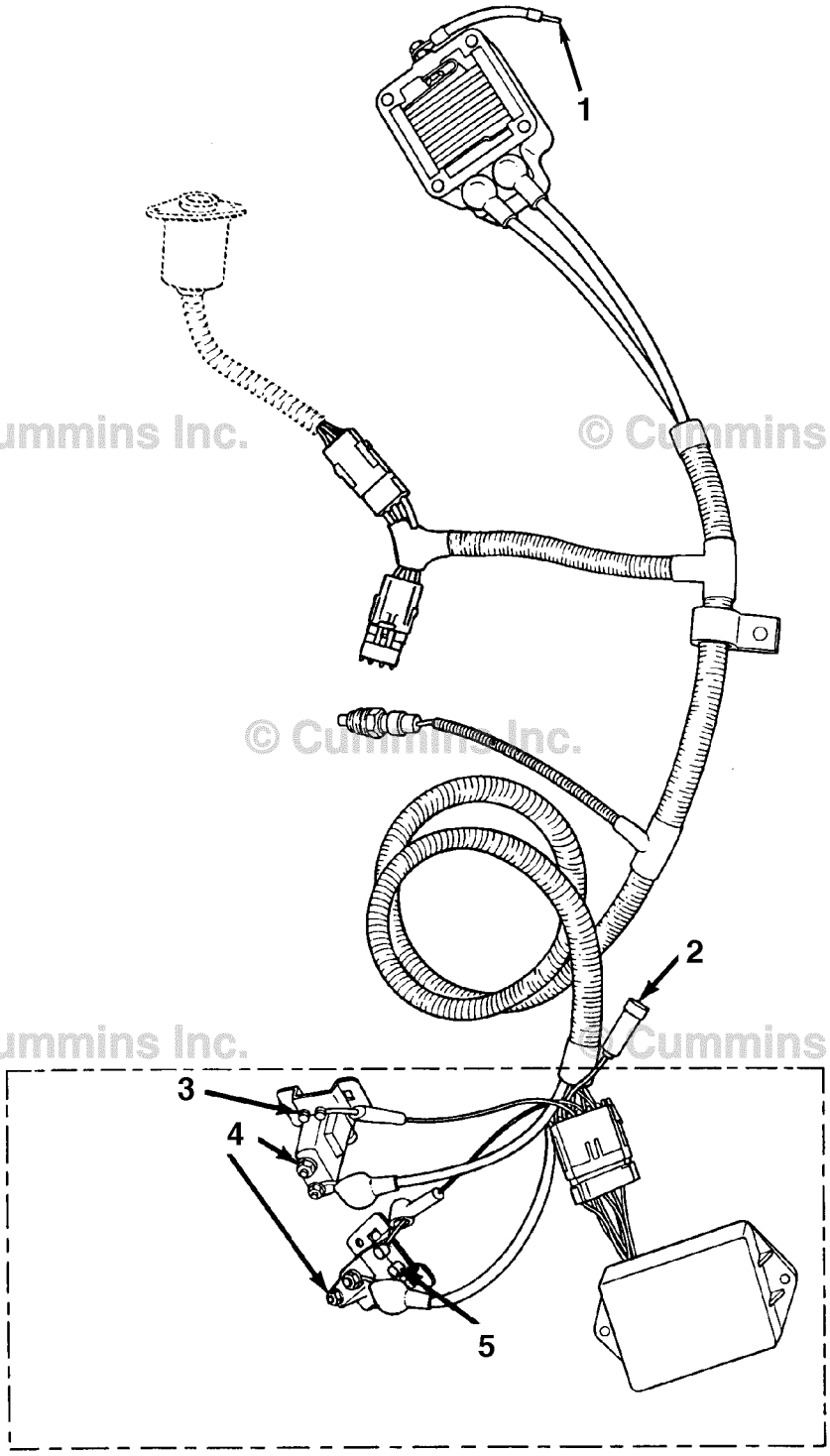
Cold Starting System

1. Grid heater
2. Air intake temperature sensor

The following illustration shows grid heater components.

Grid Heater Component Connections

1. Ground connection
2. To WAIT-TO-START lamp(s) (dash mounted)
3. Ground connection
4. To fuse and battery
5. Ground connection



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10900272

Troubleshooting for Heater System	
Wait-to-Start (WTS) Lamp **Not** Functioning	Check wiring, socket, bulb, ground signal from controller, and bulb power supply from the keyswitch. Correct any electrical problems with the WTS lamp. WTS lamp will flash one time a second if an open circuit is detected in the temperature sensor.

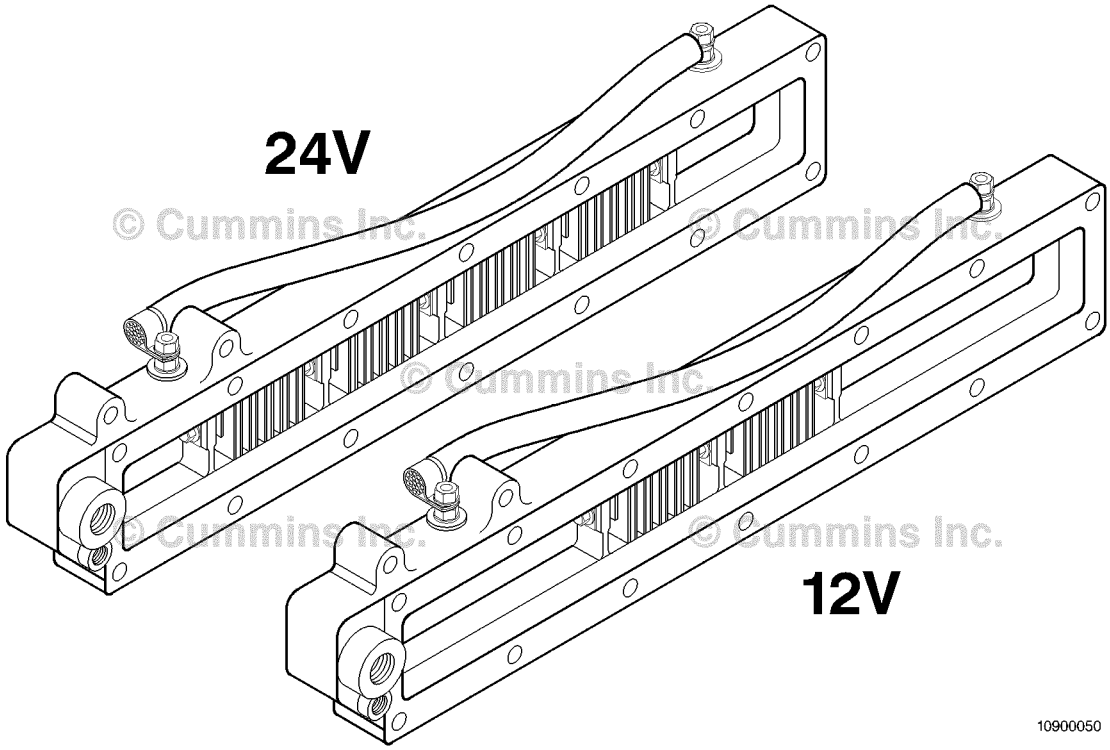
Troubleshooting for Heater System	
Temperature Sensor Failed	Check resistance across the temperature sensor pins J1A and J1B at room temperature and in an ice bath 0°C [32°F]. The resistance should be approximately 800 ohms at room temperature and 2000 ohms for the ice bath. Check the resistance to ground (-) for an open circuit.
	Note: Make resistance checks with the keyswitch in the ON position to make sure there are no ground (-) problems.
	Replace defective sensor.
Relay or Contactor Failure	Check relays or contactors for an audible click during operation. Check for pitting or burning in the relay by measuring resistance across the high-amperage terminals when relay is closed. Replace relay(s) if the resistance is high or an audible click is **not** heard when it is actuated.
Insufficient Ground (-) Connections	Check pin J1B for ground to the controller. Check the ground (-) strap to the grid heater for high resistance. Repair or replace wiring.
Controller Malfunctioning	Check pin J2A for 12-VDC signal; inspect the wiring harness for shorting, chafing, or burning. The controller operates between 6.5 VDC and 16 VDC. Check the connectors for good connections. Replace the controller, if necessary.
	Note: The controller will abort postheat if it senses a voltage drop below 9.5 VDC during preheat or a 10-second delay or more between WAIT-TO-START (WTS) lamp off and cranking, or an open temperature circuit.

6B Industrial Grid Heater

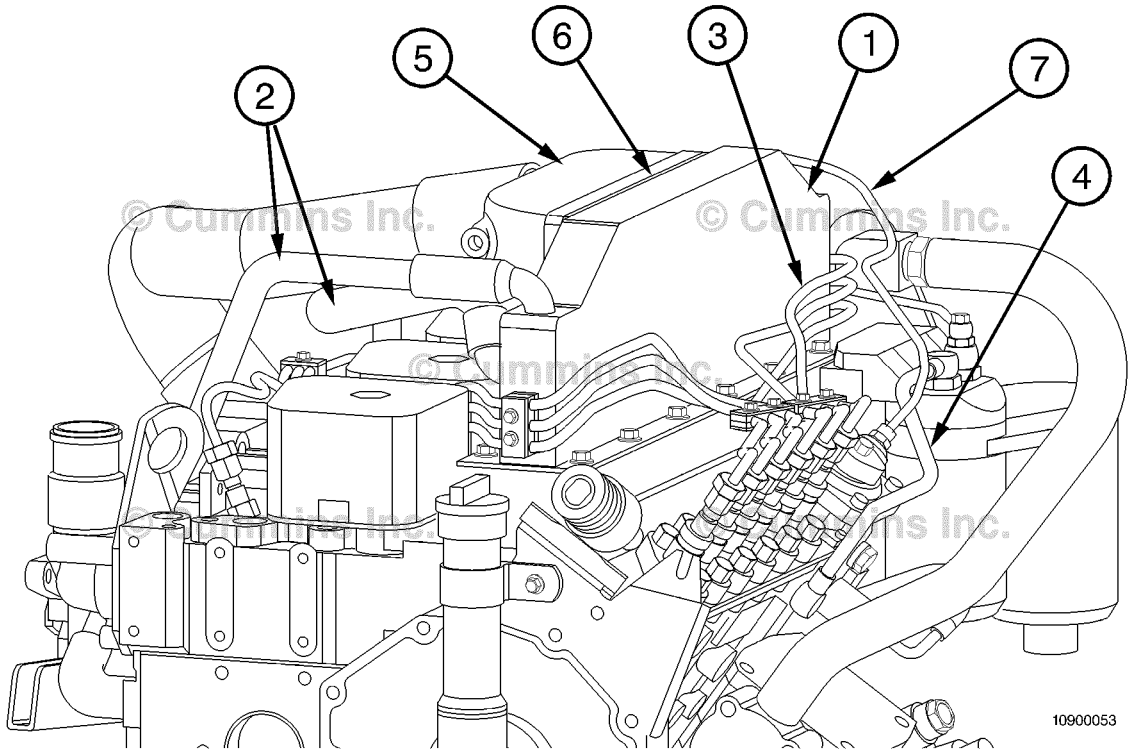
The air intake manifold heater is preferred starting aid option in production on all 185- and 200-hp ratings and optional on all other water jacket aftercooled (WJAC) engines with Bosch® in-line injection pumps. For engines **not** equipped with the air intake manifold heater option, a spacer block will be installed instead of an intake heater.

The intake heater improves cold weather starting characteristics by heating the intake air during cranking. It can also serve to reduce white smoke if it is engergized during cold ambient temperatures while the engine is at idle. The intake heaters are available for both 12-VDC and 24-VDC systems, and both draw 195 amps while energized.

New hardware has been designed to support the grid heater installation. The engine will have the same overall installation height. The grid heater also has a provision for an air compressor intake line.



Description	Part Number	Quantity
Grid Heater (12 VDC)	3928465	1
Grid Heater (24 VDC)	3928463	1
Spacer Block	3928464	1
Ground Wire	3928702	1

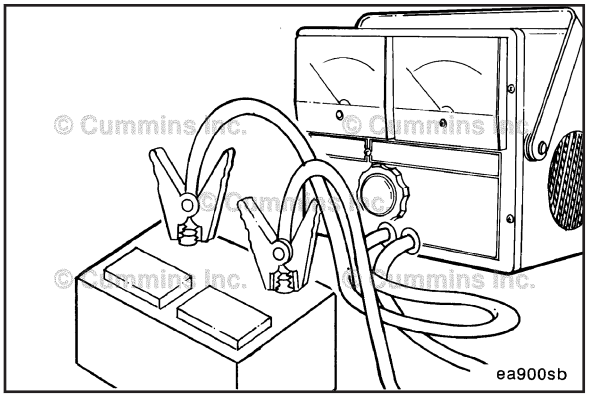


Redesigned hardware installed on the engine to grid heater include:

1. Water jacket aftercooler

2. Water jacket aftercooler plumbing
3. High-pressure fuel lines
4. Low-pressure fuel lines
5. Crossover duct
6. Crossover duct gasket
7. Air-fuel control line.

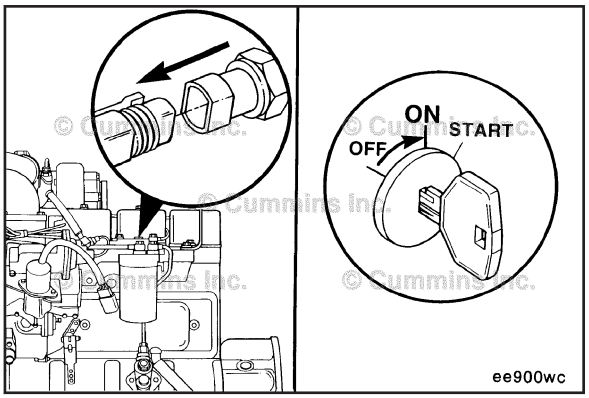
NOTE: This hardware will be installed on all water jacket aftercooled industrial engines with the Bosch® in-line pump. Part numbers will be listed in the 6B industrial engine parts catalog.



Maintenance Check

Check the battery voltage.

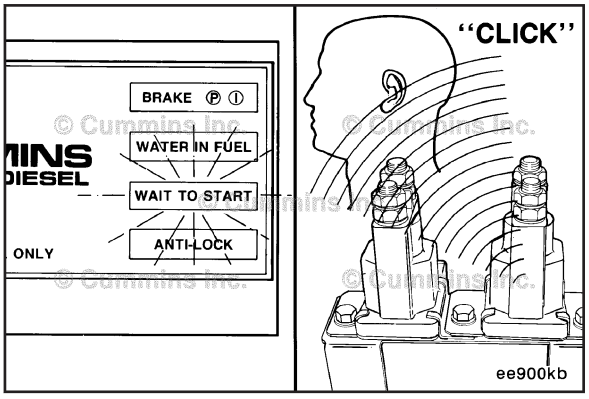
Minimum: 6.5 VDC



Check the thermistor.

Disconnect the thermistor.

Turn the ignition switch to the ON position.



NOTE: The WAIT-TO-START light should come on.

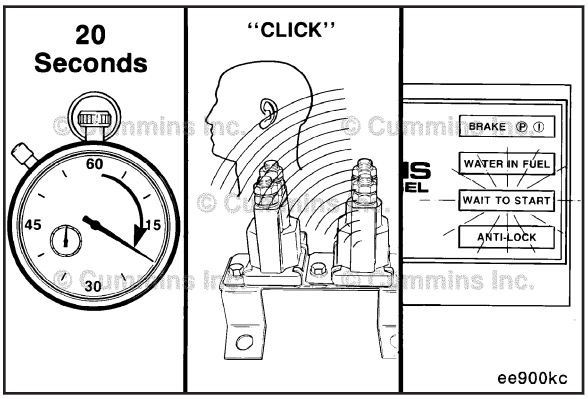
The solenoids should click on.

Wait 20 seconds.

The solenoids should click off.

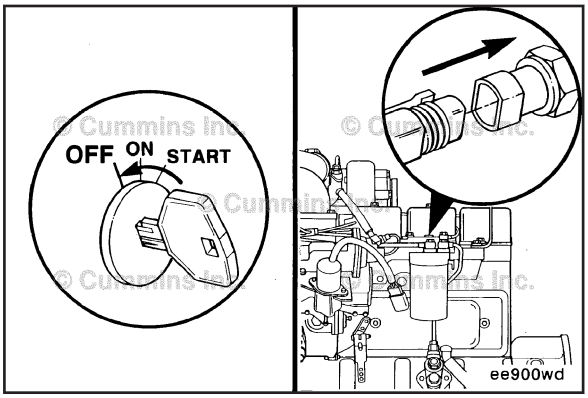
The WAIT-TO-START light should begin flashing.

NOTE: The WAIT-TO-START light will flash, indicating an open circuit in the thermistor wiring. Disconnecting the thermistor simulates this condition.



Turn the ignition switch to the OFF position.

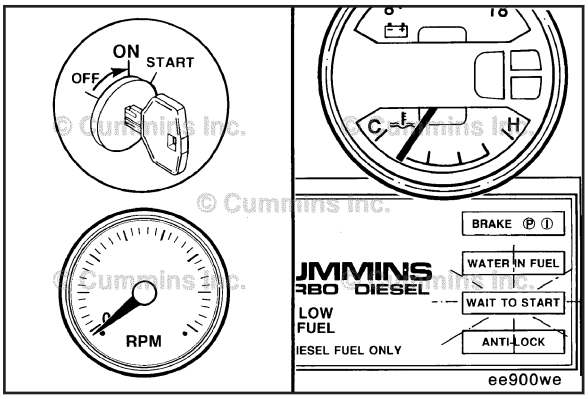
Connect the thermistor wire harness.



Preheat Cycle - Check

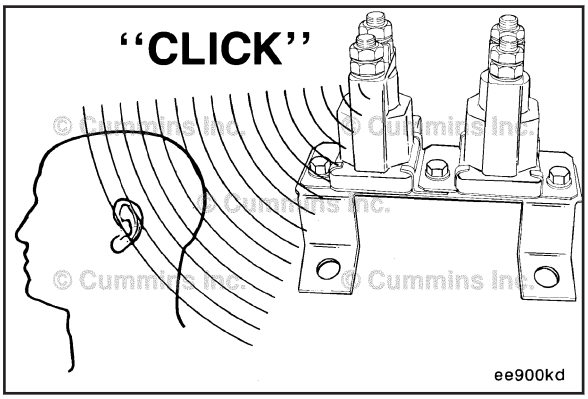
Turn the ignition switch to the ON position.

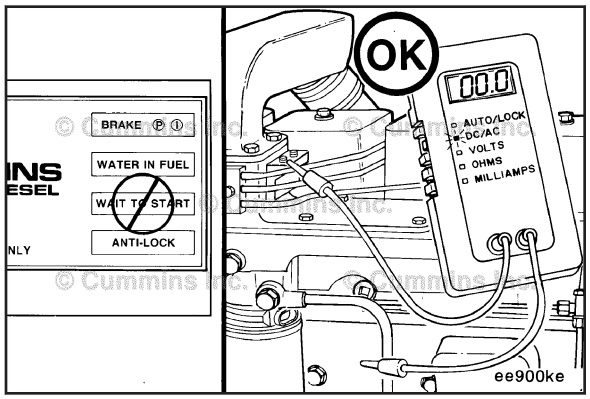
Do **not** start the engine.



The solenoids should click on.

NOTE: If the engine has been running, the temperature is probably above 15°C [59°F].

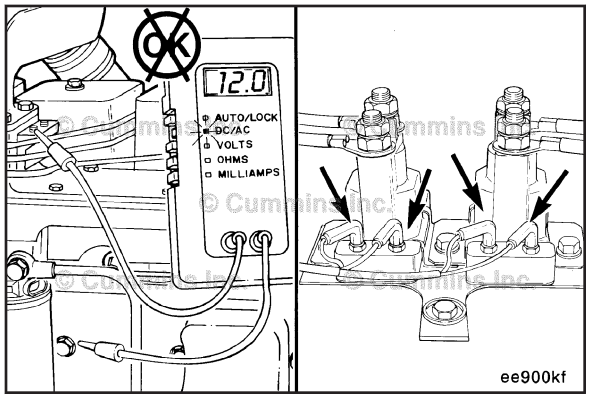




After the preheat period, the WAIT-TO-START light will go off and **not** flash.

Set the multimeter scale to read DC voltage.

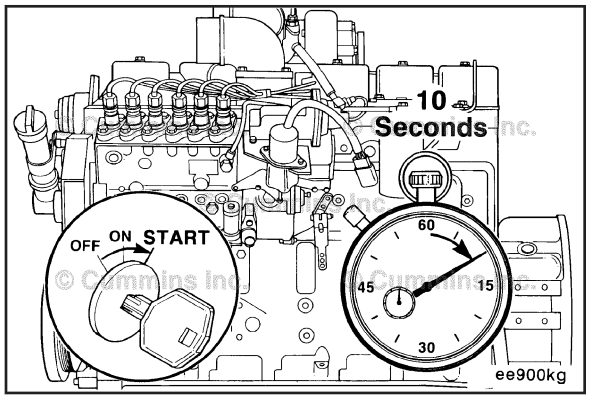
Connect the multimeter, Part Number 3822666, lead to the intake manifold heater terminals. Check each terminal individually.



If voltage is present, check the pull-in coil of the solenoids.

Check for voltage at the pull-in coil of solenoid.

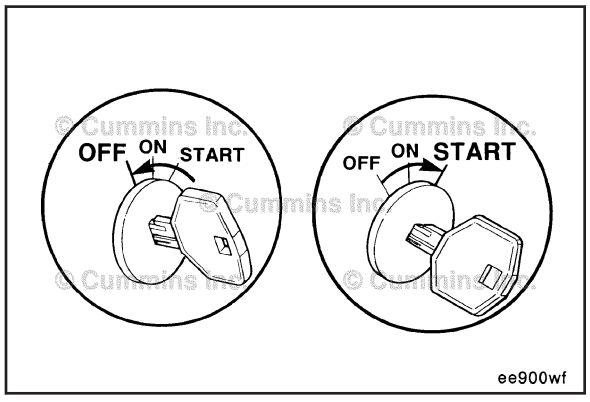
1. If voltage at pull-in coil, replace electronic control module.
2. If no voltage present at pull-in, replace solenoid.



Start the engine.

Do **not** hold the ignition switch in the start position longer than 10 seconds.

If the engine does **not** start, turn the ignition switch to the OFF position.

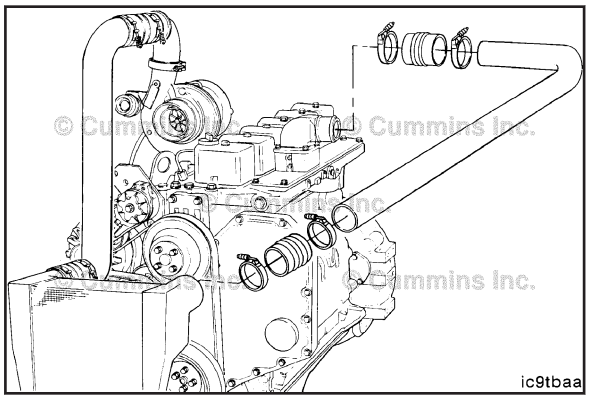


Return the ignition switch to the ON position; then begin the normal starting cycle again.

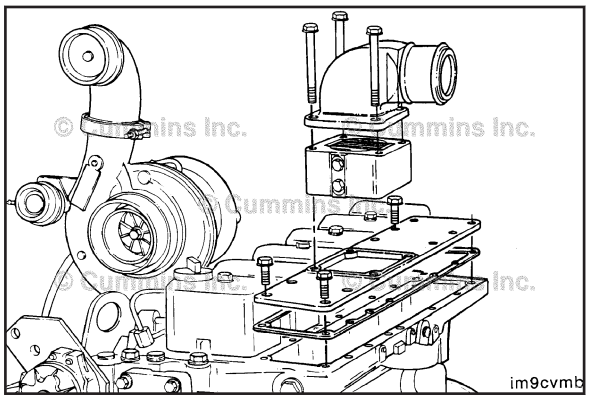
Remove

⚠WARNING⚠
Always lock and tag out the ignition system before working on the engine. Disable the preheater electrical system to reduce the possibility of property damage and personal injury from electrical shock.

Remove the air intake elbow from the cover.



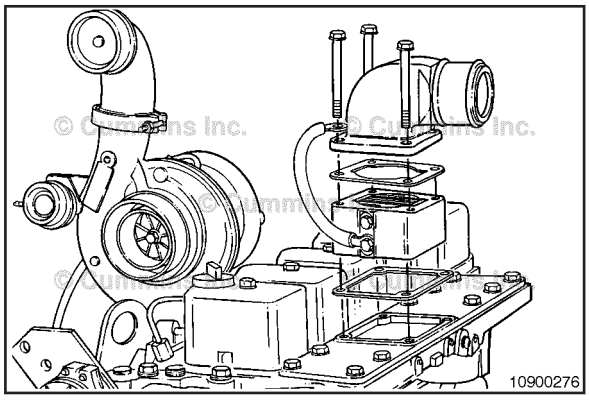
Remove the air intake spacer, Part Number 3917938, from the intake cover and discard. If a manifold spacer is **not** used, replace the elbow with elbow, Part Number 3918982, or equivalent.



Install

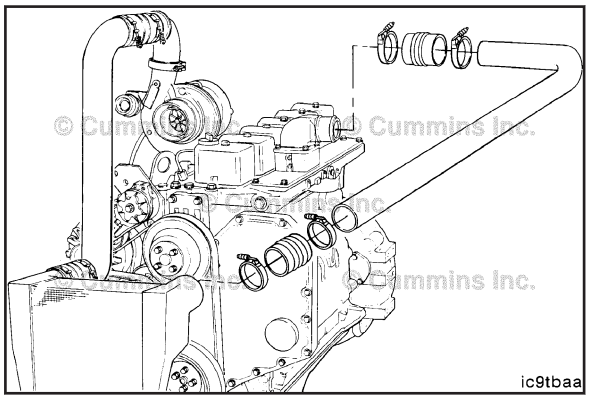
Install the two gaskets, Part Number 3913352, above and below the grid heater, Part Number 3924594, with the ground (-) strap under the grid heater mounting capscrews.

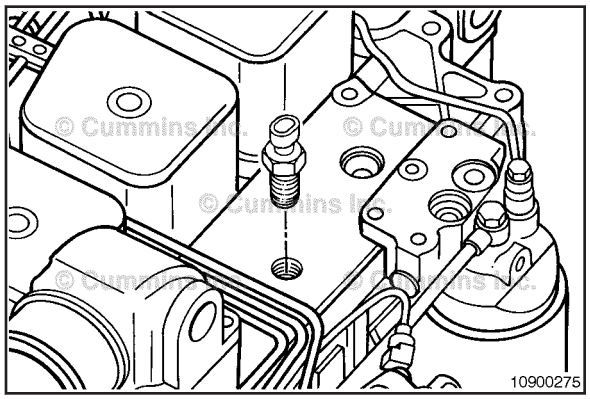
Torque Value: 24 N•m [18 ft-lb]



Install the air intake clamps.

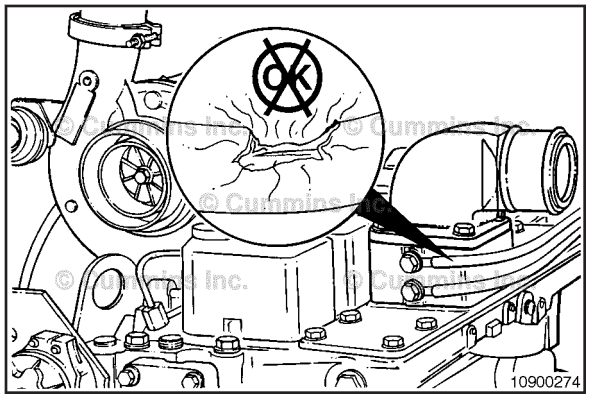
Torque Value: 8 N•m [71 in-lb]





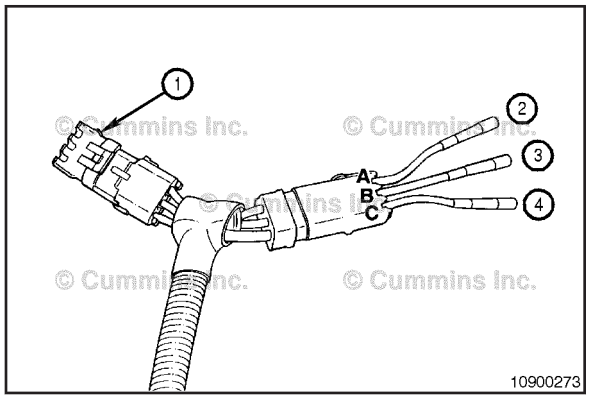
Install the temperature sensor in the intake cover nearest the intake elbow.

Torque Value: 35 N•m [26 ft-lb]



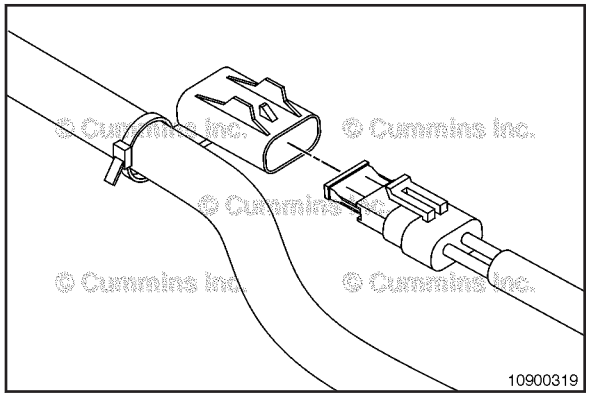
NOTE: The wiring harness **must** be secured within 152 mm [6 in] of any connection to reduce the possibility of connector or ring terminal damage.

Install the wiring harness, and secure to avoid chafing or burning.



If the engine does **not** have an electrical shutdown solenoid or it has a timer module for the shutdown solenoid, use the 3-pin connector tee to wire the vehicle as illustrated. See the table below.

Connector Letter	Function	Recommended Location
A	Module Power	Keyswitch ON power supply
B	Crank Sensor	"S" Terminal on starter or keyswitch "Crank"
C	Ground (-)	Engine, Chassis, or Battery Ground (-)



Intake Manifold Air Heater Wiring Harness (010-122)

Initial Check

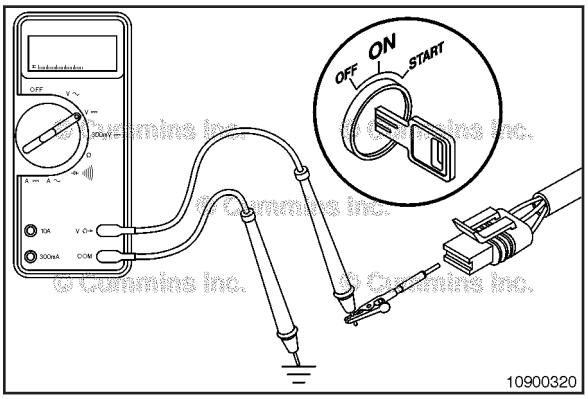
Remove and check the fuse in the power circuit to the heater control module.

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.

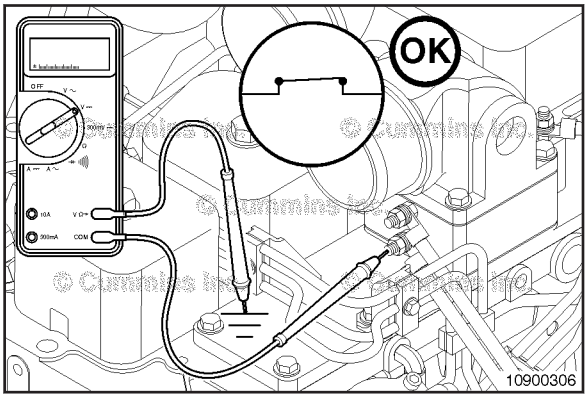
The air heater will **not** function properly unless the specified voltage is obtained.



Voltage Check

Connect the positive lead of the multimeter to the air heater element terminals.

Ground the negative lead to a good known ground.



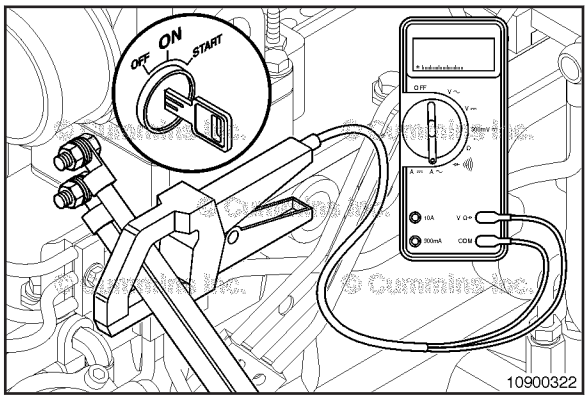
⚠WARNING⚠
Heater grids and studs can get hot enough to burn skin.

△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.



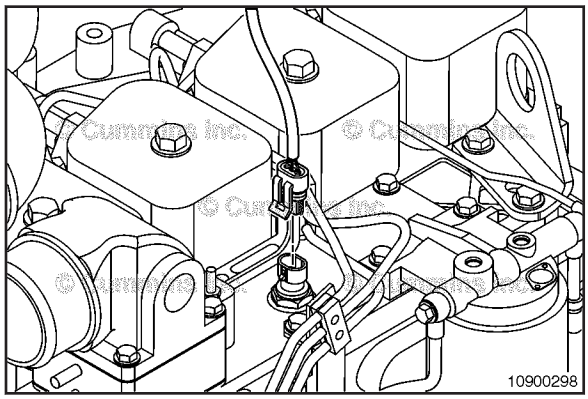
System Voltage	Voltage Range	Amperage Range
12	10.5 to 17	80 to 110 (1 grid)
12	10.5 to 17	160 to 220 (2 grids)
24	22 to 29	80 to 110

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.



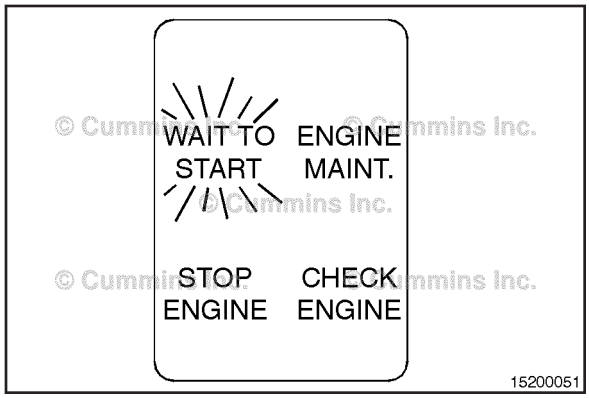
If no voltage is detected, disconnect the intake temperature sensor.

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.

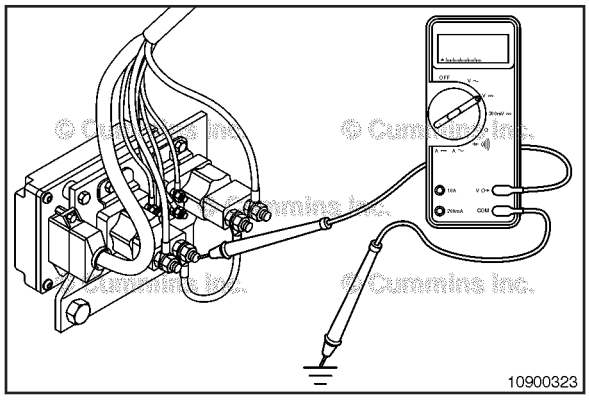
Recheck the voltage and ampere readings.

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.



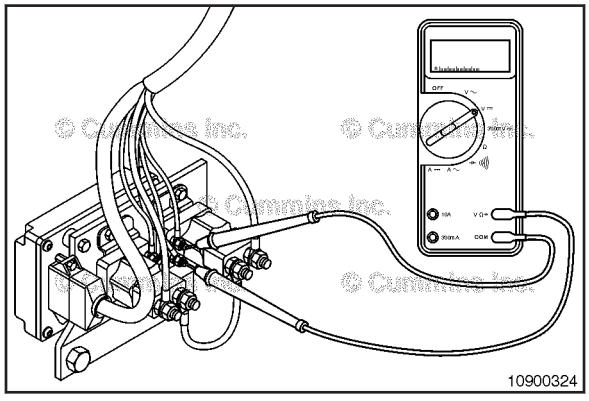
If no voltage is detected at the heater grid with the intake temperature sensor disconnected, check the voltage to the solenoid.

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.

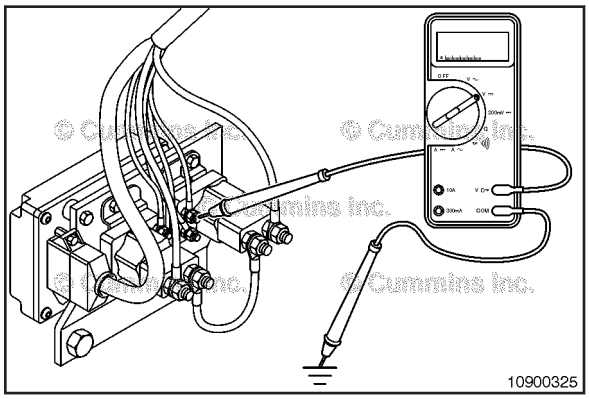
If no voltage is present, check the ground.

If voltage is present at both terminals, replace the solenoid.

Check the voltage from the solenoid positive primary circuit to a good known ground.

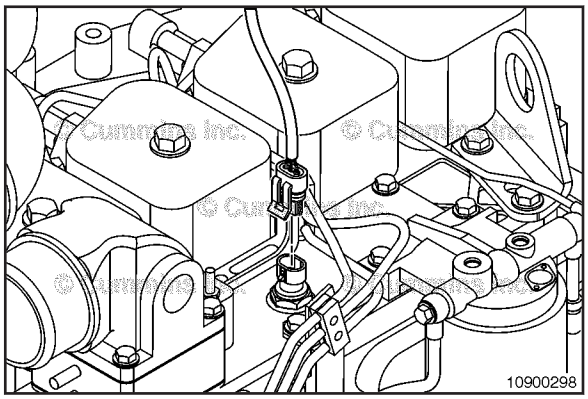
If no voltage is present, check the voltage to the heater control module.

If voltage is present, restore the ground to the solenoid.



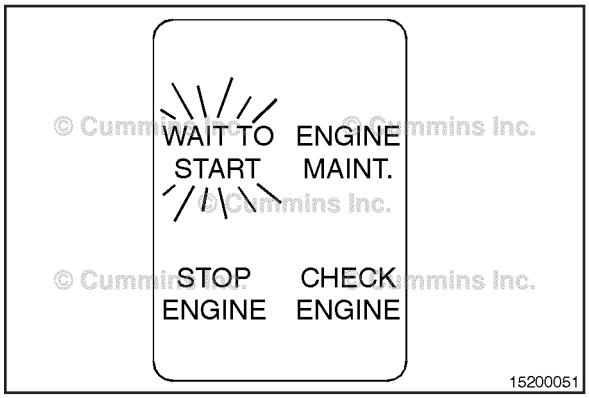
The solenoid and heater control module share the same ground.

Check the wire or clean the connectors.



Check the voltage to the heater control module.

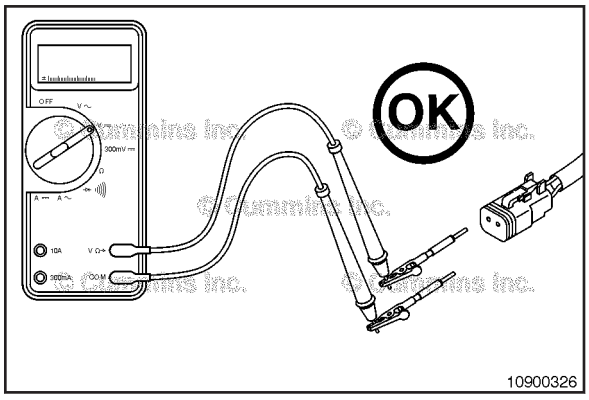
The WAIT TO START lamp, if equipped, will stay on if there is no voltage to the heater control module.

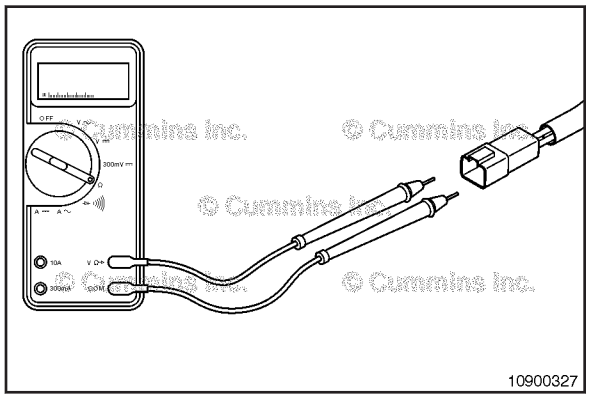


If there is no WAIT TO START lamp, check the voltage at the resistor in the supply wire from the fuse to the heater control module.

If no voltage is present, repair the wiring harness.

Refer to the wiring diagram.

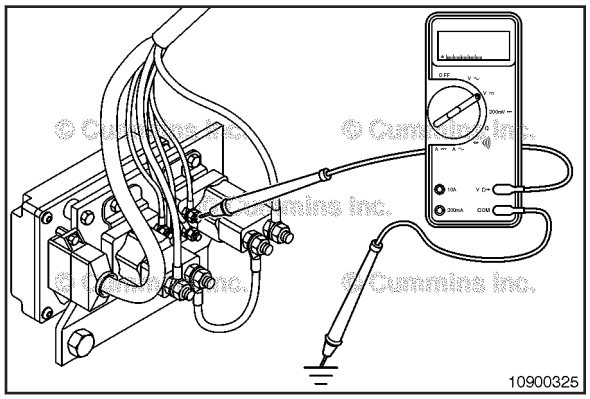




If voltage is present, check the resistor with an ohmmeter.

Replace the resistor if necessary.

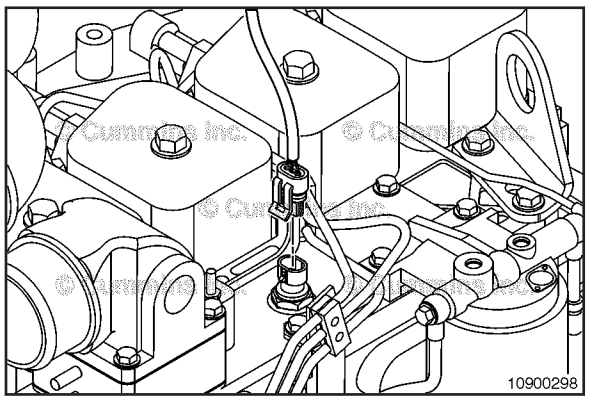
Resistance: 15.8k ohms at 12-VDC



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

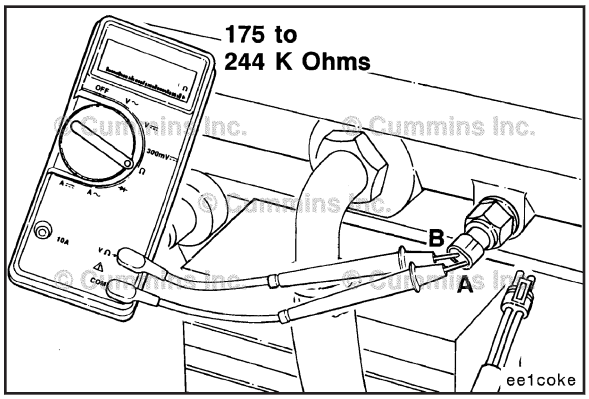
Use an ohmmeter to measure the resistance between the two pins of the intake air temperature sensor.

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.

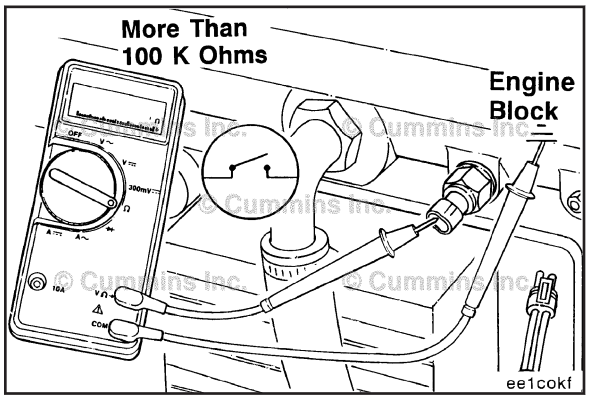
Temperature (°C)	Temperature (°F)	Acceptable Resistance Range (ohms)
0	32	30k to 36k
25	77	9k to 11k
50	122	3k to 4k
75	167	1350 to 1500
100	212	600 to 675



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.

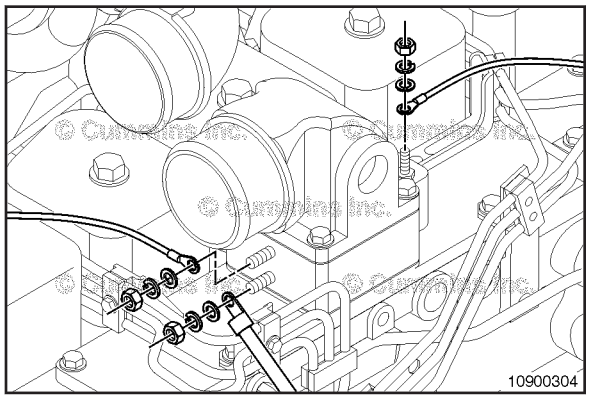


Intake Manifold Air Heater Element (010-124)

General Information

There are two types of intake manifold heater elements covered by this procedure:

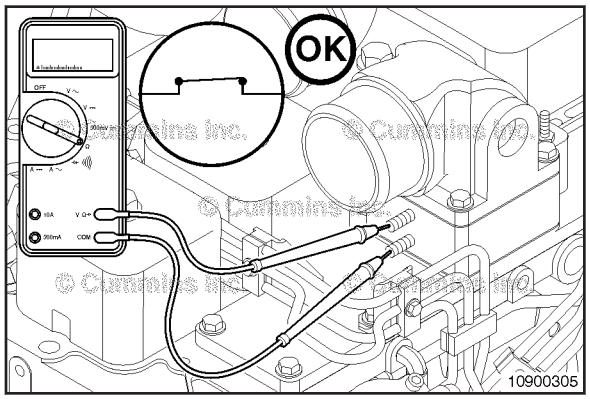
1. Brick type
2. Cylindrical type.



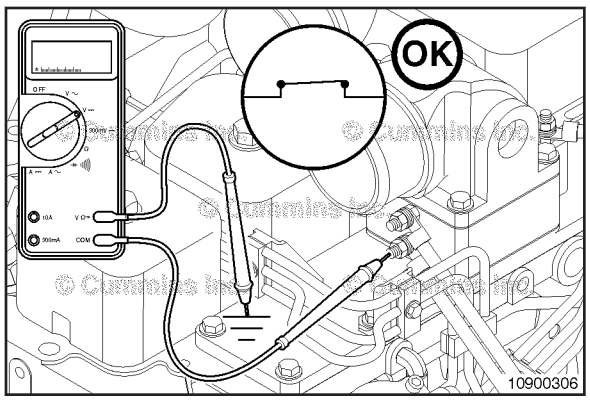
Resistance Check

NOTE: The following checks apply to brick typed intake manifold heater elements only. Cylindrical type intake heater elements do **not** have any external ground wires.

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.

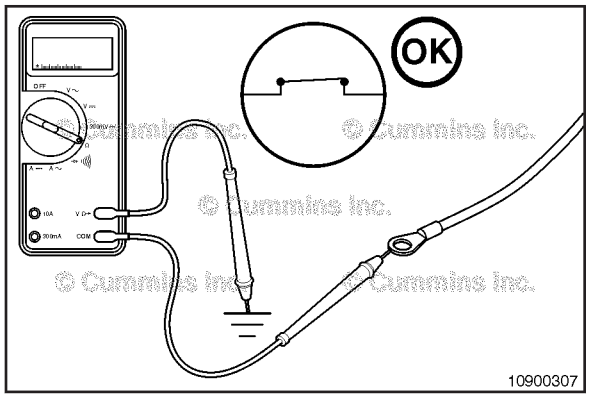


Use an ohmmeter to check the resistance from the ground of each positive heater terminal.

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.

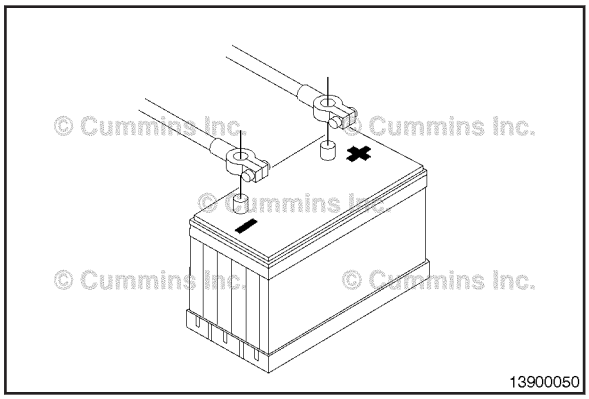
The reading should be less than 10 ohms. If **not**, replace the heater ground wire.

Preparatory Steps

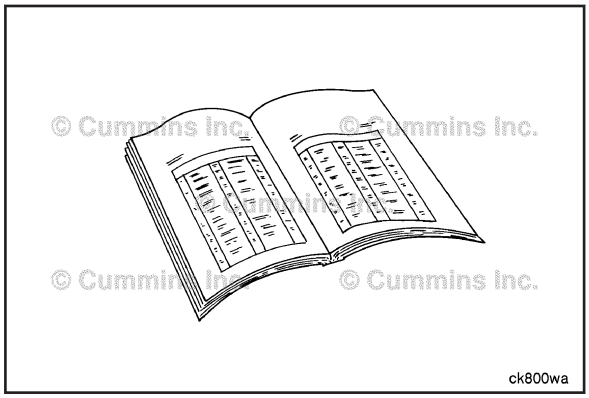
Brick Type

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

- Disconnect the batteries.



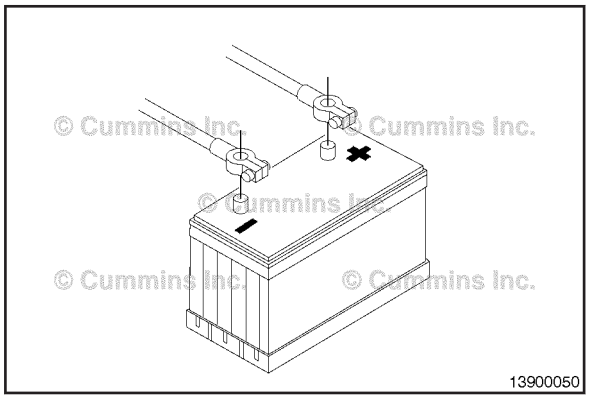
- Remove the air intake piping. Refer to Procedure 010-024
- Remove all three electrical leads from the intake manifold heater.



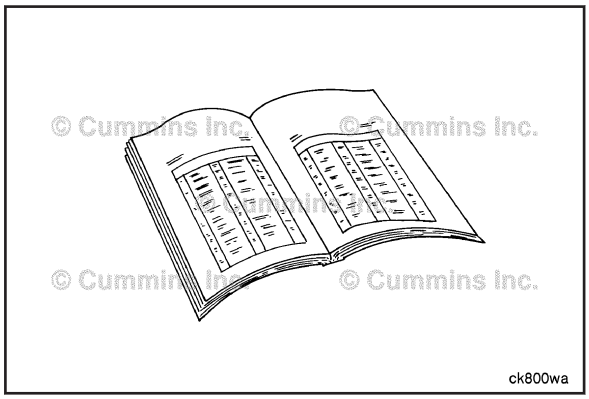
Cylindrical Type

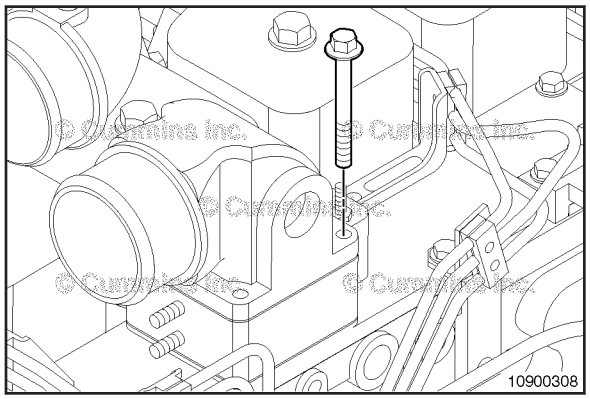
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries.



- Disconnect the cold starting aid. Refer to the OEM manual.
- Remove the air intake piping. Refer to Procedure 010-024
- Remove the air intake connection adapter. Refer to Procedure 010-131.

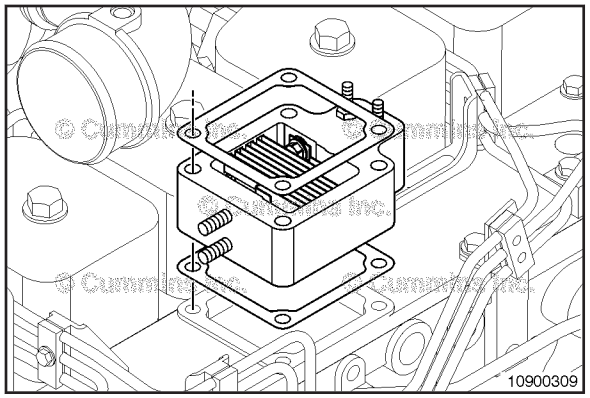




Remove

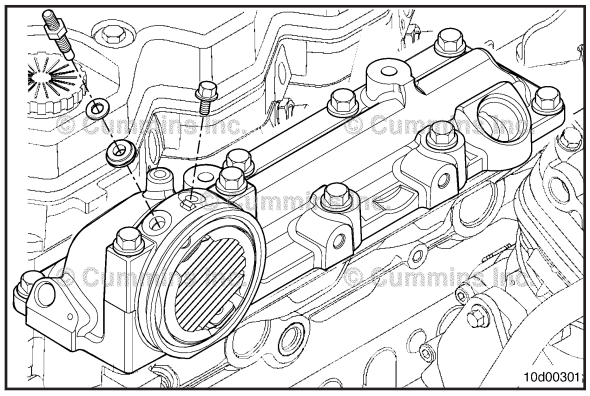
Brick Type

Remove the four capscrews that attach the air-crossover connection and heater.



Remove the heater and gaskets.

Clean the mounting surface.

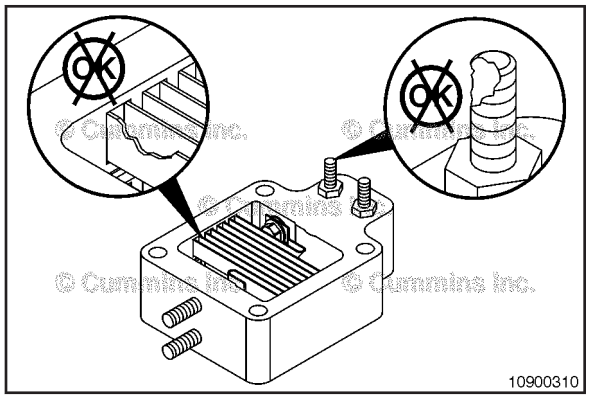


Cylindrical Type

Remove the electrical supply terminal (3), isolater/spacer (4) and washer (1).

Remove the retaining capscrew (2) from the air intake manifold.

Remove the cylindrical air intake manifold heater element assembly from the air intake manifold.



Clean and Inspect for Reuse

Check the intake manifold heater leads and grids for corrosion and damage.

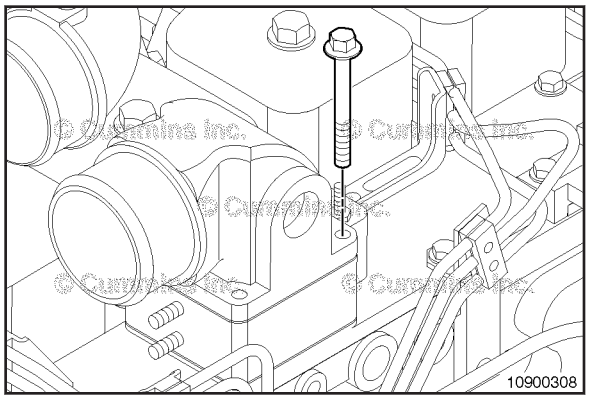
Replace the heater if any damage is found.

Install

Brick Type

Install new gaskets and the intake manifold heater.

Install the four capscrews and the single black (ground) heater lead.



Cylindrical Type

Fit the air intake manifold air heater into the intake manifold.

Rotate the cold starting aid to align the electrical supply terminal with the machined hole in the top of the air intake manifold.

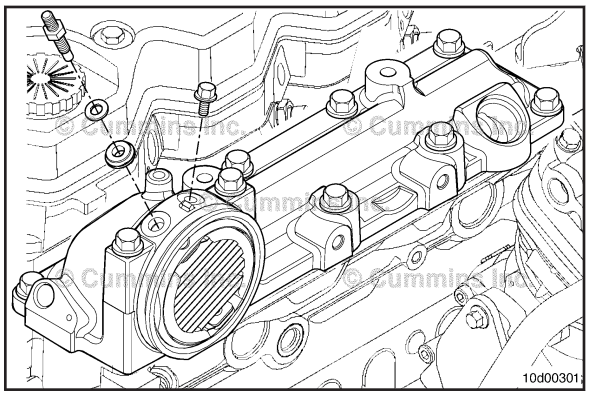
Install the electrical supply terminal (3), isolater/spacer (4) and washer (1) into air intake manifold heater element through the air intake manifold hole.

Tighten electrical supply terminal into the cold starting aid.

Torque Value: 8 N•m [71 in-lb]

Install the retaining capscrew (2) and tighten.

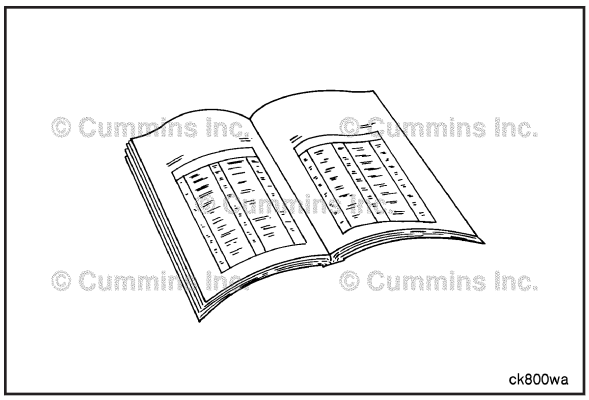
Torque Value: 8 N•m [71 in-lb]



Finishing Steps

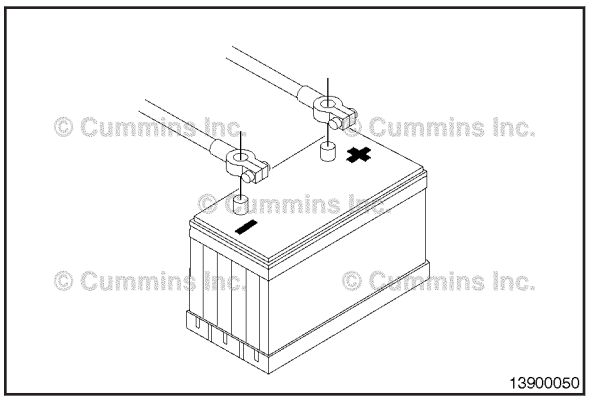
Brick Type

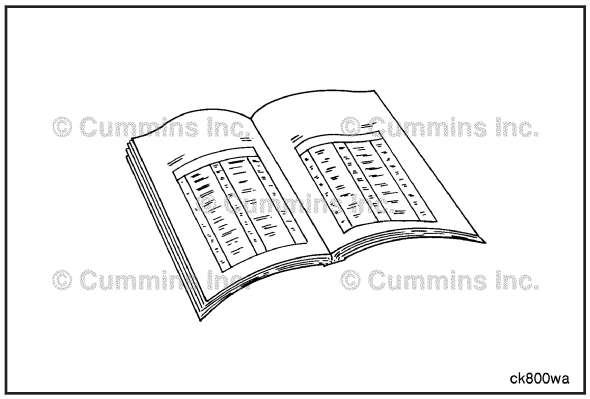
- Install the intake manifold heater leads on the terminals
- Install the air intake piping. Refer to Procedure 010-024.



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

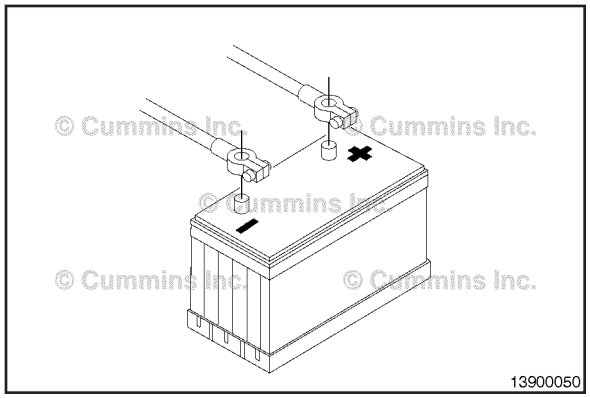
- Connect the batteries.





Cylindrical Type

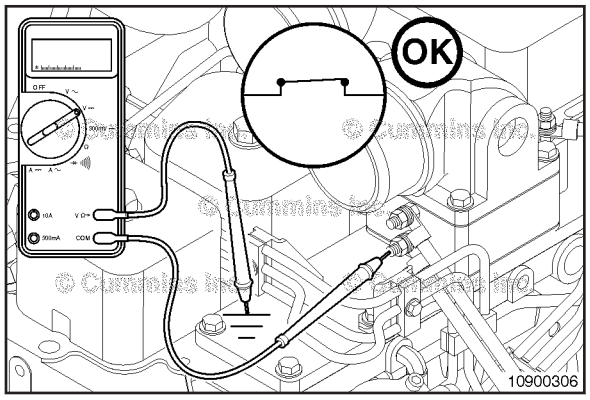
- Install the air intake connection adapter. Refer to Procedure 010-131
- Connect the cold starting aid. Refer to the OEM service manual
- Install the air intake piping. Refer to Procedure 010-024.



⚠WARNING⚠

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

- Connect the batteries.

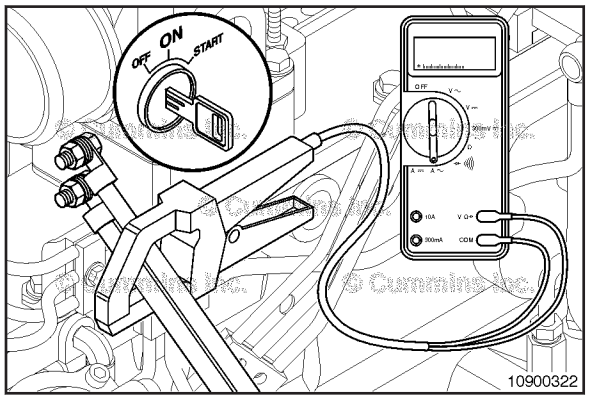


Intake Manifold Air Heater Control Module (010-125)

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.

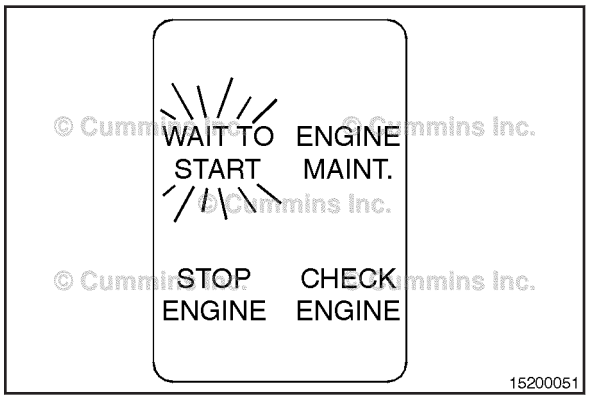
If there is no voltage to the heater control module, check the system voltage. Refer to Procedure 010-122.

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.



If no voltage was detected, disconnect the intake temperature sensor.

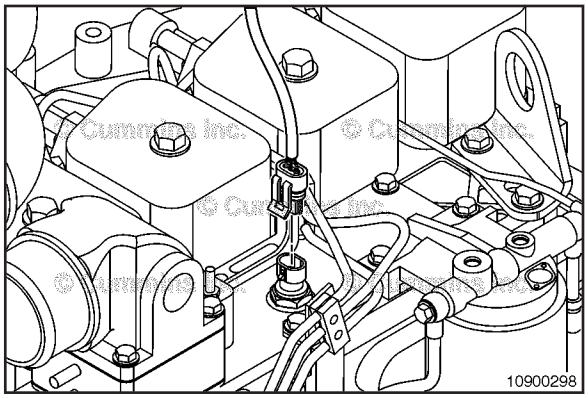
Disconnecting the intake temperature sensor simulates an intake manifold temperature of less than 0°C [32°F].

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.

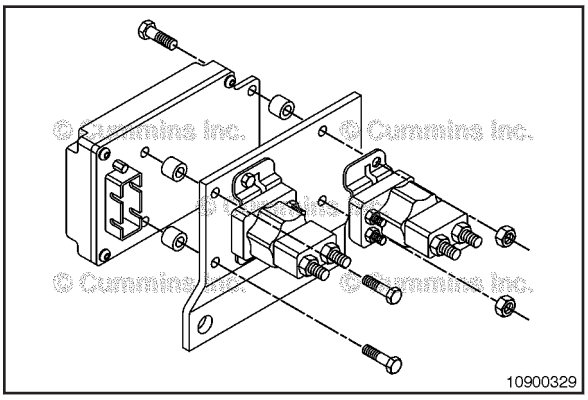


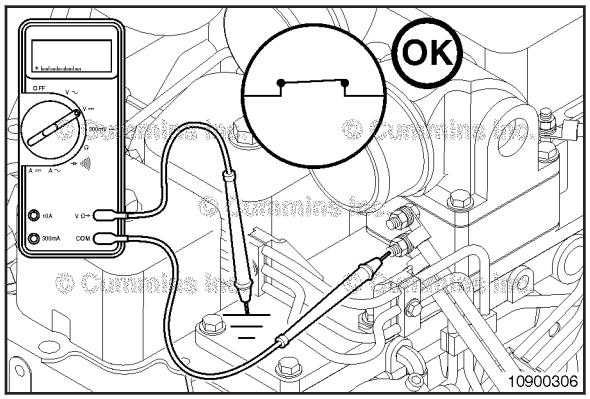
System Voltage	Voltage Range	Amperage Range
12	10.5 to 17	80 to 110 (1 grid)
12	10.5 to 17	160 to 220 (2 grids)
24	22 to 29	80 to 110

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.

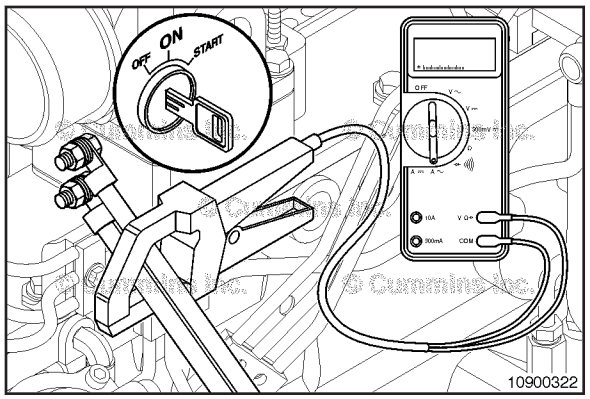




Post Heat Cycle

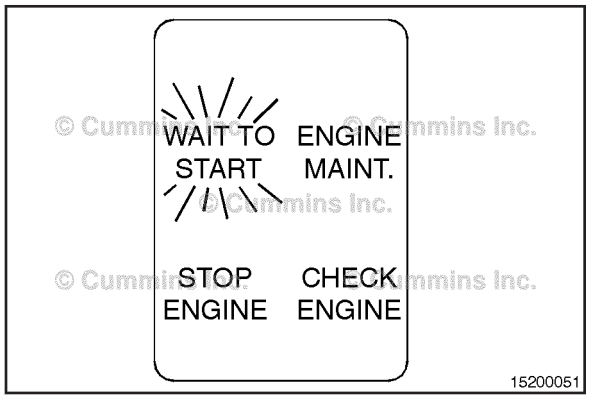
Connect the positive lead of the multimeter to the heater element terminal.

Ground the negative lead to the engine block.

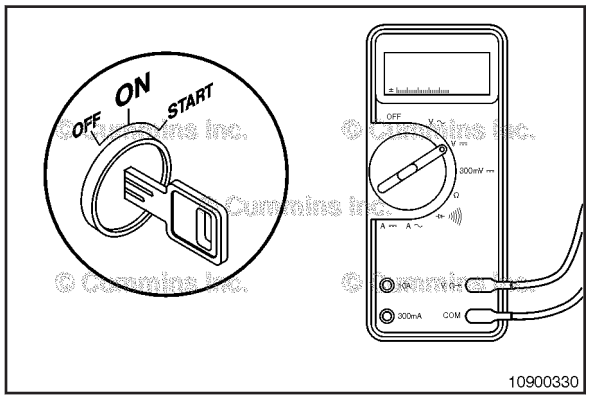


Attach a multimeter to the heater wires.

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.

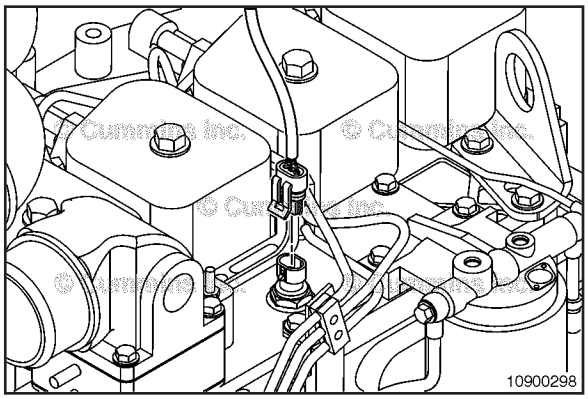
If no voltage is detected, disconnect the intake manifold air temperature sensor.

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.

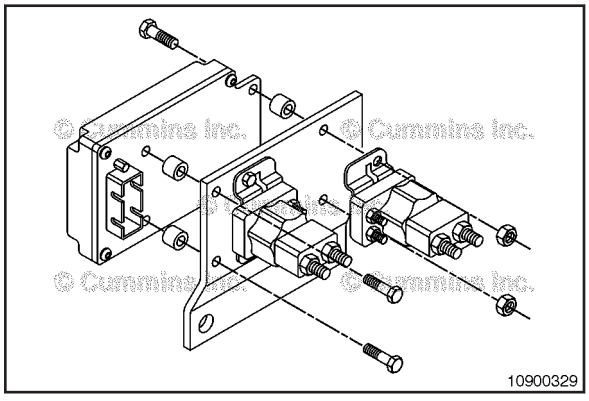
If the intake manifold temperature, voltage, or engine rpm exceed system parameters prior to the 20 second time cycle completion, the system will reset and a new 20 second heat cycle will begin.

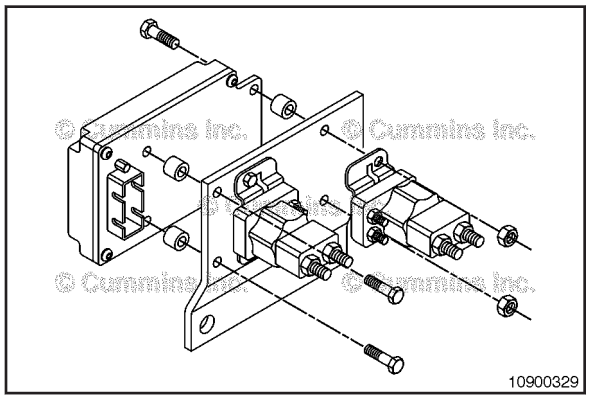
Refer to the Intake Manifold Air Heater System General Information in Section F to verify the proper cycle.

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

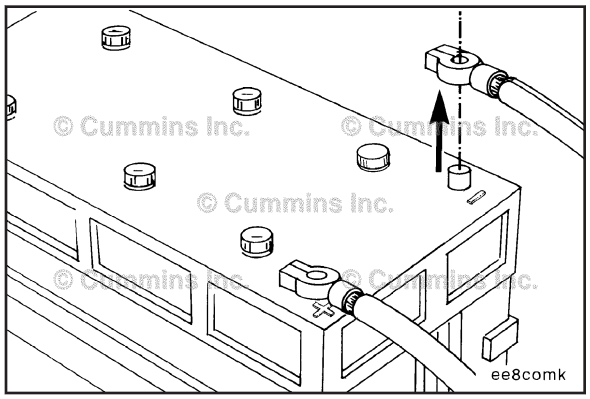
If the intake manifold temperature, voltage, or engine rpm exceeds the test parameters prior to 20 minutes time cycle completion, the system will reset and a new 20 minute post heat recycle will be available.

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.

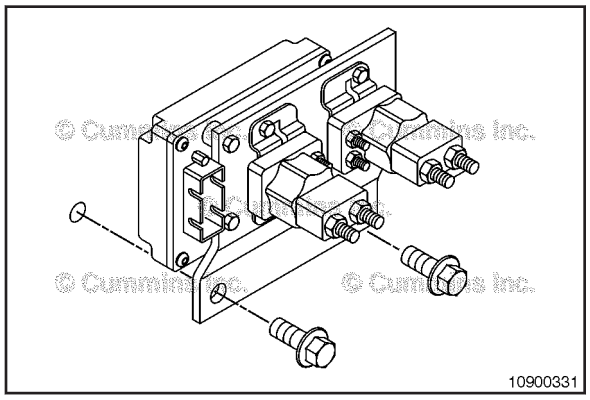
Verify that the heater control module is functioning to the known temperature value being simulated for the intake manifold sensor.

If the system is **not** operating at these known values, replace the heater control modules.



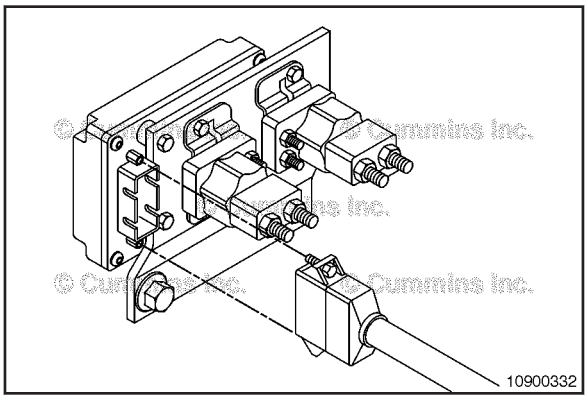
Remove

Disconnect the ground cable from the battery terminal.



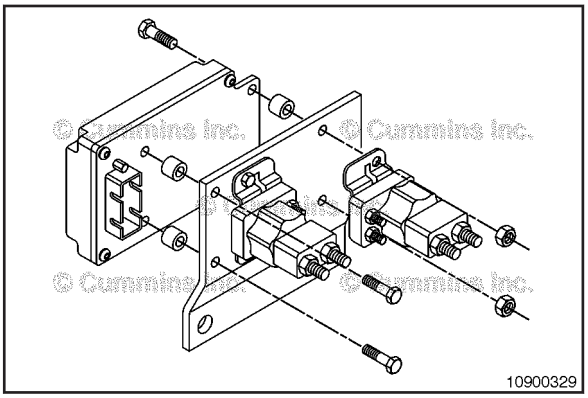
Remove the two mounting capscrews that hold the bracket to the engine block.

Remove the plug from the heater control module.



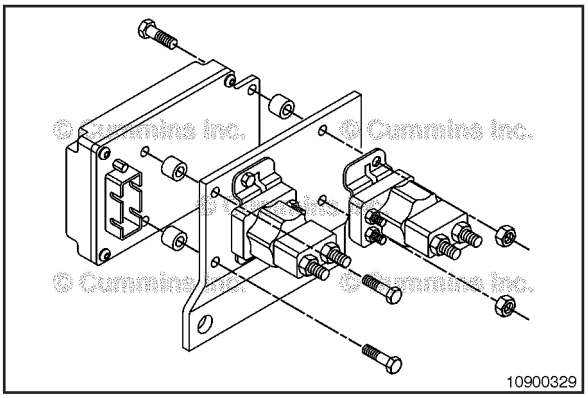
Remove the nut from the top right solenoid bracket.

Remove the heater control module mounting capscrews and spacers.

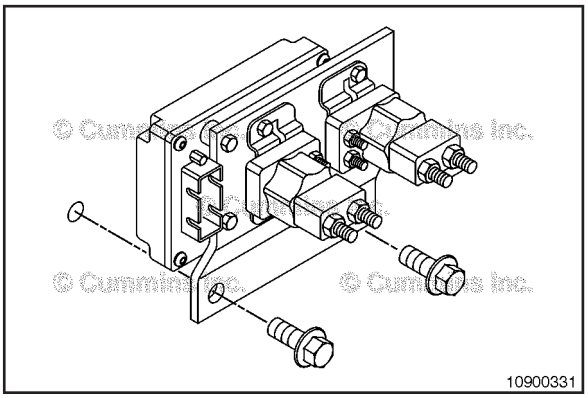


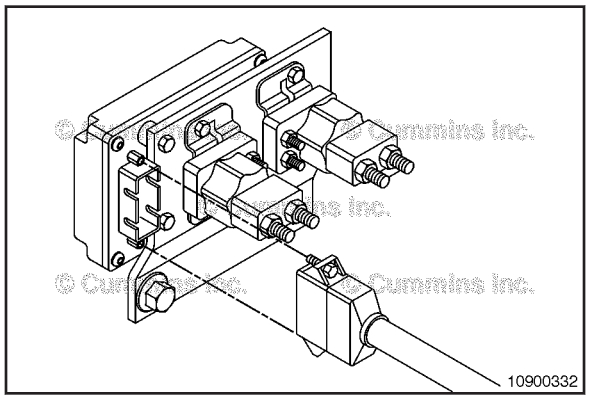
Install

Install the new heater control module on the bracket.



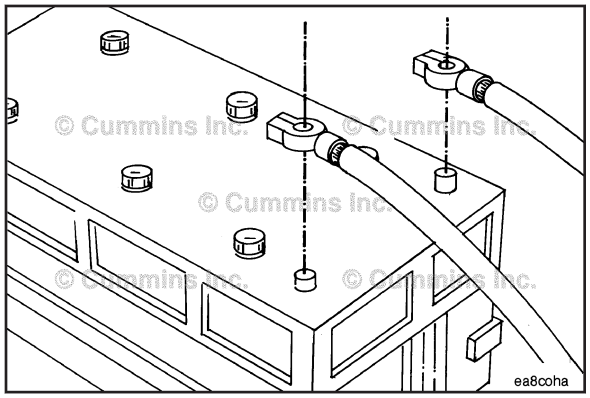
Install the bracket on the engine block.



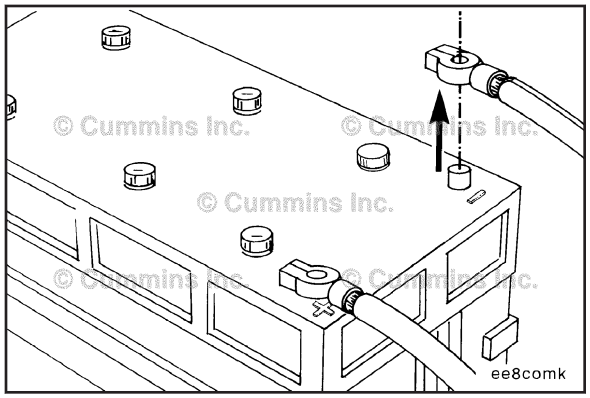


Install the heater control module plug.

Torque the hold down screws hand tight.



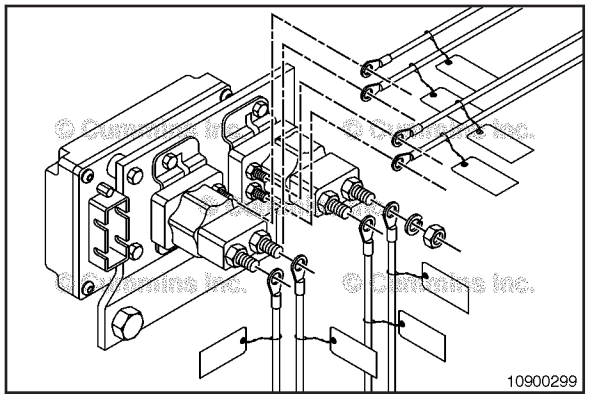
Connect the ground cable to the battery terminals.



Intake Manifold Air Heater Solenoid Switch (010-126)

Resistance Check

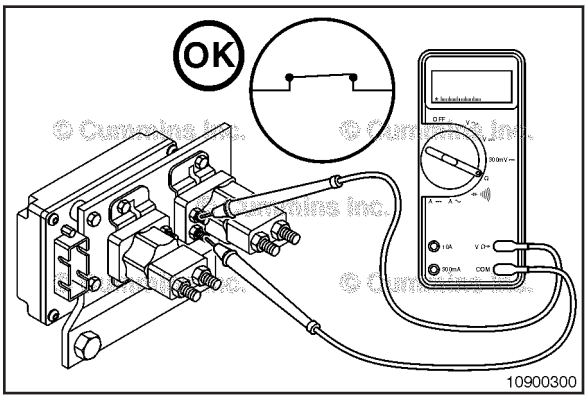
Disconnect the ground cable from the battery terminal.



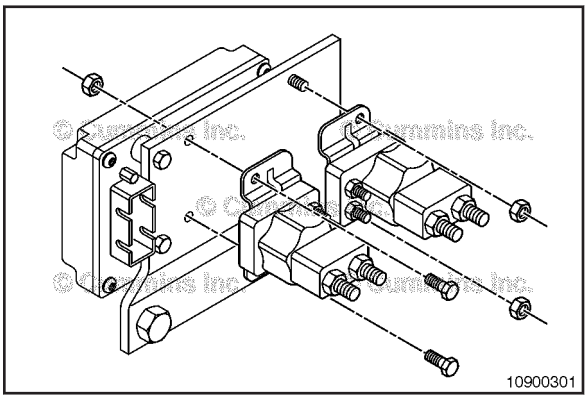
Label and remove the leads on the air heater solenoid(s) to be tested.

Use an multimeter to check the continuity between the small terminals at the base of the solenoid.

Continuity: 50 to 100 ohms

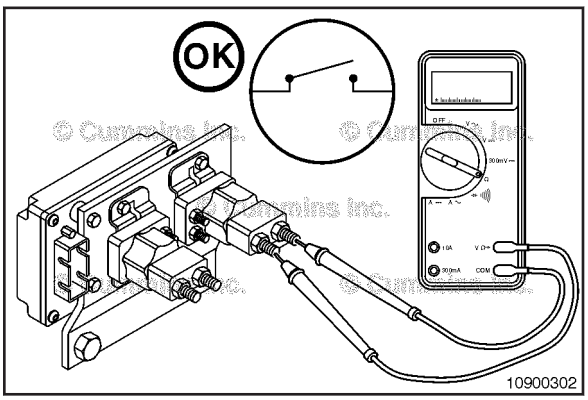


If the circuit is open, replace the solenoid.

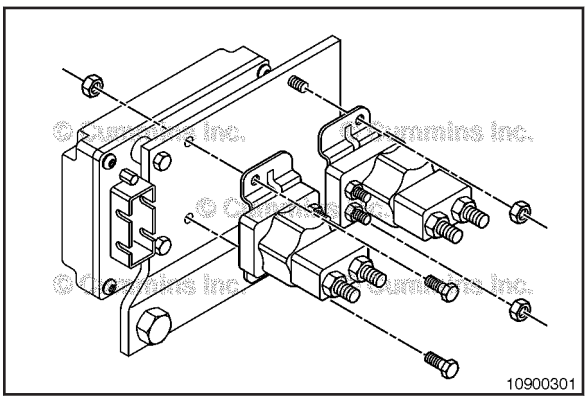


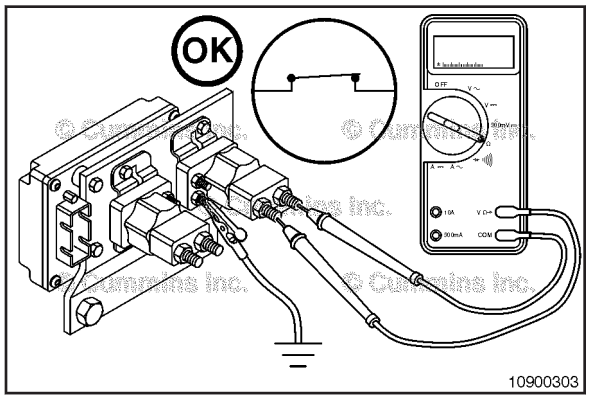
Check for continuity between the two large terminals on the top of the solenoids.

The multimeter should indicate an open circuit.



If any resistance or continuity is detected, replace the solenoids.





Test

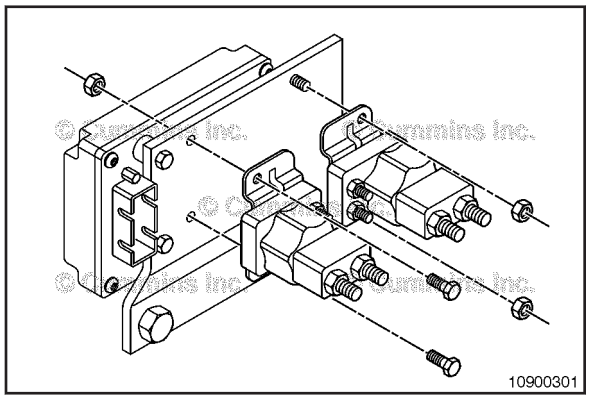
Check the solenoid for proper operation.

Connect an multimeter to the two large terminals.

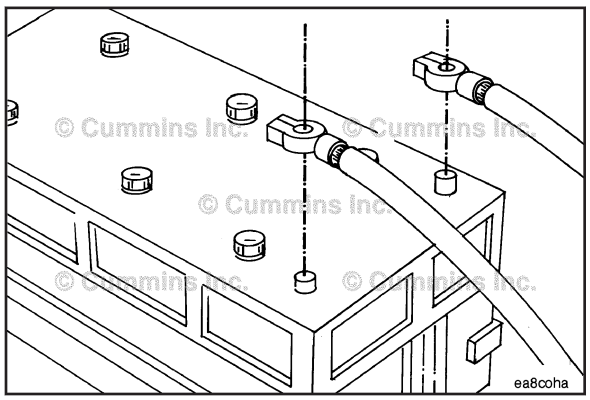
Ground one of the small terminals to the battery ground.

Apply system voltage to the other small terminal.

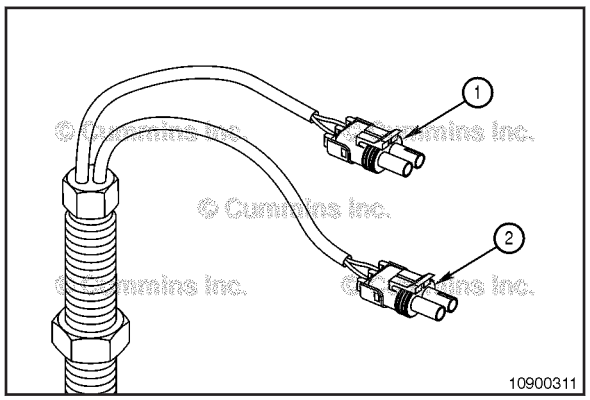
The multimeter should indicate zero ohms.



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

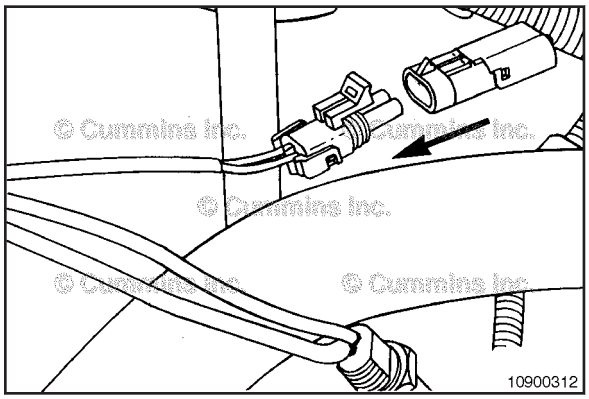
There are two connections coming from the sensor, one is for the engine tachometer and the other is for the air intake heater system.

1. White and green: to engine wiring harness
2. Red and black: to air heater control harness.

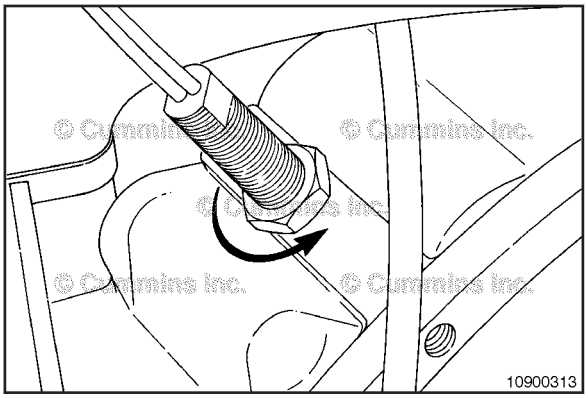
Check to verify they are connected.

Remove

Disconnect the engine speed sensor from the engine wiring harness.



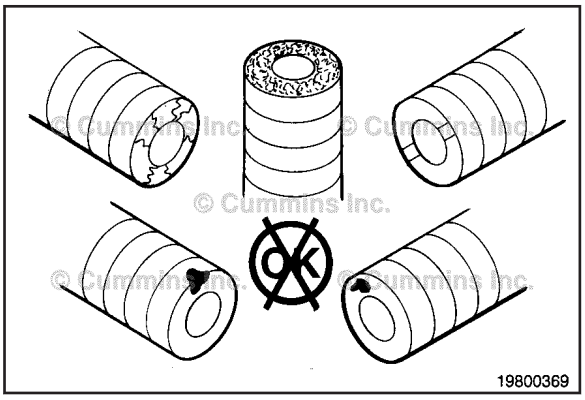
Remove the sensor from the flywheel housing.



Inspect for Reuse

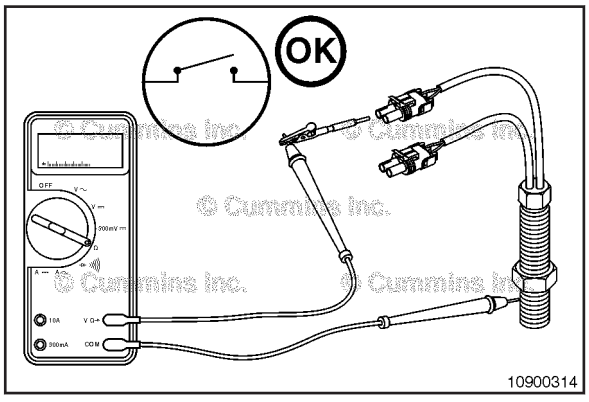
Inspect the engine speed sensor for debris, cracked or chipped potting, and damage from contact with the flywheel.

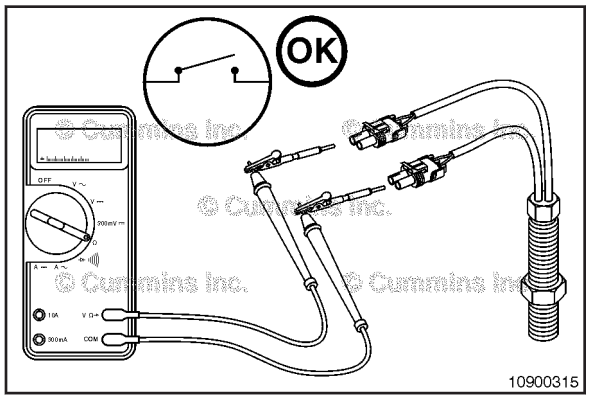
Clean or replace the engine speed sensor if necessary.



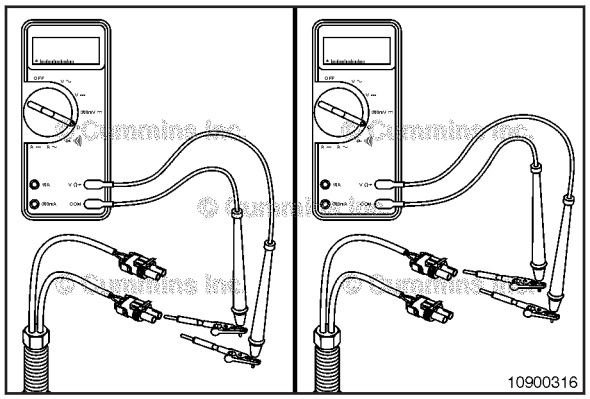
Test

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.



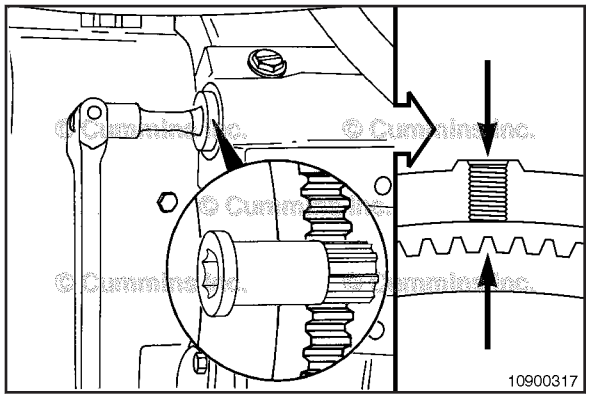


2. Short Circuit Between Coils: Check the resistance between connectors (Pin A to Pin A and Pin B to Pin B) with a multimeter. The multimeter **must** show an open circuit (100k ohms or more). If fewer than 100k ohms are measured, there is a short circuit in the sensor. Replace the sensor.



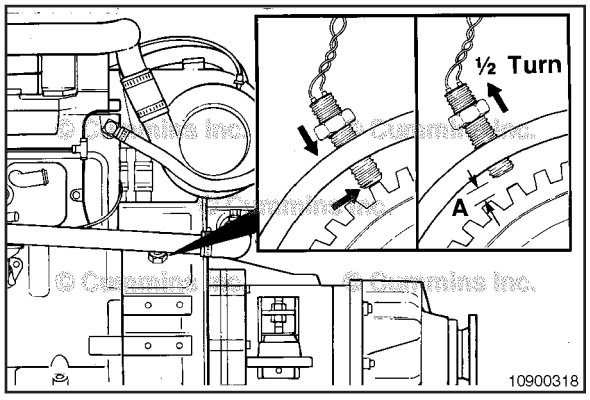
3. Coil Resistance: Check the resistance between the pins of each connector (Pin A to Pin B).

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.

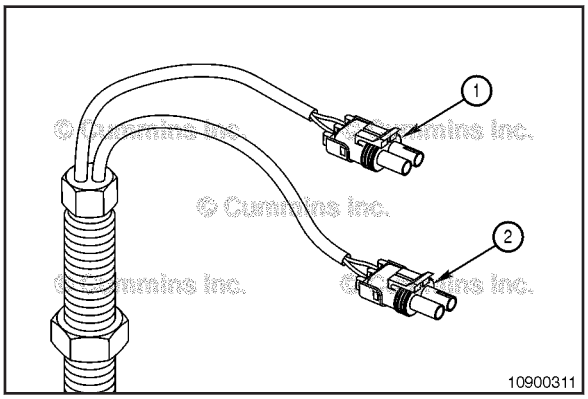
Torque Value: 34 to 47 N•m [25 to 35 ft-lb]

Overtightening will damage the sensor.

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.

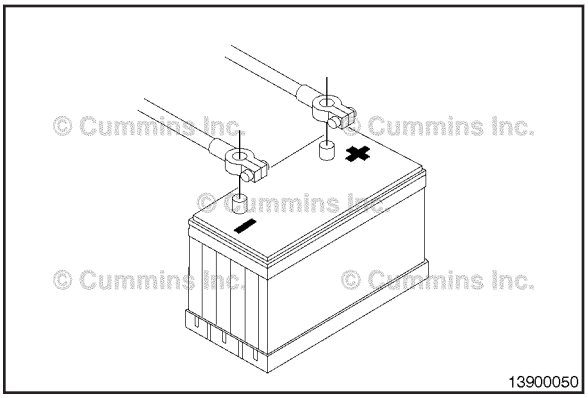


Air Intake Connection Adapter (010-131)

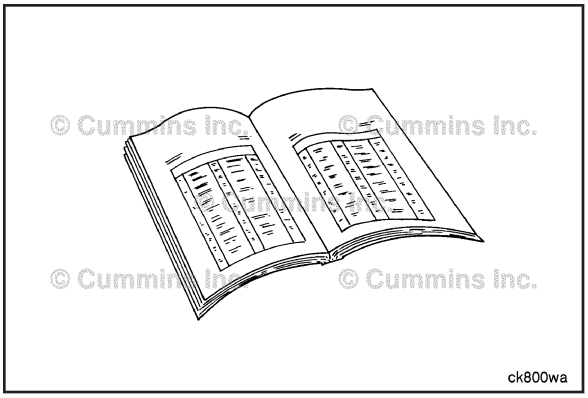
Preparatory Steps

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

- Disconnect the batteries.

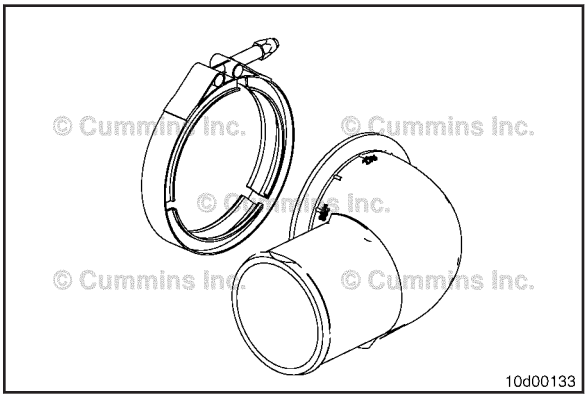


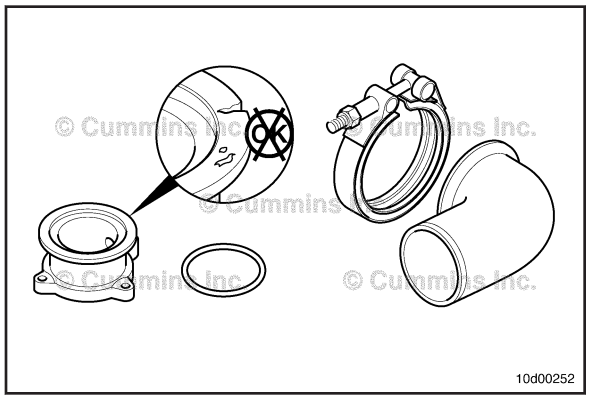
- Remove the air intake piping. Refer to Procedure 010-024.



Remove

Remove the v-band clamp, the elbow piece of the air intake connection adapter, and the seal.





Clean and Inspect for Reuse

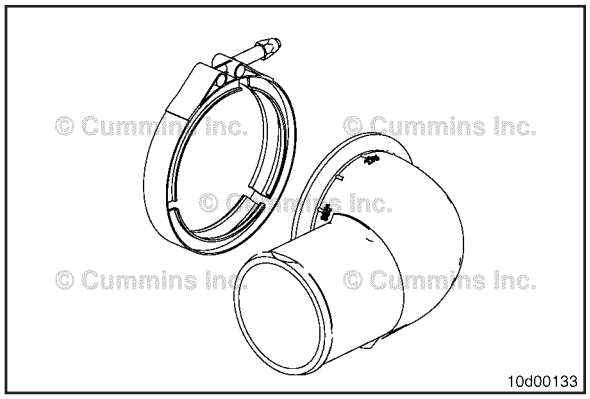
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

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

Clean the air intake connection adapter with solvent and dry with compressed air.

Inspect the air intake connection adapter, seal, and clamps for damage, cuts, cracks, holes, or worn sections.

Replace components if necessary.

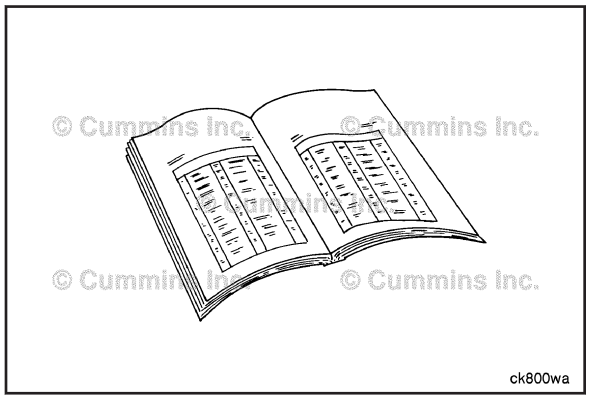


Install

Install the seal, air intake connection adapter elbow, and V-band clamp.

Tighten the V-band clamp.

Torque Value: 8 N•m [71 in-lb]

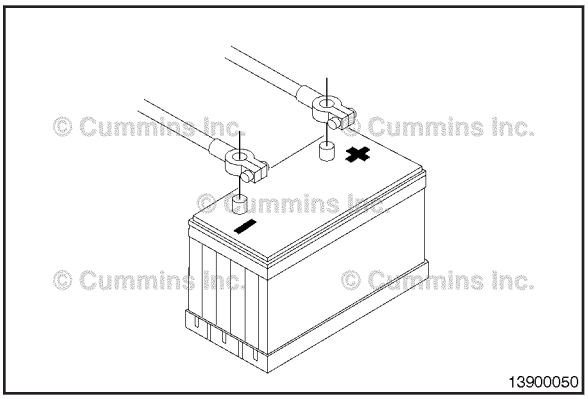


Finishing Steps

- Install the charge air piping. Refer to Procedure 010-024.

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

- Connect the batteries
- Operate engine and check for leaks.



Notes

Section 11 - Exhaust System - Group 11

Section Contents

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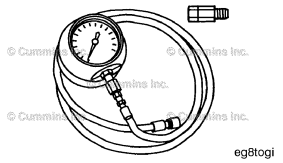
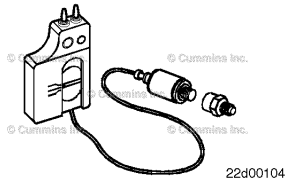
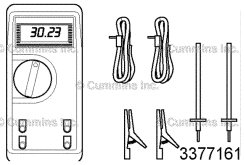
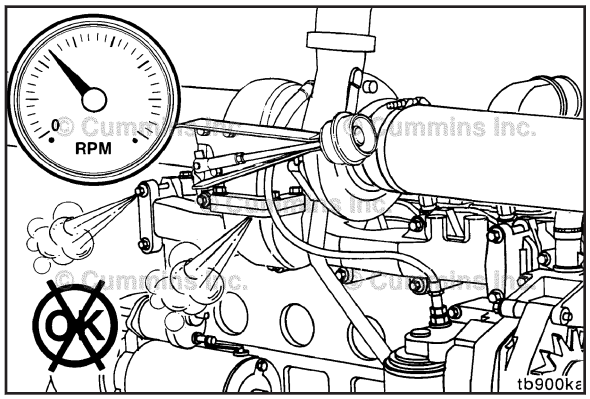
Service Tools

Exhaust System

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

Tool No.	Tool Description	Tool Illustration
ST-1273	**Pressure Gauge** Used to measure exhaust restriction.	
3164491	**Pressure/Vacuum Module** Used to measure pressure and vacuum. Use with digital multimeter 3164488 or 3164489.	
3164488 or 3164489	**Digital Multimeter** Used to measure electrical circuits: Voltage (volts), resistance (ohms), and current (amps). 3164488 — Standard meter. 3164489 — Automotive meter with built in temperature adapter and tachometer.	

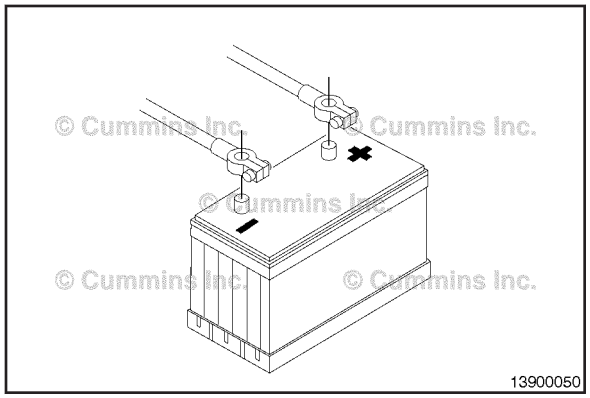


Exhaust Manifold, Dry (011-007)

General Information

Inspect for exhaust leaks at the exhaust manifold, turbocharger (if equipped), mounting gaskets, or exhaust pipe, muffler or catalyst restrictions. Refer to Procedure 010-024 and Procedure 010-019.

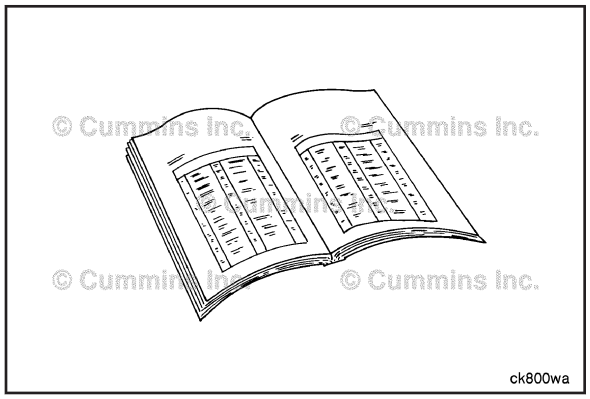
For turbocharged engines, leaks or restrictions will cause turbine and impeller to operate at a lower speed and reduce the amount of air being forced into the cylinder. Again, the symptom will be excessive smoke, low manifold pressure, and low power.



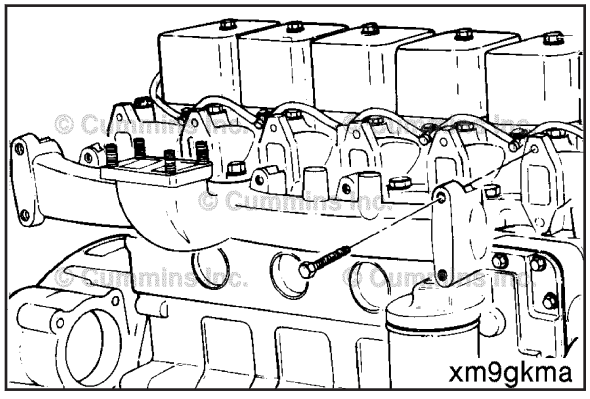
Preparatory Steps

⚠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.



- If equipped, remove the air crossover. Refer to Procedure 010-019
- If equipped, disconnect the charge air cooler piping. Refer to the OEM service manual
- Disconnect the exhaust piping. Refer to the OEM service manual
- For turbocharged engines, disconnect the air intake piping. Refer to the OEM service manual
- If equipped, remove the turbocharger. Refer to Procedure 010-033.



Remove

For 6 cylinder engines, remove the exhaust manifold mounting capscrews and spacers.

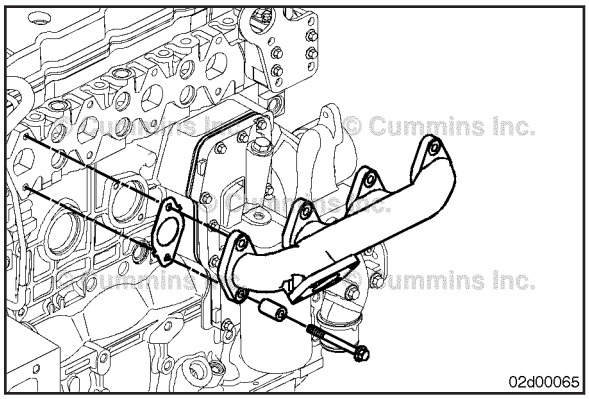
Remove the exhaust manifold and gaskets.

Discard the exhaust manifold gaskets.

For 4 cylinder engines, remove the exhaust manifold mounting capscrews and spacers.

Remove the exhaust manifold and gaskets.

Discard the exhaust manifold gaskets.

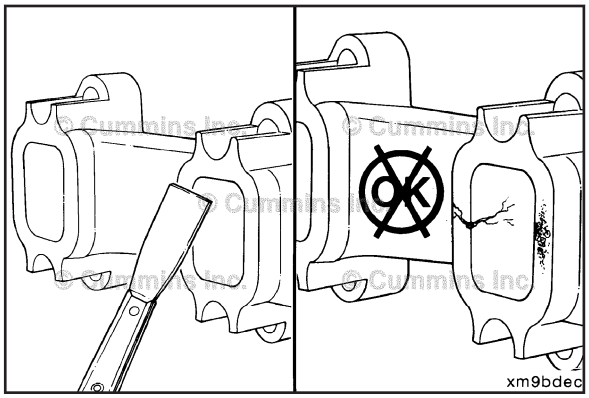


Clean and Inspect for Reuse

Clean the sealing surfaces of the head.

Clean the sealing surfaces of the exhaust manifold.

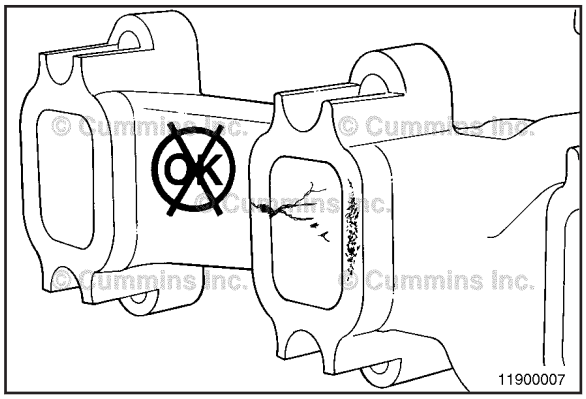
Use 240-grit inert cloth to remove carbon deposits from the sealing surface.



Inspect the parts for cracks, burnout, or damage.

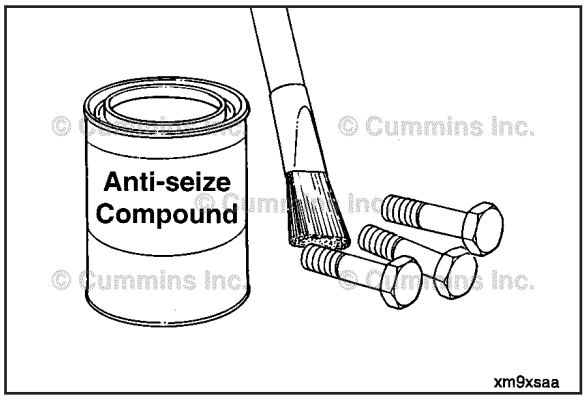
NOTE: If the exhaust manifold is damaged, for turbocharged engines, check the charge air cooler. A charge air cooler failure can cause progressive damage to the exhaust manifold. Refer to Procedure 010-027.

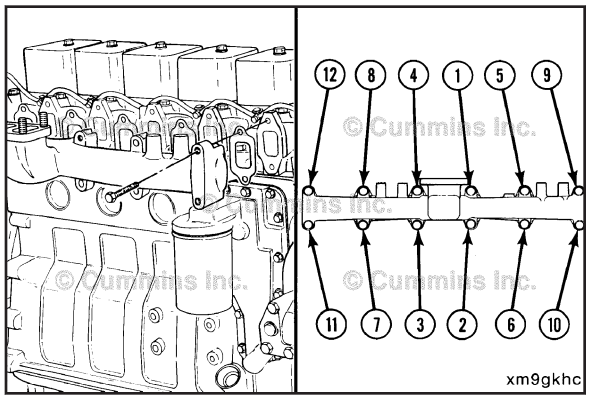
Inspect the gasket surfaces for gouges, scratches, or burnout.



Install

Coat all capscrew threads with an unleaded anti-seize compound.



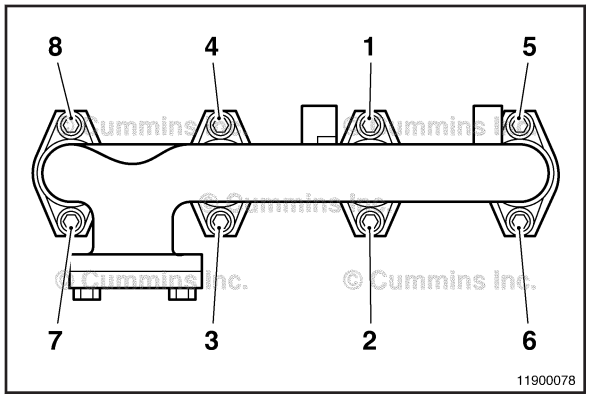


For 6 cylinder engines, install the exhaust manifold, new gaskets, spacers and mounting capscrews.

Follow the tightening sequence shown in the illustration.

Tighten the exhaust manifold mounting capscrews.

Torque Value: 43 N•m [32 ft-lb]

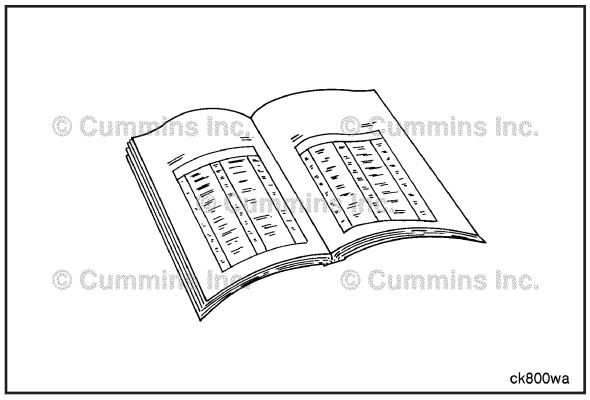


For 4 cylinder engines, install the exhaust manifold, new gaskets, spacers and mounting capscrews.

Follow the tightening sequence shown in the illustration.

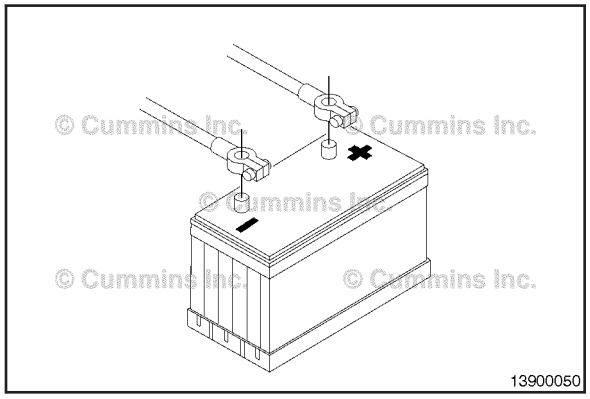
Tighten the exhaust manifold mounting capscrews.

Torque Value: 43 N•m [32 ft-lb]



Finishing Steps

- If equipped, install the turbocharger. Refer to Procedure 010-033.
- Connect the exhaust piping. Refer to the OEM service manual
- For turbocharged engines, connect the air intake piping. Refer to the OEM service manual
- If equipped, install the air crossover. Refer to Procedure 010-019
- If equipped, connect the charge air cooler piping. Refer to the OEM service manual.



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

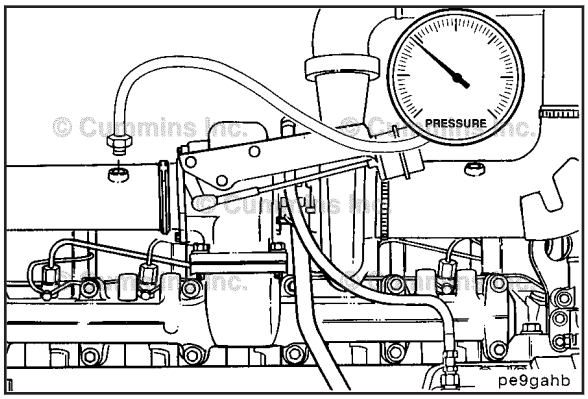
- Connect the batteries
- Operate the engine and check for leaks.

Exhaust Restriction (011-009)

Measure

Install pressure gauge, Part Number ST-1273, to the pressure tap in the exhaust head pipe or at the inlet to the catalyst/muffler assembly.

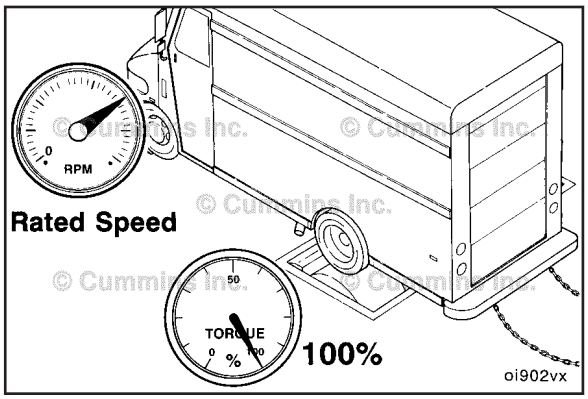
Operate the engine at rated speed and load. Record the exhaust restriction.



If restriction exceeds specification, inspect the oxidation catalyst and/or muffler and replace according to the vehicle manufacturer's instructions.

Exhaust Restriction

	mm Hg		in Hg
Industrial	76	MAX	3
1991 EPA Certification	114	MAX	4.5
1994 EPA Certification with Oxidation Catalyst	152	MAX	6



Notes

Section 12 - Compressed Air System - Group 12

Section Contents

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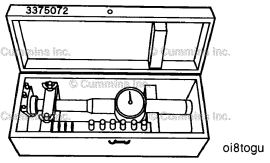
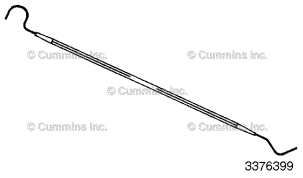
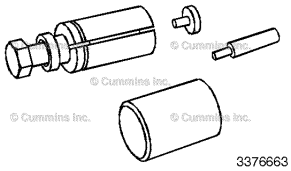
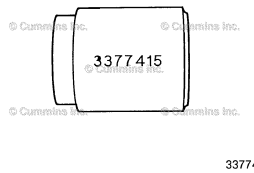
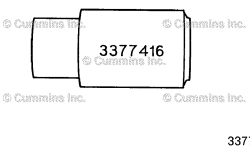
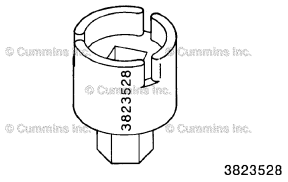
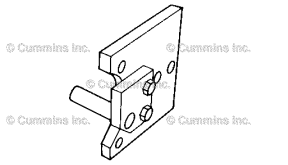
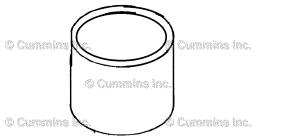
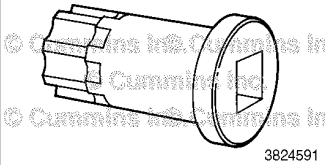
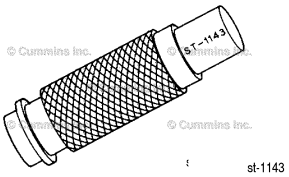
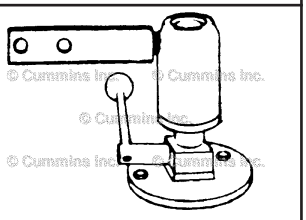
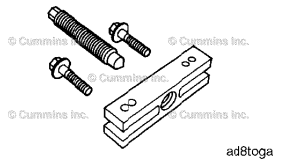
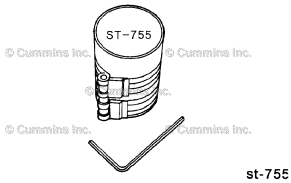
Service Tools

Compressed Air System

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

Tool No.	Tool Description	Tool Illustration
3375072	**Dial Bore Gauge** Used to measure the cylinder bores.	
3375182	**Valve Spring Tester** Used to check spring tension.	
3376399	**O-ring Pick** Used to remove and install o-rings.	
3376663	**Coupling Puller** Used to remove the spline coupling hub.	
3377415	**Air Compressor Seat Installation Tool** Used to install the exhaust valve seats.	
3377416	**Air Compressor Seat Removal Tool** Used to remove the exhaust valve seats.	

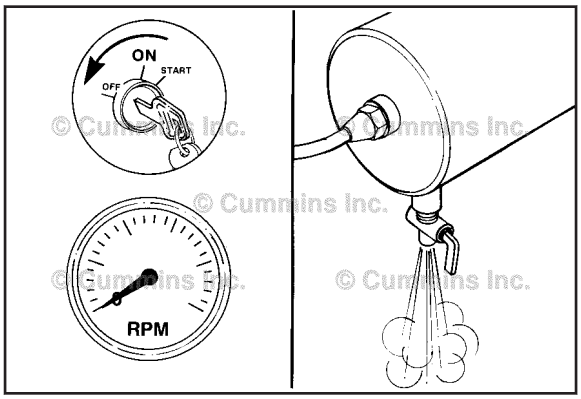
Tool No.	Tool Description	Tool Illustration
3823528	**Air Compressor Seat Socket** Used to remove the exhaust valve seat and the inlet valve cage.	
3823597	**Mounting Plate** Used to mount the air compressor to the vise.	
3823923	**Spacer** Used with coupling puller, Cummins Part Number 3376663, to remove the hydraulic pump drive coupling.	
3824591	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	
ST-1143	**Air Compressor Bushing Mandrel** Used to remove and install the crankshaft bushing in the crankcase and the support.	
ST-302	**Ball Joint Vise** Used to hold the air compressor for disassembly or assembly.	
ST-647	**Standard Puller** Used to pull the drive gear. Use with puller capscrews that have M8 x 1.25-6H threads.	
ST-755	**Piston Ring Compressor** Used to compress all piston rings to permit easy installation of piston and rod assemblies.	

Air Compressor Carbon Buildup (012-003)

Initial Check

Shut off the engine.

Open the draincock on the wet tank to release compressed air from the system.

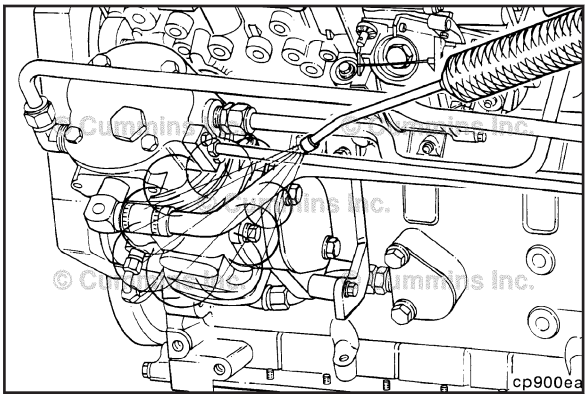


⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

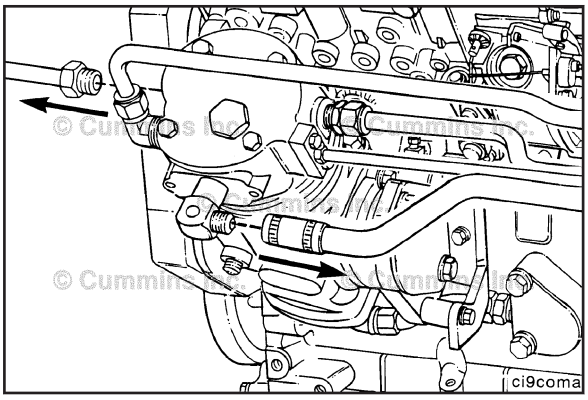
⚠WARNING⚠
Compressed air used for cleaning purposes should not exceed 207 kPa [30 psi]. Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

Use steam to clean the compressor.

Use compressed air to dry.

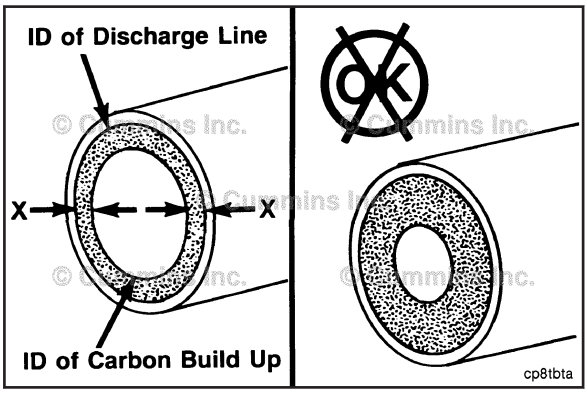


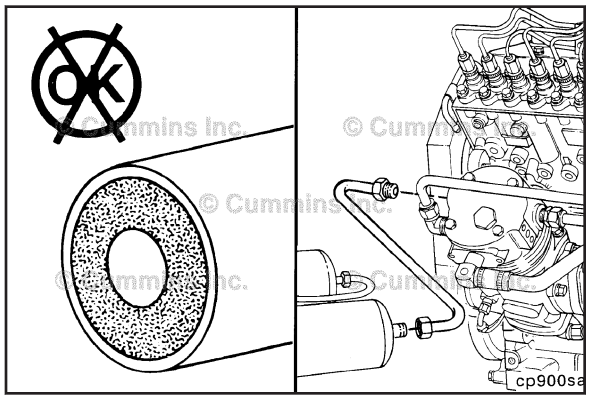
Remove the air inlet and outlet connections from the air compressor.



Measure the total carbon deposit thickness inside the air discharge line as shown.

NOTE: The carbon deposit thickness **must not** exceed 1.6 mm [0.0630 in].

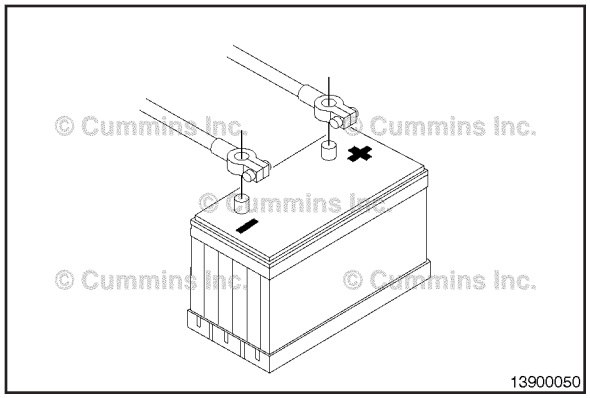




⚠WARNING⚠
The air discharge line must be capable of withstanding extreme heat and pressure to prevent personal injury and property damage. Refer to the manufacturer's specifications.

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 and inspect unloader components and cylinder head.

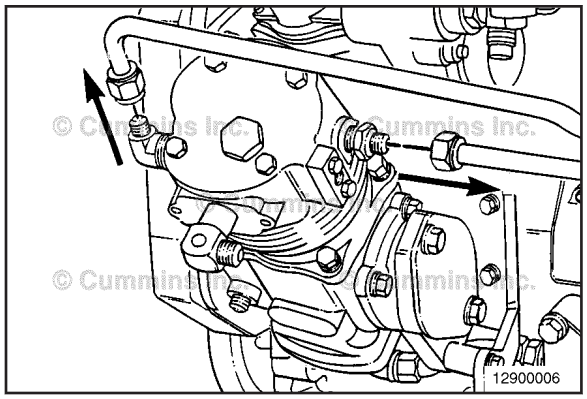


Air Compressor Coolant Lines (012-004)

Preparatory Steps

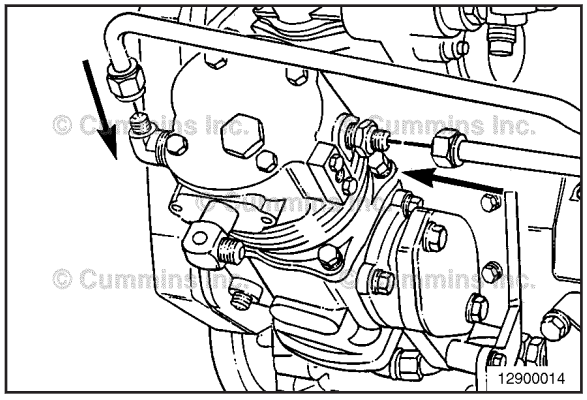
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries.



Remove

Remove the coolant lines from the air compressor (does **not** apply to air cooled compressors).



Install

△CAUTION△
If rubber grommets are used on the coolant lines, be sure they are installed carefully to prevent cuts or tears to the grommets which will cause leaks.

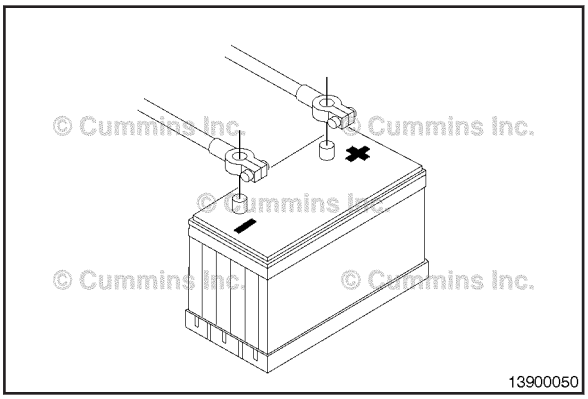
Install the coolant lines.

Torque Value: 24 N•m [18 ft-lb]

Finishing Steps

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

- Connect the batteries
- Operate engine and check for leaks.



Air Compressor Pin Bore Wear (012-010)

Initial Check

⚠WARNING⚠
The unloader valve body is installed with spring tension. Use care when removing to prevent personal injury. Always wear protective eyewear.

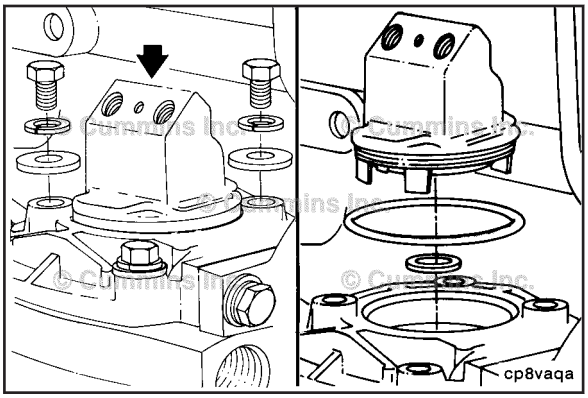
NOTE: This procedure applies to SS and ST models **only**.

Hold the unloader valve body down, and remove the two captive washer capscrews and the two plain washers.

Remove the unloader valve body.

Remove the o-ring seal.

Remove the rectangular ring seal.



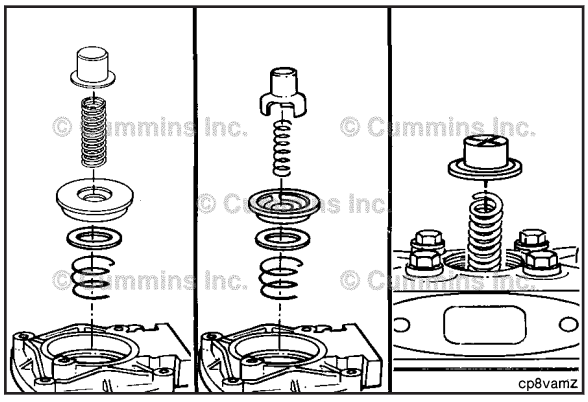
Remove the unloader valve cap and the unloader valve spring.

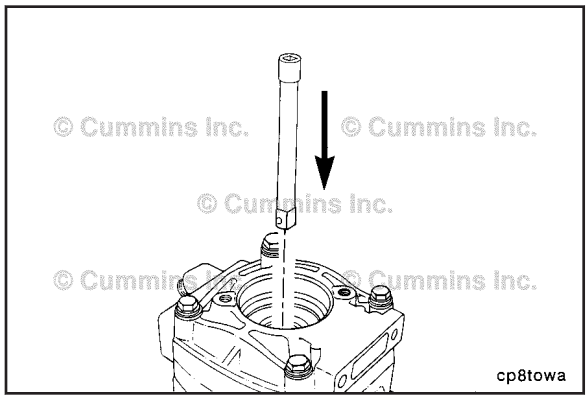
NOTE: Disassembly of the center unloader valve on Holset® two-cylinder air compressors is similar to the single-cylinder unloader valve.

Remove the intake valve seat and valve.

Remove the intake valve spring.

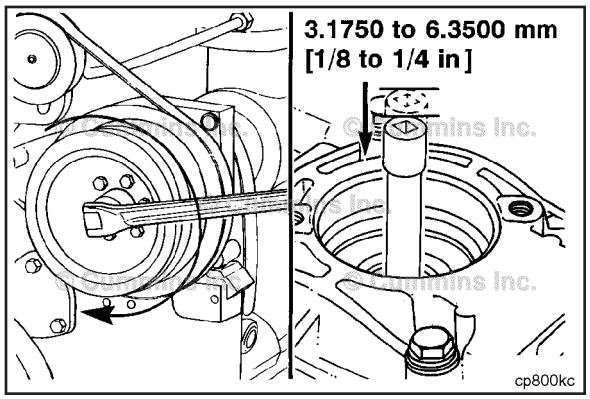
To avoid damage to the air compressor, do **not** allow any debris to fall into the air compressor cylinder.



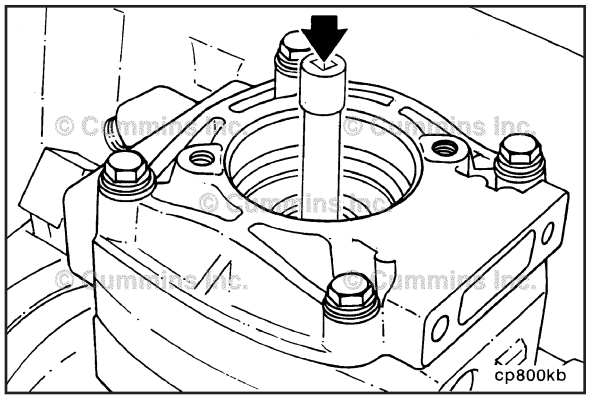


NOTE: Do **not** use a screwdriver. A screwdriver can gouge the top of the piston.

Insert the small end of a 3/8-inch drive socket extension (6 to 10 inches long) through the exhaust valve seat onto the top of the piston.

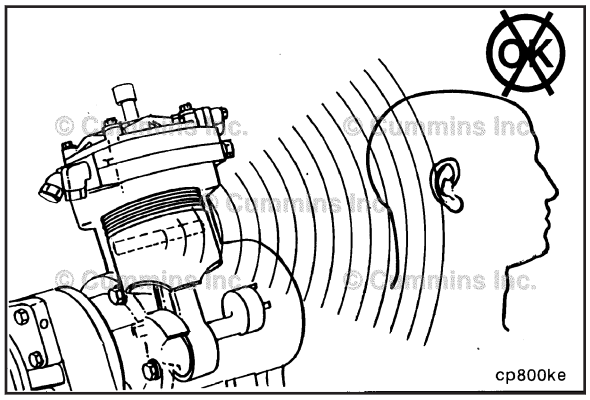


Bar the crankshaft over until the compressor piston reaches top dead center, and the extension starts to move downward approximately 3 to 6 mm [1/8 to 1/4 in].



NOTE: To prevent damage to the top of the piston, do **not** use a hammer.

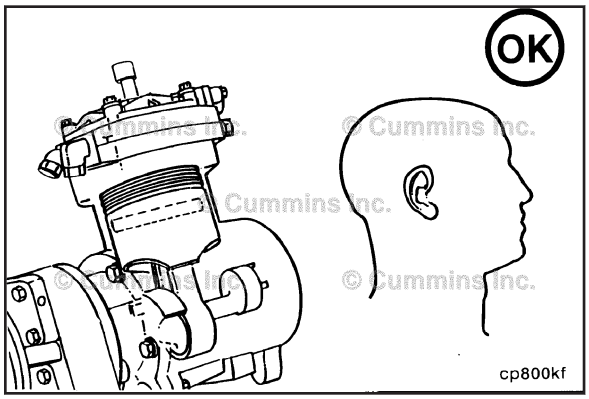
Give a quick, hard push downward on the extension and listen for a metallic click as wear clearance is taken up.



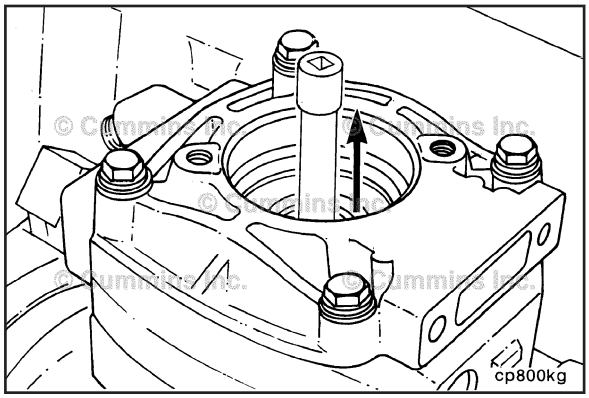
If significant piston motion is felt or a metallic click is heard, the pin bores can be worn, and the compressor **must** be examined further.

If no motion or sound is heard, the compressor is in satisfactory condition and does **not** need to be replaced.

NOTE: Not all air compressors will exhibit pin bore wear.



Remove the extension.



Install the intake valve spring with the tang down.

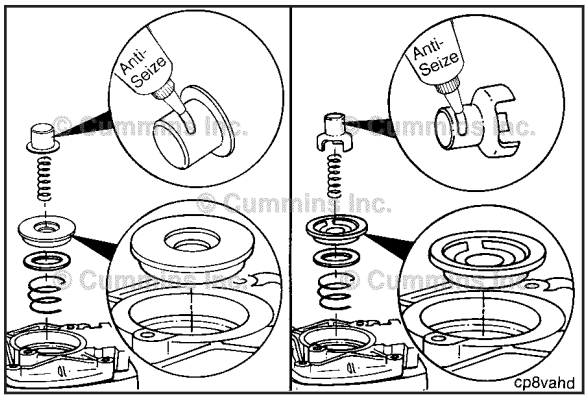
Install the intake valve.

Install the intake valve seat with the flange side up.

Install the unloader valve cap spring.

Install the unloader valve cap.

Use high-temperature grease (Accrolube lubrication Teflon™ grease, or equivalent) to lubricate the outside diameter of the cap.



NOTE: The rectangular ring seal **must** be installed with the grooved side up.

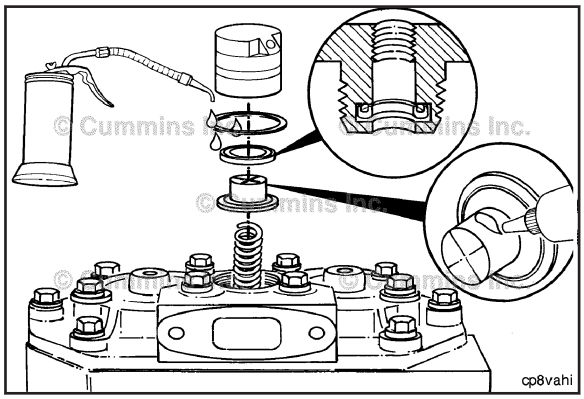
Install the rectangular ring seal.

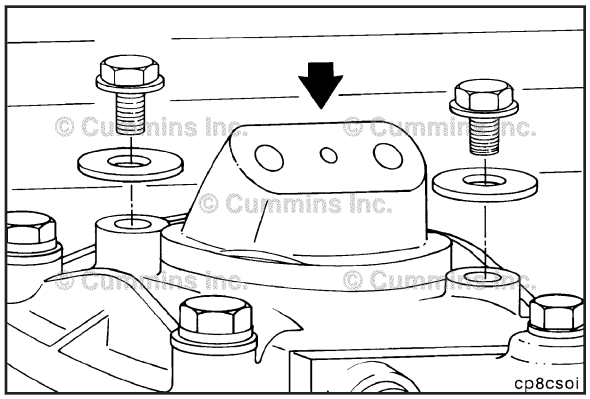
Install the o-ring seal.

Use clean engine oil to lubricate the o-ring seal.

Install the unloader valve body.

NOTE: Press the unloader valve body down to be sure the tangs of the unloader valve cap are in the three slots of the intake valve seat.



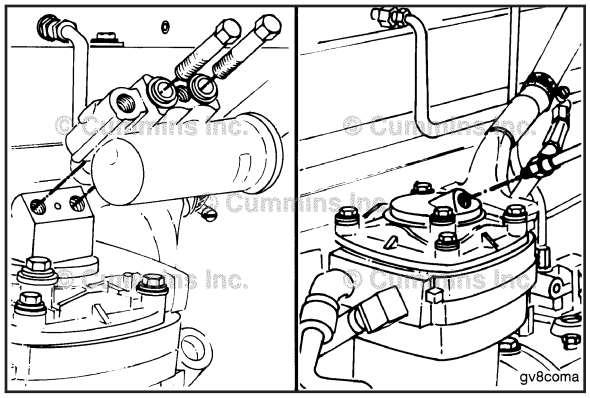


CAUTION
Do not overtighten. Failure to do so can cause compressor damage.

Hold the unloader body down and install the two plain washers and captive washer capscrews.

Tighten the capscrews.

Torque Value: 14 N•m [124 in-lb]



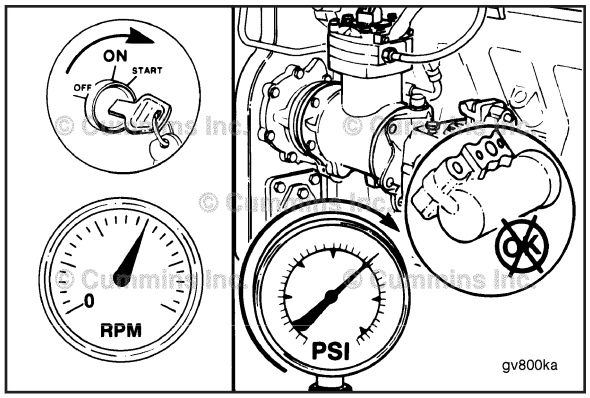
Air Compressor Unloader and Valve Assembly (012-013)

Initial Check

WARNING
Air pressure must be released from the system before removing the air governor. The governor can be under pressure and cause personal injury.

NOTE: The illustrations shown will be of the SS model single-cylinder air compressor. Differences in procedures for SS, QE, and ST model Holset® air compressors will be shown where necessary.

Remove the air governor or air governor hose from the air compressor unloader body.



Operate the engine to activate the air compressor.

If the air compressor is **not** pumping, the unloader valve is malfunctioning, and **must** be repaired or replaced.

Remove

⚠WARNING⚠
The unloader valve body is installed with spring tension. Use care when removing to prevent personal injury. Always wear protective eyewear.

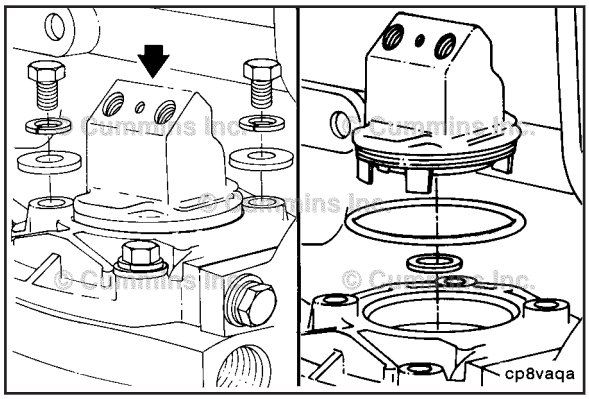
Holset® SS, E-Type, and ST Models

Hold the unloader valve body down, and remove the two captive washer capscrews and the two plain washers.

Remove the unloader valve body.

Remove the o-ring seal.

Remove the rectangular ring seal.

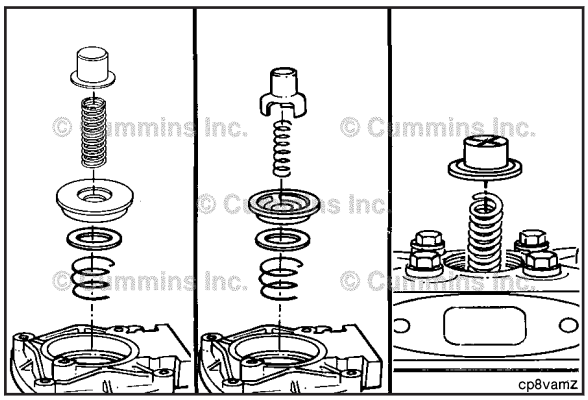


Remove the unloader valve cap and the unloader valve spring.

NOTE: Disassembly of the center unloader valve on Holset two-cylinder air compressors is similar to the single-cylinder unloader valve.

Remove the intake valve seat and valve.

Remove the intake valve spring.



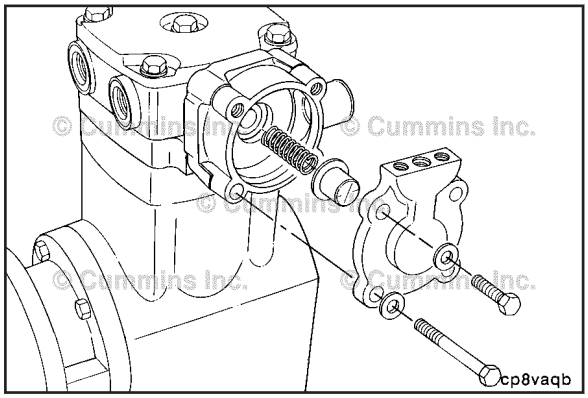
⚠WARNING⚠
The unloader body is installed with spring tension. Use care when removing to prevent personal injury. Always wear protective eyewear.

Holset® QE Models

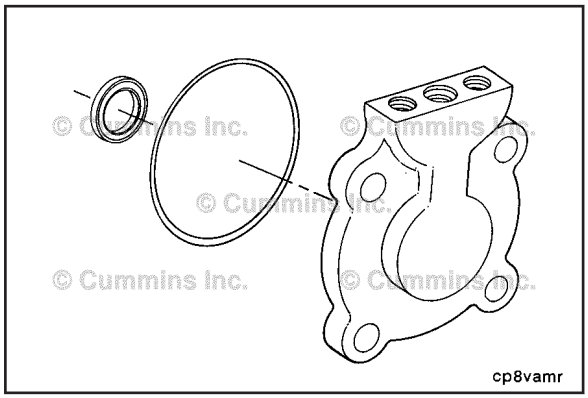
Hold the unloader valve body down, and remove the four capscrews.

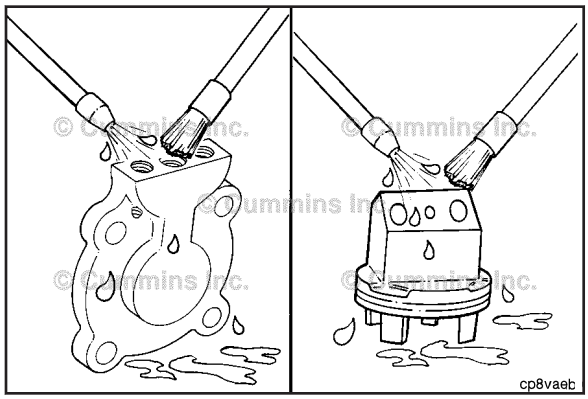
Remove the unloader valve spring.

Remove the unloader valve cap.



Remove the unloader body gasket and unloader valve cap rectangular ring seal.

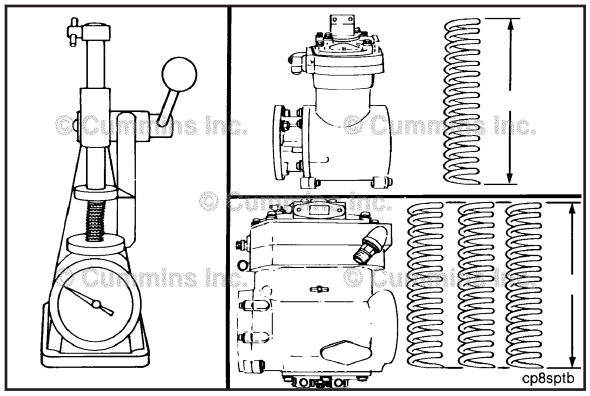




Clean

⚠CAUTION⚠
Do not use caustic cleaners. Failure to do so can cause compressor damage.

Remove all carbon and varnish from the unloader valve cap body.

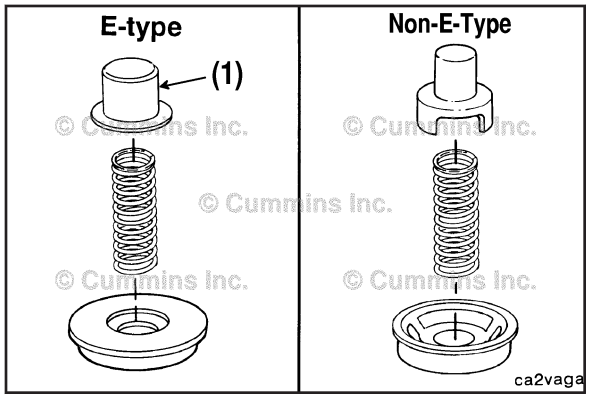


Inspect for Reuse

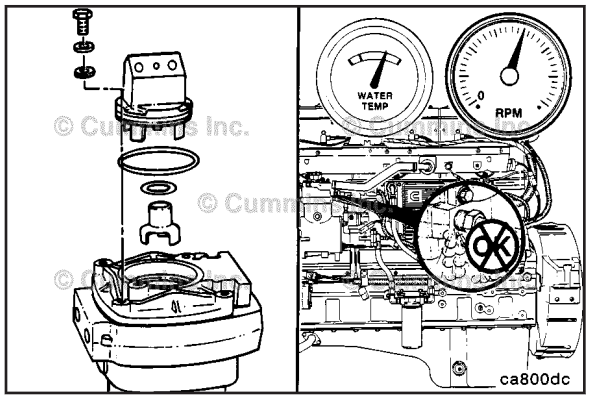
Use the valve spring tester, Part Number 3375182, to check the unloader spring.

Replace the unloader spring if it does **not** meet the specifications shown, or the wrong spring has been used.

NOTE: For Holset® two-cylinder air compressors, check both cylinder and center unloader springs. Holset® recommends that new springs be installed during rebuild.



NOTE: If the compressor has a flat-hat-type unloader cap (1), it **must** use an unloader spring and valve seat different from that used with the three-prong unloader.



Install

Holset® SS, E-Type, and ST Models

Assemble the air compressor.

- Grease rectangular ring seal, unloader cap, and unloader body bore with high-temperature grease (Accrolube lubrication Teflon™ grease, or equivalent).

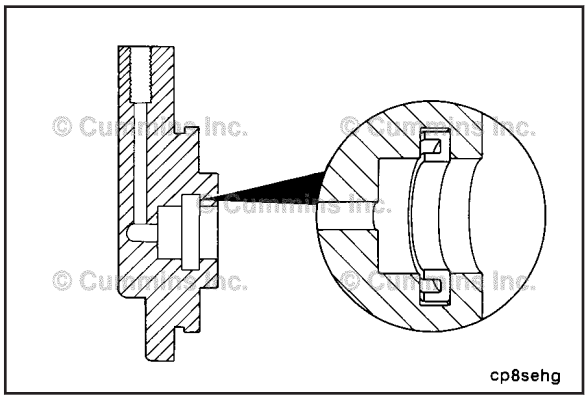
Torque Value: 14 N•m [124 in-lb]

Operate the engine, and check the compressor for air leaks.

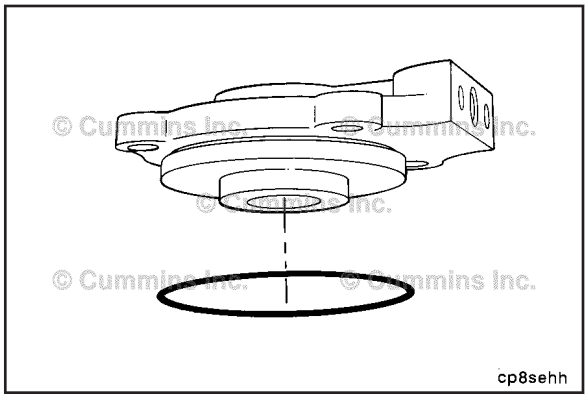
Install the new rectangular V-seal into the unloader body.

NOTE: The seal **must** be installed with the grooved side up.

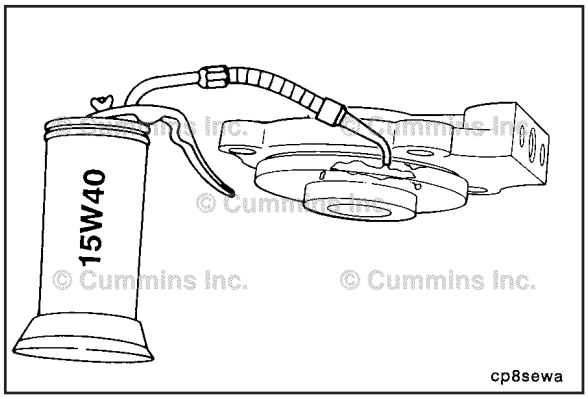
Liberally lubricate the unloader valve bore above and below the rectangular ring seal with high-temperature grease (Accrolube lubrication Teflon™ grease, or equivalent).



Install a new o-ring seal on the unloader valve body.



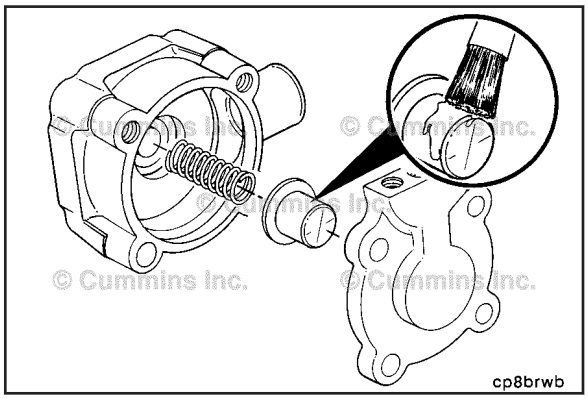
Use clean lubricating engine oil or Accrolube lubrication Teflon™ grease, or equivalent, to lubricate the seal.

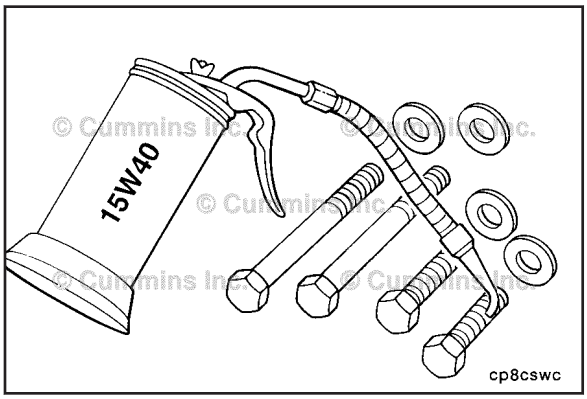


Liberally lubricate the unloader valve body bore and unloader cap with high temperature grease (Accrolube lubrication Teflon™ grease, or equivalent).

Install the unloader cap.

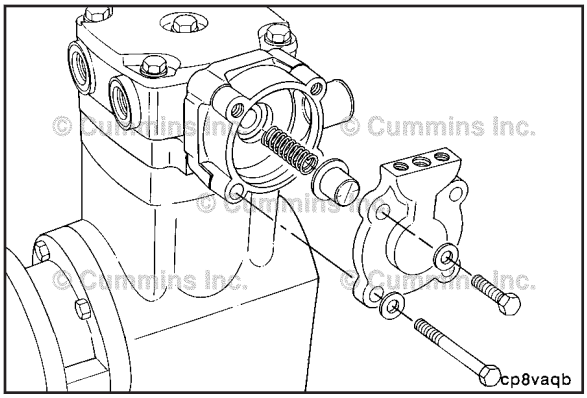
Install the unloader spring.





Lubricate the unloader screw threads and underhead with clean lubricating engine oil before installation.

NOTE: The two unloader body screws **must not** be used to attach any brackets.

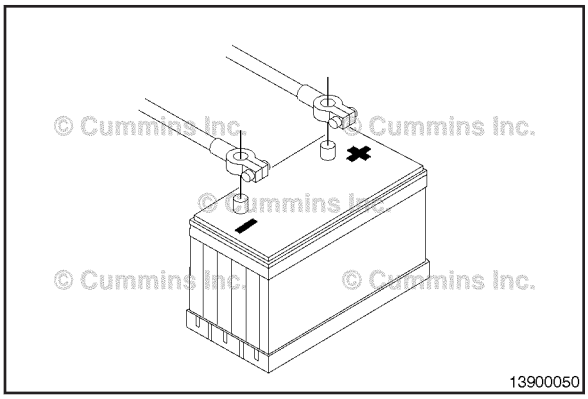


Assemble the unloader components, and attach the unloader assembly to the valve plate with the four capscrews and washers.

NOTE: The longer capscrews are used to mount the manifold to the air compressor.

Torque Value: 27 N•m [20 ft-lb]

Operate the engine, and check the air compressor for air leaks.

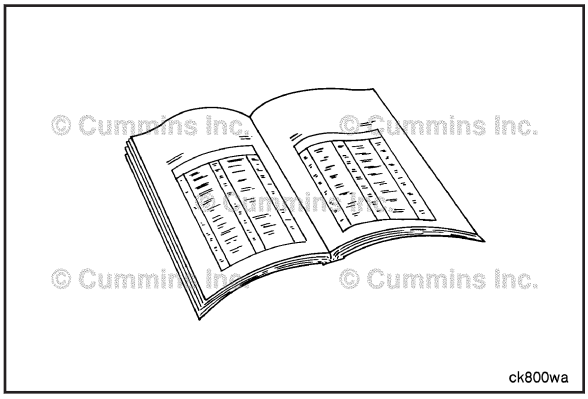


Air Compressor (012-014)

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.

- Disconnect the batteries.



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

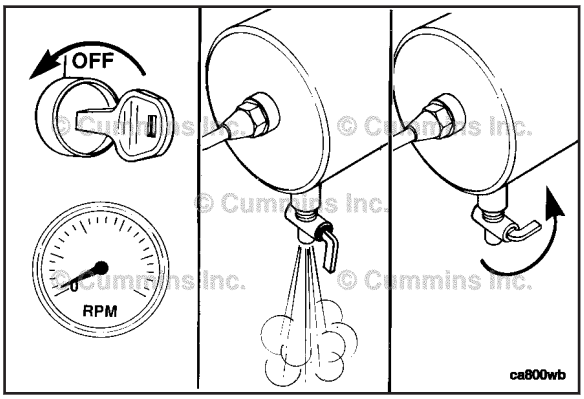
⚠WARNING⚠
Wait until the temperature is below 50°C [120°F] to avoid personal injury from hot coolant.

- Drain the engine coolant. Refer to Refer to Procedure Procedure 008-018
- Remove the coolant lines from the air compressor. Refer to Refer to Procedure Procedure 012-004
- Remove the hydraulic pump (if equipped). Refer to Refer to Procedure Procedure 009-016.

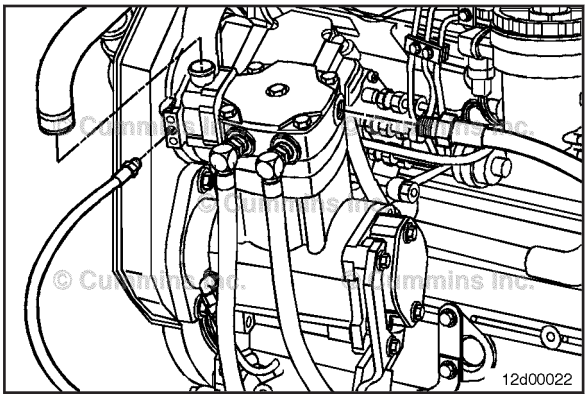
Remove

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

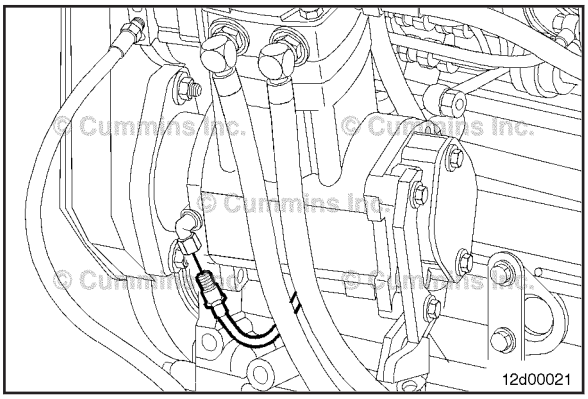
Open the draincock on the wet tank to release air from the system. Close the draincock after the pressure is released.



Remove the air connections from the air compressor.

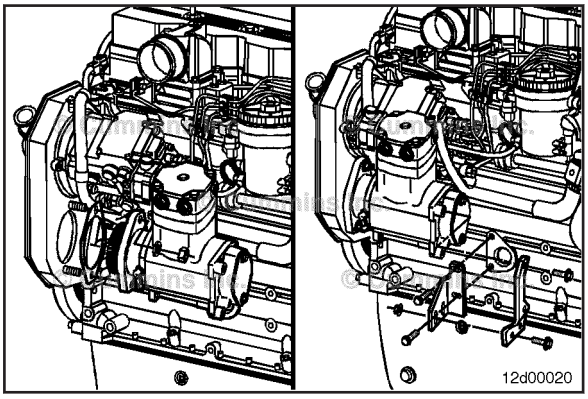


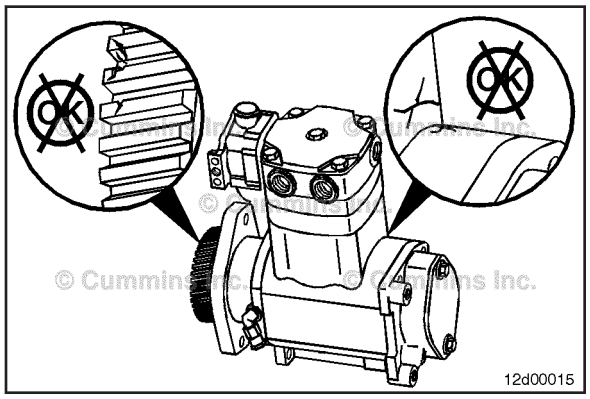
Remove the oil supply line.



Remove the air compressor support bracket and capscrews.

Remove the air compressor mounting capscrews and the air compressor.

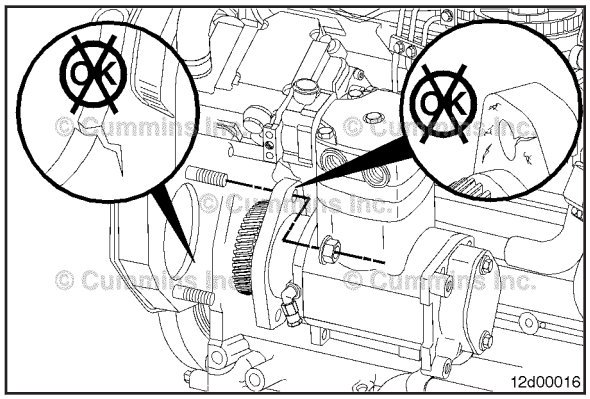




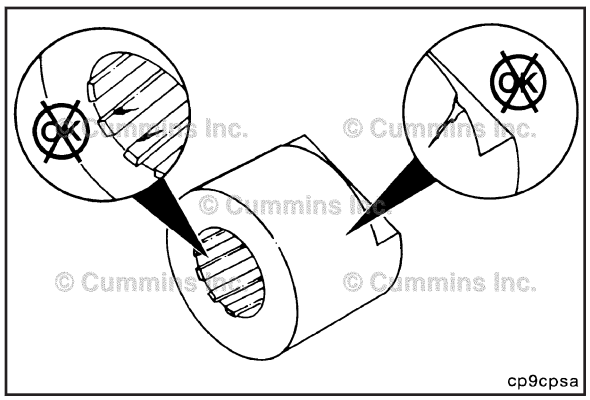
Clean and Inspect for Reuse

Inspect the compressor housing for cracks or damage.

Inspect the drive gear for cracks or damage.



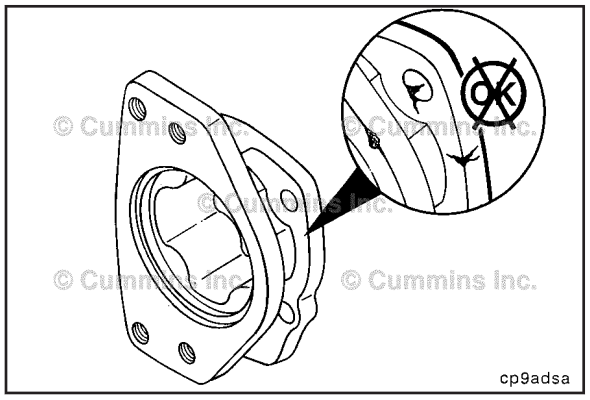
The gasket surfaces of the gear housing and air compressor **must** be clean and **not** damaged.



Power Steering Coupling (if applicable)

Inspect the coupling for wear or cracks.

Replace the coupling, if damaged. Refer to the OEM repair manual.



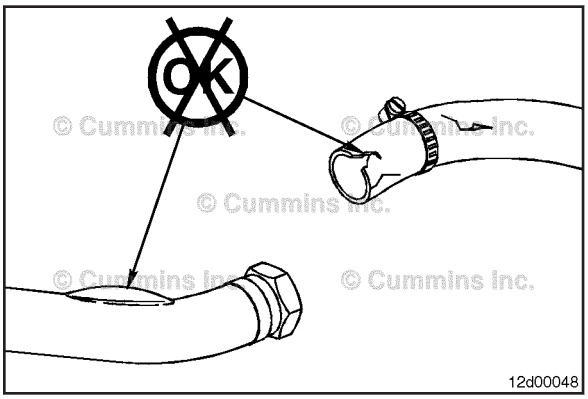
Power Steering Adapter

Inspect the adapter for wear or cracks.

Replace the adapter if any damage is found. Refer to the OEM repair manual.

Inspect the drive clips or connectors for damaged threads.

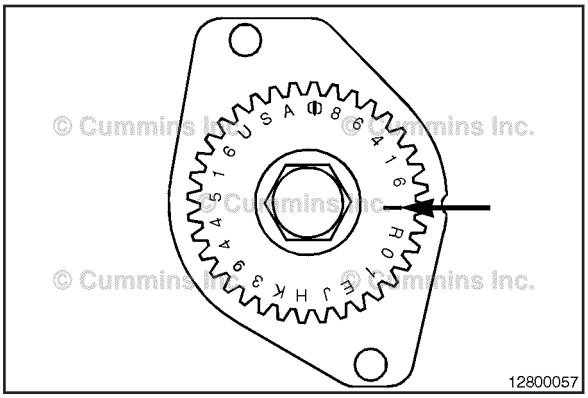
Inspect the coolant hoses and coolant lines for restrictions of coolant flow.



Install

Compressor Timing Procedure:

- Rotate the engine to Top Dead Center (TDC) using Refer to Procedure Procedure 003-004.
- Rotate the gear in the air compressor until the I is in line with the V-notch on the air compressor housing, located at the 3-o'clock position as viewed from the front.



Install air compressor, two capscrews, and a new gasket onto the front gear housing.

Install the air compressor support bracket.

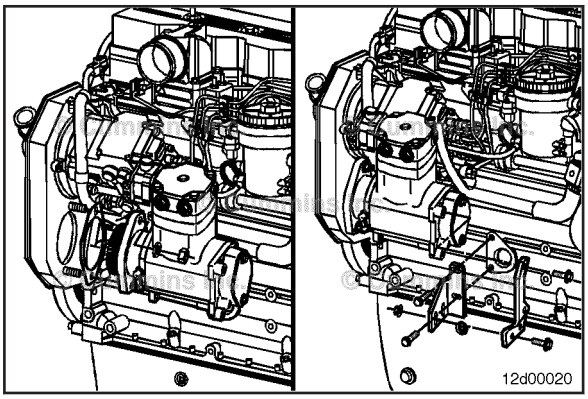
Torque Value:
Mounting Nuts 77 N•m [57 ft-lb]

Torque Value:
Support Capscrews to Air Compressor Support 43 N•m [32 ft-lb]

Torque Value:
Capscrews to Block 57 N•m [42 ft-lb]

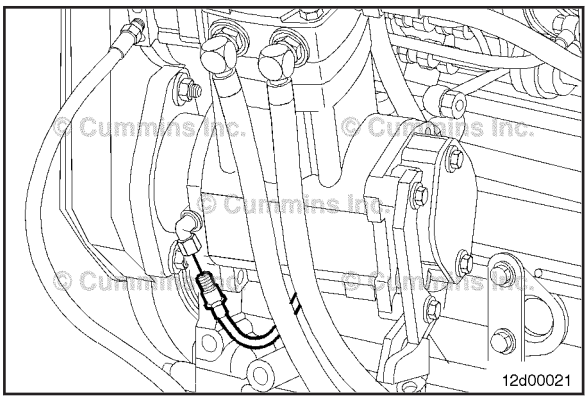
Compressor drive gear mounting nut torque:

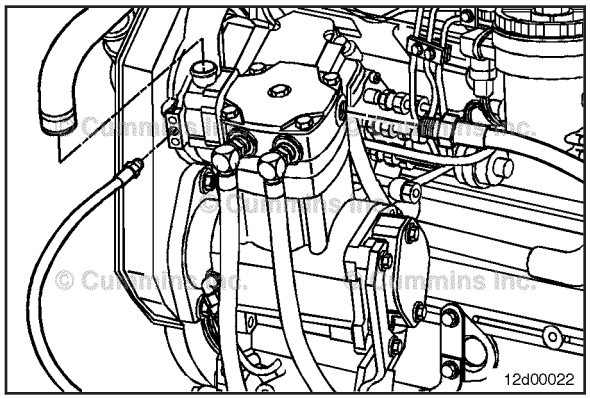
Torque Value:
Knorr-Bremse™ 165 N•m [122 ft-lb]



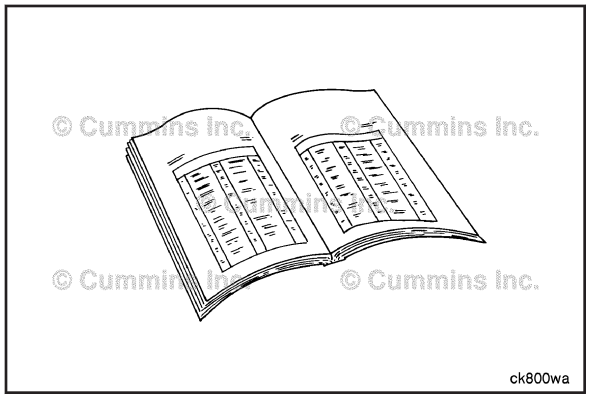
Install the oil supply line.

Torque Value: 15 N•m [133 in-lb]



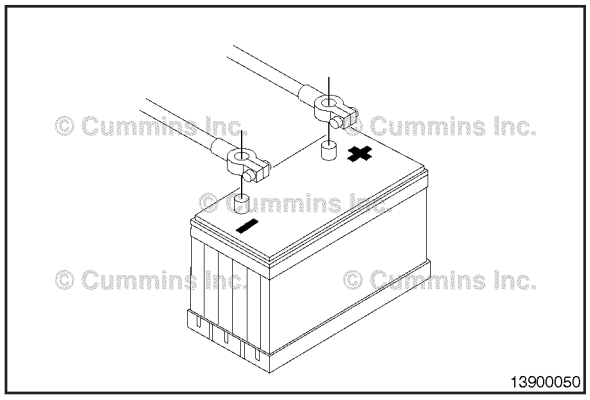


Install the air lines.



Finishing Steps

- Install the coolant lines from the air compressor. Refer to Refer to Procedure Procedure 012-004
- Install the hydraulic pump (if equipped). Refer to Refer to Procedure Procedure 009-016
- Fill the coolant system. Refer to Refer to Procedure Procedure 008-018.



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

- Connect the batteries.

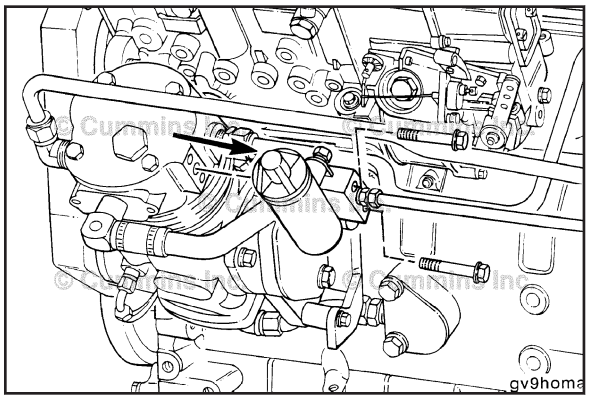
- Operate the engine to check for coolant and oil leaks
- Operate the engine to actuate the air compressor
- With the air compressor pumping between 550 kPa to 690 kPa [80 psi to 100 psi], use a solution of soapy water to check for air leaks.

Air Governor (Air Compressor Will Not Pump) (012-017)

Test

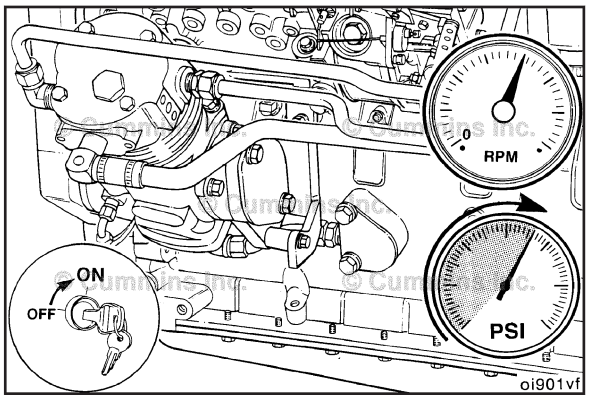
Remove the air governor hose from the air compressor unloader body.

If the air governor is mounted directly on the air compressor, then remove the air governor from the compressor.



⚠CAUTION⚠
During this test, do not exceed maximum vehicle air system pressure or 1035 kPa [150 psi], whichever is lower. Refer to the manufacturer's specifications.

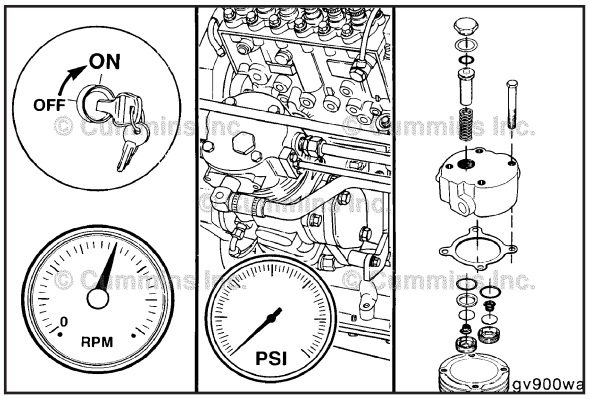
Operate the engine to activate the air compressor.



If the air compressor does **not** pump, then the fault is in the air compressor.

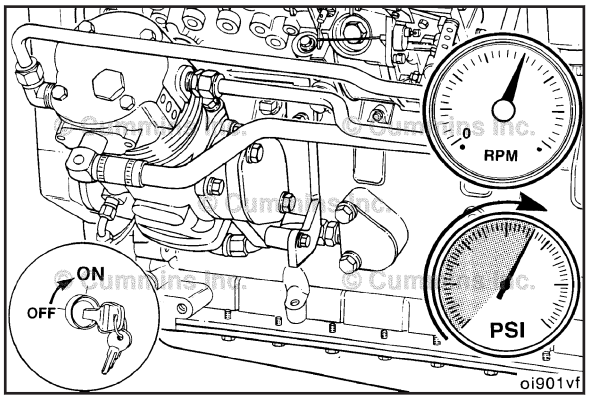
Remove and inspect the cylinder head and unloader components. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121. If no problems are found during disassembly or inspection of the cylinder head or unloader components, then the compressor should be removed and disassembled to determine the cause of the problem.

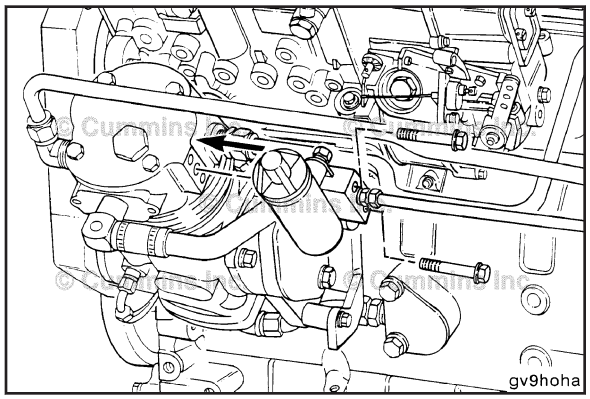
Refer to and SS191 Single-Cylinder Air Compressor Shop Manual, Bulletin 3810433.



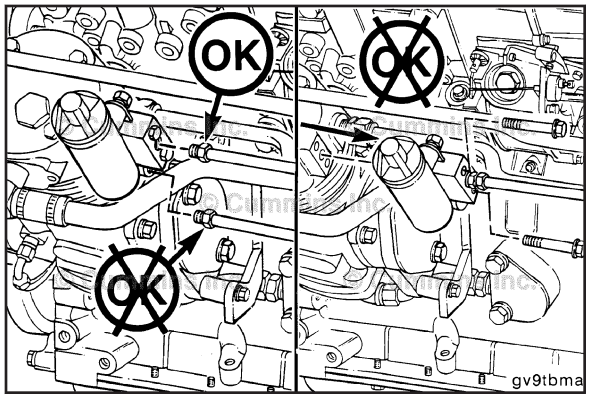
⚠CAUTION⚠
During this test, do not exceed maximum vehicle air system pressure or 1035 kPa [150 psi], whichever is lower. Refer to the manufacturer's specifications.

Operate the engine, and check air compressor operation with the air governor removed.





Install the air governor line to the unloader body and tighten.

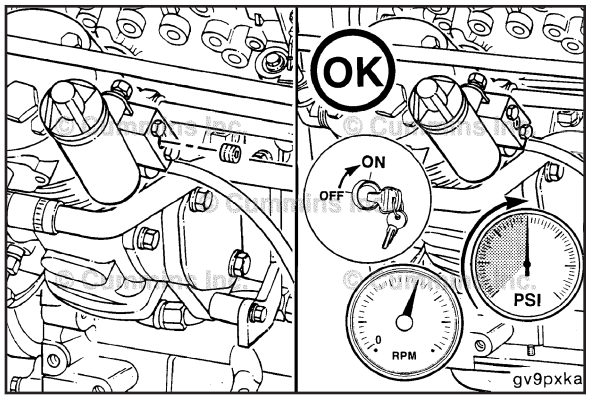


Air Governor (Air Compressor Pumps Continuously) (012-018)

Test

Remove the accessory air lines from the air governor unloader port.

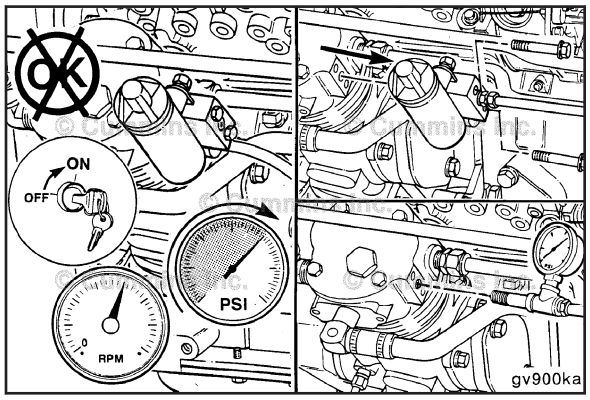
NOTE: Do **not** disconnect the line from the air compressor unloader valve. Do **not** disconnect the reservoir air line from the air governor. If the governor is mounted on the compressor, do **not** remove the governor from the compressor.



Install pipe plugs in the air governor unloader ports where 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 equipment manufacturer's instructions for troubleshooting and repair.

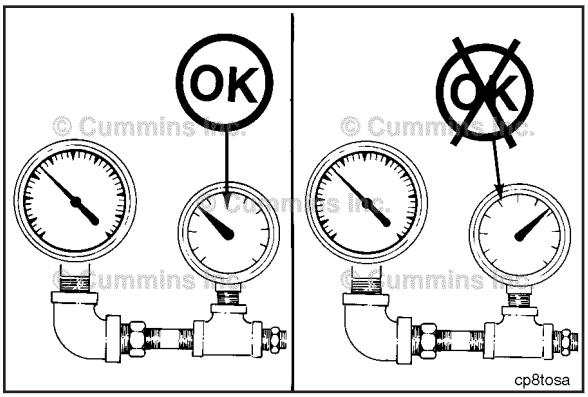


If the air compressor does **not** stop pumping (air pressure continues to rise) at the governed air pressure, connect a regulated shop air pressure line to the air compressor unloader valve port.

NOTE: If the governor is mounted on the air compressor, then the governor will have to be removed.

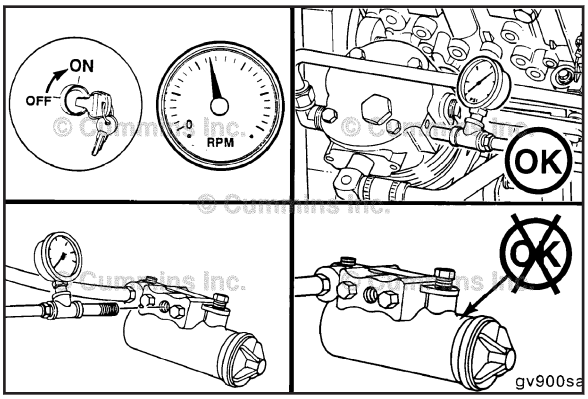
NOTE: Be sure the air pressure gauge is accurate and the supply lines and fittings are in good condition before performing any air pressure checks.

Use a master gauge of known accuracy to check the air pressure gauge.

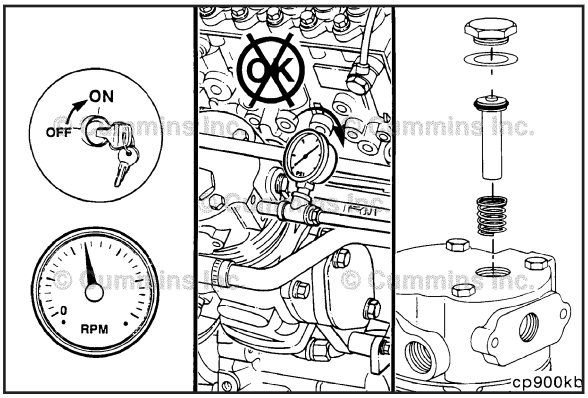


Apply 690 kPa [100 psi] of air pressure to the unloader port.

If the air compressor stops pumping (air pressure stops rising), the air governor is malfunctioning and **must** be repaired or replaced. Refer to the manufacturer's instructions.



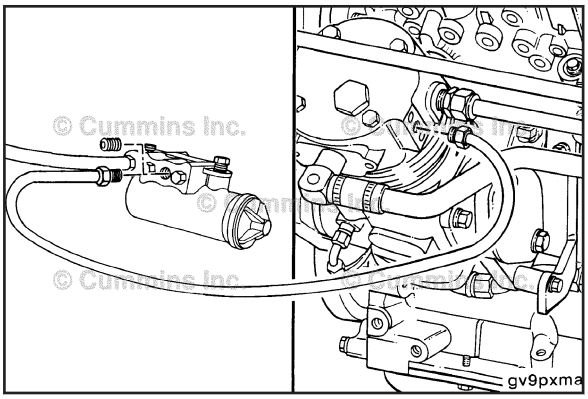
If the air compressor continues to pump (air pressure continues to rise), the unloader valve is malfunctioning and **must** be repaired or replaced. Refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121.

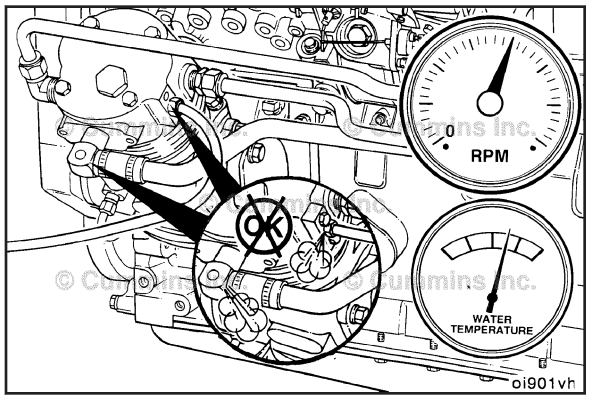


Remove the pipe plugs from the unloader ports used for accessory air lines.

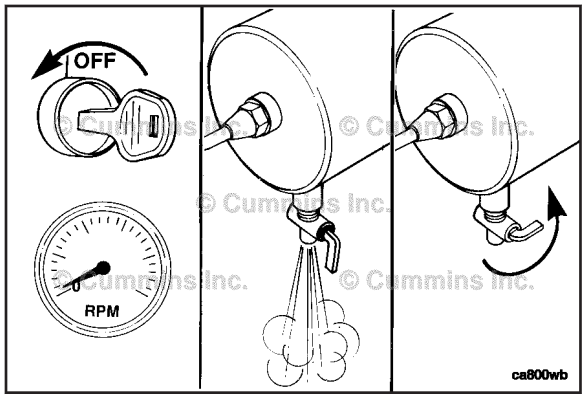
Install and tighten the accessory air lines.

Connect the line to the unloader valve.





Operate the engine, and check for air leaks.

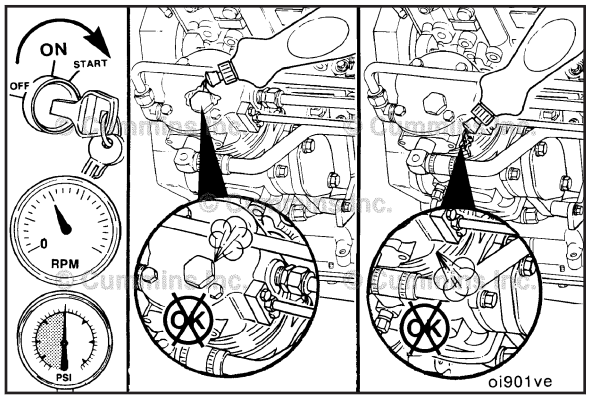


Air Leaks, Compressed Air System (012-019)

Leak Test

Shut off the engine.

Open the drain cock on the wet tank to release air from the system. Close the draincock after the pressure is released.

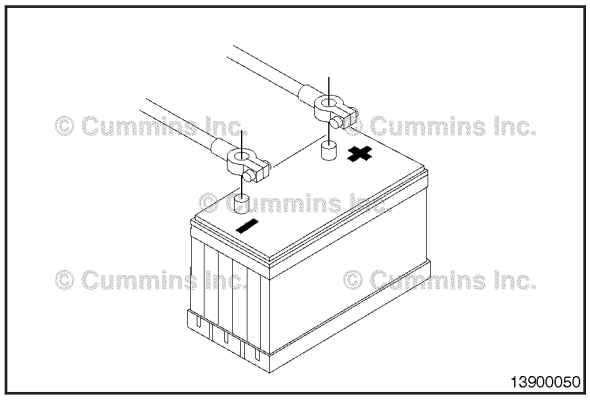


Operate the engine to activate the air compressor.

With the air compressor pumping between 550 to 690 kPa [80 to 100 psi], use a solution of soapy water to check for air leaks in the following areas:

- Unloader cover gasket
- Unloader pin o-ring
- Air compressor head gasket.

If air leaks are found, refer to the Master Repair Manual, Holset® Air Compressors, Bulletin 3666121 for repair of these components.



Air Compressor Cylinder Head (Holset® SS191 Model) (012-101)

Preparatory Steps

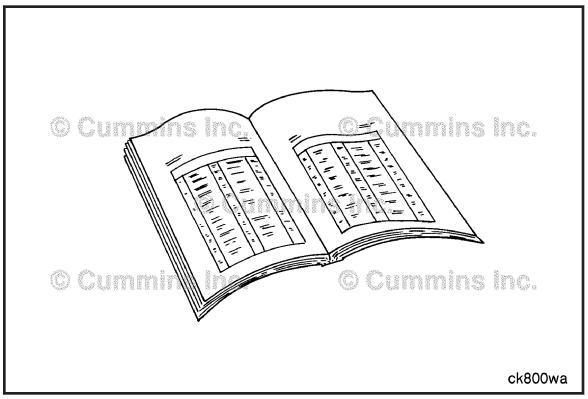
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Remove the batteries.

⚠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.

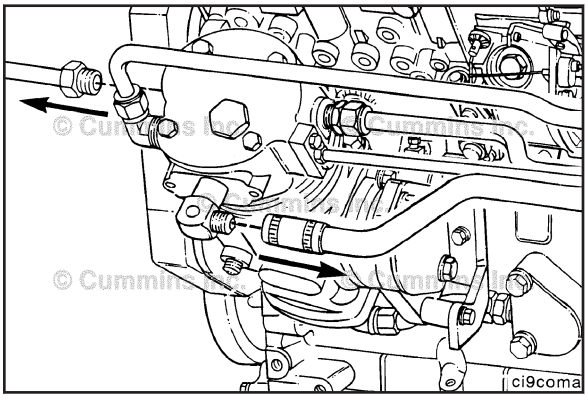
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

- Steam-clean the air compressor and dry with compressed air.
- Drain the engine coolant if the air compressor has a liquid cooled cylinder head. If compressor is air cooled, then the engine coolant need **not** be drained. Refer to Procedure 008-018 if coolant needs to be drained.
- Open the draincock on the wet tank to release air from the system. Close the draincock after the pressure is released.

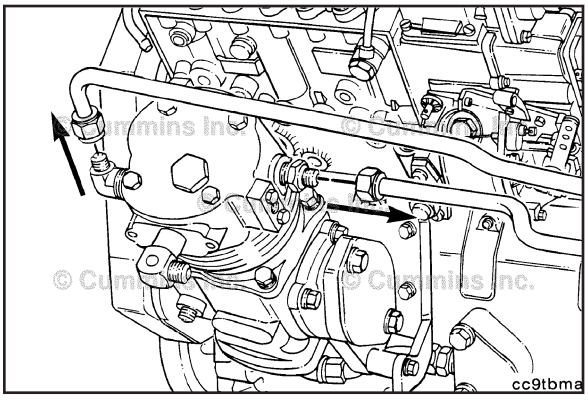


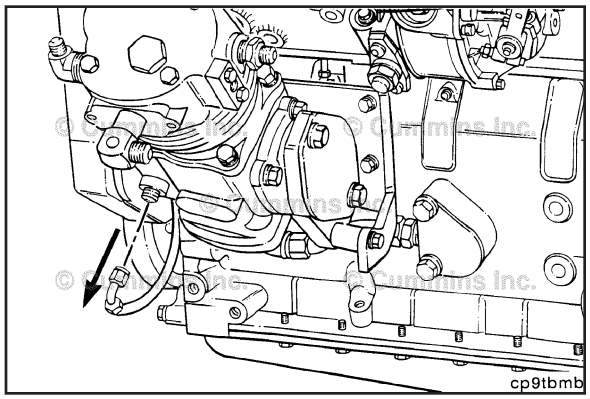
Remove

Remove the air connections from the air compressor.

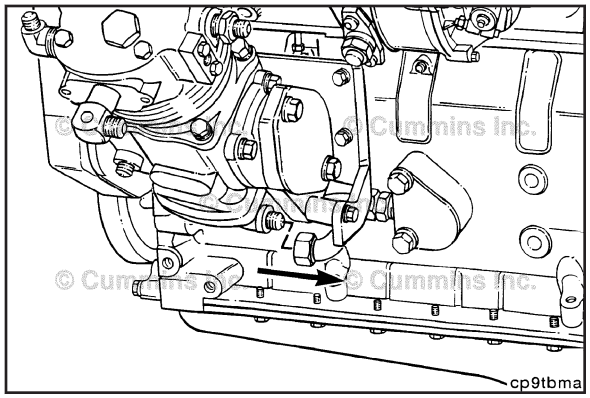


Remove the coolant lines from the air compressor (does **not** apply to air cooled compressors).

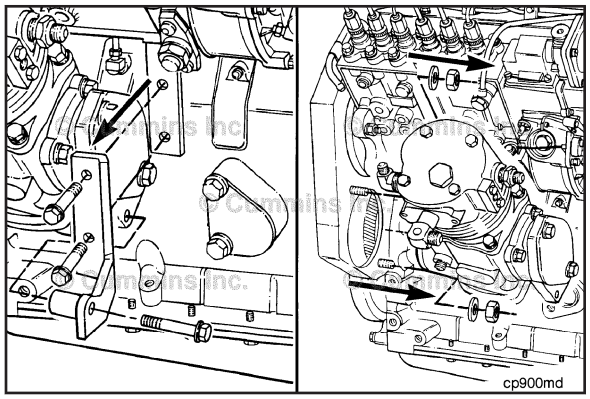




Remove the oil supply line.



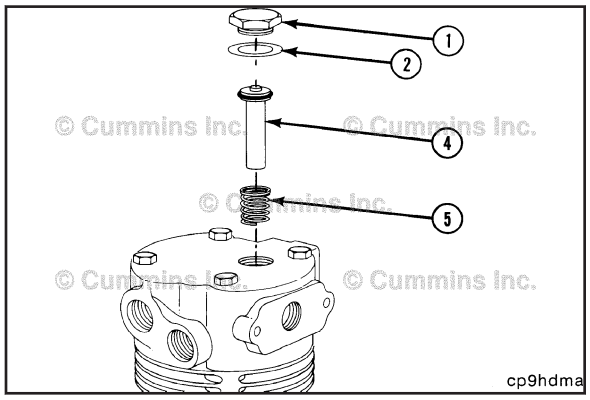
Remove the oil return line from the bottom of the air compressor.



Remove the air compressor support bracket and capscrews.

Remove the air compressor mounting nuts.

Remove the air compressor.



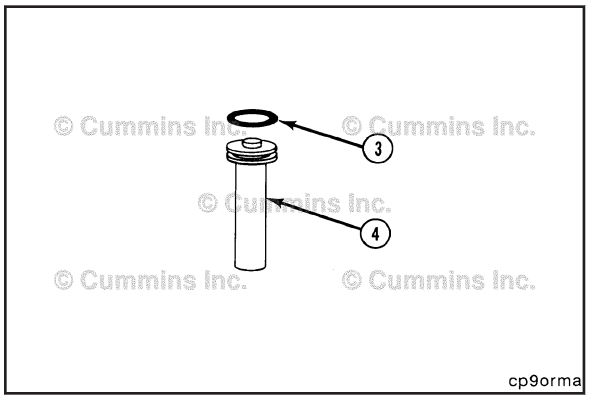
Disassemble

Remove the following parts:

- Unloader cover (1)
- Copper washer (2)
- Unloader pin (4)
- Spring (5).

Discard the copper washer.

Remove and discard the o-ring (3) from the unloader pin (4).

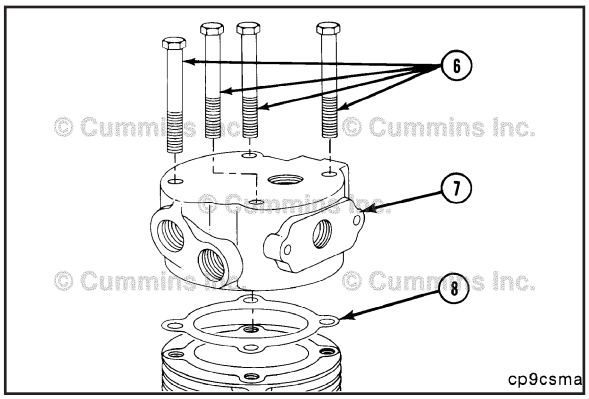


Remove the four cylinder head capscrews (6).

Remove the cylinder head (7).

Remove and discard the cylinder head gasket (8).

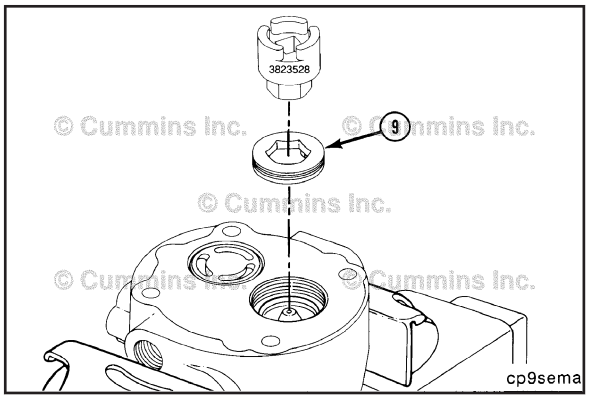
Service Tip: Scribe a mark to show proper head orientation before removing the head.



Air Compressor Seat Socket or 3/4-Inch Allen Wrench, Part Number 3823528

Install the head with the bottom side up in a soft-jawed vise.

Remove the exhaust valve seat (9).

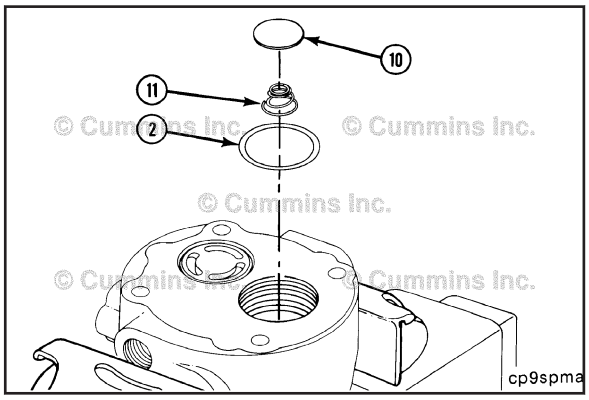


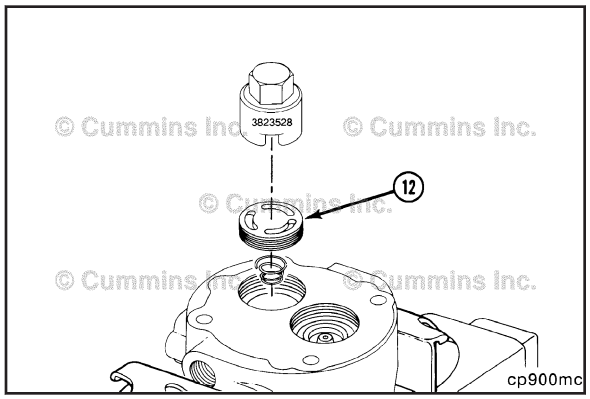
Remove the following parts:

- Exhaust valve disc (10)
- Spring (11)
- Copper washer (2).

Discard the copper washer.

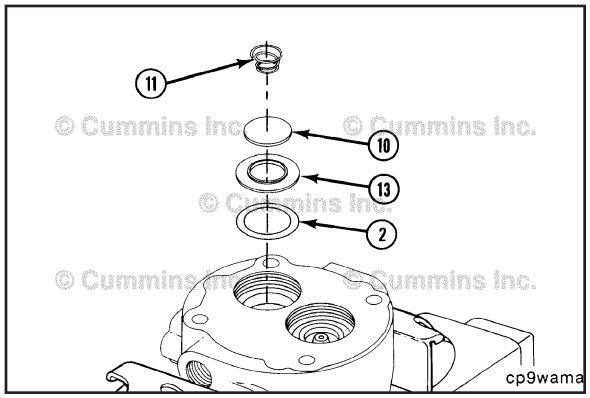
NOTE: The exhaust valve stop is pressed in place and **must not** be removed.





Air Compressor Seat Socket, Part Number 3823528

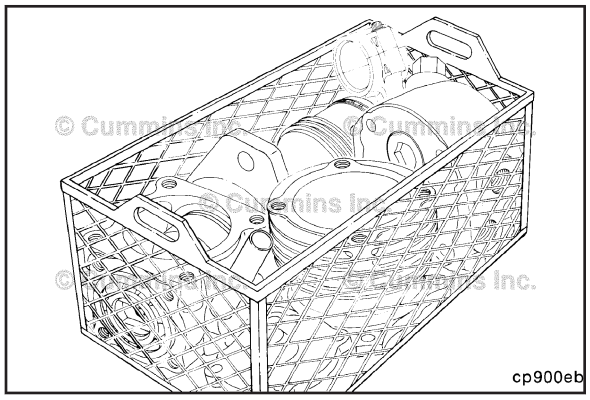
Remove the inlet valve cage (12).



Remove the following parts:

- Spring (11)
- Inlet valve disc (10)
- Inlet valve seat (13)
- Copper washer (2).

Discard the copper washer



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.

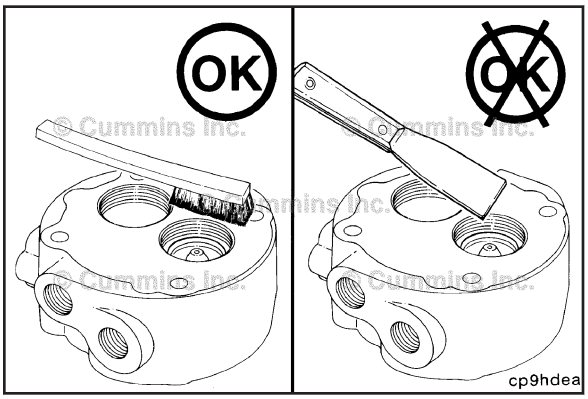
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause bodily injury.

Soak the parts in a kerosene emulsion-based cleaner designed to remove carbon. The cleaner **must** have a pH of 9.5 or less to avoid turning aluminum parts black. The cleaner manufacturer or supplier can be contacted about solution concentration, temperature, and soak time.

Dry with compressed air.

⚠CAUTION⚠
Do not use a scraper to remove carbon and scale. This can damage sealing surfaces.

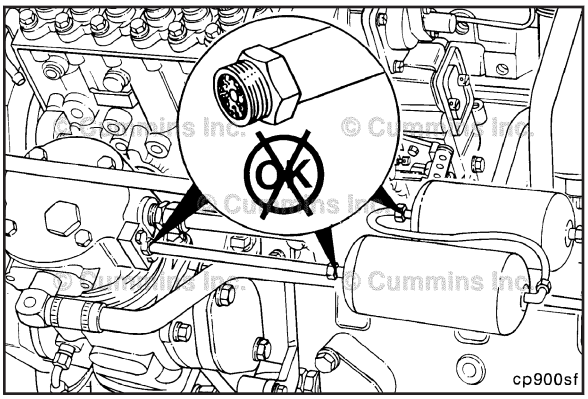
Use a stiff, nonmetallic bristle brush to scrub the parts.



⚠WARNING⚠
The air discharge line must be capable of withstanding extreme heat and pressure to avoid the possibility of personal injury and property damage. Refer to the manufacturer's specifications.

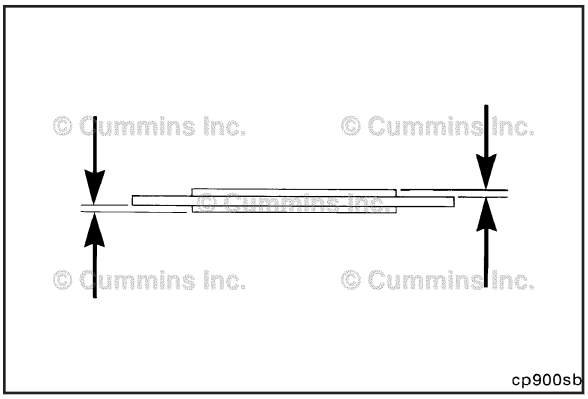
Continue to check for carbon buildup in the air discharge line connections up to the first or wet tank.

Clean or replace any lines and fittings with carbon deposits greater than 1.6 mm [0.06 (1/6) in]. Refer to the manufacturer's specifications for cleaning or replacement instructions.



Valve Discs

Inspect and replace if cracked, pitted, or grooved in excess of 0.13 mm [0.005 in].

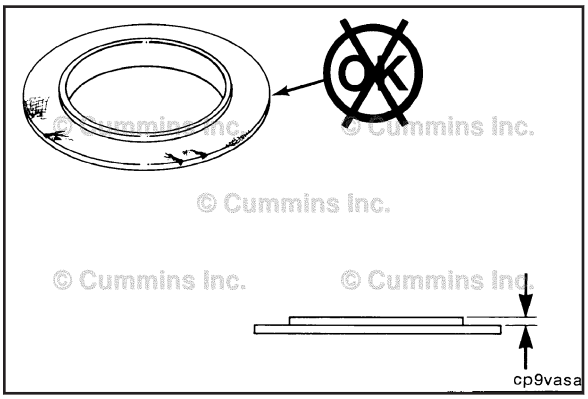


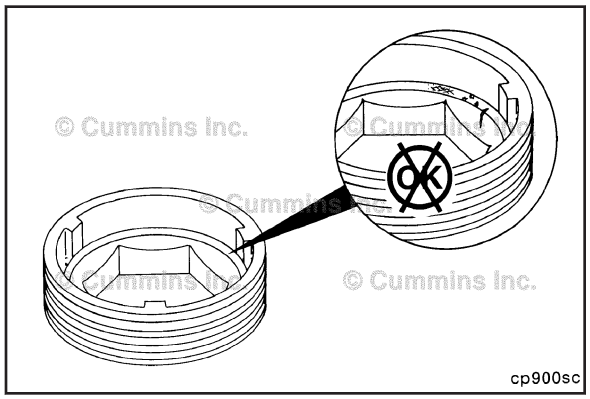
Inlet Valve Seat

Measure the distance from the valve seating surface to the surface that contacts the valve cage.

Intake Valve Seat		
mm		**in**
0.597	MIN	0.0235
0.673	MAX	0.0265

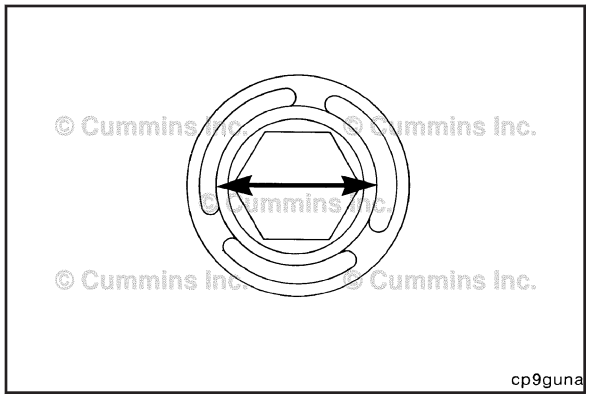
Replace the intake valve seat if **not** within limits or if cracked or damaged.





Exhaust Valve Seat

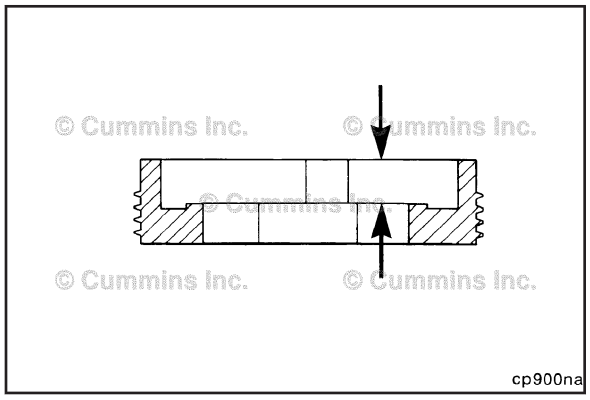
Inspect the seat for damage and wear.



Measure the valve guide diameter.

Valve Guide Diameter		
mm		**in**
25.53	MIN	1.005
25.65	MAX	1.010

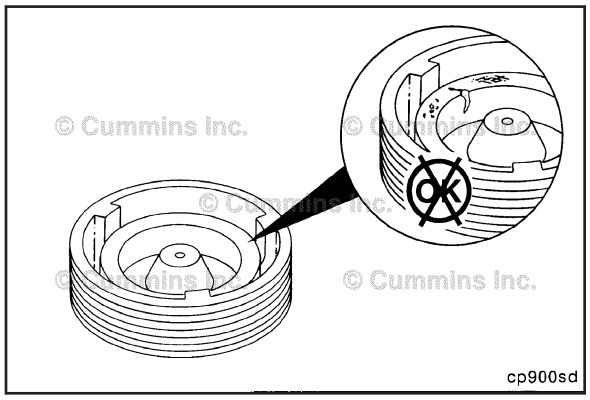
Replace the exhaust valve seat if **not** within limits.



Measure the distance from the top of the valve seat to the valve seating surface.

Set Height		
mm		**in**
4.01	MIN	0.158
4.11	MAX	0.162

Replace the exhaust valve seat if **not** within limits.



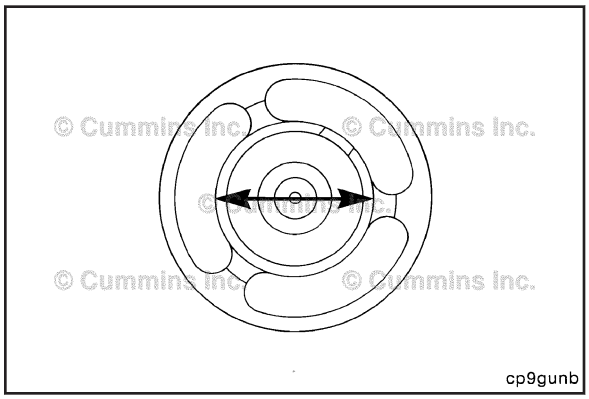
Inlet Valve Cage

Inspect the inlet valve cage for damage and wear.

Measure the valve guide diameter.

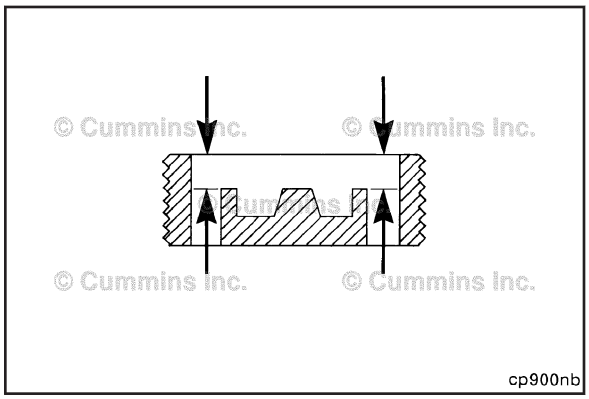
Valve Guide Diameter		
mm		in
25.53	MIN	1.005
25.65	MAX	1.010

Replace the inlet valve cage if **not** within limits.



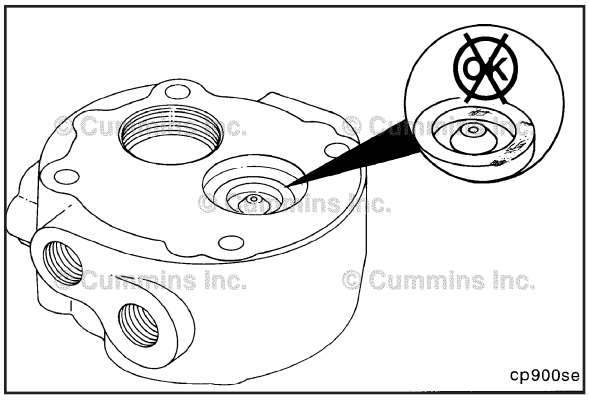
Measure the top of the cage to the valve stop.

Stop Depth		
mm		in
3.63	MIN	0.143
3.78	MAX	0.149



Exhaust Valve Stop

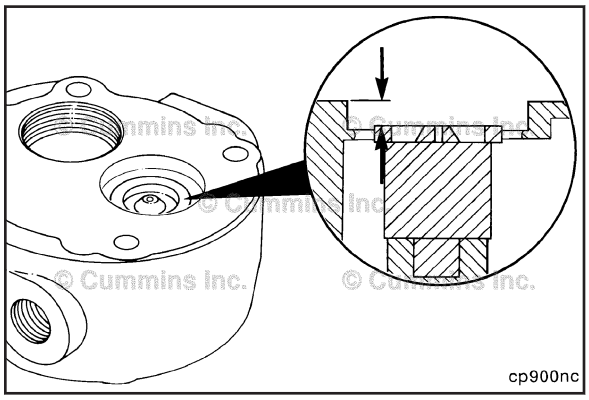
Inspect the exhaust valve stop. Replace the cylinder head assembly if the stop is loose or damaged.

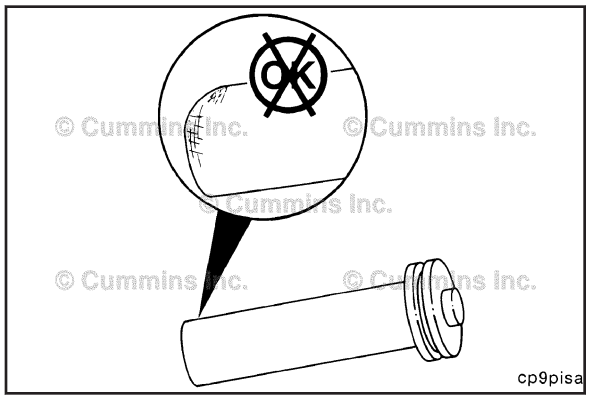


Measure the distance from the valve end of the stop to the face of the cylinder head.

Stop Height		
mm		in
4.42	MIN	0.174
4.70	MAX	0.185

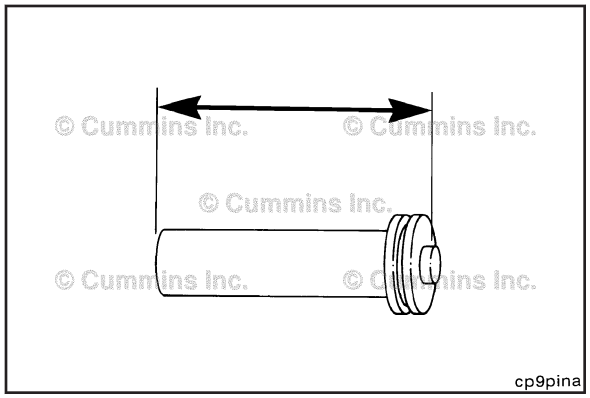
Replace the cylinder head if **not** within limits.





Unloader Pin

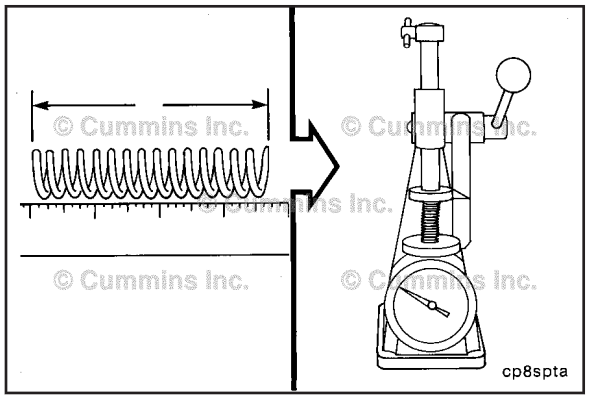
Inspect for scoring or pitting.



Measure the length of the pin.

Pin Length		
mm		**in**
40.51	MIN	1.595
40.72	MAX	1.603

Replace the pin if **not** within limits.



Valve Springs

Valve Spring Tester, Part Number 3375182

NOTE: Cummins Inc. recommends that new springs be installed during rebuild.

Use valve spring tester, Part Number 3375182, to check the springs.

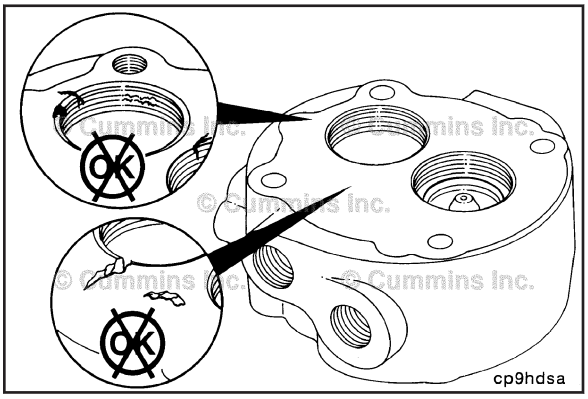
Replace if **not** within limits in Table 1, shown below.

Table 1: Spring Data

Load Required to Compress Spring to Length						
	Spring Length		Minimum		Maximum	
	mm	in	Kg	lb	Kg	lb
Inlet Valve	5.08	0.20	0.272	0.60	0.340	0.75
Unloader	10.0330	0.395	1.53	3.37	1.90	4.19
Exhaust Valve	5.08	0.20	0.272	0.60	0.340	0.75

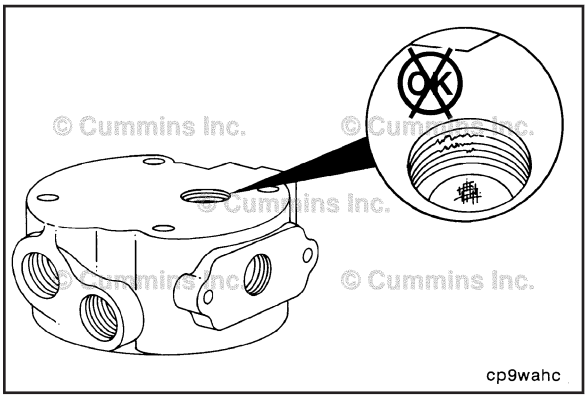
Cylinder Head

Inspect and replace if cracks, nicks, gouges, or damaged threads are found.



Inspect the unloader seal bore for scoring or pitting.

Replace the cylinder head if damaged.

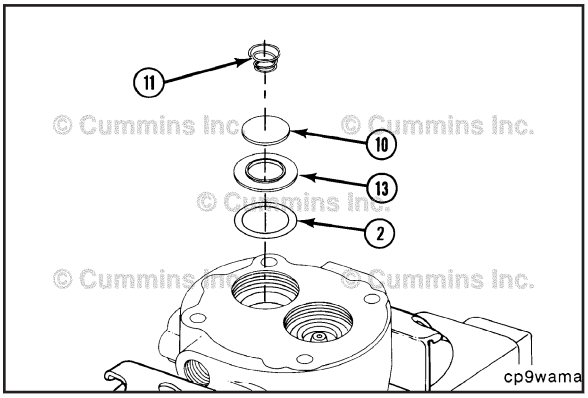


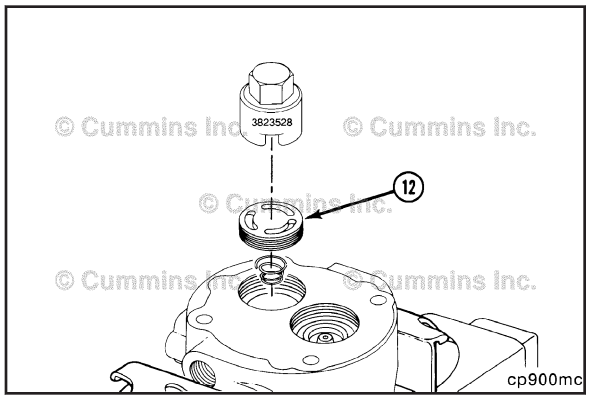
Assemble

Turn the cylinder head bottom side up, and install it in a soft-jawed vise.

Install the following parts.

a. New washer (2)
b. Inlet valve seat (13)
c. Inlet valve (10)
d. Inlet valve spring (11).

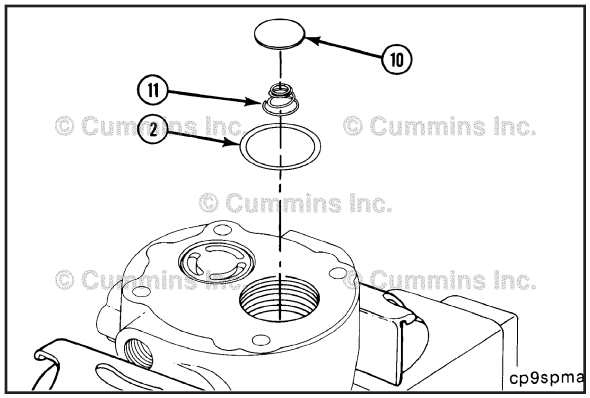




Air Compressor Seat Socket, Part Number 3823528

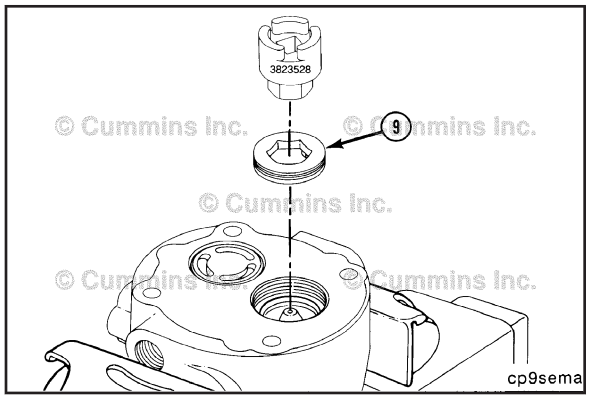
Tighten the cage (12).

Torque Value: 108 N•m [80 ft-lb]



Install the following parts:

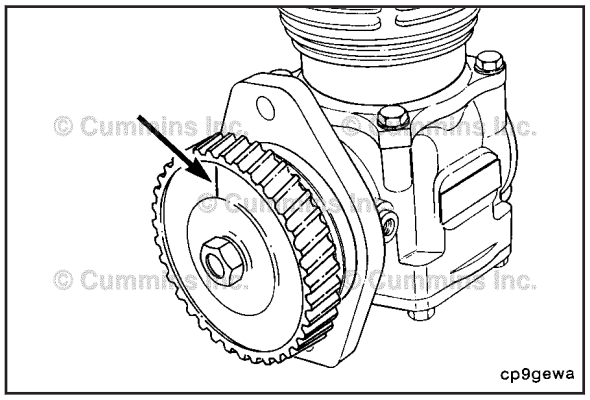
a. New washer (2)
b. Exhaust valve spring (11)
c. Exhaust valve disc (10).



Air Compressor Seat Socket, Part Number 3823528, or 3/4-Inch Allen Wrench

Tighten the seat (9).

Torque Value: 108 N•m [80 ft-lb]



Prior to installing the cylinder head, locate top dead center of the piston on the air compressor.

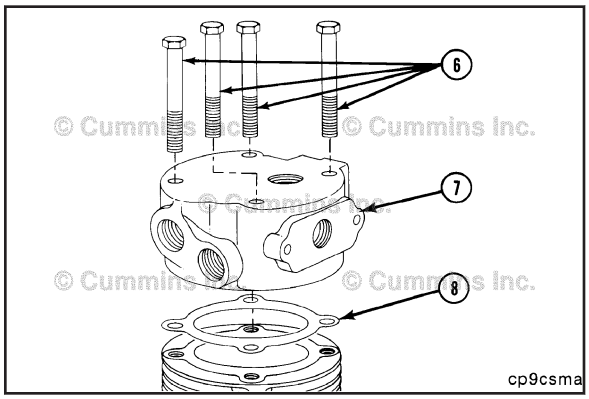
Rotate the air compressor so that the piston is at the top.

Use ink or Dykem® to mark the air compressor gear face at top dead center (12-o'clock position when viewed from the front).

NOTE: Top dead center does not have to be exact. The system is tolerant of some misalignment.

Install a new gasket (8) and the cylinder head (7) to the cylinder block, aligning the scribe marks.

Install the four capscrews (6).

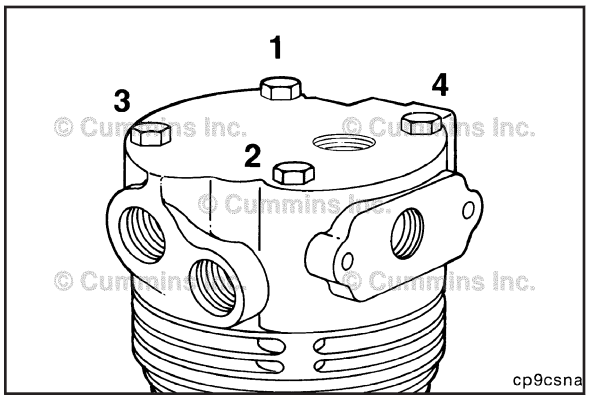


Tighten the capscrews.

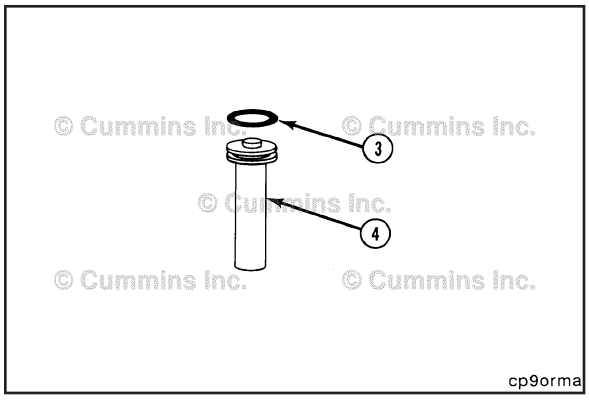
Torque Value: 30 N•m [22 ft-lb]

Tighten the capscrews again, in the sequence shown.

Torque Value: 41 N•m [30 ft-lb]



Install a new o-ring (3) on the unloader pin (4).

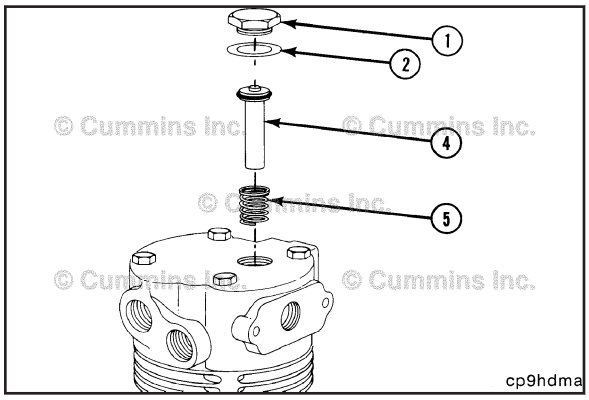


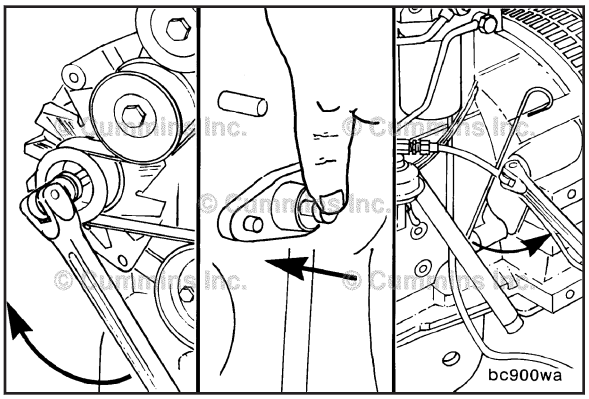
Install the following parts:

a. Spring (5)
b. Unloader pin (4)
c. New washer (2)
d. Unloader cover (1).

Tighten the cover.

Torque Value: 41 N•m [30 ft-lb]

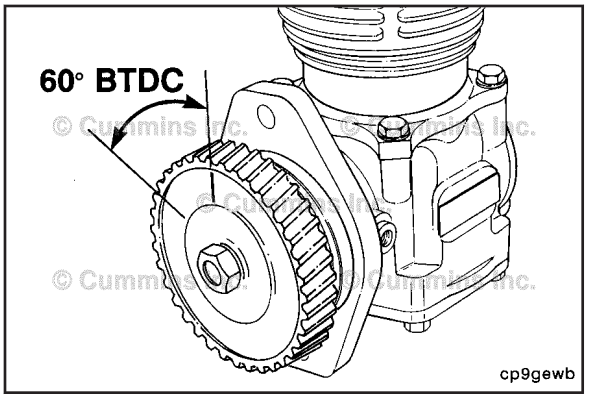




Install

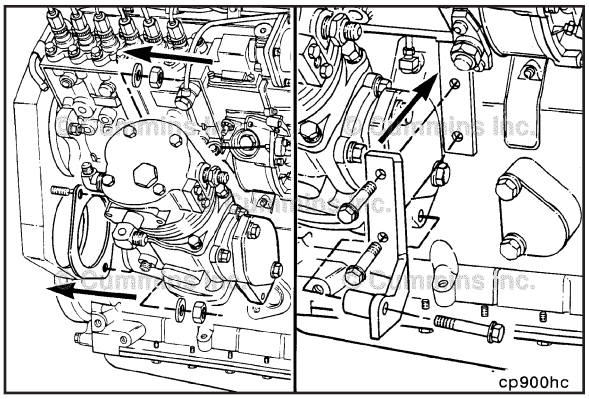
NOTE: Be sure to disengage the timing pin after locating top dead center .

Locate top dead center for cylinder Number 1 by barring the crankshaft slowly while pushing on the timing pin.



Rotate the compressor top dead center mark to 60 degrees, or 6 teeth on a 36-tooth gear, before top dead center. This is approximately 10-o'clock when viewed from the front of the air compressor.

NOTE: Holset® air compressors Series SS, QE296 and 338 will have a radial line etched on the gear representing top dead center .



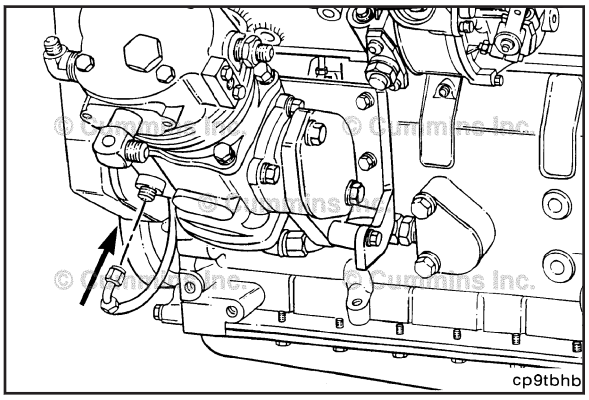
Use a new gasket. Install the air compressor to the gear housing.

Install the air compressor support bracket.

Torque Value:

Mounting Nuts	77 N•m	[57 ft-lb]
Support Capscrews	24 N•m	[18 ft-lb]

NOTE: No timing of gears is necessary.

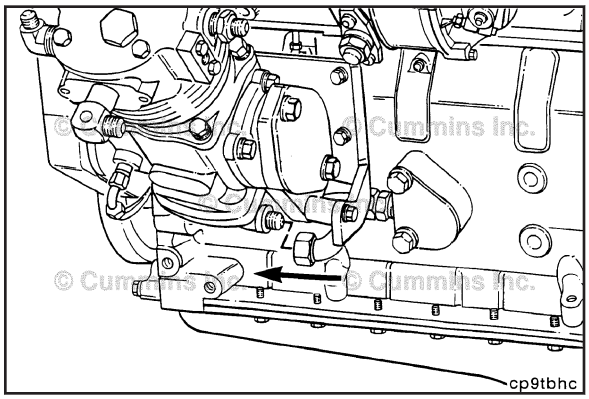


Install the oil supply line.

Torque Value: 15 N•m [133 in-lb]

Install the oil drain to the bottom of the compressor.

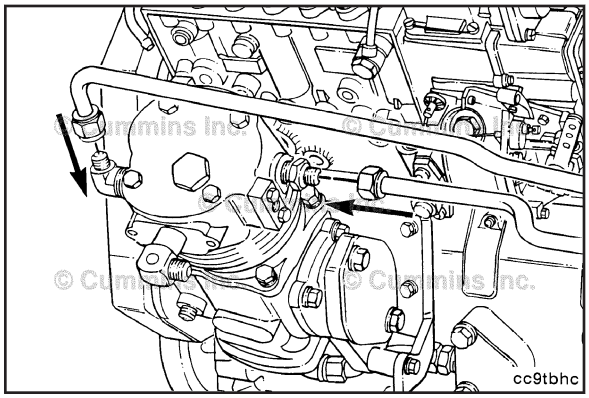
Torque Value: 24 N•m [18 ft-lb]



⚠CAUTION⚠
If rubber grommets are used on the coolant or air lines, be sure they are installed carefully to prevent cuts or tears to the grommets, which will cause leaks.

Install the coolant lines.

Torque Value: 24 N•m [18 ft-lb]



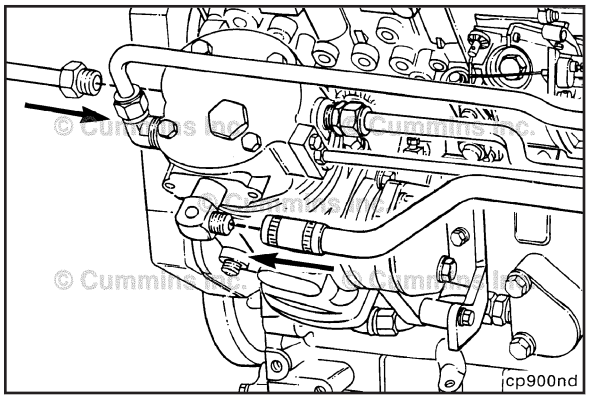
Install and tighten the air inlet and outlet connections.

Torque Value:

Inlet	5 N•m	[44 in-lb]
*Outlet	24 N•m	[18 ft-lb]

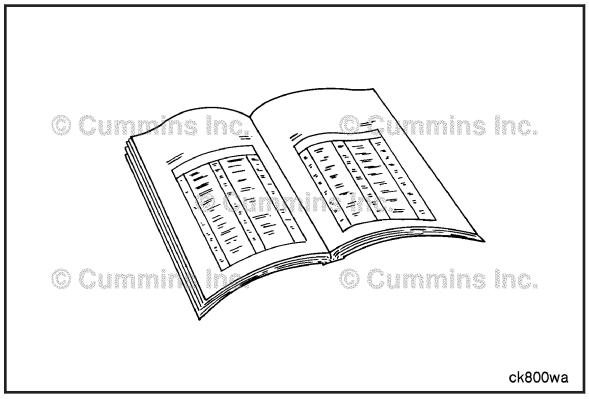
*1/2 NPT fitting in head

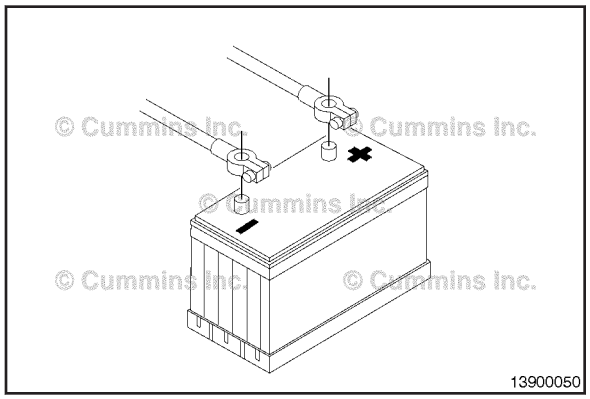
NOTE: Torque of the discharge line is dependent upon line size and type. Consult vehicle manufacturer for correct torque value.



Finishing Steps

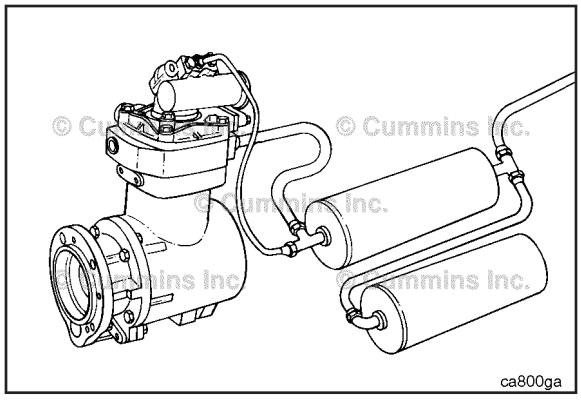
- Fill the engine cooling system (liquid cooled air compressor **only**). Refer to Procedure 008-018.





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

- Connect the batteries
- Close the wet tank draincock
- Operate the engine to activate the air compressor. With the air compressor pumping between 550 to 690 kPa [80 to 100 psi], use a solution of soapy water to check for air leaks.

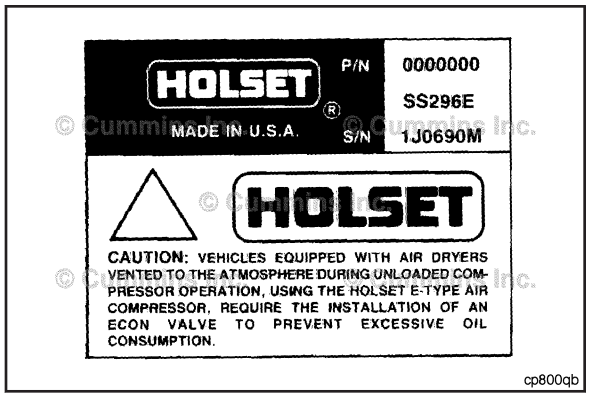


Air Compressor Cylinder Head (Holset® QE Models) (012-104)

General Information

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

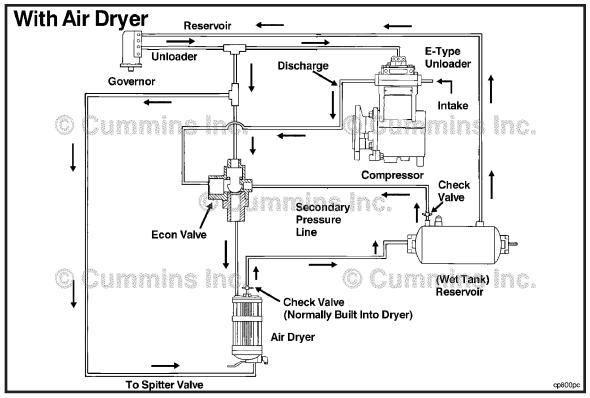
The Holset® single-air compressors are engine-driven, piston-type compressors that supply compressed air to operate air-activated devices. The compressor runs continuously, but has a loaded and unloaded operating mode.



E-Type Air Compressor

Holset® SS model air compressors built with the E-Type unloader can be identified by the letter “E” (SS296E, and SS338E) and by the caution on the dataplate.

All QE (QE296 and QE338) model air compressors are equipped with the E-Type unloader.



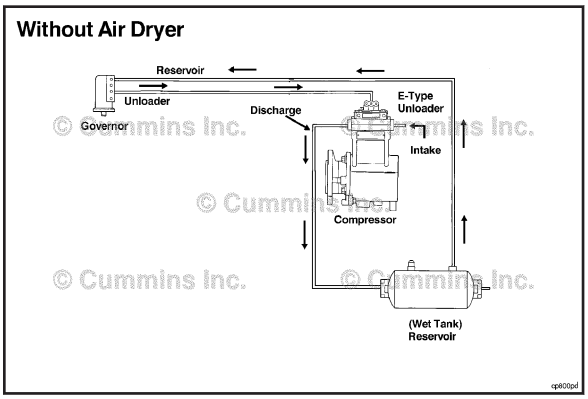
E-Type System with Air Dryer

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

NOTE: Some air dryers can have a built-in econ valve. Check with the manufacturer as to which type is installed.

E-Type System without Air Dryer

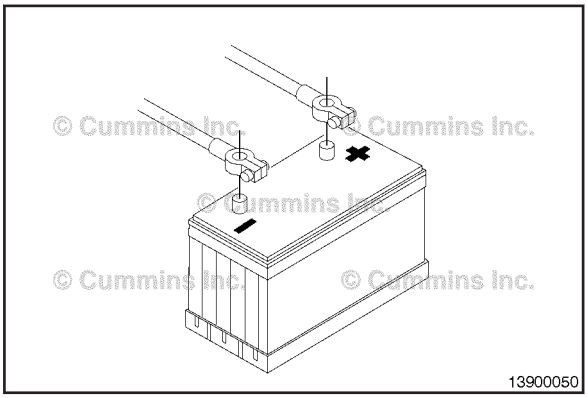
Air systems **without** air dryers, or with air dryers **not** vented to the atmosphere during unloaded compressor operation, can use the Holset E-Type unloader valve without modifying the air system.



Preparatory Steps

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

- Disconnect the batteries.

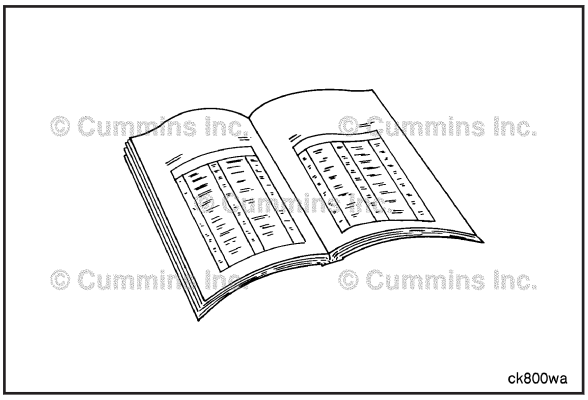


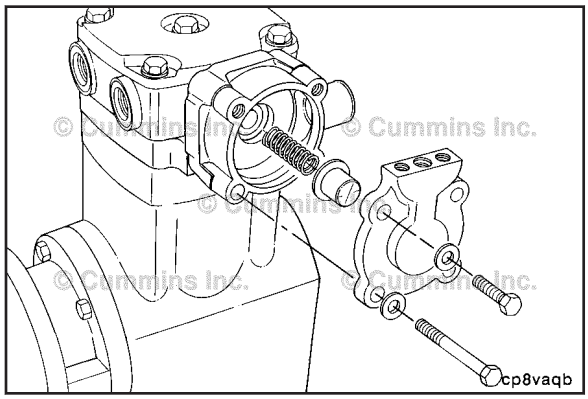
⚠WARNING⚠
Coolant is toxic. Keep away from pets and children. If not reused, dispose of in accordance with local environmental regulations.

⚠WARNING⚠
Do not remove the pressure cap from a hot engine. Wait until the coolant temperature is below 50°C [122°F] before removing the pressure cap. Heated coolant spray or steam can cause personal injury.

NOTE: If the cylinder head is removed while the air compressor is on the engine, drain the engine coolant. Refer to Procedure 008-018.

NOTE: Since the valve plate, head, and unloader body are indexible, marking these parts is recommended to make sure they are reassembled in the proper orientation.





Disassemble

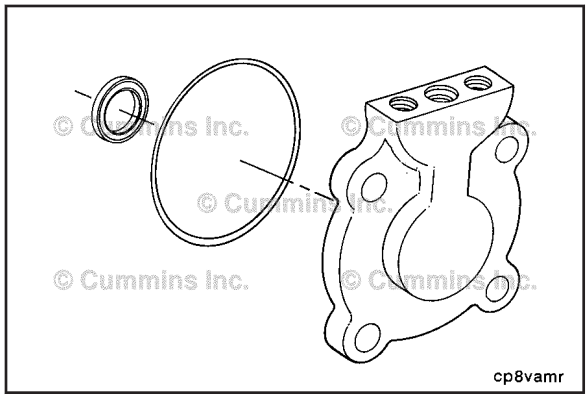
⚠WARNING⚠
The unloader body is installed with spring tension. Use care when removing to prevent personal injury. Always wear protective eyewear.

Hold the unloader valve body down, and remove the four capscrews.

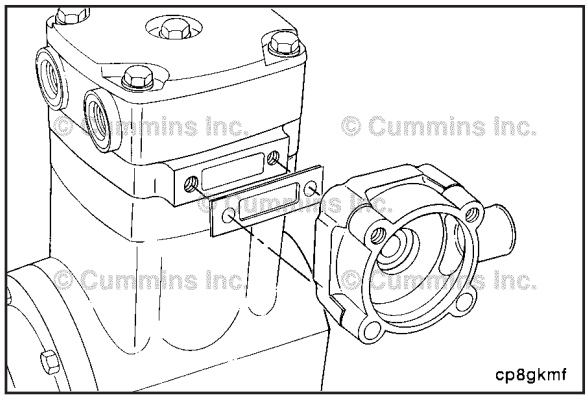
Remove the unloader valve body.

Remove the unloader valve spring.

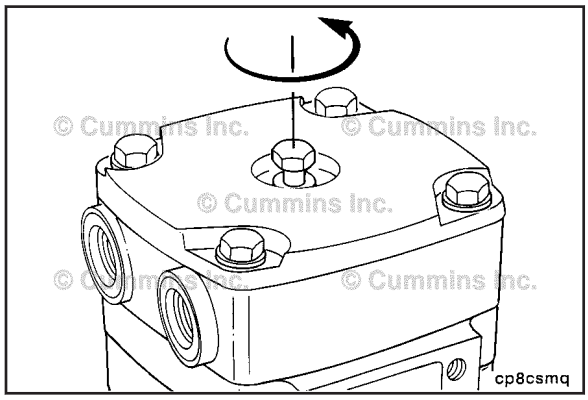
Remove the unloader valve cap.



Remove the unloader body gasket and unloader valve cap rectangular ring seal.



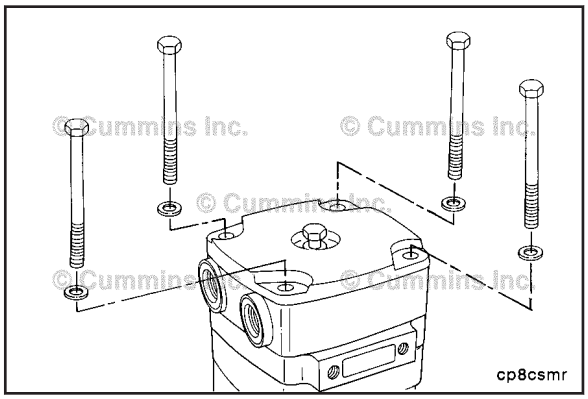
Remove the compressor intake manifold and gasket.



Loosen, but do **not** remove, the center head capscrew.

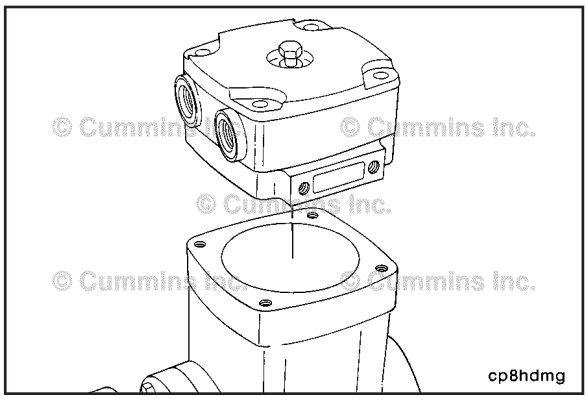
Mark the head for orientation during assembly.

Loosen and remove the four corner head capscrews. Save the capscrews for reuse.



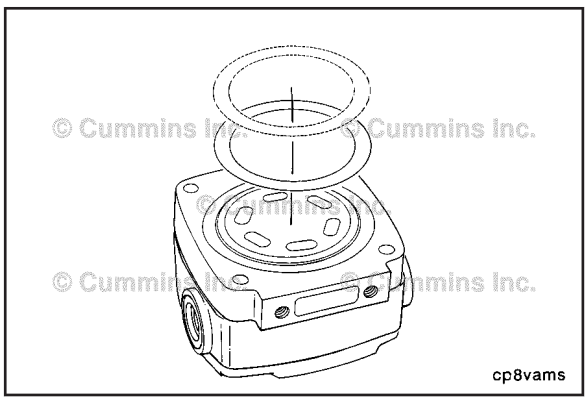
Remove the head, cover, and valve plate assembly and place it on a clean work surface with the intake valve facing upward.

NOTE: If continuing with disassembly of the head, valve plate, and cover, be sure the work surface is clean. Grit pushed into the valve sealing surfaces by setting components on a dirty surface will cause a malfunction after assembly.



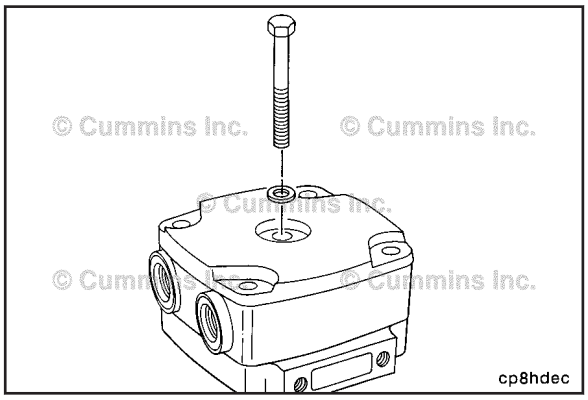
Some units have a press-fit intake valve retainer. If present, carefully remove it to prevent part damage.

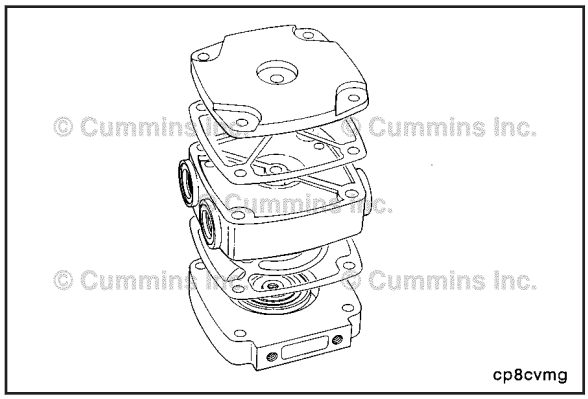
Remove the intake valve.



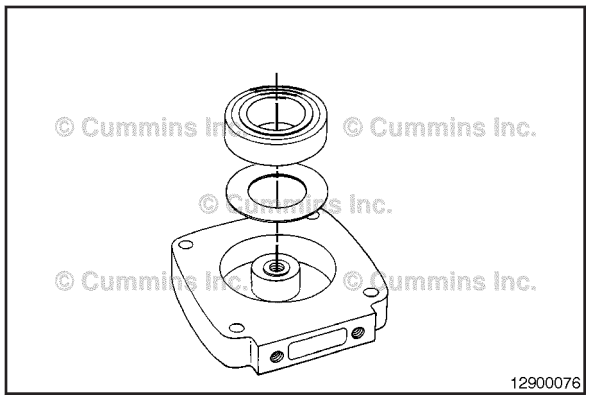
Turn the head assembly over and set it on a clean surface. Remove the center capscrew. This capscrew can be reused.

NOTE: The center capscrew is shorter than the four corner capscrews.



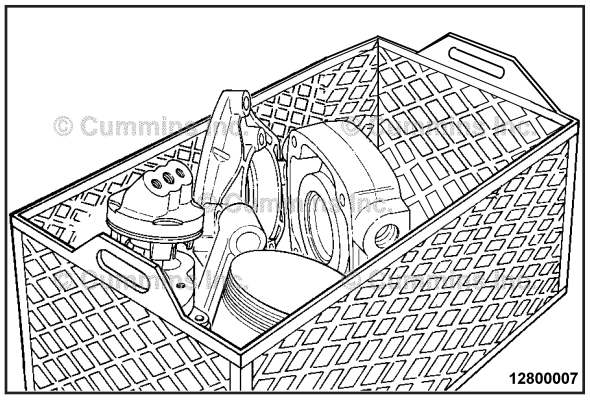


Remove the cover, cover gasket, head, and head gasket.



Remove the exhaust valve retainer and exhaust valve.

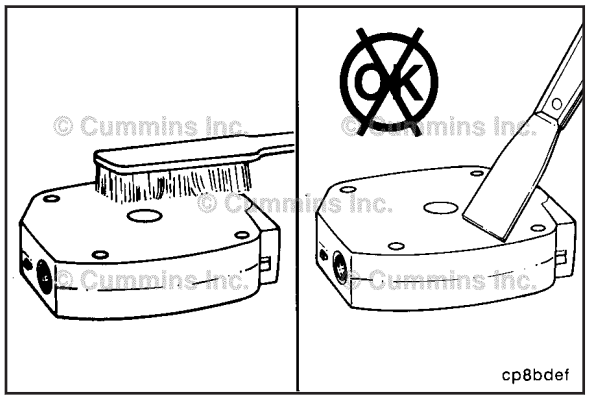
NOTE: The wave washers **must** be replaced.



Clean and Inspect for Reuse

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

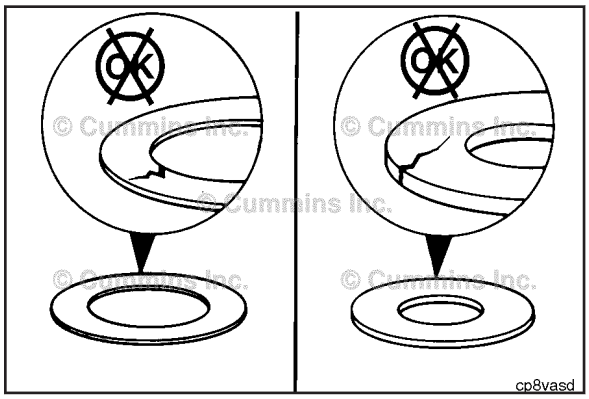
Soak the parts in a kerosene emulsion-based cleaner designed to remove carbon. The cleaner **must** have a pH of 9.5 or less to avoid turning aluminum parts black. The cleaner manufacturer or supplier can be contacted about solution concentration, temperature, and soak time.



NOTE: Do **not** use a scraper to remove carbon and scale; the sealing surfaces can be damaged.

The parts can be scrubbed with a stiff, nonmetallic bristle brush.

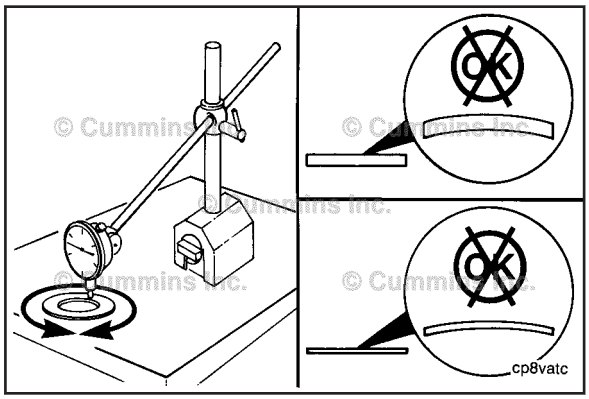
Inspect the intake and exhaust valves for cracks or damage.



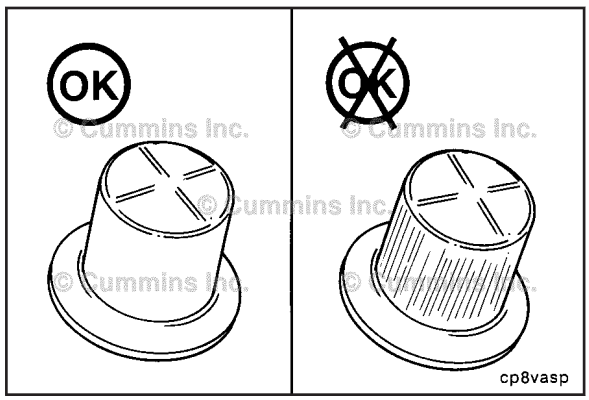
Measure the flatness of the intake and exhaust valves. Both valves **must** be flat within 0.03 mm [0.001 in].

Replace valves if cracked, damaged, or **not** flat.

NOTE: Holset® Engineering Co., Inc., recommends new valves be installed.



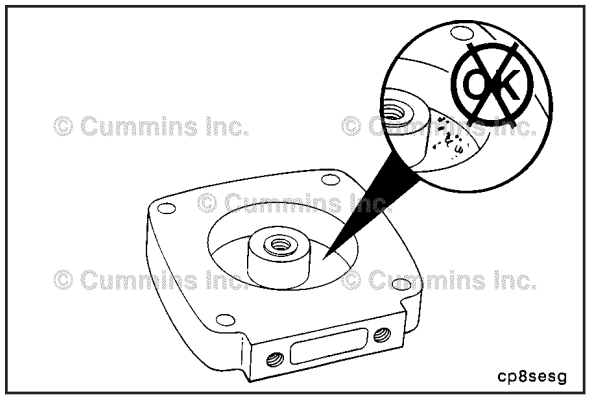
Inspect the upper part of the unloader valve cap where the rectangular v-seal operates. Check for scoring.

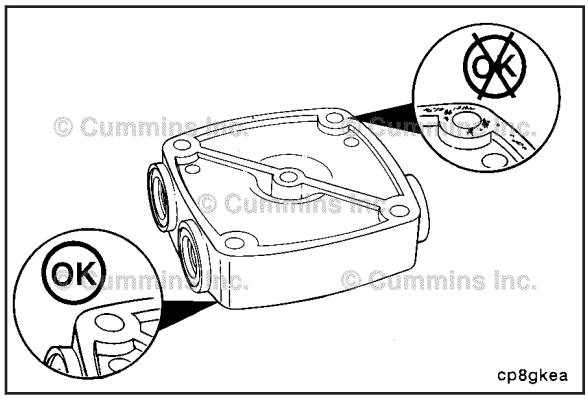


Inspect the valve seat surfaces.

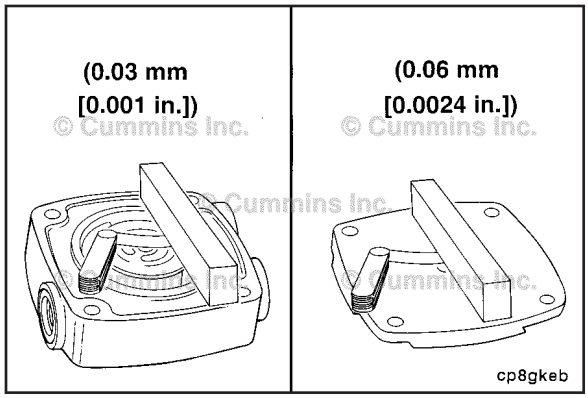
NOTE: Inspection of the valve seats in the valve plate requires specialized equipment and is beyond the scope of field service.

If the valve seat is visibly damaged, or can **not** be cleaned, a new valve plate is available in a service kit. Otherwise, a QE valve plate service assembly can be used.

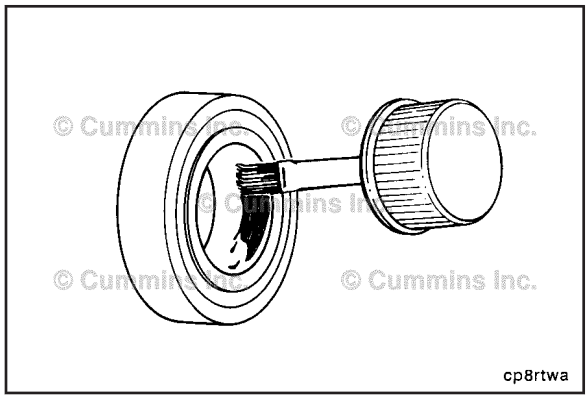




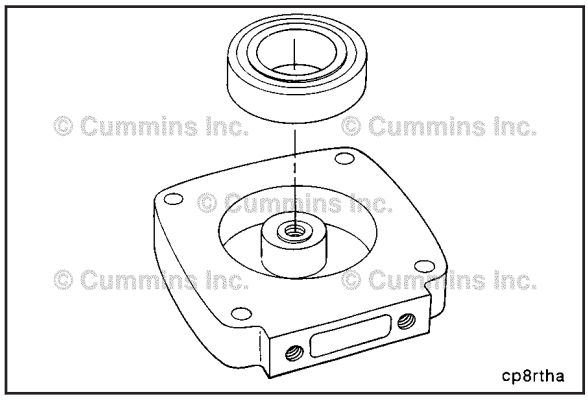
Gasket sealing surfaces **must** be clean and free of all old gasket material, carbon, rust, and other buildup. Surfaces **must** be free of scratches, gouges, burrs, and other deformities.



After making sure all gasket surfaces are clean and free of the above, inspect the head and cover for flatness. Use the flat plate and the feeler gauges.

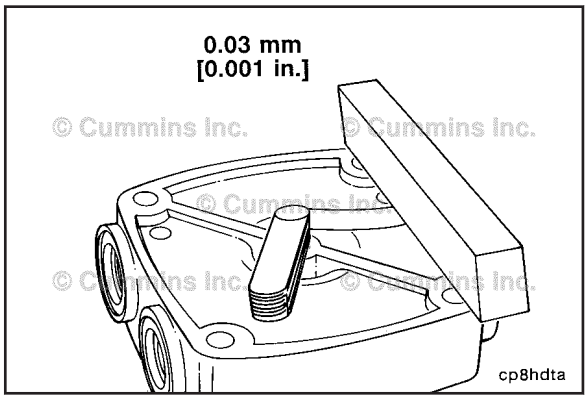


Apply a thin coating of anti-seize compound to the inside diameter of the exhaust valve retainer.

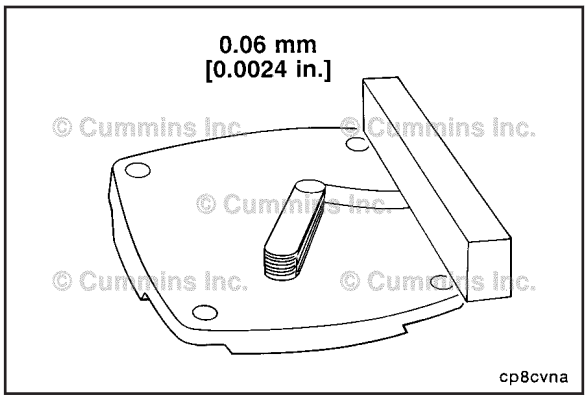


Slide the exhaust valve retainer over the valve plate. Make sure that the end of the retainer with the groove faces upward.

Single-cylinder heads **must** be flat within 0.03 mm [0.001 in] between any two adjacent capscrew holes.



Single-cylinder top cover **must** be flat within 0.06 mm [0.0024 in] between any two adjacent capscrew holes and 0.10 mm [0.004 in] total.



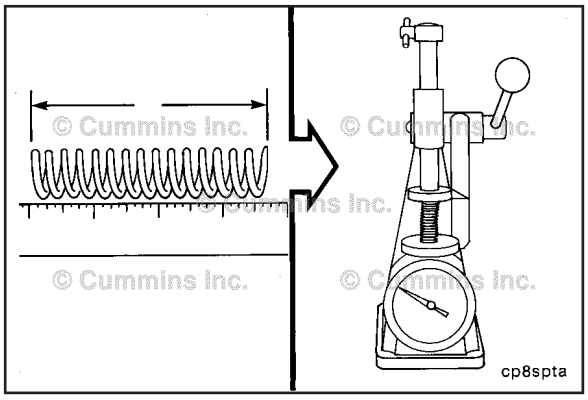
Use the valve spring tester, Part Number 3375182, to check the unloader valve spring (blue stripe).

Replace any spring that does **not** meet specifications.

Compress springs to 24.9 mm [0.98 in].

Force Specification		
kg		lb
10.4	MIN	23
12.5	MAX	27

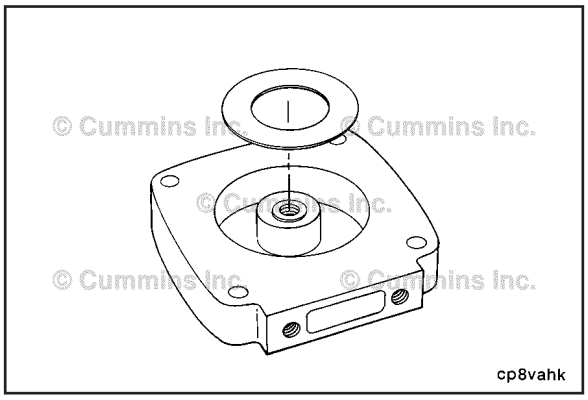
NOTE: Holset® recommends new springs be installed.

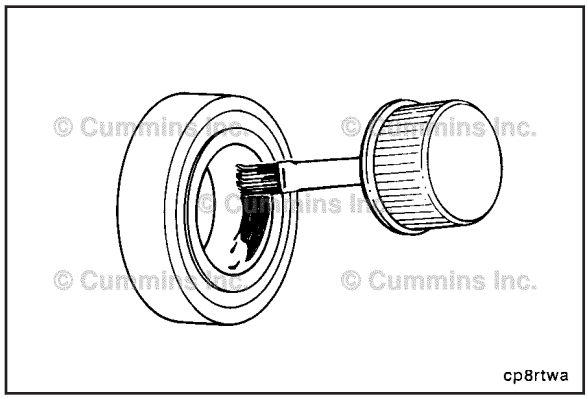


Assemble

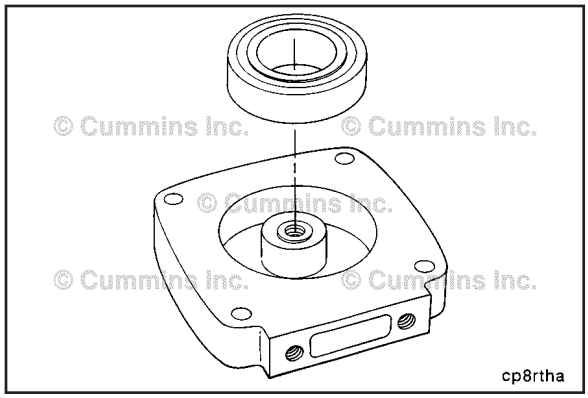
QE, Non-European

Install the exhaust valve over the post in the valve plate.

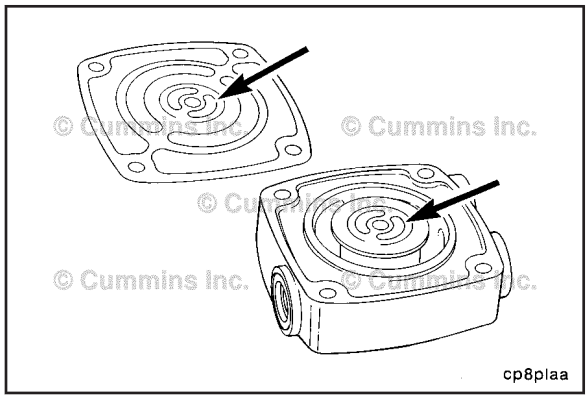




Apply a thin coating of anti-seize compound to the inside circumference of the exhaust valve retainer.

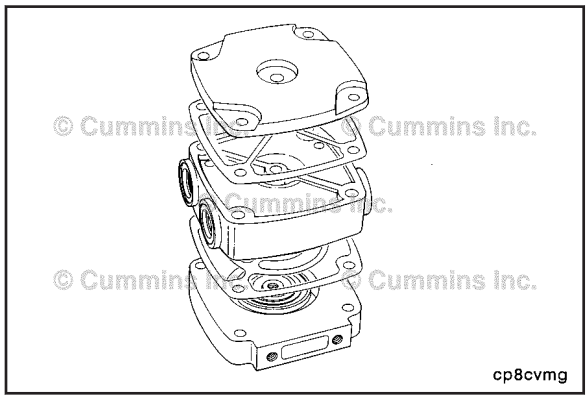


Slide the exhaust valve retainer over the valve plate. Make sure that the end of the retainer with the groove faces upward.



Determine the final orientation of the valve plate (air intake location) and the head (coolant ports in relation to air inlet or manifold location). Align the kidney-shaped slots in the head with the kidney-shaped slots in the gasket.

If orientation marks were made before disassembly, use them.



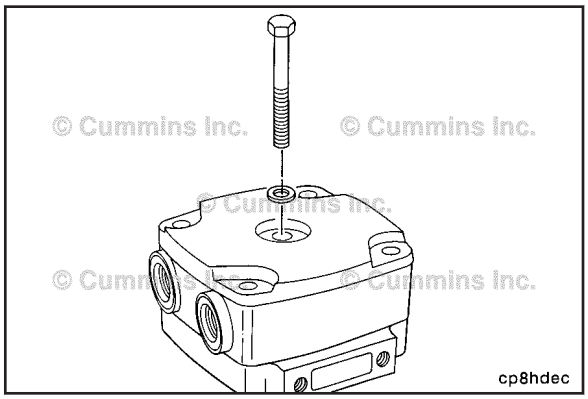
Assemble the cover, cover gasket, head, head gasket, and valve plate.

NOTE: Make sure corner capscrew holes are aligned.

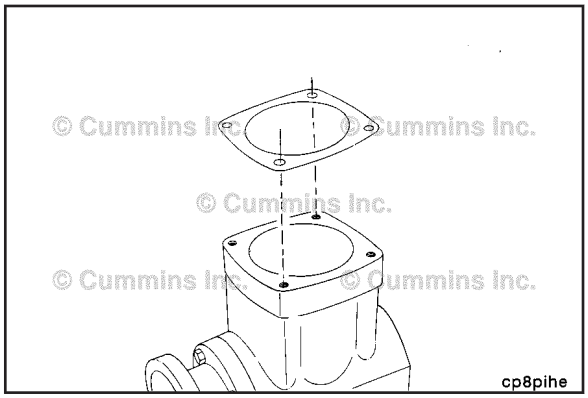
Lubricate the threads under the head.

Install the shorter capscrew with washer through the center hole.

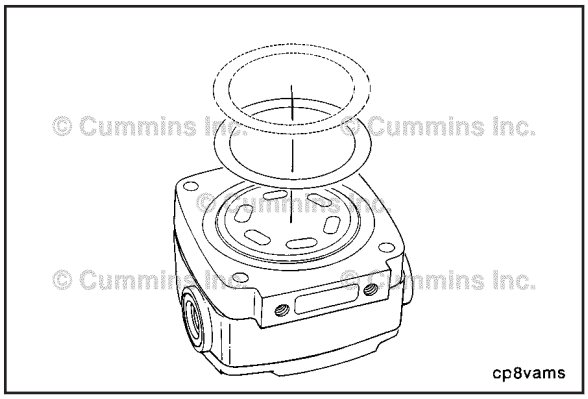
Torque Value: 14 N•m [124 in-lb]



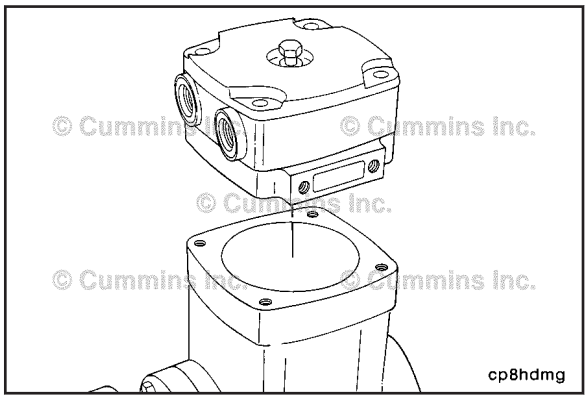
Install the valve plate gasket.

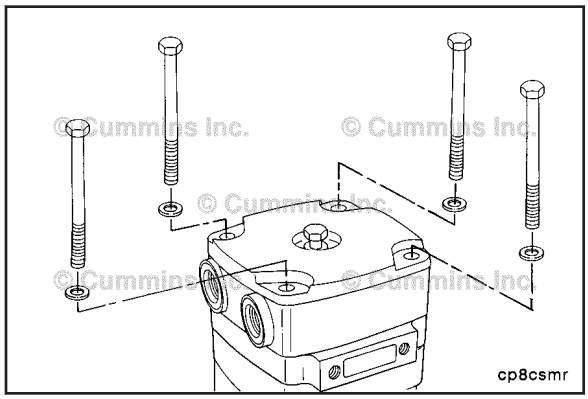


Carefully place the intake valve in the valve plate. Install the intake valve retainer.



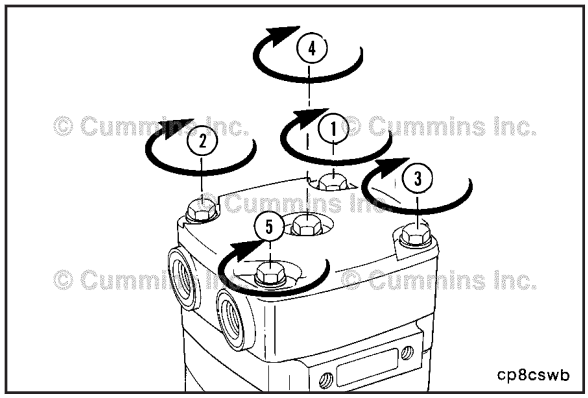
Install the valve plate assembly.





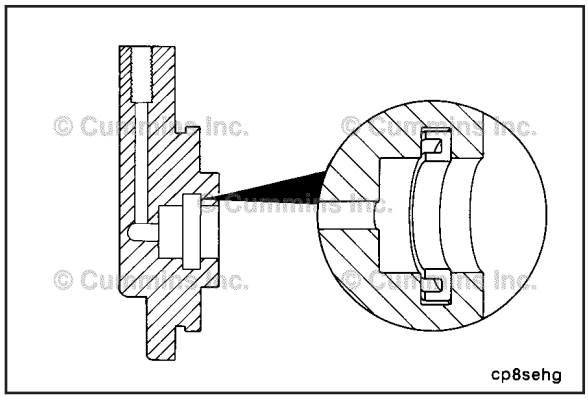
Lubricate the threads under the head and washer of the capscrews, if initially installed.

Install the four head capscrews and washers.



Tighten all five capscrews in the proper sequence.

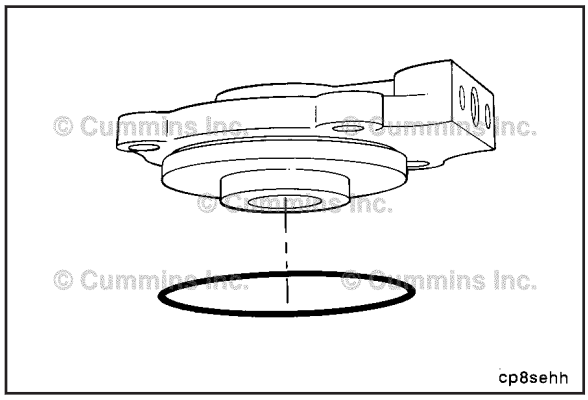
Torque Value: 28 N•m [21 ft-lb]



Install the new rectangular v-seal into the unloader body.

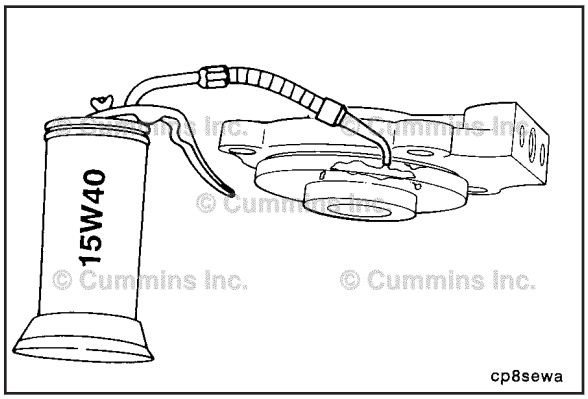
NOTE: The seal **must** be installed with the grooved side up.

Liberally lubricate the unloader valve bore above and below the rectangular ring seal with high-temperature grease (Accrolube lubrication Teflon™ grease or equivalent).



Install a new o-ring seal on the unloader valve body.

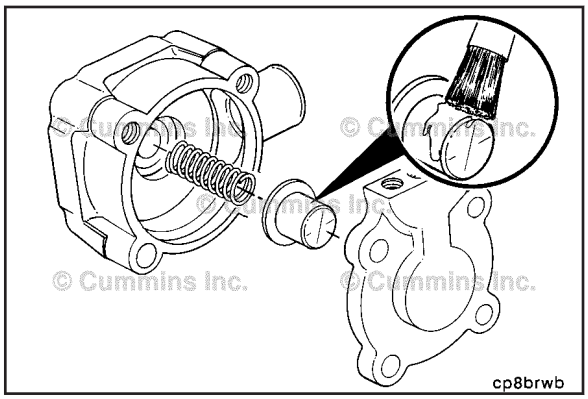
Use clean lubricating engine oil or Accrolube lubrication Teflon™ grease, or equivalent, to lubricate the seal.



Liberally lubricate the unloader valve body bore and unloader cap with high-temperature grease (Accrolube lubrication Teflon™ grease or the equivalent).

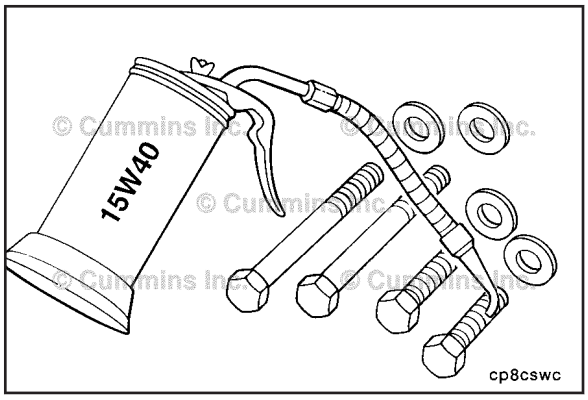
Install the unloader cap.

Install the unloader spring.



Lubricate the unloader screw threads and underhead with clean lubricating engine oil before installation.

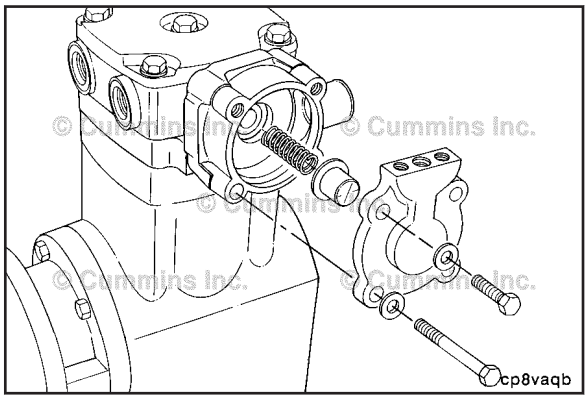
NOTE: The two unloader body screws **must not** be used to attach any brackets.

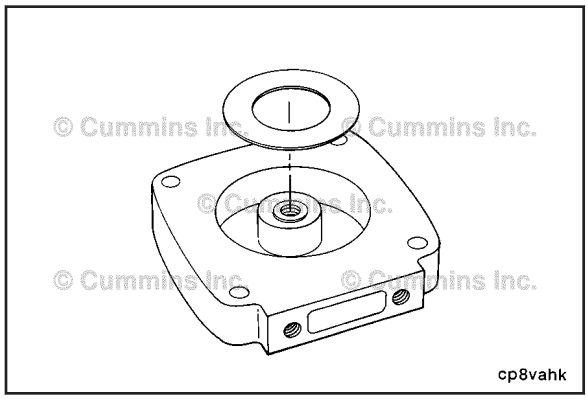


Assemble the unloader components, and attach the unloader assembly to the valve plate with the four capscrews and washers.

NOTE: The longer capscrews are used to mount the manifold to the air compressor.

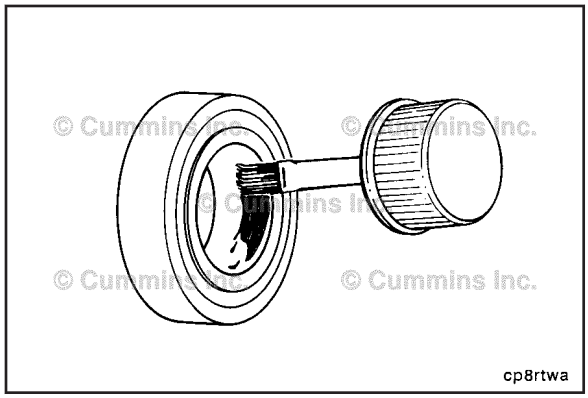
Torque Value: 27 N•m [20 ft-lb]



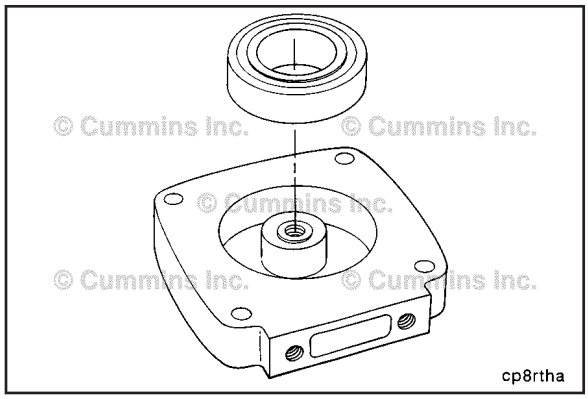


QE, European

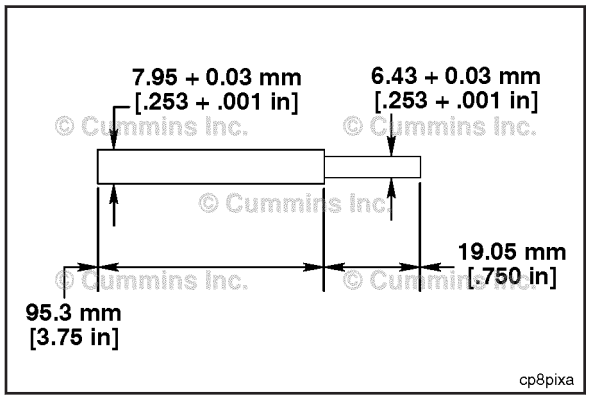
Install the exhaust valve over the post in the valve plate.



Apply a thin coating of anti-seize compound to the inside circumference of the exhaust valve retainer.

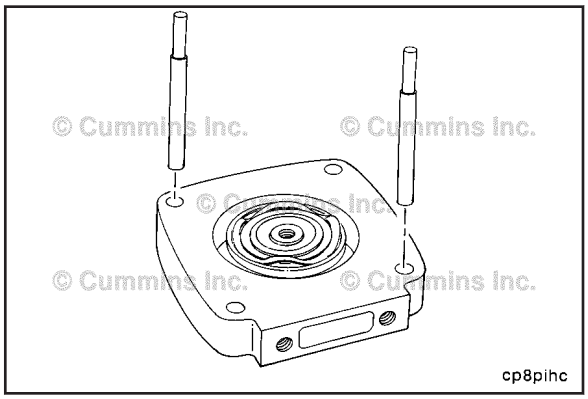


Slide the exhaust valve retainer over the valve plate. Make sure that the end of the retainer with the groove faces upward.



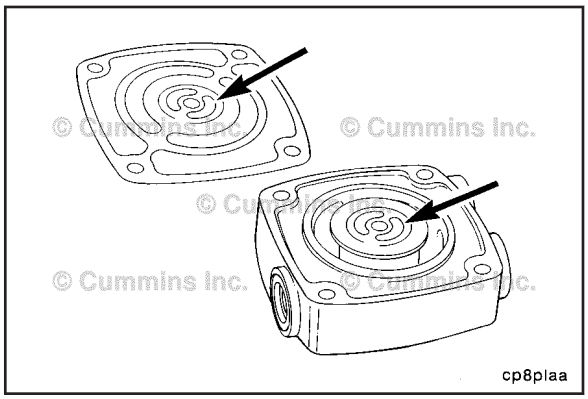
Fabricate or reuse the four guide pin tools.

Insert the larger end of two guide pins in opposite corner holes of the valve plate.

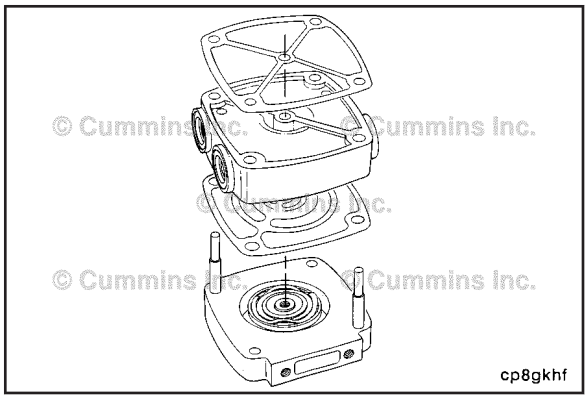


Determine the final orientation of the valve plate (air intake location) and the head (coolant ports in relation to air inlet or manifold location). Align the kidney-shaped slots in the head with the kidney-shaped slots in the gasket.

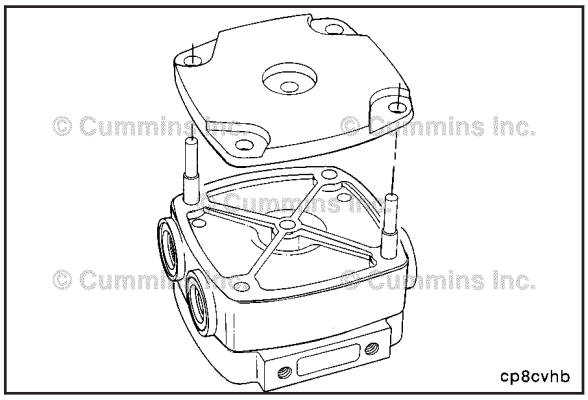
If orientation marks were made before disassembly, use them.

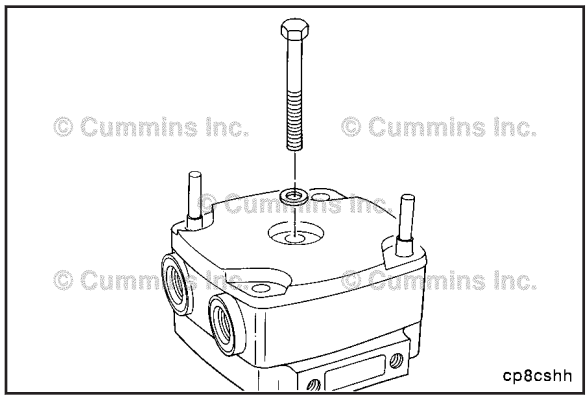


Install the head gasket onto the guide pins (either side up, but with correct slot orientation). Install the head onto the guide pins with the kidney-shaped slots aligned and toward the valve plate. Install the cover gasket over the guide pins.



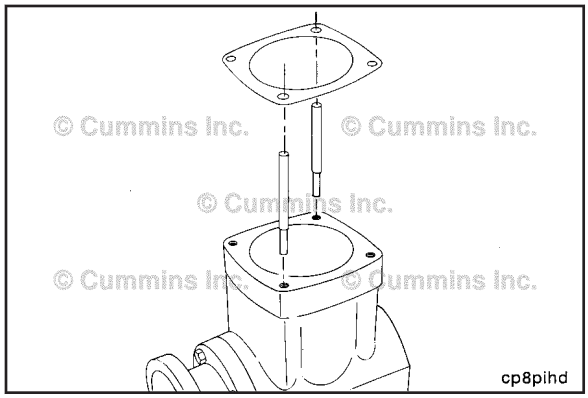
Assemble the cover.





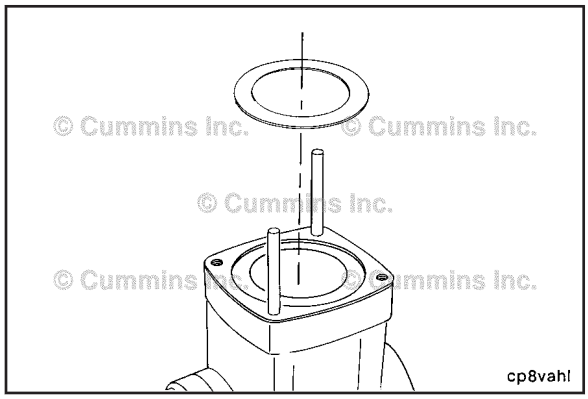
Install the shorter capscrew with washer, if initially installed, through the center hole.

Torque Value: 14 N•m [124 in-lb]

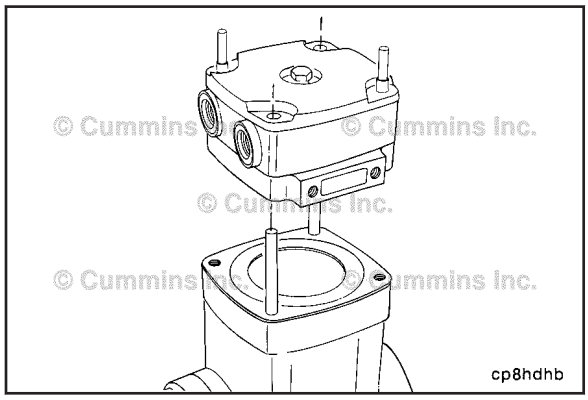


Place the remaining two guide pins in the crankcase head capscrew holes (that will **not** interfere with the guide pins already in the head assembly).

Install the valve plate gasket.

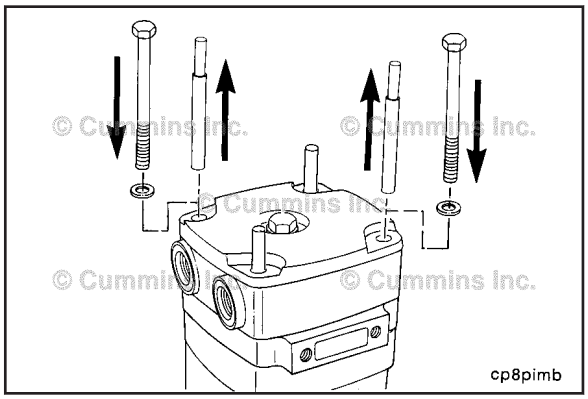


Carefully place the intake valve on the crankcase, located by the valve plate gasket. Do **not** allow the valve to overlap the gasket.



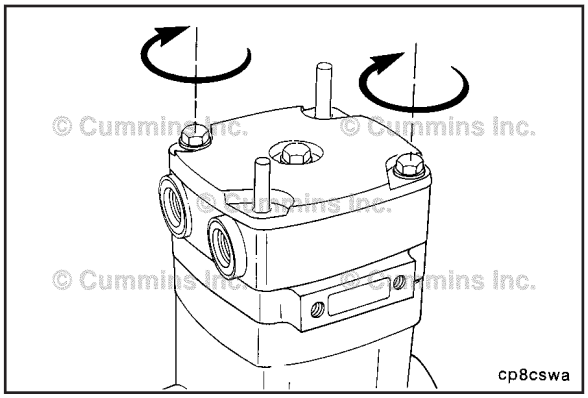
Install the head assembly over the guide pins. Be careful **not** to disturb the location of the intake valve. The compressor will **not** work if the valve overlaps the gasket and is pinched.

Carefully remove two of the guide pins and replace with two head capscrews and washers, if initially installed.

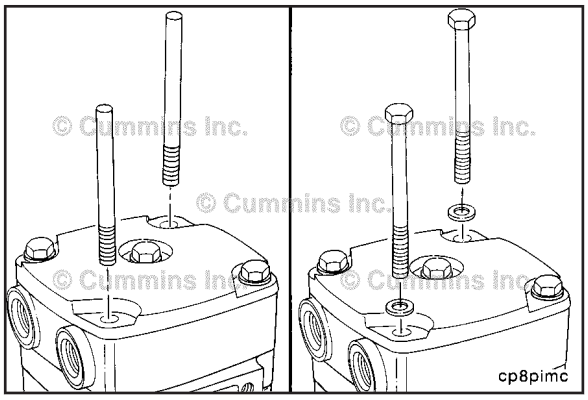


Tighten the two head capscrews.

Torque Value: 14 N•m [124 in-lb]

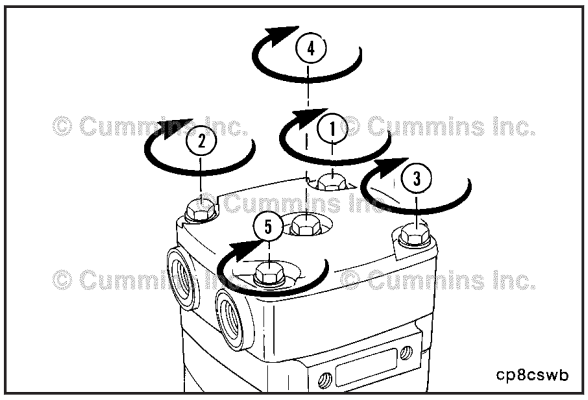


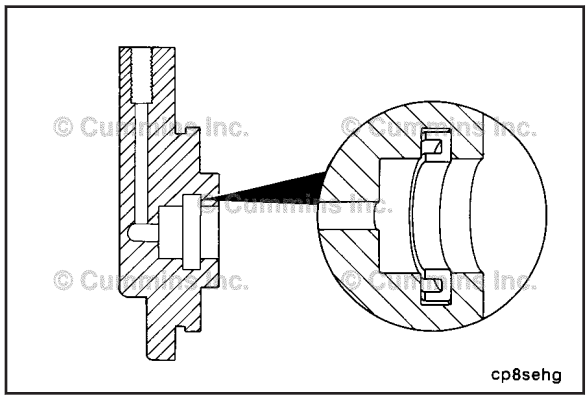
Remove the remaining two pins and replace with two head capscrews and washers, if initially installed.



Tighten all five capscrews in the proper sequence.

Torque Value: 28 N•m [21 ft-lb]

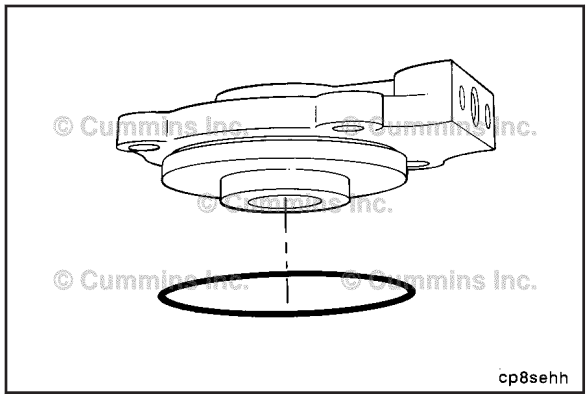




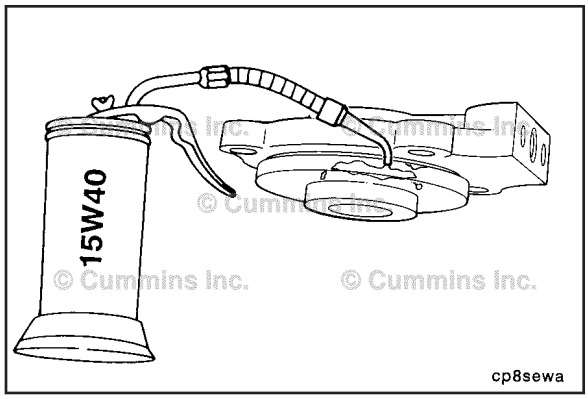
Install the new rectangular v-seal into the unloader body.

NOTE: The seal **must** be installed with the grooved side up.

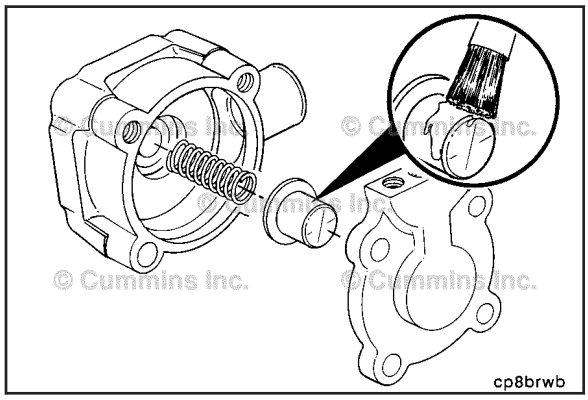
Liberally lubricate the unloader valve bore above and below the rectangular ring seal with high-temperature grease (Accrolube lubrication Teflon™ grease or equivalent).



Install a new o-ring seal on the unloader valve body.



Use clean lubricating engine oil or Accrolube lubrication Teflon™ grease, or equivalent, to lubricate the seal.



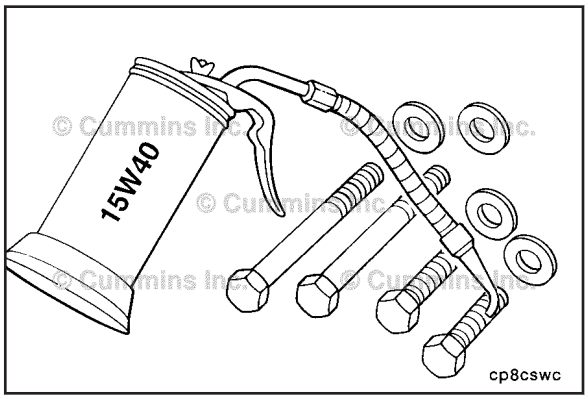
Liberally lubricate the unloader valve body bore and unloader cap with high temperature grease (Accrolube lubrication Teflon™ grease or the equivalent).

Install the unloader cap.

Install the unloader spring.

Lubricate the unloader screw threads and under the head with clean lubricating engine oil before installation.

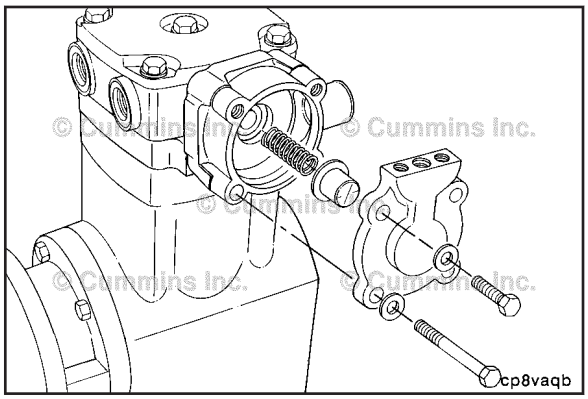
NOTE: The two unloader body screws **must not** be used to attach any brackets.



Assemble the unloader components, and attach the unloader assembly to the valve plate with the four capscrews and washers.

NOTE: The longer capscrews are used to mount the manifold to the air compressor.

Torque Value: 27 N•m [20 ft-lb]

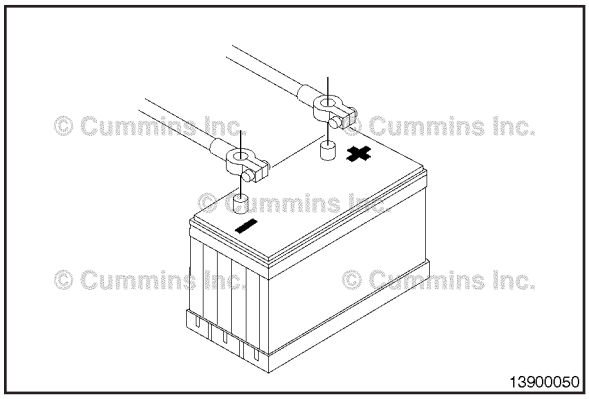


Finishing Steps

NOTE: If the cylinder head was removed while the air compressor was on the engine, fill the engine coolant. Refer to Procedure 008-018.

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

- Connect the batteries
- Operate the engine and check for leaks.



Notes

Section 13 - Electrical Equipment - Group 13

Section Contents

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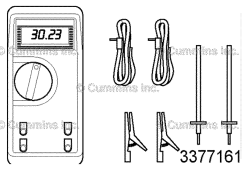
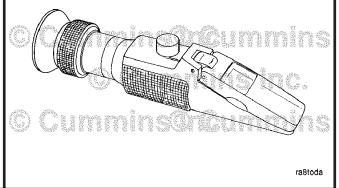
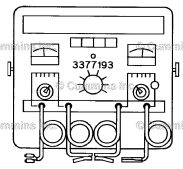
Service Tools

Electrical Equipment

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

Tool No.	Tool Description	Tool Illustration
3377161	**Digital Multimeter** Use to measure electrical circuit: Voltage (VDC), resistance (ohms), and current (amps).	
CC-2800	**Refractometer** The Fleetguard® refractometer is used to check the charge condition of a conventional battery.	
3377193	**System Analyzer/Battery Tester** Use to test the output amperage of maintenance-free or conventional vent cap batteries.	

Alternator (013-001)

General Information

Due to the number of different alternator brands and configurations, the following procedure has been generalized to cover the most common configurations. Consult the alternator manufacturer for any information that is **not** covered in this procedure.

Typical Delco™ Alternator Wiring System

Indicator (I) Terminal

The main function of the indicator (I) terminal is to indicate if the alternator is working correctly. Typically, an indicator light is wired to this terminal. If the alternator is **not** charging properly, the light turns on. Another function of the indicator (I) terminal is that it can be used to supply up to 1 ampere of output at system voltage.

Lamp (L) Terminal

Similar to the I terminal, the L terminal is used to indicate if the alternator is working correctly. The difference between the L terminal and the I terminal is that the L terminal is a current sink **only** and can **not** be used to reduce turn on speed.

Relay (R) Terminal

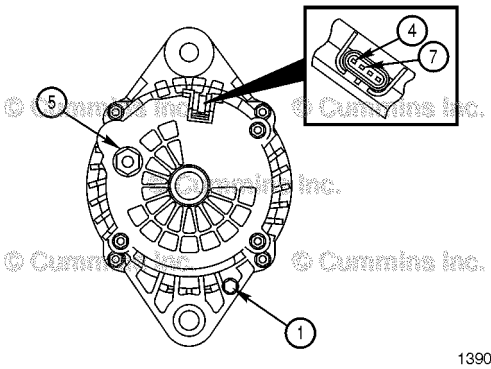
The function of the relay (R) terminal varies. It can supply up to 4 amperes of output at one-half nominal alternator voltage to power items such as a tachometer or an hour meter.

One-Wire System

This is the simplest of the wiring systems because the **only** wires connected to the alternator are at the battery (BAT) and ground terminals. (See Table 5.) Connecting to the R terminal, L terminal, and I terminal is optional.

Three-Wire System

This system requires more wiring because it has a battery (BAT) terminal, R terminal, two blade terminals identified as number 1 and number 2, and a ground terminal. Typically, in the three-wire system, the number 1 blade terminal serves as the I terminal. (See Table 5.) The advantage of the three-wire system is that it provides the same features as the one-wire system, plus remote sense. By connecting the number 2 blade terminal to the battery's positive (+) terminal, the voltage is both sensed and regulated at the battery, instead of at the alternator. This eliminates the potential for voltage losses in the wiring from the alternator to the battery.

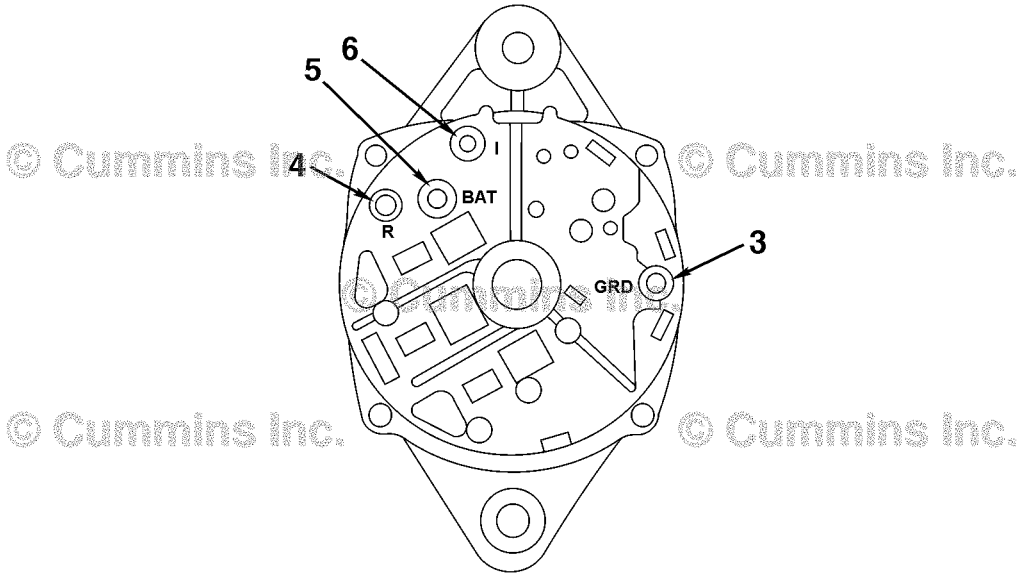


One Wire System, Typical Alternator (Delco-Remy™) with Combined Metri-Pack™ Connector

One Wire System, Typical Alternator (Delco-Remy™) with Combined Metri-Pack™ Connector		
1	**GRD***	**Ground**
4	**R***	**Charge indicator, automatic lockout system, tachometer****
5	**BAT**	**Battery**
7	L	Lamp Terminal

***Not** all alternators have this feature.

**Provides voltage pulses at about one-half system voltage at a frequency of one-tenth of generator rpm.



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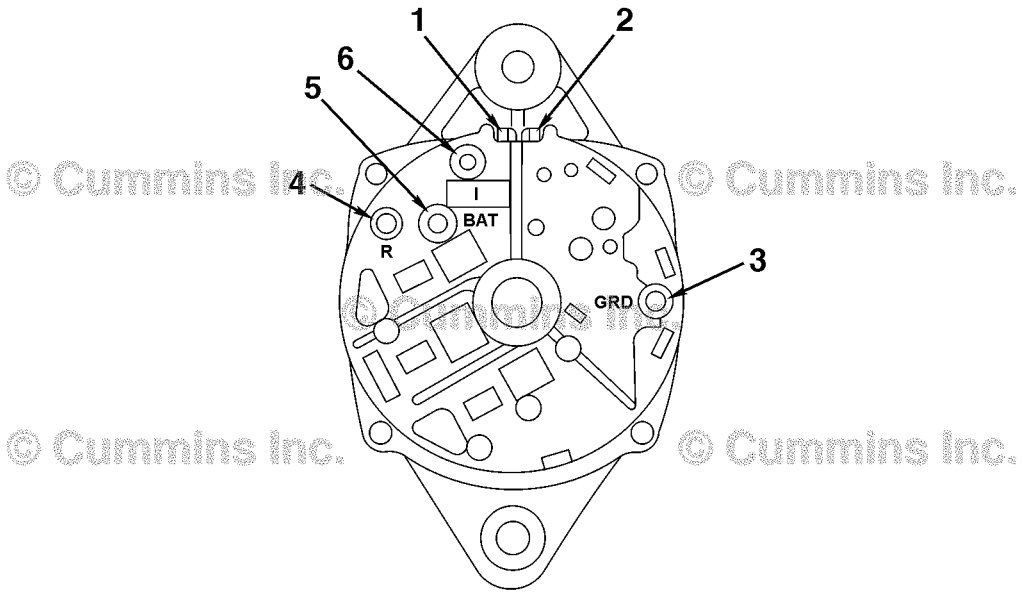
13900134

One Wire System, Typical Alternator (Delco-Remy™)

One Wire System, Typical Alternator (Delco-Remy™)		
3	**GRD***	**Ground**
4	**R***	**Charge indicator, automatic lockout system, tachometer****
5	**BAT**	**Battery**
6	I*	Indicator light

***Not** all alternators have this feature.

**Provides voltage pulses at about one-half system voltage at a frequency of one-tenth of alternator rpm.



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Three Wire System, Typical Alternator (Delco-Remy™)

Three Wire System, Typical Alternator (Delco-Remy™)		
Key	**Terminal**	**Connected To**
1	Blade number 1*	Indicator light
2	Blade number 2	Voltage sense
3	GRD*	Ground
4	R*	Charge indicator, automatic lockout system, tachometer**
5	BAT	Battery
6	I*	Indicator light

***Not** all alternators have this feature.

**Provides voltage pulses at about one-half system voltage at a frequency of one-tenth of generator rpm.

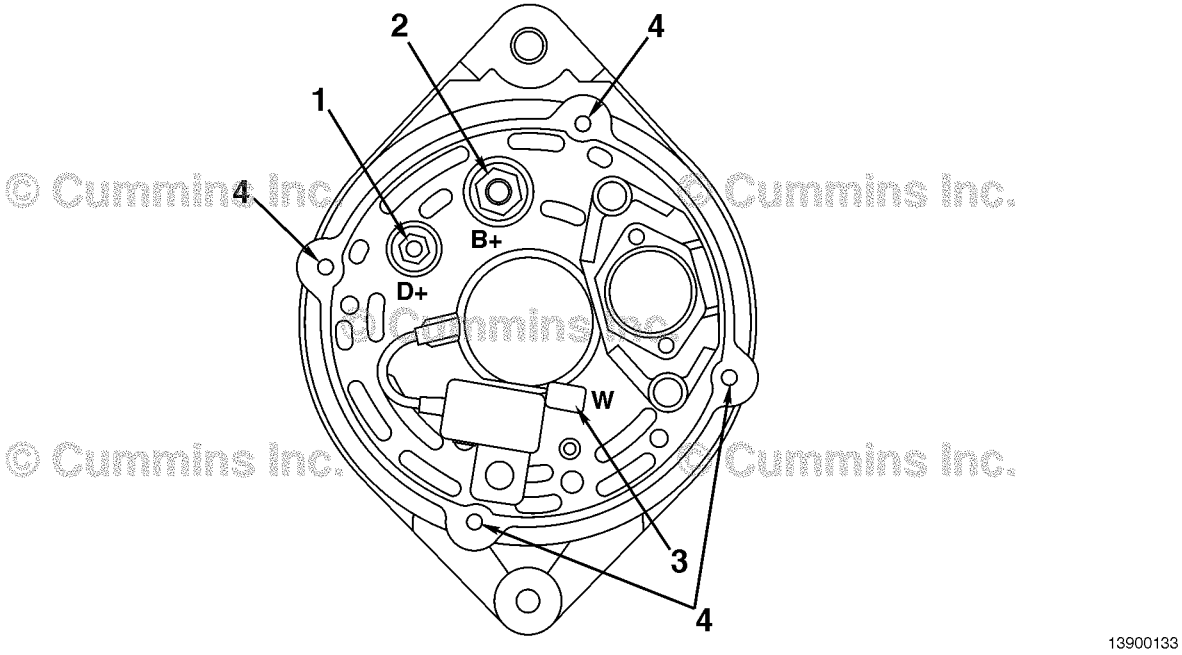

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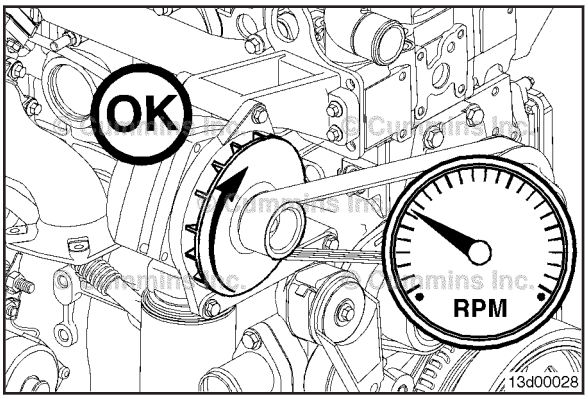
Table 6, Typical Alternator (Bosch™ K1)

Typical Bosch™ K1 Wiring System		
Key	**Terminal**	**Connected to**
1	D+	Electrical charging system status light
2	B+	Positive battery
3	W	Tachometer
4	—	Ground/assembly

Initial Check



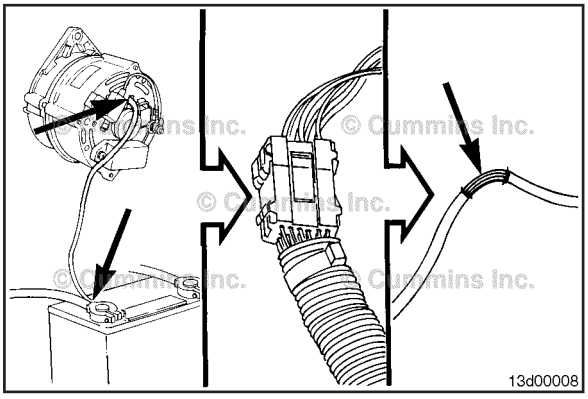
Check the drive belt and alternator pulley to be sure the alternator is rotating properly.

If any problems exist, check the following:

1 If the drive belt is slipping on the alternator pulley, use the following procedure to inspect the drive belt. Refer to Procedure 008-002 in Section 8. Use the following procedure to inpect the belt tensioner. Refer to Procedure 008-087 in Section 8.

2 Remove the drive belt. Refer to Procedure 008-002 in Section 8. Check if the alternator pulley is loose on the shaft. If loose, remove the pulley and inspect for damage. Refer to Procedure 013-006 in Section 13.

3 If the alternator will **not** rotate or does **not** rotate freely, the alternator **must** be replaced. See the Remove and Install sections of this procedure.



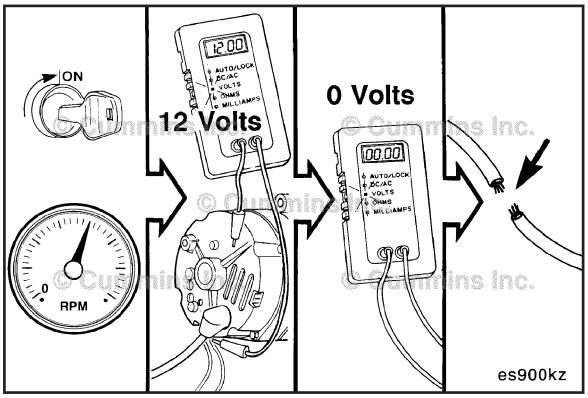
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Check the battery and all wiring connections.

Inspect the wiring for defects.

Check all connections for tightness and cleanliness, including the slip connectors at the alternator and engine compartment bulkhead, and the connections at the battery.

Test



NOTE: Any multimeter reading of zero voltage indicates an open circuit.

Check for open circuits.

Turn the keyswitch to the ON position.

Connect a multimeter, Cummins® Part Number 3164488 or 3164489, to the following locations:

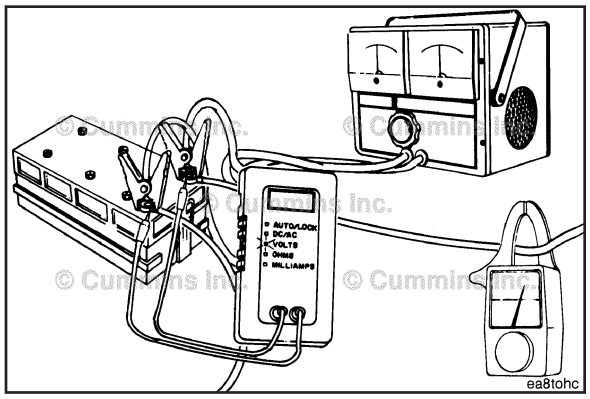
Delco™ Alternators

1 Alternator “BAT” terminal to ground

2 Alternator blade terminal “Number 1” to ground

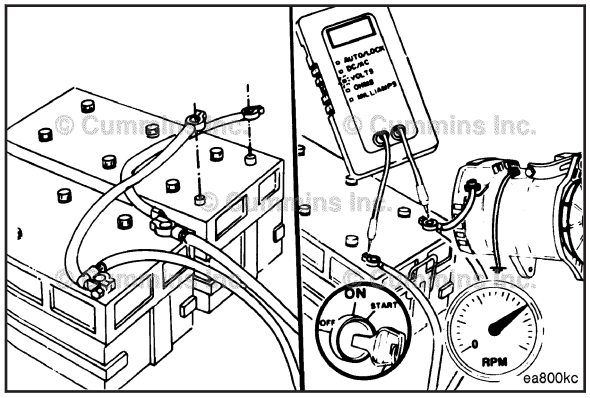
3 Alternator blade terminal “Number 2” to ground.

Locate and repair the open circuit.



Connect a carbon-pile load (battery/alternator tester) across the batteries in one of the battery boxes.

Clamp an induction pickup-type ampere-hour meter around the battery cable; or use the digital multimeter, Part Number 3164488 or 3164489, with the clamp-on current probe, Part Number 3164490.

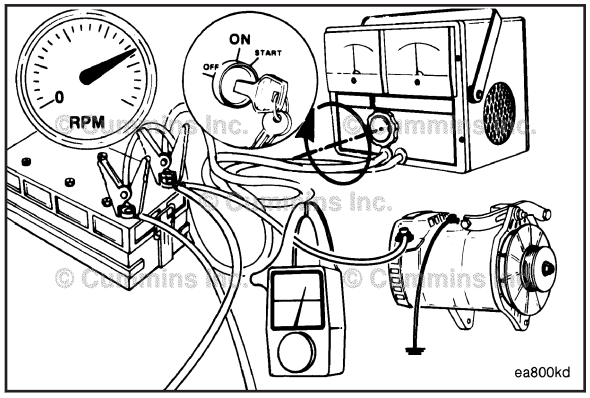


⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

⚠WARNING⚠
Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.

Disconnect any cables that lead to any other battery boxes in the circuit, negative (-) cables first.

Operate the engine at high idle; and measure the alternator voltage output to the batteries with digital multimeter, Part Number 3164488 or 3164489. Refer to the OEM service manual.



Operate the engine at high idle and adjust the carbon-pile load-testing equipment to apply the maximum rated amperage load to the alternator. Refer to the OEM service manual.

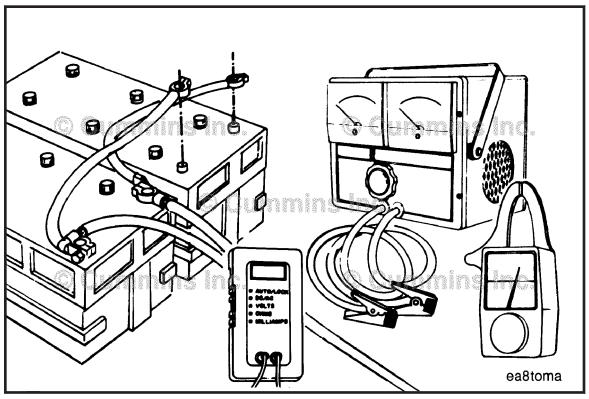
NOTE: The alternator maximum rated amperage output is normally stamped or labeled on the alternator.

Measure the alternator amperage output. Refer to the OEM service manual.

If the alternator output (amps) is **not** within 10 percent of rated output, repair or replace the alternator. Refer to the OEM service manual for repair procedures.

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

⚠WARNING⚠
Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.



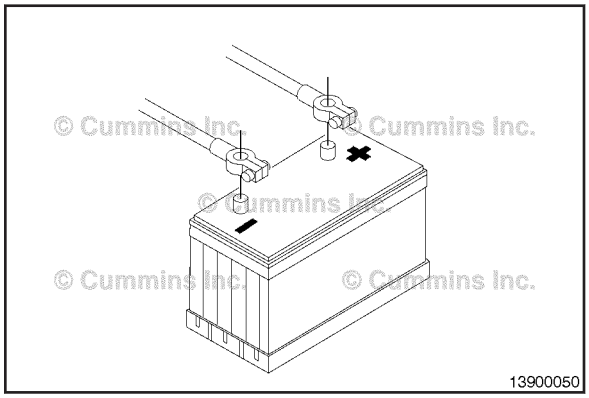
Shut off the engine and remove the test equipment.

Connect all battery cables, negative (-) cable last.

Preparatory Steps

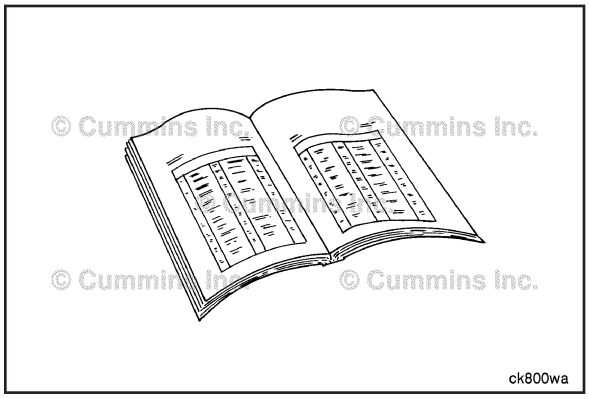
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

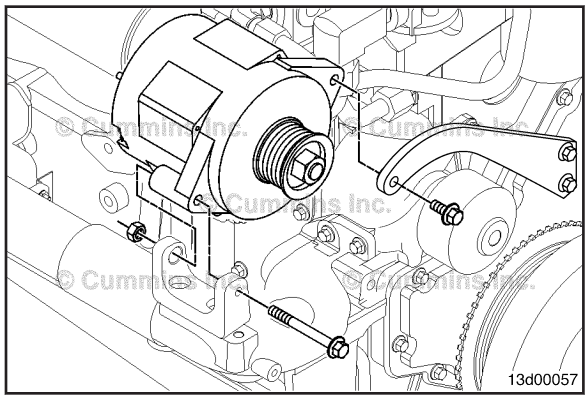
⚠WARNING⚠
Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.



- Disconnect the batteries.

- Remove the drive belt from the alternator pulley. Refer to Procedure 008-002 in Section 8..
- Tag and label all wires on the alternator.
- Disconnect the wires.





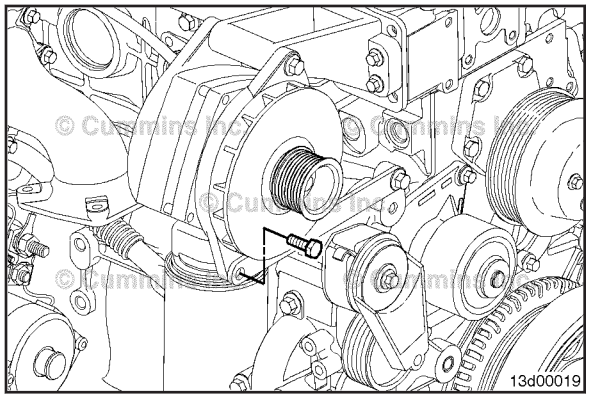
Remove

Spool Mount.

Remove the upper alternator link capscrew.

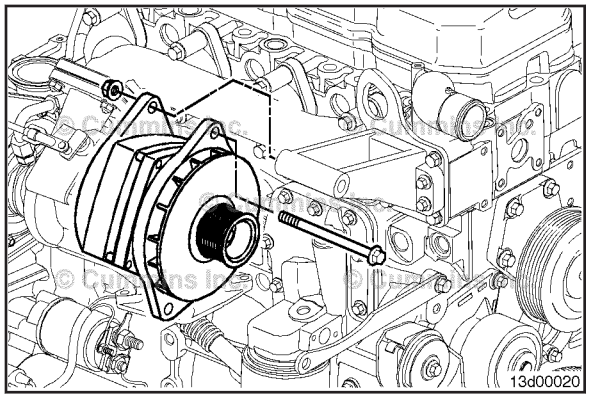
Remove the mounting capscrew and nut at the bottom of the alternator and alternator mounting bracket.

Remove the alternator.



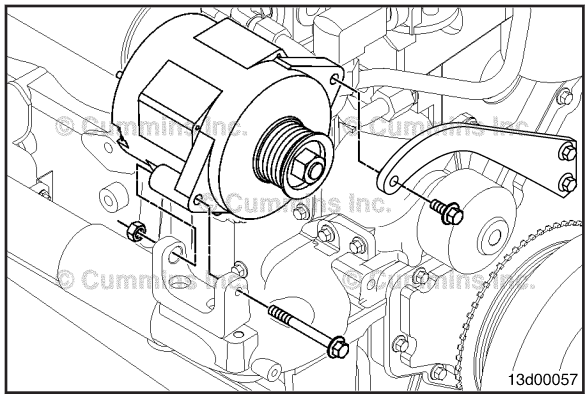
Hinge Mount

Remove the alternator link capscrew.



Remove the alternator mounting capscrew.

Remove the alternator.



Install

Spool Mount

Install the alternator and the bottom alternator mounting capscrew and nut.

Install the upper alternator link mounting capscrew at the top of the alternator.

Tighten the capscrews.

Torque Value:
Lower Mounting Capscrew
Step 1 40 N•m [30 ft-lb]

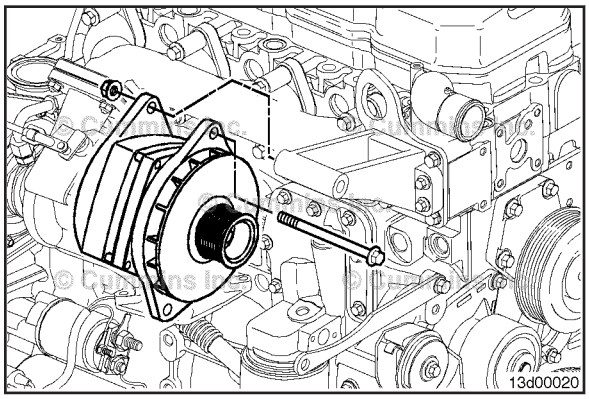
Torque Value:
Upper Link Mounting Capscrew
Step 1 24 N•m [212 in-lb]

Hinge Mount

Install the alternator.

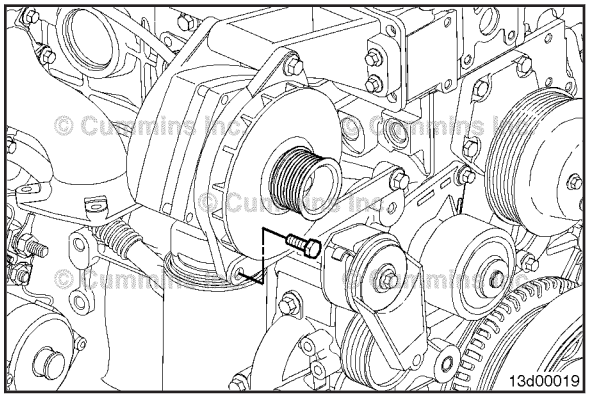
Install and tighten the alternator mounting capscrew.

Torque Value: 40 N•m [30 ft-lb]



Install the alternator link capscrew.

Torque Value: 24 N•m [212 in-lb]



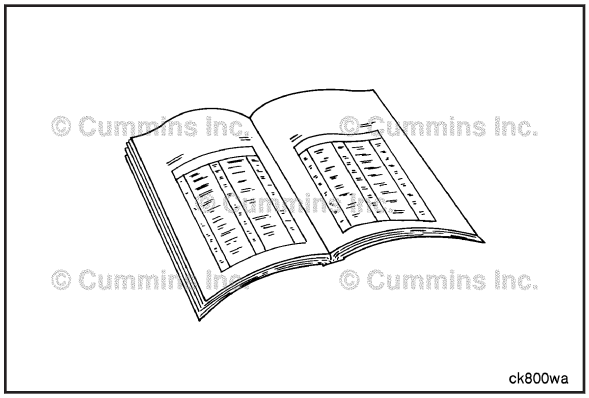
Finishing Steps

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

⚠WARNING⚠
Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing the batteries. Wear goggles and protective clothing to reduce the possibility of serious personal injury.

Delco-Remy™ Alternator

- Connect all wires to the alternator.
- Install the drive belt. Refer to Procedure 008-002 in Section 8.



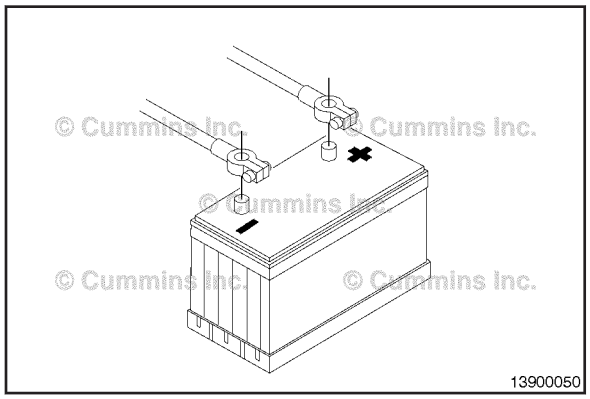
Bosch™ K1 Alternator

- Connect all wires to the alternator.

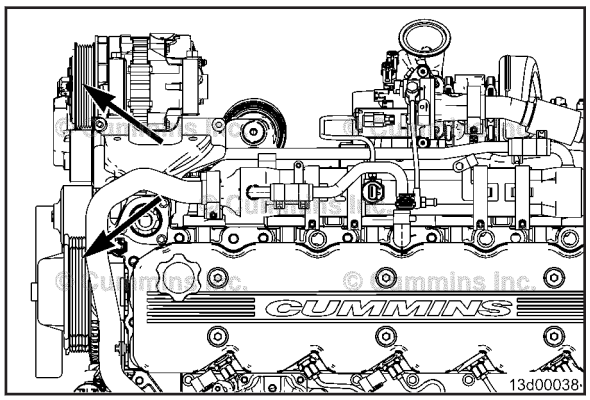
Torque Value: 2.7 to 9.8 N•m [23.9 to 86.7 in-lb]

Torque Value: 7.5 to 8.0 N•m [66.4 to 70.8 in-lb]

- Install the drive belt. Refer to Procedure 008-002 in Section 8.



- Connect the batteries.
- Start the engine and check for correct operation.

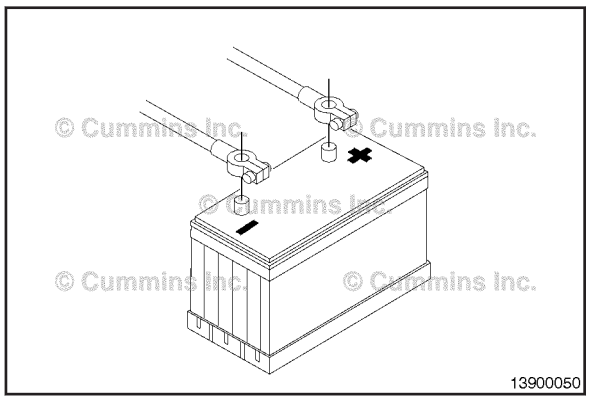


Alternator Bracket (013-003)

Initial Check

Check that the alternator pulley is in line with the other belt driven pulleys. Use Pulley Alignment Fixture, Part Number 3163524, to check the alignment.

If alternator pulley is out of alignment, verify that the correct alternator brackets have been used and/or have been installed correctly.

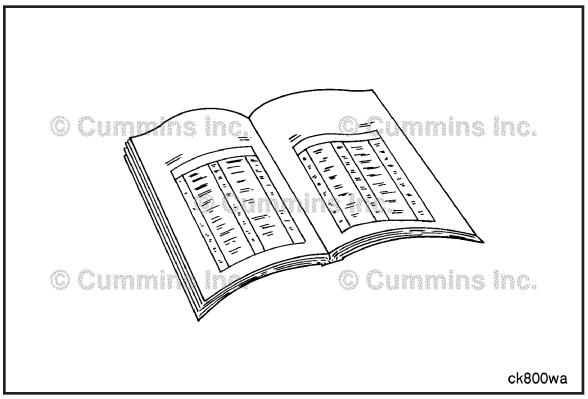


Preparatory Steps

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

- Disconnect the batteries.

- Remove the drive belt. Refer to Procedure 008-002
- Remove the alternator. Refer to Procedure 013-001.

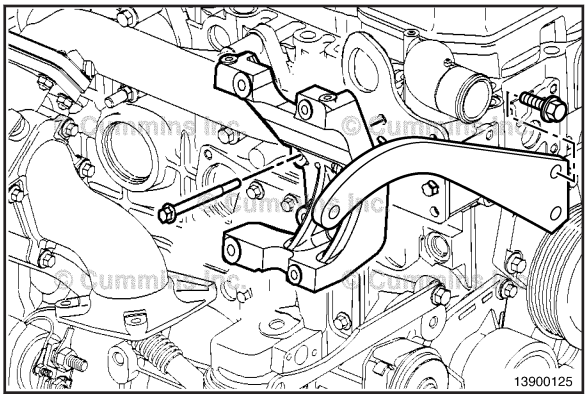


Remove

Spool Mount:

Remove the upper alternator bracket mounting capscrews.

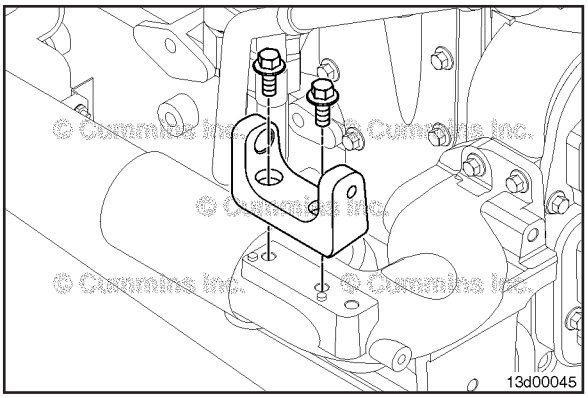
Remove the alternator bracket.



NOTE: On some applications, the alternator bracket and water inlet are combined in the same bracket. Refer to Procedure 008-082, where applicable.

Remove the lower alternator bracket mounting capscrews.

Remove the alternator bracket.

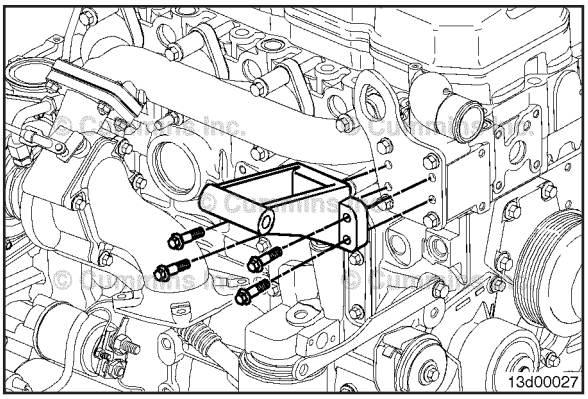


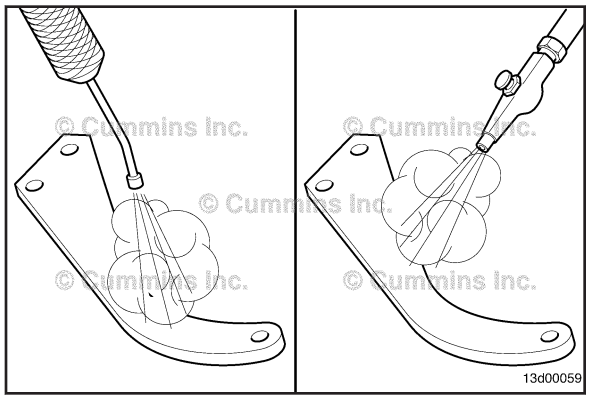
Hinge Mount:

Remove the upper alternator bracket mounting capscrews.

Remove the lower alternator bracket mounting capscrews.

Remove the alternator brackets.





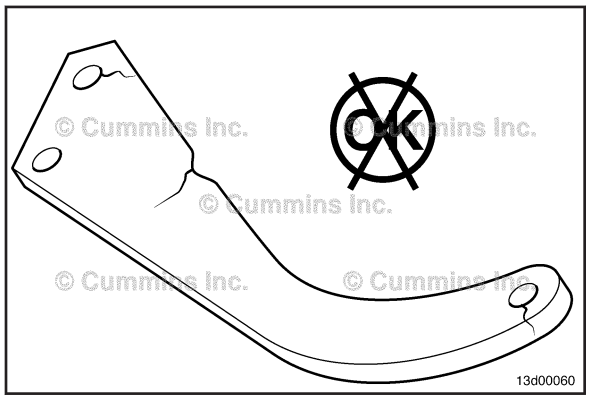
Clean and Inspect for Reuse

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

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

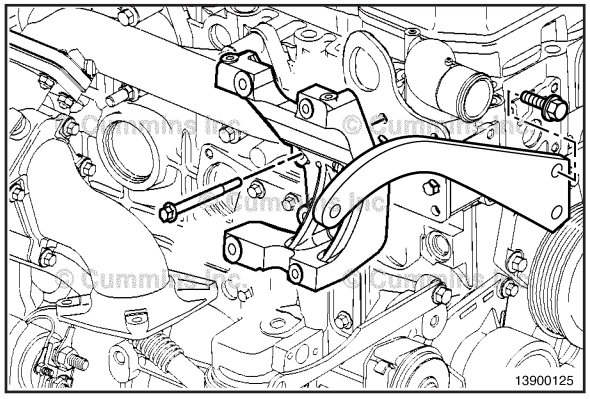
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

Use steam or solvent to clean the alternator brackets. Dry with compressed air.



Inspect the alternator brackets for cracks or damage.

If any cracks are found on the alternator brackets, they **must** be replaced.



Install

Spool Mount:

Install the upper alternator bracket and mounting capscrews.

Tighten the upper and lower alternator bracket mounting capscrew.

Torque Value:

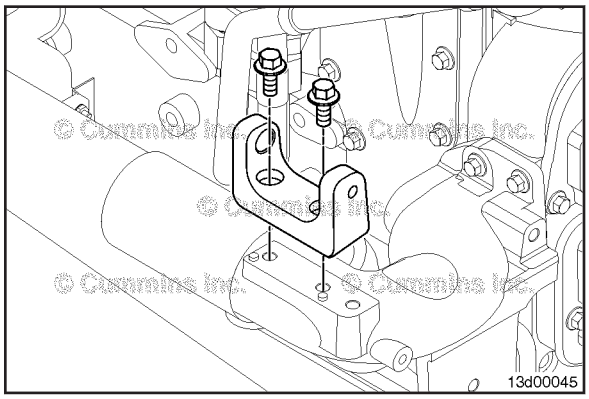
M8	24 N•m	[18 ft-lb]
M10	43 N•m	[32 ft-lb]

NOTE: On some applications, the alternator bracket and water inlet are combined in the same bracket. Refer to Procedure 008-082, where applicable.

Install the lower alternator mounting bracket over the two dowel pins.

Install the two alternator bracket mounting capscrews and tighten.

Torque Value: 54 N•m [40 ft-lb]



Hinge Mount:

Install the upper alternator bracket and mounting capscrews.

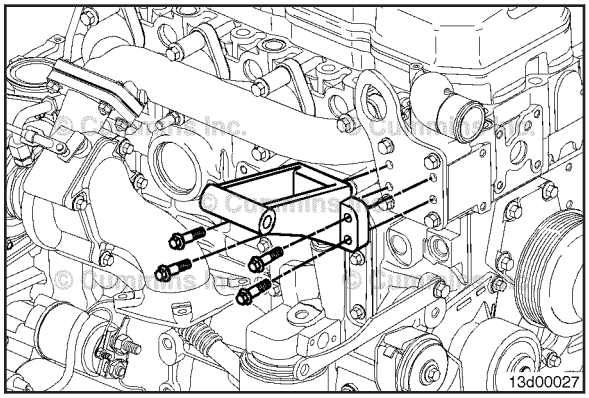
Install the lower alternator bracket and mounting capscrew.

NOTE: Depending on the alternator configuration, it may be necessary to wait until the alternator is installed before tightening the lower alternator bracket. This will allow adjustment of the bracket.

Tighten the upper and lower alternator bracket mounting capscrew.

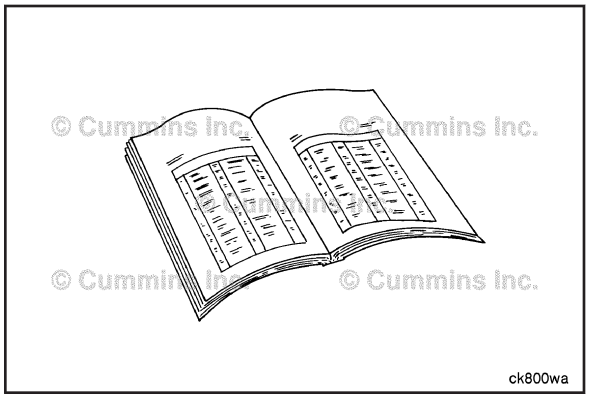
Torque Value:

M8	24 N•m	[18 ft-lb]
M10	43 N•m	[32 ft-lb]



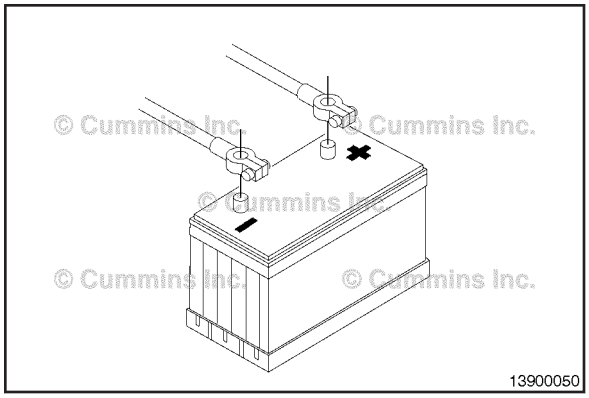
Finishing Steps

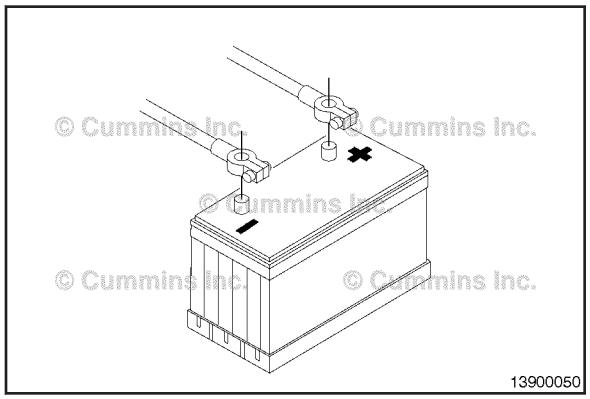
- Install the alternator. Refer to Procedure 013-001.
- Install the drive belt. Refer to Procedure 008-002.



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

- Connect the batteries.



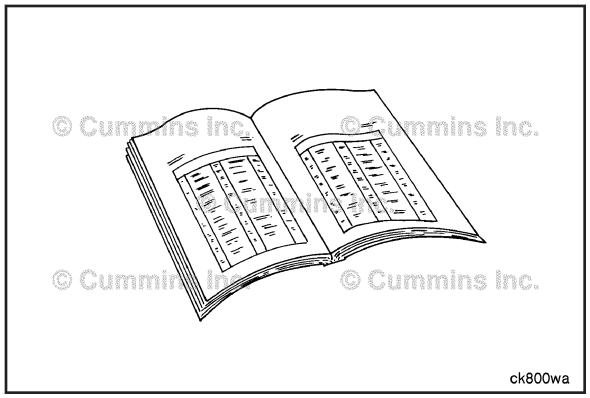


Alternator Pulley (013-006)

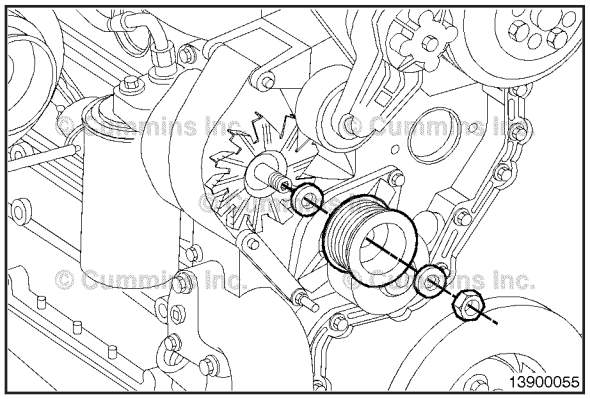
Preparatory Steps

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

- Disconnect the batteries.



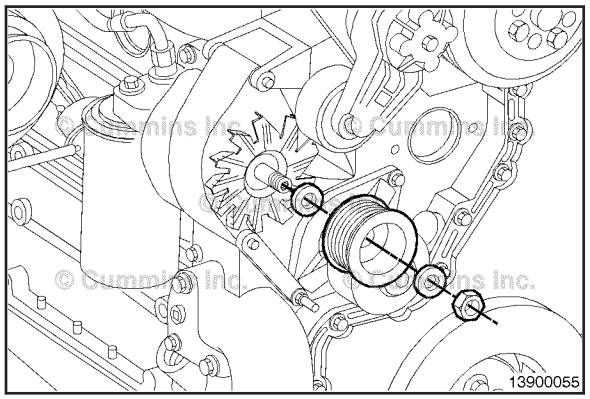
- Remove the drive belt. Refer to the Procedure 008-002.



Remove

Hold the shaft or pulley to prevent turning.

Remove the alternator pulley.



Install

Install the alternator pulley, mounting fastener, and any washers/spacers.

Hold the shaft or pulley to prevent turning.

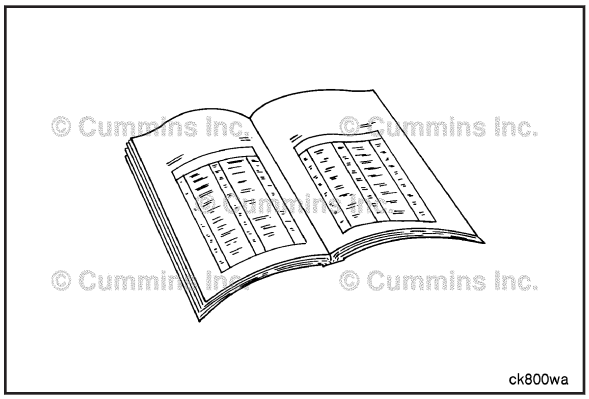
Tighten the alternator pulley mounting fastener.

Torque Value:

Bosch® K1	70 N•m	[52 ft-lb]
Bosch® NCB1	65 N•m	[48 ft-lb]
Bosch® NCB2	65 N•m	[48 ft-lb]
Delco 11 SI	95 N•m	[70 ft-lb]
Delco 20 SI	102 N•m	[75 ft-lb]
Delco 24 SI	102 N•m	[75 ft-lb]
Delco 33 SI	102 N•m	[75 ft-lb]

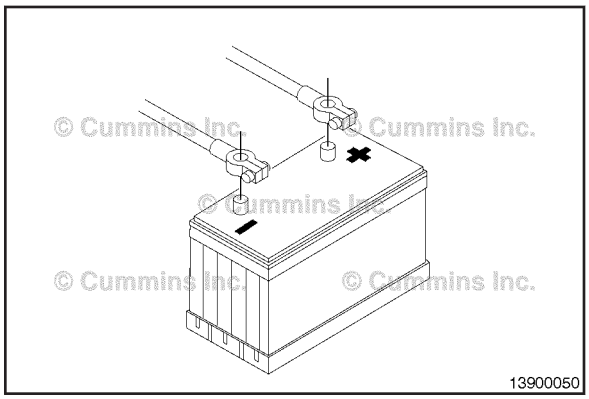
Finishing Steps

- Install the drive belt. Refer to Procedure 008-002.



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

- Connect the batteries.



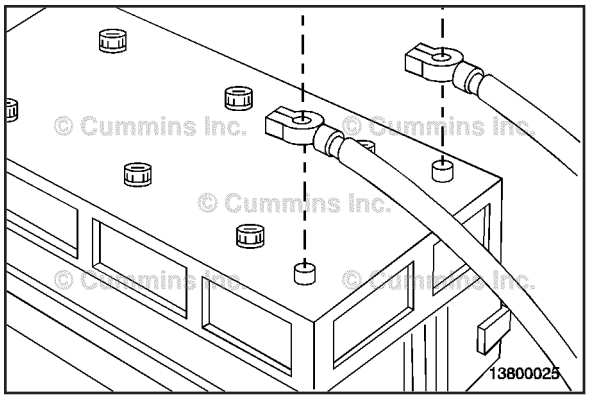
Batteries (013-007)

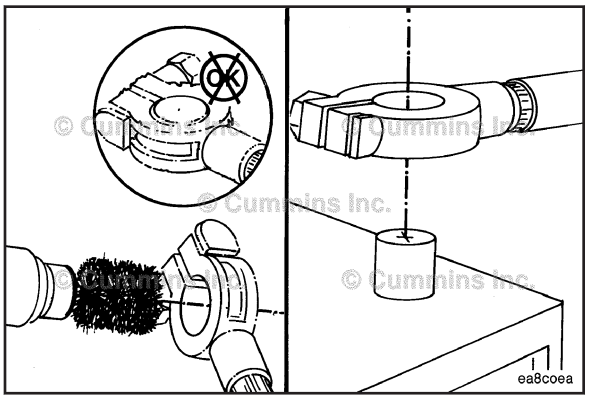
Initial Check

⚠WARNING⚠
Acid is extremely dangerous and can damage the machinery and can also cause serious burns. Always provide a tank of strong soda water as a neutralizing agent when servicing batteries. Wear goggles and protective clothing to avoid serious bodily injury.

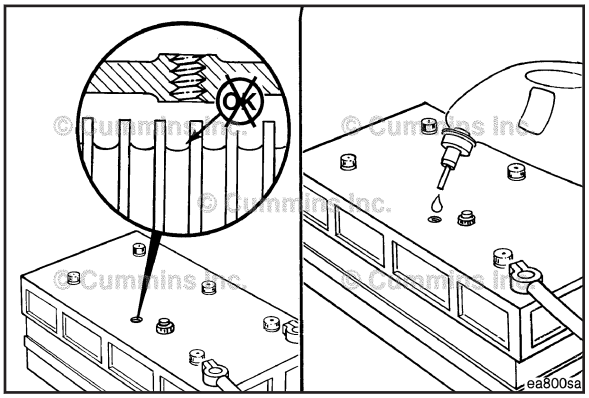
⚠WARNING⚠
Batteries can emit explosive gases. To avoid injury, always ventilate the compartment before servicing the batteries. To avoid arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

Label and disconnect all battery cables.





Clean corrosion and debris from battery and terminals.

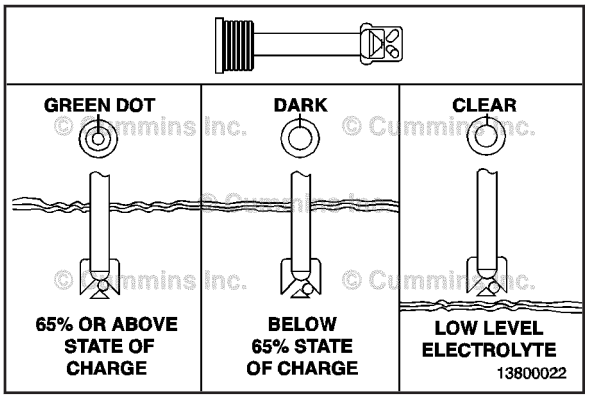


NOTE: Maintenance-free batteries are sealed and do **not** require the addition of water.

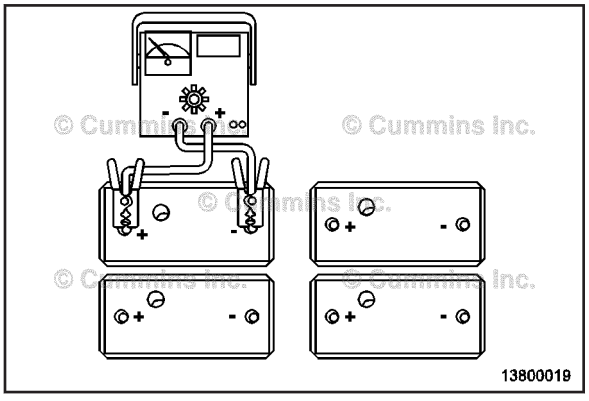
If conventional batteries are used, remove the cell caps or covers, and check the electrolyte level.

NOTE: If water is added to the battery it **must** be charged before any testing can be accomplished.

Fill each battery cell with distilled water. Refer to the battery manufacturer's specifications.

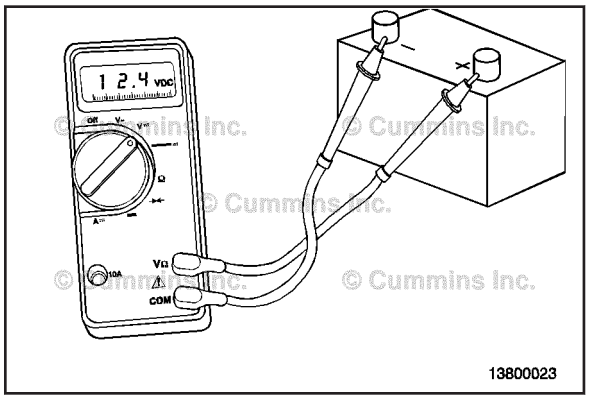


Check the “Eye” on the maintenance-free battery. Refer to the OEM specifications.

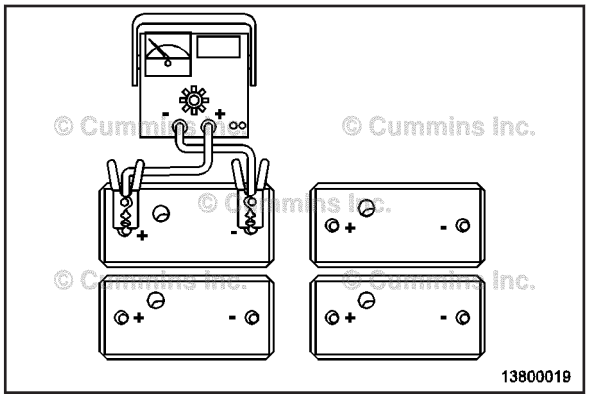


Remove the surface charge by attaching the battery to a 300-amp load for 30 seconds for heavy-duty batteries.

Remove the load, and wait 1 minute; if the battery voltage is greater than or equal to 12.4 VDC, continue testing. If the voltage is below 12.4 VDC, recharge or replace the battery.



Load-test the batteries at 1/2 of the cold cranking amp rating of the battery (rating at -18°C [0°F] for 15 seconds).

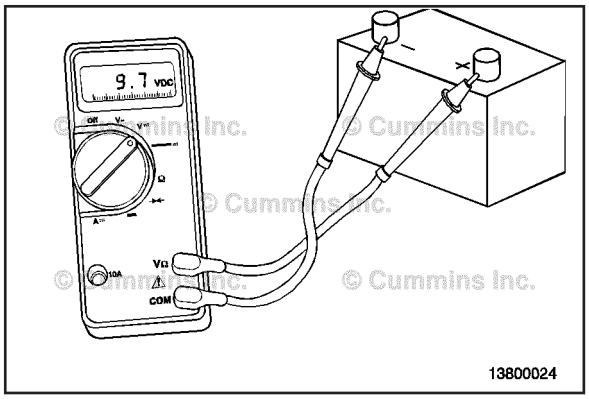


Check the battery voltage, and compare to the table:

Temperature and Voltage Relationship								
Temp (F)	70	60	50	40	30	20	10	0
Temp (C)	21	16	10	4	-1	-7	-12	-18
Min. VDC	9.6	9.5	9.4	9.3	9.1	8.9	8.7	8.5

Turn the load off.

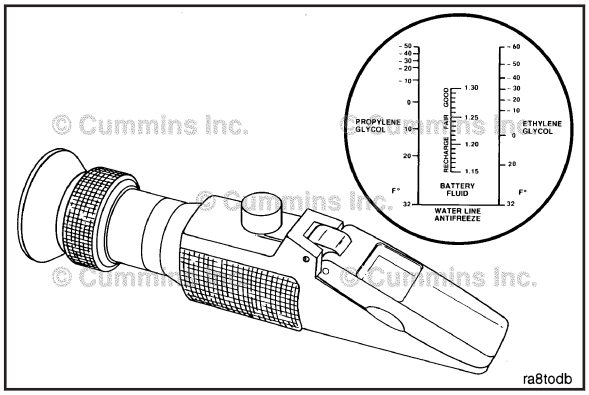
Replace the battery if it does **not** meet the above specifications.

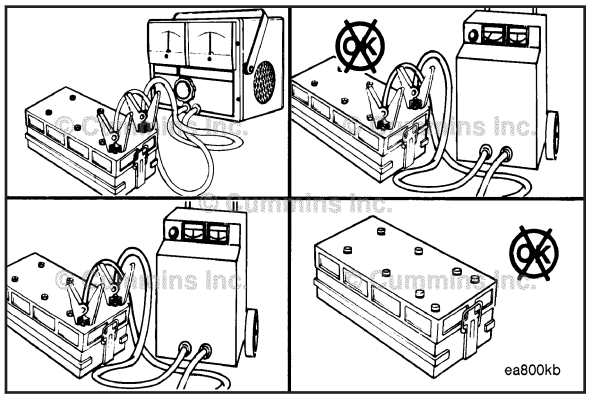


Use the Fleetguard® Refractometer, Part Number CC-2800, to check the specific gravity of the battery electrolyte.

Refer to the battery fluid column in the refractometer to determine the state of charge of each battery cell.

If water has been added to a dry cell, recharge the battery to mix the added water with the existing battery electrolyte to prevent incorrect readings.





⚠CAUTION⚠
Do not connect battery charging cables to any electronic control system part. This can damage the electronic control system parts.

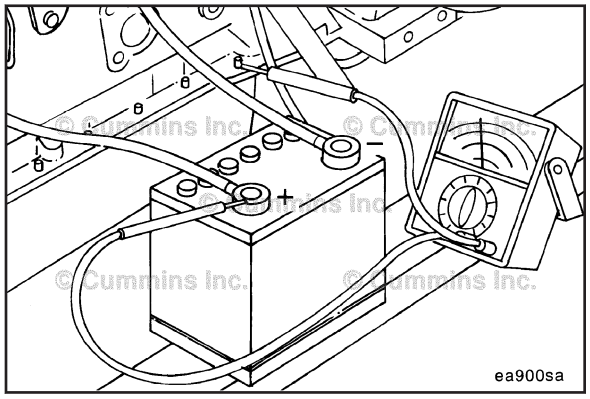
Use the systems analyzer/battery tester, Part Number 3377193, to test the output amperage of maintenance-free or conventional vent-cap batteries.

If the output amperage is low, use a battery charger to charge the battery. Refer to the manufacturer's instructions.

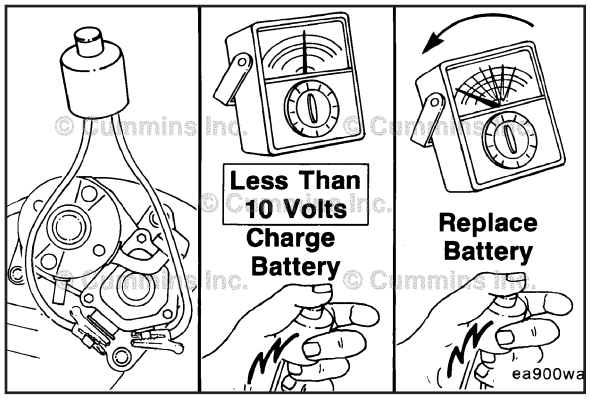
Replace the battery if it will **not** charge to the manufacturer's specifications or will **not** maintain a charge.

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



All batteries, including maintenance-free ones, can be checked by measuring the voltage between the positive (+) battery cable and the engine block ground (-). Note the voltage.



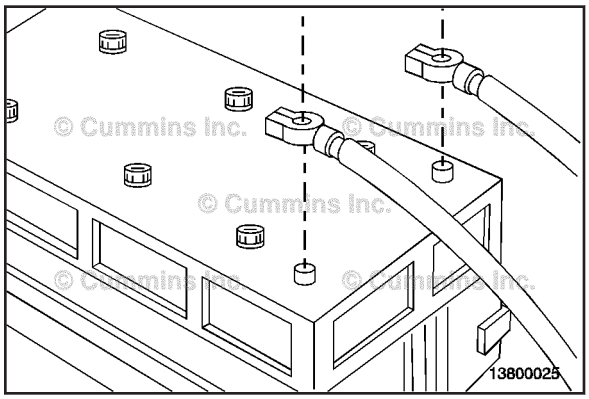
Using a remote start connection, attempt to engage the starter while observing the voltage.

If the voltage reads less than 10 VDC, charge the battery.

If the voltage drops rapidly more than 2 VDC, replace the battery.

⚠WARNING⚠
Batteries can emit explosive gases. To avoid 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.

Connect all battery cables.

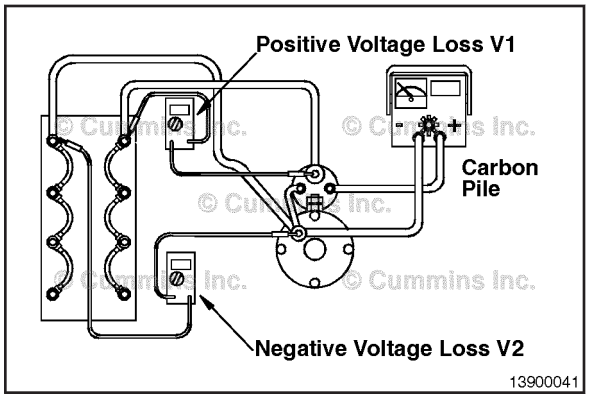


Battery Cables and Connections (013-009)

Initial Check

Cranking Circuit or Battery Cable Test

Attach the carbon pile tester and multimeter. Apply 500 amps of load (250 amps for a 24-VDC system), and measure the positive and negative voltage losses. Add (V1) and (V2) together for a total battery cable voltage drop. The measured voltage drop **must** be less than 0.5 VDC for a 12-VDC system or less than 1 VDC for a 24-VDC system. If the voltage drops are excessive, repair or replace the wiring system.

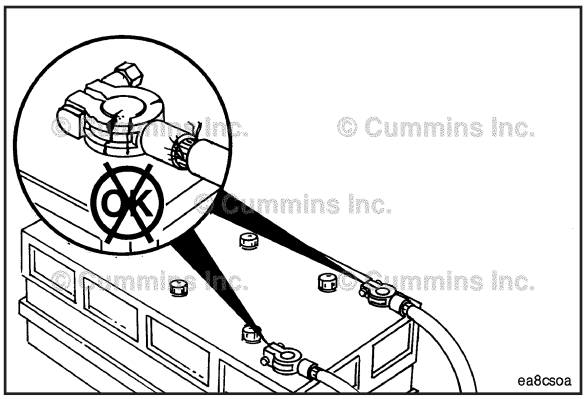


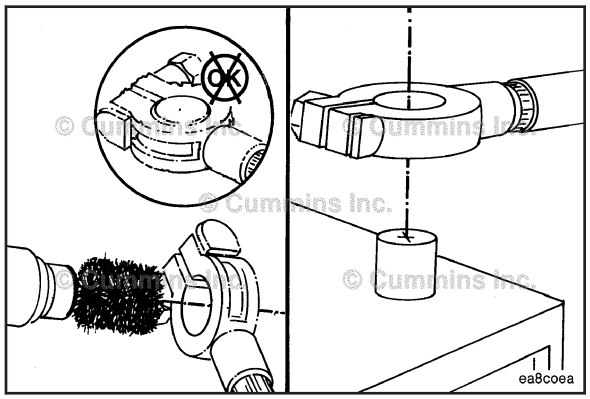
System Voltage	Maximum Voltage Drop
12 VDC	0.5 VDC
24 VDC	1.0 VDC

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

Inspect the battery terminals for loose, broken, or corroded connections.

Repair or replace broken cables or terminals.

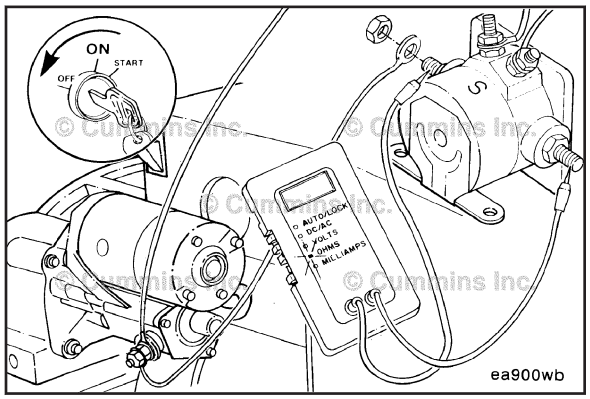




If the connections are corroded, remove the cables, and use a battery brush to clean the cable and battery terminals.

Install and tighten the battery cables.

Use dielectric grease to coat the battery terminals to prevent corrosion.



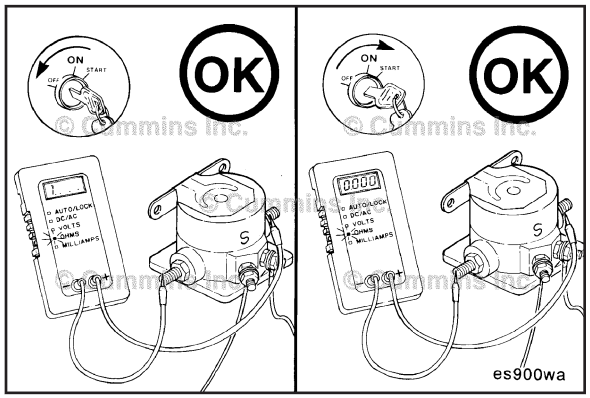
Starter Magnetic Switch (013-017)

Initial Check

⚠WARNING⚠
Be 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 Number 3377161, or equivalent, to the two large switch terminals.

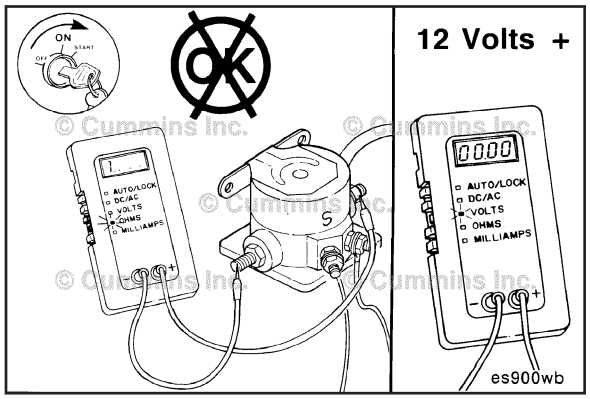


Set the multimeter to measure resistance (OHMS).

With the starting motor switch in the OFF position, the multimeter **must** indicate resistance at infinity.

Turn the starting motor switch to the START position.

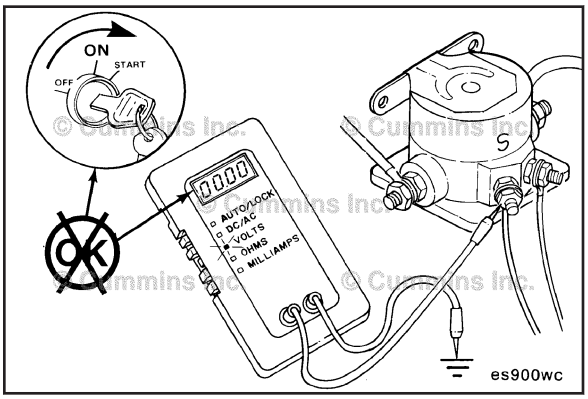
The multimeter **must** indicate zero or very little resistance.



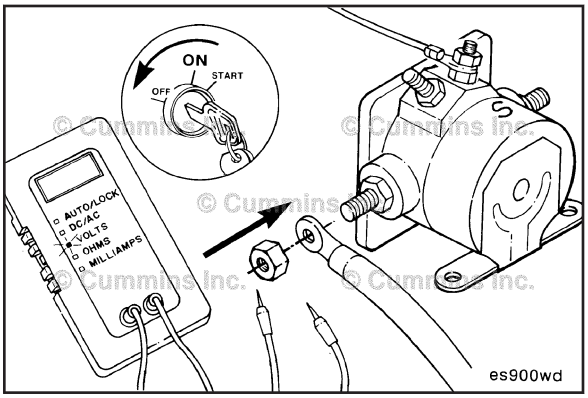
If the multimeter indicates resistance at infinity with the starting motor switch in the START position:

- 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 the 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.
- 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.



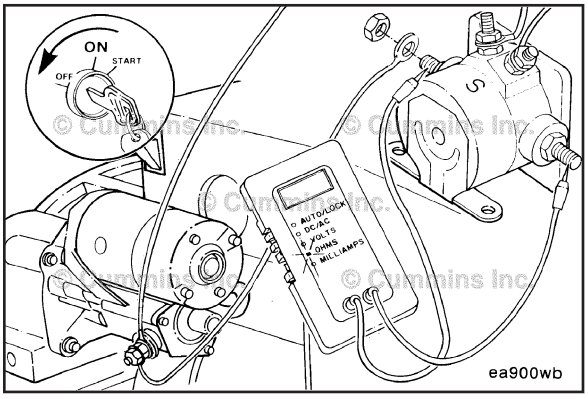
Resistance Check

⚠WARNING⚠
Be sure the starter motor switch is in the OFF position to reduce the possibility of personal injury from electrical shock.

Remove the cable connecting the magnetic switch to the starter motor solenoid from the magnetic switch terminal.

Connect the leads of the digital multimeter, Part Number 3377161, or equivalent, to the two large switch terminals.

Set the digital multimeter, Part Number 3377161, to measure resistance (ohms).

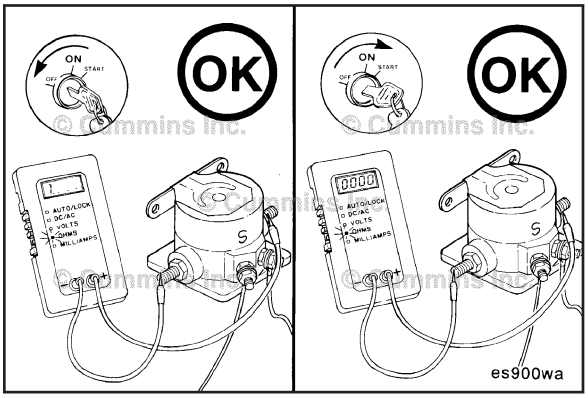


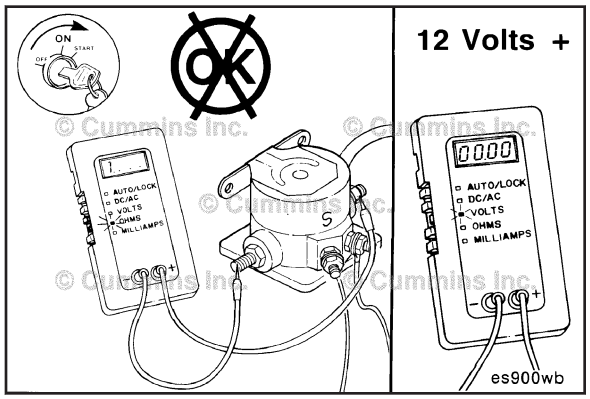
Connect the leads to the two large switch terminals.

With the starter motor switch in the OFF position, the multimeter **must** indicate resistance greater than 100k ohms.

Turn the starter motor switch to the START position.

The multimeter **must** indicate less than 10 ohms. If **not** within specifications, replace the starter magnetic switch according to the manufacturer's instructions.

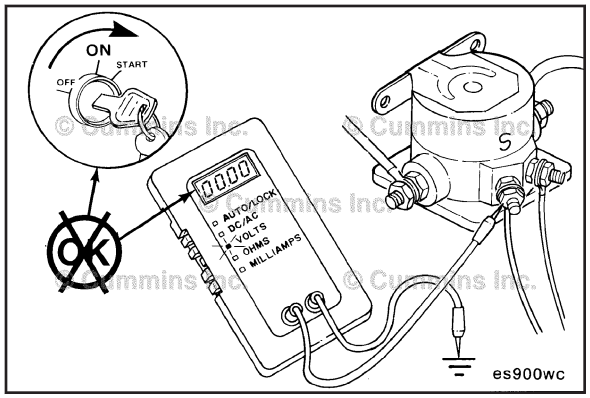




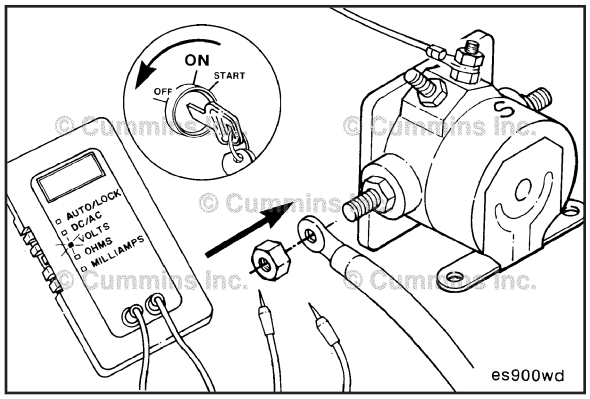
Voltage Check

If the multimeter indicates resistance greater than 100k ohms with the starter motor switch in the START position:

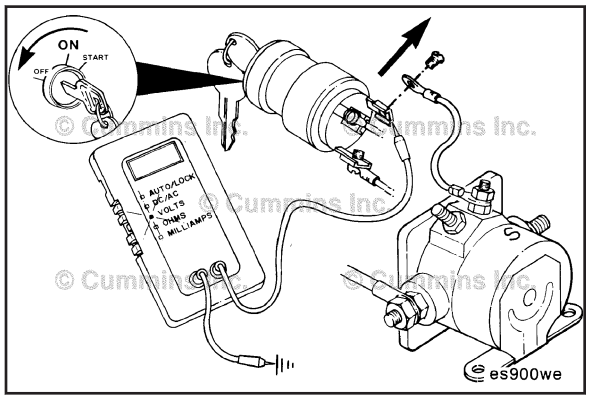
- Turn the starter motor switch to the OFF position.
- Set the multimeter scale to read DC voltage.



- Connect one multimeter lead to the magnetic switch terminal marked "S" and the other lead to the ground.
- Turn the starter motor switch to the START position.
- If the multimeter indicates no voltage, the magnetic switch is **not** the cause of the complaint. Refer to Procedure 013-018. If the starter magnetic switch is **not** within specification, replace the switch according to the manufacturer's instructions.



- Turn the starter motor switch to the OFF position.
- Remove the multimeter leads, and connect the magnetic switch to the starter motor solenoid wire.



Starter Switch (013-018)

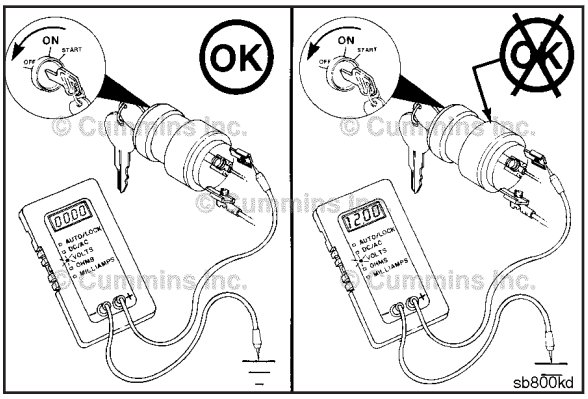
Initial Check

⚠WARNING⚠
Be sure the starting motor switch is in the OFF position to reduce the possibility of personal injury from electrical shock.

Remove the wire connecting the starting motor switch to the magnetic switch (marked "S" or START) from the starting motor switch terminal.

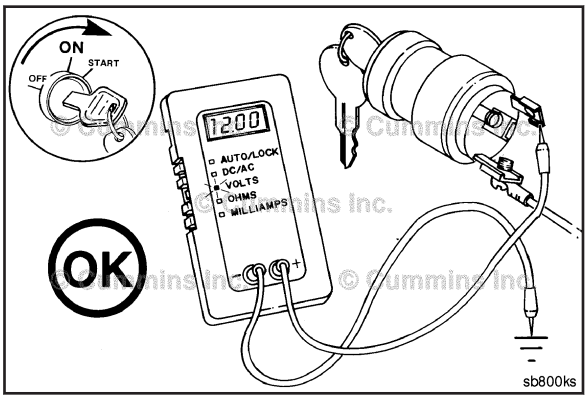
Connect the positive lead of digital multimeter, Part Number 3377161, or equivalent, to the starting motor switch terminal and the negative lead to a chassis or engine ground location.

NOTE: With the starting motor switch in the OFF position, there **must not** be voltage at the starting motor switch terminal. If the meter indicates voltage, the starting motor switch is malfunctioning and **must** be replaced.



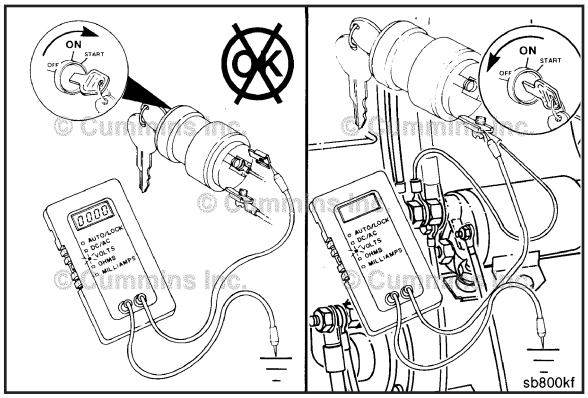
Turn the starting motor switch to the START position.

The multimeter **must** indicate system voltage.



If there is no voltage:

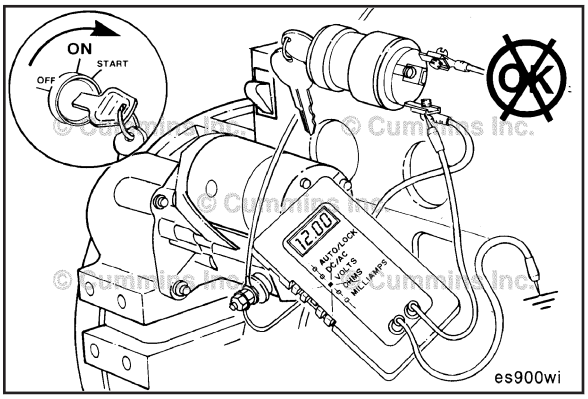
- Turn the starting motor switch to the OFF position.
- Connect the multimeter positive lead to the starting motor switch terminal having a wire connecting the starting motor switch to the starting motor solenoid “B” terminal.

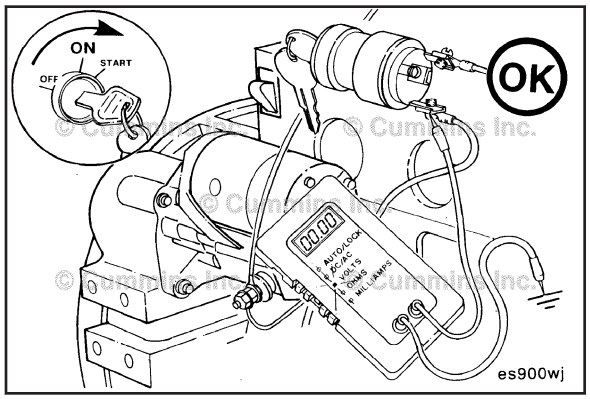


Turn the starter switch to the START position.

If the meter indicates system voltage at the starting motor switch input terminal, the starting motor switch is **not** the cause of the complaint.

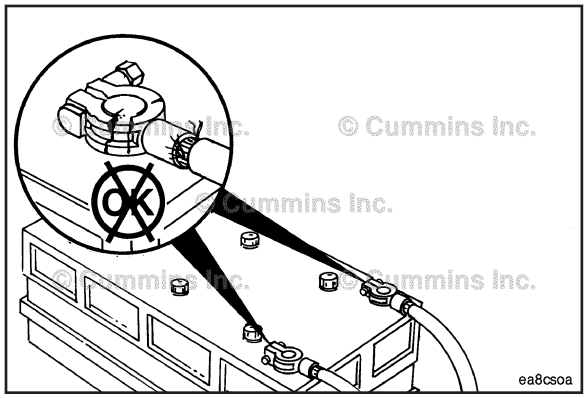
Check the wiring from the starting switch to the starting motor solenoid “B” terminal, and from the starting motor solenoid to the battery for broken or damaged wires.





If the meter indicates no voltage, the switch is defective and **must** be replaced.

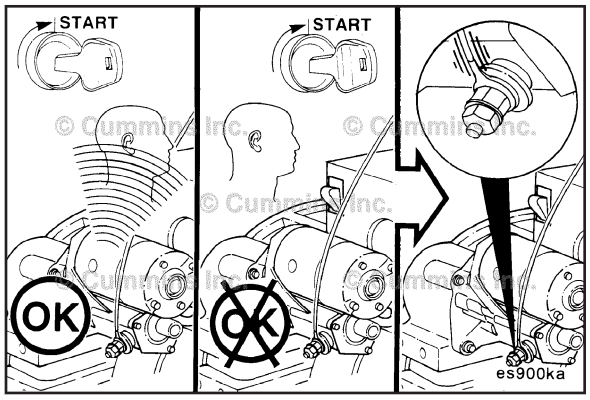
Check the wiring from the starting switch to the starting motor solenoid "B" terminal and from the starting motor solenoid to the battery for broken or damaged wires.



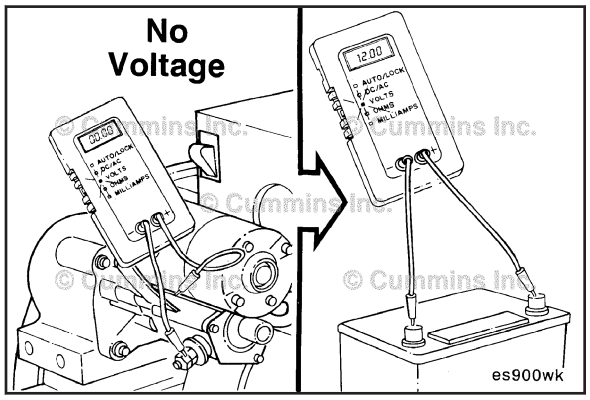
Starter Solenoid (013-019)

Initial Check

Before troubleshooting the starting motor, make sure the battery terminals are **not** loose or corroded.



If the starting motor solenoid does **not** make a sound, check for loose wiring connections.

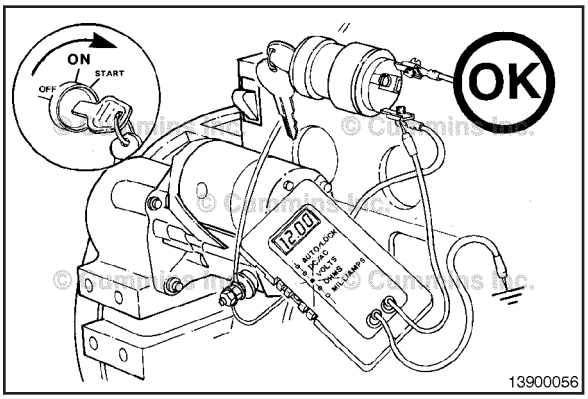


Use a digital multimeter, Part Number 3377161, or equivalent, to set the voltage scale.

Check for system voltage at the starting motor solenoid battery terminal.

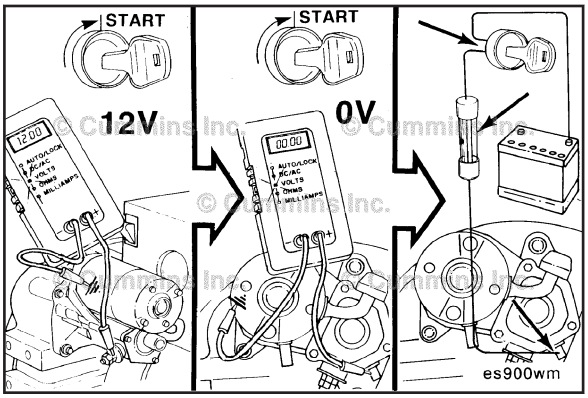
If the multimeter indicates system voltage at the starting motor battery terminal, check the voltage at the starting motor solenoid "S" terminal, while the starting switch is energized.

If the multimeter indicates system voltage at "S" terminal but the starter does **not** engage, the starting motor solenoid is malfunctioning and the starter **must** be replaced.



If the multimeter does **not** indicate system voltage at the "S" terminal, check:

- Fuses
- Voltage to the ignition switch and magnetic switch.
- Application safety shutoff systems.

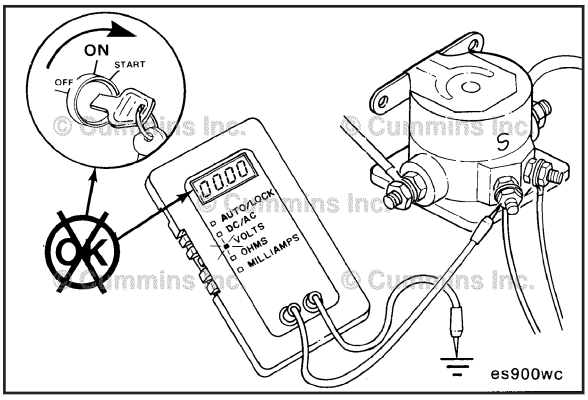


Voltage Check

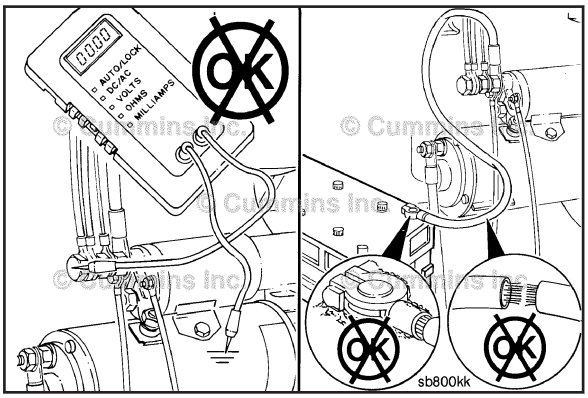
Set the digital multimeter, Part Number 3377161, to measure DC volts.

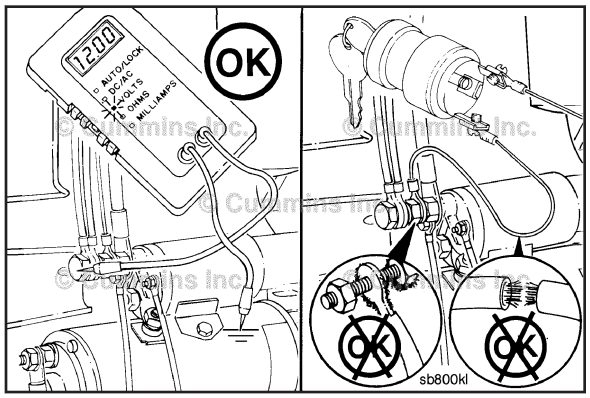
Connect the multimeter positive (+) lead to the starter solenoid positive cable terminal and the negative (-) lead to a chassis or engine ground location.

The multimeter **must** show voltage with the starter switch in the OFF position to be normal.



If the multimeter does **not** indicate voltage, check the cable connecting the starter solenoid and battery for breaks. Also, check for loose or corroded connections.

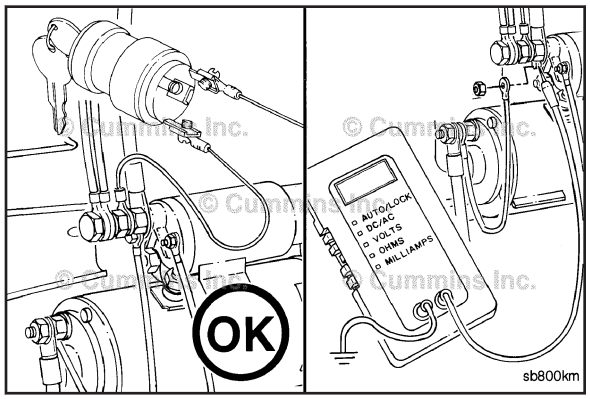




If the multimeter indicates voltage but the starter will **not** operate, check the wire connecting the starter solenoid to the starter switch for breaks, and also check for loose or corroded connections.

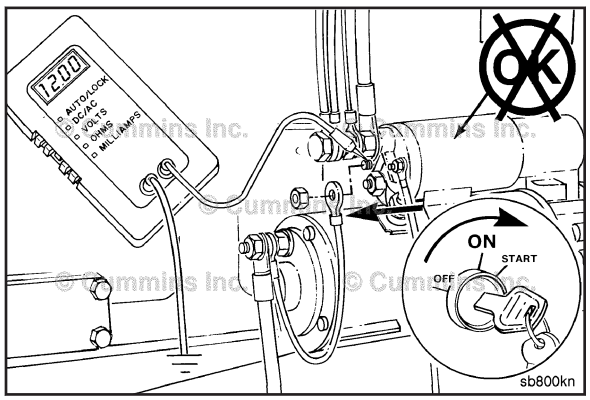
In addition be sure to check for:

- Fuses
- Application engine shutoff systems.

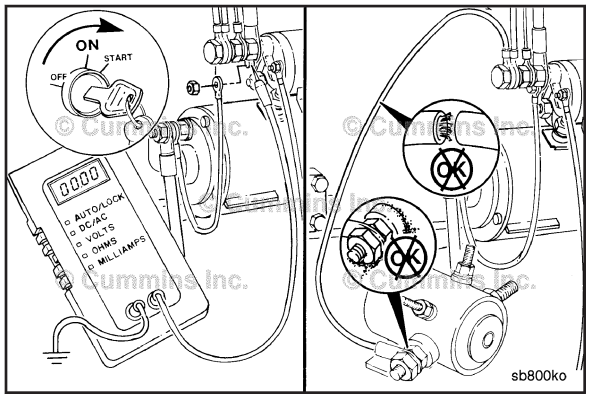


If the wire connecting the starter solenoid and starter switch is **not** loose or damaged and the starter will **not** operate:

- 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.



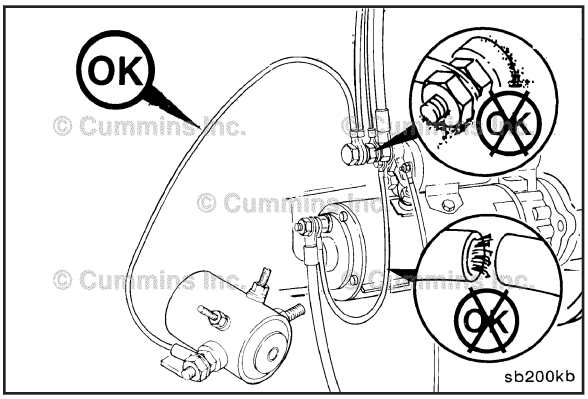
- Turn the starter switch to the START position.
- If the multimeter indicates voltage, the starter solenoid is malfunctioning and **must** be replaced.



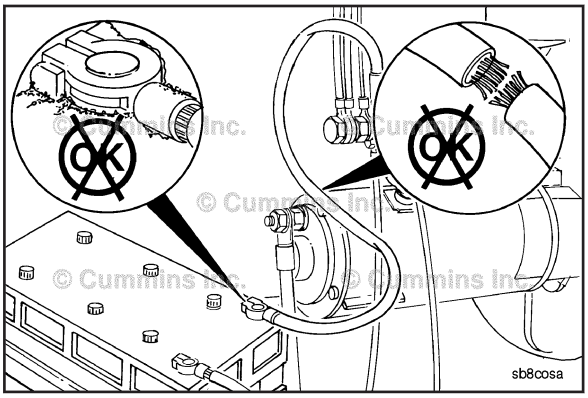
- If the multimeter does **not** indicate voltage, check the wire connecting the starter solenoid to the magnetic switch for breaks, and for loose or corroded connections.

If the wire connecting the starter solenoid to the magnetic switch is **not** loose or damaged and the starter will **not** operate:

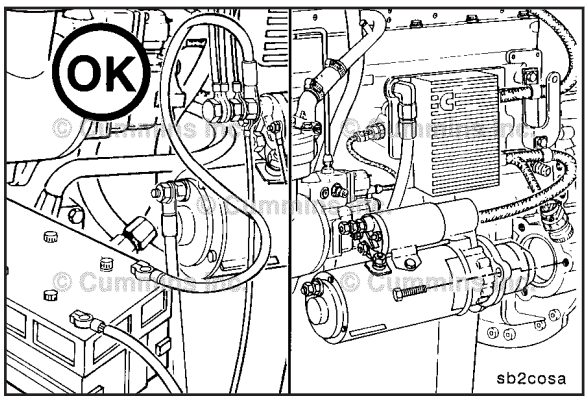
- Check the cable connecting the starter solenoid to the starter motor for breaks, and for loose or corroded connections.



- Check the cable connecting the starter motor to the battery for breaks, and for loose or corroded connections.



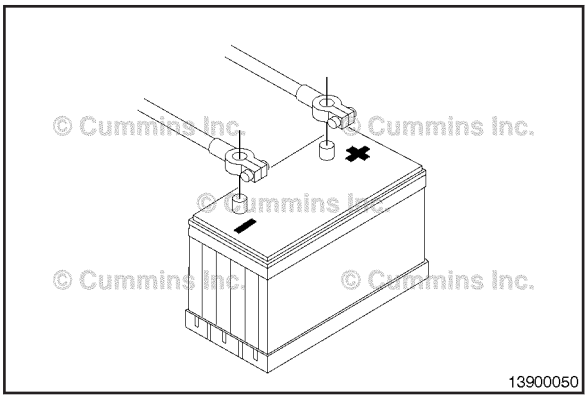
- If the cables are **not** loose or damaged, the starter motor is defective and **must** be replaced. Refer to Procedure 013-020.

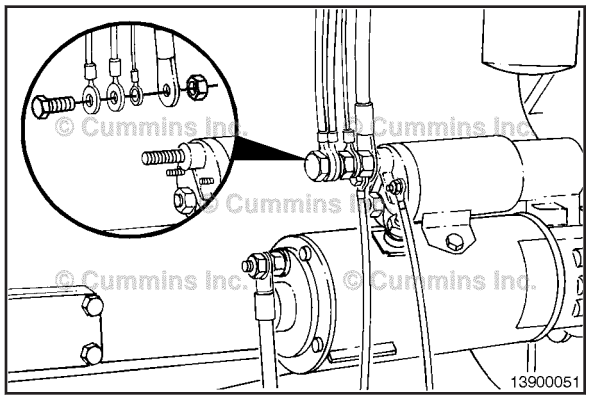


Solenoid Control Circuit Voltage Drop on Delco® Starters.

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

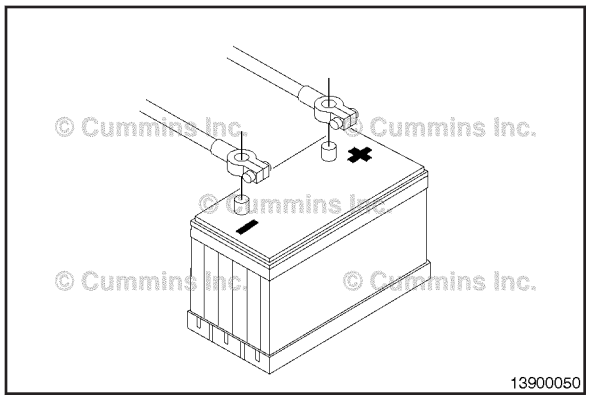
Disconnect the battery.





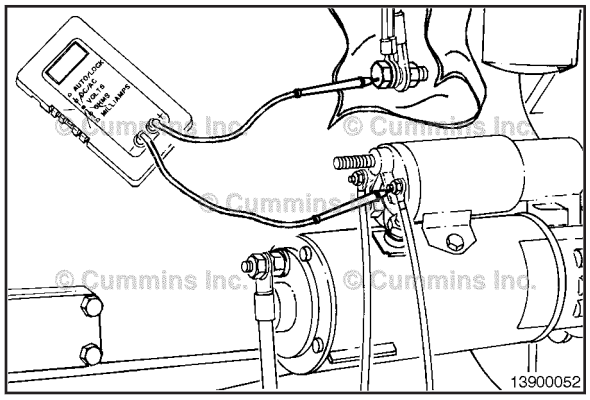
Remove all cables and connections from the battery terminal of the cranking motor.

Clamp all cables and connections together (a 1/2-inch bolt and nut works for clamping connections). Wrap a heavy cloth around the battery terminal of the cranking motor to be certain it does **not** touch any metal.



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

Connect the battery.



Connect a digital multimeter, Part Number 3377161, between battery positive (+) and the “S” terminal (the multimeter should show battery open circuit voltage, about 12.5 to 12.6 VDC).

Close the vehicle start switch and the very first reading is the voltage drop. If you wait, the voltage reading will drop rapidly as the solenoid heats up and raises the solenoid resistance. Be certain to record the very first reading.

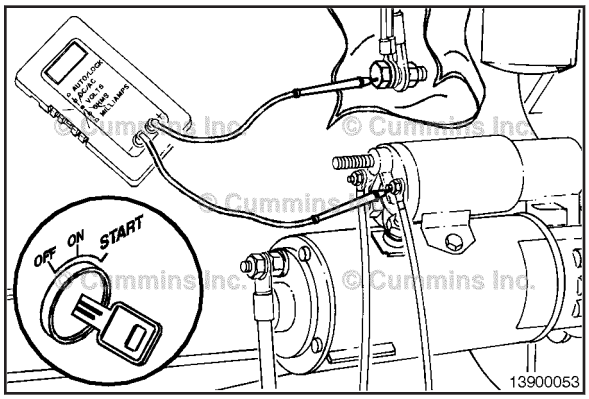
NOTE: The motor will **not** crank if there is no voltage supplied to the motor.

Repeat the step with the multimeter connected between the battery negative (-) and motor negative (-). Add the voltages from the previous step and this step to get the control circuit voltage drop. Values are included in the table below.

With the hold-in and pull-in circuits both activated the maximum allowable voltage drop at 20°C [68°F] is:

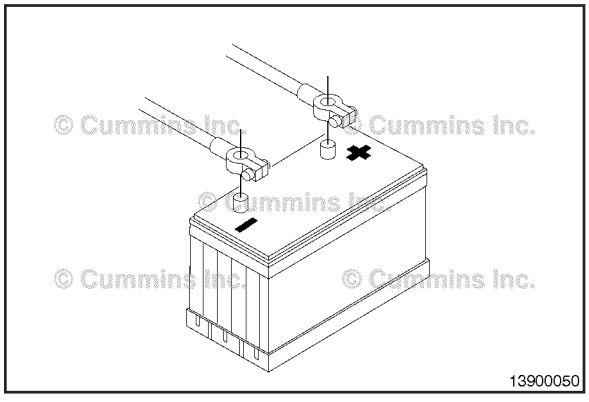
VDC	Voltage Drop (maximum)
12	1.0 VDC
24	2.0 VDC
32	2.6 VDC

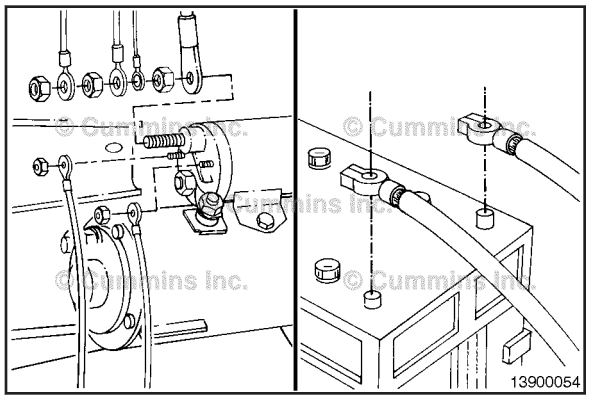
Solenoid Average Amperage Draw			
Motor	**VDC**	**PI & HI Amps**	**HI Amps**
28MT	12	69	13
	24	120	13
37MT	12	74	19
	24	36	6
41/42MT	12	97	18
	24	57	13
50MT	12	86	15
	24	49	6
	32	38	6
	64	10	2
For 12 -DC systems, apply 10 VDC to the "S" terminal.			
For 24-VDC systems, apply 20 VDC to the "S" terminal.			
For some 32-VDC systems, apply 30 VDC to the "S" terminal.			
For some 32-VDC and all 64-VDC systems, apply 30 VDC to the "B+" terminal.			



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

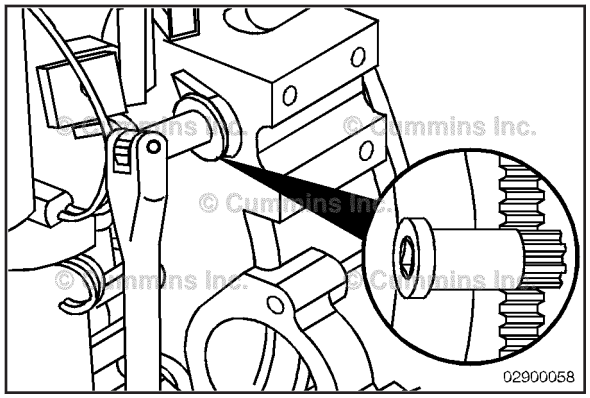




⚠WARNING⚠

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

Replace all connections to the battery terminal of the motor and then reconnect the battery.



Starting Motor (013-020)

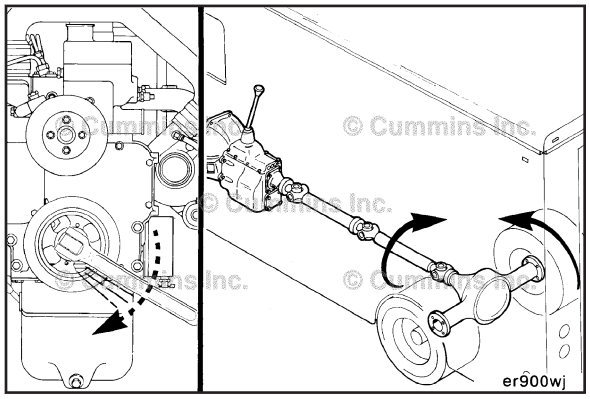
Rotation Check

If the starter solenoid is making a sound but the engine is **not** rotating, turn the keyswitch to the OFF position, and attempt to bar the crankshaft in both directions.

Bar the engine with the barring tool, Part Number 3824591.

If the crankshaft will bar over, attempt to start the engine. If the starter motor cranks the engine, check the starter motor pinion gear and flywheel ring gear for damage.

If damage to the starter motor pinion gear and/or flywheel ring gear is found when replacing the components, make sure to measure the distance from the starting motor mounting flange to the forward face of the front side of the flywheel ring gear. Follow the measure step of this procedure.

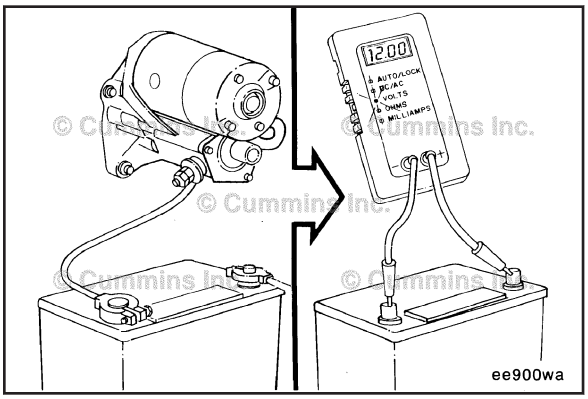


If the crankshaft does **not** rotate or requires more than the normal effort to bar, check for an internal malfunction or a problem with the drive unit and/or accessories.

If the engine cranking speed is too slow/will **not** crank at all, and the engine rotates freely:

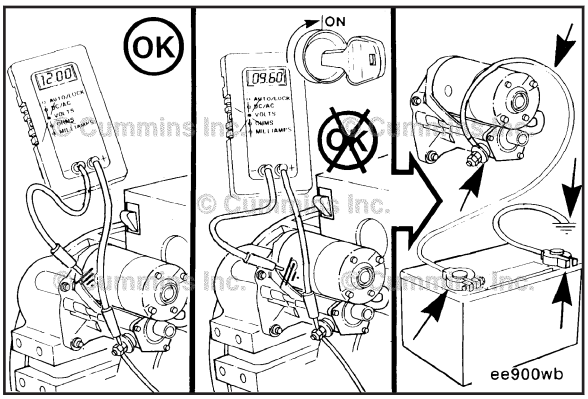
Make sure the wiring connections are clean, tight and **not** damaged.

Check the battery voltage.Refer to Procedure 013-007 in Section 13.



Check the voltage at the starting motor during cranking. If the voltage drops more than 2.4-VDC on a 12 volt system and 4.8 volt on a 24-VDC system, check that all connections are clean and tight.

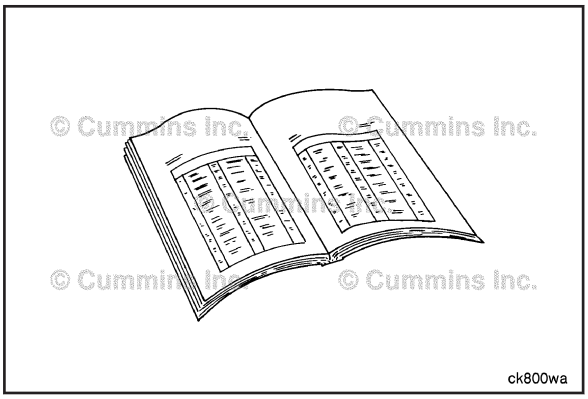
If the cables are correct and the voltage drop exceeds the limit, replace the starting motor.

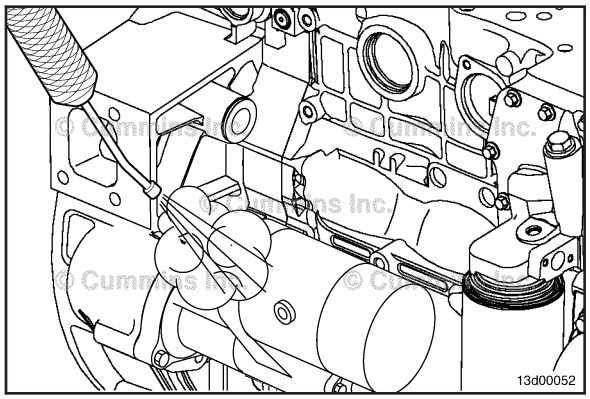


Preparatory Steps

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

- Disconnect the ground cable from the battery terminal. Refer to the OEM service manual.
- Identify each wire with a tag indicating location on starting motor.
- Remove the electrical connections from the starting motor.





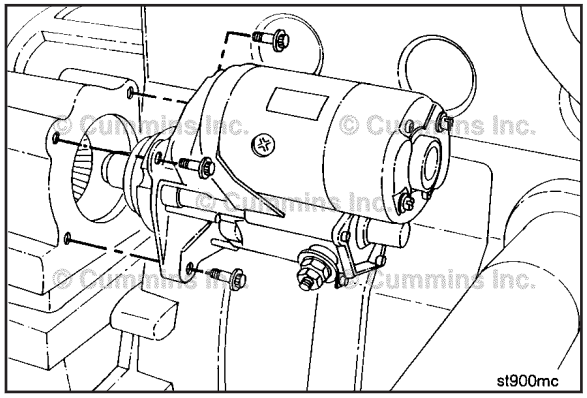
Remove

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

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

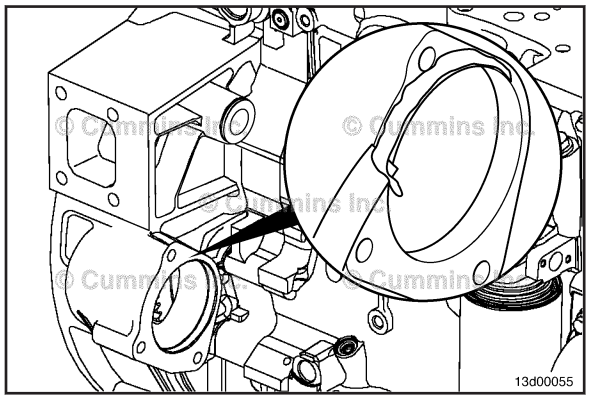
Prior to removing the starter, use steam to clean the area around the starting motor to prevent debris from entering the flywheel housing.

Dry with compressed air.



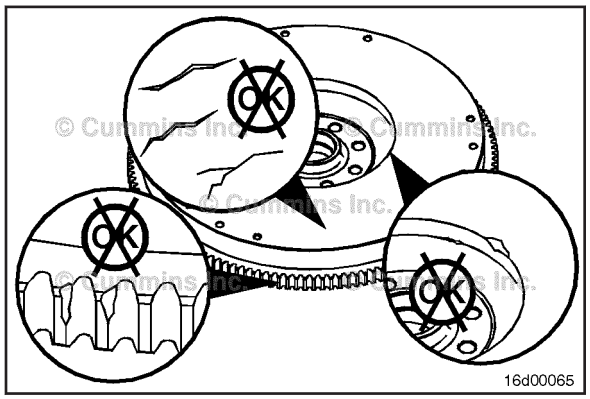
Remove the three capscrews and the starting motor.

NOTE: If equipped with a starting motor spacer, remove the spacer and clean all surfaces between the starting motor, starting motor spacer, and flywheel housing with a wire brush.



Clean and Inspect for Reuse

For engines that use wet flywheel housings, clean any left over sealant from the starting motor mounting flange on both the flywheel housing and starting motor. Make sure these surfaces are clean of oil and debris.



Inspect the starter motor pinion gear and/or flywheel ring gear for chipping or uneven wear.

NOTE: If the starter motor pinion gear and/or flywheel ring gear teeth are damaged, they **must** be replaced.

Use the following procedure, if equipped with a flywheel. Refer to Procedure 016-005 in Section 16.,

Use the following procedure, if equipped with a flexplate. Refer to Procedure 016-004 in Section 16.

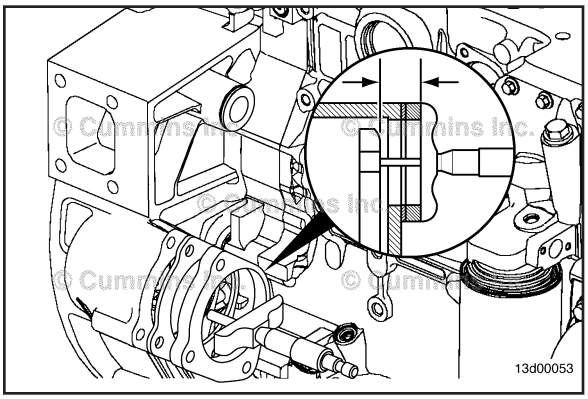
Measure

Using an inside micrometer or a vernier caliper, measure the distance from the starting motor mounting flange to the forward face of the front side of the flywheel ring gear.

NOTE: Include any spacers previously removed when completing the measurement.

Starting Motor Spacing		
mm		**in**
49.28	MIN	1.94
52.32	MAX	2.06

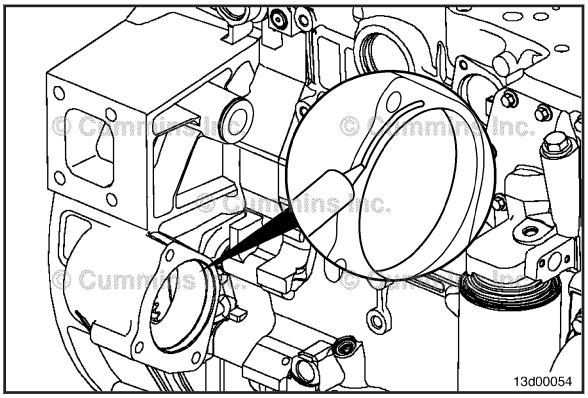
Add or remove spacers as necessary to achieve the correct starting motor spacing.



Install

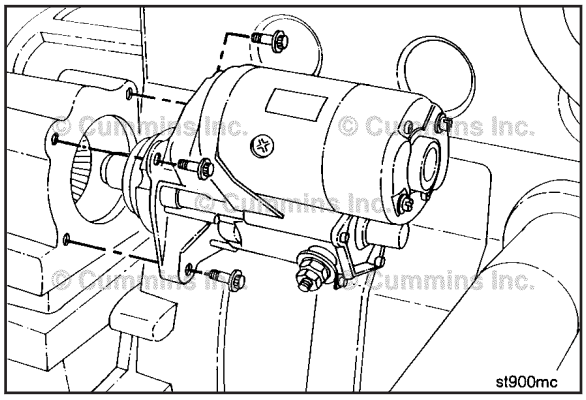
For engines with wet flywheel housings, apply a 1.5 to 2.0 mm [0.06 to 0.09 in] wide bead of sealant, Part Number 3164067, to the flywheel housing starting motor mounting flange.

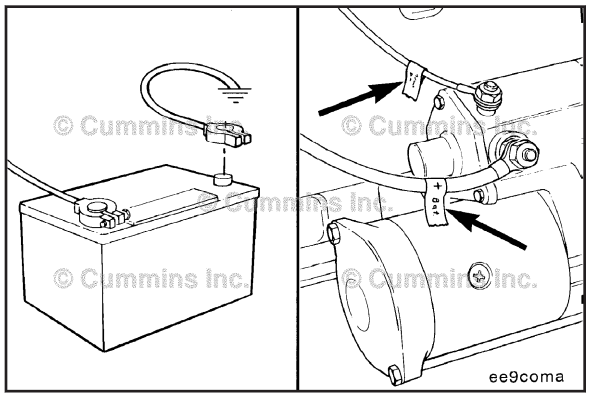
NOTE: If a starting motor spacer is required, make sure to apply sealant to the side of the spacer that contacts the starting motor.



Install the three capscrews, the starting motor, and starting motor spacer, if required.

Torque Value: 43 N•m [32 ft-lb]





Cummins® Branded Starters

⚠CAUTION⚠
Do not overtighten the electrical connections. Starter damage can result.

NOTE: Use the location tags to help identify where each wire connection goes.

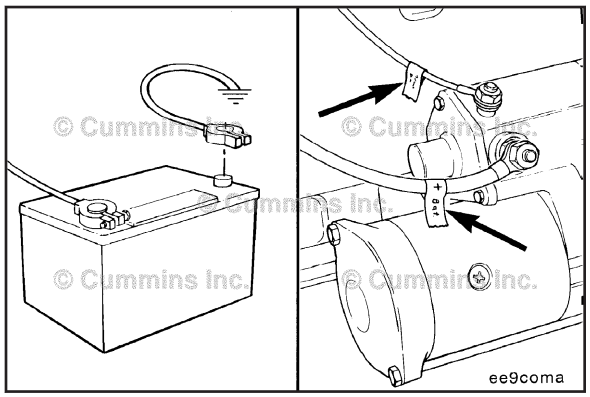
Connect the electrical connections to the starter motor.

Torque Value:
M5
Step 1 4 N•m [35 in-lb]

Torque Value:
M10
Step 1 21 N•m [185 in-lb]

Install the jump start protection (JSP) cover and cover nut on the M terminal post.

NOTE: The JSP cover nut is the third nut on the M terminal, M5 terminal size. Failure to observe the proper torque specification can result in loss of conductivity to the M lead and result in a no crank condition for the starter and engine.



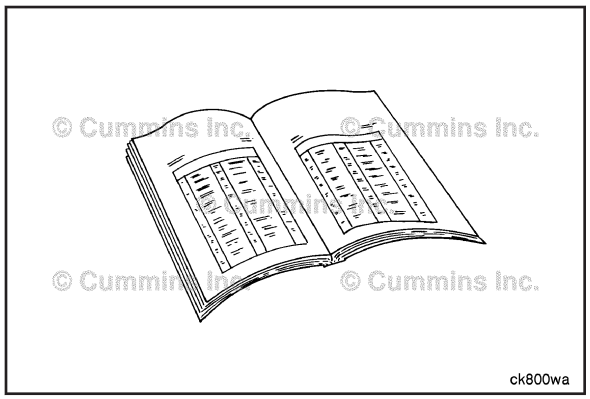
Non-Cummins® Branded Starters

⚠CAUTION⚠
Do not overtighten the electrical connections. Starter damage can result.

NOTE: Use the location tags to help identify where each wire connection goes.

Install the starter motor electrical connections.

For Non-Cummins® branded starters, refer to the OEM manual for torque specifications.



Finishing Steps

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

- Connect the ground cable to the battery terminal.

Section 14 - Engine Testing - Group 14

Section Contents

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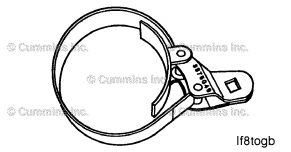
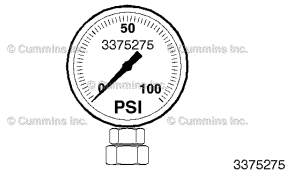
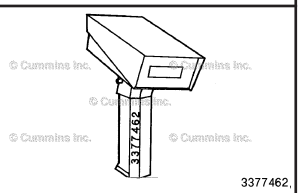
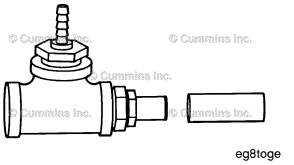
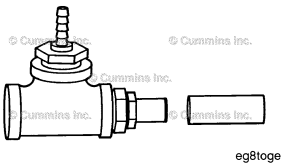
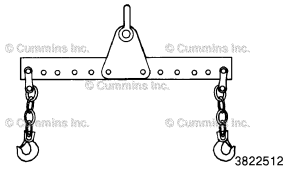
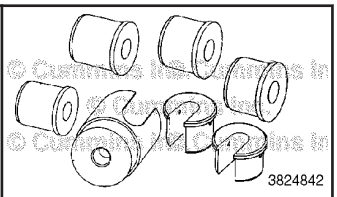
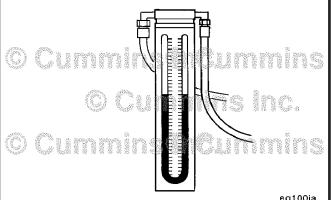
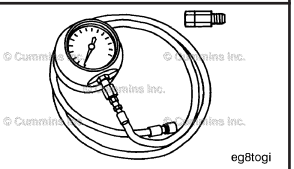
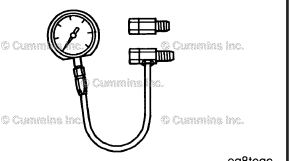
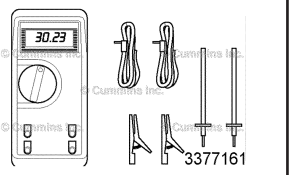
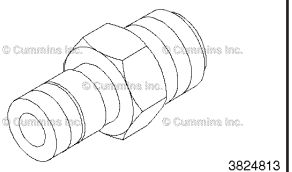
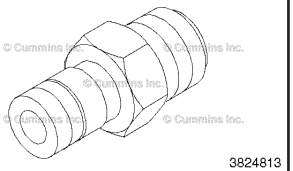
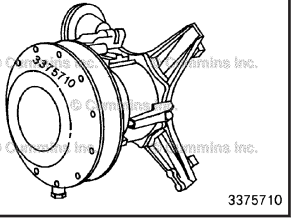
Service Tools

Engine Testing

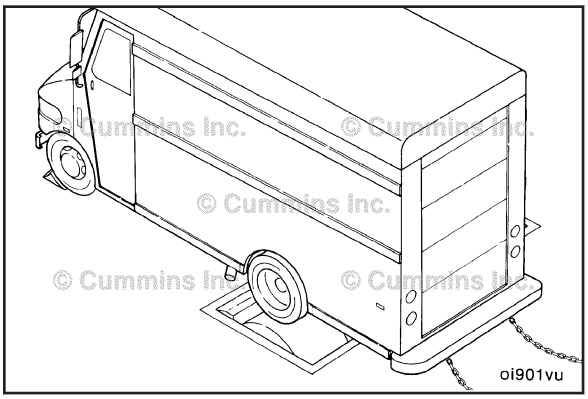
The following special tools are recommended to perform procedures in this section. The use of these tools is shown in the appropriate procedure. These tools can be purchased from a local Cummins® Authorized Repair Location.

Tool No.	Tool Description	Tool Illustration
3375049	**Oil Filter Wrench** Use to remove or tighten spin-on lubricating oil or fuel filters.	
3375275	**Pressure Gauge (0 to 160 psi)** Used to measure lubricating oil pressure.	
3377462	**Digital Optical Tachometer** Used to measure engine speed (rpm).	
3822476	**Blowby Checking Tool** Use to check engine crankcase blowby (.221 inch orifice).	
3822566	**Blowby Checking Tool** Use to check engine crankcase blowby (.302 inch orifice).	
3822512	**Engine Lifting Fixture** Used to remove and install the engine.	

Tool No.	Tool Description	Tool Illustration
3824842	**Compuchek® Fitting** Used for connection to diagnostics machine.	
ST-1111-3	**Manometer** Used with the blowby check tool to measure engine crankcase pressure.	
ST-1273	**Pressure Gauge** Used to measure engine intake manifold pressure, exhaust restriction, lift pump output pressure, and pressure drop across the fuel filter.	
ST-434	**Vacuum Gauge** Used to measure lift pump inlet restriction. Hose adapter, Part Number ST-434-2, and vacuum gauge, Part Number ST-434-12, are used to perform the test.	
3164488 or 3164489	**Multimeter** Used to measure electrical circuits: Voltage (volts), resistance (ohms), and current (amps). 3164488 — Standard meter. 3164489 — Automotive meter with built in temperature adapter and tachometer.	
3377244	**Compuchek® Fitting** Used to connect diagnostics machine. With 1/8 NPT connection.	
3824842	**Compuchek® Fitting** Used to check fuel filter restriction. With 10 mm O-Ring connection.	
3375710	**Drivetrain Dynomometer** Used to measure engine horse power.	

Engine Testing (Chassis Dynamometer) (014-002)

Setup



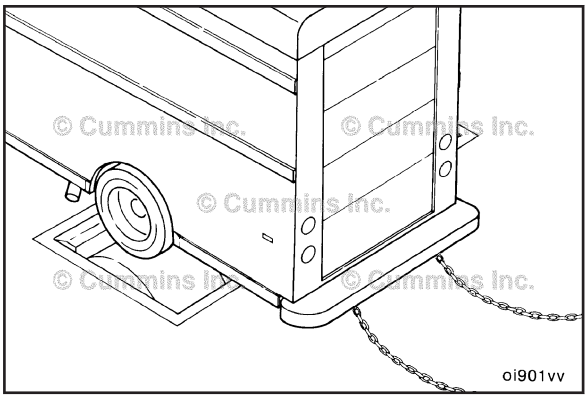
The performance of an engine installed in on-highway vehicles can be tested on a chassis dynamometer.

NOTE: Because of driveline efficiency and engine-driven accessories, the engine horsepower when measured at the rear wheels will be reduced by approximately:

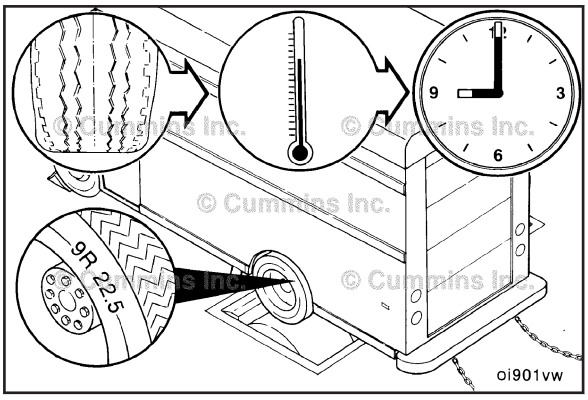
- 20 percent for single-axle vehicles
- 25 percent for tandem-axle vehicles
- 35 percent for recreational vehicles.

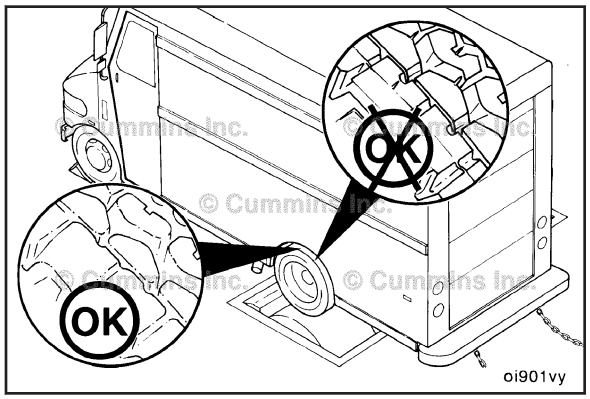
NOTE: These percentages are used for engine run-in **only** and are **not** to be used as absolute figures.

⚠WARNING⚠
Follow all of the vehicle manufacturer's safety precautions before installing or operating a vehicle on a chassis dynamometer. Failure to do so can cause damage to the vehicle and/or harm personnel.



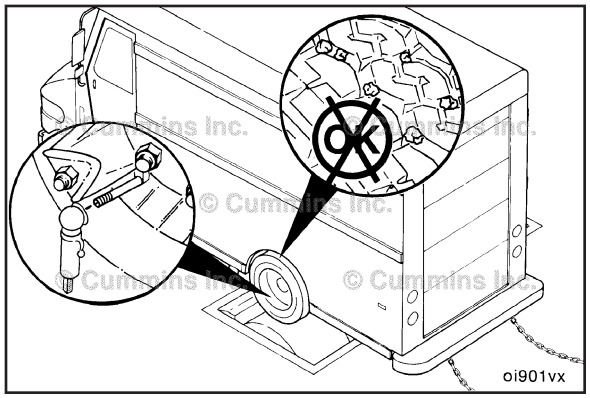
⚠CAUTION⚠
Low-profile tires are more sensitive to heat than bias ply tires. Excessive operating time at full load can damage the tires due to overheating. Check the tire manufacturer's recommendations for the maximum allowable chassis dynamometer operating time.



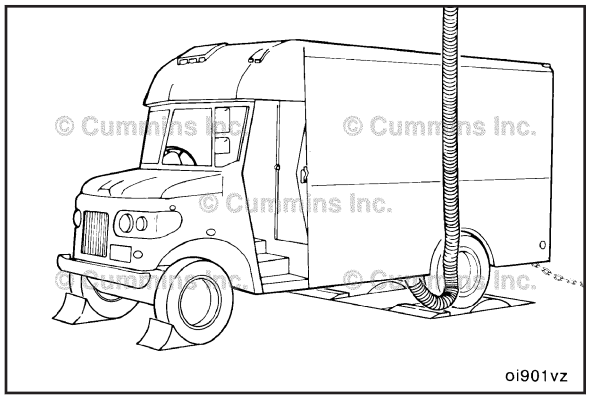


While operating the chassis dynamometer, follow the general safety precautions listed below:

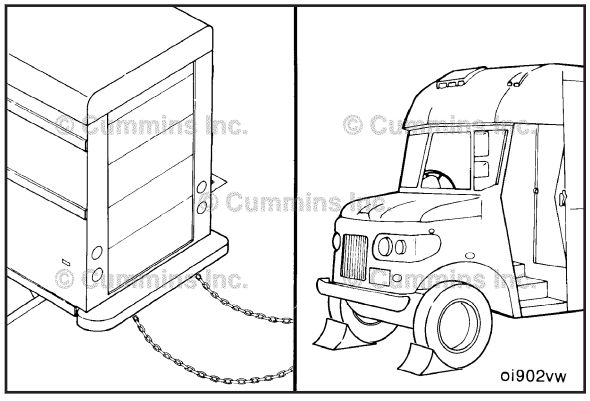
- Use tires that have more than 160 km [100 mi] of use. Do **not** use new tires.
- Do **not** use recapped tires or tires of different sizes or designs.



- Make sure the tires are inflated to the manufacturer's specifications.
- Remove all rocks or other materials from the treads of the tires that will be rotating on the dynamometer rollers.



- Make sure there is correct overhead clearance for exhaust stacks, air deflectors, or other attachments above the cab.



△CAUTION△
To prevent damage to the chassis dynamometer, make sure there is enough slack in the tie-down chains.

Carefully position the vehicle on the rollers.

Attach the tie-down chains to the rear of the vehicle.

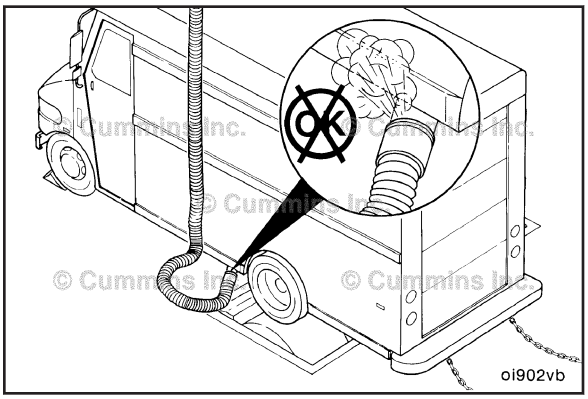
Place wheel chocks in front of the front tires.

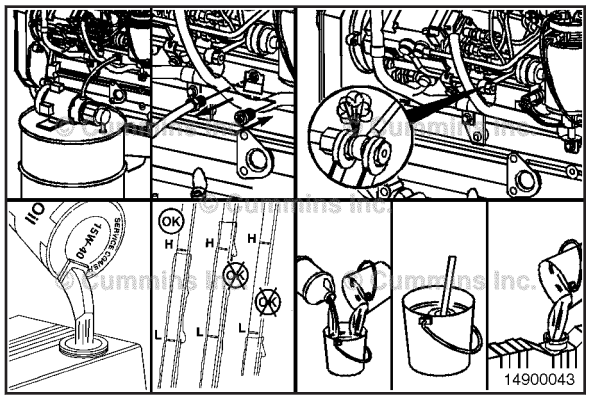
⚠WARNING⚠

Some exhaust gas constituents may be toxic and/or carcinogenic. Make sure the ventilation hose does not leak.

Adjust the vehicle and dynamometer room exhaust system to make sure all the exhaust gases are removed from the room.

Read the chassis dynamometer and vehicle manufacturer's recommendations and specifications for testing procedures.





Test

⚠WARNING⚠
Check the coolant level only when the engine is stopped. Wait until the coolant temperature is below 50°C [120°F] before removing the pressure cap. Failure to do so can cause personal injury from heated coolant spray.

The following procedure assumes that the lubricating oil and fuel systems were correctly primed, the dipstick calibrated, and the engine filled to the correct levels with lubricating oil and coolant during installation of the engine into the chassis. If these systems were **not** serviced during installation of the engine.

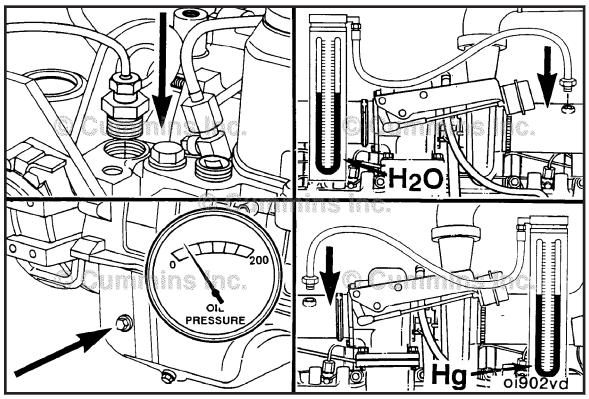
Use the following procedures for instructions on priming the lubricating oil and the fuel system and calibrating the dipstick.

- Use the following procedure in the Service Manual, ISF2.8 CM2220 F101. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the Service Manual, ISF2.8 CM2220 E and ISF2.8 CM2220 AN Bulletin 4022178. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the Service Manual, ISF2.8 CM2220 E and ISF2.8 CM2220 AN Bulletin 4022178. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the Service Manual, ISF3.8 CM2220 Bulletin 4021704. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the Troubleshooting and Repair Manual, ISC, ISCe, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB, ISBe 4 and 6 Cylinder, Bulletin 4021271. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207. Refer to Procedure 014-006 in Section 14.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 014-006 in Section 14.

Reference the Operation and Maintenance Manual for instructions on filling the lubricating oil and the cooling systems.

The number of instruments and gauges required to perform a chassis dynamometer test will vary according to type and the capability of the test equipment used.

See the service tools listed at the beginning of this section.



To correctly monitor an engine's performance, record the following parameters:

- Lubricating oil pressure (vehicle instrument panel)
- Engine speed (rpm) (vehicle instrument panel)
- Wheel horsepower (whp) (dynamometer controls)
- Blowby: Refer to Procedure 014-010 in Section 14.
- Exhaust back pressure:
- Use the following procedure in the Service Manual, ISF2.8 CM2220 F101, Bulletin 4310846. Refer to Procedure 011-009 in Section 14.
- Use the following procedure in the Service Manual, ISF2.8 CM2220 E and ISF2.8 CM2220 AN Bulletin 4022178. Refer to Procedure 011-009 in Section 11.
- Use the following procedure in the Service Manual, ISF3.8 CM2220 Bulletin 4021704. Refer to Procedure 011-009 in Section 11.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193. Refer to Procedure 011-009 in Section 11.
- Use the following procedure in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087. Refer to Procedure 011-009 in Section 11.
- Use the following procedure in the Troubleshooting and Repair Manual, ISC, ISCe, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418. Refer to Procedure 011-009 in Section 11.
- Use the following procedure in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003. Refer to Procedure 011-009 in Section 11.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB, ISBe 4 and 6 Cylinder, Bulletin 4021271. Refer to Procedure 011-009 in Section 11.
- Use the following procedure in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207. Refer to Procedure 011-009 in Section 11.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 011-009 in Section 11.
- Coolant temperature (vehicle instrument panel):
- Use the following procedure in the Service Manual, ISF2.8 CM2220 F101, Bulletin 4310846. Refer to Procedure 008-018 in Section 18.
- Use the following procedure in the Service Manual, ISF2.8 CM2220 E and ISF2.8 CM2220 AN Bulletin 4022178. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Service Manual, ISF3.8 CM2220 Bulletin 4021704. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, ISC, ISCe, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB, ISBe 4 and 6 Cylinder, Bulletin 4021271. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 008-018 in Section 8.
- Coolant pressure:
- Use the following procedure in the Service Manual, ISF2.8 CM2220 F101, Bulletin 4310846. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Service Manual, ISF2.8 CM2220 E and ISF2.8 CM2220 AN Bulletin 4022178. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, ISC, ISCe, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB, ISBe 4 and 6 Cylinder, Bulletin 4021271. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207. Refer to Procedure 008-018 in Section 8.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 008-018 in Section 8.
- Intake manifold pressure:
- Use the following procedure in the Service Manual, ISF2.8 CM2220 F101, Bulletin 4310846. Refer to Procedure 010-057 in Section 10.
- Use the following procedure in the Service Manual, ISF2.8 CM2220 E and ISF2.8 CM2220 AN Bulletin 4022178. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the Service Manual, ISF3.8 CM2220 Bulletin 4021704. Refer to Procedure 010-057 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193. Refer to Procedure 010-057 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087. Refer to Procedure 010-057 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, ISC, ISCe, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418. Refer to Procedure 010-057 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003. Refer to Procedure 010-057 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB, ISBe 4 and 6 Cylinder, Bulletin 4021271. Refer to Procedure 010-057 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207. Refer to Procedure 010-057 in Section 10.
- Inlet air restriction:
- Use the following procedure in the Service Manual, ISF2.8 CM2220 F101, Bulletin 4310846. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the Service Manual, ISF2.8 CM2220 E and ISF2.8 CM2220 AN Bulletin 4022178. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the Service Manual, ISF3.8 CM2220 Bulletin 4021704. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, ISC, ISCe, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB, ISBe 4 and 6 Cylinder, Bulletin 4021271. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207. Refer to Procedure 010-031 in Section 10.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 010-031 in Section 10.
- Fuel supply pressure:
- Use the following procedure in the Service Manual, ISF2.8 CM2220 F101, Bulletin 4310846. Refer to Procedure 006-024 in Section 10.
- Use the following procedure in the Service Manual, ISF2.8 CM2220 E and ISF2.8 CM2220 AN Bulletin 4022178. Refer to Procedure 005-016 in Section 5.
- Use the following procedure in the Service Manual, ISF3.8 CM2220 Bulletin 4021704. Refer to Procedure 006-024 in Section 6.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB and QSB5.9 Engines, Bulletin 3666193. Refer to Procedure 006-024 in Section 6.
- Use the following procedure in the Troubleshooting and Repair Manual, B3.9, B4.5, and B5.9 Series Engines, Bulletin 3666087. Refer to Procedure 006-024 in Section 6.
- Use the following procedure in the Troubleshooting and Repair Manual, ISC, ISCe, QSC8.3, ISL and QSL9 Engines, Bulletin 4021418. Refer to Procedure 006-024 in Section 6.
- Use the following procedure in the Troubleshooting and Repair Manual, C Series, Bulletin 3666003. Refer to Procedure 006-024 in Section 6.
- Use the following procedure in the Troubleshooting and Repair Manual, ISB, ISBe 4 and 6 Cylinder, Bulletin 4021271. Refer to Procedure 006-024 in Section 6.
- Use the following procedure in the Troubleshooting and Repair Manual, B Series, Bulletin 3810207. Refer to Procedure 006-024 in Section 6.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 006-024 in Section 6.

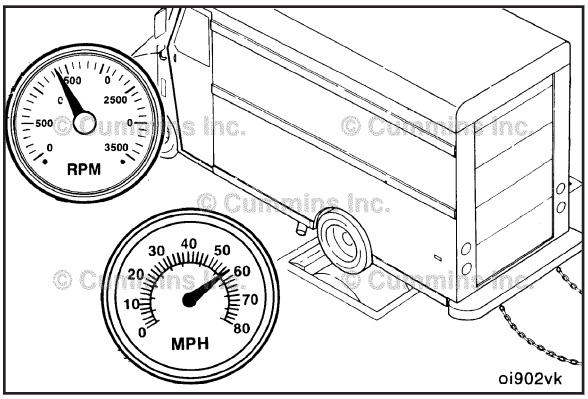
Engine Run-in (Chassis Dynamometer) (014-003)

Test

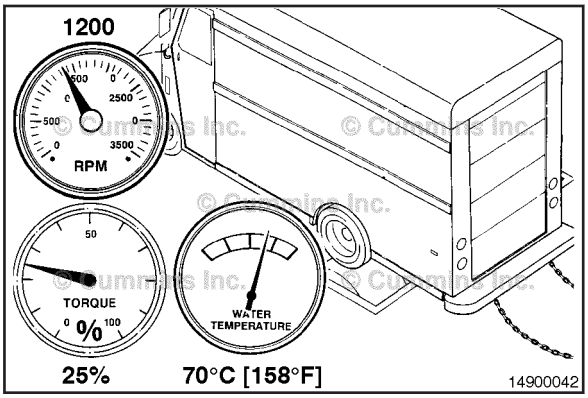
NOTE: Refer to Procedure 014-002 before operating the engine to reduce the possibility of internal component damage.

NOTE: Refer to Procedure 014-005 for general operating procedures and safety precautions.

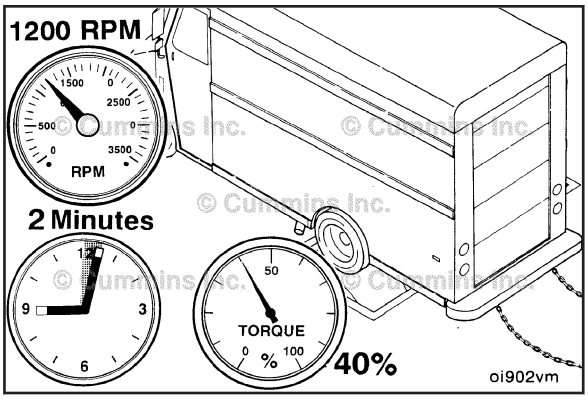
NOTE: Operate the vehicle in a gear that produces a road speed of 90 to 95 km/h [56 to 59 mph].



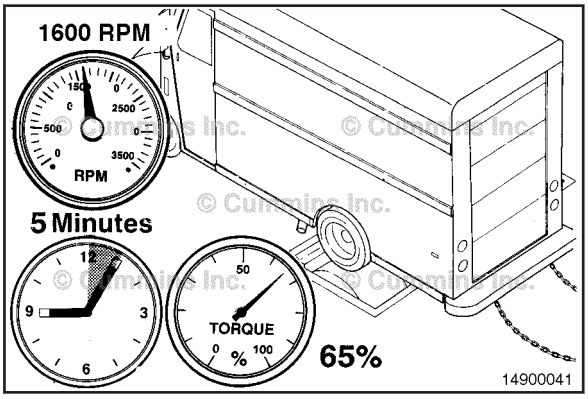
Operate the engine at 1200 rpm and 25 percent of torque peak load until the water temperature reaches 70°C [158°F].

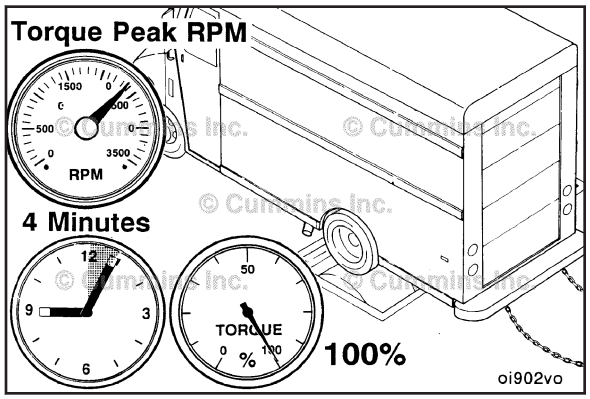


Operate the engine at 1200 rpm and 40 percent of torque peak load for two minutes. Check the gauges, and record the readings.



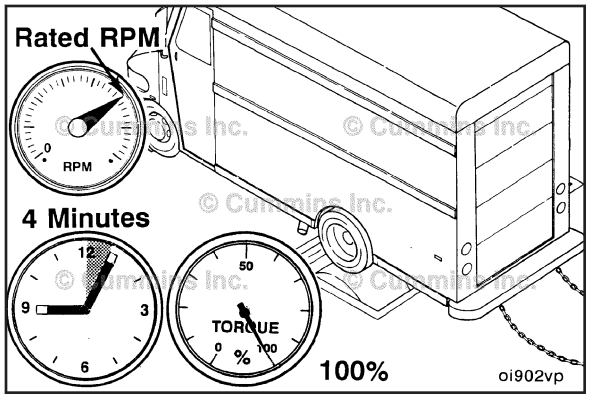
Operate the engine at 1600 rpm and 65 percent of torque peak load for five minutes. Check the gauges, and record the readings.





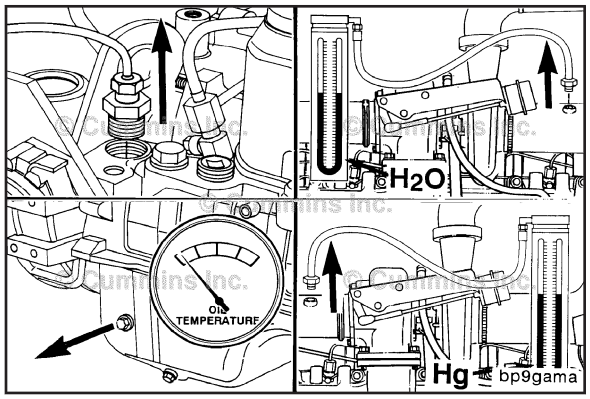
Operate the engine at torque peak rpm and full load for 4 minutes. Check the gauges and record the readings.

NOTE: Refer to the engine data sheet for the torque peak rpm of the engine model being tested.

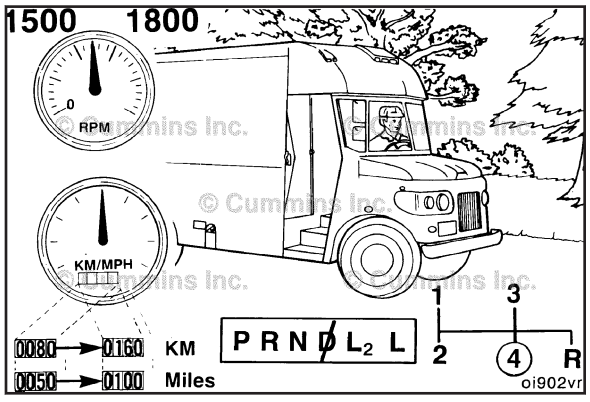


Operate the engine at rated speed (rpm) and full load for four minutes. Check the gauges, and record the readings. Compare the readings to those published on the appropriate engine data sheet.

⚠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 three minutes to reduce the possibility of internal component damage.



Make sure all instrumentation is removed before removing the vehicle from the dynamometer.



Engine Run-in (Without Dynamometer) (014-004)

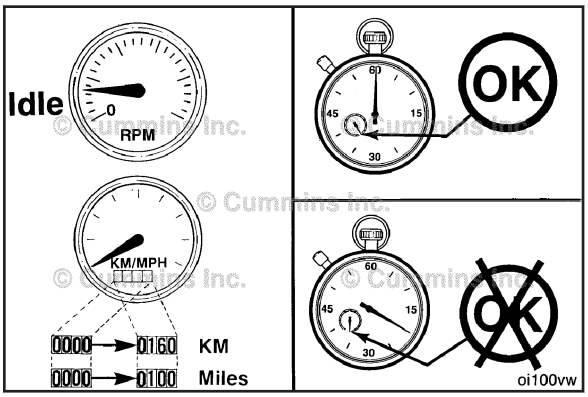
Test

On-Highway Applications

NOTE: Refer to General Engine Test Procedures (Chassis Dynamometer) (Procedure 014-005) before operating the engine to avoid internal component damage.

Operate the engine at 1500 to 1800 rpm in high gear for the first 80 to 160 km [50 to 100 mi] after rebuild.

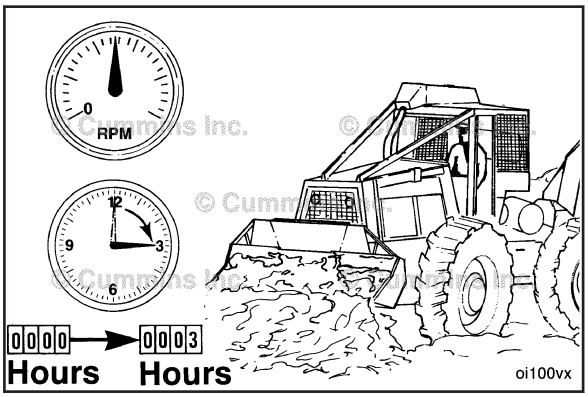
NOTE: Do **not** idle the engine for more than 5 minutes at any one time during the first 160 km [100 mi] of operation.



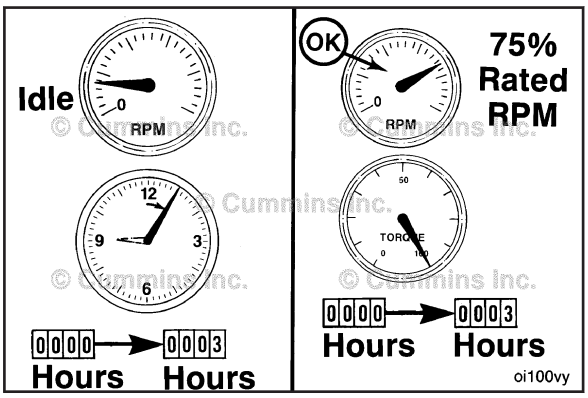
Off-Highway Applications

NOTE: Refer to General Engine Test Procedures (Chassis Dynamometer) (Procedure 014-005) before operating the engine to avoid internal component damage.

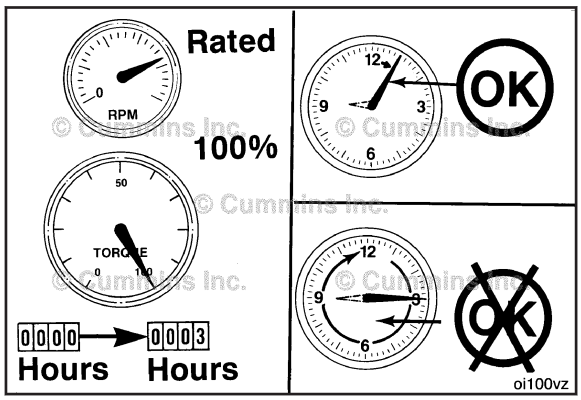
Operate the engine as follows during the first 3 hours after rebuild:

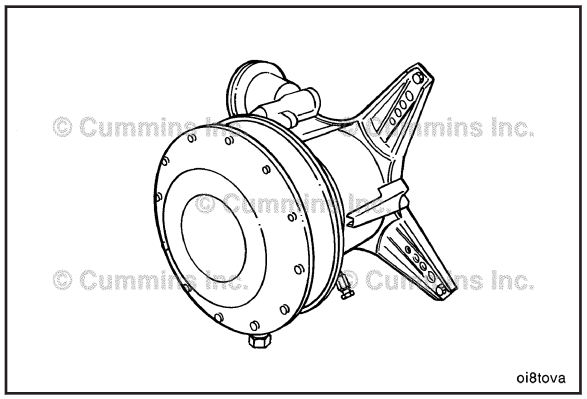


1. Do **not** idle the engine for more than 5 minutes at any one time.
2. Operate the engine at 75-percent throttle while loaded.



3. Do **not** operate the engine at rated speed (rpm) and full load for more than 5 minutes at any one time.





Engine Testing (Engine Dynamometer) (014-005)

Setup

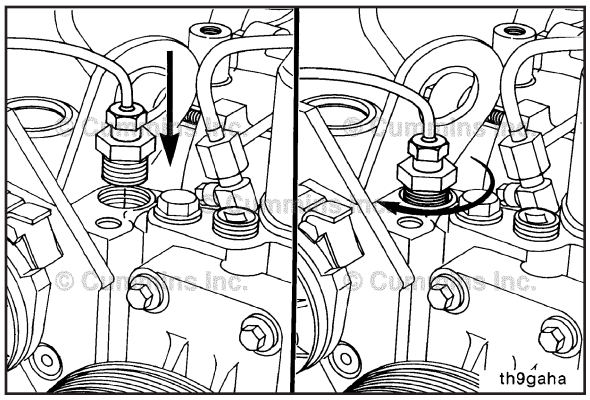
Engine Lifting Fixture, Part Number 3822512

Use engine lifting fixture, Part Number 3822512, to remove the engine from the chassis. Refer to Procedure 000-001.

Install the engine to the test stand.

Align and connect the dynamometer. Refer to the manufacturer's instructions for aligning and testing the engine.

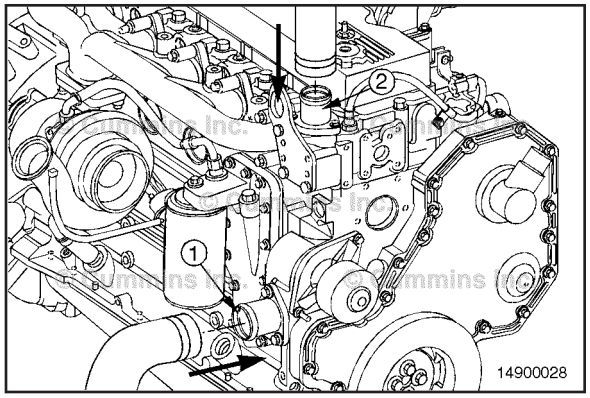
NOTE: Make sure the dynamometer capacity is sufficient to permit testing at 100 percent of the engine-rated horsepower. If the capacity is **not** enough, the testing procedure **must** be modified to the restrictions of the dynamometer.



Coolant Plumbing

Install the coolant temperature sensor.

Minimum Gauge Capacity: 107 °C [225 °F]

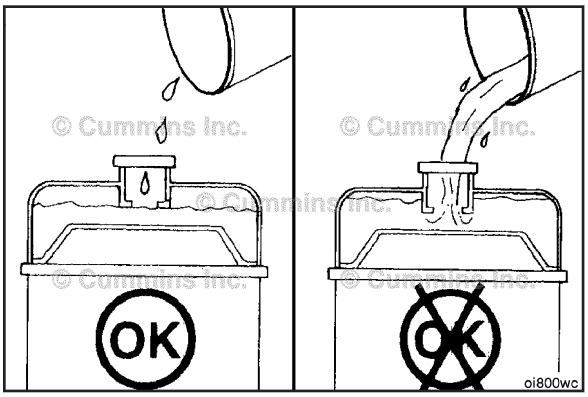


Connect the coolant supply to the water inlet connection (1).

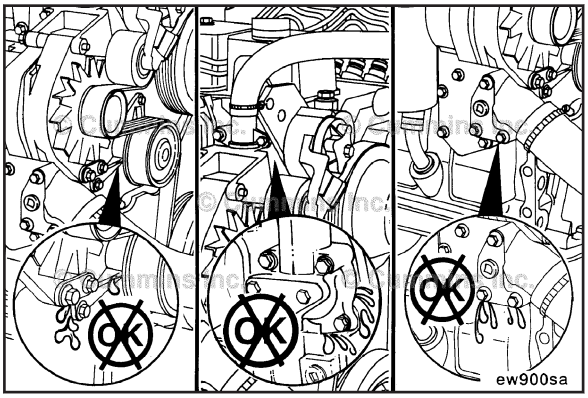
Connect the coolant return to the water outlet connection (2).

Install the drain plugs, close all the water drain cocks, and make sure all the clamps and fittings are tight.

Fill the cooling system with coolant to the bottom of the fill neck in the radiator fill (or expansion) tank.



Inspect the engine for coolant leaks at connections, fittings, plates, and plugs. Repair as necessary.



Water Manometer, Part Number ST-1111-3

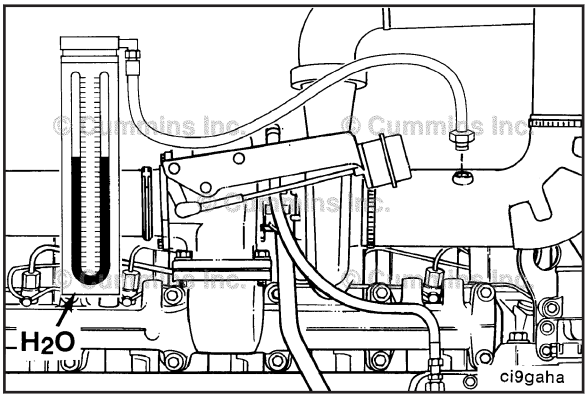
Air Inlet Restriction

Connect a water manometer, Part Number ST-1111-3, to the turbocharger air inlet pipe to test air restriction.

NOTE: The manometer connection **must** be installed at a 90-degree angle to the air flow in a straight section of pipe, one pipe diameter before the turbocharger.

NOTE: A vacuum gauge, Part Number ST-434, can be used in place of the water manometer.

Minimum Gauge Capacity: 760 mm H_2O [30 in H_2O]



Pressure Gauge, Part Number ST-1273

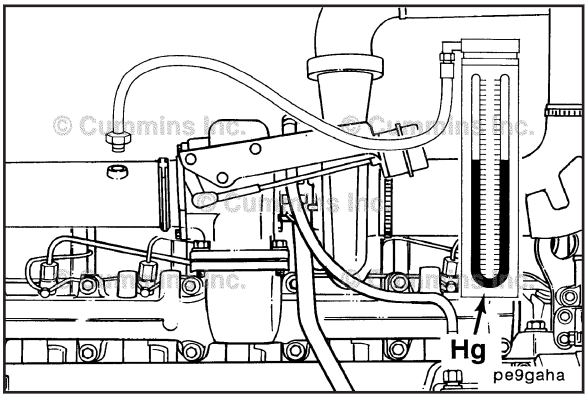
Exhaust Restriction

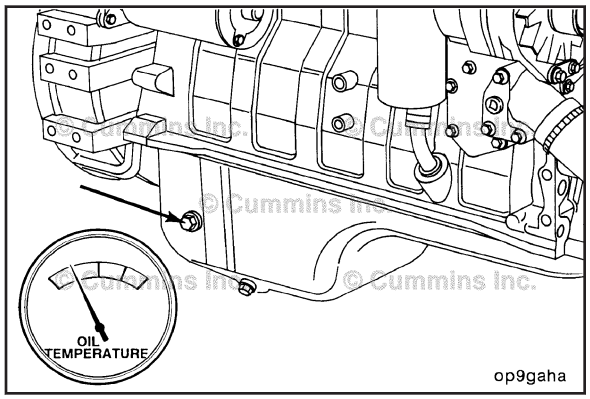
Connect a mercury manometer to a straight section of the exhaust piping near the turbocharger outlet to check exhaust restriction.

NOTE: A pressure gauge, Part Number ST-1273, can be used in place of the mercury manometer.

NOTE: For automotive applications a tapped hole is provided on the inlet side of the catalyst for checking exhaust restrictions.

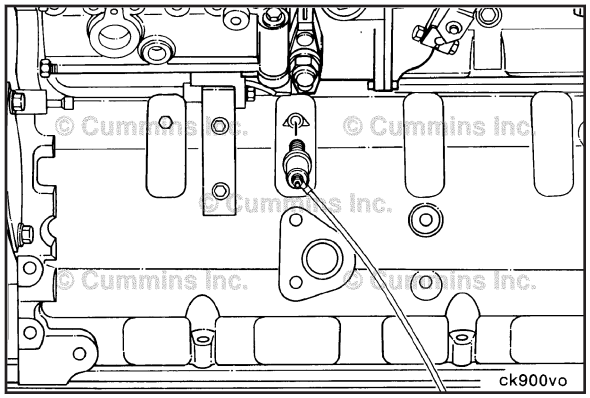
Minimum Gauge Capacity: 254 mm Hg [10 in Hg]





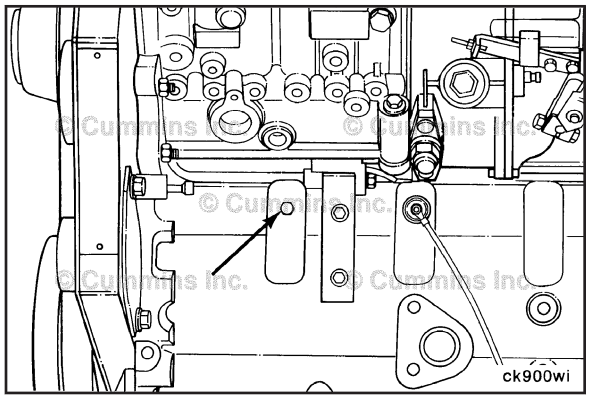
Attach the lubricating oil temperature sensor in the location shown.

Minimum Gauge Capacity: 150 °C [302 °F]



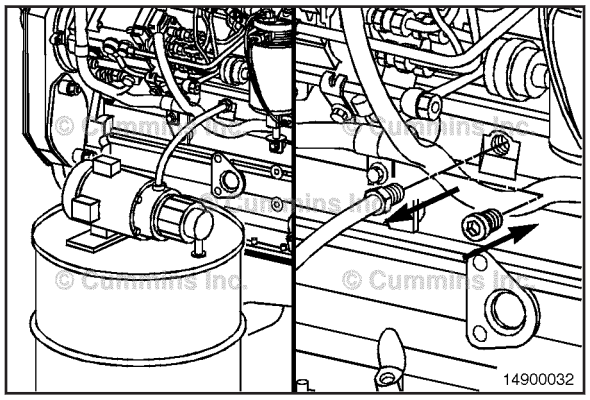
Attach the lubricating oil pressure sensor to the main oil rifle drilling in the cylinder block.

Minimum Gauge Capacity: 1034 kPa [150 psi]



⚠CAUTION⚠
The lubricating oil system must be primed before operating the engine after it has been rebuilt to avoid internal damage.

To prime the system using external pressure, connect the supply to a tapped hole in the main lubricating oil rifle.

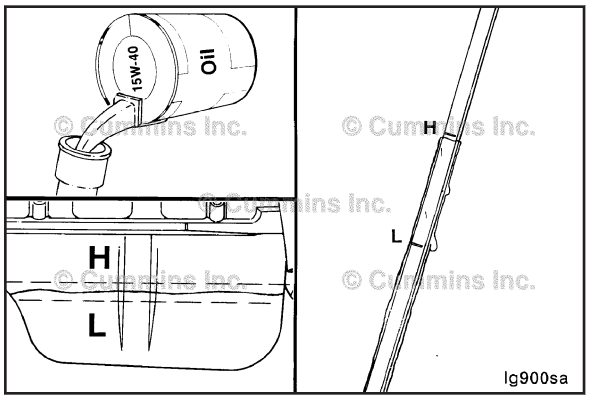


Use a pump capable of supplying 210 kPa [30 psi] of continuous pressure. Connect the pump to the port on the main lubricating oil rifle as shown.

Use clean lubricating engine oil to prime the system until the oil pressure registers on the gauge.

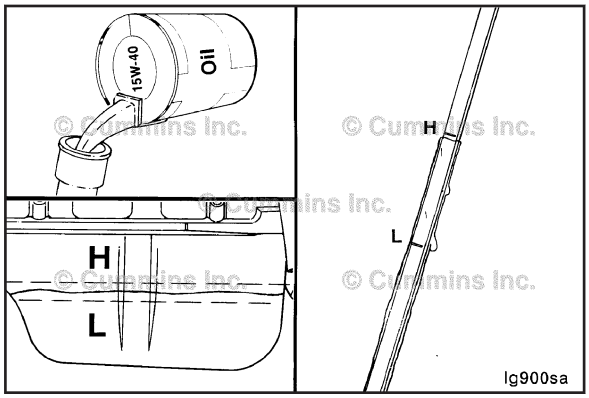
Remove the lubricating oil supply tube, and install the plug.

Make sure the lubricating oil has had time to drain to the lubricating oil pan, and fill the engine to the high mark as measured on the dipstick.



If an external pressure pump is **not** available, prime the lubricating system according to the following procedure.

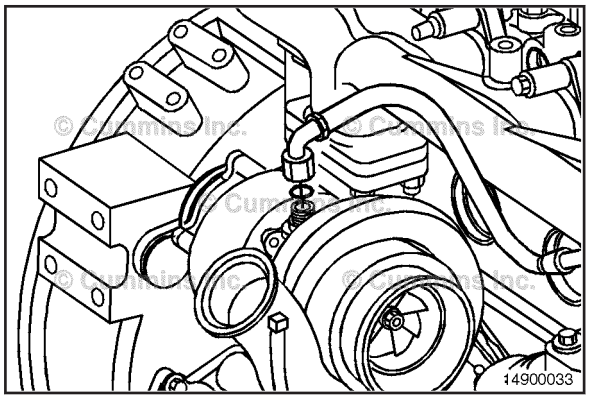
Fill the engine with lubricating oil to the high level mark on the dipstick.



Disconnect the turbocharger lubricating oil supply tube.

Pour 50 to 60 cc [2.0 to 3.0 fl oz] of clean lubricating engine oil into the turbocharger lubricating oil supply hole.

Connect the lubricating oil supply tube to the turbocharger.

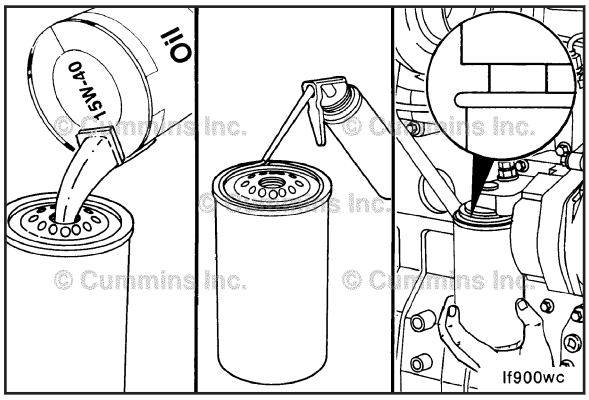


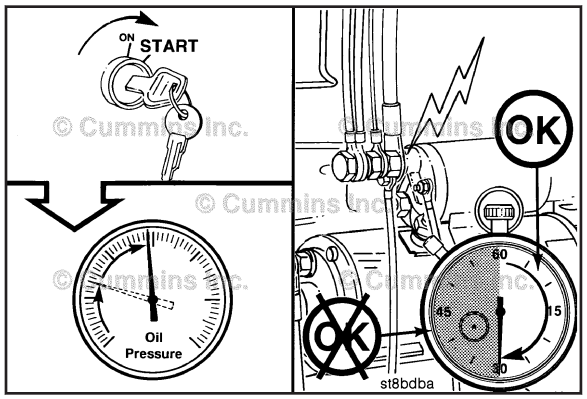
⚠CAUTION⚠
Mechanical overtightening can distort the threads or damage the filter element seal.

Fill the lubricating oil filters with clean lubricating engine oil.

Screw the filters onto the filter head fitting until the gasket contacts the filter head surface.

Tighten the filter as specified by the manufacturer.





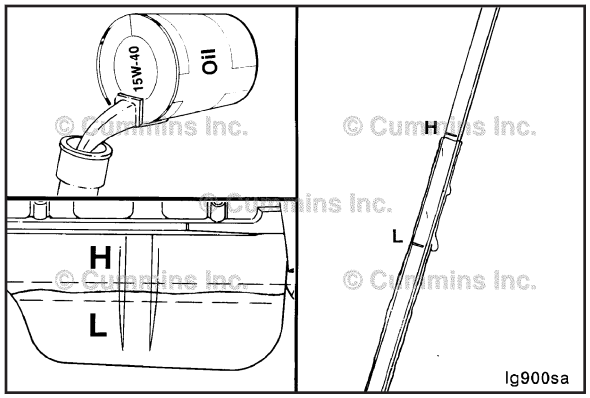
⚠CAUTION⚠

Do not crank the starter motor for periods longer than 30 seconds. Excessive heat will damage the starter motor.

Crank the engine until the lubricating oil pressure gauge indicates system pressure.

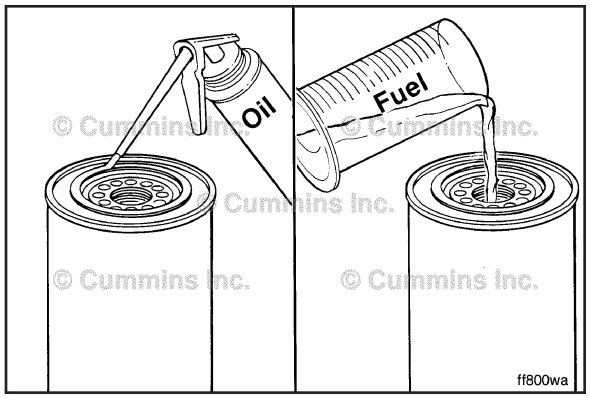
NOTE: Allow 2 minutes between the 30-second cranking periods so the starter motor can cool.

NOTE: If pressure is **not** indicated, find and correct the problem before continuing.



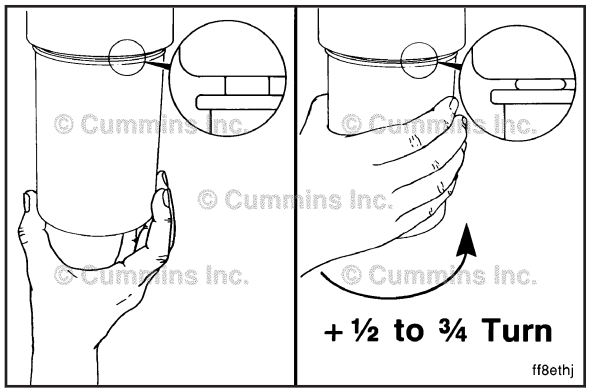
Allow the lubricating oil to drain into the lubricating oil pan, and measure the lubricating oil level with the dipstick.

Add lubricating oil, as necessary, to bring the level to the high level mark.



Lubricate the gasket on the fuel filter with clean lubricating engine oil.

Fill the fuel filter with clean fuel.



Screw the fuel filter onto the filter head until the gasket contacts the filter head surface.

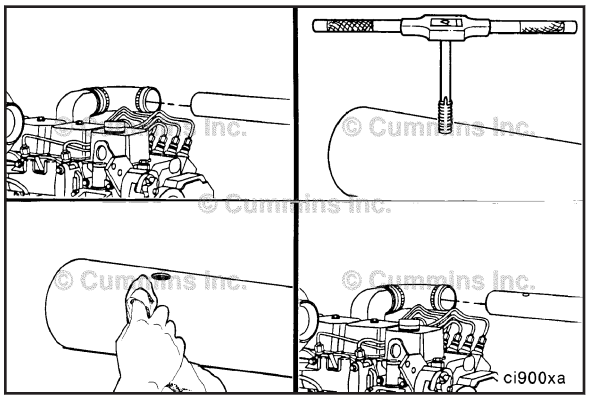
Tighten the filter as specified by the manufacturer.

⚠CAUTION⚠

Do not attempt to install pipe thread fittings in plastic or rubber intake piping. Failure to do so will result in damage to threads.

If the air crossover **not** have a pipe plug and tapped hole, perform the following procedure:

- Remove the crossover.
- Drill and tap a 1/8-inch pipe thread hole in the crossover.
- Clean all metal shavings from the air crossover.
- Install the crossover.

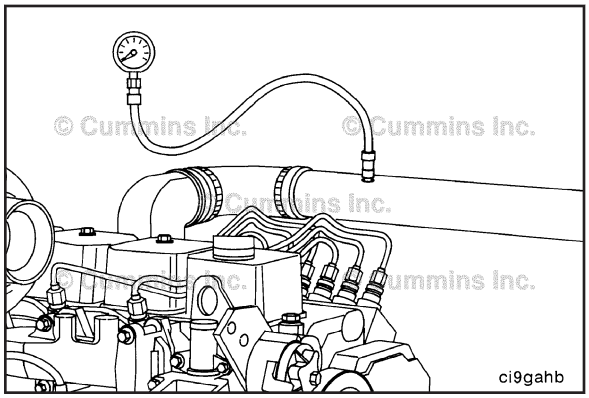


Pressure Gauge, Part Number ST-1273

To determine the amount of turbocharger boost, remove the pipe plug in the air crossover tube.

Install the intake manifold pressure sensor or pressure gauge, Part Number ST-1273.

Minimum Gauge Capacity: 1905 mm Hg [75 in Hg]



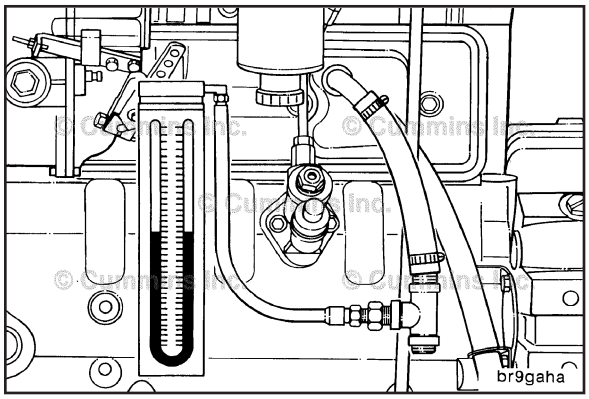
Blowby Checking Tool, Part Number 3822476

Water Manometer, Part Number ST-1111-3

For accurate engine crankcase blowby measurement, insert a blowby checking tool in the crankcase breather vent.

Connect a water manometer to the blowby tool. A pressure gauge can be used in place of the manometer.

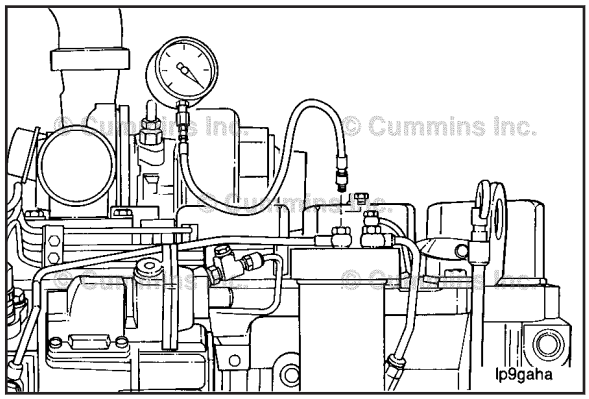
Minimum Gauge Capacity: 1270 mm H_2O [50 in H_2O]

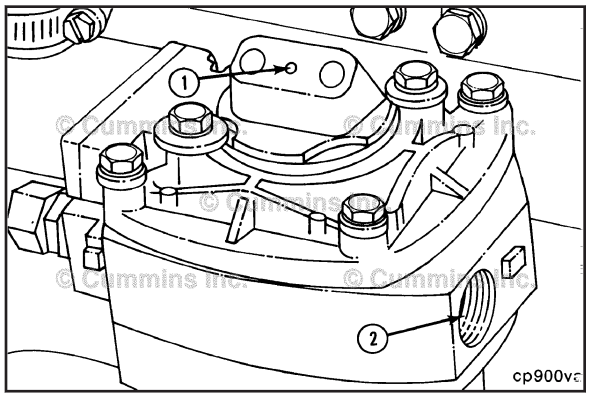


Vacuum Gauge, Part Number ST-434

To measure fuel filter restriction, connect vacuum gauge, Part Number ST-434, to the injection pump inlet line.

Minimum Gauge Capacity: 760 mm Hg [30 in Hg]

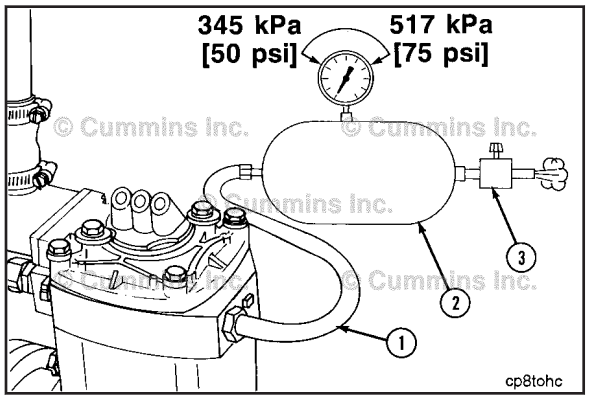




To be able to unload the compressor, connect a source of compressed air to the unloader (1). This air line **must** contain a valve between the source and the unloader.

NOTE: All air compressors manufactured by Cummins Inc. **must** be loaded during engine run-in. All air compressors **must** be unloaded during the engine performance check.

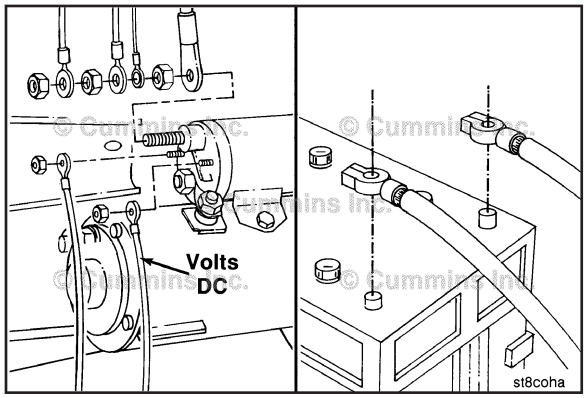
NOTE: The compressed air load in the accompanying illustration **must** be attached to the air compressor outlet (2).



To provide a load on the air compressor, connect an air tank (2) to the compressor outlet; use steel tubing or a high-temperature hose (1).

Install an air regulator (3) that can maintain tank air pressure of 345 kPa to 517 kPa [50 psi to 75 psi] at both the minimum and the maximum engine rpm.

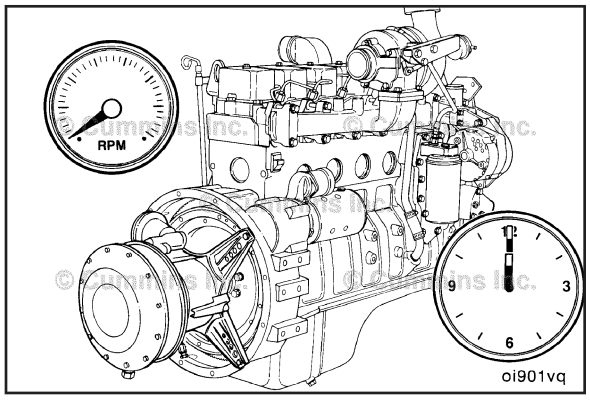
Hose Temperature (Minimum): 260 °C [500 °F]



Inspect the voltage rating on the starter motor before installing the electrical wiring.

Attach electrical wires to the starter motor and the batteries if used, negative (-) cable last.

NOTE: If another method of starting the engine is used, follow the manufacturer's instructions to make the necessary connections.



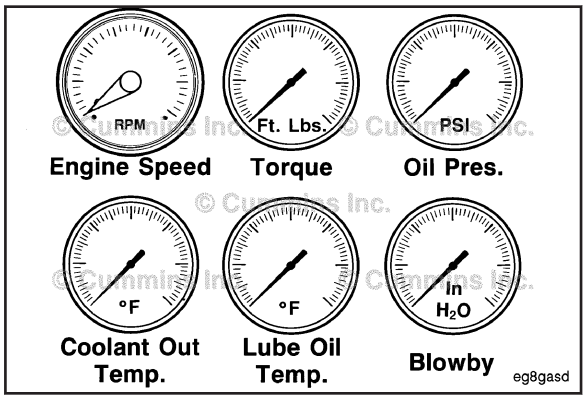
Engine Run-in (Engine Dynamometer) (014-006)

Test

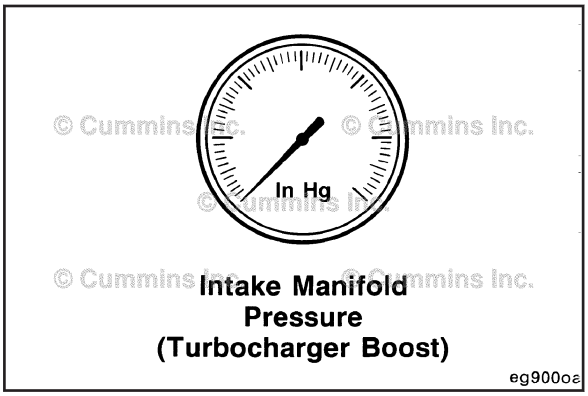
The engine run-in period allows the tester to detect assembly errors and to make final adjustments needed for performance that meets specifications.

NOTE: The amount of time specified for the following engine run-in phases are minimums. Additional time can be used, if desired, at each phase **except** engine idle periods.

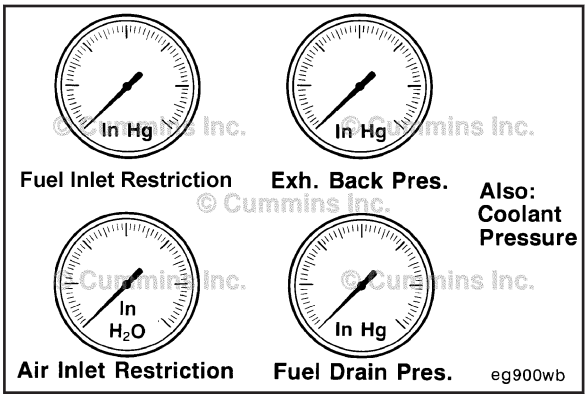
Measurements from these indicators and gauges **must** be observed closely during all phases of the engine run-in period. Refer to the appropriate sections for specifications and acceptable readings.



To evaluate the engine's performance correctly, this additional measurement **must** be observed during engine run-in phases.

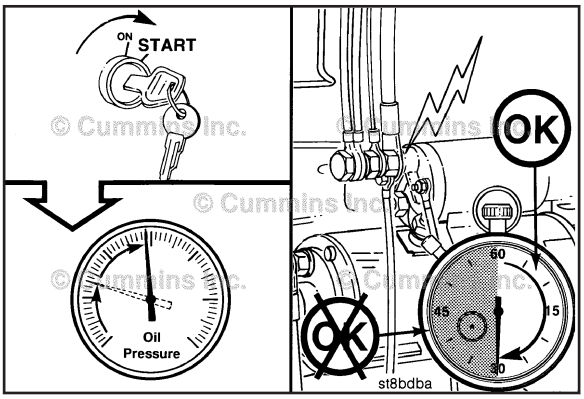


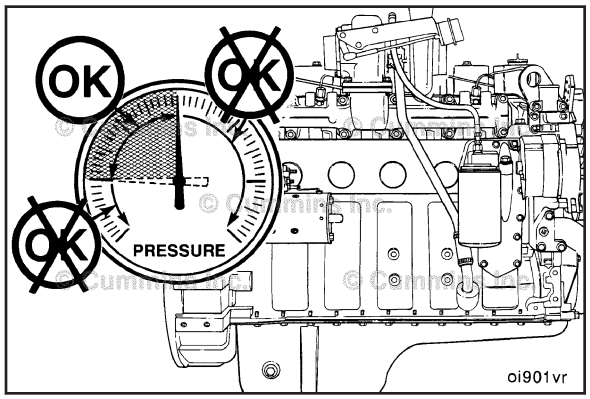
It is good practice to observe these measurements even if engine performance meets specifications. If engine performance does **not** meet specifications, these measurements can indicate possible reasons for nonperformance.



⚠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 two minutes before cranking the engine again.

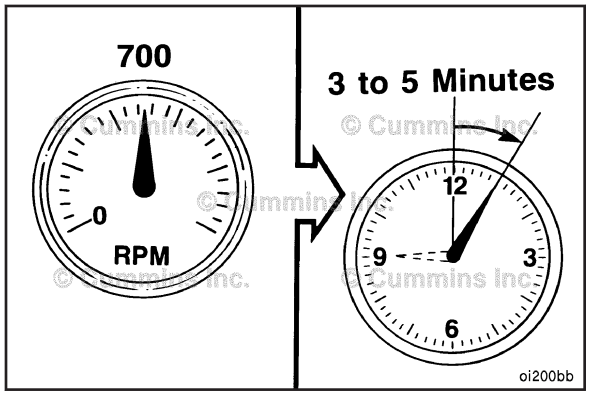




⚠CAUTION⚠
If the lubricating oil pressure is not within specifications, shut off the engine immediately. Low lubricating oil pressure will cause severe engine damage.

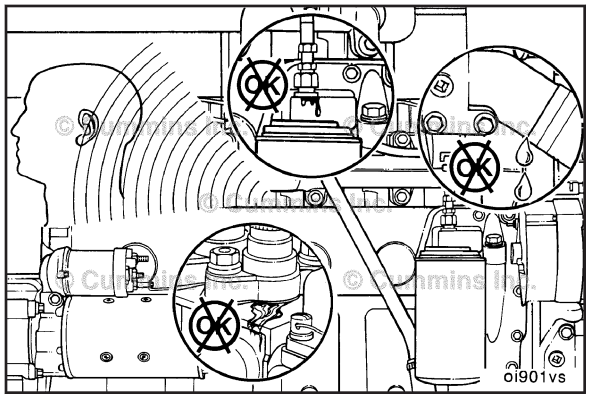
Engine lubricating oil pressure **must** be at least 69 kPa [10 psi] at 700 rpm.

Correct the problem if the lubricating oil pressure is **not** within specifications.



⚠CAUTION⚠
Do not operate the engine at idle speed longer than specified during engine run-in. Excessive carbon deposits will form in cylinders, causing damage to the engine.

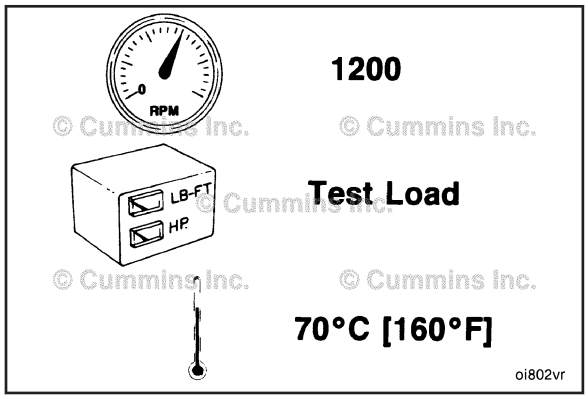
Operate the engine at approximately 700 rpm for three to five minutes.



Listen for unusual noise; watch for coolant, fuel, and lubricating oil leaks.

Check for correct engine operation.

NOTE: Repair all leaks or component problems before continuing the engine run-in.



Move the throttle to obtain 1200-rpm engine speed, and set the test load to 25 percent of the rated load.

Operate the engine at this speed and load level until the coolant temperature is 70°C [158°F].

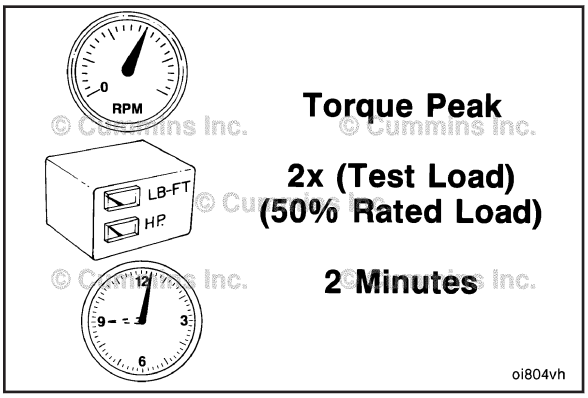
Check all gauges, and record the data.

NOTE: Do **not** proceed to the next step until a steady blowby reading is obtained.

Open the throttle to the speed 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 two minutes.

Check all gauges, and record the data.

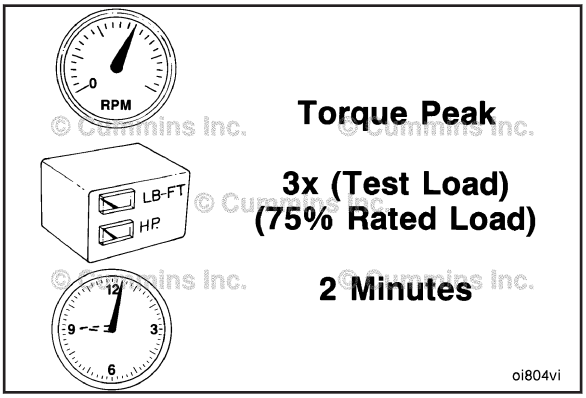
NOTE: Do **not** proceed to the next step until blowby is stable and within specification.



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 two minutes.

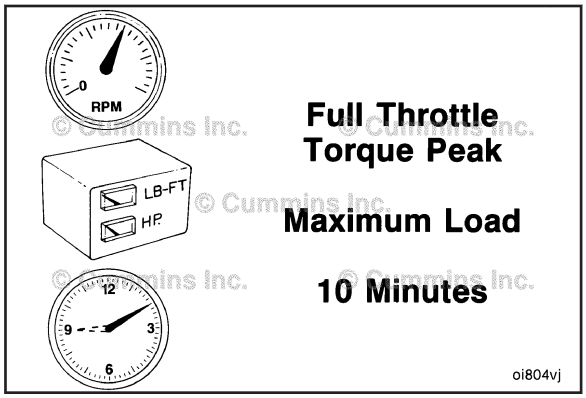
Check all gauges, and record the data.

NOTE: Do **not** proceed to the next step until blowby is stable and within specification.



Move the throttle lever to its full capacity in the 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 ten minutes, or until the blowby becomes stable and within specification.

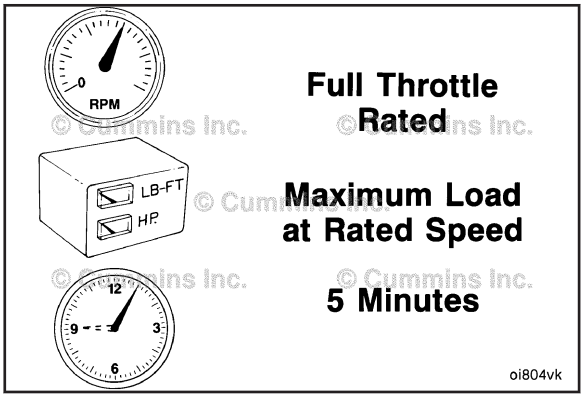
Check all gauges, and record the data.

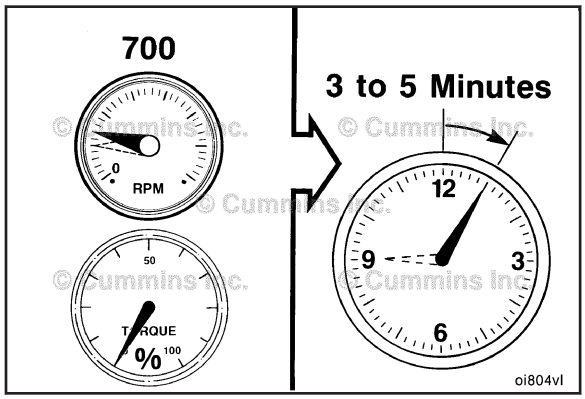


Reduce the dynamometer load until the engine speed increases to the engine's rated rpm.

Operate the engine at rated rpm for five minutes.

Check all gauges, and record the data.

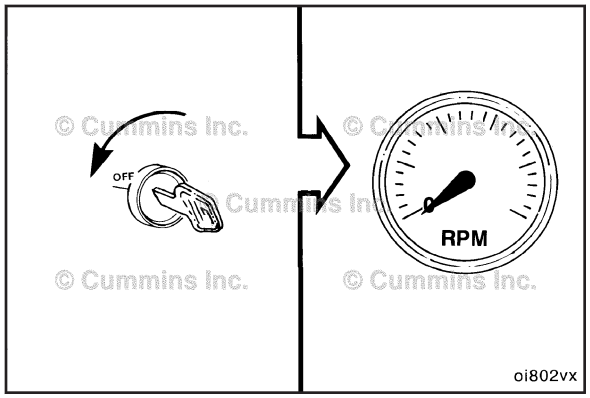




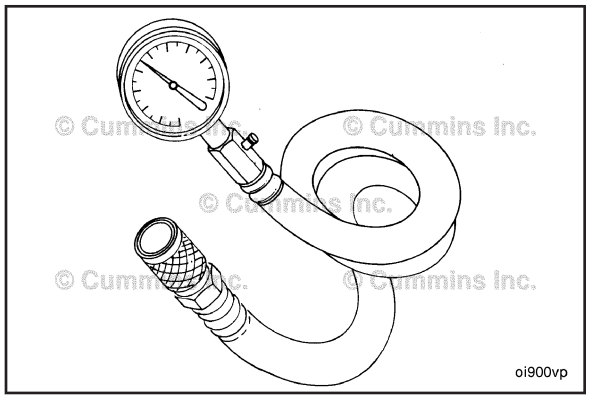
CAUTION

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 three to five minutes. This period will allow the turbocharger and other components to cool.



Shut off the engine.

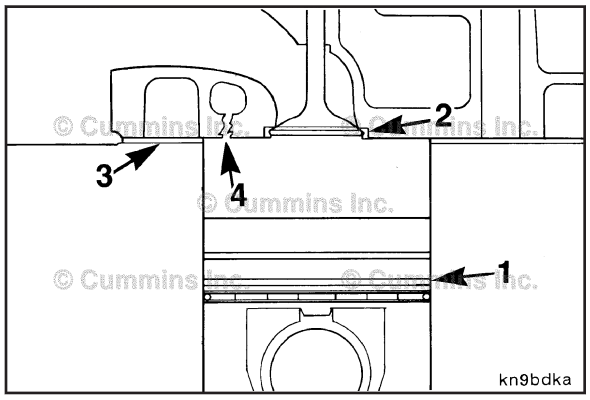


Engine Testing (In Chassis) (014-008)

Initial Check

B3.9, B5.9, and B4.5 Engines

It is very time consuming and expensive to remove internal engine components to diagnose failures. A compression gauge and adapter can be used as an aid in checking for failures.



Use the compression gauge and adapter to check for following component failures:

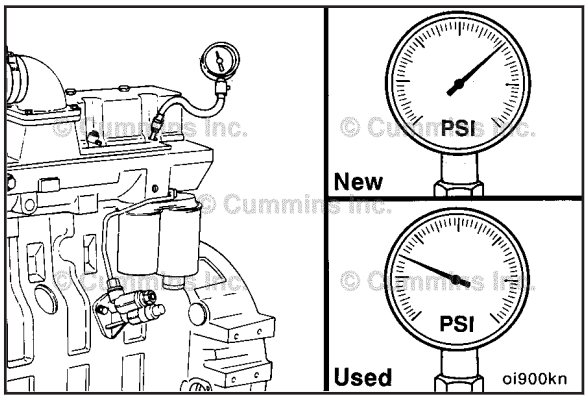
1. Piston ring sealing
2. Intake and exhaust valve sealing
3. Cylinder head gasket sealing
4. Cylinder head cracked.

See the appropriate procedures for the 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 @ 250 rpm) 2413 kPa [350 psi]
- Used engine (cranking speed @ 250 rpm) 2068 kPa [300 psi].

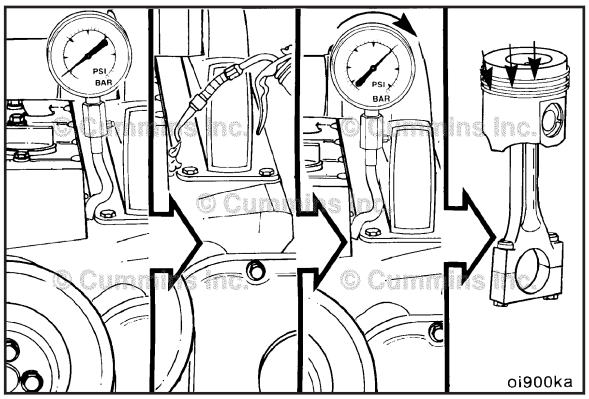
It is recommended that the compression pressure be checked on all cylinders and then compared to specification. All cylinders **must** be within 690 kPa [100 psi] of each other.



Piston Ring Sealing

If the compression is low but can be increased significantly by squirting oil into the cylinder, the cause is inadequate sealing between the rings and the cylinder walls.

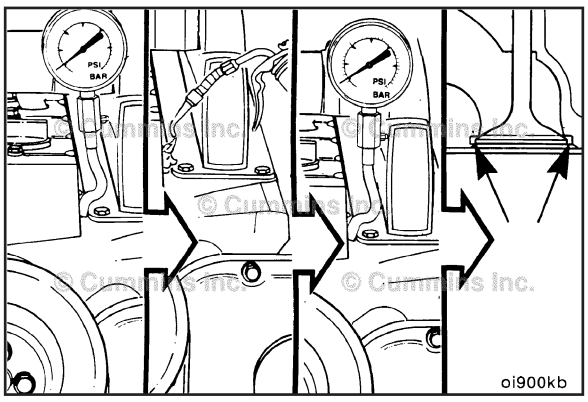
Refer to Procedure 001-054 for piston ring replacement.



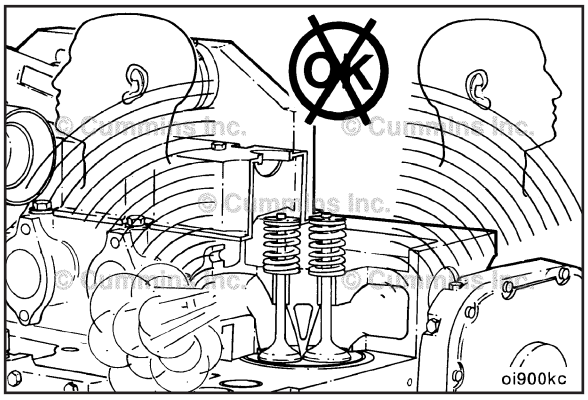
Intake and Exhaust Valve Sealing

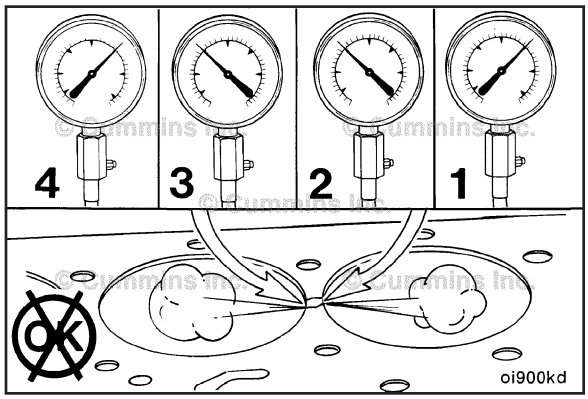
If the compression is low on one or more nonadjacent cylinders, and the pressure can **not** be increased by oiling the rings, poor valve sealing is suspected.

Refer to Procedure 002-004 for cylinder head replacement.



Valve leakage is often an audible sound from the intake and exhaust manifolds.

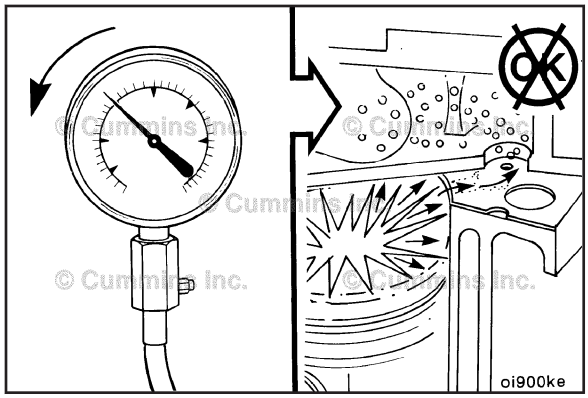




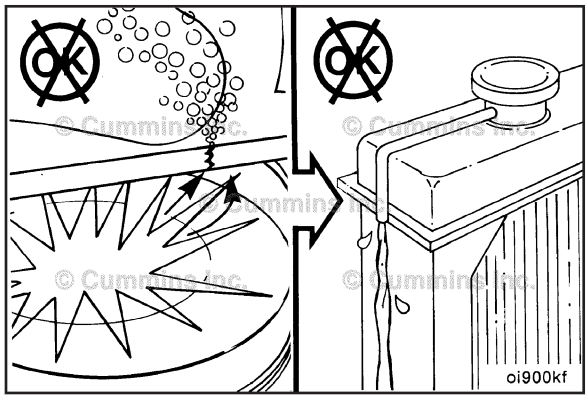
Cylinder Head Gasket Sealing

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 for cylinder gasket replacement.



NOTE: 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 a loss of coolant as the coolant is blown from the cooling system.

Service Tip: Remove the drive belt from the water pump. Refer to Procedure 008-002 for removal and installation of drive belt.

Run the engine for one to two minutes, and check for coolant being blown from the radiator by compression gases.

B4.5 RGT Engines

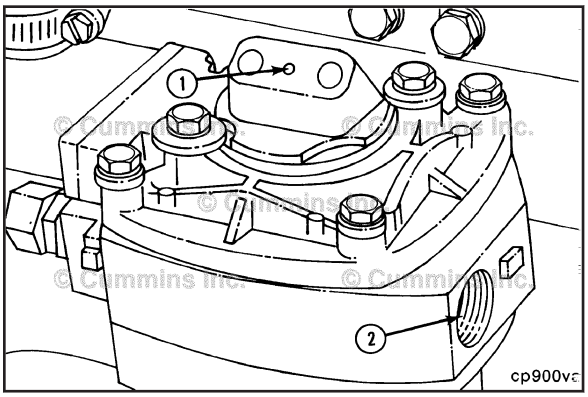
For B4.5 RGT engines, no compression service tools are available. To inspect for loss of compression, a blow-by check should be performed. Refer to Procedure 014-010.

Test

NOTE: The compressed air load in the accompanying illustration **must** be attached to the air compressor outlet (2).

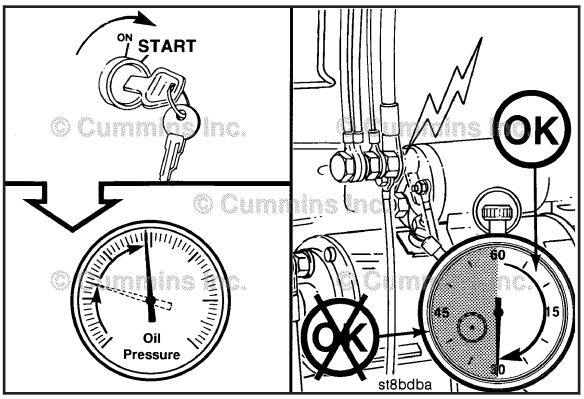
Make sure the air compressor will be unloaded during the performance check.

Apply regulated air pressure of 655 kPa [95 psi] to the air compressor unloader (1).



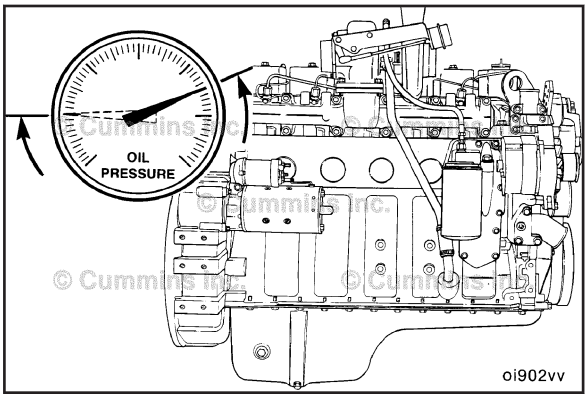
⚠CAUTION⚠
Do not crank the engine for more than 30 seconds. Excessive heat will damage the starting motor.

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 two 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.



NOTE: The horsepower readings will **not** be accurate if the lubricating oil temperature and fuel temperature are **not** within specifications.

Make sure the engine is at operating temperature.

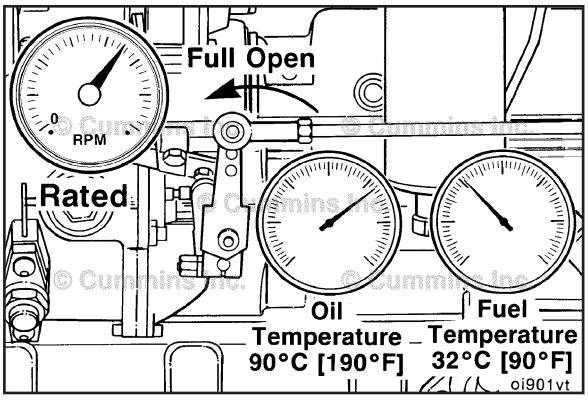
Move the throttle lever to the FULL-OPEN position. Adjust the dynamometer load until the engine maintains the rated rpm.

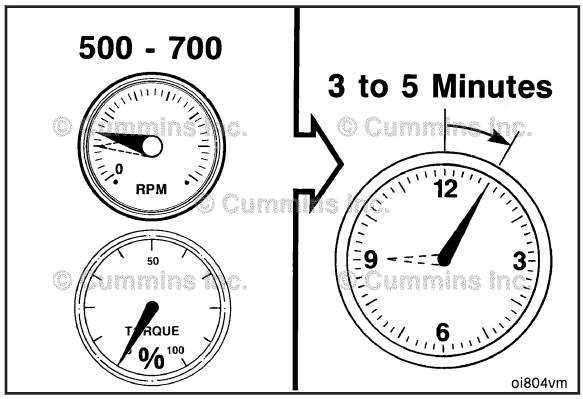
Allow the readings to stabilize. Read the horsepower.

Check all gauges, and record the readings.

Lubricating Oil Temperature 90 °C [194 °F]

Fuel Temperature 32 °C [90 °F]



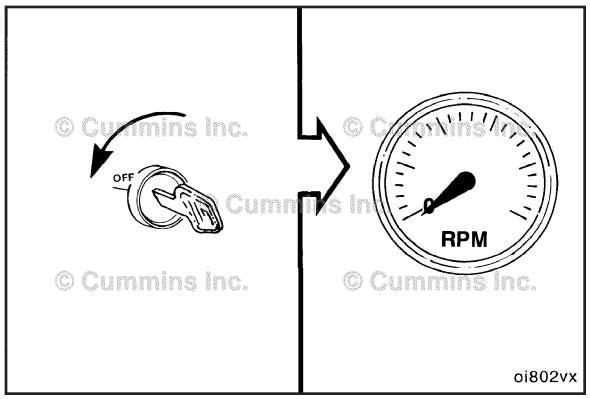


⚠CAUTION⚠

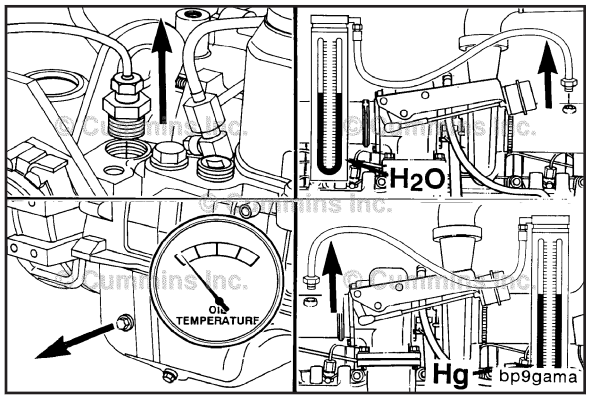
Do not shut off the engine immediately after it has been loaded. It must be allowed to cool sufficiently. Failure to do so will result in engine damage.

NOTE: Idle periods longer than five minutes are to be avoided.

Remove the dynamometer load completely, and operate the engine at idle speed for three to five minutes. This will allow the turbocharger and other components to cool.



Shut off the engine after the cool-down period.



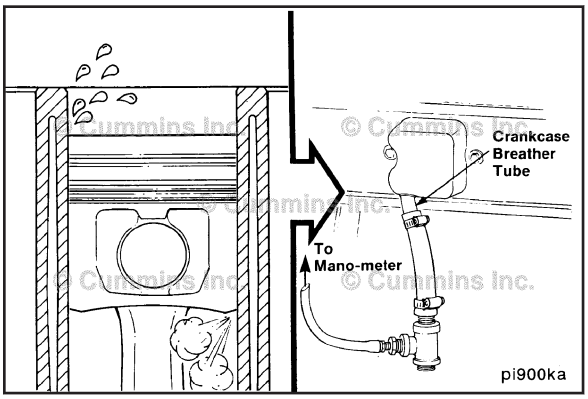
NOTE: If the engine is to be stored temporarily and does **not** have permanent-type antifreeze, it is necessary to drain all coolant.

Remove all test instrumentation.

Remove the engine from the dynamometer.

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.

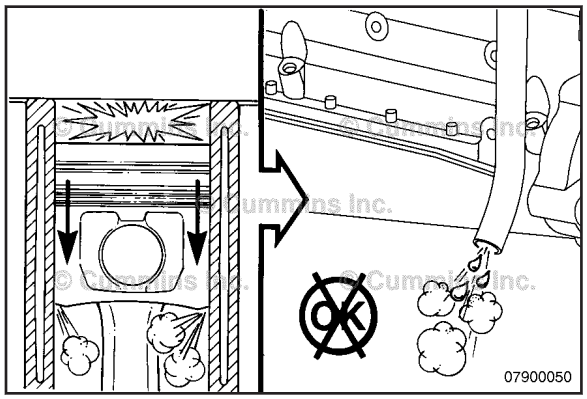
Blowby is typically measured for the following situations:

- 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.



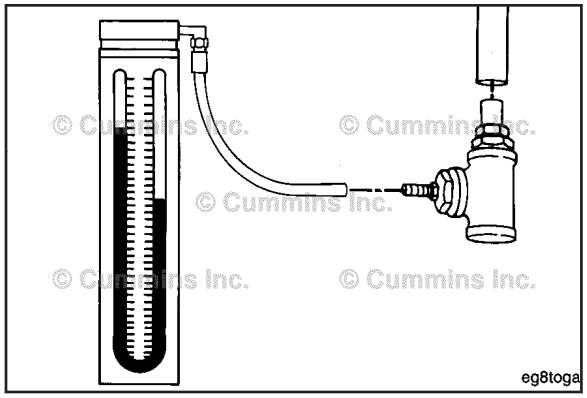
It is important to note that the terms blowby and carryover (oil out of the breather tube) are commonly used interchangeably.

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.

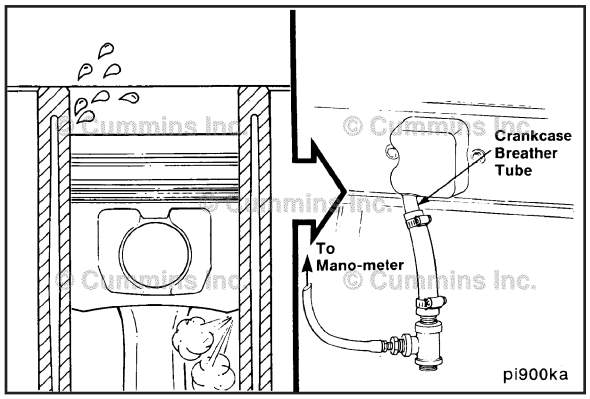
NOTE: Water manometer, Part Number ST1111-3, can measure a maximum of 944 mm [36 in] of water.

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 H_2O	**Liter [cfm] per Minute**
25.4 [1]	27 [0.953]
50.8 [2]	40 [1.413]
76.2 [3]	48 [1.695]
101.6 [4]	58 [2.048]
127 [5]	64 [2.260]
152.4 [6]	71 [2.507]
177.8 [7]	76 [2.684]
203.2 [8]	81 [2.860]
228.6 [9]	86 [3.037]
254 [10]	90 [3.178]
279.4 [11]	94 [3.320]
304.8 [12]	98 [3.461]
330.2 [13]	102 [3.602]
355.6 [14]	105 [3.708]
381 [15]	109 [3.849]
406.4 [16]	112 [3.955]
431.8 [17]	115 [4.061]
457.2 [18]	118 [4.167]
482.6 [19]	121 [4.723]
508 [20]	124 [4.379]
533.4 [21]	128 [4.520]
558.2 [22]	131 [4.626]
584.2 [23]	135 [4.767]
609.6 [24]	137 [4.838]
635 [25]	140 [4.944]
660.4 [26]	144 [5.085]
685.8 [27]	147 [5.191]
711.2 [28]	150 [5.297]
736.6 [29]	154 [5.438]
762 [30]	157 [5.544]
787.4 [31]	160 [5.650]
812.8 [32]	163 [5.756]
838.2 [33]	166 [5.862]
863.6 [34]	169 [5.968]
889 [35]	172 [6.074]

Blowby Conversion Table (7.67-mm [0.302-in] orifice, Blowby Tool, Part Number 3822566)	
mm [in] of H_2O	**Liter [cfm] per Minute**
25.4 [1]	50 [1.766]
50.8 [2]	84 [2.966]
76.2 [3]	103 [3.637]
101.6 [4]	119 [4.202]
127 [5]	133 [4.697]
152.4 [6]	145 [5.121]
177.8 [7]	155 [5.474]
203.2 [8]	164 [5.792]

Blowby Conversion Table (7.67-mm [0.302-in] orifice, Blowby Tool, Part Number 3822566)	
mm [in] of H_2O	Liter [cfm] per Minute
228.6 [9]	172 [6.074]
254 [10]	180 [6.357]
279.4 [11]	187 [6.604]
304.8 [12]	193 [6.816]
330.2 [13]	200 [7.063]
355.6 [14]	206 [7.275]
381 [15]	211 [7.451]
406.4 [16]	217 [7.663]
431.8 [17]	222 [7.840]
457.2 [18]	226 [7.981]
482.6 [19]	229 [8.087]
508 [20]	235 [8.299]
533.4 [21]	239 [8.440]
558.8 [22]	242 [8.546]
584.2 [23]	246 [8.687]
609.6 [24]	248 [8.758]



The following chart contains general blowby specifications for MidRange engines. Due to the wide variety of engine types, configurations, and ratings, these specifications are intended to **only** be used as a guide to help identify if a problem exists. These specifications are **not** intended to be used as engine condemnation limits.

NOTE: If internal engine damage is suspected to be the cause of the excessive blowby condition, other steps can be taken to confirm this.

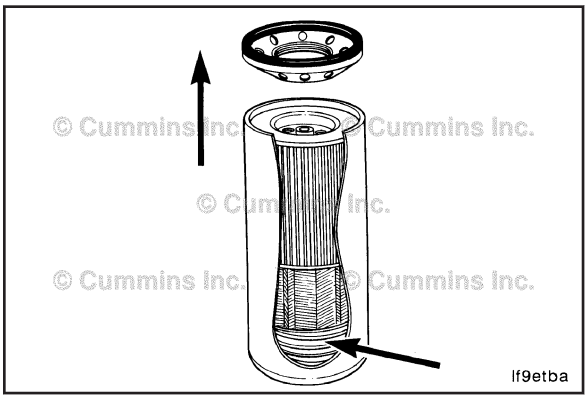
Measuring blowby **must only** be considered when confirming engine break-in after a rebuild or if another symptom is present. These symptoms can include:

- Excessive carryover (oil out of the crankcase breather tube)
- High crankcase pressure (for engines equipped with a crankcase pressure sensor)
- Low power
- Oil consumption
- Exhaust smoke.

If no other symptom is present, blowby measurements need **not** be taken.

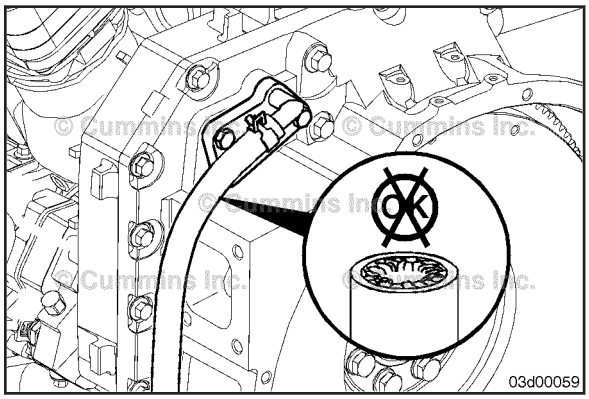
If internal engine damage is suspected to be the cause of the excessive blowby condition, other steps can be taken to confirm this. The steps include:

- Confirm engine maintenance practices
- Cut the oil filter open and check for debris
- Take an oil sample and inspect for contamination.



MidRange Blowby Specifications Chart				
	Blowby Specification For New or Rebuild - mm [in] H_2O		Blowby Specification For Troubleshooting - mm [in] H_2O	
Engine Model	Blowby Tool 3822476-5.61 mm [0.221 in] Orifice	Blowby Tool 3822566-7.67 mm [0.302 in] Orifice	Blowby Tool 3822476-5.61 mm [0.221 in] Orifice	Blowby Tool 3822566-7.67 mm [0.302 in] Orifice
A1400 and A1700 (Naturally Aspirated)	25.4 [1]		25.4 [1]	
A2000 and A2300 (Naturally Aspirated)	25.4 [1]		38.1 [1.5]	
A2000 and A2300 (Turbocharged)	38.1 [1.5]		50.8 [2]	
ISF2.8	147.3 [5.8]		711.2 [28]	
ISF3.8		71.1 [2.8]		254 [10]
B3.3 Tier 1, 2		50.8 [2]		101.6 [4]
B3.3, QSB3.3 Tier 3		101.6 [4]		152.04 [6]
B3.3, QSB3.3 Tier 4 Interim (Less than 74 HP)		50.8 [2]		101.6 [4]
B3.9, QSB3.9-30, B4.5, QSB4.5-30, and B4.5^{s} (Naturally Aspirated) (Less than 250 hp)	25.4 [1]		76.2 [3]	
B3.9, QSB3.9-30, B4.5, QSB4.5-30, and B4.5^{s} (Turbocharged) (Less than 250 hp)	101.6 [4]		431.8 [17]	
B3.9, QSB3.9-30, B4.5, QSB4.5-30, and B4.5^{s} (Turbocharged) (Greater than 250 hp)		25.4 [1]		127 [5]
B5.9 (Naturally Aspirated)	50.8 [2]			
B5.9, and QSB5.9-30, (Less than 250 hp)	228 .6 [9]		863.6 [34]	
B5.9, and QSB5.9-30, (Greater than 250 hp)		50.8 [2]		228.6 [9]
ISB, ISB^{e}, QSB^{e}, ISD^{e}, QSB5.9-44, ISB6.7, and QSB6.7		101.6 [4]		254 [10]
C8.3		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

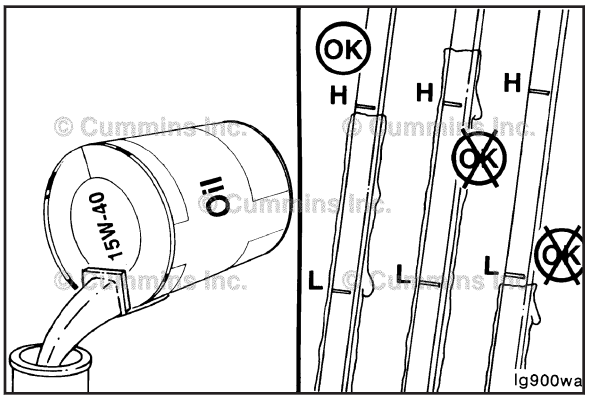


NOTE: The location and type of crankcase breathers vary by engine configuration (Front Gear Train or Rear Gear Train) and/or engine application (Marine, Industrial, and Automotive).

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.

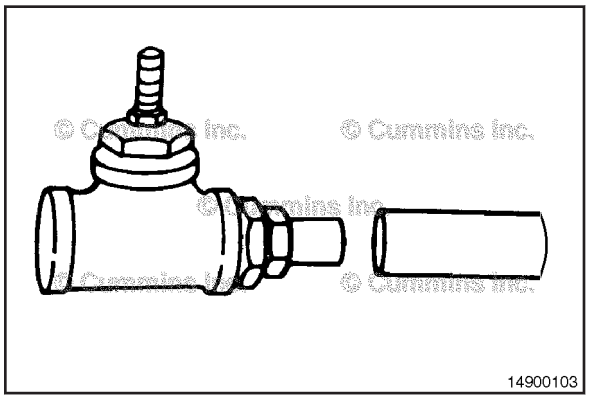
If troubleshooting a complaint of excessive oil out of the breather tube, it can be necessary to remove the breather components to clean and remove any lubricating oil buildup before performing any blowby measurements.



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.

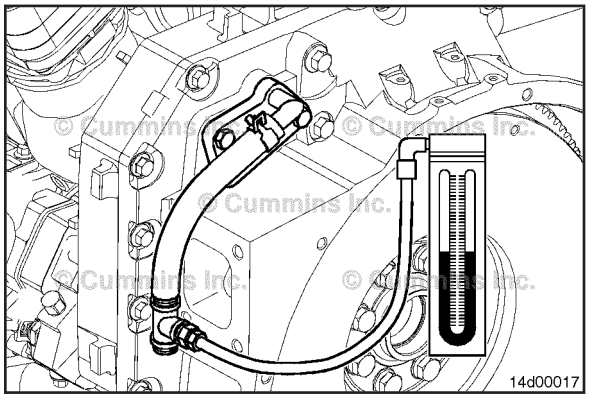
Measure



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.

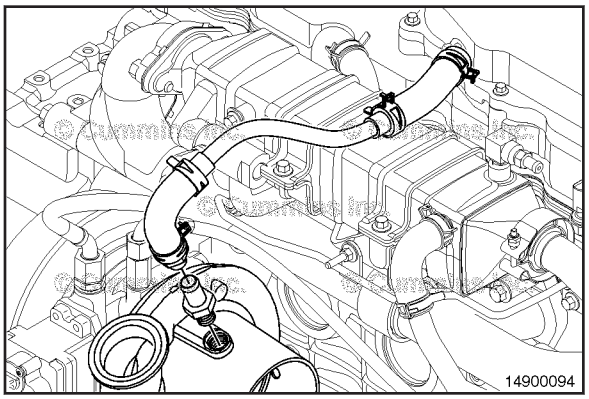


To measure the crankcase blowby pressure, connect a water manometer, Part Number ST1111-3, pressure gauge, or transducer to the blowby measurement service tool.

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.

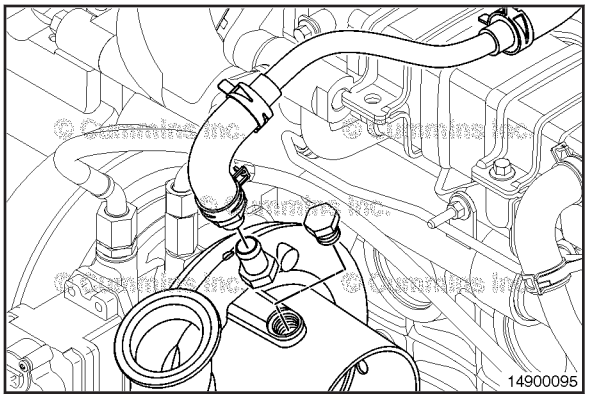
Install the appropriate blowby service tool(s):

- 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.



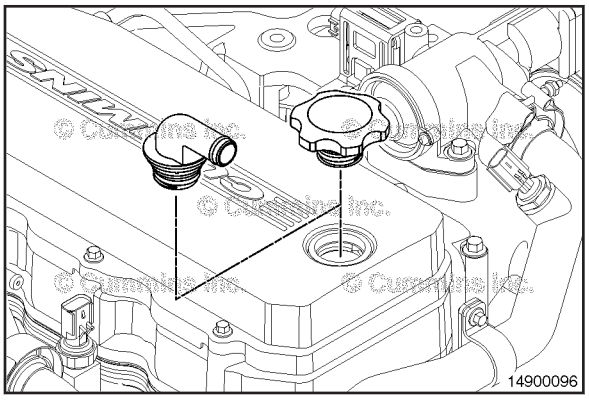
For ISB CM2150 engines that have the crankcase ventilation filter located on top of the rocker lever cover, use the following steps to connect the blowby measurement tools.

- 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.

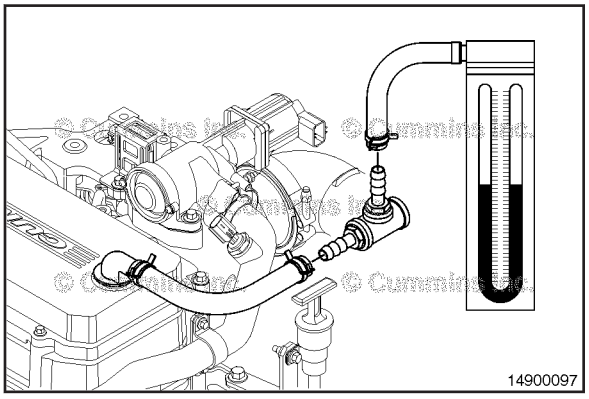


- If the crankcase ventilation line is connected to the turbocharger housing, install a straight thread plug, Part Number 3089567. Plug the crankcase ventilation line with a suitable fitting.

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.



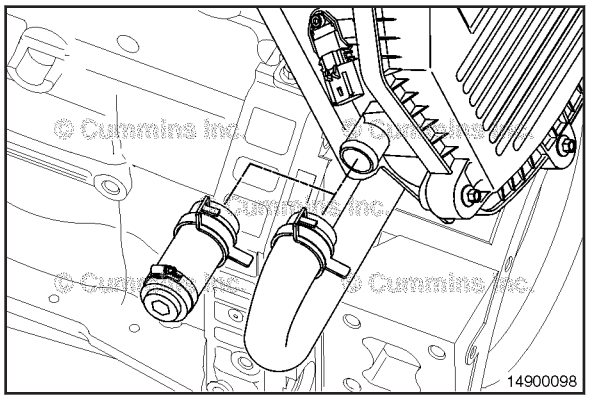
- Remove the oil fill cap from the rocker lever cover. Install an oil fill adapter, Part Number 3990099.



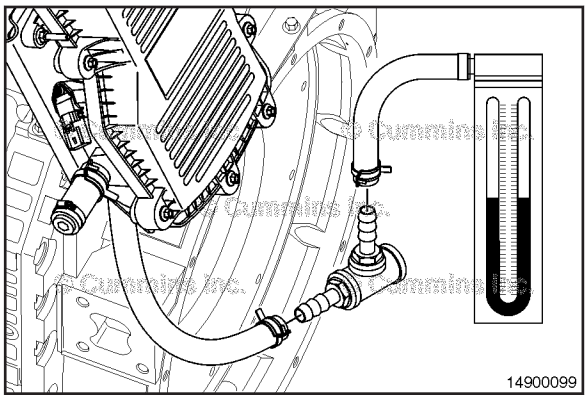
- Connect the appropriate blowby service tool to the outlet of the oil fill adapter. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.

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.

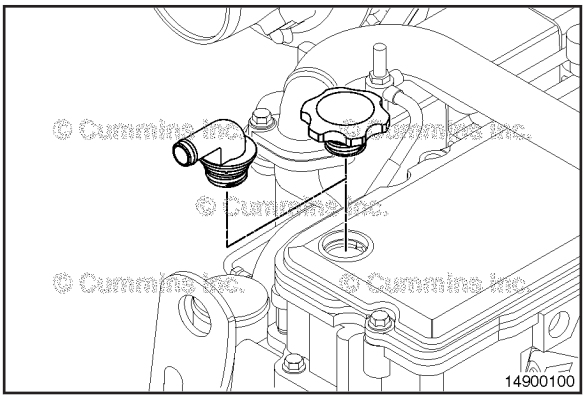


- Connect the appropriate blowby service tool to the crankcase ventilation line exiting the flywheel housing. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.

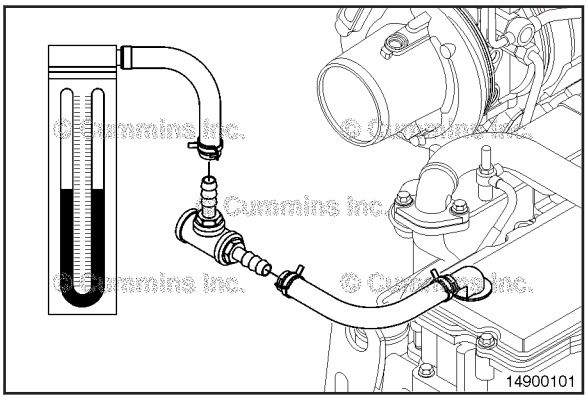


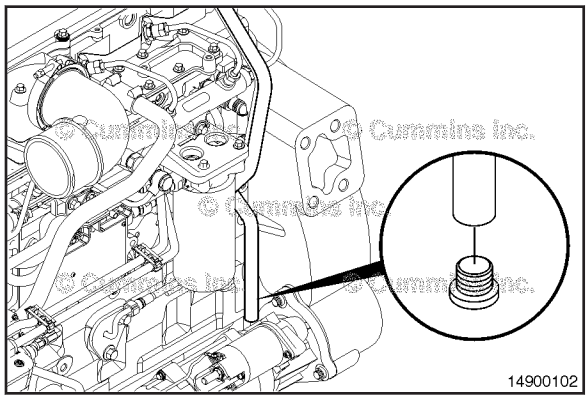
For ISC and ISL CM2150 engines, use the following steps to connect the blowby measurement tools.

- Remove the oil fill cap from the rocker lever cover. Install an oil fill adapter, Part Number 3990099.

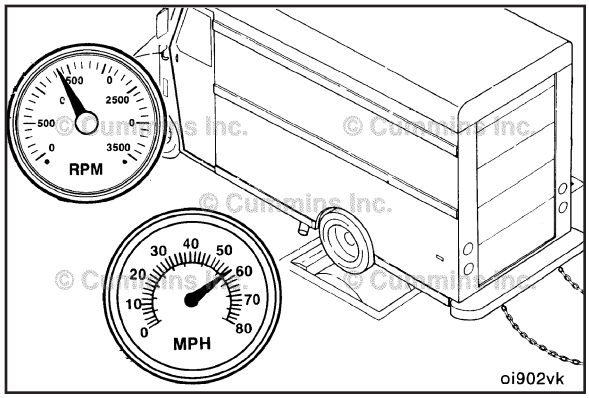


- Connect the appropriate blowby service tool to the outlet of the oil fill adapter. Connect a water manometer, pressure gauge, or transducer to the blowby service tool.





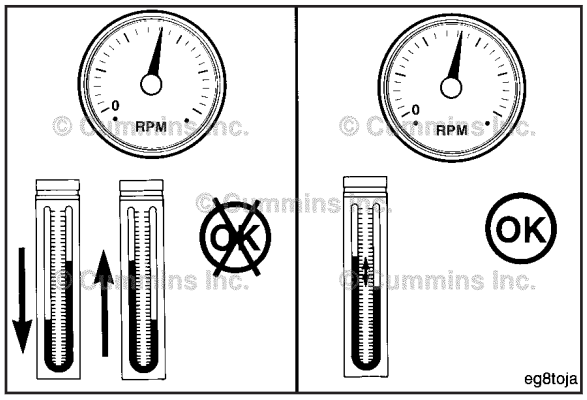
- Use a suitable fitting to plug the crankcase breather tube.



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.

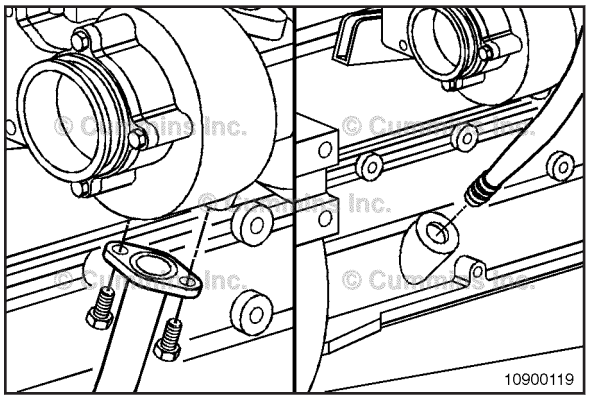
Remove the engine blowby service tool and the water manometer, pressure gauge, or transducer, if the blowby is within specification.

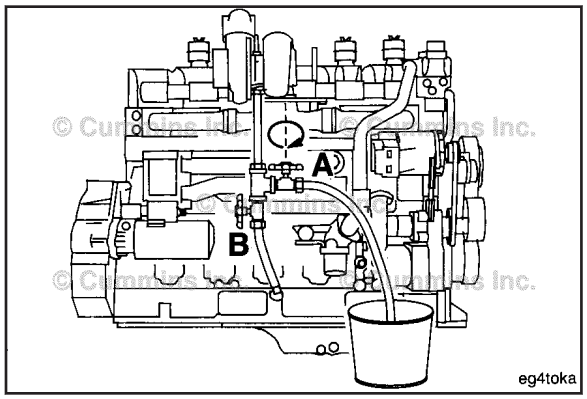
Turbocharger Blowby Contribution:

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.



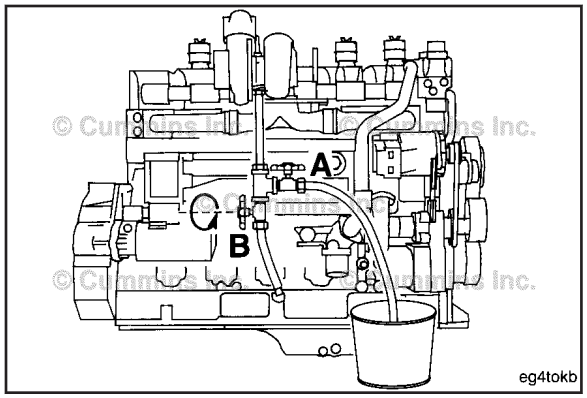


Preferred Turbocharger Isolation Method:

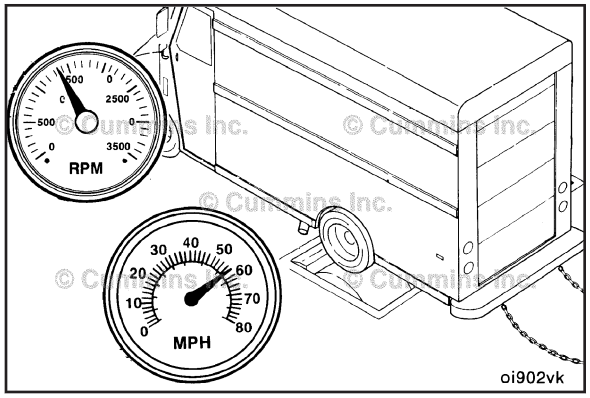
Install a hose assembly with two shutoff valves (A and B), as shown in the illustration, between the turbocharger and turbocharger drain line location in the cylinder block. The valves **must** have a minimum inside diameter of 19 mm [0.75 in]. Place the other hose in a 8 to 9 liter [2 to 3 gal] container.

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.

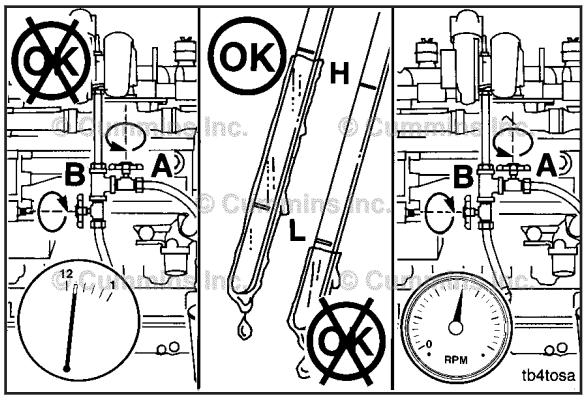
⚠WARNING⚠
Troubleshooting presents the risk of equipment damage, personal injury, or death. Troubleshooting must be performed by trained, experienced technicians.

△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:

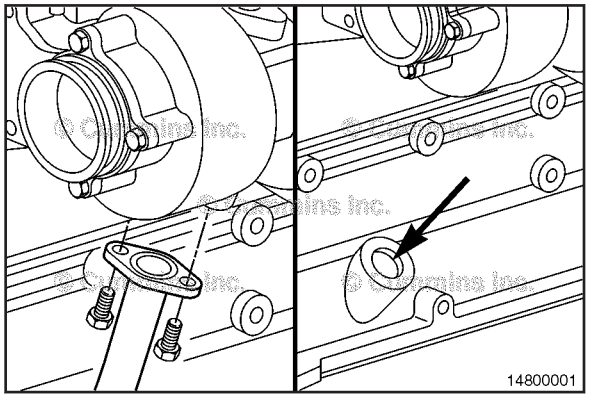
With the turbocharger oil drain line disconnected from the cylinder block, run the turbocharger drain line into a large container.

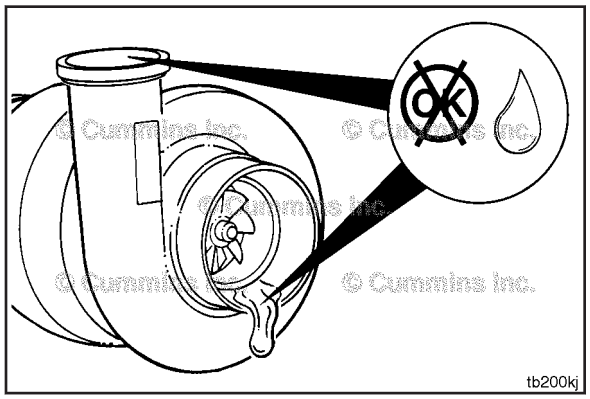
Plug the turbocharger oil drain port in the cylinder block.

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

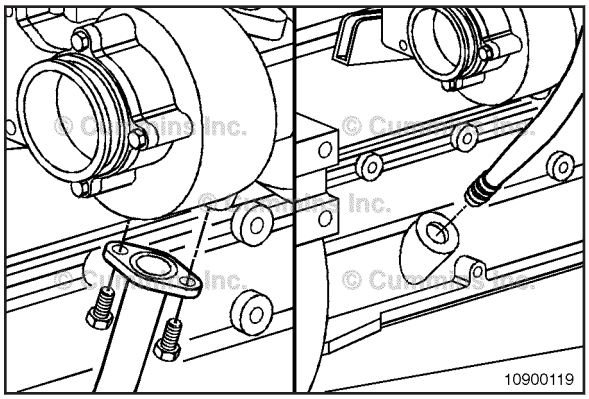
If the turbocharger blowby contribution is out of specification, inspect the compressor and turbine areas of the turbocharger for signs of an oil leak. Replace the turbocharger, if necessary.

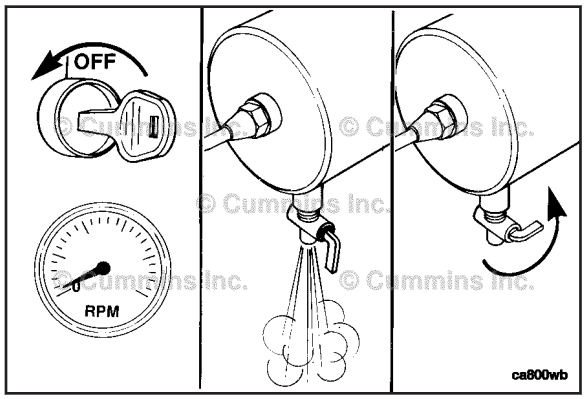
- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 010-033 in Section 10.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 010-033 in Section 10.
- Use the 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.

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.



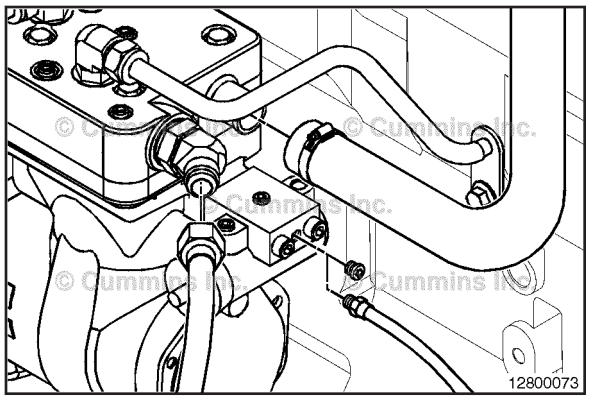


⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

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.

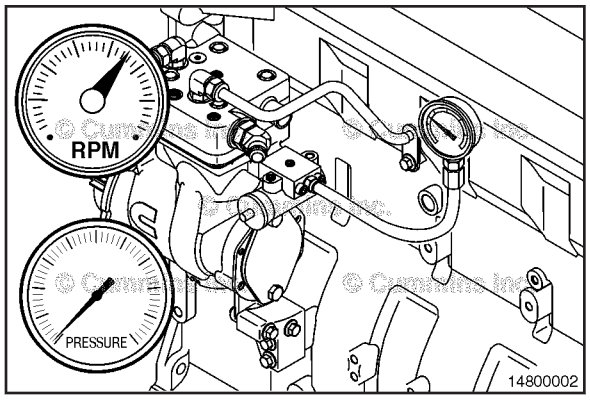


NOTE: The air compressor governor/unloader location can vary on each engine application. The air governor/ unloader can be air compressor mounted or chassis mounted.

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.

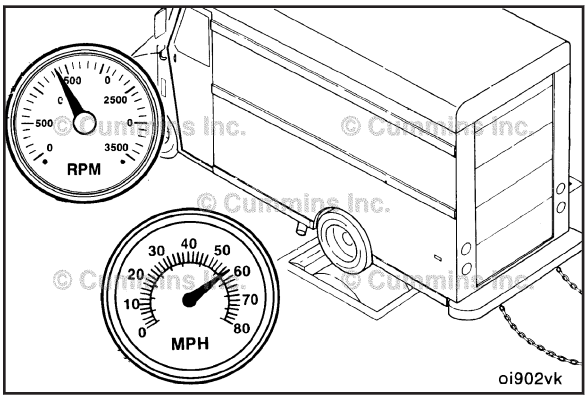
NOTE: When performing the test, make sure that the air system pressure does **not** exceed the manufacturer's maximum allowable pressure.

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.



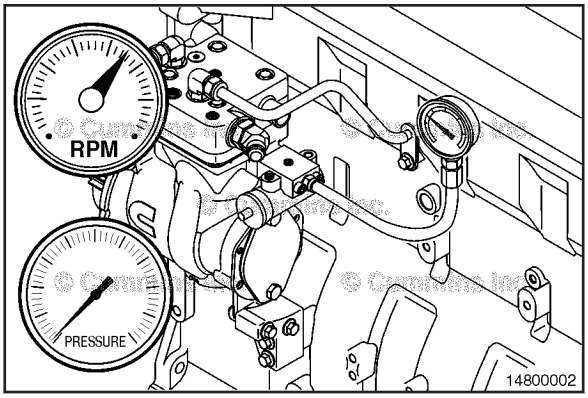
Operate the engine at rated speed and under load by either:

- 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.

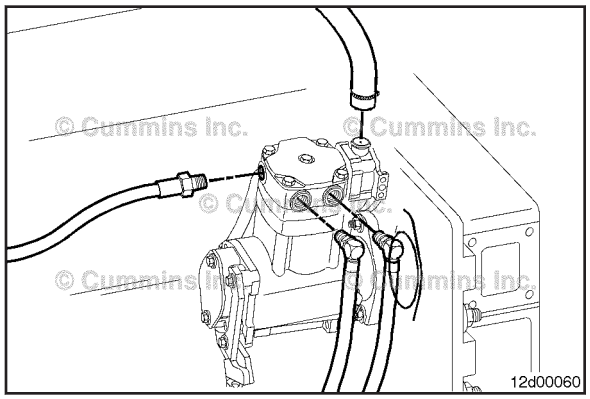
Continue operating the engine at rated speed and load.



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

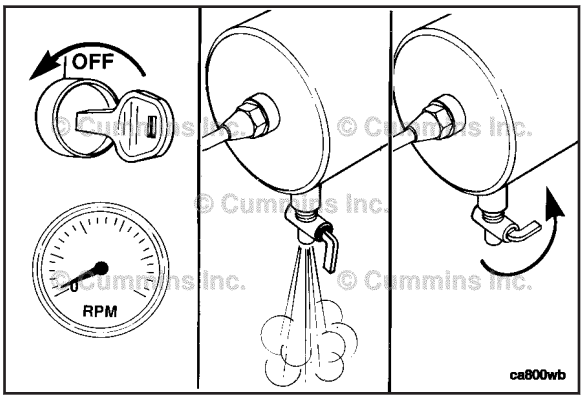
If the air compressor blowby contribution is out of specification, replace the air compressor.

- 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.



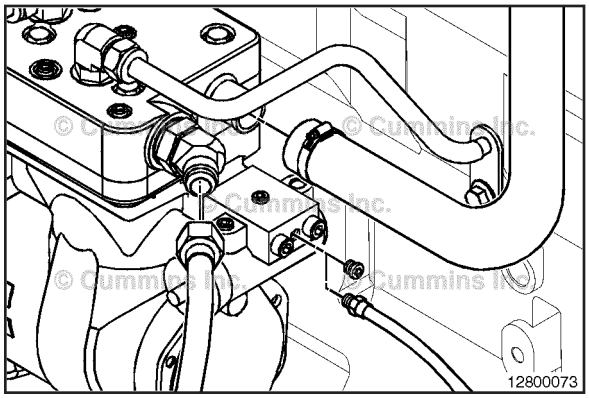
Disconnect the regulated shop air pressure line, with pressure gauge, from the air compressor governor/ unloader air signal port.

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.

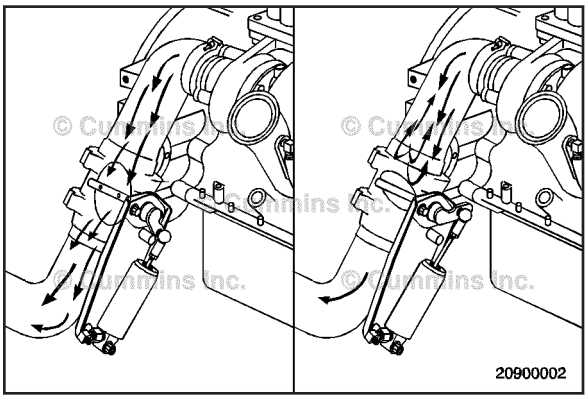


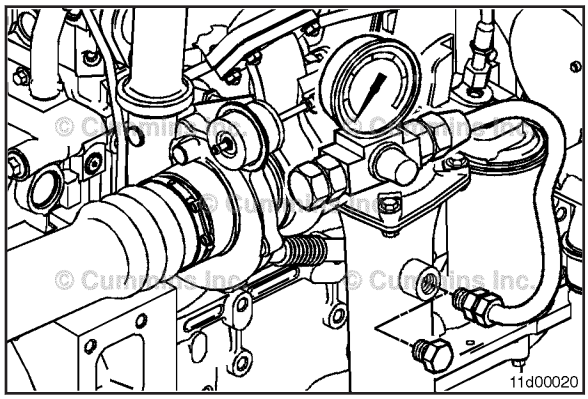
Exhaust Brake Blowby Contribution:

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.

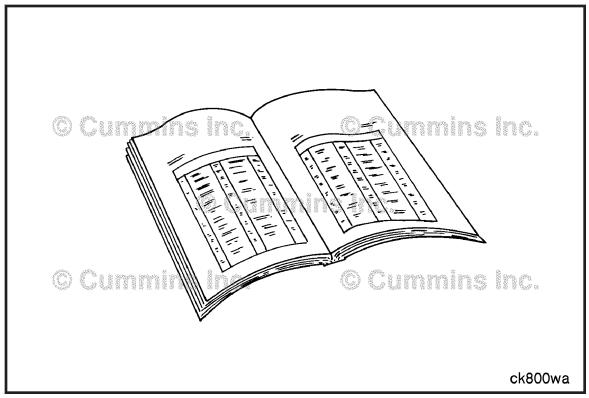
If blowby pressure is above specification during exhaust brake operation and exhaust back pressure is above specification, repair or replace the exhaust brake. See the manufacturer's instructions.

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.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISF3.8 CM2220 Service Manual, Bulletin 4021704. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 012-014 in Section 12.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 012-014 in Section 12.

Piston or piston rings are worn or damaged.

- Use the following procedure in the C Series Engines Troubleshooting and Repair Manual, Bulletin 3666003. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the B3.9, B4.5, B4.5 RGT, and B5.9 Service Manual, Bulletin 3666087. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB and QSB5.9-44 Engines Troubleshooting and Repair Manual, Bulletin 3666193. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISBe, ISB, and QSB (Common Rail Fuel System) Service Manual, Bulletin 4021271. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the Industrial QSB3.9-30, QSB4.5-30, and QSB5.9-30 Series Engines Troubleshooting and Repair Manual, Bulletin 4021398. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISC, ISCe, QSC8.3, ISL, ISLe3, ISLe4 and QSL9 Engines Troubleshooting and Repair Manual, Bulletin 4021418. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISC and ISL CM2150 Service Manual, Bulletin 4021569. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB CM2100 and CM2150 Service Manual, Bulletin 4021578. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISBe and ISDe CM2150 Service Manual, Bulletin 4021597. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISLe CM2150 Service Manual, Bulletin 4021630. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISL G CM2180 Service Manual, Bulletin 4021649. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISF3.8 CM2220, ISF3.8 CM2220 AN and ISF3.8 CM2220 IAN Service Manual, Bulletin 4021704. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB4.5, ISB6.7, ISD4.5 and ISD6.7 CM2150 SN Service Manual, Bulletin 4022188. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISF2.8 CM2220, ISF2.8 CM2220 E, ISF2.8 CM2220 AN and ISF2.8 CM2220 IAN Service Manual, Bulletin 4022178. Refer to Procedure 001-043 in Section 1.Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB6.7 Service Manual, Bulletin 4022254. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB6.7 CM2350 B101 Service Manual, Bulletin 2883567. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB4.5 CM2350 B104 Service Manual, Bulletin 4332646. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the ISB6.7 CM2350 B103 Service Manual, Bulletin 4332641. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the QSB6.7 CM2350 B105 Service Manual, Bulletin 4332778. Refer to Procedure 001-043 in Section 1.
- Use the following procedure in the QSL9 CM2350 L102 Service Manual, Bulletin 4332796. Refer to Procedure 001-043 in Section 1.

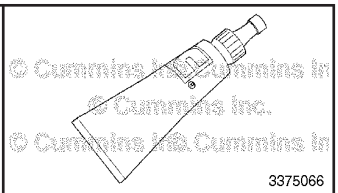
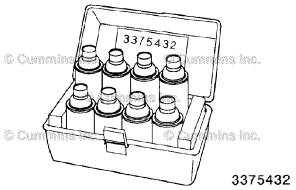
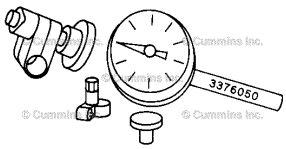
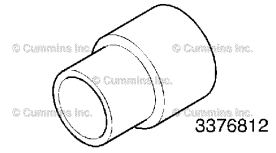
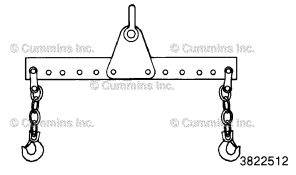
Section 16 - Mounting Adaptations - Group 16

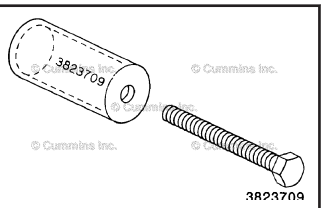
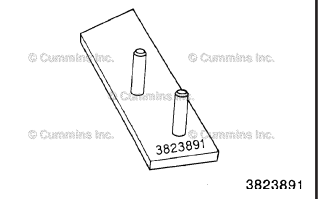
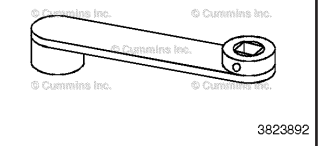
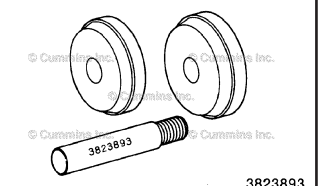
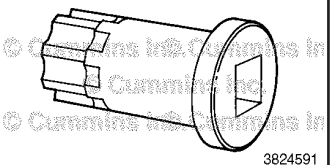
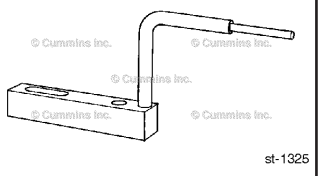
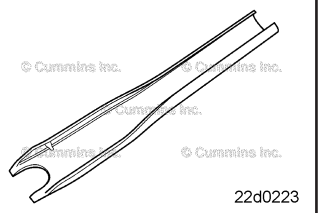
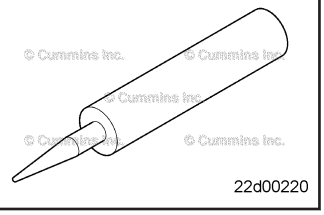
Section Contents

Service Tools

Mounting Adaptations

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

Tool No.	Tool Description	Tool Illustration
3375066	**Pipe Sealant** Used on capscrew threads and pipe plugs.	
3375068	**Cup Plug Sealant** Used when installing cup plugs.	
3375432	**Crack Detection Kit** Used to detect cracks in engine components.	
3376050	**Dial Indicator Gauge** Used for checking flywheel housing runout and/or checking end play on various components.	
3376812	**Cup Plug Driver** Used to install cup plug in flywheel housing.	
3822512	**Engine Lifting Fixture** Used to remove and install the engine.	

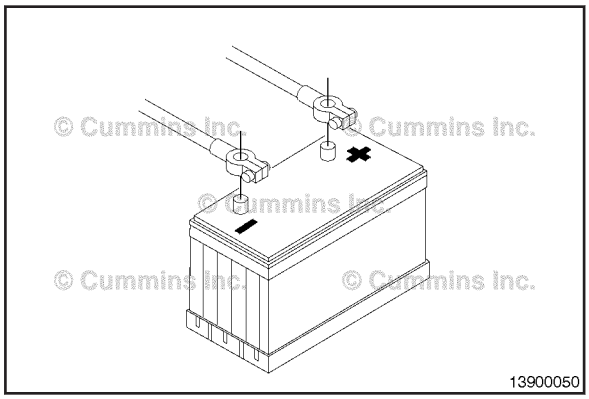
Tool No.	Tool Description	Tool Illustration
3823709	**Idler Shaft Puller and Capscrew** Used to remove idler shaft from idler gear and flywheel housing.	
3823891	**Gear Locking Tool** Used to prevent rotation of the power take-off output shaft while tightening the output flange capscrew.	
3823892	**Offset Wrench** Used to tighten the hidden capscrews in the REPTO flywheel housing.	
3823893	**Bearing Race Driver** Used to install output shaft bearing races.	
3824591	**Barring Tool** Used to engage the flywheel ring gear to rotate the crankshaft.	
ST-1325	**Dial Gauge Attachment** Used to mount on the crankshaft flange when checking flywheel housing runout.	
3165175	**Barring Plug Remover** Removes flywheel housing plug. Removal of this plug is required prior to using barring tool, Part Number 3824591.	
3164070	**RTV Sealant** Used to seal flywheel housing to gear housing joint.	

Engine Support Bracket, Front (016-002)

Preparatory Steps

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

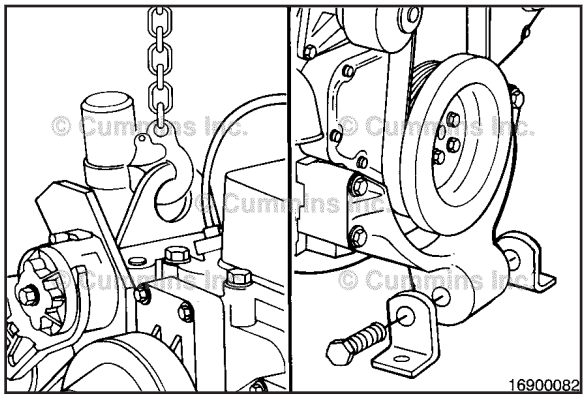
- Disconnect the batteries.



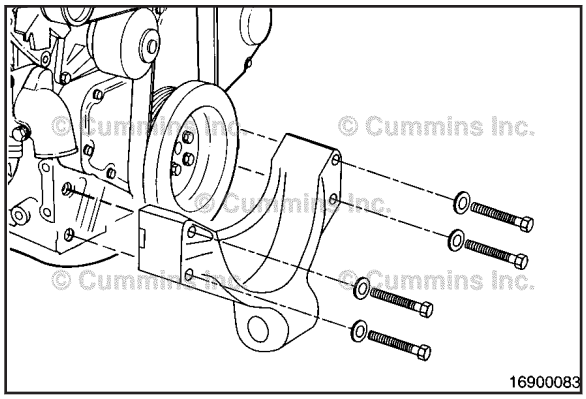
Remove

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

Remove the capscrews from the front engine mount.



Remove the four mounting capscrews and the front engine support.



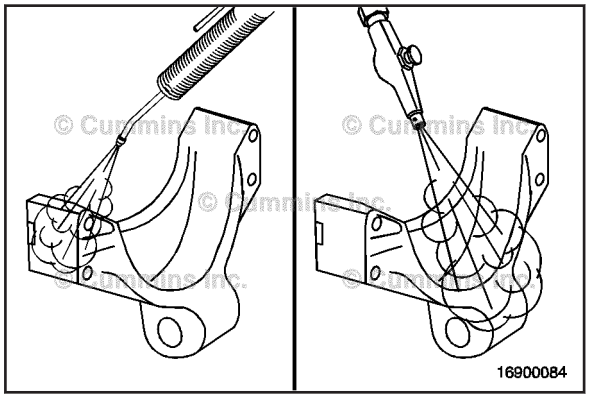
Clean and Inspect for Reuse

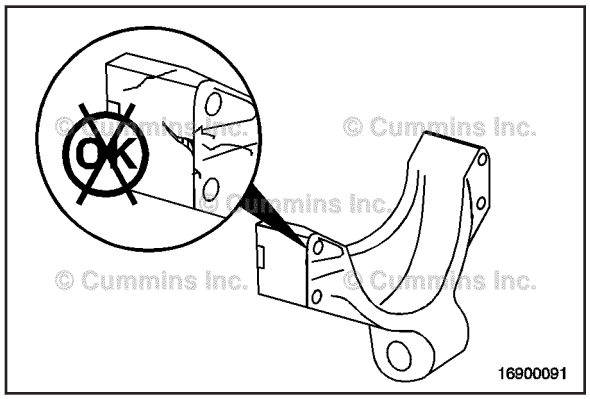
⚠WARNING⚠
When using a steam cleaner, wear protective clothing, and safety glasses or a face shield. Hot steam can cause serious personal injury.

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

Use steam or solvent to clean the front engine support.

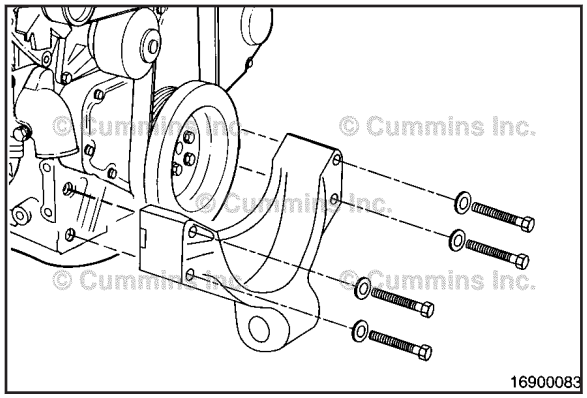
Dry with compressed air.





Inspect the support for cracks or damage.

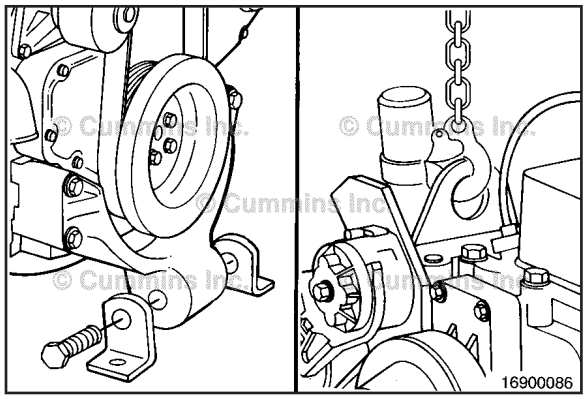
If the support is cracked, it **must** be replaced.



Install

Install the front support and mounting capscrews.

Torque Value: 68 N•m [50 ft-lb]

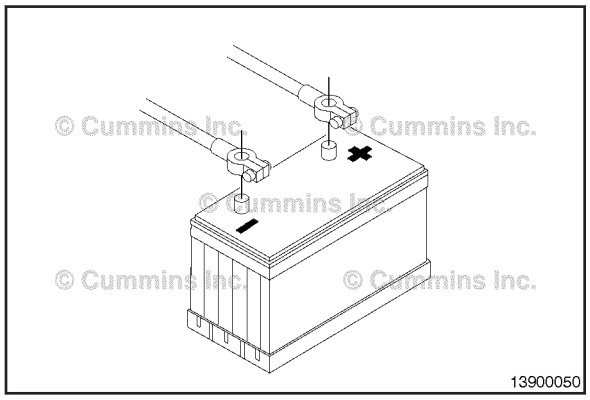


Lower the front of the engine.

Install the front engine mount capscrews.

Tighten the capscrews to the manufacturer's specifications.

Remove the lifting fixture or hoist from the front of the engine.



Finishing Steps

⚠WARNING⚠

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

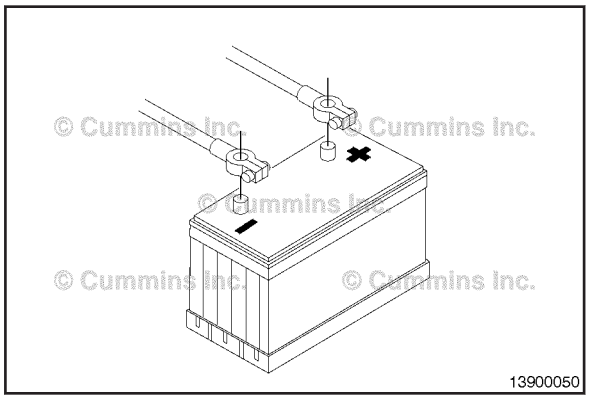
- Connect the batteries.

Engine Support Bracket, Rear (016-003)

Preparatory Steps

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

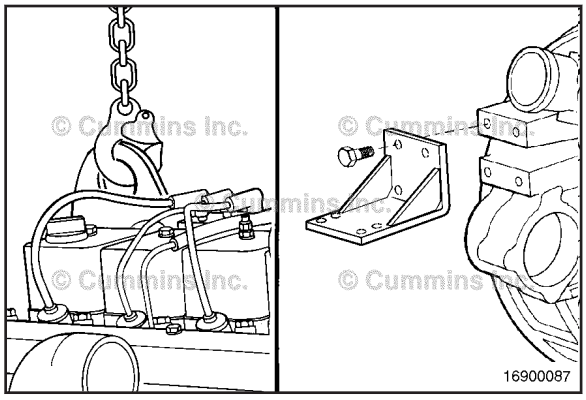
- Disconnect the batteries.



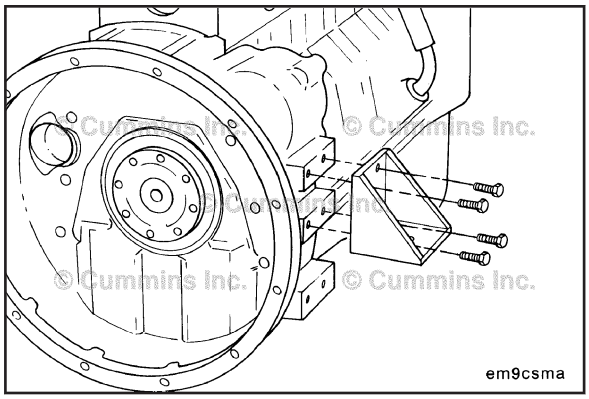
Remove

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

Remove the capscrews from the rear engine mount.



Remove the four capscrews and rear support bracket.



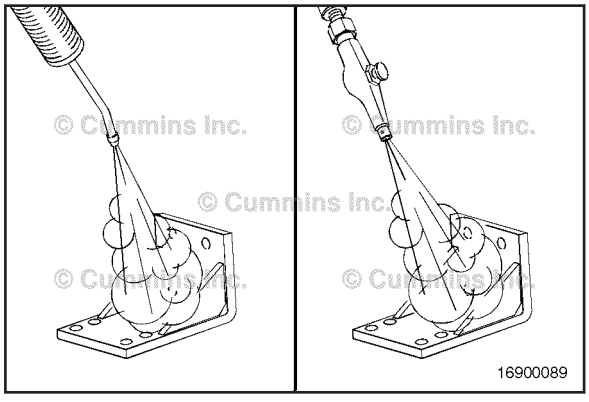
Clean and Inspect for Reuse

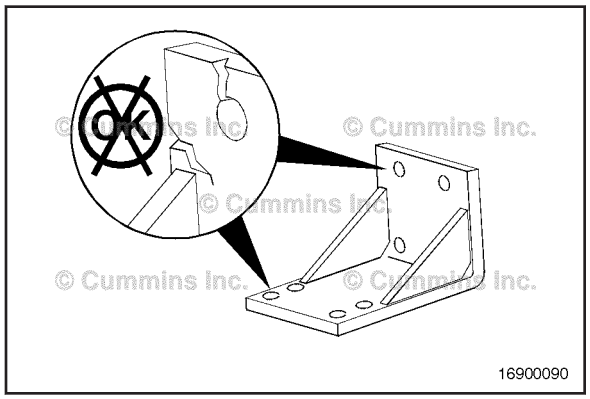
⚠WARNING⚠
When using a steam cleaner, wear safety glasses or a face shield, as well as protective clothing. Hot steam can cause serious personal injury.

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

Use steam or solvent to clean the front engine support.

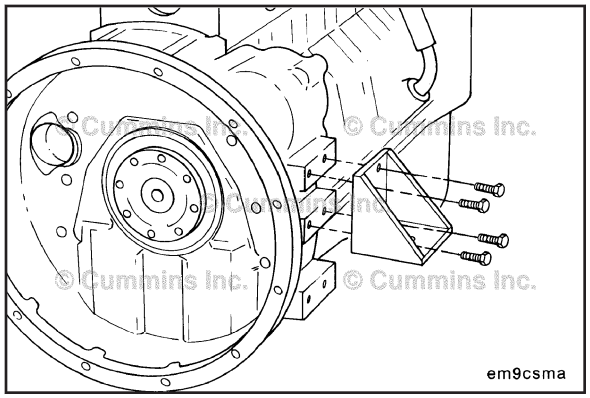
Dry with compressed air.





Inspect the support bracket for cracks or damage.

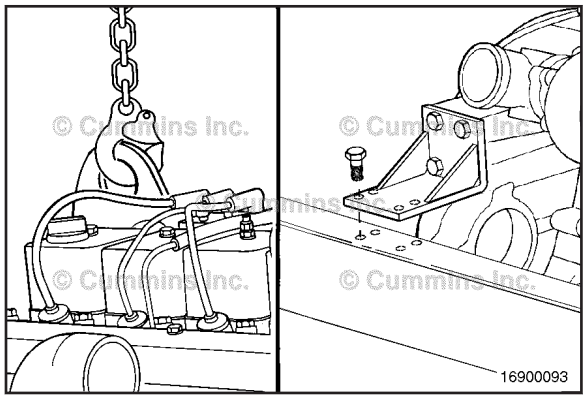
If the support bracket is cracked, it **must** be replaced.



Install

Install the support bracket and mounting capscrews.

Torque Value: 71 N•m [52 ft-lb]

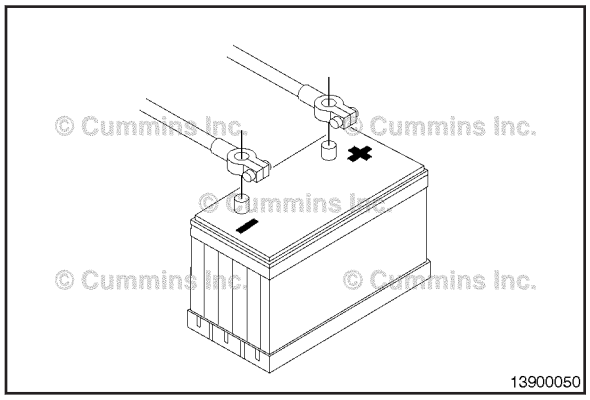


Lower the rear of the engine.

Install the rear engine mount capscrews.

Tighten to the manufacturer's specifications.

Remove the lifting fixture or hoist from the rear of the engine.



Finishing Steps

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

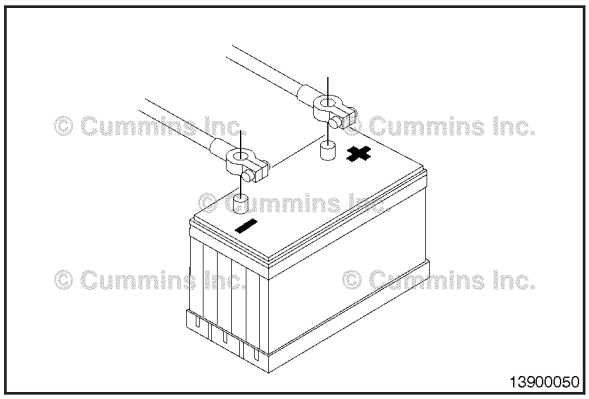
- Connect the batteries.

Flexplate (016-004)

Preparatory Steps

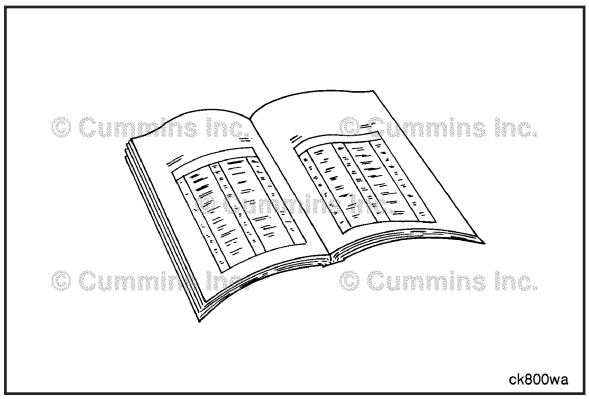
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Disconnect the batteries.



⚠WARNING⚠
This assembly weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this assembly.

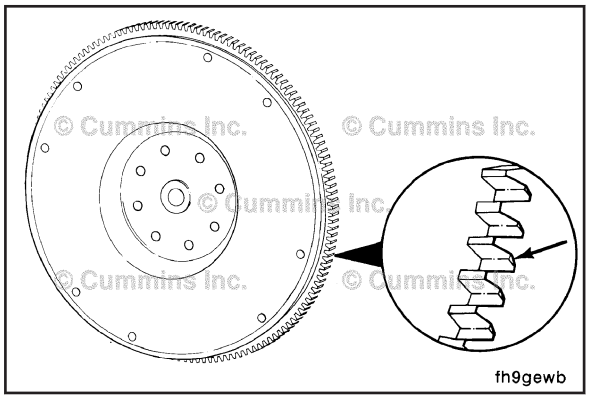
- Remove the transmission and related components. Refer to the OEM service manual.

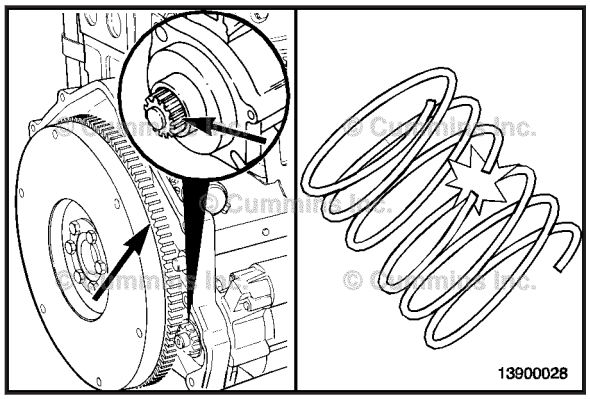


Initial Check

Inspect the flexplate ring gear teeth for damage.

If the flexplate ring gear is damaged make sure to inspect the following possible causes prior to replacing the flexplate.

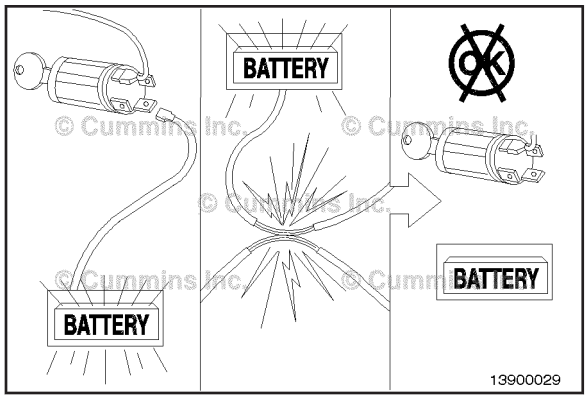




Mechanical

A mechanical issue can typically be identified by seeing damage to the ring gear of the flexplate in 3 distinct locations for 6 cylinder engines (commonly called 120 degree milling), and 2 locations for 4 cylinder engines (commonly called 180 degree milling). The following could be causes for mechanical issues:

1. Upon installation of the flexplate, make sure to check for proper starter motor spacing. Refer to Procedure 013-020
2. Interference between the ring gear land area and the starting motor pinion. The wrong starting motor may be installed. Refer to the original equipment manufacturer's specifications
3. There may be a defect with the starter motor pinion. Inspect the pinion for nicks and burrs. If replacement of the starting motor is necessary, refer to Procedure 013-020
4. Torque Converter/transmission is damaged/ incorrectly mounted. Refer to the original equipment manufacturer's specifications
5. Incorrect starting motor pinion to flexplate ring gear pitch/teeth match. Refer to the original equipment manufacturer's specifications.



Electrical

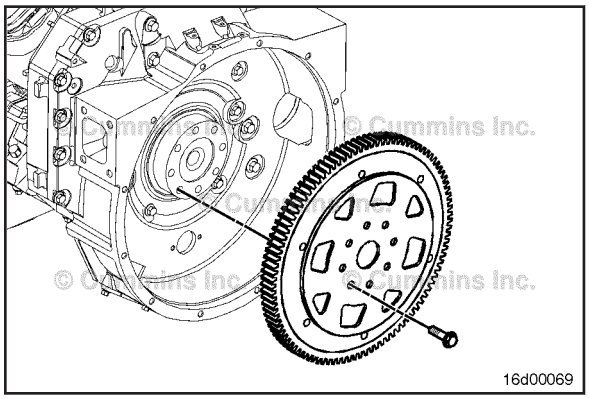
An electrical issue can typically be identified by seeing damage to the ring gear of the flywheel 360 degrees around the circumference of the ring gear (commonly called 360 degree milling). The following could be causes for electrical issues:

1. Operator is attempting to start engine while engine is already running. Check if a starter lockout feature is available through the OEM or the starting motor manufacturer
2. Key switch causing intermittent starting motor engagement when the engine is running. Inspect the key switch. Refer to the OEM service manual
3. Orientation of the starter relay so that the direction of the pull contact is in the direction of the vehicle's travel. This results in intermittent starter motor engagement when the engine is running. Relocate the starter relay. Refer to the original equipment manufacturer's specifications
4. Intermittent starter motor wiring issues. Refer to the original equipment manufacturer's specifications.

Remove

Remove the flexplate capscrews and flexplate.

NOTE: Some flexplates require mounting plates and/or adapters. It may be necessary to remove any mounting plates and/or adapters prior to or with the flexplate. Make sure to note the location of any mounting plates and/or adapters for later installation.

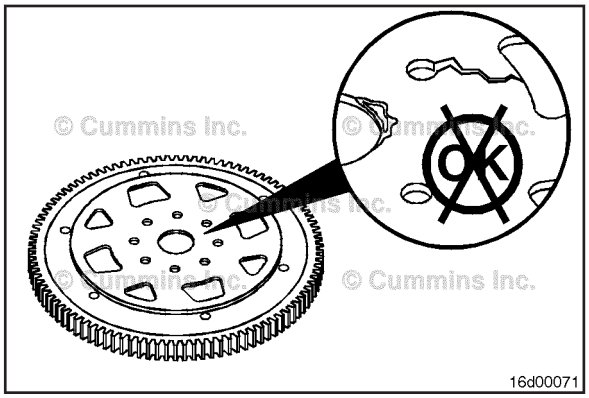


Inspect for Reuse

Inspect the teeth of the ring gear for chips or uneven wear.

Check the flexplate for cracks.

Replace the flexplate if any damage is found.



Install

NOTE: Some flexplates require mounting plates and/or clamp rings. It may be necessary to install any mounting plates and/or clamp rings prior to or with the flexplate as noted during removal.

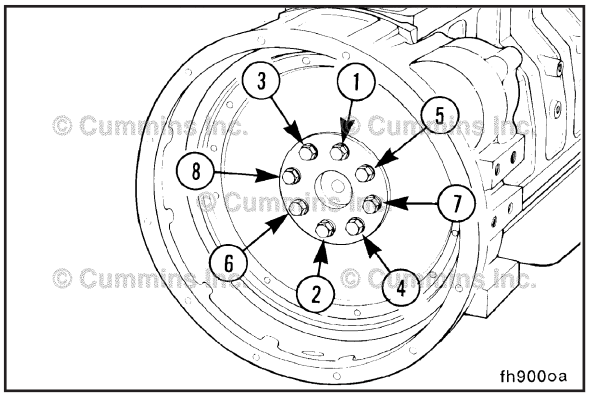
Install the flexplate capscrews, flexplate, and tighten.

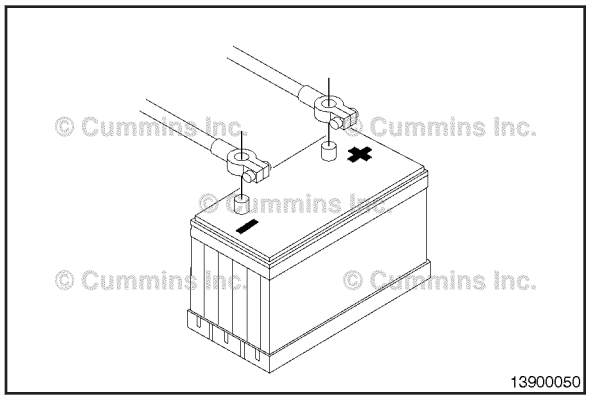
Torque Value:

Rear Gear Train Engines Flexplate Capscrews	Step1	30 N•m [22 ft-lb]
	Step2	Plus 60-degree turn

Torque Value:

Front Gear Train Engines Flexplate Capscrews		137 N•m [101 ft-lb]



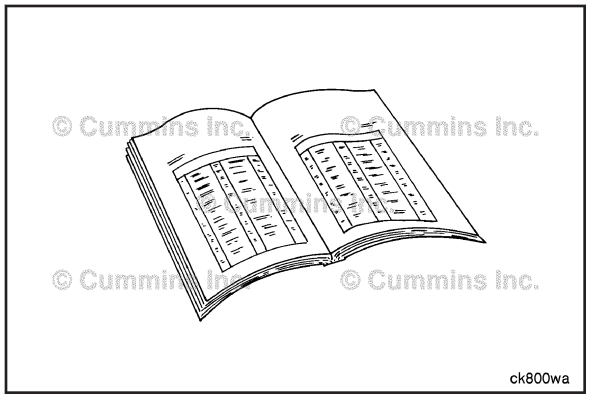


Finishing Steps

Automotive and Industrial

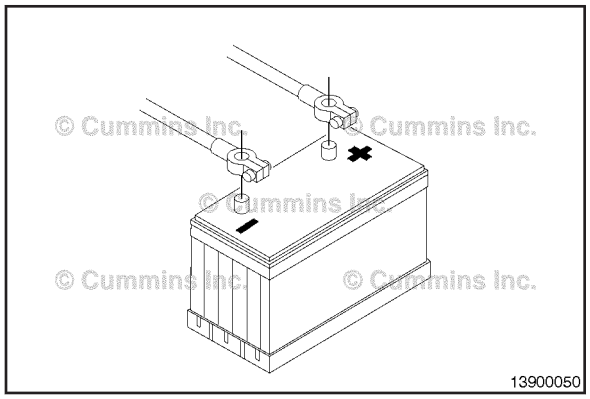
⚠WARNING⚠
Batteries can emit explosive gases. To reduce the possibility of personal injury, always ventilate the compartment before servicing the batteries. To reduce the possibility of arcing, remove the negative (-) battery cable first and attach the negative (-) battery cable last.

- Connect the batteries.



⚠WARNING⚠
This assembly weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this assembly.

- Install the transmission and related components. Refer to the OEM service manual
- Operate the engine and check for noise or vibration.

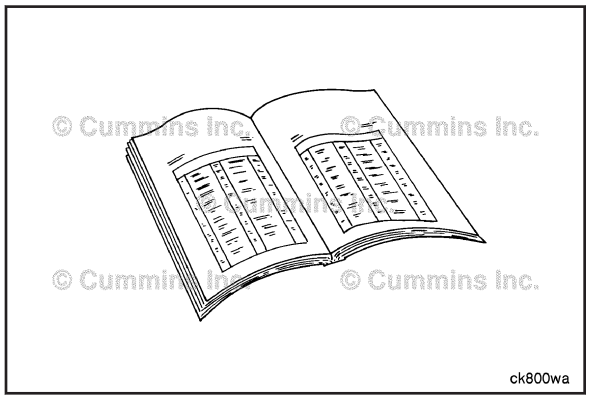


Flywheel (016-005)

Preparatory Steps

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

- Disconnect the batteries.



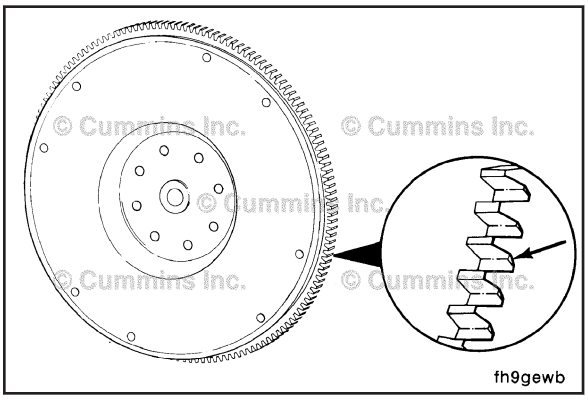
NOTE: Use a container that can hold at least 26 liters [27 US qt] of lubricating oil.

- If equipped with a wet flywheel housing, drain the oil from the flywheel housing by removing the plug in the bottom of the flywheel housing
- Remove the transmission and all related components (if equipped). Refer to the OEM instructions.

Initial Check

Inspect the flywheel ring gear teeth for damage.

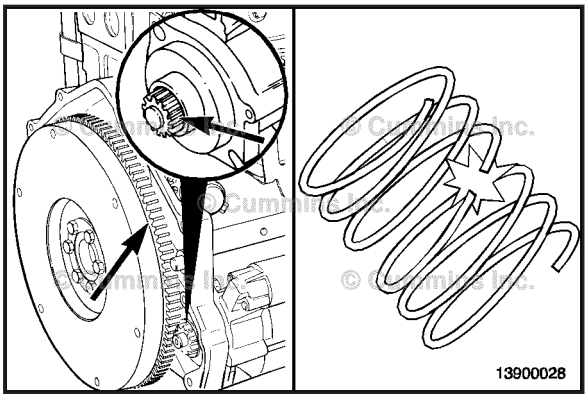
If the flywheel ring gear is damaged make sure to inspect the following possible causes prior to replacing the flexplate.

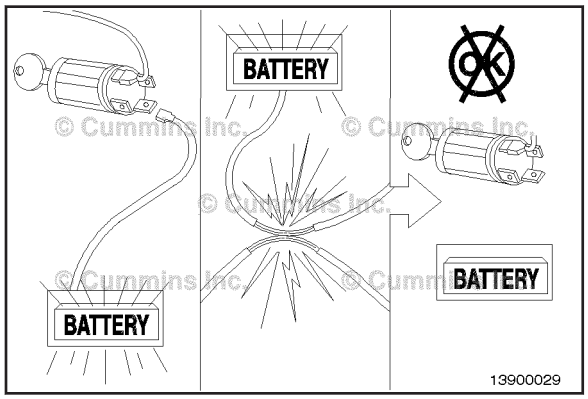


Mechanical

A mechanical issue can typically be identified by seeing damage to the ring gear of the flywheel in 3 distinct locations for 6 cylinder engines (commonly called 120 degree milling), and 2 locations for 4 cylinder engines (commonly called 180 degree milling). The following could be causes for mechanical issues:

1. Upon installation of the flywheel, make sure to check for proper starter motor spacing. Refer to Procedure 013-020
2. Interference between the ring gear land area and the starting motor pinion. The wrong starting motor may be installed. Refer to the original equipment manufacturer's specifications
3. There may be a defect with the starter motor pinion. Inspect the pinion for nicks and burrs. If replacement of the starting motor is necessary, refer to Procedure 013-020
4. The ring gear may be improperly installed or damaged. Refer to Procedure 016-008
5. The flywheel face runout may be out of specification. See the Measure section of this procedure
6. Incorrect starting motor pinion to flywheel ring gear pitch/teeth match. Refer to the original equipment manufacturer's specifications.

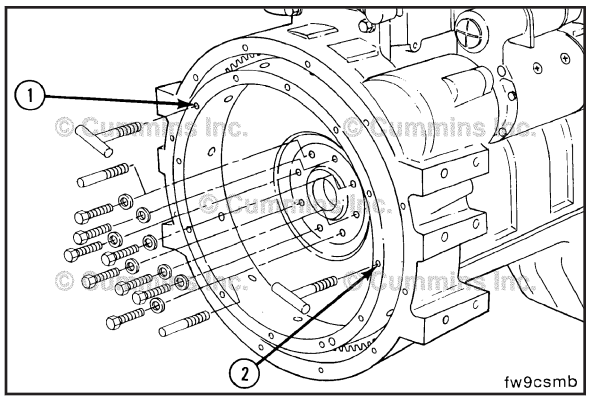




Electrical

An electrical issue can typically be identified by seeing damage to the ring gear of the flywheel 360 degrees around the circumference of the ring gear (commonly called 360 degree milling). The following could be causes for electrical issues:

1. Operator is attempting to start engine while engine is already running. Check if a starter lockout feature is available through the OEM or the starting motor manufacturer
2. Key switch causing intermittent starting motor engagement when the engine is running. Inspect the key switch. Refer to the OEM service manual.
3. Orientation of the starter relay so that the direction of the pull contact is in the direction of the vehicle's travel. This results in intermittent starter motor engagement when the engine is running. Relocate the starter relay. Refer to the original equipment manufacturer's specifications
4. Intermittent starter motor wiring issues. Refer to the original equipment manufacturer's specifications.



Remove

NOTE: Use the barring tool, Part Number 3824591, to hold the flywheel to prevent rotation.

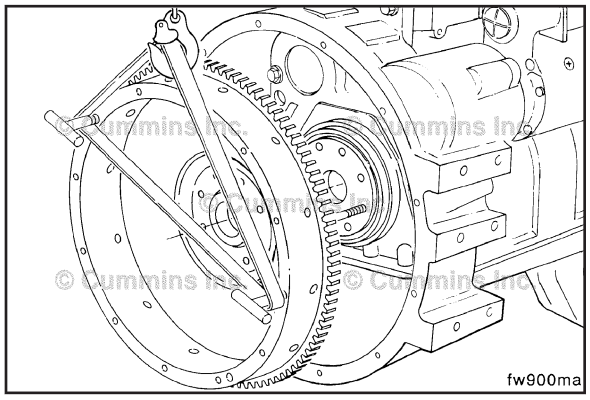
Remove two capscrews 180 degrees apart.

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

NOTE: If a clutch is used in the equipment, the threads in the clutch pressure plate mounting capscrew holes can be metric or standard. Be sure to use the correct capscrews.

Determine the capscrew thread design and size, and install two T-handles in the flywheel at points (1 and 2).

Remove the remaining six flywheel mounting capscrews.



⚠WARNING⚠
This component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this component.

Remove the flywheel from the guide pins.

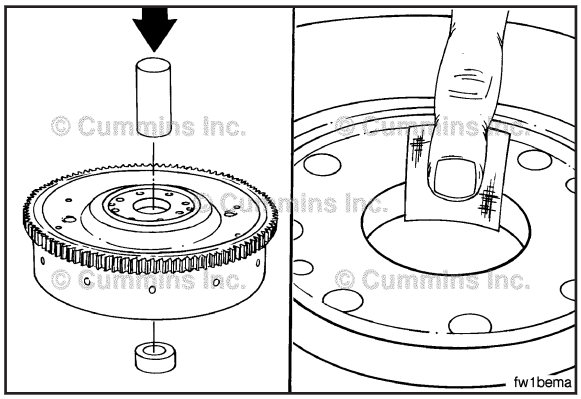
Disassemble

NOTE: Removal of the pilot bearing is only necessary if damaged or when installing a new or rebuilt clutch.

If equipped, remove the pilot bearing.

Use a mandrel and hammer to remove the pilot bearing.

Use an abrasive pad, Part Number 3823258, or equivalent, to clean the pilot bore



Clean and Inspect for Reuse

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

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

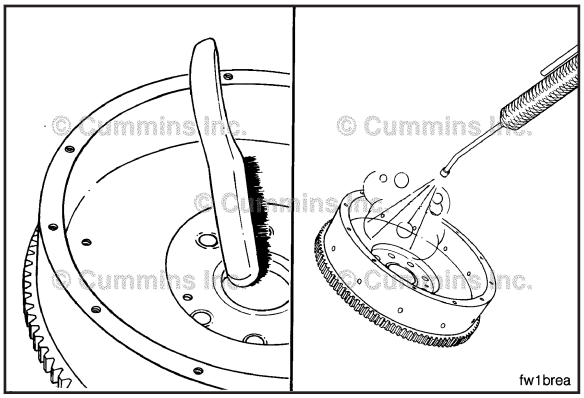
⚠WARNING⚠
Some solvents are flammable and toxic. Read the manufacturer's instructions before using.

⚠WARNING⚠
Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

If the pilot bearing was removed, use a wire brush to clean the crankshaft pilot bore.

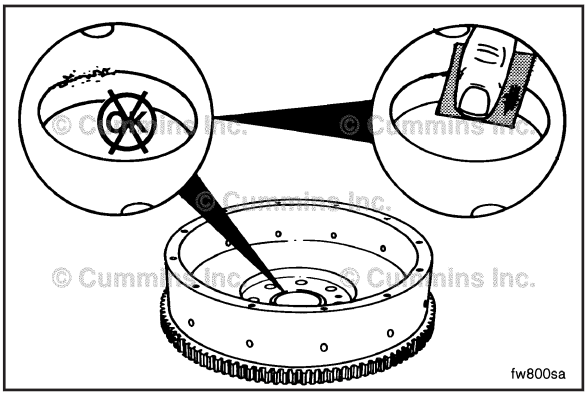
Use steam or solvent to clean the flywheel.

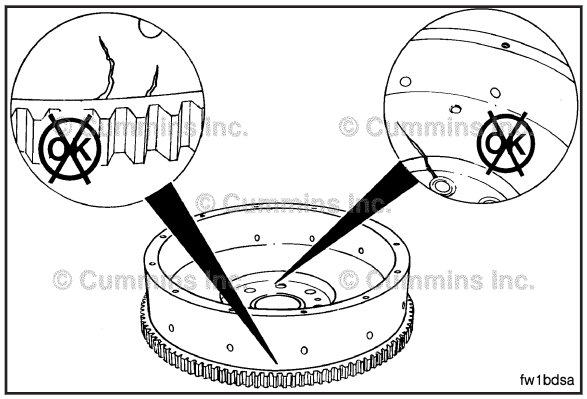
Dry with compressed air.



Inspect for nicks or burrs.

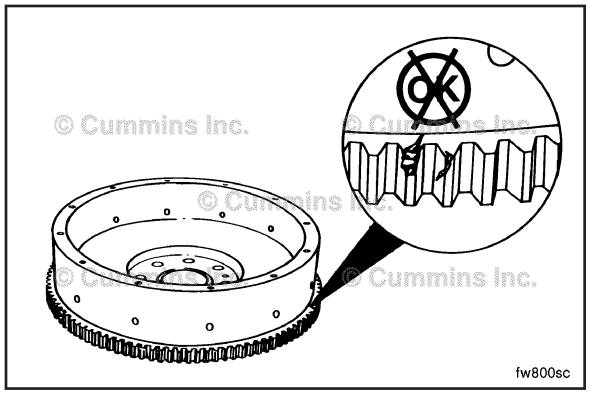
Use Scotch-Brite™ 7448 abrasive pad, or equivalent, to remove small nicks and burrs.





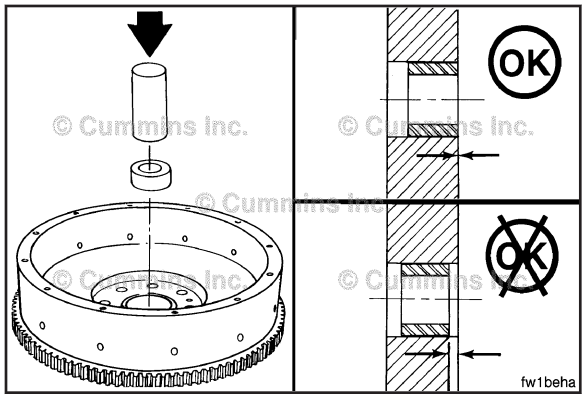
⚠WARNING⚠
Do not use a cracked or resurfaced flywheel. These can break, causing serious personal injury or property damage.

Use the crack detection kit, Part Number 3375432, to check for cracks in the flywheel. Follow the instructions provided with the kit.



Inspect the flywheel ring gear teeth for cracks and chips.

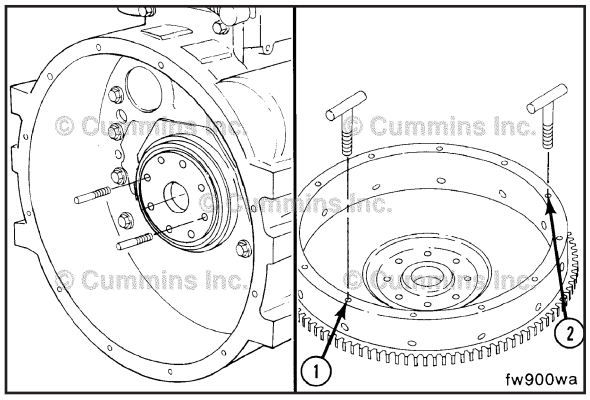
If the ring gear teeth are cracked or broken, the ring gear **must** be replaced. Refer to Procedure 016-008.



Assemble

If removed, install a new pilot bearing.

Use a mandrel and hammer to install the pilot bearing. The pilot bearing **must** be installed evenly with the pilot bore surface.



Install

Install two M12 x 1.25 x 90-mm guide pins into the crankshaft flange 180 degrees apart.

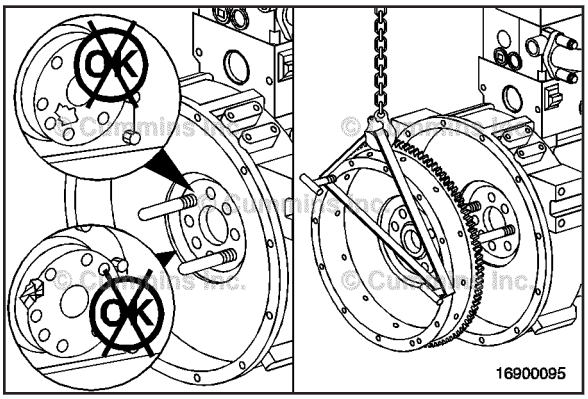
NOTE: If a clutch is used in the equipment, the threads in the clutch pressure plate mounting capscrew holes can be metric or standard. Be **sure** to use the correct capscrews.

Determine the capscrew thread design and size, and install two T-handles into the flywheel (at points 1 and 2).

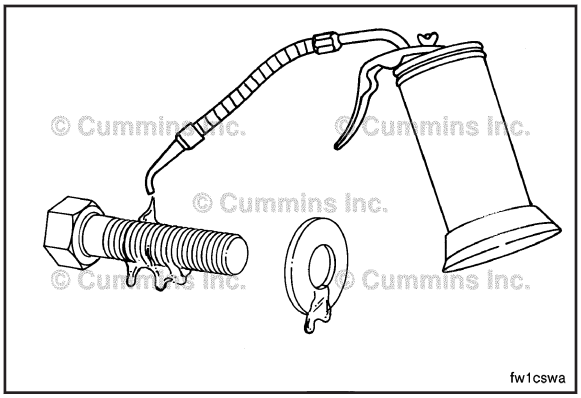
⚠WARNING⚠
The component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift the component.

Inspect the rear face of crankshaft and flywheel mounting flange for cleanliness and raised nicks or burrs.

Install the flywheel on the guide pins.



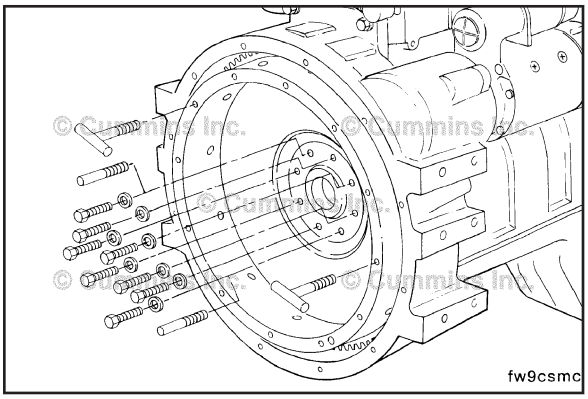
Lubricate the threads of the capscrews and the surface of the washers with clean lubricating engine oil.



Install the six capscrews.

Remove the T-handles and guide pins.

Install the remaining capscrews into the holes from which the guide pins were removed.



NOTE: Use the barring tool, Part Number 3824591, to hold the flywheel to prevent rotation.

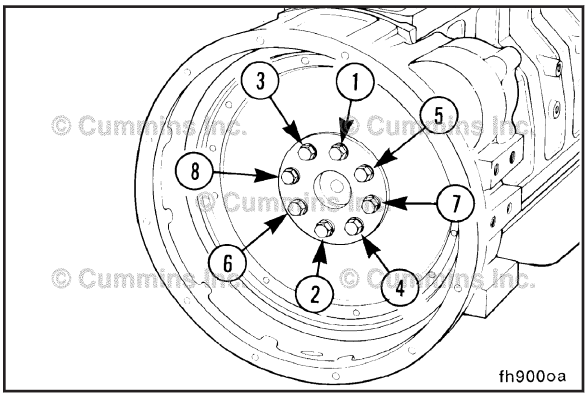
Tighten the capscrews in a star pattern.

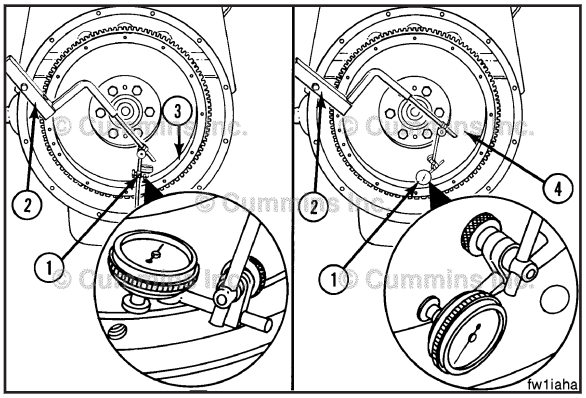
Torque Value:

Rear Gear TrainStep1 Engines Flywheel Capscrews	30 N•m	[22 ft-lb]
Step2	Plus 60-degree turn	

Torque Value:

Front Gear Train Engines Flywheel Capscrews	137 N•m	[101 ft-lb]





Measure

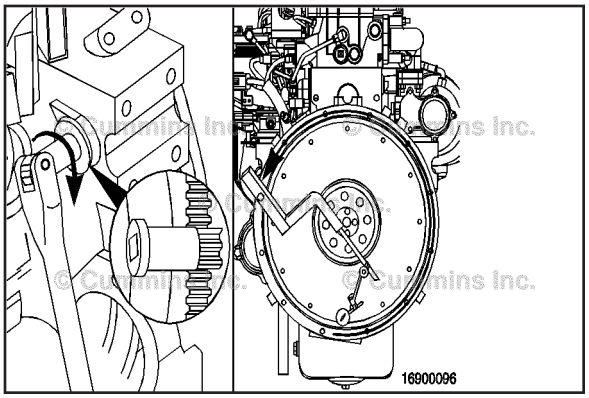
Bore Runout

Use the dial indicator gauge (1), Part Number 3376050, or its equivalent, and dial gauge attachment (2), Part Number ST-1325, to inspect the flywheel bore (3) and the surface (4) runout.

Install the attachment to the flywheel housing.

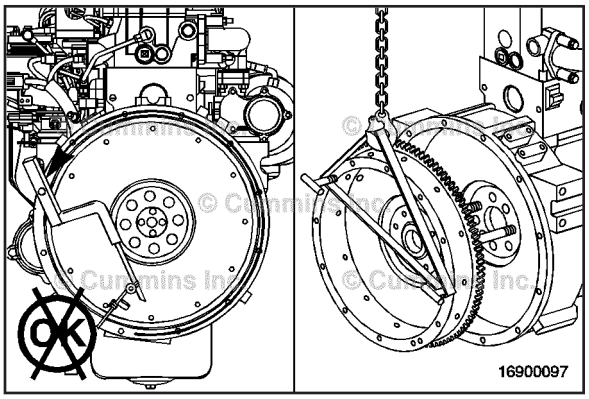
Install the gauge on the attachment.

Install the contact tip of the indicator against the inside diameter of the flywheel bore, and set the dial indicator at zero.



Use the barring tool, Part Number 3824591, to rotate the crankshaft one complete revolution.

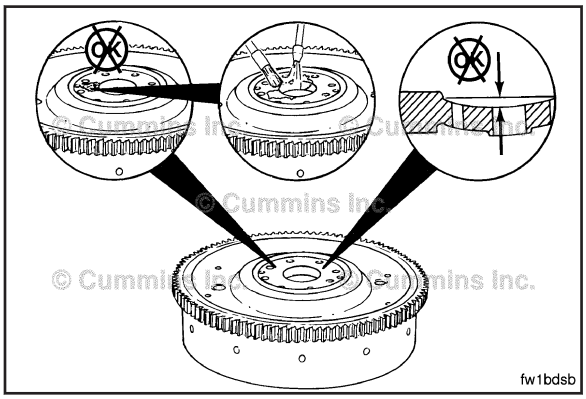
Flywheel Total Indicator Reading		
mm		**in**
0.127	MAX	0.0050



⚠WARNING⚠
The component weighs 23 kg [51 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift the component.

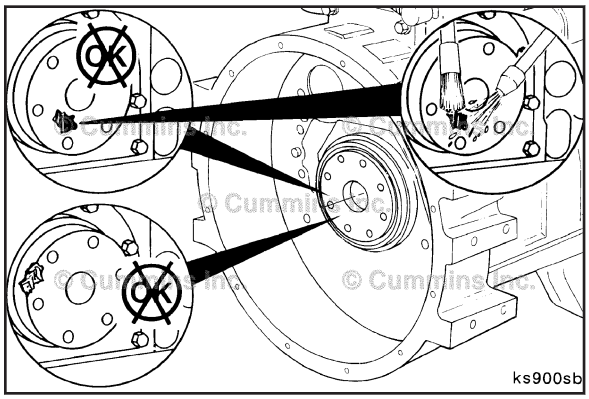
If the total indicator reading total indicator reading is greater than the specification, do the following:

- Remove the flywheel.



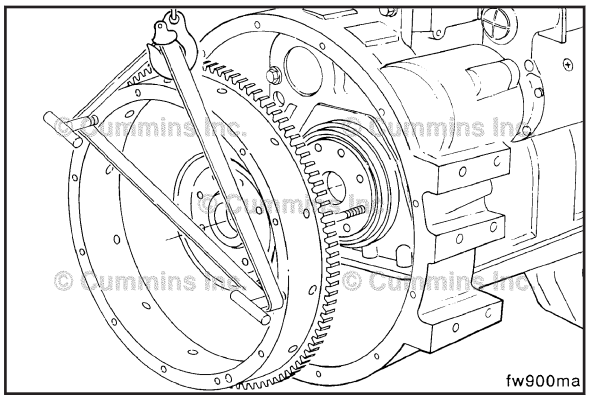
- Inspect the flywheel mounting surface for dirt or damage.

- Inspect the crankshaft for dirt or damage.



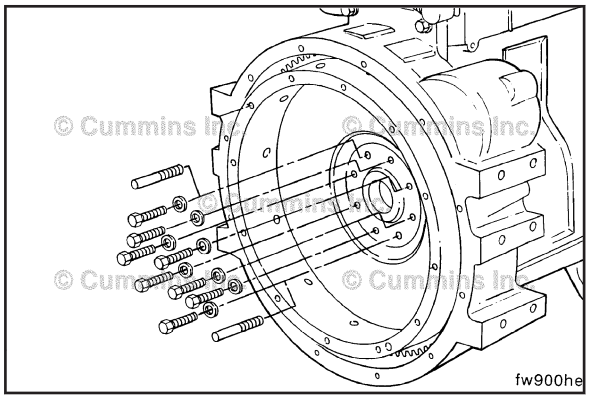
⚠WARNING⚠
The component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift the component.

- Install the flywheel.
- Inspect the bore runout again.



- Replace the flywheel if the runout does **not** meet specifications.

Flywheel Bore Runout		
mm		in
0.127	MAX	0.005

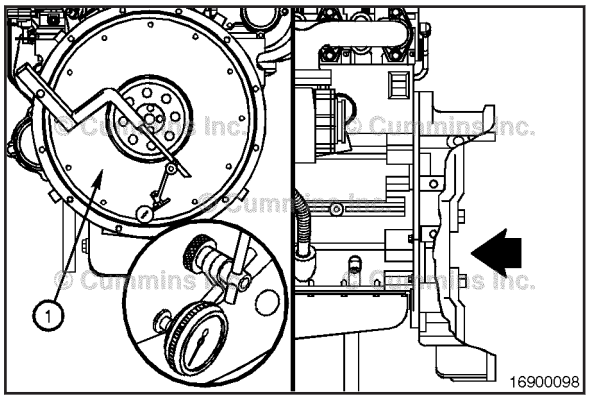


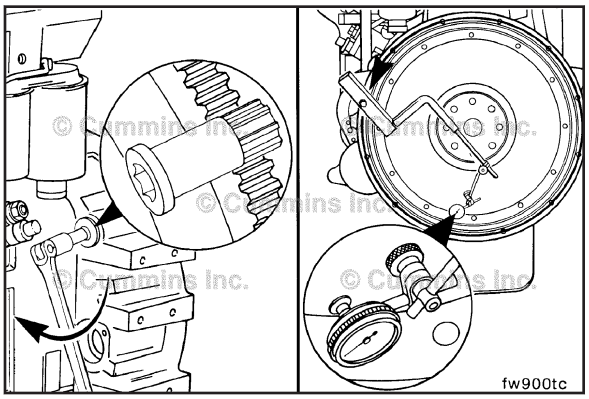
Face Runout

Install the contact tip of the indicator against the flywheel face.

When locating the contact tip, see the Flywheel Face Runout Total Indicator Reading Table later in this procedure. Locate the contact tip so that it corresponds with a radius listed in the table, but is still as close to the outside diameter of the flywheel as possible, to inspect the flywheel face (1) runout.

Push the flywheel forward to remove the crankshaft end clearance. Adjust the dial on the indicator until the needle points to zero.



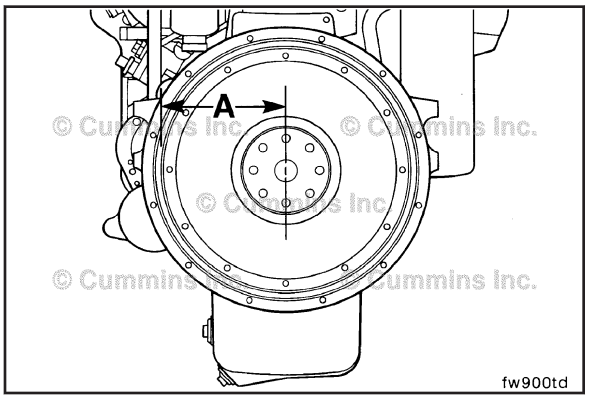


Use the barring tool, Part Number 3824591, to rotate the crankshaft one complete revolution. Measure and record the flywheel runout at four equal points on the flywheel.

The flywheel **must** be pushed toward the front of the engine to remove the crankshaft end clearance each time a point is measured.

Determine the total indicator reading (TIR).

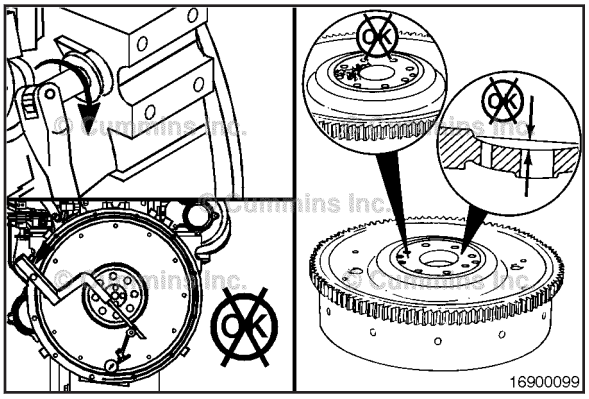
TIR is determined by calculating the difference between the highest and lowest measurement from the four locations measured.



Measure the distance from the center of the flywheel to the contact tip of the indicator (A). Use this measurement to determine which specification to use from the table below.

The total indicator reading **must not** exceed the following specifications:

Flywheel Radius (A)		**Maximum Total Indicator Reading of Flywheel Face**	
mm	**in**	**mm**	**in**
101.6	4	0.140	0.004
127	5	0.13	0.005
152.4	6	0.156	0.006
177.8	7	0.182	0.007
203.2	8	0.208	0.008
228.6	9	0.234	0.009
254	10	0.26	0.01

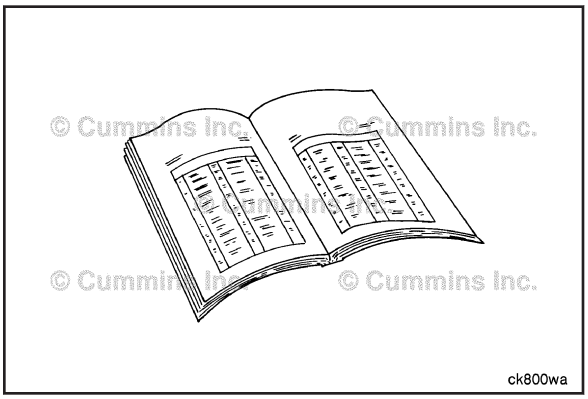


If the flywheel face runout is **not** within specifications, remove the flywheel. First check for nicks, burrs, or foreign material between the flywheel mounting surface and the crankshaft flange.

Replace the flywheel if the runout is **not** within specification.

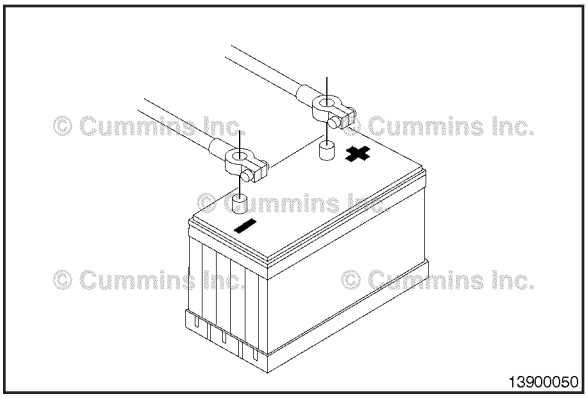
Finishing Steps

- Install the transmission and all related components (if equipped). Refer to the OEM instructions
- If equipped with a wet flywheel housing, fill the flywheel housing with oil. Refer to the OEM Instructions.



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

- Connect the batteries
- Operate the engine and check for noise or vibration

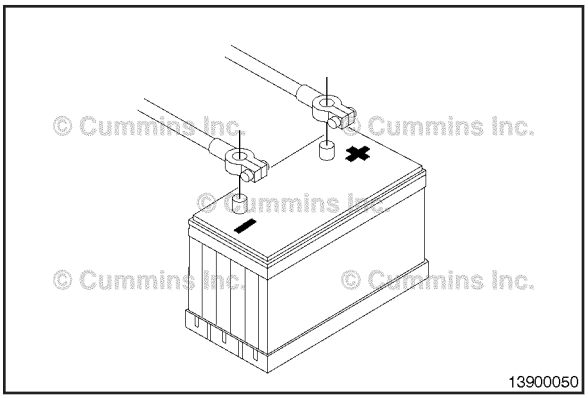


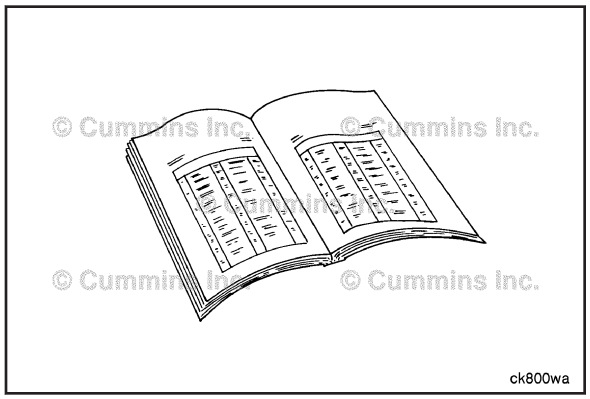
Flywheel Housing (016-006)

Preparatory Steps

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

- Disconnect the batteries.



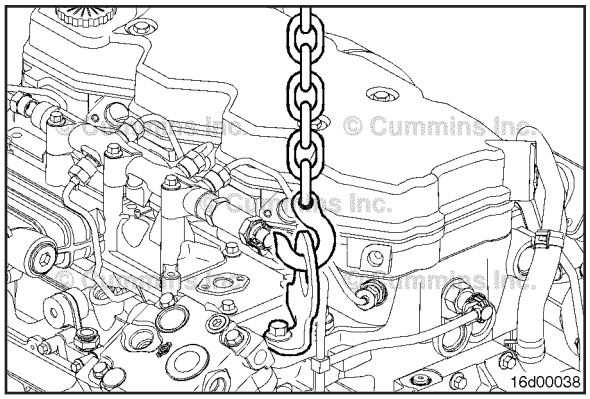


⚠WARNING⚠
This component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this component.

⚠WARNING⚠
Support the rear of the engine using the rear support attached to the cylinder head. Failure to support the engine can cause personal injury.

NOTE: Use a container that can hold at least 16 liters [27 US qt] of lubricating oil.

- If equipped with a wet flywheel housing, drain the oil from the flywheel housing by removing the plug in the bottom of the flywheel housing
- Remove the starting motor. Refer to Procedure 013-020
- Remove the transmission, clutch, and all related components (if equipped). Refer to the OEM service manual
- Remove the flywheel/flexplate assembly. Refer to Procedure 016-005 or Procedure 016-004
- For rear gear train engines, remove the rear crankshaft seal. Refer to Procedure 001-024
- For rear gear train engines, disconnect the closed crankcase ventilation hose from the flywheel housing. Refer to Procedure 003-024
- Remove any OEM attached components (mufflers, shift mechanisms, air filters, etc.) to the flywheel housing. Refer to the OEM instructions.

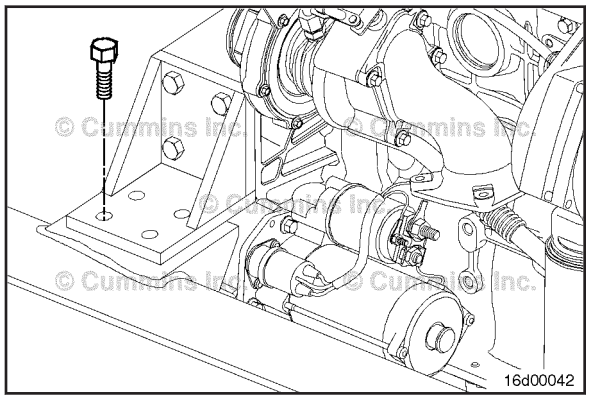


Remove

All Applications

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

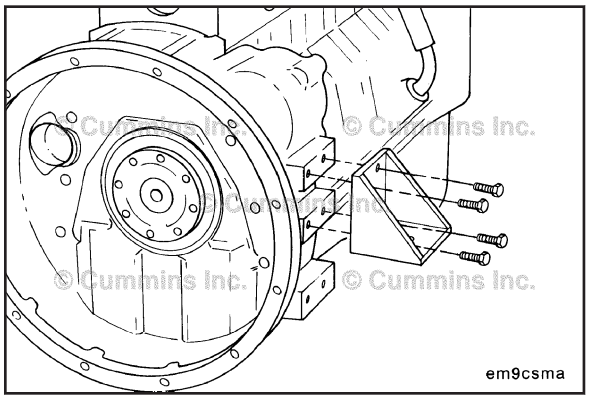
Use a hoist or lifting fixture to support the rear of the engine.



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

Remove the engine mount fasteners.

Remove the rear support capscrews and bracket.



Rear Gear Train

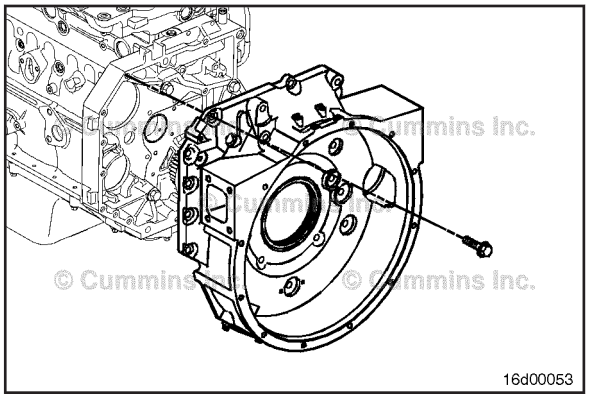
⚠WARNING⚠
This component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this component.

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

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

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

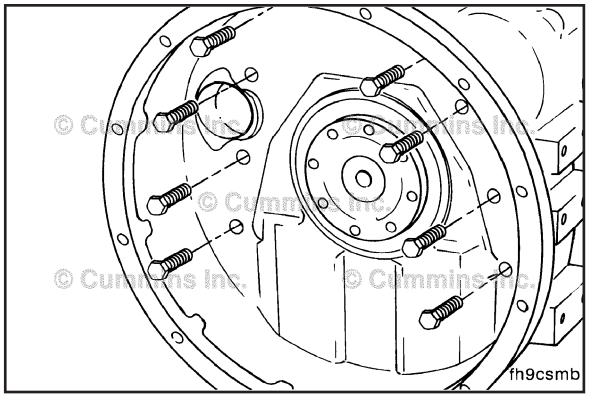
Note the location of the flywheel housing capscrews as removed. Some of the capscrews are different length/size fasteners and **must** be installed in the same location as removed.

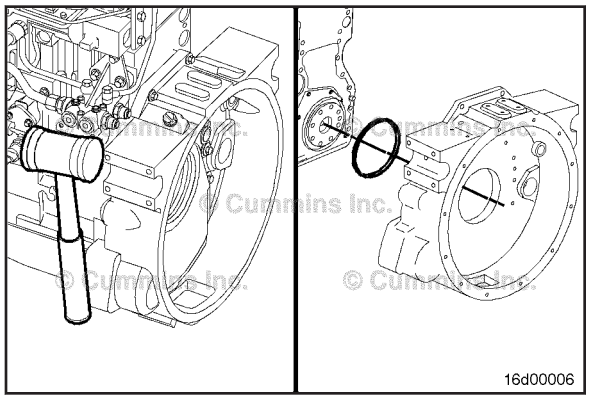


Front Gear Train

⚠WARNING⚠
This component weighs 23 kg [50 lb] or more. To reduce the possibility of personal injury, use a hoist or get assistance to lift this component.

While supporting the flywheel housing, remove the mounting capscrews.



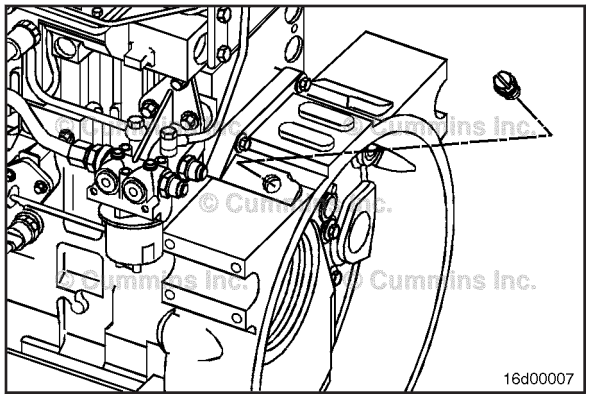


While supporting the flywheel housing, use a rubber hammer to loosen the flywheel housing.

Remove the flywheel housing.

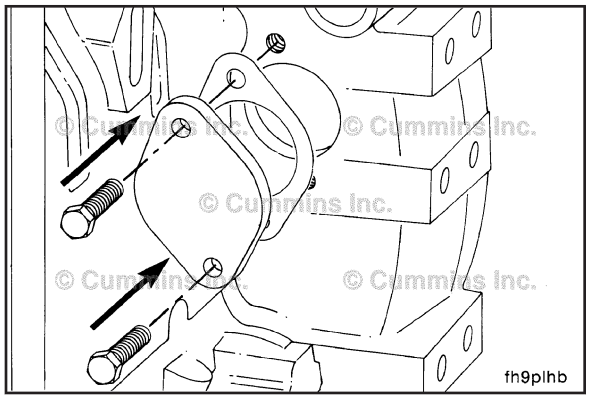
NOTE: Some engines may have an additional rectangular seal between the flywheel housing and the rear seal carrier

NOTE: When removing the flywheel housing, note the location of any locating dowel rings.

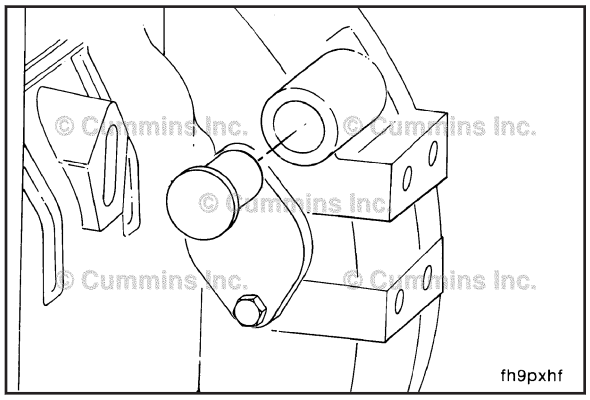


Disassemble

Remove and note the location of any threaded plugs in the flywheel housing.



Remove the access plate and, if equipped, the gasket.

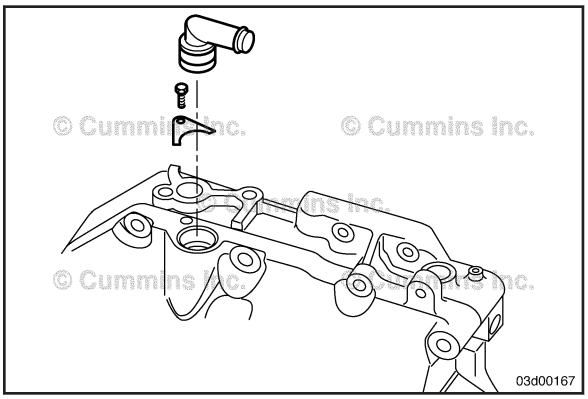


Remove the plug from the barring gear hole.

For rear gear train engines, remove the capscrew securing the closed crankcase ventilation tube adapter clamp plate to the flywheel housing.

Remove the clamp plate.

Remove the closed crankcase ventilation tube adapter.



Clean and Inspect for Reuse

All Applications

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

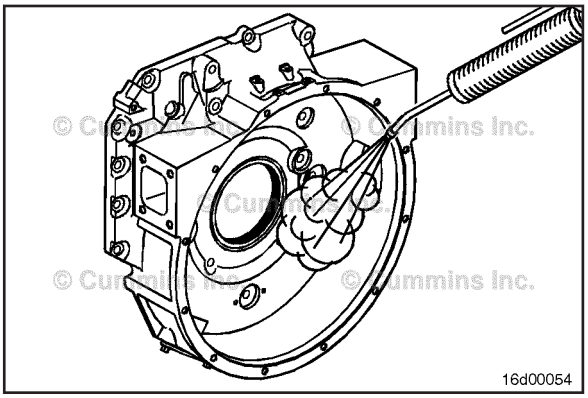
⚠WARNING⚠
When using solvents, acids, or alkaline materials for cleaning, follow the manufacturer's recommendations for use. Wear goggles and protective clothing to reduce the possibility of personal injury.

⚠WARNING⚠
Compressed air used for cleaning should not exceed 207 kPa [30 psi]. Use only with protective clothing, as well as goggles/shield, and gloves to reduce the possibility of personal injury.

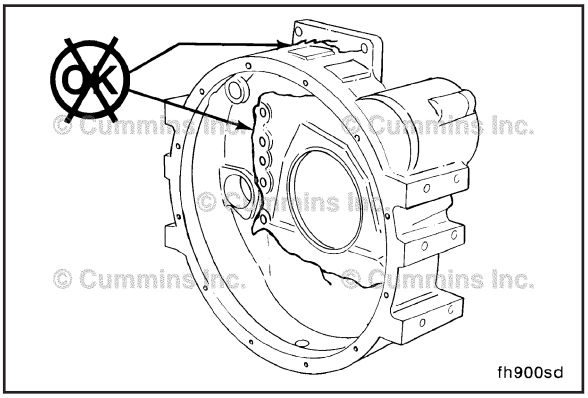
⚠WARNING⚠
Wear appropriate eye and face protection when using compressed air. Flying debris and dirt can cause personal injury.

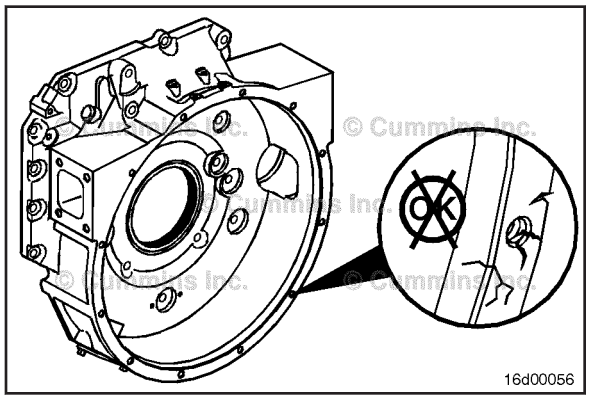
Use steam or solvent to clean the flywheel housing.

Dry with compressed air.



Inspect the flywheel housing for cracks, especially in the area of the flywheel housing that mounts to the cylinder block or rear gear housing.

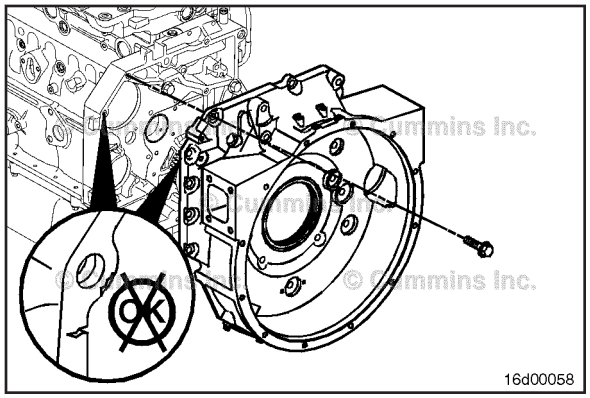




Inspect the flywheel housing transmission/drive unit mounting surface for cracks.

Also inspect for damaged threads commonly caused by cross-threaded capscrews or installing an incorrect capscrew.

NOTE: Helicoils are available to repair damaged threads.

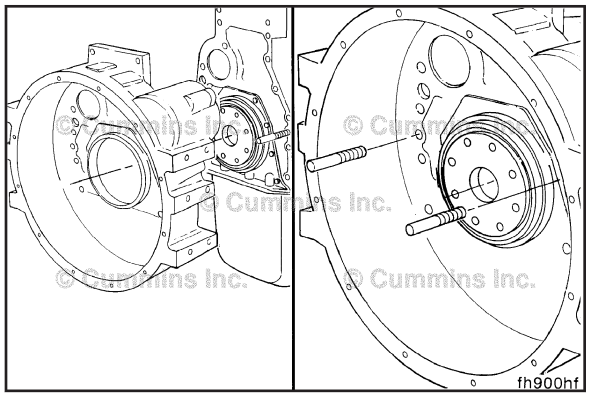


Rear Gear Train

Inspect the rear face of the gear housing and flywheel housing mounting surface for cleanliness and raised nicks or burrs.

Use fine crocus cloth to remove small nicks and burrs.

Thoroughly clean the flywheel housing and gear housing mating surfaces. These surfaces **must** be clean of oil and debris.



Measure

NOTE: Follow this step **only** if the flywheel housing (or rear gear housing for rear gear train engines) is being replaced or if troubleshooting a vibration/alignment issue. It is **not** necessary to measure bore alignment or face alignment when installing the original flywheel housing unless the dowel rings were removed during a previous repair.

Install the flywheel housing following the Install Step of this procedure, but do **not** torque the capscrews. Only tighten the capscrews enough to hold the flywheel wheel in place.

Service Tip: For rear gear train engines, when installing a new flywheel housing to check flywheel housing bore alignment and face alignment, do **not** apply sealant to the flywheel housing prior to installing for measurement.

⚠CAUTION⚠
When barring the engine using service tool, Part Number 3824591, be careful to not apply excessive side loading to the flywheel housing. This may cause the flywheel housing to move and cause inaccurate measurement readings.

Face Alignment

⚠CAUTION⚠
The dial indicator tip must not enter the capscrew holes, or the gauge will be damaged.

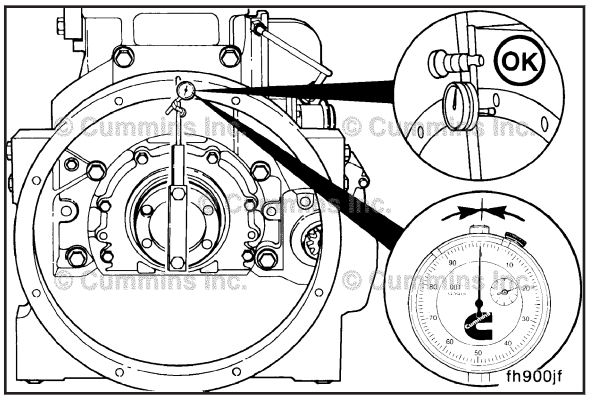
Face alignment is determined by calculating the total indicator reading (TIR).

Attach the dial indicator gauge, Part Number 3376050, to the crankshaft. Use mounting tool, Part Number ST1325, to attach the dial indicator to the crankshaft as illustrated.

NOTE: The dial indicator can be mounted by any method that holds the extension bar of the indicator rigid, so it does **not** sag. If the bar sags or the indicator slips, the readings obtained will **not** be accurate.

Position the indicator at the 12-o'clock position, and zero the gauge.

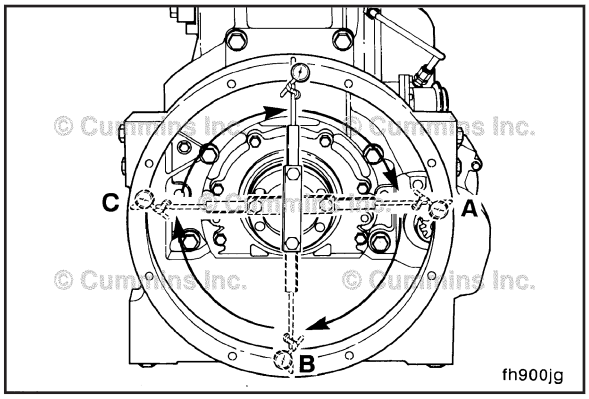
NOTE: The crankshaft **must** be pushed toward the front of the engine to remove the crankshaft end clearance each time a position is measured.



Using the barring tool, Part Number 3824591, slowly rotate the crankshaft.

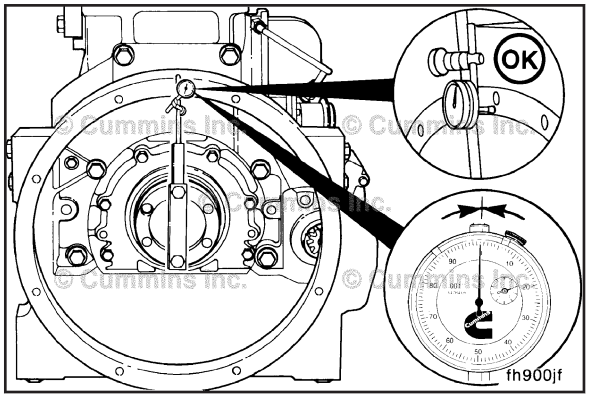
Record the readings at the 3-o'clock (A), 6-o'clock (B) , and 9-o'clock positions (C).

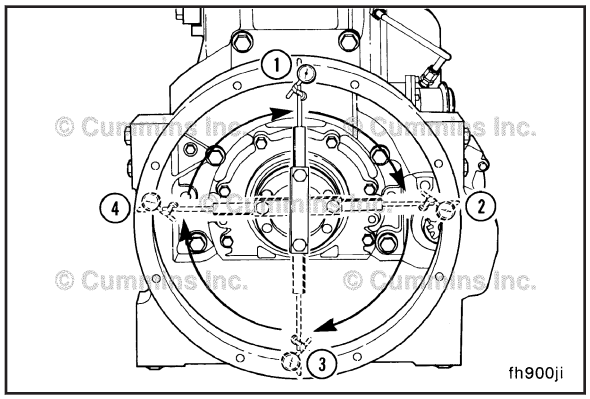
The values for A, B, and C could be positive or negative.



Continue to rotate the crankshaft until the indicator is at the 12-o'clock position.

Check the indicator to make sure the needle points to zero. If it does **not**, the readings will be incorrect and the procedure will have to be redone.





Determine the total indicator reading (TIR).

TIR is determined by calculating the difference between the highest and lowest measurement from the four locations measured.

As the example below illustrates, the TIR would be:

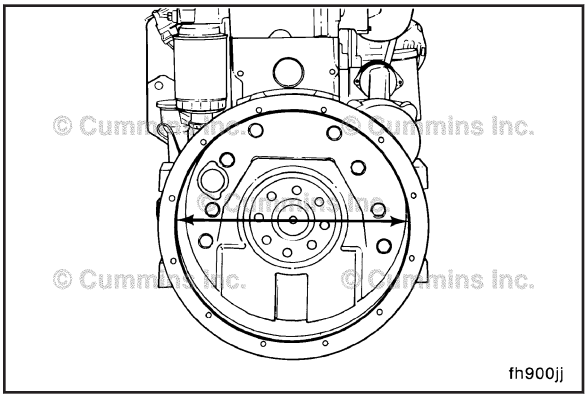
+ 0.08 mm — (-0.05 mm) = 0.13 mm

[+.003 in — (-0.002 in) = 0.005 in]

Example:		
12 o'clock	0.00 mm	[0.000 in]
3 o'clock	+0.08 mm	[+0.003 in]
6 o'clock	- 0.05 mm	[- 0.002 in]
9 o'clock	+0.08 mm	[+0.003 in]
Equals TIR	0.13 mm	[0.005 in]

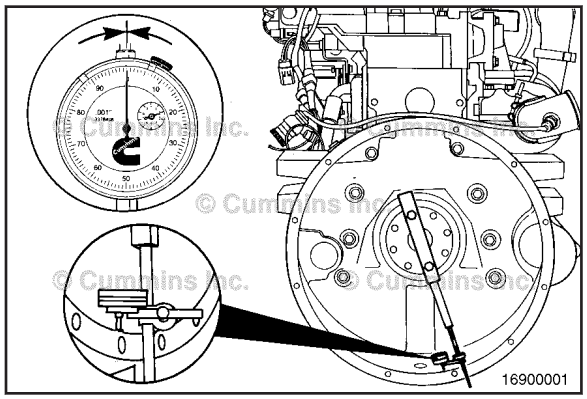
The maximum allowable total indicator reading (TIR) is determined by the diameter of the housing bore. If out of specifications, replace the housing.

NOTE: For rear gear train engines, the rear gear housing may also be the cause of the TIR being out of specification.



Front Gear Train Engine Flywheel Housing Bore and Face Runout				
SAE	Bore Diameter		Total Indicator Reading Maximum	
Number	mm	in	mm	in
00	784.15 to 784.65	30.990 to 31.010	0.48	0.019
0	657.45 to 647.95	25.490 to 25.510	0.41	0.016
1/2	584.00 to 584.40	22.992 to 23.008	0.36	0.014
1	510.98 to 511.38	20.117 to 20.133	0.30	0.012
2	447.55 to 447.81	17.620 to 17.630	0.28	0.011
3	409.45 to 409.71	16.120 to 16.130	0.25	0.010

Rear Gear Train Engine Flywheel Housing Bore and Face Runout				
SAE	Bore Diameter		Total Indicator Reading Maximum	
Number	mm	in	mm	in
00	784.15 to 784.65	30.990 to 31.010	0.30	0.012
0	657.45 to 647.95	25.490 to 25.510	0.28	0.011
1/2	584.00 to 584.40	22.992 to 23.008	0.25	0.010
1	510.98 to 511.38	20.117 to 20.133	0.40	0.016
2	447.55 to 447.81	17.620 to 17.630	0.40	0.016
3	409.45 to 409.71	16.120 to 16.130	0.40	0.016

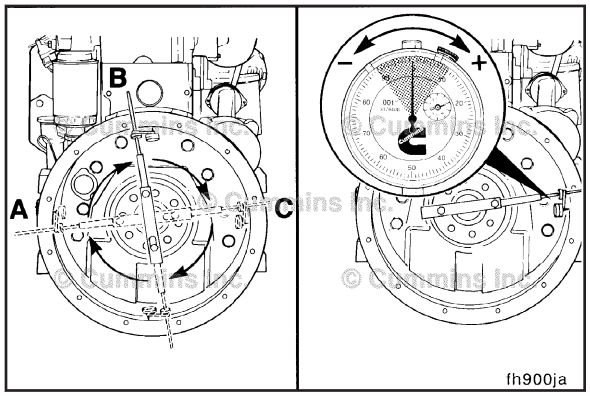


Bore Alignment

Attach the dial indicator gauge, Part Number 3376050, to the crankshaft. Use mounting tool Part Number ST1325 to attach the dial indicator to the crankshaft as illustrated.

NOTE: The dial indicator can be mounted by any method that holds the extension bar of the indicator rigid, so it does **not** sag. If the bar sags or the indicator slips, the readings obtained will **not** be accurate.

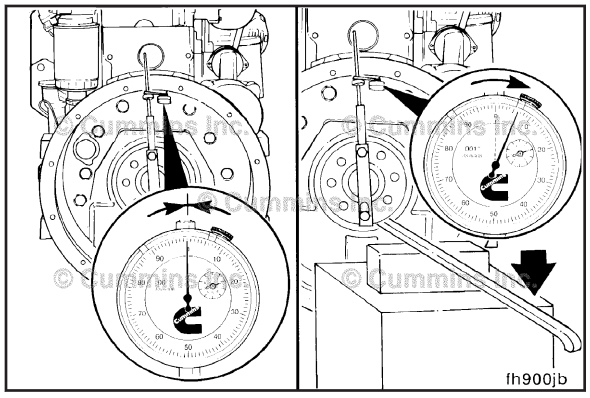
Position the indicator in the 6-o'clock position, and zero the gauge.



Slowly rotate the crankshaft. Record the readings obtained at the 9-o'clock, 12-o'clock, and 3-o'clock positions as A, B, and C in the concentricity work sheet.

Recheck zero at the 6-o'clock position. If it does **not**, the readings will be incorrect and the procedure will have to be redone.

The values for A, B, and C could be positive or negative. See the accompanying figure to determine the correct sign when recording these values.



△CAUTION△
Do not force the crankshaft beyond the point where the bearing clearance has been removed. Do not pry against the flywheel housing. These actions could cause false bearing clearance readings and result in engine damage.

Rotate the crankshaft until the dial indicator is at the 12-o'clock position and zero the gauge.

Using a pry bar, raise the rear of the crankshaft to its upper limit. Record the value as D on the concentricity work sheet. This is the vertical bearing clearance adjustment, which will **always** be positive.

Create a concentricity work sheet as illustrated to determine the values for the “total vertical” and “total horizontal” values.

NOTE: The values listed in the concentricity work sheet illustrated are for example only and are listed in inches. The actual numbers measured may differ.

Input the values recorded for A, B, C and D into the concentricity work sheet.

The total horizontal is the 9-o'clock reading, A, minus the 3-o'clock reading, C.

The total vertical is the 12-o'clock reading, B, plus the bearing clearance, D.

Example:

- Six o'clock = reference = 0
- Nine o'clock = (a) = 0.004
- Twelve o'clock = (b) = 0.003
- Three o'clock = (c) = (-0.002)

Using the work sheet and the numbers from the example, the total horizontal value equals 0.006 and the total vertical value equals 0.005.

Concentricity Worksheet

9 o’clock	a = 0.004
3 o’clock	c = -0.002
Total Horizontal	a – c = .006
12 o’clock	b = .003
Bearing Clearance	d = .002
Total Vertical	b + d = .005

oi900vf

NOTE: Use the corresponding chart for the SAE 1, 2 or 3 flywheel housings being measured.

Using the illustration, mark the total horizontal value on the horizontal side of the chart and the total vertical on the vertical side of the chart.

Using a straightedge, find the intersection point of the total horizontal and total vertical values. The intersection point **must** fall within the shaded area for the flywheel housing concentricity to be within specification.

Using the total horizontal and total vertical values from the previous example, the intersection point falls within the shaded area. Therefore, the flywheel housing concentricity is within specification.

NOTE: Make sure to use the correct total indicator reading (TIR) specifications for the flywheel housing being measured when comparing measurements.

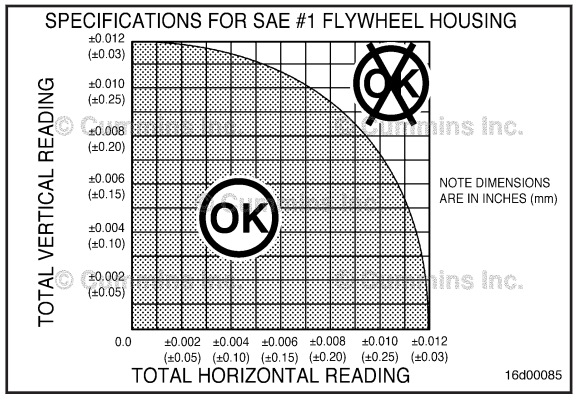
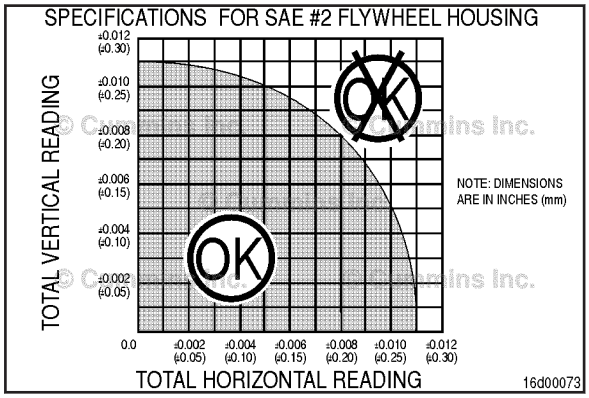


Chart for an SAE 2 flywheel housing.



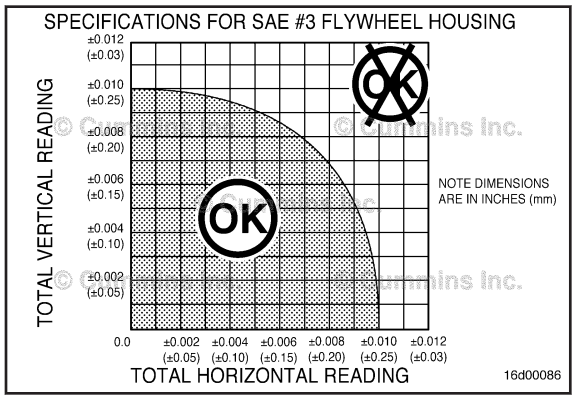
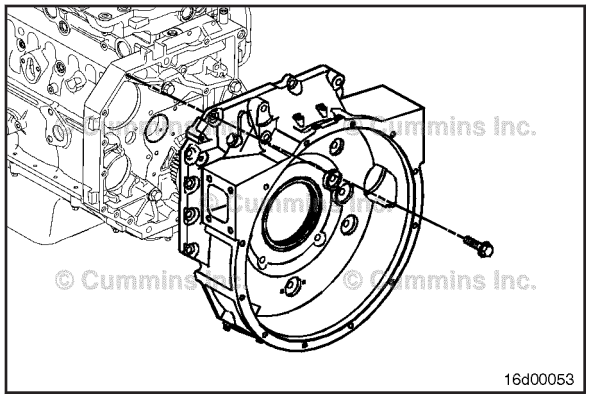


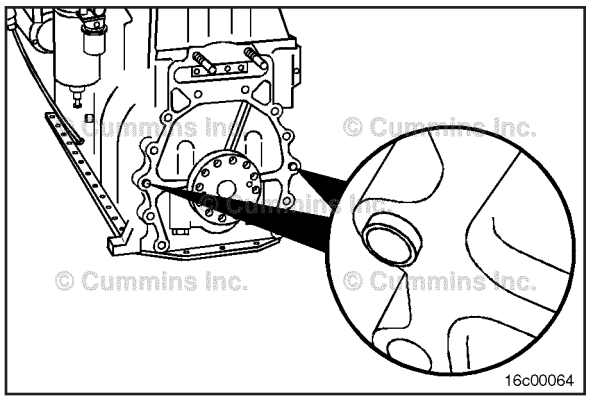
Chart for an SAE 3 flywheel housing.



⚠CAUTION⚠
Do not remove the dowel rings located in the rear gear housing in an attempt to relocate the flywheel housing. The dowel rings are required to locate the rear gear housing to the cylinder block for proper gear alignment. Improper gear alignment will result in engine damage.

For rear gear train engine, if the bore alignment is out of specification:

1. Determine if the flywheel housing, rear gear housing or cylinder block has recently been replaced. If any of these components have been replaced, remove and inspect/replace the component.
2. If the flywheel housing, rear gear housing or cylinder block have **not** been recently replaced. Remove the flywheel housing. Inspect the rear gear housing and flywheel housing mounting surfaces. If no damage is found, remove the rear gear housing and inspect the cylinder block and rear gear housing mounting surfaces.



For front gear train engine, if the bore alignment is out of specification:

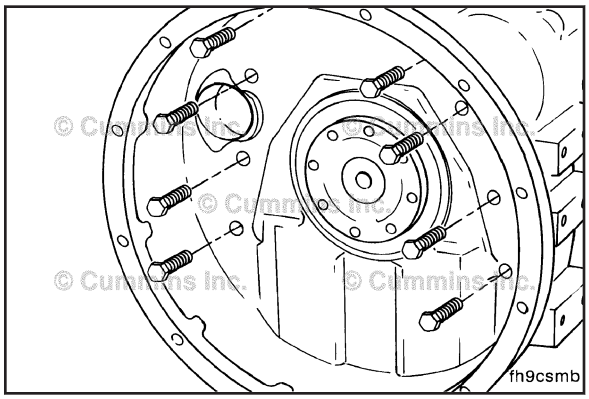
The ring dowels **must** be removed and the flywheel housing repositioned.

Use the dowel pin extractor service tool, Part Number 3163720, to remove the dowel pins from the block.

NOTE: The ring dowels are **not** required to maintain concentricity of the housing; the clamping force of the capscrews holds the housing in place.

After the ring dowels are discarded, install the flywheel housing on the engine following the Install Step of this procedure, but do **not** torque the capscrews. Tighten the capscrews enough to hold the flywheel housing in place, but loose enough to allow small movement when struck lightly with a rubber mallet.

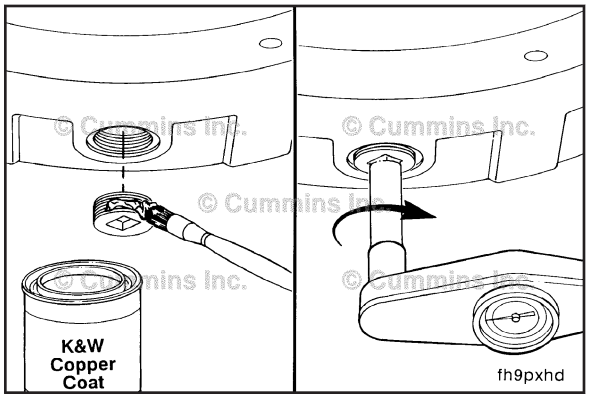
Recheck the bore alignment. When bore alignment is within specification, tighten the capscrews to the specified torque value outlined in the Install Step of this procedure.



Assemble

For wet flywheel housings, apply pipe sealant, Part Number 3375066, to any threaded plugs previously removed.

Install and tighten the plugs. Refer to Procedure 017-007 for pipe plug torque values for different plug sizes.

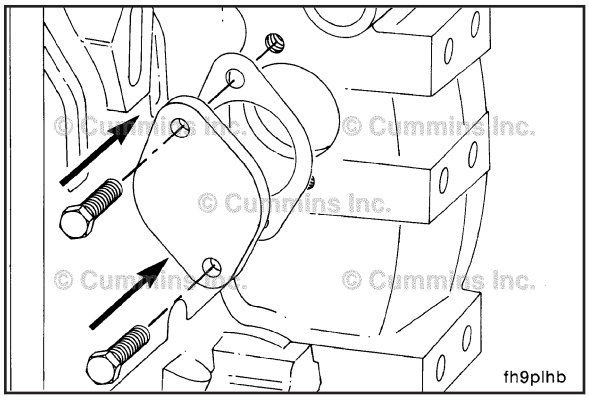


Install the access plate and new gasket.

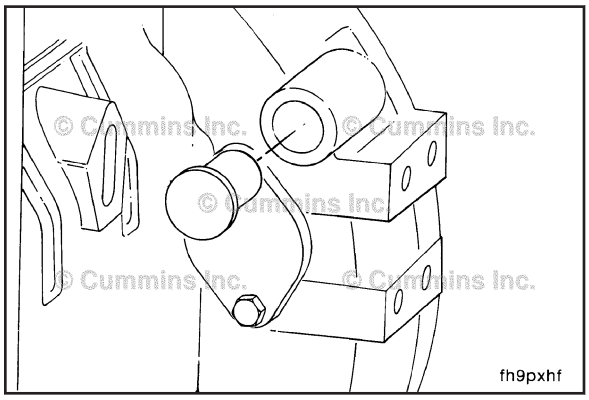
Install the capscrews and tighten.

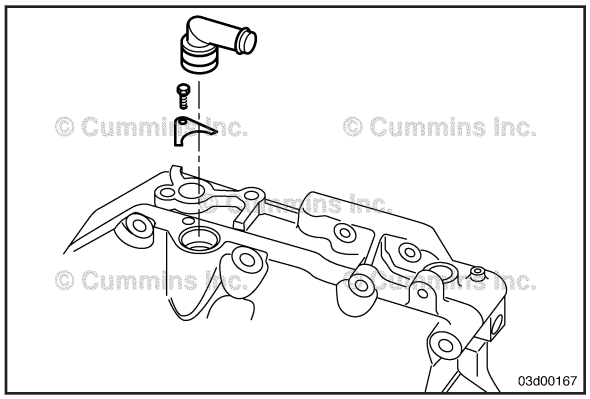
Torque Value: 24 N•m [18 ft-lb]

NOTE: If a gasket was **not** previously installed, apply sealant, Part Number 3164067, to the perimeter of the access plate.



With a new o-ring, install the barring gear hole plug.



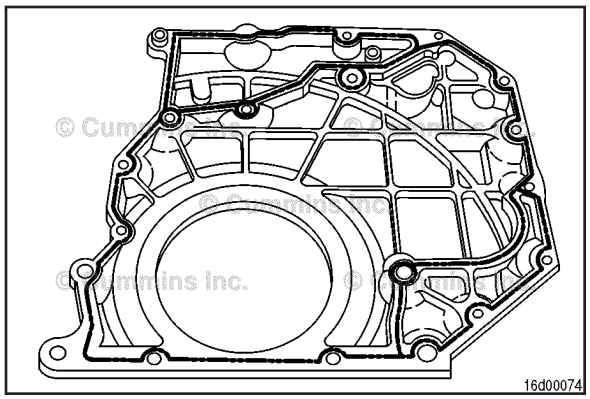


For rear gear train engines, lubricate the o'ring on the closed crankcase ventilation tube adapter with clean engine oil.

Install the breather tube adapter in the flywheel housing.

Install the capscrew and clamp plate to secure the breather tube adapter to the flywheel housing.

Torque Value: 24 N•m [18 ft-lb]



Install

Rear Gear Train

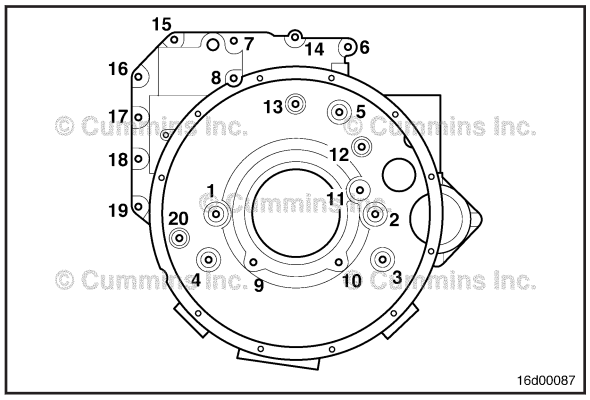
NOTE: Before installing the flywheel housing, make sure any locating dowel rings are in the same position as when the flywheel housing was removed.

NOTE: The sealant called for in the following step may appear different than what was originally used to build the engine.

Apply a 1.5 to 2.0 mm [0.06 to 0.08 in] wide bead of sealant, Part Number 3164070, to the back side of the flywheel housing in the path illustrated.

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

Install the flywheel housing and capscrews.



Tighten the flywheel housing capscrews in the sequence shown.

NOTE: Due to different SAE size flywheel housings, the location of the mounting capscrews shown may appear different than the illustration shown. The sequence shown will work for all sizes of flywheel housings.

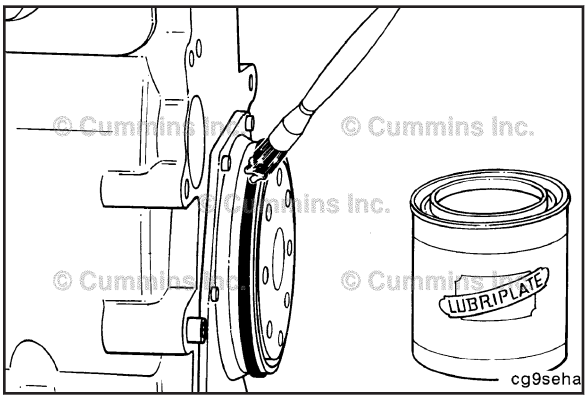
Torque Value:

M10	49 N•m	[36 ft-lb]
M12	85 N•m	[63 ft-lb]

Front Gear Train

NOTE: Before installing the flywheel housing, make sure any locating dowel rings are in the same position as when the flywheel housing was removed.

If previously equipped, install a new rectangular seal on the rear seal carrier and apply assembly lube, Part Number 3163087.

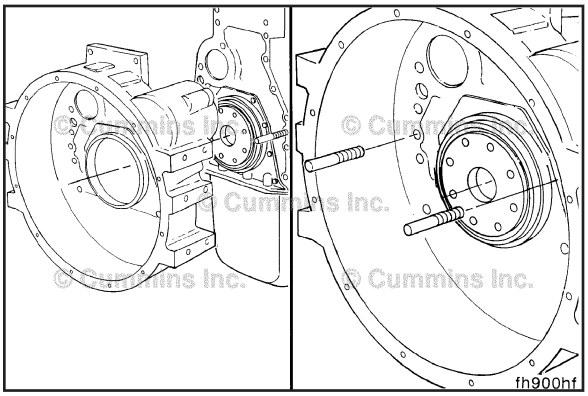


Inspect the rear face of the cylinder block and flywheel housing mounting surface for cleanliness and raised nicks or burrs.

Install two guide pins. Part Number 3163934.

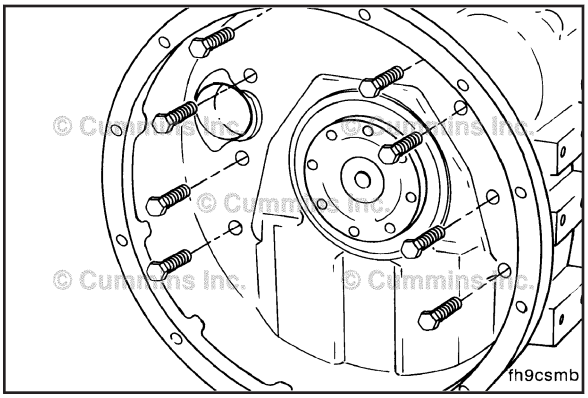
Install the flywheel housing over the guide pins, making sure the flywheel housing is located on the dowel rings.

NOTE: Be sure the sealing ring is **not** damaged during installation.



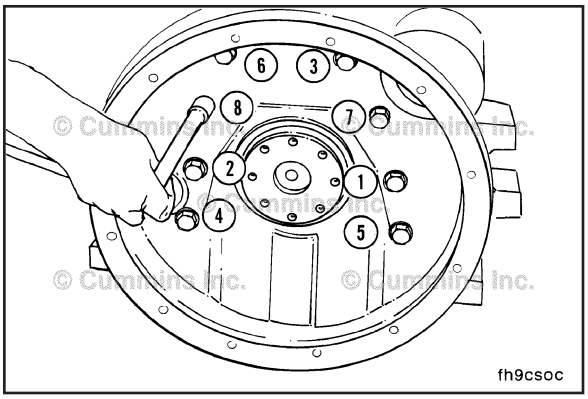
Remove the guide pins.

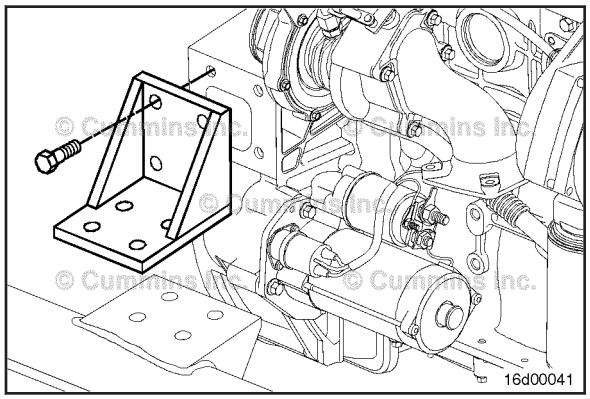
Install the mounting capscrews.



Tighten the flywheel housing capscrews in the sequence shown.

Torque Value: 77 N•m [57 ft-lb]

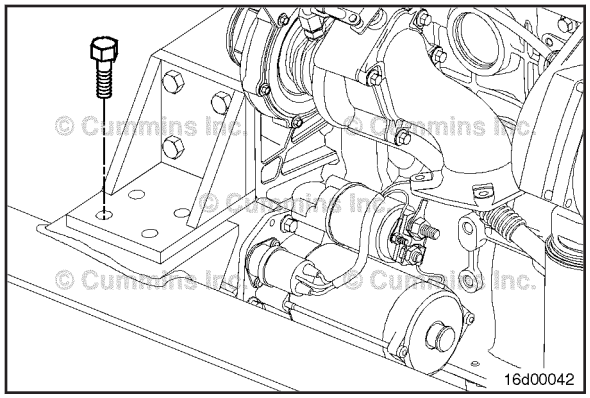




All Applications

Install the rear engine support bracket and mounting capscrews.

Torque Value: 77 N•m [57 ft-lb]



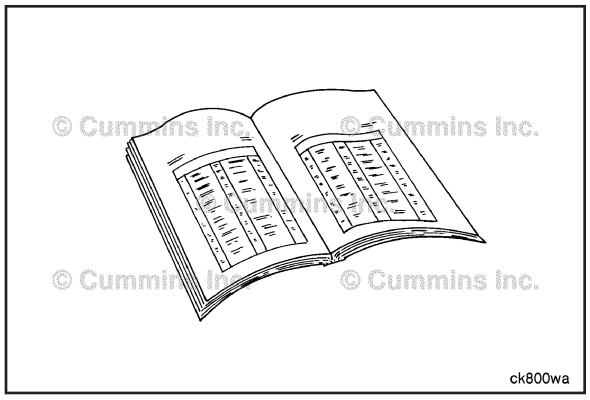
NOTE: Make sure to install any shims or spacers in the same location as removed.

Lower the rear of the engine.

Install the rear engine mount fasteners.

Tighten to the OEM specification.

Remove the lifting fixture or hoist from the rear of the engine.

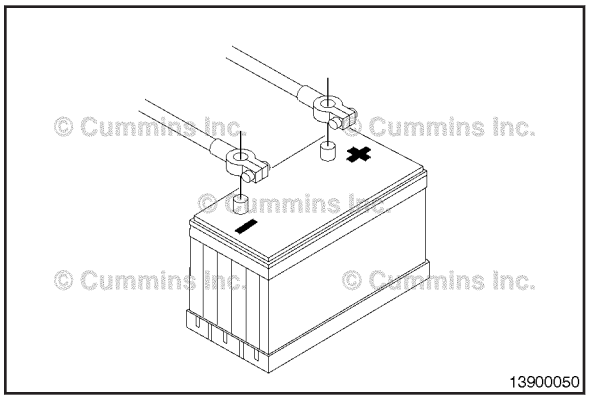


Finishing Steps

- For rear gear train engines, connect the closed crankcase ventilation hose from the flywheel housing. Refer to Procedure 003-024
- For rear gear train engines, install the rear crankshaft seal. Refer to Procedure 001-024
- Install the flywheel/flexplate assembly. Refer to Procedures 016-005 and Procedure 016-004
- Install the starting motor. Refer to Procedure 013-020
- Install the transmission and related components (if equipped). Refer to the OEM service manual
- If equipped with a wet flywheel housing, fill the flywheel housing with oil. Refer to the OEM instructions
- If previously removed, attach any OEM components (mufflers, shift mechanisms, air filters, etc.) to the flywheel housing. Refer to the OEM instructions.

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

- Connect the batteries
- Operate the engine and check for leaks.



Flywheel Ring Gear (016-008)

General Information

Prior to removing the damaged flywheel ring gear, first check if:

1. The ring gear is removable/replaceable
2. A replacement ring gear is available.

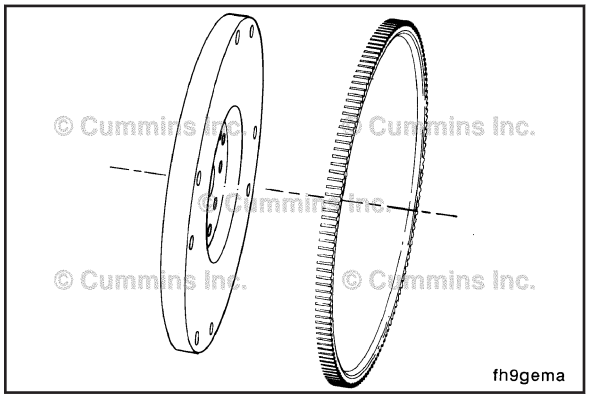
If may be necessary to replace the entire flywheel assembly.

NOTE: The ring gear on a flexplate is **not** replaceable. If the ring gear is damaged on a flexplate, the flexplate **must** be replaced as an assembly.

Disassemble

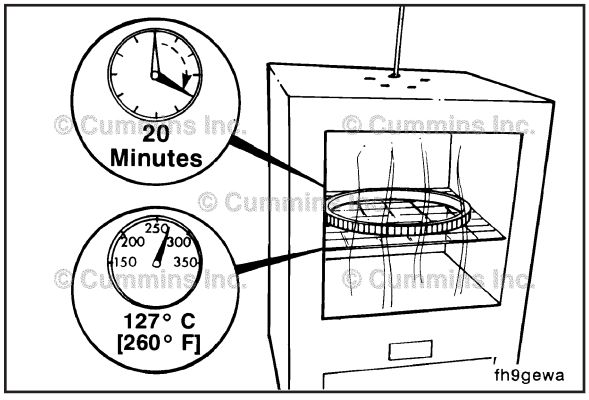
⚠WARNING⚠
To reduce the possibility of severe eye damage, wear eye protection when you drive the gear from the flywheel. Do not use a steel drift pin or damage to the component can occur.

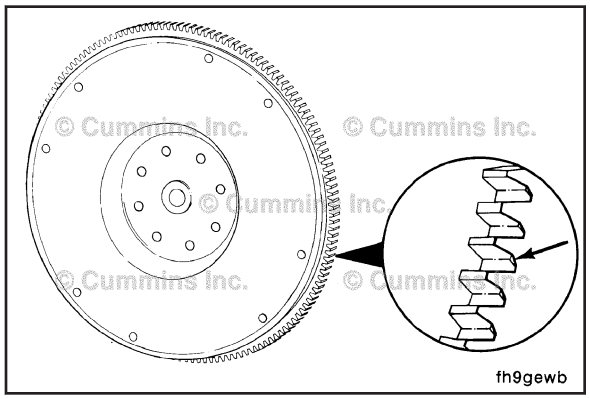
Use the brass drift pin to drive the ring gear from the flywheel.



Assemble

Heat the new ring gear for 20 minutes in an oven preheated to 127°C [261°F].

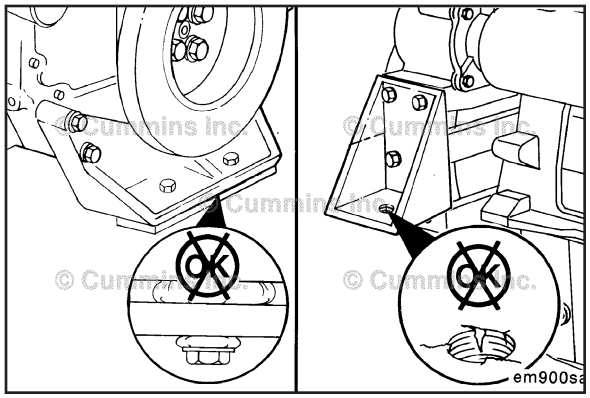




⚠WARNING⚠
To reduce the possibility of burns, wear protective gloves when installing the heated gear.

The ring gear **must** be installed so the bevel on the teeth is toward the crankshaft side of the flywheel.

Install the ring gear.



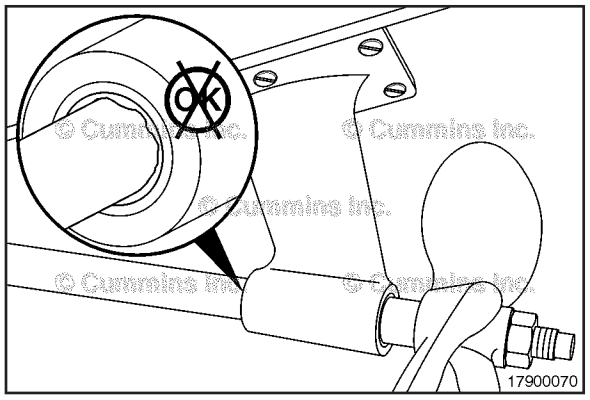
Engine Mounts (016-010)

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.

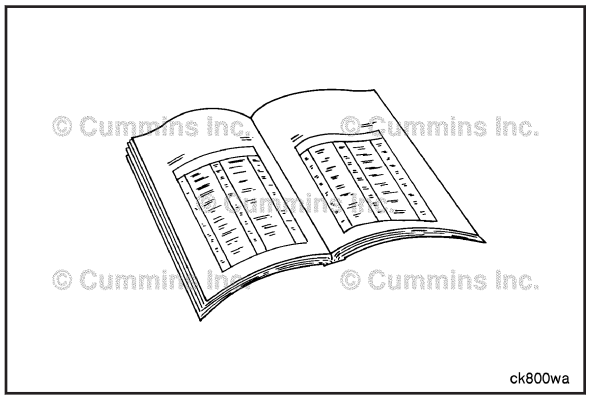
Inspect all mounting brackets for cracks or damaged bolt holes.



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.



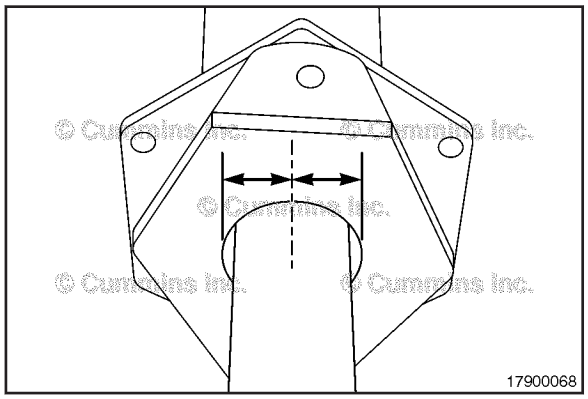
Preparatory Steps

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.

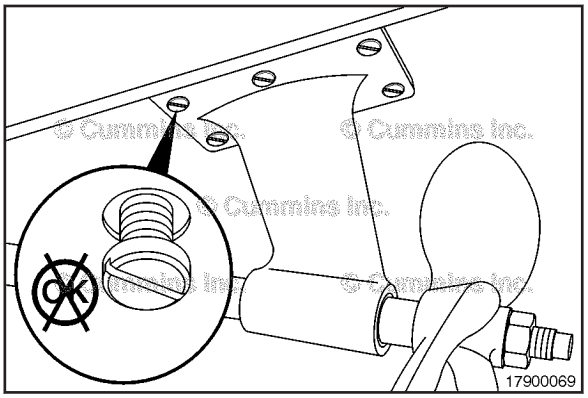
Check that the shaft is centered in the opening of the stuffing box flange. The specifications will vary by manufacturer. If any problems are noted, refer to an authorized OEM service location.



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.

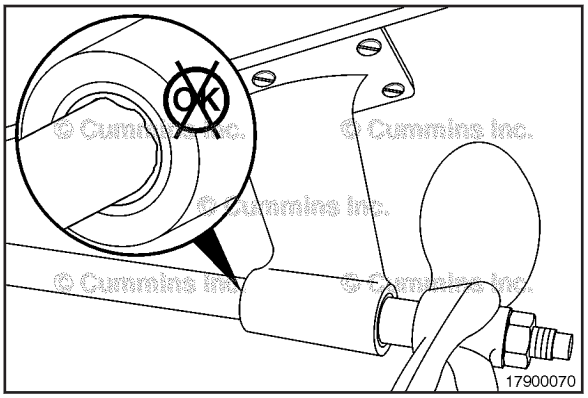
If any problems are noted, refer to an authorized OEM service location.



A misaligned shaft will cause uneven wear of the cutlass bearing.

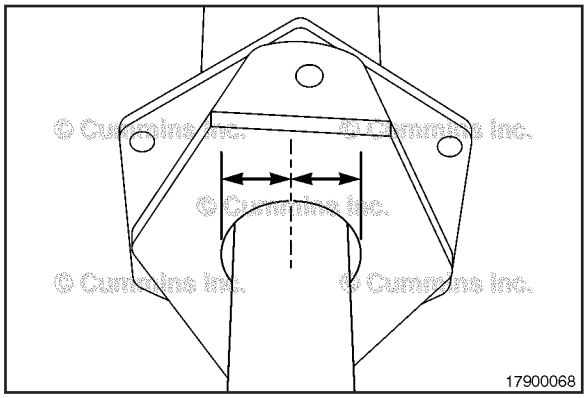
If the strut or cutlass bearing needs to be repaired or replaced, refer to an authorized OEM service location.

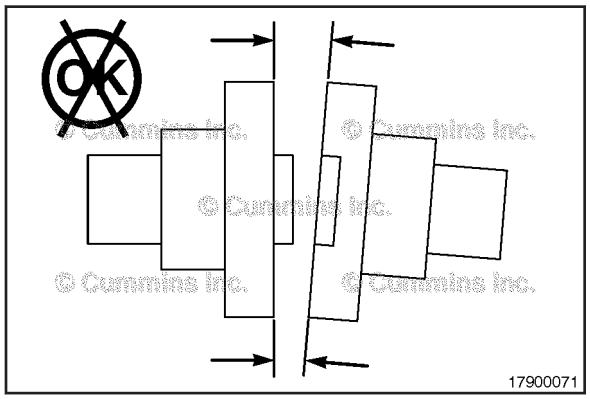
NOTE: Initially align the shaft out of the water using the following instructions, then perform a final alignment after the vessel is in the water.



Alignment

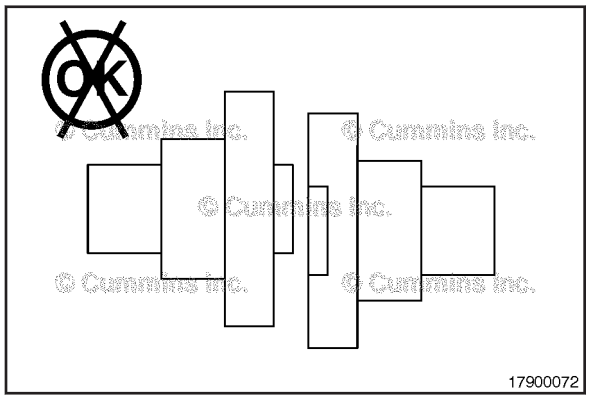
Check that the shaft is centered in the opening of the stuffing box flange.





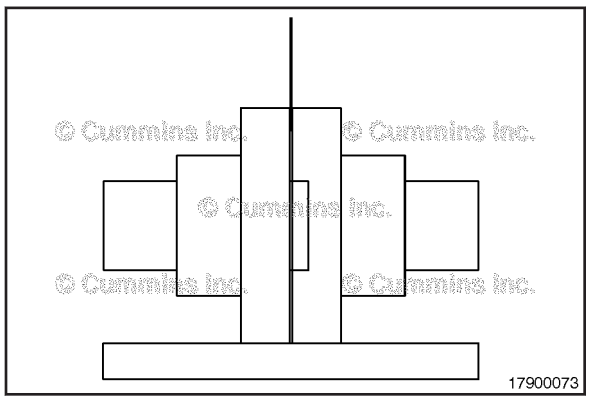
Unbolt the propeller shaft coupling from the marine gear coupling.

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

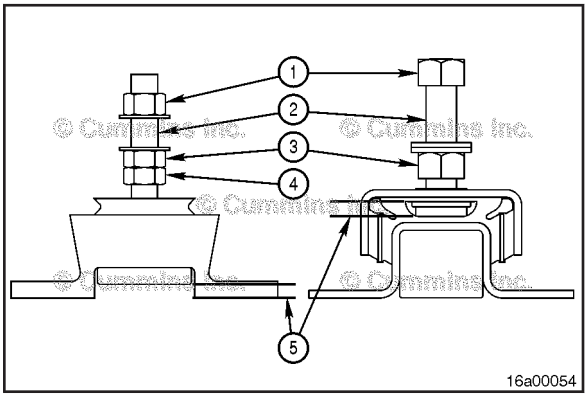
Capscrews, Bolts and Nuts Torque for Fine and Coarse Threads				
	SAE Grade 5		SAE Grade 8	
	(1) As Received	(2) Lubricated	(1) As Received	(2) Lubricated
	N•m [ft-lb]	N•m [ft-lb]	N•m [ft-lb]	N•m [ft-lb]
1/4	12 ± 1 [9 ± 1]	9 ± 1 [7 ± 1]	19 ± 1 [14 ± 1]	15 ± 1 [11 ± 1]
5/16	26 ± 3 [19 ± 2]	20 ± 3 [15 ± 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]

Capscrews, Bolts and Nuts Torque for Fine and Coarse Threads				
	SAE Grade 5		SAE Grade 8	
3/4	380 ± 27 [280 ± 20]	305 ± 27 [225 ± 20]	529 ± 41 [390 ± 30]	434 ± 34 [320 ± 25]
7/8	607 ± 43 [448 ± 32]	488 ± 41 [360 ± 30]	854 ± 68 [630 ± 50]	691 ± 54 [510 ± 40]
1	922 ± 68 [680 ± 50]	732 ± 61 [540 ± 45]	1302 ± 95 [960 ± 70]	1051 ± 81 [775 ± 60]
1 1/8	1152 ± 81 [850 ± 60]	915 ± 81 [675 ± 60]	1844 ± 136 [1360 ± 100]	1491 ± 115 [1100 ± 85]
1 1/4	1593 ± 115 [1175 ± 85]	1254 ± 102 [925 ± 75]	2508 ± 203 [1850 ± 150]	2034 ± 169 [1500 ± 125]

1. Use for all capscrews, bolts, and nuts coated only with the fastener manufacturer's rust preventive oil and use for parts wiped or washed nearly free of oil. Do **not** use for plated parts.
2. Use for all capscrews and nuts whose threads and washer faces are lubricated.

Marine Vibration Isolator (016-026)

General Information



This illustration shows the different types of marine isolators, and the location of the snubber and corresponding gap used to determine loading of the isolator.

1 Top nut

2 Leveling stud

3 Adjusting nut

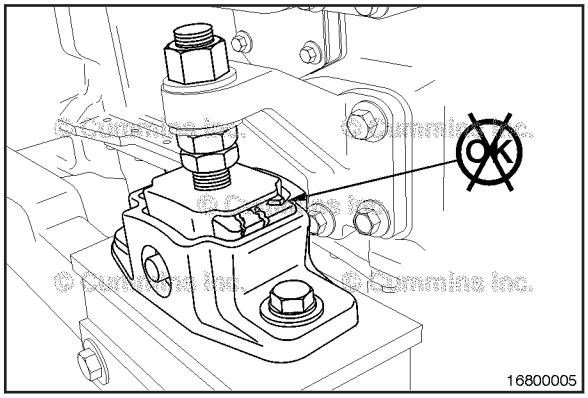
4 Jam nut

5 Snubber gap.

Generally, it is recommended to replace isolators as a set, but the age of the isolators and the conditions that caused the damage need to be reviewed.

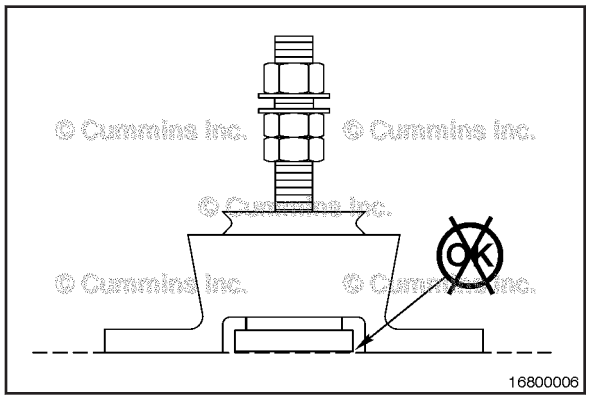
Isolators of different designs should **not** be mixed in the same installation.

Initial Check



Check that the rubber portion of the isolator is **not** cracked, damaged, or pushed out from the isolator housing.

If the rubber is damaged, the isolator will need to be replaced.

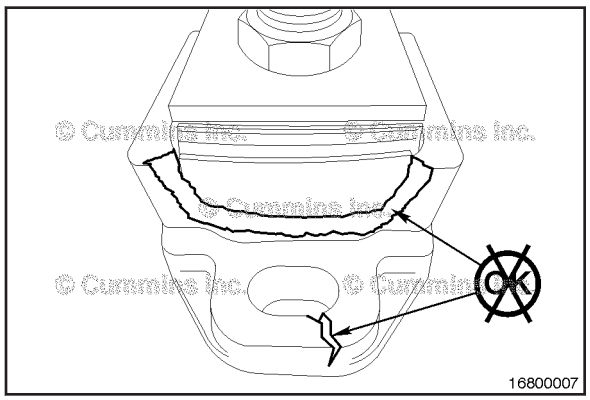


Check that the isolator is **not** fully compressed. If an isolator is in the fully compressed condition, there will be no clearance in the snubber gap.

If **only** one isolator is compressed, then the loading of the isolators may be unbalanced. Reference the Install Section of this procedure for steps to balance the load. If the isolator is still compressed after adjusting the load, then the isolator will need to be replaced.

If two isolators that are diagonally across from each other are significantly more compressed or fully compressed, then the loading on the isolators is unbalanced. Reference the Install Section of this procedure for steps to balance the load.

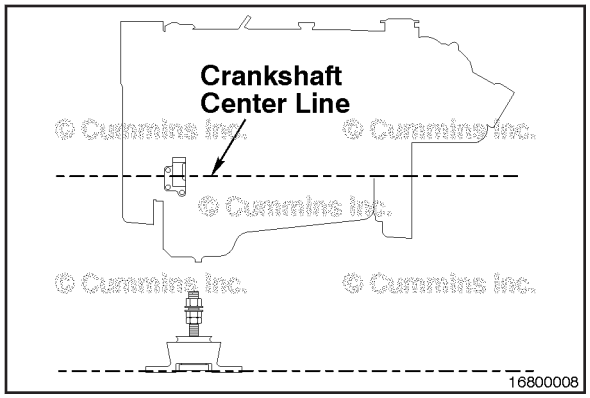
If two isolators that are both on one side of the engine or both at the front or rear of the engine are fully compressed, then the isolators will need to be replaced.



Check that the metal parts of the isolator are **not** damaged, cracked, bent, or warped. If they are, the isolator will need to be replaced.

Check for excessive corrosion. If corrosion is enough to weaken the structure or impede the function of the isolator, it will need to be replaced.

If an isolator is damaged or worn and less than one year old, check that the isolator part number is correct for the engine.



Check that the isolator mounting base is parallel with the engine crankshaft centerline and that the stud is perpendicular to the base, when looking from the side of the engine. The oil pan flange can be used as a visual reference. The engine support brackets **must** also be parallel.

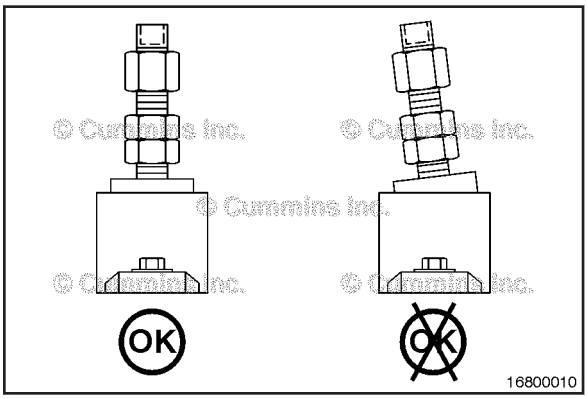
The alignment of the isolator base to the crank centerline should be within four degrees of parallel.

The alignment of the isolator stud to the base should be within four degrees of perpendicular.

Check that the isolator mounting base is parallel to the transverse crankshaft centerline and that the stud is perpendicular to the base when looking from the front or back of the engine. The engine support brackets **must** also be parallel.

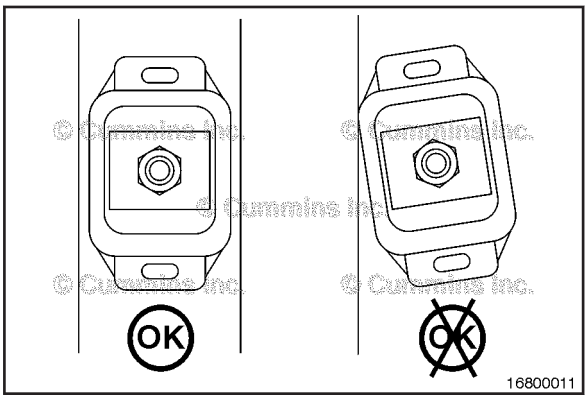
The alignment of the isolator base to the transverse crankshaft centerline should be within two degrees of parallel.

The alignment of the isolator stud to the base should be within two degrees of perpendicular.

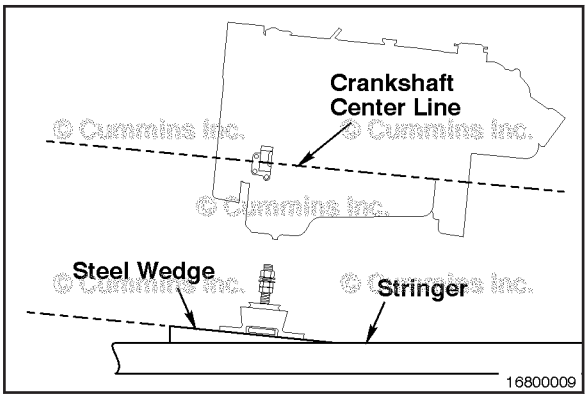


Check that the isolator mounting base is parallel to the crankshaft centerline when looking from the top of the engine.

The alignment of the isolator base to the crankshaft centerline should be within two degrees of parallel.



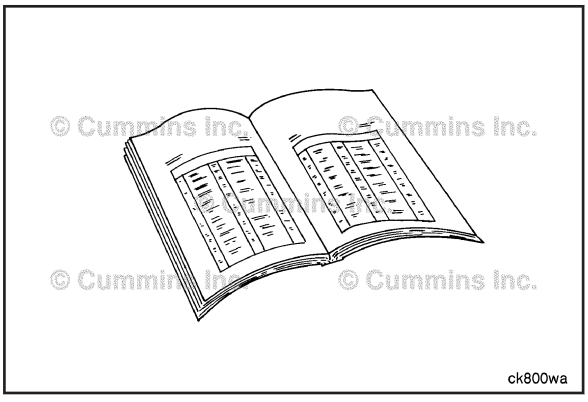
If the isolator is out of alignment, the mounting will need to be adjusted. Wedges can be used to shim the base to achieve proper alignment. Shims **must** be made of a solid material that will **not** compress under the weight of the engine.

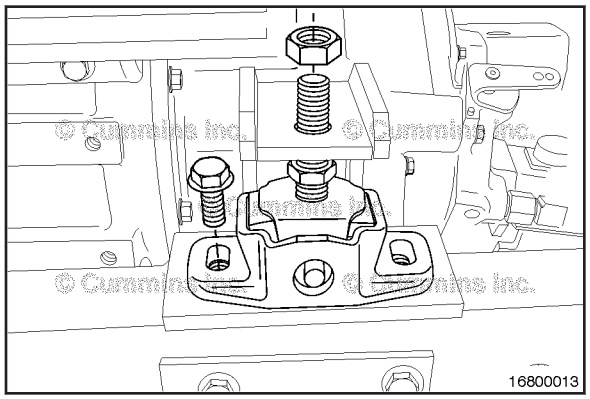


Preparatory Steps

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

- Disconnect the battery. Refer to the original equipment manufacturer (OEM) service manual.
- Disconnect the propeller shaft. Disengage the flange. Refer to Procedure 016-025 in Section 16.





Remove

⚠WARNING⚠

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

The engine needs to be supported before removing the isolators. The amount of space available will determine the best method for this support.

Remove the top nut from the isolator's adjusting stud. Remove the bolts or capscrews retaining the isolator base.

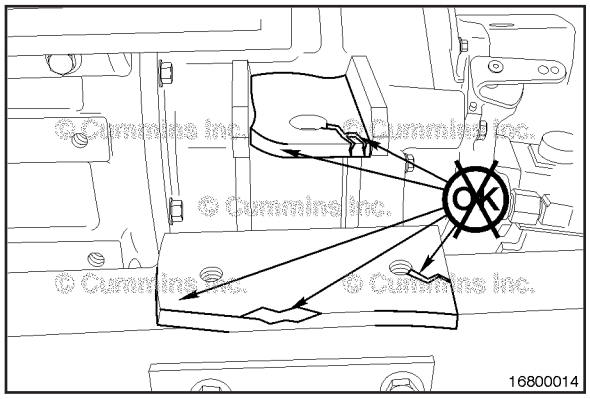
Raise the engine if necessary to facilitate the removal of the isolator.

Make sure that any equipment used for hoisting of jacking the engine is capable of handling the weight of the engine and marine gear. Any engine component used for attaching or support such as the lifting brackets or engine supports **must** be correct for the engine. Reference the appropriate manual for General Engine information in Section V for the engine weight.

Remove the isolator.

If reusing the isolator, mark the position of the isolator relative to the engine to make sure of installation in the same location.

If replacing the worn or damaged isolator with a new isolator, measure the height of the adjusting nut on the stud to assist in setting the new isolator adjusting nut height.

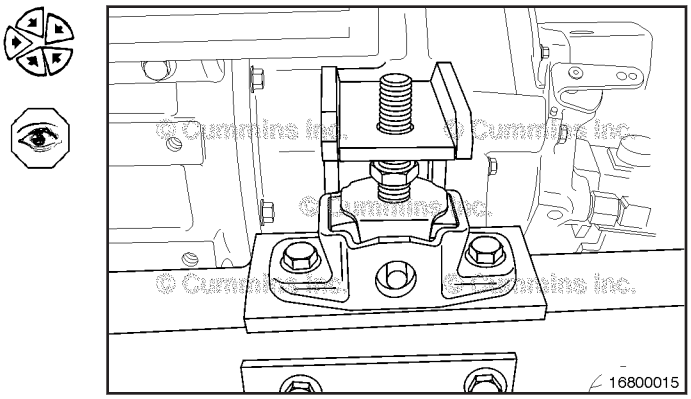


Inspect for Reuse

Inspect the vessel stringers or engine bed to make sure they have **not** been damaged and that they can continue to support the weight of the engine. This is especially true of stringers constructed of wood, wood core, or hollow fiberglass.

Inspect the mounting holes in the stringers or the engine bed for damage. If the stringers, engine bed, or mounting holes need to be repaired, contact an OEM qualified repair location.

Install



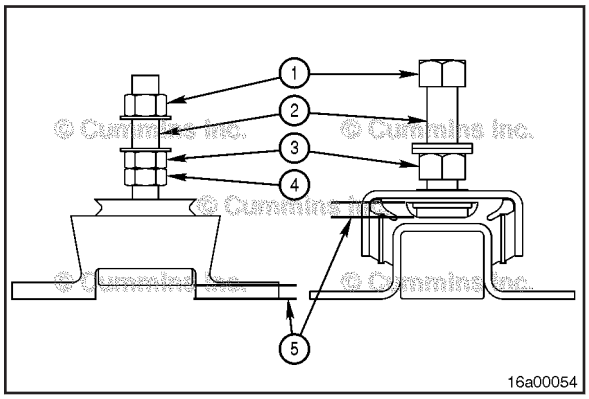
Set the new isolator in place. Check that the isolator is properly aligned. Reference the Initial Check section in this procedure for alignment information.

Set the adjusting nut at the approximate height of the isolator removed.

Replace other isolators that need to be changed using the same technique.

Install the washer and top nut.

Lower the engine so that its weight is fully supported by the isolators.



Verify that the isolators are loaded evenly. Depending on the configuration of the engine, the weight may **not** be evenly distributed on all four corners.

The engine will be heavier at either the front or back, depending the on configuration. Therefore, the isolators on the heavier end will be compressed more.

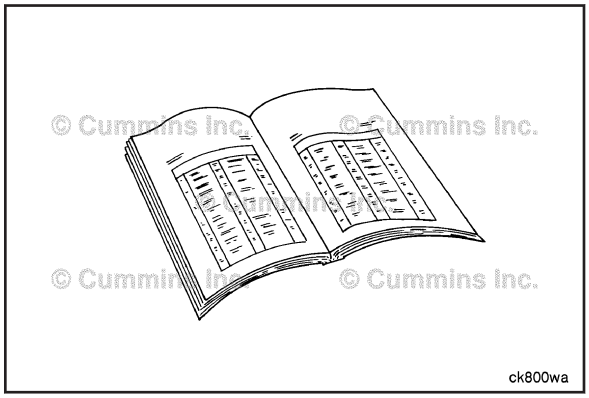
Check the snubber gap on all isolators.

If **only** one isolator or two isolators that are diagonally across from each other are significantly more compressed, the loading on the isolators is unbalanced.

Adjust the loading on the isolators by raising or lowering the adjusting nut on the stud. Raising the adjusting nut will increase the load. Lowering the adjusting nut will decrease the load.

The engine should be lifted and the load removed from the isolator before moving the adjusting nut, to prevent damage to the threads.

Finishing Steps



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

- Align the propeller shaft. Refer to Procedure 016-025 in Section 16.
- Connect the battery cables. Refer to the OEM service manual.
- Start the engine and check for proper operation.

Notes

Section 17 - Miscellaneous - Group 17

Section Contents

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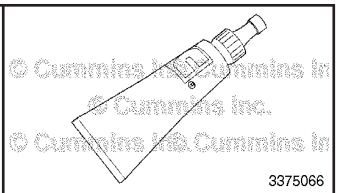
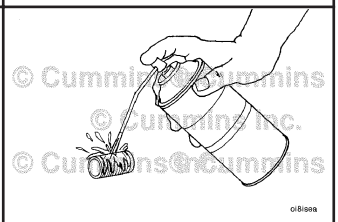
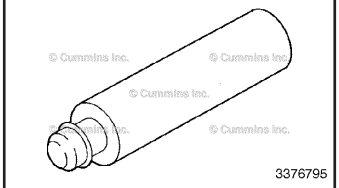
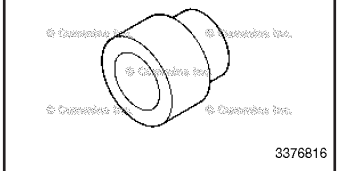
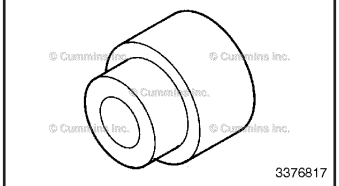
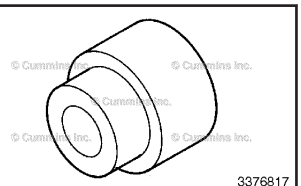
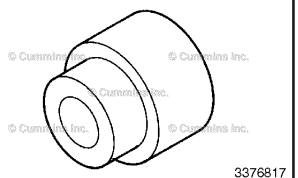
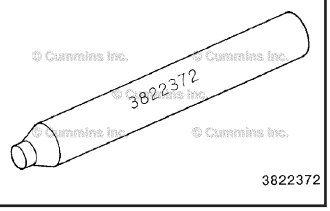
Service Tools

Miscellaneous

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

Tool No.	Tool Description	Tool Illustration
3375066	**Pipe Plug Sealant** Used when installing pipe plugs to reduce the possibility of leaks.	
3375068	**Cup Plug Sealant** Used when installing cup plugs to reduce the possibility of leaks.	
3824510	**QD Spray Cleaner** Used to clean cup plug opening.	
3164085	**Cup Plug Driving Tools (universal handle)** Required use with driver heads to install new cup plugs to their proper depth, plus avoiding damage to the cup plug and the surrounding area.	
3376816	**Cup Plug Driving Tools (driver head, 1-inch nominal)** Required to install new cup plugs to their proper depth, plus avoiding damage to the cup plug and the surrounding area.	
3376817	**Cup Plug Driving Tools (driver head, 1-1/4-inch nominal)** Required to install new cup plugs to their proper depth, plus avoiding damage to the cup plug and the surrounding area.	

Tool No.	Tool Description	Tool Illustration
3823520	**Cup Plug Driving Tools (driver head, 11/16-inch nominal)** Required to install new cup plugs to their proper depth, plus avoiding damage to the cup plug and the surrounding area.	
3823524	**Cup Plug Driving Tools (driver head, 2-1/4-inch nominal)** Required to install new cup plugs to their proper depth, plus avoiding damage to the cup plug and the surrounding area.	
3822372	**Cup Plug Driving Tools** Required to install new cup plugs to their proper depth, plus avoiding damage to the cup plug and the surrounding area.	

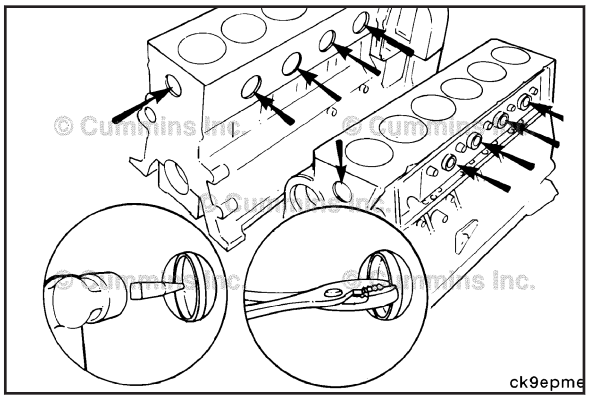
Cup Plug (017-002)

Remove

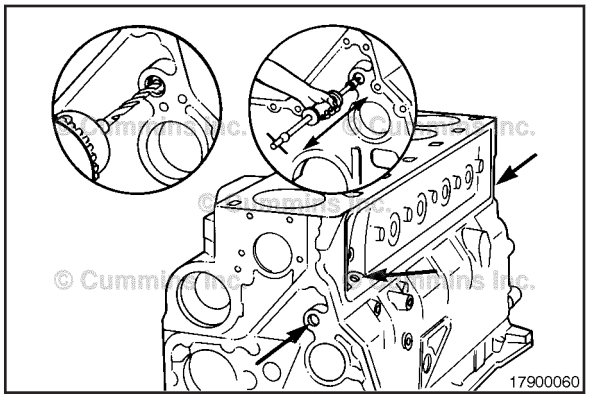
⚠CAUTION⚠
Do not allow metal shavings to fall in the engine when drilling a hole in the cup plug. Damage to engine components can occur.

Use a center punch to mark the cup plug for drilling.

Drill a 1/8-inch hole into the cup plug.



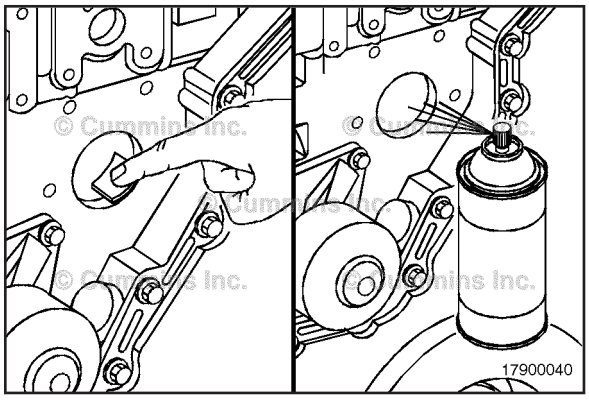
Use a dent puller to remove the plug.



Clean

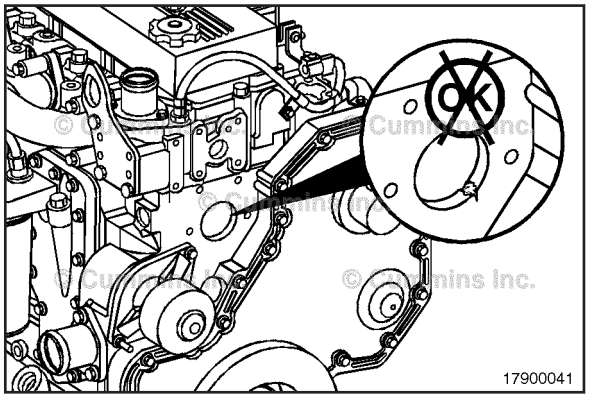
Thoroughly clean the cup plug hole using Scotch-Brite™, or equivalent.

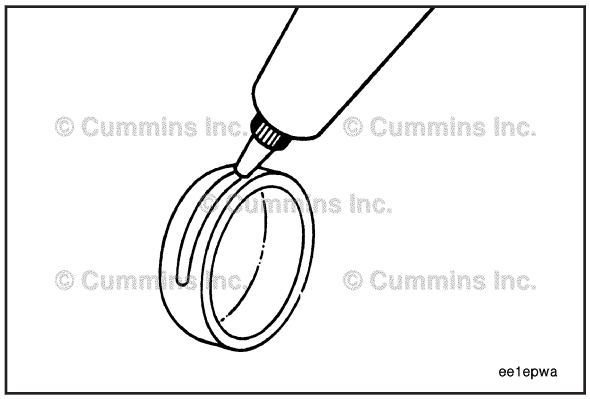
Use spray cleaner, Part Number 3375433, or equivalent, to clean the bore for the final time.



Inspect for Reuse

Inspect the cup plug bores for damage.





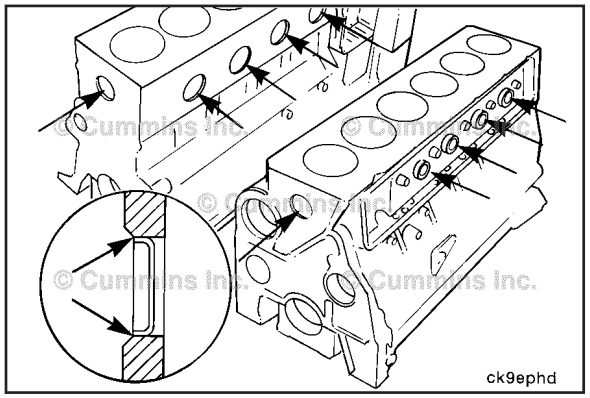
Install

⚠CAUTION⚠

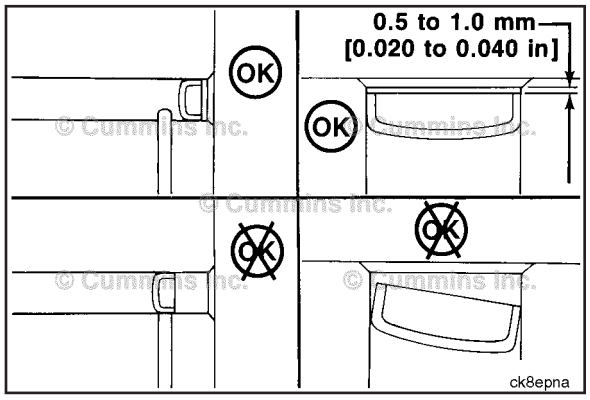
Excessive sealant can run back into the engine and cause damage to other components. Allow the sealant to dry for a minimum of 2 hours before operating the engine. The plug can come out of the bore if the sealant is not dry.

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.



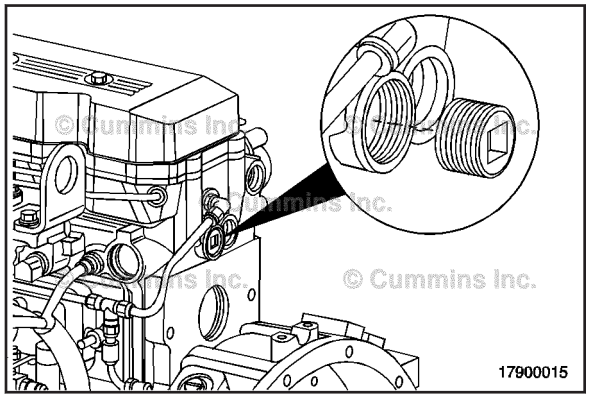
Install the cup plug with the appropriate cup plug driver. Refer to the Service Products Catalog, Bulletin 3377710.



⚠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.



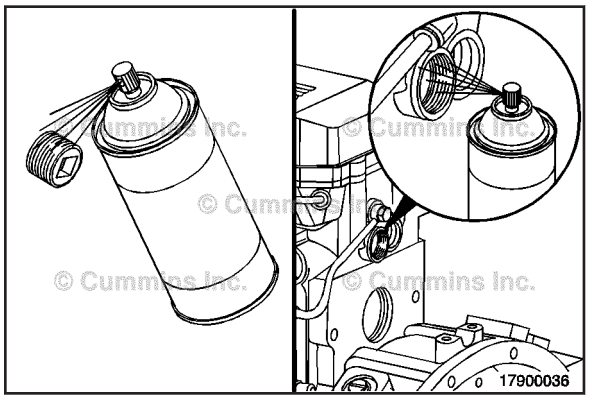
Pipe Plug (017-007)

Remove

Remove the pipe plug.

Clean

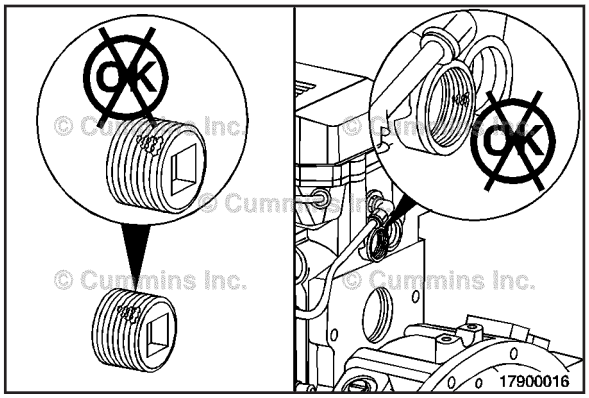
Use spray cleaner, Part Number 3375433, or equivalent, to clean the threads of the pipe plugs and threaded bores.



Inspect for Reuse

Inspect the threads of the pipe plugs for mutilation or damage.

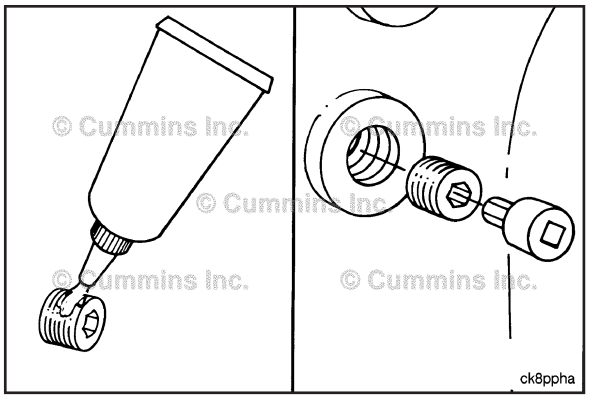
Inspect the threaded bores for damage.



Install

Apply a film of pipe plug sealant, Part Number 3375066, or equivalent, to the threads.

Install the pipe plugs.

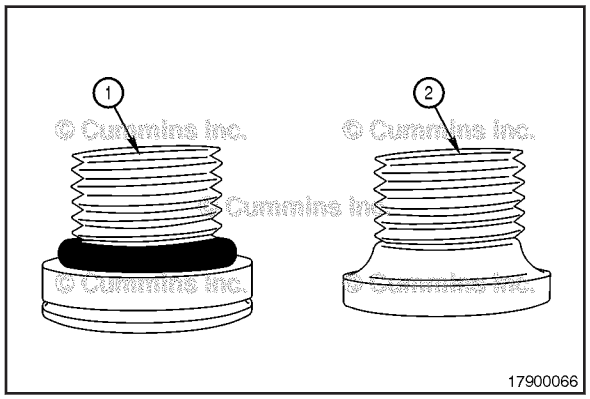


Tighten the pipe plugs. Refer to the adjoining chart for the appropriate torque values.

Pipe Plug Torque Values

Size			Torque		Torque	
Thread	Actual Thread O.D.		In Aluminum Components		In Cast Iron or Steel Components	
in.	mm	[in]	N•m	[ft-lbs]	N•m	[ft-lbs]
1/16	8.1	[0.32]	5	[45 in-lb]	15	[10]
1/8	10.4	[0.41]	15	[10]	20	[15]
1/4	13.7	[0.54]	20	[15]	25	[20]
3/8	17.3	[0.68]	25	[20]	35	[25]
1/2	21.6	[0.85]	35	[25]	55	[40]
3/4	26.7	[1.05]	45	[35]	75	[55]
1	33.5	[1.32]	60	[45]	95	[70]
1¼	42.2	[1.66]	75	[55]	115	[85]
1½	48.3	[1.90]	85	[65]	135	[100]

ck8ppoa



Straight Thread Plug (017-011)

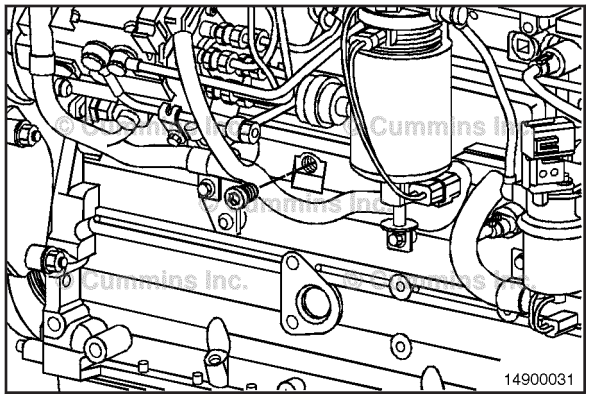
General Information

Two types of straight thread plugs are used:

1 Straight thread plug with o-ring

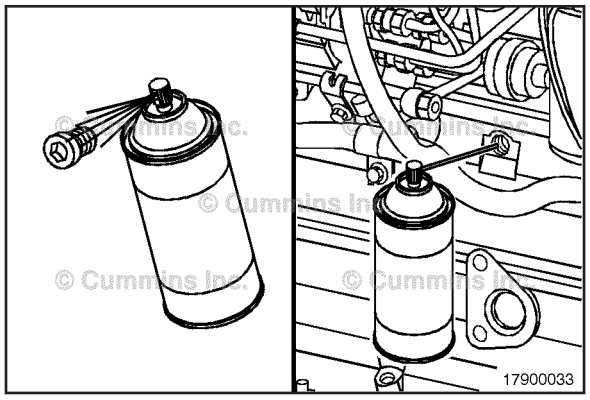
2 Straight thread plug with formed in-place sealant.

The two plugs are interchangeable and reusable. The **only** difference between the two plugs is the installation torque value. See the install step of this procedure.



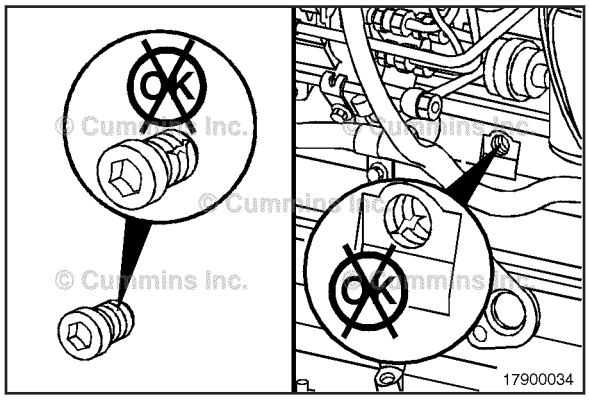
Remove

Select the appropriate size Allen wrench or socket, and remove the plug.



Clean and Inspect for Reuse

Use spray cleaner, Part Number 3375433, or equivalent, to clean the threads of the straight-thread plugs and threaded bores.



Inspect the threads of the pipe plugs for mutilation or damage.

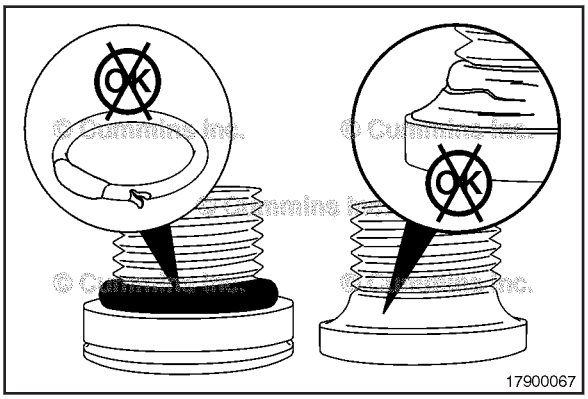
Replace the plugs, if damaged.

Inspect the threaded bores for damage.

Repair the bores, if necessary.

For straight thread plugs with an o-ring, inspect the o-ring for cuts, tears, or deformation. Replace the o-ring if necessary.

For straight thread plugs with formed in-place sealant, inspect the sealant for damage. If damaged, replace the entire plug.



Install

If equipped with a straight thread plug with o-ring, install a new o-ring on the straight-thread plug, if required.

Lubricate the o-ring with clean 15W-40 oil.

Install and tighten the plug.

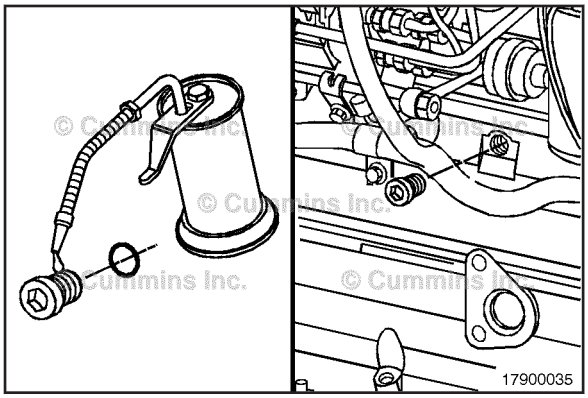
Torque Value:
M10 10 N•m [89 in-lb]

Torque Value:
M12 20 N•m [177 in-lb]

Torque Value:
M14 25 N•m [221 in-lb]

Torque Value:
M16 35 N•m [25 ft-lb]

Torque Value:
M18 45 N•m [33 ft-lb]



If equipped with a straight thread plug with formed in-place sealant, install and tighten the plug.

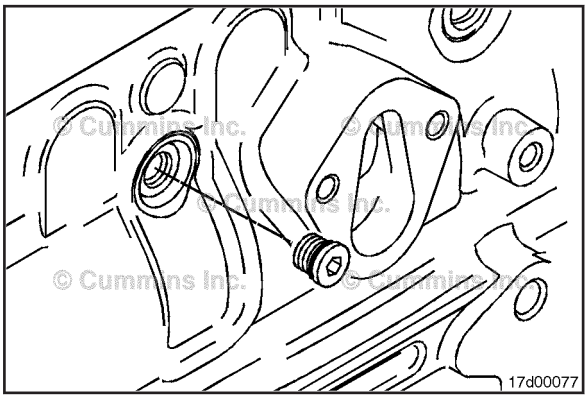
Torque Value:
M10 18 N•m [160 in-lb]

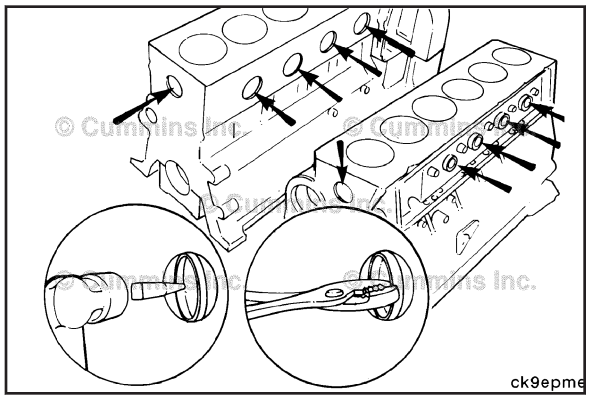
Torque Value:
M12 25 N•m [221 in-lb]

Torque Value:
M14 30 N•m [22 ft-lb]

Torque Value:
M16 40 N•m [30 ft-lb]

Torque Value:
M18 50 N•m [37 ft-lb]





Expansion Plug (017-015)

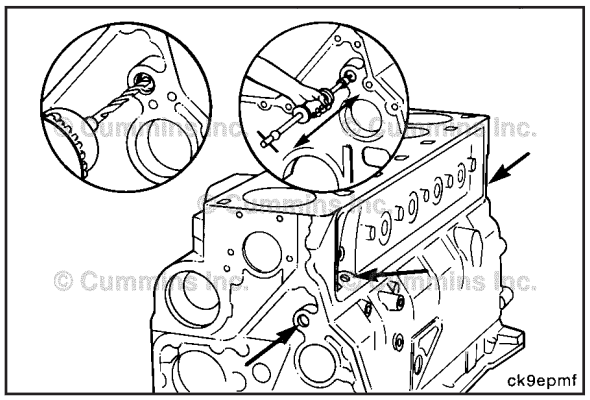
Remove

Coolant Passages

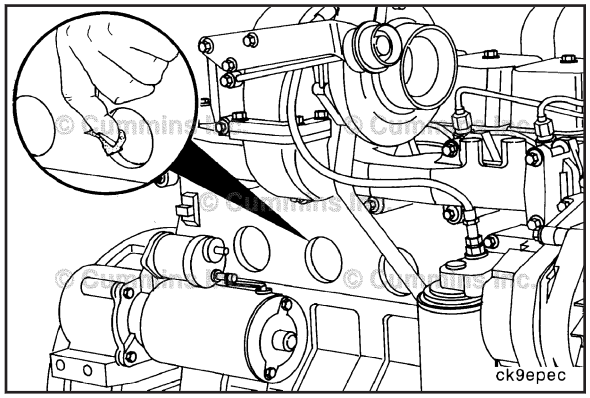
NOTE: Care should be taken **not** to drive the expansion plug out and into the water jacket, especially the plug on the end of the cylinder block.

Remove the expansion plugs from the coolant passages as shown.

Service Tip: If it becomes apparent the expansion plug is **not** going to pivot in the bore, use a center punch to catch the edge of the expansion plug and pry against the cylinder block to pivot the expansion plug out.

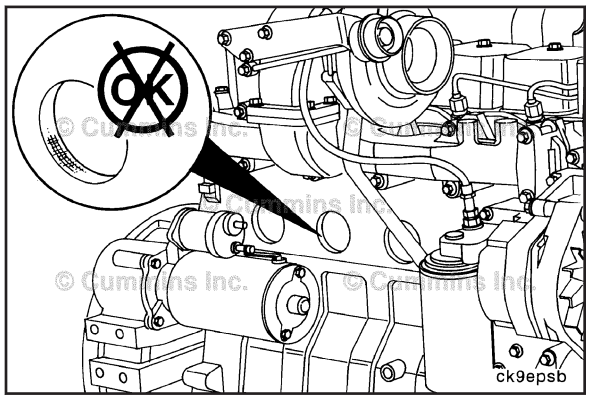


Remove the expansion plugs from the oil passages.



Clean

Thoroughly clean the expansion plug hole using Scotch-Brite™, or equivalent. Use spray cleaner 3375433, or equivalent, to finish cleaning the bore.

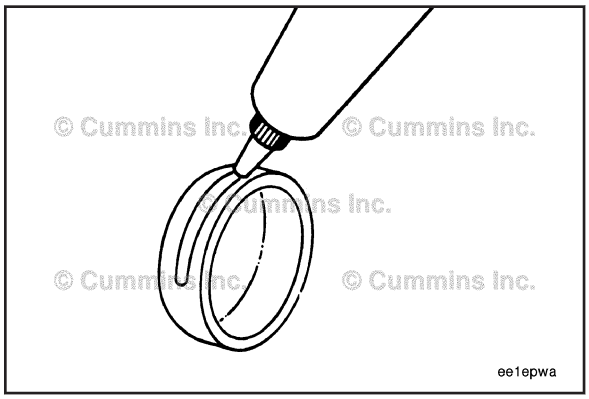


Inspect the cup plug bores for damage.

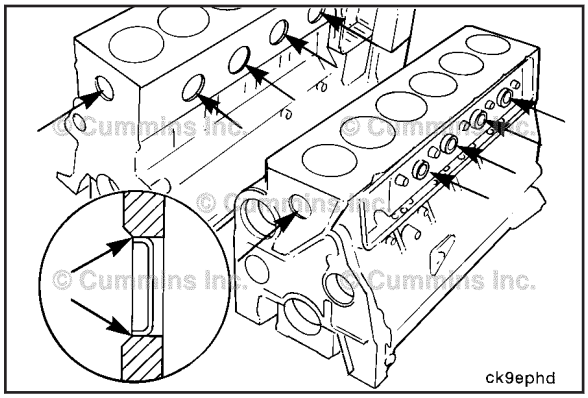
Install

Coolant Passages

Apply a 2 mm [1/16 in] of Loctite 277, or equivalent, to the coolant passage expansion plugs. Apply Loctite 277 to the inside diameter of the expansion plug installation bore.



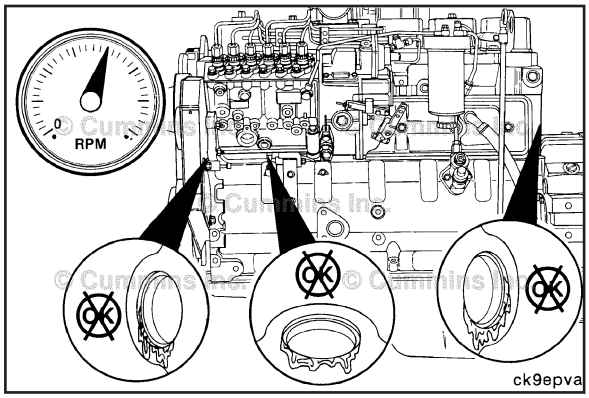
Drive the expansion plug in until the outer edge is flush with the countersink in the block.



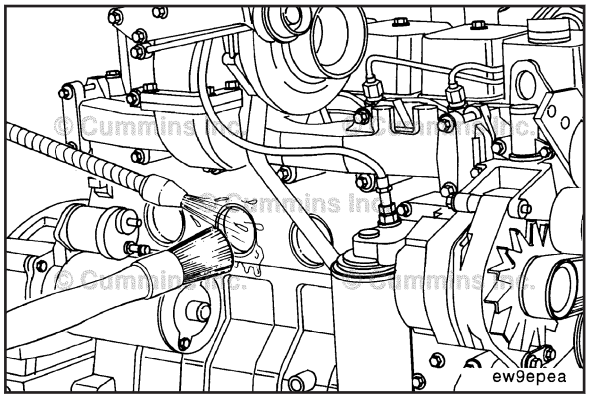
Fill the engine with clean lubricating engine oil.

Operate the engine, and check for leaks.

Stop the engine, and check the lubricating oil level with the dipstick.



Clean the area near the expansion plug of all debris.



Notes

Section L - Service Literature

Section Contents

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Additional Service Literature

General Information

The following publications can be purchased by contacting your Cummins distributor:

Bulletin	Title of Publication
3666109	Alternative Repair Manual, B and C Series Engines
3379000	Air For Your Engine
3666132	Coolant Requirements and Maintenance
3810340	Cummins Engine Oil Recommendations
3379001	Fuels for Cummins Engines
3379009	Operation - Cold Weather

Service Literature Ordering Location

Contact Information

Region	Ordering Location
United States and Canada	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.

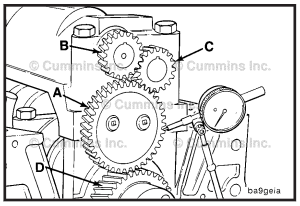
Notes

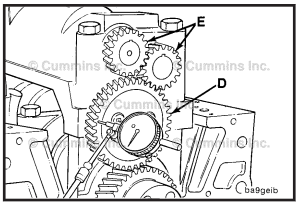
Section V - Specifications

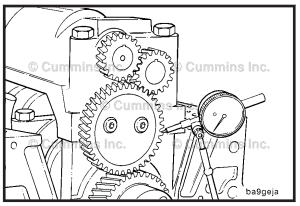
Section Contents

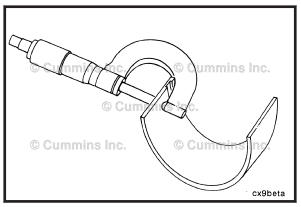
Cylinder Block - Group 01 - Specifications

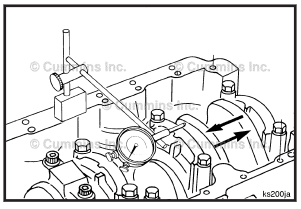
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Balancer (001-004)				
Balancer Gear Backlash				
Idler (A) to (D)		0.088	MIN	0.003
		0.420	MAX	0.017
Upper Shaft (B) to (A)		0.153	MIN	0.006
		0.355	MAX	0.014
Lower Shaft (C) to (B)		0.088	MIN	0.003
		0.420	MAX	0.017
Balancer End Play				
(D)		0.130	MIN	0.005
		0.630	MAX	0.024
(E)		0.075	MIN	0.003
		0.175	MAX	0.007
Idler Gear Backlash		0.088 mm	MIN	0.003 in
		0.420 mm	MAX	0.017 in
Bearings, Connecting Rod (001-005)				
Connecting Rod Bearing Dimensions B3.9, B4.5 RGT, and B5.9 Engines				
Standard		1.955	MIN	0.0770
		1.968	MAX	0.0775
0.25 mm [0.010 in]		2.080	MIN	0.0819
		2.093	MAX	0.0824
0.50 mm [0.020 in]		2.205	MIN	0.0868
		2.218	MAX	0.0873
0.75 mm [0.030 in]		2.330	MIN	0.0917
		2.343	MAX	0.0922
1.00 mm [0.040 in]		2.455	MIN	0.0967
		2.468	MAX	0.0972
Connecting Rod Bearing Dimensions B4.5 Engines				
Standard		1.809	MIN	0.0712
		1.818	MAX	0.0716
0.25 mm [0.010 in]		1.934	MIN	0.0761
		1.943	MAX	0.0765
0.50 mm [0.020 in]		2.059	MIN	0.0811
		2.068	MAX	0.0814
0.75 mm [0.030 in]		2.184	MIN	0.0860
		2.193	MAX	0.0863
1.00 mm [0.040 in]		2.309	MIN	0.0909
		2.318	MAX	0.0913
Bearings, Main (001-006)				
Crankshaft End Play		0.102 mm	MIN	0.004 in
		0.432 mm	MAX	0.017 in

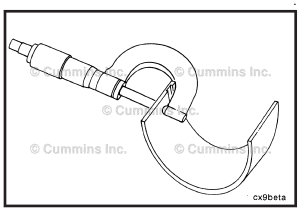
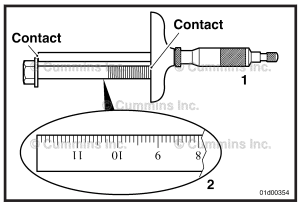
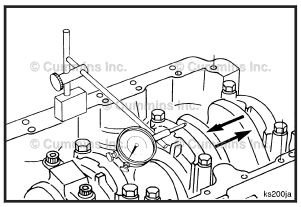
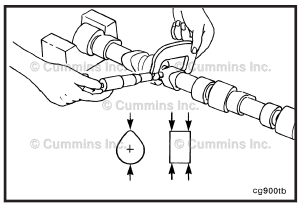
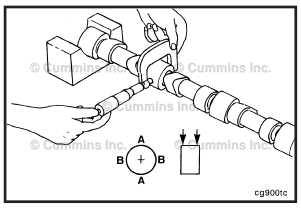
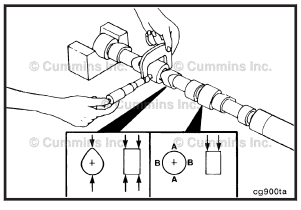


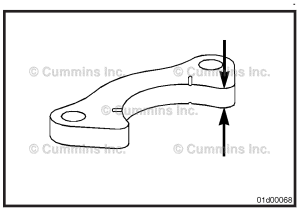
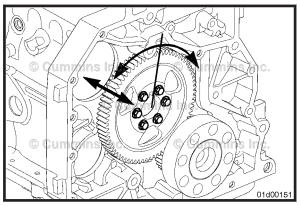
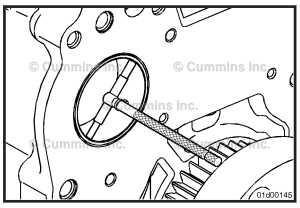
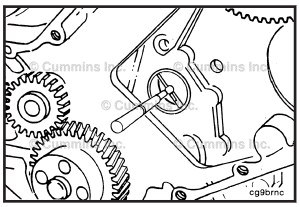
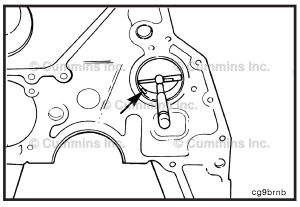
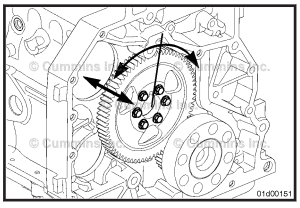


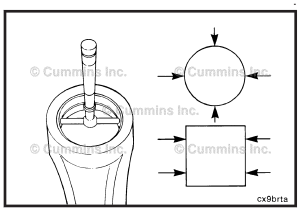
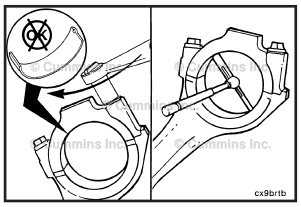
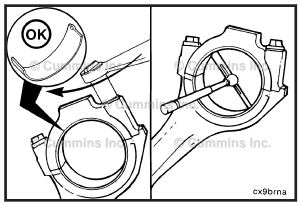
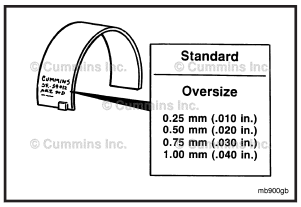


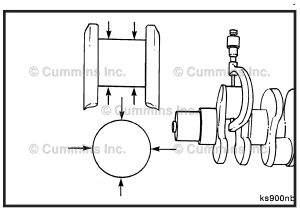
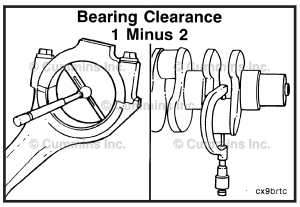
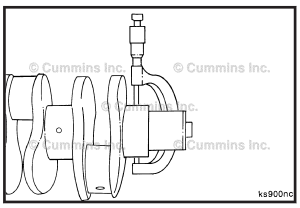


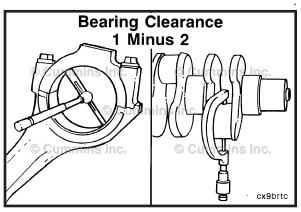
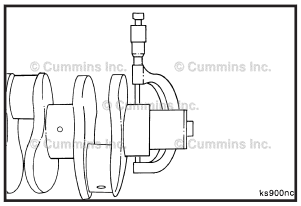
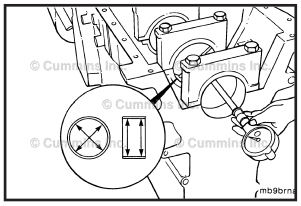
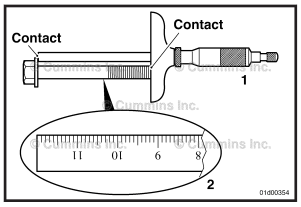
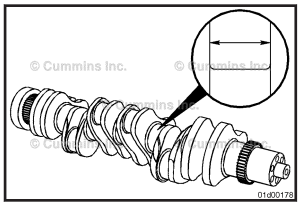
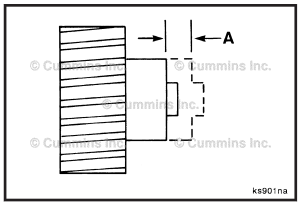
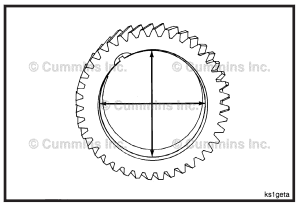


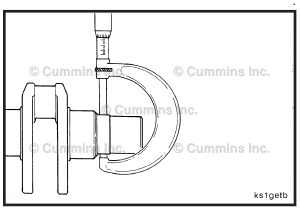
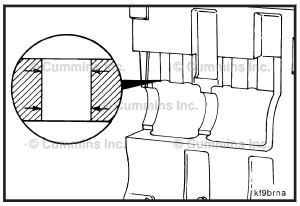
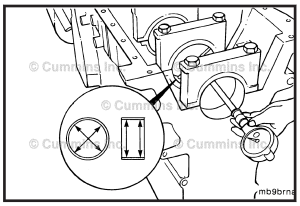
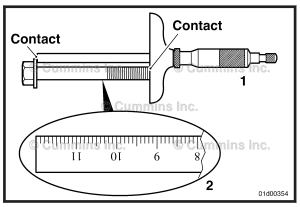
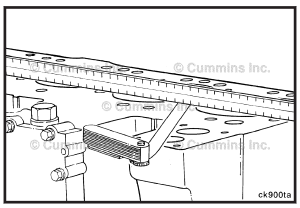
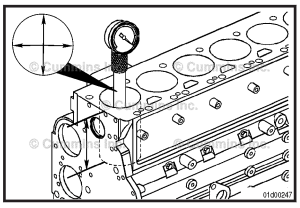
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Main Bearing Dimensions					
Standard		2.456	MIN	0.0967	
		2.464	MAX	0.097	
Oversize 0.25 mm [0.010 in]		2.706	MIN	0.1067	
		2.714	MAX	0.117	
Oversize 0.50 mm [0.020 in]		2.956	MIN	0.1167	
		2.964	MAX	0.117	
Oversize 0.75 mm [0.030 in]		3.206	MIN	0.1267	
		3.214	MAX	0.127	
Oversize 1.00 mm [0.040 in]		3.456	MIN	0.1367	
		3.464	MAX	0.137	
Main Bearing Underhead Capscrew Length		120.00 mm	MAX	4.724 in	
Crankshaft End Play		0.102 mm	MIN	0.004 in	
		0.432 mm	MAX	0.017 in	
Camshaft (001-008)					
4 Cylinder		60.96	MIN	24	
6 Cylinder		81.28	MIN	32	
Intake		46.132	MIN	1.8162	
Exhaust		45.632	MIN	1.797	
Journal Diameter		53.962 mm	MIN	2.1245 in	
		54.013 mm	MAX	2.1265 in	
Fuel Transfer Pump Lobe Diameter		35.50 mm	MIN	1.398 in	
		36.26 mm	MAX	1.428 in	

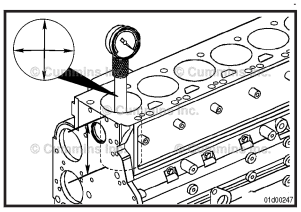
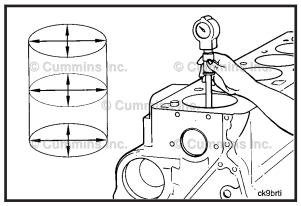
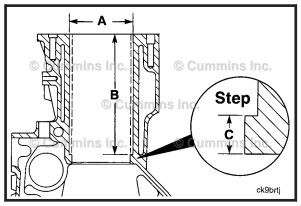
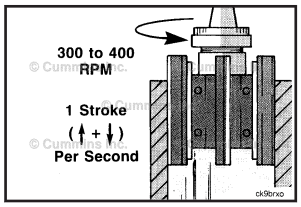
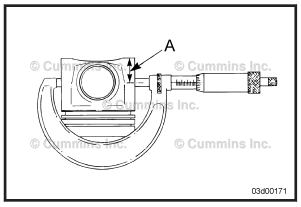
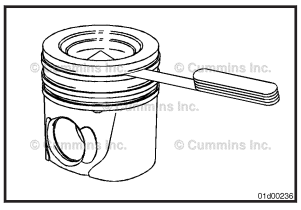
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Rear Gear Train Camshaft Thrust Plate Thickness		5.25 mm	MIN	0.207 in	
		5.35 mm	MAX	0.211 in	
Front Gear Train Camshaft Thrust Plate Thickness		9.40 mm	MIN	0.370 in	
		9.60 mm	MAX	0.378 in	
Camshaft End Play (A)		0.10 mm	MIN	0.004 in	
		0.36 mm	MAX	0.014 in	
Camshaft Gear Backlash Limits (B)		0.076 mm	MIN	0.003 in	
		0.280 mm	MAX	0.011 in	
Camshaft Bushings (001-010)					
Camshaft Bore Diameter without camshaft bushing (maximum)					
Camshaft Bore (Camshaft Bushing Previously Installed)		59.248	MAX	2.3326	
Camshaft Bore (Camshaft Bushing not Previously Installed)		54.164	MAX	2.1324	
STORM Block Camshaft Bore Diameter without camshaft bushing (maximum)					
Camshaft Bore (Camshaft Bushing Previously Installed)		59.248	MAX	2.3326	
Camshaft Bore (Camshaft Bushing not Previously Installed)		54.164	MAX	2.1324	
Pre-STORM Block Camshaft Bore Diameter without camshaft bushing (maximum)					
Camshaft Bore (Camshaft Bushing Previously Installed)		57.248	MAX	2.2539	
Camshaft Bore (Camshaft Bushing not Previously Installed)		54.164	MAX	2.1324	
Camshaft Bore (Bushing Installed)		54.083 mm	MIN	2.1293 in	
		54.147 mm	MAX	2.1318 in	
Camshaft Gear (Camshaft Installed) (001-012)					
Camshaft End Play		0.100 mm	MIN	0.004 in	
		0.360 mm	MAX	0.014 in	
Camshaft Backlash		0.076 mm	MIN	0.003 in	
		0.280 mm	MAX	0.011 in	

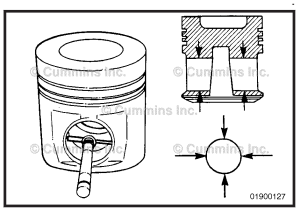
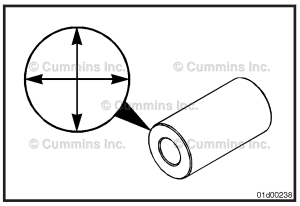
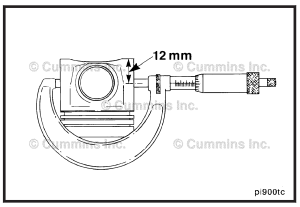
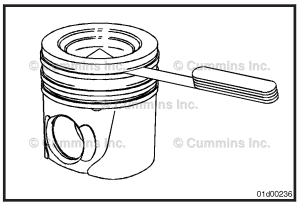
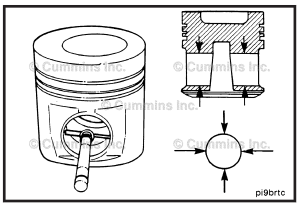
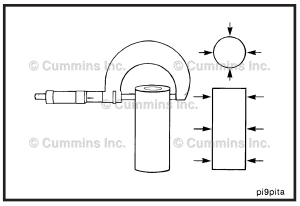
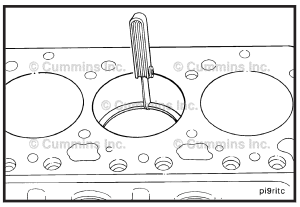
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Connecting Rod (001-014)					
B3.9, B4.5 RGT, and B5.9 Engines Connecting Rod Piston Pin Bushing Diameter		40.019 mm	MIN	1.5756 in	
		40.042 mm	MAX	1.5765 in	
B4.5 Engines Connecting Rod Piston Pin Bushing Diameter		34.51 mm	MIN	1.3586 in	
		34.54 mm	MAX	1.3596 in	
B3.9, B4.5 RGT, and B5.9 Connecting Rod Crankshaft Bore Diameter Bearings Removed		72.99 mm	MIN	2.873 in	
		73.01 mm	MAX	2.875 in	
B4.5 Connecting Rod Crankshaft Bore Diameter Bearings Removed		69.675 mm	MIN	2.7431 in	
		69.694 mm	MAX	2.7439 in	
Standard		69.05	MIN	2.719	
		69.10	MAX	2.720	
Standard		66.051	MIN	2.6004	
		66.103	MAX	2.6025	
Oversize					
0.25 mm [0.010 in]		68.80	MIN	2.709	
		68.85	MAX	2.711	
0.50 mm [0.020 in]		68.55	MIN	2.699	
		68.60	MAX	2.701	
0.75 mm [0.030 in]		68.30	MIN	2.689	
		68.35	MAX	2.691	
1.00 mm [0.040 in]		68.05	MIN	2.680	
		68.10	MAX	2.681	
Oversize					
0.25 mm [0.010 in]		66.801	MIN	2.6300	
		66.853	MAX	2.6320	
0.50 mm [0.020 in]		65.551	MIN	2.5809	
		65.603	MAX	2.5828	
0.75 mm [0.030 in]		65.301	MIN	2.5709	
		65.353	MAX	2.5730	
1.00 mm [0.040 in]		64.051	MIN	2.5587	
		65.103	MAX	2.5608	

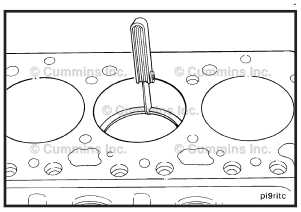
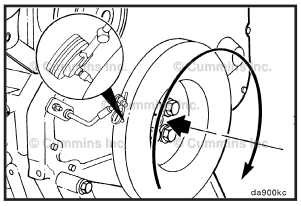
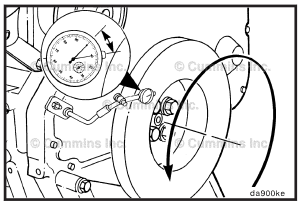
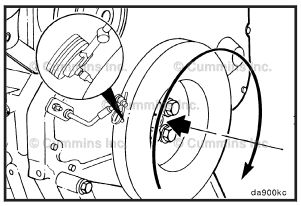
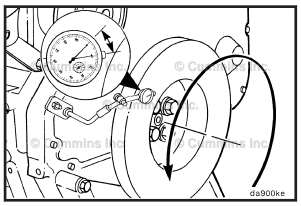
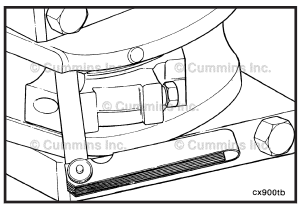
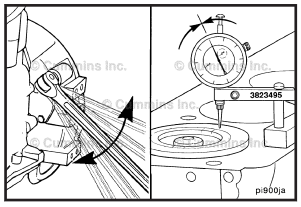
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Standard		68.962	MIN	2.7150	
		69.013	MAX	2.7170	
Undersize					
0.25 mm [0.010 in]		68.712	MIN	2.7052	
		68.763	MAX	2.7072	
0.50 mm [0.020 in]		68.462	MIN	2.6954	
		68.513	MAX	2.6974	
0.75 mm [0.030 in]		68.212	MIN	2.6855	
		68.263	MAX	2.6875	
1.00 mm [0.040 in]		67.962	MIN	2.6767	
		68.013	MAX	2.6787	
Standard		65.987	MIN	2.5979	
		66.103	MAX	2.5989	
Undersize					
0.25 mm [0.010 in]		65.737	MIN	2.5879	
		65.763	MAX	2.5889	
0.50 mm [0.020 in]		65.487	MIN	2.5779	
		65.513	MAX	2.5789	
0.75 mm [0.030 in]		65.237	MIN	2.5679	
		65.263	MAX	2.5689	
1.00 mm [0.040 in]		64.987	MIN	2.5579	
		65.013	MAX	2.5589	
Connecting Rod to Crankshaft Bearing Clearance		0.04 mm	MIN	0.002 in	
		0.12 mm	MAX	0.005 in	
Crankshaft (001-016)					
Standard		68.962	MIN	2.7150	
		69.013	MAX	2.7170	
Undersize					
0.25 mm [0.010 in]		68.712	MIN	2.7052	
		68.763	MAX	2.7072	
0.50 mm [0.020 in]		68.462	MIN	2.6954	
		68.513	MAX	2.6974	
0.75 mm [0.030 in]		68.212	MIN	2.6855	
		68.263	MAX	2.6875	
1.00 mm [0.040 in]		67.962	MIN	2.6767	
		68.013	MAX	2.6787	
Standard		65.987	MIN	2.5979	
		66.013	MAX	2.5989	
Undersize					
0.25 mm [0.010 in]		65.737	MIN	2.5879	
		65.763	MAX	2.5889	
0.50 mm [0.020 in]		65.487	MIN	2.5779	
		65.513	MAX	2.5789	
0.75 mm [0.030 in]		65.237	MIN	2.5679	
		65.263	MAX	2.5689	
1.00 mm [0.040 in]		64.987	MIN	2.5579	
		65.013	MAX	2.5589	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Connecting Rod to Crankshaft Bearing Clearance		0.04 mm	MIN	0.002 in	
		0.12 mm	MAX	0.005 in	
Standard		82.962	MIN	3.2662	
		83.013	MAX	3.2682	
Undersize					
0.25 mm [0.010 in]		82.712	MIN	3.2564	
		82.763	MAX	3.2584	
0.50 mm [0.020 in]		82.462	MIN	3.2465	
		82.513	MAX	3.2485	
0.75 mm [0.030 in]		82.212	MIN	3.2367	
		82.263	MAX	3.2387	
1.0 mm [0.040 in]		81.962	MIN	3.2268	
		82.013	MAX	3.2289	
Main Bearing Bore to Crankshaft Bearing Clearance		0.04 mm	MIN	0.002 in	
		0.12 mm	MAX	0.005 in	
Main Bearing Underhead Capscrew Length		120.00 mm	MAX	4.724 in	
Thrust Distance		37.475 mm	MIN	1.4754 in	
		37.576 mm	MAX	1.4794 in	
Crankshaft End Play		0.102 mm	MIN	0.004 in	
		0.432 mm	MAX	0.017 in	
Crankshaft Gear, Front (Crankshaft Removed) (001-019)					
Crankshaft Gear Bore Inside Diameter		70.51 mm	MIN	2.776 in	
		70.55 mm	MAX	2.779 in	

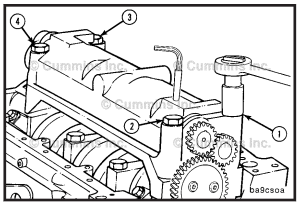
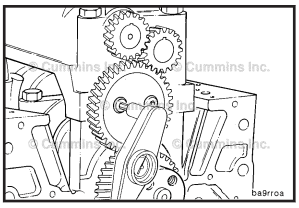
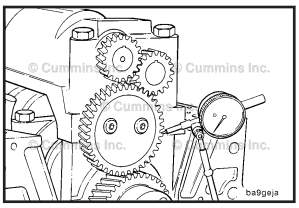
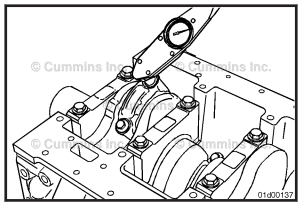
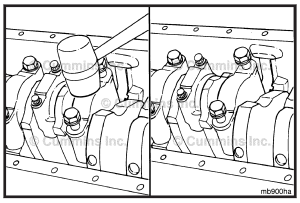
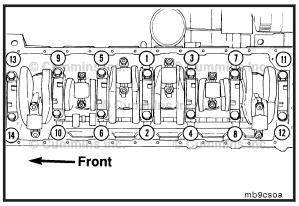
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Crankshaft Gear Journal Outside Diameter		70.59 mm 70.61 mm	MIN MAX	2.779 in 2.780 in	
Cylinder Block (001-026) Tappet Bore Diameter		16.000 mm 16.055 mm	MIN MAX	0.630 in 0.632 in	
Main Bearing Bore Diameter with Bearings Removed		87.983 mm 88.019 mm	MIN MAX	3.4639 in 3.4653 in	
Main Bearing Underhead Capscrew Length		120.00 mm	MAX	4.724 in	
End-to-End Side-to-Side		0.076 0.051	MAX MAX	0.003 0.002	
Cylinder Bore Diameter - B3.9, B4.5, and B5.9 Series Engines Only (New Cylinder Block)		102.010 mm 102.030 mm	MIN MAX	4.0161 in 4.0169 in	
Cylinder Bore Diameter - B3.9, B4.5, and B5.9 Series Engines Only (Used Cylinder Block)		102.010 mm 102.050 mm	MIN MAX	4.0161 in 4.0177 in	
Out-of-Roundness		0.038 mm	MAX	0.0015 in	
Taper		0.076 mm	MAX	0.003 in	

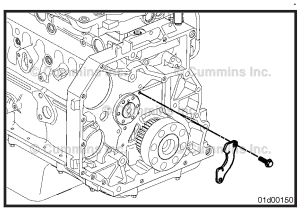
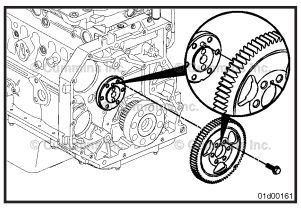
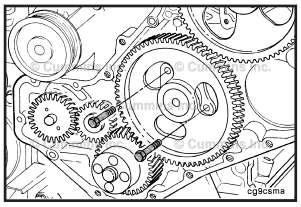
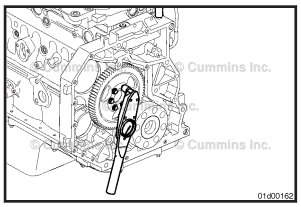
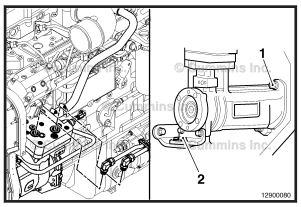
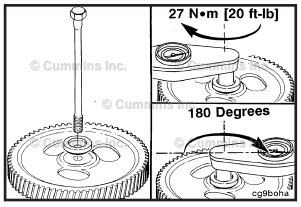
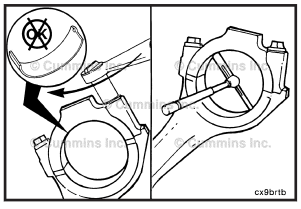
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Cylinder Bore Diameter - B4.5 RGT Series Engines Only (New Cylinder Block)		106.990 mm	MIN	4.2122 in	
		107.010 mm	MAX	4.2130 in	
Cylinder Bore Diameter - B4.5 RGT Series Engines Only (Used Cylinder Block)		106.990 mm	MIN	4.2122 in	
		107.030 mm	MAX	4.2138 in	
Out-of-Roundness		0.038 mm	MAX	0.0015 in	
Taper		0.076 mm	MAX	0.003 in	
First Rebore		102.469	NOM	4.0342	
Second Rebore		102.969	NOM	4.0539	
Rebore		107.45	NOM	4.2303	
Cylinder Bore Diameter (A)		109.700 mm	MIN	4.3189 in	
		109.715 mm	MAX	4.3195 in	
Cylinder Bore Depth (B)		192.65 mm	MAX	7.5846 in	
Standard Bore/Repair Sleeve		102.000	MIN	4.0157	
		102.040	MAX	4.0173	
First Rebore		102.500	MIN	4.0354	
		102.540	MAX	4.0370	
Second Rebore		103.000	MIN	4.0551	
		103.040	MAX	4.0567	
Standard Bore/Repair Sleeve		106.990	MIN	4.2122	
		107.010	MAX	4.2130	
Rebore		107.490	MIN	4.2319	
		107.510	MAX	4.2327	
Piston (001-043)					
B4.5 RGT Standard Piston Skirt Diameter		106.878 mm	MIN	4.2078 in	
		106.892 mm	MAX	4.2083 in	
B4.5 RGT Piston Ring Clearance					
Intermediate		0.040	MIN	0.0016	
		0.110	MAX	0.0043	
Oil Control		0.040	MIN	0.0016	
		0.085	MAX	0.0033	

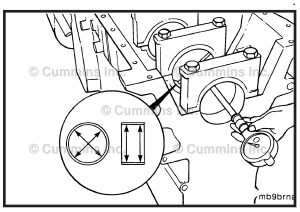
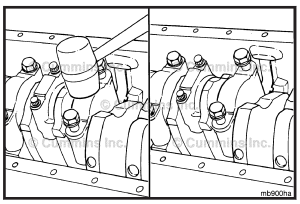
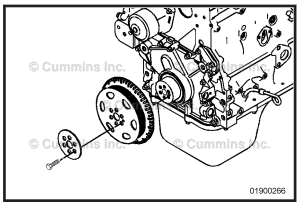
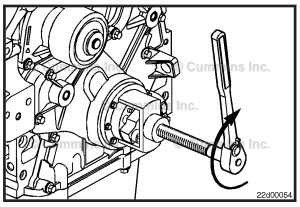
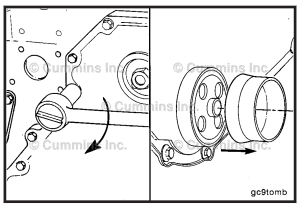
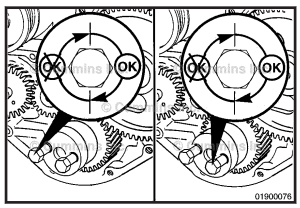
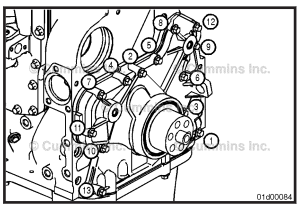
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
B4.5 RGT Piston Pin Bore		40.006 mm	MIN	1.5750 in	
		40.012 mm	MAX	1.5753 in	
B4.5 RGT Piston Pin Diameter		39.997 mm	MIN	1.5747 in	
		40.003 mm	MAX	1.5749 in	
B3.9 and B5.9 Piston Skirt Diameter		101.823 mm	MIN	4.0088 in	
		101.887 mm	MAX	4.0107 in	
B4.5 Piston Skirt Diameter		101.833 mm	MIN	4.0092 in	
		101.906 mm	MAX	4.0120 in	
B4.5 Front Gear Train Piston Ring Clearance					
Intermediate		0.040	MIN	0.0016	
		0.110	MAX	0.0043	
Oil Control		0.040	MIN	0.0016	
		0.085	MAX	0.0033	
B3.9 and B5.9 Piston Pin Bore Diameter		40.006 mm	MIN	1.5750 in	
		40.025 mm	MAX	1.5758 in	
B4.5 Piston Pin Bore Diameter		34.503 mm	MIN	1.3584 in	
		34.522 mm	MAX	1.3591 in	
B3.9 and B5.9 Pin Diameter		39.990 mm	MIN	1.5744 in	
		40.003 mm	MAX	1.5749 in	
B4.5 Pin Diameter		34.483 mm	MIN	1.3576 in	
		34.495 mm	MAX	1.3581 in	
Piston Rings (001-047)					
Oil Control		0.25	MIN	0.010	
		0.55	MAX	0.022	

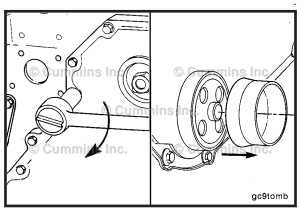
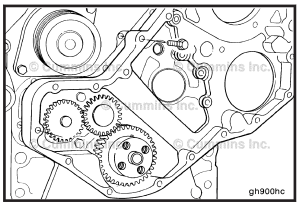
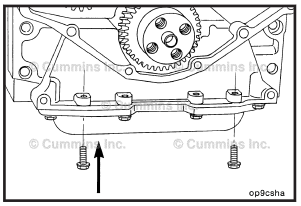
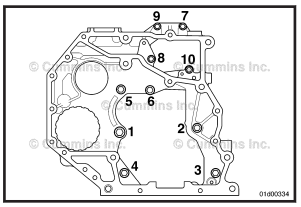
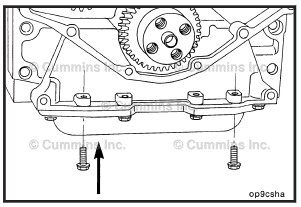
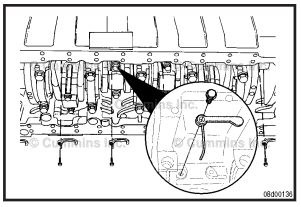
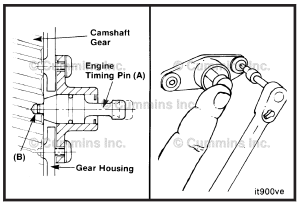
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Top		0.30	MIN	0.012	
		0.46	MAX	0.018	
Intermediate		0.82	MIN	0.032	
		1.18	MAX	0.047	
Oil		0.22	MIN	0.010	
		0.58	MAX	0.023	
Vibration Damper, Rubber (001-051)					
Vibration Damper Eccentricity per 25.4 mm [1.0 in] of Diameter		0.10 mm	MAX	0.004 in	
Vibration Damper Wobble per 25.4 mm [1.0 in] of Radius		0.18 mm	MAX	0.007 in	
Vibration Damper, Viscous (001-052)					
Vibration Damper Eccentricity per 25.4 mm [1.0 in] of Diameter		0.10 mm	MAX	0.004 in	
Vibration Damper Wobble per 25.4 mm [1.0 in] of Radius		0.18 mm	MAX	0.007 in	
Piston and Connecting Rod Assembly (001-054)					
Side Clearance Limits		0.10 mm	MIN	0.004 in	
		0.33 mm	MAX	0.013 in	
B4.5 RGT Piston Protrusion		0.151 mm	MIN	0.006 in	
		0.485 mm	MAX	0.019 in	
B3.9, B4.5, and B5.9 Piston Protrusion		0.609 mm	MIN	0.024 in	
		0.711 mm	MAX	0.028 in	

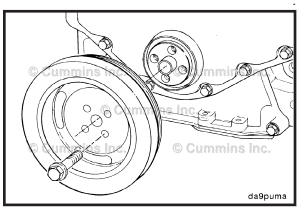
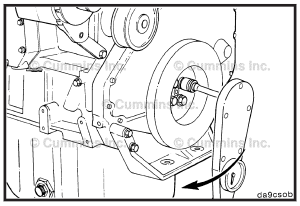
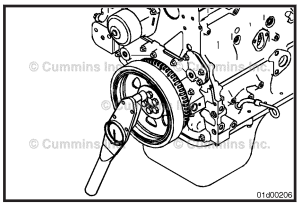
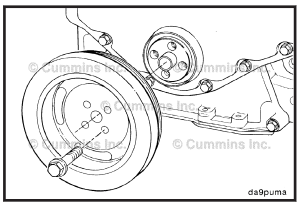
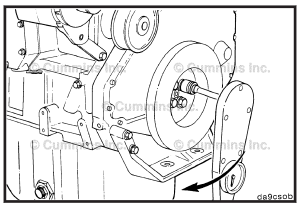
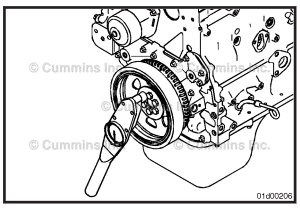
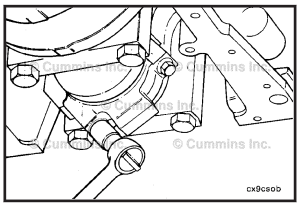
Cylinder Block - Group 01 - Torque Values

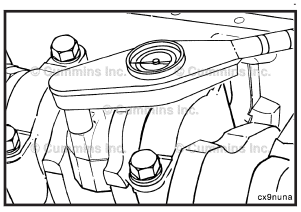
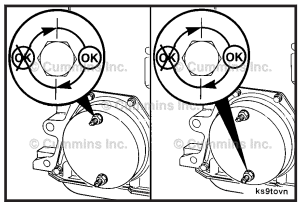
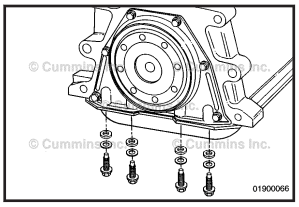
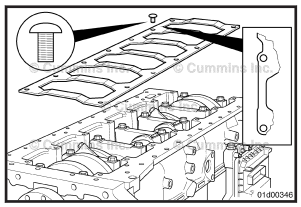
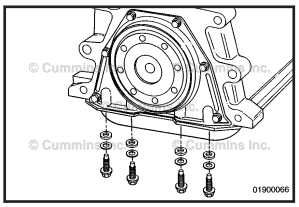
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Balancer (001-004)				
Main Bearing Capscrews	1	60 N•m	[44 ft-lb]	
	2	119 N•m	[88 ft-lb]	
	3	176 N•m	[130 ft-lb]	
Idler Gear Retainer Capscrews		57 N•m	[42 ft-lb]	
Idler Gear Capscrews		57 N•m	[42 ft-lb]	
Bearings, Connecting Rod (001-005)				
B3.9, B4.5 Rgt And B5.9 Engines Connecting Rod Capscrews	1	30 N•m	[22 ft-lb]	
	2	60 N•m	[44 ft-lb]	
	3	Rotate 60 degrees.		
	1	25 N•m	[18 ft-lb]	
	2	Rotate 60 degrees.		
Bearings, Main (001-006)				
Main Bearing Capscrews.		50 N•m	[37 ft-lb]	
4.5L (Rgt) Main Bearing Capscrews. Previously Installed Main Bearing Capscrews	1	60 N•m	[44 ft-lb]	
	2	90 N•m	[66 ft-lb]	
	3	Rotate 90 degrees.		
4.5L (Rgt) Main Bearing Capscrews. New Main Bearing Capscrews	1	60 N•m	[44 ft-lb]	
	2	80 N•m	[59 ft-lb]	
	3	Rotate 90 degrees.		
	1	120 N•m	[89 ft-lb]	
	2	Loosen completely		
	3	60 N•m	[44 ft-lb]	
	4	85 N•m	[63 ft-lb]	
	5	Rotate 120 degrees.		

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Camshaft (001-008)				
Thrust Plate Capscrews		24 N•m	[212 in-lb]	
Camshaft Gear Capscrews		36 N•m	[27 ft-lb]	
Camshaft Thrust Plate Retaining Capscrews		24 N•m	[18 ft-lb]	
Camshaft Gear (Camshaft Installed) (001-012)				
Camshaft Gear Capscrews		36 N•m	[27 ft-lb]	
Air Compressor Support Mounting Capscrews. M8		77 N•m 24 N•m	[57 ft-lb] [18 ft-lb]	
Air Compressor Support Mounting Capscrews. M10		43 N•m 77 N•m	[32 ft-lb] [57 ft-lb]	
Air Compressor Support Mounting Capscrews. M12				
Camshaft Gear (Camshaft Removed) (001-013)				
Bolted Camshaft Gear Bolt	1	27 N•m	[20 ft-lb]	
	2	Rotate capscrew 180 degrees.		
Connecting Rod (001-014)				
B3.9, B4.5 Rgt, And B5.9 Connecting Rod Capscrews		100 N•m 70 N•m	[74 ft-lb] [52 ft-lb]	

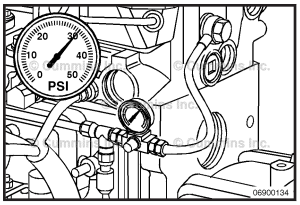
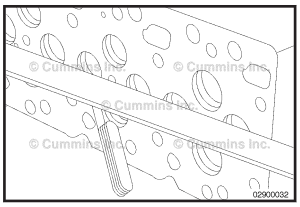
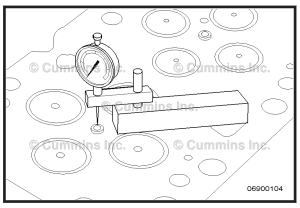
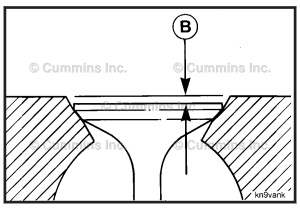
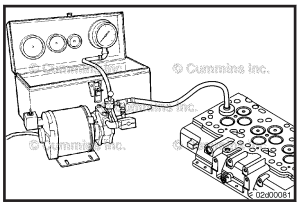
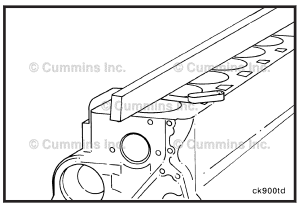
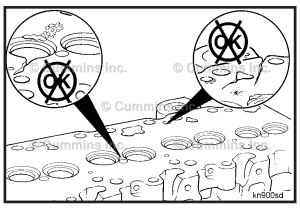
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Crankshaft (001-016)				
Main Bearing Capscrews		176 N•m	[130 ft-lb]	
		50 N•m	[37 ft-lb]	
Crankshaft Pulley (001-022)				
Crankshaft Pulley Capscrews	1 2	50 N•m Rotate 90 degrees	[37 ft-lb]	
Crankshaft Seal, Front (001-023)				
Crankshaft Seal Replacer Capscrews		33 N•m	[45 ft-lb]	
Front Cover Capscrews.		24 N•m	[18 ft-lb]	
Crankshaft Wear Sleeve, Front (001-025)				
Wear Sleeve Capscrew Torque		20 N•m	[15 ft-lb]	
Gear Cover, Front (001-031)				
Front Cover Capscrew		24 N•m	[212 in-lb]	

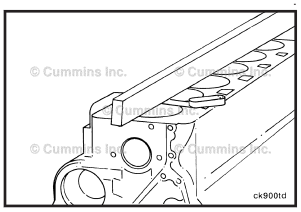
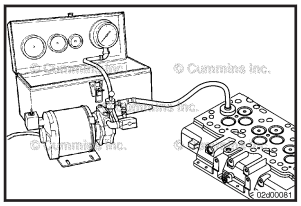
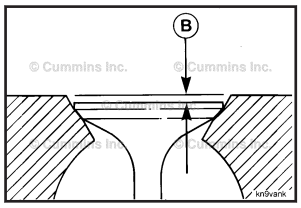
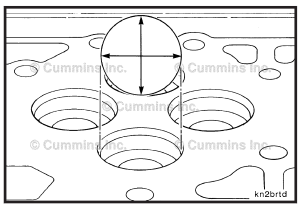
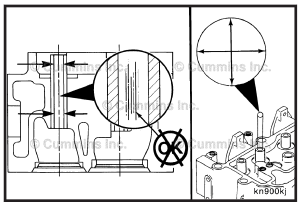
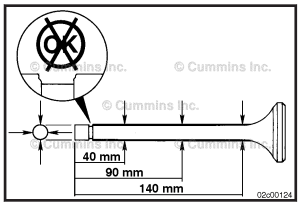
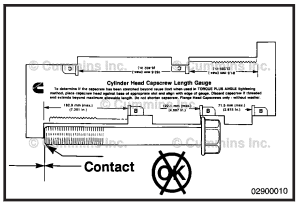
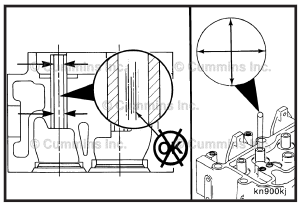
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Front Gear Cover Capscrews.		24 N•m	[212 in-lb]	
Gear Housing, Front (001-033)				
Front Gear Housing Mounting Capscrews		24 N•m	[18 ft-lb]	
Oil Pan To Gear Housing Mounting Capscrews		24 N•m	[18 ft-lb]	
Gear Housing, Rear (001-034)				
Rear Gear Housing Capscrews M12		50 N•m	[37 ft-lb]	
Rear Gear Housing Capscrews M10		47 N•m	[35 ft-lb]	
Rear Gear Housing Capscrews M8		24 N•m	[212 in-lb]	
		28 N•m	[21 ft-lb]	
Piston Cooling Nozzle (001-046)				
J-Jet Capscrew		15 N•m	[133 in-lb]	
Timing Pin Housing (001-049)				
Timing Pin Housing Capscrews.		5 N•m	[48 in-lb]	

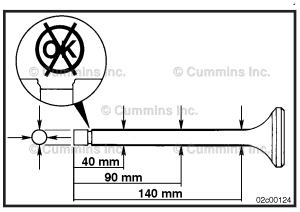
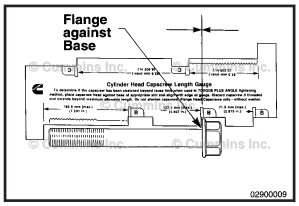
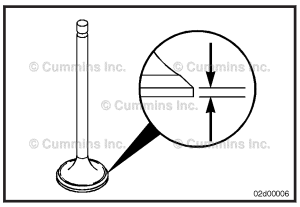
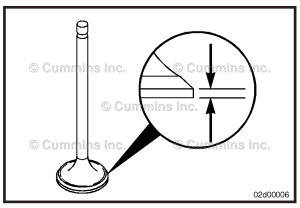
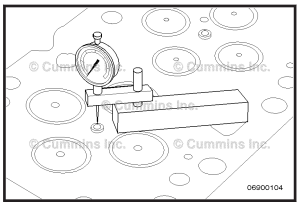
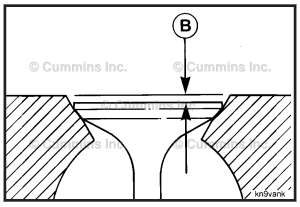
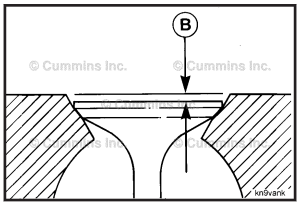
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Vibration Damper, Rubber (001-051)				
Crankshaft Damper Capscrew Torque		125 N•m	[92 ft-lb]	
Vibration Damper Capscrews		200 N•m 77 N•m	[148 ft-lb] [57 ft-lb]	
Vibration Damper Capscrews	1 2	50 N•m Rotate 90 degrees	[37 ft-lb]	
Vibration Damper, Viscous (001-052)				
Crankshaft Damper Capscrew Torque		125 N•m	[92 ft-lb]	
Vibration Damper Capscrews		200 N•m 77 N•m	[148 ft-lb] [57 ft-lb]	
Vibration Damper Capscrews	1 2	50 N•m Rotate 90 degrees	[37 ft-lb]	
Piston and Connecting Rod Assembly (001-054)				
Connecting Rod Cap Capscrews		35 N•m	[26 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Connecting Rod Capscrews B3.9, B4.5 RGT And B5.9 Engines	1	30 N•m	[22 ft-lb]	
	2	60 N•m	[44 ft-lb]	
Connecting Rod Capscrews B4.5 Engines	3	Turn 60 degrees clockwise.		
	1	25 N•m	[18 ft-lb]	
	2	Turn 60 degrees clockwise.		
Crankshaft Wear Sleeve, Rear (001-067)		20 N•m	[177 ft-lb]	
		24 N•m	[212 in-lb]	
Block Stiffener Plate (001-089)				
Block Stiffener Plate Capscrews		43 N•m	[32 ft-lb]	
Crankshaft Seal Carrier, Rear (001-104)		24 N•m	[212 in-lb]	

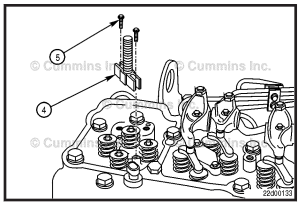
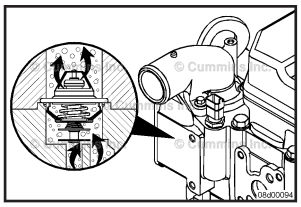
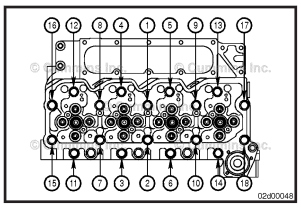
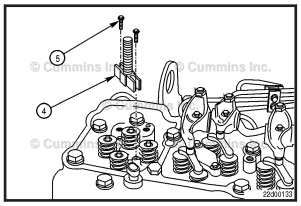
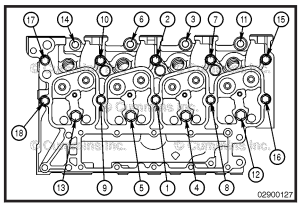
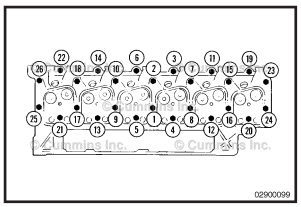
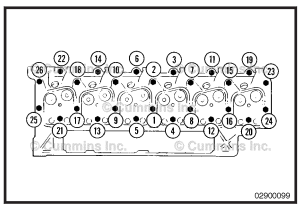
Cylinder Head - Group 02 - Specifications

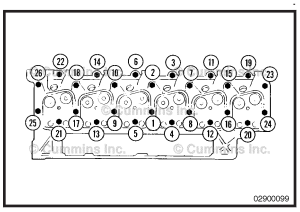
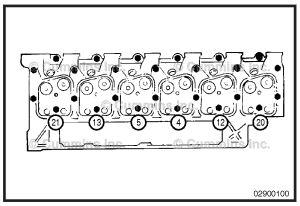
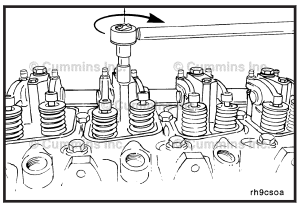
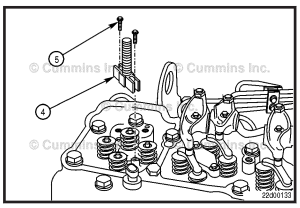
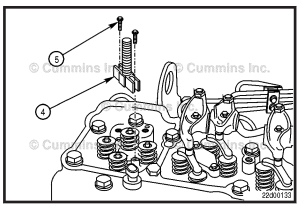
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Cylinder Head (002-004)					
End-to-End		0.305	MAX	0.012	
Side-to-Side		0.076	MAX	0.003	
Injector Protrusion		2.45 mm	MIN	0.096 in	
		3.15 mm	MAX	0.124 in	
Intake Valve Depth (Installed)		0.584 mm	MIN	0.023 in	
		1.092 mm	MAX	0.043 in	
Exhaust Valve Depth (Installed)		0.965 mm	MIN	0.038 in	
		1.473 mm	MAX	0.058 in	
Used		51	NOM	15	
New		69	NOM	20	
End-To-End		0.075	MAX	0.003	
Side-To-Side		0.075	MAX	0.003	
End-to-End		0.305	MAX	0.012	
Side-to-Side		0.076	MAX	0.003	
End-to-End		0.203	MAX	0.008	
Side-to-Side		0.076	MAX	0.003	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
End-To-End Side-To-Side		0.075 0.075	MAX MAX	0.003 0.003	
Used New		457 635	MIN MIN	18 25	
Valve Depth (Installed)		0.99 mm 1.52 mm	MIN MAX	0.038 in 0.060 in	
Cylinder Head Insert Bore Inside Diameter (I.D.)		34.847 mm 34.863 mm	MIN MAX	1.3719 in 1.3726 in	
Valve Guide Bore Diameter		7.027 mm 7.077 mm	MIN MAX	0.2767 in 0.2786 in	
Valve Stem Diameter		6.96 mm 7.01 mm	MIN MAX	0.2740 in 0.2760 in	
Cylinder Head Capscrew Free Length		152.1 mm	MAX	5.99 in	
Valve Guide Bore Diameter		8.01 mm 8.10 mm	MIN MAX	0.315 in 0.319 in	

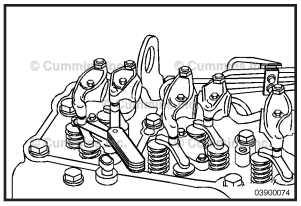
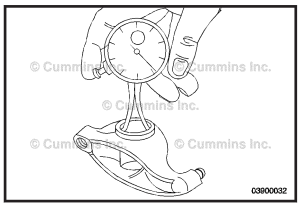
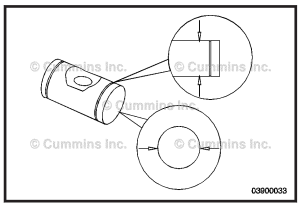
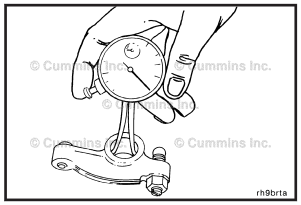
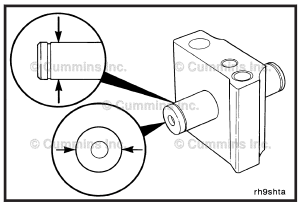
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Valve Stem Diameter		7.90 mm 7.96 mm	MIN MAX	0.311 in 0.313 in	
Short Medium Long		71.5 122.1 182.9	MAX MAX MAX	2.815 4.807 7.201	
Valve Rim Thickness Limit		0.79 mm	MIN	0.031 in	
Valve Rim Thickness Limit		0.79 mm	MIN	0.031 in	
Injector Protrusion		2.45 mm 3.15 mm	MIN MAX	0.096 in 0.124 in	
Intake Valve Depth (Installed)		0.584 mm 1.092 mm	MIN MAX	0.023 in 0.043 in	
Exhaust Valve Depth (Installed)		0.965 mm 1.473 mm	MIN MAX	0.038 in 0.058 in	
Valve Depth (Installed)		0.99 mm 1.52 mm	MIN MAX	0.038 in 0.060 in	

Cylinder Head - Group 02 - Torque Values

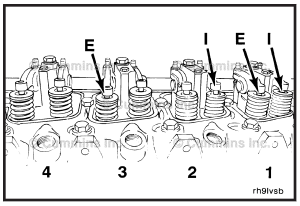
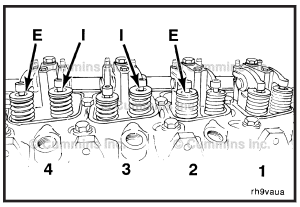
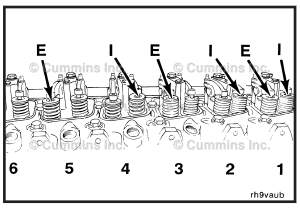
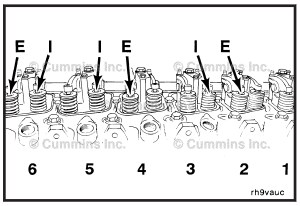
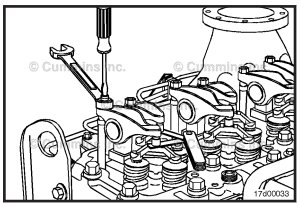
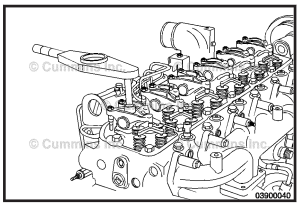
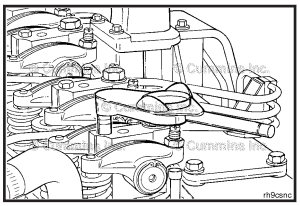
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Cylinder Head (002-004)				
Valve Spring Compressor Capscrews.		5 N•m	[44 in-lb]	
Thermostat And Water Outlet Connection Capscrews		10 N•m 18 N•m	[89 in-lb] [159 in-lb]	
Pressure Test Fixture Nuts		80 N•m	[59 ft-lb]	
		5 N•m	[44 in-lb]	
Short Capscrew Torque		90 N•m	[66 ft-lb]	
Short Capscrew Torque		90 N•m	[66 ft-lb]	
Long Capscrew Torque		120 N•m	[89 ft-lb]	

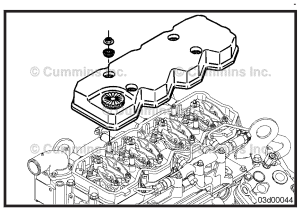
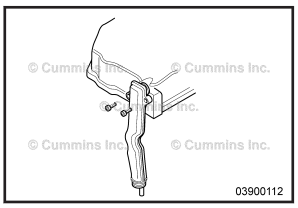
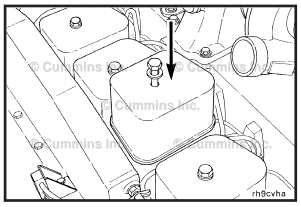
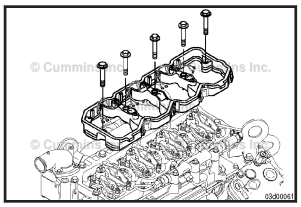
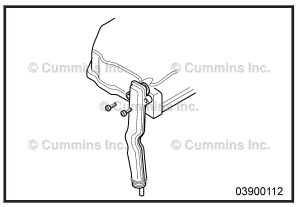
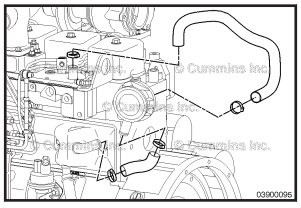
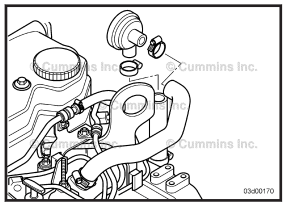
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Short Capscrew Torque		90 N•m	[66 ft-lb]	
Long Capscrew Torque		120 N•m	[89 ft-lb]	
Rocker Lever Pedestal (8 Mm) Capscrew Torque		24 N•m	[212 in-lb]	
Valve Guide Seal, Cylinder Head (002-016)		5 N•m	[44 in-lb]	
		5 N•m	[44 in-lb]	

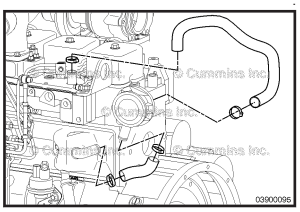
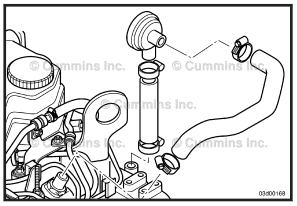
Rocker Levers - Group 03 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Overhead Set (003-004)					
Lash Check Limits					
Intake		0.152	MIN	0.006	
		0.381	MAX	0.015	
Exhaust		0.381	MIN	0.015	
		0.762	MAX	0.030	
					
Rocker Lever (003-008)					
Rocker Lever Bore		22.027 mm	MAX	0.867 in	
					
Rocker Lever Shaft		21.965 mm	MIN	0.865 in	
					
Rocker Lever Bore		19.00 mm	MIN	0.748 in	
					
Rocker Lever Shaft		18.98 mm	MAX	0.747 in	
					

Rocker Levers - Group 03 - Torque Values

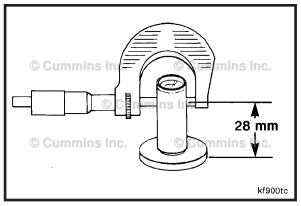
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Overhead Set (003-004)		24 N•m	[18 ft-lb]	
Rocker Lever Adjusting Screw Locknut		24 N•m	[18 ft-lb]	
Rocker Lever Adjusting Screw Locknut		24 N•m	[18 ft-lb]	
Rocker Lever Adjusting Screw Locknut		24 N•m	[18 ft-lb]	
Locknut	Lash Specifications mm in Intake 0.254 0.010 Exhaust 0.508 0.020	24 N•m	[212 in-lb]	
Rocker Lever (003-008) Pedestal Mounting Capscrews		36 N•m	[27 ft-lb]	
Rocker Lever Pedestal Capscrew		24 N•m	[18 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Rocker Lever Cover (003-011)				
Rocker Lever Cover Mounting Nuts.		24 N•m	[18 ft-lb]	
Breather Tube Connections Capscrews		10 N•m	[89 in-lb]	
Rocker Lever Cover Capscrew Torque		24 mm	[18 ft-lb]	
Rocker Lever Housing (003-013)				
Rocker Lever Housing Capscrews		24 N•m	[212 in-lb]	
Crankcase Breather Tube (003-018)				
Crankcase Breather Tube Connection Capscrews		10 N•m	[89 in-lb]	
Closed Crankcase Ventilation Valve (003-023)				
Front Gear Train Closed Crankcase Ventilation Hose Clamps		8 N•m	[71 in-lb]	
Rear Gear Train Closed Crankcase Ventilation Hose Clamps		8 N•m	[71 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Closed Crankcase Ventilation Hoses (003-024)				
Front Gear Train Closed Crankcase Ventilation Hose Clamps		8 N•m	[71 in-lb]	
Rear Gear Train Closed Crankcase Ventilation Hose Clamps		8 N•m	[71 in-lb]	

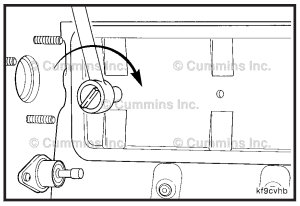
Cam Followers/Tappets - Group 04 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Tappet (004-015)				
Valve Tappet Stem Diameter		15.936 mm	MIN	0.627 in
		15.977 mm	MAX	0.629 in

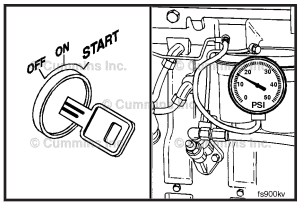
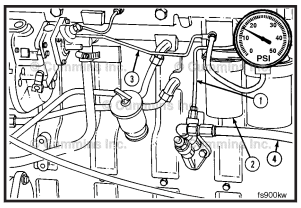
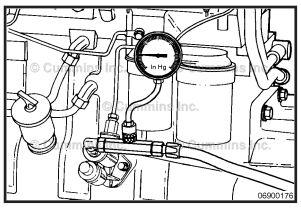


Cam Followers/Tappets - Group 04 - Torque Values

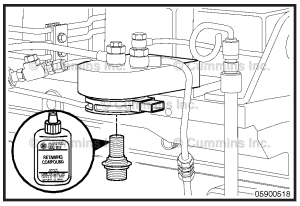
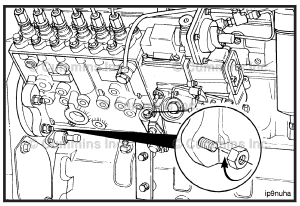
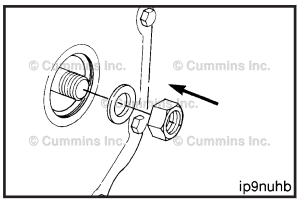
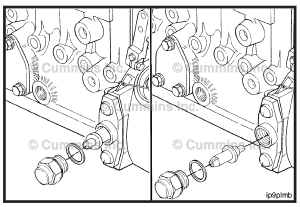
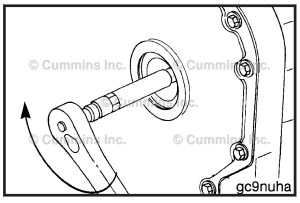
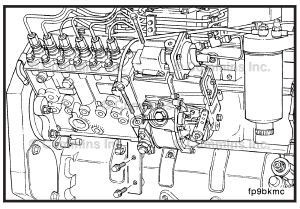
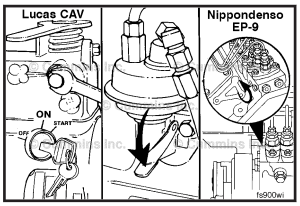
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.
Tappet Cover (004-017)			
Tappet Cover Mounting Capscrews		24 N•m	[18 ft-lb]

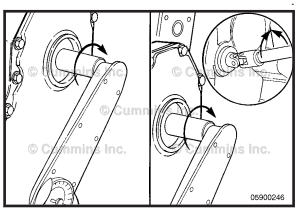
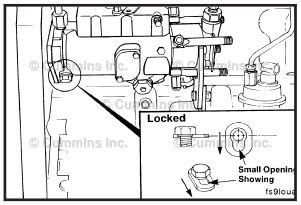
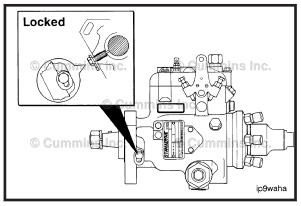
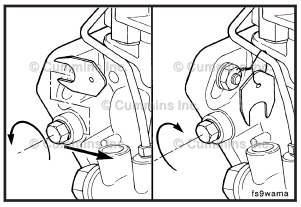
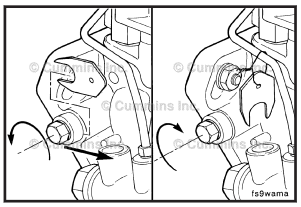
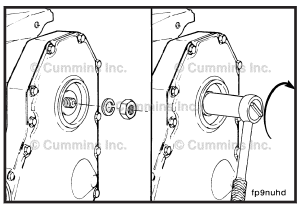
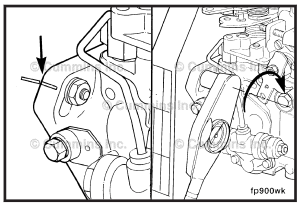


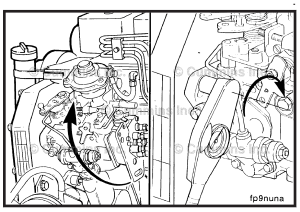
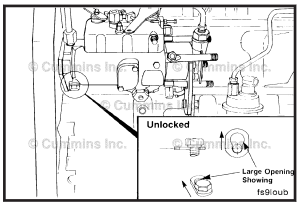
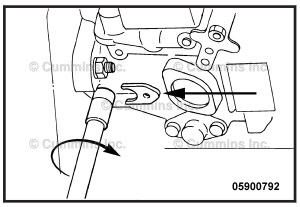
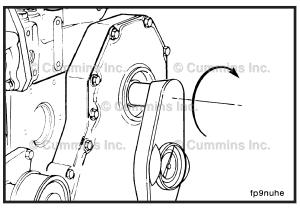
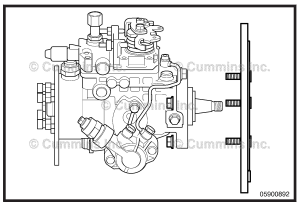
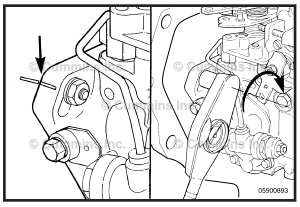
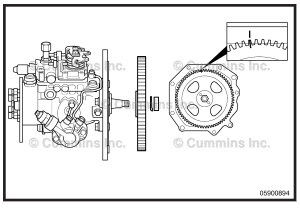
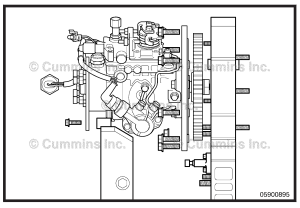
Fuel System - Group 05 - Specifications

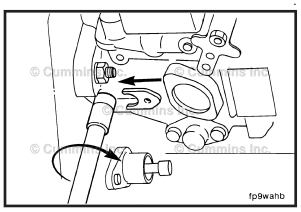
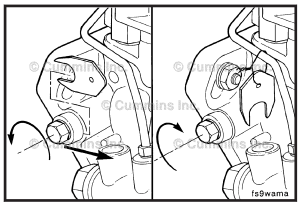
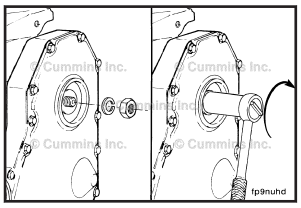
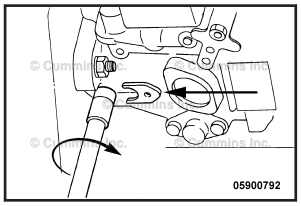
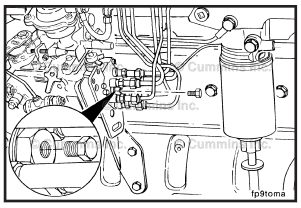
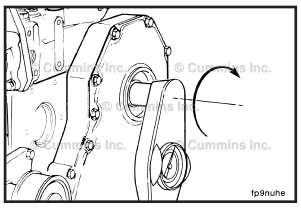
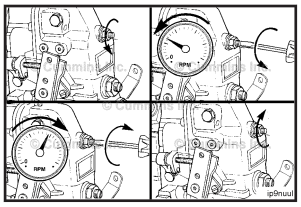
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Fuel Flow (005-011)					
Fuel Transfer Pump Output Pressure at Rated Speed					
High-flow-automotive		172	MIN	25	
Low-flow-industrial		83	MIN	12	
Fuel Transfer Pump Inlet Restriction		13.55 kPa	MAX	4 in Hg	
Fuel Lift Pump (005-045)					
Fuel Lift Pump Inlet Restriction - Clean Fuel Filter		63.5 kPa	MAX	2.5 in Hg	
Fuel Lift Pump Inlet Restriction - Dirty Fuel Filter		100 kPa	MAX	4.0 in Hg	

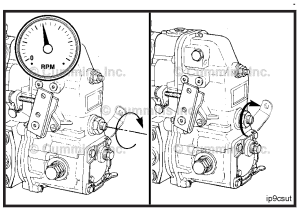
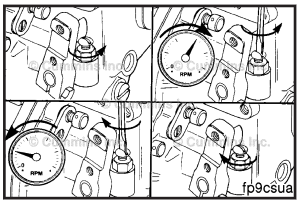
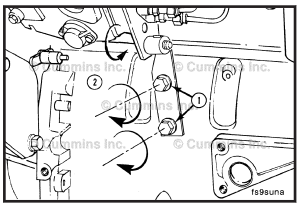
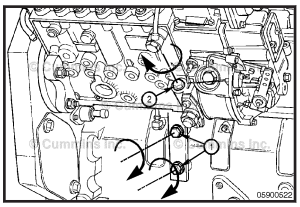
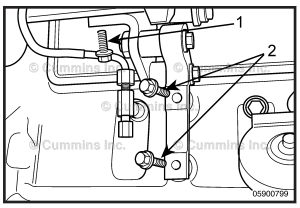
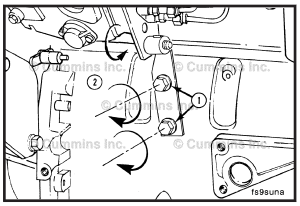
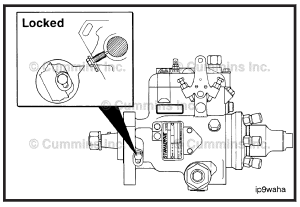
Fuel System - Group 05 - Torque Values

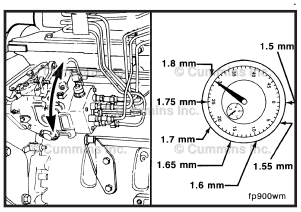
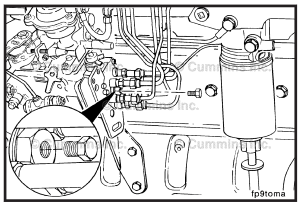
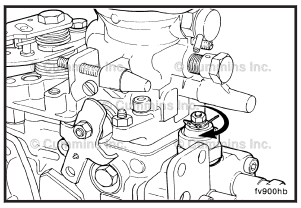
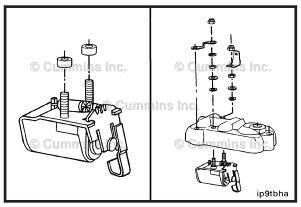
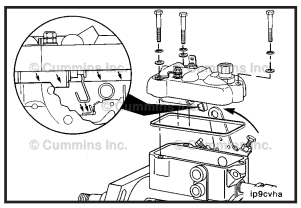
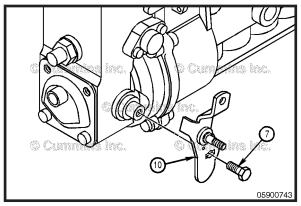
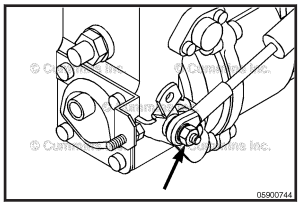
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Engine Fuel Heater, Electric (005-008)				
Fuel Filter Spud		27 N•m	[20 ft-lb]	
Fuel Injection Pumps, In-Line (005-012)				
		43 N•m 32 N•m	[32 ft-lb] [24 ft-lb]	
		10 to 15 N•m	[89 to 133 in-lb]	
		27 N•m	[20 ft-lb]	
Fuel Injection Pump Drive Nut “A” Pump Fuel Injection Pump Drive Nut P3000 And P7100 Fuel Injection Pump Drive Nut Nippondenso		85 N•m 195 N•m 123 N•m	[63 ft-lb] [144 ft-lb] [91 ft-lb]	
Fuel Injection Pump Mounting Bracket Capscrew		24 N•m	[18 ft-lb]	
Vent Screw		9 N•m	[80 in-lb]	

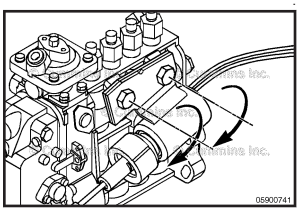
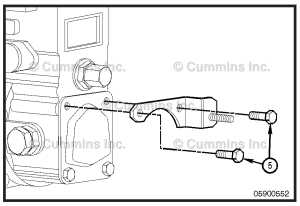
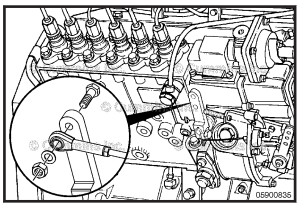
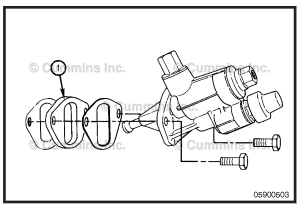
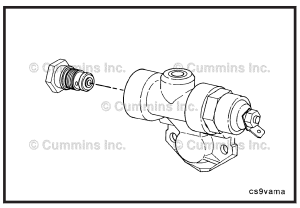
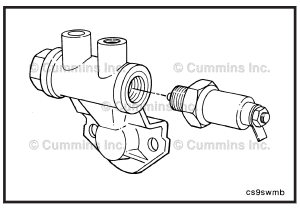
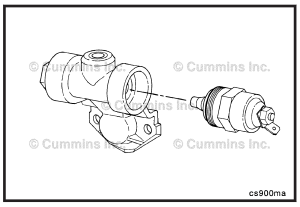
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Fuel Injection Pump, In-Line, Spill Port Timing (005-013)		15 N•m 165 N•m	[133 in-lb] [122 ft-lb]	
Fuel Injection Pump, Rotary (005-014)		7 N•m	[62 in-lb]	
		12 N•m	[106 in-lb]	
		30 N•m	[22 ft-lb]	
		40 N•m	[22 ft-lb]	
		15 to 20 N•m	[132 to 177 in-lb]	
		24 N•m	[18 ft-lb]	

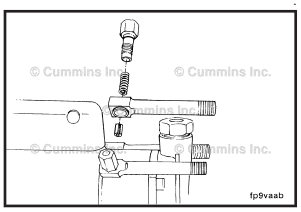
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
		24 N•m	[18 ft-lb]	
		20 N•m	[177 in-lb]	
Boach Fuel Lock Timing Screw Torque		13 N•m	[115 in-lb]	
Bosch® VE (M14-1.5 Nut) Bosch® VE (M12 Nut) Lucas CAV/DPA Stanadyne Delphi DP21		98 N•m 65 N•m 81 N•m 65 N•m 93 N•m	[72 ft-lb] [48 ft-lb] [60 ft-lb] [48 ft-lb] [68 ft-lb]	
Fuel Pump To Fuel Pump Mounting Plate Torque (Rear Gear Train)		18 N•m	[159 in-lb]	
		18 N•m	[159 in-lb]	
Fuel Pump Gear Retaining Nut Torque (Rear Gear Train)		98 N•m	[72 ft-lb]	
Fuel Pump, Mounting Plate, And Gear Assembly To Rear Gear Train M8 Fuel Pump, Mounting Plate, And Gear Assembly To Rear Gear Train M10		18 N•m 30 N•m	[159 in-lb] [266 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Bosch Fuel Pump Special Washer Lockscrew Torque		13 N•m	[115 in-lb]	
Fuel Pump Drive Shaft Lock Screw Torque		30 N•m	[22 ft-lb]	
Fuel Pump Retaining Nut Bosch® VE (M14-1.5 Nut) Fuel Pump Retaining Nut Bosch® VE (M12 Nut) Fuel Pump Retaining Nut Lucas CAV/DPA Fuel Pump Retaining Nut Stanadyne Fuel Pump Retaining Nut Delphi DP21		98 N•m 65 N•m 81 N•m 65 N•m 93 N•m	[72 ft-lb] [48 ft-lb] [60 ft-lb] [48 ft-lb] [68 ft-lb]	
Boach Fuel Lock Timing Screw Torque		13 N•m	[115 in-lb]	
Fuel Pump Timing Gauge Plug Torque		10 N•m	[89 in-lb]	
Fuel Pump Retainign Nut Bosch® VE (M14-1.5 Nut) Fuel Pump Retainign Nut Bosch® VE (M12 Nut) Fuel Pump Retainign Nut Lucas CAV/DPA Fuel Pump Retainign Nut Stanadyne Fuel Pump Retainign Nut Delphi DP21		98 N•m 65 N•m 81 N•m 65 N•m 93 N•m	[72 ft-lb] [48 ft-lb] [60 ft-lb] [48 ft-lb] [68 ft-lb]	
Fuel Pump Idle Speed (005-029)		8 N•m	[71 in-lb]	

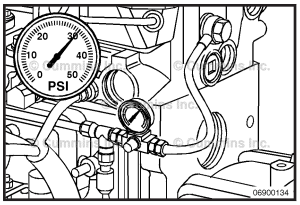
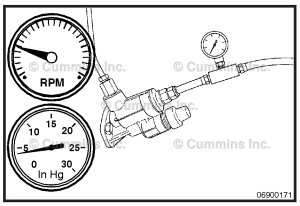
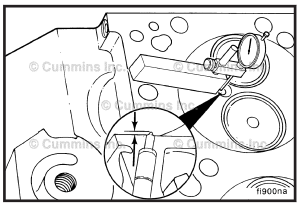
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
		8 N•m	[71 in-lb]	
		8 N•m	[71 in-lb]	
Fuel Pump Support Bracket (005-033)		24 N•m	[18 ft-lb]	
		24 N•m	[18 ft-lb]	
4 Cylinder A Type Bosch In-Line Pump Support Bracket Capscrews		24 N•m	[18 ft-lb]	
		24 N•m	[18 ft-lb]	
Fuel Pump Timing (005-037) Fuel Injection Driveshaft Locking Screw		11.9 N•m	[105 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Flange-Mounting Nut		24 N•m	[18 ft-lb]	
Fuel Pump End Plug		10 N•m	[89 in-lb]	
Fuel Shutoff Valve (005-043) Solenoid Nut		43 N•m	[32 ft-lb]	
Fuel Shutoff Valve Cover Nut		14 N•m	[124 in-lb]	
Fuel Injection Pump Cover Capscrew		4.6 N•m	[41 in-lb]	
Fuel Shutoff Valve Lever Capscrew		9 N•m	[84 in-lb]	
Shutoff Lever Nut		9 N•m	[84 in-lb]	

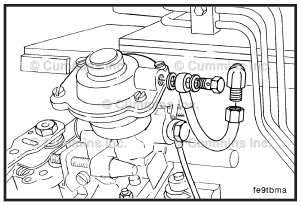
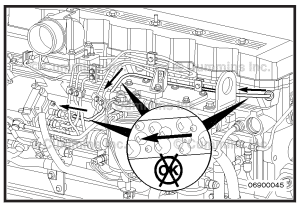
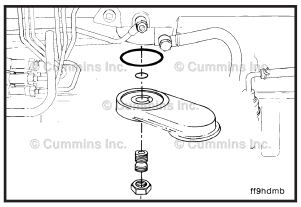
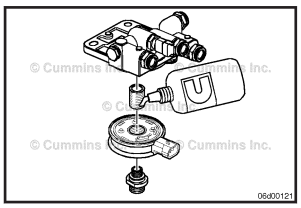
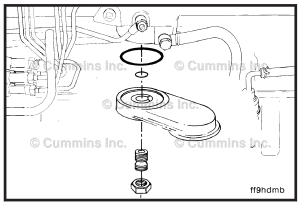
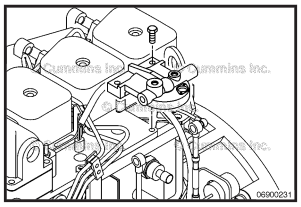
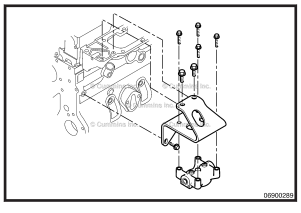
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Solenoid Mounting Capscrew		24 N•m	[212 in-lb]	
Stop Bracket Assembly Capscrew		7 N•m	[60 in-lb]	
Shutoff Lever Nut		9 N•m	[80 in-lb]	
Fuel Lift Pump (005-045)				
10 Mm Fuel Line		24 N•m	[212 in-lb]	
Cold Start Timing Advance System (KSB) Remote (005-046)				
Pressure Relief Valve Torque		13 N•m	[115 in-lb]	
Ksb Electrical Element		22 N•m	[16 ft-lb]	
Ksb Solenoid Torque		22 N•m	[16 ft-lb]	

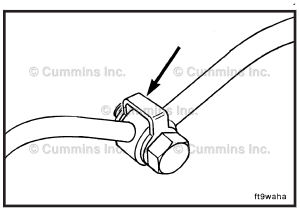
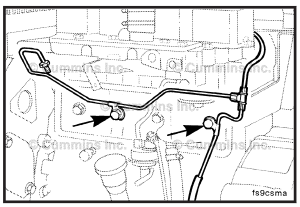
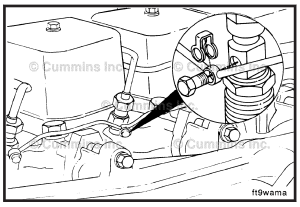
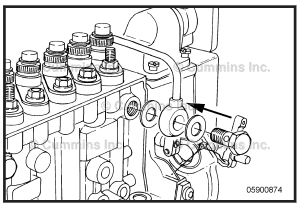
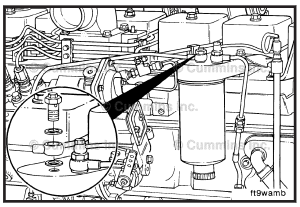
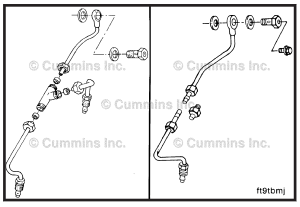
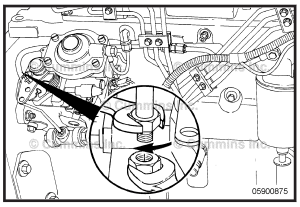
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Fuel Pump Back Leakage Valve (005-059)				
Fuel Pump Back Leakage Valve Torque		30 N•m	[22 ft-lb]	

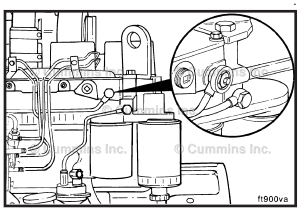
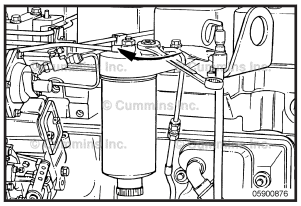
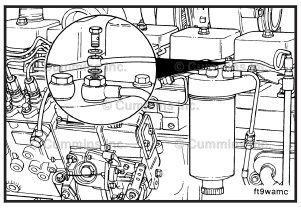
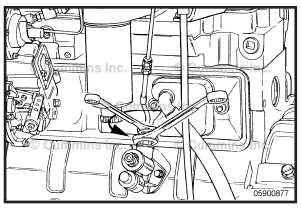
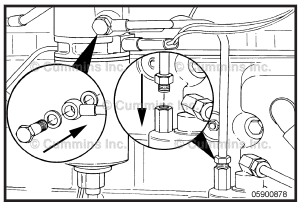
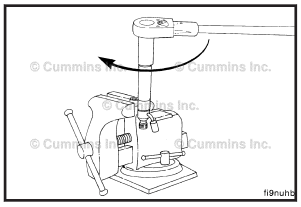
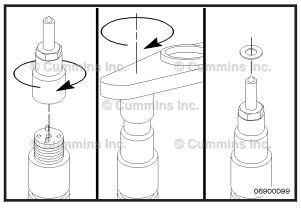
Injectors and Fuel Lines - Group 06 - Specifications

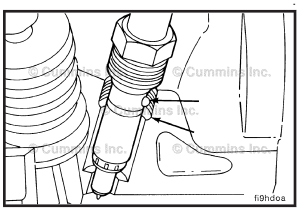
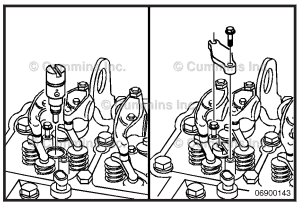
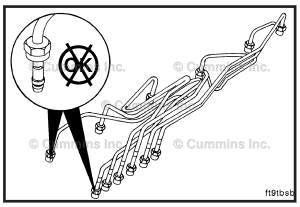
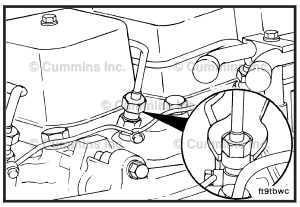
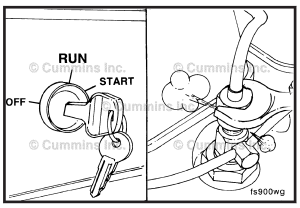
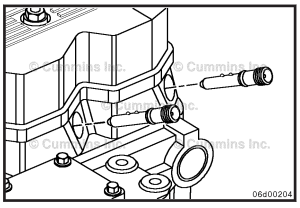
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Fuel Drain Line Restriction (006-012)					
Fuel Drain Line Restriction		518 mm Hg	MAX	20.4 in Hg	
Fuel Inlet Restriction (006-020)					
Allowable Inlet Restriction at Low/High Idle		101.6 mm Hg	MAX	4.0 in Hg	
Injector (006-026)					
Injector Tip Protrusion All Other B Series Pre 1991 Automotive and 1994 Automotive		4.5 mm	MIN	0.1772 in	
		5.5 mm	MAX	0.2165 in	
Injector Tip Protrusion Non-Automotive B Series		3.0 mm	MIN	0.1180 in	
		4.0 mm	MAX	0.1575 in	

Injectors and Fuel Lines - Group 06 - Torque Values

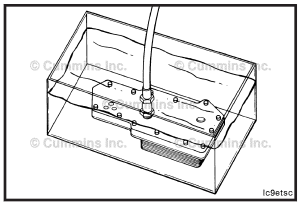
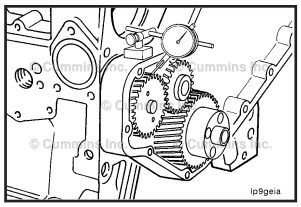
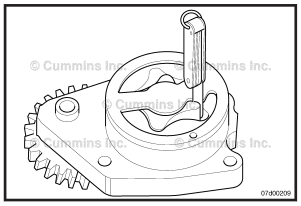
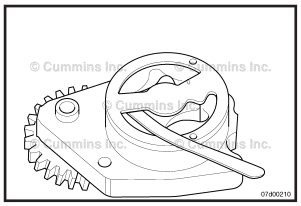
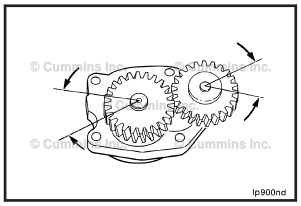
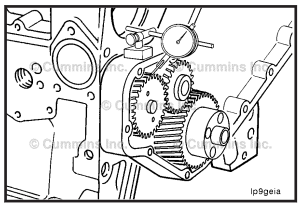
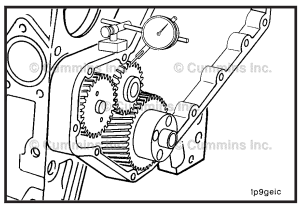
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
AFC Air Tube (006-001)				
Afc Tube		9 N•m	[80 in-lb]	
Air in Fuel (006-003)		24 N•m	[212 in-lb]	
Fuel Filter (Spin-On Type) (006-015)				
Fuel Filter Adapter		32 N•m	[24 ft-lb]	
Fuel Filter Head (006-017)				
Fuel Filter Adapter And Fuel Heater Assembly Torque.		27 N•m	[20 ft-lb]	
Dual Fuel Filter Adapter Torque.		32 N•m	[24 ft-lb]	
Fuel Filter Head (Front Gear Train - Engine Mounted) Capscrew Torque.		24 N•m	[18 ft-lb]	
Fuel Filter Head To Fuel Filter Head Bracket Mounting Capscrew Torque (Rear Gear Train) M8		18 N•m	[14 ft-lb]	
Fuel Filter Head Mounting Capscrews Torque (Rear Gear Train) M8		23 N•m	[17 ft-lb]	
Fuel Filter Head Mounting Capscrews Torque (Rear Gear Train) M10		45 N•m	[33 ft-lb]	

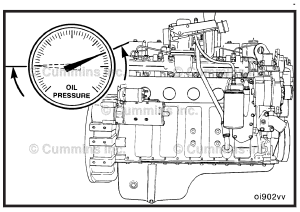
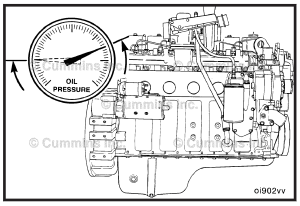
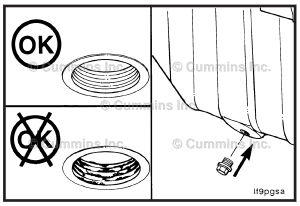
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Fuel Manifold (Drain) (006-021)				
Banjo Fitting Screw		9 N•m	[80 in-lb]	
Fuel Drain Clamp Capscrew		24 N•m	[18 ft-lb]	
Injector Banjo		9 N•m	[80 in-lb]	
Fuel Filter Head		13 N•m	[115 in-lb]	
Fuel Supply Lines (006-024)				
Bosch In-Line Fuel Pump Supply Line Torque		32 N•m	[24 ft-lb]	
Fuel Filter Head Banjo Capscrew Torque		24 N•m	[18 ft-lb]	
Fuel Supply Line To Lucas Cav Injection Pump Fitting Torque		24 N•m	[18 ft-lb]	
Fuel Line To Bosch Injection Pump Fitting Torque		32 N•m	[24 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Distributor-Type Pump Bleed Screw Banjo Fitting Torque		24 N•m	[18 ft-lb]	
Ditributor-Type Fuel Pump Fuel Line To Filter Head Torque		24 N•m	[18 ft-lb]	
Fuel Drain Manifold To Filter Head Torque		13 N•m	[10 ft-lb]	
Bosch In-Line Pump Fuel Line To Transfer Pump Torque		24 N•m	[18 ft-lb]	
Distributor-Type Pump Fuel Line (Transfer Pump To Fuel Filter) Torque		24 N•m	[18 ft-lb]	
Injector (006-026) Nozzle Retaining Nut		30 N•m	[22 ft-lb]	
		47 N•m	[35 ft-lb]	

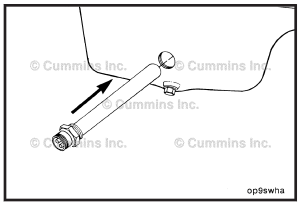
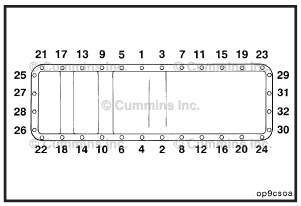
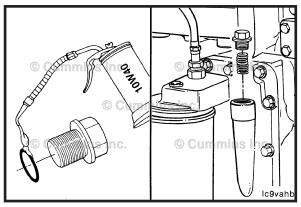
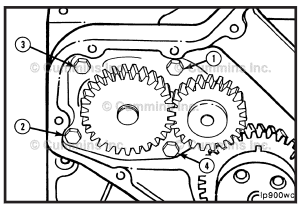
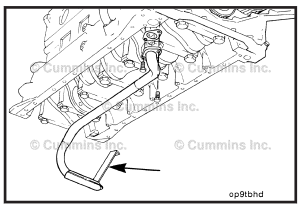
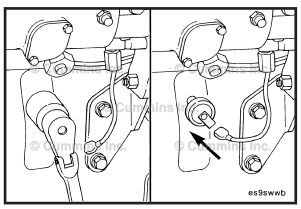
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Injector Hold-Down Capscrew		60 N•m	[44 ft-lb]	
Injector Hold-Down		10 N•m	[89 in-lb]	
Injector Supply Lines (High Pressure) (006-051)				
Injector Supply Lines, Pump Side Fitting Torque		24 N•m 38 N•m	[18 ft-lb] [28 ft-lb]	
High-Pressure Fuel Lines To Injector Torque		38 N•m	[28 ft-lb]	
High Pressure Fuel Line Cylinder Head Fitting Torque		38 N•m	[28 ft-lb]	
Fuel Connector (Head Mounted) (006-052)				
Fuel Connector (Cylinder Head-Mounted) Fitting Fuel Connector (Cylinder Head-Mounted)		50 N•m	[37 ft-lb]	

Lubricating Oil System - Group 07 - Specifications

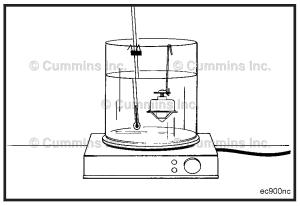
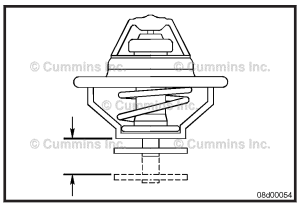
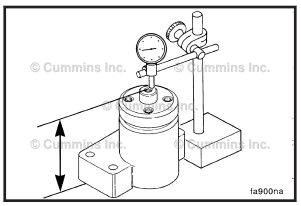
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Lubricating Oil Cooler (007-003)					
Air Pressure Test		449 kPa	MIN	65 psi	
		518 kPa	MAX	75 psi	
Lubricating Oil Pump (007-031)					
Rear Gear Train Lubricating Oil Pump Gear Backlash Limits		0.170 mm	MIN	0.007 in	
		0.300 mm	MAX	0.012 in	
Front Gear Train Lubricating Oil Pump Gear Backlash Limits		0.076 mm	MIN	0.003 in	
		0.330 mm	MAX	0.013 in	
Tip Limit		0.178 mm	MAX	0.007 in	
Gerotor Drive/Planetary to Port Plate Limit		0.127 mm	MAX	0.005 in	
Rear Gear Train Backlash Limits (used pump)		0.170 mm	MIN	0.007 in	
		0.300 mm	MAX	0.012 in	
Front Gear Train Backlash Limits (used pump)		0.076 mm	MIN	0.003 in	
		0.330 mm	MAX	0.013 in	
Oil Pump Driven Gear Backlash Limits (new pump)					
Rear Gear Train		0.300	MIN	0.011	
		0.500	MAX	0.019	
Front Gear Train		0.076	MIN	0.003	
		0.330	MAX	0.013	
Oil Pump Idler Gear Backlash Limits (new pump)					
Rear Gear Train		0.150	MIN	0.005	
		0.250	MAX	0.009	
Front Gear Train		0.076	MIN	0.003	
		0.330	MAX	0.013	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Lubricating Oil System (007-037)					
Oil Pressure at Low Idle		69 kPa	MIN	10 psi	
Oil Pressure at Rated Engine Speed		207 kPa	MIN	30 psi	
Steel Oil Pan Drain Plug Torque					
M18		60	MIN	44	
M22		80	MIN	59	
Cast Aluminum Oil Pan Drain Plug Torque					
M22		60	MIN	44	

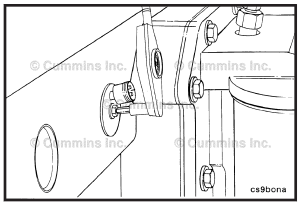
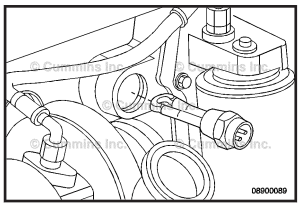
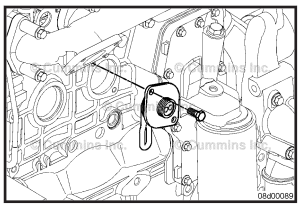
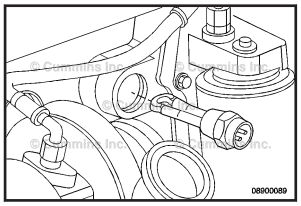
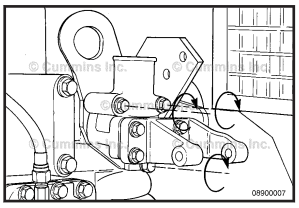
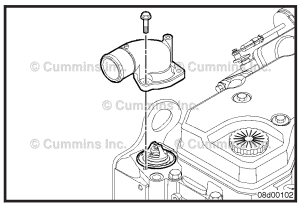
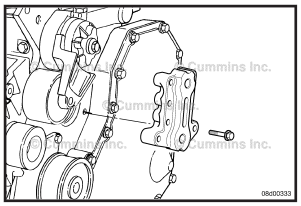
Lubricating Oil System - Group 07 - Torque Values

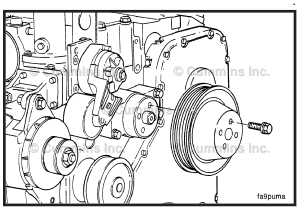
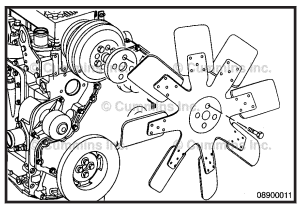
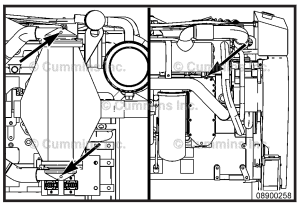
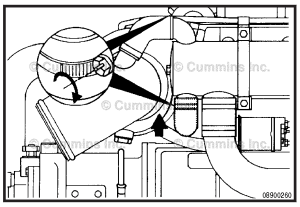
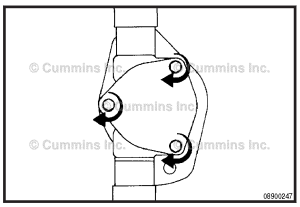
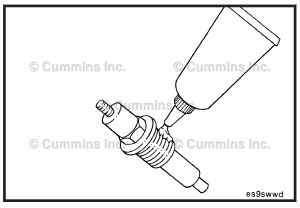
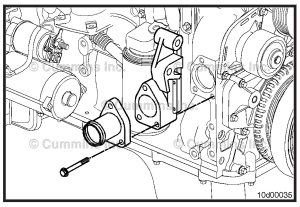
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Engine Oil Heater (007-001)				
Heater Element		80 N•m	[59 ft-lb]	
Lubricating Oil Pan (007-025)				
		24 N•m	[212 in-lb]	
Lubricating Oil Pressure Regulator (Main Rifle) (007-029)				
Lubricating Oil Pressure Regulator Torque		80 N•m	[59 ft-lb]	
Lubricating Oil Pump (007-031)				
Lubricating Oil Pump Capscrews Initial		8 N•m	[70 in-lb]	
Torque		24 N•m	[212 in-lb]	
Lubricating Oil Suction Tube (Block-Mounted) (007-035)				
Suction Tube Capscrews		24 N•m	[212 in-lb]	
Lubricating Oil Pressure Sensor, OEM (007-052)				
Lubricating Oil Pressure Switch Torque		16 N•m	[142 in-lb]	
(Installed Into Cast Iron)		10 N•m	[89 in-lb]	
Lubricating Oil Pressure Switch Torque (Installed Into Aluminum)				

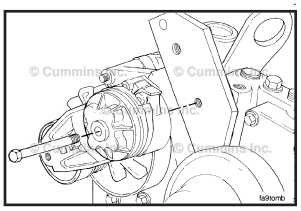
Cooling System - Group 08 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Coolant Thermostat (008-013)					
Flow Valve and Flange Clearance		6.6 mm	MIN	0.26 in	
Thermostat Opening Temperatures - Industrial Engines					
Initial Opening Temperature		87	MIN	188	
		89	MAX	192	
Fully Opened Temperature		96	MAX	205	
Fan Hub, Belt Driven (008-036)					
Fan Hub End Play		0.15 mm	MAX	0.006 in	

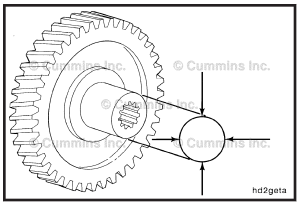
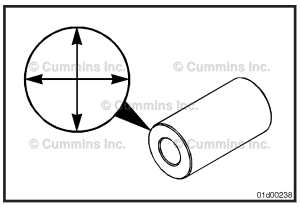
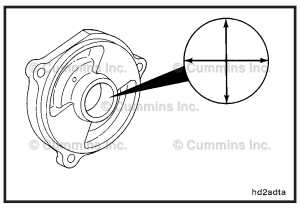
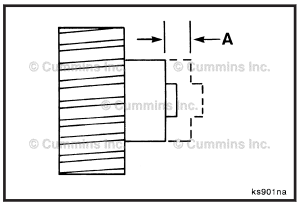
Cooling System - Group 08 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Coolant Heater (008-011)				
Cylinder Block Water Heater Torque Minimum:		1.3 N•m	[12 in-lb]	
Cylinder Block Water Heater Torque Maximum:		2.8 N•m	[25 in-lb]	
Coolant Heater Mounting (Threaded)		55 N•m	[41 ft-lb]	
Coolant Heater Retaining Capcsrews (Flange-Mounted)		24 N•m	[212 in-lb]	
Coolant Heater Mounting (Threaded)		55 N•m	[41 ft-lb]	
Coolant Thermostat (008-013)				
Thermostat Housing Capscrew		24 N•m	[18 ft-lb]	
Water Outlet Tube Mounting Capscrews		10 N•m	[89 in-lb]	
Fan Clutch, Electric (008-026)				
Fan Clutch Support Bracket Mounting Capscew Torque		33 N•m	[24 ft-lb]	

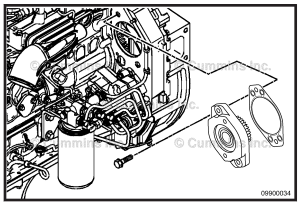
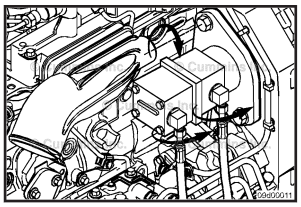
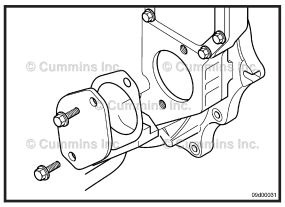
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Fan Spacer and Pulley (008-039)				
Engine Driven Cooling Fan Pulley Mounting Capscrews M6		10 N•m	[89 in-lb]	
		43 N•m	[32 ft-lb]	
Engine Driven Cooling Fan Pulley Mounting Capscrews M10		77 N•m	[57 ft-lb]	
Engine Driven Cooling Fan Pulley Mounting Capscrews M12				
Engine Driven Cooling Fan Mounting Capscrews M6		10 N•m	[89 in-lb]	
		43 N•m	[32 ft-lb]	
Engine Driven Cooling Fan Mounting Capscrews M10		77 N•m	[57 ft-lb]	
Engine Driven Cooling Fan Mounting Capscrews M12				
Heat Exchanger (008-053)				
Zinc Plugs		22 N•m	[196 in-lb]	
Seawater Inlet And Outlet Connections		5 N•m	[44 in-lb]	
Sea Water Pump (008-057)		24 N•m	[212 in-lb]	
Coolant Temperature Sensor (008-070)				
Temperature Sensor Torque (Installed Into Cast Iron)		50 N•m	[37 ft-lb]	
		30 N•m	[22 ft-lb]	
Temperature Sensor Torque (Installed Into Aluminum)				
Water Inlet Connection (008-082)				
Water Inlet Connection M10		43 N•m	[32 ft-lb]	
Water Inlet Connection M12		80 N•m	[59 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Cooling Fan Belt Tensioner (008-087)				
Belt Tensioner Capscrew		43 N•m	[32 ft-lb]	

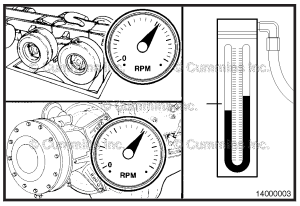
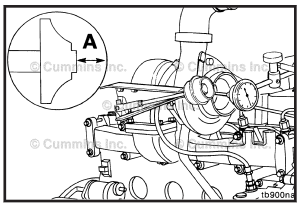
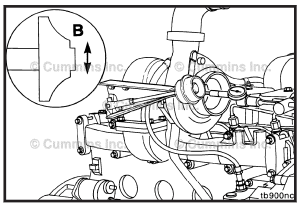
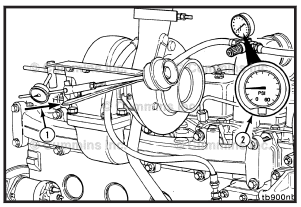
Drive Units - Group 09 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Accessory Drive (009-001)					
Accessory Drive Gear Bore Inside Diameter (Accessory Drive Adapter)		38.920 mm	MIN	1.5323 in	
		38.945 mm	MAX	1.5333 in	
Accessory Drive Shaft Outside Diameter (Accessory Drive Adapter)		39.008 mm	MIN	1.5357 in	
		39.020 mm	MAX	1.5362 in	
Bearing Bore Inside Diameter (Accessory Drive Adapter)		67.759 mm	MIN	2.6755 in	
		67.983 mm	MAX	2.6765 in	
Accessory Drive Gear End Play		0.5 mm	MIN	0.020 in	

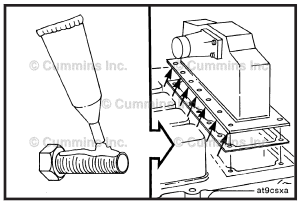
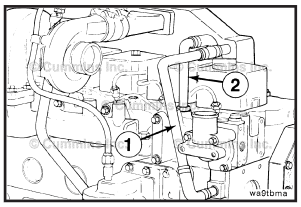
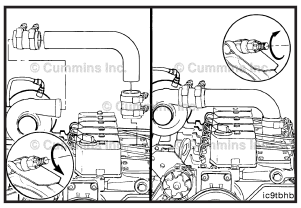
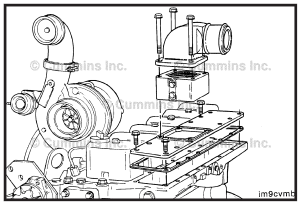
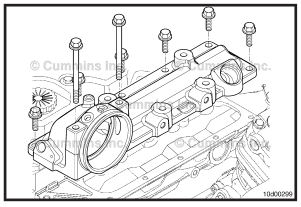
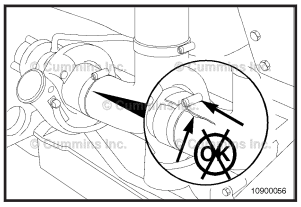
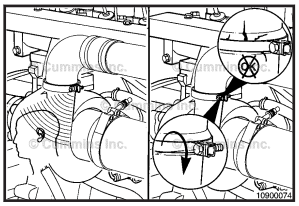
Drive Units - Group 09 - Torque Values

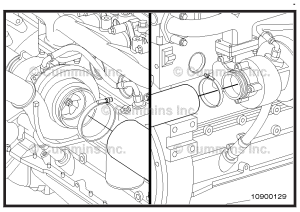
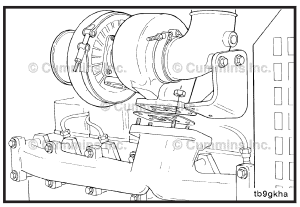
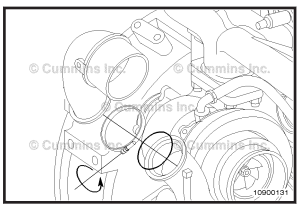
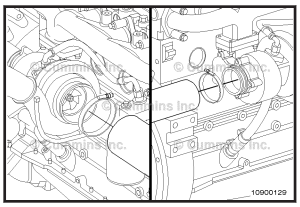
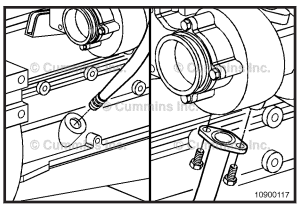
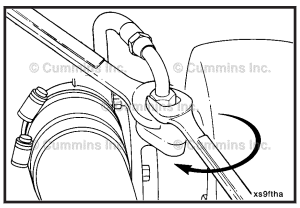
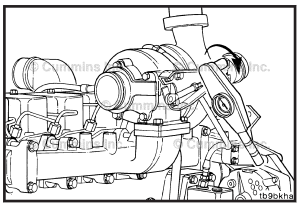
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Accessory Drive (009-001)				
Accessory Drive To Rear Gear Housing Capscrews		62 N•m	[46 ft-lb]	
Hydraulic Pump Drive (009-016)				
Mounting Capscrews		62 N•m	[46 ft-lb]	
Accessory Drive Cover (009-039)				
Accessory Drive Cover Capscrews		50 N•m	[40 ft-lb]	

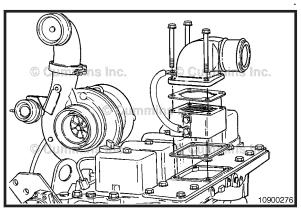
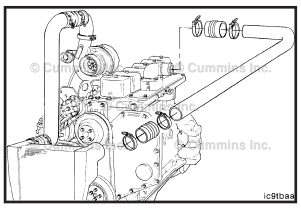
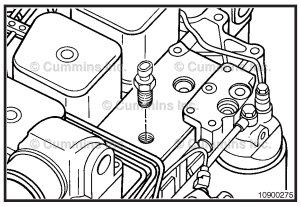
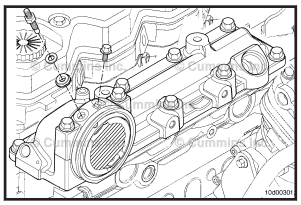
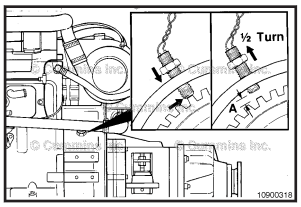
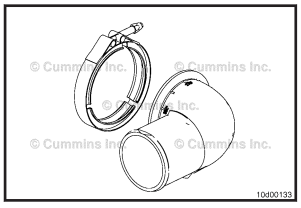
Air Intake System - Group 10 - Specifications

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Air Intake Restriction (010-031)					
Inlet Air Restriction		635 mm H_2O	MAX	25 in H_2O	
Turbocharger (010-033)					
Axial Clearance		0.038 mm 0.093 mm	MIN MAX	0.0015 in 0.0037 in	
Radial Bearing Clearance		0.30 mm 0.46 mm	MIN MAX	0.012 in 0.018 in	
Turbocharger Wastegate Actuator (010-050)					
Wastegate Actuator Travel Measurement		0.033 mm 1.27 mm	MIN MAX	0.013 in 0.050 in	

Air Intake System - Group 10 - Torque Values

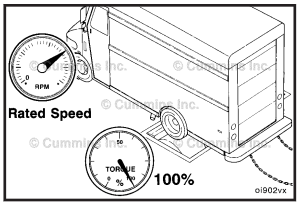
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Aftercooler (010-001)				
Aftercooler Mounting Capscrew		24 N•m	[18 ft-lb]	
		8 N•m	[71 in-lb]	
Air Crossover (010-019)				
Air Crossover Tube Clamp Torque		8 N•m	[71 in-lb]	
Air Intake Manifold (010-023)				
Intake Manifold Cover		24 N•m	[18 ft-lb]	
Air Intake Manifold Mounting Capscrews		24 N•m	[18 ft-lb]	
Air Leaks, Air Intake and Exhaust Systems (010-024)				
Intake Air Piping Clamp		8 N•m	[71 in-lb]	
		8 N•m	[71 in-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Turbocharger (010-033)				
Intake Pipe Clamp		8 N•m 8 N•m	[71 in-lb] [71 in-lb]	
Turbocharger Mounting Capscrew		45 N•m	[33 ft-lb]	
Turbocharger Compressor Outlet Elbow V-Band Clamp		8 N•m	[71 in-lb]	
Intake Pipe Clamp		8 N•m 8 N•m	[71 in-lb] [71 in-lb]	
Turbocharger Oil Drain Line (010-045)				
Turbocharger Drain Line		24 N•m	[18 ft-lb]	
Turbocharger Oil Supply Line (010-046)				
Turbocharger Oil Supply Line Torque		24 N•m	[212 in-lb]	
Turbocharger Wastegate Actuator (010-050)				
Actuator Mounting Bracket Mounting Capscrew		4.5 N•m	[40 in-lb]	

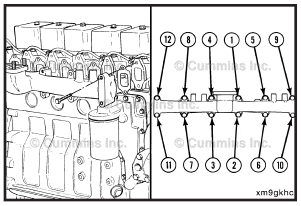
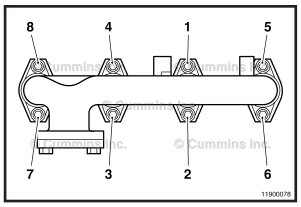
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Air Intake Manifold Heater (010-072)				
Grid Heater Mounting Capscrews		24 N•m	[18 ft-lb]	
Air Intake Clamp Capscrews		8 N•m	[71 in-lb]	
Temperature Sensor		35 N•m	[26 ft-lb]	
Intake Manifold Air Heater Element (010-124)				
Air Intake Manifold Heater Element		8 N•m	[71 in-lb]	
Elecrtical Supply Terminal		8 N•m	[71 in-lb]	
Intake Manifold Air Heater Speed Sensor (010-127)				
Engine Speed Sensor Locknut		34 to 47 N•m	[25 to 35 ft-lb]	
Air Intake Connection Adapter (010-131)				
Two Piece Air Intake Connection Adapter V Band Clamp		8 N•m	[71 in-lb]	

Exhaust System - Group 11 - Specifications

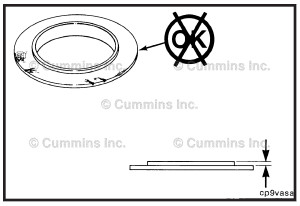
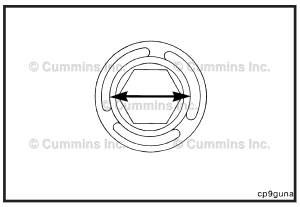
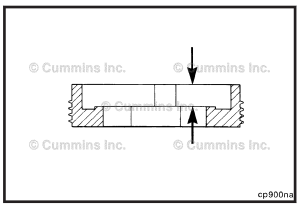
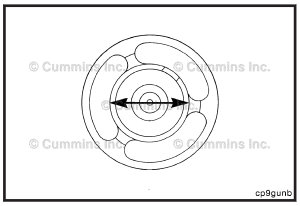
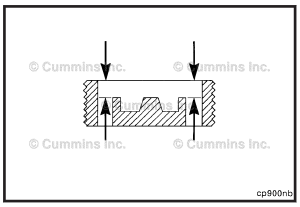
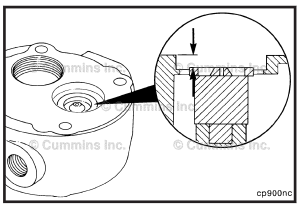
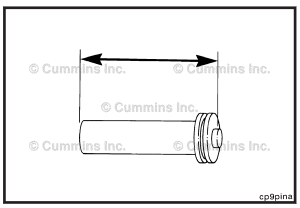
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Exhaust Restriction (011-009)				
Exhaust Restriction				
Industrial		76	MAX	3
1991 EPA Certification		114	MAX	4.5
1994 EPA Certification with Oxidation Catalyst		152	MAX	6



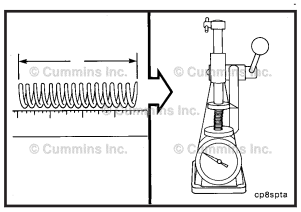
Exhaust System - Group 11 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Exhaust Manifold, Dry (011-007)				
Exhaust Manifold Mounting Capscrew Torque - 6 Cylinder Engines		43 N•m	[32 ft-lb]	
Exhaust Manifold Mounting Capscrew Torque - 4 Cylinder Engines		43 N•m	[32 ft-lb]	

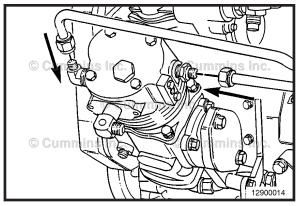
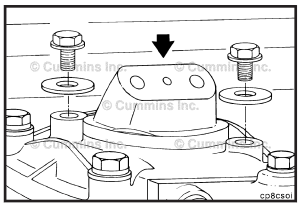
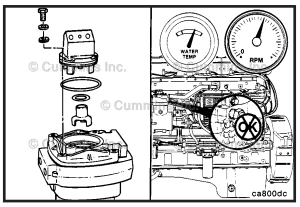
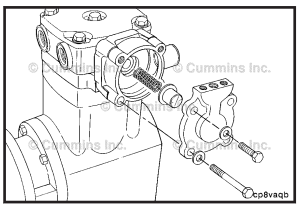
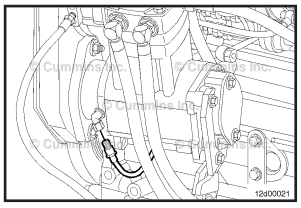
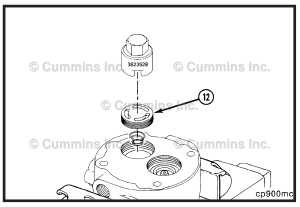
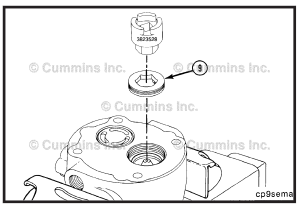
Compressed Air System - Group 12 - Specifications

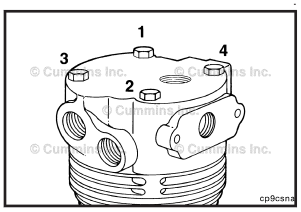
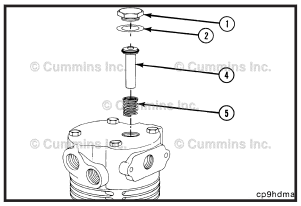
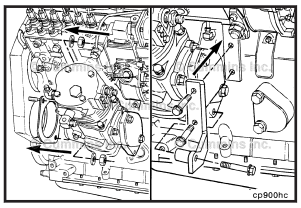
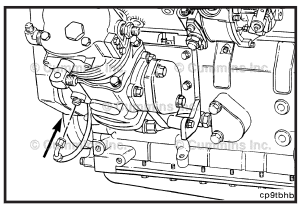
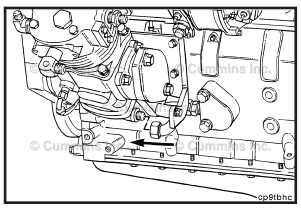
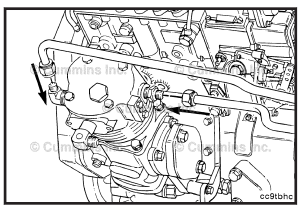
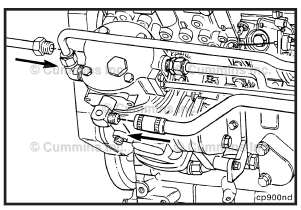
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Air Compressor Cylinder Head (Holset® SS191 Model) (012-101)					
Intake Valve Seat		0.597 mm 0.673 mm	MIN MAX	0.0235 in 0.0265 in	
Valve Guide Diameter		25.53 mm 25.65 mm	MIN MAX	1.005 in 1.010 in	
Set Height		4.01 mm 4.11 mm	MIN MAX	0.158 in 0.162 in	
Valve Guide Diameter		25.53 mm 25.65 mm	MIN MAX	1.005 in 1.010 in	
Stop Depth		3.63 mm 3.78 mm	MIN MAX	0.143 in 0.149 in	
Stop Height		4.42 mm 4.70 mm	MIN MAX	0.174 in 0.185 in	
Pin Length		40.51 mm 40.72 mm	MIN MAX	1.595 in 1.603 in	

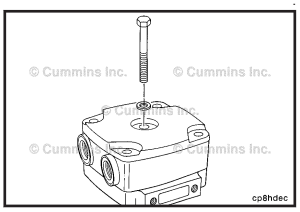
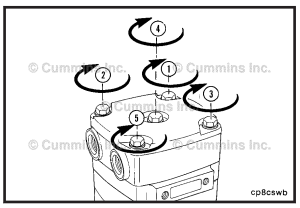
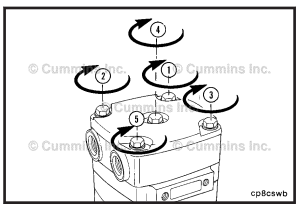
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Air Compressor Cylinder Head (Holset® QE Models) (012-104)				
Force Specification		10.4 kg	MIN	23 lb
		12.5 kg	MAX	27 lb



Compressed Air System - Group 12 - Torque Values

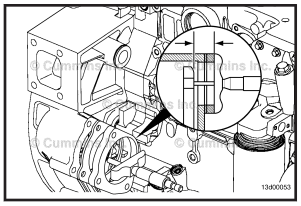
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Air Compressor Coolant Lines (012-004)				
Coolant Lines		24 N•m	[18 ft-lb]	
Air Compressor Pin Bore Wear (012-010)		14 N•m	[124 in-lb]	
Air Compressor Unloader and Valve Assembly (012-013)				
Holset® Ss, E-Type, And St Unloader		14 N•m	[124 in-lb]	
Holset® Qe Unloader		27 N•m	[20 ft-lb]	
Air Compressor (012-014)		15 N•m	[133 in-lb]	
Air Compressor Cylinder Head (Holset® SS191 Model) (012-101)				
Air Compressor Inlet Valve Cage Torque		108 N•m	[80 ft-lb]	
Exhaust Valve Seat		108 N•m	[80 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Air Compressor Head Capscrew Torque		30 N•m Tighten the capscrews again, in the sequence shown. 41 N•m	[22 ft-lb] [30 ft-lb]	
Air Compressor Cover		41 N•m	[30 ft-lb]	
Air Compressor Mounting Nuts Air Compressor Support Capscrews		77 N•m 24 N•m	[57 ft-lb] [18 ft-lb]	
Air Compressor Oil Supply Line		15 N•m	[133 in-lb]	
Air Compressor Oil Drain Line		24 N•m	[18 ft-lb]	
Air Compressor Support Bracket		24 N•m	[18 ft-lb]	
Air Compressor Inlet And Outlet Torque Inlet Air Compressor Inlet And Outlet Torque *Outlet		5 N•m 24 N•m	[44 in-lb] [18 ft-lb]	

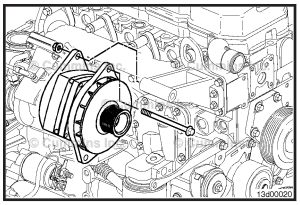
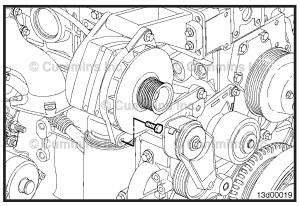
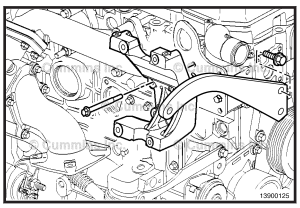
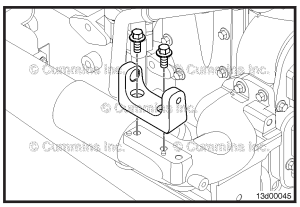
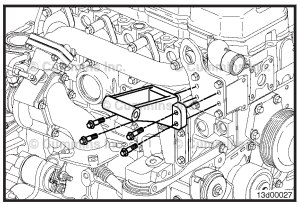
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Air Compressor Cylinder Head (Holset® QE Models) (012-104)		14 N•m	[124 in-lb]	
Holset Qe, Non-European Cylinder Head		28 N•m	[21 ft-lb]	
Holset Qe, European Cylinder Head		28 N•m	[21 ft-lb]	

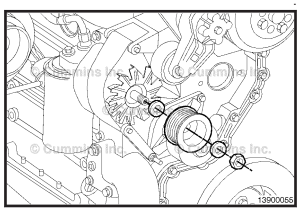
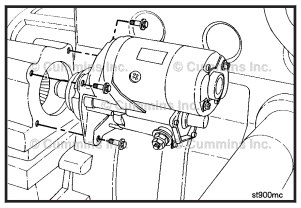
Electrical Equipment - Group 13 - Specifications

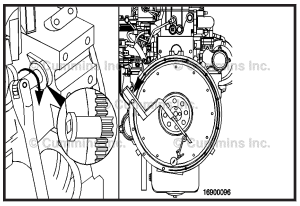
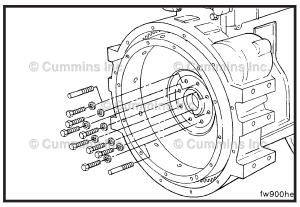
Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.
Starting Motor (013-020)				
Starting Motor Spacing		49.28 mm	MIN	1.94 in
		52.32 mm	MAX	2.06 in



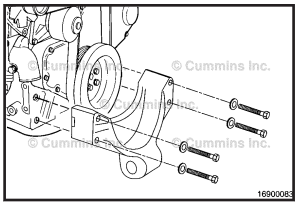
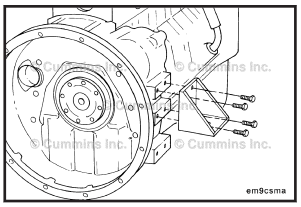
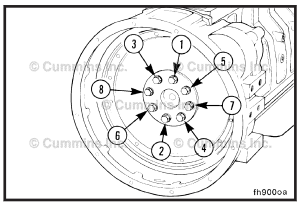
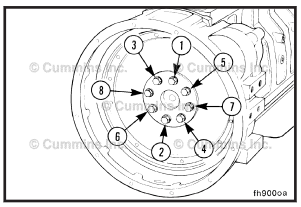
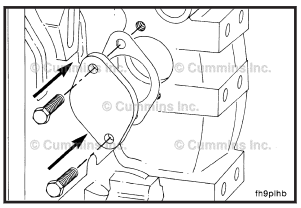
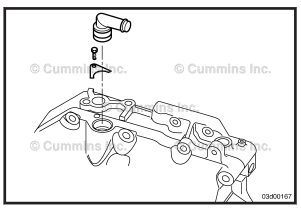
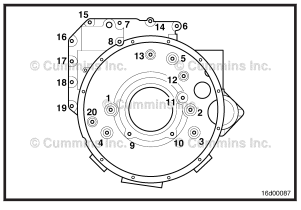
Electrical Equipment - Group 13 - Torque Values

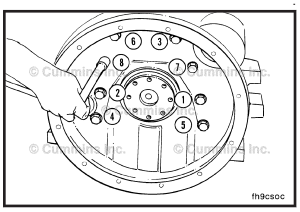
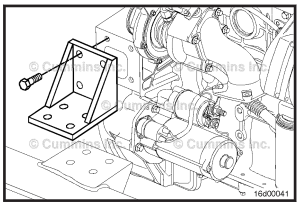
Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Alternator (013-001)				
Alternator Capscrew		40 N•m	[30 ft-lb]	
Alternator Link Capscrew		24 N•m	[212 in-lb]	
D+		2.7 to 9.8 N•m 7.5 to 8.0 N•m	[23.9 to 86.7 in-lb] [66.4 to 70.8 in-lb]	
Alternator Bracket (013-003)				
Spool Mount Alternator Bracket Mounting Capscrew Torque M8 Spool Mount Alternator Bracket Mounting Capscrew Torque M10		24 N•m 43 N•m	[18 ft-lb] [32 ft-lb]	
Spool Mount Alternator Mounting Capscrew Torque		54 N•m	[40 ft-lb]	
Hinge Mount Alternator Bracket Mounting Capscrew Torque M8 Hinge Mount Alternator Bracket Mounting Capscrew Torque M10		24 N•m 43 N•m	[18 ft-lb] [32 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Alternator Pulley (013-006)				
Alternator Pulley Mounting Fastener Torque		70 N•m	[52 ft-lb]	
Bosch® K1		65 N•m	[48 ft-lb]	
Alternator Pulley Mounting Fastener Torque		65 N•m	[48 ft-lb]	
Bosch® NCB1		95 N•m	[70 ft-lb]	
Alternator Pulley Mounting Fastener Torque		102 N•m	[75 ft-lb]	
Bosch® NCB2		102 N•m	[75 ft-lb]	
Alternator Pulley Mounting Fastener Torque		102 N•m	[75 ft-lb]	
Delco 11 SI				
Alternator Pulley Mounting Fastener Torque				
Delco 20 SI				
Alternator Pulley Mounting Fastener Torque				
Delco 24 SI				
Alternator Pulley Mounting Fastener Torque				
Delco 33 SI				
Starting Motor (013-020)				
Starting Motor Mounting Capscrews		43 N•m	[32 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric		U.S.	
Mounting Adaptations - Group 16 - Specifications					
Flywheel (016-005)					
Flywheel Total Indicator Reading		0.127 mm	MAX	0.0050 in	
Flywheel Bore Runout		0.127 mm	MAX	0.005 in	

Mounting Adaptations - Group 16 - Torque Values

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Engine Support Bracket, Front (016-002)				
Front Engine Support Bracket Mounting Capscrews		68 N•m	[50 ft-lb]	
Engine Support Bracket, Rear (016-003)		71 N•m	[52 ft-lb]	
Flexplate (016-004)				
Rear Gear Train Engines Flexplate Capscrews	1	30 N•m	[22 ft-lb]	
Rear Gear Train Engines Flexplate Capscrews	2	Plus 60-degree turn 137 N•m	[101 ft-lb]	
Front Gear Train Engines Flexplate Capscrews Front Gear Train Engines Flexplate Capscrews				
Flywheel (016-005)				
Rear Gear Train Engine Flywheel Capscrew Torque Rear Gear Train Engines Flywheel Capscrews	1	30 N•m	[22 ft-lb]	
	2	Plus 60-degree turn 137 N•m	[101 ft-lb]	
Front Gear Train Engine Flywheel Capscrew Torque Front Gear Train Engines Flywheel Capscrews				
Flywheel Housing (016-006)				
Access Cover Capscrews		24 N•m	[18 ft-lb]	
Closed Crancase Ventilation Tube Adapter Plate Mounting Capscrew Torque		24 N•m	[18 ft-lb]	
Flywheel Housing Capscrew M10		49 N•m	[36 ft-lb]	
Flywheel Housing Capscrew M12		85 N•m	[63 ft-lb]	

Component or Assembly (Procedure)	Ref.No./ Steps	Metric	U.S.	
Marine Flywheel Housing Capscrews		77 N•m	[57 ft-lb]	
Rear Engine Support Bracket Capscrews		77 N•m	[57 ft-lb]	

General Engine

Specifications

Automotive Applications

Horsepower
B3.9, B5.9.....Refer to engine dataplate
Bore
B3.9, B5.9.....102 mm [4.02 in]
Stroke
B3.9, B5.9.....120 mm [4.72 in]
Displacement
B3.9.....3.9 liters [238 C.I.D.]
B5.9.....5.9 liters [360 C.I.D.]
Engine Weight (dry) Less Flywheel and Electric Components
B3.9.....308 to 329 kg [679 to 725 lb]
B5.9.....388 to 411 kg [855 to 906 lb]
Firing Order
B3.9.....1-3-4-2
B5.9.....1-5-3-6-2-4
Valve Clearance
B3.9 and B5.9
Intake.....0.25 mm [0.010 in]
Exhaust.....0.51 mm [0.020 in]
Compression Ratio
B3.9.....(rotary pump) 17.6:1
B5.9.....(in-line pump) 17.9:1
Crankshaft Rotation (viewed from the front of the engine)
B3.9 and B5.9..... **Clockwise**
Aspiration
Turbocharged
B3.9.....Yes
B5.9.....Yes
Aspiration
Charge Air Cooled
B3.9.....Yes
B5.9.....Yes

Industrial Applications

Horsepower..... Refer to engine dataplate
Engine Weight (Dry) Less Flywheel and Electronics
B4.5 (naturally aspirated).....326 kg [721 lb]
B4.5 and B3.9 (turbocharged).....338 kg [745 lb]
B5.9.....432 kg [952 lb]
Compression Ratio.....18:1
Bore
B3.9 and B5.9.....102 mm [4.02 in]
B4.5.....107 mm [4.21 in]
Stroke
B4.5.....138 mm [5.42 in]
B4.5 RGT.....124 mm [4.88 in]
B3.9 and B5.9.....120 mm [4.72 in]
Displacement
B3.9.....3.9 liters [238 C.I.D.]
B4.5.....4.5 liters [275 C.I.D.]
B5.9.....5.9 liters [359 C.I.D.]
Firing Order
B3.9 and B4.5.....1-3-4-2
B5.9.....1-5-3-6-2-4
Valve Clearance
Intake.....0.25 mm [0.010 in]
Exhaust.....0.51 mm [0.020 in]
Crankshaft Rotation (viewed from the front of the engine)..... **Clockwise**
Engine Weight (Dry) Less Flywheel and Electronics

B4.5 (naturally aspirated).....326 kg [721 lb]
B4.5 and B3.9 (turbocharged).....338 kg [745 lb]
B5.9.....432 kg [952 lb]
Compression Ratio.....18:1
Bore
B3.9, B4.5, and B5.9.....102 mm [4.02 in]
Stroke
B4.5.....138 mm [5.42 in]
B3.9 and B5.9.....120 mm [4.72 in]
Displacement
B3.9.....3.9 liters [238 C.I.D.]
B4.5.....4.5 liters [275 C.I.D.]
B5.9.....5.9 liters [359 C.I.D.]
Firing Order
B3.9 and B4.5.....1-3-4-2
B5.9.....1-5-3-6-2-4
Valve Clearance
Intake.....0.25 mm [0.010 in]
Exhaust.....0.51 mm [0.020 in]
Crankshaft Rotation (viewed from the front of the engine)..... **Clockwise**

Fuel System

Specifications

Automotive

Distributor-Type Fuel Injection Pumps B3.9 and B5.9 Engines

Maximum Inlet Restriction to the Fuel Transfer Pump **Must Not** Exceed.....100 mm Hg [4 in Hg]
Maximum Allowable Return Line Restriction.....518 mm Hg [20.4 in Hg]
Maximum Allowable Pressure Drop across Fuel Filter.....35 kPa [5 psi]
Maximum Inlet Pressure to the Injection Pump **Must Not** Exceed.....70 kPa [10 psi]

In-Line-Type Fuel Injection Pumps B3.9 and B5.9 Engine

Maximum Inlet Restriction to the Fuel Transfer Pump **Must Not** Exceed.....100 mm Hg [4 in Hg]
Fuel Transfer Pump Minimum Output Pressure.....175 kPa [25 psi] at Rated rpm
Fuel Filter Restriction (maximum pressure drop across filters).....35 kPa [5 psi]
Fuel Pressure Gallery Pressure.....140 kPa [20 psi] at Rated rpm
Fuel Return Maximum Restriction.....518 mm Hg [20.4 in Hg]

Industrial Applications

For performance and fuel rate values, refer to the Engine Data Sheet or the fuel injection pump for the particular model involved.

Distributor-Type and In-Line-Type Fuel Injection Pumps

Engine Idle Speed.....700 to 1000 rpm
Maximum Fuel Inlet Restriction to Lift Pump.....14 kPa [4 in Hg]
Maximum Allowable Return Line Restriction.....69 kPa [20 in Hg]
Fuel Pressure Range at Fuel Filter Outlet (engine cranking).....21 to 28 kPa [3 to 4 psi]
Fuel Pressure Range at Fuel Filter Inlet (engine running at idle).....34 to 48 kPa [5 to 7 psi]
Maximum Pressure Drop across Fuel Filter.....34 kPa [5 psi]
Fuel Drain Line Maximum Restriction.....70 kPa [10 psi]
Fuel Transfer Pump Minimum Output Pressure (low flow).....37.9 kPa [5.5 psi]
Fuel Transfer Pump Minimum Output Pressure (high flow).....172 kPa [25 psi]
Minimum Fuel Injection Pump Gallery Pressure (low flow fuel transfer pump).....82.7 kPa [12 psi]
Minimum Fuel Injection Pump Gallery Pressure (high flow fuel transfer pump).....140 kPa [20 psi]
Fuel Inlet Maximum Temperature.....70°C [158°F]
Engine Minimum Cranking Speed.....110 rpm

Lubricating Oil System

Specifications

Automotive

Lubricating Oil Pressure at Idle (minimum allowable)..... 69 kPa [10 psi]
Lubricating Oil Pressure at Rated (minimum allowable).....207 kPa [30 psi]
Regulating Valve Opening Pressure..... 449 kPa [65 psi]

Lubricating Oil Capacity
Standard Pan Only
B3.9.....9.5 liters [10 qt]
B5.9..... 14.2 liters [15 qt]

Lubricating Oil Capacity
Total System - Liters [U.S. qt]
B3.9.....11 liters [11.6 qt]
B5.9.....16.4 liters [17.3 qt]

Lubricating Oil Capacity
Low to High
B3.9.....0.9 liter [1 qt]
B5.9.....1.9 liters [2 qt]

NOTE: If the type/oil capacity of the oil pan in **not** known:

1. Contact a local Cummins Distributor/Dealer
2. Determine the capacity of the oil pan option for the engine being serviced by using QuickServe OnLine and the engine serial number
3. Fill the lubricating oil pan to the smallest oil pan capacity listed for the engine being serviced. Then add 0.95 liters [1 qt] of oil at a time until it reaches the high mark on the dipstick. Record the number of quarts added so that capacity is known the next time the oil is drained.

Industrial Applications

Oil Pressure
Low Idle (minimum allowed).....69 kPa [10 psi]
At Rated Speed (minimum allowed).....207 kPa [30 psi]

Regulated Pressure
B3.9, B4.5, and B5.9.....345 kPa [50 psi]
B4.5 RGT.....448 kPa [65 psi] to 517kPa [75 psi]

Oil Capacity of Standard Engine
Standard - Oil Pan Only
B3.9 and B4.5.....9.5 liters [10 qt]
B4.5 RGT.....11 liters [11.6 qt]
B5.9.....14.2 liters [15 qt]

Oil Capacity of Standard Engine
Total System - Standard Oil Pan
B3.9 and B4.5.....10.9 liters [11.5 qt]
B4.5 RGT.....13 liters [13.7 qt]
B5.9.....16.3 liters [17.2 qt]

Oil Capacity of Standard Engine
Oil Pan Low — High - Standard Oil Pan
B3.9 and B4.5.....8.5 to 9.5 liters [9 to 10 qt]
B4.5 RGT.....9 to 11 liters [9.6 to 11.6 qt]
B5.9.....12 to 14.2 liters [13 to 15 qt]

Oil Capacity of Standard Engine
Deep Sump - Oil Pan Only
B3.9 and B4.5.....14.5 liters [15.3 qt]
B4.5 RGT.....16 liters [16.9 qt]
B5.9.....24.0 liters [25.4 qt]

Oil Capacity of Standard Engine
Total System - Deep Sump Oil Pan
B3.9 and B4.5.....15.9 liters [16.8 qt]
B4.5 RGT.....18 liters [19.0 qt]
B5.9.....26.1 liters [27.6 qt]

Oil Capacity of Standard Engine
Oil Pan Low — High - Deep Sump Oil Pan
B3.9 and B4.5.....11.5 to 14.5 liters [12.1 to 15.3 qt]
B4.5 RGT.....10 to 16 liters [10.3 to 16.9 qt]

B5.9.....16.5 to 24.0 liters [17.4 to 25.4 qt]

NOTE: If the type/oil capacity of the oil pan in **not** known:

1. Contact a local Cummins Distributor/Dealer
2. Determine the capacity of the oil pan option for the engine being serviced by using QuickServe OnLine and the engine serial number
3. Fill the lubricating oil pan to the smallest oil pan capacity listed for the engine being serviced. Then add 0.95 liters [1 qt] of oil at a time until it reaches the high mark on the dipstick. Record the number of quarts added so that capacity is known the next time the oil is drained.

Cooling System

Specifications

Automotive Applications

Coolant Capacity (engine only)

B3.9.....7 liters [7.4 qt]
B5.9.....10.5 liters [11.1 qt]

Standard Modulating Thermostat Range

Start to Open.....83°C [181°F]
Fully Open.....95°C [203°F]

Pressure Cap

104°C [220°F] Systems.....103 kPa [15 psi]
99°C [210°F] Systems.....48 kPa [7 psi]

Industrial Applications

Coolant Capacity (engine only)

B3.9 and B4.5.....7.9 liters [8.3 qt]
B4.5 RGT.....8.5 liters [8.9 qt]
B5.9.....9.8 liters [10.4 qt]

Standard Modulating Thermostat - Range

B3.9, B4.5 and B5.9.....82 to 93°C [180 to 199°F]
B4.5 RGT.....88 to 97°C [190 to 207°F

Maximum Allowed Operating Temperature

B3.9, B4.5 and B5.9.....102°C [215°F]
B4.5 RGT.....107°C [225°F]

Minimum Recommended Operating Temperature.....71°C [160°F]
Minimum Recommended Pressure Cap.....48 kPa [7 psi]
Maximum Recommended Pressure Cap.....103 kPa [15 psi]

Air Intake System

Specifications

Automotive Applications

Maximum Allowable Intake Restriction

Clean Air Filter Element.....254 mm H_2O [10 in H_2O]
Dirty Air Filter Element.....635 mm H_2O [25 in H_2O

Refer to the following table for the control parts list (CPL), engine model, engine horsepower rating, and corresponding rated turbocharger boost pressure.

NOTE: Measurement of boost pressure is **not** a shortcut to logical troubleshooting. Low power can be caused by the fuel used, filter maintenance, and several engine components. Follow the troubleshooting charts for Engine Power Output Low, and measure boost pressure as indicated. Refer to this section, General Information, for measurement instructions.

These pressures are valid **only** at rated conditions (rated speed and power). Any attempt to use the values at engine speeds and loads other than those specified will result in an incorrect diagnosis.

B Series Engines' Turbocharger Boost Pressure Specifications

CPL	MODEL ENGINE	hp @ rpm RATING	PEAK TORQUE ft-lb @ rpm	RATED BOOST (in Hg)			PEAK TORQUE BOOST (in Hg)		
				min	nom	max	min	nom	max
591	4B3.9	64 @ 2200	N/A	N/A	N/A	N/A	N/A	N/A	N/A
591	4B3.9	64 @ 2200	N/A	N/A	N/A	N/A	N/A	N/A	N/A
592	4BTA3.9	70 @ 2100	N/A	11	14	17	N/A	N/A	N/A
592	4BTA3.9	71 @ 2200	N/A	12	15	18	N/A	N/A	N/A
592	4BTA3.9	80 @ 2200	N/A	14	17	20	N/A	N/A	N/A
592	4BTA3.9	92 @ 2100	N/A	16	19	22	N/A	N/A	N/A
592	4BTA3.9	93 @ 2200	N/A	18	21	24	N/A	N/A	N/A
592	4BTA3.9	94 @ 2200	N/A	18	21	24	N/A	N/A	N/A
592	4BTA3.9	96 @ 2300	N/A	19	22	25	N/A	N/A	N/A
592	4BTA3.9	100 @ 2500	N/A	22	25	28	N/A	N/A	N/A
594	4BTA3.9	95 @ 2200	N/A	15	18	21	N/A	N/A	N/A
594	4BTA3.9	112 @ 2300	N/A	21	24	27	N/A	N/A	N/A
594	4BTA3.9	125 @ 2200	N/A	25	28	31	N/A	N/A	N/A
646	4BT3.9	71 @ 1500	N/A	9	12	15	N/A	N/A	N/A
646	4BT3.9	82 @ 1800	N/A	11	14	17	N/A	N/A	N/A
710	4BT3.9	75 @ 2200	N/A	13	16	19	N/A	N/A	N/A
710	4BT3.9	100 @ 2500	N/A	22	25	28	N/A	N/A	N/A
711	4BT3.9	71 @ 1500	N/A	9	12	15	N/A	N/A	N/A
711	4BT3.9	82 @ 1800	N/A	11	14	17	N/A	N/A	N/A
721	4B3.9	80 @ 2800	N/A	N/A	N/A	N/A	N/A	N/A	N/A
730	4BT3.9	85 @ 2500	235 @ 1200	17	20	23	9	10	11
730	4BT3.9	91 @ 2200	259 @ 1400	17	20	23	11	12	13
741	4BT3.9	130 @ 2500	N/A	18	21	24	N/A	N/A	N/A
741	4BT3.9	150 @ 2800	N/A	25	28	31	N/A	N/A	N/A
741	4BT3.9	150 @ 2800	N/A	25	28	31	N/A	N/A	N/A
762	4BT3.9	105 @ 2500	N/A	28	32	36	N/A	N/A	N/A
762	4BT3.9	105 @ 2800	N/A	31	35	39	N/A	N/A	N/A
763	4BT3.9	67 @ 2200	N/A	10	14	16	N/A	N/A	N/A
763	4BT3.9	71 @ 2200	N/A	10	14	16	N/A	N/A	N/A
767	4BT3.9	105 @ 2500	N/A	24	28	31	N/A	N/A	N/A
767	4BT3.9	105 @ 2800	N/A	27	30	33	N/A	N/A	N/A

826	4BT3.9	87 @ 1500	N/A	15	18	21	N/A	N/A	N/A
857	4BT3.9	120 @ 2500	N/A	40	44	48	N/A	N/A	N/A
858	4BT3.9	105 @ 2500	N/A	35	39	43	N/A	N/A	N/A
937	4BT3.9	74 @ 1500	N/A	10	13	16	N/A	N/A	N/A
971	4BT3.9	96 @ 2200	N/A	19	22	25	N/A	N/A	N/A
971	4BT3.9	100 @ 2500	N/A	22	25	28	N/A	N/A	N/A
986	4BTA3.9	120 @ 2500	N/A	28	31.0	34	17	19.4	21
1201	4BT3.9	80 @ 2500	N/A	19	22	25	N/A	N/A	N/A
1202	4BT3.9	74 @ 2500	N/A	18	21	24	N/A	N/A	N/A
1260	4BTA3.9	105 @ 2500	N/A	22	24.5	27	14	15.6	17
1268	4BT3.9	105 @ 2500	N/A	28	32	36	N/A	N/A	N/A
1520	4BTG2	104 @ 1800	N/A	19	21	23	N/A	N/A	N/A
1521	4BT3.9	74 @ 1500	N/A	3.4	6.4	9.4	N/A	N/A	N/A
1521	4BT3.9	86 @ 1800	N/A	5.8	8.8	12.0	N/A	N/A	N/A
1521	4BT3.9	88 @ 1800	N/A	19	21	23	N/A	N/A	N/A
1525	4BT3.9	72 @ 1500	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1525	4BTG2	87 @ 1500	N/A	12	13	14	N/A	N/A	N/A
1963	4BTA3.9	116 @ 2500	295 @ 1500	36	39.3	42	23	25.6	29
1963	4BTA3.9	116 @ 2500	299 @ 1500	37	39.9	43	23	26	29
1963	4BTA3.9	125 @ 2200	350 @ 1500	37	40	43	29	32	35
1963	4BTA3.9	130 @ 2500	344 @ 1500	36	39	42	27	30	33
1965	4BT3.9	80 @ 2200	229 @ 1500	39	42	45	17	20	23
1965	4BT3.9	85 @ 2200	242 @ 1500	43	46	49	19	22	25
1965	4BTA3.9	85 @ 2200	254 @ 1500	43	46	49	19`	22	25
1965	4BT3.9	90 @ 2200	269 @ 1500	45	49	53	22	26	30
1965	4BT3.9	92 @ 2100	293 @ 1500	46	49.3	52	28	31	34
1965	4BT3.9	92 @ 2100	295 @ 2100	45	49	53	25	29	33
1966	4BT3.9	92 @ 2000	302 @ 1300	31	33.7	37	20	22.7	26
1967	4BT3.9	85 @ 2500	239 @ 1500	38	41.5	45	16	20	24
1967	4BT3.9	90 @ 2500	254 @ 1500	38	42	45	20	24	28
1967	4BT3.9	95 @ 2200	285 @ 1500	38	42.2	45	24	27.9	32
1967	4BT3.9	100 @ 2200	298 @ 1500	41	44	47	27	30	33
1967	4BT3.9	105 @ 2100	293 @ 1500	39	42.3	45	26	29.2	32
1967	4BT3.9	105 @ 2400	280 @ 1500	41	44.3	47	23	26.6	31
1967	4BT3.9	110 @ 2500	293 @ 1500	42	44.8	48	25	29	33
2021	4BT3.9	93 @ 2200	353 @ 1550	N/A	N/A	N/A	N/A	N/A	N/A
2109	4BTA3.9	107 @ 2100	327 @ 1500	40	42.7	46	30	32.5	36
2109	4BTA3.9	107 @ 2100	334 @ 1500	39	42	45	30	33	36
2109	4BTA3.9	107 @ 2100	328 @ 1600	40	42.7	46	30	32.5	36
2109	4BTA3.9	110 @ 2200	328 @ 1500	39	42	45	30	33	36
2109	4BTA3.9	110 @ 2200	328 @ 1500	39	42.0	45	30	33	36
2109	4BTA3.9	110 @ 2200	333 @ 1500	39	41.7	45	30	33.3	36
2109	4BTA3.9	116 @ 2500	300 @ 1500	39	42	45	29	32	35
2109	4BTA3.9	116 @ 2500	312 @ 1500	40	43	46	29	32	35
2264	4BTA3.9	125 @ 2200	355 @ 1500	36	39	42	29	32	35
2302	4BT3.9	110 @ 2500	278 @ 1500	41	43.7	47	24	26.6	30
2302	4BT3.9	110 @ 2500	278 @ 1500	40	43	46	23	26	29
2302	4BT3.9	110 @ 2500	293 @ 1500	41	43.7	47	26	28.6	32
2351	4BTA3.9	110 @ 2200	328 @ 1500	37	39.9	43	27	29.5	33

2359	4BT3.9	85 @ 2500	239 @ 1500	39	41.5	45	17	20	23
2361	4B3.9	74 @ 2500	201 @ 1200	N/A	N/A	N/A	N/A	N/A	N/A
2361	4B3.9	80 @ 2500	201 @ 1200	N/A	N/A	N/A	N/A	N/A	N/A
2361	4B3.9	80 @ 2500	201 @ 1200	N/A	N/A	N/A	N/A	N/A	N/A
2374	4B3.9	75 @ 2200	201 @ 1200	N/A	N/A	N/A	N/A	N/A	N/A
2478	4BT3.9	80 @ 2200	229 @ 1500	39	41.8	45	17	20	23
2486	4B3.9	75 @ 2200	201 @ 1200	N/A	N/A	N/A	N/A	N/A	N/A
2488	4B3.9	54 @ 2000	179 @ 1200	N/A	N/A	N/A	N/A	N/A	N/A
2489	4B3.9	60 @ 2200	179 @ 1200	N/A	N/A	N/A	N/A	N/A	N/A
2490	4B3.9	67 @ 2200	192 @ 1200	N/A	N/A	N/A	N/A	N/A	N/A
2599	4B3.9	75 @ 2200	193 @ 1200	N/A	N/A	N/A	N/A	N/A	N/A
2599	4B3.9	80 @ 2500	193 @ 1200	N/A	N/A	N/A	N/A	N/A	N/A
2601	4B3.9	60 @ 2000	180 @ 1200	N/A	N/A	N/A	N/A	N/A	N/A
2601	4 B3.9	60 @ 2000	190 @ 1200	N/A	N/A	N/A	N/A	N/A	N/A
2808	4BT3.9	110 @ 2500	293 @ 1500	41	43.7	47	24	26.6	30
596	6B5.9	93 @ 2200	262 @ 1100	N/A	N/A	N/A	N/A	N/A	N/A
598	6BT5.9	160 @ 2500	N/A	28	32	36	N/A	N/A	N/A
598	6BT5.9	160 @ 2800	N/A	31	35	39	N/A	N/A	N/A
600	6BTA5.9	180 @ 2500	N/A	39	43	47	N/A	N/A	N/A
692	6BT5.9	160 @ 2500	N/A	30	34	38	N/A	N/A	N/A
692	6BT5.9	160 @ 2600	N/A	31	35	39	N/A	N/A	N/A
697	6BT5.9	113 @ 1500	N/A	15	19	21	N/A	N/A	N/A
697	6BT5.9	134 @ 1800	N/A	21	24	27	N/A	N/A	N/A
713	6BT5.9	113 @ 1500	N/A	12	18	21	N/A	N/A	N/A
713	6BT5.9	134 @ 1800	N/A	21	24	27	N/A	N/A	N/A
715	6BTA5.9	143 @ 2100	N/A	26	29	32	N/A	N/A	N/A
716	6BT5.9	156 @ 2500	N/A	45	49	53	N/A	N/A	N/A
728	6BT5.9	128 @ 2800	N/A	19	22	25	N/A	N/A	N/A
728	6BT5.9	130 @ 2650	N/A	19	22	25	N/A	N/A	N/A
729	6BT5.9	134 @ 2200	N/A	23	26	29	N/A	N/A	N/A
742	6BT5.9	152 @ 2500	N/A	30	33	36	N/A	N/A	N/A
742	6BT5.9	180 @ 2500	N/A	39	43	47	N/A	N/A	N/A
742	6BT5.9	210 @ 2600	N/A	47	51	55	N/A	N/A	N/A
766	6BT5.9	160 @ 2500	N/A	28	32	36	N/A	N/A	N/A
766	6BT5.9	160 @ 2800	N/A	31	35	39	N/A	N/A	N/A
791	6B5.9	120 @ 2800	N/A	N/A	N/A	N/A	N/A	N/A	N/A
791	6B5.9	120 @ 2800	N/A	N/A	N/A	N/A	N/A	N/A	N/A
804	6BT5.9	145 @ 2600	N/A	39	43	47	N/A	N/A	N/A
804	6BT5.9	160 @ 2500	N/A	38	41	44	N/A	N/A	N/A
807	6BT5.9	99 @ 2200	N/A	13	16	19	N/A	N/A	N/A
834	6BTA5.9	180 @ 2500	N/A	32	36	40	N/A	N/A	N/A
856	6BTA5.9	180 @ 2500	N/A	46	50	54	N/A	N/A	N/A
912	6BTA5.9	190 @ 2600	N/A	34	38	42	N/A	N/A	N/A
938	6BT5.9	135 @ 2200	442 @ 1400	23	25	28	19	21	23
938	6BT5.9	137 @ 2200	393 @ 1600	18	21	24	16	18	20
938	6BT5.9	140 @ 2200	426 @ 1300	24	27	30	15	17	19
938	6BT5.9	145 @ 2200	425 @ 1500	25	28	31	19	21	23
938	6BT5.9	87 @ 2200	265 @ 1200	10	13	16	5	6	7

938	6BT5.9	97 @ 2200	270 @ 1200	13	16	19	6	7	8
943	6BT5.9	120 @ 2100	N/A	18	21	24	N/A	N/A	N/A
947	6BT5.9	145 @ 2600	N/A	24	27	30	N/A	N/A	N/A
947	6BT5.9	160 @ 2500	N/A	29	33	37	N/A	N/A	N/A
947	6BT5.9	160 @ 2600	N/A	31	35	39	N/A	N/A	N/A
947	6BT5.9	130 @ 2500	N/A	20	23	26	N/A	N/A	N/A
948	6BT5.9	145 @ 2600	N/A	24	27	30	N/A	N/A	N/A
949	6BT5.9	88 @ 2000	N/A	10	13	16	N/A	N/A	N/A
949	6BT5.9	121 @ 2200	N/A	14	17	20	N/A	N/A	N/A
949	6BT5.9	124 @ 2400	N/A	21	24	27	N/A	N/A	N/A
949	6BT5.9	126 @ 2100	N/A	19	22	25	N/A	N/A	N/A
949	6BT5.9	130 @ 2500	N/A	23	26	29	N/A	N/A	N/A
949	6BT5.9	140 @ 2200	N/A	24	27	30	N/A	N/A	N/A
949	6BT5.9	142 @ 2100	N/A	24	24	30	N/A	N/A	N/A
949	6BT5.9	145 @ 2200	N/A	25	28	31	N/A	N/A	N/A
949	6BT5.9	148 @ 2300	N/A	27	30	33	N/A	N/A	N/A
949	6BT5.9	152 @ 2500	N/A	28	32	36	N/A	N/A	N/A
950	6BT5.9	120 @ 2100	N/A	18	21	24	N/A	N/A	N/A
953	6BTA5.9	220 @ 2500	N/A	23	26	29	N/A	N/A	N/A
953	6BTA5.9	250 @ 2600	N/A	44	48	52	N/A	N/A	N/A
961	6BT5.9	115 @ 1500	N/A	16	19	22	N/A	N/A	N/A
961	6BT5.9	135 @ 1800	N/A	22	25	28	N/A	N/A	N/A
970	6BTA-M2	250 @ 2600	N/A	32	36	40	N/A	N/A	N/A
970	6BTA-M2	300 @ 2800	N/A	46	50	54	N/A	N/A	N/A
970	6BTSWA	300 @ 2800	N/A	40	44	48	N/A	N/A	N/A
983	6BTA5.9	157 @ 2500	N/A	35	39	43	N/A	N/A	N/A
983	6BTA5.9	177 @ 2500	N/A	38	42	46	N/A	N/A	N/A
998	6BTA5.9	200 @ 2500	N/A	45	49	53	N/A	N/A	N/A
1160	6BT5.9	160 @ 2500	N/A	29	33	37	N/A	N/A	N/A
1165	6BTA5.9	227 @ 1760	N/A	37	41	45	N/A	N/A	N/A
1165	6BTA5.9	255 @ 2100	N/A	46	50	54	N/A	N/A	N/A
1168	6BT5.9	148 @ 2300	N/A	25	28	31	N/A	N/A	N/A
1168	6BT5.9	152 @ 2500	N/A	27	31	35	N/A	N/A	N/A
1209	6BTA5.9	176 @ 2300	N/A	30	33	36	N/A	N/A	N/A
1266	6BT5.9	142 @ 2500	N/A	27	31	35	N/A	N/A	N/A
1279	6BT5.9	125 @ 2200	412 @ 1400	18	20	22	14	16	18
1322	6BTA-M1	220 @ 2500	N/A	32	36	40	N/A	N/A	N/A
1322	6BTA5.9	250 @ 2600	N/A	34	38	42	N/A	N/A	N/A
1322	6BTA-M1	250 @ 2600	N/A	42	46	50	N/A	N/A	N/A
1419	6BT5.9	250 @ 2500	N/A	38	42	46	N/A	N/A	N/A
1518	6BT5.9	169 @ 1800	N/A	32	35	39	N/A	N/A	N/A
1549	6BTA5.9	160 @ 2500	400 @ 1600	30	34	38	23	25	28
1552	6BTA5.9	210 @ 2500	485 @ 1600	44	47.7	52	29	31.9	35
1570	6BTJWA	250 @ 2600	N/A	35	39	43	N/A	N/A	N/A
1579	6BTA5.9	160 @ 2500	400 @ 1600	31	35.4	39	14	17.2	20
1613	6BTSWA	250 @ 2600	N/A	36	40	44	N/A	N/A	N/A
1640	6BTA5.9	185 @ 2200	531 @ 1500	41	45	50	27	30	33
1863	6BTAA	180 @ 2500	42- @ 1500	36	39	42	22	25	28
1889	6BTA5.9	185 @ 2400	550 @ 1500	43	46	49	30	33	36

1889	6BTA5.9	200 @ 2500	550 @ 1500	48	51	54	30	33	36
1914	6BTA5.9	190 @ 2300	475 @ 1600	44	48	52	22	26	30
1945	6BT5.9	200 @ 2200	583 @ 1500	41	46	51	31	34	37
1945	6BTA5.9	200 @ 2500	581 @ 1500	41	46	51	30	33	36
1948	6BT5.9	148 @ 2200	440 @ 1600	38	41	44	25	28	31
1948	6BT5.9	148 @ 2200	440 @ 1600	37	40	43	43	24	37
1948	6BT5.9	152 @ 2500	414 @ 1600	40	43	46	24	27	30
1948	6BT5.9	155 @ 2100	449 @ 1600	39	41.8	45	24	27	30
1959	6BTA5.9	160 @ 2500	400 @ 1600	30	34	38	18	21	24
1962	6BTA5.9	147 @ 2000	428 @ 1500	33	36	39	21	24	27
1962	6BTA5.9	150 @ 2200	466 @ 1500	35	38	41	23	26	29
1962	6BTA5.9	150 @ 2200	466 @ 1500	35	38	41	23	26	29
1962	6BTA5.9	150 @ 2200	483 @ 1500	35	38.4	41	26	28.6	32
1962	6BTA5.9	160 @ 2000	462 @ 1500	38	41	44	23	26	29
1962	6BTA5.9	166 @ 2075	474 @ 1500	42	44.6	48	25	28.1	31
1962	6BTA5.9	167 @ 2000	480 @ 1500	36	39	42	24	27	30
1962	6BTA5.9	150 @ 2200	483 @ 1500	35	38	41	26	29	32
1962	6BTA5.9	153 @ 2200	485 @ 1500	37	40	43	24	27	30
1962	6BTA5.9	165 @ 2200	512 @ 1500	42	45	48	28	31	34
1962	6BTA5.9	165 @ 2200	532 @ 1500	42	44.6	48	29	31.6	35
1962	6BTA5.9	168 @ 2200	541 @ 1500	37	40	43	24	27	30
1962	6BTA5.9	167 @ 2000	479 @ 1500	40	43	46	25	28	31
1962	6BTA5.9	170 @ 2300	475 @ 1500	42	45	48	23	26	29
1962	6BTA5.9	169 @ 2100	480 @ 1500	41	44	47	25	28	31
1962	6BTA5.9	169 @ 2100	480 @ 1500	41	44	47	25	28	31
1968	6BTAA	160 @ 2500	400 @ 1600	30	34	38	19	22	25
1975	6BTA5.9	330 @ 2800	687 @ 2000	52	57	62	37	41	45
1989	6BTA5.9	185 @ 2500	553 @ 1500	47	51	55	33	37	41
2016	6BTAA5.9	129 @ 2500	347 @ 1500	25	29.2	33	11	13.9	17
2017	6BTA5.9	178 @ 2500	474 @ 1500	34	36.6	40	19	21.6	25
2023	6BTAA	21 @ 2600	440 @ 1600	48	51	54	23	26	29
2035	6BTA5.9	195 @ 2800	420 @ 1600	32	35	38	25	28.5	31
2063	6BTA5.9	185 @ 2300	580 @ 1500	40	43	46	33	36	39
2063	6BTA5.9	185 @ 2400	558 @ 1500	46	48.7	52	30	33.1	36
2063	6BTA5.9	185 @ 2200	566 @ 1500	40	43	46	33	36	39
2063	6BTA5.9	174 @ 2200	590 @ 1500	45	48	51	36	39	42
2071	6BT5.9	97 @ 2200	267 @ 1700	21	24	27	13	16	19
2071	6BT5.9	97 @ 2200	270 @ 1700	20	24	28	12	16	20
2071	6BT5.9	101 @ 2200	313 @ 1500	23	26	29	11	14	17
2071	6BT5.9	118 @ 2400	327 @ 1600	35	38	41	16	19	22
2071	6BT5.9	110 @ 1900	341 @ 1600	27	30	33	17	20	23
2071	6BT5.9	110 @ 2200	341 @ 1600	28	31	34	18	21	24
2071	6BT5.9	120 @ 2200	372 @ 1500	32	35	38	22	25	28
2071	6BT5.9	126 @ 2100	380 @ 1600	29	32	35	19	22	25
2071	6BT5.9	130 @ 2200	388 @ 1600	33	36	39	20	23	26
2071	6BT5.9	130 @ 2500	368 @ 1600	42	44.9	48	18	21	24
2071	6BT5.9	135 @ 2100	404 @ 1600	30	33	36	19	22	25
2071	6BT5.9	135 @ 2200	419 @ 1500	32	35	38	19	22	25
2071	6BT5.9	135 @ 2200	419 @ 1600	35	38	41	23	26	29

2071	6BT5.9	135 @ 2400	379 @ 1600	42	45	48	21	24	27
2071	6BT5.9	135 @ 2200	419 @ 1600	37	40	43	25	28	31
2071	6BT5.9	135 @ 2100	419 @ 1500	30	33	36	19	22	25
2071	6BT5.9	140 @ 2000	416 @ 1600	32	35	38	23	26	29
2071	6BT5.9	145 @ 2100	438 @ 1500	38.4	41.4	44.4	40	42.1	44
2071	6BT5.9	137 @ 2000	440 @ 1600	32	35.1	38	28	31	34
2072	6BTA5.9	174 @ 2500	458 @ 1500	43	46.1	49	24	27.2	30
2072	6BTA5.9	174 @ 2500	470 @ 1500	42	45	48	24	27	30
2174	6BTAA5.9	180 @ 2500	420 @ 1500	36	39	42	22	25	28
2175	6BTAA5.9	215 @ 2600	440 @ 1600	48	51	54	23	26	29
2122	6BTA5.9	177 @ 2500	480 @ 1500	N/A	N/A	N/A	N/A	N/A	N/A
2208	6BTA	370 @ 3000	726 @ 2200	56	59	62	40	43	46
2249	6BTAA5.9	232 @ 2500	590 @ 1500	50	52.6	56	30	32.5	36
2292	6BTA5.9	147 @ 2000	438 @ 1500	35	38	41	23	26	29
2292	6BTA5.9	160 @ 1900	479 @ 1500	38	41	44	23	26	29
2292	6BTA5.9	169 @ 2100	480 @ 1500	41	44	47	25	28	31
2292	6BTA5.9	169 @ 2100	485 @ 1500	41	44	47	23	26	29
2292	6BTA5.9	169 @ 2100	485 @ 1500	45	47.5	51	29	31.6	35
2292	6BTA5.9	167 @ 2000	480 @ 1500	37	39.6	43	25	27.5	31
2308	6BTAA5.9	180 @ 2500	420 @ 1500	36	39	42	22	25	28
2479	6BTA5.9	174 @ 2200	590 @ 1500	46	48.4	51	37	39.9	43
2530	6BT5.9	135 @ 1800	N/A	30	32.5	35	N/A	N/A	N/A
2530	6BT5.9	143 @ 1800	N/A	29	31.9	35	N/A	N/A	N/A
2530	6BT5.9	170 @ 1800	N/A	20	21.8	23	N/A	N/A	N/A

Industrial Applications

Maximum Intake Restriction

Clean Air Filter Element.....254 mm H_2O [10 in H_2O]

Dirty Air Filter Element.....635 mm H_2O [25.0 in H_2O]

Recommended Intake Piping Size (inner diameter)

B3.9, B4.5 and B4.5 RGT.....76 mm [3 in]

B5.9.....101.6 mm [4 in]

Exhaust System

Specifications

Automotive Applications

Maximum Allowable Exhaust Restriction at Rated Speed and Loaded

1991 to 1993 EPA Certified.....114.3 mm Hg [4.5 in Hg]
1994 to 1998 EPA Certified (with oxidation catalyst).....152.4 mm Hg [6 in Hg]

Industrial Applications

Maximum Back Pressure from Piping and Silencer (combined)

Hg.....76 mm Hg [3 in Hg]
H_2O.....1016 mm H_2O [40 in H_2O]

Recommended Exhaust Piping Size (inner diameter)

B3.9, B4.5 and B4.5 RGT.....76 mm [3 in]
B5.9.....101.6 mm [4 in]

Electrical System

Specifications

Automotive Applications

Minimum Recommended Battery Capacity @ −18°C [0°F]

12-VDC Starter
With Light Accessories(1)
B3.9.....625 CCA
B5.9.....800 CCA
12-VDC Starter
With Heavy Accessories(2)
B3.9.....800 CCA
B5.9.....950 CCA
24-VDC Starter
With Light Accessories(1)
B3.9..... 400 CCA
B5.9.....400 CCA
24-VDC Starter
With Heavy Accessories(2)
B3.9.....400 CCA
B5.9.....475 CCA
Maximum Allowable Starting Circuit Resistance
12-VDC Starter
B3.9.....0.0012 ohms
B5.9.....0.0012 ohms
Maximum Allowable Starting Circuit Resistance
24-VDC Starter
B3.9.....0.0020 ohms
B5.9.....0.0020 ohms

1. Typical light accessories include alternator, small steering pump, and disengaged clutch.
2. Typical heavy accessories include hydraulic pump and torque converter.

Industrial Applications

Minimum Recommended Battery Capacity @ −18°C [0°F]

12-VDC Starter
With Light Accessories(1)
B3.9, B4.5 and B4.5 RGT.....625 CCA
B5.9.....800 CCA
12-VDC Starter
With Heavy Accessories(2)
B3.9, B4.5 and B4.5 RGT.....800 CCA
B5.9.....950 CCA
24-VDC Starter
With Light Accessories(1)
B3.9, B4.5 and B4.5 RGT.....400 CCA
B5.9.....400 CCA
24-VDC Starter
With Heavy Accessories(2)
B3.9, B4.5 and B4.5 RGT.....400 CCA
B5.9.....475 CCA
Maximum Allowable Starting Circuit Resistance
12-VDC.....0.001 ohm
24-VDC.....0.002 ohms

1. Typical light accessories include alternator, small steering pump, and disengaged clutch.
2. Typical heavy accessories include hydraulic pump and torque converter.

Batteries (Specific Gravity)	
Specific Gravity at 27° C [80° F]	**State of Change**
1.260 to 1.280	100%
1.230 to 1.250	75%

Batteries (Specific Gravity)	
Specific Gravity at 27° C [80° F]	**State of Change**
1.200 to 1.220	50%
1.170 to 1.190	25%
1.110 to 1.130	Discharged

Compressed Air System

Specifications

Holset® SS296, SS296E, and SS338E A/C Model

A/C Model QE296 Specifications

Compressor Swept Volume at 1250 rpm.....6.2 L/sec [13.2 SCFM]
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 x Engine rpm
Cooling.....Engine Coolant
Lubrication.....Engine Lubricating Oil
Plumbing Line Sizes:
Coolant Inlet and Outlet (pipe fitting).....1/2-in NPTF [0.50 in]
Air Inlet (inside diameter).....19-mm [0.75-in] Nipple
Air Outlet (minimum inside diameter).....1/2-in NPTF [0.50 in]
Height, Overall (approximate).....305 mm [12 in]
Width, Overall (approximate).....159 mm [6.25 in]
Length, Overall (approximate).....267 mm [10.5 in]
Weight (approximate).....20 kg [44 lb]

A/C Model QE338 Specifications

Compressor Swept Volume at 1250 rpm.....7.1 L/sec [15 SCFM]
Piston Displacement.....338 cc [20.6 C.I.D.]
Bore.....98.43 mm [3.875 in]
Stroke.....44.45 mm [1.750 in]
Speed.....1.135 x Engine rpm
Cooling..... Engine Coolant
Lubrication.....Engine Lubricating Oil
Plumbing Line Sizes:
Coolant Inlet and Outlet (pipe fitting).....1/2-in NPTF [0.50 in]
Air Inlet (inside diameter).....19-mm [0.75-in] Nipple
Air Outlet (minimum inside diameter).....1/2-in NPTF [0.50 in]
Height, Overall (approximate).....305 mm [12 in]
Width, Overall (approximate).....159 mm [6.25 in]
Length, Overall (approximate).....267 mm [10.5 in]
Weight (approximate).....18 kg [40 lb]

A/C Model HD650 Specifications

Compressor Swept Volume at 1250 rpm.....6.2 L/sec [13.2 SCFM]
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 x Engine rpm
Cooling.....Engine Coolant
Lubrication.....Engine Lubricating Oil
Plumbing Line Sizes:
Coolant Inlet and Outlet (pipe fitting).....1/2-in NPTF [0.50 in]
Air Inlet (inside diameter).....19-mm [0.75-in] Nipple
Air Outlet (minimum inside diameter).....1/2-in NPTF [0.50 in]
Height, Overall (approximate).....305 mm [12 in]
Width, Overall (approximate).....159 mm [6.25 in]
Length, Overall (approximate).....267 mm [10.5 in]
Weight (approximate)..... 20 kg [44 lb]

A/C Model HD850 Specifications

Compressor Swept Volume at 1250 rpm.....7.1 L/sec [15 SCFM]
Piston Displacement.....338 cc [20.6 C.I.D.]
Bore.....98.43 mm [3.875 in]
Stroke.....44.45 mm [1.750 in]
Speed.....1.135 x Engine rpm
Cooling.....Engine Coolant

Lubrication.....Engine Lubricating Oil
Plumbing Line Sizes:
Coolant Inlet and Outlet (pipe fitting).....1/2-in NPTF [0.50 in]
Air Inlet (inside diameter).....19-mm [0.75-in] Nipple
Air Outlet (minimum inside diameter).....1/2-in NPTF [0.50 in]
Height, Overall (approximate).....305 mm [12 in]
Width, Overall (approximate).....159 mm [6.25 in]
Length, Overall (approximate).....267 mm [10.5 in]
Weight (approximate).....18 kg [40 lb]

Holset® SS191 A/C Model

A/C Model SS191 Specifications

Compressor Swept Volume at 1250 rpm.....4.0 L/sec [8.5 SCFM]
Piston Displacement .....191 cc [11.65 C.I.D.]
Bore.....80 mm [3.15 in]
Stroke.....38.1 mm [1.50 in]
Speed.....1.135 x Engine rpm
Cooling.....Engine Coolant
Lubrication.....Engine Lubricating Oil
Plumbing Line Sizes:
Coolant Inlet and Outlet (pipe fitting).....1/2-in NPTF [0.50 in]
Air Inlet (inside diameter).....19-mm [0.75-in] Nipple
Air Outlet (minimum inside diameter).....1/2-in NPTF [0.50 in]
Height, Overall (approximate).....289 mm [11.4 in]
Width, Overall (approximate).....125 mm [4.9 in]
Length, Overall (approximate).....186 mm [7.32 in]
Weight (approximate).....13.6 kg [30 lb]

Engine Testing

Specifications

Maintain the following limits (see note) during a chassis dynamometer test:

Intake Restriction (maximum)
Clean Filter:
Light-Duty.....254 mm H_2O [10 in H_2O]
Medium-Duty.....305 mm H_2O [12 in H_2O]
Heavy-Duty.....381 mm H_2O [15 in H_2O]
Intake Restriction (maximum)
Dirty Filter:
Light-Duty.....635 mm H_2O [25 in H_2O]
Medium-Duty.....635 mm H_2O [25 in H_2O]
Heavy-Duty.....635 mm H_2O [25 in H_2O]
Exhaust Back Pressure (maximum) Nonautomotive.....76 mm Hg [3.0 in Hg]
Exhaust Back Pressure (maximum) Automotive with Catalyst.....152 mm Hg [6.0 in Hg] to 127 mm Hg [5.0 in Hg]
Back Pressure (maximum) Automotive without Catalyst.....114 mm Hg [4.5 in Hg] to 102 mm Hg [4.0 in Hg]
Oil Pressure:
Low Idle (minimum allowable).....69 kPa [10 psi]
Rated Speed (minimum allowable).....207 kPa [30 psi]
Fuel Inlet Restriction (maximum).....100 mm Hg [4 in Hg]
Fuel Return Restriction (maximum).....518 mm Hg [20.4 in Hg]

NOTE: Due to variations in ratings of different engine models, refer to the specific engine data sheet for the particular engine model being tested.

Cummins®/Fleetguard® Filter Specifications

General Information

Fleetguard® is a subsidiary of Cummins Inc. Fleetguard® filters are developed through joint testing at Cummins and Fleetguard®. Fleetguard® filters are standard on new Cummins engines. Cummins Inc. recommends their use.

Fleetguard® products meet all Cummins Source Approval Test standards to provide the quality filtration necessary to achieve the engine's design life. If other brands are substituted, the purchaser should insist on products that the supplier has tested to meet Cummins high-quality standards.

Cummins can **not** be responsible for problems caused by nongenuine filters that do **not** meet Cummins performance or durability requirements.

Lubricating Oil Filter Part Numbers			
	B3.9 and B4.5	**B4.5 RGT**	**B5.9**
Cummins Part Number	3934429	3937736	3937743
Fleetguard® Part Number	LF3805	LF3790	LF3959

NOTE: The following fuel filter part numbers are the most common fuel filters used on the engines covered by this manual. Due to the number of fuel system configurations and applications, the filters listed below may **not** be correct for your application. Always replace the fuel filter with an exact replacement or contact your local Cummins Dealer to determine the correct fuel filter for your application.

Automotive and Industrial Applications[1] Fuel Filter Part Numbers			
	Single Fuel Filter Option	**Dual Fuel Filter Option**	
	Fuel Filter/Water Separator	**Fuel Filter**	**Water Separator**
	B3.9 and B5.9	B3.9 and B5.9	
Cummins Part Number	3903202	3903640	3890706
Fleetguard® Part Number	FS1251	FF5052	FS1280

NOTE: [1]. The filters listed are for automotive (1991 and 1994 certification levels) and industrial Tier 1 certifications level.

Industrial Applications Only[2] Fuel Filter Part Numbers		
	Single Fuel Filter Option	
	Fuel Filter/Water Separator	
	B3.9 and B4.5 and B5.9	**B4.5 RGT**
Cummins Part Number	3991350	3991498
Fleetguard® Part Number	FS19608	FS19616

NOTE: [2]. The filters listed are for industrial engines meeting industrial Tier 2 certifications level.

Fuel Recommendations and Specifications

Fuel Recommendations

⚠CAUTION⚠

Due to the precise tolerances of diesel injection systems, it is extremely important that the fuel be kept clean and free of dirt or water. Dirt or water in the system can cause severe damage to both the fuel pump and the fuel injectors.

Cummins Inc. recommends the use of ASTM Number 2D fuel. The use of Number 2 diesel fuel will result in optimum engine performance.

At operating temperatures below 0°C [32°F], acceptable performance can be obtained by using blends of Number 2D and Number 1D.

NOTE: Lighter fuels can reduce fuel economy or possibly damage the fuel injection pump.

The viscosity of the fuel **must** be kept above 1.3 cSt at 40°C [104°F] to provide adequate fuel system lubrication.

The following chart lists acceptable alternate fuels for B Series engines.

Acceptable Substitute Fuels - Cummins B Fuel System									
Number 1D Diesel (1) (2)	Number 2D Diesel (3)	Number 1K Kerosene	Jet-A	Jet-A1	JP-5	JP-8	Jet-B	JP-4	CITE
A	OK	A	A	A	A	A	**NOT** OK	**NOT** OK	**NOT** OK
• An "A" means OK **only** if fuel lubricity is adequate. This means the BOCLE number is 3100 or greater as measured with the US Army scuffing BOCLE test.									
• Any adjustment to compensate for reduced performance with a fuel system using alternate fuel is **not** warrantable.									
• Winter blend fuels, such as found at commercial fuel dispensing outlets, are combinations of Number 1D and Number 2D diesel fuel, and are acceptable.									

Additional information for fuel recommendations and specifications can be found in Fuel for Cummins Engines, Bulletin 3379001. See ordering information in the back of this manual.

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.

Engine Component Torque Values

General Information

Component	Wrench Size	N•m	ft-lb or in-lb
Aftercooler Mounting	10 mm	24	18 ft-lb
Aftercooler Water Hose Clamp	8 mm	5	44 in-lb
Alternator Link (Delco 10-15 SI)	13 mm	24	18 ft-lb
Alternator Link (Delco 20-27 SI)	3/4 in	43	32 ft-lb
Alternator Mtg. Bolt 10-15 SI	15 mm	43	32 ft-lb
Alternator Mtg. 27 SI	18 mm	77	57 ft-lb
Alternator Support (Upper)	10 mm	24	18 ft-lb
Belt Tensioner Flat Bracket	Allen 5 mm	24	18 ft-lb
Belt Tensioner Mounting	15 mm	43	32 ft-lb
Crankshaft Damper and Pulley	15 mm	137	101 ft-lb
Crossover Clamp	5/16 in	5	44 in-lb
Tee Bolt Type Clamp	11 mm	8	71 in-lb
Exhaust Outlet Pipe, V Band Clamp	7/16 in	8	71 in-lb
Fan Bracket Mounting	10 mm	24	18 ft-lb
Fan Pulley	10 mm	24	18 ft-lb
Fan Pulley	13 mm	43	32 ft-lb
Fuel Filter	75 to 85 mm	Install as specified by filter manufacturer	
Fuel Filter Adapter Nut	24 mm	32	24 ft-lb
Lubricating Oil Filter	75 to 85 mm	3/4 Turn after Contact	
Lubricating Oil Cooler Assembly	10 mm	24	18 ft-lb
Lubricating Oil Pan Drain Plug (steel)	17 mm	80	59 ft-lb
Lubricating Oil Pan Drain Plug (aluminum)	17 mm	30	22 ft-lb
Lubricating Oil Pan Heater Plug	27 mm	80	59 ft-lb
Lubricating Oil Pressure Regulator Plug	19 mm	80	59 ft-lb
Starter Mounting	10 mm	43	32 ft-lb
Thermostat Housing	10 mm	24	18 ft-lb
Water Inlet Connection	15 mm	43	32 ft-lb
Water Pump Mounting	13 mm	24	18 ft-lb
Rocker Lever Cover	15 mm	24	18 ft-lb
Water-in-Fuel Sensor	19 mm	Hand-Tighten	
Top - Load Filter Lid	10 mm	Hand-Tighten	

Capscrew Markings and Torque Values

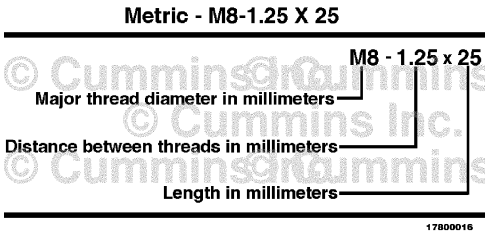
General Information

⚠CAUTION⚠

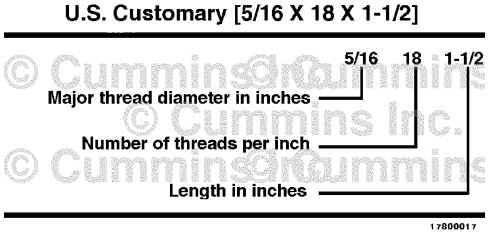
When replacing capscrews, always use a capscrew of the same measurement and strength as the capscrew being replaced. Using the wrong capscrews can result in engine damage.

Metric capscrews and nuts are identified by the grade number stamped on the head of the capscrew or on the surface of the nuts. U.S. Customary capscrews are identified by radial lines stamped on the head of the capscrew.

The following examples indicate how capscrews are identified:

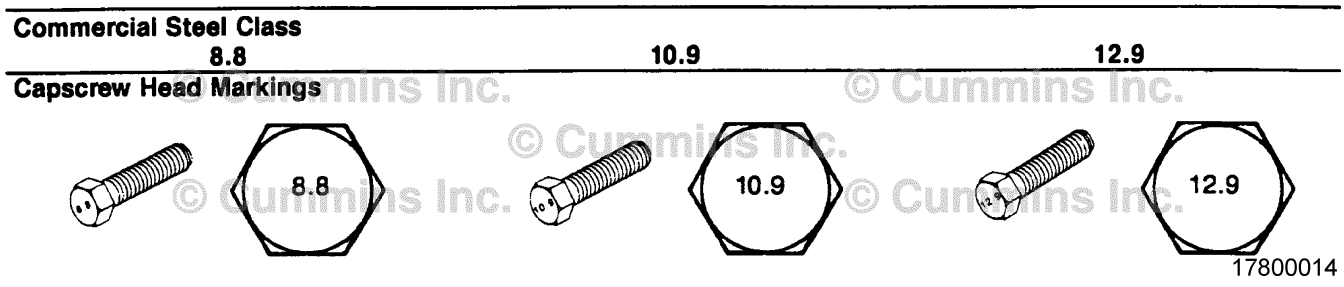


- **Always** use the torque values listed in the following tables when specific torque values are **not** available.
- Do **not** use the torque values in place of those specified in other sections of this manual.
- The torque values in the table are based on the use of lubricated threads.
- When the ft-lb value is less than 10, convert the ft-lb value to in-lb to obtain a better torque with an in-lb torque wrench. Example: 6 ft-lb equals 72 in-lb.



- **Always** use the torque values listed in the following tables when specific torque values are **not** available.
- Do **not** use the torque values in place of those specified in other sections of this manual.
- The torque values in the table are based on the use of lubricated threads.
- When the ft-lb value is less than 10, convert the ft-lb value to in-lb to obtain a better torque with an in-lb torque wrench. Example: 6 ft-lb equals 72 in-lb.

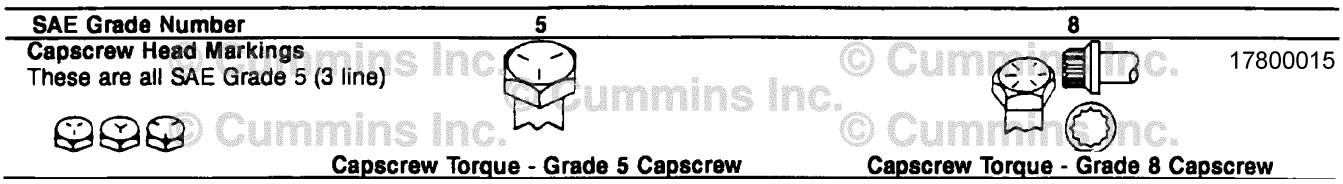
Capscrew Markings and Torque Values - Metric



Body Size	Torque				Torque				Torque			
Diameter	Cast Iron		Aluminium		Cast Iron		Aluminium		Cast Iron		Aluminium	
mm	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
6	9	5	7	4	13	10	7	4	14	9	7	4
7	14	9	11	7	18	14	11	7	23	18	11	7

Body Size	Torque				Torque				Torque			
Diameter	Cast Iron		Aluminium		Cast Iron		Aluminium		Cast Iron		Aluminium	
mm	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
8	23	17	18	14	33	25	18	14	40	29	18	14
10	45	33	30	25	65	50	30	25	70	50	30	25
12	80	60	55	40	115	85	55	40	125	95	55	40
14	125	90	90	65	180	133	90	65	195	145	90	65
16	195	140	140	100	280	200	140	100	290	210	140	100
18	280	200	180	135	390	285	180	135	400	290	180	135
20	400	290	—	—	550	400	—	—	—	—	—	—

Capscrew Markings and Torque Values - U.S. Customary



Capscrew Body Size	Cast Iron		Aluminium		Cast Iron		Aluminium	
	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
1/4 - 20	9	7	8	6	15	11	8	6
1/4 - 28	12	9	9	7	18	13	9	7
5/16 - 18	20	15	16	12	30	22	16	12
5/16 - 24	23	17	19	14	33	24	19	14
3/8 - 16	40	30	25	20	55	40	25	20
3/8 - 24	40	30	35	25	60	45	35	25
7/16 - 14	60	45	45	35	90	65	45	35
7/16 - 20	65	50	55	40	95	70	55	40
1/2 - 13	95	70	75	55	130	95	75	55
1/2 - 20	100	75	80	60	150	110	80	60
9/16 - 12	135	100	110	80	190	140	110	80
9/16 - 18	150	110	115	85	210	155	115	85
5/8 - 11	180	135	150	110	255	190	150	110
5/8 - 18	210	155	160	120	290	215	160	120
3/4 - 10	325	240	255	190	460	340	255	190
3/4 - 16	365	270	285	210	515	380	285	210
7/8 - 9	490	360	380	280	745	550	380	280
7/8 - 14	530	390	420	310	825	610	420	310
1 - 8	720	530	570	420	1100	820	570	420
1 - 14	800	590	650	480	1200	890	650	480

Fraction, Decimal, Millimeter Conversions

Conversion Chart

Fraction	inch	mm	Fraction	inch	mm
1/64	0.0156	0.397	33/64	0.5156	13.097
1/32	0.0313	0.794	17/32	0.5313	13.494
3/64	0.0469	1.191	35/64	0.5469	13.891
1/16	0.0625	1.588	9/16	0.5625	14.288
5/64	0.0781	1.984	37/64	0.5781	14.684
3/32	0.0938	2.381	19/32	0.5938	15.081
7/64	0.1094	2.778	39/64	0.6094	15.478
1/8	0.1250	3.175	5/8	0.6250	15.875
9/64	0.1406	3.572	41/64	0.6406	16.272
5/32	0.1563	3.969	21/32	0.6563	16.669
11/64	0.1719	4.366	43/64	0.6719	17.066
3/16	0.1875	4.763	11/16	0.6875	17.463
13/64	0.2031	5.159	45/64	0.7031	17.859
7/32	0.2188	5.556	23/32	0.7188	18.256
15/64	0.2344	5.953	47/64	0.7344	18.653
1/4	0.2500	6.350	3/4	0.7500	19.050
17/64	0.2656	6.747	49/64	0.7656	19.447
9/32	0.2813	7.144	25/32	0.7813	19.844
19/64	0.2969	7.541	51/64	0.7969	20.241
5/16	0.3125	7.938	13/16	0.8125	20.638
21/64	0.3281	8.334	53/64	0.8281	21.034
11/32	0.3438	8.731	27/32	0.8438	21.431
23/64	0.3594	9.128	55/64	0.8594	21.828
3/8	0.3750	9.525	7/8	0.8750	22.225
25/64	0.3906	9.922	57/64	0.8906	22.622
13/32	0.4063	10.319	29/32	0.9063	23.019
27/64	0.4219	10.716	59/64	0.9219	23.416
7/16	0.4375	11.113	15/16	0.9375	23.813
29/64	0.4531	11.509	61/64	0.9531	24.209
15/32	0.4688	11.906	31/32	0.9688	24.606
31/64	0.4844	12.303	63/64	0.9844	25.003
1/2	0.5000	12.700	1	1.0000	25.400

Conversion Factor: 1 inch = 25.4 mm

Newton-Meter to Foot-Pound Conversions

Conversion Chart

N•m	ft-lb	N•m	ft-lb	N•m	ft-lb
1	9 in-lb	55	41	155	114
5	44 in-lb	60	44	160	118
6	53 in-lb	65	48	165	122
7	62 in-lb	70	52	170	125
8	71 in-lb	75	55	175	129
9	80 in-lb	80	59	180	133
10	89 in-lb	85	63	185	136
11	97 in-lb	90	66	190	140
12	106 in-lb	95	70	195	144
14	124 in-lb	100	74	200	148
15	133 in-lb	105	77	205	151
16	142 in-lb	110	81	210	155
18	159 in-lb	115	85	215	159
20	15 ft-lb	120	89	220	162
25	18	125	92	225	165
30	22	130	96	230	170
35	26	135	100	235	173
40	30	140	103	240	177
45	33	145	107	245	180
50	37	150	111	250	184
NOTE: To convert from Newton-Meters to Kilogram-Meters divide Newton-Meters by 9.803.					

Pipe Plug Torque Values

Torque Table

Size		Torque		Torque	
Thread	Actual Thread O.D.	In Aluminum Components		In Cast Iron or Steel Components	
in	**in**	**N•m**	**ft-lb**	**N•m**	**ft-lb**
1/16	0.32	5	45 in-lb	15	10
1/8	0.41	15	10	20	15
1/4	0.54	20	15	25	20
3/8	0.68	25	20	35	25
1/2	0.85	35	25	55	40
3/4	1.05	45	35	75	55
1	1.32	60	45	95	70
1-1/4	1.66	75	55	115	85
1-1/2	1.90	85	65	135	100

Tap-Drill Chart - U.S. Customary and Metric

General Information

NOTE ON SELECTING TAP-DRILL SIZES: The tap drill sizes shown on this card give the theoretical tap drill size for approximately 60% and 75% of full thread depth. Generally, it is recommended that drill sizes be selected in the 60% range as these sizes will provide about 90% of the potential holding power. Drill sizes in the 75% range are recommended for shallow hole tapping (less than 1 1/2 times the hole diameter) in soft metals and mild steel.

Tap Size		Drill
60%	75%	Size
		48
		1.95mm
		5/64
	3-48	47
		2.00mm
	M2.5x.45	2.05mm
		46
3-48	3056	45
		2.10mm
M2.5x.45	M2.6x.45	2.15mm
3-56	4-36	44
		2.20mm
M2.6x.45		2.25mm
4-36	4-40	43
		2.30mm
		2.35mm
4-40	4-48	42
		3/32
	M3x.6	2.40mm
4-48		41
		2.45mm
		40
M3x.6	M3x.5	2.50mm
		39
	5-40	38
M3x.5		2.60mm
5-40	5-44	37
		2.70mm
5-44	6-32	36
		2.75mm
		7/64
		35
		2.80mm
		34
6-32	6-40	33
	M3.5x6	2.90mm
		32
M3.5x6		3.00mm
6-40		31
		3.10mm
		1/8
		3.20mm
	M4x.75	3.25mm
		30
	M4x.7	3.30mm
M4x.75		3.40mm
M4x.7	8-32	29
		3.50mm
	8-36	28
8-32		9/64
		3.60mm
8-36		27
		3.70mm
		26
	M4.5x.75	3.75mm
	10-24	25
		3.80mm
		24
M4.5x.75		3.90mm
		23
		5/32
10-24		22
	M5x1	4.00mm
	10-32	21
		20
	M5x.9	4.10mm
M5x1	M5x.8	4.20mm
10-32		19
M5x.9		4.25mm
M5x.8		4.30mm
		18
		11/64
		17

Tap Size		Drill
60%	75%	Size
		4.40mm
	12-24	16
		4.50mm
		15
	M5.5x.9	4.60mm
12-24	12-28	14
		13
		4.70mm
M5.5x.9		4.75mm
12-28		3/16
		12
		4.80mm
		11
		4.90mm
		10
		9
	M6x1	5.00mm
		8
		5.10mm
	1/4-20	7
		13/64
		6
M6x1		5.20mm
		5
	M6x.75	5.25mm
		5.30mm
1/4-20		4
M6x.75		5.40mm
	1/4-28	3
		5.50mm
		7/32
		5.60mm
1/4-28		2
		5.70mm
		5.75mm
		1
		5.80mm
		5.90mm
		A
		15/64
	M7x1	6.00mm
		B
		6.10mm
		C
M7x1		6.20mm
		D
	M7x.75	6.25mm
		6.30mm
		E
		1/4
M7x.75		6.40mm
		6.50mm
	5/16-18	F
		6.60mm
		G
		6.70mm
		17/64
	M8x1.25	6.75mm
5/16-18		H
		6.80mm
		6.90mm
	5.16-24	I
M8x1.25	M8x1	7.00mm
		J
		7.10mm
5/16-24		K
		9/32
M8x1		7.20mm
		7.25mm
		7.30mm
		L
		7.40mm
		M

Tap Size		Drill
60%	75%	Size
		7.50mm
		19/64
		7.60mm
		N
		7.70mm
	M9x1.25	7.75mm
		7.80mm
		7.90mm
	3/8-16	5/16
M9x1.25	M9x1	8.00mm
		O
		8.10mm
M9x1		8.20mm
		P
		8.25mm
		8.30mm
3/8-16	1/8-27NPT	21/64
		8.40mm
	3/8-24	Q
	M10x1.5	8.50mm
		8.60mm
		R
3/8-24		8.70mm
1/8-27NPT		11/32
	M10x1.25	8.75mm
M10x1.5		8.80mm
		S
		8.90mm
M10x1.25	M10x1	9.00mm
		T
		9.10mm
		23/64
M10x1		9.20mm
		9.30mm
	7/16-14	U
		9.40mm
	M11x1.5	9.50mm
		3/8
		V
		9.60mm
		9.70mm
		9.75mm
M11x1.5		9.80mm
7/16-14		W
		9.90mm
	7/16-20	25/64
		10.00mm
7/16-20		X
	M12x1.75	10.20mm
		Y
		13/32
M12x1.75	M12x1.5	Z
	1/2-13	10.50mm
M12x1.5	M12x1.25	27/64
M12x1.25		10.75mm
1/2-13		11.00mm
1/4-18NPT		7/16
		11.25mm
		11.50mm
		29/64
		11.75mm
		11.50mm
	1/2-20	29/64
	9/16-12	15/32
	M14x2	12.00m
		12.25mm
9/16-12		31/64
M14x2	M14x1.5	12.50mm
	9/16-18	1/2
M14x1.5	M14x1.25	12.75mm
M14x1.25		13.00mm
9/16-18		33/64

Tap Size		Drill
60%	75%	Size
		13.25mm
	5/8-11	17/32
	M15x1.5	13.50mm
M15x1.5		13.75mm
5/8-11		35/64
	M16x2	14.00mm
		14.25mm
	5/8-18	9/16
M16x2	M16x1.5	14.50mm
5/8-18		37/64
		14.75mm
M16x1.5		15.00mm
		19.32
		15.25mm
		39/64
	M17x1.5	15.50mm
M17x1.5	M18x2.5	15.75mm
		5/8
M18x2.5	M18x2	16.00mm
M18x2		16.25mm
3/4-10		41/64
M18x1.5		16.50mm
3/4-10	M19x2.5	21/32
M18x1.5		16.75mm
M19x2.5		17.00mm
		43/64
		17.25mm
3/4-16	3/4-16	11/16
	M20x2.5	17.50mm
		17.75mm
		45/64
M20x2.5	M20x2	18.00mm
M20x2		18.25mm
		23/32
	M20x1.5	18.50mm
		47/64
M20x1.5		18.75mm
		19.00mm
		3/4
		19.25mm
	7/8-9	49/64
	M22x2.5	19.50mm
7/8-9		25/32
		19.75mm
M22x2.5	M22x2	20.00mm
	7/8-14	51/64
M22x2		20.25mm
	M22x1.5	20.50mm
7/8-14		13/16
		20.75mm
M22x1.5	M24x3	21.00mm
		53/64
		21/25mm
		27/32
M24x3		21.50mm
		21.75mm
		55/64
	M24x2	22.00mm
	1"-8	7/8
M24x2		22.25mm
	M24x1.5	22.50mm
1"-8		57/64
M24x1.5		22.75mm
	M25x2	23.00mm
	1"-12	29/32
M25x2		23.25mm
1"x12	1"-14	59/64
	M25x1.5	23.50mm
M20x1.5		23.75mm
1"-14		15/16

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Weights and Measures - Conversion Factors

Conversion Chart

Quantity	U.S. Customary		Metric		From U.S. Customary To Metric Multiply By	From Metric To U.S. Customary Multiply By
	Unit Name	Abbreviation	Unit Name	Abbreviation		
Area	sq. inch	in^2	sq. millimeters	mm^2	645.16	0.001550
			sq. centimeters	cm^2	6.452	0.155
	sq. foot	ft^2	sq. meter	m^2	0.0929	10.764
Fuel Consumption	pounds per horsepower hour	lb/hp-hr	grams per kilowatt hour	g/kW-hr	608.277	0.001645
Fuel Performance	miles per gallon	mpg	kilometers per liter	km/l	0.4251	2.352
	gallons per mile	gpm	liters per kilometer	l/km	2.352	0.4251
Force	pounds force	lbf	Newton	N	4.4482	0.224809
Length	inch	in	millimeters	mm	25.40	0.039370
	foot	ft	millimeters	mm	304.801	0.00328
Power	horsepower	hp	kilowatt	kW	0.746	1.341
Pressure	pounds force per sq. inch	psi	kilopascal	kPa	6.8948	0.145037
	inches of mercury	in Hg	kilopascal	kPa	3.3769	0.29613
	inches of water	in H_2O	kilopascal	kPa	0.2488	4.019299
	inches of mercury	in Hg	millimeters of mercury	mm Hg	25.40	0.039370
	inches of water	in H_2O	millimeters of water	mm H_2O	25.40	0.039370
	bars	bars	kilopascals	kPa	100.001	0.00999
	bars	bars	millimeters of mercury	mm Hg	750.06	0.001333
Temperature	fahrenheit	°F	centigrade	°C	(°F-32) ÷1.8	(1.8 x °C) +32
Torque	pound force per foot	ft-lb	Newton-meter	N•m	1.35582	0.737562
	pound force per inch	in-lb	Newton-meter	N•m	0.113	8.850756
Velocity	miles/hour	mph	kilometers/hour	kph	1.6093	0.6214
Volume: liquid displacement	gallon (U.S.)	gal.	liter	l	3.7853	0.264179
	gallon (Imp*)	gal.	liter	l	4.546	0.219976
	cubic inch	in^3	liter	l	0.01639	61.02545
	cubic inch	in^3	cubic centimeter	cm^3	16.387	0.06102
Weight (mass)	pounds (avoir.)	lb	kilograms	kg	0.4536	2.204623
Work	British Thermal Unit	BTU	joules	J	1054.5	0.000948
	British Thermal Unit	BTU	kilowatt-hour	kW-hr	0.000293	3414
	horsepower hours	hp-hr	kilowatt-hour	kW-hr	0.746	1.341

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